DISTRIBUTED CONTROL
A CANDIDATE MILITARY COMSAT CONTROL SYSTEM

PAUL R. MARCHIONDA
PROJECT ENGINEER, System Engineering Office
The Aerospace Corporation
1320 Orleans Drive
Sunnyvale, California 94086

INTRODUCTION

Advanced Military Satellite Communications Systems providing communications capability supporting projected minimum essential military wartime communications that will accommodate force message distribution, force direction and force report back, and force/force or group-to-group communications.

These dedicated communications resources must be continuously available to the wide variety of military users. It is necessary, therefore, that the command/control implementation of these systems be capable of (a) long-term resource allocation to fulfill user requirements with a minimum of delay and system overhead, and (b) insuring system capability to fulfill real-time users service requests. Anticipated operational use indicates that a considerable amount of day-to-day control will be required to coordinate the user access to communications, to provide communications for internal user network control, and to support routine system maintenance activities.

This paper discusses a candidate centralized system management and distributed control framework that provides a system operations capability meeting the interconnection requirements needed for such a military type communications satellite system.

ABSTRACT

The command/control concept set forth in this paper features a centralized system management with distributed system control. Such a concept is intended to maximize user flexibility in the utilization of the communication resources while maintaining maximum system readiness for operation throughout all levels of conflict.

SYSTEM CONTROL CONCEPT

Successful strategic and tactical mission execution requires a control system that is survivable, suffers little interference, and does not unduly tax mission capability through excessive control overhead. The distributed command/control concept, illustrated in Fig 1, fulfills long-term user requirements by allocating system resources in accordance with JCS directives. This allocation is accomplished within the Master Control Center (MCC) of a MILSAT type system. The MCC will direct all administrative functions including system maintenance, satellite replenishment, crew training, and coordination of the control data base. Day-to-day satellite control and communications network operations are performed by selected Distributed Control Stations (DCSs) members. Satellite installation, on-orbit checkout, and anomaly correction are performed by the Air Force Satellite Control Facility (AFSCF). These command/control elements are combined into a structure nearly transparent to the system user. “Nearly transparent” requires that each user must abide by priority levels and is provided up-to-date system access data by the Command Elements. Portions of such data may be supplied via a satellite borne controller. The role of each command/control element, the user, and the satellite controller is discussed below.

MASTER CONTROL CENTER

Conceptually the centralized management functions can be pictured as resident within a Master Control Center (MCC). Since this is to be a survivable system, a second facility would perform critical MCC functions should the MCC be non-available during a crisis period. This backup function could be assigned to the AFSCF or could be one of the distributed control stations with an enhanced data base capability. The master control center is responsible for the operational management of a system that includes members of all services (Fig 2) and therefore is conceived to be staffed by representatives from each service in a manner similar to NORAD Cheyenne Mountain Complex operations. The MCC would implement JCS-validated user communications requirements by allocating communications resources among the current users. To accomplish this, the MCC must maintain the highest possible level of system readiness - as measured by the quality and quantity of available communications. This requires the MCC to perform system resource analysis involving satellite state-of-health and resource performance quality and capability. In short, the MCC must perform most of the analysis tasks of a typical mission control center. However, the MCC as a management center, need not perform, that subset of mission control center tasks associated with raw data processing. MCC functions include those shown in Fig 3.

Although the MCC need not have full mission control capability, it does need the capability to receive processed telemetry data, perform data updates, and insure the timeliness of data in use at the distributed control stations and support agencies. In this

later role, the MCC may be thought of as an electronic post office. The MCC receives JCS directives and guidance, and transmits resource allocations and control data to the distributed control stations. The communications required to accomplish these transactions are shown in Fig 4.

The MCC also converses with various support agencies (SCF, host bases, contractors, etc.) to coordinate both routine and emergency support actions. The communications requirements for these transactions are shown in Fig 5.

Routine MCC/Support Agency management functions range from coordination of planned prelaunch, launch, and on-orbit installation activities to the procurement of spares and direction of crew proficiency training. Emergency or anomaly operations include satellite anomaly operations by the SCF, coordination of backup control activities, and restoration of physical security.

DISTRIBUTED CONTROL STATION

The Distributed Control Element is a front line working group consisting of several geographically Distributed Control Stations (DCSs). Each DCS is responsible for the day-to-day evaluation and maintenance of a selected portion of the system's resources. Resources in this instance include three major items: satellites, control elements, and user communications. The DCS will perform only those satellite control tasks necessary to maintain system mission operations capability. These tasks, shown in Fig 6, are somewhat limited because the MCC insures satellite mission readiness allowing the DCS to concentrate on those tasks necessary to insure communications performance. Also, communications performance need be "insured" only for the desired mission period and the post-mission recovery interval. DCS task performance will be continually evaluated by comparison with SCF operational data. The MCC will coordinate DCS/SCF operations in the areas of telemetry reception, command processing, satellite state-of-health/failure correction, and ephemerides determination. Each DCS will be capable of full communications command and control while the SCF will maintain full capability to perform satellite anomaly investigation and correction and system TT&C functions. To assure crisis period operations, routine stationkeeping would be an SCF task, but could be performed by a DCS during emergency operations. The SCF will not backup the user network coordination of the DCS command/control tasks since these are typical program unique (communications use) functions. Each DCS will be assigned another DCS that can assume the satellite communications control function upon failure or degradation of the primary DCS. DCS-to-DCS data transfer will be required to assure the timeliness and correctness of backup operations. The MCC will monitor the transfer of these data while providing each DCS with resource allocation changes and system coordination data. Each DCS will also be assigned a backup DCS to perform the coordination functions within the

user community serviced by the primary DCS. Primary and Backup DCS will periodically exchange data bases to maintain the capability and assure timely handover. Each DCS would have the communications defined in Fig 7.

USER COMMUNICATIONS

User Communications (Fig 8) consist of two tasks: (1) forming the allocated resources into communications channels assigned to specific user(s), and (2) coordinating the use of allocated resources by a specific set of users. Formation of communication channels is accomplished using the MCC resource allocation criteria. This criteria may be changed whenever a user's mission communications requirements are revalidated by the JCS. The actual assignment of channels to specific users may be accomplished by user priority levels in conjunction with resource and communication path availability. However, a low priority user may be granted service simply because resources are available and are not in high priority use. User communications terminals must have user/satellite, user/network, and internal user communications capabilities as shown in Fig 9. In turn, each user communications terminal must be relatively small and inexpensive, must be easily deployed and used, and be readily adaptable to network control. The overall goal of user network control is to obtain a high level of utilization of the system resources with minimal control overhead. The achievement of this goal is complicated by the fact that there are multiple user networks in all parts of the world, and that effective communications service requires multiple satellites each compatible with all user communications terminals. A potential solution is to place a portion of the network control function onboard each satellite. Such equipment could be designated a communications controller.

COMMUNICATIONS CONTROLLER

The communications controller performs those "pre-programmed" network control functions as shown in (Fig 10).

User access coordination includes tasks such as system time, frequency or channel assignment, and network coordination data dissemination. The communications controller receives service requests and performs sufficient processing to determine the resources required and their availability based upon the directory data resident within the controller. Available resources are then assigned and the service performed.

Availability in this sense, includes resources not assigned as well as resources assigned to lower priority service. Upon need, lower priority users are preempted and service is returned to a higher priority requester. The communications controller will notify a user prior to preemption. Some service requests may be satisfied from resources within a single satellite. Others will require multiple paths (satellite communications terminal to satellite to

communications terminal) to complete. Insofar as possible, the communications controller will determine multipath service routes. Difficult, or new routes will be determined by one or more network control stations.

CONCLUSION

A centralized management and distributed control concept has several advantages when applied to a survivable communications system. System management functions (replenishment, utilization directive, user/service/higher authority coordinator) are readily performed by a staff of resident experts. System management decisions are based upon timely, management pertinent, information inputs. Similarly, system control functions are executed in dedicated control stations, concentrating upon system control data. In absence of management authority, a control station can, by prearranged procedures, exercise the required level of management necessary to maintain a pre-specified system mission operational readiness. These advantages are obtained at the cost of control distribution which, if not carefully planned, can unduly increase the amount of communications capability needed to service the initial user requirement. Reduction of this control overhead increases system complexity (the introduction of communications controller) and to some extent, may limit the overall deployment flexibility of the system.

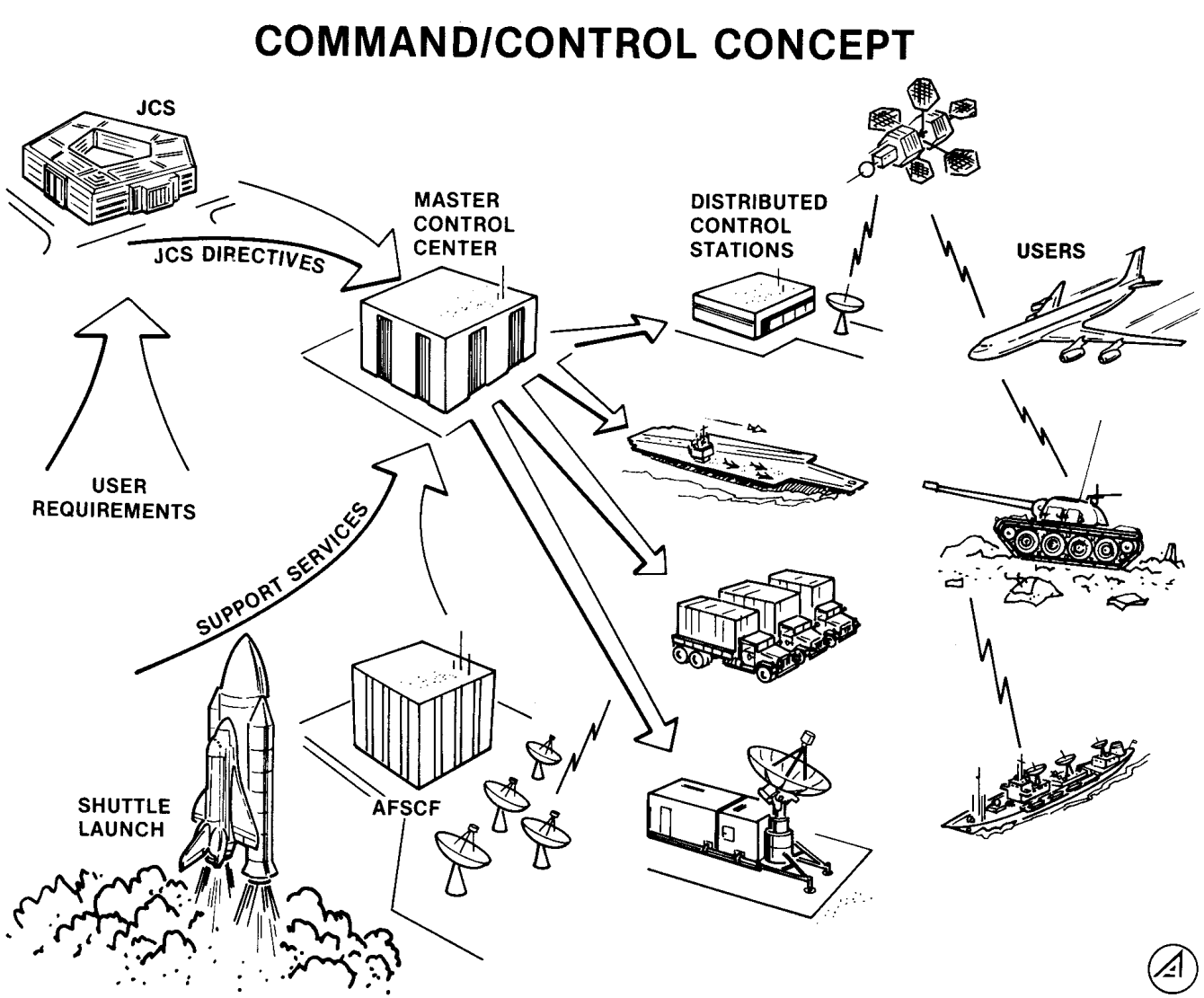


FIGURE 1 MILSTAR/COMMAND/CONTROL CONCEPT

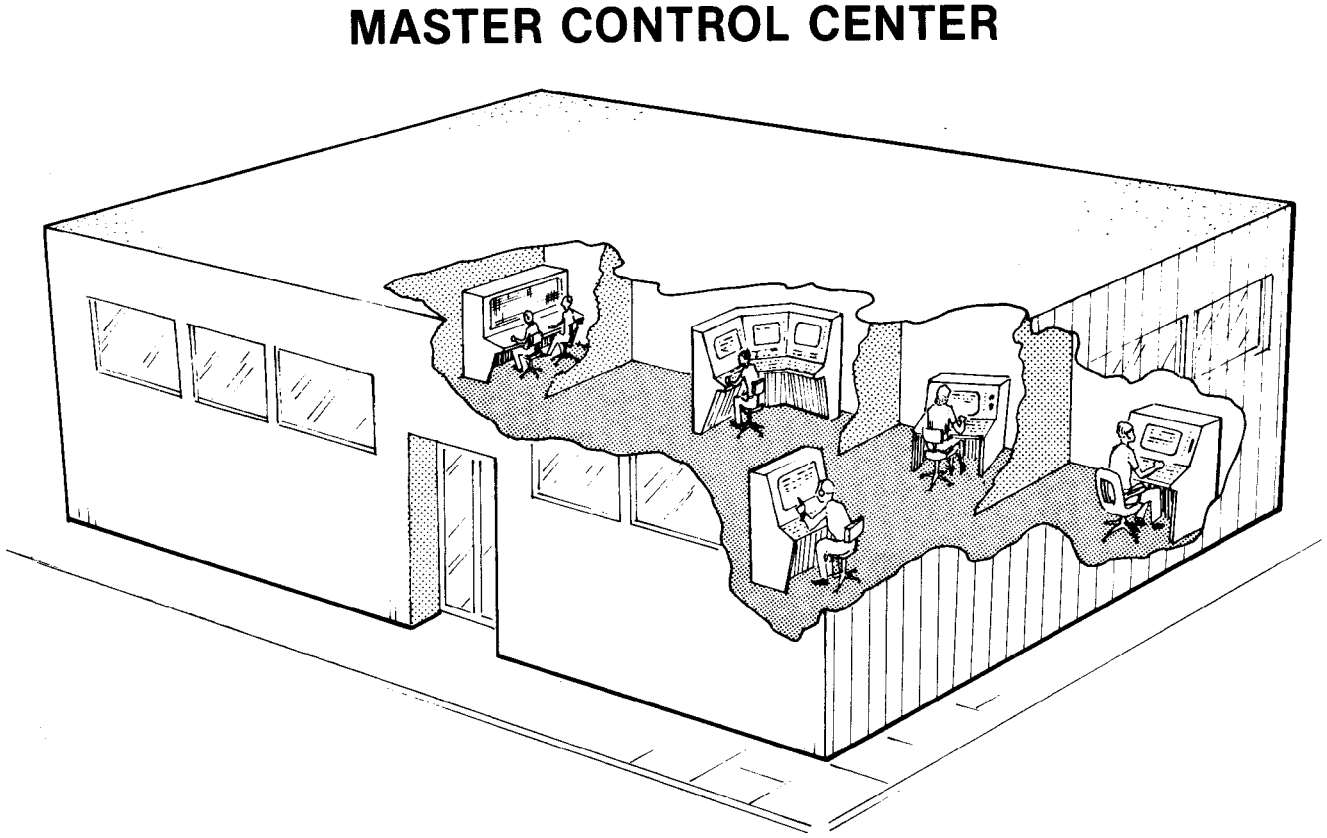
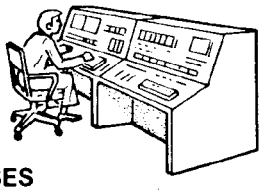


FIGURE 2 MILSTAR MASTER CONTROL CENTER

MASTER CONTROL CENTER FUNCTIONS



- OPERATIONS ANALYSES
  - RESOURCE MAINTENANCE
  - ELEMENT/SUBSYSTEM PERFORMANCE ANALYSES
- OPERATIONS DIRECTION
  - RESOURCE ALLOCATIONS
  - RESOURCE UTILIZATION COORDINATION
  - SUPPORT ACTIVITY COORDINATION

FIGURE 3 MASTER CONTROL CENTER FUNCTIONS

MCC OPERATIONS/CONTROL COMMUNICATIONS

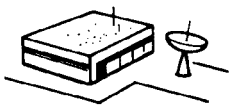
• JCS/MCC	
• DIRECTIVES	LOW RATE DATA
• DAY-TO-DAY GUIDANCE	VOICE
• MCC/DISTRIBUTED CONTROL	
• RESOURCE UTILIZATION	LOW RATE DATA
• USER COORDINATION	VOICE, LOW RATE DATA
• PROCESSED TELEMETRY	LOW RATE DATA
• PROBLEM SOLVING	

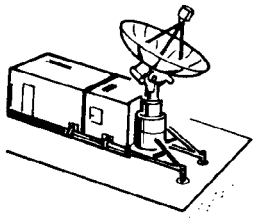
FIGURE 4 MCC OPERATIONS/CONTROL COMMUNICATIONS

MCC/SUPPORT AGENCY COMMUNICATIONS

- AFSCF
  - TASK COORDINATION — VOICE, LOW RATE DATA
  - PROBLEM ANALYSES — LOW RATE DATA
- HOST BASE
  - LOGISTICS — VOICE, LOW RATE DATA
  - SECURITY — VOICE
- OTHER — VOICE, LOW RATE DATA

FIGURE 5 MCC/SUPPORT AGENCY COMMUNICATIONS





DISTRIBUTED CONTROL STATION FUNCTIONS

- TELEMETRY RECEPTION AND PROCESSING
- SATELLITE STATE-OF-HEALTH EVALUATION
- SATELLITE COMMAND GENERATION
- EPHEMERIDES DETERMINATION/ORBIT MAINTENANCE
- FAILURE DETECTION AND LIMITED CORRECTION
- USER NETWORK COORDINATION

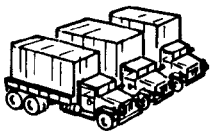


FIGURE 6 DISTRIBUTED CONTROL STATION FUNC.

DISTRIBUTED CONTROL COMMUNICATIONS

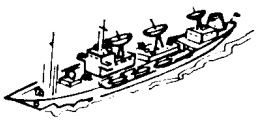
• MCC	VOICE, LOW RATE DATA
• CONTROL/CONTROL	
◦ COORDINATION	VOICE, LOW RATE DATA
◦ BACKUP DATA	LOW/MEDIUM DATA RATES
• SATELLITE	
◦ SATELLITE COMMANDS	LOW RATE DATA
◦ TRACKING/TELEMETRY	WIDEBAND
◦ MANAGEMENT/CONTROL DATA	VOICE, LOW RATE DATA

FIGURE 7 DISTRIBUTED CONTROL COMMUNICATION

USER NETWORK CONTROL FUNCTIONS

- RESOURCE UTILIZATION
  - CHANNEL FORMING
  - CHANNEL MIX
- ASSIGN RESOURCES TO USERS
  - PRIORITY
  - CURRENT USE

FIGURE 8 USER NETWORK CONTROL FUNCTIONS



USER COMMUNICATIONS TERMINALS

- FUNCTIONS
  - USER/SATELLITE COMMUNICATIONS
  - USER/NETWORK CONTROL
  - USER INTERFACE
- CHARACTERISTICS
  - SMALL
  - RELIABLE
  - INEXPENSIVE

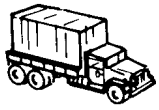


FIGURE 9 USER COMMUNICATIONS TERMINALS

COMMUNICATIONS CONTROLLER FUNCTIONS

- USER ACCESS COORDINATION
- SERVICE REQUEST PROCESSING
- CALL ROUTING
- RESOURCE DEDICATION

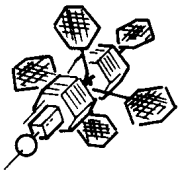


FIGURE 10 COMMUNICATIONS CONTROLLER FUNC.