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SIMULATION IN RAND'S SYSTEM RESEARCH LABORATORY

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To be presented at the joint AIIE-ORSA-TIMS Symposium on System Simulation, Hotel Statler, New York City, May 16-17, 1957.

(In conjunction with P-1075, Simulation in RAND's Logistics System Laboratory, by William W. Haythorn, and SP-6, Simulation in Air Force System Training, by Thomas C. Rowan.)

The Need, the Concepts, the Approach

Operations analysis and system analysis often need to consider the effect of the human factor on system performance. Usually a "degradation factor" is used to qualify the predicted effectiveness. In an effort to better understand the human element in systems, RAND set up the System Research Laboratory to study man's performance in complex man-machine systems.

The underlying notion behind this research was that it might be possible to obtain the predictable features of a "closed" system by exploiting man's capacity to seek and find problem solutions. That is, if man could be motivated to seek the system's goal, and if he were provided knowledge of operational results, a disparity between actual and desired performance might serve as an error feedback to trigger adaptation of operating practices to improve effectiveness.

To explore this possibility, a particular man-machine system, a part of the air-defense network, was simulated in the laboratory. Included in the laboratory system were not only functional representations of the machine components but also the men themselves--under such conditions as to permit them the latitude of action found in the real world. Such a system was exposed to successively more difficult task situations, the results of performance were reported back to the crew, and the questions asked were: Could men learn to improve system performance; "what" did they learn; and "why" did they learn?

Four experiments were carried out. Each involved about forty men and extended over a six-week period. The results were: the crews did learn--surprisingly well (increased their load-carrying capacity several fold); what they learned was to distinguish between important and unimportant information input and to shortcut their data-processing procedures; "why" they learned seems to be found in the well-known answers--practice, under realistic conditions, and knowledge of results.

Because of the implication of these results for improving air-defense effectiveness, RAND was asked to develop a System Training Program for the Air Defense Command. This program has been under way for several years; Dr. Rowan will discuss the extension of the laboratory simulation techniques to the field situation and the progress that has been made in enriching the simulation and developing production methods for producing problem material.[1] Somewhat later RAND was asked to apply simulation techniques to the study of the Air Force Logistics system; Dr. Haythorn will report progress in adapting these methods to a problem having quite different demands.[2]

While the other RAND speakers will report their research activities in specific terms, I will discuss quite generally the principles and implications arising from the original work on simulation at RAND.

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[1] Simulation in Air Force System Training - T. C. Rowan, SP-6, April 30, 1957.

[2] Simulation in RAND's Logistics System Laboratory, W. W. Haythorn, P-1075, April 30, 1957.

The Simulation Techniques and Their Limitations

There are obviously many different phenomenon to be simulated, using a variety of techniques, and for a multitude of purposes--as the speakers of this symposium are sure to point out. It may be appropriate to circumscribe somewhat what kind of simulation we three speakers from RAND will be talking about. We are concerned with the exploitation of man's capability for finding solutions to complex problems, because we feel that this resource must be used if the intricate systems of the present day are to develop their full potential. And so we try to simulate the complex environment in which men work to discover efficient operating procedures and how men can be aided in their search for these procedures. (Other research at RAND, of course, is devoted to simulating systems completely by machine.)

Fig. 1 shows how respective elements of the real world situation were translated by simulation techniques into their laboratory counterparts. Several methods were used: the generation of the system's complex information inputs by means of electronic computers; the construction of the laboratory replica of the physical aspects of the real system using an amount of stagecraft; bringing the real world culture into the laboratory--the art of carrying out psychological experiments helps us here, as well as in motivating and shaking down a new crew.

These simulation techniques, which seemed to be quite successful in stimulating realistic system activity, just barely scratch the surface of simulation requirements. In the four defense experiments, for example, only the complex information inputs were programmed for machine computation; playing out the consequences of system action (the fighter-bomber duel once the interceptor had made contact, for instance) was carried out by hand. For many systems, the implications of their actions will be so intricate as to require machine programs. It was also possible in this air-defense study to play in real time and to have a man-for-man match between lab and real-life crew. Dr. Haythorn will discuss extensions of simulation methods needed for the logistics study along both these lines: mechanizing the involved embedding systems and time-personnel aggregation--having several people in the lab represent many in the real world and simulating action faster than real time.

The air-defense problem permitted distorting input simulation into static form. That is, the problem situations could be precomputed, because they were not much affected by system actions. However, a dynamic stimulus is required when system actions feed back and influence the problem situation to a large degree. Dr. Rowan will talk about the technological advances in machine generation of inputs necessary for field application of simulation techniques--both to produce the needed quantity and quality of material; these advances may very well lead to the capability of providing the dynamic stimulus.

Another limitation is a substantive one. Simulation can be done only as our understanding of phenomena will permit. Certain activities can be modeled with confidence--the time-space relations of an aircraft's flight and the radar detection of that flight. Other activities, however, cannot be represented mathematically with precision, such as, the effects on the national economy of pricing practices. So we will have to select for simulation those activities valid theories can model for us or suffer the uncertainties in results that approximations give us.

The Scope of Applications and Practical Criteria for Use

Rapid technological developments of the last several decades have exposed wide vistas of opportunity. Not only our military but our industrial institutions as well have been vastly empowered. But along with this opportunity is posed the accentuated need for the effective use of these technical innovations. Tremendous commitment of resources is required to establish such technologically-enriched systems. And the hope is that they will continue to prove adequate in the face of changing, and seemingly uncertain, world conditions.

Simulation is only one method for studying and improving the management of our limited resources, but one having particular advantages (and disadvantages). Several applications of this technique, and practical criteria for its use, can be suggested. The other RAND speakers will focus on the use of simulation studies to design and pretest proposed systems and to develop training methods. I would like to mention another hope of this research--that which initially motivated the air-defense experiments.

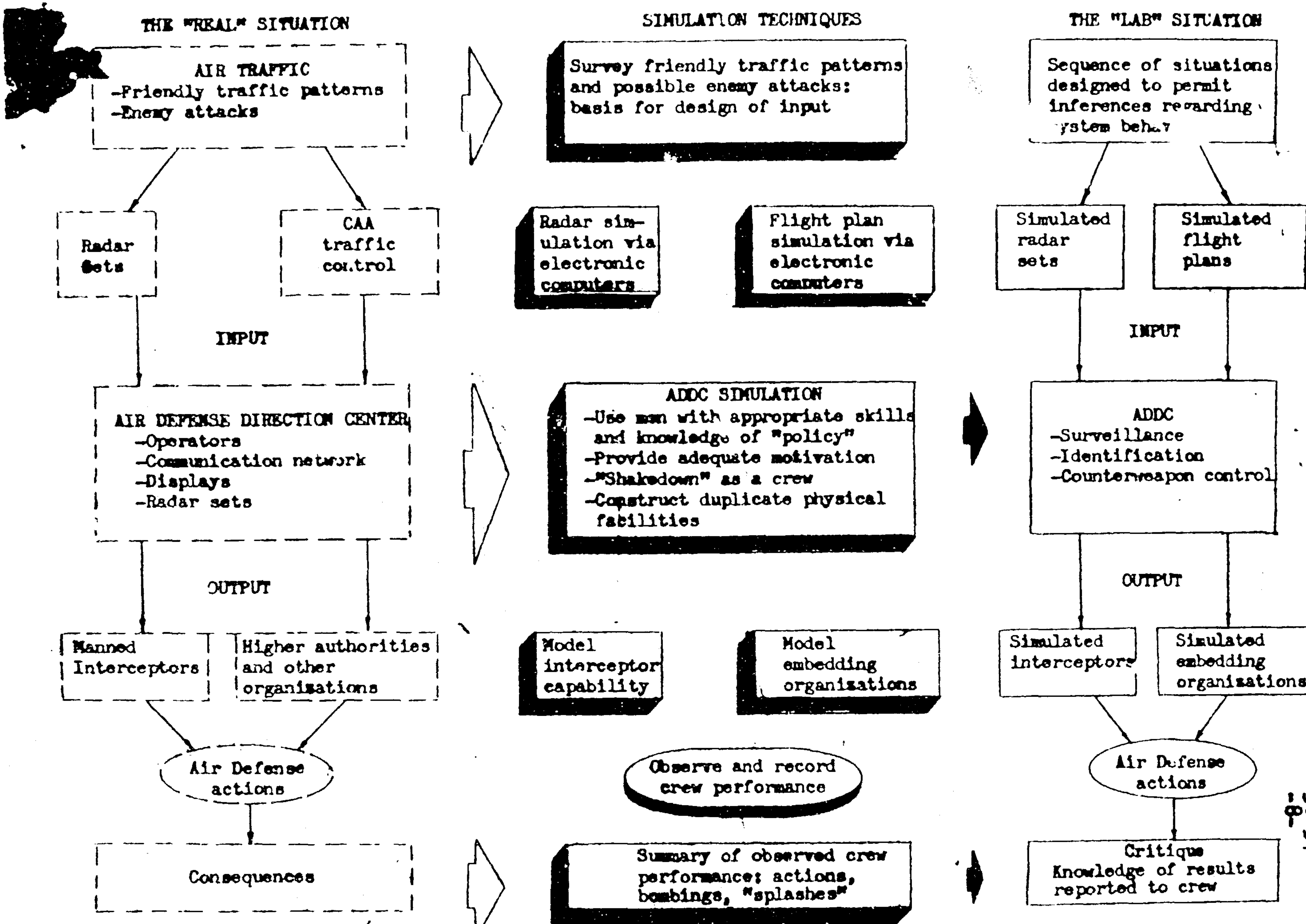
We wished to develop a theory of man-machine systems, to model the system for whose benefit an environment is simulated. Some progress along this line can be reported, but the generality, and validity, of our model remains to be evaluated. The implications of this formulation seem to promise practical help in the design, training, and management of systems.

Some of our theory is implicit in the following discussion of criteria to use in deciding whether this kind of simulation is to be used.

System designers, and operators too, are frequently plagued by uncertainty: uncertainty about the situations the system will face (raising questions of how much information-gathering ability, data-processing capacity, and action potential to build in); uncertainty about technological breakthroughs to come and how they can be incorporated in an established system (how data-processing mechanisms can be adapted to new information and response repertories); uncertainty about how to match output against input (what is the appropriate reaction to certain information).

If there is a large payoff for reducing the uncertainty of the input-output match or for maintaining flexibility in system operation, perhaps a simulation study is indicated. (Actually, in some cases, simulation is the only feasible approach, as some of Dr. Rowan's remarks will illustrate.) The chief advantage of simulating man-machine systems over other research techniques is that it permits the exploration of a wider range of alternatives in integrating information, devising responses, and in matching the two. Men who operate systems can, in fact, perform effectively in situations which are extremely complicated while scientific analysts can solve problems only in the simpler realm that their methods can circumscribe.

The increase in system potential or reduction in system vulnerability that can be realized through simulation studies will often warrant the expense of such a study (and they can be expensive, both in time and money). We all, of course, look forward to the day when we can predict the usefulness of design and management interventions in a man-machine system from a valid model. And it is to that end that our separate endeavors should all contribute.



THE "REAL" SITUATION
SIMULATION TECHNIQUES
THE "LAB" SITUATION
AIR TRAFFIC
-Friendly traffic patterns
-Enemy attacks
Survey friendly traffic patterns and possible enemy attacks: basis for design of input
Sequence of situations designed to permit inferences regarding system behav
Radar Sets
CAA traffic control
Radar simulation via electronic computers
Flight plan simulation via electronic computers
Simulated radar sets
Simulated flight plans
INPUT
INPUT
AIR DEFENSE DIRECTION CENTER
-Operators
-Communication network
-Displays
-Radar sets
ADDC SIMULATION
-Use men with appropriate skills and knowledge of "policy"
-Provide adequate motivation
-"Shakedown" as a crew
-Construct duplicate physical facilities
ADDC
-Surveillance
-Identification
-Counterweapon control
OUTPUT
OUTPUT
Manned Interceptors
Higher authorities and other organizations
Model interceptor capability
Model embedding organizations
Simulated interceptors
Simulated embedding organizations
Air Defense actions
Observe and record crew performance
Air Defense actions
Consequences
Summary of observed crew performance: actions, bombings, "splashes"
Critique
Knowledge of results reported to crew

Figure 1.