The RCA 110A computer—ground checkout and launch control of Saturn

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The RCA 110A Saturn Ground Computer System currently being used by NASA for integrated checkout and launch control of the Saturn-Apollo manned lunar mission was originally conceived and designed for industrial process control.* To meet the early NASA requirement, the original system progressed through a series of major design changes. These changes provided larger memory storage, new discrete input/output capability, more data channels, and increased complement of peripheral equipment.

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received the BSEE from the University of Southern California in 1958. He has completed graduate studies in digital computers at the University of California at Los Angeles and finished a program through the seminar phase on advanced management techniques. Mr. Freed joined RCA in 1958 as a member of the Missile and Surface Radar Division Design Engineering Staff. He participated in a wide variety of design and development programs, including design of solid-state circuits for portable mortar-detection equipment, airborne communication receivers, BMEWS display consoles, analog switching equipment and a power amplifier for radars at the five megawatt power level. In 1961 he was assigned to Electromagnetic and Aviation Systems Division Project Engineerig Staff. His experience includes the project responsibility on three systems of electronic display equipment for the USAF. During the period of 1962-1964 he was Project Engineer on the Ranger ground display equipment and Program Manager for three general-purpose digital computers now in use as the BMEWS checkout data processors. From 1964 through 1967, Mr. Freed was assigned to the Project Engineering Staff for the design, development, and production of the Saturn Ground Computer System, its peripheral equipments, and the Saturn 1-B Displays. For the past two years, Mr. Freed has held the assignment as Manager, Saturn Program. This effort involves five major NASA contracts and responsibilities that encompass the total RCA support provided to NASA. Mr. Freed is a member of Eta Kappa Nu, the IEEE, and is a licensed amateur radio operator.

SINCE THE SATURN'S PROGRAM'S INCEPTION, RCA/EASD has delivered to NASA a total of 30 computer systems, and provided a continuum of Engineering and Logistics support through the present time. The precepts of the original engineering thoughts concerning checkout and launch of a complex vehicle may be summed up through the following goals for an automatic checkout system:

- Provide for processing large numbers of parameters;
- Reduce the man/machine interface;
- Remain flexible so as to accommodate change;
- Provide a high degree of reliability.

To reach these goals, NASA surveyed available equipment in the early 1960's and chose the RCA 110 System. This paper discusses the seventeen Saturn V Ground Computer Systems delivered to NASA under contract NAS8-13007.

General Characteristics

To meet the goals previously outlined, the design of the original RCA 110 was realigned to meet the requirements for increased checkout capacity with corresponding emphasis on speed and flexibility. The result was the RCA 110A Saturn Ground Computer System which provides a number of significant capabilities:

- Input/output processing simultaneously,
- General purpose data processing and reduction,
- Ability of two RCA 110A's to work in tandem via data link,
- General purpose computing,
- Real-time control monitoring and testing of multiple digital and analog systems, and
- Versatile peripheral equipments.

The RCA 110A System consists of the following complement of cabinets:

- Main frame
- Power supply
- Memory
- Data link
- Discretes
- Switching
- Peripherals

The peripherals consist of a line printer, card reader, card punch and magnetic tape stations. Fig. 1 illustrates a typical computer system configuration; Fig. 2 shows the functional interconnections of the various equipment cabinets. Note that Fig. 1 also shows the display equipment; while not considered as part of the Saturn V system, RCA/EASD did deliver a number of S1B Display Systems under contract to NASA. These systems were used during the launch of Saturn S1B vehicles from Complex 34 and 37 and Kennedy Space Center.

Speed of operation, while not outstanding by today's technology standards, is considered acceptable for this application. The clock rate is 9.36 kHz; memory cycle is 9.7 μs; word time, including access, is 28.9 μs; and the add time is 57.7 μs. Operationally, the system has sufficient speed to perform at the upper limit required by the test condition frequency in real time. Program speed may be considered as enhanced by the system's capability at the input/output level. A number of buffered input/output data channels (IODC) permit simultaneous operation of I/O and general calculations or processing.

The priority interrupt system was retained from the original industrial processor. Thus, a program may be interrupted by one of a higher priority with all the register contents of the lower priority program stored until the higher level program has been

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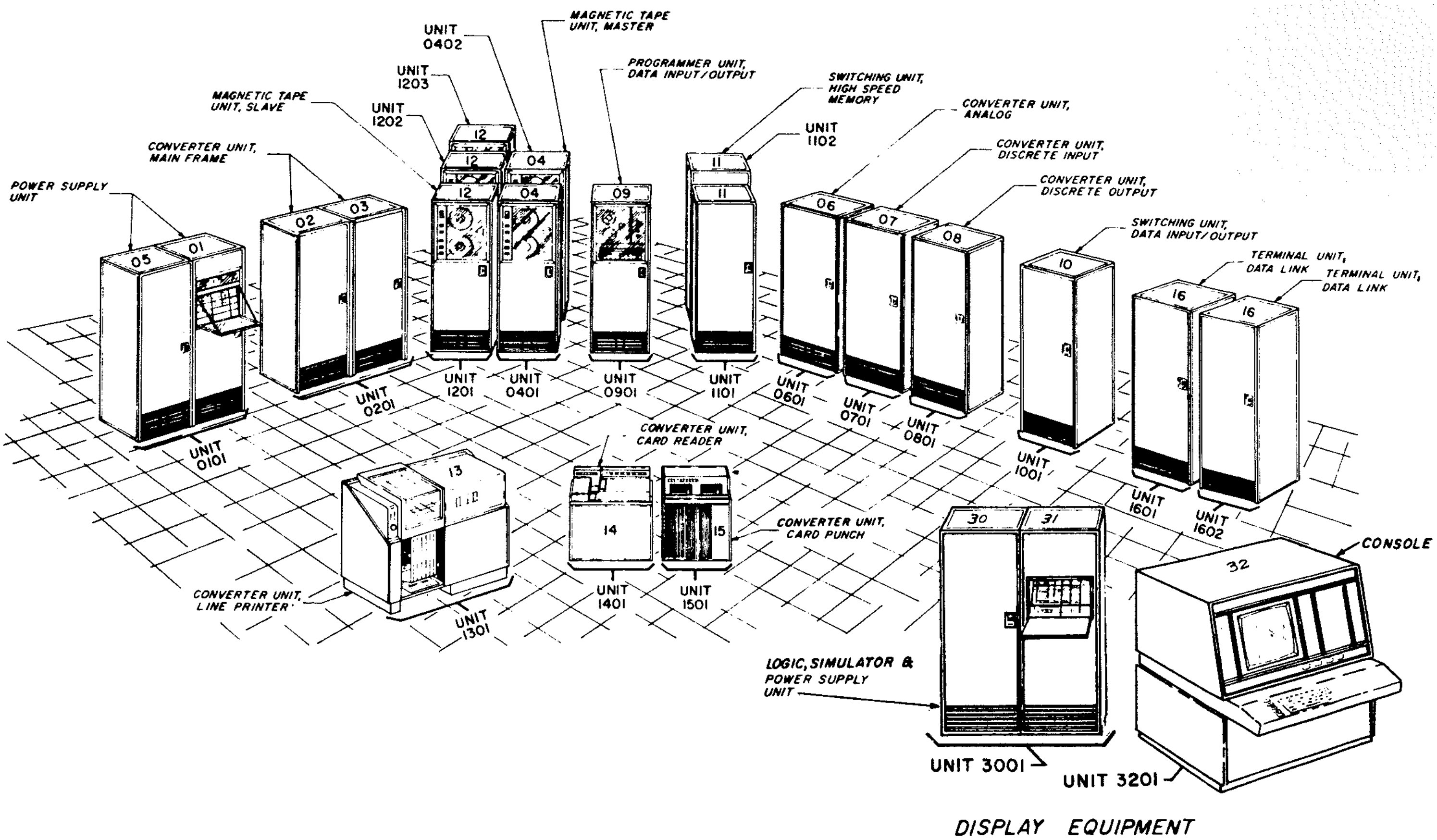

Fig. 1—The RCA-110A computer system configuration, including display equipment.

serviced. In addition to the simple form of interrupt described above, multiple-priority interrupts may cause the computer to sequence through several priority levels prior to returning to the program originally interrupted. This feature will permit incomplete programs to be finished during available time increments. This concept permits the RCA 110A to monitor overall vehicle status while servicing requests from test operators/conductors. It may be noted that in periods of slack time during the checkout of a vehicle, the computer system will run those programs assigned the lowest priority levels. These are primarily self-check routines.

The storage capacity of the RCA 110A System complements the system requirements; 32 k words of high-speed magnetic-core storage with 32 k words on drum plus up to 20 magnetic tape stations are provided. The 24-bit word length provides a precision to better than one part in eight million and the validity of data transfer is verified by an additional parity bit. During a parity alarm, the address of the executed instruction is stored to enable use of automatic software recovery routines.

Multiple computer operation is provided via a full duplex high-speed data link. This system, independent of the processor, performs all synchronization, formatting, and error detection/correction. The technique of retransmission is used for correcting errors without interruption of the word sequence. The detection of errors is accomplished through the following:

Horizontal and vertical parity,
Retransmission count,
Parity check on data channel transfer, and
Incoming modulation check.

It should be noted that the undetected error rate is 2.8×10^{-14} words/word for a 10^{-4} single-bit error rate.

Fail-safe operation in terms of local power failure has been incorporated into the system design. Upon detecting an interruption of the power, the contents of all registers required in order to reinitialize at the proper program point are automatically stored in core memory. In addition, the computer's power system is down sequenced in the proper order. These actions permit the computer to resume operation at the point of interruption once power has been restored.

System Considerations

RCA 110A computer system

The RCA 110A Saturn Ground Computer primarily supports the Saturn V manned lunar missions from Complex 39 as shown in Figs. 3 and 4. Computer systems are located in the Launch Control Center (LCC) and in each Launch Umbilical Tower (LUT). These systems provide central processing with communication to other equipment through Input/Output Data Channels (IODC); an IODC is provided to route each general class of signal (discrete, analog, command, etc.) to the central processor.

Discretes (28-volt commands) may be processed in this manner at operational speeds of up to 15,000 signals/second. The discrete IODC is capable of

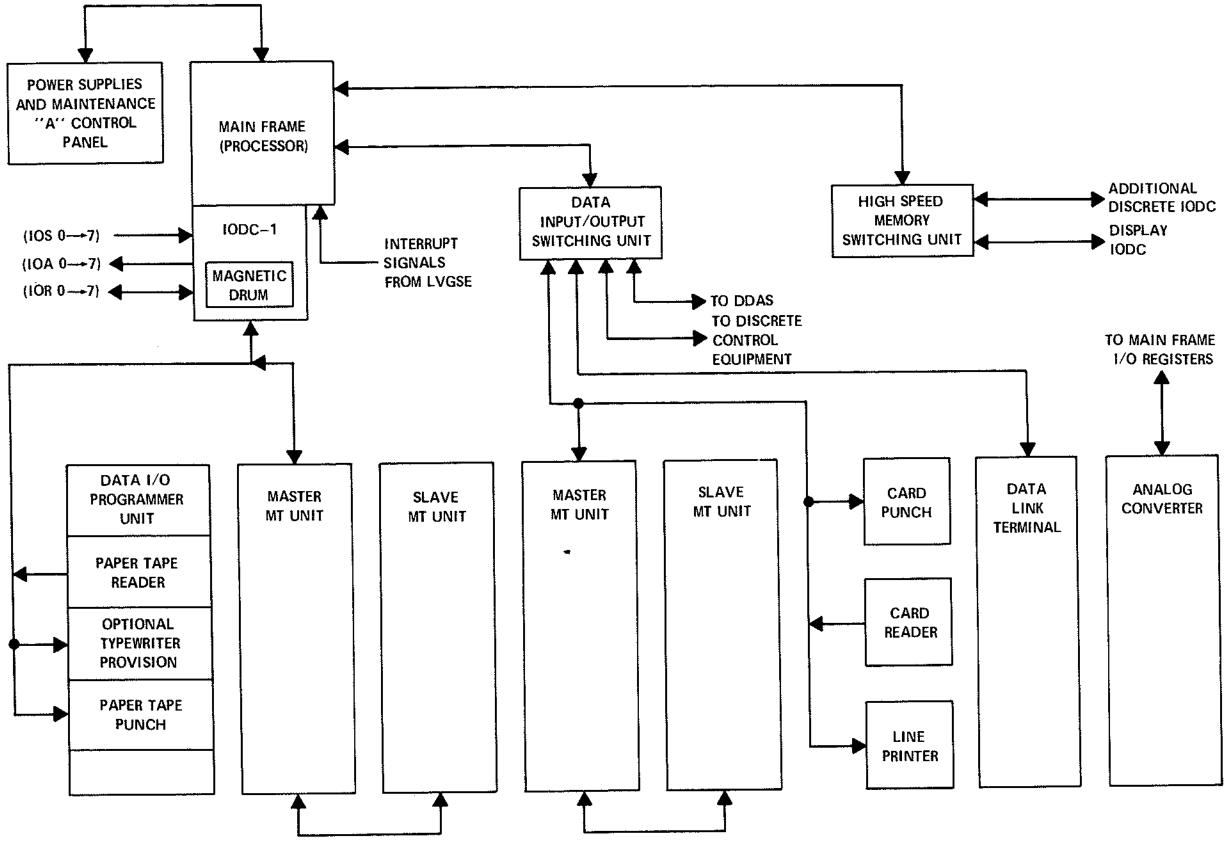

Fig. 2—The RCA-110A computer equipment interconnection.

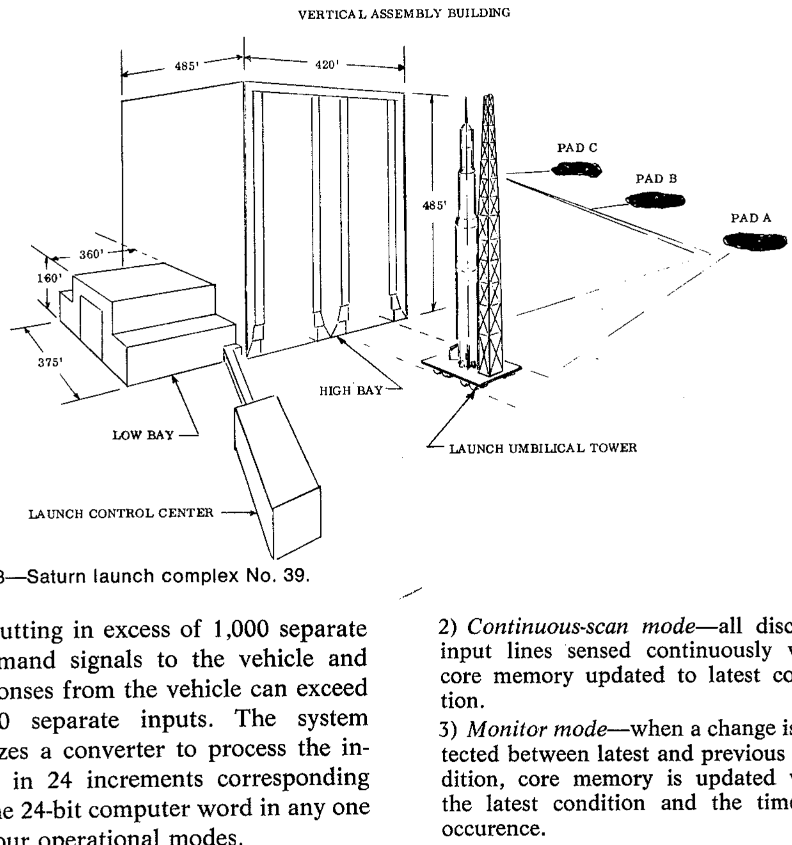

Fig. 3—Saturn launch complex No. 39.

outputting in excess of 1,000 separate command signals to the vehicle and responses from the vehicle can exceed 3,000 separate inputs. The system utilizes a converter to process the inputs in 24 increments corresponding to the 24-bit computer word in any one of four operational modes.

1) *Single-scan mode*—all discrete input lines sensed once and condition stored in core memory.

2) *Continuous-scan mode*—all discrete input lines sensed continuously with core memory updated to latest condition.

3) *Monitor mode*—when a change is detected between latest and previous condition, core memory is updated with the latest condition and the time of occurence.

4) *Selective monitor mode*—same as monitor mode with the exception that only preselected groups may be monitored. If a change occurs in a preselected group, a priority interrupt may be given the computer system.

The IODC's are capable of providing data transfers that are not under direct program control. This may be accomplished in parallel with normal computer operations. The complement of IODC's available is summarized below:

1) IODC *1*—control I/O operations of drum memory and the Ampex magnetic tape stations. This IODC is also capable of operating with an output typewriter, paper tape reader, paper-tape punch, and the RCA S1B display system.

2) *Magnetic tape* IODC—controls I/O operations of the line printer, card reader, card punch plus additional magnetic tape stations and a communications data set.

3) *Data link* IODC—controls data transfers between RCA 110A systems.

4) DDAS IODC—controls I/O operations between the digital data acquisition system and the computer.

5) *Discrete* IODC—controls I/O activity of discrete signal converters.

6) *Display* IODC—controls I/O operations between the computer and the Saturn V Display System.

Input/output registers (IOR's), input/output address lines (IOA's), and input/output sense lines (IOS's) provide alternate paths for communication be-

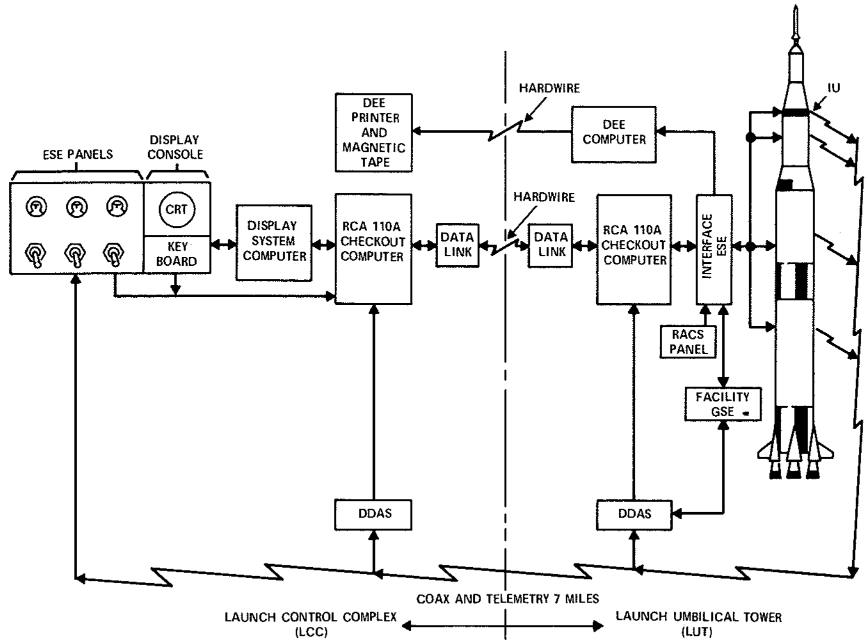

Fig. 4—Equipment interconnection for prelaunch checkout and launch control.

tween the computer and external devices. The IOR's are standard 24-bit registers that provide additional data transfer paths to remote computers and telemetry systems. The IOA's are generally used to set up command signals to external devices, while IOS's will sense the response of these devices. Contrary to the IODC concept, IOR's, IOA's, *and* IOS's are under the direct control of the program and number as follows:

1) IOR—8 registers.
2) IOA and IOS—192 lines.

Fig. 5 illustrates and summarizes the RCA 110A input/output capabilities. Additionally, the system provides other features such as D/A and A/D conversion at a rate of 2,000 signals/second, real-time clock registers to permit the reading of countdown or time inputs, and a capability for data communication with the digital computer on-board the launch vehicle.

Automatic saturn ground checkout

The Ground Support Equipment (GSE) under computer control is used to check out each stage of the Saturn V vehicle. Responses from each stage are evaluated based on the applied stimuli. Such entities as hydraulics or pneumatics may not originate with the computer and are therefore generated by devices external to the computer, but under its control. The test conductor's CRT console is the focal point for maintaining control of all test operations and the computer.

Two general modes (semi-automatic and automatic) of operation are available for use. The normal mode now being used is semi-automatic. This mode consists of the following operations (refer to Fig. 4):

Command initiated through electrical support equipment (ESE) panels or the display system keyboard in the Launch Control Complex (LCC).

Upon receipt of command, the computer at LCC transmits a signal via data link to the Launch Umbitical Tower (LUT) computer.

A command is then furnished to the stage under test via ESE, with a response returning by the same route.

The automatic mode would consist of the initial command, initiated by ESE panel or display system keyboard, being generated by the execution of a stored program instruction. All other sequences of events would remain as previously stated.

To summarize the checkout of a Saturn V vehicle at Kennedy Space Center, three basic features are available:

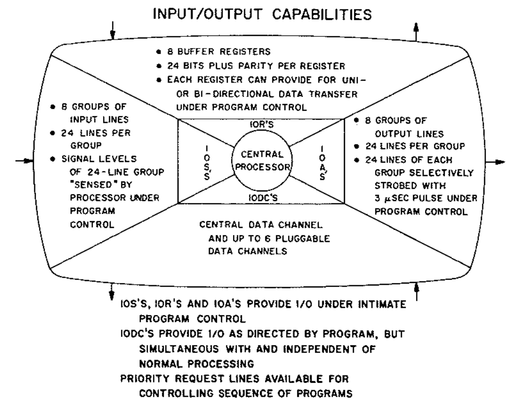

Fig. 5—RCA-110A input/output capabilities.

Discrete actions called up from the ESE switches;

Call up from the display consoles of test programs and discrete requests or monitoring; and

Periodic monitoring of test points, discrete status, and red-line values.

Data received through these tests are displayed locally at the stimulus-generating equipment. In addition, data received via the digital-data-acquisition system (DDAS) is recorded for later hard copy (strip) printout. Certain functions are monitored by test personnel on a full-time basis. To supplement the capability of the RCA-110A computers to monitor discrete events, a digital events evaluation (DDE) computer continuously scans a large portion of the ground support equipment and stage discrete information and records changes and the time they happen.

RCA's present role

Through June of 1970, RCA/EASD is under contract to the NASA Marshall Space Flight Center for program management, engineering, field service, and quality assurance in support of the RCA-110A computers. Also, in support of this contract, EASD has a 15,000 square foot facility at Huntsville, Alabama, and a sustained/dedicated group of support personnel at the Van Nuys plant.

Saturn launches

Through the writing of this article, the RCA 110A Computer System has successfully supported all Saturn 1B launches (AS 201—AS 205) and all Saturn V launches (AS 501—AS 507). This schedule included Apollo 11 and 12 and meant that NASA was able to meet all major test schedules plus all launch windows.