ENGINEERING RESEARCH INSTITUTE
DEPARTMENT OF AERONAUTICAL ENGINEERING
UNIVERSITY OF MICHIGAN

A STUDY OF THE COMPUTER SECTION OF FLIGHT SIMULATORS

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Project 2164

Submitted for the project by:

V. S. Haneman
R. M. Howe

Personnel Employed On This Project

J. E. Broadwell	Assistant Professor
E. G. Gilbert	Instructor
E. O. Gilbert	Instructor
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Note:

Captain V. S. Haneman Jr. is a USAFIT student officer at the University of Michigan as a Ph. D. applicant and is working on this project as part of his doctoral thesis.

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1. General

During this reporting period, 10 July to 10 August 1953 two trips were made; the equations of motion used by Erco Inc. and Melpar Inc. on the F86D simulator are being prepared for mechanization on the electronic differential analyzer; equations of motion used by Link Inc. on the B47 simulator are being studied and prepared for mechanization on the electronic differential analyzer; and some basic studies were made on the analyzer.

2. Trips

Dr. R. M. Howe and Captain V. S. Haneman visited Electronics Division, Curtis Wright Corporation, Carlstadt, New Jersey on 20 July 1953. Discussions covering Curtis Wright trainer design and general trainer problems were held with Dr. R. C. Dehmel, Mr. H. Moles, and Mr. A. J. Sherman. Dr. Dehmel presented the following ideas and thoughts on simulators.

A. The weapons systems concept, if applied to the simulator business might degenerate into a condition far worse than the present situation. This would be true with those aircraft manufacturers who desire to hide or ignore certain unsatisfactory characteristics that they would like their airplanes to match instead of the actual characteristics which exist.

B. It appears that standardization is possible for the computing elements of flight simulators. Curtis Wright have certain standard configurations for various systems; i.e., flight equations, radio aids, etc. To these are added special racks to modify or include specific items that appear in the aircraft under simulation. The problem involved in standardization is the balance of excess equipment versus special service techniques, increased logistic problems and redesign or new design for each new simulator.

C. Sixty cycle carrier amplitude modulated is preferred. One objection to dc is that continuous integration is not possible (with reference to events which take place through 360 degrees of rotation)*note comments.

D. The use of special function cards is required to obtain the accuracy necessary. Places where this is necessary are in drag polars and in the computations to obtain velocity versus power where 0.1% accuracy is necessary. To date, no special function cards have worn out due to pure wear. Five percent of the non-linear function are function of Mach or velocity.

E. AC feedback amplifiers are used throughout. These amplifiers have greater than 70 db of feedback using two tube amplifiers. There has been no change in the amplifier design since 1943. No information on amplifier design, servo design or characteristics of computing elements will be given to anyone if it does not aid Curtis Wright directly.

F. B50 simulator requires 20 KVA (plus or minus 5 KVA) of power. This unit has over 150 amplifiers, 100 servos, and from 400 to 500 special cards.

G. There is no reason to use separate power supplies in simulators except where the circuits are critical. The Air Force should not attempt to specify conditions on power supplies.

H. No self testing equipment or routines should be built into the simulator. These are absolutely unnecessary.

Discussions with Mr. A. J. Sherman of the Aerodynamics group brought forth the following items:

A. The Curtis Wright simulators are designed to meet steady state specifications, the dynamic response takes care of itself automatically due to the equations of motion used.

B. The items included in the equations of motion are chosen to meet the steady state response characteristics required for a particular aircraft. For example, in the B36 simulator, items that were made functions of Mach number were lift coefficient, drag coefficient, and outside air temperature.

C. The small angle assumptions were used in the flight equations plus refinements as necessary. Cross coupling effects are included in all units. Cross product terms have very small effects and are ignored. The computations are made in body axis and then converted to space co-ordinates.

On 21 July 1953, Dr. Howe and Captain Haneman visited the Navy Special Devices Center at Sands Point, Long Island, New York. The conference included the following members of the Navy Special Devices Center: R. Dreves, N. Governale, P. Staderman, Vincent Amico, Harold Voss, Lt. Cmdr. L. Bunce, and Lt. J. Monoghan. The conference covered flight simulators cost, design, maintenance, reliability, computation and general engineering problems.

Specific data of interest to the project included the following items:

A. The cost breakdown of the Navy Operational Flight Trainer is as follows:

Housing 10%, cockpit 15%, instructors station 15%, computers (engine, aerodynamics, weight and balance, position) 35%, radio aids 20%, supplemental items 5%.

The Navy operational flight trainers simulate only the aircraft. Additional trainers (tactical trainers) are used for the special equipment to simulate anit-sub missions, etc.

B. The Navy includes items for simulation depending on the type of aircraft simulated. There is no gas consumption integration on heavy aircraft simulators since the duration of the simulator flight is a very small part of that of the aircraft. For taxi and breaking action, computation is based on the Turn and Bank Computer.

C. A large amount of the design data for Navy trainers is obtained from flight test reports of the actual aircraft. Dynamic stability problems have arisen due to the frequency response of the computers (60 cycle carrier amplitude modulated).

In the rate of climb and maximum velocity computation, the errors due to the method of computation used become quite evident. Using carrier modulated signals, the computations can

get out of phase and gearing and other sources of generation of large nulls become extremely important.

D. The Navy has the following system requirements for their simulators:

1. Center of gravity, fixed -- three locations for all aircraft.
2. Jet fuel consumption is based on rmp and atmosphere, changes weight and inertia about important axis.
3. Reciprocating engine -- no change of weight with fuel and oil consumption. Fuel is a function of engine operation and atmosphere.
4. Normal gross weight and weight and balance will change with release of significant quantities of stores.
5. No motion to seat or cockpit in future trainers (certain units have this at present).
6. Sound effects will not include changes due to variation in slip stream sound due to velocity but will include all system noises of importance.
7. Auto pilot and radio aids will be included only if a required part of the problem.
8. Fighters will have pitch motion plus and minus 80 degrees, roll motion plus and minus 360 degrees. Bombers will have plus and minus 80 degrees in roll.
9. No take off distance indicator in future units.
10. Precession of gyros not to be included in future trainers.
11. Oxygen simulation systems will be included.
12. There will be a limit to tell-tale lights to the following items: engine start--ground and air, fire, ejection, VG limit, crash.
13. The G shaft may be used to actuate the G suit in fighters.
14. No oil consumption simulation.

E. Control tolerances cannot be specified as either percent of full scale or percent of the value at any instant, but must include a second specification to insure that the rate of change of control forces with position simulates the true condition.

F. Maintenance is accomplished by field service men employed by the Navy and factory trained Navy personnel. The following three modification types are recognized in the maintenance system:

1. Trainer design requiring improved methods such as a new type of electronic tube.
2. Aircraft change requiring trainer modification.
3. Changes in the training problem.

Preventative maintenance is practiced including tube checking every so many hours. The heaters on the tubes are run 24 hours a day.

G. Curtis Wright non-linear potentiometer cards on the F2H1 simulator have worn out.

H. The Navy Special Devices Center maintenance people feel that it is important to have test equipment and routines including test points and fuse alarms included in the trainers.

I. The Goodyear Aircraft Corp., Akron, Ohio is building simulators of the ZP4K and the F3H for the Navy. Goodyear is using 400 cycle carrier amplitude modulated computing circuits.

J. The Computation Section of the Navy Special Devices Center feels that dc is to be highly recommended for future use in simulators. One of the least problems with the operation of Cyclone, Typhoon, and Whirlwind has been tube failure. Experience with Electronic Research Associates equipment has indicated excellent life for Leeds and Northrup choppers. The University of Pennsylvania has been investigating methods of programming the flight simulator problem to use digital equipment. They have been successful using a repetition rate as low as one megacycle.

A meeting was held with John Hunt, L. Fogerty, William Wood at Link Aviation, Binghampton, New York on 22 July 1953. This meeting covered the coordinate axis used for computation for the aerodynamic characteristics, the assumptions required for the computation in the various axis systems, ac versus dc methods of computation, data requiredto build a simulator, computing elements, and Link simulators. The flight equations, mechanization of the problem, and other pertinent data on the B 47 simulator was obtained.

Link feels that flight test data is desired as early in the design stages of the simulator as possible. At the time that flight test or other data is obtained from the aircraft manufacturer, accuracy values and the method of obtaining this information should be given to aid in planning. An example of the importance of knowing not only the necessary data to compute an end item but also the accuracy of the data used for the computation is the rate of climb. Over 150 items effect the rate of climb computation and the rate of climb must be within certain very close tolerances for given configurations. It may be that the approved data used is inconsistent with the accuracy specifications on the rate of climb.

Link has established a tube reliability policy in design of their computers. This includes designing to a certain percent of the tube rating.

Radar scintillation is not included in the F 89 presentation since small travel of the target is poor and would mask any possible scintillation.

Link feels that it will be necessary to change the method of accomplishing the computations for high speed high performance aircraft in the near future. They feel that they have nearly reached a limit in their present simulators using 60 cycle carrier amplitude modulated system. One difficulty that all 60 cycle carrier systems have is that of residual noise in their integrators.

A Link affiliate in England is attempting the type computing configuration that appears to meet our future requirements. This company, Air Trainers Ltd., is using dc plus direction cosines for the coorinate transformation.

Link also feels that a certain amount of standardization is possible and desirable and it is also beneficial to have automatic checking equipment included in all trainers.

During the week of 3 August Dr. J. E. Broadwell, Dr. R. M. Howe, Mr. E. Gilbert and Capt. V. S. Haneman visited MacDill Air Force Base, Tampa, Florida; Tyndal Air Force Base, Florida; and Hunter Air Force Base, Savannah, Georgia. The meetings at each of these bases involved the use, operation, and maintenance of their respective simulators.

The following problems were common to all bases:

a) Extreme lack of sufficient electronic testing and maintenance equipment such as oscilloscopes, tube testers, and electronic volt meters.

b) Difficulty in obtaining replacement parts through normal supply channels.

c) It is necessary to have the trainers meet current training requirements such as modifications of aircraft instrument panels and switch locations.

The trainers should be up to date with the aircraft the pilots are flying.

d) Pilot criticisms of the simulators appear to have as an underlying cause, the lack of dynamic simulation.

e) One important item that appears to have been slighted on several types of simulators is the inter-relationship of indications.

f) On many position type servos, gear train lag, backlash and friction have appeared as the simulators become older.

g) There appears to be no engineering feedback on the part of the companies building these simulators. A difficulty corrected in the field in unit A appears and has to be corrected in units constructed years later. The same mistakes could be corrected by the company if there were closer liason with their field representatives.

3. Comments

The Navy Special Devices Center, in particular Mr. Dreves and Mr. Amico, and Link Aviation, Mr. John Hunt, have been exceptionally helpful in giving this information and their thoughts on simulation. The Navy Special Devices Center provided the project with reports and Navy specifications for simulators. Link Aviation supplied the project with information and reports on their B 47 simulator.

With the information currently at hand, a study of the B 47 simulator has been initiated similar to that being carried out on the F 86 D simulators. Further information on these two simulators was obtained fromthe Florida trip.

All three air bases, MacDill (Captain Campbell), Tyndall(Captain Games) and Hunter (Major Stoker) were very cooperative and assisted the project materially in their comments and resume on the operation of their trainers.

The question of 60 cycle carrier amplitude modulated systems versus any other method of computation does not appear to be argued engineering wise but mainly inertia wise. The question of dc continuous integration for a cyclic function such as continuous rotation through 360 degrees is possible with dc circuitry. There are many similar arguments presented by certain manufacturers for the continuance of 60 cycle systems, when it is strongly possible that new and better methods of accomplishing the computation have appeared in recent years.

4. Studies

The F 86 D studies have progressed and initial setting-up of the equations on the electronic differential analyzer has been initiated. The B 47 data and simulation study is progressing in the same manner. It appears to be highly desirable to obtain an Electronic Associate servo multiplier for testing and evaluation for future use. Dr. Howe plans to visit these people in mid-August.

5. Funds

Expenditure of Funds to date

Salaries and Wages	4531.45
Overhead on above 35%	1589.51
Travel and Communication	397.56
Total	6518.52

Total manhours abour 1285 hours

Expenditure of Funds for July

Salaries and Wages	3651.85
Overhead	1281.65
Travel and Communication	247.48
Computer Services	150.00
Total	5330.98

Manhours 1072

Expenditures expected for August

Salaries and Wages	3880.00
Overhead	1358.00
Travel and Communication	1000.00
Computer Services	150.00
Total	6388.00

Manhours 1200

Payment requested by vouchers submitted for the period covered by this report will be submitted by 31 August 1953