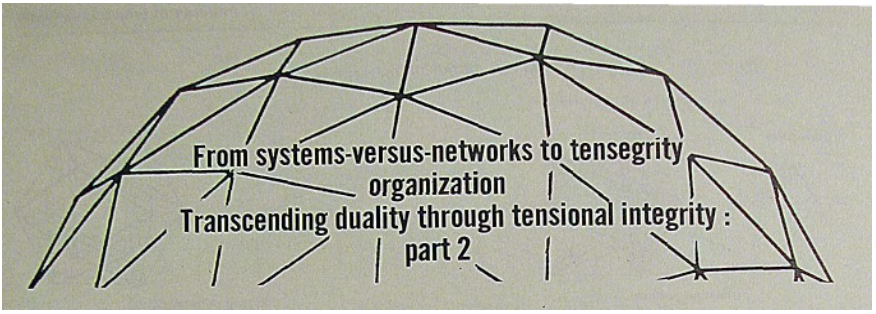


From systems-versus-networks to tensegrity organization
Transcending duality through tensional integrity : part 2

Psycho-social Parallel : the Parts

Those who have handled models of tensegrity structures (discussed in Part 1 of this article, pages 248-257) are tantalized by their relative indestructibility despite their apparently extreme fragility — they seem to have some as yet hidden significance. The principles have only been used so far to build geodesic domes, whether large or small (13), although they are important to design for space missions (14). But, as Kenner notes; « If tensegrity has a practical use... the first princi ples of that usefulness remain to be investigated » (p. ix-x). Anthony Pugh goes even further : « Tensegrity systems are so fascinating that one instinctively feels they must be significant, even if it may be difficult to predict their most important application... The major importance of tensegrity may not be for structures but for something entirely different, such as philosophy...» (p. 56). Fuller's own focus is on tangible structures, but he uses them in his somewhat elusive fashion to demonstrate principles which are far more general and do not apparently exclude relevance to psycho-social structures (as the title of his book indicates); he argues, for example, that if tension is secondary and local in all men's structural projections, that tension must also be secondary in man's philosophic reasoning (p. 350). The first task then is to explore some of the lines of equivalence between psycho-social structures and the architectural elements referred to in the previous sections (see Part 1. pages 248-253). Structure : The meaning to be attached to « structure » is a topic of continuing debate in the social sciences (15). Attention in this article is focussed primarily on structure in organizations as networks, and in networks of organizations (16), « world problems » (17), and concepts /beliefs (18). Such concepts of structure are not purely descriptive but lend themselves to an element of design in any social transformation process. Structure is therefore considered to be the relationship among elements in a psycho-social unit.

« Tensegrity and Philosophy »

Mohists; each denies what the other affirms, and affirms what the other denies. What use is this struggle to set up " No " against " Yes ". and . Yes " against . No • ? Better to abandon

by the change in conditions.
The wise man therefore... sees that on both sides of every argument there is both right and wrong. He also sees that in the end they are reducible to the same thing, once they are related

there he stands while « Yes " and « No » pursue each other around the circumference «.
— The Way of Chuang Tzu. interpreted by Thomas Merton. London, Unwin, 1970.

Node : At the nodes compression and tension elements meet. Fuller gives a very abstract description of them which is valid for psycho-social systems (see footnote 12, page 257 this article). In the case of organizations, they may be tentatively thought of as roles, functions, or function-roles since these are indeed the focal points for energy events in an organization system. Compression element : If nodes A and B are linked in « compression », then its nature in an organization system appears to lie in the following :

— A is counter-function of B, and vice versa
— A and B are mutually controlling, or mutually « marking » (to use a football term)
— A acts in counter-response to B, and vice versa
— A is constrained by B, and vice versa
— A acts to eliminate the effects of B, and vice versa

— A - struggles » and « bargains » with B, and vice versa. In some way A and 8 each act to keep the other « backed against the ropes » (to use a boxing term), to keep each other under pressure. They " work " or " operate " on each other and in response to each other, providing input to each other and transforming each other's output (19). It is a stimulus-response, action-reaction relationship. It is the essence of a working relation-

(13) Lloyd Kahn et al. Domebook 2. Bolinas, Cal.. Shelter Publications 1971.
John Prenis (Ed.). The Dome Builders Handbook. Philadelphia, Running Press, 1973.

(14) J. Clinton. Advanced Structural Design Concepts for Future Space Missions. (NASA Contact NGR-U-008-002, 1970). Distributed by National Technical Information Service (Springfield, Va) as ; Advanced Structural Geometry Studies. Part 1.

(15) Roger Bastide (Ed.), Sens et usages du terme « structure . dans les sciences humaines et sociales. The Hague, Mouton, 1962.

(16) International organization networks; a complementary perspective In: Paul Taylor and A J R Groom (Ed) International Organisation. London, Frances Pinter, 1977, pp. 381-413.

(17) Yearbook of World Problems and Human Potential. Brussels. Union of international Associations/Mankind 2000, 1976.

(18) John N Wartleld. Structuring Complex Systems. Columbus. Battelle

L. Tester et al. A directed graph representation for computer simulation of belief systems. Mathematical Biosciences. 2. 1/2, Feb 1968, pp. 19-40.

(19) The compression elements may bo conceived as « transformative " paths whereby energy/material at one end is converted through an appropriate work cycle into a different form at the other end. The finite time for this process establishes the " distance " between the two ends.

ship in which contiguous boundaries are defined in order to maintain the operational distinction between two fundamentally different approaches (to energy transformation, in its most general sense), which are nevertheless each the prime justification for the other's existence (20). The concept of the classicial syzygy is also indicative : state of being yoked together; a pair of correlatives or opposites. the existence of which is maintained by its essential complementarity. Complementarity itself is intimately associated with the concept underlying compression (21). At best, it is a relationship of creative opposition appreciated for its real and meaningful challenge, fundamental to the dynamics of the system. At worst it is a source of extreme hostility whose consequences constantly endanger the integrity of the system (or possibly even prevent its creation, in the case of an organization). It may be argued that many psycho-social systems do not appear to have such opposed elements within them. However, as will be argued below, such « systems » are usually sub-systems whose elements do have such relationships to elements in other sub-systems, which are the justification for their continued existence. The « other » sub-system need not be an organization, for example, it could well be a problem complex, which is the focus of the first sub-system's concern. In fact, it may well be argued that a system is not stable if such opposed elements cannot be integrated within it to provide it with adequately structured dynamics.

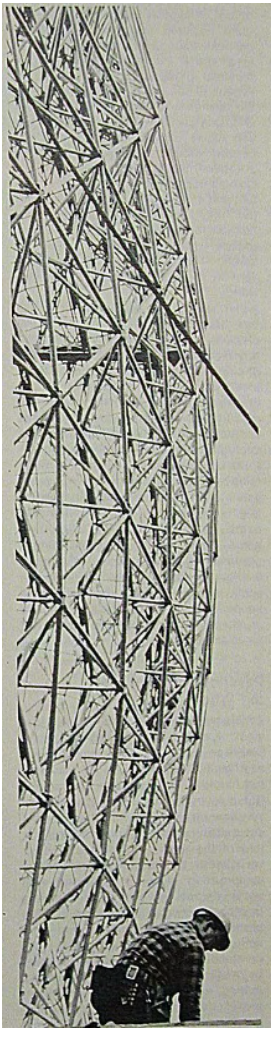
If there is a parallel between the building principles favoured and those embodied in social structures, then most of our social structures should have a " compressive " element predominating, whereas the « tension » element should be secondary, in the case of a conventionally structured organization (whether a government bureaucracy, a commercial enterprise or a military unit), the nature of the compressive element seems to be embodied in the constraint associated with formal lines of authority and command, or in the employer / employee relationship of management and orders. Such formal relationships are usually asymmetric : A constrains B by directives and not the reverse. Similarly in buildings, beam A compresses beam B and not the reverse. (Although, in both cases, A is not unconstrained by its relationship to B.) In compressively discontinous tensegrity structures, however, A acts on B as much as B acts on A, since they are forced together by the continuity of the tensional elements to which they are respectively linked. The relationship is symmetric, although momentary asymmetry may emerge whenever the equilibrium of the tensegrity system is disturbed (22). The corresponding tension element would then be associated with liaison and advisory relationships or influence (as opposed to command). Clearly it is standard practice to maintain continuity between the compressive elements of the organizational system, with occasional (i.e. discontinuous) tensional (liaison) elements where necessary to keep the organization functioning coherently as a whole. With this approach society has succeeded in constructing extremely sophisticated organizational hierarchies — and there is a parallel with the progressively more sophisticated techniques for constructing load-bearing arches (see Diagram 1), if one considers the resemblance between multi-level arches and any conventional organization chart. Such structures are not proving adequate to the times however. They are cumbersome and ineffective in many ways — the term « spastic dinosaurs » has been used. Fuller suggests however : « Compression is that « realistic hard core » that men love to refer to, and its reality was universal, ergo comprehensive. Man must now break out of that habit and learn to play at nature's game where tension is primary and where tension explains the coherence of the whole. Compression is convenient, very convenient, but always secondary and discontinuous » (p. 356). The same could prove to be true for organizations.

Tension element : If nodes A and C are linked in « tension ., then its nature in an organizational system appears to lie in the common factor in the following :

- — A shares with C, and vice versa
- — A has an affinity to C, and vice versa
- — A responds in sympathy to C, and vice versa
- — A adjusts itself in relationship to C, and vice versa
- — A relates to and communicates with C, and vice versa
- — A defines itself in relationship to C, and vice versa
- — A cooperates with C, and vice versa.

In an organization tension is closely linked to the notion of a bond in its most general sense and the consequences of the associated information transfer.

In contrast to compression elements which are by definition discontinuous (in a tensegrity system), the special nature of a tension element only emerges in terms of its relationship to the continuous tensional network as an integral pattern (23). (This is considered



Dome construction (Expo 76) Photo : National Film Board (via Canadian Embassy, Brussels).

(20) Fuller makes the following points about compression, it accumulates potential, it is specifically directional, it is dispersive, inherently partial end tends to local dichotomy and multiplication by separation (p. 359).

(21) Gerald Holton. The roots of complementarity. Daedalus, Fall 1970, pp 1015-1055.

(22) Asymmetric effects are also Introduced by the tensegrity's orientation with respect to gravity.

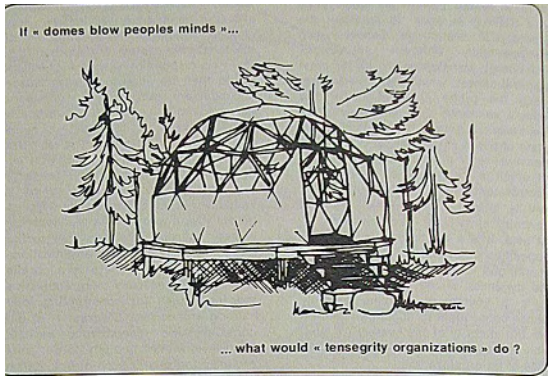
(23) Fuller makes the following points about tension. It Is comprehensive, attractive and inherently integral. It is both omni- and supradirectional. It is universally cohering and comprehensively Unite. It Is inherently total (p. 359).

below). In social psychology, this has been explored (although perhaps not exhaustively) under the concept of small group " cohesiveness » or interpersonal attraction, namely « The resultant of all the forces acting on all the members to remain in the group » (24). One consequence of cohesiveness can cause another, and many of the consequences can cause interpersonal attraction, particularly in small groups. Communication, which is both an effect and a cause of interpersonal attraction, may however be of greater significance to the cohesiveness of larger groups where face-to-face contact is limited — and may thus be more relevent to the notion of a tensional network.

Fuller makes the point that little use has been made of tensile structural elements and that it is only in this century that materials have been developed of comparable strength to compression elements. Whether or not this is true in psycho-social systems, it can be argued that tensile liaison-type bonds characteristic of most organizations (including « cooperative relationships ", « old boy networks >, etc.) have been relatively weak compared to other bonds which have been used in the past (e.g. « blood bonds > or the « binding oaths » used by secret societies, religious orders, and extremist political groups). Alternative kinds of strong tension bonds may be possible — some may result from the operational bonds between those intensively linked in computer conferencing networks, for example.

Psycho-social Parallel : the Whole

Tensional integrity system : At first sight, a model of a tensegrity system surprises by its seeming improbability and fragility, as well as by the unexpected harmony of its various symmetries. But it is in its « beauty » that lies its very real strength (as handling the model quickly shows). Explaining the nature of the totality is not easy, however. Clearly it consists of a number of compression elements balanced with some degree of symmetry within a tensional network. But ability to comprehend the phenomenon tends to be limited to a *(*" two-dimensional ") understanding of the collection of parts before the tensional network is tautened. Indeed, when constructing a tensegrity model, its suprising nature only emerges (1) when sufficient tensional links are made to cause the flat network to curve into three-dimensions, (2) when the final links are made to bring out from the confusing complex of elements the full spheric symmetry which renders it comprehensible, and (3) when, as a result of pulling on one or more elements (or bouncing it on the floor), it becomes apparent how the system responds as a dynamic whole (quite capable of « taking care of itself »).



If a « tensegrity organization » does constitute a radical departure, then there will be few parallels by which to explain how it would function. What is done, however, is to take pairs of essentially opposed or « incompatible » function-roles and to « bind » them into a mutually constraining relationship within a communication network, possibly based on some special social bond. The network of bond-based communications is then « tightened » to the degree permitted by the set of incompatibilities. Consequently, the latter are collectively forced by the symmetrical sphericity of the tensional network towards the « centre > of the system. The greater the mutual incompatibility, the greater the tendency of the compression elements to avoid confrontation and proximity to the centre, the greater the tension required to maintain them in position, and the greater the energy inherent in the system (25 26).

To avoid creating the impression that this is simply another way of forcing people or groups into unsatisfactory relationships, the following points may be emphasized. The « incompatible » function-roles are brought into a stressful relationship by the binding nature of shared understanding amongst those involved (of which the centre represents the focus), which brings out as much of each functional incompatibility as the role-occupants are prepared to handle within that context. It is the unique equilibrium (made possible by a tensegrity pattern) between what unites (i.e. the tensional network) and what divides (i.e. the many distinct compressional incompatibilities) which gives rise to (and derives from) the new kind of organizational structure. The functional incompatibilities are those which have to be faced (to create a viable organization) when all the functional realities (i.e. negative feedback loops ?) are accepted and brought into focus rather than avoided, whether deliberately or out of ignorance. The more functional incompatibilities explicitly incorporated, the more specific each becomes (and the less vulnerable will be the the organizational integrity to imbalance in any one of them), the more viable and resource-conserving the resulting organization — namely the more spherically symmetrical the resulting tensegrity pattern and the more elegant the dynamic equilibrium between the functional elements. Perhaps one suggestive parallel is the naval term for keeping or running a « tight ship ., by which is meant that all elements of the crew are bound into a disciplined pattern of relationships to one another and there is « no slackness «. The parallel is unsatisfactory in that this is usually achieved by hierarchical discipline and ordering. Another illustration is the notion of a « system of checks and balances » frequently advocated in drawing up a constitution. A final illustration is the situation frequently explored in fiction in which an objective can only be achieved by

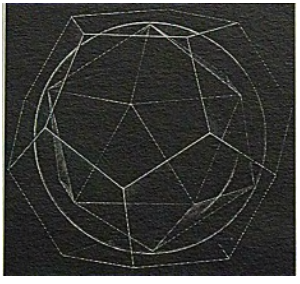
(24) D Cartwright and A. Zander, Group Dynamics; research and theory. Evansion, Row Peterson, 1960. p. 74.

(25) In sociology this Is known as the equilibrium problem noied by R. Bales (1955). The group solidarity acts In opposition to differentiation and divison of labour necessary In adapting to its environment; all groups are caught in transient equilibrium resulting from these forces. A structure most effective for the ends of the group may not be most satisfying interpersonally. (The meaning of « most satisfying Interpersonally " remains to be explored.)

(26) The question of synergy in small groups has been investigated by R. Cattell (see Cattell and Nice. 1960), He also explored « syntality » (as the small group equivalent of individual personality), and the problem of the classification of syntalities,

a group which overcomes its Inherent weaknesses, and that of its members, by obliging incompatible individuals to work in a team (i.e. a tensional network) and to transform creatively the energy and stimulation of their mutual hostility — leading to mutual respect for the contribution of each, and of both together, to the whole. It may well be the case that under special circumstances groups slip into a tensegrity configuration semi-deliberately. Extreme examples might include family networks provoking schizophrenia (27), or military and fanatical « suicide » squads. Such examples however only reflect intuitive or instinctive understanding of the nature of such systems. An advantage of the tensegrity approach is that it can give considerable precision to a whole range of patterns for consciously ordering such relationships. System and network : An especially interesting characteristic of tensegrity is the manner in which « network » and « system » are explicitly and interdependently blended. For a number of years now, « systems » (despite their so-called efficiency) have been condemned as typical of the inequitable « establishment » mode of centralized organization. « Networks » have come to be regarded by some as a more equitable and participative alternative, less subject to abuse, and more appropriate to the needs of society at this time. The distinction between the two remains elusive, as a recent debate demonstrated (28). It is certainly not clear that networks can replace systems in all instances, although they may complement them in many cases (e.g. environmental networks vis-a-vis industrial corporations), or be viable where people or groups do not wish to become members of organized systems (e.g. the civil rights network). In a tensegrity model, by definition, a continuous network of tension elements is clearly evident. None of the nodes is privileged in this respect — there is no central node or group of nodes. On the other hand, as the term " tensegrity system " implies, the interplay between the tension and compression elements may be interpreted as a whole as systemic behaviour unpredictable from the behaviour of the parts considered individually. It could be argued that the network and systemic characteristics counter-balance each other at a new level of synthesis at which the usual weaknesses of each are by-passed. The usual disadvantage of a network in society is its inability to achieve a consensus with regard to implementing any precise course of action (if such can even be defined). It has difficulties in acting as a whole without being partly hierarchized. An organizational system is only able to act by martialling resources in a hierarchically ordered manner and thus alienating or eliminating many who are unable to conform to its operational exigencies — thus eroding its own support and rendering its policies progressively cruder, since those who could refine them are excluded (or exclude themselves). It may be argued that an appealing feature of network organizations is their openness to participation of other nodes and to extension of the linkage pattern, and these are apparently not a feature of tensegrity. Additional nodes or tension compression elements can however be added to any structure. This may affect the " symmetry " with

Diagram 4 : Polyhedral « duals »
Icosahedron within dodecahedron



consequences to be explored below. This question will be considered later in connection with the growth of tensegrity organizations and their relation to « potential associations ». It may also be argued that tensegrity organizations would seem to lack the coordinative element essential to the effective operation of conventional organizations. This question is considered in the following section. Symmetry and coordination : If tensegrity organization is to be considered a viable alternative to conventionally hierarchized organization, it must be possible to demonstrate how the coordinative features of a hierarchy are recovered within a tensegrity organization. For those impressed by the need for transitional phases, it is desirable to view this as a transformation in which a degree of continuity should be evident (29).

A typical (and simplified) organization chart has features like those shown in Diagram 5. which incidentally is always two-dimensional, however complex the organization. This may be compared with the two-dimensional " net " of a tensegrity model based on a regular polyhedron (see Annexe 1), In what way could one be « mapped • into the other ? (30).

There seem to be several clues ;

1. Coordination in a hierarchy is achieved by having a focal person (« the boss ») or body to which the coordinated bodies report and from whom they receive orders. In a tensegrity system, the coordinated response of the parts results from the symmetry of their positioning within the whole. There is no hierarchy of «bosses», but there are various kinds of symmetry. If the coordinative elements in the hierarchy could be transformed into symmetry features of the tensegrity organization, then coordination would be achieved without having to be « organized ».

2. A spherically symmetrical tensegrity system is a balanced and integrated breakdown of a functional whole. In other words, depending on the number of elements, a greater or lesser number of sub-functions are rendered explicit. It may well be the case therefore that a particular hierarchy may be missing explicit functions (perhaps left implicit in job descriptions) which would need to be explicit in the tensegrity organization because of the special importance of functional balance.

3. The concept of a compression element requires that there be genuine (creative) opposition between the two nodes. It may well be the case that this is absent from a particular hierarchy because the « functional opponent » of the unit in question is either a problem with which it is struggling or a functional unit in the hierarchy of a competing organization. This brings out a very important point. A tensegrity system is by definition complete and independent. A hierarchy invokes a counter-hierarchy, whether of problems or of competing organizational units (or of the problems which they represent). A tensegrity system can only maintain its form and characteristics by integrating opposition into its structure. A hierarchy can only continue to justify its existence by maintaining the importance of its external counter-part(s). In terms of the mapping problem therefore it may be necessary to integrate two or more counter-vailing hierarchies into one tensegrity system to achieve functional balance.

4. A polyhedron is usually the basis for a tensegrity system. There are very many polyhedra to guide selection of appropriate patterns of symmetry. It is probable that the range is much richer than is required "by the kinds of hierarchies in use at present or our sensitivity to the possible variety of

(27) R V Speck and C L Atlneave. Family Networks. New York, Pantheon, 1973.

(28) Organizational systems versus network organization. Transnational Associations. 29, 1977. 9, PP 360-364 (Part 1); 11, pp 479-484 (Pan 2).

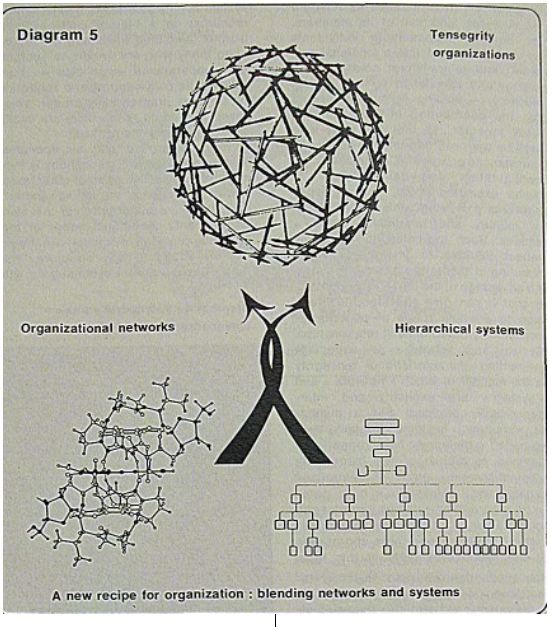
(23) Rather than as a simple diamanting, of hierarchies, which also has its advocates.

(30) There is inherent elegance In the expectation that better organization will emerge in transforming from a Planar unidirectional representation to one which curves back upon Itself symmetrically in a plurality of directions.

organizations which they represent. On the other hand some configurations may be inherently less probable for reasons which remain to be clarified. In the light of these points, preliminary investigation has shown that a transformation is possible. Space limitations and the need for more detailed exploration preclude further discussion at this point.

The manner in which spherical symmetry « coordinates » the tensegrity system has been explained in an earlier section. (There is however no substitute for personally handling a model as suggested above.) In practice, the great-circle tensional pathways in a tensegrity organization could possibly be constituted by direct information /communication links (perhaps by topic, operating mode, etc.). Elements can fail or be omitted, or « redundant » elements could be added but Fuller makes it very clear that in the case of geodesic-type systems, the presence or absence of many elements does not affect the integrity of such systems. The full significance of the various kinds of symmetry (centre of symmetry, plane of symmetry, axis of symmetry, etc.), of which Fuller identifies seven (pp. 668-672), remains to be explored, although clearly they constitute « reference bases » about which equilibrium is maintained. Fuller considers that each (internal) plane indicates the existence of a (sub) system (31).. Of special interest is the significance of the centre which is defined by the spherical symmetry. This is obviously a « coordinative focus > although it is not « occupied » by any element of the system (32). In a psycho-social system it represents the integration of all the system elements and as such is an abstraction in relation to the system itself as are the other symmetry features. It would be useful to explore the relationship between the system of « matrix management >, developed for complex organizations (33), and tensegrity coordination. The former permits coordination across the matrix in two dimensions, whereas the latter offers the coordination associated with spherical symmetry, namely the great-circle linkages and inter-linkages. It would also be valuable to relate the concepts of symmetry and coordination to that of structural balance (34).

Nested and linked tensegrities : The centres of the faces of the regular polyhedra defined by the tensional network of tensegrity systems are not occupied in any way, even though they mark the position of axes of symmetry. Polyhedral « duals > are in fact delineated bu linking the centre points of neighbouring faces. In this way, for example, the cube is the dual of an octahedron (Diagram 4). This sort of approach may be used to « nest » one tensegrity within another, linking the two by tension elements to the nodes at the face centres. Although many could be nested in this way (and they need not be duals), the significance in terms of the coordination of the equivalent social organization is not clear. Instead of nesting two or more tensegrity systems they may be linked together (i) by matching surfaces or volumes, (ii) as masts or trusses, or (Mi) as grids or skeletal .structures. Although this implies a rich variety of structures, again it is not clear what is the significance in terms of the equivalent social organization.



Tensegrity equilibrium :

« When the tension members of a tensegrity are taut, it is in a state of equilibrium. To this state, however stressed, it always seeks to return... It is impossible to pull any line so tight that it could not, with sufficient effort, be pulled a little tighter. Hence the capacity of the system to absorb displacements and restore itself » (35). Tensegrities are extremely resilient under light loads. A complex tensegrity model is never quite still, however tightly the tendons are stretched. On the other hand it stiffens rapidly as loading increases. However the system is disturbed, the tendons are stretched, hence at equilibrium the total length of the tendon system (and of each tendon) is minimal. A tensegrity is therefore brought to its equilbrium state by pulling everything as tight as possible (36). Thereafter any outward or inward force, in attempting to make the system larger or smaller, must also strive to make the tendons longer and will be inhibited by their restoring elasticity (37). Tensegrities multiply the elasticity of tension members. It might be supposed that if

(31) « it is experimentally demonstrable that an apparent " plane" , is a "surface" area of some structural system " (p. 270).

(32) The geometry requires that a compression element passing relatively close by the centre should constitute a longer chord than one passing further away. The former coold then only be part of a tensegrity based on a simpler and less spherical polyhedron (e.g. a tetrahedron), increasing length may then be associated with greater functional incompatibility and "cruder" (or more fundamental) systems. In the extreme case, when the chord passes through the (coordinative local) centre, opposition is at a maximum and may be uncontainable within the system -- as is typical of unmediated conflict.

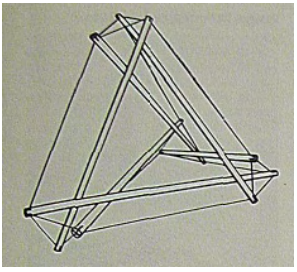
(33) Matrix organization and organizational networks. International Associations, 23. 1971. 3. PP 154-170.

(34) D Cartwright and F Harary. Structural balance : a generalization of Heider's theory. In : D Carwright and A Zander. Op. cit.. PP 705-726.

(35) Kenner, p. 12.

(36) « If you Just tauten one point in a tensegrity system, all the other parts of it lighten evenly. If you twang any tension member anywhere In the structure, It will give the same resonant note as the others... Until its tension is altered, each tensegrity structure... has its own unique frequency» (Fuller, p. 395).

(37) Kenner. p. 32-35.



a strut were displaced by 10 per cent a tendon would break because of inability to stretch 10 percent without failure. In fact, depending on the material and the tensegrity, a 10 per cent strut displacement may be absorbed by an increase of tendon length of 0.167 per cent — effectively multiplying the tendon elasticity (especially for small displacements, e.g. by 600 for 1 per cent, by 60 for 10 per cent, by 10 for 60 per cent). By analogy, the tensile network hidden in geodesic domes quite defeats all normal calculations of their strength (37).

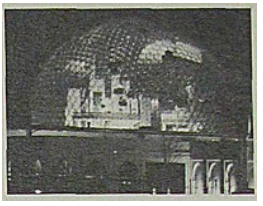
« Tightening up » the tension elements. may possibly be related to increasing the rate of information exchange in an organization. But exactly how to interpret these properties in the case of organizations remains to be seen (39). They do however recall a point made by Stafford Beer regarding reformers, critics of institutions, consultants in innovation and people who < want to get something done » : « They cannot understand why their strictures, advice or demands do not result in effective change. They expect either to achieve a measure of success in their own terms or to be flung off the premises. But an ultrastable system (like a social institution)... has no need to react in either of these ways. It specializes in equilibria! readjustment, which is to the observer a secret form of change requiring no actual alteration in the macrosystemic characteristics that he is trying to do something about » (40). The " alterations » he makes are simply absorbed and adjustements are made around them.

This could imply that tensegrity type organizations already exist effectively and are in fact a characteristic of our society — and it is the lack of understanding of their nature which prevents their amelioration in response to current social needs. Clearly if such organizations can be created, they could probably be used as effectively to maintain a status quo as to maintain a change process. The question is how to switch between tensegrities and what is a . better » tensegrity system ?

Tensegrity Choice and Change

Which tensegrity should be used to represent or construct an organization ? There is a large range of polydedra which have only been partially analyzed, and rarely as a basis for tensegrity systems. There are facinating patterns of symmetry, regularity and transformation relationships between many of them. But since the whole area is very new and as yet has few applications, there is still much confusion. One would expect a comprehensive « periodic table » of polyhedra and associated shapes and structures to be produced in the near future (41). Until that is done, each useful point of entry cannot be seen in an adequate context and exploration is therefore confined to well-defined paths of investigation. Most of the published material converges on the construction of geodesic domes based on the octahedron or the icosahedron — a single application of a tiny fraction of the range of polyhedra.

If Fuller's approach is accepted, the range of polyhedra and related tensegrities effectively map the more or less viable « work paths ». A « periodic table » of these « energy patterns » would indicate the variety of ways of organizing and operating — although only a proportion could give rise to tensegrity-type systems. The question is then how to « improve » the energy pattern by switching from one tensegrity to another. It is not clear what the advantages of different types of structure might be in the case of organizations. The extremes, discussed earlier, of the tetrahedron and the sphere are however suggestive : the first, being most suitable to with standing external forces (as in an organizational hierarchy ?), and the second most suitable to handling internal forces (the current organizational problem, isomorphic with the « global » problem ?). Switching between tensegrity patterns might be relatively easy if the organization was supported by an appropirate information system (42). The relationships between the regular polyhedra are well-known : a node can become the centre of a face (triangular, square, pentagon, etc.), or the centre of a face can become a node, etc. These << operation » options give rise to the notion of pathways between tensegrities, some



of which are dead-ends or unexplored. All such changes are ways of restructuring in response to different kinds of stress : « retreat > into simpler structure, « expand > into a more complex structure, « integrate » into a more comprehensive structure with greater symmetry, etc.

Ultimately the challenge is not one of switching from a « bad » structure to a * good , one, but rather of having sufficient grasp of the whole range of patterns to be able to switch between any structure according to need (43). American football, for example, lays great stress on the ability of the team during the game to switch between 10 to 50 patterns of play. A form is always necessary, but any one of a variety of forms may be used, whether changed irregularly or regularly, frequently or infrequently.

A set of people, groups or organizational units could therefore « flip > between forms in responding to different circumstances, provided that each knew what « position > to take in each new patterns, and what functions to take care of.

A given network of people might therefore be maintained in tension by a variety of tensegrity configurations. This possibility has been explored in connection with the notion of a « potential association ».

Communication net experiments

Experiments on communication nets were originated by Bavelas (1948,1950) and Leavitt (1951) and have been followed by a large number of studies. According to one literature review (Glanzer and Glazer. 1961) : « The area has been worked not only exhaustively, but to exhaustion. After a promising start, the approach has led to many conflicting results that resist any neat order ». And more recently : « It is almost impossible to make a simple generalization about any variable without finding at least one study to contradict the generalization » (45).

(39) Note also the sense underlying the phrase < tightening up> . an argument, a proof, or a legal case.

(40) Stafford Beer, Chairman's Address to the international Cybernetic Congress. 1969.

(41) Keith Critchlow, Order In Space; a design source book, London, Thames and Hudson, 1969.
Robert Williams. Natural Structures ; toward a form language. Moorpark , Cal,, Eudaemon Press. 1972.
Anthony Pugh, Polyhedra; a visual approach. Los Angeles, University of California Press, 1976.

(42) See articles on computer conferencing. Transnational Associates. 29, 1977, 10.

(43) In fact Keith Critchlow has attempted to show that the pattern of relationships between suuch structures can itself be mapped by them. See Order In Space, pp. 18-23, PP. 38-39.

(45) B E Collins and B H Raven , Group structure : attraction, coalitions,communication, and power. In: The Handbook of Social Psychology. Reading, Addision-Wesley. 2nd ed.

Such research is only partial relevant to that proposed, for the following reasons :

1. It is based on groups of 3 to 5 persons. On the basis of Fuller's analysis of structures, such a small number of elements does not give rise to stable tensegrity configurations. The simplest 3-D tensegrity requires 3 compression elements (i.e. 6 (unction-roles). The first two which are spherically symmetrical (and enclose a space) require 6 or 12 elements. The first with extensive great-circle symmetry requires 30.

3. The communication nets investigated are necessarily conceived in two-dimensions. Their patterns, in many cases (e.g. triangle, square, pentagon, wheel, etc.) of course constitute parts of a tensegrity tension network, but not the whole which requires specific combinations of such sub-networks (see Annexe I).

3. The emphasis is on communication, whether one-way or two-way, and the nets do not distinguish between tension and compression features (essential to the formation of a tensegrity configuration).

4. Little attention is paid to the differentiation of roles. Although H. Guetzkow distinguished factors operating to allow role formation from those which induced interlocking roles into organizational structures (46), only 3 roles (plus a role-less role) emerged. As groups get larger, and the task more complex, more specialized roles tend to emerge — to a point where there is only very indirect interaction between some roles (47). As the group gets still larger, distant roles have problems knowing of each others existence and understanding each other's relevance to the purposes of the group — namely an « horizon effect », if the differentiated function-roles are represented as distributed around a sphere (48). Opposed or counter-functions are required in maturer groups to counter-balance each other's excesses. It is at this level of complexity and functional < incompatibility > that tensegrities could prove of value.

5. Such task-oriented groups in fact are dependent on external factors for the justification of their artifical (laboratory) activity. As such they are essentially sub-systems for which a state of equilibrium can only be reached within the context of a larger system. Tensegrity is primarily of interest in exploring systems at equilibrium (or switching between equilibrium states), namely systems with a richer variety of counter-balancing functions.

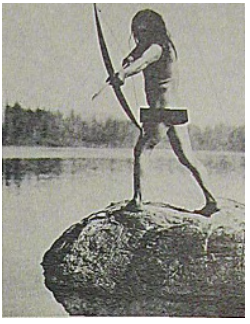
Possibilities for Experiment

Clearly further thought is required before any actual experiments are possible. However at least three areas of investigation should prove fruitful at some stage. The first could be an attempt to set up a relatively small group (e.g. 12 to 60 individuals) such that each was paired with another in a compressive relationship and had defined tension links with some others in accordance with the selected tensegrity structure, if necessary one individual could fulfil several roles (i.e. act as several distinct nodes) since it is the activated role-functions which are directly interrelated by the tensegrity pattern, and not necessarily the individuals (Or two individuals could handle one role). A more ambitious experiment would have each role-function activated by a small group or organizational unit. A third approach would focus primarily on the design and functioning of an information system whose nodes, would be distributed and interlinked according to the selected tensegrity pattern (49).

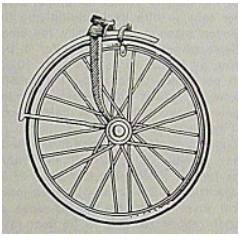
Two questions need to be clarified before (tentatively) undertaking such experiments. The first concerns the breakdown and distribution of role-functions for a tensegrity of a given complexity. Normally in an organization the number and relationship of functions is settled empirically in the light of past experience and in response to foreseen weaknesses. Such insights need to be used to work out for an organization with N function-roles, just what they tend to be. The second question is how such organizational tensegrities are to be «tightened up». Two approaches seem possible. The first involves increasing the -rate or intensity of interaction between the role-functions in tension relationship. The second is to add more compression relationships to the network until it is forced into a state of tension, namely by increasing the effective number of elements in the tensegrity (50). In either case, it should be noted that tensegrities are very tolerant of considerable departures from symmetry.

As any one who has built a tensegrity model knows, until almost all of the elements are tightened in place the result looks like an « unwholly » mess.

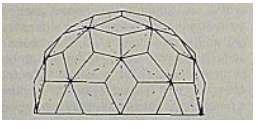
Stages in tensegrity innovation ?



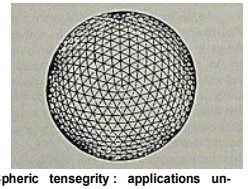
Semi-circular « tensegrity » : the bow



Circular tensegrity : the bicycle wheel



Hemispheric tensegrity : the dome



Spheric tensegrity : applications unknown

(46) H. Guetztaw. Differentiation of roles in task-oriented groups. In: Cartwright and Zander. Op. cit.. pp. 683-704.

(47) There is at» the question of the structuring effect of the limitation on channel capacity and the effects arising with more than 7 channels per role. See ; G. Miller. The magical number seven plus or minus two; some limitations on our capacity for processing information. In his ; Psychology of Communication. New York, Basic Books, 1967.

(48) There is then a tendency lor each role-function to act as though It was at a central point on a " flat-earth" rather than appreciating that it has to deal with " functional roundness " and that even the most distant and apparently "irrelevant" are in no danger of "falling off" an edge.

(49) This raises very interesting problems In the case of computer based Information systems, particularly the file design in the case of conferencing-type systems which should reflect the « great-circle " tensional pathways between participants, possibly only permitting certain links lor each participant. Even more interesting are the computer implications of « flipping » between tensegrity patterns according to the problem faced by the group.

(50) " A fully relaxed spherical tensegrity structure may be crumpled together in a light bundle without hurling it, (list as a net shopping bag can be stuffed into a small space... As struts are Inserted into the spheric-tension network, the whole spheric system is seen to be expanding omnioutwardly as do pneumatic balloons when air is progressitely introduced Into their previously crumpled skins " [Fuller, p. 386-7).

It is unlikely that creating a tensegrity organization would avoid this stage, particularly in view of the lack of experience and the uncertainly as to exactly what are the snags — if such an organization can be constructed at all. The significant moment, as when constructing a model, would be when suddenly the symmetry and dynamic integrity of the whole emerges from the jumble of the parts. Whether and in what way, this awareness is more richly structured than that of a group which suddenly recognizes that « we're a team », remains to be seen,

Other possible implications

As indicated in the introduction, the significance of tensegrity is not limited to organizations. Since it is a very general approach to tension /compression relationships, wherever they may occur, it may be significant wherever there is any question of organization. It could be useful to order sets of world problems in tensegrity patterns to clarify why it is so difficult to have any impact on such equilibrium systems (51), The approach could be useful for clarifying conflicting values and needs (possibly in relation to problems). It could provide insights into a new approach to ordering, and interrelating concepts to bring out interdisciplinary dimensions (linked to great-circle patterning and symmetry ?), It also has interesting implications as a kind of three-dimensional mandata (or « psycho-cosmogramma ») with whose elements an individual can associate and interrelate a complete range of psycho-spiritual functions (52). « In becoming conscious, we gain awareness of the dualities that have moulded our psyches : activity-passivity, competition-cooperation, independence-dependence, logic-intuition, and many more... the human psyche is comprised of many different dualities that must be kept in balance in order for the individual to be whole, to be truly human » (53). Hitherto we have lacked bridges between such dualities, precisely related to a larger whole, and which are at the same time isomorphic with external realities. Tensegrity ordering restates a problem of organization. By the method of handling the dualistic compression relationships, it is no longer a question of what one is « for » or - against », of what one considers - right » or « wrong ", or « correct » or «incorrect», etc. Each such polarized perspective merely invokes the activation of the other and any associated conflict, of whatever form. Tensegrity ordering balances and interrelates such dualistic perspectives within a wider context, but without suppressing their significance — the reality of each dualistic dynamic is in fact essential to the structure of the larger whole. The challenge is then more to see (i) how such dualities interweave, (ii) whether irregularities in the pattern are due to inadequate attention, discrimination or detachment, and (iii) what emerges from consideration of the whole and how this affects understanding of the parts. A possible step then becomes one of switching to new tensegrity patterns by « reinterpreting " the whole. Each such pattern may bring out or suppress nodes, although each is always potentially present.

There is also the possibility that tensegrities may be used to represent stages in a process over time, rather than processes at a particular time. Tensegrities also seem to be helpful in relation to the dialectic approach, especially in the manner in which they represent thesis, anti-thesis and synthesis within a larger whole, itself susceptible to refinement.

Another important possibility arises from the fact that the most fundamental dyadic relationships are of such a degree of abstraction that they cannot be properly contained by verbal descriptors whose elements are often themselves determined by. affected by, or in some way incorporated within such relationships. It is therefore difficult to comprehend them adequately, because of the proportion of the totality of experience which is inherent within them. They may however be « projected » down into a system of more elements in which aspects of the dyadic relationship are represented. It may well be that only such aspects can be understood and that not even the existence of the basic relationship is suspected. This is particularly so because at each new step down in the projection, new axes and planes of symmetry may emerge accompanying the new surface features. Each of these may help to say something different about the fundamental relationship and be closer to everyday experience.

Conclusions

The implication of the suggested parallel seems somewhat incredible. It appears preposterous to expect that any useful social structure could emerge from any approach which involved weakening the continuity within formal lines of authority (normally considered as priomordial and sacrosanct) and ensuring a continuity of liaison-type bonds (normally considered as unfortunate, necessities, it they cannot be avoided). Aside from the break with tradition, it is personally very threatening to the extent that conventional structures provide some support for a person's own personality structure — because, of course, some personalities match well with the usual hierarchical structure. Sophisticated hierarchies seem to constitute the epitomy of order, whether personal or social (54).

It is not to be expected that a conclusive case could be made in such a limited space for what constitutes a rather dramatic departure from conventional approaches to organization. The questions raised are very instructive, but further investigation is of course required to substantiate the argument, if it is valid. The social system equivalents of compression and tension need to be related more closely to existing organizational concepts. In particular it would appear that they are equivalent to some characteristics associated with formal and informal organization respectively, rather than to all such characteristics. The same distinction must be made in the case of « communication » and « task performance ». The extent to which the concepts cut across such conventional categories, or are more fundamental (56), remains to be determined — as does the manner in which the contrasting characteristics are integrated within a tensegrity pattern.

The balance struck between « system » and « network » — both sophisticated concepts of organization compared to those that came before (55) — certainly suggests the possibility of the kind of « quantum leap » in organization that is being sought everywhere with some degree of desperation. It is particularly interesting in that systems are now being seen by some as masculine, yang-type structures, whilst the rise in interest in networks is seen to be associated with a feminine, yin-type influence. The global problems we face are however unlikely to be adequately met by switching between extremes, however great the need to compensate for past imbalance. It is intriguing therefore that tensegrity offers the possibility of a kind of - androgynous » organization which could take us beyond the swings of the historical pendulum (56). It could prove fundamental to the creation of a - New Transnational Social Order ». •

(51) Yearbook of World Problems and Human Potential. Brussels. Union of International Associations/ Mankind 20X50. 1976 (especially introduction).

(52) Giuseppe Tucci. The Theory and Practice of the Mandala. London, Rider, 1961.

(53) June Singer. Androgyny. New York, Doubleday. 1976, p. 1 and 5.

(54) A few years ago Fuller's geodesic domes (one application of lensegrity principles) seemed equally preposterious. Yet an early dome, 145 feel in diameter, was erected in 22 hours for immediate use as a concert hall. Another. 384 feet in diameter, weighs only 1.200 tons, compared to the 10.000 ton dome of St Peter's in Rome (diameter 131 feet). A three-quarter sphere, 250 feet in diameter, weighs 600 tons (USA pavilion at Expo 76).

(55) system/Network complementarity. Transnational Associations. 29. 1977, 9. PP. 365-368 (especially too table).

(56) June Singer (Androgyny. Op. cit.) discusses many of the more fundamental aspects of psycho-social duality and their Integration, which should help to clarify equivalents to tension and compression.