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"PREVIEW OF BUILDING"

R. BUCKMINSTER FULLER LECTURE, Ann Arbor Conference

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I was given my subject which was "Preview of Building." I note that Mr. Owings is going to talk about big buildings, so I shall talk about small buildings.

I have not prepared a paper, not through carelessness but deliberately. I read an article in a recent issue of SCIENCE on "How to Prepare a Poor Speech." Rule number one was to "be sure not to prepare your speech----." By their rule I have given several audiences a bad time. However, this deliberate lack of preparation is a way of getting one's self into enough trouble to require quick thinking to save the situation, --and I am an inveterate into-trouble-getter. But remember, as I am speaking spontaneously in the atmosphere of this audience, your tacit response will be regenerative. I may have to circle the field several times before coming in for a safe landing where nestles that elusive affair "the small building of the next half century." Here goes and I hope you'll have to hold on to your mental hats!

I listened with great interest this morning to the discussions regarding decentralization and centralization and I have thought that the question of whether it is valid to decentralize or centralize is unanswerable because it deals with one one-way sign in two-way traffic. It is a static question in a dynamic universe.

Man was invented a mobile device and process. He has survived through ability to advance or retreat as his mortal requirements have dictated. Of his two primary faculties quickness is of great importance but intellect is first.

He recongizes that vital quickness may be momentary reflex, but that satisfactory continuities are proportional to his degree of comprehension of the consequence of his initiative. Degree of comprehension he measures in the terms of the complex interaction of all-individuals' all-time experience, as processed by intellectual integrity. His quickness would be spontaneous servant to that integrity.

Despite intermittent submissiveness to runaway momentums of residual ignorance, man guards most dearly and secretly his freedom of thought and initiative. Therefrom emanates the social-industrial relay, --from self starter to group starters.

Out of this freedom alone understanding may be generated. He recognizes understanding to be an activated circuit of mutual comprehension by individual minds. Understanding must be plural. However, because individual experience is unique, understanding can be developed only in principle out of the compounding significance of plurality of experience. Thus--man knows that the voluntary interactions of understanding dealing in fundamental principles will always master involuntary mass actions, -- and that individual freedom ever anticipates and ultimately masters mutual emergency.

As man has become knowledgfull he has translated the principles discovered in universe into abetting his quickness and mobility. The physical effect of this translation has been demonstrated in important degree only within this past half-century. Born with legs and not with roots man is in principle mobile. Prior to World War I man's locomotion was primarily accomplished by his legs. He rode in vehicles only about 300 miles per year. Oft repeated army surveys show that man has always walked an average of 1300 miles per year, -- probably always will.

In 1919 it was evidenced that the species "man" had changed. Man had become an invention which moved about primarily by mechanical means. In the United States, he to and fro-ed in 1919 about 1600 miles mechanically. He continued walking 1300 miles per year but instead of sitting in rocking chairs was sitting in moving automobiles. Thus he totalled 2900 miles in 1919. At the beginning of World War II average U.S. man was moving mechanically 6000 miles per annum; however, he continued walking an additional 1300 miles per annum, for a total of 7300 M.P.Y. The U.S. behavior curve in this respect is a pilot or "tendrill" curve of the "world" curve to accomplishment of equivalent mechanical acceleration per capita. The world-man curve is now visibly rising toward ultimate coincidence with U.S. man's curve.

Up to World War I man's primary economic ideas and social viewpoints were those developed within the visible horizon. Those who went beyond the horizons were rated as escapists, --"irresponsibility" was thought to increase with motion. But as of 1940 the average U.S. housewife was clocking up an annual 10,000 mechanical miles and 1300 foot miles, a total of 11,300, or a seven-fold step-up from her pre-1914 1600 miles. The average salesman was clocking 35,000 mechanical miles, the average air hostess 100,000 miles, while continuing her pedestrian 1300 miles. Our young people were about to accelerate en masse their annual comings-and-goings by world encirclement. Clearly, we could no longer insist that motion indicated irresponsibility--quite the reverse! Those who were masters of greatest motion and velocity were the top members of society. Responsible participation of all workers involved accelerating mobilization synchronous to the evolving needs of the world deploying industrial complex.

We have come to the realization that we are in an all-dynamic universe, that the old concept of "at rest" is not normal. When we lie down to go to sleep we do not shut off the valves, and freeze into rigid statues, --our billions of atoms take on a myriad of constellation activities in lieu of a few galaxy motions (of the day's routine regimentation of the body's sub-assemblies).

All our curves of measurement of man's earthly doings show an acceleration "upward," -- that is: with "AT REST" regarded as normal the curves of man's doings have taken the shape of a ski (reading from heel to toe). The curves have ascended now into almost vertical ABNORMALITY. Is this race schizophrenia? No! It is just that our "standards of reference" are cockeyed.

Obviously, we must now abandon the unrealistic "at rest" and reference all our affairs to the realistic yardstick of energy and its velocity aspect, as recently and universally adopted by science from Albert Einstein's work. To do so we need only revolve our charts 90 degrees of angle so that we may see the curves descending precipitously from the old heights of ignorance and ABNORMALITY and now tending to level off into dynamic equilibrium with the all-motion universe, infinitely normal about us. Thus "quickness" displaces static "death" as the normal of both life and universe, --i.e. life is no longer exceptional-to but inherent-in universe.

To Einstein's  $C^2$  which is the symbol of speed of omni-directional growth of the surface of a light wave which is 186,000 miles per second squared the speed of Sight, --(our personal eyesight) is normal, for it too operates at the speed of light, and not "instantly" which is an obsolete word of yesterday's static magic. 186,000 miles per second is only relatively fast as compared to the velocities of man's invented vehicles. 186,000 m.p.s. is relatively very slow compared to the man-invented nonsense called "instantaneous," i.e. infinite-super-billions-of-miles-in-no-time-at-all. Instantaneous is one of those out-of-this-universe concepts which we are now abandoning.

One of the most important contributions of science to society is its development of the ability to consider all of the wonders of the physical universe as measurable and rational and of immediate practical significance. The paradise of nature is for now and not for never-never.

Man's voice travels over the telephone circuit, wired or wireless, at 186,000 miles per second. Sunbathing he "sees" heat waves with his skin, received at 186,000 m.p.s. All this is now distinctly normal to his reality. Man spontaneously relegates his other sensorial faculties to secondary consideration. He can only hear by air-waves arriving at the tawdry velocity of 1/5 of a mile per second. He can rarely smell events occurring at a mile's distance, but, aided by a hurricane, may receive his "whiffed" report at 1/50 of a mile per second. Man can acquire tactile report at ranges no greater than that of his fingertip. He can grope no faster than 1/1000 m.p.s. Limited to apprehension of the phenomena of universe by his groping tactile faculty alone, the velocity factor becomes approximately nil.

The world seems at rest. Relative only to the apparent inertia of universe, as apprehended by this lowest-order faculty--the tactile--could the velocity of visual apprehension be rated as "instantaneous."

Fortunately for man, he has always subconsciously asked "to see" the vital phenomena. Thus he "witnesses."

Only within the paltry dimensions of life as serviced preponderantly by hearsay, smell-say and touch-say have the blinders of habit persuaded man to accept the ignorant "reality" which excitedly references experience but to the negligible velocity of "AT REST". "Fixed" brains will apprehend as "radical and revolutionary" every discovery and intellectually informed articulation of the individual as won through progressive augmentation of the faculties of highest order, --instrumented science.

Man "sees" only by omni-dimensional images activated within the experience-inventoried brain impressions as progressively illumined by the energy of momentary sensorial scannings. It is significant that he gets direct or non-delayed "visual" report only from the actively radiant energetic centers of universe, notably the stars. All other visual reports wait upon indirect routing by their superficial reflection from passive structures of energetic impasse, --the planetary "mass" phenomena.

With this coming of the realization of the normal velocity of energy, -- in the all-energy physical universe, --we have to recognize that man is increasing magnificently his range and frequency of informed activity. Manifesting intellect as well as energy man is taking progressive measure of universe and through intellect is slowly mastering degrees of the infinite energy.

Obviously, man now has to think beyond the limits of yesterday's politics, beyond the limits of yesterday's personal ambitions. By "personable" we mean the limited dimensions of the lower order senses. We will have to look at the problem of discovering the trends to tomorrow's building in a delimited manner else we will have a poor preview of that building.

Do not assume that delimited thought is now easy. We all say we know that it is 500 years since Copernicus postulated and 400 years since Galileo demonstrated that the earth was not the static center of a universe revolving about it. The latter idea we now declare "silly." But listen to your most advanced astronomer, -- when professionally off-guard, at, for instance, a seashore picnic on a summer evening, say to his daughter, "Look at the beautiful sunset, darling", --and worse--he "sees" the sun setting--and so do you.

You are, practically speaking, 500 years behind your own assertions of fact. You still say "up" and "down" when there are no such directions in universe. You mean "in" and "out" from center of spinning, cosmos-zooming earth ball. If you will

say, "I am going out to the attic and into the ground level," you will accelerate your reliable reality. In that fast moving "advanced" scientific activity to which man proudly refers us for up-dated thinking, -- the aeronautical world, the professional meteorologist reports to us of "winds blowing from the northwest" just as though the wing-headed little zephyrs drawn upon ancient maps were still puffing away up in the northwest, wherever that is! Whereas, we know that the air is being "drafted" to the southeast by the thermals and their low pressure centers--for you can't "blow" wind more than a few hundred feet--it turns around on itself. Every ring-puffing smoker knows that. However, air may be draughted over vast circuits. Then too we all speak and think of "things" when no things exist--all is dynamic interaction. So don't let's feel too smart--let us humbly seek to put our reality into dynamic order.

While the atomic space-ship may become the dramatic headliner in nearby decades, in the structure mechanics and life of tomorrow's single family dwelling we will witness by far the greatest evolutionary change from the traditionally familiar. Traditional house, embodying the residue of personable ignorance, has by its "at rest" fixations contrived to stem the dynamic flows of emergent reality to a greater degree than any other category of life's fixed preoccupations. Thus, dwelling inertia has, in effect, stretched the delicate flexible tension structure of comprehensive evolution flowing by until like a shot suspended in the sharp vertex of universal distortion, it must be impelled violently forward to our present and its needs, eventually to take equilibrious and dynamic position after the severe reverberations have subsided. This gretest single evolutionary change in men's way of solving their living problems will be witnessed in the coming half-century.

Stated in a less literary manner, the single family dwelling represents the very last major item of the whole of man's contrived environmental paraphernalia to come under his scientific scrutiny and subsequent realization through the astronomically augmented interactions of the world-embracing dynamic principles of industry.

All large buildings are processed by an army of engineers, economic experts, social scientists and the combined tactical thinking of our day's financial and labor leaders. In this respect of conception-by-combined-scientific-expertness, big buildings are almost on a par with the complex end products of industrial society, e.g. the ocean steamship, the automobile, the steel mill, the telephone system.

In contrast to the circumstances of conception of the complex industrial end products, less than 4% of this country's single family dwellings were erected by union labor, less than 2% were designed by architects and approximately 0% engaged the services of the engineer in their primary complex designing. Engineers have only had a part in the original design of the mass produced household equipment, which is secondary.

The scientist, physical or sociological, has had an absolute-zero relationship to the structuring of the single family dwelling, which latter nonetheless clearly persists as the major physical environment-contriving of the human specimen. In it are gestated the first and all important phases of the individual's group life. Here the individual learns that he is not only the product of union but its infinite servant.

The lack of application of the historically accumulated intellectual advantage of mankind (as realized through the prototyping activities of the industrial complex) to the conceptioning of the family habitat is not because the single family dwelling trends to obsolescence as a way of life. It is because:

1. an a priori theory of life's trends and purposes has not been evolved,
2. an a priori theory of dwelling has not been evolved, and

3. the priority of full industrial-advantage has hitherto never been applied to the problem of the single family dwelling!

Where relative scarcities exist in the overall scheme of satisfaction of man's needs and emergencies develop therein, priorities are established.

The general principles of industrialization may be looked upon as comprising one great big complex and still scarce tool which wraps up all latest technical advantage in realizing predictable performance.

It is obvious that up to now man could not justify assigning "priority" of technical advantage to housing in wartime. He would not "up" his home standard of living while the boys were in tent, trench or barrack and required no up-ed standards for these shifting purposes.

In peace time priority of scientific and technical knowledge and effort went either to home industry or field occupations or to outright emergency services.

In peace time home industry priority went to the building of the universal tools, simple or complex, to consolidate the gains of his intellectual "hunting" and technical experience.

In the interactive permeations taking place in home industry the houses of the commerce-expeditors were essentially instruments of propaganda, persuasively proclaiming the physical wealth-increments exploitable in the industrial principle. This propaganda mansioning represented the natural coloring of a short lived evolutionary phase. Houses of the workers were the meagerest of knocked-up contrivances and hovels, designed only to bring their efforts into proximity with the evolving industrial complex. No priority of scientific acumen was involved in the conception of either type of establishment.

In the field-preoccupations of hunting, animal husbandry and agriculture, the first two obviously required no priority of scientific and technical conception in the realization of dwelling or permanent abode. Hunting was inherently swift, dangerous, single-handed activity of a man sleeping under the stars. Animal husbandry, though seasonally mobile, involved the most scientific and technical preconception of the mobile habitat for the shepherd family, but the realizations of the scientific principles of his tenting were entirely remote from industrial rendition. Ships of the industrial commerce embodied the only industrial rendering of mobile habitat--habitats, however, designed with approximately no direct concern with family gestation.

In his original agricultural frontiering or field industry man gave all priority of effort, and technical advantage, to affairs of the soil because not only his own family's survival needs could thereby be supplied, but, if nature were bountiful, his excess increments could be converted to increasing the technical advantage of man over nature by feeding the specialists who were building industrialization. For this he received omni-purpose wealth articulators, in the form of money or credit, with which to participate in the growing advantages generated by the industrial complex.

His housing was, therefore, contrived in an expedient manner out of salvage materials culled from the land, incidental to the clearing of soil for agricultural purposes. He attended to his building in the "off" periods and after "regular" priority work. His housing was contrived as fortress and shelter against marauders and element. As noted, it was contrived out of the salvage--trees and stones--on a hopeful basis and not upon scientific and industrial predetermination of its behavior

and stress capacities. He hoped that fire, and tornado, and termite, and flood, and pestilence, and rot would not come, for he could not "design" these salvage materials into competence by making them "look" like a "castellated" fortress. Housing was never designed upon a scientifically predetermined schedule of comprehensive performance requirement--rendered in knowledgeable techniques by a vast orchestra of tools out of world-garnered and industrially-evolved substances which would not only assure predictable standards of performance in each category of structural and mechanical requirement but would make possible complete logistic advance planning regarding the involvement.

Historically speaking, the important eras of technical advance has been precipitously introduced through the obvious wartime emergency which articulates the between-wars scientific accumulation of new degrees of potential advantage over the energetic properties of nature. The magnitudes of the between-war scientific accumulation represent a geometrical progression. At termination of each war phase the "ins" level off their economy to exploit the new degree of technical advantage. Deprived of participation in the technical advantage at this proven level, the "outs" take advantage of the geometric progression of the scientific potential and introduce once more degrees of technical advantage which, though of seemingly lesser physical investment, threaten supremacy over the economics of the previous technical level, --because of the imponderable yet enormous knowledge-gains in means of impounding larger blocks of cosmic energy within given pounds of terrestrial matter, thereby disposed in more power-full arrangement. The incompatibility of the two levels of technical preoccupation is further aggravated by the failure to transfer priority of use of the industrial complex to realization of the theory of continuous anticipatory economic volition from its preoccupation with the traditional and intermittent curative volition. Economic and eventually civil rupture ensue and the cycle is repeated.

As the science potential ever accelerates to greater magnitude the severity of rupture would seem to promise like progression. But history has produced a fundamental surprise constituting an entirely new orientation commensurable with our rotation of the frame of reference from a static to a velocity "normal."

Historically viewed, wars were "carried" to a relatively remote front. When the front was driven home to one side, that side gave in. As wars have ever employed the industrial complex by priority and as the industrial complex has come to be total to world resource, so has war become total. With the development of totality, war has come to be waged not as much on many fronts as on many spots. Significance of land and sea have been lost in significance of one-sky. Blitzkrieg brought the war into many spots over all earth as a descending plague. Latest phase of total war involves ultimate controlling of missiles from anywhere on earth to anywhere on earth. Long distance is total and the concept of front vanished.

War is dynamic and its two dynamic phases are offense and defense. As offense obtains omni-directional parity supremacy lies in relative defense advantage. Relative defense advantage lies in the direction of relative mobility, --in the ability to dodge widely and without loss of poise.

The historical surprise develops as the result of:

A. The contraction of interval between increasing emergencies until naught but emergency exists. (That is our condition today despite our none-too-confident whistling in the dark.)

B. Enforced occupation of hitherto hostile equatorial and polar environments.

C. The interim conquest of the environmental extremes in the military conquest of the air.

D. Reorientation of the exploitation course of the industrial complex, --with the 92 chemical elements isolated, and the original total industrial machine completed out of the inventory of the 92 chemical element resources, and with unlimited cosmic energy, piped and valved ready to be loosed into economic circulation. It has been realized that, inasmuch as the technical advantage trends to the infinite production for increasing numbers by lesser numbers, the key to economic and subsequent political expansion is the consumer, --the more consumers the greater the expansion. The more numerous the consumers' needs and the more frequent their satisfaction, the greater the expansion. The economic volition trends to accelerate total world occupation by total world man in total dynamic enjoyment.

The biological competition (inherent in evolution) to accelerate standards of satisfaction bi-polarizes in total world struggle for management of the industrial complex. Conscious courting of world Society as potential consumer by competitive world managements looms. Promises to world-man of advancement of his standards of living and growth by the competitive managements must be fulfilled.

E. Increasing world population by new birth and increasing longevity with increased actual or potential mobilization of the population and total potential communication and education has accelerated the individual pressures of society; as does increased increment of energy accelerate the molecules of gases, to exercise increasing pressure against circumventing systems. Historically, man's solution of increasing pressure has been linear. He has come to complete the network of total inter-linkage of the pressurized centrals. Attempting radial dispersion to relieve pressure, he has been unable to deploy other than in a veined or linear manner as his increasing standards of mechanical advantage have been dependent upon piped, wired, tracked paths. Dynamically speaking, his linear paths are all pipes, -- his car or his train is a section of pipe surrounding him which section moves progressively to enclose him, --to allow his existence in previously prohibitive environmental extremes. The linear frequencies of sectional tube increase until the total linear dynamics approach chain or escalator continuity of tube. Radial and deploying veinage of the linear tubal expansion encounter geometrically diminishing economy. The dynamic population, increasingly energized from the cosmic resource, finding no relief in inter-center connections and radially confined, trends to surge within the system with increasing velocity. Only relief of the surges, oscillating outwardly and inwardly, is that of centrally articulated upwardness, as the linear services of pipe and wire can be most economically extended at center. The upsurgings articulated in multiple-story and skyscraper structures until laws of diminishing returns set in. The pressures continued and filled all the interstices, as designed not only for the intermittent occupations of economic interaction in the fixed "hoteling," but kept a constant population in occupation of the shuttling facilities. The centrally upward and outward pressure grew finally to articulate omni-directional outwardness by wireless, trackless and pipeless. Potential travel and communication became omni-directional.

Surprise interaction of A, B, C, D and E is that scientific dwelling facility suitable for all times and climates, able to deploy the family to high standard living in preferred location of natural privacy without sacrifice of potential participation in total complex is being advanced to first position of priority in use of the industrial-scientific advantage not only by the military, by the political and by the industrial management but by rank and file labor and last, but not least, common man. In the ranks of common man the clamoring for priority of the scientific dwelling facility and autonomous deployment and, thereby, historical emancipation of man becomes louder amongst the most recently maturing.

Physical key to rapid amplification of the industrial logistic-ability to provide additional deployed dwelling facilities for two and one-half billion people within decades, at hitherto undreamed degrees of advance of technical standards, is the same key that unlocked the door to structuring the initial and total industrial complex. This key is the increasing structural ability of man as realized through amplifying tensile ability.

Dr. Turpin C. Bannister, Head of the Department of Architecture, University of Illinois, who is taking part in this symposium, has written a book, which we hope will soon be published, tracing history of the progressive inclusion of metals as structural component of buildings as well as engines and the industrial complex in general.

Throughout the ages man was limited in his structuring to the processing and manipulation only of the compressive functions and components of structure. Stone afforded 50,000 pounds compressive strength to the square inch. It was relatively imperishable. Best tensile abilities available in nature were provided by the vegetable fibers, --as solid wood or separated fiber. Tensile strength of wood or fiber could not be counted upon for more than 5,000 pounds to the square inch, and that in exceptional cases. The wood and fiber were perishable. Stone and masonry could be counted upon to afford no more than 50 pounds tensile strength to the square inch. Man's structural ability seemingly favored compressive organizations on a 10 to 1 or better basis, --width and weight were amplified to increase the stabilities provided by inertia. That his primary philosophic reference was inert and pressive was inevitable.

As structural systems are omni-directionally comprehensive, tensile factors were unwittingly taken advantage of to cohere man's invented structures. Comprehensive tensile coherent provided by nature was gravity, the enormous amount of which induced into action was manifested by the weight of the structural masses.

With the coming of modern chemistry man learned not only to extract but to alloy the metallic elements, --in increasing quantity, --to progressively reuse them, --to progressively augment the sum total of the metals in service by further extraction of the elements from their original chaotic occurrence in the matrix of the earth and stone he so ignorantly had been employing of yore.

With the availability of production metals for building man's conscious employment of the tensile factor in his invented structures grew rapidly, --both structurally and dynamically. The alloyed and worked iron, called steel, provided tensile ability initially at parity with his best compressive abilities--50,000 pounds to the square inch. Since inauguration of metallic tensioning of structures the tensile abilities have increased rapidly through chemical knowledge while compression ability has remained at its maximum of 50,000 pounds. The last quarter-century has seen tensile ability moved forward from 50-60 P.S.I. to 70-80-120-150-185--400,000 and with no indication of a break in the increasing rate of ability.

The enormous increment of energy impounded in the industrial complex has been won directly by the intellectual factor which adduced the principle of tension and its improved rendering.

Throughout universe compression and tension are energetically juxtaposed. Their juxtaposition provides dimension, --the basis of awareness of life itself. Compression is limited to dimensionally miniscule tasks in universe, -- to the spherical convergencies of energy in elemental systems. The tight balls of energy, -- stars, planets, atoms, --are ever-dynamically disposed and systematically positioned



by energy as tension. The incredible distances of universe are methodically inter-coursed by the incredibly compact ponderosities at incredible speeds and degrees of precision by functions of tension. Tension is comprehensive to universe.

Man's structuring ability is by principle distinctly limited in the proportional ratios of width and length of compression members. Elongated compression tends to deflect and fail. Best compression abilities are in the planetary form of the sphere, --whose neutral axis is protected by its omni-directional symmetry. Ball bearings are man's best accomplishment in compressive structuring.

Tensile principle has no such ratioed limitation of length to section. Tension members, no matter how elongated, tend to pull true. Tension is limited only to the initial cohesiveness of the chemical elements. As man's knowledge of chemical interaction improves the length of tensile members, relative to given section or given stress, trend to ever increasing amplification of length. They trend to infinite length with no section. Incredulous, --no! Every use of gravity is a use of such sectionless tensioning. The electrical tension first employed by man to pull energy through the non-ferrous conductors and later to close the wireless circuit was none other than such universally available sectionless tension.

In the phenomena tension man is in principle given access to unlimited performance. Seems fantastic, but there it is!.

Essence of this essence of the historical surprise in general reorientations is the discovery that tension structure is not a linked, or chain, phenomena. Tension members represent "milky way like" arrangements of atoms, the atomic or inter-stellar spaces of which are relatively infinite. The tension members may no longer be thought of as chains--no stronger than their weakest link. Tension structures arranged by man depend upon his relative knowledge in purest principle--in purest initial volition of interpretation--of pure intellect.

Over a period of 32 years I have made sorties in the realm of mathematics. There has developed therefrom a rational system of mensuration comprehensive to physics and chemistry. It is a geometry originating in the assumption that dimension must be physical. It follows that, inasmuch as physical universe is entirely energetic, all dimension must be energetic. Vectors and tensors constitute all elementary dimension. Thus, original assumptions eliminate the necessity of subsequent assignment of physical qualities to abstract mathematical devices in the manner we have, of necessity, assigned progressively discovered attributes of physical universe to irrational relationships within the a priori ghostly Greek geometry.

Knowledge gained from the energetic geometry has given me aid in periodic research and development in other directions, --as, for instance, with the original Dymaxion house, the Dymaxion cartographic projection, etc. Throughout the last two years I have been preoccupied with developing what appears to be dynamic principles of structure inherent in the atom and its nucleus. While my efforts are entirely outside the work of formally recognized authority on atomic phenomena and the significance which I am inclined to assign to my discoveries may never be formally verified by the academy, I have, nonetheless, gained therefrom knowledge of technical advantage in structure that needs no further theoretical verification for it has been confirmed by physical experiment.

The degree of new technical advantage provided by the discovered principles may be appreciated by the fact that one pound of structure can hereby accomplish space enclosure heretofore requiring one ton of structure (when complying with the scantiest of U.S. city codes) while at the same time arriving at predictably stable conditions under extreme stress of earthquake, typhoon, arctic cold, tropic heat in the

presence of which the behavior of the contemporary city dwelling structure referred to is dubious. This 2000/1 ratio of comparative advantage is made regarding structures of approximately 8,000 square feet of ground coverage. The new structure has been named GEODESIC STRUCTURE because of its employment of great circle geometry.

I was recently requested by the Air Corps to erect a small GEODESIC STRUCTURE in the courtyard of the Pentagon Building in Washington. Army engineers on seeing it said, "Why, it is as good as a tent! No, it is better, --it can stand stresses a tent cannot!"

Taking a cue from this spontaneous compliment of the Army engineers I am going to suggest to you a way of envisioning a solution of the AUTONOMOUS FAMILY DWELLING FACILITY suitable for installation in the 100 mile or more range.

We have witnessed a half-century's continuous shrinking of dwelling structures produced at increasing costs per pound and per cubic foot. During the same half century we have seen all the historical outdoor living controls, such as ice house, washing shed, root cellar, water supply and waste disposal mechanized and brought indoors. To a gradually improving mechanics of solution of these facilities have been added an increasing host of controls and mechanical devices. Cold that required winter's harvesting and degrees of cold not to be harvested are arrived at in minutes and precisely maintained within increasingly economical dimension. Functions of the past which required months, weeks, days and hours have been reduced to minutes and seconds while new degrees of precision of maintenance of desired conditions previously undreamed of are now routine. As over all result, life expectancy at birth has been approximately doubled in this remarkable yet exquisitely short fifty-year era.

While we continuously lost advantage in degrees of structural satisfaction to be obtained per unit of investment (pounds, dollars, time and energy), we have continually gained in degrees of performance to be obtained per unit of investment in household mechanics. For fractions of a cent and ounces of material we can get instantaneous reports from around the world where the same would have cost thousands of dollars and involved thousands of tons 50 years ago to obtain the same personal home facility.

In view of these trends and looking to their further extension in the next 50 years I propose that we eliminate the shrinking and ever-less economic house altogether and concentrate entirely on amplification of the mechanics. Let's go camping with paraphernalia competent to make us masters of our environment and time as man has never dared to dream.

Briefly, I propose a super-camping structure consisting of a 600 pound, 50 foot diameter hemisphere. It consists of a triangular network of aircraft tubing, laced together internally by aircraft cable. Its airframe structure rises into a rigid truss in seconds as its steel sinews are hydraulically tensed, somewhat as a tinkertoys is drawn taut. A transparent plastic skin of double wall construction is inflated to withstand hail, or other similar impact loads. An interior shuttering mechanism provides 100% variable optic control.

Accompanying the GEODESIC STRUCTURE will be an AUTONOMOUS DWELLING PACKAGE. Research regarding this has been done by 40 advanced students in product design and architecture at the Institute of Design in Chicago. Given an hypothetical problem that all cities of 50,000 or more population were to be bombed within 10 days, they were instructed to compile a household package of all equipment they might conceive of needing for "luxurious living." Price was not to be considered, only the best merchandise in any field was to be "purchased." They shopped all the best sources--

Marshall Field's, Macy's, Sears and Wards--furniture, electrical appliance, radio, camera, sporting goods shops, garden club machinery, home machine and woodworking shop suppliers. Every conceivable area of high standard of living was covered. Tabulation revealed that the whole package of modern mechanics for a family of 6 had cost only \$18,000, bulked 1,600 cubic feet and weighed 12,000 pounds!

Because this household machinery and paraphernalia had to be marketed piecemeal with unpredictable lags on shelves and in intermediary warehouses, its cost ran \$2.00 per pound for its net 9000 pounds. The same grade of production goods when mass purchased and assembled by the automobile industry with appropriate wiring and plumbing, as are the radio and heater in the automobile, runs 50¢ per pound. Therefore, the total 1949 advanced standard of living package could also be mass produced, purchased, assembled and distributed under a comprehensive chattel mortgage at 50¢ per pound. This may be immediately effected by integration of the electrical appliance and automobile manufacturing industries without inauguration of new components. It involves only modification of what is to be assembled along the production line. Each of the 6 surfaces of a 25' x 8' x 8' trailable container will move down the line separately. To them will be affixed all the household items of the super mechanical package. In logical use arrangement and spacing when the panels are hinged together and opened in an 864 foot platform, the arrangement also allows the panels to be hinged into a closed box with intermeshing of the fixed parts. "A neat trick if you can do it, and we have!"

There were many other problems of water supply and sanitation but all of these are now under control in economical manner.

You may say, "What is new about a dome?" The answer is that while there is nothing new about a dome, the way that it is accomplished, in this case, represents first a new advantage taken of the most recent increases of tensile ability and, secondly entirely new structural geometry.

Emulating the compound curvature trussing of the atom's dynamic structure, comprised of great circle forces our GEODESIC STRUCTURE, though not inventing the principles, employs them for the first time in a man-made structure.

A barrel represents an advanced phase of the roman arch or principle of stability accomplished by simple curvature. The parallel barrel staves constitute a ring held together in compression by encompassing tension bands. Thus compression, which tends to curve, is favored in that tendency until the curving line of compression closes itself to thrust against itself. The tension line, which tends to pull true, forms itself in a series of infinitely short true chords, --because tension members may be flexed while they are in tension without tendency to failure. The tension ends are closed to pull against one another. Thus we have two closed circuits, of tension juxtaposed to compression in dynamic stability. Tension lines may also be flexed while under load; without tendency to failure, --as a compound corollary of the principle to pull true and the ability to tolerate bending while tensed. Pressures exerted either outside or inside of the barrel result in outward thrust of the staves against the tension members. Thus the latter absorb the working or random loads.

We can also demonstrate the great structural gain inherent in the principle of simple curvature over rectilinear structures when we take a limp sheet of paper and curve it into a tube; previously an amorphous diaphragm of little structural advantage, it affords dramatic structural ability in the form of a tube. When the paper is curved the concave side forms an arch of infinitely minute parallel compression staves, fulcrums or pinched rows of atoms. The convex surface of the curved paper is stretched around the compression arch of parallel fulcrum lines.

The paper may be reversed so that what has been the inside of the cylinder's surface becomes the outside surface. Thus it is seen that simple curvature structure is a principle and not a unique characteristic of the atom's constituting one surface or the other. The stability of simple curvature is enhanced by the length of the parallel lines. As the lines shorten to approach points the compression of the arch approaches the condition of a simply compressed line which can then tend to curve in any direction. The curved compression in the barrel or cylinder was confined to articulate its tendency to curvature within one plane by the compression (strutted) positioning of every point of the line of curvature afforded by the parallelism of the staves, --and their inertia.

Parallel lines can be torqued. So may the parallel lines of a cylinder be twisted as we see them in a rope. A rope and a cone are both forms of simple curvature.

When we press against a barrel the stress is, as earlier noted, satisfied by the tension hoop. The hoop represents the circle of a single plane. Thus it is seen that simple curvature stresses act in a single plane, ultimately articulating that stress in diametric opposition of a line within the plane. The stresses are then ultimately focused to compressive poles of the one plane because the latter is unaided in its stability.

In a simple curvature tube of paper all the circles of tension including all the circles of compression are parallel to one another and give one another no help. Therefore, a cylinder may be flattened in which case each circle becomes a double line. In order to do so we see that the tension circles exerted all their pull in levering the many compression points within to compress exquisitely the two opposite or polar compression points. This is then the genesis of the ultimate two-way focussing compression tension line resultant upon stressing simple curvature.

In our GEODESIC STRUCTURES the surface of a sphere is interlaced by unique numbers of great circles properties of which are that they intercept one another in such a manner that all the surface areas described by the intersections are triangular. As triangles are non-distortable this intersecting, if substantially structured, represents a rigid trussing of the spherical surface. If, between each of the vertexes or intersections of the great circles occurring in the surface of the sphere, we will construct chords or straight lines these lines must fall below the surface between their surface terminals. The lines converging at any one vertex all leading away below the point on the surface, must form a convex intersection or a pyramidal point. As we press against any convex vertex, and if the other ends of the line are elastically restrained, the vertex will subside and the lines will tend to form a flat plane.

As each of the chordal ends between vertexes of our GEODESIC STRUCTURE are rigidly restrained by the comprehensive trussing of the sphere, it is seen that when pressure is exerted inwardly against any vertex that it will thrust outwardly against each of the chords leading radially from it. It will be seen that, inasmuch as each vertex represents a pyramid of triangular planes, the bases of the planes opposite the vertex constitute a closed linkage or ring. Because the linkage is of great circle chords and because sections of the great circle always represent the shortest distance between any two points on a sphere and the chords of the great circle represent the shortest distance between the two points in space through the sphere, therefore, the ring of chords tensionally opposing the compression thrust of the pyramidal lines from any one vertex may not be elongated.

Thus it is seen that the GEODESIC STRUCTURE employs the principle of compound curvature as the stress is radially distributed from a single point. All the ver-

texes surrounding any one vertex are secondarily actuated and each in turn thrusts outwardly to adjacent vertexes, rings of triangles of geodesic lines are successively activated from the original thrust against one vertex until six rings have been activated and the equator is reached. All thrusting outwardly against equator symmetrically, their outward thrust is compoundingly restrained by the opposite hemisphere.

In the case of a GEODESIC STRUCTURE representing a portion of a sphere the functions of the balance of the sphere are rendered by the earth which tends to complete the spherical structure by stress extension within the earth. Thus in compound curvature structures of nature, emulated in principle by our GEODESIC STRUCTURE, working stresses are ultimately translated into omni-directional outward thrust from the system's center and are ultimately satisfied throughout all the cohesiveness of all the enclosing tension. In contra-distinction to simple curvature which is ultimately satisfied in polar focus upon two compression points, compound curvature invokes ultimate activation of comprehensive tension.

In a compound curvature sphere of paper all the surface represents an intertriangulation of great circles--wherefore each great circle helps the other--each is a compression circle enclosed within a tension circle. If we try to flatten the sphere its equator cannot move outwardly to accommodate the down thrust as did the girth of the paper cylinder. Therefore, no one circle can lever its compressive interior against polar points, --and disunited fail. In the sphere the pressure at one point must invoke an infinity of great circles to crush an infinity of points simultaneously in a progressively rolling radius as the sphere is pushed gradually inside out--but is never flattened, --only rolls the wave to the equator which holds. Even in its inside-outness the sphere maintains its comprehensive interaction of system, seeking to reestablish its shape. Thus do balls tend to bounce.

There are many ways of rendering GEODESIC STRUCTURES but all represent closed systems in which compression is comprehensively encompassed by tension. In principle this emulates the structuring of universe.

It is to be noted that men have employed GEODESIC STRUCTURES before in the form of the octahedron. While useful in small structures, the relative sizes of spans or chords of this well known continuity of great circle triangulation becomes so great in unsupported length when applied to structures appropriate to men's buildings that its virtues were unavailable for practical purposes.

The surprise factor in my introduction of geodesic structures to you is the surprise provided by nature. We have discovered and not invented all-triangular interaction of 25 great circles and 31 great circles whose relative chordal lengths make them appropriate for structures up to 100 feet in diameter.

There are further occurrences in greater numbers of great circles embodying the all-triangular interaction. Because of the shortness of the chords, which make possible the application of compression members between vertexes of a practical length-width ratio, --while the system of short compression members may be comprehensively cohered by ground to ground tension lines, it is now theoretically possible to conceive of structures of spans approximating the great suspension bridges. A dome one mile in diameter appropriately skinned in may, in the future, economically encompass the activity of city. Such a city would require no weather walls for its individual parts and could be entirely air conditioned.

There is special advantage of the hemisphere over other geometrical forms. For instance, the upper or enclosing surface of a hemisphere ("geodesic") or of a half cylinder (quonsette) is always twice the area of its base (floor). The upper surface

of a half cube structure (typical of one-story box house) is always three times its base (floor). The upper surface of a cube is always five times its base (floor). The above ratios indicate clearly the initial advantages of curved enclosure over rectilinear. The advantage is spelt out in weight of material per unit of function and in surface cooling areas, etc. The peak-roofed box is at greater disadvantage than the flat-roofed box. The dome sheds its snow and rain in a superior fashion to a peak or a cylinder.

While it is customary to identify office and manufacturing space in the terms of square feet of floor area, the actual fact is that--because man and his goods are not two dimensional--the space is volumetrically employed. For this reason, the unique advantages displayed by the sphere (as dimension is amplified) in the rate of volumetric increase as of the third power over surface increase at the rate of the second power has direct bearing on use.

It may be argued that the hemisphere provides unusable heights of volume and, therefore, the floor area is a better means of appraising the value of the space, but this aspect is only true under special forms of use which emphasize only the ground need. Storgewise the whole of the hemispherical volume can be employed. In the case of our GEODESIC housing where a fifty-foot hemisphere is employed, we find it appropriate to create a second deck.

Further uses are made of the hemispherical volume which take advantage of the unique geometry of the hemisphere; that is, atmospheric circulation takes advantage of the natural fountain-wise flow of heated air, i.e. air heated at the center tends to expand and rise as the heavier air is pulled down by gravity. As it rises it further expands, it cools and flows outward and downward to floor level and then centers for reheating and recirculation.

This natural fountain motion of heated air may be observed as an isolated phenomena in the case of explosion and in great fires. Notably, the Bikini bomb may be remembered as demonstrating the upward-outward-downward and center rolling doughnut hemispherical shape. Inasmuch as this is the natural atmospheric circuit of energy as heat, it is seen that--if the hemisphere is designed of the right size to accommodate the natural dimensions of a given heat fountain--there is no tendency of heat to be lost nor additional energy expended to impel atmospheric flows through unnatural chambering in order to distribute "comfort" atmosphere.

The hemisphere has further advantages relative to the phenomena energy-as-heat-in-the-form-of-radiation (in contra-distinction to energy-as-heat-as-articulation-by-molecular-acceleration in gases, which latter is commonly identified by the combined behaviors known as conduction and convection). Energy-as-radiation (heat or light or radio) is refracted by the atmosphere. The lumen reduction as the light meter recedes from source of light is rapid. As the longer waves of light radiation are progressively deflected by air molecules, they tend to turn back on themselves. This atmospheric deflection effect on radiation may be witnessed by observation of a street lamp in a mist in which it is seen that a unique sphere is illuminated, and that but a small fraction of the high frequency and shortest wave light penetrates to the distant eye.

The long infra-red radiation is turned about most rapidly and forms a relatively small sphere around the heat-light source. We demonstrate our familiarity with heat radiation's spherical limits as we back into and walk away from the glowing fireplace. The spherical surfaces of relative heat "fronts" are well identified. Again, as in the case of convection fountain enclosure, it is seen that, if a structural hemisphere is of adequate size, heat losses by radiation (where the origin of heat is

near the center of the hemisphere) may be scaled down to negligible, and that such heat radiation as does reach the surface may be turned around by reflection and thrown directly back toward point of origin.

There is a third aspect of unique advantage in the matter of hemispherical volume, gained at the third power, against surface growth of the second power, to wit, that advantage accruing to "Relative Size." Relative Size, very naturally affects heat balance because extreme chilling by conduction occurs in direct relationship to the second power surface, while the heat is being impounded by the air mass growing at the third power. A large heated sphere such as Earth can maintain high internal heat without important challenge by exterior cooling surface. A large internal combustion engine cylinder cools off slowly in comparison to a small combustion cylinder (large Diesel vs small motor cycle). In reverse, the principle of relative size effect may be noted in the relatively slow velocity at which a large cake of ice melts as against the accelerating velocity at which a small cake of ice melts.

The principle of Relative Size effects may be observed where heat is no consideration; for instance, in the relative rate of dissolution of several small cakes of soap vs one large cake of soap of equal total weight. The principle is exhibited by a steel needle floating on water.

Because the amount of volume that can encompass a given center for a given amount of pounds of structure is larger in the case of the sphere vs any other kind of geometrical form, and because our particular type of tube-and-cable "necklace" structure (which takes advantage of triangulation of geodesic lines) entitles us to the encompassment of relatively large volumes with relatively low logistic investment, optimum conditions may be economically obtained in consideration of these various "special" aspects of interior energy behavior.

There is a further advantage unique to this geometrical form not at first anticipated, that is the exterior aeronautical advantage. The hemisphere provides the least resistant form (to the sum total of omni-directional air motions about it) of any of the geometrical forms. (For this reason hay mows do not tend to deform in the wind.) The wind tunnel discloses that interior heat losses of permeable wall structures are proportional to drag. This is to say, that the exterior low pressures created by the passage of air about a structure are satisfied by interiorly generated energy expenditure to pass the high pressure gases through the permeable passages of the walls of the structure. (A high energy expenditure.)

Other experiments have disclosed this principle to be in operation. Cubical houses heated by return circuit hot water systems have been mistakenly supposed to be cool in the windward rooms in the wintertime because the wind was blowing on that side and was, therefore, supposedly chilling the radiators in the windward rooms. Experiments disclose that no heat rises from the boiler to the windward rooms because the total B.T.U.'s being generated are required to process the transfer of the heated atmosphere in the lee side of the building through the walls to satisfy the low pressure occurring in the lee exterior of the building and that the whole heat flow is to the lee side.

It can be seen that the four factors noted above--(a) heat convection fountain, (b) radiation reflection to spherical shape, (c) Relative Size, (d) Aeronautical properties--combine to provide unique energy economies, but with no further expenditure in physical structure in the way of conduits, partitioning impellers thus displaying surprise advantage in new magnitudes of available controlled environment.

Employing components now manufactured by American industry one of our engineering research teams has now completed a tentative flow sheet of the sewage disposal

and water supply system, --the latter for 600 gallons per day of chemically pure, sterilized, sweet water. This apparatus serves as a general energy exchanger, taking heat from the refrigerating system to satisfy the pressure distillation processes. It heats the water for general cleansing purposes while shunting a fraction to refrigeration for chilling. This total energy-sanitation-refrigeration system weighs approximately one ton.

Autonomous living under hurricane-proof hemispherical enclosure of 50 foot diameter (864 sq. ft. of platform plus 986 sq. ft. of interior garden) with all modern super-luxury appurtenances and sanitary controls is now feasible. Weighing in toto 14,000 pounds, it may be mass produced at \$7,000. Push button erected it may be occupied at well below the present cost of bare miniature mansions sewerred and paved together in "Siamese twinness."