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DESIGN OUTLINE FOR A NEW MULTIMAN ATC SIMULATION FACILITY AT NASA-AMES RESEARCH CENTER

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ABSTRACT

A new and unique facility for studying human factors aspects in aeronautics is being planned for use in the Man-Vehicle Systems Research Division at the NASA-Ames Research Center. This facility will replace the existing three cockpit-single ground controller station and be expandable to include approximately seven cockpits and two ground controller stations.

Unlike the previous system, each cockpit will be mini-computer centered and linked to a main CPU to effect a distributed computation facility. Each simulator will compute its own flight dynamics and flight path predictor. Mechanical flight instruments in each cockpit will be locally supported and CRT cockpit displays of (e.g.) traffic and or RNAV information will be centrally computed and distributed as a means of extending the existing computational and graphical resources.

An outline of the total design will be presented which addresses the technical design options and research possibilities of this unique man-machine facility and which may also serve as a model for other real time distributed simulation facilities.

INTRODUCTION

Studying air traffic control systems requires a realistic simulation facility which faithfully captures pilot-pilot and pilot-controller interactions as well as those unique human characteristics vital to any evaluation of complex systems. A recent study(1) has shown the dangers of drawing conclusions from all computer studies or even from simulation studies not using actual piloted simulators.

The human factors problems in the present and proposed ATC systems are extensive. For example, to accommodate future increases in aircraft densities a very high emphasis will be placed on precision in both air and ground sides. Some of these human factors problems impacting precision are listed below.

The interactive air-ground and air-air control loops will affect precision through the time delays and lags between situation apprisement, commands and executions.

Errors, blunders, emergencies, failures, priorities, etc. as well as smaller perturbations from pilot or controller decisions will have a decided effect on maintaining any required precision. Recovery from local unplanned situations are crucial human factors aspects.

Basic ATC procedures for actual traffic management (e.g. multiple curved approaches) will affect precision. Different alternatives must be studied in the human contexts of information display requirements and realizations.

Both pilots and controllers will require displays specially designed for information, control and navigation purposes in order to achieve a high degree of precision without excessive workloads. High density could mean high display clutter for controllers.

Pilot and controller acceptances of the different or alternative regimes for traffic control must be determined to prevent enforcing a theoretically workable but practically unsatisfactory and hence error prone system.

The basic pilot and controller workloads could be excessive in strategic control particularly as related to closely spaced runways and other methods of handling high density traffic.

High speed decision making by controllers and pilots will be required to maintain high precision and safety. This basic ability is an issue by itself and can be expected to interact strongly with the displays used as well as possible computer aids to decision making.

General aviation must be accommodated in the future NAS as well as commercial aviation. Basic techniques, capabilities, workloads, displays, etc. must be determined for general aviation traffic control just as for commercial aviation. In fact, all of the comments made previously apply to general aviation as well.

These and other human factors issues must be studied on a fully interactive multiman simulation facility.

Considerable work has already been completed at NASA-ARC studying ATC alternative management regimes such as distributed management based on the availability of Traffic Situation Displays in the cockpit. A three pilot-two controller simulation facility was developed in 1972 for this purpose and has been used extensively since. However, the ever expanding problem size and types have nearly exhausted the resources of the present system. For instance, studies of simultaneous multiple curved approaches to two closely spaced runways cannot adequately be supported on the present 3 simulator-1 controller station facility primarily because of the low simulator density available for a required high density environment.

Therefore, to investigate either human factors problems impacting complex ATC systems and/or studying alternative ATC management regimes, a larger multiman interactive simulation facility is presently being planned for the Man-Vehicle Systems Research Division of NASA-ARC.

There is a third use of this facility as well. At present, human factors replication studies are performed sequentially. That is, single subjects are scheduled on successive days under the same experimental protocol. This naturally ties up the computer facility supporting the experiment for these experimental hours on the successive days. In addition, the set-up and take-down time is also incurred for each successive replication. Considering the number of other experiments and program developments always under way, this can be a very inefficient and nonproductive procedure.

The planned facility will lend itself to an ensemble manner of replications. Since the simulators will be identical and locally positioned, as many replications can be obtained simultaneously as the facility will support. For instance, instead of scheduling ten running days of two hours per day (1 hour-experiment, 1 hour-set up and take down) for a total of 20 hours (usually in prime time) to achieve 10 replications of a single pilot experiment, the same thing may be accomplished in (say) two days of two hours per day for a total of 4 hours with 5 simultaneous replications per day.

Planning of the facility is in the initial phases. A broad overview followed by some prototyping specifics will be given here.

DESIGN OVERVIEW

Figure 1 is a conceptual picture of the facility showing 10 identical fixed base simulator cabs, the two ATC controller stations (two man per station) and an experimenter station with a small local computer. A remotely located large computer and graphics system is also shown.

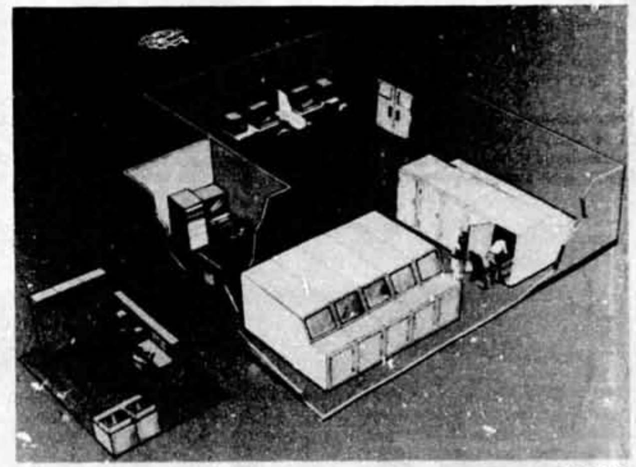

Figure 1 Conceptual Plan for the Multiman Interactive ATC Simulation Facility

In the planned facility, each simulator cab will contain a mini/micro computer enabling it to perform functions previously performed by the main large CPU. That is, instead of centralized computing, the planned facility will utilize distributed computing. A centralized computing system quickly becomes compute bound in real time simulation work. Distributed computing will support the increase in simulators needed as outlined previously.

The existing 3 simulator system is CRT based as well as centrally computer supported. The simulators use all electronic displays which also causes a graphic bottleneck when all 3 are simultaneously operating. Therefore, the CRT Vertical Situation Display will be replaced by traditional mechanical instruments and the CRT retained primarily for Horizontal Situation Information (HSI) and traffic display. Figure 2 is a conceptualization of a simulator showing the micro/mini, mechanical flight instruments and CRT HSI.

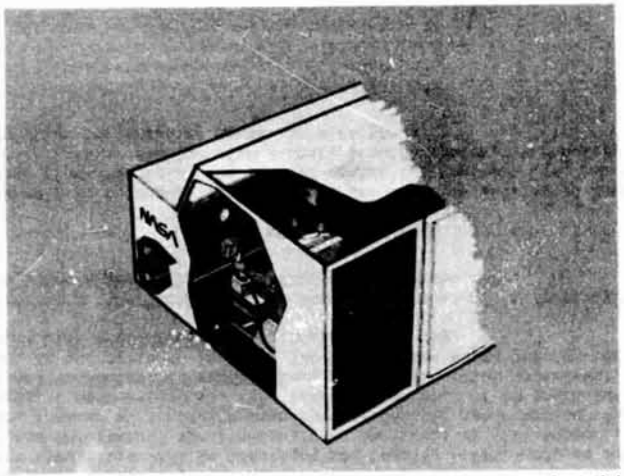

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Figure 2   Conceptual Drawing of a Micro/Mini Computed Based Simulator

Figure 3 presents in more detail the major features of the facility.

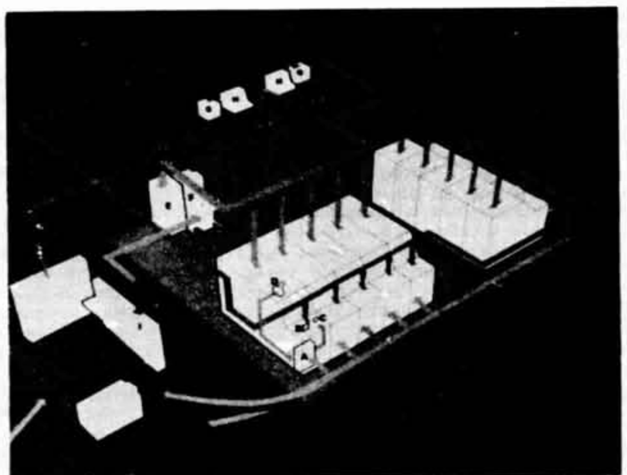

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Figure 3   Major Information Linkages in the Multiman ATC Facility

The micro/mini computer simulators will be supported by a small host computer at the experimenter's station so that if the CRT is not needed the facility can stand alone from the main CPU which permits full utilization of all facilities.

PRELIMINARY DESIGN SPECIFICS

FLIGHT INSTRUMENTS

A PACER Mk II flight simulator(2) was chosen to supply the basic pilot inputs (aileron, elevator, throttle, rudder) and displays (altitude, navigation, status). Figure 4 shows the PACER unit (without rudder pedals).

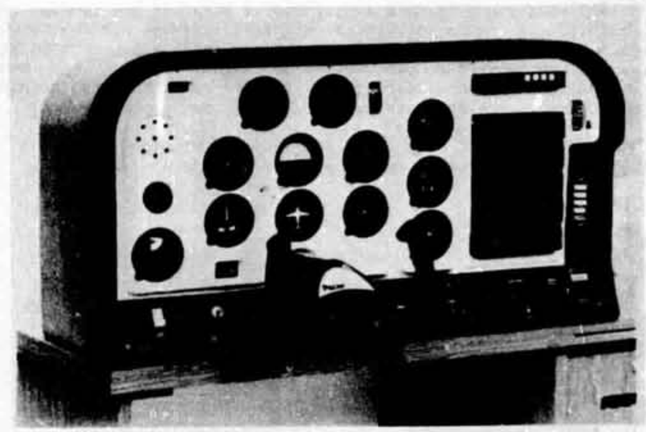

Figure 4   Basic Flight Instrument PACER Mk 2

This unit is capable of very realistic instrument flight and navigation from take off to landing. This unit will be modified to accept a small color CRT perhaps by relocating the navigation radios on the panel. The PACER is an all electronic system and thus is suitable for A/D and D/A interfacing. The unit as shown is a fully functional simulator-trainer.

COMPUTER

After considerable study and analysis, the LSI-11 computer from Digital Equipment Corporation was chosen as both the mini/micro for the PACER and as the host computer for the multiple identical simulators. The LSI-11 is a

16 bit system with an optional extended arithmetic unit. The smaller 8 bit machines do not presently provide the resolution and speed necessary for this real time application. For example, 8 bits provide a resolution of less than one degree which is not suitable for navigation purposes and double precision arithmetic is too slow for the anticipated computational load.

The LSI-11 also is well supported in hardware and software as well as a very wide range of physically compatible I/O circuitry. A/D and D/A, fast memory, multiple serial and parallel I/O are available from a multitude of sources.

DEVELOPMENT SYSTEM

Figure 5 shows the equipment purchased for development work.

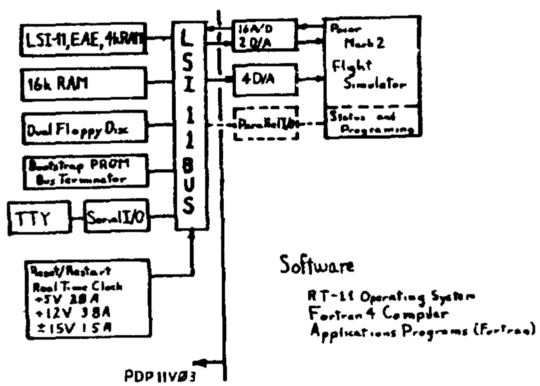

Figure 5 Development system Consisting of the PACER Mk II Simulator and PDP-11V03 Computer.

The equipment shown to the left of the bold line is essentially identical to DEC's minicomputer PDP-11V03. The unit as shown with 20k RAM and dual floppy discs will permit initial experimental development as to language, function allocation, etc. in order to make the basic PACER into a smart simulator. The optimal arrangement of task sharing between the analog dynamics of the simulator and digital dynamic calculations of the minicomputer will be implemented. There are three basic variations of task sharing.

1. Simulator as Display

In this mode, the simulator provides only input and output functions - yoke, throttle, rudder, etc., and the panel dials and status indicators. This arrangement does not make use of the existing analog dynamics and imposes a heavy computational load on its minicomputer. It is unlikely that this approach will be used in this strict form.

2. Simulator as Aircraft

This approach, which will be tried first, makes maximum use of the simulator dynamic functions. The minicomputer will perform some navigational tasks such as programming to follow curved approaches and input all necessary flight data (airspeed, etc.) for analysis purposes. The simulator basically sends aircraft attitude to its minicomputer which calculates map position and runs the navigation displays.

3. Simulator as Navigator.

This approach makes maximum use of all simulator functions with the simulator computer primarily a data gatherer and special purpose navigation computer. This approach may present problems in keeping reckoned aircraft positions in step throughout the system.

The minicomputer will in any case also have control over any additional status information such as flaps, warning lights, etc.

The basic philosophy is to push as much of the computing load as far toward each simulator as possible.

SMART SIMULATOR

Figure 6 shows a "smart simulator" as finally prototyped. This is identical to the development system with all unnecessary equipments stripped away.

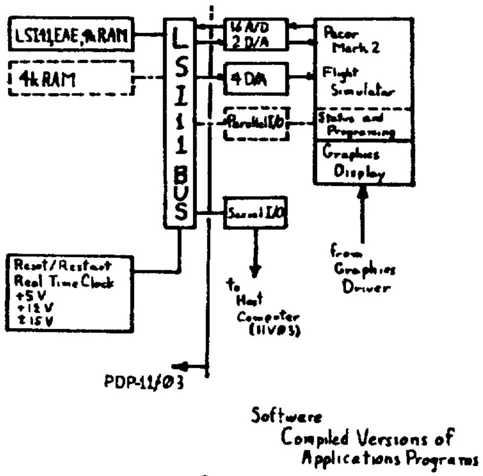

Figure 6 The Prototype Smart Simulator

This simulator can only execute programs down line loaded to it from the PDP-11V03 host computer. It is anticipated that 8k RAM will be sufficient for its local purposes. Note that a graphics display (CRT) is shown attached to the PACER unit. This display will be driven from the existing graphics system and main CPU.

All programs will be developed on the host computer except graphics and some data handling programs reserved for the remotely located CPU.

ATC FACILITY

Figure 7 shows the basic arrangement for the total multiman interactive ATC facility.

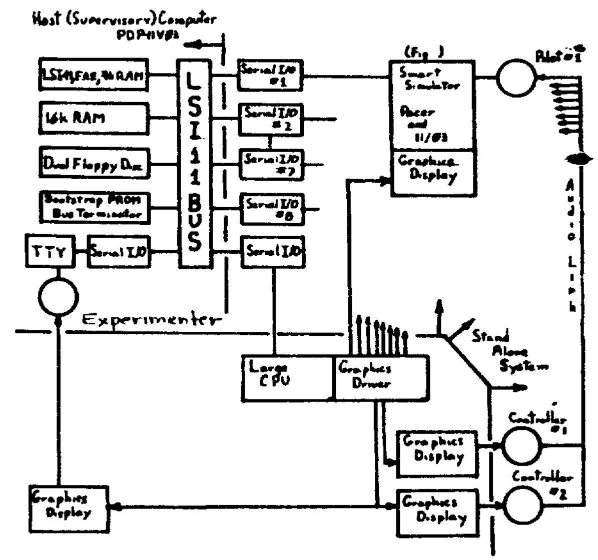

Figure 7 Minicomputer Based ATC Facility

The host computer (11V03) is essentially as shown in Figure 5 and the smart simulator as in Figure 6. Host and simulator are connected by two serial I/O units (one on each side). The host computer connects with the large CPU for two way exchange while the large CPU and graphics system supports the CRT in each simulator as well as graphics at each of the two controlled stations. As indicated, with the exception of the main CPU and graphics, the host + simulators will be a stand alone system for program development and some experimentation not requiring graphic displays.

All participants are connected by a programmable audio link which can simulate different verbal communication networks such as data link, etc.

SYSTEM OPTIONS

Next to digital computation of flight dynamics, path predictor computations produce a heavy computational load. Unloading flight dynamics to each simulator will free up considerable time in the system. Path predictors might possibly be computed locally or at the host computer or in the main CPU for each simulation.

Position information also could be done in the simulator, host of main CPU as could special navigation programming (e.g. curved approaches). Resolution of these and other options will occur during development.

STATUS

The development system is being assembled. For reference, a parts list and cost is given in Table 1. Pieces were obtained from different vendors for best price/delivery.

TABLE 1 Development System (PACER and 11V03) Parts List

Source	Item	Part #	Price
DEC	CPU with 4k RAM	KD11-F	$842
DEC	Extended Arithmetic	KEV-11	162
Monolithic systems	16k RAM with Refresh	---	1125
DEC	Bootstrap Prom/Bus Terminator	REV11-A	272
DEC	Serial I/O including Cables	DLV-11	251
ADAC	16 Channels Analog to Digital	600-LSI-11-16-PD-2?	795
ADAC	2 Channel D/A for above		400
ADAC	4 Channel Digital to Analog	600-LSI-11D-4-X	750
DEC	Dual Floppy Disc	RXV11-BA	3655
DEC	Cabinet	H909C	298
DEC	LSI-11 Bus Backplane 6x9	DDV-11B	340
Quadex	Power Supply Panel & Restart	---	150
Quadex	Cables & other Hardware	---	150
DEC	RT-11F/B Operating System	QJ003-AY	1173
DEC	Fortran 4	QJ925-AY	748
Power 1	Power Supplies	---	244
DEC	Decwriter 20ma loop	LA-36-DE	1475
Bud Radio	Rack Panel 30" Deep 21" High	---	381
Pacer Systems	Pacer Mark 2 Flight Simulator	(full capability)	3600
			$16811

The development system as acquired has capability for editing and compiling higher level languages (FORTRAN, PASCAL) in addition to executing machine language programs.

Parallel I/O may be required or it may be possible to substitute digital I/O for some of the analog I/O.

The simulator as aircraft is expected to be operational within 4-6 months. The aircraft will send attitude information to the computer with the computer calculating map position, predictor and running navigation displays.

The development system will then be stripped down to essentials for executing downline loaded optimized machine language programs. This smart simulator will be a prototype for replication.

The host computer will then be configured to support the 8 or 10 smart simulators as a single facility. Interfacing the host and main CPU will also be accomplished.

Estimated completion time for the total design is in the order of 1½-2 years. It is quite likely that by the time the prototype simulators are designed, more powerful and less expensive minicomputers will be available. These will be used in the final designs to the extent possible.

SUMMARY

The new mini/micro computer based ATC facility will greatly increase the complexity and realism of ATC human factors problems for modeling and study. This will in turn permit a firmer and more translatable set of findings and designs. It is also necessary to develop in conjunction with the facility more sophisticated methods for treating multivariable, realistic simulation experiments.

REFERENCES

1. Kreifeldt, J.G., Parkin, L., Hart, S., "Air Traffic Control by Distributed Management in a MLS Environment." Proc. 13th Annual Conference on Manual Control. MIT 1977.

2. ——— Pacer Systems, Inc., 87 Second Ave., Northwest Industrial Park, Burlington, Mass., 01803.

ACKNOWLEDGMENT

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