The Development of a Visual Extension to Synectics Theory

A THESIS

Submitted by

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ABSTRACT

A background investigation into the meaning of creativity and visualization was made, examining in particular the role played by visualization in the creative acts of science and engineering. From this grew the hypothesis that there is a relationship between an individual's creative ability and his skills of visualization. A sequence of tests is described which finally led to an experiment collaborating this hypothesis. This test used 28 subjects from Tufts University's College of Engineering who worked on an open ended technological problem. Their final design, redrawn for uniformity, was ranked for creativity, while their actual work was scored for visual content. The Spearman Rank Correlation Coefficient between rankings for creativity and visualization was .685--significant beyond the .01 level. Concordance between the six creativity judges was .378, and between the three visualization judges was .889. Both of these agreements were significant beyond the .001 level. In the final chapter implications of this result on education, psychology, science and Synectics are discussed.

FOREWORD

The driving force behind this thesis was the conviction that my own supposedly high quality engineering education was far from ideal. Specifically it: A) had treated a basically beautiful subject, science, in such a way as to remove any notion of beauty; B) had totally disregarded the way in which I learn; and C) had not given any indication, other than in rhetoric, that engineering was a creative field.

Four years in industry convinced me I was right. Engineering can be beautiful, and fun. It is a very human activity. This thesis is intended to help right the above complaints in my own mind and hopefully help restore the aesthetic in engineering so that others may benefit as well. Its subject is the role visualization plays in creative acts. It is necessarily a personal statement, but builds on scientific fact and sound psychological experimentation. To have left out the human element would have been to continue the ills listed above.

I wish to thank Percy H. Hill, William J.J. Gordon, Tony Poze, John Kreifeldt, Samuel McLaughlin, Al Schidel and especially my wife Linda for all the assistance and encouragement they have given this project.

Rolf A. Faste

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The Development of a Visual Extension to Synectics Theory

CHAPTER 1 WHAT IS CREATIVITY?

1.1 INTRODUCTION

The subject of creativity is one which each of us has at one time or another, thought about and discussed. This is not surprising because not only is each of us concerned with the creativity of our own lives, but the subject itself falls into almost every area of intellectual investigation. To answer, for example, the question, "What is a creative act?" we must turn to Science and the Arts in general. The question "How does one create?" is examined by Psychology and now, Artificial Intelligence and Cybernetics. "What is the best way to encourage creativity?" is commented on by Education, Child Study, Business and Economics. Architecture and Anthropology are concerned with the question, "How does the environment and culture affect creative abilities?", and History also provides clues to the answer. "Why don't we encourage creativity more?" is a Sociological and Political question. And finally, the question which cuts to the core of our existence: "Why does man create?" is dealt with by Religion and Philosophy.

1.2 CREATIVITY DEFINED

As a result of the attention of all of these disciplines, the term creativity has come to mean many things to many people. I prefer a rather simple explanation. Creativity has to do with man's ability and predilection to create. And create means to bring something new into being. Since man does not yet appear to be capable of creating something out of nothing, to create something new means to rearrange, reorder or combine previous materials or ideas to form a new whole. In its most elemental form a creation would involve the combination of two components in a way which had never been done before.

Whenever a man thinks of an idea which is new to him he is being creative. However when a man thinks of an idea which is not only new to himself but to the whole of society we say that he is somehow more creative. The term creative usually connotes this idea of originality. A child rediscovering say, the displacement principle of Archimedes, is certainly creative, but the effect of his creativity on society is zero. And, as George Kneller in The Art and Science of Creativity points out, such a child has had the benefit of living in a society where this discovery is already common knowledge. (13;4, that is, Reference 13; Page 4)

There is a second requirement often imposed on the creative act, especially in engineering. And that is that it be useful and capable of implementation. I suspect this is a result of the fact that few people work for themselves any more, and employers are more concerned with short range profitability, than in long range contributions to society. In any case, I balk at this requirement. At the time a new idea is proposed, the tools for judging it quite often do not exist. The invention will, in fact, also invent new criteria for judging itself. Creative ideas are inevitably met with hostility, as they disrupt what preceded--witness Copernicus, Galileo, and Einstein. It is not so long ago that Duryea's automobile was met with cries of "get a horse", and the Wright brothers' propelled glider with "it will never fly". These cries mock us daily as we sit stuck in traffic jams and holding patterns. Indeed, they work too well.

With the increase in scientific knowledge this notion of relevance is catching up with wild ideas at accelerating rates. Thirty years ago pollution control was largely unthought of. Yet the architect, Paolo Soleri, has been working on his nature preserving Megastructures since that time. Relevance for his work caught up with him within his lifetime; in another twenty years it may even be feasible, and ten years after that imperative. Was his work uncreative twenty years ago because it lacked relevance? Obviously not.

However, when it came time during this thesis to judge creativity, it was felt that some limit should be placed on totally impractical or facetious problem solutions. The criteria imposed was one of intellectual honesty. A solution was deemed intellectually honest if it was a serious and conscientious attempt to find a workable solution. If it was not, it did not receive credit.

1.3 CREATIVITY AND INTELLIGENCE

Intelligence is defined as the power to meet any situation, especially a novel one, successfully by proper behavior adjustments; and also the ability to apprehend the inter-relationships of presented facts in such a way as to guide action towards a desired goal. (17) It would appear that creativity is certainly one aspect of intelligence.

Yet today, the concept of intelligence can not be disengaged from the IQ (Intelligence Quotient) test which measures an individual's ability to verbalize, categorize, remember, recognize and solve problems having one correct answer. Creativity, on the other hand, deals more with open ended problems requiring skills of exploration, imagination, and invention. If intelligence is truly measured by the IQ test, creativity is not a part of it.

So a distinction is made between creative and non creative (not necessarily a derogatory name, as opposed to uncreative) thought. Kneller states it this way:

> Creative thought is innovative, exploratory, venturesome. Impatient of convention, it is attracted by the unknown and the undetermined. Risk and uncertainty stimulate it. Noncreative thought . . . is cauti us, methodical, conservative. It absorbs the new into the already known and expands existing categories in preference to devising new ones. (13;7)

In the words of Getzels and Jackson:

> The one mode tends toward retaining the known, learning the predetermined, and conserving what is. The second mode tends toward revising the known, exploring the undetermined, and constructing what might be. A person for whom the first mode or process is primary tends toward the usual and expected. A person for whom the second mode is primary tends toward the novel and speculative. The one favors certainty, the other risk. (5;13-14)

These two styles of thought are called by many names: divergent and convergent by J. P. Guilford, growth and safety by A. H. Maslow, openness and defensiveness by Carl H. Rogers, lateral and vertical by Victor DeBono, and in the real world of engineering, loose and tight assed.

The dissociation of creativity from intelligence does not date from the IQ test. In The Act of Creation, Arthur Koestler traces this split from what he terms the Cartesian catastrophe. Descartes' "Cogito ergo sum" ("I think, therefore I am".) had the effect of dividing the world into the realms of matter and mind, and the identification of "mind" with conscious thinking. (14;148) Prior to this, no distinction had been made between conscious and unconscious thinking, indeed, unconscious mentation was accepted as part of thinking and no split was seen as necessary.

L. L. Whyte in a book titled The Unconscious Before Freud, describes the long slow recovery from this philosophical blow. Today it is generally conceded that:

> if there are two realms, physical and mental, awareness cannot be taken as the criterion of mentality (because) the springs of human nature lie in the unconscious . . . as the realm which links the moments of human awareness with the background of organic processes within which they emerge. (14;63)

Perhaps Einstein summed the situation up best when he said, "full consciouness is a limit case which can never be fully accomplished." (14;146)

In summary, intelligence (as measured by the IQ test) and creativity are mutually compatable aspects of the human mind; they both share the brain as home base. The former solves our everyday problems, the latter is called to play in cases requiring a totally new approach.

> When a situation is blocked, straight thinking must be superseded by 'thinking aside' -- the search for a new, auxiliary matrix which will unblock it, without having ever before been called to perform such a task. The essence of discovery is to hit upon such a matrix -- as Gutenberg hit on the wine-press and Kepler on the sun-force.
>
> In the trivial routines of thinking, we are exploring the shallows on the twilight periphery of awareness, guided by a more or less automatized scanning procedure.

In creative thinking we are exploring the deeps, without any obvious guidance. (13;163)

1.4 SYNECTICS--AN OPERATIONAL APPROACH TO CREATIVITY

The ancients ascribed creativity to such various forces as divine inspiration, madness, and intuitive genius. Of the modern psychological theories (e.g., Associationism, Psycho-analysis, Neo-psychoanalysis, Factor Analysis, Bisociation, Gestalt Theory, etc.), only one, Synectics (meaning the joining together of different and apparently irrelevant elements (6;3)) has become operational. Operational simply means applicable to the solution of real problems. Because this thesis is interested in creativity in relationship to the solution of engineering problems, the rest of this chapter will be spent on a brief introduction to the Synectics problem solving approach. A much more detailed description may be obtained from the two references this material, for the most part, is extracted from: W.J.J. Gordon's Synectics (1961) and The Metaphorical Way of Knowing and Learning (1971).

According to Synectics theory, the key to problem solving is Making the Familiar Strange. In other words, when straight thinking is blocked, a new way of viewing the problem is required. Gaining such a viewpoint is Making the Familiar (your problem) Strange. In order to achieve this, Synectics has refined the use of three types of metaphor: the Personal Analogy, the Direct Analogy, and the Compressed Conflict.

Personal Analogy (PA) is a metaphor in which a person identifies himself empathically with an object or animal. There are four levels of PA, first person description of facts, first person description of emotions, empathetic identification with a living object, and empathetic identification with a non-living object. These four are listed in order of increasing value to the Synectic approach. An example of a scientist using this technique to solve engineering problems is T.A. Rich of General Electric. He "puts himself in the middle of a problem, trying as he says to 'think' like an electron whose course is being plotted or imagine himself to be a light beam whose reflection is being measured." (8;24) Such an empathetic approach has given Mr. Rich 109 patents.

Direct Analogy (DA) is a comparison made between objects by discussing one in terms of the other. Buckminster Fuller, the American designer-architect-engineer suggests the role of DA in discussing his geodesic domes:

> 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. This was a patentable invention. (4;216)

An important concept which governs the usefulness of direct analogies is strain. That is, the more strain exists between the problem object and analogue, the more useful it is in gaining a new view point. For example, comparing a physical problem such as a fastener with some analogue which is alive in nature would introduce more strain than would contrasting it to some other type of fastener, say one found in the space industry.

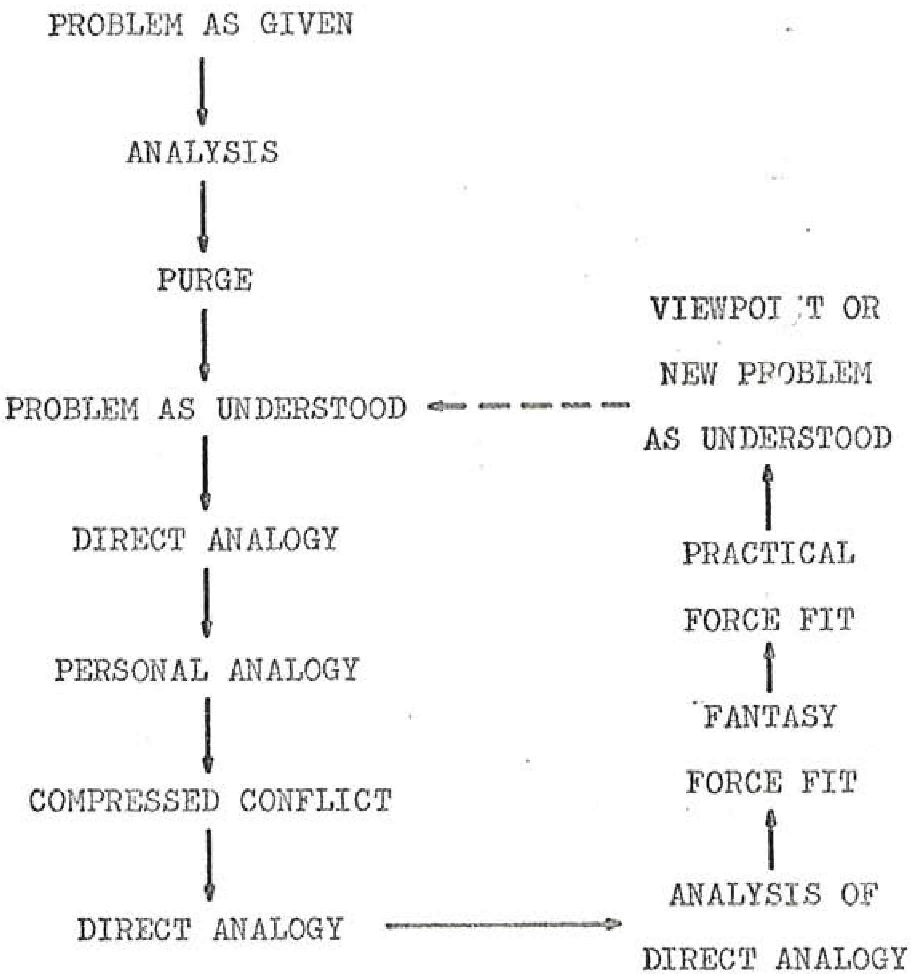
Compressed Conflict (CC) is a "poetic, two word description on a high level of generality where the two words do not seem to fit and sometimes actually contradict each other." (8;25) Pasteur, in inventing the antitoxin vaccine, talked of a "safe attack" long before he experimented in this area. The usefulness of a Compressed Conflict is a result of the amount of stretch, generality and surprise contained in a new view of the problem.

One of the fundamental features of the metaphors -- ironic as it might seem -- is that in studying them, inconsistencies can provide as much of a key to a solution as consistencies.

In their wild state, metaphors contain too much ambiguity to be of much use in a given situation. The flow chart in figure 1.1, is a device for bringing the power of analogies under control in order to reach a goal.

The first step is the Problem as Given (PAG), in which the problem is stated in the most general form possible to incorporate all the points of view possible. A very brief Analysis is then done to locate the problem. The third stage includes all the solutions to the problem which can be thought up, being written down and analyzed. This Purge stage accomplishes two objectives. It rids the conscious

Figure 1.1 Synectics Flow Chart



mind of anything which it feels might solve the problem, thus freeing the mind for the process to come. And second, analyzing these suggestions becomes the best possible analysis of the problem. A listing of the faults of each preferred solution concentrates the problem into its critical areas. This then leads to the formation of the Problem As Understood, (PAU), which is the true key to the problem.

I was once given the task of developing an underwater device to drag equipment along a tensioned cable. After purging it became evident that the Problem As Understood was to increase the coefficient of friction between some sort of gripping device and the wire rope. Solving this Problem As Understood would lead to an elegant solution of this specific problem, and many other problems elsewhere.

After these four steps have been done an excursion is then made from the Problem As Understood, out through several analogies and back in a loop to the Problem As Understood. That is, one proceeds from the Problem As Understood, to a Direct Analogy, to a Personal Analogy derived from the Direct Analogy, to a Compressed Conflict which best describes the essence of the feeling described in the Personal Analogy. This Compressed Conflict is then used to trigger a new Direct Analogy, which then may be analyzed to discover how it works in detail. From this point one returns to a solution via a Fantasy Force Fit (FFF) and a Practical Force Fit (PFF). In the Fantasy Force Fit one tries to imagine a solution derived in any fantastic way from the new Direct Analogy. The Practical Force Fit attempts to resolve the technical problems involved in making the FFF work, that is, it tries to think of a practical way to achieve the idea contained in the FFF. At this point, either a solution worthy of investigation has been found, or a new viewpoint has been reached in respect to the problem. From this a new PAU may be decided upon and another excursion made.

Solutions may be judged on a criteria of elegance, which is defined as the multiplicity of variables over the simplicity of solution. (6;12) That is, an elegant solution is one which uses a simple idea to solve a complex problem. In practice, an excursion may be terminated at any point where it is felt that enough strain has been introduced to result in an elegant solution.

The object of the Synectics approach is not to confine problem solutions to rigid paths but rather to achieve new solutions by quickly creating the psychological states required to find elegant solutions.

CHAPTER 2 CREATIVE ACTS IN SCIENCE

2.1 DIRECT ANALOGIES FROM THE HISTORY OF SCIENCE

It is instructive at this point to examine the way in which numerous men solved their problems in the past. When Synectics Education Systems is asked to substantiate their claims that problem solutions are easily obtainable using metaphorical techniques, they send out a short booklet called Synectics Direct Analogy Examples. It is with William J. J. Gordon's kind permission that the following selections are quoted. (7)

ARCHIMEDES (c.287-212 B.C.), DISPLACEMENT PRINCIPLE. The "Eureka!" experience of Archimedes is the best known of all discoveries and represents a modest analogical leap. He had been ordered to determine whether a crown, supposed to be pure gold, had been adulterated with any baser metal. He knew the proper weight of gold as well as that of the base metals and he knew the weight of the crown. What he did not know was the cubic area of the crown because its shape was so elegantly tortured. He was stumped until one day when getting into his bath he observed the water in the tub rising in direct proportion to the immersion of his body. He then made an important if simple analogy. He transferred the implications of this observation in relation to his own body's displacement of the water in the tub to the problem of evaluating the golden crown. By measuring the amount of water displaced by the immersion of the crown, he found the exact cubic area of the crown.

BRUNEL, SIR MARC ISAMBARD (1769-1849), TUNNEL 'SHIELD'. Brunel had already made a variety of inventions in machine tools, saw-mills, and cannon when he was faced with the problem of how to build under water tunnels more efficiently. He was having no success until one day he was observing the action of a shipworm tunneling through a timber. The worm constructed a tube for itself as it moved forwards, and Brunel used this phenomenon as a metaphorical basis for developing the first practical approach to tunnel excavation.

It is quite rare that such a one-to-one relationship will exist between analogue and invention. Usually, the analogue provides the critically important conceptual leap; and technology takes over immediately the idea for the invention or discovery is born. In the instance of Brunel's caisson, however, there was so much parallelism between analogue and invention that the technology tried to produce a mechanical model of the living model. Brunel's 'shield' is a short steel cylinder which is pushed forward (like the shipworm) by mechanical means as the work progresses. It is a huge boring-machine without which river tunneling would be next to impossible.

DURYEA, CHARLES B., INJECTION CARBURETOR, 1891. Duryea was _one_ of the inventors and developers of the internal combustion automobile, but he was _the_ inventor of the spray injection carburetor. In 1891 he realized the need for a better way to introduce fuel into his engine and he was looking for a simple way of spraying gasoline into the combustion chamber. The problem remained unsolved until one day he noticed his wife using a perfume atomizer. What is especially interesting here is that, although he knew about the function and existence of perfume atomizers, they did not come to his mind until he observed his wife using one.

FREUD, SUBLIMATION. Freud developed his concept of sublimation from a cartoon in a magazine which is the German equivalent of _Punch_. The first picture showed a little girl herding goslings with a stick. The next picture showed a governess herding young ladies with a parasol. What came to Freud's mind was the idea of the little girl repressing her herding job and making it into the fantasy of being a proper governess with real young ladies instead of mere geese. And this idea led to the concept of sublimation, where a reality is repressed in favor of a more acceptable fantasy alternative.

HARVEY (1578-1697), HEART AS PUMP. Up to the time of Harvey, Galen's theory of bodily functions held sway. The common view was that blood was formed in the liver from food and that it passed through the veins and back the same way to the heart in a tidal ebb and flow. Harvey's radical discovery of the circulation of the blood derived directly from watching the action of the exposed heart of a fish and making the analogy of a pump.

KEKULE (1829-1896), BENZENE RING. In 1865 in Ghent, Kekule fell into a reverie while working on the problem of the structure of carbon molecules; and the following image came upon him.

> My mind's eye sharpened by repeated visions of a similar sort, now distinguished larger structures of varying forms. Long rows frequently rose together, all in movement, winding and turning like serpents; and see! What was that? One of the serpents seized its own tail.

The visual analogue of the snake biting its own tail led to one of the most important fundamentals of science, i.e., in benzene the carbon molecules are not open structures but closed chains or rings. This view accounts for benzene having only six free bonds when it has six carbon atoms.

LISTER (1827-1912), LIGATURES. Lister was on the look-out for a better form of ligatures than was available to him. In his time silk was used to sew up cut or torn flesh. This thread tended to cause infections around it in the course of healing and, at best, dangerously irritated otherwise nicely healing wounds. He wanted to develop ligatures that would not cause this trouble. One day he was examining a partly cured wound in which a piece of loose bone had been left, since its removal would have required a deepening and enlarging operation. He noticed that the bone was smaller than before ("had been eaten up"). Some of it had become absorbed in the course of the healing process. Why not the same with ligatures? Why couldn't they also be absorbed before they caused trouble and after they served their purpose? He experimented with a variety of guts and special tanning treatments before he developed a proper material. Thus, he invented his ligatures by making the direct analogical connection between the dead bone being absorbed and ligatures being absorbed.

MAXIM (1869-1936), GUN SILENCER. Maxim was keen on developing a silencer so that his target practice would not bother his neighbors. Good engineering approaches were unavailing and he was at a loss. One morning, after shaving, he gazed absently at the water as it went down the drain with a rotary motion. The whirlpool action left an opening near the center of the drain while the water was going out.

He immediately made the analogy with the gases from an exploding cartridge in a gun barrel. If these gases could be made to rotate and follow a gradually expanding path as they emerged from a gun barrel, they would make less noise. And this insight led directly to the famous Maxim silencer.

MAXWELL, JAMES CLARK (1831-1879), ELECTROMAGNETIC WAVE THEORY. Maxwell made mental images to represent the elements of problems - symbols without words. They were a kind of private painting. The development of his electromagnetic wave theory in particular was based on a mechanical model of balls and cylinders. And this model gave way to a more sophisticated vision of tubes carrying a fluid, but without spaces between tubes so that they became mere surfaces. With this later model as an analogue, Maxwell opened the conceptual way to the beginning of the post-Newtonian era in physics, the era of waves and fields of force. Thus, the mechanical model was no more than an aid to thinking, to be abandoned after the mathematical abstraction was developed . . . and properly so. However, the process of Maxwell's line of thinking was metaphorical in the strictest sense.

METCHNIKOFF, PHAGOCYTES, 1884. Metchnikoff was intensely bothered by the problem of how the human organism fought infection. No matter what he did, this problem was always in the back of his mind. For example, one day he was observing the activity of some transparent larvae of starfish. He threw in a few rose thorns to see the reaction of the larvae. The thorns were surrounded by the larvae and digested into their transparent bodies. Metchnikoff immediately made the analogical connection with what happens when a person's finger is infected by a splinter. The splinter becomes surrounded by pus which, like the starfish larvae, will try to digest the foreign body. By the process of making this analogy, Metchnikoff discovered the organism's main defense against patholgical, invading cells: the 'phagocytes,' which are the cell eaters among the white blood corpuscles.

PRIESTLY (1733-1804) developed a connec ive analogue between the appearance of burnt mercury and rusted iron, both of which were conversions of metal into red powder. This led to the discovery of oxygen.

WRIGHT BROTHERS, AIRPLANE. The Wright brothers had worked out most of the problems connected with their airplane design. They knew how to get off the ground and fly in a straight line and get back down to earth again. But they could not turn their airship and keep it stabilized when aloft. They were unable to solve their problem until they happened to be watching a buzzard keeping its balance in flight. When one wing dropped, the bird twisted the dropped wing. This increased the pressure on the wing and leveled out the bird. "The two men proved this out in tests with gliders equipped with wing tips they could twist, or warp, from the ground by means of control wires." Then they linked control wires to be operated on board the plane and "they could turn the craft smoothly, tilting the wings in a graceful bank, and then, just as smoothly, restore horizontal balance."

2.2 CLASSES OF OBSERVATION

As one reads these Synectics Direct Analogy Examples, describing a cross section of creative acts, one is immediately struck by the major role visual events play. In each case the inventor saw something quite ordinary in a new light which resulted in the solution to his problem. This visual solution finding can be broken down into three classifications.

I) Both the solution analogue and the problem are seen together.

II) One element is seen, the other immediately thought of:

- A) An analogue is seen, the problem remembered, or
- B) A solution analogue comes to mind while looking at the problem.

III) Both the problem and the solution analogue are thought of inside the head, as in a dream or vision, without a physical stimulus being present.

Each of the preceeding examples falls into one of these categories.

As an example of the first class, Priestly's discovery of oxygen can be cited: he developed a connective analogue when he saw the red powder of both burnt mercury and rusted iron. This formed a visual pun, i.e., two objects with similar appearance.

Most inventors' visualizations fall into the IIA category, that is, they see a solution in their everyday world, and draw an analogy to their problem. The frequency of this solution finding approach is understandable because a problem is always in the back of an inventor's mind, even while he is relaxing. As a result, everything seems to be seen in relationship to this problem. In this way Archimede's analogical leap came from an observation of his bath water. Likewise, Brunel's approach to tunnel excavation copied a shipworm he saw tunneling through a timber. Duryea watched his wife spray perfume with her atomizer, and solved his problem of injecting gasoline into engine combustion chambers.

Pictures in magazines often supply a type IIA cue as was the case for Freud. While not mentioned, Westinghouse got his idea for the air brake and Bissel the idea for the oil pump from magazine pictures also.

Lister's observation was perhaps not so obvious a solution, but the idea of an absorbed bone led to experimentation which eventually solved the problem of ligatures.

Maxim, Mitchnikoff, and the Wright brothers are further examples of this mode of solution finding.

In this selection of examples there is only one falling in the IIB classification: Harvey's discovery of blood circulation. As Arthur Koestler states, "William Harvey, watching the exposed heart valve at work in a living fish, suddenly visualized it as a pump--but the analogy between the gory mess he actually saw and the neat metallic gadget existed in his mind's eye only."(14;182)

Kekule and Maxwell provide excellent examples of class III visualization in which both problem and analogue are seen internally. This will be discussed further in the next section.

The order of classification I, IIA, IIB, and III also represents an increasing scale of versatility. That is, class I observations are entirely dependant on the environment and require the chance conjunction of three elements: the problem, the analogue and the observer. On the other extreme, class III observations are entirely independent of the environment, and are not tied to temporal requirements as well.

Synectics proceedures aim at achieving type IIB and III events. When problem solutions are completely frustrated, type IIA observations are encouraged by field trips, museum visits or reading magazines. This allows an opportunity for new visual experiences--and new ideas.

2.3 A CLOSER LOOK AT CLASS III THINKERS

Of the examples cited in the first section of this chapter, Kekule and Maxwell were the only ones who used class III, or internal, visualization. Were they exceptional? Or is this style thought not uncommon?

Kekule certainly seems unusual in the quantity and quality of his visual experiences. The vision of a snake biting its tail cited earlier was the culmination of eight years work. Concerning a much earlier experience he related the following:

> One fine summer evening I was returning by the last omnibus, "outside" as usual, through the deserted streets of the metropolis, which are at other times so full of life. I fell into a reverie, and lo ! the atoms were gambolling before my eyes. Whenever, hitherto, these diminutive beings had appeared to me, they had always been in motion; but up to that time, I had never been able to discern the nature of their motion. Now, however, I saw how, frequently, two smaller atom united to form a pair; how a larger one embraced two smaller ones; how still larger ones kept hold of three or even four of the smaller; whilst the whole kept whirling in a giddy dance. I saw how the larger ones formed a chain...I spent part of the night putting on paper at least sketches of these dream forms.(14;169)

While Kekule's visions seem exceptional, he is not alone. In 1945 Jacques Hadamard made an investigation into the thinking behavior of America's outstanding mathematicians. Concerning himself he said:

> I distinctly belong to the auditory type; and precisely on that account my mental pictures are exclusively visual. The reason for that is quite clear to me: such visual pictures are more naturally vague, as we have seen it to be necessary in order to lead me without misleading me.(11,85)

and he sumarized the results of his study as follows:

> Among the mathematicians born or resident in America ...phenomena are mostly analogous to those which I have noticed in my own case. Practically all of them... avoid not only the use of mental words but also, just as I do, the mental use of algebraic or any other precise signs; also as in my case, they use vague images... The mental pictures...are most frequently visual, but they may also be of another kind for instance, kinetic. There can also be auditive ones, but even these... quite generally keep their vague character.(11;85)

Among the mathematicians questioned was Albert Einstein. He answered the questionaire this way:

> The words or the language, as they are written or spoken, do not seem to play any role in my mechanism of thought. The physical entities which seem to serve as elements in thought are certain signs and more or less clear images which can be 'voluntarily' reproduced and combined....
>
> ...Taken from a psychological viewpoint, this combinatory play seems to be the essential feature in productive thought--before there is any connection with logical construction in words or other kinds of signs which can be communicated to others.
>
> The above-mentioned elements are, in any case, of visual and some of muscular type. Conventional words or other signs have to be sought for laboriously only in a secondary stage, when the mentioned associative play is sufficiently established and can be reproduced at will.
>
> According to what has been said, the play with the mentioned elements is aimed to be analogous to certain logical connections one is searching for.
>
> In a stage when words intervene at all, they are, in my case, purely auditive, but they interfere only in a secondary stage as already mentioned.(11;142-143)

Einstein says his theory of relativity was the solution to a visual paradox which had troubled him for many years. In his words again, this revolutionary idea came to him one morning as he got out of bed after

> ten years of contemplation, of considering a paradox which had struck me at the age of sixteen: if I pursue a ray of light with the speed c--the speed of light in a vacuum--I must accept such a ray of light as a stationary, spatially oscillating electro-magnetic field... intuitively it seemed clear to me that, judged by such an observer, everything should follow the same laws as for a stationary observer.(14;183)

Yet another 'visionary' thinker was Michael Faraday. In The Act of Creation Koestler describes him thus:

> He saw the stresses surrounding magnets and electric currents as curves in space, for which he coined the name 'lines of forces', and which, in his imagination, were as real as if they consisted of solid matter.

> He visualized the universe patterned by these lines--or rather by narrow tubes through which all forms of 'ray-vibrations' or energy-radiations are propagated. This vision of curved tubes which 'rose up before him like things' proved of almost incredible fertility; it gave birth to the dynamo and the electric motor; it led Faraday to discard the ether, and to postulate that light was electro-magnetic radiation. Perhaps the most remarkable fact about Faraday is that he lacked any mathematical education or gift, and was 'ignorant of all but the merest elements of arithmetic'; and mathematics is of course regarded as an indispensable tool of the physicist.(14;170)

These men certainly undermine the notion transferred by most scientific educations that mathematics and other similar skills (language, logic, etc.) are the only tools' required for creation in engineering and science. It would appear that, in one form or another, the ability to visualize is equally important.

CHAPTER 3 WHAT IS VISUALIZATION?

3.1 VISUALIZATION DEFINED

In the last chapter we examined several creative acts and observed that these acts were noteworthy for the visual activity which took place. Furthermore, this activity could be classified into three types according to what occurred during each creative event. Specifically, analogies had been made between two objects seen together (Class I), between one object which was seen and a second one which was thought of (Class II), and between two objects which were thought of (Class III).

The field of psychology divides the events we are talking about into two categories: sensory perception and cognition. Sensory perception deals with the way in which information is received from the environment, i.e., how the eyes, ears, etc. work. Cognition is the word given to the way in which this information is processed, or generally, how the brain works. Traditionally these two processes have been separated and, with a few exceptions, considered to be independent of each other. Today a different point of view is rapidly gaining acceptance -- that a person's perceptive experience cannot be divorced from the so called higher order vents of cognition. Perception is an active event in which prior experiences play an essential role. According to the former attitude, the term visualization would only be applied to Class III events, that is, those events in which something was 'seen' even though there was nothing in the immediate physical environment to justify it. According to the latter viewpoint, visualization would also include Class II events, and Class I events as well. It is in this more general sense that I use the word visualization.

It may seem that the difference between these two meanings of the word visualization is largely semantical -- but in fact the problem is more significant than that. The dichotomy between perception (especially visual perception) and cognition dates from as early as the Greeks, and perhaps even before that. The Greeks held the highest regard for the workings of the mind while profoundly distrusting the senses.

(1;4-12) Their eyes were obviously lying when for example, a stick stuck into water appeared bent. This begins to explain their great concern for 'correcting' perceptual experiences as in the Parthenon where the center was made higher in order to appear straight, etc. It was felt that the civilized mind could overcome faulty senses. Their interest in philosophy and mathematics (music was felt to be a form of mathematics) and disdain for the eyes is reminiscent of the feud (Cartesian Catastrophe, Chapter 1.3) between conscious and unconscious thought.

3.2 HOW VISUALIZATION WORKS

A closer look at the arguments which support the general view taken of visualization in the prefious section will also serve to explain how such visualization takes place.

Perception is an active event rather than a passive one. One important reason for this may be found in the structure of the eye. Our visual acuity is greatest in the central part of the retina called the fovea which subtends an arc of only 1.5°(from graph 3;137). In order to concentrate on something we must aim our eyes at it. When we view a new scene our eyes continuously move from one fixation point to another. Even while staring at one small object our eyes still move involuntarily.(3;100) Indeed, experiments at

McGill University in 1960 demonstrated that when retinal images are fixed, vision goes haywire. Images fixed in this way disintegrate and disappear, only to reappear distorted or in fragments and disappear again. "Static vision does not exist; there is no seeing without exploring." (14;158)

Even though our eyes are constantly moving, we perceive a stable integrated world. Perception then, is a constructive event. "Our visual experience is never the stimulus directly. It is always a construction, based only in part on currently arriving information." (18;146) Earlier on the same page Neisser states,

> There is no getting around the fact that people often see things which are not physically present at all. We try to exclude this fact from consideration by distinguishing 'hallucination' and 'imagery' from 'perception', but the phenomena themselves remain: dreams, hypnagogic images, eidetic images, psychotic hallucinations, and so on. . . (18;146)

These quotes are from his book Cognitive Psychology (1967) in which he builds on Bartlett, Schachtel and others to argue that visual memory, like vision itself, is a construction which uses the same or similar perceptual apparatus. Memory he says, does not consist of a recall of prior constructions (copies of finished mental events) but an actual new construction on the spot. Only such new constructions could explain the variation and adaptability of human behavior. (18;282) What raw material or information do we make these new constructions out of? "The only plausable possibility is that it consists of traces of prior processes of construction."

(18;285) In other words our memory behaves in the same fashion as our initial perception does -- we synthesize an image in both cases, and out of the same sort of information.

Rudolf Arnheim in his book, Visual Thinking, describes how the memory traces of these prior constructions may be modified in two opposite directions. First is a tendency toward tension reduction -- toward the simplest structure. "The trace pattern will shed details and refinements and increase in symmetry and regularity." (1;81) There is at the same time, a countertendency to preserve and even sharpen the distinctive features of a pattern.

> Distinguishing characteristics will also be preserved and exaggerated when they arouse reactions of awe, wonder, contempt, amusement, admiration, and so forth. Things are remembered as larger, faster, uglier, more painful than they actually were. (1;81-83)

Arnheim goes on to say,

> Antagonistic though the tendencies of leveling and sharpening are, they work together. They clarify and intensify the visual concept. They streamline and characterize the memory image. This process is further enhanced but also hampered by the fact that no trace is left to its own devices. Every one of them is susceptible to continuous influence by other traces. Thus, repeated experiences do not simply re-enforce the existing ones but subject them to unending modification ... (1;83)

These memory images also help us interpret, identify, organize, and supplement what we see. The result is that no neat line distinguishes our 'perceptual image' from one completed by memory information or one completely formed by memory.

Gregory, in Eye and Brain (1966), states it this way:

> Perception is not determined simply by the stimulus patterns; rather it is a dynamic searching for the best interpretation of the available data. The data is sensory information, and also knowledge of the other characteristics of objects. Just how far experience affects perception, how far we have to learn to see, is a difficult question to answer; . . . it seems clear that perception involves going beyond the immediately given evidence of the senses: this evidence is assessed on many grounds and generally we make the best bet, and see things more or less correctly. But the senses do not give us a picture of the world directly; rather they provide evidence for checking hypotheses about what lies before us. Indeed, we may say that a perceived object <u>is</u> a hypothesis, suggested and tested by sensory data. (9;11-12)

It should be clear now why no distinction should be made between visualization which occurs when one is looking at an object. Thus the 'visual events' classified in 2.2 are all similar insofar as what went on inside the mind. Rather than isolate different forms of visualization these categories simply demonstrate different ways in which visualization may be triggered.

3.3 PERCEPTUAL WORLDS DIFFER

We may now begin to comprehend the extent to which personal experience, cultural influences or professional training can modify what we see. Examples are plentiful. Anthropologist Edward Hall tells of field expeditions in which he would pick up arrowheads his students walked right over. (11;69) I recall being out sailing once and not being able to see a course marker until several minutes after the seasoned skipper could. "The radiologist whom experience has taught to see a peptic ulcer or a lesion of the lungs, treats the much sharper contours of the ribs as 'background'." (13;526) In a more humorous example Hall states that,

> I may be able to spot arrowheads on the desert but a refrigerator is a jungle in which I am easily lost. My wife however, will unerringly point out that the cheese or leftover roast is hiding right in front of my eyes. Hundreds of such experiences convince me that men and women often inhabit quite different visual worlds. These are differences which cannot be attributed to variations in visual acuity. Men and women simply have learned to use their eyes in very different ways. (11;69-70)

If examples of different perceptual worlds within our own society are as plentiful as this, just imagine how differently individuals from other cultures see. Consider the Eskimo who have twelve words for wind and even more for snow. They are capable of navigating hundreds of miles under circumstances in which we would quite literally perceive nothing except gray and cold. In The Hidden Dimension, Edward Hall points out that art provides an excellent record of how a culture perceives the world, in fact, "one of the principle functions of the artist is to help the layman order his cultural universe." (12;81) Eskimo art looks like x-rays, Chinese art has no perspective. Both provide significant insight into how two different cultures perceive.

However, in order to gain further insight into problem solving it is more informative to understand how differently two men from our own culture may perceive things and even how each of us may perceive the world differently on different occasions. When, for example, I look at a steep mountain meadow, I will view it differently depending on what I am looking for. If I wish to climb to the top I will look for the shortest route with good footing. If I am making a trail, the contours will become important and I will try to find a way up requiring minimal effort (i.e., a constant gradient). If I am looking for wild flowers, color will be the most important guide to my scan of the slope. Hunting would require concentration on movement rather than color or shape. I may even think about how nice it would be to ski down it in the winter and look for bowls and jumps. My visual experience would provide a kinesthetic one. What I see then, depends on the code I decide to impose on the experience. And while the selection of this code may be conscious, the operation of the code must be unconscious. If this were not so, we would be faced with the paradox of the code within the code, the code within that code and so forth.

3.4 HYPOTHESIS

So we have seen that vision is an active, constructive event in which no clear distinction can be made between what is being 'seen' and what is being supplied by memory, and furthermore, the same is true for visual memory itself. As a result no two people see the same thing (have the same perceptual experiences) in any given circumstance. Also, the code which guides either the scanning (construction) of a 'real' scene or an 'internal' scene operates at an unconscious level. In chapter 2 we noted the visual aspect of more than a dozen inventions and scientific discoveries. In light of the above, it would appear that these men literally came to see things in a new way. It seems quite reasonable to hypothesize the following: there is a relationship between a person's visualization skills and his creative abilities.

Koestler states in italics:

> the temporary relinquishing of conscious controls liberates the mind from certain constraints which are necessary to maintain the disciplined routines of thoughts but may become an impediment to the creative leap; at the same time other types of ideation on more primitive levels of mental organization (thinking visually as in pictures) are brought into activity. (13;169, parenthetical statement from 168)

Rudolf Arnheim, in his book Visual Thinking makes an eloquent appeal for ridding the distinction between perception and cognition. He even argues further that all thinking is perceptual in nature. The line of reasoning both men pursue is similar to the one very briefly presented in this chapter. Psychologists appear to be approaching this point of view, as shown by Gregory's quotation, that the eye is making hypothesis when it sees. But none of these men have sought to demonstrate a connection between creative behavior and visualization. This is the goal of this thesis.

3.5 OTHER FACTS EXPLAINED

There are a few miscellaneous facts lying outside those discussed above which would also be explained if a connection were found as suspected.

The first of these relates to the Barron Welsh Art Scale. According to one expert, Dr. Gough, "if there is one test of Scientific Creativity this is it." (2;88) This test consists of 86 abstract line drawings which each subject is asked whether he likes or not. People with demonstrated creativity have been found to consistently fall into the 40 to 30 point range, noncreatives in the 10 to 20. In summary, Frank Barron states:

> Personality correlates of this scale, as determined in several subsequent studies, may be summed up briefly as follows:
>
> 1) Artistic preference is related positively to rapid personal tempo, verbal fluency, impulsiveness, and expansiveness.
>
> 2) It is related negatively to rigidity, control of impulse by repression, social conformity, ethnocentrism, and political-economic conservatism.
>
> 3) It is related positively to independence of judgment, originality, and breadth of interest. (2;22-23)

Concerning these results Dr. MacKinnon has said,

> If one considers for a moment the meaning of these preferences; it is clear that creative persons are especially disposed to admit complexity and even disorder into their perceptions without being made anxious at the resulting chaos. (2;17)

We should not be surprised by this fact if a relationship between creativity and visualization is established.

The second fact to be explained is the confusion which seems to exist between seeing and knowing. Examples are: "I see" or "I get the picture" for "I understand", and "blind" for "I do not understand"; farsighted, or visionary, or seer, or to foresee, for acts of imagination; viewpoint or gain perspective, or insight, for conclusions or new information. Gregory states, "Perceiving and thinking are not independent: 'I see what you mean' is not a puerile pun, but indicates a connection which is very real." (9;12) We shall see.

CHAPTER 4 ESTABLISHING A RELATIONSHIP BETWEEN VISUALIZATION AND CREATIVITY

4.1 TESTING PROCEDURE --- FIRST ROUND

This chapter discusses the sequence of testing which was to establish the relationship between visualization and creativity hypothesized in the preceeding chapter. Up until the last test the approach used was to try to find an improvement in creativity scores by various means of visual stimulation. It was not until the very end that I thought to make a visual scoring system and in this way establish a direct correlation between visualization and creativity.

In the first test, (figs. 4.1 - 6) subjects were given an article photocopied from "Progressive Architecture" (fig. 4.2) describing a previous and traditional attempt to design a two mile high tower and were asked to develop new and imaginative solutions. The control subjects were given plain paper to work on, the test subjects were given a sheet describing several historic scientific events which involved visual analogies (fig. 4.3) and were asked to follow a procedure to help them develop a solution. This procedure consisted of choosing an analogy from a page full of drawings (fig. 4.5) and pointing out all the similarities between it and the tower. They were then asked to develop a new design from this analogy.

The problem of designing a two mile high tower was chosen because it is a real engineering problem, yet is one which no one is likely either to have thought about before or to have seen anything similar. That is, it had an air of realism, especially since someone with $300,000,000 to spend wanted one, yet it was wild enough not to constrict imaginations to traditional solutions. It was real, and free. A few students objected to its irrelevance, which is of course undeniable, however, once this objection was voiced, the challenge of the problem took hold, and usually did not let go even after the hour they had to work on it was over. It is lamentable that this problem should be so impractical, but is an observation from Synectics training that the closer one comes to a real problem in a person's own experience, the more he will freeze up. A later problem which involved finding new airport fire fighting techniques demonstrated this very fact.

The rationale behind this experiment was as follows: hopefully the test group, having been supplied with visual stimulation of the II A type discussed in Chapter 2.2, would see possible connections between these pictures and the given problem. As a result they would do better, on the whole, than the test group who had to rely on class III visualization (completely internal) for ideas. The resulting designs were tentatively planned to be judged for creativity by a panel of four experts.

Subjects were solicited from the College of Engineering at Tufts University. Represented were a cross section of engineering disciplines: Civil, Mechanical, and Electrical, and of classes: freshman through senior. Included also were a handful of Engineering Design Graduate students. All problems given were of a general technical nature, which offered no advantage or handicap to any one group of students.

The results of the first test did not bear out expectations for numerous reasons. First of these was due to some mistakes made in writing the questions for the test group. In order to explain what the test subjects were to do with their chosen visual analogy, they were given a small example in the right margin next to the question (see fig. 4.4.). This example showed a kangaroo being compared to the tower with two comparisons drawn in: support and balance. This channeled the thinking of the test subjects directly into worrying about balance and support. As a result, over half ([illegible] out of 9) of them chose a tightrope walker, and the rest split themselves between the rocket and sailboat. This demonstrates how sensitive students are to what they think is expected of them. After years of schooling, they have learned there is only one right answer and will use any clue to help find that answer.

A second problem with the test was the selection of analogies supplied. In Synectics terminology they did not have enough "strain" to provide material for truly creative solutions. They were rather mechanical in nature, and led to the straight forward type solutions usually expected from engineers.

A third problem arose in attempting to divide the subjects equally into test and control groups. For the sake of fairness, subjects with good visual abilities should be equally divided between test and control group. However their inclusion in the control group penalizes that which is being tested for. Test results confirmed this. Subjects with good visual abilities (at least as evidenced by their drawings) were included in the control group and they accomplished naturally what was being forced on the test subjects artificially. Their work as a result, exhibited more uninhibited idea generation with such analogies as snakes, cloud 9, molecular structures, cat tails, etc., than the test group. This gives rise to the suspicion that subjects would do better if the analogies they had to work with were their own, rather than supplied.

This leads to a fourth observation. The control group, because they were left to themselves with no instructions, were free to put down as many ideas as came to mind. The implication for the test group was that one basic idea was wanted. Given a certain minimum requirement, all subjects met it, but few went further. Not knowing what was expected of them, the control subjects put down as much as they could --an interesting observation from a motivational standpoint.

A fifth factor which perhaps could account for some of the poor performance exhibited by the test group was the additional time they had to spend reading and comprehending the sheet of analogies and all the instructions.

This test was pretested, and it is interesting to note that the pretest subject did not indicate any of these problems. This subject also chose a rocket, but came up with many innovative ideas and a credible design. Quite possibly the explanation for this was the "conspiratorial atmosphere" involved in a pretest. He knew he was the first one to do it, therefore, he was in on it. This author was one of the first two engineers to take the <u>Synectics Basic Course</u>. At that time I noted this feeling myself, the direct result being a desire to do an outstanding job. The first test of the airport crash problem which was done at the same time had the same result.

In summary, the implications for the next series of tests were:

1) Do not "channel" subjects, i.e., do not hint at a desired solution or solution approach.

2) Test and control groups should be organized in such a way as to be fair to both the experiment, and to the hypothesis which is being tested.

3) Test and control groups should have equal working times.

4) All tests should be open ended enough to allow each subject to be his own judge of the quantity and quality work he does.

5) Visual analogues, if used, should have large amount of strain.

6) If possible, the subjects should be their own source of visual stimulation.

A second design problem was developed incorporating these changes (fig. 4.7-8). This problem involved finding a faster system to extinguish fires due to crashes at airports. In order to introduce more strain the visual stimulation centered around the concept "instantaneous", e.g., balloon popping, blinking eye, gun, idea, firecracker explosion, etc. (fig. 4.8). Subjects were asked to circle the one drawing which best embodied the concept "instantaneous". They were then asked to use that concept to put out the fire. Because the subject had chosen an analogy before he realized what it was going to be used for, it was hoped that the student would be forced into using an analogy incorporating more strain. This test was tried on three subjects, and while the "channelling effect" seemed to be eliminated, it appeared that I was asking too much of the students. It was too big a leap from a blinking eye to a fire fighting system for anyone not trained in Synectics' Fantasy Force Fit.

4.2 ENCOURAGEMENT AND FRUSTRATION

At about this time the question was raised whether or not I was really testing for the basic concept of visualization. Wasn't I supplying a hint to the test subjects which could simply help them do better? Couldn't such a hint be given in words? Wasn't the basic question whether visualization existed at all, and if it did was it really a necessary part of creative problem solving?

The first of these questions did not upset me that much as I felt demonstrating the effectiveness of visual stimulation would make a case for improving a person's ability to see new connections between things on his own. Such stimulation certainly does involve visualization. The subjects in the test groups who saw more connections between the analogue and problem did seem to be doing better solution wise. And even if the "hint" were in word form, the connection would still have to be made, in all likelihood by comparing images of the "hint" with the problem.

The second question was of such fundamental nature that I decided to conduct a quick experiment involving a problem which lends itself to visual solution. This test consisted of each subject's being seated in a comfortable office at a desk with a tape recorder and drawing materials available at the side, and being given a riddle. The problem was as follows:

> One morning, exactly at sunrise, a Buddist monk began to climb a tall mountain. The narrow path, no more than a foot or two wide, spiralled around the mountain to a glittering temple at the summit.
>
> The monk ascended the path at varying rates of speed stopping many times along the way to rest and to eat the dried fruit he carried with him. He reached the temple shortly before sunset. After several days of fasting and meditation, he began his journey back along the same path, starting at sunrise and again walking at variable speeds with many pauses along the way. His average speed decending, was of course greater than his average climbing speed.
>
> Prove that there is a spot along the path that the monk will occupy on both trips at precisely the same time of day. (Carl Duncker in 13;184)

This problem has a "correct" answer which yields quickly to any number of variations of the following visual approach: if the monk were to leave the bottom and the top on the same day, he would have to meet himself as there is only one path. Removed to a separate day, that point is the one which is passed at the same time on both days. While I myself am more concerned with visualization in open-ended problems, this test permitted analysis of success-failure as related to solution approach.

Twenty three persons took the test and fifteen people found the correct answer. Of these 15, 12 could clearly be called visual solutions: 7 were explicit with a graphical approach (fig. 4.9); 3 were internal but explicit visual solutions, "Imagine a movie camera" or "I saw the two monks approaching", etc. (fig. 4.10); 2 were implicitly visual, that is, while not saying the were 'seeing' anything, their language clearly demonstrated they were verbalizing visual images (fig. 4.11). The remaining 3 who answered correctly either used a strictly analytical approach or described the solution in such an ex post facto way that classification was impossible (fig. 4.12). One person out of the 8 who answered the riddle incorrectly tried to solve it graphically. However, his graph was an extremely tentative one with only the starting and end locations marked. Had he connected these points together as had the other subjects using graphs, he would have seen that these lines intersect each other at some point in space and time. Of the remaining 7 incorrect answers, two attempting analytical approaches are shown in figs. 4.13-14.

Encouraged by these results I began work on two new versions of the airport crash test. One approach which seemed worthwhile was to have each subject act as his own control. In this approach each subject would first do a control test, then later he would be given a test with visual stimulation. In this way, both the test and control would contain persons of equal talent and visual ability. Unfortunately giving one test first blocked any other solutions in the second. Once the problem was 'solved' the subject seemed unable to put any effort into a new solution.

A second idea was to have the student find one solution using words, and another with pictures. Subjects were asked to think of ten things in nature which were instantaneous and number them as they did so. From the odd numbered concepts they were to develop a solution using only words, and from the even numbered ones, a solution using only drawings. This had the drawback of not really investigating the process by which ideas are thought up. The problems instead involved communicating with out either words or pictures. As it turned out, one person tried this and turned in a test having a few pictures with his word solution and a few words with his picture solution.

This all seemed to be leading nowhere. The frustrating thing was that the more visual a person seemed to be, the better the solution he came up with. Finally in a meeting with William Gordon and Tony Poze at Synectics Educational Systems, it was decided the connection between visualization and creativity could be shown by coming up with a way to score each subject's work for evidence of visualization. Then a comparison could be made with the results they achieved on their final design.

4.3 THE FINAL TEST

In order to increase the applicable material I had already gathered, ten more subjects were given the tower problem in a form similar to the original control test. Again subjects were given a statement of the problem, the "Progressive Architecture" reprint, and plenty of plain paper. The only change was the addition of a tape recorder which each subject was encouraged to talk into while he worked on the problem. It was hoped that this would make detection of visualization easier to achieve. As it turned out, this was a needless complication. Little information was added in return for the long and difficult task of transcribing the recordings. Subjects tended to use the recorder to say what they would have written on the paper if they had not had it.

Analyzing the final test consisted of: 1) scoring each subjects's work for visual elements; 2) ranking the creativity of each subject's final design; and 3) correlating these two results.

Scoring for evidence of visual elements in the actual solution finding process was accomplished as follows. A score sheet was drawn up which had a column for each of the explicit ways in which visual elements might be expressed. (see fig. 4.15). The test numbers were entered on the right side, and checks were placed in the appropriate visual element columns. Each test's score consisted of the sum of the checks marked.

The first visual element column was for ex post facto drawings, i.e., drawings made after the invention process was complete. Since it was an engineering problem some sort of final drawing was called for, and if this was all that the subject recorded, it usually represented a minimal effort. Thus everyone who honestly made some attempt at finding a solution got one check.

The six remaining columns represented visual elements which were an actual part of the problem solving process. The first two were for drawings of a different sort than the final design. If a paper had a tentative, formulative type sketch or droodle, it was given one check, if there were more than one such drawing, it got another. These process drawings are easily distinguishable because they are incomplete "trial balloons" lacking the elaboration and labeling of a finished idea. (Refer to samples in Appendix 1)

Visualization may be evidenced in other ways in addition to drawings. Consider a poem, for example. So credit was given for two styles of verbalized visualization: visual words and more rare, visual descriptions. If a paper had one or two words denoting a visual feeling (MacDonald's Arch, steel roots, beehive like windows) it was given one check, three or more, two checks. The same was done for visual descriptions (punching up into the air).

As was stated earlier, this visual score is a measure of visualization only as indicated by explicit material. That is, if a subject were an active visualizer but did not put anything on paper, he did not receive any credit. Since this probably did occur, the visual scores may be seen as a conservative estimation of the visualization which took place. Until we can find a way to actually find out what is going on in the brain, such techniques will have to suffice.

Judging for the creativity of each design was not done from the student's own work. Instead, each subject's final design was redrawn incorporating the ideas which he had developed. For many tests this only required copying the subject's finished tower exactly. For a few this meant bringing ideas together from several different pages, or substantial redrawing of the final design in order to make it look presentable. The result was that each drawing had a similar format and neat appearance. In this way bias due to differing artistic abilities and presentation techniques was hopefully eliminated. Three subjects suggested two final designs. Each of these was drawn and given a separate test number (pairs were: 11 and 44, 30 and 45, 26 and 46). When the judging was complete, these subjects were given credit for their best solution.

The judges were given a sheet of instructions (fig. 4.16) asking them to rank each test in relation to the others, (from 1 to 31) and to assign a number grade from 0, intellectually dishonest, to 10, exceedingly elegant (see Chapter

1.2). While it would appear that the number score is redundant, this was requested in order to find the judges' overall opinions of the quality of ideas presented to them.

The judges for the visual scoring were William J.J. Gordon and Tony Poze of Synectics Educational Systems and myself. The judges for creativity were the members of my thesis committee: Percy H. Hill, John Kreifeldt, and Samuel McLaughlin.

4.4 TEST RESULTS

In all, thirty one solutions were gathered from twenty eight individuals and are included in Appendix 2. By the time all this information had been graded, six judges, excluding myself, had ranked the final designs for creativity and three had scored each individual's work for visual content. The data and resulting rankings are shown in fig. 4.17. Because the creativity rankings seemed particularly mixed, I decided to use creativity rankings averaged over all six judges in addition to those averaged over the original three planned. It could be objected that two of these three additional judges were biased (William Gordon and Tony Poze) in that they previously had scored each subject's work for visual content. However, their scores are in line with other judges (Percy Hill's for example) and in fact, it would have been difficult if not impossible to remember each subject's original work, let alone how he scored, while looking at the neatly redrawn final designs.

The Spearman Rank Correlation was calculated between the tests' visual ranks and creativity ranks. The flow chart of figure 4.18 should be useful for understanding how this was done. All calculations are included in the appendix as well. The visual scores had to be given ranks in order to use the Spearman Test. Where ties occurred, the tests were given the average of the ranks those tests would have gotten without ties. (Example: two tied tests which come after the 8th ranked test would get an equal rank of (9+10)/2 or 9.5). These ranks were then summed over all three visual judges and ranked again. The creativity ranks were summed over three and six judges and also re-ranked. These two new average ranks for the visual and creativity results were then correlated with each other. (See scatter plot in fig. 4.19) r_s for the visual ranking versus creativity ranking with three judges equalled .411 which is significant beyond the .05 level. r_s for the visual ranking versus the creativity ranking with six judges was .685 which is significant beyond the .01 level. (Critical values for Spearman Rank Correlation were obtained from Siegal, 19;236). These correlations included compensation for ties in the visual rank. For each set of rankings the Kendall Coefficient of Concordance W was calculated, and from this $r_{s_{av}}$ was found, which is also equal in value to the average of all the partial correlations between each ranking and every other ranking. For the judges' ranking of visual content, W equalled .926 and r_s equalled .889 which was significant beyond the .001 level. The concordance between three judges of creativity was .649 or $r_{s_{av}} = .473$. A chi square test showed this to be significant beyond the .01 level. The coefficient of concordance between all six judges was .473. And while the resulting $r_{s_{av}}$ at .378 was lower than for three judges, it was more significant at beyond the .001 level. In summary, the Spearman Rank Correlation Coefficients and Kendall Coefficients of Concordance were all significant. As a back up check to these calculations, the original visual scores (1-7) were correlated with the creativity scores (0-10) which the creativity judges had also given. In this case, rho equalled .519 which a t test revealed to be significant beyond the .001 level. These numerical results are all included in fig. 4.18.

4.5 DISCUSSION OF RESULTS

A few interesting observations may be drawn from the original creativity rankings (see fig. 4.17). The first is that, out of seven people who ranked the final designs, there was no agreement as to which design should be ranked first. And while four of these choices were backed up by second place votes, the tests which placed second, third and fourth in the over-all re-ranking were not among these original seven tests!

The explanation for this is not all that difficult to find, and gives a real insight into the nature of creativity. As it turns out, 4 of these original top 7 also received votes for 30 and 31 (last place), and in all but one case (test 44) the majority of judges disagreed with the first place vote completely. Agreement was not impossible as is shown by tests 8, 18, and 27; and in one case it was even remarkable: scores for test 20 were 13, 13, 14, 14, 14, 11, and 10. Over all then, there was much agreement in the center and wild disagreement at the extremes.

How is all this to be explained? Certain tests are standouts. You can not help but notice them because they are different. It is easy to decide which of several similar tests is best. But what to do about the loner, the one that is not similar to anything? To make a long story short, we either like this odd ball or we do not. Like a flamboyant personality, we either love it and put it first, or hate it and put it last. Anywhere in between simply will not do. And this is not surprising. Traditionally creative work is always greeted by a small number of admirers and a large crowd of skeptics.

Since each judge is an individual with his own emotional and intellectual background he will react differently to each design. We find then, not only disagreement at the extremes, but occasionally sprinkled throughout the experiment an 'out-lier' popping up. For some reason, one idea may seem rather appealing for one person, but not for the rest. It is this spark of interest which may be capitalized upon so profitably in a Synectics session, especially where numerous disciplines are represented.

And so while it may seem appealing to rationalize discarding these 'outliers' the overall rankings were arrived at by the expedient of straight forward averaging.

The number which I feel best expresses the relationship between visualization and creativity is .685, the correlation arrived at using six creativity judges. With a significance beyond the .01 level there can be little argument that a relationship exists. (Even the lesser value using three judges is significant beyond the .05 level.) Furthermore, it can be argued that this number is a better approximation because the significance of the agreement between six judges, .001, despite an expected decrease in concordance, is greater than between three judges, .01. As was mentioned earlier, until we can get inside the brain, it will be hard to do better. No matter what correlation is taken as most representative-- what I set out to find was whether the relationship between visualization and creativity was positive, significant, and large enough to be concerned about. It is.

Imagine that you are a world renowned designer known for creative ideas. You have been asked to re-evaluate the feasibility of a two mile high tower. The sponsor of this project was disappointed at the traditional approach of the original consultants. He feels they could have been more active in suggesting more dynamic ways for surmounting the technological problems.

Your job is to develop new concepts for this tower. Read the next two pages containing a description of the first tower design, then use the attached paper to come up with your own design. Show all your work (and play), including the process by which you got your ideas. Day dreaming is permitted!

Figure 4.1 Test 1, Page 1: Instructions

construction technically possible (scale model photo shows Eiffel Tower in background) but economically unfeasible.

A TWO-MILE HIGH TOWER?

Figure 4.2 Test 1, Pages 2 and 3: Reprint of Progressive Architecture Article

Photos: Lois M. Bower

FOR NOW, FORGET IT

An entrepreneur from Japan presented a trio of design firms with a proposal for an observation tower so tall that, if it were built, would certainly discourage any others with the ambition to own the world's tallest anything, if, indeed, it would not extinguish their hopes altogether. The objective of the structure envisioned was to provide an observation point that would overtop Mount Fuji, which, at 12,389 ft above sea level, is the highest point on the island of Honshu. For the site selected, this would have required a structure that itself would be 12,250 ft high, just over two miles.

The scale of the tower contemplated exceeded the boundaries of known structural parameters so far as to require the consultants to prepare a 100-page report just to decide whether it was practicable to prepare a feasibility study. The answer was no, but, in arriving at that answer, they uncovered some relationships between height, cost, and life at the top that are interesting in themselves, and, incidentally, may shed some light on any schemes planners may have for buildings substantially taller than the 100-story structures now under construction.

Among the problems faced by the designers that are not normally encountered in the design of buildings or even, for that matter, tall towers of the size that have been built to date were: icing, high winds, high ratio of structural weight to loads supported, and the need for pressurization of the occupied space at the top.

From the best available data, the designers were forced to assume that all structural members might accumulate as much as 12 in. of ice; moreover, in any lattice-like arrangement of structural members, spaces between members less than 5 ft apart would have to be considered as completely plugged with ice. Not only would the mass of ice add substantially to the gravity load imposed on the tower and its foundation; the encrusted ice would also increase the effective area exposed to wind, and because of its rough surface, the drag coefficient would be increased, too.

Exact data on wind velocity at the elevation contemplated was not available, but the designers suspected it might possibly be as high as 300 mph. The effect of high wind velocity at high altitudes is offset somewhat by the lower density of the air at those elevations. Nevertheless, the lateral forces imposed by wind loading became "the single most important determinant of [the tower's] safety and economy," according to the engineers.

For the comfort of most airline passengers, and for the very health and well-being of some, the cabins of most aircraft cruising at altitudes above 10,000 ft are pressurized to correspond to an altitude of between 5000 and 8000 ft — about 10 psi. Similarly, the pod atop a 12,250-ft tower would require pressurization, as would the elevators serving the pod.

Quite aside from the problem of providing air locks for the elevator doors at both top and bottom terminals, pressurization of the capsule at the top of the tower adds considerably to the structural requirements of the shell of the capsule. The negative air pressure induced on the leeward side of the capsule at design wind velocity, when added to the positive internal pressure, would create unit pressures of 700 to 800 psf, much higher than the unit pressures encountered by conventional building wall systems.

Indeed, the design of the occupied observation and recreation facility planned for the top of the tower would not be unlike the design for an aircraft fuselage intended for cruising at 300 mph at an altitude of 12,250 ft. Unlike an aircraft body, however, the tiny, porthole-like windows that serve well enough in airplanes would be wholly unsuitable for an observation tower, since a wide, unobstructed view of the surrounding countryside would have to be one of the tower's most important features.

Structure

Two types of configurations were considered: a free-standing tower and a guyed structure. Also, two constructional materials were considered: type T-1 steel (minimum yield point 90,000 psi), and type 7075-T6 aluminum (minimum yield point 60,000 psi).

- Free-standing tower configuration with three hollow legs with tubular horizontal and diagonal was selected as having the best potential for further study by structural optimization.
- A computer program was developed to assist optimization of dimensions and weight for above free-standing tower configuration.
- Computer program permitted optimization of weight and dimensions and substantial study of parameters such as magnitude of wind load, weight supported at top, and height of tower.
- A similar approach was used for guyed tower. Basic configuration with three sets of guys, one at each of three corners of triangular central tower. A computer program was developed to determine the optimum guy slope, the optimum number of guy levels, and weight of structure.

Free-Standing Cantilever

The most economical free-standing tower 12,250 ft high turned out to be a three-legged structure with hollow, circular legs spaced about 1000 ft apart at the base. It would weigh about 3200 million lb, which, at an estimated cost of $500 per 1000 lb of erected steel, would be $1600 million (excluding foundations), very much more than the $300 million the sponsor of the project had originally envisioned. (A similar tower of aluminum would weigh about 30 per cent less, but the erected cost of aluminum is nearly twice that of steel.) Curves plotted from the computer printouts show how extremely sensitively the total weight, and hence the cost, of the structure reacts to relatively small changes in the design parameters. By cutting the height from 12,250 ft to 10,000 ft, the weight of the structure drops by 46 per cent. Changing the arbitrarily assigned wind velocity from 300 mph to 200 mph cuts the weight by 61 per cent.

Stayed Mast

An analysis of a guyed tower 12,250 ft high disclosed that this configuration could dramatically reduce the weight of the required structure. The optimum design would weigh just 700 million lb, just under 22 per cent of the comparable free-standing tower. Of the 700 million lb, the shaft accounted for 570 million lb, at an estimated $500 per 1000 lb erected, and the guy cables for 170 million lb at $750 per 1000 lb erected, a total of $400 million (excluding foundations), which of course is much closer to the sponsor's original expectation.

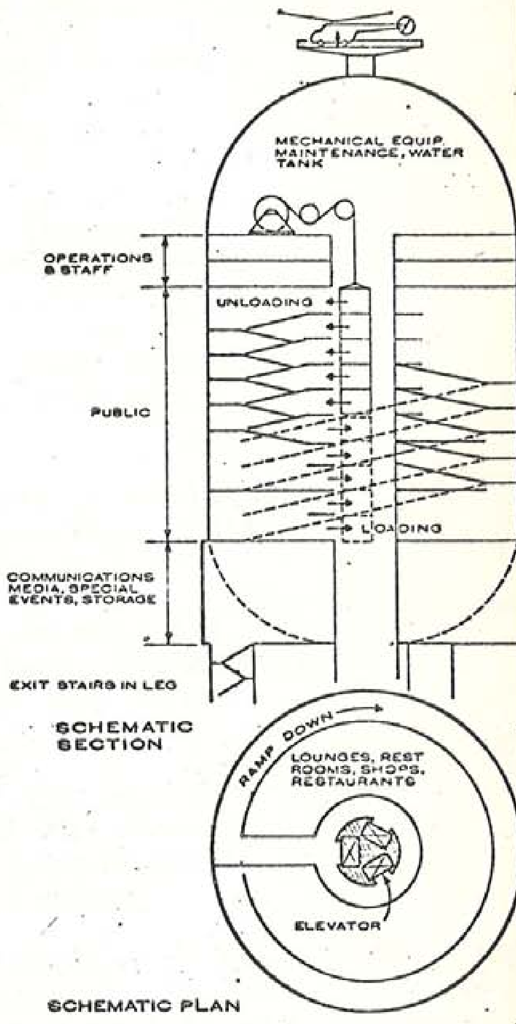
However, the longest of each of the three sets of guy wires (spaced 120 ft apart) would have reached out over 10,000 ft from the base of the mast. The vast amount of land beneath the three sets of guy wires posed a severe problem; to acquire the land outright would be costly, and it is doubtful if acquiring air rights alone would be practical in view of the hazardous conditions that would occur under the cables when they shed accumulated ice during a thaw.

Since the guyed tower with its attendant real estate problems exceeded the cost for which the sponsor was prepared, the designers proposed an alternative. They recommended an 8000-ft, semi-guyed structure, a model of which is illustrated. Limiting the height to 8000 ft eliminated the need for pressurization; by adding three massive structures around the base of the mast, the designers not only provided solid anchorages for the short guys that stay the lower section of the tower, they also generated space that could be turned to revenue-producing activities that would help to amortize the cost of the tower.

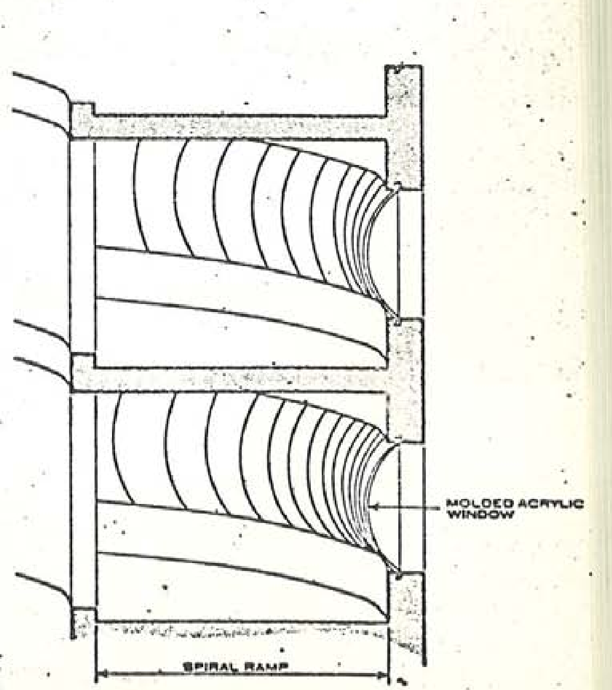
Because the preliminary study ruled out the economic feasibility of extending the tower above the height of Mount Fuji, the sponsor felt that the project would have sacrificed its greatest potential for attracting visitors; the project is now indefinitely deferred.

Participating in the study were: Fuller-Sadao/Geometrics, architects and engineers; and Simpson, Gumpertz & Heger, Inc., consulting engineers.

Figure 4.2 cont.



TOWER SUMMIT FACILITY



SCHEMATIC SECTION

Analogies have a long history in science and engineering for providing the insight necessary to come up with new ideas. A few examples are:

ALEXANDER GRAHM BELL made an analogy between the ear's structure and a device for translating audio vibration into mechanical motion (the microphone).

SIR MARC BRUNEL observed the action of a shipworm through a piece of lumber and from this got the idea for erecting caisons to help dig tunnels.

LOUIS PASTEUR viewed the generation of disease as analogous to the action of yeast in the brewing process. This led to the prevention of disease by inoculation.

MAXIM watched the whirlpool action of water running out of his sink and thought of a way to silence firearms by spinning and expanding the gasses as they came out the end of the gunbarrel.

LAPLACE drew on the self-healing process of the body as the basis for developing a theory about the status quo of the solar system continually being restored in spite of temporary and radical derangements.

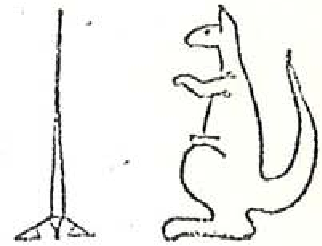
KEKULE's vision of a snake biting his own tail led to the realization that bending the benzene molecule around into a ring would account for benzene having only six free bonds when it has six carbon atoms.

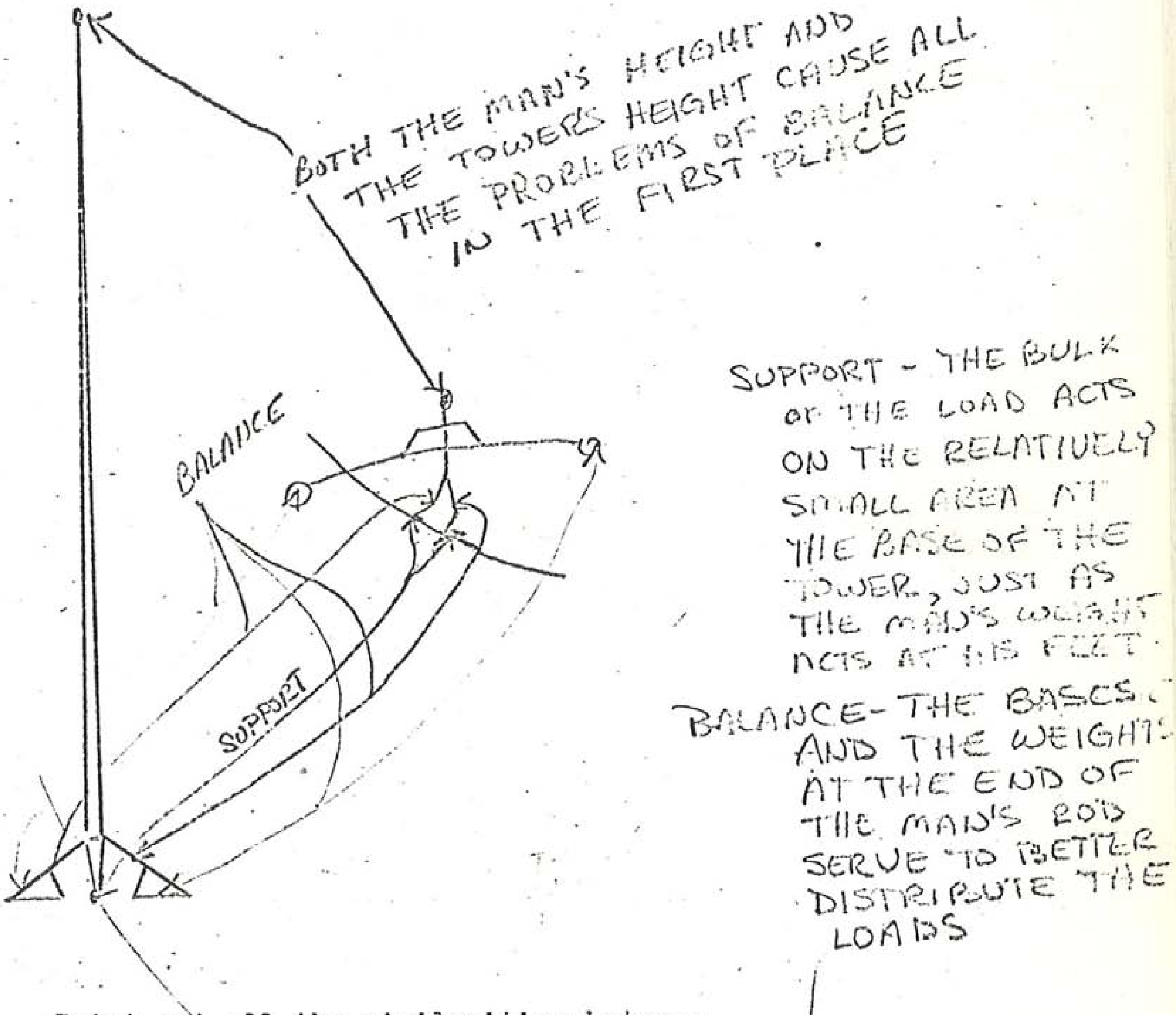
This concept of analogies is going to be used to help you think up new ideas.

Figure 4.3 Test 1, Page 3: Examples of Direct Analogies

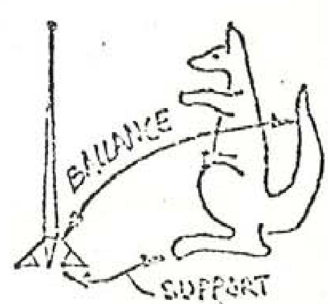
Figure 4.4 Test 1, Page 5: Instructions (Real Example)

On the next page are drawings of several objects which might provide useful analogues to the problem. Pick one of them and sketch it below next to the drawing of the two mile high tower. (An example is shown at the right)





Point out all the similarities between your analogue and the tower. You may call these out right on the drawing above by linking similarities (form, function, ets.) with a line and adding explanation. (Again, note the example on the right)



THE MAN'S LEGS AND THE WIRES BOTH BALANCE THE RESPECTIVE SYSTEMS.

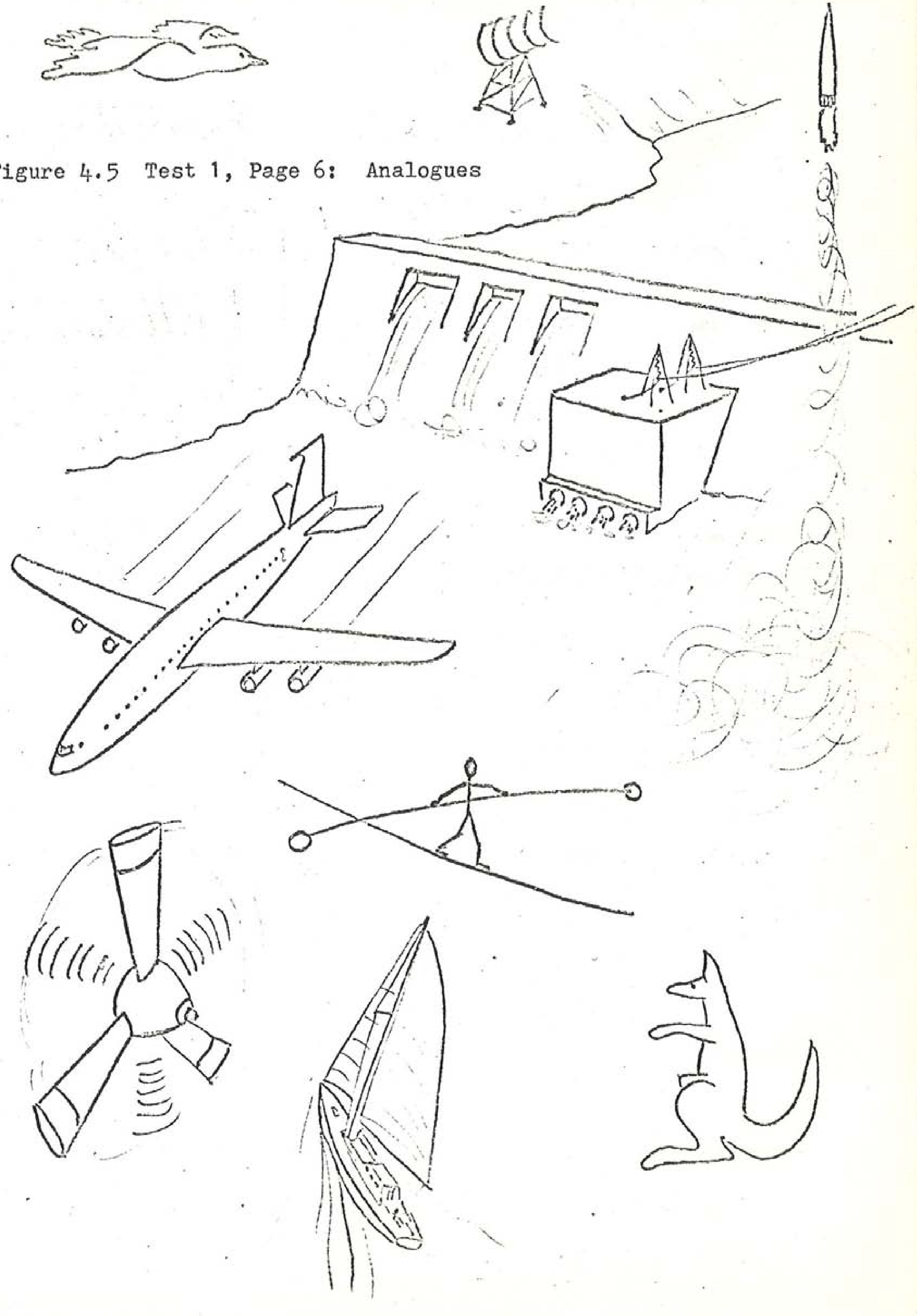


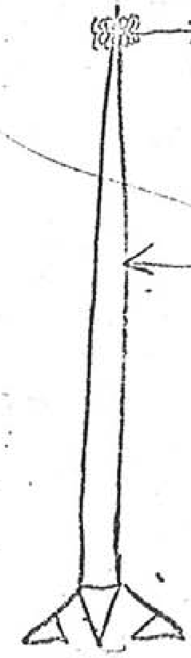
Figure 4.5 Test 1, Page 6: Analogues

14PB-IT

Figure 4.6 Test 1, Page 7: Final Design (Real Example)

If a new design for the tower were suggested by the analogue you picked how would it work? Don't be concerned if your description sounds fantastic. Just make some rough sketches to show your concepts.

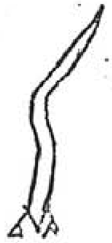
I just decided I like the propeller idea. Propellers can make planes go forward, so why couldn't they make buildings stay straight?



then the propellers could be started up to apply a moment in the opposite direction to cancel out the first. Since wind can act in all directions a computer could decide how hard to turn on which propellers.

say the wind forces act here

You'd have to be sure that you had enough horizontal* supports in this tower, though, or the thing would go:



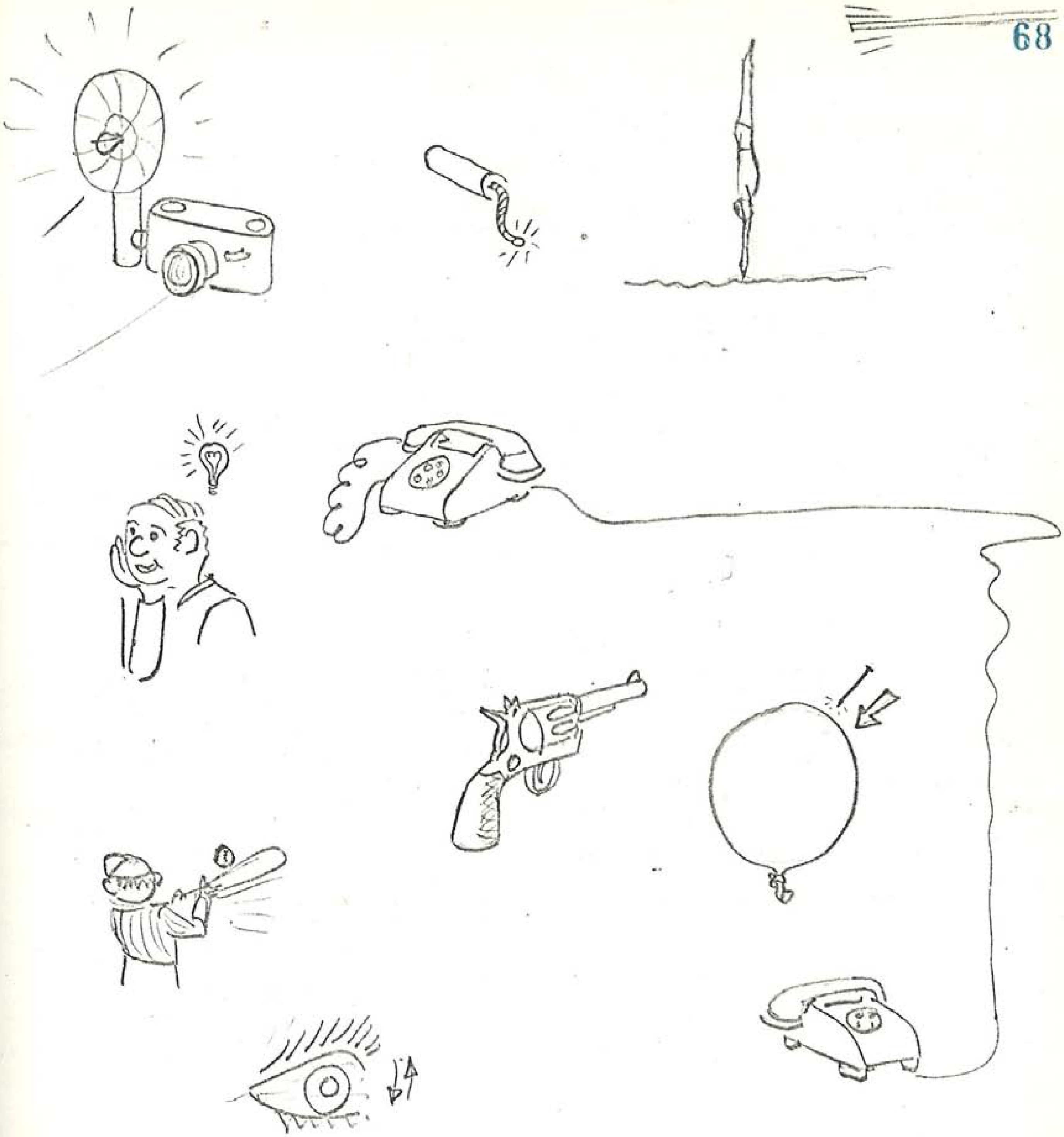
or something similar

*attached firmly to the vertical

Airport fires that are due to crash landings of planes present a great problem. In order to have equal access to all runways, fire fighting equipment must be garaged in a central location. As a result, the apparatus rarely can make immediate connections with any given accident or crash because large distances are usually involved. It has been established that the first few seconds right after a crash are the critical ones. At present it is simply impossible to get there fast enough even though considerable sums are available. Foam is often effective in certain emergencies, but it takes far to long to lay down a runway of foam.

You are given the problem of proposing a new system for dealing with these emergencies 'instantaneously' (within approximately 30 seconds). Follow the proceedure on the following pages to help you get new ideas. Show all your work (and play!). Remember: conventional approaches have failed--an imaginative solution is needed!

Figure 4.7 Test 2, Page 1: Instructions for Test Subjects



Above are some things which seem to happen instantaneously. Circle the one which seems to best embody the concept of 'instantaneous'.

Figure 4.8 Test 2, Page 2: Instructions with Analogues

Figure 4.9 Success: Graphical Visualization

The Monk's position as he walks up the hill was dependent on time and as he descended the hill was also dependent on time. These both can be considered as functions, although not known functions. If plotted on a piece of graph paper the position as he goes up the hill will be basically a curve going from the lower left to the upper right and as he comes down the hill will be from the top left to the bottom right. Where these two functions intersect would correspond to the position that the monk would occupy on both trips.

Figure 4.10 Success: Explicit Visualization

Well, if you take a film of the guy on his journey so that you start the camera exactly when he starts his trip at sunrise and you film him with a constant speed all the way up the mountain and then when he comes back down the mountain you take another film starting at sunrise when he starts his trip and you film it at a constant speed all the way down the mountain--then if you play these films at the same time, supposing this could be done, you'll find a point where their bodies and the scenery will exactly overlap, which would mean that he would be at exactly the same point as he was before.

Figure 4.11 Success: Implicit Visualization

If a man starts walking at the bottom of the mountain at the same time at which another man starts walking down from the top at a faster rate they will both meet at some instant in time at some place. As both starting times are the same and they meet, then they are at the same spot at the same instant in time.

Figure 4.12 Success: Ex Post Facto Visualization?

Since there is only one path up to the temple, and since the path is only a foot or two wide, then there is no way he can get up there without at least at one point on the trip being in the same location (part of him at least in the same location) at the same time.

Figure 4.13 Failure: Analytical Approach

First of all it is not necessarily true. We know that the average rate uphill can be described as R_u and the average rate downhill can be described as R_d. Therefore at some spot on the path if sometime t times the sum of R_u plus R_d equals the entire distance we have a true statement that along the path at some point the man will occupy the same exact spot at the same time. This is from $R_u t + R_d t$ = total distance. We know that $R_u + R_d$ is less than $2 R_u$. This is true because we know the descending speed is less than R_u, the ascending speed. If $R_u + R_d$ is less than $2 R_u$, then obviously the upward trip $R_u t \doteq D$. We can substitute $R_u + R_d$ into that assuming that of course, it must be less than $2R_u$, thus we know that $\frac{1}{2}(t \times 2R_u)$ will have to be equal to R_d. This is for of course the outside case if this can be satisfied then the statement is true that some where along the path at the same time the man will occupy the same spot. I said this is not always true and that will be in the case where the trip coming down occupies less than $\frac{1}{2}t$, or the time to ascend the mountain. In other words if the monk ascends in a 12 hour period and descends in less than 6 hours, it is impossible for him to occupy the same place at the same time. But as it would infer the trip down was only slightly faster than the trip up and, if in fact this is true then it stands to reason that he must pass the same spot at exactly the same time.

Figure 4.14 Failure: Analytical Approach

In attempting to solve this problem let me first say that I know nothing about probability or statistics from the mathematical point of view, and that any attempt I made was intuitive just thinking through it logically. I first read through the problem and thought if I had heard it before--I just heard it mentioned once and I did not know the answer then and I am still not sure of the answer. I went about it this way: I read through it and went back and tried to attack it as a mathematical problem looking for any constants or variables which we can find in it and I find that there is no real way I can see of predicting where he was on both trips at precisely the same time of day. The only thing I can say is that the only precise measurements given are that he began to climb the mountain at precisely sunrise which would put him at the begining of the path at exactly sunrise, and when he descended he started his descent at exactly sunrise--at the top of the hill, at first I thought that was the answer but then those aren't the same spots. Other than that everything varies so much that I find I can't come up with a precise answer. Let me also say that this is very frustrating because it reminds me of a similar problem we used to do in grammar school where we would start out by saying you are a busdriver and the busdriver drives a bus and at the first bus stop you pick up 27 people and that you drop off three and continue giving mathematical facts and at the end you are asked how old is the busdriver? And so I thought this was the same type of thing where it says one morning exactly at sunrise a Buddhist monk begins to climb a tall mountain and I looked through and I said "A ha! At exactly sunrise he began to walk down" and I thought that was the answer but according to the question it is not.

FIGURE 4.15 VISUAL SCORE SHEET

JUDGE:

T.P.

TEST NUMBER	EX POST FACTO DRAWING	1 VISUAL PROCESS DRAWING	SEVERAL VISUAL PROCESS DRAWINGS	1 VISUAL WORD OR PHRASE	SEVERAL VISUAL WORDS	1 VISUAL DESCRIPTION	SEVERAL VISUAL DESCRIPTIONS	TOTAL
1	X	X		X				3
2	X	X	X	X	X	X	X	7
3	X	X	X	X		X		5
4	X	X	X			X	X	5
6	X							1
7	X			X	X			3
8	X	X						2
10	X	X		X				3
44	X	X	X	X	X	X	X	7
13	X			X				2
14	X	X						2
15	X	X		X	X			4
26	X	X	X	X		X		5
17	X							1
18	X			X				2
19	X	X		X	X			4
20	X	X		X		X		4
24	X	X		X	X	X	X	6
25	X	X						2
26	X	X	X	X		X		5
27	X							1
28	X	X						2
45	X	X	X					3
31	X	X	X	X				4
32	X	X	X					3
33	X	X	X					3
34	X	X						2
35	X	X		X				3

Figure 4.16 Judges' Instructions: Scoring for Creativity

I would like two numbers for each test: a grade from 0 to 10, and a ranking from 1 to 31. Please write these two numbers in the form Grade/Rank to the right of the test number on each page (examples: 9/2, 5/17). When you are done also list the tests in order of rank on the attached form.

The grade from 0 to 10 should represent your opinion of the creativeness of the ideas expressed. Please note that the primary emphasis is on ideas. In order to reduce bias due to appearance, each design has been redrawn to look as good as possible without altering the concept. A rough idea for this scale follows:

0 Not intellectually honest, that is, either shows non-participation in the test or the solution does not honestly attempt to solve the problem.

1 Solution addresses itself to the problem only marginally, or, it is a cop out--a wild idea which might solve the problem but allows the designer to avoid making a commitment which would reflect on his ability.

2 Minimum deviation from old design.

... 5 Median effort.

... 10 Exceedingly elegant and unique solution.

The ranking from 1 to 31 should indicate your preferences from best to worst. How you think the design may work in actual practice may enter more strongly here. Some ideas which may help you during scoring:

-- Taking two old ideas and putting them together generally represents a lower level of innovation than coming up with one new idea.

-- Creative designs may deviate the greatest amount from existing ones, however just because a design looks different does not mean it is creative. A novel but useless design may be generated by chance as opposed to thought.

-- Elegance is a useful criteria:

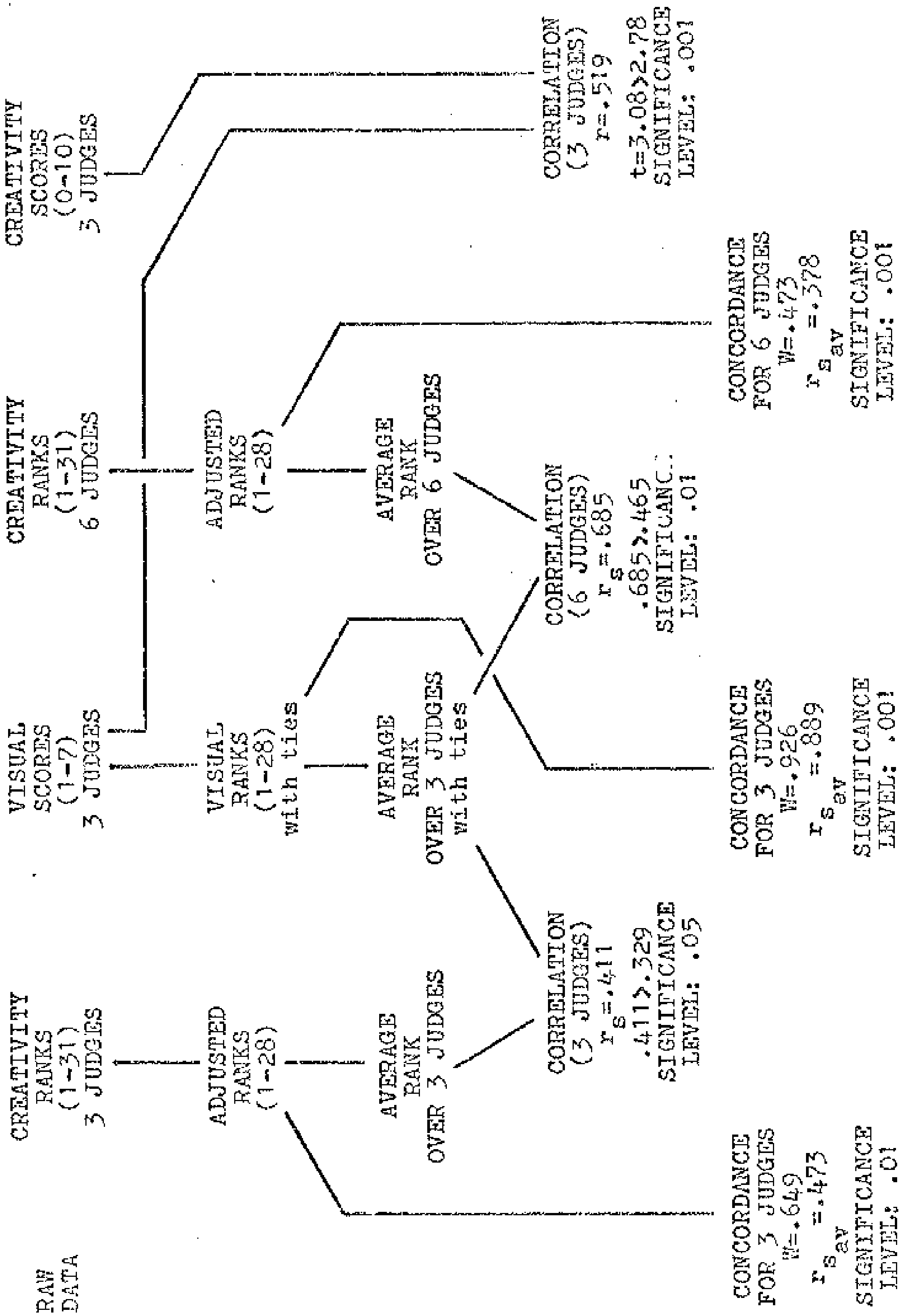
$$\text{Elegance} = \frac{\text{Multiplicity of Variables}}{\text{Simplicity of Solution}}$$

I would also appreciate any comments you might have on your results, your difficulties or your own personal criteria for judging. Please read the old article before proceeding.

Figure 4.17 Table Showing Raw Data and Final Rankings

TEST NO.	RANK FOR CREATIVITY (1-31)							CR. RANK AVE. OVER 3	CR. RANK AVE. OVER 6	VISUAL SCORES			VIS. RANK AVE. OVER 3
		⌐——— 6					———⌐						
					⌐— 3		—⌐						
	RF	LF	WG	TP	JK	PH	SM	3	6	RF	WG	TP	3
1	3	3	15	16	6	13	11	9.5	4.0	5	3	3	8.5
2	4	4	3	2	15	3	20	14.5	3.0	6	4	7	1.0
3	1	15	7	12	10	16	8	12.5	8.0	6	4	5	3.0
4	11	9	16	6	13	8	17	14.5	11.0	5	2	5	6.0
6	14	17	12	15	4	9	12	7.0	9.5	2	1	1	26.0
7	31	28	17	20	22	1	2	5.0	15.0	2	1	3	19.0
8	27	25	28	25	26	21	25	21.5	26.5	2	1	2	21.0
10	9	7	13	13	11	5	16	11.0	6.5	4	4	3	8.5
11	{ 8	5	5	5	17	20	23			5	3	7	
44	{ 2	1	6	4	9	4	9	3.0	1.0	5	3	7	5.0
13	23	29	31	7	25	24	24	23.5	23.0	1	1	2	26.0
14	17	20	22	18	20	29	19	20.0	22.0	2	1	2	21.0
15	19	16	26	10	27	17	27	23.5	21.0	3	1	4	15.0
16	21	8	20	23	16	22	6	16.0	16.0	1	2	1	23.5
17	24	26	23	26	30	28	13	21.5	25.0	1	2	1	23.5
18	22	24	25	24	24	23	29	26.0	26.5	1	1	2	26.0
19	5	12	18	21	23	25	26	25.0	20.0	4	3	4	7.0
20	13	13	14	14	14	11	10	12.5	12.0	3	3	4	10.0
24	16	22	8	22	21	19	21	19.0	18.0	5	5	6	2.0
25	25	30	24	8	29	30	22	27.0	24.0	2	1	2	21.0
26	{ 7	2	10	3	5	14	5	5.0	2.0	5	7	5	4.0
46	{ 20	10	27	19	28	6	30			5	7	5	
27	26	31	29	27	31	31	28	28.0	28.0	1	1	1	28.0
28	15	14	9	17	7	15	7	8.0	9.5	4	1	2	18.0
30	{ 10	6	19	11	12	18	18			3	3	3	
45	{ 30	19	2	28	1	2	14	2.0	6.5	3	3	3	12.0
31	18	11	21	9	8	12	1	1.0	5.0	3	2	4	13.0
32	12	27	30	1	19	26	3	17.0	17.0	3	2	3	14.0
33	6	21	11	21	18	10	4	9.5	14.0	4	3	3	11.0
34	28	18	4	31	3	27	31	18.0	19.0	3	2	2	17.0
35	29	23	1	31	2	7	15	5.0	13.0	2	2	3	16.0

Figure 4.18 Calculation Flow Chart and Results



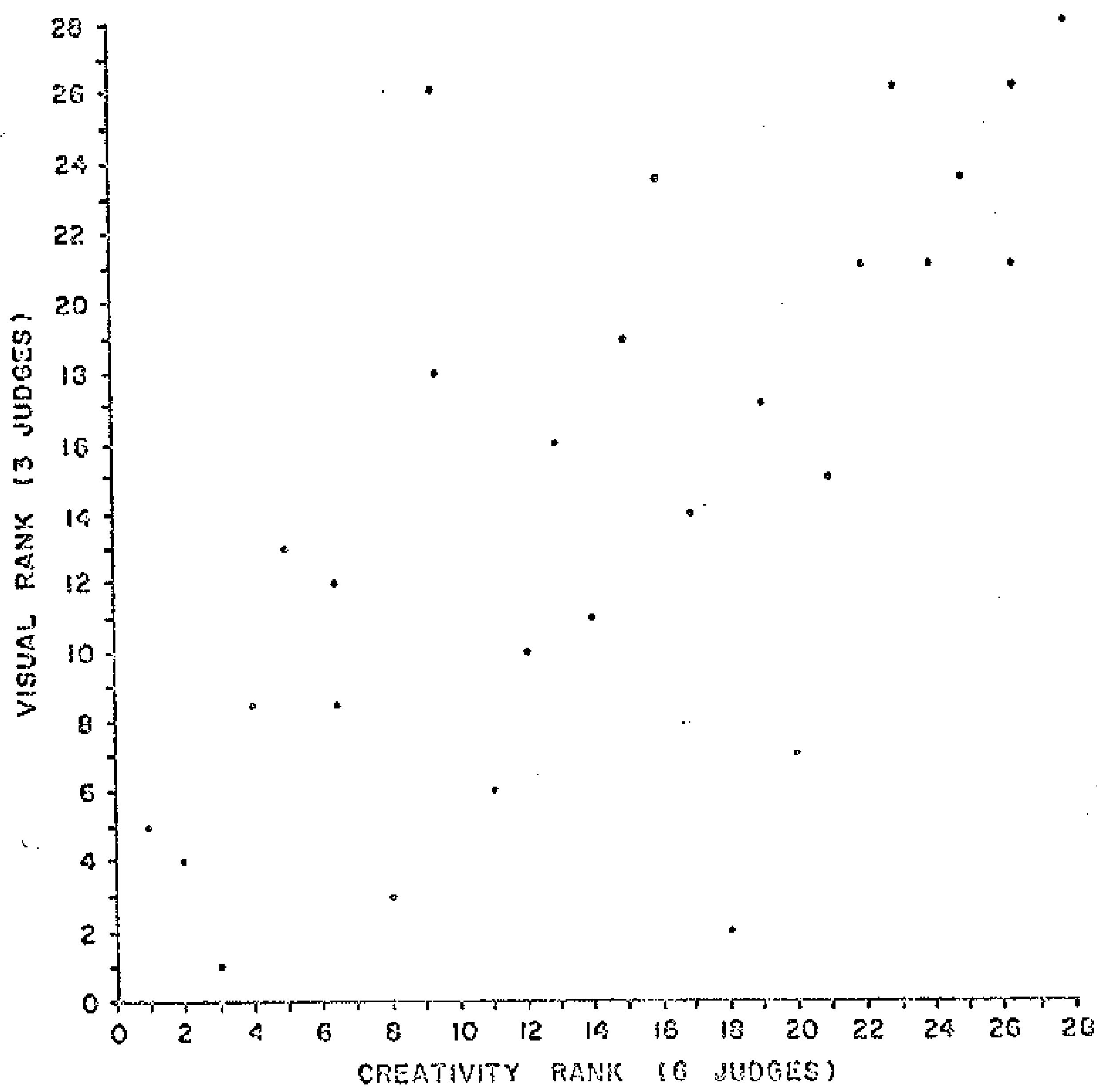


FIGURE 4.19 SCATTER PLOT OF VISUAL RANK VS CREATIVITY RANK (6 JUDGES)

CHAPTER 5 IMPLICATIONS

5.1 IMPLICATIONS FOR SYNECTICS AND PROBLEM SOLVING

Uncovering a positive correlation between visualization and creativity was only the first of several objectives listed in my rather ambitious thesis proposal. I had also hoped to develop some operational visual approaches to problem solving. Indeed it was the lack of such devices in the Synectics problem solving techniques that led to my involvement there. It had struck me that Synectics had gained a largely poetic nature rather than visual, due perhaps, to the oral-verbal way in which Synectics sessions are run. I knew my own mode to be visual, so I inquired why this was so.

Synectics had, in fact, begun to work on visual material, especially in connection with their educational program. There, in workbooks, pictures provide an ideal way to present metaphorical material and elicit drawings in response. The existing operational mechanisms have taken many years to develop, (Chapter 1.4; D.A., P.A., C.C., etc.) and perhaps it was naive to think visual techniques could be easily discovered. Nevertheless, changes, or more correctly, additions to the Synectics approach are in the making.

At first glance it would seem that Direct Analogies would benefit the greatest amount from visual techniques, but it presently appears that Personal Analogies may gain the most. Personal Analogies (empathetic identification with one's analogue) are the most difficult for beginners to have success with. Identifying with an object may be eased into by imagining what this object <u>sees</u> prior to imagining what the object feels. In chapter 3.3 we saw that what a person sees is a function of the code he decides to impose on a scene. Often, in fact, this code will be chosen by what he feels (hungry, for example). Thus figuring out the code which an animal or object would impose on a scene, and imagining what it would see with such a code applied, is a big step towards understanding how something feels.

The Compressed Conflict is not so well suited to visualization. Actually, it may be thought of as a null state between two images. The Compressed Conflict wrings a two word description of the conflict contained in the image which is being developed. These two words then act as a verbal pivot. Momentarily they hang by themselves, words without meaning. Quickly new images and analogies are evoked. Thus the Compressed Conflict acts as a bridge between two images.

It is not unreasonable to think about creating a 'visual pivot'. Perhaps the first thought or idea could be symbolized, much in the same way as corporate identities are. Such a symbolized conflict would then act as a Rorschach inkblot -- bringing new images to different people. In this way a new concept would emerge. Unfortunately such a visual distillation would probably be time consuming, and one of the advantages of the Compressed Conflict is the speed and ease with which a group of people can arrive at one.

A more profitable approach to solving problems by visual means is probably to discard the formal Synectics structure but retain the goal that structure attempts to achieve -- Making the Familiar Strange. To that end I have begun a book which will hopefully provide new ways at looking at problems. So far I have thought of over two dozen ways in which the familiar can be made strange using visual techniques. While many of them are humorous in nature, one or two may strike home for any given individual. More important than the separate exercises will be the attitude encouraged by the whole: a willingness to play with new ways of perceiving the problem.

The long range effect of this thesis on Synectics will probably be subtle; but now that the importance of thinking about creativity in terms of visualization has been demonstrated, it should be significant.

5.2 IMPLICATIONS ON EDUCATION

Synectics has grown to encompass both the creative process and the learning process. The learning process is a creative act in itself. The student must make an original jump from what is known and what is unknown. "Making the Strange Familiar" (learning) may be thought of as the reverse of "Making the Familiar Strange" (Invention). In The Metaphorical Way of Knowing and Learning, William Gordon shows that the Synectics mechanisms work in both directions.

A connection has been demonstrated between visualization and creativity, therefore, we have every reason to suspect an equally strong relationship between visualization and learning.

> Creative perception depends on making metaphors that are necessary and sufficient connective conditions between known and unknown, and between known and known. Learning in art and science is simply an extension of creative perception. (8;7)

How can teachers encourage such creative perception?

1) Teachers should provide visual footholds, i.e., illustrations and examples. It is especially important to encourage students to find their own "footholds". Metaphorical tech-

niques provide one effective way in which this may be done.

2) Learning may be thought of as gaining new codes for looking at things. Because learning such a code looks easy after it has been accomplished, teachers should attempt to remember the specific difficulties they had while they were learning the material, and recall the ways in which those problems were surmounted.

3) Teachers should be on the lookout for the odd ball, especially those students whom they do not like. Probably one of the more difficult things a teacher must do is to encourage the creative student with whom he does not agree.

4) Conduct 'how to see', not 'what to see', training.

Of these the first three are reasonably self explanatory. Number four is more ambiguous. What immediately comes to mind is education in the arts. Such training may have two approaches: Art History, in which one learns to appreciate perceptions of the past and other cultures in order to tolerate new ones of our own; and Studio courses, where one learns to manipulate forms and create new images.

Darwin once said, "In order to be a good observer one must be an active theorizer." (7;5) Drawing may be one of the best techniques for learning to make hypothesis because it requires making guesses in an iterative fashion. In engineering education the vehicle for teaching such drawing exists in graphics courses. However these courses at the present time emphasize graphics as a communication skill rather than an aid to thinking.

In Visual Thinking, Arnheim says, "The most effective training of perceptual thinking can be offered in the art studio." (1;296) In general I agree, but there are pitfalls. Generally art classes make the same mistake all classes make by assuming that everyone enrolled is going to become an artist. The resulting class is often too slow and laborious, especially concerning technique, for a person really desirous of becoming a physicist. Of the art courses I have had, one was a delightful exception tought by Richey Kehl at the University of Washington (see 100 Ways to Have Fun with an Alligator by Norman Laliberte and Richey Kehl). This course sought to teach what artists refer to as innocent vision--a way of looking at things which discourages labeling in order to see what is really there. Such a viewpoint encourages what Guilford calls "transfer recall" as opposed to "replicative recall", the usual school fare. (10;11) Kehl's course did not attempt to make artists, rather, it stressed creative ideas over techniques, and as a result was excellent for non-majors as well, especially engineers.

A second problem with art courses, related to the first, could be eliminated with less effort. If non-art students are to take art courses they should be graded as such. Grades are a major deterrent to taking art courses for many students especially science students who wish to go to graduate school. In fact there are many good reasons for eliminating grades for

for the artist as well. We saw in chapter 4 how difficult it was to grade or rank the truly creative tower designs, even for experts. In the last analysis the judge or teacher is only expressing his opinion.

Two more points may be added to the list then:

5) Eliminate grades in <u>any</u> course which claims to encourage creativity, new points of view, or open ended discussion. Grades in such courses mock the freedom they advertise.

6) Teachers should attempt to expand their own viewpoints and become as open minded as possible.

It may appear that a castle is being built out of sand. To go from a significant positive correlation between visualization and creativity to a ban on grades may seem like a big step. My explanation is that this result simply confirms discussions I have read elsewhere, notably in A.S. Neill's <u>Summerhill</u>, Paul Goodman's <u>Compulsory Miseducation and the Community of Scholars</u>, Jerry Farber's <u>The Student as Nigger</u>, and so on. If the reader is interested in the last points made above he will be interested in reading these authors.

One final comment is necessary in respect to the extreme word orientation of our educational system. There should be no conflict between language and visualization. The two work together to help us solve our problems in our everyday world. Words are used by our conscious minds to express and manipulate rational thoughts. It is not until we become "blocked" (chapter 1.3) that this becomes a problem. In Poincare's words we must then "think aside" and take advantage of our unconscious and visualization. You might say the language for a new way of looking at something has to be invented. The attitude is fostered in school that words (and mathematics) are the only tools required to be creative. We have seen that this is not so.

5.3 IMPLICATIONS ON PSYCHOLOGY

The relationship demonstrated between visualization and creativity supports the important role some psychologists have suggested the eyes play in the actual functioning of our intelligence. It does not however, tell us any more about how vision, or visualization works. For the time being this result will be of more interest to psychologists concerned with creativity and learning, than to those working in cognition and perception. This is due largely to the fantastic amount still left to find out about how vision works. In order to find qualitative differences between the way in which men see, knowing how they see would seem to be a prerequisite.

Nevertheless, the few facts I do know about vision, gleaned from Neisser, Gregory, Cornsweet, and Paiget, encourage speculation about the possibilities. Haber and Haber have shown for example, that eidetikers (people with so-called photographic memories) scan scenes presented to them much more than non-eidetikers. (17;148) Held and Heim's experiment with kittens demonstrated that perceptual learning does not take place in an animal when it is not allowed to actively and kinesthetically explore. Held's passive kitten remained effectively blind. (9;210) It would seem that in between the two extremes of kittens remaining blind when not allowed to actively explore and eidetikers being able to remember (reconstruct) almost everything they see, must fall a whole spectrum of differing visual skills. Frank Barron has said, "Originality is almost habitual with individuals who produce a really singular idea. What this implies is a highly organized mode of responding is a precondition for consistant creativity." (2;7) It also hints at the value of investigating differing visual abilities.

The following lines of inquiry appear profitable:

A) To collect the scratch work of famous creative engineers or conduct an experiment in order to see how their explicit visualization compares with their product. William Gordon says that people who draw really well during Synectics sessions tend to produce fewer ideas because they are so busy detailing their drawings. Since this has not been my experience I would be curious to see the extent to which this is true.

B) Oppenheimer once said, "There are children playing in the streets who could solve some of my top problems in Physics, because they have modes of sensory perception that I lost long ago." (15;93) It would be interesting to test this statement also. Perhaps a test could be devised, somewhat similar to the tower test, which would enable children and adults of all ages to be tested for both creativity and skills of perception. Would curves of such data plotted versus age climb steadily? Would it have varying rates of climb? Or would it peak out? At age 8? Or at age 55?

C) Perhaps such an experiment could zero in on one age group. Psychologists have documented a phenomena known as the fourth grade slump in creativity. By the time a child has reached his ninth or tenth year he has learned to be able to ask better questions than the teacher can answer. (2;99) What are the effects of this particular "slump" on perceptual abilities and/or learning?

D) The testing sequence in chapter 4 indicated the extreme sensitivity students have for differing instructions. A modified tower test could become an excellent device for testing the effects of these variations on creativity.

E) Finally, it would be instructive to check the correlation in creativity scores between rankings given to the redrawn tower design and those given to the initial scratch work. Such an experiment would test judge bias due to neatness. Perhaps this could even be done with the data which has already been collected.

5.4 CONCLUSION: ART vs. SCIENCE

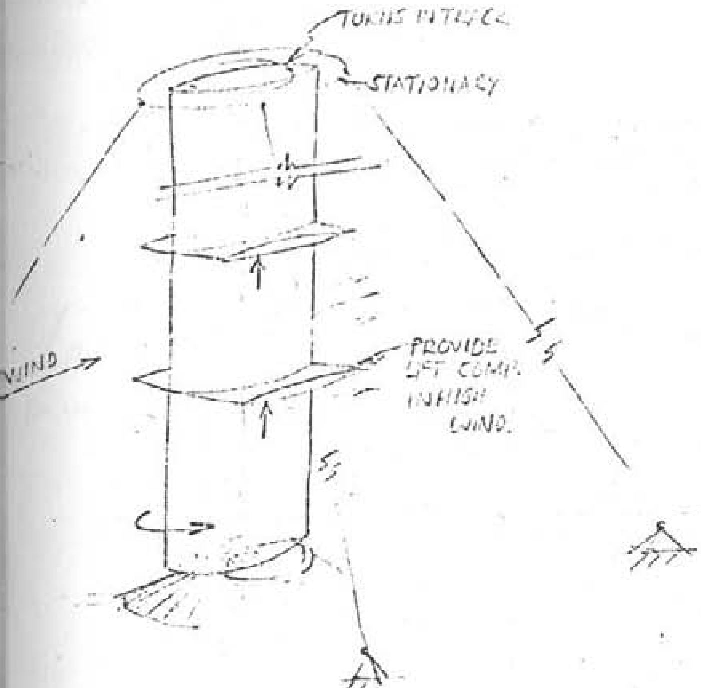
The conflict between art and science has been going on for twentyfour hundred years. At times I wonder whether this struggle has not been one of the driving forces of Western Civilization. Kenneth Boulding, in The Meaning of the Twentieth Century, points out that the conflict between Russia and the United States is good in the sense that it prevents a stiffling mediocrity from taking over. Perhaps in a similar way, the feud between the arts and the sciences has fueled each other, providing inspiration and energy, and goading each other on. Perhaps. But it also appears that we could use a fifty year truce to get some pressing problems solved.

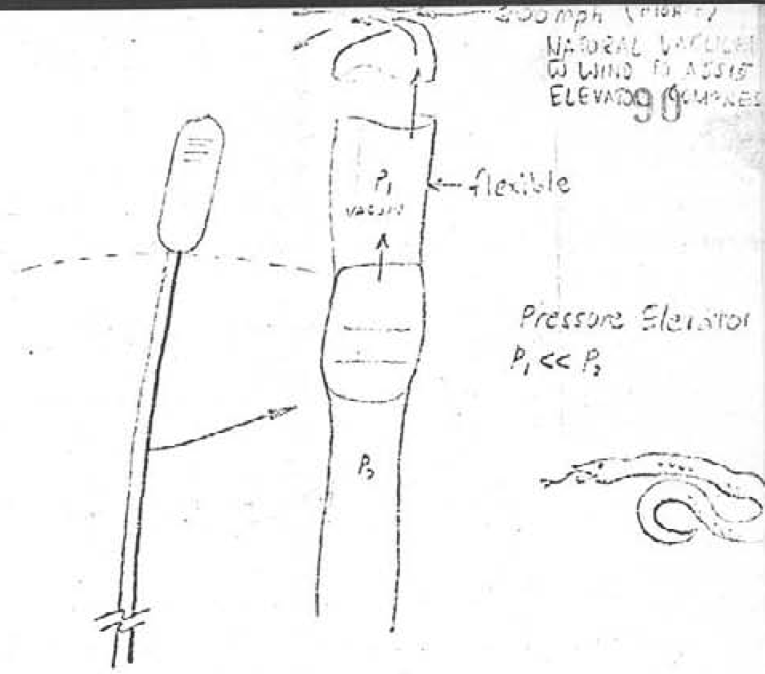
The source of the strife is a philosophical disagreement about what is real and what is not. The scientist says that reality exists without man, the artist that reality does not exist without man. The artist should certainly be able to concede that, if man did not exist, the subject matter of science still would. At the same time the scientist should face up to the consequences of the Heisenburg Uncertainty Principle: man is inextricably entangled in his scientific observations. If the reader has read this far, he should have some realization of the extent to which man's vision has governed the course of scientific history. It is time to turn that vision to the solution of the world's problems, which are undeniably due to man's inclusion in reality.

This thesis began with a discontentment in my undergraduate education. I had not felt it to be the aesthetic experience it should have been. When I first voiced this complaint to William Gordon, he cited a study made by an Engineering Society to find why young men were not going into engineering. The report concluded that potential students felt engineering was not aesthetic. We know that great scientist and engineers are, "distinguished by their profound commitment to the search for esthetic and philosophic meaning in all science." (2;86) In chapter 2 we saw numerous examples of direct analogy solutions in science. Poincare once said these combinations are found by "the aesthetic sensibility of the real creator. The useful combinations are precisely the most beautiful, I mean those best able to charm this special sensibility." (13;165) Admitting the role which visualization plays in creativity should greatly help the revival of the aesthetic in scientific education. Such a revival would have two beneficial effects: it would encourage students to enter engineering thus providing the manpower needed to solve our manifold problems, and it would insure that the solutions arrived at would be ones which man can live with.

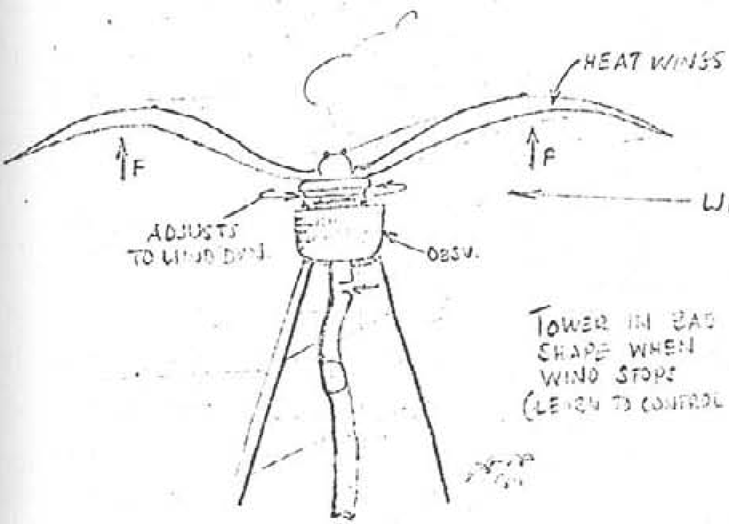
Appendix 1 Selected Examples of Test Subjects Actual Work

This appendix includes 14 pages of actual work out of over 150 pages of work done by subjects taking the two mile high tower test. This work was selected to demonstrate the range of differing visual abilities exhibited by the test subjects. The test number in the lower right corner may be used to check both the visual scores given by the judges (figure 4.17) and the way in which they were redrawn for the creativity judging (appendix 2).

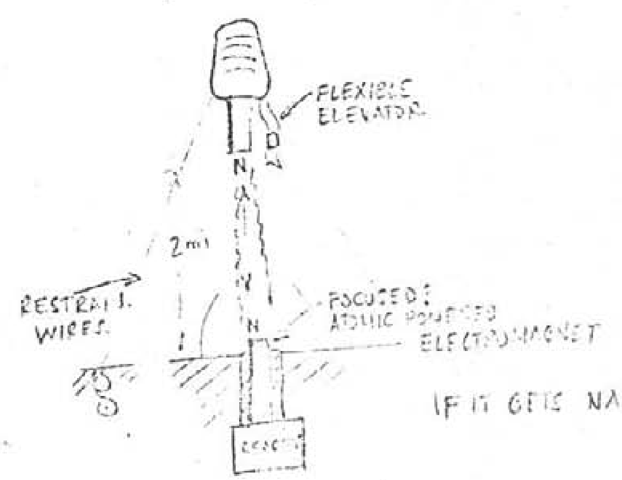




Pressure Elevator
$P_1 << P_2$



TOWER IN BAD SHAPE WHEN WIND STOPS
(LEARN TO CONTROL WEATHER)



IF IT GETS NASTY, LOWER THE TOWER?

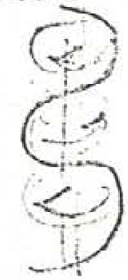
CAN YOU FOCUS A MAGNET?
CAN YOU MAKE ONE? (NO!)

Feasibility — of the reading article, I was more discouraged from attempting to design the tower than before reading it

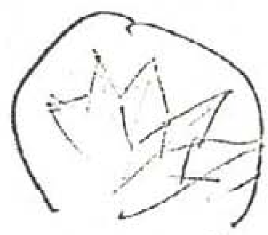
Major problem

Looking at windows — ① weight
② wind
③ cost
④ ice build up.

Tube — allow structure to turn with wind



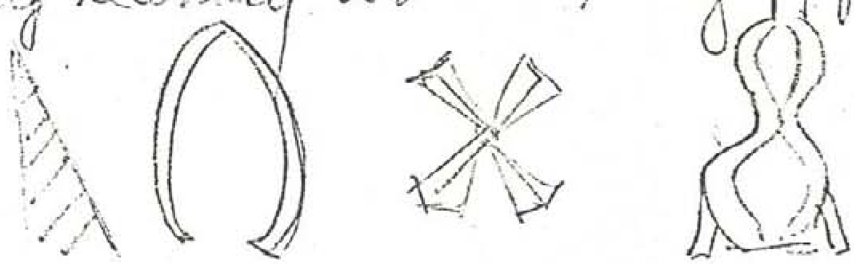
① Trees
② Eiffel Tower
③ Dome at World's fair
Structure is light + self supporting.



Organic Chem
Carbon Chains

④ Aluminum construction
Wood
Nylon

⑤ Not totally necessary to build straight up.



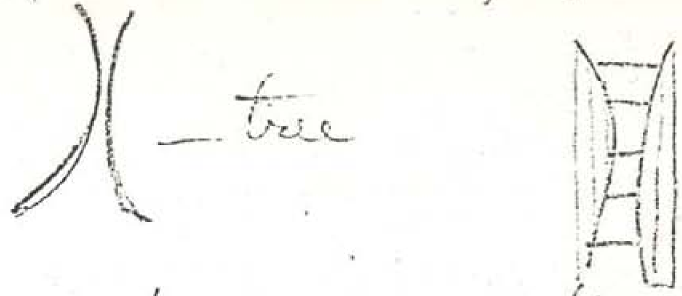
⑥ Structure of molecules — tetrahedral
hexagonal (Trigonal)
linear
orthogonal

②

⑦ Michael Brake
⑧ Washington Monument

⑪ California Redwood

Inverted arch (Stand like construction



Alternatively, if arch is used, the structure must be repeated several times
Should find optimum angle for strength, least material.

Could combine)(and () to

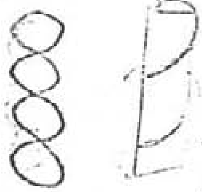
Math relations:
Curves described parametrically

$$f(t) = \begin{pmatrix} u\cos v \\ u\sin v \\ v \end{pmatrix} \rightarrow$$

②

2CJ3-1C

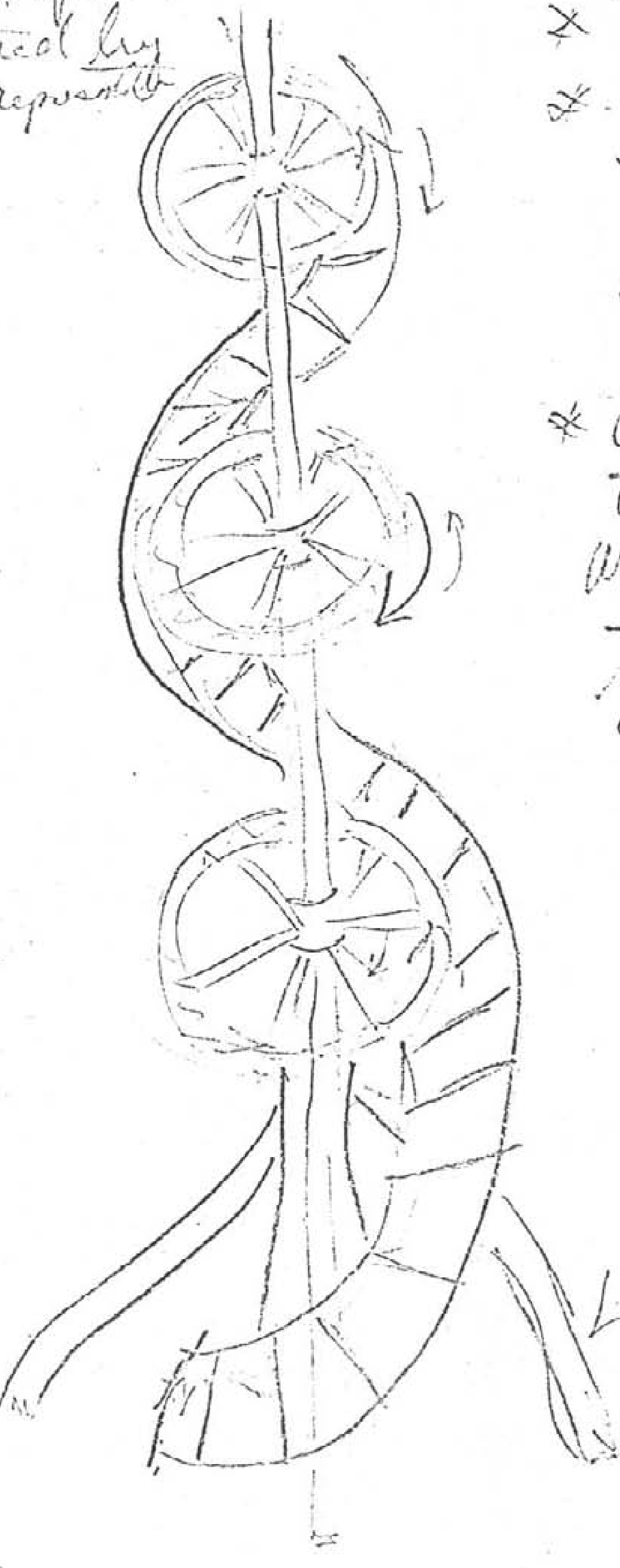
Twisted Rubber Band — Under stop



Coil — Lasso?

→ Seems to be leading to structure with a wrapping

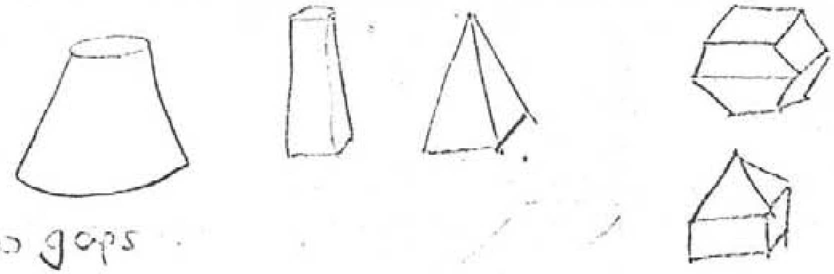
* Must be same way & incorporate graph attained by primitive representation



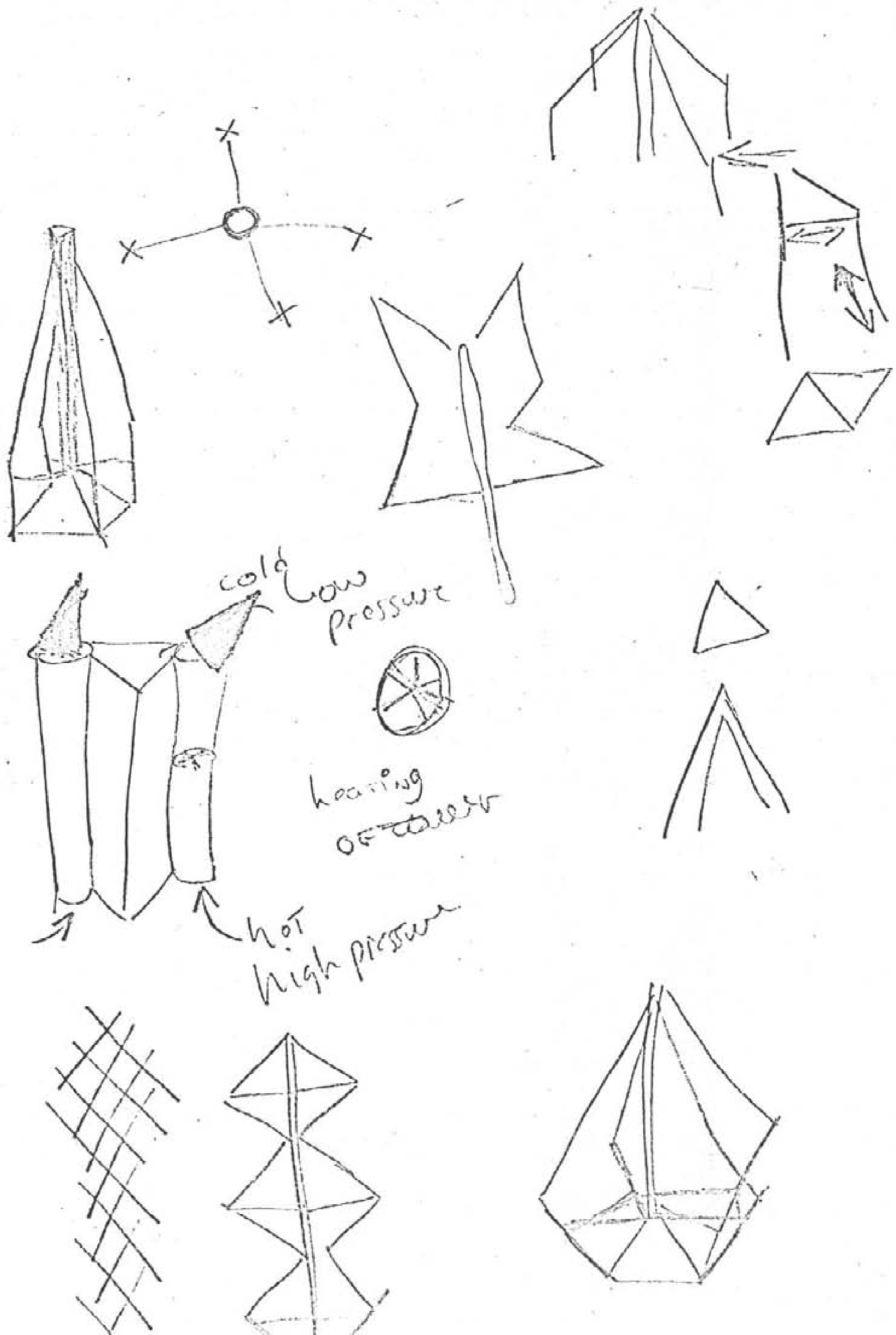
* Tube
* Wheels — tend to rotate with wind. Include primitive representation ($u \cos\theta$ / $u \sin\theta$).
* Energy of wind transmitted to wheels

Wrapping of interior tube gives strength — support, protection.

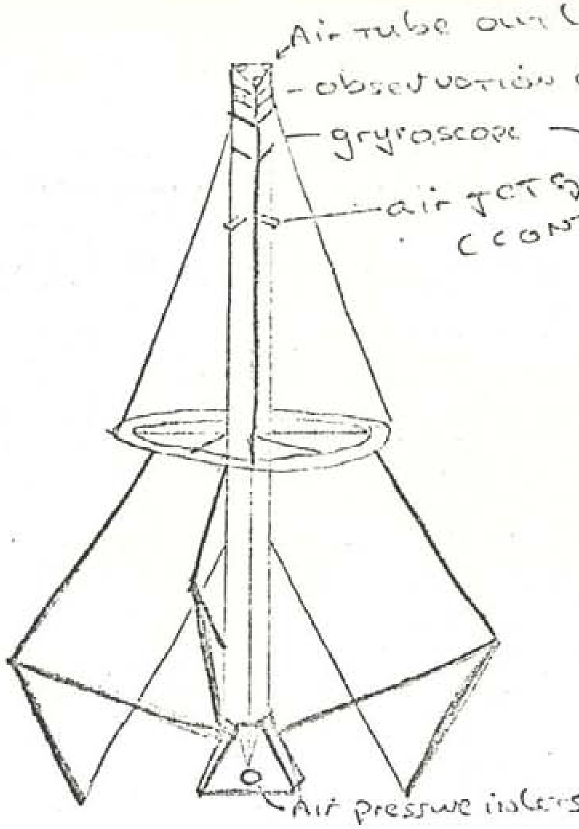
TALL
pressure
resistance



can have no gaps



③

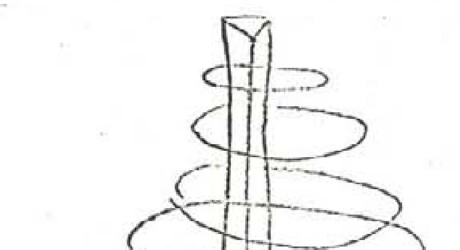


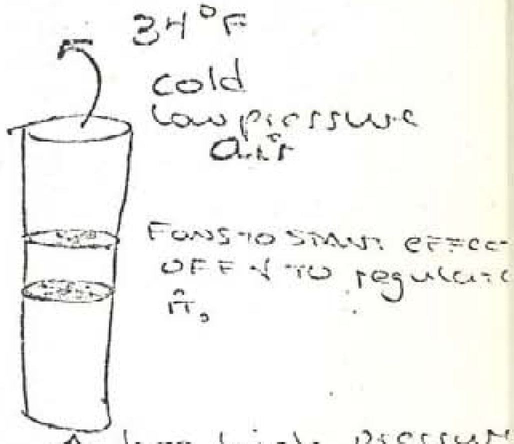
TOP VIEW

Stability: possibilities:

a) gyroscope -
b) air pressure - (reaction powered)
c) guy wires -

} All of these can (will?) be used

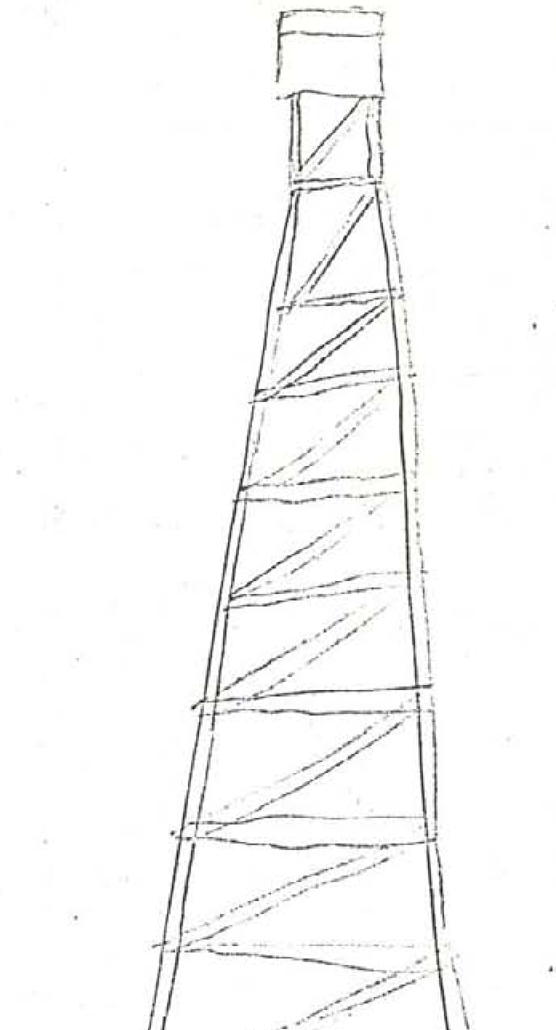


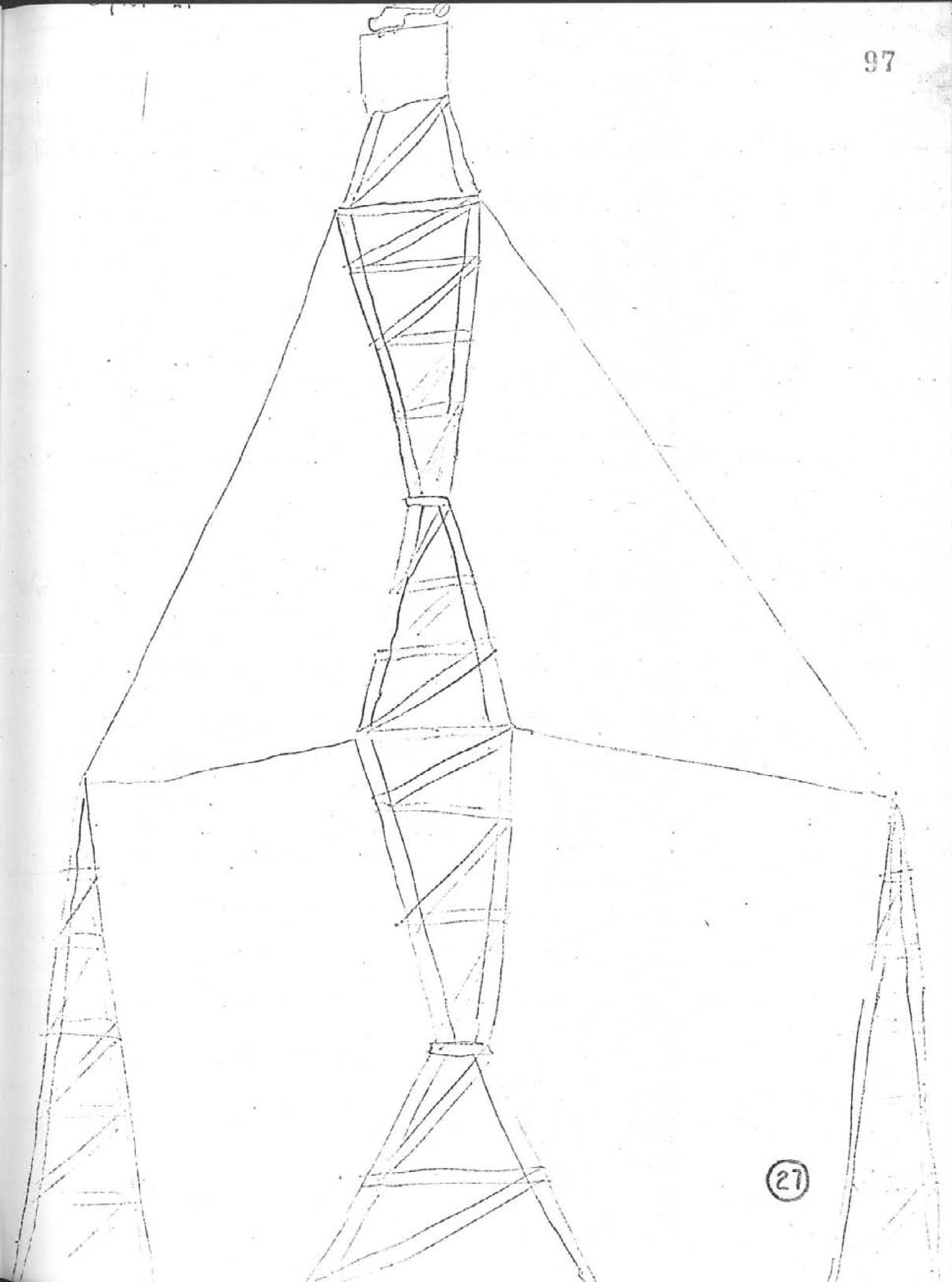


heating + pressurization

③

1) heating aided by flow of warm surface air
2) pressurization by compressing air flowing up air ducts
Observation shaft need not be pressurized, but it

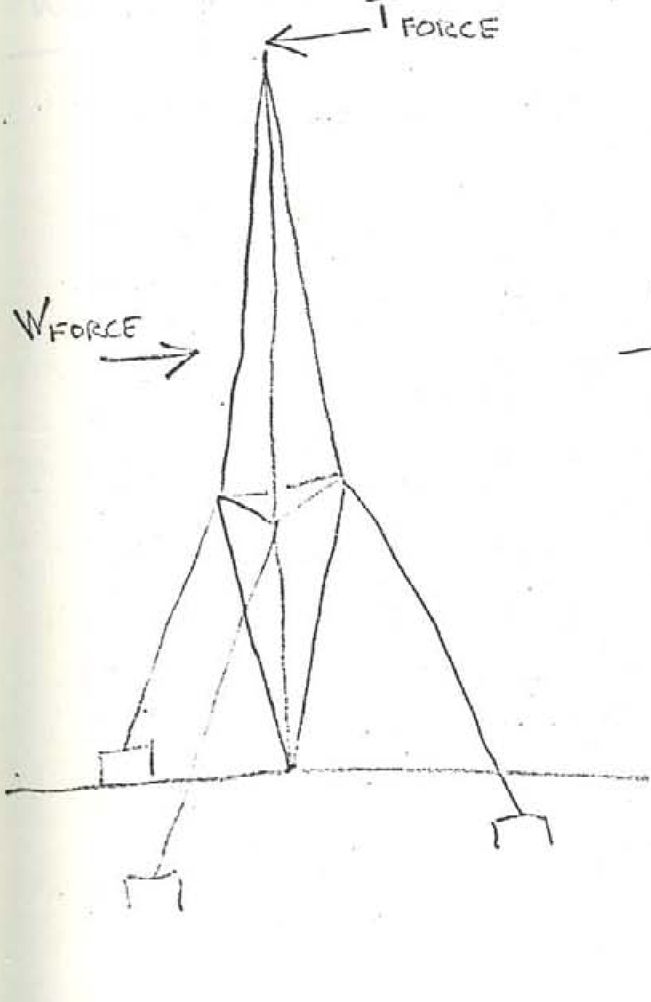



27

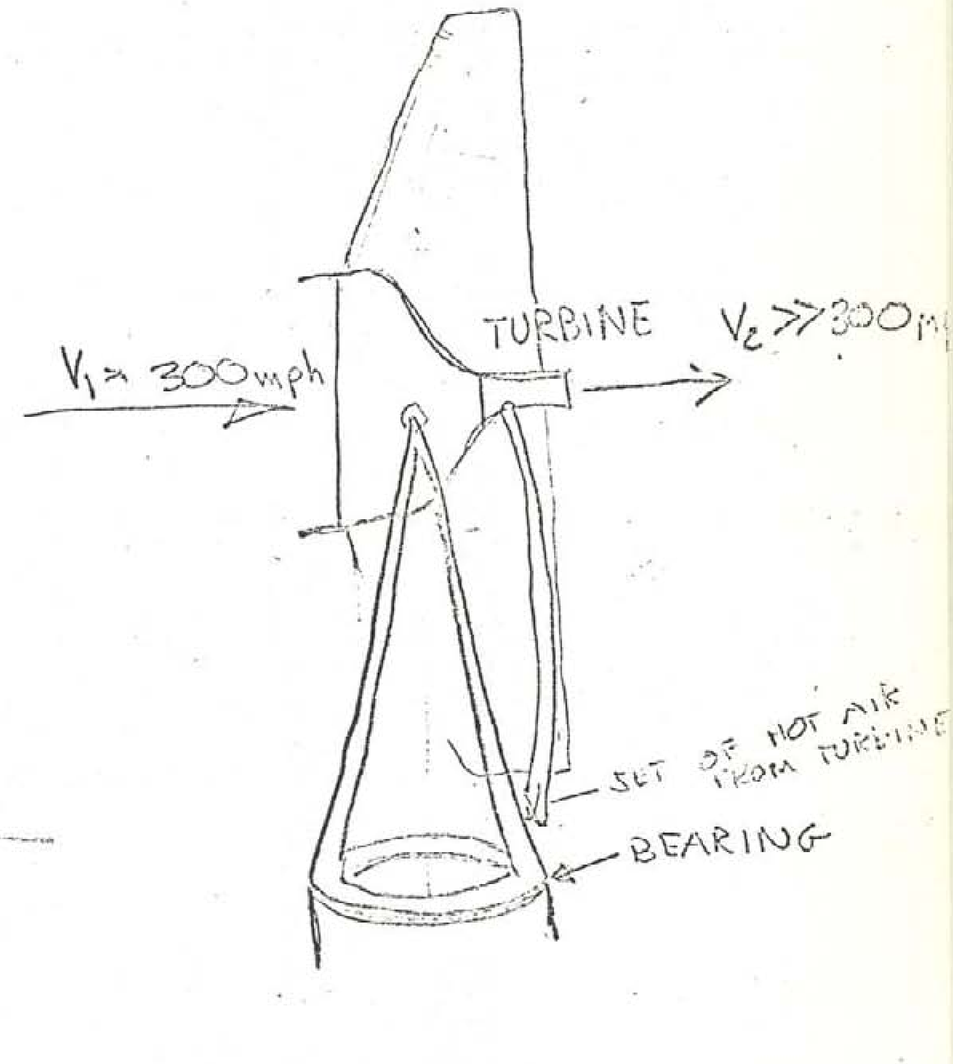
① ICING – ALL STRUCTURAL MEMBERS ACCUMULATE 12 IN. ICE
② HIGH WINDS – 300 mph
③ NEED FOR PRESSURIZATION OF: POD, ELEVATOR

8000 ft
12,250 ft

4,250



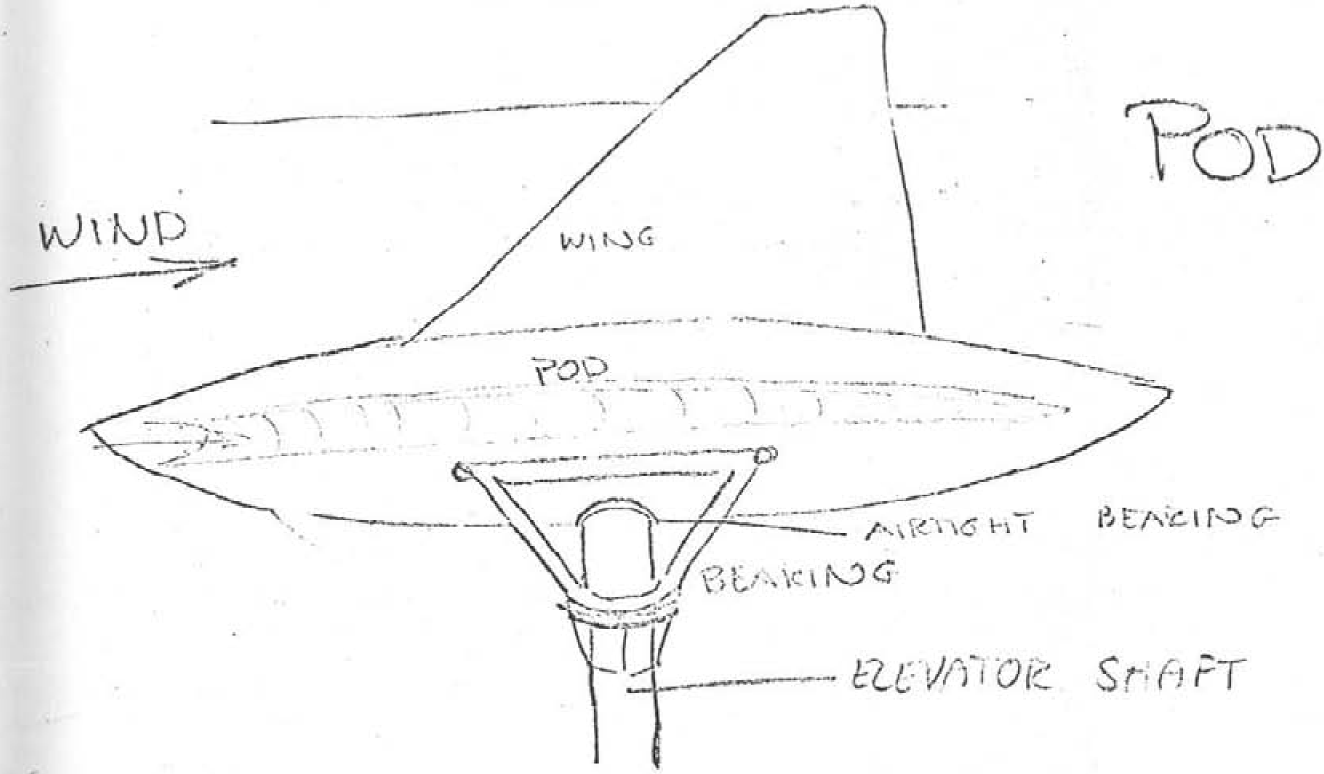
IDEA 1



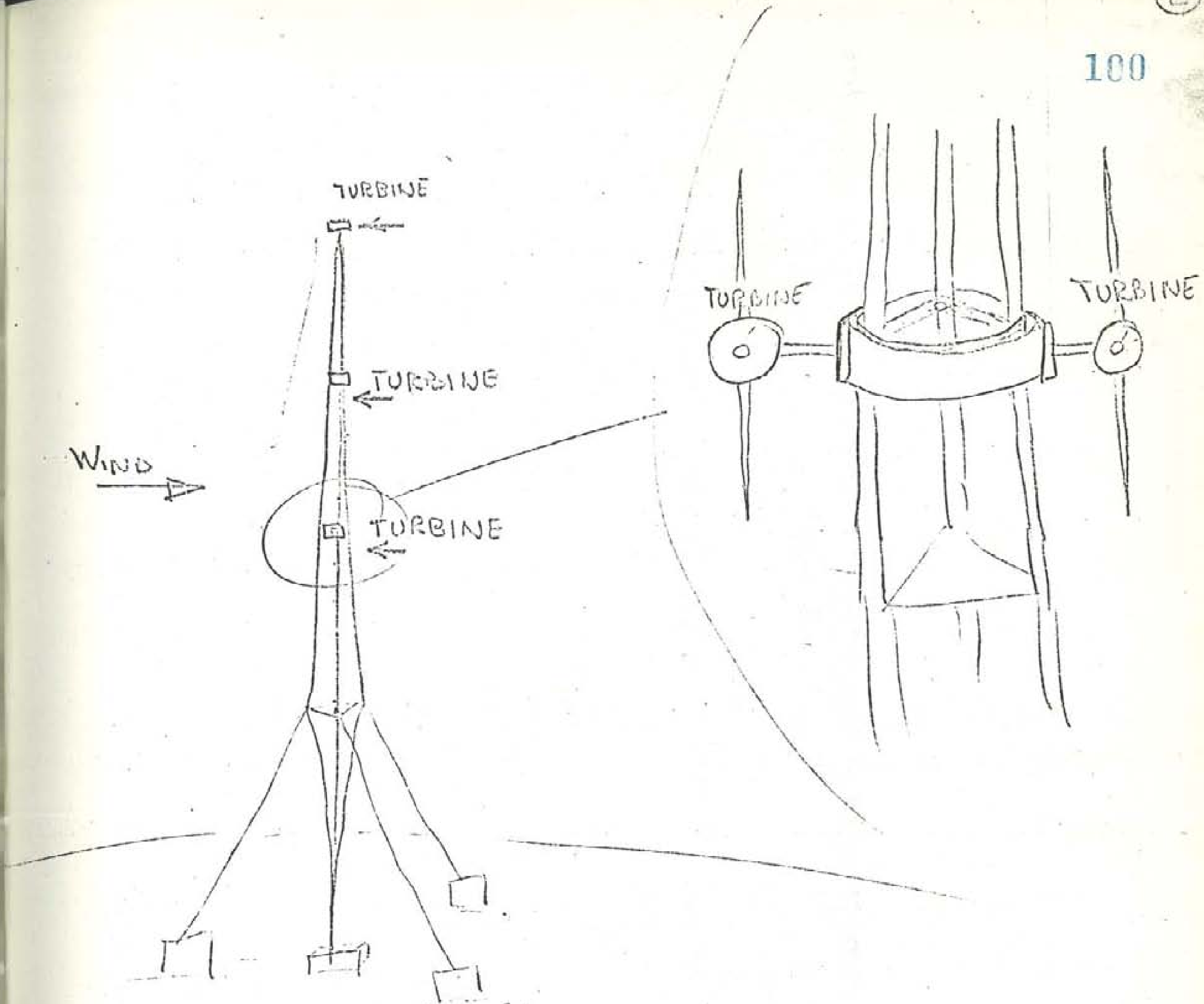
TURBINE PROVIDES ELECTRICAL ENERGY TO

RUN:

1. ELEVATOR
2. PRESSURIZATION OF POD
3. POWER TO POD

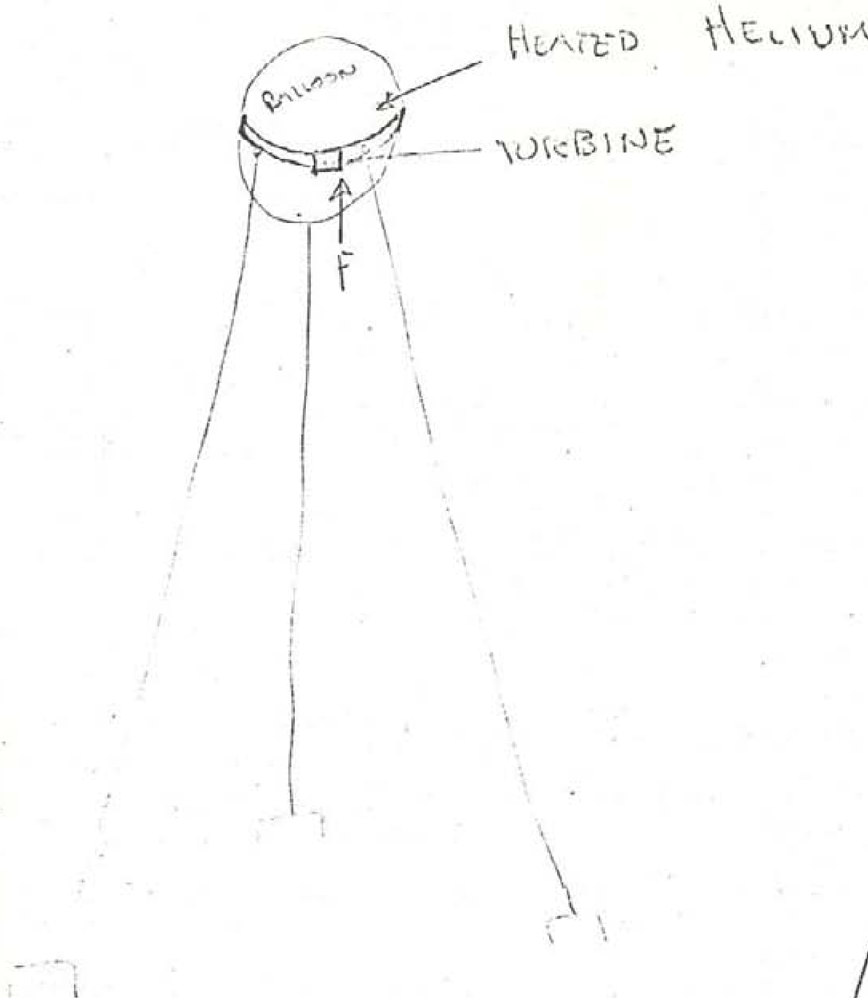


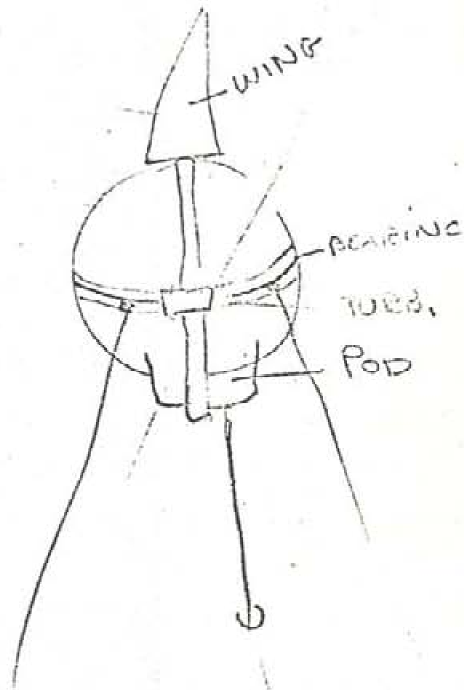
ELEVATOR RUN
BY
CABLE



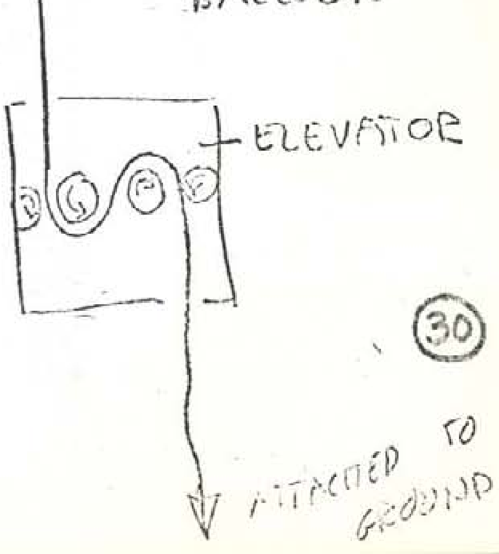
EACH TURBINE HAS A WIND VELOCITY METER WHICH CALIBRATES TOTAL WIND FORCE AT EACH FT. ON THE TOWER WHICH IN TURN REGULATES THE FORCE EXERTED BY THE TURBINE

IDEA 2

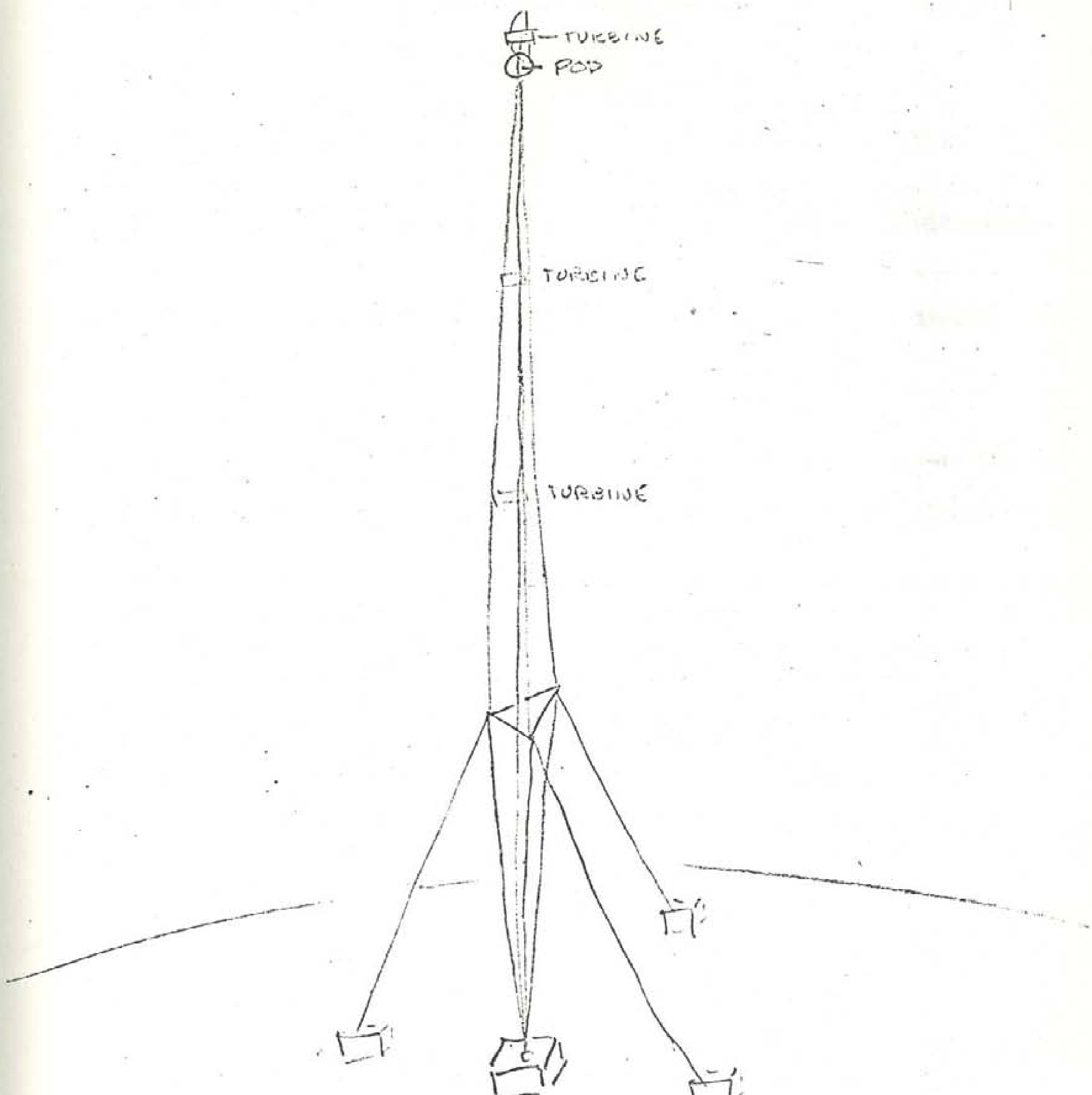


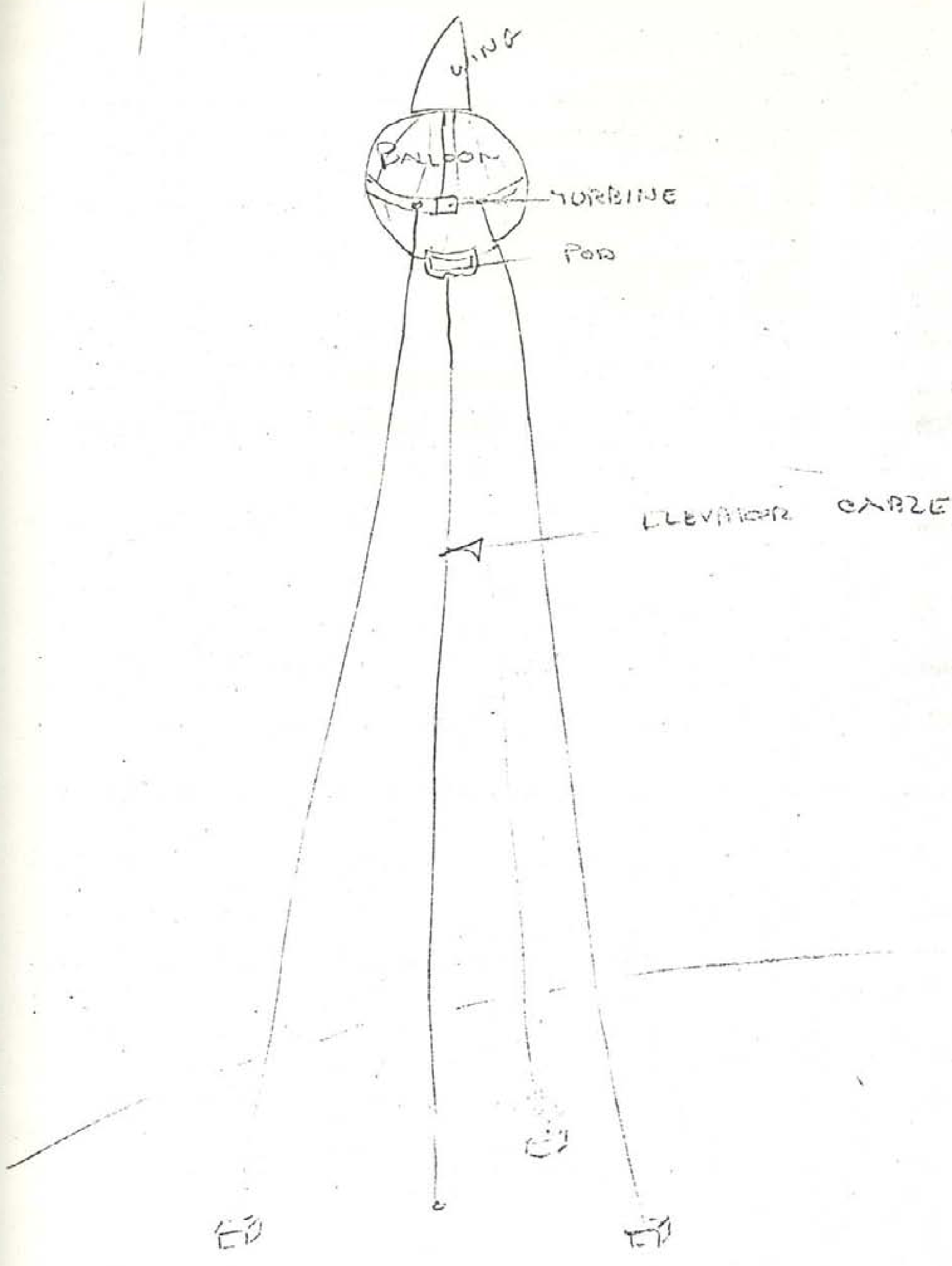


ELEVATOR



(30)


TURBINE
POD
TURBINE
TURBINE



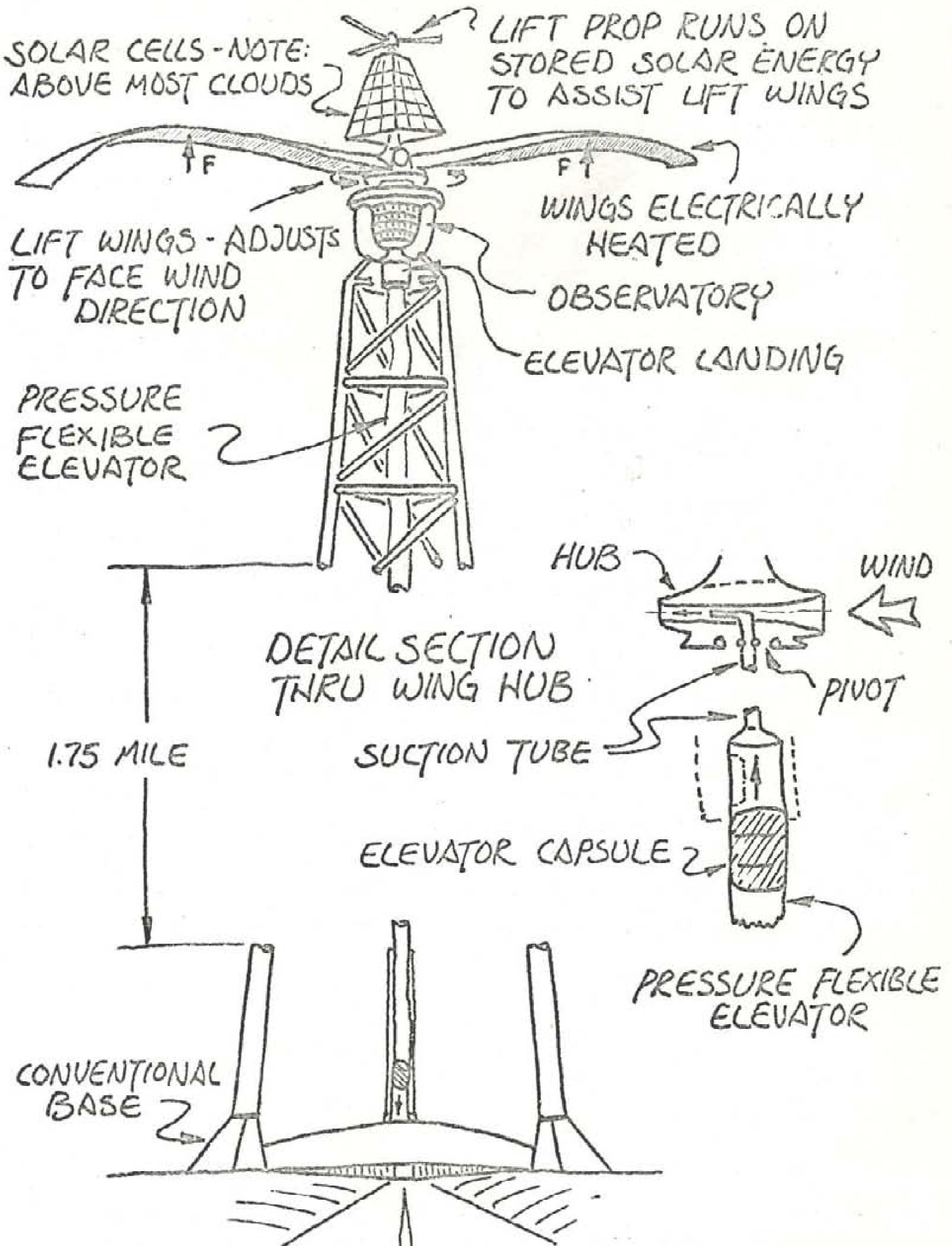
(30)

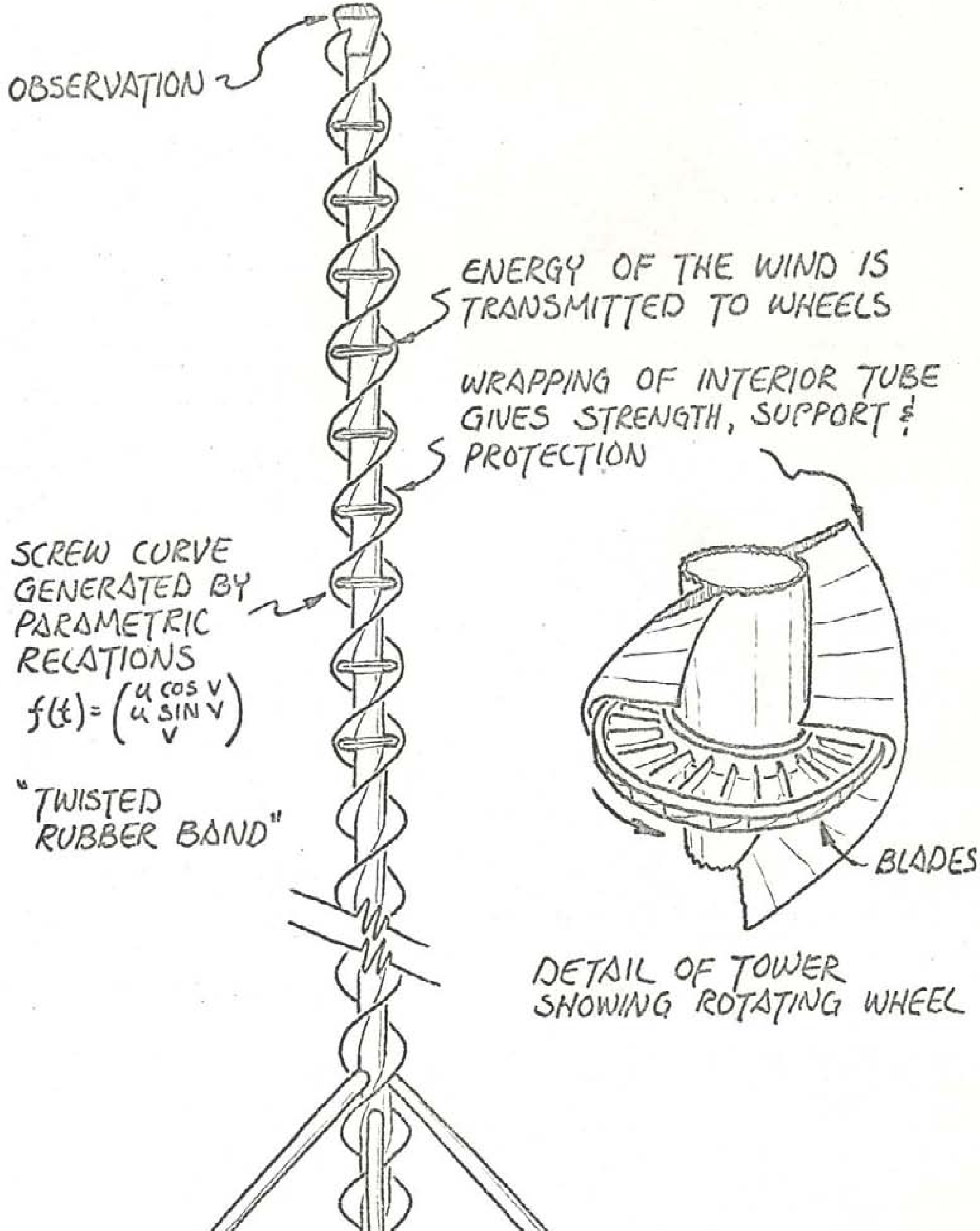
END TIME

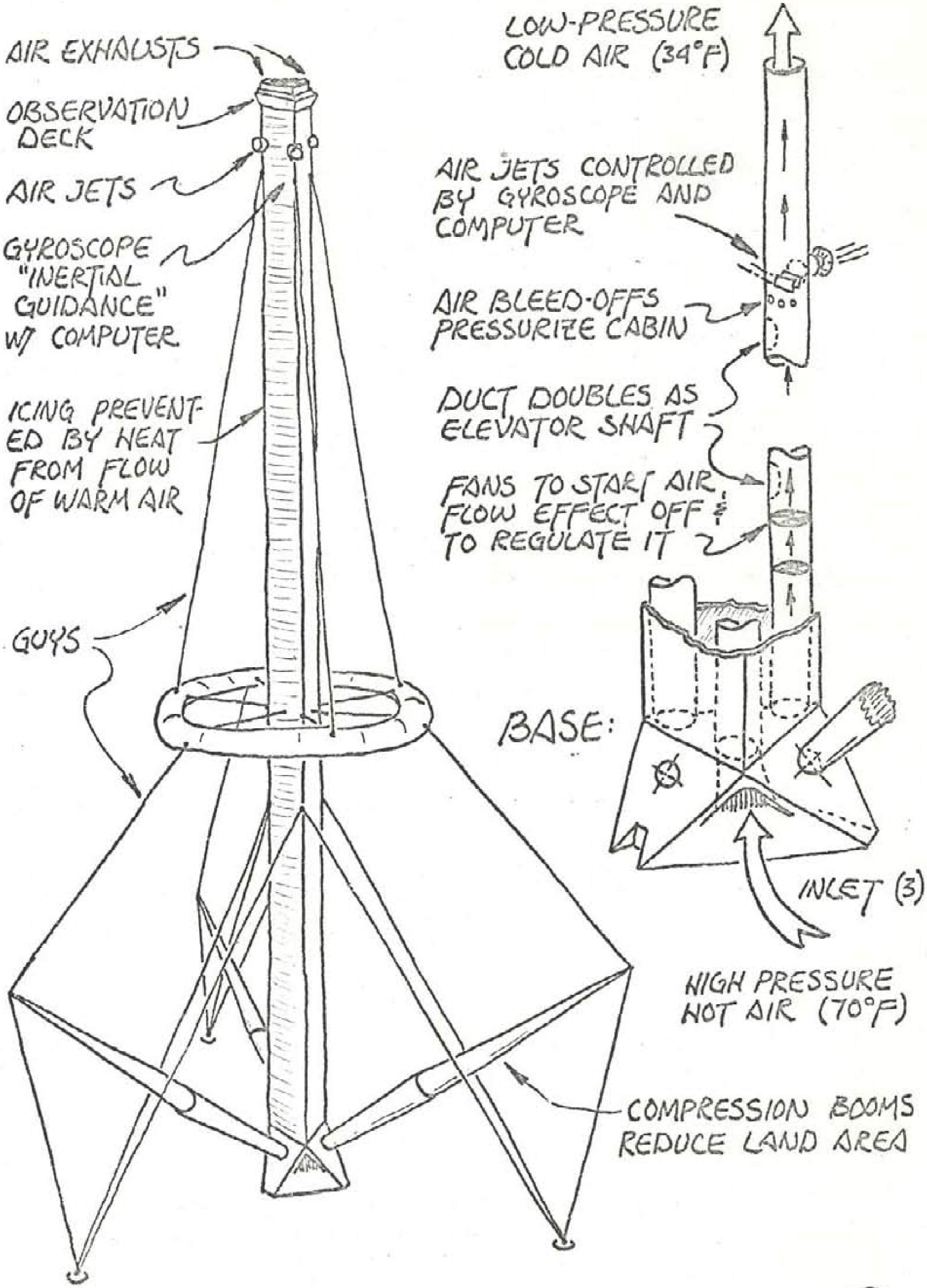
Appendix 2 Redrawn Tower Solutions

Included in this appendix are the redrawn two mile high towers exactly as they appeared to the creativity judges. They are in order by test number. For reference they have been listed in the chart on the right according to creativity as ranked by 6 judges. 1 is highest, 28 is lowest.

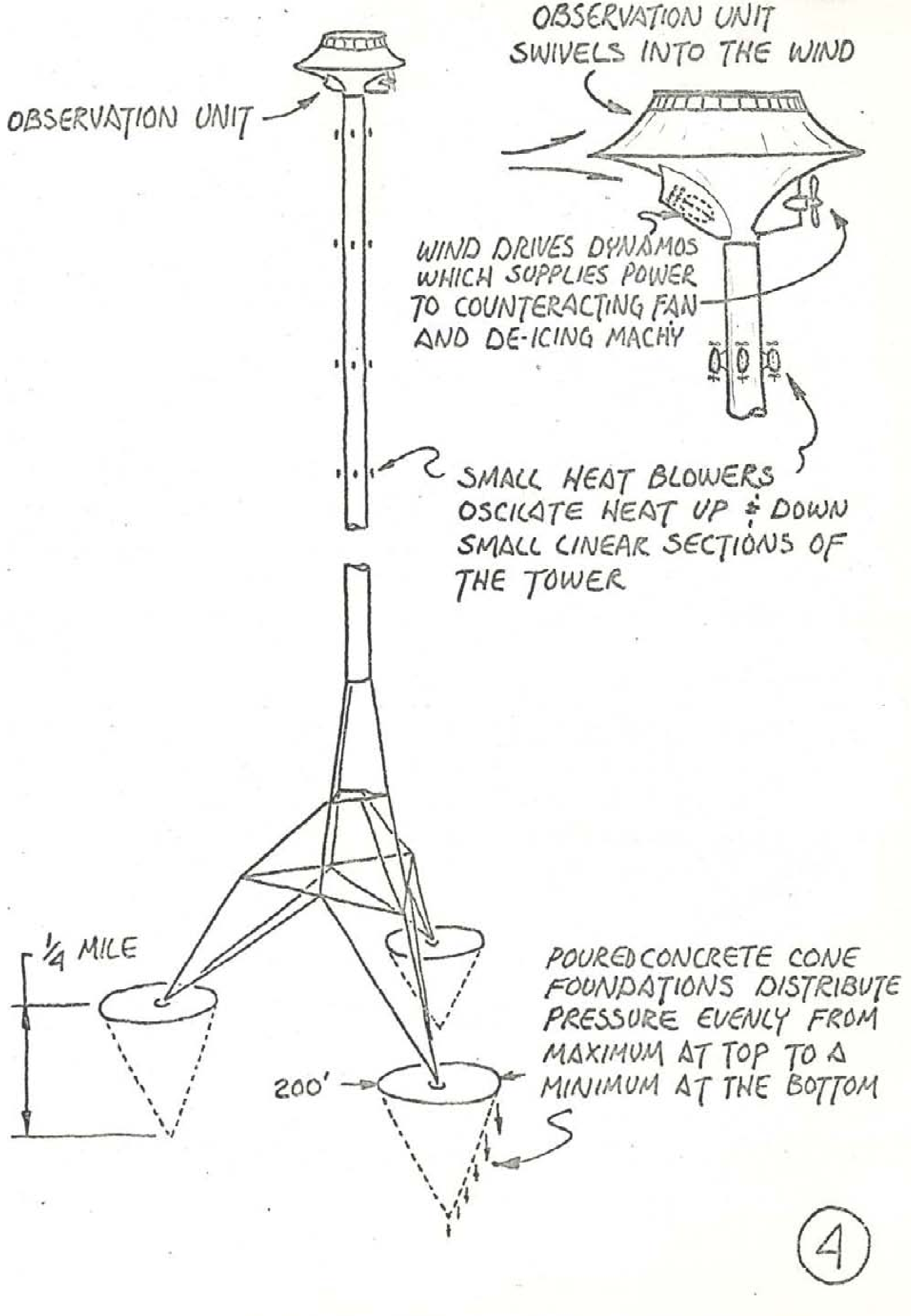
CREATIVITY RANK	TEST NUMBER	VISUAL RANK
1	44	5
2	26	4
3	2	1
4	1	8.5
5	31	13
6.5	10	8.5
6.5	45	12
8	3	3
9.5	28	18
9.5	6	26
11	4	6
12	20	10
13	35	16
14	33	11
15	7	19
16	16	23.5
17	32	14
18	24	2
19	34	17
20	19	7
21	15	15
22	14	21
23	13	26
24	25	21
25	17	23.5
26.5	8	21
26.5	18	26
28	27	28

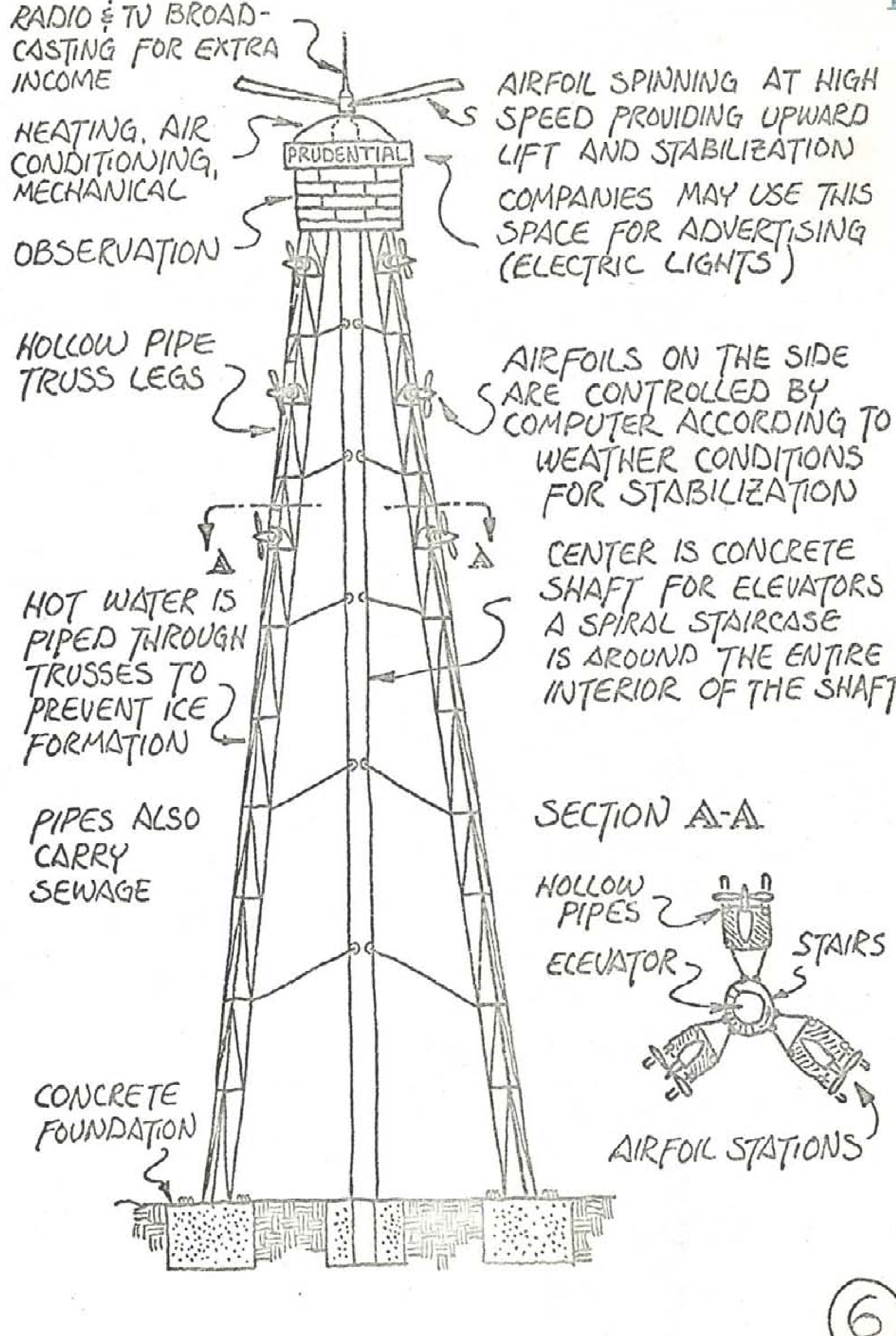

LIFT PROP RUNS ON STORED SOLAR ENERGY TO ASSIST LIFT WINGS
SOLAR CELLS - NOTE: ABOVE MOST CLOUDS
F
F
WINGS ELECTRICALLY HEATED
LIFT WINGS - ADJUSTS TO FACE WIND DIRECTION
OBSERVATORY
ELEVATOR LANDING
PRESSURE FLEXIBLE ELEVATOR
HUB
WIND
DETAIL SECTION THRU WING HUB
PIVOT
1.75 MILE
SUCTION TUBE
ELEVATOR CAPSULE
PRESSURE FLEXIBLE ELEVATOR
CONVENTIONAL BASE

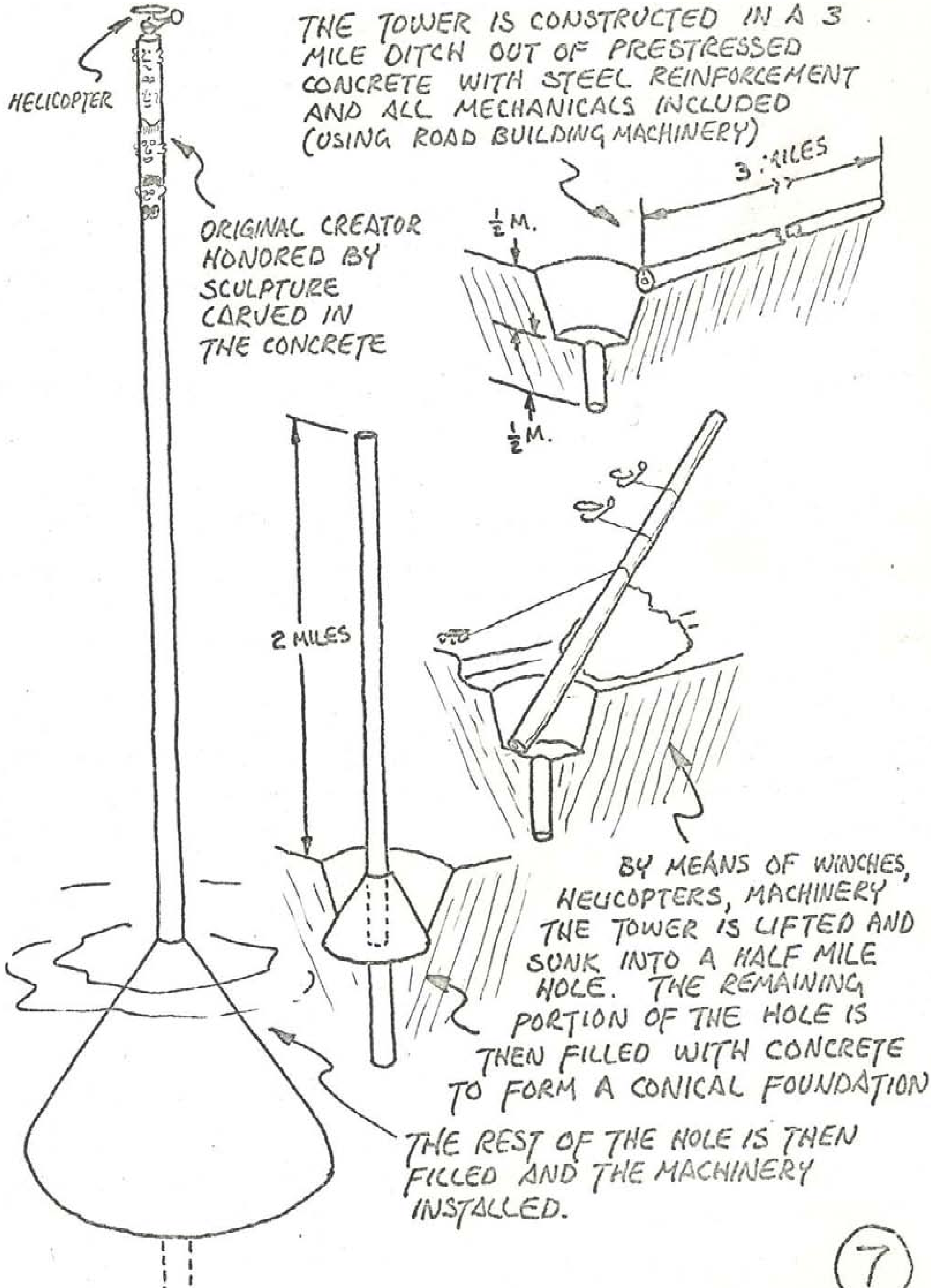

OBSERVATION
ENERGY OF THE WIND IS TRANSMITTED TO WHEELS
WRAPPING OF INTERIOR TUBE GIVES STRENGTH, SUPPORT & PROTECTION
SCREW CURVE GENERATED BY PARAMETRIC RELATIONS
f(t) = (u cos v, u sin v, v)
"TWISTED RUBBER BAND"
BLADES
DETAIL OF TOWER SHOWING ROTATING WHEEL

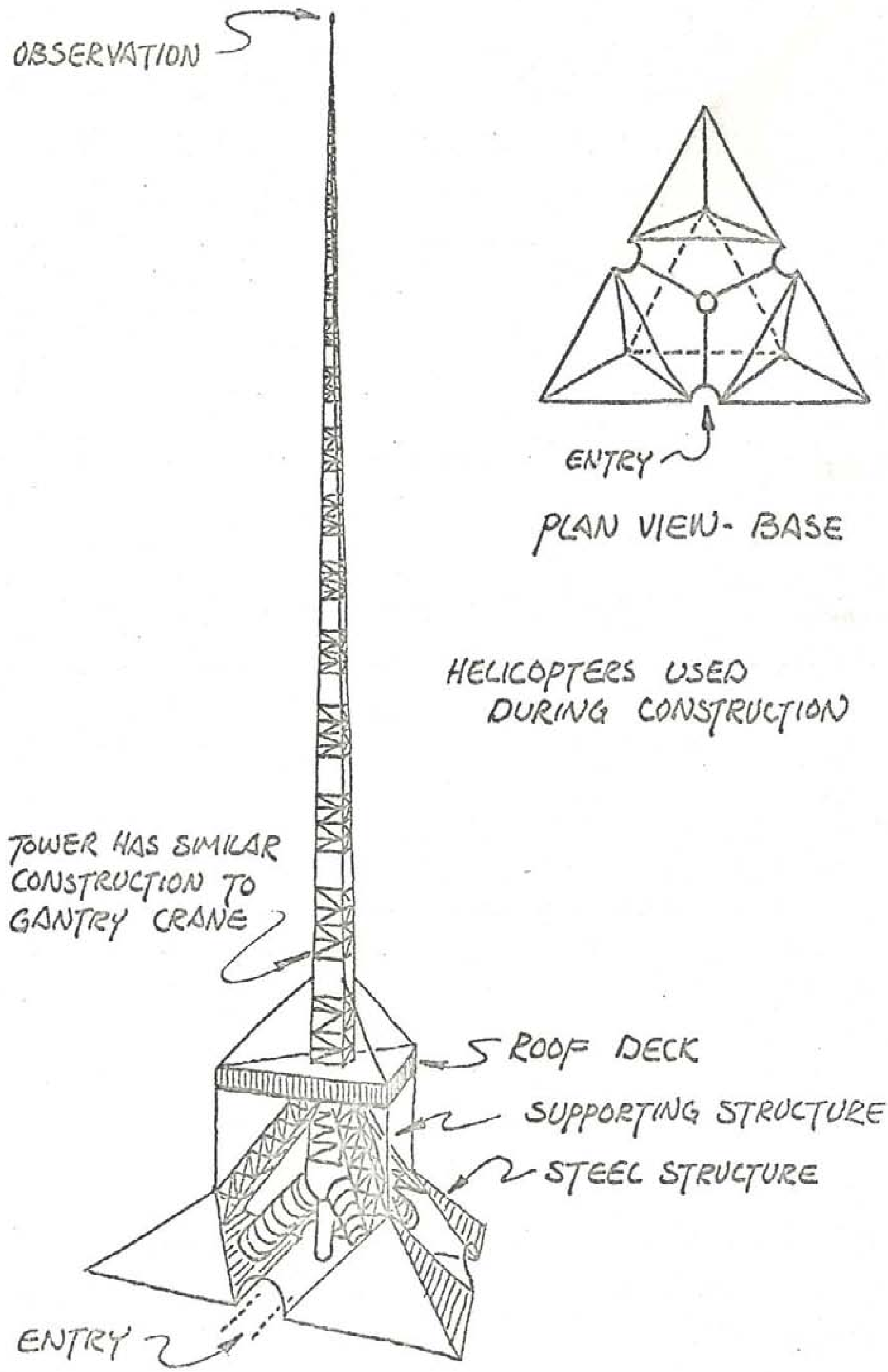

AIR EXHAUSTS
OBSERVATION DECK
AIR JETS
GYROSCOPE "INERTIAL GUIDANCE" W/ COMPUTER
ICING PREVENTED BY HEAT FROM FLOW OF WARM AIR
GUYS
LOW-PRESSURE COLD AIR (34°F)
AIR JETS CONTROLLED BY GYROSCOPE AND COMPUTER
AIR BLEED-OFFS PRESSURIZE CABIN
DUCT DOUBLES AS ELEVATOR SHAFT
FANS TO START AIR FLOW EFFECT OFF & TO REGULATE IT
BASE:
INLET (3)
HIGH PRESSURE HOT AIR (70°F)
COMPRESSION BOOMS REDUCE LAND AREA

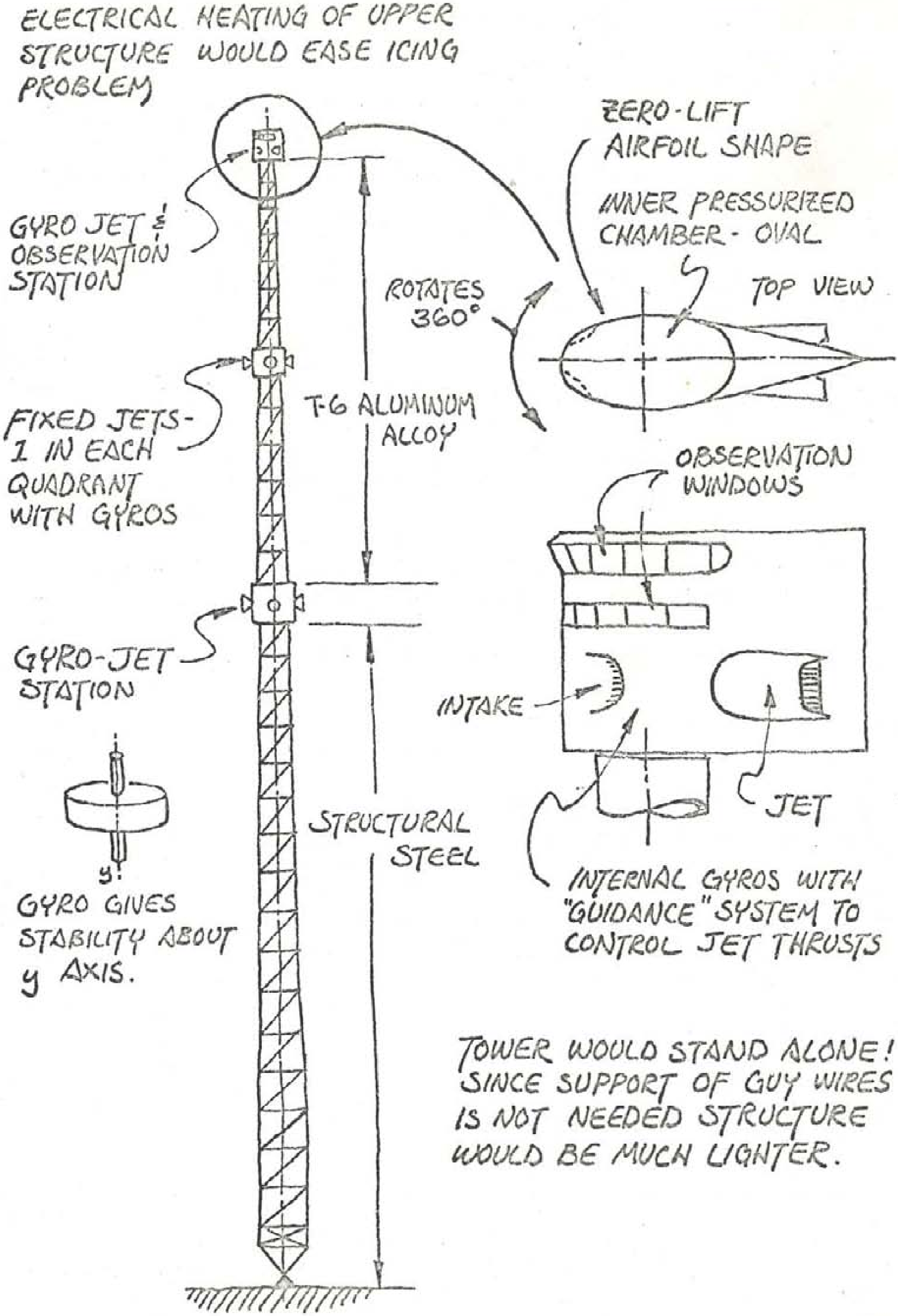
3

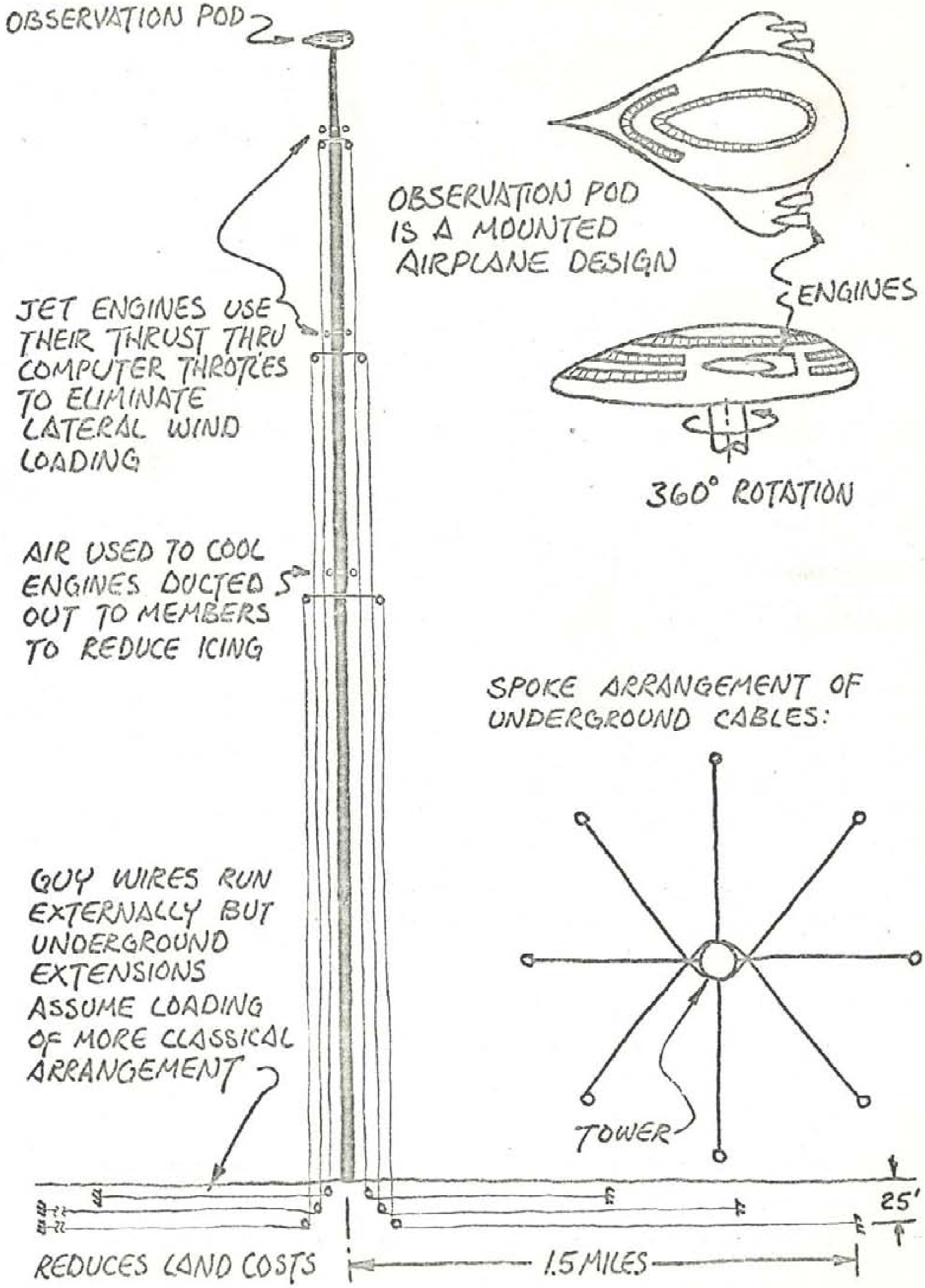

OBSERVATION UNIT
SWIVELS INTO THE WIND
OBSERVATION UNIT
WIND DRIVES DYNAMOS
WHICH SUPPLIES POWER
TO COUNTERACTING FAN
AND DE-ICING MACH'Y
SMALL HEAT BLOWERS
OSCILATE HEAT UP ÷ DOWN
SMALL LINEAR SECTIONS OF
THE TOWER
1/4 MILE
200'
POURED CONCRETE CONE
FOUNDATIONS DISTRIBUTE
PRESSURE EVENLY FROM
MAXIMUM AT TOP TO A
MINIMUM AT THE BOTTOM
4


RADIO & TV BROADCASTING FOR EXTRA INCOME
AIRFOIL SPINNING AT HIGH SPEED PROVIDING UPWARD LIFT AND STABILIZATION
HEATING, AIR CONDITIONING, MECHANICAL
PRUDENTIAL
COMPANIES MAY USE THIS SPACE FOR ADVERTISING (ELECTRIC LIGHTS)
OBSERVATION
HOLLOW PIPE TRUSS LEGS
AIRFOILS ON THE SIDE ARE CONTROLLED BY COMPUTER ACCORDING TO WEATHER CONDITIONS FOR STABILIZATION
A
A
CENTER IS CONCRETE SHAFT FOR ELEVATORS A SPIRAL STAIRCASE IS AROUND THE ENTIRE INTERIOR OF THE SHAFT
HOT WATER IS PIPED THROUGH TRUSSES TO PREVENT ICE FORMATION
PIPES ALSO CARRY SEWAGE
SECTION A-A
HOLLOW PIPES
ELEVATOR
STAIRS
AIRFOIL STATIONS
CONCRETE FOUNDATION

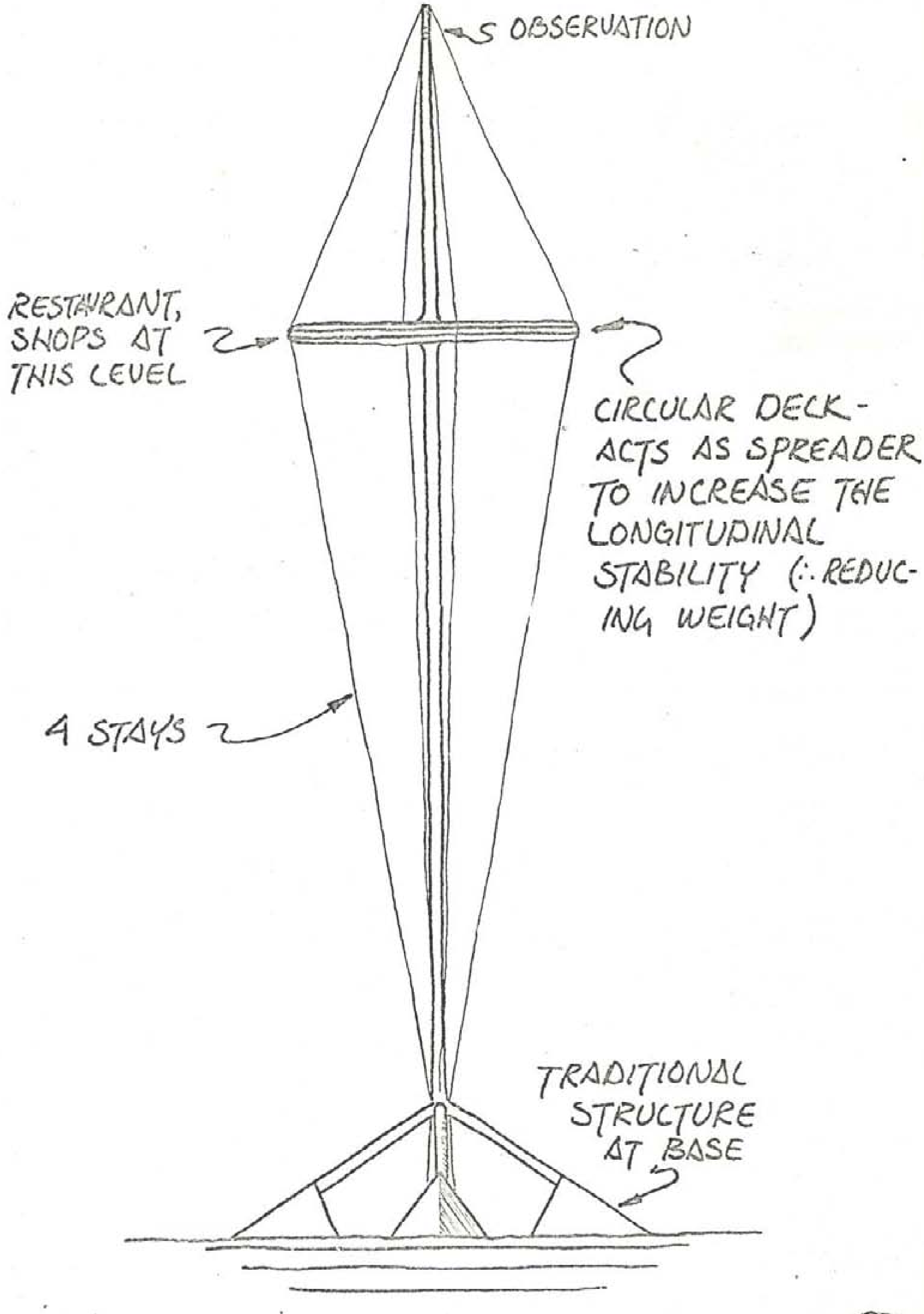

THE TOWER IS CONSTRUCTED IN A 3 MILE DITCH OUT OF PRESTRESSED CONCRETE WITH STEEL REINFORCEMENT AND ALL MECHANICALS INCLUDED (USING ROAD BUILDING MACHINERY)
HELICOPTER
ORIGINAL CREATOR HONORED BY SCULPTURE CARVED IN THE CONCRETE
3 MILES
½ M.
½ M.
2 MILES
BY MEANS OF WINCHES, HELICOPTERS, MACHINERY THE TOWER IS LIFTED AND SUNK INTO A HALF MILE HOLE. THE REMAINING PORTION OF THE HOLE IS THEN FILLED WITH CONCRETE TO FORM A CONICAL FOUNDATION
THE REST OF THE HOLE IS THEN FILLED AND THE MACHINERY INSTALLED.

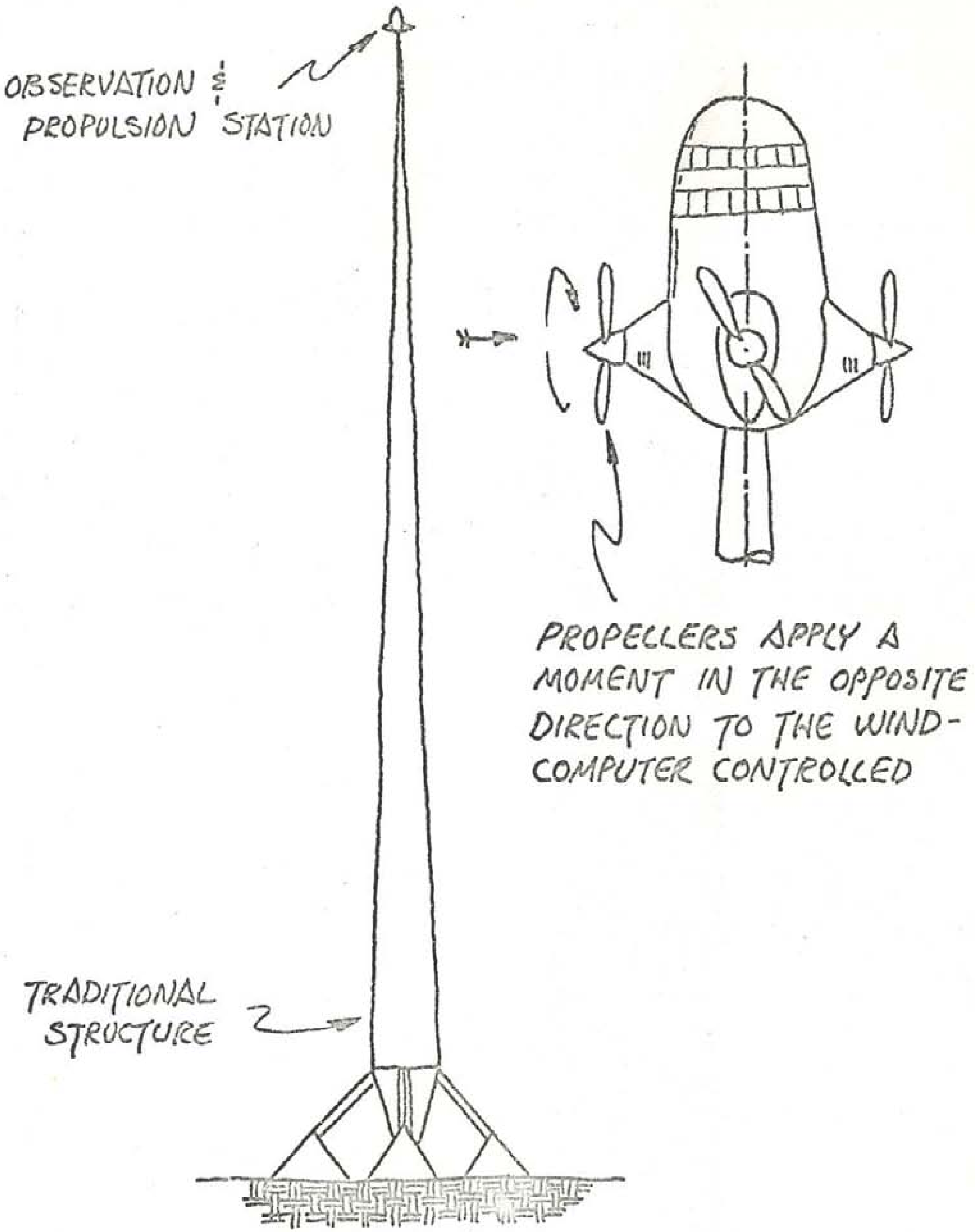

OBSERVATION
ENTRY
PLAN VIEW- BASE
HELICOPTERS USED
DURING CONSTRUCTION
TOWER HAS SIMILAR
CONSTRUCTION TO
GANTRY CRANE
ROOF DECK
SUPPORTING STRUCTURE
STEEL STRUCTURE
ENTRY

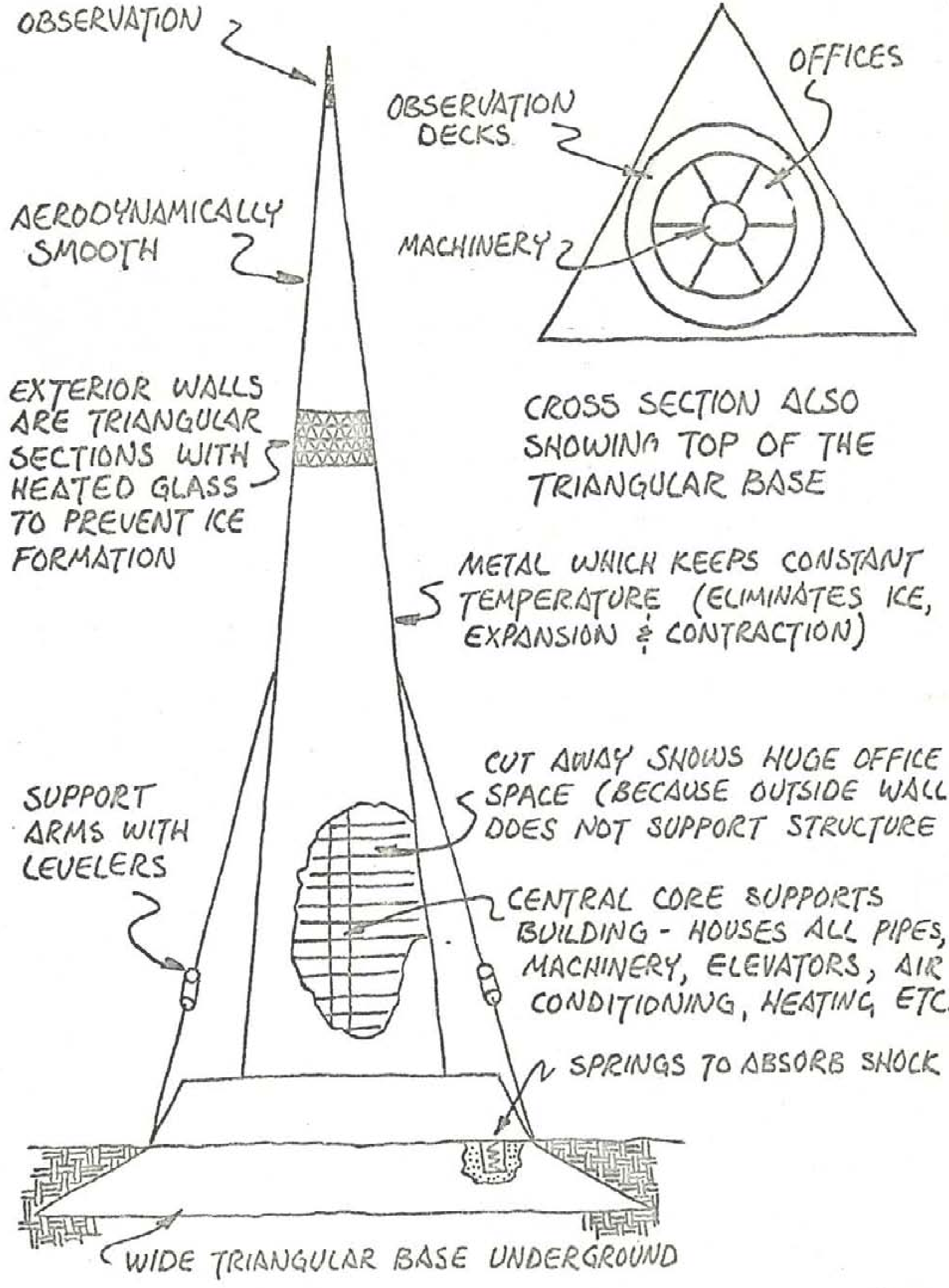

ELECTRICAL HEATING OF UPPER STRUCTURE WOULD EASE ICING PROBLEM
GYRO JET & OBSERVATION STATION
FIXED JETS - 1 IN EACH QUADRANT WITH GYROS
GYRO-JET STATION
y
GYRO GIVES STABILITY ABOUT y AXIS.
ROTATES 360°
T-6 ALUMINUM ALLOY
STRUCTURAL STEEL
ZERO-LIFT AIRFOIL SHAPE
INNER PRESSURIZED CHAMBER - OVAL
TOP VIEW
OBSERVATION WINDOWS
INTAKE
JET
INTERNAL GYROS WITH "GUIDANCE" SYSTEM TO CONTROL JET THRUSTS
TOWER WOULD STAND ALONE! SINCE SUPPORT OF GUY WIRES IS NOT NEEDED STRUCTURE WOULD BE MUCH LIGHTER.

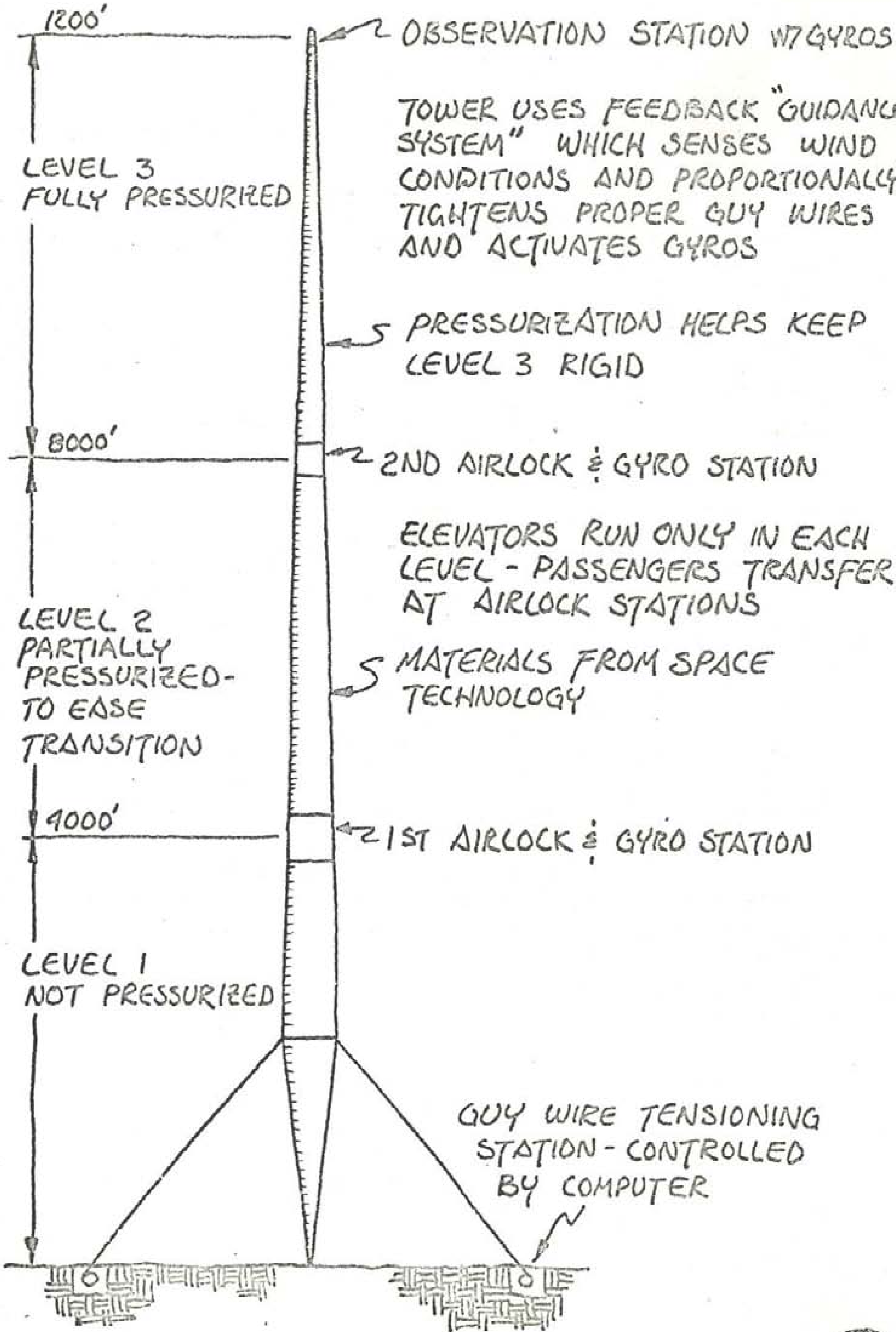

OBSERVATION POD
OBSERVATION POD IS A MOUNTED AIRPLANE DESIGN
ENGINES
360° ROTATION
JET ENGINES USE THEIR THRUST THRU COMPUTER THROTLES TO ELIMINATE LATERAL WIND LOADING
AIR USED TO COOL ENGINES DUCTED OUT TO MEMBERS TO REDUCE ICING
SPOKE ARRANGEMENT OF UNDERGROUND CABLES:
TOWER
GUY WIRES RUN EXTERNALLY BUT UNDERGROUND EXTENSIONS ASSUME LOADING OF MORE CLASSICAL ARRANGEMENT
25'
REDUCES LAND COSTS
1.5 MILES

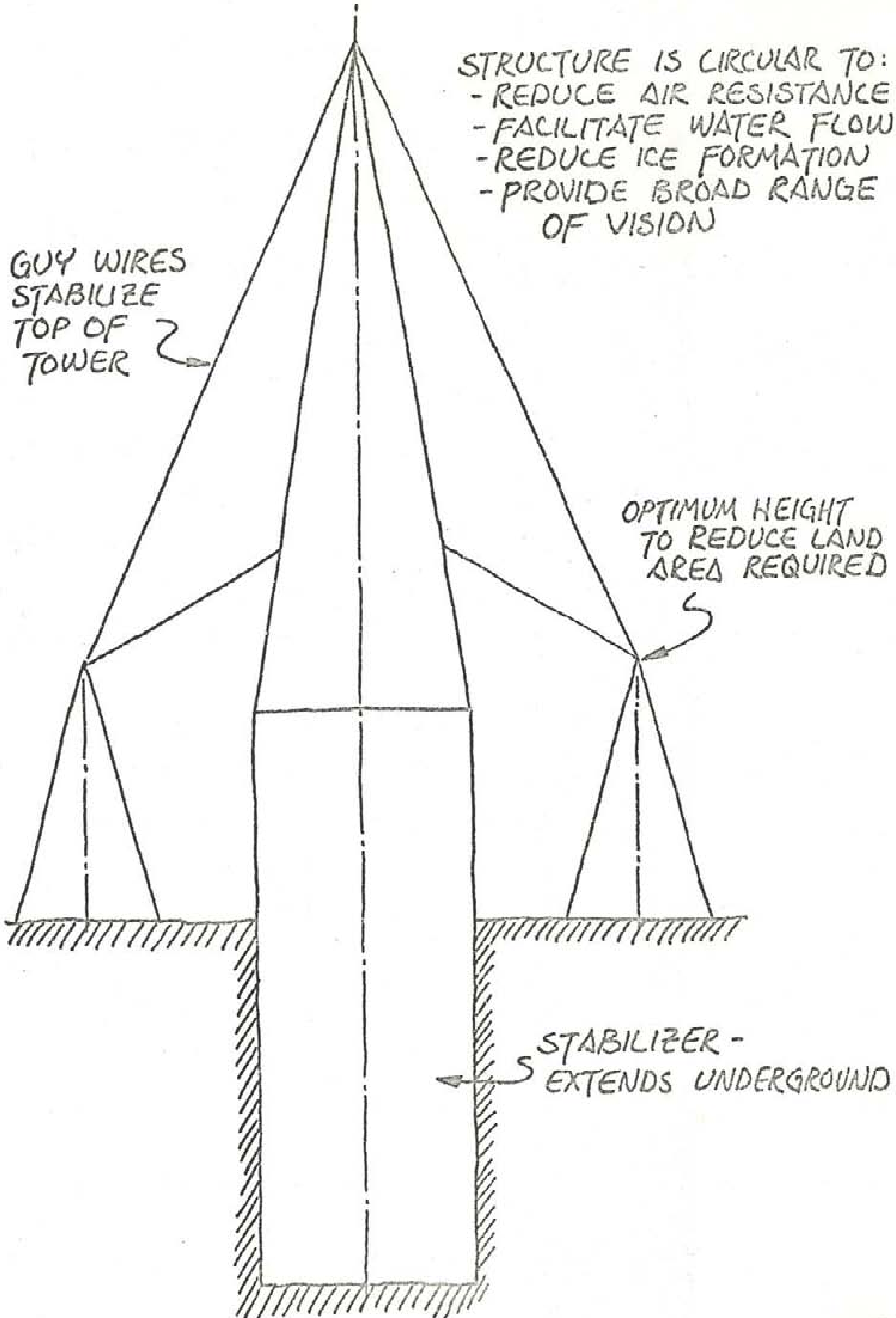
11

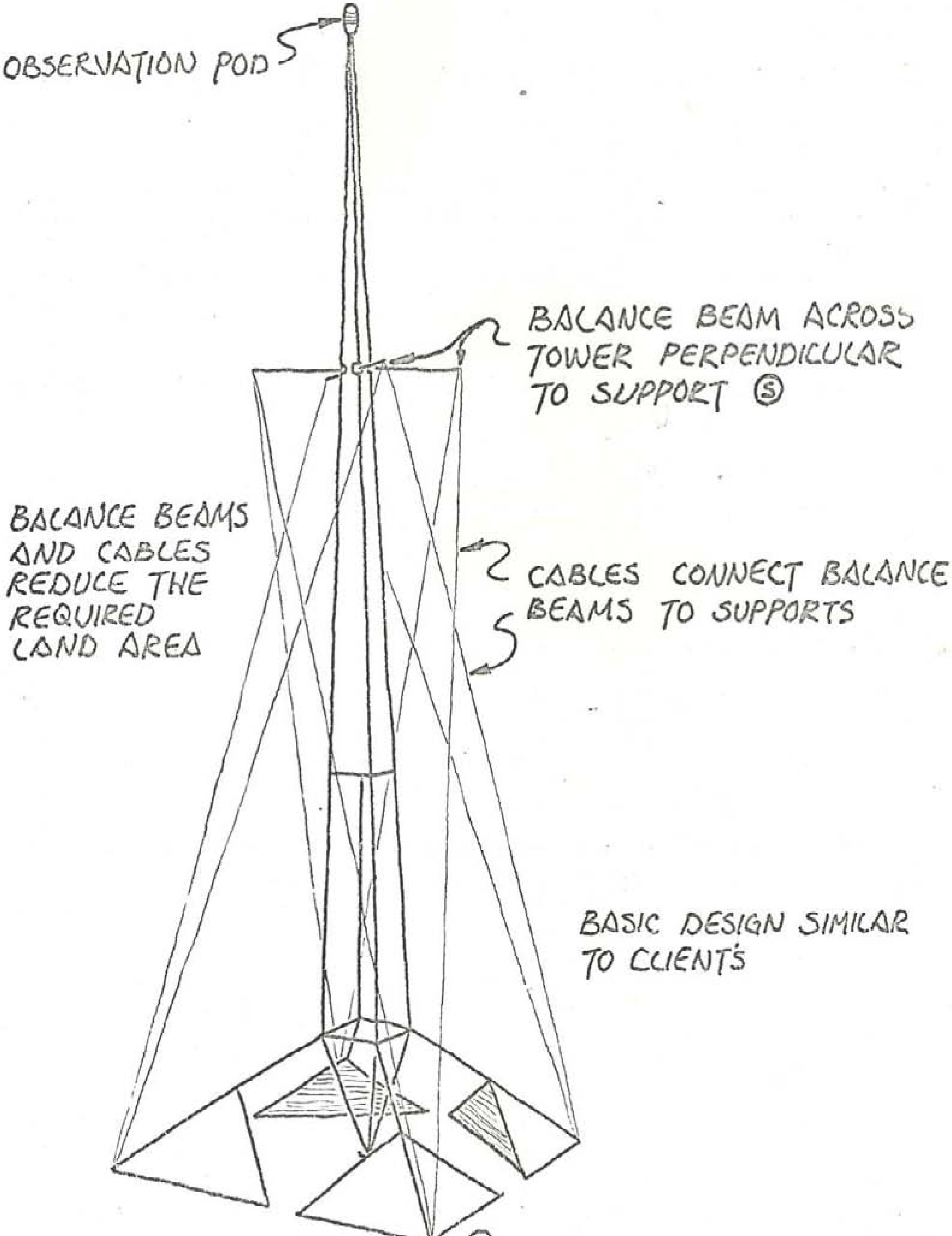

OBSERVATION
RESTAURANT, SHOPS AT THIS LEVEL
CIRCULAR DECK - ACTS AS SPREADER TO INCREASE THE LONGITUDINAL STABILITY (∴ REDUCING WEIGHT)
4 STAYS
TRADITIONAL STRUCTURE AT BASE

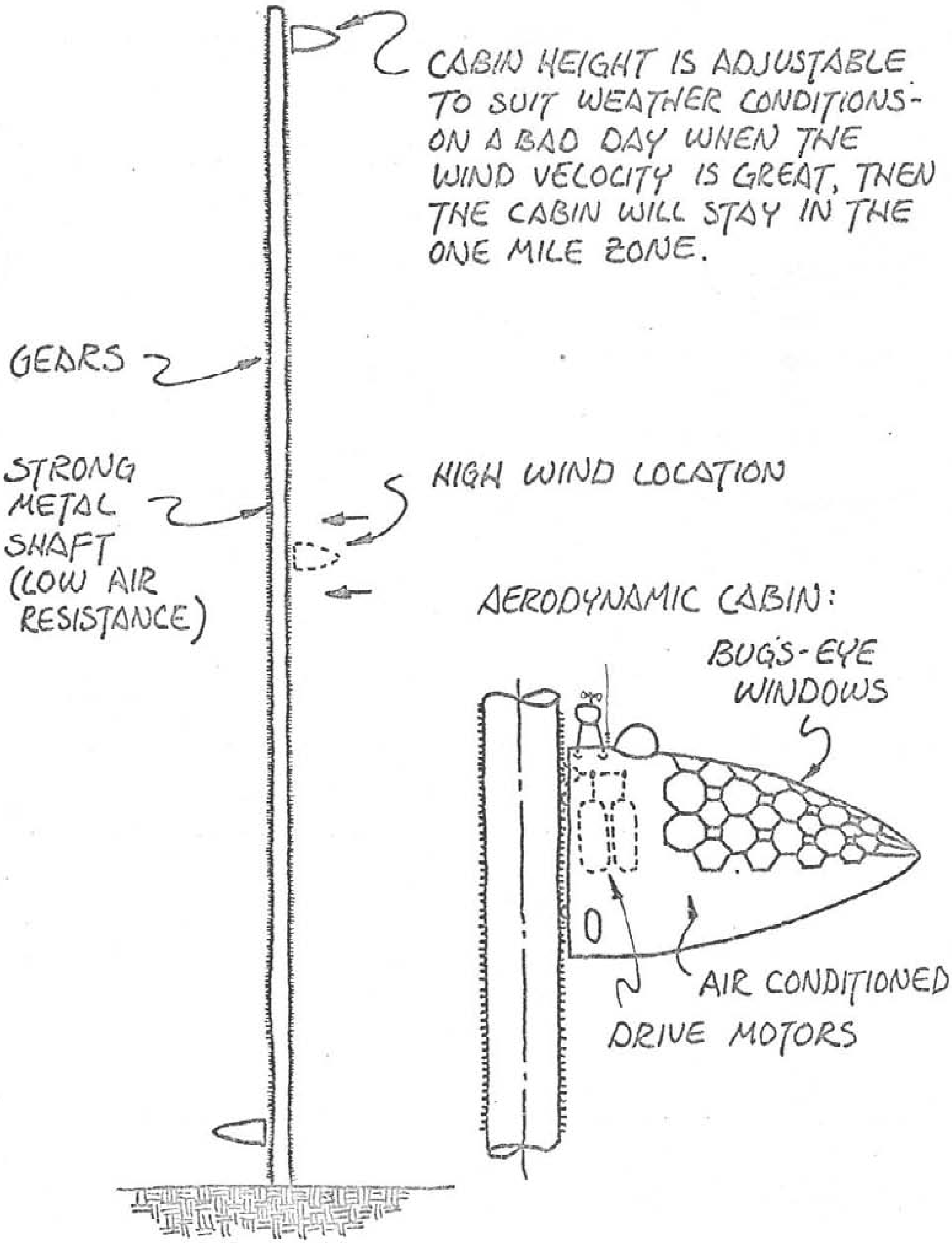

OBSERVATION &
PROPULSION STATION
PROPELLERS APPLY A
MOMENT IN THE OPPOSITE
DIRECTION TO THE WIND-
COMPUTER CONTROLLED
TRADITIONAL
STRUCTURE

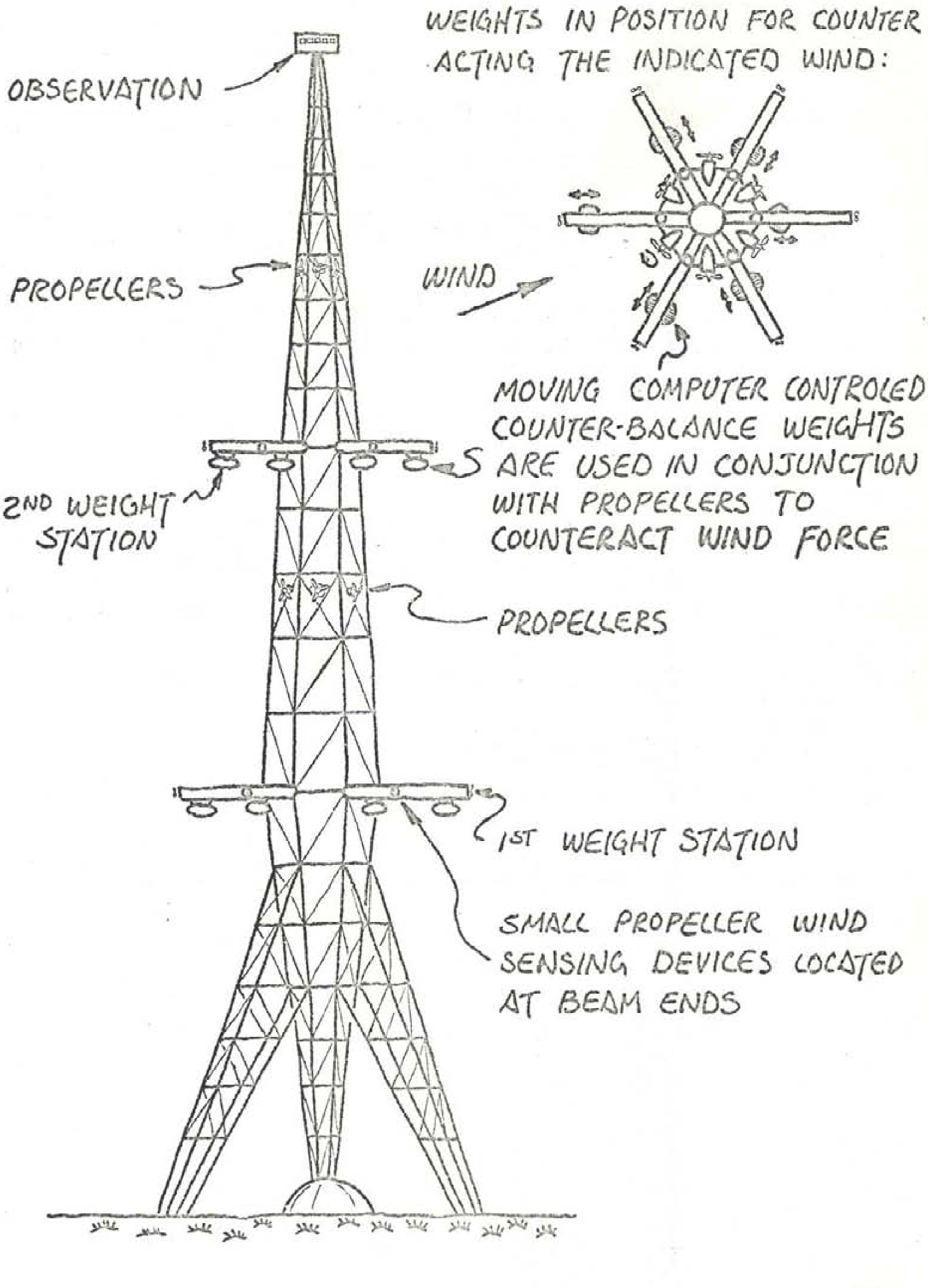

OBSERVATION
AERODYNAMICALLY SMOOTH
EXTERIOR WALLS ARE TRIANGULAR SECTIONS WITH HEATED GLASS TO PREVENT ICE FORMATION
SUPPORT ARMS WITH LEVELERS
OBSERVATION DECKS
OFFICES
MACHINERY
CROSS SECTION ALSO SHOWING TOP OF THE TRIANGULAR BASE
METAL WHICH KEEPS CONSTANT TEMPERATURE (ELIMINATES ICE, EXPANSION & CONTRACTION)
CUT AWAY SHOWS HUGE OFFICE SPACE (BECAUSE OUTSIDE WALL DOES NOT SUPPORT STRUCTURE
CENTRAL CORE SUPPORTS BUILDING - HOUSES ALL PIPES, MACHINERY, ELEVATORS, AIR CONDITIONING, HEATING, ETC.
SPRINGS TO ABSORB SHOCK
WIDE TRIANGULAR BASE UNDERGROUND

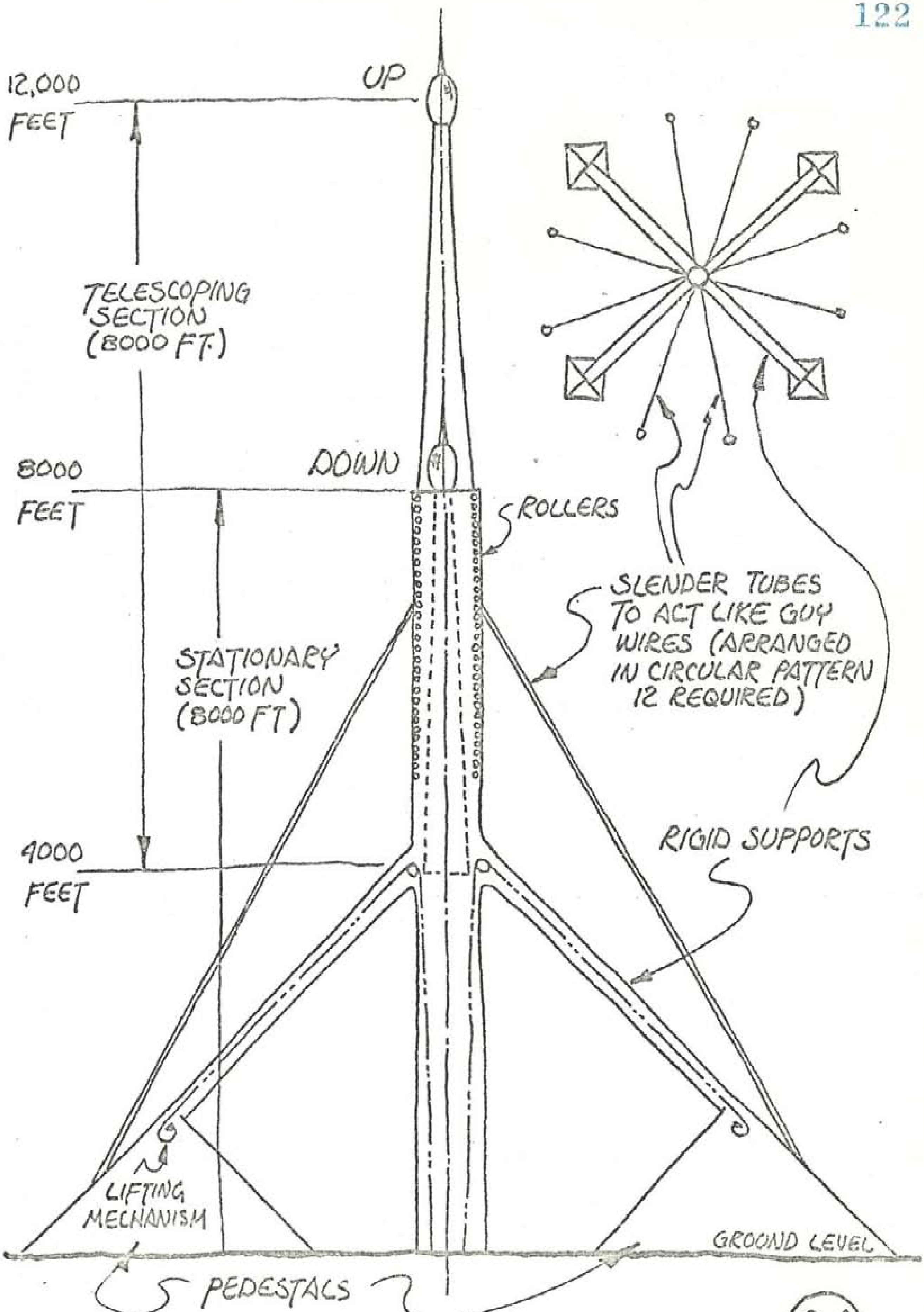

1200'
OBSERVATION STATION W/ GYROS
TOWER USES FEEDBACK "GUIDANCE SYSTEM" WHICH SENSES WIND CONDITIONS AND PROPORTIONALLY TIGHTENS PROPER GUY WIRES AND ACTUATES GYROS
LEVEL 3
FULLY PRESSURIZED
PRESSURIZATION HELPS KEEP LEVEL 3 RIGID
8000'
2ND AIRLOCK & GYRO STATION
ELEVATORS RUN ONLY IN EACH LEVEL - PASSENGERS TRANSFER AT AIRLOCK STATIONS
LEVEL 2
PARTIALLY PRESSURIZED - TO EASE TRANSITION
MATERIALS FROM SPACE TECHNOLOGY
4000'
1ST AIRLOCK & GYRO STATION
LEVEL 1
NOT PRESSURIZED
GUY WIRE TENSIONING STATION - CONTROLLED BY COMPUTER


STRUCTURE IS CIRCULAR TO:
- REDUCE AIR RESISTANCE
- FACILITATE WATER FLOW
- REDUCE ICE FORMATION
- PROVIDE BROAD RANGE OF VISION
GUY WIRES STABILIZE TOP OF TOWER
OPTIMUM HEIGHT TO REDUCE LAND AREA REQUIRED
STABILIZER - EXTENDS UNDERGROUND


OBSERVATION POD
BALANCE BEAM ACROSS TOWER PERPENDICULAR TO SUPPORT Ⓢ
BALANCE BEAMS AND CABLES REDUCE THE REQUIRED LAND AREA
CABLES CONNECT BALANCE BEAMS TO SUPPORTS
BASIC DESIGN SIMILAR TO CLIENT'S
Ⓢ

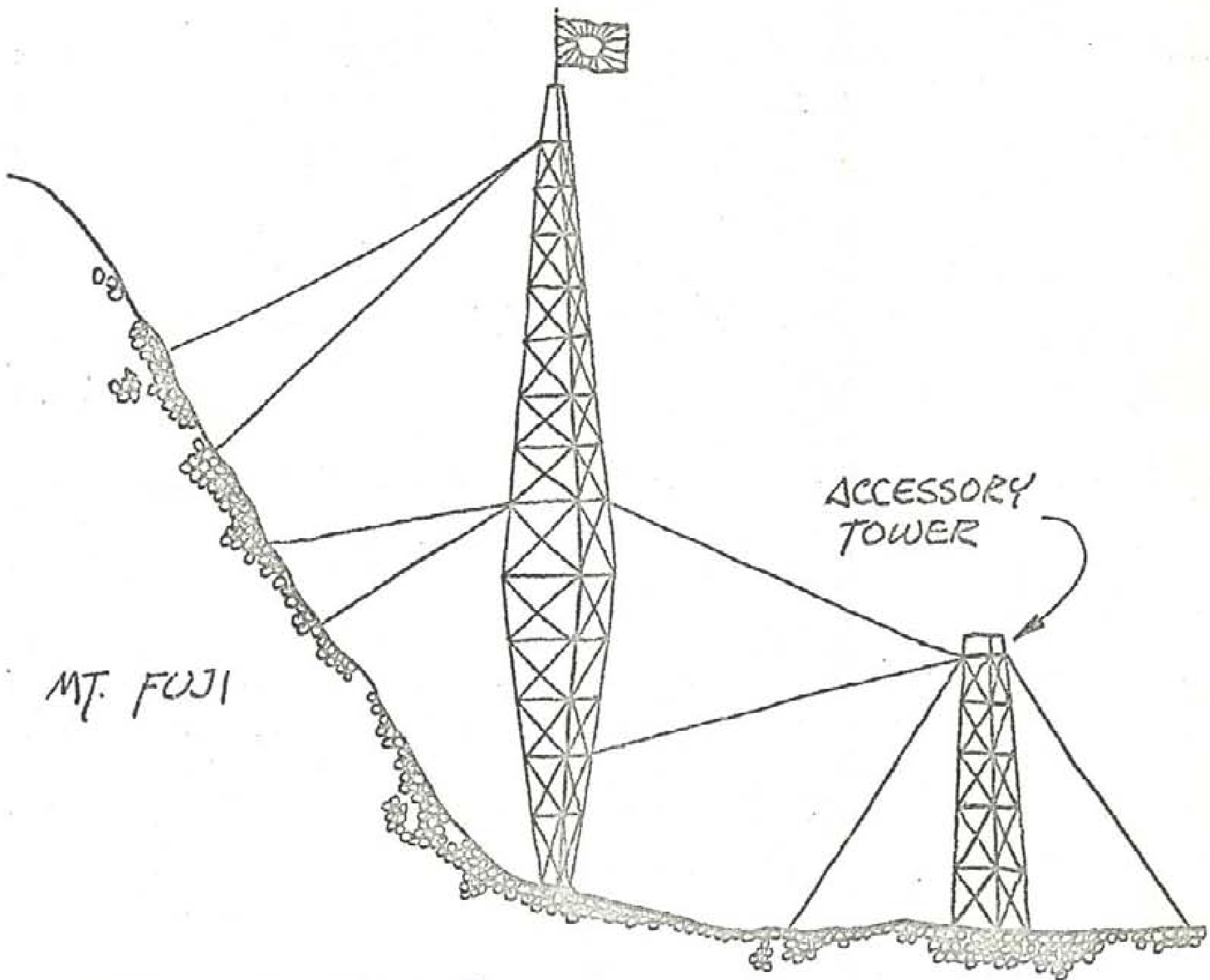

CABIN HEIGHT IS ADJUSTABLE TO SUIT WEATHER CONDITIONS- ON A BAD DAY WHEN THE WIND VELOCITY IS GREAT, THEN THE CABIN WILL STAY IN THE ONE MILE ZONE.
GEARS
STRONG METAL SHAFT (LOW AIR RESISTANCE)
HIGH WIND LOCATION
AERODYNAMIC CABIN:
BUG'S-EYE WINDOWS
AIR CONDITIONED
DRIVE MOTORS


WEIGHTS IN POSITION FOR COUNTER ACTING THE INDICATED WIND:
OBSERVATION
PROPELLERS
WIND
MOVING COMPUTER CONTROLED COUNTER-BALANCE WEIGHTS ARE USED IN CONJUNCTION WITH PROPELLERS TO COUNTERACT WIND FORCE
2ND WEIGHT STATION
PROPELLERS
1ST WEIGHT STATION
SMALL PROPELLER WIND SENSING DEVICES LOCATED AT BEAM ENDS

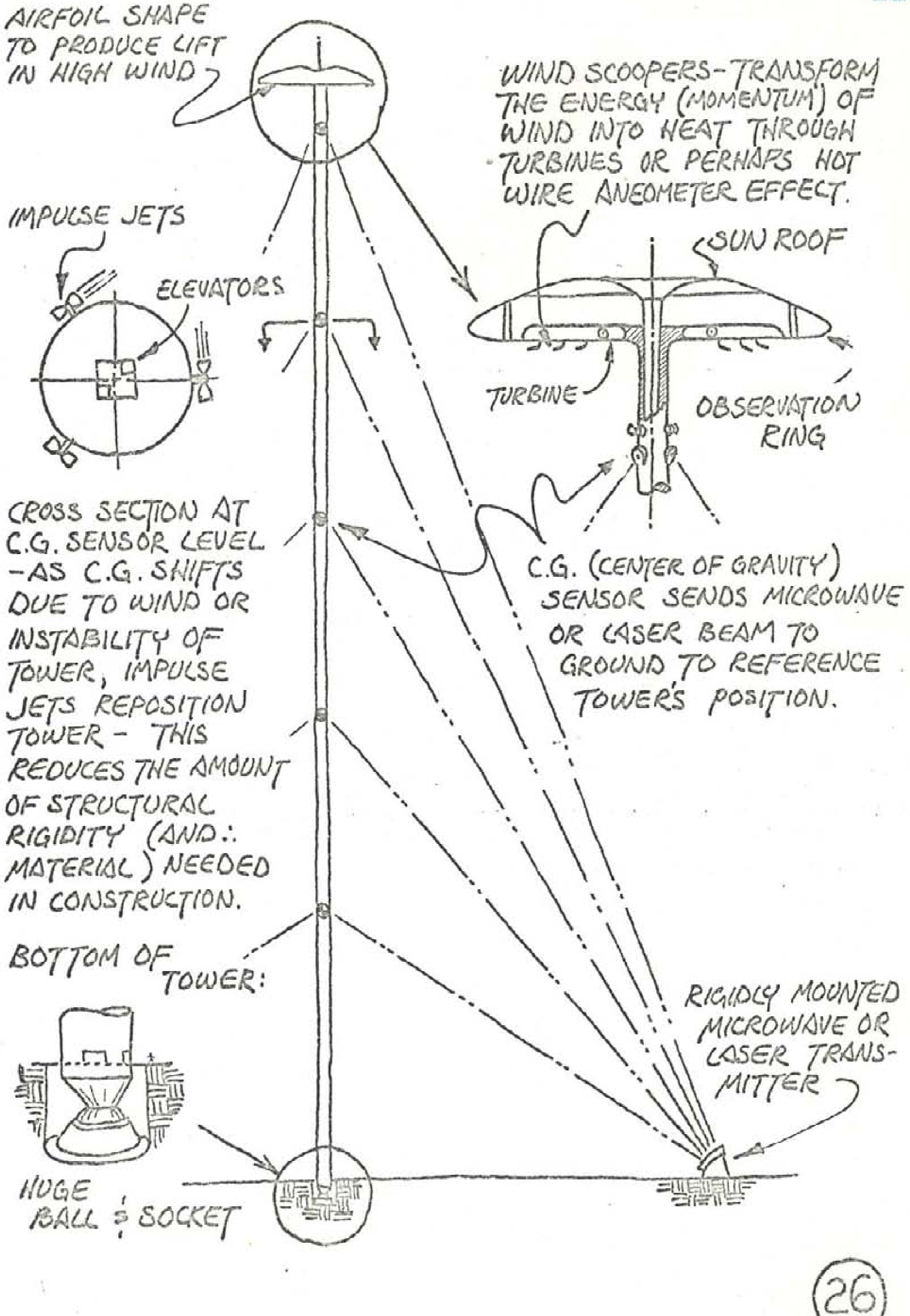


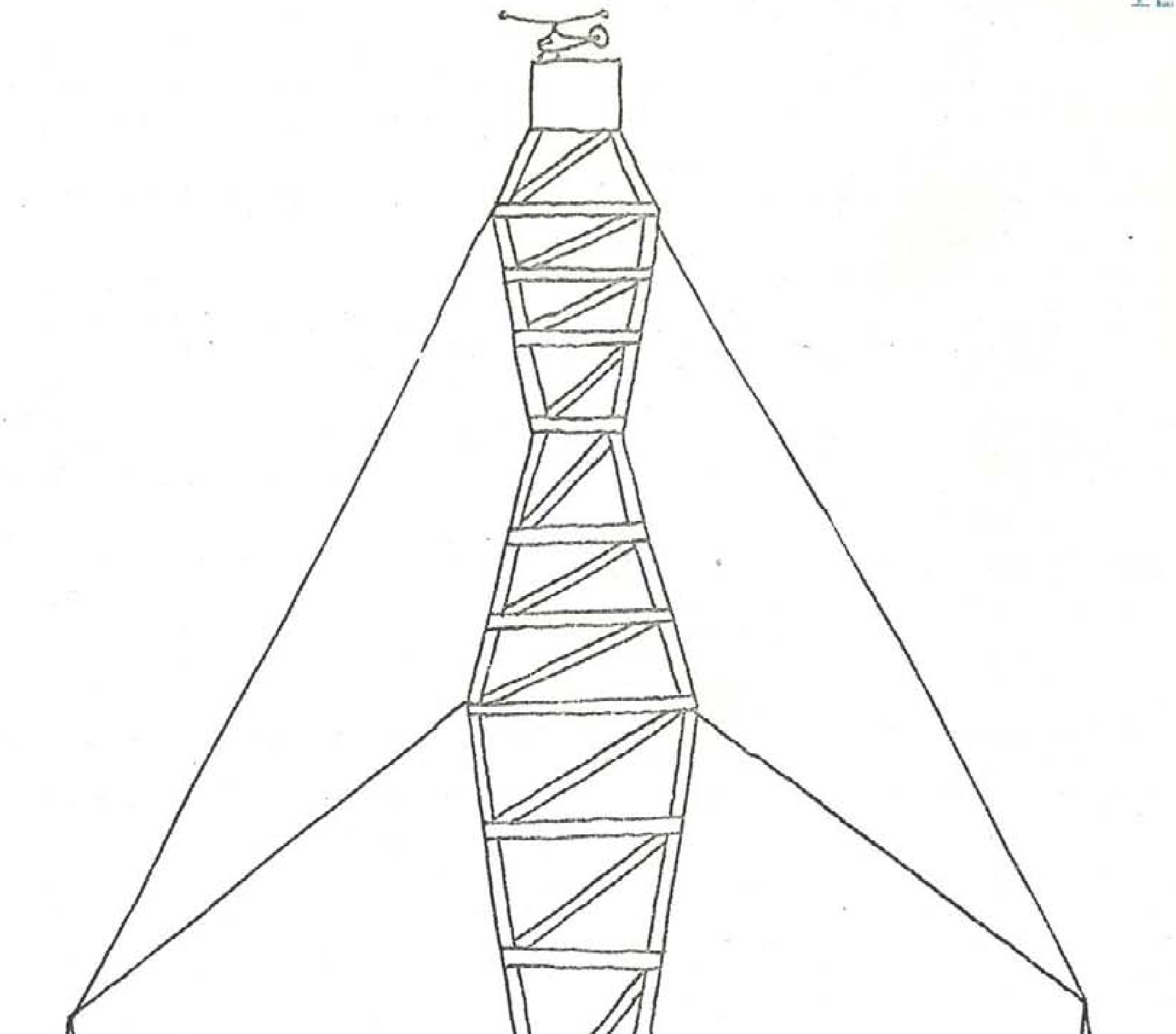
12,000 FEET
UP
TELESCOPING SECTION (8000 FT.)
8000 FEET
DOWN
ROLLERS
SLENDER TUBES TO ACT LIKE GUY WIRES (ARRANGED IN CIRCULAR PATTERN 12 REQUIRED)
STATIONARY SECTION (8000 FT)
4000 FEET
RIGID SUPPORTS
LIFTING MECHANISM
GROUND LEVEL
PEDESTALS

24

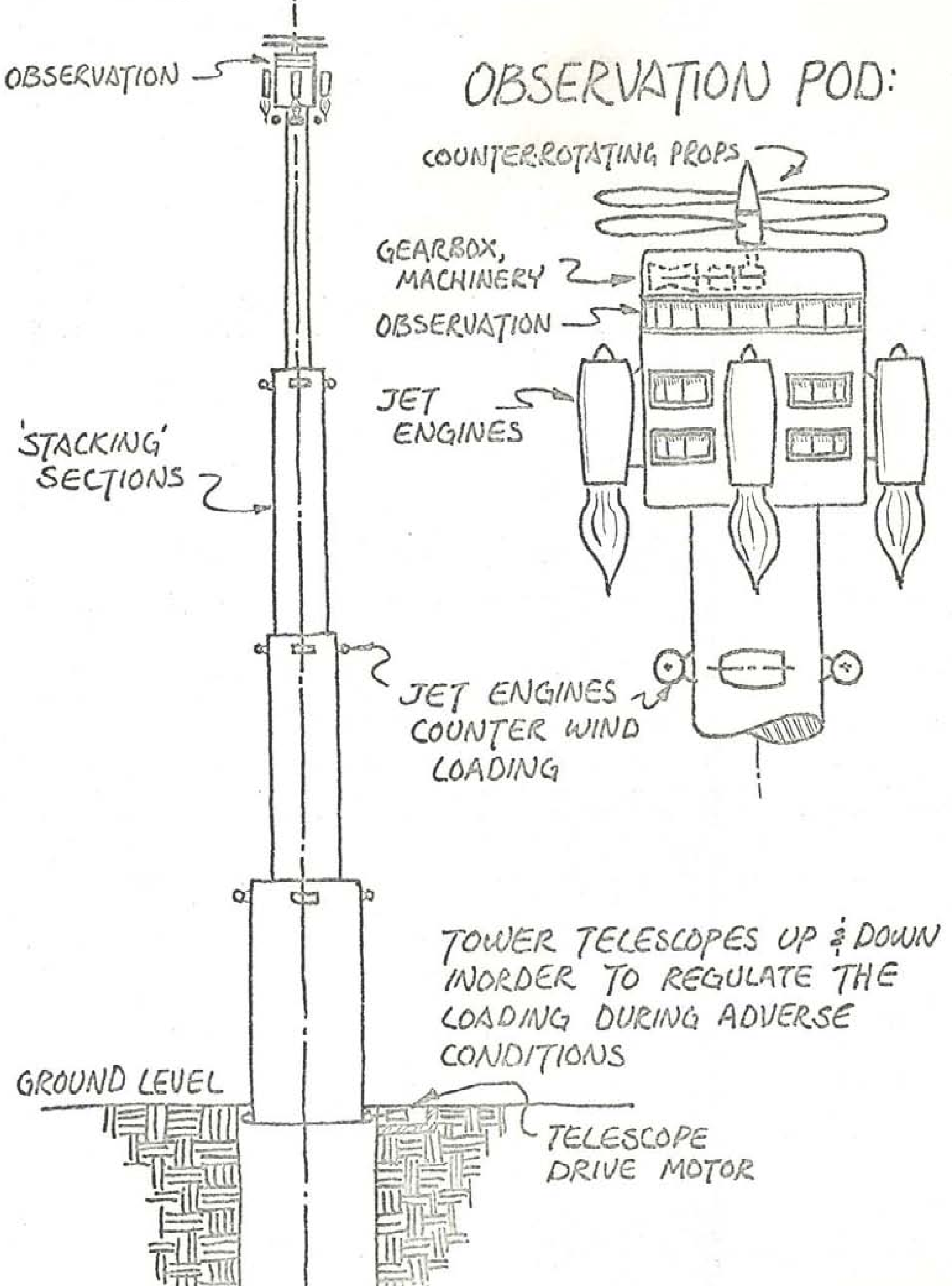


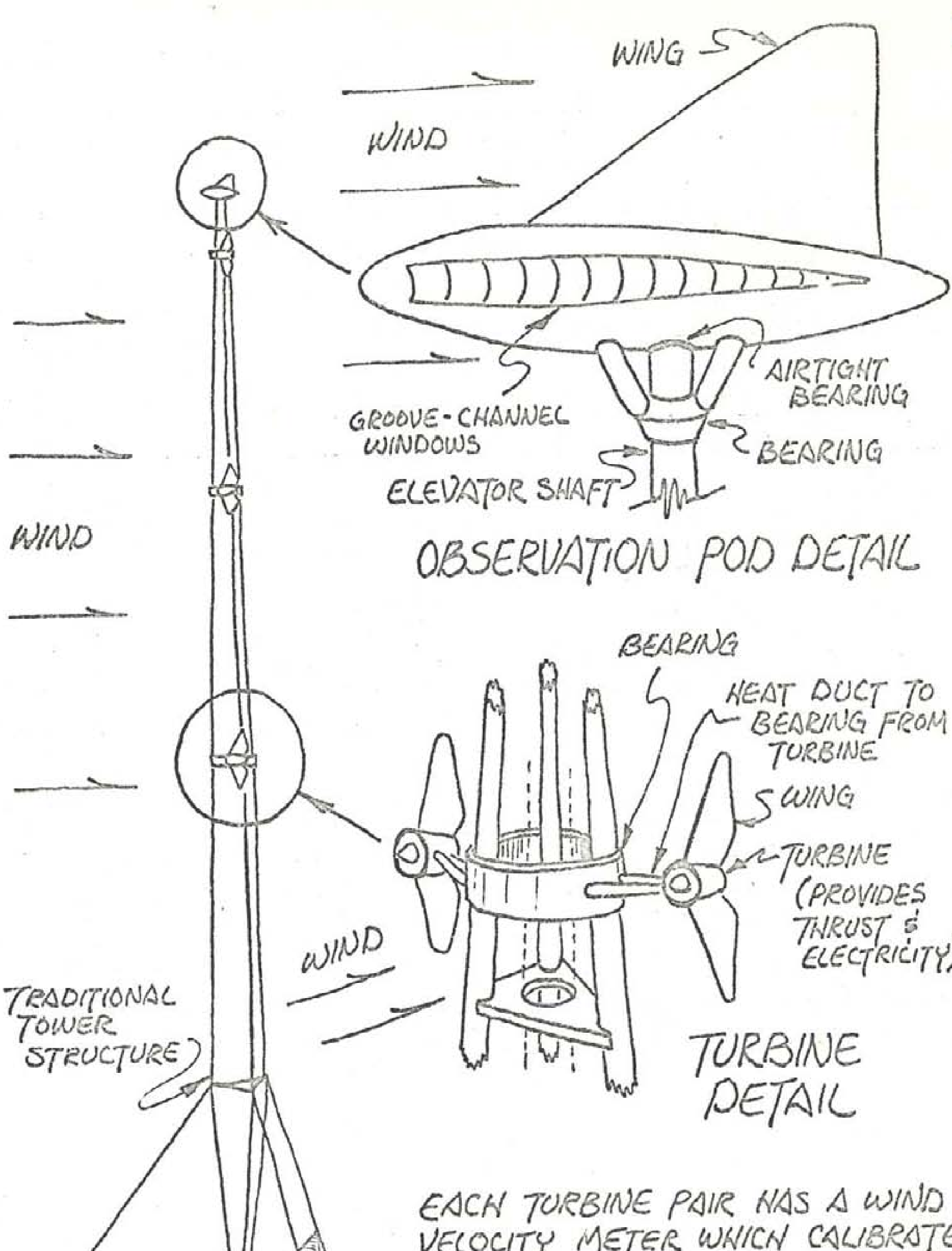
TOWER TO BE BUILT IN
CLOSE PROXIMITY OF MT. FUJI


AIRFOIL SHAPE TO PRODUCE LIFT IN HIGH WIND
WIND SCOOPERS - TRANSFORM THE ENERGY (MOMENTUM) OF WIND INTO HEAT THROUGH TURBINES OR PERHAPS HOT WIRE ANEOMETER EFFECT.
SUN ROOF
IMPULSE JETS
ELEVATORS
TURBINE
OBSERVATION RING
CROSS SECTION AT C.G. SENSOR LEVEL - AS C.G. SHIFTS DUE TO WIND OR INSTABILITY OF TOWER, IMPULSE JETS REPOSITION TOWER - THIS REDUCES THE AMOUNT OF STRUCTURAL RIGIDITY (AND ∴ MATERIAL) NEEDED IN CONSTRUCTION.
C.G. (CENTER OF GRAVITY) SENSOR SENDS MICROWAVE OR LASER BEAM TO GROUND TO REFERENCE TOWER'S POSITION.
BOTTOM OF TOWER:
RIGIDLY MOUNTED MICROWAVE OR LASER TRANSMITTER
HUGE BALL & SOCKET

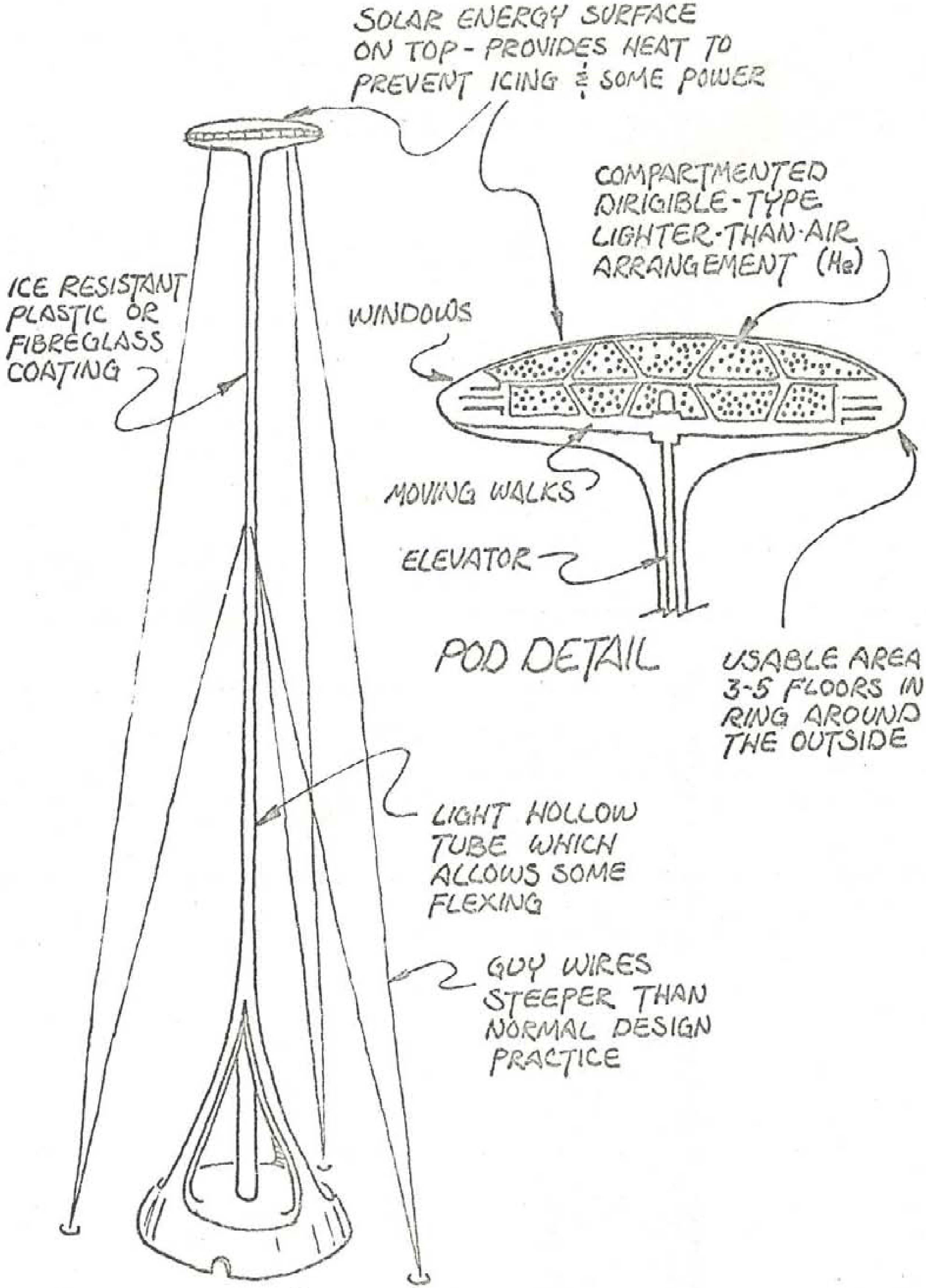


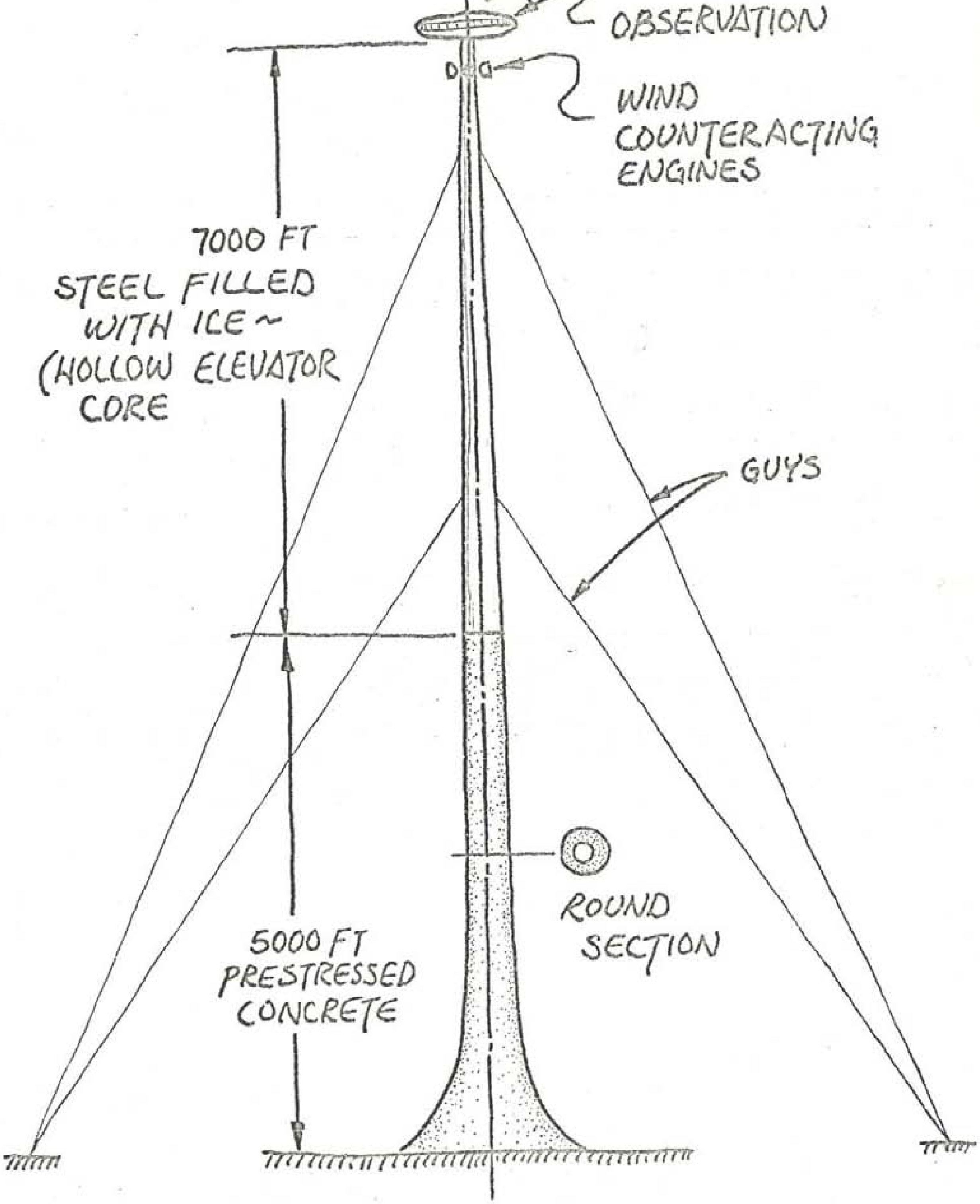
(27)


OBSERVATION POD:
OBSERVATION
COUNTER-ROTATING PROPS
GEARBOX, MACHINERY
OBSERVATION
JET ENGINES
'STACKING' SECTIONS
JET ENGINES COUNTER WIND LOADING
TOWER TELESCOPES UP & DOWN INORDER TO REGULATE THE LOADING DURING ADVERSE CONDITIONS
GROUND LEVEL
TELESCOPE DRIVE MOTOR

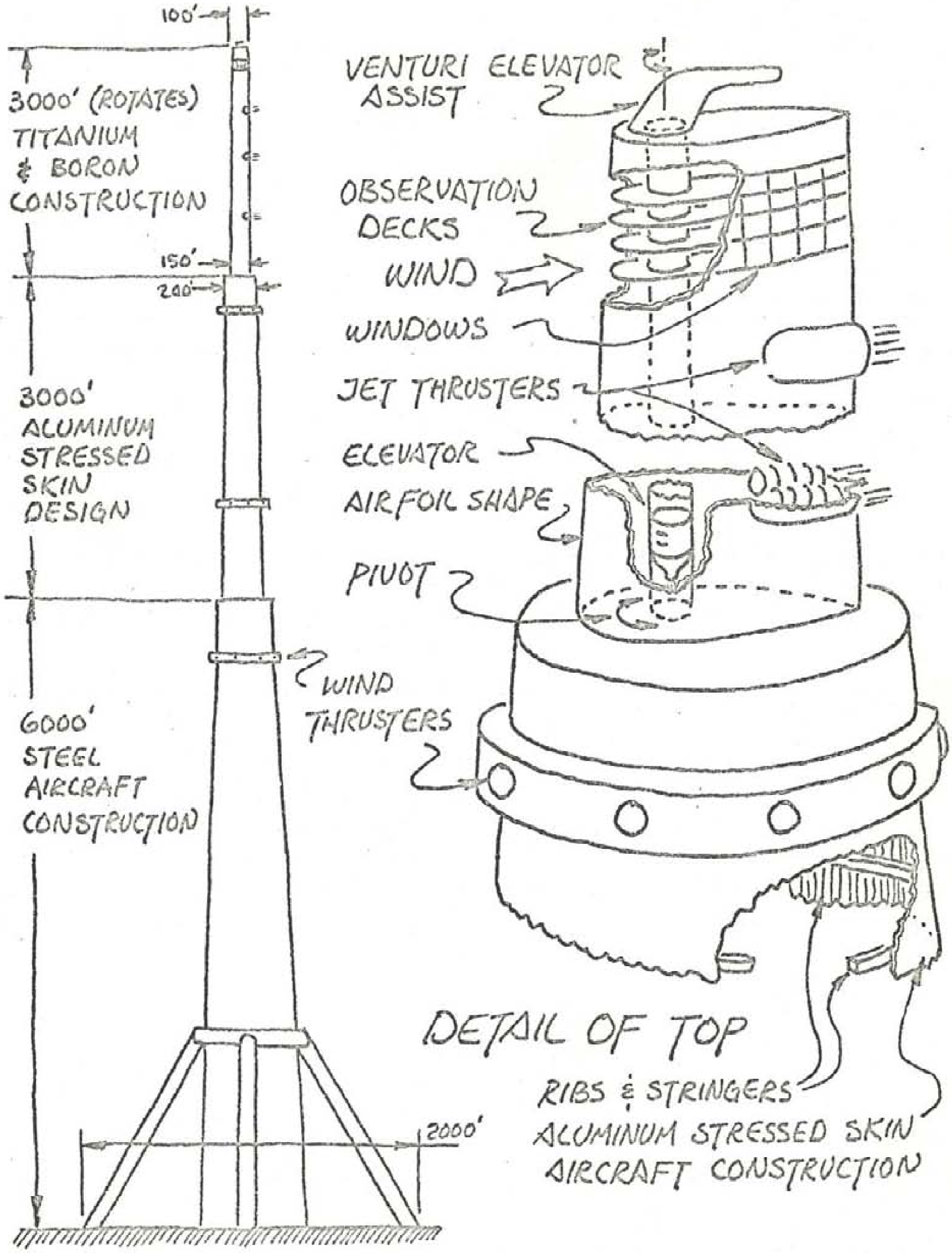


EACH TURBINE PAIR HAS A WIND VELOCITY METER WHICH CALIBRATES TOTAL WIND FORCE AT EACH POINT ON THE TOWER WHICH IN TURN REGULATES THE FORCE EXERTED BY THE TURBINE.

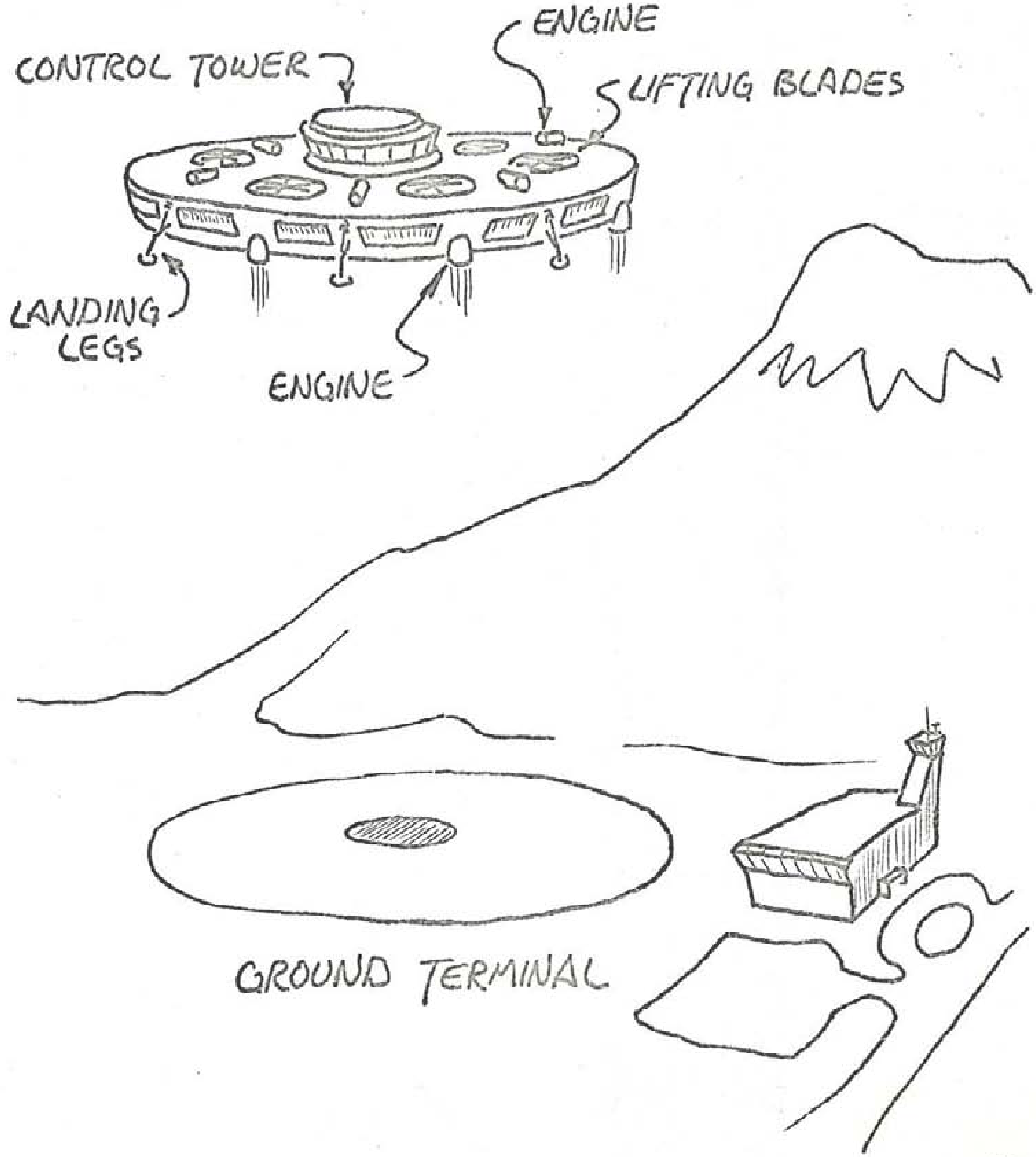

SOLAR ENERGY SURFACE
ON TOP - PROVIDES HEAT TO
PREVENT ICING & SOME POWER
COMPARTMENTED
DIRIGIBLE-TYPE
LIGHTER-THAN-AIR
ARRANGEMENT (He)
ICE RESISTANT
PLASTIC OR
FIBREGLASS
COATING
WINDOWS
MOVING WALKS
ELEVATOR
POD DETAIL
USABLE AREA
3-5 FLOORS IN
RING AROUND
THE OUTSIDE
LIGHT HOLLOW
TUBE WHICH
ALLOWS SOME
FLEXING
GUY WIRES
STEEPER THAN
NORMAL DESIGN
PRACTICE

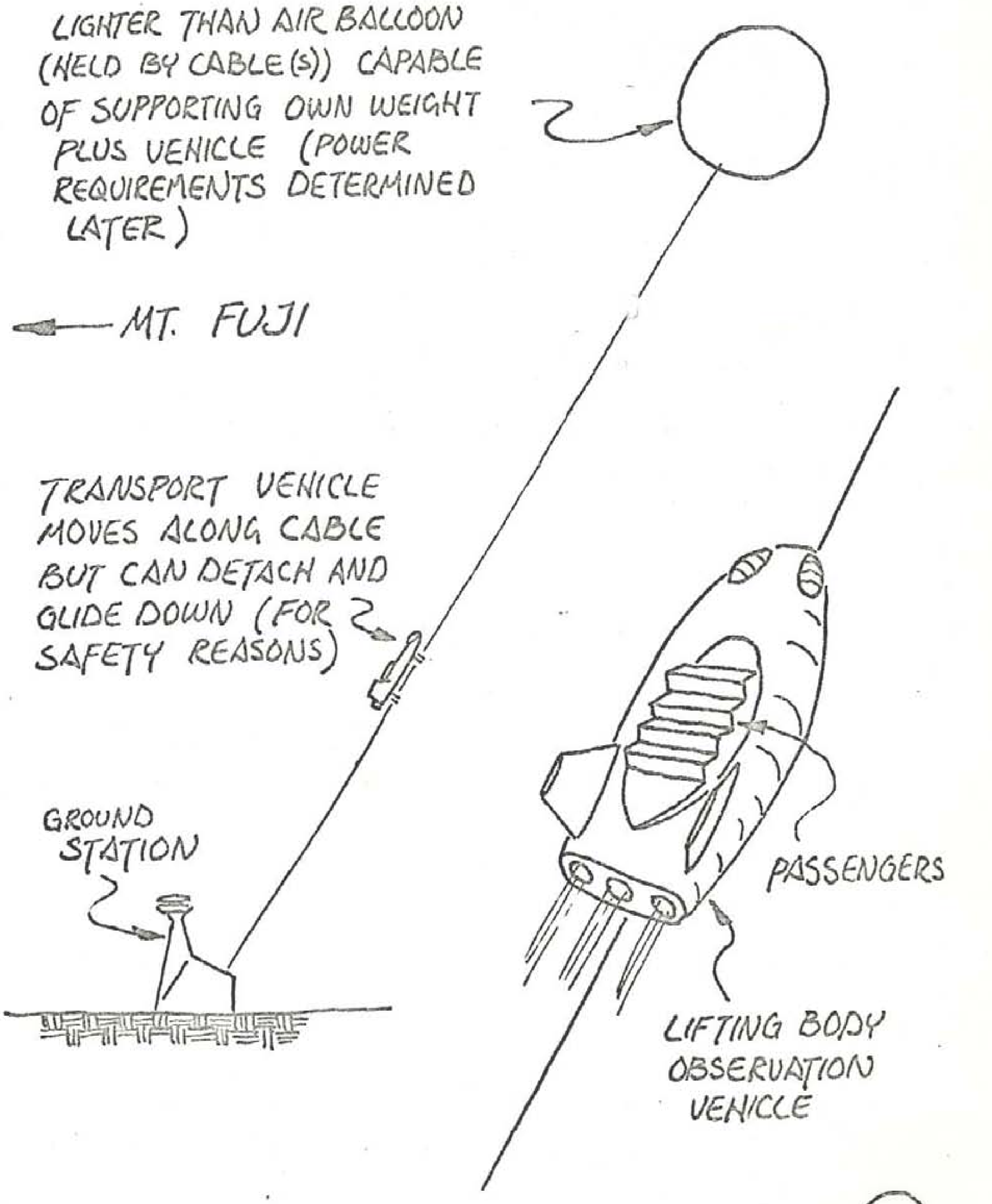

OBSERVATION
WIND
COUNTERACTING
ENGINES
7000 FT
STEEL FILLED
WITH ICE ~
(HOLLOW ELEVATOR
CORE
GUYS
ROUND
SECTION
5000 FT
PRESTRESSED
CONCRETE

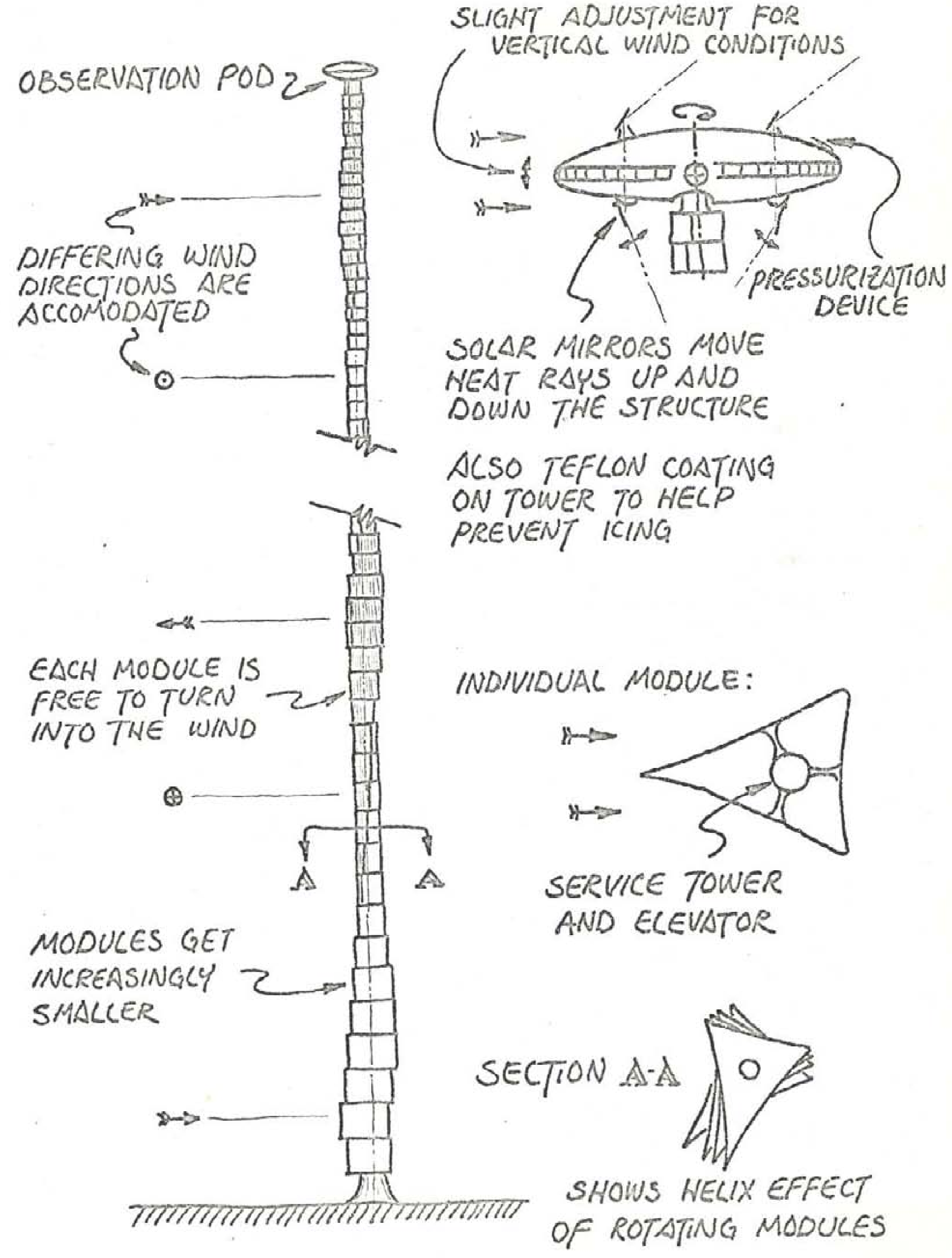
32

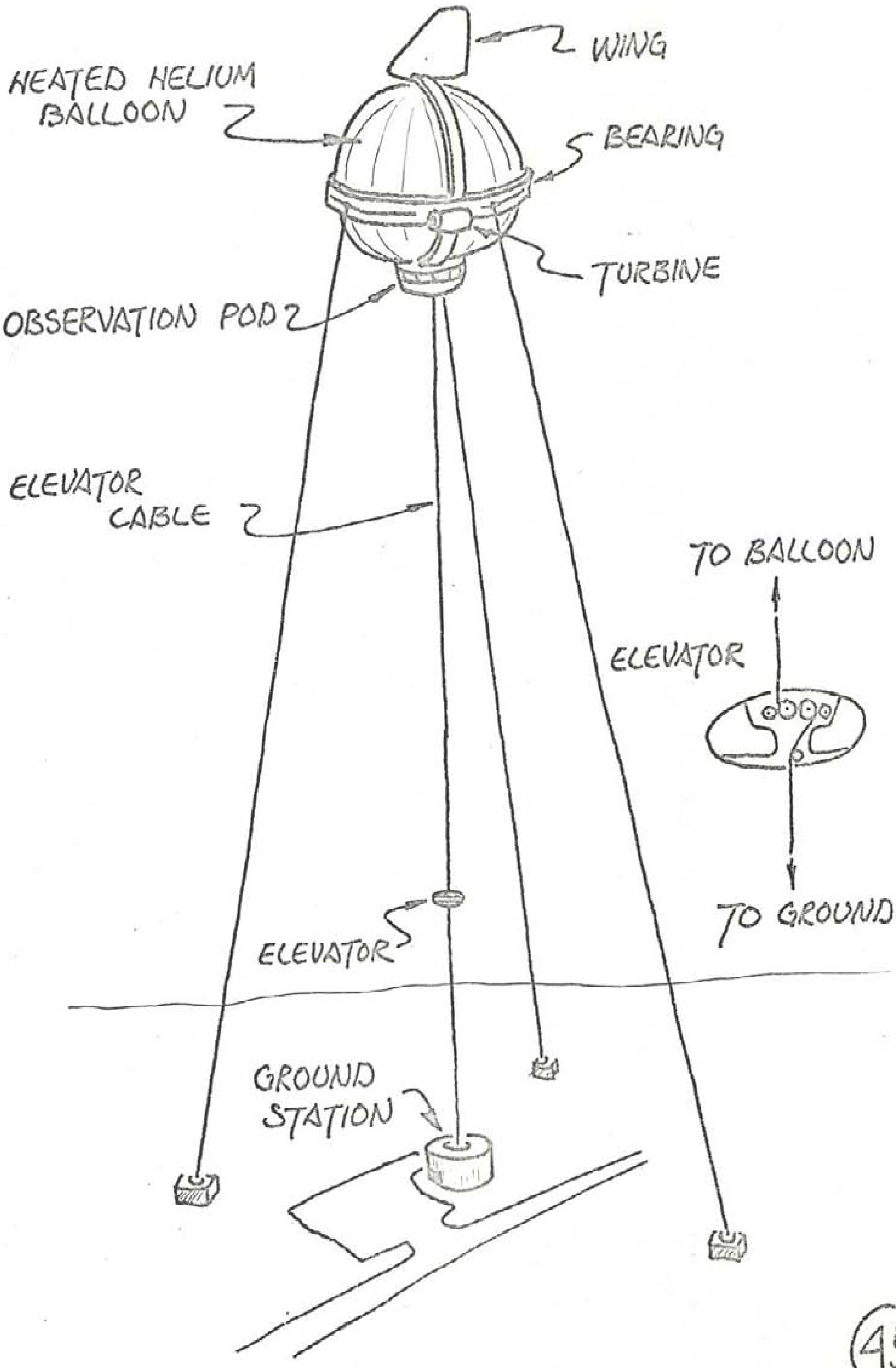


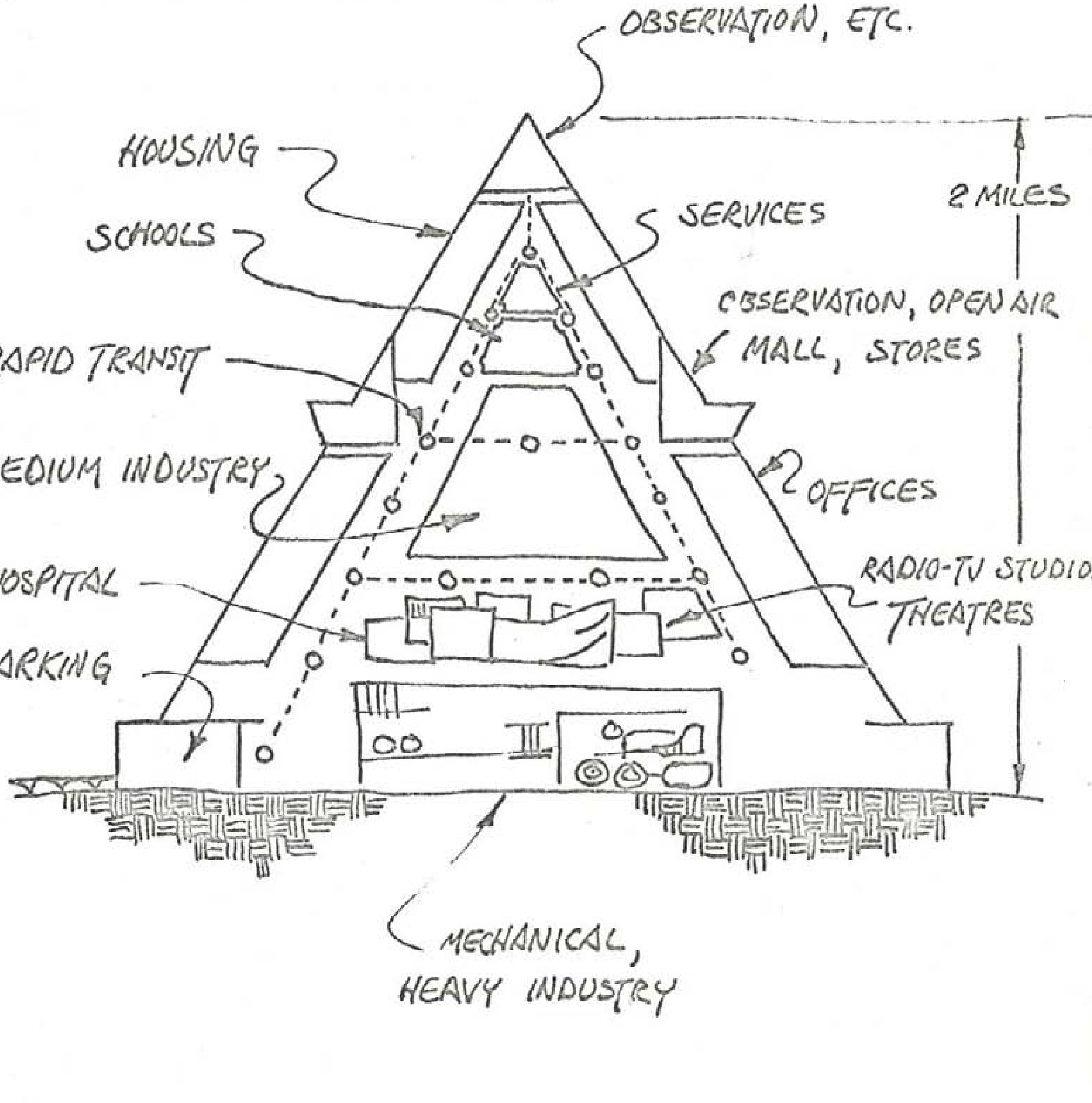
DETAIL OF TOP


ENGINE
CONTROL TOWER
LIFTING BLADES
LANDING LEGS
ENGINE
GROUND TERMINAL


LIGHTER THAN AIR BALLOON (HELD BY CABLE(S)) CAPABLE OF SUPPORTING OWN WEIGHT PLUS VEHICLE (POWER REQUIREMENTS DETERMINED LATER)
MT. FUJI
TRANSPORT VEHICLE MOVES ALONG CABLE BUT CAN DETACH AND GLIDE DOWN (FOR SAFETY REASONS)
GROUND STATION
PASSENGERS
LIFTING BODY OBSERVATION VEHICLE


SLIGHT ADJUSTMENT FOR VERTICAL WIND CONDITIONS
OBSERVATION POD
DIFFERING WIND DIRECTIONS ARE ACCOMODATED
PRESSURIZATION DEVICE
SOLAR MIRRORS MOVE HEAT RAYS UP AND DOWN THE STRUCTURE
ALSO TEFLON COATING ON TOWER TO HELP PREVENT ICING
EACH MODULE IS FREE TO TURN INTO THE WIND
INDIVIDUAL MODULE:
A
A
SERVICE TOWER AND ELEVATOR
MODULES GET INCREASINGLY SMALLER
SECTION A-A
SHOWS HELIX EFFECT OF ROTATING MODULES


WING
HEATED HELIUM BALLOON
BEARING
TURBINE
OBSERVATION POD
ELEVATOR CABLE
TO BALLOON
ELEVATOR
TO GROUND
ELEVATOR
GROUND STATION


OBSERVATION, ETC.
HOUSING
SCHOOLS
SERVICES
2 MILES
OBSERVATION, OPEN AIR MALL, STORES
RAPID TRANSIT
MEDIUM INDUSTRY
OFFICES
HOSPITAL
RADIO-TV STUDIOS THEATRES
PARKING
MECHANICAL, HEAVY INDUSTRY

APPENDIX 3 CALCULATIONS

Equations for the Spearman Rank Correlation Coefficient r_s

Data:

$$x_1, x_2, x_3, \ldots, x_n$$
$$y_1, y_2, y_3, \ldots, y_n$$

Differences:

$$d_i = x_i - y_i$$

For r_s with no ties:

$$r_s = \frac{-6 \sum_{i=1}^{n} d_i^2}{n^3 - n} + 1$$

For r_s with ties:

$$r_s = \frac{\sum x^2 + \sum y^2 - \sum d^2}{2\sqrt{\sum x^2 \sum y^2}}$$

where:

$$\sum x^2 = \frac{n^3 - n}{12} - \sum T_x$$

$$\sum y^2 = \frac{n^3 - n}{12} - \sum T_y$$

$$T = \frac{t^3 - t}{12}$$

t = the number of observations tied at each rank

Equations for the Kendall Coefficient of Concordance W

For W with no ties:

$$W = \frac{\left[\sum R_j - \frac{\sum R_j}{n}\right]^2}{\frac{1}{12} k^2(n^3 - n)}$$

where

R_j = the sum of ranks for each item

k = the # of sets of rankings, i.e., # of judges

n = the # of individuals tested

$\frac{1}{12} k^2(n^3 - n)$ = max. sum of squared deviations

For W with ties:

$$W = \frac{\left[\sum R_j - \frac{\sum R_j}{n}\right]^2}{\frac{1}{12} k^2(n^3 - n) - k\sum_T T}$$

where

$\sum_T T = \sum T_x + \sum T_y + \sum T_z + \ldots$ etc. for # of judges

$\sum T_x = \frac{(t^3 - t)}{12} + \ldots$ etc. for each tie in X, etc.

t = the number of observations tied at each rank

To test significance in samples greater than 7, use X^2 test

$$X^2 = \frac{s}{\frac{1}{12} kn(n + 1)} = \text{chi squared}$$

$$= k\,(n - 1)\,W$$

with the degrees of freedom, df, equal to n - 1

For $r_{s_{av}}$:

$$r_{s_{av}} = \frac{kW - 1}{k - 1}$$

where

W = Kendall Coefficient of Concordance

k = the # of sets of rankings, i.e., # of judges

note: $r_{s_{av}}$ is equivalent to the average of all the partial correlations between each judge and every other judge.

Calculation of Spearman Rank Correlation Coefficient:

r_s for Visual Rank vs. Creativity Rank with 3 judges

no correction for ties:

$$r_{s_3} = 1 - \frac{6 \sum d_i^2}{n^3 - n} = 1 - \frac{6(2,146.5)}{21,924} = .412$$

with correction for ties:

$$T_{x_3} = \frac{(3^3-3) + 6(2^3-2)}{12} = \frac{54}{12}$$

$$T_y = \frac{2(3^3-3) + 2(2^3-2)}{12} = \frac{60}{12}$$

$$r_s = \frac{\sum x^2 + \sum y^2 - \sum d^2}{2\sqrt{\sum x^2 \sum y^2}}$$

$$= \frac{\left(\frac{21,924 - 54}{12}\right) + \left(\frac{21,924 - 60}{12}\right) - (2,146.5)}{2\sqrt{(1822.5)(1822)}}$$

$$= .411$$

test for significance:

.411 > .329 (19;236), significant beyond .05 level

r_s for Visual Rank vs. Creativity Rank with 6 judges

no correction for ties:

$$r_{s_6} = 1 - \frac{6(1150)}{21,924} = .685$$

with correction for ties:

$$T_{x_6} = \frac{3(2^2-2)}{12} = \frac{18}{12}$$

$$T_y = \frac{60}{12} \quad \text{(same as before)}$$

$$r_s = \frac{\left(\frac{21,924 - 18}{12}\right) + \left(\frac{21,924 - 60}{12}\right) - (1150)}{2\sqrt{(1825.5)(1822)}}$$

$$= .6847 \text{ ; round off to } .685$$

test for significance:

$.685 > .465$ (19;236), significant beyond .01 level

Calculation of Kendall Coefficient of Concordance:

W for creativity ranking with 3 judges:

$$W = \frac{\left[\sum R_j - \frac{\sum R_j}{n}\right]^2}{\frac{1}{12}k^2(n^3 - n)} = \frac{10,679}{\frac{1}{12}3^2(21,924)}$$

$$= .649$$

$r_{s_{av}}$ for creativity ranking with 3 judges:

$$r_{s_{av}} = \frac{kW - 1}{k - 1} = \frac{3(.649) - 1}{3 - 1}$$

$$= .473$$

test for significance:

$$X^2 = k(n - 1)W = 3(28 - 1).649 = 52.5$$

$52.5 > 46.96$, significant beyond the .01 level

W for creativity rankings with 6 judges:

$$W = \frac{31,127.65}{\frac{1}{12}\, 6^2(21,924)}$$

$$= .473$$

$$r_{s_{av}} = \frac{6(.473) - 1}{3 - 1}$$

$$= .378$$

test for significance:

$$X^2 = 6(28 - 1).473 = 76.5$$

$76.5 > 55.48$, significant beyond the .001 level

W for visual rankings with 3 judges having ties:

Chart Showing Ties in Judging

	JUDGE RF		JUDGE WG		JUDGE TP	
SCORE	RANK	FREQ.	RANK	FREQ.	RANK	FREQ.
7	----	----	1.0	1	1.5	2
6	1.5	2	----	----	3.0	1
5	5.0	5	2.0	1	5.0	3
4	9.5	4	4.0	3	8.5	4
3	14.5	6	8.5	6	14.0	7
2	20.5	6	15.0	7	21.0	7
1	26.0	5	23.5	10	26.5	4
totals		28		28		28

$$\sum T_{RF} = \frac{1}{12}\left((2^3-2)+(4^3-4)+2(5^3-5)+2(6^3-6)\right) = \frac{726}{12}$$

$$\sum T_{WG} = \frac{1}{12}\left((3^3-3)+(6^3-6)+(7^3-7)+(10^3-10)\right) = \frac{1560}{12}$$

$$\sum T_{TP} = \frac{1}{12}\left((2^3-2)+(3^3-3)+2(4^3-4)+2(7^3-7)\right) = \frac{822}{12}$$

W with the above correction for ties:

$$W = \frac{\left[\sum R_j - \frac{\sum R_j}{n}\right]^2}{\frac{1}{12} k^2(n^3-n) - 6\sum T}$$

$$= \frac{13,834.13}{\frac{1}{12} 3^2(21,924)-6\left(\frac{726+1560+822}{12}\right)}$$

$$= .929$$

$$r_{s_{av}} = \frac{3(.926) - 1}{3-1}$$

$$= .889$$

test for significance:

$$X^2 = 3(27).929 = 84.33$$

$84.33 > 55.48$, significant beyond the .001 level

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