Conestoga Launch Vehicles

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CONESTOGA LAUNCH VEHICLES

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Abstract

Several major applications for commercial and government markets have developed recently which will make use of small satellites. A launch vehicle designed specifically for small satellites brings many attendant benefits. Space Services Incorporated has developed the Conestoga family of launch vehicles to meet the needs of five major markets: low orbiting communication satellites, positioning satellites, earth sensing satellites, space manufacturing prototypes, and scientific experiments. The Conestoga provides low cost, rapid schedules, one-stop shopping, flexible launch sites, multiple satellite deployments, insurability, reliability, and modularity.

I. Background

Space Services Incorporated (SSI) was established in 1980. The founder, David Hannah, Jr., intended to develop a small launch vehicle to serve a developing sector of space commercialization, the small satellite market. At the time, Mr. Hannah envisioned this market developing out of a trend toward miniaturized components, a need for lower cost space systems, and a mass-production concept for small satellites which would allow for economies of scale.

After an initial difficulty with a liquid-fueled rocket system, the company switched to a more dependable, solid-fueled design. In September, 1982, the company successfully launched the Conestoga I. Subsequently, a series of Conestoga vehicles have been developed to service the 300 to 4000 pound payload range for launch to low earth orbit.

The Conestoga I mission was a suborbital launch from Matagorda Island, Texas. The trajectory took the vehicle 192 nautical miles up and 350 nautical miles down range. The vehicle was powered by a Minuteman M56 motor. Although the technology demonstration was important for the company, proving its ability to organize and conduct launches, it was not a significant technical advance for aerospace engineering. For the launch industry, however, it was unprecedented. It was the first privately funded, privately operated launch into space. As such, it represents an important precedent for all other space launch companies.

In order to conduct the launch, the company solicited and received approvals from 18 different Federal agencies. Among these were the Air Force, the State Department, the Navy, and the Commerce Department. Commerce required SSI to obtain an export license, due to the extra-territoriality of the vehicle's splashdown point.

Since that time, the company has organized a team of subcontractors to develop the Conestoga family of vehicles and conduct upcoming launches. The team includes Eagle Engineering, a Houston-based engineering and design firm, and Morton Thiokol, a nationally recognized aerospace contractor.

Recently, the company signed an agreement with NASA for the use of Wallops Flight Facility in Virginia as a long term launch site. Also, SSI has obtained financial backing from Houston Industries, the parent company of Houston Lighting and Power, and has agreed to provide five launches to Starfind, Incorporated.

II. Markets

In any business, it is logical to analyze the market before designing a product. Therefore, before discussing the launch vehicles which SSI has developed, let's look at the markets it is intended to serve.

Broadly, the market is divided into two segments. The commercial segment is concerned with profitable satellite operations, short-term development, and high return on investment. The government segment is concerned with budgetary constraints, long-term development, high reliability, and political advantage. Clearly, to design a single vehicle to meet the needs of both market segments is challenging.

Within each of these segments, five major applications have been identified. These are low orbiting networks of communications satellites, positioning or navigation systems, earth sensing systems, space manufacturing prototypes, and scientific experimentation. Each of these

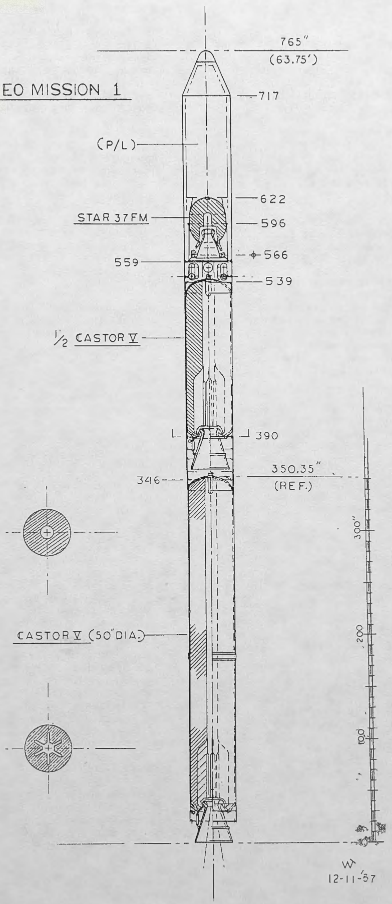
LEO MISSION 1
765"
(63.75')
717
(P/L)
622
STAR 37FM
596
566
559
539
1/2 CASTOR V
390
350.35"
(REF.)
346
300"
CASTOR V (50"DIA.)
200
100
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Figure 1

applications benefits from the use of smaller satellites.

Small satellites have several advantages.

1. They can be as capable as their larger counterparts. Miniaturization of components has allowed increasingly sophisticated circuitry to occupy less volume and weight.

2. Smaller satellites can cost less, both to develop and to launch. Small components weigh less, are often easier to mass produce, and frequently come "off-the-shelf."

3. Smaller satellites are easier to insure, simply because they cost less. With less at risk, insurance companies can afford lower premiums.

4. Smaller satellites offer increased survivability and decreased capacity risk. Individually, a small satellite is less of a target. As a network with many interconnected elements, a group of small satellites in different orbits can continue to provide capacity despite the loss of one or two elements.

5. Smaller satellites are more easily replaced. With lower production and launch costs, it is easier to have spare satellites in inventory, ready to replace defective or destroyed satellites. This replaceability removes the burden of high cost, highly reliable components which make many long-lived spacecraft so expensive.

Together these benefits provide sufficient incentive to satellite operators to reconsider the use of traditional, large, long-lived, expensive systems. A growing trend toward small satellites has been seen, with certain government users leading the way.

The analysis of the market suggests the characteristics that a launch vehicle should possess.

1. Its total purchase price should be low. The price is particularly important in view of the Government's need to meet budgetary constraints, and the commercial sector's need to provide a high return on investment. Dollars saved at launch return directly to the "bottom line" of the satellite operator.

2. It should have a broad range of capabilities. Modular components, such as strap-on motors and a variety of upper stages could provide such a range. Therefore, a single vehicle is not sufficient; a family of vehicles is needed.

3. A commercial approach is needed. A commercial approach is characterized by reduced manpower and paperwork requirements, good quality control, fixed price contracts, and turnkey launch services. The commercial operator pays for the development cost, rather than having the customer (government) pay for it. Commercial customers find such an approach attractive because it is familiar and dependable. Commercial clients of the government, for instance shuttle users, often fail to evaluate the risks associated with a supplier whose policies are not determined by the market. Government launch vehicle users find a commercial approach politically advantageous at present due to the attitude of the current Administration. Certain laws require the use of commercial launch services where possible.

4. The launch system should have limited risk factors. Use of flight-proven components and experienced contractors could provide a significantly less risky vehicle. Such an approach offers advantages in insurance, reliability, and cost. Advanced designs can be both more costly to develop and more costly to operate.

III. Options

Currently, small satellite operators are faced with many options for launching their payloads. Unfortunately, most of these are unappealing.

A. Space Shuttle.

In August, 1986, President Reagan signed an Executive Order requiring the removal of commercial payloads from the shuttle. Even without this policy (which, after all, is subject to change without notice), the shuttle has inherent disadvantages for the small satellite user. These include:

1. **Long lead time to launch.** Even prior to the Challenger tragedy, lead times for payload operators could be lengthy. Integration time, especially for space available payloads which must be ready for integration on any of several flights, could be long. This waiting period is particularly unfortunate for experimenters with biological or other perishable materials.

2. **Tight Manifest.** With the down-time associated with the loss of 51L, an increasing backlog has accumulated. Today, a new payload for the shuttle faces a wait of years, even assuming a full fleet flies as often as expected.

LEO MISSION 2

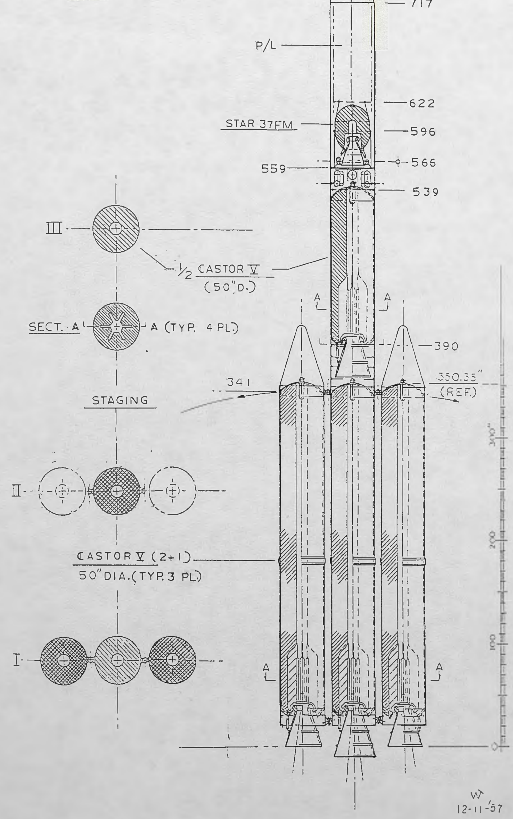

Figure 2

GEO MISSION 1

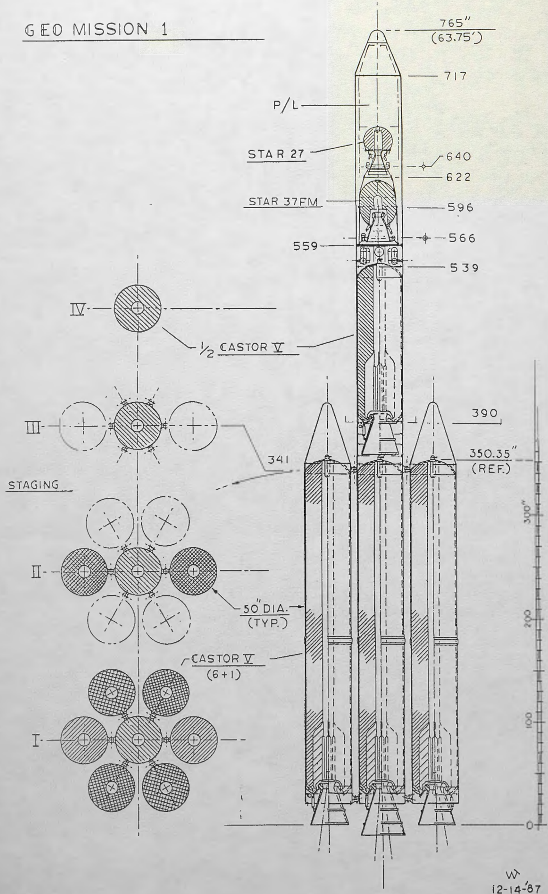

Figure 3

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3. **Inflexibility**. The shuttle has limited capabilities. It cannot reach altitudes higher than a few hundred nautical miles, and it cannot reach all inclinations. Small satellites with special orbital needs must expect a shuttle launch to take them only part of the way; the final orbital insertion must be accomplished with an additional propulsion unit.

4. **Man-rating**. One cost associated with a manned system is the valid requirement that no payload pose a threat to the astronauts. Demonstrating this harmlessness can be impose a significant cost on a low-cost satellite's budget.

B. Titan, Delta, Atlas, Ariane, CZ-3.

These launch systems are expensive and poorly suited to smaller spacecraft. The Titan III, Delta, and Atlas were designed for much larger payloads and have correspondingly high prices. The European Ariane and Chinese CZ-3 have unique problems associated with all foreign launchers. National security issues virtually rule out their use for U.S. Government launches. Foreign launchers impose added costs to commercial users due to export licensing. As well, technology transfer questions may limit their use. Technology transfer questions seem to have prevented the use of Soviet launch vehicles.

C. The Scout.

The Scout is an expensive launch system for the capability it provides. Those currently in inventory are probably not available for use outside the Navy, which has possession and intends to use them for its Transit program.

As currently configured, the Scout has limited capabilities, providing less than 500 pounds to low earth orbits. The Scout also lacks a modern guidance system, giving it limited accuracy. Since the Algol III motor used by Scout is out of production, it is likely that the configuration will change. Use of the available Castor motor and other solid upper stages would yield a vehicle surprisingly like the SSI Conestoga.

Even with a new configuration, the Scout suffers from lack of a commercial approach. The manufacturer is unlikely to make the Scout available on a commercial basis without a reasonable base of production guaranteed by a government procurement. Experience has shown that procured systems tend to be high in cost and late in schedule.

D. Refurbished Missile Boosters.

The government has retired several of its missile systems, notably the Minuteman and Polaris. Motors from these and other missiles may be available for certain government launches. However, the limited inventory that does exist seems to have already been fully committed. Such boosters are probably not available for commercial systems. As well, they have very limited capabilities. Due to their age, many are unreliable, and a certain proportion of those that pass inspection are likely to fail. Although current cost estimates for such systems are low, such cost estimates are historically lower than the actual cost of procurement and operation.

IV. The Conestoga

Faced with a clear market need which was not being satisfactorily met by any existing launch system, SSI developed the Conestoga family of launchers.

A. The Team.

The Conestoga team is composed of SSI, Eagle Engineering and Morton Thiokol. SSI provides project management, in-house engineering, quality control, marketing and financing. SSI's technical team is headed by Deke Slayton, who led the Conestoga I team to a successful launch. Eagle Engineering provides mission analysis, vehicle design, and additional engineering expertise as needed, much as they did on the Conestoga I flight. Morton Thiokol provides Star motors for upper stages through its Elkton, Maryland division, and Castor motors for lower stages through its Huntsville, Alabama division. Also, Thiokol's Wasatch, Utah, division, is developing the company's thrust vector control (TVC) system for use on the Castor motors.

B. The Components.

The main elements of the Conestoga family of boosters are its motors. Other important elements are the payload fairing, interstages, TVC system, guidance/navigation and control system, and aerodynamic elements such as nose cones and skirts. Figure 1 shows a Conestoga IA with an orbital capability of over 500 pounds. The motor stack uses a Castor V as the first stage, a half-length Castor V as the second stage, and a Star 37 FM as the third and final stage.

The Castor V is a 50 inch diameter, solid fueled motor similar to those used as strap-ons for the Delta rocket. The Castor has a thirty year development history. Over that period, over 1700 Castor motors have been fired with only two failures. Each of the Castor V motors used in the Conestoga will be equipped with a TVC actuator system using flex-seal nozzles. This system will provide for control of the vehicle during powered flight. The first stage motor uses a nozzle with an 8:1 expansion ratio, with a higher ratio for upper stages operating above most of the atmosphere.

The Star 37 FM is one of a family of upper stage motors. Star motors are defined by their diameters, with the Star 37 having a 37 inch diameter. The range goes as low as the Star 17, with a 17 inch diameter. One potential upgrade for the Conestoga design is to include TVC on the Star upper stages, providing greater accuracy for final insertion.

Figure 2 shows a Conestoga II/3-2. This vehicle is similar to the Conestoga IA, with two additional Castor V motors as strap-ons. These motors increase the payload capacity of the vehicle to over 1000 pounds to a 150 nautical mile orbit.

Figure 3 shows a Conestoga IV. This vehicle is designed for the launch of geosynchronous satellites. It adds four more strap-ons to the Conestoga II design, with an additional upper stage. The first stage consists of these four

MULTIPLE SATELLITE DEPLOYMENT SYSTEM

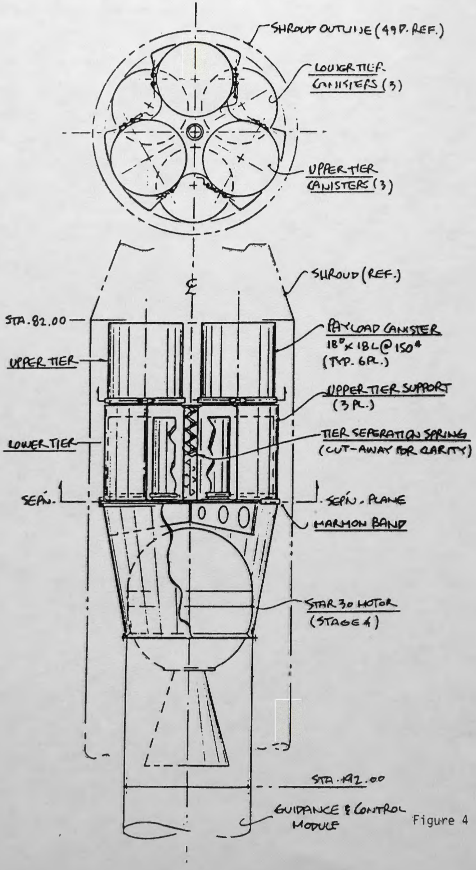

Figure 4

Conestoga Vehicles Performance
From Wallops, 38° Inclination

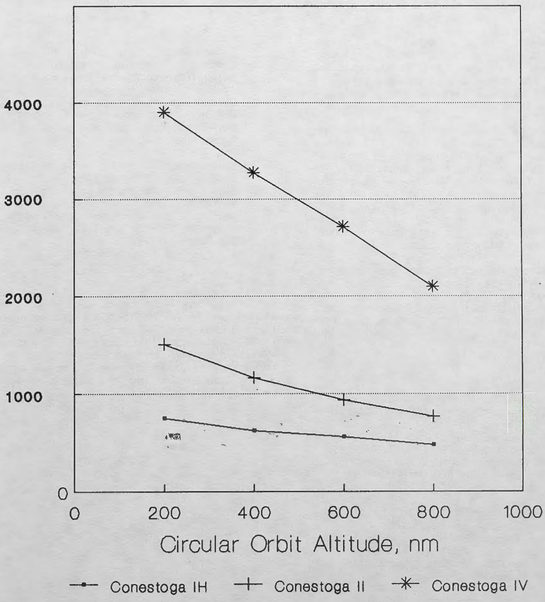

Figure 5

strap-ons which are dropped at an altitude of some 400,000 feet. The second stage is the two remaining strap-on motors. The third stage is the remaining full Castor, with the fourth stage being a half-length Castor. These four stages can lift about 4000 pounds to 150 nautical miles. In a geosynchronous mission, the Star 37FM acts as a perigee kick motor, and the Star 27 is used as an apogee kick motor. The payload deployed at geosynchronous can weigh as much as 595 pounds.

C. Capabilities.

The Conestoga family of vehicles provides launch capacity for payloads weighing 300 to 4000 pounds. It is available for the full range of orbital inclinations. Conestogas can deploy 2500 pounds to a 450 nautical mile, sun synchronous orbit, 595 pounds to geosynchronous, and 4000 pounds to a 150 nautical mile, 38 degree inclination orbit.

Conestoga vehicles can be launched from a number of launch sites. Customers with particular preferences can be accommodated at any existing site. In addition, the campaign style of operation used by SSI allows for the development and use of new launch sites.

The company has an agreement with NASA for the use of the Wallops Flight Facility in Virginia. Wallops has been used in the past as a site for launching Scouts and sounding rockets. The company is awaiting the "Air Force Model ELV Commercialization Agreement" before pursuing the use of Vandenberg Air Force Base for polar launches. Other existing sites under consideration include White Sands Missile Range, and the San Marco platform in Kenya.

Undeveloped sites which have been considered by SSI include Matagorda Island, the site of the company's first two launch campaigns, Cat Island in Mississippi, and South Point, Hawaii. Such sites offer some advantages of location, either improved logistics or better launch characteristics.

D. Advantages.

The Conestoga family of vehicles provides many advantages to the small satellite operator.

1. **Low cost.** Conestogas range in price from $10 to $25 million. The total price of a Conestoga launch is lower for any given payload weight than other launch systems now available.

2. **Accelerated schedule.** With certain vehicle elements now available, the schedule from contract signing to launch can be as short as 15 months. Normal schedules for Conestoga are as short as 18 months.

3. **Turnkey launch services.** Conestoga launch services provide delivery to orbit. Procured vehicles systems generally provide vehicle hardware delivered to a warehouse. Turnkey launch services provide one-stop shopping, with more accurate pricing.

4. **Campaign Approach.** As mentioned, SSI's campaign approach allows the use of diverse launch sites.

5. **Multiple satellite deployment.** Figure 4 shows SSI's multiple satellite deployment system, capable of deploying up to six Get Away Special sized satellites at once. This system can bring down the per spacecraft launch cost to very low levels.

6. **Insurability.** SSI's insurance broker, Corroon and Black has assured the company of the availability of insurance for Conestoga launches, for payloads deployed by Conestoga, and for third party liability coverage. Due to the expected reliability of the system, insurance premiums are expected to be low. In addition, the company offers reflight insurance for a fee.

7. **Reliability.** Use of flight-proven components and established designs helps increase the reliability of the system. New approaches are being considered for advanced Conestoga designs, but the current designs benefit from using well-proven technology.

8. **Modular Design.** Using strap-on motors to increase lift capacity limits the design risk associated with the larger vehicles. This approach has been used successfully in many other rocket programs, notably the Titan series and the Delta series.

V. Conclusion

Small satellites have unique needs which make the use of most available launch systems inappropriate at best. These difficulties can be surmounted through the use of a commercially available vehicle, the Conestoga. Various Conestogas are available to provide launch services to any orbit for a wide range of payloads. The use of such as system can provide low cost access to space for many applications.