CONESTOGA II
A LOW COST COMMERCIAL SPACE TRANSPORT SYSTEM

by

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ABSTRACT

Conestoga II is currently under development. It will be capable of inserting 500 Kg satellites into 800 Km circular polar orbits. Conestoga II makes maximum use of existing (developed) technology and hardware. Its commercial objective is to fill a need for low cost low earth orbital transport not efficiently served by Shuttle or larger space transport systems. The paper will expand on low earth orbit markets, foreign participation, and launch site considerations. Technical and economic trade-offs will be examined.

INTRODUCTION

The Conestoga II, when completed, may very well be the world's first all commercial orbital transport vehicle. It is designed to be capable of inserting a 500kg (1100 lbs) satellite into an 815 Km (440 nm) circular polar orbit. The Conestoga II vehicle, as currently configured, is shown in Figure 1. Conestoga II will have over 3 times the orbital weight capability of Scout.

The value of Conestoga II rests on the premise that as the world continues into the space age, there will be an ever increasing need for efficient, low cost orbiting transport systems. The Conestoga II will serve a different market than the Shuttle and Ariane. The Shuttle and Ariane market involves very heavy payloads, many going into geostationary orbits. In an attempt to concentrate on the Shuttle, U.S. policy has been to abandon most of its dedicated expendable launch vehicles.

The Soviet Union, France (as part of ESA), Japan, China, and India all currently have national space programs with orbital vehicle capability. These Government programs may or may not constitute real competition in a commercial sense. The competition will depend on the degree of subsidizing which those countries offer to space transport users. It is our contention that the efficiencies inherent in a commercially directed program will provide Low Earth Orbital transport so low in cost that subsidized competition cannot long prevail.

The technology for producing reliable, dedicated Low Earth Orbiting rocket vehicles is mature. That is to say, no breakthroughs are required. It remains only to select existing technology and hardware and to combine them efficiently.

Peaceful uses of low earth space include, but are certainly not limited to:

1. Data Collection and Communications Systems for Remote Sites. Applications include monitoring unattended oil wells, pipelines, and electical power systems, water resources, communications with isolated outposts, and electronic mail.

2. Vehicle Location, Search and Rescue. Through the use of satellite Doppler data, trucks, ships, boats, railroad cars or any mobile vehicle can be position-monitored from space with location reporting several times per day. The ability of satellites to find downed aircraft and distressed ships at sea has already been proven.

3. Earth Resource Monitoring. Low Earth orbiting satellites similar to the U.S. Landsat systems can monitor renewable and non-renewable earth resources. These include oil field and mineral site surveying, agricultural monitoring for crop disease or drought, and for irrigation control.

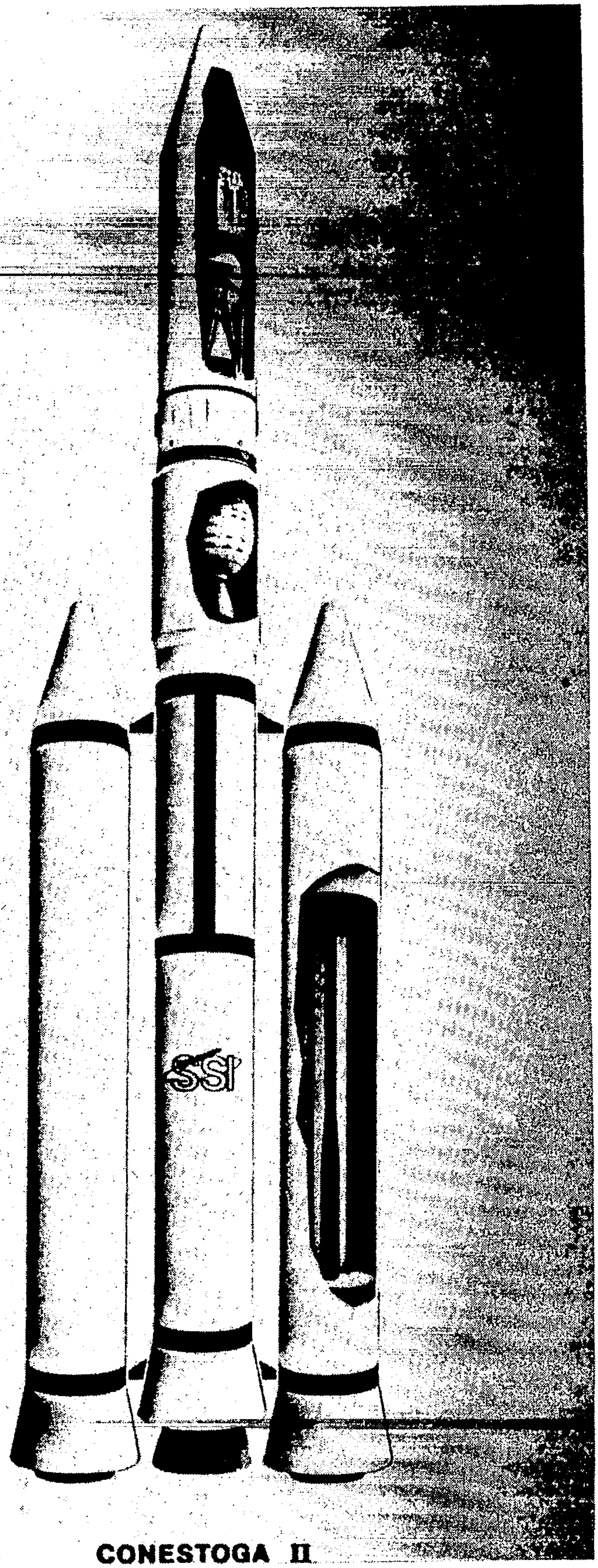
4. Border Security Monitoring and Law Enforcement. Low Earth satellites with sufficient resolution can determine border infringement and illegal offshore operations.

5. Space Processing. The ability to process special medicines and to create new alloys in zero "G" environments is in its infancy. Space processing may ultimately dominate all other aspects in commercial importance.

6. Navigation and Surveying. The Transit satellites and now the Global Positioning System (GPS) satellites have revolutionized navigation. Interferometric systems using space technology offer the potential of establishing even greater accuracy with position fixes to within better than a meter.

Space transport technology involves a multiplicity of technical disciplines. They include: (1) rocket propulsion, (2) aerodynamics, (3) guidance, (4) control, (5) communications, (6) digital data processing, and (7) tracking. Reliable hardware and software is available in all of these disciplines.

The Conestoga II program will combine these existing elements to produce an efficient and low cost orbital launch system.



CONESTOGA II

FIGURE 1

BACKGROUND

In January 1982, Space Vector Corporation (SVC) received a contract from Space Services, Inc. of America (SSI) to design, fabricate, and launch the first commercially sponsored suborbital rocket vehicle. This vehicle, designated Conestoga I, is shown in Figures 2 through 4. The principle mission of the Conestoga I was to demonstrate procedures and systems required for a full-up orbital space launch and establish a precedence for commercial ventures into space.

Conestoga I was successfully launched into space from Matagorda Island, Texas, September 9, 1982. The flight was a simulation of an orbital insertion sequence and successfully demonstrated booster guidance and control, payload separation, shroud separation, attitude control maneuvering, payload and 4th stage motor spin-up, and orbital insertion motor ignition. The payload followed a ballistic trajectory (see Figure 5), reaching a maximum altitude of 309 Km (192 statute miles). It re-entered the atmosphere and splashed down in the Gulf of Mexico 516 Km (321.5 statute miles) south of the Matagorda launch site.

The vehicle and launch facilities constructed at Matagorda to accomodate the Conestoga I launch were designed and put in place in less than 9 months. Radar tracking for flight safety and a telemetry receiving station were provided by subcontracting the services of DFVLR's Mobile Rocket Group. No U.S. Government facilities were used.

The successful launch operations of the Conestoga I program, covered extensively by U.S. and World news services, proved to be a milestone in the commercialization of space.

CONESTOGA II

The Conestoga II orbital launch vehicle, now under development, is a four stage booster that will maintain this new impetus and provide the world with a low cost, multi-purpose, space launch system. The Conestoga II, as shown in Figure 6 is a four stage rocket using solid propellant motors. It has been configured to orbit second generation payloads in the 200 to 800 Kg class, and thus fill a void created by current government programs dedicated to Shuttle and Ariane class boosters.

The key elements in the evolution of the Conestoga II booster are:

- The development of the first and second stage booster rocket motors which are modified Castor IV motors produced by the Morton-Thiokol Corporation.
- The integration of the Castor motors with current U.S. technology flexible, vectorable nozzles (flex nozzles) and controlling them in a manner identical to Conestoga I.
- Controlling the 3rd and 4th stage motors by spin precession control using proven SVC control techniques demonstrated as on Conestoga I.

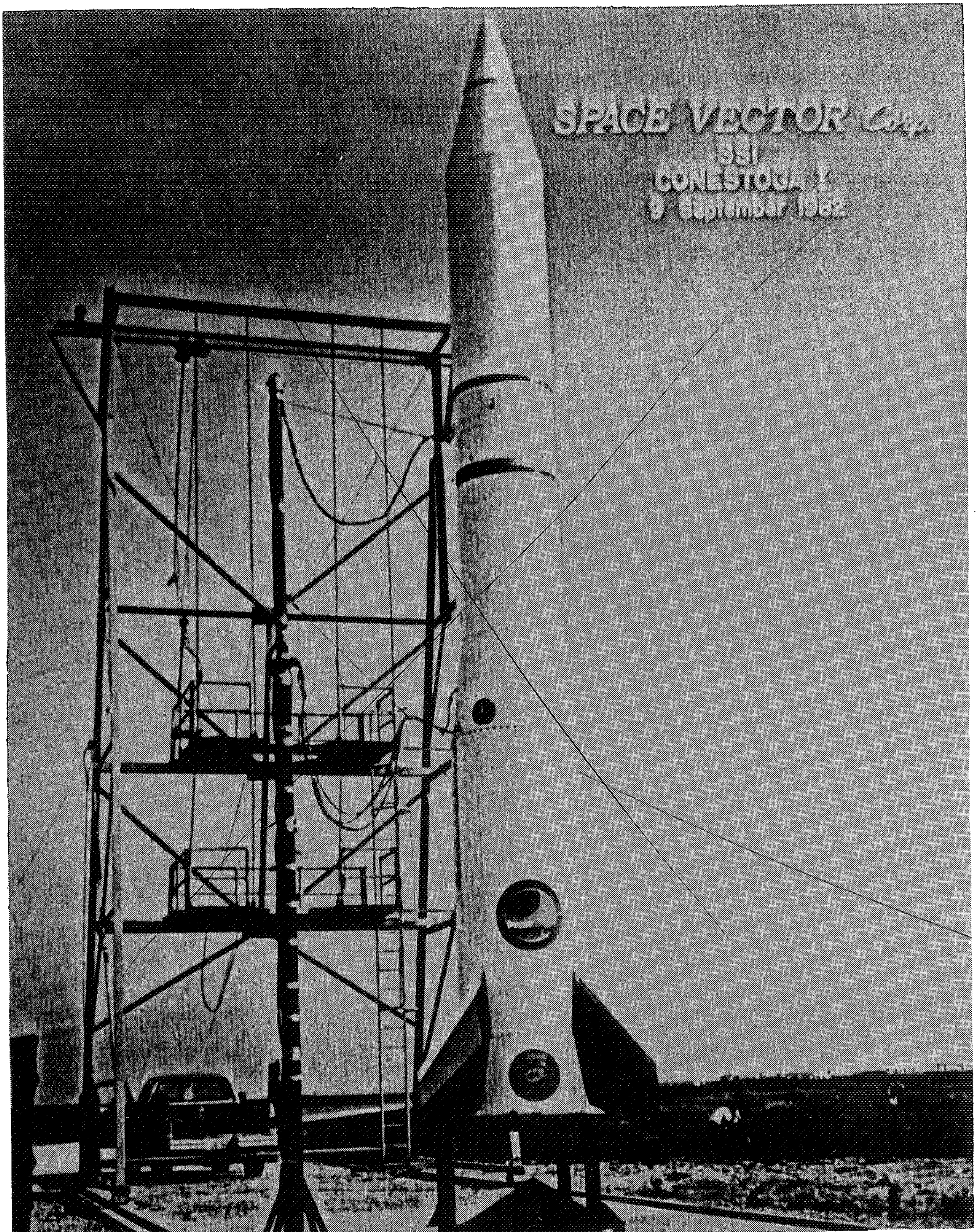
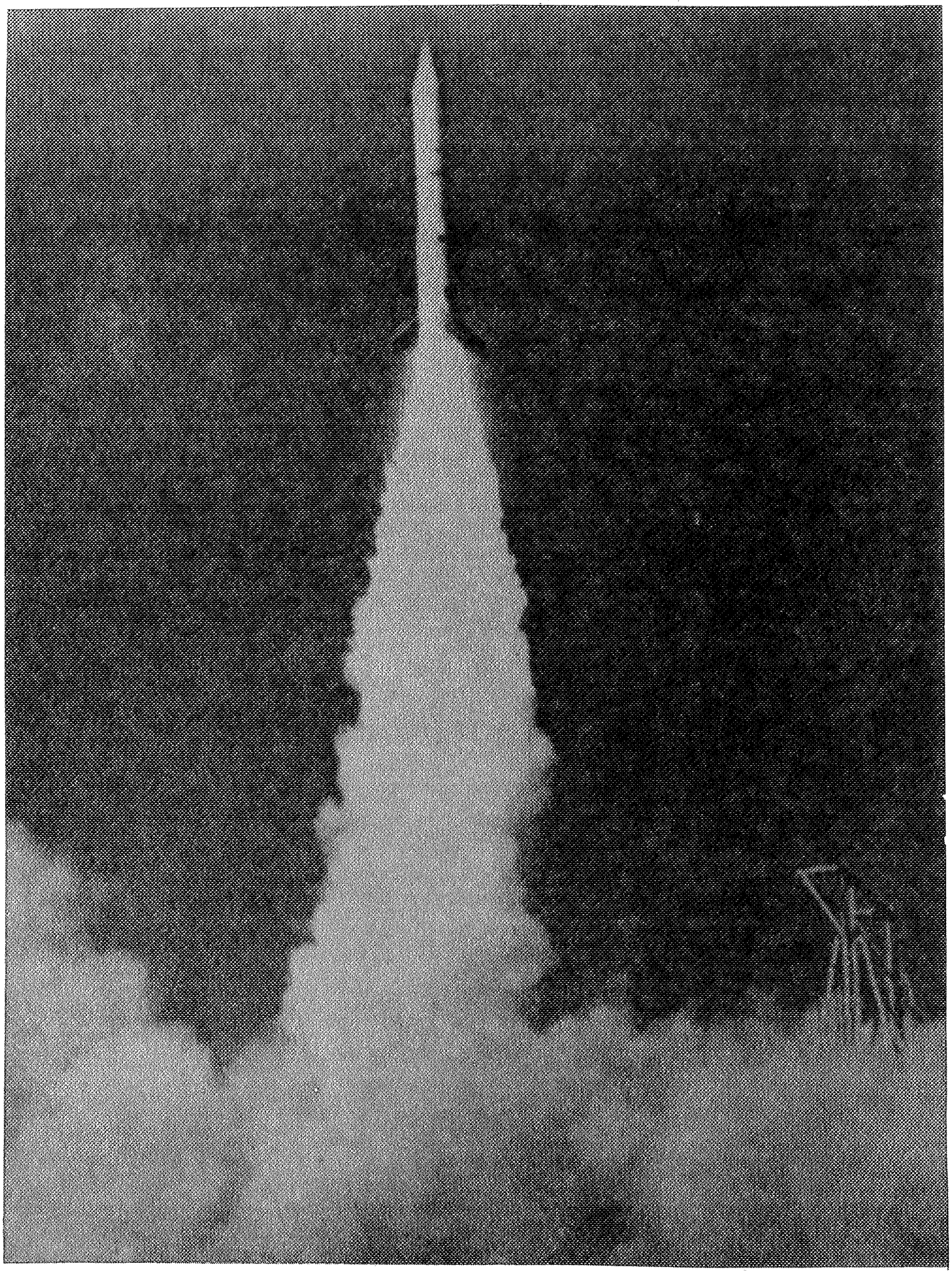
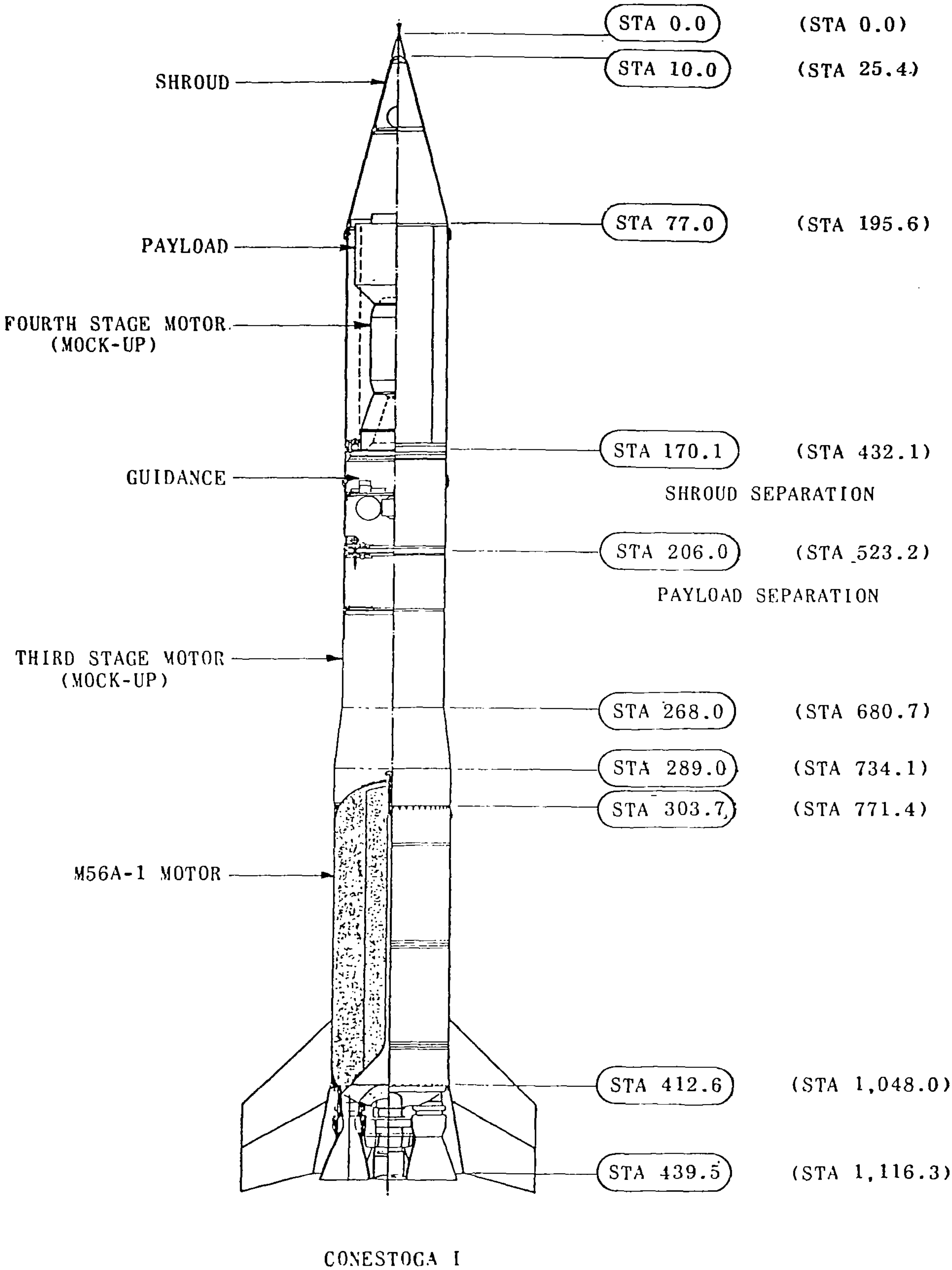


FIGURE 2



CONESTOGA I at Liftoff

FIGURE 3



CONESTOGA I

FIGURE 4

STATION #'S IN PARENTHESES ARE IN CM

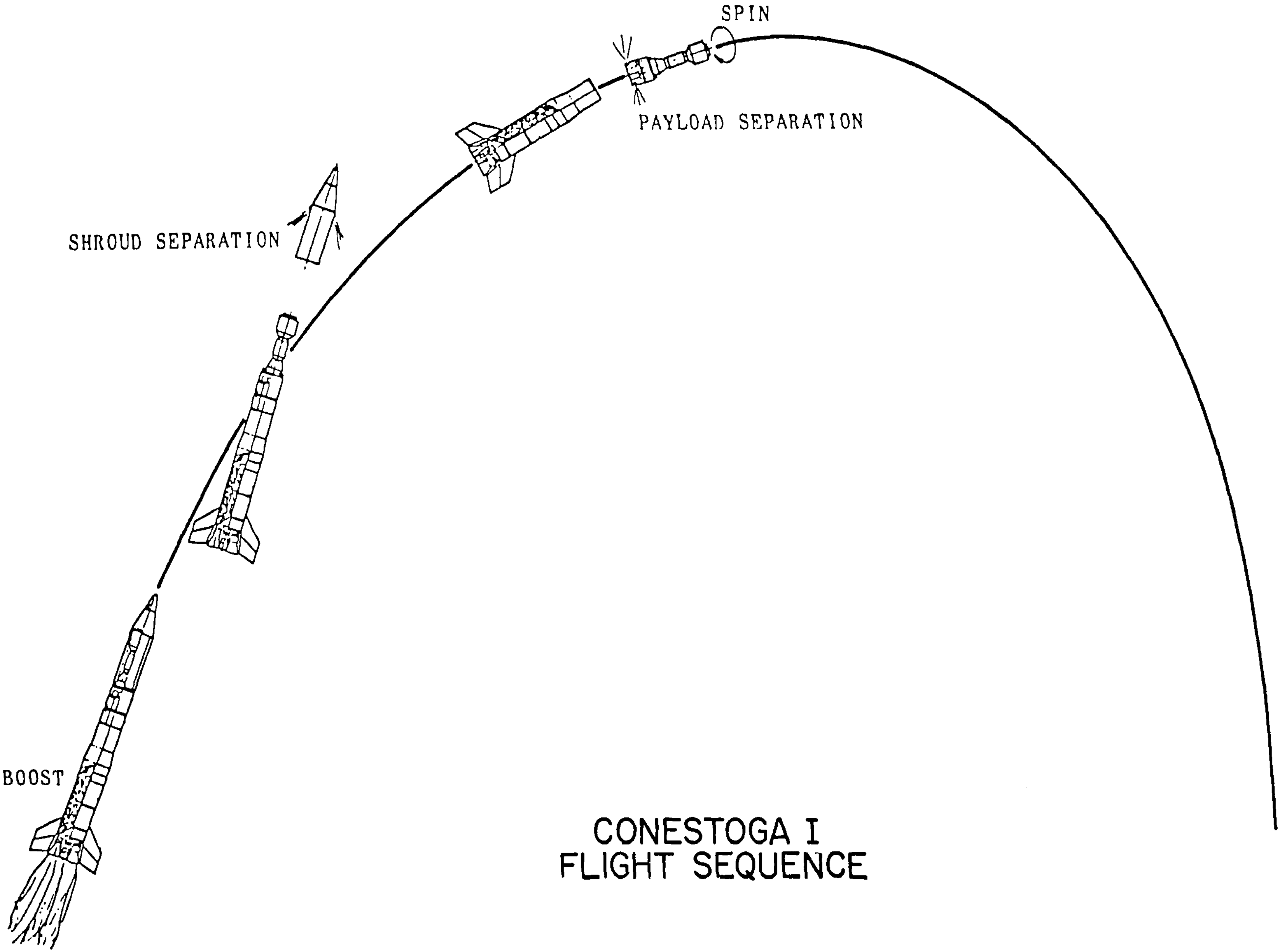

SPIN
PAYLOAD SEPARATION
SHROUD SEPARATION
BOOST
CONESTOGA I
FLIGHT SEQUENCE

FIGURE 5

- Providing precision boost guidance with an inertial guidance system currently under development and being tested at SVC. Modern computer technology has made this approach commercially available to all users.

The program is currently concentrating on:

- Castor IV modification and test.
- Integration of the flex-nozzle to the Castor IV.
- Preliminary design and specifications for the hydraulic nozzle control unit.
- Testing of the SVC advanced inertial guidance unit.
- Systems design and integration.

To assure reliability and reduce development and launch costs, the vehicle is based on proven hardware and technology available from past and existing programs.

Stage 1 is composed of two Castor 4H motors with fully vectorable nozzles ($\pm 6^{o}$) with 8:1 expansion ratios. These two motors are attached to either side of the central core Stage 2 motor. Following Stage 1 burnout, the two Stage 1 motors are separated from the remaining vehicle.

Stage 2 is also a Castor 4H motor with a vectorable nozzle. The nozzle has an expansion ratio of 11:1. After Stage 2 burnout, the expended motor case is released.

A Star 48 or equivalent class motor with a fixed nozzle has been chosen as the 3rd stage. Stage 3 ignition occurs above 400,000 ft. (123 km), i.e., above the sensible atmosphere. The third stage will be spin stabilized and guided by a cold gas system in the Guidance and Control Module.

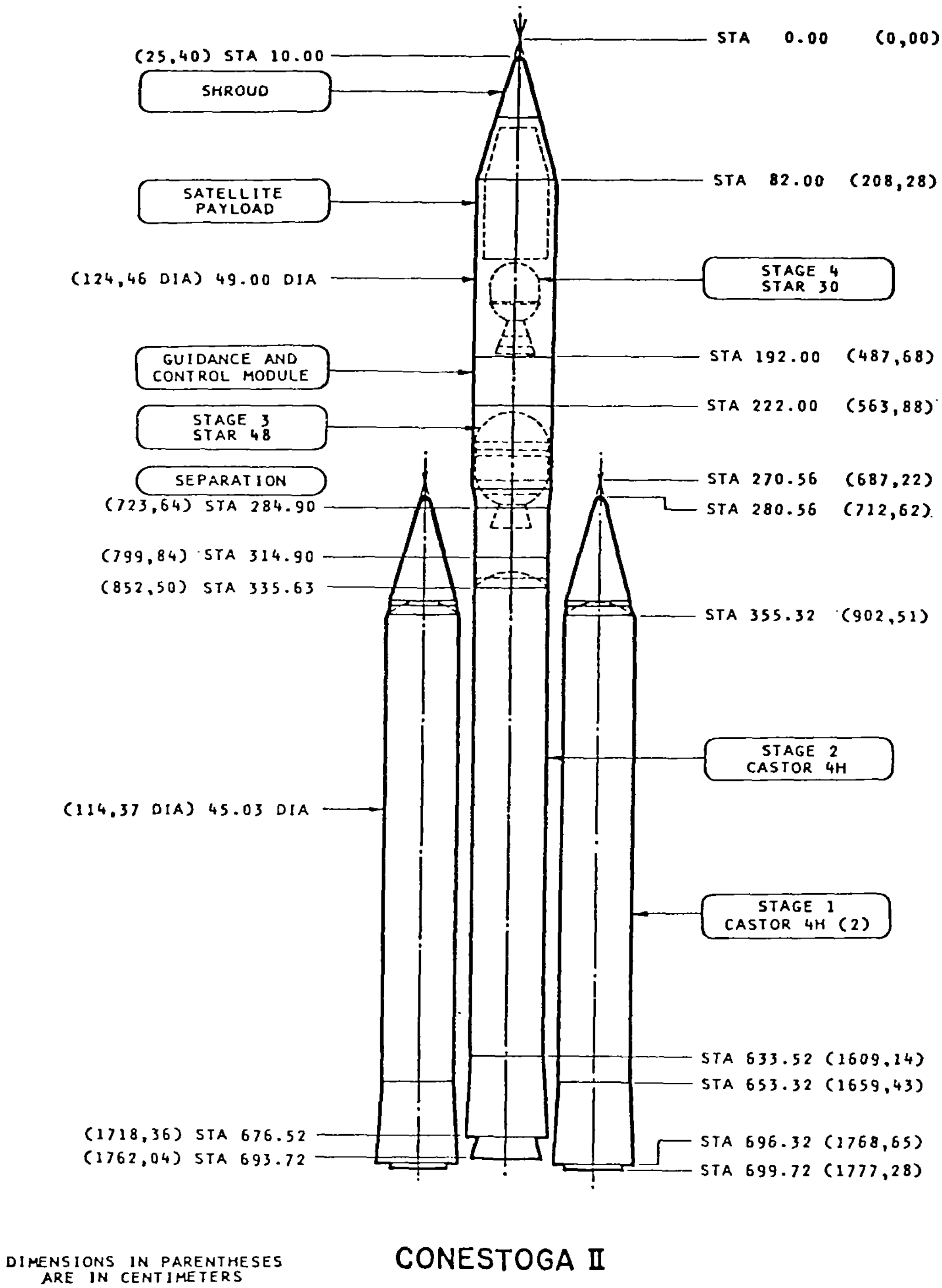
The choice of the Stage 4 orbital injection motor will depend on the size of the payload and any special acceleration limits it may have. On the baseline Conestoga II configuration, a Star 30 motor is depicted.

The Guidance and Control Module, located between Stage 3 and Stage 4, contains the inertial guidance platform, computer electronics, telemetry, and the cold-gas Attitude Control System (ACS).

Enclosed over the payload and Stage 4 motor is a clam-shell split shroud which is separated and released when the vehicle has ascended above the atmosphere. A variety of shroud lengths and diameters can be accommodated.

A weight summary is presented in Table 1.

The four stage Conestoga II is a flexible launch system capable of placing a variety of satellite payloads into near earth orbits. It can place satellites into a full spectrum of orbital inclinations, from pure easterly to polar and retrograde planes.



CONESTOGA II

FIGURE 6

The estimated performance of the baseline Conestoga II for easterly and polar orbits is shown in Figure 7.

Preliminary error analysis of the Conestoga II inertial guidance system indicates that orbital insertion accuracies of ± 15 Km in apogee/perigee and $\pm 0.5^{o}$ inclination error are possible without ground updating.

The Conestoga II can place upper stage velocity packages into low Earth parking orbits for boost out to geosynchronous transfer and other elliptical orbits. The Conestoga II can place 274 Kg (600 lbs) into geosynchronous transfer orbit and, with the proper apogee motor, a 137 Kg (300 lbs) satellite could be stabilized in geosynchronous orbit. Similar sized payloads could be launched on interplanetary trajectories.

Figure 8 shows the Conestoga II mission profile. Figure 9 shows the vehicle after 3rd stage separation undergoing spin up. Both 3rd and 4th stages will be attitude oriented prior to firing using the ACS system under the control of Conestoga's inertial guidance system.

Figure 10 shows nominal acceleration profiles of 1st, 2nd, and 3rd stages. The 4th stage acceleration, being motor and payload weight dependent, is shown with a number of choices in Figure 11.

Figure 12 shows altitude and dynamic pressure as a function of time.

The system inertial guidance utilizes the Space Vector Corporation RIMS II inertial guidance platform originally built and qualified for Sandia National Laboratories. Figures 13 and 14 show this unique roll stabilized inertial guidance platform. Its ability to withstand high spin rates and accelerations is the key to the ability to use inertial guidance during operation of the spinning 3rd and 4th stages.

A payload shroud is provided to protect the payload during ascent. The shroud will be jettisoned during second stage burn after the vehicle has risen above the atmosphere. Aerodynamic loads and heating inputs are carried through the shroud to the forward face of the Guidance and Control Module. The shroud design is a standard cone-cylinder configuration and will be fabricated in two half shells constructed of a composite material structure utilizing an inner honeycomb sandwich. A stainless steel nose tip will protect the shroud at the point of maximum heating.

A variety of payload sizes can be accomodated. The standard shroud size is 462 centimeters (182 inches) long and 124 centimeters (49 inches) in diameter. This shroud allows a payload volume of 0.84 cu. m. (30 cu. ft.) if a Star 30 motor is used as stage four.

Concerning satellite separation, there will be only a simple mechanical interface between the satellite and the booster. The mechanical interface will be a standardized adapter to permit a single-point-release, attach/deployment mechanism. The adapter/deployment mechanism will be capable of imparting a 1.53 meter per second (5 foot per second) separation velocity between the payload and final stage.

The satellite will be electrically self-contained with no electrical interconnection between the satellite and the launcher.

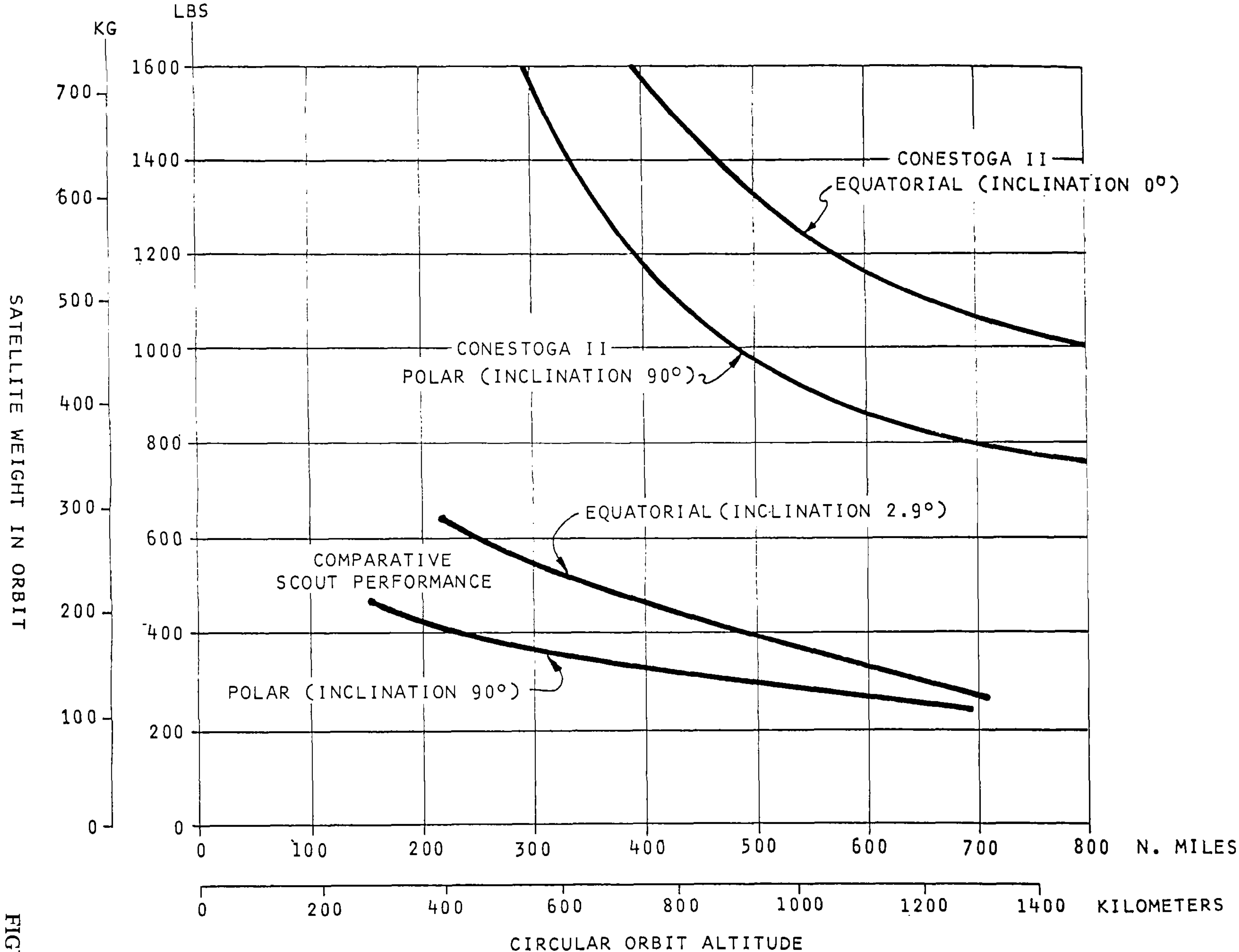
CONESTOGA II

Vehicle Weight Summary

	Weight, lbs.	Kgs
Satellite	800	363.6
Shroud*	300	136.3
Satellite Separation System	22	10.0
Stage 4 Inert Motor (Star 30)	57	25.9
Stage 4 Propellent (Star 30)	1027	466.8
Guidance and Control Module	445	202.3
Stage 4 Separation System	20	9.1
Stage 3		
Separation System	20	9.1
Inert motor (Star 48)	235	106.8
Propellent (Star 48)	4425	2011.3
Structure	102	46.3
ACS Nozzles	20	9.1
Spin Rockets	5	106.8
Stage 2 (Castor 4H)		
Inert motor	2997	1362.2
Propellent	28029	12740.4
Hydraulic System	46	20.9
Attachment Fittings - Separation System	60	27.3
Aft Skirt	160	72.7
Stage 3 adaptor	140	63.6
Stage 1 (2 Castor 4H)		
Inert Motors (2)	5734	2606.3
Propellent	56058	25480.9
Aft Skirts (2)	320	145.4
Motor Nose Cones (2)	240	109.0
Attachment Structure	320	145.4
Hydraulic System (2)	92	41.8
Total Lift-off Weight	101,674	46,215.44

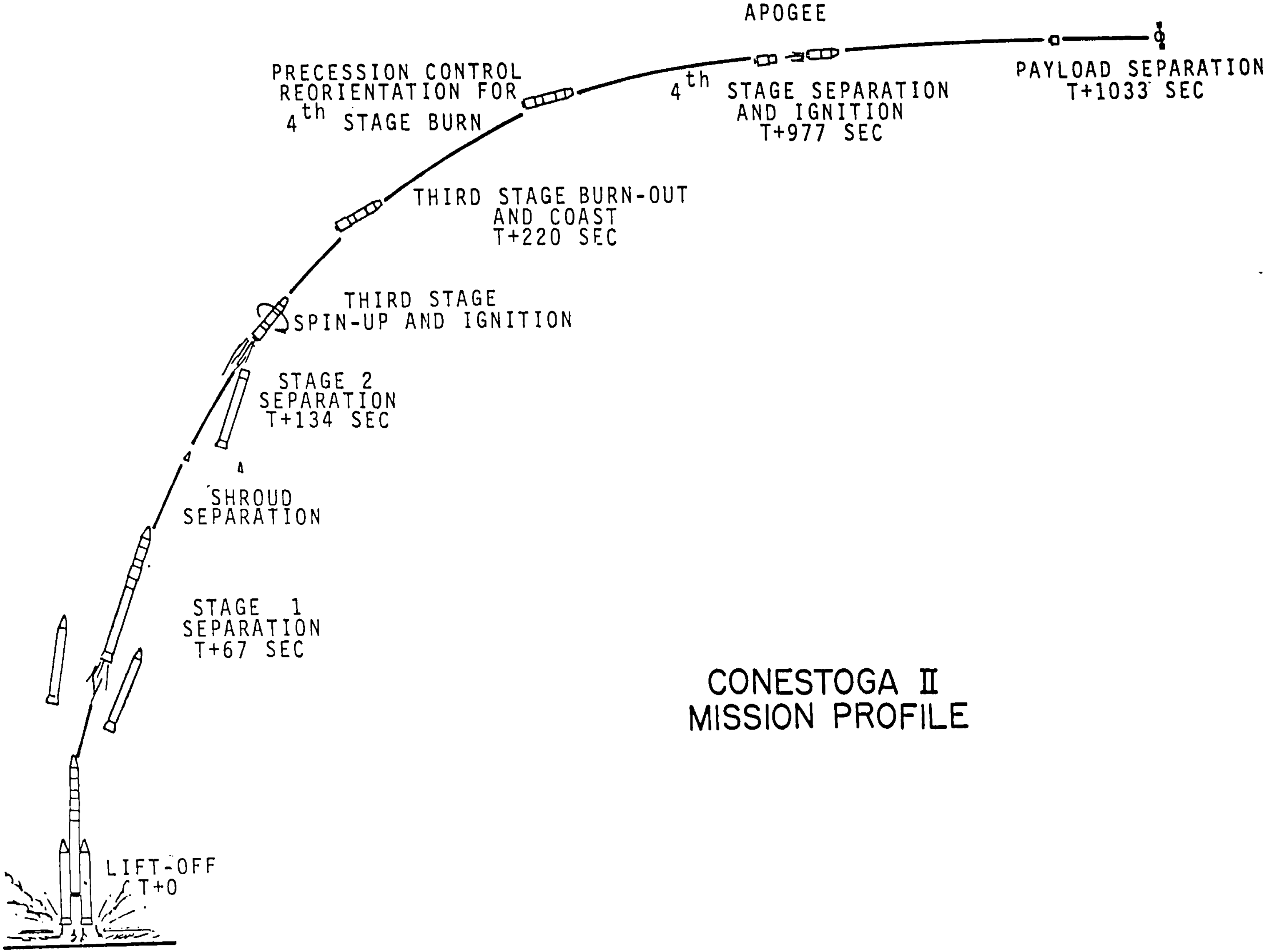
*Jetisoned during Stage 2 burn

Table 1



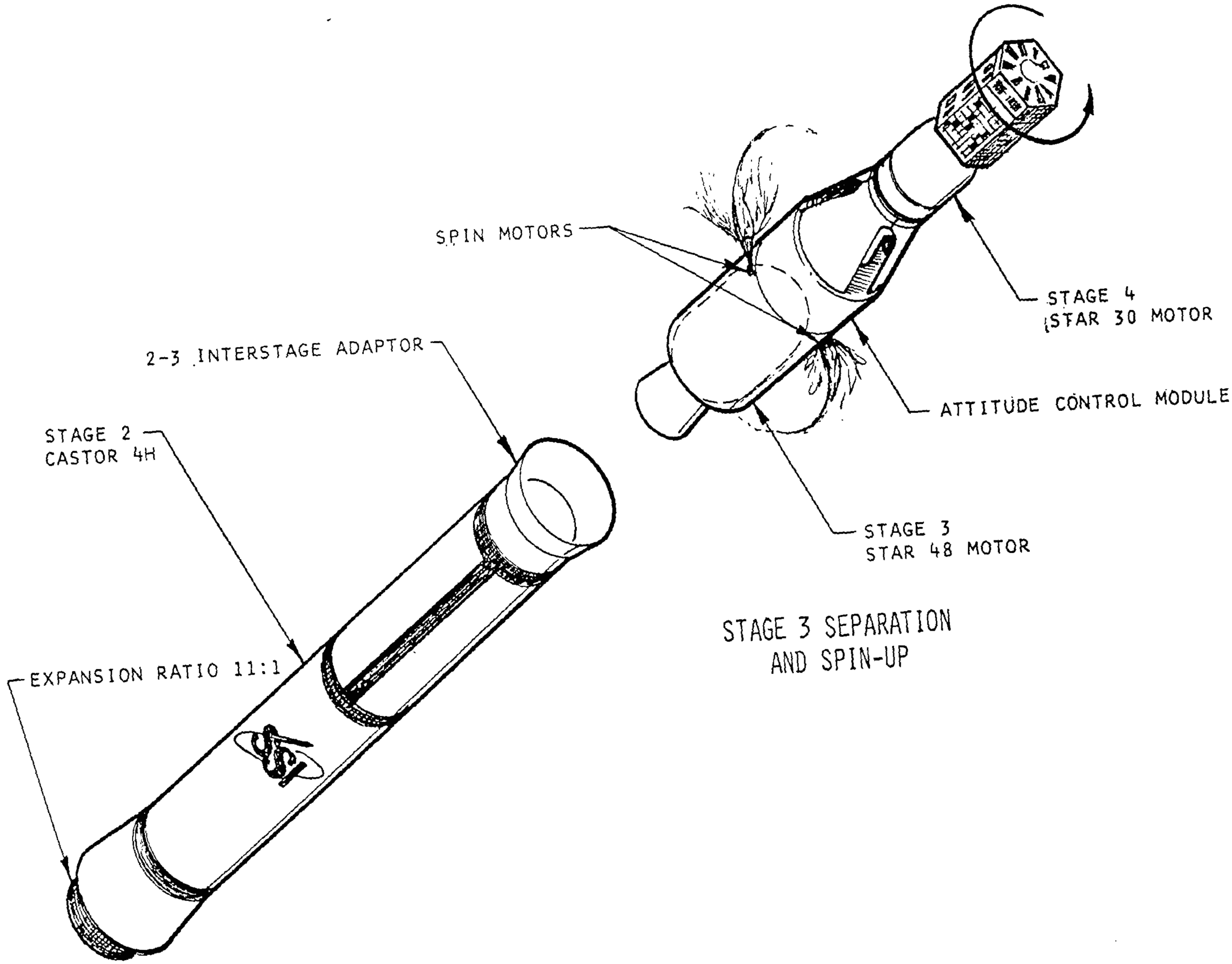
<u>CONESTOGA II PERFORMANCE TO LOW EARTH ORBIT</u>

FIGURE 7



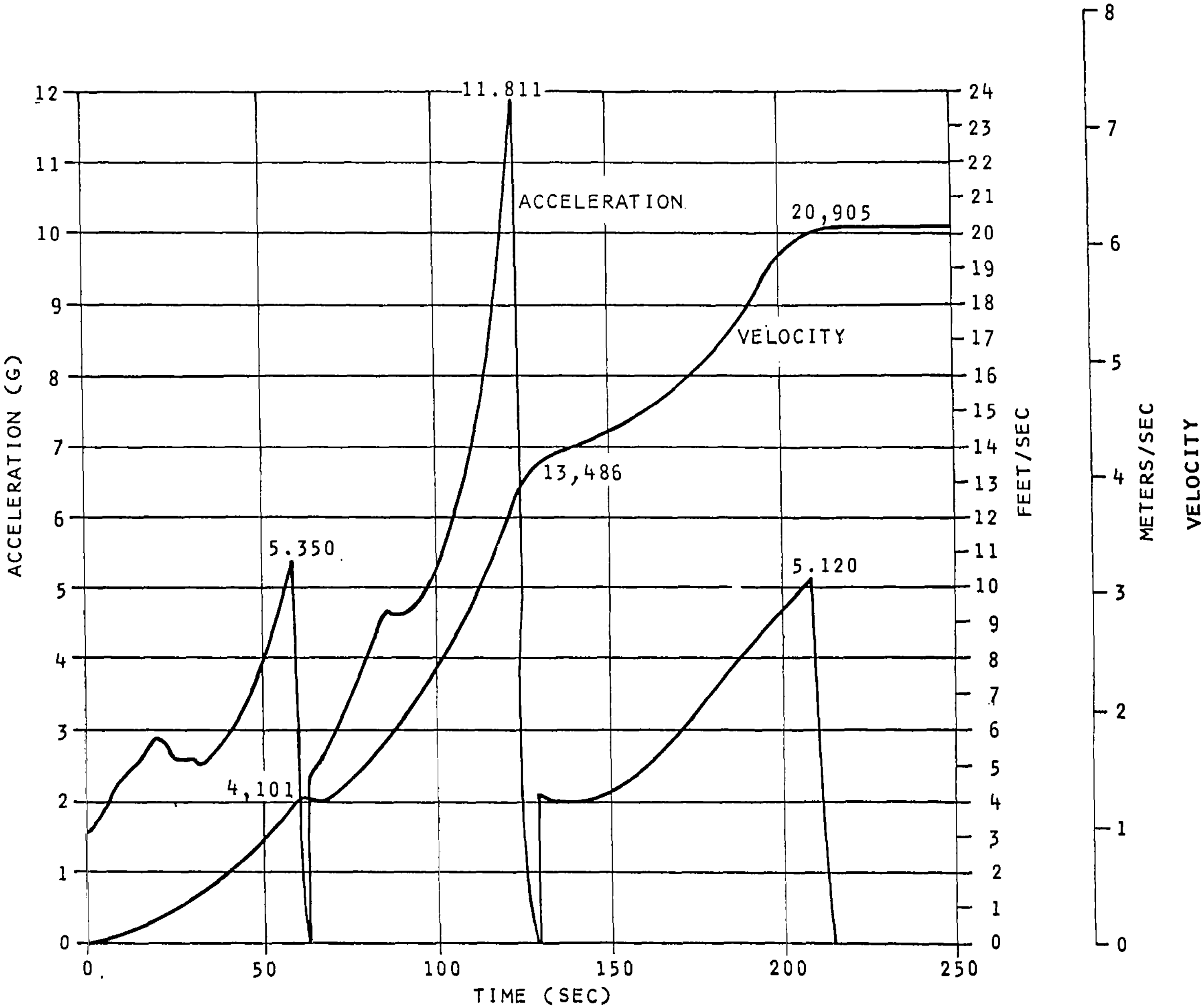
CONESTOGA II
MISSION PROFILE

FIGURE 8



STAGE 3 SEPARATION
AND SPIN-UP

FI



CONESTOGA II

VELOCITY AND ACCELERATION HISTORY

FIGURE 10

MAXIMUM G LEVEL vs SATELLITE WEIGHT FOR VARIOUS STAGE 4 MOTORS DURING STAGE 4 THRUSTING

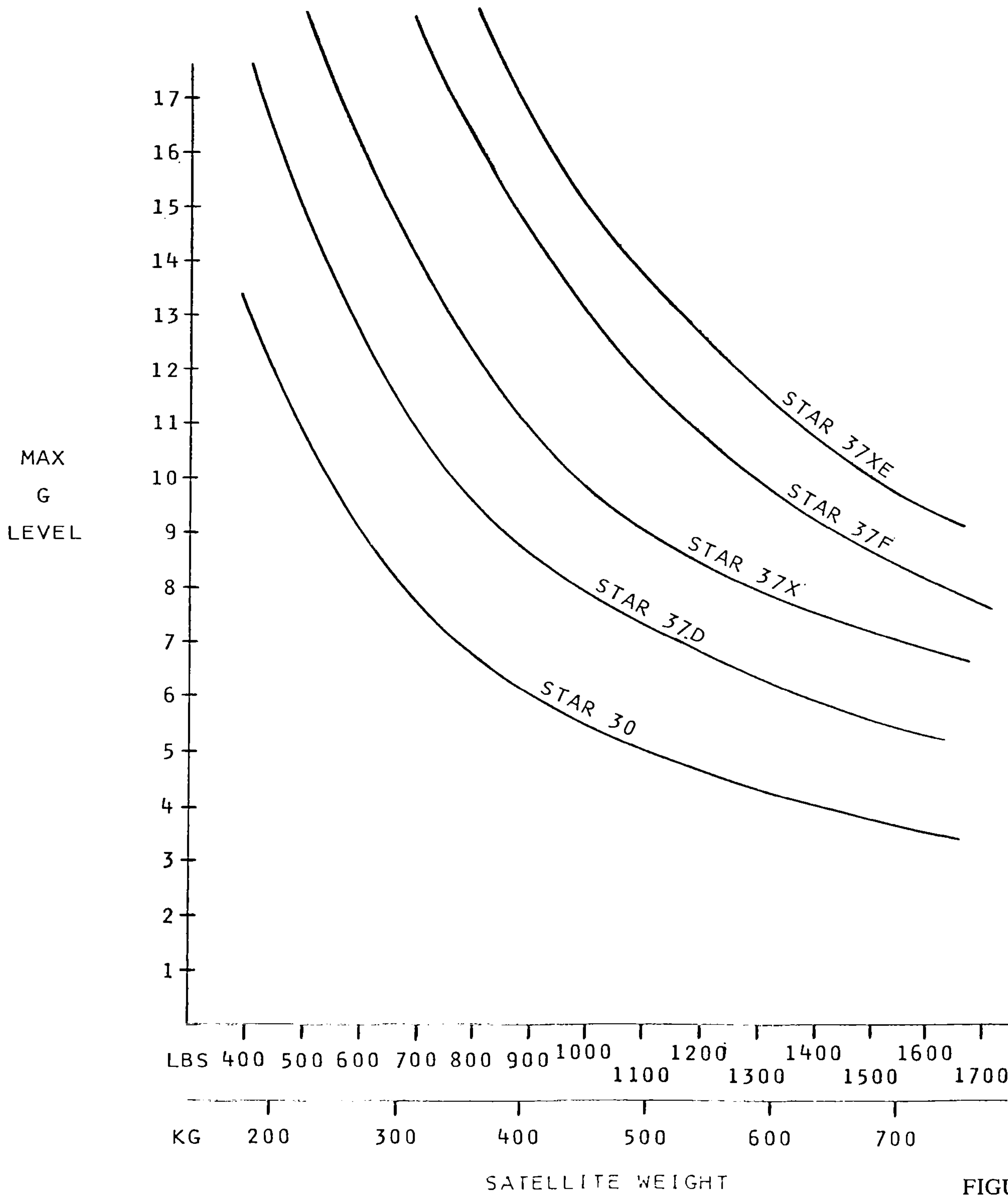
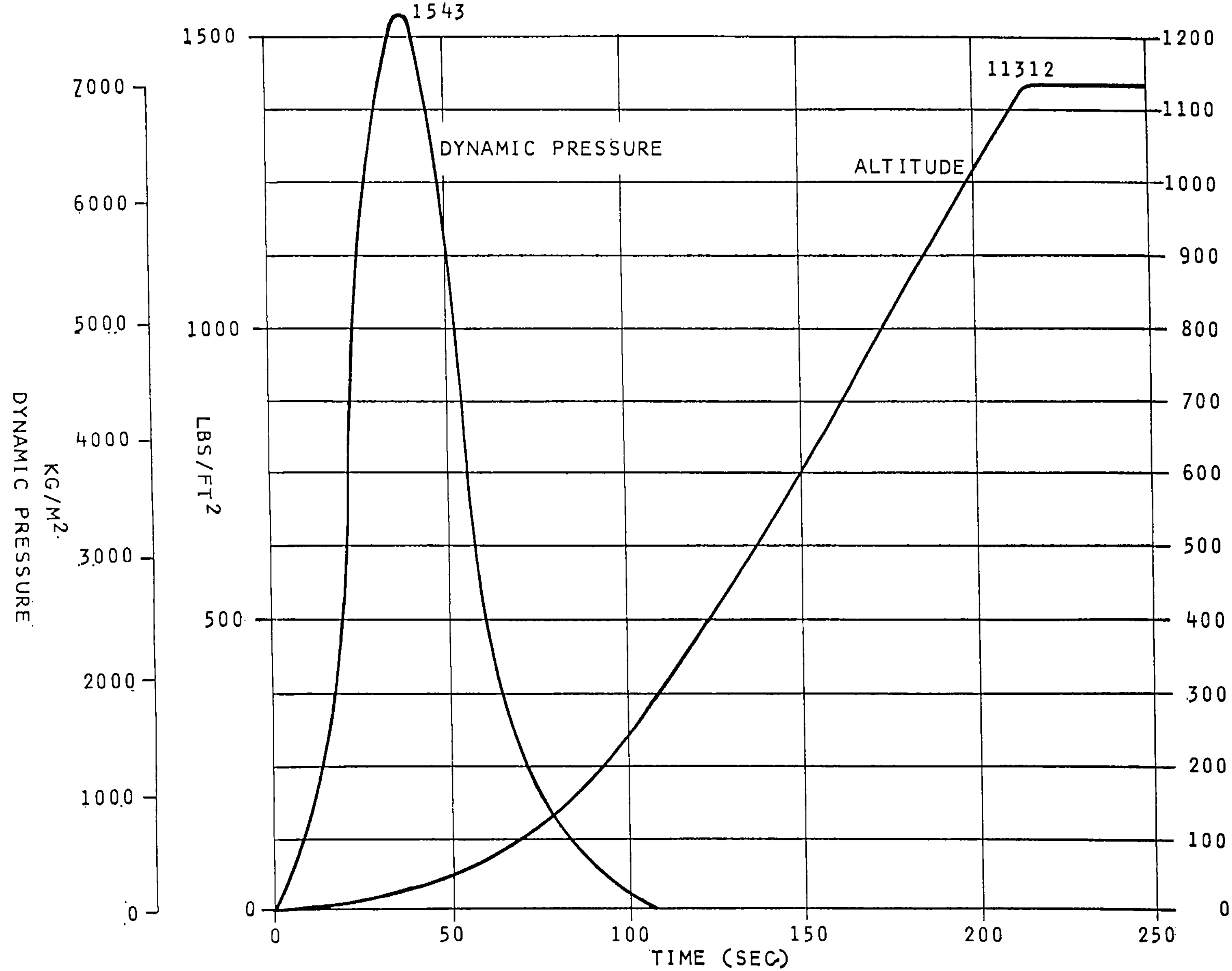


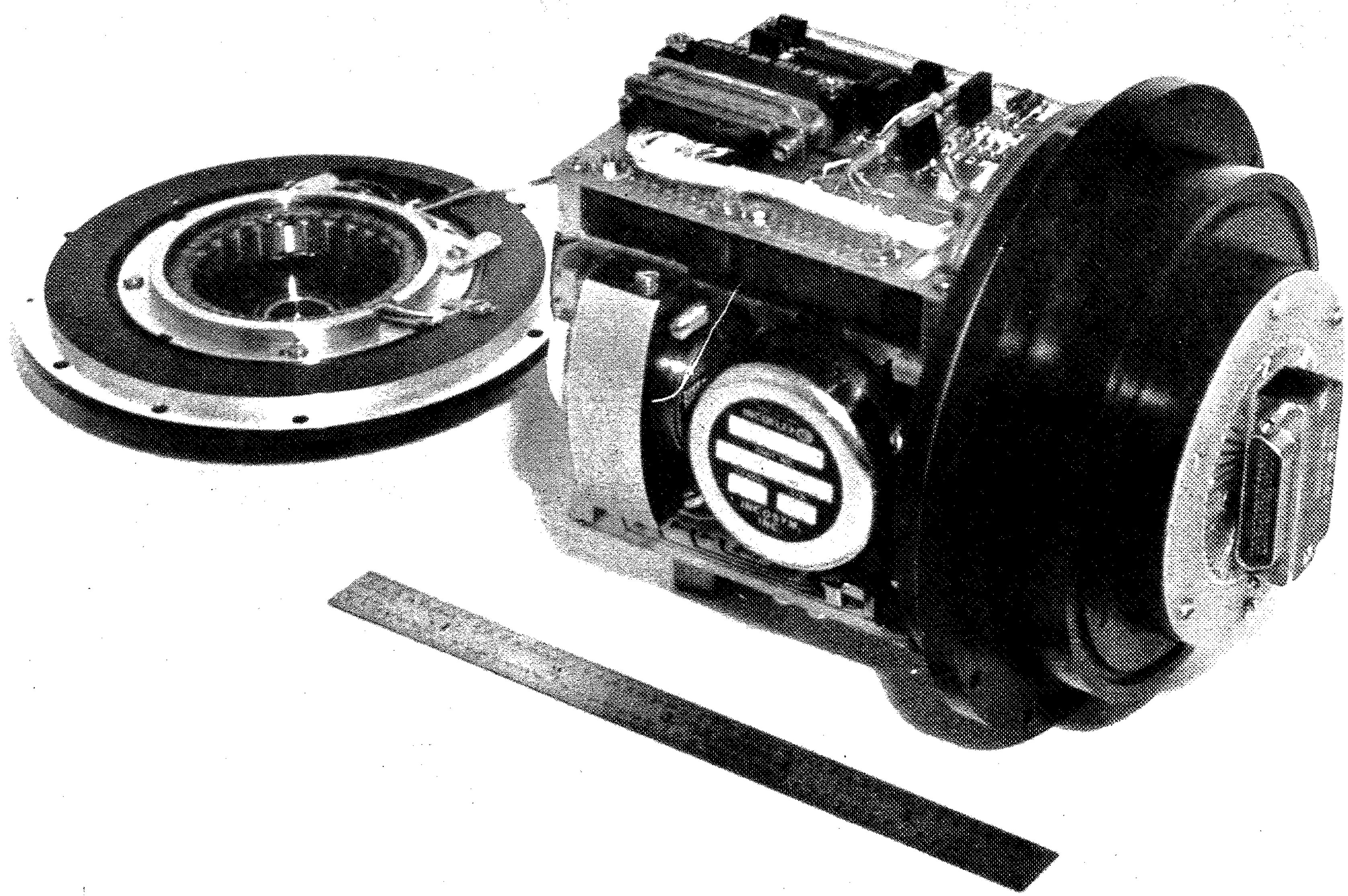
FIGURE 11



CONESTOGA II

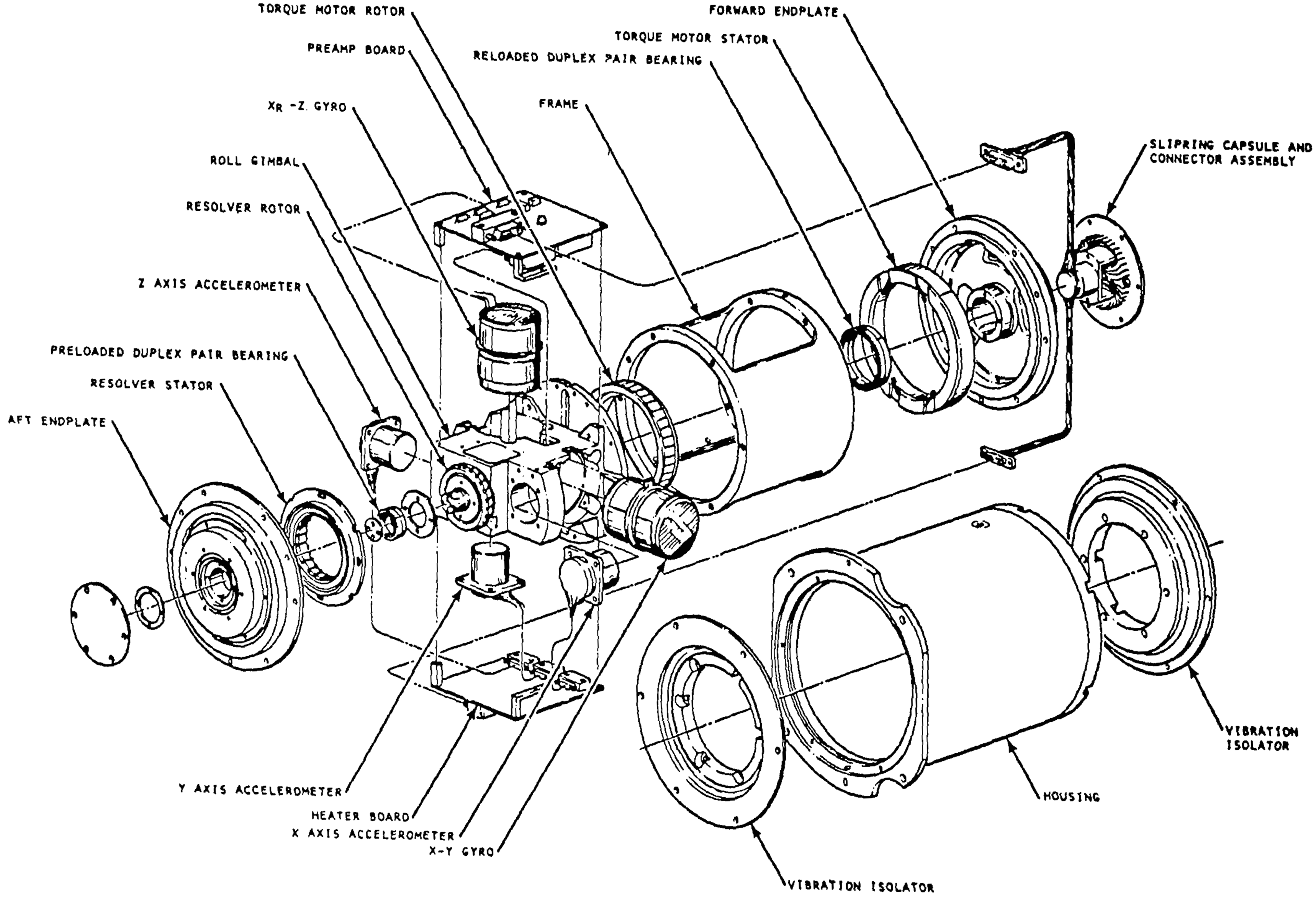
ALTITUDE AND DYNAMIC PRESSURE

FIGURE 12



THE RIMS II ROLL-STABLE INERTIAL PLATFORM

FIGURE 13



PLATFORM ASSEMBLY, RIMS IIA

FIGURE 14

LOGISTICS AND LAUNCH OPERATIONS

The Conestoga vehicle has been designed for practical logistic support and mobile operations.

Minimum time is required to assemble and launch the rocket since all systems are pre-tested prior to shipping.

For support purposes, the motors and payload sections can be shipped in standard 40 ft. (12.19 meters) cargo shipping containers. The Castor IV H motors each require a container with the fourth container holding the upper stages, the control module, and the payload.

The launch gantry will either be built as a kit and shipped by container to the launch site or will be built from local materials.

The launch control center can be built into a container module, tested with the vehicle and shipped anywhere in the world.

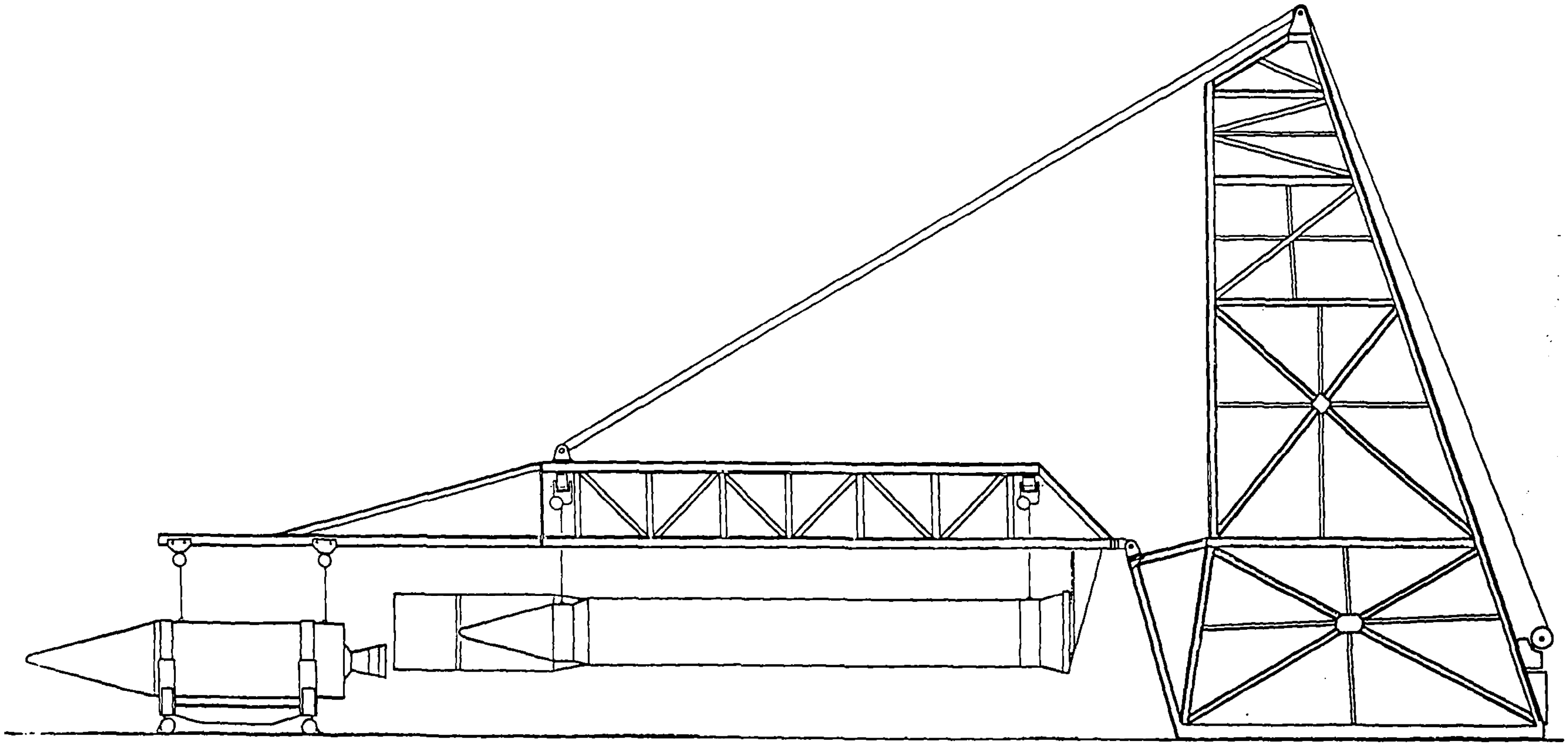
Launch operations include vehicle integration on the pad, prelaunch tests of all launch vehicle, systems, launch, telemetry, tracking, and range safety.

The facilities required to launch the Conestoga II include:

1. Launch pad and roll away gantry
2. Vehicle Assembly Building (VAB)
3. Payload preparation and inspection facility (depending on payload)
4. Launch Control Block house
5. Facility Cable Plant
6. Tracking Radar
7. Telemetry
8. Thrust Termination System Transmitter
9. Required facilities for on-site personel
10. Communications
11. Electrical power
12. Transporter-erector, crane, or hoist

The vehicle will be horizontally assembled and erected in the vertical position as shown in Figure 15.

Because of the vehicle's all solid rocket motor configuration, the launch facility requirements are considerably reduced as compared to those required for liquid propulsion systems. Depending on the launch site, launches can be conducted



CONESTOGA II
HORIZONTAL ASSEMBLY

FIGURE 15

on a campaign basis with operations beginning two months prior to launch and requiring a launch crew of approximately 15 engineers and technicians. If the launch rate is sufficiently high, a permanent launch orgainzation would be established.

ECONOMIC CONSIDERATIONS

A key question as relates to Conestoga II is how to predict the satellite market. It is most difficult to "crystal ball" sales for any systems related to rapidly advancing technology. I suspect Henry Ford had similar difficulties in justifying sales projections for the Model T prior to its development. He may have erred on the low side.

The world demand for space launches is not likely to disappear. If space transport costs can be significantly reduced, volume will increase. An important factor in cost is the inherent efficiency of a commercial operation as opposed to government operations. Our analysis shows that after development of Conestoga II, we could be very competitive at profit margins up to 50%. We do not need many sales to recognize break-even and substantial earnings.

We have examined the space transport market from four points of view: 1) extrapolation from previous satellite launch density, 2) a survey of potential foreign users, 3) a summary of known or planned future programs including civil and military government and private utilization, and 4) an analysis of the market by payload type and satellite use. Two of these analyses are summarized in this paper.

Figure 16 shows the overall market projection based on an extrapolation from historical market data.

A ten year projection, Figures 17 and 18, is based upon analysis performed by consultants to SVC. This study tends to substantiate the low end of the projection, Figure 16, and provide some measure of probable time phasing. Our market effort has been directed primarily towards the near term (5 year projection) indicated on the Figure. These data are based primarily upon currently planned satellite missions. The U.S. commercial applications would appear to be a sustaining level of support. The project shows a dramatic increase in the subsequent five year period based upon the near certainty of South American and smaller nations' satellites in this time frame.

The USAF, paradoxically, could be a large user. This projection hinges on three conditions. The first is that the U.S. ballistic missile defense posture remains bullish, thus requiring a significant program of sensor and space weapons testing. The second condition is that through demonstration of performance during our commercial launches, we can sell the military on a turnkey service -- at a great savings in both cost and development time to the U.S. government. Preliminary indications are that at least the policy making level of government is receptive to this approach. The third condition, and the least constraining, is that due to the classified nature of military test launches, we must provide services at CONUS launch facilities.

LOW EARTH ORBITER MARKET DATA

Total Annual Space Budget - USA*	$ 7.5 billion
Total Annual Aerospace Budget - USA*	65.0 billion
Estimated Total Annual Space Budget - World	16.0 billion
Number of Satellite Launches - USA** Period of 1969 through 1981	347
Number of Satellite Launches - World** Period of 1970 through 1981	1,708
Number of Scout Launches** Period of 1961 through 1983	102
Estimate of Low Earth Orbit Satellites Period of 1983 through 1993 (excluding Soviet Union)	330
Estimated Conestoga II Share	30-60
Estimated Vehicle Operation Gross at $8.0 Million/Launch (Less Range Costs)	$ 240-480 million

*Aviation Week, March 14, 1983.

**TRW Space Log - 1982

FIGURE 16

A 10-YEAR PROJECTION FOR CONESTOGA II ORBITAL LAUNCHES

User Country or Group	Low Earth Orbiter Satellites	Specifically Identified Near Term Planned Missions Which Could Use Conestoga II
A	Location, search, & rescue	4
B	Earth resources	1
C	Data collection	2
D	Earth resources	1+
E	Uncommitted	0
U.S. NASA/ Air Force (CONUS Launch Facility)	Targets/navigation satellites	2
U.S. Commercial		4+

FIGURE 17

A 10-YEAR PROJECTION FOR CONESTOGA II ORBITAL LAUNCHES

User Country or Group	Low Earth Orbiter Satellites		Years - Beginning 1984: 5	10	20
A	Location, search, & rescue		1	1	
B	Earth resources				
C	Data collection		1	1	
D	Earth resources		2	2	Major market for multiple satellite applications.
E	Uncommitted		0	4	
U.S. NASA/ Air Force (CONUS Launch Facility)	Targets/navigation satellites		0	6	Sustained defense testing.
U.S. Commercial			3	5	
		Subtotal:	7	19	
User	**High Altitude/Geosynchrnous**				
Foreign countries	Communication & geopolitical		1	3	Expanding market. Dependent upon advanced technology.
U.S. Commercial	Advanced communications systems		0	2	
USAF (CONUS Launch Facility)	Space based defense testing		0	3	
		Subtotal	1	8	
	Total Projected Satellite Launches		8	27	

FIGURE 18

SUMMARY

In summary, we feel that Conestoga II may very well be the Model "T" of space over the next decade. There is no reason that an excellent balance cannot be obtained between cost and reliability. Conestoga I has gone a long way toward proving the commercial space transport option. Conestoga II should make this option a reality.