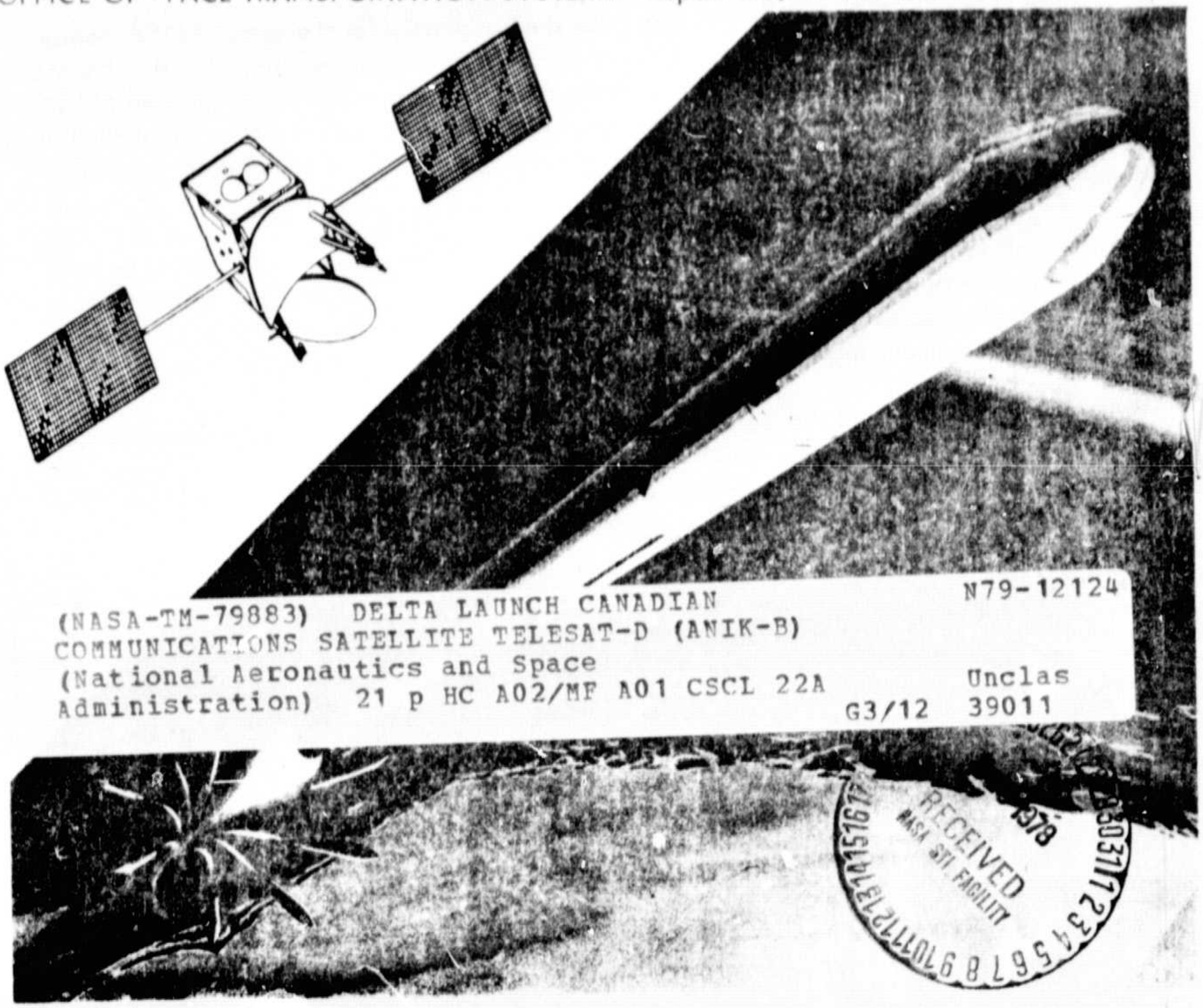
NASA
National Aeronautics and
Space Administration

Mission Operation Report

OFFICE OF SPACE TRANSPORTATION SYSTEMS Report No. M-492-201-78-04



Delta Launch
Canadian Communications Satellite
Telesat-D (Anik-B)

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BACKGROUND

A contract was signed between NASA and Telesat, Canada (a company formed by an act of the Canadian Parliament in 1970) on March 11, 1978, which sets forth terms and conditions whereby NASA will furnish Delta launch vehicle support on a fully reimbursable basis for the Canadian Telesat-D mission.

In accordance with the contract, NASA will provide the following services:

- Provide and launch a Delta launch vehicle into the transfer orbit desired
- Provide working area for the Telesat-D spacecraft at ETR
- Provide for spacecraft telemetry reception during launch preparation and during the ascent
- Provide network communications support necessary for launch and initial orbit phase
- Provide certain specified miscellaneous services if required to support the launch

Telesat/Canada will undertake to do or certify that the following has been done:

- Provide mission requirements
- Assure spacecraft compatibility with launch vehicle and tracking and data facilities
- Provide a spacecraft interface specification
- Provide a flight-ready spacecraft to the range
- Assure to NASA that spacecraft has been properly tested
- Provide documentation that apogee motor meets range standards
- Determine launch criteria for spacecraft and supporting stations

NASA MISSION OBJECTIVES FOR THE TELESAT-D MISSION

To place the Telesat-D (Anik-B) satellite into a synchronous transfer orbit of sufficient accuracy to allow the spacecraft to achieve with its apogee kick motor a stationary synchronous orbit while retaining sufficient stationkeeping propulsion to meet the mission lifetime requirements.

Joseph B. Mahon

Joseph B. Mahon, Director
Expendable Launch Vehicle Program
Office of Space Transportation Systems

Date: December 7, 1978

John F. Yardley
Associate Administrator for Space
Transportation Systems

Date:

MISSION DESCRIPTION

Telesat-D (Anik-B) is the first of a series of three (Telesat-D, -E, -F) second generation satellites developed for Telesat/Canada by RCA-Astroelectronics of Princeton, NJ. These second generation satellites will replace the initial three first generation HS-333 satellites (Telesat-A, -B, -C) developed for Telesat/Canada by Hughes and launched by Delta 2914 vehicles in 1972, 1973, and 1975 and successfully placed in orbit as Anik-A1, -A2, and -A3.

The Telesat-D (Anik-B) satellite will be placed in sync-transfer orbit by a Delta 3914 launch vehicle--currently scheduled for launch on December 15, 1978. The satellite's Aerojet SVM-7 Apogee Kick Motor will be fired roughly three days after launch (seventh apogee) to circularize the satellite orbit at a geosynchronous altitude of 36,000 KM above the equator with zero inclination. The satellite hydrazine gas system will be utilized to then draft the satellite to 109 degree west longitude near the Anik-Al (Telesat-A) satellite whose function it will replace into the 1980's with its expected seven year lifetime.

The Telesat-E and -F (Anik-C1 and -C2) missions are scheduled for launch on the Space Shuttle in 1981 to replace the function of the Anik-A2 and -A3 (Telesat-B, and -C) satellites.

The Anik-B will provide point-to-point voice, TV, and data communications traffic to Canada's ten provinces.

In addition to its 12 commercial channels in the 6 and 4 gigaHertz frequency bands, Anik-B has four channels for operation at the 12 and 14 gigaHertz frequencies.

The full capacity of the satellite's higher frequency bands will be leased to Canada's Department of Communications for two years with an option for two additional year's use. These channels will be used for a series of 14 pilot projects which stem from the Communications Technology Satellite (CTS), a joint U.S.-Canadian experimental satellite.

Included in these projects are social experiments such as TeleMedicine, TeleEducation, TeleConferencing, and Eskimo Broadcasting all intended to further evaluate the use of satellites for reaching remote locations equipped with small ground stations.

Other, purely technical projects are designed to produce experimental information about such subjects as signal propagation as well as power generation and usage.

Control of the Anik-B will be transferred to Telesat's Satellite Control Center, headquartered in Ottawa, after separation from the Delta vehicle. Tracking, transmission, and reception of data will be provided by the Telesat Earth station near Allan Park, Ontario, about 130 km (80 miles) west of Toronto.

SPACECRAFT DESCRIPTION

The Telesat-D spacecraft is designed for Telesat Canada's Domestic Communications Satellite System to provide communications coverage for all of Canada in the 6/4 GHz and 14/12 GHz bands. The satellite configuration, shown in Figure 1, is such that it has a length of 128.3 inches including antennae (44 inches excluding antennae) and a diameter of 85.6 inches. The spacecraft weighs 1956 pounds in transfer orbit. The spacecraft contains an Apogee Kick Motor which is fired at the apogee of the transfer orbit to reduce the inclination to zero and place the spacecraft in a 24-hour equatorial geostationary orbit. After some preliminary maneuvers, the spacecraft performs a dual-spin turn by energizing its momentum wheel, deploys the solar panels, and locks on to the Earth with its pitch control loop. The satellite weight at that time has been reduced to 1045 pounds by the burning of the AKM.

TELESAT-D (ANIK-B) SATELLITE CONFIGURATION

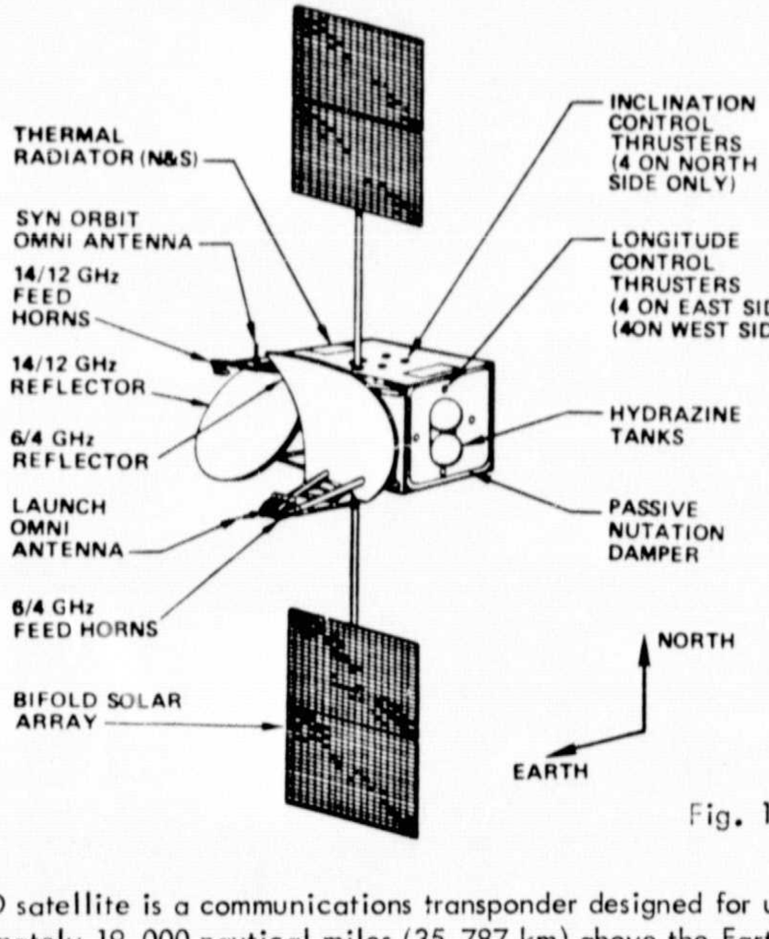

Fig. 1

The Telesat-D satellite is a communications transponder designed for use in geostationary orbit approximately 19,000 nautical miles (35,787 km) above the Earth's equator. Once on station, an onboard hydrazine mono-propellant propulsion system is used to maintain the satellite's position to within 0.05 degree North and South latitudes and 0.05 degree

East and West longitudes by means of ground-generated commands. The communications subsystem uses the 500 MHz, 6/4 GHz common-carrier band, and the 500 MHz, 14/12 GHz communications band.

The 6/4 GHz antenna covers Canada (see Figure 2) with 36 dBW effective isotropic radiated power (EIRP), horizontally polarized, at 4 GHz. On the uplink at 6 GHz, the antenna provides the same coverage with a minimum of G/T of -6 dB/°K. The 14/12 GHz antenna covers Canada with four spot beams, West, Central West, Central East, and East, radiating 46.5 dBW EIRP, horizontally polarized at 12 GHz. On the uplink, the antenna provides all Canada coverage at 14 GHz with a G/T of -1 dB/°K.

TYPICAL GEOGRAPHICAL COVERAGE OF THE TELESAT-D SATELLITE AT 109°W LONGITUDE

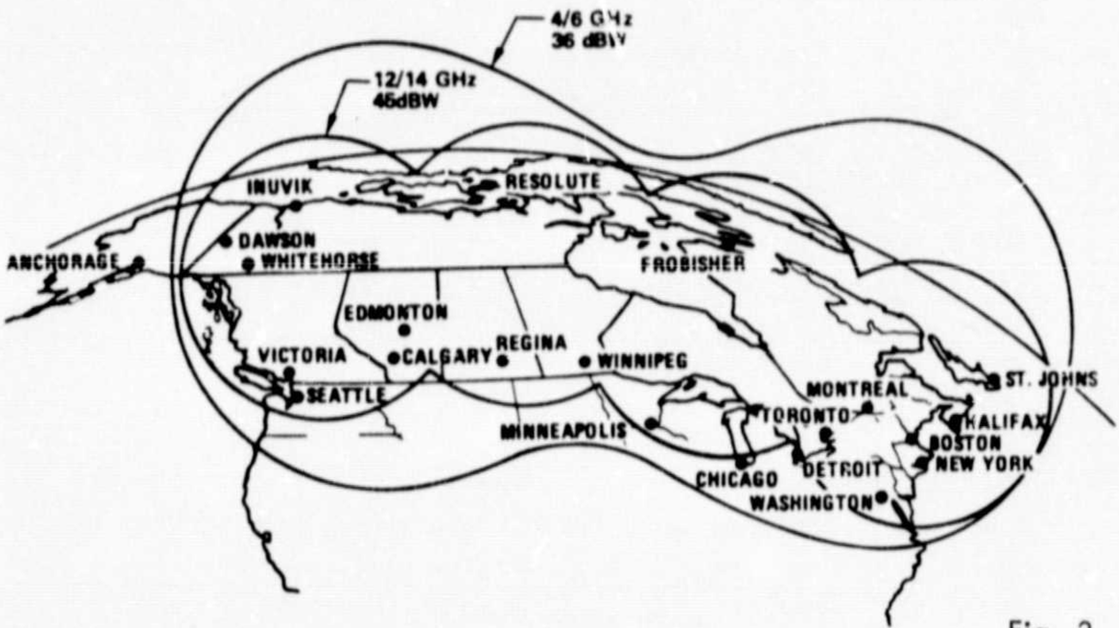

Fig. 2

The Telesat-D spacecraft has seven functional subsystems:

- Command, Ranging, and Telemetry (CR&T)
- Power
- Propulsion (apogee kick motor and reaction control)
- Attitude Control
- Thermal Control
- Communications (transponder and antenna)
- Structure

a) Command, Ranging, and Telemetry Subsystem - The Command, Ranging, and Telemetry (CR&T) subsystem provides: the command link with the ground stations for controlling the spacecraft; a transponder for ranging by connecting the output of the command receiver to the input of the telemetry beacon; and a telemetry subsystem for monitoring the status and health of the spacecraft.

b) Power Subsystem - The Power Subsystem consists of the following: 75 square feet (6.95 square meters) of solar array for converting solar energy into electrical energy; the power supply electronics (PSE) for charging the batteries and limiting the maximum bus voltage (it contains the battery reconditioning circuitry); the three nickel-cadmium, 17 ampere-hour batteries for storing the energy for use in the eclipse periods; and the solar-array-drive mechanism for rotating the solar array once a day.

c) Propulsion Subsystem - The Propulsion Subsystem consists of an Aerojet SVM-7 solid fuel apogee kick motor (AKM) and the reaction control subsystem (RCS). The solid-propellant AKM is designed to provide the final orbit insertion and is an integral part of the spacecraft. The AKM has a length of 56.9 inches, diameter of 30 inches, weighs 974 pounds, initially, and 63 pounds after burnout, a specific impulse of 294, thrust of 9800 pounds for 27.8 seconds. The hydrazine-monopropellant RCS system is designed to provide spacecraft control for spin-axis orientation, orbit-injection-error correction, and on-orbit stationkeeping and attitude control. The spacecraft is required to maintain orbital position to within 0.05° in both latitude and longitude. The largest propellant requirement is for out-of-plane north-south drift correction that is required primarily because of lunar and solar gravitational disturbances. A much smaller propellant requirement is associated with the east-west drift caused by Earth-asphericity and solar-pressure disturbances. All of these corrections are performed by direct ground command of the propulsion subsystem.

d) Attitude Control Subsystem - A single body-mounted momentum wheel provides full three-axis control by virtue of the gyroscopic rigidity of the wheel and its servo-controlled exchange of angular momentum with the spacecraft main body. The inertial stability permits attitude determination by a single roll/pitch Earth-horizon sensor without the complexity of a yaw gyro or star sensor. Continuous control of the pitch axis alignment to the Orbit normal is achieved using magnetic torquing with no expendables or moving parts. All active components of the subsystem, including the momentum wheel, have standby spares to eliminate single-point failure modes.

The Attitude Control Subsystem consists functionally of:

- Pitch control with active nutation damping,
- Magnetic roll/yaw control with backup thruster control,
- Roll/yaw control with thrusters during orbit adjust, and
- Attitude sensing equipment.

e) Thermal Control Subsystem - The Thermal Control Subsystem uses heater-augmented passive thermal control. The passive surface finish and insulation elements of the subsystem accommodate the seasonal or orbit variations in solar inputs, while the heaters compensate for the wide range of internal dissipation due to the number of transponder channels in operation and the state of the electrical power subsystem.

f) Communications Subsystem - The Communications Subsystem consists of three components: the antenna assemblies, the transponders, and the power and telemetry conditioner (PTC).

The antennas are arranged on the spacecraft Earth-facing panel (antenna panel) and consist of two separate systems. One system operates in the 6/4 GHz band and the other operates in the 14/12 GHz band. Each has separate feed towers and reflectors. The 6/4 GHz antenna has three feed horns and provides complete Canadian coverage on the up and down links. The 14/12 antenna has four feed horns and provides full Canadian coverage on the uplink and has four separate beams on the downlink called West, Central West, Central East, and East. The path a signal takes is a function of its frequency and the position of switches on the spacecraft.

g) Structure - Two opposing equipment panels support most of the internal spacecraft components, and are joined at their upper and lower ends by the antenna panel and the baseplate. The box structure is completed by a pair of opposing cover panels through which the propellant tanks partially protrude. A conical adapter extends downward from the baseplate and terminates in a separation ring which mates with the Marmon clamp joint of the Delta 3731A adapter. An internal conical structure extends upward from the separation ring and provides support for the apogee kick motor.

The equipment and antenna panels are of honeycomb construction, utilizing aluminum-alloy skins and core. The baseplate is aluminum honeycomb on an aluminum beam grid, and serves as a transition structure between the spacecraft box shape and conical adapter. Stiff beams near the ends of the baseplate provide for attachment of the adapter cone and are the baseplate's principal structural elements. The other baseplate members provide local load paths, beam stability, and skin stiffening.

LAUNCH VEHICLE DESCRIPTION

The Telesat-D spacecraft will be launched by the thrust-augmented NASA Delta 3914 launch vehicle (Figures 3 and 4). The Delta 3914 launch vehicle characteristics are shown in Table 1. A schematic of the launch vehicle is shown in Figure 4. This will be the 147th flight for Delta. Of the previous 146 flights, 134 have successfully placed satellites into orbit.

LAUNCH VEHICLE FOR THE TELESAT-D (ANIK-B) MISSION
DELTA 3914

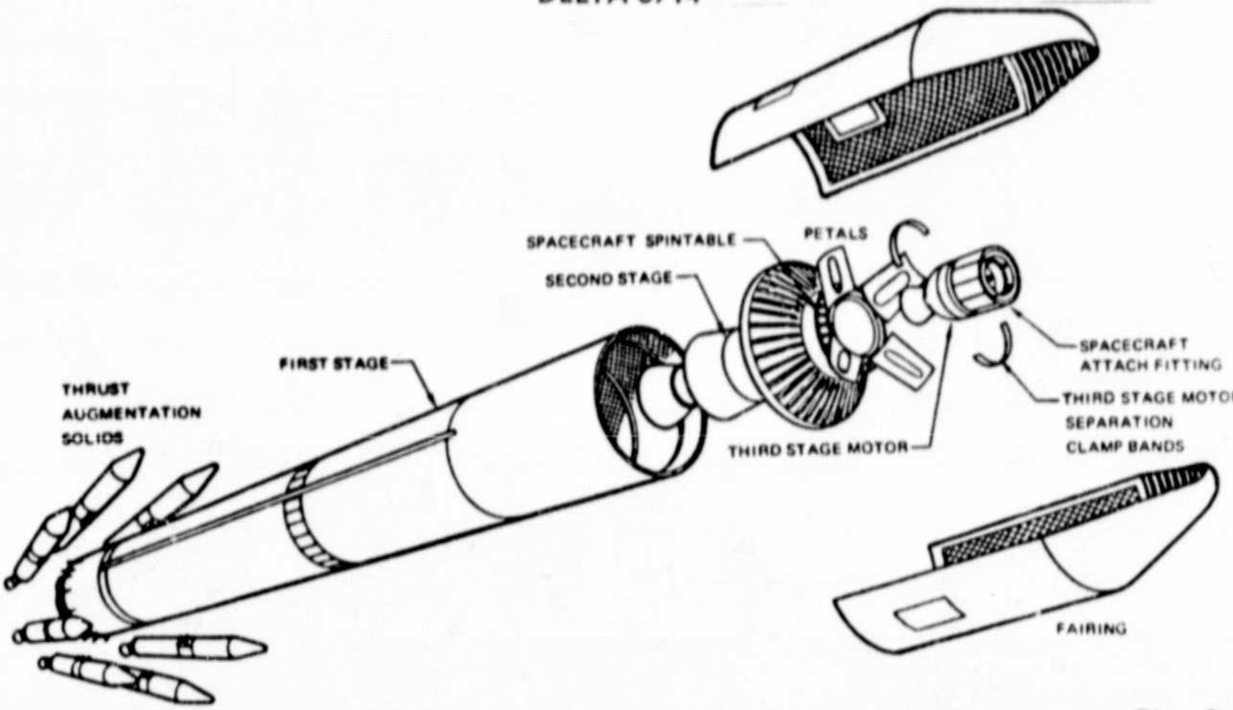

Fig. 3

Delta is managed for the NASA Office of Space Transportation Systems by the Goddard Space Flight Center, Greenbelt, MD. Launch operations management is the responsibility of Kennedy Space Center's Expendable Vehicle Operations Division. The McDonnell-Douglas Astronautics Corp., Huntington Beach, CA, is the Delta prime contractor for the vehicle and launch services.

Overall the Delta 3914 is 35.5 meters long (116 ft) including the spacecraft shroud. Liftoff weight is 190,630 kg (420,269 lb) and liftoff thrust is 2,058,245 newtons (462,714 lb) including the startup thrust of five of the nine solid motor strapons (the remaining strapons are ignited at 64 seconds after liftoff).

The first stage booster will be extended long-tank Thor powered by the Rocketdyne RS-27 engine system which uses Hydrazine (RP-1) and liquid oxygen propellants. Pitch and yaw steering is provided by gimballing the main engine. The vernier engines provide roll control during powered flight and control during coast.

DELTA 3914 - VEHICLE ELEMENTS

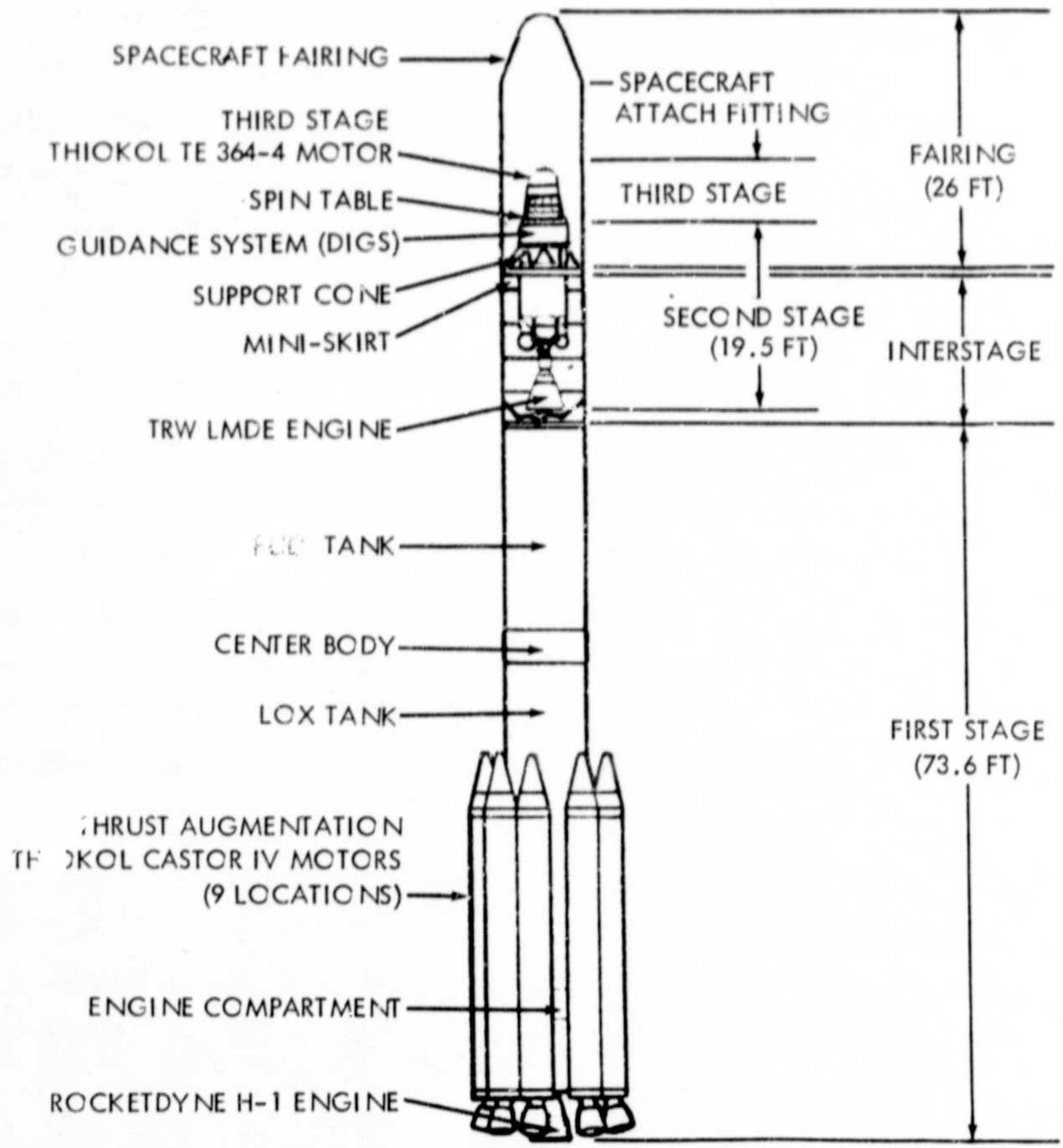

Fig. 4

TABLE 1
DELTA 3914 LAUNCH VEHICLE CHARACTERISTICS

	Strap-On	Stage I	Stage II	Stage III
Length	11.3 m (37.0 ft)	21.3 m (70.0 ft)	700.0 cm (276 in)	180 cm (72 in)
Diameter	101.6 cm (40 in)	243.3 cm (96 in)	139.7 cm (55 in)	9 cm (37 in)
Engine Type	Solid	Liquid	Liquid	Solid
Engine Manufacturer	Thiokol	Rocketdyne	TRW	Thiokol
Designation	TX-526	RS-27	TR-201	TE-M-364-4
Number of Engines	9	1 (+2VE)	1	1
Specific Impulse Ave	229.9	262.4	302	285.5
Thrust (per engine)(Avg.)	407,000 N (91,520 lb)	911,840 N (205,000 lb)	43,398 N (9,756 lb)	66,656 N (14,985 lb)
Burn Time	58.2 (sec)	228 (sec)	315 (sec max)	43.6 (sec)
Propellant	TP-H-8038	RP-1 (LOX oxid)	A-50 (N_2O_4 oxid.)	TR-H-3062

The second stage is powered by the TRW TR-201 liquid bipropellant engine using N_2O_4 as the oxidizer and Aerozene-50 as the fuel. Pitch and yaw steering during powered flights are provided by gimballing the engine. Roll steering during powered flight and all steering during coast are provided by a GN_2 cold gas system.

The third stage is Thiokol's TE-364-4 solid motor. The third stage and spacecraft are spin stabilized by spin rockets ignited before third-stage powered flight.

The guidance and control system of the vehicle is located on top of the second stage. The strapdown Delta Inertial Guidance System (DIGS) provides guidance and control for the total vehicle from liftoff through attitude orientation and ignition of the spin stabilized third stage solid propellant motor. The system is composed of a digital computer provided by Delco and either the Inertial Measurement Units (IMU) provided by Hamilton Standard or the Delta Redundant Inertial Measurement System (DRIMS) developed by MDAC.

First and second stage telemetry systems are similar, both combining the use of pulse duration modulation and frequency modulation. Critical vehicle functions are monitored to provide data for determining which components, if any, are not functioning properly during ascent. A separate self-contained S-band telemetry system monitors third stage performance.

Tables 2 through 5 show the flight sequence of events, the mission requirements, the flight mode description, and the predicted orbit dispersions. Figure 5 shows the vehicle ascent profile for the Telesat-D mission.

TABLE 2
TELESAT-D MISSION FLIGHT SEQUENCE OF EVENTS

Events	Time	Altitude Kilometers	Altitude Miles	Velocity Km/hr	Velocity mph
Liftoff (5 solid motors ignition)	0 sec.	0	0	0	0
Five Solid Motor Burnout	57.2 sec	9.9	5.4	2,795	1,509
Jettison Three Solid Motor Casings	1 min. 4 sec.	12.3	6.7	2,795	1,509
Four Solid Motor Ignition	1 min. 4 sec.	12.03	6.7	2,795	1,509
Jettison Two Solid Motor Casings	1 min. 5 sec.	12.7	6.8	2,833	1,529
Four Solid Motors Burnout	2 min. 1 sec.	42.8	23.1	8,426	4,550
Jettison Four Solid Motor Casings	2 min. 7 sec.	47.2	25.5	8,764	4,732
Main Engine Cutoff (MECO)	3 min. 45 sec.	112.5	60.7	21,040	11,361
Stage II Ignition	3 min. 58 sec.	121.5	65.6	21,068	11,376
Jettison Fairing	4 min. 18 sec.	133.3	72.0	21,379	11,544
First Cutoff--Stage II (SECO-1)	8 min. 16 sec.	188.9	102.0	28,069	15,156
Restart Stage II	20 min. 34 sec.	185.3	100.1	28,077	15,160
Final Cutoff--Stage II (SECO-2)	21 min. 17 sec.	184.2	99.4	29,814	16,098
First Spin Rockets	22 min. 7 sec.	183.7	99.2	29,816	16,099
Stage II/III Separation	22 min. 9 sec.	183.7	99.2	29,816	16,099
Stage III Ignition	22 min. 50 sec.	185.8	100.3	29,807	16,095
Stage III Burnout	23 min. 34 sec.	192.9	104.2	36,893	19,920
Stage III/Anik-B Separation	24 min. 43 sec.	231.6	125.0	36,768	19,853
Transfer Orbit Apogee	5 hrs. 38 min.	35,786	19,323	5,745	3,100

TABLE 3
TELESAT-D (ANIK-B) MISSION REQUIREMENTS

NOMINAL ORBIT PARAMETERS AT SPACECRAFT INJECTION

Apogee Altitude	35,787 KM
Perigee Altitude	185 KM
Inclination	27.25 Degrees
Spin Rate	60 RPM

SPACECRAFT WEIGHT (AT LIFTOFF)	1956 LB
(IN FINAL ORBIT)	1045 LB

TABLE 4
TELESAT-D FLIGHT MODE DESCRIPTION

Launch from PAD 17A at ETR
Launch Window is 7:21 p.m. to 8:59 p.m., EST
Five Solids Ignited at Liftoff
Four Solids Ignited at 64 seconds
Fairing Separation occurs at 259 seconds
Marginal ground coverage of third stage burn from Ascension
(ARIA Airplane will be deployed)

TABLE 5
TELESAT-D PREDICTED ORBIT DISPERSIONS (99% PROBABILITY)

Apogee Altitude	$\pm$ 600 NM
Perigee Altitude	$\pm$ 10 NM
Inclination	$\pm$ 0.3 Degree
Spin Rate	$\pm$ 6 RPM

TELESAT-D BOOST PROFILE
- DELTA 3914 - ETR LAUNCH -

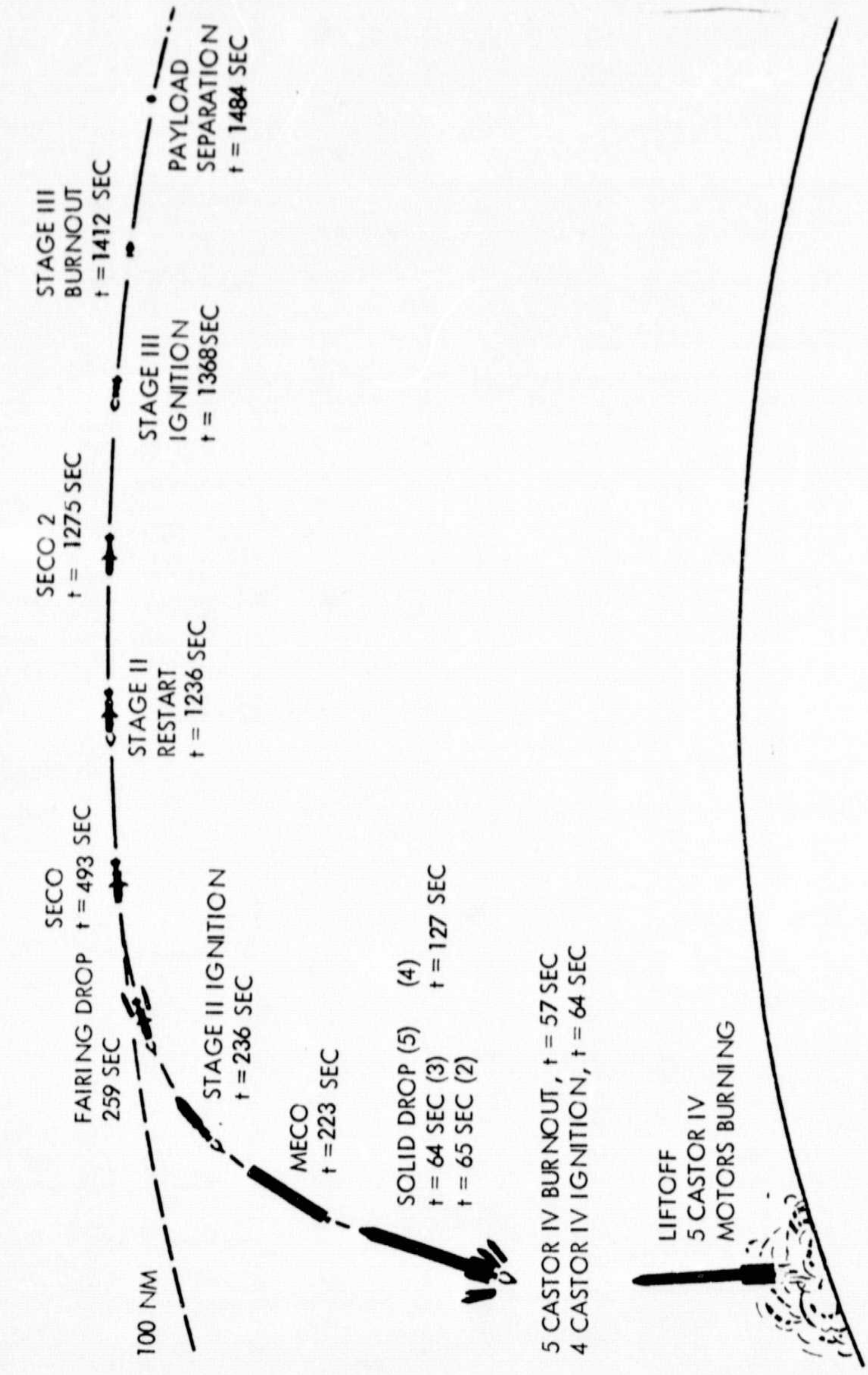

Fig. 5

MISSION SUPPORT

RANGE SAFETY

Command destruct receivers are located in the first and second stages and are tuned to the same frequency. In the event of erratic flight, both systems will respond to the same RF modulated signal sent by a ground transmitting system upon initiation by the Range Safety Officer.

LAUNCH SUPPORT

The Eastern Test Range, the launch vehicle contractor, McDonnell-Douglas, and NASA will supply all personnel and equipment required to handle the assembly, pre-launch checkout, and launch of the Delta vehicle.

TRACKING AND DATA SUPPORT

ETR Range stations will track the first and second stages. Two ARIA aircraft will track and record data for second and third stage operations. A nominal orbit will be provided approximately 30 minutes after launch based on this data and the assumption that the third stage was nominal.

The Apogee Kick Motor (AKM) firing 3 days after liftoff will be controlled from the Telesat central ground station at Allan Park, Ontario near Toronto, which is responsible for all tracking and data recovery activities after the spacecraft reaches transfer orbit. Launch vehicle tracking as well as early orbit spacecraft tracking will be provided by NASA's Space Tracking and Data Network (STDN) with all spacecraft data sent simultaneously to Telesat/Canada.

DELTA/TELESAT-D LAUNCH TEAM

NASA HEADQUARTERS

John F. Yardley	Associate Administrator for Space Transportation Systems
Joseph B. Mahon	Director, Expendable Launch Vehicles Program
Peter T. Eaton	Manager, Delta Program

GODDARD SPACE FLIGHT CENTER

Dr. Robert S. Cooper	Director
David Grimes	Delta Project Manager
William R. Russell	Deputy Delta Project Manager, Technical
Robert Goss	Chief, Mission Analysis & Integration Branch, Delta Project Office
Philip Frustace	Telesat-D Mission Coordinator

KENNEDY SPACE CENTER

Lee Scherer	Director
George F. Page	Director, Expendable Vehicle Operations
William Thacker	Manager, Delta Launch Operations
William Fletcher, Jr.	Manager, Delta Spacecraft Operations

TELESAT/CANADA

William Zatychec	Telesat-D Project Manager
George Martch	Telesat-D Spacecraft Manager (RCA-Astroelectronics)
David Griffiths	Telesat-D Launch Vehicle Coordinator