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30/20 GHZ FLIGHT EXPERIMENT SYSTEM PHASE II FINAL REPORT

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VOLUME 3.
EXPERIMENT SYSTEM REQUIREMENT DOCUMENT

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16. Abstract

Volume 3 is an approach recommended by Hughes to the requirements document which will be used to procure the system by NASA. The basic approach is similar to the requirements document used in the commercial communication satellite. Enough detail requirements are given to define the system without tight constraints.

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ILLUSTRATIONS

1. COMMUNICATIONS REQUIREMENTS

In addition to the specific requirements herein, the communication system will be capable of supporting the experiments in the Experiment Plan.

1.1 TRUNKING SERVICE

1.1.1 Area Coverage

Beams with HPBW = 0.4° centered at trunk stations at:

1) Los Angeles
2) Cleveland
3) New York
4) Houston
5) Washington, D. C.
6) Tampa

1.1.2 Burst Rate

The burst rate on each beam will be 256 Mbps, QPSK.

1.1.3 Link Definition

1) Links will be provided between all possible combinations of the six locations except that sites 3 and 4 are not served simultaneously and sites 5 and 6 are not served simultaneously. The systems will be capable of broadcast operation from any site to any combination of sites.

1.1.4 Link Reconfiguration

It will be possible to vary the distribution of a beam's capacity at any time during the mission in any way desired, subject only to the following restrictions:

1) The link capacity quantization is 1 Mbps.*

2) The desired link capacities must be consistent with a frame format which does not require two or more beams to be connected simultaneously to a single beam.

3) The minimum burst is 1000 bits.**

4) Reconfiguration of the satellite switching format shall be a nonreal time operation.

5) Assignment of messages within a station's link allocations is a user function.

1.1.5 TDMA Efficiency***

The TDMA design parameters (frame period, guard time, preamble length) will be such that in a 20 beam system requiring 200 reconfigurations per frame, the efficiency would be no less than 90 percent on these beams.

1.1.6 Data Quality†

The bit error rate shall be $\leq 10^{-6}$.

1.1.7 Rain Margin

The trunk earth terminal EIRP will have a power margin of 18 dB. The satellite EIRP will have a power margin of 8 dB. The earth station EIRP will be varied to match the rain attenuation to within ±2 dB. The satellite EIRP will be constant.

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*Link capacity quantization is the smallest change which can be made in the capacity of a link between two beams by varying the IF switch matrix switching times.

**Minimum burst is the number of bits in the shortest subframe which the switch matrix can implement.

***This requirement drives the synchronization requirements and the switch speed.

†This requirement drives the detailed communication requirements such as bandpass characteristics, linearity, etc.

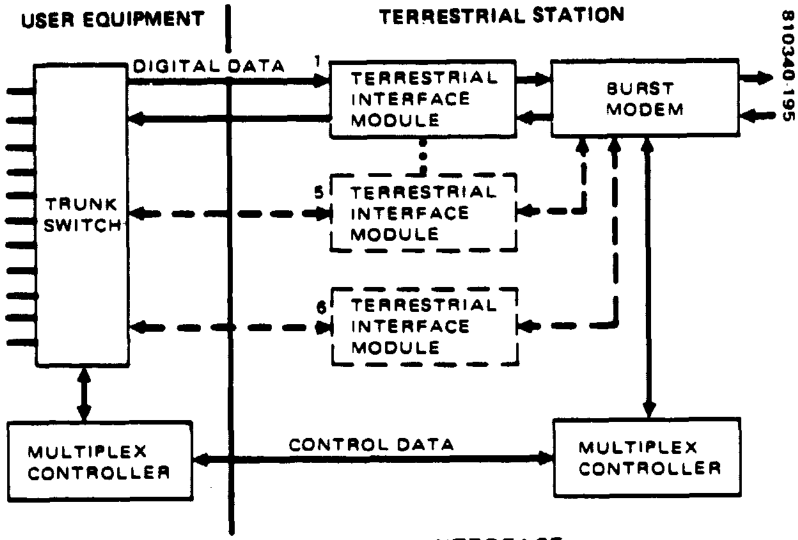

FIGURE 1. TRUNK INTERFACE

In addition, the terminal will have RF site diversity. NASA will define the locations of the two sites. No bit errors shall result from diversity switching. No loss of data shall occur if the attenuation at either RF site is such that communication can be successful at that site.

1.1.8 User Interface

The user interface is defined in Figure 1.* The characteristics are as follows:

The trunk terminal will be capable of receiving from the user six DS3 carriers (44.736 Kbps). The user will supply an orderwire to the terminal defining the distribution of the data in each signal by destination. The system contractor will supply an interface manual which defines the details of the interface. The output to the user will also be six DS3 carriers. Source and specific user destination information will be embedded in the data by the user.

1.2 CUSTOMER PREMISE SERVICE

1.2.1 Area Coverage

The area shown in Figure 2 will be covered by two uplink scanning beams and two downlink scanning beams. The characteristics of these beams are described in Section 4, under Space Segment Characteristics, below.

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*This definition places all of the functions of collecting and multiplexing data from individual users on the user side of the interface. This approach is necessary because of the lack of a definition of the user complex.

1.2.2 Burst Rates

Each uplink beam will have provision for either four 32 Mbps burst rate channels or a single 128 Mbps burst rate channel, QPSK.

Each downlink beam will be at a burst rate of 256 Mbps.

1.2.3 Link Definition

It will be possible to interconnect any CPS station with any other.

1.2.4 Capacity

The total throughput will be 256 Mbps equally divided between the two beams.

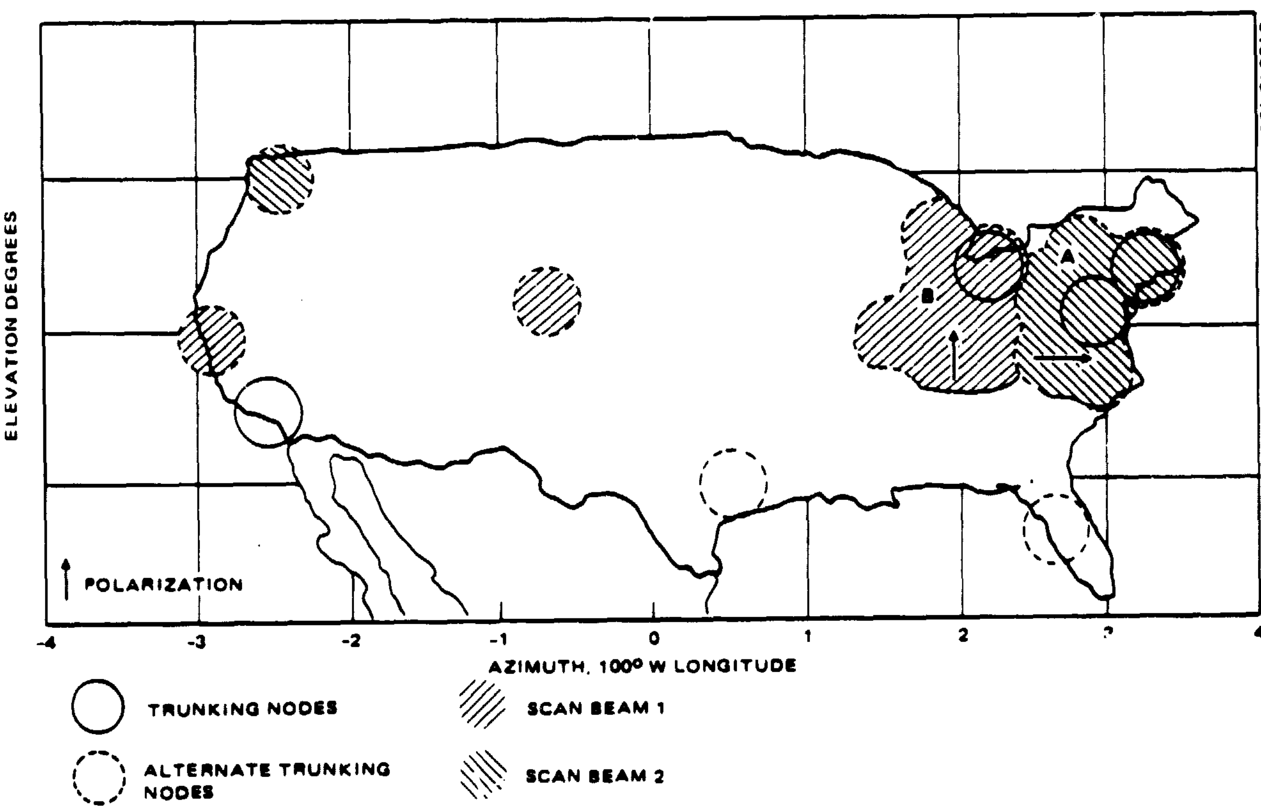

FIGURE 2. TYPICAL DEMONSTRATION SYSTEM COVERAGE

The distribution of the capacity of a beam between the geographical spots it covers will be completely variable at any time with the following restrictions:

1) The quantization of spot capacity will be 128 Kbps on the 32 Mbps channels and 512 Kbps on the 128 Mbps channels. Reconfiguration of the scanning beam format shall be nonreal time.

2) Individual messages at rates as low as 64 Kbps shall be demand assigned by the central control station using an orderwire through the satellite payload.

1.2.5 TDMA Efficiency*

The TDMA parameters (frame period, guard time, preamble) shall be such that a beam with 12 spots, each containing 16 stations simultaneously active, will have an efficiency of 90 percent for each of five 32 Mbps channels.

1.2.6 Data Quality

BER $\leq 10^{-6}$

1.2.7 Rain Margin

The uplink will have a total rain margin of 15 dB of which 7.6 dB will be power margin. The downlink will have a total rain margin of 6 dB. The earth station EIRP will be varied to match the rain attenuation to 2 dB. The satellite EIRP will be constant. In addition, forward error correction coding will be available to provide additional margin. This coding will be applied only to individual links (from a specific earth station to the satellite or from the satellite to a specific earth station) which experience rain attenuation which exceeds the available power rain margin. FEC will be available to 25 Mbps of data in any frame no matter how the demand for FEC is distributed between the terminals of the network. The FEC will provide 7.4 dB of additional margin with no change of symbol burst rate.

In addition, a downlink EIRP margin of at least 2 dB will be provided on the downlink to avoid excessive use of the FEC capability.

1.2.8 User Interface

The user interface is shown in Figure 3. The characteristics are:

1) The CPS terminal will be capable of receiving one digital data stream at 6.3 Mbps for the 32 Mbps channel and one at 22 Mbps for the 128 Mbps channel.

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*A baseband processor is required to meet this specification.

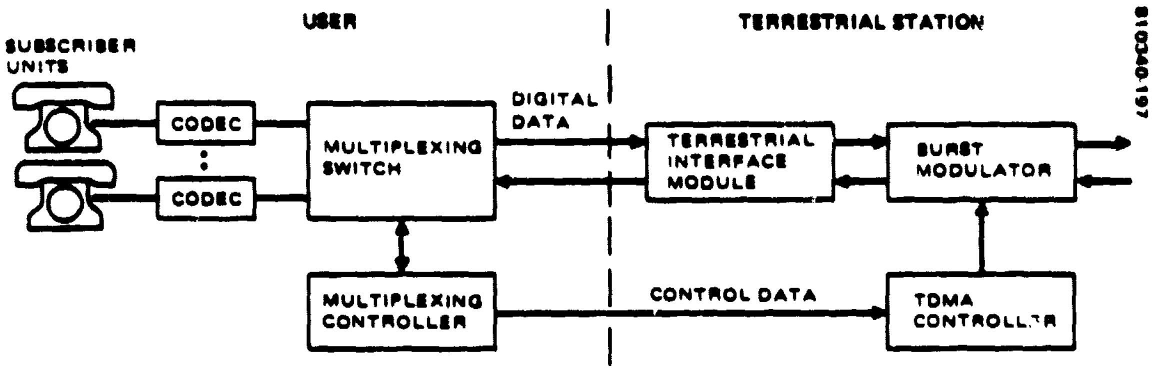

FIGURE 3. CPS USER INTERFACE

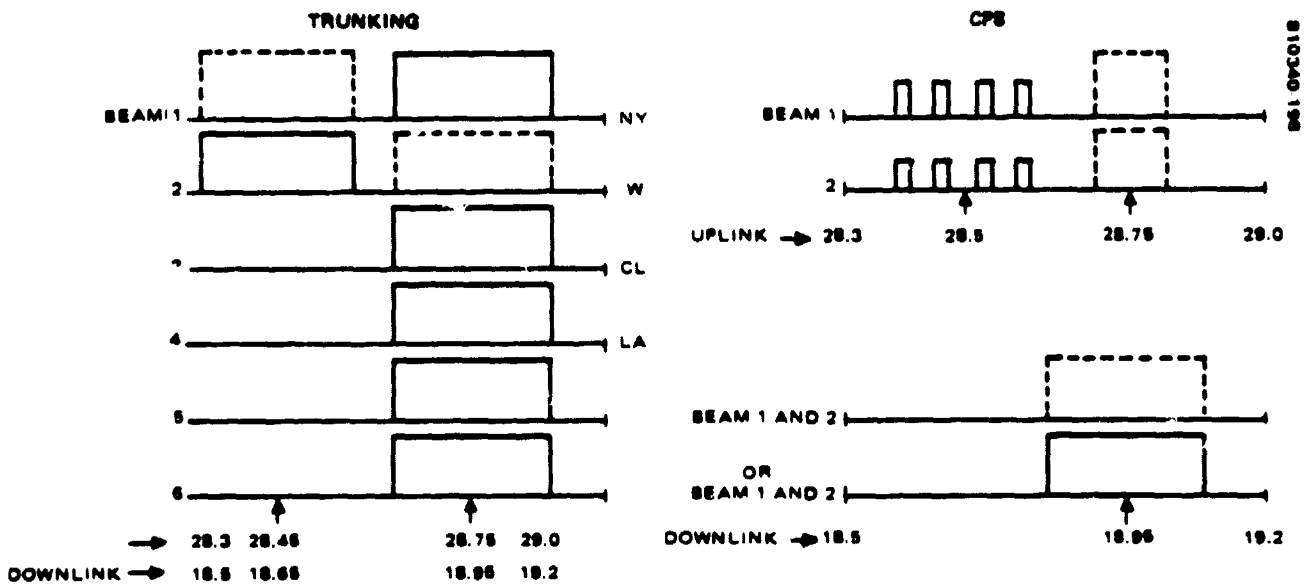

FIGURE 4. TYPICAL FREQUENCY PLAN

2) A control line connecting the customer multiplexing switch controller with the TDMA controller will provide the destination, bit rate, and sequence of multiplexing to the TDMA controller.

3) Output from the TDMA equipment will be in the same format as the input.

The system contractor will provide an interface manual which defines the details of the interface.

1.3 FREQUENCY PLAN

The frequency plan is defined in Figure 4.

1.4 DESIGN CONSTRAINTS

Design tradeoffs will be made on the basis of minimizing the total system cost assuming the network model of Appendix 2.** All CCIR and WARC flux density and interference constraints will be observed.

1.5 ANTENNA POINTING ACCURACY

All satellite beams will be pointed to within ±0.05°·(3σ) of their designated targets to avoid degradation of C/I.

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*This definition places all of the functions of collecting and multiplexing data from individual users on the user side of the interface. This approach is necessary because of the lack of a definition of the user complex.

**To be supplied by NASA

2. COMMUNICATIONS OPERATIONS

2.1 COMMUNICATION OPERATIONS REQUIREMENTS

The contractor will develop and execute the communications operations plan required for:

1) Payload configuration control

2) System synchronization

3) Station control

4) Link control

5) Demand assignment

2.2 PAYLOAD CONFIGURATION CONTROL

Telemetry data from the payload will be received, processed, and evaluated to determine payload health. Commands will be generated and transmitted via the command link to control the payload configuration to maintain payload health and to place the payload in the configuration required by the experiment operations.

2.3 SYSTEM SYNCHRONIZATION

2.3.1 Trunk Synchronization

A system will be implemented to synchronize the trunk terminal transmissions with the payload IF switch matrix so that these transmissions arrive at the IF switch matrix at the proper time for them to be connected to the beam for which the data is intended.

The trunk synchronization system will be capable of bringing new stations into synchronization and of maintaining synchronization with sufficient accuracy to meet the efficiency requirements of 1.1.5.

2.3.2 CPS Synchronization

A system will be implemented to synchronize the CPS terminal transmissions with each other and with the scanning beam antenna so that uplink transmissions reach the spacecraft at a time when the uplink scanning beam is pointed at the transmitting station and when no other cochannel signal is being received by the scanning beam.

The CPS synchronization scheme will be capable of bringing a station on line without interfering with other stations' signals when as little as 5 us of the scan beam dwell are unoccupied. The CPS synchronization accuracy will be compatible with the efficiency requirement of 1.2.5.

2.4 STATION CONTROL

A system will be provided to monitor the health, performance and configuration of the earth stations and to control the configuration and parameters of the stations as required to maintain station health. Monitoring and control of the earth stations will be performed by MCT via the communications orderwire. A backup terrestrial link will also be provided.

2.5 LINK CONTROL

The uplink transmitter power will be increased above the clear weather value as rain attenuation at the earth terminal increases. The power augmentation will match the rain attenuation so that the received signal strength at the spacecraft does not vary by more than ±2 dB. This control will be provided by the terminals using the 20 GHz spacecraft beacon to determine rain attenuation at 30 GHz. The MCT will monitor the status of each uplink transmitter to prevent a terminal from interfering excessively with other signals by transmitting excessive power.

2.6 DEMAND ASSIGNMENT

A system shall be provided for the customer premise service to assign traffic to channels on demand. The antenna scanning pattern will be preformatted and will only be changed on a nonreal time basis. Within a scanning beam dwell time, time slots and frequency channels shall be assigned by the MCT in response to channel requests received from the CPS terminals via the orderwire. A channel assignment shall be transmitted to the CPS terminal within 15 seconds of the time the request is received by the CPS terminal from the user.

3. EXPERIMENT OPERATIONS

The contractor will provide the hardware, software, personnel and resources necessary to coordinate and conduct the service and technology experiments defined in the experiment plan. Experiment control will be conducted at the MCT in conjunction with communications operations. Experiment control operations include planning and scheduling experiments, collection and dissemination of experiment data, analysis of experiment results, and coordination of experimenters using 30/20 GHz experiment system resources.

The contractor will develop an experiment plan consisting of descriptions and schedules of the service and technology experiments to be conducted, and a description of the experiment support resources required to conduct the experiments. It will be a detailed extension of the experiment plan generated by NASA from the responses to the Opportunities to Experiment. The experiment descriptions will include experiment objectives, variables, evaluation technique, methods, and means to be used in performing the experiment. The experiment support description will define the resources required to coordinate and conduct experiments, and to distribute data and analysis for those experiments.

4. SPACE SEGMENT

4.1 BASIC REQUIREMENT

The basic requirement on the space segment is that it meets the communications requirements of Section I when the spacecraft is combined with the terrestrial segment, the Communication Operations and the Mission Operations.

4.2 ADDITIONAL REQUIREMENTS AND CONSTRAINTS

In addition to satisfying the requirements of Section 1, the space segment will satisfy the following constraints and requirements which may not derive from the basic requirement.

4.2.1 Spacecraft Payload

4.2.1.1 Satellite Antenna

1) The satellite transmit antenna will have an aperture diameter of approximately 3 meters.

2) The satellite receiver antenna will have a half power beamwidth less than or equal to that of the transmit antenna. The receive aperture will be selected by the contractors and based on a tradeoff between antenna cost and complexity, earth terminal transmitter power and spacecraft weight margin.

3) The antenna sidelobe envelope will be at least 26 dB below peak gain beyond 2 half power beamwidths from boresight.

4) The spacecraft payload will have all capabilities required by the experiment plan.

4.2.1.2 Satellite Transmitter

The satellite transmitter will use 40 watt helix TWTAs for each of the four active trunk beams. Two of these TWTAs shall also be used for the scanning beams. A 7 watt GaAs FET amplifier will be provided as a spare for each pair of TWTAs.

4.2.2 Spacecraft Bus

The spacecraft bus will be an existing bus requiring minimal modification.

4.2.2.1 Bus Functions

The spacecraft will provide adequate power to the payload and associated bus subsystem. In addition, the spacecraft will provide all necessary TT/C, thermal, structural, attitude and propulsion support for the payload and bus.

4.2.2.2 Weight and Power Capability

The bus shall provide a margin of 10 percent of payload weight and 10 percent of payload power for 4 years.

4.2.2.3 Eclipse Capability

The bus will provide power during eclipse to support full communication operation with the margin specified above.

4.2.2.4 Orbit Keeping Capability

The spacecraft, in conjunction with its upper stage will be capable of achieving the specified geostationary orbit position. It will have all of the capabilities necessary to permit its orbital position to be maintained within ±0.02 degrees of the designated orbit position.

4.2.2.5 Attitude Keeping Capability

The spacecraft will have all of the capabilities necessary to permit its attitude to be controlled so that antenna pointing with error $\leq$ 0.05 degrees (3σ) can be maintained.

4.2.2.6 Launch Vehicle Interface

The spacecraft will be launched on the STS. The contractor will provide a suitable existing upper stage to place the spacecraft in transfer orbit. This stage may be a motor integral to the spacecraft or a PAM-D or SSUS A upper stage.

The spacecraft and upper stage will meet all shuttle interface requirements and be able to withstand the shuttle environment.

4.3 RELIABILITY

The spacecraft shall have a 4 year lifetime with the following reliability:

Trunk

a) 90 percent probability of at least three beams operative for 4 years.

b) 90 percent probability of at least 10 of the 16 possible links operative for 4 years.

CPS

a) 90 percent probability that at least 75 percent of spots in each beam can be operated on both up and down links.

b) 90 percent probability that at least two of four 32 Mbps channels on each beam and at least one 128 Mbps channel is operative.

c) 90 percent probability that at least 67 percent of baseband processor throughput is operative for 4 years.

5. TERRESTRIAL SYSTEM CHARACTERISTICS

The terrestrial system will be capable of operating with the communications payload to meet the requirements in Sections 1 and 2.

The terrestrial system is composed of a master control terminal (MCT) and a customer premise terminal.

5.1 MASTER CONTROL TERMINAL

The MCT will consist of a central control station , a trunk station, and two antenna sites. It shall provide central control of the system, trunking service at 256 Mbps, and customer premise service at 128 Mbps.

5.1.1 Central Control Station (CCS)

The contractor will define, develop, and provide the hardware, software, and resources to establish the CCS. The CCS provides the functions to implement a control concept for mission operations, experiment operations, and communications operations. (Mission operations* may be performed at a separate location if such concepts enhance the mission operations functions.) The CCS design philosophy will assume a minimum cost approach. Communications operations will be accomplished with as little software and automatic control as possible, yet still satisfy the requirements of Sections 1 and 2.

The contractor will define, develop, and provide the hardware and software for a central data processing facility for communications and experiment control.

The CCS will provide resources to perform planning and scheduling to effectively use communication system resources, manage and allocate TDMA channel assignments, and operate the 30/20 GHz communications system.

The contractor will define, develop and provide the hardware and software necessary for the network synchronization concept specified by the contractor under 2.3.

*Specified in Section 6.

5.1.2 Trunk Station

The contractor will define, develop, and provide the customer interface and/or the signal generation equipment required to establish the trunk station. The trunk station provides bulk transmission capacity for digital multiplexed data at 256 Mbps burst rates.

The contractor will define, develop, and provide the customer interface* and/or the signal generation equipment required to conduct the experiments specified by the experiment plan.

The contractor will define, develop and provide the equipment required to implement the trunk station synchronization concept specified by the contractor under 2.3.1. The synchronization concept will permit changes in the frame format to be made without loss of synchronization. It will also provide a means for orderly entry of new stations in the network without interruption of synchronization or interference with other stations.

The contractor will define, develop, and provide the communications equipment required to buffer and multiplex traffic data for burst transmission at 256 Mbps.

The trunk station will be connected to the antenna sites through a diversity switch located in the trunk station. The diversity switch will select an antenna site which is capable of providing the required link performance whenever either of the antenna sites is experiencing rain attenuation which is less than the rain margin provided for the trunk link. The process of switching antenna sites will cause no bit errors in communications traffic.

The trunk station will also provide a customer premise service at 128 Mbps. The contractor will design, develop, and provide the equipment to provide this service through the trunk station and local antenna site. This customer premise service will provide CPS orderwire access to the CCS and CCS access to the CPS network for experiment operations.

Maintenance requirements are as follows:

Over the 4 year mission life, the contractor shall maintain the station such that:

1) No station outage shall exceed 72 hours.

2) No more than two outages greater than 36 hours shall occur.

3) No more than six outages greater than 18 hours shall occur.

4) No more than ten outages greater than 6 hours shall occur.

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*See Figure 1.

5.1.3 Antenna Site

The antenna sites will be identical except for the equipment associated with the diversity links. One antenna site will be located adjacent to the trunk station and the other site will be approximately 27 km (15 miles) from the trunk station. The contractor will provide suitable links to interconnect the antenna sites with the diversity switch. The links shall be selected to minimize cost.

The contractor will define, develop, and provide the hardware and software required to implement signal transmissions and reception at the antenna site. The antenna diameter shall be 5 to 7 meters. The equipment selected shall be sufficient to implement the concepts specified by the contractor under Sections 1 and 2.

5.2 CUSTOMER PREMISE TERMINAL

The contractor shall define, develop, and provide the hardware and software required to establish the customer premise terminal. The CPS terminal provides transmission capacity for digital multiplexed data at 32 Mbps burst rate.

The contractor will design, develop, and provide the customer interface, and/or the signal generation equipment required to conduct the experiment specified by the contractor under Section 3.

The contractor will design, develop and provide the equipment required to implement the CPS synchronization concept specified by the contractor under 2.3.2. The synchronization concept will permit changes to be made to the frame format without the loss of synchronization. It will also provide a means for orderly entry of new stations into the CPS network without interruption of synchronization, or interference with other station transmissions.

The contractor will define, develop and provide the equipment to provide FEC coding as specified in 1.2.7.

The contractor will define, develop, and provide the hardware and software required to implement signal transmission and reception. The antenna diameter shall be 3 meters.

Maintenance requirements dictate that over the 4 year mission life, the contractor will maintain the station so that:

1) No station outage will exceed 72 hours.

2) No more than two outages greater than 36 hours will occur.

3) No more than six outages greater than 18 hours will occur.

4) No more than ten outages greater than 6 hours will occur.

The station shall be transportable.

6. MISSION OPERATIONS

6.1 MISSION OPERATIONAL REQUIREMENT

The contractor will develop and execute the mission plan required to place the STS launched spacecraft in the allocated geostationary orbit slot, to maintain the orbital position and attitude of the spacecraft as required below, and to monitor and maintain the health and status of the spacecraft throughout the mission. The plan will include both the nominal mission and contingency plans. In order to develop this plan the contractor will perform a mission analysis to establish the sequence of events from launch vehicle separation to final orbit deployment and on-station operation. This analysis will include consideration of launch window constraints, attitude and orbital error sources occurring during all phases of mission operation, the error determination and correction techniques to be employed, and the frequency with which correction will be required. This analysis will also show how the on-station operating life of the satellite is maximized. The analysis will be included as part of the Preliminary System Design Review.

6.2 LAUNCH AND PARKING ORBIT

6.2.1 Launch Parking Orbit Operation STS Launch Constraint

Any anomalous indication about the spacecraft that will adversely affect its in-orbit performance will preclude the spacecraft's ejection from the shuttle and the spacecraft shall be returned to earth.

6.2.2 Launch Window Constraints

The contractor will provide analysis defining all launch window constraints and injection sequences including error budgets and injection targets for STS launch.

6.3 TRANSFER ORBIT OPERATIONS

During the transfer orbit op ations, the spacecraft spin axis orientation, spin rate, spin position, and spin axis nutation will be monitored at the mission control center from telemetered sensor data. The spacecraft will be tracked from suitable ground stations and the tracking data will be used for the determination of the transfer orbit.

The accuracy of the attitude measurements required during the transfer orbit will be sufficient to achieve the final injection targets.

The spacecraft orientation and spin rates will be adjusted at the appropriate time in the transfer orbit to allow accurate firing of the apogee motor and the subsequent attainment of the operational orbit.

6.4 EARTH ACQUISITION AND DRIFT ORBIT

Subsequent to the firing of the apogee motor, the spacecraft shall perform the earth acquisition maneuver and drift towards the station within the planned drift rate.

6.5 OPERATIONAL ORBIT

6.5.1 Attitude

The accuracy of the attitude measurement during acquisition and normal geostationary orbit operation will be sufficient to achieve the antenna pointing accuracy required by the link specifications of Section 1.

6.5.2 Orbit Parameters

The orbit parameters will be determined and corrected to maintain the satellite position within ±0.05° (3σ) of the designated position.

6.5.3 Spacecraft Health and Status

Telemetry data relating to the health of the spacecraft bus and the operating mode of its subsystems will be received and evaluated and commands required to maintain these characteristics shall be generated and transmitted as required.

6.6 MISSION OPERATIONS SYSTEM

The terrestrial hardware, software, and personnel will be made available by the contractor at either the MCT or other suitable site selected by the contractor. The contractor will arrange for acquisition of telemetry and tracking data and the transmission of commands during transfer orbit. When the spacecraft is on station the MCT can be used for the telemetry, tracking, and command (TT&C) links.