SPACE TRANSPORTATION: OPTIONS AND OPPORTUNITIES

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This paper will summarize the Earth to orbit and beyond transportation options expected to be available in the period 1990 and beyond. The basic performance of available systems will be characterized and the most significant issues in payload interfaces summarized.

The basic objective of the paper is to provide a synoptic summary of available capability and some assessment of the most significant design and operations issues for new systems.

Current launch capability is a combination of continued production of systems designed 20 years ago and a family of more recent designs. New designs range from the partially reusable Space Shuttle systems, new design expendables such as the Ariane and H-II LOX Hydrogen systems to new simple systems such as Space Systems Inc. solid propellant Conestoga and the American Rocket Company hybrid Industrial Launch Vehicle. The systems available today are adequate to near term demands.

Any substantial increase in space activity will require a new generation of vehicles that must have significant improvement over current systems. Among the more significant improvements required are reliability, reduced unit cost, reduced lead time on production and improved payload accommodations. Systems definition and technology efforts are in progress to define how these goals can be achieved.

Introduction

Space launch vehicles serve no useful purpose in and of themselves, they are a means to achieve other objectives. The only useful function of a space launch vehicle is to place a useful payload in a productive environment i.e., to convert kinetic into potential energy.

This is a very significant point because the flame and thunder of launch is visible to the press and public and thus launch capability becomes in the public mind synonomous with space capability. It is a misleading perception; and potentially counterproductive. The true significance of space is what occurs out of sight but not necessarily out of mind. The real value of space operations is not in launch but in the assets on-orbit for their contribution to information acquisition and distribution and other process operations such as materials formulation.

Space launch vehicles are unique among all transportation systems. Space launch requires a system to accelerate continuously throughout its effective life, approximately 600 seconds. No other transportation system makes such demands on its components. Most transportation systems, with which we are familiar, require a few seconds of acceleration and many hours of sustained but significantly derated operation to overcome resistance - air drag for aircraft, rolling friction and drag for other systems.

Because space launch systems are in essentially fundamental opposition to a basic law of nature - gravity; they are energy intensive, beyond the bounds of more customary systems and easily misunderstood. The fact that the fuel pump for a single main engine on the Shuttle has a greater shaft horse power than any ship afloat, is a direct consequence of the mass ejection - four tons per second - that is required of Shuttle vehicle to combat the law of gravity, which is an acceleration term. All launch vehicles are similarly energy intensive.

The value of an asset in space is that it enjoys a unique environment -

- minimal gravitational influence 10^{-5} or 10^{-4}g
- potentially constant lighting
- constancy or periodic constancy of position relative to a point on Earth.
- predictable position
- and above all a one time investment in translating it from the Earth surface through a gravity well to a point where it possesses essentially indefinite enjoyment of the energy investment in converting kinetic to potential energy.

As a practical matter there are a few meters per second per annum veolocity increment required to maintain a given state as contrasted to the 8 kilometer per second required to attain a low Earth orbit.

Because space launch is so energy intensive it is inherently hazardous. Effective space launch requires high energy density, low mass fraction and consequently minimum structural margins of safety, but to be economically useful there must be some reasonable reliability.

All original space launch vehicles were derived from military missile systems. When they were converted to space launch systems the inherent 80-90% reliability proved unacceptable because the payload to launch cost ratio exceeded unity and continued to grow. Space transportation advocates focused on the cost of a pound of mass to orbit, users and insurers focus on the cost of transportation in relation to the cost of the payload and other assets at risk. Increasing capability and costs of payloads requires significant increases in the reliability of transportation. By systematic control of components and processes reliabilities of 93-96% have been achieved for the most frequently used space launch systems but they are sustained only by maintaining tight process and component control and a certain minimal rate of use. A significant aspect of recent U.S. expendable launch vehicle failures can be potentially ascribed to the use of long shelf life items i.e., these failures likely would not have occured had the vehicle flown two years earlier i.e., when it was 'fresh' and when manufacturing and operations personnel were at higher training levels.

Through experience we have arrived at a condition in which a .96% reliability of the launch vehicle is consistent with the cost and operational life of a spacecraft whose value approximates the cost of launch. Less costly spacecraft can be flown economically on less reliable launch vehicles and much more costly spacecraft or partially reusable launch systems require significantly higher reliability to be economically effective. In all cases higher reliability in launch activities benefits all users.

Over the last twenty five years much has been learned about both space launch and space based systems and their economic potential. There are potential opportunities in Earth surveillance systems for weather, crops, minerals; for microgravity processing of glasses, ceramics, solid state devices and biologicals; and of course in exploiting many more aspects of communication than the point-to-point systems currently in use e.g., point-to-points and broadcast systems.

Many forms of scientific study in astronomy, astrophics, solar dynamics and planetary exploration can only be done with space based instruments.

In such a context the natural question is what are the launch system alternatives and what issues should users consider as they plan for such systems.

Earth to Orbit

Figure 1 illustrates the launch systems currently available. They are all mature systems for the state-of-the-art at the time of their commitment to production. A brief characterization of each of the U.S. vehicles follows:

Scout

Scout is the smallest and one of the oldest designs in NASA use, it is derivative of sounding rockets used in the mid 1950's. The Scout space launch vehicles is a four stage solid rocket motor system using inertial reference for guidance in the first three stages and spin stabilization for the fourth stage.

Scout has had 106 launches since 1960, 92 of which have been successful. Seventy nine of the last 83 launches have been successful for a recent reliability value of .95. The last 37 launches have been successful.

Orbital payload to 500 km is 210 kg for the G-1 configuration in current use. Alternative growth versions have been studied for payloads of 270, and 560 kg; achieved by strap-on boosters to augment the first stage and the use of larger second and third stage motors.

Launches are conducted from the Wallops Island launch facility on the East coast of the U.S., Vandenberg AFB on the West coast and San Marco on the East coast of Africa.

Scout has had a typical growth history in that payload mass capability has been increased by a factor of three and available volume within the launch shroud by a factor of 12 from its initial configuration to the present G-1 operational configuration.

Launch costs are a function of launch site, payload service requirements and other factors but are approximately 9M̂ US $ 1986.

Delta

The Delta launch vehicle was derived from the Thor missile system developed in 1955. The Delta space launch system has been in use since 1960, and has been operated in more than thirty configurations over its 180 flights to date. Delta has been NASA's most extensively used launch vehicle. There have been 12 failures for an overall reliability of .93. Two stage delivery to low Earth orbit has had .95 success rate. Prior to the Delta 178 failure in 1986, there had been 43 successful launches over 8 years.

The core vehicle consists of two storable propellant stages inertially guided and a variety of spin stabilized third stages. The first stage has been augmented by a variety of solid rocket motors. The 3920 configuration, currently in use, has nine Castor IV solid boosters which are operated in a sequence of six ignited at lift off and 3 sustaining the first stage after the first 6 are jettisoned at T+57 seconds.

The 3920 has a 500 KM payload of 3100 kg due east from KSC and 1950 kg to 196° from VAFB. This represents a significant growth over the life of the program; thirty times the lift of the first Thor Delta.

The 3920 PAM (Payload Assist Module) injects 1295 kg into geosynchronous transfer orbit. The original Delta launched 45 kg to GEO transfer in 1960.

Launches are conducted from KSC and VAFB.

Launch costs vary as a function of the configuration of the basic vehicle, upper stage and the payload services negotiated and can range from 35M̂ to 50M̂ 1986 US $.

Atlas Centaur

The Atlas vehicle was developed in the early 1950's as a ballistic missile. As a space launch vehicle its first flight was in 1959. The Centaur upper stage development began in 1958 to provide a high performance geosynchronous transfer or planetary injection capability.

Atlas Centaur has had 67 launches of which 56 have been successful for an 84% success rate. The Atlas E-F is used without Centaur for low Earth orbit payload delivery. Eighty nine launches have been performed since 1958 with 80 successes for an overall reliability of .90.

The Atlas core stage is a liquid oxygen-hydrocarbon (RP-1) system which is a stage and a half configuration using three engines at lift off. The two boosters engines are jettisoned at 153 seconds and the sustainer engine continues for another 130 seconds.

The Centaur is a cryogenic stage using liquid oxygen and liquid hydrogen to supply two engines. The stage has multiple start capability and a burn time of 404 seconds.

Guidance for Atlas Centaur is inertial and carried in the equipment section of the Centaur stage. The Atlas E-F uses a radio guidance system for low Earth orbit missions.

The Atlas Centaur can deliver 4020 kg to low Earth orbit or 2098 kg to geosynchronous transfer.

The Atlas Centaur is launched from KSC and the Atlas E-F from VAFB.

Atlas Centaur launch costs are approximately 80M̄ 1986 US $ depending upon the payload services negotiated.

Titan 34 D

The Titan 34 D, the current heavy lift vehicle for DoD payloads is a derivative of the Titan ballistic missile system. The Titan 34 D uses two large solid rocket boosters to augment a liquid storable nitrogen tetroxide (N_2O_4)-UDMH (Unsymetrical Dismethyl Hydrazine) two stage core. It is the successor to the Titan III series which began development in 1961. Seventy five vehicles were launched in the Titan III series and the total of space launches to date for the design is 135 with 5 failures for an overall reliability of .96.

The Titan launch uses the solids for initial lift off and ignites the core first stage engine in flight. Depending upon configuration, guidance is radio or inertial. A number of upper stages have been designed to interface with Titan; the Centaur, the IUS (Inertial Upper Stage), Transtage, the Transfer Orbit Stage and design studies are in progress for the PAM (Payload Assist Module).

Delivery performance to low Earth orbit is 14685 kg and to geosynchronous orbit 2230 kg to 3500 kg depending upon the upper stage elected.

The Titan 34D currently launches from VAFB and launch capability at KSC will be provided in 1989.

Cost of the Titan 3 launch varies as a function of payload services negotiated and the selection of upper stage and can vary from 90M̄ to 120M̄ US $ 1986.

Shuttle

The space Shuttle was developed as the first reusable space transportation system to provide not only orbital delivery but recovery of payloads. The Shuttle flew 24 successful flights before the failure and loss of Challenger in January, 1986 on the 25th flight.

The Shuttle uses two solid rocket boosters to augment initial thrust. The Shuttle main engines are ignited and brought to full thrust before ignition of the solids. The solids are separated at 126 seconds and the system continues into an eliptical orbit under the thrust of the main engines. After separation of the external tank for ocean disposition, the orbit maneuver engines are used to circularize and raise the orbit as required for the mission objectives.

The expected launch capability when the Shuttle flies again is 22765 kg which is reduced from the original 29010 kg by growth in system inert weight to enhance system reliability and safety and by reduced throttle settings on the main engines to minimize the risk of turbo-machinery failure.

There are a number upper stages designed to fly in the Shuttle; the PAM (Payload Assist Module), the IUS (Inertial Upper Stage) and a number of spacecraft with internal propellants e.g., Leasat. Payload deliveries to geosynchronous orbit are consistent with the upper stage performance.

The Shuttle launches from KSC. Launch pad provisions at VAFB are in caretaker status pending return to flight. The space Shuttle no longer offers commercial satellite delivery services. Costs for sortie payloads are a function of the use of all the different resources offered by the Shuttle.

Also illustrated in figure 1 are launch vehicles operated by Japan, the Peoples Republic of China, ESA/Arianespace and the USSR. They are included to illustrate the lift capability relationship among the currently active launch vehicles. The PRC has offered the Long March 3 for commercial services and has entered into contract with two users. The USSR through Glavkosmos is offering the Proton for commercial services but as yet has not contracted for such use.

Figure 2 illustrates comparative delivery capability of each of the launch vehicles to low Earth orbit.

Figure 3 illustrates the launch vehicles currently in development and planned for the 1990's.

Conestoga

The Conestoga launch system has multiple configurations. The Conestoga II is illustrated. The Conestoga I uses no first stage augmentation and the Conestoga IV uses six rather than two first stage boosters. All elements are solid rocket motors.

The core vehicle has two solid motor stages, each with vectorable nozzles, an inertial guidance and control module and a spin table for 3rd stage stabilization. The Conestoga IV can be configured with six stages to place a 180 kg spacecraft at geosynchronous orbit or inject a 530 kg spacecraft on planetary trajectory.

The Conestoga is in development but has flown one successful suborbital test.

Agreements have been signed with NASA to use the Wallops Island facility for launch of the Conestoga and negotiations for launch capability at VAFB are in progress. Because its launch facility requirements are minimal, Conestoga can be launched from other locations as well.

Launch capability is offered 18 months from authority to proceed with launch cost and ranging from approximately 9M $ US 1986 for the Conestoga II depending upon the payload services and performance options elected.

Industrial Launch Vehicle

The American Rocket Company design is unique in using a hybrid propulsion system with a solid fuel and liquid oxygen as the oxidizer. The first stage arrangement of the 12 fuel motor units around the common oxidizer tank forms a plug nozzle that enhances high altitude motor performance.

The second, third and fourth stage are, in plan view, a hexagonal cluster of seven motor-tank units. Four of the exterior motors are the second stage, the two remaining outer motors the third stage and the central unit the fourth stage. All the motor units are identical except for the larger expansion ratio nozzle of the upper stage units. The seven upper stage motors each has integral oxidizer tankage to facilitate staging.

Guidance is by inertial reference and control during first stage and second stage burn, is achieved by the use of liquid O_2 injection into selected nozzles. For third and fourth stage operations head end monopropellant thrusters are used for pitch yaw and roll control.

Launch vehicle delivery capability is currently scheduled for the end of 1988 at a cost of approximately 8M $ US 1986 depending upon payload services negotiated. Negotiations are in progress for use of KSC and VAFB as launch sites.

Titan II

There are 52 Titan II ballistic missiles that could be refurbished as space launch vehicles. Thirteen have been placed in work to be upgraded to space launch vehicles to launch polar Earth orbit satellites. The first unit will be available in late 1988. At present this vehicle's use is planned only for U.S. government payloads and would replace the Atlas E-F for such launches.

Delta II

The Delta II or Medium Launch Vehicle (MLV) is another growth increment for the Delta vehicle. The growth is achieved by extending the first stage tanks 3.34M to increase the storable propellant mass and by using stretched solid rocket motors with graphite epoxy cases. The rest of the vehicle remains basically the same.

In the Delta 7920 configuration the vehicle provides 4300 kg to low Earth orbit and 1600 kg to geosynchronous transfer orbit. In the enhanced Delta II configuration performance is 4960 kg to low Earth orbit and 1790 kg to geosynchronous transfer.

Costs for commercial use of this system have yet to be determined but the terms on which government use units are purchased provide that the company may offer the system for commercial launch services.

Titan IV

This extension of Titan capability is achieved by increasing the solid rocket motor size from 5½ segments to 7 segments and extending the first stage propellant tankage. These changes increase the 500 km due East lift by 2600 kg. With a Centaur upper stage the system has a 4465 kg capability to geosynchronous orbit. At present this vehicle is used only by the U.S. Government.

HLLV

The heavy lift launch vehicle being studied by NASA and the DoD is now referred to as the Advanced Launch System (ALS). The objective in these studies is to define a system with a lift capability more than twice that of any current system but with a lower direct operating cost and higher reliability. The design studies are based on analyses that indicate that advanced technology in materials, design techniques, automation in manufacture and operations and performance de-rating can attain such goals. The studies are oriented to first availability of such a new system in 1995.

The ESA Ariane V and the Japanese H-II are larger vehicles in development for use in the early to mid 1990's and are illustrated for reference. Both of these systems are new designs using liquid oxygen and hydrogen in both first and second stages with solid rocket augmentation at lift off.

Figure 4 summarizes the low Earth orbit performance of this family of vehicles.

Since launch vehicle performance varies as a function of launch site and desired orbit figure 5 illustrates the performance of the primary U.S. launch vehicles of the 1990's for the most common operational orbits.

The geosynchronous orbit performance assumes KSC launch, 3-5 degrees plane change in the transfer orbit injection, with the balance, 23-25 degrees of plane change at geosynchronous altitudes. The 12 hour orbit is a semi-synchronous 20,240 km orbit at 63 degrees inclination. Polar orbit is 920 km sun synchronous from Vandenberg AFB and low Earth orbit is a due East launch from KSC to 500 km at 28.5 degrees inclination.

Upper Stages

Figure 6 illustrates the existing U.S. stages. In this fig. and the next two, details of the stages are characterized in terms of the manufacturer, primary spatial dimensions, performance parameters, mass properties, delivery capability, profile view, planned schedules, and the nature of the enterprises which sponsor and execute the development.

The PAM (Payload Assist Module) D is Delta compatible, as well as STS compatible, and was developed by the McDonnell-Douglas Company as a commercial venture under an agreement with NASA that the government would not develop an equivalent stage. The PAM-D has flown 16 times on the STS and 11 times on the Delta launch vehicle.

The IUS (Inertial Upper Stage) was developed to accommodate payloads to fly on the Titan 34D, or the STS. To date it has flown once on the Titan 34D and once on the STS. It may also be used on the Titan IV.

Figure 7 illustrates a number of stages currently under development. These stages are in development and funded for certification but not all have identified a first use payload and flight schedule date.

The Centaur-G is a wide-body modification of the Centaur stage used on the Atlas and Titan expendable vehicles.

The Centaur-G Prime (G^{I}) is a larger version of the stage developed to support NASA planetary missions. In addition to the larger hydrogen tank, the G^{I} stage has a lower mixture ratio, a larger engine expansion ratio engine cone and 6 seconds increase in specific impulse.

The TOS (Transfer Orbit Stage) is being developed by Martin-Marietta Corporation for Orbital Science Corporation, a new company formed to develop and market the system. The TOS uses the same first stage motor as the IUS and is targeted for payloads too heavy for the PAM and not large enough to warrant the use of a Centaur-G or G^{I} system. It offers a different avionics and data processing system than the IUS.

Orbital Sciences is also developing an AMS (Apogee and Maneuver Stage) which can be used independently or as an apogee stage in conjunction with the TOS. In this configuration the TOS/AMS has slightly better performance than the IUS due to the higher specific impulse of the storable propellants relative to the solid motor of the IUS upper stage.

The IRIS (Italian Research Interim Stage) is being developed by Aeritalia under the sponsorship of the Italian Government. Its capability is a little less than the PAM-D. Its first use is scheduled for the LAGEOS mission in late 1987.

The PAM-D II is a larger version of the PAM-D system. The solid rocket motor is larger, as is the ASE (Airborne Support Equipment) structure and spin table. The avionics system is not changed in any significant detail. Its first flight was in late 1985 in support of Satcom KU-1.

RCA Astronautics has been developing the SCOTS (Shuttle Compatible Orbit Transfer Stage) as a perigee or transfer orbit stage for future geosynchronous satellites. Its capability is slightly greater than the PAM-A, but not as large as the TOS. It will first fly with the RCA Direct Broadcast Satellite in 1987.

In figure 8, some but not all, of the stages being studied for future development by commercial firms are illustrated. Orbital Systems Corporation is examining a larger version of the AMS and TOS/AMS combinations to provide performance comparable to the Centaur-G.

The STV (Satellite Transfer Vehicle) is a storable bipropellant stage that has been studied by Scott Science and Technology and British Aerospace. It is designed to accommodate payloads too large for the PAM-A, but not so large as to need a TOS.

The LPM (Liquid Propulsion Module) is a storable bipropellant stage using a pump fed engine to get higher specific impulse; therefore, mass fraction efficiency. The Aerojet Technical Systems Company has proposed it as a stage to accommodate payloads from the PAM-D class up to two and a half times that mass. The Transtar 1 engine for the stage is in development but no date for stage availability has been published.

The HPPM (High Performance Propulsion Module) is a joint effort by Aerojet Technical Systems Company and Ford Aerospace to examine a somewhat smaller system also based on the Transtar engine and sized to roughly twice the PAM-D performance.

Not illustrated is a vehicle currently being studied by NASA and the DOD. It is a Shuttle compatible storable propellant upper stage designed to place a 4465 kg payload at geosynchronous orbit.

It is noteworthy that so many of the developments and studies identified here are commercial undertakings not sponsored by government agencies. It also is worth noting that there is increasing interest in fluid systems rather than continued reliance upon solid motors for upper stages.

In addition to basic lift capability there are numerous other issues of significance to spacecraft developers and users of space systems. An extended generic discussion is not practical in a short paper but among the more significant considerations are:

- Induced environments
  - acceleration
  - vibration
  - thermal
- Prelaunch access
  - physical
  - data and command
- Launch date and period of availability
- Priority in sequence for reflight in the event of launch failure
- Cost and terms of payment
- Guidance accuracy

To illustrate the significance of some of these considerations consider figure 9 which reflects the lifetime reliability of U.S. launch systems through the end of calendar year 1985. Despite long experience and substantial efforts to enhance reliability there are still a significant number of failures. The cost of such unreliability falls primarily on the spacecraft user who has at risk his only or one of his few spacecraft. The effect is to limit the value that can be commited to any one spacecraft. Another unit of a launch system in use can be ready long before the spacecraft can be replicated.

Launch delay is another figure of merit in assessing launch service. Do not assign significance to the delay term as a property of the launch system.

Figure 10 illustrates the sources of delay. Note that most sources of launch delay are not the launch vehicle but other factors. Further note that almost half of all the launch delays assigned to the launch vehicle are due to winds aloft shear loads. Weather delays in the tabulation are ground fog, hurricane-typhoons or other local weather constraints on operation.

There are some longer term issues that will have to be dealt with in future space launch operations. The two most prominent are the short term environmental effects of the use of solid propellants and the long term effects of leaving spent stages and spacecraft in orbit.

Solid propellants have very good performance but in the near launch pad environment they create a not insignificant source of acid rain if atmosphere conditions are not considered carefully. Their use on orbit creates a cloud of micron sized particles that disperse or enter the atmosphere reasonably soon but while present abrade spacecraft thermal and optical surfaces. While these effects are minor at current levels of activity they could become more significant as the level of space activity increases. When other considerations are combined with performance evaluations the longer term preference will be for liquid systems.

Since space operations began, over 16,000 objects have been placed in low Earth orbit i.e., between 300 and 2000 km and over 6000 are in orbit now. Only a small fraction of these are useful operational spacecraft. These objects represent 2,000,000 kg of mass contrasted with the 10,000 to 20,000 kg of natural meteoritic material that passes through these same regions. Further the man-made material is not uniformly distributed. In the not too distant future it will no longer be wise to leave spent stages and spent spacecraft in low Earth orbit. Objects no longer useful become a hazard to those in use. There will be a performance penalty to operate placement stages for controlled entry and to enter spent spacecraft. The penalty will never be less than when it is dealt with in the initial design. Obviously such action will require agreement and common action among all launch system and spacecraft operators when an appropriate course of action can be defined. Studies are in progress among all the launching organizations to better understand all the issues and to define what are the most effective preventive and palliative measures that can be adopted.

Summary

Launch systems have improved significantly in performance and reliability over the last 30 years. The combined effect has been to make space based systems more cost and performance effective by more than two orders of magnitude. We may be approaching a performance asymptote as more systems use liquid oxygen and hydrogen for maximum potential chemical impulse but there is certainly another order of magnitude or two that we can achieve in reliability and that has been the traditional path of growth for other transportation systems; I expect it will be so for space transportation. That, as I see it, is where our challenges will be.

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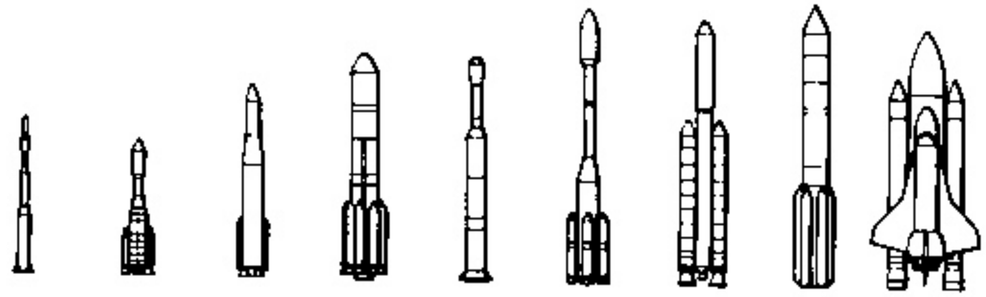
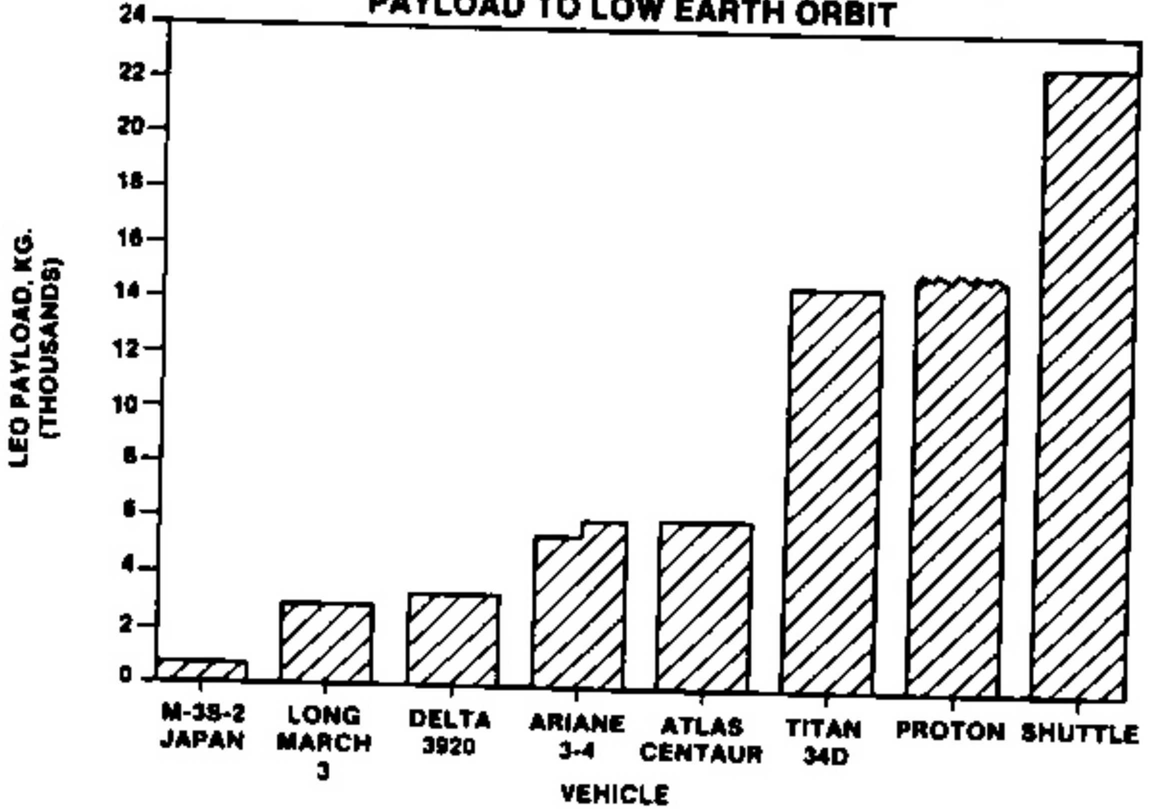
OPERATIONAL LAUNCH VEHICLES

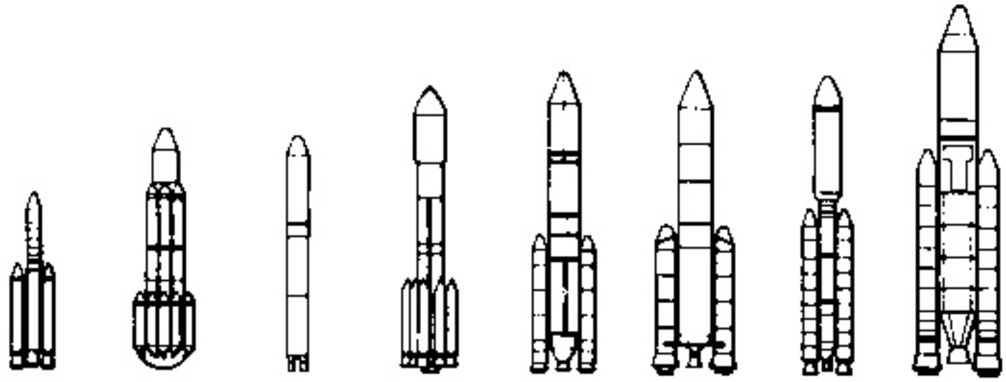


NAME	SCOUT	M 3S 2	ATLAS G CENTAUR	DELTA 3 920	LONG MARCH 3	ARIANE 4	TITAN 34D	PROTON	SHUTTLE
MANUFACTURER	VOUGHT	NISSAN MOTORS	GENERAL DYNAMICS	MCDONNEL DOUGLAS	GREAT WALL INDUSTRY	ARIANE-SPACE	MARTIN MARIETTA	SLX 16 USSR	ROCKWELL INTERNATIONAL
PAYLOAD 500KM	255 M ‡	758	6 120	3 393	3 000	8 000	14 685	15 000	22 765
GROSS WEIGHT	21 071 M ‡	80 893	161 000	191 205	192 000	462 053	686 180	900 000	2 093 000

OPERATIONAL LAUNCH VEHICLES
PAYLOAD TO LOW EARTH ORBIT



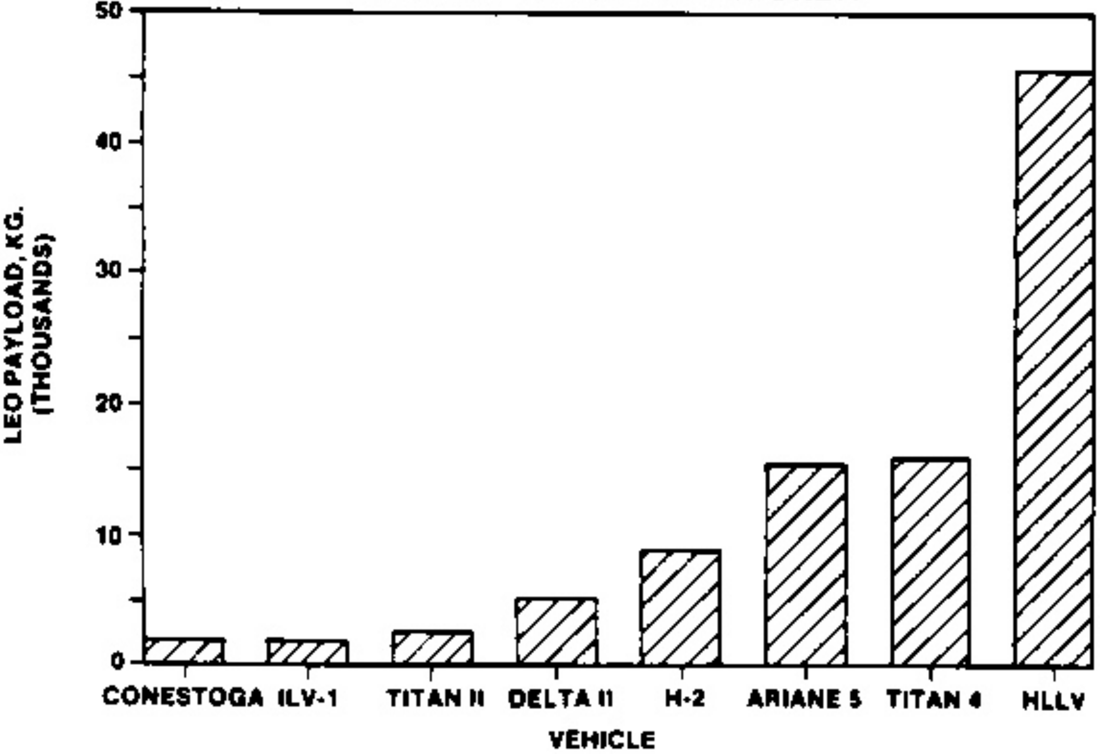
PLANNED LAUNCH VEHICLES



VEHICLE	CONESTOGA	ILV-1	TITAN II	DELTA II	H-2	ARIANE 5	TITAN 4	HLLV
DEVELOPER	SPACE SERVICES INC	AMERICAN ROCKET CO	MARTIN MARIETTA	MCDONNELL DOUGLAS	MITSUBISHI HEAVY IND	AEROSPATIALE	MARTIN MARIETTA	NASA/USAF
PAYLOAD 500KM	1 785 [illegible]	1 785	2 320	5 000	8 000	17 000 4 025	17 450 4 465	45 000
DATE AVAILABLE	(1989)	(1988)	(1988)	(1989)	(1992)	(1995)	(1989)	(1995)

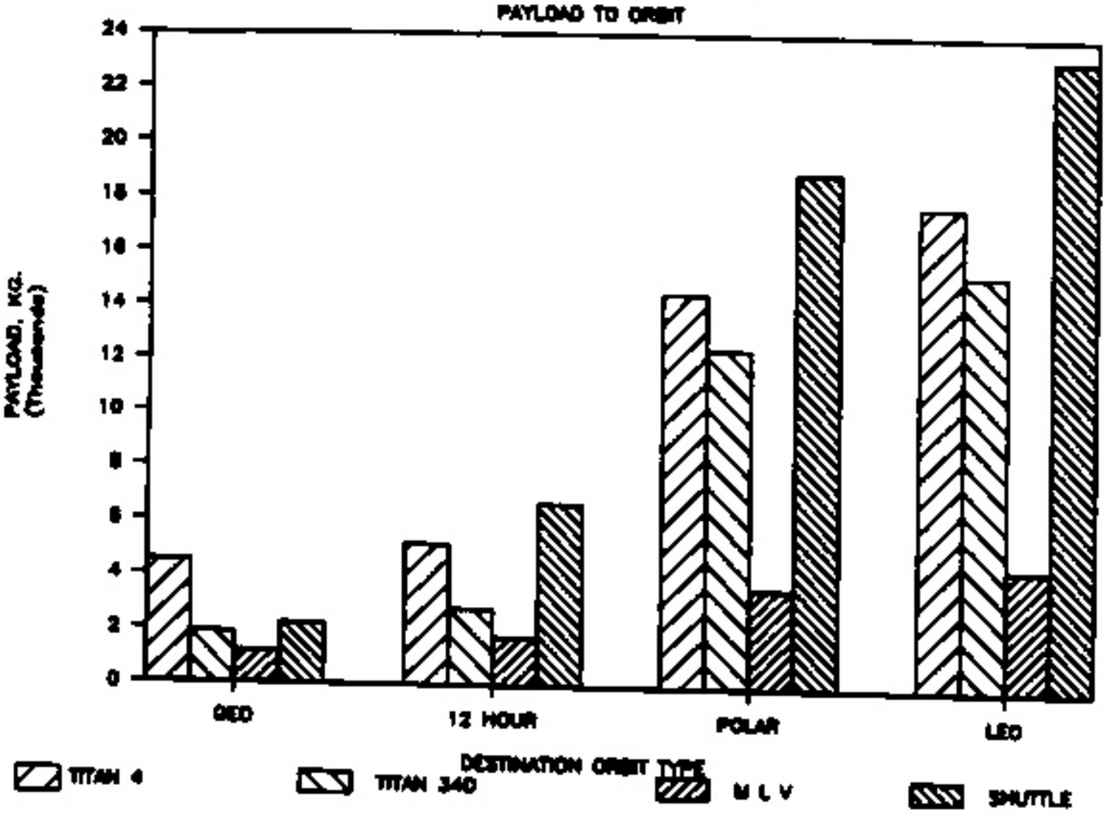
PLANNED LAUNCH VEHICLES TO 1995

PAYLOAD TO LOW EARTH ORBIT



L V CAPABILITIES

PAYLOAD TO ORBIT



[illegible]

UPPER STAGES (EXISTING)

CHARACTERISTICS		PAM D	PAM A	IUS (TWO STAGE)
STAGE				
MANUFACTURER		MCDONNELL-DOUGLAS (MDAC)	MDAC	BAC
LENGTH	(m)	[illegible]	[illegible]	[illegible]
DIAMETER	(m)	1.2	1.2	[illegible]
ENGINE				
MANUFACTURER		THIOKOL	THIOKOL	CSD
TYPE		(STAR 48)	[illegible]	
NUMBER		1	1	SRM-1 SRM-2
FUEL		SOLID	SOLID	SOLID
COMPOSITION		[illegible]	[illegible]	HTPB
TOTAL THRUST	(N)	[illegible]	[illegible]	[illegible]
SPECIFIC IMPULSE	SEC	[illegible]	[illegible]	[illegible]
BURN TIME	SEC	[illegible]	[illegible]	[illegible]
STAGE				
FAD WEIGHT	(kg)	[illegible]	[illegible]	[illegible]
PROPELLANT WEIGHT	(kg)	[illegible]	[illegible]	[illegible]
BURN-OUT WEIGHT	(kg)	[illegible]	[illegible]	[illegible]
SUPPORT EQUIP WEIGHT	(kg)	[illegible]	[illegible]	[illegible]
PAYLOAD[1]				
TO GEO - ONE WAY STAGE	(kg)	[illegible]	[illegible]	[illegible]
TO GEO TRANSFER ORBIT (GTO)	(kg)	[illegible]	[illegible]	[illegible]
ILLUSTRATION NOTES 1 REF [illegible] INCLINATION & [illegible] N.M. CIRCULAR * REQUIRES KICK STAGE		 PAM D	 PAM A	 IUS (TWO STAGE)
SCHEDULE				
START DATE		[illegible]	[illegible]	[illegible]
OPERATIONAL DATE		[illegible]	[illegible]	[illegible]
TYPE OF DEVELOPMENT		COMMERCIAL	COMMERCIAL	US GOVT
SPONSOR		MDAC	MDAC	USAF

UPPER STAGES (PRE-DEVELOPMENT)

CHARACTERISTICS	AMS HIGH PERFORMANCE	TOS AMS HIGH PERFORMANCE	STV	LPD	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]					
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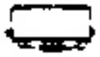
[illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]
[illegible]					
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[illegible]	[illegible]	[illegible]	[illegible]	–	–
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

UPPER STAGES (UNDER DEVELOPMENT)

CHARACTERISTICS	CENTAUR G	CENTAUR G	TOS	AMS	TOS/AMS	[illegible]	PAM D-II	SCOTS
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
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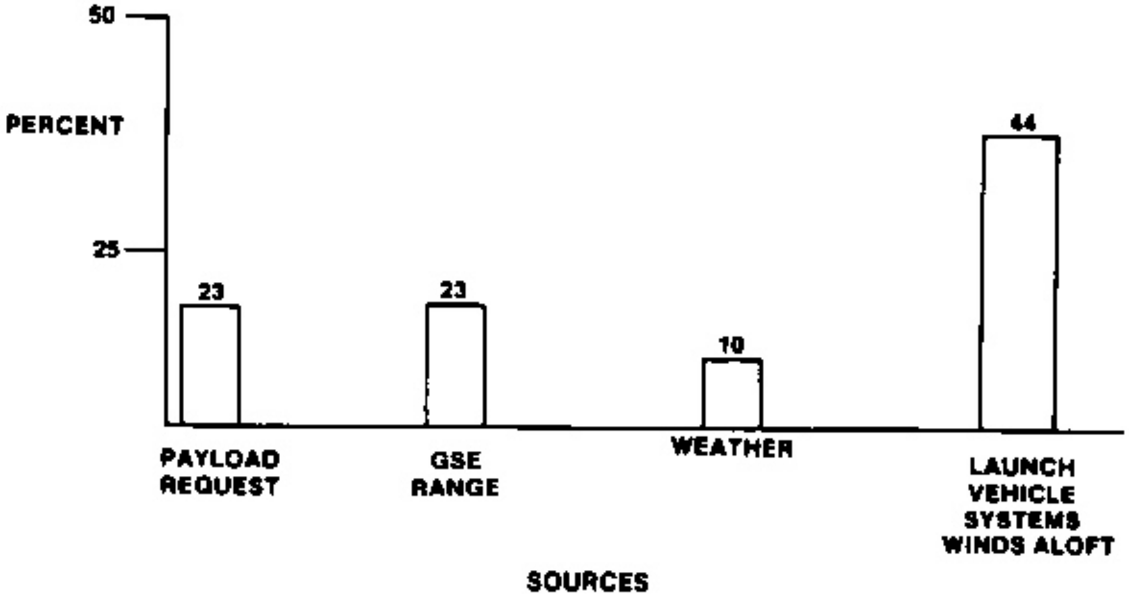
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	–	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]	 [illegible]	 SCOTS
[illegible]								
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

LAUNCH SUCCESS/LAUNCH DELAY EQUIVALENT DAYS

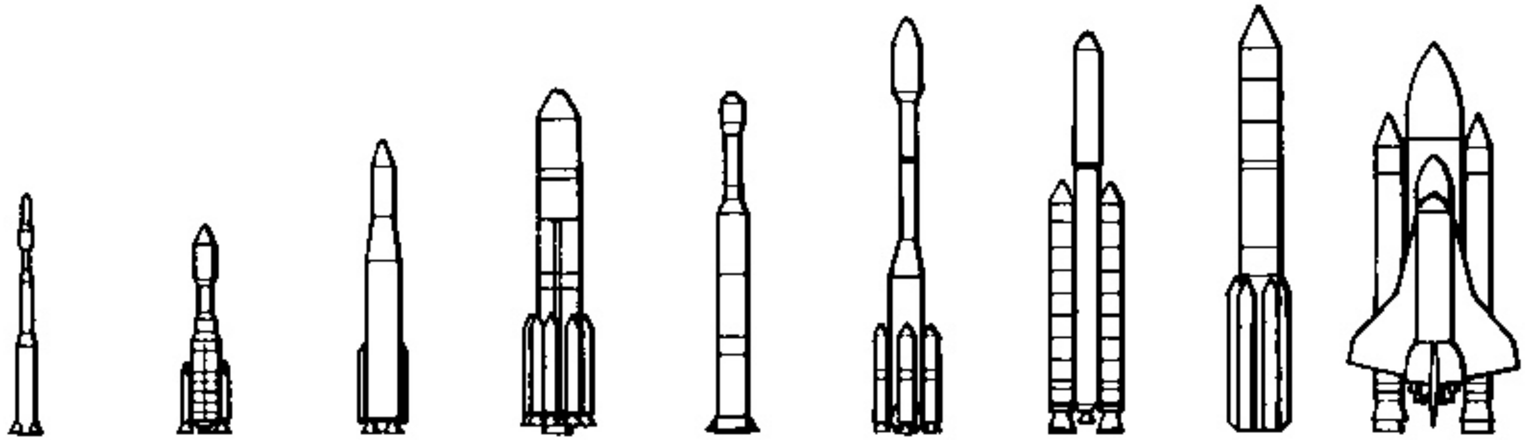
SCOUT	.96	3
DELTA	.96	3
ATLAS/CENTAUR	.95	1
TITAN	.95	?
SHUTTLE	1.00	.5

1981-1985 DATA FOR SCHEDULED LAUNCH DATE AS OF 60 DAYS BEFORE ACTUAL LAUNCH. TITAN DATA ARE INDETERMINATE BECAUSE OF CLASSIFICATION OF PLANNED DATES PRIOR TO LAUNCH.

CHANGES IN LAUNCH DATE



OPERATIONAL LAUNCH VEHICLES



NAME	SCOUT	M-35-2	ATLAS G CENTAUR	DELTA 3 820	LONG MARCH 3	ARIANE 4	TITAN 34D	PROTON	SHUTTLE
MANUFACTURER	VOUGHT	NISSAN MOTORS	GENERAL DYNAMICS	MCDONNEL DOUGLAS	GREAT WALL INDUSTRY	ARIANE-SPACE	MARTIN MARIETTA	SLX 16 USSR	ROCKWELL INTERNATIONAL
PAYLOAD 500KM	255 Kg	758	6 120	3 393	3 000	8 000	14 685	15 000	22 765
GROSS WEIGHT	21 071 Kg	60 893	161 000	191 205	192 000	462 053	666 160	600 000	2 893 000