Bits

This month we cover two Eastern Simulation Council meetings, at Avco in Lawrence, Mass., and at Republic Aviation in Mineola, Long Island, both meetings reported by Bob Yeager; and a Central Simulation Council get-together at the University of Wichita and Boeing in Wichita, Kansas, reported by Ted Williams.

The talks covered are:

"The Avco TAVET (Temperature Acceleration Vibration Environmental Test)" by Charles Cohen;

"Computer Problems in Aircraft and Missile Simulation" by George Mayer and Richard Kopp;

"The Simulation of Non-Linear Phenomena" Dr. A. T. Murphy, chairman.

"Circuits for Friction Simulation" by George Castile;

"Conducting Sheet Simulation of Field Problems" by Robert Schrag;

"Digital Simulation of an Air War" by Donald Wendland;

"Simulation of Non-Linear Servomechanisms" by Warren Murray.

Pieces

EASTERN SIMULATION COUNCIL MEETING OF FEBRUARY, 1958 AT AVCO

Bob Yeager (Electronic Associates, Long Branch, N. J.), Secretary of the Eastern Simulation Council, reports that their February meeting at Avco Manufacturing Company's Advanced Research and Development Division in Lawrence, Mass. was almost snowed out.* Talks were scheduled by Henry Bowes (Electric Boat) on the Universal Submarine Simulator and Frank Davidson (Avco) on the Avco Dynamic Pressure Simulator. We don't know if it was because of the weather or not, but only Charles Cohen's talk on the Avco TAVET was reported, so it's the only one described here.

Cohen on TAVET

TAVET is derived from Temperature, Acceleration, Vibration, Environmental Tester, and is a centrifuge encased in a temperature chamber and mounted on a vibration unit.

The need for highly reliable components for unmanned vehicles has increased the importance of efforts to simulate the true flight environment in laboratory testing. In particular, the ICBM experiences high levels of heat, sustained acceleration, and vibrations, all of which act together to induce failures during powered climb and again during re-entry.

To determine the feasibility of combined environmental testing Avco developed a test facility in which the component is subjected simultaneously to high or low temperatures, sustained acceleration, and vibration. To get the use of the facility as quickly as possible, readily available commercial equipment was specified. The following performance specifications represented a compromise between the anticipated missile environment and performance limitations of the equipment:

- Specimen weight: 25 lbs.
- Specimen size: 18" cube
- Sustained acceleration: Variable from 1 to 75 g's
- Vibration frequency: 20 to 500 cps
- Vibration level: 10 g max.
- Temperature: -65°F to +250°F

The basic units selected were Genisco's C-159 centrifuge and an
MB 25h vibration exciter system. The centrifuge has a capacity for a 100-lb specimen and an infinitely variable range of 1 to 75 g with a limiting centrifugal capacity of 2000 g·lb at 280 rpm. The vibration exciter is a 3500-lbs force generator with a frequency range of 2 to 2000 cps. The initial design approach was to enclose the test specimen in a small temperature chamber mounted on the centrifuge arm, but the required size of the chamber precluded use of the Genisco centrifuge. By insulating and temperature-controlling the entire centrifuge enclosure, however, it was found that a good balance could be maintained between specimen size and weight of vibrating components. The centrifuge was then modified to provide vibrating acceleration at right angles to the plane of the radial vector, by replacing the Genisco arm with one made of magnesium thin wall casting. The Genisco framework was mounted above the MB exciter and fastened to the exciter body in such a way that its vertical shaft axis was concentric with and perpendicular to the top of the exciter shake table. The arm and shake table were connected by means of a push rod extending up through the centrifuge shaft to the arm hub.

Heat exchangers supplied with brine were attached to the outside of the centrifuge tub, which was insulated and provided with a vapor barrier. The brine is trichloroethylene because of its inherent stability for the temperature range of -65° to +250°F. The brine is cooled by a cascaded Freon 13-Freon 22 refrigeration system, and there is a chemical dryer for low-dew-point air. Air supplied to the chemical dryer furnishes about 15 cubic feet per minute of -65°F dew-point air for purging the test space and maintaining a positive pressure so that all air leakage will be to the outside.

Preliminary tests indicate that vibratory accelerations of 10 g’s for a specimen weight of 20 pounds can be obtained from 30 to 400 cps. Vibration at higher frequencies is possible, but only at levels below 10 g. The use of compensating networks to flatten the response is being studied, and the adaptability of the machine to the use of random as well as sinusoidal inputs is under consideration.

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**KOPP ON AIRCRAFT AND MISSILE SIMULATION**

Mr. Kopp introduced his subject by remarking that very little information is available concerning the actual techniques of aircraft and missile simulation and expressed the hope that his presentation would inspire others to write of their experiences. The analog computer facility at Grumman Aircraft has grown from a 40-amplifier, 4-servo installation in 1949 to an installation now consisting of 250 amplifiers, 32 servos and considerable nonlinear equipment. Problems also have grown, usually somewhat faster than the computer installation. This resulted in the need for specialized equipment, which was designed to make use of available parts.

Early simulations at Grumman were linearized about some trim point, and offered few difficulties. But in 1954 a simulation of the F11F-1, which covered dynamic stability, trim change with speed, speed stability, pitch-up characteristics,

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**FIG. 1. TARGET**

Appears on screen in front of simulator.

**FIG. 2. SIMULATOR**
control sensitivity, and inertia coupling in roll changed all this.

One of the first problems encountered was incorporation of the human pilot in the control loop. Two real-time flight simulators were designed which included much of the actual aircraft longitudinal control hardware. Information was presented to the pilot in the form of a visual display, instruments, and force feedback applied to the stick. Figs. 1 and 2 show one of the simulators.

The program was divided into two stages. First was the study of longitudinal stability, trim change, pitch-up characteristics, and control sensitivity. A three-degree of freedom (pitch, longitudinal motion, vertical motion) simulator was constructed. Aerodynamic derivatives were a function of Mach number only. The generation of these nonlinear functions and multiplication by other variables in the problem were performed using a modified Reeves input-output table. Six functions were generated on one table by dividing the roll into two portions and again dividing the plotting area into three segments. Small, 2½" wire-wound, resistor cards were used to pick off the function.

Buffet boundary was generated by comparing lift coefficient with a function of angle of attack. Linear corrections were then made to the lift and moment coefficients, and a buffet signal was applied to the force stick servo.

The pilot wore a g-suit to simulate normal "g" acceleration; a voltage proportional to normal g's actuated a servo system which controlled the pressure in the g suit. Another attempt to provide g force was the use of shoulder straps on the pilot which pulled him into the seat with a force proportional to g's. Pre-loading the straps gave a feeling of negative g's when the pre-loaded force was decreased.

The instrument panel shown in Fig. 3 consisted of modified standard aircraft meters. These were an altimeter, a combination Mach-knots meter, rate of climb meter, accelerometer, speed brake indicator, rpm meter, and an elevator indicator.

The visual display presented to the pilot was generated by an optical projection system. A colored slide taken of the horizon was projected onto a translucent screen using a servo-positioned mirror.

The second stage of the study was a roll investigation for which a five-degree-of-freedom simulator was needed, with roll, pitch, yaw, vertical, and lateral motions. The major problem encountered here was the generation and multiplication of twelve functions of angle of attack, because frequencies of two cycles per second with reasonable amplitudes could be expected. This prohibited use of the input-output tables, so a hydraulic function generator was made using a hydraulic servo with non-linear cams driving linear Bourns potentiometers.

The instrumentation was the same as for the three-degree-of-freedom simulator except that the Mach-knots meter and angle of attack meter were not used, and a combination sideslip, rudder deflection meter, a combination angle-of-attack, stabilizer deflection meter, a roll rate meter, an attitude gyro indicator, and a compass were added. The same type of visual display was used, but roll was added by mounting the colored slide in the center of a gear which was controlled by a servo system driven by roll rate, and yawing motions were added by mounting the projector and mirror on a Reeves roll table.

A target tracking attachment was added to the three-degree-of-freedom simulator to determine the effectiveness of the F11F-1 fighter as a gun platform. The target (See Fig. 1) consisted of a front-view silhouette of a fighter scaled down to appear to be at a distance of one mile. This was attached to a wire and raised or lowered in front of the visual display by a servo positioned from a twice-integrated random noise signal representing the expected accelerations. Summed along with this target position voltage were voltages representing pitch and attitude of the simulator. A gun sight reticle was projected from the rear of the screen using another mirror servo. The object was to keep the target in the gun sight reticle. To evaluate the F11F-1 as a gun platform the RMS values of the error were recorded for different pilots.

Next a research simulator was designed to evaluate STOL (short take-off and landing) aircraft, using the same five-degree-of-freedom simulator as a base. The visual display consisted of a scaled-down side view of an airplane silhouette capable of moving vertically and pitching about its CG. This was accomplished by attaching the silhouette to two wire pulley systems, one at the nose and one at the tail. A continuous belt painted with a landscape and driven by a velocity servo was used to give the illusion of forward motion.

Presenting the pilot with the necessary flight instruments was a problem of major concern. Originally galvanometer-type meter movements were used. This type of display seemed satisfactory to the analyst and engineers with no actual flight experience. However, serious objections were raised when experienced...
test pilots were asked to evaluate the simulator's performance. Even though the necessary information was being presented to the pilot, the unrealistic instruments distracted the pilot so much that they impeded his efforts to truly evaluate the flight condition. It was therefore decided to modify standard flight instruments by removing the actuating mechanisms and replacing them with synchro receivers. Synchro transmitters geared to servos could thus drive multi-turn dial instruments directly from the analog computer.

Mr. Kopp then gave details concerning the instrument system and the function generator used to generate and multiply six functions of angle attack. The latter is shown in Fig. 4. Details and performance figures for the visual display, for stick feel, and some other factors included to add realism were also given.

The problem of parameter scaling and time scaling when trajectory studies are being made was also discussed. The main drawback to the separation of the problem into a number of phases, as is often done, is that the initial conditions of one phase usually depend on the final conditions of another. A solution investigated at Grumman was to program the two parts of a homing phase using a different time scale for each part. The initial conditions for the second part were automatically computed from the first and a technique was developed to apply them automatically. The two phases were programmed on different computers with a 10-to-1 difference in time scale. While the first subphase was in operation the second was kept in reset.

A method of varying the time scale continuously was analyzed in an attempt to overcome limiting of servos at the end of the homing phase and to extend the solution time where parameters were changing rapidly. Since the amplitude of the variables does not change with a time-scale change, there is no reason why the time scale could not be changed in the middle of the solution. If this premise is accepted, there is likewise no reason why the time scale could not be changed 10 or even 100 times during the solution; the limiting case would be a continuously varying time scale. To accomplish this, every integrator in the problem would need a pot preceding it. A servo having the necessary number of multiplying pots and driven by integrating a constant was used to produce the desired continuously-changing time scale.

Mr. Kopp explained the mathematical justification for his varying time scale and concluded his informative presentation by describing Grumman's plans for a multi-purpose research flight simulator and combined analog-digital simulation.

CENTRAL SIMULATION COUNCIL MEETING OF 5 MAY ON NON-LINEAR PHENOMENA

Thirty-six members of the Central Simulation Council met at the University of Wichita in Wichita, Kansas for their eighth meeting, held on 5 May 1958. Dr. A. T. Murphy of the University's Electrical Engineering Department served as chairman of the technical session, which followed a delicious lunch in the Pine Room of the Commons Building. Theme of the session was "The Simulation of Non-Linear Phenomena."

Castile on Friction

George E. Castile (Engineer, Computers, Beech Aircraft Corp., Wichita, Kansas) spoke on "Circuits for Friction Simulation", giving examples of the occurrence of dry friction and of the circuits suitable for its simulation. George showed that dry friction could be approximated as a combination of "coulomb friction" and of "striction" (Fig. 5). Striction is the high force required initially to move an object which is subject to dry friction over and above inertia effects, and coulomb friction is the force required to sustain motion. He showed that striction can vary depending on the direction of motion of the object and on the frequency to which it is subjected. He considers the circuit shown in Fig. 6 as the most desirable.

Schrag on Field Problems

Dr. Robert L. Schrag (Associate Professor, Department of Electrical Engineering, University of Wichita) presented his paper, "Conducting Sheet Simulation of Field Problems" next on the program.

Bob described how field problems with mathematics too complicated for ready solution by standard computational means can be solved by experimental means using homogeneous and heterogeneous mildly conducting media. The possibilities of simulating a cylindrically symmetrical electrode by means of a conducting sheet formed the basis of his talk. He reviewed the mathematics of the usual field problem in cylindrically symmetrical cases as expressed
by LaPlace’s equation for the non-space-charge case and by Poisson’s equation for the cases involving space charges. He discussed several methods of expressing the analog of space charge on the conducting sheet, including the use of holes punched into a conducting sheet to reduce its conductivity and also the use of light-sensitive paper to form a source of charges. Bob also told about the use of an electrolytic tank with varying conductivity.

Art Murphy asked if it were possible to mechanize the readout of lines of constant field strength by the use of a probe equipped with feedback mechanism. Bob replied that this was certainly possible, but would require a very complicated mechanism. He went on to say that an even more difficult problem was drawing the electron rays in such fields, and this he did not know how to mechanize.

Jerome Kennedy (Electronic Associates, Inc., Mt. Prospect, Illinois) described the work of a professor at the University of Michigan* who uses a system of distributed current sources in a conducting sheet to achieve a known variable space-charge effect. This permits the rapid change of problems since there is no necessity for a change in the physical configuration of the test tank. Only rheostats attached to each one of the matrix of electrodes in the sheet need be changed to achieve a completely different space-charge simulation.

**Wendland on Air War Simulation**

The third paper, entitled “Digital Simulation of an Air War”, was presented by Donald E. Wendland (Supervisor, Operations Analysis for the Preliminary Design Department, Boeing, Wichita, Kansas). Donald’s paper was a fascinating discussion of the use of an IBM 701 to simulate by operations-research techniques the problems faced by the offense and defense in a bombardment raid during a modern air war. The simulation procedure contains factors to handle the phases of Friendly Environment, Peripheral Defense, Area Defense, and Local Defense in the attack. It includes warning and guidance radar, surface-to-air missiles, and fighters for the defense; while it considers air-to-surface missiles, gravity bombs, and electronic countermeasures for the offense. Its main use is in testing various concepts of attack and defense strategy as a function of the capabilities of various possible bomber designs. The effects of raid and bomber strength as strategy factors were vividly illustrated by Don in his talk.

Don described the mechanism of his so-called “bookkeeping method” of keeping track of the status and remaining capabilities of both attack and defense on the computer as the air battle proceeded. The possible variability of the air battle is handled by allowing a Monte Carlo procedure of random numbers to specify some of the possible attack and defense procedures.

The model allowed the offense to be varied in light of a specific defense strategy. However, no provision was made for the corresponding variation of the defense strategy.

An especially valuable item in the program is the “events tape” which records each event of the campaign and maintains a running score of the campaign as it proceeds. This is equivalent to the commander of our Strategic Air Command’s having a blow-by-blow account of the air war as it proceeds.

The talk evoked great interest in the audience and resulted in a large number of questions at the end. Some of these follow:

R. W. Hippe (IBM) asked whether the monetary value of the bombers, targets, and so forth were included in the model for cost analysis purposes. Don replied no; he’d like to do this but hasn’t yet.

David Hohlfeld (Beech Aircraft, Wichita, Kan.) asked if factors of bad weather and faulty navigation were taken into account. Don answered yes, as a statistical factor supplied by the Air Force.

Asked by A. J. Craig (University of Wichita) if the model gave any surprising results, Don said yes, several, and described how the improper spacing of bomber waves could result in the first wave’s getting to the target and causing a huge amount of damage while succeeding waves sustained very large losses.

Bob Beck (Digital Computer Laboratory, Boeing, Wichita, Kansas) explained that each set of campaign conditions requires about 15 minutes of computer time to calculate and print out, and that the limit of the campaign size is the storage of the computer.

Don offered to discuss details of the program with any interested individuals.

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**Murray on Non-Linear Servomechanisms**

The last paper on the program was presented by Warren A. Murray (Engineer, Flight Test, Boeing Aircraft, Wichita, Kansas) and entitled “Simulation of Non-Linear Servomechanisms.” It discussed work he is doing for his master’s thesis at the University of Kansas and describes the analysis of a non-linear contactor servomechanism with dead
zone (Fig. 7). The servo he is analyzing combines a linear transfer function with another non-linear one. It was analyzed by the method of “characteristic loci.” The input used was a pure sine wave clipped by the dead zone, with only the fundamental of the clipped wave (i.e., with center missing, Fig. 8) transmitted to the non-linear mechanism. This permitted him to express the Fourier Transform of the input to the non-linear element.

Warren plotted a family of phase-plane diagrams of the non-linear portion of the servomechanism as a function of amplitude and frequency. He also plotted a phase-plane diagram of the linear portion of the servo as a function of frequency alone. He was thus able to find intersections of the linear curve with the proper non-linear curve by noting that the frequency at the intersection had to be the same for both curves. Thus the amplitude of the output as a function of the input amplitude could be found for various frequencies of oscillation.

He was able to obtain the foregoing results both from theoretical calculations and by simulating the servomechanism on an analog computer.

Warren also showed the application of his method of analysis to the case of control of liquid level on a tank fitted with a float showing dead space.

Following the technical session, a tour was conducted through the analog computer facilities at Beech Aircraft Corporation. The Beech facility (under the direction of Jim Pierce) consists of two expanded Electronic Associates 16-31R consoles with considerable non-linear equipment. There is also a quantity of BEAC (Boeing Electronic Analog Computer) equipment.

George Castle ran his dry friction simulation for the benefit of Council members, giving a vivid demonstration of points brought out in the discussion following his paper.

Also demonstrated was the simulation of the control system of a drone aircraft complete with “beeper box.” Visitors were able to “fly” the drone and watch its progress on a large plotting board.

Everyone who attended this enjoyable and worthwhile meeting was impressed with the hospitality of the University of Wichita and Beech Aircraft.

He Went Thataway:

Eric Weiss to Sun Oil Company in Newton Square, Pennsylvania.

Information (Without Theory)

By the time you read this we hope all who ordered the Proceedings of the National Simulation Council will have received their copies*

Those who have not yet ordered this very informative volume are reminded that for $3.00, sent to Simulation Councils, Inc., 3434 La Jolla Shores Drive, La Jolla, Calif., they can get their volume of reprints of eighteen valuable papers.

Mid-Century Instrument Corporation (611 Broadway, New York 12, N.Y.) has a novel gimmick for acquainting people with their new MC-5800 “Master Precision Analog Computer,” which they say “differs in concept from older computers in two respects: Expandability and packaging.” This gimmick is a set of five color transparencies of their computer and a collapsible cardboard viewer, all in a 3 x 4½” plastic case which would make a good carrying case for credit cards, driver’s license, etc., if one should get tired of looking at the pretty pictures. Bob Stern’s covering letter also mentions a “new Card-Programmed Diode Function Generator” and “and AM/FM Multiplier with unusual performance specifications.”

*We built an AM/FM multiplier with “unusual” performance specs when I was at Pt. Mugu. The performance was so unusual, in fact that we gave up the whole idea! — Ed.

Computer Events

Association Internationale pour le Calcul Analogique

Dates: 1-7 September 1958
Place: Strasbourg, France
Subject: “Journées Internationales de Calcul Analogique”
An exhibit of analog equipment will open 30 August and continue until 10 September. Because of increasing interest in the combination of analog and digital techniques, a section of the “Journées” will be devoted to this subject. For further information write Monsieur F. H. Raymond (138 Boulevard de Verdun, Courbevoie, Seine, France).
Conference rooms will be equipped for simultaneous translation. Discussions following the reading of papers will be in French and English.

Midwestern Simulation Council

Date: 8 September 1958
Place: Caterpillar Tractor Company, Peoria, Illinois
Subject: “Land Vehicle Simulation” (tentative)

Central Simulation Council

Date: 8 September 1958
Place: Midwest Research Institute
Kansas City, Missouri
Subject: “The Digital Differential Analyzer—How It Works, How It Is Used”
Election of officers will take place at this meeting.

National Simulation Conference

Place: Statler-Hilton Hotel, Dallas, Tex.
The conference will be sponsored by the IRE PGE and the Dallas Section of the IRE. For further information write J. E. Howard, 2100 Menefee Drive, Arlington, Texas.

Eastern Joint Computer Conference

Dates: 3-5 December 1958
Place: Philadelphia, Penna.