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ORBITAL/GROUND CHECKOUT STUDY EXECUTIVE SUMMARY REPORT

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ORBITAL/GROUND CHECKOUT STUDY

EXECUTIVE SUMMARY REPORT

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FOREWORD

This report summarizes a study pursuant to conceptual determination of both onboard and ground checkout systems appropriate to the Space Station/Space Base Program of 1975-85. Some consideration is also given to a 1986 Manned Mars Mission. Detailed results and discussions are contained in IBM document 69-M91-001-CKF "Final Technical Report for Orbital/Ground Checkout Study." The work was conducted by the Federal Systems Division of the International Business Machines Corporation under Contract NAS10-6376 for the John F. Kennedy Space Center of the National Aeronautics and Space Administration. Technical control and guidance was furnished by Mr. Wallace H. Boggs of the Future Studies Office at the John F. Kennedy Space Center. Mr. Paul D. Toft served as alternate technical monitor.

Publication of this report does not constitute National Aeronautics and Space Administration endorsement of the findings or conclusions of the report.

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SECTION I

INTRODUCTION

This conceptual study analyzed the checkout and data management system requirements anticipated for the 1975-85 Space Station/Space Base Program. A 1986 Mars Mission was also considered. In the light of expected technology advances, system concepts (both onboard and ground-based) were developed to satisfy the expected requirements. An implementation plan for the preferred concept of the ground-based system is presented. The study contract was initiated on January 17, 1969 with a performance period of eight months. This period was extended two additional months by contract amendment to accommodate the incorporation of information resulting from developments in the two concurrent Space Station Definition Studies.

Phase I of the study (Figure 1) consisted of an analysis of the anticipated Space Station/Space Base Mission leading in turn to a definition of requirements for the onboard system. The data management requirements were defined for guidance and navigation, attitude control, experiments, displays, as well as the checkout function.

Phase II entailed development of onboard system concepts which satisfied the derived requirements. The concepts developed take maximum advantage of the expected available technology. A projection of this technology was also conducted in this study phase. Other determinants, such as earlier system designs, operational experience and commodity availability, were also considered.

Phase III consisted of the development of concepts for the ground-based system which were compatible with the onboard concepts and made efficient use of the applicable technology as projected. Other determinants of the onboard configuration were also considered.

Phase IV of the study entailed selection of preferred concepts for both the onboard and ground systems and their development to a system architecture level. Trade studies were performed in necessary areas. System increments uniquely necessary for the planetary mission were also developed.

Phase V consisted of an analysis of present ground system capabilities and the formulation of a system implementation plan which permits orderly evolution into a configuration necessary for the support of post-Apollo missions.

The most significant ground rules imposed by NASA/KSC for the performance of the study were as follows:

- Maximum study effort was to be expended on the NASA 1975-85 Space Station/Space Base Mission with the Manned Planetary Mission considered as an increment.
- A Data Relay Satellite System (DRSS) will be assumed operational.
- Current space vehicle checkout systems will be assessed utilizing existing documentation.
- Recommended system concepts will be developed to a system architecture level.

SECTION II

OBJECTIVES

2.1 GENERAL

The primary study objective was the development of checkout system concepts applicable to the 1975-85 NASA manned missions which will be substantially unaffected by subsequent program detail definition activity. Specifically, the study was addressed to the following:

- An assessment of technology advances applicable to instrumentation, communication, checkout and data management systems for two projected NASA space programs:

  - 1975-85 Space Station/Space Base
  - 1986 Manned Planetary Flyby.

- The conceptual development of onboard and ground checkout systems required to support both programs

- The development of a time-phased plan for ground system transition to accommodate the projected onboard capability.

2.2 BACKGROUND

The study has been performed within the dynamic NASA space program environment. In addition to the success of Apollo 11 in July, the modest Space Station concept with a crew of 9 - 12 has evolved into the Space Base with a crew exceeding 50. The Manned Mars Mission has gained inpetus while the Space Shuttle, which makes an ambitious manned program economically feasible, is now receiving emphasis. The Phase B Space Station Definition Study in which IBM is a participant has been initiated. The NASA in-house Manned Space Computer Study may also make timely use of the material developed in the Orbital/Ground Checkout Study.

2.3 GROUND RULES AND GUIDELINES

The following ground rules and guidelines were used throughout the study:

- Mission analysis:

  - Two missions will be addressed: the 1975-85 Space Station/Space Base and the circa 1985 Manned Planetary Flyby.
  - The Space Station/Space Base Mission will be emphasized with the planetary mission considered as an increment.
  - Ground-based in-orbit mission support will be reduced to the maximum degree possible.
  - A Data Relay Satellite System (DRSS) will be assumed operational.
  - Mission analysis will form a major baseline for onboard requirements definition.

- Onboard requirements definition:
    - Orbital operations have first priority on OCS design.
    - OCS capabilities will be used to minimize prelaunch testing time and manpower requirements.
    - Checkout requirements must be defined for conceptual subsystems.
    - Maintenance levels determine checkout levels of test.
- Ground requirements definition:
    - Nonelectronic requirements will be developed as required only to define checkout requirements.
    - Minimize operating time and manpower requirements.
    - If feasible, use OCS for prelaunch checkout augmented where necessary to assure testing to the smallest replaceable level.
    - Current spacecraft and launch vehicle checkout systems will be assessed utilizing existing documentation.
- OCS configuration analysis:
    - Function allocations between ground and orbital systems are made in accordance with operational requirements.
    - High reliability and some in-flight maintenance are essential to mission success.
    - The OCS will be considered the independent variable, the ground system the dependent variable.
    - Checkout system concepts making maximum use of expected technology advances will be developed to a system architecture level.
- Ground system configuration:
    - Checkout system concepts making maximum use of expected technology advances will be developed to a system architecture level.
    - Maximum utilization of the onboard checkout system for other than in-orbit functions will be considered.
    - The ground system at KSC must be capable of efficiently accommodating varying workloads and vehicle/user mixes.
    - Consider the feasibility of integrating and centralizing computer support for prelaunch and launch activities for the total space vehicle.
- Ground systems capability analysis:
    - Maximum utilization will be made of existing documentation.
- System implementation plan:
    - Maximum utilization of existing equipment through modifications will be considered as well as new use after retirement.
    - Checkout of an onboard checkout system is a requirement.
    - The mission support role will be optimized over NASA centers.
- Technology assessment:
    - A comprehensive 1975-85 technology projection will be made, concentrating on the checkout and checkout-related capabilities made possible by expected advances in the pertinent technologies.

SECTION III

CONCLUSIONS

The following conclusions were derived from this study:

1. A substantial amount of multiprocessor computer capability can be installed in the initial Space Station Module (1975). Consideration should be given to reserving a significant portion of this capability for in-orbit developmental use, i.e., to be assigned as appropriate applications develop in the mission.

2. An onboard computer system with programmable preprocessors monitoring subsystem performance, and a general-purpose digital computer performing executive and backup functions, is the most reasonable approach. Flexibility, redundancy and ease of accommodation of later arriving modules is thus obtained.

3. Unless Space Base Module design is such that each has a "stand-alone" onboard checkout capability, substantial ground-based computer capability will be required to support Space Station/Space Base Module launches. An interdependent onboard checkout/data management system, wherein full capability is obtainable only in the assembled multimodule configuration, would necessitate such ground computer support.

4. Certain technology developments necessary to optimum Space Station/Space Base systems design appear to require Governmental encouragement as commercial market pressure is not sufficient to produce a compatible maturation date. One such area is thin film bulk storage.

5. A centralized ground computer complex which derives flexibility through the utilization of data bus techniques is the most reasonable approach to the launch site configuration.

6. Software, both for onboard checkout and ground, is the greatest identifiable problem area and requires early attention. The development of a flexible, standardized test and control language to accommodate systems engineers/technicians, principal investigators and perhaps astronauts is required, and can be meaningfully addressed today.

7. The operational philosophy of the Space Station/Space Base should be one of evolution. Ultimate Space Base autonomy is feasible; however, it will develop gradually with 100 percent ground backup required over the first two years.

8. As onboard capability increases, the Space Base should be considered for use as a test facility for planetary mission equipment and also as the mission control facility for orbital assembly, checkout and launch. Thus, the transfer of the KSC experience and mission into orbital operations should be considered.

9. In view of the projected ten-year lifetime for the Space Station/Space Base, the key issue of high system reliability design goals versus an ease of repair/replacement philosophy must be addressed as well as the total fault isolation methodology question.

SECTION IV

FUTURE TECHNOLOGY ASSESSMENT

4.1 GENERAL

To define reasonable configurations for onboard and ground-based systems having instrumentation and communication system interfaces, it is appropriate to focus initial attention on the computer systems architectural possibilities followed by an assessment of instrumentation and communication system technologies. In the process of structuring a computerized checkout/data management system, a number of major design options are available with respect to system architecture. As an initial starting point, consideration must be given to the manner of distribution of the major processing function. Should a decentralized approach be taken wherein the systems monitored are serviced by a substantially independent hardware and software subsystem, or should centralization be opted for wherein a single general-purpose computer does all? Further, is the ground solution different from the onboard? And, in either case, is there a compromise solution between these two disparate system arrangements wherein the advantages of both are preserved? Without performing a realistic technology projection in both hardware and software to determine the expected subsystem capability, this fundamental decision cannot be intelligently made. Additional technology projections in such related fields as image processing and data storage are also essential to the development of a coherent system structure.

The availability of advanced technology is a function of launch date which determines the necessary design completion date. The 10-year Space Station lifetime suggests initial system designs which provide retrofit capability later to take advantage of forecasted technology maturation. By using this approach throughout the manned-orbital program, anticipated technology advances can be further exploited. In those instances where a particular technological capability is necessary or desirable for Space Station utilization but where commercial market pressure is not sufficient to produce a compatible maturation date, Governmental encouragement should be considered.

4.2 INTEGRATED CIRCUITS

The degree of sophistication that can be put into the restricted volume of a spacecraft obviously depends on the circuit density of the electronic components. Fortunately, spacecraft are getting larger while circuits are getting smaller. As Figure 2 shows, the Space Station core module will use Medium Scale Integration (MSI) at about 30-40 circuits per chip area.

Integrated circuit technology is presently advancing by an order of magnitude every seven years, indicating that for the Space Base and the Manned Mars Mission, Large Scale Integration (LSI) will be in use extensively. It is hard to predict what will happen between 1981 and 1985 because of the seemingly insurmountable problems associated with fabrication, cooling and testing. This may cause a flattening effect in the curve unless breakthroughs occur in these fields.

4.3 STORAGE

Medium and large scale integrated circuits using bipolar and field effect transistor arrays also form the emerging technology for computer memory applications.

The dominant magnetic core technology now will give way gradually in ground-based equipment, but its susceptibility to magnetic fields will make earlier replacement more attractive in airborne computers. Table 4-1 shows the significant technologies that have been and are being used for main memory. It is important to note that, although monolithic semiconductor technology offers the best cost/performance factor, the radiation-hardened feature of plated wire memories may be a vital advantage in the space environment.

Table 4-1. Memory Technology for Main Memory and Control Storage

• Monolithic semiconductor array	• Good cost/performance • Error correction coding very effective in increasing reliability • Nondestructive read and electrical alterability
• Delay lines	• Phasing out completely
• Ferro-electrics	• Aging and stability problems have not been adequately resolved
• Tunnel diodes	• Inferior to other technologies in cost and performance
• Ferrite cores	• Offers less advantage than thin films and monolithic semiconductors in terms of power density and speed factors
• Plated wire	• Power and speed an improvement over discrete ferrite cores • Radiation hardened
• Transformers and capacitors	• Continued exclusive use for read only storage

4.4 FUTURE STORAGE, OPTICS AND DISPLAY TRENDS

In general, a different technology is required to solve the problems associated with bulk memory (see Table 4-2). Unlike main memory and control storage, three technologies are being developed that offer great promise for the future. Within the next few years and possibly by 1973, thin film bulk storage will be commercially available. By 1985, research in holographic storage will have matured, offering tremendous capacities and ultra-fast access times, but laser may have to compete with ovonics. Named after its discoverer Ovshinsky, this technology is based on the diode-like properties of amorphous semiconducting material. It is fabricated as a thin film, and since it has no regular crystalline structure, its properties are unaffected by X-Ray or Gamma Ray bombardment. Although largely undeveloped, ovonics appears to be the best potential memory device for aerospace applications.

Table 4-2. Memory Technology for Large Capacity Storage

Thin film	Low cost and power dissipation very suitable for bulk storage (10^6 bits/substrate Can be used for main memory application
Batch ferrite	Power speed improvement over discrete ferrite cores Inferior to thin films in terms of drive power, pulse propagation, and switching mechanism
Superconductors	No unique advances over thin films Many technical problems arise because of the very low temperatures involved The cryogenic tunneling phenomenon may prove useful in some novel applications
Beam addressable technologies	Offers the greatest density potential (2.5×10^6 bits/square inch)
Ovonics	The best potential memory device Resistant to X-Ray and Gamma-Ray radiation Not presently under extensive development High fabrication cost, particularly in the near-term environment

Figure 3 shows the anticipated development of TV vidicon tubes and metric cameras from the present to 1985. The number of resolvable elements expressed in line pairs per millimeter is proportional to the distance between objects on the ground expressed in feet. For example, today's 12-inch metric camera at an altitude of 250 miles can resolve objects 100 feet apart. Some of the earth resource requirements are plotted based on this altitude showing that expected technological growth will not keep pace with some demands. Also, resolution requirements are expected to become more stringent by 1985 (10 feet at 250 miles). Vidicons with a 9-inch format and a resolution capability consistent with projected requirements may become available in 1980 provided transition from an analog to digital sweep can be made in time.

Figure 4 shows the development trends for cueing indicators and readout devices. By the time the Space Station core module is launched, the light emitting diode array could become a successor to the incandescent lamp because of its high brightness, low voltage efficiency, and monolithic fabrication. Holographic displays will come into being by 1980 if their development is accented. Development to date has primarily addressed the construction of holograms and long-term storage of holographic data. The real-time application of holograms for image construction requires extensive development activity.

4.5 SPACE STATION ONBOARD COMPUTERS

By using conservative future technology projections, the two computer types antici- to be onboard the Space Station have been sized. The executive machine (see Table

4-3) is a group of modules connected to perform as a multiprocessor. Only 15 cubic feet, which is less than 0.15 percent of the total Station volume, are required for all units including the I/O channels. The smaller remote checkout computers also require an insignificant amount of space, but there may be as many as 10 of this type processor. It is easily seen that the most serious limitation is the electrical power that must be supplied to run the computers. For a Station with 25 kw average bus power, almost 25 percent of it would be required for the onboard computers. It must be stressed, though, that all the figures were chosen to be somewhat pessimistic.

Table 4-3. Projected Computer State-of-the-Art for 1975

Feature	Executive Computer
Architecture	Parallel processor
Speed	600,000 instructions/second
Memory	256 x 32 bit words
Volume	15 FT^3, includes all accessory modules
Weight	500 pounds, includes all accessory modules
Power	1000 watts, includes all accessory modules

4.6 RECOMMENDATIONS

In each of the following key areas, there is a technology "gap." The pressures from the commercial market will not be sufficient to develop these technologies for spacecraft application. Research in the following fields should be accelerated to ensure an adequate technology base for both the near-term and long-term missions:

- Encourage development of all electronic bulk storage.
- Investigate potential of ovonic technology for space applications.
- Determine the optimum computer architecture for spacecraft applications by studying the possible parallel processing systems.
- Encourage development of coherent optical communication systems.
- Develop real-time holographic image construction techniques.
- Develop camera and television technology to meet 1985 resolution requirements.

SECTION V

MISSION ANALYSIS

5.1 SPACE STATION/SPACE BASE EVOLUTION

A design reference model for the 1985 Space Base is shown to put the system evolution concepts in their proper perspective (see Figure 5).

5.1.1 Experiments

Experiment groupings will increase dramatically over the ten-year Station life. Initially, most experiments will have their sensors and equipment distributed throughout the Station; but soon new modules, both attached and free flying, will be added. Eventually a balanced grouping will result with entire sections of the Space Base devoted to research laboratories. The number of system test points for the experiments would grow from approximately 1000 in 1975 to 3,500 by 1985. Assuming that the requirements do not change over the decade of interest, it is easy to see that the new 33-foot diameter stages should have their own onboard checkout systems with sufficient capacity to handle the added experiments. This practice will ultimately result in three or more such checkout systems. Salient experiments are:

1975	1985
● Minimum core groupings	● Balanced groupings
- IMBLMS	- Biomed and Bioscience labs
- Astronomy module	- Advanced technology
- Earth resources	- Advanced astronomy module
	- Space manufacturing system
	- Space physics lab
● 1000 system test points	● 3500 system test points
● Only one onboard checkout system available	● Three or more onboard checkout systems available

5.1.2 Data Management System

During the ten-year life of the Space Station, the experiment data management system is expected to change more than any other subsystem. When the full Space Base concept has evolved, all experiment data will be processed and analyzed onboard by scientists and principal investigators that are part of the crew. This is in stark contrast to the early phases of the mission where the experiment data is transmitted to the ground continuously and where onboard processing is limited to data compression by a Read-Only-Store (ROS) computer. With these end points established, further studies should be made to determine the best transition plan for onboard data management. Initially, all data gathered on film or by vidicons will be sent to the ground by either a television system or film return in small reentry vehicles. Eventually, however, the onboard computer system must be able to process pictures and other imagery data without intermediate ground handling.

1975	1985
Data compression and format generation routines preformed by ROS computer	All data manipulation performed by an onboard data processing system
Data transmitted to the ground continuously	Data transmitted to the ground on request only
Most scientific analysis of the data performed on the ground	Most scientific analysis of the data performed onboard with principal investigators part of the Space Station crew
All video information returned to the ground by physical film return or TV	Onboard picture evaluation with image processing and enhancement done by Space Station computers

5.1.3 Computer System

Onboard computers can be arranged advantageously so that it will be easy to incorporate the additional computing power when future modules are sent up. Initially, the onboard computers are performing primarily checkout and station-keeping functions; but as more equipment becomes available, the computing capability can go up enormously. At first, two systems can be tied together. Then a third module can add another level of executive machine to control and coordinate the onboard checkout activity. The same machine will also serve as an electronic data processing facility for the entire Station. Time-sharing terminals can be located in the major laboratories and experiment modules for access to the onboard computing center. Evolution can occur as follows:

1975	1985
Programmable computers for guidance, checkout, and experiment support	Programmable computers for guidance, checkout, data processing, and scientific analysis
Centralized executive computer operates in conjunction with preprocessors	Centralized station control computer coordinates several OCS executive machines and serves as an off-line electronic data processing center
Executive computer has multiprocessor architecture	Multiprocessor/architecture for expanded operating system for time sharing and multitasking and terminal units located in onboard laboratories
Checkout computers are conventional single processors	

5.1.4 Man/Machine Interface

Advances in technology over the ten-year Station life will greatly influence the evolution of the man/machine interface. Although the initial core modules will have only two-dimensional displays, three-dimensional techniques such as holography will become available about 1980. Computer input devices will undergo little change from the keyboard and light pens available today. There will be some type of voice control and audio response available by 1985, but comprehensive vocabularies will not be feasible. There will be a significant change in the evolution of programming languages. By 1985, there will be language compilers available that will convert free-form English text into machine language. When a full data processing facility is established onboard, there will be several members of the crew designated as center controllers in much the same way that computer operators and system engineers are used in ground-based facilities now. It must be pointed out that in the initial core module at least one member of the twelve-man crew should have a system engineering understanding of the onboard computers. This will be especially important if any kind of hardware maintenance is planned. A comparison follows:

1975	1985
• Two-dimensional displays with deformagraphic tubes, light emitting diodes and plasma	• Three-dimensional displays having color holography and kinoforms
• Graphic and keyboard inputs for computer control having tutorial control by displays and capacitive or Hall-Effect keyboards	• Multiple computer control inputs having graphic inputs, automatic or system generated direct digital control, voice control and Hall-Effect keyboards and switches
• One crew member must have in-depth knowledge of the onboard computer system	• Several crew members designated as data processing center controllers
• Unique programming language required that is test and control oriented	• Complete set of language compilers available including free form English text

5.1.5 Requirements Summary

The following list summarizes the checkout requirements for the 1975 Space Station experiment and vehicle subsystems. A total of approximately 4800 test measurements are required for the early Space Station operations. The increase in testing requirements is evidenced by the increase in experiment test measurements or approximately 1000 additional measurements by 1980 and 2500 additional measurements by 1985:

SUBSYSTEM	TEST MEASUREMENTS
Guidance and control	896
Power	122
ECS and life support	393
Communications	317
Experiments	992
Logistics vehicle	150
Experiment data	1000
Subtotal	3870
25% contingencies, including instrumentation calibration requirements	967
Total	4837

Expected growth evidenced by increase in experiment test points is:

ERA	TEST POINTS	INCREASE
1975	992	----
1980	2038	1046
1985	3517	2525

The Space Station experiment data requirements summary is:

- Balanced grouping - 10^{12} equivalent bits/day

- Astronomy	1.4×10^{12}
- Biomedicine	1.7×10^{10}
- Man/machine evaluation	0.9×10^{10}
- Earth resources	9.9×10^{10}
- Space physics	2.4×10^{10}
- Space biology	1.3×10^{10}
- Space manufacturing	0.8×10^{10}

- Medium grouping - 10^{11} equivalent bits/day

- Astronomy	2.0×10^{10}
- Biomedicine	0.9×10^{10}
- Man/machine evaluation	0.5×10^{10}
- Earth resources	5.0×10^{10}
- Space physics	1.2×10^{10}
- Space biology	0.6×10^{10}
- Space manufacturing	0.4×10^{10}

- Core grouping - 10^{10} equivalent bits/day

- Astronomy	0.8×10^{10}
- Biomedicine	1.6×10^{8}
- Man/machine evaluation	0.3×10^{8}
- Earth resources	1.4×10^{10}

5.2 MANNED PLANETARY MISSION

5.2.1 Mission

The mission chosen for analysis is the 1986 Manned Mars Mission. The mission profile is characterized by an out-bound, swing-by of the Planet Venus on the 164th day of the mission, a Mars arrival at 367 days, a Mars departure at 427 days, and an Earth return on the 676th day. Although the actual space vehicle configuration and launch operations (see Figures 6 and 7) may differ markedly from those shown, the majority of the elements depicted will most probably appear in the mission as flown. The essential mission characteristics including multiple launches and orbital assembly, checkout and launch will be present.

During the transplanetary and planetary mission phases, the Space Base could serve as a communication relay. The out-of-atmosphere capabilities of optical communications systems can thus be exploited. Transmission through the atmosphere (to and from mission control) can be accommodated via an appropriate RF link (see Figure 8).

Some significant mission characteristics which differentiate the Mars Mission from the early Space Station are:

- Optical communication link with Earth
- All mission critical systems will be self-repairing or maintainable
- Duplicate spacecraft may be sent to ensure mission success
- Man/machine interface can be a voice-controlled tutorial system
- Onboard computer programs can run simultaneously.

5.2.1 Onboard Capability

A highly capable onboard computer system can be expected in the Manned Mars Mission spacecraft. Significant capabilities which cannot be expected in the earlier Space Station/Space Base computer system are:

- Navigation and control with three-dimensional display of position and trajectory
- Rendezvous and docking with three-dimensional displays
- Subsystem and experiment checkout with history file for long-term trend analysis, active fault isolation routines and stores all system prints and documentation
- Data reduction and processing with image processing
- Scientific computations
- Simulation and training.

SECTION VI

ONBOARD SYSTEMS

6.1 SYSTEM ALTERNATIVES

Three onboard system alternatives ranging from centralized through decentralized were analyzed and are presented.

6.2 CONCEPT A

In Concept A, all functions of limit checking, trend analysis, stimulus generation, etc. are carried out in the central computer complex. The Built-In Test Equipment (BITE) indicated is actually built-in stimulus equipment since its only function is to apply stimuli generated by the central computer. The remote encoders shown in Figure 9 remain to be defined both as to the number required to service a given number of subsystems and as to their location with respect to subsystems and experiments. Definition of the number and location of the remote encoders should be the subject of an additional study.

The chief advantages of this system lie in the fact that all logical and arithmetic functions take place in a single processing system. From the standpoint of software generation and control, the single system reduces the number of programming languages and groups required. From a hardware standpoint, a single processor will provide more speed and capacity for a given power and weight than some number of smaller processors. A summary of Concept A advantages are:

- Single processor with one programming language
- Single software system with ease of configuration management
- Minimum space and power requirements.

This system's major disadvantage derives from the same source. A single system means a single point of failure (this is particularly true of software problems). The lack of modularity in this system also implies that until the entire operational software system is running no one section of it can be considered safely checked out. A summary of Concept A disadvantages are:

- Modular program checkout extremely difficult
- Backup must duplicate complete system
- Complex system in operation all the time
- Single point of failure both machine and software
- Interconnection of additional computer is difficult.

6.3 CONCEPT B

Concept B configuration (see Figure 10) differs from Concept A in that the remote encoders have been replaced by Remote Checkout Units (RCU). The RCU are microprogrammed, special-purpose units which perform both passive monitoring and stimulus generation. Since the RCU are special purpose, they must be individually specified and developed (although they will share technology and basic logic). With the exception of the functions now being performed by the RCU and the additional services required to support the RCU, the central processing complex will be the same as Concept A.

Since some functions such as limit checking have been removed from the central processing complex, this system requires the least software. Otherwise, its positive factors are similar to those of Concept A. The major disadvantage of this concept is its inflexibility. The RCU are difficult to modify to accommodate new functional requirements. The system is still subject to a single point of failure, and backup of the RCU by the central processing complex would require the generation of computer programs to duplicate the functions peculiar to each RCU. Finally, since each of the RCU might in some way be unique, replacement at the unit level implies a troublesome spares problem. A summary of Concept B disadvantages are:

- Expansion requires redesign of onboard installations
- Difficult to change basic functions
- Diagnostics most difficult
- Single point of failure
- Complex spares provisioning problem.

6.4 CONCEPT C

In Concept C (see Figure 11), which is the preferred concept, the RCU are replaced by Remote Checkout Computers (RCC). Note that replacement is not on a one-for-one basis and that several RCU can be replaced by one RCC. In this system, passive status monitoring and short-term trend analysis take place in the RCC with display control, data logging and mathematical analysis performed by the central computer complex. To take full advantage of this system's inherent redundancy, the RCC should have access to the onboard telemetry system (in backup mode) and some form of rudimentary display controllable from the RCC is desirable.

Concept C, because of its modularity, is extremely flexible. The RCC can be used as backup for each other, and the central computer complex could be used as a final level of backup. Additional functions are readily included. If the software/hardware system is properly designed, additional RCC modules which are brought up later in the life of the Space Station can be incorporated with a minimum of difficulty. A summary of Concept C advantages are:

- Modular program checkout
- N-Way backup is possible
- Fail-Soft
- Checkout computers are physically interchangeable.

On the other hand, this system is the most complex of the three. More than one machine type must be programmed and maintained. The number of computation modules implies that, in terms of volume and power, requirements are highest for the same level of computation capability. A summary of Concept C disadvantages are:

- Multiprocessors are difficult to program
- More than one machine type
- Maximum space and power required.

Figure 12 is an expanded version of Concept C drawn to meet the requirements of the 1975 Space Station core module. An attempt has been made to show all the subsystems and experiments that might be included for this mission. The number of Remote Checkout Computers (RCC) used is arbitrary. The arrangement shown illustrates that more than one system should be connected to a single RCC unless the functions of that system are critical.

Imagine for the moment that the navigation system is connected directly to the top RCC, while the water and food management systems are connected to the second RCC. This is the system configuration under normal operation; the Switchable Selector Unit (SSU) patches the inputs appropriately. Now, if a malfunction occurs, the SSU can connect the navigation and control functions to the second RCC while at the same time disconnecting the inputs from the first RCC. In addition to this functional redundancy, the Executive Computer can also run the RCC programs providing a full three-way backup capability. Ordinarily, the Executive Machine is servicing displays, handling interfaces with other systems, and controlling the peripheral equipment. Since it is important to retain as much computing power as possible in the master computer, these are all the functions that would be planned for the initial application. The computer does have access to the data management system so that it can serve in a support role for experiment analysis.

The onboard bulk storage shown should be all electronic thin-film or monolithic circuit technology. High density magnetic tapes will be unreliable mechanically, and the medium will ultimately fail to meet the growing demands of Station evolution because the present state-of-the-art is already beginning to push the basic physics of the tape/head interface.

6.5 TELEMETRY SYSTEM

Figure 13 illustrates a possible telemetry system for the early Space Station. The test points for the vehicle subsystems and experiments will be predominantly analog signals that will require signal conditioning, multiplexing, conversion to digital form and serializing. After the checkout data has been encoded to form an Non-Return to Zero (NRZ) Pulse Code Modulation (PCM) wave train, it is interleaved with the serial wave trains from other PCM encoders. It is in this form that the data is sent to the remote checkout computers. The interleaved wave train is then reformatted by a Flexible Format Generator (FFG) that operates under computer control so that the ground can change the order and sequence of measurements being transmitted. After the FFG, the checkout data is routed to the appropriate transmitter and antenna through a computer-controlled transmission selector, which enables flexible use of RF transmitters in case of failure. It is important to notice that the Executive Computer plays no role in the Telemetry System other than the simple control functions mentioned.

6.6 DATA MANAGEMENT SYSTEM

The onboard Data Management System (see Figure 14) is fundamentally a part of the Telemetry System. In fact, as can be seen from the diagram, the measurement conditioning and encoding are identical. The big difference is in format generation and data compression. Unlike the checkout measurements, there will be more data from the experiments than the ground can handle without some form of onboard compression. It would not be wise to overload the Executive Computer with these routine operations. Instead, a Read-Only-Store (ROS) computer can be used. This kind of hardwired logic performs much like the programmable computer except that all the logic elements are capacitor or transformer storage devices. Although any kind of hardwired logic can be used, ROS is simpler and more reliable than other forms. For more complex data management schemes, it might be necessary to replace the ROS concept with a programmable machine, but a study should be undertaken to determine the point at which this switch should be made.

6.7 ONBOARD CHECKOUT SYSTEM

Figure 15 shows the evolutionary trend for the onboard checkout system of the Space Station's core module. Initially, it will monitor 80 percent of the electrical test points and transducers provided by the component manufacturers; but as crew confidence in the vehicle subsystems grows, the number of in-flight checkout measurements will decrease somewhat. The exact number will depend on the amount of computing power required to perform the Space Station's research and development tasks. Initially, the flight controllers on the ground will want the capability to monitor all the vehicle test points; but again as confidence grows, more and more reliance will be placed in the onboard system, and most ground status monitoring will be stopped. The shape of the curve reflects the way in which this will be accomplished. All but one of the original telemetry transmitters will be shut down so that their frequencies may be used on other core and experiment modules.

SECTION VII

GROUND SYSTEMS

7.1 GENERAL

The ground system includes ground support equipment, ground computers, and their associated computer programs. Discussion of the ground system will begin with software because the user of the ground computer system is affected more by the programs which are run on the ground computers than by the specific characteristics of the hardware itself. Following the discussion on software, there will be a review of some of the ground system configurations which were considered, a detailed presentation of the ground system which we recommend, and finally a discussion of some possible transition plans and recommendations for near-term and long-term future activity.

7.2 REQUIREMENTS

The ground system was defined by first considering overall requirements and system characteristics for the 1975-1985 time frame. Of the requirements and characteristics listed, there are some which are already being performed at KSC and some which are imposed by the change in mission requirements. The requirement for checkout of complex onboard checkout systems and the possible need for the KSC ground computer system to serve as a data reduction facility for the Space Station constitute a major impact upon the capabilities of the KSC ground system. From the following list of requirements, it can be seen that the overriding consideration in system design should be that of producing a system which is capable of handling a workload which can fluctuate greatly both in volume and in the type of data to be processed:

- Checkout the onboard checkout system
- Checkout the non-orbiting stages
- Monitor and control propellant loading
- Serve as data reduction computers for principal investigators once vehicle is launched
- Ground computer should be compatible with onboard computers
- RF links.

7.3 SOFTWARE

As has been noted previously, the user of a computer system is more affected by the software system than by the particular characteristics of the computer hardware itself. Whether the computer system is easy to use, whether it presents the data to the user in a form suitable to his needs, and even the length of time the user must wait for his results are at least as much a function of the software system as they are of the hardware system. The software system discussion will include an appraisal of the present software available at KSC, a brief survey of other software systems being developed at this time, and recommendations concerning the development of software specifically required at KSC.

7.3.1 Projections

A comprehensive software projection must be based upon expected developments in the field of commercial (vendor supplied) packages. Before such a projection can be considered valid, it is necessary to establish a parallel between the commercial market place and KSC operations. The following list shows in both areas (KSC, 1964-5 commercial market) a large investment in programming support for a number of incompatible computer types had been made. However, programmers could not readily move from one machine type to another nor could programs written for one machine be run on another:

Key Parameters	KSC 1969	Commercial Market 1965
Number of computer types	7	8
Support programming number of instructions	500K	700K-1.0M
Approximate man years represented	400	600-800
Program compatibility	No	No
Retraining required	Yes	Yes

The analogy between KSC and the 1965 commercial market extends beyond existing conditions to future requirements. In both cases, the overall goals are: to protect software investment by reducing the impact of hardware technology improvements; to improve processor loading by increasing the variety of tasks being performed by available processors; availability of processors, particularly, to non-programmer personnel. The use of computer systems by non-programmer personnel has increased greatly since 1965, and a number of software systems to support this type of activity have been developed. It should be noted that a similar situation exists in the space program for both the ground-based computer system and the onboard computer system. In both cases, there is a need for test conductors, test engineers, principal investigators, and other crew members to make use of the computing facilities available in either the ground system or the onboard system:

KSC	COMMERCIAL
• Apply computer capability to non-checkout problems	• Improve processor utilization
• Improve user access for test engineers and PI	• Improve user access for programmers and non-programmers
• Reduce onboard/ground incompatibility	• Merge scientific and business applications
• Improve program test and checkout	• Reduce future technology impact
• Reduce future technology impact	

7.3.2 Available Systems

The following list of software systems is not intended to be exhaustive. It is intended to give examples of the various types of computer languages available for use by programmers, non-programmers, and system users at remote terminals. The programmer-oriented compilers are designed for use in writing complex arithmetic programs. The terminal systems are broken down into two subsections, tutorial and non-tutorial. As used, a tutorial system is one in which the user need not be familiar with the details of the system in use. Directions for system usage are displayed at the terminal to be followed by the user. In a non-tutorial system, the user is expected to be familiar with the conventions of the language he is employing or the system he is using.

Of the software system listed here, two require additional commentary: CLASP, a Computation Language for Aeronautical and Space Programming; and ATOLL, the Acceptance Test Or Launch Language. CLASP is a specially designed system for use in solving guidance and navigation equations, which will be commented upon later. ATOLL is a test-oriented compiler level language designed and implemented for vehicle checkout. It is in extensive use at KSC and is being used by engineers to write test and checkout programs. The software system survey conducted for this study did not uncover any other languages which were applicable directly to vehicle checkout or onboard checkout:

- Programmer-oriented compilers

SPL	Space Programming Language
CLASP	Computation Language for Aeronautical and Space Programming
PL-1	Programming Language - 1

- Remote terminal systems - non-tutorial

CPS	Conversational Programming System
RJS	Remote Job System

- Remote terminal systems - tutorial

QUIP	Query/Inquiry Program
LGP	Language Generator and Processor
CTS	Computer Terminal System

- Test-oriented languages

ATOLL	Acceptance Test Or Launch Language

7.3.3 Tutorial Display Control

An example of the type of tutorial display control which would be used in conjunction with the onboard computer system follows. The user, either by scribing the appropriate letter or by using a light pen, can call up detailed information about each of the topics listed here. As each page of detailed information appears, it is accompanied by instructions to move forward or backward in the display sequence:

- To select subsystem display option, write appropriate letter

Guidance and navigation	A
Life support systems	B
Experiment groupings	C
Maintenance records	D
Computer system status	E

- To terminate sequence, depress tab key.

7.3.4 Test and Checkout

A complete real-time test and checkout system would include each of the following items. Those items which apply to the operating system itself, namely multiprogramming support and the real-time operating system for both onboard and ground systems support, require the selection of a hardware system before a complete definition can be made. However, the test language, display techniques, and malfunction analysis techniques can be investigated thoroughly prior to the advent of any subsequent hardware systems. At the same time, careful analysis of the workload to be imposed upon any projected hardware system can yield important constraints which would aid in the definition of the real-time operating system to be used. Software requirements for a real-time test and checkout system include:

- A test language suitable for use by engineers
- A real-time operating system applicable to both onboard and ground system support
- Display techniques directed at test and checkout
- Malfunction analysis techniques
- Multiprogramming support for data reduction and analysis.

7.3.5 Recommendations

The division of the recommendations into near term and long term follows from the point previously made that the complete operating system definition must await hardware system specification, but that certain preliminary tasks can be defined and begun now. The need for compatibility between onboard and ground systems has already been pointed out. For test and checkout, this compatibility could be achieved by means of a standard test and checkout language which could be employed both on the ground and onboard the spacecraft. Since a ground version of the test and checkout language already exists, it is recommended that the possibility of use of this test and checkout language for the onboard system be investigated. In addition, any needed extensions to the language, which would make it more useful either on the ground or onboard, should be defined. Development of malfunction analysis routines and the extension of the number and type of test execution programs can be undertaken using existing equipment. The data display and system control techniques previously discussed represent only a few of many such applications already in existence or in the planning stage. They are the result of a survey undertaken as part of this study, but this survey was by no means exhaustive and additional study is recommended. Near-term recommendations are:

- Begin definition phase for required onboard/ground test and checkout language
- Begin development of malfunction analysis routines
- Extend test execution programs
- Begin survey of applicable data display techniques.

Long-term recommendations deal almost exclusively with the operating system itself. The ease with which an operating system can be used is often an inverse function of the generality of that operating system. If an operating system is designed to handle all possible cases of input data, program execution type of job type, the result can be that to describe any particular job to the operating system a language almost as complex as a complete programming language is required. If, on the other hand, reasonable constraints as to data set type, job execution type, etc.

can be set because of prior knowledge of the type of work to be run on the system, then the operating system can be made smaller, more efficient and more easily used. Finally, if the operating system implemented at KSC can be similar to the operating systems in use at other scientific computing centers, it is possible that much programming work, which has been done elsewhere, can be applied at KSC. Each of these operating system characteristics is in itself an important area for study. If a good balance of required characteristics can be achieved, considerable savings can be realized over the course of the 1975-1985 decade. Long-term recommendations define operating system specifications for:

- Compatible operating system subsets
- Trade-offs between generality and system size
- Compatibility between KSC system and other operating systems.

7.4 HARDWARE

In a decentralized system, each section in the space vehicle and each unique source of input data has a section of the total checkout equipment system devoted specifically to it. In some cases, this dedicated checkout equipment is built into the system to be tested. The checkout equipment in turn routes data to the displays and Launch Control Center consoles. The checkout equipment shown in Figure 16 may be either general-purpose digital computers, specially-built hardwired computers, or combinations of the two.

7.4.1 Centralized System

In a centralized system, all data input to the system from whatever source is routed by means of conventional interleaving equipment to one or more processing units which comprise the central processing complex. In turn, the central processing complex routes data through the interleaving system to the Launch Control Center consoles and displays and to the vehicle itself. In this type of system, specific data is routed to a particular processor. Similarly, each processor controls some number of displays and launch control consoles. If system reconfiguration is required, this is usually accomplished by means of patch panels or recabling. Figure 17 shows a conventional centralized system.

7.4.2 Data Identifier System

The Data Identifier System shown in Figure 18 is a centralized system but differs from the conventional centralized system in that the data can be routed to or from any processing unit to any console or display under program or console operator control. The data identifier unit and the data routing and switching unit depicted in this chart perform functions identical to that of a programmable decommutator. Programmable decommutators have been used in other systems at KSC, notably the ACE System. A more detailed description of the Data Identifier System follows.

Figure 19 offers a more detailed look at the method employed in the Data Identifier System for routing data between data sources and computers, consoles, displays, and the vehicle. Incoming data is tagged upon receipt with a functional ID which describes the data as to type and record length. When the incoming data is received at the data routing and switching unit, a table search is made to determine if the function identification is valid. At the same time that the validity of the functional identification is checked, a destination address for that data is also obtained. Once the destination address is known, the necessary route is set up to transfer the incoming data to the appropriate destination. This destination can be either one of the computing units or one of the consoles, displays, or a recording device. For data being output from one of the computing units, a similar process is followed except that the functional identification is appended to the message by the computer itself or to an input/output unit which is a part of the I/O adapters for the consoles and displays. The verification of identification and the data destination is obtained from the output table in the same way as is done for input data. The address tables for both output and input can be updated under program control from the processors or manually from the control consoles. In this way, the console operator has the option of overriding the programmed address settings should that be required.

7.4.3 System Comparison

Table 7-1 shows a comparison of the characterisitcs of the decentralized, conventional centralized and data identifier systems. Because of the specialized nature of the checkout equipment employed in a decentralized system, any new checkout functions require additional checkout equipment. Spares for each of these specialized pieces of checkout equipment must be carried, and maintenance problems are increased. The overriding disadvantage of a decentralized system is its lack of flexibility and growth potential. The conventional centralized system and the data identifier system are seen to have similar advantages and disadvantages. However, the data identifier system offers very rapid system reconfiguration, the ability to switch system application from one type of checkout task to another is of primary importance when support for multiple missions and in-orbit support concurrent with vehicle checkout and other multiple tasks are considered. It is also possible that the rapid switching between the primary checkout computer and a backup computer will permit other applications to be run on the backup system without impairing its ability to take over the primary checkout process should the main checkout processor fail. Because of its greater flexibility and rapid turn-around time, the data identifier system or flexible decommutator system is considered to be the best of the three systems postulated here.

7.4.5 Recommendations

Before discussing in detail the recommended ground system configuration, it is necessary to define what is meant by a basic processing unit. By using the data depicted in Figure 20 and by factoring in specific information concerning the individual computers listed here, a processor which in terms of raw speed and memory capability is equal to the sum of the other computers in the chart is postulated.

The following list shows the characteristics of the composite processor in somewhat more readable form. Note that the estimates made as to processor speed and size are conservative in that no allowance was made for improvement in system thru-put due to improved processor architecture, such as overlapped instruction fetch and executive and instruction stacking:

● Cycle time	0.5μ seconds
● Word size	30 bits
● Main memory	128K words
● Random access storage	
- Drum	1×10^6 words
- Disk	50×10^6 words
● Features	
- Priority interrupt	
- Fail safe	

Figure 21 shows a detailed layout for the recommended ground system configuration. Note that, with the exception of the hardwire backup for critical functions, all other data is routed to and from the computer complex, the firing room consoles and displays, and the vehicle command system by means of the routing switching subsystem. The vehicle command system, shown on the right-hand side of the chart, differs from the existing command system in that hardwares are replaced wherever possible with RF links. The function encoders, function selectors and stage selectors are similar to the carry-near equipment, data transmission and verification converters currently employed in the ACE System.

The checkout processor layout, shown in Figure 22 is conventional to the extent that the stand-by processor is not used for any function other than total backup of the primary checkout processor. Backup functions are carried out in the third processor. It may be possible, through the rapid switching speed of the data identifier system, to eliminate the function of the stand-by processor and to devote it to analysis functions, such as data trending, data logging and retrieval. Should the primary processor fail, the secondary processor, which has been performing analysis functions, can be switched in to perform the functions of the primary checkout processor. The I/O adapters shown are used in conjunction with the data identifier system to verify the functional ID codes which have been appended to the incoming data by the data identifier system. The data compare units perform both discrete and non-discrete comparison functions. The data compare units access core storage of the processors to obtain the limits used for checking Dnon-discrete data. Discrete comparisons are done similar to that employed in the Digital Events Evaluator (DEE)-6 comparison unit. In this way, the processors are relieved of as many repetitive time-consuming operations as possible. Each of the processors shown here is on the size and internal speed previously indicated for a standard checkout processor unit. By 1975, processor units of the approximate size and speed should represent the middle of the commercial line for most manufactures are thus well within the state of the art.

Table 7-1. System Characteristics

DECENTRALIZED	CONVENTIONAL CENTRALIZED	DATA IDENTIFIER
● MULTIPLE CHECKOUT EQUIPMENT TYPES	● CHECKOUT BY SINGLE PROCESSOR TYPE	● CHECKOUT BY SINGLE PROCESSOR TYPE
● BACKUP REQUIRES DUPLICATION OF EACH DEDICATED SYSTEM	● BACKUP REQUIRES DUPLICATE PROCESSOR OPERATION	● RAPID SWITCHING PERMITS OTHER USE OF BACKUP PROCESSOR
● CHANGE IN FUNCTIONAL LOAD REQUIRES CHANGE IN CONFIGURATION	● BASIC SYSTEM CAPABILITY LIMITED TO CAPACITY OF INDIVIDUAL PROCESSORS	● BASIC SYSTEM CAPABILITY LIMITED TO CAPACITY OF INDIVIDUAL PROCESSORS
	● SYSTEM TURN-AROUND LIMITED BY MANUAL OPERATION	● SYSTEM TURN-AROUND UNDER PROGRAM CONTROL
	● SYSTEM GROWTH CAN REQUIRE ADDITIONAL INTERFACE EQUIPMENT	● INTERFACE EQUIPMENT CAN INCLUDE GROWTH CAPABILITY

SECTION VIII

SYSTEM IMPLEMENTATION PLAN

8.1 PLAN A

Consider two possible transition plans involving existing computer hardware. The first plan is centered upon the central processing unit used for the DEE-6 System, that is the SDS 930 System. A single SDS 930 processor would be upgraded by providing random access storage by developing a discrete and digital data interface and a Sanders Display interface. An upgraded SDS 930 System of this type could be installed in either Firing Room 3 or 4. This processor would then be used to develop software required for test and checkout as well as display control. Additional SDS 930s would then be upgraded on a one-at-a-time basis, and the checkout load transferred to this system on a phased basis. Salient features of this plan are:

- Develop interface for discrete out and digital data for SDS 930
- Provide random access storage - disk or drum
- Provide Sanders Display interface
- Develop software using single system
- Upgrade additional SDS 930s and transfer load on phased basis.

The main advantage of this transition plan is that the basic computer hardware is available and can be used on a non-interference basis. Its primary disadvantage is that the system, once installed and employing four SDS 930 processors, would have a capability about equal to the present system. In view of the cost of the effort required to develop a new system based on the SDS 930 processors, the resulting system does not represent a sufficient improvement over existing systems. Salient advantages are:

- Basic hardware is already available in LCC
- Minimum interference during development
- Trained programmers available.

Disadvantages of Plan A are:

- Limited system - maximum capability about equal to present system
- Need to obtain costly mass storage equipment
- High level software support is minimal
- Second generation equipment.

8.2 PLAN B

A second possible transition plan centers about the GE 635 processors installed at the CIF. In this plan, the primary hardware emphasis would be placed upon the RF link between the CIF, and the transmitters and receiver would have to be upgraded to include uplink command capability and the availability of all measurements on the downlink. The receivers at the LCC would have to be upgraded to provide interface with the LCC display equipment. Once the RF link had been upgraded as indicated, it would be then possible to develop software for the GE 635 to be used in vehicle checkout. The system could then be tested using firing room 3. Salient features of Plan B are:

- Extend RF link between CIF and LCC to include uplink command capability and total downlink availability
- Interface LCC display equipment with CIF RF link
- Develop GE 635 software for vehicle checkout and test using firing room 3.

This is an attractive plan in that the GE 635s represent large, modern computer systems with a high level of software system support. Hardware expenditures would be limited to the RF link between the CIF and the LCC. The major disadvantage of this plan is that the GE 635s are both launch mandatory items and cannot be considered to be available during CDDT and Launch Countdown for developmental work. Advantages are:

- Computer system complete - add only to RF link
- High level software system available
- Third generation computer hardware.

The disadvantage of Plan B is:

- Interference with launch mandatory function - guidance and navigation computer

The following recommendations are based upon two premises: first, that a new checkout system cannot be developed without the acquisition of additional computer processor hardware; and second, that the problem of data transmission between consoles and processors, and processors and the vehicle and other data sources represents an area for development at least of equal importance to that of the computer processors themselves. The recommendations for ground system development can, therefore, be divided into two groups. The first group consists of the first three items, that is, data acquisition, improved transmission systems and software techniques development. These three items can be accomplished in any order, but it is our recommendation that all three areas be thoroughly investigated before attempting computer hardware replacement. Software techniques can be developed and data routing systems tested using Firing Room 3 as a test bed. One of the available SDS 930 processors would serve as an interim computer processor for such a test bed. Recommendations are:

- Ground system should be developed in this order

  - Data acquisition and routing system
  - Improve transmission systems
  - Software techniques development
  - Computer hardware replacement

- Test bed for ground system using Firing Room 3

- SDS 930 would serve as interim processor for test bed.

SECTION IX

RECOMMENDATIONS FOR FURTHER EFFORT

Specific areas requiring developmental activity and further study have been uncovered during the progress of the study. They are defined in the following paragraphs.

9.1 TECHNOLOGY DEVELOPMENT

The pressures from the non-aerospace market may not be sufficient to develop certain technologies which now appear attractive for Space Station/Space Base Application. Attention and encouragement should be directed to the following areas to ensure an adequate technology base for both the near-term and long-term missions:

- All-electronic bulk storage
- Ovonic technology potential
- Parallel processor computer architecture
- Coherent optical communication techniques
- Real-time holographic image construction
- Television and optical image resolution.

9.2 SYSTEMS DEVELOPMENT

Simulation technique development should be undertaken which addresses the problem of system verification for one-of-a-kind vehicles, e.g., Space Base Modules. The interfaces between stages and modules as well as those between modules and ground systems warrant attention.

The development of automated malfunction isolation and trend analysis techniques for large scale systems should continue.

9.3 FURTHER STUDY

It is recommended that the system concepts developed in this study be further refined in the light of the results of the current Space Station Program Definition (Phase B) Studies. The practical limitations of onboard checkout system utilization in the prelaunch mode warrant particular attention.

The nuclear-powered, post-1985, Manned Mars Mission should be addressed via the same methodology applied to the Space Station/Space Base Mission in this study. The potential interdependencies between the planetary modules and the Space Base should be analyzed in depth.

The extension of the study into the consideration of the potential application of the centralized ground computer complex for launch site support of a Space Station Module - Space Shuttle mix is most strongly recommended. The practical limitations of the Shuttle's onboard checkout system utilization warrants attention. Potential ground computer system support, both off and on-line, should be considered.

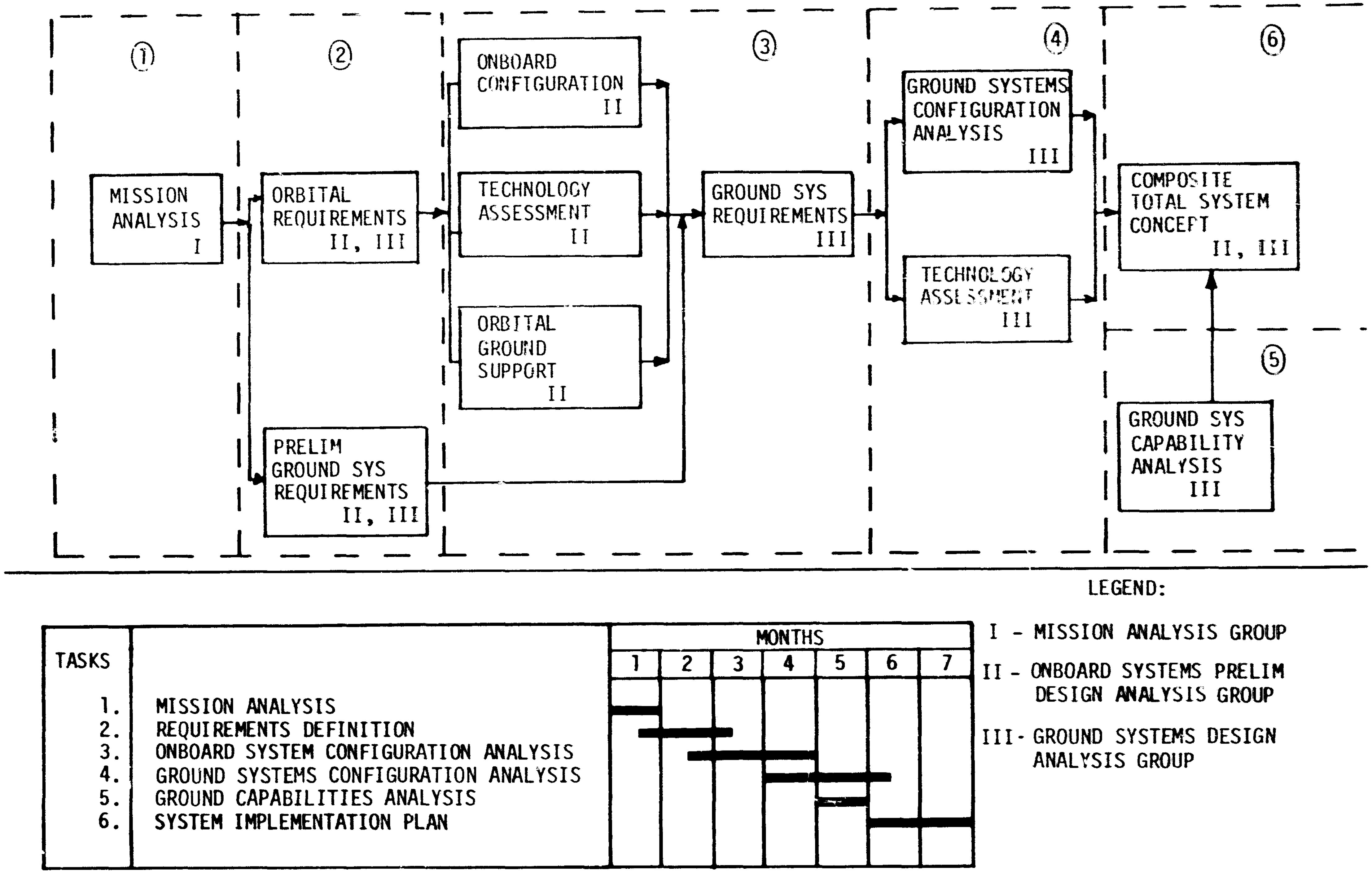


Figure 1. Orbital/Ground Checkout Study Approach

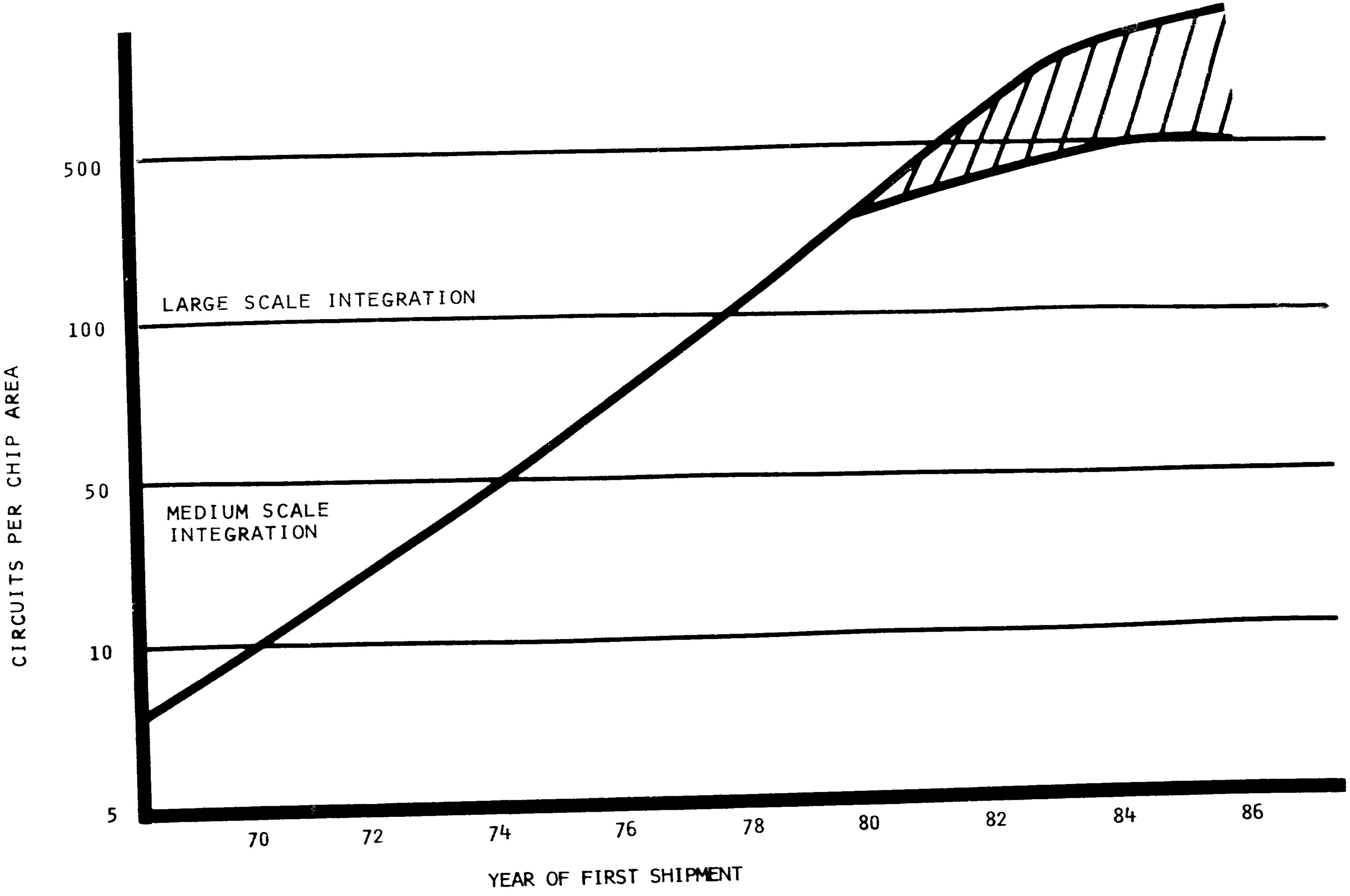


Figure 2. Integrated Circuit Technology Projection

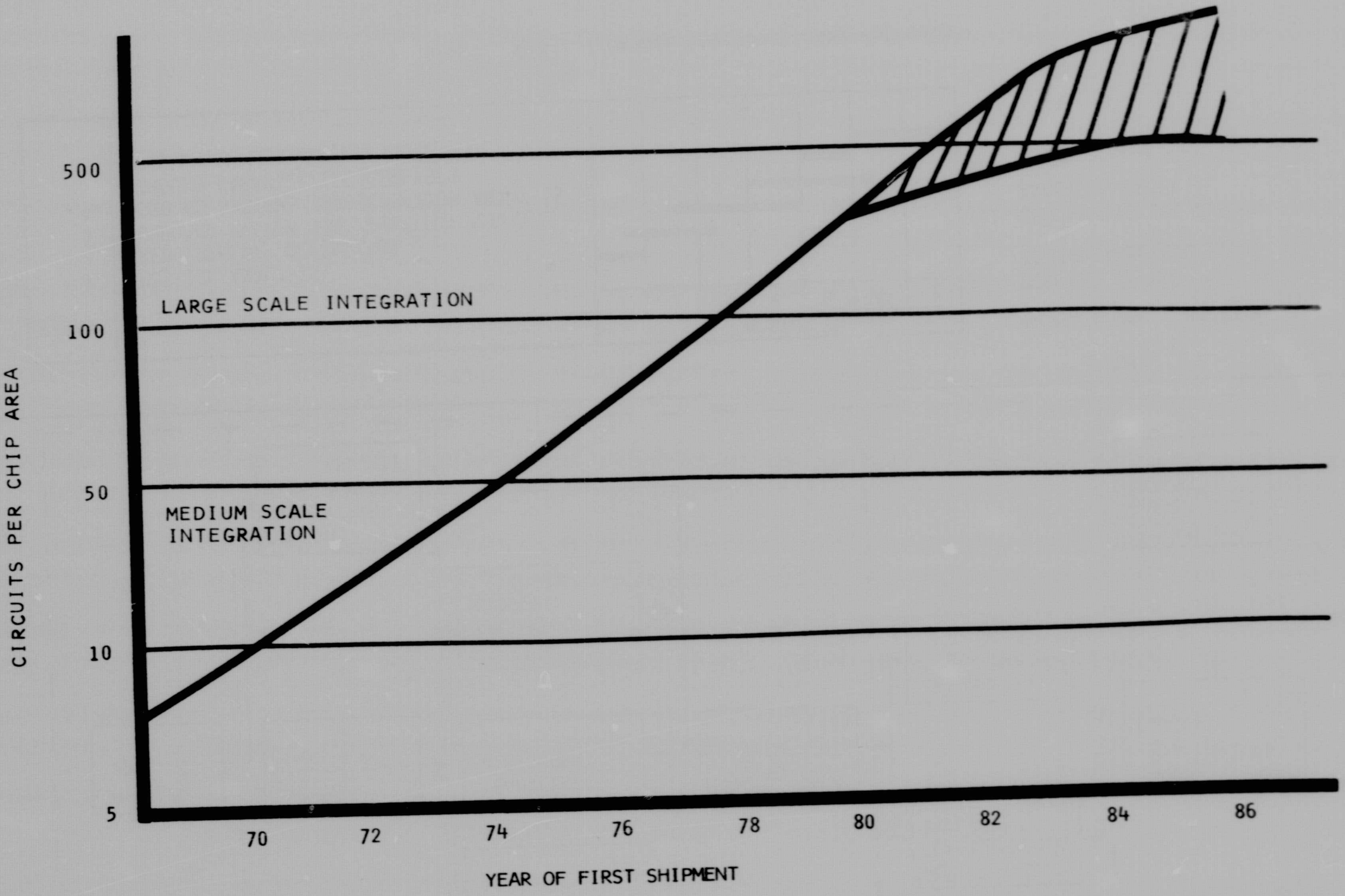


Figure 2. Integrated Circuit Technology Projection

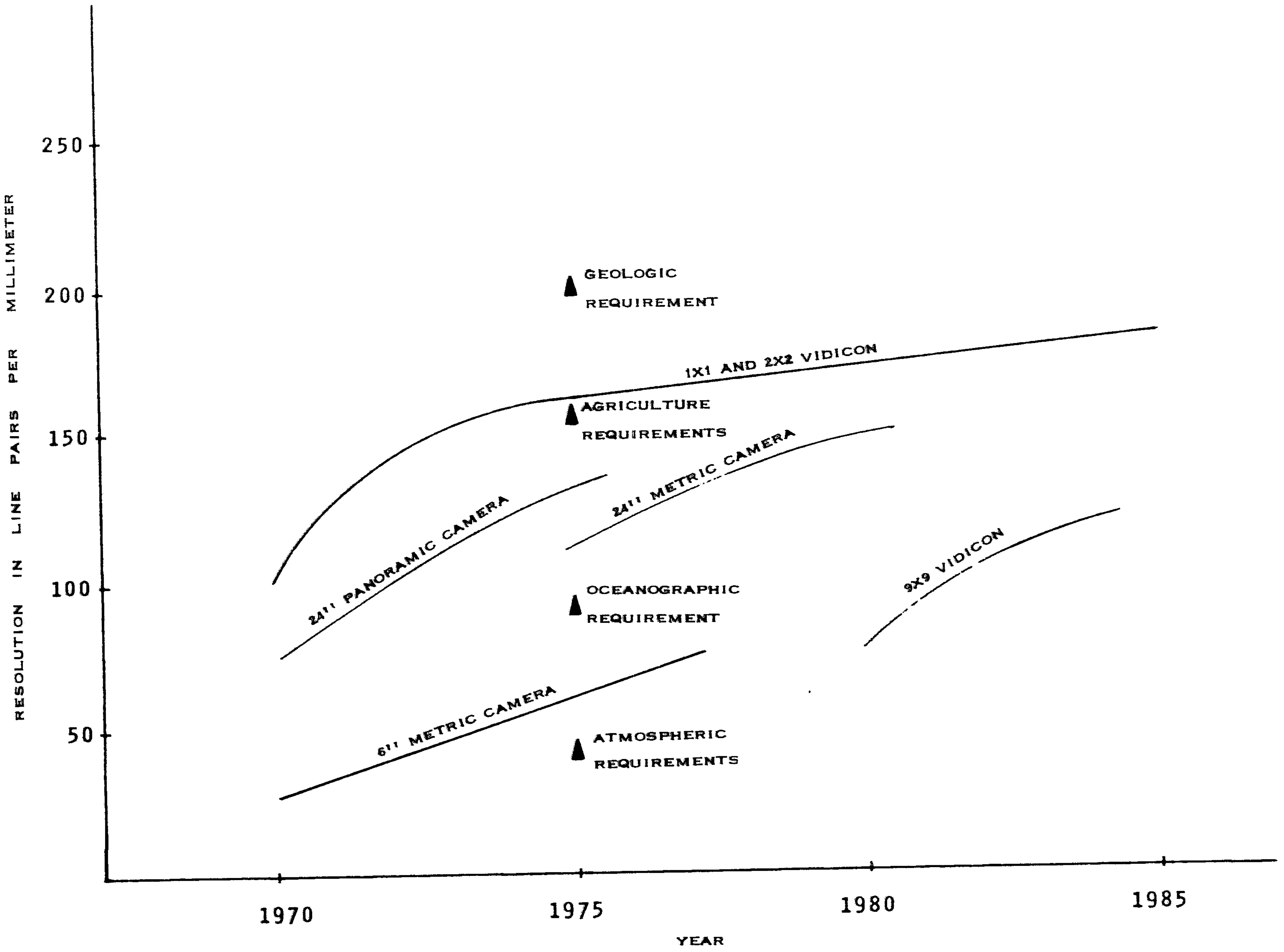
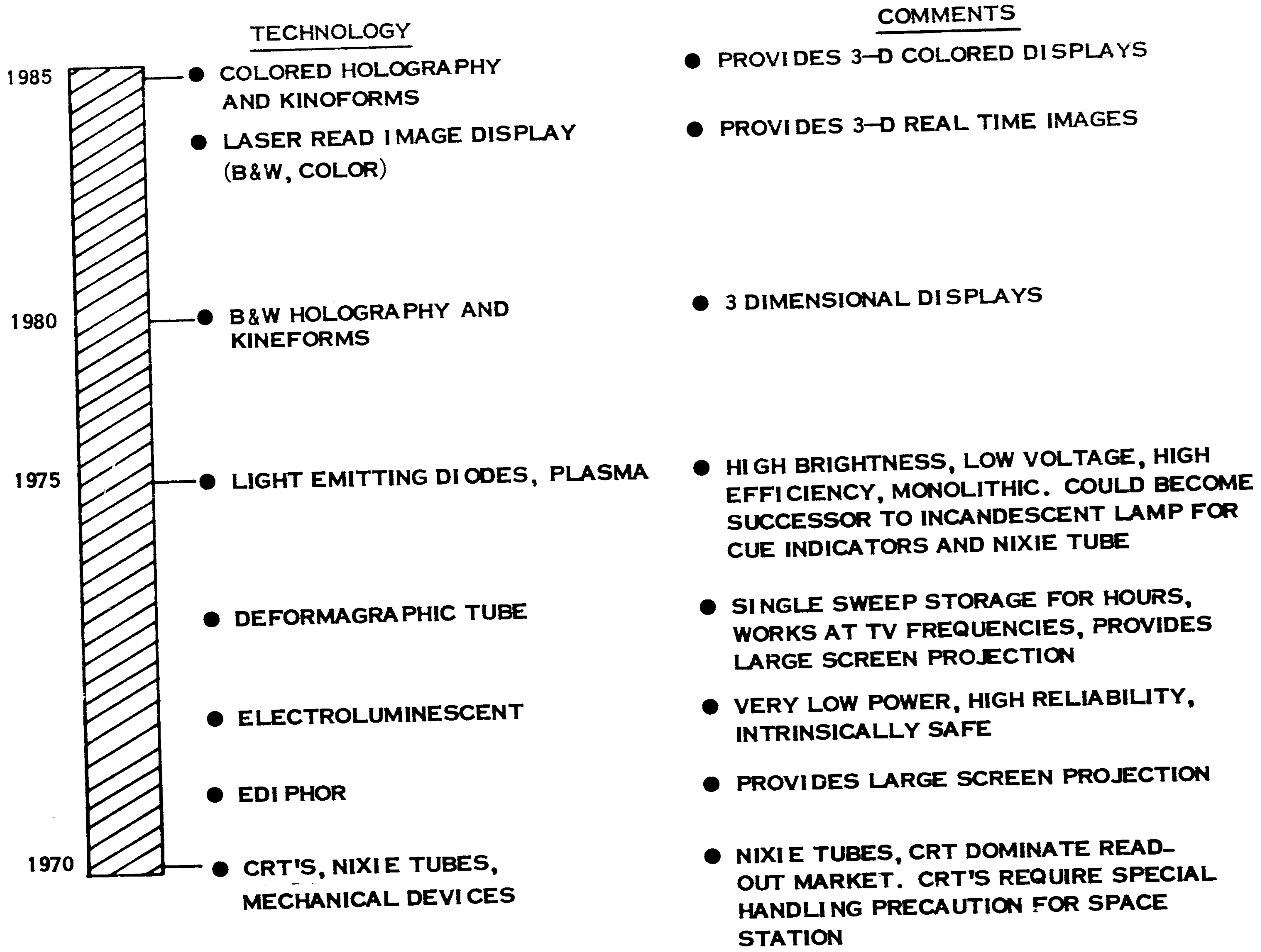


Figure 3. Optical System Resolution Projection



	TECHNOLOGY	COMMENTS
1985	● COLORED HOLOGRAPHY AND KINOFORMS	● PROVIDES 3–D COLORED DISPLAYS
	● LASER READ IMAGE DISPLAY (B&W, COLOR)	● PROVIDES 3–D REAL TIME IMAGES
1980	● B&W HOLOGRAPHY AND KINEFORMS	● 3 DIMENSIONAL DISPLAYS
1975	● LIGHT EMITTING DIODES, PLASMA	● HIGH BRIGHTNESS, LOW VOLTAGE, HIGH EFFICIENCY, MONOLITHIC. COULD BECOME SUCCESSOR TO INCANDESCENT LAMP FOR CUE INDICATORS AND NIXIE TUBE
	● DEFORMAGRAPHIC TUBE	● SINGLE SWEEP STORAGE FOR HOURS, WORKS AT TV FREQUENCIES, PROVIDES LARGE SCREEN PROJECTION
	● ELECTROLUMINESCENT	● VERY LOW POWER, HIGH RELIABILITY, INTRINSICALLY SAFE
	● EDIPHOR	● PROVIDES LARGE SCREEN PROJECTION
1970	● CRT'S, NIXIE TUBES, MECHANICAL DEVICES	● NIXIE TUBES, CRT DOMINATE READ-OUT MARKET. CRT'S REQUIRE SPECIAL HANDLING PRECAUTION FOR SPACE STATION

Figure 4. Display Technology

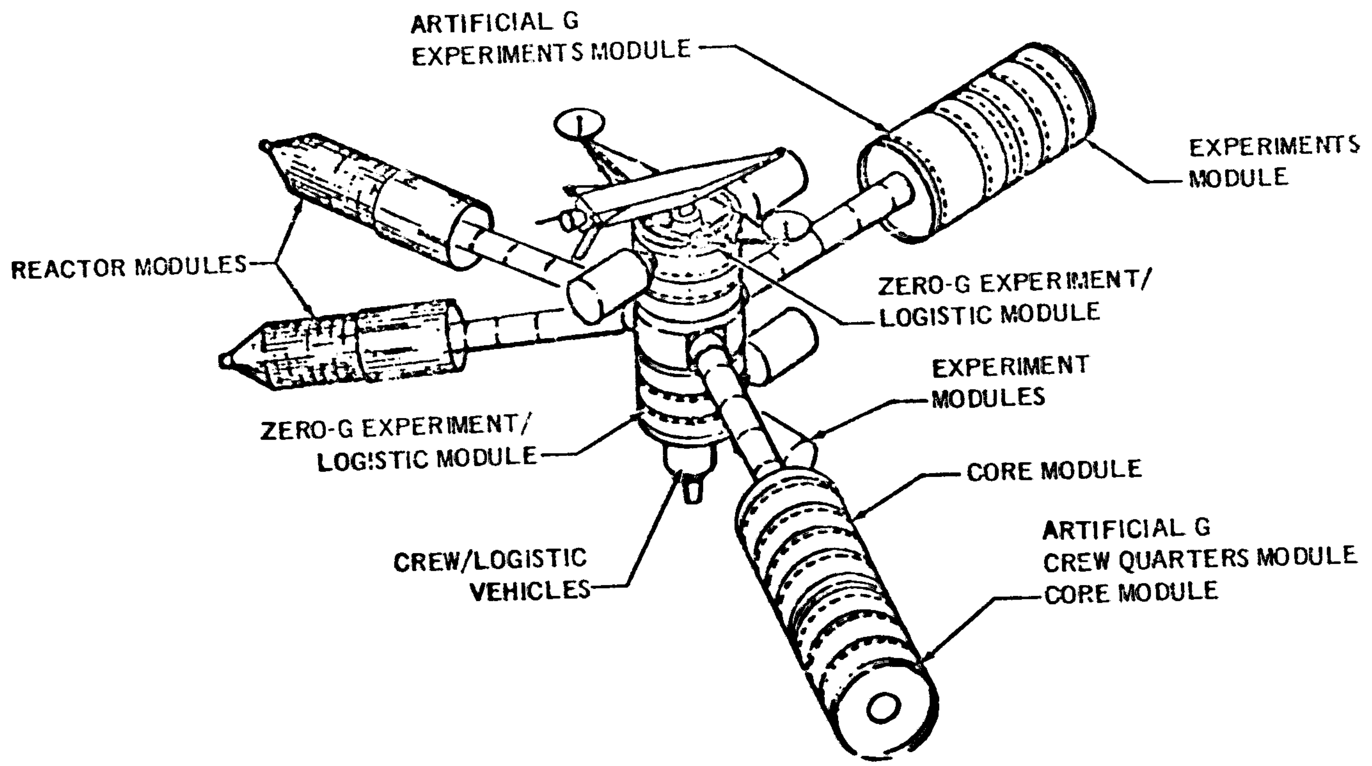


Figure 5. Candidate 1985 Space Base Configuration

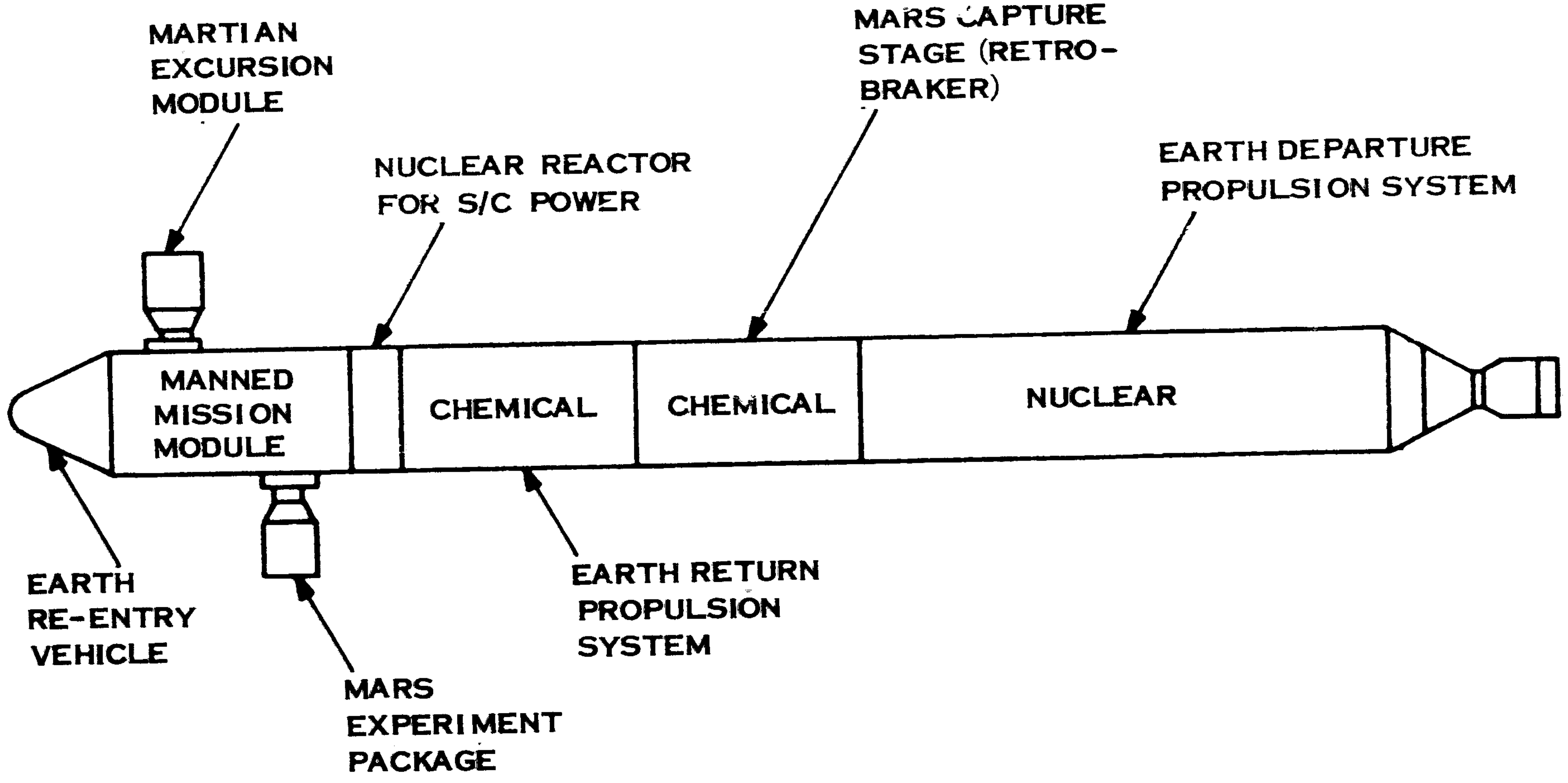


Figure 6. Manned Mars Mission Configuration

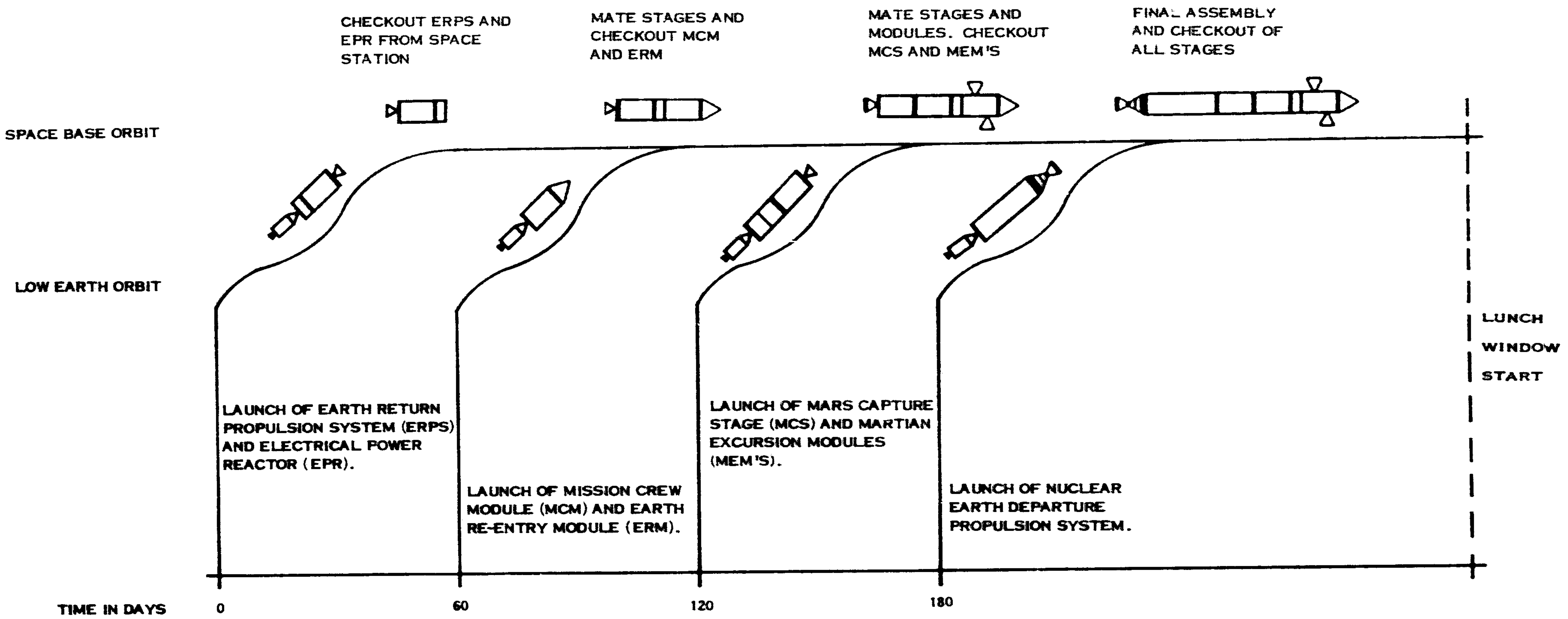


Figure 7. Launch and Assembly Operations for Mars Mission

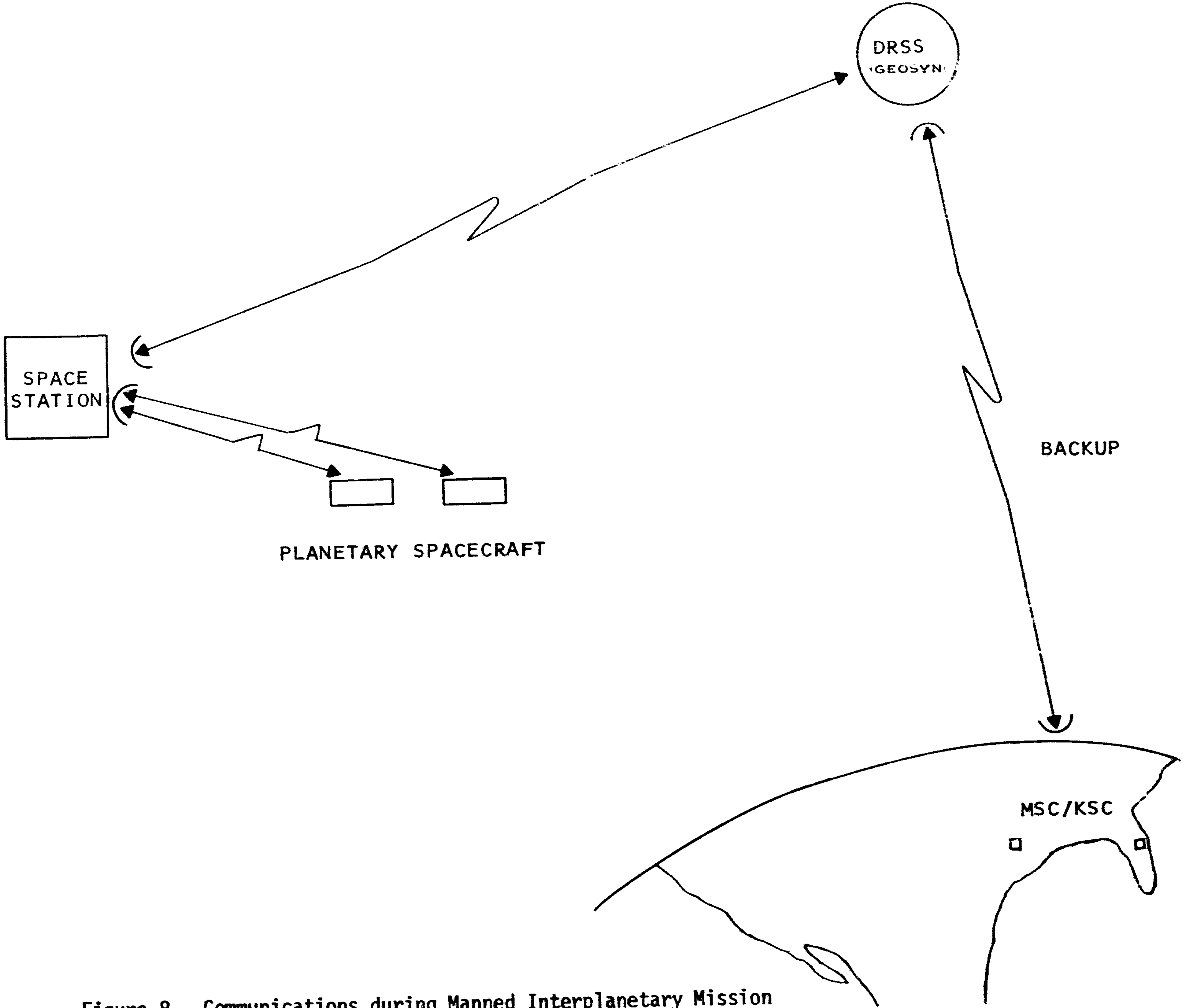


Figure 8. Communications during Manned Interplanetary Mission

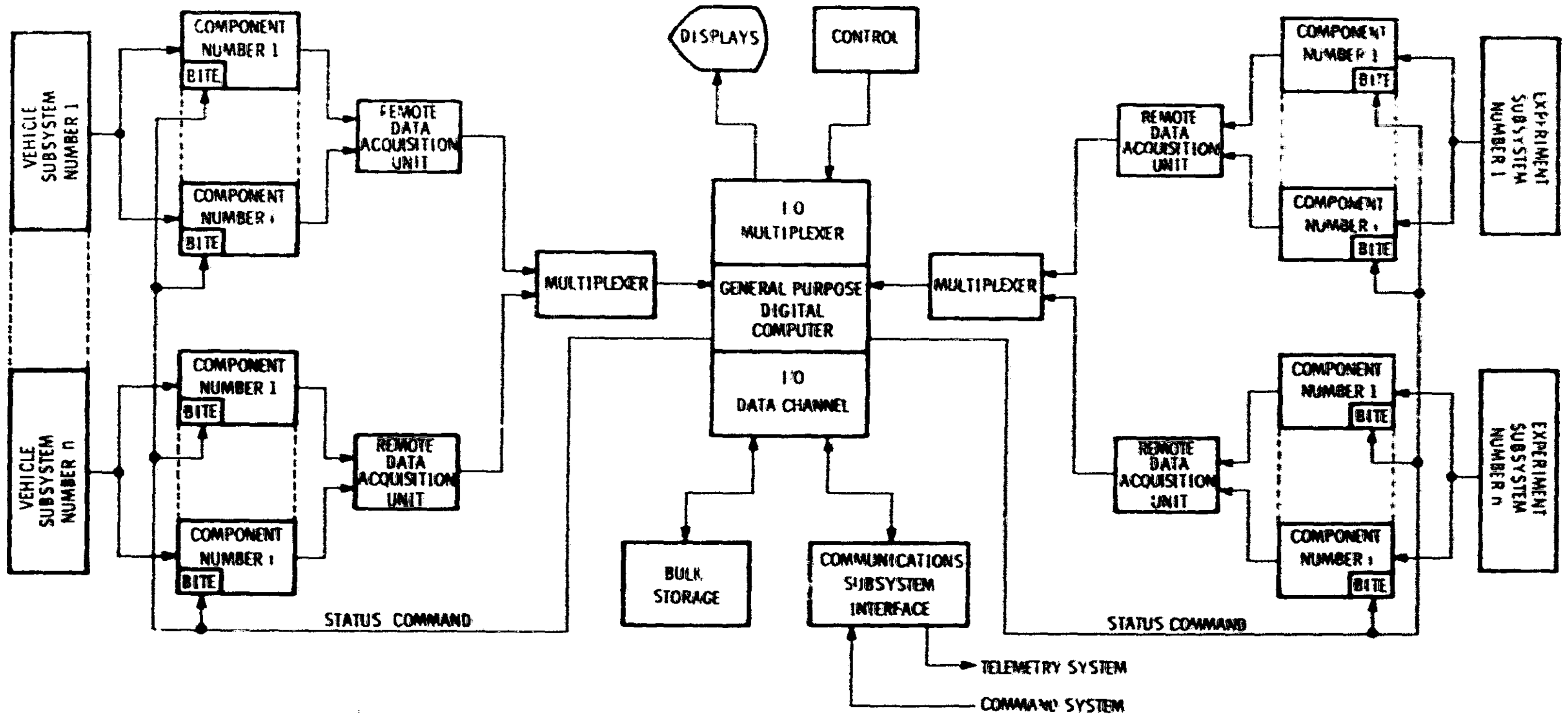


Figure 9. Concept A

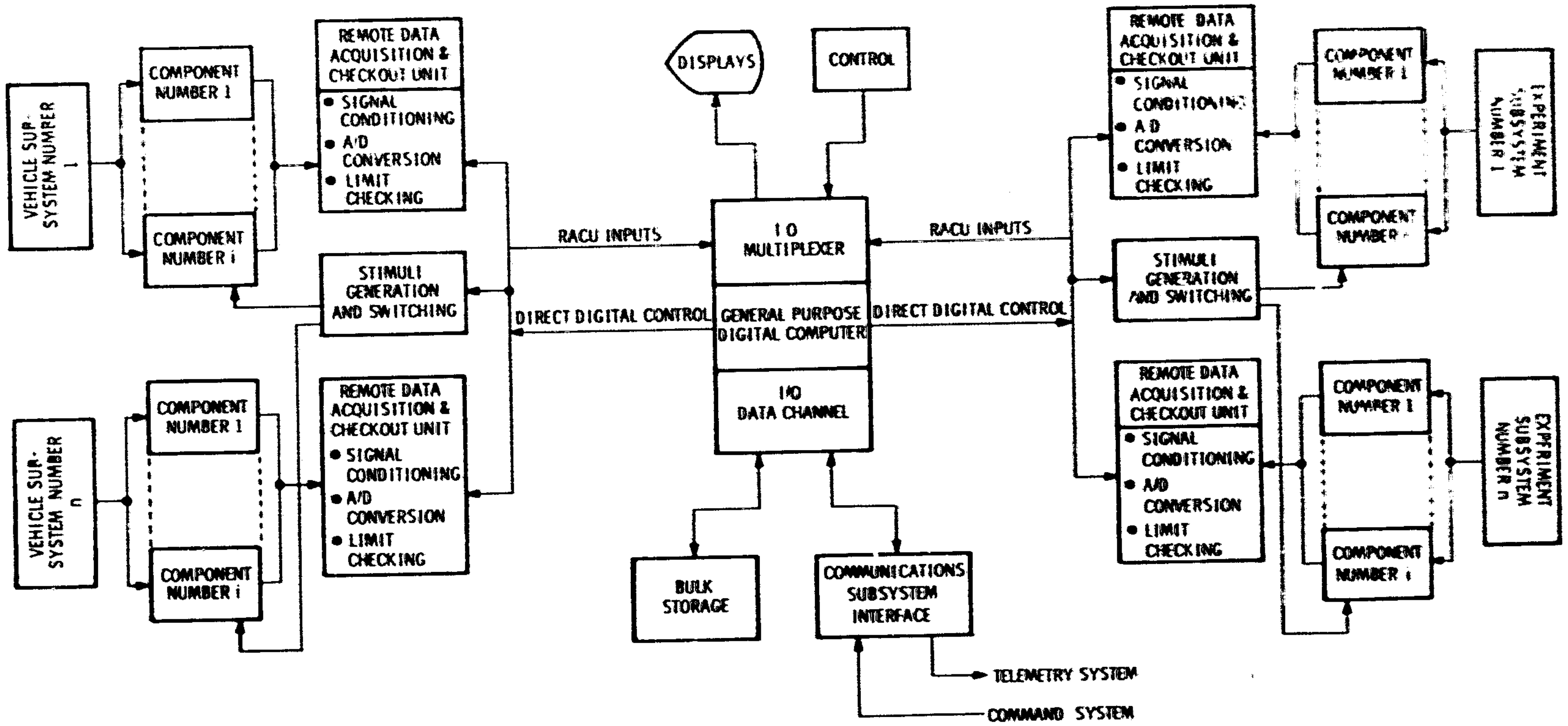


Figure 10. Concept B

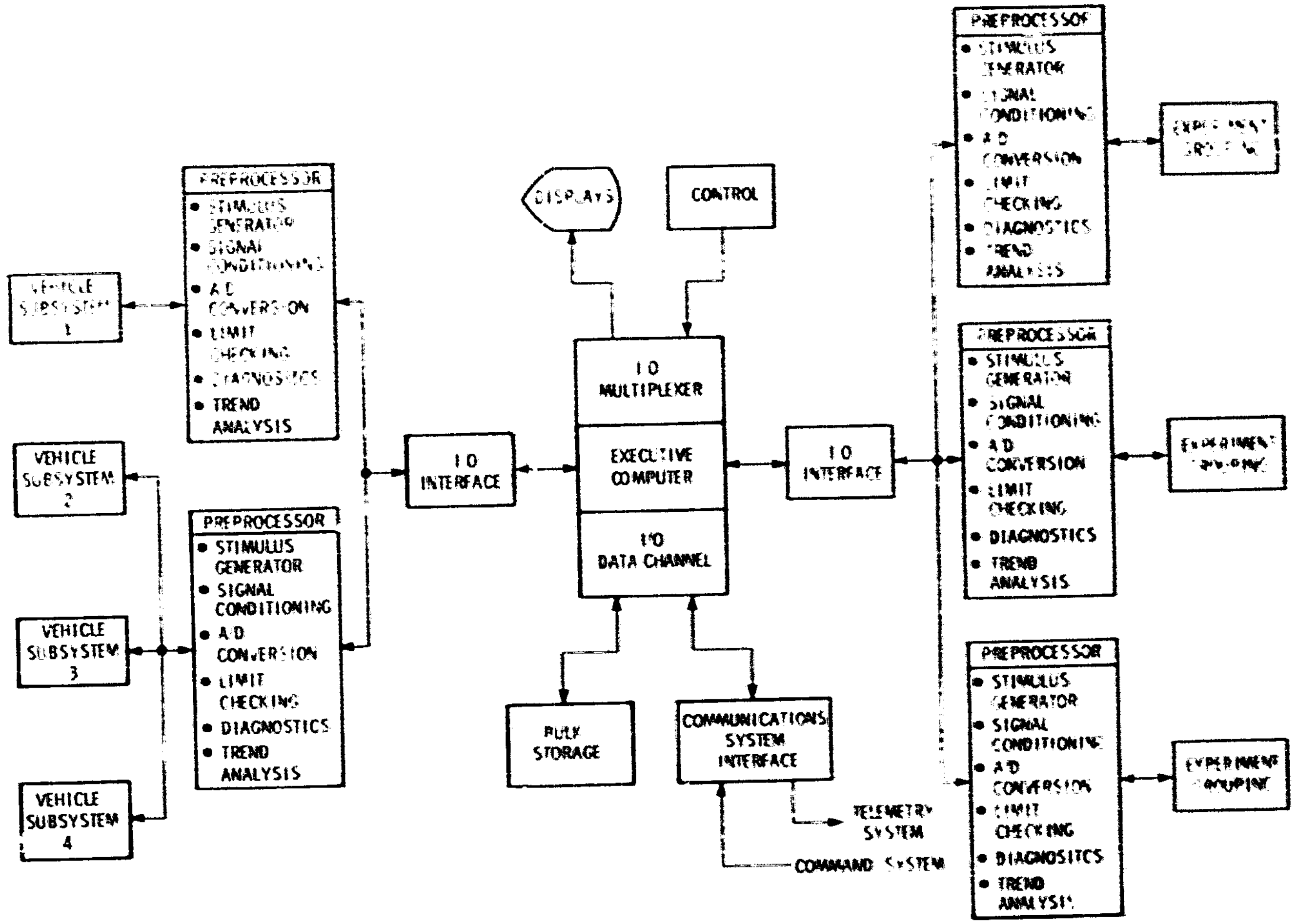


Figure 11. Concept C

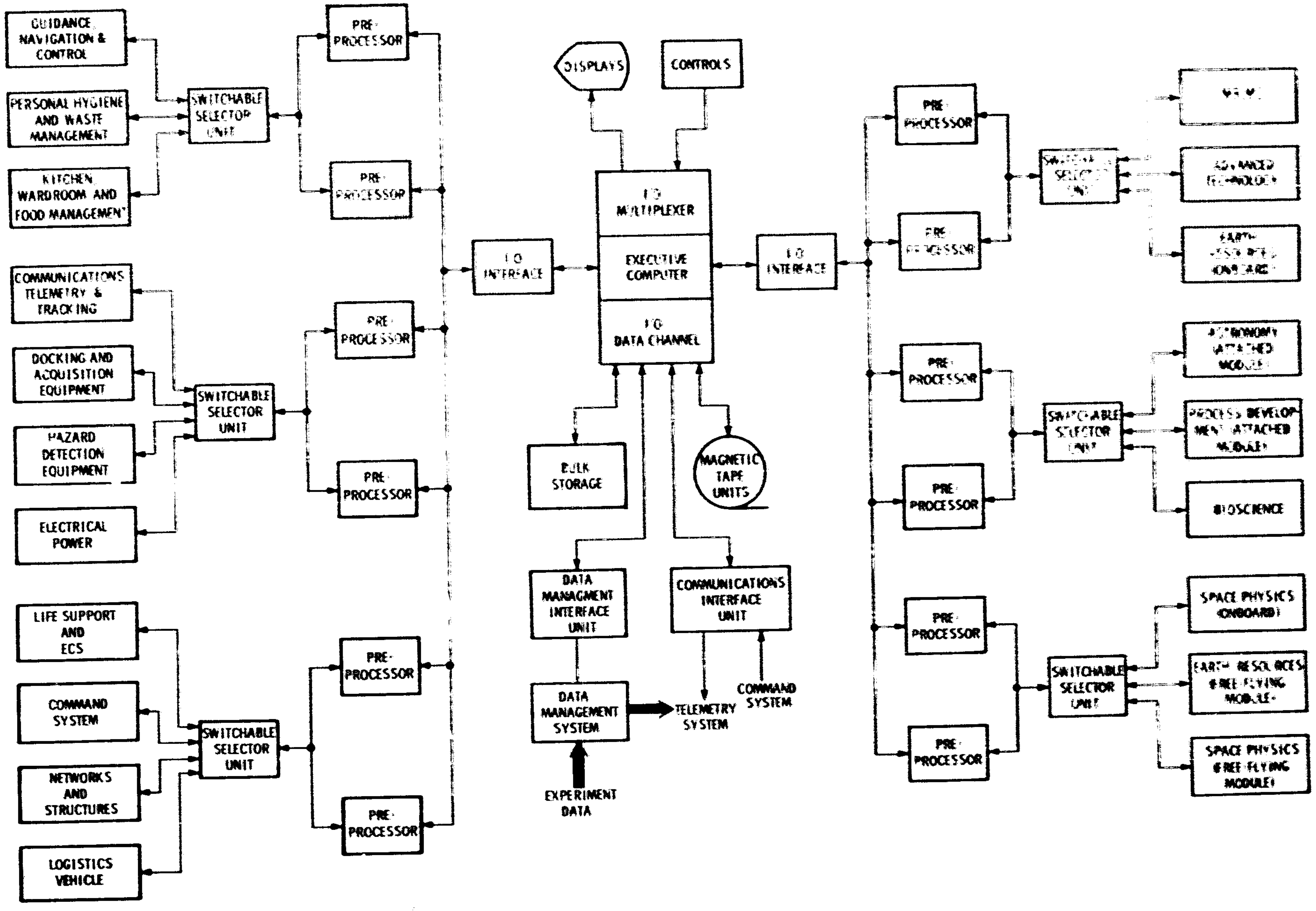


Figure 12. Onboard Configuration

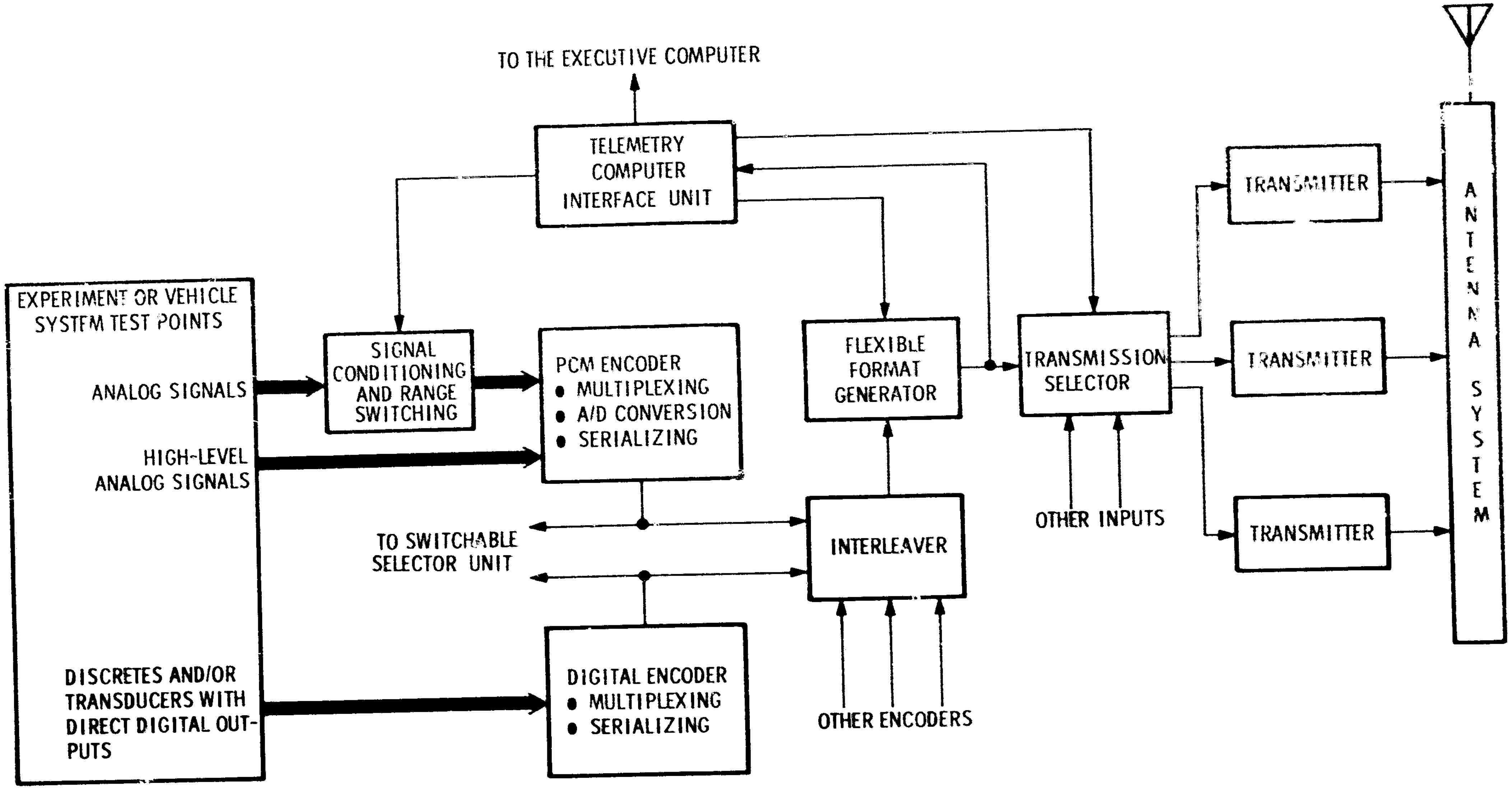


Figure 13. Candidate Telemetry System

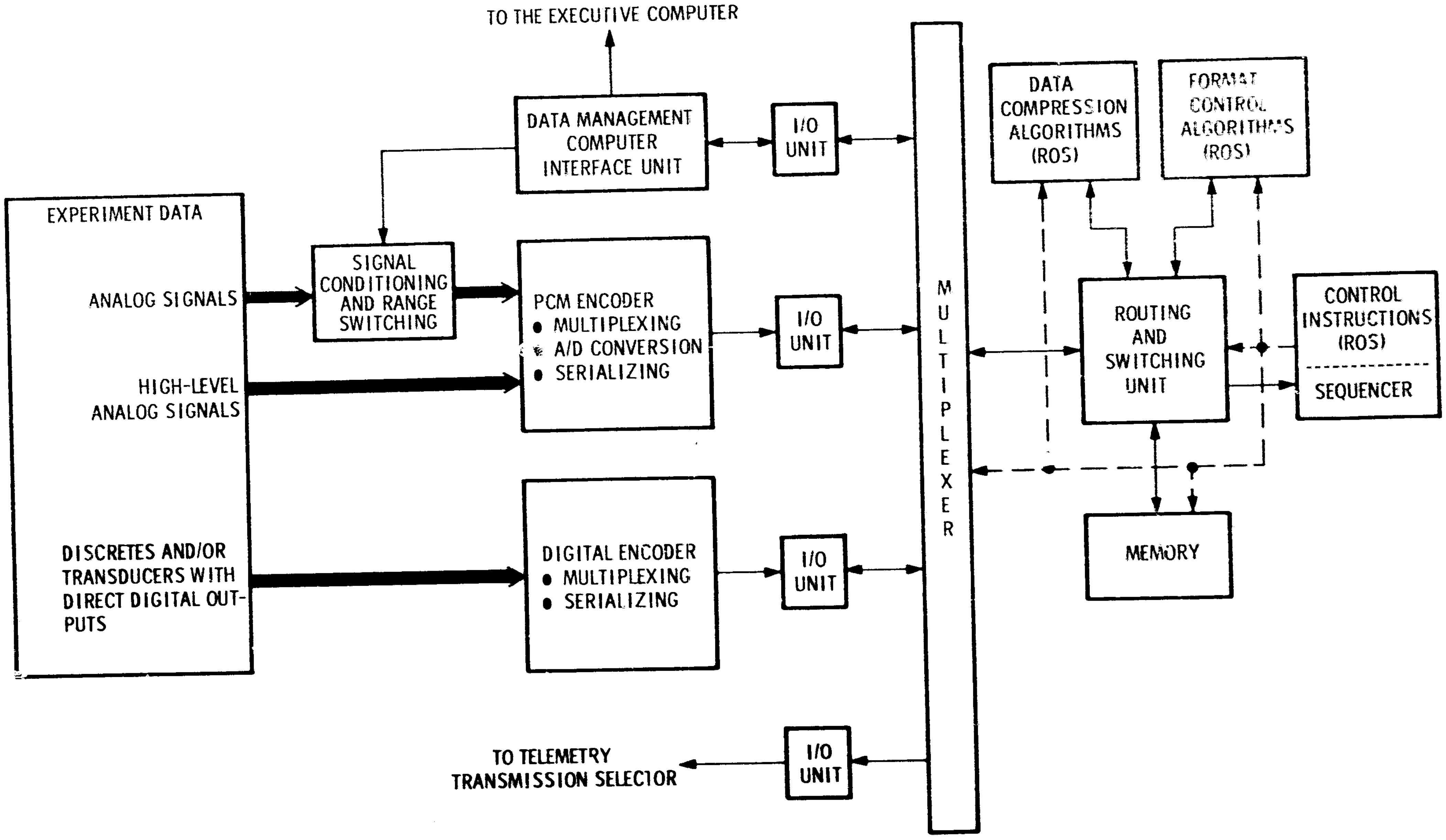


Figure 14. Candidate Data Management System

EVOLUTIONARY TREND FOR SPACE STATION TEST POINTS MONITORED ON BOARD AND BY GROUND STATIONS

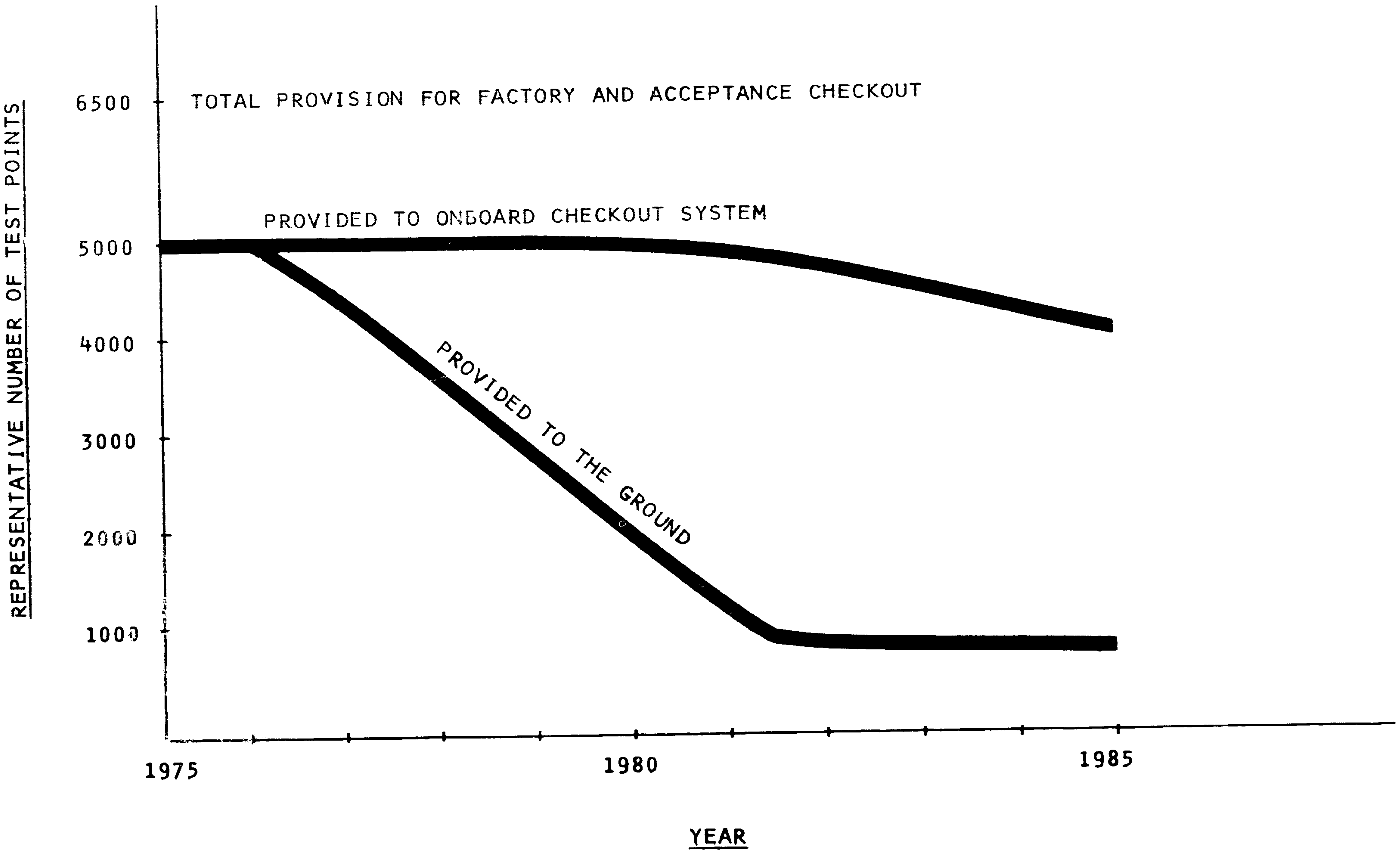


Figure 15. Onboard/Ground Monitoring Evolution

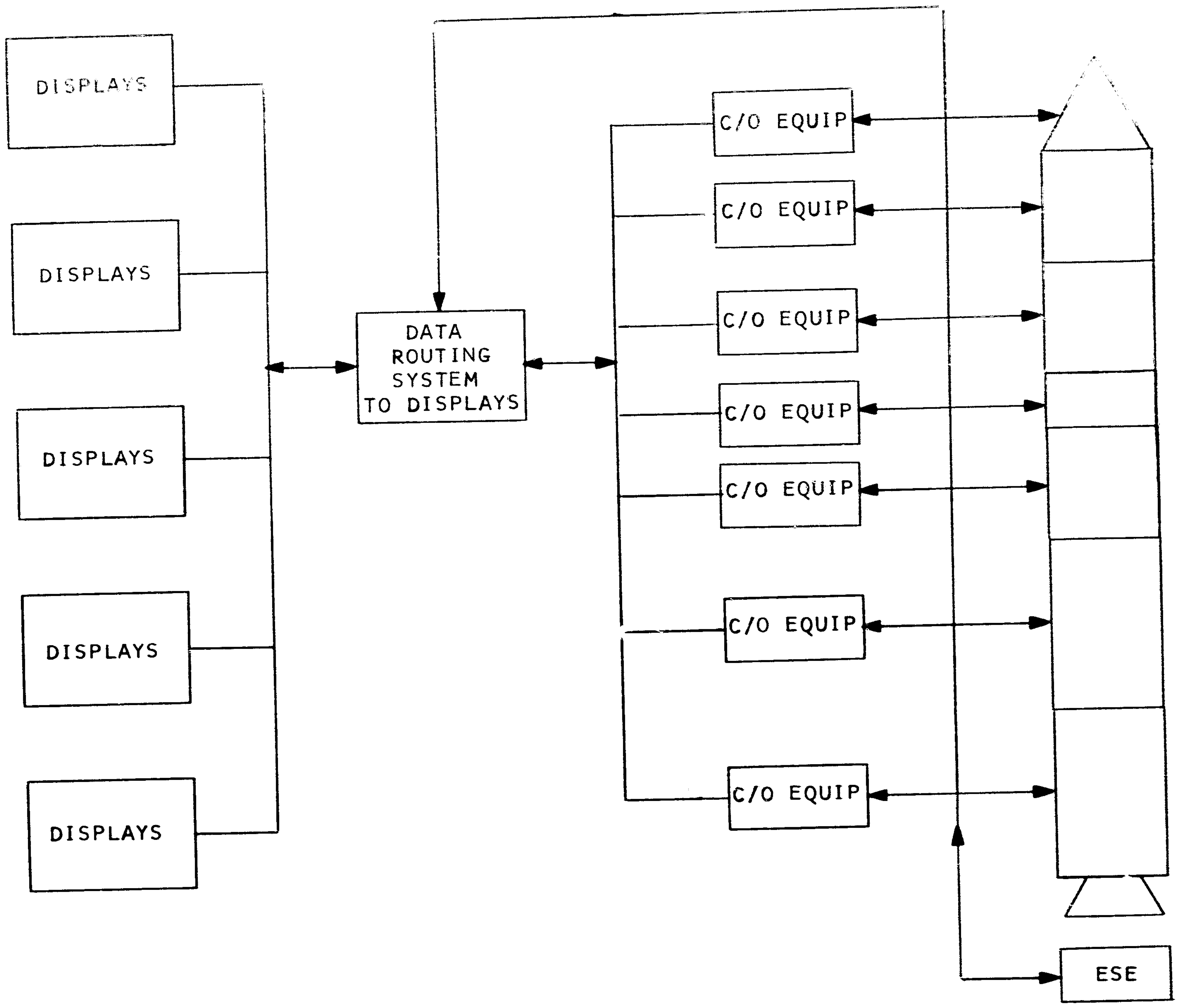


Figure 16. Decentralized System

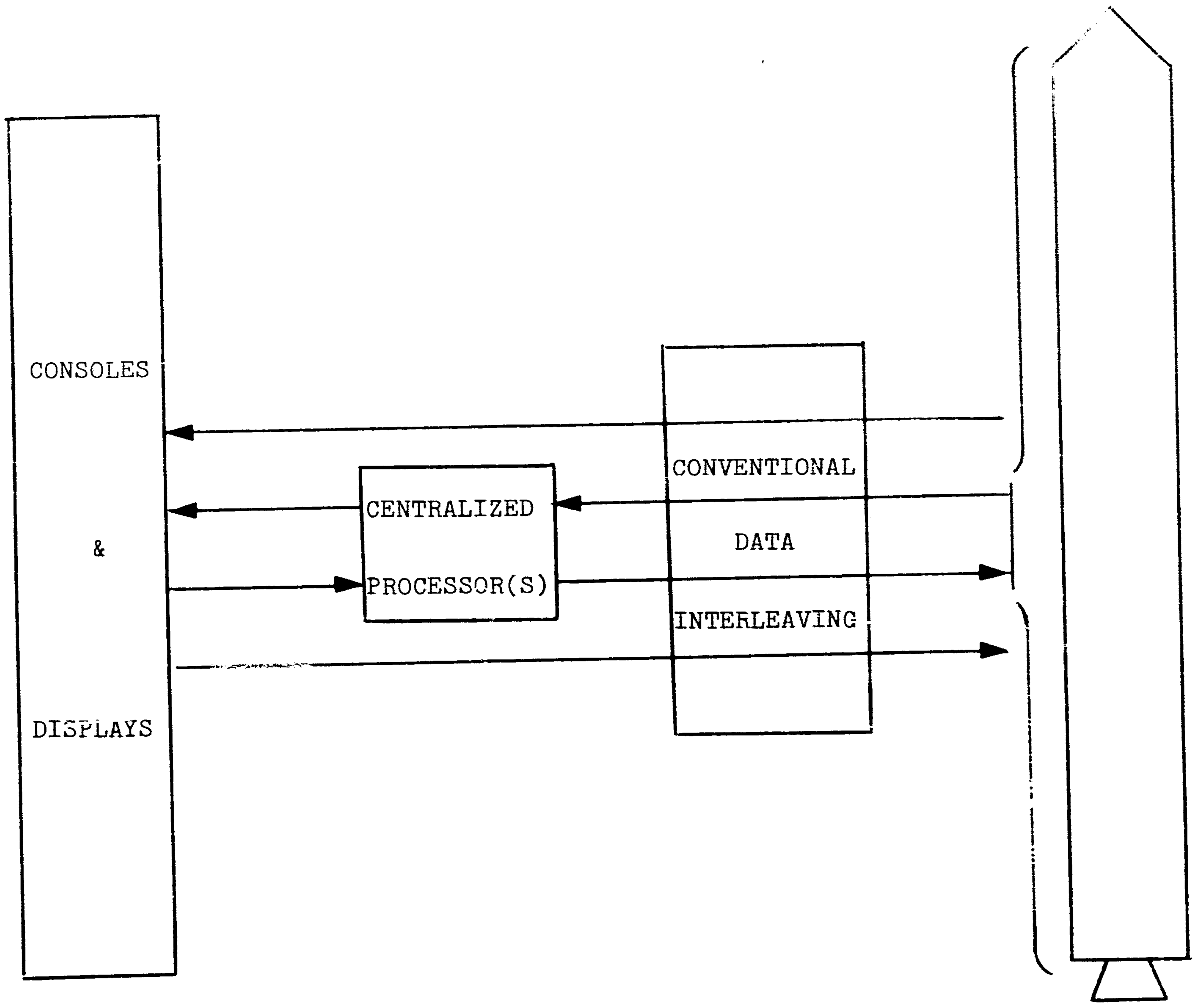


Figure 17. Conventional Centralized System

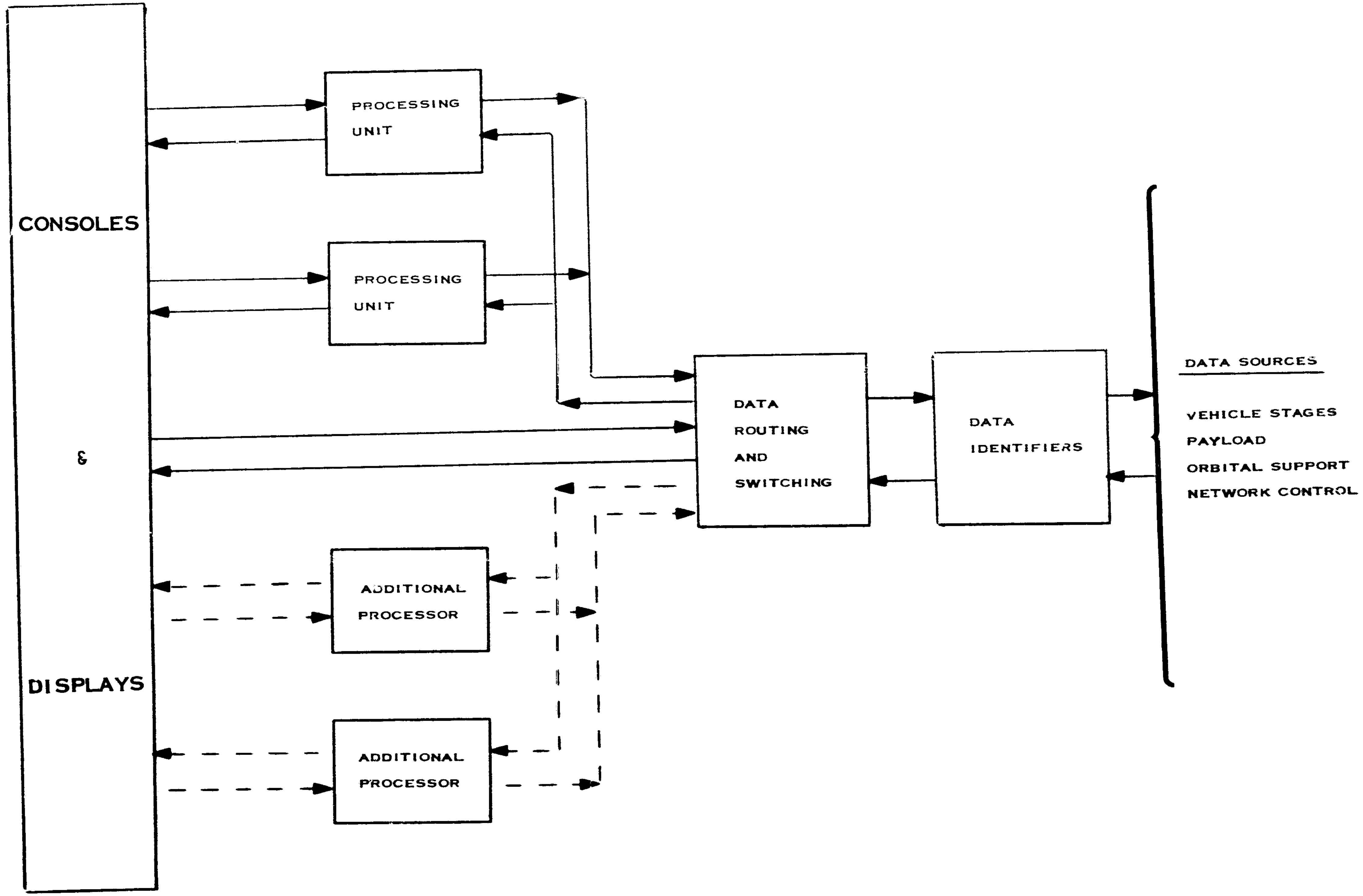


Figure 18. Data Identifier System (Simple)

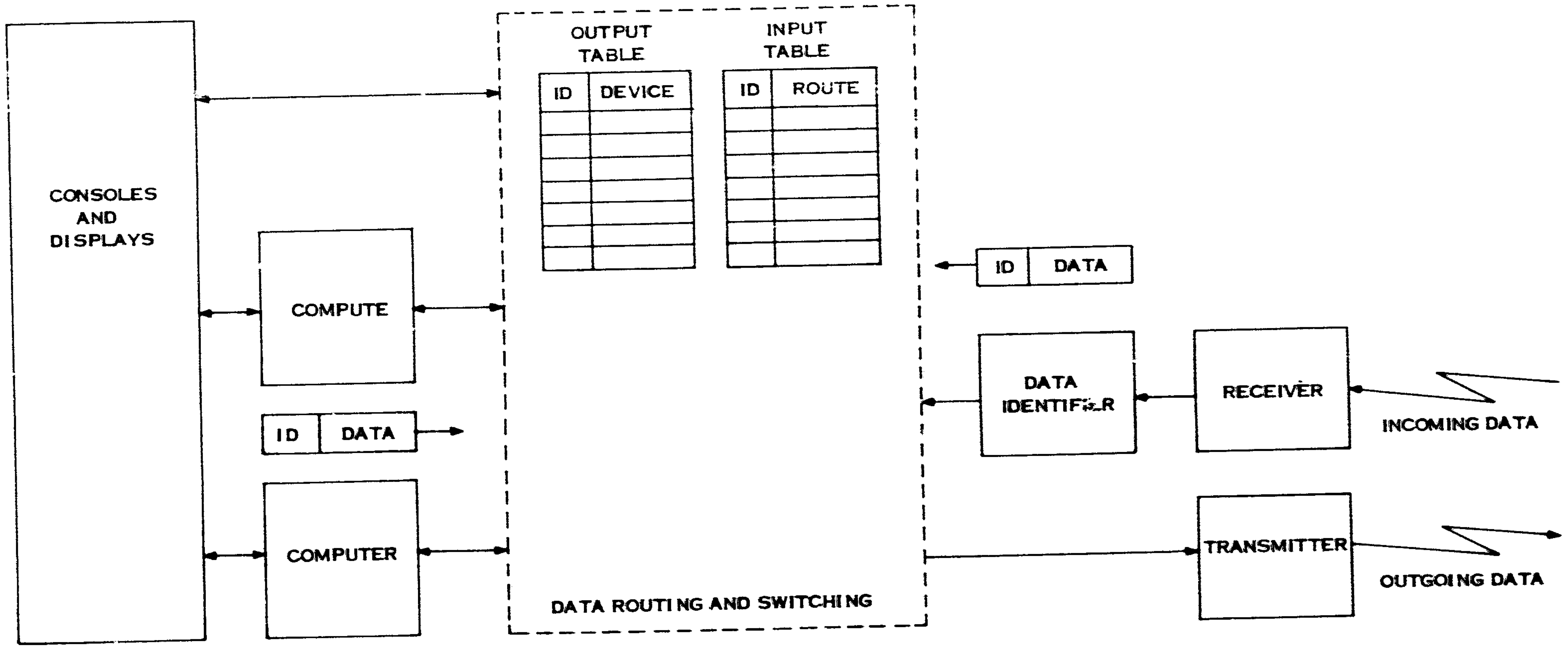


Figure 19. Data Identifier System (Complex)

COMPUTER	CYCLE (μSEC)		WORD SIZE	CORE SIZE	DIRECT ACCESS S. D.	TAPES	I/O OTHER	ADDRESSABLE MEMORY	SPECIAL FEATURES
	*								
DEE-3 (SDS910)	1	8.0	24B	16K	NO	1 15KC	PAPER TAPE ASR 33 EVENT LIGHTS	16K	INDIRECT ADDRESSING 1 KHZ EXT. CLOCK DISCRETE SCAN
DEE-6 (SDS930)	1	1.75	24B	32K	NO	2 15KC	PAPER R/P FRANKLIN (5)	16K	INDIRECT ADDRESSING DISCRETE SCAN
RCA 110A	1	10.25	24B	32K	DRUM 8.5 MSEC	4 15KC	CARD READER PRINTER REAL-TIME F.E.	4K	I/O SPECIAL INTERRUPT FAIL SAFE DI, DO ANALOG/I/O
DDP224	1	2.1	24B	32K	NO	NO	PAPER TAPE SANDERS	32K	8 LEVELS OF INTERRUPT
GE635	1	1.0	36B	128K	DISK 225MS DRUM 8.5MS	16 83KC 120K	CRP, LINE PRINT CRTS	262K	INTERRUPT TIMER 3 LEVELS PRIORITY INTERRUPT RELOCATION REQUIREMENTS REAL-TIME I/O
CDC 160G	2	1.5	13B	8K 48K SHARED	NO	2 DED 20KC 2 SWITCHABLE	CRP, 1000 LPM CRTS	8K	REAL-TIME CONT.
GROSS 1**		.5	24B	112K (24 BIT WORDS)	110 DRUM	11 15-20KC			
GROSS 2		.25	30B	230K	DRUMS, DISKS	11 15-20KC 16 90KC			

* NUMBER REQUIRED TO SUPPORT COUNTDOWN & LAUNCH
** NOT INCL. GE635

Figure 20. Present KSC Computer Capability

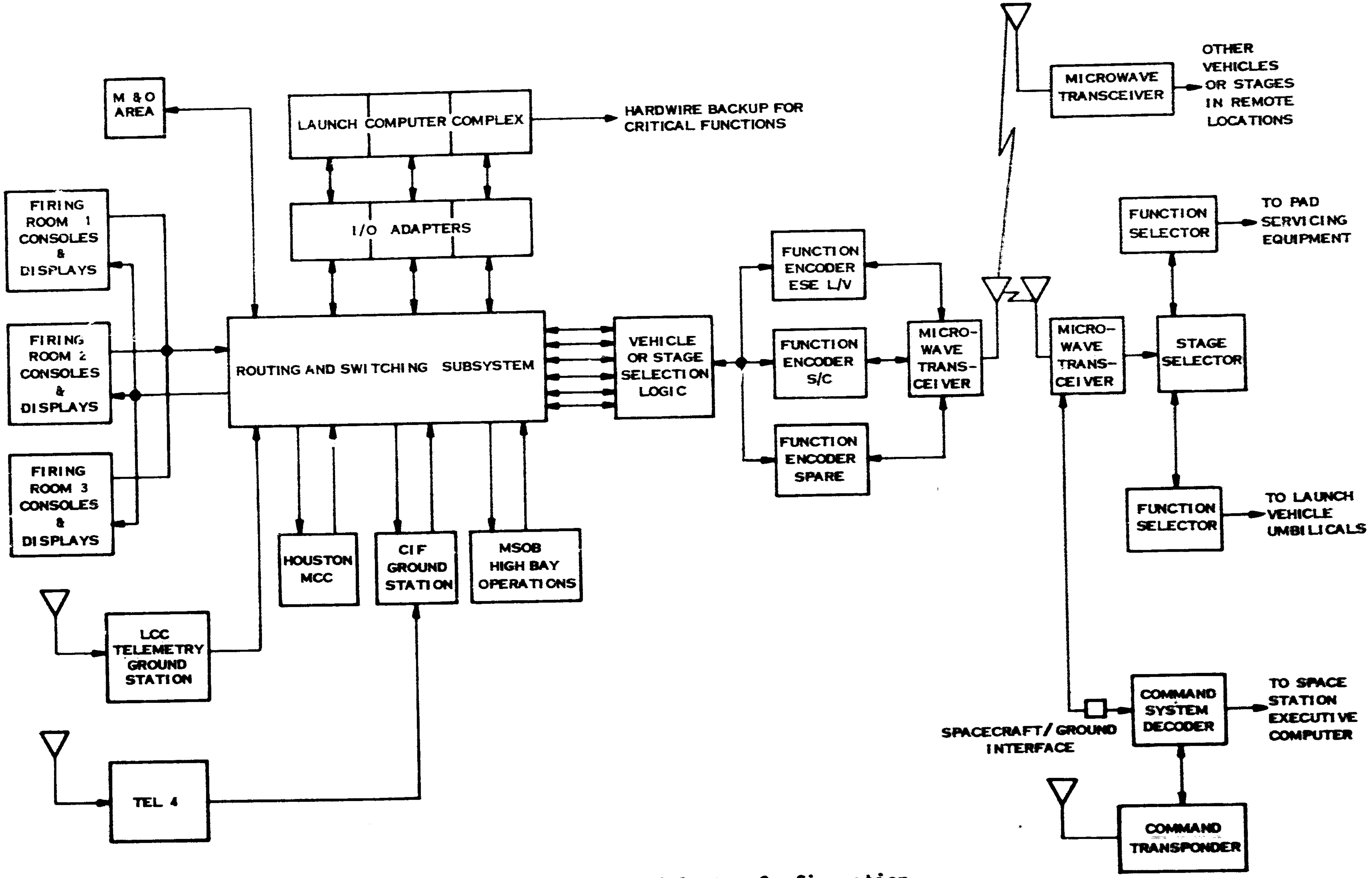


Figure 21. Ground System Configuration

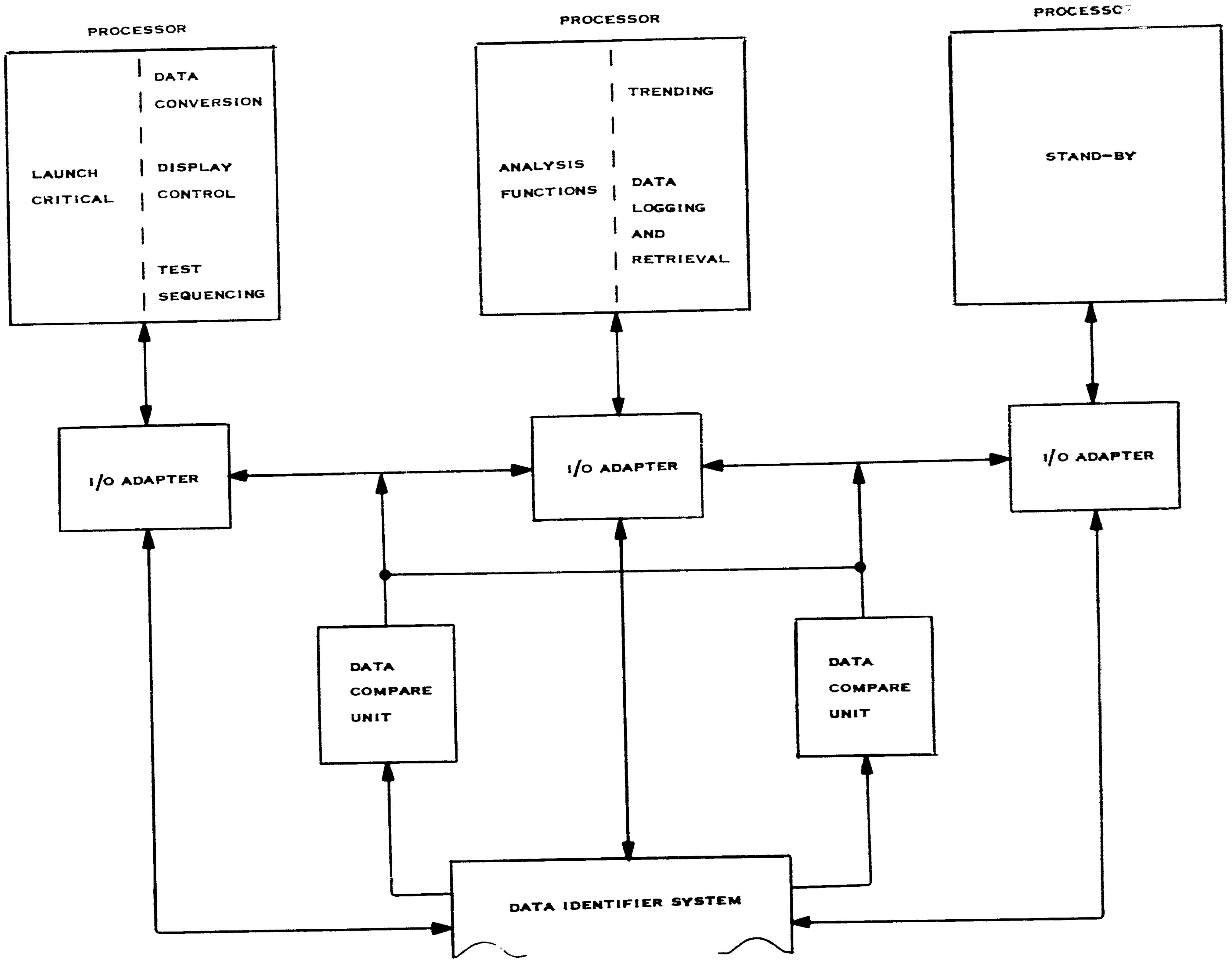


Figure 22. Checkout Processor Layout

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