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Real-Time Simulation Applications

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ABSTRACT

This paper deals with development of the real-time simulation systems. Two systems, one for supporting the research and development programmes of the aircraft industry and the other to provide pilot training of modern aircraft are described. The presentation brings out the effectiveness of such systems in their respective roles and the techniques developed in the design and realisation of hardware and software.

This also gives a overview of various activities which have culminated in the establishment of research simulation facility and training simulators. Also plans of actions and techniques proposed to be employed in terms of future programmes are discussed.

1. INTRODUCTION

Simulation is an extremely useful technique which enables a better understanding the dynamic behaviour of complicated physical systems[1,2], through mathematical modelling. Simulation with an operator in the loop is an extension of this technique that enables the simulation of the behaviour of the real life physical system. With the advances in the technology of computational sciences, a very high degree of fidelity has been achieved resulting in an unprecedented degree of realism that could be used not only as a cost effective design tool, but also as a research and development aid to support futuristic programmes for building even more advanced systems. Similar real-time simulation systems would support activities towards studies and analysis of various problems that may arise during the operational life of these expensive physical systems from the point of view of supporting design modifications towards improvement of operational effectiveness of such systems. The real-time ground based simulator systems have proved efficient in providing *ab-initio* training to human operators, withtout putting them at risk on the real life systems being simulated thus

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increasing the operational life of sophisticated but expensive modern weapon systems and saving expensive fuel. So, it is seen that the real-time simulator systems play an important role from design through operation and continuous development of modern weapon systems.

2. RESEARCH FLIGHT SIMULATION SYSTEMS

This programme was taken up in two phases. The first phase concerns a program for establishing a research flight simulation facility to support research activities in flight mechanics in respect of handling quality studies covering various flight profiles. This facility has already been completed. The second phase programme, which is now in progress, is to extend the capabilities of the former by including air-to-air combat simulation and thus build up a capability to support futuristic aircrtaft designs and development programmes. The hardware and the software of these simulation systems, are described in the following sections.

2.1 Research simulator

The schematic representation of the research simulator is shown in Fig. 1. This facility consists of the following major subsystems.

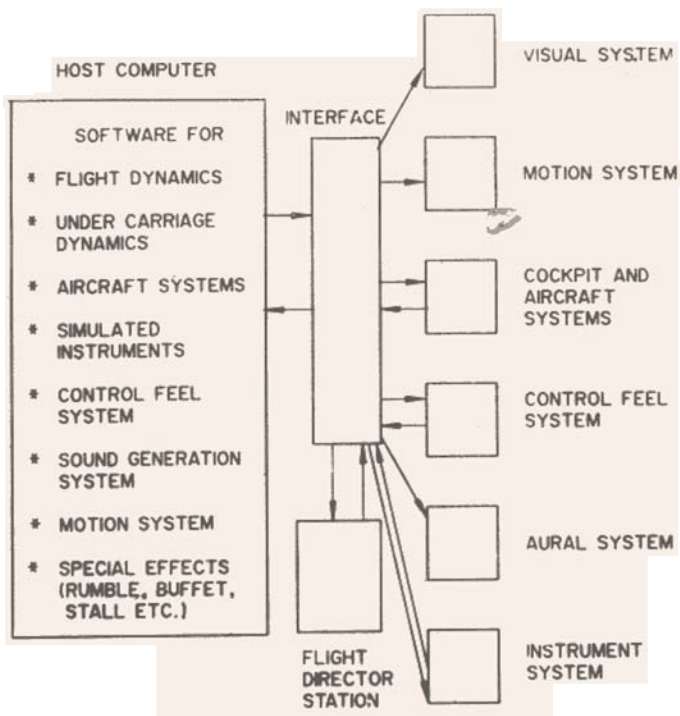

Figure 1. Flight simulation facility PH I.

(1) Host computer,(2) 6 d.o.f. motion cue generation system, (3) CCTV based visual cue generation system, (4) Simulated flight instrumentation, (5) Control feel cue generation system, (6) Aural cue generation system and (7) Cockpit system.

2.1.1 The host computer is a hybrid computer – (PACER 600) in which the program modules of real-time software organisation, dynamics of aircraft, engine, under-carriage, weapon systems, aircraft systems, simulated instruments, motion cue generation, etc. are resident. A block diagram representing flight software organisation is shown in Fig. 2. The salient features of the software are :

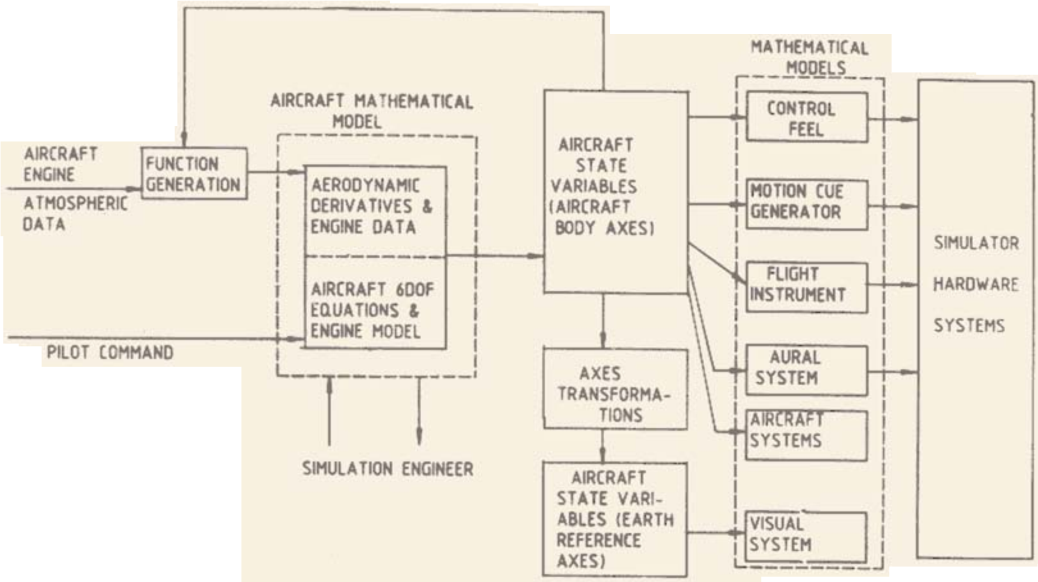

Figure 2. Flight software organization-block diagram.

(a) Aircraft mathematical modelling[3] which includes aircraft dynamics, airframe, engine and undercarriage. The solution of non-linear differential equations is by using step by step numerical methods like Euler's Adam-Bashforth method when accuracy of calculation required is high[4].

(b) Function generation techniques using the basic aerodynamic data and the atmospheric model to obtain the relevant aerodynamic derivatives and the engine data necessary for flight simulation.

(c) Simulation engineer interacts with the aircraft mathematical model and has the facility to vary the aircraft, engine, and atmospheric data so that the aircraft performance can be assessed taking into account all foreseeable flight conditions or configurations changes (in case of design of new aircraft).

(d) The aircraft state variables, once obtained through appropriate calculation techniques (of course through high speed computers), are fed to various software modules which generate the necessary commands to hardware systems for providing motion, control feel, flight, sound and other essential cues.

(e) The state variables referred to aircraft body axes are transformed to generate the aircraft flight trajectory which in turn is fed to the software modules that generate necessary commands to the system for generating the necessary visual cues.

The system configuration and the software modules not only generate cues to make the simulated flight mission highly realistic but also make it possible for the simulation engineers to interact usefully with the aircraft designers to study every possible aspect of the configuration consisting of engine, undercarriage and cockpit systems.

For a pilot in the loop assessment of aircraft performance, the simulated flight mission has to be in real-time. A block diagram representation of the real-time executive is shown in Fig. 3. The salient features of this module are :

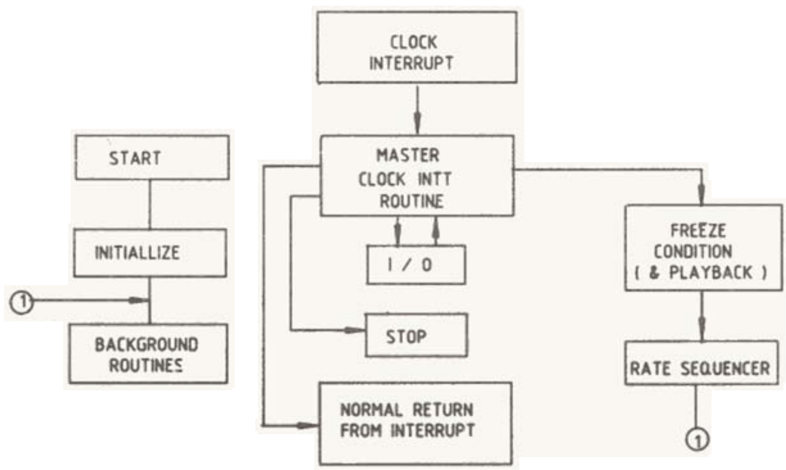

Figure 3. Real-time executive-block diagram.

(a) Clock frequency to provide the required update rate and interrupt feature for the real-time operation.

(b) 'Initialise' provision to enable the start of the simulated flight at any of the specified start conditions.

(c) Background routines which enable the simulation engineers to effectively interact with the total mathematical model of the aircraft.

(d) Rate sequencing to enable optimisation of computational time by providing for the optimum update rates for each of the software modules.

(e) Provision for freezing and playback of the flight mission at any time to provide for the on-line interaction with the aircraft mathematical model and the pilot.

(f) Synchronization of I/O between computer and simulator hardware systems.

A real-time interface system provides the requisite communication, either way where necessary, between the computer and the respective hardware. The hardware and software features are designed to generate flight cues, which create highly realistic flying environment.

This versatile real-time simulation facility has been engineered to provide research and development support towards the study of configurations and their modifications with the objective of assessing handling qualities of present and future generation aircraft.

2.2 Air combat simulator

The air combat simulation facility provides for the assessment of the combat capabilities of a combat aircraft vis a vis performance capabilities of other combat aircraft. This facility will be essential for the evaluation of capabilities of proposed configuration of futuristic combat aircraft and also to study the capabilities of new generation weapon systems covering both dog fights and beyond visual range (BVR) weapon release. A block diagram representation of such a facility featuring twin dome

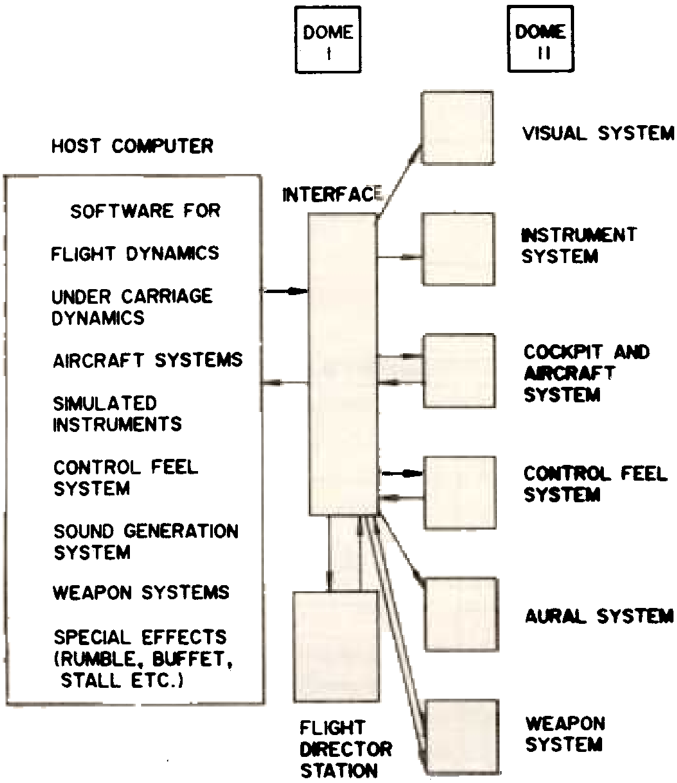

Figure 4. Flight simulation facility PH II.

system is shown in Fig. 4. A schematic representation of the proposed system is shown in Fig. 5. While there is commonality between most of the simulator hardware systems earlier described, noticable differences are :

(a) Faster computer with higher memory capacity. (Schematic representation shown in Fig. 6.)

(b) Visual cue consists of horizon reference, aircraft target image and missile projections inside a dome. They provide aircraft angular attitude cues, target flight path trajectory and trajectory information of missiles and bullets. Earth horizon projector gives a generalized view of ground terrain and sky background from high altitude.

(c) Motion cue in this configuration is of the nature of normal accelerations buffets and weapon hit effects.

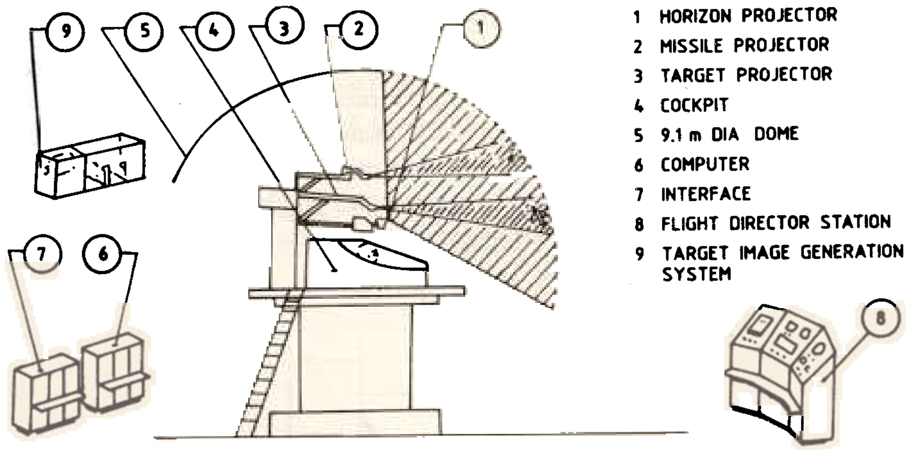

Figure 5. Proposed air combat simulation facility.

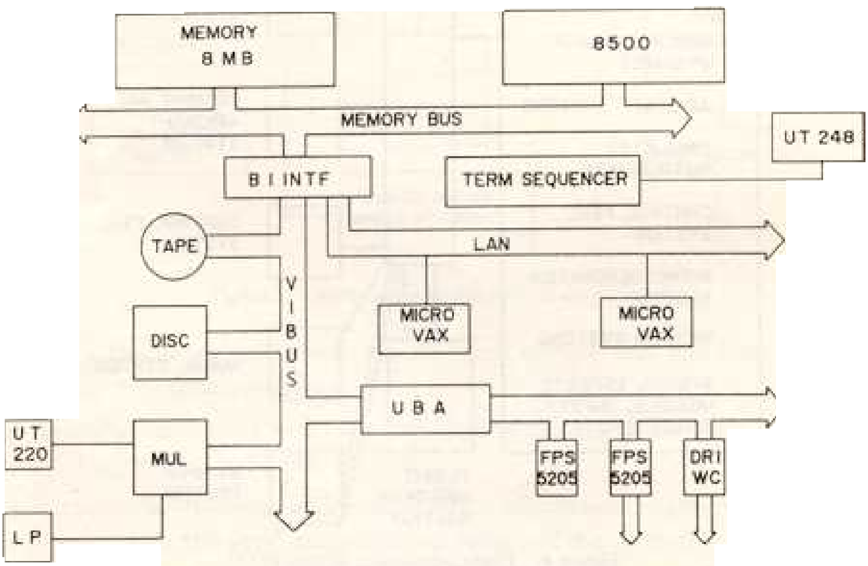

Figure 6. Computer configuration (Air combat simulator)

While the hardware system for generation of the above cues is quite complicated, it should be appreciated that the development of the software for achieving these effects and also the air-to-air combat logic is even more complex. The distributed processors can greatly help to optimise the computational time and reduce the interface complexity. Actions are in progress to develop hardware systems and the associated software towards achieving an air-combat simulation of high fidelity.

A state of-the-art technique that is proposed to be implemented in this programme is parallel computations through distributed processors. By this, the computational loads towards various sub-systems are met through dedicated microprocessors and only the essential interaction between various sub-systems and the host computer (through management processor) is provided through a suitably designed digital communication system.

3. FLIGHT TRAINING SIMULATOR SYSTEMS

A simulator system, that has the necessary hardware and supported by software which provide synchronized flight cues and thus provide an highly realistic training environment to the student pilots has been configured, designed and fabricated. The advantage of such a system are as follows :

(a) Most of the flight training, except the minimum time required in air for psychological and physiological reasons. can be on the ground based simulator, which not only saves considerable expenditure due to the reduction in consumption of expensive and scarce fuel and costly maintenance and depreciation of expensive systems, but also makes it possible to use these systems much more effectively to achieve the main objectives for which these systems have been designed.

(b) The training can be made highly effective because of the features of the simulator which enable intensive and well planned programme to be complemented.

(c) The training simulator is available at all times and special facilities such as freeze, playback, initialization, etc, enable closer interaction between trainee and instructor. These provide for instantaneous correction of mistakes and also repetition of critical profiles, with environmental variations if so desired.

The real-time simulation system which is configured to support a training programme is usually more involved since the entire mission profile is to be simulated unlike a research simulator where only a critical part of a mission profile needs to be simulated. Also, since the system is meant for total *ab-initio* training, the simulation should be total, including every type of cue, again unlike a research simulator where cues such as transient motions, sound effects, etc., need not be simulated since experienced test pilots are involved. In the case of training simulators, navigation and communication systems would also have to be simulated to complete the training effect. The system configuration is similar to that of the research simulation facility, the notable differences being (i) the visual system based on the computer generated imagery technique[7], where the data base is digitized and the scene generation is achieved through software techniques (Figs. 7 and 8), and (ii) the host computer is a VAX 11/780 computer with 1 MB memory (Fig. 9). The interface system links the computer with the simulator hardware systems and has the following salient features :

(i) Microprocessor based I/O system to provide flexible I/O requirements.

(ii) Extensibility of the I/O system as a front end processor.

(iii) Built in on-line and off-line diagnostics for the I/O system.

(iv) System availability is enhanced by improved diagnostics.

(v) Interface software driver is written to cater real-time environments. (Flight update frequency as high as 50 Hz).

(vi) Interface I/O system is built to cater two types of inputs and outputs (Analog and Digital).

(vii) The I/O signals are processed near the site of origination by configuring two consoles independantly (cockpit and ground consoles).

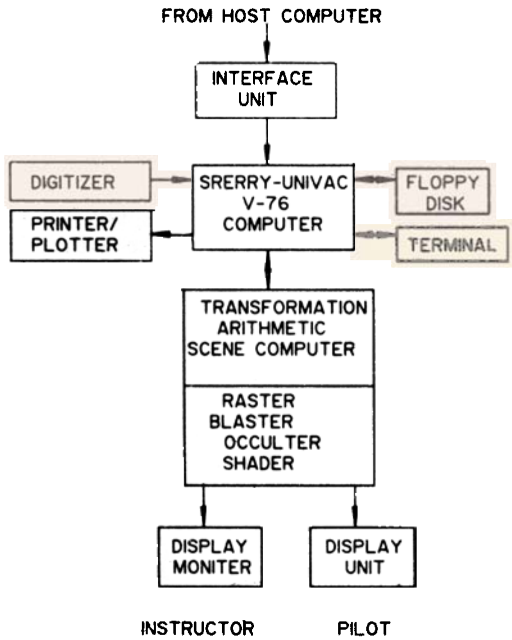

Figure 7. Computer generated imagery system.

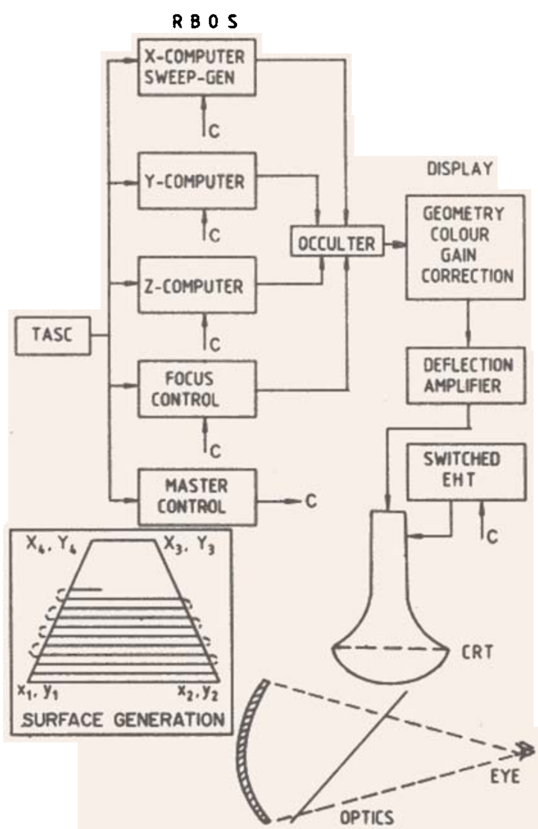

Figure 8. Visual scene generation unit.

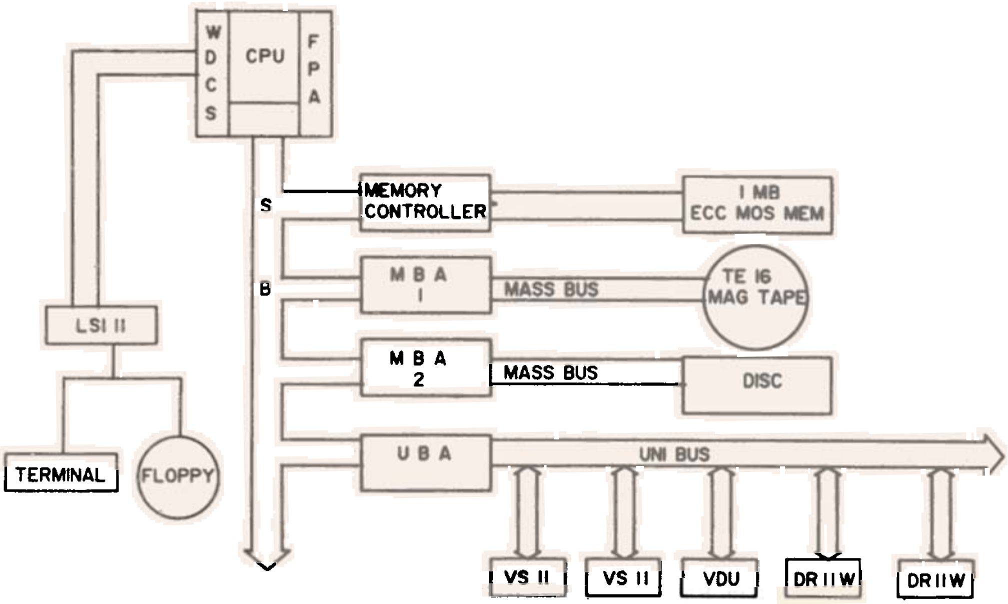

Figure 9. VAX 11/780 computer system.

The application software modules include all the software to make the simulation effect total and realistic. Additional software modules developed especially for the training simulator programme are :

(a) Motion cue generation which includes washout and sneakback[5] for simulation of continuous acceleration.

(b) Freeze and long duration playback.

(c) Navigation and communication.

(d) Variable gradient (real-time) control feel forces.

(e) Sound effects to cover all aspects such as engine noise, aerodynamic effects, weapon systems, activation of aircraft systems, etc.

The salient features of the training simulator developed at ADE[6], are:

(a) Realistic simulation of the aircraft performance over the entire flight envelope, excepting loop and spin, which are possible without motion cues.

(b) Introduction of all possible failures and malfunctions by instructor.

(c) Facilities at the instructor's station to monitor, guide and correct the actions by pupil pilot.

(d) Mission playback facility upto a duration of one hour, including activation of all simulation cues.

(e) Options to the instructor to choose initial conditions for a training programme.

(f) Impart training on weapon delivery (bombs, rockets, missiles, gun firing etc.) and ground attack mode.

(g) Pursuit and attack training against a target aircraft (within limited field of view).

The major spin-offs from this programme are

(a) Competance for the generation of aircraft model by semi-empirical methods and its validation through interaction with experienced pilots.

(b) Development of software and hardware techniques to stimulate a realistic flight environment.

This programme has thus enabled developement of the capability to configure and develop real-time man-in-loop simulator systems to support cost effective training programmes in respect of sophisticated military systems.

4. CONCLUSION

Fast and powerful computational systems and associated software techniques make it possible to configure and develop real-time man-in-loop simulation system, which provide cost effective and time saving support towards research, design, development and training programmes in respect of complex military systems with similar possibilities in civil sector. Microprocessor based distributed parallel processing computational systems together with structured software techniques reduce not only the cost of the real-time training simulator systems but also provide future growth capabilities and the flexibility to reengineer the systems to meet changing requirements.

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