CONSOLIDATED SPACE OPERATIONS CENTER

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ABSTRACT

The Consolidated Space Operations Center (CSOC) is being designed by the Air Force Systems Command Space Division to centralize all Department of Defense Space Shuttle and satellite operations within a single secure facility. CSOC will be located near Colorado Springs, Colorado. It will provide DOD with enhanced space command and control capabilities in the late 1980s and 1990s. It will include a Satellite Operations Complex (SOC), a Shuttle Operations and Planning Complex (SOPC), and communications, facilities, and support segments. An initial operational capability is planned for mid-1986 that will include appropriately selected portions of SOC, SOPC, and the integrated segments. These early limited capabilities will be expanded in the late 1980s to satisfy the requirements of the DOD mission model.

SOC will share command and control of space satellite missions with the Satellite Test Center (STC) in Sunnyvale, California. The STC is part of the Air Force Satellite Control Facility (AFSCF). Both the STC and SOC will control assigned satellite missions using the AFSCF remote tracking stations located at seven sites around the world. SOC will be functionally equivalent to a portion of the STC as improved by the data systems modernization program. SOC and STC will be interoperable to permit mutual backup in the event of an extended failure at either center.

SOPC will be functionally equivalent to portions of the Shuttle operations complex at the NASA Johnson Space Center (JSC). It will provide for flight planning, flight readiness, and flight control of DOD Shuttle flights. As with SOC and STC, SOPC and JSC flight control facilities will be able to provide critical backup support to each other in the event of an extended failure at either center.

External wideband communications circuits at CSOC will interface with both NASA and Air Force space facilities, such as the eastern and western launch sites, JSC, and the AFSCF remote tracking stations. Satellite relay techniques using both Defense Satellite Communication System (DSCS) satellites and Domestic Communications Satellites (DOMSAT) will be the basic method of network communication. Dedicated narrowband

circuits, provided by leased lines accommodating both voice and data, will interface mostly with other Air Force space facilities.

This paper discusses the CSOC program background, configuration, operations concept, external interfaces, and acquisition status.

INTRODUCTION

DOD's commitment to launch all space missions on the Space Shuttle and the long acquisition cycle projected for CSOC required some modification of the Shuttle control capability at JSC to accommodate DOD security requirements. Continued expansion of JSC facilities to permit more highly classified DOD missions is not compatible with the NASA goals of widespread public visibility in peaceful exploitation of space.

Projected increases of satellite-mission traffic requires augmentation of STC control capabilities. The present location of STC at Sunnyvale, in a congested industrial park near urban centers and freeways, makes expansion there both difficult and less attractive than at a less urban site. CSOC will accommodate DOD security requirements at a location favorable for DOD satellites and Shuttle operations for the projected future.

CSOC OVERVIEW

Figure 1 is a map of the Colorado Springs area showing the CSOC location approximately 10 miles east of Peterson Air Force Base. An artist's concept of the CSOC installation in Figure 2 shows a technical building, an engineering and administration building, a central utility plant, and several antennae. CSOC construction is to start in 1983 and to be completed in 1985. Initial space operations are planned for 1986.

Figure 3 shows how the 478,000 square feet of floor space at the site will be allocated. Approximately 1000 persons will be employed at CSOC during early operations. Staffing will expand to about 2000 when the mature operations capability shown in Figure 4 is achieved. Staffing will be about 52 percent military, 22 percent civil service, and 28 percent contractor.

Figure 5 shows that CSOC will support the planning of Shuttle and satellite operations; the training of astronauts, flight controllers, mission specialists, and support personnel; and the command and control of Shuttle flights and satellite missions.

The interaction of CSOC with existing control capabilities is depicted in Figure 6. Shuttle systems will be unable to discern whether ground-based communications come from JSC or SOPC. The software used at the two centers will be virtually identical so that either center could provide critical backup for Shuttle operations in case the other center became inoperable.

Satellite systems will be unable to discern whether ground-based communications come from SOC or STC. Hardware in the SOC will be a replicated subset of the hardware at STC, and software and procedures will be virtually identical. Therefore, either center will be able to conduct critical mission operations for the other center in case of an unexpected failure.

BACKGROUND

The AFSCF evolved during the past 20 years from a satellite research and development facility into the prime control center for DOD satellite missions. As U.S. space technology matured during the 1960s and 1970s, significant defense roles evolved for space systems. AFSCF facilities and systems were upgraded to meet these changing and expanding needs. Data systems modernization equipment is being acquired to serve these needs and reduce future operational costs. However, projected DOD space operations will require additional capabilities for satellite control. Locating these capabilities at an inland site away from urban congestion and seismic faults has many advantages over expanding at the present control center.

Space launch vehicle operations have also evolved over the past two decades. NASA and DOD developed separate launch facilities for expendable launch vehicles at Kennedy Space Center (KSC) and Vandenberg Air Force Base (VAFB), respectively. NASA recently developed the Space Transportation System (STS), which had its highly successful first flight in April 1981. DOD has pledged to a transition from expendable launch vehicles to the STS as part of the National commitment to the Space Shuttle.

From 1975 through 1977, a number of studies were conducted relative to a second STC and a dedicated Shuttle operations and planning facility for DOD missions. In mid-1977, the Air Force recommended collocation of these two functions in a Consolidated Space Operations Center. The long leadtime required for review, approval, and implementation of this recommendation prompted the Air Force to initiate an interim Shuttle control solution at JSC called Controlled Mode. Controlled Mode is a secured subset of the JSC flight operations and planning capability. It was designed to provide limited secure control of Shuttle flights until a dedicated DOD Shuttle operations and planning complex could be built. Controlled Mode is well advanced and initial secure operations are planned within two years.

The Office of Management and Budget directed USAF to review satellite and Shuttle-control baseline studies in early 1979. These studies analyzed seven alternatives for

CSOC, including collocation at places such as VAFB, the current STC, JSC, and other locations. The studies examined survivability, security, economics, and operational issues for each location. A consolidated facility at a central U.S. location was recommended by the Secretary of the Air Force and a site selection study was initiated. Colorado Springs was designated as the preferred site in late 1979, and subsequent environmental studies culminated in its final selection early in 1981.

A CSOC task force was established at Space Division early in 1980 to coordinate and focus diverse Air Force space efforts, identify priority requirements, establish a transition plan, and define a CSOC initial operational capability within austere fiscal constraints. The task force recommendations were mostly established by mid-1980 and a final report was published. Program management direction to proceed with the implementation of CSOC was issued to the Air Staff in December 1980.

CSOC OPERATIONS AND TRANSITION

Figures 7 and 8 show the Space Operating Network before and after the integration of CSOC. Currently operating DOD space missions are controlled by the STC and its remote tracking stations. The stations provide the STC interface to space systems such as generic DOD satellites, Global Positioning System Satellites (GPSS), and Inertial Upper Stages (IUS). The Vandenberg Tracking Station and the Space Launch Complex (SLC) at VAFB are also part of the DOD network. STC also interfaces with the Space Defense Operations Center and a Remote Vehicle Checkout Facility in Florida.

The hub of the NASA Space Shuttle operations is JSC, and the center of the NASA communications network is Goddard Space Flight Center (GSFC). KSC and its Launch Control Complex (LCC) are a part of the NASA network. The interface to space vehicles is via the Ground-Space Tracking Data Network, which will be replaced eventually by the Tracking and Data Relay Satellite System.

Figure 8 shows the planned integration of CSOC into the Space Operating Network. CSOC will be an important hub in the network, with interfaces to all major points in both the NASA and DOD nets. CSOC will conduct DOD Shuttle flight operations directly and the STC and CSOC will share control of satellite missions.

CSOC CONFIGURATION

CSOC consists of five functional segments: SOC, SOPC, and communications, support, and facilities segments. These segments are described in the following paragraphs.

SATELLITE OPERATIONS COMPLEX

The SOC segment and its primary interrelationships are shown in Figure 9. The major elements in the SOC will be eight mission control complexes (MCC), a range control center (RCC), a data distribution system (DDS), and a software development and test laboratory (SDTL). These elements will be an identical subset of the STC equipment being acquired under the AFSCF data system modernization program. During a pass over one of the seven remote tracking stations, a satellite contact is made via the station's telemetry, tracking, and command segment. Most of the communication with CSOC will occur over wideband links through DSCS and DOMSAT satellites. Narrowband links will provide supplemental data paths, as was stated previously.

Different satellite missions will use separate MCCs with dedicated data processing capability to provide data privacy and security. A typical MCC will have two IBM 4341 computers. One computer will support satellite contacts, the second will support non-real time planning and evaluation. The latter computer will quiescently maintain the contact-support functions for immediate real-time backup. One MCC will be equipped with more powerful IBM 3033 computers instead of 4341's to accommodate special mission requirements.

MCCs typically will be staffed by mission controllers, space-vehicle controllers, system controllers, orbital specialists, planner-analysts, range controllers, and operations officers. Some of the functions performed in MCCs will be telemetry and tracking data processing, status control and evaluation, command generation and issuance, orbit planning and evaluation, spacecraft-related planning and evaluation, and operations and resource planning.

The RCC equipment will be similar to MCC equipment. One RCC computer will be dedicated to active range resource management. The second will be dedicated to range planning and scheduling and the backup of the management function. Typically, the RCC will be staffed by an MCC support controller, a data distribution controller, a range resource controller, and a maintenance controller. Primary functions performed by the RCC will include test-data generation, resource-status checking and allocation, data distribution status checking and control, MCC request processing, voice configuration management, DSCS antenna pointing and link operation, and range planning and scheduling. The RCCs at the STC and CSOC will cooperatively schedule and control AFSCF resources.

SDTL will be used primarily for software development and validation to support future satellite missions.

The DDS will provide the interface between the remainder of the SOC segment and the CSOC communications segment, which, in turn, will interface with the outside world. The DDS will perform compression, formatting, syncronization and time-tagging of telemetry data, formatting of command data, and encryption and decryption. Both simulated and active missions will be supported. The major external inputs to DDS are telemetry, tracking, echo check, status, and time data. The major external outputs are satellite commands, control directives, and antenna-pointing data.

SHUTTLE OPERATIONS AND PLANNING COMPLEX

The SOPC will comprise three functional areas: flight planning, flight readiness, and flight control. Figure 10 presents an overview of the SOPC configuration.

The flight planning element will consist of three major systems: System X, System Y, and the Crew Activity Planning System. System X is an interactive, long-range flight-feasibility planning system that uses a minicomputer and a word processor. It provides for early definition of Orbiter attitudes and pointing, consumables utilization, mass properties, trajectory and ephemeris data, and experiment support data.

System Y will be a detailed flight-design system consisting of software for batch processing to generate high-fidelity simulations of ascent, on-orbit, sortie, propulsive-consumables, and descent functions. The outputs of System Y are a mission-profile tape, a crew-simulator data package, and computer-generated plots and listings.

The Crew Activity Planning System will use a minicomputer and word processor to support the analysis of timeliness trajectory data, and crew activities. In addition, the system will handle the documentation, data management, and flight-procedures checklists required to plan and support Shuttle crew operations.

The SOPC flight readiness element will prepare and validate flight data files, generate tapes for loading the Shuttle avionics computers, and support the training of Shuttle crews and support personnel. The Data Load Preparation System (DLPS) and the CSOC Simulation System (CSS) are the primary systems in the flight readiness element.

A block diagram of the DLPS is shown in Figure 11. The DLPS will be compatible with the JSC software production facility and will be able to use JSC software, containing over one million lines of source code. The host computer is interfaced to two or more flight computers through flight equipment interface devices. The flight computers are replicates of the Shuttle avionics computers.

The primary role of the CSS will be to support training of personnel and validate preoperations readiness. This includes verification of the CSOC configuration; testing the operability of the SSV and upper-stage configurations, software, and command loads; development of operations procedures; and analysis of anomalies. Figure 12 is a block diagram of the CSS. The fixed base crew station will have both forward flight deck stations for pilot proficiency training and aft deck stations for on-orbit payload specialist training. Network, telemetry, and command simulators will be provided for early crew training. The CSS will interface through the communications segment with the SOPC flight control rooms and the SOC mission control centers for integrated rehearsals. Simplified part-task trainers will be provided for initial proficiency training in basic tasks. A phased implementation of the CSS will provide an on-orbit simulation capability, initially, and ascent-descent simulation at a later date. Satellite-related simulations will be integrated into the CSS capability during development.

The flight control element will provide facilities and equipment for flight operations personnel to monitor and control Shuttle flights in real-time from liftoff to landing rollout. It will also support flight operations planning, personnel training, integrated rehearsals, testing of vehicles and networks, and equipment reconfiguration between flights. Figure 13 is a block diagram of the flight control element.

The element will have two flight control strings capable of supporting two flight operations simultaneously, e.g., one on-orbit flight and one test or simulation exercise. Each string will include a flight control room and a multipurpose support room, and will share data computation equipment, an interface communication system, a display and control system, and a reconfiguration system.

The interface communication system (ICS), a part of the data computation complex (DCC), will contain two strings of network communication interfaces, telemetry processing computers, network output multiplexers, and cryptographic equipment that will interface with the integrated CSOC communications segment. Each string will provide the capability to process one real-time and one prerecorded downlink data stream. The telemetry processing computers will preprocess downlink data in order to permit economies in subsequent processing and distribution to the Shuttle data processors and the display and control system.

The Shuttle data processing computers (SDPC), also part of the DCC, will support the processing of real-time Shuttle command, trajectory, telemetry, and display data. Approximately 2.5 million lines of source code are required for these functions. Software compatibility between the CSOC and JSC computers is required to minimize acquisition and operating cost and to ensure interoperability. Redundant SDPCs are required to meet operational, reliability, security, and data-privacy requirements. Each SDPC will require approximately eight million bytes of main memory and a processing rate of about three million instructions per second. The SDPCs will share a pool of peripheral equipment, such as magnetic tape units, mass memory disks, printers, and other input-output devices.

The multibus interface (MBI) will provide a redundant bidirectional data bus for multiple, high-speed exchanges between the SDPC and the ICS. The configuration and switching equipment (CSE) will provide the capability to configure the SDPC interfaces to ICS and the display and control system. The SDPCs, peripheral equipment pool, multibus interface, and CSE will be physically located in the DCC.

The Display and Control System (DCS) will provide the major operator interface for Shuttle flight operations. It will accept, encode, and transmit operator requests to the system and will generate and update operator displays in response to these requests and other real-time data. Much of the DCS equipment will be physically located in the flight control rooms and multipurpose support rooms. It will consist of functionally grouped keyboards, video displays, and analog-event indicators mounted in several consoles, each of which is configured for a specialized operational function.

The reconfiguration system is used to automate the flight-to-flight reconfiguration process. Since the flight control software is table-driven, it is practical to reconfigure the tables externally and avoid software design modifications and extensive software regression testing when adding, deleting, or changing flight events (e.g., rendezvous). The reconfiguration system will comprise a reconfiguration data collection system (RDCS), a configuration requirements processor, and a display retrieval and formatting system. This equipment will collect, modify, and validate extensive measurement data base entries for a specific Shuttle configuration, provide for interactive building of new display formats, and convert these results, along with flight planning, analysis, and other inputs, into tables for driving the flight control element software on a subsequent flight.

COMMUNICATIONS SEGMENT

The communications segment consists of equipment for internal and external voice, data, and facsimile transmissions. External communications systems include operational administrative voice nets, wideband and narrowband data links, and facsimile equipment for transmission between CSOC and other elements of the space operational network. Internal communications includes administrative and secure phone systems, paging system, and intercoms. Internal and external communications for SOC- and SOPC-related requirements will be integrated into the single communications segment.

CSOC internal communications are depicted in Figure 14. Both the SOC and SOPC require multilevel security circuits between support areas. Each console requires access to a large number of internal and external circuits. In addition to the voice switching gear required for each security level, internal communications equipment includes data switching and routing elements, encryption interfaces, paging and public address systems, intercoms, recording devices, and line key sets for all mission consoles. Commercial unclassified telephone service will also be incorporated for the entire site. Physical security communications will include base radio, intrusion sensors, and TV monitors.

The external communications equipment includes both wideband and narrowband elements. External interfaces are shown in Figure 15. The wideband circuits (≤ 50 Mbps) are provided by satellite relay that uses DSCS and DOMSAT satellites. Path diversity is implemented where possible for minimization of single critical nodes. Both voice and wideband data communications for SOC and SOPC are required between CSOC and other elements of the Space Operating Network. The circuits with JSC, KSC, GSFC, WSGT, VAFB, and some remote tracking stations are via DOMSATS. Existing ground terminal equipment will be used where possible, and path diversity will be provided within existing or projected DOMSAT capabilities. The CSOC-STC interoperational (cross-link) circuits will be provided via both DSCS and DOMSAT satellites.

External leased narrowband circuits (≤ 9.8 kbps) accommodating both voice and data will be provided between CSOC and Air Force global weather central, SPADOC, GPS, Defense Support Program, Defense Meteorological Satellite Program, Air Force Technical Analysis Center, RTSs, Edwards Air Force Base, and FAA control centers. Backup circuits will be provided also to the NASA and AFSCF centers.

SUPPORT SEGMENT

The support segment will consist of logistic support capabilities and common-equipment and functions that support more than one other segment. Common items consist of a timing subsystem, a weather support unit, an uninterruptable power subsystem, a technical data center, and miscellaneous other common elements. The timing subsystem will provide accurate time signals to support several CSOC operations and operator displays. The weather support unit will provide mission-specific meteorological support and allow a more independent operations capability at CSOC. The technical data center will consist of a management information system to handle both classified and unclassified information and other facilities to automate the control of CSOC configuration, inventories, change status, and documentation catalogs.

ACQUISITION STATUS

Program management direction was given to the Air Force Systems Command in December 1980 to proceed with the acquisition of CSOC. An architectural and engineering contract was awarded in February 1981 for the design of the CSOC facilities. The AFSCF awarded a data systems modernization contract in December 1980 for STC upgrades with options to deliver identical equipment for the SOC segment at CSOC. The Space Division has prepared a Request for Proposal for a CSOC integration support contract. Full coordination and approval for release of this request is expected soon. The Space Division has organized an SOPC project office in Houston, staffed by Air Force and NASA personnel, to define the SOPC segment for subsequent acquisition. The Space Division, with Aerospace support, has initiated requirements definitions and other pre-RFP actions for the communications, support, and simulation and training areas. RFP releases for these acquisitions are planned in approximately one year.

SUMMARY

CSOC will provide DOD with a direct line of command and control for Shuttle flight operations and the required augmentation of its satellite operations capability at a secure installation. Full exploitation of space for national security defense missions will be possible only after these capabilities have been developed. CSOC will be interoperable with STC and JSC to permit mutual backup among centers. The capability for growth is intrinsic in planning and designing to preclude early obsolescence.

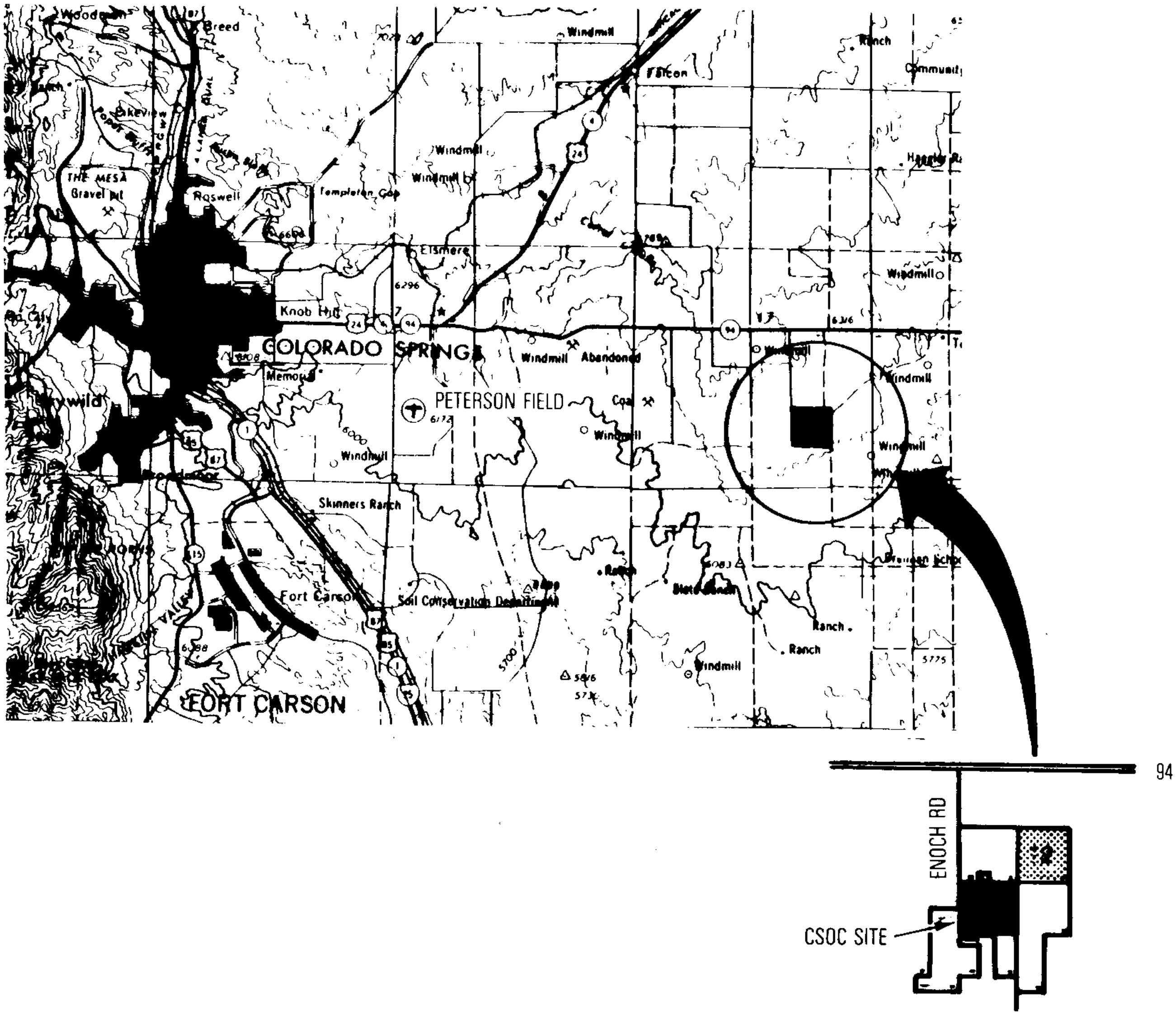


Figure 1. CSOC Site

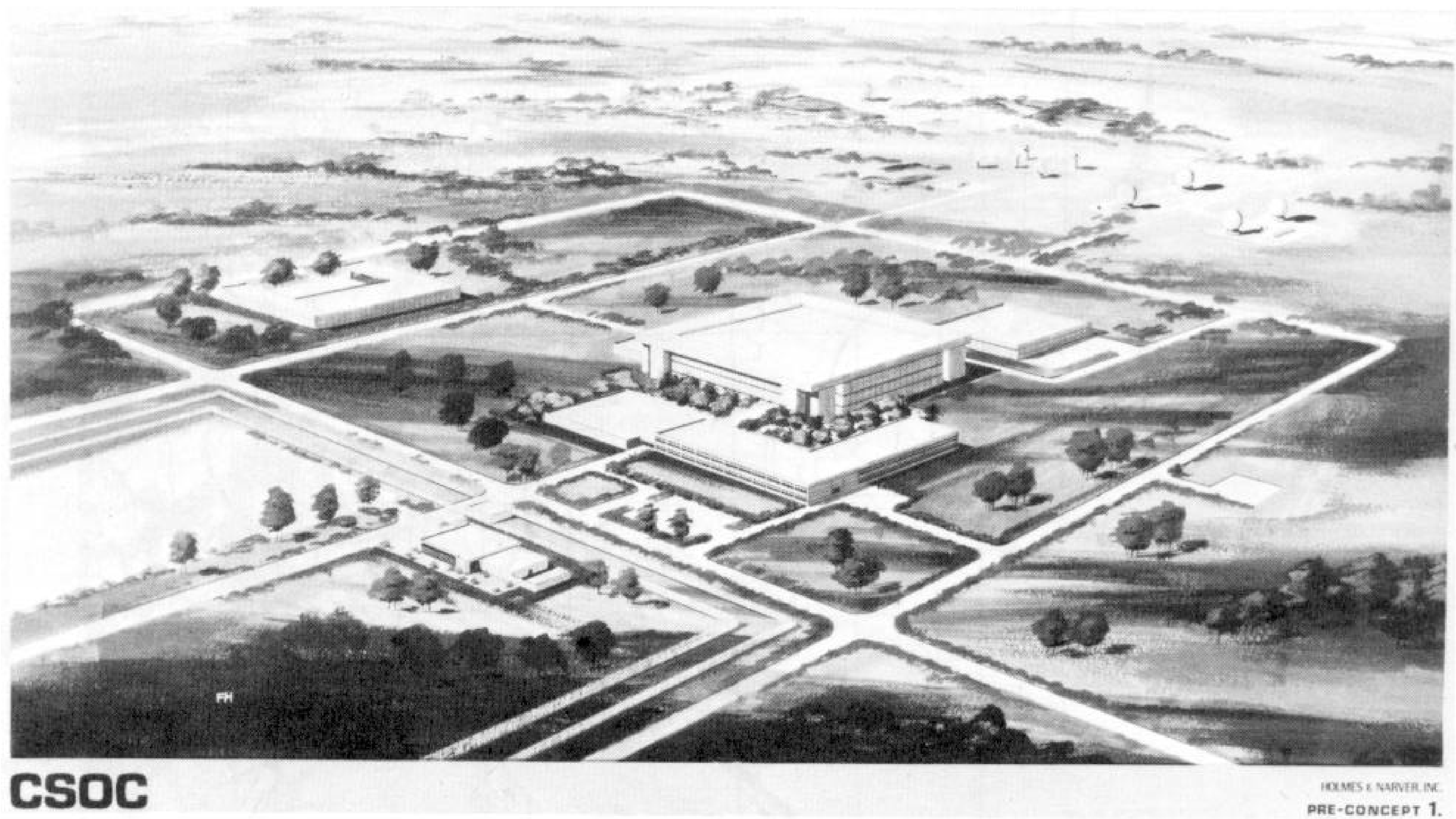


Figure 2. Artist's Concept of CSOC Facility

	ft²
TECHNICAL BUILDING	280,000
ENGINEERING AND ADMINISTRATION	110,000
CENTRAL PLANT	42,000
SUPPORT BUILDING AND MISCELLANEOUS	34,000
ANTENNA TERMINAL SUPPORT STRUCTURES	12,000
	478,000

Figure 3. Space Allocations

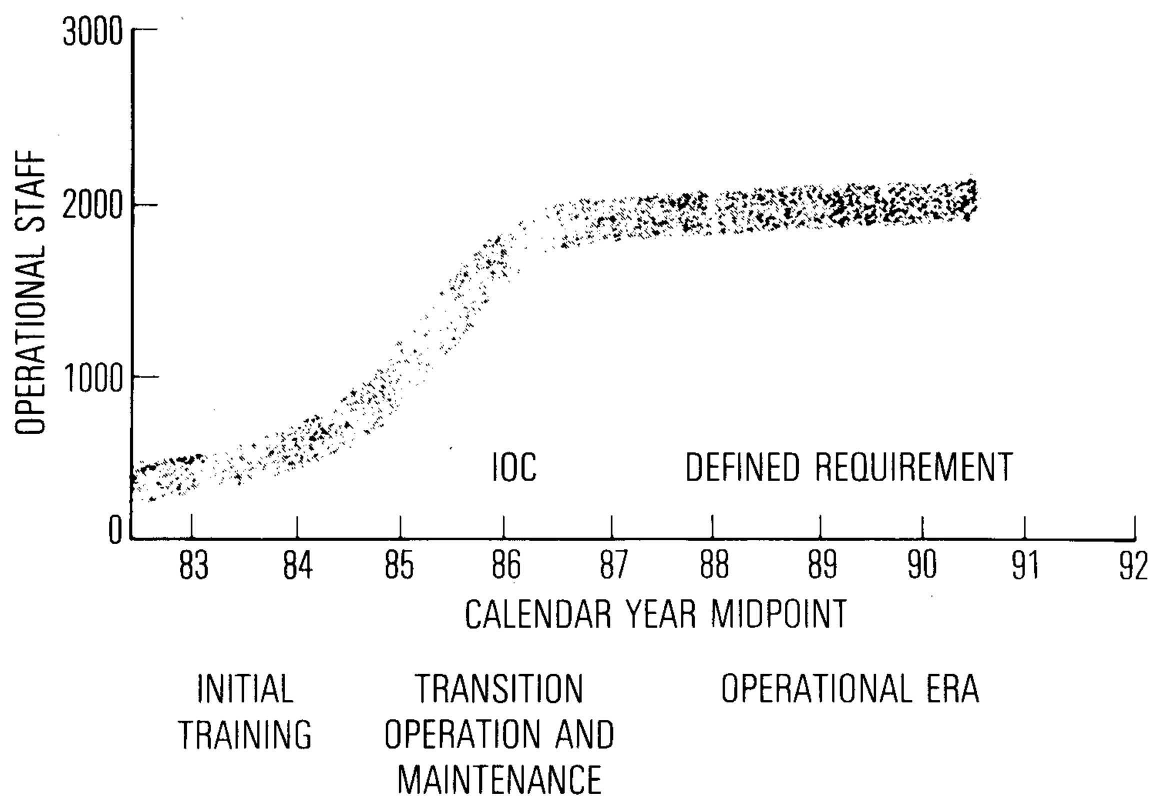


Figure 4. Projected Staffing

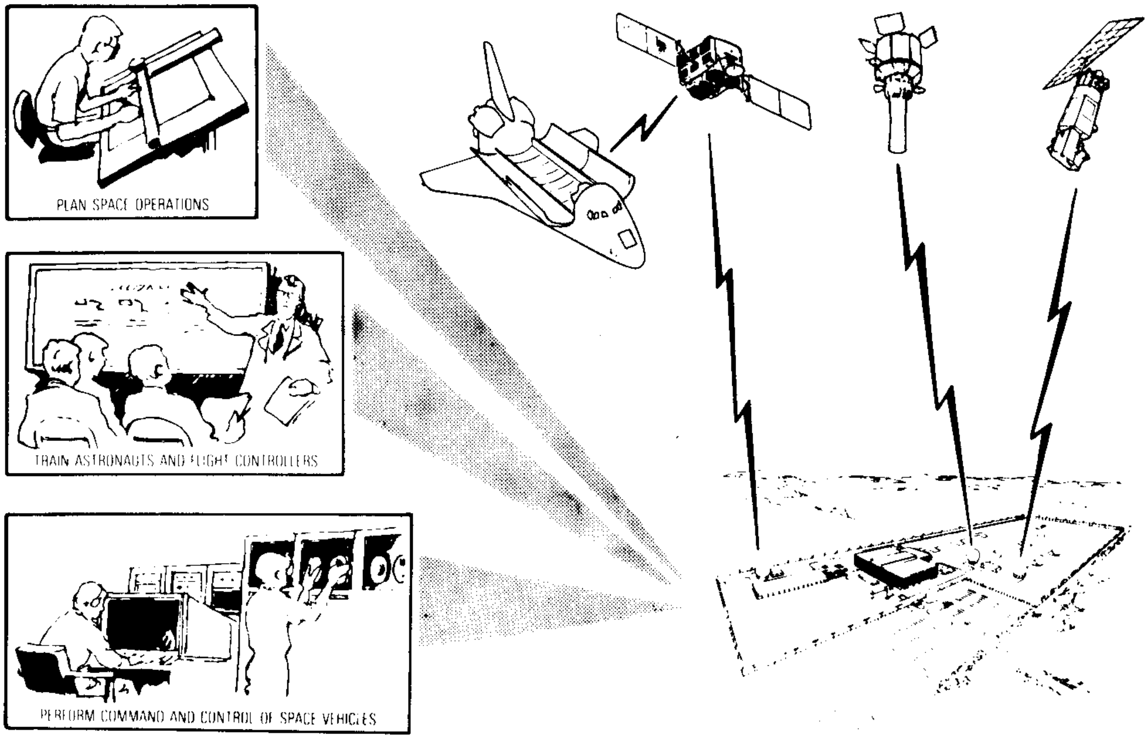


Figure 5. CSOC Capabilities

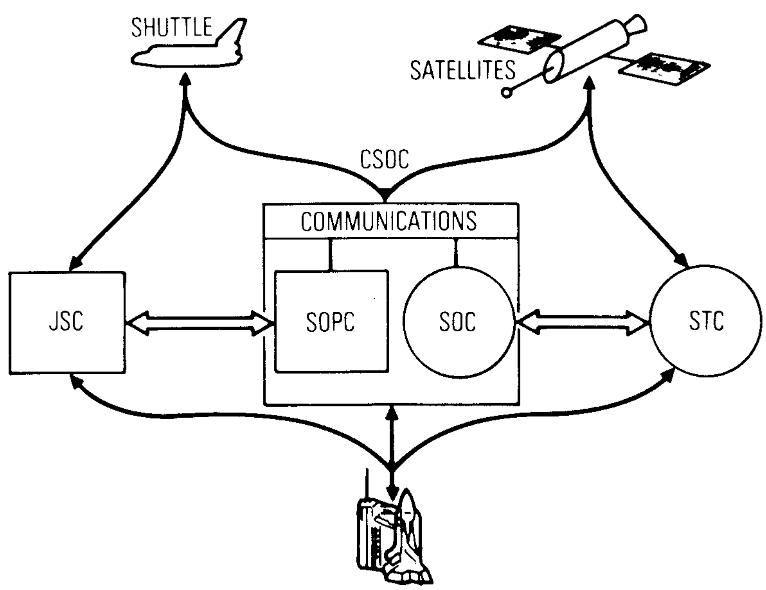
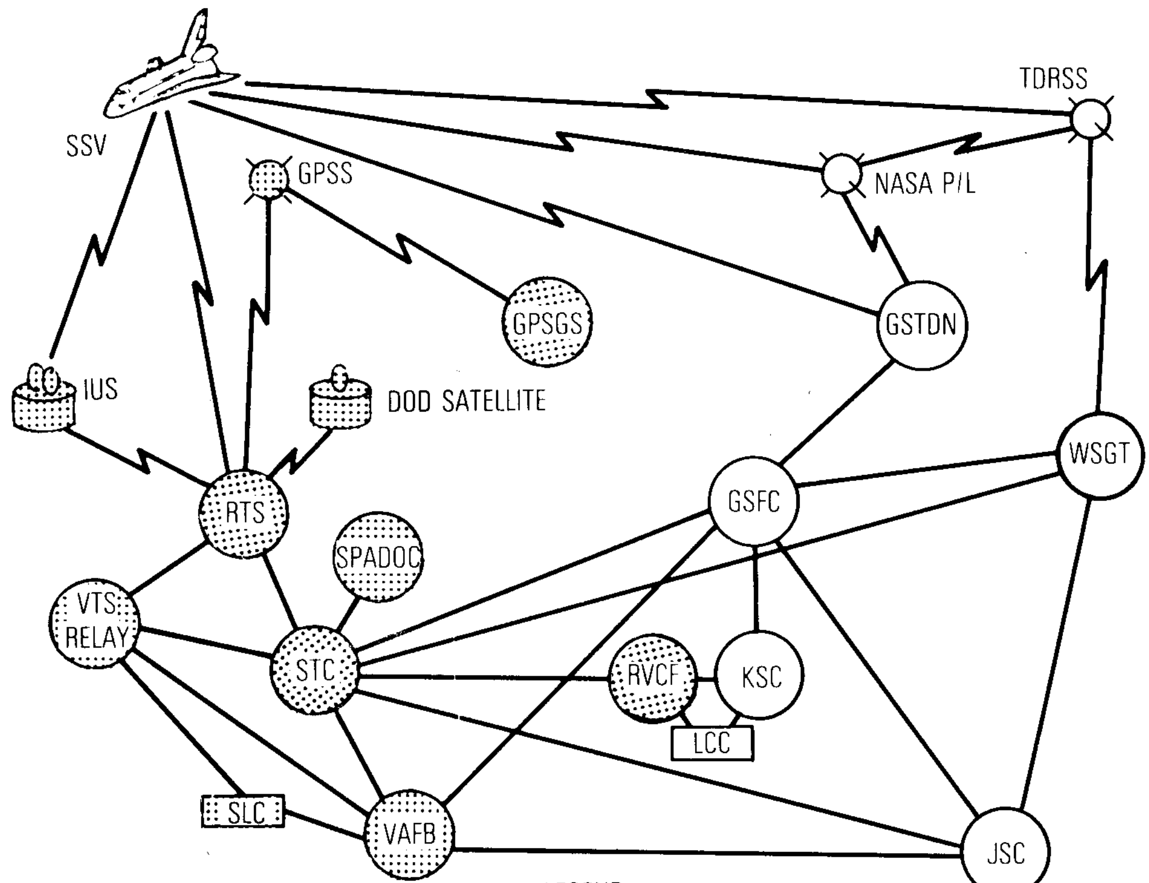


Figure 6. CSOC Interoperability



LEGEND

DOD

GPSS	GLOBAL POSITIONING SYSTEM SATELLITE
GSPGS	GLOBAL POSITIONING SYSTEM GROUND STATION
IUS	INERTIAL UPPER STAGE
RTS	REMOTE TRACKING STATION
SPADOC	SPACE DEFENSE OPERATIONS CENTER
VTS	VANDENBERG TRACKING STATION
STC	SATELLITE TEST CENTER
RVCF	REMOTE VEHICLE CHECKOUT FACILITY
VAFB	VANDENBERG AIR FORCE BASE
SLC	SPACE LAUNCH COMPLEX

NASA

SSV	SPACE SHUTTLE VEHICLE
TDRSS	TRACKING DATA RELAY SATELLITE SYSTEM
GSTDN	GROUND-SPACE TRACKING DATA NETWORK
WSGT	WHITE SANDS GROUND TERMINAL
GSFC	GODDARD SPACE FLIGHT CENTER
KSC	KENNEDY SPACE CENTER
LCC	LAUNCH CONTROL COMPLEX
JSC	JOHNSON SPACE CENTER

Figure 7. Current Space Operating Net

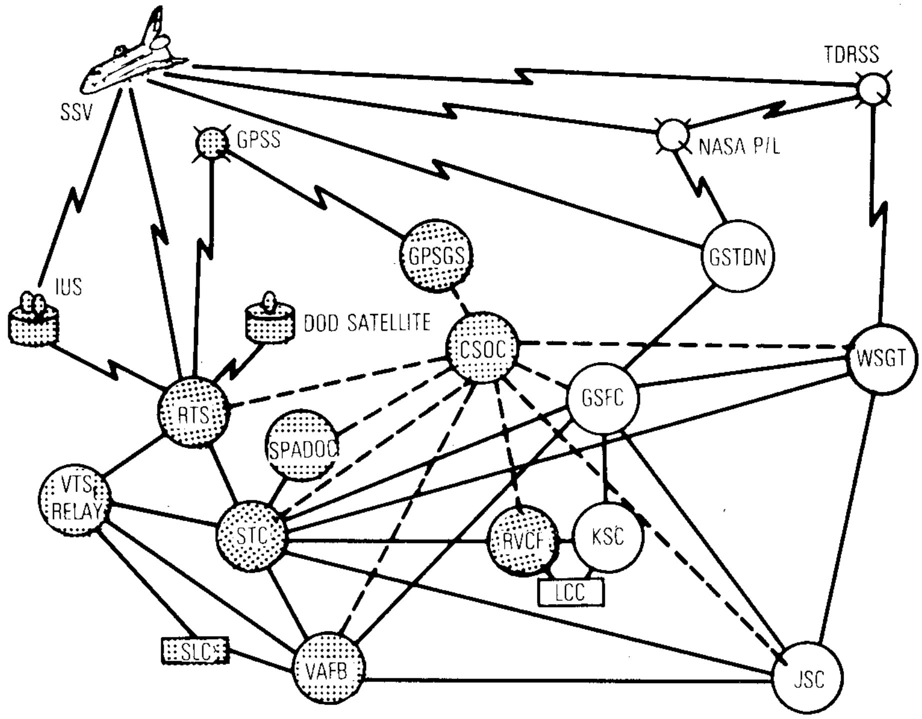


Figure 8. CSOC Integration into Space Operating Net

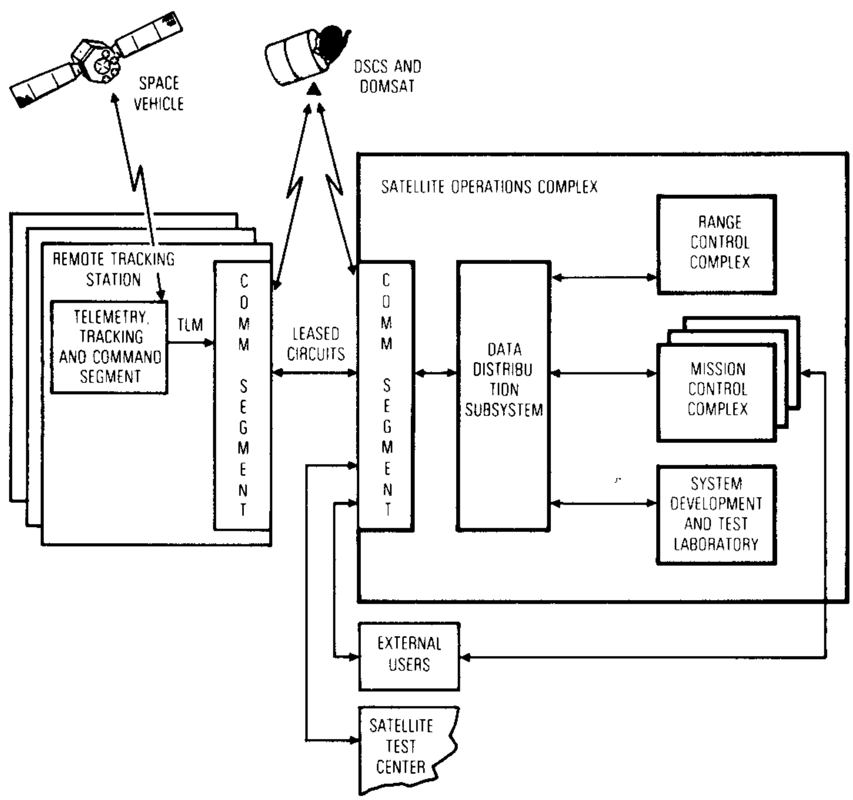


Figure 9. SOC Segment and External Relationships

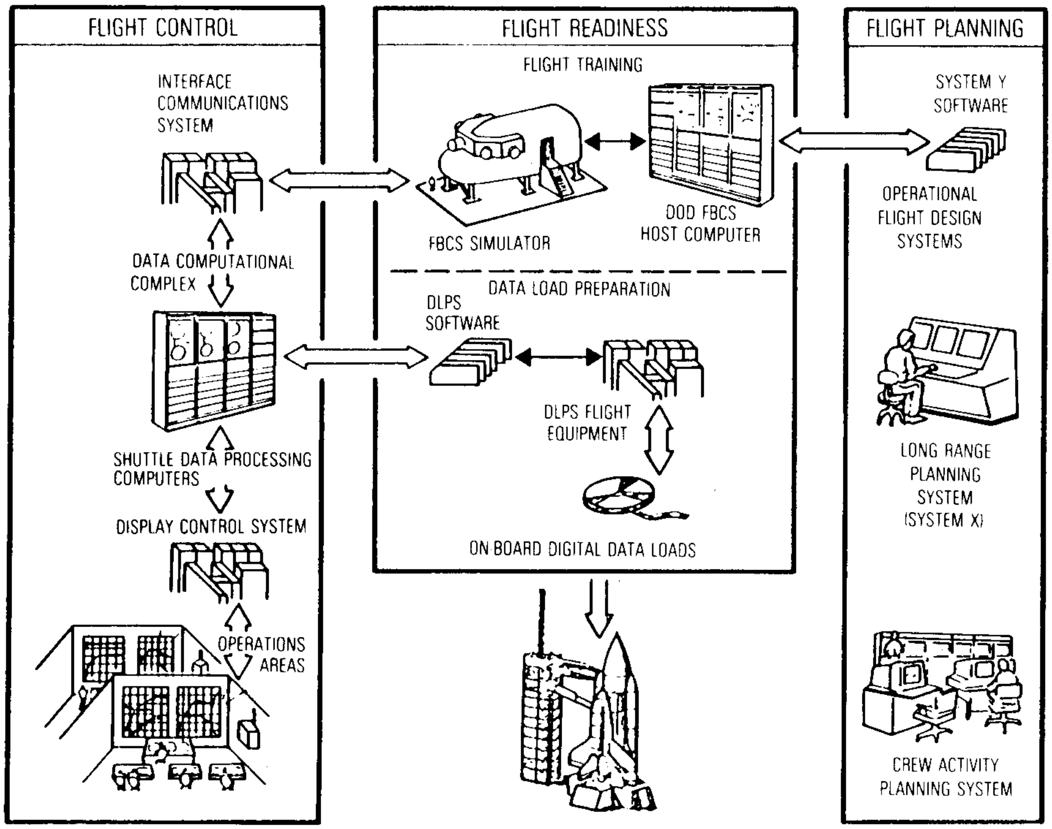


Figure 10. SOPC Segment Configuration Overview

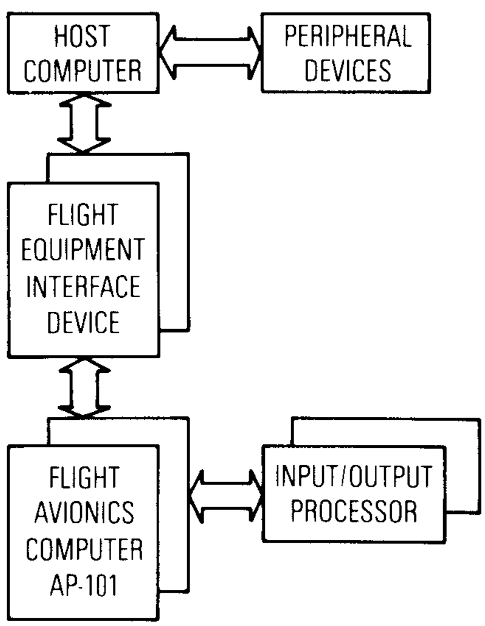


Figure 11. Data Load Preparation System

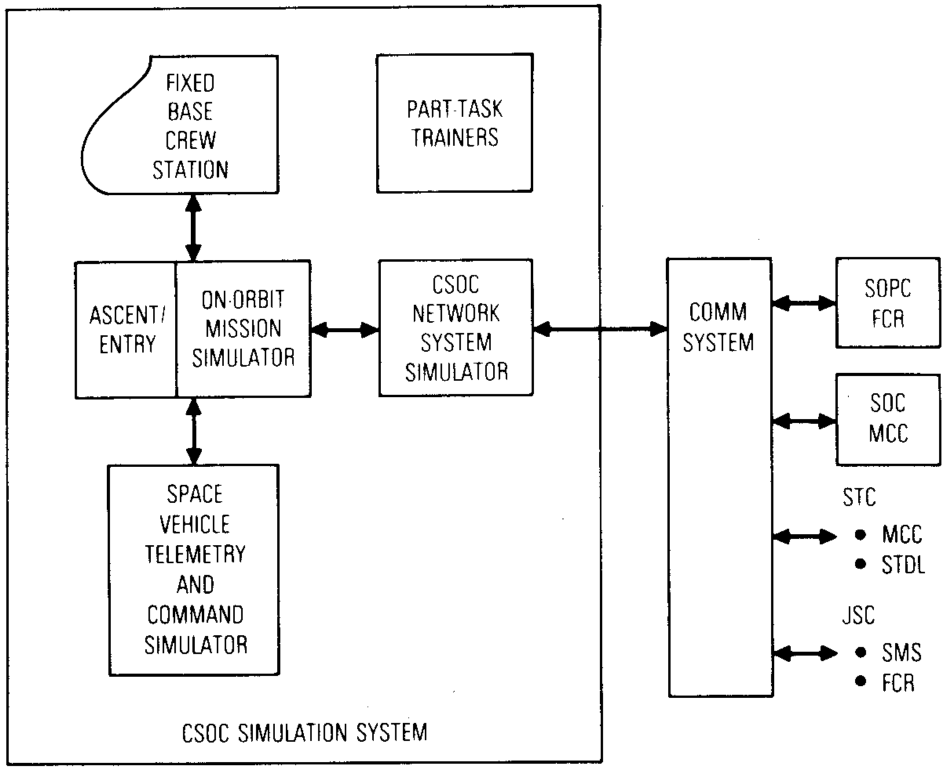


Figure 12. CSOC Simulation System Overview

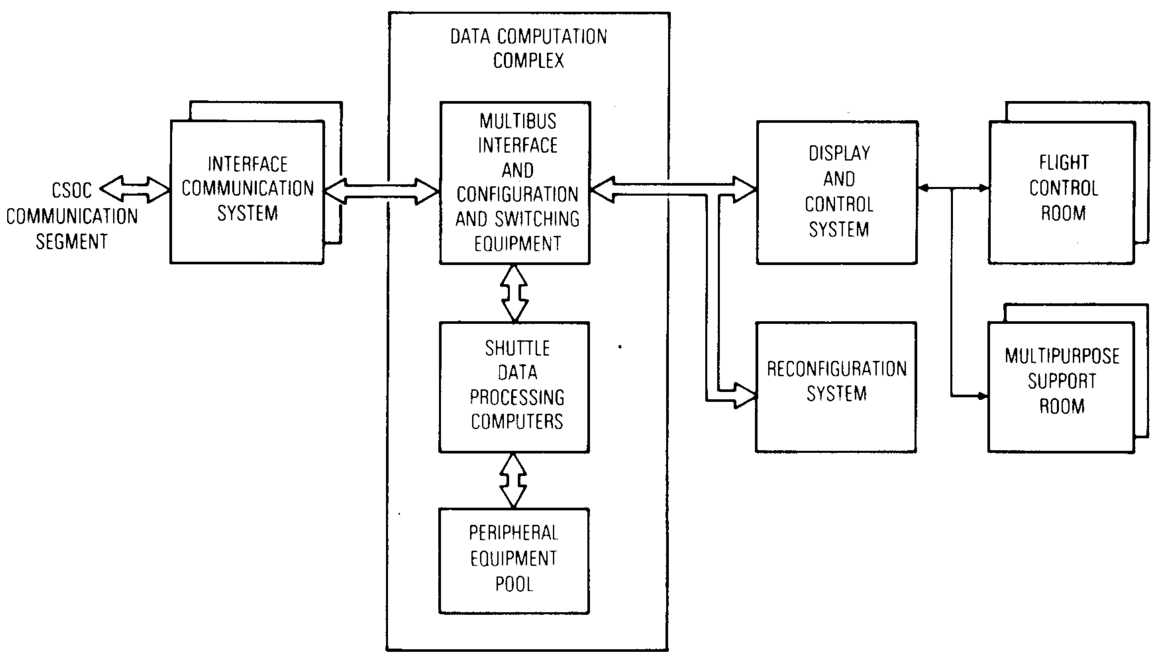


Figure 13. Flight Control Element

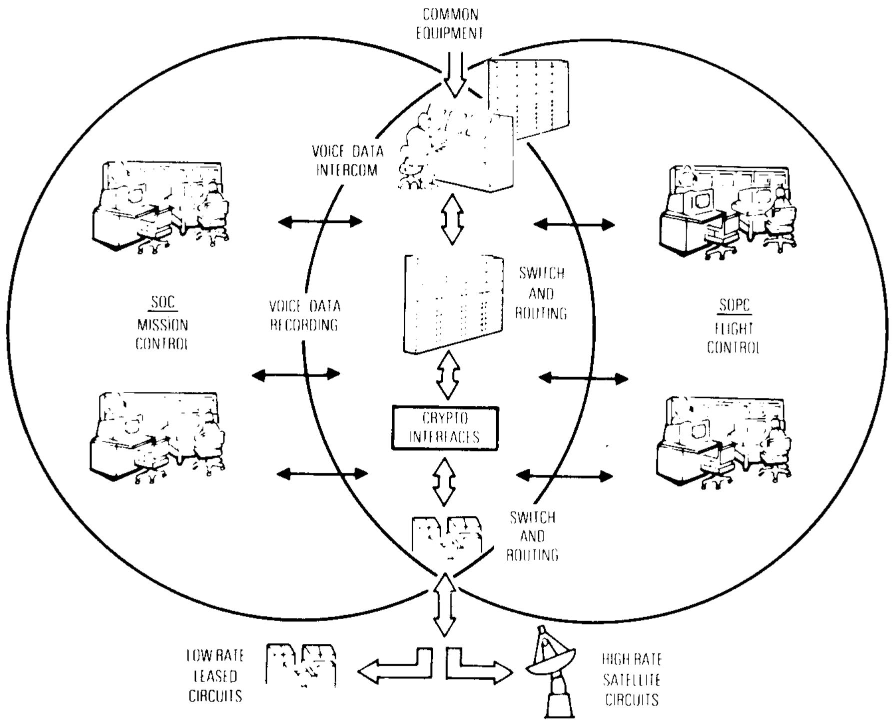


Figure 14. CSOC Internal Communications

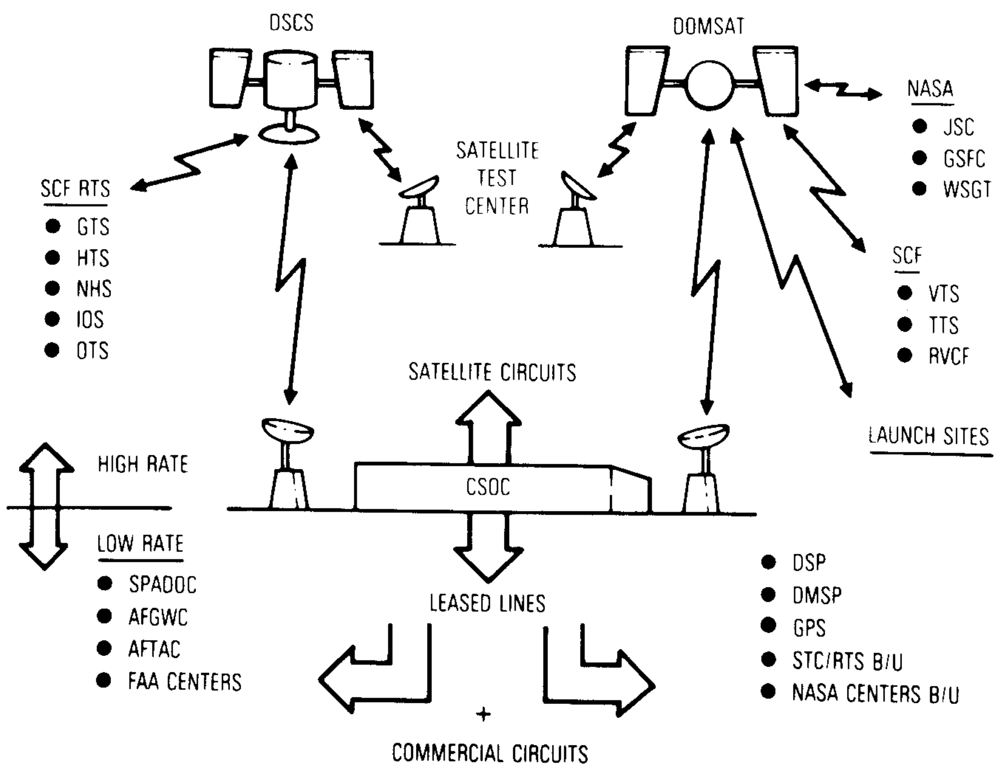


Figure 15. CSOC External Communications