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Telesat Canada

MISSION AND OPERATION ANALYSIS

FOR M-SAT

Mar /82

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333 River Road
Ottawa, Ontario
Canada, KlL 8B9

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AUTHOR(S): Prepared by the staff of the Engineering and
            Operations Departments of Telesat Canada.

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PREPARED BY: Telesat Canada
             333 River Road
             Ottawa, Ontario
             K1L 8B9

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7-3	J.S. Moore and L.D. Ohlrogge "TT&C System for AT&T TELSTAR3" Ibid p. 627.
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1.0 INTRODUCTION

This document presents the results of an analysis of the mission and operations requirements for the M-SAT demonstration mobile satellite system, proposed for a 1987 launch. The two volumes of this report, together with the report on the system availability study (Report #DOC-CR-SP-82-006), fulfill the terms of the DSS contract 15ST.36001-1-0800.

The structure of this report follows the organization of tasks identified in the Statement of Work, defining activity schedules for all phases of the satellite lifetime from launch-site integration to end-of-life. Support requirements, in terms of facilities, personnel, procedures and test plans, are proposed and costed, based on Telesat's experience applicable to the proposed M-SAT baseline.

Where appropriate, both of the proposed bus designs (L-SAT and augmented SATCOM) are examined, as are the two proposed launch vehicles (STS and Ariane). Some implications of a proposed military payload are also included.

2.0 LAUNCH WINDOWS AND VEHICLE AVAILABILITY

2.1 DETERMINATION OF REALISTIC LAUNCH WINDOWS

Launch window studies were performed for the following three spacecraft/space vehicle missions:

1) ESA L-SAT with Ariane launch,

2) ESA L-SAT with STS/SPM launch, and

3) RCA SATCOM with STS/SPM launch.

For each case, plots show the injection window throughout the year 1987. All assumptions used in producing these injection windows are provided. The launch window is obtained by removing the time from lift-off to injection from the injection window.

2.1.1 ESA L-SAT Bus

One of the main characteristics of the L-SAT satellite in transfer orbit is that it will be three-axis stabilized after a few hours from injection. In the initialization, coast and AMF attitudes, it is assumed that the power and thermal requirements are met, regardless of the injection time and thus do not influence the launch window.

The L-SAT satellite has a set of infrared earth sensors on the +Z face of the spacecraft and a set of digital sun sensors on the -Z face. The other set of digital sun sensors are mounted on the X and -X faces. For M-SAT, they are located on the sides of the S-band antenna tower. Because of the location of these sensors and because of the requirements for earth lock and gyro calibration, injection is restricted to a local midnight injection window only (i.e., the local noon injection windows are not possible). For an early midnight injection, the earth lock and gyro calibration will occur late in the first orbit; for a late midnight injection, the events will occur early in the orbit. No limitation was found, in any of the references, regarding the time of the earth lock and gyro calibration events. This information should be provided, typically, one year prior to launch. For this study, the projection of the sun line onto the transfer orbit plane is restricted to ± 35° from the transfer orbit node line, thus constraining the time of these events.

2.1.1.1   L-SAT Launched with Ariane

Prior to separation, the Ariane will orient the satellite with the -Z axis pointing to the sun, with nominally zero rates about each axis. This orientation can be as large as 180°, thus imposing no constraint on the window. Also, the maximum shadow duration for a midnight injection window will be less than 30 minutes, assuming the window is less than ± three hours from local midnight.

Figure 2.1 shows the injection window for the L-SAT
bus launched by the Ariane assuming the following
orbital parameters:

Latitude	(deg)	0.000
Longitude	(deg + West)	14.222
Radius	(km)	6575.339
Velocity	(m/sec)	10241.378
Flight Path Angle	(deg)	0.0
Azimuth Angle	(deg)	9.650

2.1.1.2 L-SAT with STS/SPM

For a STS launch there are basically four
launch/injection cases:

1) Midnight launch with a descending node
   injection,
2) Midnight launch with an ascending node
   injection,
3) Noon launch with a descending node
   injection,
4) Noon launch with an ascending node
   injection.

Because L-SAT is restricted to a midnight injection
window, cases 1 and 4 are the only possibilities. It
is assumed that L-SAT is capable of orientating the -Z
face to the sun after perigee motor firing.

There are 32 injection opportunities in a given day
and the payload user does not know in advance which
one will be used. For this reason, NASA requires
injection windows in the following format: the right

Injection Time (hour GMT)
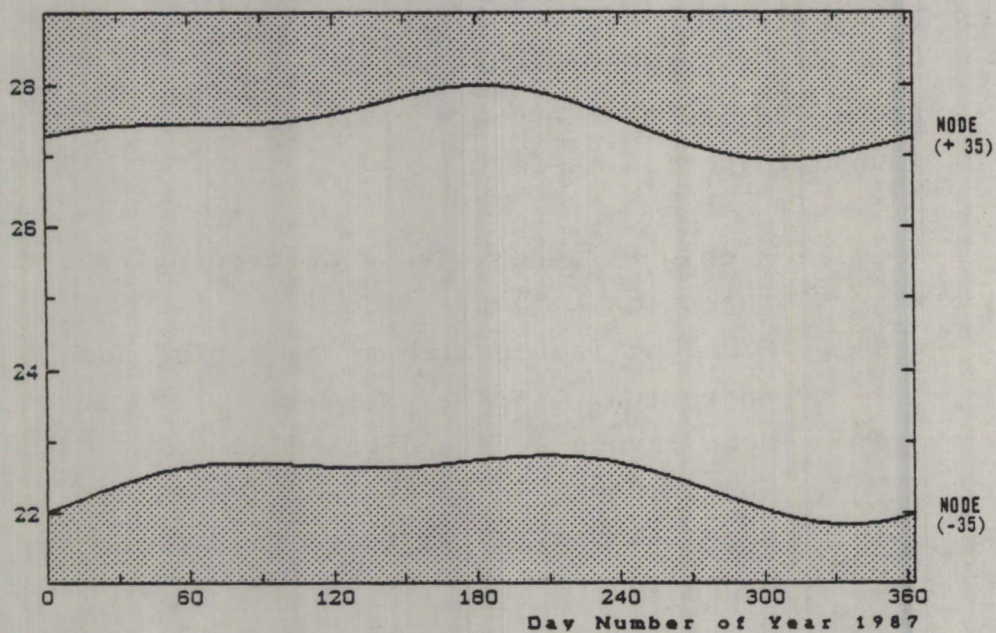
Fig. 2.1   L-Sat ARIANE Injection Window

ascension of the ascending node of the desired
transfer orbits pertaining to the opening and closing
of the window, referenced to zero hour Greenwich Mean
Time (GMT) on the day of injection. The nodes will
change by approximately 1° per day due to the sun
motion. In addition to the node limits, the injection
opportunities are restricted in order to ensure first
orbit acquisition, orbit/attitude determination
accuracy and visibility for apogee motor firing
(AMF). This constraint is provided in terms of
longitude bands in which the perigee motor must be
fired (PMF). Also, assuming that AMF does not occur
in the first two orbits, releasing at a different
injection opportunity will not affect the spacecraft
fuel requirements. It is NASA's responsibility to
ensure that a proper STS launch is selected, such that
when M-SAT is injected into transfer orbit, the above
conditions are met and that other payload constraints
are also met.

The following orbital and attitude parameters were
used for the L-SAT bus launched by the STS/SPM:

		Descending Node Injection	Ascending Node Injection
Latitude	(deg)	0.0	0.0
Longitude	(deg)	0.0	0.0
Radius	(km)	6674.5	6674.5
Velocity	(m/sec)	10157.94	10157.94
Flight Path Angle	(deg)	0.0	0.0
Azimuth Angle	(deg)	-28.5	28.5
Declination of +Z Axis	(deg)	-28.5	28.5
Right Ascension of +Z Axis		⊥ to node line	⊥ to node line

The sun angle constraint, imposed for thermal reasons is between 65° and 115°. Again, the shadow duration will be less than 30 minutes for the midnight injection window. Figure 2.2 and Figure 2.3 show these injection windows. Since the node rotates by 360° in one year, in order to reduce the range of the ordinate in the plots, the node minus the day number of the year is plotted as a function of injection date.

The above studies assumed an L-SAT bus launched by the STS/SPM, where the SPM is assumed to be basically a spinner solid (or liquid) motor. If the IUS is used and if it provides power to the spacecraft, then the sun angle constraints may possibly be removed, leaving basically the same window constraint as in the Ariane case (assuming the same mission scenario), except for the perigee motor firing longitude restrictions. If a two stage IUS is assumed, the mission scenario would change significantly and thus a completely new launch window study would be required.

2.1.2   RCA SATCOM Bus Launched with STS/SPM

The RCA SATCOM satellite is assumed to be a spinner during the complete transfer orbit phase. Both the midnight and noon injection windows are possible. The sun angle (angle, measured from the spin axis, is 180° when the sun is pointing in the AMF end) is restricted between 55° and 125°, for injection attitude, and 70° and 120°, for AMF attitude, due to thermal and power constraints. In addition, the sun should not be shining in the earth sensor during AMF attitude, since a spurious pulse will occur in the sensor telemetry. This will have the effect of reducing the accuracy of

NODE-DAY# (deg)
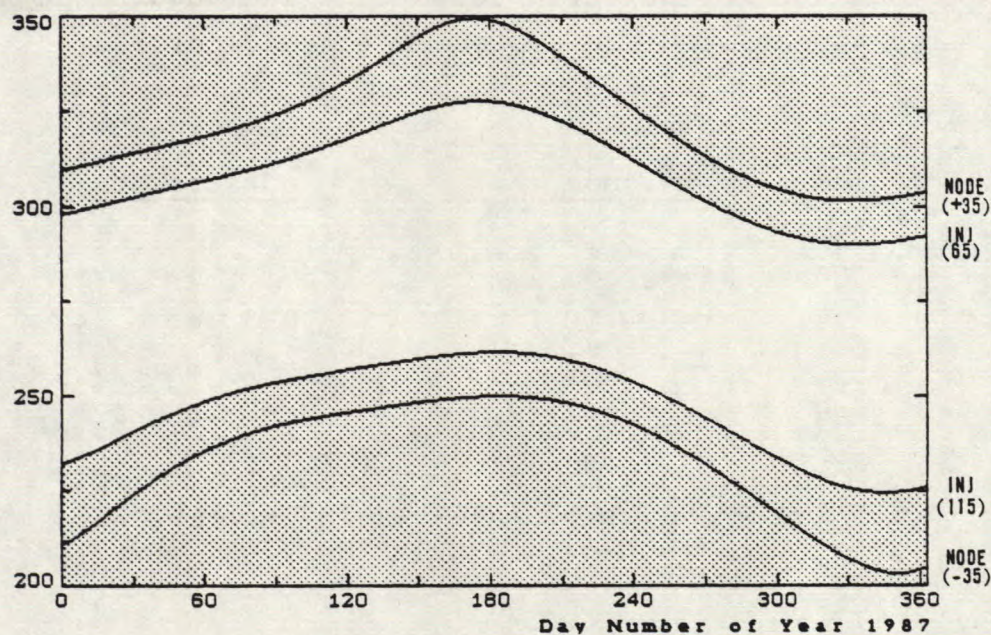
Fig. 2.2 L-Sat STS Midnight Launch-Descending Node Inj.

NODE-DAY# (deg)
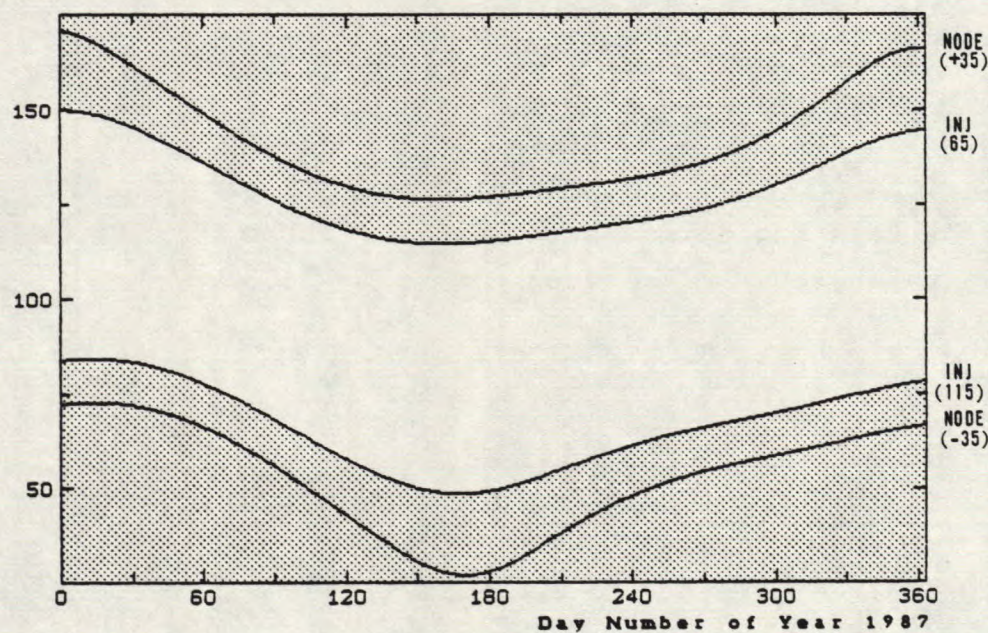
Fig. 2.3 L-Sat STS Noon Launch-Ascending Node Inj.

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attitude determination in AMF attitude. It may be possible to remove this extra pulse by electronic ground equipment in certain cases. For this study, the cutouts in the window, produced by not allowing the sun in the earth sensor are included. The sun angle constraints are summarized as follows:

Attitude	Sun Angle Constraints
Injection	$55° < \phi < 125°$
AMF	$70° < \phi < 84°$
	$88° < \phi < 92°$
	$96° < \phi < 120°$

The following orbital and attitude parameters were used:

		Descending Node Injection	Ascending Node Injection
Latitude	(deg)	0.0	0.0
Longitude	(deg)	0.0	0.0
Radius	(km)	6674.5	6674.5
Velocity	(m/sec)	10157.94	10157.94
Flight Path Angle	(deg)	0.0	0.0
Azimuth Angle	(deg)	-28.5	28.5

PMF Attitude

Declination (deg)	-28.5	+28.5
Right Ascension	$\perp$ to node	$\perp$ to node
Time spent in this attitude	first two orbits	first two orbits

AMF Attitude

Declination (deg)	-24.0	+24.0
Right Ascension	$\perp$ to node	$\perp$ to node
Time spent in this attitude	first apogee to 12 apogee	first apogee to 12 apogee

Figures 2.4 to 2.7 show the windows for the four injection cases. Note, that for each constraint (except for the shadow case), two lines are produced because of the sun motion during the period being considered.

NODE-DAY# (deg)
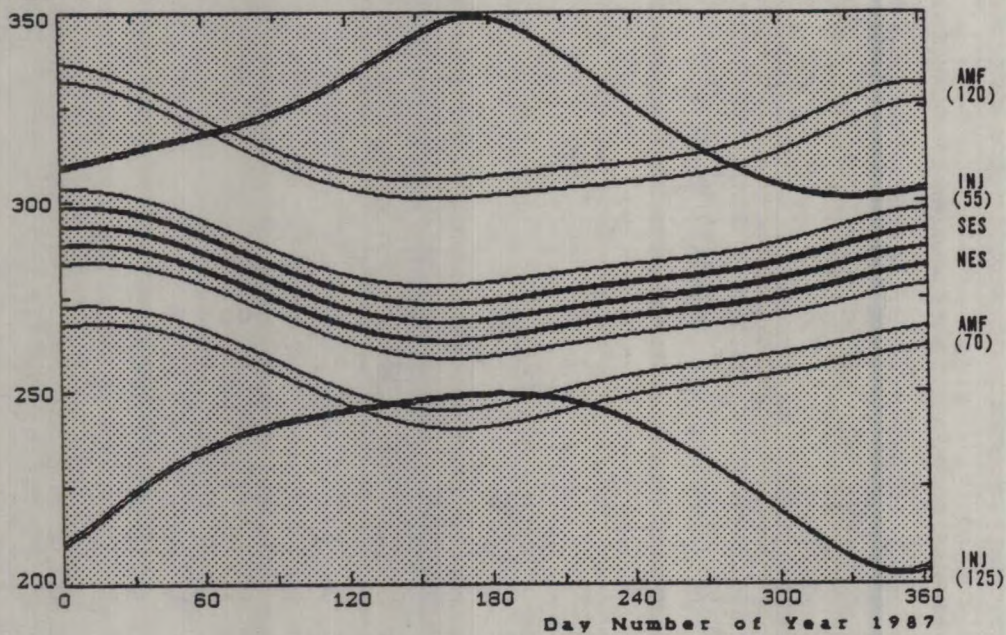
Fig. 2.4 RCA STS Midnight Launch-Descending Node Inj.
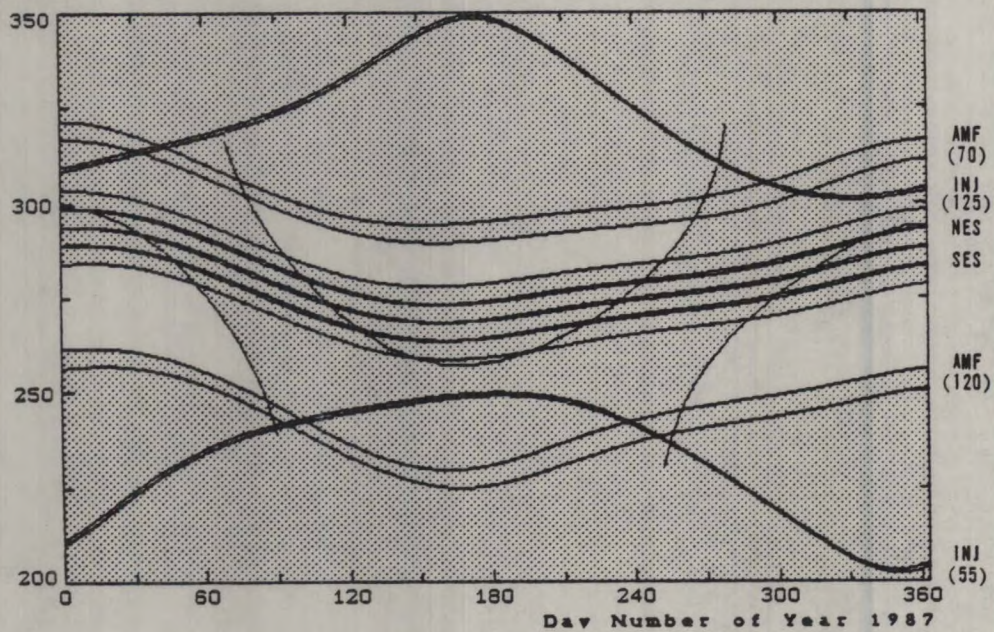
NODE-DAY# (deg)

Fig. 2.5 RCA STS Midnight Launch-Ascending Node Inj.
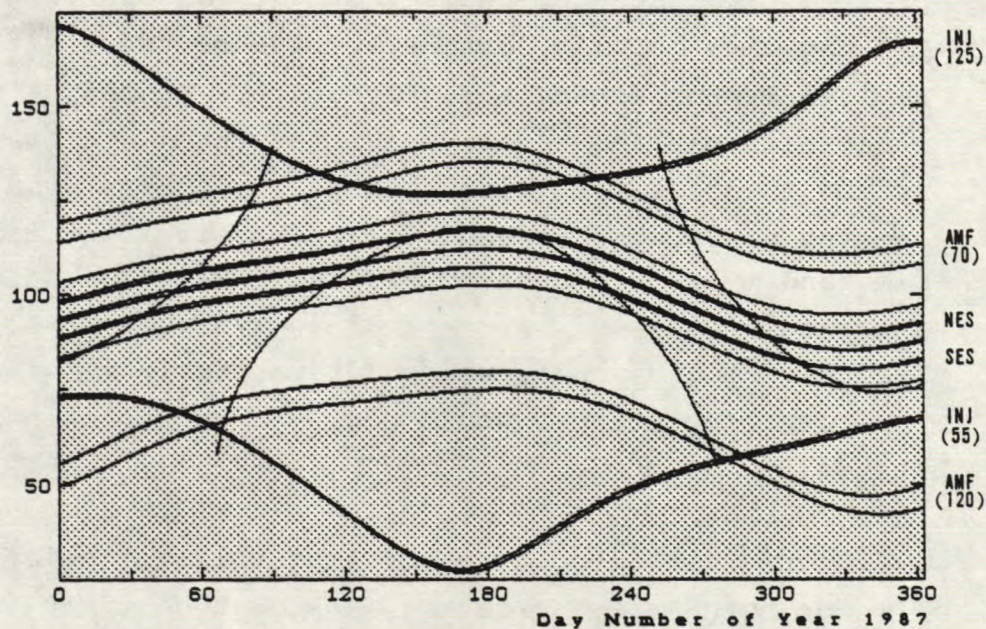
NODE-DAY# (deg)

Fig. 2.6 RCA STS Noon Launch-Descending Node Injection

NODE-DAY# (deg)
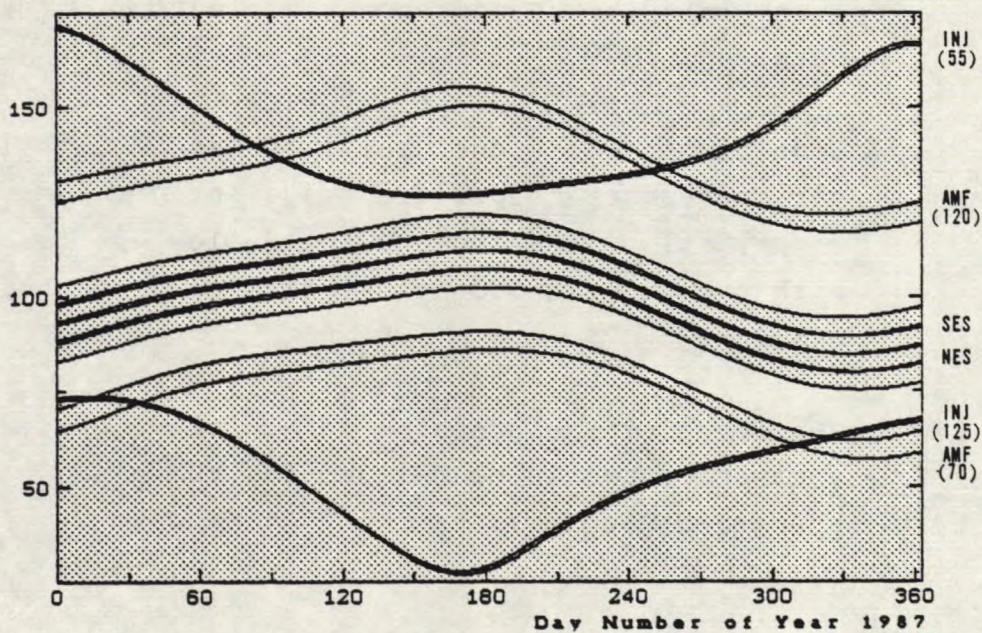
Fig. 2.7 RCA STS Noon Launch-Ascending Node Injection

2.2   LAUNCH VEHICLE ISSUES, ACTIONS, REQUIREMENTS

It is strongly recommended that launch vehicle reservations be processed as soon as possible to protect the planned M-SAT launch date and to obtain booking date priority over other future users with similar launch schedule requirements. Issues concerning booking and payments for the shuttle and Ariane launches were discussed in the DOC/Telesat meeting at CRC on 25 January 1982, as itemized in the memorandum of 17 February 1982 (File M-SAT 3-4-14) attached as Appendix F. A full analysis of M-SAT launch vehicle issues, which Telesat feels is of paramount importance, would address the following issues:

o   Significant launch reservation policy implications for both Arianespace and NASA must be identified;

o   Launch vehicle costing for the current planned launch date and associated vehicle pricing must be detailed;

o   Significant additional costs for an STS mission for spacecraft to perigee stage integration, compatibility testing and pre-deployment checkout with the related STS safety requirements should be examined;

o   The scope of the proposed launch vehicle related activities should be defined for the next phase of the M-SAT program;

o   Launch services related technical and management
    manpower requirements support should be identified;

o   The implications of a classified security
    requirement against an M-SAT mission, as
    identified to date, must be considered.

3.0   TEST PLAN FOR SATELLITE IN-ORBIT
PRE-OPERATIONAL ACTIVITIES

3.1   L-SAT BUS WITH MILITARY CONSIDERATIONS

As more details will be known about the actual M-SAT
design, the Test Plan could be suitably modified by
going into more depth in the test description, by
modifying some tests and by even adding new ones.

The final Test Plan should take into consideration the
recommended satellite operating procedures and
constraints which will have to be issued by the prime
contractor and approved by the scientific authority.

3.1.1   <u>Purpose and Scope of Tests</u>

As early as practicable into the mission, various
tests should be performed, and satellite data analyzed
to:

1)   verify that the satellite has survived the launch
     and transfer orbit, and that its performance has
     not been measurably altered,

2)   utilize the unusual attitudes and maneuvers
     involved in getting on station to measure
     satellite characteristics that would otherwise be
     difficult to obtain,

3)   test specific features, especially where these
     cannot be checked out adequately on the ground,

4) initially characterize the capabilities and
    performance of the satellite to obtain a baseline
    for future comparisons, and

5) verify that the satellite is capable of providing
    communications capability, as defined in the
    Spacecraft Contract.

The test philosophy is to measure (and, wherever
possible, calibrate) all spacecraft performance
parameters, and to functionally test all primary and
backup operations, to establish a baseline capability
at Beginning of Life (BOL).

3.1.2   Classification of Tests

Testing is divided into two basic areas: Subsystems
Tests and RF Performance Tests. Within each of these
areas, two types of testing should be performed:
Calibration and Measurement, and Functional and
Redundancy Tests.

The Calibration and Measurement Tests provide a
baseline for the degree of performance of significant
satellite parameters (e.g., EIRP, SFD, CMD and TM
Thresholds, Tracking Stability, Currents, etc.) The
Functional and Redundancy Tests provide a baseline of
configuration capability; that is, they establish
whether primary and backup units, modes, or systems
are available by automatic operation and/or by
exercising two-state commands (on/off,
cross-strap/normal, select 1/2, primary/backup).

The depth to which specific tests can be identified in this Test Plan depended on the detail of the proposed spacecraft bus design that was available.

3.1.3   Implementation

As many of the tests as practicable should be performed during the drift orbit phase. Many of the Functional and Redundancy Tests of the Subsystems can be interleaved with maneuvers and deployment activities. Much information can be gathered on the Telemetry, Command and Ranging (TC&R) and the Attitude and Orbit Control (AOCS) subsystems during transfer orbit operation, but only a limited amount of information can be obtained on the Power and Thermal Subsystems from transfer orbit eclipses.

RF performance tests should be given priority when practicable, in order to make the satellite available for use as soon as possible. Detailed communications performance tests, however, should be implemented only at the final on-station attitude.

Unless otherwise indicated, no particular test sequence is recommended other than that dictated by the type of orbit and attitude required. The test schedule should consider the avoidance of any interference with satellite maneuvers and with other satellites passed by while drifting, and the compatibility with satellite attitude.

The recommended in-orbit pre-operational tests are summarized in Table 3.1.

TABLE 3.1   SUMMARY OF RECOMMENDED SATELLITE IN-ORBIT PRE-OPERATIONAL TESTS

Reference	Test	In Transfer Orbit	In Drift Orbit	In Final Position	Comments
3.1.4.1	Command link verification	X			
	Command threshold		X	X	
	Command functions	X	X	X	Most during operations and other tests
	TM transmitter frequency stability		X	X	
	TM EIRP and stability		X	X	
	TM transmitter modulation index		X		
	TM Modes	X	X	X	Most during operations and other tests
3.1.4.2	AOCS sensors		X		
	Automatic reconfigure mode		X		
	Reaction wheel characterization		X		
	CEU Processor check		X		
	Solar Array drive modes redundancy		X		

TABLE 3.1   SUMMARY OF RECOMMENDED SATELLITE IN-ORBIT PRE-OPERATIONAL TESTS (continued)

Reference	Test	In Transfer Orbit	In Drift Orbit	In Final Position	Comments
	Stability in normal mode		X	X	
	Stability in station-keeping mode			X	
	Reaction wheel desaturation		X		
	Effects of solar torques			X	
	AOCS redundancy		X	X	Most during other tests
3.1.4.3	RC Thruster calibration	X	X		
	RC Thruster redundancy		X		
	Plume impingement		X		
3.1.4.4	Solar Array output		X		
	Battery parameters		X		
	Battery charge control function redundancy		X X		
	Bus voltage regulation		X		

Reference	Test	In Transfer Orbit	In Drift Orbit	In Final Positions	Comments
	Battery discharge control function		X		
	redundancy		X		
	Supply of AC power function			X	
	redundancy			X	
3.1.4.5	Heater control function		X		
	redundancy		X		
	Spacecraft temperatures	X	X	X	
3.1.5.3	Flux density and EIRP		X	X	
3.1.5.4	Swept frequency response		X		
3.1.5.5	Translation frequency		X		
3.1.5.6	Intermodulation			X	
3.1.5.7	Spurious search		X		
3.1.5.8	Antenna pattern measurements		X	X	

NOTE: Any or all power S/S
tests can be done in final
position if lacking available
testing time in drift orbit.

3.1.4　Satellite Subsystems Tests

3.1.4.1　Telemetry, Command and Ranging (TC&R)

Most of these tests are standard in principle,
performed on all satellites, with the detailed test
requirements and methods tailored to specific
designs. When more details will be available on the
M-SAT TC&R subsystem design, addition of more tests
may be required.

Command Link Verification. After a command link has
been established, the proper operation of the
spacecraft and ground station command systems should
be verified by means of a spare command, using each
command receiver and decoder.

Command Threshold. To establish the minimum uplink
power required to ensure commandability, the minimum
uplink RF drive required to produce correct command
verification for each of the receiver-decoder chains
should be measured through both the S-band omni
antenna and the payload frequency link.

Command Functions. As many non-hazardous commands as
practicable should be exercised to provide a high
degree of confidence that all command functions can be
executed through both command receivers and both
decoders. Many of these command functions will be
verified during other subsystem tests and/or mission
operations in specified command receiver-decoder
configurations.

TM Transmitter Frequency Stability. The frequencies of both TM transmitters should be measured several times within a 24-hour period to verify short-term stability, and to establish a baseline for long-term stability trend projection.

TM EIRP and Stability. The EIRP should be measured several times within a 24-hour period to verify the EIRP and its short-term stability, and to establish a baseline for long-term stability trend projection with both TM transmitters, through both the S-band omni antenna and the payload frequency link.

TM Transmitter Modulation Index. The modulation index should be determined for both TM transmitters in all telemetry modes, by measurement of carrier suppression.

TM Modes. a) All telemetry modes (Dwell and Ranging included) should be verified that they function as predicted. Most of the telemetry modes will have been exercised during transfer orbit operations. b) The redundancy-provided telemetry values should be compared with each other and with the predicted values.

3.1.4.2 Attitude and Orbit Control Subsystem (AOCS)

Expected performance of those functions which are to be used only once will be proven by their actual in-flight operation. Therefore, it is recommended to test only those functions which are to support the operational phase.

Redundant and backup configurations, functions and modes should be verified.

Consideration should be given whether to check out the Emergency Sun Acquisition (ESA) mode, which is the backup mode of the Automatic Reconfiguration Mode (ARM), itself a backup mode. ESA mode checkout would cause loss of earth pointing for a substantial length of time and would require extra fuel for the thrusters.

When more details will be available on the M-SAT AOCS design, addition of more tests may be required.

AOCS Sensors. Proper operation of all AOCS sensors should be checked. Performance of redundant sensors should be compared and analysed. The characteristics of both Infra-Red Earth Sensors (IRES) should be calibrated for pitch and roll. Gyro drift compensation should be checked.

Automatic Reconfigure Mode (ARM). The ARM mode should be activated by ground command and its proper operation should be verified.

Reaction Wheel (RW) Characterisation. Operation, speed, friction torque and consumption of all four RW's should be checked through telemetry.

Control Electronics Unit (CEU) Processor Check. The correct operation of the CEU Processor should be verified and its redundant functions checked.

Solar Array Drive. Proper operation of the Solar Array Drive Electronics (SADE) and the Solar Array Drive Mechanism (SADM) should be verified in all operational modes, in both primary and redundant configurations.

Stability in Normal Mode. Spacecraft stability and pointing accuracy should be checked in Normal Mode with each of the Infra-Red Earth Sensors.

Stability in Stationkeeping Mode. It should be verified that the stationkeeping control loop is able to maintain spacecraft stability and pointing accuracy in the Stationkeeping Mode.

Reaction Wheel Desaturation. The RW desaturation function of the CEU should be checked.

Effects of Solar Torques. It should be verified by analysis and measurement that the AOCS can adequately cope with the torques generated by solar radiation pressure on the large areas of the deployed antennas and arrays.

AOCS Redundancy. Redundancy of all functions and components to be used in on-station operation should be verified.

3.1.4.3 Combined Propulsion Subsystem (CPS)

Reaction Control Thrusters (RCT). Subsequent to maneuvers, the impulse level and relative orientation of each thruster should be calibrated and their operation verified. The calibration should be updated regularly. The operational redundancy of the RCT's should be verified.

<u>Plume Impingement</u>. It should be verified that plume impingement reaction effects on the deployed antenna reflectors and solar arrays will not degrade the mission. It may be necessary to perform a detailed calibration of the effect, if significant, for future reference during maneuvers.

3.1.4.4 Power Subsystem

<u>Solar Array Output</u>. The available array power should be established by measuring the array load and shunt currents and the main bus voltage over several diurnal cycles to establish a baseline at BOL for trend analysis. Test results should be compared to predictions.

<u>Battery Parameters</u>. Battery performance characteristics, including capacity, should be measured using a low discharge rate by subjecting each battery in turn to a 'recondition' sequence. Battery and cell voltages, charge and discharge currents, pressures and temperatures should be monitored regularly. In addition, if practicable, an eclipse should be simulated by steering the array away from the sun for approximately 70 minutes.

<u>Major Power Electronics Functions</u>. Proper operation of all major power electronic functions should be verified with both primary and redundant circuits: a) Battery charge control, provided by the Battery Management Unit (BMU) and the Battery Charge Regulator

(BCR); b) Bus voltage regulation, provided by the
Mode Control Unit (MCU) and the Shunt Dump Modules
(SDM); c) Battery discharge control, provided by the
Mode Control Unit (MCU) and the Battery Discharge
Regulators (BDR); d) Supply of AC power by the
Essential Load Inverters (ELI).

3.1.4.5   Thermal Subsystem

Proper heater control operation provided by the Heater
Switching and Instrumentation Unit (HSIU) should be
verified.

Predicted temperature values should be verified, and
all temperatures should be monitored regularly.

Temperatures should be allowed to stabilize over a one
day cycle for each of the various prime transponder
operating modes, to provide a baseline for future
thermal analyses.

3.1.5   Transponder RF Tests

3.1.5.1   General

A major portion of the test program will involve the
RF testing of all transponders of the satellite. With
the military package on-board, this becomes an
extremely complex and time consuming process, even
without regard to the testing of communications
performance, because of the large number of uplink and
downlink paths involved at various frequency bands.

Communications performance testing is not covered in
detail in this plan as this is an overall system
matter involving the individual earth station
characteristics, propagation losses, modulation
techniques, etc. These tests are usually performed by
the users of the system rather than by the crew
involved in checkout of the satellite itself.

This section of the plan concentrates on those tests
concerned with the performance of the satellite
hardware, excluding the inter-satellite link.

The following basic tests should be performed, as
described in more detail below, for all redundant
units:

Flux Density vs. EIRP*
Swept Frequency Response
Translation Frequency*
Intermodulation
Spurious Search
Antenna Patterns

These tests would be performed after the satellite had
arrived on-station. In addition, a functional
"throughput" test through each path would be performed
as early as practicable in drift orbit, after
deployment of the antennas, to verify the integrity of
the transponders. This would not necessarily involve
accurate measurements. Tests marked with an asterisk
should also be performed routinely throughout life.

3.1.5.2 Facilities

The major area requiring careful planning and possibly significant expenditure is the test facility. With the military package, earth stations of accurate measurement capabaility are required in the following bands:

Uplink	335-406	MHz	Downlink	275-287	MHz
	821-825	MHz		866-870	MHz
	1.6	GHz		1.5	GHz
	7.9-8.4	GHz		7.25-7.75	GHz
	43.6	GHz		20.2	GHz

While it is recognized that facilities will exist to handle all these frequencies, their location (e.g., inside secure military areas) as well as inherent measurement capability and calibration accuracy, may result in a very difficult, expensive, protracted and unsatisfactory measurement program. The ideal solution is to have all facilities in one area, so that the measurement program can proceed with maximum efficiency using carefully calibrated equipment, paying particular attention to the antennas. The last-named are usually the inherent limitation in measurement accuracy of transponder uplink/downlink characteristics.

Such facilities are also necessary to perform measurements on a routine basis to be able to detect any changes in performance over life. Scattered uncontrolled facilities would make it very difficult to correlate data and detect any subtle changes, and even gross changes would be open to question as to the source of the change.

Grouping the test facilities in one place is ideal for automation of the test program. This will greatly reduce test time, allow for more thorough testing and greatly improve repeatability by removing the human element as a variable in measurement techniques.

In addition to the above, consideration should be given to portable test units to be used as secondary standards as a means of making accurate field measurements. In particular, small receive-only stations, equipped as EIRP monitors, should receive special attention as EIRP can be the most-questioned characteristic of a satellite's performance.

3.1.5.3 Flux Density and EIRP Tests

EIRP should be measured against uplink flux density over the expected operating range of each viable path of the transponder, to produce a set of input/output transfer curves. In the case of TWTA output stages, the curve would be taken to about 3 dB above saturation. The transfer curve would be measured at the centre frequency of each band on RF channel. In the case of the spot beams at high UHF, it is necessary that the satellite be capable of being rotated in pitch in order to access other spot beams from Allan Park or Ottawa. This will allow access to the Western and Central Western beams. Otherwise, a portable calibrated T/R facility could be taken to the vicinity of Regina for the measurements.

Where Automatic Level Control (ALC) is employed in the transponder, the input level should be taken well below the ALC threshold. It is recommended that all ALC circuits be capable of inhibition by command, to facilitate testing. Measurements of EIRP vs. uplink

power should be taken repeatedly over a 24-hour period
with the ALC inhibited to verify gain stability. This
requires that a computerized facility be available.
Paths should be selected to test various receivers and
output stages on a representative basis.

These tests should also be performed routinely
on-station, but the paths can be selected to reduce
the number of measurements, provided each receiver and
each transmitter is tested.

3.1.5.4   Swept Frequency Response Tests

Each path should be frequency swept over the full
channel bandwidth at an input level corresponding to
maximum EIRP (saturation in the case of a TWTA). This
should be repeated, if appropriate, at a suitable
backed-off level, usually 10 dB input back-off. Where
ALC is employed, the back-off could be set to some
point above the ALC threshold, e.g., +5 dB, to ensure
correct operation of the ALC across the band. An ALC
inhibit command would allow examination of the
frequency response without the smoothing effect of
ALC. Alternatively, the measurement should be
repeated below the ALC threshold.

It might be worth considering repeating this test at
one year intervals.

3.1.5.5 Translation Frequency Measurement

A direct measurement of the overall translation frequency in each link should be made. This is best accomplished using a mixer technique, in which the earth station transmitter output provides the local oscillator (LO) signal, and the received signal is amplified and provides the signal input to the mixer. The mixer output is further amplified and applied to a frequency counter. This technique has been used successfully for many years to provide accurate translation frequency measurements of the Anik satellites. It requires special test sets to be built.

Sufficient paths should be chosen to determine the accuracy of each LO source and any major faults in the frequency multiplication circuits. The choice will depend on the final configuration of the transponders. In addition, a series of measurements should be performed over a 24-hour period to verify LO short term stability, and at monthly intervals thereafter to verify long term stability. A measurement should be performed through the largest · sun eclipse period also.

3.1.5.6 Intermodulation (IM) Tests

In the UHF bands, because of the effects of passive intermodulation mechanisms, it is very important to make careful measurements. Two separate earth stations are used to provide the uplinks, to avoid any possibility of IM products generated on the ground. The carrier frequencies are selected by analysis in order to provide combinations which are most likely to

produce in-band products. A careful search is made of
the downlink using a spectrum analyser. The exact
frequencies to be selected would depend on the final
configuration and a careful study should be made to
determine the most likely combinations.

In the SHF and EHF bands, intermodulation is usually
less of a problem, as it is primarily governed by the
output TWTA characteristics, which are measured on the
ground during TWTA and spacecraft acceptance tests.
Two separate transmitters are needed for each band.
Passive intermodulation is not normally a significant
problem.

3.1.5.7   Spurious Search

It is advisable to perform a search for spurious
outputs in the presence of a single uplink carrier.
An analysis should be performed in order to determine
the most likely carrier frequencies which could give
in-band spurious outputs, based on LO frequencies.
This will reduce the time taken, as spurious searches
can be very slow and time-consuming. Also, any known
likely spurious generation in the output TWTA's, based
on pre-launch test data, should be investigated.

3.1.5.8   Antenna Pattern Measurements

In order to be able to measure antenna patterns, it is
important that the spacecraft be equipped with a pitch
control capable of providing offsets of at least $\pm 7°$.
This will allow for a cut in the E-W (azimuth) plane
of all fixed earth-coverage beams, including the UHF
spot beams. Further azimuth and elevation cuts can be
made if roll off-sets are also introduced.

The ALC of the transponder will allow for easy
measurement of the transmit patterns. However, to
measure the receive patterns it will be necessary to
standardize the receive level at the satellite in some
way, such as by measuring the ALC threshold. An
output power monitor, combined with the ability to
disable the ALC, would be an even better solution. In
the case of the EHF service, the uplink spot beam can
easily be measured by steering the antenna. The
downlink pattern can be measured by maintaining the
uplink spot beam pointing at the test station. It is
assumed that the steering mechanism will have accurate
telemetry of the beam pointing angle.

3.1.6   Communication Performance Tests

Insufficient detail is known regarding the types of
traffic to allow for in-depth recommendations on
performance testing of the various communications
systems. This might be a subject for study during
Phase B. However, some general observations can be
offered.

To provide the security required by the military, and
to obtain the maximum capability in the UHF bands, it
is assumed that some form of digital transmission will
be used, with or without scrambling, as appropriate.
Therefore the types of testing which would be
appropriate would be for bit error rate in a digital
stream, between various points in the system. Such
testing would include measurements at various kF
levels to determine fade margins, and the setting-up
of digital signals for long-term testing to measure
fading effects and determine availability. In the

unlikely event that any of the links employed FM
transmissions, the signal-to-noise ratio would be
measured, instead of bit error rates. Measurements
through sun eclipse and sun transit periods should be
included.

3.1.7   Hardware Costs

Most satellite tests will be made through existing T&C
facilities. However, special RF test facilities
should be included in the budget. This includes the
cost of an antenna farm, requiring about 4 - 5
different antennas, some helical (for UHF) and some
reflector types (for SHF and EHF), plus associated
transmitters and LNA's. Common test equipment can be
used, the major expense items being signal generators,
a spectrum analyzer and a small computer facility. If
the components are bought separately and assembled by
in-house effort, approximately $1.0 M should suffice
for such a facility. It is considered beyond the
scope of this study to make a detailed design for
costing purposes, but this should be given attention
during Phase B.

3.2   SATCOM BUS

The SATCOM bus would be very similar to that of the
Anik B satellite. Therefore its Test Plan would be
similar also. The Anik B Test Plan could be used as a
baseline and would be modified as necessary when the
differences between Anik B and the improved SATCOM
satellite will be identified.

The Test Plan actually used for the in-orbit
pre-operational testing of the Anik B satellite was
copied from the Anik B Mission Plan for inclusion in
this study as Appendix A.

4.0 ON-STATION OPERATIONS AND TEST SCHEDULE

4.1 STATIONKEEPING OPERATIONS

The on-station functions of the satellite control system include satellite commanding, tracking and ranging, telemetry decoding and display, satellite health monitoring and eclipse planning, and stationkeeping. This section will deal with the aspect of controlling the satellite orbit and attitude, particularly with respect to the software requirements. The computer system will be described in 7.0, as will the organizational aspects of the satellite control system. The remaining functions are described in the test plan and procedures definition.

To support the design of the Telemetry, Tracking and Command (TT&C) station and mission software, it is necessary to define the orbit and attitude control objectives required to match the performance criteria of the satellite and the ground system. Feasible stationkeeping strategies can then be proposed which will meet the control objectives. These studies will lead to the accuracy requirements and preferred location(s) of the TT&C station(s), as exemplified in Reference 4.1.

The necessary stationkeeping software will require specification of the following basic characteristics:

- Dynamics and observation models;

- Computation precision and speed;

- Data volumes to be processed;

- Parameters to be estimated;

- Maneuver strategies.

The Telesat mission and stationkeeping software comprises all software necessary to determine, predict and control the orbit and attitude dynamics of the satellite in a fuel-efficient and timely manner. Reference to the M-SAT situation will apply to both the L-SAT and SATCOM bus, except where otherwise indicated.

4.1.1 Satellite State Determination

To achieve the control tolerances of $\pm$ 0.05° in both longitude and latitude satellite excursion, a wide baseline tracking system was used to provide dual range measurements. In addition, higher order terms in the mathematical models were accurately defined and sophisticated filtering techniques applied. The state is defined by the six parameters of the satellite position and velocity at a given epoch, plus the biases in the measured pointing angles. Since the

satellite has a relatively large area-to-mass ratio,
the solar radiation force has a significant influence
on the accuracy of orbit determination. Consequently,
a correction to the internal radiation model must be
included in the estimated state.

In view of the firing requirements for desaturation
purposes as stated in Reference 4.2 and 4.3, and the
necessity for estimation of the solar torque model, it
becomes apparent that a least squares method of state
estimation would prove inadequate. The ideal
technique would be a real-time Kalman filter, which
has proven its value in the Telesat experience, as
well as others. This filter operates with little user
interference by updating the state estimate
automatically with the receipt of tracking data and by
incorporating the effects of maneuvers using
pre-stored parameters of planned maneuvers. Data
residual analysis verifies filter operation by
performing a backward propagation of the current state
(including previously executed maneuvers) and
comparing the computed data values with historical
tracking data.

4.1.2   Prediction Capability

4.1.2.1 Ephemeris Generation

Software must be available to accurately propagate the
satellite orbital parameters, using the same
propagation method as the orbit determination
software. The ephemeris generator should be capable
of applying previously computed maneuver parameters

retrieved from a common storage area, and present
predictions of any orbital elements requiring limit
checks. In order to warn of any potential limit
violations, the propagator will require a set of
nominal maneuvers for at least the following week.

4.1.2.2 Eclipse Predictions

In order to prepare the satellite for eclipse
conditions, software should exist to determine the
times of entry and exit of penumbra and umbra for both
earth and moon shadows. It should print the minimum
percentage of the sun visible from the satellite.

4.1.2.3 Sensor and Sun-Transit Interference Predictions

In order to preserve satellite pointing accuracy,
there should be available a program to predict
occurrences of the sun or moon within the field of
view of each earth sensor. Interruptions by the earth
of the interference should be indicated. For any
geographic location, there should be the capability to
compute the time and duration of the occurrence of the
sun in the RF field of view of the earth station
antenna.

4.1.3 Maneuver Planning

The orbital corrections which maintain the satellite
within the latitude and longitude limits require
strategies to minimize fuel usage throughout the life
of the satellite and to optimize the time between
successive maneuvers. In order to favourably affect
the orbit, the time of day should be optimized for

wheel desaturation (pitch axis for the SATCOM bus and all three axes for the L-SAT bus). Analytical computation of the non-singular mean orbital elements facilitates the maneuver calculations by removing short term perturbations. The capability should exist to propagate these mean elements, including the effects of future maneuvers.

The computed correction requirements are now translated into applicable maneuver execution parameters, based on a supplied performance model or the Reaction Control System (RCS). There should be provision to use performance calibration results from previous maneuvers, including access to records containing plume impingement effects on thrust efficiency and thruster off-modulation. Fuel usage should be monitored together with other important satellite mass properties. All maneuver information should be entered on a common storage medium, to be accessed by the ephemeris propagation and orbit determination software. Information should be provided on pre-maneuver positioning of the solar array panel in order to reduce attitude disturbance during north-south maneuvers on the SATCOM bus. This information is obtained from pre-operational tests and updated with results from stationkeeping maneuvers. These tests are also necessary to reassess the need for similar requirements for the L-SAT bus.

A facility should be provided to compute maneuver error and efficiency factors from actual pre- and post-maneuver orbital elements. Additional information can be obtained from the relation between the predicted torque and the actual change in reaction wheel speed during desaturation maneuvers.

With regard to attitude control behaviour, there should be software capability to retrieve historical data to keep track of daily and seasonal variations in reaction wheel readings and magnetic coil currents (SATCOM) bus. This will help to identify any changes in control biases due to varying sources such as thermal environment.

4.1.4 Data Requirements

An error analysis in the form of a detailed simulation must be performed to assess the tracking requirements to stationkeep M-SAT within given limits. This simulation would have to account for various error sources such as: size, frequency and duration of maneuvers, propagator accuracy, tracking data noise and availability.

As an example of system accuracy, Telesat uses two sets of data requirements, depending on the control limits. For Anik B (SATCOM bus) limits of $\pm 0.05°$ in longitude and latitude, data is collected every two hours, alternating between two stations separated by 44° in longitude. One station provides azimuth, elevation and range measurements, while the second measures range only. For the Anik A limits of $\pm 0.1°$ in longitude and latitude, every four hours a set of azimuth, elevation and range measurements are taken from the same station. The following charts indicate the frequency of maneuvers on both satellite types and the orbital accuracy obtained.

Maneuver Type	Cycle	
	A3	B1
North-South	2 - 3 months	4 - 8 weeks
East-West	4 weeks	4 weeks
		(2 burn, 36 hours apart)
Attitude	3 - 4 weeks	n/a
Momentum Adjust	n/a	> 2 weeks

Orbital Parameters		Three-Sigma Uncertainty	
		A3	B1
Longitude	(deg)	1.1×10^{-4}	8.1×10^{-5}
Drift	(deg/day)	6.0×10^{-5}	5.1×10^{-5}
Inclination	(deg)	5.1×10^{-4}	2.3×10^{-4}

To reduce the estimated state uncertainty due to orbital correction maneuvers, tracking data is collected hourly for six hours afterward. This procedure becomes particularly useful when the estimation is via the Kalman filter technique (Ref. 4-4) which gives an immediate feedback on the effect of the maneuver and acceptability of the tracking data. In the worst case situation for the proposed L-SAT bus (Ref 4-2, 4-3), there could be up to six hours per day dedicated to pulse mode jet firing (0.01 seconds ON : 200 seconds OFF) for wheel desaturation. It would be preferable, even for relatively small velocity increments, to be able to assess the effects on the orbit in real-time, rather than batch process the data at some later time. Also, the two-station tracking system gives a more powerful set of data and is preferred when daily orbital control maneuvers are applied.

It is assumed that all thruster firing is either
ground initiated or, if under the control of on-board
logic, the exact firing parameters (thruster
identification, pulse duration) are available through
telemetry, for processing. This would hold true for
both the normal mode and stationkeeping mode of
operation, including off-modulation.

4.2 ON-STATION TEST SCHEDULE

4.2.1 L-SAT Bus

The recommended on-station tests for M-SAT using the
L-SAT bus are summarized in Table 4.1. The future
availability of more design details may necessitate
the addition of new tests and/or the modification of
those identified in the Table.

4.2.2 SATCOM Bus

As the pre-operational tests are expected to be
similar to those of Anik B, so are the tests to be
performed regularly on-station in the operational
phase.

These Anik B tests are identified, and the frequency
of testing is shown in Table 4.2 for reference.

TABLE 4.1

RECOMMENDED ON-STATION TESTS FOR M-SAT USING THE L-SAT BUS

Test Description	Frequency of Testing
TM Transmitter frequency and long term stability	Monthly
TM EIRP and long term stability	Monthly
Solar Array output	Weekly
Solar Array drive redundancy	Every 6 months
Battery parameters	In every eclipse season
Battery charge control redundancy	Yearly
Battery discharge control redundancy	Yearly
Supply of AC power redundancy	Yearly
Spacecraft temperatures	Daily evaluation
RC Thruster redundancy	By alternate use in maneuvers
Command receiver redundancy	Every six months
Command decoder redundancy	Every six months
Telemetry stream redundancy	Every six months
Telemetry transmitter redundancy	Every six months
AOCS redundancy	Every six months
Transponder SFD (as appropriate)	Initially daily, then weekly
Transponder EIRP versus flux density	Initially daily, then weekly
Transponder translation frequency	Monthly

TABLE 4.2

ON-STATION TESTS FOR ANIK B (SATCOM BUS)

Test Description	Frequency of Testing
TM Transmitter frequency and long term stability	Monthly
TM EIRP and long term stability	Monthly
Solar Array capacity	Daily evaluation
Solar Array drive redundancy	Every six months
Battery parameters	In every eclipse season
Battery charge control redundancy	Yearly
Power supply redundancy for CMD and TM Units	Every six months
Battery backup heaters redundancy	Yearly
Spacecraft temperatures	Daily evaluation
Thruster control redundancy	Every six months
Thruster redundancy	By alternate use in maneuvers
Command receiver and decoder redundancy	Every three months
Command receiver sensitivity	Every three months
Telemetry stream redundancy	Every six months
Roll and Yaw control redundancy	Every six months
Gyro redundancy	Every six months
Momentum wheel redundancy	Yearly
Earth sensor redundancy	Yearly
Transponder SFD	Weekly
Transponder EIRP	Weekly
Transponder translation frequency	Monthly
Receiver redundancy	Every three months

5.0   PRE-OPERATIONAL ACTIVITIES

5.1   PRE-LAUNCH ACTIVITIES

Analysis of the activities and support required prior
to launch has been performed under the assumption that
the M-SAT Launch Campaign will be conducted as Telesat
would for one of its own commercial launches.

The task of spacecraft assembly, integration and test
at the launch site has been assumed to be independent
of launch site and launcher. From the point in time
when the spacecraft starts activities to integrate it
with the launch vehicle the campaigns differ as
indicated in Figures 5.1 through 5.4.

It has been assumed that the baseline configuration of
the spacecraft is as per Configuration 7A or Para.
4.20 g in Ref. 4-3.

5.1.1   Time-Phased Sequence of Operations

During the proposal phase of a spacecraft contract it
is expected that the spacecraft contractor will
outline a launch site test plan based on the proposed
design.

This plan should identify major test phases and
related special problems or test facility
requirements. As the design becomes firm and the
knowledge of assembly and test of the spacecraft is
gained, this plan should be updated to reflect actual

5-2

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	-45 • LAUNCH TEAM TRAVEL	**-44** • TRUCKS ARRIVE 0800 • REMOVE EQUIPMENT FROM WAREHOUSE • STE ASSEMBLY AND CHECKOUT • ASSEMBLE ANECHOIC HOUSE	**-43** • S/C ARRIVES 0800 • UNPACK & INSPECT • SET DESPUN ON FLOOR • SETUP ALIGNMENT DOCK • INSTALL ANTENNA OFF LOADER • STE CHECKOUT	**-42** • MATE SPUN TO STAND • DESPUN RF TEST SET UP	**-41** • UNCRATE SOLAR PANELS • DESPUN RF TEST • START BATTERY CONDITIONING (0800) • ASSEMBLE SPIN HOUSE • DEPLOY ANTENNA	**-40** • BATTERY CONDITIONING
-39 • BATTERY CONDITIONING	**-38** • DESPUN RF TESTS • CLEAN SOLAR PANELS	**-37** • PRESSURE DEMO. • LEAK TEST • RCS TESTS • SOLAR PANEL FUNCTIONAL • DESPUN RF TESTS	**-36** • RESTOW ANTENNA • REMOVE ANTENNA OFF-LOADER • DESPIN PREPS SETUP	**-35** • SQUIB AND SOLENOID DRIVER TESTS • MATE SPUN TO SPIN MACHINE • INSTALL BAPTA EXTENDER • MATE DESPUN TO SPUN • DESPIN PREPS	**-34** • SPT-DESPIN • DSTF & PAD VALIDATIONS • PAF HARNESS CHECK	**-33**
-32	**-31** • SPT-DESPIN • SETUP & LEVEL PANEL MATE FIXTURE	**-30** • SPT-DESPIN	**-29** • DEMATE DESPUN • REMOVE BAPTA EXTENDER • INSTALL RCS ORDNANCE • REMOVE PURGE EQUIP. • REMATE DESPIN TO SPUN • SPT-T&C	**-28** • MOVE S/C TO ROTAB • ALIGNMENT VERIF. • TOP-OFF BATTERY (IF REQUIRED) • SPT-T&C	**-27** • SPT-POWER • MOTOR VISUAL INSPECTION • MOTOR TO COLD SOAK • MATE SOLAR PANEL TO FIXTURE • STOW REFLECTOR	**-26** • MOTOR COLD SOAK
-25 • MOTOR COLD SOAK	**-24** • INSTALL SHELF, OMNI & REFLECTOR ORDNANCE • MOTOR X-RAY	**-23** • COMPLETE ORDNANCE INSTALLATION • MATE SOLAR PANELS • INSTL. PANEL OFF-LOADERS • INSTL. BALLAST WTS. • MOTOR PREPS-5 DAYS • INSTL FWD BARRIER	**-22** • MOVE S/C TO ROTAB & ALIGN • SUN SENSOR ALIGNMENT • MATE DEPLOYMENT STAND TO SPIN MACHINE	**-21** • MOVE S/C TO SPIN MACHINE • PANEL DEPLOYMENT • PANEL ILLUMINATION TEST • CHECKOUT SUN SENSOR • LOAD N_2H_4 CART	**-20** • RESTOW PANEL • REMOVE SOLAR PANEL OFF-LOADERS • INSTALL SOLAR PANEL ORDNANCE • PREP CAN & TRAILER	**-19** • COMPLETE MOTOR PREPS
-18	**-17** • CAN FOR MOVE • MOVE S/C TO DSTF • MOVE MOTOR TO DSTF & MATE TO STAND • TOP OFF BATTERIES (IF REQUIRED)	**-16** • LINCAN & MATE S/C TO MOTOR • HOOK UP S&A AND ETAs • S/C TURN-ON & HEATER TESTS • INSTALL INNER AFT BARRIER	**-15** • RCS SERVICING • INSTALL SOLENOID PLUG • THRUSTER LATCH VALVE CHECK	**-14** • COMPLETE BARRIER INSTALLATION • S/C FLIGHT WEIGHT	**-13** • S/C FUNCTIONAL TEST	**-12**
-11	**-10** • MATE S/C TO PAM • INSTALL IN TRANSPORTER	**-9** • MOVE TO PAD • MATE TO LAUNCH VEHICLE	**-8** • S/C FUNCTIONAL TEST	**-7** • F-0 DAY REHEARSAL • FLT PROGRAM VERIFICATION	**-6** • VEHICLE STRAY VOLTAGE CHECK • VEHICLE ORDNANCE	**-5** • BATTERY CONDITIONING
-4 • BATTERY CONDITIONING	**-3** • FAIRING PREPS • FAIRING INSTL. • S&A EXERCISE	**-2** • VEHICLE PROPELLANT SERVICING	**-1** • F-1 DAY OPERATIONS	**-0** • F-0 DAY OPERATIONS • LAUNCH	• PACK	• RETURN EQUIPMENT TO WAREHOUSE • TRAVEL

FIGURE 5.1 DELTA LAUNCH OPERATIONS SCHEDULE

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
	L-80 • LAUNCH TEAM TRAVEL	**L-79** • TRUCKS ARRIVE 0800 • REMOVE EQUIPMENT FROM WAREHOUSE • STE ASSEMBLY AND CHECKOUT • ASSEMBLE ANECHOIC HOUSE	**L-78** • S/C ARRIVES 0800 • UNPACK & INSPECT • SET DESPUN ON FLOOR • SETUP ALIGNMENT DOCK • INSTALL ANTENNA OFF-LOADER • STE CHECKOUT	**L-77** • MATE SPUN TO P80 STAND • DESPUN RF TEST SET UP	**L-76** • START BATTERY CONDITIONING (0800) • UNCRATE SOLAR PANELS • DESPUN RF TEST SETUP • ASSEMBLE SPIN HOUSE • DEPLOY ANTENNA	**L-75** • BATTERY CONDITIONING
L-74 • BATTERY CONDITIONING	**L-73** • DESPUN RF TESTS • CLEAN SOLAR PANELS	**L-72** • PRESSURE DEMO • LEAK TEST • RCS TESTS • SOLAR PANEL FUNCTIONAL • DESPUN RF TESTS	**L-71** • RESTOW ANTENNA • REMOVE ANTENNA OFF-LOADER • DESPIN PREPS SETUP	**L-70** • SQUIB AND SOLENOID DRIVER TESTS • MATE SPUN TO SPIN MACHINE • INSTALL BAPTA EXTENDER • MATE DESPUN TO SPUN • DESPIN PREPS	**L-69** • SPT DESPIN • DSTF & PAD VALIDATIONS • PAF HARNESS CHECK	**L-68**
L-67	**L-66** • SPT DESPIN • SETUP & LEVEL PANEL MATE FIXTURE	**L-65** • SPT-DESPIN	**L-64** • DEMATE DESPUN • REMOVE BAPTA EXTENDER • INSTALL RCS ORDNANCE • REMOVE PURGE EQUIP • REMATE DESPIN TO SPUN • SPT T&C	**L-63** • MOVE S/C TO ROTATE • ALIGNMENT VERIF • TOP-OFF BATTERY (IF REQUIRED) • SPT T&C	**L-62** • SPT POWER • MOTOR VISUAL INSPECTION • MOTOR TO COLD SOAK • MATE SOLAR PANEL TO FIXTURE • STOW REFLECTOR	**L-61** • MOTOR COLD SOAK
L-60 • MOTOR COLD SOAK	**L-59** • INSTALL SHELF OMNI & REFLECTOR ORDNANCE • MOTOR X-RAY	**L-58** • COMPLETE ORDNANCE INSTALLATION • MATE SOLAR PANELS • INSTL PANEL OFF LOADERS • INSTL BALLAST WTS • MOTOR PREPS 3 DAYS • INSTL FWD BARRIER	**L-57** • MOVE S/C TO ROTATE & ALIGN • SUN SENSOR ALIGNMENT • MATE DEPLOYMENT STAND TO SPIN MACHINE	**L-56** • MOVE S/C TO SPIN MACHINE • PANEL DEPLOYMENT • PANEL ILLUMINATION TEST • CHECKOUT SUN SENSOR • LOAD N_2H_4 CART	**L-55** • RESTOW PANEL • REMOVE SOLAR PANEL OFF-LOADERS • INSTALL SOLAR PANEL ORDNANCE • PREP CAN & TRAILER	**L-54** • COMPLETE MOTOR PREPS
L-53	**L-52** • CAN FOR MOVE • MOVE S/C TO DSTF • MOVE MOTOR TO DSTF & MATE TO STAND • TOP OFF BATTERIES (IF REQUIRED)	**L-51** • UNCAN & MATE S/C TO MOTOR • HOOK UP S&A AND ETA • S/C TURN ON & HEATER TESTS • INSTALL INNER AFT BARRIER	**L-50** • RCS SERVICING • INSTALL SOLENOID PLUG • THRUSTER LATCH VALVE CHECK	**L-49** • COMPLETE BARRIER INSTALLATION	**L-48** • S/C FUNCTIONAL TEST	**L-47**
L-46	**L-45** • FLIGHT WEIGHT • MATE S/C TO PAM	**L-44** • PAM ORDNANCE • MISCELLANEOUS PAM OPERATIONS	**L-43** • INSTALL PAYLOAD IN TRANSPORT CAN	**L-42** • MOVE PAYLOAD TO VPF • RECEIVE AT VPF AIRLOCK	**L-41** • CLEAN P/L TRANSPORTER • MOVE INTO VPF HIGH BAY	**L-40**
L-39	**L-38** • ROTATE PAYLOAD AND INSERT INTO WORKSTAND	**L-37** • MATE REMAINDER OF PAYLOADS INTO WORKSTAND	**L-36**	**L-35**	**L-34**	**L-33**
L-32	**L-31** • VPF INTEGRATION AND INTERFACE VERIFICATION	**L-30**	**L-29**	**L-28**	**L-27**	**L-26**
L-25	**L-24** • VPF INTEGRATION AND INTERFACE VERIFICATION	**L-23**	**L-22**	**L-21** • CITE TESTS	**L-20**	**L-19**
L-18	**L-17** • CITE TESTS	**L-16**	**L-15**	**L-14**	**L-13**	**L-12** • BATTERY CONDITIONING
L-11 • BATTERY CONDITIONING	**L-10** • VPF CLOSEOUT OPERATIONS	**L-9** • VPF CLOSEOUT OPERATIONS	**L-8** • TRANSFER CARGO TO CANISTER	**L-7** • TRANSFER CARGO TO RSS • RSS OPERATIONS	**L-6** • S/C RF FUNCTIONAL TEST • RSS OPERATIONS	**L-5**
L-4	**L-3** • COMPLETE RSS OPERATIONS	**L-2** • TRANSFER CARGO TO ORBITER • ORBITER OPERATIONS	**L-1** • ORBITER OPERATIONS	**L-0** • COMPLETE ORBITER OPERATIONS • LAUNCH	**L+1** • POSTLAUNCH SUPPORT	

NOTE: NASA DICTATES THAT PAYLOAD ENTERS VPF ON L-42.

FIGURE 5.2 STS LAUNCH OPERATIONS SCHEDULE

Telesat	LEGEND:	NETWORK: PREPD BY: G. GAGNE APPVD BY:	TELESAT EXPENDABLE LAUNCHER CAMPAIGN

	46	0	REMARKS

S/C ARRIVES

UNPACK &SETUP

BATTERY CONDITIONING

RF TESTS

DEPLOYMENT MECH. CHECKS

SYSTEM PERF. TESTS

AKM PREPS

RCS SERVICING

RF FUNCTIONAL

MATE S/C-   L/V

PAD OPS

BATTERY CONDITIONING

L/V PROPELLANT SERVICE

LAUNCH

ISSUE #001   DATE: 23-02-82

FIGURE 5.3   ARIANE LAUNCH SCHEDULE

Tele𝓈at	**LEGEND:** ◆ POTENTIAL 16 DAY STAND DOWN IF MULTIPLE PAYLOAD	**NETWORK:** PREPD BY: G. GAGNE APPVD BY:	**STS** LAUNCH CAMPAIGN

114   63   0

S/C ARRIVES

UNPACK SETUP

BATTERY CONDITIONING

RF TESTS

DEPLOYMENT MECH. CHECKS

SYSTEM PERF. TESTS (BUS)

RCS SERVICING

MATE-S/C-PAM

VPF ACTIVITIES

RSS ACTIVITIES

PLB OPERATIONS

LAUNCH

POST LAUNCH ACTIVITIES

ISSUE #001   DATE: 23-02-82
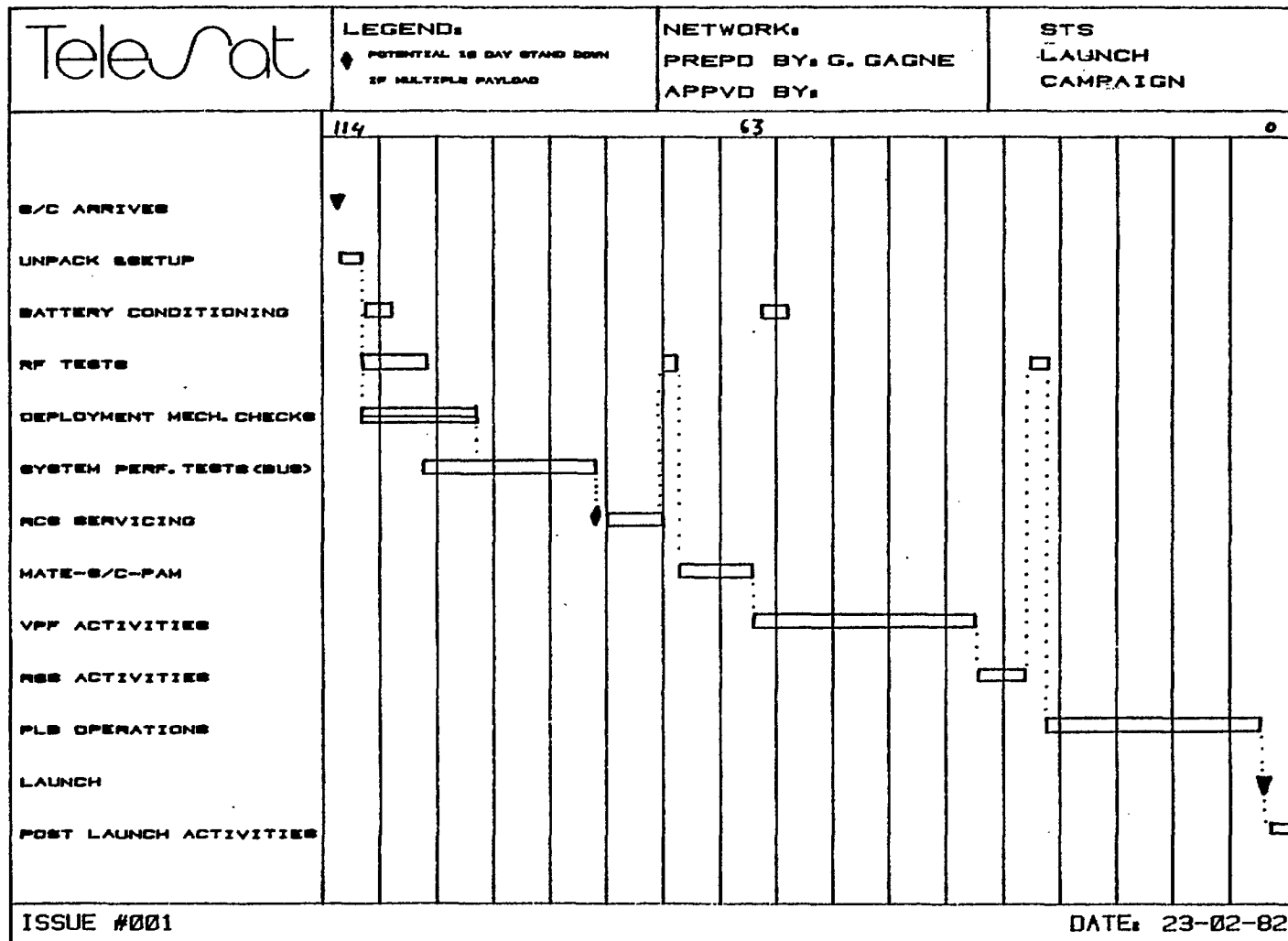
FIGURE 5.4   STS LAUNCH SCHEDULE

5 - 5

requirements. Thus, it is not possible to generate an
accurate time-phased sequence of events for the
proposed M-SAT demonstration spacecraft at this time,
but it is possible to present a good outline flow of
activities.

Considering the baseline design for M-SAT, it is
evident that the Thor-Delta launch vehicle is not a
candidate, and that the two possible launch vehicles
are Ariane 3 and the Space Transportation System (STS).

Figure 5.1 and 5.2 are detailed day-by-day activity
charts for Delta (equivalent to Ariane) and STS launch
campaigns for the Anik-series spacecraft. As can be
seen, the spacecraft assembly and integration
activities up to, and including, RCS servicing are
identical.

Figures 5.3 and 5.4 depict, in less detail, what can
be expected as launch campaigns for Ariane and STS
launches of the demonstration M-SAT.

Factors that have been considered in generating
Figures 5.3 and 5.4 include:

o   The launch campaign is expected to be less than
     seven weeks from spacecraft arrival to lift off.
     This is consistent with facility utilization at
     both Kourou and KSC.

o   The L-SAT bus will have been previously flown,
     thus bus integration and test activities will be
     "routine" and there will be no special test
     requirements specific to M-SAT.

o   The M-SAT RF payload experiments final testing at
    launch site will be qualitative rather than
    quantitative, in order to achieve acceptable test
    durations.

5.1.2   Launch Site Test Activities

5.1.2.1 Spacecraft Integration and Tests

Figures 5.3 and 5.4 are shown to be identical through
the activity "RCS Servicing", thus the preceding
activities can be outlined as follows and are common
to either launch site:

o   Unpacking of spacecraft, handling equipment and
    electrical ground checkout equipment and setting
    up prior to initial test is routine, but will
    require support equipment such as cranes, fork
    lift trucks and transporters which will have to be
    defined during the contract. Some calibration
    facilities for electrical equipment and proof
    loading of handling equipment may be necessary.

o   Battery conditioning is usually planned to occur
    over a weekend when there is no activity on the
    rest of the spacecraft. This will normally be
    performed with contractor-supplied test
    equipment. Some range support (e.g., security)
    may be necessary.

o   RF testing should be limited to health check type
     of tests rather than performance checks to ensure
     the duration of testing is consistent with the
     overall launch site test duration. With a modular
     construction, as envisaged in the baseline design,
     it may be possible to perform payload and bus
     tests in parallel; this would allow more detailed
     RF testing, but would require additional test
     equipment and personnel. The possibility of
     having encryption and decryption units on some of
     the military experiments would necessitate higher
     levels of security; this should be addressed in
     the next phase of the contract.

o   The large number of deployable items, and their
     associated mechanisms, included in the baseline
     design is seen as one of the most problematic
     items in the launch campaign. For this reason it
     is highlighted by hatching on Figs. 5.3 and 5.4
     and shown as being in parallel with RF testing and
     system performance testing. There should be
     separate studies on how each of the deployable
     items can be tested, either before launch site
     activities or at the launch site, without the
     bus. For example, the deployable reflectors could
     be checked adequately prior to shipment and only
     the deployment of the booms and associated
     pyrotechnic circuitry checked at the launch site.
     Similarly, the Solar Array could be checked on a
     rig both for initial and full deployment using
     test equipment rather than the spacecraft bus
     subsystem. The interfaces between deployment
     mechanisms would then be checked as part of the
     final assembly included in system performance
     tests. If suitable parallel testing of mechanisms
     cannot be arranged, then a longer launch campaign
     should be negotiated.

o   System performance tests repeat much of the final
    systems testing performed at the contractor's
    facility after environmental testing of the
    spacecraft, and check that each subsystem is still
    functioning correctly. Again, since the basic bus
    is the same as L-SAT, few M-SAT specific
    requirements are expected. Since Attitude Control
    System testing will probably be performed using
    simulated inertia loads, these may be different
    for the M-SAT array size. Final alignments during
    this phase may require some contractor-supplied
    equipment as well as standard launch site
    facilities.

o   The Reaction Control System (RCS) Servicing, for
    the baseline design, includes the loading of the
    liquid apogee motor propellant. Both of the
    considered launch sites have adequate explosive
    safe facilities for these activities. Provision
    of some propellant is included in the normal
    launch site services package. When M-SAT
    propellant requirements are known, the adequacy of
    this quantity can be assessed and more requested
    if necessary. Final weighing of the spacecraft is
    performed and, depending on mission requirements,
    it may be necessary to check or perform balancing
    of the spacecraft. Facilities exist at both
    launch sites but, with the unsymmetrical
    appendages on the baseline M-SAT, a spin of some
    description would be necessary to ensure accuracy
    of results; this would have to be supplied by the
    contractor.

o   On completion of RCS servicing, the spacecraft
    would be subjected to a command functional check,
    including check of RF payload operation without RF
    carriers, as will be performed on integration with
    the launch vehicle. This check will be performed
    with local power supplies (in the explosive safe
    facility) and through an RF link to the Payload
    Processing Facility and the electrical ground
    support equipment.

At this juncture, the launch site activities for an
Ariane launch begin to differ from those for an STS
launch and will therefore be discussed separately in
the following sections.

5.1.2.2   Spacecraft Integration with Ariane Launcher

Expendable launcher campaign activities on the
spacecraft, after its integration as the payload of
Ariane, are mainly controlled by launcher activities
and limited to a command functional health check,
topping up or conditioning of batteries and a final
check leaving the spacecraft commanded into launch
configuration ready for launch day activities.
Mechanical and safety related activities also occur in
concert with launcher build-up activities. Detailed
activities will have to be defined during the contract
in association with the launcher authority.

5.1.2.3   STS Payload Integration

The activities shown after "RCS Servicing" in Fig. 5.4
are those experienced by an Anik-sized spacecraft
which flies as a partial STS payload. After
spacecraft integration with the Perigee Assist Module

(PAM), there is an interface verification test prior to transportation to the Vertical Processing Facility (VPF). At the VPF, the spacecraft is integrated as part of the STS cargo and undergoes interface verification tests and CITE (Cargo Integration Test Equipment) tests. After final battery conditioning, the VPF activities are completed and the cargo transferred to the Rotating Service Structure (RSS) at the launch pad where a spacecraft command functional test may be performed as a final health check prior to cargo installation into the STS Orbiter Bay.

For an M-SAT-sized payload it may be decided to use the Horizontal Processing Facility (HPF) to integrate the spacecraft into the cargo. This integrates the spacecraft and PAM (Inertial Upper Stage?) and performs interface verification tests and CITE testing in a horizontal position.

The combined spacecraft and PAM payload is then transferred directly to the orbiter bay prior to erection and transportation of the orbiter to the launch pad.

The actual flow to be followed for M-SAT will have to be negotiated during subsequent contract phases and will impact launch campaign activities and durations.

It would be expected to maintain the satellite checkout equipment at the launch site to monitor spacecraft performance after ejection from the STS in parking orbit.

5.1.3   Launch Campaign – Customer Activities

Telesat, operating as a customer organization, would normally monitor all launch site activities associated with the integration and test of the spacecraft and the assembly of the launch vehicle. The liaison activities between spacecraft contractor, launch vehicle contractors, and range authorities are also controlled by Telesat as customer. The typical structure of a Telesat launch team is shown in Fig. 5.5 and will suffice for either an Ariane or STS launch.

Figures 5.6 and 5.7 show the manpower deployment to monitor contractor activities associated with spacecraft, Ariane and STS launcher activities, respectively, as outlined in Section 5.1.

Figure 5.8 shows how the launch team is typically deployed for an expendable launch during final countdown. Figure 5.9 shows a suggested deployment of personnel for STS launch countdown and ejection in parking orbit. Figures 5.8 and 5.9 indicate lines of communication between both personnel and facilities, some of which are covered by normal launch site facilities, and some of which will need to be rented from utility companies.

The responsibilities of the launch team members are explained below:
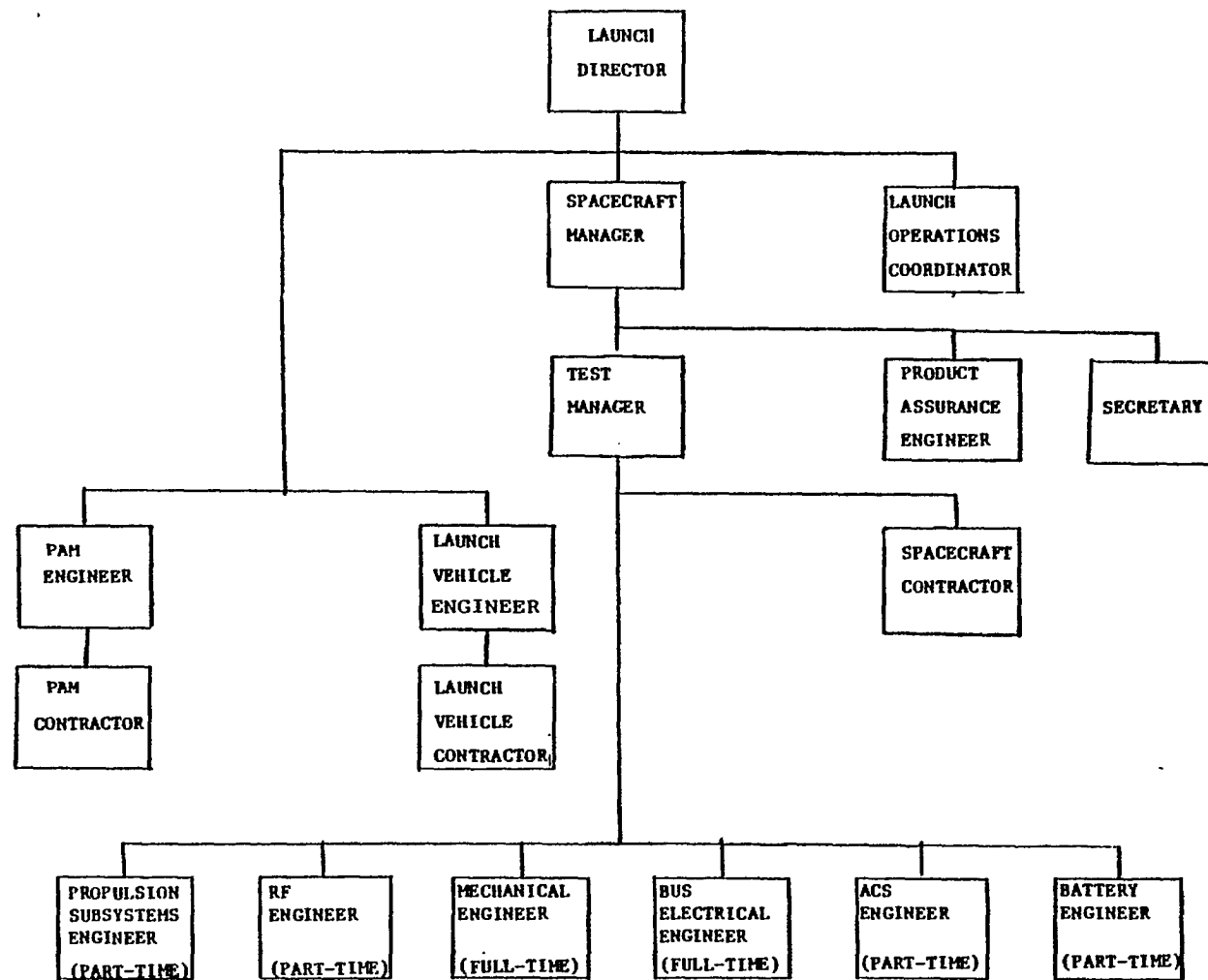
FIGURE 5.5   LAUNCH TEAM - CUSTOMER ORGANIZATION

Telesat

LEGEND:

NETWORK:

PREPD BY: G. GAGNE

APPVD BY:

MANPOWER REQUIREMENTS
FOR EXPENDABLE
LAUNCHER

REMARKS

45   0

R/F ENGINEER

COMMS

TTAC

MECH ENGINEER

PROP. S/S

MECH

SUS ENGINEER

SUS ELEC

ACS

BATTERY ENGINEER

P.A:

MANAGEMENT &
CO-ORDINATION TEAM

ISSUE #001   DATE: 23-02-82
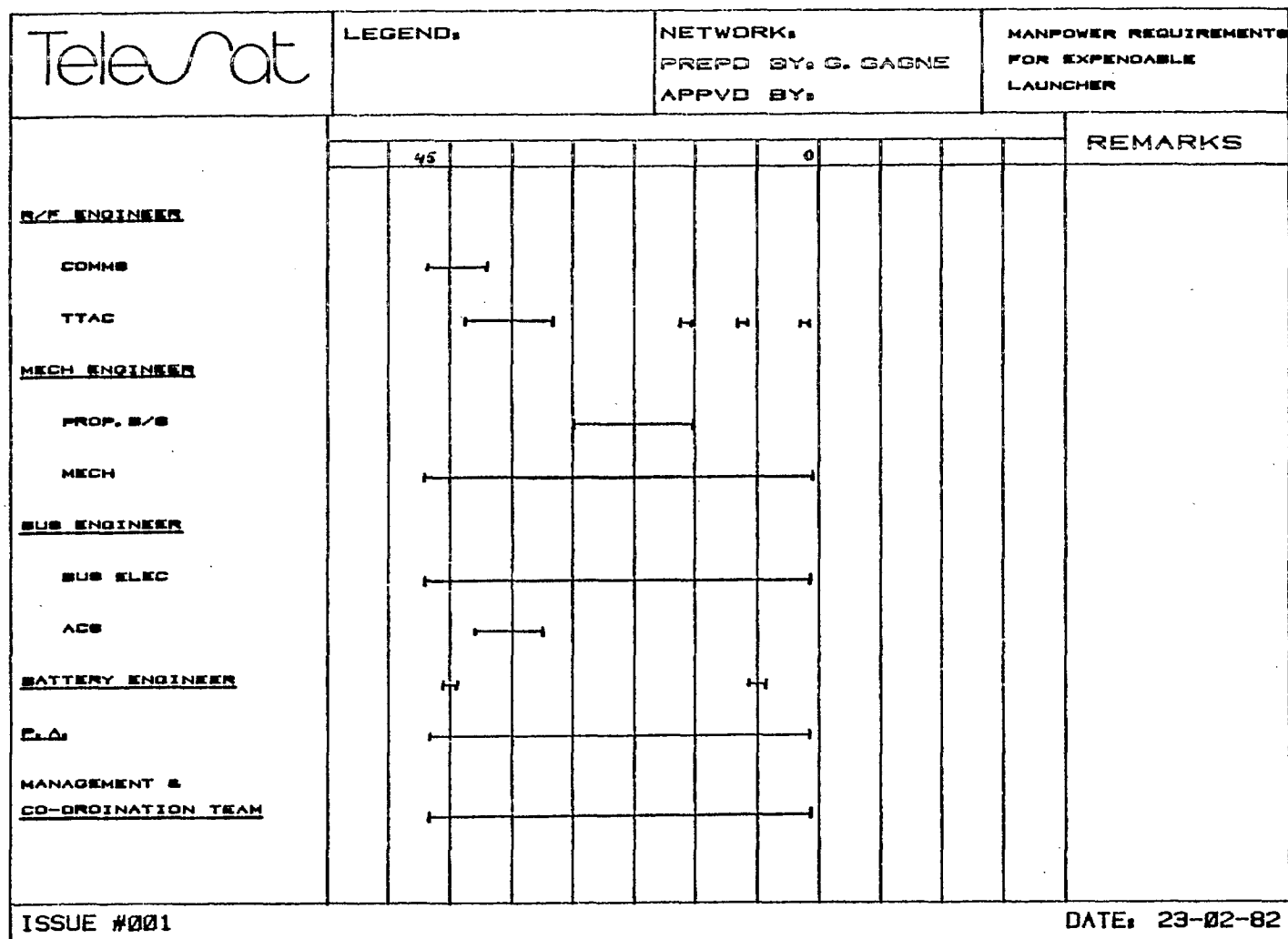
FIGURE 5.6   LAUNCH TEAM DEPLOYMENT – FINAL
COUNTDOWN FOR EXPENDABLE LAUNCH

Telesat

| LEGEND: | NETWORK:
PREPD BY: G. GAGNE
APPVD BY: | MANPOWER REQUIREMENTS
FOR STS LAUNCH |

R/F ENGINEER

    COMMS

    TTAC

MECH ENGINEER

    PROP. S/S

    MECH

BUS ENGINEER

    BUS ELEC

    ACS

BATTERY ENGINEER

P. A.

**MANAGEMENT &
CO-ORDINATION TEAM**

ISSUE #001   DATE: 23-02-82
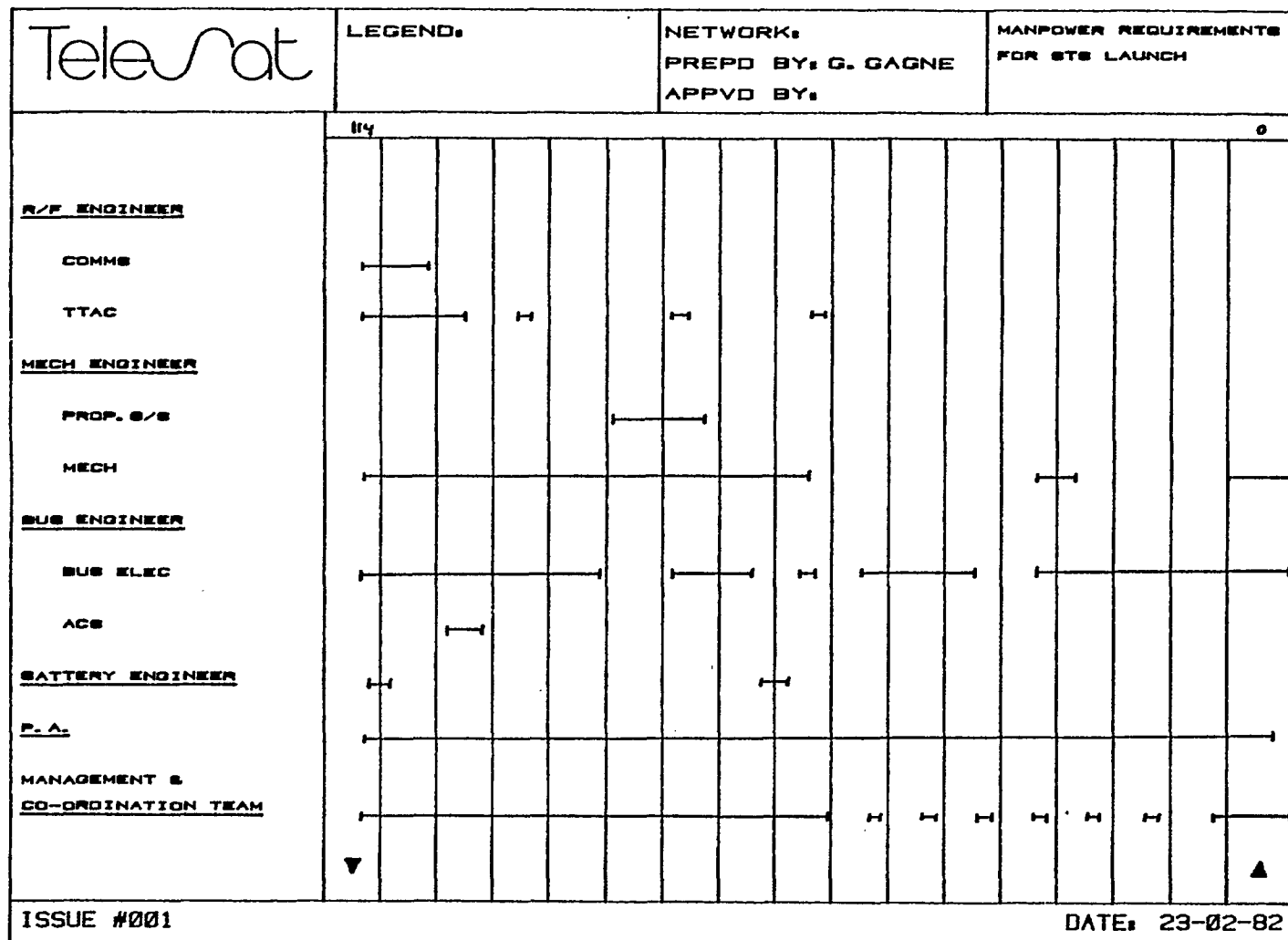
FIGURE 5.7   DEPLOYMENT OF PERSONNEL FOR STS
LAUNCH AND PARKING ORBIT EJECTION
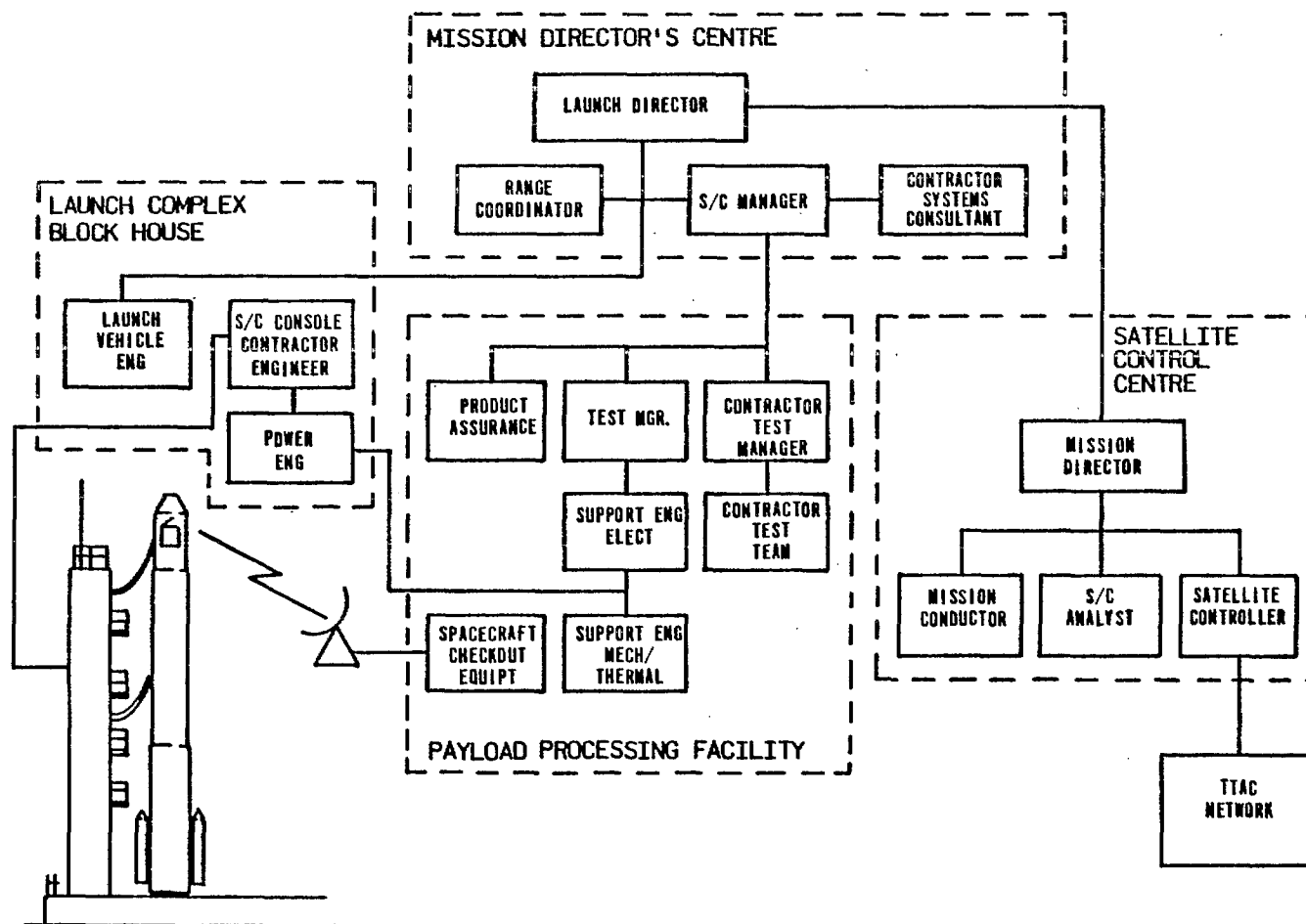
FIGURE 5.8   FINAL COUNTDOWN ORGANIZATION - EXPENDABLE LAUNCHER

Telesat

ORBITER

| MISSION SPECIALIST | ←→ | COMMANDER |

STS

SMCC

| PAYLOAD OFFICER | ←→ | FLIGHT DIRECTOR |

DECISION PATH
DISCUSSION LOOP
DATA LINK

GSFC STDN

USER MANAGEMENT SUPPORT ROOM

JSC **SPIDPO**

TELESAT REPRESENTATIVE

KSC/ETR
TELESAT
LCC/POCC
LAUNCH DIRECTOR

OPERATIONAL

MANAGEMENT

NASA KSC STS OPERATIONS

JSC
MPSR
TELESAT REP

OTTAWA
TELESAT MCC
MISSION DIRECTOR

TELESAT LAUNCH OPERATIONS TEAM

JSC MPSR

NASA PAYLOAD SYSTEMS
NASA PAYLOAD DATA
STS PAYLOAD OPS TEAM (CONTRACTOR)
PAM PAYLOAD OPS TEAM (CONTRACTOR)

| CONTRACTOR SPACECRAFT OPERATIONS ETR | CONTRACTOR PAM OPERATIONS ETR | NASA KSC PAYLOAD OPERATIONS |

TELESAT TT&C NETWORK

HOME BASES

FIGURE 5.9   TELESAT STS MISSION - ORGANIZATIONAL INTERFACES

Launch Director. The Launch Director is in overall charge of the launch operations. He will hold daily meeting to review progress. He will also interface with the Launch Site Authority and with the Mission Director in Ottawa, both informally and at prescribed periods of time.

Spacecraft Manager. The Spacecraft Manager will be responsible for all spacecraft activities including coordination via his Test Manager with the Spacecraft Contractor Test Manager to ensure that procedures are followed and appropriate personnel are available at the required times. During countdown, while located in the Mission Directors Centre, he will be giving permission to the Spacecraft Contractor to start defined tasks.

Launch Operations Coordinator. The Launch Operations Coordinator will interface with Telesat Satellite Control, Spacecraft Contractor and launch site authorities to ensure the required facilities, equipment, and personnel of the various groups are available at the appropriate times. He will also ensure that all the final spacecraft technical information is forwarded to the launch site authority to satisfy all the launch requirements.

Test Manager. The Test Manager will ensure monitoring and verification of spacecraft assembly and test operations. He will select those Telesat Subsystem Engineers that should be present for a particular test or activity. He will also ensure that the appropriate spacecraft data is forwarded to the Satellite Control Centre via Allan Park. He will coordinate spacecraft assembly and test activities with the spacecraft contractor's launch director.

Product Assurance Representative. The Product
Assurance representative will be responsible for
monitoring the Contractor Test Team for adherence to
formally agreed procedures, reviewing the results and
closing out anomalies. Also, he will encompass Launch
Vehicle Product Assurance Activities.

Launch Vehicle Engineer. The Launch Vehicle engineer
will monitor launch vehicle preparations and Range
Activities, and will interface with launch vehicle
contractors and range authorities.

Perigee Assist Module Engineer. The Perigee Assist
Module engineer will monitor Perigee Assist Module
(IUS?) preparations and interface with the perigee
stage contractor.

In order to be able to perform these activities in the
manner described, it would be a prerequisite that
Telesat personnel be involved directly in the
spacecraft program during the preceding phases to be
fully conversant with all design aspects of both
spacecraft and launcher.

5.2   M-SAT   SEQUENCE OF EVENTS - LAUNCH TO ON-STATION

5.2.1   Introduction

In general, a geostationary satellite mission may be broken into several phases, as follows:

a)   launch;

b)   parking orbit;

c)   transfer orbit;

d)   drift orbit;

e)   pre-operational checkout and performance verification;

f)   operation.

The launch and parking orbit phases are directed at placing a payload into a specified low earth orbit in a specified orientation, in preparation for injection into transfer orbit. As these activities are generally the responsibility of the launch agency, they will not be described in detail here.

The transfer orbit begins with the firing of a large rocket motor, injecting the payload into a highly elliptical, inclined transfer orbit, with an apogee at approximately synchronous altitude. The principal activities during this phase are assessing the overall health of the spacecraft, and determining the most optimal attitude and time at which to fire the next large rocket motor, in order to most efficiently inject the spacecraft into a nearly circular equatorial drift orbit.

During the drift orbit phase, the principle activities
are those of final station acquisition, maneuvering
the spacecraft into its final earth pointing attitude
and the deployment of appendages, such as solar arrays
and communications reflectors. In the pre-operational
checkout and performance verification phase, all the
spacecraft subsystems and functions are tested, and
performance and calibration measurements made.
Particular attention is paid to the attitude control
system and the communications system. Following
completion of these tests, the spacecraft is placed
into operation, to carry out its communication mission.

The following sections describe mission scenarios for
four cases; the first assumes an Ariane launch
vehicle, and the remaining three assume an STS launch,
and the use of a large, solid upper stage for
injection into transfer orbit.

5.2.2   Tracking, Telemetry and Command Stations

Throughout this study, the tracking stations used in
Table 5.1 have been assumed. This network consists of
stations from the ESA S-Band network, and an M-SAT
S-Band station, assumed to be located at Allan Park,
Ontario. The latter site was chosen for convenience
only. Similar if not identical results would be
obtained using a station located up to 1000 kilometers
from Allan Park, say at Ottawa or North Bay.

In general, only two or three tracking stations are
required for the successful completion of a mission,
assuming that the stations are appropriately placed
around the world. Given the tracking stations are
part of an existing network, and therefore have
adequate redundancy and maintainence policies, extra
stations beyond this number do not provide any
significant increase in reliability or visibility, but
do add extra mission costs and complexity. The point
to be made here is that in the following scenarios,
all of the stations shown in Table 5.1 have been used,
but are not necessarily required for a successful
mission. The precise number of stations to be used is
a topic that requires further study.

TABLE 5.1   LOCATIONS OF S-BAND TT&C STATIONS

Name	Latitude deg:min:sec	Longitude deg:min:sec	Altitude meters
Allan Park-TTAC	44:10:22	80:56:12	298
Carnarvon	-24:52:10	246:17:50	35
Madrid	40:27:20	5:49:54	800
Malinde	-4:00:00	320:00:00	0
Kourou	5:00:00	52:30:00	0

5.2.3   Launch Vehicle and Upper Stages

Both the Ariane 3 and STS launch vehicles have been
considered in this study. In the case of the STS, a
large, high thrust perigee stage (IUS or equivalent)
has been assumed. If spin stabilization is used, the
perigee stage will also require an active nutation
control system, and a spinup and deployment system
which presumably would return to earth with the
orbiter.

5.2.4   Mission Scenarios

Four mission scenarios have been examined, and are
described below.

The first scenario considered uses the Ariane 3 as a
launch vehicle. The transfer orbit parameters were
taken from the Ariane Users Guide AR(75)01, rev 2, Oct
1977, and propagated to determine the location of each
apogee. Table 5.2 shows this information. With final
station at 109 degrees longitude, it can be seen that
the seventh apogee is the best choice for LAE firing.
Ninth apogee is the backup opportunity. Using the
tracking station network defined above, a visibility
study was carried out. The results are shown in
Figure 5.10. Using the periods of command and
telemetry visibility thus determined, a sequence of
events was established, and is discussed in section
5.2.5.
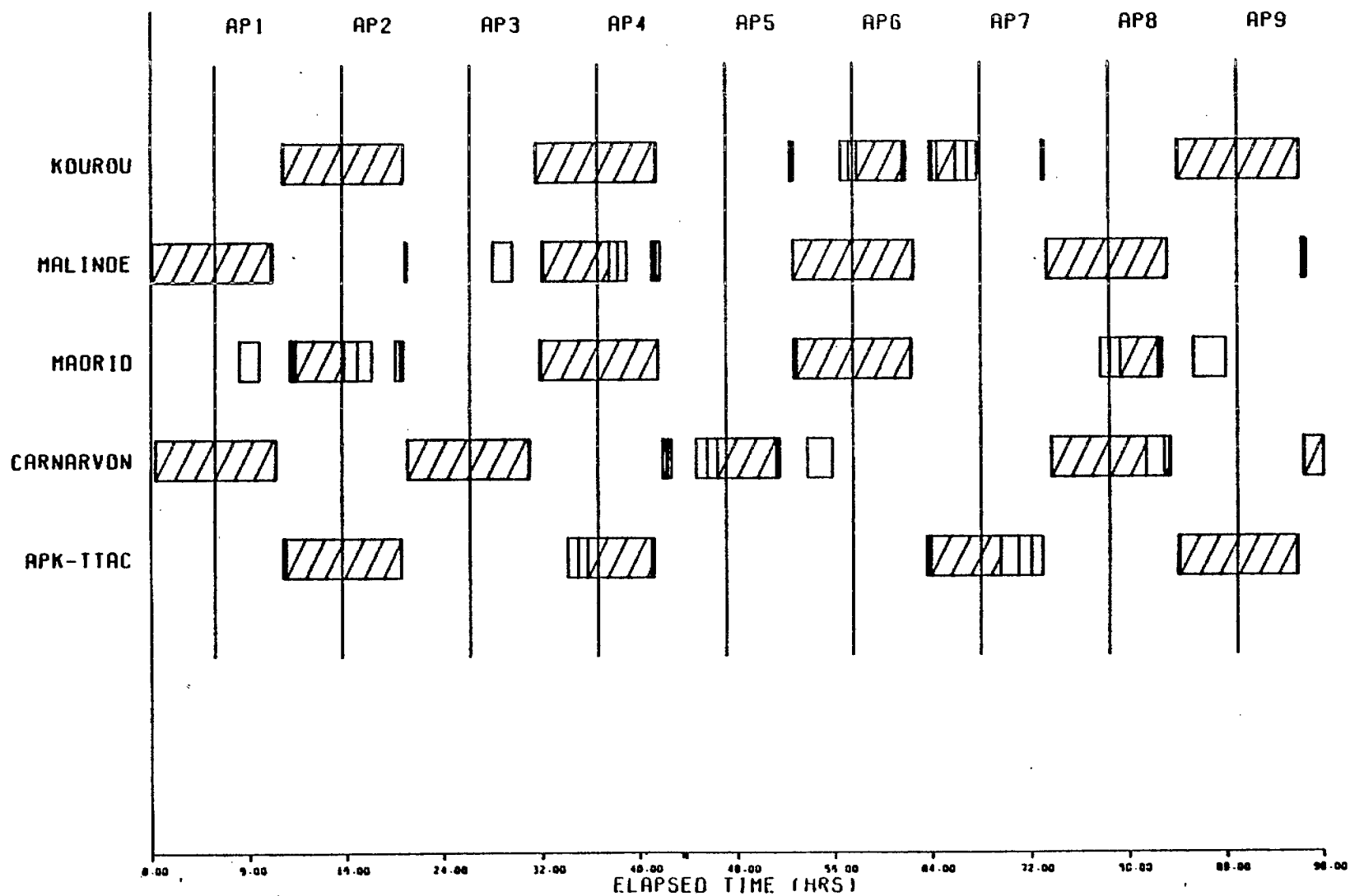
FIGURE 5.10   ARIANE EARTH STATION VISIBILITY

TABLE 5.2   TABLE OF APOGEE LONGITUDES

Apogee Number	Longitude (deg,+W)			
	Ariane	STS 1	STS 2	STS 3
1	272.9	259.4	49.4	49.4
2	69.9	58.1	208.1	208.1
3	227.1	216.8	6.8	6.9
4	24.2	15.5	165.5	212.9
5	181.3	174.2	324.2	58.9
6	338.5	332.9	122.9	264.9
7	135.6	131.6	281.6	110.9
8	292.7	290.3	80.4	316.9
9	89.8	89.0	239.1	162.9

Note: 1)   Ariane launch, injected into transfer orbit at 14.2 degrees west.

2)   STS launch, injected into transfer orbit at 14.2 degrees west.

3)   STS launch, injected into transfer orbit at 150 degrees west.

4)   STS launch, injected into transfer orbit at 150 degrees west, apogee motor fired at third apogee to provide 50% of required delta V.

The remaining scenarios involve the use of the NASA Space Transportation System (STS) as a launch vehicle. Because the STS remains in parking orbit for up to several days, the point of injection into transfer orbit becomes a free parameter to be chosen by mission planners. For the first STS scenario, an injection point identical to that of the Ariane mission was chosen. The apogee longitudes in this case are shown in Table 5.2. Seventh apogee is prime for apogee motor firing, with ninth apogee as backup. For the second and third STS scenarios, it was decided to make Allan Park the first TT&C station to acquire the spacecraft. An injection longitude of 150 degrees was chosen, in order to fullfil this requirement. For the second scenario, sixth apogee is prime for apogee motor firing, with eight as a backup opportunity. Since the duration of the apogee motor firing maneuver is approximately twice as long as for the Ariane case, the maneuver was broken into two parts, with the first occurring at third apogee, and the second at seventh. A detailed scenario for the second STS mission is presented in section 5.2.6.

5.2.5   Sequence of Events - Ariane Launch

5.2.5.1 Transfer Orbit

A typical sequence of events for the launch phase of an Ariane based mission is shown in Table 5.3. The details of this sequence would be the responsibility of the launch agency, Arianespace.

TABLE 5.3   SEQUENCE OF EVENTS
FOR ARIANE LAUNCH VEHICLE

Elapsed Time (sec)	Event
0	liftoff, from Kourou launch facility
148	first stage burnout
153	first stage - second stage separation
157	second stage maximum thrust
250	fairing jettison
293	second stage burnout
298	second stage - third stage separation
306	third stage maximum thrust
871	third stage shut down
873	start to orient payload
1051	third stage - payload separation

Sequence taken from Ariane User's Guide AR(75)01, rev 2, Oct 1977.

Following separation of the payload from the launch vehicle, control transfers to the mission control center and its associated TT&C stations. The sequence of events for this mission is outlined below. It is assumed that the LAE is fired at seventh apogee, with ninth as backup. Figure 5.1 shows the ground station visibility for this case, during the transfer orbit. In preparing this figure it was assumed that no apogee motor firing occurred.

Rev #1

| Elapsed Time | Event |
| (hr, from injection) | |

0.0	Injection into transfer orbit, orient payload with -Z axis towards the sun
0.05	Separation from third stage
0.10	Malinde Acquisition
0.35	Carnarvon Acquisition
0.42	Command initial solar array deployment
0.65	Command array to sun
0.78	Array on sun, array power available
5.23	Apogee #1
7.25	Madrid Acquisition
8.83	Madrid Loss
9.95	Malinde Loss
10.20	Carnarvon Loss
10.46	Perigee #2

Functions to be carried out

1. Acquire signal at Malinde and Carnarvon, and establish T&C link to spacecraft.

2. Deploy solar arrays and rotate to point at sun.

3. Verify spacecraft health, and confirm that AOCS and CPS have been properly initialized.

4. Determine initial attitude.

5. Collect tracking data, commence orbit determination; assess Ariane performance, and need for perigee raising maneuver.

6. Acquire signal at Madrid.

7. Commence collection of all TM data types, build history of spacecraft performance, establish trends, and take corrective action, as required.

8. Calibrate attitude reference gyros, using sun and earth; perform attitude maneuvers as required, and establish initial earth lock.

9. Maneuver to coast attitude.

10. Use maneuvers to assess the performance of the AOCS, and establish biases for use in LAE pointing during major maneuvers.

11. Update predictions at the control center and the tracking stations as required, based upon the measured orbit.

12. Configure spacecraft for loss of signal at Malindi, Carnarvon and Madrid, and eclipse near perigee.

13. Calibrate CPS for attitude control, and commence bookkeeping of fuel usage.

Rev #2

Elapsed Time	Event
10.77	Kourou Acquisition
10.85	Allan Park Acquisition
11.41	Madrid Acquisition
15.69	Apogee #2
18.10	Madrid Loss
20.07	Madrid Acquisition
20.56	Allan Park Loss
20.70	Madrid loss
	Kourou loss
20.90	Malinde Acquisition
20.92	Perigee #3

Functions to be carried out

1. Acquire signal at Kourou, Allan Park, and Madrid, establish T&C link.

2. Assess atmospheric drag effects on orbit and attitude.

3. Continue collection of TM data, and monitor health of spacecraft.

4. Continue collection of tracking data, and orbit determination.

5. Calibration of gyros, as required (at least once every rev), with maneuvers to appropriate attitudes.

6. Commence AMF planning; use measured orbit to determine best time and attitude in which to fire the LAE.

7. Update predictions at the control center and tracking stations, as required.

8. Prepare for acquisition of signal at Carnarvon and Malinde.

9. Configure spacecraft for loss of signal at Allan Park, Kourou and Madrid, and eclipse near perigee.

10. Update CPS calibration.

Rev #3

Elapsed Time	Event
21.06	Malinde loss
21.10	Carnarvon Acquisition
26.15	Apogee #3
28.00	Malinde Acquisition
29.60	Malinde Loss
30.95	Carnarvon Loss
31.37	Perigee #4

Functions to be carried out

1. Acquire signal at Carnarvon and Malinde, and establish T&C link.
2. Assess atmospheric drag effects on orbit and attitude.
3. Continue collection of TM data, and monitor spacecraft health.
4. Continue collection of tracking data, and orbit determination.
5. Calibrate gyros, as required, with maneuvers to the appropriate attitudes.
6. Update AMF planning.
7. Update predictions at control center and tracking stations.
8. Prepare for acquisition of signal at Kourou, Allan Park, Madrid and Malinde.
9. Configure spacecraft for loss of signal at Carnarvon and Malinde, and eclipse near perigee.
10. Update CPS calibration.

Rev #4

Elapsed Time	Event
31.54	Kourou Acquisition
31.84	Madrid Acquisition
32.05	Malinde Acquisition
34.20	Allan Park Acquisition
36.60	Apogee #4
38.99	Malinde Loss
41.10	Malinde Acquisition
41.22	Allan Park Loss
41.44	Kourou Loss
41.60	Madrid Loss
41.70	Malinde Loss
41.83	Perigee #5

Functions to be carried out

1. Acquire signal at Kourou, Madrid, Malinde, and
    Allan Park, establish T&C link.

2. Assess atmospheric drag effects on orbit and
    attitude.

3. Continue collection of TM data, and monitor
    health of spacecraft.

4. Continue collection of tracking data, and orbit
    determination.

5. Calibration of gyros, as required (at least once
    every rev), with maneuvers to appropriate
    attitudes.

6. Update AMF planning.

7. Commence drift orbit maneuver planning, based
    upon current AMF planning.

8. Update predictions at the control center and
    tracking stations, as required.

9. Prepare for acquisition of signal at Carnarvon.

10. Configure spacecraft for loss of signal at Allan
    Park, Kourou, Madrid and Malinde, and eclipse
    near perigee.

11. Update CPS calibration.

Rev #5

Elapsed Time	Event
41.90	Carnarvon Acquisition
42.70	Carnarvon Loss
44.70	Carnarvon Acquisition
47.06	Apogee #5
51.48	Carnarvon Loss
52.29	Perigee #6

Functions to be carried out

1. Acquire signal at Carnarvon, establish T&C link.
2. Assess atmospheric drag effects on orbit and attitude.
3. Continue collection of TM data, and monitor health of spacecraft.
4. Continue collection of tracking data and orbit determination.
5. Calibration of gyros, as required (at least once every rev); with maneuvers to appropriate attitudes.
6. Update AMF planning.
7. Update drift orbit planning.
8. Update predictions at the control center and tracking stations, as required.
9. Prepare for acquisition of signal at Kourou, Allan Park, and Malinde.
10. Configure spacecraft for loss of signal at Carnarvon, and eclipse near perigee.
11. Update CPS calibration.

Rev #6

Elapsed Time	Event
52.30	Kourou Acquisition
52.60	Malinde Acquisition
	Madrid Acquisition
52.70	Kourou Loss
53.78	Allan Park Acquisition
55.82	Allan Park Loss
56.50	Kourou Acquisition
57.52	Apogee #6
61.71	Kourou Loss
62.30	Madrid Loss
62.60	Allan Park Acquisition
62.75	Perigee #7

Functions to be carried out

1. Acquire signal at Kourou, Allan Park, and Madrid, establish T&C link.

2. Assess atmospheric drag effects on orbit and attitude.

3. Continue collection of TM data, and monitor health of spacecraft.

4. Continue collection of tracking data, and orbit determination.

5. Calibration of gyros, as required (at least once every rev), with maneuvers to appropriate attitudes.

6. Update AMF planning.

7. Update drift orbit planning.

8. Update predictions at the control center and tracking stations, as required.

9. Prepare for acquisition of signal at Allan Park and Kourou.

10. Configure spacecraft for loss of signal at Allan Park, Kourou and Madrid, and eclipse near perigee.

11. Update CPS calibration.

Rev #7

Elapsed Time	Event
63.90	Kourou Acquisition
65.95	Gyro initialization
66.37	Commence AMF attitude acquisition
66.97	Commence firing of LAE
67.70	Kourou Loss
67.98	Apogee #7
68.99	End of firing of LAE

Functions to be carried out

1. Acquisition of signal at Kourou.

2. Finalize AMF planning.

3. Initialization of gyros.

4. Maneuver to acquire AMF attitude.

5. Firing of LAE, to inject spacecraft into drift orbit.

5.2.5.2 Drift Orbit

Following the firing of the LAE, the immediate concern is to determine the drift orbit parameters as quickly as possible, and to plan corrective maneuvers that will place the satellite on its final station in a timely and fuel efficient manner. Hence the spacecraft will be maneuvered into an attitude with the +Z axis earth facing, the Y axis normal to the orbit plane, and the solar arrays on the sun. The following is a general list of events to be carried out in the early drift orbit phase:

- Maneuver to an earth facing attitude, with the arrays normal to the orbit plane and on the sun;
- Collect tracking data, and carry out orbit determination; assess the need for further LAE maneuvers to remove large drift orbit errors;
- Isolate and purge the LAE, and isolate the pressure tanks;
- Plan, execute and evaluate a series of maneuvers to acquire final station in a fuel efficient manner, and on a non-interference basis with other geostationary satellites operating in the same frequency band.

At a convenient time during the drift orbit, deployment activities must be carried out. The communication antennas and feed systems must be sequentially deployed to place the spacecraft in its operational configuration. It is expected that this can be done at any time following the completion of major drift orbit maneuvers. The general sequence for deployment is as follows:

- Deploy communication antenna support structures and reflectors;
- Deploy communication feed systems (if required);
- Run up reaction wheels;
- Reacquire earth lock, and repoint the solar array at the sun.

Following successful deployment, testing of the AOCS in its operational mode can commence. Final station acquisition will probably be accomplished in this configuration.

5.2.6 Sequence of Events - STS Launch

5.2.6.1 Parking and Transfer Orbits

A typical sequence of events for the launch phase of an STS based mission is shown in Table 5.4. It is assumed that a standard parking orbit will be used (i.e., a 160 nautical mile, circular orbit, inclined at 28.5 degrees). The details of this sequence are the responsibility of the launch agency, NASA.

TABLE 5.4 SEQUENCE OF EVENTS FOR STS LAUNCH
AND PARKING ORBIT

ELAPSED TIME FROM LIFTOFF (MN:SC)	EVENT	DESCRIPTION
00:00	LIFTOFF	12:30 GMT
	SOLIDS SEPARATE	
08:40	MECO	
10:43	START OMS-1	DF=236 FPS. RAISE ORBIT
12:45	END OMS-1	TO 160 X 60 nmi
45:50	OMS-2	DV=194 FPS. RAISE ORBIT
		TO 160 X 160 X 28.5

During the parking orbit phase, prior to deployment, there is the opportunity to "turn on" the spacecraft and have its telemetry data transmitted to the ground via the orbiter downlink. The type of checking to be done is an item for further study, as are all other pre-deployment activities, such as battery charging. Near real time adjustment of the deployment parameters is also possible, to take into account variations in the achieved STS parking orbit. This is especially useful in recovery from an "Abort to Orbit" situation, in which the orbiter was not able to achieve its planned parking orbit. Variation of the pointing of the perigee motor will permit recovery of most of the mission life, that otherwise would be lost.

As the scheduled deployment opportunity approaches,
the STS crew will commence deployment activities.
These are expected to include:

- IMU alignment;
- spacecraft and deployment hardware power up and
  checkout;
- maneuvering of the orbiter to the deployment
  attitude;
- removal or opening of a thermal protection shield;
- elevation of spacecraft;
- spinup of spacecraft;
- deployment;
- evasion maneuvers by the orbiter, once a safe
  distance has been reached.

Table 5.5 shows a typical deployment sequence for a
Delta PAM type of spacecraft, similar to Anik C. It
is included to outline the major events. Deployment
will typically occur 45 minutes prior to perigee motor
firing. Active nutation or pointing control will be
required by the spacecraft/perigee motor combination
for the 45 minute coast period. Shortly after
deployment, the orbiter will carry out an evasion
maneuver, such that, at perigee motor firing, it is at
least 10 nautical miles away from the spacecraft.
This is largely to avoid contamination of the thermal
protection system by the perigee motor plume and
combustion products.

TABLE 5.5   STS DEPLOYMENT SEQUENCE FOR DELTA
PAM-TYPE SPACECRAFT

ELAPSED TIME FROM DEPLOY- MENT (MN:SC)	EVENT	DESCRIPTION
-45:00	SHUTTLE POWER ON	
-39:00	WITHDRAW RESTRAINTS	
-38:00	OPEN SUNSHIELD	
-10:00	SHUTTLE POWER OFF	
	INTERNAL POWER ON	
-1:30	PREARM PKM, AKM	
-0:05	ARM DEPLOYMENT	
00:00	DEPLOYMENT	SPRING DV=5 FPS
01:00	INITIAL EVASIVE MANEUVER	DV=1.7 FPS
10:00	MAIN EVASIVE MANEUVER	DV=25 FPS
45:00	PMF	INJECTION TO TRANS- FER ORBIT

Following separation of the spacecraft from the perigee motor, control is transferred to the mission control center and its associated TT&C stations. As indicated above, three different scenarios were considered. Ground station visibility plots for each are shown in Figures 5.11 to 5.13. The only major difference between an Ariane-based mission and one using the STS, apart from ground station visibility, is the need for a large despin maneuver almost immediately after perigee motor separation. The maneuver will have to be performed automatically by the AOCS and CPS, using on-board attitude and rate sensors.

A detailed sequence for the second STS scenario is presented below.
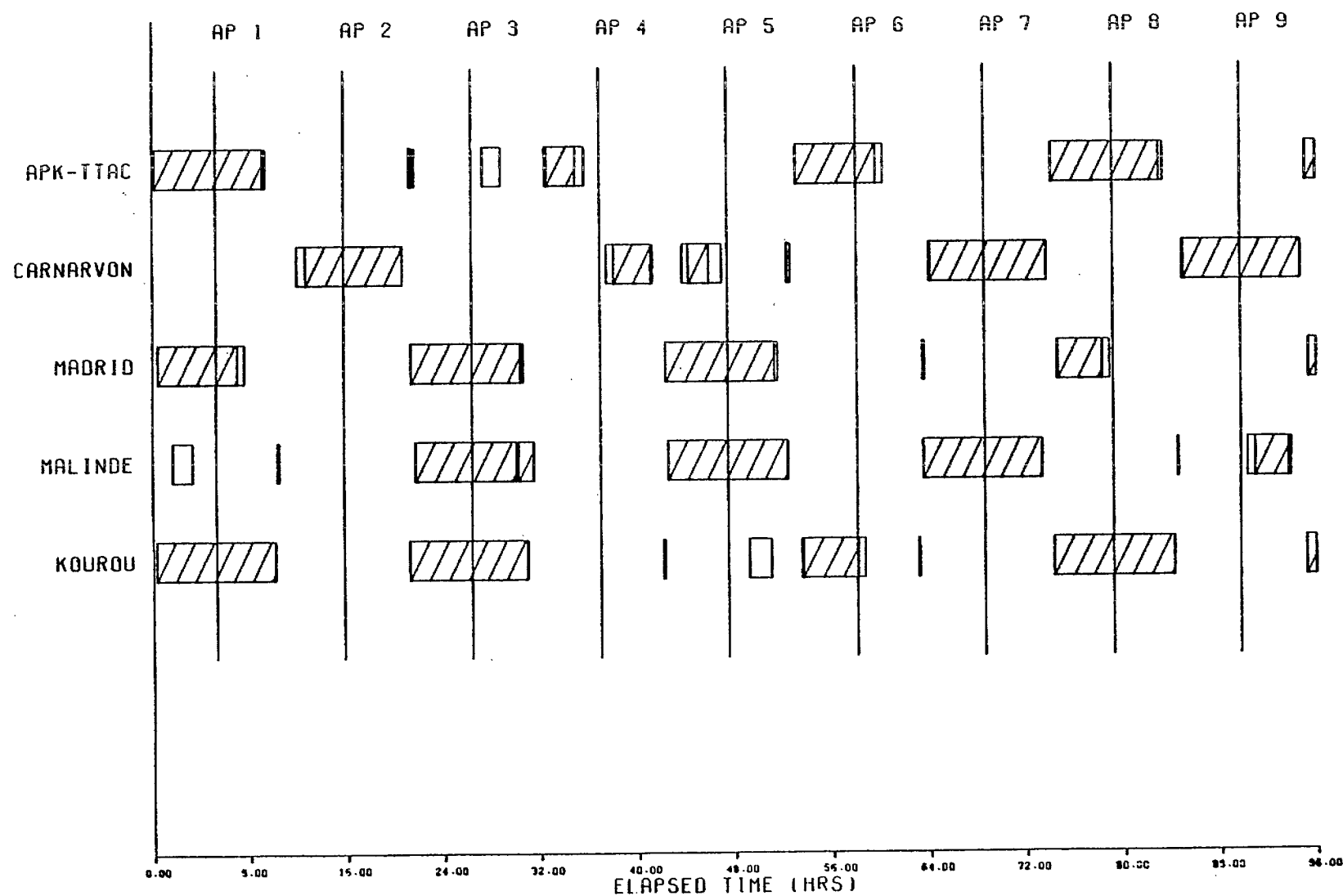
FIGURE 5.11   STS EARTH STATION VISIBILITY FOR SCENARIO 1
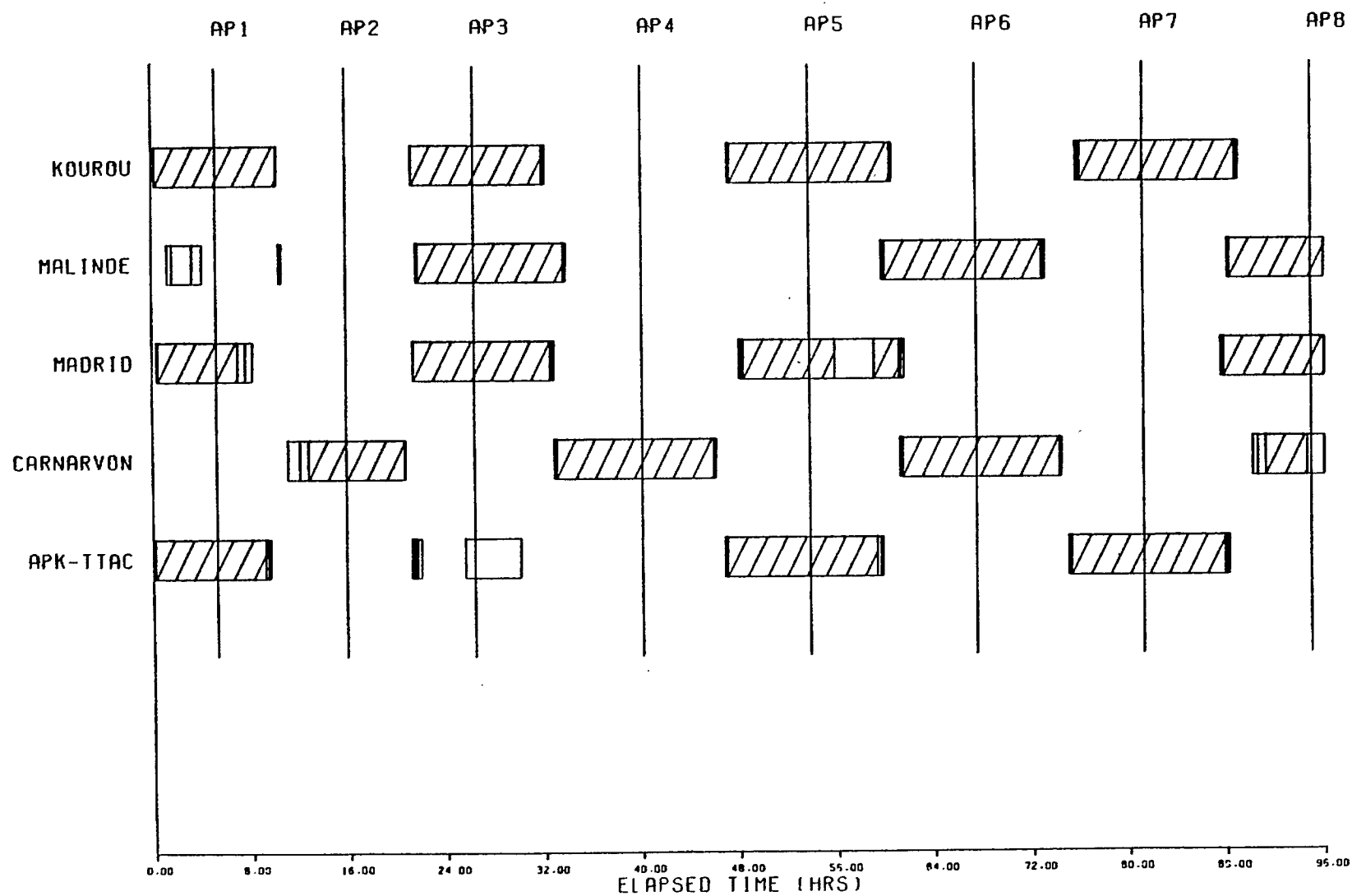
FIGURE 5.12   STS EARTH STATION VISIBILITY FOR SCENARIO 2

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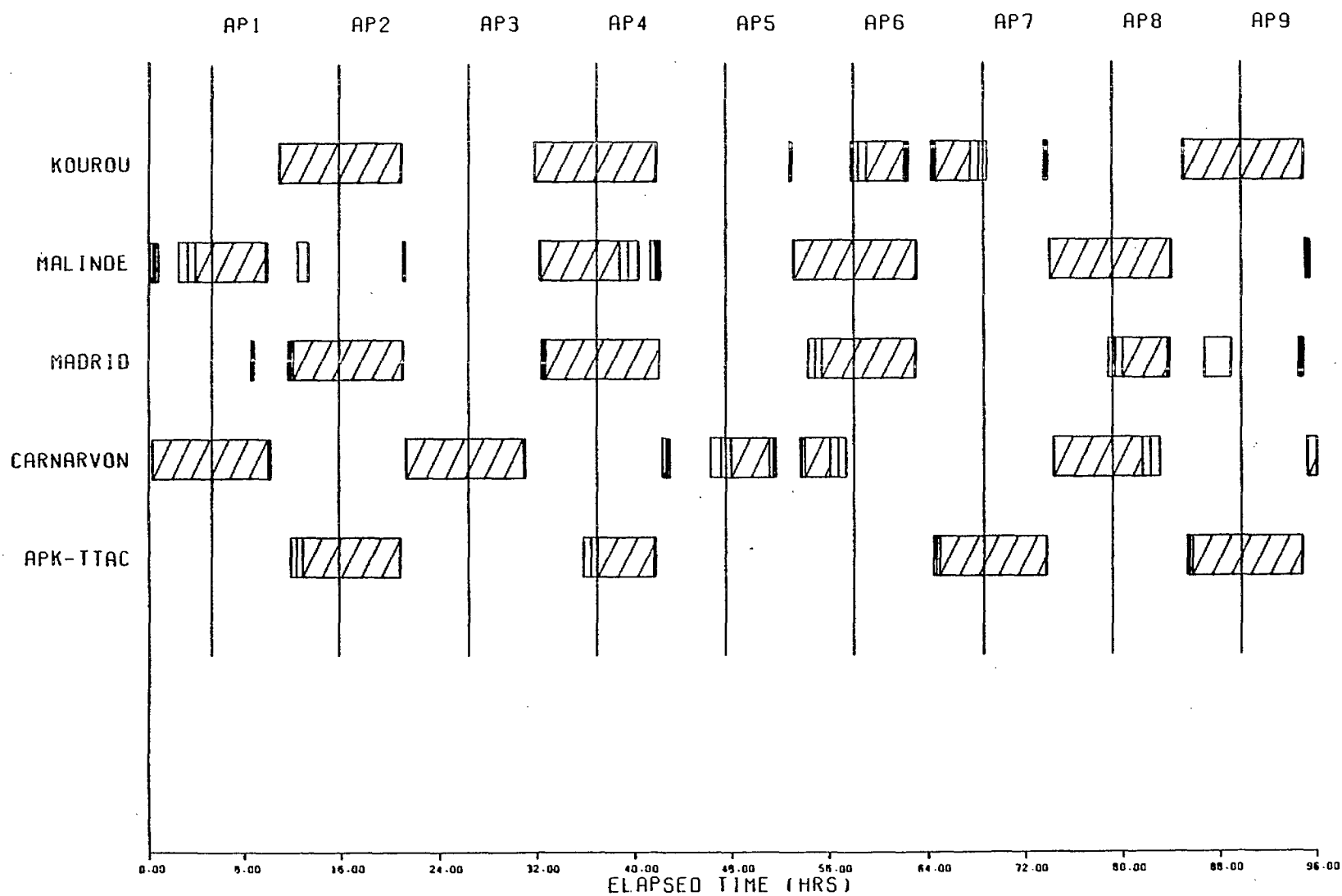
FIGURE 5.13   STS EARTH STATION VISIBILITY FOR SCENARIO 3

TRANSFER   ORBIT

Rev #1

Elapsed Time (HR:MN)	Event
00:00	INJECTION
00:11	TTAC AOS
00:13	LEAVE EARTH SHADOW
00:16	KOUROU AOS
00:26	MADRID AOS
01:43	MALINDE AOS
03:21	MALINDE LOS
05:17	1ST APOGEE
07:37	MADRID LOS
09:26	TTAC LOS
10:13	KOUROU LOS
10:24	ENTER EARTH SHADOW
10:25	MALINDE AOS
10:33	2ND PERIGEE

Functions to be carried out

1. Acquire signal at Allan Park, Kourou, Madrid and Malinde, and establish T&C link to spacecraft.

2. Confirm spacecraft is despun.

3. Deploy solar arrays and rotate to point at sun.

4. Verify spacecraft health, and confirm that AOCS and CPS have been properly initialized.

5. Determine initial attitude.

6. Collect tracking data, commence orbit determination; assess shuttle performance, and need for perigee raising maneuver.

7. Commence collection of all TM data types, build history of spacecraft performance, establish trends, and take corrective action, as required.

8. Calibrate attitude reference gyros, using sun and earth; perform attitude maneuvers as required, and establish initial earth lock.

9. Maneuver to coast attitude.

10. Use maneuvers to assess the performance of the AOCS, and establish biases for use in LAE pointing during major maneuvers.

11. Update predictions at the control center and the tracking stations as required, based upon the measured orbit.

12. Configure spacecraft for loss of signal at Allan Park, Kourou, Malinde and Madria, and eclipse near perigee.

13. Calibrate CPS for attitude control, and commence bookkeeping of fuel usage.

Rev #2

Elapsed Time (HR:MN)	Event
10:33	2ND PERIGEE
10:34	MALINDE LOS
10:47	LEAVE EARTH SHADOW
12:02	CARNARVON AOS
15:50	2ND APOGEE
20:42	CARNARVON LOS
20:58	ENTER EARTH SHADOW
21:07	3RD PERIGEE

Functions to be carried out

1. Acquire signal at Carnarvon, establish T&C link.
2. Assess atmospheric drag effects on orbit and attitude.
3. Continue collection of TM data, and monitor health of spacecraft.
4. Continue collection of tracking data, and orbit determination.
5. Calibration of gyros, as required (at least once every rev); with maneuvers to appropriate attitudes.
6. Commence AMF planning; use measured orbit to determine best time and attitude in which to fire the LAE.
7. Update predictions at the control center and tracking stations, as required.
8. Prepare for acquisition of signal at Kourou, Allan Park, Madrid and Malinde.
9. Configure spacecraft for loss of signal at Carnarvon, and eclipse near perigee.
10. Update CPS calibration.

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Rev #3

Elapsed Time (HR:MN)	Event
21:07	3RD PERIGEE
21:15	KOUROU AOS, TTAC AOS
21:20	LEAVE EARTH SHADOW
21:22	MADRID AOS
21:43	MALINDE AOS, TTAC LOS
26:24	3RD APOGEE
27:22	TTAC AOS
28:54	TTAC LOS
30:44	MADRID LOS
31:05	KOUROU LOS
31:31	ENTER EARTH SHADOW
31:33	MALINDE LOS
31:40	4TH PERIGEE

Functions to be carried out

1. Acquire signal at Kourou, Allan Park, Madrid and Malinde, and establish T&C link.

2. Assess atmospheric drag effects on orbit and attitude.

3. Continue collection of TM data, and monitor spacecraft health.

4. Continue collection of tracking data, and orbit determination.

5. Calibrate gyros, as required, with maneuvers to the appropriate attitudes.

6. Update AMF planning.

7. Update predictions at control center and tracking stations.

8. Prepare for acquisition of signal at Allan Park and Carnarvon.

9. Configure spacecraft for loss of signal at Kourou, Allan Park, Madrid and Malinde, and eclipse near perigee.

10. Update CPS calibration.

Rev #4

Elapsed Time (HR:MN)	Event
31:40	4TH PERIGEE
31:53	LEAVE EARTH SHADOW
32:31	TTAC AOS
35:42	TTAC LOS
36:57	4TH APOGEE
37:32	CARNARVON AOS
41:21	CARNARVON LOS
42:05	ENTER EARTH SHADOW
42:12	KOUROU AOS
42:14	5TH PERIGEE

Functions to be carried out

1. Acquire signal at Allan Park and Carnarvon, establish T&C link.
2. Assess atmospheric drag effects on orbit and attitude.
3. Continue collection of TM data, and monitor health of spacecraft.
4. Continue collection of tracking data, and orbit determination.
5. Calibration of gyros, as required (at least once every rev), with maneuvers to appropriate attitudes.
6. Update AMF planning.
7. Commence drift orbit maneuver planning, based upon current AMF planning.
8. Update predictions at the control center and tracking stations, as required.
9. Prepare for acquisition of signal at Madrid, Carnarvon, Kourou and Malinde.
10. Configure spacecraft for loss of signal at Allan Park and Carnarvon, and eclipse near perigee.
11. Update CPS calibration.

Rev #5

Elapsed Time (HR:MN)	Event
42:14	5TH PERIGEE
42:22	MADRID AOS
42:23	KOUROU LOS
42:27	LEAVE EARTH SHADOW
42:34	MALINDE AOS
43:48	CARNARVON AOS
47:04	CARNARVON LOS
47:30	5TH APOGEE
49:16	KOUROU AOS
51:07	KOUROU LOS
51:41	MADRID LOS
52:24	CARNARVON AOS
52:31	MALINDE LOS
52:38	ENTER EARTH SHADOW
52:43	CARNARVON LOS
52:47	6TH PERIGEE

Functions to be carried out

1. Acquire signal at Madrid, Carnarvon, Kourou and Malinde, establish T&C link.
2. Assess atmospheric drag effects on orbit and attitude.
3. Continue collection of TM data, and monitor health of spacecraft.
4. Continue collection of tracking data and orbit determination.
5. Calibration of gyros, as required (at least once every rev); with maneuvers to appropriate attitudes.
6. Update AMF planning.
7. Update drift orbit planning.
8. Update predictions at the control center and tracking stations, as required.
9. Prepare for acquisition of signal at, Allan Park.
10. Configure spacecraft for loss of signal at Madrid, Carnarvon, Kourou and Malinde and eclipse near perigee.
11. Update CPS calibration.

Rev #6

Elapsed Time (HR:MN)	Event
52:47	6TH PERIGEE
53:01	LEAVE EARTH SHADOW
53:12	TTAC AOS
56:01	GYRO INITIALIZATION
56:43	COMMENCE AMF ATTITUDE ACQUISITION
57:07	COMMENCE FIRING OF LAE
58:04	6TH APOGEE
59:04	END OF FIRING OF LAE

Functions to be carried out

1. Acqusition of signal at Allan Park.

2. Finalize AMF planning.

3. Initialization of Gyros.

4. Maneuver to acquire AMF attitude.

5. Firing of LAE, to inject spacecraft into drift orbit.

Drift Orbit

Following the firing of the LAE, the immediate concern
is to determine the drift orbit parameters as quickly
as possible, and to plan corrective maneuvers that will
place the satellite on its final station in a timely
and fuel efficient manner. Hence, the spacecraft will
be maneuvered into an attitude with the +Z axis earth
facing, the Y axis normal to the orbit plane, and the
solar arrays on the sun. The following is a general
list of events to be carried out in the early drift
orbit phase:

- Maneuver to an earth-facing attitude, with the
  arrays normal to the orbit plane and on the sun;
- Collect tracking data, and carry out orbit
  determination; assess the need for further LAE
  maneuvers to remove large drift orbit errors;
- Isolate and purge the LAE, and isolate the pressure
  tanks;
- Plan, execute and evaluate a series of maneuvers to
  acquire final station in a fuel efficient manner,
  and on a non-interference basis with other
  geostationary satellites operating in the same
  frequency band.

At a convenient time during the drift orbit, deployment
activities must be carried out. The communication
antennas and feed systems must be sequentially deployed
to place the spacecraft in its operational
configuration. It is expected that this can be done at
any time following the completion of major drift orbit
maneuvers. The general sequence for deployment is as
follows:

- Deploy communication antenna support structures and reflectors;
- Deploy communication feed systems (if required);
- Run up reaction wheels;
- Reacquire earth lock, and repoint the solar array at the sun.

Following successful deployment, testing of the AOCS in its operational mode can commence. Final station acquisition will probably be accomplished in this configuration.

5.2.7   Areas Requiring Rurther Study

As the mission scenarios were being developed, several areas were identified that required further study, either because insufficient information was available or because the level of detail required was considered to be beyond the scope of a Phase A study. These topics are discussed below, in the order in which they should be carried out.

1)   Selection and Optimization of Transfer Orbit
     Parameters

The purpose of this study is to determine the set of transfer orbit parameters which will optimize mission performance parameters, such as on-station weight and mission life. The parameters to be determined are apogee and perigee altitudes and orbit inclination. To carry out this study, it is necessary to know the range of performance parameters of the launch vehicle, the perigee motor and the spacecraft propulsion subsystem. Of particular importance are: the range of payload weight, as a function of orbit parameters, that can be put into either transfer orbit, in the case of an Ariane launch, or parking orbit, in the case of STS; the range of propellant load for the perigee motor and the propulsion subsystem. It is also necessary to know the sequence of mission maneuvers and stationkeeping requirements. All of this information is used to develop a complete fuel budget. Transfer orbit and propulsion fuel requirements are varied until a maximum mission life (or on-station payload weight) is determined. Dispersion in the performance of the launch vehicle, perigee motor and propulsion system can also be taken into account, and the set of transfer orbit parameters

that maximizes the expected mission life can be selected. The sensitivity to changes in payload weight and launch vehicle performance are also determined.

2) LAE Maneuvers

The number of maneuvers using the liquid apogee engine (LAE) should be studied. For the STS mission, approximately 27 degrees of inclination must be removed using this engine. Because of the low thrust level, this maneuver will be 3-4 hours long. By breaking the maneuver into two or three parts to be carrried out at consecutive apogees, the efficiency of inclination removal can be increased, reducing the amount of fuel required for the maneuver.

3) Drag Effects of Perigee

With the large solar arrays deployed in transfer orbit, atmospheric drag will cause a reduction in apogee altitude. The amount of such a reduction needs to be assessed, as does the need for a maneuver at first apogee to raise the perigee by 10-20 nmi, reducing the drag effect.

4) Injection Opportunities - STS Missions

Using the STS as a launch vehicle provides the opportunity of selecting the longitude of injection into transfer orbit. Criteria to be used in selecting the injection longitudes are derived from ground station visibility

requirements such as initial acquisition, LAE
firing and an overall requirement to provide
adequate command and telemetry coverage throughout
the mission. Once the locations of the tracking
stations have been determined, visibility plots
are produced for a series of injection points.
These are examined in detail, and those injection
regions meeting the requirements are selected.
Further visibility plots are produced for the
selected regions, combining the effects of
transfer orbit dispersions on visibility. The
process is iterated as required until suitable
regions for injection are defined.

Care must be taken to ensure that the constraints
are not overly restrictive. NASA will take the
injection regions and determine when the actual
deployment may occur. A very narrow region will
lead to only one opportunity per day. Contingency
or backup deployments are also difficult to plan
if only a small region exists. Some iteration
with NASA may be required.

5.2.8   Mission Simulations and Rehearsals

A mission rehearsal constitutes a major test of the
satellite control system, conducted in real-time with
the primary purpose of exercising each element of the
system, and demonstrating that it is ready for the
mission. Two rehearsals will be held prior to the
first mission, one several weeks before the launch and
one approximately ten days prior to the launch.

Beginning approximately one year before the expected
launch date, mission software and analysis simulations
are conducted every one to two months, involving
analysis staff only. As the frequency increases to
three or four week intervals, more components of the
system become involved, culminating in a full system
rehearsal involving the tracking stations.

Each exercise is preceded by a planning session, in
which the mission sequence, system components, staff
and performance expectations are identified.
Immediately after each of the simulations/rehearsals,
a mission readiness review will be conducted to assess
the exercise and determine the mission-readiness
status of the satellite control system.

As part of the mission software system, Telesat has a
real-time mission simulator which is capable of
introducing noised telemetry, attitude sensor and
tracking data into the data acquisition system. This
program coupled with a telemetry and command simulator
is used to exercise the satellite control system in a
realistic manner. The approximate cost of this
software package is $100,000.

5.2.9   Mission Analysis and Planning Software

The software developed by Telesat to assist in the
planning and analysis of a mission can be applied to
any launch vehicle and spacecraft choice. The
functional organization of this software follows:

- State estimation;
- Ephemeris generation;
- Mission design;
- Maneuver planning;
- Earth station visibility assessment.

All of these areas are based upon:

- Sequential state estimation of a stochastic
  process;
- Accurate numerical integration;
- Keplerian orbit dynamics;
- A physical model of the spacecraft and ground
  system.

This aspect of the overall Telesat mission software
system shares many algorithms and software modules
with the stationkeeping software described in section
4.1.

5.2.9.1 State Estimation

In the description of stationkeeping software
requirements, a Kalman filter system is recommended
for satellite state estimation. This element of the
system will be compatible with all phases of satellite
activity.

5.2.9.2 Ephemeris Generation

This function, too, assumes that the numerical integration software used in stationkeeping can be applied to transfer orbit operation. Other aspects, such as shadowing and satellite interference also apply in transfer orbit.

5.2.9.3 Mission Design

Software is needed to aid in the prediction of satellite orbits and attitudes required for a particular mission, and consists of the following components:

- Computation of nominal parameters to effect orbit transfer;

- Modelling of maneuver dispersions and trajectory optimization;

- Computation of a fuel budget for the entire satellite life.

5.2.9.4 Maneuver Planning

Once orbit and attitude parameters are computed, and the thrust vectors to transfer between them determined, the actual maneuvers to be executed are planned in two steps:

- Computation of perigee, apogee and reorientation maneuvers;

- Calibration of the propulsion subsystems to accomplish these maneuvers;

The first task requires the facility to apply motor
dispersions and to optimize maneuver parameters in the
presence of these dispersions. The second requires an
accurate model of the spacecraft propulsion system.

5.2.9.5 Earth Station Visibility Assessment

Analysis is required to determine that the satellite
visibility from the tracking stations is adequate to
meet all mission requirements. This analysis is of
particular importance for an STS mission, for which
acceptable regions for injection into transfer orbit
will be defined, assuming the visibility constraints
imposed by the above-mentioned tracking network. Once
a nominal mission sequence is established, sufficient
coverage can be determined for the entire mission, as
well as during critical maneuvers, including the
effects of injection and maneuver dispersion. In
addition to ground visibility, satellite earth sensor
coverage is examined, as is T&C antenna signal strength.

6.0 PRE-OPERATIONAL SUPPORT

6.1   SUPPORT COSTS FOR INTEGRATION AND LAUNCH SITE
COORDINATION

The only items costed in this section will be
manpower, travel and subsistence and freight costs
associated with spacecraft integration, test and
launch monitoring activities described in Section 5.1.

Tables 6.1 and 6.2 list the expenditures which will be
incurred in performing the activities described in
Section 5.1. Manpower and travel requirements are
derived directly from Figures 5.6 and 5.7.

All costs are at current spring 1982 rates. No
escalations to the year when costs will be incurred
have been performed.

Items not costed here, but which should be considered,
include:

o   communications links between launch related
facilities (see Figures 5.8 and 5.9 and comment in
Section 5.1.3)

o   manpower and associated travel and subsistence
costs for monitoring launcher activities.

o   all manpower is costed on the basis of a normal
working day. Overtime and shift premiums may be
necessary for certain activities.

TABLE 6.1 ARIANE LAUNCH CAMPAIGN COSTS

	Man-days (Inc. Travel)	Number of Visits	Cost
Launch Director	47	2	
S/C Manager	47	2	
Test Manager	47	2	
Launch OPS Coord.	47	2	
Secretary	47	2	
RF Engineer			
Comms	10	1	
TTAC	23	4	
Mech Engineer			
Prop. S/S	17	1	
Mech.	47	1	
Bus Engineer			
Bus Elec.	47	1	
ACS	7	1	
Battery Engineer	10	2	
P.A.	47	1	
Total Man-days	443		180,000
Total Visits		22	
Subsistence and Accommodation			46,500
Car Rental and Consumables			13,200
Transportation of Documentation and Office Equipment (Kourou vicinity)			3,000

TABLE 6.2   STS LAUNCH CAMPAIGN COSTS

	Man-days (Inc. Travel)	Number of Visits	Cost
Launch Director	85	4	
S/C Manager	85	4	
Test Manager	85	4	
Launch OPS Coord.	85	4	
Secretary	60	1	
RF Engineer			
Comms	11	1	
TTAC	28	4	
Mech Engineer			
Prop. S/S	14	1	
Mech.	93	3	
Bus Engineer			
Bus Elec.	93	5	
ACS	5	1	
Battery Engineer	10	2	
P.A.	113	4	
Total Man-days	767		320,000
Total Visits		38	17,480
Subsistence and Accommodation			65,195
Car Rental and Consumables			13,300
Transportation of Documentation and Office Equipment			1,250

6.2   SUPPORT REQUIREMENTS - LAUNCH TO ON-STATION PHASE

6.2.1   Launch Mission Personnel

A Mission Team is required to be assembled at least
six months prior to the launch. During this period,
training, simulations and rehearsals are carried out
to learn the system and to prove the software,
hardware and procedures. The team is required until
after the Apogee Motor has been fired and the main
deployment activities have been completed.

Most of the team positions are required to be staffed
on a 24-hour per day basis. There will be short
periods, however, when neither of the tracking
stations can see the spacecraft.

The organization of a typical Launch Mission Team is
shown in Table 6.1. The total staffing required and
related qualifications are detailed in Table 6.2.
This plan assumes that the Control Centre is remote
from the tracking stations.

6.2.2   Mission and Station Procedures

A complete set of Mission and Station Procedures will
be required to support the M-SAT Mission. It is
recommended that the procedures be generated using the
guidelines described in the following paragraphs.
These procedures would provide detailed instructions
to cover all phases of the mission and would be used
by members of the Mission Team both at the Satellite
Control Centre and Tracking Stations.

LAUNCH DIRECTOR — (1)

MISSION DIRECTOR — (1)

ADMIN/ LOGISTICS — (1)

(8) PRIME TRACKING STATION

(3) SYSTEM SOFTWARE

(1) MISSION CONDUCTOR

(3) SATELLITE CONTROLLER

(6) SYSTEMS HARDWARE

(3) SATELLITE ENGINEER

(4)* LEASED TRACKING STATION

PRIME TRACKING STATION:
— CO-ORDINATOR
— SYSTEM MONITOR
— SATELLITE ENGINEER
— COMPUTER OPERATOR
— RECORDING/TIMING OPERATOR
— MAINT TECHNICIAN

T & C OPERATOR
TRACKING OPERATOR
EER OPERATOR

MISSION CONDUCTOR:
(4) MISSION ANALYSTS

SATELLITE CONTROLLER:
(3) LOGKEEPER
DATA ROOM 2 (2)
— CMD TTY OPERATOR (3)
— DATA ROOM 1 (2)
— CLERICAL COURIER (3)

LEASED TRACKING STATION:
CO-ORDINATOR —
SATELLITE ENGINEER —
T&C OPERATOR —
COMPUTER/ COMMAND OPERATOR

(3) = TOTAL PERSONNEL FOR THAT POSITION
TOTAL PERSONNEL = 50.
* ADD 4 PERSONNEL FOR EACH ADDITIONAL LEASED TRACKING STATION

TABLE 6.3 LAUNCH MISSION TEAM ORGANIZATION

6 - 5

LAUNCH MISSION PERSONNEL

POSITION	QUALIFICATIONS	TOTAL REQUIRED
Mission Director	Director level - Satellite experience	1
Launch Director	Senior Manager. Launch experience	1
Admin/Logistics	Senior Administrator	1
Mission Conductor	Senior Supervisor - Programmer/Mathematician	1
Satellite Conroller	Senior Supervisor - Mission experience	3
Satellite Engineer	Electrical Engineer - Spacecraft experience	5
Systems Software	Computer Programmer	5
Systems Hardware	Electronics Technologist	3
Systems Hardware	Computer Operator	3
Coordinator	Electrical Engineer - Mission experience	2
Mission Analyst	Programmer/Mathematician	4
Clerical Courier	Secretarial or Clerical - Mission experience	3
All other	Electronic Technologist	<u>18</u>
TOTAL		50

TABLE 6.4   STAFFING QUALIFICATIONS

For the purpose of this description it is assumed that the main participants in the M-SAT mission, following a successful injection into transfer orbit, will be located in three areas:

a. The Satellite Control Centre (SCC), either operating as a separate identity or collocated with the Western Hemisphere Tracking Station.

b. The Eastern Hemisphere Tracking Station (EHTS).

c. The Western Hemisphere Tracking Station (WHTS).

NOTE: Additional Tracking Stations can be provided for, by expanding the Mission and Station Procedures to encompass same.

The procedures should be contained in a Mission and Station Procedures Manual which would be divided into Chapters and Parts of Chapters as required to adequately segregate the information. For example, Chapter 1 would describe the make-up of the Mission and Station Procedures, including a brief description of the main satellite subsystems and of key mission activities from lift-off to on-station. Chapter 2 would contain the mission procedures which will be used between the various Tracking Stations and the Satellite Control Centre. Chapter 3 would contain the Station Operating Procedures (local procedures) used by the Tracking Stations and Satellite Control Centre to perform local functions. Chapters 2 and 3 would be further subdivided into parts as required to delineate the activities. See Appendix B for a typical Mission and Station Procedures Manual breakdown.

All the examples provided in Appendix B relate to a SATCOM Bus. The Mission Procedures required to support a M-SAT launch utilizing a L-SAT Bus would be very similar, in that the requirements to collect various types of data, maneuver the satellite, fire the apogee motor, plus perform all the deployment/check activities related to drift orbit, must be completed on a scheduled basis regardless of what type of bus is used. For this reason, only the SATCOM Bus type of procedures are discussed with the understanding that the philosophy described can easily be extrapolated to include most types of Buses, Launch Vehicles and Tracking Stations as required.

6.2.3 Eastern Hemisphere Tracking Facilities

Section 7.1 defines the facilities required for on-station operation of M-SAT, to which must be added facilities for transfer orbit support. In the past, Telesat has leased TT&C antennas and RF equipment from both Hughes (located in Guam) and INTELSAT (located in Italy and Australia). The basic control setup consists of two computers: one at the tracking station to control the GCE and data acquisition; an interface computer in the SCC in Ottawa to provide the control and display ability, as well as to route data to the data processing system.

For Telesat's missions, the TT&C antenna, RF equipment and station operational staff are made available to Telesat as required to prepare for and perform its mission. Operation of the EHTS during the mission will be similar to the Allan Park station, with remote control at the SCC.

The cost breakdown, in 1982 Canadian funds, is as follows:

Engineering Support (manufacture and integration of components)	0.7M
Deliverable Hardware (GCE, Computer, displays)	1.6M
Recurring costs (Antenna hookup)	0.8M
	3.1M

7.0 OPERATIONAL SUPPORT

7.1 GROUND SEGMENT SATELLITE CONTROL FACILITIES

A complete satellite control system, shown in Figure 7.1, required to control one or more satellites from launch to end-of-life will include:

- Satellite Control Centre (SCC), from which all space segment operations are controlled;

- Telemetry, Tracking and Command (TT&C) station;

- Backup or supplementary TT&C facility;

- A remote ranging station, if necessary;

- A real-time computer network to operate the Ground Control Equipment (GCE);

- Mission software system (as described in Section 4.1) and associated data processing computers required for transfer and geostationary orbit control;

- An eastern hemisphere TT&C station (EHTS) during transfer orbit (Section 6.0);

- In many operational systems, facilities to test the communications performance of the satellite are included in the TT&C system.

ANIK D TAC

ALLAN PARK

OTTAWA

DATA STORAGE
AND
PROCESSING

ANIK C/D TTAC

GROUND CONTROL
EQUIPMENT
AND
COMPUTER
SYSTEM

ANIK C KTAC

COMPUTER
SYSTEM

MISSION
ANALYSIS
AND
STATION-
KEEPING

HUGGETT

ANIK C KTAC

GROUND
CONTROL
SYSTEM

GUAM

ANIK C/D

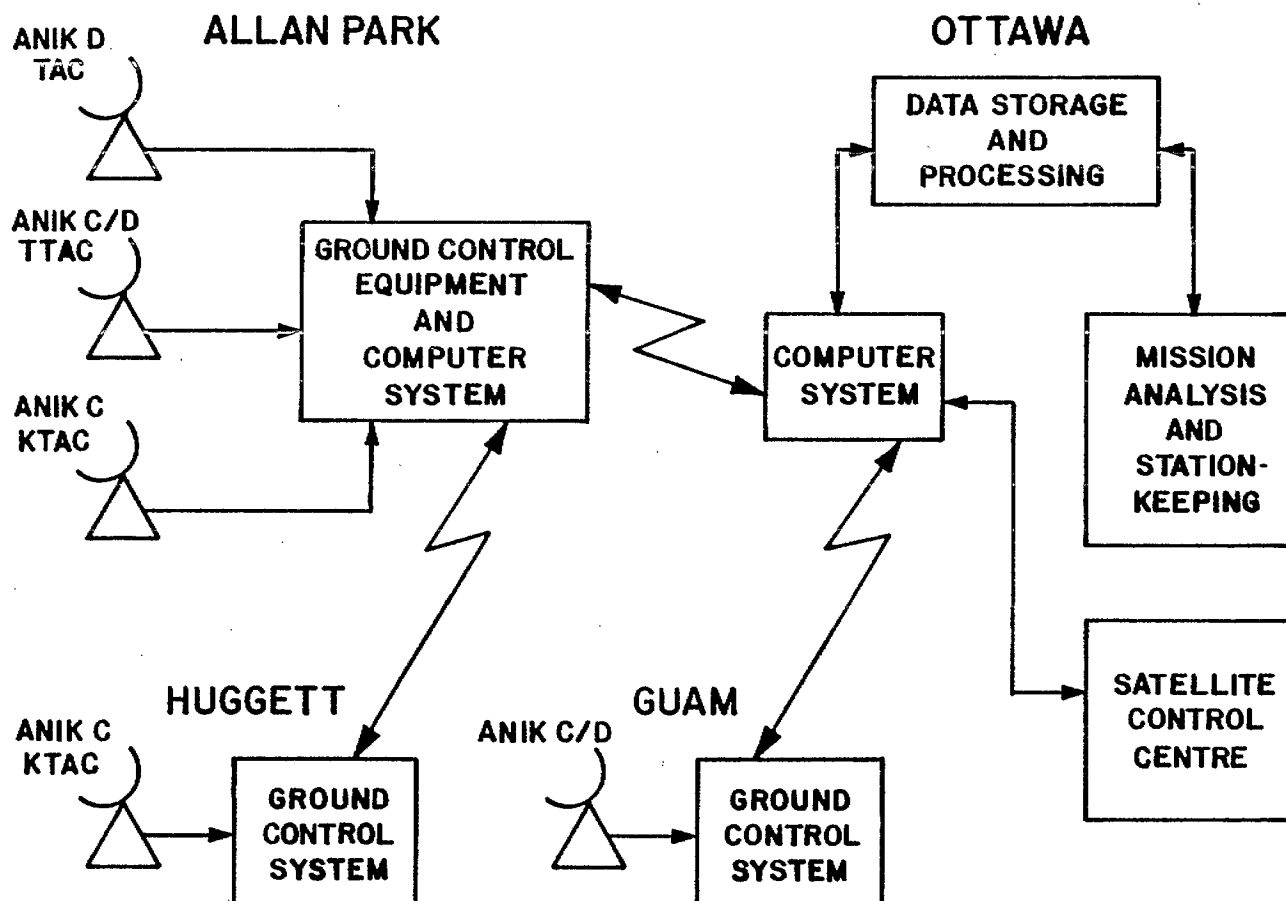GROUND
CONTROL
SYSTEM

SATELLITE
CONTROL
CENTRE

FIGURE 7.1   SATELLITE CONTROL SYSTEM BLOCK DIAGRAM

These facilities and the associated costs will be
described in more detail, particularly as they relate
to Telesat System. Consideration will be made of
options for the M-SAT concept, such as: frequency
band of operation, SCC and TT&C collocation,
associated facilities and dual station T&C.

System definition for an M-SAT TT&C system must
include specification of the following design
parameters:

-   Performance requirements for the RF subsystem;

-   Locations and tracking capabilities of the TT&C
    station(s);

-   Satellite commanding mode (manual versus computer
    control);

-   Satellite health and status monitoring methods;

-   Computer system characterists (including
    performance requirements for the control of
    satellite TT&C functions, and for the storage and
    retrieval of real-time data);

-   Basic transfer orbit and stationkeeping software
    requirements;

-   Stationkeeping strategy and accuracy analysis.

7.1.1   Satellite Control Centre and Computer Network

7.1.1.2 Area Organization

The Telesat SCC, like the INTELSAT SCC, is
geographically separated from the TT&C facility. The
SCC is, however, the centre from which all satellite
operations are initiated and monitored. The three
main functions performed are operations, data
processing and analysis. The operations area (Figure
7.2) is manned 24 hours a day and contains the control
consoles, status display boards, and the central
command teletype. This equipment enables Telesat
personnel to monitor the physical health of the
satellites in day-to-day operation and to remotely
command the on-board systems of the satellites to keep
them operating within their designated parameters.

The mission analysts, responsible for solving mission
dynamics problems, are located in the Analysis Centre
which is connected to the SCC by voice intercom. The
room contains a number of data displays and
interactive computer terminals. Satellite maneuver
messages originate in this area and are forwarded to
the SCC for implementation.

The Computer Centre is responsible for handling all
displays, routing satellite commands and incoming
telemetry data, and real-time data storage and
retrieval. The computer system operates fully
in-house, and requires no outside utility for mission
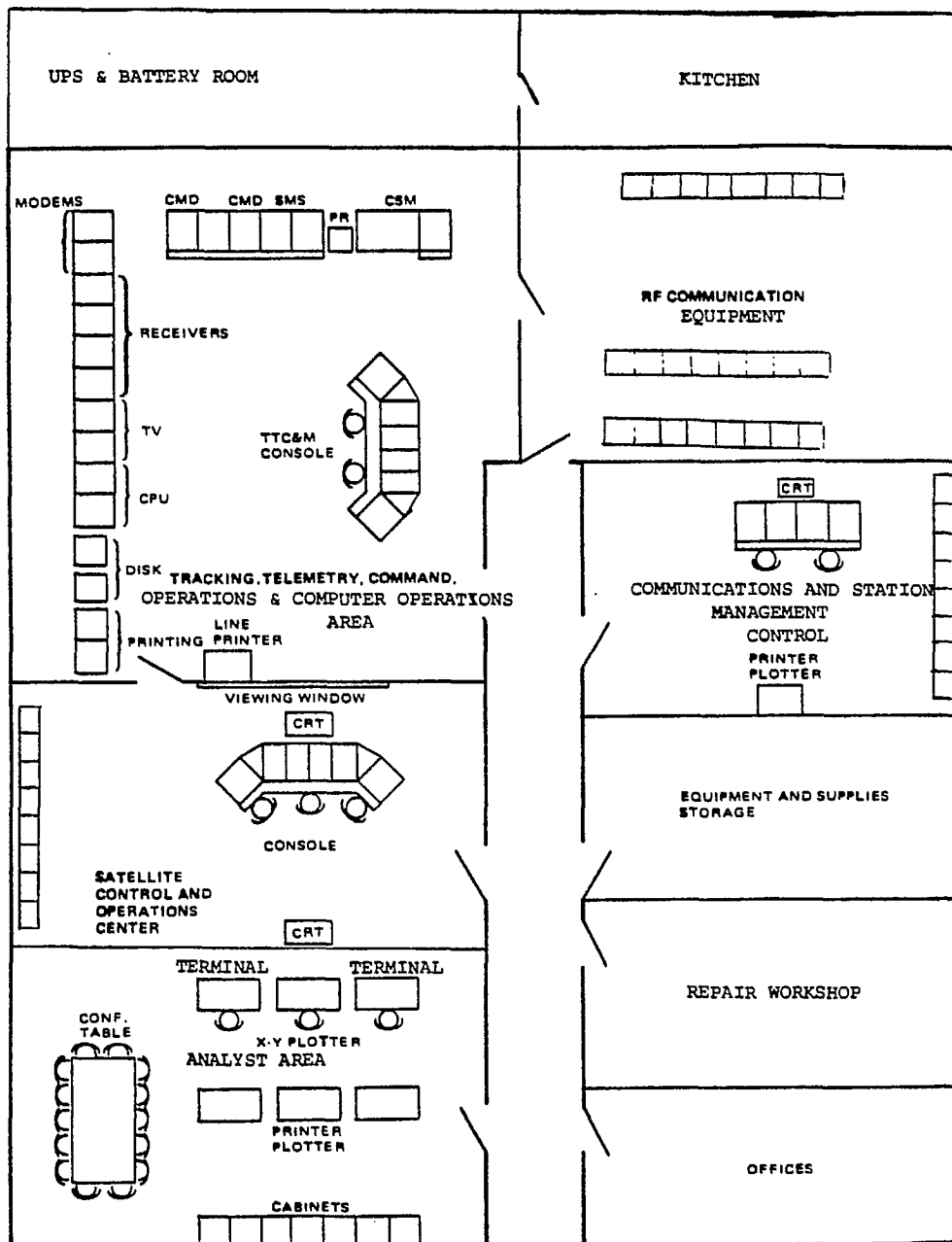operations. To ensure a high degree of reliability,

FIGURE 7.2 TYPICAL TT&C/SCC STATION LAYOUT
(5000-8000 sq. m.)

the computer system is redundant at all critical
levels, with on-site spares. A maintenance shop
supports all operations.

7.1.1.2 Computer and Software Systems

System Description. The Telesat computer system is
functionally separated into:

- The real-time system, which interfaces through the
  GCE located at the tracking station, to command
  the satellite and collect telemetry data. This
  data is then converted to engineering units,
  displayed locally at the tracking station and
  transmitted via leased data lines to the Data
  Control Computer (DCC) in Ottawa.

- The data processing system accepts the data from
  the DCC, permanently stores the data on the Data
  Storage Computer (DSC); this data is available for
  retrieval by the analysis software resident on the
  Data Processing Computer (DPC).

Systems Software. This package consists of the
Hewlett-Packard operating system, all required
processors necessary for system maintenance and
modification, a system monitor facility, accounting
capabilities, an extensive program subroutine library,
a file management package and satellite control
functions. Vendor supplied software includes a
real-time executive (RTE VI), graphics package,
diagnostics, FORTRAN 77 compiler and a vector
instruction set. The operating system is a

7 - 6

multi-programming, virtual memory system. The file management package contains a versatile interactive file manager, as well as a program subroutine library used for program file handling. The data control functions include storage, retrieval, archiving, status display, plotting and listing.

TT&C Computer Hardware. The data acquisition system, located at the TT&C station, is comprised of four HP 21MX E series minicomputers (32K words memory), together with Winchester-technology discs, interfaces compatible with the supplier's GCE and peripherals. An alpha-numeric video system, including monitors and video switcher (used to display satellite status information), is part of the system. Each of these computers has a time source to maintain a software time-of-day clock, as well as to perform interval timing. The inter-computer links are via microcircuit interface board and cable, except for the Allan Park to Ottawa link which uses full-period private line complete with modems and interface kits.

SCC Computer Hardware. The DSC and DPC are HP 1000 E series minicomputers with memory and with the following associated equipment: large moving head discs, Winchester disc with cartridge, three tape drives, eight terminals (four for the DSC) and terminal switching, interfaces and spooling processor with two line printers and spooling disc. The DCC is a 1000 E series computer as well, but with only a

floppy disc attachment. It controls a video graphic
system (with colour monitors and controls) which
display a mimic of the satellite configuration
information.

7.1.1.3   Data and Status Displays

A method to continuously display/update all
significant telemetry data being received from the
satellite is an absolute necessity. The data assigned
to each display should be in some recognizable order
(power, attitude control, communications, etc.) and
should be clearly displayed to avoid confusion and
possible misinterpretation.

A system of check limits is also a major requirement.
All data would be assigned adjustable, minimum and
maximum limits. The computer system would check each
telemetry word as it is received and would generate an
alarm for all words exceeding the preset limits. This
alarm would be displayed on all screens on which that
particular word appeared.

Figure 7.3 indicates a typical Anik B alphanumeric
display of related power subsystem.

The complexity and size of the proposed M-SAT
satellite dictates that either a hardwired status
panel (similar to that shown in Figure 7.4 for the
Anik B) or some form of graphics display system be
utilized to provide an up-to-date pictorial

```
                          ANIK B POWER SUBSYSTEM (PAM H)
                                      TEMPERATURES (C)
DATE                 82:047      82:047     IB SOLAR PANEL       51.9        86.5
TIME               13:32:24    13:02:13     OB SOLAR PANEL       45.8        48.4
                                            PARTIAL SHUNT        32.6        23.8
VOLTAGES                                    BATTERY 1             6.9         2.1
   MAIN BUS            35.09       35.32     BATTERY 2             4.8         1.6
   TLM BUS            21.83       21.61     BATTERY 3             3.2         3.1
   BATTERY 1          30.12       29.59   SOLAR ARRAY
   BATTERY 2          32.32       32.32     POSITION (DEG)       21.8        14.2
   BATTERY 3          32.15       32.36     SUN ANGLE (DEG)     -23.8       -22.9
CURRENTS (AMPS)                             MOTOR TEMP (C)       28.3        27.5
   MAIN BUS           14.58       14.88     MOTOR CURR (MA)        92          73
   14/12 GHZ BUS       3.82        3.87     SHOR                  271         266
   PARTIAL SHUNT       3.38        3.76     SPEED:  NORM      DIRECTION:  FWD
   SOLAR ARRAY        17.34       16.95     ADE:        1        MOTOR:        1
   BATTERY 1 DIS       0.08        0.85   SCA 1:     CON     SCA 2:        CON
   BATTERY 2 DIS      -0.01        0.00   BATTERY/CHARGER STATUS
   BATTERY 3 DIS      -0.01       -0.01                    BUS  BATT          STATUS
   BATTERY 1 CHG       1.70        1.71   CH. REG 1:  PRI  PRI    BATT 1    CON
   BATTERY 2 CHG       0.28        0.30   CH. REG 2:  PRI  PRI    BATT 2    CON
   BATTERY 3 CHG       0.27        0.27   CH. REG 3:  PRI  PRI    BATT 3    CON
                                          TIMER-SEQUENCER:  BKU
           PAM DATA ALARM ON SCREENS:
```

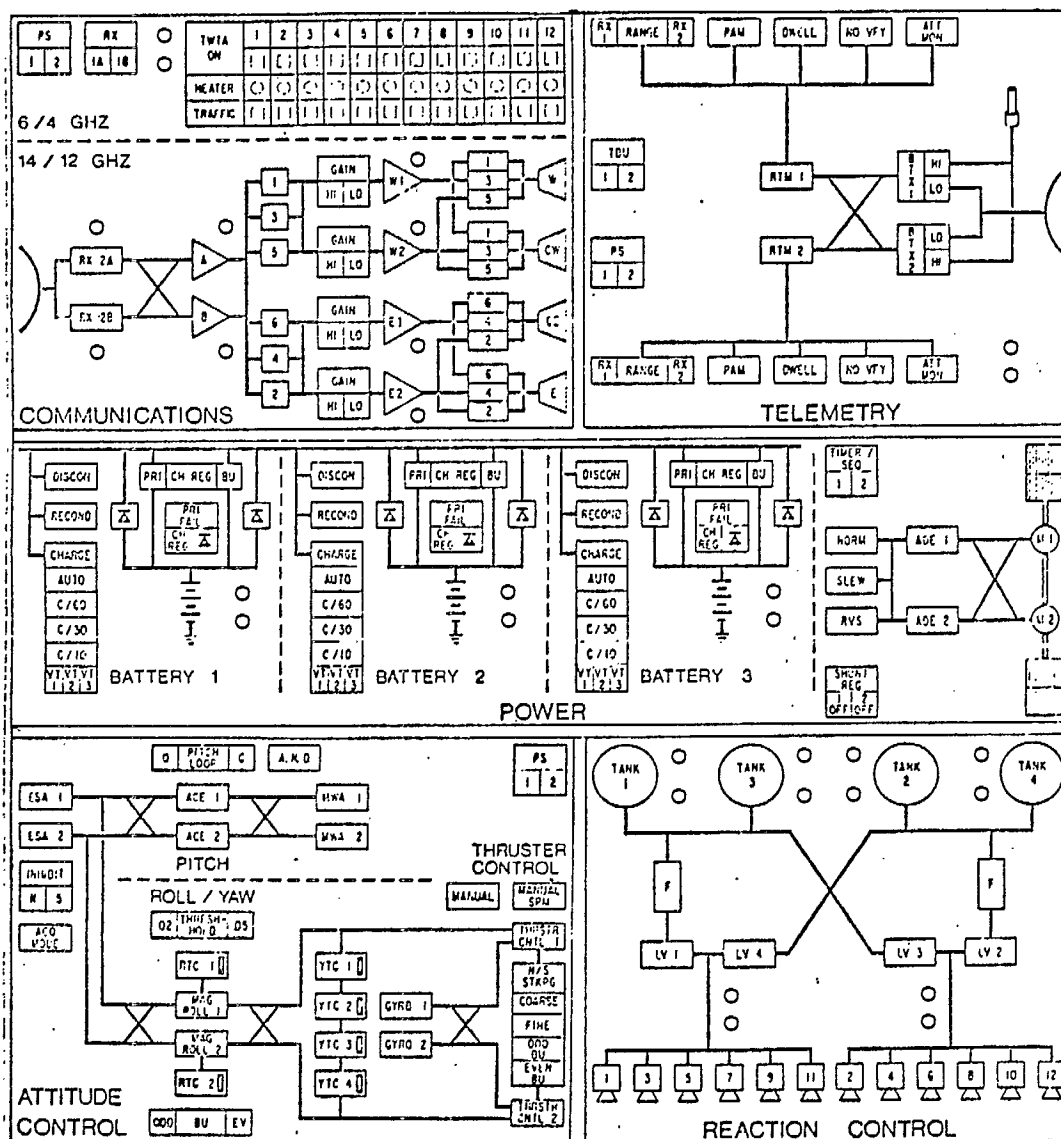FIGURE 7.3   ANIK B (SATCOM BUS) ALPHANUMERIC DATA DISPLAY

FIGURE 7.4   ANIK B (SATCOM BUS) STATUS DISPLAY PANEL

representation of satellite status. This system should be capable of being updated from one of three possible sources:

a) Manually via keyboard-entered commands;

b) Automatically via telemetry status information (bi-level) from the satellite;

c) Automatically by detecting executed commands and updating status accordingly.

There are advantages and disadvantages related to both systems. The status board approach is less expensive but is very rigid in concept and, once the final product has been defined and ordered, it becomes very expensive to modify. The graphics display is much more expensive but can be expanded and modified at will, and can be used to display status information related to other areas than satellites (e.g., tracking station GCE configurations). Regardless of which system is used, care should be taken to ensure that all commandable aspects of the satellite are represented and that these pictorial representations are accurate and clearly illustrated.

7.1.2   TT&C Facility

7.1.2.1 Antenna Characteristics

The following areas of TT&C station performance must
be addressed in the system design:

-   EIRP and G/T;

-   Tracking and pointing errors;

-   Survey requirements;

-   RF link performances for tracking, ranging,
    command and telemetry functions;

-   Building and floor space requirements;

-   Environmental control and backup power
    requirements;

-   Spare parts and maintenance philosophy.

The TT&C antenna at Allan Park is equipped to operate
in both the C- and Ku-bands, with parameters listed in
Table 7.1.

TABLE 7.1 PARAMETERS TYPICAL OF COMMERCIAL TT&C SYSTEMS

PARAMETER	DESCRIPTION
Reflector Diameter	11.0 meters
Mount	EL/AZ
Autotrack	Monopulse
Tracking Velocity (deg/sec)	1.0
3 sigma Pointing Error (deg)	± 0.015 (noise)*; ± 0.09 (bias)*
Angular Travel AZ (deg)	± 270 from south
EL (deg)	0 to 92

	C-Band	Ku-Band
Polarization		
Rotation (deg)	± 360	-60 to +230
G/T (dB/°K)	28.0 at 4.0 GHz	34.8 at 12.0 GHz
LNA (°K)	80 GaAs FET	140 Parametric
EIRP (dBW)	85	91
HPA Subsystem	Two 3 kW klystrons with optional phase-combining.	One 1.6 kW klystron, and two 600 W TWTA's with optional phase-combining.

*Static pointing error between C- and Ku-Bands is 0.030° RSS in both axes.

7.1.2.2 System Elements

The complete system comprises:

- Reflector assembly mounted on an elevation-over-azimuth pedestal, supported by a concrete tower and foundation;

- Antenna control system;

- Tracking receiver, telemetry down-converter, and transmitter;

- RF up and downlink equipment;

- Recording, monitoring and display equipment;

- Computers and associated equipment for control of the GCE, data handling and display, interfacing with the DCC in Ottawa;

- TT&C control console;

- GCE (all baseband equipment necessary to control or collect data from the satellite).

7.1.3 M-SAT Considerations

In order to determine a realistic configuration for the TT&C and SCC concept, the following information must be addressed:

- Frequency Band of Operation

   There are several choices in this area, for
   example:

   ESA   VHF/2GHz

   S-Band (commonly employed by NASA)   2 GHz
   Commercial C-Band   4/6 GHz
   Military Band   7/8 GHz also 2.0GHz
   Commercial Ku-Band   12/14 GHz

   The choice of frequency for T&C operations will
   determine the transfer orbit support requirements,
   requirement for a backup site, as well as a
   requirement for a geographical separation. In
   Ku-Band, two TT&C sites, separated by distances of
   100 km are desirable to avoid commanding problems
   resulting from local fading conditions.

- Collocation of SCC and TT&C Operations

   Most satellite communications companies collocate
   SCC and TT&C facilities. Exceptions to this are
   Telesat and INTELSAT. This may be desirable from
   security considerations, since provision can be
   made for operating the satellite from two
   locations. A floor layout of a typical combined
   TT&C/SCC facility is shown in Figure 7.2.

- Associate Facilities

   The cost and complexity of the TT&C Station will
   be significantly increased if it is desired to add
   extensive communications test and monitor

facilities or automatic station configuration
control. Communications test facilities are often
included with TT&C facilities to allow in-orbit
testing and communications performance monitoring
of operational satellites. Automatic station
configuration control is expensive but can reduce
operating expenses by reducing manpower
requirements.

-   Multiple TT&C Facilities

    For reliability, as well as the geographical
    separation mentioned in previously, two TT&C
    facilities may be required.

These parameters have been addressed by several
satellite systems operators, as shown in Table 7.2.

Company	On-Station Operation	Transfer Orbit Operation
Telesat Canada (Ref 7-1)	- C- and Ku-Band satellites - SCC & TT&C operations separated - Routine T&C Operations via fixed antenna systems - Orbit determination via either a dual C- and Ku-Band tracking antenna (azimuth/elevation/range solution) or joint use communications/T&C facilities (Range/Range solution) - TT&C C-Band systems in Allan Park, Ontario TT&C Ku-Band systems in Allan Park and Huggett, Alberta	- Telesat manages own missions - Eastern Hemisphere TT&C services C- and Ku-Band via a facility leased from Hughes - One mission conducted using facilities leased from INTELSAT - First commercial Ku-Band transfer orbit
SBS (Ref 7-2)	- Ku-Band satellite systems - Routine T&C via limited motion antenna at Clarksburg, Maryland - Fully tracking antenna at Castle Rock, Colorado	- C-Band in Transfer Orbit - Transfer orbit operation contracted out to COMSAT/INTELSAT
RCA Americom	- C-Band satellites - SCC and TT&C operations collocated - Orbit determination via full tracking antennas on East and West coasts	- Missions subcontracted to RCA-ASTRO but using Americom Western Hemisphere facilities - Eastern Hemisphere facilities obtained from INTELSAT

TABLE 7.2 DOMESTIC COMMUNICATIONS SATELLITE CORPORATIONS TT&C CONFIGURATIONS (Continued)

Company	On-Station Operation	Transfer Orbit Operation
AT&T (Ref 7-3)	- C-Band satellites; - SCC and TT&C Operations collocated; - Orbit determination via tracking station at Hawley, P.A.; - Backup TT&C via a limited motion T&C station at Three Peaks, California.	- C-Band in transfer orbit, with missions subcontracted to HAC and COMSAT.
Western Union	- C-Band satellites - SCC and TT&C operations collocated - Orbit determination via tracking station at Glenwood, New Jersey	- Transfer orbits subcontracted to Hughes Aircraft. - Eastern Hemisphere facilities have been provided via either the Hughes Guam Station, the Indonesian Domestic System or recently with the INTELSAT system.

Clearly there are numerous possible solutions and the final configuration of the TT&C configuration is the product of a number of design decisions.

One possible configuration for the demonstration M-SAT system is as follows:

i) Establish one TT&C Antenna System for tracking in the frequency band of interest;

ii) Establish a fixed mount or limited motion antenna for communications. For reliability and diversity, install a system which allows joint use T&C and communications operations.

iii) Locate the SCC at the T&C tracking station.

Expansion of this system for operational M-SAT use can be achieved by adding further fixed communications antennas with T&C facilities incorporated.

Military security/reliability considerations can be addressed separately. Generally speaking, adding a second SCC/TT&C operational station does not guarantee security because if one can be disabled easily, so can the second. An improved security approach would be to establish a transportable TT&C terminal as is being done by the U.S. Air Force to support their satellite programs. This is described in Reference 7-4. This approach would also solve the Eastern Hemisphere support problem as this station could be used temporarily to provide short term support.

7.1.4   System Costs

The costs associated with each segment of the ground
segment system described in Section 7.1 are presented.

The quoted costs are order of magnitude predictions in
1982 Canadian funds. No inflation considerations were
included.

Computer Hardware:	Real-time System	0.2M
	Data Processing System	0.8M
	Common Equipment, Spares	0.3M
	Maintenance Integration,	
	Documents	0.3M
		1.6M

Computer Software:	Vendor supplied and	
	Telesat System Software	3.4M
	Mission software	2.0M
	Manuals, SCC Procedures	0.2M
	System Integration,	
	Installation, Tests	0.2M
		5.8M

TT&C Facility:	Antenna	15.0M
	Support Building	1.0M
	Addition of T&C to Comms	
	Antenna	1.0M
	Mobile TT&C	6.0M
	GCE	1.0M
		24.0M

7.2   SATELLITE CONTROL PROCEDURES

Two sets of procedures will be required to support the operational phase of the M-SAT satellite. One set of procedures will be used primarily by the Satellite Controllers located at the Satellite Control Centre; the other set will be for use by the TT&C Technicians located at the Tracking Station. A technical description/operations manual will also be required. This manual will be used to supplement the Satellite Operations Procedures.

7.2.1   Satellite Operations Procedures

These will be used by the Satellite Controllers. The set should consist of two chapters to separate the ground control equipment and peripheral routine operating procedures from the satellite commanding procedures.

Procedure indices and a recommended format for the Satellite Operations Procedures are contained in Appendix C. It should be noted that a complete index of procedures can only be identified after final details of the control facility and satellite are known and some operational experience has been gained.

7.2.2   TTAC Operating and Maintenance Procedures

These will be used by the technicians responsible for ensuring the continuous availability of the telemetry, tracking and commanding facilities. This set should also consist of two chapters to separate the equipment operating procedures from the maintenance procedures. The procedure indices and recommended format for the TTAC Operating and Maintenance Procedures are contained in Appendix D.

7.2.3 Satellite Control Operations Manual

A Satellite Control Operations Manual similar to the
outline contained in Appendix D will be required. The
outline lists the major areas which should be covered,
and although it has been postured to resemble a L-SAT
Bus, could be reworked to encompass any type of Bus as
required.

7.3   SATELLITE CONTROL STAFFING

A staff of approximately 24 personnel backed by
engineer-level support is required to control the
satellite throughout its operational phase.   The
organization of a control facility is shown in Table
7.3.   The qualifications of the personnel are listed
in Table 7.4.   The organization shown is for an
integrated facility, i.e. the Control Centre is an
integral part of the Telemetry and Command station.

The qualifications of the Satellite Controllers
include satellite operating experience.   In the
absence of this, an intensive training period of
several months duration at an active satellite control
facility would be required.

Staffing requirements should be the same whether there
is a military participation or not.   With military
participation, personnel qualifications would have to
include the necessary security clearances and the
method of operating would be subjected to the military
influence.
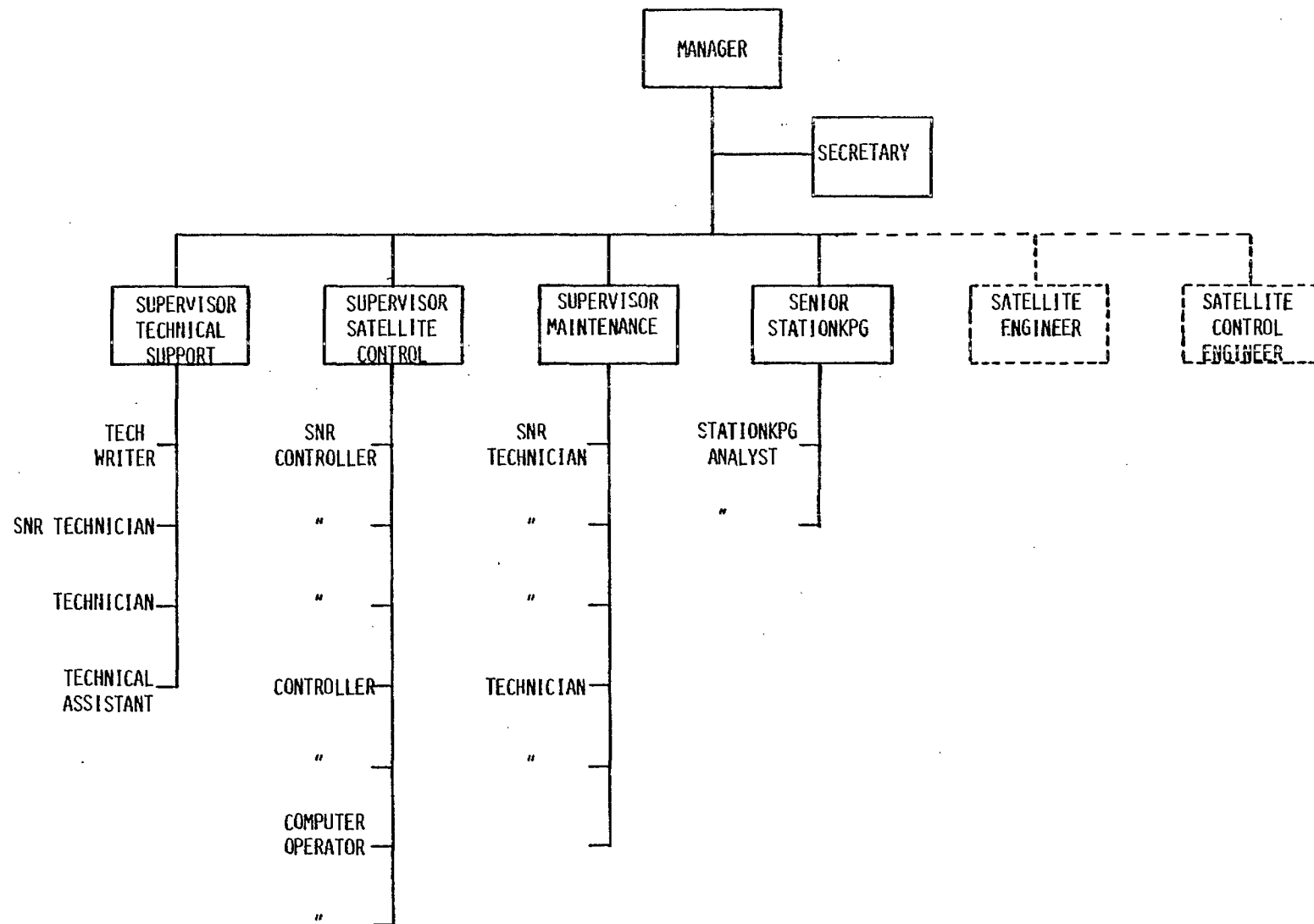
TABLE 7.2   OPERATIONAL TEAM - ORGANIZATION CHART

OPERATIONAL PHASE PERSONNEL

POSITION	QUALIFICATIONS	TOTAL REQUIRED
Manager	Senior Manager - Sat Ops experience	1
Supervisor	Electronic background - Sat Ops experience	3
Stationkeeping Analyst	Programmer/Mathematician	3
Technical Writer	Electronic background - Sat Ops experience	1
Senior Technician	Electronic Technologist - Sat Ops experience	4
Senior Controller	Electronic Technologist - Sat Ops experience	3
Technician	Electronic Technician - Sat Ops experience	4
Controller	Electronic Technician - Sat Ops experience	2
Computer Operator	Computer Operator	2
Technical Assistant	Clerical with technical aptitude	1
TOTAL		24

NOTE:

Engineering-level backup is required for solving satellite and ground control equipment problems and for computer software.

TABLE 7.4 OPERATIONAL TEAM - PERSONNEL QUALIFICATIONS

APPENDIX A

SATELLITE IN-ORBIT PRE-OPERATIONAL

TEST PLAN FOR ANIK B

11.0 SATELLITE IN-ORBIT TEST PLAN

11.1 Purpose and Scope of Tests

As early as practicable into the mission, various tests will be performed, and satellite data analyzed to enable Telesat to do the following:

1) Verify that the satellite has survived the launch and transfer orbit, and that its performance has not been measurably altered;

2) Utilize the unusual attitudes and maneuvers involved in getting on station to measure satellite characteristics that would otherwise be difficult to obtain;

3) Initially characterize the capabilities and performance of the satellite to obtain a baseline for future comparisons;

4) Measure the dynamic characteristics and calibrate the RCS system;

5) Verify that the satellite is capable of providing the communications capability, as defined in the Spacecraft Contract;

6) Measure and check out the 14/12 GHz transponder performance prior to acceptance testing, in order to satisfy the DOC Service Agreement.

The test philosophy is to measure (and, wherever possible, calibrate) all spacecraft performance parameters, and to functionally test all primary and backup operations to establish a baseline capability at beginning of life (BOL).

A - 1

11.2   Classification of Tests

11.2.1   Testing Sequence

The testing is delineated in brief in the main body of this test plan by subsystem in the nominal sequence in which it will be performed. The nominal sequence will be Command, Ranging, Telemetry, Power, Thermal, Attitude Control and Reaction Control. RF tests of the transponder will be given priority as and when practicable, in order to make the satellite available for use at the earliest possible opportunity. Exceptions to this nominal sequence may include any or all of the following schedule-critical tests:

1)   Plume Impingement Calibration;

2)   Momentum Trim Alignment;

3)   MWA/Pitch Loop Tests;

4)   Stationkeeping Calibration and Maneuver;

5)   Antenna Pattern Measurements;

6)   Solar Torque Drift Tests.

As many of the tests will be conducted as is practicable during the drift orbit phase. Testing which does not disturb attitude or orbit, including transponder RF Tests, will be inter-leaved with the Plume Impingement Calibration Testing.

11.2.2   Testing Types

Two types of testing will be performed: Calibration and Measurement, and Functional and Redundancy. The Calibration and

Measurement Tests will provide a baseline for the degree of performance of significant satellite parameters (e.g., EIRP, SFD, REA Impulse, Bandwidths, Currents). The Functional and Redundancy Tests will provide a baseline of configuration capability or remaining operational modes. That is, the Functional and Redundancy Tests will establish whether primary and backup units, modes, or systems are available by exercising two-state commands (on/off, cross-strap/normal, select 1/2, primary/backup).

11.2.3   Test Library

Appendix A contains more specific details of test objective, description, equipment required, and satellite configuration constraints.

11.3   Command Tests

11.3.1   Calibration and Measurements

11.3.1.1   Command Sensitivity Threshold

To establish the minimum uplink power required to ensure commandability, the minimum uplink RF drive required to produce correct command verification for each of the four receiver/ decoder chains will be measured through both the orbit omni and the communications antenna.

11.3.1.2   Command Receiver Bandwidth

The effective 3 dB IF bandwidth will be measured for both command receivers. The measurement will be performed by using a

carrier level 3 dB higher than the EIRP determined in the command receiver threshold sensitivity test. While a "NO-OP" command is being repeatedly transmitted to the satellite, the RF carrier frequency will be increased from nominal until command verification does not occur. This procedure will be repeated while decreasing the RF carrier frequency to the command verification drop-out level. These will be the effective 3 dB points.

11.3.2   Functional and Redundancy Tests

11.3.2.1   Redundancy Tests

To provide a high degree of confidence that all commands can be executed through all four redundant chains, all commands will be exercised and each of the command lines from the 32-line command bus going to each of the final decode units (CLD, CLP, PT&C) will be activated via each of the four receiver/decoder chains. The large majority of these tests will be done as integral parts of other subsystem tests and/or launch transfer orbit mission operations. The satellite configuration for those other tests will include a priori specification of the receiver/decoder chain to be used.

11.3.2.2   Invalid Address Rejection

Three innocuous valid commands (NO-OP) will be sent with invalid addresses: 06, 17, 77. (Note: CMD verify function will be checked during telemetry tests.)

11.4   Ranging Bandwidth and Redundancy Verification

11.4.1   Ranging Bandwidth (Receiver Baseband Bandwidth)

The baseband command receiver bandwidth will be measured for each receiver in the ranging mode by frequency sweeping the baseband audio signal and noting the 3 dB points. Baseband bandwidth will be measured for the following satellite configurations:

1)   CMD   Rx 1 - RTM 1 - BTx 1

2)   CMD   Rx 1 - RTM 1 - BTx 2

3)   CMD   Rx 2 - RTM 2 - BTx 2

4)   CMD   Rx 2 - RTM 2 - BTx 1

11.4.2   Redundancy Verification

Redundancy verification will be achieved during the ranging bandwidth tests. The following configurations will be tested for operation without bandwidth measurements:

1)   CMD   Rx 1 - RTM 2 - BTx 1

2)   CMD   Rx 1 - RTM 2 - BTx 2

3)   CMD   Rx 2 - RTM 1 - BTx 2

4)   CMD   Rx 2 - RTM 1 - BTx 1

## 11.5	Telemetry Tests

### 11.5.1	Calibration and Measurement

#### 11.5.1.1	Frequency

The two beacon transmitter frequencies, 4197.0 and 4197.5 MHz, will be measured at several times in a diurnal cycle to verify short-term frequency stability, and to establish a baseline for long-term frequency stability trend projection.

#### 11.5.1.2	EIRP

The EIRP at Allan Park will be measured for each combination of beacon transmitters OFF/LO/HI POWER modes to establish levels of telemetry power margins for each configuration.

#### 11.5.1.3	Beacon Transmitter Modulation Index

The modulation index for each transmitter will be measured, using a range tone at a known uplink flux density to verify that the command receiver/beacon transmitter satellite link has not been degraded through launch environment. It will also be measured with the RTM in PAM mode.

### 11.5.2	Functional and Redundancy Tests

#### 11.5.2.1	Redundancy Tests

Although it is highly likely that each telemetry mode will have been exercised during transfer orbit, this test will exercise

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each mode in a controlled pattern of RTM data words to verify and document the proper operation of each mode and relay. The test record will include an analog record of the PAM (discriminator output).

11.6   Attitude Control Subsystem

11.6.1   Calibration and Measurement Tests

11.6.1.1   Solar Array Plume Impingement Test

The North-South inclination control thrusters are located such that the plume of these thrusters impinges on the solar array panels and booms. This plume impingement produces significant disturbance torques during the North-South stationkeeping maneuver and these disturbances can be very much greater than the torques available from the on-board closed-loop attitude control system if the solar array is not favorably positioned. To minimize the plume induced disturbances, the solar array must be positioned approximately parallel to the X (Yaw)-axis. Due to thruster misalignments, thrust level differences, spacecraft center of mass uncertainty, and dissimilar solar panel faces (front vs. back), the array position for minimum plume disturbance will be calibrated when the spacecraft is on station. The calibration will be generated by measurement of disturbance torques caused by test thruster firings performed at various array positions and at various points in the orbit.

11.6.1.2   Attitude Drift Test

It is necessary to verify the effectiveness of the recommended roll/yaw coil settings of 32/84 atm^2 at the

recommended control threshold of 0.02 degrees. Proper setting of the dipole levels of these coils requires a reasonable knowledge of the disturbance environment. In order to acquire this knowledge, it is necessary for the spacecraft to undergo two drift tests, separated by approximately a month, during the mission check-out period. During each test, the spacecraft is allowed to drift, control free, in roll and yaw for a period of at least 24 hours. Normal closed-loop pitch control will be maintained.

A continuous record of roll error angle will be recorded and from this data an estimate of the total external disturbance torques will be made.

11.6.1.3   Pitch Optimization and Antenna Pattern Measurements

SFD and EIRP measurements will be made for varying pitch offsets to establish a cut of antenna patterns, and to determine optimum pitch offset (see para. 11.10.1.3).

11.6.1.4   Momentum Trim Adjust Optimization

In order to eliminate as near as possible the residual misalignment between the ESA optical axis and the MWA momentum axis, the optimum selection of roll angle offset data word must be determined. This will be done by observing the roll and yaw coil duty cycle, and setting the roll angle offset in accordance with the duty cycle/misalignment curves supplied by RCA.

11.6.1.5   Nutation Damping Time Constant

11.6.1.5.1   Passive Nutation Damping Time Constant

The nutation damping time constant due to the combined effects of the PND and the fuel tanks will be calculated by measuring the yaw gyro analog output for approximately a six-hour period after the Dual Spin Turn, and again after final despin and after solar panel deployment for the short period before commanding pitch loop closed.

11.6.1.5.2   Active Nutation Damping Time Constant

The nutation damping time constant for the ACE Active Nutation Damping system will be characterized through calculations made on the telemetered roll angle (or ESA output with one RTM in Attitude Monitor Mode) for the period immediately following initial pitch capture, and again immediately following the first N-S stationkeeping maneuver.

11.6.1.6   Redundant MWA Switch-On Transient Calibration

In order to be able to limit the communications interference during MWA check-out to a negligible level, it is necessary that pitch (pointing) error transients do not exceed approximately 0.1°. The pitch error induced is a function of the "ON" time of the redundant MWA. Therefore, during the in-orbit check-out of the satellite, the length of "ON" time allowed for the redundant MWA before the pitch error exceeds 0.1° will be determined. This time constant will be used for the subsequent periodic checks of the redundant MWA during life.

11.6.1.7 RCS Thruster Calibration

As part of each RCS maneuver, the performance (impulse, thrust, specific impulse) will be measured by assessing the actual change in the orbit or attitude of the satellite, and comparing these measured numbers to the values predicted by the thruster performance model. Deviations will be noted and used as a basis for generation of new calibration factors for the thrusters.

In particular, a series of test firings will be performed to accurately determine the relation between momentum "dumped" from the system and the number of pulses used.

11.6.1.8 RMA Drift Rate Test

Although the N-S stationkeeping logic subtracts the yaw gyro drift rate prior to using the yaw angle for stationkeeping attitude control thruster firings, it is useful for diagnostic purposes to calibrate the gyro drift rate as a function of "ON" time both for prediction of stationkeeping performance and for a BOL data base for trend analysis. The drift rate will be determined prior to and after slewing the array for the first N-S stationkeeping maneuver by enabling the gyro and recording telemetered relative yaw angle and RMA analog output.

11.6.2 ACS Functional/Redundancy Tests

11.6.2.1 ESA Checkout

The telemetered pitch and roll angle will be monitored while the inactive ESA/ACE is turned on. Both sets of pitch/roll/D-A converter outputs (for each redundant side) should be nearly identical. The cross-strapping relays will be exercised by set-up of the four possible configurations of ESA/ACE.

11.6.2.2 ACE Checkout

Both ACEs will be turned on, and the pitch error (D-A converter) and compensation amplifier outputs recorded. ACE switchover will be exercised, and the small pitch transients will be recorded.

11.6.2.3 MWA Checkout

Confidence that each MWA is capable of providing the response for proper active control will be established via a single MWA switchover on arrival on station. That is, the Dual Spin Turn will take place with MWA #2, and after arrival on station control will be switched to MWA #1. The calibration test of para. 11.6.1.6 must be performed after switchover. Note that at BOL the satellite control software assumes MWA #1 is operating in the control loop.

11.6.2.4 Roll/Yaw Control Electronics and Torquer Coil Check

In order to verify proper operation of the roll control electronics (RCE) and their roll torquer coils, the roll angle and roll and yaw coil current telemetry will be observed while the satellite drifts through the roll control threshold. This will be repeated for each redundant RCE/RTC/YTC. This test will precede the momentum trim select test. To further check the individual yaw coils, they will be sequentially enabled after the satellite roll angle has exceeded threshold and the current levels recorded.

11.7 Power Subsystem Tests

11.7.1 Calibration and Measurement

11.7.1.1 Array Position Calibration (Electrical)

The solar array/SAD position telemetry will be calibrated against the orientation of the array relative to the sun through observation of telemetered solar array and partial shunt currents and pitch offset. This will permit determination of optimum array pointing for maximum power output, simultaneous calibration of shorted cell current vs. array positions, and verification of array pointing vs. SAD position register telemetry.

11.7.1.2 Battery Capacity

Battery performance characteristics, including capacity, will be measured under a low-discharge rate by subjecting each battery in turn to a recondition sequence. If thermal conditions permit, battery characteristics will also be determined at the high-discharge rates by offsetting the array to electrically simulate an eclipse period.

11.7.1.3 Array Output

The output of the array wil be measured over one diurnal cycle to establish a baseline at BOL for trend analysis, and to verify that the array output is as predicted and that no major degradation has occurred.

11.7.2 Power Functional and Redundancy Tests

11.7.2.1 SAD Functional Test

The solar array drive will be commanded to the four possible modes to verify complete drive capability; i.e., NORM/FWD, NORM/REV, SLEW/FWD, SLEW/REV.

11.7.2.2 ADE/SAD Redundancy Tests

The four possible combinations of ADE/SAD will be exercised to verify all redundant backup modes; i.e., ADE 1/SAD 1, ADE 1/SAD 1 & 2, ADE 2/SAD 2, ADE 2/SAD 1 & 2.

11.7.2.3 PSE Functional Test

The charge regulators and timer/sequencer operation will be exercised through a selected combination of configurations (i.e., VT Curve/Charge Reg. Primary/Time Seq. Primary).

11.8 RCS TESTS

11.8.1 Calibrations and Measurements

Thruster calibrations will be done as part of the ACS testing. Initial on-station fuel status measurements will be made by recording pressure and temperature, and by calculating the remaining fuel volume.

11.8.2   Functional/Redundancy Tests

Verification of thruster function will be achieved during
SPM, spin adjust and stationkeeping maneuvers through observation
of REA catalyst bed temperature, REA fire status, and REA enable
status telemetry. All latching valves, cross-strap and
main-line, will be exercised and confirmation obtained via
telemetry.

11.9   Thermal Tests

All primary and backup heaters will be exercised.

The amount of heat dissipated by the shunts is dependent on
solar array output. Under conditions of relatively constant
loads, the satellite temperature can be controlled by varying
the array offset and concomitant partial shunt dissipation.
Using several telemetered temperatures (particularly south panel
temperatures), the variation of satellite temperature with array
offset will be established.

11.10   Transponder RF Tests

11.10.1   Calibration and Baseline Measurement

The transponder RF tests comprise all those tests performed
on the transponder to verify that the characteristics of the
subsystem are close to those predicted prior to launch. Of
particular interest will be the compilation of a set of baseline
measurements to which all future periodic measurements will be
referenced. Due to the fact that the 14/12 GHz downlink uses
spot beams, the RF tests for this transponder will be performed
as the E-W pitch offset of the satellite is changed. This will

include the following tests at 14/12 GHz: SFD, EIRP, telemetry calibration of RF power monitors, and antenna pattern measurements. The Field Strength Monitor will be calibrated during the same period. Other tests to be performed as each spot beam is accessible are amplitude frequency response and group delay response. In addition, a search for spurious signals will be performed. The 6/4 GHz tests will be performed at Allan Park using the TTAC antenna and, unless otherwise stated, 14/12 GHz tests will be performed using the mobile test facility (MTF).

11.10.1.1   SFD, EIRP and TWT Transfer Curve (6/4 GHz)

Saturating flux density and EIRP will be measured for each channel. SFD measurements will be performed on both Receiver #1 and Receiver #2, thus verifying transponder loop gain. Discrete measurements of flux density and EIRP will be performed on each channel with up to 20 dB output backoff, thus establishing the TWT transfer curve. During SFD and EIRP measurements, the RF power monitors (6/4 GHz) and TWT helix current will be calibrated by recording the telemetry. EIRP measurements will be performed by comparing the received signal with a calibrated signal injected into the front end of the LNA. SFD measurements will use the 7/X rule.

11.10.1.2   SFD, EIRP and TWT Transfer Curve (14/12 GHz)

The saturating flux density for each channel will be measured. All RF channel beam routing (including 5 dB attenuators) will be exercised, in order to verify that the 14/12 GHz transponder meets all gain requirements. As a consequence, all commands pertaining to RF routing will be tested. Similarly, the EIRP for each TWT will be measured for each channel through all RF routings. SFD and EIRP measurements will be performed in the same manner as for the 6/4 GHz transponder; i.e., using the

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7/X rule for SFD and a calibrated injected signal for EIRP. The TWTA transfer characteristic will also be determined by taking discrete readings of flux density with up to 20 dB output backoff. During TWT transfer characteristic measurements, the 14/12 GHz RF power monitors and helix current in each TWT will be calibrated. The downlink EIRP data will be used to calibrate the Field Strength Monitor. In order to access each spot beam the spacecraft will be oriented appropriately, using the available pitch offset capability of up to $\pm 5^{\circ}$.

11.10.1.3 <u>Antenna Pattern Measurements</u>

In addition to the SFD and EIRP measurements of 11.10.1.1 and 11.10.1.2 above, similar measurements will be made at spot frequencies with various settings of pitch angle over its full range. If practicable, further measurements will be made at various roll angles obtained during the drift test (see para. 11.6.1.2). Use will be made of the data to verify that the antenna patterns and their alignments agree with pre-launch data and to obtain the optimum pitch angle setting (see para. 11.6.1.3).

11.10.1.4 <u>Field EIRP Measurements (12 GHz)</u>

The Field Strength Monitor (FSM) will be calibrated at Allan Park during EIRP measurements of the 12 GHz spot beams on the 14/12 GHz transponder. A calibration table will be produced for each channel.

After the satellite is on station and a preliminary checkout completed (after EIRP and FSM calibration), the EIRP of the 12 GHz spot beams on appropriate channels will be measured using the FSM in the following locations:

1)   Halifax

2)   Frobisher Bay

3)   Regina

4)   Lake Cowichan.

The measurements are performed for contractual compliance with the DOC-Telesat services agreement. In addition, these measurements will be used for additional verification of the antenna patterns and the pitch angle optimization.

11.10.1.5   Amplitude Response/Group Delay (6/4 GHz)

After suitable calibration of the earth station using a test translator, the group delay and amplitude response of each channel will be measured at IF using a microwave link analyzer. A sweep of ±20 MHz will be performed. Amplitude response and group delay will be measured for both receivers.

11.10.1.6   Amplitude Response/Group Delay (14/12 GHz)

The 14/12 GHz transponder amplitude response and group delay measurements will also be performed at IF, after suitable calibration of the MTF using a test translator. Due to the wide bandwidth of the 14/12 GHz channels, the up- and down-converters will be offset by 20 MHz using a frequency synthesizer to provide a total sweep for each channel. The transponder will be configured to test all RF channel routings, in order to ensure performance of all input and output multiplexers. These tests will be performed for both receivers, FETAs uncrossed.

11.10.1.7 Translation Frequency and Stability

The translation frequency for the 6/4 GHz and 14/12 GHz transponders will be measured by mixing the uplink and downlink frequencies and recording the difference frequency. This will demonstrate the performance of the satellite local oscillators. Both receivers on the 6/4 GHz and 14/12 GHz transponders will be tested.

At the first opportunity during an eclipse season, the satellite temperature/frequency characteristics will be monitored and recorded as baseline measurements.

11.10.1.8 Spurious Measurement

The entire transponder bandwidth will be scanned to detect spurious emissions at 14/12 GHz and 6/4 GHz. The 14/12 GHz transponder will be scanned while the 6/4 GHz transponder is illuminated to determine if any interference signals exist from the 6/4 GHz to 14/12 GHz transponder and vice versa. These measurements will be performed for both receivers on each transponder.

11.10.1.9 Intermodulation

A two-carrier intermodulation measurement will be performed on both the 6/4 GHz and 14/12 GHz transponders at such time as suitable facilities are available, each capable of radiating an independent carrier.

11.10.1.10   RF Monitors

The RF output power monitors on both transponders will be calibrated during SFD and EIRP measurements, as outlined in these tests.

11.10.2   Functional and Redundancy Tests

During transponder calibration measurements, the following redundant configurations will be tested:

1)   6/4 GHz Receiver redundancy;

2)   14/12 GHz Receiver redundancy;

3)   14/12 FETA cross-strapping;

4)   14/12 Channel Beam routing of RF channels (TWT, Horns).

The remaining functional tests that will be performed are:

1)   TWTAs ON (3)
     TWTAs OFF (16)

2)   Transponder power supply redundancy.

APPENDIX B

M-SAT

MISSION AND STATION PROCEDURES MANUAL

GENERAL OUTLINE

(ASSUMING A SATCOM BUS)

M-SAT

MISSION AND STATION PROCEDURES MANUAL

CHAPTER 1

INTRODUCTION

This Chapter would provide a simplified description of the
function and use of the manual. Included would be a
description of the manual's content, a basic description of
the satellite to subsystem level, a basic description of
the software, which was developed to assist in the control
of the satellite during the transfer and drift orbit phases
of the mission and, any other information considered
essential to the mission.

Chapter 1

Introduction

Table of Contents

M-SAT

MISSION AND STATION PROCEDURES MANUAL

CHAPTER 2

MISSION PROCEDURES

PART 1

PRE-LAUNCH AND IN-ORBIT ACTIVITY SCHEDULES

This part would contain the Pre-Launch plus all the
In-Orbit Activity Schedules required to support an
M-SAT mission. Attached are copies of Pre-Launch
and Orbit 1 Activity Schedules related to the Anik B
satellite which utilized a bus very similar to that
for SATCOM. The activities detailed therein were
performed during Orbit 1 with visibility from the
Tracking Station in Carnarvon and control from the
Satellite Control Centre in Ottawa.

Chapter 2   Mission Procedures

Part 1   Pre-Launch and In-Orbit Activity Schedules

Table of Contents

ANIK B NOMINAL ACTIVITY SCHEDULE   ORBIT 1   CARNARVON
    (DUAL BTX OPERATION)

GMT	E/T	PROC NO.	SEQ. NO.	CMD NO.	ACTIVITY
	-01:00	01			Station Status Check,
	00:00				LIFTOFF
	00:30	08			Preparation for Acquisition
	01:02				Acquisition of Signal
	01:10				AZ/EL Data Collection
	01:30				PAM Data Collection from RTM 1
					PAM Diagnostic Printout
					from RTM 1
	01:40				AZ/EL Data Collection
	02:00				PAM Data Collection from RTM 2
					PAM Diagnostic Printout
					from RTM 2
	02:15				AZ/EL Data Collection
	03:00	08	-	xxx	No-Ops Manual Entry
	03:30	08	-	xxx	No-Ops Computer Entry
	03:35	08			Initial Commanding Sequence
			18	*xxx	MWA 1 OFF
			18	xxx	MWA 2 OFF
			18	xxx	HSA 1 and 2 ON
			18	xxx	RCS B/U Line Heaters ON
	03:40	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	03:45	12			Preparation for RCS Maneuvers
					(Spin Adjust)
			7	xxx	Thruster Control 1 ON
			7	xxx	Thruster 5 Enable
			7	xxx	Thruster 7 Enable
			7	xxx	Thruster 10 Enable
			7	xxx	Thruster 12 Enable
	03:50	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	04:00	05			PAM Data Collection
			-	xxx	RTM 2 to PAM (Low Priority)
					PAM Diagnostic Printout
					from RTM 2
	04:05	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor

*Hazardous Command

GMT	E/T	PROC NO.	SEQ. NO.	CMD NO.	ACTIVITY
	04:08	25			Dwell (Low Priority) Data Collection
			68	xxx	RTM 1 to Dwell on Currents
			68	xxx	RTM 1 to PAM (Low Priority)
	04:15	05			PAM Data Collection from RTM 1 PAM Diagnostic Printout from RTM 1
	04:18	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	04:19				SEC Acquisition
	04:28	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	04:30	13			60 RPM Spin Adjust Maneuver (Part I)
	04:35		34(35)	xxx	Thrusters 5, 7, 10 and 12 Disable
			34(35)	xxx	Thruster x Enable
			34(35)	xxx	Thruster x Enable
		13	D	xxx	Fire Enabled Thrusters
			D	xxx	Reset Backup Timer xxx Times
			D	xxx	Stop Firing Thrusters
	04:50	13			60 RPM Spin Adjust Maneuver (Part II)
	04:55		34(35)	xxx	Thrusters 5, 7, 10 and 12 Disable
			34(35)	xxx	Thruster x Enable
			34(35)	xxx	Thruster x Enable
		13	D	xxx	Fire Enabled Thrusters
			D	xxx	Reset Backup Timer xxx Times
	05:15		D	xxx	Stop Firing Thrusters
	05:18	13	27	xxx	Thrusters 5, 7, 10, and 12 Disable
		13	27	xxx	Thruster Control Disable
	05:20	12			Preparation for RCS Maneuver (Spin Precession)
	05:25		6	xxx	Thruster 6 Enable
			6	xxx	Thruster 8 Enable
			6	xxx	Thruster 9 Enable
			6	xxx	Thruster 11 Enable
	05:30				NEC Acquisition

ANIK B NOMINAL ACTIVITY SCHEDULE   ORBIT 1   CARNARVON
     (DUAL BTX OPERATION)

GMT	E/T	PROC NO.	SEQ. NO.	CMD NO.	ACTIVITY
	05:30	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	05:37				APOGEE #1
	05:40	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	05:45	20			Auto SPM Preliminary (Only if less than four thrusters are used)
			-	xxx	Disable Thrusters 6, 8, 9 and 11
			-	xxx	Thruster 6 Enable
			-	xxx	Thruster 8 Enable
			-	xxx	Thruster 9 Enable
			-	xxx	Thruster 11 Enable
	05:55	20			Auto Spin Precession Maneuver (PART I)
	06:00		-	*xxx	Auto SPM ON
	06:10				Fucino Acquisition of Signal
	06:15		1	xxx	Reset Backup Timer
	06:20				SEC Loss
	06:30		1	xxx	Reset Backup Timer
	06:40				PALAPA I, No Commanding 5° Zone BEGINS
	06:50				Backup Timer ends PART I of Maneuver
	07:00				NEC Loss
	07:20				NEC Acquisition
	07:20				PALAPA I, No Commanding 5° Zone ENDS
	07:20	20	-	xxx	Auto SPM OFF
	07:22	20			Auto Spin Precession Maneuver (PART II)
	07:25		-	*xxx	Auto SPM ON
	07:40		1	xxx	Reset Backup Timer
	07:55		1	xxx	Reset Backup Timer

*Hazardous Command

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ANIK B NOMINAL ACTIVITY SCHEDULE ORBIT 1 CARNARVON
 (DUAL BTX OPERATION)

GMT	E/T	PROC NO.	SEQ. NO.	CMD NO.	ACTIVITY
	08:00				SEC Acquisition
	08:05	20	-	xxx	Auto SPM OFF
	08:10		-	xxx	Thrusters 6, 8, 9 and 11 Disable
	08:15	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	08:25	05			PAM Data Collection RTM 2 to PAM (Low Priority) PAM Diagnostic Printout from RTM 2
	08:30	25			Dwell (Low Priority) Data Collection
			69	xxx	RTM 2 to Dwell on Currents
			69	xxx	RTM 2 to PAM (Low Priority)
	08:40	05			PAM Data Collection from RTM 1 PAM Diagnostic Printout from RTM 1
	08:45	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
		OR			
	08:45	07			Tracking Data Collection
			-	xxx	RTM 2 to Ranging Ranging from Carnarvon Ranging from Fucino
	09:05	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	09:20	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	09:30	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	09:40	04			Tracking Data Collection
			-	xxx	RTM 2 to Ranging
	09:50	06			Sensor Data Collection
			-	xxx	RTM 2 to Sensor
	09:58				Fucino Loss of Signal
	10:05	05			PAM Data Collection from RTM 1 PAM Diagnostic Printout from RTM 1

GMT	E/T	PROC NO.	SEQ. NO.	CMD NO.	ACTIVITY
	10:10	05			PAM Data Collection
			-	xxx	RTM 2 to PAM (Low Priority)
					PAM Diagnostic Printout from RTM 2
	10:20	03			Preparation for Loss of Signal
					AZ/EL Data Collection
	10:50				Carnarvon Loss of Signal

NOTE 1:   Alternate Station Ranging may be performed during this orbit with Carnarvon doing the commanding, followed by Ranging from both Carnarvon and Fucino.

NOTE 2:   If Fucino should become the prime tracking station for this orbit vice Carnarvon, the Nominal Activity Schedule for Carnarvon will be modified to apply to Fucino for the time period during which Fucino sees the satellite. The Fucino Mission Procedures will then be the ones used.

M-SAT

MISSION AND STATION PROCEDURES MANUAL

CHAPTER 2

MISSION PROCEDURES

PART 2

TRANSFER ORBIT

WESTERN HEMISPHERE TRACKING STATION

This part would contain all the Transfer Orbit
Mission Procedures for the Western Hemisphere
Tracking Station. Following is a sample of the Anik
B Table of Contents listing those procedures which
were required to support the Anik B transfer orbit
activities as they related to the Western Hemisphere
Tracking Station. Also included is a sample of a
typical Anik B Transfer Orbit Mission Procedure for
Telesat's Western Hemisphere Tracking Station at
Allan Park.

Chapter 2 Mission Procedures

Part 2   Transfer Orbit Western Hemisphere Tracking Station

Table of Contents

Procedure No. 2-14   Title: Apogee Motor Firing

STEP	SCC ACTION	STATION ACTION

NOTE: The Mission Director will announce the proposed plan of action as related to Apogee Motor Firing prior to the start of this activity.

1   Allan Park. Apogee Motor Firing Procedure 2-14 is now in progress. AMF will occur at: All stations acknowledge.

--- -- -- -- GMT.
Allan Park will be prime.
No backup will be available.

2   Allan Park. Are you go for AMF?   Affirmative. All systems are go (or otherwise).

3   Allan Park. If a failure in communications occurs prior or subsequent to AMF you will continue with the programmed AMF activities unless instructed otherwise.   Affirmative.

4   Allan Park. This is a time check; on my mark the time will be: --- -- -- -- GMT.   Affirmative. Clocks are (not) in sync.

5, 4, 3, 2, 1, Mark!

5   Allan Park. Please setup to monitor PAM Channel 91, AKM Temperature using a DVM.   Acknowledged. We are setup to monitor PAM Telemetry Channel 91, AKM Temperature

6   (Only if required.)

Allan Park. Transmit Doppler Analog on line to SCC.   Acknowledged. Doppler analog now on Line Number ----.

7   DR. Please set up to record and display AMF data.   Acknowledged. AMF Data is being recorded and displayed.

8   Allan Park. Confirm RTM 1 is in --- Mode and RTM 2 is in --- Mode.   Acknowledged. RTM 1 is in --- Mode and RTM 2 is in --- Mode.

9   CO. Get Apogee Motor Firing Sequence Number xx and edit according to Mission Conductor's input.   Acknowledged. Sequence Number xx edit is complete.

(Use Sequence Number xx if AMF is to be performed without Command Verification.)

Procedure No. 2-14   Title: Apogee Motor Firing

STEP	SCC ACTION	STATION ACTION

10   Allan Park. Implement the
preliminary steps of AMF Backup
Procedure 2-012.

Acknowledged. The prelim-
inary steps of AMF Backup
Procedure 2-012 have been
completed.

11   Allan Park. The steps leading to
AMF will now be executed using
Sequence Number xx. Please stand
by.

Acknowledged. Allan Park
is now standing by.

12   CO. Execute Sequence Number xx at:

-- -- -- GMT.

(Observe, record and announce the
completion of each sequence step.)

a.   Acknowledged. Sequence
Number xx initiated.

b.   Cmd xxx, AKM Heaters
OFF, executed.

c.   Cmd xxx, MWA 1 ON (at
200 rpm), entered.

d.   Sequence has Paused
Execute.

13   Allan Park. Please enable the
CRTG Hazardous Command switch.

Acknowledged. Hazardous
Command switch has been
enabled.

14   CO. Resume sequence to execute
Command xxx.

a.   Acknowledged. Cmd xxx,
MWA 1 ON, executed.

b.   Cmd xxx, MWA 2 ON, (at
200 rpm), entered.

c.   Sequence has Paused
Execute.

15   Allan Park. Please enable the
CRTG Hazardous Command switch.

Acknowledged. Hazardous
Command switch has been
enabled.

16   CO. Resume sequence to execute
Command xxx.

a.   Acknowledged. Cmd xxx,
MWA 2 ON, executed.

b.   Sequence has Paused
Open.

17   (Confirm that both MWAs are ON by
observing related Motor Current.)

Procedure No. 2-14   Title: Apogee Motor Firing

STEP	SCC ACTION	STATION ACTION
18	CO. Resume sequence to enter Command xxx.	a. Acknowledged. Cmd xxx, Squib Bus Enabled, entered.
		b. Sequence has Paused Execute.
19	Allan Park. Please enable the CRTG Hazardous Command switch.	Acknowledged. Hazardous Command switch has been enabled.
20	CO. Resume sequence to execute Command xxx.	a. Acknowledged. Cmd xxx, Squib Bus Enabled, executed.
		b. Sequence has Paused Open.
21	CO. Note and then set PAM Group H Data averaging rate to 5.	Acknowledged. PAM Group H Data averaging rate changed from ___ to 5.
22	(At AMF minus 3 minutes.)	
	CO. Resume sequence to enter Command xxx.	a. Acknowledged. Cmd xxx, Fire Apogee Motor, entered.
		b. Sequence has Paused Execute.
23	Allan Park. Please enable the CRTG Hazardous Command switch. Carry out Procedure 2-012 immediately following execution of Command xxx.	a. Acknowledged. Hazardous Command switch has been enabled.
		b. We will carry out Procedure 2-012 immediately following execution of Cmd xxx.
24	(At AMF minus 1 minute.)	
	CO. Resume sequence to execute Command xxx, Apogee Motor Firing on my signal at:	a. Acknowledged. Cmd xxx, Fire Apogee Motor, executed at:
	-- -- -- GMT. 30 seconds, 10 seconds, 5, 4, 3, 2, 1, MARK!	-- -- -- GMT.
		b. Sequence has Paused Open.

Procedure No. 2-14   Title: Apogee Motor Firing

STEP	SCC ACTION	STATION ACTION
25	Allan Park. Proceed with AMF Backup Procedure 2-012.	Acknowledged. AMF Backup Procedure is in progress.
	Report the execution time of each command and report when DVM indication begins to relate to an increase in AKM Temperature.	(The Logkeeper and the Allan Park Station Coordinator will record the times of execution.)

a. Cmd xxx, Squib Bus Enabled executed at:

   -- -- -- GMT.
(using address 2A and CRTG 1.)

b. Cmd xxx, Fire Apogee Motor, executed at:

   -- -- -- GMT.
(using address 2A and CRTG 1.)

c. Cmd xxx, Squib Bus Enabled, executed at:

   -- -- -- GMT.
(using address 2B and CRTG 1.)

d. Cmd xxx, Fire Apogee Motor, executed at:

   -- -- -- GMT.
(using address 2B and CRTG 1.)

e. Cmd xxx, Squib Bus Enabled, executed at:

   -- -- -- GMT.
(using address 1A and CRTG 1.)

f. Cmd xxx, Fire Apogee Motor, executed at:

   -- -- -- GMT.
(using address 1A and CRTG 1.)

STEP   SCC ACTION   STATION ACTION

g.   Cmd xxx, Squib Bus
                                                                  Enabled, executed at:

                                                                  -- -- -- GMT.
                                                                  (using address 1B and
                                                                  CRTG 1.)

                                                             f.   Cmd xxx, Fire Apogee
                                                                  Motor, executed at:

                                                                  -- -- -- GMT.
                                                                  (using address 1B and
                                                                  CRTG 1.)

26   (Observe telemetry data for positive
        indication of AMF and announce:)

        AMF HAS (NOT) OCCURRED.

        CAUTION: Do not execute AMF more than _____ minutes after
                  scheduled time unless authorized by the Mission
                  Director.

27   CO. Ensure CRTG is in Computer Mode   a.   Acknowledged. Cmd xxx,
        then resume sequence to enter Cmd   MWA 1 OFF, entered.
        xxx.
                                                 b.   Sequence has Paused
                                                      Execute.

28   Allan Park. Please enable the   Acknowledged. Hazardous
        CRTG Hazardous Command switch.   Command switch is enabled.

29   CO. Resume sequence to execute   a.   Acknowledged. Cmd xxx,
        Cmd xxx.   MWA 1 OFF, executed.

                                                 b.   Cmd xxx, Squib Bus
                                                      Disabled, executed.

                                                 c.   Cmd xxx, MWA 2 OFF,
                                                      executed.

                                                 d.   Sequence has ended.

30   CO. Set PAM Group H Data averaging   Acknowledged. PAM Group H
        rate to that noted in Step 21.   Data averaging rate set to

                                                 ----.

31   Allan Park. That completes the   Acknowledged.
        Apogee Motor Firing Sequence. We
        will now continue with normal
        scheduled activities.

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MISSION AND STATION PROCEDURES MANUAL

CHAPTER 2

MISSION PROCEDURES

PART 3

TRANSFER ORBIT

EASTERN HEMISPHERE TRACKING STATION

The procedures contained in this part of the manual
would be very similar to those contained in Part 2.
Only those changes to incorporate equipment
differences between tracking stations would be
required.

Chapter 2   Mission Procedures

Part 3   Transfer Orbit Eastern Hemisphere Tracking Station

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MISSION AND STATION PROCEDURES MANUAL

CHAPTER 2

MISSION PROCEDURES

PART 4

DRIFT ORBIT

WESTERN HEMISPHERE TRACKING STATION

This part of the manual would contain all the Drift
Orbit Mission Procedures for the Western Hemisphere
Tracking Station. Following is a sample of the
Table of Contents listing those procedures which
were required to support the Anik B drift orbit
activities as they related to the Western Hemisphere
Tracking Station. Also included is a sample of a
typical Anik B Drift Orbit Mission Procedure for
Telesat's Western Hemisphere Tracking Station at
Allan Park.

Chapter 2 Mission Procedures

Part 4   Drift Orbit Western Hemisphere Tracking Station

Table of Contents

Procedure No. 2-22   Title: Despin to On-Orbit Mission
                                               Momentum (Dual BTX Operation)

STEP   SCC ACTION   STATION ACTION

     NOTE   1: Thrusters will be enabled 1 hour prior to firing to
                permit the catalyst bed to reach an optimum operating
                temperature of 200°C. Minimum temperature at which
                Thrusters can be fired is 100°C. Use Procedure 1-12 to
                enable selected Thrusters.

     NOTE   2: In order to obtain the full data pertinent to this
                Maneuver, one ACE/ESA combination must be ON to
                determine Spin Rate and Attitude. If both Beacon
                Transmitters are ON, one RTM must be set to PAM, Low
                Priority Mode and the other set to Yaw Gyro Analog
                Mode. The Yaw Gyro connected to the RTM set to Yaw
                Gyro Analog Mode must also be ON so that its output can
                be used as the Thruster Firing Reference.

     NOTE   3: Refer to Procedure 1-22A for instructions to Despin to
                On-Orbit Mission Momentum using one Beacon Transmitter.

1   Allan Park. The Despin to On-Orbit   Acknowledged. Despin to
     Mission Momentum Maneuver is   On-Orbit Mission Momentum
     scheduled to begin at: Maneuver to start at:

     --- -- -- -- GMT.   --- -- -- -- GMT.

2   (Only if not already switched on.)

     CO. Switch on Yaw Gyro 1 (2).   Acknowledged. Cmd xxx
     Enter and execute Cmd xxx (xxx).   (xxx), Yaw Gyro 1 (2) ON,
                                              executed.

3   CO. Edit Sequence Number xx   Acknowledged. Sequence
     according to the Mission Conductor's   Number xx edit completed.
     and Spacecraft Analyst's require-
     ments.

4   CO. Execute Sequence Number xx at: a. Acknowledged. Sequence
                                                  Number xx initiated.
     -- -- -- GMT.
     (Observe, record, and announce   b. Cmd xxx (xxx), BTX 1
     the completion of each sequence   (2) ON at Low Power,
     step.)   executed.

                                             c. Cmd xxx, BTX to High
                                                 Power, entered.

                                             d. Sequence has Paused
                                                 Execute.

5   Allan Park. Please enable the   Acknowledged. Hazardous
     CRTG Hazardous Command switch.   Command switch is enabled.

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STEP	SCC ACTION	STATION ACTION
6	CO. Resume Sequence to execute Cmd xxx.	a. Acknowledged. Sequence Number xx resumed.
		b. Cmd xxx, BTX High Power ON, executed.
		c. Cmd xxx, ACE 1 and 2 ON, executed.
		d. Cmd xxx DW 122600, ACE Pitch Offset to 1.5 Degrees Negative, ACE Roll Trim to zero, ACE Roll Threshold to 0.05 Degrees, executed.
		e. Cmd xxx, ESA 1 and 2 ON, executed.
		f. Cmd xxx (xxx), ACE 2 (1) OFF, entered.
		g. Sequence has Paused Execute.
7	Allan Park. Please enable the CRTG Hazardous Command switch.	Acknowledged. Hazardous Command switch is enabled.
8	CO. Resume Sequence to execute Cmd xxx (xxx).	a. Acknowledged. Sequence Number xx resumed.
		b. Cmd xxx (xxx), ACE 2 (1) OFF, executed.
		c. Cmd xxx (xxx), ESA 2 (1) OFF, entered.
		d. Sequence has Paused Execute.
9	Allan Park. Please enable the CRTG Hazardous Command switch.	Acknowledged. Hazardous Command switch is enabled.
10	CO. Resume Sequence to execute Cmd xxx (xxx).	a. Acknowledged. Sequence Number xx resumed.
		b. Cmd xxx (xxx), ESA 2 (1) OFF, executed.
		c. Sequence has Ended.

Procedure No. 2-22   Title: Despin to On-Orbit Mission
                                               Momentum (Dual BTX Operation)

STEP   SCC ACTION   STATION ACTION

11   CO. Switch off data collection   Acknowledged. Cmd xxx
     from RTM 1 (2) then command RTM 1   (xxx), RTM 1 (2) to Yaw
     (2) to Yaw Gyro Analog Mode.   Gyro Analog Mode,
     (Use Data Word DA=20.)   executed.

12   Allan Park. Please transmit Yaw   Acknowledged. Yaw Gyro
     Gyro Analog Data from RTM 1 (2)   1 (2) Analog Data is now
     to Ottawa.   on Line No. ____.

13   DR. Display Yaw Gyro Analog Data.   Acknowledged. Yaw Gyro
                                            Analog Data is now being
                                            displayed.

14   Allan Park. The Despin to On-Orbit   Acknowledged.
     Momentum Maneuver will be executed
     under Computer Control using Special
     Sequence D. Thrusters 6 and 9 will
     be fired for approximately 105
     seconds for Part I of the Maneuver.

15   CO. Edit Special Sequence D   Acknowledged. Special
     according to Mission Conductor's   Sequence D edit is
     requirements.   complete.

     (SE,SE,D,PW,___,TP,___,NP,___)   (Logkeeper sets the E/T
                                            Clock to start at
     PW - pulse width in seconds   Thruster Firing Time.)
     TP - time between pulses in seconds
     NP - number of pulses

     The Backup Timer will be auto-
     matically reset by the Computer
     at 8-second intervals throughout
     the course of the Maneuver.

     The first part of this Maneuver
     will terminate at:

     __ __ __ GMT.
     unless a halt is requested before
     that time by the Mission
     Conductor.

16   CO. Execute Special Sequence D at: a. Acknowledged. Special
                                                 Sequence D initiated.
     __ __ __ GMT.
                                             b. Cmd xxx, Fire Enabled
     (Observe, record and announce the   Thrusters, executed.
     completion of each sequence step.)
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STEP   SCC ACTION   STATION ACTION

        NOTE: Special Sequence D will be
                  allowed to terminate the
                  Maneuver unless the third
                  positive to negative zero
                  crossing of the observed
                  Yaw Gyro Analog Output
                  occurs first, at which
                  time the Maneuver will be
                  halted IMMEDIATELY on
                  direction from the Mission
                  Conductor.

17   (If a halt is requested by the
        Mission Conductor:)

        CO. Halt the Maneuver Now!   a. AB,B1 initiated.

                                               b. Cmd xxx, Stop Firing
                                                   Thrusters, executed.

                                               c. Maneuver halted at:

                                                   -- -- -- GMT.

                    OTHERWISE

        Maneuver will end on my signal   a. Cmd xxx, Stop Firing
        (based on E/T Clock).   Thrusters, executed.

        10, 5, 4, 3, 2, 1, MARK!   b. Maneuver ended at:

                                                   -- -- -- GMT.

18   Allan Park and DR. That completes   Acknowledged.
        Part I of this Maneuver. We are
        now going to Switch RTM 1 (2) to
        Attitude Monitor Mode to observe
        Sensor Analog Data for Spin Rate
        determination. Following that,
        we will switch RTM 1 (2) back to
        Yaw Gyro Analog Mode for Part II
        of this Maneuver. Please leave
        your equipment configured to transmit
        and display Analog Data.

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Title: Despin to On-Orbit Mission
                                          Momentum (Dual BTX Operation)

STEP   SCC ACTION   STATION ACTION

19   CO. Switch RTM 1 (2) to Attitude   Acknowledged. Cmd xxx
      Monitor Mode. (Use Data Word DA=10.) (xxx), RTM 1 (2) to
                                             Attituae Monitor Mode,
                                             executed.

20   CO. Switch HSA 1 and 2 On. Enter   Acknowleagea. Cma xxx,
      and execute Cmd xxx.   HSA 1 and 2 ON, executea.

21   CO. Switch HSA 1 Off. Enter and   Acknowleagea. Cma xxx,
      execute Cmd xxx.   HSA 1 OFF, executea.

22   Allan Park. Please confirm that   Acknowledged. Sensor
      Sensor Analog Data is now being   Analog Data is now peing
      transmitted to Ottawa.   transmittea on Line Number
                                             ----.

23   DR. Display Sensor Analog Data.   Acknowleagea. Sensor
                                             Analog Data is now being
                                             aisplayea.

24   (Mission Analyst will calculate
      Spin Rate and Thruster Firing Time
      for Part II of this Maneuver based
      on the displayed Sensor Analog Data.)

25   (Confirm that Mission Analysts
      have had sufficient Sensor Analog
      Data, then:)

      CO. Switch HSA 2 Off. Enter and   Acknowleagea. Cma xxx,
      execute Cmd xxx.   HSA 2 OFF, executea.

26   Allan Park and DR. That completes   Acknowleagea.
      our collection of Sensor Analog
      Data. We are now going to switcn
      RTM 1 (2) to Yaw Gyro Analog Mode
      and resume collection of Yaw Gyro
      Analog Data. Please leave your
      equipment configured to transmit
      and display Yaw Gyro Analog Data.

      NOTE: If Mission Analysts were
              unable to aetermine Spin
              Rate from the Sensor Analog
              Data, it may be necessary
              to Dwell on South Shorted
              Cell Current, DA 50004.

27   CO. Switch RTM 1 (2) to Yaw Gyro   Acknowleagea. Cmd xxx
      Analog Mode. (Use Data Word DA=20.)   (xxx), RTM 1 (2) to
                                             Yaw Gyro Analog Moae,
                                             executea.

Title: Despin to On-Orbit Mission
                                    Momentum (Dual BTX Operation)

STEP	SCC ACTION	STATION ACTION
28	Allan Park. Please confirm transmission of Yaw Gyro Analog Data on line to Ottawa.	Acknowledged. Yaw Gyro Analog Data is being transmitted on Line Number ---.
29	DR. Display Yaw Gyro Analog Data.	Acknowledged. Yaw Gyro Analog Data is now being displayed.

30   (Obtain Thruster Firing Time from
        Mission Analysts for second part
        of Maneuver.)

        Thrusters 6 and 9 will be fired
        for approximately 45 seconds
        for Part 2 of the Maneuver.

31   CO. Edit Special Sequence D   Acknowledged. Special
        according to Mission Conductor's   Sequence D edit is complete.
        input.

        (SE,SE,D,PW,___,TP,___,NP,___)   (Logkeeper sets the E/T
                                                 Clock to start at
        PW - pulse width in seconds   Thruster Firing Time.)
        TP - time between pulses in seconds
        NP - number of pulses

        The Backup Timer will be auto-
        matically reset by the Computer
        at 8-second intervals throughout
        the course of the Maneuver.

        NOTE: Thrusters 6 and 9 are
                 fired when the RMA Analog
                 Output indicates a positive
                 to negative zero crossing
                 of body yaw rate, and
                 continued for approximately
                 45 seconds as specified
                 by the Mission Conductor.

32   CO. Execute Special Sequence D on   a. Acknowledged. Special
        the Mission Conductor's signal.   Sequence D initiated.

        Standby.....MARK!   b. Cmd xxx, Fire Enabled
                                                     Thrusters, executed.
        (Observe, record and announce the
        completion of each sequence step.)

Procedure No. 2-22   Title: Despin to On-Orbit Mission
                                               Momentum (Dual BTX Operation)

STEP	SCC ACTION	STATION ACTION
33	(If a halt is requested by the Mission Conductor:)	
	CO. Halt the Maneuver Now!	a. AB,B1 initiated.
	(AB,B1)	b. Cmd xxx, Stop Firing Thrusters, executed.
		c. Maneuver halted. at:
		-- -- -- GMT.
	<u>OTHERWISE</u>	
	Maneuver will end on my signal (based on E/T Clock).	a. Cmd xxx, Stop Firing Thrusters, executed.
	10, 5, 4, 3, 2, 1, MARK!	b. Maneuver ended at:
		-- -- -- GMT.
34	(Obtain confirmation from Mission Conductor that additional Thruster Firing will not be required at this time, then:)	
	CO. Disable Thrusters 6 and 9. Enter and execute Cmd xxx.	Acknowledged. Cmd xxx, Thrusters 6 and 9 Disabled, executed.
35	Allan Park and DR. That completes this Maneuver and our requirement for Yaw Gyro Analog Data. Please restore your equipment to the normal configuration.	Acknowledged.
36	(Only if Yaw Gyro Analog Data will no longer be required:)	
	CO. Switch Off the Active Yaw Gyro. Enter and execute Cmd xxx.	Acknowledged. Cmd xxx, Yaw Gyro OFF, executed.
37	CO. Command RTM 1 (2) to PAM, High Priority Mode. (Use Data Word DA=30.)	Acknowledged. Cmd xxx (xxx), RTM 1 (2) to PAM High Priority Mode, executed.

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STEP	SCC ACTION	STATION ACTION
38	CO. Initiate PAM Data collection.	Acknowledged. PAM Data collection from RTM 1 (2) initiated.
39	Allan Park. Please report when Decom is locked on RTM 1 (2) PAM Data. (Continue with normal scheduled activities.)	Acknowledged. Decom is locked.

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MISSION AND STATION PROCEDURES MANUAL

CHAPTER 2

MISSION PROCEDURES

PART 5

COMMAND SEQUENCES

This part of the manual would describe the contents
of all Special Command Sequences required to support
the mission. The following Table of Contents lists
the command sequences which were required to support
the Anik B Transfer and Drift Orbit Procedures.

GENERAL

The following sequence descriptions apply to just
those sequences which will be utilized between the
time of Initial Acquisition in Revolution 1 and Pitch
Capture at the beginning of Drift Orbit.

It should also be noted that no sequence is final, in
that sequences can be edited and changed right up to
the time of execution, depending on the satellite
system configuration and state of operation.

Sequence descriptions can be obtained by querying the
particular sequence number. This is a mandatory
requirement prior to the execution of any sequence to
ensure that the sequence is still programmed to
perform the functions for which it was generated.
Refer to Procedure 4-008, Anik B Commanding Using
Normal Sequences, for a detailed description of how
sequences are generated, edited and generally used.

COMMAND SEQUENCE INDEX

SEQUENCE NO.	DESCRIPTION
1	Backup Timer Reset (Date)
2	Disable Auto SPM
3	Solar Array Forward Slewing
4	Fire the Primary Squibs
5	Fire the Backup Squibs
6	Enabling Thrusters 6, 8, 9 and 11
7	Enabling Thrusters 5, 7, 10 and 12
9	Dual Spin Turn
10	Apogee Kick Motor Firing (with Cmd Verification)
11	MWA Coastdown to 4000 rpm
12	Battery Charge Control
13	Battery Disconnect Sequence
14	Despin to 5 rpm Preliminary
18	Initial Commanding Sequence
26	Apogee Kick Motor Firing (No Command Verification)
27	Disabling Thrusters 5, 7, 10 and 12
28	Post Solar Array Deployment
30	Main Bus Loading
34	Disable Thrusters 7 and 10/Enable 5 and 12
35	Disable Thrusters 5 and 12/Enable 7 and 10
36	Solar Array Reverse Slewing
37	High Priority Dwell on Battery Currents Using RTM 1 (10 second wait)
38	High Priority Dwell on Battery Currents Using RTM 2 (10 second wait)
39	High Priority Dwell on North Shorted Cell Current Using RTM 1

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COMMAND SEQUENCE INDEX

SEQUENCE NO.	DESCRIPTION
40	High Priority Dwell on South Shorted Cell Current Using RTM 2
43	High Priority Dwell on Battery 1 Charge/Discharge Current Using RTM 1
44	High Priority Dwell on Battery 1 Charge/Discharge Current Using RTM 2
45	High Priority Dwell on Battery Currents Using RTM 2 (Pause Open)
46	High Priority Dwell on Battery Currents Using RTM 1 (Pause Open)
47	Initial Pitch Capture
48	Initial Mag Roll, Yaw Coil Switch-On
49	Despin to 5 rpm Preliminary (One BTX)
60	Enable Thruster 5/Disable 7
61	Enable Thruster 7/Disable 5
62	Enable Thruster 10/Disable 12
63	Enable Thruster 12/Disable 10
64	Low Priority Dwell on Solar Array, Battery Charge/Discharge, Main Bus, and North Shorted Cell Currents using RTM 1 (10 second wait)
65	Low Priority Dwell on Solar Array, Battery Charge/Discharge, Main Bus, and South Shorted Cell Currents using RTM 2 (10 second wait)
66	Low Priority Dwell on North Solar Panel Shorted Cell Current Using RTM 1
67	Low Priority Dwell on South Solar Panel Shorted Cell Current Using RTM 2
68	Low Priority Dwell on Solar Array, Battery Charge/Discharge, Main Bus, and North Shorted Cell Currents using RTM 1 (3 second wait)
69	Low Priority Dwell on Solar Array, Battery Charge/Discharge, Main Bus, and South Shorted Cell Currents using RTM 2 (3 second wait)

COMMAND SEQUENCE INDEX

SEQUENCE NO.	DESCRIPTION
70	Low Priority Dwell on Solar Array, Battery Charge/Discharge, Main Bus, and North Shorted Cell Currents using RTM 1 (Pause Open)
71	Low Priority Dwell on Solar Array, Battery Charge/ Discharge, Main Bus, and South Shorted Cell Currents using RTM 2 (Pause Open)

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MISSION AND STATION PROCEDURES MANUAL

CHAPTER 3

MISSION PROCEDURES

PART 1

WESTERN HEMISPHERE STATION PROCEDURES

This part would contain all the Station Procedures
applicable to the Western Hemisphere Tracking
Station. Attached is a copy of the Table of
Contents listing those procedures which were used to
support the Anik B Mission. Also included is a
sample of a typical Station Procedure for Telesat's
Western Hemisphere Tracking Station at Allan Park.

Chapter 3   Station Procedures

Part 1   Western Hemisphere Station Proceaures

Table of Contents

STATION PROCEDURE NO. 1-011   TITLE: Calibration of 1.5 KHz
                                                                    VCO/Discriminator
                                                                    System

RESPONSIBILITY: COMMAND OPERATOR
LOCATION: APK-TTAC

1.0   INTRODUCTION

This procedure provides the necessary instructions to calibrate the 1.5 KHz Analog Discriminator in the Data Room in Ottawa. The procedure should be performed before any data is sent to SCC via Order Wire.

2.0   PROCEDURE

STEP   ACTION

1.   a.   Verify that 1.5 KHz VCO is connected to a voice line to SCC Ottawa.

      b.   The 1.5 KHz VCO at APK has a built-in calibrator.

      c.   On the 1.5 KHz VCO, select the "-" position. This will apply -2.5 VOLTS at the input of the VCO and deviate the output to 1.25 KHz (250 Hz below centre).

      d.   Select the "0" position. The VCO will remain at centre frequency, 1.5 KHz.

      e.   Select the "+" position. This will apply +2.5 VOLTS at the input of the VCO and deviate the output to 1.75 KHz (250 Hz above centre).

      f.   This completes the calibration. Return the 1.5 KHz VCO to "ON" position.

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MISSION AND STATION PROCEDURES

CHAPTER 3

STATION PROCEDURES

PART 2

EASTERN HEMISPHERE STATION PROCEDURES

The Eastern Hemisphere Tracking Station Proceaures
would be similar to those requirea to support the
Western Hemisphere Tracking Station except for
differences in Ground Control Equipment.

Chapter 3   Station Procedures

Part 2   Eastern Hemisphere Station Procedures

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MISSION AND STATION PROCEDURES

CHAPTER 3

STATION PROCEDURES

PART 3

SATELLITE CONTROL CENTRE PROCEDURES

This part would contain all the Station Procedures
required to support the Satellite Control Centre.
Attached is a copy of the Table of Contents listing
those procedures which were used to support the Anik
B mission. Also included is a sample of a typical
Station Procedure for Telesat's Satellite Control
Centre in Ottawa.

Chapter 3   Station Procedures

Part 3   Satellite Control Centre Procedures

Table of Contents

Proceaure No. 3-011   Title: Analog Data Processing
                                       Via Voice Line (APK-SCC)

1. INTRODUCTION

This proceaure details the steps to set up and aisplay Sensor, PAM, Dwell, Apogee Motor Pressure, Yaw Gyro Analog ana Doppler Analog Data in the Data Centre.

NOTE: Set up in accordance with Allan Park Procedure 1-011 before proceeding.

2. EQUIPMENT REQUIRED

    a. Audio Line Monitor.

    b. Analog Discriminator EMR 4150.

    c. Low Pass Filter HP 5489A.

    d. Visicorder Honeywell 2206.

    e. Accudata D-C Amplifier Moaules Honeywell Moael 107.

    f. Honeywell 8-Channel Recorder - Model 2525.

3. PROCEDURE

STEP	ACTION	REMARKS
1.	SENSOR DATA	
	a. Turn power ON for units listed in para. 2.	All units ON.
	b. Set up the following patch connections:	
	(1) ANALOG DISC OUT to Filter A IN (input BNC).	
	(2) FILTER OUTPUT A to VISICORDER INPUT (Selectable).	AMP 480 PP
	(3) Remove back-up Wescom Rx and patch to Audio Line Monitor.	Patching complete.
	c. Set the Visicorder as follows:	
	(1) TRACE INTENSITY to maximum (black).	

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STEP			ACTION	REMARKS
1.	c.	(2)	GRID INTENSITY to maximum (black).	
		(3)	TIME to .1 (second).	
		(4)	SPEED to .8/20.	
		(5)	MULTIPLIER to X10.	
		(6)	POWER to LAMP.	Visicorder settings completed.
	d.		Set the Accudata D-C Amplifier as follows:	
		(1)	GAIN to .05.	
		(2)	CAL to full CCW position.	
		(3)	SHORT and REV buttons out.	Amplifier settings completed.
	e.		Request APK to patch sensor data from Anik B satellite on the back-up voice line.	Audible tones at the Audio Line Monitor.
	f.		Remove Audio Line Monitor patch and connect to ANAL jack.	
	g.		Set the Analog Discriminator OFF/CA/CD switch to CD.	Analog Discriminator front panel meter should deflect.
	h.		Set the HP 5489A Filter A controls as follows:	
		(1)	GAIN to 1.	
		(2)	CUTOFF (Hz) to 300.	Settings completed.
	i.		Obtain a chart record as follows:	
		(1)	Press Visicorder RECORD DRIVE.	Paper flows out.
		(2)	After 5 seconds, press RECORD DRIVE again to stop recording and paper flow.	After exposure, the sensor data is apparent.

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Procedure No. 3-011   Title: Analog Data Processing
                                        Via Voice Line (APK-SCC)

STEP   ACTION   REMARKS

1.   i.   (3)   Note data type and satellite   Sensor recording
                  I.D. on record (if a scope   completed.
                  presentation is required,
                  the paralleled filter O/P
                  may be input to the HP 181AR
                  oscilliscope).

2.   PAM DATA

      a.   Perform steps 1.a., 1.c., 1.d.,   Steps completed.
            and 1.g. as for sensor data.

      b.   Set up the following patch
            connections:

            (1)   ANAL DISC OUT to
                  Filter B (input BNC).

            (2)   FILTER OUTPUT B to   AMP 480 PP
                  Visicorder input.

            (3)   Line Rx patch to Audio   Patching complete.
                  Line Monitor.

      c.   Request APK to patch PAM   Audible tones at the
            data from Anik B satellite   Audio Line Monitor.
            on the back-up voice line.

      d.   Remove Audio Line Monitor patch   Analog Discriminator
            and connect to ANAL jack.   meter deflects.

3.   DWELL DATA

      a.   Perform steps 1.a., 1.c., 1.d.,
            and 1.g. as for sensor data.

      b.   Set up the following patch
            connections:

            (1)   ANAL DISC OUT to Filter
                  B (input BNC)

            (2)   FILTER OUTPUT B to selected
                  chart recorder input.

                        B - 43

STEP		ACTION	REMARKS
3.	b.	(3) Line Rx patch to Audio Line Monitor.	Patching completed.
	c.	Request APK to patch Dwell data from Anik B satellite on the back-up voice line.	Audible tones at the Audio Line Monitor.
	d.	Remove Audio Line Monitor patch and connect to ANAL jack.	Analog Discrimininator meter deflects.
	e.	If accurate amplitude determination is required for any specific channel, switch the satellite to dwell on the calibration zero, 2.5V and 5 V channels and scale the chart recorder accordingly.	Channels 124, 128 and 125 respectively.

4. APOGEE MOTOR PRESSURE/YAW GYRO ANALOG

    a.   Perform set up as for Dwell data.

	b.	Increase Chart Recorder speed to 10 MM.	Ensure that pen ink flows freely.

5. DOPPLER DATA

Doppler set-up and calibration are performed as part of the SCC READINESS CHECKS and during AMF pre-pass QUICK-CHECKS.

EQUIPMENT SET-UP AND CALIBRATION

	a.	Turn power ON for units listed on para. 2.	All units ON.
	b.	Set up the following patch connections:	
		(1) ANALOG DISC OUT to FILTER A IN (input BNC).	
		(2) FILTER OUTPUT A to 8-Channel Recorder input.	Display next to Apogee Motor Temp on Chart Recorder £2.

Procedure No. 3-011   Title: Analog Data Processing
                                     Via Voice Line (APK-SCC)

STEP		ACTION	REMARKS
5.		(3) Back-up Wescom Rx to Audio Line Monitor.	Patching complete.
	c.	Set the analog Discriminator OFF/CA/CD switch to CD.	
	d.	Set the HP 5489A Filter A controls as follows:	
		(1) GAIN to 1.	
		(2) CUTOFF (Hz) to 3.	
	e.	Set the HONEYWELL 8-Channel Chart Recorder as follows:	
		(1) Selected doppler recording channel gain (V/cm) to .2.	
		(2) Centre the pen using ZERO ATTENUATOR.	Coarse adjustment only
		(3) CHART SPEED TO 10 MM/MIN.	Annotate Chart Recorder.
	f.	Request APK to set up for doppler calibration on the back-up voice line. When audible tone changes, remove AUDIO LINE MONITOR jack and patch to ANAL. Request APK to perform the following:	
		(1) Simulate 0 kHz shift (0 volts); SCC adjusts chart recorder for 10 mm from left edge.	(Annotate as 0 kHz).
		(2) Simulate +3.0 kHz shift.	Pen shifts to extreme right edge (annotate as +3.0 kHz).
		(3) Return to 0 kHz.	
		(4) Simulate -1 kHz shift.	Pen shifts to extreme left edge (annotate as -1 kHz).
	g.	Return back-up line patch patching to normal and request APK to do likewise.	Maintain basic set-up until AMF.

STEP   ACTION   REMARKS

5.   SIMULATED DOPPLER

      Steps 5.a. to 5.f. (inclusive)
      are performed during the pre-pass
      QUICK-CHECKS and the doppler
      calibration instruments are main-
      tained in a "ready" configuration.
      At the Satellite Controller's
      request (approx. T-45 minutes),
      APK patches the simulated data
      (at 0 kHz) to SCC.

      h.   Patch back-up Wescom Rx
             to ANAL.

      i.   Position Video Camera to   Focus as required.
             display Solar Panel Current,
             Apogee Motor Temperature
             and Doppler data.

             At T-0, APK simulates a fre-   IF SCC/APK COORDINATOR
             quency shift of approximately   IS REQUIRED, DR-1 WILL
             1.4 kHz (1.4 volts) over a   USE DIAL-UP SYSTEM.
             period of 40 seconds.

      j.   At T-0, press MARKER pulse
             and annotate Chart Recorder
             to denote AMF.

      AMF DOPPLER

      Steps 5.a. to 5.f. are performed
      during the pre-pass QUICK-CHECKS.
      Upon completing the doppler
      calibration, APK prepares for real-
      time data transmission. At the
      Satellite Controller's request
      (approx. T-45 minutes), APK patches
      the doppler data to SCC.

      l.   Patch back-up Wescom Rx
             to ANAL.

      m.   Position Video Camera to   Focus as required.
             display Solar Panel Current,
             Apogee Motor Temperature
             and Doppler data.

Procedure No. 3-011   Title: Analog Data Processing
                                      Via Voice Line (APK-SCC)

STEP   ACTION   REMARKS

5.   NOTE: Shortly prior to AMF
               APK/DR-1 will adjust the
               doppler equipment for
               0 kHz shift.

        n.   At T-0, press MARKER pulse
               and annotate Chart
               Recorder to denote AMF.

        o.   When the doppler data is
               no longer required, request
               APK to return the back-up
               voice line to normal patching.

APPENDIX C

M-SAT

SATELLITE OPERATIONS PROCEDURES MANUAL

GENERAL OUTLINE

M-SAT

SATELLITE OPERATIONS PROCEDURES MANUAL

CHAPTER 1

SATELLITE CONTROL CENTRE

ROUTINE OPERATIONS

Satellite Control Centre personnel will use the
procedures contained in this Chapter for on-station
operation of the ground control equipment including
computers and peripheral equipment. Procedures
detailing satellite data handling, computer system
operating and restoring, message equipment operating
and other routines required in the operation of the
Control Centre are included. A partial index of
procedures is attached.

Chapter 1   Satellite Control Centre Routine Operations

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M-SAT

SATELLITE OPERATIONS PROCEDURES MANUAL

CHAPTER 2

SATELLITE COMMANDING PROCEDURES

PART 1

SATELLITE ROUTINE OPERATIONS

Satellite Control Centre personnel will use the procedures
contained in this part of the manual for on-station operation
of the satellite. Each procedure should deal with only one
major operation and should contain all information that the
Controller requires to ensure safe and efficient completion of
the operation. The procedure must be precise and concise and
when signed by the appropriate office, it is the Controller's
authority to proceed. A recommended procedure format and a
partial index of procedures is attached.

Chapter 2   Satellite Commanding Procedures

Part 1   Satellite Routine Operations

Table of Contents

Chapter 2   Satellite Commanding Procedures

Part 1   Satellite Routine Operations

Table of Contents

PROCEDURE TITLE: (This states the operation detailed in the procedure.)			PROCEDURE No. x.y.z (x,y,z identify Chapter, Part and Procedure No.)
DATE/APPROVED	DATE/APPROVED	DATE/APPROVED	ISSUE No.

1.   INTRODUCTION

(A brief statement outlining the purpose and content of the procedure.)

2.   GENERAL

(General information pertinent to the operation but not critical to its successful completion. This could include background information concerning the need for the operation, results of previous similar operations, etc.)

3.   SCHEDULE

(If applicable, the schedule or frequency for performing this operation is stated here, e.g., quarterly redundancy testing, battery reconditioning, etc.)

4.   PRELIMINARY SET-UP

(This paragraph describes any equipment set-up, configuration or special status that must exist prior to proceeding with the satellite operation.)

5.   CONSTRAINTS

(All satellite operating constraints pertinent to this operation and which must be observed in the course of the operation are detailed here.)

Date of Issue

REVISIONS										PROCEDURE CONTAINS PAGES
1	2	3	4	5	6	7	8	9	C - 6	TO

6.   OPERATION

STEP	ACTION	REMARKS / RESPONSE
	(The operation is detailed in step format. The Controller performs the steps in chronological order unless clearly directed otherwise.)	(This column contains explanatory detail, expected results, spaces to enter execution times, etc.)
1.	(Each step must be clear, concise and precise.)	

(Date of issue)

M-SAT

SATELLITE OPERATIONS PROCEDURES

CHAPTER 2

SATELLITE COMMANDING PROCEDURES

PART 2

SATELLITE SPECIAL OPERATIONS

This part will contain non-routine operations, the
need for which might not become known prior to
gaining operating experience. These could involve
non-emergency satellite anomalies such as
reflections in the earth sensors.

Chapter 2   Satellite Commanding Procedures

Part 2   Satellite Special Operations

Table of Contents

M-SAT

SATELLITE OPERATIONS PROCEDURES MANUAL

CHAPTER 2

SATELLITE COMMANDING PROCEDURES

PART 3

SATELLITE EMERGENCY OPERATIONS

This part would contain all the procedures required
to recover from the various failure modes considered
hazardous to the health of the satellite. This
procedures would detail the action to be taken in
response to a satellite emergency. The actions
described are usually an engineering best-estimate
in the absence of an actual occurrence.

Chapter 2   Satellite Commanding Procedures

Part 2   Satellite Emergency Operations

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APPENDIX D

M-SAT

TTAC OPERATING AND MAINTENANCE PROCEDURES MANUAL

GENERAL OUTLINE

M-SAT

TTAC OPERATING AND MAINTENANCE PROCEDURES MANUAL

CHAPTER 1

TTAC EQUIPMENT OPERATING PROCEDURES

PART 1

ROUTINE OPERATING PROCEDURES

This part contains the procedures which will be used
by the Technicians responsible for operating the
TTAC station. If the TTAC facility is integrated
with the Satellite Control Centre, the Satellite
Controller will use the procedures. The actual
procedures required will depend upon the equipment
and configuration of the station. A partial index
of typical procedures is attached.

Chapter 1   TTAC Equipment Operating Procedures

Part 1   Routine Operating Procedures

Table of Contents

M-SAT

TTAC OPERATING AND MAINTENANCE PROCEDURES MANUAL

CHAPTER 1

TTAC EQUIPMENT OPERATING PROCEDURES

PART 2

EMERGENCY PROCEDURES

This part of the manual would provide the procedures
which would be used by the TTAC Technician in the
event of an emergency involving the GCE and in some
instances, the satellite. If the TTAC facility is
integrated with the Satellite Control Centre, the
Satellite Controller will use the procedures. The
actual procedures required will depend upon the
equipment and configuration of the station. A
partial index of typical procedures is attached.

Chapter 1   TTAC Equipment Operating Procedures

Part 2   Emergency Procedures

Table of Contents

CHAPTER 2

SATELLITE COMMANDING PROCEDURES

Satellite Control Centre personnel will use these
procedures for on-station operation of the satellite. Each
procedure should deal with only one major operation and
should contain all information that the Controller requires
to ensure safe and efficient completion of the operation.
The procedure must be precise and concise and when signed
by the appropriate office it is the Controller's authority
to proceed. A recommended procedure format and a partial
index of procedures is attached.

CHAPTER 2

TTAC EQUIPMENT OPERATING PROCEDURES

This part of the manual would provide the procedures
which would be used by the TTAC Technicians
responsible for maintaining the TTAC station. In many
cases, the manual supplied with the equipment will
contain the necessary maintenance data and a separate
procedure will not be required. For this reason, an
index of procedures can only be determined after the
equipment has been selected.

Chapter 2   TTAC Equipment Operating Procedures

Table of Contents

PROCEDURE NO.	TITLE	ISSUE NO.	REVISION NO.

APPENDIX E

M-SAT

SATELLITE CONTROL OPERATIONS MANUAL

GENERAL OUTLINE

LIST OF REVISIONS

DATE	PAGE NO.	DATE	PAGE NO.

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CHAPTER	PARAGRAPH	TITLE	PAGE NO.

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LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

CHAPTER 1

SATELLITE SYSTEM DESCRIPTION

1.1 INTRODUCTION

1.1.1   One or more paragraphs to describe the contents and purpose of this technical manual.

1.2 FUNCTIONAL DESCRIPTION

1.2.1   Provide a basic description of the satellite to major subassembly level referenced to an overall subsystem functional block diagram.

Figure 1-1 M-SAT - Functional Block Diagram

1.2.2   Included will be a basic diagram of the following subsystems:

   a.   Communications, including the

      (1)   Canadian Military Communications Segment,

      (2)   Maritime Mobile Communications Segment, and

      (3)   Commercial Mobile Communications Segment.

   b.   Power, including the

      (1)   Solar Array Segment, and

      (2)   Batteries and related charge/discharge control circuits.

   c.   Telemetry and Command.

   d.   Intersatellite Link.

   e.   Pyrotechnics.

   f.   Attitude Control.

   g.   Reaction Control.

   h.   Thermal Control.

1.3 PHYSICAL DESCRIPTION

1.3.1   Provide an overall physical description of the satellite.
This description could reference both tables and figures
which would list all physical characteristics and also
depict the physical location and interrelationship of all
satellite subassemblies.

CHARACTERISTIC	PARAMETER

Table 1-1 M-SAT - Physical Characteristics

Figure 1-2 M-SAT - Subassembly Location Diagram

1.4 ELECTRICAL CHARACTERISTICS

1.4.1   List all pertinent electrical characteristics to major
subassembly level. Data to include expected stationkeeping
performance, pointing errors, communications subsystem
performance and beam coverage, etc.

CHARACTERISTIC	PARAMETER

Table 1-2 M-SAT - Electrical Characteristics

1.5 OTHER PERTINENT DATA AT OVERALL SATELLITE LEVEL

CHAPTER 2

COMMUNICATIONS SUBSYSTEM

ALTHOUGH INCLUDED AS A CHAPTER IN THIS OUTLINE, IT IS RECOMMENDED THAT THIS CHAPTER BE BROKEN OUT AND SUPPLIED UNDER SEPARATE COVER AS PART 2 AND 3 OF THE SATELLITE OPERATION INSTRUCTION MANUAL. PART 2 COULD INCLUDE ALL INFORMATION RELATED TO THE CANADIAN MILITARY COMMUNICATIONS SATELLITE SYSTEM (CMCSS) AND PART 3, ALL INFORMATION RELATED TO THE COMMERCIAL & MARITIME COMMUNICATIONS PACKAGES.

2.1   GENERAL

2.1.1   A paragraph describing the purpose and content of this chapter.

2.2   FUNCTIONAL DESCRIPTION

2.2.1   A basic description of the communications subsystem to a functional block diagram level.

A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram.

Figure 2-1   Communications Subsystem - Functional Block Diagram

2.2.2   A typical sample of the communications subsystems identified in the block diagram is as follows:

a.   CMCSS UHF Segment.

b.   CMCSS SHF Segment.

c.   CMCSS EHF Segment.

d.   Maritime Mobile Communications.

e.   Commercial Mobile Communications.

2.3   ELECTRICAL CHARACTERISTICS

2.3.1   A paragraph to introduce Table 2-1 which shall list the electrical characteristics of all the various communications subsystems including expected performance at BOL and EOL. The power monitor calibration curves should also be referenced in this paragraph.

CHARACTERISTIC	PARAMETER

Table 2-1   Communications Subsystem - Electrical Characteristics

Figure 2-2   Power Monitor Calibration Curves (Specifics)

2.4 COMMUNICATIONS SUBSYSTEM RELATED COMMANDS

2.4.1   Text to introduce Table 2-2 which will provide a list of commands for each of the communications subsystems identified on Figure 2-1.   Abbreviated descriptions for each command listed would also be provided.

FIG 2-1 DESIGNATION	CMD NO.	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 2-2   Communications Subsystem - Related Commands

2.5 COMMUNICATIONS SUBSYSTEM RELATED TELEMETRY DATA

2.5.1   Text to introduce Table 2-3 which will provide a list of telemetry words for each of the communications subsystems identified on Figure 2-1.   Abbreviated descriptions for each telemetry word listed would also be provided.

FIG 2-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 2-3   Communications Subsystem - Related Telemetry Data

2.6 OPERATING INSTRUCTIONS - CMCSS UHF

PARAGRAPHS 2.6.1 THRU 2.6.7 FOLLOWING, WOULD BE REPEATED FOR EACH COMMUNICATIONS SUBSYSTEM AS APPLICABLE.

2.6.1   RECEIVER SWITCHING AND RELATED SWITCH CONTROL

2.6.1.1   Text describing the correct method to switch receivers and related switches.

2.6.1.2   Where applicable, text should include:

a.   List of telemetry data points which, if monitored, will provide an indication of change.

b.   Recommended event sequences where applicable in order to maintain near continuous communications traffic without jeopardizing the health of the satellite.

c.   All special instructions related to this event plus justification where applicable.

2.6.2   RECEIVER HEATER CONTROL

2.6.2.1   Text describing the circumstances related to communications receiver heater switching.

2.6.2.2   Where applicable, text should include all information referenced in para. 2.6.1.2, items a. and c.

2.6.3   COMMUNICATIONS CHANNEL CONTROL

2.6.3.1   Text describing the correct method to re-route communications channels.

2.6.3.2   Where applicable, text should include all information referenced in para. 2.6.1.2, items a., b. and c.

2.6.4   GAIN CONTROL

2.6.4.1   Text describing the correct method to operate the many gain control (variable attenuator) circuits.

2.6.4.2   Where applicable, text should include all intormtion referenced in para. 2.6.1.2, items a., b. and c.

2.6.5   TWTA AND POWER AMPLIFIER CONTROL

2.6.5.1   Text describing the correct method to switch TWTAs.

2.6.5.2   Where applicable, text should include all information
            referenced in para. 2.6.1.2, items a., b. and c.

2.6.6   TWTA HEATER CONTROL

2.6.6.1   Text describing the correct method to switch TWTA heaters.

2.6.6.2   Where applicable, text should include all information
            referenced in para. 2.6.1.2, items a., b. and c.

2.6.7   OTHER COMMUNICATIONS SUBSYSTEM RELATED OPERATING
            INSTRUCTIONS AS APPLICABLE

CHAPTER 3

POWER SUBSYSTEM

3.1   GENERAL

3.1.1   A paragraph describing the purpose and content of this chapter.

3.2   FUNCTIONAL DESCRIPTION

3.2.1   A basic description of the power subsystem to a functional block diagram level.

> A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram

Figure 3-1 Power Subsystem - Functional Block Diagram

3.2.2   Included in this description will be coverage of all aspects of the battery charge, discharge and reconditioning units; the bus limiter circuits; and the solar array circuitry including the various modes of the array drive electronics, the purpose and use of the array sun sensors, plus any other areas of the solar array requiring specific operational procedures.

3.3   ELECTRICAL CHARACTERISTICS

3.3.1   A paragraph to introduce Table 3-1 which shall list all power subsystem electrical characteristics including expected performance at BOL and EOL.

CHARACTERISTIC	PARAMETER

Table 3-1 Power Subsystem - Electrical Characteristics

3.4   POWER SUBSYSTEM RELATED COMMANDS

3.4.1   Text to introduce Table 3-2 which will provide a list of all commands related to the power subsystem as identified in

Figure 3-1. This table shall be divided to group all
commands related to the battery circuits under one heading,
commands related to the solar array under a second heading
and other peripheral commands under a third heading.
Abbreviated descriptions for each command listed would also
be provided.

FIG 3-1 DESIGNATION	CMD NO.	DESCRIPTION
1	xxx	-- -- -- -- -- -- --
2	xxx	-- -- -- -- -- -- --

Table 3-2 Power Subsystem - Related Commands

3.5 POWER SUBSYSTEM RELATED TELEMETRY DATA

3.5.1 Text to introduce Table 3-3 which will provide a list of all
telemetry words related to the power subsystem as identified
on Figure 3-1. Abbreviated descriptions for each telemetry
word listed would also be provided.

FIG 3-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION
1	xxx	-- -- -- -- --
2	xxx	-- -- -- -- --

Table 3-3 Power Subsystem - Related Telemetry Data

3.6 OPERATING INSTRUCTIONS

3.6.1 BATTERY CHARGE CONTROL

3.6.1.1 Text describing the correct method to arrive at the
following charge configurations:

a. Trickle.

b. Medium.

c. High.

d. Recommended charge combinations.

3.6.1.2 Where applicable, the text should also include:

a. Any special instructions related to this event plus an
explanation as to why these special instructions are
required.

b. Any desirable event sequence which should be followed to promote satellite (battery) health.

c. List of all responses (telemetry data) which should be monitored to confirm event has actually occurred as planned.

3.6.2 BATTERY RECONDITIONING

3.6.2.1 Text describing the prescribed method of reconditioning the batteries, including AH OUT Vs AH IN, temperature/voltage profiles, etc. Text should also include instructions as to how the remaining two batteries are to be maintained during this period.

3.6.2.2 Where applicable, text should also include all information referenced in para 3.6.1.2, items a., b., and c.

3.6.3 BATTERY MANAGEMENT - ECLIPSE SEASON

3.6.3.1 Text describing the prescribed method to manage the batteries during the eclipse season including any special instruction related to dual and single battery operation.

3.6.3.2 Where applicable, text should also include all information referenced in para 3.6.1.2, items a., b., and c.

3.6.4 BATTERY DISCHARGE REGULATORS

3.6.4.1 Text describing the prescribed method to switch discharge regulators for redundancy check/unit failure correction purposes.

3.6.4.2 Where applicable, text should also include all information referenced in para 3.6.1.2, items a., b., and c.

3.6.5 BATTERY HEATER CONTROLLER AND HEATER SWITCHING

3.6.5.1 Text describing the prescribed method to switch battery heaters and related controllers for redundancy check/unit failure purposes.

3.6.5.2 Where applicable, text should also include all information referenced in para 3.6.1.2, items a., b., and c.

3.6.6   SHUNT MODULATOR SWITCHING

3.6.6.1   Text describing the prescribed method to switch shunt
           modulators for redundancy check/unit failure purposes.

3.6.6.2   Where applicable, text should also include all information
           referenced in para 3.6.1.2, items a., b., and c.

3.6.7   LOAD INVERTER SWITCHING

3.6.7.1   Test describing the prescribed method to switch load
           inverters for redundancy check/unit failure purposes.

3.6.7.2   Where applicable, text should also include all information
           referenced in para 3.6.1.2, items a., b., and c.

3.6.8   SOLAR ARRAY DRIVE CONTROL

3.6.8.1   Text describing the various drive modes available (normal
           forward, reverse, slew) and the prescribed method to select/
           change modes. Also any special instructions related to
           switching array drive electronics as related to redundancy
           check/unit failure conditions.

3.6.8.2   Where applicable, text should also include all information
           referenced in para 3.6.1.2, items a., b., and c.

3.6.9   ARRAY SUN SENSOR CONTROL

3.6.9.1   Text describing, where applicable, the correct method to
           select/switch sun sensors for redundancy check/unit failure
           purposes.

3.6.9.2   Where applicable, text should also include all information
           referenced in para 3.6.1.2, items a., b., and c.

3.6.10   SOLAR DRUM CURRENT CAPABILITY DETERMINATION

3.6.10.1   Text describing the recommended method to determine solar
           drum current capability. A graph depicting expected solar
           drum current Vs time (years) would be desirable.

3.6.10.2 Where applicable, text should also include all information
          referenced in para 3.6.1.2, items a., b., and c.

3.6.11   OTHER POWER SUBSYSTEM RELATED OPERATING INSTRUCTIONS

CHAPTER 4

COMMAND AND TELEMETRY SUBSYSTEM

4.1   GENERAL

4.1.1   A paragraph describing the purpose and content of this chapter.

4.2   FUNCTIONAL DESCRIPTION

4.2.1   A basic description of the command and telemetry (C & T) subsystem to a functional block diagram level.

> A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram.

Figure 4-1   C & T Subsystem - Functional Block Diagram

4.3   C & T SUBSYSTEM RELATED COMMANDS

4.3.1   Text to introduce Table 4-2 which will provide a list of all commands related to the C & T subsystem as identified on Figure 4-1. Abbreviated descriptions for each command listed would also be provided.

FIG 4-1 DESIGNATION	CMD NO.	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 4-1   C & T Subsystem - Related Commands

4.4   C & T SUBSYSTEM RELATED TELEMETRY DATA

4.4.1   Text to introduce Table 4-2 which will provide a list of all telemetry words related to the C & T subsystem as identified on Figure 4-1. Abbreviated descriptions for each telemetry word listed would also be provided.

FIG 4-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 4-2 C & T Subsystem - Related Telemetry Data

4.5 OPERATING INSTRUCTIONS

4.5.1 ENCODER/SUBCOMMUTATOR SWITCHING VS MODE SELECTION

4.5.1.1 Text describing the correct method to configure the encoders in the following modes:

    a.   PCM.

    b.   PCM Dwell.

    c.   FMRT (sensor).

    d.   Yaw Gyro.

    e.   Ranging.

    f.   Normal/Cross-strap.

4.5.2 SENSOR DATA REFERENCE CONTROL

4.5.2.1 Text describing the selection of the three reference sources as applied to sensor data collection:

    a.   NES.

    b.   SES.

    c.   SUN.

4.5.3 RANGING

4.5.3.1 Text describing operating considerations in ranging.

4.5.4 YAW GYRO

4.5.4.1 Text describing the correct method to collect yaw gyro data and the expected results under various operating conditions.

4.5.5   TELEMETRY TRANSMITTER CONTROL

4.5.5.1   A detailed description of the low/high power modes and the
            recommended method of switching from low to high power. A
            list of the available options and an explanation of the
            preferred operating high power configuration would also be
            desirable.

4.5.5.2   Where applicable, text should include:

            a. List of telemetry data points (PCM data) which, if
                monitored, will provide an indication of change.

            b. Recommended event sequences where applicable in order to
                maintain near continuous communications traffic without
                jeopardizing the health of the satellite.

            c. All special instructions related to this event plus
                justification where applicable.

4.5.6   COMMAND DECODER SELECTION

4.5.6.1   A paragraph stressing the importance of selecting the correct
            command decoder (spinning/despun) especially since command
            numbers are common to both.

4.5.7   MEMORY LOAD COMMANDS

4.5.7.1   Text describing those units which require memory load
            commands plus the proper method to construct and execute the
            commands.

4.5.8   OTHER COMMAND AND TELEMETRY SUBSYSTEM-RELATED OPERATING
            INSTRUCTIONS

CHAPTER 5

STEERABLE SPOT BEAM ANTENNA

5.1   GENERAL

5.1.1   A paragraph describing the purpose and content of this chapter.

5.2   FUNCTIONAL DESCRIPTION

5.2.1   A basic description of the Steerable Spot Beam Antenna circuitry to a functional block diagram level.

A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram

Figure 5-1 Steerable Spot Beam Antenna - Functional Block Diagram

5.3   ELECTRICAL CHARACTERISTICS

5.3.1   A paragraph to introduce Table 5-1 which shall list all steerable spot beam electrical characteristics including expected performance under various operational conditions, eg. maneuvers.

CHARACTERISTIC	PARAMETER

Table 5-1 Steerable Spot Beam Antenna
- Electrical Characteristics

5.4   STEERABLE SPOT BEAM ANTENNA RELATED COMMANDS

5.4.1   Text to introduce Table 5-2 which will provide a list of all commands related to the Steerable Spot Beam Antenna as identified on Figure 5-1. Abbreviated descriptions for each command listed would also be provided.

FIG 5-1 DESIGNATION	CMD NO.	DESCRIPTION				
1	XXX	--	--	--	--	--
2	XXX	--	--	--	--	--

Table 5-2   Steerable Spot Beam Antenna - Related Commanas

5.5   STEERABLE SPOT BEAM ANTENNA RELATED TELEMETRY DATA

5.5.1   Text to introduce Table 5-3 which will provide a list of all telemetry words related to the Steerable Spot Beam Antenna as identified on Figure 5-1. Abbreviated descriptions for each telemetry word listed would also be proviaea.

FIG 5-1 DESIGNATION	TELEMERTY WORD	DESCRIPTION				
1	XXX	--	--	--	--	--
2	XXX	--	--	--	--	--

Table 5-3   Steerable Spot Beam Antenna - Relatea Telemetry Data

5.6   OPERATING INSTRUCTIONS

5.6.1   ANTENNA E-W CONTROL

5.6.1.1   Text detailing the correct method to control the E-W positioning of the antenna relatea spot beams.

5.6.1.2   Where applicable, text should include:

a.   List of telemetry data points (PCM aata) which, it monitorea, will proviae an inaication or change.

b.   Recommended event sequences where applicable in oraer to maintain near continuous communications trarric without jeopardizing the healtn or the satellite.

c.   All special instructions relatea to this event plus justification where applicable.

5.6.2   ANTENNA N-S CONTROL

5.6.2.1   Text describing the correct methoa to control the N-S positioning of the antenna related spot beams.

5.6.2.2   Where applicable, text should include all information
           referenced in para. 5.6.1.2, items a., b. and c.

5.6.3   OTHER STEERABLE SPOT BEAM ANTENNA INSTRUCTIONS AS APPLICABLE

CHAPTER 6

INTERSATELLITE LINK ANTENNA POSITIONING ELECTRONICS

6.1   GENERAL

6.1.1   A paragraph describing the purpose and content of this
         chapter.

6.2   FUNCTIONAL DESCRIPTION

6.2.1   A basic description of the Intersatellite Link Antenna
         Positioning Electronics to a functional block diagram level.

A functional block diagram to a level sufficient to identify
those units which can be commanded and from which telemetry
data is available. Related commands and telemetry data words
should be identified on the diagram.

Figure 6-1 Intersatellite Link Antenna Positioning Electronics
            - Functional Block Diagram

6.3   ELECTRICAL CHARACTERISTICS

6.3.1   A paragraph to introduce Table 6-1 which shall list the
         Intersatellite Link Antenna Positioning Electronics
         electrical characteristics including expected performance
         under various operational conditions, eg. maneuvers.

CHARACTERISTIC	PARAMETER

Table 6-1 Intersatellite Link Antenna Positioning Electronics
           - Electrical Characteristics

6.4   INTERSATELLITE LINK ANTENNA POSITIONING ELECTRONICS
         RELATED COMMANDS

6.4.1   Text to introduce Table 6-2 which will provide a list of all
         commands related to the Intersatellite Link Antenna
         Positioning Electronics as identified on Figure 6-1.
         Abbreviated descriptions for each command listed would also be
         provided.

FIG 6-1 DESIGNATION	CMD NO.	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 6-2   Intersatellite Link Antenna Positioning Electronics
- Related Commands

6.5   INTERSATELLITE LINK ANTENNA POSITIONING ELECTRONICS RELATED TELEMETRY DATA

6.5.1   Text to introduce Table 6-3 which will provide a list of all telemetry words related to the Intersatellite Link Antenna Positioning Electronics as identified on Figure 6-1. Abbreviated descriptions for each telemetry word listed would also be provided.

FIG 6-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 6-3   Intersatellite Link Antenna Positioning Electronics
- Related Telemetry Data

6.6   OPERATING INSTRUCTIONS

6.6.1   ANTENNA POSITIONING CONTROL

6.6.1.1   Text describing the correct method of stepping the antenna drive in order to establish proper communications with a second satellite.

6.6.1.2   Where applicable, text should include:

a.   List of telemetry data points (PCM data) which, if monitored, will provide an indication of change.

b.   Recommended event sequences where applicable in order to maintain near continuous communications traffic without jeopardizing the health of the satellite.

c.   All special instructions related to this event plus justification where applicable.

6.6.2   FREQUENCY AND POLARIZATION CONTROL

6.6.2.1   Text describing the correct method to switch the antenna
           frequency and polarization capabilities in order to match
           that of a second satellite.

6.6.2.2   Where applicable, text should include all information
           referenced in para. 6.6.1.2, items a., b. and c.

6.6.3   OTHER INTERSATELLITE LINK ANTENNA POSITIONING ELECTRONICS
           RELATED OPERATING INSTRUCTIONS AS APPLICABLE

ATTITUDE CONTROL

7.1   GENERAL

7.1.1   A paragraph describing the purpose and content of this chapter.

7.2   FUNCTIONAL DESCRIPTION

7.2.1   A basic description of the Attitude Control Electronics to a functional block diagram level.

A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram.

Figure 7-1 Attitude Control Electronics - Functional Block Diagram

7.2.2   Some of the assemblies which should be covered in this description are:

    a.   Solar array sun sensors.

    b.   Two-axis infra-red earth sensors.

    c.   Sun acquisition sensors.

    d.   Digital sun sensors.

    e.   Gyro circuitry.

    f.   Thruster drive electronics.

    g.   Momentum wheel drive electronics.

    h.   Momentum wheels.

    i.   Electronics control unit.

    j.   Apogee engine drive electronics.

7.3   ELECTRICAL CHARACTERISTICS

7.3.1   A paragraph to introduce Table 7-1 which shall list all Attitude Control Electronics electrical characteristics including expected performance at BOL and EOL.

CHARACTERISTIC	PARAMETER

Table 7-1   Attitude Control Electronics
- Electrical Characteristics

7.4   ATTITUDE CONTROL ELECTRONICS RELATED COMMANDS

7.4.1   Text to introduce Table 7-2 which will provide a list of all
           commands related to the Attitude Control Electronics as
           identified on Figure 7-1. Abbreviated descriptions for each
           command listed would also be provided.

FIG 7-1 DESIGNATION	CMD NO.	DESCRIPTION					
1	xxx	-- --	--	--	--	--	--
2	xxx	-- --	--	--	--	--	--

Table 7-2   Attitude Control Electronics - Related Commands

7.5   ATTITUDE CONTROL ELECTRONICS RELATED TELEMETRY DATA

7.5.1   Text to introduce Table 7-3 which will provide a list of all
           telemetry words related to the Attitude Control Electronics
           as identified on Figure 7-1. Abbreviated descriptions for
           each telemetry word listed would also be provided.

FIG 7-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

Table 7-3   Attitude Control Electronics - Related Telemetry Data

7.6   OPERATING INSTRUCTIONS

7.6.1   MOMENTUM WHEEL DRIVE ELECTRONICS SELECTION

7.6.1.1   Text describing the correct method to select and/or switch
           Momentum Wheel Drive Electronics for either normal
           operations or redundancy checking.

7.6.1.2   Where applicable, the text should also include:

a. Any special instructions related to this event plus an explanation as to why these special instructions are required.

b. Any desirable event sequence which should be followed to promote satellite health plus ensure that the satellite remains despun.

c. List of all responses (telemetry data) which should be monitored to confirm event has actually occurred as planned.

7.6.2 MOMENTUM WHEEL SELECTION

7.6.2.1 Text detailing the correct method to select the redundant momentum wheel for redundancy test purposes.

7.6.2.2 Where applicable, text should include all information referenced in para 7.6.1.2, items a., b., and c.

7.6.3 SENSOR SELECTION

7.6.3.1 Text describing the correct method to select/switch sensors plus precautions related to sensor reconfiguration.

7.6.3.2 Where applicable, text should include all information referenced in para 7.6.1.2, items a., b., and c.

7.6.4 YAW GYRO SELECTION

7.6.4.1 Text describing the correct method to select/switch yaw gyros plus all the precautions which should be taken when switching.

7.6.4.2 Where applicable, text should include all information referenced in para 7.6.1.2, items a., b., and c.

7.6.5 THRUSTER DRIVE ELECTRONICS

7.6.5.1 Text describing the correct method to select/switch/operate the Thruster Drive Electronics.

7.6.5.2 Where applicable, text should include all information referenced in para 7.6.1.2, items a., b., and c.

7.6.6 MOMENTUM ADJUSTMENT

7.6.6.1   Text describing the correct method to transfer momentum from
           the reaction wheels to the spacecraft. Graph portraying
           thruster pulses Vs wheel speed would be desirable.

7.6.6.2   Where applicable, text should include all information
           referenced in para 7.6.1.2, items a., b., and c.

7.6.7   NUTATION DAMPING

7.6.7.1   Text describing the correct method to detect and reduce
           nutation. Text should also provide a summary of expected
           results Vs time.

7.6.7.2   Where applicable, text should include all information
           referenced in para 7.6.1.2, items a., b., and c.

7.6.8   ELECTRONICS CONTROL UNIT

7.6.8.1   Text describing the correct method to configure and operate
           the Electronics Control Unit.

7.6.8.2   Where applicable, text should include all information
           referenced in para 7.6.1.2, items a., b., and c.

7.6.9   REACTION WHEEL FAILURE DETECTION CIRCUITRY CONTROL

7.6.9.1   Text describing how to detect a failed Reaction Wheel and
           what steps to take to recover from same.

7.6.9.2   Where applicable, text should include all information
           referenced in para 7.6.1.2, items a., b., and c.

7.6.10   OTHER ATTITUDE CONTROL RELATED OPERATING INSTRUCTIONS AS
           APPLICABLE

CHAPTER 8

REACTION CONTROL

8.1   GENERAL

8.1.1   A paragraph describing the purpose and content of this chapter.

8.2   FUNCTIONAL DESCRIPTION

8.2.1   A basic description of the Reaction Control subsystem to a functional block diagram level.

A functional block diagram to a level sufficient to identify those units which can be commanded and from which telemetry data is available. Related commands and telemetry data words should be identified on the diagram

---

Figure 8-1   Reaction Control System   - Functional Block Diagram

8.2.2   Some of the units which will be covered in this description are:

    a.   Reaction control thrusters.

    b.   Latching valves.

    c.   Pyrotechnic valves.

    d.   Fuel tanks.

    e.   Pressurant tanks.

8.3   ELECTRICAL CHARACTERISTICS

8.3.1   A paragraph to introduce Table 8-1 which shall list all Reaction Control subsystem electrical characteristics including expected performance at BOL and EOL.

CHARACTERISTIC	PARAMETER

Table 8-1   Reaction Control Subsystem - Electrical Characteristics

8.4   REACTION CONTROL SUBSYSTEM RELATED COMMANDS

8.4.1   Text to introduce Table 8-2 which will provide a list of all
           commands related to the Reaction Control subsystem as
           identified in Figure 8-1. Abbreviated descriptions for each
           command listed would also be provided.

FIG 8-1 DESIGNATION	CMD NO.	DESCRIPTION					
1	xxx	-- --	--	--	--	--	--
2	xxx	-- --	--	--	--	--	--

           Table 8-2   Reaction Control Subsystem - Related Commands

8.5   REACTION CONTROL SUBSYSTEM RELATED TELEMETRY DATA

8.5.1   Text to introduce Table 8-3 which will provide a list of all
           telemetry words related to the Reaction Control subsystem as
           identified on Figure 8-1. Abbreviated descriptions for each
           telemetry word listed would also be provided.

FIG 8-1 DESIGNATION	TELEMETRY WORD	DESCRIPTION				
1	xxx	--	--	--	--	--
2	xxx	--	--	--	--	--

           Table 8-3   Reaction Control Subsystem - Related Telemetry Data

8.6   OPERATING INSTRUCTIONS

8.6.1   VALVE CONTROL

8.6.1.1   Text describing the recommended RCS valve configuration and
           instructions related to any changes which may be required to
           that configuration. Test should also describe what methods
           are available to circumvent a possible valve/line/tank/
           thruster failure.

8.6.1.2   Where applicable, the text should also include:

           a.   Any special instructions related to this event plus an
                explanation as to why these special instructions are
                required.

           b.   Any desirable event sequence which should be followed
                to promote satellite health.

c.   List of all responses (telemetry data) which should be monitored to confirm event has actually occurred as planned.

8.6.2   THRUSTER CONTROL

8.6.2.1   Text describing the purpose and use of each of the 20 thrusters. Text should also describe all contingency plans to circumvent the possible failure of one or more thrusters.

8.6.2.2   Where applicable, text should include all information referenced in para 8.6.1.2, items a., b., and c.

8.6.3   HEATER CONTROL

8.6.3.1   Text explaining how best to monitor RCS Tank Temperature in the absence of tank sensors and related telemetry.

8.6.3.2   Text describing what precautions should be taken in the absence of RCS heaters.

8.6.4   PLUME IMPINGEMENT CALIBRATION

8.6.4.1   Text explaining the correct method to perform a plume impingement calibration including any data related to expected thruster performance for all positions of the solar array. The expected optimum solar array position Vs possible power limitations should also be highlighted.

8.6.4.2   Where applicable, text should include all information referenced in para 8.6.1.2, items a., b., and c.

8.6.5   N-S STATIONKEEPING MANEUVERS

8.6.5.1   Text explaining the correct method to perform a N-S station-keeping maneuver including any data related to expected satellite performance Vs thruster firing Vs solar array position.

8.6.5.2   Where applicable, text should include all information referenced in para 8.6.1.2, items a., b., and c.

8.6.6   E-W STATIONKEEPING MANEUVERS

8.6.6.1   Text explaining the correct method to perform an E-W
            stationkeeping maneuver including any data related to
            expected satellite performance Vs thruster firing.

8.6.6.2   Where applicable, text should include all information
            referenced in para 8.6.1.2, items a., b., and c.

8.6.7   ATTITUDE MANEUVERS

8.6.7.1   Text explaining the correct method to perform an attitude
            correction maneuver including any data related to expected
            satellite performance Vs thruster firing.

8.6.7.2   Where applicable, text should include all information
            referenced in para 8.6.1.2, items a., b., and c.

8.6.8   MOMENTUM ADJUSTMENT MANEUVERS

8.6.8.1   Text explaining the purpose of momentum adjustment maneuvers
            plus tables detailing frequency of maneuvers and thruster
            selection Vs pulse width Vs number of pulses Vs expected
            change in momentum.

8.6.8.2   Where applicable, text should include all information
            referenced in para 8.6.1.2, items a., b., and c.

8.6.9   OTHER RCS SUBSYSTEM RELATED OPERATING INSTRUCTIONS

CHAPTER 9

THERMAL

9.1   GENERAL

9.1.1 A paragraph describing the purpose and content of this
       chapter.

9.2   PHYSICAL LOCATION OF HEATERS AND SENSORS

9.2.1 Diagrams detailing the exact physical location of each
       heater and each temperature sensor.

Figure 9-1   Heater/Temperature Sensor
             - Physical Location Diagram

9.3   ELECTRICAL DESCRIPTION OF HEATERS

9.3.1 A general description of the various heaters used in the
       satellite and the power requirements of each.

9.4   ELECTRICAL DESCRIPTION OF TEMPERATURE SENSORS

9.4.1 Text describing temperature sensor operation including
       calibration curves.

Figure 9-2   Temperature Sensor (Type   ) Calibration Curve

9.5   HEATER RELATED COMMANDS

9.5.1 Text to introduce Table 9-1 which lists all heater related
       commands and descriptions.

CMD NO.	DESCRIPTION

Table 9-1   Heater Related Commands

9.6   THERMAL CONTROL RELATED TELEMETRY

9.6.1   Text to introduce Table 9-2 which lists all thermal control
           related telemetry and descriptions.

TM NO.	DESCRIPTION

                Table 9-2   Thermal Control Related Telemetry

9.7   OPERATING INSTRUCTIONS

9.7.1   COMMUNICATIONS RECEIVER HEATERS

9.7.1.1   Text describing all particulars related to communications
           receiver heaters including selection and use.

9.7.2   TWTA AND POWER AMPLIFIER HEATERS

9.7.2.1   Text describing all particulars as related to TWTA and power
           amplifier heaters.

9.7.3   BATTERY HEATERS

9.7.3.1   Text describing all particulars related to battery heater
           and heater controller selection and use.

9.7.4   RCS HEATERS

9.7.4.1   Text describing all particulars related to RCS heater usage.

9.7.5   MISC HEATERS

9.7.5.1   Text describing all particulars related to all other
           miscellaneous heaters including selection and use as
           applicable.

9.8   ENVIRONMENTAL FACTORS AND CONSTRAINTS

9.8.1   Text describing the factors and constraints which should be
           taken into consideration for proper satellite thermal
           control.

9.9   PREDICTED DISSIPATIONS AND TEMPERATURES

9.9.1   Text describing the predicted temperatures and heat
            dissipation factors for the following conditions:

            a.   Transfer Orbit (Phase 1).

            b.   Drift Orbit (Phases 2 and 3).

            c.   On-station (Phase 4) - total dissipations in different
                  operating modes.

9.10   OTHER THERMAL RELATED OPERATING INSTRUCTIONS AS APPLICABLE

CHAPTER 10

EMERGENCY OPERATIONS

10.1   <u>GENERAL</u>

10.1.1   A paragraph describing the purpose and content of this chapter.

10.2   <u>POWER</u>

10.2.1   BATTERY FAILURE

10.2.1.1   Text describing the proposed method to recover from eclipse operation with one or two failed batteries.

10.2.2   SHUNT MODULATOR FAILURE

10.2.2.1   Text describing the correct method to detect a shunt modulator failure and how to compensate for same.

10.2.3   BATTERY DISCHARGE REGULATOR FAILURE

10.2.3.1   Text describing the correct method to recover from a battery discharge regulator failure while the satellite is being eclipsed, and the hazards involved.

10.2.4   LOAD INVERTER FAILURE

10.2.4.1   General discussion of the options available to counteract the effect of a load inverter failure.

10.2.5   SOLAR ARRAY DRIVE FAILURE

10.2.5.1   Text describing the options available in the presence of a solar array drive failure.

10.3   <u>ATTITUDE CONTROL SUBSYSTEM</u>

10.3.1   ELECTRONICS CONTROL UNIT FAILURE

10.3.1.1   Text describing the proposed method of detecting and recovering from an Electronics Control Unit failure.

10.3.2   MOMENTUM WHEEL DRIVE ELECTRONICS FAILURE

10.3.2.1   Text describing the proposed method of detecting and
            recovering from a Momentum Wheel Drive Electronics failure.

10.3.3   MOMENTUM WHEEL FAILURE

10.3.3.1   Text describing the proposed method of detecting and
            recovering from a momentum wheel failure.

10.3.4   EARTH SENSOR FAILURE

10.3.4.1   Text describing the proposed method of detecting and
            recovering from an Earth Sensor failure.

10.3.5   SUN SENSOR FAILURE

10.3.5.1   Text describing the proposed method of detecting and
            recovering from a Sun Sensor failure.

10.4   REACTION CONTROL SUBSYSTEM

10.4.1   FAILED THRUSTER

10.4.1.1   Text describing how maneuvers could be performed in the
            presence of one or more failed thrusters.

10.4.2   FAILED LATCH VALVE

10.4.2.1   Text describing how best to utilize the RCS system in the
            presence of a failed latch valve.

10.4.3   BLOCKED FILTER

10.4.3.1   Text describing the contingency plans available to enable
            RCS operations in the presence of a partially or completely
            blocked filter.

10.5   OTHER FAILURE RELATED RECOVERY INSTRUCTIONS

CHAPTER 11

CONSTRAINTS SUMMARY

11.1   GENERAL

11.1.1   A paragraph describing the purpose and content of this chapter.

11.2   COMMUNICATIONS

11.2.1   Provide a list of all constraints related to the Communications Subsystem and, where possible, justification for each constraint.

11.3   POWER

11.3.1   Provide a list of all constraints related to the Power Subsystem and, where possible, justification for each constraint.

11.4   COMMAND AND TELEMETRY

11.4.1   Provide a list of all constraints related to the Command and Telemetry Subsystem and, where possible, justification for each constraint.

11.5   ATTITUDE CONTROL

11.5.1   Provide a list of all constraints related to the Attitude Control Subsystem and, where possible, justification for each constraint.

11.6   REACTION CONTROL

11.6.1   Provide a list of all constraints related to the Reaction Control Subsystem and, where possible, justification for each constraint.

11.7   OTHER OPERATIONAL CONSTRAINTS AS REQUIRED

CHAPTER 12

DETAILED COMMAND LIST

12.1   GENERAL

12.1.1   A paragraph describing the purpose and content of this
          chapter.

12.2   COMMANDS, NUMERICALLY LISTED

12.2.1   Text to introduce Table 12-1 which should provide a list of
          all commands in numerical order with a detailed description
          for each command.

CMD	DESCRIPTION

Table 12-1 Command List, Numerically

12.3   COMMANDS, BY SUBSYSTEM

12.3.1   Text to introduce Table 12-2 which should provide a list of
          all despun commands grouped according to subsystem with a
          detailed description for each command.

CMD	DESCRIPTION

Table 12-2 Command List, By Subsystem

CHAPTER 13

DETAILED TELEMETRY LIST

13.1   GENERAL

13.1.1 A paragraph describing the purpose and content of this
        chapter.

13.2   TELEMETRY DATA

13.2.1 Text explaining any difference between eight and sixteen
        telemetry data words, analog Vs bi-level data, etc.
        Paragraph should introduce Table 13-1, listing all telemetry
        data and providing a detailed description of each data word.

WORD	DESCRIPTION

Table 13-1   Telemetry Data List

13.3   SENSOR DATA

13.3.1 A detailed description of the sensor data stream and the
        inter-relationships of one pulse to the other. A Table of
        T-times and an accompanying figure would be desirable.

MEASUREMENT IDENTIFICATION	DESCRIPTION

Table 13-2   Time Interval Measurements
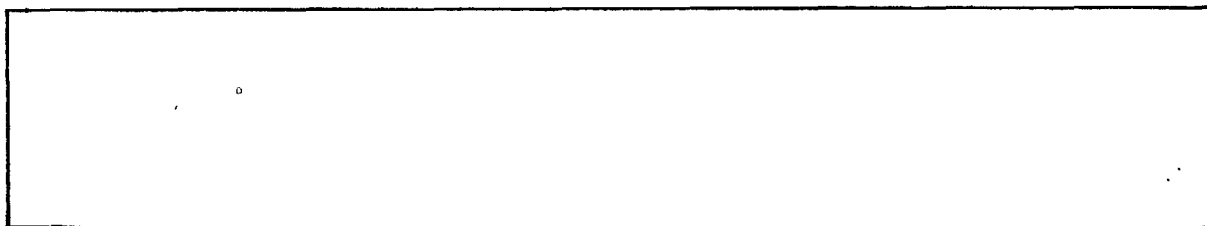
Figure 13-1   Attitude Sensor Time Line

13.4   <u>YAW GYRO ANALOG</u>

13.4.1   A comparison of yaw gyro output Vs satellite nutation
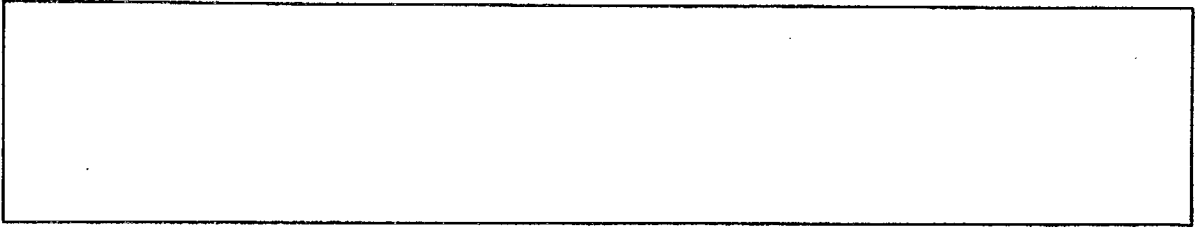   referenced to Figure 13-2.

Figure 13-2   Yaw Gyro Analog Output Vs Satellite Nutation

MISSION OPERATIONS

14.1   GENERAL

14.1.1   A paragraph describing the purpose and content of this chapter.

14.2   MISSION SEQUENCE SUMMARY

14.2.1   Text introducing a major event sequence summary from launch, through transfer and drift orbit to on-station including:

a.   Launch and Injection.

b.   Transfer Orbit Maneuver, etc.

c.   Apogee Motor Firing.

d.   Drift Orbit Maneuvers.

e.   Activities including Antenna Deployment, Solar Array Deployment, Testing and Calibration.

EVENT	DESCRIPTION

Table 14-1   Mission Sequence Summary

14.3   LAUNCH WINDOW CONSTRAINTS

14.3.1   Description of all constraints applicable to launching on either the Delta or STS.

14.4   LAUNCH CONFIGURATION

14.4.1   Text describing the satellite pre launch configuration for all commandable units (assemblies).

UNIT	STATUS

Table 14-2   Satellite Launch Configuration

14.5   TRANSFER ORBIT OPERATIONS AND CONSTRAINTS

14.5.1   Text describing all operations to be performed during transfer orbit including applicable constraints.

14.6   APOGEE MOTOR FIRING

14.6.1   Text describing all operations to be performed during apogee motor firing including applicable constraints.

14.7   DRIFT ORBIT OPERATIONS AND CONSTRAINTS

14.7.1   Text describing all operations to be performed during drift orbit including applicable constraints.

14.8   SWITCH TO ON-STATION OPERATION

14.8.1   Text describing all operations and constraints applicable to final positioning of the satellite at its correct target longitude.

14.9   EMERGENCY OPERATIONS

14.9.1   Text detailing what steps may be required to correct for a failed unit in any of the previous operations.

14.10   TESTING AND CALIBRATION

14.10.1   All testing and/or calibration requirements as related to the previous operations.

14.11   WOBBLE MEASUREMENT AND CORRECTION

14.11.1   Text describing the correct method to measure and correct for satellite wobble including all applicable constraints.

APPENDIX F

NOTES ON MEETING WITH TELESAT

AT

COMMUNICATIONS RESEARCH CENTRE

25 JANUARY 1982

H.R. Raine

J.D. Andean

SUBJECT
OBJET

NOTES ON A MEETING WITH TELESAT, 25 JANUARY, 1982

1.   A meeting with Telesat was held at C.R.C. on 25 January, 1982, to
discuss several aspects of the current contract on Mission and Operations
Analysis and System Availability for MSAT (DSS Contract No. 15ST.36001-1-0800),
with emphasis on the launch campaign.

Attendees were:

DOC/CRC   Telesat

H.R. Raine (SCOPO)   I. Flockton (Satellite Systems Division)
J.L. Pearce (DSS)   E.R. Gubby (Launch Services Group)
J.A. Heal (DSS)   D. Griffiths (Launch Services Group)
R.D. Caswell (DSM)
A.H. Reynaud (DSM)
W.B. Graham (DSM)
J.D.R. Boulding (SCOPO)   SPAR
J.D. Andean (SCOPO)
                                 G. Lewis (S&ASD)

2.   Mr. Raine opened the meeting with introductions, and noted the presence
of a SPAR representative (G. Lewis) as previously agreed to with the Telesat
Project Manager (R. Lagowski). Mr. Lewis was to act as an observer, and provide
an interface on areas of current SPAR activity related to the Telesat contract.
He also made valuable contributions in many of the discussions that followed.
        Mr. Raine then described the background to the Telesat contract, and
outlined the general objectives of the study, the schedule requirements, the
likely impacts on other areas of the MSAT Project, and some scenarios for
possible Telesat contributions to later Phases of the Project.

3.   Telesat said that their primary objectives at the meeting were to obtain
a clear idea of exactly what C.R.C. wanted them to do, and to get answers to
certain specific questions. Telesat provided Mr. Raine with a confidential list
of topics they proposed to cover in certain parts of the study; this list was
reviewed by Mr. Raine and Telesat in a separate discussion following the
meeting. Telesat also described a number of areas that are closely related to
the study, but which they felt the prime contractor should cover, with Telesat

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reviewing the results. Telesat then discussed the breakdown of Task 5 into:

- define the sequence of events at the Cape,

- define what Telesat would do to monitor these events,

- define Telesat activities from launch through to the end of on-orbit testing,

and stated that it would be difficult to provide much detail until the spacecraft was much better defined than at present. (This was a recurring theme - Telesat emphasized several times that level of detail in various areas of the study will be quite limited due to the lack of detailed spacecraft information, and the need to cover two possible buses - LSAT and SATCOM - and two possible launch vehicles - shuttle and Ariane).

4. In answer to a C.R.C. question on booking and paying for shuttle and Ariane launches, Telesat said:

- a down payment of $100K is required for a series of shuttle launches, or a single Ariane launch.

- for a series of shuttle launches, the $100K assumes all use the same launch site, and all are generally the same size; in the event of a delay, priority is lost, but not money.

- first payment is 33 months before first launch date (Telesat is currently booking TBD payloads for launches in 1987-1991).

- series does not include backups, which are covered by other procedures for S/C or launch vehicle failures, but not for program delays.

- IUS will not be commercially viable for the operational MSAT - very difficult to get costs on IUS - guesstimates range from $12M to $25M for H/W only - may reach $75M when development costs are included.

- Telesat suspects that IUS will not be commercially viable for anybody.

- pacing item for launch system is likely to be the perigee kick stage (Telesat suggested putting PKS in S/C, but C.R.C. pointed out this negates the concept of using a standard bus).

- might be able to get appropriate PKS capability from INTELSAT-6 systems. Telesat believes the MacDAC stage will be cost competitive with IUS.

- for LSAT, on the shuttle, given the MSAT time frame, have to use IUS, and this probably would cost the program out of existence - possibility of getting IUS at reduced cost if MSAT carries a military payload that the USAF is interested in.

5.   C.R.C. and SPAR commented that they (and NASA) were very concerned about shuttle launch costs, but suggested NASA might give MSAT a preferred rate. Telesat should, in any case, define the problems and the questions that should be asked of NASA, perhaps attaching a suggested draft letter to their report. C.R.C. has been told that Boeing will provide detailed IUS costs in October, 1982, after they have gone through the current USAF/US State Department loop, and agreed to get more details on this for Telesat. Telesat said that current PAM developments will provide a 3500 lb. capability for around $6M, but the next step up would probably cost around $20M (quoted by C.R.C. as a very rough budget for PKS).

6.   In response to Telesat questions on LSAT and Ariane, C.R.C./SPAR said:

- LSAT-1 is going up on Ariane 3, late 86/early 87.

- MSAT would also be sized for Ariane 3.

- for the MSAT program, the use of Ariane is considered more likely, with the shuttle as back-up (assuming LSAT not SATCOM), but the shuttle/IUS option must be kept open in case NASA rejoins the Program.

- for LSAT, Boeing recommends an off-loaded 2-stage IUS as being cheaper than a single stage (which would have the required lift· capability) because of the costs of adaptation; in either case MSAT is length-limited (not weight) - approximately 70% usage for 2-stage IUS.

- BAe has developed a conceptual design for a PKS using the LSAT bipropellant AKM system, but it has not been funded; it was suggested it might be cheaper to fund this development than to pay for a large PAM or for IUS.

- BAe is hoping the INTELSAT-6 program will come up with a PKS.

- concern was expressed regarding using spinning PKS and/or AKM systems. C.R.C. thought that LSAT was constrained to less than some very low spin rate (somewhere between 2 and 10 rpm). C.R.C. are to verify this.

7.   In an open discussion of the effects of shuttle safety requirements, points raised included:

- BAe is designing/building LSAT to conform to all shuttle safety regulations (including the required number of levels of inhibits on pyrotechnics, etc.) as far as possible, and is trying to avoid problems in this area by keeping all related tests/operations/etc. well away from the shuttle.

- the last checkout on the ground should be as thorough as possible
  to minimise on-shuttle in-space operations.

- if something goes wrong during in-flight tests on the shuttle,
  basically the S/C will be jettisoned rather than risking returning
  to ground with it, so testing might as well be avoided in the
  shuttle altogether, and the S/C put into orbit whether it has
  survived the launch or not.

- Telesat does not believe the LSAT bus is shuttle-compatible.

8.   Several other areas were discussed in somewhat less detail:

- Telesat feels there will not be enough facilities at the Cape.

- NASA is offering a fixed price 7-week integration and test package
  at the Cape - can do tests that do not require orbiter interfaces
  (e.g. battery charging) while in the orbiter. Telesat would
  recommend an absolute minimum of on-orbiter (whether on-ground
  or in-flight) tests and operations.

- encryption/decryption systems may cause some security problems at
  the Cape, possibly requiring different facilities; treatment will
  be significantly different depending on whether systems are U.S.
  or Canadian; simulated black boxes would be used until spacecraft
  arrives at launch site.

- also there is some impact of security requirements on post-launch
  operations. Encrypted data can be transferred over non-secure lines,
  but any remote G/S (e.g. during station acquisition) would have to
  pass encrypted data through transparently or would have to have a
  secure area within the remote site.

- schedules for range operations were discussed, and it was pointed
  out that, for Delta-class payloads, Ariane required 1 extra week
  over Delta with some indication of more severe penalties for larger
  payloads.

9.   The meeting ended with C.R.C. providing Telesat with copies of documents
related to LSAT, Ariane and the IUS/shuttle situation.

J.D. Andean

JDA:amc

c.c. J.L. McNally
      W.D. Hindson
      Attendees
      MSAT File

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5. CONTRACTOR v.2—Mission and operation analysis for M-SAT Telesat Canada		
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