SATELLITE CONTROL SYSTEM*

Lt. Col. J. Baker and Lt. S. Vest
Space Service Division
Air Force Systems Command, Los Angeles, California
and
A. S. Gilcrest and T. M. Rodriguez
The Aerospace Corporation, El Segundo, California

ABSTRACT

The motivations are discussed for considering a dedicated military satellite system that will provide tracking, telemetry, and command (TT&C) services, wideband mission data relay to the continental United States (CONUS), and narrowband mission data relay on a worldwide basis for United States Air Force (USAF) satellite systems. Mission models for the next 20 years are discussed. A concept study is in progress, and the guidelines for this effort are presented.

INTRODUCTION

The USAF currently maintains worldwide facilities for supporting approximately 50 satellites that carry out communication, navigation, meteorological, surveillance, and research and development (R&D) missions. Studies performed in the late 1960s and mid1970s have revealed the potential benefits to be derived from supporting these mission satellites with relay satellites and from the use of CONUS-based ground facilities instead of the present complement of dispersed worldwide ground sites. To date, the development of a Satellite Control System has not been pursued for a combination of reasons, which include insufficient cost benefits, an inadequate technological base, and a lack of mission requirements that could only be satisfied by a spaceborne relay system.

Because of the military's increased dependence on space assets, there is a greater need for more survivable space systems, a desire for less reliance on foreign countries, an increased potential for mission requirements that can be fulfilled only by relay systems, and an ever-continuing need to more cost effectively satisfy functional requirements. Thus, the USAF has initiated concept studies (1 and 2) to reexamine the entire spectrum of spaceborne satellite control and data relay issues.

* This research was supported by the Space Service Division (SSD) of Air Force Systems Command under Contract No. F04701-79-C-0080.

In this paper, the needs of a satellite control system that might eventually become requirements for such a system are discussed, and postulated mission models that provide a basis for defining system alternatives are presented. The most significant guidelines imposed on the concept studies are delineated.

NEEDS

General representation of the satellite control system concept is depicted in Figure 1. The main features of the system are the duplex interconnections between a variety of mission satellites with CONUS-based fixed or mobile ground control nodes via relay satellites. Two-way communications between both fixed and mobile overseas military are shown. The functional concept provides for total TT&C as well as mission data processing support from CONUS-based ground nodes for all mission satellites supported by the USAF. The links from CONUS to the mission satellites would support low (to 100 kbps) to medium (to 1 Mbps) bandwidth commanding and tracking signals. In addition, low bandwidth signals consisting of processed mission data could be forwarded from CONUS to overseas fixed or mobile military users. The return links from mission satellites to CONUS would consist of medium bandwidth tracking signals and wide (to 5Gbps) bandwidth mission data. The system network would also provide for the direct distribution of low bandwidth mission data from mission satellites to worldwide users. Some limited control of network routing functions is postulated from certain CONUS or worldwide users, such as Airborne Command Posts and certain theater-based mobile or fixed assets. The Satellite Control System concept could support the following current and future DoD needs:

1. Increased Survivability

Both physical and electronic survivability of satellite assets will be significantly enhanced by the Satellite Control System. Physical survivability will be improved by obviating the need for overseas ground-based facilities for TT&C or mission-related functions. Electronic survivability will be improved by the increased antijam capability naturally derived from the use of 60-GHz (high atmospheric attenuation) or very narrow beamwidth optical beams for the cross-links between the mission and relay satellites. Communications between the relay satellites and the surface of the earth are antijam enhanced by utilizing spread spectrum techniques. In addition, communications between the relay satellites and CONUS will be very narrow beam, which will further improve antijam characteristics. Limited network routing control from airborne or ground mobile points will be possible in the event of nuclear warfare.

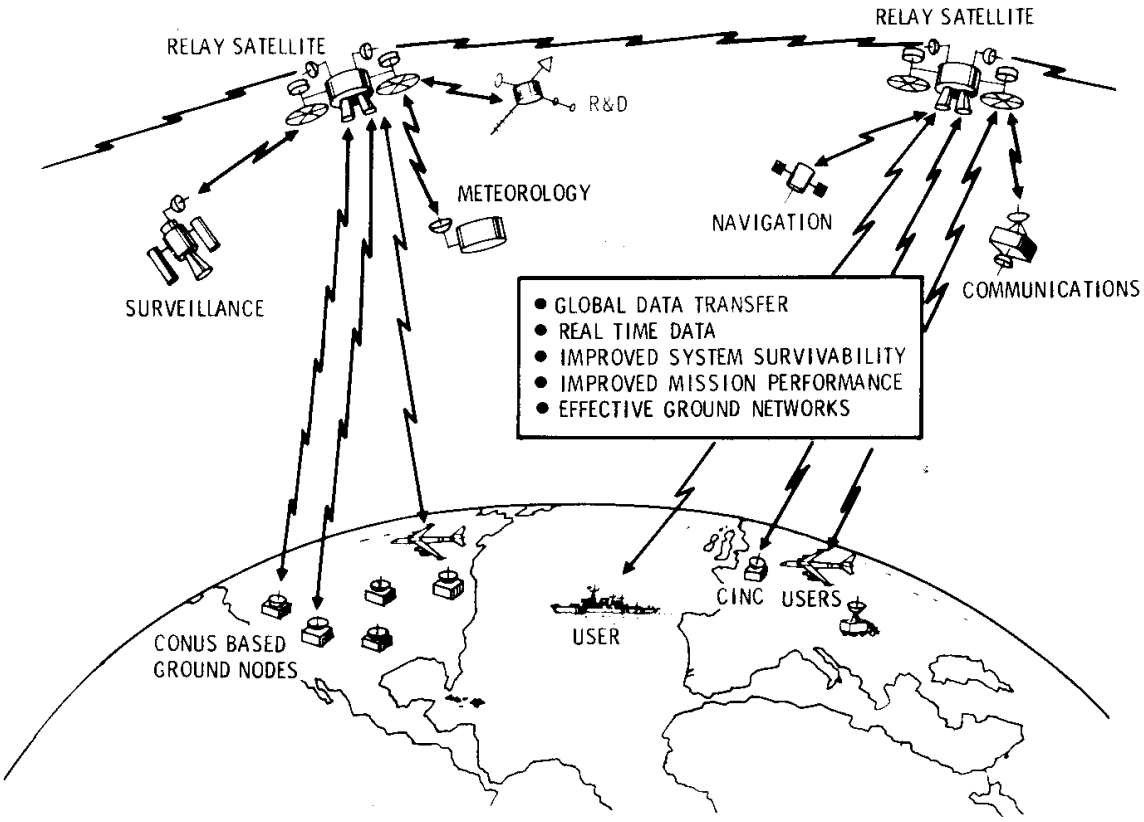

Figure 1. Satellite Control System Concept

2. Unique Mission Requirements

A given TT&C or mission ground facility has limited access to other than an equatorial synchronous altitude satellite within its own field of view. The problem is especially exacerbated for low-altitude satellites. For instance, the USAF Satellite Control Facility has remote tracking stations at seven worldwide locations, and for satellites at a 200-nm altitude, access duty cycles are less than 7%. Any mission requirement for either continuous access or access at a particular time between the ground and mission satellites can, in general, only be satisfied by a satellite relay system. Mission requirements that necessitate continuous or frequent communication accesses between the ground control point and the mission satellites include real-time or near real-time mission data transfer needs, inability or impracticality of recording mission or telemetry data, or continuous command capability to aid in dynamic contingency situations.

3. Reduced Dependence on Foreign Assets

Changing political alignments and pressures exerted by continuing localized crises dictate that less reliance be placed on assets in foreign countries.

4. Potential Economic Benefits

Globally dispersed ground facilities for either TT&C or mission processing are expensive to build and maintain. Reducing or eliminating the need for such facilities provides significant potential for cost savings. In addition, the unique mission benefits that can be practically provided only by the system described herein potentially result in a cost-effective solution to increased military effectiveness. Finally, the cost-effective potential for increasing the survivability of this country's military space assets is believed to be considerable.

MISSION MODELS

Postulated mission models were formulated for the 1984 to 1989 and the 1990 to 2000 time periods. The basic model functions are depicted in Figure 2 and matrixed in Table I. Twenty different satellite systems (114 individual satellites) are assumed for all mission models. For the near-term model (user Model No. 1), all ground nodes are assumed to be contained within CONUS. The model permits five ground stations dispersed throughout CONUS. Mission Model No. 2 covers the 1990 to 2000 time period and includes the worldwide distribution of processed mission data of up to 100 kbps. Mission Model No. 3 is for the same time period and also includes some limited network routing from other than CONUS ground-based locations. The main distinction between the earlier and later models is the higher assumed mission data rates (5 Gbps versus 1 Gbps maximum) for the later period. The requirement for handling higher mission data rates is somewhat counterbalanced by assuming that by the 1990s certain satellite programs will use onboard data processing of mission data so that links at 100 kbps or less are directly available to worldwide field users. For such satellites, it is assumed that the nonprocessed wideband data must be returned to CONUS only 2% of the time.

For each satellite system, the following model parameters are defined:

1. Number of Prime and Backup Satellites
2. Orbital Altitude Range
3. Telemetry, Commanding, and Raw Mission Data Rates
4. Link Duty Cycles
5. Priority

There are three priorities:

1. Priority 1 - Scheduled activities will occur on schedule 99. 7% of the time.
2. Priority 2 - All scheduled activities must be completed. However, support phasing may be adjusted 50% of the time.
3. Priority 3 - All scheduled activities must be completed. However, support phasing may be adjusted 100% of the time.

The mission models contain additional details on data sources and sinks so that an objective baseline exists for defining alternative options for a Satellite Control System.

CONCEPT STUDY GUIDELINES

Before concept study contracts could be initiated, guidelines and requirements over and above those covered in the mission model had to be formulated. The principal guidelines are summarized in Table II. The concept studies are currently under way, and final results will be available by late 1979 or early 1980.

CONCLUSIONS

Because of the military's increased dependence on space, more survivable space systems are required. The system concept delineated in this paper could provide an additional measure of survivability and at the same time fulfill mission support functions for which there are no practical alternative means of accomplishing. System alternatives for satisfying the postulated mission model requirements delineated in this paper are currently being formulated by the study contractors (1 and 2). Costs will be determined for each alternative. In addition, cost savings that would result from the potential elimination of existing or planned capabilities that would not be required with the employment of a satellite control system will be delineated. Thus, the referenced studies will provide the basis for a cost-effectiveness analysis. The study results will be available by late 1979 or early 1980.

TABLE I. Satellite Control System User Models

User Model	Time Period	Data Sources			Data Sinks	
		TT&C	Mission Data	C^2 from Major Stations	AFSCF/ Dedicated Terminals	Worldwide Command Posts
1	1984 - 1989 Baseline	X	X		X	
2	1990 - 2000	X	X		X	X
3	1990 - 2000	X	X	X	X	X

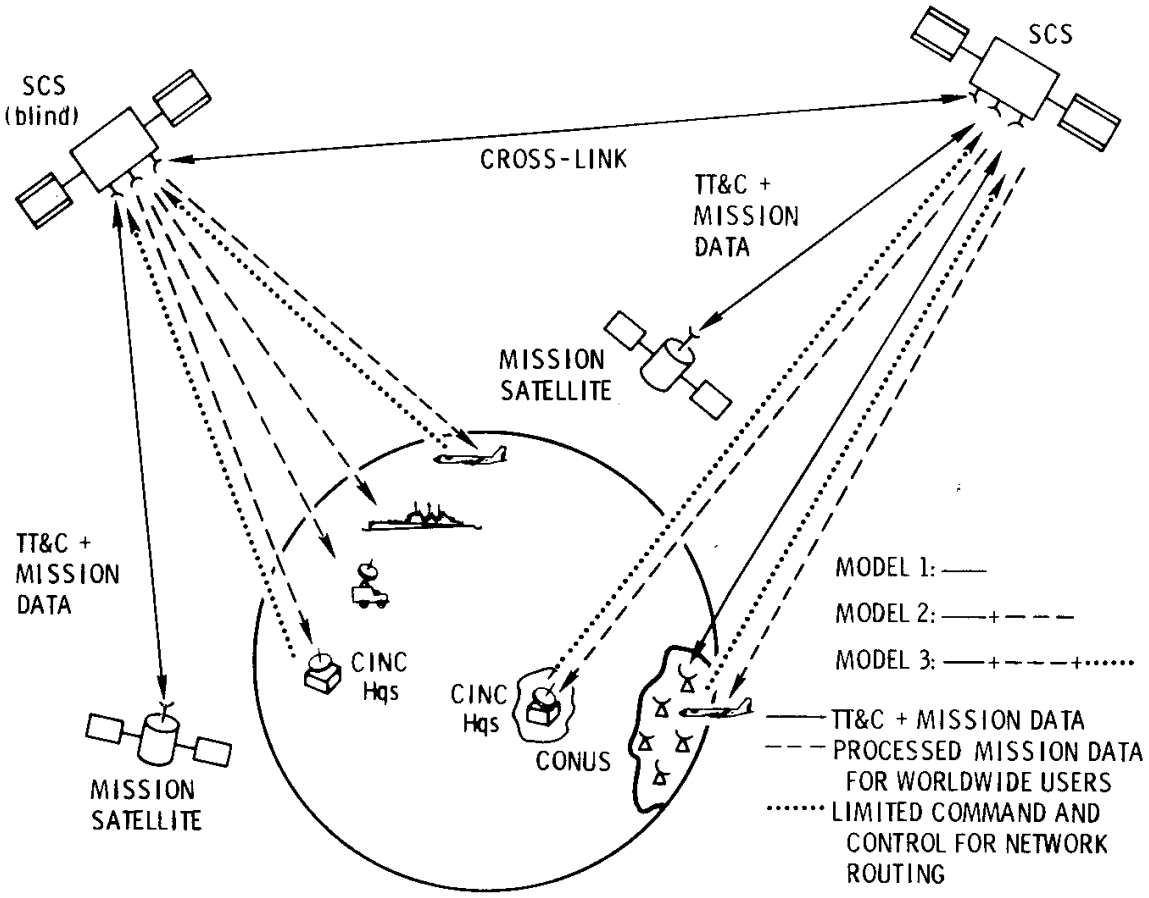

Figure 2. User Model: TT&C plus Mission Data

ACKNOWLEDGMENTS

The authors express their gratitude to Col. B. Browning, Space Services Division, AFSC, for his support and guidance. Also, our gratitude is extended to the following individuals who were instrumental in formulating the mission models and initiating the concept study contractual effort: Lt. Col. E. Gruenler, Space Services Division, AFSC, and D. Moore, L. Rider, and D. Speece, The Aerospace Corporation.

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2. Laser Communications, Contract No. F33615-76-C-1052, Contractor: McDonnell Douglas Corporation.

TABLE II. General Guidelines Under Consideration

Category	Guideline	
Coverage	Worldwide coverage for satellites exceeding 200-nm altitude	
	Global broadcast coverage of processed mission data (100 kbps) between 70°S and 70°N latitudes	
Frequency Ranges	Downlinks	Uplinks
CONUS	15 Ghz	18 Ghz
	20 Ghz	30 GHz
	40 Ghz	49 Ghz
Worldwide Links	7 Ghz	8 GHz
	20 Ghz	30 Ghz
Cross-links	60 GHz or optical	
Survivability	System must operate in a USAF designated physical and electronic threat environment.	
	Redundancy for all functions.	
Data Rates		
Mission Data		
Worldwide	Maximum processed = 100 kbps	
CONUS	Maximum raw = 5 Gbps	
Telemetry	Maximum = 128 kbps	
Commands	Maximum = 10 kbps	
CONUS Ground Entry Points	Five entry regions	
	Satellite TT&C and its mission data may be transmitted to separate CONUS entry points.	