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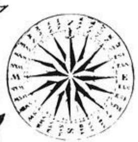
NOVEMBER 1966

wisconsin engineer

WISCONSINS OAO-A UFO?

Go Westinghouse, Young Man!

A modern fable with technical overtones



Once there was a young college senior named Jack who wanted desperately to climb the beanstalk of success, facing the kind of challenges his forefathers faced on the frontiers of early America.

But Jack wasn't sure which kind of beanstalk he wanted to climb.

His mother wanted him to take a job at the local store so he'd be close to home.

His friends urged him to join a protest movement.

His professors wanted him to go on to graduate school.

Then Jack met a Mr. Greeley from Westinghouse. Mr. Greeley was a recruiter of college students. He was a kindly man with a warm smile, and he explained how Jack could get an advanced tuition-free degree while working at Westinghouse.

Mr. Greeley also explained that Westinghouse, being a giant organization, was in a much better position than most to undertake projects that would benefit the less fortunate peoples of the world.

Mr. Greeley's advice was:

"Go Westinghouse, young man!"

And Jack did.

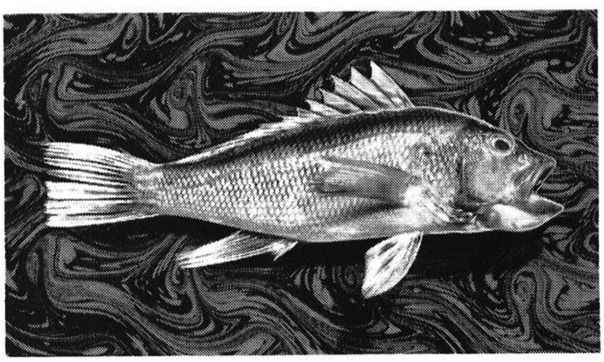
Given a choice of six large operating groups* within Westinghouse, Jack elected to join the Atomic, Defense and Space Group and was promptly assigned to work on an oceanographic project.

A fast learner, Jack took root quickly, reassuring his graying but still pleasant-faced mother, "Don't worry, Mom, I'm on my way to the top."

Though officially a trainee, Jack was a big help in the development of *Deepstar*—a Jules Verne-like underseas vehicle designed to explore the ocean depths. One of *Deepstar's* many missions was to search for food sources to meet the growing needs of a hungry world.

The project was an enormous success; Jack's management was delighted.

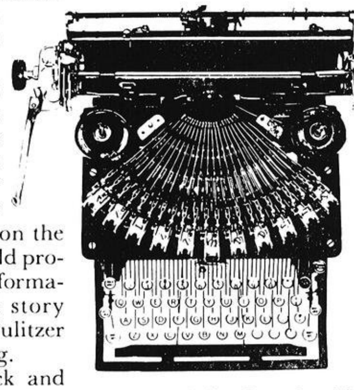
But before a grateful UNESCO could honor him publicly, Jack obtained a transfer to one of the many space projects Westinghouse coordinates.



Jack's assignment: help develop a rendezvous system for Gemini capsules.

To the news publications of the nation, this was the story of the year. In fact, one of the big syndicates assigned their most beautiful, technically oriented woman reporter to get an exclusive story from Jack . . . at any cost.

One night while returning from work . . . Jack was accosted by the beautiful young newswoman, who suggested that Jack give her an exclusive bylined story describing the project in detail.



Though taken aback by her beauty, Jack never lost sight of his duty. He pleaded with the reporter to hold her story until after the launching. She agreed on the condition that Jack would provide her with enough information for a subsequent story that would win her a Pulitzer Prize for news reporting.

The pressure on Jack and his closely knit engineering team tightened. By day, they'd work on the space guidance system; by night, Jack would feed background information to the beautiful, technically oriented reporter. It was hard work, but it was important work.

Finally the day arrived for which the world had long waited. America's two capsules rendezvoused successfully. Mankind was now assured of a stairway to the stars.

While television-viewing millions rejoiced, Jack was as good as his word, offering the beautiful lady reporter the story she wanted so badly.

However, the girl, now smitten with Jack, turned her back on the Pulitzer Prize, preferring instead to join Westinghouse, attend its Advanced Education School and obtain a degree in engineering. (Women are welcome at Westinghouse, an equal opportunity employer.)

Now they both work at Westinghouse—while Jack designs atomic reactors for America's newest missile-firing submarines, his beautiful ex-reporter wife, an education specialist, helps train Peace Corps volunteers for overseas duty—and they're only a bean's throw from the neat white cottage they share with his mother.

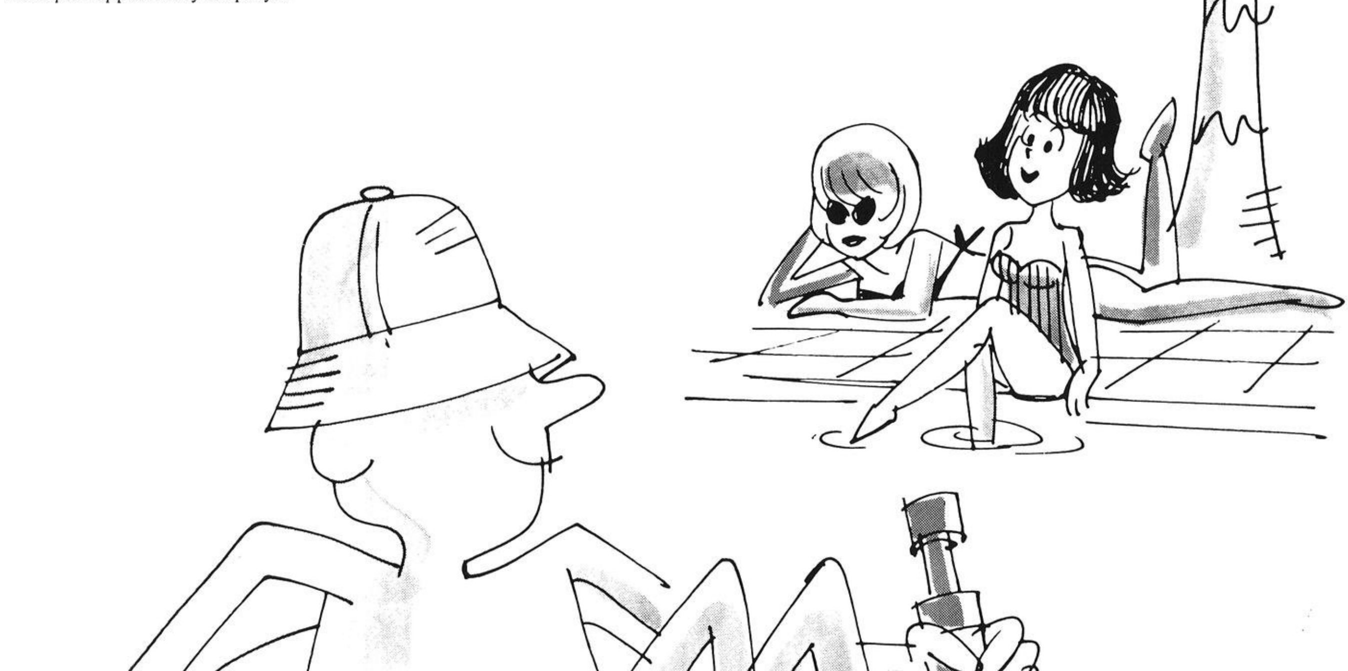
And they all lived happily ever after.

Moral: By planting your career seeds with Westinghouse, you, too, can climb the beanstalk of success, overcoming giant obstacles and earning a lot of golden rewards.

You can be sure if it's Westinghouse

For further information, contact the Mr. Greeley from Westinghouse who will be visiting your campus during the next few weeks or write: L. H. Noggle, Westinghouse Educational Center, Pittsburgh, Pennsylvania 15221.

*The Westinghouse Operating Groups: Consumer Products; Industrial; Construction; Electronic Components & Specialty Products; Atomic, Defense & Space; Electric Utility.



MARTY MURPHY

COVER STORY

ARTICLES

FEATURES

wisconsin engineer

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THE 'AYES' HAVE IT

I've always wanted to open a column with "Well, sports fans . . .", but considering Wisconsin's record lately, it would seem somewhat inappropriate. Oh well, maybe our Rugby team will make it this year.

The main purpose in my scratchings (editorial) this month is to let you know something about this year's annual convention. You may not realize it, but *The Wisconsin Engineer* is privileged to belong to ECMA (Engineering College Magazines Associated), a national organization of some 50 college magazines. Every year one of the member schools holds the national convention, which is sort of a giant business meeting and a giant party combined.

The convention this year was given by Drexel, in Philadelphia. Four of our staff, Gerry Melotke, Dick Friede, Abby Trueblood, and myself left on Wednesday night, October eighth, via Northwest Airlines. Arriving in Philly, we obtained a yellow Mustang and proceeded to the hotel. Unfortunately, we got a little lost and made it to the Sheraton via New Jersey. But undaunted, we had a small staff meeting in the hotel lounge and ventured back into the streets of the city for a wild night. (Everything closed at 12:00)

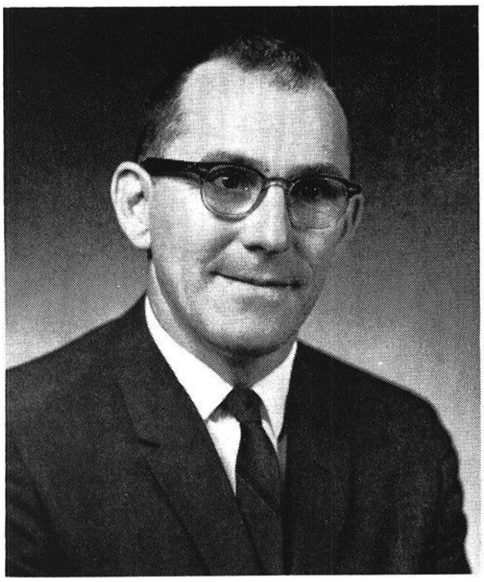
Thursday was the actual start of the convention, and Wisconsin was a staunch member of the membership committee. We are pleased to announce that Rice, San Diego, Texas U., Brigham Young, and Wyoming are now associate members of ECMA. Thursday night saw the staff at G.E.'s research center, viewing the room where they built the Nimbus, and learning how they test space vehicles for "in-space" operation. After dinner at G.E., we returned to the Sheraton hotel for an extended social hour. It is interesting to note that it was at this very party that a long-standing feud between the *Minnesota Technolog* and the *Wisconsin Engineer* was settled.

Friday afternoon, the convention was continued on a Showboat for luncheon with the critic and a trip up the Delaware river. Friday night found us at Kuegler's restaurant for the annual awards banquet. Unfortunately, due to a small staff error last spring, Wisconsin didn't win anything, but we plan to take the top honors next year. Later Friday, Drexel threw a happy hour which was continued around 2:00 A.M. in Wisconsin's rooms. Needless to say, the big business meeting on Saturday morning came entirely too early!

But we're glad to say that Wisconsin made it in body, and mostly in mind. The biggest decision of the day was that the convention was a huge success.

An interesting point came up in the general discussion in Philadelphia. What should be the aim of an engineering magazine on a campus such as ours? Should we publish a magazine for the upperclassman who can appreciate a highly technical article, or should we strive to make each magazine of interest to the majority of people interested in science. In other words, should anyone on campus be able to pick up a copy of the *Wisconsin Engineer* and enjoy reading it? We honestly can't answer that question by ourselves, so we're asking—What do you, the readers, want to see more of in your magazine? Please drop us a note via campus mail and let us know what *you* think.

Mary E. Ingeman



FROM THE DEAN'S DESK

It is pleasant to have this opportunity to say a few words to the readers of the Wisconsin Engineer, on behalf of myself and the staff of the Engineering Freshman Office.

First, let me introduce the staff. Besides myself, there are Mrs. Lois B. Greenfield, Assistant Professor of Engineering Education and Mr. Richard S. Hosman, Assistant to the Dean. Professor Donald F. Livermore of Mechanical Engineering and Professor John B. Miller of Electrical Engineering are available to assist during registration week and the six weeks grade conferences. Mrs. Doris Mita, Administrative Assistant, Mrs. Orla Erickson, Secretary, and Mrs. Charlotte Mathews, Secretary, all make real contributions to the smooth running and effectiveness of our operation.

Although we are new as a team, we are not inexperienced as individuals. Mrs. Greenfield has been associated with us since 1956 and has her doctorate in Educational Psychology. Mr. Hosman, formely Colonel Hosman, now retired, last year was Commandant of the University of Wisconsin Department of Air Force Aerospace Studies, and has an MA degree in Educational Psychology. Professors Livermore and Miller have had advising experience in the Mechanical and Electrical Engineering departments, and are with us because of their interest in and experience with undergraduate students.

We have set certain goals for the relationship we would like to maintain with the student body. Stated simply, we would like to be known as a group of friendly, understanding people who are available to engineering freshmen, to prospective engineering freshmen, to their parents, and to high school counselors, to provide accurate information and wise counsel. We are a student service facility of the College of Engineering, and are therefore dedicated to assisting engineering freshmen to become engineering sophomores, and eventually successful engineers. More importantly, we are concerned with engineering freshmen as individuals. We would like to help them to become engineers if that is their aptitude, but we will be pleased to guide them to a successful start in another field if that is their aptitude.

We are not unmindful of the traditions of our office, and are aware that we are carrying on and expanding traditions of service that started under the direction of the late Dean A. V. Miller and Miss Mary O'Keefe, and more recently were continued by Dean K. G. Shiels. Our job is made easier by the fact that freshman engineering students from generations back have pleasant memories of the Engineering Freshman Office. Among students who have used the facilities of this office are pioneer aviator

Charles A. Lindbergh, Jr. (freshman class of 1920–21), pioneer astronaut James A. Lovell (freshman class of 1946–47), and many persons prominent in varied fields of engineering and other endeavors today. One of the satisfactions of being a part of the operation of this office comes in meditating that the students in this year's class will be the leaders of tomorrow.

We are assisted by many people demonstrating a sense of responsibility and dedication that is wonderful to behold. One such group is the student membership of the Tau Beta Pi honorary fraternity, under the direction of Educational Chairman Richard Argue, EE 4, who unselfishly man Room 11 in Building T-24 each Tuesday and Thursday evening to tutor those freshmen who are having difficulty in mathematics, chemistry, and engineering graphics, and during the second semester, physics. Another such group is the Student Committee for Public Relations in the College of Engineering, under the Presidency of Elric Saaske, NE 3, who voluntarily carry "the engineering story" back to their high schools. Still another group consists of busy and loyal faculty and practicing engineers who give of their time and energy to such important activities as Freshman Lectures, high school career days, and high school visits.

We are also pleased that we are a part of the greater university administration that stresses the value of student services. We have many excellent service groups to which we can refer students, such as the Student Counseling Center, Student Financial Aids Office, Student Health, Student Psychiatry, Office of High School Relations, Residence Halls, and others.

We have very strong beliefs about freshmen that we voice at every opportunity. One is that freshmen are very special people, with problems peculiar only to themselves, and quite unlike others in their needs for understanding and approval and guidance. They are in the greatest period of change in their lives, far removed from being high school seniors, but still far less sophisticated than college sophomores. Freshmen know that their opportunities are unlimited; the very thought of these opportunities, new found freedoms and associated responsibilities, mingled perhaps with a touch of homesickness, frightens them. Since they are special people, they need a special kind of attention.

I would close with a word directed to those students for whom the Engineering Freshman office exists. We wouldn't want you to think that we can do the job of learning for you. We have no method by which we can drill a hole in the top of your head, put in a funnel, and pour the knowledge in. We have no information on "How to Succeed in College Without Really Trying." (You can't!) We do believe that most of you that aren't afraid of hard work and are willing to apply personal discipline to your lives can succeed in some field at college and in life. Hopefully, this would be in engineering, but whatever it is, won't you let us be on your side? We want to help, and we think we can.

What can we do for you? We can show you the regulations that inform you of what you are permitted to do and what you cannot do, and interpret them for you. Occasionally, if in my judgment, the regulation is unjust to you, I can and do modify it. We can enlarge upon course descriptions, assist you with preparing your study list, and advise you about adding or dropping courses to accommodate your situation. We can refer you to student service organizations already mentioned for help with your finances, or with your health (and this includes both physical and mental). We can speak for you if you feel that somewhere on campus you are being dealt with unfairly (which doesn't happen often, but could). We can be on your side if you get into trouble. We can be good listeners when you are homesick and want to talk about it. We want to be your first faculty friend, and we can be if you will take the initiative to come in and let us know how and where we can help.

Fred O. Leidel, *Assistant Dean*

HOWARD HUGHES DOCTORAL FELLOWSHIPS. Applications for the Howard Hughes Doctoral Fellowships in engineering, physics, or mathematics are now available for the academic year beginning in Autumn 1967.

The program offers the qualified candidate an outstanding opportunity for study and research at a selected university, plus professional industrial summer experience at a Hughes facility. Each Doctoral Fellowship includes tuition, books and thesis preparation expenses, plus stipend ranging from $2,200 to $3,100, depending upon the Program year and the number of candidate's dependents. Full salary is paid the Fellow during his summer work at Hughes. Salaries are reviewed periodically and increased with the growth of the individual. Fellowships are awarded to outstanding students who have completed a master's degree (or equivalent) and have been accepted as a candidate for the doctoral degree.

HUGHES MASTERS FELLOWSHIPS. Approximately 100 new awards for '67-'68 are available to qualified applicants with a baccalaureate degree in engineering, mathematics or physics. Most of these awards are Work-Study Fellowships; a very limited number are Full-Study. Upon completion of the Masters Program, Fellows are eligible to apply for and are given special consideration for a Hughes Doctoral Fellowship.

Fellows who associate with a Company facility in the Los Angeles area usually attend the University of Southern California or the University of California, Los Angeles. Tuition, books and other academic expenses are paid by the Company, plus a stipend ranging from $500 to $850 for the academic year. A significant advantage offered by the Work-Study Program is the opportunity to acquire professional experience working with highly competent engineers and scientists while pursuing the M.S. degree. Selected Fellows have the option to work in several different assignments during the Fellowship period to help them decide on their field of concentration and optimum work assignment.

Fellows earn full salary during the summer and pro-rata salary for 24 hours work a week during the academic year. The combined salary and stipend enables Fellow to enjoy an income in excess of $6,500 per year during his two years as a Work-Study Fellow. Salaries are increased commensurate with professional growth and Fellows are eligible for regular Company benefits.

Work assignments are matched closely to the Fellow's interests. Primary emphasis at Hughes is research and development in the field of electronics for application to defense systems and space technology. Fields of interest include stability and trajectory analysis, energy conversion, structural design and analysis — computer and reliability technology, circuit and information theory, plasma electronics, microminiaturization, and human factor analysis — research, development and product design on such devices as parametric amplifiers, masers and lasers, microwave tubes, antenna arrays, electron-tube and solid-state displays, and components — design analysis, integration and testing of space and airborne missile and vehicle systems, infrared search and tracking systems, and computer, data processing and display systems — theoretical and experimental work in solid-state and ion physics.

Citizenship: American citizenship and eligibility for security clearance are required.

Closing date for all applications: Early application is advisable. All materials should be postmarked not later than February 1 for the Doctoral Fellowships, and March 1 for the Masters Fellowships.

How to apply: To apply for either the Doctoral or Masters Fellowship, write to: Mr. James C. Cox, Manager, Personnel Administration — Corporate Industrial Relations, Hughes Aircraft Company, P.O. Box 90515, Los Angeles, California 90009.

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Hughes Fellowship Programs

BOOM-ZOOM

(space nuclear propulsion)

by: Jay H. Bradford

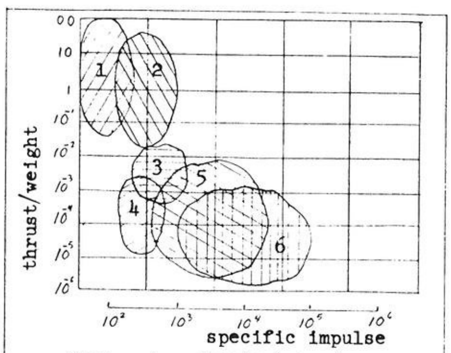
IN THE field of space technology, as perhaps in no other field, heavy emphasis must of necessity be placed upon anticipation of future needs and extensive research and development programs to supply these needs when the occasion arises. This is the result of the long lead times (often 10 to 15 years) encountered, which in turn are the result of the complexity of technology and cost of development required. It is essential, then, that future needs be identified well in advance of their realization.

Future Missions

In the next thirty years of space exploration it appears that missions will fall into one of three broad categories: earth-orbital missions, lunar missions, and interplanetary missions. The earth-orbital mission category has already been encountered in such programs as Mercury and Gemini, as well as numerous satellite launchings, and is well illustrated by these activities. The first lunar mission, Apollo, is not scheduled for another three years, but development of equipment and techniques is already well under way, and actual launchings of Apollo spacecraft will occur within a year. Other future lunar missions could take the form of exploration of the lunar surface or the establishment of either permanent or temporary manned installations on the lunar surface. Interplanetary missions have also been encountered in the form of unmanned planetary probes, such as Mariner, but such missions as manned flybys of Mars and Venus, actual landings upon planetary surfaces, and deep space missions are still in the stage of speculation.

Propulsion System Requirements

The requirements for a space propulsion system depend, naturally, on the type of mission envisioned for the system. The earth-orbital mission demands a high level of thrust for a relatively short period of time. Further, the system must not contaminate the atmosphere as it ascends from launching. The lunar mission also demands high thrust, since the gravitational fields of the Earth and the Moon must be combatted, but here longer duration is required because of the greater distances to be covered. Finally, the interplanetary mission demands long duration, but not necessarily high thrust. If the mission consists only of a flyby from a start in earth orbit, thrust levels need not be high, just constant. If descent to a planetary surface is envisioned, at least one stage of the vehicle used must produce relatively high thrust for a short period. Fig. 1 illustrates the various applications for different levels of thrust produced by propulsion systems.



Key: 1 chemical engines
2 nuclear engines
3 solar heat engines
4 isotope engines
5 arc plasma engines
6 ion & magneto-plasma engines

Fig. 1—Impulse-Thrust Relations

Another index of the performance of a propulsion system is the specific impulse, or pounds of thrust per pounds of fuel consumed per second. The chemical rocket appears to be limited to a specific impulse of approximately 400 to 450 seconds. Ralph S. Cooper estimates that a system producing a specific impulse of from 1100 to 1500 seconds would be valuable as a single stage reusable earth-orbital vehicle and that a system developing a specific impulse of from 2000 to 3000 seconds would provide valuable capability for interplanetary flight. These, then, are the criteria for propulsion systems of the future.

The Solid-Core Nuclear Engine

The solid-core nuclear heat-exchange rocket engine is the oldest of the several concepts for nuclear space propulsion. The present developmental version of the solid-core engine, the NERVA engine (Nuclear Energy Rocket Vehicle Application), traces its history back to early feasibility studies conducted by the United States in 1946. These studies led to the establishment, in 1950, of the joint Aircraft Nuclear Propulsion program (ANP), which spent the next decade gathering data on reactors, shielding, and engines. The major emphasis of the ANP was on manned-aircraft-nuclear-propulsion systems, but in 1961 it was decided that these systems were not of immediate value, and the ANP was cancelled and the emphasis shifted to the development of nuclear-propulsion systems for rockets. This led to Project Rover, which was designed to test reactors and demonstrate the feasibility of nuclear rocket propulsion. This has given way to NERVA, which

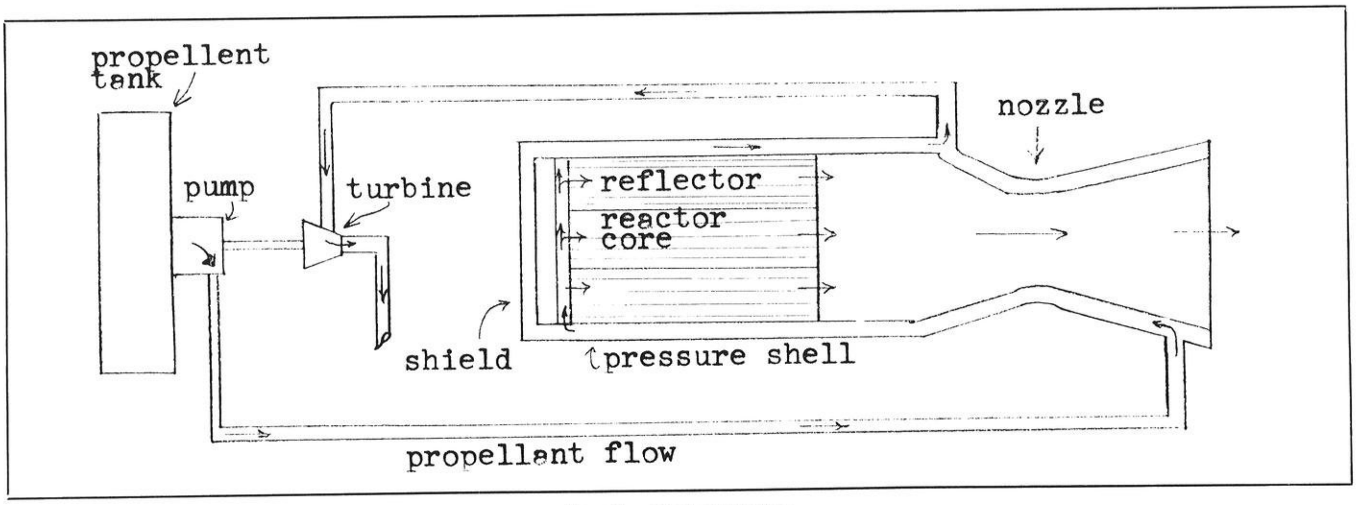


Fig. 2.—Nuclear Engine

is designed to develop a practical nuclear rocket.

Principle of Operation of Solid-Core Nuclear Engine

Reactor. The basic principle behind the nuclear rocket engine is the substitution of the heat from nuclear fission for heat produced by combustion and to use this heat to impart a high velocity to the propellent. In order to heat the propellent, it is obviously necessary that the propellent pass through the reactor. In the NERVA engine —Fig. 2—this is accomplished by employing a solid-core reactor perforated with passages through which the propellent flows and is heated. The reactor uses either graphite or uranium oxide.

Propellant. The nuclear engine operates with hydrogen, H_2, as its propellant. The chief advantage of this propellant is its low molecular weight of two. The significance of the molecular weight of the propellant is its effect upon the specific impulse produced. It can be shown that

$$I_{sp} = \sqrt{\frac{2\ \delta}{\delta - 1}\ \frac{RT}{g}}\sqrt{\frac{1}{M}}$$

where

I_{ps} = specific impulse (seconds),
δ = ratio of specific heats,
R = specific gas constant (foot-pounds force per pound mass degree Rankine),
T = temperature (degrees Rankine,
g = gravitational acceleration (feet per second per second),
and
M = molecular weight of propellant.

Here it is important to note that the specific impluse is inversely proportional to the molecular weight of the propellant. In order to maximize the specific impulse, then, it is necessary to obtain a propellant with as low a molecular weight as possible. This propellant is hydrogen.

Operating Characteristics of the Solid-Core Nuclear Engine

Performance. The present version of the NERVA engine was tested in February, 1966 and delivered a nominal thrust of 55,000 pounds with a specific impluse of approximately 800 seconds, or more than twice the specific impulse of a chemical system. The version under test used a reactor designed to deliver 1100 megawatts of power, and by 1967 it is hoped to test reactors delivering 4000 to 5000 megawatts of power.

Applications. Since NERVA's exhaust is radioactive, the engine would not be suitable for extensive use in the atmosphere of the Earth, but the engine would be well suited for use as an upper stage for the Saturn V chemical rocket, and it is expected that this will extend the useful life of the Saturn for many years. H. B. Finger estimates that by using a nuclear third stage on the Saturn, it would be possible to increase the payload landed on the Moon from 45% to 75%. Howard B. Schmidt agrees, estimating that the Saturn V/S-N nuclear version of the Saturn could deposit 140,000 pounds on the Moon and return 17,000 pounds to Earth, as compared to the conventional Saturn V/S-IVB, which could deposit 93,000 pounds and return only 8000 pounds. Fig. 3 illustrates the potential increase in lunar mission capability. However, the solid-core engine would not be limited to lunar missions alone. Finger predicts that its primary application will be manned planetary exploration, since the weight required in orbit for a specific mission can be nearly 10^6 pounds less for a nuclear system, as opposed to a chemical system. Also, the higher specific impulse would mean that correspondingly greater payloads could be delivered by the nuclear system.

Limitations. The primary limitation of the solid-core nuclear engine is temperature. The peak temperature to which the propellant can be heated determines the degree to which the propellant can be accelerated, thus, it determines the thrust and specific impluse. This peak temperature, in turn, depends upon the temperature which can be tolerated by the solid materials in the reactor, and this is a relatively set value, since the types of materials which can be used in reactors are limited. Cooper estimates that with future improvements in design, afterheaters, and carbide or metal fuels, the specific impluse of the solid-core nuclear engine could be raised to about 1000 seconds. Thus, although it offers much better performance than present chemical systems in use, the solid-core nuclear engine is also limited in its potential performance. Since it would be desirable to develop a propulsion system with significantly higher specific impulse, other, more advanced concepts for propulsion systems are clearly called for.

The Liquid-Core Nuclear Engine

The first step beyond the basic solid-core heat exchanger is the liquid-core engine, which offers a potentially large gain in specific impulse with relatively little increase in engineering complexity. Still in the theoretical stage, no actual experimentation has been done on this concept, but the great amount of theoretical investigation of this concept being carried on indicates that it would be a useful system to develop.

Principle of Operation of Liquid-Core Nuclear Engine

In the reactor of the liquid-core nuclear engine, the reactor fuel is allowed to become molten. It is contained in a drum which is rotated.—Fig. 4—so that the centrifugal force exerted on the fuel causes it to form a layer along the surface of the drum. The propellant is forced through holes in the drum and flows radially inward to the center of the drum then exists axially to the rear through a nozzle. Again, hydrogen propellant is employed in order to optimize specific impulse. In most versions, several rotating fuel drums are employed, rather than a single rotating drum, in order to improve performance.

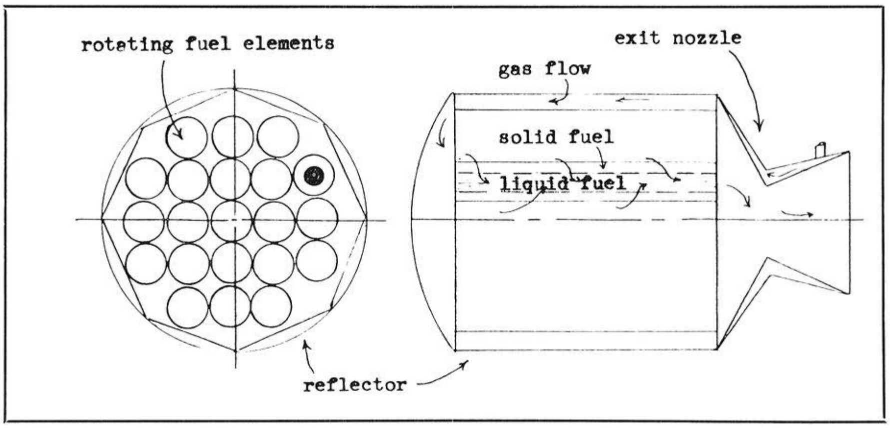


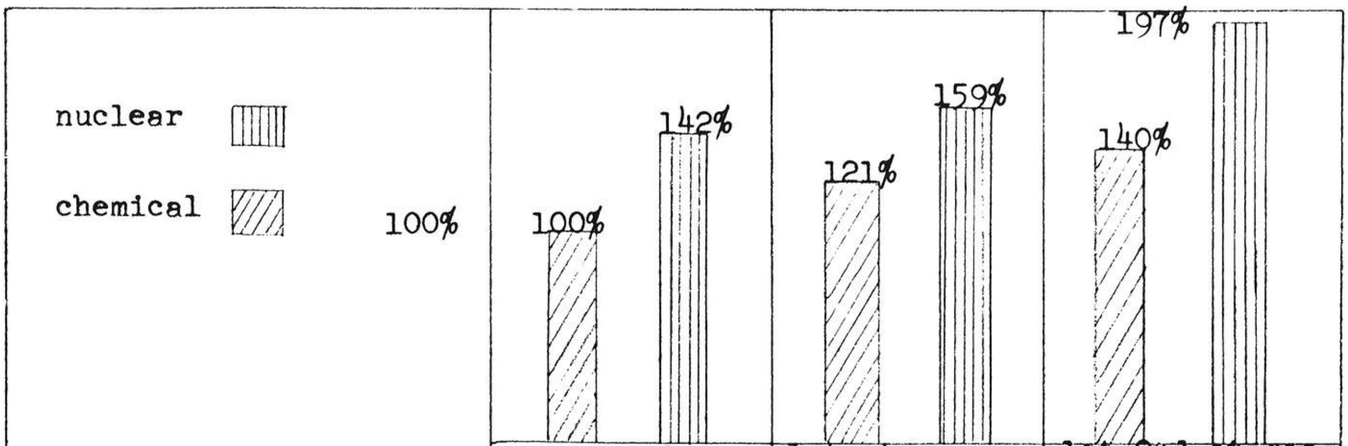
Fig. 4—Liquid-Core Nuclear Engine Reactor

Operating Characteristics of the Liquid-Core Nuclear Engine

Performance. With the basic configuration of the liquid-core engine, i.e. a single cell core and uranium carbide fuel in the reactor, the specific impulse appears to be limited to about 1200 seconds, significantly higher than the specific impulse of the solid-core nuclear engine. Use of a multicelled core and dilution of the fuel with zirconium carbide, in order to reduce vapor pressure, appears to allow a specific impulse of approximately 1500 seconds to be obtained.

Limitations. The chief problem in obtaining high specific impulse in the liquid-core nuclear engine is the vapor pressure in the core. Experimentation has shown that below a certain core temperature, vapor pressure has almost no effect upon specific impulse, but that above that temperature, vapor pressure becomes the dominant factor in determining specific impulse. It has been noted that when the fuel's partial pressure becomes even a small fraction of the core pressure, there is a rapid drop in specific impulse. The pressure is, of course, directly proportional to the temperature in the core. When the temperature passes the boiling point, however, the specific impulse again begins to climb with increasing temperature. Much more data is needed in this area, however, before truly authoritative conclusions may be drawn.

Another limitation is that of thrust; the result of the theoretical limitation on the flow rate of propellant bubbles through the liquid



	current Saturn V	1st stage up rated	1st,2nd stages rated
weight (10^5) lb.	6.0	7.2	7.2
stage 1 thrust (10.0^6)	7.5	9.0	9.0
stage 2 thrust (10.0^6)	1.0	1.0	1.5

Fig. 3—Lunar Mission Capability

fuel (10^3 smaller than through solid fuel). This would make the use of the liquid core nuclear engine confined to regions of relatively low gravitational force, where high levels of thrust are not essential.

Applications. With the expected levels of specific impulse, it appears that the liquid-core nuclear engine will find use in Earth-orbital missions as a single-stage, reusable vehicle. Radioactive exhaust, the result of inevitable fuel leakage, could again be a problem in this area, though. Lunar and interplanetary missions hold possible opportunities for the liquid-core nuclear engine, but much more work must be done on this concept before specific levels of performance can truly be determined. This, in turn, necessitates confining possible applications to the purely speculative level.

The Gaseous-Core Nuclear Engine

Previously, the solid-core heat-exchanger rocket engine had been considered. The next logical step beyond that concept was the liquid-core nuclear engine, in which reactor core fuel was allowed to become molten. The culmination of this trend is, obviously, the gaseous-core nuclear engine. Unlike the liquid-core engine, however, some work is presently being done by the United States Government upon the gaseous-core concept, but the amount of funds allocated for this project is less than 1% of the total annual nuclear rocket budget. Despite this official lack of effort, the gaseous-core nuclear engine does have distinct advantages and is the logical step beyond the liquid-core nuclear engine.

Principle of Operation of Gaseous-Core Nuclear Engine

The gaseous-core engine, shown in Fig. 5, features a nuclear cavity with sloping sides. Two electrodes are present, the inner and the outer, the latter being insulated from the walls. The electrodes produce an electric field inside the cavity as shown, while a solenoid provides an exactly opposed magnetic field. The solenoid is combined with a reflector to form the walls of the cavity. The hydrogen propellant flows through the outer electrodes and uranium fuel radially into the center of the core. Energy is transferred to the hydrogen from the fissioning uranium, and some of the hydrogen is gradually dissociated, forming a plasma with the uranium. The interaction of the magnetic and electric fields produces a tangential force (Lorentz force) on the plasma, causing it to spin in the cavity and thus inducing the plasma to remain in a layer around the walls. The hydrogen passes to the center of the core and exits axially to the rear through a thrust nozzle.

Operating Characteristics of the Gaseous-Core Nuclear Engine

Performance. The hydrogen passing through the exhaust nozzle of the gaseous-core nuclear engine is of relatively high pressure, thus the nozzle accelerates it to high velocity, producing high thrust. It is estimated that specific impulses on the order of 2000 to 3000 seconds could be attained, along with a desireably high thrust/weight ratio. Table I illustrates the performance of a typical system.

Limitations. The gaseous-core concept suffers from many specific types of limitations, chief of which are flow separation and temperature levels. Accompanying and underlying all of the limitations is the general problem of engineering complexity, since the fabrication of the gaseous-core engine would be no small task in itself.

The maintenance of a smooth layer of plasma in the reactor cavity, with minimal mixing of the reactor fuel and propellant, is both essential and difficult to ensure. Should any turbulence occur in the flow, mixing of the fuel and hydrogen propellant would significantly increase, thus causing fuel to be lost with the escaping exhaust. When it is considered that hydrogen costs approximately $0.50 per pound and uranium $5000 per pound, the undesirability of fuel loss becomes readily apparent. Further, the loss of fuel brings about the necessity of a larger critical mass for the reactor. Since it has been shown that operating pressures within the cavity are directly proportional to the critical mass, the operating pressure would thus increase. The problem here is that even with minimal critical mass, the operating pressures required (on the order of 500 psi) are already beyond the present state of the art in large pressure shells, pumps, and other components. Cooper estimates that a separation ratio (ratio of propellant to fuel in the exhaust) of at least 1000 would be required for an earth-orbital mission to provide reasonably economic transportation.

Another problem, one which plagued both the solid- and liquid-core nuclear engines, was that of temperature levels. The temperature levels in a high-performance gaseous-core nuclear engine would be high, as in the other concepts.

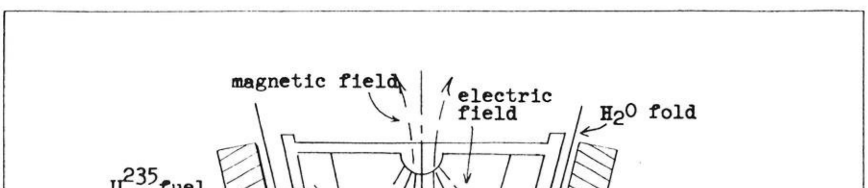


Fig. 5—Gaseous-Core Nuclear Engine

Reactor volume	10.7 m^3
Mass U^{235} fuel	15 kg
Reactor total power	1.21 x 10^6 kw
Reactor radius	1.0 m
Radial electric current	348 amp
Magnetic field	10^4 gauss
Thrust	16,900 lb
Average H_2/U particle ratio	108

(Courtesy R. A. Gross)

Table I. Specifications for and Performance of a Gaseous-Core Nuclear Engine.

The primary difficulty here, of course, is the protection of the solid walls of the cavity, and this is the task of the reflector, whose job it is to reflect heat radiated from the cavity back into the center of the core. Another heating problem is encountered here, in the form of energy imparted to the cavity walls by nuclear radiation, specifically in the form of neutrons and gamma rays. The energy deposited by nuclear radiation can amount to up to 10% of the total fission energy produced. For a specified material, then, only ten times the amount of energy which can be safely absorbed by the material can be produced in the core, thus limiting performance. A solution to this problem is to increase the opacity of the hydrogen propellant to radiation. Within the general operating temperature ranges, hydrogen is relatively transparent to radiation, but its opacity can be noticeably increased by seeding the propellant with various materials, specifically carbon particles and refractory metals. The carbon particles, however, tend to react chemically with the hydrogen, and the refractory metals are usable at higher temperatures because of their higher boiling points. This solution, while feasible in principle, presents considerable difficulty in its engineering aspects, particularly in achieving uniform dispersion of seeding particles in the propellant on a large scale. Much more work needs to be done on this and other problems facing the gaseous-core concept.

Applications. The very high levels of specific impulse and thrust/weight ratio make the gaseous-core nuclear engine ideally suitable for the long range interplanetary missions of the future. As has been noted, though, considerable limitations have still to be overcome, and Jerry Grey estimates that an operational gaseous-core nuclear rocket could not be developed in less than 10 to 20 years. Thus, there is no immediate prospect of any practical gaseous-core nuclear rocket engine, but rather a working model should emerge at about the stage of space exploration when its potential performance will be needed.

The Pulse Nuclear Engine

The first three types of nuclear rocket engines considered were of the same general type in that they featured a reactor acting as a heat exchanger through which propellant flowed and was accelerated, thus producing thrust. The un-

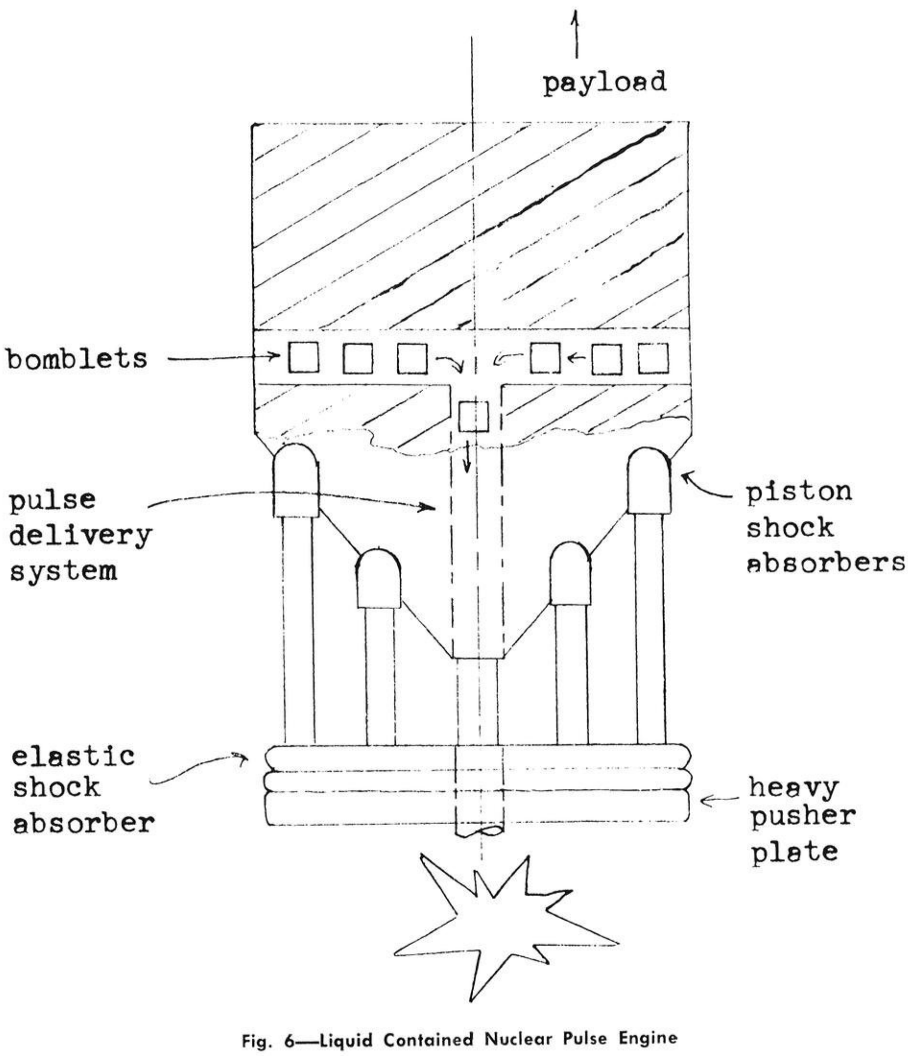


Fig. 6—Liquid Contained Nuclear Pulse Engine

contained-nuclear-pulse engine, however, does not employ the heat-exchanger concept in its operation and is a primary type of nuclear engine in itself.

In principle, the pulse engine expels small bomblets through a hole in a large pusher platform to the rear of the vehicle. These bomblets, actually small atomic bombs, explode behind the plate—see Fig. 6. The bomb is surrounded by a propellant, and this propellant impinges upon the plate and pushes the vehicle forward. Some sort of cushioning mechanism is necessary between the pusher platform and the payload in order to keep g forces to an acceptable level. For an average size vehicle, it has been estimated that a yield per pulse would have to be on the order of several tons of high explosive. Typically, the pulse repetition rate would be on the order of one pulse per second, and a typical mission would require about 1000 pulses. A 100-ton system has been designed which could be placed in orbit by a conventional Saturn V rocket. The 33-foot-diameter nuclear engine would produce a specific impulse of between 1800 seconds and 2500 seconds.

Although the pulse technique offers both high performance and relative engineering simplicity, it is at present a purely academic concept. Present political conditions, namely the existence of a worldwide treaty prohibiting nuclear explosions either within the Earth's atmosphere or in outer space renders the pulse nuclear engine unusable. Should political limitations ever be removed, however, this concept offers a propulsion system for both lunar and interplanetary missions.

Electric Propulsion

A third general type of nuclear propulsion is electric propulsion. Unlike the two types previously discussed, this form of propulsion system must be considered indirectly from the standpoint of nuclear propulsion, in that nuclear power is used only as the source of power for a distinct type of propulsion system. In fact, nuclear power is only one of several alternatives for the source of power

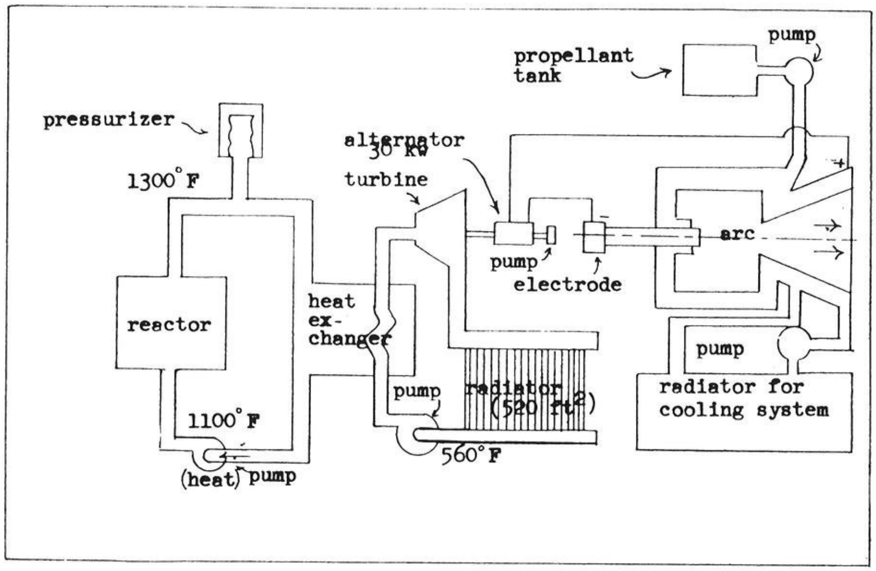


Fig. 7—Nuclear Electric Propulsion System

in electric propulsion; but since nuclear power does offer peculiar advantages in this field, a brief examination of the concept is in order.

Principle of Operation for Nuclear-Electric Propulsion

Nuclear Power Supply. At present, two types of nuclear electric power supplies are being considered. The first approach uses heat from the radioactive decay of radioisotopes to generate electricity by direct conversion, while the second approach uses heat from compact reactors to drive turbines and thermoelectric converters, which in turn produce electricity. The radioisotope systems are generally designed for low power levels (about 60 kw), while the reactor systems are capable of much higher power levels.

Propulsion systems. A typical electric propulsion system is illustrated in Fig. 7. The reactor design specifies 600 thermal kilowatts and sodium–potassium coolant with an exit temperature of 1300°F. The energy from the sodium–potassium coolant is transferred to mercury vapor in the heat exchanger. The mercury vapor then expands through the turbine, providing power to the alternator and sodium–potassium and mercury pumps. The alternator provides power for the propulsion device, in this case, an arc plasma engine. The arc plasma engine utilizes the electric power in heating the propellant to an electrically neutral plasma as it passes between two electrodes. Thrust is then produced

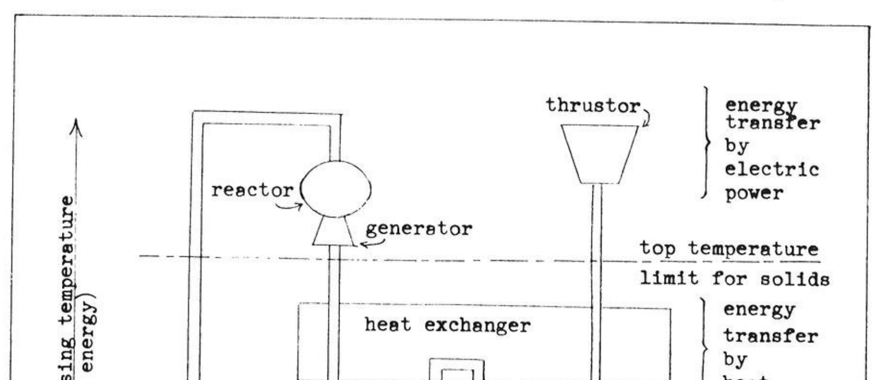


Fig. 8—Energy Transfer in an Electric System

by expanding the plasma through the exit nozzle.

A chief advantage of electric propulsion is shown in Fig. 8. Since the reactor is used to transfer energy by electric power alone, temperature limits are not encountered. All energy exchange by heat transfer occurs in the heat exchanger and the propulsive device and in a temperature range well below solid limits. Thus, there is no temperature limitation to produce a limitation on specific impulse. The arc plasma engine operates with an optimum specific impulse of about 1000 seconds, but the potential increase in performance is apparent when it is considered that the ion engine is easily capable of producing specific impulses on the order of 5000 to 6000 seconds, and the magneto-hydrodynamic engine can produce a specific impulse of 25,000 seconds, or perhaps more. However, each of these types of electric propulsion systems produces a very low thrust, (on the order of one pound), so electric propulsion would characteristically be employed for gradual acceleration over long periods of time and distance.

Limitations. A crucial problem in the design of a nuclear electric propulsion system is that of designing the radiator. This is the case because at the contemplated temperatures of operation, the radiator would take up most of the surface area of the vehicle. When certain power levels are reached, increased radiator size will dictate the use of deployable radiator panels. One possible alternative to merely increasing radiator size is to raise the temperature of radiation, thus allowing more energy to be radiated to space from the same size panel. This, however, introduces the old problem of material temperature limits.

Applications. As would be expected, the principal application of nuclear electric propulsion is in long range missions of at least interplanetary scope. Low thrust levels preclude the use of electric propulsion within strong gravitational fields, while their high specific impulse makes electric propulsion ideal for long-duration flights.

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Miss Engineer For November Mary LaFollette

"Miss Engineer" for this frosty month of November is a sparky little lass, and that warm cheery smile which greets you from its lofty perch on Abe Lincoln's knee belongs to our girl of the month, who is none other than Miss Mary T. LaFollette, a member of Alpha Xi Delta. Mary is a sophomore who is as yet undecided on her major, but she did make it clear to the photographer that it would not be engineering. That's alright fellas! We can't limit ourselves to one field of interest—unless of course it might be the *WISCONSIN ENGINEER's* girl of the month. Besides playing piano and being active in the Campus Crusade for Christ, Mary enjoys outdoor activities—and consequently we found her scrambling enthusiastically up onto Honest Abe's lap for a survey of Bascom Hill and a charming pose on a rainy November day. And though her efforts won the approval of our feature staff and a few curious on-lookers, the iron-clad standards of Old Abe allowed him to lend poor Mary nothing but a cold, cold shoulder and a steel-eyed glare for all her alluring charm. After such a confidence-shaking experience, a girl like Mary is only temporarily discouraged, as she returns sympathetically to her campus tiger, who awaits her soft caress with outstretched arms and a loving heart. And perhaps that's a tip to all you campus tiger engineers.

FRAT NEWS

"FRATERNITIES are nothing but a group of guys interested in drinking and raising hell." How many times have you said or thought something along these lines? Are fraternities just obnoxious noise in your mind? Have you looked into the professional fraternity?

Wisconsin with its free social life also supports many active professional fraternities, four of which are designed for engineers. These are not the same fraternities found along Langdon Street. Each of these groups has been formed for the specific purpose of binding its members together through a common linkage with their work and interests. The members not only get to drink and party, but also get to work together towards common goals in related and often over-lapping fields. A helping hand can always be found from a brother who has already gone through the misery of a particularly rough course or hard professor. Reference books (so necessary to us engineers who "look it up in a handbook") are almost always found somewhere in the house. Academics is always stressed very rigorously throughout the professional fraternity system.

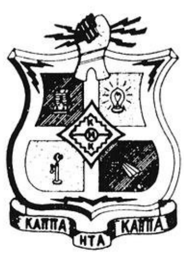
What have us engineers come up with here at Madison? These following professional fraternities all operate their own houses as separate living units.

Triangle

Triangle fraternity was founded in 1907 at the University of Illinois. It moved to Wisconsin in 1913 and has operated here since then. It now maintains a house on Breese Terrace, and that ain't all—

A service many of your parents may have taken advantage of a few weeks ago—Parents day tours of the Engineering Campus. Triangle conducted tours that included the nuclear reactor, M&ME's electron microscope, ME's heat power lab, EM's structural lab, and demonstrations by the CE, Chem E and EE departments.

Parties much? Much! Triangle has ten parties this semester, and four beer suppers to keep engineers happy with more than enough girls and good food. Homecoming's always a big event, and this year's festivities were held at Quality Courts Motel for a dinner and dance after the game.



Kappa Eta Kappa

Ever been in a house wired for every kind of sound possible? Kappa Eta Kappa, an all Electrical Engineering fraternity located on Orchard Street is like that. They not only have a complete internal wiring of speakers, switches, intercoms, etc., but also have their own radio station licensed to put out 10,000 watts of power. With this they maintain contact with their other three chapters around the nation. They are also quite active socially with nine parties and five beer suppers this semester. Their Homecoming bash was held at the Holiday Inn West.

Like all the other fraternities KHK has meetings every Monday night. They do, however, have occasional program meetings during which they have a guest come to the house and speak on some contemporary subject—sometimes engineering, but often just points of interest.

Alpha Chi Sigma

Alpha Chi Sigma may be well known for its Chemistry, but it is also made of approximately 40% engineers. Its membership, however, is restricted to Chemical and Nuclear Engineers. Like the other fraternities it has both beer suppers and parties, all the liquid details of which shouldn't be too closely explored. It actively distributes safety pamphlets to the freshman Chemistry labs of many colleges. About 50,000 pamphlets have been distributed this year alone. It also makes a practice of being available to the Boy Scout office for tutoring in the Boy Scout Merit Badge in Chemistry.

Theta Tau

Last, but certainly not least, is Theta Tau. Theta Tau, just installed in their house last year on Monroe Street, leads a social life slightly less active than the other fraternities. They hold meetings once every two weeks, and are comprised of engineers from all fields. Their Madison chapter was founded in 1923 and has operated without a house until this year. Also like the other fraternities it competes in the professional fraternities' intramural athletic program.

The professionals on a whole feel that they combine the best parts of a social fraternity's merrymaking with the serious minded attitudes of the engineering student interested in completing his studies while learning as much as possible. They attempt to find a balance between strict academics and strict socializing.

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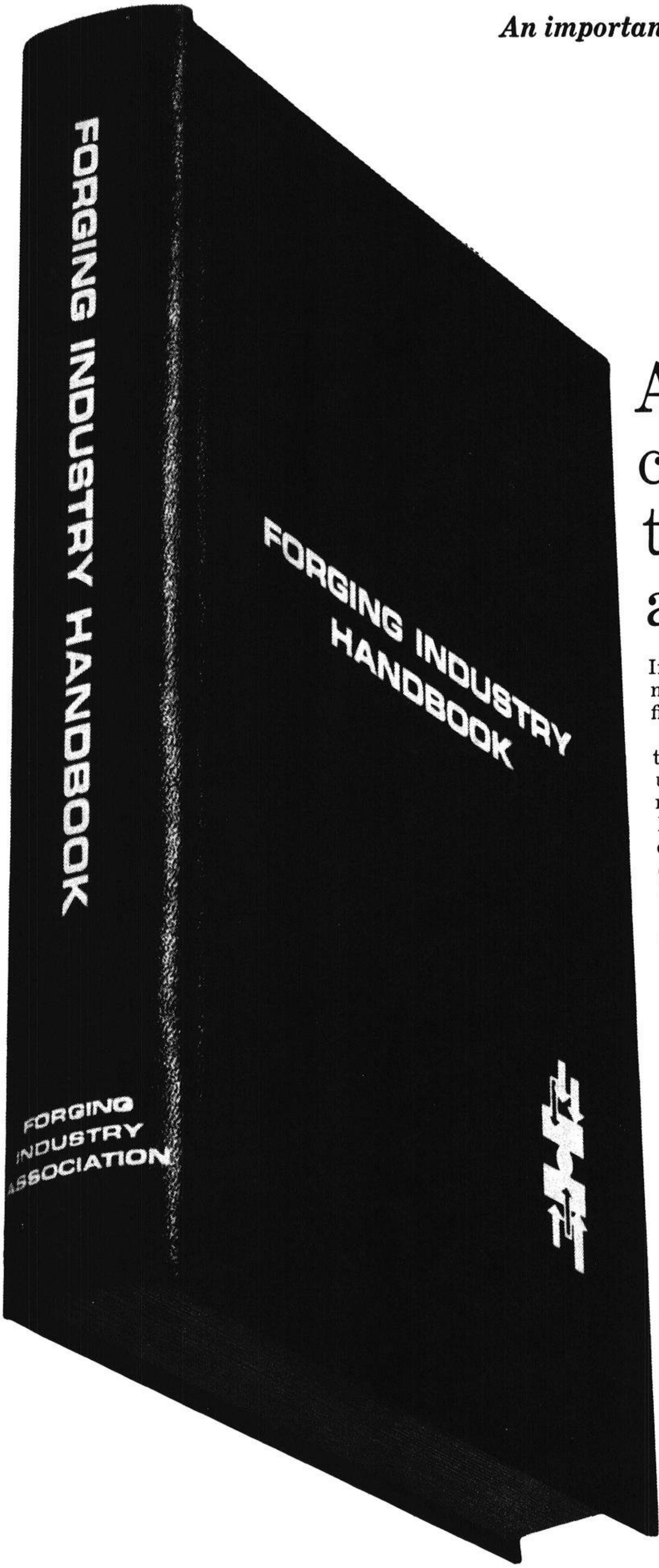

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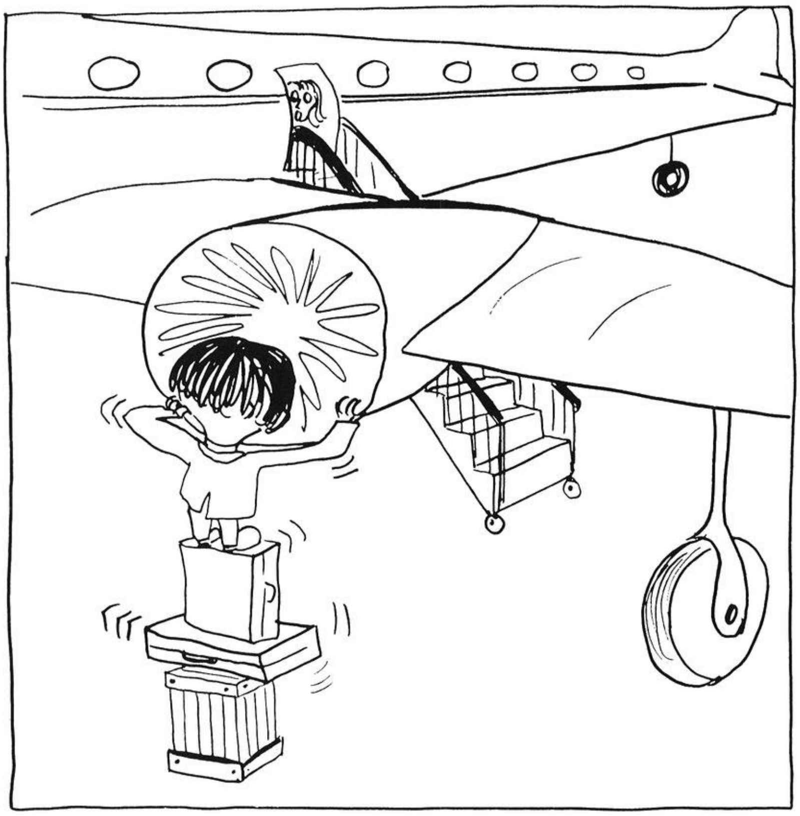
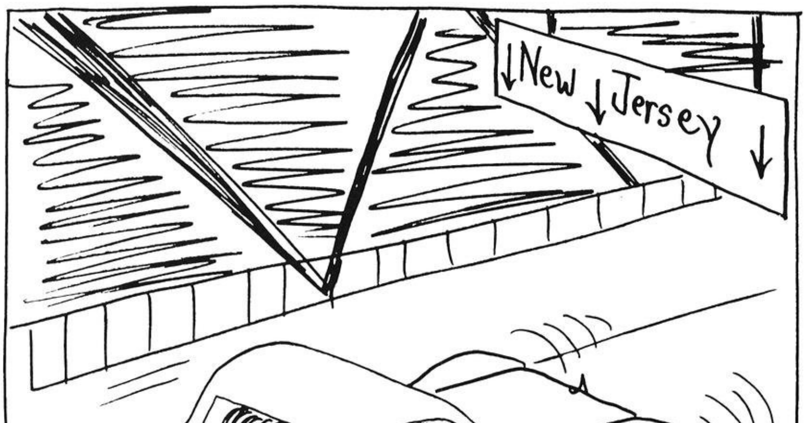
the 1966 engineering magazine's convention . . .

ECMA '66

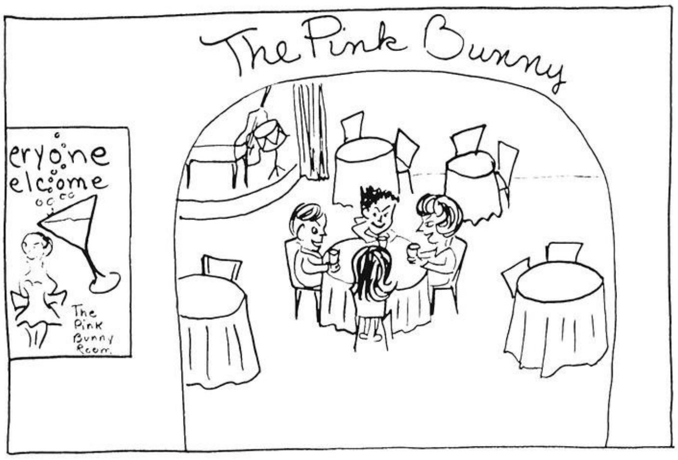


Jerry hadn't been on a plane before so he had to check it out thoroughly . . .

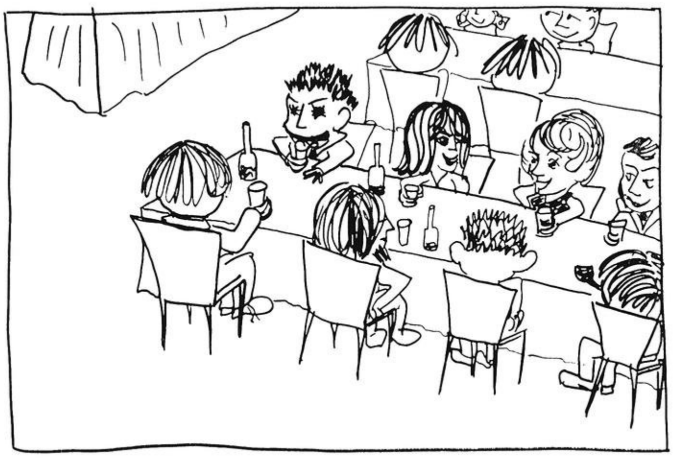


We got out of the airport with our rented car, but we couldn't find Philadelphia . . .

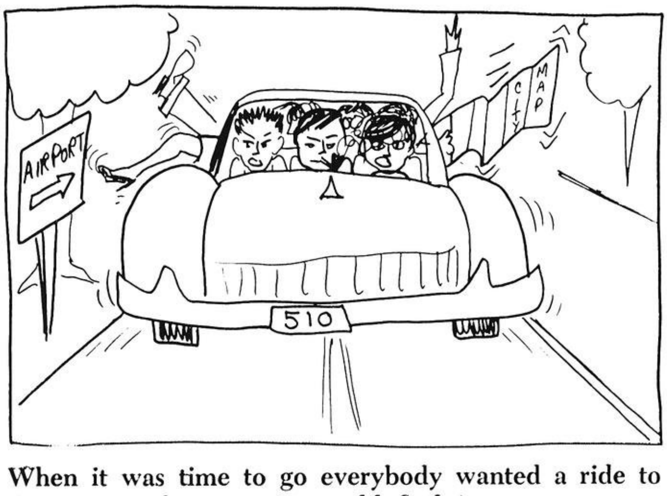
Cartoons by Inge



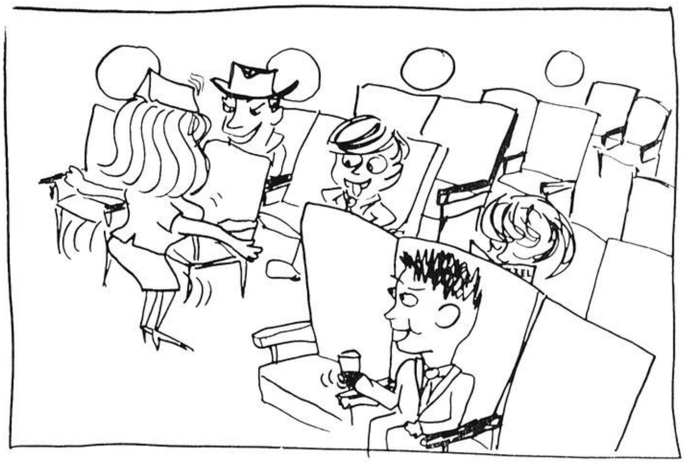
Of course, we had to have a pre-convention staff meeting . . .



The banquet was great . . .



When it was time to go everybody wanted a ride to the airport, but no one could find it . . .



The plane ride home was the best part of the trip, according to most of the staff . . .

Well, we had lots of fun, and were sorry to leave, but there's always next year!!!!

(P. S. The Wisconsin Engineer still has several staff openings . . .)

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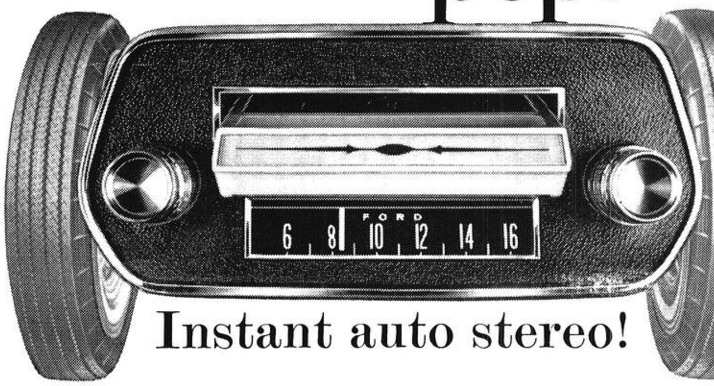

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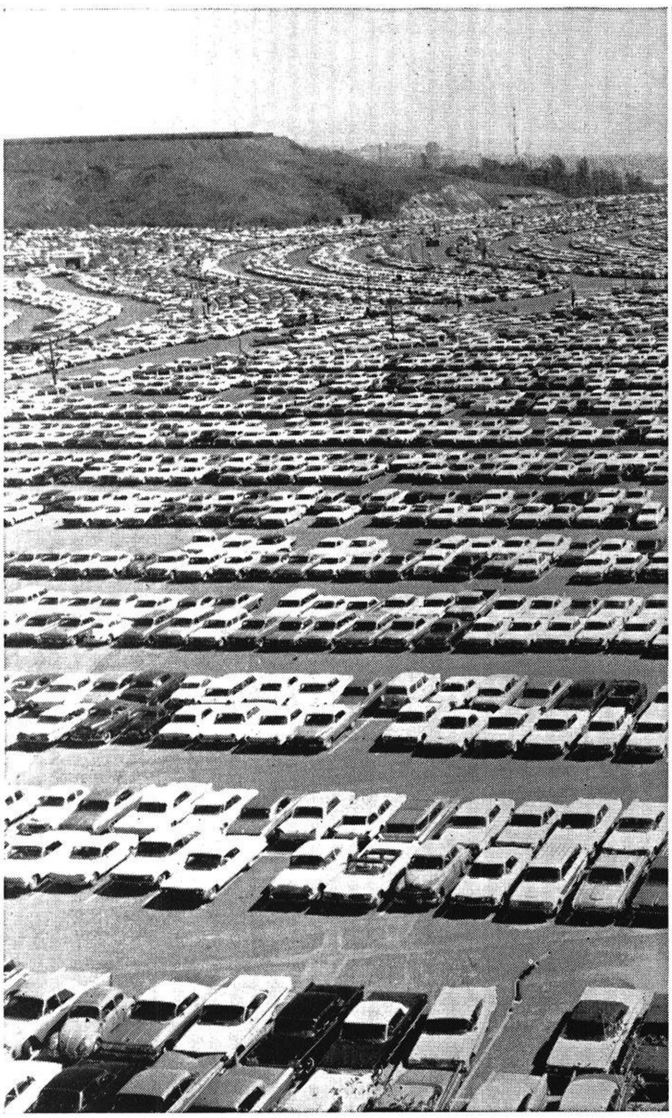


Wisconsin's

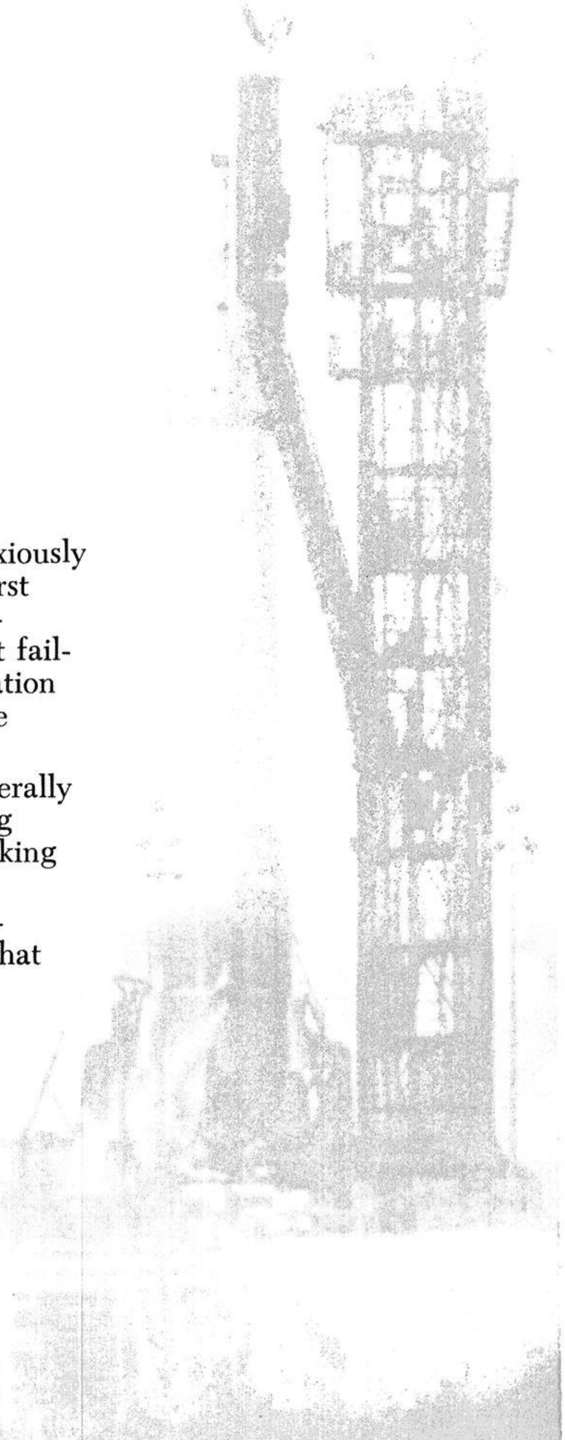
OAO

a

UFO?

(useless flying object)

by Abby Trueblood



April 1966 saw the University of Wisconsin looking anxiously towards Florida's Cape Kennedy for the launch of the first Orbiting Astronomical Observatory (OAO), which contained a Wisconsin instrument package. The subsequent failure of the satellite did not end the University's participation in the NASA program, and plans remain to carry out the full OAO program.

The University of Wisconsin's participation in the federally supported NASA program is indicative of the increasing number of colleges and universities across the nation taking part in similar space oriented programs.

The following article is about this first Orbiting Astronomical Observatory, and explains why scientists hope that there will be a more successful launch of this kind of satellite soon.

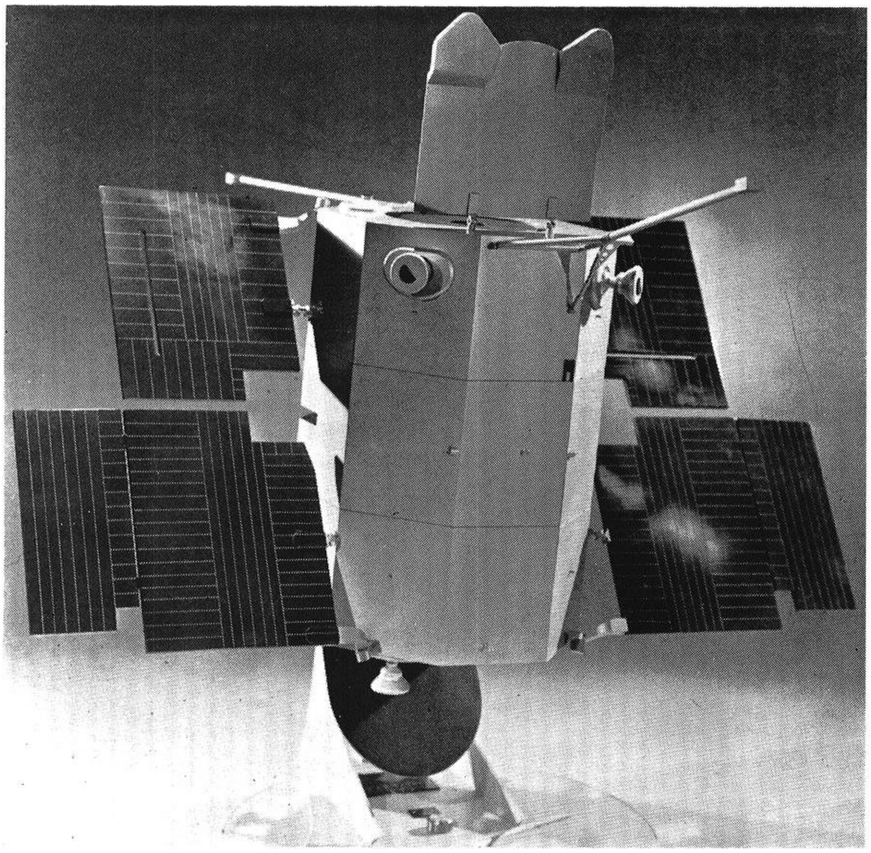


Fig. 1—Model of OAO 1, Constructed at the University of Wisconsin.

EARLY IN THE spring of 1966 the heaviest and most complex unmanned satellite ever planned by the United States was ready to be shot into space by an Atlas Agena rocket. Within ten days several launches had been scheduled and attempted without success. Finally, on April 8, 1966 a launch of the spacecraft was achieved to the delight of all concerned with the project. However, within three days the satellite had gone silent and the experiment had to be ruled a failure.

This failure to transmit information has remained a mystery to scientists and, of course, it is a bitter disappointment to those who had worked with the satellite.

This first OAO satellite is of particular importance to scientists and students at Wisconsin's Washburn Observatory. It represented the end of over eight years of research and design of Wisconsin's instrument package.

However, the failure of this experiment does not lessen its importance. Plans remain to carry out the rest of the OAO program, which includes another satellite with a Wisconsin instrument package.

The satellite, the first of the Orbiting Astronomical Observatories (OAO), would have been the first in a series of astronomical research stations placed high above the earth's atmosphere. As a part of a program undertaken by the National Aeronautics and Space Administration (NASA), the OAO 1 would have been the first satellite to study the stars.

The idea to orbit an astronomical station above the earth's atmosphere results from the fact that man has been hindered in his observations of the stars from the ground. Up to ninety percent of the ultra-violet light emitted by the sun is absorbed before it reaches the ground. For this reason only the brightest stars can be seen to an observer on the ground. This has prevented astronomers from making accurate conclusions about much of the galaxies.

Even the observations that can be made from earth are not clear because the atmosphere refracts the light waves. This tends to make the stars appear fuzzy despite high powered telescopes.

By orbiting a satellite above the atmosphere these difficulties in observations would be removed. Scientists would then be able to learn a great deal about the galaxies.

The University of Wisconsin entered the federally supported OAO program in 1959 in conjunction with the National Aeronautics and Space Administration. However, planning for the satellite began in the summer of 1958. Arthur D. Code, who is the director of Wisconsin's Washburn Observatory, guided the entire development of the University's experimental package for the OAO 1.

Professor Code was aided in the completion of this package by numerous undergraduates. Many of these student assistants were electrical engineers. Several of these students connected with the satellite chose to go into space oriented programs upon their graduation from the University.

The same Washburn team that did the work for this experiment has been instrumental in the past in the design and development of specialized optical and electronic devices for high altitude viewings.

THE SPACECRAFT

The spacecraft has two wing-like paddles on either side which are made up of solar cells. These cells are designed to power a transmitter and a magnetic core

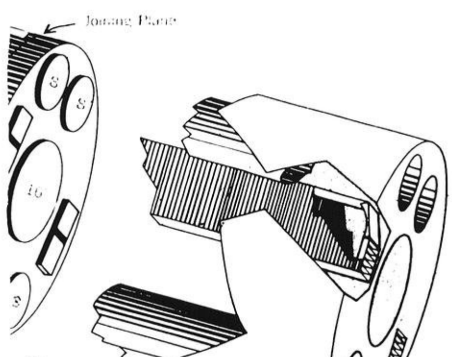
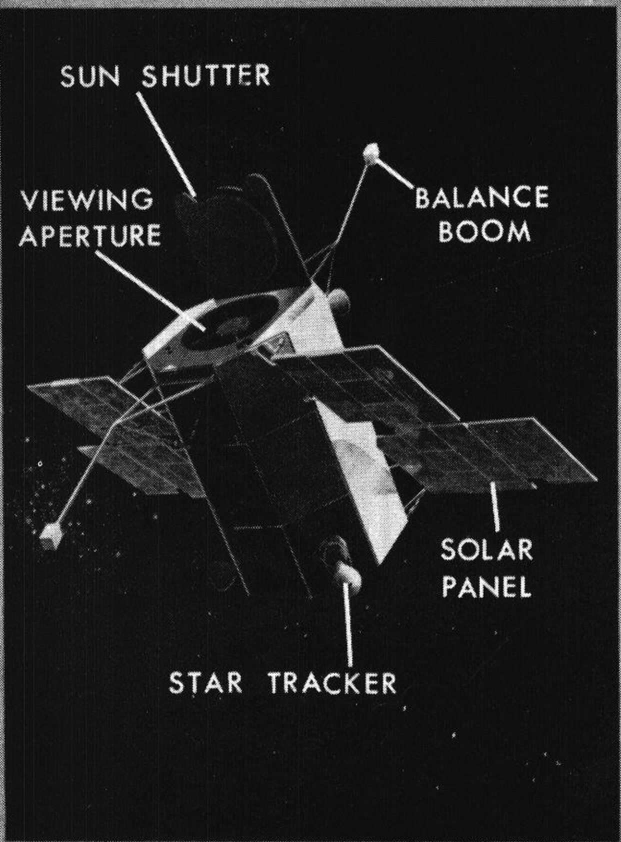


Fig. 2—UW-Built Instrument Package for OAO.

ORBITING ASTRONOMICAL OBSERVATORY



GROSS WEIGHT	3,600 LBS.
INSTRUMENT WEIGHT	1,000 LBS.
INVESTIGATIONS	SEVERAL/SPACECRAFT
STABILIZATION	ACTIVE 3 AXIS
DESIGN LIFE	1 YEAR
LAUNCH VEHICLE	ATLAS-AGENA
ORBIT	CIRCULAR 500 MI. INCLINATION 32°
PLAN	FIRST FLIGHT 1965

NASA SG64-210
REV. JAN., 1964

Fig. 3—NASA data for OAO Program

memory. An instrument at one end of the observatory is to receive signals from earth.

The University of Wisconsin instrument package occupies the front half of the OAO. Packages from Goddard Space Center, Lockheed Aircraft and the Massachusetts Institute of Technology make up the rear.

Originally the rear of the satellite was to house a package from the Smithsonian Institute but it was unable to be completed in time for the orbit. At that point Wisconsin's package was joined by the other three to make up the total instrument package aboard the OAO 1.

The University package consists of seven telescopes and light measuring photometers. They are built to record emissions from young stars and interstellar clouds. Both Goddard and MIT have supplied gamma ray detectors. Lockheed donated an X-ray telescope, All three would be studying radiations with wave lengths shorter than the ultra-violet.

The plan was that once in orbit the lens cover would open at one end and expose the telescopes. The telescopes were to relay information to the magnetic core memory.

The information from the memory was to be transmitted, in the form of numbers, to receiving stations on earth. These receiving stations are located in Rosman, North Carolina, Quito, Ecuador, and Santiago, Chile.

WISCONSIN'S INSTRUMENT PACKAGE

The University of Wisconsin package was supplied by Washburn Observatory under the direction of Arthur D. Code. The object of the experiment was to measure the radiations of several hundred stars and nebulae at wavelengths between 800 and 4,200 angstroms, or from the ultraviolet to the blue ranges of the spectrum.

The instrument package is a forty inch cylinder, five feet long, black with ridges. It was once described by associate professor Robert C. Bless of Washburn as looking very similar to a big garbage can.

Besides the photo-electric photometers and their electronic circuitry there is a sixteen inch reflecting telescope, four reflectors, each with an eight inch aperture, and two scanning spectrometers with six by eight inch gratings.

Operation of the telescopes is controlled by an electronic package of 500 low digital logic elements with an average power drain of 9.5 watts.

NEWS for 1966 1967 ENGINEERING GRADUATES

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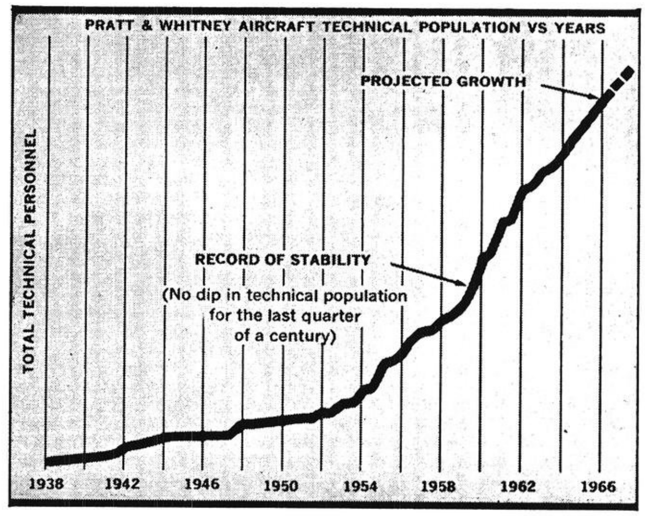

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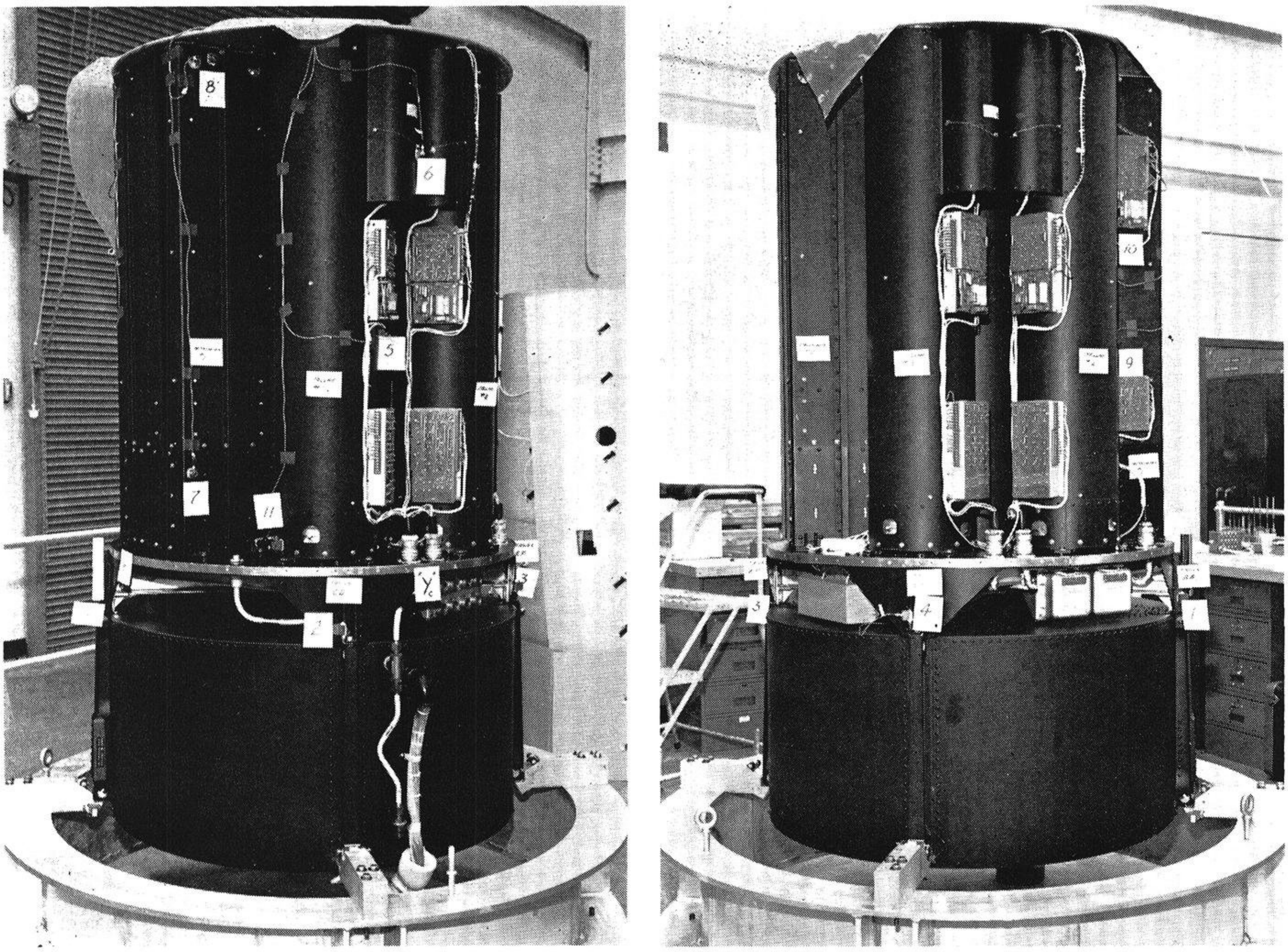


Fig. 4—Instruments of OAO with Shroud Removed

Nebulae would be observed by the sixteen inch, seventy-four pound telescope, which also contains a photo-electric photometer. The viewing arcs and the passage of the readings through the four filters are controllable from the ground.

The four eight inch telescopes are designed to study the stars. Each of these four telescopes weighs twenty-eight pounds and has a field of two or ten minutes of arc.

The two scanning spectrometers are alike except that one covers 1000 to 2000 angstroms and the other covers 2000 to 4000 angstroms. During the operation of these spectrometers a drive motor tilts the grating to scan the desired spectral range in 100 steps. The operator can reduce the number of steps or he can stop the drive motor and take repeated measurements at a certain wavelength.

The University of Wisconsin telescopes were made on contract by the Cook Electric Company in Morton Grove, Illinois. Upon their completion, each telescope was sent to Washburn, where it was carefully tested and calibrated. They were then shipped out for final assembly and then on to Cape Kennedy to await lift-off.

ATTEMPTED LAUNCH

The final attempt to launch the first Orbiting Astronomical Observatory was made on April 8, 1966. The spacecraft was shot 500 miles into space by an Atlas Agena rocket. Once launched it assumed a standard orbit, slanting along an equatorial range similar to that of the Gemini flights. Despite its successful launching, the OAO 1 failed after three days. Within seventy-two hours the first satellite to study the stars had sputtered its last message and had become silent.

The OAO was to have remained in orbit for one year and, after the first month, was to relay a fantastic amount of information back to earth. The first month of orbit was to be used to put the spacecraft through a series of maneuvers.

The computer programs necessary to operate the satellite are as large as those of the entire North America Air Defense Command and four times as large as those of the Gemini missions. After the blastoff the men who worked on the project met at Goddard Space Flight Center in Greenbelt, Maryland to take turns working on the data as it came in from the satellite.

The expected results probably would have brought a number of surprises to the attention of scientists. It was hoped that the satellite would be useful in obtaining information necessary to use in mathematical models of the universe and in formulating theories about the properties of interstellar particles and formation of the stars.

It was also an engineering test to learn how to operate a space laboratory from the ground. Unfor-

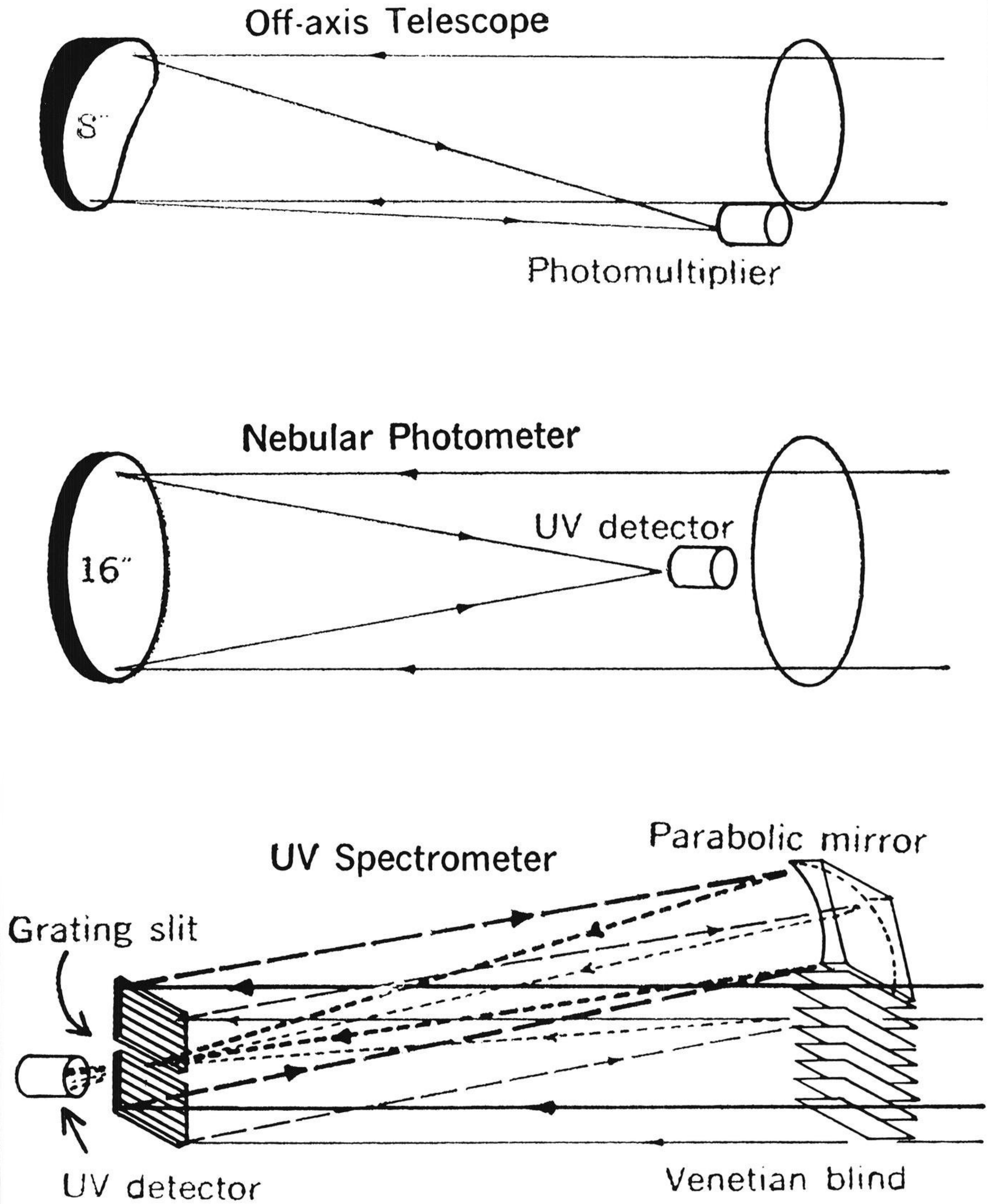


Fig. 5—Optical Details of the OAO Mechanism

tunately the satellite went silent before scientists and engineers could really benefit from the experiment. However, by the continuing the OAO program these people will again have an opportunity to benefit from this kind of experiment.

FUTURE OAO'S

Future Orbiting Astronomical Observatories are expected to be launched every nine months to a year. This would put the launching of OAO into 1967. The program now calls for three more satellites of a similar nature as OAO 1.

OAO 2 is to carry a thirty-six inch telescope from the Goddard Space Flight Center. OAO 3 will carry a University of Wisconsin instrument package again. OAO 3 will also carry the Smithsonian package that was originally to go with Wisconsin's on OAO 1. OAO 4 will carry a large telescope developed at Princeton University.

The Orbiting Astronomical Observatory program is one of three large satellite programs currently being undertaken by NASA. The others are the Orbiting Geophysical Observatory (OGO), and the Advanced Orbiting Solar Observatory (AOSO). The first will be an all-purpose satellite to test a cross-section of solar, magnetic, radiation, and atmospheric phenomena. The final project, AOSO, will study the sun.

Disappointment over the failure of the first OAO to operate as expected is mingled with hope that NASA will go through with the entire program. Speculation that the proposed 1967 launch of OAO 2 will be cancelled has the scientists working on the project alarmed, but there has been no official word that this will be the case.

The second Wisconsin instrument package, slated for OAO 3, will probably only have one telescope. It will be larger than any of the ones on this satellite and will have a mirror that will be a yard wide.

If the OAO 2 is successfully orbited then all the disappointment over the failure of the first such satellite can be erased. The second OAO would then become the "first" satellite to study the stars, and the dream of astronomers to look at the stars clearly will have been accomplished at last. END

★ The Student Committee for Public Relations is asking engineering students to join its efforts to familiarize high school students, transfer students and high school guidance counselors with engineering and the University of Wisconsin College of Engineering. Among the activities planned by the Student Commitee for the coming year are

1) Visits to local high schools to present facts about engineering
2) Invitations to high schools to visit the engineering campus
3) Cooperation with the Engineering Exposition Commitee on plans for High School Day
4) Invitations to potential transfer students to familiarize them with the campus and to help them to understand and meet the problems they will face when they transfer.

All students are cordially invited to attend the next meeting.

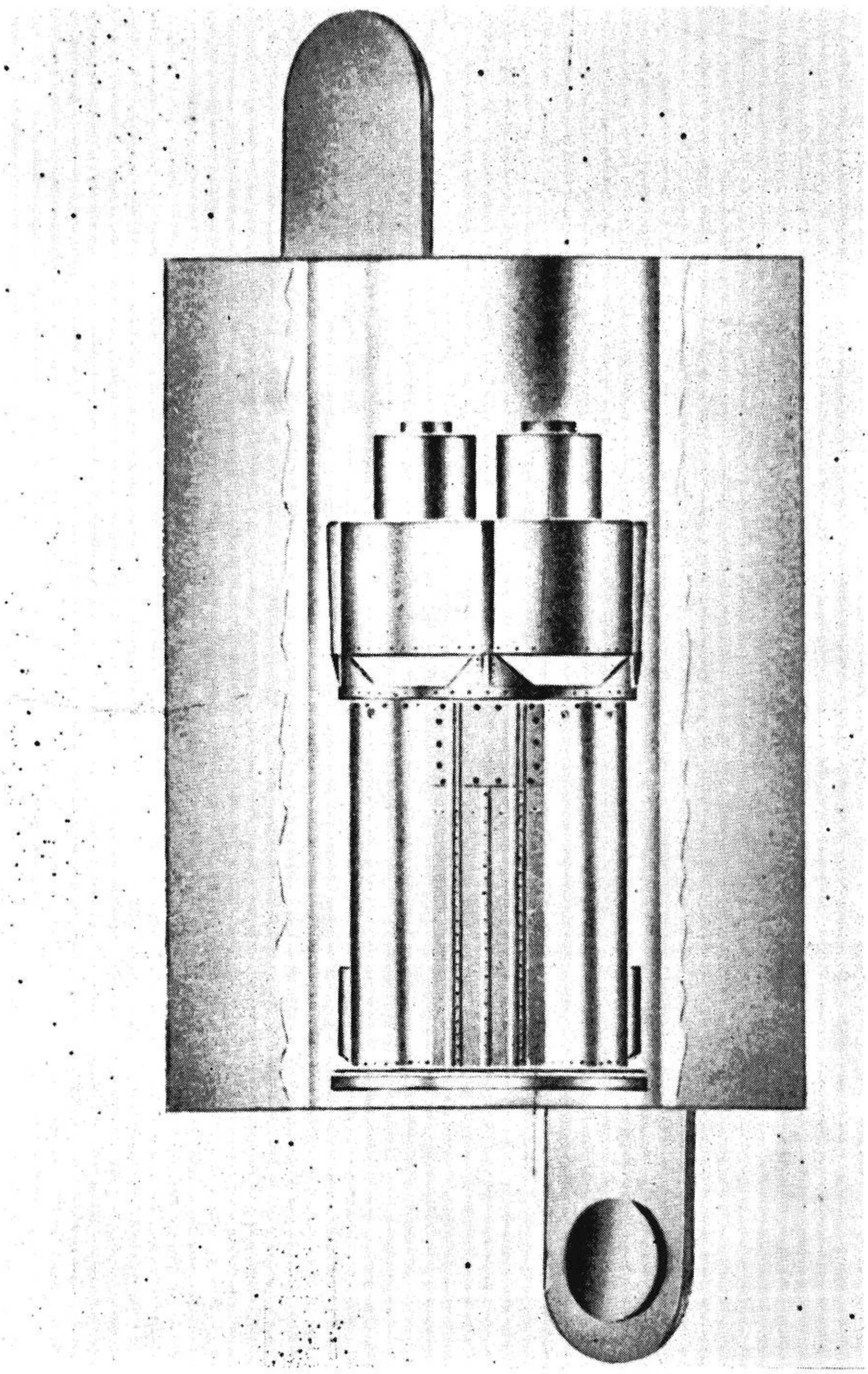
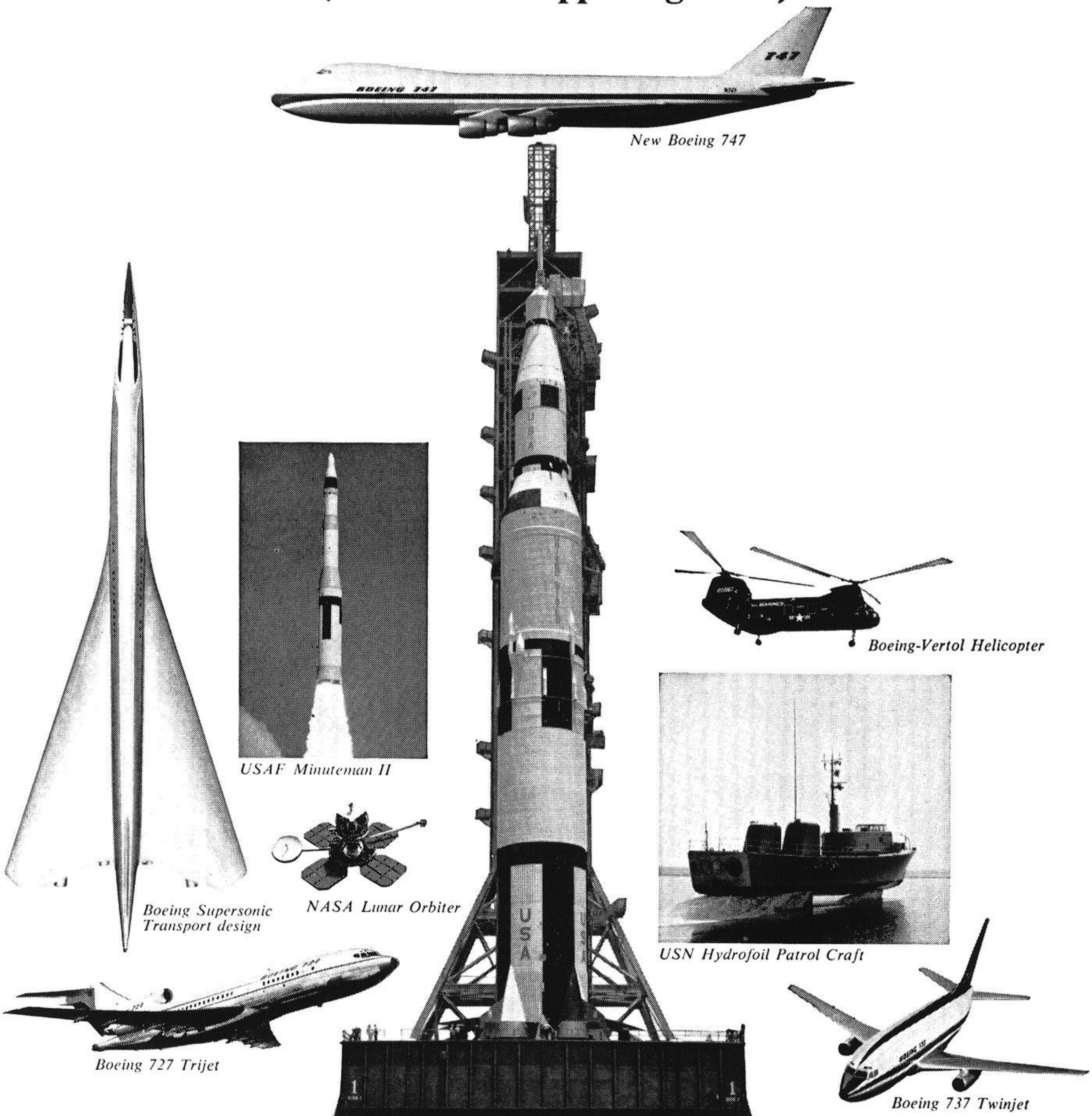


Fig. 6—Experiment Arrangement for Spacecraft No. 1

Fifty years ago we only made 'aeroplanes'.
(See what's happening now!)



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Pop Up Aircraft

By DOUG PANEITZ

THE STARTING flag has dropped and the race is on—a race to achieve total mobility in military and commercial aircraft. Research in the past ten to twelve years has shown that the concept of vertical-take-off-and-landing (VTOL) is indeed feasible.

The purpose of this report is to describe some of the methods proposed to achieve VTOL and the most successful VTOL aircraft tested in recent years. Some of the problems and perspectives of this type of aircraft are also discussed. Since there are many ways to achieve VTOL, only those possessing definite application and being actively tested at this time are included in this survey. Helicopters, convertiplanes, and tail-sitters are not considered.

I. METHODS FOR ACHIEVING VTOL

Current research has shown that vertical-take-off-and-landing (VTOL) aircraft are possible. To achieve VTOL an aircraft must:

(1) Generate enough vertical thrust to lift the aircraft.
(2) Rotate the thrust from vertical for take off to horizontal for normal flight.
(3) Maintain stability of the aircraft during the transition from vertical to normal flight.

Some of the most promising methods which are currently being studied to achieve VTOL are:

(1) Rotating the airscrews 90° (Tilt-wing or Tilt-prop).
(2) Lift producing fans (Lift-fan).
(3) Turbojets with the jet stream deflected downward to provide vertical lift (Lift-jet).

Fig. 1—VTOL

The method of lift to be used on a particular aircraft design can be determined by the performance required of the aircraft. For example, on a transport plane the Tilt-wing or Tilt-prop appears to be the most practical method; whereas, the Lift-fan or Lift-jet would probably be used on a fighter or reconnaissance plane.

Tilt-wing and Tilt-prop

The most technologically advanced VTOL aircraft at the present time use the Tilt-wing design. On these tircraft the engines are rigidly attached to the wings and the entire wing rotates through approximately 90°. The wings are tilted up to provide VTOL and are gradually returned to the normal position after take-off for forward flight.

A high payload capability and limited speed make this configuration a natural for transport aircraft. The LTV Aerospace Corporation is currently testing the XC-142A, the world's largest VTOL, which has trans-oceanic range. It is powered by four GE turboshaft engines which are cross-shafted into the transmission so that the airplane is able to maintain hovering flight on any two engines. This airplane made its first full cycle transition on January 11, 1965.

Another proposed design which is very similar to the entire the Tilt-wing is the Tilt-prop. Instead of rotating the entire wing, these aircraft have swivelling propeller shafts. The wing and the engines remain fixed in the normal position at all times. For vertical take-off

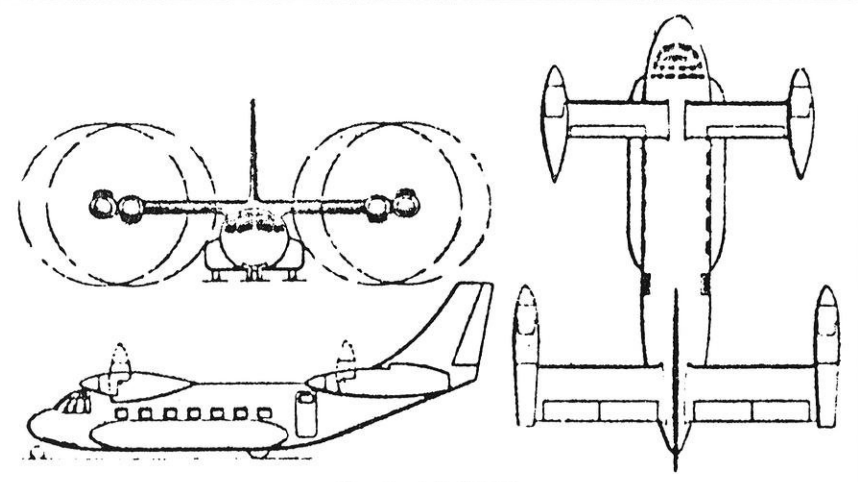


Fig. 2—Bell X-22A

the propellers are rotated up approximately 90° from normal to provide vertical thrust. After take-off they are gradually rotated back to the normal position for conventional flight.

The Bell Aerosystems Corporation has designed an interesting variation to the Tilt-prop for their X-22A, shown in Fig. 2. They have placed the airscrews in shrouds which function to some degree as airfoils. The basic operation of this aircraft is the same as previously described for the Tilt-prop. However, it is claimed that the shrouded airscrews provide up to fifty percent more thrust than unshrouded airscrews. It should also be noted that the shrouds cause more drag than conventional wings.

Probably the most intriguing VTOL aircraft ever conceived is Avro's Lift-fan Avrocar. This disc-shaped machine uses three turbojet engines to drive a centrally located fan which provides vertical thrust. The jet is deflected to the rear for forward flight. In forward flight the Avrocar's body develops lift from the same way as an airfoil. The first partial transition of this aircraft was accomplished in 1961, however, technical difficulties prevented its further development.

Lift-jet

The Lift-fan augments the installed power to achieve VTOL and another method for doing this is the lift-jet. To achieve VTOL this type of aircraft diverts the exhaust from the turbojet engines into ducts along the top of the fuselage from which it is discharged downward through multiple nozzles. Doors along the top and bottom of the fuselage are opened to expose ejector mixing chambers wherein the primary nozzle thrust is augmented by inducing a secondary flow. To change to normal flight after lift-off the doors are closed and the jet exhaust is directed out the tailpipes in the coventional manner.

Control during vertical and hovering flight is provided by four reaction jets: roll-control nozzles in the wingtips, pitch-control nozzles at each end of the fuselage, and

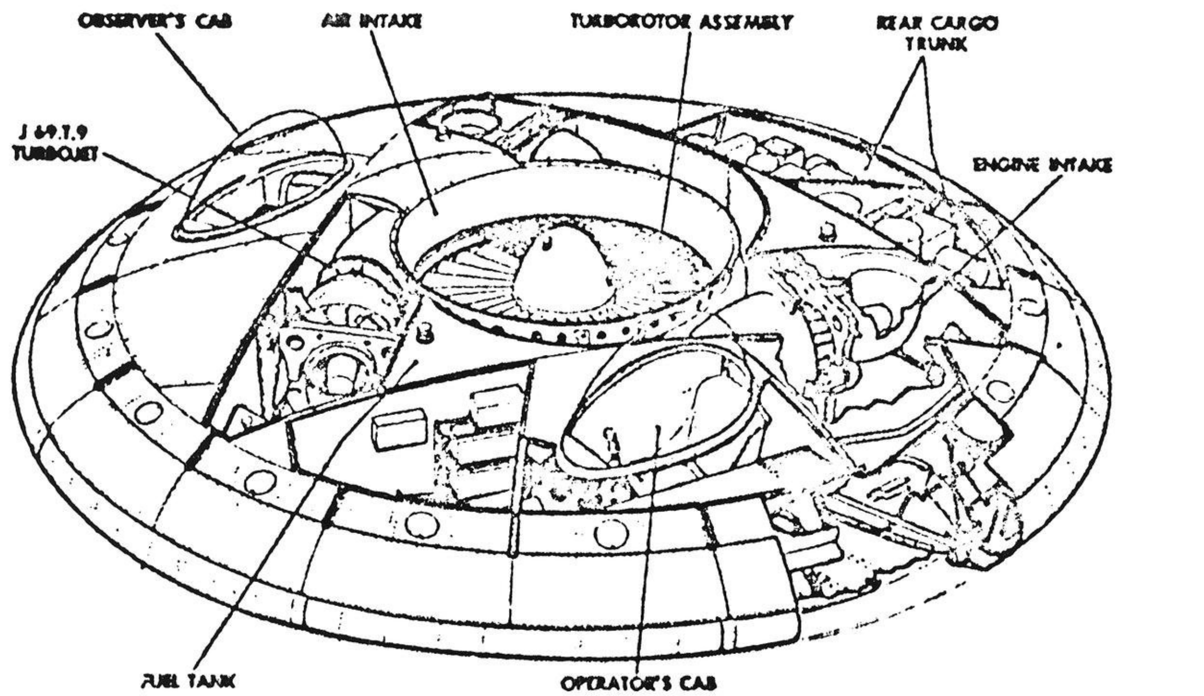


Fig. 3—Fan Lift Avrocar

yaw-control by rotating the pitch control nozzles.

This type of aircraft has the advantage of simplicity of design. It could be designed to operate with one engine, and it uses less extra fuel for vertical flight than the other designs.

II. PROBLEMS OF VTOL DESIGNS

Seven years have passed since the first tilt-wing aircraft was flown. The first successful lift-jet flight occurred eleven years ago. To date no VTOL aircraft has become operational. There are still many problems in existing aircraft of this type which must be overcome before the advantages of VTOL can be fully utilized. What are some of these problems, and what is being done to solve them?

Weight

The fact that VTOL aircraft weigh considerably more than conventional aircraft with the same payload and range is the most commonly cited problem. This extra weight is due to the larger engines and greater fuel required for vertical flight.

In an effort to reduce the excess weight, aircraft manufacturers are developing new engines with higher horsepower-to-weight ratios. They have also designed propellers in which fiber-glass and polyurethane foam has replaced part of the steel in the structure. In the basic airframe, aluminum-balsewood sandwich panels used in the side walls of the fuselage and several other improvements have helped reduce the overall weight.

Another way to increase the payload of VTOL aircraft is to reduce the required hover and vertical flight time. This could be done by designing the aircraft to land conventionally whenever possible and using VTOL only when required for a specific purpose. All of the aircraft previously described have this ability. This greatly reduces the amount of fuel necessary and increases the range of the aircraft.

Handling and Required Hover Times

Pilot response time becomes a very important factor during the hover and transition phases of VTOL. Having to overcome the inertia of the aircraft in pitch and roll makes it difficult to stay within the flight pattern when making a steep approach in turbulent weather. It is also difficult to insure that the aircraft is free from drift at touchdown. Two minutes of hover time would be ample for one take-off and landing. However, in most present-day VTOL aircraft this would be an unreasonable fuel requirement.

With current instrument approach systems an additional three to five minutes are required for an instrument, as opposed to visual, landing. This time would be at slow speeds that would impose severe fuel consumption penalties on VTOL aircraft. Research is currently being done to develop an instrument that would enable the pilot to land essentially the same as he would be able to under visual conditions, by projecting an image of the landing area on the windshield of the airplane.

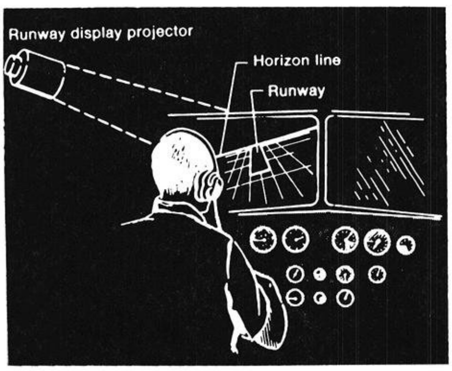


Fig. 4—Landing Aids

The development of more economical engines and improved instrumentation should solve most of these problems. There is no reason to doubt that closed-loop control systems will be developed in the near future which will enable VTOL aircraft to make drift free landings and take-offs in most weather conditions as rapidly and safely as conventional aircraft.

Maintenance

Problems of maintenance of VTOL aircraft arise from the environmental conditions under which they operate and from technological sources. Limited experience with these aircraft also adds to the problems and cost of their maintenance.

Some VTOL will undoubtedly be required on occasion to operate from unprepared surfaces. In these areas the downwash required for VTOL will create the possibility of reingesting air contaminated with particles and exhaust products. One solution may be to put their air intakes on top of the aircraft. Another may be the development of filtration techniques and other devices to protect the engine inlets.

VTOL aircraft are subjected to some unusual vibratory loads during vertical flight and transition. These include sonic loads from jet efflux and harmonic airloads. Present knowledge of these undesirable phenomena is very limited, and efforts to understand their basic mechanism are currently in progress. The ability to control these vibrations should soon be obtained reducing maintenance problems.

III. POTENTIAL OF VTOL

The future of VTOL aircraft continues to look extremely promising. Both military and commercial users would like the advantages of the helicopter and conventional aircraft in a single plane. If the costs involved can be made reasonable and the technical problems solved such aircraft will undoubtedly find a place in modern aviation.

Military Potential

Even though no military VTOL aircraft is operational to date, military planners are very favorably impressed by these aircraft and are giving them serious consideration as possible replacements for present systems. The Army would like VTOLs to replace the UH-1 weapons helicopter for advanced aerial support and to be used as tactical transports.

The prospect of VTOL has long been of particular interest to the Navy for aircraft based on aircraft carriers. VTOL would also increase the Navy's effectiveness in antisubmarine warfare.

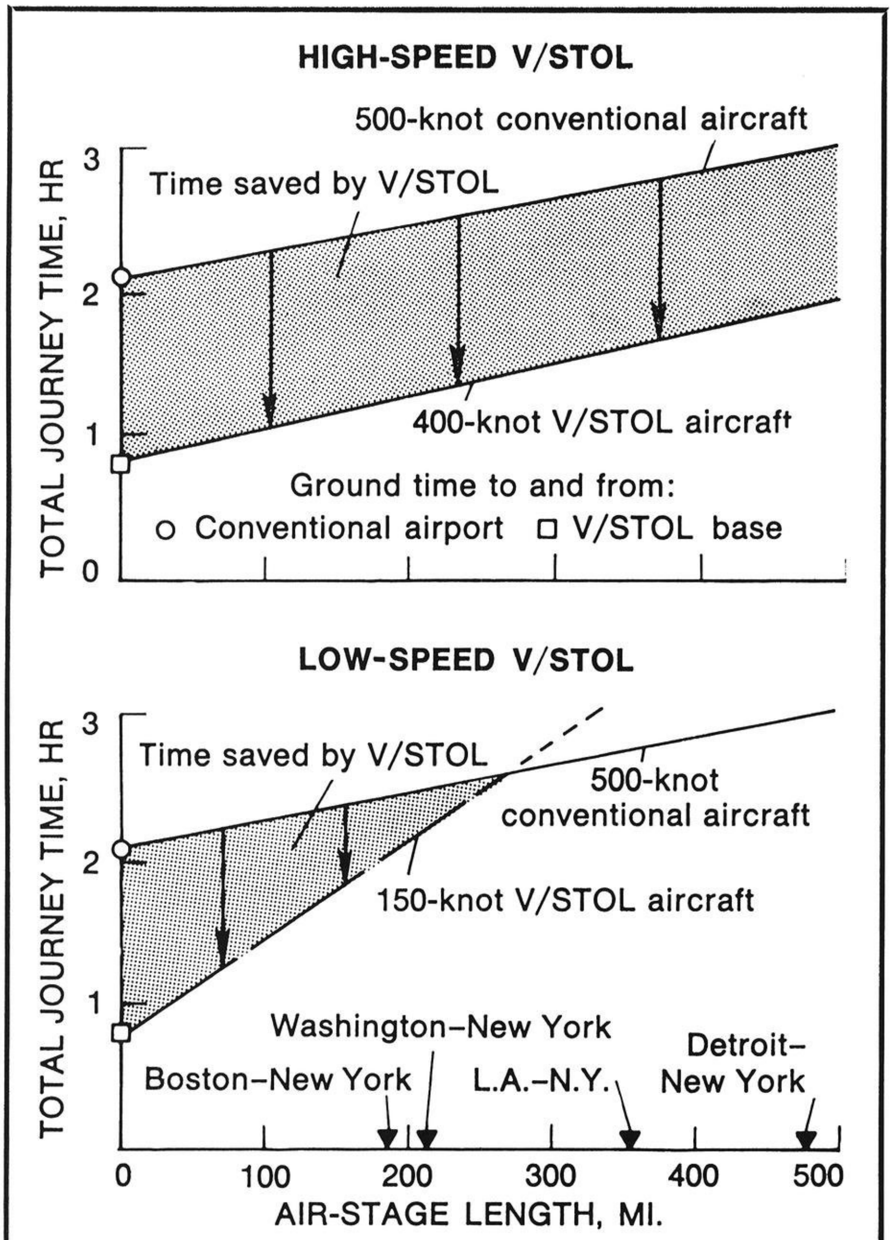


Fig. 5

An advanced study of VTOL fighter systems is currently in progress by the Air Force in conjunction with West Germany. They hope to develop an operational prototype within the next few years. The Air Force is also supporting the development of the XC-142A troop transport as a possible successor to the aging C-130. Ultra large transports such as the C-5A, presently being developed, may require smaller, more maneuverable transports to compliment the system to make it more efficient.

This list of possible military uses is far from complete. Military planners will undoubtedly continue to conceive new applications. However, since no operational VTOL systems exist, their combat effectiveness remains conjectural. Before these systems can become widely used they must prove their military value in combat situations.

The entire military mission must be considered to fully evaluate the potential of VTOL aircraft. Some of their advantages, such as independance from fixed runways, are highly desirable. However, runways are only a small part of the total facilities necessary for air operations. Least cost is an important factor in comparing military systems. For this reason VTOL systems will probably not constitute more than 10% of our total military aircraft. Conventional aircraft and helicopters will continue to be used for missions on which they prove to be more efficient.

So far the military has not considered VTOL to be worth their high cost. Knowledge gained by the research projects presently in progress could soon advance the VTOL to operational status. The XC-142A transport could well become operational within one or two years. Commercial applications cannot be far behind the development of satisfactory military systems.

Commercial Potential

The airline industry has already captured a large share of the common-carrier traffic for ranges of over 500 miles. With commuter traffic increasing every year a significant potential exists for passenger service for the airlines if they could provide rapid, relatively inexpensive transportation on the short-haul intercity routes of less than 500 miles. The VTOL could well be the ideal vehicle for this type of service. Helicopters are already providing VTOL service from city to airport and from airport to airport, but for ranges of over 50 miles helicopters have not proven to be satisfactory. Hence, the airlines are looking at the new VTOL aircraft to bridge the gap between helicopters and conventional aircraft.

One of the major advantages that would be offered to passengers of VTOL aircraft is the saving of time. VTOL bases could be built in the heart of the city close to businesses and downtown. This could almost completely eliminate passenger complaints of time lost traveling to and from the airport. Taxi and air maneuver times would also be shortened. Fig. 5.

Ground and air maneuvering times have a large effect on the direct operating cost (DOC) of very short flights. The fact that VTOL aircraft can maintain low direct operating costs on the short haul is shown in Fig. 10. This graph shows the DOC as a function of distance for VTOL and CTOL aircraft designed to cruise at 400 knots. The advantage of the VTOL can increase for very short flights if it is specifically designed for that purpose as is shown by the dashed line.

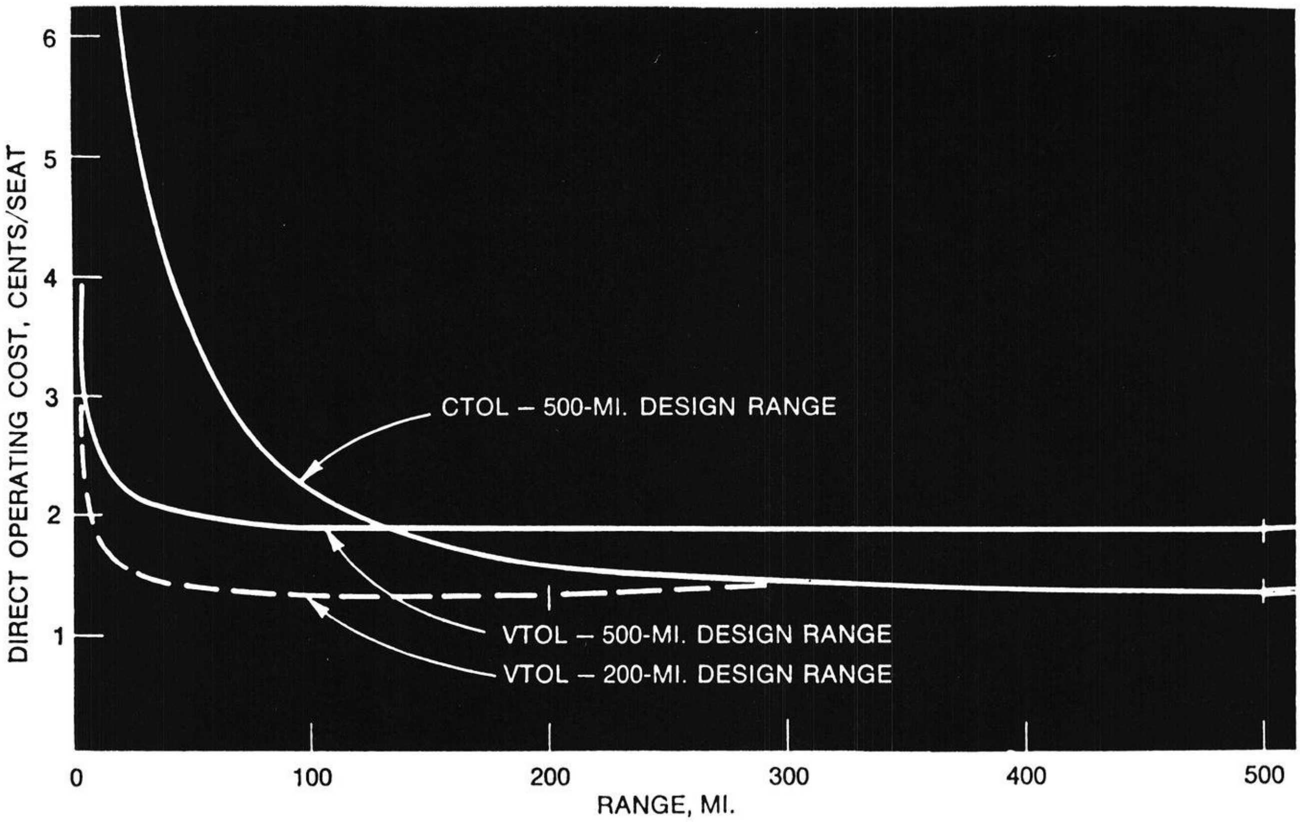


Fig. 6—Maintenance Costs of VTOL Compared to Conventional

In order to provide the schedule reliability essential for passenger service VTOLs would have to have the instrumentation necessary for operation in bad weather. Their time-saving advantage of close in bases would be lost if the VTOLs had to rely on congested conventional instrument flight patterns. One solution to this problem may be to operate completely separate from conventional traffic by flying at low altitudes and using separate improved navigation systems.

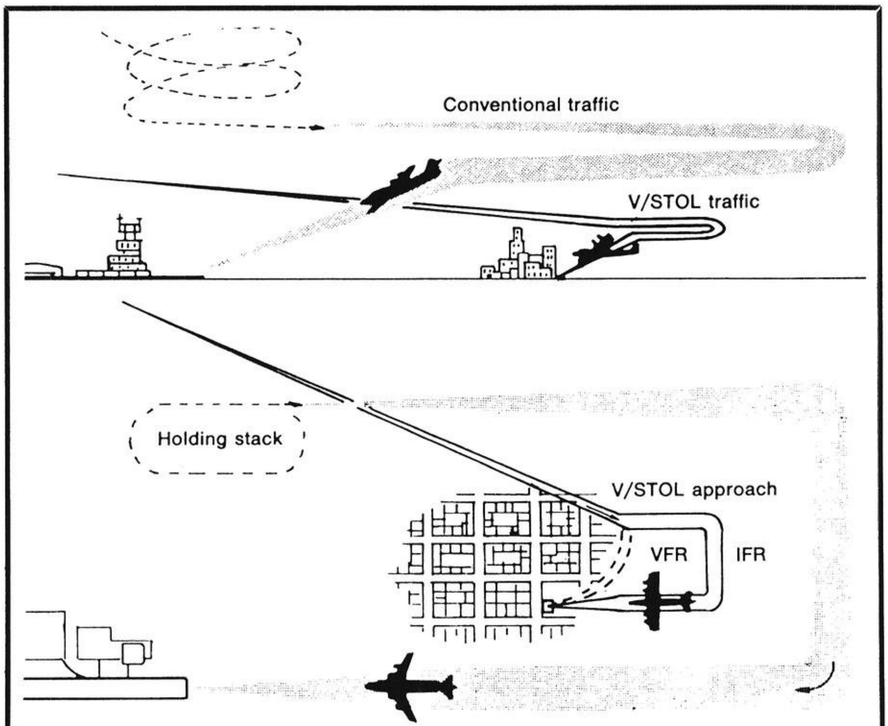


Fig. 7—Traffic Patterns of UTOL

Landing areas for VTOLs would be extremely small by conventional standards. Two or three acres would be sufficient in many cases. They could be located in the heart of the city and possibly even on the tops of tall buildings.

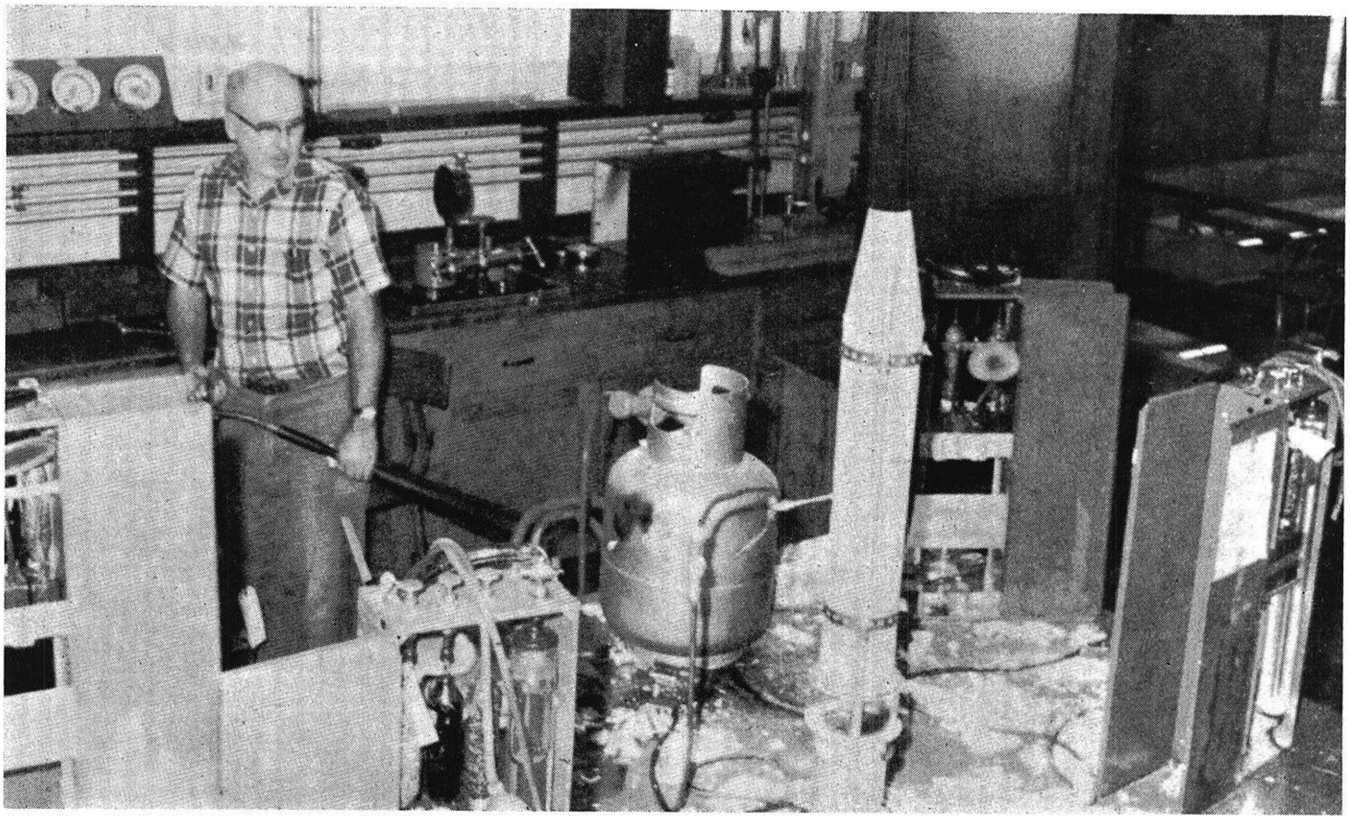
CONCLUSION

Rene H. Miller, Slater Professor of Flight Transportation at MIT, predicted the future of VTOL aircraft very appropriately when he wrote:

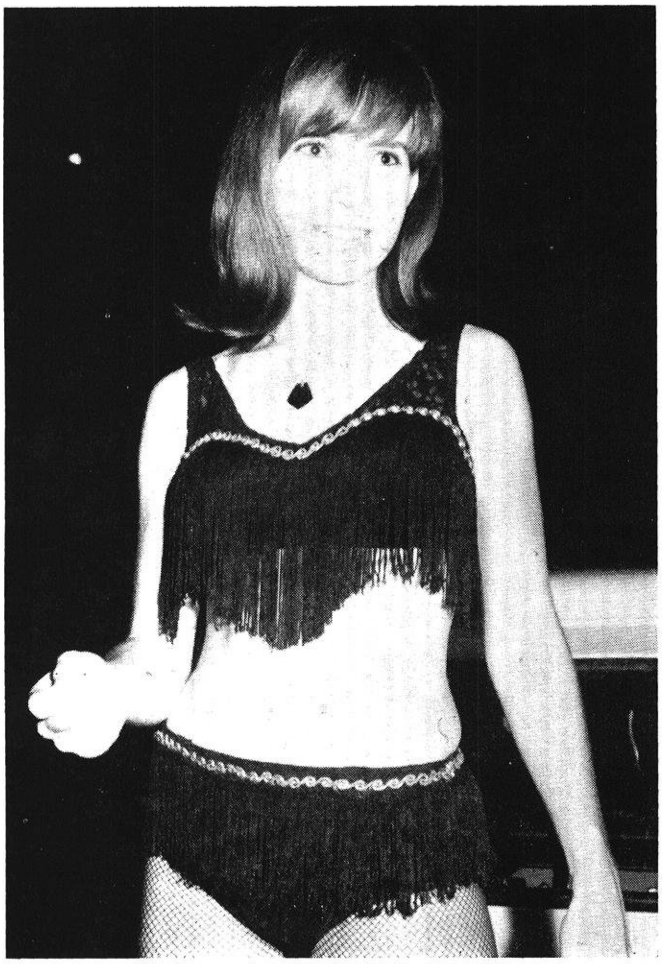
> Successful solution of these engineering problems will almost certainly usher in an age of considerably increased mobility that could have as profound an effect on military tactics and commercial transportation as the introduction of the aircraft produced some fifty years ago.

CAMPUS NEWS

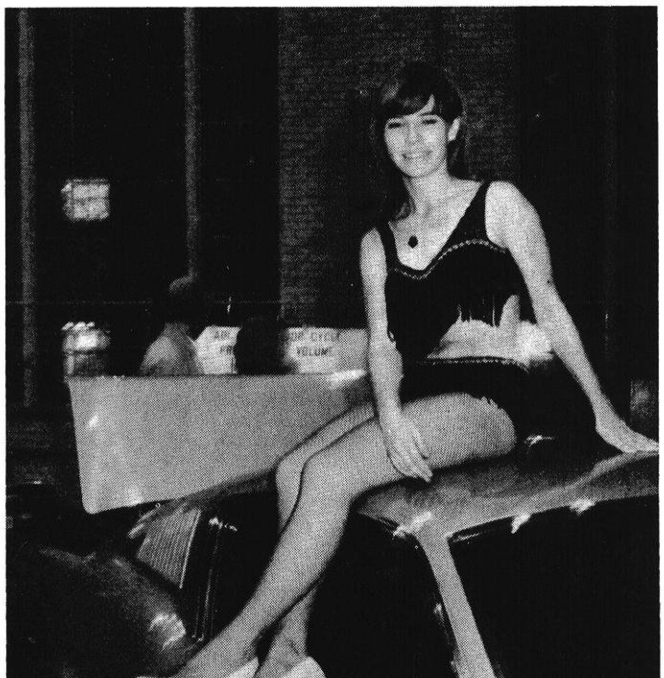
FLASH FIRE SPARKS STUDENT INTEREST

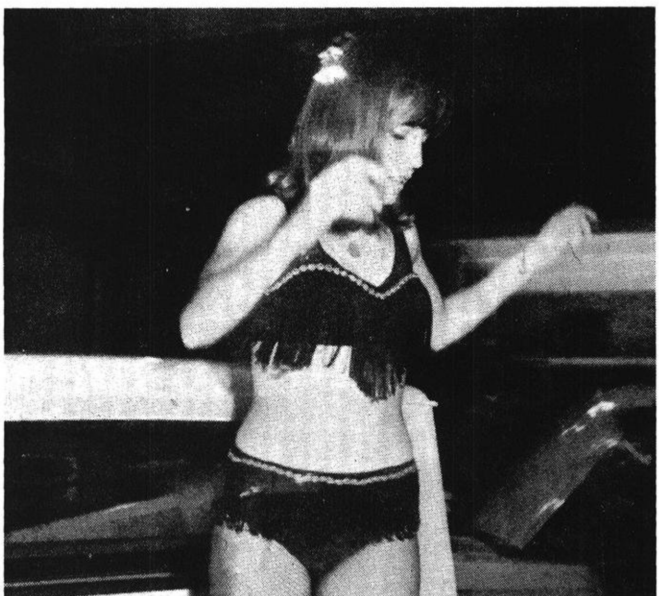


Students kindled a lively interest in laboratory demonstrations when a gas analysis test being conducted in the ME-170 laboratory was brought to a fiery and unexpected conclusion last month. Students attending classes in the Mechanical Engineering building at 2:30 P.M. on the afternoon of October 17 were evacuated from the premises when a fire alarm was activated at the scene of the experiment in a second floor laboratory. The incident was provoked when pressure contained in a propane tank employed in the experimental measurement of fluid gas compression forced a gas line from a lighted bunsen burner, spraying flaming propane in all directions, scorching plaster and spreading fire to nearby books and clothing. Two alert students from the Plasma Dynamics Laboratory rushed fire extinguishers to the scene of the accident and succeeded in bringing the fire under control before the arrival of the Madison fire department. The students, Mr. Warren Hingst and Mr. Fred Ahrens were responsible for containing what might have been a costly accident, though two students, John Reynolds and Bob Draper received damage to personal property as a result of the incident.

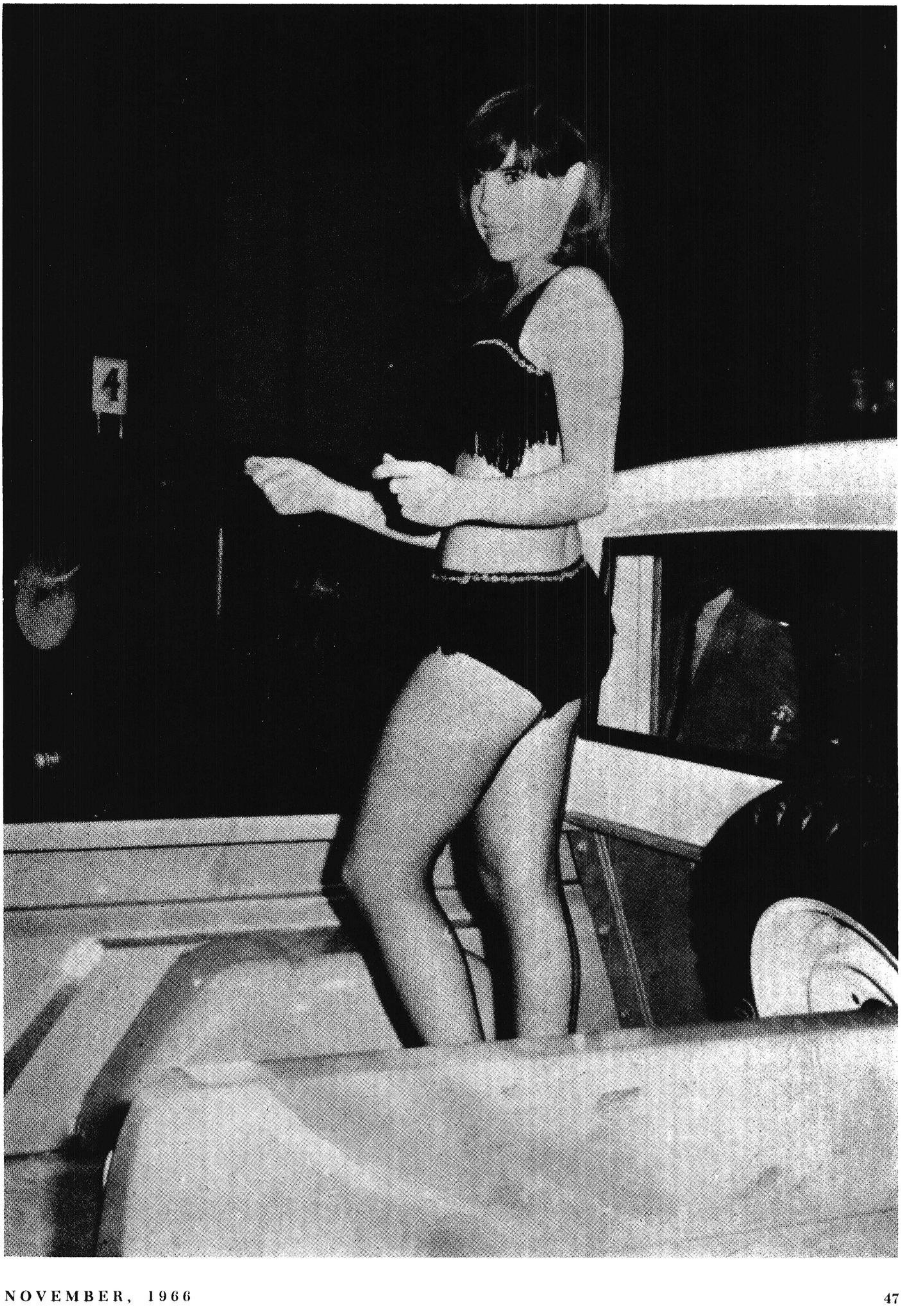


ASME presents *Joanne*





At 7:15 on the evening of October the twenty-ninth, the ASME gave the Thermoscience lab in the Mechanical Engineering Building a temporary but very interesting new appearance. Not only were a new Mustang and a new Ford Bronco parked in the lab, but the Bronco became the dance floor for the very interesting Joanne Jackson, a dancer from Johnny's A Go Go. The entertainment by Joanne, as well as the cars had been brought in by the ASME for the pre-meeting enjoyment of members and prospective members.



TECH CHECK

JUNGLE RADIO

A commercial version of the jungle radio being used by the Army in Vietnam now is being offered by the Delco Radio Division of General Motors.

Known as the Delco 5300, the commercial version weighs less than ten pounds complete with a spare battery, and travels in an over-the-shoulder carrying bag. It measures approximately four by five by ten inches.

Rugged and dependable, the unit could provide radio communications for forest rangers over long distances, forest fire fighters, explorers, prospectors, big game hunters, and others who travel for distances over difficult terrain where light weight and small size of items to be carried are important considerations.

The unit comes equipped with a ring microphone and two earphones. This allows monitoring by two persons. The earphone also may be used as a microphone in case of emergency.

It has proved to be extremely effective in the widest of environments, having been tested under both jungle and arctic conditions. Adequate frequency range has been provided to allow reliable communications at any time of day or night.

New Jungle Radio

"HARDIMAN"

A contract has been awarded the General Electric Company for development and construction of a set of "mechanical muscles" that will give an ordinary man the strength of a giant.

By means of an advanced system of levers, control linkages, and servomechanisms, this unique machine will mimic and amplify the movements of its operator—dramatically extending his strength and endurance. This man-machine marriage will essentially combine the operator's dexterity, brain-power, and all-round versatility with a machine's strength, size, and ruggedness.

Worn like an external skeleton, the "mechanical muscles" machine —nicknamed HardiMan—will permit its operator to lift a 1500-pound load while exerting only a fraction of this force. He will be able to perform general load-handling tasks, including walking, lifting, climbing, pushing, and pulling. The machine—technically described as a "powered exoskeleton" by its developers—will be attached to the operator at the feet, forearms, and waist.

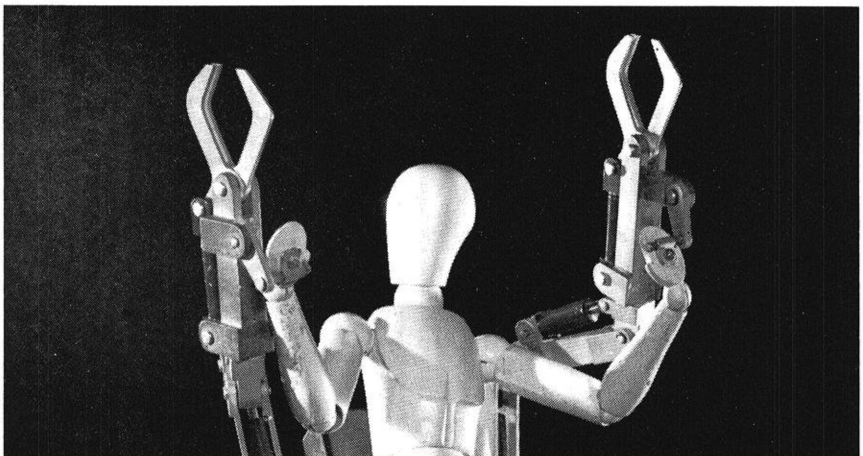
Potential applications for the HardiMan are foreseen in warehouse and factory operations, bomb loading, and underwater salvage. Although the prototype will be connected to a separate power supply by means of flexible hydraulic lines, it is anticipated that later models will have self-contained power units.

The HardiMan project is funded under a program jointly supported by the U. S. Army Natick (Massachusetts) Laboratory and the U. S. Office of Naval Research.

The contract announced today resulted from 15 years of work on cybernetic anthropomorphous machines (CAMS) at the General Electric Research and Development Center. The engineering technology for "force feedback" control —the key to HardiMan—was developed by Ralph S. Mosher, who will guide development of the machine.

Force feedback means that proportions of the forces generated or encountered by the machine are duplicated and reflected to the operator. If the machine's arm or leg strikes a solid object, the operator feels that identical force situation of striking a solid object with his arm or leg.

As a result, the machine simply becomes an extension of the man, and the operator is able to concern himself solely with performing the task at hand. Thus, man now has the ability to control a multi-motion machine in a natural way and to move loads at higher speed, with greater dexterity, than ever before. The control concept makes training time almost nonexistent.



This is a model of a set of "mechanical muscles" that will give a human being the strength of a giant, and permit him to lift a 1500-pound load while exerting only a fraction of this force. Attached to its operator at his feet, forearms, and waist, this General Electric development—nicknamed HardiMan—will mimic and amplify his movements, enabling him to perform a great variety of load-handling tasks.

RECONSTRUCTING PHOTOS FROM LUNAR ORBITER—ON EARTH

From highly detailed photographs in the United States' Lunar Orbiter . . . to a series of electrical signals . . . back to highly detailed photographs on earth. How is it done?

In Lunar Orbiter, photographs of the moon's surface are taken on 70mm Kodak High Definition Aerial Film. Two exposures are made simultaneously—one high-resolution photo and one medium-resolution photo. These two exposures, constituting one "spacecraft frame," fill a strip of the film 11.7 inches long.

The continuous length of film is processed automatically within the spacecraft by placing it in contact with Kodak Bimat Transfer Film, a material that has been pre-soaked in processing chemicals.

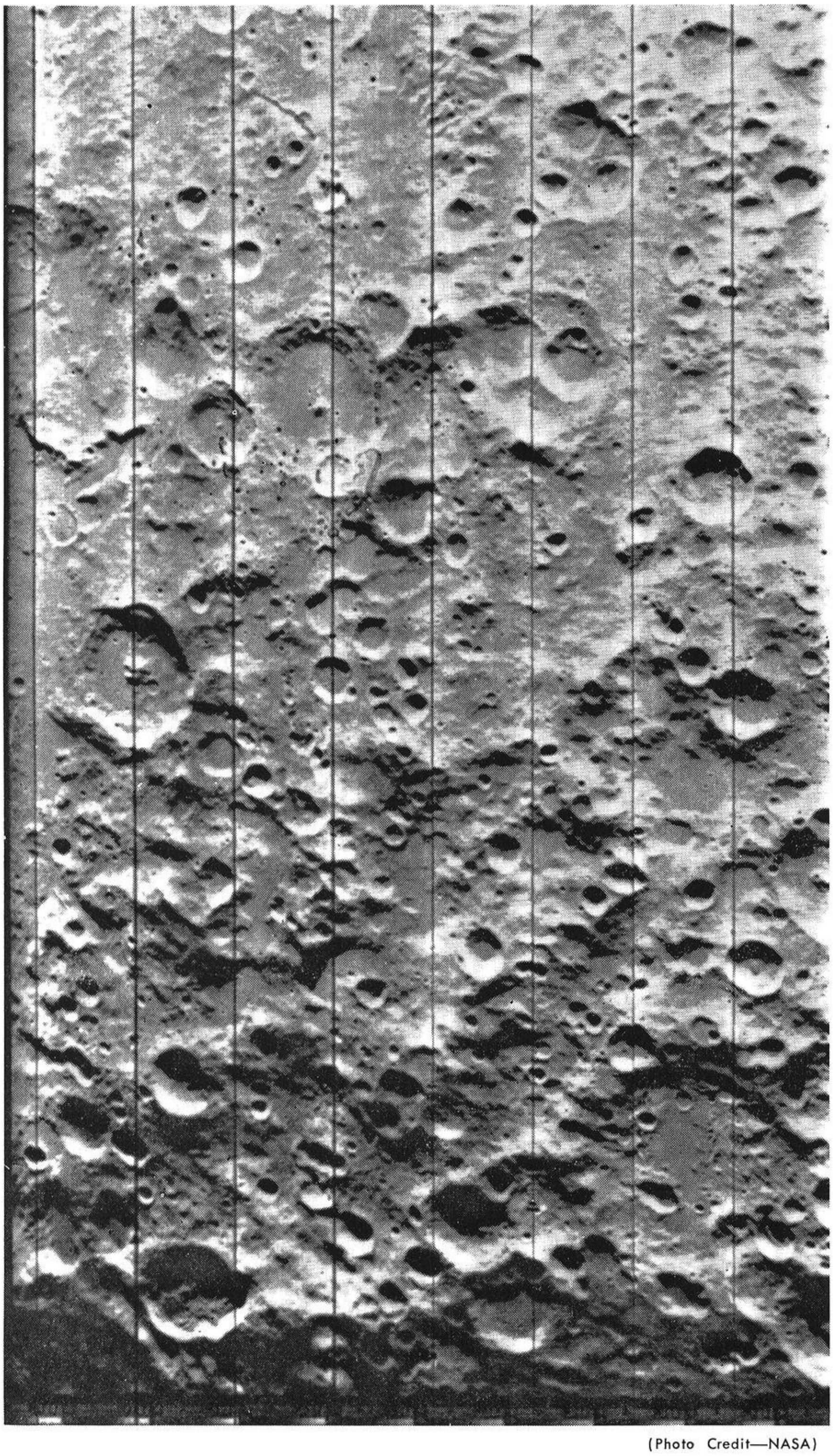
Each frame of the processed film is transmitted to earth in the form of separate "framelets"—1/10-inch-wide (2½-millimeter-wide) bands across the width of the film. A high-intensity spot of light scans each narrow framelet 18,942 times, generating electrical signals for transmission to earth.

The signals are received at tracking stations at Goldstone, Calif.; Woomera, Australia; and Madrid, Spain. To avoid the distortion of any intermediary device, the signals are immediately displayed on a cathode-ray tube—a tube similar in some respects to that used in a television set.

The face of the tube is then photographed on 35mm Eastman Television Recording Film. A single framelet is reproduced as an 18-inch-long strip of film, thus providing an enlargement of about 7.2 times the original dimensions of the framelet. About 20 seconds is needed to transmit a single framelet.

The 35mm film, containing positive images, is processed at the tracking stations and then sent to the Eastman Kodak Company in Rochester, N. Y.

From the films and from additional tracking station data, Kodak technicians secure information con-



(Photo Credit—NASA)

PASADENA, CALIF.—This is a United States photograph of the backside of the Moon. It was taken by Lunar Orbiter I spacecraft on August 19 and radioed to the Goldstone, Calif. station of the Deep Space Network at 1:00 p.m. PDT on August 21.

The picture was taken by Lunar Orbiter's moderate-resolution camera.

North is approximately at the top of the photograph when it is viewed with the narrow strip of photographic test patterns on the right side. The test patterns are used to calibrate the photography.

When the picture was taken, the Sun was on the left at an elevation of 20 degrees. The spacecraft was moving from left to right across this area of the Moon as it took the photograph.

The picture shows an area of the lunar surface approximately 590 by 220 miles. It is centered on a point which is approximately 150 degrees West longitude and 5 degrees South latitude.

This is the most highly detailed photograph of the Moon's unseen face ever taken.

Following this preliminary reassembly, the prime Lunar Orbiter data will be automatically reassembled at Eastman Kodak Co. for detailed study at NASA's Langley Research Center, Hampton, Va.

cerning the photography, such as its approximate location, time of taking, etc. Then they insert the roll of 35mm film, together with punched paper tape containing the data and instructions, into a reassembly printer—a huge machine about the size of a truck (7 feet high by 5 feet wide by 12 feet long).

In this machine, the roll of 35mm film is fed automatically through a pair of optical printers. Fourteen of the framelets are projected in sequence, side by side, and in optical register on a 9½-inch-wide roll of Kodak Aerographic Duplicating Film.

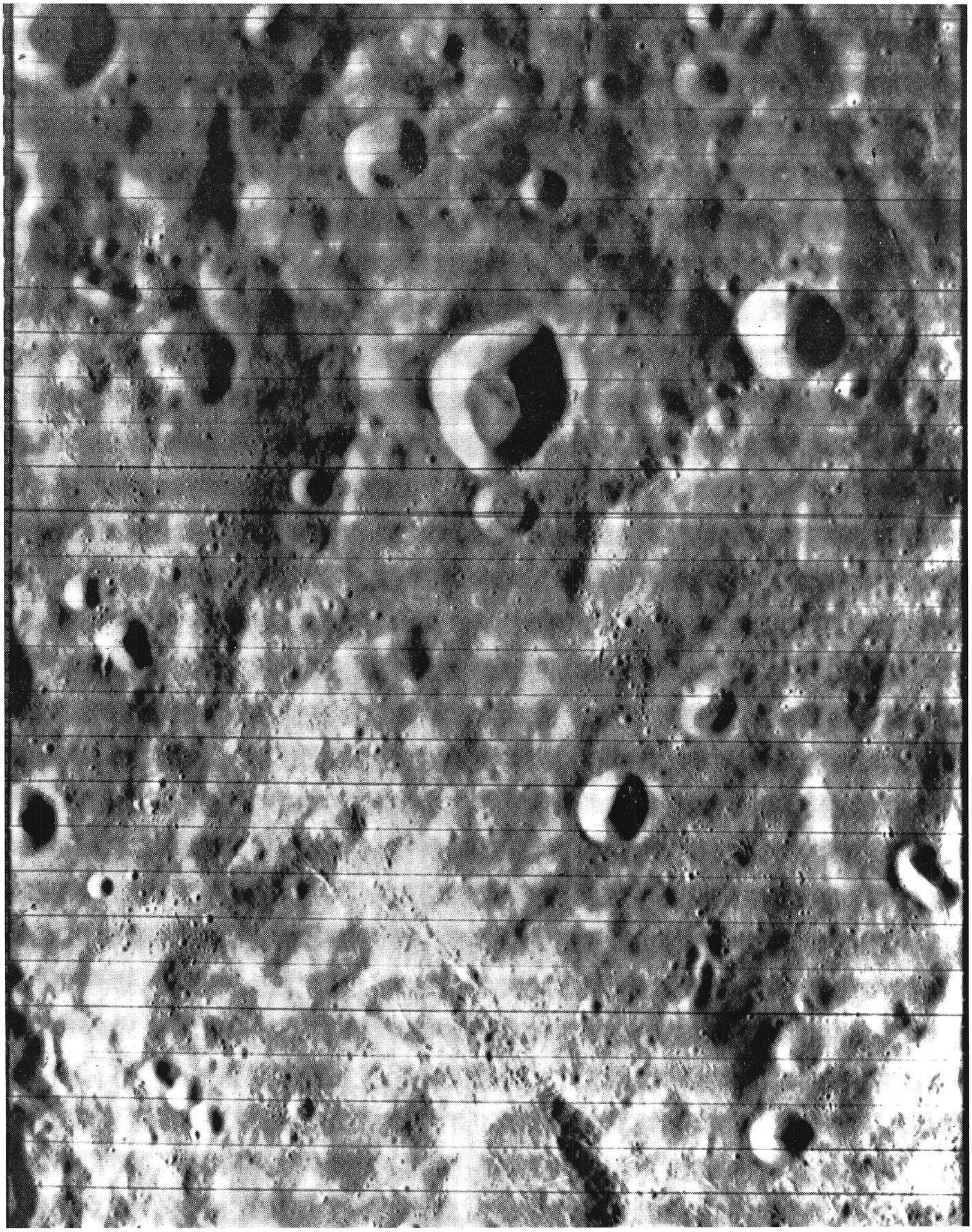
These fourteen framelets compose one "subframe". (Eleven of these subframes constitute a full spacecraft frame—eight subframes for a high-resolution photo and three for a medium-resolution photo.)

Beside each subframe on the duplicating film, data from the punched paper tape is converted to readable information by a separate projection system in the reassembly printer. The wide roll of film, containing negative images, is then processed in an automatic Kodak Versamat Processor.

Succeeding copies of subframe transparencies, both positive and negative, are made on the same kind of duplicating film. Positive prints of the subframes are made on a Kodak Polycontrast Rapid emulsion coated on an improved water-resistant paper base. Kodak also makes exact 35mm copies of the film exposed and processed by the tracking stations. Eastman Fine Grain Duplicating Film is used for these copies.

Through careful study of the photographs from Lunar Orbiter, scientists hope to map and select potential sites for a manned landing on the moon.

The Lunar Orbiter program is managed by the U.S. National Aeronautics and Space Administration Langley Research Center, Hampton, Virginia. The prime contractor is the Boeing Company.



(Photo Credit—NASA)

PASADENA, CALIF.—This is the first United States photograph of the backside of the Moon taken with the high-resolution camera. It was taken by Lunar Orbiter 1 spacecraft on August 20 and radioed to the Goldstone, Calif. station of the Deep Space Network at 1:00 p.m. PDT on August 21.

North is approximately at the top of the photograph when it is viewed with the narrow strip of photographic test patterns on the right side. The test patterns are used to calibrate the photography.

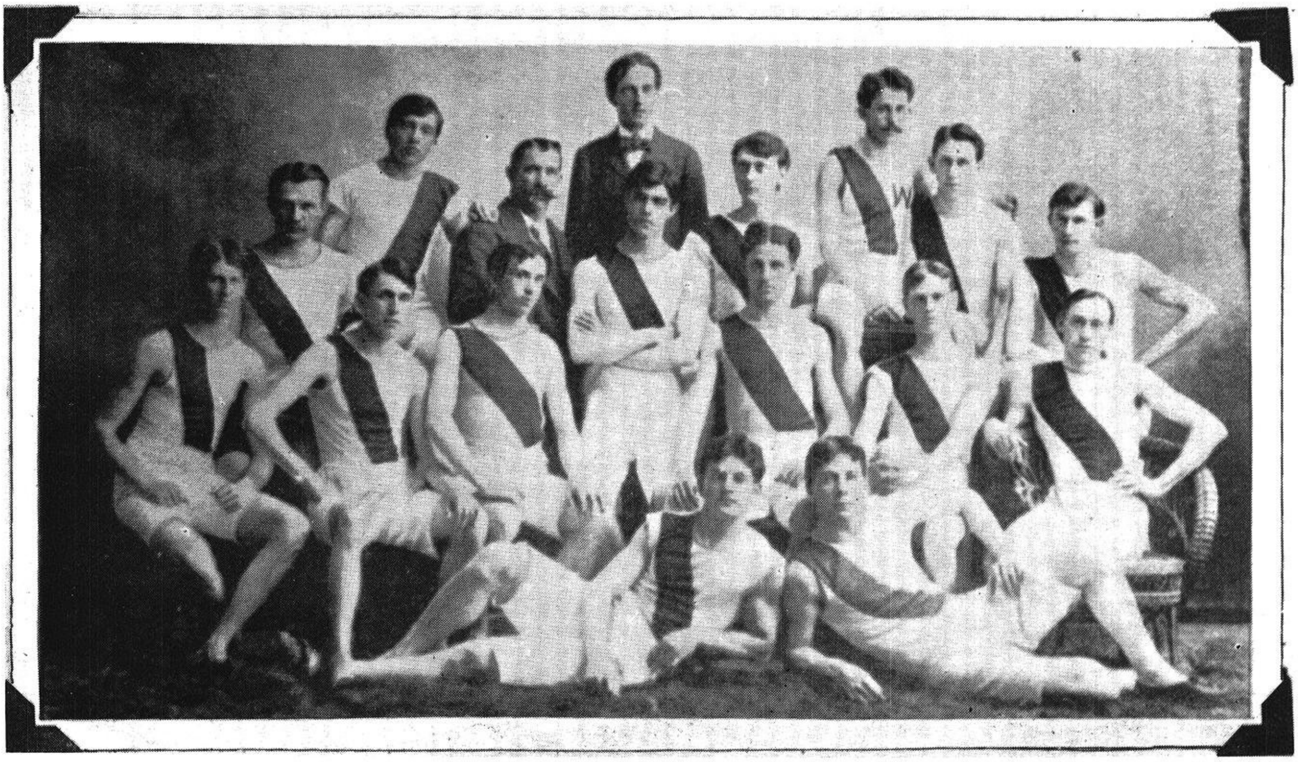
When the picture was taken, the Sun was on the left at an elevation of 20 degrees. The spacecraft was moving from left to right across this area of the Moon's surface as it took the photograph.

The picture shows an area of the lunar surface approximately 75 by 100 miles. It is centered on a point which is approximately 150 degrees West longitude and 5 degrees South latitude.

This photograph shows objects about eight times smaller than the moderate-resolution photograph of the same area.

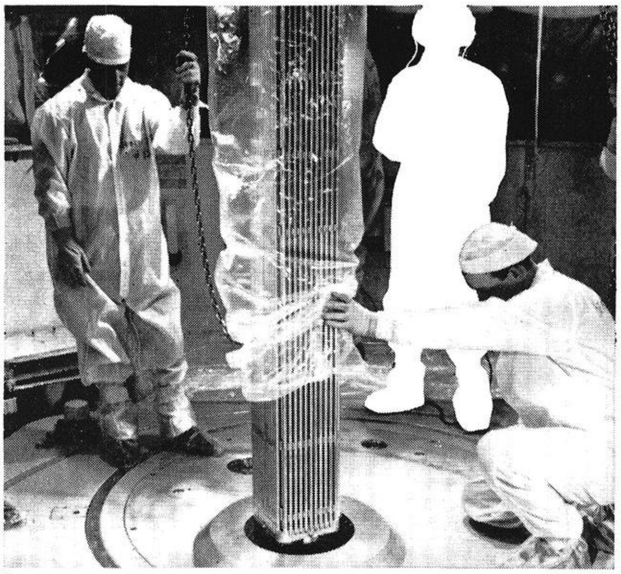
WISCONSIN'S ALBUM

. . . our teams haven't changed much . . .



WISCONSIN'S BADGER TRACK TEAM—1896

WISCONSIN'S BADGER FOOTBALL TEAM—1896



Loading nuclear core in the N.S. *Savannah*.

Put yourself in our place.

Come grow with us. We started in boilers and steam generation, then moved on to atomic power stations, nuclear marine propulsion, computers and control systems, closed circuit TV and specialty machine tools. (We still make the best boiler in America.)

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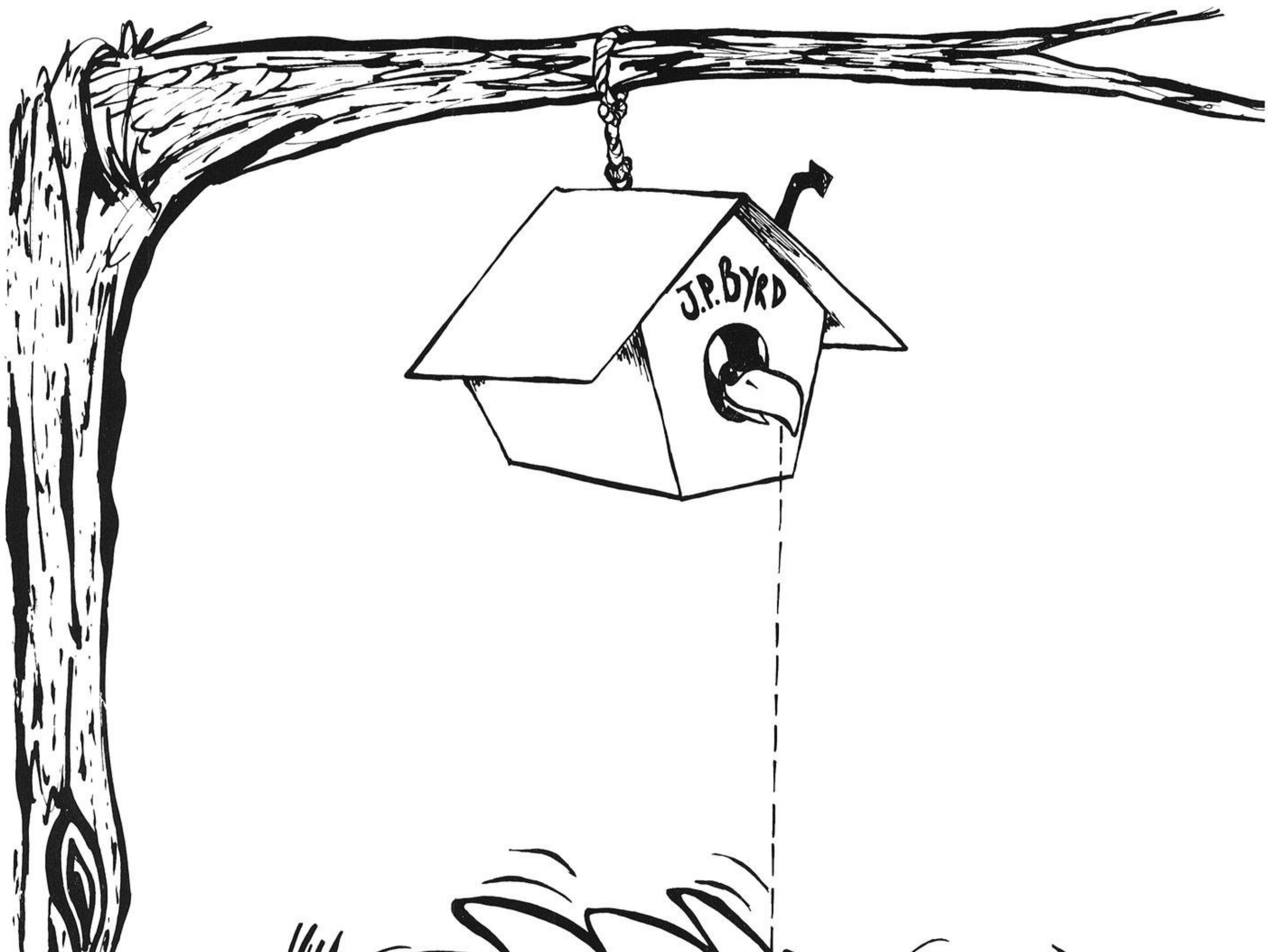


(Another addition to Wisconsin's long list of cartoon greats . . .)

THE BYRD'S BRAINTICKLERS

by The Byrd, bs'69

Another semester is with us and The Byrd would like to issue a warm welcome to all you new students. And just in case any old students are still reading this column, The Byrd extends his sympathy to you and in the words of a hill student: "Stout Fellows!"

Solve the division problem below by finding the correct digits to replace each of the letters.

```
        EFM
AQG | FXNQG
      XJM
      ---
       GXQ
       QAE
      ----
       AEJG
       ASGG
       ----
        AQS
```

* * *

There is a train crew consisting of 3 men, an engineer, a fireman, and a brakeman. Their names in alphabetical order are: Buckholtz, Finn, and Robbins.

On the same train there are 3 passengers. Their names in alphabetical order are: Mr. Buckholtz, Mr. Finn, and Mr. Robbins.

The following facts are known:

Mr. Finn lives in Detroit.

The brakeman lives half way between Chicago and Detroit.

Mr. Buckholtz earns exactly $10,000.00 a year.

Robbins once beat the fireman at billiards.

The brakeman's next door neighbor, one of the three passengers mentioned, earns exactly 3 times as much as the brakeman.

The passenger living in Chicago has the same last name as the brakeman.

Who is the engineer?

* * *

That well known contractor, Muns Ronson, is figuring an a water tunnel from a point A to a point B which is 300 feet below A and at a distance of 500 feet from A horizontally. He is allowed to go in any direction through the earth and rock. The cost from his records for this type of excavation is $10 per linear foot in earth and $30 per linear foot in rock. What distances in earth and rock will give a minimum cost for the construction? Assume the depth of the earth is negligible compared with the depth of rock.

* * *

For you fellows who like probabilities, here's a little problem. Figure out the probability that a stick, being broken in three chance pieces, may be arranged in the form of a triangle. Realize that if a 12" stick is broken into two pieces 2" long and an 8" piece, no triangle can be made.

* * *

The other evening The Byrd and a group of fellow engineers went slumming and stopped at a place called Ratscaller. The place was teeming with frail, long-haired little men who Engineer Robert Smith immediately identified as hill students. Over in one corner of the room a little fellow with greenish skin was snickering merrily while the others in the group were cheering him on in their squeaky, high-pitched voices. Finally, after several toasts of carbonated orange had been drunk, the hero protested that he must leave now before he caught a chill. He just put on his overshoes when Engineer Dick Friede walked up, puffing contentedly on the stub of a pipe held firmly in his granite-like teeth. The fumes from the pipe were too much for the hill students' hero and the fellow collapsed on the floor, still clutching his black umbrella in his withered, scaly hands. On the floor beside him lay a piece of paper entitled, "2=1". It read as follows:

$1-3=4-6$

$1-3+9/4=4-6+9/4$

$(1-3/2)2=(2-3/2)2$

$1-3/2=2-3/2$

$1=2$

Engineer Gerald Johnson immediately saw the error in this "proof". Can you?

Send your answers to The Byrd at *The Wisconsin Engineer*.

FILEABLES

Continued

"Carry your bag, Sir?"
"No, let her walk."

* * *

"You were away without official leave," his superior barked.
"Why?"
"Well, sir," the harassed private began," my first day in the Army we were issued combs, and that afternoon all my hair was cut off. The next morning they issued us toothbrushes, and that afternoon the dentist pulled six of my teeth. The following morning, I was issued an athletic supporter. That's when I went AWOL."

* * *

"Papa," questioned the son, "what is the person called who brings you in contact with the spirit world?"
"A bartender, my son," was the spirited reply.

* * *

A man stopped by the excavation of a new subway and yelled to the men working in the pit, "Say, watcha' doin' down there?"
"Building a subway," one of them answered.
"How long is it going to take to build it?"
"Three years," came the answer.
"Three years! Phooey—I'll take a taxi."

* * *

Bus. Ad. student: "I have a splinter in my finger."
Engineer: "Been scratching your head?"

* * *

I. E.: He (in low-lit living room, as he pressed his lips into her ear): "What are you thinking about, darling?"
She (shyly): "The same thing you are, Dear."
I. E.: "O.K. I'll race you to the ice box."

"Is it true that an alligator in these swamps won't hurt you if you carry a torch?"
"Dat all depends on how fas' yo all carry it."

* * *

Bus Driver: "All right back there?"
Feminine voice: "No, wait till I get my clothes on."
Then the bus driver led the stampede to the rear to watch the girl get on with a basket of laundry.

* * *

"Don't yell through the screen door, Grandma—you're straining your voice."

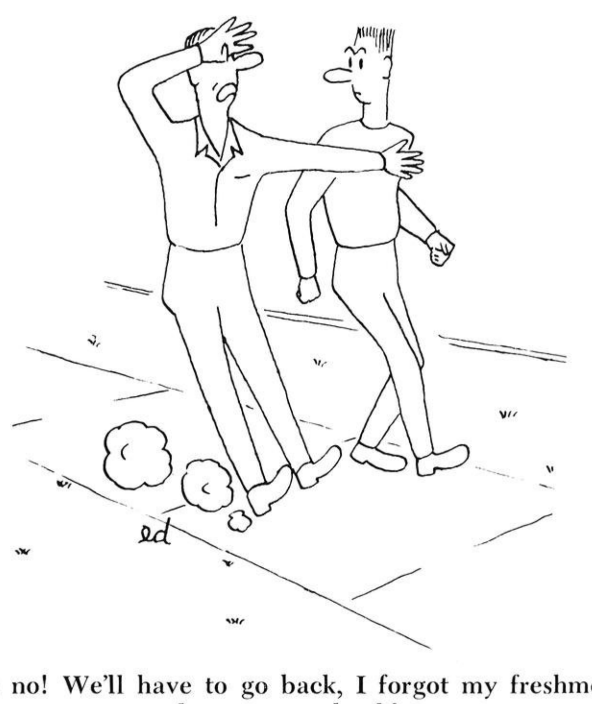
* * *

Wisdom: Knowing what to do.
Skill: Knowing how to do.
Virtue: Not doing it.

A patient at a mental hospital who had been certified cured was saying good-by to the head psychiatrist.
"And what are you going to do when you get out in the world?"
"Well I may go back to Wisconsin and finish my CE course. Then, I liked the Army before, so I may enlist again." He paused a moment and thought. "Then, again, I may be a teakettle."

* * *

A young man and date pulled over to the side of the road.
She: "You're not going to pull that out of gas routine, are you?"
He: "Naw, I use the hereafter routine."
She: "The hereafter routine?"
He: "If you're not here after what I'm here after, then you'll be here after I'm gone."



Oh no! We'll have to go back, I forgot my freshmen lectures notebook!

The engineer was out with a flirt, and when his buddy left the table to buy a paper she pursed her lips invitingly and leaned across the table toward her date and, putting her face against his, whispered, "Now is your chance, darling."

Glancing around hastily, the engineer muttered, "So it is!" and quickly leaned over and drank his buddy's beer.

* * *

Jack: "I'll bet you think twice before you leave your wife alone evenings."

Mack: "I'll say. First I have to think up a reason for going out—then I have to think up why she can't go with me!"

* * *

Selectee: "They can't make me fight."

Draft Board: "Maybe not—but they can take you where the fighting is and let you use your own judgment."

* * *

The best way to get rid of fleas is to take a bath in sand, then rub down with alcohol. The fleas get drunk and kill each other throwing rocks.

* * *

Two stuttering blacksmiths had finished heating a piece of pig iron, and one placed it upon the anvil with a pair of tongs.

"H-h-h-h-h-h-h-hit, it," he stuttered.

'W-w-w-w-w-w-w-wh where?" asked the other.

"Aw -h-h-h-h-hell, we'll have to h-h-h-heat it again, now."

* * *

A person who claims that absolute zero is impossible to obtain hasn't taken a thermo test yet.

* * *

Engineer on telephone: "Doctor come quick! My little boy just swallowed my slide rule."

Doctor: "Good heavens man, I will be right there. What are you doing in the meantime?"

Engineer: "Using log log tables."

* * *

Something to look forward to—women's wigs with built-in brains.

The wild crowd has new game going. Three guys rent a hotel room and each brings a quart of Old Screech with him. They sit and drink for an hour, then one of them gets up and leaves. The other two have to guess which one left.

* * *

"What are you putting in your vest pocket there, Murphy?"

"That's a stick of dynamite. Every time Riley sees me he slaps me on the chest and breaks all my cigars. The next time he does it, he's going to blow his hand off."

* * *

He: My wife worships me.

Him: Is that so?

He: Yeah, she places burnt offerings before me every evening.

* * *

Hit by a speeding midget sports car as she was strolling across a country road, a little hen got up, smoothed down her feathers and muttered: "Lively little cuss, but he didn't get anywhere."

* * *

Diogenes met a veteran.

"What were you during the war?" he asked.

"A private," replied the veteran.

So Diogenes blew out his lamp and went home.

* * *

First Inmate: "And what are you doing now?"

Second Inmate: "Buying old wells, sawing them up, and selling them for post holes."

* * *

Girls are just like cigarettes—a fact you must admit—
You can't enjoy them fully until you get them lit.

* * *

Question: Since pro means the opposite of con, can you give an illustration?

Answer: Yes, Progress and Congress.

* * *

Don't drink while you drive, because you might hit a bump and spill your drink.

"Shay, lady, you're the homeliest woman I ever saw."

"Well, you're the drunkest man I ever saw."

"I know lady, but I'll get over it in the morning."

* * *

Art Student: "Perhaps you, too, are a lover of nature. Have you seen the rosy-fingered dawn spreading across the eastern sky, the red-stained, sulphurous islets floating in the ladle of fire in the west, ragged clouds at midnight blotting out the shuddering moon?"

Engineer: "Nope, not lately. I've been on the wagon for more than a year."

* * *

"What is the heaviest penalty for bigamy?" the judge asked a young man.

"Two Mother-in-laws," he replied.

* * *

Little Jack Horner
Sat in the corner—
B.O.

* * *

Football Game: A contest where a spectator takes four quarters to finish a fifth.

It's a good system if you like it

There are slots.
Slots need people to fill them.
Someone exists who was born and educated to fill each slot.
Find him. Drop him in. Tell him how lucky he is. Look in once in a while to make sure he still fits his slot.

This orderly concept has much to commend it, plus one fault: some of the people most worth finding don't like it. Some very fine employers have not yet discovered the fault. It is not up to us to point it out to them. Luckily for us, we needn't be so tightly bound to the slot system.

We can offer *choice*. A certain combination of the factors diversification, size, centralization, and corporate philosophy makes it feasible to offer so much choice.

Choice at the outset. Choice later on. Choice between quiet persistence and the bold risks of the insistent innovator. Choice between theory and practice. Choice between work in the North and South. Choice between work wanted by the government and work wanted directly by families, by business, by education, by medicine, by science. To the extent that the slot idea helps channel choice we use it, of course.

A corporation such as this is one means of coordinating the strength of large numbers of effective persons. You may feel that in the years ahead this type of organization must change. You may feel that it must not change. Either way, to get a chance to steer you have to come on board.

Advice to electrical engineers, mechanical engineers, chemical engineers, chemists, and physicists—still on campus or as much as ten years past the academic procession: while one starts by filling a slot, it soon proves more fun to make one. No detailed list of openings appended herewith. Next week it would be different. G. C. Durkin is Director of Business and Technical Personnel, Eastman Kodak Company, Rochester, N. Y. 14650.

Kodak
TRADEMARK