Bits

This month a report on the Southwestern Simulation Council meeting of 23 January 1959 at ARO, and one paper from the Eastern Simulation Council meeting of 16 February 1959 at Grumman.

The first consists of the abstract of a paper, “Determination of Forcing Functions from the Response of a Known Physical System” by W. K. McGregor, and a guess by ye Ed as to what Mac really explained in the talk, plus a description of the subject matter of a paper “Solution of Simultaneous Partial Differential Equations” by S. P. Ragsdale, and an abstract of a thesis by Homer Powell on “Solution of Differential Equations through the Use of Number Series.”

The paper from the Eastern Council, entitled “Development of a Multipurpose Research Simulator” by E. J. Kennelly describes what we usually refer to as Flight Trainers.

There is little Info and no Thot in the rest of the Newsletter.

We will try to do better next month, but at the moment many of our Thots are not printable, and some are not concerned with Simulation!

Pieces

SOUTHWESTERN S/C MEETING OF 23 JAN ON FORCING FUNCTIONS AND PARTIAL DIFFERENTIAL EQUATIONS

Twenty-six representatives of about a dozen different organizations signed the register for the January 23rd meeting of the Southwestern Simulation Council at the Arnold Engineering Development Center in Tullahoma, Tennessee.

McGregor on Determination of Forcing Functions

Dallas Russell (ARO, Inc., Tullahoma) welcomed the group and introduced W. K. McGregor, who spoke on “Determination of Forcing Functions from the Response of a Known Physical System.”

Here is Mac’s own abstract of his talk, verbatim:

The age-old instrumentation problem, known generally as the “Converse Problem,” is attacked in a new light by use of simulation and feedback techniques. The problem is described as “given the response and law of a known physical system, what is the forcing function?”

Previous methods of solving this problem were to attempt to correct transient data taken on high-speed recording oscillographs. Methods used depended on knowledge of the differential equation and on the ability to obtain slope measurements or Fourier series from the records. The results were time-consuming and usually inadequate.

The simulation method introduced in this paper is based on accurate simulation of the measurement system dynamics on an electronic analog computer. From an oscillogram of the measurement system response to a known forcing function, the differential equation of the measurement system is obtained. The equation is simulated on an analog computer, and by use of feedback around the simulated system, a compensated system with much faster and more stable response is produced. The input to this new system is the measurement system output. The error signal of the new system is then a faithful reproduction of what must have been the input to the measurement system.

(Editor’s Note)

Get it? (I don’t). Mac’s a smart boy, but this time his abstract was too abstract. What this dense one guesses he means is: Given an imperfect measuring system (Fig. 1) with input $e_{in}$ the output $e_{o}$ will be $e_{o} = e_{im} + e_{m}$, where $e_{m}$ is the error introduced by the measuring system. If this measuring system is then simulated, the simulated system will have an output $e_{os} = e_{im} + e_{m}$ for an input $e_{os}$; and if the simulation is accurate, $e_{m}$ will equal zero. If a feedback loop around the simulated system can now be developed which will make $e_{os} = e_{os}$, the output of this feedback system must be $-e_{os}$.

If then the output of the measuring system $e_{os}$ is the input to the simulated system $e_{os}$ we have:

$$e_{os} = e_{os} = e_{im} + e_{m}$$

At the summing junction the feedback signal $-e_{os}$ is added, so the signal actually driving the original simulated system (which we will call $e_{d}$ to prevent confusion
with the other error signals) is:
\[ e_0 = e_{im} + e_m - e_i \]
and as \[ e_m = e_{ma} + e_{ma} = e_{im} \],
which is what Mac said to begin with (I think).—Ed.

Three methods of applying the measurement system output to the simulated system are discussed. They are (1) direct input of the instrument signal to the simulation; (2) replay of magnetic tape recorded signal into the simulation; and (3) transfer of an oscillograph record to graph paper and subsequent relay into the simulation at extended time scale from an x-y curve follower.

Questions following Mac's talk brought out the facts that:
The frequency of the simulated system is the most critical part;
The acceleration term as well as the velocity term must be cancelled out;
They were dealing with a second-order system, specifically a thrust stand which was shocked by displacing it with a piano wire, then cutting the wire.

**Ragsdale on Simultaneous Partial Differentials**

Sam Ragsdale (ARO, Inc.) was the next speaker. However his paper, “Solutions of Simultaneous Partial Differential Equations,” a copy of which was sent to us by Ed Holmes, Secretary of the Southeastern Simulation Council, is too erudite for full treatment in this Newsletter.

Suffice it to say that it described a method of using an analog computer (in this case a GEDA) to solve equations of the form

\[ \frac{\partial T_x}{\partial x} = H_x(T_a - T_x) - H_p \]
\[ \frac{\partial T_x}{\partial t} = H_x(T_x - T_i) + \alpha \frac{\partial^2 T_x}{\partial x^2} + H_e \]

which arose in connection with the development of a graphite heater for simulating trajectory temperatures at the Gas Dynamics Facility of ARO, Inc.

The values of five of the variables required as functions of time are derived from x-y plotters with curve followers, and are fed into the analog computer, which solves the equation necessary to plot the temperature histories of stations along the graphite bar heater.

Those interested in (and capable of understanding) more about the technique are urged to get in touch with S. P. Ragsdale, Technical Service, ARO Inc., AEDC, Tullahoma, Tenn.

**Powell on Number Series**

The third speaker was Homer Powell, also of ARO Inc., who spoke on “The Solution of Differential Equations through the Use of Number Series,” which Ed Holmes tells us was part of a Master's thesis. Ed sent us an abstract of this talk, as follows:

The scope of this research study is essentially the development and presentation of a Number Series method for the numerical solution of many types of differential equations. The method is applicable to manual or digital computer solutions.

The approach draws upon the methods and techniques of analog-computer solutions. The components required for an analog solution are simulated on a digital computer by programming the equivalent mathematical function of that component. The justification for the method is provided by Number-Series operations. For example, the development of a formula for use as a simulated integrator is obtained from the Number-Series integrating operation. The simulated components are then interconnected in such a way that during the sequence of computer instructions, the stepping from component to component mathematically represents the differential equation or system under study.

Various degrees of accuracy are available by this method, and a variety of equation types may be solved. The most serious disadvantage when compared to analog computer solutions is the time required to solve the problem.* * * *

After lunch the group toured the Gas Dynamics Facility, the Propulsion Wind Tunnel, and the Engine Test Facility.

At a dinner meeting Dr. C. H. Weaver (University of Tennessee) told about using operational amplifiers in teaching the University's Electrical Engineering Department.

**Eastern 5/C Meeting of 16 Feb on Multipurpose Research Simulator**

We will comment further on the 16 February meeting of the Eastern Simulation Council at Grumman Aircraft Engineering Corporation, (Bethpage, Long Island, New York) in a subsequent Newsletter, but we want to take the opportunity this month to present separately E. J. Kennelly's paper on "Development of a Multi-purpose Research Simulator," which was given at that meeting.

One reason we do this is that we found it unusually interesting and, judging others by ourselves, thought you would. Another is that it is the only complete presentation which we received from that meeting. We give it to you just as the author wrote it, because we can find no room for improvement.

**Kennelly on Development of Simulator**

By way of introduction, Mr. Kennelly said that research simulators have been used at Grumman for a number of years. These simulators consisted of an airplane cockpit with typical flight instrumentation, associated hardware that could not be easily analogued, and an optically projected horizon viewed through the wind screen (Fig. 2).

From our past experience we decided to design a multi-purpose research simulator consisting of equipment which could be breadboarded together to meet the requirements of the engineers and scientists doing the various studies, Kennelly continued. This equipment consists of a motion simulator, a large variety of servo equipment for driving various instruments, and a visual display of the "outside world."

The criterion for determining the

*Another way of saying "over my head.".—Ed.

*Good! Now what's a Numbers Series?—Ed.
need for this type of simulator is simply whether or not the human is a critical element in the system, either as a controller or as a decision maker, since the inclusion of a human being defies a paper analysis. As a matter of fact, the degree of simulation required is determined by how critical the performance of the human controller is. Fortunately, in the past, the human performance has not been the limiting factor and therefore the degree of simulation has not been especially critical.

However, there are a number of trends today which are rapidly reducing the margin of pilot error. This is graphically illustrated by the rapid increase in accidents reported by the Armed Services that are attributed to pilot error. Two of the most important trends have been the increase in aircraft speeds and the increase in system complexity which the pilot must control. The first reduces the pilot’s decision time, and the second increases the number of decisions required. Some people believe that present-day systems have reduced the margin for pilot error below any reasonable minimum, and the accident reports support this argument.

To study these areas our dynamicists and our human factors people set up requirements for new simulation equipment. This equipment can be broken down into several broad fields.

In the VTOL and STOL areas, there are problems of control which are not only unusual in our experience, but also particularly unusual because near-the-ground flight poses critical control problems which require special simulation of ground proximity in the visual display. Since this field places a premium on pilot response, we felt that the angular accelerations and velocities of the cockpit would be a particularly useful feature in this study.

A requirement for radar-displays simulation is anticipated in connection with research activities involving “combat simulation,” the Eagle Missile combination being a good example along with ASW and AEW work.

After surveying the requirements above, it was evident that much of the simulation equipment required was parallel in function as illustrated in Fig. 3. That is, the requirements for a visual presentation of the outside world, the accelerations of the vehicle, the instrumentation, and the radar displays were common to many projects. We decided, therefore, to

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CIRCLE 46 ON READER-SERVICE CARD
July 1959—Instruments & Control Systems—Page 1053
Do computers really pay?

47 users in the civil engineering field alone, are proving that the Bendix G-15 more than pays its way.

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Many problems are being solved today on the Bendix G-15 that have never been solved before, because of the many man-years of math that manual methods would require. Profits here are so great that it is difficult to even measure them. Then there is the increased accuracy of electronic computing, with the resulting reduction of checking time.

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assemble equipment with a great deal of flexibility built in so that it could be patched together for the desired results. Dick Kopp and I made a trip to many simulator installations around the country to gather state-of-the-art information on motion simulators, visual displays, instrumentation, and radar displays.

Motion Simulation

Many different combinations of angular and linear degrees of freedom are being used on motion simulators. Bell Helicopter is having one installed with four degrees of freedom—roll, pitch, yaw, and heave. Ryan has two degrees of freedom—pitch and yaw. NACA Ames, two degrees—roll and pitch. NACA Langley, two degrees—pitch and heave; and NADC Johnsville has its centrifuge.* All these simulators of course have mechanical limits to all degrees of freedom. We have chosen a different combination for our work—roll, pitch, and heave.

Fig. 4 gives the specifications on performance to which the motion simulator had to be designed. Fig. 5 is an isometric of the configuration arrived at. It consists of three hydraulic servos driving points A, B, and C. These servos are driven from the outputs of a computer and, in essence, position three points in a plane. With this arrangement the pitch axis can be any place from the mechanical axis A-B to infinity. Pitch is limited from about ±15° about axis A-B down to an angle subtended by an arc six feet long, depending upon the radius of rotation. In other words, the vertical component of pitch is limited to six feet.

For the purpose of simulation, where the objective is to give a physical cue as to what the aircraft is doing, it is possible to reduce and/or modify these accelerations. Two factors are to be considered at this point. First, it would be mechanically impossible to duplicate a sustained acceleration of any reasonable magnitude by the motion of the simulator platform. Second, we believe that the human body is most sensitive to changes in force of acceleration, and tends to acclimate itself to constant quantities. We feel, therefore, that the following approach would prove most suitable where resulting displacements are beyond the platform's limit. Signals proportional to the accelerations of the aircraft will be fed to the hydraulic servos from the REAC. The resulting velocities will be "washed out" at a rate which is imperceptible to the operator. After reaching zero velocity at some displacement the platform will return slowly to its neutral position. The visual display will be used for steady-state rotations.

High-speed flight at low altitudes poses many problems of control, primarily because of gusts and terrain clearance. This motion simulator includes, in its design, provisions for the reproduction of a range of gust conditions by vertical movement of the platform. With a 1,000-lb load on the simulator, up to 3g accelerations may be produced. Fig. 6 shows the envelope within which the platform will operate. Fig. 7 shows the power required for this motion.

The platform will be capable of any simultaneous combination of the motions described above. A "normal g" simulation device, which was employed successfully in the F11F simulator, will be included in this simulator. This apparatus consists of straps over the shoulders of the pilot which, by pulling him down into the seat, gives the feeling of normal "g's."

The three hydraulic servos consist of three Vickers 3911 series piston-type hydraulic motors with 0.598 cu in/rev displacement. These motors are capable of producing 17.1 hp continuously or 38.5 hp intermittently.

These motors drive the load through three 15-1 Ohio Gear Co. reducers. The output of the gear box is a 6" diameter drum around which is wrapped a 1/4" steel cable. This cable goes up and around the top pulley and then is fastened to the moving part of the rig. Three-turn potentiometers are used for position feedback and are geared to the shaft of the top pulley. This allows slippage of the cable on the lower drum without changing the position of the poten-

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*Which some who have ridden say involves "heave."
Simulation Council—CONT.

tiometer with respect to the platform.

Moog servo valves convert the output of the amplifiers to control the flow of the hydraulic oil. These valves are capable of a 10 gal/min flow rate and have an extremely high response. Two 20 gal/min hydraulic pumps are manifolded together to supply 3000-psi pressure to the valves.

The mechanical part of the platform consists of two 2" diameter vertical rods which guide linear motion ball bushings, as can be seen in Fig. 5. There is a horizontal sliding rod mounted in two other linear motion ball bushings which makes up the change in length of the main axis of the platform when it is rolled. Two of the hydraulic servos are used to position the outer ends of this axis for roll. The third servo is at the rear, and positions the platform in pitch. This servo is on a pivot so as to be able to follow the arc which the point C describes in pitch.

By using this type of configuration, pure roll and pitch are not obtained. A yaw angle is induced, but this angle is small with small angles of roll and pitch. We feel that this induced yaw will not have detrimental effects on our studies.

We are installing limit stops on the servos which will first cut off the output of the amplifiers and put the REAC into Re-set. If these limits fail, the hydraulic pressure will be shut down by another set of limits. The operator will have a "panic button" available with which he can dump the hydraulic pressure at any time.*

Servo System

We found in the past that we were always fabricating servo equipment to drive different instrumentation, displays, targets, etc. These then had to be wired into the system, which meant that the system was under continuous change and therefore difficult to keep track of. To forestall a repetition of this, a flexible servo system has been designed. It consists of 24 servos, both velocity and positional, with changeable gear trains and output transducers. These are all wired in several relay racks and connected with inters to the simulator platform and the computers. There is a patch panel on the front of the relay cabinets which allows the inputs of both the computer and servo system to be interconnected easily.

The most formidable obstacle to simulation is the visual presentation of the outside world in a ten-foot room.* Many different schemes have been tried, all with limited success. To mention a few—the Point Light Source used primarily with helicopter simulators; the closed-loop TV system using models, such as Link and Curtiss-Wright used for simulated landings; the optical system being developed by Rheem consisting of three 3-dimensional maps representing different altitude ranges and covering an area of 40 square miles; and the contact analog system used by both Bell and Douglas in the ANIP program. Each of these systems has its limitations, and none of them lends itself to use in the general studies for which we plan to use the simulator. We are now studying the problem and have some ideas on a solution, but that is as far as we have gone at present. In the interim we plan to use our old system consisting of a horizon projected on the screen.

Information

(Without Theory)

We received the following just too late to include it in the June Newsletter:

CALL FOR PAPERS—1959 EASTERN JOINT COMPUTER CONFERENCE

The 1959 EJCC, sponsored by AIEE, ACM, and IRE, will be held at the Statler-Hilton Hotel, Boston, Massachusetts, on December 1, 2, and 3, 1959. Papers will be accepted on any phase of computing. Persons wishing to present papers should submit by August 15, 1959, four copies of a 100 word abstract and a 1,000 word summary. Present plans call for a single session conference, and papers will be limited to a presentation time of 20 minutes followed by a brief discussion period. At the discretion of the program committee, papers of exceptional interest may be allowed a longer period of time for presentation, provided written request by the author is made at the time the abstract and summary are submitted. Abstracts should be suitable for inclusion in the program of the conference. It is requested that summaries be submitted which accurately describe the author's work in order to assist the program committee in selecting papers of greatest merit. The chairman of the conference will be Mr. F. E. Heart, Lincoln Laboratory, Lexington, Mass., and Mr. H. W. Fuller, Laboratory for Electronics Inc., Boston, Mass., will direct the local arrangements. Exhibit management will be handled by John Leslie Whitlock Associates, Arlington, Virginia. Abstracts and summaries should be sent by August 15, 1959, to J. H. Felker, Chairman, EJCC Program Committee, Bell Telephone Laboratories, Mountain Avenue, Murray Hill, New Jersey, Room 5C-101.

We hope that you have seen and heeded this call for papers elsewhere elsewhere, this, because it is important.

This month's "Understatement of the Month" winner.—Ed.

It is important because there are too many forums for the presentation of papers purported to advance the state of the art of interest to us. The obvious result is that the really worthwhile papers are scattered far and wide in a time-space continuum which makes it impossible for anyone who must do anything else for a living to keep up with them. A corollary of this is that the papers at the meetings we can get to are diluted to a discouraging if not actually alarming extent (alarming if these meetings really reflect our technical progress).

Realizing this the ACM, AIEE, and IRE joined forces to create the JCC, which has two meetings a year, the EJCC and the WJCC.

Realizing this, the Board of Directors of the Simulation Councils, Inc. decided to cooperate with the JCC to the greatest extent possible to have two, and only two, really good computer meetings a year—one on each coast.

Realizing this, we—the Simulation Councils, Inc.—implore, beseech, beg, entreat you to save, or create, for the JCC meetings any worthwhile contributions of which you are capable. Your other efforts you may present elsewhere: your plagiarisms to your boss (who might not have had time to read the original); your vague and obscure mathematical ramblings to your Newsletter (your Ed. won't understand them either, but he has a convenient circular file); and your half-baked ideas to your colleagues in the Simulation Council meetings. This last is also very important: food for thought must be underdone.

We have been interested in the fast-changing status of our friends in Mid-Century Instrumatic as reflected in News Releases by their hardworking publicity agents Smith, Winters, Mabuchi, Inc.: "Mid-Century Instrumatic now named Computer Systems, Inc."

"Schlumberger Acquires Interest in Computer Systems, Inc."

"New Process Master Analog Computer Shown by Computer Systems, Inc. at World Petroleum Congress."

Never a dull moment in our chosen (?) field!

Computer Events

Central Simulation Council

Date: October 1959
Place: McDonnell Aircraft Co., St. Louis, Missouri
Subject: "Computer Environment"

July 1959—Instruments & Control Systems—Page 1057