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LEASED MILITARY SPACE COMMUNICATION SYSTEMS

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ABSTRACT

The Navy GAPFILLER satellite system, which consists of the UHF portion of the MARISAT satellite system, represents the first instance of a military Service leasing a space communication capability. This approach involves a marked departure from the traditional acquisition approach employed for military satellites. The Navy LEASAT leased communication satellite system, which will provide the follow-on to the DoD-owned FLTSATCOM satellite system for a significant number of military users of space communications, will be substantially more capable than the GAPFILLER system.

The LEASAT program is briefly described. Key features of the system, spacecraft, TT&C system and contract are presented. Some essential characteristics of a military communication satellite system are identified and the constraints on achieving them in leased systems of the future are discussed.

INTRODUCTION

Leasing of a communication satellite system by the Department of Defense was initiated by the U. S. Navy through the GAPFILLER program. The space segment for this program consists of the UHF (240-400 MHz band) portion of the Marisat satellites, which were built by Hughes Aircraft for COMSAT General Corporation.

The GAPFILLER program(1) was initiated in March 1973 by a Naval Electronic Systems Command (NAVELEX) contract awarded to COMSAT General Corporation. The program, as implied by the name, was implemented to provide a continued DoD UHF satellite communication capability following the MIT Lincoln Laboratory LES-6 spacecraft and the DoD TACSATCOM 1 spacecraft, pending the delayed availability of the FLTSATCOM spacecraft(2).

In part because of the success of this program, but also due to some delays and difficulties experienced in other DoD space programs, the Congress directed (3) that the FLTSATCOM program be terminated at five spacecraft and that a leasing program be implemented to continue this service. In response to this direction, the office of the Secretary of Defense appointed the U. S. Navy as the executive agent for this system (subsequently to be called LEASAT) and directed the Navy to acquire a leased capability with spacecraft channelization within the bounds established in the memorandum as baseline and target. Table I illustrates these channelizations. For purposes of comparison, the final LEASAT spacecraft channelization, as currently being constructed, is also shown. This channelization was settled upon following issuance of a draft Request for Proposals (RFP) to Industry, an assessment of schedule and technical risk as well as program viability for lease as a function of satellite design, and the assessment of the program by the Assistant Secretary of Defense (C3I), the MILSATCOM Systems Office of DCA (MSO), and the Services.

With the satellite channelization established, NAVELEX completed the structuring of a lease program and issued the formal RFP on April 28, 1978. Following proposal evaluation, the LEASAT contract was awarded to Hughes Communication Services, Inc. (HCSI) on October 1, 1978.

LEASAT SYSTEM

The LEASAT System consists of a space segment and a control segment. (The user community will be the same as that which is currently utilizing the GAPFILLER and FLTSATCOM systems.) The space segment consists of five years of service at each of four geostationary orbital locations to be specified by the Navy 240 days prior to commencement of service at a location. The spacecraft at these
locations will have the characteristics indicated in Table II.

As previously stated, these spacecraft will provide for a DoD UHF satellite communication capability following FLTSATCOM. Therefore, the specified spacecraft locations are likely to be similar to the planned FLTSATCOM locations. The resultant coverage achieved is shown in Figure 1.

LEASAT will have fewer UHF channels available than does the FLTSATCOM, but substantially more than GAPFILLER. The motivation for this fact is based partially on the desire to permit a spacecraft design which, while it meets the DoD needs, has adequately constrained technical, cost, and schedule risks compatible with a leasing philosophy. Of even more importance, however, is the fact that the UHF Demand Assigned Multiple Access (DAMA) system (4), which is currently under development by NAVELEX for multiservice use, is scheduled for implementation prior to the LEASAT service dates. Since DAMA permits a substantial increase in the number of 2.4 Kbps and 75 bps (TTY) links which can be passed through a 25 kHz channel, the number of 25 kHz channels required is reduced. Although spacecraft simplicity is achieved by this approach, a disadvantage is that failure of a single channel causes loss of significantly more possible links than is the case in single link-per-channel systems. A final factor in reducing the number of channels is the movement of the AFSATCOM user community from the FLTSATCOM follow-on (LEASAT) to an alternate system.

Since it is intended as a continuation of UHF satellite communication capability to the FLTSATCOM program, LEASAT will use the same frequencies. Since fewer channels are included in the LEASAT, a subset of the FLTSATCOM frequency plans is being used. This fact permits the avoidance of the third order, passively generated intermodulation products (IMPs) encountered by FLTSATCOM, a factor which contributed largely to the delay and increased program costs of FLTSATCOM. The lowest order IMP of this type which falls into the LEASAT receive band is fifth order. As for FLTSATCOM, three orthogonal frequency plans will be available to the LEASAT system to permit flexibility in orbit selection and coverage.

SPACECRAFT

The LEASAT spacecraft will appear as shown in Figure 2 when they are constructed. The spacecraft will be launched via the Space Transportation System (STS), i.e., the Space Shuttle. Each spacecraft will occupy 4.2 m (160 inches) of the shuttle length and have 4.2 m (170 inches) diameter. Some 6,400 kg (14,000 lbs.) of the total shuttle payload will be allocated to each spacecraft. A point of interest is that the fraction of total satellite weight occupied by the LEASAT spacecraft and the fraction of total satellite payload weight are about equal. Thus, in keeping with the NASA pricing policy of determining launch cost by the larger of these two fractions, the LEASAT spacecraft utilize length and weight in a balanced fashion.

The mission sequence which will be followed for the LEASAT spacecraft launches is shown in Figure 3. The spacecraft will go from the parking orbit of the shuttle through a transfer orbit and drift orbit to the selected geostationary orbit. On separation from the Shuttle (STS) parking orbit at a velocity of 1.3 fps and spin rate of 1.8 rpm, the omniantenna of the spacecraft is deployed, and the X-and (7250-7750 MHz and 7900-8400 MHz bands) TT&C system, selected communications systems and heaters are turned on. After a safe distance is achieved, the spin-up jets are fired to increase the spin rate to 30 rpm. After 45 minutes the solid propellant subsystem (SPS), i.e., perigee kick motor is fired to place the spacecraft in initial transfer orbit. The SPS is then ejected and the position is checked by TT&C data. During the next two perigee passages the liquid bipropellant subsystem (LBS) is activated to achieve velocity increments which will place the spacecraft in the final transfer orbit with apogee at synchronous altitude. Spin axis is then reoriented for the LBS firing at apogee. Once the LBS has injected the spacecraft in the drift orbit, the reaction control subsystem (RCS) will be used to reduce orbit eccentricity and remove any other orbit variation. When the selected geostationary orbit is achieved, the platform is despun, UHF antennas are deployed, and earth pointing is accomplished.

TT&C

The LEASAT system, by virtue of its leased nature, is technically controlled and monitored by the lessor, HCSI, in coordination with and as directed by U. S. Navy representatives. The control and monitoring of the LEASAT spacecraft will be carried out from six possible locations, as shown in Figure 4. At the four primary sites, there will exist both a government and contractor satellite control function (GSCCs and CSCCs). These sites are the three Navy Communications Area Master Stations (NAVCAMS) at Norfolk, VA; "Honolulu, Hawaii"; and Guam, as
well as the Naval Communications Station at Stockton, CA. At Norfolk and Guam movable ground stations (MGSs) are used for telemetry, tracking, and control (TT&C) functions during the ascent, for initial checkout and positioning phases of the spacecraft launches, and for backup of the primary stations.

Central control of the government responsibilities for TT&C is coordinated at the Naval Telecommunications Operation Center (NTCOC) at the Naval Telecommunications Command in Washington, D.C. The central control point for the contractor responsibilities for TT&C is the Contractor's Operations Control Center (COCC) at El Segundo, CA. All spacecraft commands are structured and coded by the contractor. The commands which affect the communication payload will generally be initiated by the government through the NTCOC and relayed to the COCC to be carried out. All other commands are initiated by the contractor at the COCC after coordination with the government NTCOC.

All commands are ultimately forwarded through the CSCS to the GSCS at the primary site for the spacecraft to be commanded and sent to the spacecraft at X-band through a Navy AN/FSC-79 terminal. An emergency capability to permit initiation of commands from these sites is also provided.

Telemetry monitoring and tracking functions are also carried out through use of the Navy AN/FSC-79 terminals. Telemetry information processing is primarily conducted at the COCC, and summaries of appropriate data are provided to the government.

LEASAT CONTRACT HIGHLIGHTS

As noted, the LEASAT contract calls for the provision of five years of satellite service at each of four locations. The total lease cost for this service is $335M, i.e., $16.75M per spacecraft year.

The service commencement dates are as shown in Table III. The government may, however, notify HCSI at least 240 days prior to any service start date to delay the service date by six months. Up to two of these delays per location are permitted, each independent of the others. In return for this delay in service, the government must pay the contractor $10,000 per day of delay, to be deducted from the initial charges for that spacecraft. Though the starting date of the services is delayed, the contractor is still obligated to provide services for the full lease period for that spacecraft. In no event, however, does the reduction in lease charge exceed a total of $5,000,000 for all spacecraft.

Delays which are not attributable to the government nor the contractor, i.e., delays which arise "out of causes beyond control and without the fault or negligence of the contractor..." are termed "excusable delays" under this contract. These include but are not limited to "acts of God or of the public enemy, acts of the Government in either its sovereign or contractual capacity, fires, floods..." etc. There is no penalty on the government nor contractor in these events. Service start and service periods are merely delayed in time if an excusable delay occurs.

After the spacecraft orbital locations have been specified, the government may require up to two relocations of the spacecraft to the position of a failed spacecraft at a rate of 5 degrees/day. The fuel required for relocation of spacecraft is independent of that required for normal station keeping.

HCSI has reserved the right to incorporate an additional payload into the LESAT spacecraft. Any payload which is to be included, however, must be approved by the government, based upon a formal request, along with adequate documentation to permit evaluation and assurance by the government that no adverse technical or schedule impact will be incurred by the LEASAT program. However, the contractor "will not incorporate any design modification... pending receipt of approval"; "will provide... bread board ground demonstration testing (and/or analytical data) in order to assure the Government that any additional payload... will not cause delay... schedule, nor cause the LEASAT payload to perform below Specification"; and "agrees either to remove the additional payloads... or to neutralize such payloads, in the event removal is impracticable or impossible..."

GFE

The government is providing substantial government-furnished equipment (GFE) to the LEASAT contractor, HCSI, both for on-ground testing and for implementation into the space and ground operating seg-
ments. This includes the satellite on-board processor which supports the fleet broadcast (a broadcast from the NAVCAMS to all fleet units) and command on-board processing functions in the spacecraft, as well as the equipment used for security purposes regarding the TT&C.

This on-board processor concept was developed by the Navy, and single channel processors (MD-942s) were procured and provided by the Navy to the FLTSATCOM program, for incorporation into the FLTSATCOM spacecraft in accordance with a Navy-generated interface specification.

In keeping with the proven successful approach employed in FLTSATCOM, NAVELEX currently has a contract with TRW to produce six dual-channel on-board processors (MD-942As) through a modest extension of the MD-942 design. These processors will be provided to the LEASAT contractor, HCSI, along with interface specifications.

FUTURE MILSATCOM LEASING

The GAPFILLER system represented the initiation of the leasing approach for military communication satellite systems and LEASAT represents a second generation. All indications at this time are that both systems will be fully successful in accomplishing their intended objectives. A question which can be asked, then, is what are the constraints on the leasing of military communication satellite systems?

The essential characteristics of a military communication satellite system are the following:

First, such a system must provide flexibility. Its utilization can be planned for, but the nature of application requires substantial flexibility to adapt to unplanned circumstances. Some examples include repositioning of spacecraft or reconfiguration of the system, rapid adaptation to changing earthborne assets and communication loading, etc.

Second, the system must provide for near state-of-the-art capability, at least in some technologies. This generally implies greater risk, and can be related to the cost of leasing this capability.

Finally, a necessary characteristic of a military communication satellite system is survivability, i.e., low vulnerability to physical or electromagnetic threats. This characteristic, of course, is coupled with the first two.

The manner in which a leased system can provide these essential features is discussed in the following.

Survivability or low vulnerability is generally provided through system design and/or proliferation. Both of these approaches can be employed for a leased system. Proliferation is simply a matter of specifying, contracting, and paying for the desired system. System design is a more difficult problem. The increased complexity of the payload, number of technical specifications and extent of testing and verification result in increased lessor risk and thus lease cost. Even without these additional considerations, very few corporations with the technical resources have the financial resources to offer this type of leased system. The additional constraints may eliminate some of them. Significant levels of survivability through system design may therefore be difficult to achieve with a leasing approach.

Next, consider the need for a military communication satellite system to maintain a continuing advancement in capability. Some portion of the payload must be upgraded to nearly a state-of-the-art level to maintain a capability which exceeds the threats likely to be encountered. Therefore, uncertainties are associated with this part of the system; they imply risk, and in a leasing arrangement, increased risk means increased lease costs. Thus, this factor may also lead to a loss of candidates to act as lessor for the desired system.

An approach to alleviate this difficulty may be one of conducting a parallel R&D program to result in partial payloads that can be introduced into the leasing arrangement as government-furnished equipment (GFE). Alternatively, the results of the government contracted and managed R&D programs can be introduced in the form of a specification on the functional characteristics to be designed into the system by the lessor. The key factor is that the essential upgrade in capability can be developed through a separate, parallel government R&D effort and the results transferred to the lease program.

This approach could also partially apply to the system-design problems related to survivability. The difficulty is that many of the required features extend beyond the payload, encompassing the bus and all support systems as well.

Finally, consider the issue of flexibility. An approach which appears to have significant merit to furnish a degree of flexibility before the leasing agreement is negotiated is to incorporate sepa-
rately priced options in the competition for the leasing of the system. However, this approach leads to increased complexity in the evaluation process, so it must be used sparingly. Once the initial contract is agreed to by lessor and lessee, changes are more difficult and more expensive than for a purchased system. This is largely a result of the fact that under a leasing arrangement it is more difficult for the lessee, the Government, to determine the best way of incorporating changes and to determine the incremental costs associated with them, because of its more limited visibility into the program. Also, changes may place an additional burden on the lessor due to his financial arrangement. Leasing of a system thus tends to provide less flexibility than purchasing of a system.

CONCLUSIONS

Leasing of satellite communications services by and for military services has been demonstrated to be practical and successful, from both the Services' and the lessor's point of view.

This paper discusses some of the unique characteristics of military satellite communications and outlines means whereby they can be accommodated in leased systems, while pointing out that in some instances they may mitigate against leasing.

REFERENCES


Figure 1. Planned LEASAT Communication Coverage
Figure 2. LEASAT Spacecraft
Figure 3. LEASAT Spacecraft Launch Sequence

REORIENTATION TO COMMENCE COMMUNICATIONS SERVICE
- DRIFT TO STATION
- DEPLOY UHF ANTENNAS
- IN-ORBIT TESTS TO CHECK SPACECRAFT PERFORMANCE

REORIENTATION AND APOGEE FIRING OF LBS
- INJECTS SPACECRAFT IN SYNCHRONOUS ORBIT

SPS FIRING AND STAGING
- INJECTS SPACECRAFT INTO INTERMEDIATE TRANSFER ORBIT
- EJECTS SPENT SPS

PERIGEE FIRINGS OF LBS
- OCCUR AT SUCCESSIVE PERIGEES OF INTERMEDIATE TRANSFER ORBIT
- PLACES SPACECRAFT INTO TRANSFER ORBIT WITH APOGEE AT SYNCHRONOUS ALTITUDE

LAUNCH
- FRISBEE EJECTION IMPARTS SLOW SPIN TO SPACECRAFT

PARKING ORBIT COAST
- SPACECRAFT SPUN UP TO 30 rpm
- TT&C ANTENNA DEPLOYED

SPACECRAFT COAST
- SPACECRAFT SPUN UP TO 30 rpm
- TT&C ANTENNA DEPLOYED
Figure 4. LEASAT Control and Monitor Stations