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EARTH RESOURCES TECHNOLOGY SATELLITE FINAL REPORT

16. OPERATIONS CONTROL CENTER STUDIES

PREPARED FOR

GODDARD SPACE FLIGHT CENTER
NATIONAL AERONAUTICS
AND SPACE ADMINISTRATION

UNDER CONTRACT NAS5-11260

TRW SYSTEMS GROUP

IBM FEDERAL SYSTEMS DIVISION

Itek OPTICAL SYSTEMS DIVISION

EARTH RESOURCES TECHNOLOGY SATELLITE

FINAL REPORT

Volume 16. Operations Control Center Studies

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THE FOLLOWING VOLUMES CONSTITUTE TRW'S PROPOSAL FOR PHASE D OF THE ERTS PROJECT SHADING INDICATES THE FEBRUARY SUBMITTAL WHICH IS REVISED BY THE APRIL SUBMITTAL, THE UNSHADED VOLUMES ARE EITHER NEW OR ENTIRE VOLUME REVISIONS OF THE FEBRUARY SUBMITTAL

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1. INTRODUCTION AND SUMMARY

The design requirements for the ERTS OCC are defined in the study specification only in very general terms. From paragraph 7.14.2, "The OCC will provide

"Focal point for project unique missions

"Spacecraft activity plan

"Coordinate schedules with STADAN/MSFN

"Direct and monitor all ERTS operations support

"Operate the spacecraft

"Operate the sensors

"Determine spacecraft health, configuration and performance at a system and subsystem level

"Determine sensor configuration, health and performance

"Compile and maintain operational records and data"

A key purpose of the study was thus to determine detailed requirements for equipment which would permit the above objectives to be met.

1.1 PHILOSOPHY OF DESIGN

The principles upon which design of an operations center for a spacecraft such as ERTS must be based are:

- Skilled technical direction of operations. A project operations director can only fulfill his role with an intimate knowledge of the spacecraft and ground equipment he is using. The most important ingredient is the trained operator.
- OCC equipment must be designed for peak loading conditions, (launch for example). Under such conditions a greater variety of data must be available than under routine operation.
- Maximum overview of the spacecraft situation must be possible under worst conditions, such as noise due to equipment malfunction, spacecraft tumbling, etc.
- Redundancy is essential; several independent means of data evaluation and commanding must be available.
- Communications between individuals in the OCC and outside must be clear and continuous.

- Test methods must insure readiness of the center and ground stations to support the launched observatory.
- Payload data quality must be readily assessed and required adjustments must be readily commanded.

1.2 SPECIFIC REQUIREMENTS

The OCC design becomes specific when the characteristics of the orbit spacecraft, payload and ground stations are fixed. These are, in fact, all relatively firm and will be reviewed in turn.

1.2.1 Orbit

The sun synchronous orbit insures a singular regularity of activity in the control center. Passes over ground stations will recur daily at approximately the same hour repeating the sequence every 18 days. The constant 492-nautical-mile altitude establishes a maximum pass time of about 15 minutes at all ground stations. Throughout the 18-day cycle pass times vary in a completely predictable manner.

Daytime activity at the control center will typically include real time passes as follows: 10 at Alaska, two or three each at Greenbelt and Corpus Christi. The latter two overlap about 50 percent but no overlap of consequence with Alaska is encountered. Night passes are about the same, displaced 12 hours in time. Quick look imaging seen at Greenbelt will generally be from 9 a.m. EST (eastern United States and Canada) to 12 noon (midwestern United States).

Similarly the playback video data will be arriving in the control center between 9 and 12 p.m. The rest of the 24-hour period will be filled with active passes (mostly at Alaska) except for about 6 to 8 a.m. when no ground station will contact the spacecraft. The above presumes no use of ground stations other than those equipped for image reception and Rosman.

Overlap between Greenbelt and Corpus Christi plus Rosman (used only for commands) will require simultaneous communications with three stations. At night the activity will include continuous 30-minute contact with the spacecraft as it passes from the United States to Alaska coverage patterns, interspersed with 70-minute periods of silence.

Thus the orbit sets the schedule of operations at the control center and limits the time during which activity may be conducted. It also establishes Alaska as more useful than the other two stations combined, with regard to typical spacecraft visibility in a 24-hour day (Figure 2-1).

	Spacecraft Visibility/Day (minutes)
Alaska	100
Greenbelt*	49
Corpus*	51

1.2.2 Spacecraft Characteristics

The key spacecraft characteristics which influence operations, and thus OCC design, are data volume, command volume, and the extent of "out-of-sight" operations. The latter, conducted by tape recorder and command programmer, may be included with data and command implications as merely an increase in volume of activity.

There are two distinct and quite dissimilar phases of operation:

- Initial or abnormal phases requiring close scrutiny of all data and use of a wide variety of commands.
- Routine image data production phase requiring repetitious use of a few commands and examination of a few health data items, plus automatic surveillance of all other telemetry.

As stated earlier, the design of a control center is set by the abnormal operations requirement; the routine operations requirement permits certain labor saving aids to operation. The latter is predictable, the former is not.

Spacecraft PCM data arrives at the control center having the following characteristics:

Data rate (kbit/sec)	1 or 32
Bits per word	9
Format	128-word main frame
Subcommuntators	3

*Station visibility is common for 50 percent of time.

	Data Rate	
Sampling rates (kbits/sec)	1	32
Main frame (sec)	1.152	0.036
Subcommutators (sec)	147.16	4.6
Different data items	~420	

Although the observatory design provides about 360 separate and distinct commands, only a fraction of these are used in routine operation. Routine action is largely limited to payload manipulation plus those spacecraft functions which relay data to the ground. In an active pass, including real-time and recorded image data, about 25 commands would be required. The stored command programmer will control ERTS as often as real-time commands; loading it with commands will suffice for 12 hours. Specific command sequences for initial operations are given in Appendix A and for routine operations in Section 3.

1.2.3 Payload

The ERTS payload places a new requirement on the control center — the need for a means to view image quality and to make adjustments by command to restore quality. Since such data arrives in the control center from only one of three ground stations, this quality check will be feasible in near real time only from about 9:00 to 12:00 a.m. local Greenbelt time.

The control center may wish to delegate quality adjustments of the sensors to Alaska and Texas stations. Alaska can unload video-taped data during 10 revolutions a day.

1.2.4 Ground Stations

The ground station characteristics needed for control center operation of ERTS are defined by the command uplink, PCM telemetry downlinks, video downlinks, and tracking system characteristics. Standard voice and teletype circuits are needed. Standardized telemetry and command formats permit use of existing equipment but video reception and recording is a new requirement to all stations.

1.3 OCC SPECIFICATION

A skeleton functional specification for the OCC is given in Table 1-1. This is based on operating requirements developed in subsequent sections

Table 1-1. OCC Equipment Requirements

PCM Data Display

1) From input format which is
   - 1, 32 kbit/sec
   - 9 bit/word
   - 1 main frame, 128 words
   - 3 subcommutators, 128 words each
   - Total Different Word Potential of 450 words

2) Select and display on analog strip chart
   - A permanent record with time code
   - 32 different words at once, 8 on one page
   - Paper speeds variable 30 to 0.1 mm/sec
   - Change selection of any one word to any other of 450 words in 10 seconds

3) Select and print out programmed format
   - Out of limit words, any or all of 150 words
   - Subsystem engineering units

     Attitude control 75 words
     Power 75 words
     Communications 85 words
     Thermal 80 words

   - Commanded status, spacecraft, 80 items
   - Commanded status, payload, 75 items

   (In the above 6 printouts a common set of 11 analog word values, spacecraft time, GMT equivalent time, and status of data processing system will be printed on all pages.)

   - Given a 32-kbit/sec data stream, all of above printouts will be completed in sequence in less than 2 minutes after requested
   - For 1 kbit/sec, data print out response will be less than 3 minutes
   - Raw data processor, every data point of each of 20 words through entire data train selected. Print in engineering units.

Format Commands

- From input typewriter accept

  Time (GMT desired)
  Command by octal number
  Command transmitter type (STADAN or unified S-band)

- From internal program

  Relate spacecraft clock to GMT
  (Accept typewriter reprogram)

- Output to typewriter literal command train
- Output to tape

  Standard format command 32 to 56 bit message

Command Communication to ERTS S/C

- From switch input

  Command by octal number
  Successive commands every 5 seconds
  Format Standard 32 to 56 bit

- From tape manually started

  Command sequence as switch input above at 0.6 sec/command

Verify Command Execution

- Receipt and storage at ground station
- Receipt and storage at spacecraft
- Receipt and execution at spacecraft as limited by spacecraft design

Data Storage Tape Recorders

Three data (PCM) tape recorders

Image Display

RBV and MSS images available from NTTF for quality assessment and correction

DCS Data

Process sufficiently to assess quality

Communication

- Telephone to ground stations, SCAMA or equivalent
- Commercial telephone
- Teletype to ground stations
- Internal telephone to all OCC operating positions
- Data lines to and from ground stations

  Telemetry from Alaska, 16 kbit/sec
  Telemetry 32 kbit/sec from Rosman, NTTF
  Telemetry 2 4 kbit/sec from Corpus (DTS)
  Video from NTTF (2)
  Command lines to Alaska, Corpus, NTTF and Rosman, accept command bit stream for real-time modulation

Weather Data

- For specified locations
- Predict cloud cover 6 hours in advance

Simulation Tapes to Checkout OCC

- PCM
- Video

Miscellaneous

Clocks, current time GMT (digital), wall map, etc and on experience with existing NASA spacecraft. Volume 19 of proposal gives complete OCC specification.

1.4 STUDY REQUIREMENTS

As a convenience, the requirements of Study Specification S-701-P-3 for the OCC are abstracted here and the TRW response cited. Where this volume is not pertinent to the item listed, a reference to the appropriate volume is given.

SPECIFICATION S-701-P-3	TRW RESPONSE
7.14.2 "OCC will provide	
"Focal point for project unique mission requirements...."	Centralized control lies in the ERTS OCC. See Section 3.
"spacecraft activity plan..."	Initial activity is best presented in Appendix B. Routine operations are given in Section 3.
"coordinate schedules with STADAN/MSFN..."	
"Direct and monitor all ERTS operations support."	
"Operate the spacecraft"	See Section 2 and Appendix B.
"Operate the sensor"	Section 3
"determine spacecraft health configuration and performance at a system and subsystem level"	Same
"determine sensor configuration health and performance"	Same
"Compile and maintain operational records and data"	Volume 25, Phase D proposal
7.14.2.1 "OCC will	
"generate plans for the scheduling and the interrogation of the ERTS."	Volume 16
a. "Generate, display and verify commands for 1. Spacecraft status 2. orbit corrections 3. sensor operations	See Volume 14 for format

SPECIFICATION S-701-P-3	TRW RESPONSE
b. "Receive, process, display, distribute and store spacecraft data"	See Volume 14
c. "Analyze and evaluate data...."	See Volume 14
d. "Generate schedules for picture taking and platform data acquisition..."	See Volume 14
e. Provide ... sensor and spacecraft displays and controls...."	See Volume 14
f. "Provide realistic spacecraft simulation capability for command data acquisition"	Requirements are defined in this volume, Section 11
7.14.2.2	
a. "Identify types of data needed in the OCC and handling and processing the same."	Section 4
1. Command data	Section 4
2. Derived spacecraft data	Section 4
3. Telemetry and housekeeping data	Section 4
4. Orbital position data Spacecraft attitude data	Section 4
5. ERTS payload data	Section 4
6. Cloud cover, sun angle, other	Section 12
7. User requests"	
b. "Identify displays and other equipment required at OCC	Section 8
"Identify ERTS unique equipment needed at STADAN/MSFN stations	Section 13
"Submit preliminary hardware specifications for	See Phase D Volume 19
1. Computer system	
2. Displays	
3. Other"	

SPECIFICATION S-701-P-3	TRW RESPONSE
c. "Study software types needed and supply flow diagrams for	See Volume 14
1. Control center operations	
a. Annotation of data	
b. Monitor spacecraft performance	
c. PCM processing for OCC STADAN/MSFN	
d. History logs data coverage plots	
e. Spacecraft utilization"	
2. "Study spacecraft simulation software (for control center simulation)"	See Section 11
3. "Study test and diagnostic software"	
d. "Study computation capacity required to forecast/predict orbital position from NASA furnished orbital elements."	No work done at request of NASA
e. "Analyze and identify hardware/software tradeoffs."	
f. "Specify a spacecraft simulator system to checkout spacecraft/STADAN/MSFN/OCC/NDPF compatibility and operations." "Consider feasibility of using actual spacecraft components."	Section 11
g. "Provide a staffing plan."	Section 10
h. "Provide detailed time based outlines of preliminary operational procedures" "Provide ... an ERTS utilization plan demonstrating a typical 18 day operations cycle ......"	See Section 2 and Appendix B.

2. Orbit Constraints

2. ORBIT CONSTRAINTS

The ERTS orbit is precisely defined and controlled. Considerations of choice and adjustment are discussed in Volume 2 of the Phase B/C report. This section will develop the aspects of the orbit which influence spacecraft operation. The physical interrelationship of the ground stations which will be used for this mission is closely related to this subject.

The ERTS orbit is sun synchronous; its plane rotates one revolution per year keeping a relatively constant sun line angle. Being inclined about 99.1 degrees means that the plane of the orbit passes to the left of the North Pole by about 9.1 degrees when viewed from the ascending crossing of the equator (which is in darkness). Spacecraft daylight passes over the equator proceed in a southwesterly direction as shown on Figure 2-1 and become the primary data gathering passes. Data may also be gathered during nighttime passes over data collection platforms and on ERTS-B from the infrared channel of the line scanner.

The opportunities for imaging land masses in daylight are graphically shown in Figure 2-2. This graph includes data from the 14 typical revolutions of Figure 2-1 and also from a set of 14 revolutions midway between those shown, which would occur 9 days later. It is seen that the longest continuous land imaging strip is 33 minutes when the spacecraft passes from northern Russia to South Africa.

While only half the surface of the earth is in sunlight at one time, about two-thirds of the orbital path is illuminated. Figure 2-3 shows this relationship in scale. The average eclipse time is about 31 minutes, the orbital period 103.3 minutes.

Ground station coverages of the spacecraft are shown on Figure 2-1 centered at Fairbanks, Alaska; Corpus Christi, Texas; and Rosman, North Carolina. The spacecraft altitude and a minimum elevation angle of 5 degrees establish the maximum time of contact with the spacecraft as 15 minutes. Figure 2-4 shows the time of contact with the spacecraft for the revolutions plotted in Figure 2-2. While Figure 2-4 shows the

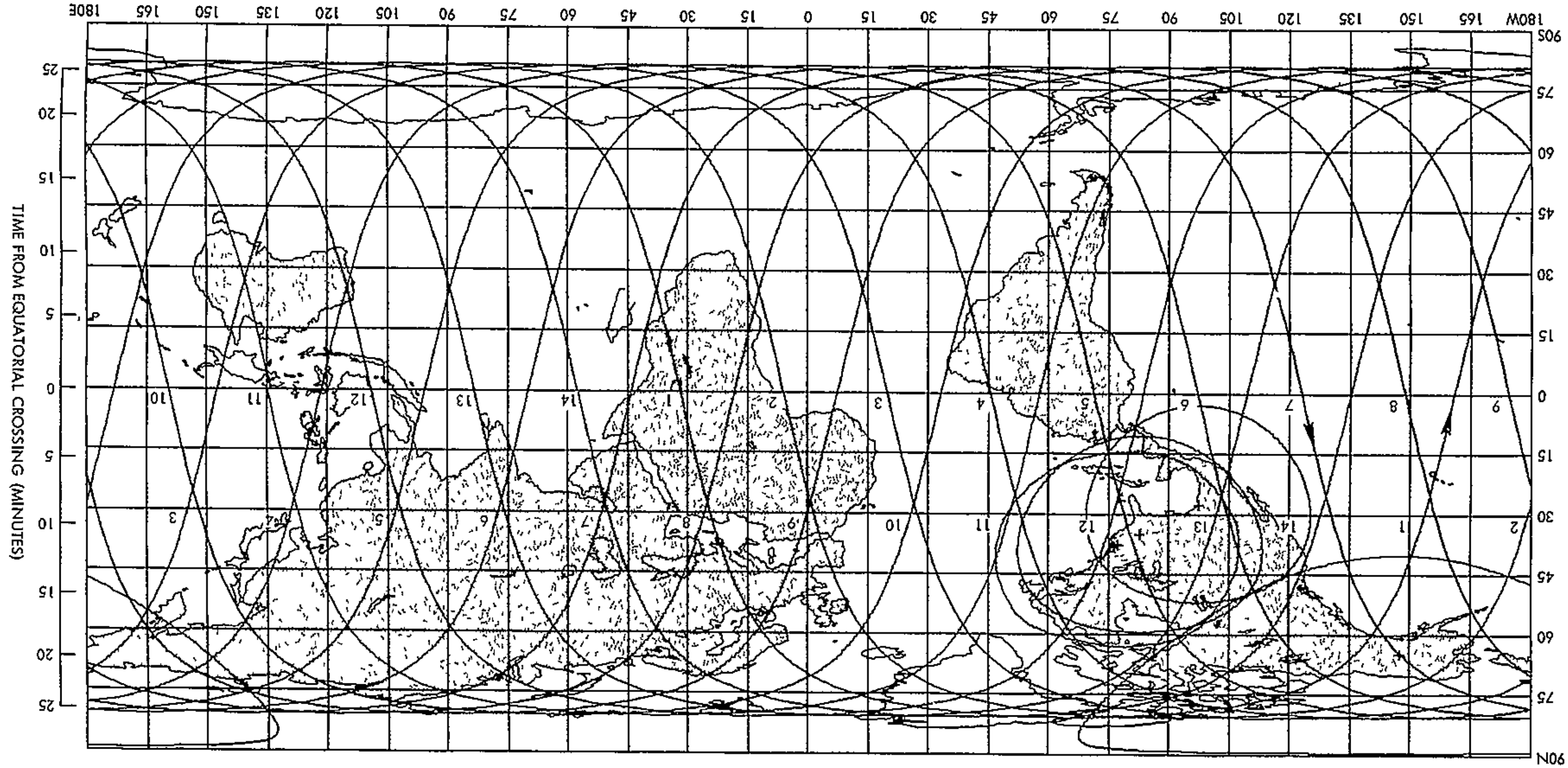


Figure 2-1

24-HOURS ERTS GROUND TRACE showing coverage of ground stations
Daylight passes are southbound, nighttime passes are northbound

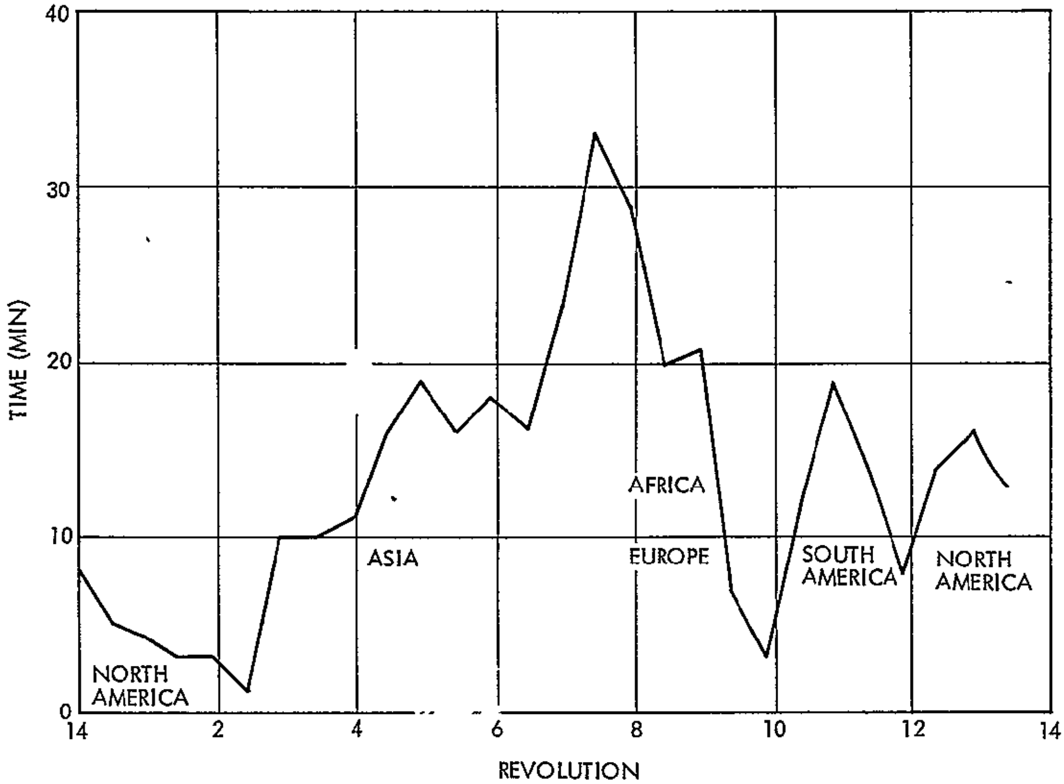


Figure 2-2

DAYLIGHT LAND MASS viewing time as a function of successive revolutions

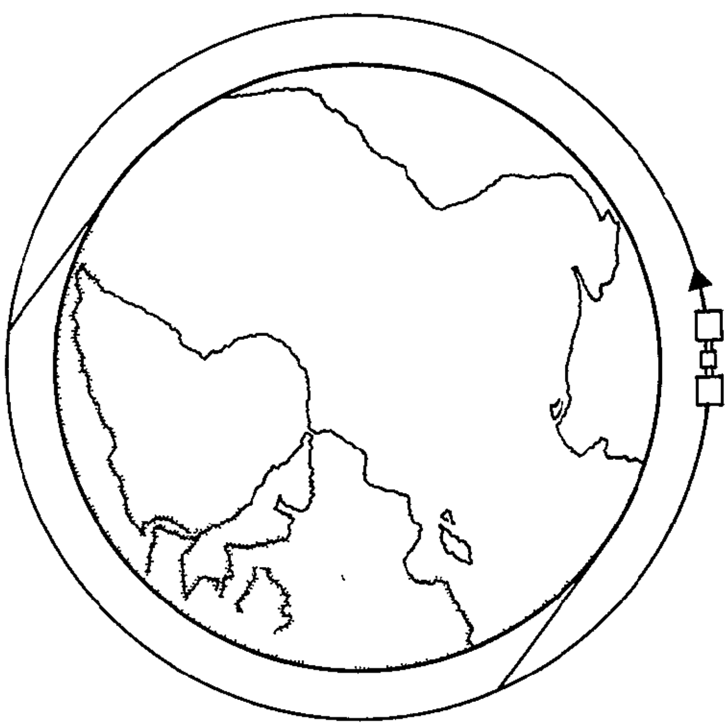


Figure 2-3

SUNLIGHT ILLUMINATES half the earth and about two-thirds of the orbital path

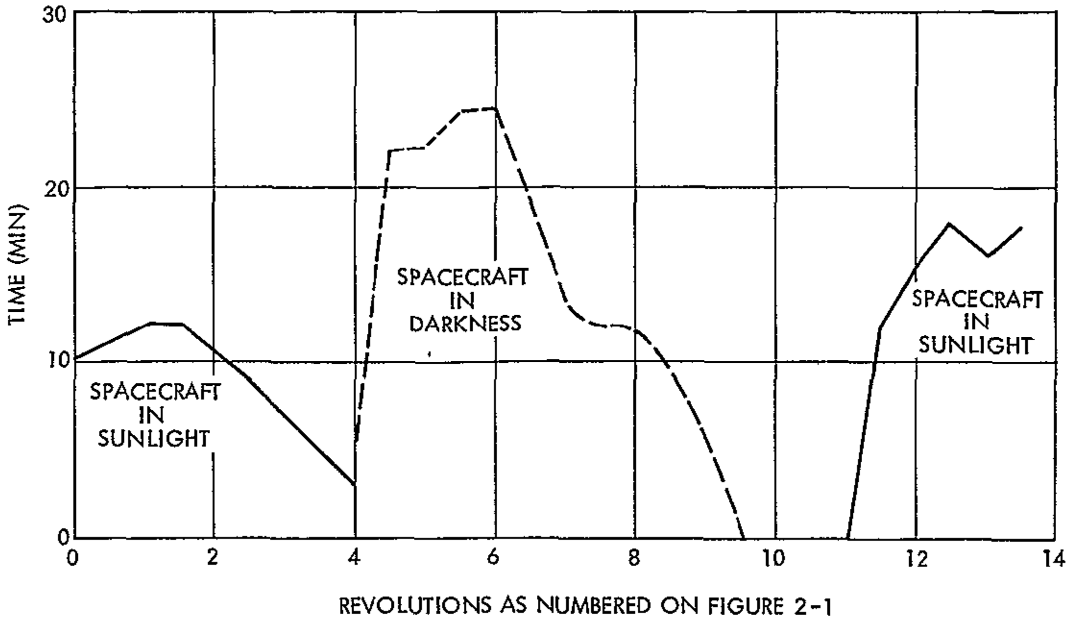


Figure 2-4

SPACECRAFT VISIBILITY TIME from Alaska, Corpus, or Greenbelt ground stations, overlap in coverage excluded

total time of spacecraft communication with the ground stations, Figure 2-5 shows spacecraft visibility for each ground station individually. From this figure the superior utility of the Alaska station is readily apparent. Figure 2-5 shows one typical day of station coverage, there are 18 different visibility charts like it for one year of operations.

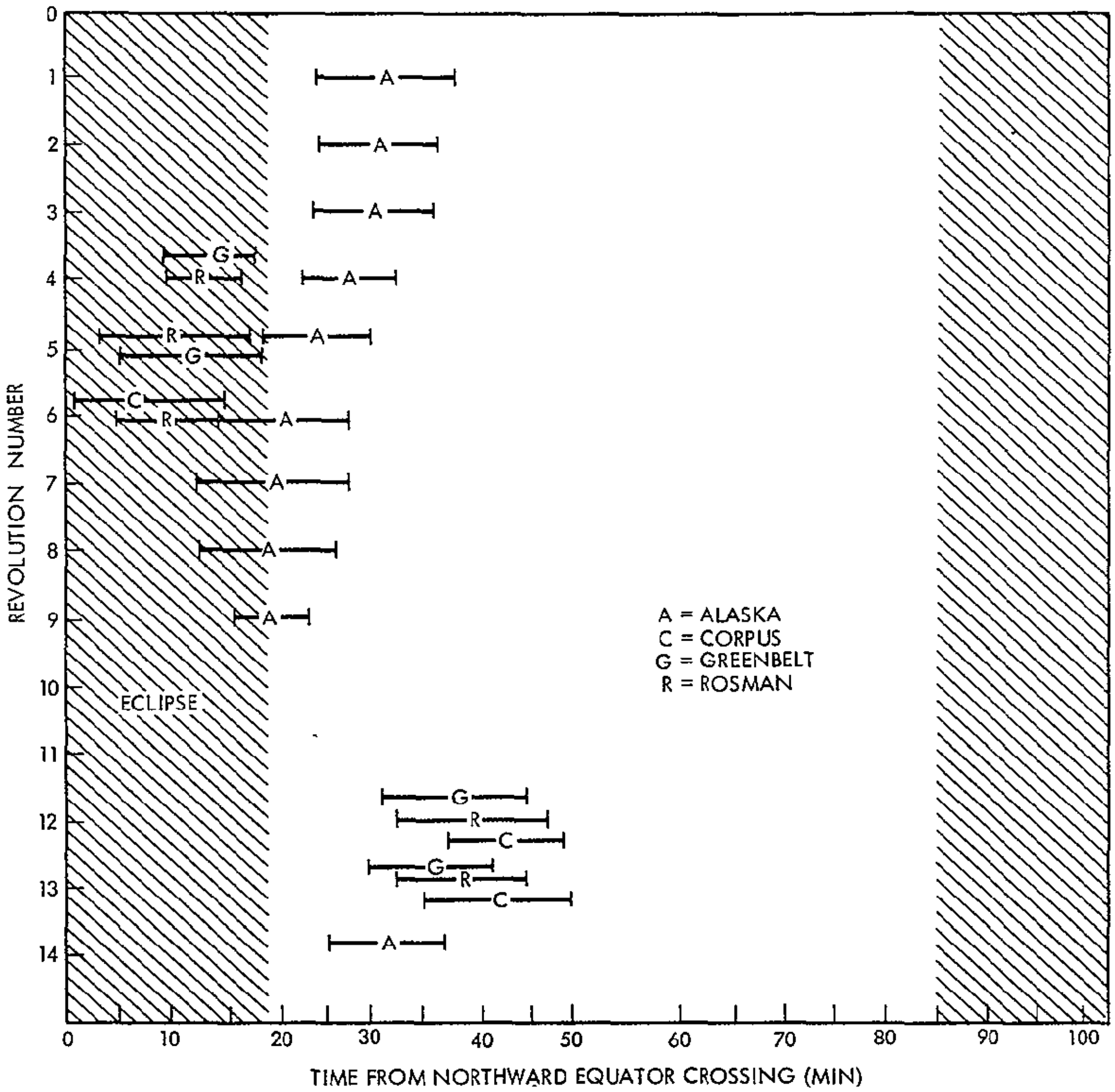


Figure 2-5

GROUND STATION VISIBILITY of spacecraft, 14 successive typical revolutions

3. Operation Plan

CONTENTS

3. OPERATION PLAN

3.1 OPERATION PHASES

The initial stages in the Operation Control Center procedure leading to spacecraft launch and orbital operation are very similar to that for OGO However routine operations differ markedly because of the differences in the sensors used.

A specific ERTS operations plan has been prepared and is included as Appendix A to this volume. The actions needed to prepare for launch and to effect control in orbit are grouped in four main categories by time of occurrence:

- Early planning
- Prelaunch
- Initial operations
- Routine operations

3.1.1 Early Planning

Early planning extends from six months to a year before launch. In this phase the operators who will control the spacecraft must become intimately acquainted with its design. Information which must be accumulated includes:

- Telemetry measurements. What does each measured item really mean? How is it instrumented and at what point in the circuit does it originate? Are there filters which reduce or iron-out transients? An accurate calibration must be obtained for each telemetry word; this is generally done by reference to spacecraft test data if feasible. A calibration book and simple schematic for each measurement is published.

- Commands. What does each command do? How is it implemented in the circuit? What safeguards are provided? A publication showing each command function in simplified schematic form is required.

- Spacecraft design. The responsible technical controller must understand the idiosyncracies of spacecraft design.

- Payload design. All of the telemetry command and general design data on the payload must be obtained. The controller must know how to determine that the payload is operating properly and what commands to use to correct an observed fault.

From the detailed knowledge described above, the tools for operation must be designed and produced. The computer programs to format data must be perfected. Interpretive cards for strip charts are very useful; one is required for every analog word. Plans must be written for all phases of operations which will follow. Although emphasis here is on physical products the most important tool will be the skilled operators and their ability to react quickly to noisy data in a tense launch situation.

Checkout of ground stations and control center with realistic data sources is an important activity in the early period. A spacecraft simulator, which will generate all ERTS peculiar signals, realistically modulated, and will receive and decode commands etc., is used. Subsequent tests can be abbreviated through the use of magnetic tapes to represent incoming data for rehearsal routines. A realistic simulation in the OCC requires a data train taken from the spacecraft itself, exercised such that telemetry functions move in a realistic manner. Tapes made in observatory thermal-vacuum tests have been used in the past.

3.1.2 Prelaunch Activities

Prelaunch activities are planned long in advance but they peak just prior to launch. Selected experts, usually subsystem designers, are dispatched to the control center or outlying ground stations. Readiness tests are conducted with all stations participating to check out data processing, interpretation, and reporting. On a reasonably representative time scale a readiness check (about 10 days prior to launch) proceeds through all stations with reports of data words from analog strip charts or lights required. Commands are requested and sent just as planned for spacecraft orbital encounter. (See also Appendix A, Section 4).

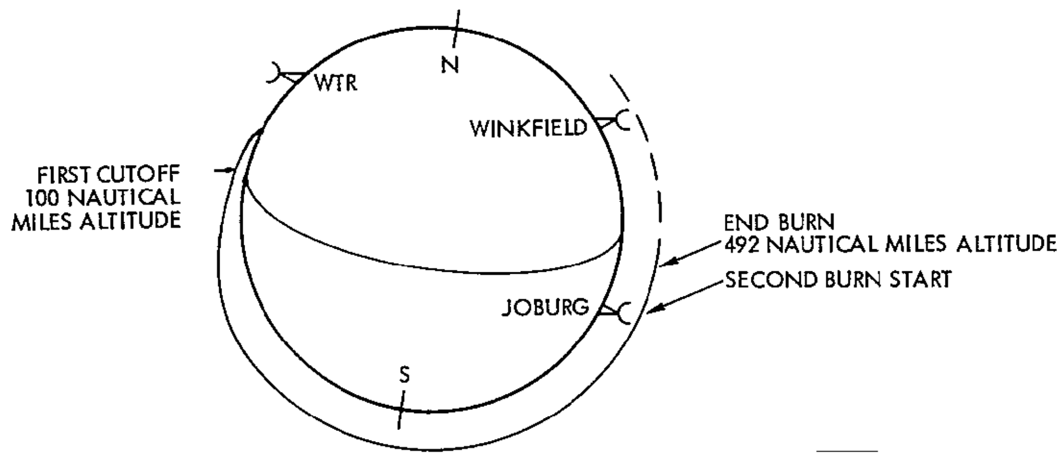
With a complex management superstructure situated at telephone stations in Greenbelt or the launch site, the countdown begins. From an orbital operations standpoint the only requirements on the spacecraft prior to launch are:

- The configuration of the spacecraft (command status) should be as agreed in the operations requirement (Appendix A, Table A-1).

- Spacecraft clock time must be correlated with GMT.
- The batteries must be fully charged.

3.1.3 Initial Operations

Initial operations begin officially when the booster has injected the spacecraft into orbit. This process occurs after a sequence of events as shown on Figure 3-1. Delta first burn terminates at about 100-nautical-miles altitude and the spacecraft coasts half way around the earth. Delta second burn is brief but circularizes the orbit to within a few miles. Deployment is observed at both Joburg and Madgar stations.



TIME-SECONDS	SEQUENCE OF EVENTS	STATION
0	LIFTOFF	WTR
40	SOLID SHUTOFF	WTR
220	THOR SHUTOFF, MECO	WTR
235	THOR DELTA SEPARATION	WTR
289-524	DELTA FIRST FIRING	NONE
3300-3304	DELTA SECOND FIRING	MADGAR
3364	ERTS-DELTA SEPARATION	MADGAR

Figure 3-1
SEQUENCE OF EVENTS

Johannesburg and Madagascar stations will monitor telemetry data but will send only one command, deploy backup. Attitude control will remain in Mode I, with the spacecraft tumbling slowly until the Alaska sighting. At Alaska the attitude control system will be allowed to proceed into Mode 2b and sun acquisition monitored. Telemetry data from Madgar, Alaska, and several other STADAN stations will be available real time at the control center for monitoring the events. Mode 2b calls for acquisition of the sun using sensors at the end of the array. Reaction wheels and control gas jets come into play to torque the spacecraft. The array is fixed with its solar cell active surface facing toward the tape recorder (+Y) end of the spacecraft. At the same time that the control forces begin to bring the spacecraft around to point at the sun, a rate gyro is spun up and develops an error signal which can only be removed by a low rate of rotation of the spacecraft around its long (pitch) axis. The sun acquisition and pitch spin-up maneuver takes only a few minutes and should be complete during the real-time viewing from Alaska. The spacecraft housekeeping tape recorder is dumped at Alaska toward the end of the 12-minute pass. This playback requires three minutes.

The spacecraft continues to track the sun and is not viewed from a ground station until it is in eclipse over Joburg. Real-time data is relayed from Joburg to Greenbelt via a low rate communication link which suffices since only a selected small portion of the data is needed. A similar arrangement gives the OCC data from Winkfield which has a 15-minute pass next. As the spacecraft continues to rotate in pitch (at 0.5 deg/sec) it will drift off the sun pointing line and when exiting from eclipse a small amount of gas might be used to reacquire the sun. To prevent this the control gas will be disabled.

If all is well to this point, as revealed by examination of tape playback and real time data, entry into earth acquisition Mode 2c is commanded at Alaska on the third revolution. Earth stabilization begins when three of four horizon tracker heads lock on the earth. Again the control forces act to orient the spacecraft until the error signal from the tracker is nulled, a condition where the +Z body axis is closely aligned to earth center. Mode 3 describes this condition and in this mode the solar array is permitted to rotate until the array normal vector points toward the sun.

The spacecraft is next viewed at the Orroral tracking station, Australia, for about 13 minutes. Again real-time data is relayed to GSFC but this must be interrupted to dump the housekeeping tape recorder for four minutes. Again the tape playback will be sent to the OCC via low data rate link.

Yaw acquisition will be delayed until the sequence of stations: Santiago, Quito, Rosman (or NTTF), and Alaska provides 45 minutes of continuous viewing. This occurs on the fourth revolution which becomes the fifth revolution at the equator. This sequence occurs in eclipse which in Mode 3 sees the spacecraft pointing to earth but drifting slowly in yaw as a result of wheel, run-down. It is likely that the operators will wait for the appropriate moment to command Mode 4 which in this case would be the attitude near as possible to alignment with the yaw plane. At entry into eclipse the spacecraft would have been 60 degrees off the desired yaw attitude (-X axis leading along flight path), and it is likely that the yaw wheel run-down in eclipse will rotate the spacecraft towards the desired attitude. Mode 4 is entered with a slow turning rate and (in this case 60 degrees initial error) about 50 minutes will be required to reduce yaw error to a few degrees.

All of this action will be viewed primarily via the strip chart recorders. Normal performance can be confirmed via sporadic reports of word values and digital printouts of status and subsystem data snapshots, but anomalous operation requires all the data visibility possible. At the stage of attitude control analysis just described, the dynamic situation is important. The other key ingredient for successful reaction to the unexpected is the presence of skilled interpreters, some of whom have operated OGO and of others who have designed the new aspects of ERTS.

From this point on we enter the payload turn-on phase which is delayed at least until revolution 12 when sunlight is available at Greenbelt. Outgassing may require a further delay but if this is not critical revolution 12 provides a sweep over northeastern Canada which may be used for a quick check of RBV imagery. The data collection system is also commanded on at this time and will remain on. Revolution 13 provides a midcontinent sweep of North America and will be used to activate the MSS. The NTTF and Corpus stations can simultaneously receive most of this pass. On subsequent pass number 14 the two video tape recorders are first used together with the two sensor data sources. Only a brief trial is feasible since record and playback must be completed in the 11-minute Alaskan pass. Subsequent recording operations will be entirely commanded by stored programmer with playback in eclipse. Checkout of the stored programmer will begin with operations in view of the ground station by altering the status of unimportant functions on a short time scale. With confidence in the programmer the orbit adjustment process may begin.

3.2 ORBIT ADJUSTMENT

To provide a complete mapping of the earth surface in 18 days, a precisely controlled orbit is required. The orbit parameters needed are:

Period	103.3 min.
Inclination	99.098
Eccentricity	0.001
Altitude	490 nmi

The orbit desired is as circular as feasible for constancy of picture dimensions. Period control is a first-order requirement for overlap of adjacent tracks, and inclination and altitude together determine sun synchronism, i.e., orbit rotation of about 1 degree per day.

The booster is not sufficiently accurate to achieve the desired orbit. A full description of its errors and the required correction is given in Volume 2 of the Phase B/C study report, 11 February 1970.

To correct the orbit which results from booster injection the following actions are required.

- The orbit must be precisely measured with the unified S-band MSFN tracking network.
- The required correction in spacecraft velocity must then be computed. The required velocity increment must be computed together with points in orbit at which it is required.
- Given the required velocity and point of application the time of thruster turn-on and -off must be read out from orbit prediction printouts. Thrust is to be turned on 250 seconds before the required position is reached and turned off 250 seconds after same. This must be repeated on successive revolutions as required.
- Commands for thrust will generally be required by storage mode in the spacecraft since the chance of real-time coverage is very low and the number of successive thrustings covers two to four days. The specific commands for a thrust addition in the direction of the velocity vector are:

Command 055 orbit adjust arm, time tag
Command 200 + X Thrust on, time tag
Command 260 orbit adjust off time tag
Command 064 orbit adjust disarm, time tag

In general, the orbit adjustment function will require only in-plane thrustings.

It is recommended that only about two-thirds of the required velocity be added to the spacecraft on the first correction. After completion, a second orbit measurement and velocity correction should be computed. An iterative approach will limit effect of errors in computation outside the control of the control center.

Operation of each orbit adjustment thruster results in 0.05 pounds of thrust, a power drain of 75 watts (to heat the gas), and minor pointing errors in attitude control. Operation of all other spacecraft and payload functions is permissible during thrusting. Increased errors in payload imagery will result from increased body rates and pointing:

	Body Rates (deg/sec)			Body Pointing Error (deg)		
	X	Y	Z	X	Y	Z
Normal performance	0.011	0.008	0.011	0.5	0.7	0.5
During orbit adjust	0.03	0.03	0.03	1.0	2.0	1.5

The spacecraft installation of orbit adjustment thrusters is shown on Figure 3-2 where identical units are used on +X, -X and +Y body sides. When a thruster is operated, the torque caused by error in alignment through the center of gravity or plume impingement on array causes body rotation, which must be countered by reaction wheel and occasional control gas torque. It is likely that control gas will pulse on and off on a duty cycle of 3 to 5 percent. Yaw gas is activated automatically by the arming of the orbit adjust system, since gas torque is required around all three axes. Yaw control torques are not required in normal spacecraft use and yaw gas control is inhibited.

From orbital calculations it appears that no adjustment in velocity will be required in the first year other than the initial series which may

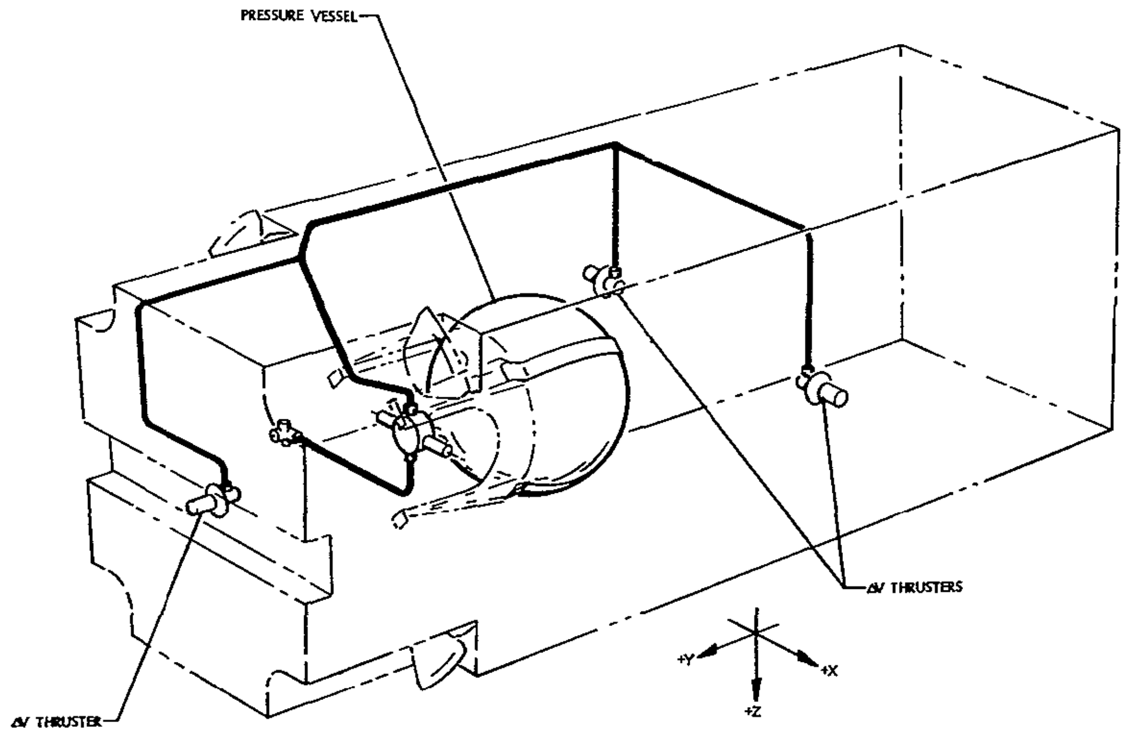


Figure 3-2
ORBIT ADJUST THRUSTERS allow velocity correction
in four directions

easily be completed in a week. In successive years some trimming will be necessary if it is required that corresponding revolutions over the 18-day cycle track to a few miles. As revealed in Volume 2, previously cited, an adjustment of up to 17 ft/sec (cross plane) is required to compensate for drift caused by the solar gravity gradient across the orbit during one year. This torque on the orbit is compensated in the first year by an intentional 0.015 degree inclination of the plane to 99.098 degrees. The plane then drifts through the desired 99.083 degrees inclination and beyond. In subsequent years a single orbit adjustment per year should suffice.

3.3 ROUTINE DATA ACCUMULATION

Typical activity in the OCC and ground stations in the routine phase of data accumulation is described in this section. This phase is divided into three distinct periods: pre-contact operations, contact operations, and post-contact operations. Each imposes unique demands upon ground facilities and will be discussed in detail in the following paragraphs.

3.3.1 Pre-Contact Operations

Pre-contact operations are initiated two days before the scheduled contact between spacecraft and ground facilities. This period is characterized by making ready all personnel and ground facilities for the approaching contact and assignment of specific duties during the contact. During this period the remote station is given its pass assignment by teletype, advised of the type of telemetry data it can expect to receive from the spacecraft, and in what manner it is to handle the data. Specific instructions are given concerning the real-time recording of all data and simultaneous transmission of housekeeping PCM data to the OCC. Additional instructions are given for post-contact replay of the housekeeping PCM and DCS data to the OCC as are instructions on labeling and mailing of recorded sensor data tapes to the NDPF for picture processing.

A punched command tape which was generated during the operations planning phase is teletyped to the station along with the pass assignment. The tape reader-writer of the station teletype unit creates a command tape which is directly readable by the station command encoder and which will be retained at the station as a backup to be used at the direction of the OCC controller in the event of loss of real-time command capability from the OCC. The full tape is immediately retransmitted by teletype to the OCC for assignment and command message validation.

ESSA weather predictions for the geographic region traversed will be updated until at least six hours prior to contact and command lists may be changed within a few minutes prior to spacecraft contact. The impact of last minute changes on personnel may cause some confusion and result in command errors. The ability to accommodate late changes in plan caused by weather predictions will be determined by experience. The ability to reschedule at any time on the basis of emergency requests or spacecraft contingencies is implicit in the design of the OCC.

3.3.2 Contact Operations

Contact operations begin approximately 45 minutes before the predicted time that the spacecraft enters ground station antenna range, T-45.

At this time all OCC personnel are at their assigned stations under direction of the operations controller. The command assignment is reviewed and error-checked. The predicted commanded status of the spacecraft and payload in the ADPE data base is examined in light of the stored command executions since the last contact. All hardware and operational software is readied and closed loop checked with the OCC. The command list is loaded into the ADPE memory, displayed, checked, and readied for real-time transmission.

At T-20, NETCOM is advised by telephone to bring on line the remote station, NASCOM data links, and SCAMA II voice line. For the next 15 minutes the station-NASCOM-OCC loop is tested and verified.

- Pass Assignment. The pass assignment is verified over the SCAMA II line by the OCC command generation technician and the remote station controller.

- Command Translocation Test. Dummy commands are translocated over the high speed data link to the station command encoder and reception is validated by the OCC ADPE.

- Uplink Command Transmission Test. Dummy commands are translocated through the station command encoder, uplink radiated into a dummy load, and validated by the OCC ADPE.

- Command Translocation. The entire command list is translocated to the memory of the station command encoder and validated by the OCC ADPE as a backup precaution. The previously teletyped punched command tape residing at the remote station will only be utilized in the event of command translocation failure during this period. In that case, the command tape will be loaded into the station command encoder memory for transmission under the verbal direction of the OCC controller. Assuming no translocation difficulties, the command list stored in the station command encoder memory is switched off line. The OCC ADPE, with its full command list retained in memory and displayed to the OCC controller, remains on-line ready for real-time transmission of commands through the station command encoder to the station command antenna.

- PCM Data Tests. The remote station places its PCM simulator on-line over the NASCOM high speed data link or wideband data link to the OCC. Remote station PCM data handling equipment, strip chart recorders and visual display units are checked for operation using the simulator. Similar OCC equipment plus all software and their associated CRT displays to be used during the pass will be exercised for readiness using the station simulated data. The station simulator will remain on-line until removed at T-1 minute.

As shown by Table 3-1 the activity of all personnel and the use of equipment reaches a peak during spacecraft contact. Of greatest importance is the ability to analyze the health and performance of the spacecraft in the shortest possible time so that command activities may proceed. The use of the ADPE and unified display system will greatly facilitate this analysis.

3.3.3 Post-Contact Operations

Post-contact operations are characterized by the assembly and processing of all data in the OCC. PCM playback data which was recorded at the 32 kilobit rate by the ground station during spacecraft contact is now replayed to the OCC at a slower speed of 8 or 16 kilobits, depending on the capability of the NASCOM link between the station and the OCC. During this period, all narrowband housekeeping PCM data is analyzed thoroughly to assess spacecraft and payload performance. The PCM data is converted by the ADPE and tape recorded for input to the NDPF. Immediately thereafter, the DCS data recorded by the station is similarly played back to the OCC, digitized, and transported to the NDPF. Digitization of both PCM and DCS data is necessary since the NDPF requires computer readable tapes to be used in DCS data reduction and picture processing. Finally, the commanded status in the ADPE data base is updated for those commands which will be executed by the stored command programmer while the spacecraft is out of range of the station. Update of real-time commands is unnecessary since the data base was updated automatically in real time as the commands were transmitted out of the ADPE.

The cycle from mission planning through data acquisition and analysis is now complete. It will be repeated on a routine basis.

Pre-contact DCS data tests will be performed only by the NTTF since it is the only station capable of real-time transmission of DCS data to the OCC. The OCC DCS demodulator/synchronizer and data handling equipment will be exercised using the signal generated by the NTTF DCS simulator until T-1 minute.

Tapes are loaded into the tape recorder and tested for proper operating speed and signal levels. Strip charts are calibrated and data

Table 3-1. Typical Command Schedule for a 10-Minute Daylight Station Contact

Time	Command Type	Function
T_o		Acquisition of signal (AOS)
		Receive S band signal, record at station Receive unified S band signal, record at station Receive VHF signal, record at station Relay PCM *housekeeping* data to OCC, OCC records
T+00 15	Real time	Initiate video tape recorder playback on rising S-band AGC
T+00 30	Real time	Initiate PCM housekeeping playback on rising VHF AGC, record at station
		OCC begins check of spacecraft and payload performance based upon display and software analysis
T+02 30	Real time	OCC completes analysis and transmits corrective commands as necessary
		OCC permits 30-second ranging interrogation by *MSFN tracking station*
		OCC begins readout of stored command progammer
T+03 00	Real time	OCC completes readout of stored command programmer
	Real time	OCC begins deletion of executed stored commands and loading of new stored commands
		Station begins reception of DCS data on unified S band signal
		NTTF transmits in real time to OCC
T+03 15	Real time	OCC completes stored command loading and verification
	Real time	OCC turn on RBV and MSS for warm up
		PCM playback *automatically halts and spacecraft* record cycle begins
		Stop playback recording at station begin tape rewind of reverse data
T+03 30		United States northern border crossing
	Real time	OCC halts video tape recorder playback station stops recording playback
T+03 31	Real time	OCC switches RBV and MSS to *S*-band transmitters station receives and records real-time video data
		NTTF transmits data to OCC for real-time imagery analysis
		Real-time commanding ceases
	Stored command programmer	*Sensor picture taking* events are cycled as scheduled in stored command programmer or cameras remain on in real-time over continental United States
T+07 00		United States southern border crossing
		Stored programmer commands cease
	Real time	OCC switches video tape recorders to *S*-band transmitters, station real-time video data recording ceases
		OCC turns sensors off
T+07 02	Real time	OCC begins video tape recorder playback station records
T+07 15		Loss of reception of DCS data on unified *S* band signal
T+10 00	Real time	OCC halts video tape recorder playback on *falling* AGC, station stops *recording*
	Real time	OCC turns off *S*-band transmitters, station stops recording
		Loss of signal (LOS)
		Lose VHF signal, station stops recording
		Lose unified S-band signal, station stops recording, halts data transmission to OCC
The commands loaded into the stored command programmer at T+3 00 will execute the following procedures out of range of the ground station		
T+10 31	Stored command programmer	Rewind video tape recorders to prepare for recording
T+11 58	Stored command programmer	Halt video tape recorders
	Stored command programmer	*Switch* MSS and RBV to video tape recorders
The following sensor picture taking sequence will be repeated as scheduled by the stored command programmer		
T+50 00	Stored command programmer	Video tape recorders to standby
		Turn on MSS and RBV
T+50 10	Stored command programmer	Video tape recorders to record
T+51 00	Stored command programmer	Turn off MSS and RBV
		Turn off video tape recorders
The following sequence will be initiated prior to and in preparation for acquisition by the next ground station		
T-05 00	Stored command programmer	Rewind video tape recorders to prepare for playback
T-03 03	Stored command programmer	Turn off video tape recorders
T-03 30	Stored command programmer	Switch video tape recorders to S-band transmitters
T-01 00	Stored command programmer	Turn on S-band transmitters for warm up
	Stored command programmer	Video tape recorders to standby to bring head up to proper speed
T_o		AOS, repeat above contact assignment

channels selected. Visual display units are checked for failed light elements.

3.3.4 Spacecraft Contact Activities

Operations during spacecraft contact will vary somewhat from pass to pass, depending upon the use of the sensor while out of sight of the station and whether the pass is northbound (night) or southbound (daylight). In general, the command schedule shown in Table 3-1 will be typical for revolutions culminating in a 10-minute daylight station contact.

Through use of the on-board stored command programmer, all of the spacecraft and payload components which are to be utilized during the pass will be readied and warmed-up beyond range of the station. Upon first sighting of the spacecraft by the ground station, real-time commands will be transmitted to actuate the spacecraft communications system to obtain real-time housekeeping and DCS data and video tape recorder playback. The real-time PCM housekeeping data will be recorded at the ground station while being transmitted directly to the OCC over the NASCOM data links. Payload data will be recorded at the ground station for later mail transmittal to the NDPF.

Immediately upon receipt in the OCC, real-time PCM data will be examined by software and displayed for quick analysis to determine the health and commanded status of the spacecraft. Any anomalous conditions detected will be corrected by manual commands. As the spacecraft approaches the northern boundary of the United States, video tape recorder playback will be halted and real-time RBV and MSS operations will commence. During this period, new stored command programmer commands will be loaded and executed commands will be deleted. As the observatory reaches the southern United States boundary, real-time RBV and MSS operations are halted and playback of video tape recorders re-commences. As the spacecraft approaches the outer range limits of the station antenna, playback of the video tape recorders is halted and all real-time spacecraft operational.equipment is commanded off. While out of sight of the ground station, the command list contained in the stored command programmer rewinds the video tape recorders in preparation for recording, performs the scheduled picture taking events, rewinds the recorders in preparation for playback at the next ground station sighting, and readies the transmitters prior to the next real-time pass.

3.4 SPECIAL OPERATIONS

The class of operations which is carried on during the routine operations phase, but is conceptually quite apart from data accumulation, we call "special" operations. Such operations will generally be planned and executed by manual control, there being insufficient repetition of the same actions to justify computer programming of the command sequence generation. Real-time commanding is planned for these functions:

3.4.1 Battery Reconditioning

Battery reconditioning is an operation to improve charge storage capacity which may occur as often as every 30 days. Nickel-cadmium batteries used repeatedly in a charge-discharge cycle exhibit an inability to support a heavier drain when it occurs after a series of similar cycles. This "memory" effect may be erased by occasional deep discharges followed by recharge. The ERTS application is sporadic in that discharge will be proportional to use of the sensors and this varies with land mass under the flight path. Thus it may be that reconditioning will not be required. Facility for reconditioning has been provided and initiation will require the following command sequence in real time

Command 374	Regulator 1 disconnect
Command 124	Battery 1 disconnect
Command 165	Battery 1 recondition
Command 120	Execute

A discharge of about 3 amperes will result, automatically terminating when the battery voltage reaches 22 volts. To restore the battery to the charge bus the following commands are required

Command 145	Battery 1 conditioned
(Wait about one revolution and then)	
Command 104	Battery connect
Command 120	Battery execute
Command 354	Regulator 1 normal

All of these commands will be effected in real time, there being no critical timing aspect which would require use of the programmer.

3.4.2 Moon Avoidance

Moon avoidance is an operational requirement easily met and practiced in present day OGO operations. Moon interference in ERTS will occur about two to three times each month when the rising moon may be seen by a horizon tracker. It may repeat on several successive revolutions. This phenomenon is only important at the horizon and in the case where the moon is emerging from eclipse (by the earth as viewed by the spacecraft). The procedure now used for moon avoidance on OGO 6 will be simplified on ERTS by availability of individual tracker head inhibitor circuits. The procedure to be used will be as follows

- Controller examines orbit predict for moon-tracker line coincidences less than 5 degrees (Figure A-9, Appendix A)
- Controller orders command sequence as follows, about one day prior to expected coincidence:

Command 067	OSA arm
Command 155	Head D disable
Command 047	OSA off

The reverse of this sequence is used a day after the moon coincidence to place the spacecraft in the original (redundant head available) configuration.

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4. DATA

The data required to operate an ERTS observatory was reviewed to size the processing and display task. Basis for this review was the functioning spacecraft and the nature of its use. The objectives were to determine if data rates and quantities telemetered were proper for convenient operations.

The two primary modes of operation place quite different demands for data on the system:

- Initial or abnormal operations demanding high visibility of a wide range of spacecraft data while the payload is turned off.
- Normal data production requiring payload and command verification data whereas spacecraft data at a low sample rate is sufficient.

The spacecraft data system design which was chosen earlier to meet the above objectives is made up of one main frame plus three subcommutators. A second operating mode allows subcommutator 2 to be accelerated to the main commutator rate and all data in the main commutator, except time, is lost. These two modes support the two operations modes. When subcommutator 2 is accelerated, spacecraft initial operations are facilitated since all needed spacecraft data is assigned to that subcommutator. For routine data operations the main commutator is suitable and experiment plus command verification data is at high rate.

As part of the control center study the data assignments to commutator formats (see Appendix B) were made. These assignments followed the previous OGO assignments.

4.1 PCM TELEMETRY DATA VOLUME

With very few exceptions the entire telemetry output of the spacecraft must be accepted, processed, and displayed in some manner to operate ERTS. The exceptions are a function of time, e.g., after array deployment it is no longer necessary to be concerned with deployment telemetry. The data volume required is thus defined by the total number of different words times the sample rate. The current telemetry list is slightly revised from the February ERTS spacecraft report and is included in Appendix B.

The types of data and quantities assigned to commutators are shown in Table 4-1.

Table 4-1. Data Assignments to Commutators. Presumes Routine Operations use Main Commutator

	Words	
Main Commutator		
Payload data	82	
Attitude determination	7	
Time, sync, etc.	10	
Programmer store	14	
Command status, spacecraft	7	
Spares	5*	
		125
Subcommutator 1		
Attitude control	1	
Power	38	
Data	19	
Spares	70	
		128
Subcommutator 2		
Attitude control	78	
Structure	5	
Power	23	
Data	9	
Spares	8	
		123
Subcommutator 3		
Communication	56	
Thermal	24	
Data	11	
Spares	21	
		112
	Total	580*

*Multiple sampling explains the increase over the 420 different quantities telemetered.

In the above table multiple samplings of the same item are each counted. For example: the control gas firings are each sampled eight times in subcommutator 3 thus increasing the data volume. The basic data rate is either 0.009 or 0.00028 second per word depending on bit rate (1 or 32 kbits/sec, respectively). The maximum data volume requirement is the sum of the telemetered items or 580 words. Certain items are multiply sampled; there are a maximum of 488 different possible data items.

Data rate to be accommodated is 1 and 32 kbits/sec. The higher rate will be routinely used for real time activities.

A possible inconvenience in spacecraft operation can result from 147-second sampling of data needed for routine operations in the 1 kbit/sec mode. The low bit rate is universal for all out-of-sight operations (88 percent of all time) and may be used for real-time passes as well, if allowable. The data presented by commutators have been analyzed to develop a list of items requiring timely reporting during routine operations. Ground rules for this analysis included:

- Power commands routinely used are limited to those used in reconditioning the batteries.
- Attitude control commands are limited to head selection for moon evasion.
- Routinely operated are RBV and MSS on, off; video transmitters; payload converters; command programmer.
- VHF and unified S-band transmitters are always on.

This analysis resulted in the following list of telemetry data items which should be reported promptly to speed up stimulus and response activity:

Item	Description	Commutator	Sample Interval at 1 kbit/sec
Several	Payload command status	Main	1.152
I1, I15	VTR tape footage	Main	1.152
A17, A18, A19	Reaction wheel count	Main	1.152
A44, A47	Jets, status	Sub 2	147.16

Item	Description	Commutator	Sample Interval at 1 kbit/sec
	Video transmission status	Main	1.152
D10, D59	Load bus current and voltage	Sub 2	147.16
F42, F43	Tape recorder status	Sub 2	147.16
F54 to F65	Programmer verification	Main	72
F68, F69	Programmer parity	Main	1.15
D83	Payload converter status	Main	1.15

The apparent unsatisfactory aspects of spacecraft data rates above are, in order of importance: (1) programmer verification, (2) load bus current and voltage, and (3) jet status. While the last item (jet inhibit) is not expected to be used routinely, it is cited because of a history of frequent use. Reassignment of the telemetry words to the main commutator will solve the problems except for command programmer verification. Increased data rate is required to improve the rate of the latter.

Use of 32 kbits/sec on VHF is permitted only in emergency and use on the unified S-band is feasible unless playback of PCM data is in process or while range code is in use. It should be well worth working around the tape recorder playback periods, to speed-up reporting of programmer load. This is feasible when it is considered that real-time contact with the spacecraft averages about 175 minutes per day. Housekeeping tape recorder playback requires about 50 minutes per day.

4.2 COMMAND VOLUME

An estimate of likely command volume has been made based on typical high-activity payload operation periods. The activity is described in Section 2 and includes activity corresponding to a daylight pass over the USA. Table 4-2 shows this activity and the number of commands associated with each.

From the following activity profiles it is concluded that an extreme pass will have at least 125 commands. Since most of these are to load the store command programmer, many real-time passes will not exceed 25 commands.

Table 4-2. Command Activity in Real-Time Pass, Extreme Case

Time	Action	Commands	Total Commands
T+00:15	Initiate video tape recorder playback on	157, 325, 203 B330, B350	5
	S-band transmitters on	300, 320	2
T+00:30	Initiate PCM recorder playback	061	1
T+3:00	Load stored command programmer	116*, 217	110*
	Warm-up RBV and MSS	A311, 206	2
3:30	Stop video tape recorder	263, 303	2
	RBV and MSS on	205, 306	2
	Switch data to MSS-RBV	151	1
	RBV and MSS off	225, 207	2
	Video transmitters off	201, 221	2
		Total	129

*The store is presumed loaded for six revolutions times 18 commands (Table 4-3).

Table 4-3. Stored Command Activity in Non-Real-Time Imaging

Time	Action	Commands	Total Commands
T_o	Warm-up RBV, MSS	A311, 206, A231	3
	Standby video tape recorder	203, 325	2
	Rewind video tape recorder	243, 365	2
T_o + 1:00	RBV and MSS on	205, A251, 151	3
	Video tape recorders run	223, 345	2
T_o + 12:00	RBV and MSS off	225, 207	2
	Video tape recorder rewind	243, 365	2
	Video recorders off	263, 303	2
		Total	18

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5. DATA COLLECTION SYSTEM

In this section, several key DCS design problems and their solutions are discussed. In addition, alternate methods of ground data processing are discussed. The method chosen is described in detail in Volume 14. The handling of DCS data is unique because of the special nature of the received signal at the ground station.

The data are transmitted to the spacecraft from numerous data collection platforms on individual carriers at approximately 402 MHz within a bandwidth of 100 kHz. Each message transmission is a PCM stream 110 bits long at 2 kbits/sec and takes 55 milliseconds. Each platform transmits approximately one message every two minutes.

The combined carrier content containing the various messages appears at the spacecraft in a random time/frequency multiplex manner. The randomness is due to the fact that:

- There is no attempt to synchronize the timing between platforms.
- The carriers are subject to modification in frequency due to doppler components and oscillator drift.

The spacecraft converts the received spectrum to an IF centered at 75 kHz but retains the original bandwidth of 100 kHz. This is then transmitted via S-band using subcarrier techniques. At the receiving ground station the receiver and subcarrier demodulators recover the original IF.

The problem now is to separate the various randomly occurring carriers, extract the PCM message from each, decommutate the PCM, and provide data inputs to the OCC computer.

There are two principal areas of concern in the recovery of DCS data: the transmission link from the receiving ground station to the OCC, and the processing of data within the OCC.

5.1 DATA TRANSMISSION TO THE OCC

The specialized equipment needed for processing the DCS data, must be properly located at the receiving ground station or at the OCC.

NASA does not favor locating special equipment at MSFN stations (e.g., Texas and NTTF). Hence the raw IF must be transmitted to the OCC. Although the constraint on special equipment does not apply to Alaska, it appears desirable for the GDHS to receive data from all of the three stations in the same form. Therefore, the goal for ERTS-A and -B is to arrange for all DCS data entering the GDHS to do so at the IF level.

The IF from NTTF can be received by hardline since the NTTF is close to the GDHS. From Alaska to GSFC the NASCOM wideband link has the capability to transmit analog up to 23 kHz. The IF would, therefore, have to be handled by means of a 1/8 speed playback, providing a received band between the limits of 1.5 and 17.2 kHz. A 10-minute pass will then require 80 minutes on the data link to be relayed to the GDHS. The NASCOM wideband link does not exist between Texas and GSFC. The proposed solution is a tariffed line of 300 Hz to 20 kHz width. The same technique as for Alaska would then be used.

Although no technological barrier prevents data transmission in the manner described, there is a restraint in the use of the wideband link from Alaska. This is because 10 12-minute passes per day will yield 120 minutes of data time. When this is played back at 1/8 speed, it will take 16 hours occupancy of the link to record it in the OCC. This in itself is an argument in favor of doing the IF demodulation at the Alaska site.

Texas is not a serious problem since the orbital overlap with NTTF approximates 66 percent. Therefore, this station with four 12-minute passes need only contribute one-third of its data to cover that not obtainable via NTTF. However, there still appears to be a potential cost tradeoff in favor of providing this station with IF demodulation equipment as against the requirement for the special tariffed line mentioned above.

At this point it is essential to realize that the output of the DCS data handling equipment proposed by TRW is a synchronous serial PCM bit stream. As such, it is capable of being transmitted by any part of the NASCOM network; or, as in the case of the OCC, being handled by any conventional decommutator. The data handling equipment has been deliberately designed toward this for possible future use at remote ground stations. As noted above, NASA has indicated that they prefer not to have this equipment at MSFN stations for ERTS-A and -B; hence, its location in the OCC. However, for global coverage the restriction on transmission lines would not permit transmission of the 125-kHz IF spectrum even at reduced speeds. In such a case, there would be no alternative but to reduce the data to PCM at remote stations, and then transmit this via normal NASCOM links. Mail is not considered an alternative to the expeditious receipt of the data by land line.

5.2 OCC DATA HANDLING EQUIPMENT

DCS data processing is not required in real time, but only as expeditiously as possible. It is proposed to utilize the PCM decommutator on a time-shared basis with the observatory data. Therefore, equipment is needed to accept the IF spectrum and translate it into a single synchronous PCM bit stream. The bit stream should be accompanied by a clock signal to facilitate processing by a conventional PCM decommutator. The equipment is required to: (a) demodulate the IF and extract the individual PCM messages, and (b) synchronize these by serializing and shifting them out in an orderly manner. To meet these requirements a DCS demodulator and a DCS synchronizer are needed. To permit routine verification of the DCS demodulator-synchronizer a DCS IF simulator is required.

It has been estimated that as many as five messages may be present in the IF at any time. There is a good chance that some of these will collide because of the randomness in frequency. However, the computer software can detect the collisions by means of the error code at the message tail.

In summary, the demodulator reduces the IF to five PCM outputs each containing random bursts of messages. The synchronizer accepts these and assembles them onto a single bit stream which is processed by the stored program PCM decommutator for presentation to the computer.

5.3 ALTERNATE DCS/DATA HANDLING EQUIPMENT DESIGN APPROACHES

The various alternate approaches to the DCS data handling equipment design which have been considered during the study are as follows:

a) A proposed design which uses a spectrum scanning technique.

b) A system using five phase-lock loops with steering logic as discussed in Section 5. 1.

c) An extension of system (b) but using multiple phase lock loops as discussed in Section 5.2.

d) A purely manual approach using a single phase-lock loop to scan segments of the spectrum in successive tape replays; not seriously considered due to its being cumbersome and time consuming. This is mentioned here only for the sake of completeness.

e) Other variations on (a) (b) or (c) as discussed in Section 5.3.

5. 3. 1 Five Phase-Lock Loops

The general scheme of this approach is illustrated in Figure 5-1. The spectrum is divided into 48 subspectra by a contiguous filter bank. A signal detector on the output of each filter drives logic which selects an unoccupied phase-lock loop. At the same time this loop is slewed to the appropriate frequency for acquisition.

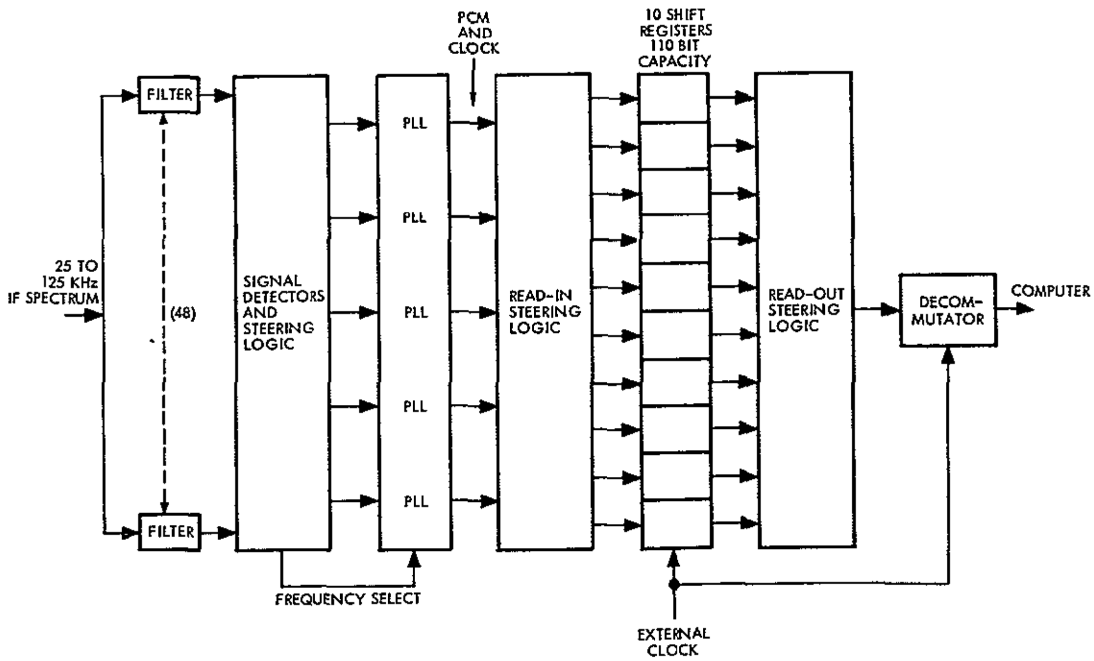


Figure 5-1

DCS DEMODULATOR AND SYNCHRONIZER using five phase-lock loops

The output of each loop module is PCM and clock. Since all messages are asynchronous with each other, the clocks from each loop are also asynchronous. By means of the read-in steering logic the individual clock is used to fill an unoccupied shift register. When filled, the shift registers are emptied into a single data stream using an external clock. The output data is thus synchronous.

The basic shortcoming of this approach is the slew time required by the phase-lock loop to reach the frequency required. Analysis showed that this time plus the lock-on time of the loop and clock detector would in many cases exceed the 25-bit preamble time and result in data loss.

5.3.2 Multiple Phase-Lock Loops

This approach is illustrated in Figure 5-2. Significant changes over that described in Section 5.1 are:

- Each loop is assigned to a small segment of the spectrum and driven by a unique filter. This eliminates the need for loop slewing.
- The steering logic is used to channel the output from any active loop into one of the five shift logic sections.

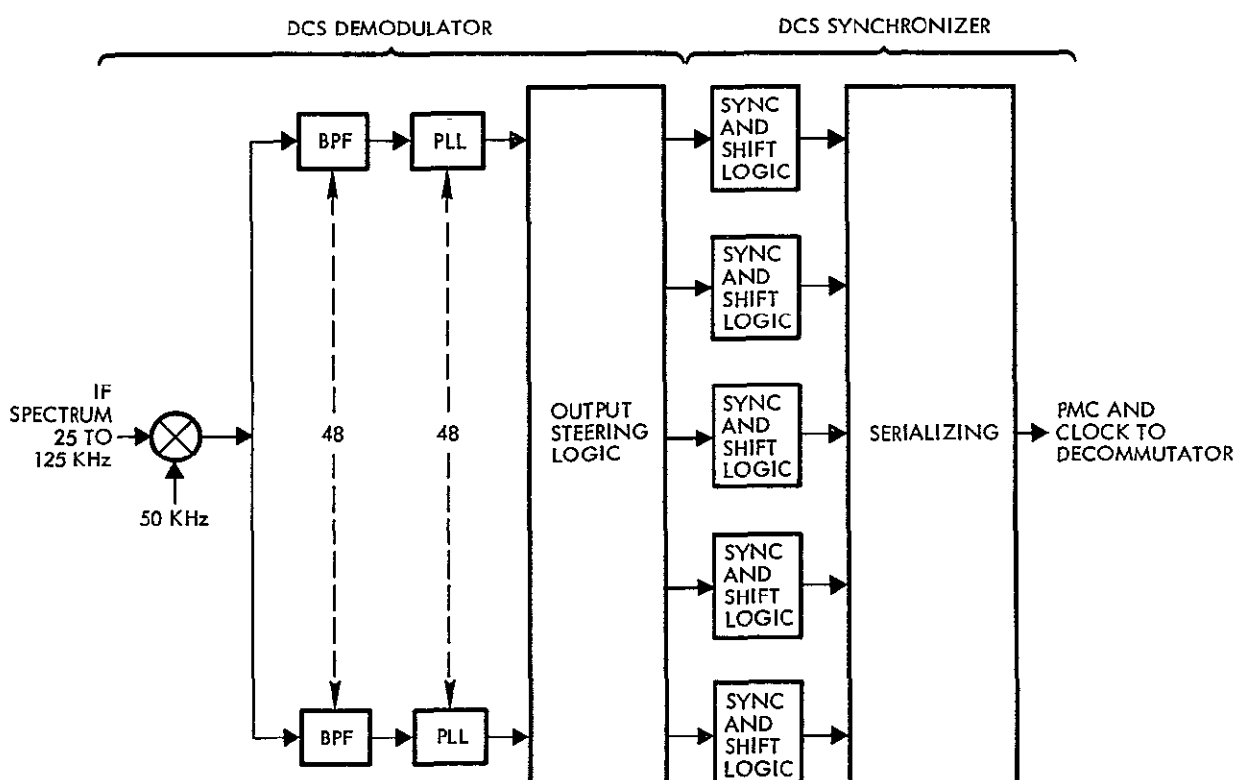


Figure 5-2
DCS DEMODULATOR AND SYNCHRONIZER simplified block diagram

- The shift logic sections each contain a serial shift register. This, when full, is dumped parallel fashion to a storage register. Thus there are a total of 10 shift registers.
- It occupied six drawers while the current demodulator and synchronizer occupies two.
- There are 48 phase-lock loops instead of five.
- There are 48 bandpass filters, instead of six. The application of these loops is·also different in the two cases.
- The steering logic was complex since it had to handle outputs from 48 possible sources.

This approach was discarded in favor of the current one when it became obvious that although it was a workable scheme it was more complex and therefore more costly.

5.4 OTHER VARIATIONS

There were two variations on the schemes described above:

- The use of five-channel PCM recording for temporary storage of outputs from the five phase-locked loops of Section 5.3.1. This was intended to be used instead of the readout steering logic which provides total serializing. This had two disadvantages:
  - a) It required five replays of the tape to feed the data into the decommutator.
  - b) There would be considerable gaps between messages since there was no means of filling the gaps as in the currently proposed design. This would make the decommutation difficult if not impossible. However, it would have required only one bit synchronizer.
- The provision of parallel data outputs instead of PCM. This had the disadvantage that if it were ever required to transmit the output over NASCOM links it would have to be converted to PCM anyway.

6. Command

CONTENTS

6. COMMAND

6.1 COMMAND GENERATION

ERTS command generation is significantly different and somewhat more exacting than for OGO spacecraft. The requirement of ERTS to store commands in the spacecraft with time tags affixed is in response to the need to begin imaging at specific geometric positions. This in turn requires computation of time tags from orbital data and user requests.

The concept finally evolved for generating commands was reached after several proposed concepts had been rejected in turn:

a) A first proposal was to generate the command bit stream by computer, producing a punched tape which would then be transmitted to the desired ground station. The ground station would load this bit stream into its encoder and transmit on authority of the OCC. As a backup method in case of computer failure, a command encoder was included as part of the operations center.

b) A second concept resulted from a suggestion that command trains be sent directly from the OCC to the spacecraft during a real-time pass. This used either the computer or command encoder over a high speed data link to the station encoder for immediate transmission to the spacecraft. This concept included a validation loop which showed correct reception at the station encoder and at the command transmitter antenna. To accomplish validation at the OCC command encoder required a second smaller computer or significant addition to the main OCC computer.

c) A significant simplification is evident in the final configuration. This uses the OCC computer to generate the command bit stream while the NDPF computer serves as backup in case of failure. No command encoder is used at the operations center. When required the switching onto the backup computer is nearly instantaneous. A third alternative is available in that commands ordered by the OCC may be generated by tape or manually at the ground station concerned. The description of the command generation equipment and functional operation is included in Volume 14.

6.2 COMMAND VALIDATION

The command message is validated at every opportunity along the trans-location path. In the OCC, the command console operator will be able to call up the command message for visual display before the message is sent to the remote sites. Also, the computer will have an off-line capability of making a bit-by-bit validation check between the data interface buffer and the ADPE.

At the STADAN sites, command word parity errors are registered on the STADAN command encoder. The command message is automatically returned to the OCC for a bit-by-bit validation by the computer and the validation status is displayed on the command console.

At the MSFN site, the command data processor accepts the command message from the transmission lines if it has the correct station address. The processor then performs the following checks to determine that the commands are valid:

- Checks the MSFN error coding added to the message by the OCC computer
- Checks the vehicle address
- Checks the command word structure by comparison with the words of a complete command library stored in the memory of the MSFN command data processor.

If invalid, a retransmission of the command is requested from the OCC command operator.

Upon validation of the translocated command (in the primary mode), the computer automatically sends an uplink transmission instruction to the ground station command encoder.

During the uplink transmission phase, the STADAN station command encoder output can perform a bit-by-bit detection and verification of the PCM/FSK modulating signal. Also, the VHF transmitter output is sampled by a command verification receiver mounted on the command antenna and the detected (PCM/FSK) signal is routed back to the encoder where a bit-by-bit check on the radiated signal is performed. Any error will halt the command transmission and transmitter keying immediately; also, a ground verification error signal will be automatically sent back to the OCC for operator intervention.

During the MSFN uplink transmission phase, the PCM/PSK signal generated in the up-data buffer is simultaneously demodulated and sent back to the command data processor for bit-by-bit verification. Also, the S-band signal is sampled at the transmitter output by a unified S-band receiver which restores the PCM/PSK subcarrier modulating signal and returns it to the up-data buffer demodulator and the data processor for a complete echo check. Any echo check error observed at the MSFN site will halt command transmission and an error message will be returned to the OCC for operator intervention.

6.3 COMMAND VERIFICATION

Each uplink transmitted command is verified automatically in the primary mode by the OCC ADPE continually examining the spacecraft telemetry. Acceptance of a real-time command by the spacecraft and its transfer to the spacecraft command distribution unit is indicated by an enable bit. Execution of ERTS unique commands is verified by commanded relay status changes; stored programmer commands by readout of the entire stored command programmer memory; and all commands by functional changes in the commanded spacecraft components. Displays, printouts, and strip charts associated with the OCC PCM data handling equipment present the verification data as a backup to the ADPE.

7. Scheduling

CONTENTS

7. SCHEDULING

The ERTS scheduling problem is negligible if North America only is to be covered but becomes somewhat complex as global coverage is approached. Ground station visibility (cloud cover) is the primary limiting factor on accumulation of world-wide data.

The factors which must be considered in planning imaging sensor operation are:

- User need. What are the geographical areas to be imaged and what priorities are attached?
- Weather. Is there recent cloud cover data which precludes obtaining good images?
- Tape recorder capacity. Is there a conflict for use of the limited observatory recording time? This does not pertain to North America where real-time coverage is almost complete.
- Power. Is there a limit set by array output or battery discharge capability?

This section will assess the importance of all these factors in scheduling observatory operations. There is one other factor which weighs heavily on operations by video tape recorder. With a limited recorder life of 500 hours, what data is important enough to warrant recorder use?

7.1 TOTAL AVAILABLE IMAGE

Since the ERTS sensors are primarily to be used over land, an estimate may readily be made of the maximum possible imaging which could be accomplished if no other factors limited operations

Figure 2-1 shows a typical day of 14 revolutions. The north to south passes are in daylight and consititute all data accumulation passes. A first conclusion from this figure is that Greenbelt, Corpus Christi, and Alaska stations provide sufficient coverage for all North American data to be relayed in real time, little resort to the tape recorder is required.

Figure 7-1 has been prepared from an examination of Figure 2-1 to arrive at the total time per revolution for land-in-sun and real-time

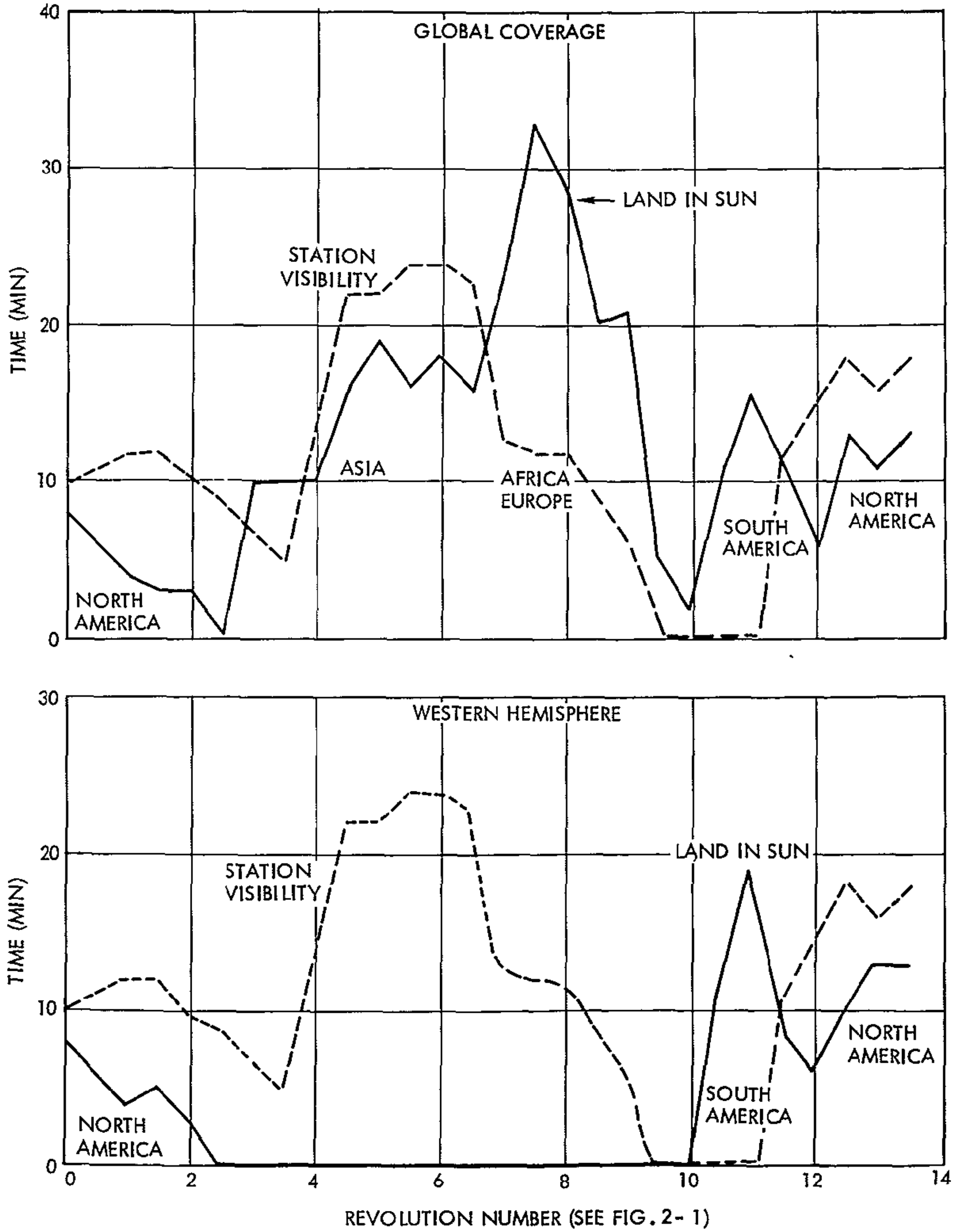


Figure 7-1

ERTS STATION VISIBILITY compared to sunlit land traversed by orbit coverage. Without respect to other limitations, such as cloud cover, the lower part of Figure 7-1 shows that the coverage of South America (all by tape recorder) can be effected without exceeding 30-minute tape recorder capacity; but capacity is almost reached on revolution 11.

The upper part of Figure 7-1 shows generally that from revolutions 7 to 11 accumulated data will exceed the capacity of the tape recorder to store, and ground stations to read out, the data. Since there is no real-time coverage the integral of the data curve must not exceed the station visibility curve integral by more than 30 minutes for increasing revolution number (negative accumulated coverage neglected). Most tape data will be read out at night.

To more precisely evaluate the global imaging possibilities the following procedure was used:

a) Two typical sets of 14 revolutions were used as a base for study. The first set is numbered 1 to 14 on Figure 2-1. The second set is not shown but lies midway between those shown (12 hours later). For convenience these latter revolutions are called 1-1/2, 2-1/2 etc. on Figure 7-1. A revolution begins at the north-going equatorial crossing.

b) Land mass under a sunlit (descending trace) requires payload operation.

c) If land is within a coverage circle for Corpus, Alaska, or Greenbelt this payload operation is real time.

d) All other payload operation is recorded.

e) Only land between +75 and -75 degree latitude was considered.

f) If the recorder reaches 30 minutes of stored MSS data or 50 minutes of RBV data, operation of the appropriate sensor was discontinued.

g) Data was dumped at every opportunity but not when real-time imaging was possible.

The tabular data accumulated by this analysis of operations is shown in Table 7-1 for one case. The beginning of operations at revolution 1 was without accumulated data. When revolution reappears it is seen that residual tape recorder data remains. Hence, the process was continued to the end of revolution 3 where, as can be seen, the cycle begins to repeat.

Table 7-1. MSS Operations for One Day in Revolutions 1 through 14

	Revolution																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	1	2	3
Real time data, min	4	3	3	1	-	-	-	-	-	-	-	5	12	8	4	3	3
Record data, min	-	-	7	10	19	18	23	13	6	-	-	-	4	-	-	-	7
Video playback, min	-	-	-	7	10	19	12	12	6	-	-	10	5	2	8	2	-
Residual on VTR*, min	-	-	7	10	19	18	29	30	30	30	30	20	15	13	5	-	7
Data lost, min			-	-	-	-	-	16	15	3	19	3	-	-	-		

*At north-going crossing of equator.

The process was continued for more than 14 revolutions to determine whether the residual tape recorder data could be fully unloaded in available passes. This could always be accomplished. The gross conclusions of this study were as follows, with no other limitation than tape recorder capacity:

	Revolutions	
	1 to 14	1-1/2 to 14-1/2
Total land traverse time, min/day	192	180
Real-time data, min/day	36	37
Lost MSS data for lack of tape recorder capacity, min/day	56	33
Lost RBV data for lack of tape recorder capacity, min/day	40	22

Figure 7-2 shows the possible global coverage lost as a result of limited tape recorder capacities, again under the artificial condition that cloud cover was nonexistent.

7.1.1 Ground Station Coverage

The limit described above could be lifted somewhat by increased tape recorder capacity, but then limited ground station time (for dumping

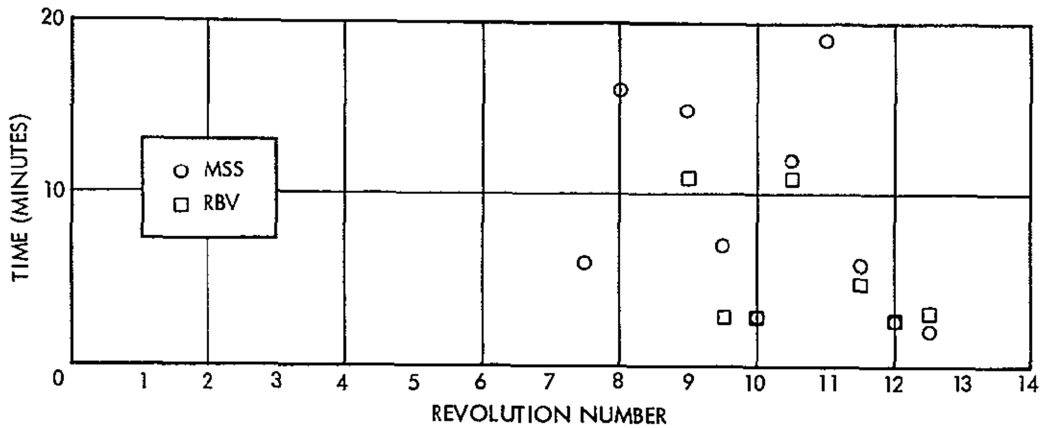


Figure 7-2

IMAGE DATA lost for lack of tape recorder capacity. Two typical sets of 14 revolutions were analyzed.

recorded data) would rule. The total available ground station pass time (Corpus plus Greenbelt plus Alaska) is 160 minutes for revolutions 1 through 14 and 175 minutes for the 14 revolutions 9 days later. Clearly 5 to 32 minutes data would be lost for lack of ground contact with the observatory.

7.1.2 Weather

Estimates of cloud cover vary with the season but 33 percent cloud cover is suggested as a minimum figure. If this figure is uniformly assumed throughout all land masses, the total imaging time lost in the 14 revolutions of Figure 7-1 is 24 minutes instead of 56 minutes for the cloud-free case. Data obtained in this case (1/3 lost due to clouds) is 114 minutes of which 86 minutes is recorded.

7.1.3 Tape Recorder Life

The life of a video tape recorder is about 500 hours. Assuming the case stated above with 86 minutes ($\cong$ 1-1/2 hours) per day imaging by recorded data, the life of an average tape recorder will be 300 days (where 50 hours is required for ground testing). Tape recorder life will be one of the factors to be weighed in the scheduling process.

7.1.4 Array Energy

The energy required to support imaging activity can be computed from known power requirements. For simplicity again, and merely to bound the problem, it is assumed that no cloud cover exists; sensors will be operated up to the limit of tape recorder capacity.

In calculating energy need, the assumption was made that all payload is on at once, that all land is imaged until the recorder is full, and that power requirements are:

Spacecraft plus DCS	164 watts
Payload, real time	340
Payload, record	450
Payload, playback	250
Battery losses	22

The energy required for the two sets of 14 revolutions previously used is shown in Figure 7-3. Here it is seen that the real-time data accumulation from North America (revolutions 12, 13, 14, 1 and 2) requires substantially less than the array design point energy of 29,500 watt-minutes Revolutions 5, 6 and 7 require about 31,000 watt-minutes in consequence of recording 15 to 20 minutes of data in sunlight and playing 12 to 19 minutes back in eclipse.

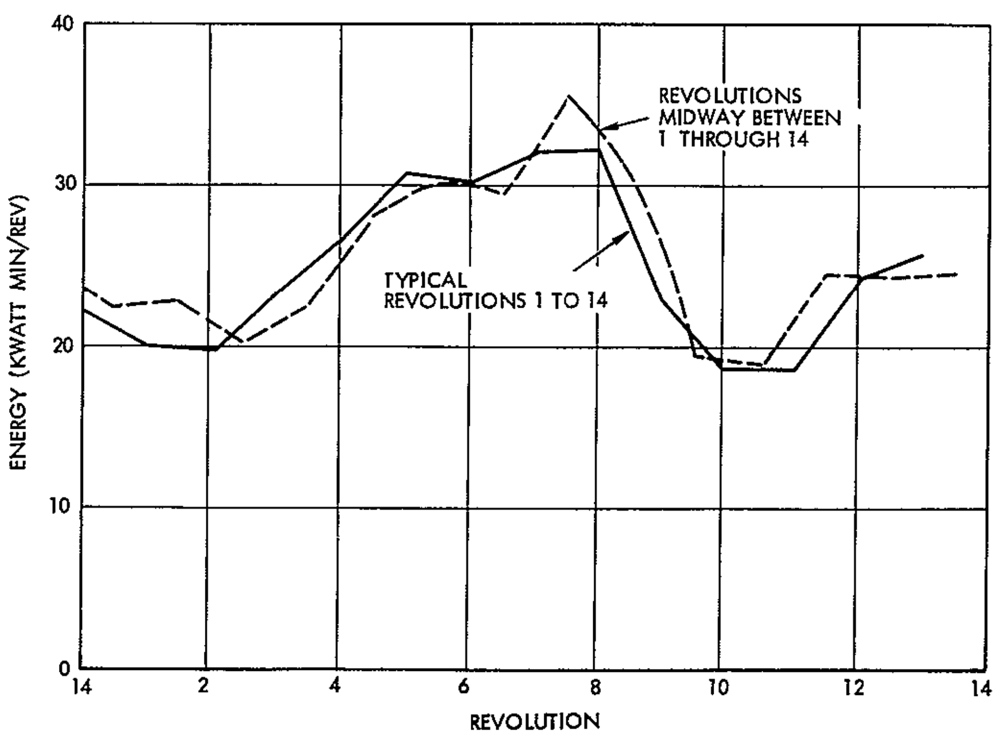


Figure 7-3

ENERGY REQUIRED for global imaging as limited only by recorder capacity

Examination of the energy availability profile, reproduced as Figure 7-4 from Volume 3 Final Report, shows a surplus of energy. Assuming a 9:30 a. m. launch the least power in the first year of operation is 33, 000 watt-minutes. Thus it appears that energy availability from the array will not be a significant limit on the sensor scheduling activity.

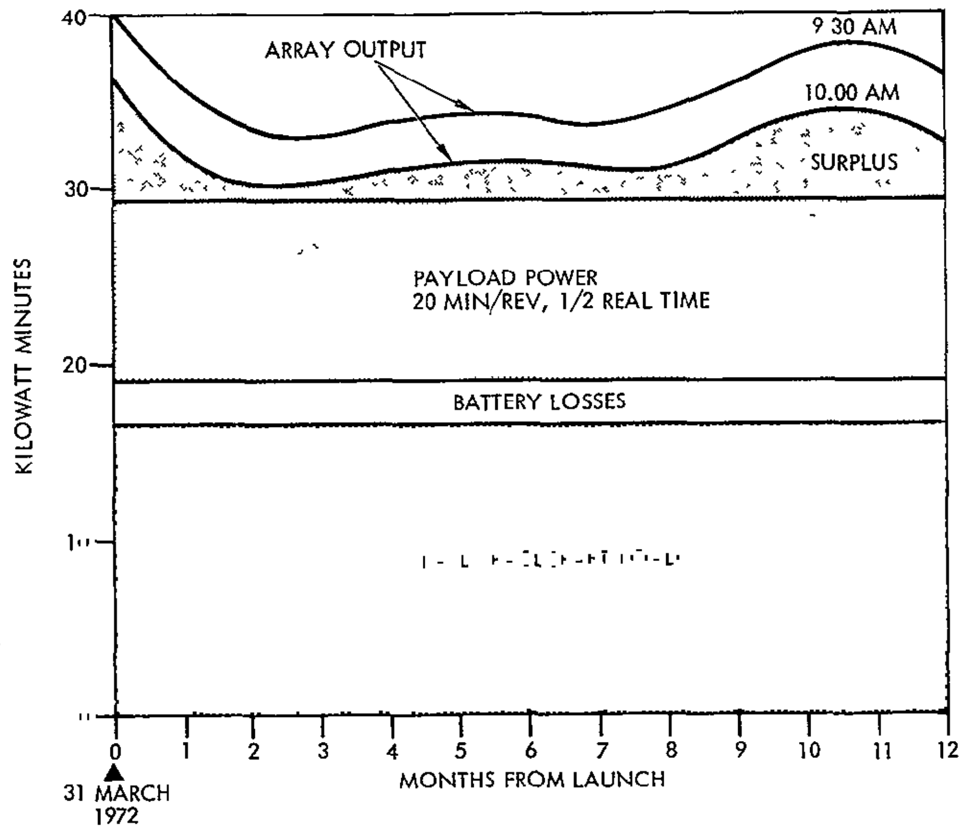


Figure 7-4

ELECTRICAL POWER during first year of operation

7. 2 BATTERY CAPACITY

In Volume 4, Section 11 of the Phase B/C report it was shown that a depth of discharge of 25 percent is reached for a specified set of standard conditions. Primary among these conditions was 20-minute sensor operation; 10 minutes real time and 10 minutes record and playback in one revolution. The purpose of this section is to determine a realistic depth of discharge with the global coverage pattern used above as the model. Again no factor other than tape recorder capacity is used in limiting sensor operation.

Figure 7-5 shows a typical day of orbital operating activity. Specifically the revolutions shown are 1 through 14 of Figure 2-1. Since the bulk of the land areas are situated in the northern hemisphere it often happens that battery discharge occurs in sunlight. To determine the approximate battery discharge in excess of 13 percent by one-third. Data shown is for the spring or fall seasons. Discharge will be less in summer, more in winter.

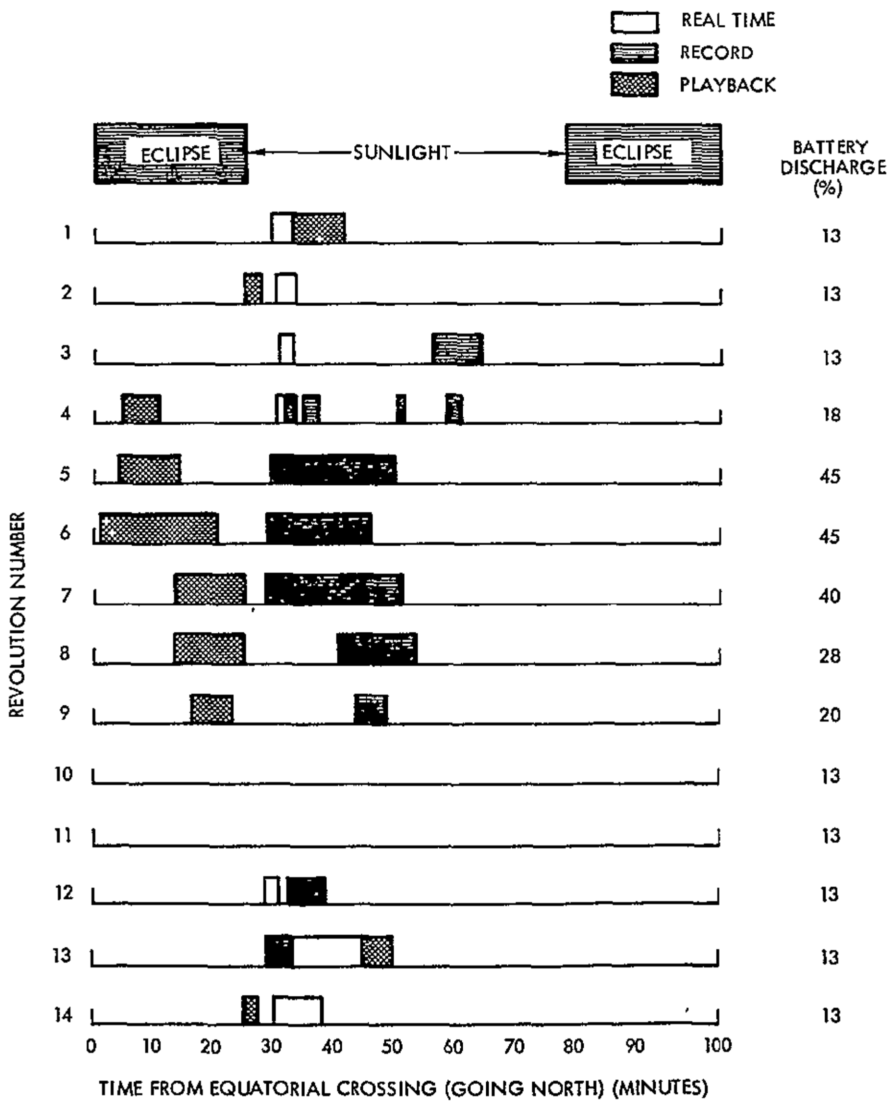


Figure 7-5

TYPICAL DAY of orbital operating activity

The conclusion on battery discharge is, that a mild limit on global operations exists and that the specified payload use-cycle is easily met. In practice, it is doubtful if operations will need to be limited by battery characteristics.

7.3 EVENT SELECTION

The scheduling process uses the above considerations plus weather and user requests as follows.

Periodic requests for sensor coverage will be received at the OCC via the User Liaison Office of the NDPF. These requests, in the form of polygon overlays on the surface of the earth, are converted to 30 x 30 nautical mile squares or "cells." The centers of the "request" cells are tagged with latitude and longitude and the resultant information stored in the data base for subsequent comparison with potential swath coverage.

Upon receipt of ephemeris data and selection of a particular time interval, the 100-mile-wide swath or ground trace is determined. All cells whose centers lie within the swath of full coverage are computed and compared with cells which have been requested for sensor coverage. Those cells which have been requested for coverage and lie within the ground swath are assigned "event" status. The software assigns "event" status to all visible cells requested for coverage.

Because of the possibility of later video recorder conflict if all visible cells are granted sensor coverage, a "value" is assigned to each "request" cell. This "value" is determined from the priority, or relative worth of data received, and the probability of clear sky (no cloud cover).

For each "request" cell it is determined if the spacecraft, while overhead, lies within view of one of the three dedicated stations. If the spacecraft is within view, sensor data will be received in real time for that cell, otherwise use of the tape recorder is dictated. The design methodology utilized in actual event selection is discussed below.

The amount of current tape recorder use is determined at the beginning of the time interval of interest. Planning will always occur for integral revolutions, with initiation at the ascending node. Beginning at this time for the revolution of interest, the orbit is stepped around at constant time intervals corresponding to the time it takes to cover one cell length, approximately eight seconds. If a station contact occurs, the current time on the tape recorder is determined. If there is data on the tape recorder, as much of it as possible is read out during station contact time. If there are requests for cell coverage during tape recorder read-out, one of two options must be selected: 1) either the tape recorder read-out takes precedence, or 2) cell coverage requests are granted and the tape recorder is read out at the next opportunity. This selection is made by operator input.

If the tape recorder is full and a request for cell coverage occurs, all conflicts are stored for display to the operator. The data necessary for the operator to resolve the conflict is stored. When the time interval of interest is completed, manual events such as orbit adjust, battery reconditioning, etc., are added to the planned event list at the appropriate time. When all events have been entered, the event list is displayed for operator approval. The operator, when confronted with the event list generated by software execution, may elect to resolve schedule conflicts, change events, add events, or delete events from the schedule. When he is satisfied, the event list is stored for use by the command generation software.

There are several basic design philosophies incorporated in the sensor event selection process. These are:

a) No data which has been stored on the video tape recorders will be deleted unless input by operator control.

b) In the event of conflict between requested cell coverage and tape recorder readout one of two possibilities exists: the operator elects to read out the recorder, or he elects to grant cell coverage. The decision is made at the beginning of software execution and is followed for all conflicts of the computer run.

c) Manual events are entered after sensor event selection is complete.

d) Upon generation of the event list the operator may change, add, or delete events at his descretion.

e) All conflicts for coverage on the video tape recorder are resolved by the operator.

7.4 SUMMARY

The problem presented in scheduling observatory use in the presence of conflicting demands has been examined. The conclusion reached is, that no limit except cloud cover exists in North America and that full global coverage is limited only by tape recorder capacity. Array power, battery depth of discharge, and tape recorder life are not significant inputs to the scheduling choice. If the video tape recorders are used as heavily as needed, the only limit being cloud cover, their nominal life will be 300 days.

8. DISPLAY

The purpose of display in the control center is to permit operators to readily assimilate information needed for decision making. The information will consist of past history, current state, and planned future state of many variables. Display takes many forms; those commonly found useful in control centers today are:

- Fixed printed forms such as maps, telemetry formats, command matrix charts. Such material is invariant and cheap, but essential, especially where a variety of spacecraft are operated from one center by the same people.

- Printouts from computer sorting of telemetry data, command status, etc. Such pages (Appendix B) constitute a ready historical reference and inexpensive storage. Current pages are posted for review by operators coming on duty, visitors, etc. They are indispensable.

- Volatile display from computer memory of current and recent data or proposed schedule, commands, etc. This display, usually by television picture tubes, can be readily altered by the operator. Memory of recent past history is expensive and limited but can be supplanted by magnetic tape storage already required for long term storage of data. The extreme flexibility of television display favors its use. The same station can display alphanumeric charts, images from cameras, in space or nearby, etc.

- Strip Charts, commonly in banks of eight pens, writing on special sensitized paper. These units are invaluable in a dynamic situation and provide facility to see through noise which renders other displays meaningless. Operator annotation of records as they are being made is quite valuable. Strip chart record is commonly the primary data for reports and flight analysis.

Each of the above display methods has its place in the ERTS control center, each is planned. The data to be displayed is briefly described as follows:

- Observatory Analog Telemetry Measurements. These are the commonly accepted temperature, voltage, current, shaft angle, etc. data used in evaluating health and in planning future use of the observatory. They are called analog measurements and are quantized to 8 bits for transmission.

- Observatory Status Measurements. These items are on-off state only and indicate the condition of many switching functions controlled automatically in the spacecraft or by command from the ground. Transmitted by the same pulse count or digital telemetry this data is often single bit in form, i. e., on = one; off = zero. Status measurements include charge rate, attitude control mode, tracker heads in use, etc. This category also includes the store of the command programmer which is read out bit-by-bit in a selected section of the telemetry commutator.

- Control Center Plans. This category includes all actions planned and available from the computer store which will at a future time modify the observatory status. Typical items are commands to be transmitted for real-time effect or for store in the stored command programmer of the spacecraft. If storage is intended, the time for execution is also listed.

Only a brief study of the above types of data is needed to show that:

a) Analog data generally deserves analog display if it is fast moving. Examples are: attitude control error signals, bus current, array temperatures, etc.

b) Much of the analog telemetry data is extremely slow moving and is adequately served by the printout or television digital display. Examples are converter voltages and temperatures.

c) All of the status data is properly displayed by digital printout or television. Past use of an analog chart recorder for displaying response to a ground command can probably be supplanted by real-time viewing of the television digital display.

The choice of display is not so much which category will be used but how much of each is needed — a question of utility versus cost. The wall map or chart will be used to the extent it is useful. Similarly the printout from computer sorted data is indispensable. The short term storage utility of the printed page is high in effectiveness/cost ratio.

Analog strip charts are invaluable during initial or abnormal orbital conditions. Thus the number required is set by the quantity of data which must be seen in real time. It is common practice to use additional strip chart display physically separate from the control center during initial operations. The items to be displayed on the control center strip charts during initial operations, 36 in all, are listed in Appendix D. Since each bank of recorders allows eight records we have chosen to install six racks. One rack is spare to the launch requirements.

The television display provides a working tool for man-computer operations. In addition, the television display can be duplicated in as many positions as desired. The functions which television display will readily perform in observatory operations are:

- Telemetry data grouped for convenience can be read.
- Commanded status can be examined and new commands verified.
- Computer-stored plans for future activity can be called out for review.
- Results of computer limit checking of performance can be signalled.

In addition to the above alphanumeric displays, the digital television system is suited for display of sensor images for quality checks and may be used for analog plotting. A limit is set on the latter by the available storage; the strip chart made from real time or magnetic tape stored data is more useful.

The arguments favoring digital television are overwhelming — the only system disadvantage is limited analog plotting capability, but this is supplied by strip charts. The chosen configuration is related to the operational requirements as follows:

- 17-inch displays serve individual operators at consoles.
- 25-inch displays serve the control area from ceiling-mounted positions.
- All positions have access to the same selection of display formats.

A comparison of video display methods was made before selecting the digital television system. This is reported under the display section in Volume 15.

9. Operational OCC Software

9. OPERATIONAL OCC SOFTWARE

This section reviews the software defined by detailed operating plans in earlier sections.

The operational software for the ERTS OCC consists of that software which operates in real-time or during the time interval the spacecraft is in view of a station, and that which operates in non-real time, or during the time the spacecraft is outside of station view. The design of the non-real-time software is dependent upon the requirements for real-time software.

Real-time software must be capable of processing a 128-word (9 bits/word) main frame at 1 kbits/sec minimum and 32 kbits/sec maximum; this corresponds to processing one main frame of data every 1.152 seconds at 1 kbit and every 0.036 second at 32 kbits. Because the 128-word main frame contains three words corresponding to three 128-word subcommutators, approximately 450 different words must be processed every 147 seconds at 1 kbit and every 4.6 seconds at 32 kbits. Processing of telemetry includes limit-checking a maximum of 150 words, conversion to engineering units of 320 words, computation of engineering parameters, and printing out these words in fixed format within 2 minutes after a request is received. During real-time operations, displays must be continually updated.

In addition to the above requirements two additional functions must be accomplished if requested. The first function required is command generation during real-time telemetry processing. An operator must have the capability to either enable a pre-selected command sequence for transmission, or punch in (via console) GMT, command octal number, and transmitting station code to effect transmission of a particular spacecraft command. Having done so, the software must then encode the command in proper format for transmission.

The second function required is the validation and verification of commands transmitted to and executed by the spacecraft. Validation of command transmission proceeds in steps. The computer formatted command output is routed to a data input buffer for translocation to a remote station. Upon translocation via NASCOM, the command itself (in the case of STADAN) or a command message (in the case of MSFN when an anomaly is recognized) is returned to the OCC for validation. If the command was translocated properly, the transmission process continues. Upon actual transmission of the command signal to the spacecraft an "echo check" is conducted by the remote station, and a bit is returned to the OCC indicating that the proper command configuration was transmitted. In the event that an erroneous command is detected during either of the two validation steps, the transmission process is interrupted and operator intervention occurs. Telemetry processing, however, continues. The operator may choose to resend or drop the command; in either case a decision must be made. Upon validation of correct command transmission, the verification process begins.

The verification software must be initiated following validation of proper command transmission. This software must search the telemetry frame for the word, or words, corresponding to the vehicle function activated by command. These words are filed and indicators are routed to displays for operator monitoring. If a command execution verification is needed prior to additional command transmission and this verification is not received, operator intervention occurs. The entire software package during real-time operations must be structured to allow operator control and intervention precedence over software operation.

The above requirements indicate that capability must exist for three functions to operate simultaneously during real time. These functions are:

- PCM telemetry processing function (RPROSTM)
- Command generation function (ROMAN)
- Command message update function (RCOMESUP)

While all spacecraft station passes will not require the operation of these three functions simultaneously, for some passes tri-functional operation will be mandatory.

The operational OCC software is divided into five specific, but interrelated, functions. The real-time portions of three of these functions have been briefly described above with respect to the requirements imposed on them. The five functions are briefly described below. For a more detailed description see Part II, Volume 21 and Volume 24.

Observatory Scheduling Function (RUTSKED). This non-real-time software operation must begin two weeks or more before spacecraft commanding occurs. User requests for sensor coverage are examined by RUTSKED and from these requests a list or "set" of necessary observatory events is generated. The event list includes communications times with ground stations, sensor events for RBV and MSS operation, orbit adjust events, wideband tape recorder events, and events which occur outside of station view and must utilize the capabilities of the stored command programmer. During the software operation, the event list is periodically displayed for operator monitoring. If he desires, he may change the priority of events, thereby causing rescheduling. When he is satisfied with the event schedule, the schedule is stored for later call by the command generation function. At any time prior to command generation the operator may call for changes or additions to the event schedule.

Command Generation Function (ROMAN). The command generation software is divided into real-time operation and non-real-time operation. The non-real-time operation begins when command generation (ROMAN) accepts the event list from RUTSKED and, together with manually input commands, transforms it into a command list. The command list is a schedule of the actual commands to be sent to the spacecraft together with the time of transmission and, in the case of SCP commands, their planned execution time. This list is displayed to the operator and he is permitted to make manual changes to it. Since the command list is subjected to comprehensive checking by ROMAN it is suggested that if manual changes are made that the ROMAN software be permitted to check the list again. In any event, the operator is in control and the re-check is run at his option. When the operator is satisfied that the command list is correct, he has several options and may choose any subset of them. He may prepare a punched paper tape of the command list. With this tape he may transmit the command list to one or more remote stations via teletype or NASCOM, to enable them to act as a backup command station. In any case, the actual command list is stored for use during real-time operations.

The task of ROMAN during real-time operations is to transmit by commands to the spacecraft. When ROMAN gains control, it scans the list of prestored real-time commands with transmission times to determine if it is time to send a command. If it is time to send a command the operator is interrogated for his permission to enable the transmission of one or more real-time commands. The operator additionally may compose a command to be transmitted. When the operator's permission is granted the command validation process begins. Basically, this process consists of communication between ROMAN and the remote station via NASCOM transmission facilities. For STANDAN stations, ROMAN transmits the command to the station and the station returns the command to ROMAN. ROMAN performs a bit-by-bit comparison of what was sent and received, and if the same, ROMAN tells the remote station to transmit this command to the spacecraft. For MSFN stations, ROMAN encodes the command with a polynomial error code. The station decodes the command, and if the code does not check, returns an error signal to ROMAN. If the error code checks, no signal is returned, and, after an interval of time, ROMAN orders the station to transmit the command to the spacecraft. In the case where the command does not satisfy the bit-by-bit check, or the error code does not check, ROMAN stops the commanding process, the command is not sent to the spacecraft, and the operator is asked for instructions. First he will probably try retransmission of the command. If that is repeatedly unsuccessful, he must enter a backup mode of commanding, utilizing voice communications with the remote station to enable transmission of the commands that were pre-stored at the station. After ROMAN has determined that a command or command block has been properly received at a remote station, transmitted, and echo checked, it passes control to the command message update function (RCOMESUP) for its portion of real-time operations.

Command Message Update Function (RCOMESUP). Initiation of the non-real-time portion of RCOMESUP software occurs when the command sequence for a particular time interval has been generated. RCOMESUP annotates each command on the schedule with the indicators which will allow software execution of command execution verification. These indicators consist of the telemetry word or words corresponding to the function or functions which will change following command execution. Following execution of the annotation routine, this information may be printed out upon request.

Another non-real-time portion of RCOMESUP software is executed to predict vehicle status to a time T; this time T corresponds to the time at which ERTS is acquired by a station following an out-of-sight interval. Upon entrance into station view during real-time operations, the predicted status will be compared to actual status; if congruence is achieved, all stored command programmer commands can be assumed to have executed properly. If anomalies are noted, they are displayed for the operator. In addition to status prediction RCOMESUP will output a command execution history following each pass.

During real-time operations it is the task of RCOMESUP to determine that the spacecraft has properly acted upon the transmitted command. RCOMESUP maintains a continuous record of the last main frame received. When it gains control after a command has been sent, it updates that record. Thereafter, each time it gains control, it searches the working buffer of changed telemetry parameters updated by RPROSTM (to be explained below). From this telemetry, RCOMESUP determines the spacecraft response to the command. RCOMESUP checks to insure that the proper vehicle function is executed in response to the command and also that no other vehicle function executed. During these operations, the operator is informed of command status via continually updated displays.

PCM Telemetry Processing Function (RPROSTM). The telemetry processing function is primarily a real-time operation although capability exists for non-real-time processing of ERTS tape-recorded telemetry. RPROSTM performs simple algorithmic processing on the telemetry parameters to accomplish conversion to engineering units, combination or averaging parameters, and limit checking. Parameters are displayed, and if not within prescribed limits, are noted to the operator. The operator may at his option change the prescribed limits. The raw main frame data converted to engineering units is stored on a historical tape for later use by the NDPF. Additionally, up to 10 parameters are stored for fast access for real time or post-pass trend analysis. One further task of RPROSTM is to compare each telemetry main frame with its predecessor and store those parameters which have changed in a working buffer. After the telemetry processing is complete, control is passed to the command generation function (ROMAN). As noted above, ROMAN may either send a command or relinquish control. Upon sending a command and validating transmission, control passes to RCOMESUP for the command verification process. Upon completion of verification, control passes to RPROSTM and the cycle begins again. Each time a main frame of data is processed, the above cycle occurs. At 1 kbit/sec, the cycle time is 1.152 seconds with RPROSTM, ROMAN, and RCOMESUP assuming control and executing every 1.152 seconds. At the maximum data rate of 32 kbits/sec, severe requirements are placed on RPROSTM. RPROSTM must process approximately 28 main frames of telemetry data per second. However, because commands cannot be accepted by the ERTS spacecraft when spaced less than 0.5 second apart, the functions ROMAN and RCOMESUP need only operate approximately twice as fast as they do at the 1 kbit/sec data rate.

Sensor Coverage Evaluation Function (RSENSCOV). RSENSCOV operates in the post-pass processing mode. From the command execution history, the approximate times of camera operation are extracted.

Using these times as a basis, the shutter times are determined from a propagation model, and the corner coordinates of each camera image are fixed. The times and the coordinates are checked with the expected coverage to insure that user requests have been satisfied. This information is routed to the observatory scheduling function and the user request files are updated.

Alternate Software Approaches

The OCC software design calls for five basic OCC software functions. These are the observatory scheduling function, command generation function, PCM telemetry processing function, command message update function, and the sensor coverage evaluation function. Preliminary software design requirements imposed a sixth function, ground facilities scheduling. This function was to schedule ground stations when it appeared that a large number of STADAN and MSFN stations would take part in command and control of ERTS. When the requirements solidified, and it was recognized that only three dedicated stations would be involved in normal operations, the necessity for a computer software function to schedule station contacts was greatly reduced. Considering the cost of this software, it was removed from the baseline design. The remaining five functions enumerated above remain in ERTS OCC software and are briefly discussed with respect to function design meeting ERTS imposed requirements.

Observatory Scheduling Function

The observatory scheduling function converts user requests into a sensor event list, adds any manual events required for spacecraft control, and purges the request file upon receipt of fulfilled sensor coverage information. While the user request file could be managed using a card system (key punch, printer, sorter, and interpreter), the volume of requests, the number of images, and the problem of converting requests for coverage into sensor events lends itself ideally for computer solution. A card system would require extensive clerical help and knowledgable technicians to convert requests into events with proper times and purge the files of those images which have satisfied the users. With the present software design, a skilled operator can accept a set of requests, convert them to an event list using a computer routine, display the event list, make any discretionary changes, and store this list for use by the command generation function in a short period of time.

Another tradeoff study resolved by the present software design involves the question of whether or not to solve by software routines video tape recorder conflicts as they appear during the scheduling process. Previous designs displayed the conflicts between full tape recorders and additional requests for sensor coverage, then computed various options. Extensive software was required to search ahead on the event schedule, store all conflicts, and compute the options for operator on-line decision. Studies revealed that for U. S. coverage, no tape recorder conflicts would occur, and for worldwide coverage, conflicts would occur at approximately the same times during each 18-day ERTS cycle. When scheduling, the present design displays the conflicts as they appear and does not attempt to compute various options. The operator makes a decision based on predicted weather data or other information and resolves the conflicts.

In most cases he will be aware of potential conflicts between full tape recorder and sensor requests because of their periodic nature.

Command Generation Function

The command generation function accepts the event list for a period of time, converts it to a spacecraft command list, and stores the command sequences for OCC commanding during real-time operations. With a large number of commands to be transmitted each day, this function is best performed by computer processing. A large portion of commands will utilize the stored command programmer and require conversion of GMT scheduled events to vehicle clock time commands stored in the SCP memory. A simple computer routine causes this process to become error free. During real-time commanding prestored sequences are activated for transmission from the computer, through NASCOM, and to the remote station for radiation. Validation checks are automatically performed and any anomalies cause operator intervention. This process insures rapid response capability to nonnominal situations.

Command Message Update Function

The command message update function verifies that commands have been executed properly. The function possesses the capability of verification from processed telemetry tapes or during real-time operations. Preliminary designs examined did not incorporate automatic command execution verification. This meant that if certain commands were dependent upon previous command executions, they either would not be sent until verification was received (which could consume important station pass time), or commands would be transmitted without previous command verification. Under the present design the operations monitor is continually advised via display of the verification status of all commands transmitted.

Another design requirement imposed on the command message update function is that of predicting spacecraft status. Because commands will be executed from the SCP memory when the spacecraft is out of view of a ground station, and because station contact time during which recorded spacecraft telemetry can be processed is limited, present design calls for a comparison between predicted status (assuming proper SCP command execution) and actual status derived upon receipt of telemetry. If the comparison is exact, the spacecraft is assumed to be functioning properly and real-time commanding may commence. If anomalies are found, these are displayed for operator intervention. Without the present computer-software design this "instant response" capability would not be possible.

A final design requirement involves the loading of SCP commands. Upon loading a series of commands in the SCP, the SCP is commanded to a standby/verify mode, and the contents of the SCP are telemetered back for verification. Each word stored is compared bit-by-bit to the proper configuration; any anomalies are displayed and retransmission of that command may occur at the operator's discretion. Without the present design configuration, this process would require manual comparison after printout of telemetry and consume a considerable amount of time.

PCM Telemetry Processing Function

The PCM telemetry processing function makes it possible to determine the state of the observatory, perform command verification in real time, and display this data to the operator. Without this capability, the strip chart recorders must be used with manual interpretation of the raw data. The function stores parameters during a pass and allows immediate display of trends. Problems which could become critical are noticed and rectified. Without computer utilization much manual analysis would be required and a real-time response to a non-nominal situation would not normally occur.

The rapid processing of telemetry allows command execution verification to occur in real-time. The software searches the telemetry frame at the appropriate time for command execution indicators. Depending on the value of these indicators, the operator is continually informed of the status of commanding via displays in engineering units. Without computer processing the conversion of telemetry units to engineering units could not be readily and conveniently accomplished.

Sensor Coverage Evaluation Function

The sensor coverage evaluation function operates post-pass and is designed to eliminate from the user request file those requests which have been fulfilled. Reading the command execution history produced by the command message update function, the sensor coverage evaluation function extracts sensor commands and calculates nominal shutter times. The corner coordinates of the sensor images are calculated and are used to update the user request file in the observatory scheduling function. Utilization of the computer allows this process to proceed much more rapidly than would be possible if a manual or card system were used. The volume of images and calculations would require a large amount of clerical and technical help. Present design allows rapid feedback to the observatory scheduling function thereby causing the files to be kept as current as possible.

Previous configurations of the software called for the sensor coverage evaluation function to read the processed telemetry data and calculate shutter events. The added cost to perform this processing was not justified for the increase in accuracy in the shutter time determination. As the shutter times are not used for frame annotation, the requirement for high accuracy times does not exist.

CONTENTS

10. PERSONNEL

Functional flow diagrams and requirements allocation sheets were analyzed to identify those functions and tasks requiring human intervention. Further analysis of the function/tasks, related equipment, and operation procedures required to meet mission objectives led to the identification and categorization of tasks in generic terms. The tasks were reviewed and assigned to manned positions based on task flow information, task criticality, amount of time required to perform each task, task frequency and schedule, task commonality and the equipment associated with the task performance. Task and equipment requirements were then reviewed to determine the number of personnel and operational shifts required during routine orbital operations to accomplish the tasks at each manned position, and, in turn the organizational structure of each operating area.

Results of the analyses indicate that during routine orbital operations 20 positions require manning for 8 hours per day, 5 days per week, and seven for 24 hours per day, 7 days per week. In computing the total staffing requirements, a manning factor of 1.0 was used for single shift operations and 5.0 for those positions requiring manning around the clock.

10.1 TASK IDENTIFICATION/ALLOCATION

Functions and tasks allocated to manual processing in the requirements allocation sheets, Volume 2, were itemized and assigned to positions. Positions were selected on the basis of operational aspects required to accomplish command control of the observatory, i.e., 24 hours per day, 7 days a week operation. The operational aspects selected and position assigned were:

Position Identification	Operational Aspects of the Position
M. Operations planner controller	Plans and commands spacecraft in order to meet user/mission requirements. Serves as operations crew chief and conducts and communicates with ground tracking stations and with spacecraft commander, data analysts, and ground equipment operations.

	Position Identification	Operational Aspects of the Position
N.	Data analyst	Monitors and evaluates spacecraft and payload performance.
O.	Command generation technician	Provides manual backup for the commanding and preliminary preparation of spacecraft commands.
P.	PCM technician	Operates and maintains telemetry ground handling equipment.
Q.	Data technician	Prepares schedules, plans, and related activities.

Table 10-1 is a list of selected tasks and their assignment to positions M through Q as shown on the organization chart, Figure 10-1.

In order to support the operational group, management, staff, personnel, and clerical support is required on a routine basis. Management structure with the associated operational group is depicted in the organization chart, Figure 10-1. Table 10-2 provides the overall planning estimates for the OCC manning including time required of personnel, personnel classifications, and allocation of CRT display consoles to positions.

10.2 PRE-LAUNCH STAFFING

The build up of the OCC operations team will proceed over a period of 12 months as shown in Figure 10-2. Beginning with a nucleus of the OCC manager, staff analyst, and one secretary, personnel will be added until the full complement required for routine orbital operations is staffed two months prior to launch.

The concept of self-teaching will be utilized from the start. The functions of the OCC manager and staff analyst are to define the selection and training requirements of all other personnel, based upon a working knowledge of spacecraft, payload, and GDHS operations requirements and design. The training supervisor will be among the personnel added nine months prior to launch and will be responsible for developing and implementing a training program for all personnel whose responsibility it is to operate and maintain the control center. An overall training plan will be generated describing methods and procedures required to conduct

Table 10-1. Allocation of Tasks to Operational Positions* Within the OCC

Function Task	Operations Planner Controller (M)	Data Analyst (N)	Command Generation Technician (O)	PCM Technician (P)	Data Technician (Q)
Responsible for command activity	X				
Provide weather predictions	X				
Determine fulfillment of user requirements	X				
Coordinate station support	X				
Establish links with station	X				
Communicate with station	X				
Request orbit data	X				
Verify receipt of command messages	X				
Evaluate observatory health		X			
Perform trend analysis		X			
Review history on critical items		X			
Maintain observatory continuity			X		
Review generated list			X		
Review SCP information			X		
Communicate with NDPF user			X		
Operate PCM data handling equipment				X	
Operate PCM tape recorder				X	
Operate strip charts				X	
Maintain PCM data handling equipment, tape recorder and strip charts				X	
Handle recorder outputs				X	
Prepare schedules					X
Monitor OCC consumables					X
Generate station pass check list					X
Perform readiness tests					X
Repair malfunction equipment					X

*Operational positions are manned 24 hours per day, 7 days a week in contrast to management and staff positions which are manned 8 hours per day, 5 days a week.

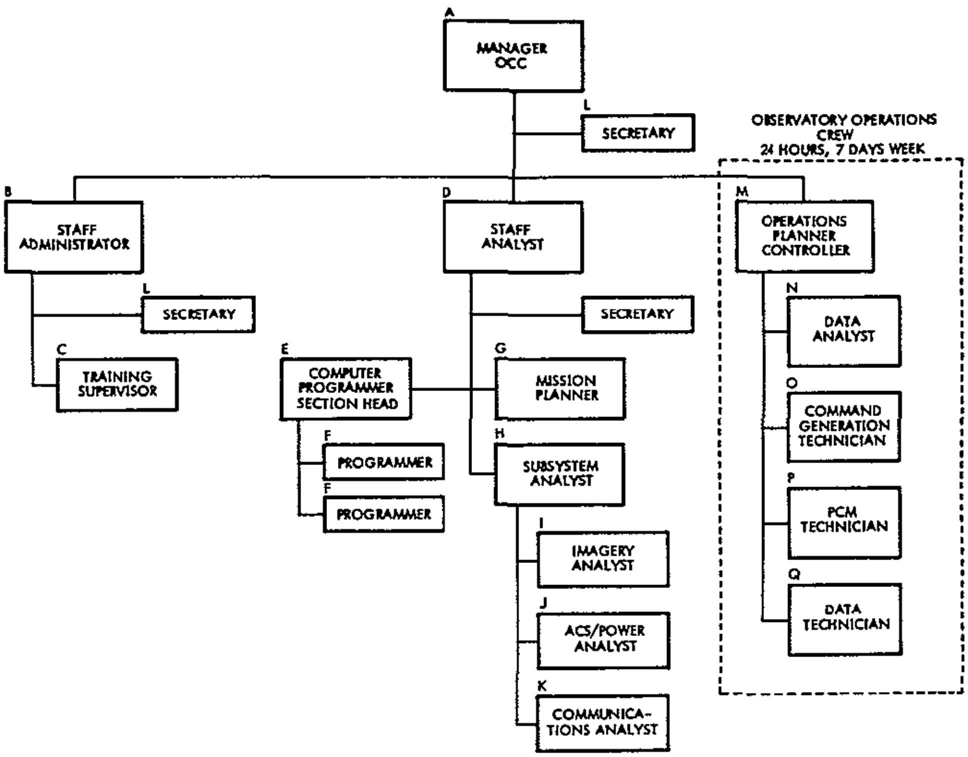


Figure 10-1

CONTROL CENTER ORGANIZATION chart showing line of authority

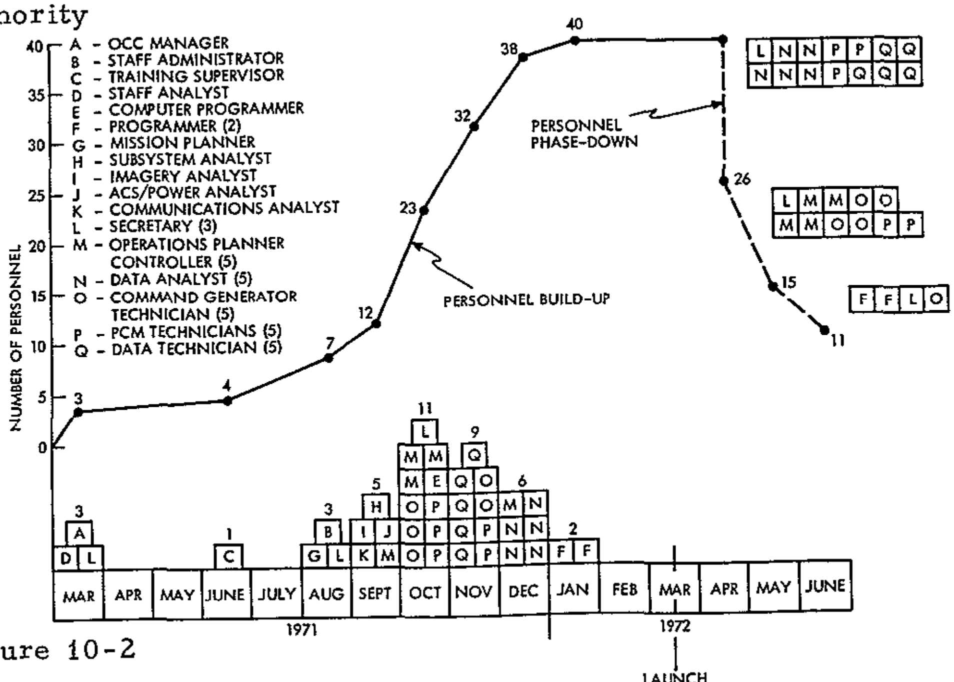


Figure 10-2

CONTROL CENTER STAFF BUILDUP leading to launch in March 1972

Table 10-2. Planning Estimates

Position	Total No. of Personnel Required	Personnel Type	Console Employed
8 hours a day, 5 days a week			
A. Manager OCC	1	Engineer	
L. Secretary	1	Secretary	
B. Staff administrator	1	Administrator	
L. Secretary	1	Secretary	
C. Training supervisor	1	Engineer	
D. Staff analyst	1	Engineer	
L. Secretary	1	Secretary	
E. Computer programmer	1	Engineer	
F. Programmer	1	Technician	
F. Programmer	1	Technician	
G. Mission planner	1	Engineer	
H. Subsystem analyst	1	Engineer	
I. Imagery analyst	1	Engineer	
J. ACS/power analyst	1	Engineer	
K. Communications analyst	1	Engineer	
24 hours a day, 7 days a week			
M. Operations planner controller	5	Engineer	Yes
N. Data analyst	5	Engineer	Yes
O. Command generation technician	5	Technician	Yes
P. PCM technician	5	Technician	
Q. Data technician	5	Technician	
TOTAL	40		

training for maintenance and operation of all hardware and software. The training supervisor will be required to translate all spacecraft, payload, and OCC equipment information into an integrated training plan. After approval of the plan by the OCC Manager, he will coordinate and implement the training program to produce operational personnel capable of performing all aspects of their stated job assignments.

A staff administrator will be responsible for preparing and maintaining daily personnel, facilities, and activities schedules during the training period.

The remaining operating personnel will be added in stages. This will permit the original nucleus to train the first group, which after completing its training, will in turn assist in training the next group to be brought in. This process of using personnel who have completed their training to assist in training newcomers following them will be used until the entire OCC operating staff is fully trained.

10.3 INITIAL OPERATIONS STAFFING

The personnel shown in Table 10-2 are supplemented by spacecraft engineers during late prelaunch and early orbit operations. These engineers are not part of the ERTS personnel discussed above.

The spacecraft engineers will be available for assignment to the OCC or to any remote ground station to monitor and assist in spacecraft earth and sun acquisition sequences. During the three-month postlaunch period they will return to their normal TRW assignments but will be available for further OCC activity upon demand.

10.4 POSTLAUNCH STAFFING

A gradual replacement of TRW operations personnel by other NASA contact personnel will continue throughout the three-month period following launch. Staggered phasing of personnel and training will produce a fully integrated and trained team at the end of that period. All of the training techniques developed during the personnel buildup will be employed during the personnel phase-over.

10.5 OCC STAFF DESCRIPTION

The duties for the positions shown in the OCC organization of Figure 10-1 are presented with parenthetical numbers indicating the number of personnel required.

a) <u>OCC Manager</u> (1)

- Responsible for the operation of the OCC and for the performance of the operations and support personnel.
- Plans, supervises, and coordinates operations and maintenance activities within the OCC.
- Presents command and control operations to ERTS project management.
- Interprets NASA policies and activities for OCC personnel.
- Determines optimum personnel practices, manpower levels, budget requirements, and training programs.
- Establishes schedules and manning necessary to meet operating requirements and determines alternate sources of action as schedules change.
- Reviews and approves the OCC daily activities schedule.

b) <u>Staff Administrator</u> (1)

- Insures that administrative requirements of ERTS staff and operational personnel are satisfied.
- Prepares reports in conjunction with other staff members.

c) <u>Operations Training Supervisor</u> (1)

- Provides simulated training exercises to newly assigned OCC personnel utilizing script material; utilizes hardware and software in training exercises as they become available.
- Responsible for the training of all personnel.
- Coordinates with operations controller-planners and systems analysts in obtaining training material and training assistance.
- Provides refresher training to experienced personnel and cross-training of equipment procedures.

d) Staff Analyst (1)

- Reviews accomplishment of daily schedules and reports deviations.
- Prepares daily OCC activity schedules.
- Prepares inputs in the form of prioritized maintenance tasks for inclusion in the OCC daily schedule.
- Prepares spacecraft and payload operational reports.
- Coordinates activities of subsystem analysts.

e, f) Computer Programmer (3)

- Maintains all OCC application programs.
- Coordinates work with NDPF programming head.
- Writes programs and routines and prepares flow charts and diagrams as required.
- Checks equipment and performs readiness tests to ensure OCC data processing and display equipment are in an operational mode.
- Assists training supervisor during simulated training sessions; operates tape decks and ensures equipment is operating properly.

g) Mission Planner (1)

- Provides weather predictions and interpretations to operating personnel.
- Provides on-the-job training to operational planner-controller for around-the-clock weather predictions.
- Generates operating procedures for STADAN stations to support ERTS passes.
- Establishes schedules of activities required to generate and distribute command lists for each observatory pass.
- Establishes schedules and manning necessary to meet operating requirements, and determines alternate courses of action as schedules change.
- Reviews the OCC daily schedule to determine position-related assignments.

- Provides master schedule and long term planning; coordinates with all shifts to ensure continuity of operations.
- Prepare reports.

h, i, j, k) Subsystem Analyst (4)

- Reviews pass schedules for observatory activity.
- Receives data and selects video signals for display.
- Evaluates observatory performance; examines video images for quality and cloud cover; confirms basic data quality.
- Evaluates mission performance; compares sensor coverage against effected coverage.
- Specifies corrective measure; determines actions required to improve image quality.
- Adds annotation comments to video data.
- Generates quick-look report including unfulfilled sensor coverage report.

m) Operations Planner Controller (5)

- Coordinates OCC activities.
- Coordinates station support schedule with OPSCON.
- Coordinates the establishment of voice and data links required for ERTS operations.
- Communicates with STADAN stations during pre- and post-pass activities.
- Requests orbital data, weather data, and STADAN/MSFN support.
- Forwards messages and instructions necessary to support ERTS passes to STADAN/MSFN stations.
- Verifies receipt of command messages by STADAN/MSFN.
- Reviews assignment of observatory acquisition opportunities versus users requests.
- Reviews command list, event list, orbit corrections, recorder budget, power budget, and weather data.

- Reviews support schedule.
- Monitors observatory command status.
- Monitors stored command-programmer status and contents.
- Checks observatory command sequence against user requests and resolves conflicts.
- Transmits commands to spacecraft as required.
- Reviews observatory command history.
- Checks observatory telemetry for parameter values and equipment status changes associated with verification of command execution.
- Reviews and modifies command lists for each station pass.
- Alters command list based upon weather predictions.
- Performs long term trend analysis.

n) <u>Data Analyst</u> (5)

- Monitor and evaluate current observatory and sensor health.
- Perform trend analysis on required observatory and payload data.
- Perform subsystem engineering utilizing displays and strip charts.
- Recommend corrective action to improve observatory and payload performance.
- Maintain history of utilization of critical observatory and payload items.
- Perform long term trend analysis.

o) <u>Command Generation Technician</u> (5)

- Compares systems analyst requests with payload and observatory status to maintain observatory continuity.
- Inputs user requests from NDPF to computer.
- Reviews computer generated event list for: accuracy, conflicts, and additions, deletions.

- Review stored command programmer preliminary command sequence, command history.
- Communicates spacecraft and sensor events to NDPF.
- Maintains OCC historical file.

p) PCM Technician (Maintenance and Operations) (5)

- Maintains and operates PCM tape recorders, PCM data handling equipment strip chart recorders and scopes.
- Implements requested strip chart and tape recorder channel assignments and prepares an updated list of channel allocations.
- Configures and monitors telemetry data handling equipment prior to pass related activities.
- Labels, packages, and stores tape and strip chart recorder outputs.

q) Data Technician (5)

- Reviews ephemeris and orbit data versus station pass time.
- Prepares and distributes daily OCC time sequence activity to support ERTS operations
- Maintains surveillance of OCC consumables
- Prepares ground support schedules
- Generates station pass check list

CONTENTS

11. SIMULATION AND TRAINING

Successful operations on the day of launch demand a rigorous program of equipment compatibility testing and training of personnel. This should be scheduled far enough in advance to permit correction of observed deficiencies. The scope of such programs is now well established from experience with existing spacecraft. The principles on which success are based are these:

- New elements of the system require the most testing.
- A spacecraft in orbit is better than a simulator.
- Radio-frequency interfaces should be realistically simulated; magnetic tape signals from the spacecraft to be launched are a desirable source of operations checkout.
- The best possible source of test signals is a set of prototype spacecraft equipment. Attenuation of transmitter outputs to simulate realistic levels is desirable.
- A convenient vehicle for moving from one ground station to another is a small aircraft. Equipment mounted therein is used in flight.

The need for compatibility testing is minimal based on previous experience. A shift in command carrier frequency, for example between launches, would not require simulation testing other than frequency measurement.

11.1 ERTS COMMUNICATION SIMULATION TASK

The ERTS communication system carrier frequencies are entirely different from OGO. VHF modulations are unchanged (Table 11-1).

The only apparent exception to a uniform need for simulation is the VHF system for command and digital telemetry. Stations which will use these STADAN carriers are already operating with spacecraft in orbit which employ modulations identical to ERTS. A review of the ground stations to be used versus experience of each is given on Table 11-2. The zero (0) entries in this table represent the real communication simulation requirement.

Table 1-1. Spacecraft Equipment Similarity to OGO

	Modulation Unchanged From Orbiting Spacecraft	Completely New Modulation System	Notes
VHF command receiver	X		Carrier shifted 4 MHz from OGO
S-band command receiver	X		
PCM VHF transmitter	X		OGO carrier was 400 MHz
Unified S-band transmitter		X	Baseband +5 subcarriers
Video transmitter		X	Very wideband

Table 11-2. Ground Station Proven Compatibility with ERTS Signal Modulations

Ground Station	VHF Command	VHF PCM Data	Unified S-Band Range Data, Command	S-Band Video
Alaska	X	X	0	0
Greenbelt (NTTF)	*	*	0	0
Rosman	X	X	*	*
Corpus	*	*	0	0
Quito	X	X	*	*
Santiago	X	X	*	*
Orroral	X	X	*	*
Madgar	X	X	*	*
Joburg	X	X	*	*
Winkfield	X	X	*	*

Note:

0 No experience with ERTS modulation complex

X Orbital experience exists

* No orbital interface is required

For completeness, and at some increase in expense, the VHF carriers can be included in the tests but in no case is this needed for STADAN stations outside the United States. Use of outlying stations is planned for initial operations (Appendix A) and may be relied upon in case of emergency. Inclusion of the VHF links in simulation tests at Corpus, NTTF, and Alaska checks out possible interference between VHF and S-band systems. A cost figure for this aspect of testing is needed for a decision. The most pressing interference possibility is at the spacecraft where VHF power is radiated and weak S-band signals are received. A second is between S-band signals at the ground station.

The modulations to be employed in the flyby test are most easily obtained from magnetic tape and could most usefully be actual modulating signals from the first spacecraft. A test pattern generator for imaging check should be effective yet reasonable in cost.

11.2 ERTS FUNCTIONAL SIMULATION

With the radio frequency interface simulated as above, subsequent tests at ground stations and OCC can be effectively accomplished with data tapes. This follows past successful practice in use of tapes actually made from spacecraft data with a known configuration. Rehearsal and training exercises employ such tapes as described in Appendix A. Plans for personnel training are included in Volume 26 of the TRW ERTS Phase D proposal.

11.3 EQUIPMENT SOURCES

An investigation has been conducted to determine which simulator equipment can be used from spacecraft prototype or engineering models. The results are shown in Table 11-3. This list assumes complete simulation including VHF frequencies. Items marked "as is" or "modified" are available at small expense from the spacecraft program. Those marked with an asterisk will be identical designs to the spacecraft configuration.

Table 11-3. Equipment Sources for ERTS Spacecraft Simulator

Nomenclature	Program Derivation	As Is	Modified	New	Make	Buy	GFE	Quantities
RF and Data Simulation Rack								
VHF Command Receiver	OGO		X					1*
VHF Diplexer/Coupler	OGO		X					1*
VHF Digital Decoder	OGO		X					1*
Antenna Assembly				X	X			1*
Telemetry Switch Unit	OGO		X					1*
VHF Power Monitor	OGO		X					1*
Stored Command Programmer				X	X			1*
Transmitter Driver	SGLS		X					2*
Video Switch Assembly				X	X			1*
TWT Amplifier	MAR-69		X					2*
USB Transponder Assembly	TETR		X					1*
USB Baseband Assembly	MOD 35		X					1*
RF Distribution Assembly	TETR		X					1*
VHF Transmitter				X	X			1*
MSS Simulator		X				X		1
RBV Simulator		X				X		1
Tape Recorder		X				X		1
PWR Control Panel				X	X			1
PWR Supply Assembly		X				X		1
Patch and Control Panel				X	X			1
Reject Filter				X		X		2*
Equipment Rack	OGO		X				X	1
Command Status Display Rack								
Spacecraft Status Display	OGO		X				X	1
Payload Status Display	OGO		X				X	1
Matrix Monitor	OGO		X				X	1
Console Power Supply	OGO	X					X	1
Equipment Rack	OGO	X					X	1

*Spacecraft Equipment

12. Other Supporting Studies

CONTENTS

12. OTHER SUPPORTING STUDIES

12.1 MSFN/STADAN ERTS PECULIAR EQUIPMENT

Four ground stations have been delegated as ERTS support stations: Gilmore Creek, Alaska; Corpus Christi, Texas; the NASA Tracking and Training Facility (NTTF) in Greenbelt, Maryland; and Rosman, North Carolina. To enable these ground stations to operate effectively as ERTS support stations certain additions and modifications are required. The majority of these changes have been previously identified and are being implemented or planned by NASA. These changes are listed here for information purposes. Other changes listed are not presently planned but are required to implement the TRW ERTS approach.

12.1.1 RF Circuits

Table 12-1 gives a listing of present and planned observatory/ground station interfaces pertinent to the ERTS mission.

Table 12-1. Observatory-Ground Station Interfaces

Station	Affiliation	Uplink		Downlink		Downlink Wideband Sensor Data
		USB	VHF	USB	VHF	
Alaska	STADAN		X	P	X	P
Texas	MSFN	X		X		P
NTTF	MSFN			X		P
Rosman	STADAN		X		X(1)	

Note:

"X" Present capability.

"P" Planned capability.

(1) Generally speaking, NTTF receives ERTS downlinks, while Rosman transmits uplink commands. Rosman may receive downlink telemetry for command verification.

Table 12-2 lists changes to the RF circuits at each ground station. It is TRW's understanding that all of these changes are in the process of being implemented.

Table 12-2. RF Circuit Changes (Presently Planned by NASA)

Modifications or Additions	Texas	Alaska	NTTF	Rosman	Explanation
Antenna feed modification	X	X	X		Texas, NTTF feeds need to be modified to accept ERTS downlink spectrum that extends from 2219 5 to 2288 75 MHZ For ERTS and Apollo compatibility, the feed should have a passband extending from 2219 5 to 2300 MHz Alaska cannot receive above 1700 MHz and will need a complete S-band feed system
Diplexer		X			To update the receive band to S-band frequencies
Waveguide filter	X	X	X		MSFN stations will need a waveguide filter with a passband of 80 5 MHz for ERTS/Apollo compatibility
Preselect filter	X	X	X		Mission preculiar equipment to aid crosstalk attenuation
Multifunction receiver with S-band front end		X			Multifunction multichannel receiver with X, Y antenna steering outputs The multifunction receiver will demodulate wideband sensor data and the USB downlinks to baseband frequencies
Cooled preamplifier	X	X			Needed for carrier margins ERTS downlink subcarriers would be really marginal with uncooled preamplifiers
MSS wideband FM receiver	X		X		ERTS mission peculiar equipment, necessary for sensor data reception One operational and one spare unit required
RBV wideband FM receiver	X		X		

Note: Reference, "Preliminary MSFN Support Plan for ERTS A and B," NASA document, X-834-69-529

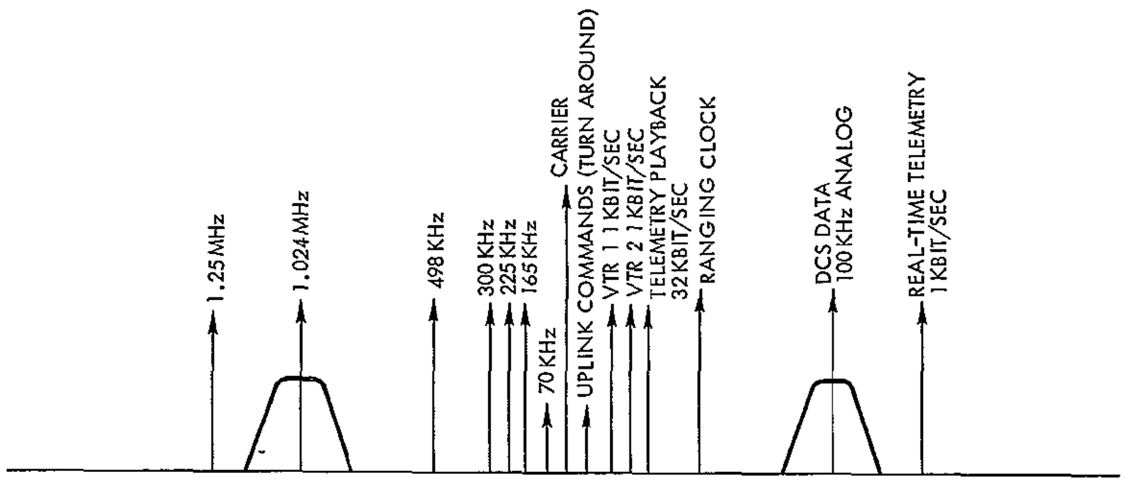
The RBV and MSS receivers and discriminators will be located in the RF sites at each of the three data acquisition ground stations. The tape recorders, quick look displays, and the MSS demultiplexer will be colocated with telemetry equipment. This arrangement will require a wideband coaxial cable or microwave link, between RF site and equipment building at Alaska and at Texas.

An alternate arrangement would be to locate the recorders and displays at the RF site to avoid interstation wideband links, but this arrangement has been decided against for the following reasons:

- Personnel operating the spacecraft at the OCC or the telemetry/computer site at Texas will need to observe the quick look displays and to oversee tape recorder operations.
- Housekeeping telemetry must be made available to the recorders. Remotely located recorders would require wire runs and associated electronics.

12.1.2 Narrowband Telemetry Station

Texas, NTTF and Alaska must be able to receive, demodulate, and process data in the unified S-band downlinks. The S-band signal spectrum is shown below.



NORMAL-MODE DOWNLINK
(RANGING-CLOCK MODULATION ONLY)

12.1.3 Wideband Sensor Data Handling Equipment

Table 12-3 presents changes to existing ground stations capability that are presently planned by NASA (see also Table 12-2).

The NTTF and Texas stations presently have the capability to receive and process ERTS unified S-band downlink telemetry. These two stations, both equipped for MSFN operation, will receive the telemetry downlink with a standard unified S-band receiver. The receiver will output a 50 MHz IF to unified S-band signal data demodulators that will present decommutated PCM data to a decommutation system distribution unit. The decommutation system distribution unit will also accept inputs from the VHF telemetry system and from tape recorders. The distribution unit outputs data to a PCM decommutator that, under program control, will select words from the incoming PCM data for input to Univac MoD-642B computer. Telemetry data will next be routed through a Univac 1299 distribution switchload to WECO 205B modems that will transmit data to the OCC via voice/data circuits. At the NTTF, 1 and 32 kbits/sec PCM will be routed to the OCC by wire.

Table 12-3. Wideband Data Handling Equipment

Equipment	Functional Description
FM demodulation and bit synchronizer	FM demodulates NRZ-MSS data, removes bit jitter/restores pulse levels, reshapes rise and fall times.
MSS demultiplexer	Demultiplexes the 14.6 Mbit/sec NRZ data into 25 channels. One spare required per station.
MSS recorder	28 channel recorder to record 25 channels of MSS data. One spare per station.
Video FM discriminator	FM discriminator accepts the RBV receiver IF and outputs a 4-MHz bandwidth AM waveform.
Rotary head tape recorder	Records 4 MHz bandwidth AM waveform. One spare per station.
Quick look video display	Provides a video picture display for ground station personnel for subjective picture quality judgement. Has ability to receive video from any one of the three RBV's. One spare per station.
Quick look MSS status monitor	Essentially an oscilloscope which can display a video representation of any one of the 25 channels of MSS data. One spare per station.
Wideband coaxial cable or microwave links	Two links required at OCC-NTTF.
Wideband coaxial cable	Two links required at Texas RF site to telemetry/computer complex.

The Alaska station does not presently have the capability to receive or demodulate the ERTS S-band downlinks. Multifunction, multichannel receivers will be installed at Alaska to demodulate all three S-band downlinks to baseband frequencies. Subcarrier oscillator demodulators will need to be added to demodulate the narrowband telemetry 165, 225, 300 kHz, 1250, and 1024 MHz subcarriers. Bit synchronizers will need to be added to restore PCM data. Alaska has sufficient PCM data handling capability for ERTS, since equipment at Alaska has handled OGO telemetry previously.

It is required that housekeeping telemetry signals sent from MSFN ground stations be formated in standard STADAN 600-bit blocks. This feature permits a single standardized incoming housekeeping-telemetry format from all stations resulting in a considerable reduction in OCC hardware. This can be accomplished by modifying the software for the 642B computer.

12.1.4 DCS Data Acquisition

All three ERTS receiving stations will obtain a 25 to 125 kHz DCS signal which will be sent to the OCC over a coaxial cable circuit. At Alaska and Texas, DCS data will be recorded. From these stations, three methods being considered for retransmission of DCS data are: (1) install DCS signal recovery equipment at each site and transmit recovered PCM via high speed display circuits to GSFC-OCC, (2) use a slow tape recorder playback technique to transmit DCS data over wideband data link circuits, or (3) mail the DCS tapes to the OCC. For example, if a 48-kHz bandwidth circuit were installed between Corpus Christi, Texas, and the OCC, DCS data could be played back to an OCC tape recorder at 1/4 the original record speed. The OCC tape recorder would then play back to the DCS signal recovery system at four times the record speed. From Alaska, the slow playback method could use an existing 23-kHz analog channel in the X-144 circuit. The cost of constructing a wideband circuit from Corpus Christi to GSFC could very likely be minimized by constructing the wideband circuit from Corpus Christi to the MCC-Houston (200 miles) and modifying an existing wideband circuit from MCC-Houston to GSFC.

Use of the slow playback techniques will require quality tape recorders that have accurately controlled capstan speeds and low flutter specifications.

A summary of new station equipment necessary for narrowband telemetry is presented in Table 12-4.

Table 12-4. DCS Data Acquisition Required Changes

Equipment	Functional Description
USB subcarrier demodulators and bit synchronizers	Required at Alaska for baseband separation and subcarrier demodulation of ERTS S-band down-link (Presently planned by NASA)
Coaxial cable circuit	Required between NTTF and OCC for real time transmission of DCS data (25 to 125 kHz circuit)*
Wire circuits (2)	For transmission of 1 and 32 kbit/sec from the NTTF to the OCC. *
Tape recorders	Quality tape recorders (Ampex FR 1600 or better) will be required at the OCC and remote sites if the slow playback technique of transmitting DCS data is utilized.
48-kHz wideband circuit from Texas to the ERTS-OCC	Required at Texas if the slow playback technique is used. *

*These additions have been informally discussed with and agreed to by NASA representatives.

12.1.5 Command Equipment

Changes will be required to facilitate the encoding of ERTS commands. The required methodology differs between STADAN and MSFN ground stations.

12.1.5.1 STADAN Stations

In addition to the basic functional requirements established in GSFC Specification S-573-P-1, the command encoders which are planned to be installed at STADAN stations must be capable of providing for the following:

- Upon receipt of a command from the OCC the command encoder will return the received message for a bit-by-bit check at the OCC.
- Upon successful completion of a bit-by-bit echo check by the STADAN station, a signal signifying "verification OK" will be sent to the OCC.

12.1.5.2 MSFN

Modification of software for the 642B computer at the Texas station will be required to accomplish the following:

- Send a message requesting "command repeat" in the event that a command error check is invalid.
- Send a message indicating "command not sent" in the event that the bit-by-bit echo check was not successful.

12.2 EFFECT OF DELETION OF VIDEO TAPE RECORDER ON CONTROL CENTER OPERATIONS

The study specification suggests a possibility that video tape recorders may not be carried in the spacecraft. Deletion of these units would change operations markedly and reduce correspondingly the function of the spacecraft stored command programmer.

Figure 2-1 shows that in the absence of airborne video tape recorders, data coverage is limited to North America. This leads to the gross conclusion that video tape recorders are needed in the spacecraft to provide global coverage. Typical days of operation produce 160 minutes of global data with the tape recorder and only 35 minutes without. The longest possible data acquisition pass with the tape recorders is 33 minutes (Russia to Africa). Without tape recorders this becomes 13 minutes.

The process of commanding the spacecraft will be greatly simplified if video tape recorders are eliminated. The need for time tags will be reduced since operation becomes largely real-time. Warm-up commands will be desirable via stored program. Since the number of data passes reduces from 18 per day to about seven, the commanding activity will be reduced in about the same ratio.

12.3 CLOUD COVER FORECASTING

The relative importance of cloud cover forecasts for ERTS is dependent upon station proximity. In the case that direct readout of the camera system is possible, the use of cloud cover forecasts in the sensor selection algorithms amounts to little more than a nicety by decreasing the amount of bulk processing required in the NDPF. With quick look capability, even the necessity for the extra bulk processing is mitigated.

Should direct readout not be possible, wideband video tape recorder management becomes extremely important. If tape recorder life is to be extended as long as possible, its activity periods must be limited as much as possible, to periods of nearly clear sky in order to maximize efficiency.

While cloud cover forecasts have not been entirely precise in the past, they have been shown to be of sufficient accuracy and reliability to justify their use on ERTS. The closer the cloud cover observations, and therefore the meteorological forecasts, are to the time of scheduled sensor activity, the more accurate the forecast. Conversely, the older the cloud cover observations used in the forecast are, the more degraded are the results, until a point is reached, corresponding to approximately a 12-hour forecast, such that the forecast has nearly the same reliability as would be gained by using the cloud cover history of the area.

Having addressed the validity and value of cloud cover forecasts, the procedures described below for integration of meteorological cloud cover data into the ERTS OCC have been developed during discussions with Mr. Kenneth Nagler, Chief, Space Operations Support Division, ESSA/ Weather Bureau. It is important to note that these procedures increase the capability and flexibility of ERTS with almost no additional cost to NASA. The Space Operations Support Division at Suitland, Maryland, has three meteorologists and one technician that have been developing cloud cover forecasts for manned flights. They are colocated in the National Meteorological Center and the National Environmental Satellite Center and thus able to draw information from both sources. Due to the stretch-out of the manned program, the Space Operations Support Division should be able to support both ERTS-A and -B without any financial augmentation.

The function RUTSKED of the OCC software schedules the payload activity. Given the user requests and the orbit ephemeris as input, a time ordered list of acquisition areas (30 x 30 miles) is generated. For purposes of the weather interface with ESSA the contiguous areas are considered individually by dividing the bounding subarc of the ground trace for each such area into 50-mile segments. A square 50 miles on a side is generated for both the left and right sides of the ground track segments. The center of each such square is then determined by its latitude and longitude and corresponding time. See Figure 12-1.

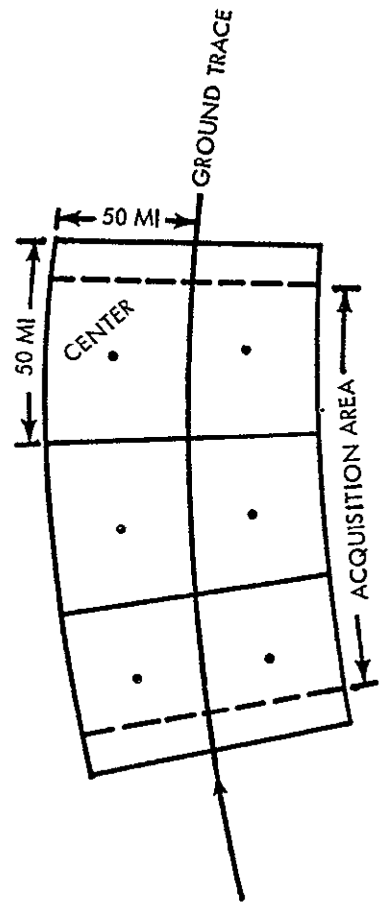


Figure 12-1
GEOMETRY of cloud cover request

This process of center determination continues until the entire acquisition list has been processed and a table of centers built. This table is output on paper tape specifying

- Day, month
- Revision number
- Latitude of square center
- Longitude of square center
- Acquisition time of square center
- Serial number of center

The paper tape output is manually mounted and used to drive a teletype machine in the OCC. Thus, the message sent by teletype to the Space Operations Support Division of ESSA/Weather Bureau is printed, for verification, as it is sent.

The meteorologist on duty at the end of the teletype in Suitland, Maryland, then determines the forecasted cloud cover and sends a minimal set of parameters by teletype back to the ERTS OCC.

- Cloud cover in percent
- Revision number
- Serial number of center

At the OCC the teletype punches a paper tape and simultaneously prints the message for verification checking. This paper tape weather information is read by the RUTSKED software, merged with the acquisitions list, and the acquisitions areas are deweighted accordingly for the sensor selection algorithm optimally.

Thus, the design allows requests selectively to be or not to be generated and to be applied or not applied to individual cells. Any questions, further analysis, or message repeats required in the communications between the ERTS OCC and the meteorologist at ESSA may be detailed with an OCC telephone. Other advantages to this design, besides the obvious cost factor, are that ERTS will not be required to have a meteorologist and the growth factor in ERTS/ESSA communication as uses of the satellite sensors become more sophisticated.

12.4 EARTH ACQUISITION ANALYSIS

The specific orbit is a key factor in earth acquisition. The ERTS spacecraft rotates at a rate of 0.5 deg/sec, with the solar array locked at zero degrees as described in the Phase B/C Final Report, Volume 3. While rotating, the horizon trackers search for the earth and when three simultaneously lock on the earth, transfer to Mode 3 (earth acquisition) is permitted (Figure 12-2). Many orbits result in "windows" which are not suitable for earth acquisition since three trackers are not able to intersect the earth. The EGO orbit is an example.

To determine the conditions under which earth acquisition is possible, the ERTS orbit and the rotating spacecraft geometry were analyzed. Figure 12-3 shows the result; the shaded areas are permissible regions of transfer. This pattern is not much different from

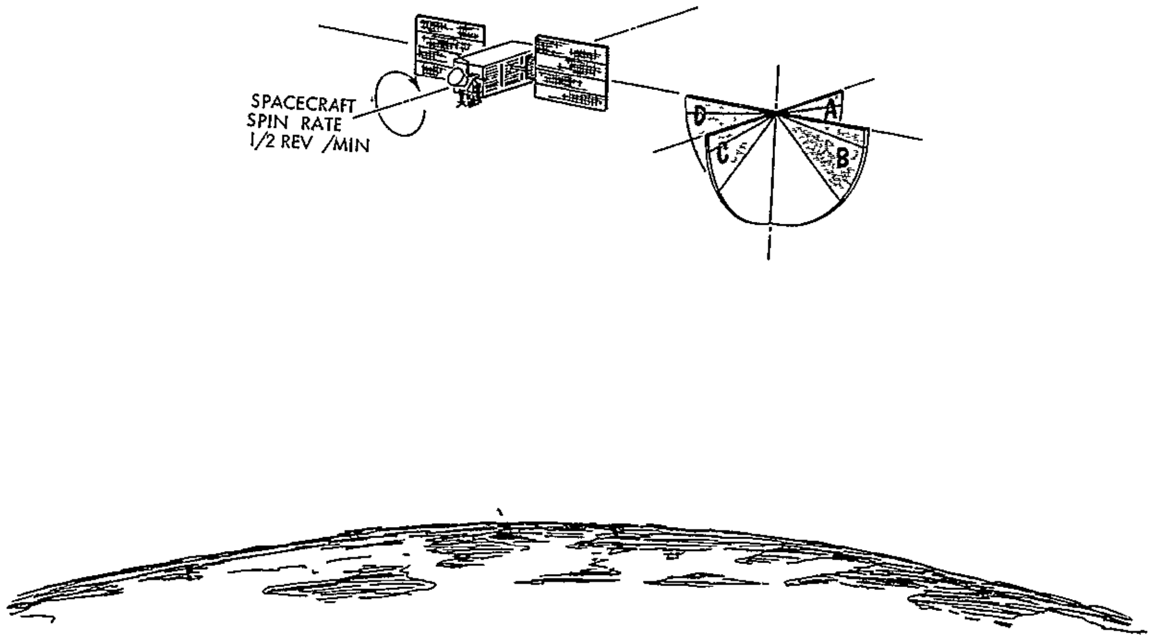


Figure 12-2
ERTS EARTH ACQUISITION GEOMETRY

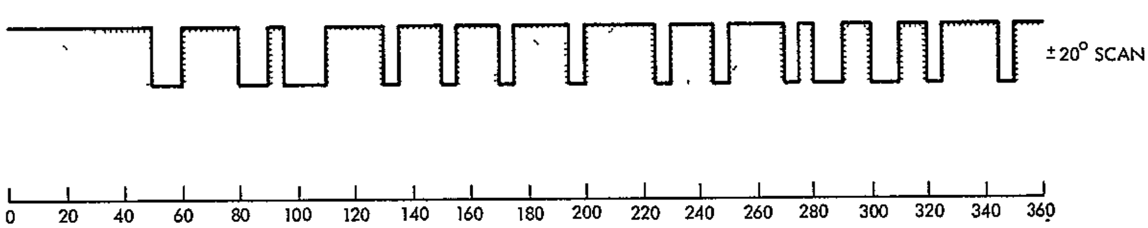


Figure 12-3
ACQUISITION OPPORTUNITIES in the ERTS orbit are similar to those in the OGO polar orbit.

that which typical polar orbiting OGO spacecraft exhibit. The open spaces constitute regions of time when the spacecraft +Z axis is pointing approximately earthward and earth edge trackers are scanning space. Since a 15-minute pass over a ground station is equivalent to about a 45 degree orbital angle there are opportunities at any ground station for earth acquisition.

As described in Section 2 the plan for first earth acquisition is that it be allowed to proceed over Alaska on revolution 3. (See also Appendix B.)

12.5 COMMUNICATION ERROR RATES

The following discussion demonstrates that bit error rates associated with NASCOM communication circuits and related equipment are sufficiently low to adequately perform ERTS commanding and communication services. There are two primary concerns associated with bit error rates in a spacecraft-ground communication network. One is that communication circuit bit errors will cause a satellite response to a false command. The second concern is that bit errors will degrade the downlink data stream. For the ERTS program, it has been determined that simple error detection schemes will prevent false commands being sent to the ERTS satellite and that software implementation at the OCC and NDPF data computation centers will adequately minimize the effect of bit errors in the satellite downlink.

12.5.1 Probability of Satellite Response to a False Command

It is assumed that a valid command originates from the OCC. Design of the command system is given in Volumes 3 and 14 of the Study Report. Calculations will show: (1) the probability that the ground station will transmit a false command, and (2) the probability that the satellite will respond to a false command.

Assumed values of communications circuit bit error rates were obtained from NASCOM Data System Development Plan, Revision 5, and the ERTS Design Studies Specification.

Circuit Segment Description	Bit Error Rate
Teletype link	1 in 10^5 characters
High-speed data line	1 in 10^5 bits
Circuits between NASCOM switching centers	1 in 10^{12} bits
Mission Control, Houston, to MSFN stations command uplink	1 in 10^9
RF space links	1 in 10^6

Furthermore, the bit error rate in a communication circuit is given as the sum of the bit error rates of each segment in tandem.

OCC to STADAN Command Error Probabilities

Only the OCC to Gilmore Creek, Alaska, link will be analyzed since the long circuit path between the OCC and Alaska will very likely cause this link to have the greatest bit error probability of any link. For OCC to Alaska, P_e = (P_e in a high speed data line) $\times$ (the number of tandem links) $= (1 \times 10^{-5})(2) = 2 \times 10^{-5}$. The probability of one or more errors in a 43-bit stored command word, P_{fc}, is

$$P_{fc} = 1 - (0.999980)^{43} = 1 - 0.98317 = 0.017$$

To verify commands, the STADAN stations retransmit the commands back to the OCC for validation. STADAN stations do not normally use error detecting codes for command communications, and validation by retransmission is a simple and expedient error detection system.

The most likely situation where retransmission could fail to detect an error is in the event that Alaska receives a message with exactly one error, and during the validation retransmission exactly one bit error occurs to "correct" the message the OCC receives and thus spoofs the OCC into believing Alaska has a correct command message.

The probability that Alaska receives a command message with exactly one error is

$$(43)\ (2 \times 10^{-5})\ (1 - 2 \times 10^{-5})^{42} = 85.9 \times 10^{-5}$$

The probability that during retransmission from Alaska a bit error "corrects" the previous bit error is 2×10^{-5}. The probability for both events is $(2 \times 10^{-5})\ (86 \times 10^{-5}) = 1.72 \times 10^{-8}$. This is the probability that retransmission error checking will validate a false message at Alaska.

As an additional check, STADAN sites can also check incoming command errors with parity.

OCC to MSFN

The MSFN utilizes error encoding, vehicle address code checking, and command word bit error comparisons. If a MSFN remote station invalidates a command, a retransmission by the OCC is requested. In prime mode operation, all MSFN commands originate from the OCC. The probability of an MSFN station receiving and transmitting a false command is given as less than 10^{-9}.

12.5.2 Satellite/False Command Interactions

This section is concerned with the probability that the spacecraft will accept a false command.

VHF Uplink Errors

Two types of commands are sent on the VHF uplink; one type is a 43-bit stored command and the other is a 28-bit real time command. The 43-bit stored command has two parity bits; one parity bit is for the entire command, and the other parity bit is for the 6-bit command word. Parity bits only detect odd numbers of errors that fall within the range of the parity bit check.

The spacecraft decoder will accept a false command that has two errors in the 7-bit command and command parity bit parity word. The probability of this happening is

$$\begin{aligned} P_{fc} &= (\text{P of no errors in 36 bits})\ (\text{P of 2 bits in 7 bits}) \\ &= (1 - 10^{-6})^{36}\ \frac{7!}{5!\,2!}\ (1 \times 10^{-6})^{2}\ (1 - 1 \times 10^{-6})^{5} \\ &= 20.999 \times 10^{-12} \end{aligned}$$

where 10^{-6} is the probability of a noise induced uplink error. Another likely error situation is that no errors occur in the seven bits of command plus parity and two errors occur elsewhere. The probability of this occuring is

$$\begin{aligned} P_{e} &= (1 - 10^{-6})^{7}\ \frac{36!}{34!\,2!}\ (1 \times 10^{-6})^{2}\ (1 - 10^{-6})^{34} \\ &= 0.63 \times 10^{-9} \end{aligned}$$

These values are acceptably small probabilities that a false uplink VHF stored command will be accepted.

The 28-bit real time command contains a redundant complement of the command and the internal address word. Again an even number of errors are required for acceptance. The most likely error situation is one where a command bit error occurs, and nine successive bits occur with no error and then another bit error occurs (this can happen eight ways), or similarly an internal address bit error can occur, with nine successive error free bits, and then another error bit. This can happen two ways. The probability of a falsely accepted real time command is

$$P_e \cong 8 \times 10^{-12} + 2 \times 10^{-12} \cong 10^{-11}$$

S-Band Uplink Errors

The command formats for the S-band uplinks are identical to the VHF formats with the exception that the S-band command formats have 13 bit decoder addresses rather than seven bits. The unified S-band/ Apollo command system encodes each bit with five subbits. Thus a 49-bit stored command word is expanded to 245 bits and likewise a 34-bit real time command is expanded to 140 bits. The ERTS S-band decoder will reject a command if one to four subbit errors are detected in any bit. Five subbit errors in any one bit would have to occur before the decoder would recognize the complement of the bit transmitted and thus recognize a false bit. Subbit encoding is a valuable technique to prevent noise induced false bits. One concern with subbit encoding is that under noisy conditions the probability of a good command being received can become small. For ERTS this is no concern since the probability of a good command received is large:

$$
\begin{aligned}
P_{good}\text{ command} &= P\text{ of 245 error free bits} \\
&= (1 - 10^{-6})^{245} = 1 - 245 \times 10^{-6} \\
&= 0.998787
\end{aligned}
$$

The probability that the S-band decoder will accept a false stored command or real time command is found in a manner similar to the VHF commands with the following being considered: (1) each command contains five times more bits, and (2) a bit error occurs when all subbits encoding the bit are in error. The probability of one bit error is therefore $(10^{-6})^5$ and the probability of two bit errors is near an order of magnitude of 10^{-60}. The probability of an S-band command being accepted due to an RF link noise induced error is insignificant.

Spacecraft-Induced Errors

Bit error rates for the ERTS memory and logic circuits are given as 10^{-8}. (See page 8-3, Volume 4, of the ERTS Phase B/C Final Report.) 10^{-8} affords adequate protection in the spacecraft. For example, if the probability of a noise induced error is 10^{-6}, the probability the parity check will fail is 10^{-8} for a resultant error probability of 10^{-14}. The probability of the stored programmer producing a false command is discussed in the above reference. The result is that the probability of the stored programmer causing a false command is 0.000021 per year.

Command Validation

At all stations the command encoder or command computer performs a bit-by-bit detection and check of the radiated command via a receiver mounted on the command antenna. Command transmission is halted upon detection of an error.

The spacecraft telemetry data is also analyzed as a command verification technique. Remote stations and the OCC will receive spacecraft command enable bits that indicate command acceptance by the spacecraft. Other command verifications, done at the OCC, are the monitoring of spacecraft relay status telemetry, readout of the stored command programmer, and trend analysis of spacecraft parameters.

12.5.3 Downlink Telemetry PCM Errors

Errors in downlink telemetry are due to logic decision errors in on-board data processing equipment, RF noise in the space downlink, and tape recorder dropouts in the spacecraft and ground station recorders. Assume

$$P_e = 1 \times 10^{-8} \text{ for a logic error}$$

$$= 1 \times 10^{-6} \text{ for a spacecraft tape recorder bit dropout (per record or playback cycle)}$$

$$= 10^{-8} \text{ for a ground station tape recorder bit dropout}$$

$$= 10^{-5} \text{ for a high speed data circuit bit error}$$

$$= 10^{-6} \text{ due to RF noise and noise induced errors during demodulation}$$

The worst-case telemetry bit error condition exists when 32 kbits/sec playback telemetry is being received at the ground station, recorded, played back at a slow speed to the OCC over noise lines,

$$\begin{aligned} P_e\,(\text{telemetry}) &= P\,(\text{spacecraft logic error}) + 2P\,(\text{spacecraft recorder error}) + P\,(\text{RF noise error}) \\ &\quad + 2P\,(\text{ground station recorder error}) \\ &\quad + P\,(\text{high speed circuit bit error}) \\ &= 10^{-8} + 2 \times 10^{-6} + 1 \times 10^{-6} + 2 \times 10^{-8} \\ &\quad + 1 \times 10^{-5} \\ &= 1.3 \times 10^{-5} \end{aligned}$$

The above error probability will cause telemetry bit errors (1.3 false bits per 100,000 or approximately one false word per 77,000 bits) at the OCC. The effects of these errors will be minimal since the telemetry data is highly repetitive (approximately one frame per second at 1 kbit/sec), and software implementation at the OCC will "smooth" out the effect of anomalous telemetry words.

Wideband Sensor Data Degradation

A worst-case MSS PCM error situation exists when MSS data is being played back from the spacecraft video tape recorder. The probability of an error is the probability of an MSS encoding error plus probability of a record bit dropout in the spacecraft recorder plus the probability of playback bit dropout plus the probability of a ground station tape recorder plus the probability of a playback error at the OCC plus the probability of an RF link-demodulation link error.

$$P_e MSS = 10^{-8} + 10^{-6} + 10^{-6} + 10^{-8} + 10^{-8} + 10^{-6}$$
$$= 3 \times 10^{-6}$$

MSS data will contain a large number of redundant bits and error proliferation from the spacecraft to the OCC will not noticeably degrade MSS data.

RBV data is recorded at remote stations and mailed to the NDPF for playback into video image restitutors. Each time a tape is recorded and played back, the data signal-to-noise ratio decreases. RBV data is available at remote stations with a S/N ratio of 38.7 db. The RBV is recorded and played back at the NDPF. Assume the ground station tape recorders have 32 db pk-pk signal/rms noise ratios. Therefore, for 1 volt pk-pk signal, the rms noise present as tape recorder background noise is 0.63 mv rms.

The rms noise after one record/playback cycle becomes

$$N_{rms} = \sqrt{2\,(0.63)^2} = 0.892 \text{ mv rms, a 2-db degradation}$$

The RBV data output to the image restitutor will then have a S/N ratio of 30 db. This is adequate margin since at least 26 db is required for good picture quality.

DCS Data

The ERTS spacecraft will receive DCS data at 401.9 MHz in a bandwidth of 100 kHz. All signals within the 100 kHz bandpass are in turn phase modulated on a 1.024 MHz subcarrier oscillator and transmitted to ground stations on the unified S-band downlink. Each DCS platform will be transmitting at a preset, but random, frequency in the 100 kHz bandpass. Furthermore, each platform will transmit for only 55 msec every two minutes with the time of transmission being a random occurrence in relation to the other DCS platforms. The result is that the DCS data obtained at the ground station is a complex composite of many DCS transmissions; often with several DCS platform transmissions being received at the same time. Simultaneous DCS transmissions, received at the satellite receiver, that overlap in the frequency domain will have bit errors due to message collision. (Each DCS signal has a nominal bandwidth of 2.5 kHz.) Specifications imposed by GSFC pertinent to message errors are as follows:

- Probability of failure to recognize a message error will be less than 1 percent
- Probability of obtaining at least one good message from each platform every 12 hours will be 95 percent or better

<u>DCS Noise Induced Bit Error Rates.</u> As established in the previous paragraph, the probability of a noise (i.e., thermal noise) induced message error was assigned the value of 10 percent of 0.05 or 0.005. A message is in error when one or more of the 110 message bits is in error. The probability of a message error P_m is

$$\begin{aligned} P_m &= 1 - (\text{probability that all bits are correct}) \\ &= 1 - (\text{probability of one correct bit})^{110} \\ &= 1 - (1 - P_e)^{110} \end{aligned}$$

where P_e = bit error rate. Solving for P_e, where P_m = 005,

$$P_e \cong 4.6 \times 10^{-5}$$

TRW has chosen differentially coherent phase-shift-keying as the modulation technique which requires a S/N ratio of 0.6 db for a $P_e = 5 \times 10^{-5}$. Current link margins show that the DCS channel has a margin of 4.6 db (with worst case space loss). This margin is adequate to satisfy the bit error rate requirement for DCS messages.

<u>DCS Message Error Recognition.</u> TRW will add an 8-bit cyclic code word to each DCS message word. This 8-bit cyclic code word will detect both bit errors due to noise and burst errors due to message collisions with a probability of 2^{-8}. $2^{-8} = 0.0039$, which is smaller than the GSFC specification of 1 percent. (Refer to ERTS Final Report, Volume 5, February 11, 1970.)

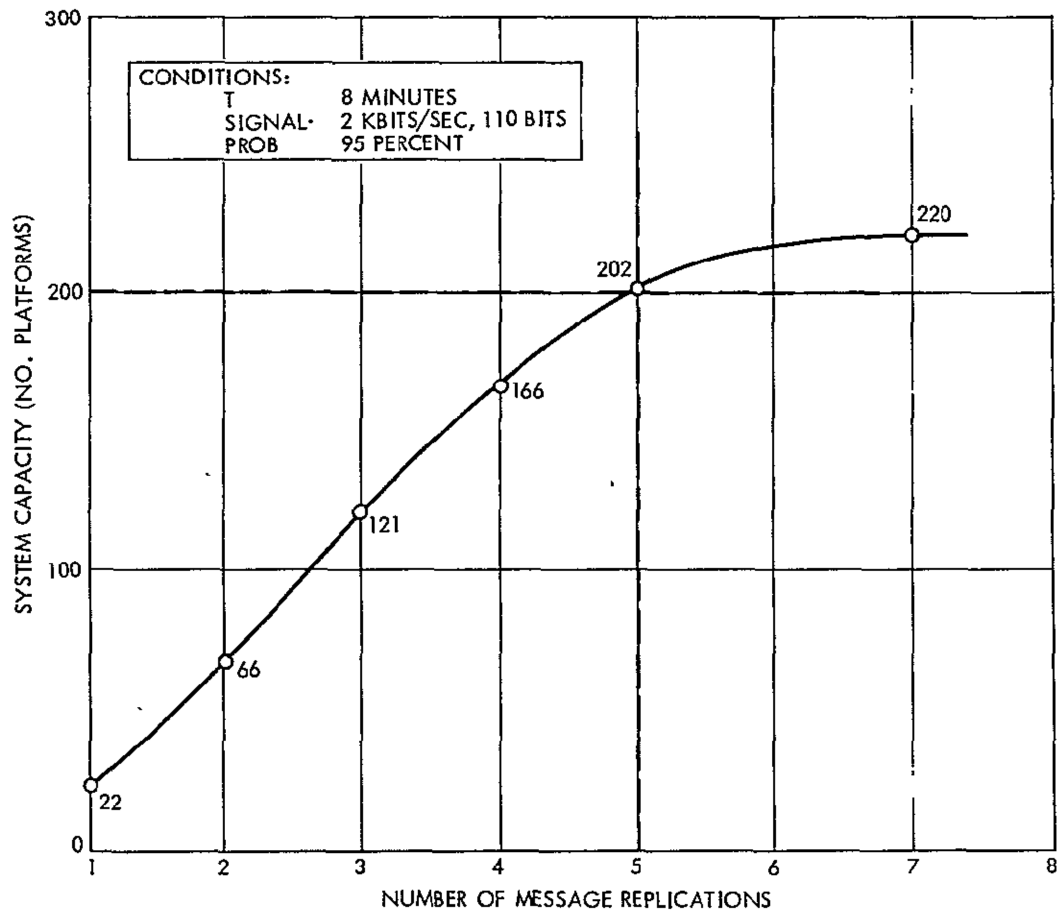
<u>Probability of Receiving One Good Message.</u> ERTS specifications require that the system will obtain at least one good message every 12

hours from each platform with a probability of 0.95, or conversely that the probability of no message received at all will be 0.05. To maximize time domain density TRW has established a design criterion that 90 percent of all message errors will be due to frequency domain collisions and 10 percent will be due to bit decision errors due to noise.

Messages Lost Due to Message Collisions. The DCS is to be designed to receive at least one good message from each of 1000 platforms located throughout the United States. Each platform will be viewed by the satellite for a nominal time of eight minutes, which means that three to four transmissions will be received per pass. Perhaps 90 percent of the stations will be viewed twice per orbit with the result of six to eight message replications being received from these platforms. Platforms directly under the satellite trajectory will only be viewed once per orbit. At a 5-degree elevation angle from each DCS platform, the satellite will view a circular area on the earth's surface of 2940 miles diameter which could bring the satellite into position to receive transmissions from nearly all 1000 platforms. For a design value, it will be assumed that the satellite is receiving messages from 1000 platforms.

Calculating the probability of one good message per 12 hours is seen to be a highly involved study concerned with message statistics in random time and frequency domains, ability of ground station receivers to demodulate the random narrowband signals (2.5 kHz) in a wideband search band (100 kHz), and the extent that ground software can piece together a good message from several damaged ones.

Ability of the DCS to handle 1000 platforms may be illustrated by the following case presented in Volume 5 of the ERTS Final Report, pages 2-27 to 2-28. The following curve indicates the system capacity assuming that all platforms are transmitting one frequency:



This curve indicates that with five message replications, 202 stations can be handled on a common carrier channel frequency. Assuming momentarily that each platform will have a very stable transmit frequency, the bandwidth required by any data carrier is ±8.5 kHz for doppler shift and approximately 5 kHz for data. Thus, each channel would require 22 kHz of bandwidth, allowing for five channels in the 100 kHz bandpass for a total capacity of 1010 stations. However, the DCS platforms will not be assigned frequency channels, but due to random frequency settings and thermal frequency drift, will be allowed to transmit at a random frequency in the 100 kHz bandpass, with the result that system capacity should increase since platforms will not be bunched together in groups.

Appendix A

APPENDIX A

ERTS PROJECT OPERATIONS REQUIREMENTS

1. INTRODUCTION

The purpose of this document is to define the operational requirements for the ERTS project. Implementation of support for these requirements is accomplished through the Support Instrumentation Requirements Document, which is prepared and issued by the NASA/GSFC ERTS Project Office The operational concepts contained herein reflect the capabilities of the entire ERTS system, including observatory, Space Tracking and Data Acquisition Network (STADAN), Man Space Flight Network (MSFN), ERTS Operations Control Center (ERSOCC), support communications and specialized NASA facilities.

The ERTS observatory is shown in Figure A-1.

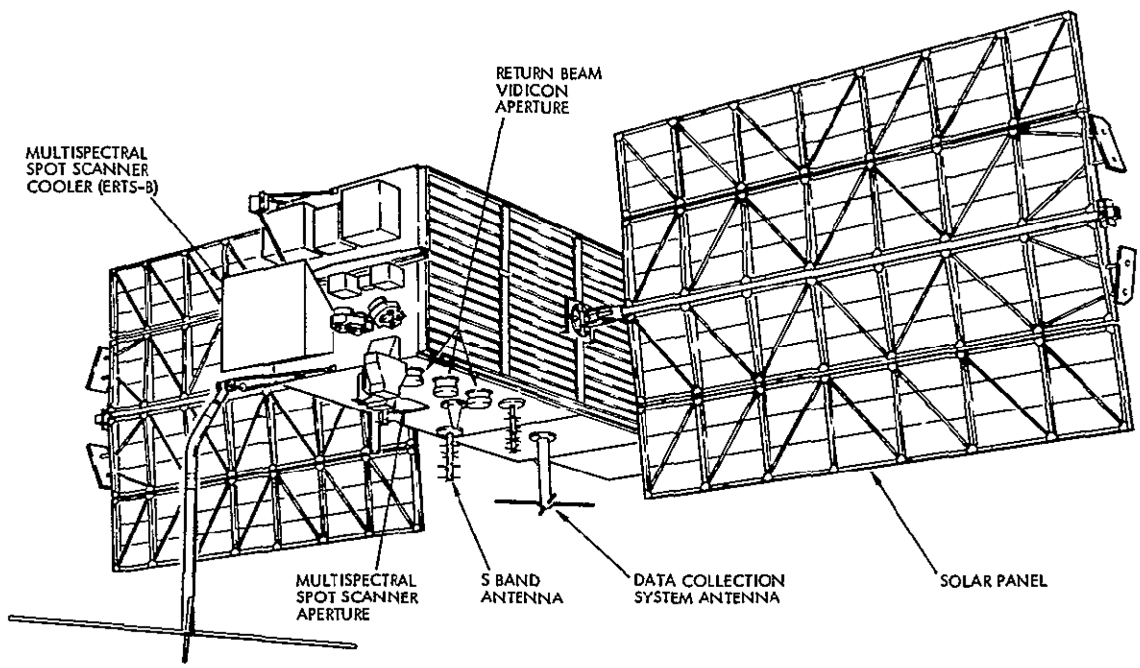


Figure A-1
ERTS OBSERVATORY

1 1 General Considerations

The operations plans for ERTS are primarily based on the combined requirements of the payload sensors. The data acquisition plan outlined in Section 7 reflects these requirements. In general, all operations will be conducted as necessary to optimize the data acquisition requested by each using agency

1.1.1 Operational Duty Cycle

ERTS will primarily be a real-time operation with limited data storage coverage. It is planned to operate sensors up to 30 minutes with the housekeeping tape recorders on nearly 100 percent of the time. Ground station visibility periods for this mission will average 11 minutes allowing for video tape playback in eclipse only. The in-orbit operation will be primarily in the main frame data storage configuration for housekeeping data.

1.1.2 Operational Configuration

The planned operational configuration for ERTS is as follows:

- Data collection receiver on 100 percent
- Payload sensors on according to detailed schedule as long as video tape recorder capacity and power permit
- All heaters on 100 percent
- 137 MHz, 0.5 watt transmitter on 100 percent
- Unified S-band transponder on 100 percent
- Housekeeping tape recorder on nearly 100 percent; playback as scheduled.

1.2 Orbital Parameters

The initial orbital parameters planned for ERTS are as follows:

Period	103.3 min
Semi-major axis	3936.5 n mi
Eccentricity	0.001
Inclination	99.098 deg

A subsatellite plot of this orbit from liftoff through the 14th revolution is shown in Figure A-2. Revolutions are, by convention, numbered between northbound crossings of the equator.

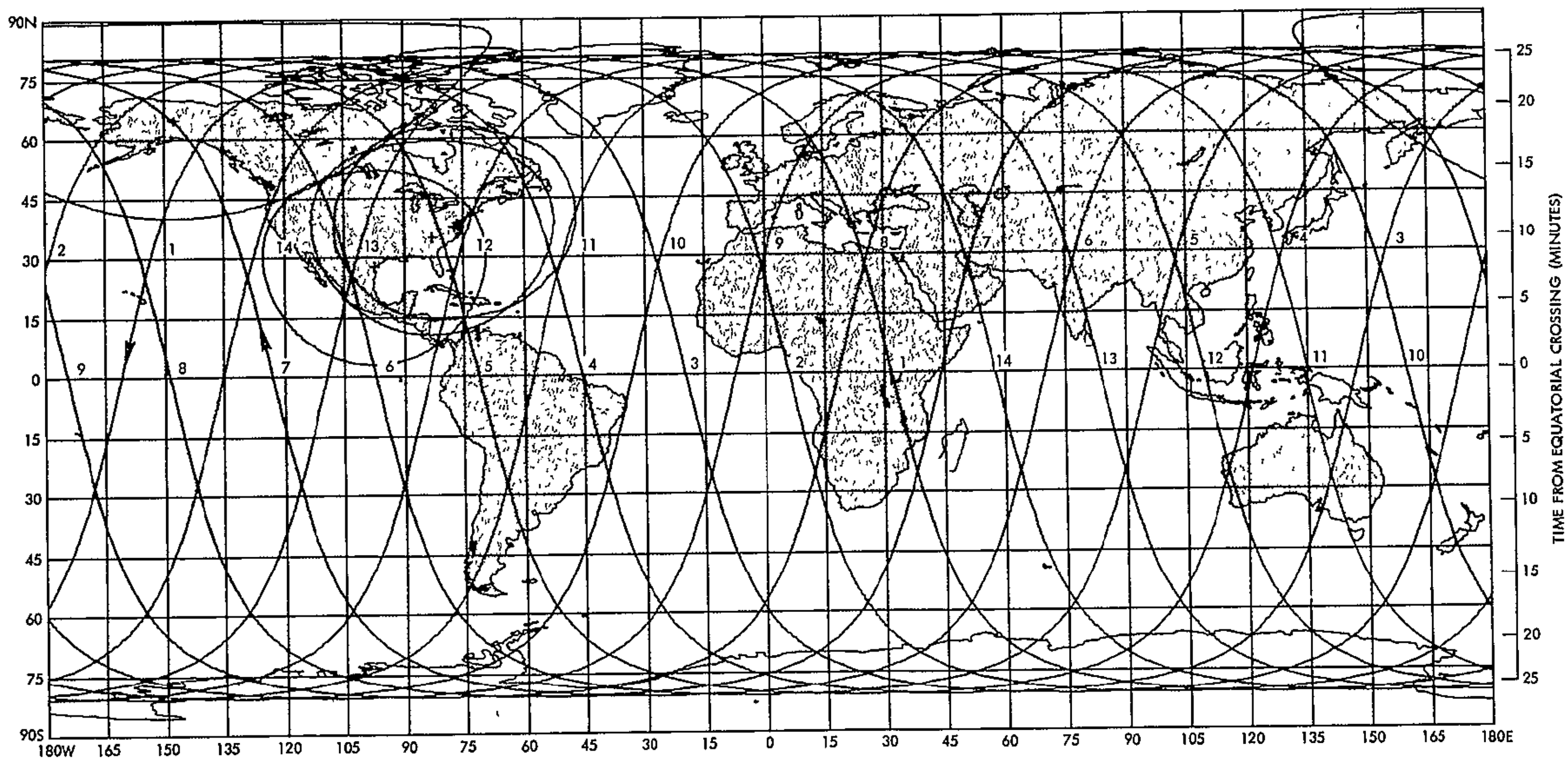


Figure A-2

TYPICAL 24-HOUR ERTS GROUND TRACE showing ground station coverage patterns for Alaska, Corpus, Rosman, and Greenbelt

1.3 System Operations

System operations are defined as those oriented specifically toward operation of the observatory in orbit. This includes the necessary prelaunch planning and exercises as well as the day-by-day routine postlaunch operations. System operations can be divided into the following phases:

1) Prelaunch Operations
- Preparations
- Pre-liftoff

2) Postlaunch Operations
- Initial
- Routine

All operations with the observatory after liftoff are performed in accordance with operating plans generated by the ERTS Operations Control Center at GSFC.

1.3.1 Prelaunch Operations

Prelaunch preparations are primarily directed toward practicing for the initial period of orbital operations and demonstrating the functional reliability of ERSOCC and the ground station network. Payload requirements are coordinated and operational plans are generated which are designed to optimize data acquisition. These requirements are reflected in all subsequent phases, since liaison with the users of data is maintained throughout the life of the observatory.

Of prime importance during the prelaunch phase are the readiness tests. These tests are exercises designed to demonstrate both the capability of the ground stations and GSFC facilities to support the observatory and the acceptability of operational planning procedures. The readiness tests are discussed in detail in Section 4. Other functions performed during this phase, such as the preparation of calibration data, generation of computer programs, etc., are too numerous and varied for detailed discussion.

General launch preparations are conducted in accordance with specific detailed plans and will not be discussed in this document. The interface between the launch operations and pre-liftoff operations occurs immediately prior to vehicle launch.

The pre-liftoff operations interface between the Western Test Range (WTR) and the ERTS Operations Control Center is to verify the following:

a) Once the in-flight jumper has been permanently installed, it is necessary to establish correlation between the spacecraft clock (as monitored on main frame words 33, 34 and 35) and GMT.

b) The the batteries are in full-charge condition at the time of launch.

c) That the initial sequencing circuits are reset and the observatory is in the proper electrical configuration at liftoff. Table A-1 lists the planned observatory electrical configuration at liftoff.

1.3.2 Postlaunch Operations

Initial orbital operations begin at vehicle liftoff and continue through the first 48 hours or orbital life. A typical launch sequence of events is summarized in Table A-2. Initial data acquisition will be accomplished by WTR from liftoff until loss of signal.

The ground station visibility periods during initial operations are shown in Figure A-3. It is planned to operate through revolution 012 during most of these periods.

The initial operations period is necessary not only to sequence the observatory through the proper sun and earth acquisition modes, but also to verify the aliveness and operational status of the payload and spacecraft subsystems. This period will also allow for evaluation of the horizon scanners while they view different infrared environments. The period assumes the observatory will be injected into its nominal orbit and that all systems perform properly. The remote stations will have specific telemetry word assignments to monitor and report to ERSOCC so that a continuous evaluation of the observatory can be made during this phase. (These word assignments are contained in Appendix D).

The nominal functions planned during the initial operations period are listed in Section 5. It should be noted that this plan may be deviated

Table A-1. ERTS Launch Configuration

	Item	Condition
1	Undervoltage bus 1	Reset
2	Undervoltage bus 2	Reset
3	No 1 and 2 regulator charge rate	3.7 amps
4	No 1 charge rate	Full array
5	No 2 charge rate	Full array
6	No 1 and 2 charge mode	Cycle
7	Regulator 1	Normal
8	Regulator 2	Normal
9	Battery 1	Connect
10	Battery 2	Connect
11	95°F thermal switch	Normal
12	Charge bus parallel	Normal
13	No 1 battery	Normal
14	No 2 battery	Normal
15	Payload converter 1	Disable
16	Payload converter 2	Disable
17	Wheel delay	Disable
18	Gas delay	Disable
19	Array delay	Disable
20	Pitch rate gyro	On
21	Control switching assembly	Safe
22	ACS bus	On
23	Gas jets	Disable
24	ACS mode select	Mode 1
25	ACS mode control	Normal
26	Array slew	Normal
27	X jet	Disable
28	Y jet	Disable
29	Z jet	Disable
30	Yaw gyro select	Auto
31	Yaw gyro power	On
32.	Gyro 1 select	On
33	Gyro heater	On
34	Tracking heads	Normal
35	Orbit adjust	Safe
36	USB transponder converter	A on/B off
37	Baseband	1 on/2 off
38	Baseband SCO's	On
39	Wideband transmitter drivers A and B	Off
40	Wideband transmitter drivers C and D	Off
41	TWTA 1	Off
42	TWTA 2	Off
43	TWTA 1 power mode select	10 W
44.	TWTA 2 power mode select	10 W
45	TX drivers A/B signal	Normal
46.	TX drivers C/D signal	Normal
47	MSS real time data	Channel 1

Table A-1. ERTS Launch Configuration (Continued)

	Item	Condition
48	RBV real time data	Channel 2
49	Wideband telemetry channel 1	Pos 1
50	Wideband telemetry channel 2	Pos 1
51	Real time EG	MC
52	D/S EG	ASC
53	EG 1	On
54	EG 2	On
55	EG 1	Real time
56	Clock select	A On
57	HFTU	EG 1
58	Real time bit rate	Low
59	Stored command programmer 1	Off
60	Stored command programmer 2	Off
61	Stored command programmer mode select	Standby
62	Ordnance	Safe
63	Payload ordnance	Disable
64.	Payload heater	On
65	Narrowband tape recorder 1	On
66	Narrowband tape recorder 2	On
67	VHF transmitter	A on/B off
	Payload, RBV	
68	Camera 1	Off
69	Camera 2	Off
70	Camera 3	Off
71	Calibrated lamps	Off
72	Ordnance	Safe
	Payload, MSS	
73	Spectral band 1	Off
74	Spectral band 2	Off
75	Spectral band 3	Off
76	Spectral band 4	Off
77	Scan mirror drive	Off
78	Mirror pick-off	Off
79	Rotating shutter drive	Off
80	Calibration lamp	Off
81	Main inverter A	Off
82	Main inverter B	Off
	Payload, VTR	
83	VTR 1	Off
84	VTR 2	Off
	DCS	
85	DCS 1 power	Off
86	DCS 2 power	Off

Table A-2. ERTS-A Nominal Launch Sequence of Events

Time from Liftoff (sec)	Event	Station Coverage
0	Liftoff (VAFB)	WTR
40	Solid BECO	WTR
102	Solid ejection	WTR
220	Thor MECO	WTR
229	Thor VECO	WTR
235	Thor-Delta separation	WTR
289	Delta ignition	WTR
299	Initiate shroud separation	WTR
524	Delta first cutoff	None (tape)
3476	Delta second ignition	Madgar
3480	Delta second cutoff	Madgar
3485	ERTS-Delta separation	Madgar
3500	Array deployment	Madgar
3517	ACS start	Madgar

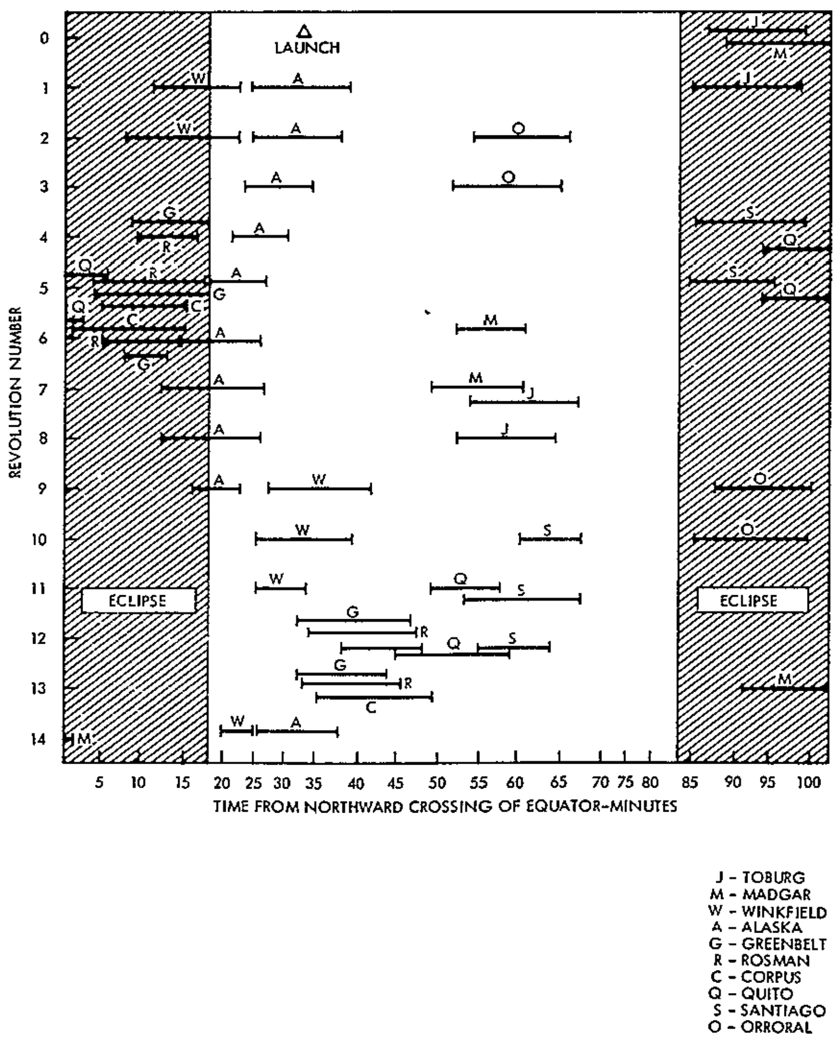


Figure A-3

GROUND STATION VISIBILITY during first 14 revolutions from at any time it appears that the observatory is not functioning in a proper or predicted manner.

The routine operations phase commences after the successful completion of the initial phase noted above. Day-to-day scheduling, evaluation of the observatory, and preparation of summary reports will be accomplished on a routine basis. Refer to Section 6 for a discussion of these functions.

2. PAYLOAD

The payload consists of two image sensing equipment, two video tape recorders for storing image data for later recovery, and two data collection receivers. Detailed descriptions of this equipment will be found elsewhere. Only the key characteristics which affect operation of each will be listed here.

2.1 Return Beam Vidicon

This three-color television camera system is used for imaging land areas only. The three cameras may be controlled separately but will generally be used in concert. Status of all internal commandable functions is telemetered. Its 155-watt dissipation makes it a critical item for OFF command but if missed a timer in the spacecraft will shut it off after 24 minutes. Normal mode of use produces a 100 x 100 nautical mile picture every 25 seconds, an automatic internal sequence action.

2.2 Multispectral Line Scanner

The multispectral line scanner continually scans a strip 100 nautical miles long perpendicular to the velocity vector, thus accumulating a continuous picture strip. Four color channels are generated and choice of color channels is provided by command. Normally, all will be on at once. Status of all commandable states is reported by telemetry. Power dissipated is 65 watts and a shutoff timer is provided as above.

2.3 Video Tape Recorder

Wideband data from the RBV and MSS will be telemetered via S-band links or stored in two identical tape recorders for later relay. These units also have full status reported via telemetry. The two recorders may be used for sequential storing of data from one source but a more normal use is for one recorder to store each of the two camera outputs. Two recorders draw 144 watts in record mode and each is automatically shut off after 24 minutes if not commanded off. Thirty minutes of data can be stored from the MSS and 50 minutes from the RBV.

2.4 Data Collection Receivers

This redundant system receives bursts of data at 400 MHz. One receiver will be used continuously. After first turn-on no further commands will be required in normal use. Data is modulated on the unified S-band 2287.5 MHz link. Real-time relay of data is all that is allowed. Power drain is about 1 watt.

3. PARTICIPATING STATIONS AND AGENCIES

3.1 Introduction

The NASA STADAN and MSFN stations are required to transmit commands to ERTS and to acquire telemetry data. These stations receive instructions from Operations Control (OPSCON) as requested by the ERTS Operations Control Center. These stations and the ERTS Operations Control Center are briefly described in the following paragraphs.

The telemetry data tapes (PCM and video) recorded at each station are mailed to GSFC for processing and formating in accordance with individual user requirements. This function is briefly described in Section 3.4.

A variety of support communications are required for ERSOCC to conduct operations during all operational phases. These requirements are listed in Section 3.5.

3.2 ERTS Operations Control Center

The ERTS Operations Control Center located at GSFC has complete responsibility for the conduct of the in-orbit operations of ERTS. The center has the capability of receiving data in real time from the NTTF, Rosman, Corpus, and Alaska ground stations. Limited real-time capability is also available in ERSOCC from most STADAN ground stations via a data transmission system low data rate link. Real-time control of

ERTS may be exercised during the periods when these stations are scheduled to perform functions with the observatory during initial operations.

ERSOCC issues all operating instructions in the form of detailed pass assignments and performs all necessary evaluations of spacecraft data.

All operations are under the cognizance of the project operations director (POD), who is a member of the GSFC project office and has responsibility for directing operations to assure fulfillment of project requirements.

During operations with Rosman, NTTF, Corpus, and Alaska, ERSOCC may receive real-time data via communication links. The links from Rosman, Alaska, and Corpus will also be utilized to send commands to the observatory from the control center. All commands transmitted by ground stations will be in strict compliance with operations plans as outlined in Section 6. The ERTS portion of the communication link to Rosman has a 64 kbit/sec (and 120 kHz special purpose) capability.

3.3 Ground Stations

The specific NASA STADAN ground stations that will be utilized in the operations of ERTS and their general equipment characteristics are listed in Table A-3. (MSFN ground stations may prove useful but this decision is left for NASA choice.)

3.4 Other Supporting Agencies

In addition to the ground tracking stations and ERSOCC, several other supporting agencies and complexes are directly involved in ERTS operations. The Western Test Range will participate in the readiness tests and monitor data from liftoff until loss of signal.

The NASA Data Processing Facility will be utilized to monitor data during the initial operations phase and to provide quick look data processing until two weeks after launch.

The Manned Space Flight Network operations center will cooperate in linking up MSFN stations used.

Table A-3. Ground Station Equipment Availability

Station	Location	Receiving Antenna*	Command System***	Data Word Selectors	Strip Chart Recorders
Rosman	Rosman, North Carolina	85 ft X-Y 35-db gain	2500 W 12 db/ 5000 W 22 db	20	8 Ch. Offner **S-350 (1) S-320 (1)
Alaska	Fairbanks, Alaska	85 ft X-Y 35-db gain	2500 W 12 db/ 5000 W 22 db	20	8 Ch. Offner 8 Ch. Sanborn
Joburg	Johannesburg, South Africa	40 ft X-Y 30-db gain	2500 W 22 db	20	8 Ch. Offner 8 Ch. Offner (2)
Corpus	Corpus Christi	30 ft	200 W		
Quito	Quito, Ecuador	40 ft X-Y 30-db gain	2500 W 22 db	20	8 Ch. Offner 8 Ch. Sanborn
Santiago	Santiago, Chile	40 ft X-Y 30-db gain	2500 W 22 db	20	8 Ch. Offner S-860 (2) S-350 (2) S-320 (1)
Wnkfld	Winkfield, England	14 ft AZ-EL 19-db gain	200 W 12 db	16	8 Ch. Offner 8 Ch. Sanborn
Ororal	Canberra, Australia	85 ft X-Y 35-db gain	2500 W 12 db/ 5000 W 22 db	20	16 Ch. Sanborn
Madgar	Tananarive, Madagascar	40 ft X-Y 30-db gain	2500 W 22 db	20	16 channels
NTTF	Greenbelt, Maryland				

*Antenna gains referenced to 400 MHz.

**Sanborn recorders.

***Antenna gains referenced to 150 MHz.

NOTE: Most stations also have barscopes and visicorders available.

3.5 Support Communications

During routine operations, teletype communications will be required to all ground stations from GSFC for the purpose of disseminating operations plans, tracking predictions, operations summary reports, and other traffic of a general nature. This circuit will be via the NASA Communications Network (NASCOM).

In addition to the above, teletype communications (normally commercial) will be required to all users for the purpose of disseminating quick look operations summary reports and receiving users requests for data acquisition requiring fast reaction at the control center. Quick look summaries will be TWXed to users for the first month of the mission. Thereafter, they will be mailed on a weekly basis.

During launch operations, additional communications will be required in the form of telephone and teletype circuits for the first two days of the orbital mission.

3.6 Mandatory Launch Requirements

The minimum mandatory launch requirements are as follows:

a) Ground stations and support equipment up:

- Joburg (minimum of 16 data channels)
- Madgar (data transmission system link up, minimum of 16 data channels)
- Winkfield (data transmission system link up, minimum of 16 data channels)
- Corpus (link must be up, minimum of 16 data channels)
- Santiago (minimum of 16 data channels)
- Ororal (data transmission system link up, minimum of 16 data channels)
- Corpus (data link up)
- Alaska (link must be up, minimum of 16 data channels)
- Rosman (link must be up, minimum of 16 data channels)
- NTTF (link must be up, minimum of 16 data channels)

b) Voice and TWX communications to above stations

c) ERSOCC will be up and have communications to WTR, computer up, minimum of 32 data channels, all subsystems and command status programs operational, all inter- and intra- communications up.

d) An " Auxillary" Operations Control Center (ASOCC) will be prepared to support ERTS from liftoff until approximately one day after launch. This will be used by special subsystem experts.

e) The status of the above launch requirements will be reported by the T&DS manager to Mission Control at the following times:

- T-170 minutes (five minutes prior to start of Delta tanking)

- Ten minutes prior to picking up the count at T-60 minutes

- T-7 minutes

f) Project representatives may be located at designated stations for launch. They will arrive on site five days prior to launch in order to participate in prelaunch readiness tests.

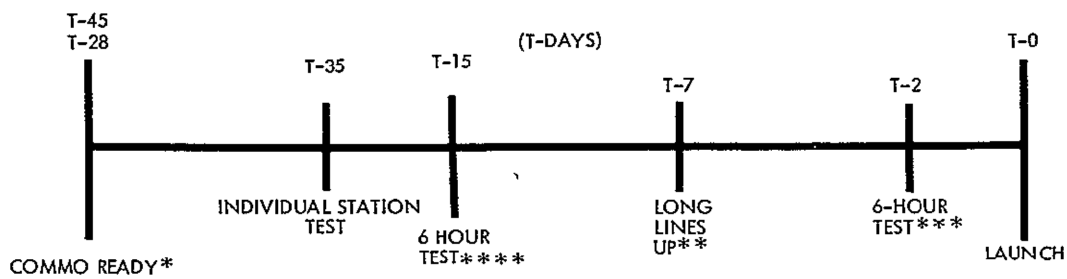
4. READINESS TESTS

4.1 Introduction

A series of tests will be conducted by each ground station and support facility individually to demonstrate station readiness and collectively to demonstrate system readiness. These tests are primarily an exercise to demonstrate the capability of station hardware and acceptability of the operational procedures. The readiness test also allows operations personnel to gain familiarity with spacecraft system characteristics prior to actual operations. A state of readiness exists when each ground station and support agency has demonstrated that all phases of a simulated operational pass can be successfully performed in accordance with basic operational procedures and that all personnel and equipment function properly. Testing to be conducted to determine readiness consists of the following:

- Operational readiness tests which exercise the entire system.
- Tests conducted individually by a station or supporting agency to determine operational support capability.
- Tests designed for the basic purpose of exercising the telephone, teletype, and video support communications.

The time phasing of the radiness tests and support requirements is shown in Figure A-4.



*ROUTINE COMMO LINES IN, CHECKED, AND READY
**ALL SPECIAL COMMO LINES FOR LAUNCH
***IF REQUIRED
****REPEAT IF NECESSARY

Figure A-4

READINESS SEQUENCE of events

4.2 Support Communication Readiness

All telephone, teletype, and video microwave links necessary to support ERTS orbital operations are considered support communications. These have critical requirements depending upon the particular operational phase. During the countdown and launch phase, it is necessary for support communications to be established between launch operations (WTR) and ERSOCC. During the first critical phases of ERTS after injection, it will be necessary to establish telephone communications between most remote ground sites and ERSOCC. It is necessary to establish these networks long before launch to assure that adequate communications are available to handle the critical information and data handling requirements for launch and early orbit support. The readiness demonstration of all telephone communications is simply accomplished by the establishment of the desired network and voicing a simple communications go. Teletype readiness will be demonstrated by establishing the appropriate conferences and transmitting a standard test. Readiness of the video link between ERSOCC and supporting facilities at GSFC will likewise be demonstrated by the transmission of standard test signals and recorded spacecraft telemetry.

4.3 Routine Telemetry Data Processing

A demonstration of the readiness and acceptability of computer programs designed for the processing of telemetry data will be undertaken. This readiness demonstration can be performed individually, as an individual station readiness, or in conjunction with the operational system readiness test. Readiness is demonstrated when recorded observatory telemetry tapes can be reliably processed.

4.4 Individual Station Readiness

Readiness tests will be conducted independently to verify checkout and acceptance. The initial demonstration tests to be performed by individual stations will utilize observatory pre-recorded telemetry tapes and a spacecraft signal simulator. Functional operation of all ground station elements will have been demonstrated 35 days prior to launch.

4.5 Operational System Readiness (World Wide Readiness)

Operational system readiness tests are performed to demonstrate the functioning of the command system and the real-time telemetry data processing system. System readiness is demonstrated with primary emphasis on the operation of the ERTS Operations Control Center.

4.5.1 Purpose

The operational system readiness demonstration is necessary to verify that spacecraft commands can be transmitted from ERSOCC through Alaska, Corpus, and Rosman command transmitters. This test is also necessary to demonstrate that spacecraft telemetry data can be played through the system at Rosman, NTTF, Corpus, Alaska and through the microwave link to ERSOCC for subsequent processing. This test requires that all aspects of data processing at ERSOCC be verified. All computer programs will likewise be implemented to demonstrate functional acceptability. Data word selectors in the subsystem work area will be configured to obtain strip chart recordings and displays of those items that will be monitored during the initial orbit and experiment turn-on.

All remote sites will likewise configure data word selectors to process data and report critical values to ERSOCC. Further, the tests are designed to check out communications and drill personnel.

4.5.2 Procedure

At the date and time specified for the system readiness test, detailed pass assignments will be transmitted to all test participants. The pass assignments will be in identical format to those which will be used during routine orbital operations. All commands to be transmitted by ERSOCC will be listed in the readiness test pass assignments. All times that functions are to be performed by all participants will likewise be specified. The detailed readiness test procedures are listed in Table A-4.

5. INITIAL OPERATIONS

5.1 Introduction

Initial orbital operations for ERTS are defined as those operations which occur from launch until approximately 48 hours thereafter, assuming a normal orbit and proper functioning of all observatory subsystems. After 48 hours, the normal or routine operational phase begins except for experiment interference testing. Initial operations are of necessity directed toward verification of a successful mission with all experiments and observatory subsystems operating properly.

Table A-5 lists the nominal operations plan for the first 48 hours of the ERTS mission. It should be noted that this plan may be deviated from at anytime it appears or is suspected that the observatory is not functioning normally. This deviation may be made by the ERTS Operations Control Center only.

5.2 Ground Stations and Complexes

The ground stations and complexes which will participate in initial operations are as follows:

- Western Test Range Complex (WTR)
- Johannesburg, South Africa, ground station (Joburg)

Table A-4. ERTS Readiness Test

Station	Test Time	Item
WTR	T-10	Report first spacecraft clock GMT correlation
	T-0	Announce T-0 (time)
	T+3	Record second spacecraft clock, GMT correlation. Report when requested by project operations director.
	T+5	Report loss of signal.
Madgar	T+30	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock
		Relay real-time data to ERSOCC via data transmission system
		<u>Command 100 Ordnance Sequence Arm</u>
		<u>Command 140 Array Deploy</u>
ERSOCC	---	Verify deployment and evaluate spacecraft status
Madgar	T+38	1) Report loss of signal 2) Report final value of words
Joburg	T+40	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock
		Report value of assigned words if requested by project operations director.
	T+48	Report loss of signal.

NOTES

1) All commands are to be transmitted into dummy load, and address xxxxxxx will be used

2) T-times refer to this test only.

3) Data on readiness test tapes does not necessarily coincide with commands sent or events that occur The data contained on the tapes was obtained from the ERTS spacecraft.

4) Words displayed on strip charts at remote sites will be reported as values varying from 0 to 5 telemetry volts, words displayed on lights only will be reported in octal values. Words will be identified by T/M codes, e.g., A10 is 2.5 volts or C57 is 144. Words reported in the work area will be in engineering units

5) Telemetry word assignments for this test and actual operations are listed in Appendix D.

6) The standard procedure for transmitting commands in real time is as follows:

<u>From</u>		
SOC*	CCO (or station)	Set up Command XYZ (literal description)
CCO*	SOC	XYZ Set Up
SOC	CCO	Command XYZ transmit
CCO	SOC	Transmitted (remote stations reply "verified" or "not verified" as indicated by the enable bit or available data)

When applicable, the work area will report command verification to the SOC.

It is understood that the above procedure applies to all commands in this test as well as to actual operations.

7) No payload commands have been included in Table A-4 since payload turn-on will not occur during the first few hours of the mission.

*SOC satellite operations controller
CCO command console operator

Table A-4. ERTS Readiness Test (Continued)

Station	Test Time	Item
Wnkfld	T+58	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock 4) Relay real-time data to ERSOCC via data transmission system Report value of assigned words if requested by project operations director.
ERSOCC	---	Verify spacecraft status
Wnkfld	T+60	Report loss of signal
Alaska	T+68	1) Start tape 2) Report acquisition and AGC on 137.86 and 2287.5 MHz 3) Report PCM lock 4) Relay data to ERSOCC via data transmission system <u>Command 141 ACS Enable</u> <u>Command 146 ACS On</u> Report value of assigned words if requested by project operations director.
ERSOCC	---	Verify spacecraft status, power status
Alaska		<u>Command 061 Tape Playback</u> Report end of playback and lock on real time
	T+76	Report loss of signal
	T+80	Relay tape playback data to ERSOCC at 16 kbit
ERSOCC	---	Examine revolution 001 playback, evaluate deployment and sub-system performance
Alaska	T+94	End of playback relay
Joburg	T+104	1) Start tape 2) Report acquisition and AGC on 137 86 MHz 3) Report PCM lock Report value of assigned words
	T+112	Report loss of signal
Alaska	T+122	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock 4) Relay real time data to ERSOCC <u>Command 142 ACS Mode 2C</u> <u>Command 161 ACS Execute</u> <u>Command 121 ACS Normal</u> <u>Command 067, 034, 014, 355, 047 Delays In</u> Report value of assigned words if requested by project operations director. Evaluate earth acquisition

Table A-4. ERTS Readiness Test (Continued)

Station	Test Time	Item
	T+130	Report loss of signal
Quito	T+140	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock
		Report value of assigned words
	T+148	Report loss of signal
	T+158	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock
		Report value of assigned words
		<u>Command 061 Tape Playback</u>
		Report end of playback and lock on real time
	T+166	Report loss of signal
Santiago	T+176	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock
		<u>Command 031 Real Time Accelerated Subcommutater</u>
		<u>Command 373 ACS Mode 4</u>
		<u>Command 161 ACS Execute at ERSOCC Direction</u>
		1) <u>Command 121 ACS Normal</u> After Mode 4 verified (ERSOCC direction) 2) Report value of assigned words
	T+184	Report loss of signal
Rosman	T+194	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock 4) Relay 32 kbit data to ERSOCC
NTTF	T+196	1) Start tape 2) Report acquisition and AGC on 2287.5 MHz and PCM lock 3) Report loss of signal
ERSOCC	---	Examine assigned words and report earth acquisition status to project operations director
Rosman		Report value of assigned words if requested by project operations director
	T+202	Report loss of signal
Quito	T+212	1) Start tape 2) Report acquisition 3) Report AGC on 137 86 MHz and PCM lock
		<u>Command 061 Tape Playback</u>
		1) Report end of playback and lock on real time 2) Report value of assigned words
	T+220	Report loss of signal

Table A-4. ERTS Readiness Test (Continued)

Station	Test Time	Item
Rosman	T+231	1) Start tape 2) Report acquisition and AGC on 137.86 MHz 3) Report PCM lock 4) Relay 32 kbit data to ERSOCC
ERSOCC	---	Perform quick look
Rosman	T+231	1) <u>Command 061 Tape Playback</u> 2) Continue to relay data to ERSOCC
ERSOCC	---	Evaluate spacecraft and payload status
Rosman		Report end of playback and lock on real time
		Report value of assigned words if requested by project operations director
	T+239	Report loss of signal
Ororal	T+249	1) Start tape 2) Report acquisition 3) Report AGC on 137.86 MHz and PCM lock
		<u>Command 061 Tape Playback</u>
		1) Report end of playback and lock on real time 2) Report value of assigned words if requested by project operations director
	T+257	Report loss of signal
	T+261	Relay tape playback data to ERSOCC via data transmission system
ERSOCC	---	Evaluate spacecraft performance
Ororal	T+267	End of playback relay
Alaska	T+277	1) Start tape 2) Report acquisition 3) Report AGC on 137 86 and 2287.5 MHz and PCM lock 4) Relay 16 kbit real time data to ERSOCC
ERSOCC	---	Perform quick look
Alaska	T+285	Report loss of signal
Madgar	T+295	1) Start tape 2) Report acquisition 3) Report AGC on 137 86 MHz and PCM lock
		<u>Command 061 Tape Playback</u>
		1) Report end of playback and lock on real time 2) Report value of assigned words if requested by project operations director
	T+303	Report loss of signal
	T+311	Relay tape playback data to ERSOCC via data transmission system
ERSOCC	---	Evaluate spacecraft performance
Madgar	T+317	End of playback relay

- Fairbanks, Alaska, ground station (Alaska)
- GSFC ERTS Operations Control Center (ERSOCC)
- GSFC NTTF ground station, Greenbelt
- GSFC production data processing
- Rosman, North Carolina, ground station (Rosman)
- Corpus Christi, Texas, ground station (Corpus)
- Winkfield, England, ground station (Wnkfld)
- Santiago, Chile, ground station (Sntago)
- Quito, Ecuador, ground station (Quito)
- Tananarive, Madagascar, ground station (Madgar)
- Canberra, Australia, ground station (Ororal)

All remote stations will have data word assignments to monitor and report to ERSOCC. These assignments are specified in Appendix D.

5.3 Operational Ground Rules

The operational ground rules for the period of initial operations are as follows:

a) WTR: No commands will be transmitted after liftoff.

b) Rosman, Winkfield, Santiago, Quito, Ororal, Corpus Christi: No command will be transmitted except at ERSOCC direction.

c) Johannesburg, Madagascar: Commands will be transmitted as authorized by ERSOCC, except commands 100 and 140 (arm bus/array deploy) which are to be transmitted automatically as scheduled.

d) Alaska: All commands are to be transmitted at ERSOCC direction only. If communications are lost, Alaska project representative is authorized to take action as described in the contingency plan.

e) ERSOCC

1) The tracking and data systems manager is responsible for reporting the state of readiness of all remote stations and ERSOCC in terms of equipment, communications, data links, backup provisions and adequate personnel.

2) The tracking and data systems manager reports readiness of (1) above to the project manager prior to launch.

3) The control center manager is responsible for maintaining control center discipline and equipment in the required state of readiness. He will inform the project operations director of any change in status.

4) The work area manager is responsible for reporting the state of readiness of the work area and any spacecraft subsystem malfunctions that may occur. He is also responsible for maintaining discipline in the work area.

5) There will be a designated satellite operations controller in the control center for the entire initial phase of operations.

6) All payload operational requirements will be channeled through a designee in the work area to the satellite operations controller for implementation.

f) Project Representatives

1) During the initial operations phase, no commands except as noted in the contingency plan for Alaska and Johannesburg, scheduled or otherwise, are to be transmitted without authorization by the project operations director.

2) Assessments of performance by any station must be in terms of that station's primary assigned telemetry words. Other information, as a function of the disciplines of the project representative involved, are secondary. Every opportunity of utilizing the capabilities of the project representative at a remote station will be made only after key spacecraft information is obtained.

5.4 Assumptions

For simplicity, the initial operations plan outlined in Table A-5 is based on the following assumptions:

a) Rosman and Corpus Christi will transmit all real-time housekeeping data to ERSOCC. Alaska will transmit all real-time 1 kbit data to ERSOCC. Both Rosman and Alaska will replay tape playback data at 32 and 16 kbit minimum respectively and transmit to ERSOCC, in the forward direction, after each such pass as scheduled. Winkfield, Ororal and Madagascar will transmit real-time data to ERSOCC via the data transmission system and replay playback data to ERSOCC as scheduled.

b) ERSOCC is assumed in quick look or monitor status for all passes.

c) All remote stations will verify commands. Repeated commands will be directed by ERSOCC as necessary.

d) Housekeeping data will be via the 137 MHz transmitter and by unified S-band transmitters continuously after liftoff.

e) Multiple commands listed at one time are to be transmitted by tape or the command sequencer.

f) Passes less than two minutes in duration are not operationally considered unless necessary for playback of the tape recorders to insure data coverage or other contingency use.

Notes and Precautions

1. All times are GMT referenced to T = 000Z at liftoff and are listed as HHMM:SS times (e.g., 1143:30 is 11 hours, 43 minutes and 30 seconds after liftoff).

2. The command decoder address normally used will be xxxxxxx (The alternate address is xxxxxxy).

3. Payload turn-ons are scheduled for Rosman or Alaska in order to observe data in real time at ERSOCC.

4. Payload turn-on is limited to one per pass during orbits where the first orbit of data storage operation may be played back at Rosman or Alaska and transmitted back to ERSOCC for analysis.

5. Mode commands for payload will be scheduled as requested.

6. Commands will be sent by the paper tape and sequencer mode (up to five commands in sequencer) when possible. Commands sent in this manner are transmitted at 600-millisecond intervals. Command tape functions and commands will be listed as part of the weekly command logs. At time of transmission, only the start time of the tape and the function will be listed. Tape numbers and function are not re-assigned if tapes become obsolete (and are destroyed) to avoid later confusion.

7. Real-time commands only will be sent to T+48 hours.

8. The order and time of command functions reflect outgassing, deployment, and other constraints as supplied by GSFC and the payload contractors.

6. ROUTINE OPERATIONS

6.1 Introduction

Once successful completion of the initial operations phase, discussed in Section 5, has been accomplished, the routine operations phase begins. It is expected that the phase will begin approximately two days after launch. Advanced operations plans and detailed pass assignments will be generated, based upon observatory performance, station availability, and data acquisition requirements. The data acquired is mailed to GSFC for processing and subsequent transmittal to users in accordance with specific format requirements. The routine phase also requires evaluation of observatory performance. Station pass summary reports and weekly operations reports are used to summarize all operations during this phase. Figure A-5 depicts the basic elements of the routine operations phase.

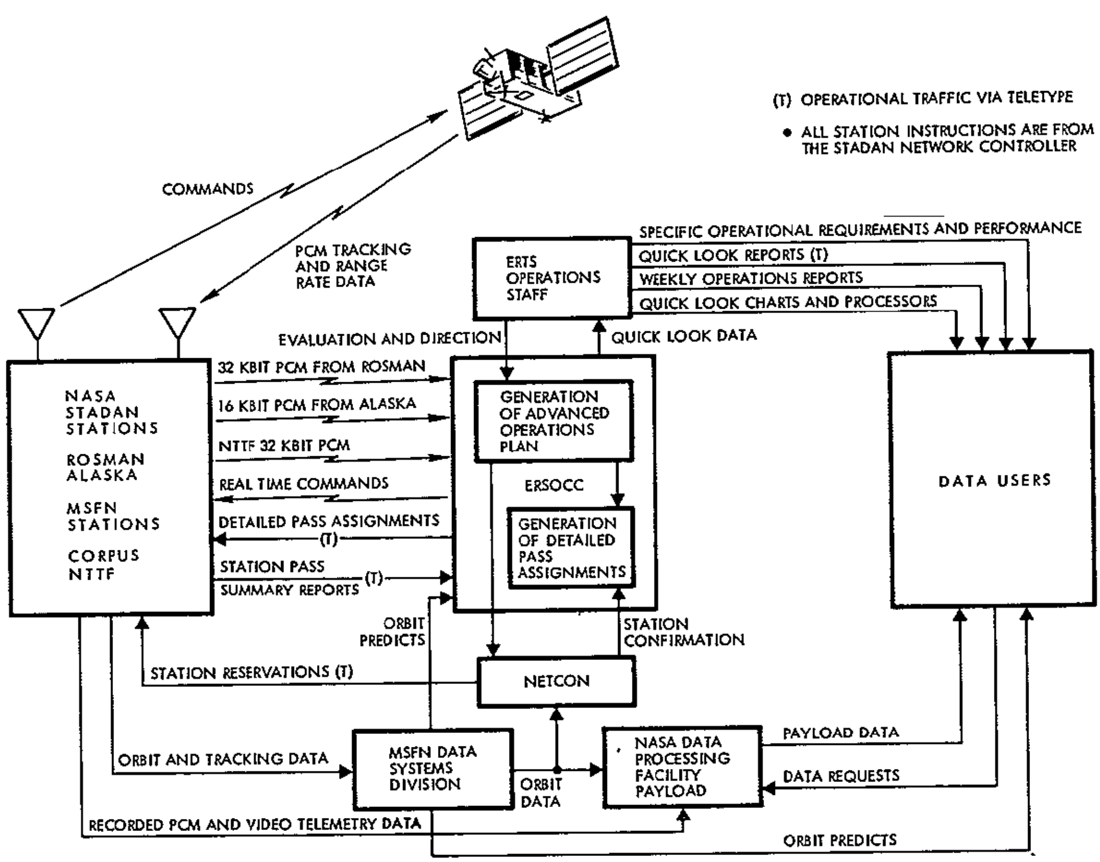


Figure A-5
ROUTINE ERTS OPERATIONS, interrelationship of cooperating agencies

The routine operations phase will be performed with limited real-time operation of ERSOCC. Most of the commands transmitted to the observatory will be from ground sites originated at ERSOCC. ERSOCC will normally be in contact with these stations during the period of spacecraft visibility. Quick look operations (real-time data at ERSOCC) will be performed at least twice per day.

6.2 Operations Scheduling

All functioning of the observatory will be accomplished in accordance with strict operational plans. All command functions will be detailed in specific plans prepared well in advance of actual operation. These plans consist of the advance operations plan and the detailed pass assignments. All operations to be performed with the observatory will be listed in the detailed pass assignments and no operations will be permitted which are not specifically listed therein. Emergency changes can be effected by verbal instructions of the project operations director or a designated satellite operations controller from ERSOCC.

6.2.1 Scheduling Concept

The basis for all operational scheduling is to exercise the observatory in the most efficient manner so as to obtain maximum utilization of sensors and perform orbital operations with a minimum of switching and commanding. Scheduling assumes unlimited availability of Rosman (command), Corpus Christi, NTTF, and Alaska.

Operational scheduling is accomplished by first considering ground station coverage and availability two weeks in advance of actual operations The advance operations plan is generated two weeks in advance and is utilized to request ground station commitments from the Net Controller (NETCON). NETCON confirms station reservations at least four days in advance, permitting generation of detailed pass assignments at least two days in advance. Figure A-5 depicts the elements required to generate this plan.

6.2.2 Orbital Data

The orbital data required for generation of the advance operations plan will be supplied by GSFC Data Systems Division as outlined in Section 8. During normal operations, the predicted satellite map and the orbit plot are provided to ERSOCC and project operations on a weekly basis, two weeks in advance of actual operations and covering a two-week operational period by MSFN.

This data is used to determine ground station to observatory visibilities, station local terrain restrictions, eclipse periods and position in orbit. Along with sensor requirements and day-to-day evaluation of observatory performance, it provides the basis for all operational scheduling.

6.2.3 Advance Operations Plan

The advance operations plan will be generated two weeks in advance for project operations use in overall scheduling. It will be submitted for coordination to NETCON one week in advance to assure station availability. The plan is simply a chronological listing of the dates and times the stations and data links are required, and whether each station will be required to command and/or record. Detailed command instructions are not included. Recipients of this plan must bear in mind that it is merely a prediction of future operations and may be materially altered due to operational priorities, station outages, and spacecraft performance.

6.2.4 Detailed Pass Assignments

The detailed pass assignments will be generated two days in advance and distributed by teletype to remote stations at least 24 hours prior to the beginning of the pass. Figure A-6 illustrates a typical assignment in teletype format. All functions to be performed are listed in time sequence, with time appearing in minutes and seconds. Commands are listed by octal number and literal, along with the command verification.

6.2.5 Spacecraft Performance

Evaluation of spacecraft performance is a major consideration in scheduling observatory operations. The observatory duty cycle is determined on a routine basis by a detailed examination of spacecraft subsystem performance. Payload aliveness and operational status are also a major factor in this determination.

The electrical power subsystem will be examined to determine its ability to support the total power requirements of the observatory throughout its operational life. However, it is expected that the solar cells will

TYPICAL DETAILED PASS ASSIGNMENT FOR ERTS

PP GERS GROS

INFO GERS

REF 1972-XX ERTS-A REV 010

A. PASS ASSIGNMENT 15/2358Z APR 72 TO 16/0005Z

B. RECORD 1 KB/RT, VIDEO

START	15/2358Z
STOP	16/0005Z

C. DATA WORD SELECTOR ASSIGNMENT AS FOLLOWS:

ITEM	S2-021	MF-037	S2-079	MF-067
FRAME	057	N	116	N
WORD	142	045	142	102
VERNIER	OC01	VT02	OC01	0102
TAG	0457	0045	0516	0102

D. GROS COMMAND USING ADDRESS XXXXXXX EXCEPT AS NOTED

GMT	CMD	LITERAL	VERIFICATION	EB
SET ADDRESS TO XXXXXXX				
2358:00	340	WB A ON	2229.5 AOS	N/A
2358:30	052	DS	MF-067 TO 053	N/A
0001:30	002	TR 1 ON	S2-079 TO 400	YES
SEQ	231		X14 VARYING	YES
		P 17.8		
0005:00	241	WB OFF	2229.5 LOS	N/A

E. REMARKS: NONE

Figure A-6

TYPICAL DETAILED PASS ASSIGNMENT

not experience sufficient degradation nor that the battery capacity will decrease to such an extent that operations will be restricted during the first year, although a power budget will be necessary. Items to be monitored will include voltages, currents, and temperatures of all critical areas of the subsystem. The analysis of these items will provide an input to the operations schedule as they become applicable.

The attitude control subsystem will be routinely examined to determine its ability to orient the observatory and solar paddles effectively. Gas consumption plus performance predictions will have a direct bearing on operations scheduling.

The thermal subsystem of the observatory will be monitored on a routine basis to verify and maintain proper thermal environment.

The Communications and Data Handling subsystem will be utilized to determine overall observatory status. The measurements to be monitored will include ground receiver input signal strength, transmitter power outputs, telemetry regulated voltages, and other instrumentation. These items will determine the validity of data received and will have a direct bearing on operations scheduling.

6.2.6 Payload

A user data file will be maintained and will contain the basic input for scheduling data acquisition for all users. There will be a separate file for each user which will contain information regarding requirements such as data acquisition required with respect to orbital parameters, time of year, etc. It will also list the various modes of operation and when each is applicable with respect to data acquisition. The operations schedule must reflect these requirements in order to fulfill user objectives.

When a user requires a change in operational requirements, a request will be made to ERTS operations by telephone, teletype, or mail depending upon the urgency of the situation. The user may contact ERTS operations by the following means:

a) Telephone:

Operations Office:	301-982-XXX 301-982-XXY	
Control Center:	301-982-XXYY	satellite operations controller
(ERSOCC)	301-982-XYYY	scheduling operations

b) Teletype:

NASA com system address "GERS"
TRW: dial 710-828-XXXX
TELEX: 089-XXX

c) Mail: Goddard Space Flight Center

ERTS Operations
Greenbelt, Maryland 20771
Attn: Project Operations Director, Code XXX
Copy to: ERTS Sensor Operations, Code XXX.Y

6.3 Operational Control

6.3.1 Command Responsibility

Station command responsibility will always be stipulated in the detailed pass assignment and all commands will be transmitted in accordance with this plan. Contact with ERSOCC may or may not be maintained with the commanding station during scheduled operations. All commands are listed in Appendix B.

ERSOCC has the capability of transmitting commands directly through the Rosman, Alaska and Corpus ground sites. When ERSOCC is the commanding site, all commands will still be issued in accordance with the detailed pass assignment, although some latitude is allowed since data is being monitored in real time.

Normally, no deviations are made to the command schedule listed in the detailed pass assignment. The planned command sequence may be modified whenever examination of the data indicates anomalous spacecraft performance. All changes to planned operation are effected only by the project operations director or satellite operations controller and are issued only by ERSOCC.

All station command equipment tests will be performed with command address YXXXXXX and command 213 (spare). Only during an authorized ERTS pass will any other address be inserted into the command console.

6.3.2 Command Verification

Command verification will be accomplished at remote stations or ERSOCC by monitoring enable bits and/or telemetry items. At ERSOCC the command status of the spacecraft and sensors can be determined either manually with data word selectors or by computer programs.

A printout of the status of all sensor commands has been implemented for ERTS. This program will be run with the normal spacecraft subsystem programs to provide real-time sensor status, and an historical record of sensor operations. Sample printouts are shown in Figures A-7 and A-8.

6.4 Summary Reports

6.4.1 Station Pass Summary Reports

Since a deviation from the planned command schedule may occur, it is vital to obtain a report from each station which lists all radiated commands, the time of transmission and whether or not the command was verified. These station pass summary reports will be transmitted via the GSFC teletype network to ERSOCC within 30 minutes after each performed operation, and should also include observatory acquisition times, signal level measurements and a notation of any anomalous performance observed with either the observatory or ground equipment. These reports are required in addition to the station malfunction and maintenance forecast supplied to the net controller on a routine basis.

6.4.2 Weekly Operations Reports

All station pass summary reports will be summarized by project operations into weekly operations reports which will be disseminated to all users and participants as a permanent record of actual operations. It will include a complete chronological command history. This report will be generated on a weekly basis and mailed several days thereafter.

6.4.3 Quick Look Reports

A quick look operations report will be transmitted to all participants, via TWX initially, but after the first few weeks of the mission, only by mail. This report will provide a brief description of the quick look operations and observatory status.

```
01/27R3416RT DATA FRZ MODE  A          OGO-6/F     S/C COMMAND STATUS-04                    OGO-OCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23

                                                   A23 ACS MODE/SUN       3S/ ON   021
        MC        DS          RCVD                 D10 LOAD BUS (VOLTS) 30.23      327        D59 LOAD BUS  (AMPS) 12.19    313 *
        MC        RT EG 1              64 KB       D8  BAT 1    (VOLTS) 31.34      336        D9  BAT 2    (VOLTS) 31.19    335
        S/C CLOCK    063 560 017                   D1  BAT 1     (AMPS) 2.682      055 *      D2  BAT 2     (AMPS) 2.741    056 *
        CLOCK BIAS   105 664 050                   D64 BAT 1 CUR DIRECT  CHRG      112        D65 BAT 2 CUR DIRECT  CHRG    112
        S/C GMT      70 027 1656  04               D4  ARRAY 1   (AMPS) 7.123      263 *      D5  ARRAY 2   (AMPS) 9.471    356

      ** ACS **                                    ** POWER SUPPLY **                           ** DATA HANDLING **
    146 ACS           ON        D43=257          354 REG 1         NORM     D03=000         011 RT              MC        F46=544
    047 CSA           SAFE      A44=000          315 REG 2         NORM     D03=000         053 RT RATE         64 KB     F44=106
    355 ARRAY DELAY   ENABLE    B02=000          376 REG 1         8.3 A    D61=332         012 DS              MC        F46=544
    014 WHEEL DELAY   ENABLE    B01=001          337 REG 2         8.3 A    D61=332         003 EG 1            ON        D28=256
    103 SUN SENSOR    NORM      A23=021          164 REG 1+2       3.7 A    D61=332         043 EG 2            ON        D32=256
    XXX ACS           MODE 3S   A23=021          316 CHARGE        CONT     D62=127         041 EG              1 RT      M65=005
    146 PITCH JETS    ENABLE    A44=000              BAT 1                  D62=127         030 MO              2 SEL     F46=544
    146 YAW JETS      ENABLE    A47=210          037 BAT 2         RECOND   D62=127         070 HFTU            2 SEL     F46=544
    146 ROLL JETS     ENABLE    A47=210          104 BAT 1         NORM     D63=000         042 TR 2            ON        F43=513
    167 OPEP          ENABLE       NVER          016 BAT 2         NORM     D63=000         002 TR 1            ON        F42=417*
    147 OPEP          DISABLE      NVER          056 CHG BUS PAR   NORM     D11=000         127 EXP ORD         SAFE      F40=103
    072 OP GYRO       ON/1 SEL      VER          105 95 F SW       NORM     D11=000         061 RCVD T M        TAPE PB   M66=216
                                                 006 UV 1(XMTR)    RESET       NVER
    027 OPEP SCAN     MODE         NVER          026 UV 1(XMTR)    OVRD        NVER           ** COMMUNICATIONS **
    007 OPEP GYRO     MODE         NVER          046 UV 2 (EXP)    RESET       NVER         020 WB              A ON       C5=143
    267 ARRAY SLEW    NORM         QVER          066 UV 2 (EXP)    OVRD        NVER         024 SP              ON         C9=045
    247 ARRAY SLEW    CCW(+Z)      QVER          120 BATT          EXECUTE     NVER         001 WB              OVERRIDE     NVER
    207 ARRAY SLEW    CW(-Z)       QVER                                                     054 SP MOD          NORM         NVER
    015 PR GYRO       OFF          QVER                                                     074 SP MOD          SWITCHED     NVER
    035 PR GYRO       ON           QVER                                                     143 SP TO           OMNI 1       NVER
    141 ACS MODE      ENABLE       NVER            ** HEATER **                             163 SP TO           OMNI 2       NVER
    161 ACS MODE      EXECUTE      NVER          362 OPEP/ASEP     HTR ON   X22=052
    121 ACS MODE      NORM         NVER          106 WRAP-UP HTR   OFF         NVER
    034 GAS DELAY     ENABLE       NVER          126 WRAP-UP HTR   ON          NVER
    F174PITCH/+ROLL   PRE-SEL      NVER          347 EP HTRS       ON          NVER
    E334 YAW/-ROLL    PRE-SEL      NVER          367 EP HTRS       OFF         NVER
    D314 -PITCH(3+6)SEL            NVER                                                       ** CMD **
    E314 +PITCH(1+4)SEL            NVER                                                     134 CMD NET         2 SEL     F49=153
    H334 +ROLL (2)    SEL          NVER            ** TRACKING **                               CMD GROUP                 F50=205
    H173 -ROLL (5)    SEL          NVER          370 R+RR  2          OFF    C19=000        357 CMD ADD 060 ENABLE         NVER
    F173 -YAW (3+4)   SEL          NVER          055 R+RR  1          ON     C17=147        073 CMD ADD 060 DISABLE        NVER
    B173 +YAW (1+6)   SEL          NVER
    004 GAS PULSE     EXECUTE      NVER
    366 SAI           OFF       A46=000

                                                 **  **  **  **  **  *   NOTES  *  **  **  **  **  **  **
                                                 1)  NVER = CMD CAN NEVER BE VERIFIED
                                                 2)  QVER = CMD CANNOT BE VERIFIED WITH PRESENT T/M VALUES
                                                 3)  VER  = CMD IS VERIFIED WITH PRESENT T/M VALUES
                                                 4)  BLANK CMD NO. AND CONFIG LITERAL INDICATE T/M VALUE
                                                     IS NOT IN CALIBRATED RANGE
```

Figure A-7

SPACECRAFT COMMANDED STATUS (OGO 6 example)

```
OGO-F EXPERIMENT STATUS PROCESSOR          MC  DS EG-2     LOAD BUS 30.23  VOLTS   SYS F13 01/14/70 IN 027 1949  28          OGO-OCC
S/C CLCK 063 560 017    BIAS 105 664 050   LOW BPS S/C     LOAD BUS 12.19  AMPS    EXPER. PROCESSOR IN 027 2003  40     01/27R3416RT
DATA GMT 027  1656  04                     ** KBPS H/W     ACS MODE/SUN 3S/ ON     PROGRAM MODE A    P-DATA FREEZE           OFF-LINE

MC65/66/67   OC1 216 625      OTHER EG  RT  MC         F51 DSA SW SIG          EG 2 173       ***** DSA SWITCHED TO THIS EG - YES ****

A7  TRACK CHECK(HDS)A,B,C,D 370 F42 TR 1 STATUS      RECORD 417-D1  BAT 1      (AMPS) 2.682  055-C5  WB A FWD  (WATT) 4.236  143
A12 ARRAY SIN  (DEG)240-292 020-F43 TR 2 STATUS          PB 513 D2  BAT 2      (AMPS) 2.741  056-C6  WB A REV  (WATT) .0129  005
A13 ARRAY COS  (DEG) 243.9  072-F49 CMD NETWORK       NET 2 153 D4  ARRAY 1    (AMPS) 7.123  263-C7  WB B FWD  (WATT)   OFF  000
A14 OPEP SIN   (DEG)USE COS 031-F50 CMD GROUP         GRP D 205 D5  ARRAY 2    (AMPS) 9.471  356 C8  WB B REV  (WATT)   OFF  000
A15 OPEP COS   (DEG) 83.95  151-A16BARRAY DRIVE         OFF 371 D17 ARRAY 1C   (AMPS) .0655  006-C9  SP FWD PWR(WATT) .5614  045
A46 SUN ASPECT (DEG)        000 A31AROLL WHEEL DRIVE    OFF 371-D6  ARRAY 1C  (VOLTS) 17.83  176

TLM     FUNCTION            STATUS          OCTAL    CMD STATUS

        F01 SHARP OPEP 1
S15       PWR STATUS        PWR ON           251       (200)
S10       IFC STATUS        OFF              004     A110 STEPS
S57       PWR SUPPLY        2.36             166

        F02 NAGY OPEP 2
S42       CMD STATUS      SYS 1 ON           160       (217)
          IMP CMD - GRP A  000                       ALL RESET

        F03 HANSON OPEP 1
S11       ELECT RANGE       PWR ON           124       (201)
S85       MODE STATUS       FAST SCAN        253     A150 STEPS

        F04 REBER OPEP 2
S37       HV SUPPLY         PWR ON           266       (307)
S23       ANODE I                            214
S25       EMISSION I                         377
S94       CMD STATUS        ON               036       (307)
          FILAMENT          ON                         /330)
          ELECTRON GUN      1                           A153
          IMP STS - GRP A STEPPING                   ALL RESET

        F05 PICKETT OPEP 2
S55       20V MONITOR       PWR ON           345       (202)
S39       G1 VOLT LEVEL    -15V              032
S35       RF VOLT MON.                       366
S45       G15 VOLT MON.                      047
S**       VS MON. S19/49/81/113    000 262 271 262

        F06 HANSON OPEP 1
S90       2.7V PWR          PWR OFF          000       (231)
M59       APERATURE POT    -12V              000    211/A314 STP
          MODE

        F07 MCKEOWN OPEP 1
S13       TUBE TEMP         PWR ON           062       (212)
M42       SYNC                               406

        F08 KREPLIN SOEP 1 -X
M57       EXP STS/DATA      PWR ON           745       (213)
          IFC/DATA          DATA
          SCN GAIN          AUTO
          PROP GAIN         AUTO
S117      SUBC STATUS                        244

TLM     FUNCTION            STATUS          OCTAL    CMD STATUS

        F09 BEDO SOEP 2 +X
S31       HVPS 1            ON               216
S62       HVPS 2            OFF              005
          EXP PWR           PWR ON                     (214)
M49       SCAN MODE         LONG             401        B135
          DRIVE DIR         513-0
          DATA MODE         DS                          B133
          SMPL MODE         NORM                        B135
M50       COL POSITION      455              707
M49       ASPECT DATA                    776 355
/50       ARRAY X           374
          ARRAY Z           355

        F10 REGENER SOEP 1 -X
S70       PWR STATUS        PWR ON           130       (215)
S56       EXP STATUS     10 0 1 011 0 0      454
          BITS 1-2          SOLAR DATA
          BIT 4             SUN 5 DEG
          A RANGE             3

        F11 BLAMONT EP3
S27       PMT TEMP          PWR ON           254       (216)
M115      DIG STATUS                         167
S66       DIG STATUS                         736
          MOTOR 12V         ON
          FILTER CMDS       NORM                        B174
          MIRROR            STEP                        B174
          FILTER IN         6300A

        F12 CLARK -Z
S44       HVPS MONITOR      PWR OFF          000       (324)
M38       SCNR POS          .000             000
M48       INST STATUS                        000
          H CELL FILMNT     DISABLE
          SR F2 FILTER      IN
          CAL LAMP          OFF
S59       FIL PWR                            000

        F13 BARTH -Z
S88       +15V MONITOR      PWR OFF          000
S109      CMD STATUS        000 NORM.        000
          PWR STATUS        OFF                        (261)
          DOOR LATCH        LATCH                      (263)
          DOOR CONTROL      OPEN                       (262)
```

Figure A-8

SENSOR STATUS PRINTOUT (OGO 6 example)

7. PAYLOAD DATA ACQUISITION

7.1 Introduction

7.2.1 Real-Time Data

Real-time data is restricted by the brief duration of ground station visibility associated with the orbit. For one orbital period, the cumulative real-time data coverage can vary from zero to approximately 15 minutes. Passes shorter than five minutes usually will not be considered adequate for operational use. During the initial operations phase, real-time data will be scheduled. During the routine operations phase, about four passes per day will be scheduled for acquisition of real time video data.

Since the housekeeping tape recorders will normally be operated 100 percent of the time, three to four of the scheduled night time passes will be required for tape playback. During these passes, real-time housekeeping data will be acquired during tape playback operation only when using the unified S-band data system.

7.2.2 Data Storage

The on-board narrowband tape recorders are the primary mode of housekeeping data acquisition and will provide 100 percent orbital coverage. Approximately three minutes is required to play back one orbit of data. The playback periods will normally be preceded by a short period of real-time data to verify data acquisition.

The two video tape recorders will be used to play back image data when real-time data is not required. This will generally be in eclipse or when other conditions preclude camera use (clouds, etc.).

7.2.3 Payload Configuration

Not yet available.

7.2.4 Long-Term Data

Not yet available.

7.3 Quick Look Operations

Quick look operations will be conducted at ERSOCC during real-time data acquisition at Alaska, NTTF, Corpus Christi, or Rosman. However, due to the brief duration of real-time passes, it will be necessary to play back over the data link the ground station housekeeping tapes recorded during the pass for a detailed evaluation of payload operation. This data will normally be from the observatory tape recorders, since each data storage playback will provide from 1.5 to 6 hours of continuous data.

7.3.1 Initial Phase

The first two days of orbital life are considered the initial operational phase during which ERSOCC facilities will be utilized for an extensive evaluation of observatory status. The initial phase of payload operations may cover a two-week period after initial turn-on. Equipment and space limitations in ERSOCC preclude user access during this period. All payload quick look operations defined in Section 7.4.3 will be conducted by the payload operations coordinator. However, to supplement ERSOCC operations all real-time housekeeping data will also be transmitted simultaneously to the GSFC NDPF for exclusive use by the payload engineers. Communications between ERSOCC and the NDPF will be maintained continuously during all such passes.

It should be noted that access to ERSOCC is restricted at all times during the initial phase and not just during real-time passes, since extensive replaying of data tapes in ERSOCC will be required by the various subsystem engineers. This restriction may be relaxed only if deemed feasible by the project operations director.

All quick look operational requirements, both during the initial and routine phases, will be specified in detailed pass assignments prior to their implementation. Payload design representatives must direct their requirements to the payload operations coordinator as far in advance as possible (see Section 6.2.6). The payload operations coordinator will maintain a data file in the operations office of all such requests for mode changes or emergency commands based on data monitored by payload engineers or users.

7.3.2 Routine Phase

The routine operational phase will commence two days after launch, assuming the observatory is operating normally. Quick look operations will be conducted at least twice per day. The operations staff will schedule payload commands to be transmitted during the quick look operation based on requirements submitted by the payload engineers. The operations staff will verify the proper status of all payload commandable functions.

7.4 Payload Operational Checks

There are four basic types of operational checks to be performed either during quick look real-time contacts or by playing back data tapes. These checks are:

- Aliveness check
- Commanded status
- Daily quick look data
- Image quality

Special tests may also be conducted periodically. This type of test must be coordinated with all applicable users and approved by the project scientist.

7.4.1 Aliveness Check

Payload aliveness checks will be performed during all real-time quick look operations. The check will usually be performed by a combination of the status computer printout which indicates the on/off status of the payload, and manually with data word selectors, strip charts, and cathode ray tube displays.

In many cases, the words chosen will also provide an indication of general payload operation, such as internal commutation, wheel stepping, commanded status, etc., as well as aliveness. Where possible, main frame words are preferred over subcommutator words during main frame operation to minimize time required between samples - response to commands, etc.

7.4.2 Payload Status

This type of quick look check is intended to indicate the configuration status of the payload. It should be noted, however, that thermal data are not included in the status printout. All single function payload thermal words have been incorporated into the observatory thermal printout. Both the payload status and thermal printouts will be available during all quick look operations. If the computer is down, the status words and critical thermal points will be monitored on strip charts.

Whenever possible, subcommutator words have been used in establishing the status criteria.

7.4.3 Quick Look Data

The daily quick look data checks are generally more comprehensive than the aliveness or status checks and include detailed data processing as defined by the payload designer. The strip charts and/or computer processors resulting from this operation will be mailed immediately to the individual payload engineer. Due to the time required, these checks will normally not be performed in real time but from data tapes played back at ERSOCC after a real-time pass or from tape playback operation. The check will be performed approximately three times per day.

8. ORBIT PREDICTIONS

8.1 Orbital Computations

The MSFN orbit group will be responsible for orbital computations and for the generation of station satellite acquisition predictions. The Information Processing Division will use these computations to generate the user orbit position data. Magnetic tapes and printout books will be required.

8.1.1 Nominal Prelaunch Prediction Requirements

Prelaunch computer predictions of the ERTS observatory's position will be supplied by the GSFC orbit group. The prelaunch predictions will be computed for the first 14 days of the mission based on a nominal orbit and issued at least three months prior to the launch date. Times indicated in the predictions will be based on a 0000Z liftoff time.

8.1.2 Nominal Postlaunch Requirements

Immediately after launch, predictions will be generated 24 hours in advance until the orbit has been well defined. At this time, the predictions will be generated for two-week periods, three weeks in advance of the period for which it is valid.

8.2 Prediction Requirements and Formats

Orbit predictions will be produced in several formats, depending upon usage. The predictions for STADAN will be published and distributed on a routine basis in accordance with the tracking and data systems directorate requirements. Predictions for users and the ERTS project operations office require unique formats as described below.

8.2.1 Advanced Operational Planning Prediction (Orbit Plot)

The orbit information necessary for routine operational planning will be generated for two-week periods and distributed two weeks in advance of the period for which it is valid. This prediction is referred to as the orbit plot and will provide a visual display of the duration and relative chronological position of individual station visibilities.

The elements plotted in this prediction are as follows:

- Revolution number
- Universal time (hr-min-sec) at start of revolution
- Longitude at start of revolution
- Height above the earth at start of revolution
- Stations with visibility
- Universal time (hr-min-sec) at start of pass
- Pass duration
- Station antenna maximum elevation tracking angle
- Observatory eclipse information, "sunlight or darkness"
- Time of apogee, perigee, descending node, northernmost and southernmost point of orbit

8.2.2 STADAN Predictions (Predicted Satellite Map)

STADAN requirements include an orbit prediction printout available for last minute scheduling details. This prediction contains the geocentric position of the subsatellite point, height above the earth's surface and spacecraft eclipse times. It also contains antenna pointing information for each of the ground stations and covers a period of one week. It will be distributed approximately one week in advance of the period for which it is valid.

8.2.3 ERSOCC Orbital Requirements (ORB 3A - Edit X)

ERSOCC must have a real-time comparison between actual and predicted spacecraft velocity, orientation and position for the first 24 hours after launch. Thereafter, this information will be available about once a week. The elements of the format shown in Figure A-9 are as follows:

a) Universal Time
   1) Date (month-day)
   2) Time (hour-minute to tenths)
   3) Printout interval is one minute

b) Geodetic coordinates of observatory position
   1) Longitude (deg)
   2) Latitude (deg)
   3) Height above earth surface (km)

c) True anomaly (deg)

d) Phi P: predicted array shaft angle

e) Nu: Angle between satellite-earth vector and the satellite-moon vector (in degrees to tenths)

f) Upsilon: angle between satellite-earth vector and the satellite-sun vector (in degrees to tenths)

g) Tau: angle between the satellite +X coordinate and the projection of the satellite-moon line on the satellite X-Y plane (in degrees to tenths)

h) Zeta: angle between the spacecraft's Z axis and the earth's horizon

49511 1970 028 P.050

DATE MMDD	TIME HHMM	GEODETIC COORDINATES LONG.	LAT.	HEIGHT	TRUE ANOMALY	PHI F	PSI E	GAM-MA	THE-TA E	NU*	UPSI-LON	TAU*	ZETA	
0128	1334.0	163.790	04.756	000432.9	028.866	104.0	-082.0	01.3	01.3	120.5	014.0	028.6	069.5	
0128	1335.0	164.088	00.675	000443.6	032.391	107.9	-083.7	01.4	01.4	121.8	017.9	024.6	069.2	
0128	1336.0	164.383	-03.033	000455.7	036.223	111.8	-084.8	01.5	01.5	123.0	021.8	021.1	069.0	
0128	1337.0	164.680	-06.927	000469.1	040.067	115.7	-085.5	01.7	01.7	124.0	025.7	017.7	068.7	
0128	1338.0	164.993	-10.803	000483.8	043.927	119.6	-086.1	01.8	01.8	124.8	029.6	014.5	068.4	
0128	1339.0	165.299	-14.660	000499.7	047.804	123.5	-086.5	01.9	01.9	125.4	033.5	011.3	068.1	
0128	1340.0	165.622	-18.456	000516.7	051.700	127.3	-086.8	02.1	02.1	125.8	037.3	008.2	067.7	
0128	1341.0	165.958	-22.309	000534.7	055.614	131.1	-087.1	02.2	02.2	126.0	041.1	005.1	067.4	
0128	1342.0	166.375	-26.099	000553.5	059.543	135.0	-087.3	02.3	02.3	126.1	045.0	002.0	067.0	
0128	1343.0	166.800	-29.862	000573.2	063.485	138.8	-087.4	02.3	02.3	125.9	048.8	-001.0	066.7	
0128	1344.0	167.274	-33.599	000593.6	067.433	142.5	-087.6	02.4	02.4	125.6	052.5	-003.9	066.3	
0128	1345.0	167.808	-37.308	000614.8	071.382	146.3	-087.7	02.5	02.5	125.1	056.3	-006.7	065.9	
0128	1346.0	168.419	-40.986	000636.0	075.325	150.0	-087.8	02.6	02.6	124.4	060.0	-009.4	065.6	
0128	1347.0	169.122	-44.632	000657.8	079.253	153.7	-087.9	02.6	02.6	123.6	063.7	-012.0	065.2	
0128	1348.0	169.948	-48.247	000679.9	083.161	157.4	-087.9	02.6	02.6	122.6	067.4	-014.5	064.9	*
0128	1349.0	170.928	-51.825	000702.1	087.039	161.1	-088.0	02.7	02.7	121.4	071.1	-016.8	064.5	*
0128	1350.0	172.110	-55.364	000724.4	090.881	164.7	-089.0	02.7	02.7	120.2	074.7	-018.9	064.1	*
0128	1351.0	173.560	-58.859	000746.6	094.681	168.3	-088.0	02.7	02.7	118.8	078.3	-020.9	063.8	*
0128	1352.0	175.376	-62.305	000768.7	098.434	171.9	-088.1	02.7	02.7	117.3	081.9	-022.8	063.5	*
0128	1353.0	177.705	-65.690	000790.5	102.137	175.5	-088.1	02.7	02.7	115.8	085.5	-024.4	063.1	*
0128	1354.0	-179.221	-68.997	000812.0	105.786	179.1	-088.1	02.6	02.6	114.2	089.1	-026.0	062.8	*
0128	1355.0	-175.020	-72.198	000833.1	109.381	182.6	-088.1	02.6	02.6	112.4	092.6	-027.4	062.5	*
0128	1356.0	-169.040	-75.236	000853.7	112.922	186.1	-088.1	02.6	02.6	110.7	096.1	-028.6	062.2	*
0128	1357.0	-160.149	-78.015	000873.6	116.410	189.6	-088.1	02.5	02.5	108.9	099.6	-029.7	061.9	*
0128	1358.0	-146.842	-80.322	000892.9	119.848	193.1	-088.0	02.4	02.4	107.0	103.1	-030.7	061.6	*
0128	1359.0	-126.855	-81.778	000911.5	123.238	196.6	-088.0	02.4	02.4	105.1	106.6	-031.6	061.3	*
0128	1400.0	-102.456	-81.932	000929.3	126.584	200.0	-088.0	02.3	02.3	103.2	110.0	-032.3	061.1	*
0128	1401.0	-081.318	-80.739	000946.2	129.891	203.5	-087.9	02.2	02.2	101.2	113.5	-032.9	060.8	*
0128	1402.0	-066.593	-78.628	000962.2	133.164	206.9	-087.9	02.1	02.1	099.2	116.9	-033.4	060.6	*
0128	1403.0	-056.973	-76.018	000977.2	136.407	210.3	-087.8	02.0	02.0	097.2	120.3	-033.8	060.4	*
0128	1404.0	-050.554	-73.147	000991.2	139.626	213.6	-087.7	01.9	01.9	095.2	123.6	-034.0	060.2	*
0128	1405.0	-046.085	-70.133	001004.2	142.826	217.0	-087.6	01.7	01.7	093.2	127.0	-034.2	060.0	*
0128	1406.0	-042.841	-67.037	001016.1	146.013	220.4	-087.5	01.6	01.6	091.2	130.4	-034.2	059.9	*
0128	1407.0	-040.401	-63.890	001026.9	149.191	223.7	-087.4	01.5	01.5	089.2	133.7	-034.1	059.7	*
0128	1408.0	-038.512	-60.711	001036.6	152.366	227.1	-087.2	01.3	01.3	087.2	137.1	-033.9	059.6	*
0128	1409.0	-037.014	-57.511	001045.1	155.542	230.4	-087.0	01.2	01.2	085.3	140.4	-033.6	059.4	*
0128	1410.0	-035.801	-54.297	001052.4	158.723	233.7	-086.8	01.0	01.0	083.3	143.7	-033.2	059.3	*
0128	1411.0	-034.802	-51.072	001058.5	161.915	237.0	-086.5	00.9	00.9	081.3	147.0	-032.6	059.2	*
0128	1412.0	-033.969	-47.839	001063.5	165.119	240.3	-086.2	00.7	00.7	079.4	150.3	-031.8	059.1	*
0128	1413.0	-033.262	-44.599	001067.2	168.340	243.6	-085.8	00.6	00.6	077.5	153.6	-030.9	059.1	*
0128	1414.0	-032.658	-41.354	001069.6	171.580	246.9	-085.2	00.4	00.4	075.6	156.9	-029.7	059.0	*
0128	1415.0	-032.135	-38.104	001071.1	174.839	250.2	-084.4	00.3	00.3	073.8	160.2	-028.3	059.0	*
0128	1416.0	-031.679	-34.848	001071.3	178.121	253.5	-083.4	00.1	00.1	072.0	163.5	-026.4	059.0	*
0128	1417.0	-031.275	-31.587	001070.2	181.427	256.8	-081.8	-00.1	00.1	070.2	166.8	-023.9	059.0	*
0128	1418.0	-030.916	-28.321	001068.1	184.748	260.0	-079.1	-00.2	00.2	068.5	170.0	-020.2	059.0	*
0128	1419.0	-030.593	-25.048	001064.7	188.093	263.2	-073.9	-00.4	00.4	066.9	173.2	-013.9	059.0	*

Figure A-9

ORB-3A (Edit X) predict format

i) Moon on horizon: printout an "H" next to the sunlight/ eclipse column (item j) when nu is within ±5 deg of zeta.

j) Observatory eclipse data

1) Asterisk: sunlight
2) No asterisk: eclipse

8.2.4 Time Reference

The time reference for all predictions will be Universal Time (UT).

8.3 Data Processing Orbit Data

Requirements for orbit position as a function of time (history) exist in the Imagery Processing Facility (TIDP). These are separately stated and do not affect operations concerned herein.

9. DATA ACQUISITION AND ANALYSIS

9.1 Introduction

This section is concerned with the data resulting from the launch and operation of ERTS. The major categories of data include initial operations data, routine operations data and tracking and orbit data.

9.2 Initial Operations Data

Prior to injection, data acquisition is primarily concerned with launch vehicle performance and tracking, although some observatory data will be acquired. Launch vehicle performance data is recorded at various WTR sites, with the Delta project office responsible for acquisition and analysis. Observatory telemetry will also be recorded at WTR and evaluated by the ERTS test facility.

During the initial operations period, ground stations will be scheduled to acquire the maximum amount of real-time data possible. Each remote station will have data word selectors (or its equivalent) and strip chart recorders available for monitoring telemetry word assignments which will be reported to ERSOCC. Word assignments for these real-time telemetry items are detailed in Appendix D.

To evaluate the health of the observatory, ERSOCC can process telemetry data in real time from all receiving sites. The data can be processed directly by computer resulting in several different printouts and can simultaneously be displayed on 48 channels of data word selectors and stripcharts. Figure A-10 depicts the ERSOCC telemetry data flow. The specific ERSOCC computer programs have the capabilities outlined in Section 9.3 of this section. Examples of printout formats resulting from these programs are given in Appendix C.

9.3 Routine Operations Data

Routine data acquisition is dependent on user requirements (see Section 7). In general, 80 to 90 percent orbital coverage is provided by the on-board housekeeping tape recorders and 30 minutes coverage per video tape recorder. A limited amount of real-time housekeeping data at 32 kbits is planned for quick look purposes. The stations defined in Section 3 will record all data on 14-inch reels of magnetic tape.

Routine operations housekeeping data during real time or from tape playback, as well as initial operations data, will be processed by the ERSOCC computer with software function RPROSTM (as outlined in the following paragraphs), when the receiving site is Rosman, Corpus Christi, Alaska, or NTTF.

9.3.1 Monitor Program

This program is the master control program for all on-line computer operations in ERSOCC and performs all necessary housekeeping functions required for processing PCM data. It accepts incoming telemetry, regulates assembly of the data, establishes main-commutator and subcommutator images for various spacecraft and experiment library processors, drives the CRT displays, and controls the operation of the printer for outputting data. Sample printouts are contained in Appendix C.

9.3.2 Continuous Limits Check

This program checks limits on approximately 150 preselected data words and determined whether they are in or out of limits. All words checked are tested for frame sync and correct MC-65 before they are used.

If a word is out of limits twice in succession, a printout is made of the octal number of the word, the telemetry identification, and an L or H

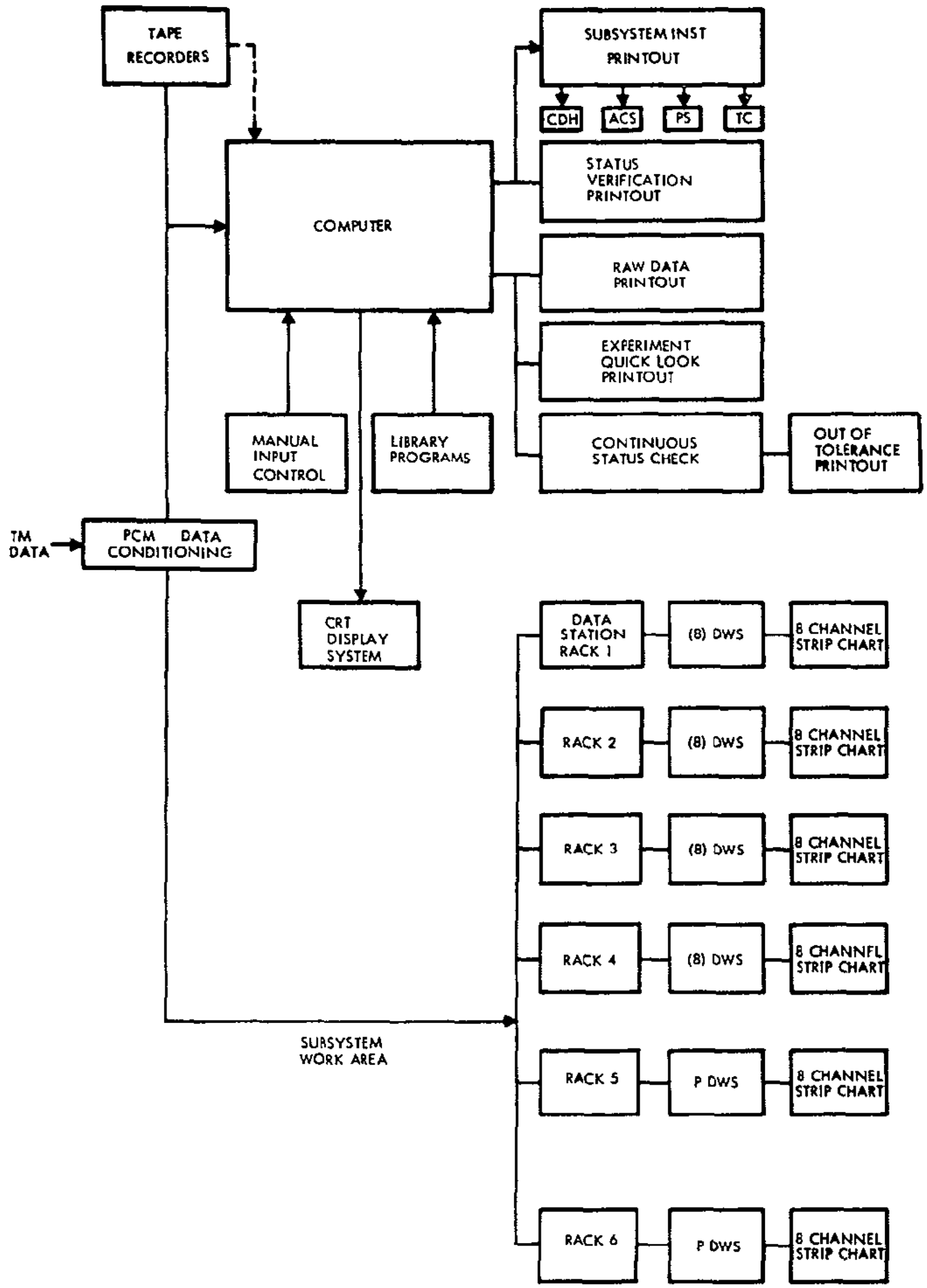


Figure A-10
ERTS DATA FLOW in the OCC

preceding the octal value of the word to indicate which limit was exceeded. In the monitor limits check, a second printout occurs if the word remains outside limits. No further printout will occur unless either the word momentarily returns within limits, which resets the printout, or two minutes elapse which also causes a printout reset. If a point is still outside limits at the end of the two minutes, another double printout will occur. Only subcommutator 2 data points are tested during accelerated subcommutator operation.

Table A-6 lists the upper and lower limits of the ERTS items presently considered. Figure A-11 is an example of a suitable format.

9.3.3 Raw Data Printout

This library processor provides comprehensive examination of a maximum of 16 different telemetry items. The desired items must be requested by typewriter. The printout lists the selected words in engineering units under labelled headings, with GMT and spacecraft clock printed out once on the form. The first column lists the value of MC 35 and the second column lists the seven most significant bits of MC 65 in octal. In the remainder of the printout maincommutator and/or subcommutator words can be requested. The sample rate of the printout is determined by the data rate of the first telemetry word selected for display. Figure A-12 shows this format.

9.3.4 Instrumentation Printouts

These are all library programs and are necessary for bookkeeping and data analysis. There are four individual processors: attitude control subsystem, power supply, communications and data handling and thermal. Each processor uses the subcommutator images assembled by the monitor program and converts the raw telemetry data into engineering units. If one processor is working and any others are stacked, both processors use the data from the same image, which remains frozen until all processing is completed. This feature provides correlation of data between subsystems. For examples see figures in Appendix B.

Table A-6. ERTS Continuous Limit Checks

		Engineering Unit High	Engineering Unit Low
Attitude Control			
A-2	Gas, low pressure (psia)	54 9	44.9
A-3	Gas bottle temperature (°C)	35 0	5.0
A-4	Pitch error signal (deg)	2.02	-1.97
A-5	Roll error signal (deg)	2.03	-2.03
A-6 A	Sun alarm signal head A	No sun	
B	Sun alarm signal head B	No sun	
C	Sun alarm signal head C	No sun	
D	Sun alarm signal head D	No sun	
A-7 A	Track check signal head A	No track check	
B	Track check signal head B	No track check	
C	Track check signal head C	No track check	
D	Track check signal head D	No track check	
A-9	Horizon scanner head A temperature (°C)	35.0	0.25
A-10	Yaw error signal (deg)	2.0	-2 0
A-11	Array error signal (deg)	3	-3
A-21 A	Gas control valve 1	Off	
B	Gas control valve 2	Off	
C	Gas control valve 5	Off	
A-22 A	Gas control valve 3	Off	
B	Gas control valve 4	Off	
C	Gas control valve 6	Off	
A-23	ACS mode, sun on/sun off	Alarm if not Mode 4 Alarm if sun off	
A-25	Sun sensor 1 temperature (°C)	65	-18
A-26	Sun sensor 2 temperature (°C)	65	-18
A-27	Yaw gyro status	Alarm if off	
A-28	Yaw gyro motor tachometer (rpm)	Synchronized	
A-30	Yaw gyro blanket temperature (°C)	71	50
A-32	ACS inverter temperature (°C)	90	19
A-33	Yaw reaction wheel temperature (°C)	60	19
A-34	Pitch reaction wheel temperature (°C)	60	19
A-35	Pitch rate gyro tachometer (rpm)	Off	
A-40	Head A angle	63	58
A-41	Head B angle	63	58
A-42	Head C angle	63	58
A-43	Head D angle	63	58
A-44 B	CSA status bus armed	Alarm if armed	
C	pitch jets enabled	Alarm if enabled	
A-47 A	Roll jets enable/disable	Alarm if enabled	
B	Yaw jets enable/disable	Alarm if enabled	
Structure			
B-3 A	Array 1, hinge 1	Alarm if not locked	
B	Array 1, hinge 2	Alarm if not locked	
C	Array 1, hinge 3	Alarm if not locked	
B-4 A	Delta ERTS separation	Not separated	
B	Array 2, hinge 1	Alarm if not locked	
C	Array 2, hinge 2	Alarm if not locked	
D	Array 2, hinge 3	Alarm if not locked	

Table A-6. ERTS Continuous Limit Checks (Continued)

			Engineering Unit	
			High	Low
B-7	A	Predeployment array 1 (-X)	Alarm if latched	
B-8	B	Predeployment array 2 (+X)	Alarm if latched	
B-11		Deploy bottle pressure 1 (psia)		2000
B-12		Deploy bottle pressure 2 (psia)		2000
Communications				
C-50		TWTA 1 anode voltage	Limits not yet established	
C-54		TWTA 2 anode voltage		
C-57		VHF transmitter 1, forward power		
C-58		VHF transmitter 1, reverse power		
C-61		VHF receiver 1, AGC-1		
C-63		VHF receiver 2, AGC-1		
C-65		USB receiver "A", signal present		
C-67		USB receiver "B", signal present		
C-69		USB transmitter "A", power monitor		
C-70		USB transmitter "A", temperature monitor		
C-72		USB transmitter "B", temperature monitor		
Power				
D-1		Battery 1 current (amps)	15 00	0 00
D-2		Battery 2 current (amps)	15.00	0 00
D-3	A	No. 1 solar array normal/regulator 2	Array = 1	
	B	No. 1 charge bus normal/parallel 2	Normal	
	C	No. 2 solar array normal/regulator 1	Array = 2	
	D	No. 2 charge bus normal/parallel 1	Normal	
D-8		Battery 1 voltage	33 0 33.0	24.5 (sun off) 30.0 (sun on)
D-9		Battery 2 voltage	33 0 33.0	24.5 (sun off) 30.0 (sun on)
D-10		Load bus voltage	32.5	25.0
D-11	D	No 1 and No. 2 95°F switch normal/override	Normal	
	E	Charge bus parallel command	Normal	
	F	Discharge path normal/open	Normal	
D-13		Array 1 (-X) Sec A thermal fin temperature	90.0	-145.0
D-14		Array 2 (+X) Sec A thermal fin temperature	90.0	-145 0
D-15		Sync signal amplifier (400 Hz)	Enable	
D-16		Sync signal amplifier (2461 Hz, 0 and 90 deg)	Enable	
D-20		Converter 2 (+16 volts)	16 3	15.7
D-21		Converter 2 (+9 volts)	9.30	8.7
D-22		Converter 2 (+5 volts)	5 20	4.80
D-23		Converter 2 (-6 volts)	6.2	5.8
D-28		Converter 5 (+16 volts)	16.4	15.6
D-29		Converter 5 (+9 volts)	9.3	8 7
D-30		Converter 5 (-6 volts)	-6.2	-5 8
D-31		Converter 5 (-16 volts)	-16.4	-15.6
D-32		Converter 6 (+16 volts)	16.4	15.6
D-33		Converter 6 (+9 volts)	-9.3	-8.7

Table A-6. ERTS Continuous Limit Checks (Continued)

		Engineering Unit	
		High	Low
D-34	Converter 6 (-6 volts)	-6.2	-5.8
D-35	Converter 6 (-16 volts	-16.4	-15 6
D-36	Converter 7 (+16 volts)	16.5	15.6
D-37	Converter 7 (+9 volts)	9.3	8.7
D-38	Converter 7 (-6 volts)	-6.2	-5.8
D-39	Converter 8 (+16 volts)	16.4	15.6
D-40	Converter 8 (+9 volts)	9.3	8.7
D-41	Converter 8 (-6 volts)	-6 2	-5.8
D-42	Converter 9 (+20 volts)	20.6	19.4
D-43	Converter 9 (+10 volts)	10.3	9.7
D-44	Converter 9 (-20 volts)	-20.6	-19.4
D-45	Converter 9 (+28 vac)	29.3	27 2
D-46	ACS inverter (400 Hz)(volts)	118	110
D-50	Battery 2 (-X panel)(°C)	30.0	10
D-51	Battery 1 (-X panel)(°C)	30.0	10
D-59	Load bus current	22.0	6
D-61 A	Regulator 1 and 2 charge rate trickle/1A		1A
B	No. 1 regulator normal/full array	Normal	
C	No. 2 regulator normal/full array	Normal	
D-62 A	No. 1 battery normal/recondition	Condition	
B	No. 2 battery normal/recondition	Condition	
C	No. 1 and 2 regulator charge modes constant volt/trickle at V_B limit	Constant voltage	
D-63 A	No. 1 battery normal/disconnect	Alarm if disconnect	
B	No. 2 battery normal/disconnect	Alarm if disconnect	
D-75	Converter 2B (+16 volts)	16.4	15.6
D-76	Converter 2B (+9 volts)	9.3	8.7
D-77	Converter 2B (+5 volts)	5.2	4.8
D-78	Converter 2B (-6 volts)	-6.2	-5.8
D-79	RBV battery current (amp)	--	0.1
D-80	RBV battery voltage	36	24
D-81	Payload converter input current (amp)	11	--
D-82	Payload converter output voltage	-24.6	-23.4
D-84	Payload converter temperature (°C)	40	15
Temperature			
E-1	Array 1 (in-board) -X temperature (°C)	90.0	-148
E-4	Array 2 (out-board) +X temperature (°C)	90.0	-148
E-5	Panel mid-third (+X) temperature (°C)	30.4	5.0
E-6	Panel aft third (+X) temperature (°C)	30.4	5.0
E-7	Panel mid-third (-X) temperature (°C)	30.4	5.0
E-8	Panel aft third (-X) temperature (°C)	30.4	5.0
E-21	Panel top third (-Z) temperature (°C)	35.0	5.0
E-22	Panel mid-third (+z) temperature (°C)	35.0	5.0
E-23	Panel top third (+X) temperature (°C)	35.0	5.0
E-24	Panel aft third (-X) temperature (°C)	35.0	5.0
E-30	Panel (-Y) middle temperature (°C)	30.4	5.0

Table A-6. ERTS Continuous Limit Checks (Continued)

		Engineering Unit High	Engineering Unit Low
E-50	+X panel temperature (°C)	35.0	5 0
E-51	+X panel temperature (°C)	35 0	5 0
E-52	-X panel temperature (°C)	35.0	5.0
E-53	-X panel temperature (°C)	35.0	5.0
E-54	Payload temperature sensor 1 (°C)	30 0	10
E-55	Payload temperature sensor 2 (°C)	30.0	10
E-56	Payload temperature sensor 3 (°C)	30 0	10
E-57	Payload temperature sensor 4 (°C)	30.0	10
E-58	+Y panel temperature (°C)	35.0	5.0
E-59	+Z panel temperature (°C)	35.0	5.0
E-60	+Z panel temperature (°C)	35 0	5.0
E-61	-Z panel temperature (°C)	35.0	5.0
E-62	-Z panel temperature (°C)	35.0	5.0
Data Handling			
F-1	Tape recorder 1 (+9 5 volt)	9.7	9.3
F-2	Tape recorder 1 (-9.5 volt)	-9.7	-9 3
F-5	Tape recorder 1 enclosure pressure (psia)	17 6	10 1
F-8	Tape recorder 1 base temperature (°C)	35.0	5 00
F-9	Tape recorder 2 (+9.5 volt)	9 7	9 3
F-10	Tape recorder 2 (-9.5 volt)	-9 7	-9 3
F-13	Tape recorder 2 enclosure pressure (psia)	17 6	10 1
F-14	DDHA 1 oscillator temperature (°C)	55 5	10 0
F-15	DDHA 2 oscillator temperature (°C)	55.5	10 0
F-16	Tape recorder 2 base temperature (°C)	33.0	5 0
F-17	No. 1 LFTA board 3 temperature (°C)	50 0	15 0
F-20	DDHA 1 board 3 temperature (°C)	55.0	0
F-22	DDHA 2 board 3 temperature (°C)	55 0	0
F-24/32	ADHA in service temperature (°C) (F-24 = EG-1, F-32 = EG2)	35 0	5 00
F-25/33	Calibration 1 (F-25 = EG-1, F-33 = EG-2)	0.020	0 000
F-26/34	Calibration 2 (F-26 = EG-1, F-34 = EG-2)	0.520	0 500
F-27/35	Calibration 3 (F-27 = EG-1, F-35 = EG-2)	1.720	1.700
F-38/36	Calibration 4 (F-28 = EG-1, F-36 = EG-2)	2 660	2 640
F-29/37	Calibration 5 (F-29 = EG-1, F-37 = EG-2)	3 200	3 180
F-30/38	Calibration 6 (F-30 = EG-1, F-38 = EG-2)	4.140	4.120
F-31/39	Calibration 7 (F-31 = EG-1, F-39 = EG-2)	5.080	5.060
F-40 A	Arm bus on	Alarm if bus on	
B	Payload ordnance armed	Alarm if armed	
C	Array deploy	Alarm if undeployed	
C	Sequence relay switched	Alarm if unswitched	

Table A-6. ERTS Continuous Limit Checks (Continued)

		Engineering Unit	
		High	Low
F-41 A	Receiver 1 signal present	Alarm if off	
B	Receiver 2 signal present	Alarm if off	
C	Deployment safe	Alarm if not safe	
F-70	Stored command programmer 1 (+16 volts)	16.4	15.6
F-71	Stored command programmer 1 (+9 volts)	9.3	8.7
F-72	Stored command programmer 1 (+5 volts)	5.2	4.8
F-73	Stored command programmer 1 (-5 volts)	-5.2	-4.8
F-74	Stored command programmer 2 (+16 volts)	16.4	15.6
F-75	Stored command programmer 2 (+9 volts)	9.3	8.7
F-76	Stored command programmer 2 (+5 volts)	5.2	4.8
F-77	Stored command programmer 2 (-5 volts)	-5.2	-4.8
F-79	No. 2 LFTA board 3 temperature (^{o}C)	50.2	15.1
Return Beam Vidicon			
G-1	G-1 voltage	These limits not established	
G-2	Target voltage		
G-3	Vidicon cathode current		
G-5	Focus current		
G-6	Combined alignment currents		
G-9	Deflection power supply		
G-10	Low voltage power supply		
G-11	Minus 28-volt shutter current		
G-12	Temperature, faceplate		
G-13	Temperature, yoke/focus coil		
G-14	Temperature, electronics		
G-15	Temperature, low voltage power supply		
G-17	Temperature, camera controller		
Multispectral Scanner			
H-14	Low voltage supply output		
H-15	Low voltage supply output		
H-16	Low voltage supply output		
H-18	Low voltage supply output		
H-22	Temperature		
H-23	Temperature		
H-24	Temperature		
H-25	Temperature		
H-26	Rotating shutter housing temperature		
H-27	Calibration lamp base temperature		
H-28	Temperature		
H-29	Temperature		
H-30	Temperature		
H-31	Temperature	These limits not established	

Table A-6. ERTS Continuous Limit Checks (Continued)

		Engineering Unit High	Engineering Unit Low
Video Tape Recorder			
I-2	VTR 1 pressure	These limits not established	
I-3	VTR 1 temperature, electronics unit		
I-4	VTR 1 temperature, transport unit		
I-8	VTR 1 capstan motor speed		
I-9	VTR 1 dc motor current, headwheel		
I-10	VTR 1 dc motor current, capstan		
I-15	VTR 2 tape footage		
I-16	VTR 2 pressure		
I-17	VTR 2 temperature, electronics unit		
I-18	VTR 2 temperature, transport unit		
I-19	VTR 2 average record current		
I-20	VTR 2 average playback voltage		
I-22	VTR 2 capstan motor speed		
I-23	VTR 2 dc motor current, headwheel		
I-24	VTR 2 dc motor current, capstan	These limits not established	

9.3.5 Payload Processor Programs

Two payload processors will be used to make a quick look analysis of specific sensor health data.

9.4 Tracking and Orbit Data

The MSFN tracking and data group will be responsible for tracking and orbit data acquisition. Primary tracking will be accomplished by stations using the unified S-band range and range rate system.

9.5 Special Data Requests (Launch)

All special data requests, including tape duplications and strip charts, should be submitted to ERSOCC within one week after launch. The requests will be satisfied as soon as possible thereafter. Requests made after one week will be at the bottom of the priority list. A library of all data will be maintained at GSFC and will be available to any interested parties.

```
01/27R3416RT DATA FRZ MØDE  A            ØGØ-6/F     LIMIT CHECK INSTRU PRINT-12                                   ØGØ-ØCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23
                                          A23 ACS MØDE/SUN      3S/ ØN  021
             MC       DS         RCVD     D10 LØAD BUS (VØLTS) 30.23   327             D59 LØAD BUS  (AMPS) 12.19    313 *
             MC       RT EG 1        64 KB D8  BAT 1    (VØLTS) 31.34   336             D9  BAT 2    (VØLTS) 31.19    333
             S/C CLØCK   063 560 017       D1  BAT 1     (AMPS) 2.682   055 *           D2  BAT 2     (AMPS) 2.741    056 *
             CLØCK BIAS  105 664 050       D64 BAT 1 CUR DIRECT  CHRG   112             D65 BAT 2 CUR DIRECT  CHRG    112
             S/C GMT     70 027 1656  04   D4  ARRAY 1   (AMPS) 7.123   263 *           D5  ARRAY 2   (AMPS) 9.471    356

TELEMETRY PØINT         TELEMETRY VALUE    LØW/                    ---HIGH LIMIT---                 ----LØW LIMIT---
PØINT   LITERAL        ENGR     ØCT  DEC   HIGH                    ENGR      ØCT DEC                ENGR      ØCT DEC

D22 CØNV 2    (+5 V)   .0000   000* 000    LØW                     5.107   263  179                 4.907   254  172
D62ABAT 1 STATUS               127  087    HIGH                            017  015                         000  000
F2  TR 1  ,  (-9.5 V)          113  075    LØW                    -9.338   126  086                -9.824   114  076

             END ØF RUN.
```

Figure A-11

CONTINUOUS LIMITS PRINTOUT (OGO 6 example)

RAW DATA PROCESSOR
S/C CLCK 054 407 506   BIAS 701 232 276   MC RT 4.   LOAD BUS 30.235 VOLTS   SYS E14-12/12/68 IN 355 0740 62   0G0-0CC
DATA 341 354 1415 49   MED 3PS S/C   LOAD BUS 11.445 AMPS   EXPER. PROCESSOR IN 355 0746 00   12/19R0112RT
0S KBPS H/A   ACS MODE 3S SUN ON   PROGRAM MODE A   NO DATA FREEZE   OFF-LINE

**** TELEMETRY WORDS ARE SPECIFIED BY DECIMAL NUMBERS PRECEDED BY M FOR MAINCOM, X FOR SUBCOM 1, Y FOR SC2 OR Z FOR SC3. ****

M35	FRM	X020	X049	X060	M034	Y021	Y128	Y099	I098	M199	Z048	Z067	Z023	Z035	M067	M001	M002
	001						544	112									
712	001	122	047	072	607	334	544	112	001	335	256	342	230	241	200	062	370
732	001	122	050	072	607	332		112	001	335	256	360	227	241	200	062	370
	001						544										
752	001	122	044	072	607	331	544	112	001	335	256	337	226	271	200	462	370
772	001				607				001	336					200	062	370
	001		043	072		324	544	112			256	336	227	251			
012	001	122	050	072	714	331	544	112	335	336	256	341	324	241	200	062	370
032	001	173	060	072	610	333	544		001	336	254	342	224	241	200	062	370
052	001	122	150	072	610	334	544	112	*441	335	256	442	223	261	200	062	370
072	001	122	042	072	610	324	544	112	001	335	256	342	222	241	200	062	370
112	001	122	042	072	610	331	544	112	001	435	256	340	221	241	200	063	370
132	001	122	063	072	610	330	544	112	001	335	256	336	220	251	200	062	370
152	001	122	050	072	610	327	544	112	001	336	256	336	220	241	200	063	370
172	001	122	060	472	610	326	544	112	001	336	256	335	217	241	200	062	370
212	001	122	047	072	610	326	544	112	002	335	356	335	216	241	200	062	370
232	001	122	377	777	610	325	263	112	000	335	775	102	216	241	200	062	370
	001	122	043	072		327	544	112			C04	337	215	241			
272	001	122	045	072	610	331	544	112	003	335	004	340	215	241	200	062	370
312	001	122	050	072	610	332	544	112	003	335	004	333	214	241	200	062	370
332	001	122	040	072	610	330	544	112	003	436	004	337	214	241	200	062	370
352	001	122	046	072	610	326	544	112	003	335	004	335	213	241	200	062	370
372	001	122	042	072	610	325	544	112	003	335	004	333	212	241	200	062	370
412	001	451	130	072	610	342	544	112	003	335	004	333	257	241	200	062	370
432	001	122	046		610	323	544	112	003	335	004	331	212	241	200	067	370
452	001	122	047	072	610	321	544	112	003	335	004	330	211	241	200	062	370
472	001	122	044	072	610	320	544	112	003	935	004	367	211	241	200	062	370
512	001	122	047	072	610	320	545	112	003	336	004	327	210	241	200	062	370
532	001	122	055	072	610	320	544	112	003	335	004	326	210	241	200	062	370
552	001	122	050	072	610	320	544	112	003	335	004	326	210	241	200	062	370
572	001	122	057	072	610	321	544	112	003	335	004	330	207	241	200	062	370
612	001	122	045	072	610	322	544	112	003	335	004	331	207	241	200	062	370
632	001	122	041	072	610	321	544	112	003	335	004	331	207	241	200	062	370
652	001	122	065	072	610	322	544	112	*003	336	004	331	206	241	200	062	370
672	001	122	065	072	610	322	544	112	003	335	004	331	206	241	200	062	370
712	001	122	042	072	610	323	544	112	003	335	004	332	205	241	200	062	370
732	001	122	063	072	610	323	544	112	003	335	004	332	205	241	200	062	370
752	001	122	055	072	610	323	544	112	003	335	004	332	205	241	200	062	370
772	001	122	045	072	610	324	544	112	003	335	004	333	204	241	200	062	370
012	001	122	544	445	611	325	454		003	335	564	113	204	241	200	062	370
133	001	622			131	131	544		226	226			445	110	455	457	113
052	001	176	047	072	611	176	544	112	003	335	004	335		241	200	062	370
072	001	122	052	072	611	325	544	112	003	335	004	334	211	241	200	062	370
112	001	122	047	072	611	325	544	112	003	335	004	334	212	241	200	062	370
132	001	122	065	072	611	325	544	112	003	335	004	330	214	241	200	062	370
152	001	122	062	072	611	325	544	112	003	335	004	335	215	241	200	062	370
572	001	122	047	072	651	327	544	112	003	335	004	336	216	241	200	062	370
212	001	127	043	072	611	327	544	112	003	335	004	337	216	241	200	062	370
232	001	122	065	072	511	330	544	112	003	335	004	340	220	241	200	062	370
252	001	127	052	072	511	331	544	112	003	335	004	340	220	241	200	062	370
272	001	122	064	035	611	332	544	112	003	335	004	777	221	241	200	062	370

Figure A-12

RAW DATA PRINTOUT (OGO 5 example)

APPENDIX B

COMMAND AND TELEMETRY INSTRUMENTATION FORMATS

ERTS TELEMETRY LIST

Item	Name	Commutator Sampling Rate
Multispectral Point Scanner (Cont)		
H3A	Band 4 gain low/high	MC
H3B	Main inverter A on/off	
H3C	Main inverter B on/off	
H3D	Mirror pick-off on/off	
H4A	Band 1 high voltage A on/off	MC
H4B	Band 1 high voltage B on/off	
H4C	Band 2 high voltage A on/off	
H4D	Band 2 high voltage B on/off	
H5A	Band 3 high voltage A on/off	MC
H5B	Band 3 high voltage B on/off	
H5C	Scan mirror drive on/off	
H5D	Band 5 focus on/off	
H6	Band 5 preamplifier output voltage	MC
H7A	Calibration lamp No 1 on/off	MC
H7B	Calibration lamp No 2 on/off	
H7C	Rotating shutter drive on/off	
H7D	Spare	
H8	Silicon photodiode preamplifier output	MC
H9	Silicon photodiode preamplifier output	MC
H10	Silicon photodiode preamplifier output	MC
H11	Silicon photodiode preamplifier output	MC
H12	Silicon photodiode preamplifier output	MC
H13	Silicon photodiode preamplifier output	MC
H14	Low voltage supply output	MC
H15	Low voltage supply output	MC
H16	Low voltage supply output	MC
H17	Low voltage supply output	MC
H18	Low voltage supply output	MC
H19	To be defined	MC
H20	To be defined	MC
H21A	To be defined	MC
H21B	To be defined	
H21C	To be defined	
H22	Temperature	MC
H23	Temperature	MC
H24	Temperature	MC
H25	Temperature	MC
H26	Rotating shutter housing temperature	MC
H27	Calibration lamp base temperature	MC
H28	Temperature	MC
H29	Temperature	MC
H30	Temperature	MC
H31	Temperature	MC

Item	Name	Commutator Sampling Rate
Wideband Video Tape Recorders		
I1	VTR 1 tape footage	MC
I2	VTR 1 pressure	MC
I3	VTR 1 temperature, electronics unit	MC
I4	VTR 1 temperature, transport unit	MC
I5	VTR 1 average record current	MC
I6	VTR 1 average playback voltage	MC
I7	VTR 1 servo voltage	MC
I8	VTR 1 capstan motor speed	MC
I9	VTR 1 DC motor current, headwheel	MC
I10	VTR 1 DC motor current, capstan	MC
I11A	VTR 1 standby power on/off	
I11B	VTR 1 record on/off	MC
I11C	VTR 1 playback on/off	
I11D	VTR 1 rewind on/off	
I12A	VTR 1 fast forward on/off	
I12B	VTR 1 primary end of tape (EOT)	MC
I12C	VTR 1 secondary end of tape	
I12D	VTR 1 primary beginning of tape (BOT)	
I13A	VTR 1 secondary beginning of tape	
I13B	VTR 1 recorder current adjust levels (8)	MC
I13C	VTR 1 recorder current adjust levels (8)	
I13D	VTR 1 recorder current adjust levels (8)	
I14A	VTR 1 picture/wideband mode (RBV/MSS)	
I14B	VTR 1 lap at BOT	MC
I14C	VTR 1 spare	
I14D	VTR 1 spare	
I15	VTR 2 tape footage	MC
I16	VTR 2 pressure	MC
I17	VTR 2 temperature, electronics unit	MC
I18	VTR 2 temperature, transport unit	MC
I19	VTR 2 average record current	MC
I20	VTR 2 average playback voltage	MC
I21	VTR 2 servo voltage	MC
I22	VTR 2 capstan motor speed	MC
I23	VTR 2 DC motor current, headwheel	MC
I24	VTR 2 DC motor current, capstan	MC
I25A	VTR 2 standby power on/off	
I25B	VTR 2 record on/off	MC
I25C	VTR 2 playback on/off	
I25D	VTR 2 rewind on/off	
I26A	VTR 2 fast forward on/off	
I26B	VTR 2 primary end of tape (EOT)	MC
I26C	VTR 2 secondary end of tape	
I26D	VTR 2 primary beginning of tape (BOT)	

Item	Name	Commutator Sampling Rate
Return Beam Vidicon		
G1	G1 voltage	MC
G2	Target voltage	MC
G3	Vidicon cathode current	MC
G4	Video output	MC
G5	Focus current	MC
G6	Combined alignment currents	MC
G7	Horizontal deflection output	MC
G8	Vertical deflection output	MC
G9	Deflection power supply	MC
G10	Low voltage power supply	MC
G11	Minus 28-volt shutter current	MC
G12	Temperature, faceplate	MC
G13	Temperature, yoke/focus coil	MC
G14	Temperature, electronics	MC
G15	Temperature, low voltage power supply	MC
G16	Thermoelectric cooler current	MC
G17	Temperature, camera controller	MC
G18A	Vidicon filament current	
G18B	Anode voltage supply	MC
G18C	G2 voltage supply	
G18D	Minus 24 5-volt input voltage	
G19A	Anode/target mode (command status)	MC
G19B	Power on/off (command status)	MC
G19C	One cycle/sec rephasing	MC
G19D	50-kHz clock input	MC
G20A	Horizontal sync	
G20B	Vertical sync	MC
G20C	Clock A-B (command status)	
G20D	Cycle, continuous/single (command status)	
G21A	P3 auto/P2-P1 (command status)	
G21B	P2 auto/P3-P1 (command status)	MC
G21C	Mode-record/direct-record (command status)	
G21D	Mode-direct/direct-record (command status)	
G22A	Dynamic beam regulator in/out (command status)	MC
G22B	Spare	
Multispectral Point Scanner		
H1A	Spectral band 1 on/off	
H1B	Spectral band 2 on/off	MC
H1C	Spectral band 3 on/off	
H1D	Spectral band 4 on/off	
H2A	Spectral band 5 on/off	
H2B	Band 1 gain low/high	MC
H2C	Band 2 gain low/high	
H2D	Band 3 gain low/high	

Item	Name	Commutator Sampling Rate
Wideband Video Tape Recorders (Cont.)		
I27A	VTR 2 secondary beginning of tape	MC
I27B	VTR 2 recorder current adjust levels (8)	
I27C	VTR 2 recorder current adjust levels (8)	
I27D	VTR 2 recorder current adjust levels (8)	
I28A	VTR 2 picture/wideband mode (RBV/Mss)	MC
I28B	VTR 2 lap at BOT	
I28C	VTR 2 spare	
I28D	VTR 2 spare	
Structures		
B3A	Array No. 1, hinge No 1	SC2
B3B	Array No 1, hinge No 2	
B3C	Array No 1, hinge No. 3	
B4A	Delta ERTS separation	SC2
B4B	Array No 2, hinge No 1	
B4C	Array No 2, hinge No 2	
B4D	Array No 2, hinge No 3	
B7A	Predeployment array 1 (-X)	SC2
B8B	Predeployment array 2 (+X)	
B11	Deploy bottle pressure 1	SC2
B12	Deploy bottle pressure 2	SC2
Data Collection System		
J1	To be defined	MC
J2	Negative analog	MC
Attitude Control		
A1	Gas, high pressure	SC2
A2	Gas, low pressure	SC2 X2
A3	Gas, bottle temperature	SC1
A4	Pitch error signal	MC+SC2 X2
A5	Roll error signal	MC+SC2 X2
A6A	Sun alarm signal head A	SC2 X2
A6B	Sun alarm signal head B	
A6C	Sun alarm signal head C	
A6D	Sun alarm signal head D	
A7A	Track check signal head A	SC2 X2
A7B	Track check signal head B	
A7C	Track check signal head C	
A7D	Track check signal head D	
A9	Horizon scanner head A temperature	SC2
A10	Yaw error signal	MC+SC2 X2

Item	Name	Commutator Sampling Rate
Attitude Control (Cont)		
A11	Array error signal	SC2
A12	Array shaft angle (sine)	SC2
A13	Array shaft angle (cosine)	SC2
A14	Body roll rate	
A16	Solar array drive	SC2 X2
A17	Reaction wheel count	MC
A18	Reaction wheel pitch count	MC
A19	Reaction wheel yaw count	MC
A21A	Gas control valve No 1	SC2 X8
A21B	Gas control valve No 2	
A21C	Gas control valve No 5	
A22A	Gas control valve No 3	SC2 X8
A22B	Gas control valve No 4	
A22C	Gas control valve No 6	
A23A	ACS modes logic	SC2 X2
A24	Pitch rate gyro demodulator signal (error)	SC2 X2
A25	Sun sensor No 1 temperature	SC2
A26	Sun sensor No 2 temperature	SC2
A27	Yaw gyro status	SC2
A28	Yaw gyro motor tachometer	SC2 X2
A29	Orbital switching status	SC2 X2
A30	Yaw gyro blanket temperature	SC2
A31A	Reaction wheel drive-roll	SC2 X4
A31B	Reaction wheel drive-pitch	
A31C	Reaction wheel drive-yaw	
A32	ACS inverter temperature	SC2
A33	Yaw reaction wheel temperature	SC2
A34	Pitch reaction wheel temperature	SC2
A35	Pitch rate gyro tach	SC2 X2
A40	Head "A" angle	SC2 X4
A41	Head "B" angle	SC2 X4
A42	Head "C" angle	SC2 X4
A43	Head "D" angle	SC2 X4
A44A	CSA status, bus safe	SC2
A44B	CSA status, bus armed	
A44C	Pitch jets enabled	
A44D	Pitch, jets disabled	
A47A	Roll jets enable/disable	SC2
A47B	Yaw jets enable/disable	
Communication		
C50	TWTA No 1, anode voltage	SC3
C51	TWTA No 1, helix plus anode current	SC3

Item	Name	Commutator Sampling Rate
Communication (Cont)		
C52	TWTA No 1, temperature transducer	SC3
C53A	TWTA No 1, power mode indicator	SC3
C53B	TWTA No 2, power mode indicator	
C54	TWTA No 2, anode voltage	SC3
C55	TWTA No 2, helix plus anode current	SC3
C56	TWTA No 2, temperature transducer	SC3
C57	VHF transmitter No 1, forward power	SC3
C58	VHF transmitter No 1, reverse power	SC3
C59	VHF transmitter No 2, forward power	SC3
C60	VHF transmitter No 2, reverse power	SC3
C61	VHF receiver No 1, AGC-1	SC3
C62	VHF receiver No 1, AGC-2	SC3
C63	VHF receiver No 2, AGC-1	SC3
C64	VHF receiver No 2, AGC-2	SC3
C65	USB receiver "A", signal present	SC3
C66	USB receiver "A", loop stress	SC3
C67	USB receiver "B", signal present	SC3
C68	USB receiver "B", loop stress	SC3
C69	USB transmitter "A", power monitor	SC3
C70	USB transmitter "A", temperature monitor	SC3
C71	USB transmitter "B", power monitor	SC3
C72	USB transmitter "B", temperature monitor	SC3
C73	USB converter "A" +15 Vdc	SC3
C74	USB converter "A" -15 Vdc	SC3
C75	USB converter "A" +28 Vdc	SC3
C76	USB converter "B" +15 Vdc	SC3
C77	USB converter "B" -15Vdc	SC3
C78	USB converter "B" +28 Vdc	SC3
C79	Wideband driver A, Afc loop stress	SC3
C80	Wideband driver B, Afc loop stress	SC3
C81	Wideband driver C, Afc loop stress	SC3
C82	Wideband driver D, Afc loop stress	SC3
Power Supply		
D1	Battery 1 current	SC2 X2
D2	Battery 2 current	SC2 X2
D3A	No 1 solar array norm/reg 2	
D3B	No 1 charge bus norm/parallel 2	
D3C	No 2 solar array norm/reg 1	SC1
D3D	No 2 charge bus norm/parallel 1	
D4	Array 1 (-X) current	SC2
D5	Array 2 (+X) current	SC2
D6	Array 1 (-X) sec C unreg	SC1
D8	Battery 1 voltage	SC2
D9	Battery 2 voltage	SC2
D10	Load bus voltage	SC2

4

Item	Name	Commutator Sampling Rate
Power Supply (Cont)		
D11D	No 1 and No 2 95^{o}F switch norma/override	
D11E	Charge bus parallel command	SC1
D11F	Discharge path normal/open	
D13	Array 1 (-X) Sec A thermal fin temperature	SC1
D14	Array 2 (+X) Sec A thermal fin temperature	SC1
D15	Sync signal amplifier 400 Hz	SC2
D16	Sync signal amplifier 2461 Hz 0 and 90 degrees	SC2
D17	Array 1 (-X) sec C unreg I amplifier	SC2
D20	Converter 2A + 16 volt	SC1
D21	Converter 2A + 9 volt	SC1
D22	Converter 2A + 5 volt	SC1
D23	Converter 2A - 6 volt	SC1
D28	Converter 5 + 16 (DDHA and ADHA)	SC1
D29	Converter 5 + 9 (DDHA and ADHA)	SC1
D30	Converter 5 - 6 (DDHA and ADHA)	SC1
D31	Converter 5 - 16 (DDHA and ADHA)	SC1
D32	Converter 6 + 16 volt	SC1
D33	Converter 6 + 9 volt	SC1
D34	Converter 6 - 6 volt	SC1
D35	Converter 6 - 16 volt	SC1
D36	Converter 7 + 16 volt	SC1
D37	Converter 7 + 9 volt	SC1
D38	Converter 7 - 6 volt	SC1
D39	Converter 8 + 16 volt	SC1
D40	Converter 8 + 9 volt	SC1
D41	Converter 8 - 6 volt	SC1
D42	Converter 9 + 20 volt	SC1
D43	Converter 9 + 10 volt	SC2
D44	Converter 9 - 20 volt	SC2
D45	Converter 9 + 28 volt	SC2
D46	ACS inverter 400 Hz	SC1
D50	Battery 2 (-X rad. panel)	SC1
D51	Battery 1 (+X rad. panel)	SC1
D57	No. 1 thermal fin drive volts (-X)	SC1
D58	No 2 thermal fin drive volts (+X)	SC1
D59	Load bus	SC2
D61A	Regulator charge rate No 1 reg/No 2 reg trickle/1A	
D61B	No. 1 reg. normal/full array	SC1
D61C	No 2 reg. normal/full array	
D62A	No 1 battery normal/recondition	
D62B	No. 2 battery normal/recondition	SC1
D62C	No. 1 reg. No. 2 reg. charge mode. Constant volt/trackle at V_B limit	
D63A	No 1 battery normal/disconnect	SC2
D63B	No. 2 battery normal/didconnect	

Item	Name	Commutator Sampling Rate
Power Supply (Cont)		
D64	No 1 battery current direction	SC2
D65	No 2 battery current direction	SC1
D75	Converter 2B + 16 volt	SC2
D76	Converter 2B + 9 volt	SC2
D77	Converter 2B + 5 volt	SC2
D78	Converter 2B - 6 volt	SC2
D79	RBV battery current	SC1
D80	RBV battery voltage	SC1
D81	Payload converter input current	SC1
D82	Payload converter output voltage	SC1
D83	Payload converter status (No 1 or 2)	SC1
D84	Payload converter temperature	SC1
Thermal Control		
E1	Array 1 (inboard) -X temperature	SC3
E4	Array 2 (outboard) +X temperature	SC3
E5	Panel mid third (+X) temperature	SC3
E6	Panel aft third (+X) temperature	SC3
E7	Panel mid third (-Z) temperature	SC3
E8	Panel aft third (-X) temperature	SC3
E21	Panel top third (-Z) temperature	SC3
E22	Panel mid third (+Z) temperature	SC3
E23	Panel top third (+X) temperature	SC3
E24	Panel aft third (-X) temperature	SC3
E30	Panel (-Y) middle temperature	SC3
E50	+X panel temperature	SC3
E51	+X panel temperature	SC3
E52	-X panel temperature	SC3
E53	-X panel temperature	SC3
E54	Payload temperature sensor No 1	SC3
E55	Payload temperature sensor No. 2	SC3
E56	Payload temperature sensor No 3	SC3
E57	Payload temperature sensor No 4	SC3
E58	+Y panel temperature	SC3
E59	+Z panel temperature	SC3
E60	+Z panel temperature	SC3
E61	-Z panel temperature	SC3
E62	-Z panel temperature	SC3
Data Handling		
F1	Tape record 1 + 9 5	SC1
F2	Tape record 1 - 9 5	SC1
F5	Tape record 1 encl pressure	SC1
F8	Tape record 1 base temperature	SC1
F9	Tape recorder No 2 + 9 5V	SC1

Item	Name	Commutator Sampling Rate
Data Handling (Cont)		
F10	Tape recorder No 2 - 9 5V	SC1
F13	Tape recorder pressure	SC1
F14	Clock No 1 oscillator temperature	SC1
F15	Clock No 2 oscillator temperature	SC1
F16	Tape recorder No 2 temperature	SC1
F17	No 1 LFTA Bd 3 temperature	SC1
F20	DDHA 1 Bd 3 temperature	SC1
F22	DDHA 2 Bd 3 temperature	SC1
F24/32	ADHA in service temperature	SC1
F25/33	Calibration No 1	SC1
F26/34	Calibration No 2	SC2
F27/35	Calibration No 3	SC1
F28/36	Calibration No 4	SC2
F29/37	Calibration No 5	SC1
F30/38	Calibration No 6	SC2
F31/39	Calibration No 7	SC1
F40A	Arm bus On	SC2
F40B	Payload ordnance armed	
F40C	Boom deploy	
F40E	Sequence relay switches	
F41A	SIU, Rx 1 sig present	SC2 X2
F41B	SIU, Rx 2 sign present	
F41C	SIU, deployment safe	
F42	TR No 1 status	SC2
F43	TR No 2 status	SC2
F44	LFTA status	SC2
F45/47	DDHA status	SC2
F46/48	DDHA status	SC2
F49	Command status word No 1	MC
F50	Command status word No 2	MC
F51	Command status word No 3	MC
F52	Command status word No 4	MC
F53	Command status word No 5	MC
F54	Stored command programmer No 1 verification	MC
F55	Stored command programmer No 1 verification	MC
F56	Stored command programmer No 1 verification	MC
F57	Stored command programmer No 1 verification	MC
F58	Stored command programmer No 1 verification	MC
F59	Stored command programmer No 1 verification	MC
F60	Stored command programmer No 2 verification	MC
F61	Stored command programmer No 2 verification	MC
F62	Stored command programmer No 2 verification	MC
F63	Stored command programmer No 2 verification	MC
F64	Stored command programmer No 2 verification	MC

Item	Name	Commutator Sampling Rate
Data Handling (Cont)		
F65	Stored command programmer No 2 verification	MC
F66	Stored command programmer No 1 temperature	SC3
F67	Stored command programmer No 2 temperature	SC3
F68	Stored command programmer No. 1 parity	MC
F69	Stored command programmer No 2 parity	MC
F70	Stored command programmer No 1 +16 volt	SC3
F71	Stored command programmer No 1 +9 volt	SC3
F72	Stored command programmer No 1 +5 volt	SC3
F73	Stored command programmer No 1 -5 volt	SC3
F74	Stored command programmer No 2 +16 volt	SC3
F75	Stored command programmer No 2 +9 volt	SC3
F76	Stored command programmer No 2 +5 volt	SC3
F77	Stored command programmer No. 2 -5 volt	SC3
F78	Spacecraft identification	MC
F79	No 2 LFTA Bd 3 temperature	SC1
F80A-D	Z axis status "A"	
F81A-D	Z axis status "B"	

DIGITAL — DIGITAL OR ANALOG

FRAME SYNC 1	2	3	F78 4	A4 5	G18 6	A10 7	G19 8	D F54 9	D/A A14 10	D/A G20 11	D/A H1 12	H2 13	H3 14	I 11 15	I 12 16
D A17 17	D F55 18	D F56 19	D/A H4 20	H5 21	A5 22	H21 23	I 13 24	D F49 25	D/A I 14 26	D/A I 25 27	D/A G21 28	G22 29	I 26 30	I 27 31	I 28 32
ACCUMULATED TIME 33	34	35	G1 36	G2 37	G3 38	H6 39	H7 40	F57 41	D/A H8 42	D/A H9 43	D/A H10 44	I 1 45	I 2 46	I 3 47	I 4 48
D F58 49	D A18 50	D F59 51	D/A I 5 52	I 6 53	I 7 54	G4 55	G5 56	D F50 57	D/A G6 58	D/A I 8 59	D/A J1 60	H11 61	H12 62	H13 63	H14 64
D IDENTIFICATION WORDS 65	D 66	D 67	D/A H15 68	H16 69	H17 70	H18 71	H19 72	D F60 73	D/A I 9 74	D/A G7 75	D/A G8 76	G9 77	I 10 78	I 15 79	I 16 80
D F61 81	D F62 82	D A19 83	D/A I 17 84	I 18 85	I 19 86	I 20 87	J2 88	D F51 89	D/A 90	D/A H22 91	D/A H23 92	H24 93	G10 94	G11 95	G12 96
SUBMULTIPLEXER NO. 1 97	NO. 2 98	NO. 3 99	G13 100	G14 101	G15 102	I 21 103	I 22 104	D F63 105	D/A 106	D/A 107	D/A 108	I 23 109	H25 110	H26 111	H27 112
D F64 113	D F65 114	D F52 115	D/A H28 116	H29 117	H30 118	G16 119	G17 120	D F53 121	D/A 122	D/A F80 123	D/A F81 124	I 24 125	H31 126	H32 127	H20 128

← TELEMETRY WORD NO.

← INSTRUMENTATION LIST IDENTIFICATION

▨ = SPARE

1 POSITIVE ANALOG/DIGITAL
7 NEGATIVE ANALOG/DIGITAL

UNASSIGNED WORD

ERTS MAIN MULTIPLEXER TELEMETRY FORMAT

DIGITAL

TELEMETRY WORD NO.

DIGITAL OR ANALOG

INSTRUMENTATION LIST IDENTIFICATION

F24 IN EQUIPMENT GROUP NO. 1
F32 IN EQUIPMENT GROUP NO. 2

D 1	D 2	D 3	D 4	D 5	D 6	D 7	D 8
A2 9	D3 10	D6 11	D11 12	D13 13	F1 14	F2 15	F5 16
D/A 17	D/A 18	D/A 19	D/A 20	D/A 21	D/A 22	D/A 23	D/A 24
D14 25	D20 26	D21 27	D22 28	F8 29	F9 30	F10 31	32
D/A 33	D/A 34	D/A 35	D/A 36	D/A 37	D/A 38	D/A 39	D/A 40
41	F13 42	F14 43	F15 44	D23 45	D28 46	D29 47	D30 48
D/A 49	D/A 50	D/A 51	D/A 52	D/A 53	D/A 54	D/A 55	D/A 56
D31 57	D32 58	D33 59	D34 60	F16 61	F17 62	F20 63	F22 64
D 65	D 66	D 67	D 68	D 69	D 70	D 71	D 72
F24/32 73	F25/33 74	F27/35 75	F29/37 76	D35 77	D36 78	D37 79	D38 80
D39 81	D40 82	D41 83	D42 84	F31/39 85	F79 86	87	88
89	90	91	92	D46 93	D50 94	D51 95	D57 96
D58 97	D61 98	D62 99	D65 100	101	102	103	104
105	106	107	108	D79 109	D80 110	D81 111	D82 112
D83 113	D84 114	115	116	117	118	119	120
121	122	123	124	125	126	127	128

UNASSIGNED WORD

ERTS SUBMULTIPLEXER 1 FORMAT

B3 1	B4 2	A9 3	D4 4	D5 5	D2 6	A1 7	A2 8
A21 9	A22 10	A42 11	A43 12	A7 13	D8 14	A11 15	A10 16
A12 17	A13 18	B7 19	B11 20	A25 21	A26 22	23	24
A21 25	A22 26	A31 27	A40 28	A41 29	A32 30	A33 31	A34 32
A44 33	A47 34	A48 35	A49 36	B12 37	A50 38	39	40
A21 41	A22 42	A42 43	A43 44	A23 45	D10 46	D15 47	A24 48
A4 49	A5 50	A6 51	A16 52	A28 53	A29 54	A35 55	D1 56
A21 57	A22 58	A31 59	A40 60	A41 61	D16 62	D17 63	D43 64
D44 65	D45 66	D59 67	D63 68	D64 69	D2 70	D75 71	A2 72
A21 73	A22 74	A42 75	A43 76	A7 77	78	D F42 79	A10 80
D76 81	D77 82	D78 83	F40 84	F41 85	A27 86	87	88
A21 89	A22 90	A31 91	A40 92	A41 93	94	D F43 95	96
F26/34 97	F28/36 98	F30/38 99	D9 100	A30 101	A51 102	103	104
A21 105	A22 106	A42 107	A43 108	A23 109	110	D F44 111	A24 112
A4 113	A5 114	A6 115	A16 116	A28 117	A29 118	A35 119	D1 120
A21 121	A22 122	A31 123	A40 124	A41 125	126	D F45/47 127	D F46/48 128

TELEMETRY WORD NO.

UNASSIGNED WORD

INSTRUMENTATION LIST IDENTIFICATION

BLANKED WORD

DIGITAL

F45 IN EQUIPMENT GROUP # 1
F47 IN EQUIPMENT GROUP # 2

ERTS SUBMULTIPLEXER 2 FORMAT

C52 1	C56 2	C73 3	C74 4	C75 5	C76 6	C77 7	C78 8
C50 9	C51 10	C53 11	C54 12	C55 13	C70 14	C57 15	C58 16
E1 17	E4 18	E5 19	E6 20	E7 21	E8 22	E21 23	E22 24
C59 25	C60 26	C61 27	C62 28	C63 29	C72 30	C64 31	C65 32
E23 33	E24 34	E30 35	E50 36	E51 37	E52 38	E53 39	40
C66 41	C67 42	C68 43	C69 44	C71 45	E55 46	C79 47	C80 48
C81 49	C82 50	F66 51	F67 52	53	54	55	56
57	58	59	60	61	62	63	64
E56 65	E57 66	E58 67	E59 68	E60 69	E61 70	E62 71	E70 72
C50 73	C51 74	C53 75	C54 76	C55 77	78	C57 79	C58 80
F71 81	F72 82	F73 83	F74 84	F75 85	F76 86	F77 87	E54 88
C59 89	C60 90	C61 91	C62 92	C63 93	94	C64 95	C65 96
97	98	99	100	101	102	103	104
C66 105	C67 106	C68 107	C69 108	C71 109	110	C79 111	C80 112
C81 113	C82 114	F66 115	F67 116	* 117	* 118	* 119	* 120
* 121	* 122	* 123	* 124	* 125	126	* 127	* 128

INSTRUMENTATION LIST IDENTIFICATION

TELEMETRY WORD NO.

UNASSIGNED WORD

CROSS-STRAPPED WORDS FOR SUPER-MULTIPLEXING WORDS 53 THROUGH 64

BLANKED WORD

ERTS SUBMULTIPLEXER 3 FORMAT

ERTS COMMAND LIST

Command No	Description
	Return Beam Vidicon
A210	Clock A (spacecraft)
A230	Clock B (spare)
A250	Single cycle
A270	Continuous cycle
E310	Camera 1 on*
E330	Camera 1 off*
E350	Camera 2 on*
E370	Camera 2 off*
E211	Camera 3 on*
E231	Camera 3 off*
A310	Exposure automatic
244	Preset 1 (8 msec)*
264	Preset 2 (12 msec, nominal)*
305	Preset 3 (16 msec)*
A330	Anode mode
A350	Target mode
A370	Dynamic beam regulator in
A211	Dynamic beam regulator out
A231	Record mode
A251	Direct mode
A271	Direct/record mode
A311	Start prepare
205	Power on 1*
225	Power off 1*
364	Power on 2*
344	Power off 2*
A331	Aperture compensation in
A351	Aperture compensation out
A371	Calibrate 1
B210	Calibrate 2
B230	Calibrate 3
B250	Calibrate 4
B270	Calibrate 5
B310	Calibrate 6
363	Enable
	Video Tape Recorder
325	Standby 1*
203	Standby 2*
345	Record 1*
223	Record 2*
365	Rewind 1*
243	Rewind 2*
B330	Playback 1
B350	Playback 2
323	Fast forward 1*
343	Fast forward 2*
263	Off 1*
303	Off 2*
B370	Record current adj 1
B211	Record current adj 2
B231	RBV 1
B251	RBV 2
B331	Lap at Bot 1
B351	Lap at Bot 2
B271	MSS 1
B311	MSS 2
	Multispectral Spot Scanner
206	Standby on*
207	Standby off*
226	Calibration fast sequence, on
246	Calibration fast sequence, off
306	Rotating shutter drive, on
326	Rotating shutter drive, off
346	Calibration lamp 1, on
366	Calibration lamp 2, on
227	Calibration lamps 1 and 2 off
247	Scan mirror drive, on
267	Scan mirror drive off
B371	Step gain band 1
C210	Step gain band 2
C230	Step gain band 3
C250	Step gain band 4
C270	Step gain band 5
C310	Spectral band 1 on
C330	Spectral band 2 on
C350	Spectral band 3 on
C231	Step band 5 focus, up
C251	Step band 5 focus, down
C271	Increase data rate, on
C311	Increase data rate, off
C331	Sync pickoff 1 on
C351	Sync pickoff 1 off
D211	Uncap optics
D330	Uncage scan
D350	Uncage cooler
D370	Uncap cooler
D371	Spectral band 4, on
E250	Sync pickoff 2, on
E270	Sync pickoff 2, off
E271	Spectral band 1, off
E311	Spectral band 2, off
E331	Spectral band 3, off
E351	Spectral band 4, off
E251	Spectral band 5, on
E371	Spectral band 5, off
D231	ON function 1
D251	ON function 2
D271	ON function 3
D311	ON function 4
D331	ON function 5
D351	ON function 6
307	Cooler heater on
327	Cooler heater off
367	MSS off
	Data Collection System (DCS)
113	DCS 1 power on
173	DCS 1 power off
154	DCS 2 power on
254	DCS 2 power off
	Attitude Control
014	Wheel delay
015	Pitch rate gyro off
035	Pitch rate gyro on
034	Gas delay
067	CSA arm
047	CSA safe
146	ACS on/jets enabled
101	ACS off/jets disabled
102	ACS mode 1
122	ACS mode 2A
142	ACS mode 2C
162	ACS mode 3
373	ACS mode 4
121	ACS normal
141	ACS enable
161	ACS execute
045	Array slew CW
007	Array slew CCW
110	Array slew normal
355	Array delay enable
375	Array delay disable
004	Jet pulse execute
166	Roll jet disable
051	Pitch jet disable
103	+Yaw select
150	Yaw jet disable
273	Yaw - Roll select
216	-Yaw select

*in storage

ERTS COMMAND LIST

Command No	Description
257	Yaw + Roll select
131	-Roll select
163	+Roll select
253	Gyro auto
074	Gyro 1 select
235	Gyro 2 select
077	Yaw gyro off, heater on
117	Tracking head A disable
136	Tracking head B disable
155	Tracking head D disable
174	Tracking head normal
055	Orbit adjust arm
200	Orbit adjust +X thrust*
220	Orbit adjust -X thrust*
240	Orbit adjust +Y thrust*
064	Orbit adjust disarm
260	Orbit adjust off*
	Communications
020	USB converter A
143	USB converter B
114	Baseband 1 on, 2 off
133	Baseband 2 on, 1 off
065	Baseband SCO's (165, 225, 300 kHz) on
024	Baseband SCO's (165, 225, 300 kHz) off
167	Baseband DCS SCO on
340	Wideband transmitter driver A on, B off
360	Wideband transmitter driver B on, A off
241	Wideband transmitter driver A and B off
261	Wideband transmitter driver C on, D off
301	Wideband transmitter driver D on, C off
321	Wideband transmitter driver C and D off
300	Wideband transmitter 1 on
201	Wideband transmitter 1 off
320	Wideband transmitter 2 on
221	Wideband transmitter 2 off
071	TWTA 1 10 watt
112	TWTA 1 20 watt
040	TWTA 2 10 watt
170	TWTA 2 20 watt
147	Summed transmitter driver signal on TWTA 1
137	Summed transmitter driver signal on TWTA 2
333	Transmitter driver A/B signal normal
152	Transmitter driver C/D signal normal
151	MSS Real time ch 1/RBV Real time ch 2
072	RBV Real time ch 1/MSS Real time ch 2
033	MSS Real time ch 1/VTR 1 ch 2
134	VTR 1 ch 1/MSS Real time ch 2
115	RBV Real time ch 1/VTR 1 ch 2
057	VTR 1 ch 1/RBV Real time ch 2
172	MSS Real time ch 1/VTR 2 ch 2
233	VTR 2 ch 1/MSS Real time ch 2
214	RBV Real time ch 1/VTR 2 ch 2
275	VTR 2 ch 1/RBV Real time ch 2
157	VTR 1 ch 1/VTR 2 ch 2
256	VTR 2 ch 1/VTR 1 ch 2
005	VHF transmitter A on/B off
025	VHF transmitter B on/A off
	Power
104	Battery 1 normal
124	Battery 1 disconnect
016	Battery 2 normal
036	Battery 2 disconnect
120	Battery execute
354	Regulator 1 normal
374	Regulator 1 disconnect
315	Regulator 2 normal
335	Regulator 2 disconnect
165	Battery 1 condition
145	Battery 1 reconditioned
037	Battery 2 condition
017	Battery 2 reconditioned
144	Charge rate trickle
164	Charge rate 3 7 amp
356	Reg 1 charge rate normal
376	Reg 1 charge rate 8 7 amp
317	Reg 2 charge rate normal
337	Reg 2 charge rate 8 7 amp
316	Charge mode control limit
336	Charge mode cycle
056	Charge bus parallel normal
076	Charge bus parallel inhibit
105	Thermal switches normal (95 deg)
125	Thermal switches override
006	Undervoltage bus 1 reset
026	Undervoltage bus 1 override
046	Undervoltage bus 2 reset
066	Undervoltage bus 2 override
111	Payload converter 1 on
132	Payload converter 2 on
073	Redund, converters on
135	Payload converters off
156	Switch converter 1
177	Switch converter 2
044	Battery 3 recondition
106	Battery 3 condition
	Data Handling
061	Tape playback
002	Tape recorder 1 on
022	Tape recorder 1 off
042	Tape recorder 2 on
062	Tape recorder 2 off
011	Real time main commutator
031	Real time ASC
012	Data storage main commutator
032	Data storage ASC
003	EG 1 on
023	EG 1 off
041	EG 1 real time
010	Clock select A on, B off
050	EG 1 HFTU
043	EG 2 on
063	EG 2 off
021	EG 2 real time
030	Clock select B on, A off
070	EG 2 HFTU
013	Low bit rate
053	High bit rate
314	LFTA 1 on, 2 off
175	LFTA 2 on, 1 off
313	Real time to VHF
274	DS to USB
215	Real time to USB
176	Hi BR real time to USB
237	DS to VHF
	Command
357	Redundant enable on
130	SCP 1 on
171	SCP 1 off
052	SCP 2 on
153	SCP 2 off
054	SCP 2 clear
100	Ordnance armed
140	Array deploy
107	Payload ordnance on
127	Payload ordnance off
126	Payload heater on
060	Payload heater off
075	SCP 1 clear
116	SCP 1 fill
217	SCP 1 process
334	Redundant enable off
341	SCP 1 standby
361	SCP 2 standby
353	SCP 2 fill
276	Timer normal
277	Timer override

Payload Expanded Matrix

A = 212	E = 312
B = 232	F = 332
C = 252	G = 352
D = 272	H = 372

*in storage

000	020 USB CONV A	040 TWTA 2 IOW	060 P/L HEATER OFF	100 ORD ARM	120 BAT EXCUT	140 ARRAY DEPLOY	160 SHUTTER OVRD	200 ORBIT ADJ +X	220 ORBIT ADJ -X	240 ORBIT ADJ +Y	260 ORBIT ADJ OFF	300 TWTA 1 ON	320 TWTA 2 ON	340 WB TMTR A ON	360 WB TMTR B ON	
001 BAT 3 PULSE	021 EG 2 RT AND DS	041 EG 1 RT AND DS	061 PCM TAPE PLAYBK	101 ACS OFF/ JETS DISABLE	121 ACS NORMAL	141 ACS ENABLE	161 ACS EXCUT	201 TWTA 1 OFF	221 TWTA 2 OFF	241 WB TMTR A/B OFF	251 WB TMTR C ON	301 WB TMTR D ON	321 WB TMTR C/D OFF	341 SCP 1 STDBY	361 SCP 2 STDBY	
002 TR 1 ON	022 TR1 OFF	042 TR2 ON	062 TR 2 OFF	102 ACS MODE 1	122 ACS MODE 2A	142 ACS MODE 2C	162 ACS MODE 3	202	222	242	262	302	322	342	362	
003 EG 1 ON	023 EG 1 OFF	043 EG 2 ON	063 EG 2 OFF	103 +YAW SELECT	123 ARAY DSABL OVERRIDE	143 USB CONV B	163 + ROLL SELECT	203 VTR 2 STDBY	223 VTR 2 RECD	243 VTR 2 REWD	263 VTR 1 OFF	303 VTR 2 OFF	323 VTR 1 FAST FWD	343 VTR 2 FAST FWD	363 RBV ENABLE	
004 JET PULSE EXECUT	024 BASE BAND SCO 5 OFF	044 BAT 3 RECOND	064 ORBIT ADJ DISARM	104 BAT 1 NRML	124 BAT 1 DISC	144 CHARGE RATE TRICKLE	164 CHARGE RATE 3 7	204 CAMERA 1 ON	224 CAMERA 1 OFF	244 RBV PRESET 1	264 RBV PRESET 2	304 CAMERA 3 ON	324 CAMERA 3 OFF	344 RBV PWR OFF 2	364 RBV PWR ON 2	COMMANDS TO SCP OR REAL TIME
005 VHF TMTR A ON	025 VHF TMTR B ON	045 ARRAY SLEW CW	065 BASE BAND SCO 5 ON	105 THRM SW NRML	125 THRM SW OVRD	145 BAT 1 RECOND	165 BAT 1 COND	205 RBV PWR ON 1	225 RBV PWR OFF 1	245 CAMERA 2 ON	265 CAMERA 2 OFF	305 RBV PRESET 3	325 VTR 1 STDBY	345 VTR 1 RECD	365 VTR 1 REWD	
006 UV BUS 1 RESET	026 UV BUS 1 OVRD	046 UV BUS 2 RESET	066 UV BUS 2 OVRD	106 BAT 3 COND	126 P/L HEATER ON	146 ACS ON/ JETS ENABLE	166 ROLL JET DISABL	206 MSS STDBY ON	226 MSS CAL SEQ FAST ON	246 MSS CAL SEQ FAST OFF	266	306 MSS ROTATING SHUTTER DRIVE ON	326 MSS ROTATING SHUTTER DRIVE OFF	346 MSS CAL LAMP 1 ON	366 MSS CAL LAMP 2 ON	
007 ARRAY SLEW CCW	027 BAT 3 NORMAL	047 CSA SAFE	067 CSA ARM	107 P/L ORD ARM	127 ORD SAFE	147 SUM SIGON TWTA 1	167 DCS SCO ON	207 MSS STDBY OFF	227 MSS CAL LAMP 1 AND 2 OFF	247 MSS SCAN MIRROR DRIVE ON	267 MSS SCAN MIRROR DRIVE OFF	307 MSS COOLER HTR ON	327 MSS COOLER HEATER OFF	347	367 MSS OFF	
010 CLOCK SELECT A	030 CLOCK SELECT B	050 EG 1 HFTU	070 EG 2 HFTU	110 ARRAY SLEW NRML	130 SCP 1 ON	150 YAW JET DISABL	170 TWTA 2 2 OW	210 MA 1	230 MA 2	250 MA 3	270 MA 4	310 MA 5	330 MA 6	350 MA 7	370 MA 8	
011 RT MAIN COMM	031 RT ACC SUBCOM	051 PITCH JET DISABL	071 TWTA 1 10W	111 PL CONV I ON	131 -ROLL SELECT	151 MSS RT1 RBV RT2	171 SCP 1 OFF	111 MA 9	231 MA 10	251 MA 11	271 MA 12	311 MA 13	331 MA 14	351 MA 15	371 MA 16	PAYLOAD EXPANDED MATRIX
012 DS MAIN COMM	032 DS ACC SUBCOM	052 SCP 2 ON	072 RBV RT1 MSS RT2	112 TWTA 1 20W	132 P/L CONV 2 ON	152 WB TMTR C & D NRML	172 MSS RT1 VTR 2 ON2	212 MB 1	232 MB 2	252 MB 3	272 MB 4	312 MB 5	332 MB 6	352 MB 7	372 MB 8	
013 LOW BIT RATE	033 MSS RT1 VTR1 ON2	053 HI BIT RATE	073 REDUN P/L CONV ON	113 DCS 1 ON	133 BASE BAND 2 ON	153 SCP 2 OFF	173 DCS 1 OFF	213	233 VTR2 ON1 MSS RT2	253 GYRO AUTO	273 YAW -ROLL SELECT	313 RT TO VHF	333 WB TMTR A & B NRML	353 SCP 2 FILL	373 ACS MODE 4	
014 WHEEL DELAY	034 GAS DELAY	054 SCP 2 CLEAR	074 GYRO 1 SELECT	114 BASE BAND 1 ON	134 VTR1 ON1 MSS RT2	154 DCS 2 ON	174 TRK HD NRMl	214 RBV 1 VTR2 ON2	234	254 DCS 2 OFF	274 DS TO USB	314 LFTA 1 ON	334 REDUN ENABLE OFF	354 REG1 NORM	374 REG1 DISCONT	← OCTAL COMMAND NO
015 PITCH RATE GYRO OFF	035 PITCH RATE GYRO ON	055 ORBIT ADJ ARM	075 SCP 1 CLEAR	115 RBV RT1 VTR1 ON2	135 P/L CONV OFF	155 TRK HD D DISABL	175 LFTA 2 ON	219 RT TO USB	235 GYRO 2 SELECT	255	275 VTR2 ON1 RBV RT2	315 REG 2 NORM	335 REG 2 DISCONT	355 ARRAY DELAY ENABLE	375 ARRAY DELAY DISABLE	
016 BAT2 NRML	036 BAT2 DISC	056 CH BUS PRL NRML	076 CH BUS PRL INHIB	116 SCP 1 FILL	136 TRK HD B DISABL	156 SW P/L CONV 1	176 HIBR RT TO USB	216 -YAW SELECT	236 TIMER NORMAL	256 VTR2 ON1 VTR1 ON2	276 SCP 2 PROCESS	316 CH MODE CONT LIMIT	336 CH MODE CYCLE	356 REG1 CH RATE NRML	376 REG1 CH RATE 8 7	
017 BAT2 RECOND	037 BAT2 COND	057 VTR1 ON1 RBV RT2	077 GYRO OFF/ HEATER ON	117 TRK HD A DISABLE	137 SUM SIG ON TWTA 2	157 VTR1 ON1 VTR2 ON2	177 SW P/L CONV 2	217 SCP 1 PROCESS	237 DS TO VHF	257 YAW +ROLL SELECT	277 TIMER OVRD	317 REG2 CH RATE NRML	337 REG2 CH RATE 8 7	357 REDUN ENABLE ON	377	← BLANK

ERTS COMMAND MATRIX

A210	A230	A250	A270	A310	A330	A350	A370	A211	A231	A251	A271	A311	A331	A351	A371
RBV CLK A	RBV CLK B	RBV SINGLE CYCLE	RBV CONT CYCLE	RBV EXPO AUTO	RBV ANODE MODE	RBV TARGET MODE	RBV DYNAM REG IN	RBV DYNAM REG OUT	RBV REC MODE	RBV DIR MODE	RBV DIR/REC MODE	RBV START PREP	RBV APER COMP IN	RBV APER COMP OUT	RBV CALIB 1
B210	B230	B250	B270	B310	B330	B350	B370	B211	B231	B251	B271	B311	B331	B351	B371
RBV CALIB 2	RBV CALIB 3	RBV CALIB 4	RBV CALIB 5	RBV CALIB 6	VTR1 PLAYBK	VTR2 PLAYBK	VTR1 RECD CURR ADJ	VTR2 RECD CURR ADJ	VTR1 RBV	VTR2 RBV	VTR 1 MSS	VTR2 MSS	VTR1 LAP AT BOT	VTR2 LAP AT BOT	MSS STEP GAIN BAND 1
C210	C230	C250	C270	C310	C330	C350	C370	C211	C231	C251	C271	C311	C331	C351	C371
MSS STEP GAIN BAND 2	MSS STEP GAIN BAND 3	MSS STEP GAIN BAND 4	MSS STEP GAIN BAND 5	MSS SPEC BAND 1 ON	MSS SPEC BAND 2 ON	MSS SPEC BAND 3 ON			MSS STEP BAND 5 FOCUS UP	MSS STEP BAND 5 FOCUS DOWN	MSS INCR DATA RATE ON	MSS INCR DATA RATE OFF	MSS SYNC 1 PICK OFF ON	MSS SYNC 1 PICK OFF OFF	
D210	D230	D250	D270	D310	D330	D350	D370	D211	D231	D251	D271	D311	D331	D351	D371
					MSS UNCAGE SCAN	MSS UNCAGE COOLER	MSS UNCAP COOLER	MSS UNCAP OPTICS	MSS ON FUNCTION 1	MSS ON FUNCTION 2	MSS ON FUNCTION 3	MSS ON FUNCTION 4	MSS ON FUNCTION 5	MSS ON FUNCTION 6	MSS SPEC BAND 4 ON
E210	E230	E250	E270	E310	E330	E350	E370	E211	E231	E251	E271	E311	E331	E351	E371
		MSS SYNC PICK OFF 2 ON	MSS SYNC PICK OFF 2 OFF	RBV CAMERA 1 ON	RBV CAMERA 1 OFF	RBV CAMERA 2 ON	RBV CAMERA 2 OFF	RBV CAMERA 3 ON	RBV CAMERA 3 OFF	MSS SPEC BAND 5 ON	MSS SPEC BAND 1 OFF	MSS SPEC BAND 2 OFF	MSS SPEC BAND 3 OFF	MSS SPEC BAND 4 OFF	MSS SPEC BAND 5 OFF
F210	F230	F250	F270	F310	F330	F350	F370	F211	F231	F251	F271	F311	F331	F351	F371
G210	G230	G250	G270	G310	G330	G350	G370	G211	G231	G251	G271	G311	G331	G351	G371
H210	H230	H250	H270	H310	H330	H350	H370	H211	H231	H251	H271	H311	H331	H351	H371

OCTAL COMMAND NO

A = 212 E = 312
B = 232 F = 332
C = 252 G = 352
D = 272 H = 372

ERTS PAYLOAD EXPANDED (Z AXIS) COMMAND MATRIX

APPENDIX C

TYPICAL OPERATIONS CENTER COMPUTER PRINTOUT FORMATS

```
01/27R3416RT DATA FRZ MODE  A          OGO-6/F     POWER INSTRU PRINT-07                    OGO-OCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23
                                        A23 ACS MODE/SUN      35/ ON.  021
   MC        DS         RCVD            D10 LOAD BUS (VOLTS) 30.23    327        D59 LOAD BUS  (AMPS) 12.19    313 *
   MC        RT EG 1           64 KB    D8  BAT 1     (VOLTS) 31.34    336        D9  BAT 2    (VOLTS) 31.19    335
   S/C CLOCK   063 560 017              D1  BAT 1      (AMPS) 2.682    055 *      D2  BAT 2     (AMPS) 2.741    056 *
   CLOCK BIAS  105 664 050              D64 BAT 1 CUR DIRECT  CHRG     112        D65 BAT 2 CUR DIRECT  CHRG    112
   S/C GMT     70 027 1656  04          D4  ARRAY 1    (AMPS) 7.123    263 *      D5  ARRAY 2   (AMPS) 9.471    356
```

TLM		ENGR	OCTAL
	BATTERY		
D8	BAT 1 (VOLTS)	31.34	336
D9	BAT 2 (VOLTS)	31.19	335
D50B	BAT 1 LMT(VOLTS)	32.16	203
D51B	BAT 2 LMT(VOLTS)	32.16	203
D1	BAT 1 (AMPS)	2.682	055 *
D64	BAT 1 CUR DIRECT	CHRG	112
D2	BAT 2 (AMPS)	2.741	056 *
D65	BAT 2 CUR DIRECT	CHRG	112
D50A	BAT 2 (DEG C)	18.40	203
D51A	BAT 1 (DEG C)	18.40	203
	ARRAY		
D4	ARRAY 1 (AMPS)	7.123	263 *
D5	ARRAY 2 (AMPS)	9.471	356
D57	AR 1 SHUNT(AMPS)	.0000	000
D58	AR 2 SHUNT(AMPS)	.0000	000
D6	ARRAY 1C (VOLTS)	17.83	176
D17	ARRAY 1C (AMPS)	.0655	006 *
A10	YAW ERROR (DEG)	-.8529	170
A11	ARRAY ERROR(DEG)	1.051	200
A12	ARRAY SIN (DEG)	240-292	020 *
A13	ARRAY COS (DEG)	243.9	072 *
E1	AR 1 INBD(DEG C)	112.0	366
E3	AR 2 INBD(DEG C)	75.99	344
D13	FIN 1A (DEG C)	-25.88	255 *
D14	FIN 2A (DEG C)	-6.872	271
	CONVERTER 2 (SIU,LFTA)		
D20	CONV 2 (+16 V)	16.01	255
D21	CONV 2 (+9 V)	8.985	260
D22	CONV 2 (+5 V)	.0000	000 *
D23	CONV 2 (-6 V)	-5.999	143
	CONVERTER 3 (WB A)		
D24	CONV 3 (+70 V)	70.34	257
D25	CONV 3 (+23 V)	22.87	256
	CONVERTER 4 (WB B)		
D26	CONV 4 (+70 V)	OFF	000
D27	CONV 4 (+23 V)	OFF	004
	CONVERTER 5 (EG-1)		
D28	CONV 5 (+16 V)	16.06	256
D29	CONV 5 (+9 V)	9.005	256
D30	CONV 5 (-6 V)	-6.010	142
D31	CONV 5 (-16 V)	-16.18	142

TLM		ENGR	OCTAL
	REGULATOR CONFIGURATION		
D3A	REG 1 STATUS	NORM	000
D3C	REG 2 STATUS	NORM	000
D3B	CHRG BUS 1	NORM	000
D3D	CHRG BUS 2	NORM	000
D11A	95F SWITCH	NORM	000
D11B	PARAL CHRG CMD	NORM	000
D11C	DISCHRG PATH	NORM	000
D61B	REG 1 CHRG (AMP)	12. A	332
D61C	REG 2 CHRG (AMP)	12. A	332
D62A	BAT 1 STATUS		127
D62B	BAT 2 STATUS		127
D62C	REG CHRG MODE	*	127
D63A	BAT 1 STATUS	CONNECT	000
D63B	BAT 2 STATUS	CONNECT	000
	SYNC SIGNALS		
D15	400 CPS SYNC	ENABLE	150
D16A	2461 SYNC 0 DEG	ENABLE	060
D16B	2461 SYNC 90 DEG	ENABLE	060
	ACS INVERTER		
D46	ACS INV(115 VAC)	114.8	160
A32	ACS INVER(DEG C)	35.41	125 *
	CONVERTER 6 (EG-2)		
D32	CONV 6 (+16 V)	16.02	256
D33	CONV 6 (+9 V)	9.048	256
D34	CONV 6 (-6 V)	-6.009	142
D35	CONV 6 (-16 V)	-16.10	143
	CONVERTER 7 (DDHA)		
D36	CONV 7 (+16 V)	16.04	260 *
D37	CONV 7 (+9 V)	9.082	262 *
D38	CONV 7 (-6 V)	-5.960	145 *
	CONVERTER 8 (DDHA)		
D39	CONV 8 (+16 V)	16.00	256
D40	CONV 8 (+9 V)	9.069	261
D41	CONV 8 (-6 V)	-5.943	145
	CONVERTER 9 (ACS)		
D42	CONV 9 (+20 V)	20.07	257
D43	CONV 9 (+10 V)	10.04	257
D44	CONV 9 (-20 V)	-20.00	146
D45	CONV 9 (28 VAC)	27.80	140

POWER SUPPLY INSTRUMENTATION PRINTOUT (OGO 6 example)

```
01/27R3416RT DATA FRZ MODE  A           OGO-6/F     ACS INSTRU PRINT-05                 OGO-OCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23
                                             A23 ACS MODE/SUN     3S/ ON   021
   MC        DS          RCVD                D10 LOAD BUS (VOLTS) 30.23    327        D59 LOAD BUS  (AMPS) 12.19   313 *
   MC          RT EG 1               64 KB   D8  BAT 1    (VOLTS) 31.34    336        D9  BAT 2    (VOLTS) 31.19   335
   S/C CLOCK    063 560 017                  D1  BAT 1     (AMPS) 2.682    055 *      D2  BAT 2     (AMPS) 2.741   056 *
   CLOCK BIAS   105 664 050                  D64 BAT 1 CUR DIRECT  CHRG    112        D65 BAT 2 CUR DIRECT  CHRG   112
   S/C GMT      70 027 1656  04              D4  ARRAY 1   (AMPS) 7.123    263 *      D5  ARRAY 2   (AMPS) 9.471   356
```

TLM		ENGR	OCTAL	
	ERROR STATUS			
A4	PITCH ERROR(DEG)	-.2207	170	
A5	ROLL ERROR (DEG)	.2970	200	*
A10	YAW ERROR (DEG)	-.8529	170	
A11	ARRAY ERROR(DEG)	1.051	200	
	HORIZON SCANNER			
A6	SUN ALARM (HDS)	NO SUN	370	*
A7	TRACK CHECK(HDS)	A,B,C,D	370	
A9	HEAD-A (DEG C)	20.06	176	
A40	HOR SCAN A (DEG)	61.44	256	*
A41	HOR SCAN B (DEG)	62.90	262	
A42	HOR SCAN C (DEG)	63.26	263	
A43	HOR SCAN D (DEG)	62.53	261	*
	SUN SENSORS			
A23	ACS MODE/SUN	3S/ ON	021	
A25	SUN SEN 1(DEG C)	19.40	200	
A26	SUN SEN 2(DEG C)	14.77	216	
A46	SUN ASPECT (DEG)		000	
	ROLL			
A21	JETS 1,2,5	ALL OFF	371	*
A31A	ROLL WHEEL DRIVE	OFF	371	*
A20A	ROLL WHEEL DIREC	CW	367	
A17	ROLL WHEEL (RPM)	322.7	244	
	PITCH			
A21	JETS 1,2,5	ALL OFF	371	*
A22	JETS 3,4,6	ALL OFF	371	*
A31B	PITCH WHEEL DRIV	OFF	371	*
A20B	PITCH WHEEL DIR	CW	367	
A18	PITCH WHEEL(RPM)	795.0	117	
A34	PITCH WHL(DEG C)	21.72	370	
	PITCH RATE GYRO			
A24	PR GRYO ERR(D/S)	OFF	000	
A35	PR GYRO TACH	OFF	000	
	CONVERTER 9			
D42	CONV 9 (+20 V)	20.07	257	
D43	CONV 9 (+10 V)	10.04	257	
D44	CONV 9 (-20 V)	-20.00	146	
D45	CONV 9 (28 VAC)	27.80	140	

TLM		ENGR	OCTAL	
	ACS STATUS			
A44A	CSA BUS	SAFE	000	
A44B	PITCH JET	ENABLE	000	
A47A	ROLL JET	ENABLE	210	
A47B	YAW JET	ENABLE	210	
B1B	WHEEL DELAY	ENABLE	001	
B2B	ARRAY DELAY	ENABLE	000	
	YAW			
A21	JETS 1,2,5	ALL OFF	371	*
A22	JETS 3,4,6	ALL OFF	371	*
A31C	YAW WHEEL DRIVE	OFF	371	*
A20C	YAW WHEEL DIREC	CCW	367	
A19	YAW WHEEL (RPM)	196.3	311	*
A33	YAW WHEEL(DEG C)	25.22	357	
	ARRAY			
A16B	ARRAY DRIVE	OFF	371	
A12	ARRAY SIN (DEG)	240.292	020	*
A13	ARRAY COS (DEG)	243.9	072	*
	KRYPTON			
A1	HIGH PRESS(PSIA)	2871.	262	
A2	LOW PRESS (PSIA)	49.50	174	*
A3	GAS BOTTL(DEG C)	19.40	200	
	OPEP			
A16A	OPEP DRIVE	OFF	371	
A14	OPEP SIN (DEG)	USE COS	031	*
A15	OPEP COS (DEG)	83.95	151	*
A27	OPEP GYRO STATUS	GYRO 1	102	*
A28	OPEP GYRO TACH	SYNC	016	
A29	OPEP ERR (DEG/S)	-.0051	216	*
A30	OPEP GYRO(DEG C)	58.75	055	
A37	OP SHAFT (DEG C)	18.74	202	
	ACS INVERTER			
D46	ACS INV(115 VAC)	114.8	160	
A32	ACS INVER(DEG C)	35.41	125	*
	SYNC SIGNALS			
D15	400 CPS SYNC	ENABLE	150	
D16A	2461 SYNC 0 DEG	ENABLE	060	
D16B	2461 SYNC 90 DEG	ENABLE	060	

ACS INSTRUMENTATION PRINTOUT (OGO 6 example)

```
01/27R3416RT DATA FRZ MODE  A            OGO-6/F      CDH INSTRU PRINT-06                      OGO-OCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23

                                                   A23 ACS MODE/SUN      S/ ON   021
    MC        DS         RCVD                      D10 LOAD BUS (VOLTS) 30.23   327          D59 LOAD BUS  (AMPS) 12.19   313 *
    MC        RT EG 1                   64 KB      D8  BAT 1     (VOLTS) 31.34   336          D9  BAT 2    (VOLTS) 31.19   335
    S/C CLOCK    063 560 017                       D1  BAT 1      (AMPS) 2.682   055 *        D2  BAT 2     (AMPS) 2.741   056 *
    CLOCK BIAS   105 664 050                       D64 BAT 1 CUR DIRECT  CHRG    112          D65 BAT 2 CUR DIRECT  CHRG   112
    S/C GMT      70 027 1656   04                  D4  ARRAY 1    (AMPS) 7.123   263 *        D5  ARRAY 2   (AMPS) 9.471   356
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```
TLM                                  ENGR       OCTAL
     WB A
C5       WB A FWD   (WATT)          4.236       143
C6       WB A REV   (WATT)          .0129       005
C1       WB A       (DEG C)         18.07       204 *
D24      CONV 3     (+70 V)         70.34       257
D25      CONV 3     (+23 V)         22.87       256

     WB B
C7       WB B FWD   (WATT)            OFF       000
C8       WB B REV   (WATT)            OFF       000
C2       WB B       (DEG C)         6.387       252 *
D26      CONV 4     (+70 V)           OFF       000
D27      CONV 4     (+23 V)           OFF       004

     SP XMTR
C9       SP FWD PWR(WATT)           .5614       045
C3       SP         (DEG C)         16.09       212 *

     CMND RCVRS
F41A     RECVR 1 SIG                  OFF       200
C13      REC 1 AGC 1(DBM)          -84.99       311
C14      REC 1 AGC 2(DBM)          -105.3       041
F41B     RECVR 2 SIG                  OFF       200
C15      REC 2 AGC 1(DBM)         USE C16       312
C16      REC 2 AGC 2(DBM)          -113.5       046

     RANGE+RANGE RATE
C17      R+RR 1 STATUS            STANDBY       147
C18      R+RR PWR   (WATT)                      154
C19      R+RR 2 STATUS                OFF       000

     EQUIPMENT GROUPS
F46/F48 DDHA OSC                     MB 2       544
F46/F48 DDHA HFTU                  HFTU 2       544
F46/F48 DDHA RT/DS                  MC/MC       544
F45/F47 DDHA STATUS                             016

     CDU/DSA STATUS
F49      CMD NETWORK                NET 2       153
F50      CMD GROUP                  GRP D       205
F51      DSA SW SIG                  EG 2       173

     TAPE RCDR 1
F42      TR 1 STATUS               RECORD       417 *
F1       TR1       (+9.5 V)         9.536       356
F2       TR 1      (-9.5 V)                     113
F5       TR 1 PRESS(PSIA)           17.02       172
F8       TR 1 BASE(DEG C)           21.05       173
```

```
TLM                                  ENGR       OCTAL
     DDHA 1
F14      OSC 1      (DEG C)         23.03       165
F20      DDHA 1     (DEG C)         22.04       170
D28      CONV 5     (+16 V)         16.06       256
D29      CONV 5      (+9 V)         9.005       256
D30      CONV 5      (-6 V)        -6.010       142
D31      CONV 5     (-16 V)        -16.18       142
D36      CONV 7     (+16 V)         16.04       260 *
D37      CONV 7      (+9 V)         9.082       262 *
D38      CONV 7      (-6 V)        -5.960       145 *

     DDHA 2
F15      OSC 2      (DEG C)         37.94       117
F22      DDHA 2     (DEG C)         46.10       100
D32      CONV 6     (+16 V)         16.02       256
D33      CONV 6      (+9 V)         9.048       256
D34      CONV 6      (-6 V)        -6.009       142
D35      CONV 6     (-16 V)        -16.10       143
D39      CONV 8     (+16 V)         16.00       256
D40      CONV 8      (+9 V)         9.069       261
D41      CONV 8      (-6 V)        -5.943       145

     ADHA-EG RECEIVED
F25/F33 CAL VOLT 1-1               NORMAL       000 *
F26/F34 CAL VOLT 2-1               NORMAL       031 *
F27/F35 CAL VOLT 1-2               NORMAL       125
F28/F36 CAL VOLT 2-2               NORMAL       204 *
F29/F37 CAL VOLT 1-3               NORMAL       237
F30/F38 CAL VOLT 2-3               NORMAL       316
F31/F39 CAL VOLT 1-4               NORMAL       375
F24/F32 ADHA (DEG C)                21.38       172

     LFTA
F44      LFTA RT BIT RATE           64 KB       106
F17      LFTU BD 3(DEG C)           33.72       131
D20      CONV 2     (+16 V)         16.01       255
D21      CONV 2      (+9 V)         8.985       260
D22      CONV 2      (+5 V)         .0000       000 *
D23      CONV 2      (-6 V)        -5.999       143

     TAPE RCDR 2
F43      TR 2 STATUS                   PB       513
F9       TR 2      (+9.5 V)         9.496       355
F10      TR 2      (-9.5 V)        -9.573       120
F13      TR 2 PRESS(PSIA)           16.29       160
F16      TR 2 BASE(DEG C)           20.72       174
F11      TR 2 PHASE (KBS)         REC/OFF       244 *
```

COMMUNICATIONS AND DATA HANDLING INSTRUMENTATION FORMAT
(OGO 6 example)

```
01/27R3416RT DATA FRZ MODE  A          OGO-6/F     THERMAL INSTRU PRINT-08               OGO-OCC SYSTEM TAPE F13 01/14/70
 GND GMT 70 027 2002  23
                                        A23 ACS MODE/SUN      3S/ 0N   021
        MC        DS        RCVD        D10 LOAD BUS (VOLTS) 30.23    327        D59 LOAD BUS   (AMPS) 12.19   313 *
        MC        RT EG 1          64 KB D8  BAT 1    (VOLTS) 31.34   336        D9  BAT 2     (VOLTS) 31.19   335
        S/C CLOCK   063 560 017          D1  BAT 1     (AMPS) 2.682   055 *      D2  BAT 2      (AMPS) 2.741   056 *
        CLOCK BIAS  105 664 050          D64 BAT 1 CUR DIRECT  CHRG   112        D65 BAT 2 CUR DIRECT  CHRG    112
        S/C GMT     70 027 1656  04      D4  ARRAY 1   (AMPS) 7.123   263 *      D5  ARRAY 2    (AMPS) 9.471   356
```

```
TLM                    DEG C   OCTAL
   BATTERIES
D50ABAT 2     (DEG C) 18.40    203
D51ABAT 1     (DEG C) 18.40    203

   THERMAL FIN
D13 FIN 1A    (DEG C)-25.88    255 *
D14 FIN 2A    (DEG C)-6.872    271

   TRANSMITTERS
C1  WB A      (DEG C) 18.07    204 *
C2  WB B      (DEG C) 6.387    252 *
C3  SP        (DEG C) 16.09    212 *

   EQUIPMENT GROUPS
F14 OSC 1     (DEG C) 23.03    165
F15 OSC 2     (DEG C) 37.94    117
F20 DDHA 1    (DEG C) 22.04    170
F22 DDHA 2    (DEG C) 46.10    100
F24/E32 ADHA  (DEG C) 21.38    172
F17 LFTU BD 3(DEG C) 33.72     131

   TAPE RECORDERS
F8  TR 1 BASE(DEG C) 21.05     173
F16 TR 2 BASE(DEG C) 20.72     174

   ACS
A3  GAS BOTTL(DEG C) 19.40     200
A32 ACS INVER(DEG C) 35.41     125 *
A9  HEAD-A    (DEG C) 20.06    176
A25 SUN SEN 1(DEG C) 19.40     200
A26 SUN SEN 2(DEG C) 14.77     216
A33 YAW WHEEL(DEG C) 25.22     357
A34 PITCH WHL(DEG C) 21.72     370
A30 OPEP GYRO(DEG C) 58.75     055
A37 OP SHAFT (DEG C) 18.74     202

   SOLAR PADDLES
E1  AR 1 INBD(DEG C) 112.0     366
E3  AR-2 INBD(DEG C) 75.99     344
E33 AR1 SHADE(DEG C)-29.05     253
E34 AR2 SHADE(DEG C) 70.00     341
```

```
TLM                      DEG C   OCTAL
   EXP PACKAGES
E13 EP 1 EX16(DEG C) 15.10       215
E14 EP 2 EX17(DEG C)-20.38       322
E15 EP 3 EX11(DEG C)-1.975       310
E16 EP 4 EX15(DEG C) 9.175       240
E17 EP5B EX18(DEG C) 8.617       242 *

   SOLAR EXP PKGS
E26 SOEP 1 -X(DEG C) 33.72       131
E29 SOEP 2 +X(DEG C) 22.70       166

   OPEPS
E19 OPEP 1 +Z(DEG C) 6.805       235
E20 OPEP 2 -Z(DEG C) 6.381       236

   ASEPS
E31 ASEP 1     (DEG C) 11.40     230 *
E32 ASEP 2     (DEG C) 10.84     232

   LOUVER PANELS
E5  +X MD PAN(DEG C) 14.44       217 *
E6  +X AF PAN(DEG C) 20.72       174
E8  -X AF PAN(DEG C) 23.03       165 *

   EXP MTG PLATES
E21 -Z TP PAN(DEG C) 24.02       162
E22 +Z MD PAN(DEG C) 21.38       172
E7  -Z MD PAN(DEG C) 22.04       170 *

   SUB MTG PLATES
E23 +X TP PAN(DEG C) 16.09       212
E24 -X AF PAN(DEG C) 18.74       202
E30 -Y MD PAN(DEG C) 19.73       177

   ATTITUDE
A4  PITCH ERROR(DEG)-.2207       170
A5  ROLL ERROR (DEG) .2970       200 *
A10 YAW ERROR  (DEG)-.8529       170
A11 ARRAY ERROR(DEG) 1.051       200
A12 ARRAY SIN  (DEG)240-292      020 *
A13 ARRAY COS  (DEG) 243.9       072 *
A14 OPEP SIN |  (DEG)USE COS     031 *
A15 OPEP COS |  (DEG) 83.95      151 *
```

```
SC1                        DEG C   OCTAL
    EXPERIMENTS
    04-REBER
082 ELECT PKG              17.15   130
089 ION SOURCE             27.39   170

    05-PICKETT
076 EXP                    11.06   261

    07-MCKEOWN
013 TUBE                   8.998   062

    11-BLAMONT
103 FILTER                 -2.479  254
027 PMT                    -2.479  254

    12-CLARK
079 ELECTRONICS                    002
114 FIL HEAT SINK                  000
127 HYDROGEN CELL                  003

    14-BLAMONT
061 PMT                    20.18   152
105 INTERF FILTER          31.85   307

    16-FARLEY
020 LOGIC BOX              24.28   131

    20-STONE
087 RANGE TELSC            18.30   147
106 CERENKON TELSC         21.90   136

    21-CAIN
033 LAMP A                 107.9   333
063 CELL A                 28.39   052
119 LAMP B                 93.27   226
123 CELL B                 43.39   165

    23-AGGSON
022 ANT                    10.74   052
```

THERMAL INSTRUMENTATION PRINOUT (OGO 6 example)

APPENDIX D

GROUND STATION TELEMETRY ASSIGNMENTS FOR INITIAL OPERATIONS

The telemetry items to be displayed during readiness tests and the initial operations are given in this appendix (priorities are specified by the numerical order of listing).

Joburg and Madgar Assignments

Rev	Strip Chart				Lights	
000	1.	MC-65	9.	Enable bit	11.	F40, B-3 to B4, B7 A12
	2.	A23	10.	A1	12.	B11, B12
	3.	A24	13.	D8	15.	A3
	4.	D4	14.	D9	20.	MC-67
	5.	D5	16.	A21		
	6.	A10	17.	A22		
	7.	A11	18.	D1		
	8.	D10	19.	D2		
001	1.	MC-65	9.	A11	12.	E4
	2.	A23	10.	D4	18.	A3
	3.	A24	11.	D5	19.	D50
	4.	D10	13.	A1	20.	D51
	5.	D8	14.	D1		
	6.	D9	15.	D2		
	7.	A7	16.	A21		
	8.	A10	17.	A22		

ERSOCC Assignments (via Madgar DTS)

Rev	Strip Chart									
000 and 001	1.	F40* (D17)	1.	A23	1.	A21	1.	D1	1.	A1
	2.	B11* (D59)	2.	A24	2.	A22	2.	D2	2.	D50
	3.	B2* (D60)	3.	A7	3.	A17	3.	D4	3.	D51
	4.	B3* (D61)	4.	A40	4.	A18	4.	D5	4.	C9
	5.	B4* (D64)	5.	A41	5.	A19	5.	D8		
	6.	B8* (D65)	6.	A42	6.	A10	6.	D9		
	7.	B7* (A20)	7.	A43	7.	A11	7.	D10		
	8.	MC-65	8.	A12	8.	A5	8.	A31		

*When deployment verified switch to telemetry words listed in parentheses and leave for Rev 001.

Joburg and Madgar Assignments (continued)

Rev	Strip Chart		Lights
015 and after	1. MC-65*	9. D2	17. A1
	2. A23	10. D4	18. E19
	3. D10	11 D5	19. E20
	4. D8	12. A21	20. A3
	5. D9	13. A22	
	6. A10	14. A4	
	7. A11	15. A5	
	8. D1	16. A31	

Winkfield Assignments

Rev	Strip Chart	
002	1. MC-65	9. A11
003	2. A23	10. D4
004	3. A24	11. D5
005	4. D10	12. A1
	5. D8	13. D1
	6. D9	14. D2
	7. A7	15. A21
	8. A10	16. A22

ERSOCC Assignments (via Winkfield DTS)

Rev	Strip Chart				
002	1. A23	1. A21	1. D1	1. D17	1. A1
003	2. A24	2. A22	2. D2	2. D59	2. D50
004	3. A7	3. A17	3. D4	3. D60	3. D51
005	4. A40	4. A18	4. D5	4. D61	4. C70
	5. A41	5. A19	5. D8	5. D64	
	6. A42	6. A10	6. D9	6. D65	
	7. A43	7. A11	7. D10	7. A20	
	8. A12	8. A5	8. A31	8. MC-65	

*Use MC-35 when real-time equipment group is in accelerated subcommutator mode.

Winkfield Assignments (continued)

Rev	Strip Chart	
008 and after	1. MC-65*	9. D8
	2. A23	10. D9
	3. D10	11. D59
	4. D1	12. D17
	5. D2	13. D64
	6. D4	14. D65
	7. D5	15. D50 (D51)
	8. D6	16. A31

Alaska Assignments

Rev	Strip Chart		Lights
001	1. MC-65	9. F42	17. D50
002	2. A23	10. F5	18. D51
	3. A24	11. F8	19. A3
	4. D10	12. F19	20. A1
	5. D8	13. D4	
	6. D9	14. D5	
	7. C70	15. D1	
	8. C63	16. D2	

ERSOCC Assignments (via Alaska)

Rev	Strip Chart				Lights
001	1. F40**(D6)	1. A23	1. A12	1. D1	1. Enable bit
002	2. B11**(D17)	2. A21	2. A18	2. D2	2. B8** (A1)
(real	3. B12**(D59)	3. A22	3. A19	3. D4	3. A3
time)	4. B3**(D60)	4. A7	4. A24	4. D5	4. D50, D51
	5. B4**(D61)	5. A40	5. A17	5. D8	
	6. B7**(D64)	6. A41	6. A5	6. D9	
	7. B8**(D65)	7. A42	7. A10	7. D10	
	8. MC-65	8. A43	8. A11	8. A31	
001	1. F40**(D57)	1. A23	1. B8** (A17)	1. D1	1. Enable bit
002	2. D17	2. A21	2. A18	2. D2	2. A1
(play-	3. D59	3. A22	3. A19	3. D4	3. A3
back)	4. B3**(D60)	4. A7	4. A24	4. D5	4. D50, 51
	5. B4**(D61)	5. A40	5. A4	5. D8	
	6. D4**(D64)	6. A41	6. A5	6. D9	
	7. D6**(D65)	7. A42	7. A10	7. D10	
	8. B7**(MC-65)	8. A43	8. A11	8. A31	

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*Use MC-35 when real-time equipment group is in accelerated subcommutator mode.

**When deployment verified switch to telemetry words listed in parentheses and leave for rev 002.

Alaska Assignments (continued)

Rev	Strip Chart		Lights
008 and after	1. MC-65*	9. D5	17. A1
	2. A23	10. D59	18. E1
	3. D10	11. D17	19. E30
	4. D8	12. D50	20. E55
	5. D9	13. D51	
	6. D1	14. D64	
	7. D2	15. D65	
	8. D4	16. A31	

ERSOCC Assignments (via Alaska) (continued)

Rev	Strip Chart				Lights
008 and after	1. D1	1. A10	1. Payl.	1. Payl.	1. E1
	2. D2	2. A11	2. Payl.	2. Payl.	2. E30
	3. D4	3. A21	3. Payl.	3. Payl.	3. A1
	4. D5	4. A22	4. Payl.	4. Payl.	4. A23
	5. D8	5. A4	5. Payl.	5. Payl.	
	6. D9	6. A5	6. Payl.	6. Payl.	
	7. D10	7. A7	7. Payl.	7. Payl.	
	8. MC-65*	8. A31	8. Payl.	8. Payl.	

Ororal Assignments

Rev	Strip Chart		
004	1. MC-65	9. A11	17. A3
	2. A23	10. A4	18. E1
	3. A24	11. D5	19. E30
	4. D10	12. A1	20. D50
	5. D8	13. D1	
	6. D9	14. D2	
	7. A7	15. A21	
	8. A10	16. A22	

*Use MC-35 when real-time equipment group is in accelerated subcommutator mode.

ERSOCC Assignments (via Ororal DTS)

Rev	Strip Chart				Lights
004	1. A23	1. A21	1. D1	1. D17	1. A1
	2. A24	2. A22	2. D2	2. D59	2. D50
	3. A7	3. A17	3. D4	3. D60	3. D51
	4. A40	4. A18	4. D5	4. D61	4. C57
	5. A41	5. A19	5. D8	5. D64	
	6. A42	6. A10	6. D9	6. D65	
	7. A43	7. A11	7. D10	7. A20	
	8. A12	8. A5	8. A31	8. MC-65	

Ororal Assignments (continued)

Rev	Strip Chart		
010 and after	1. MC-65*	9. D2	17. A1
	2. A23	10. D4	18. E1
	3. D10	11. D5	19. E30
	4. D8	12. A21	20. Payl.
	5. D9	13. A22	
	6. A10	14. A4	
	7. A11	15. A5	
	8. D1	16. A31	

Santiago Assignments

Rev	Strip Chart		Lights
004	1. MC-65	9. A11	12. E1
	2. A23	10. D4	18. A3
	3. A24	11. D5	19. D50
	4. D10	13. A1	20. D51
	5. D8	14. D1	
	6. D9	15. D2	
	7. A7	16. A21	
	8. A10	17. A33	
005	1. A23	9. A5	16. A1
	2. A12	10. MC-35	17. D42
	3. D10	11. Enable Bit	18. D4
	4. A7	12. A21	19. D5
	5. A40	13. A22	
	6. A41	14. A10	
	7. A6	15. A11	
	8. A4	20. A24	

*Use MC-35 when real-time equipment group is in accelerated subcommutator mode.

Santiago Assignments (continued)

Rev	Strip Chart		Lights
013 and after	1. MC-65*	9. D2	17. A1
	2. A23	10. D4	18. E1
	3. D10	11. D5	19. E30
	4. D8	12. A21	
	5. D9	13. A22	
	6. A10	14. A4	
	7. A11	15. A5	
	8. D1	16. A31	

Quito Assignments

Rev	Strip Chart		Lights
005	1. A23	9. A5	16. A1
	2. A12	10. MC-35	17. D42
	3. D10	11. Enable bit	18. D4
	4. A7	12. A21	19. D5
	5. A40	13. A22	
	6. A41	14. A10	
	7. A6	15. A11	
	8. A4	20. A24	
013 and after	1. MC-65*	9. D2	17. A1
	2. A23	10. D4	18. E1
	3. D10	11. D5	19. E30
	4. D8	12. A21	20. Payl.
	5. D9	13. A22	
	6. A10	14. A4	
	7. A11	15. A5	
	8. D1	16. A31	

Rosman Assignments

Rev	Strip Chart		Lights
006	1. A23	9. A4	17. A24
007	2. D10	10. A5	18. A1
	3. A7	11. MC-35	19. B3
	4. A40	12. A21	20. B4
	5. A41	13. A22	
	6. A42	14. A10	
	7. A43	15. A11	
	8. A6	16. A12	

*Use MC-36 when real-time equipment group is in accelerated subcommutator mode.

OCC Assignments (via Rosman)

Rev	Strip Chart				Lights
006	1. A4	1. A23	1. A42	1. D1	1. A1
007	2. A5	2. A24	2. A43	2. D2	2. A3
	3. A10	3. A7	3. A21	3. D4	3.
	4. A11	4. A6	4. A22	4. D5	4.
	5. A12	5. A40	5. A20	5. D8	
	6. A13	6. A41	6. A17	6. D9	
	7. A16	7. D43	7. A18	7. D10	
	8. MC-35	8. D45	8. A19	8. A31	

Rosman Assignments (continued)

Rev	Strip Chart		Lights
013 and after	1. MC-65*	9. D2	17. A1
	2. A23	10. D4	18. E1
	3. D10	11. D5	19. E30
	4. D8	12. A21	20. Payl.
	5. D9	13. A22	
	6. A10	14. A4	
	7. A11	15. A5	
	8. D1	16. A31	

OCC Assignments (via Corpus)

Rev	Strip Chart
013 and after	Same as ERSOCC via Alaska 008.

*Use MC-35 when real-time equipment group is in accelerated subcommutator mode.

APPENDIX E

CONTINGENCY PLAN FOR INITIAL OPERATIONS

Station	Monitor Assignment	Eventuality	Special Conditions	Action
WTR	Spacecraft data from liftoff through loss of signal	Any malfunction	None	Report to ERSOCC
Madgar* Rev 000	Deployment verification, evaluation of spacecraft subsystems	1) Loss of RF	Authorized by ERSOCC	Command 137 86 MHz transmitter off/on UV bus 1 reset
		2) Loss of modulation	Authorized by ERSOCC	Command EG-1 on Mo2/HFTU 2
		3) (2) Unsucessful	Authorized by ERSOCC	Command EG-2 on/EG-2 to real time (At loss of signal Command EG-1 to real time
		4) Deployment failure to sequence	None	Command arm bus/array deploy
Alaska Rev 001	Attitude control and power subsystems performance and data quality Command ACS in Mode 2B (and 141) Command assignment to retrieve data from liftoff Relay ERTS data via data link to ERSOCC at 16 kbit	1) Loss of communication to ERSOCC	NONE	Function as ERSOCC with discretion to perform any or all corrective actions heretofore stated In addition, may elect to postpone scheduled playback due to poor signal reception
		2) Poor signal reception	Confirmed by Joburg or attempts at improvement on ground are fruitless after two minutes	If no appreciable improvement, suspend playback until Alaska 002 Use remainder of pass to improve signal reception.
		3) Loss of RF or modulation	Authorized by ERSOCC	Same as Madgar
		4) Deployment incomplete	Authorized by ERSOCC	Send backup commands in properly timed sequence
ERSOCC (via Alaska) Rev 002	All systems performance	1) ACS in Mode 1	Deployment complete	Command ACS to Mode 2A
		2) Spacecraft unstable	No data or evidence or gas usage	Command ACS to Mode 2A
		3) Earth search pattern anomaly	Horizon scanner anomaly is concluded	Leave ACS in Mode 2B and study pattern
		4) Pitch rate gyro failure	Positive diagnosis	Command ACS to Mode 2A until rates and orientation are determined
Joburg Rev 001 Alaska Rev 002 Wnkfld Rev 002 003 Santiago Rev 005, 006 Ororal Rev 004	Attitude control, power, and thermal subsystems performance Command assignments to playback spacecraft tape recorders (Alaska 002, Wnkfld 002, 003, Santiago 005, (Communications and data handling in ACS) 006)	1) Any malfunction	a) Emergency that is clearly defined	a) Corrective commands upon authorization from ERSOCC
			b) Degradation	b) Cutback in mission for considering maximization of performance without undue risk
		2) Loss of communication with ERSOCC	None	Take no action
Alaska Rev 003	ACS performance Command assignment to place ACS in Mode 2C then normal	Horizon scanner anomaly	Confirmation prior to acquisition	Delay earth acquisition
Rosman Rev 006, 007	Power and attitude control subsystems performance Provide real time data to GSFC (PCM at 1 kbit) via data link Enables commands to be sent directly from ERSOCC	1) Loss of Rosman/ERSOCC data link	Not transitory	Functions as a remote station Monitors assigned to telemetry words and reports values
		2) Loss of communication to Rosman	None	Rosman to maintain command and data acquisition equipment per OPS plan
		3) Loss of RF or modulation		(Same as Joburg Rev 000)
ERSOCC Rev 005 (via Rosman)	All systems performance	Mode 4 abnormal		Command Mode 3

*Command assignment automatic (Commands 100 and 140)