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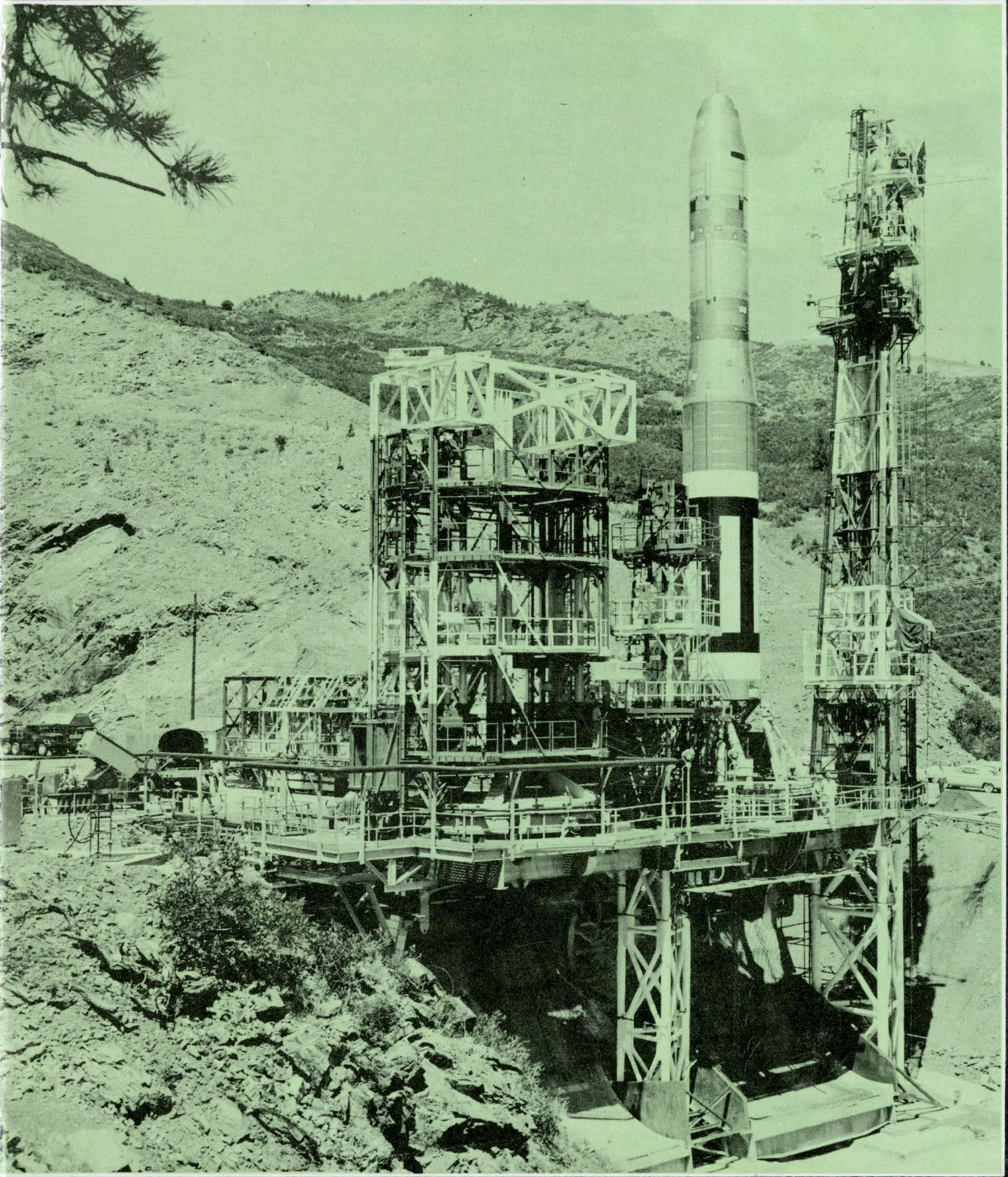

SPRING ISSUE

FEATURED IN THIS ISSUE:

MISSILE DATA SYSTEM OF MARTIN-DENVER

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With this issue the editorial staff is pleased to announce that our new size and format has become a reality. We hope that by presenting the articles in a more easily read form reader interest can be raised to the contribution level.

In future issues it is hoped that feature articles and pictures on local electronic plants can be continued. This issue features the Martin Denver test and instrumentation facilities in a series of articles that were presented at recent meetings of the Section. All pictures were furnished by the Martin Company.

THE EVOLUTION OF INSTRUMENTATION

By W. S. Griffith

If one were ask to name the engineering advances in the last twenty years, the following fields would probably be mentioned: Radar, Aircraft, Missiles, and Color TV. In the past twenty years, the Instrumentation field has moved, or has been pushed ahead equally as fast as other engineering fields. It is necessary for effective instrumentation to move as fast as the field it supports.

This evolution has attracted little attention until recently when a shortage of instrumentation men, particularly engineers, occurred. The basic instrumentation field has gone through many changes. These changes take three forms: new applications for old techniques, new types of equipment, as well as, the use of large organizations devoting full effort to instrumentation.

The d'Arsonval type galvanometer reflects a new application for an old type of instrumentation. In 1937, MIT changed this galvanometer. They removed the damping vanes and increased its natural frequency so it could follow transient and AC currents. To increase its natural frequency, the needle was removed and replaced by a mirror and a light beam. This light beam was reflected by the mirror and recorded be a moving film. The familiar galvanometer box, with its scale, gave way to a light tight housing with a film or light sensitive paper transport. We had the first light beam recording galvanometer. This record was made on 35mm film. The present recording galvanometer has 36 to 50 channels recording with a frequency response from 0 to 8,000 cycles per second on one piece of 12" wide paper at speeds from .1" to 150" per second. About 1924, a recording accelerometer was designed for the National Advisory Committee for Aeronautics. This measured as high as 10.5g" which occurred on a "F6C-4 pursuit airplane in a sharp pull-up at 173 mph."

The aircraft industry influenced the evolution of instrumentation. The two main factors contributing to this transfiguration were the number of events which should be recorded simultaneously as well as the cost of running these tests. Even before the first German missile was fired, a look at the cost of a transonic wind tunnel run against the cost of instrumentation proved that better instrumentation would be an economical factor. Most of the aeronautical measurements were of pressures.

Some of the early approaches to pressure measurements consisted of photographing a number of dial pressure gauges. Another approach was the photographing of a bank of manometers. From these photographs the lift or the drag of the airfoil could be integrated. Other interesting approaches consisted of using a common reservoir for a drag rake and measuring the difference in mercury height and multiplying that by a constant to determine the approximate drag of an airfoil. One of the first applications of multiple electrical reading of events was used in the Aerodynamics field. The wind tunnel balance scales were built with an electro-mechanical print-out system on one inch cash register tape. By pushing a single button you could get readings of lift, drag, cross-drag, pitch, roll, and yaw at the rate of one every five seconds. These tapes could be correlated and the events readily reproduced to a time scale.

In addition to photographing the manometer, cameras were also used to photograph flutter studies. The method used here consisted of a time exposure over the period of a test and the resulting picture was blurred when the wing fluttered, showing the nodes, and the magnitude of the displacement. A similar phenomenon occurred when photographing the manometers. The point of turbulence would show as a blurred column of mercury. Probably the most significant advancement in the photographic field was made when Dr. Edgerton of MIT produced the first micro-second photographs. The original version of high speed photography was one picture per event. Valuable information was obtained from these single shots but it also emphasized a need for a sequence event high speed camera. The General Electric Company developed this camera to study the failures of 30-inch super-charger impellers at over 30,000 rpm. The first unit consisted of a closed loop of film traveling at a high speed and the test object illumination was well below the film exposure level until the fracture occurred. This fracture was sensed by photo cells located at the periphery of the impeller and when the light beam to one of these cells was interrupted, the test object was then illuminated by a series high intensity flashes of one micro-second duration for the time it took the loop of film to go through the camera. Present day applications of high speed photography includes a study of both aircraft and missile phenomenon. In recent years with the development of moderate cost cameras, they could be found in most research labs. Photography is still the best means of recording high speed phenomenon either directly or from the output of transducers reproduced on cathode ray tubes. It is interesting to note at this point that the first telemetering recordings were made by photographing cathode ray tubes with a medium speed camera. This telemetering information was checked by the photographs of the missiles through a theodolite. Photography has become an important tool in instrumentation.

At this point it is realized that more detailed measurements for some events was desired. These fast occurring or complicated events could not be measured or recorded with a single instrument. This problem was then approached with an instrumentation system. The system consisted of 2 or 3 components. The first component sense the event and converts the sensing to a form of energy, a transducer. The simplest system has only two components and the second component is an end instrument or a recorder. This end instrument is driven by the transducer. There are often cases when the transducer cannot effectively drive the end instrument then a third component, or signal conditioner, can be introduced to match the transducer and end instrument. The signal conditioner is usually an amplifier, mechanical, electrical or electronic. Thus, by using a small transducer, an amplifier and a high frequency tape recorder, fundamental frequencies of one hundred thousand cycles per second may be measured and recorded continuously.

To trace the development of instruments by types, probably the best instrument to use is a timer. The measurement of accurate time has been a challenge to man ever since his creation. In retrospect, we have the Obelisk of Egypt, the Roman calendar and the pendulum. One instrument of particular interest may be seen at the V.M.I. museum. This instrument was used by Stonewall Jackson to measure the velocity of projectiles prior to the Civil War. It consists of two matched pendulums each held in place by an electro magnets. Each magnet was connected in series with a battery and another coil of wire. When the projectile was fired, it passed through the first coil and absorbed the energy, thus releasing the first pendulum. The second pendulum would fall as the projectile went through the second coil. Each pendulum has the same period of time, the first pendulum would swing pass the center and the second pendulum, in its fall, would hit the first pendulum and make a mark on a piece of paper. Thus, the angle between the center of the pendulum's swing and the mark on the paper times a constant would give the velocity of the projectile.

Let us for a moment compare art and science. Art is defined as a skill in performance acquired by experience, study, and observation, in short, a "knack." While science is defined as a branch of study concerned with the observation and classification of facts. What is the real difference between art and science? This can be summarized in one word – instrumentation. As our instrumentation systems become more complicated and sophisticated, our guard has to be up to prevent instrumentation from becoming an art in itself. It is the feeling of the author that the instrumentation field must receive more attention at the under-graduate level.

An emphasized senior year course in instrumentation offers excellent training to all Bachelor of Science pursuits. First, consider the general Science or the Physics major types. An instrumentation course would be their strongest contact with the practical or the industrial approach to the solution of a problem. On the other hand, the undergraduate who has pursued more practical and detailed study of his field as an Electrical Engineer, Electronics major, the senior instrumentation course would serve as a valuable general engineering and physics review. The instrumentation course would train the student in matching transducers, signal conditioners and end instruments. The student would become familar with the use of tolerances. He would recognize and justify the deviations between practical curves and theoretical curves he had studied in the past four years.

Instrumentation of a complex system has to be accomplished by a confident engineer. The engineer should be an instrumentation major. Instrumentation may also be accomplished by a systems engineer. But there are several major disadvantages to this approach. By using the systems engineer, you are taking time from the development of the project. You are also probably presenting different measurements from each system. Often, direct comparisons between similar systems is impossible because the instrumentation was different. The true evolution of instrumentation will be accomplished when this field has been reduced to a common denominator. However, with frequent changes and advances in instrumentation, a common denominator becomes more difficult to obtain.

A science can only advance as its instrumentation advances. The real challenge of the instrumentation field is to meet new and not yet invented systems with an adequate and practical method of instrumentation. By supporting a systems engineer with good instrumentation, we have accomplished our job.

In 1883, Lord Kelvin made a very significant stagement – quote, I often say that when you can measure what you are speaking about express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers; your knowledge is of a meager and unsatisfactory kind; it may be the beginning of knowledge, but you have scarcely, in your thoughts, advanced to the stage of science, whatever the matter may be. – unquote. Today, Lord Kelvin could have solved 90% of his problems by consulting an instrumentation engineer with a large budget.

3rd National Convention on Military Electronics

The Third National Conference on Military Electronics, sponsored by the Professional Group on Military Electronics, will be held June 29-July 1, 1959 at the Sheraton-Park Hotel in Washintgon, D. C.

A Concise Review of a Missile Data System Concept

By D. A. Rodgers

I am sure that you are all familiar to some degree with the present day Ballistic Missile Development Programs. Some of you may be directly involved in some phase of this development while others may only have read about it in the news.

How many have asked themselves this question, while reading an article on present day missile programs, – "What do we gain by tossing missiles into the Atlantic Ocean off the coast of Africa?" The answer to this is simple, – "We gain effective weapons systems for our defense as well as "data" to add to the evergrowing library of space information." Let's ask ourselves a second question. "How do we evaluate the effectiveness of these missiles?" The answer – test programs which produce meaningful "data." It follows then that the evaluation of a system as complex as a ballistic missile requires that considerable thought be given to the development of a data handling system capable of supporting the test program and producing useful data.

This then is my topic for discussion:

"A SYSTEMS APPROACH TO DATA HANDLING IN A BALLISTIC MISSILE DEVELOPMENT PROGRAM"

Several things must be considered initially in the development of an adequate data handling system through which a ballistic missile system design can be evaluated.

1) How many parameters must be measured to evaluate this missile? Here we must recognize that the actual flight test duration is a very short period of time, especially when compared with the flight test time utilized in evaluating an airplane since each time we flight test a ballistic missile we expend it. As a result of this short period we must necessarily consider several hundred parameters simultaneously measured in any given flight test of the missile.

2) How is the flight test range which has been assigned to our program instrumented? This is a very important question. What types of ground receiving equipment does the range have and how many channels of data, i.e., parameters, can be recorded simultaneously on the range for the flight test program which we must accomplish.

3) What is the total scope of the test program?

Let's for purposes of this discussion assume that we will follow a test program which has the following general categories:

a. Development Tests on equipment designed specifically for the missile in question.
b. Evaluation tests on procured components.
c. Evaluation tests on subsystems.
d. System marriage tests.
e. Captive firing tests.
f. Flight tests.

Now we shall consider where these various tests will be performed from the facilities standpoint.

a. Development, component, and subsystem tests are all performed in general laboratory facilities.
b. System marriage tests are performed in a special laboratory type facility having test cells capable of accepting a completely assembled ballistic missile.
c. Captive firing tests are performed on test stands similar to – but with greater data handling capacity than launch stands.
d. Flight tests are performed from the launch stands.

With this criteria we can begin to design a data handling system for the program.

There are certain basic factors which must be considered early in the definition of the data handling system.

1) Equipment Utilization – you want maximum utilization in hours of operating time on all data acquisition and data processing equipment.

2) Data correlation capability – you must design so that all lab data, all captive stand data, and all flight range data is compatible and can be correlated during the test program. For instance a failure on the launch stand during a launch attempt may then be simulated on the captive stand at the system level or in the lab at the subsystem level. An integrated system design will permit this type of trouble shooting with extremely good results

through the ability to properly correlate test data from all of these test facilities.

3) Maintainability – effective usage of the ability to interchange major pieces of data handling equipment between facilities. Standardization of equipment minimizing the variety of spares and recording materials to be handled and stocked. Maximum effectiveness of technician training. Flexibility of manpower assignment through standardization of equipment and equipment arrangement within the test facilities.

4) Thruput time – control of data thruput time from acquisition to data analysis by proper overall system design is required.

Figure 1 shows an integrated data handling system for a ballistic missile program. It has some important features which I would like to describe. The data acquisition equipment used in all facilities is interchangeable and it is compatible with the acquisition system in use at the flight range.

The launch complexes have individual block houses and data systems associated with each launch stand. The captive test complex has a central blockhouse and data system for each pair of static firing stands. Thus decreasing the amount of equipment and personnel required and substantially increasing the usage factor of the equipment. The development labs and systems test cells share the use of a central data recording installation for all recorded data. This increases equipment utilization and more important guarantees constant high quality data from lab tests by utilizing trained instrumentation operations personnel in the central facility. The approach described here further permits the establishment of a central data processing installation which can service all data acquisition installations within the systems regardless of physical separation in terms of miles of the various test complexes.

The cost of design, fabrication, installation, and shakedown operations of a **data system** as illustrated in Figure 1, based on 4 launch stands, 4 captive stands, 5 test cells and a large general lab is in the order of 40 million dollars. My comment on this – "If the system approach to this problem costs 40 million dollars, stop and consider for a moment what the cost might be if every test engineer or development engineer was permitted to purchase instrumentation equipment to suit his fancy for a ballistic missile program and what hideous results might come from the infinite types of data records produced on a non-integrated approach to the problem."

In summary I feel that the only logical, economical, proven approach, to gathering useful data from any program equivalent in scope to an ICBM development program, must utilize the concept of systems engineering as its basis.

Installation and Operation of a Large Central Data Recording Facility

By Ronald J. Young

This presentation is to give you a brief picture of what has been done to advance the state of the art where recording of data is concerned.

The centralization of the Data Recording operation was developed in order to achieve the following:

A. To reduce the total instrumentation equipment requirements or to give a lower cost per data point.

B. To improve the quality of data through the use of a staff of trained specialists in test set-up, operation, and recording systems.

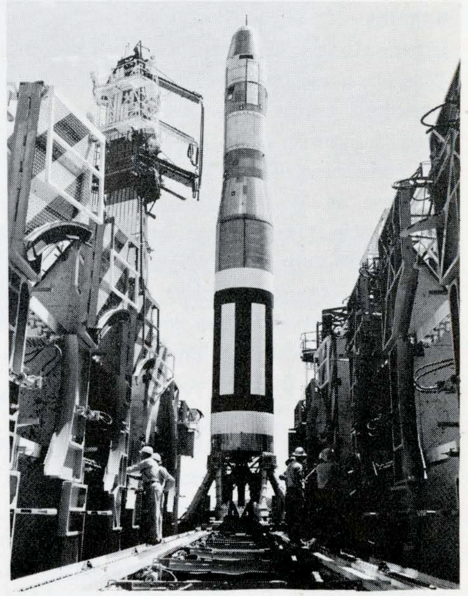
C. To remove personnel and equipment from hazardous test areas.

The centralization was carried out but with it remained the capability of recording in remote areas through the use of portable equipment. Maintained also was the ability for "on-the-spot" monitoring and "quick-look" by test personnel.

The facility supports the operations of 11 laboratories and 5 test cells through cables which we call "land-lines." The longest run of land-lines is approximately 900 feet. Recording over these lines with a 0 to 5 volt signal, our standard, there is no interference from any noise level. These land-lines consist of 36 pair of shielded cable, 15 quad shielded, 7 quad shielded, 20 conductor unshielded control cables, and coaxial cables.

The Central Data Recording room covers an area of 3,000 square feet. It is here the bulk of our recording equipment is located, capable of recording simultaneously over 1600 channels of data. Permanent equipment located in this area consists of a 400 channel millivolt level recording system, 144 channel FM carrier and tape system, a telemetering ground station FM FM PDM, 8 strip chart recorders, a time base generator system plus communications and safety warning systems. Semi-permanently based are eight 36 channel galvanometer type oscillographs. Portable equipment consists of six 6 channel direct writers, capable of recording from 0 to 100 cps., and twelve 8 channel direct writers, recording 0 to 3000 cps.

A patch board is provided for sig-



The slim and powerful USAF TITAN is shown framed by the sides of the erector at one of Martin-Denver's fourstatic test bands.

1959 Electron Devices Meeting

The annual technical meeting of the IRE Professional Group on Electron Devices will be held on October 29 and 30, 1959 in Washington, D. C.

Submission of *titles only* is requested at this time. Indication of a possible paper to be submitted will not obligate the author in any way, but will be helpful to the committee in planning the technical program.

final deadline for abstracts is August nals originating in either test cells or laboratories. Through this board these signals can be patched to any of the recording equipment located in the Central Data room, or, in rare cases, can be patched through the room to some other destination. The 400 channel systems accepts millivolt level signals from low impedance sources such as strain gages or thermocouples up to a maximum of 400 channels in one second, 0 to 2.0 cps. by multiplexing. This system provides power, balance networks and calibration means for the strain gages and attenuators for the thermocouples. It sequentially samples, digitizes and records on magnetic tape the instantaneous voltage existing on each channel. The input information is multiplexed, thereby reducing the amount of equipment required. The information on said tape must be played back on an IBM-523 to obtain punched cards. These cards are then turned over to a Data Processing unit for reduction. The FM carrier and tape system is a 144 channel oscillator phase shift type that operates on a feedback amplifier principal, recording low frequency data, or 14 channels, 0 to 10,000 cps. or 14 channels, 200 to 120,000 cps. The oscillator input is from 0 to 5 volts DC for full band width. The summing amplifiers makes the output from 12 FM oscillators into a single composite signal capable of being recorded on a single tape track. Data can be conducted from the signal conditioning carts on conventional 2 conductor shielded cables. Relatively high frequency data for modulation of the high frequency subcarrier oscillators can be conducted by coaxial cable. The telemetering ground station is designed to accommodate four RF carriers from 4 telemetry packages. Crystal controlled receivers are provided for each link. Automatic calibration equipment is provided for automatically adjusting the single channel discriminators in response to system drifts. A Panoramic Telemetering Indicator is provided to observe in minute detail the distribution of subcarrier energy and a panadapter to analyze the RF spectrum. It can receive, demodulate and record the output of four telemetering packages. Of the 8 direct writers, 6 are single point pen type reproducers recording 0 to 1 cps., capable of a digital readout through the use of encoders and printers the response time is limited to about .4 second on single strip charts and 2 seconds on multipoint recorders, and two are 12 point print-wheel type, recording from 0 to .2 cps. The 36 channel oscillographs are rack mounted. As such, they are capable of recording 24 channels of data from 0 to 3000 cps. These 24 channels have been separated into two blocks of 12, where if 12 or less channels are being used, another test might be made ready to start when the other finished. Printed circuit boards to aid in the attenuation of signals for a desired deflection in either of the blocks have been installed. This provides instant attenuation at the turn of a knob at the 0 to 5 volt level. These racks also have a remote control and communication capability. All equipment in the room, or located remotely, can receive time pulses or time-of-day pulses originating from the time base generator. This generator not only provides the immediate facility but also transmits its signals to the firing stands and to the factory.

The operation of the area is such that we receive requests for support through the medium of Measurement Request Forms. It is these forms that enable us to determine the level of signals, frequency desired, time and other data necessary to determine what signal conditioning equipment is required. An example might be the required recording of land-line measurements of 24 variables, with an additional measurement of 70 variables of telemetering data. This data could originate from strain gages, thermocouples, potentiometers, accelerometers, load cells, etc. An integral part of the operation is the ever-present paper work and scheduling of equipment. Through this medium and the patch board, one recorder can instantaneously be transferred from one test and utilized on another.

Manpower-wise, we presently require 37 operating-type technicians and engineers. There is also a small design crew which handles changes to the data recording system and prepares design sketches and drawings for installation of any end instruments. They also handle design work, such as additional portable instrumentation equipment, for other areas. In most cases, all the data that is recorded by our facility is turned over to a Data Reduction unit for processing.

Each technician working in support of any one test is responsible for the set-up, operation and recording of data. His work entails set-up at the end instrument where the test is taking place, patching through to the CDR room, selecting the recording equipment and preparing it for operation. To aid the technician in his job, there is a darkroom adjacent to the CDR for the loading of oscillograph magazines and the developing of data taken from them. His responsibility ends when good data is turned over to the test engineer.

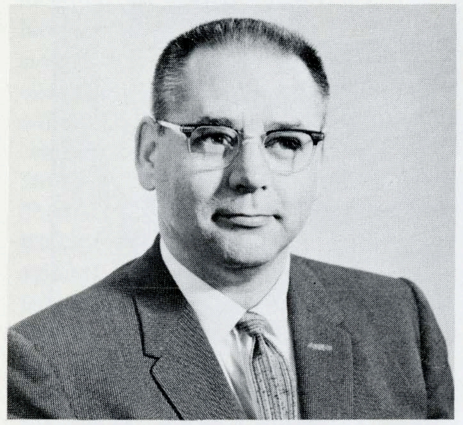
Shown in Figure 1 is a drawing of the area which was described. This is broken into the Vertical Test Fixture and the General Purpose Laboratory. Centrally located is the Central Data Recording facility. Cabling extends from this point through the various laboratories, terminating in racks which are known as "Test Area Termination Racks." In Cells 1 and 2, we have additional racks known as the "Minds Racks." This Minds system enables us to accept signals from the Structural Test Laboratory, from Cells E-1 or E-2 and from any 8 groups of General Purpose calbes. There are two separate patch systems in the CDR. One for General Purpose channels and one for Minds Channels. General Purpose channels are patched in groups of 12. This patch board has a capability to route any 12 groups to the tape recorder, any 16 groups to the oscillographs, any 3 groups to the Minds System, and any 8 groups to a patch board which gives access to each individual channel. Any channel can be connected to several different recorders simultaneously. As you can see from the area displayed and our discussion, the centralization of this equipment has achieved the objectives that were outlined.

PGMTT National Symposium To Be Held June 1 - 3

The 1959 national symposium of the IRE Professional Group on Microwave Theory and Techniques will be held at Paine Hall, Harvard Music Building, Harvard University, in Cambridge, Massachusetts

WOULD YOU LIVE IN OUTER SPACE?

Dr. James G. Gaume, Chief of Space Medicine at Martin Company, Denver Division, presents a well-rounded verbal and graphical picture of the physiological problems with which we are faced in outer space travel at the joint ISA and IRE meeting on April 2, 1959.



Dr. Gaume directs the Space Medicine Research Program which includes programs in physiology, psychology, human engineering, microbiology, hydroponic food production and bioengineering design.

HOW DO WE DEFINE SPACE?

Dr. Gaume outlined space in terms of "space equivalence," the functional borders or limits which we meet as we travel upward through the atmosphere. The following will illustrate the concept of space equivalence and problems we will meet:

52,000 feet — the space equivalent or functional border for oxygen. Above this altitude, the oxygen level is too low for human existence.

63,000 feet — the space equivalent for pressure. Above this altitude, the dissolved gases in the blood stream separate from the blood. Such separation causes bends and neuro-circulatory problems.

70,000 feet — sealed cabin is required. The ozone concentration level at this altitude is high enough to cause irritation and swelling of the lungs.

120,000 feet — cosmic ray border is met. Radiation shielding is required above this altitude.

140,000 feet — meteors are encountered. Below this altitude air density is sufficient to cause the meteors to burn out.

80 to 100 miles — severe visual problems are encountered.

120 miles — aerodynamic border is met. Beyond this altitude, there is no aerodynamic lift.

SPACE MEDICAL PROBLEMS — WHAT ARE THEY?

Dr. Gaume and his staff must determine the control parameters for all of the problem areas which are listed below:

Climitization of the sealed cabin— with especial regard to the oxygen supply, carbon dioxide, humidity, odor, temperature, and barometric pressure.

Physical protection — especially against ultra violet light, cosmic rays, and the dynamics of meteoritic hits.

Psychological problems — with especial regard to a closed system.

Space optics — with special regard to adaptation techniques.

Physiological day-night cycle — adapting the human to an artificial day-night cycle.

Telemetering of physiological data — with especial regard to super-gravity and zero-gravity conditions.

Zero gravity — probably the main problem to be resolved. In short, what will happen to the human body when subjected to a weightless environment? What will happen to our cells and bones when gravity is non-existent?

Toxicity of rocket fuels — with especial regard to launching crew safety.

ARE WE SOLVING THE PROBLEMS?

Dr. Gaume presented several slides which illustrated the progress in a few of the problem areas discussed above.

PGEWS 1959 National Symposium

The 1959 National Symposium of the IRE Professional Group on Engineering Writing and Speech will be sponsored jointly by the Boston and Los Angeles Sections and will run concurrently in both cities on September 17th and 18th, 1959.

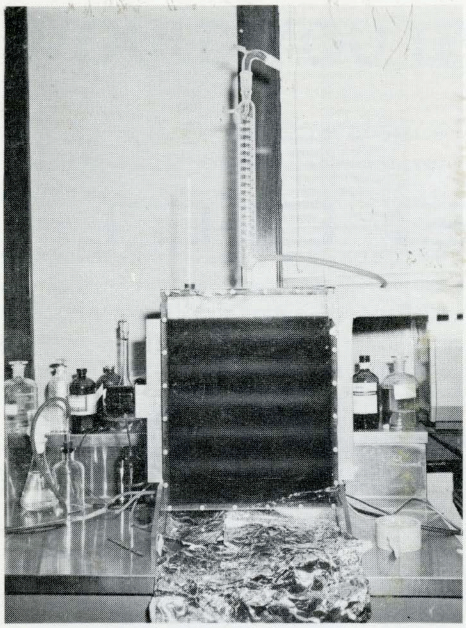
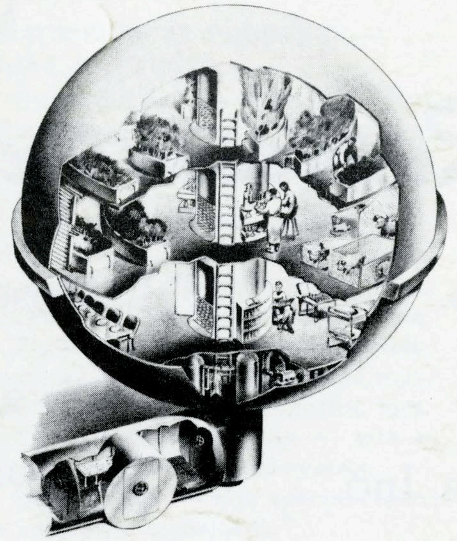


Figure 1 shows a laboratory culture chamber for an algae growth project. It has been determined that about five pounds of algae will provide enough oxygen for one human; and the human in turn will provide enough carbon dioxide for the support of the algae — in short, a balanced system.

Figure 2 illustrates the Martin-Denver "Lunar housing simulator" project, in which plants, humans, algae, and animals can exist in a balanced system for a sustained period of independent operation.



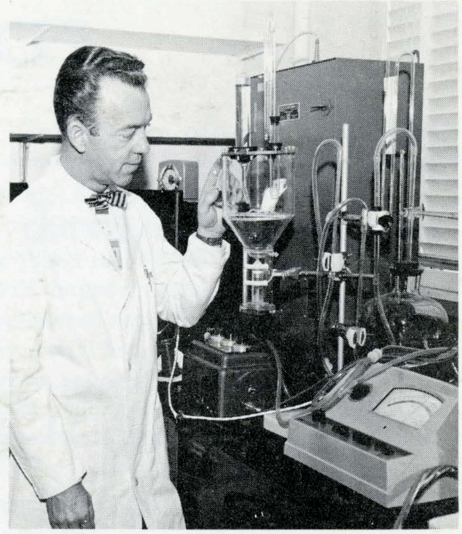


Figure 3 presents a laboratory closed system using a mouse and an algae culture.

Once the space medical problems have been solved by men such as Dr. Gaume and his staff, engineers will be confronted with the end design and production of the "manned" space vehicle, the exact configuration of which will be determined by space medical parameters.

The Central Data Recording Facility as described here required just under two million dollars and slightly over eleven months to design, purchase, and construct. This covered the period from drawing board assignments to full operation. The personnel concerned with the original engineering and design are now assisting in the operation of the facility and continuing to aid in the advancement of instrumentation recording.

Figure 1.