edited in retrospect

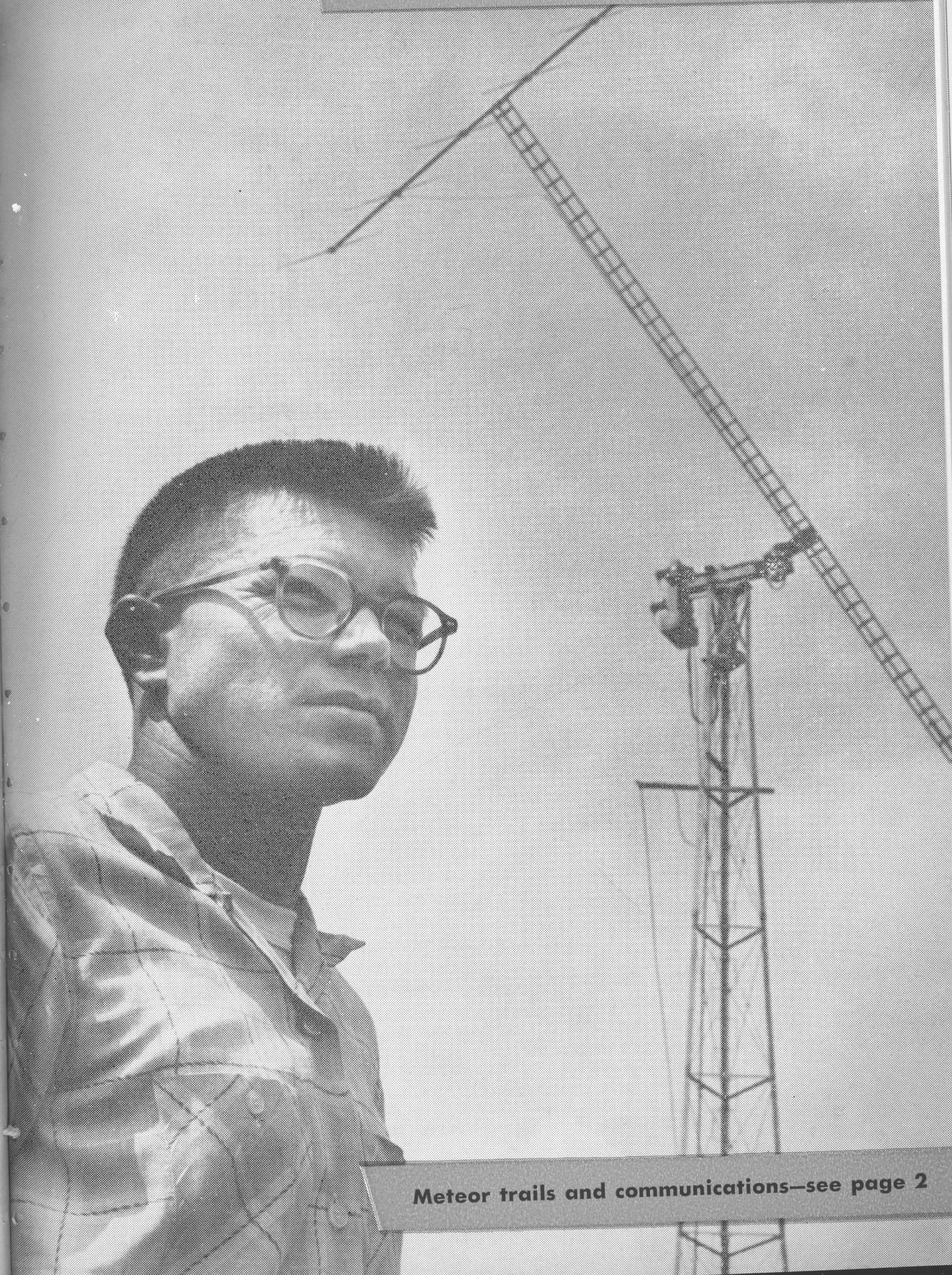
the changing scene

•A great deal of space in this issue is devoted to Tech's Increasing capabilities to carry out research. The new Mechanical Engineering Laboratory, the improved Aeronautical Engineering research facilities, the Industrial Products Laboratory and others were presented to you in detail for the first time on the preceding pages.

At the bottom of this page is the beginning of still another new Tech facility for research. It is, or will be in one month, a variable-sloped flume. It was designed for Tech's rapidly-expanding Hydraulics Laboratory by the head of the laboratory, Regents Professor Carl Kindsvater and Research Engineer Tom Elliott and Research Assistant John Steinichen of the Engineering Experiment Station.

The new flume, capable of being tilted to maintain a constant depth and uniform flow over its entire 90-foot length, will be used for basic investigations of uniform flow in open channels with varying degrees of roughness and various shaped cross-sections. The work will be done for the U. S. Geological Survey who has supported Tech's open-channel research since its inception. Tech, the pioneer research agency for the Surface Water Branch of USGS, has been so successful in its program that USGS is now supporting research in this field at various other institutions. Proof once again that successful research begats more research.

engineer JULY 1957
Georgia Tech Engineering Experiment Station



Meteor trails and communications—see page 2

the research engineer

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the cover

The young man pictured on the cover is a Georgia Tech graduate student in Electrical Engineering who goes by the rather incredible name (for a scientist) of Jesse James. Unlike his infamous namesake, this Jesse James is involved in work that will eventually prove to be of great benefit to this country. Working on his doctorate, Research Physicist James is intensely interested in the relatively new field of meteor-trail communications. His thesis, now almost completed, will be devoted to this subject on which Mr. James briefs you beginning on page 9 of this issue.

Cover photo by Bill Diehl, Jr.

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Education and industrial development

UNDER THE PRESENT STATE ADMINISTRATION, Georgians have become more and more industrial-development conscious.

One indication of the increased interest in this important facet of our State's expanding economy is the amount of space devoted to this subject by Georgia's newspapers in recent months. But an even more important reflection of it is the number of industrial development groups that have sprung up in municipalities and counties throughout the State. The result of this increased activity has been a great increase in the State's industrial growth.

Georgia's sudden upsurge in this field is no accident. It is the direct result of the vigorous work of Governor Griffin and groups like the Georgia Department of Commerce and the State Chamber of Commerce during the past two years.

Through an expanded promotional program, the Governor and these groups have taken across the country the message of Georgia's potential for industrial expansion. But along with all this increased emphasis on promotion, some hard facts on Georgia's economy were needed if Georgia was to meet the present-day competition in the industrial development field.

This is where higher education enters the picture. For a great part of the responsibility of Georgia Tech and all institutions of higher learning is a constant search for truth through an intelligent research program. Realizing this, Governor Griffin allocated $50,000 to the Board of Regents last July to permit Georgia Tech to set up an Industrial Development Branch in its Engineering Experiment Station. Its responsibilities were to provide the factual scientific foundation needed to assess the State's industrial potential and to determine what existing industries can be expanded as well as what new industries can be developed.

This month, the new branch—now on a permanent basis—has released for public consumption its first major report. On page 19 of this issue, the publication, "Georgia's New Frontiers," is briefed for you. It is just the beginning of a series of research reports in this field through which Georgia Tech can make a greater contribution to the growth of this State and region.

Paul Weber
Acting President

One of the 1957 Georgia Tech Sigma Xi award winners reports on the latest developments in the theory of verbal and written communication

SOME SCIENTIFIC ASPECTS OF LANGUAGE

by Benjamin J. Dasher, Director, School of Electrical Engineering

FAMILIARITY, it is said, breeds contempt. And familiarity likewise breeds ignorance or at least complacency, for we are inclined to take for granted the things we are near every day. The visiting tourist learns more about the interesting sights of a city in two hours than its natives learn in twenty years. We are so accustomed to familiar sights, familiar things, familiar people, that we are quite unaware of their real significance. A prophet hath no honour in his own country.

What commodity of modern society is more common than our language? And what is more varied? And what is less known? Language communication is such a complex activity, so subtle, so intricate, that it is generally accepted as an art, not to be described or explained but to be accepted and appreciated. Has it any features that may be said to be scientific?

The answer to this question obviously depends upon the point of view. On the one hand, language is totally unscientific. But if by scientific we mean organized and systematic, then there are indeed some scientific aspects of language. It is from this point of view that I make these brief comments. In so doing, I make no claim of originality or novelty. I shall only call attention to some ways of studying language that have been suggested by recent developments in the theory of communication.

information—a new concept

What is information? Can we measure it and if so, how? What is the connection between information and meaning? Before attempting an answer to these questions let us consider some of the ways of assigning meaning to a word. We may say that some words derive their meanings by association with one or more physical senses—sight, touch, smell and so on. These ideas we call "concrete." In grammar, we distinguish concrete things or ideas from abstract things or ideas, and these distinctions are usually applied to names of things or ideas (concrete noun, abstract noun). However, we can logically distinguish between other parts of speech as referring to concrete actions, processes or relationships, as opposed to abstract ones. For example, "to run" is concrete but "to understand" is abstract. Abstract words derive their meanings from other words. Thus we can say, with at least an acceptable degree of accuracy, that words derive their meanings either from an appeal to the physical senses or from other words.

These are the formal meanings—the dictionary meanings. In this sense, there are few, if any, words that have only one such meaning. Therefore, we must consider the problem of multiple meanings. This problem extends from those ideas that are similar but subtly different, to those ideas that are totally unrelated, though represented in the dictionary sense by the same word. For these distinctions we must rely on context. By context we mean the whole surroundings in which a word is found. The influence of context in fixing meaning is so strong that a skillful writer or speaker can assign almost any meaning to any word at his pleasure. In such cases, the dictionary meaning may offer some clue to the intended meaning, but often the clue is so remote as to have little bearing. When we speak of the definition of a word, we do not ordinarily take context into account, but when it comes to discovering the meaning of a given word at a given time the last appeal is to context.

Now let us return to the question, what is information? To answer this question in the ordinary way would involve us in all manner of semantic difficulties. A completely unambiguous answer has been provided by Wiener[1] and by Shannon.[2] Their definition is related to our general notions of what information is, but in its exact sense it applies only to synthetic systems—electrical, mechanical, etc., and it does not include meaning as discussed above. It cannot be applied directly to our language questions, but because it is precise and quantitative it gives as well as a definition a measure of information. On this base a mathematical theory has been built and some of the concepts of this theory may prove useful in studying language. Now, one thing that science, mathematics, art, and language have in common is a respect for form and structure. This is one feature of language that may be said to be scientific. We will return to this discussion later. For the present, let us examine a few of the basic principles of the new concept of information.

information theory

It is, of course, completely outside the purpose of this discussion to deal with information theory in any detail. However, a very brief outline of some of its main ideas is appropriate.

The first principle is that information implies uncertainty. There is no need to ask a question if the answer is known in advance. But suppose the question is

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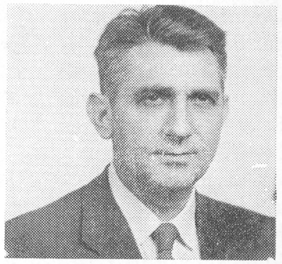
ADDENDUM - a year of equipollence



EACH YEAR, the Georgia Tech chapter of Sigma Xi, honorary research society, awards a prize for the best research paper published by a faculty member at Georgia Tech. In addition to this cash award, the winner presents a lecture at the annual Sigma Xi awards dinner. This year, the awards committee presented a co-first prize award. The winners were Dr. James R. Garrett, associate professor of mathematics for his paper, "Reduction of equations to normal form in fields of characteristic p," and Dr. Benjamin J. Dasher and Dr. Kendall L. Su of the Electrical Engineering School for their paper, "A solution to the approximation problem for R C low-pass filters." The winners then decided that Dr. Dasher, right, should present the 1957 award lecture, which is printed on these pages. Dr. Earl W. McDaniel of the Station staff and Dr. J. P. Vidosic of Mechanical Engineering were named co-winners of the second faculty prize.

asked, then no information is conveyed by its answer since the state of affairs after the question is given is exactly the same as it is before. No uncertainty, no information.

The second principle is that uncertainty about some thing or idea can eventually be removed by a sequence of "yes" or "no" answers to questions as in many popular TV quiz games of today: that is, by a process of elimination.

These two ideas lead to a formal definition of information, sometimes also called *selective information* or *information content*. Suppose I select a word out of the dictionary at random and you are required to find what word. You might begin by asking, "Is it in the first half of the book?" Suppose the answer is "no"; then, of course, you assume the word is in the second half and so the first half is no longer of interest. Now you ask, "Is it in the first half of the remainder?" After the second answer, only one-fourth of all the words remain.

Clearly, we could continue in this way to ask the same question, "First half?" until a particular page had been identified and, finally, a particular word. If we assume for convenience that the number of words remaining after every question, regardless of whether the answer is "yes" or "no," is always exactly divisible by 2, then the same number of questions will have to be asked regardless of which word is chosen.

Applying the same reasoning to other situations suggests taking the number of questions that must be asked in order to identify a particular item as a *quantitative* measure of the information contained in the answer. Thus, one selection constitutes one unit of information. A selection from one of two possible choices is called a *binary* selection, so what we have described is a "binary digit" of information, commonly called a "bit."

A third principle of information theory is that information is statistical in nature. That is, the more likely we are to receive a particular message, the less information it contains. Or, the greater the surprise value of a message, the more information it represents. When dealing with a large number of messages or message-items some of which are more likely to be chosen than others, it is convenient to deal with the average information contained in a single choice. In the notation of the statistician, we write

$$H_i = \text{average}\,(-\log_2 p_i) = -\sum_i p_i \log_2 p_i$$

bits per choice, in which p_i represents the probability that the i^{th} choice will be made.

A fourth principle is that we can never be completely certain of the identification of a choice because no system is entirely free of disturbances which we call loosely "noise." There is always some degree of uncertainty about a message as received.

A fifth principle is that no communication is possible unless both the source and the receiver of messages know and use the same "code." In particular, the receiver must know what messages the source is capable of sending and, more important, the likelihood that a given message will be sent.

Finally, a sixth principle is that repetition reduces uncertainty. This useful kind of repetition is called *redundancy* in the language of communication theory.

language communication

Any attempt to apply these principles directly to our language problem is sure to lead us astray because information theory deals with the symbols—the choices, the "bits"—and is not concerned with their meaning. Thus, literally, it has nothing to do with semantic information. However, if we confine ourselves primarily to the structure of language, information theory can bring a new point of view to some problems. Of particular interest are the last two principles mentioned: namely, that the receiver of a message must know in advance what kind of message to expect and that repetition reduces errors. These statements may appear so obvious as to be trivial, yet they are perhaps the most frequently violated principles of speaking or writing.

Although excessive redundancy is generally considered undesirable, especially in writing, we would be quite helpless without some. Redundancy is what makes it possible for us to guess what someone means when he makes a simple error in grammar or otherwise violates the "rules." Further, only the redundancy of a text permits the problem of multiple meanings to be resolved. In this sense, redundancy is represented not only by the repetition of ideas in various ways and degrees, but also by adhering to rules of form and structure, that is, grammar and syntax.

Another way to look at redundancy is to regard it as a way to let the receiver of a message anticipate what is coming. This idea is illustrated in the "agreement" we demand in the number (whether singular or plural) of verbs and their subjects, in their gender, and in their "person" (whether first, second or third). Consider a sentence that begins, "I is—." This is ambiguous, but it is not necessarily incorrect. "I am—" looks better and so does "he is —" but

I is a personal pronoun

looks better than

I am a personal pronoun.

This last may be considered grammatically correct if it is accepted as a false statement like

I am a man from Mars.

Notice that the interpretation of these sentences depends on *advance knowledge* about the relationships that can exist between the words I, personal, pronoun, man, Mars. It is their relationship, not their meanings, that is important. We expect "I am" to be followed only by certain kinds of statements, and if one of these does follow we are satisfied. If not, the result is likely to be ambiguous or to "make no sense." We ordinarily make every effort to fit such statements into acceptable patterns. If "I am a man from Mars" is followed by appropriate statements about flying saucers and other fantasy, the word *I* loses much of its personal connotation and the reader thereafter expects fiction.

Preparing the reader to expect certain particular ideas is in reality repetition. In the language of information theory it is called redundancy. In the language of rhetoric it is called unity, coherence, and consistency. Regardless of its name, it is both useful and necessary to clear expression.

Repetition doesn't mean going around in a circle. Rather, it means overlapping the thoughts in an orderly way so that the reader is always on familiar ground, and he can see both ahead and behind.

structure

We have suggested only two illustrations of the role of redundancy in language: first, its presence in the rules of grammar and then in larger units involving several sentences. It is also evident in many other ways, one of the most important of which is word order or syntax. This aspect may be more generally referred to as the structure of language. Structure has to do with the way words are put together to "make sense." It concerns not only word order but word statistics. It has been emphasized that all words are ambiguous and that repetition reduces uncertainty, i.e., ambiguity, but we do not depend on repetition alone. The order in which words are presented plays a large role in specifying what they mean. (This is true not only of words but also of phrases, sentences and even larger units of thought.) Fortunately, word order likewise involves a great deal of redundancy. This means that of all the possible ways of arranging the words of, say, a sentence, many of them have the same meaning. If this were not so, perhaps we would need fewer words but communication would become most difficult. There are 120 different ways to arrange five words and nearly 1000 ways to arrange six. Yet, the number of different meanings that can be assigned to a five word sentence is usually not large. For example, consider

Can you hear me now?

Insofar as word order alone is concerned, there is probably only one meaning. By

continued on page 8

varying the stress in speaking, or the punctuation in writing, perhaps five or six or more different meanings can be found. Word order could help to distinguish them but could not do it alone. By way of contrast, in counting we use only ten different "words" (digits) and their order tells the whole story. If a strict system of word order were used in language, a vocabulary of a few words, arranged in groups of different lengths with suitable repetition, would suffice for all communication. In principle only two different words would be needed. Under these circumstances it is unlikely that many people would learn to manage it.

The role of structure is beautifully illustrated by Lewis Carroll's immortal Jabberwock:

'Twas brillig, and the slithy toves
Did gyre and gimble in the wabe;
All mimsy were the borogroves,
And the mome raths outgrabe. . . .

The "important" words here have no dictionary meanings so we cling to the hope that we can depend on the rest. A basic sentence structure is established by the "little words," *provided we can assume they have their usual meanings.* If we rearrange the little words, we can give entirely different meanings to the rest:

The brillig and the gyre did wabe
And twas in gimble slithy toves
The mimsy and the raths outgrabe
Were all mome borogroves.

What is the mechanism that makes us willing to accept this gibberish as having any sense? It is folly to attempt a complete answer, but a few things seem reasonably certain. Surely we assume that we know what *the, and, did,* etc. mean. That is, we assign to these words their most probable meanings. This leads us to expect certain kinds of words. *The* should be followed by a noun or an adjective; if it is followed by an adjective, then the adjective should be followed by a noun. *Slithy* sounds like an adjective both because it ends in *y* and because it suggests some other "real" adjectives — slithery, slimey—either of which is in keeping with *brillig*. *Brillig* itself could only be an adjective having something to do with the weather or the mood of the occasion. In the second case, *brillig* is a noun because it follows *the*. Thus, we see that the associations suggested by the pseudo-words together with the most probable meanings of the real words give the overall effect of mystery rather than nonsense. If the familiar words are replaced by words that can serve equally well as two or three different parts of speech, the poem becomes ambiguous and senseless.

In exactly the same way, the simple, common words serve to hold language together. They do this because we are sure of their meanings. The more words we are certain of, the more certain we are of the overall meaning.

conclusion

In the conventional study of language not enough attention is given to structure. We learn the parts of speech and to parse sentences. We learn what a "topic sentence" is and what a "lead paragraph" is. But we don't learn how to turn an x-ray on our compositions and see their skeletons. Everyone knows the value of an outline for a letter or story but what about a sentence outline or a paragraph outline?

A better understanding of language structure and its interaction with words would undoubtedly be useful in translating from one language to another. Also a better understanding of the relation between language statistics and meaning is needed. The more frequently a word is used, the more confident we are of its meaning. But, paradoxically, the less forcefully it expresses our ideas. The mathematical theory of information shows that such problems can be systematized, and this is the first step in any scientific undertaking.

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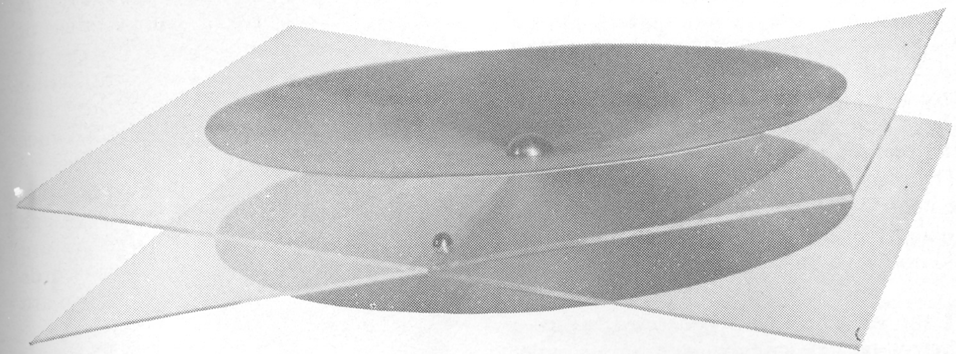
Meteor-trail communications

by Jesse James, Research Physicist



Solar-system model used at Tech in meteor studies. It shows the sun (top bead), the earth, and the region (two cones) where the meteor-particle orbits are assumed to be.

A young Georgia Tech graduate student reviews the exciting field in which he is presently working for an advanced degree

BILLIONS OF SMALL PARTICLES strike our atmosphere each day leaving trails capable of reflecting radio energy. These meteor trails are being studied to determine their usefulness as reflectors of radio signals.

Because the earth is round and high frequency radio waves essentially travel in straight lines, long-distance radio communication requires some reflector high above the earth's surface.

Ionized layers in our upper atmosphere will reflect radio waves having frequencies below 15 or 20 megacycles per second, but meteor trails will reflect radio energy of a higher frequency because of their ionization densities.

In the past, frequencies below 15 to 20 megacycles have adequately supplied the demand for radio-communication channels, but this picture is rapidly changing. The need for greater capacity in long-range radio communications is increasing and would become acute in the event of war. This shortage should be alleviated by the opening of new channels above 20 megacycles when meteor-scatter propagation becomes practical.

Meteoric particles striking our atmosphere vary in size over a wide range. The largest ones are relatively rare and strike the earth's surface before being burned up in the atmosphere. The smallest ones, called micrometeorites, are plentiful in number and account for several thousand tons of meteoric material falling to the earth each day.[1] The particles of intermediate size in the mass range from 10^{-6} grams to 10^{3} grams produce ionization trails that can be used for meteor-scatter communication. These particles account for about one ton of meteoric material swept up by the earth each day, and within this category the number of particles larger than a given mass varies approximately as the reciprocal of the mass. A bright meteor seen on a dark night may

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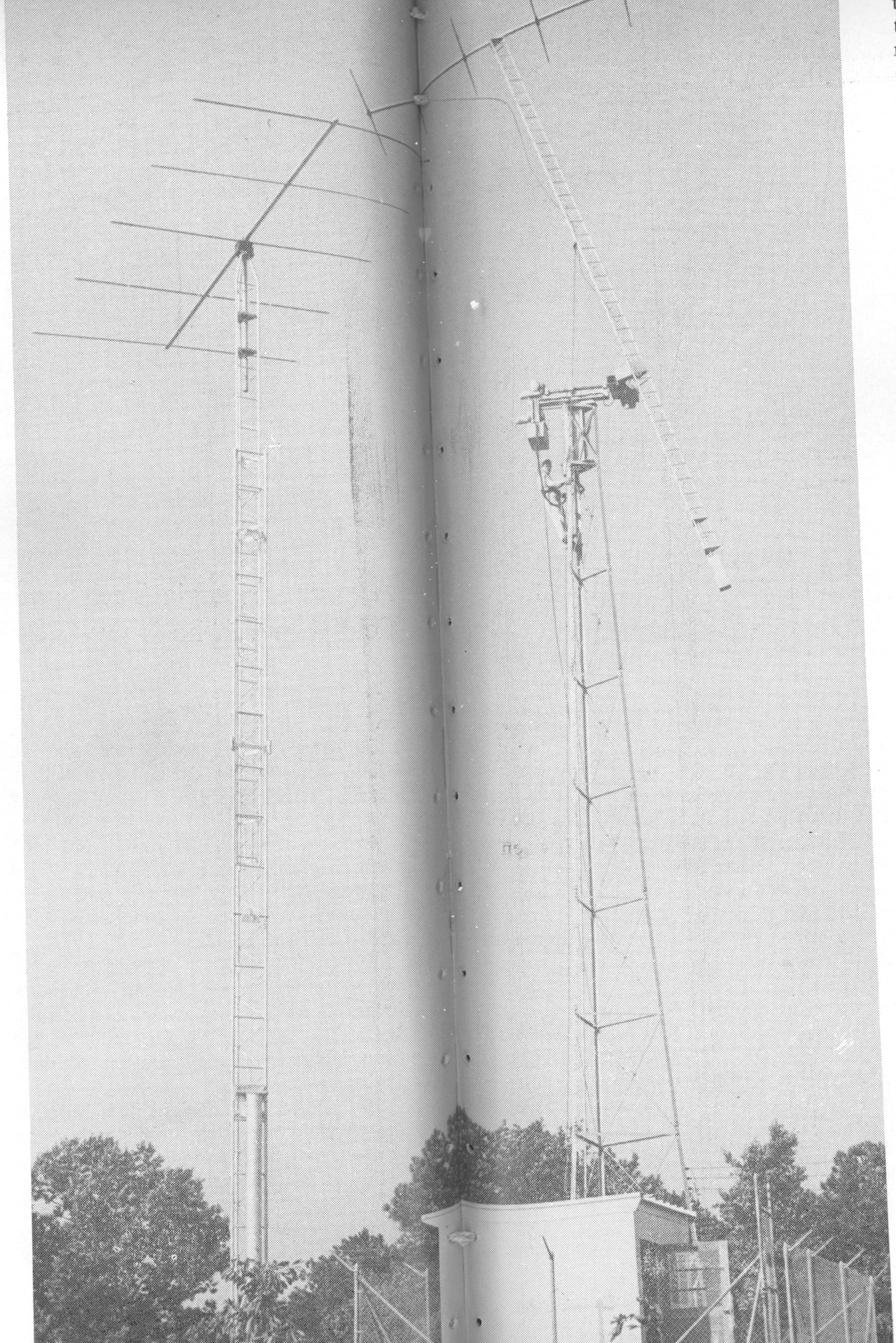

Georgia Tech's field site near Smyrna, Ga., showing the building housing equipment and two of the three antennas now being used.

Meteor-trail continued

be produced by a particle having a mass of a few milligrams, which is about the size of a grain of sand. The luminosity of the meteor is due to the excited state of the material in the wake of the particle. The process is similar to that occurring in a neon light. By far the majority of the meteors useful for radio communication do not leave trails visible to the naked eye.

THE HEAT ENERGY generated when a meteor particle collides with an air molecule is sufficient to evaporate a great many meteor atoms. For this reason the total air mass intercepted by a meteor before complete evaporation is small compared with the mass of the meteor body; thus the meteor is not appreciably retarded during its journey in the atmosphere. The atoms which boil from the meteor particle make collisions with air molecules and leave a long, thin column of ionization, which quickly diffuses in the rare upper atmosphere to a column of large diameter. Upper atmosphere winds having typical velocities of 125 kilometers per hour may move and distort the trail.

Meteor trails average about 25 kilometers in length. They occur between 80 and 120 kilometers above the earth's surface, which is only about one-fifth the proposed altitude of the first earth satellite.

In order for a trail to produce a useful reflection, it must be perpendicular to the bisector of the angle formed at the trail by lines to the transmitter and receiver. This means that the proper orientation of a trail depends upon its position in the sky and that only a small fraction of the trails will be useful to a given transmitter and receiver. Furthermore, because of gaseous diffusion a trail is ordinarily not useful as a reflector for more than a few seconds. These two facts, plus the fact that the average person sees ... meteors per hour at night, lead to the premature conclusion that there are not enough meteors to be of any value for communication purposes. Actually, many more than this can be seen under proper conditions, but the average person does not necessarily select his star-gazing nights for the optimum meteor-viewing conditions. Dark, cloudless nights in the country away from the background light of cities make good viewing conditions.

THE REQUIREMENT that a meteor trail have a proper orientation in order to be useful as a radio reflector can be more easily understood by thinking of the trails as long narrow mirrors and determining whether or not the transmitting site can be seen from the receiving site by reflection in the mirrors. For a reflection to occur directly above the midpoint of the transmitter-receiver path the trail must be horizontal. Reflections from trails behind the transmitter or receiver must come from trails that are very nearly vertical. Thus, the area of the sky that is the most useful for meteoric communication depends, among other things, upon the orientations of the meteor trails. A description of the distribution of trail orientations is conveniently given by the radiant distribution. The radiant of a meteor is that point among the stars on our celestial sphere from which the meteor particles appeared to have come.

Oddly enough, a knowledge of the distribution of meteor radiants is not accurately known. In fact, our knowledge of the astronomical significance of meteors is comparatively recent. Radar and radio techniques have done much to accelerate the study of meteors during the past few years. Most meteor astronomers now agree that meteor particles are a part of our solar system and that most of these particles are moving around the sun in the same sense that we are but in more highly eccentric orbits.

It seems that there may be a concentration of meteor radiants about the ecliptic

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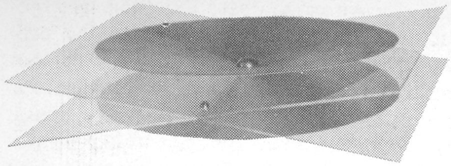

plane which is the plane defined by our earth as it revolves around the sun. The planets are concentrated near the ecliptic plane, so it does not seem unreasonable that meteor particles have a similar distribution. The radiant of a meteor is determined by its orbit around the sun and by the relative velocities of the earth and the particle at the time of the collision. Meteor particles are observed to have velocities of from 12 to 73 kilometers per second with respect to the earth.[2]

Meteor showers result when the earth encounters a large family of particles moving in parallel paths around the sun. Since they are moving in parallel paths, they all appear to radiate from the same point in the sky. That is, they all have the same radiant. There are about a dozen strong meteor showers visible on the same dates each year.

There is a considerable diurnal variation in the rate at which meteor particles strike our atmosphere. The activity is greatest at 6 A.M. and weakest at 6 P.M. This is due to our "running into" more meteors at 6 A.M. when we are near the apex of the earth's way.

METEOR RESEARCH at Georgia Tech's Engineering Experiment Station is being carried on in both theoretical and experimental veins. The work is in the Communications Branch headed by William B. Wrigley. Dr. John Taylor is the project director. One series of experiments is being conducted at 73 and 50 megacycles with transmitters at Boston, Massachusetts, and receivers at Columbia, South Carolina, and Smyrna, Georgia. One purpose of this test is to determine the amplitudes and durations of meteor signals as a function of radio frequency and time of day. Another experiment is being conducted in conjunction with the University of Tennessee with a 42 megacycle transmitter in Knoxville and the receiving equipment at Smyrna. One purpose of this test is to determine the usefulness of various areas of the sky for meteor-scatter communication.

The antennas used at Smyrna to receive the meteor-reflected signals are five and seven element Yagi arrays, similar to the Yagi antennas frequently seen in use with television receivers. The antennas used to receive the signals from Boston are fixed, but the antenna used to receive the signal from Knoxville is mounted on a rotator having three degrees of freedom so that any point of the sky can be searched.

The receivers used at Smyrna are similar to television receivers except that they have higher gain and frequency stability, and their outputs are recorded on paper tapes instead of being displayed on picture tubes.

Dr. M. L. Meeks and the author, with the help of the UNIVAC Scientific (ERA 1101) Computer in Georgia Tech's Rich Computer Center, have made several theoretical computations of the effectiveness of various sky regions to meteor-trail communication. It has been shown that when an ecliptic concentration of radiants is assumed there is a sky region of high activity and that this "hot spot" moves over a fixed path in the sky once each sidereal day. For a uniform radiant distribution there is a stationary hot spot to either side of the midpoint of the transmitter-receiver line.[3]

The property of a meteor-communication channel that makes it different from other communication channels is its intermittent character. It is possible under ideal conditions with high transmitter power to be guaranteed a continuous signal a large percentage of the time. But with non-ideal conditions, one must make the best use of the individual meteor bursts as they occur. One scheme, first suggested and tried by Canadian workers, is to store incoming information such as speech onto some storage device, such as a magnetic tape recorder, and to "fire" this information at high speed to the receiver when a properly-oriented meteor trail occurs. The receiver must be capable of accepting and storing this burst of information and then feeding it out at the normal channel rate. To determine when a properly oriented meteor trail occurs, there must be a continuously transmitted code signal that triggers the high speed transmission of information when the channel opens. This requires an auxiliary transmitter at the receiver location and an auxiliary receiver at the transmitter location.

Communications Branch Head William B. Wrigley, right, and Technician Walter Reagh outfit a trailer for use as a field site at Congaree Air Base outside of Columbia, S. C.

In the future, as our population and standard of living increase, and as technological developments continue to be made, the demand for more radio communication channels will increase. This in turn will certainly call for the maximum exploitation of the meteor trail for communication purposes.

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A MEMORANDUM

The development of new industries

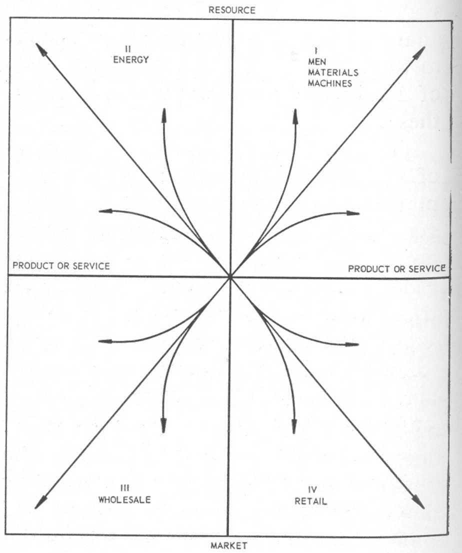
by Ernst W. Swanson, Senior Research Economist

THE LOCATION AND DEVELOPMENT of almost any industry is governed by two sets of factors. The first set comprises (a) the existence of the traditional three M's: man, materials and machines and (b) the availability of energy or power. The second set consists of (a) the nature of the retail market (reflecting consumer demand) and (b) the nature of the wholesale or intermediate market (reflecting the demand of business). The first set originates the cost and supply side of the sale of economic goods and services and the second, the demand side.

These two sets of factors are clearly interrelated and together help determine the level of economic activity enjoyed by any economic region. The first generates, through costs incurred, the income for spending and the second, through the operation of the markets, the desire for spending. Their interrelationship may be described through Graph I, the Map of Economic Activity. The dimensions of this graph are given by four sections of quadrants (called Q's) formed by the intersection at right angle of two lines. The horizontal line measures the activity entering into goods and services; the upper vertical line measures the activity entering into the use of resources, energy, and the three M's; and the lower vertical lines, the activity entering into the distribution (and the related financing) of goods and services. The distributive activity is, of course, at the intermediate (wholesale) and final (retail) levels.

In QI, men, materials and machines are brought together to produce a product or a service. The amount so produced depends upon (a) the quantities of the three M's used and the way in which they are joined together in production (the plant) and (b) the energy (QII) applied to the working of the materials through the machines by the men in control. As a rule, the greater the machines and energy applied, the greater the output and the better the use of manpower (physical and mental); and, hence, the greater the per capita income.

The activity of production moves from QI, to QII, to QIII, and finally to QIV. QIII states (a) the relationship of the flow of goods and services to the market (demand) at the intermediate level of production (of which distribution is a phase) and (b) the efficiency of this market. The market combines transportation, storage, sales promotion, finance, and product handling and packaging (when a product is involved), and it determines further the extent of flow of goods and services. Finally, the flow is into QIV, the retail market, where consumer goods and services, based upon the outputs at earlier stages of goods and services, fulfill the demands of households and governments, the two ultimate consuming units, both of which spend income to procure the goods and services.



Graph 1—Map of Economic Activity

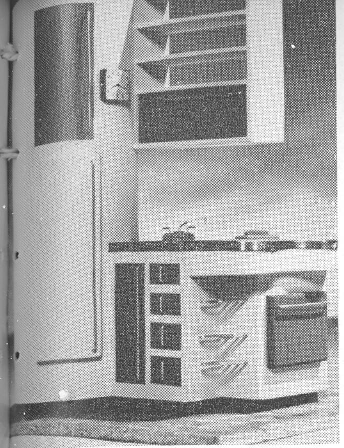
The prosperity and growth of any economic region are related to the way the four Q's of the Map of Economic Activity are organized in that region. Some regions lean more toward emphasis on the activities of QI and/or QII; others, toward QIII and/or QIV. Thus, the economic growth of the Birmingham-Gadsden region is related to QI, with some dependence on QII. The growth of the Sheffield-Tuscumbia Region along the Tennessee River is principally geared to QII, the need for energy. But Atlanta is particularly oriented toward QIII and QIV. To be emphasized is the fact that *these differences in orientation explain in no small part the differences in real income per capita of an economic region.*

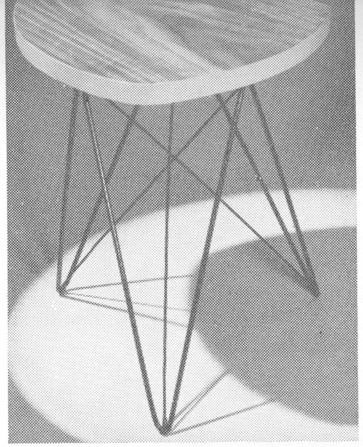
Georgia Tech's Industrial Development Branch visualizes its work in the field of economic development as comprising two closely interrelated phases of research and investigation. An industry is usually composed of several firms, and the regional economy is made up of several industries; the two elements join together to form the whole. Therefore, production structure of a regional economy must be analyzed and set in its proper perspective to the market. The two principal phases of research which accordingly arise are these:

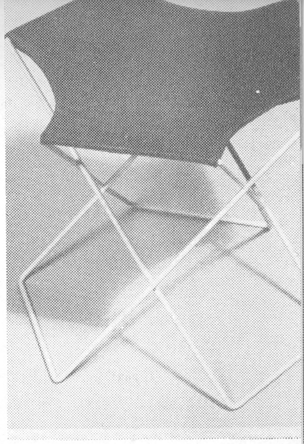
(1) The first involves the assessment of the industrial structure relative to the market to determine where, for the Georgia economic region, imports exceed exports. The industries for which exports exceed imports are termed surplus industries; those in which imports exceed are deficit industries. The best technique known today for discovering whether a surplus or a deficit exists is called input-output analysis. This method establishes the inter-industrial relationships for the national and regional economies. The input structure of industry, the cost side, states the relationship between the total output and the quantities of all the men, machines, materials, and energy which each industry buys to produce its output. The demand side is in turn given by the structure of outputs which flow to each industry or to the consumers. The relationship of the input to the output, having been found fairly stable, permits the determining of where, by regions, the surplus or deficits in outputs over demand are to be found. (2) The second phase of research is associated with the discovery of new surplus industries, those which may be developed to take advantage of special resources found within this area. To illustrate: the southern counties of Georgia possess certain nonferrous minerals which might prove to be sufficient in quantity and quality to make possible their production on a large scale at reasonable profits. Economic, geologic, and metallurgic research would, of course, be essential to determining the feasibility of ore recovery and metals processing.

Sometimes, however, the nearness of minerals (or other related materials) need not be a consideration in the promotion and development of a metals (or for that matter any other) industry. The demand for a finished metal may be growing rapidly in a certain region, to a degree which would possibly warrant the founding of furnaces and, certainly, metal working operations in that region. The size of the market alone could force the development. Other circumstances also may be attendant, however; there may be low cost transportation and power in the growing region. Or the old region from which imports come may be experiencing a fall in economy efficiency in production, a decline due to heavy industrial congestion, capable of generating such cost increases as to encourage the shift (sometimes partial, sometimes complete) of industry to a new region. Conceivably, even a steel industry could develop in a region where actually none of the raw materials is immediately available but must be brought in. Importation of these materials would thus be substituted for the importation of the finished products.

Designed by Georgia Tech students, these household items reflect the influence of industrial design in our day-to-day living.







INDUSTRIAL DESIGN AT GEORGIA TECH

by Norman Worrell, Assistant Professor
School of Architecture

INDUSTRIAL DESIGN—the appearance and use-design of products of the machine for mass consumption—deals with the development of products of industry with which man has a direct visual and physical relationship. Examples of such products include utensils, appliances, and equipment and furnishings for the home, industry, commercial and public places. According to Walter Dorwin Teague, an outstanding designer, "The word, organization, is the nearest synonym for design. Design is efficiency in (1) manufacture, (2) in performance, and (3) in use."[1]

There is a sound basis for the influence of the industrial designer in our present economy. In the industrial designer's field of endeavor, he can be of service to the manufacturer—whether he be large or small—a service company or a manufacturer of products.

background of industrial designs in U. S.

The depression gave industrial design a start in this country. In the '20's, the manufacturer's belief was that management's major problems were to hire more salesmen and to produce more products. Engineering in that age was primarily concerned with mechanics and production. A wide gap existed between engineering, sales, management and the consumer. Into this gap in our economic structure came the pioneer industrial designers—Henry Dreyfuss, Walter Dorwin Teague, Harold Van Doren, and many others—men who were able to show industry a new approach to product development which would increase its sales.

First, they recognized, along with management, that the establishment of a sound upward sales curve was now the basic management problem. Second, with business at a low point, a new approach to product development should create mass sales. The pioneer industrial designers took their ideas directly to top management. In other words, these men convinced management they could interpret the desires and needs of a consumer. In addition, they convinced management that the visual acceptance of the company product by the consumer must be a major concern in the fight to regain lost markets.

Some manufacturers immediately bought this idea. Once they were successful with it, others joined in. Today, a large percentage of all consumer goods marketed as well as a large percentage of military equipment in use is influenced by the industrial designer.

field of endeavor

Industrial design, like law, medicine, engineering and architecture, is a profession. It has gained this dignity in just one generation. The industrial designer, now a professional man in a position of trust, has only his services to sell. These services are rendered for a fee, as is the case of any professional man. All this—responsibility, service, trust—calls for imagination and creative ability, as well as integrity and judgment. The industrial designer must have an understanding of present-day manufacturing and business and know the needs, ideas and opinions of the consumer.

Today, the professional industrial designer works in applied research, development, and in the direct design of mass-produced products. He carries on his work in the profession as an employee in business and industry, through the government, as a consulting designer in private practice and as a professional educator.

role in industry

The industrial designer is playing an increasingly important role in the growth of large and small industry. Service companies and manufacturers of products use to an advantage the services of the trained industrial designer. To use effectively the skills and knowledge of the competent designer, as a consultant or as an employee, he should be made an integral part of the company responsible to management. Sound design policy permits freedom for creative endeavor integrated with the engineering, development, production and business activities and the specific needs of the company.

A brief description of the functions of the private practicing designer will be of help in defining the industrial designer's role in industry. Raymond Spilman, chairman of the Georgia Tech Industrial Design Curriculum Advisory Committee and a practicing designer, describes the major function of his own design office as: "Improving the use, safety, appearance, colors, ease of handling, cost, maintenance and materials of mass-produced products based upon the physical and mental reaction of the user of the product itself."

Since the industrial designer is primarily concerned with the appearance and use of the product from the consumer point of view, his efforts must be coordinated through all phases of the development of the product. He works in the closest cooperation with the various departments of the manufacturer's organization, such as engineering, sales, marketing and management.

In actual professional practice, the coordinated design program is set up in a planning conference with the client. The industrial designer then begins preliminary design using sketches to determine the function, form, materials, color and cost of the contemplated product. This is followed by the development of study models.

Then, the consultant designer will pretest his designs on a limited panel of representative purchasers. This indicates, in a general way, the acceptance or rejection of color, form, or functioning of a con-

continued on page 18

[1] "Industrial Design, What It is and What It Does."

templated design. The designer will tabulate and analyze these results and make design revisions to make the product meet the competition.

Market and consumer surveys are important in making a sound appraisal of proposed new design or redesign. Over 80 percent of the new products marketed since World War II that failed did so because they were not properly market-tested or merchandised. The more facts the manufacturer can give to the designer, the more effective will be his product or package.

The consultant industrial designer will evaluate a problem for a manufacturer and submit a general design program and the approximate cost of his service. If he is engaged by the prospective client, the designer is exclusively at the service of this client. During the time he is employed by the manufacturer, he will not accept any account of a competitive nature.

In addition to product design, the industrial designer can assist in giving an organization a personality that will give better identification to the company. This service includes the design of packages, labels, catalogs, business forms, stationery, showrooms, retail outlets, mobile equipment, etc.

the small company

Raymond Spilman says, "Of the several myths that surround the practice of industrial design, it seems to me that one of the most misleading is this: Industrial design is a luxury to be enjoyed only by large companies manufacturing highly competitive finished hard goods such as radios, washing machines, etc."

An increasing number of small manufacturers are using designers as one of the means of growth.

industrial design at georgia tech

As industry gained more importance in the economy of the South, the need for the industrial designer increased in all phases of manufacturing and merchandising. Consequently, it was felt that there was a substantial need for establishing an Industrial Design option at Georgia Tech. When the new architecture building was completed in 1952, Industrial Design was re-established as a separate curriculum in that school. In the summer of that year, Hin Bredendieck came from the Institute of Design in Chicago and, in a short time, worked out an approved curriculum and began to equip the design laboratory.

In the fall of 1952, the first students entered the four-year course leading to a Bachelor of Science degree.

Today, Georgia Tech is one of approximately 27 colleges, universities, technological schools and art schools that offer specialized training in industrial design. The activities of Tech's Industrial Design curriculum consist of two areas of study:

In the design course, the student begins with the analysis and design of simple objects with which he has everyday contact. Gradually, he progresses toward the solution of more and more complex design situations, including problems dealing with single objects as well as a group of related objects, interior displays, packaging, etc.

Simultaneously, in the material and technique courses, he studies the materials and processes of industry so that he will have survey of the whole field. He designs an object for each material and process, attends lectures and demonstrations dealing with the design considerations for a manufacturing process. He takes field trips to local industries and discusses with professional men technical phases of production.

To this are added subjects such as humanities, social sciences and human relations so that the design student can better understand his own work in relation to society.

Already, inquiries are coming to us for graduates to work in research and development and for consultants to work in an advisory capacity in southern industry. As industry grows in the South, an increased demand for the trained industrial designer can be anticipated.

Through its Industrial Design option, Georgia Tech hopes to be able to better serve Georgia and the South by furnishing qualified graduates to meet this anticipated increased demand.

publications

Belser, Richard B., "Electrical Resistances of Thin Metal Films Before and After Artificial Aging by Heating." Reprinted from The Journal of Applied Physics, January, 1957. Reprint 112. Gratis.

The electrical resistances of thin films of 24 metals, deposited on glass substrates (near room temperature) by evaporation, sputtering, or electroplating, have been measured before and after artificial aging by heating *in vacua*. Reductions in resistance of 25 to 50% as a result of aging were commonly noted. Evaporated films were reduced from approximately $2\rho^b$ to $1.3\rho^b$ (resistivity of the bulk metal) and sputtered films from $4\text{-}10\rho^b$ to $1.5\text{-}1.8\rho^b$. A preferred aging temperature, specific to each metal but influenced somewhat by film thickness, was noted. This temperature agreed closely with the temperature of recrystallization of the metal. Thin metal films, as usually deposited, appear to be in a state of strain not associated with the bulk metal as it crystallizes from the melt. The application of heat energy to the film promotes the removal of strains, occluded and adsorbed gas, and the growth of the crystallites of the film. These concurrent actions reduce the electrical resistance of films of 1000 A thickness to a value usually in the range 25-75% above that of the bulk metal.

Hollis, J. S. and M. W. Long, "A Luneberg Lens Scanning System." Reprinted from IRE Transactions on Antennas and Propagation, January, 1957. Reprint 114. Gratis.

A 16,000-mc scanner is described which scans a 40° azimuth sector alternately with each of two beams at a rate of 17 scans per beam per second. The beams have half-power vertical and horizontal beamwidths of 0.76° and 1.06° respectively and are separated vertically by an angle of 1.85°. Horizontal collimation of each beam is achieved by a geodesic analog of the two-dimensional Luneberg lens. The lenses feed a section of a semiparabolic cylinder for effecting vertical collimation. Feeding the lenses is a switching system, consisting of two four-way turnstile waveguide switches and a waveguide chopper switch, which gives a scan-time dead-time radio of 8:1.

Fulmer, John L. and Ernst W. Swanson, "Georgia's New Frontiers," a chartbook. Special Report No. 30. Gratis.

This chartbook is designed to present facts on Georgia's industrial development and to indicate avenues of research required to further its growth. The progress achieved to date, the characteristics of the industrialization pattern, the factors hindering development and the conditions determining future growth are shown. The opportunities and prospects for the future are also presented.

Kethley, T. W., W. B. Cown and E. L. Fincher, "The Nature and Composition of Experimental Bacterial Aerosols." Reprinted from Applied Microbiology, January 1957. Reprint 115. Gratis.

A chamber suitable for the study of the nature of bacterial aerosols is described, and supporting data presented to justify the use of the chamber for this purpose. Results of studies on bacterial aerosols dispersed from pure water, glycerol-water, beef extract broth, and beef extract broth with added sodium chloride show that the character of the bacterial aerosols is determined by the composition of the dispersion medium. Cells dispersed from pure water form particles essentially devoid of nonliving materials. In all other instances, the particles are almost entirely made up of the residual material from the dispersion medium. the cell being a negligible part of the particle. Observed and calculated particle sizes were found to be in good agreement when the calculations were made on the basis of the volume of the original atomized droplet, the concentration of solids or low vapor pressure liquids in the dispersion media, and their responses to relative humidity.

These and other technical publications may be obtained, and the complete publications list requested, by writing Publications Services, Engineering Experiment Station, Georgia Institute of Technology, Atlanta 13, Georgia.

edited in retrospect

the record makers

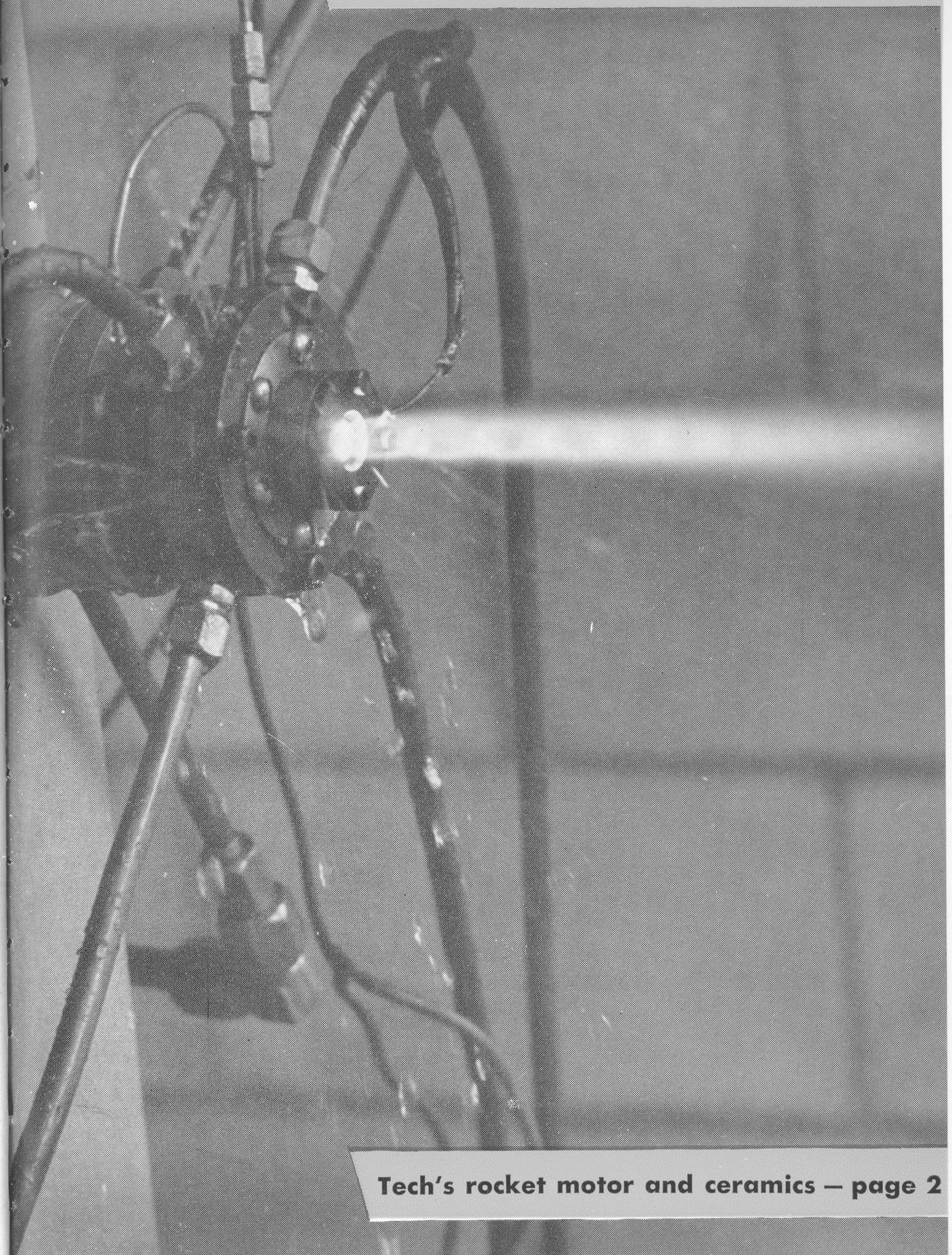
• At the American Ceramic Society meeting in Dallas, Texas, this May, Georgia Tech ceramic engineering students took three of the four prizes offered by the Ferro Corp. of Cleveland, Ohio, in its annual National Student Contest in Porcelain Enameling. It was the first time in the 8-year history of the contest—open to ceramic students throughout the country—that any one school has walked off with three of these awards.

First prize of $500 went to 1956 Tech graduate Henry P. Still, Jr., for his paper on "A study of the oxidation of steel plate as related to the wettability and adherence of porcelain enamel." Second prize of $300 was awarded to 1957 Tech graduate Edward L. Bradley for his paper, "An investigation of some problems encountered during efforts to heat harden and ceramic coat #420 stainless steel." After a University of Illinois student broke the monotony by taking third prize, 1957 Tech graduate James F. Benzel received fourth prize of $50 for his paper, "Groundwork on ground coat hairlines." The three papers were the only ones entered by Tech students this year.

Research Engineer J. D. Walton, head of the ceramics research group at the Georgia Tech Engineering Experiment Station, was the only other Tech man to ever win first prize in this contest. Mr. Walton was the winner in the first Ferro contest in 1950. His top assistant, Nick E. Poulos, was the second-place winner in 1952. All three of the 1957 Tech award winners worked with Mr. Walton's group while students at Tech. Mr. Still and Mr. Bradley used a phase of their work at the Station as the subject for their entries in the contest. This is just another example of how Georgia Tech's research organization aids in the proper education of engineers and scientists.

The October issue of this magazine will be devoted in its entirety to the work of the ceramics group at Georgia Tech. We think that you will be surprised at the volume and variety of the work now going on at Tech in this field.

engineer OCT. 1957
Georgia Tech Engineering Experiment Station



Tech's rocket motor and ceramics — page 2