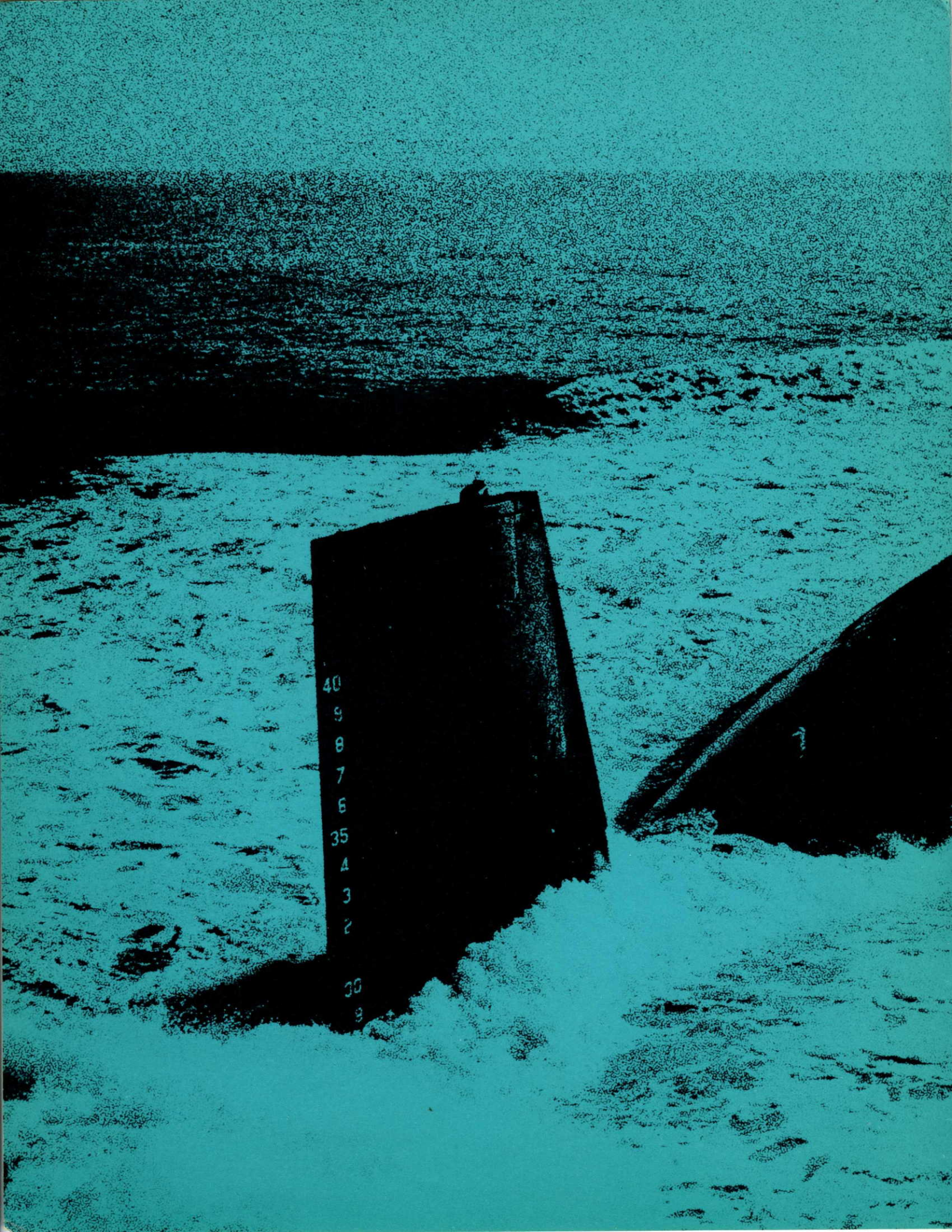
Hybrid Computing At Lockheed

CONTROL DATA
CORPORATION

APPLICATION REPORT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HYBRID COMPUTING AT LOCKHEED

When the advanced Poseidon missile goes into service aboard the U. S. Navy's Fleet Ballistic Missile submarines, another successful chapter will have been written in the history of hybrid computing.

In the hybrid computing laboratory at Lockheed Missiles and Space Company, Sunnyvale, California, a powerful digital/analog computer complex is being used to test the guidance and control mechanisms of the Poseidon missile. With a CONTROL DATA® 6400 Computer at the heart of the system, simulation of actual operating conditions is performed mathematically, data from test laboratories is collected and analyzed, and various alternatives are explored. Thus, Lockheed engineers are able to achieve an optimum design at a fraction of the time and cost that would be consumed by multiple live test-firings.

The installation at Lockheed is one of the most versatile hybrid systems in existence. It gives Lockheed personnel the ability to perform both man-in-the-loop and closed-loop simulations at whatever speeds are desired. It provides designers and analysts with an unprecedented degree of control over testing and simulation. And, through an adaptable hardware/software structure, it is capable of modification to accommodate new hybrid – and digital – tasks.

THE SYSTEM

Hybrid computation at Lockheed began in 1964 with a CONTROL DATA® 3200 computer system and two analog computers. Successful performance on the Polaris Missile System contract led to Lockheed's involvement in refitting FBM submarines with Poseidon missiles.

A new, more powerful computer system was needed to handle new and extremely complex calculations. The choice for the digital portion of the hybrid computer was the CONTROL DATA 6400.

Among the factors leading to the choice of the 6400 were its great computational speed, multiprocessing organization, extensive input/output capability, and the adaptability of its standard software. The Lockheed system contains 32K words of core memory, plus these standard Control Data peripherals: two 604 Magnetic Tape Units; one 6603 Disk Storage Drive; one 501 Line Printer; one 415 Card Punch; and one 405 Card Reader. (See Figure 1). Four Comcor Ci5000 analog computers are connected to the 6400 through two interface units providing 160 channels of analog-to-digital conversion capability.

Five CONTROL DATA® 211 Entry/Display units provide on-line communication between the user and his problem. A 211 is located at each of the four analog computers; the fifth 211 is associated with the 6400 itself. Completing the equipment array are twelve X-Y plotters and twelve 8-channel strip chart recorders.

OPERATION

Figure 2 illustrates the laboratory configuration at Lockheed. The system provides for three stages of hybrid computation.

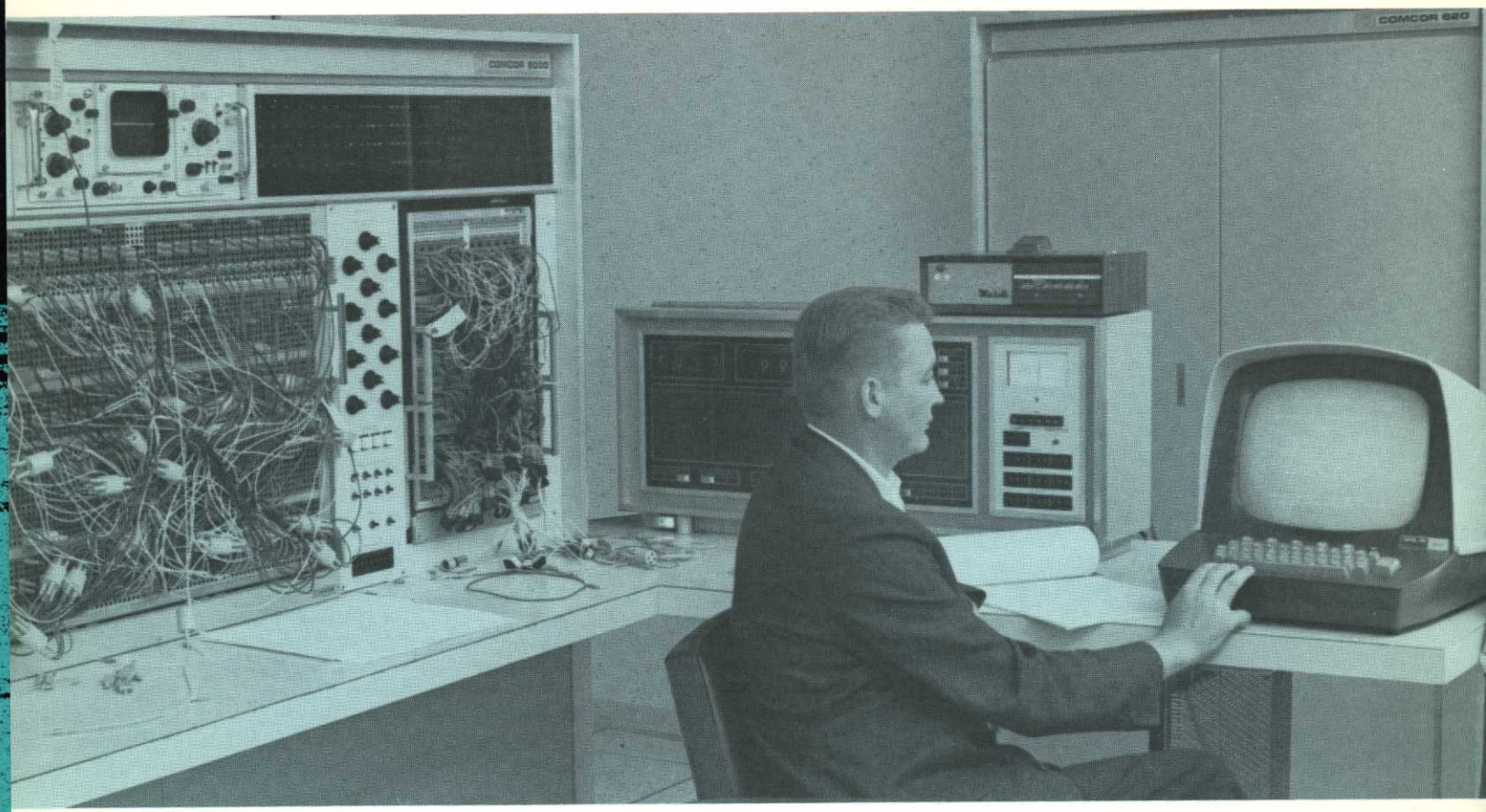
1. The most basic application makes use of the computer system alone to simulate missile flight. For example, the 6400 calculates the simulated position of the missile in space, providing the logic for decision-making, high-precision mathematical calculations, and storage of variables and results. The analog portion simulates on-board mechanisms and missile attitude, using high-speed parallel-processing to solve the time-dependent differential equations.

2. The second level of computation brings into play the actual Poseidon hardware and other mechanisms located in the various adjacent laboratories. Activation of this equipment, which is connected to the hybrid computer system, provides a basis for comparing simulated performance with pre-programmed conditions.

The Guidance Laboratory, for example, is equipped with one 3-axis flight table to which are attached actual missile hardware such as gyros and accelerometers. Missile data generated by these mechanisms (speed, location, etc.) is sent to the analog computer, where the desired conditions have been programmed. Data is also sent to a smaller digital guidance computer, which in turn presents commands to the 6400. The 6400 notes any deviations and outputs corrective signals to the hardware devices responsible for making adjustments in the flight. All decision-making and bookkeeping jobs are performed by the 6400, whose ten peripheral processors easily handle all system overhead (signal conversion, interrupt processing, etc.), freeing the central processor for vital calculating tasks.

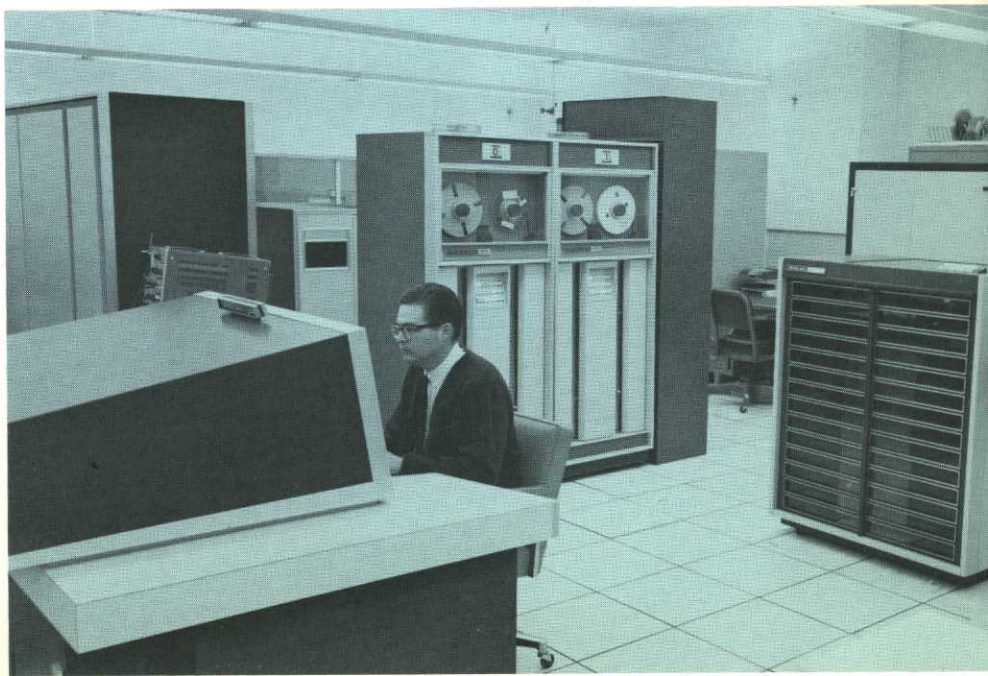
In the Hydraulic Actuation Laboratory, aerodynamic loads are simulated by hydraulic, pneumatic, and electrical means on the after section of the missile. Test data is sent to the hybrid computer system where it is analyzed and adjustments are made.

3. The third and final stage of Poseidon testing will take place at Lockheed's Santa Cruz test base, 60 miles from the computer center. Communication between



One of the four analog computers with associated CDC® Entry / Display.

The CDC® 6400 Computer, center of the Lockheed hybrid system.



the two sites will be via closed-loop microwave. The Poseidon will undergo tied-down, static firing tests, with the hybrid computer system again analyzing test data. The system will simulate the actual flight conditions so that in case of failure the problem can be quickly isolated and corrected.

On-Line Control

One of the outstanding features of the hybrid system at Lockheed is the degree of hands-on control that the analyst can exercise over both the digital and analog operations. When seated at the analog computer console, the analyst also has at his fingertips a CONTROL DATA 211 Entry/Display unit. Through this device he may interact with his program under real-time conditions. He may:

- view program results which have been converted to digital form.
- enter and modify variables and parameters.
- proceed through a problem at his own rate of speed; halt his program to analyze immediate results, while 6400 core memory is released for other jobs.
- enter programs for checkout and preventive maintenance of the digital, analog, and interface elements of the system.
- perform on-line debugging of FORTRAN programs.
- call up a historical file containing all information pertinent to his particular job.

Manipulating Time

A distinct advantage of the Lockheed hybrid system is its ability to "scale" time according to the demands of a particular problem. Computer simulations may be conducted in real-time, faster than real-time, or slower. For example, an analog simulation may be slowed to permit extended study of data. Time may also be condensed for long-running programs without sacrificing accuracy. However, when actual flight hardware is incorporated in the simulation, the entire computer must operate in real-time, (i.e. there must be a one-to-one correspondence to the "clock on the wall.")

SOFTWARE

As in any successful computer operation, the computer hardware in Lockheed's hybrid laboratory is controlled by a powerful, versatile set of programs. The software utilizes Control Data's 6000 Series "Scope" operating system, modified for real-time hybrid computing.

Known as CLASH, the Lockheed System allows simultaneous processing of two hybrid problems, while standard digital jobs are run as background tasks. The system contains a Main Monitor and a Hybrid Monitor. Under the Main Monitor are run standard jobs such as FORTRAN programs, utility routines, and diagnostics, while the Hybrid Monitor controls the real-time simulation. The Hybrid Monitor (to which the Main Monitor is subservient) responds to interrupts – a total of 48 – and controls the execution of jobs on a priority-determined basis. The Exchange Jump instruction in the 6400 computer provides a fast, efficient method of switching from one job to another.

Other elements of the software system include: Special calculation packages; hybrid utility routines; a "Dayfile" which keeps a running record of job progress to be referenced at will; and a special diagnostic routine that allows daily preventive maintenance of the entire hybrid computer (analog, interface, and digital) to be completed in two hours – a short time for such a large system. Manual checkout of the analog and interface would take more than ten hours per day without the 6400 – an impossible situation.

The capabilities of 6400 hardware and software will also permit batch-processing jobs to be run without endangering or impeding the hybrid computation.

A GIANT STEP FORWARD

The Lockheed hybrid computer system amplifies human capabilities to new heights of effectiveness. The reasons can be stated simply:

- Relationship between man and machine is made closer than ever before through the use of CDC® display devices. Problem setup, checkout, and running can be controlled every step of the way.
- The software system permits the analog user (whose digital experience may be limited) to utilize his full complement of analog techniques and experience while adding new digital techniques.
- The speed and multiprocessing capability of the 6400 permits fast throughput of problems whose requirements may differ widely.
- The 6400 can readily interface with a great number of peripheral devices, including analog equipment of various makes, so that expansion and modification can be accomplished with little difficulty.

Simulation and other forms of hybrid computing are taking on an ever-increasing importance in many areas – space and defense, scientific laboratories, industry, and education. The system at Lockheed is in the forefront of the hybrid movement, solving problems that would be difficult or impossible to handle by any other means.

FIGURE 1

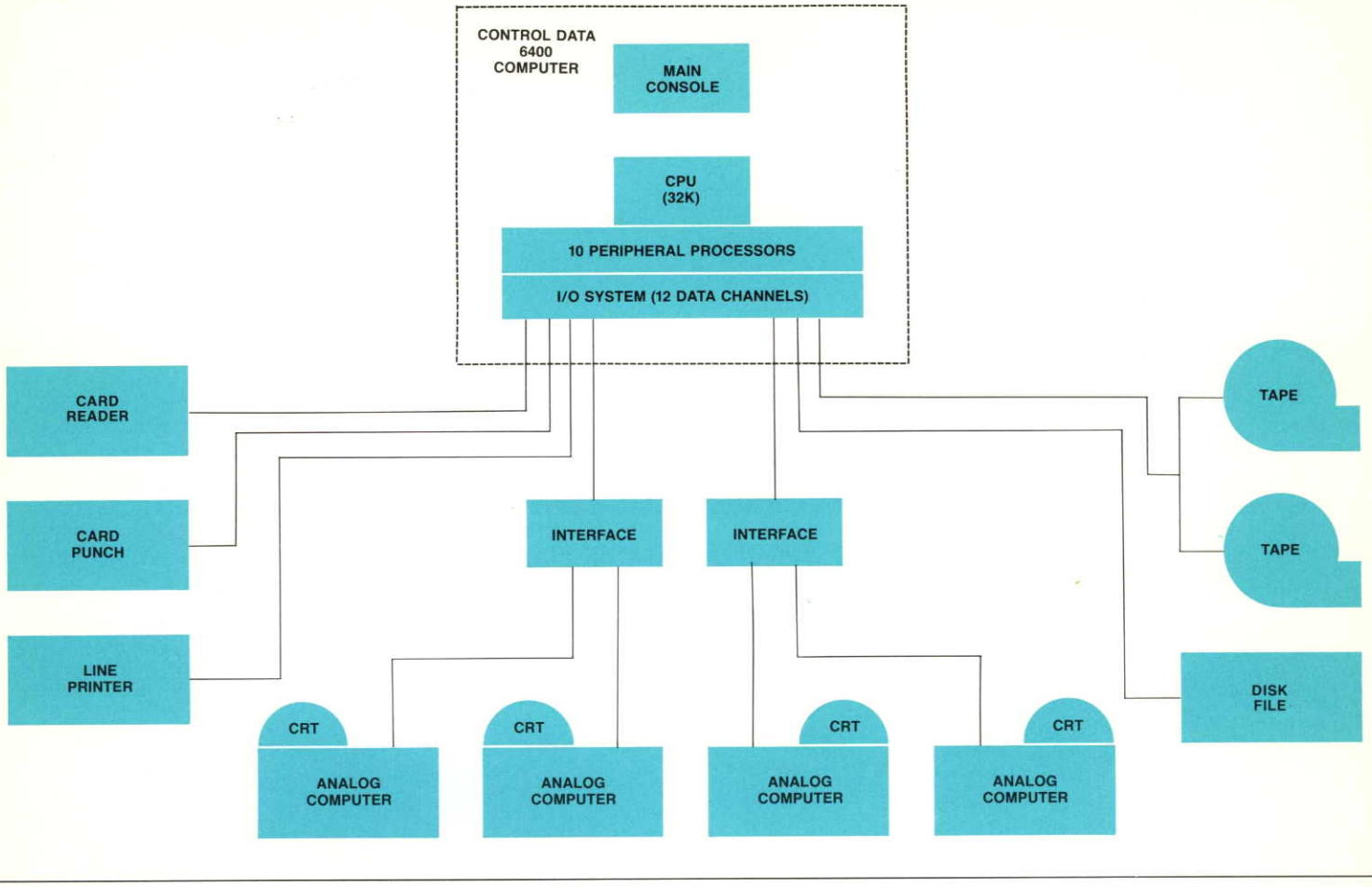
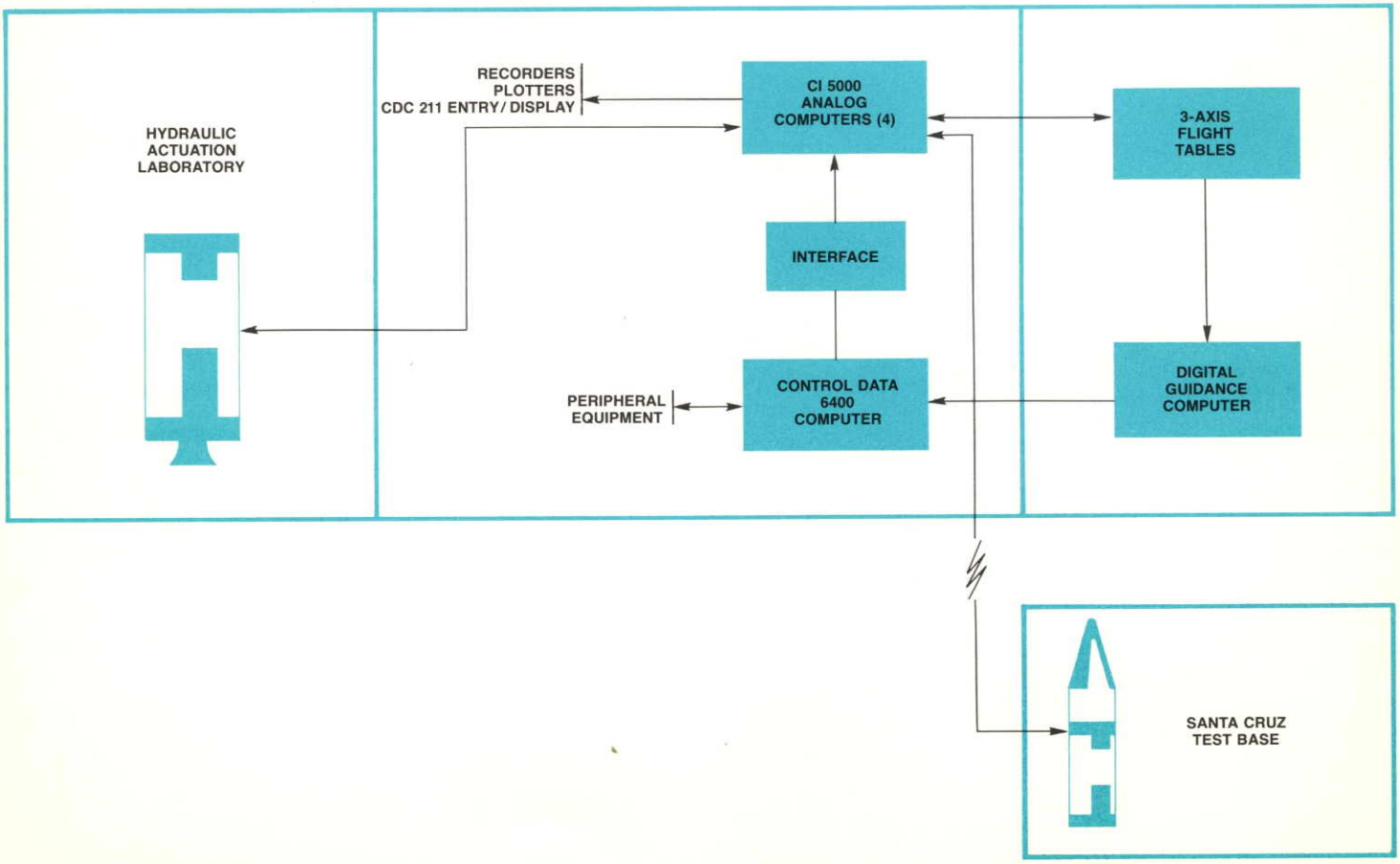


FIGURE 2



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