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Transcending Psychosocial Polarization with Tensesgrity

Biomimetic clues to collective resilience and unshackling knowledge

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Introduction

This exploration follows from the preoccupation with the current level of poisonous polarization of psychosocial dynamics, as addressed previously (*Framing Dynamic Transcendence of Simplistic Cognitive Polarization*, 2021). That concluded with a discussion of a *Container for polarization -- an analogue to geodesic domes?*

Given the tensions between one or more polarized perspectives, reference was made there to the potential role of tensegrity structures, whose organizing principle is fundamental to both the architecture of geodesic domes and to that of biological cells (Donald E. Ingber, et al. *Tensegrity, cellular biophysics, and the mechanics of living systems*, *Reports on Progress in Physics*, 77, 2014, 4; Samantha Pires, *8 Incredible Structures Around the World That Use Tensegrity to Defy Gravity*, *My Modern Met*, 2 January 2021).

A problem -- of which the world now has many -- can be understood as deriving from a conflictual polarity. Studied as "problem jostling" by management cybernetician Stafford Beer, he mapped distinct problems onto an icosahedron to derive an integrative understanding (*Beyond Dispute: the invention of team syntegrity*, 1994). Beer related the pattern of tension and compression to that of a tensegrity structure. The tensegrity possibilities had also been noted on the occasion of the UN Earth Summit (1992) in *Configuring Strategic Dilemmas in Intersectoral Dialogue* (1992).

Given the demonstrated possibility of geodesic domes -- despite their seeming improbability in architectural terms -- it would seem that there is indeed potentially the possibility of analogues in psychosocial terms as "containers of polarities". As previously argued, this would seem to be natural for a knowledge-based civilization dependent to such a high degree on knowledge architecture (*Transcending Duality through Tensional Integrity*, 1978; *From Networking to Tensegrity Organization*, 1984; *From Zoom Organization to Zome Configuration and Dynamics*, 2020).

Knowledge of tensegrity has a long history, dating from the extensive articulation in terms of synergetics by Buckminster Fuller (*Synergetics: Explorations in the Geometry of Thinking*, 1975; and *Synergetics 2: Explorations in the Geometry of Thinking*, 1979). Curiously however, despite that title and Fuller's concern with the global management of resources, the strategic and cognitive implications of his work have not been considered, as argued separately (*Geometry of Thinking for Sustainable Global Governance: cognitive implication of synergetics*, 2009).

A particular concern in what follows is the failure to draw on insights highly relevant to the challenge of polarization. The feasibility of previously unimaginal structures has been demonstrated in massive architectural constructions of global form. It has been upheld as fundamental to living systems (Graham Scarr and Stephen M. Levin, *Biotensegrity: the structural basis of life*, 2014). Related insights

with respect to tension are held to apply within the brain (David C. Van Essen, *A 2020 view of tension-based cortical morphogenesis*, *Proceedings of the National Academy of Sciences*, 117, December 29, 2020, 52).

In parallel considerable insight has been derived from biology through the discipline of biomimetics, namely the emulation of the models, systems, and elements of nature for the purpose of solving complex human problems. The process of such innovative emulation can be extended to the artifacts of technology (*Engendering a Psychopter through Biomimicry and Technomimicry: insights from the process of helicopter development*, 2011).

Why is it that **so little insight has been derived from tensegrity of benefit to the strategic challenge of polarized global crises**? Understood more generally, some have framed this as a problem of silo thinking and a failure of joined-up thinking, now increasingly perceived as vital, especially to communities. It is ironic -- even amusing -- to contrast the array of institutional silos with the strategic resilience implied by the dynamics of tensegrity structures. **Is the formal institutional preoccupation with tensegrity essentially a curious metaphor of its own failure to embody the dynamics it explores**? Are university faculties to be understood as "silos" cultivating thinking of that nature? This would follow from the insight of Gregory Bateson: *We are our own metaphor*.

A further curious phenomenon is the extent to which potentially vital **knowledge is "shackled" -- if not "incarcerated"** -- by an overriding preoccupation with intellectual property, copyright and patent claims. This is ironically evident in the early competing claims regarding tensegrity itself by Buckminster Fuller, David Georges Emmerich, and Kenneth Snelson. The associated dynamics extend to selective citation of relevant insights -- partly determined by undeclared inter-institutional and inter-personal issues (*Knowledge Processes Neglected by Science: insights from the crisis of science and belief*, 2012). Should the agents in such disputes be more appropriately understood as forming a tensegrity?

The (necessary?) contradictions are further highlighted by the original patent for tensegrity accorded to Buckminster Fuller (*Tensile-integrity structure*s, United States Patent 3,063,521, 13 November 1962) -- to be compared with Fuller's misleading promotional account of the global significance of tensegrity (*Tensegrity - The Geometry of Thinking, Exhibition Catalog, Cooper Hewitt Museum of Design*, 1976).

The challenge applies as much to "synergetics", and the developers of those insights, as to tensegrity -- most evidently in the imagery illustrative of their future potential, as envisaged by René Motro (*Tensegrity: Structural Systems for the Future*, 2003). In a period of global crisis, the world is effectively held to ransom -- as currently illustrated by the debate regarding the patenting of vaccines (*COVID-19 Vaccine: countries call on drug companies to share know-how*. *The Denver Post*, 1 March 2021). More generally it should be asked whether effective remedial strategies can be designed without being embroiled in such narrow, self-seeking preoccupations -- usefully caricatured as a "mine-field" (*Future Coping Strategies: beyond the constraints of proprietary metaphors*, 1992).

There is a further irony meriting recognition -- given the origin of "tensegrity" as a combination of "tension" and "integrity". Integrity of any kind -- institutional, academic, or personal -- is now highly challenged, suspect, if not increasingly elusive. This gives rise to highly divisive dynamics and an associated pattern of tensions. **How might the potential of "tensional integrity" then be recognized as fundamental to requisite global resilience?** That those associated with each "silo" are convinced of their own integrity is self-evident, but merits consideration of the concluding insight from a historical perspective offered by Nicholas Rescher:

> For centuries, most philosophers who have reflected on the matter have been intimidated by the strife of systems. But the time has come to put this behind us -- not the strife, that is, which is ineliminable, but the felt need to somehow end it rather than simply accept it and take it in stride. To reemphasize the salient point: it would be bizarre to think that philosophy is not of value because philosophical positions are bound to reflect the particular values we hold. (*The Strife of Systems: an essay on the grounds and implications of philosophical diversity*, 1985)

It is within this constrained context that it is appropriate to explore, however speculatively, the possibility of **global configuration of fundamental polarities in the form of tensegritie**s -- recognizing that the cognitive challenge may be dimensionality of a higher order, 4D or more. As an exercise the argument presents the Ten Commandments of the Abrahamic religions as a set of polarities coherently integrated into a dodecahedral tensegrity -- to clarify systemically the problematic dynamics relating to "Thou shalt not kill".

Eliciting provocative clues for psychosocial challenges

In the valuable summary of tensegrity by Donald E. Ingber and Misia Landau (*Tensegrity*, *Scholarpedia*, 7, 2012, 2), the authors note:

> Fuller and Snelson used the principle of tensegrity to create structures that were flexible and firm, and engineers, architects, and artists would build on their work throughout the last century and into the present one. Over the past 20 years, there has been an explosion of activity in the areas of civil engineering and architecture, inspired in part by the writings of René Motro, Robert Skelton, and Robert Burkhardt, whose efforts to systematize, categorize, and develop algorithms for the building of a wide range of tensegrity structures have made tensegrity design accessible to a wider audience (Motro, 2003; Skelton and de Oliveira 2009; Burkhardt, 2008). Mathematicians such as Robert Connelly have been studying the underlying geometric principles of tensegrity structures, defining them as a system of points and vertices, in an effort to understand how various tensegrity structures maintain their stability and to define which structures are possible and which are not (Connelly and Back, 1998). Snelson and other artists have continued to employ the principles of tensegrity to create structures of great strength, resilience, and beauty....
>
> One of Fuller's favourite sayings was that nature has no separate departments of mathematics, physics, chemistry, biology, art, or architecture. To fully explore tensegrity, one must span all these disciplines. Many have made this leap -- their efforts can be seen in fields as diverse as nanotechnology, tissue engineering, architecture and space exploration. If the future is one in which

> solutions to our most pressing societal and environmental problems come from nature, then tensegrity will likely become even more central.

Restrictive definitions of tensegrity? It is surprisingly valuable to note the variety of definitions of tensegrity in the *Tensegrity Wiki*. For example, René Motro has developed a comprehensive definition: as *systems in a stable self equilibriated system comprising a discontinuous set of compressed components inside a continuum of tensioned components*.

Despite the interdisciplinary implications suggested by some authors, it is notable that some definitions are more restrictive in implication than others. This is somewhat evident from the major categories of the *Tensegrity Wiki* and the almost complete absence of any reference to the psychosocial sciences.

Systemic reframing? In a spirit inspired by the possibilities of biomimicry and technomimicry cited above, there is therefore a case for "re-reading" the abstract of a key review of the relevance of tensegrity to biological structure, namely the *Tensegrity, cellular biophysics, and the mechanics of living systems (Reports on Progress in Physics*, 77, 2014, 4) by Donald E Ingber, Ning Wang and Dimitrije Stamenović. In engaging in re-reading the abstract, consideration could be given to the terms *[italicised]* that might be fruitfully substituted for those ***[bold, italicised]*** on which the abstract is focused:

> The recent convergence between physics and ***biology*** *[psychology? sociology?]* has led many physicists to enter the fields of ***cell*** *[group? concept? belief system?]* and developmental ***biology*** *[psychology? sociology?]*. One of the most exciting areas of interest has been the emerging field of ***mechanobiology*** *[cognitive psychology?]* that centers on how ***cells*** *[groups? belief systems?]* control their ***mechanical*** *[cognitive dynamic?]* properties, and how *physical* ***[psychosocial?]*** forces regulate *cellular* ***[group?]*** *biochemical* ***[psychosocial?]*** responses, a process that is known as ***mechanotransduction*** *[psychosocial transduction?]*. In this article ***[hypothetically]***, we review the central role that tensegrity (tensional integrity) architecture, which depends on tensile prestress for its ***mechanical*** *[psychosocial?]* stability, plays in ***biology*** *[psychosocial systems?]*. We describe how tensional prestress is a critical governor of ***cell mechanics*** *[psychosocial dynamics?]* and function, and how use of tensegrity by ***cells*** *[groups? belief systems?]* contributes to ***mechanotransduction*** *[psychosocial transduction?]*. Theoretical tensegrity models are also described that predict both quantitative and qualitative behaviors of living ***cells*** *[groups? belief systems?]*, and these theoretical descriptions are placed in context of other ***physical*** *[psychosocial?]* models of the ***cell*** *[group? belief system?]*. In addition, we describe how tensegrity is used at multiple size scales in the hierarchy of life -- from individual molecules to whole living ***organisms*** *[communities?]* -- to both stabilize ***three-dimensional*** *[N-dimensional?]* form and to channel forces from the macroscale to the nanoscale, thereby facilitating ***mechanochemical*** *[cognitive?]* conversion at the ***molecular*** *[fundamental conceptual?]* level.

This suggested exercise is necessarily ridiculous from within the perspective of an academic silo. However there are traces there of more general implications through the reference to "structures" and "forms". The exercise would however be meaningful from a general systems perspective, as originally framed in 1954 by biologists Ludwig von Bertalanffy and Ralph Gerard, economist Kenneth Boulding, and mathematician Anatol Rapoport. The exercise might be understood to be in accord with more recent quests for a pattern language. It is somewhat ironic that the excellent summary of tensegrity by the lead author (as noted) should appear in *Scholarpedia*, a specialized encyclopedia supported by the Brain Corporation, presumably with a degree of cognitive focus, given its emphasis on artificial intelligence (Donald E. Ingber and Misia Landau, *Tensegrity*, *Scholarpedia*, 7, 2012, 2)

Sociophysics? The provocative nature of the exercise merits consideration in terms of the literature of sociophysics, itself subject to the problematic dynamics between the authors and their emphases -- with several "generations" of social physicists, and a current emphasis on big data exploited for commercial purposes. Most notable is the work of Paris Arnopoulos (*Sociophysics: cosmos and chaos in nature and culture*, 2005). Elsewhere Arnopoulos explores the possibility of a "neoethics" -- which might be said to be a characteristic of a New Renaissance (*Nova Magna Moralia -- physics-ethics-politics: neoclassic concepts for postmodern times*, *Skepsis: a journal of philosophy and interdisciplinary research*, 2002-3).

More recently there have been a large number of social science papers that use mathematics broadly similar to that of physics, and described as "computational social science". However, given the recent data mining scandals in use of profile data in manipulation of democratic elections, the proponents of other flavours of "sociophysics" as a discipline merit a degree of challenge in claiming paternity of it, as with Serge Galam (*Modeling the Forming of Public Opinion: an approach from sociophysics*, *Global Economics and Management Review*, 18, 2013). The issue also merits attention in the light of the so-called Sokal Affair and related commentary (Alan D. Sokal and and Jean Bricmont, *Fashionable Nonsense: postmodern intellectuals' abuse of science*, 1998). This is especially the case with the progressive development of algorithms of relevance to aspects of governance by AI.

It is appropriate to note that the different studies of the controversial field of sociophysics do not consider derivatives of time greater than acceleration, despite their potential relevance to the modification and control of public opinion

Morphogenesis and catastrophe? With respect to the prevailing loose framing of "change", it is interesting to note the value attached to the morphogenesis of a butterfly as a metaphor for change in psychosocial systems. From the original perspective of general systems, it is intriguing to note the recognition that structurally, bodies of organisms can be described as tensegrity systems, "fractally self-similar" from whole-body to cellular levels, as argued by Patrick Cabe (*All Perception Engages the Tensegrity-Based Haptic Medium*, *Ecological Psychology*, 31, 2018, 1).

Understood in more generic terms, such transformation is a theme central to the work on catastrophe theory of René Thom (*Structural Stability and Morphogenesis*, 1972). As a topologist, he himself applied his insights to semiotics through an exploration of "semio-

physics" (*Semio Physics: A Sketch*, 1990). The question meriting exploration is the form of any "cognitive catastrophe" through which an existing pattern of understanding is transformed to enable a new pattern to emerge (*From performance to morphogenesis and transformation*, 2013).

Catastrophe theory has been applied to tensegrity structures by Alexander Heaton and Sascha Timme (*Catastrophe in Elastic Tensegrity Frameworks*, *arxiv vanity*, October 2020)

> For any fixed parameter values, the stable equilibrium position of the framework is determined by minimizing an energy function subject to algebraic constraints. As parameters smoothly change, it can happen that a stable equilibrium disappears. This loss of equilibrium is called `catastrophe' since the framework will experience large-scale shape changes despite small changes of parameters. Using nonlinear algebra we characterize a semi-algebraic subset of the parameter space, the catastrophe set, which detects the merging of local extrema from this parametrized family of constrained optimization problems, and hence detects possible catastrophe.

Quantum insights beyond a Newtonian framing? Clearly it could be argued that the failure of systems of governance to encompass effectively the challenges of the times could be attributed in part to reliance on assumptions inspired by Newtonian understandings of force -- evident in references in the above abstract to "mechanotransduction". Such assumptions are appropriately challenged by demonstrated viability of quantum computing with the potential implications for the social sciences (Alexander Wendt, *Quantum Mind and Social Science: unifying physical and social ontology*, 2015). This is consistent with the exploration of quantum cognition as an emerging field which applies the mathematical formalism of quantum theory to model cognitive phenomena such as information processing by the human brain, language, decision making, human memory, concepts and conceptual reasoning, human judgment, and perception

Curiously in the chaotic period, with its multiplicity of essentially simplistic references to "change", and the quest for growth "acceleration", the constraints of such "mechanical" metaphors are not called into question. The obvious instabilities which become evident merit reframing in the light of higher derivatives of time, as discussed separately (*Embodying the future through higher derivatives of time*, 2018). There is a nice irony in the terminology of quantum field theory in that their emergence as "ghosts" needs to be constrained by more insightful models. Ghosts as an unphysical state are necessary to keep gauge invariance in theories where the local fields exceed a number of physical degrees of freedom. To the extent that these are equivalent to "snakes" undermining viable nuclear fusion, these bear comparison with the "animal spirits" famously identified by John Maynard Keynes.

It is in this sense that there is a case for exploring higher derivatives of time (termed jerk, jolt and snap) and their cognitive implications (*Psychosocial implication of jerk, jolt, jounce and snap?* 2018). A case could then be made for relating psychosocial implications of tensegrity to "jounce" (*From sociophysics to learning to jounce?* 2018).

Cognitive physics and Psychophysics? The new framing of cognitive physics has been explored in terms of its relevance to artificial intelligence (Deyi Li and Yi Du. *Cognitive Physics for Swarm Intelligence*. *Artificial Intelligence with Uncertainty,* CRC Press, 2016). It is a feature of knowledge organization as argued by GuihuaWena, et al, *Cognitive gravitation model for classification on small noisy data Neurocomputing* 118, 22 October 2013)

> When performing the classification on the high dimensional, the sparse, or the noisy data, many approaches easily lead to the dramatic performance degradation. To deal with this issue from the different perspective, this paper proposes a cognitive gravitation model (CGM) based on both the law of gravitation in physics and the cognitive laws, where the self-information of each sample instead of mass is applied.

Potentially more intriguing, in the quest for higher orders of comprehension and memorability in the psychosocial realm, is exploration of the role of music as argued by Shankha Sanyal, et al. *Chaotic Brain, Musical Mind: a non-linear eurocognitive physics based study Journal of Neurology and Neuroscience*, 2016

> Music engages much of the brain, and coordinates a wide range of processing mechanisms. This naturally invites consideration of how music processing in the brain might relate to other complex dynamical abilities. The tremendous ability that music has to affect and manipulate emotions and the brain is undeniable, and yet largely inexplicable. The study of music cognition is drawing an increasing amount of research interest. Like language, music is a human universal involving perceptual discrete elements organized into hierarchically structured sequences. Music can thus provide the study of brain mechanisms, underlying complex sound processing, and also can provide novel insights into the functional and neural architecture of brain functions.

Yet to be explored, is there an existential dimension to tensegrity, as argued by Luca Tateo (*Tensegrity as existential condition: the inherent ambivalence of development, Cultural Psychology of Transgenerational Family Relations*, January 2017)? The possibility is developed separately:

> We conceptualized the Self as a dynamic semiotic system in constant evolutive tension, rather than a system in equilibrium adapting to the environmental changing conditions. Then, we propose to replace the concept of stability and continuity of the Self with the more fruitful idea of tensional integrity (Giuseppina Marsico and Luca Tateo, *Borders, Tensegrity and Development in Dialogue*, *Integrative Psychological and Behavioral Science*, 51, 2017, 2)

The considerations of Paris Arnopoulos with respect to sociophysics (as mentioned above) led him to reflect on the wider implications for psychophysics (*Psychophysics: nature-culture and mind-body relationships*, 2004). The discipline of psychophysics has been described as the analysis of perceptual processes by studying the effect on a subject's experience or behaviour of systematically varying the properties of a stimulus along one or more physical dimensions (G. Gescheider, *Psychophysics: the fundamentals*, 1997).

Biotensegrity? The recognition of the biological role of tensegrity noted above has more general implications. As argued by John Sharkey, bespoke dissections with a "biotensegrity" focus are providing a new vision and understanding of the continuity of human form. John Sharkey's fresh new look at human connective tissue highlights its role in providing continuous tension throughout its network. Biotensegrity is emerging as the most significant development in human anatomy in recent years. (*BioTensegrity: a new anatomy for the 21st century? International Conference on Anatomy and Physiology*, 2016).

The theme is developed by others:

- B. Bordoni, et al: *Biotensegrity or Fascintegrity?*(*Cureus* 11, 2019, 6)
- Bob Fong: *Tensegrity and your fascia: a "whole body" approach to treatment* (28 November 2016)
- Jean Claude Guimberteau and Colin Armstrong: *Architecture of Human Living Fascia: the extracellular matrix and cells revealed through endoscopy*, 2015)
- Graham Scarr and Stephen M. Levin: *Biotensegrity: the structural basis of life* (2014)
- R. L. Swanson: *Biotensegrity: a unifying theory of biological architecture with applications to osteopathic practice, education, and research*. (*Journal of the American Osteopath Association*, 2013, 113)

Organization development? As extensively argued by Gagandeep Singh, the term can be used to explore psychological and sociological dimensions of an organization including role taking, conflict, individual and group processes within the organization, where we sought to define the continuous pulls and the divergent pushes that lend a design and structure to the organization, apart from defining the nature of extant culture within (*The Tensegrity Mandala: a model for organization design*, *Integral Leadership Review*, January 2011; also incorporated into a book).

The author defines and symbolizes the nature of tension between two key "Voices" – the Voice of Wealth and the Voice of Customer. The strategizing tension, then refers to how the patterns, choices, dilemmas, and perspectives evolve and get deployed on a daily basis as opposed to the content approach -- a strategic plan or ploy.

> The Organization can be now depicted as a three dimensional Mandala, where the Tensegrity offered balances and interrelationships on dualistic perspectives and dilemmas within each two voices comprising a tension. Tensegrity helps us restate some of the problem of organizational conflicts -- technology demands versus wealth creation, employee needs versus investor concerns, employee needs versus technology constraints etc. By the handling the dualistic compression relationships in a holistic structure, 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.... We find that the tetrahedron as the most apt polyhedron for representing the Tensegrity Mandala.

Reframing catastrophic political correctness in academia? There is considerable irony to the fact that as lead author of the above extract, Donald Ingber, is located in the Wyss Institute for Biologically Inspired Engineering of the Harvard Medical School. Its website uses the slogan: **Breakthrough discoveries cannot change the world if they do not leave the lab**. It indeed focus on "biological design principles to develop new engineering innovations that will transform medicine and create a more sustainable world".

The irony derives from the fact that Harvard University is an academic icon for the world which has been highly challenged in social media by internal psychosocial dynamics over the past decade, as indicated by the following:

- Sa'ed Atshan and Scott Poulson-Bryant: *Correcting the Incorrect, Harvard Political Review*, 19 February 2012; Anonymous: *When Political Correctness Is Incorrect* (*Harvard Political Review*, 19 February 2012)
- Jenna Robinson: *Harvard bows to political correctness* (*The Detroit News*, 4 March 2018)
- Robin J. Ely, et al: *Rethinking Political Correctness*. (*Harvard Business Review* 84, 2006, 9)
- Ben Bowles: *Cancel culture demands Harvard rescind degrees of Trump officials, allies (Liberty Unyielding*, 18 January 2021)

The question to be asked is why an institute aspiring to "create a more sustainable world" has been unable to reframe the polarities underlying the dynamics of political correctness in which it is locally embedded (Pippa Norris, *Closed Minds? Is a 'Cancel Culture' Stifling Academic Freedom and Intellectual Debate in Political Science? Harvard Kennedy School of Government*, August 2020). If it is indeed the case that "breakthrough discoveries cannot change the world if they do not leave the lab", does its aspiration to "transform medicine" evoke the proverbial challenge: physician, heal thyself?

Tensegrity form-finding of relevance to integrative configuration of polarities

An appropriately general understanding of "form" is evident in the early study of the process of design by Christopher Alexander (*Notes on the Synthesis of Form*, 1964). This preceded his widely known exploration of *A Pattern Language* (1977) and was followed by an extensive study of *The Nature of Order* (2002-2004). Together these themes help to frame the question of forms relevant to structures which share organizing principles with nature.

As structures in 3D, there is a tantalizing relationship between tensegrities and relatively symmetrical polyhedra. In the quest for configuration relevant to holding arrays of polarities, it could be assumed that "form-finding" would use the many polyhedra as a resource (*Identifying Polyhedra Enabling Memorable Strategic Mapping*, 2020). This is not the approach most evident in the literature, as indicated. It is in this sense that **the following abstracts merit "re-reading" to detect their "unacknowledged" implications for**

psychosocial structures, as in the provocative exercise above.

For A. G. Tibert and S. Pellegrino. *Review of form-finding methods for tensegrity structures*. *International Journal of Space Structures* 18, 2003, 4):

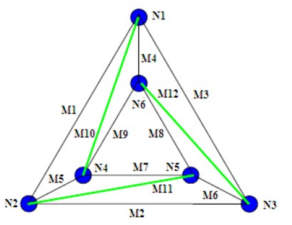
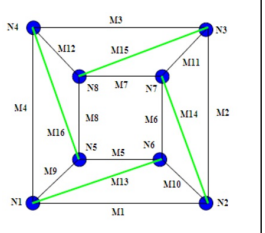
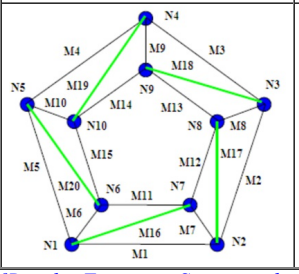
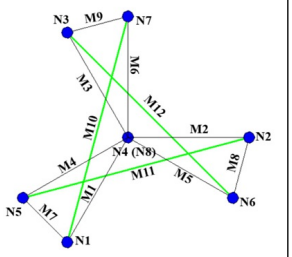
> Seven form-finding methods for tensegrity structures are reviewed and classified. The three kinematical methods include an analytical approach, a non-linear optimisation, and a pseudo-dynamic iteration. The four statical methods include an analytical method, the formulation of linear equations of equilibrium in terms of force densities, an energy minimisation, and a search for the equilibrium configurations of the struts of the structure connected by cables whose lengths are to be determined, using a reduced set of equilibrium equations. It is concluded that the kinematical methods are best suited to obtaining only configuration details of structures that are already essentially known, the force density method is best suited to searching for new configurations, but affords no control over the lengths of the elements of the structure. The reduced coordinates method offers a greater control on elements lengths, but requires more extensive symbolic manipulations.

For A. H. Nadia Farhana, C. L. OH, H. M. Yee and Anizahyati Alisibramulisi. *Overview on the Form-Finding of Tensegrity Structure*, *International Journal of Engineering and Technology*, 7, May 2018):

> This paper presents an overview of the previous research on the form finding structures which include tensegrity and biotensegrity structure. Tensegrity systems have been widely used for many applications due to the stability and flexibility of the structures. On technologies era nowadays, a stable structure is needed to implement for new developments especially robotics and machineries. Therefore, the importance of finding the shape or design configuration is to ensure it is in self-equilibrium which able to support itself. In order to build new structures which lies on general requirement, previous researchers have proposed several form-finding methods for instance by using force density method, advance force density method, finite element method, dynamic relaxation method, genetic algorithm, novel linear approach and Monte Carlo method. What kind of stable structures can be produced and how efficient the structures by using those methods? In this paper, understanding on the form-finding methods and various numerical examples of form-finding conducted in previous studies are presented to enhance researchers' knowledge on the form-finding of tensegrity structures.

For Qian Zhang, et al, *Closed-Form Solutions for the Form-Finding of Regular Tensegrity Structures by Group Elements*, *Symmetry*, 12, 2020, 3):

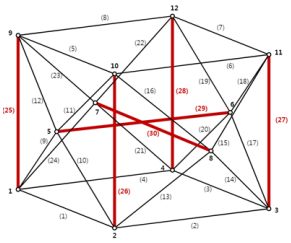
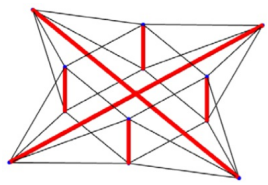
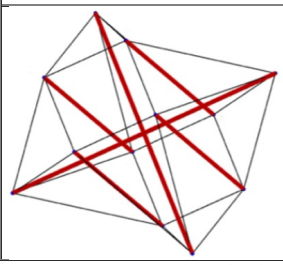
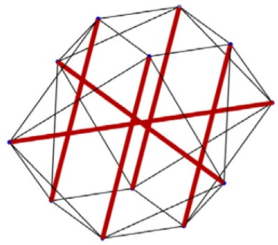
> An analytical form-finding method for regular tensegrity structures based on the concept of force density is presented. The self-equilibrated state can be deduced linearly in terms of force densities, and then we apply eigenvalue decomposition to the force density matrix to calculate its eigenvalues. The eigenvalues are enforced to satisfy the non-degeneracy condition to fulfill the self-equilibrium condition. So the relationship between force densities can also be obtained, which is followed by the super-stability examination. The method has been developed to deal with planar tensegrity structure, prismatic tensegrity structure (triangular prism, quadrangular prism, and pentagonal prism) and star-shaped tensegrity structure by group elements to get closed-form solutions in terms of force densities, which satisfies the super stable conditions.

Rotary symmetry tensegrity structures cables (black lines) and struts (green lines).			
Triangular prism (9 cables; 3 struts)	Quadrangular prism (12 cables; 4 struts)	Pentagonal prism (15 cables; 5 struts)	Star-shaped structure (9 cables; 3 struts)
			
Reproduced from *Closed-Form Solutions for the Form-Finding of Regular Tensegrity Structures by Group Elements*, *Symmetry*, 12, 2020, 3			

For Seunghye Lee, Jaehong Lee and Joowon Kang, *A Genetic Algorithm Based Form-finding of Tensegrity Structures with Multiple Self-stress States,* *Journal of Asian Architecture and Building Engineering*, 16, 2017, 1):

> A form-finding method of tensegrity systems is a process of finding an equilibrium configuration and a key step in the design of tensegrity. Over the past few years, several studies have been made on the form-finding methods of tensegrity systems, however, these methods are limited in the tensegrity systems with multiple self-stress states. In this study, a numerical method is presented for form-finding of tensegrity structures with multiple states of self-stress by using a force density method combined with a genetic algorithm. The proposed method can design the desired tensegrity shape through a genetic algorithm with appropriate constraints. The design variable can be uniquely defined in the case of multiple states of self-stress using only the constraint of the member types. An eigenvalue decomposition of the force density matrix and a singular value decomposition of

> the equilibrium matrix are performed repeatedly in order to determine a feasible solution for nodal coordinates and force densities. A genetic algorithm is then adopted to uniquely define a single integral feasible set of force densities. Several numerical examples are presented to prove efficiency in searching for self-equilibrium configurations of tensegrity structures. In all cases, the single integral feasible self-stress states can be obtained.

Successive application of constraints to form a viable 6-strut tensegrity in 3D			
Initial topology	With constraint 1	With constraints 1 and 2	With constraint 1, 2 and 3
			
Reproduced from *A Genetic Algorithm Based Form-finding of Tensegrity Structures with Multiple Self-stress States, Journal of Asian Architecture and Building Engineering*, 16, 2017			

For Seunghye Lee and Jaehong Lee *A novel method for topology design of tensegrity structures* *Composite Structures,* 152, May 2016):

> There have been few studies on a method which can specify configurations of tensegrity structures automatically. A novel method for topology design of the tensegrity structures by using a force density method combined with a genetic algorithm is presented. The method requires only nodal coordinates as initial input data. To select strut candidate groups and remove unnecessary cables, a discontinuity condition and a minimal tensegrity configuration are used, respectively. This paper will show two well-known numerical examples to prove efficiency. In conclusion, a very good performance of proposed method has been shown in the results.

For Navaneeth K. R. Pandian and G. K. Ananthasuresh, *Synthesis of tensegrity structures of desired shape using constrained minimization* *Structural and Multidisciplinary Optimization* 56, 2017, 1):

> There are two types of problems in tensegrity design: (i) form-finding when the tensegrity shape is not specified and (ii) synthesis when the tensegrity shape is specified. We address synthesis problems in this paper. We first formulated and solved an optimization problem to synthesize tensegrity structures of specified shape when the connectivity of the elements (bars and cables) is known a priori. We minimize the error in force-balance at the vertices in the desired equilibrium configuration by using force densities as the design variables. This constrained minimization problem enabled us to synthesize a known asymmetric tensegrity arch and a hitherto unknown tensegrity of biconcave shape similar to that of a healthy human red blood cell. We also extend the above method to a reduced order optimization problem for synthesizing complex symmetric tensegrity structures. Using this approach, we synthesized a truncated dodecahedron inside another truncated dodecahedron to emulate a nucleus inside a cell. We use a restricted global structure on an already available two-step mixed integer linear programming (MILP) topology optimization formulation to synthesize a non-convex tensegrity structure when only the coordinates are provided. We further improve this two-step MILP to a single-step MILP. We also present static analysis of a tensegrity structure by minimizing the potential energy with unilateral constraints on the lengths of the cables that cannot take compressive loads. Furthermore, we use this method to synthesize a tensegrity table of desired height and area under a predefined load. The prototypes of three synthesized tensegrities were made and validated.

For M. Yamamoto, B. S. Gan, K. Fujita and J. Kurokawa *A Genetic Algorithm Based Form-Finding for Tensegrity Structure* *Procedia Engineering*, 14, 2011):

> A tensegrity structure consists of a set of continuous cables in tension and a set of discontinuous struts in compression. The tensegrity structure can be classified into self-stressed and pre-stressed structures. Present paper interest is in the self-stressed tensegrity structures, since they can free standing without any support while maintaining their self-equilibrium state. In the process form-finding of a tensegrity structure, some constraints are usually introduced for geometry and/or member to ensure uniqueness of the solution. The tensegrity structures are indeterminate problems in most cases. In this paper, a genetic algorithm based form-finding for tensegrity structures is presented to assist designers to obtain tensegrity structures with less design variables. A novel and versatile numerical form-finding procedure which requires only a minimal knowledge of initial structure configuration is adopted. The procedure needs only the prototype of each member, i.e. either compression or tension, and the connectivity information of members. The connectivity of members and its prototype information are encoded to form an individual population used in genetic algorithm searching problems. As for the fitness evaluation to each population, the existence of self-stressed state in each population is sought. At the end, some numerical examples are given to show the efficiency of the present study and its ability in searching new configurations of tensegrity structures.

Psychosocial tensegrity as a necessarily mysterious collective blindspot?

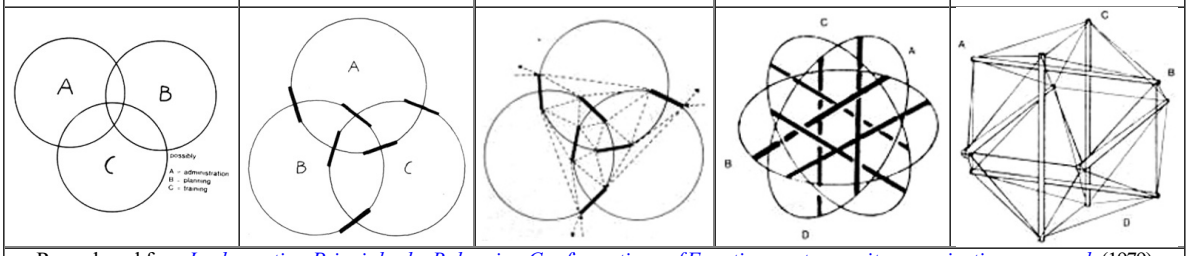
Balancing "Yes" and "No": Ironically it could be argued that the principle of tensegrity is best understood as the simple challenge of managing a seemingly incommensurable array of conditions requiring a "Yes" response, together with others requiring "No". Clearly "Yes" can be understood as what is considered "positively" desirable and relevant to any undertaking -- typically evident in the carefully cited array of references in any academic study and epitomized by any focus on "*Getting to Yes*" in negotiation. However "No" then calls for recognition of the unacceptable -- the "negative" to be firmly rejected, ignored, or excluded in some way as irrelevant.

Such rejection may notably include inadvertent or unconscious omission -- ignoring whatever is implied. Citation analysis is not designed to detect these -- even in relation to interdisciplinary research. This merits reflection in terms of the arguments of Terrence Deacon (*What's Missing from Theories of Information?* 2010) and Roberto Casati (*Counting the hoes*, 2004).

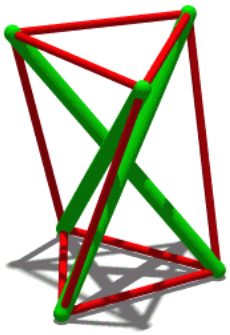
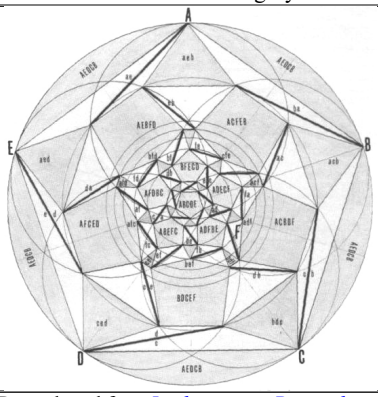
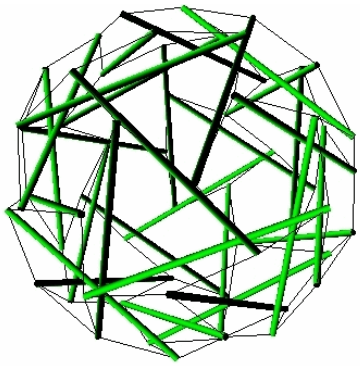
It is especially intriguing to note the focus of the *Tensegity Wiki* ("*The Encyclopedia of Tensegrity*") and the manner which -- at least in its current form -- avoids any significant reference to the psychosocial. Its focus is consistent with the prevailing preoccupation with the tangible -- whilst claiming that ***Tensegrity is the way the world organizes itself***. This avoidance is evident on the page of multiple *Definitions of Tensegrity* -- with its questionable content framed by those with vested interests in particular understandings of "the way the world organizes itself".

The challenge in practice is that viable integration calls for interrelating the "desirable" with the "undesirable" -- supporting arguments and principles with opposing arguments and contrary principles. These are the flexible "cables" and incompressible "struts" of a psychosocial tensegrity respectively. Ignoring contrary perspectives offers only a naive comprehension of a viable system -- one lacking compressive force which ensure the appropriate balance of tensions, as with the interconnected ropes and stays in the rigging of sailing ship. In cybernetic terms this can be understood as a balance between positive and negative feedback -- and potentially those of a higher order.

Balancing configurations of functions: An earlier exploration of the possibility was framed as *Implementing Principles by Balancing Configurations of Functions: a tensegrity organization approach* (1979) and explained through the following succession of diagrams.

Phases in transformation of a 2D Venn diagram representation of principles into a 3D tensegrity				
				
Reproduced from *Implementing Principles by Balancing Configurations of Functions: a tensegrity organization approach* (1979)				

Using the same approach as above, in the 1979 exercise the circles A, B, C, D, E and F can be interlinked to form the 2D pattern in the central image. This is a two-dimensional representation of the tensegrity icosidodecahedron shown (as an icosahedron in the animation) below right in three dimensions. The **shaded pentagons** in the central image are distorted progressively away from the centre but are all the same size in in the animation, as are the **shaded triangles**. The edges of these areas are the **connectors**. The **separators** are shown in thickened black lines, again distorted in length away from the centre. The five outermost shaded portions fold up together (like petals) to form the twelfth pentagon.

Indications of configurations of functions		
Animation of simplest tensegrity	Icosidodecahedron tensegrity in 2D	Animation of icosahedron
		
Cmglee, CC BY-SA 3.0, via Wikimedia Commons	Reproduced from *Implementing Principles: a tensegrity organization approach* (1979)	

Aspects of the argument have been variously developed further:

- *Using Disagreements for Superordinate Frame Configuration* (1992)
- *Tensing Associative Networks to contain the Fragmentation and Erosion of Collective Memory* (1980)
- *The Future of Comprehension conceptual birdcages and functional basket-weaving* (1980)
- *Antagonistic Dualities: Polarization and Paradox* (1983)
- *Conceptual Scaffolding and Prosthetics* (1992)

- *Configuring Conceptual Polarities in Questing: metaphoric pointers to self-reflexive coherence* (2004)
- *Polyhedral Empowerment of Networks through Symmetry: psycho-social implications for organization and global governance* (2008)
- *Oppositional Logic as Comprehensible Key to Sustainable Democracy: configuring patterns of anti-otherness* (2018)

Relevance to governance: Shann Turnbull has variously argued that the contrary behaviour of individuals maintains the integrity of their existence and ability to reproduce thereby representing "social tensegrity" -- also emerging in organizational forms. He explicitly introduces the concept in his thesis of 2000, later published in book form (*Designing Resilient Organisations -- with operating advantages for public, private, non-profit and government entities and their stakeholders*, 2014). Social tensegrity is then the ability for individuals or organizations to maximise corrective responses to disturbances while minimising the transactions within or between individuals. This provides them with a requisite variety of responses to discover those responses that will sustain their life in complex unknowable dynamic environments (*Design Concepts for Governance Architects SSRN Electronic Journal*, 2000).

Subsequently, in his role as Principal of the International Institute for Self-governance, Turnbull has argued with James Guthrie -- dropping the qualifier "social" -- that:

> A search of the titles, abstracts, and keywords of over 861,000 articles archived in the *Social Science Research Network* suggests that these concepts have not become widely recognised as being part of complexity theory... Tensegrity creates the most efficient way to either create or survive complexity... It is a feature that could improve the health, efficiency, resiliency, and survivability of organisations, yet management theorists and most practitioners have neglected it, despite its benefits. Tensegrity radically challenges a mindset seeking to promote cooperation, teamwork, and accountability only upwards, and control only downwards. (*Simplifying the management of complexity: as achieved by nature*, *The Journal of Behavioural Economics and Social Systems*, 1, 2019,1)

Mental modes from an artistic perspective: In introducing the programme of a symposium on *Tensegrity and other Contradictory Complicities* (London, 2016), Monica Ursina Jäger justified its focus from the complementary perspective of an artist, arguing that:

> Very few researchers... have elaborated on social, political or theoretical approaches to tensegrity. This symposium takes tensegrity as a starting point to examine whether 'tensional integrity' is something other than just a spatial structure of struts and strings. Where do we recognise forms of push and pull strategies, tension-pressure relationships and stability-flexibility structures within our fields of research and interests?
>
> In the face of he current political climate with social shifts, systemic ruptures and collective upheaval, notions around fragility, tension and dynamic relations become more and more important. With regard to philosophical approaches, tensegrity can be understood as moments of "discontinuities installed within the continuity of time" (Ignasi Solà-Morales, *Differences: topographies of contemporary architecture*, 1996). While Solà-Morales refers in his essay "*Difference*" to built elements of the city within the continuity of time, how can we apply this notion of 'contradictory complicity' to other disciplines such as language, performance, history, politics and sociology?
>
> Can tensegrity serve as a mental model to investigate these issues? To what extent is it valuable as point of departure to re-evaluate force fields within contemporary arts? Could this idea also be applied poetologically, as an artistic approach, allowing new forms of artistic practice? Tensegrity is seemingly precarious, but proves to be a stable force in nature. Facing the challenges of the current era, it may become clear that issues around tension, resilience and integrity are at the core of the ultimate task to save our 'spaceship earth'. If art is supposed to address these questions, could tensegrity become one of the new guiding principles?

A criticism of tensegrity by George Hart merits particular consideration:

> However, the flexibility of the result is not suitable for most space-enclosing purposes, and has found much more interesting application in sculpture. (*Soda Straw Tensegrity Structures*)

This observation may not preclude the relevance of tensegrity to psychosocial space-enclosure for which possibility artistic intuition may be indicative. There is a curious irony to the formal focus of architects, as indicated, when extraordinary forms are often desired as a focus for collective inspiration -- whatever that may be held to mean.

Strategic dilemmas: In a paper on *Complex Living Tensegrities* (2006), Chris Lucas has a section on *Social Tensegrities -- understanding people dynamics.* Lucas introduces his argument by citing management cybernetician Stafford Beer, who noted the role of tensegrity in deriving the concept of syntegrity (*Beyond Dispute: the invention of team syntegrity*, 1994). For Beer, in his earlier address as chairman of the International Cybernetic Congress (**prior** to his dramatic experience in the Chile of Allende), he offered an adaptation of *Le Chatelier's Principle*:

> Reformers, critics of institutions, consultants in innovation, people in short who 'want to get something done', often fail to see this point. 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 equilibrial readjustment, which is to the observer a

> secret form of change requiring no actual alteration in the macro-systemic characteristics that he is trying to do something about. (*The Cybernetic Cytoblast -- management itself*. Chairman's Address to the International Cybernetics Congress, 1969.)

Lucas then asks:

> In tensegrity terms, our social and cultural values create a 'norm', a point in a multidimensional state space that acts as a cybernetic reference point (or attractor) in determining how we are regarded when we 'act' in such a society... How could tensegrity ideas help us escape this 'fatal attraction' ?
>
> What is missing is effective tension elements, those links joining us together, despite our different views. And this joining must be to our advantage, otherwise it simply doesn't work, it cannot be imposed as yet another external force, a 'top-down' demand, i.e. another 'compression' element, since that would simply be resisted by the status-quo. Synergy here gives us a key, since this tells us that each individual benefits from such associations and would lose out if isolated.

Relevance to psychosocial stress: Whilst it can be considered amazing that there are so few references to the "societal" applications of tensegrity, for Patrizia Anna d'Alessio (*Tensegrity and Beyond*, *Scienza & Filosofia*, 7 July 2018):

> The tensegrity concept can also be applied to social sciences, because it has to do with life in general. Thus the gliding of fibers or the dispersion of tension, minimizing compressive forces, might play a dynamic role in social life, or at least in its communication forms. For that reason we will primarily concentrate on the concept of pre-stress, eventually created by Freyssinet, but abundantly considered by Fuller and Ingber...
>
> When the concept of tensegrity finally appeared at the beginning of the 20th century, the ancient vision that a body is maintained in its *equilibrium* structure because of the elastic properties of its geometric components reappeared. Going back to pre-stress, is it possible to develop the analogy between physical and psychological stress? If a (profound) distress is able to shorten the muscles, would conversely, an (intense) pleasure have the capacity to lengthen them?

More curious is the argument that tensegrity offers a way of framing the current pandemic, as made by Florencio Travieso (*Coronavirus, Tensegrity and CSR: Year of Living Dangerously*. *HealthManagement*, 20, 2020, 10, 2020):

> We can picture the current coronavirus vaccine race as a tensegrity moment, where multiple forces are creating tension, and while all of the forces are constantly pulling, a certain stability is achieved. This article aims to give an overview of how COVID-19 and the vaccine developments will be influenced by corporate social responsibility (CSR) and how the future months will require a constant exercise of 'tensegrity'.

Relationship-centered interactions: In the absence of a substantive literature on its social implications, it is curious to note that it has been adopted as a central feature of the International Federation of Social Workers (*Invitation to Participate in the Consultation on the 'Global Social Work Agenda: the next ten years 2020-2030*).

> The existence of self and otherness entities depends on their tensegrity relationships one to the other. Social work's claim to be relationship-centred, with its domain focus on interactions and to a strong allegiance with the co-empowerment attributes of the professional-client relationship is weak in having no clearly demonstrated model to implement this claim. With the aid of a holistic, tensegrity model, social workers can learn how to focus on the intangible (relationship-centred interactions) and work through the tangible (entity-centred person and environment targets). For social work to fully transform to a relationship-centred profession in the next decade, social workers need to be familiar with the relationship discoveries in quantum science and an understanding of tensegrity in several structural systems (e.g. body anatomy, bridge engineering, cosmic stability, social relationships).

Towards polarity containment -- psychosocial tensegrity in practice

The preoccupation of architects with the application of tensegrity to innovative design is necessarily focused on the tension and compression elements recognized as "cables" and "struts". From a psychosocial perspective, these are valuable metaphors -- although detracting from subtler implications potentially vital to a global society much challenged with appropriately viable configurations of "Yes" and "No".

In that light the architectural emphasis could be understood as a tragic instance of misplaced concreteness and reification, precluding even any focus on knowledge architecture. The point has been separately explored -- *Misplaced concreteness as a form of encryption* -- as an instance of cognitive encryption (*Cognitive Encryption enabling Collapse of Civilization*, 2021).

Beyond the preoccupations with "form" and "pattern language", as noted above with respect to physical design, there are the more elusive logical and cognitive forms (G. Spencer-Brown, *Laws of Form*, 1969; Francisco Varela, *A Calculus for Self-reference*, *International Journal of General Systems,* 2, 1975, 1). Alexander's pattern language of 254 interlinked physical forms then invites reframing in psychosocial terms (*5-fold Pattern Language*, 1984).

As argued separately, society is riven by an array of fundamental polarities sustaining poisonous global discourse (*Cultivating the*

pretence of binary simplicity, 2021). The previous section offers an appreciation of a more fruitful "psychosocial architecture" through tensegrity. There is no lack of such carefully argued intuitive appreciation, most obviously by artists and embodied in many of their installations.

Missing is the ability to give form to such intuitions in practice -- and most notably conceptually and in governance. Exactly what are the incommensurable poles which take the form of polarities -- the "struts"? What are the forms of necessary association between them -- the "cables"? How do the former ensure that the latter are appropriately "tensed", so that the array gives rise to a sustainable integrated form? Expressed otherwise, what are the cognitive "ties that bind", what are the "non-negotiables" and how to comprehend their interweaving? (Francesca Polletta, *Inventing the Ties That Bind: imagined relationships in moral and political life*, University of Chicago Press, 2020; Chris Zook, *Good Strategy's Non-Negotiables*, *Harvard Business Review*,March 2012).

Missing is the meaningful translation into psychosocial terms of what for cybernetics is described as viable system theory -- somewhat ironically, since this was developed by Stafford Beer, as originator of the practicality of "syntegrity" in transforming divisive discourse (J. Truss, et al., *The Coherent Architecture of Team Syntegrity: from small to mega forms*, 2000; John Coghlan, *Reflections on the book Beyond Dispute, by Stafford Beer -- a syntegration in Switzerland*).

The challenge of isolating fundamental "poles" is illustrated by the arguments of Max Sandor (*Tensegrity in Social Movements*, 10 July 2019):

> If Hegel's *Dialectics* can be applied to social structures and movements, as has been promoted by Karl Marx, so must the laws of tensegrity, of tensional integrity. Let us look at the pair of proclaimed opposites that haunt the history of mankind for the last 200 years, Socialism and Capitalism!...
>
> Hmm, looks like our first attempt to find a pair of opposites in today's political struggle failed utterly. There no *dialectical process* within or around the opposition of *socialism* and *capitalism*. Whoever thinks otherwise has clearly not understood what *Hegel* tried to convey. Ironically, and much to our surprise, we found the dialectical principle where we least expected it: in the definition of *capitalism*.

In the quest for an application of psychosocial tensegrity in practice, it is therefore appropriate to note a remarkable study which offers a unique confluence of themes noted above (Paulo Caldeira, et al. *Linking Tensegrity to Sports Team Collective Behaviors: towards the group-tensegrity hypothesis* *Sports Medicine Open*, 6, 2020, 24). This can be understood as integrating the preoccupations of:

- biotensegrity, with its focus on cellular organization, musculature and the dynamics of the body -- medically appreciated
- mathematical considerations consistent with "form-finding" concerns
- psychosocial behaviour, exemplified by the interactions within a team and the perception of them by participants
- viable integration, exemplified by the capacity of the team to "get its act together" -- otherwise a feature of analysis of "passing patterns"
- appreciation of emergent patterns, whether by fans, participants, or in reference to the elusive "spirit of the game"

The abstract describes the study as:

> Collective behaviors in sports teams emerge from the coordination between players formed from their perception of shared affordances. Recent studies based on the theoretical framework of ecological dynamics reported new analytical tools to capture collective behavior variables that describe team synergies. Here, we introduce a novel hypothesis based on the principles of tensegrity to describe collective behavior. Tensegrity principles operate in the human body at different size scales, from molecular to organism levels, in structures connected physically (biotensegrity). Thus, we propose that a group of individuals connected by information can exhibit synergies based on the same principles (group-tensegrity), and we provide an empirical example based on the dynamics of a volleyball team sub-phase of defense.

Indicative of the suggestive level of insight associated with the study is its citation of:

- L. Laporta, et al: *Interaction network analysis of the six game complexes in high-level volleyball through the use of eigenvector centrality*. (*PLoS One*, 11 September 2018)
- J. Ribeiro, et al: *The role of hypernetworks as a multilevel methodology for modelling and understanding dynamics of team sports performance*(*Sports Medicine*, 49, 2019, 9)

With the obvious emphasis on the movement of players in ball sports, other arguments merit consideration (Cynthia Roses-Thema, *Floating Bones: A Dancer's Tensegretic Body as Teacher*, 2020; Mark Johnson, *The Meaning of the Body: aesthetics of human understanding*, 2007).

Predetermination of tensegrity forms of relevance to integrative configuration of polarities

The earlier section focused on the extensive literature on tensegrity "form-finding", which continues to be the preoccupation of architects and designers. This can give rise to polyhedral forms, as illustrated above.

A somewhat distinct approach is to explore the various classes of semi-regular polyhedra on the assumption that fundamental polarities might be fruitfully configured by them. The focus on the symmetry giving rise to such regularity follows from the concern in the earlier discussion of *Configuring polarities for cognitive engagement of higher order* (2021). There it was noted that the challenge of the

disconnect in managing complexes of strategic polarities is seemingly of little interest to mathematicians. The unresolved question with respect to complex arrays of polarities is **which of the variety of forms of symmetry enhance comprehension and memorability of coherence -- and to what degree?**

A fundamental difficulty in the use of polyhedra widely known for the symmetry is the extent to which they are effectively abstractions. They do not explicitly hold the dynamics so characteristic of polarities in psychosocial experience; these are only elusively implied (if at all). It is for this reason that the combination of tension and compression elements in tensegrities can reflect and hold such dynamics more effectively.

Of value in this respect is the study by Mihai Gabriel Constantin, et al. (*Computational Understanding of Visual Interestingness Beyond Semantics: literature survey and analysis of covariates*, 2018). This notes that among a variety of dimensions symmetry and comprehensibility were "mostly unexplored". The authors remark:

> Symmetry reflects the extent to which shape and position of visual parts match after translation, rotation or mirroring with reference to an axis or a point in space... Balance/Harmony -- Somehow related to symmetry, compositional balance "unifies the structural elements of a pictorial display into a cohesive organization or framework that helps determine the role of each element within a composition"...The memorability of an image is its intrinsic ability of being stored by our visual memory: it reflects the extent to which the image can be remembered by human mind.

To whatever extent sets of fundamental polarities can be associated with sets of principles, contradictions, or paradoxes, **there is therefore a case for exploring how the most symmetrically regular polyhedra might suggest ways of configuring those sets as tensegrities**. Every Platonic and Archimedean solid can be converted into a tensegrity structure, as noted by Martin Friedrich Eichenauer and Daniel Lordick (*How Platonic and Archimedean solids define natural equilibrium of forces as Tensegrity*, *6th International Conference on Geometry and Graphics*, 2018)

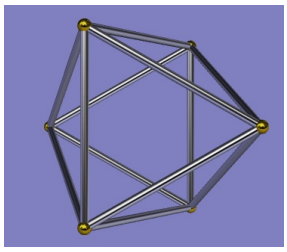
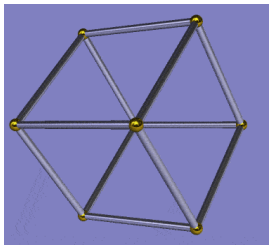
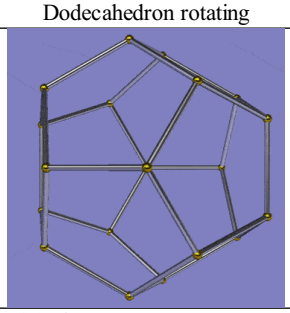
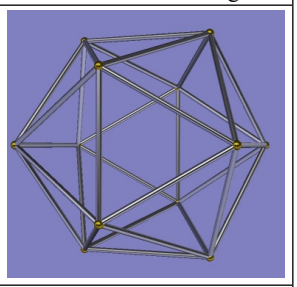
Distinct from the form-finding methods discussed above, there is a quite different set of references to methods of transforming polyhedra into tensegrities. These include:

- a procedure described and illustrated by George Hart (*Soda Straw Tensegrity Structures*)
- a development of the procedure of George Hart, with multiple illustrations, by Adrian Rossiter (*Tensegrity Models*, *Antiprism*)
- prismatic tensegrity structures, as discussed below
- a procedure described by Lutz Golbs on *Mapping solid polyhedra to tensegrity structures* (*Tensegrity Wiki*), for two methods to 'tensegrify' regular, symmetrical polyhedra (discussed further below)

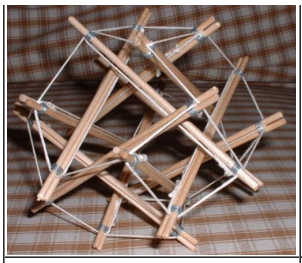
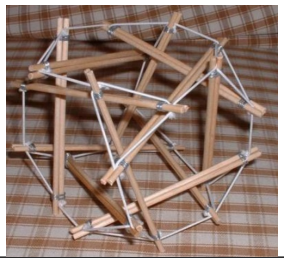
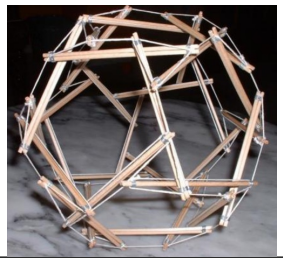
The following images, explained on the Antiprism site, are reproduced with kind permission. To clarify the explanation, animations of the associated polyhedra are juxtaposed with the tensegrity variants. The animation have been produced with the Stella 4D application, although equivalent animations can be produced with the freely available Antiprism software. The developer has indicated the intention of extending it to enable tensegrity variants of a range of polyhedra to be animated in 3D.

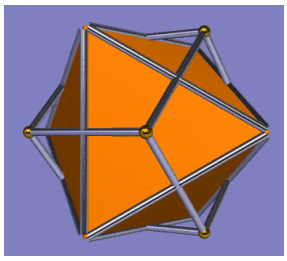
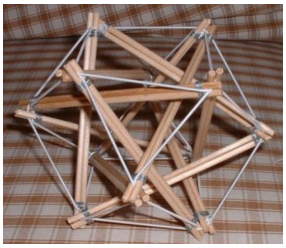
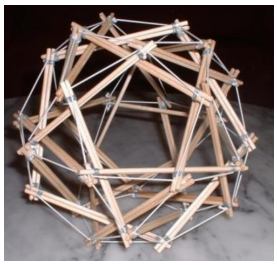
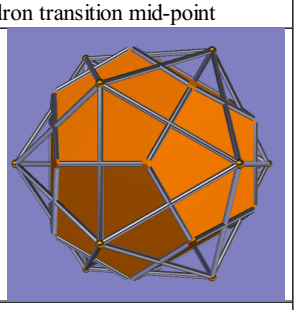
Of particular significance to the configuration of polarities, is that a process of "twisting" transforms an equal-edged polyhedron into its equal-edged geometric dual form. In the case of the regular and quasi-regular polyhedra that dual has the same shape as the "normal" dual (by polar reciprocation), although not all equal-edged polyhedra have an equal edge twisted dual. The Antiprism site notes popular puzzles associated with each form (as indicated below, where relevant).

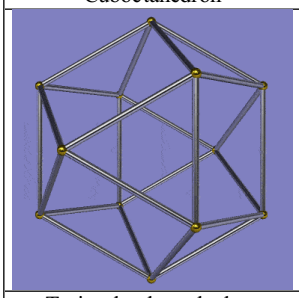
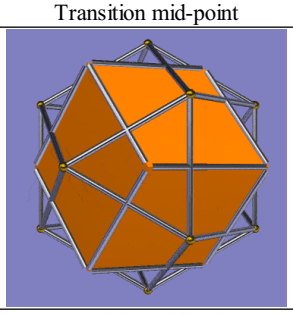
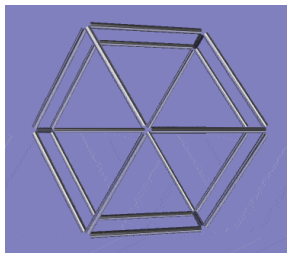
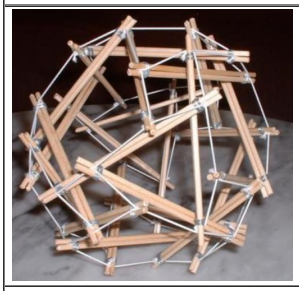
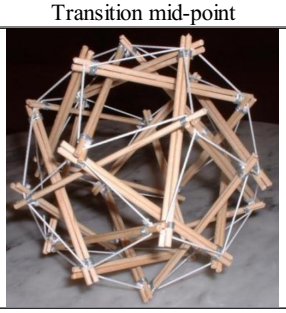
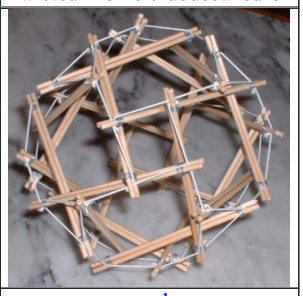
Also of relevance is the distinction between the much-studied sysmmetries of the basic polyhedra and that of the tensegrity variants. It could be assumed that the coherence of a set of polarities would be primarily associated with the former. However the tensegrity variants are derived by inserting the compression "struts" between adjacent nodes in a manner which is not evident from the form of the original polyhedra.

Basic Platonic polyhedra (sides transparent)			
Octahedron rotating	Cube rotating	Dodecahedron rotating	Icosahedron rotating
			
Prepared using *Stella Polyhedron Navigator*			

Tensegrity variants of basic Platonic polyhedra			
Reproduced from Antiprism			
Twisted octahedron	Twisted cube	Twisted dodecahedron	Twisted icosahedron

			
description / puzzles	puzzle		puzzles
struts / cables ##			

Platonic dual configurations (of the above)			
Octahedron-Cube transition mid-point		Dodecahedron-Icosahedron transition mid-point	
			
	puzzle		

Example of Archimedean polyhedron -- cuboctahedron and dual		
Cuboctahedron	Transition mid-point	Rhombic dodecahedron
		
Twisted cuboctahedron	Transition mid-point	Twisted rhombic dodecahedron
		
		puzzle

Polarities as struts? The above mentioned procedure described by Lutz Golbs on *Mapping solid polyhedra to tensegrity structures* (*Tensegrity Wiki*), indicates two methods to "tensegrify" regular, symmetrical polyhedra:

- *Connecting non-adjacent vertices with struts*: which works only for the icosahedron (v=12, e=30, f=20) and the dodecahedron (v=20, e=30, f=12). It gives rise to tensegrities with v/2 struts, namely 6 for the icosahedron and 10 for the dodecahedron

- *Converting edges into struts*: which seems universally applicable -- based on the stellation of all vertices of a regular polyhedron. The tendons then outline a stellated version of the Platonic polyhedron (for example). The vertices lose their "idealised" state and transform into a tension loop. The struts rotate around the imaginary vertex in either clockwise or counter-clockwise direction. Each strut has exactly three tendons on each end, two of which connect to the vertex loop, and one to another vertex loop. The connections from loop to loop have the same topology as the original Platonic polyhedron

Polyhedra into tensegrities using the edges to struts method								
Platonic form	faces	edges	vertices	edge per vertex	struts	'loop' tendons	'edge' tendons	minimal tendons
tetrahedron	4	6	4	3	6	4x3=12	6	18
cube	6	12	8	3	12	8x3=24	12	36
octahedron	8	12	6	4	12	6x4=24	12	36
dodecahedron	12	30	20	3	30	20x3=60	30	90
icosahedron	20	30	12	5	30	12x5=60	30	90

Matching sets of psychosocial polarities to tensegrities: case of the 10 Commandments?

Given the tensegrity models above, the basic question is what sets of polarities might be coherently configured by which models. This focuses the question of how a set of polarities is to be recognized in a generic sense.

A point of departure is the curiously unexplored collective enthusiasm for sets of a particular size. Examples include:

- *Checklist of 12-fold Principles, Plans, Symbols and Concepts: web resources* (2011)
- *Requisite 20-fold Articulation of Operative Insights? Checklist of web resources on 20 strategies, rules, methods and insights* (2018)

Corresponding 10-fold articulations might include:

- 10 hindrances (*Kleshas*) distinguished in Buddhism, as with a Ten-fold Path
- 10 Commandments fundamental to the Abrahamic religions
- 10 Guiding Principles of the International Sai Organization
- 10 Principles of Social Innovation

Given an emphasis on their singularity, comparison of the 10-fold and 20-fold sets frames the question of how these might be appropriately understood as "polarities" in a generic sense. Possibilities include

- recognition that 10-fold principles implies the polarity between adherence to them (potentially upheld as "positive" and "good") and rejection of them (potentially deprecated as "negative" and "bad"), namely 20 extremes
- recognition that a 20-fold set is potentially indicative of 20 extremes when explored in systemic terms, namely as 10 indications to be interpreted as positive feedback and 10 to be interpreted as negative feedback.

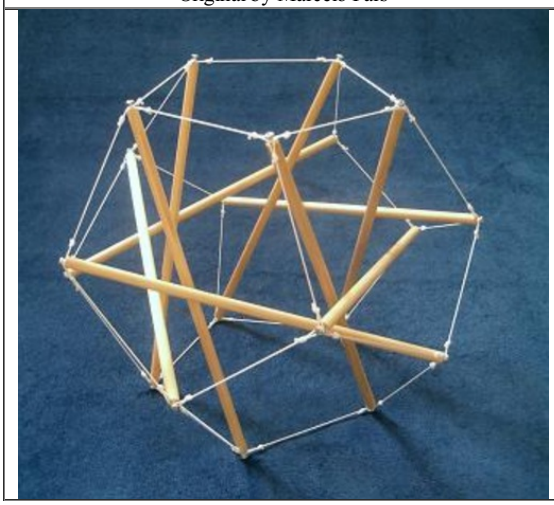
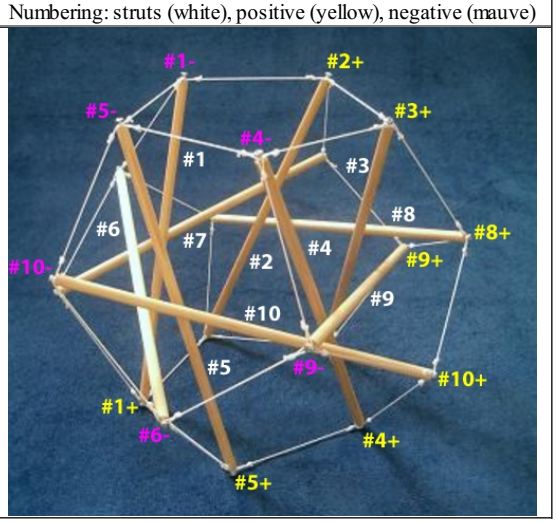
Arguably an approach of this kind recognizes the reality that in practice people may aspire to what the polarity represents in its generic sense but are effectively constrained by dynamics in which one or other pole ("positive" or "negative") is more evident. Clearly there is a question of how the "positive" pole is distinguished from, or conflated with, understanding of the polarity in its generic sense.

This question is most evident in the case of the Commandment "Thou shalt not kill". Paradoxically this is upheld as a fundamental value, with killing correspondingly deprecated. This in no way prevents sophisticated arguments justifying killing -- if not valuing it -- whether in terms of self-defence or just war theory. Typically neither of the latter undermines the value attached to the 10 Commandments.

In this exercise there is then the question of how the 10 Commandments, for example, could be coherently "contained" within a framework of "global" significance. Framed as a tensegrity, is this helpful to recognition of the dynamics between the 20 value extremes in the reality of a psychosocial system?

The argument can be speculatively developed further through indicative labelling of the 10-strut tensegrity dodecahedron of Marcelo Pars which appears on *Tensegrity Wiki* website (under a Creative Commons Attribution-ShareAlike 4.0 International (CC BY-SA 4.0)). Clearly, for the purpose of this exercise, the labelling on the right is arbitrary, as with the distinction between the positive and negative poles of each polarity.

Indicative attribution of 10 polarities to 10 struts of a tensegrity dodecahedron
(some numbering omitted for the sake of clarity)

Original by Marcelo Pars	Numbering: struts (white), positive (yellow), negative (mauve)
	

Tensegrities are renowned for their flexibility and recovery of an equilibirum configuration after being subject to any external forces. The positive and negative indications on the strut extremes might well be understood as "reversing" independently (as with the geomagnetic pole). This could usefully reflect the sense in which -- for some, and under some circumstances -- "killing" is positively valued in practice and "pacifism" is deplored.

Clearly the framework invites speculation on how the "10 Commandments" as struts might be more distinguished in relation to one another. Curiously there is little exploration in the literature of how that set constitutes a system in which its injunctions are systemically

related. Provocatively it might be asked how a 10-fold system of polarities relates to the cybernetic insights of viable system theory -- especially given Buckminster Fuller's injunction that "all polyhedra are systems".

Potentially of greatest interest is the role of the flexible links between the extremes of each polarity. In effect the set of polarities is embedded or nested within a network. Further speculation might endeavour to distinguish the role of each such link. Understood from that perspective the polarities, as incommensurables ("antipathies"), give form to a cohesive network of links ("sympathies") -- which would otherwise lack any meaningful memorable structure.

Use of the dodecahedron is potentially also of interest in suggesting a relationship between the 12-fold (so widely invoked, as noted above) and the 10-fold. In practice it could be argued that there is a cognitive disconnect between these two patterns so significant to society. As shown, it is the 12-fold pattern which offers a context for the 10-fold which performs a vital function in ensuring its coherence -- a co-dependent dynamic.

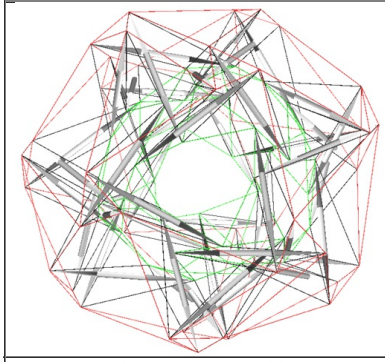
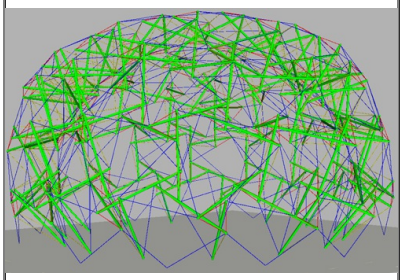
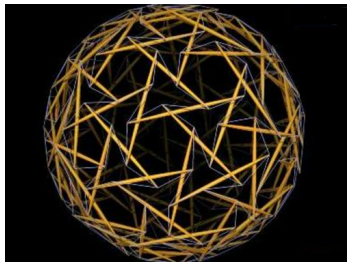
Spherical tensegrity as "container" for polarization dynamics of global civilization?

Much is made of the manner in which the most fundamental polyhedra approximate progressively to the form of a sphere -- as is evident with the Platonic and Archimedean solids. Their symmetrical regularity has long been valued as symbolizing the elusive understanding of unity to which many claim to aspire. It is in this sense that geodesic domes have been an architectural focus for global exhibitions.

Although intimately related in their construction to the principle and pattern of tensegrity, such half-spherical domes -- or their spherical counterparts -- are not tensegrities in the sense which invites most appreciation -- especially from an aesthetic perspective.

The image above of a dodecahedral tensegrity is suggestive of how a complexification of the network of links could become every more spherical in form. However, in order to ensure its integrity as a global form, those links would need to be matched by numerous struts -- the polarities which are the focus of this argument.

An indication of feasibility is offered by Robert Burkhardt (*A Technology for Designing Tensegrity Domes and Spheres*, Tensegrity Solutions, 2007) from which the screenshots of virtual reality models were reproduced (left and centre below). Another example is offered by the image below right from *Tensegrity Wiki*, potentially indicative of the configuration of 120 polarities.

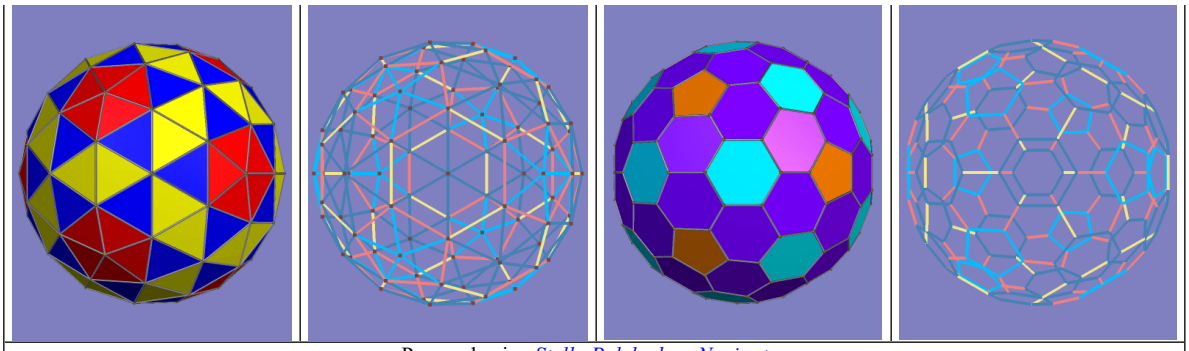
Indication of tensegrity dome and sphere structure (titles for images left and centre link to interactive VRML files)		
4v T-Octahedron Sphere	10v Double-Layer Dome	120-strut tensegrity sphere
		
Reproduced from Robert Burkhardt (*A Technology for Designing Tensegrity Domes and Spheres*, Tensegrity Solutions, 2007)		by TaffGoch from *Tensegrity Wiki*

The indications can be taken further by considering how the ca. 230 value polarities identified by the Human Values project (for the *Encyclopedia of World Problems and Human Potential*) can be spherically configured. This was discussed and illustrated in some detail in a separate exercise (*Varieties of Tone of Voice and Engagement with Global Strategy: alternating between a requisite variety of voices to engender coherence?* 2020) which included sections on:

> Confrontation of human values and checklists of tones-of-voice
> Tone-of-voice clustering in terms of value polarities
> Higher order integration of strategic voice
> Evoking imaginative appreciation of possibilities of tone-of-voice coherence

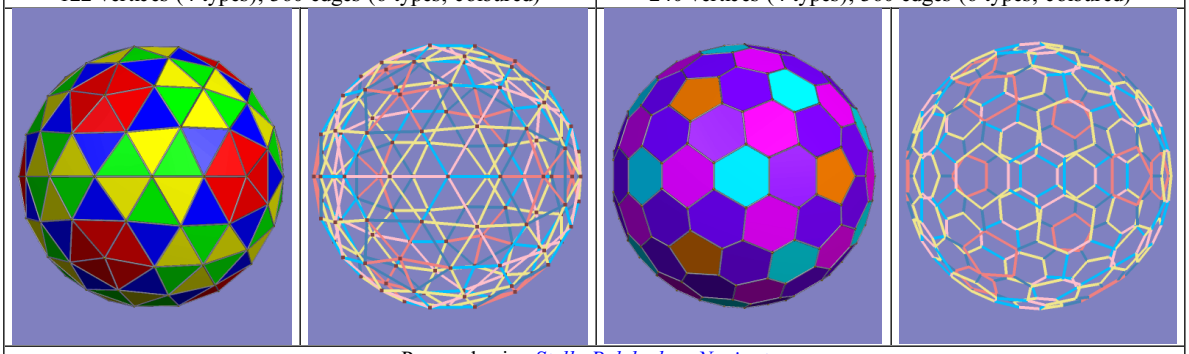
In the absence of capacity (of the author) to generate spherical tensegrities, the following are suggestive of the possibility using a geodesic sphere.

Indication of tensegrity of value polarities by converting icosahedron into geodesic sphere			
3-frequency geodesic icosahedron		3-frequency geodesic icosahedron (dual)	
92 vertices (3 types), 270 edges (5 types,coloured)		180 vertices (3 types), 270 edges (5 types, coloured)	



Prepared using *Stella Polyhedron Navigator*

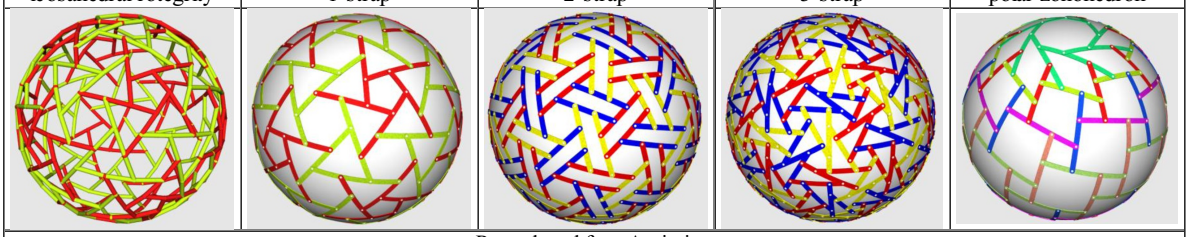
Indication of spherical tensegrity of value polarities by converting dodecahedron into geodesic sphere	
2-frequency geodesic dodecahedron	2-frequency geodesic dodecahedron (dual)
122 vertices (4 types); 360 edges (6 types, coloured)	240 vertices (4 types); 360 edges (6 types, coloured)



Prepared using *Stella Polyhedron Navigator*

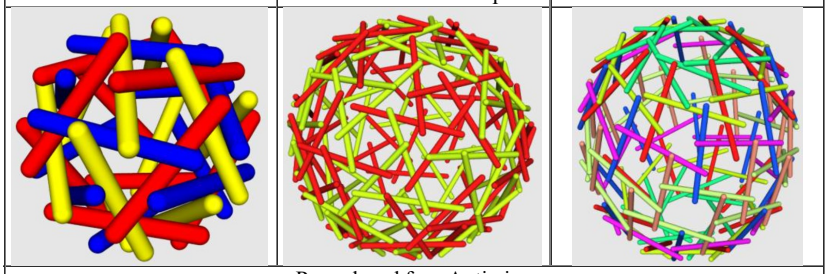
Other related modes of visual representation are suggested by use of the Antiprism application and its ability to generate 3D models as indicated by the following screenshots of possibilities of rotegrity (program commands), or nexorade -- based on tessellation of a geodesic icosahedron.

Screenshots of rotegrities based on 2-frequency icosahedron				
icosahedral rotegrity	1-strap	2-strap	3-strap	polar zonohedron



Reproduced from Antiprism

Nexorades (also termed reciprocal frames) based on 2-frequency icosahedron		
Icosahedron	Icosahedron 2-freq.	Polar zonohedron



Reproduced from Antiprism

The complexity of the images above suggest the need to distinguish limited sets of fundamental polarities from a larger array of secondary polarities. How are these to be recognized in the dynamics of society? How are the fundamental and the secondary polarities to be understood as related in order to ensure that the globality of the tensegrity is sustainable?

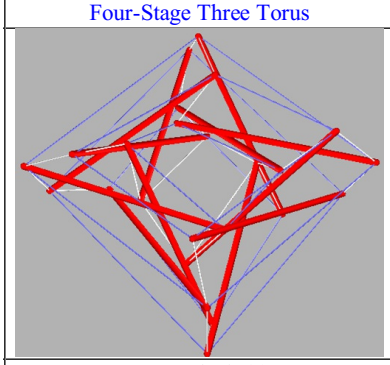
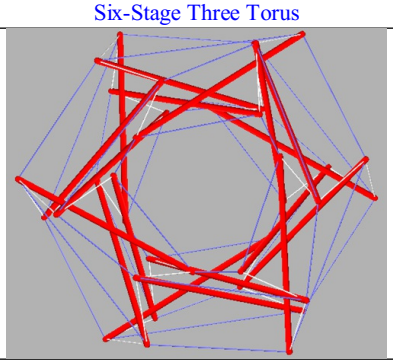
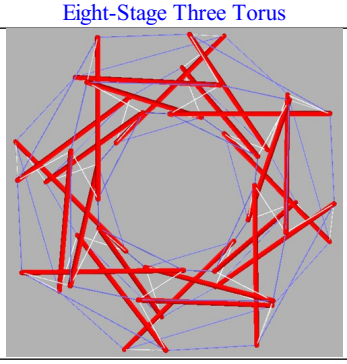
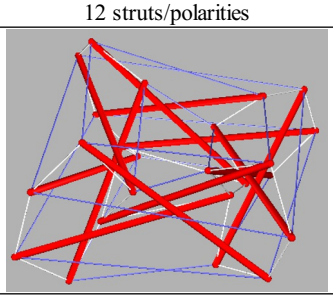
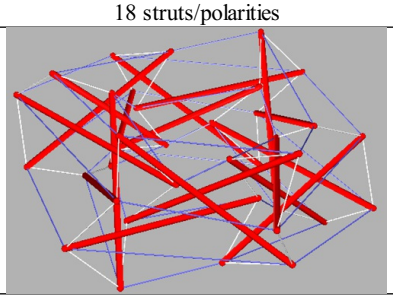
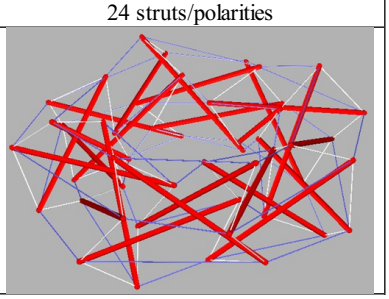
Tensegrity torus as complementary framing of integrative psychosocial structure?

A major difficulty in exploring geometrical possibilities of transformation is that very few of those with relevant insights seem to have any published interest in what the elements and configurations might signify in psychosocial terms or as mapping templates, as discussed more generally (*Engaging with Globality -- through cognitive lines, circlets, crowns or holes*, 2009). Given that many polyhedra of relevance to this exploration can be readily transformed into toroidal form, the (symbolic) significance of a torus is especially relevant (*Imagining Toroidal Life as a Sustainable Alternative: from globalization to toroidization or back to flatland?* 2019)

As portrayed above, the dodecahedral tensegrity could indeed be viewed as a torus, especially if "squashed" vertically. That possibility would of course call for the struts and links to be adjustable, perhaps using links of rubber or springs (for example). "Adjustable" is far more feasible (and evident) in psychosocial terms. It is in this sense that there is a case for exploring models of tensegrity tori. How might psychosocial polarities be configured in a toroidal context?

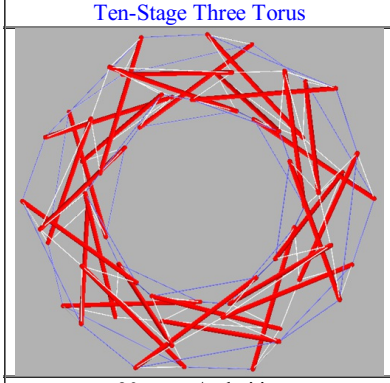
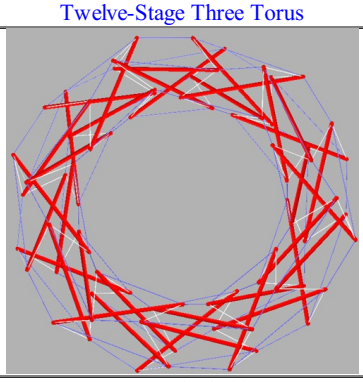
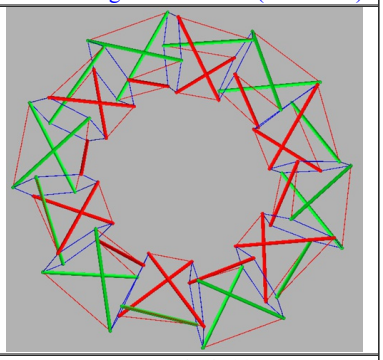
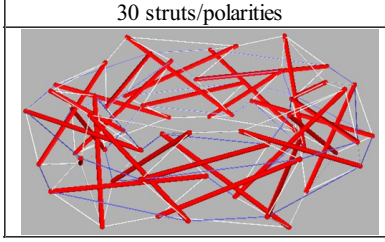
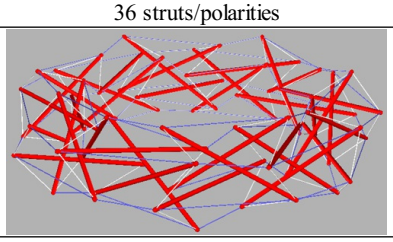
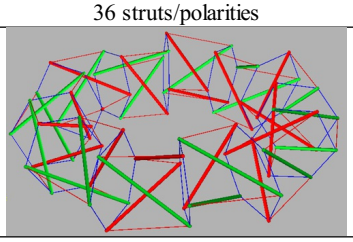
Robert Burkhardt discusses the presentation of a *Ten-stage Tensegrity Torus*, noting that David Emmerich had presented a tensegrity torus with a topology similar (*Structures Tendues et Autotendantes*, 1988). Burkhardt offers access to an extensive range of 3D models (*VRML Tensegrity Models*, 2009). Screenshots of his various virtual reality experiments with tensegrity torus models are presented below.

Screenshots of 4, 6 and 8-stage Tensegrity Torus Models in Virtual Reality
(views through torus, and angled in each case; titles link to interactive VRML models by Robert Burkhardt)

Four-Stage Three Torus	Six-Stage Three Torus	Eight-Stage Three Torus
		
12 struts/polarities	18 struts/polarities	24 struts/polarities
		

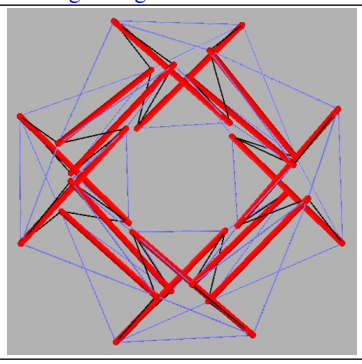
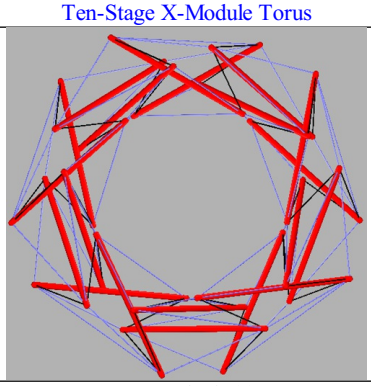
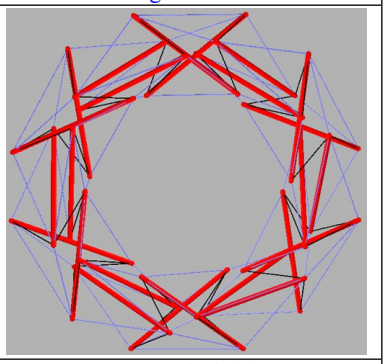
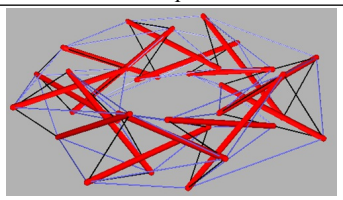
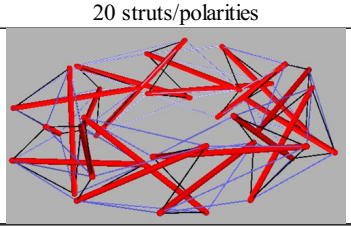
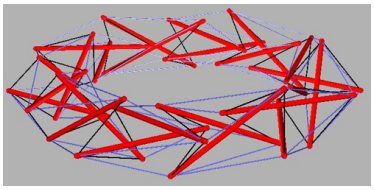
The 12-strut configuration is of course suggestive of a new way of exploring the connectivity and integration within the many 12-fold sets (*Checklist of 12-fold Principles, Plans, Symbols and Concepts: web resources*, 2011)

Screenshots of 10 and 12-stage Tensegrity Torus Models in Virtual Reality
(views through torus, and angled in each case; titles link to interactive VRML models by Robert Burkhardt)

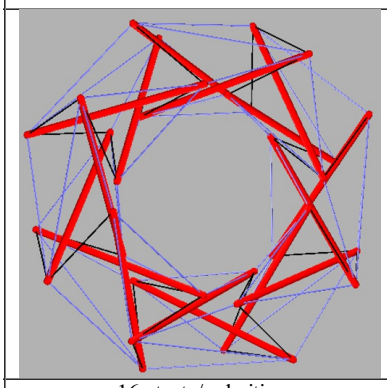
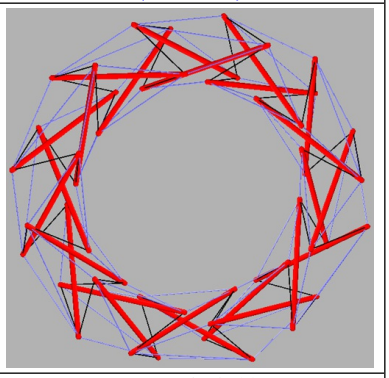
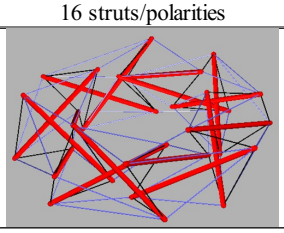
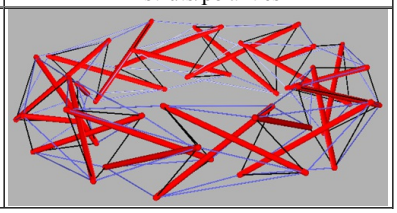
Ten-Stage Three Torus	Twelve-Stage Three Torus	Twelve-Stage Three Torus (alternative)
		
30 struts/polarities	36 struts/polarities	36 struts/polarities
		

The 30-strut configuration, and its relation to the icosahedron, is of some relevance to the cybernetic arguments of Stafford Beer (*Beyond Dispute: the invention of team syntegrity*, 1994) and the related insights into a viable system. Understood as a quest for

integrity, interpretation of the configuration may be fruitfully informed by the paradoxical insight of the journey of 30 distinctive birds in quest of the legendary Simorgh -- in the classic Sufi poem *The Conference of the Birds* (1177) by Farid ud-Din Attar.

Screenshots of 8, 10 and 12-stage Tensegrity Torus Models (X-module versions) (views through torus, and angled in each case; titles link to interactive VRML models by Robert Burkhardt)		
Eight-Stage X-Module Torus	Ten-Stage X-Module Torus	Twelve-Stage X-Module Torus
		
16 struts/polarities	20 struts/polarities	24 struts/polarities
		

The 20-strut configuration is of course suggestive of a new way of exploring the connectivity and integration within the many 20-fold sets (*Requisite 20-fold Articulation of Operative Insights? Checklist of web resources on 20 strategies, rules, methods and insights*, 2018). The 16-strut configuration is discussed below with respect to an adaptation of relevance to the UN's Sustainable Development Goals.

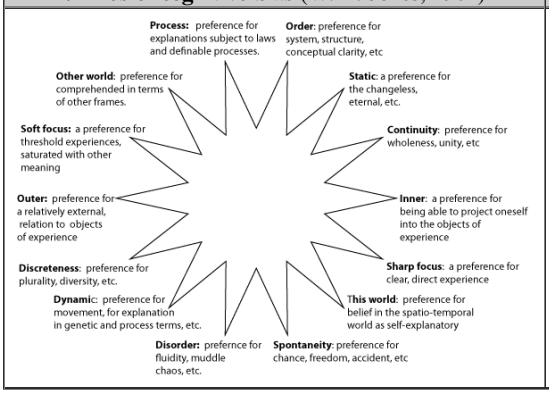
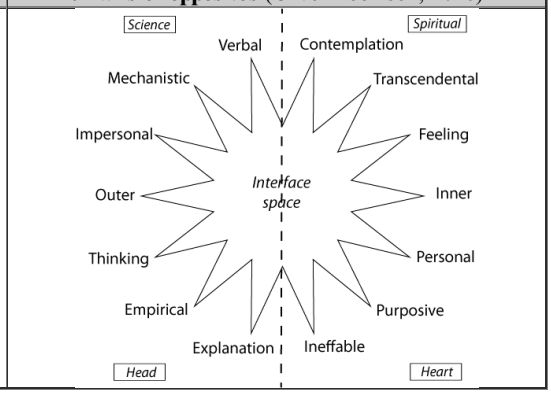
Screenshots of variants of 8 and 12-stage Tensegrity Torus Models (X-module versions) (views through torus, and angled in each case; titles link to interactive VRML models by Robert Burkhardt)		
Eight-Stage X-Module Torus (alternative)		Twelve-Stage X-Module Torus (alternative)
		
16 struts/polarities		24 struts/polarities
		

Matching sets of psychosocial polarities to tensegrities: case of Axes of Bias?

Axes of bias? In the quest for good examples of fundamental polarities to illustrate the argument, one example is the set of 7 axes of bias described by the historian of philosophy William Thomas Jones in the light of a fundamental dispute in the academic literature among a range of authors regarding understanding of the Romantic period (*The Romantic Syndrome: toward a new method in cultural anthropology and the history of ideas,* 1961). Jones indicated possibilities for use of that methodology in relation to other disputes.

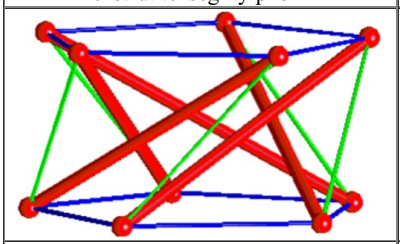
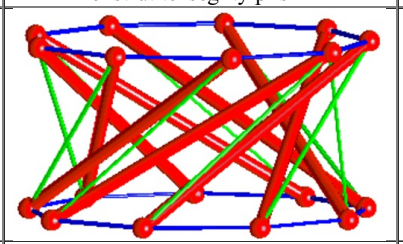
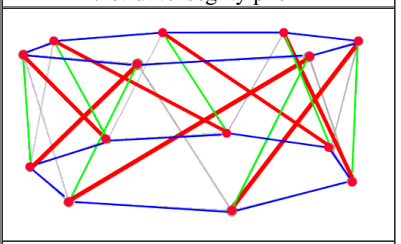
Of relevance to that quest are the distinctions noted in the diagrams below indicative of a degree of equivalence or correpondence, asd discussed separately (*Post-Apocalyptic Renaissance of Global Civilization: engaging with otherness otherwise?* 2018). The axes of bias derive (below left) from the philosophical work of W. T. Jones (1961). The image on the right is a slightly redrawn version of that of Oliver C. Robinson (*Paths Between Head and Heart: exploring the harmonies of science and spirituality*, 2018), as summarized by the author (*Palintonos Harmonia: the alchemy of opposites*, Paradigm Explorer, 2018, 2). That theme is inspired by the insight of Heraclitus and others into "taut harmony" (or "counter-stretched harmony"), as extensively reviewed by Bernd Seidensticker (*Palintonos Harmonia*,

Hypomnemata, 72, 1982)

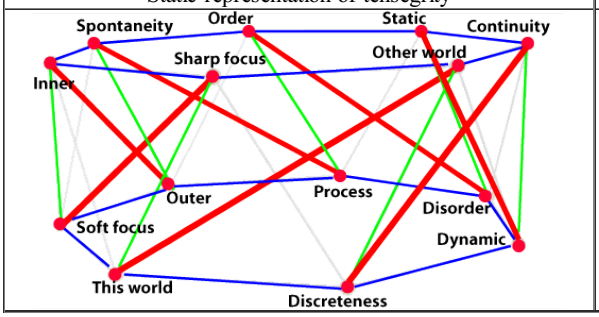
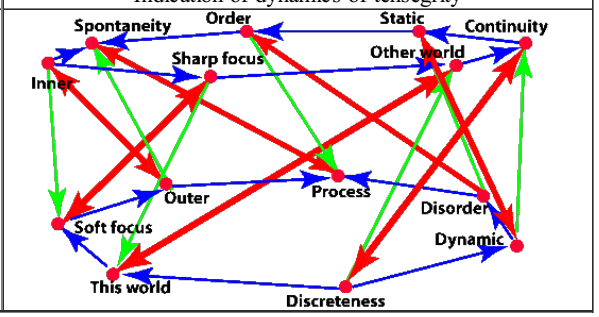
7 Axes of cognitive bias (W. T. Jones, 1961)	**7 Pairs of opposites** (Oliver Robinson, 2018)
	

With the emphasis on axes in both articulations, this suggests that any imagined "stargate" is as likely to be of higher dimensionality than is seemingly implied by those images. The "portal" is somehow to be understood as through a centre of corresponding dimensionality. Switching to a 3D depiction of values (following the argument above), the 7 axes in each case can be readily associated with semi-regular polyhedra with 14 vertices or 14 faces. Robinson's "interface space" is then at the centre of that form.

Tensegrity prism: For the purpose of this exercise this might be usefully illustrated by a 7-strut tensegrity. Examples of 5-strut and 9-strut tensegrities are described in the *Tensegrity Wiki* in relation to explanations of tensegrities based on the prism. The examples are reproduced below (left and centre). These permitted the development of an image of a 7-strut tensegrity (below right) on the basis of a heptagonal antiprism (of which the faint grey lines are a trace irrelevant to the tensegrity design). With respect to its viability as a tensegrity, the design calls for clarification and commentary in the light of the separate arguments (J. Y. Zhang, S. D. Guest and M. Ohsaki, *Symmetric Prismatic Tensegrity Structures*, *International Journal of Solids and Structures*, 46, 2009, 1). It is from that document that the examples in the *Tensegrity Wiki* have been reproduced.

Indication of 5, 7 and 9-strut tensegrity prisms		
5-strut tensegrity prism	9-strut tensegrity prism	7-strut tensegrity prism
		
Rendered by Zhang, Guest, Ohsaki on *Tensegrity Wiki*	Rendered by Zhang, Guest, Ohsaki on *Tensegrity Wiki*	Rendered according to images on left

In accordance with the argument above, the 7 axes of bias of Jones could then be indicated with their polar extremes on the 7-strut model (below left). Clarification of the meaning associated by Jones with the labels associated with each pole is presented separately (*Axes of Bias in Inter-Cultural Dialogue*, 1993). No attempt been made to present the axes of bias in any particular order. For the purposes of illustration, given the dynamics intrinsic to any tensegrity model, alternating arrows could then be indicated (simplistically) in an animation of that image (below right). No effort is made there to render consistent the directionality of the arrows in the animations in terms of the mechanics of any strut-and-link model.

Use of a 7-strut tensegrity prism to configure a 7-fold set of axes of bias	
Static representation of tensegrity	Indication of dynamics of tensegrity
	

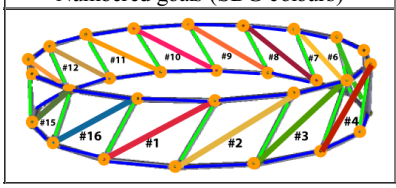
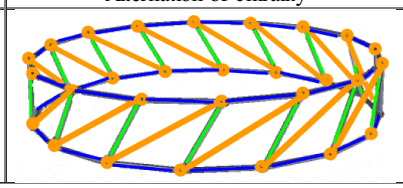
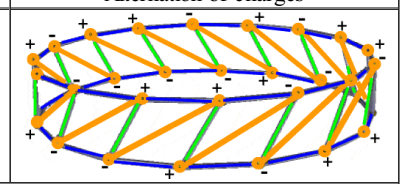
Matching sets of psychosocial polarities to tensegrities: case of Sustainable Development Goals?

Tensegrity prism: The relevance of the above method with respect to axes of bias can be explored in relation to the UN's Sustainable Development Goals -- of which there are 16, plus a coordinating 17th. Little is known about the purported (or assumed) interactions between those goals, although a recent analysis is published behind a paywall (David Tremblay, et al, *Sustainable Development Goal*

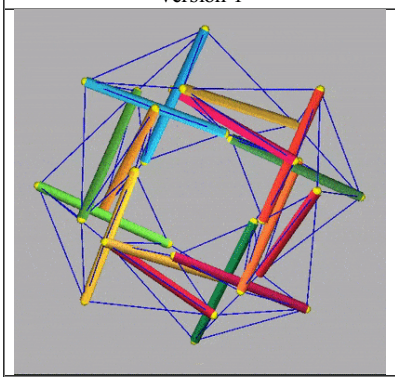
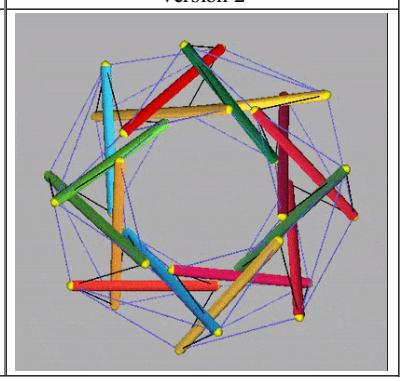
Interactions: an analysis based on the five pillars of the 2030 agenda, *Sustainable Development*, 28, 2020. 6).

Of interest in the use of tensegrity models is the explicit indication of connectivity by which the integrity of the systems of goals is rendered comprehensible. The question of how individual goals might be interrelated as polarities within a viable system is not addressed here.

As a provisional indication, the 16 can be arrayed as polarity struts as shown in the image on the left below. This can be used to indicate the issue of chirality, however that is to be interpretedd in strategic terms (as shown in the central animation below). The animation on the right offers a sense of change in polarity, possibly to be understood in terms of the changing significance of the strategic goal in the shorter or longer term.

Application of tensegrity prism approach to 16 Sustainable Development Goals		
Numbered goals (SDG colours)	Alternation of chirality	Alternation of charges
		

Tensegrity torus: The prism-based representation can be contrasted with that based on a torus, namely the Eight-Stage X-Module Torus and the Eight-Stage X-Module Torus (alternative) presented by Robert Burkhardt as interactive virtual reality files (see above). These have been slightly adapted using the standard SDG colours. In the animations below these have been converted to non-interactive video format for ease of web presentation. Again the question of how the distinct strategy-polarities might be appropriately position and connected within the tensegrity is a matter for the future.

Application of tensegrity torus approach to 16 Sustainable Development Goals (adapted versions of originals by Robert Burkhardt, shown above)		
Version 1	SDG colour coding and legend	Version 2
		

Deriving tensegrity links from data on strategic dilemmas: The animations above raise the question as to what might be the links in systemic terms between the 16 SDGs presented as struts. In tensegrity terms, it is the **tensions** associated with these links which ensure the **integrity** of the set of SDGs as a viable system.

It is appropriate to recall that the SDGs are the successor from 2016 to the 8-fold set of UN Millennium Development Goals, which were themselves a successor to Agenda 21, as elaborated on the occasion of the UN Conference on Environment and Development in 1992 (the first so-called Earth Summit).

On that occasion considerable effort was devoted to identifying some 450 strategic dilemmas implied by the submissions to the conference and in the resulting framework (*Systemic Mapping of Strategic Dilemmas*, 1992; *Declaration Issues: Sorted by Code Combination*, 1992). These were incorporated into the online database of the Global Strategies Project -- as one element of the interlinked databases of the *Encyclopedia of World Problems and Human Potential*. At that time the possibility of interrelating the network of strategies within a tensegrity framework was envisaged (*Configuring Strategic Dilemmas in Intersectoral Dialogue*, 1992; *Representation of Issue Arenas on Icosidodecahedral Net*, 1992).

Since that time, as a result of reworking, some 695 strategic profiles (of a total of 32,482) have been indicated as featuring within the framework of Agenda 21, as it has been coordinated by the UN Commission on Sustainable Development. A report by the UN Secretary-General highlighed several shortcomings in the work of the Commission, notably its lack of success in fully integrating economic, social and environmental dimensions of sustainable development into its work and outcomes (*Lessons learned from the Commission on Sustainable Development*, 26 February 2013, A/67/757).

The possibility of associating the profiled strategies by algorithm with individual SDGs is currently explored in the development of the online strategies database database. Each strategy is typically profiled with an explicit indication of the other strategies by which it is "constrained" or "facilitated". This suggests the possibility of clustering the many strategic dilemmas into 8 sets of links from each SDG to the 15 others (4 per polar extreme in the tensegrity pattern above).

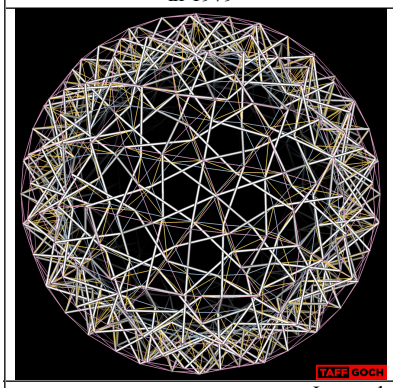
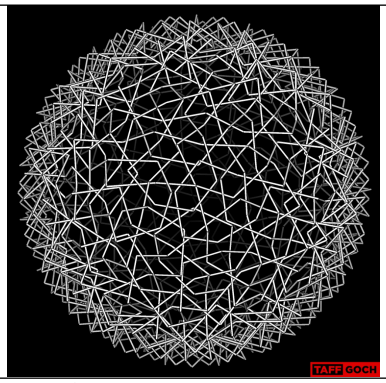
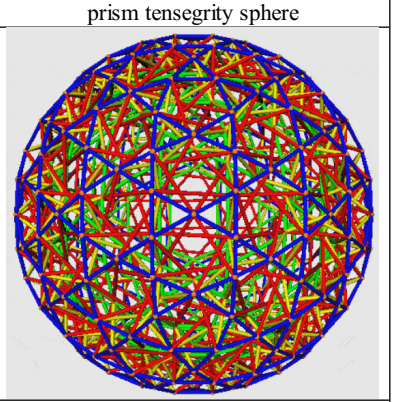
Coherent representation of higher orders of strategic complexity? It is appropriate to note the "global" preoccupations of NASA in giving attention to the design of space habitats and robots using tensegrity (Robert Skelton, *Tensegrity Approaches to In-Space*

Construction of a 1g Growable Habitat, *NASA*, 13 May 2016; Anthony Longman, *Growth Adapted Tensegrity Structures: a new calculus for the space economy*, *NASA*, 20 July 2013; *SuperBall Bot Tensegrity Planetary Lander*, *NASA*, 19 September 2012).

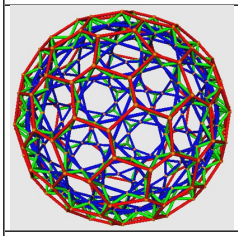
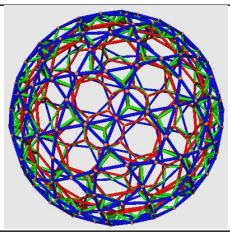
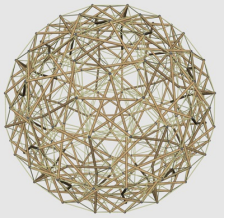
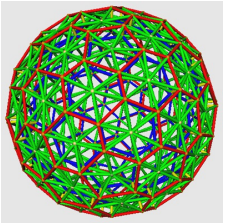
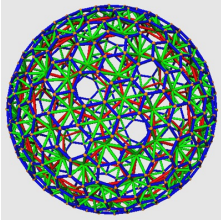
It is then appropriate to ask whether the documented complexity of interrelated "global" organizations, problems and strategies could benefit from being experimentally ordered coherently using tensegrity structures of some kind. This could be understood as an exercise in knowledge architecture applied to the global problematique and the configurations of strategic networks assumed to be addressing it (Richard Slaughter and Chris Riedy, *Understanding and Resolving the Global Problematique: assessing the balance between progressive and socially conservative foresight*, *Foresight*, August 2009).

As one example, a celebrated early image of a complex tensegrity is a feature of a page on 92-prism tensegrity in *Tensegrity Wiki* where it is analyzed by Taffgoch and Adrian Rossiter (of Antiprism). The tensegrity can now be generated by Antiprism software as indicated there.

Indication of more complex tensegrities
(reproduced from page on 92 prism tensegrity in *Tensegrity Wiki*)

92-Prism tensegrity originally presented by Buckminster Fuller in 1979	Prism tensegrity of 960 struts by Taffgoch	Multilayer dome generated with Antiprism from 3-frequency icosahedron dual as a prism tensegrity sphere
		
Images by Taffgoch		Imperfect reproduction of Antiprim animation

Screenshots of examples of domes generated by the Antiprim application
(see explanation of options)

Eden"in"	Eden "out"	Tensegrity style	Honeycomb "in"	Honeycomb "out"
				
Reproduced from animations generated by Antiprism application				

Multi-polar homeostasis, sustainability and transcendence?

Multi-polarity: There is continuing concern with polarity in international relations, with arguments regarding unipolarity and bipolarity versus multipolarity. The argument has been made that multipolarity is the most stable structure (Karl Deutsch and J. David Singer, *Multipolar Power Systems and International Stability*, *World Politics*. 16, 1964. 3). Any quest for "full-spectrum dominance" by superpowers can be seen as a quest for unipolarity -- whilst having to struggle with the reality of bipolarity or tripolarity.

As argued by Peter W. Schulze:

> .... multipolarity experienced a rebirth at the end of the 20th century and the start of the 21st century in Russia, China, and the EU. It never left the scene in the US foreign and security community or the US Congress. Today, different versions of multipolarity exist. Surprisingly, there is even debate around where, when, and who created the concept. (*Multipolarity and Multilateralism: cooperative or rival cornerstones of a new world order?* *Dialogue of Civilizations*, 3 December 2019)

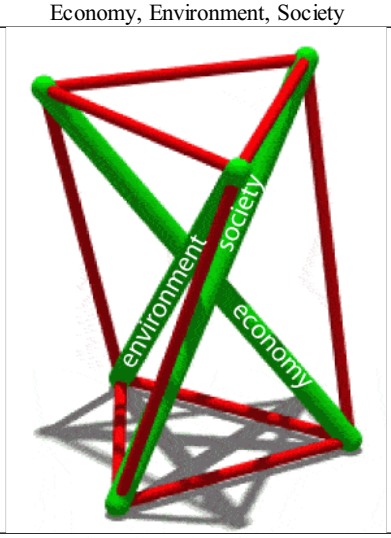
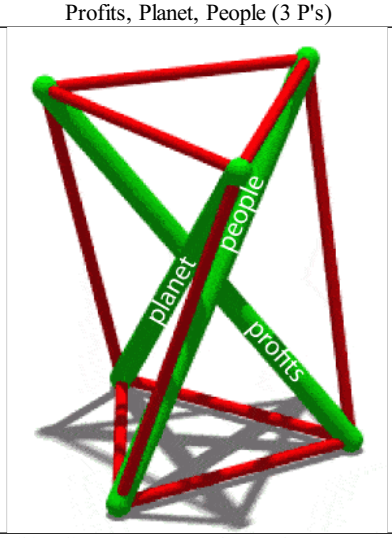
The possibility or reality of multipolarity is a particular preoccupation (Kenneth N. Waltz, *Intimations of Multipolarity*, *The New World Order*, 2000), especially of the financial community (*Five Reasons for the Trend Towards Multipolarity*, *Morgan Stanley Wealth Management*, 17 July 2020). How it might prove feasible remains a major concern:

- Antonio de Aguiar Patriota: *Is the World Ready for Cooperative Multipolarity?* (*Rising Powers in Global Governance*, 2, 2017, 2)
- Robert H. Wade: *Emerging World Order? From Multipolarity to Multilateralism in the G20, the World Bank, and the IMF* (*Politics and Society*, 30, 2011, 3)
- Michael Hudson and Pepe Escobar: *In Quest of a Multi-Polar World* (*Consortium News*, 26 March 2021)

Pillarization? In contrast with the representation above of the strategic goals as polarities, there is a degree of confusion in the definition of sustainability in terms of "pillars" -- a tendency discussed more generally (*Coherent Value Frameworks: pillar-ization, polarization*

and polyhedral frames of reference, 2008). In the case of sustainability, this is variously understood in terms of:

- 3 pillars: Sustainability is most often defined as meeting the needs of the present without compromising the ability of future generations to meet theirs. It has three main pillars: economic, environmental, and social. These three pillars are informally referred to as people, planet and profits. (Andrew Beattie, *The 3 Pillars of Corporate Sustainability*, *Investopedia*, 16 June 2019)
- 4 pillars: Sustainability is broadly used to indicate programs, initiatives and actions aimed at the preservation of a particular resource. However, it actually refers to four distinct areas: human, social, economic and environmental – known as the four pillars of sustainability. (*Future Learn*)
- 5 pillars: Sustainable development is development that is grounded in five dimensions, which have been expressed through the "5 P's", or five pillars of sustainable development: people, planet, prosperity, as well as peace and partnerships. (*Sustainable Development: what is there to know and why should we care?* *UN System Staff College*, 17 October 2016)
- 6 pillars: A policy paper on sustainability business and reporting matters, identified 6 pillars that would facilitate a better and more responsible business environment: sustainability reporting, integrated reporting, assurance of non-financial reporting and disclosures, climate change. natural capital and green economy (*Six Pillars of Sustainable Business and Reporting*, *Association of Chartered Certified Accountants*, April 2014)
- 7 pillars (and more): Articulations relating to "sustainability" are evident from any search with respect to "7 pillars", "8 pillars", "9 pillars", "10 pillars" and "12 pillars"

Tensegrity configurations of 3-pillars of sustainability (alternative labels)	
Economy, Environment, Society	Profits, Planet, People (3 P's)
	
Adaptations of Cmglee, CC BY-SA 3.0, via Wikimedia Commons (as shown above)	

Homeostasis and cybernetics: A very readable insight into the origins of homeostasis is provided by Andrew Pickering in reviewing the interplay of three icons of cybernetics (*Cybernetics and the Mangle: Ashby, Beer and Pask*, *Social Studies of Science*, 32, 2002, 3). In contrast with the conventional focus on representation in science, this notes the materiality of their practice -- the strange and fascinating devices and systems that were at the heart of their work, and the worldly projects they pursued (scientific, technological, artistic, organizational, political and spiritual). It concludes that theory does not have to remain confined to the realm of theory.

That clarification of the origins of homeostasis is of particular relevance to the challenge of multi-polarity (W. Ross Ashby, Homeostasis, *Cybernetics: Circular Causal and Feedback Mechanisms in Biological and Social Systems*, 1952; *Principles of the Self-Organizing System*, *Principles of Self-Organization*, 1962). In biology, homeostasis is the state of steady internal, physical, and chemical conditions maintained by living systems. The insight was variously explored through the collaboration and initiatives of Stafford Beer (notably in relation to syntegrity) and Gordon Pask (as the originator of conversation theory).

As indicated by Peter Cariani:

> W. Ross Ashby was a founder of both cybernetics and general systems theory. His systems theory outlined the operational structure of models and observers, while his cybernetics outlined the functional architecture of adaptive systems. His homeostat demonstrated how an adaptive control system, equipped with a sufficiently complex repertoire of possible alternative structures, could maintain stability in the face of highly varied and challenging environmental perturbations. The device illustrates his "law of requisite variety", i.e. that a controller needs at least as many internal states as those in the system being controlled. (*The Homeostat as Embodiment of Adaptive Control*, *International Journal of General Systems*, 38, 2009, 2)

Exploring the current relevance of the homeostat, and potentially of "homeostatic cognition", Stefano Franchi argues:

> W. R. Ashby's work on homeostasis as the basic mechanism underlying all kinds of physiological as well as cognitive functions has aroused renewed interest in cognitive science and related disciplines.... The paper argues that the use of computer simulations focused on the more conceptual aspects of Ashby's thought may help us recover, extend and consequently assess an overall view of life as heteronomy... The paper discusses some computer simulations of Ashby's original electro-mechanical device (the homeostat) that implement his techniques (double-feedback loops and random parameter-switching)... First simulation results show that even though Ashby's claims about homeostatic adaptivity need to be slightly weakened, his overall

> results are confirmed, thereby suggesting that an extension to virtual robots engaged in minimal cognitive tasks may be successful. Implications. The paper shows that a fuller incorporation of Ashby's original results into recent cognitive science research may trigger a philosophical and technical reevaluation of the traditional distinction between heteronomous and autonomous behavior. (*Homeostats for the 21st Century? Simulating Ashby Simulating the Brain*, *Constructivist Foundations*, 9, 2013, 1)

Homeostasis and viable multi-polarity? There is a curious similarity to the descriptions of the information transfers in the operations of Ashby's early homeostat and the interplay of forces in a physical tensegrity. This understanding was presumably fundamental to Stafford Beer's clarification of syntegrity as modelled by an icosahedron. Given increasing speculation about the nature of a "global brain" -- potentially characterized by multi-polarity -- the further insight offered by Steve Battle is pertinent:

> In *Design for a Brain*, W. Ross Ashby speculates about the possibility of creating a mobile homeostat "with its critical states set so that it seeks situations of high illumination". This paper explores an embedding of Ashby's homeostat within a simulated robot and environment, exploring the question as to whether the classic (unmodified) homeostat architecture is able to adapt to this environment. Remaining faithful to the physical design of Ashby's device, this simulation enables us to quantitatively evaluate Ashby's proposition that homeostasis can be achieved through ultrastability. Following his law of requisite variety, increasing the number of units increases the time taken to reach equilibrium, and conversely, reducing internal connectivity reduces the time taken to reach equilibrium. (*Ashby's Mobile Homeostat*, *Conference: Artificial Life and Intelligent Agents*, 2014)

The disturbances to which any multi-polar system is potentially subject can be explored as catastrophes. Such disturbances can be understood otherwise, as argued by David W. Bates:

> Catastrophe is usually seen as something that befalls the organized, adaptive system from the outside, threatening its future existence. While some cyberneticians explicitly pathologized catastrophe, the French mathematician René Thom in the 1970s redefined catastrophe as a sudden unexpected turn that is generated from within the complex system. (*Unity, Plasticity, Catastrophe: order and pathology in the cybernetic era*, University of California, 2014)

Bates explores understandings of catastrophic events -- especially "weak catastrophes" and "internal catastrophes" -- as being essential to the functioning of a complex unity.

Together with the complex pattern of switching within a homeostat -- as changes in polarity -- this reinforces the argument for recognizing the extent to which the equilibrium condition of multi-polarity is homeostatic. This is the essence of tensegrity dynamics in which each sub-system innately responds to deformation by striving to rebound to a state of homeostatic mechanical equilibrium. This is explicitly recognized in biotensegrity through linking from the micro-level of the cell, through the various tissue collectives, to the macro-level of the entire organism.

Sustainability and transcendence? References are frequently made to homeostasis in relation to sustainability understood in systemic terms. This can be defined as the process of people maintaining change in a homeostatically balanced environment in which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.

Any understanding of the interplay between the 16 Sustainable Development Goals then suggests that the elusive integrative goal of sustainability (the 17th?) is one of human-ecosystem equilibrium -- namely homeostasis. However, despite the increased popularity of the use of the term "sustainability", the possibility that human societies will achieve environmental sustainability has been, and continues to be, questioned.

The elusive nature of sustainability can be explored in terms of the Holy Grail of Western traditions (*In Quest of Sustainability as Holy Grail of Global Governance*, 2011). More elusive still is any understanding of what would be the dynamics of life in the heavenly-like context of sustainability when achieved -- in particular whether these would then frame the possibility for any transcendent evolution of humanity.**What happens after global sustainability -- if humanity ever gets there?**

A focus on transcendence in relation to sustainability has been given by Prasenjit Duara (*Sustainability and the Crisis of Transcendence*, *The Crisis of Global Modernity: Asian Traditions and a Sustainable Future*, 2014):

> Chinese intellectuals and others have turned to resources within the Chinese tradition of universalism and transcendence. Given... that all nations originate in and remain deeply embedded in global norms and institutions, this is a welcome recognition of the necessity of aligning the global and circulatory conditions of national welfare. But approaches to sustainability... have yet to be integrated with these espousals.

The University of Oslo is currently coordinating an international project on *Transcendence and Sustainability: Asian Visions with Global Promise*. It explores the question as to whether spiritually and religiously inspired environmental movements in Asia are largely overlooked as an essential contribution to the global goal of environmental sustainability.

Tensegrity as a key to psychosocial polarity reversal in practice?

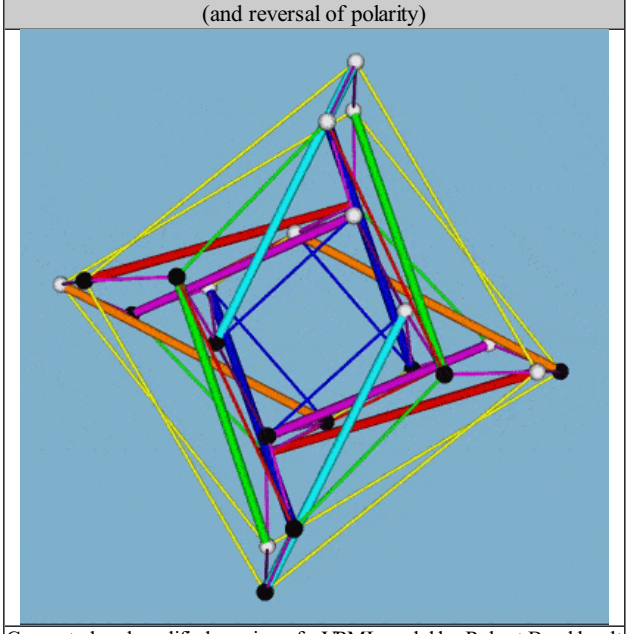
As argued above with respect to the strut-like "rules" of the 10 Commandments, a major difficulty is the manner in which the

significance of the extremes of each "pole" is reversed in practice. For example, "Thou shalt not kill" is dynamically reframed such that killing is abhorred or celebrated according to circumstances -- within the thinking of individuals or collectives. Despite such a commandment, it is unquestionably curious that a high proportion of entertainment depends on exposure to killing -- as well as to reversals of the injunctions of other commandments. The question is how a tensegrity framework might help to reframe cultivation of this alternation within a coherent systemic context.

Resilence and reversal: a 12-fold tensegrity example: The as yet unexplored collective enthusiasm for 12-fold organization has been noted above (*Checklist of 12-fold Principles, Plans, Symbols and Concepts: web resources*, 2011). Especially curious is the low level of interest in how the elements of any such 12-fold set are interrelated in any systemic sense -- whether in any archetypal roundtable, in any 12-fold set of principles, or in any 12-fold strategic plan of action. It is in this sense that a 12-strut tensegrity offers a challenging equilibrium between the tensions of contrasting elements and the integrity of their relatuonship together,

It is frustrating to note that, despite the extensive literature on tensegrities of many configurations, there are constraints to their representation over the web -- except as static images. Such images detract from the most essential feature of tensegrities, namely their resilience in response to external stresses -- as viable systems which seek an equilbirum between their internal forces. There is therefore a case for adapting the 12-strut example above from Robert Burkhardt -- which used the largely superceded VRML web protocol. In the animation below that model has been converted to the later X3D protocol to enable resilience and other dynamics to be rendered more comprehensibly -- given their potential psychosocial relevance.

Animation of 12-strut tensegrity torus indicative of resilience
(and reversal of polarity)



Converted and modified version of a VRML model by Robert Burckhardt
(VRML original; X3D version; MP4)

The animation above has the 12 polarity struts coloured by pairs to highlight symmetry within the configuration. The thinner links between them have been coloured by type (length) to offer further insight into the structure. In addition to the rotation, enabling comprehension of the model as a whole, a further dynamic has been added to offer an indication of the elastic dynamic through which it achieves equibrium in response to any disturbance in practice -- its resilience. Note however that the simple technique for representing this is misleading to the extent that it implies that **both** struts and links are elastic, whereas in fact it is necessarily **only** the links which have this characteristic.

Another feature added to the model is the alternation of the colouring of the small spheres at the end of each strut (between black and white). This is suggestive of reversal in polarity when the struts are representative of psychosocial polarities (as discussed above). Clearly many design alternative could be considered -- colouring, rate of polarity alternation, indication of elasticity. The shifting polarity could be indicated by phasing the grading of colour along each strut, for example.

Whereas typical reference to 12-fold configurations of strategies or principles tend to be limited to a simple checklist, the animation above suggests that the pattern of interrelationships between the distinctive elements is necessarily much more complex -- if the integrity of the whole is to emerge and be sustainable. How those elements and their dynamics are to be recognized is clearly a challenge for the future -- potentially to be understood in terms of patterns of distinctive feedback loops. What kinds of information pass from one specific pole to another to sustain integrity?

Interpretation of mandala-like patterns as resilient tensegrities? The many screenshots of tensegrities presented are reminiscent of the patterns in 2D of traditional mandalas and yantras. The practice of meditation they facilitate can be inferred as evoking recognition of the relationship between their parts in framing an integrative cognitive whole -- as a form of tensegrity. Many logos in 2D, indicative of the integrity of institutional initiatives, can be similarly understood.

It is therefore intriguing to explore whether a higher order of significance can be carried more explicitly by representation of polarities in 3D, as argued and illustrated separately with interactive animations (*Eliciting Insight from Mandala-style Logos in 3D: interactive engagement with mandalas and yantras in virtual reality*, 2020). That followed from an earlier exploration of how integrative mnemonic

structures might be designed (*Concordian Mandala as a Symbolic Nexus*, 2016; *Con-quest Aesthetically Reframed via the Concordian Mandala -- inspired by implications of the systemantics of the Discordian Mandala*, 2016).

In enabling and framing a cognitive focus such configurations are traditionally indicative of viable pathways to higher dimensionality beyond the constraints of binary thinking. engagement with the mandala is then understood as with a special form of "portal".

"**Jitterbug**": Studies of polyhedral forms have long given attention to the manner in which they can be topologically transformed. This is notably described and visualized by the transformations of the cuboctahedron into an array of other forms. Particular attention is given to the transformation of the cuboctahedron when folded "into" an octahedron -- and even into a tetrahedron and 2D polygons -- via intermediary Platonic polyhedra of greater complexity (*Vector Equilibrium and its Transformation Pathways*, 1980).

Hence Fuller's alternative name for the cuboctahedron as the vector equilibirum, and his naming of the dynamic of folding and unfolding as a jitterbug -- of which there are many accessible videos (*Buckminster Fuller's Jitterbug*, *YouTube*, 6 May 2007; *Buckminster Fuller Explains Vector Equilibrium*, *YouTube*, 29 November 2014). This has evoked extensive commentary (*Vector Equilibrium and Isotropic Vector Matrix*, *Cosmometry*; Joe Clinton, *R. Buckminster Fuller's Jitterbug: its fascination and some challenges*, *YouTube*, 24 May 2011). Distinct from Fuller's approach are those relating to Jensens' icosahedron.

There are other transformations variously described by Hugo Verheyen (*The complete set of jitterbug transformers and the analysis of their motion, Computers and Mathematics with Applications*, 17, 1989; *Dipolygonids: Jitterbug Transformers*, 2007). As implied and noted by the latter, instead of the technical name "Dipolygonid" scholars have also used more popular names: Jim McNeill (*Polyhedral Twisters*), Junichi Yananosem (*Juno's Spinner*), Robert W. Gray (*The Jitterbug Motion*). The regular and quasi-regular polyhedra are linked with their twisting mid-point by such jitterbug-like transformation.

The concern with tensegrity possibilities has been especially developed by Robert Burkhardt (*Tensegrity Solutions*) who offers a Java-based interactive viewer for models in a section on *Dynamic Tensegrity Views*.

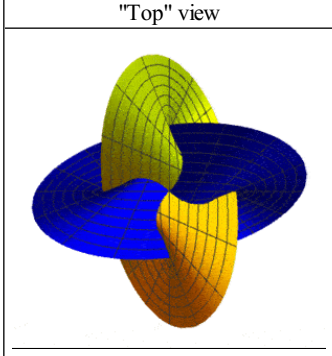
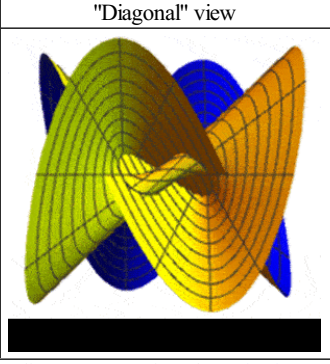
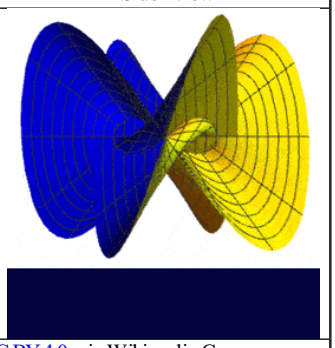
Some limitations of understanding with regard to the jitterbug transformation have been noted by Gerald de Jong on the *TensegrityWiki* site (*The Jitterbug as a Tensegrity*) and in a separate commentary (*Tensegrity Jitterbug*) which offers links to many experimental animations (in a relatively inaccessible format).

Tensegrity eversion? Tensegrity structures imply considerable dynamics through which they self-stabilize. This is a major step beyond the rigidity associated with conventional hierarchical presentations of organizational or knowledge architecture -- whatever the dynamics that may be assumed or implied. Consideration appears to have been given to such dynamics by Robert Skelton (*Dynamics and Control of Tensegrity Systems*, 24 February 2004).

It is however appropriate to ask whether some of the forms of "reversal" indicated above may take global form -- as explored in the counter-intuitive topology of sphere eversion (Eric W. Weisstein, *Sphere Eversion*, *MathWorld--A Wolfram Web Resource*; Ricky Reusser, *Sphere Eversion*, 29 June 2020; Chris Hills, *Everting a Sphere: turning a sphere inside out*; John M. Sullivan, *Sphere Eversions: from Smale through "The Optiverse"*).

This is the process in differential topology of turning a sphere inside out in a three-dimensional space. Remarkably, it is possible to smoothly and continuously turn a sphere inside out in this way (with possible self-intersections) without cutting or tearing it or creating any crease. This is surprising, both to non-mathematicians and to those who understand regular homotopy, and can be regarded as a veridical paradox; that is something that, while being true, on first glance seems false.

A very limited sense of the strange complexity of the process is offered by the following animations of distinctive views at successive stages of the eversion.

Eversion of a sphere viewed from complementary perspectives (selected stages)		
"Top" view	"Diagonal" view	"Side" view
		
Animations made by combining a gallery of screenshots by Adamb76, CC BY 4.0, via Wikimedia Commons		

Might such inversion be usefully represented in tensegrity form as an indication of how psychosocial polarities are "reversed" in practice? This could give visual significance to the paradoxical process of enantiodromia, namely the emergence of the unconscious opposite over time. Is there indeed a form of psychosocial eversion to globalization as conventionally understood? Such speculative considerations are discussed separately (*Sphere eversion as guide to the cognitive twist of global introversion?* 2013) within the context of a more general argument (*World Introversion through Paracycling Global potential for living sustainably "outside-inside"*, 2013).

Tensegrity n-polytopes (or tensegrity polychora)? There are four-dimensional analogues of the regular polyhedra in three dimensions and the regular polygons in two dimensions, named as regular 4-polytopes (or as polychoron / polychora). It could be inferred that

corresponding 4-dimensional tensegrities can be envisaged -- or tensegrities associated of higher dimensions associated with n-polytopes.

The 4-polytopes may be especially relevant to comprehending the organization of psychosocial space, as discussed separately (*Cognitive implication of tesseract and related uniform polytopes*, 2011; *Comprehending the shapes of time through four-dimensional uniform polychora*, 2015). Given the arguments above, the relevance may be all the greater in the case of the tensegrity variants.

Engaging with nonduality: The focus on the technology of tensegrity could be recognized as a means of circumventing the challenges of nonduality -- even a means of avoiding its cognitive implications, as is evident in the uptske of quantum computing. On the other hand many of the psychosocial sciences are faced with paradoxes, contradictions and inconsistences -- with their implications for decison-making and governance. The capacity to transcend such polarization by the psychosocial sciences is only to evidently limited in practice, despite a degree of preoccupation with nonduality as a topic.

Arguably the global crisis of the times could be understood in terms of epistemological panic, as separately discussed (*Epistemological Panic in the face of Nonduality: does nothing matter?* 2010). Whilst there is very little reference to the implications of tensegrity in cognitive terms, it is appropriate to note a central argument of Sally Wilcox in a doctoral thesis: *A Fractal Topology of the Transcendent Experience* (California Institute of Integral Studies, 2012):

> The unique characteristics in the transcendent experience are compared to those found in other natural boundary conditions. Analogous patterns are identified that suggest far from equilibrium conditions are present during subjective transcendent experiences which spontaneously reorder the boundary itself. The transdisciplinary method employed is tri-pronged relating dialectic philosophy, depth psychology and natural science to this investigation of boundary conditions in the transcendent experience. Carl Jung's transcendent function... is utilized in describing boundary conditions between conscious and unconscious aspects of the psyche. The transformative potential in the transcendent function suggests a dynamic process with **porous tensegrity** that I posit alters the architecture and function of the boundary itself. This psychic tensegrity is compared to Donald Ingber's thesis of structural distortion of the cell membrane that profoundly alters cellular behaviour (1993, 1997, 2003). *[emphasis added]*

With respect to "porous tensegrity", it could then be asked how this relates to what might be termed "cognitive osmosis" (*Cognitive Osmosis in a Knowledge-based Civilization: interface challenge of inside-outside, insight-outsight, information-outformation*, 2017).

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