Titan II Small Multisatellite Mission Approach

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At the present time, small satellite programs are faced with the dilemma that they are sometimes so small that they cannot afford the expense of a dedicated Expendable Launch Vehicle (ELV) and, therefore, must attempt to find a way to get into orbit as a secondary payload. This paper discusses another alternative, the use of a Titan II as a dedicated launch vehicle for a group of small satellites. Launches could be scheduled on a periodic basis as a function of predicted need. The Titan II has the capability of inserting total payload weight of 3,000 to 4,000 lbs. into high-inclination, low-earth orbits and smaller payloads to higher orbits. Orbit changes are possible depending on the altitudes and payloads weights involved. Payload fairings are available for small and large payloads.

Since the total payload could conceivably consist of satellites from several unrelated programs, some type of mission "broker" or central contracting agency would be needed to develop and implement a multisatellite mission. This paper offers an approach to implementing a mission of this type that would allow small satellites to schedule a launch on the T-II multisatellite carrier at a predetermined launch date during each year. The costs would be shared between payloads on the basis of weight and volume. This gives those small satellite programs a launch option that would provide on-orbit operation at a predetermined time.

INTRODUCTION

As more small satellite concepts evolve, the competition for existing launch options grow increasingly intense. Further, the demand for lower cost per pound delivery systems and more frequent launch opportunities will increase.

Small satellite programs are often too small to afford a dedicated booster. This is especially true if the desired orbital altitude or inclination is higher than the low-earth orbits provided by the shuttle at about 28 degrees. The shuttle manifest in the out years has few opportunities for small satellites not already scheduled. Therefore, small satellites have very limited options; i.e., assume the status of "secondary payloads" that share a ride with a larger payload, or become a "payload of opportunity" that is held on standby to fill unused launch capacity over some extended time period. These options have undesirable side effects for many small satellite programs such as launch date uncertainty, non-optimal orbits and increased costs.

Another option exists where small satellites jointly share the cost of a launch with other programs having compatible launch dates and orbital parameters. This option would involve the use of a "mission broker" or integrator and a highly flexible launch vehicle. The "mission broker" would coordinate and group compatible small satellites for each scheduled launch using a flexible vehicle having the capability to launch a wide variety of payloads to different orbits and inclinations.

The Titan Launch Program, beginning in the sixties, provides an extensive background of multiple satellite launches from which a Small Multisatellite Mission approach can be developed. The Titan II with its available thrust augmentation configuration provides an extremely wide range of total payload weights for a variety of orbital altitudes and inclinations. These past multiple satellite launches also serve to demonstrate the viability of the "mission broker" concept. The Titan II coupled with a "mission broker" approach that has proven to be highly successful in the past can be used to plan the launch of small satellite groups on a regular or predetermined launch date basis. Under the management of the Air Force Space Division acting as "mission broker," small multisatellites have been grouped in order to jointly share in the cost of a launch. The past Titan Launch Program experience is summarized in the next section.

TITAN PROGRAM MULTISATELLITE LAUNCH BACKGROUND

A review of past Titan Program manifests shows that most launches have involved more than one payload. In fact, one period from the early sixties to the late seventies involved a high ratio of multiple to single payload launches.

Figure 1 shows that of the 22 launches during that period (excluding the Ballast test launches) in late 1964, over one half were multiple satellite launches that varied from two to eight satellites per launch. The type, size and data/science mission of the satellites were widely varied. This included satellites from various government agencies such as DOD, DOE, and NOAA. The Oscar-4 satellite launched in December 1965 was built and provided by the amateur radio community. The IDSCS communications satellite launches required the use of a payload truss that could accommodate eight satellites. This configuration is shown in Figure 2. A photo of the actual IDSCS payloads and truss are shown in Figure 3.

The payload truss for the September 1968 launch of the OV2-5, OV5-2, OV5-4 and LES-6 probably presented the most complex truss design and payload release sequence. Both lateral and forward satellite releases were provided. Notice that multiple payloads were launched into circular and highly elliptical orbits. This experience and background points the way for us today as we consider various mission approaches for launching small multisatellites. The concept of using the highly flexible Titan II coupled with the Air Force Space Systems Division acting as "mission broker" offers an immediate solution for the launch of many small satellites. The various Titan II configurations that can be used to execute this mission approach are summarized in the next section.

TITAN II CONFIGURATION DESCRIPTION

The Titan II family of launch vehicles is based on the Titan ICBM, as shown in Figure 4. The configuration of the basic Titan II Space Launch Vehicle is shown in Figure 5. To meet spacecraft reliability, volume and mission requirements we have modified the Titan II avionics, structure and propulsion systems. These improvements give Titan II Stage II the same mission flexibility as the highly successful Transtage spacecraft.

The heart of the avionics system is the same Delco Magic 352 guidance system which guides Titan IV, Commercial Titan and the Titan 34D/Transtage to precision low-earth and geostationary missions. The electrical harness and electronic and ordnance components share common designs with the other Titans. This allows cost effective large builds and ensures a ready supply of spare components.

The Titan II mission software is an application of the modular software which controls and guides all Titan vehicles. This flexible design allows easy software modification and validation to meet a variety of spacecraft mission requirements.

To verify the integrity of the basic structure, we proof test propellant tanks to 110 percent of maximum flight pressure. We add a 10-foot diameter payload fairing and a 56-inch diameter spacecraft interface to the forward end of Stage II. The Universal Payload Fairing (UPLF) is built by McDonnell Douglas Space Systems Company and has performed flawlessly on 38 Titan Transtage missions. The UPLF is qualified for lengths of 15 to 50 feet in 5-foot increments. The two standard spacecraft interfaces duplicate the Atlas E and Transtage interfaces. Adapters are available to match Delta interfaces.

The Stage I and II engines were originally built by Aerojet Tech Systems Company (ATC). ATC is now refurbishing and hot-firing these engines. To meet spacecraft attitude and attitude rate requirements, we have added an attitude control system (ACS) to Stage II. This also allows Stage II to release multiple spacecraft, each with different maneuver and pointing requirements.

The first growth Titan II, shown in Figure 6, could be launched in early 1992. To the basic Titan II, we have added the capability to attach 2 to 10 solid rocket motors to Stage I. Additional ACS propellant in Stage II permits apogee burns to release spacecraft in 500 nmi orbits.

MISSION DESIGN

Figure 7 shows performance of the Titan II from the west coast. Figure 8 shows similar plots for the growth Titan II with four and eight solid rocket motors. Note that the circular orbit segments of these plots show that performance falls off rapidly as circular orbit altitude increases; the practical limit is about 150 nmi.

For achieving higher altitude circular orbits, the expanded ACS is used. This system can provide the relatively large Delta-V (for example, 656 fps for a 500 nmi circular orbit) required to circularize from an elliptical park orbit. In addition, the ACS is capable of providing additional Delta-V for satellite spacing or for modest orbit changes for multiple satellite missions. As an example of the growth Titan II capability, about 5000 pounds can be placed in a 480 nmi orbit with an inclination of 99 degrees.

This capability will allow the Titan II to be used to fly a variety of missions. A typical mission profile for a multisatellite program is shown in Figure 9. This mission could be tailored to the needs of the satellite group by selecting various Titan II performance configurations.

All of these vehicles can carry multiple satellites as shown in Figure 10. With the addition of a multisatellite truss, Stage II can now perform the same role transtage has over the last 25 years. This truss has the capability to mount each payload onto a standard spring-release interface or a standard spinner interface adapter, see Figures 11 and 12. The concept includes providing a standard interface plate to each payload user onto which he builds, or mounts, his payload prior to delivery of the payload in the clean room at SLC-4W. A number of spacecraft can be carried to different missions, spun up if desired, oriented as the user desires and then deployed.

PROGRAM DEVELOPMENT

A central contracting agency or "mission broker" is virtually essential for a sustained and efficient multisatellite program. This agency would be tasked with buying the launches to meet user requirements. This represents a formidable task. For a particular mission, the various satellites must have similar orbital requirements. They must also have compatible launch dates, and their funding profile must be compatible to support the launch. A "multisatellite consortium" would be hard-pressed to handle the mixing and matching that would be required. Traditionally, the agency working with the booster has had the responsibility of integrating the satellites, primarily because a satellite program would have difficulty meeting its mission needs as a single interest. The use of the booster agency as the satellite to booster integrator has proven successful in the past and should be extended for multisatellite missions.

The degree to which small satellites must be mixed or matched by the "mission broker" would depend heavily on a top level requirements matrix. Top-level parameters would include:

- Orbital parameters, altitude, inclination, shape
- Desired launch date
- Funding profile
- Size, weight and release requirements
- Cleanliness requirements

The orbital parameters would be the driving force in determining which small satellite missions are compatible. The desired launch date may not be a large driver for this class of satellites based on presently planned launches. The availability of small satellite program funds for the support of a launch typically will not have much flexibility.

In our proposed mission approach, the Air Force Space Systems Division would be acting as "mission broker" and would represent the multisatellite bus in terms of obtaining launch dates, flight plan approval, launch safety, and launch vehicle priorities. The "mission broker" would, of course, obtain the booster, propellant, launch services, and range support. More subtle, but equally important, the "mission broker" would arbitrate how much of the launch each satellite would fund and what funding profile would be required. In the current national budget environment, an important function would be to resolve satellite funding disruptions. It is virtually guaranteed that on some planned multisatellite launches a satellite will be canceled or delayed, perhaps even very late in the integration cycle. A simple deletion of the satellite would not be cost effective because of the added launch cost to the other satellites. The "mission broker" would identify another satellite in that case or consider a launch delay, or reconfigure the launch vehicle to provide less thrust, thus reducing costs to fly. The Titan II is designed to allow this flexibility.

If the Titan II was used as the multisatellite booster, then the "mission broker" would be the Titan II Systems Program Office (SPO) of the Space Systems Division. This SPO currently integrates both DoD and NASA satellites onto the booster and has the capability of integrating satellites from other agencies or universities. When a new satellite seeks to assess the Titan II for their needs, it is this SPO that looks at booster capability, launch dates, and on-orbit costs. The SPO has proven ability and flexibility to play a key role in future small multisatellite programs.

SUMMARY

The suggested approach for meeting the launch service needs of many existing and future small satellites is the use of the Titan II with the USAF Space Systems Division acting as "mission broker." This mission approach offers the potential for a wide range of launch dates, orbital altitudes and inclinations for many small satellite programs.

LAUNCH DATE	PAYLOADS	TOTAL PAYLOAD WT, LBS.	HIGHEST ORBITAL ALTITUDE, N MI
SEPTEMBER 1964	BALLAST	3,120	100
DECEMBER 1964	BALLAST	3,010	100
FEBRUARY 1965	LES-1	1,090	1,500
MAY 1965	LES-2 & RCS-1	1,210	1,500
JUNE 1965	BALLAST	21,000	100
OCTOBER 1965	OV 2-1 & RCS-2	1,270	400 / 4,000
DECEMBER 1965	OV 2-3, LES-3, LES-4 & OSCAR-4	960	18,200
JUNE 1966	IDSCS (7 SATELLITES) & GGTS	1,025	18,200
AUGUST 1966	IDSCS (8 SATELLITES)	1,025	18,200
NOVEMBER 1966	MOL / HSO + 12 EXPERIMENTS	20,380	160
JANUARY 1967	IDSCS (8 SATELLITES)	1,030	18,200
APRIL 1967	VELA (2 SATELLITES) ,OV 5-1, OV 5-3, & OV 5-4	1,810	4,680 / 60,000
JULY 1967	DODGE, LES-5, DATS-1 & IDSCS (3 SATELLITES	1,380	18,200
JUNE 1968	IDSCS (8 SATELLITES)	1,020	18,200
SEPTEMBER 1968	OV 2-5, OV 5-2, OV 5-4 & LES-6	1,170	19,323
FEBRUARY 1969	TACOMSAT	1,590	19,323
MAY 1969	VELA (2 SATELLITES) OV 5-5, OV 5-6 & OV 5-9	1,950	9,150 / 60,330
APRIL 1970	VELA (2 SATELLITES)	1,830	19,340 / 160,400
NOVEMBER 1970	*NO INFORMATION AVAILABLE*	1,970	19,323
MAY 1971	*NO INFORMATION AVAILABLE*	1,990	19,323
NOVEMBER 1971	DSCS-2 (2 SATELLITES)	2,320	19,490
MARCH 1972	*NO INFORMATION AVAILABLE*	1,990	19,323
JUNE 1973	*NO INFORMATION AVAILABLE*	2,130	19,323
DECEMBER 1973	DSCS-2 (2 SATELLITES)	2,580	19,323
MAY 1974	*NO INFORMATION AVAILABLE*	3,080	19,323

Figure 1. Titan II SLV launch history.

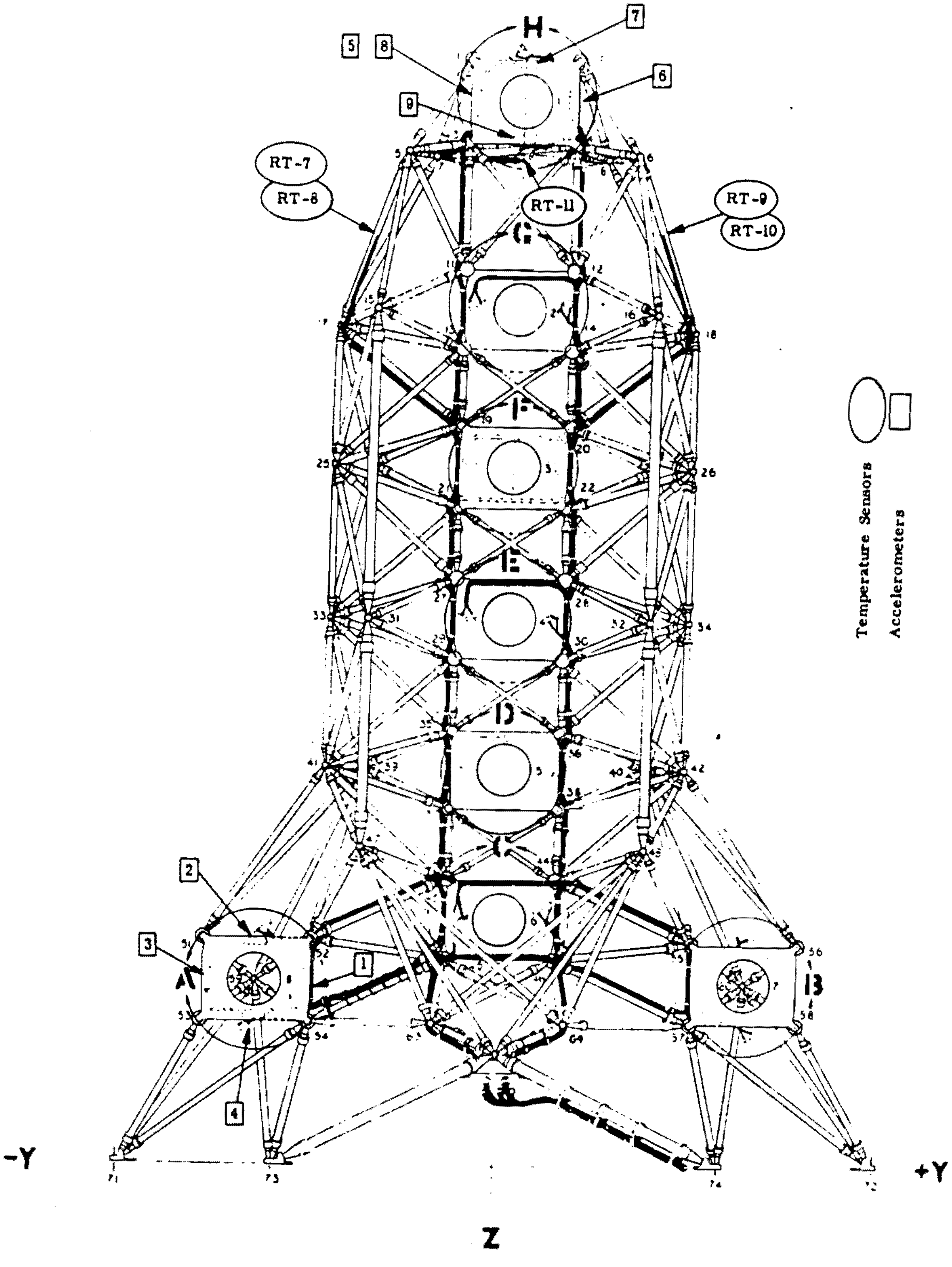


Figure 2. ICSDS support structure.

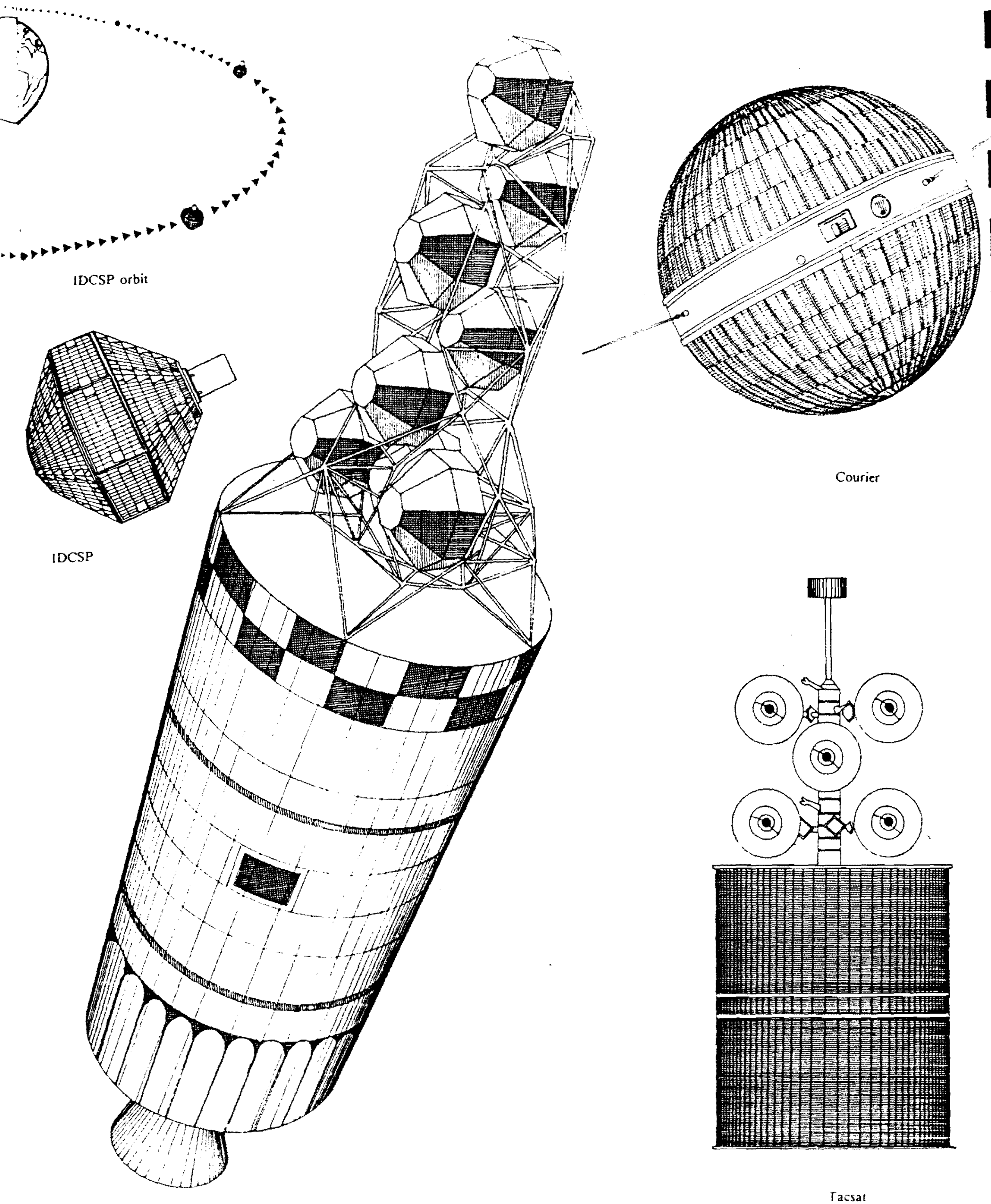
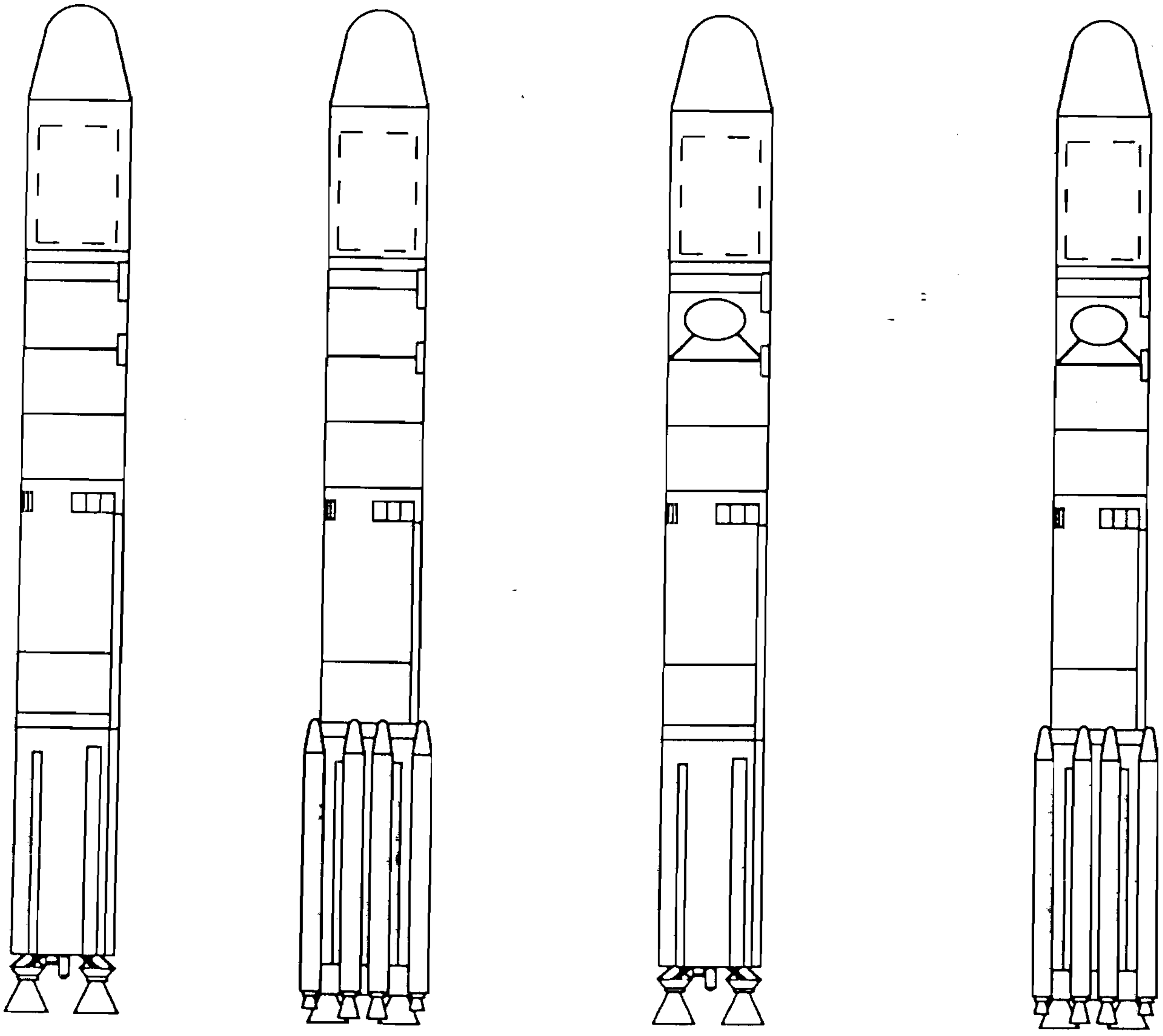


Figure 3. ICSCS payloads with support structure.



Titan II SLV

Titan II SLV / SRM's

Titan II SLV / EMK

Titan II SLV / SRM's / EMK

Figure 4. Titan II SLV configurations.

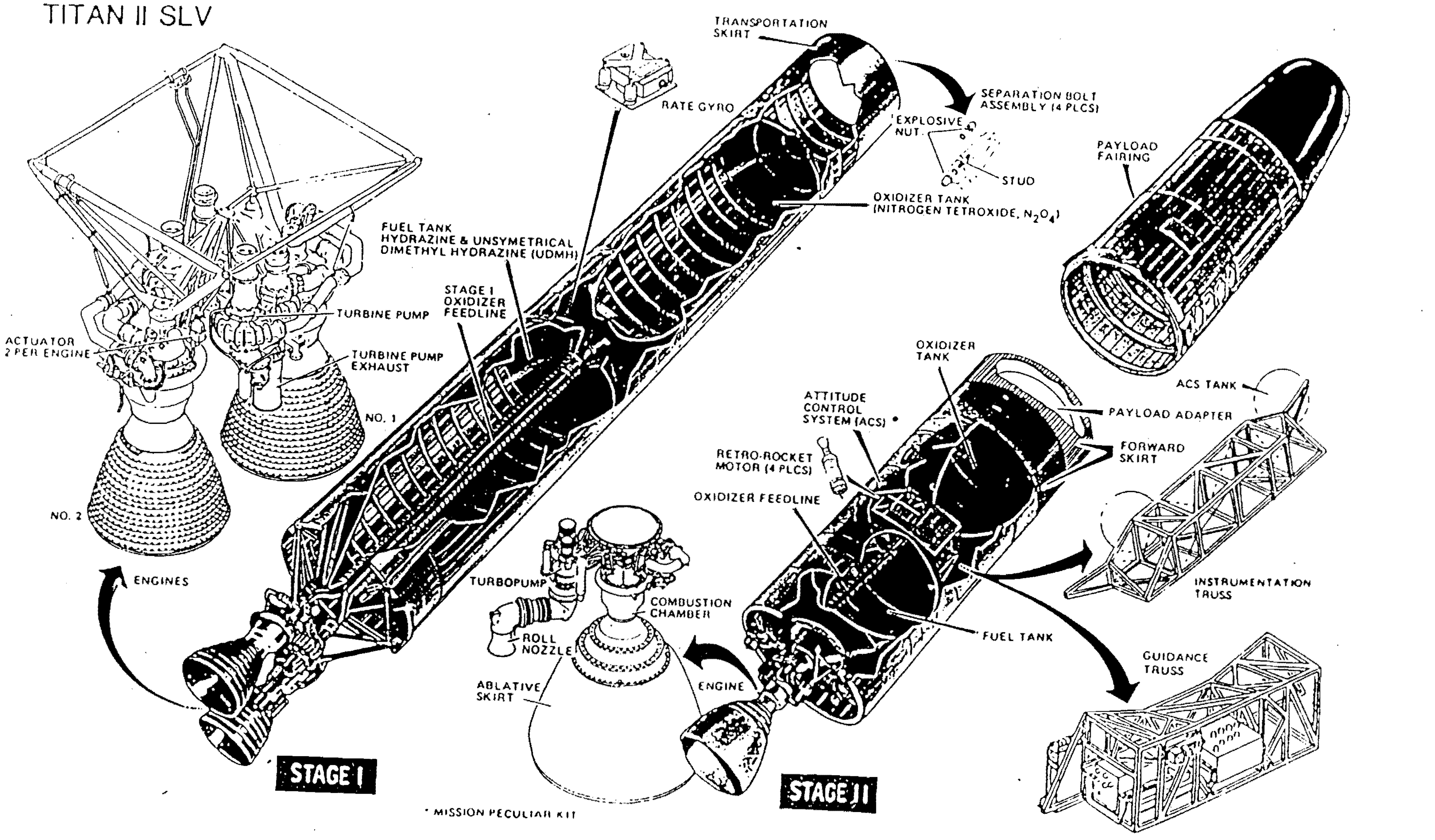


Figure 5. Titan II SLV configuration.

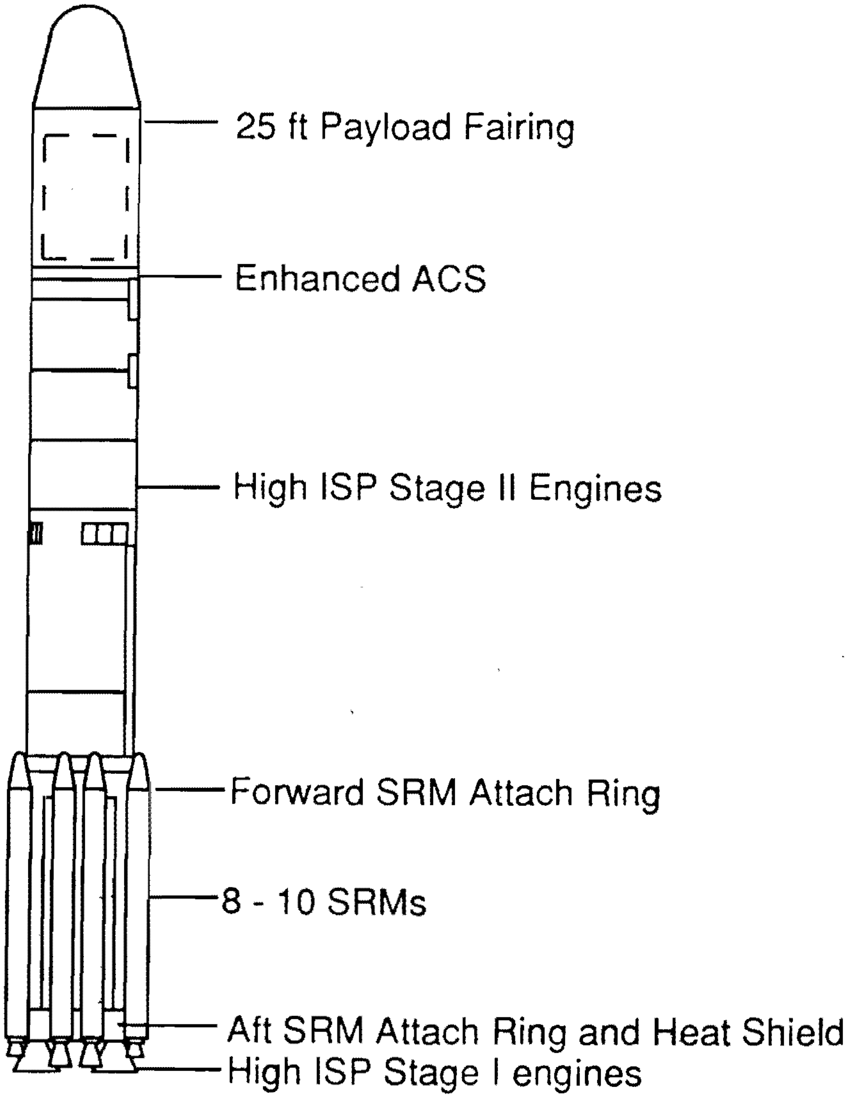


Figure 6. Titan II SLV with solid rocket motors.

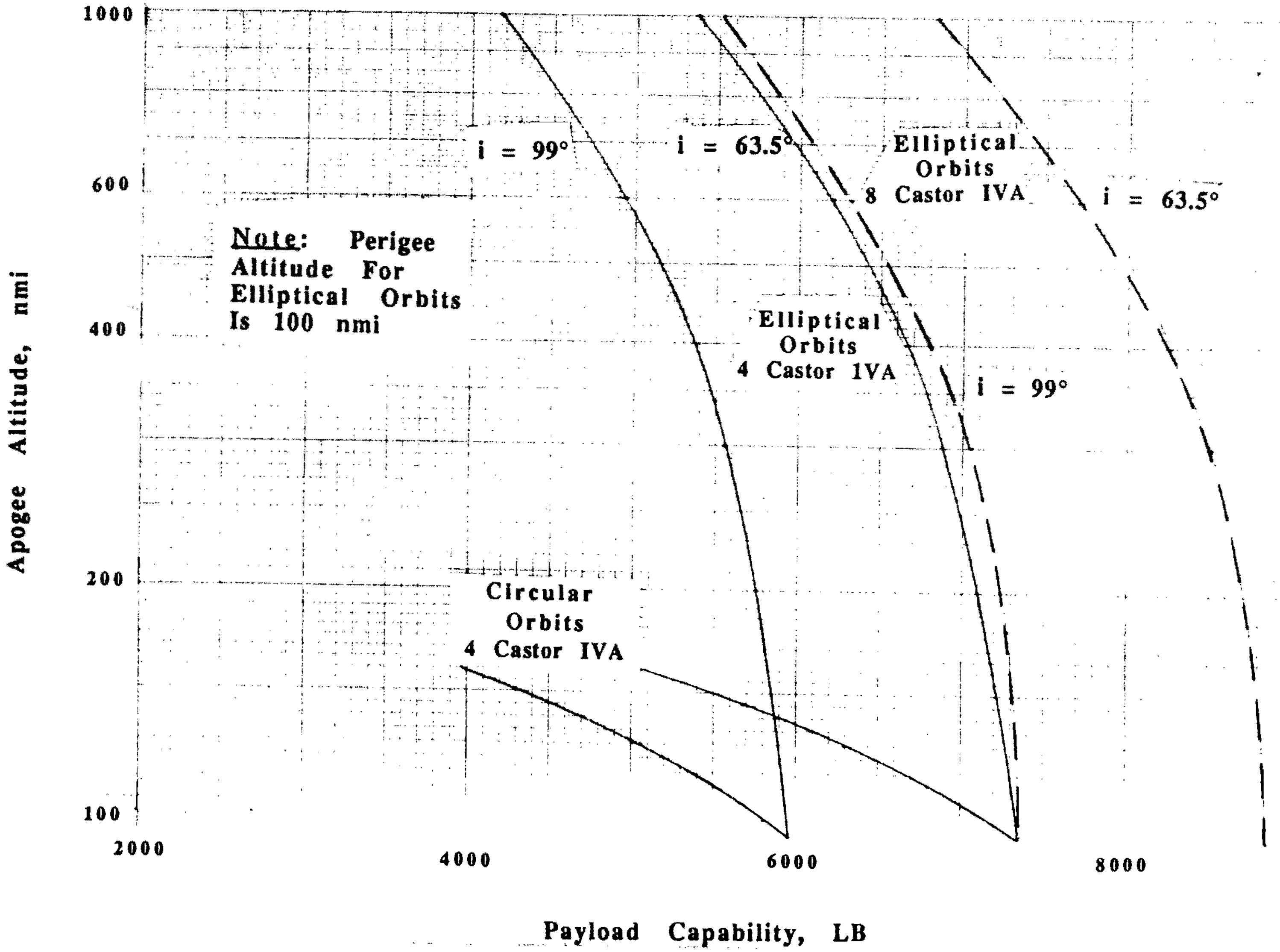


Figure 7. Titan II SLV performance - WTR launches.

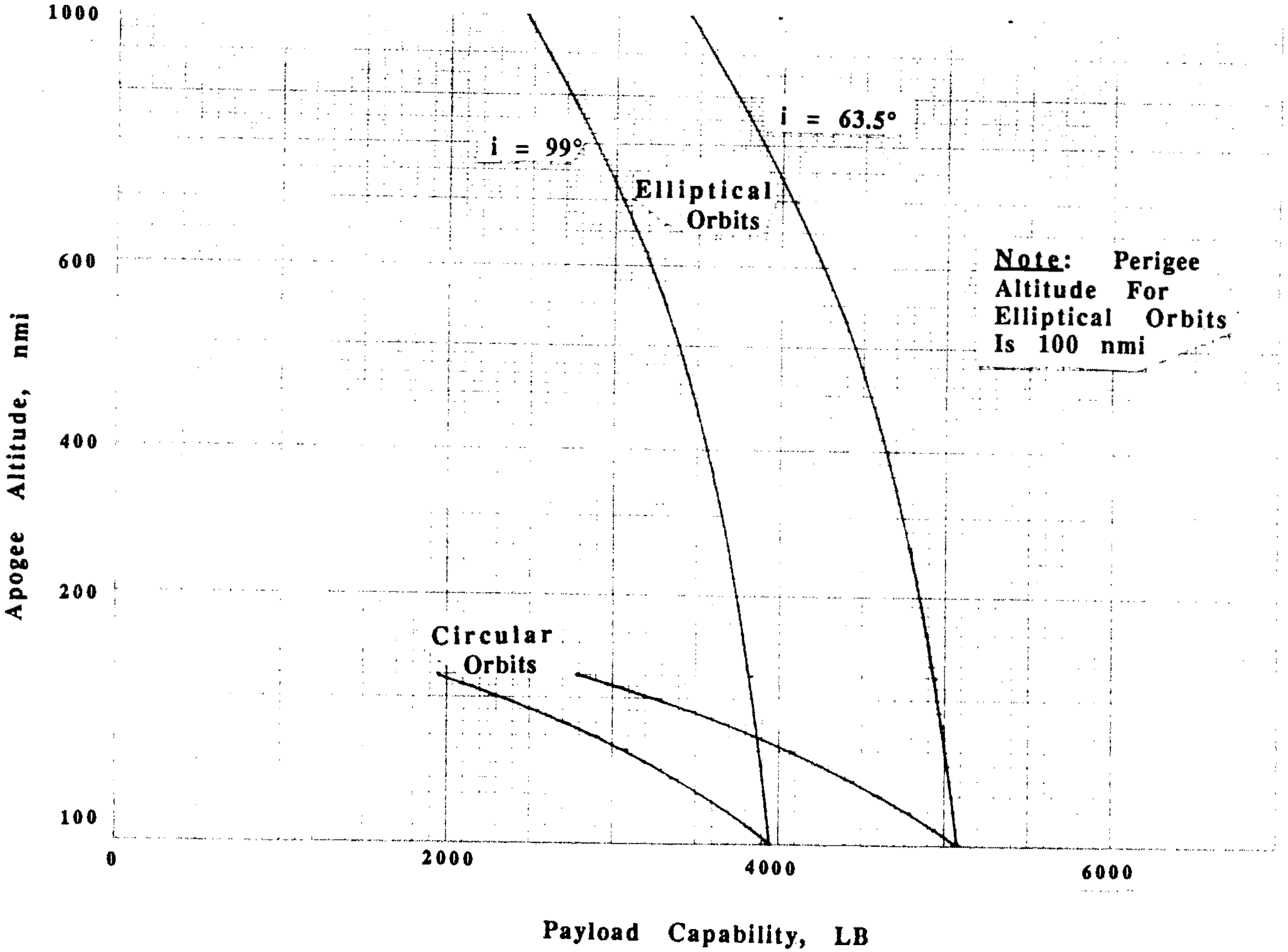
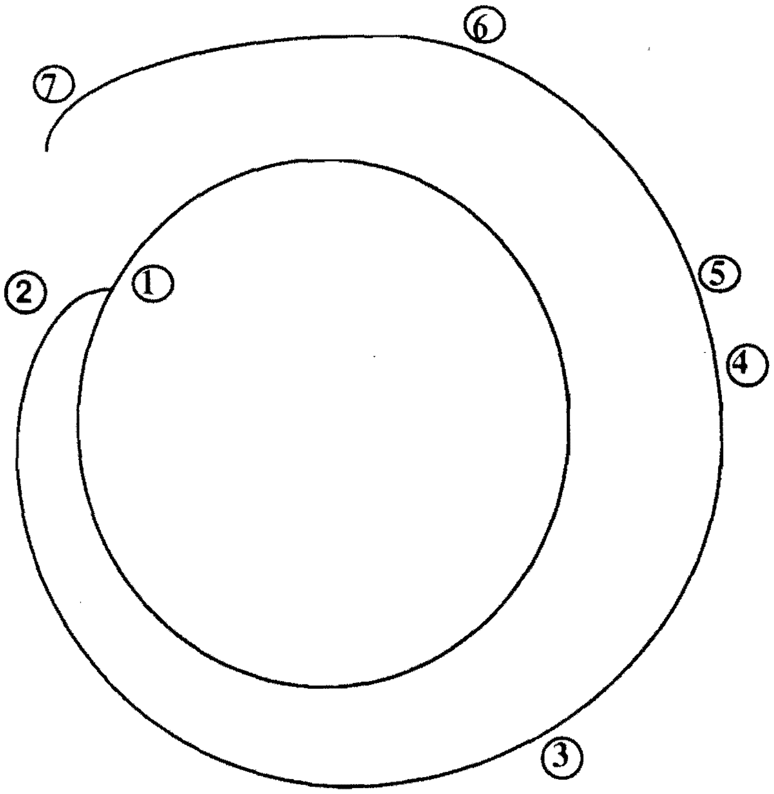


Figure 8 . Titan II SLV performance - WTR launches with solid rocket motors.



① Liftoff

② Inject Into 100 x 460 nmi
Park Orbit

③ Begin EMK Circularization Burn

④ End EMK Circularization Burn,
Inject Into 480 nmi Circular Orbit

⑤ Release First Satellite,
Perform Orbit Adjustment

⑥ Release Second Satellite,
Perform Orbit Adjustment

⑦ Release Third Satellite,
End of Mission

Figure 9. Multiple satellite mission.

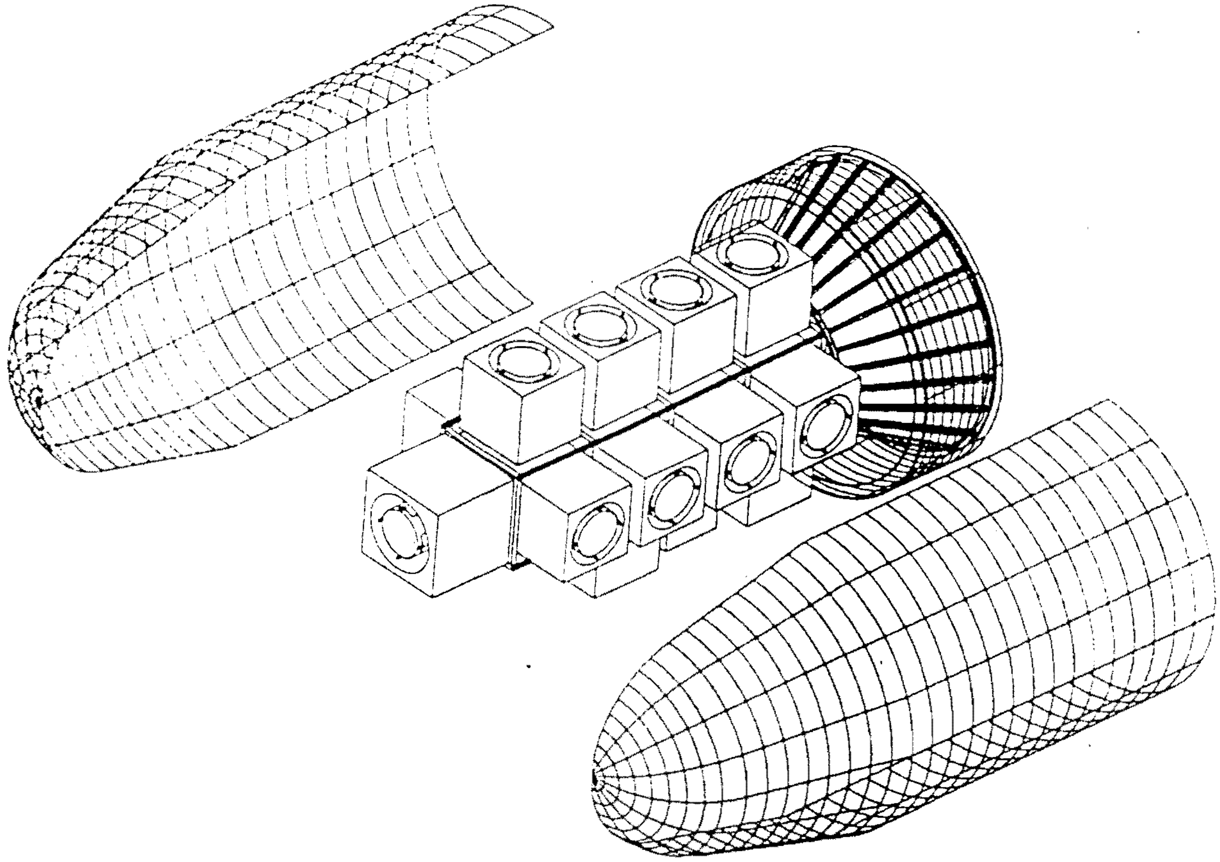


Figure 10. Multiple satellite truss configuration.

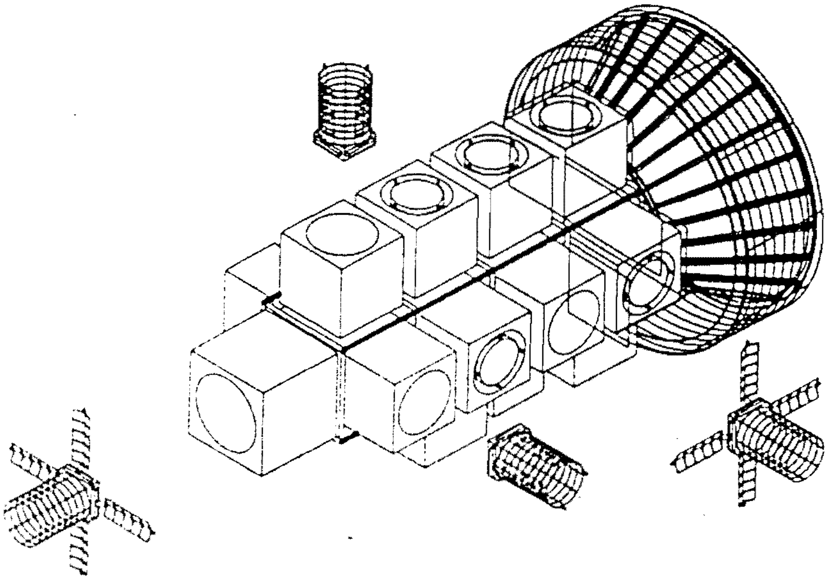


Figure 11. Multiple satellite deployment.

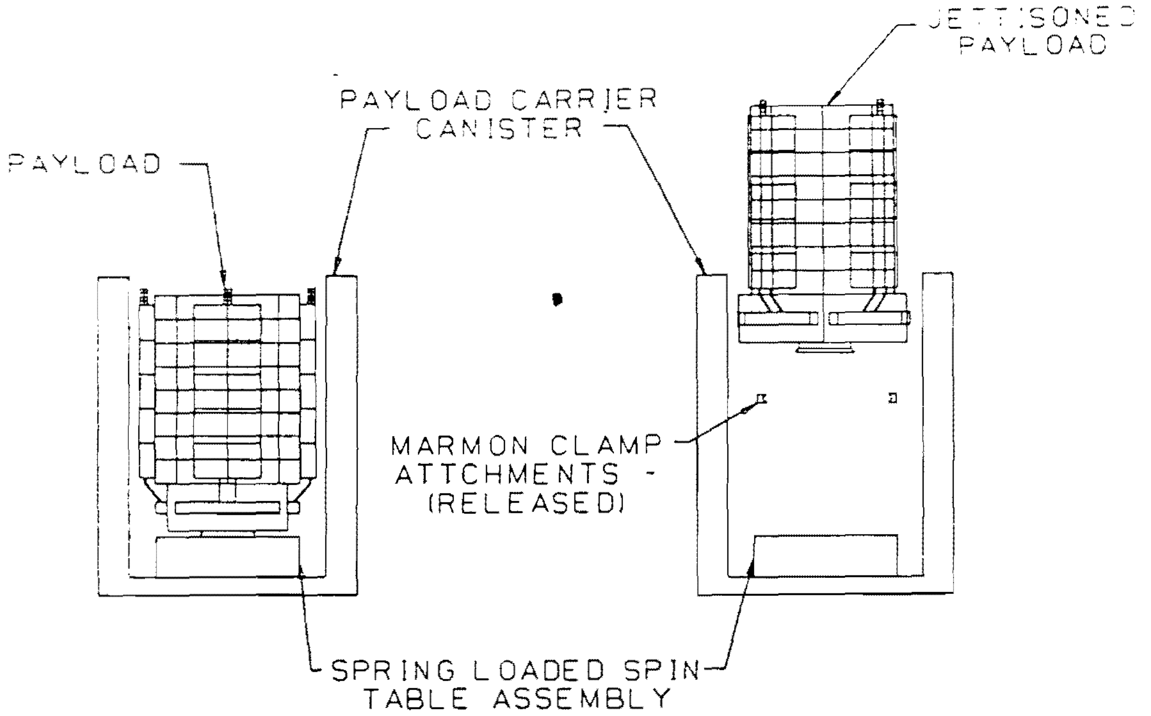


Figure 12a. Multiple satellite deployment mechanism concepts.

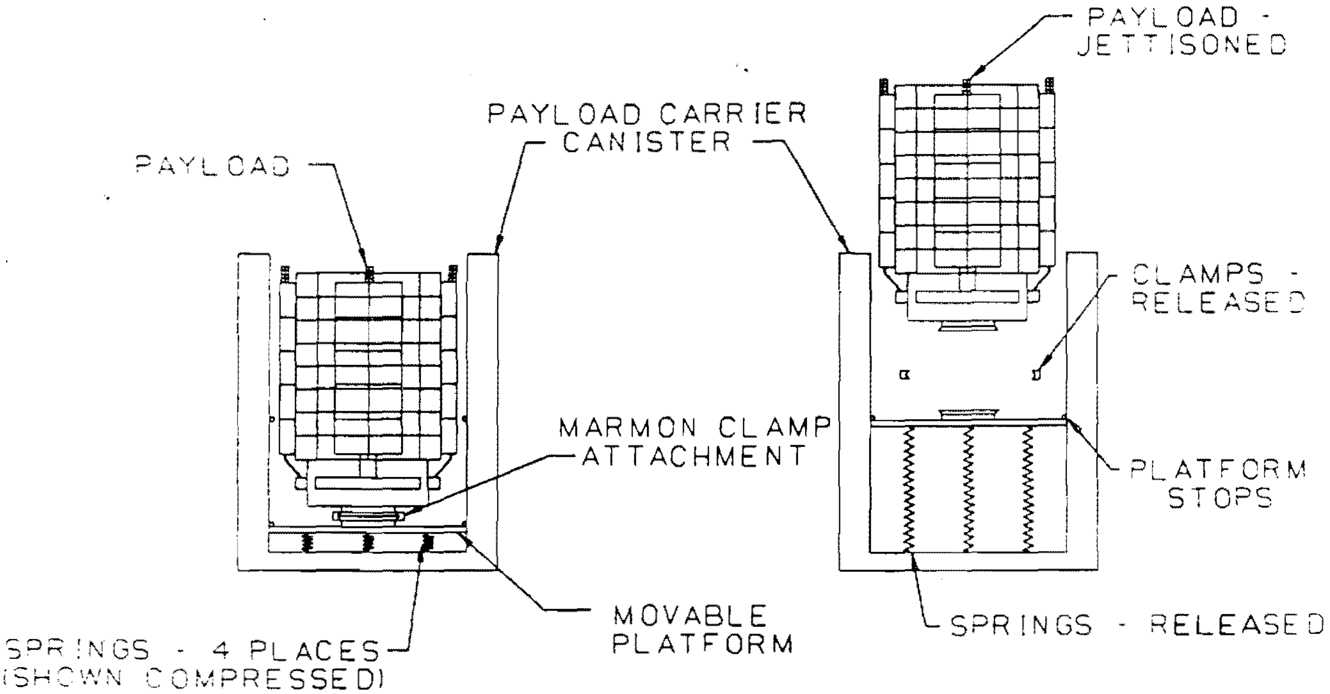


Figure 12b. Multiple satellite deployment mechanism concepts.