CTS-B For TV Broadcast

Government of Canada Department of Communications

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CTS B FOR TV BROADCAST

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This document is a technical proposal for planning purposes only. It has been assumed in the preparation of this document that the DOC tasks would be funded by Canada and the ESA tasks by ESA. It must be emphasized that no commitment financial or otherwise to initiate the program has been authorized.

TABLE OF CONTENTS

CTS-B FOR TV BROADCAST

LIST OF FIGURES

1.0 INTRODUCTION

This report describes a plan for the use of the CTS design for a new program termed CTS B. In its revised form CTS will accommodate a high powered (450 watts) travelling wave tube transmitting through a high gain steerable antenna of approximately 1^{o} beamwidth for an experimental program of direct TV broadcasting.

It is proposed that CTS B would be flown on the third Ariane test flight (L03) which is planned for launch in May 1980. Proposals for various candidate payloads for L03 will be reviewed in October 1976 at an ESA Council meeting and the final selection will be made at that time. ESA has stated that a commitment by DOC to undertake the program would be required by November 1976.

The information summarized in this report is a result of a feasibility study conducted by a task team at the Communications Research Centre of DOC supported by inputs from industry, in particular a study contract to assess the extent of redesign of the CTS structure required to meet the more severe environmental levels of the Ariane launch vehicle.

It is presumed that the reader has an understanding of the design of the present CTS spacecraft (named Hermes). Details of Hermes may be found in References 1.1 and 1.2.

The main objectives of the CTS B program were agreed upon in a meeting held between DOC and ESA at ESTEC on 20, 21 July, 1976. See Reference 1.3 for details of the ESTEC meeting. From this meeting and from subsequent meetings at DOC, the technical objectives from the Canadian standpoint have been formulated and are outlined in Section 2. In Section 3, a description of CTS B is given, outlining the manner and extent to which the present Hermes design would be modified to accommodate the higher powered European communications payload. Section 4 describes the plan for mission control during transfer, drift and on-orbit phases of the mission. The division of tasks between DOC and ESA is reviewed in Section 5 together with other program plans such as schedule and testing plans. Cost estimates are given in Appendix A.

2.0 PROGRAM OBJECTIVES

From the ESTEC meeting and from subsequent telephone conferences, it has been agreed that the payload for CTS-B will be a fully redundant single channel repeater including two 450 watt TWTs with a steerable high gain antenna of approximately 1 degree beam. the proposed mission life is two years with a plan for sharing between DOC and ESA based on shifting longitude of the satellite from 90°W to 5°W. Figure 2.1 shows typical footprints in Canada of the high gain antenna with the spacecraft at 90°W.

Canadian objectives for the program are as follows:

Political

- Expand and strengthen the present level of DOC/ESA cooperation.
- Open possibilities for greater Canadian participation in ESA and other European programs in the future.

Marketing

- Demonstrate Canadian capability in transponder, solar array and bus design to Europe and Third World countries.
- Demonstrate Canadian capability as a satellite system developer.

Technical

- Demonstrate television broadcast capability
- Demonstrate operational TWT and high gain antenna hardware
- Study interference between fixed and broadcast services
- Provide a follow-on to Hermes experiments
- Gain experience with Ariane interfaces and operations

Some additional comments may be made on the first of the technical objectives, - the demonstration of TV broadcast capabilities. It is proposed (Ref. 2.1) that the method of implementing this objective would be to set up an extended pilot project providing receivers to homes in urban and rural communities and carrying TV programs in parallel with the existing network in order to assess the impact of continuous quasi-operational use over an extended period.

3.0 SPACECRAFT DESCRIPTION

3.1 General

The general arrangement of CTS B in its launch configuration is shown in Figure 3.1 and the appearance in orbit is given in Figure 3.2. The main external feature that differs from Hermes is the antenna configuration, - with removal of the two small SHF dish antennas and the substitution of a large elliptical transmit antenna (1.3 m x 2.0 m) and a small Eurobeam receive antenna of 0.7 m diameter. Further details of these antennas are given in Section 3.2.2.

The transponder equipment is mounted on the south panel with a layout as shown in Figure 3.4. All of the equipment shown will be provided by ESA. The low-powered components of the transponder such as the receiver and the FET amplifiers, which DOC might supply, are mounted on the inside of the forward platform. This arrangement facilitates a clean interface between the two agencies such that the south panel can be separately integrated and tested in Europe while the bus, including the low-powered repeater equipment, can be integrated and checked out in Canada. (See Figure 3.3)

A fully redundant repeater system is planned, as described in Section 3.2.1, and as with Hermes, variable conductance heat pipes will be used to provide heat dissipation while the tubes are operating. The heat pipe radiating fin shown in Figure 3.4 indicates the area required, - the fin size being similar to that of Hermes. Details of the proposed thermal redesign are given in Section 3.6.

The structure of the spacecraft follows the same general arrangement of Hermes; however, as noted in Section 3.5, considerable redesign work will be required to meet the more severe launch environment of the Ariane vehicle. The design objective will be to ensure that the individual electronic units and mechanisms in the spacecraft experience G loading no more severe than those for which the units were qualified (2914 Delta launch environment).

With the revised structure and the new payload arrangement there will be a reduction in the moment of inertia ratio from that of Hermes. It is estimated that during the spinning phase of the mission, the ratio of spin moment of inertia to maximum transverse axis moment of inertia will be about 1.1. This is considered adequate and provides a reasonable margin in the event of minor changes to the mass properties of the antenna configuration. Spacecraft lift-off weight is estimated to be 1670 pounds, - see Section 3.10 for a summary of mass properties.

The CTS B design makes maximum use of existing Hermes hardware and in the case of the power system, telemetry and command, attitude control, reaction control and apogee motor, the changes are minor,—

as reviewed in subsequent sections. In most cases, it is possible to use existing flight spare equipment or "build-to-print" additional units.

The main thrust of the design effort for CTS B has been to accommodate two 450 watt tubes, as shown in Figure 3.4. It might be noted however that a 200 watt version is being considered by ESA as an alternative, and in this case, the changes to the Hermes design are fewer than with the higher powered tube. With the 200 watt tube, for example, there would be no need for a heat pipe radiating fin and the existing Hermes solar array blanket could be used whereas the 450 watt tube calls for some increase in the solar cell area, as noted in Section 3.3.1.

In summary, the design activity has given confidence that the Hermes design can be modified in a straightforward way to accommodate the new antenna arrangement and the higher powered travelling wave tubes. Although considerable rework will be required in the structure and thermal subsystems, it has been possible to leave other subsystems virtually unchanged and thereby achieve a very economical development and manufacturing program.

3.2 Payload Accommodations

3.2.1 Transponder

A block diagram of the proposed CTS B payload is shown in Fig. 3.5. A single up-link channel in the 14 GHz band is received by a separate receiving antenna with 7.5° X 4.25° beam. After bandpass filtering (component 02 of Fig. 3.5) to reject signals being transmitted by the satellite, the signal is amplified and translated to 12 GHz by a single conversion receiver identical to that used on Hermes (component 03). The receiver output is amplified by component 05, a FET amplifier similar to that of Hermes. The channel bandwidth is defined by an equalized bandpass filter (06) and the signal is subsequently amplified by another FET amplifier (08) which in turn drives the 450 watt output TWT. After output filtering to reject receive band noise generated in the TWT (14), a single channel is radiated by a separate transmitting antenna with a 0.8 x 1.4° beam. The transponder EIRP is approximately 69 dBW.

It is suggested that DOC provide the low power portion of the transponder, thereby enabling considerable use to be made of existing Hermes flight spare hardware and designs. A complete set of receiver components of flight quality is available aside from LO/mixer assemblies which could be procured to CTS designs. If the gain of FET amplifier 05 is reduced to the value used in Hermes and the gain of amplifier 08 is increased accordingly, Hermes flight spare and qualification model amplifiers could be used for amplifier 05. FET amplifier 08 requires some development effort due to the required ±10 dBm output. The development could be carried out by DOC or by RCA (Montreal) which has experience in the development of +10dBm, 12 GHz FET amplifiers.

3.2.2 Antennas

The receive and transmit antennas will be provided by ESA and hence, only brief details will be noted here.

The large transmit antenna, with a steerable elliptical reflector 1.3 x 2.0 metres, will be a new development - probably making use of carbon fibre technology being developed in Germany.

The reflector is steered with a pointing mechanism derived from the OTS program and it is planned to use a unique RF sensing system to enable the reflector to lock onto a ground station with greater pointing accuracy than can be achieved with the Hermes attitude control system. The beam shape in 1.4^{o} X 0.8^{o} and ground footprints with typical Canadian aiming points are shown in Figure 2.1. Estimated weight including pointing mechanism and the RF sensing feature is 21.2 kg.

The receive antenna is much smaller and lighter -, 0.70 m diameter and 2.4 kg, the design being that of the OTS Eurobeam antenna.

As shown in Figure 3.1, the two antennas have been located on the forward platform so as to keep their baseplates close to the thrust tube support,thereby providing a clear field of view for the infrared earth sensors, and avoiding physical interference with the heat pipe radiator fin on the forward edge of the south panel.

It might be noted that the CTS forward deck is especially designed with direct load paths and minimal transverse thermal gradients to ensure an optimum dimensional stability of the forward surface. In this way, in-orbit misalignments between the earth sensor and the antenna pointing axis are minimized.

3.3 Power System Modifications

3.3.1 Solar Array

It is suggested that ESA provide the flexible solar array blanket and hence exact details cannot be given here on the manner in which the solar cell area would be increased to accommodate the additional power requirement of the 450 watt TWT. It is probable that one additional Solar Panel Assembly (4 panels) would be required in each blanket and that one of the blank panels on the Hermes array would be filled in with cells. It is not anticipated that a change to higher output solar cells could be justified, hence the qualification model Hermes blanket could be modified and used. As blanket wiring space is limited, it will be necessary to parallel up the experiments section panels to accommodate the extra SPA. If the cells on the previously blank panel are connected to the housekeeping array, thermal control heater loads can be transferred from the experiments to the housekeeping array.

Modifications to the Solar Array Mechanical Assembly (SAMA) would be straightforward. The BI-STEM boom, which extends the flexible blanket, already has provision for sufficient boom length to accommodate the extra 4 panels and the clamping arrangement used to hold the blanket during launch can be adjusted to accommodate the additional thickness of the stowed array. The present slip rings can readily accommodate the extra current for the increased solar array power if two rings presently assigned to instrumentation wiring are transferred to power wiring.

One flight spare SAMA is presently available and would be refurbished and an additional SAMA would be manufactured to flight standard.

The body array design would be unchanged. Two east-west panels are available as Hermes flight spares. It will be necessary to procure a further two east-west and two JBSA panels.

3.3.2 Power Conditioning Equipment

Apart from minor improvements resulting from Hermes on-orbit experience, the design of power conditioning units for CTS B will be unchanged. Power conditioning for the TWTs and experiments bus switching or regulation will be an ESA responsibility. The DOC housekeeping section can accommodate the power for the CRC transponder front end and for the antenna pointing mechanism controller. Thus, the experiments power conditioner which experienced relay difficulties in the Hermes flight operation will be eliminated. Details of the manner in which existing engineering model and qualification model units will be refurbished to meet the agreed quality standards for this program are outlined in Reference 3.2

Although some spare battery cells exist from the Hermes program, it is planned to procure a new set of flight-quality batteries for the CTS B program.

3.4 ACS/RCS Performance

3.4.1 Attitude Control System

An initial assessment has been made of the influence on ACS performance of the large steerable transmit antenna and of the increased moments of inertia resulting from the larger antennas and increased solar array size. Details of this assessment are given in Reference 3.3.

Considering first the impact of the large antenna, solar pressure acting on the antenna will result in a small increase in the periodic component of pitch torque. This can be readily handled by momentum wheel speed variation with no fuel penalty. With the antenna centre displaced northwards from the centre line of the forward panel as shown in Figure 3.1, a small roll torque will be induced with a consequent fuel consumption of about 0.3 lbs/year of hydrazine. The low inertia of the antenna reflector in relation to that of the spacecraft makes it unlikely that there will be any major influence of the steering motions on the existing control system. It thus appears feasible to design an antenna steering control system (suggested by ESA) which would operate simultaneously and not interfere with the spacecraft ACS.

Estimates of moment of inertia values with the larger solar array deployed have been made. To accommodate the larger moments of inertia of CTS B, the only change necessary to the Attitude Control Electronics Assembly (ACEA) is to change the rate path delay timing to compensate for an increase in spacecraft nutation period from 5.9 to 7.5 minutes. This modification to the ACEA is straightforward to accomplish with the existing qualification model unit.

Other minor changes to the ACEA and to the infrared earth sensor may also be incorporated to make performance improvements and, in the case of the earth sensor, to eliminate a minor malfunction in the mirror assembly that presently exists on Hermes.

For the ACS equipment, either refurbished qualification models, flight spare units or, in the case of the earth sensor, new flight quality equipment will be used. No reuse will be made of engineering model units or harnesses.

3.4.2 Reaction Control System

Meetings have been held with the supplier, Hamilton Standard, to discuss an economical yet adequate program based on refurbishing the Engineering Model RCS. An agreement was reached that the following items should be supplied as new equipment for this refurbishment program:

Component	Quantity
Low Thrust Engines (LTE)	11
High Thrust Engines (HTE)	2
Propellant Fill and Drain Valves	2
Heat Shields - LTE	16
Heat Shields - HTE	2
Temperature Sensors - Tank	2
Temperature Sensors - LTE	12
Heaters - LTE Chamber	16
Heaters - LTE Valve	16
Heaters - HTE Chamber	2
Heaters - HTE Valve	2
Heaters - Latch Valve Module	1
Heaters - Tank	2
Heaters - Line	1 set

A comprehensive refurbishment program has been proposed by Hamilton Standard including the Propellant Service Cart and the Electrical Service Cart and subsystem acceptance tests. Details of the refurbishment plan are contained in Reference 3.4.

Concerning the ability of the CTS reaction control system to perform north-south stationkeeping, a study has recently been completed at CRC to determine whether this manoeuvre can be done with Hermes. Section 4.3 contains information of this and on the fuel budget for CTS B assuming north-south stationkeeping to ±.1 degrees.

3.5 Structural Redesign

A major engineering task that would be required is to redesign the structure in such a way that the existing units from the Hermes program will receive no more severe a G loading with the Ariane qualification test than with a Thor Delta launch. As this is an important consideration in the feasibility of the CTS B program, a study contract has been let with Spar Aerospace Products to examine this matter in some detail.

Although this study contract is not yet complete, the interim findings of it are summarized in Reference 3.5 which includes an estimate of the structural weight increase (about 70 lbs).

The general approach will be to maintain basic Hermes geometry, thereby minimizing cost of tooling changes and to strengthen and stiffen all panels and structure with the exception of the E/W curved panels. As there is no longer a tight weight limitation on CTS B, the redesign will endeavour also to reduce the manufacturing cost compared to the original Hermes structure by simplifying detailed design.

It should be noted in Reference 3.5 that to provide an acceptable design, it will be essential to arrange with the Ariane office for some form of notching in the longitudinal axis sinusoidal vibration test in the region above 45 Hz, where the structure is undergoing its major natural resonance. Similarly with lateral sinusoidal vibration, it will be necessary to negotiate a notching in the G levels in the range above 17 Hz. The whole subject of qualification test levels will require much more discussion.

3.6 Thermal Redesign

The major impact of the new payload complement on CTS B is in the south panel area where the high powered transponder equipment is mounted. Based on dissipation values and operating temperature limits provided by ESA, various design arrangements have been considered and an arrangement that seems well suited for thermal design is that shown in Figure 3.4 whereby the south panel is reserved for only the high powered ESA-supplied TWT, EPC and PWM. The TWT packages will be electrically cross-strapped such that the EPC of one package will operate the tube of the other package and thereby avoid the problem of redundant tube-EPC combination becoming too cold while in operative.

Thermal staff from CRC and Spar Aerospace Products have reviewed the design changes required for the south panel layout, relocation of receiver and amplifier onto the forward deck, effect of antennas on the forward deck, changes to north panel layout and to the structural design. Detailed comments on these design aspects are contained in Reference 3.6. In all cases it was considered that a satisfactory design modification could be accomplished and in the case of the south panel, the heat pipe radiating fin would be no larger than that of the present Hermes design.

A summary of comments on the various redesign areas is given below:

- Two 450 watt tubes will be located on the south platform. The high dissipations produced by the tube, its EPC and PWM will require heat pipe radiators extending in the forward or earth pointing direction. There will be 3 radiators, one for each EPC/Tube package and one for the 2 PWM's. The heat pipe systems will be vapour controlled to check heat flow to the radiators during the low power phases. The detailed thermal design of this panel would be the responsibility of ESA.

- The FET amplifiers and Receiver, all low power equipment, will be located internally on the forward platform. These components may have to be isolated from the platform to reduce the daily temperature variation experienced by this structure. Design temperatures may have to increase.

- The two shrouded SHF antennas will be replaced by two antennas which are not shrouded. The receive antenna is similar in size to the CTS model, however, the transmit antenna is much larger and in fact overhangs the north panel and comes close to the heat pipe radiators extending from the south panel. These two antennas will need to be conductively isolated from the structure to reduce the heat leak problem during the low power phases.

- The CTS beacon and experiments converter on the north panel will be removed and replaced by an interface unit which will be of low dissipation. The second surface mirror radiating area of the north panel under these components will be covered with super insulation.

- Structural changes necessary to stiffen the structure because of the severe Ariane launch environment will have to be incorporated in the thermal design analytical models and appropriate changes made.

3.7 Telemetry Tracking and Command Subsystem

No changes to this subsystem will be required by the new CTS B payload. An improvement on the Hermes channel assignment will be made in the telemetry encoders which will have complete redundancy so that the loss of one encoder will not entail the loss of some data as is now the case with Hermes.

Concerning the quality of hardware used for this subsystem, some of the Engineering Model spacecraft hardware can be used together with flight spare equipment and in some cases new flight quality units will be manufactured. In those cases where Engineering Model units are used, they will be refurbished and for the corresponding redundant unit flight quality equipment will be used. In Reference 3.7, each of the units of the TT&C subsystem is reviewed individually with notes on test history, problem areas and recommendations for refurbishment or making new units.

It is not planned to make any change to either the on-orbit telemetry and command antennas or to the belt antenna design.

3.8 Apogee Motor

A flight spare apogee motor is available, complete with handling hardware and it is planned to remove the propellant and insulation and reload the motor with a fresh charge of propellant sized to suit the needs of the CTS B program. An inert motor is also available for dynamic model testing. This motor is an exact dynamic replica of the fully loaded flight motor.

Concerning the required apogee motor fuel loading for the CTS B mission, a preliminary study has been made per Reference 3.8. This indicates that with the capabilities for off-loading or on-loading the CTS apogee motor, and for the Ariane transfer orbit characteristics, the spacecraft weight at lift-off could fall within the range of 1590 to 1777 lbs. As noted in Section 3.10 the estimated lift-off weight for CTS B is 1670 lbs.

3.9 Spacecraft Harness

The wiring harness for the proposed CTS B satellite will be essentially the same as that of Hermes. There will be no compromise in the quality of the components or workmanship.

Some subsystem harnesses that were previously fabricated in industry may be made at CRC. Much of the associated hardware required is in reserve stock at CRC. Other components required will be purchased using the same procurement specifications previously used on CTS.

3.10 Mass Properties Summary

CTS B

Mass Properties Summary

SUBSYSTEM	CTS B WT. Lb.	CTS B WT. Kg.	HERMES WT. Lb.	HERMES WT. Kg.	COMMENTS
SHF Communications	206	93.5	134	61	Additional communication equipment.
Telemetry and Command	32	14.5	32	14.5	No change.
Deployable Solar Array	136	62.0	132	60	Additional length required.
Power	90	41.0	90	41	No changes.
Electrical	33	15.0	33	15	No change.
Attitude Control	55	25.0	55	25	No change.
Structure	190	86.5	121	55	Additional thickness of critical sections.
Reaction Control	100	45.5	95	43	Additional fuel.
Thermal Control	53	24.0	44	20	Larger heat pipes.
Balance Weights	20	9.0	12	5.5	Additional allowance.
Apogee Motor	755	343.0	743	338	Additional capability required.
TOTAL PAD WEIGHT	1670	759.0	1491	678	

3.11 Launch Vehicle Interfaces

Figure 3.6 shows the location of the CTS B spacecraft in relation to the Ariane shroud and the other L03 components, the APPLE, CAT and associated adapters. The umbilical connectors with Hermes are designed for lateral release in two locations diametrically opposed. This arrangement may need to be modified for the L03 mission if the umbilical connection is via the adapter to the APPLE spacecraft.

As noted in Figure 3.6, there is ample access to the safe and arm unit for the apogee motor which is located on the exposed corner of the forward deck. Concerning the radio frequency energy radiated from the spacecraft during liftoff, the present telemetry system broadcasts at 2 watts at a frequency of 2 GHz.

It will be necessary to demonstrate that CTS B and the launch vehicle telemetry and command systems are compatible since they operate in the same 2 GHz band. A special test using a representative TT&C subsystem mounted on a test platform will be required prior to the environmental test phase.

It will be necessary to request that an acoustic insulation blanket be mounted in the shroud for L03 to reduce the acoustic energy levels to those of the Delta launch vehicle.

3.12 Electrical and Mechanical Ground Support Equipment

3.12.1 EGSE

The Electrical Ground Support Equipment will comprise of a "Main" and "Mini" station.

The Main station can be divided into the following major areas:

RF telemetry & command test set;
Data handling computer & displays, etc.
External power simulator console;
Attitude control test set;
Array simulator;
Main power distribution transformer.

All of this equipment is available in good working order except that it will be necessary to replace the DATA HANDLING COMPUTER since the one used on Hermes was also used in the ISIS program and would not survive the rigors of another test program. The computer system now used at the Ottawa Control Station would be the best replacement since all the software now in use with Hermes could be applied to the CTS B test program. No other changes are proposed.

The Mini station has very limited data handling capability and can be divided into two areas:

RF telemetry, command decom system;
External power simulator control.

No changes are proposed to this existing Mini ground support equipment.

3.12.2 MGSE

The available Mechanical Ground Support Equipment can be divided into the following areas:

Shipping containers (not suitable for CTS-B with antennas installed).
Apogee motor handling equipment
Spacecraft handling dolly
Alignment tooling bars and measuring equipment
Array handling dolly
Array extension support rigs

No changes are proposed to this equipment other than minor changes due to any satellite mechanical design changes.

4.0 MISSION CONTROL PLANS

4.1 Transfer and Drift Orbit Control

DOC and ESA held a meeting with NASA on 19 August 1976 to determine the feasibility of ESA renting from NASA the S-band network and the supporting mission operations control facilities required to manoeuvre the spacecraft from its transfer orbit to the desired synchronous orbit. The requested support involves the re-use of hardware and software utilized by NASA to perform an identical operation with the original CTS spacecraft. This includes telemetry and command processing, orbit determintion, attitude determination, manoeuvre calculations, and operations control facilities. Reference 4.1 is the material tabled by DOC at the meeting at NASA Headquarters. The official DOC/ESA request to NASA is being made with the expectation that the re-use of NASA's existing CTS - unique software and world-wide S-band network is the most cost-effective solution to transfer and drift orbit operations.

The unique nature of the request will require a NASA policy decision. NASA officials are hopeful that the policy issue can be resolved in a timely manner consistent with the DOC/ESA proposed time-line. Unofficial sources have indicated that they expect NASA will respond positively to the request.

In the event that NASA is unable to supply orbit determination, attitude determination and manoeuvre control, ESA and/or Canada will be required to modify their existing software to make it compatible with the unique CTS sensor processing system. Producing a flight qualified flight dynamics system for CTS-B is certainly within the capabilities of either ESA or DOC. Such an option however is obviously more expensive than re-use of NASA's system.

Denial of the world-wide NASA network would require the use of the CRC S-band telemetry and command station and at least one other S-band station located in the eastern hemisphere. These two stations would have to have real-time data links with the CRC Satellite operations control centre.

4.2 Attitude Acquisition and On-Orbit Control

Conversion of the spinning spacecraft to 3-axis stabilization, array deployment, and on-orbit control will be conducted using the CRC telemetry and command station and the satellite operations control facilities developed for the original CTS mission. CRC will operate the spacecraft for the duration of the mission and perform the required orbit management. Use of the spacecraft by ESA will require real-time co-ordination with the Ottawa control centre.

4.3 Stationkeeping Capability

Hermes was designed to meet a requirement for east-west stationkeeping but not for north-south stationkeeping. As there is a generous reserve of hydrazine fuel on Hermes, however, studies have been conducted at CRC to determine the feasibility of north-south stationkeeping using the yaw thrusters.

A summary of the results of this study is given in Reference 4.2. It is concluded that N/S stationkeeping is feasible, however extensive work remains before feasibility can be definitely demonstrated. The main concern is the attitude control disturbance resulting from the manoeuvre due to possible thruster misalignment, thrust imbalance and plume impingement. It is considered possible, however to interleave ground based attitude control pulses with N/S stationkeeping pulses in order to minimize the attitude control disturbances. Typically the N/S stationkeeping requirement would involve approximately 30 seconds of total firing time per day to maintain inclination control.

Concerning the fuel requirements for this manoeuvre and other operations of the RCS, preliminary calculations are given in Reference 4.2. It is concluded that if stationkeeping is conducted with the existing fuel tank capacity, CTS B would have a capability of maintaining N/S stationkeeping for slightly more than one year. It should be emphasized however that such estimates require much more detailed analyses than the time available in this study would permit.

5.0 PROGRAM PLANS

5.1 DOC & ESA DIVISION of Tasks

Based on the meeting between DOC and ESA held at ESTEC on 20, 21 July 1976 and on subsequent telephone conferences the division of tasks between the two agencies has been tentatively assigned as follows:

ESA

- Launcher and payload attach fitting
- Antenna (incl. dish, feed, etc.)
- Repeater (incl. wave guide connections to antenna, thermal control, and conditioning of bus power)
- Deployable solar array blanket
- Antenna and repeater dynamic models
- Payload integration for dynamic and protoflight models
- Payload testing during S/C assembly, test, and launch campaign
- Facilities for S/C assy. and test (incl. vib, acoustic and solar sim.)
- Ground support equipment required for payload AIT
- S/C transportation including shipping container
- Mission control during transfer orbit and drift * (incl. STDN rental)

DOC

- Structure (incl. south panel)
- Thermal control (not incl. south panel)
- Attitude control system
- Reaction control system
- Apogee boost motor
- Telemetry, tracking, and command subsystem (incl. ensuring Ariane compatibility)
- Power subsystem
- Low power repeater equipment
- Solar Array Mechanical Assembly
- Bus integration
- Bus testing, during S/C assembly, test, and launch campaign
- Ground support equipment required for bus and S/C AIT (except payload testing and S/C shipment)
- Post launch in-orbit ground control within visibility range of Ottawa station'

The cost of the DOC assigned tasks, including in-house effort and industrial cost has been estimated to a rough order of magnitude as $13M (1976 value). See Appendix A. In addition, savings to the program from the Canadian contribution of existing hardware and software are of comparable magnitude.

5.2 Program Management

It is planned that DOC will act as design authority for CTS B, providing the necessary staff for program management, contractual support, project office, systems engineering, mission operations, product assurance, assembly, integration test of the CTS B bus, and support to ESA during spacecraft level tests and launch operations.

* DOC to obtain cost estimate from NASA

5.3 Schedule Test Plans & Model Philosophy

5.3.1 Schedule

The program schedule agreed upon with ESA is shown in Figure 5.1. For convenience, five phases have been identified, as follows:

Phase 1: (July-Dec 1976) - Proposal preparation and negotiation of ESA/DOC Memorandum of Understanding.

Phase 2: (Jan-Mar 1976) - Project definition, including preparation of subsystem specifications and statements of work.

Phase 3: (Apr. 77 - Oct. 78) - Design, development, hardware procurement and dynamic model testing.

Phase 4: (Nov. 78 - Feb. 80 - Spacecraft integration and test.

Phase 5: (Mar. 80 - July 80) - Launch operations and post launch operations during transfer orbit, drift orbit and attitude acquisition.

5.3.2 Test Plans & Model Philosophy

In view of the marked increase in environmental test levels of Ariane as compared to the Delta, it is planned to build the flight structure and conduct low level vibration tests with it at CRC during early 1978. In this way, early evidence will be gained of box vibration levels and structure transmissibilities. Subsequent improvements to the structure can then be made prior to delivery to ESA in September 1978 of the Dynamic Test Model (DTM).

The DTM will comprise the flight structure and dummy units supplied by DOC and ESA. Following final assembly in Europe, the DTM will be subjected to a qualification level test program (to be negotiated with ESA).

Following return of the DTM to Canada, the structure will be stripped, inspected and flight equipment integrated. During this time, ESA will proceed with their integration and test of the transponder equipment on the south panel.

The spacecraft bus will be returned to ESA in mid 1979 for integration and between September 1979 and January 1980 the spacecraft level testing will occur. This comprises balance, vibration, acoustic and shock tests, solar simulation and in-air solar array deployment.

5.4 Spares Philosophy

The philosophy agreed upon between DOC and ESA with regard to spares is that for units in the spacecraft which incorporate redundancy, no spares will be stocked. In the event of a failure during test, off-line repairs and retest will be conducted.

For items that do not incorporate redundancy, a selection will be made and spares will be carried for critical items such as the slip rings.

6.0 CONCLUSIONS

This report has described a television broadcast mission intended for launch on the third Ariane flight and has shown that there is a good match between the requirements of the communications payload and the capabilities of the CTS bus. A fully redundant one channel repeater including two 450 watt TWT's can be accommodated, the necessary high gain steerable antenna can be mounted on the dimensionally stable forward deck and the unique design of the CTS flexible solar array facilitates a straightforward modification to increase solar cell area for the higher powered TWT's.

An economical program - for both ESA and DOC - can be achieved by the availability of a free launch vehicle, by the sharing of program costs between the two agencies, and by the opportunity to use hardware, software and support equipment from the proven and successful Hermes program and from ESA development programs currently underway.

An additional merit of the proposed program is its timeliness, in that adequate time is available for the development and test program with a May 1980 launch and the requirement for the DOC ground station in Ottawa will fit in well with the phasing out of the Hermes experimental program.

Perhaps of more significance than the suitability of CTS, or the economy and timeliness of the program, is the commonality between Canadian and European objectives - the opportunity to demonstrate hardware and to gain experience in the important new field of direct TV broadcasting and through this co-operative venture, lead to stronger technological and economic ties between Canada and Europe.

REFERENCES

1.1 Franklin, C.A. and Davison, E.H. "A High Power Communications Technology Satellite for the 12 and 14 GHz Bands". Proceedings, AIAA 4th Communications Satellite Systems Conference, Washington, D.C. 24-26 April, 1972, AIAA Paper #72-580.

1.2 SY 01-04 Final Issue December, 1975 "Configuration Control Baseline Document - Spacecraft".

1.3 Memo by G.W. Durling ESI (ESTEC) to ESA of 23 July, 1976 "CTS APEX (L03) Meeting Report" File ESI/10696/GWD/CK.

2.1 Memo of 4 August, 1976 J.D. Palmer to H.R. Warren "Possible CTS/ESA High Powered Mission".

3.1 Memo of 25 August, 1976 A.L. Vankoughnett to H.R. Warren "Transponder-CTS-II".

3.2 Memo of 26 August, 1976, J.R. Beck to addressees "CTS-B Power Conditioning Subsystem".

3.3 Memo of 19 August, 1976, F. Vigneron to W.M. Evans "CTS-Ariane-ACS Considerations & Capabilities" File CRC 7500-11 (SCOPO).

3.4 Letter of 12 July, 1976 R.E. Breeding, Hamilton Standard to H.R. Warren "Refurbishment of CTS Engineering Model Reaction Control Subsystem", File 1A-2-4.

3.5 Memo of 26 August,1976 E. Quittner to H.R. Warren "Recommended S/C Structural Configuration, Est. of Structural Weight Increase & Conclusions".

3.6 Memo of 25 August, 1976, D. Caswell to Addressees, "The Thermal Design of the CTS-B Mission", File CRC 7500-11 (SCOPO).

3.7 Memo of 24 August, 1976 P.E. Townsend to H.R. Warren "Refurbishment and Rebuild Requirements for the Engineering Model TT&C Components if used in the Proposed ESA/CTS Satellite" File CRC 7500-11 (SCOPO).

3.8 Memo of 9 August, 1976, W.M. Evans to H.R. Warren, "CTS-L03 Ignition Weight vs Apogee Motor Fuel Weight" File CRC 7500-11 (SCOPO).

4.1 Meeting between NASA and ESA/DOC to Explore the Possibilities for Cost Re-imbursable NASA Support for the Proposed Joint ESA-DOC CTS-II Mission in 1980 - 19 August, 1976.

4.2 Memo of 11 August, 1976 W.M. Evans to H.R. Warren "CTS-II N/S Stationkeeping" File CRC 7500-11 (SCOPO).

4.3 Memo of 17 August, 1976 W.M. Evans to H.R. Warren "CTS-II Preliminary Fuel Budget" File CRC 7500-11 (SCOPO).

APPENDIX - A

CTS-B COST SUMMARY (1976 DOLLARS)

DOC COSTS (INCLUDING MANPOWER) - See p. 22	$4.04 M
CONTRACT COSTS - See p. 23	6.26 M
ON-ORBIT OPERATING COSTS	2.5 M
TOTAL CANADIAN COST	$12.8 M

CTS-B
DOC MANYEAR AND COST SUMMARY
(1976 DOLLARS)

1) PROJECT MANAGEMENT

Total Manyears		127.3	
Total Costs			486K
- T & L	386 K		
- GSE	100 K		

2) ACS ANALYSIS

Total Manyears		1.4	

3) TRANSPONDER & FETA TWT DRIVER

Total Manyears		16.3	
Total Costs			360K
- T & L	25 K		
- Parts & Mat.	205 K		
Ind. Cont.	130 K		
TOTAL		145 MY	$846K
TOTAL COST (@ $ 22 K/MY)		=	$4036K

NOTES:

1) Costs Not Included
   a) David Florida Labs
   b) Computer
   c) Satellite Ground Control Staff

COST SUMMARY FOR CTS B INDUSTRIAL SUPPORT

(1976 DOLLARS)

SPAR	- Prog Mgt	$794	
	ACS	932	
	Thermal	396	
	DSA	859	
	Structure	851	
	System Eng'g	122	
			$3954K
RCA	-Prog Mgt	157	
	Power	288	
	TT&C	391	
			$ 836
HAM-STD	-Ph.1-Procurement	475	
	Ph.2-Refurb't	115	
	Ph.3-Launch Support	13	
			$ 603
SED	-Attitude Acquisition		$ 400
THIOKOL	-Apogee Motor		$ 40
SPECTROLAB	-Solar cells for body array		$ 100
GE	-Batteries		$ 75
BALL BROTHERS	-TT&C antennas		$ 250
TOTAL INDUSTRIAL CONTRACTS			$6258

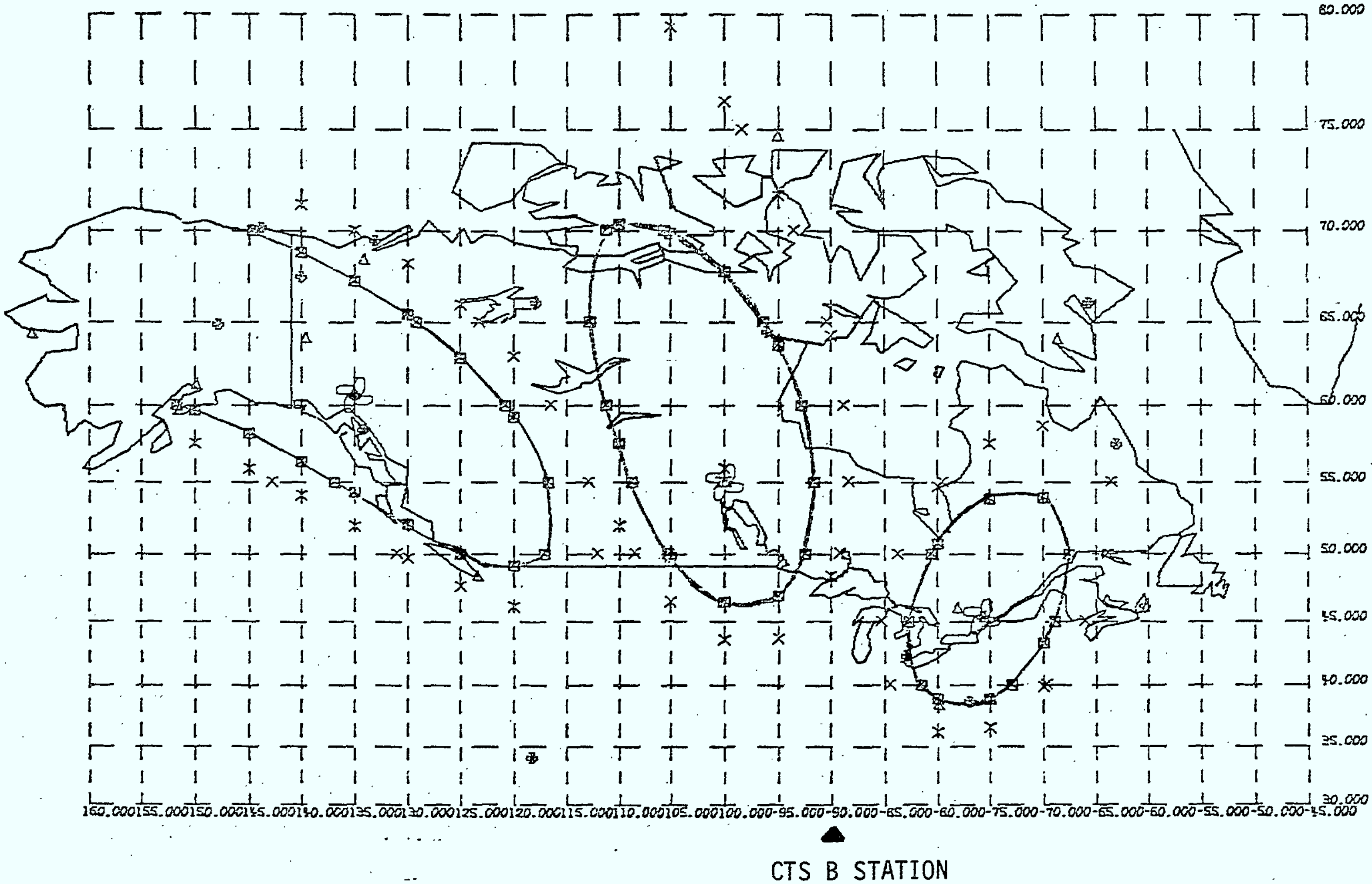
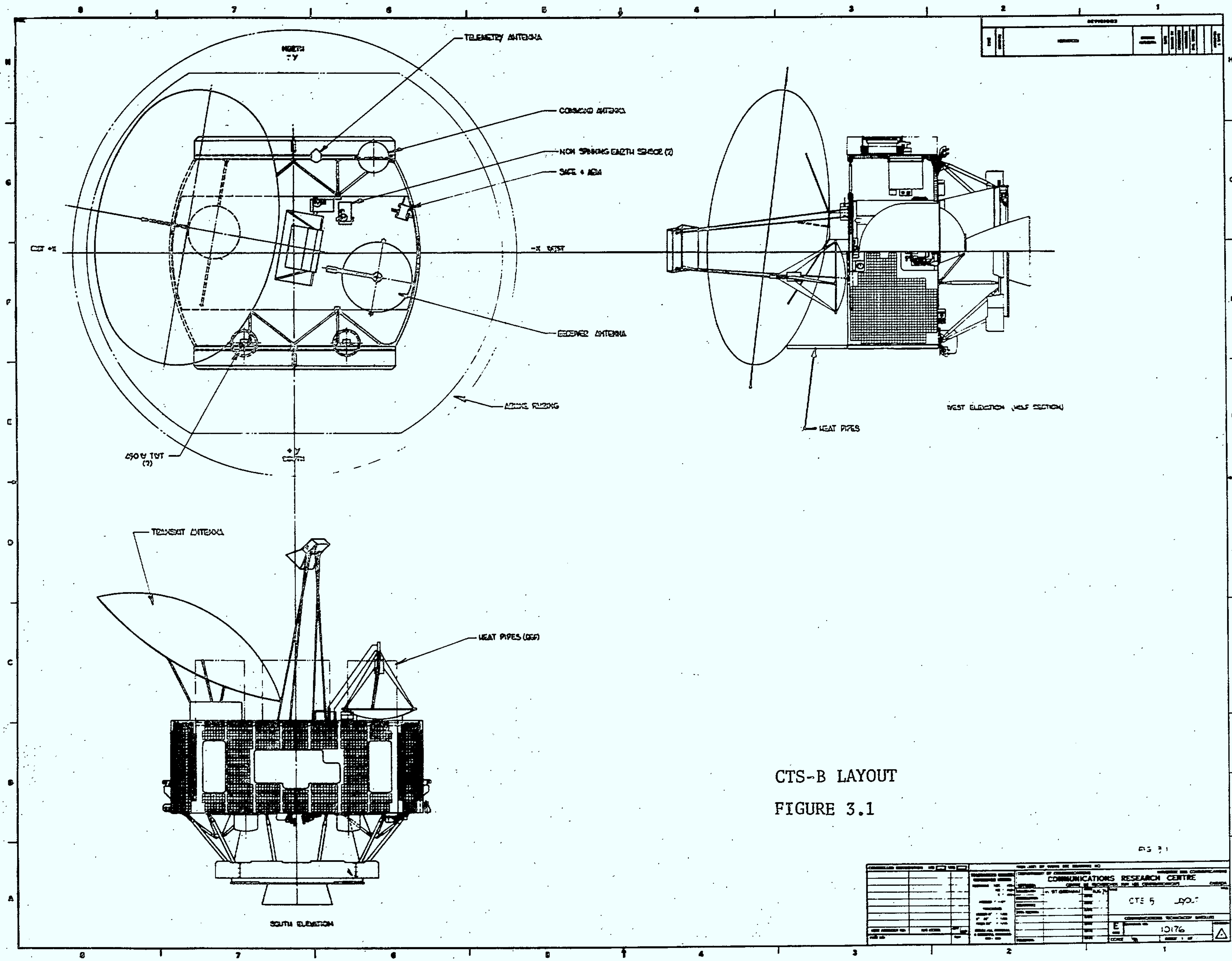
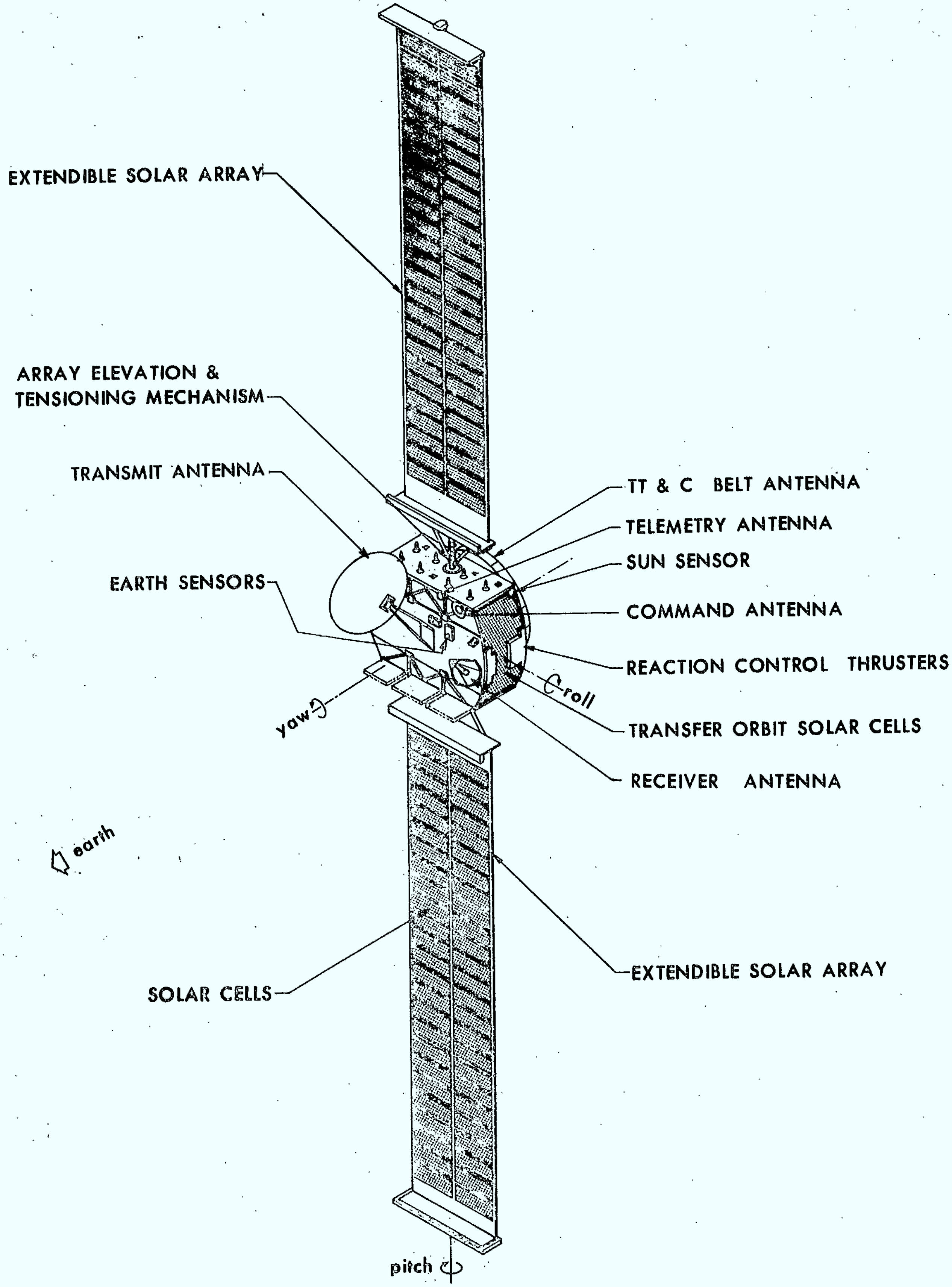


FIGURE 2.1 CØMMUNICATIØNS SATELLITE TRANSMIT ANTENNA-EARTH SURFACE EIRP CØNTØURS



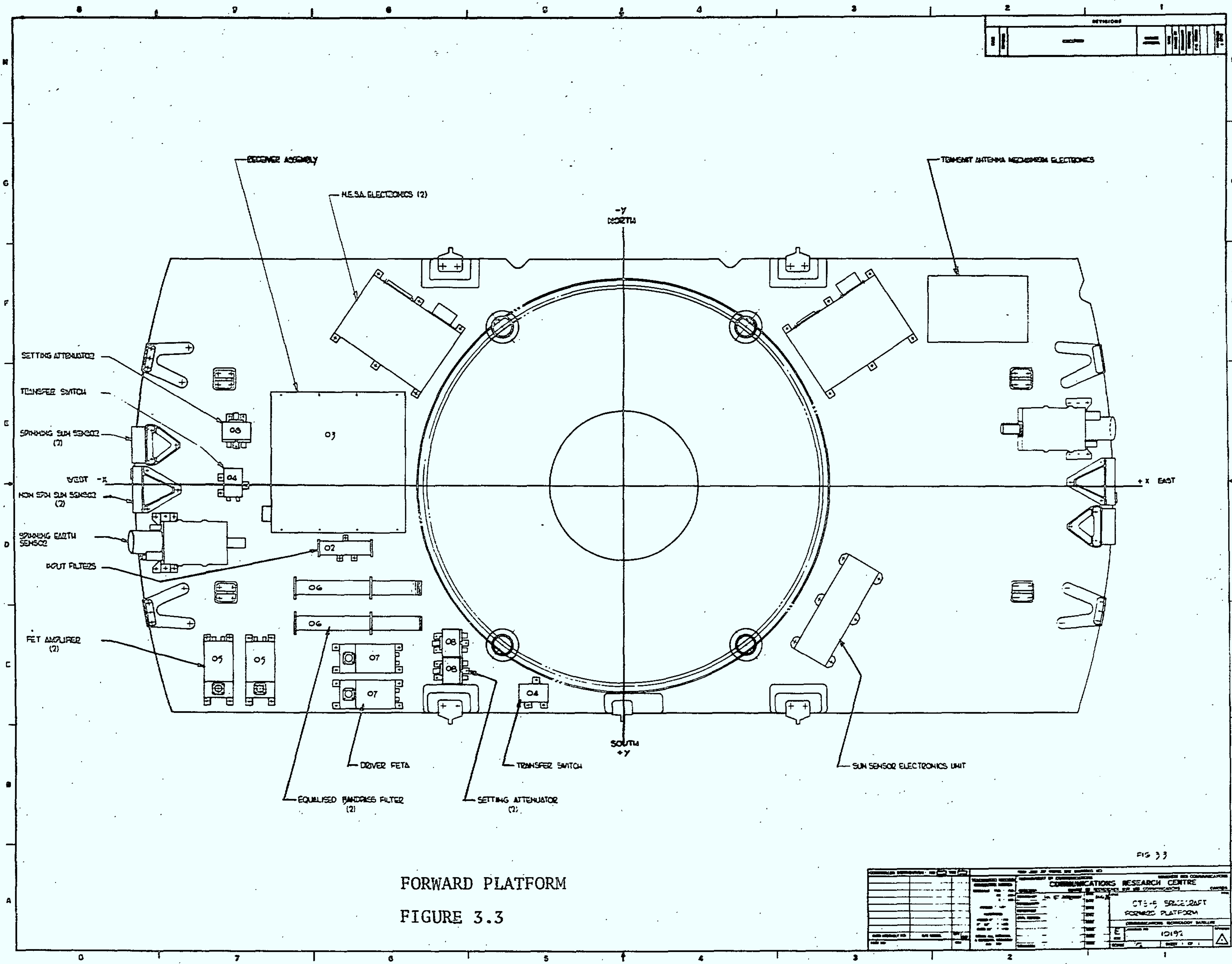
CTS-B LAYOUT

FIGURE 3.1



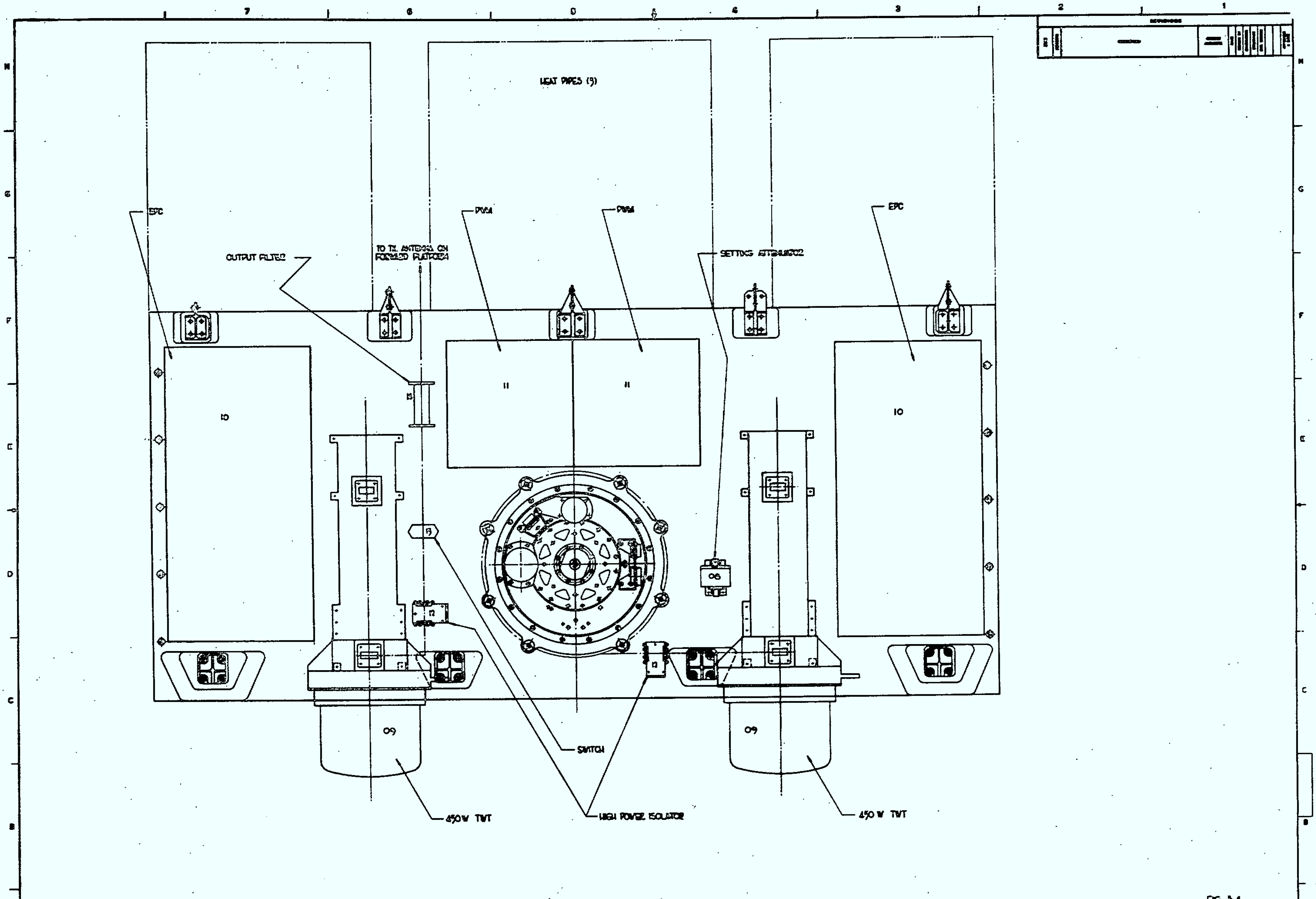
EXTENDIBLE SOLAR ARRAY
ARRAY ELEVATION &
TENSIONING MECHANISM
TRANSMIT ANTENNA
EARTH SENSORS
TT & C BELT ANTENNA
TELEMETRY ANTENNA
SUN SENSOR
COMMAND ANTENNA
REACTION CONTROL THRUSTERS
roll
yaw
TRANSFER ORBIT SOLAR CELLS
RECEIVER ANTENNA
earth
EXTENDIBLE SOLAR ARRAY
SOLAR CELLS
pitch

FIGURE 3.2



FORWARD PLATFORM

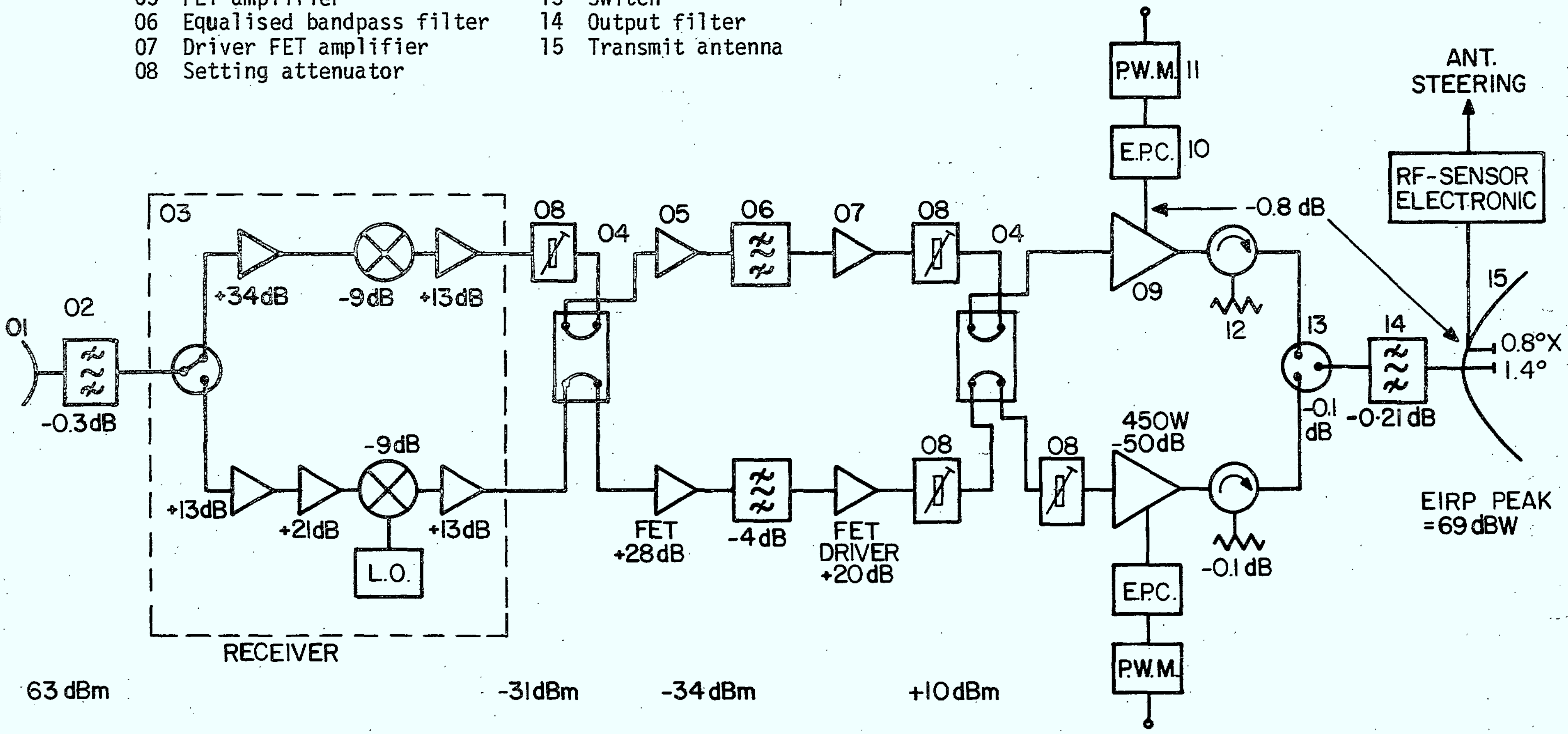
FIGURE 3.3



SOUTH PANEL LAYOUT

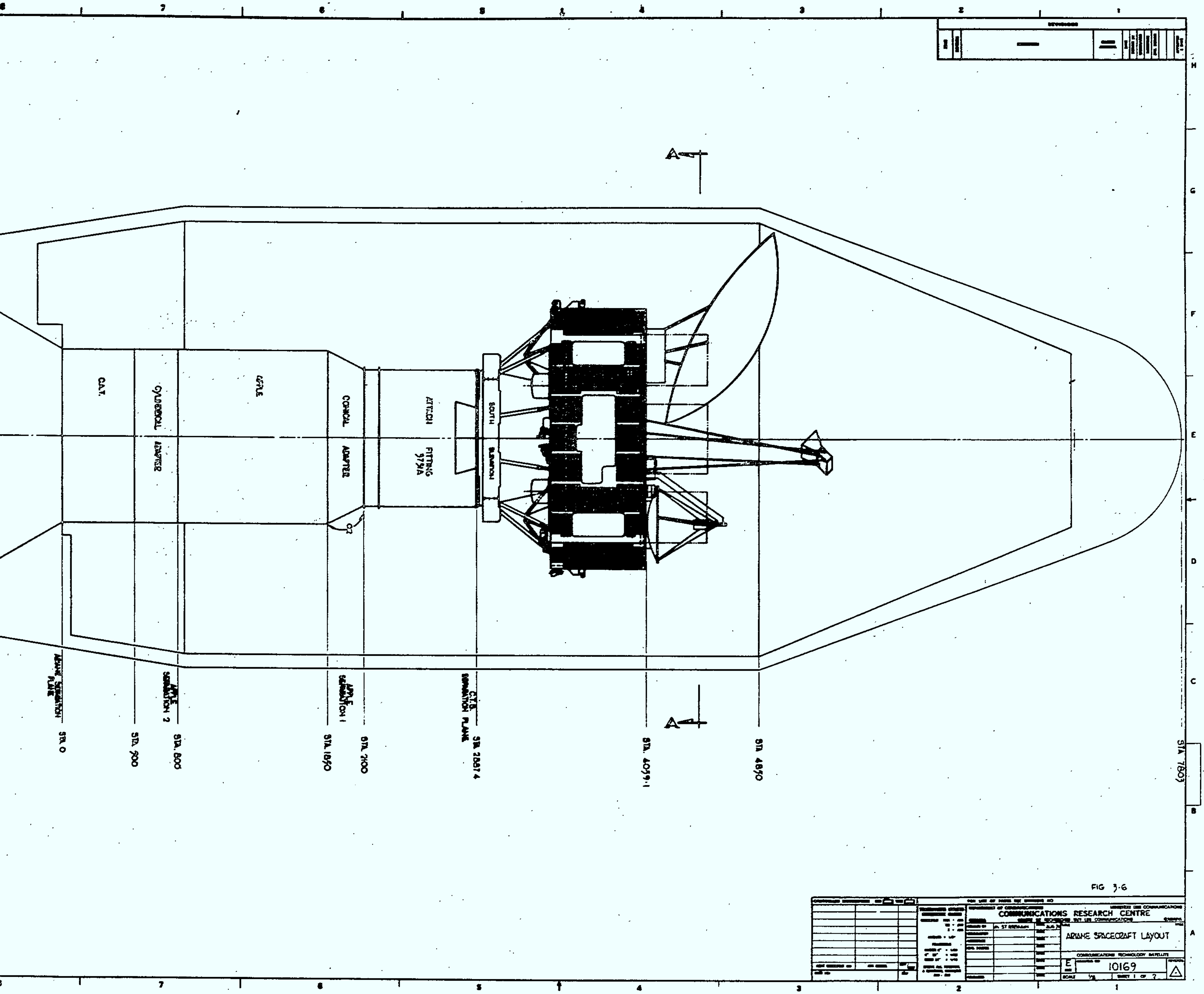
FIGURE 3.4

01 Receive antenna
02 Input filter
03 Receiver assembly
04 Transfer switch
05 FET amplifier
06 Equalised bandpass filter
07 Driver FET amplifier
08 Setting attenuator
09 450W TWT
10 EPC
11 PWM
12 High power isolator
13 Switch
14 Output filter
15 Transmit antenna

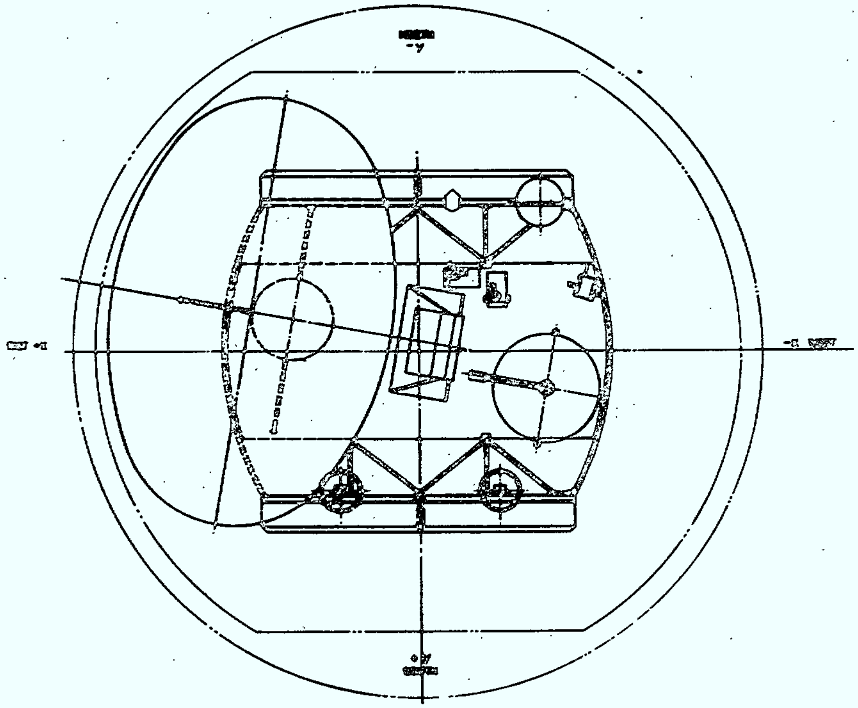


CTS B - LO 3 TV PAYLOAD

Fig. 3.5



CTS-B IN ARIANE SHROUD
FIGURE 3.6a



CTS-B IN ARIANE SHROUD

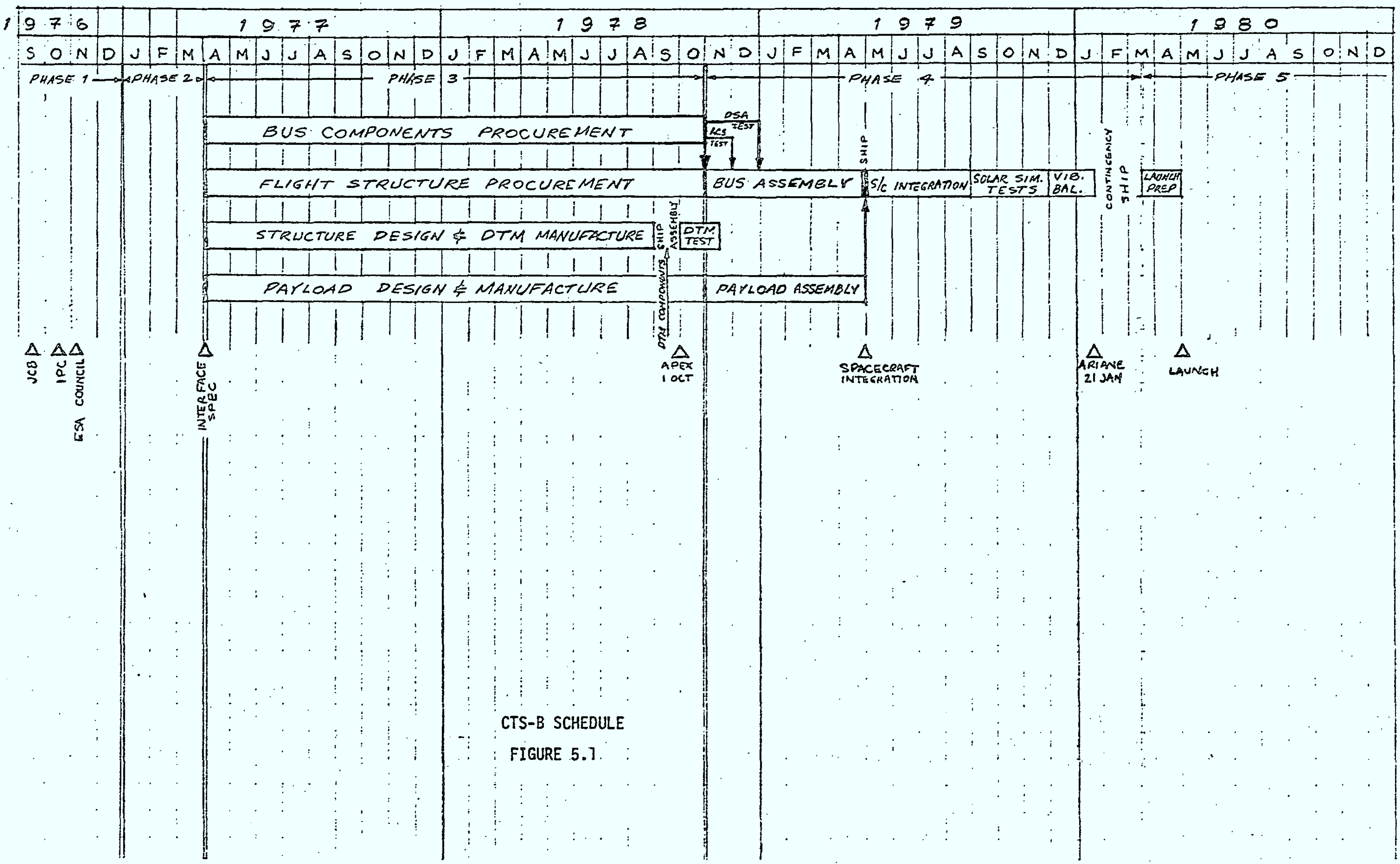
FIGURE 3.6b

FIG 3.6

COMMUNICATIONS RESEARCH CENTRE

ARIANE SPACECRAFT LAYOUT

E 10169



CTS-B SCHEDULE

FIGURE 5.1

CTS B FOR TV BROADCAST