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DISCUSSION OF THREE TYPICAL LANGLEY RESEARCH CENTER SIMULATION PROGRAMS

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ABSTRACT

This discussion deals with three typical simulation programs at Langley in the areas of aerodynamic flight, lunar flight, and near-earth space flight. The simulation requirements in terms of the mission, the vehicle, and the simulation hardware are discussed for each problem. The mathematical models are mentioned in general and particular emphasis is given to the computer considerations of each in terms of the layout and the size and types of computers utilized. The computational considerations such as integration schemes, sampling rates, and central processing unit time of an all-digital approach to an earth orbit rendezvous problem is presented and the results compared to a hybrid approach. Capabilities of Langley's future digital simulation complex are discussed.

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DISCUSSION OF THREE TYPICAL LANGLEY RESEARCH CENTER SIMULATION PROGRAMS

By Ellis J. White
Langley Research Center

INTRODUCTION

The purpose of this presentation is to acquaint other users and manufacturers of computing equipment with the computer approach made at the NASA Langley Research Center to real-time simulation problems in the research areas of aerodynamic flight, lunar flight, and near-earth space flight. A typical problem will be used to illustrate the work in each of these three areas. These problems are: first, supersonic-transport air-traffic-control studies; second, lunar-orbit and landing-approach studies for vehicles of the Apollo lunar module (LM) type; and finally, a study for earth-orbit "station keeping" of the Gemini and Agena vehicles. The emphasis in this discussion will be on computer considerations (choice of computers, layout, etc.) with respect to the simulation requirements in terms of the missions, the vehicles, and the hardware. The mathematical models are not discussed in any detail, but are given attention when they were influenced by computer considerations and simulation requirements, and vice versa. None of the research results obtained by use of these simulators will be discussed. The three typical programs will demonstrate the use of the existing Langley computer equipment in terms of an all-analog problem, a "hybrid program" using analog and a Digital Differential Analyzer (TRICE-DDA), and an experimental all-digital-simulation program using the IBM 7094II and TRICE conversion equipment. The digital simulation problem, which is the earth-orbit station keeping of the Gemini and Agena vehicles, was also done on a production basis using an analog-DDA combination. Some general comparisons of these two approaches will be discussed. Also, a short general description of Langley's future computer complex will be discussed and some of its simulation capabilities outlined. It should be mentioned here that this discussion is not meant to imply that this approach is the only one that can be made to these problems, but is one that has been very successful with the available equipment.

SUPERSONIC-TRANSPORT AIR-TRAFFIC-CONTROL STUDIES

General Considerations

The supersonic-transport project was a joint NASA-FAA study of a real-time simulation of supersonic transport (SST) arrivals and departures at large international airports. The objectives of the study were:

1. To determine the effects of the air-traffic-control (ATC) system on SST design and equipment requirements.

2. To determine the effects of the SST on ATC system requirements.

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Simulation Requirements

Some pertinent characteristics of the mission, the vehicle, and the hardware, which determine the simulation requirements are now discussed:

Mission.- Mission characteristics include:

(1) Mach number range from 0 to 4.0.

(2) Altitude from sea level to 100,000 feet.

Vehicle.- Vehicle characteristics to be considered are:

(1) Inclusion of both fixed-geometry and variable-sweep wing concepts.

(2) Complete six-degree-of-freedom representation.

(3) Provision for four completely independent engines.

Hardware and overall simulator.- A block diagram of the facilities involved in the program is shown in figure 1. The blocks on the left represent the equipment at NASA Langley Research Center in Hampton, Virginia, and those on the right represent the equipment at FAA's National Aviation Facilities Experimental Center (NAFEC) in Atlantic City, New Jersey. The analog computing facility, which is used to solve the equations of motion and will be discussed later, is coupled to the SST simulator flight compartment via underground cables. These two facilities are separated by approximately 1,000 feet. The SST position data and the voice communication between NASA and FAA are transmitted via telephone lines after the signals are converted from analog to digital. To create the air-traffic-control environment, the FAA has provided an entire Air Route Traffic Control Center and an approach control and tower complex for one airport. These facilities are staffed by 30 experienced air traffic controllers. They are provided with radar display including video maps showing airways, holding and terminal areas, flight progress strips, and radio communication equipment. The Air Traffic Sample Simulation is created by 108 personnel each operating an electronic target generator, which provides beacon information for the controller's radar scopes. Each operator, by adjusting controls and actuating switches, simulates one aircraft moving along a preprogramed flight path. Figure 2 shows the Langley SST cockpit and control room. The flight compartment is similar to that of a current jet transport aircraft with seating for pilot, copilot, flight engineer, navigator, and an observer. The instrumentation is also similar except some of the instrument ranges are modified to cover the higher altitude and increased Mach number. Accessory equipment needed to provide for navigation, communication, recording, and power requirements is located in a room behind the cockpit.

Mathematical Model and Computer Considerations

Figure 3 shows the computer equipment requirements and organization for the SST problem. This problem was solved using all analog equipment rather than hybrid since the variables were within analog computer capability. The fundamental problem was to be able to get this entire problem on the six analog consoles shown. The complete analog program includes: the basic airframe dynamics, including six complete degrees of freedom and utilizing three 231-R consoles; the four independent engines requiring two consoles, and the subsystems including an autopilot using the sixth console. The aerodynamic forces and moments are simulated in the stability axis since the wind-tunnel data are with respect to this system. The forces are transformed to wind axis and the moments to body axis. The Euler angle equations are solved in wind axis because the conversion to earth coordinate is then simplified. As in all aerodynamic problems a large number of functions are required, the SST requires as many as 75. These were generated by using servo set diode function generators which did become a burden on the setup time. The programing of the four independent engines originally would have required 82 functions for the engine thrust and fuel flow which was beyond our function generation capacity. It was possible, however, to obtain two functions of one variable each, which when multiplied together would produce the family of curves required and reduce the number of function generations to 28.

Operational Considerations

Perhaps the most stringent requirement on this simulation is the operational restrictions. These operational restrictions are, namely, the difficulty of coordinating the efforts of approximately 150 personnel at four separate facilities and synchronizing and minimizing the equipment setup and checkout time at these facilities in order to meet a commitment to operate the simulator with NAFEC at 10:00 a.m. each morning. These operational problems are further complicated by the analog computing facility operation, which is on a two-shift basis. The facility is used for other simulations on the second shift. This could, depending mainly on the number of DDFG (digital diode function generators) to be reset, require the entire SST computer program to be set up and checked out anew each morning. In order to overcome these difficulties, an organized sequence of events was used which allowed rapid setup and checkout of the computers and rapid location of errors when they occurred. Figure 4 shows this sequence of events used for the Langley end of the SST simulator. Each block or task will not be explained here, but all tasks are included to show this sequence. On the left side of the figure the minimum time for completion of each task is shown. An attempt is made to leave as many of the DDFG as possible set up from the day before without sacrificing any of the second shift problems. A special function check board is used to scan the functions quickly for accuracy and if any discrepancy occurs the DDFG reset tape is run for that particular DDFG. Time is saved during the static check by using a specially designed partial check, which examines only the main variables of an equation and then proceeds if no error occurs. If an error is present a detailed static check, which is available, is used to specifically locate it. The dynamic check is expedited by using transparent overlays for the time history recorders. All six ADIOS desks are working in parallel for the airframe as well as for the engines and subsystems. The SST simulator setup and checkout are also progressing in parallel. The minimum time, which is based on everything progressing without difficulty, is 1 hour and 35 minutes. The average time is about 2 hours and 35 minutes; therefore, most of the time the 10:00 a.m. commitment is met. These times also include a take-off check run with the pilot in the loop. With the amount of equipment involved these setup and checkout times are considered good. This SST simulator has been operating with NAFEC since May 1964. The schedule consists of approximately three 5- to 8-week running periods per year and to date approximately 700 runs have been made, roughly 450 of these have been run with NAFEC and have used experienced airline pilots. The SST cockpit has been used for other problems when not used for air-traffic-control studies.

LUNAR ORBIT AND LANDING APPROACH (LOLA) STUDIES USING THE APOLLO LM TYPE VEHICLE

General Considerations

The LOLA project is currently the largest computer simulation at Langley. The main objective of this project is to help develop manual procedures that a pilot could use to control a space vehicle in the near vicinity of the moon by providing a complete simulation of the expected vehicle dynamics, control characteristics, and visual environment to be encountered.

Simulation Requirements

Some of the more important characteristics of the mission, the vehicles, and hardware which are of interest and which imposed difficult requirements on the computer programing and the mathematical model development are outlined below:

Mission.- The following mission plans must be provided:

(1) Multiorbit capability.

(2) Complete and continuous simulation from 200 nautical miles and terminating at approximately 150 feet, which includes the following phases:

(a) Establishment of an 80-nautical-mile orbit from an altitude of 200 miles.

(b) Orbit transfer and coasting descent (Hohmann transfer) from the 80-nautical-mile orbit to perilune (50,000 feet) of the new orbit.

(c) Powered descent to approximately 10,000 feet.

(d) Hover and landing approach to 150 feet.

(3) Abort trajectories from either the powered descent or from the Hohmann transfer

Vehicle.- The vehicle requirements consist of the following:

(1) Staging of the Apollo LM type vehicle (the LM type vehicle will be hereinafter referred to as the LM for simplicity) with the Apollo remaining in the 80-nautical-mile orbit.

(2) Staging of the LM descent vehicle to obtain the LM ascent vehicle.

(3) Detailed simulation of the LM reaction control system (including four modes of control and 16 individual on-off reaction jets).

(4) Extensive moment description.

Hardware.- In figure 5 is shown the main hardware of the LOLA simulator. The system consists of four progressively scaled models of the moon, two camera transport and track systems, and the pilot's cabin and television display. Model 1 is a 20-foot-diameter sphere mounted on a rotating base and is scaled 1 in. = 9 mi. Models 2, 3, and 4 are approximately 15 × 40 feet scaled sections of model 1. Model 4 is a scaled-up section of the Crater Alphonsus and the scale is 1 in. = 200 ft. All models are in full relief except the sphere. The model system is designed so that a television camera is mounted on a camera boom on each transport cart and each cart system is shared by two models. The cart's travel along the tracks represents longitudinal motion along the plane of a nominal orbit, vertical travel of the camera boom represents latitude on out-of-plane travel, and horizontal travel of the camera boom represents altitude changes. A typical mission would start with the first cart positioned on model 1 for the translunar approach and orbit establishment. After starting the descent, the second cart is readied on model 2 and, at the proper time, when superposition occurs, the pilot's scene is switched from model 1 to model 2. Then cart 1 is moved to and readied on model 3. The procedure continues until an altitude of 150 feet is obtained. The cabin of the LM vehicle has four windows which represent a 45° field of view. The projection screens in front of each window represent 65° which allows limited head motion before the edges of the display can be seen. The lunar scene is presented to the pilot by rear projection on the screens with four Schmidt television projectors. The attitude orientation of the vehicle is represented by changing the lunar scene through the portholes determined by the scan pattern of four orthicons. The stars are front projected onto the upper three screens with a four-axis starfield generation (starball) mounted over the cabin and there is a separate starball for the lower window.

Mathematical Model and Computer Considerations

It has become increasingly evident at the Langley installation, as the physical systems to be studied on the computer become more complex, that computer capabilities and the hardware must play a more direct role in the ultimate mathematical formulation of the problem. This was a major consideration in the LOLA simulation. Figure 6 shows in block diagram form the equation distribution on the computer complex. For simplicity, interconnections between computer consoles are omitted. The total simulation utilizes six 231-R analog consoles, a TRICE (DDA) console, a PB 250 digital computer, a Mark III-S logic console, and three Euler angle computers, in addition to the hardware described previously. It is not intended here to describe in any detail the equations involved; however, a few pertinent points should be mentioned. To obtain suitable resolution on the computer (because of the large ranges of variables) both the Apollo and LM trajectory equations were perturbated about a nominal circular orbit. The most suitable nominal orbit was one whose radius was equal to the actual elliptical orbit's semimajor axis distance, but programed from the center of the moon. This gave symmetry for the vehicle's deviation from the nominal orbit, which allows optimum scaling. The perturbated trajectory equations for both Apollo and LM were programed on TRICE because of its excellent accuracy in calculation of orbital equations, and also because their configuration required a minimum of interface between the TRICE and the analog system. It would have been necessary to include TRICE anyway on a problem of this size, to be used as a seventh analog. With the serious limitation on equipment, it was necessary to keep duplication to an absolute minimum. Therefore, all vehicles were represented by the same equations of motion, with inputs from the same control system. This approach was possible, since no two vehicles were needed simultaneously, with the exception of the Apollo which remains in orbit, but needs no attitude description. For this reason two identical sets of equations of motion appear on the TRICE, and this exception requires the only significant duplication in the simulation effort. Notice that the staging logic, which is used both in the separation of the Apollo and LM vehicle and the dropping of the landing stage from the LM descent vehicle to obtain the LM ascent vehicle, appears on four of the computer consoles. A significant amount of logic is involved at the time of staging for it requires switching from one set of characteristics to another throughout the analog system. These characteristics include: mass, inertias, main thruster magnitude and direction, body rate magnitudes, control system, and attitude. Euler parameters were used for the axis transformations, the advantages of which will be mentioned in the discussion of the next problem. The Packard-Bell 250 digital computer in addition to being used as a TRICE controller is used to make scale changes for the model drives. This function is accomplished by the PB 250 changing the scale of the variables in the TRICE registers when switching from one model to another occurs. This scale change is provided so that the cart assembly can always operate with full range on each model. If this change were made on the analog, the noise amplification would be intolerable since there is approximately a 250 to 1 ratio in the scaled lunar models. The Euler angle computers will be described in the discussion of the next problem. The logic console is used for the reaction jet logic in the vehicle control system and for the jet failure display drives for the cockpit display panels. All of the LOLA hardware is not yet complete, but should be in the next few months. The computer program is complete and the simulation has already been used for some interim studies on individual phases over the past 18 months. These include some preliminary studies in orbit establishment and abort using model 1 and power descent using model 4. It is anticipated that this simulation will be useful for many lunar research studies over the next 2 to 3 years.

GEMINI-AGENA STATION-KEEPING STUDIES

General Description

This is a real-time simulation of the Gemini (observer) vehicle station keeping with the Agena (target) vehicle in a slightly elliptical orbit. Some of the objectives and overall capabilities of this study were:

(1) To investigate manual-control procedures (attitude and translational) and fuel usage for station keeping with the Agena vehicle.

(2) To evaluate pilot effectiveness for various control procedures.

(3) To evaluate "onboard" equipment and flight data display requirements. This evaluation was made with and without radar information.

(4) To study terminal rendezvous techniques and photographic study maneuvers.

Simulation Requirements

Some pertinent characteristics of the mission, the vehicle, and the hardware which are of interest and which place difficulties on the mathematical model and computer program development are outlined below:

Mission.- Mission requirements include:

(1) Unlimited angular freedom of both target and observer vehicles, thus making it possible to approach the target from any spatial direction while the target vehicle is capable of completely independent angular motion.

(2) Generation of arbitrary target orbits.

(3) Both the observer and target vehicles must have multiorbit capability in a real-time environment.

(4) The model in conjunction with the visual docking simulator (VDS) provides a realistic "out-the-window" display. Proper target aspect is to be generated for arbitrary rotational and translational motion of both the target and observer vehicles.

(5) Has station-keeping and fly around capabilities.

(6) Has complete eleven degrees of freedom, six for the observer vehicle and five for the target vehicle.

Vehicle.- The vehicle requirements are:

(1) Complete description of the Gemini vehicle with all jet controllers and cross couplings available.

(2) Three different modes of attitude control: direct, rate command, and attitude hold. Translational controls are direct only.

Hardware.- The hardware requirements may be best explained by referring to figure 7. This Visual Docking simulator is a Langley developed Virtual Image Display system which provides an "out-the-window" visual display of the target vehicle, a featureless horizon, and a starfield. The starfield and horizon projectors consist of point light sources projecting through and reflecting from a beam splitter to the upper screen. The gimbal angles involved, which are obtained from the computer, represent the attitude of the observer vehicle. The image of the Agena target vehicle is formed on the lower screen by a television projector. The input to the projector is the image of an Agena model which is mounted in a two-axis gimbal and viewed by a vidicon camera. The two-axis gimbal represents two of the three rotations of the target vehicle relative to an axis system fixed to the line of sight from the observer to the target. The third (or rolling motion) is obtained by rotation of the vidicon about the line of sight. Line-of-sight range is obtained by moving the camera assembly longitudinally with respect to the model along a range bed. The mirror gimbals are driven in azimuth and elevation as a function of the target's line-of-sight angles relative to the observer's body axis, thus representing all eleven degrees of freedom of the two vehicles. The images on the two projection screens are then mixed by the second beam splitter which is transparent to the target image but reflects the previously mixed horizon-starfield image. The composite image is then viewed by the pilot through a lens. A nominal instrument display, including a three-axis attitude indicator for the observer, is provided.

Mathematical Model and Computer Considerations

In addition to meeting mission requirements, perhaps the most stringent constraints imposed on the format of the trajectory mathematical model results from computer limitations and characteristics. An attempt was made to overcome some computing difficulties associated with the rendezvous class of piloted simulations by developing a trajectory model which is compatible with an Analog-TRICE (DDA) computing system. Figure 8, which is a general block diagram of the equation distribution on the computer complex, shows some of the computer assignments and interconnections. Again, for simplification, interconnections between computer consoles are not shown. The total simulation utilizes five 231-R analog consoles, a TRICE (DDA) console, four Euler angle computers, and the simulator complex that was described previously. Again, as in LOLA, it is not the intent here to describe in any detail the equations involved, but some pertinent points should be made. Since only the terminal phase of rendezvous is of interest in this simulation, relative equations of motion which greatly improve the scaling of the analog computer are used. Second-order correct gravity terms were used for the trajectory equations of the observer vehicle. Further scaling advantages are realized by perturbating the target equation of motion by using a similar approach as in LOLA. It is at this point that the hybrid concept is employed. The TRICE is capable of solving the perturbated target orbital equations very accurately for more than one orbit. In this case the TRICE is conceived as an open loop function generator for the target trajectory. Throughout the other consoles there are seven sets of transformations from one axis system to another to satisfy the vehicle and hardware requirements. Considering some of the mission requirements, such as unlimited motion of the vehicles and multiorbits, the quaterian approach (Euler parameters) was considered the best method of performing these transformations. The Euler angle approach is inadequate because of the singularities and the number of redundant integrators that would be required. The Euler rate equations are prohibitive mainly because of the complexity of the constraints required. Of course, the axis systems used cannot be chosen independent of the type of transformations required.

They must be chosen to hold the number of transformations to a minimum. Three sets of Euler parameter equations are solved for the target, the observer, and the control platform for the observer. The control platform is provided to allow pilot selection of a new inertial system. The Euler angle computers (EAC) are special purpose devices consisting of a set of three resolvers which accept the direction cosines and produce the associated angles for the eight-ball, star ball, horizon generator, and the model. These angles would be obtained from the general-purpose computing equipment, such as α and β are on console No. 3, if the EAC's were not available. Nearly all of console 1 is utilized by the control system. This complete system represents the mechanization of an eleven-degree-of-freedom, two-vehicle system, which provides the basis for a high-fidelity real-time simulation capable of performing all the mission requirements. This simulator has been used extensively over the past 10 months in support of studies for GT-9, GT-10, and GT-11 missions. It did, however, require nominal modification for the Gemini-Agena tether simulation.

REAL-TIME DIGITAL SIMULATION OF THE GEMINI-AGENA STATION-KEEPING PROBLEM

Introduction and Objectives

The possibility of real-time digital simulation using general-purpose digital equipment in order to advance the state of the art of computer science has been under consideration, investigation, and various stages of application for some time. To investigate and gain experience in this concept at LRC this project was undertaken. In order to make a direct comparison and prevent building another simulator, it was decided to duplicate the Gemini-Agena station-keeping problem which had already been successfully simulated using the hybrid concept just discussed. Some of the specific objectives of this study were:

(1) To demonstrate the feasibility of certain integration schemes.

(2) To evaluate programing language suitability (FORTRAN).

(3) To determine the amount of Central Processing Unit (CPU) time required to complete an iteration to help determine multiprogram capability in general.

(4) To uncover possible trouble areas which may hinder program solving on Langley's future real-time digital simulation facility.

Complement of Equipment

Figure 9 shows the equipment used in this simulation. The IBM 7094II digital computer solved the equations of motion. The 7090 buffer which is part of the TRICE equipment was used to transmit the word in parallel to and from the 7094 through the direct data channel. Extensive hardware modifications were performed on the buffer, the distributor, and the converters in order to handle the transmission of data reliably. The distributor is used to address the converters and to translate information from the 90 buffer into TRICE control functions. The sample and present timer is a real-time clock which allows transmission of data at the proper rate or time between the computer and the converters. The TRICE keyboard is used for mode control (the normal analog modes) of the computing system. Twenty-four digital-to-analog converters (DAC's) are used to send necessary signals to the visual docking simulator, which was discussed before. These signals are used to drive the starball, horizon generator, the model, mirror, range, the range-rate meter, and three velocity meters. All the desired drive signals could not be sent because of the limited number of DAC's available. Only seven analog-to-digital converters (ADC's) were required to handle the attitude and translational controls and an attitude mode selection signal for the cockpit.

Programing Considerations

Program language.- The desired approach was to program the equations of motion by using FORTRAN IV for ease and simplicity of programing and not have to resort to the more complicated but more efficient machine language in order to hold down the CPU computation time. The first attempt was to avoid "do" loops and subroutines where possible, but it was later discovered that this was not necessary for this problem. The FORTRAN logic was very useful and was used extensively in the simulation of the pulse controllers. It was necessary, however, to use machine language (MAP) for the INPUT/OUTPUT program because the required statements did not exist in FORTRAN.

Integration scheme and interval size.- It was considered desirable to use lower order multistep integration routines such as Adams Bashforth because of their speeds. The first attempt was to use Euler's routine. This routine proved adequate for the thrust and trajectory calculation because the rectangular scheme is best for the thrust's rectangular pulses and because the trajectory has an extremely low frequency. The Euler routine, however, caused instability in the other equations which resulted in intolerable errors in some of the variables. Second-order Adams Bashforth routine, however, did give adequate results.

In choosing an interval size the attempt was to simplify the program by using only one interval size if possible. Also, it was not an objective to test the lower limits of updating the pilot display to avoid flicker or the lower limits of pilot control inputs, which would only tend to confuse the investigation. Therefore, an arbitrary upper limit of 50 milliseconds was chosen for the interval size, which was considered to be good enough to avoid noticeable display jumps, as long as truncation errors were tolerable. The interval-size lower limit is determined mainly by round-off errors. As a first attempt 15 milliseconds was tried, but generated too much round-off error. Finally, 31.25 milliseconds (which is a reciprocal power of two) was used successfully for the whole problem, which allowed 32 samples per second The solution was checked against a nonreal-time solution obtained by using double precision fourth-order Runge-Kutta routine. The comparison was favorable and gave better agreement than the hybrid solution. The CPU time was estimated to be between 3.75 and 4.0 milliseconds which leaves approximately 85 percent of the CPU time unused. Also, only 35 percent of the 32K core memory was used for this problem.

General Comparison

It was not necessarily an objective of this program to improve the accuracy over that of the hybrid system but to produce a man-in-the-loop digital simulation as acceptable as that of the hybrid. The overall qualitative opinions of the research pilot who flew both simulations felt that the digital simulation performed as well as the hybrid. One task given the pilots for direct comparison was to determine a relative velocity component between the target and observer vehicle by visual techniques. The pilot would initiate a spacecraft maneuver as a result of visual sighting. The pilot would predict the unknown velocity after making another sighting 10 minutes later. This prediction was then compared with the actual velocity.

Although this problem was not the utmost challenge to the digital computer, it was a typical problem and was chosen for that reason. The computer setup time was of course reduced considerably. The objectives of this simulation effort were for the most part satisfied and this approach was considered to be successful for this type of problem. More investigations in other areas are to continue.

FUTURE DIGITAL COMPUTER COMPLEX AND CONCLUDING COMMENTS

In the near future a large percentage of the real-time simulation problems at the Langley Research Center will be performed by using the digital computer complex for which a block diagram is shown in figure 10. A contract has already been awarded and delivery of the first system is scheduled for late in 1966. From a cursory look at this diagram, the main body of the system is noted to consist of three computers, Job Shop System-1 (JSS-1), Job Shop System-2 (JSS-2), and the Real-Time Simulation System (RTSS). Computers JSS-1 and JSS-2 will be used mainly for data processing and nonreal-time applications. All three computers will share the extended core memory. The size of the core memories is indicated in each block, 512K, 65K, 65K, and 65K. The approximate power of each computer based on the power of the 7094II is shown. For example, the JSS-1 is 1.5 times (1.5X) more powerful than the 7094. Connected to the computer complex will be the auxiliary equipment shown in the six blocks in the lower part of the figure. Of major interest are the simulation application consoles (SAC) and the conversion equipment. As many as six SAC's will be available for real-time simulation (RTS) studies and as many as six RTS problems, depending on the amount of CPU time and conversion equipment used by each, can be operating simultaneously in addition to jobs being processed in the nonreal-time categories. This will be possible due to the multiprogram capability of the computing system. Because of the extensive software which will be available (including an RTS monitor), it will not be necessary for the problem engineer to be concerned about the location of his program inside the computing system, but he needs only to communicate with the SAC. It will be possible, as on the analog, to do on-line checkout and program changes as well as actually to conduct the experiment. This will provide a realistic man-simulator interface relationship with nearly zero turn-around time. The conversion-equipment block will be connected to various simulators or to any piece of analog equipment. This discussion, of course, has provided a brief look at the future computer complex with the intent of indicating the direction that Langley anticipates in simulation.

Again, the purpose of this presentation has been to acquaint other computer users with Langley's approach to real-time simulation problems. Detailed aspects of the problems discussed will be contained in papers being prepared by various members of our staff for NASA publication.

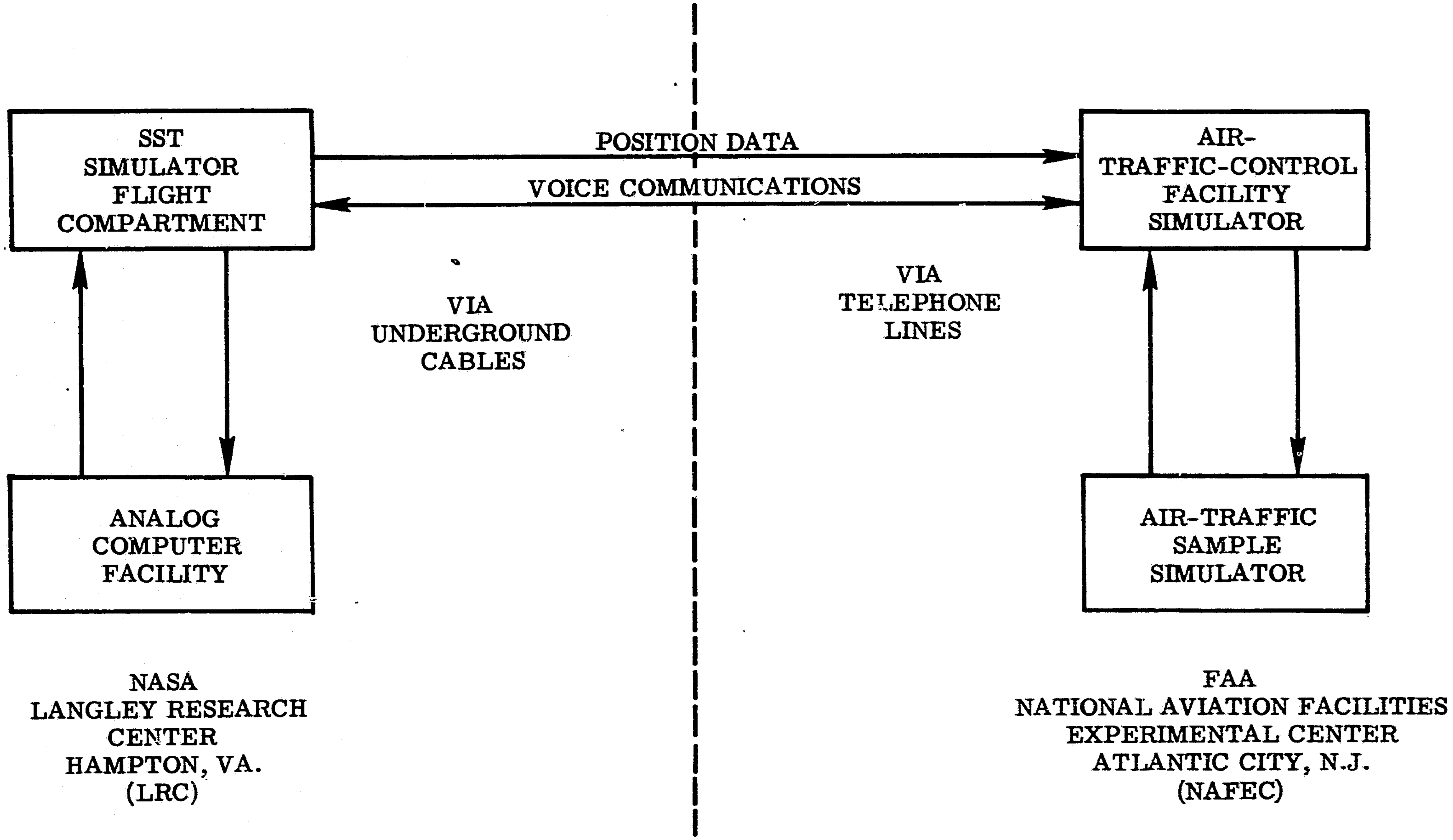

Figure 1.- Facilities involved in the SST ATC study.

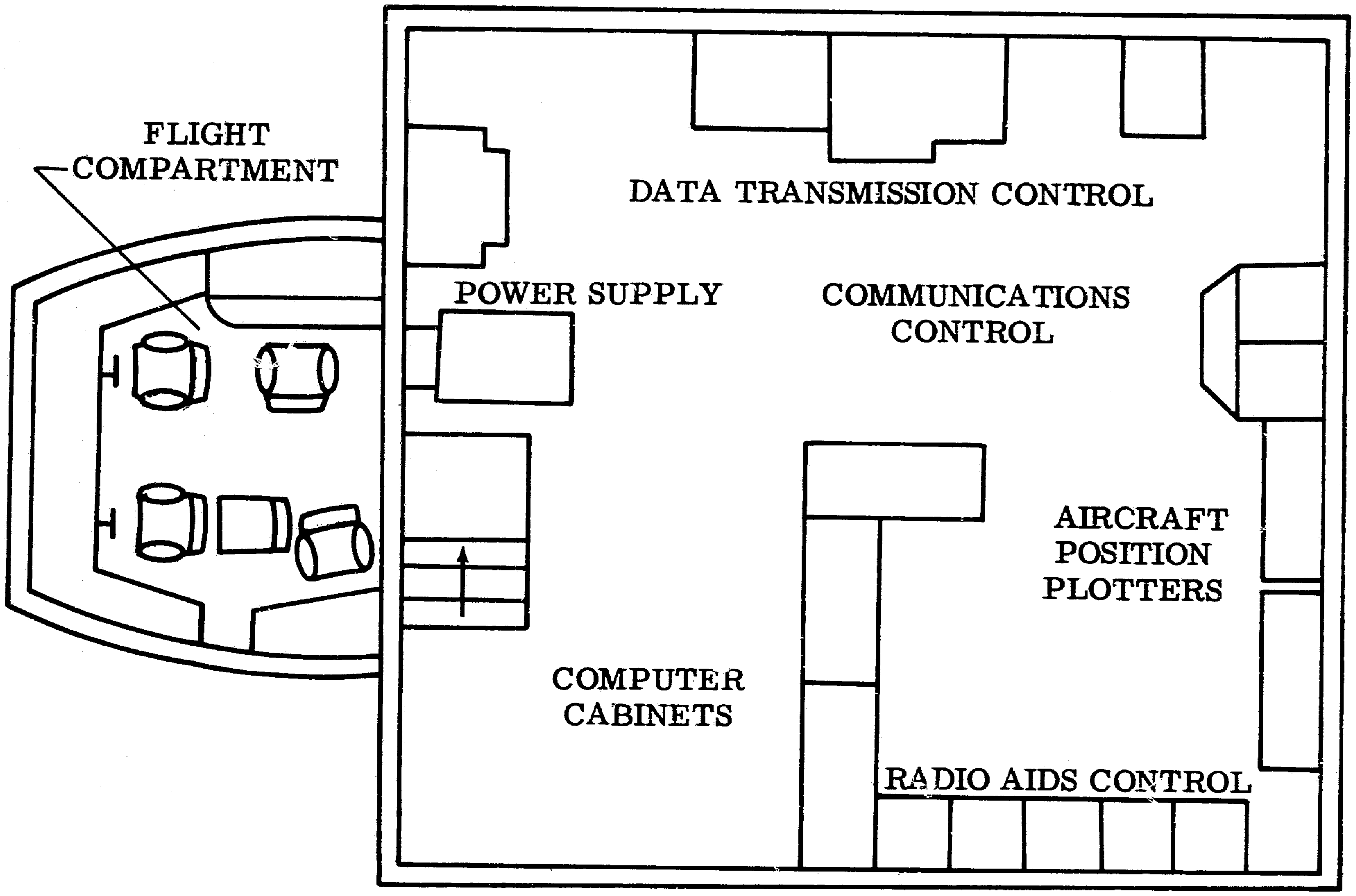

Figure 2.- Langley SST simulator and control room.

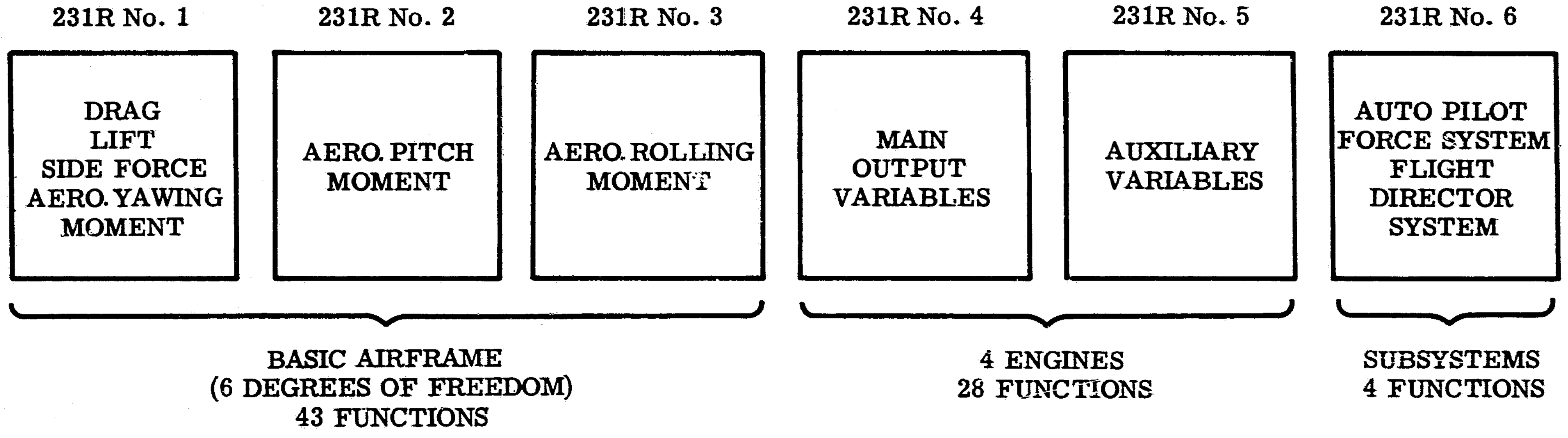

Figure 3.- Equipment requirements and organization.

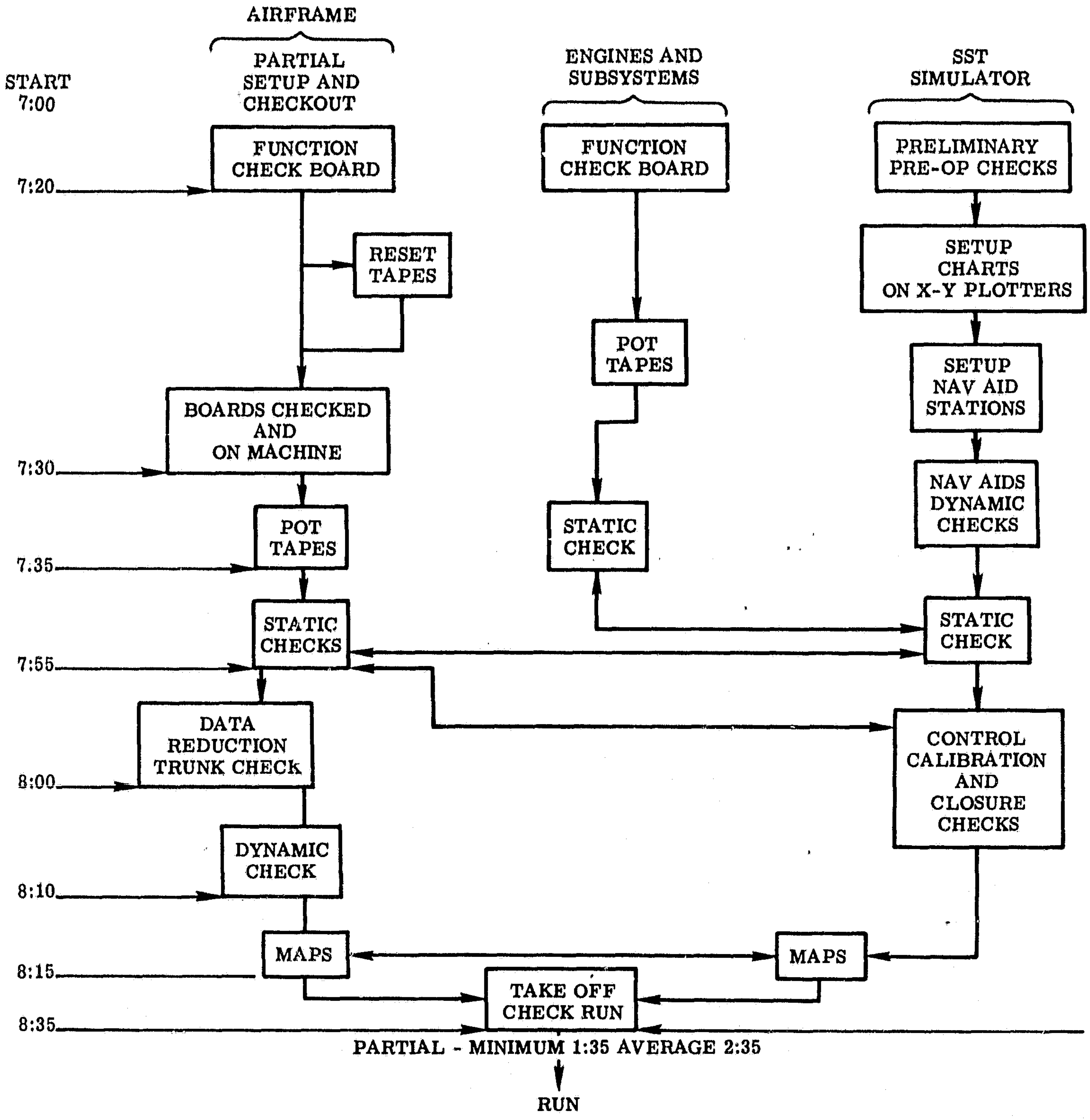

Figure 4.- Set-up and check-out sequence.

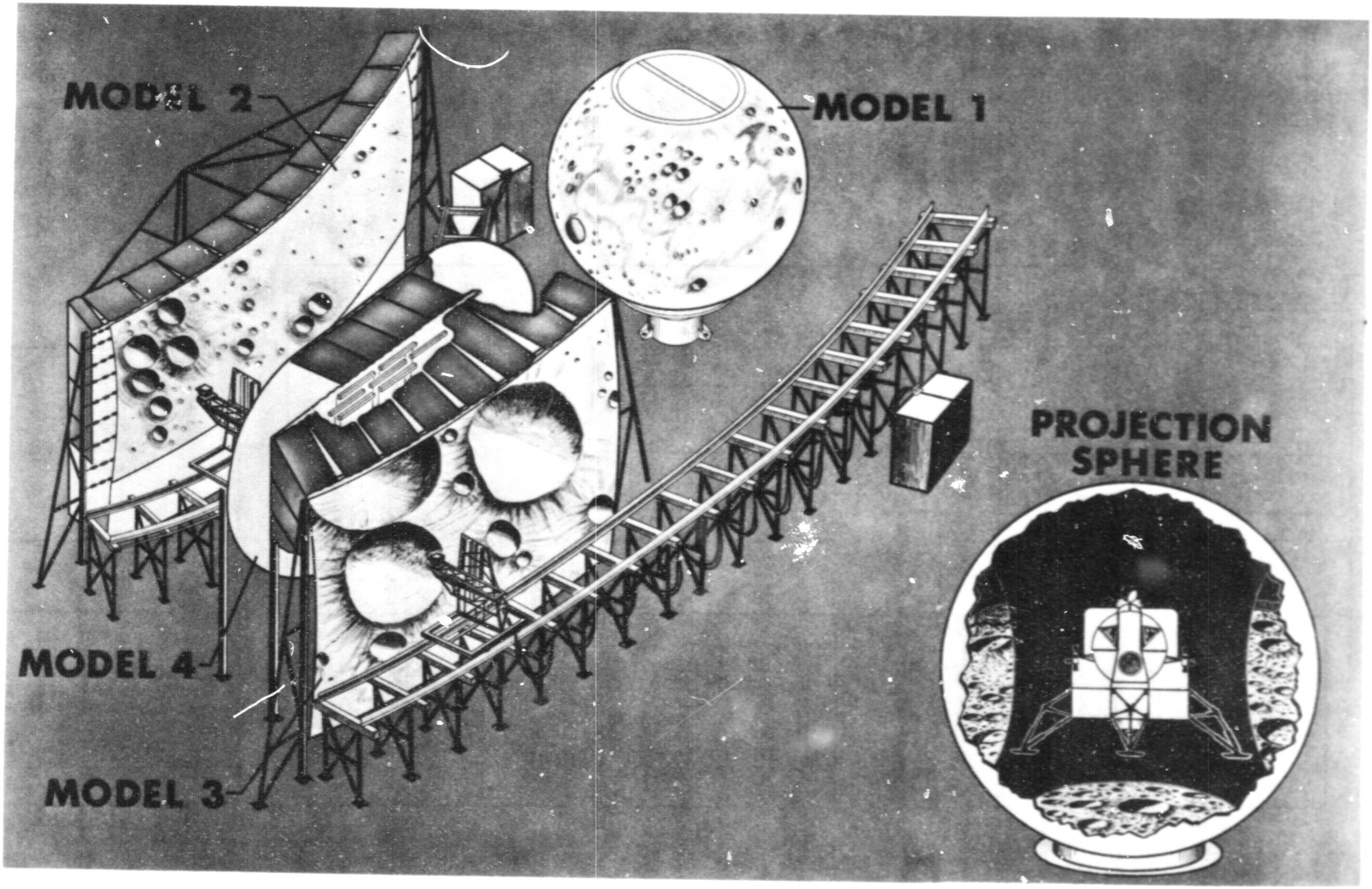

Figure 5.- Lunar orbit landing approach simulator.

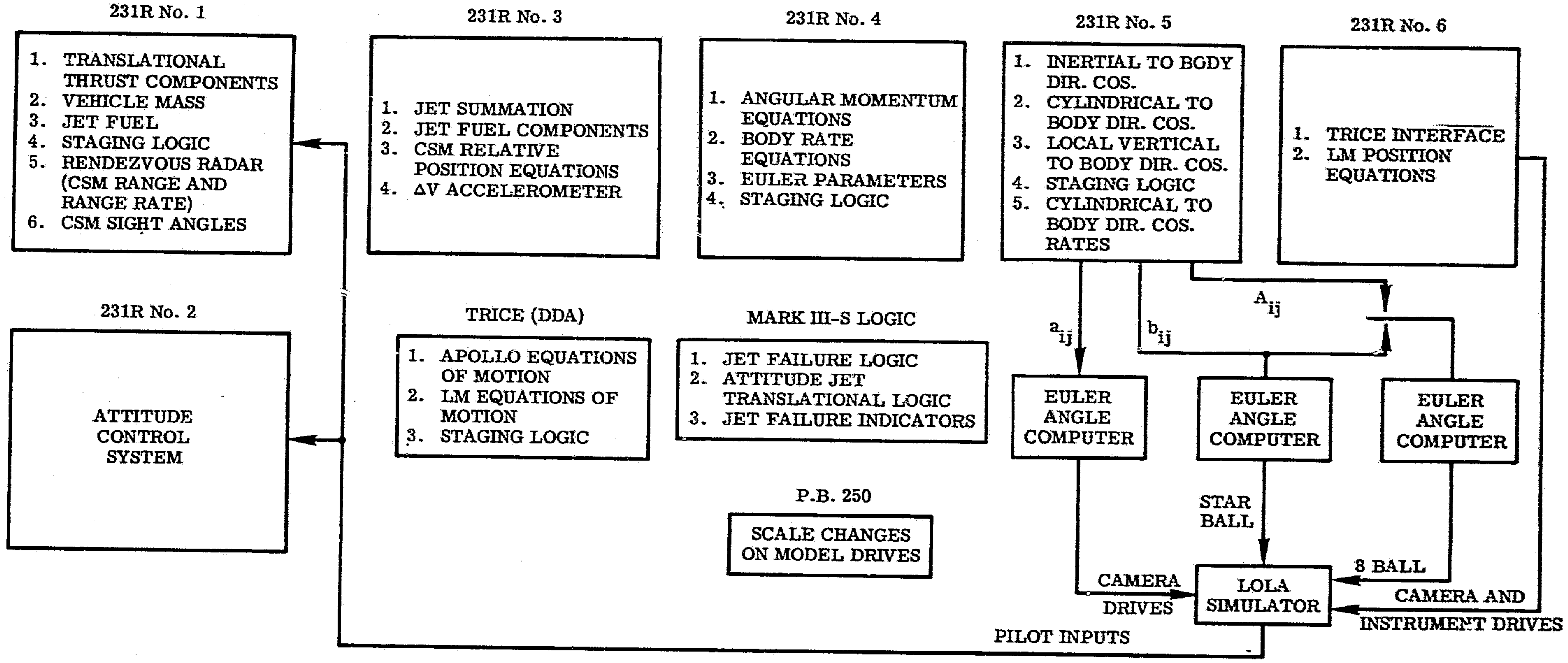

Figure 6.- Equation distribution on computer complex for LOLA studies.

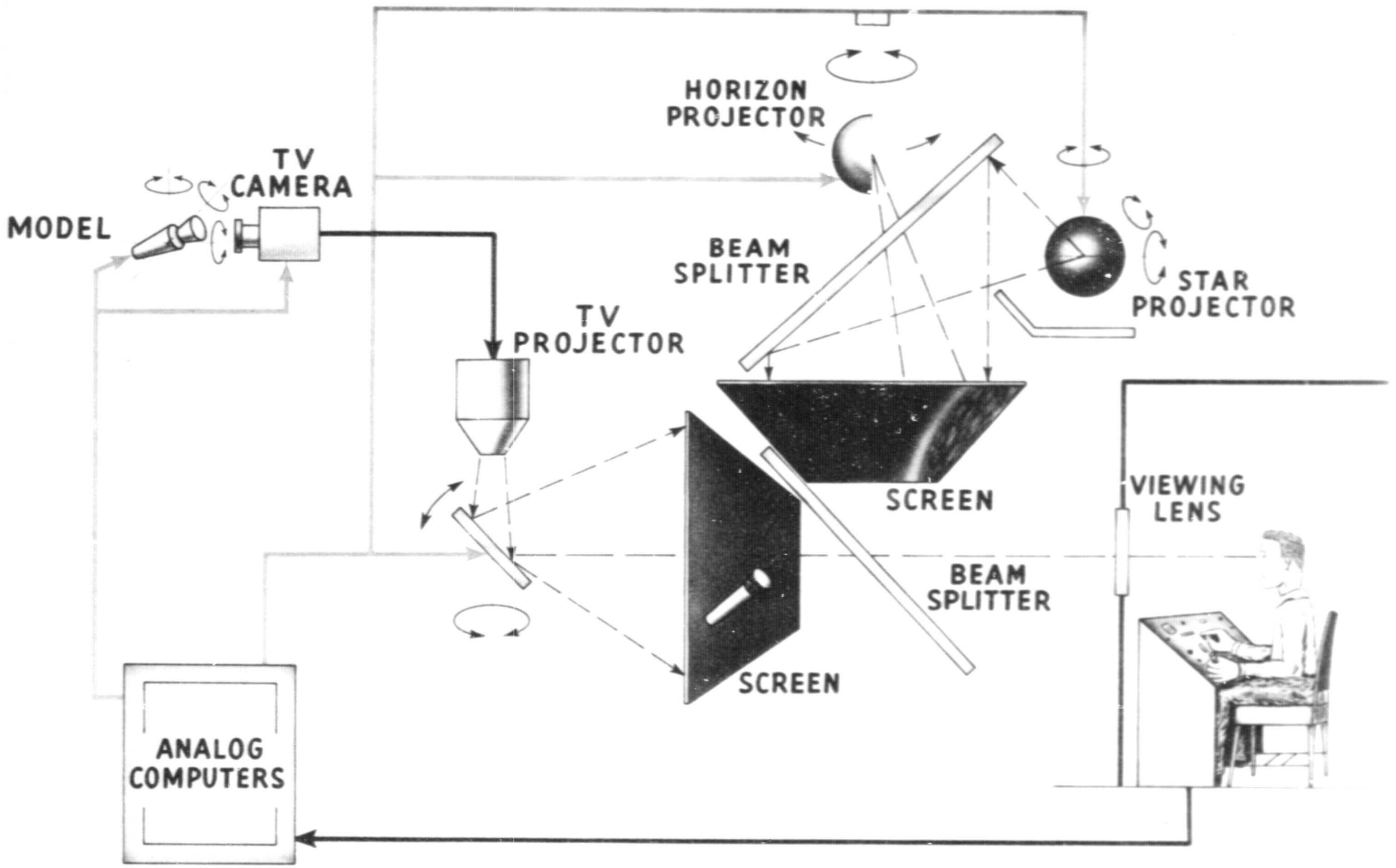

Figure 7.- Visual docking simulator.

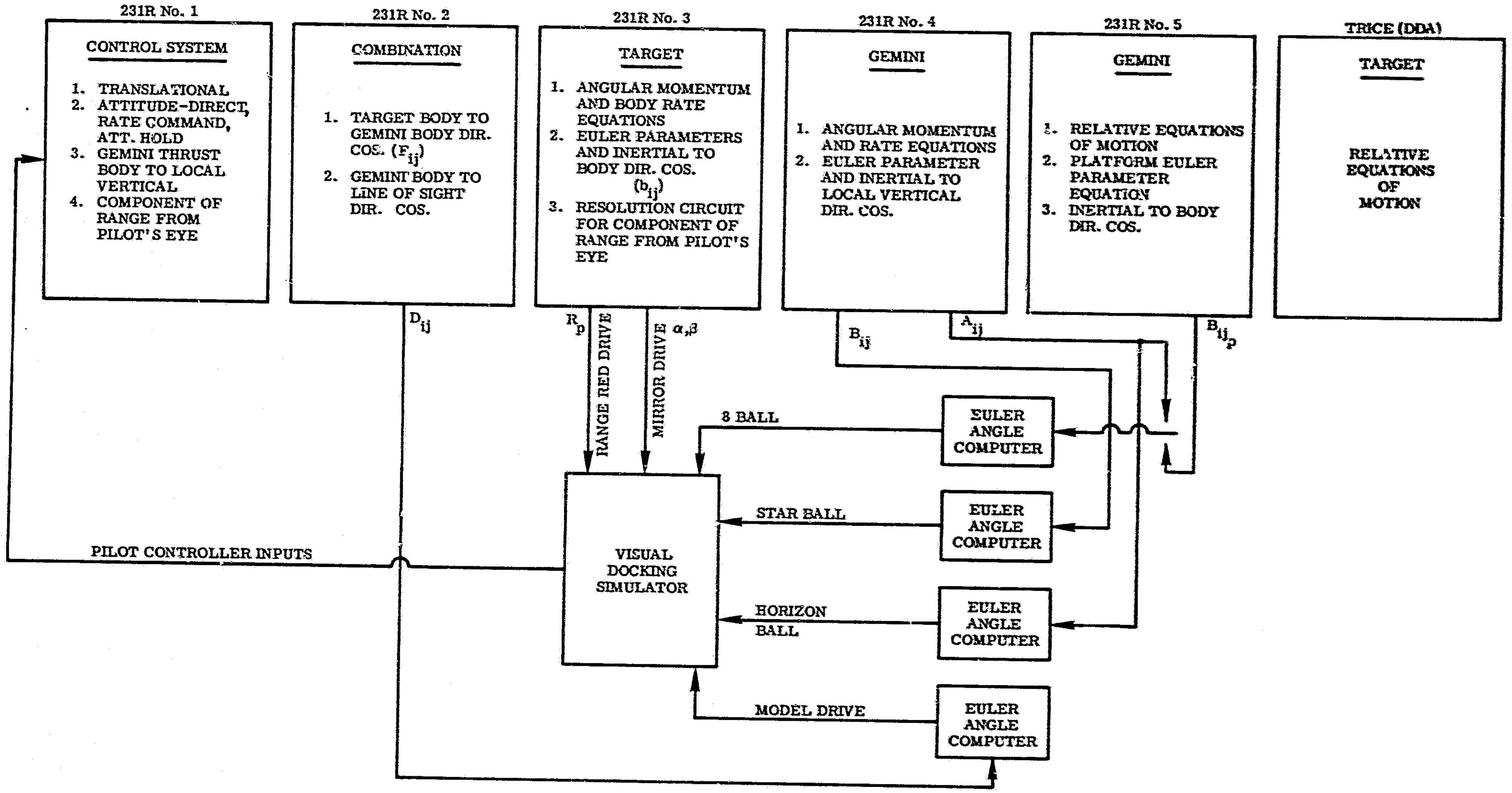

Figure 8.- Equation distribution on the computer complex.

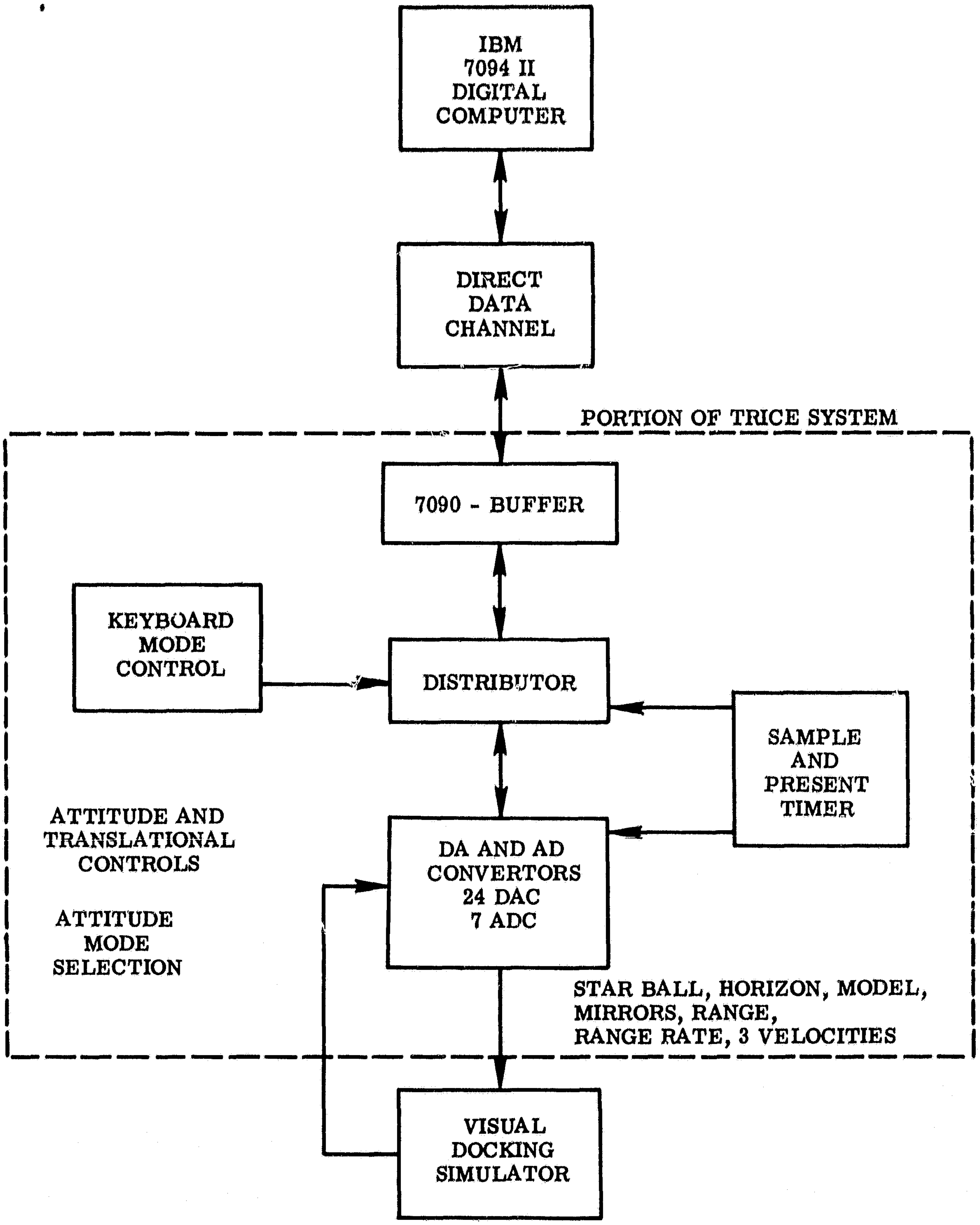

Figure 9.- Equipment utilized for digital simulation of Gemini-Agena station-keeping studies.

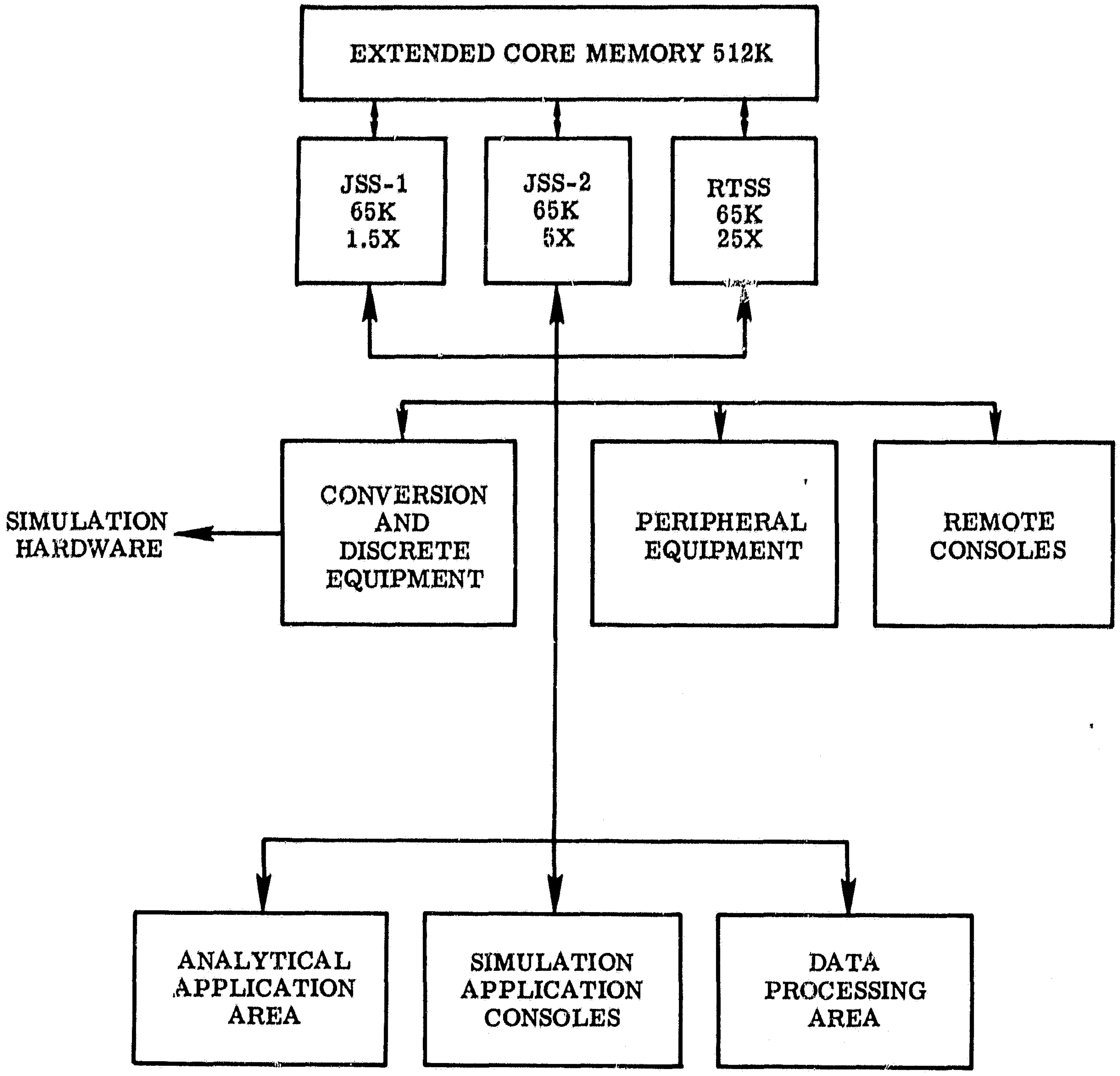

Figure 10.- Block diagram of Langley Research Center's future computing complex.

NASA-Langley, 1966