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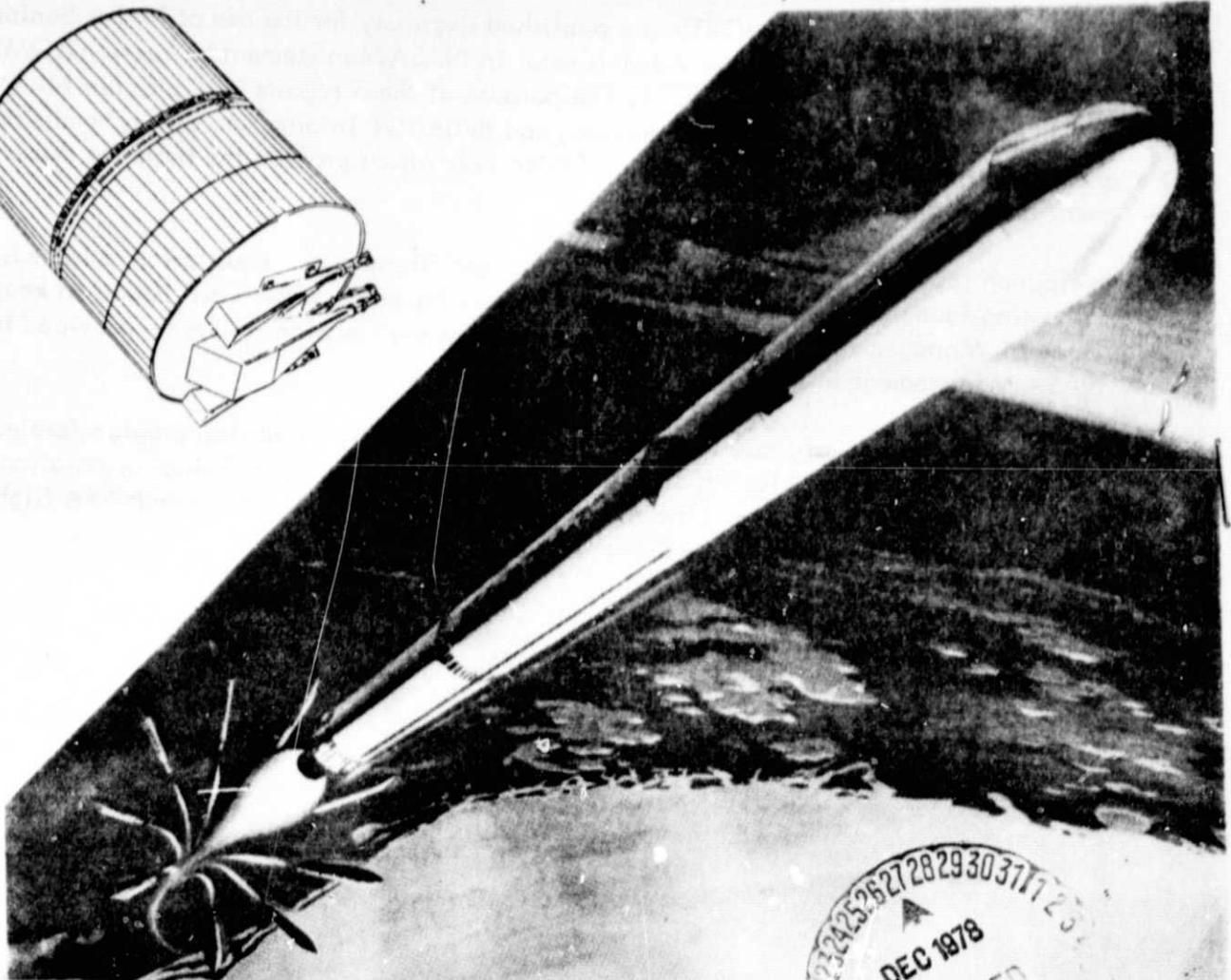
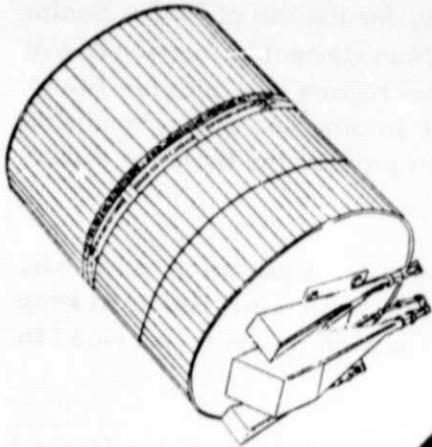
NASA

National Aeronautics and
Space Administration

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Mission Operation Report

OFFICE OF SPACE TRANSPORTATION SYSTEMS Report No. M-492-207-78-03



(NASA-TM-79884) NATO-3C/DELTA LAUNCH
(National Aeronautics and Space
Administration) 22 p HC A02/MF A01 CSCL 22A



N79-12123

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NATO-III C/Delta Launch

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GENERAL

On November 27, 1973, an Interagency Agreement was signed between NASA and USAF/SAMSO (DOD) which sets forth terms and conditions whereby NASA would furnish Delta launch vehicles and associated services on a reimbursable basis for the purpose of launching NATO-III Communications Satellites. The related Memorandum of Agreement between NATO and the U.S. DOD for NATO-III was signed July 12, 1972. Revision of the -B and -C missions to direct identifiable basis was accomplished by exchange of telex in April, 1976.

In accordance with the Agreement, NASA will provide:

- Launch of the NATO-III spacecraft into the desired synchronous transfer orbit using Delta 2914 vehicles
- Working area for the NATO-III spacecraft at ETR
- Spacecraft telemetry reception during launch preparations and during the ascent
- Network communications support necessary for launch phase
- Initial transfer orbit calculations
- Additional special services as required to support the launch

USAF/SAMSO, representing NATO, has undertaken to do or certify that the following has been done:

- Provide NATO-III 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 safety standards
- Provide launch constraint criteria for spacecraft and supporting stations

NASA MISSION OBJECTIVES FOR THE NATO-IIIC MISSION

To place the NATO-IIIC satellite into a synchronous transfer orbit of sufficient accuracy to allow the spacecraft propulsion system to place the spacecraft into a stationary synchronous orbit while retaining sufficient stationkeeping propulsion to meet the mission lifetime requirements.

for Robert O. Allen

Joseph B. Mahon, Director
Expendable Launch Vehicle Programs

Date: NOV 08 1978

John F. Yardley

John F. Yardley, Associate Administrator
for Space Transportation Systems

Date: Nov 13, 1978

MISSION DESCRIPTION

The NATO Integrated Communications Systems Management Agency (NICSMA) is responsible for establishing and operating an integrated NATO defense communications satellite system which will provide high-quality voice and data communications via satellites to appropriate military ground stations. Four satellites in this system, NATO-I, -II, -IIIA, and -IIIB were successfully launched by Delta vehicles in March 1970, February 1971, April 1976, and January 1977, respectively.

The launch vehicle will place the spacecraft in an elliptical transfer orbit with apogee of 35,813 km (22,253 st. mi. or 19,324 NM), perigee of 185 km (115 st. mi. or 100 NM), and inclination of 27.2 degrees to the equator. At fifth apogee (roughly 2 days after launch), the USAF ground stations that took over responsibility after separation of the spacecraft from the vehicle, will command firing the spacecraft AKM to circularize the orbit at roughly 35,900 km altitude and at roughly zero inclination. Over the next 10 days, the satellite will be drifted by its hydrazine system to its synchronous location at 45-50 degrees W longitude (above the east coast of the U.S., roughly) and responsibility will be handed over to NATO and its ground system.

SPACECRAFT DESCRIPTION

NATO-IIIIC is a drum-shaped spacecraft, as shown in Figure 1, 2.18 meters (86 inches) in diameter, 2.23 meters (88 inches) long, with an overall length of 2.92 meters (115 inches) counting the antennas. It weighs 706 kg (1553 pounds) at launch and after firing of the onboard apogee kick motor it will weigh 346 kg (759 pounds). Its design lifetime is 7 years. The spacecraft was developed by Ford Aerospace and Communications Corp. under contract with the USAF/SAMSO.

NATO-IIIIC SPACECRAFT

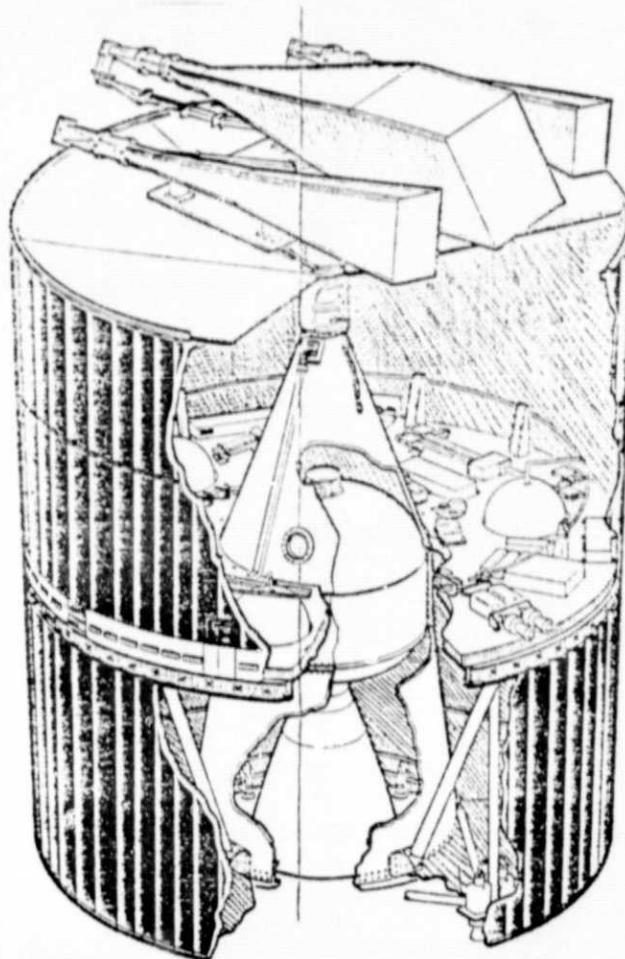


Fig. 1

The NATO-IIIIC spacecraft will be spin-stabilized with mechanical despun motors and RF rotary joints used to despun only the communications antennas.

The major subsystems of the NATO-IIIIC spacecraft are as follows:

<u>Item</u>	<u>Description</u>
Stabilization	Spin stabilized. Stable configuration in transfer orbit and throughout on-station life. 90 rpm spin rate.
Communications	Three antennas: narrow beam (NB) transmit, wide beam (WB) transmit, WB receive. WB and NB transponders each with 23-watt Hughes 265H TWTA. Two additional TWTAs switchable to either transponder.
TT&C	Performs beacon telemetry and timing function; ring array antenna. 146 commands 131 8-bit telemetry words
Attitude and Antenna Control	Four Earth sensors and two Sun sensors provide multiple redundancy for attitude reference. Antenna despun motor. pointing accuracy Azimuth: $\pm 0.3^\circ$ Elevation: $\pm 0.4^\circ$
Electrical Power	Two-segment cylindrical solar array; separate battery charge control array. Three 20-Ah, 20-cell NiCd batteries.
Reaction Control	Hydrazine monopropellant system with redundant 5-lb thrusters for attitude and velocity control; propellant for 7-year operation. 61 lb of propellant 100 ms pulse action
Thermal Control	Passive except for localized heaters. Heat transfer mainly through ends of spacecraft.
Apogee Kick Motor	Stretched SVM-5 Total impulse = 210,350 lb/sec
Structure	Monocoque shell supporting horizontal equipment platform.

Key features of the subsystems are as follows:

Communications Subsystem

Key features of the communications subsystem are:

- Three circularly polarized horn antennas operating on a multi-mode principle
- Graphite epoxy antenna construction
- Three channel coaxial rotary joint
- Single-conversion transponder
- All active components are 100% redundant
- Cross-strapping between redundant components is employed
- All amplification is in the 8 and 7 GHz region
- Two independent simultaneous operating channels are used
- Each channel has independent TWTA and transmitting antenna

Performance parameters include:

• Bandwidths	17, 50, 85 MHz
• Uplink Frequencies	8 GHz
• Downlink Frequencies	7 GHz
• Offset Frequency	725 MHz
• TWTA Output Power	23 watts
• Wide Beam Antenna Gain (Peak)	
• Transmitter	19.3 dB
• Receiver	18.5 dB
• Narrow Beam Antenna Gain	
• Transmitter	27.5 dB

Telemetry, Tracking, and Command Subsystem

The telemetry, tracking, and command (TT&C) subsystem is full redundant, cross-strapped at each available opportunity, and completely SGLS compatible. The design uses the improved RF equipment from the Skynet II satellite program and the improved digital equipment from the Synchronous Meteorological Satellite Program.

A microminiature SGLS S-band transponder, as a part of the TT&C subsystem, will provide the standard SGLS functions of: command reception, telemetry transmission, two-way Doppler tracking and turn-around PRN ranging. The transponder uses thick film and thin film construction techniques throughout. Primary characteristics are as follows:

Receiver section:

- . Input Frequency 1760-1840 MHz
- . Dynamic Range -35 dBm to Threshold
- . APC Loop Predetection Bandwidths 20kHz
- . Weight 1.0 lb

Transmitter section:

- . Output Frequency 2200-2300 MHz
- . Power Output +31.5 dBm
- . Bandwidth, 1dB +4 MHz
- . Weight, lb 0.8
- . Size, inches 1.6 x 2.0 x 4.6

Attitude and Antenna Control Subsystem

The key features of the attitude and antenna control subsystem are:

- . Stable satellite configuration during all phases of the mission, precluding the possibility of flat spin failure mode conditions
- . Communications antenna statically and dynamically balanced, combined with a motor to give torque margins of 5 to 1 for startup and 3.5 to 1 for running
- . Antenna acquisition, during all phases of the mission, to the required pointing accuracy in less than 2 minutes
- . Complete redundancy in Earth sensors where any two of the four will give attitude data to the required accuracy and any one of the four will provide steering data for antenna pointing
- . Redundant electronic units with internal cross-strapping for increased reliability
- . Antenna despun motor with isolated redundant winding in each phase
- . Redundant passive nutation dampers with a satellite damping time constant of 4.3 minutes at end of life

Power Subsystem

The power subsystem employs as the primary power source 2 cm x 3 cm N on P 10 ohm-cm silicon solar cells, which are covered by 0.012-inch-thick cover glass, and arranged into a two-section, cylindrical body-mounted array. The array will produce 538 W at beginning of life and 421 W at end of life, thus providing an estimated power margin of 79 W, or approximately 20% of the presently expected load. The secondary power source will be three 20-ampere-hour batteries, each containing 20 nickel cadmium cells connected in series.

Propulsion Subsystem

The spacecraft will be placed into a near-synchronous circular orbit by use of a modified Aerojet SVM-5 solid propellant apogee kick motor (AKM). The AKM

will be sized to give a velocity change of 5960 ft/s to a 1532 lb gross weight satellite.

Key features of the apogee kick motor:

- Low temperature fiberglass case
- Noneroding tungsten nozzle throat
- Proven propellant/liner/insulation system
- High performance nonsubmerged nozzle
- Space-qualified safe/arm device

Key features of the reaction control system:

- Previously qualified components
- Hamilton Standard thrusters which allow alignment, have good thermal soak-back properties, and use redundant hard seat valves
- Simple monopropellant blowdown system
- Centrifugal force feed

Structure/Thermal Subsystem

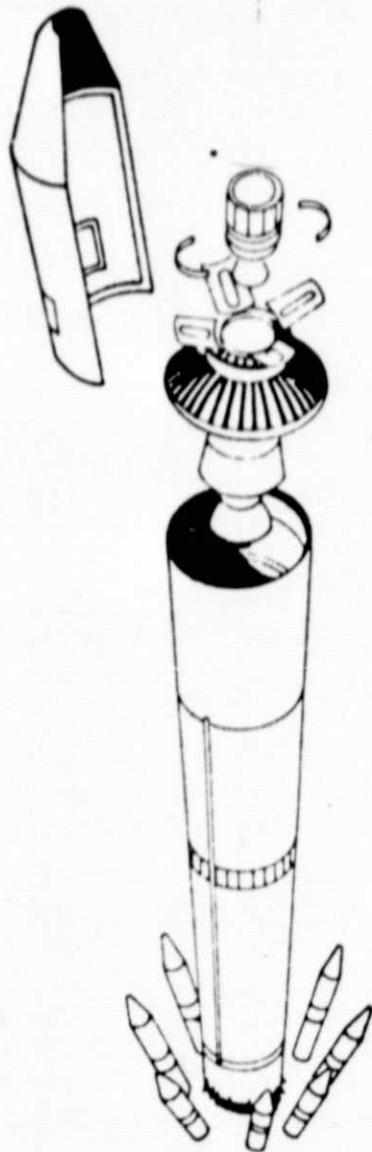
The primary structure consists of a central cone and six struts which support a 2-inch thick aluminum honeycomb horizontal equipment panel. The lower or aft end of the cone is a stiff machined ring for attachment to the 3731A launch vehicle adapter by use of an explosive-bolt-separable V-band clamp. Mounted inside the central cone is the apogee kick motor with its nozzle pointed aft. Mounted to the forward end of the central cone is the motor for despinning the antennas.

Spacecraft Ground Station System

During prelaunch activities and launch vehicle ascent, the spacecraft telemetry systems operate through existing NASA ground stations supporting the launch vehicle. During initial transfer orbit phase after separation from the vehicle, the spacecraft will operate through the primary USAF/SAMSO ground station at Sunnyvale, CA. During this transfer orbit phase and subsequent operational phases the spacecraft will operate through the Air Force Satellite Control Facilities system utilizing as required the following ground stations:

Indian Ocean station	- Seychelles Islands (INDIS)
Guam Tracking station	- Guam Island (GOAMS)
Hawaii Tracking station	- Hawaii (HULA)
New Hampshire Tracking station	- New Hampshire (BOSS)
Vandenberg Tracking station	- VAFB, CA (COOK)

LAUNCH VEHICLE FOR NATO-IIIIC (DELTA 2914)



OVERALL DIMENSIONS

Length (meters) 35.5
Basic Diameter (meters) 2.45

Fig. 2

LAUNCH VEHICLE DESCRIPTION

The NATO-IIIIC spacecraft will be launched by a three-stage, thrust augmented NASA Delta 2914 launch vehicle. Schematics of the launch vehicle and spacecraft are shown in Figures 2 and 3. This will be the 146th flight for Delta. Of the previous 145 flights, 133 have successfully placed satellites into orbit.

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

Overall the Delta 2914 is 35.5 meters long (116 ft) including the spacecraft shroud. Liftoff weight is 132,265 kg (293,100 lb) and liftoff thrust is 1,760,000 newtons (396,700 lb) including the startup thrust of six of the nine solid motor strap-ons (the remaining strap-ons are ignited at 39 seconds after liftoff).

	FIRST STAGE	STRAP-ON SOLIDS (9)	SECOND STAGE	THIRD STAGE
Name	Extended Long Tank Thor	TX-354-5, Castor II	Eight Foot Diameter TR-201	TE-364-4
Manufacturer	McDonnell Douglas, (MDAC)	Thiokol	TRW/MDAC	Thiokol
Propellant	RJ-1/LOX	Solid	N ₂ O ₄ /Aerozene-50	Solid
Liftoff Weight (kg)	84,700	40,000	5440	1080

INBOARD PROFILE — NATO-IIIC VEHICLE

STATION

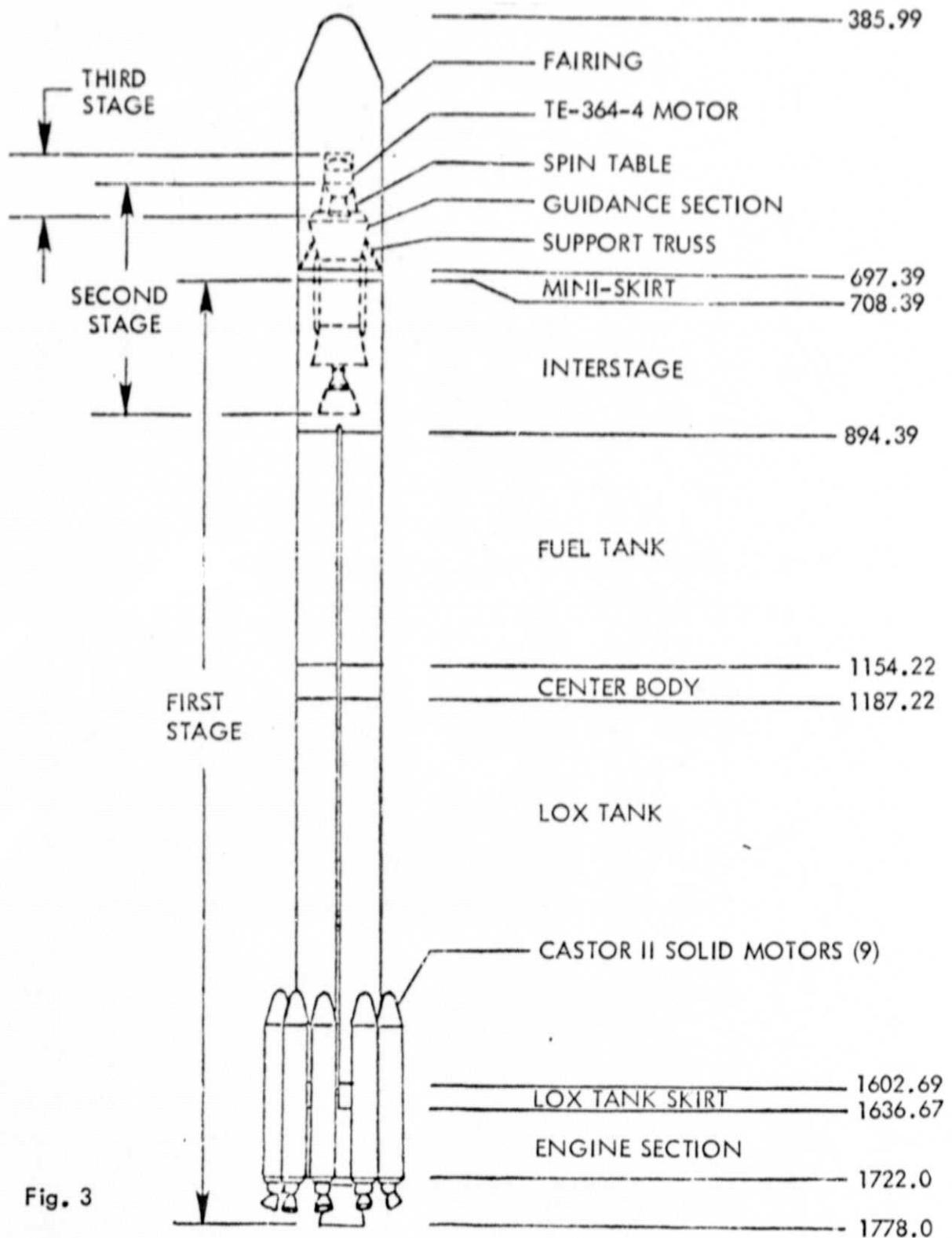


Fig. 3

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The first stage booster will be the 10-foot elongated Thor powered by the RS-27 liquid propellant Rocketdyne engine system. Pitch and yaw steering is provided by gimbaling the main engine. The vernier engines provide roll control during powered flight and control during coast.

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 flight are provided by gimbaling 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 for the booster originates from the second stage. A strapdown inertial guidance system 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 strapdown system is composed of digital computers developed by Teledyne and Delco and an inertial measurement unit developed by Hamilton Standard.

FLIGHT DESCRIPTION

Figures 4 through 9 show the ascent sequence of events, the boost and orbit profile, the mission requirements, the flight mode description and predicted orbit dispersions for the NATO-IIIIC mission.

NATO-IIIIC
FLIGHT SEQUENCE OF EVENTS

<u>EVENTS</u>	<u>TIME (SEC)</u>
Liftoff - Ignite 6 solids	
Burnout of 6 solids	38
Ignite 3 solids	39
Burnout of 3 solids	77
Jettison 9 solids	87
Main Engine Cutoff	223
Stage I - II Separation	231
Stage II Ignition	236
Jettison Fairing	277
SECO I	531
Restart Stage II	1298
SECO II	1309
Stage II - III Separation	1361
Stage III Ignition	1402
Stage III Burnout	1446
Stage III - Spacecraft Separation	1515

Fig. 4

NATO-IIIIC BOOST PROFILE

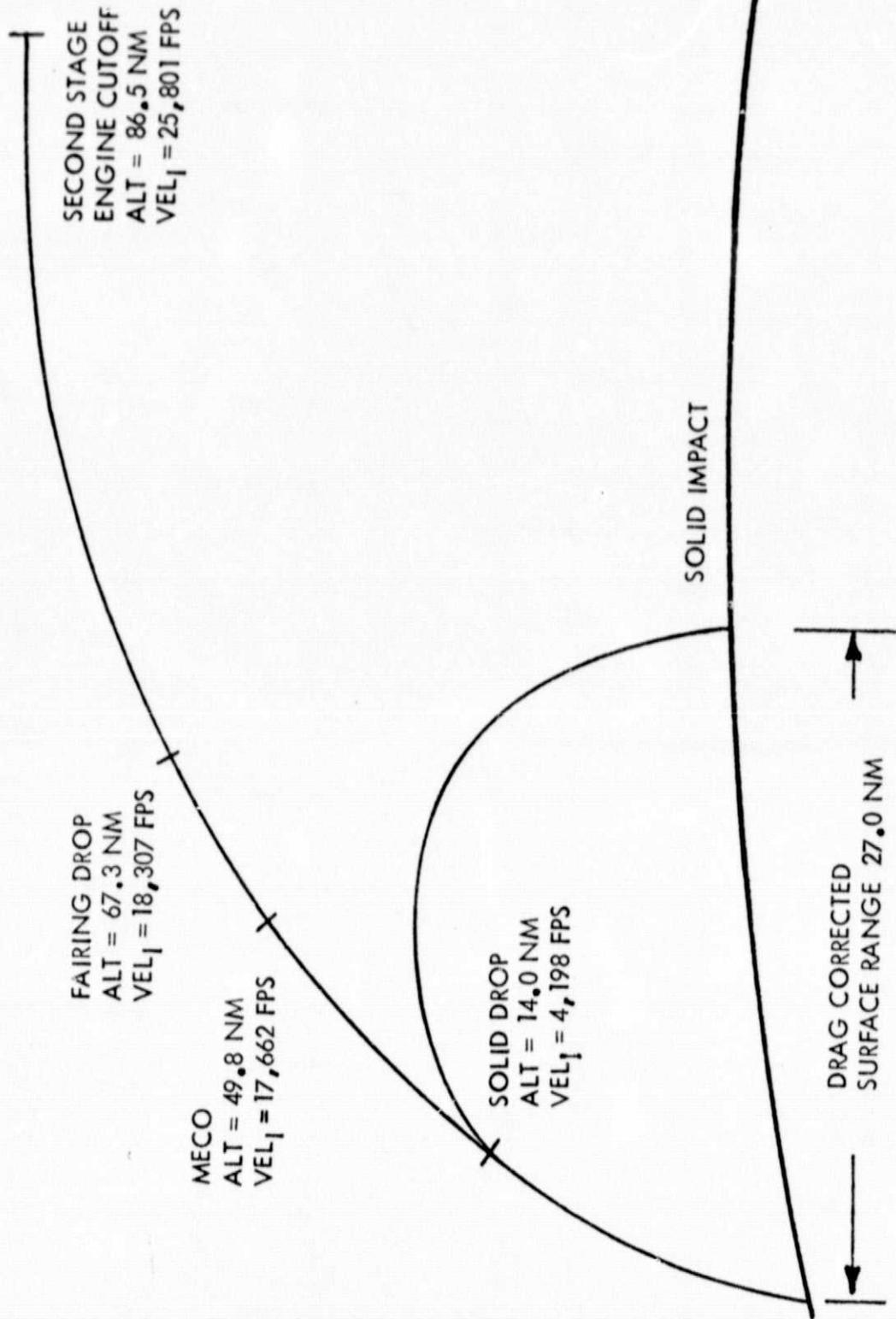


Fig. 5

NATO-IIIIC ORBIT PROFILE

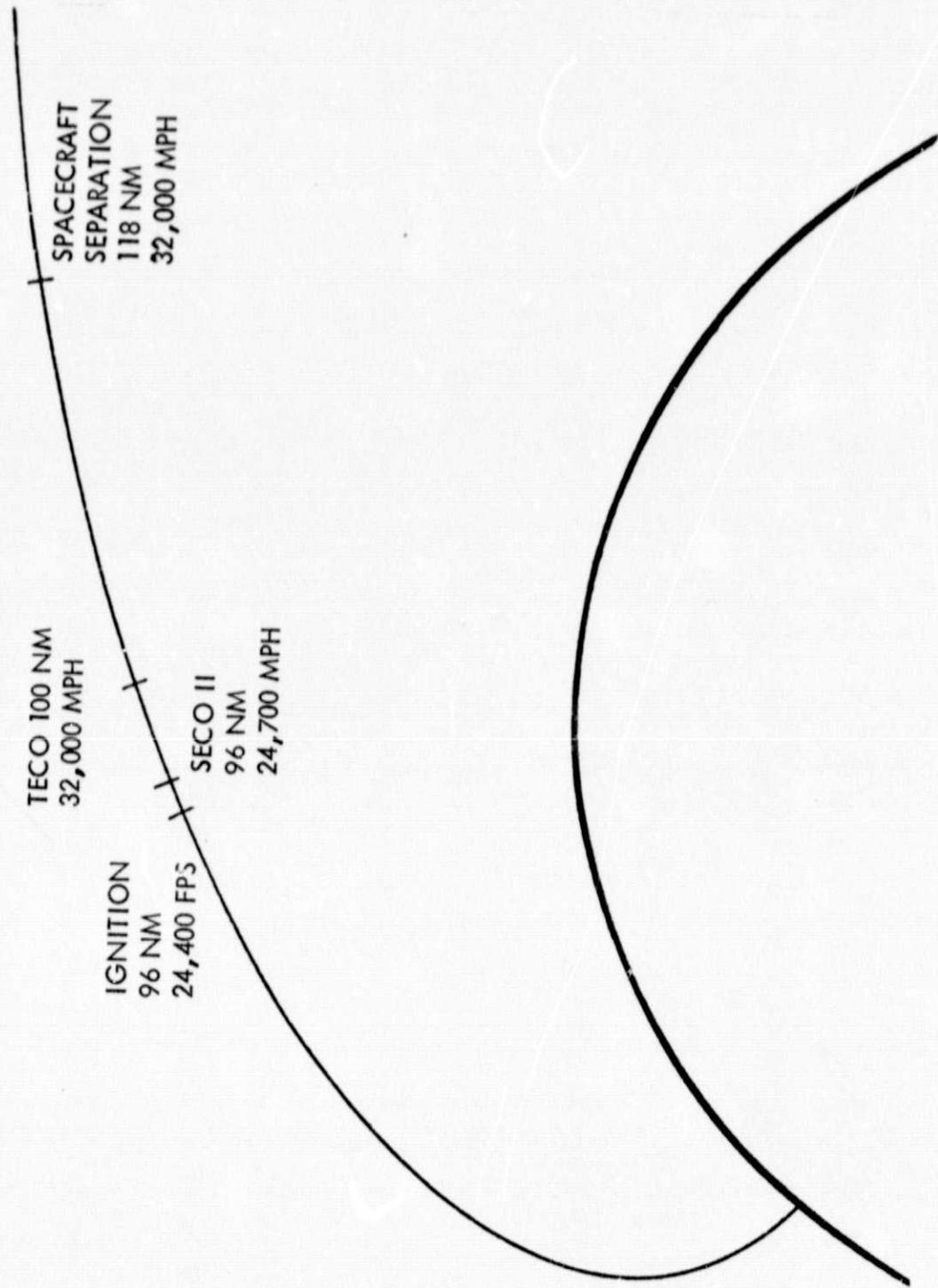


Fig. 6

NATO-IIIIC MISSION REQUIREMENTS

NOMINAL ORBIT PARAMETERS AT SPACECRAFT INJECTION	
Apogee Altitude	19,324 NM (Integrated)
Perigee Altitude	100 NM
Inclination	27.7 Degrees
Argument of Perigee	170.8 Degrees
Spin Rate	93 RPM
SPACECRAFT WEIGHT (AT LIFTOFF)	1553 LB

Fig. 7

NATO-IIIIC FLIGHT MODE DESCRIPTION

•	Launch from PAD 17B at ETR
•	Launch Window is 8:25 p.m. to 8:45 p.m. EST
•	Flight Azimuth = 95 Degrees
•	Six Solids Ignited at Liftoff
•	Marginal Ground Coverage of Third Stage Burn from Ascension (T/M Airplane will be deployed)

Fig. 8

NATO-IIIIC
PREDICTED ORBIT DISPERSIONS (99% PROBABILITY)

Apogee Altitude	+600 NM
Perigee Altitude	+10 NM
Inclination	+0.3 Degree
Spin Rate	+10 RPM
	-

Fig. 9

MISSION SUPPORT

RANGE SAFETY

Command destruct receivers are located in the first and second stages and are turned 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, prelaunch checkout, and launch of the Delta vehicle.

GSFC will provide technical advisory personnel to Ford-Aerospace, if required.

TRACKING AND DATA SUPPORT

ETR Range stations will track the first and second stages. 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 USAF has established stations that will be used to determine the final transfer orbit and also to provide data necessary for the firing of the apogee motor.

NATO/DELTA TEAMNASA HEADQUARTERS

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

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Robert Londley	Director, Projects Management
David Grimes	Delta Project Manager
Robert Goss	Chief, Mission Integration and Analysis, NASA Project Manager for NATO-III
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Thomas K. Spencer	Network Support Manager
Raymond Mazur	Mission Support Manager

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

NATO/USAF

Col. R. Browning	Program Manager, USAF/SAMSO
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CONTRACTORS

Ford-Aerospace Communications Corp. Palo Alto, CA	Spacecraft
McDonnell-Douglas Astronautics Co. Huntington Beach, CA	Launch Vehicle

ESTIMATED DIRECT IDENTIFIABLE COSTS TO USAF/SAMSO

Estimated cost of services and hardware that will be billed to USAF/SAMSO is \$8.8 million.