Spacecraft Launching Technique and Systems

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Abstract: In this paper is presented the spacecraft launching technique and different rocket systems. The launch of the satellite and controlling support services are a very critical point in the creation of space-based communication technology and the most expensive phase of the total system cost. At the same time, the need to make a satellite body capable of surviving the stresses of the launch stages is a major element in their design phase. Satellites are also designed to be compatible with more then one model of launch vehicle and launching type. In a more determined sense, the multi-stage expendable and manned or unmanned reusable launchers are described. Owing to location and type of site here are discussed land-based and sea-based launch systems. The new sea launch multinational system was developed more than ten years ago to overcome the cost of land-based launch infrastructure duplication around the world. Additional rocket motors during launching procedure, such as perigee and apogee kick propulsion systems, may also be required.

Key Words: GEO, Satellite Launcher, Hohmann Transfer Ellipse, Satellite Orbit, Launching Vehicles

1. Introduction

The process of putting in orbit a communications satellite is based mostly on launching into an equatorial circular orbit, and then in Geostationary Earth Orbit (GEO), but similar phases are used for installing all types of orbits. Thus, the processes involved in the launching technique depend on the type of launcher, the geographical position of the launching site and constraints associated with the satellite payload. In order to successfully put the satellite into the transfer and drift orbit, the launcher must operate with great precision with regard to the magnitude and orientation of the velocity vector. Launching operations necessitate either TT&T facilities at the launching base or at the stations distributed along the trajectory.

2. Satellite Installations and Launching

Satellites are usually designed to be compatible with more than one launcher. Launching, putting and controlling satellites into orbit is expensive operation, so the expenses of launcher and support services can exceed the satellite cost itself.

At this point, the basic principles of any launch vehicle are that the rocket is propelled by reaction to the momentum of very hot gas ejected through exhaust nozzles. To achieve synchronous orbit, the spacecraft must be accelerated to a velocity of 3,070 m/s in a zero-inclination orbit and raised a distance of 42,242 km from the centre of the Earth. Most rocket engines use the oxygen in the atmosphere to burn their fuel but solid or liquid propellant for a launcher in space must comprise both a fuel and an oxygen agent. There are two techniques for launching a satellite: 1. By direct ascent; and 2. By Hohmann transfer ellipse.

A satellite may be launched into a circular orbit by using the direct ascent method, shown in **Figure 1 (A).** The thrust of the launch vehicle is used to place the satellite in a trajectory, the turning point of which is marginally above the altitude of the desired orbit. The initial sequence of the ascent trajectory is the boost phase powered by the various stages of the launch vehicle. This is followed by a coasting phase along the ballistic trajectory, the spacecraft at this point consisting of the last launcher stage and the satellite **[1, 2, 3]**.

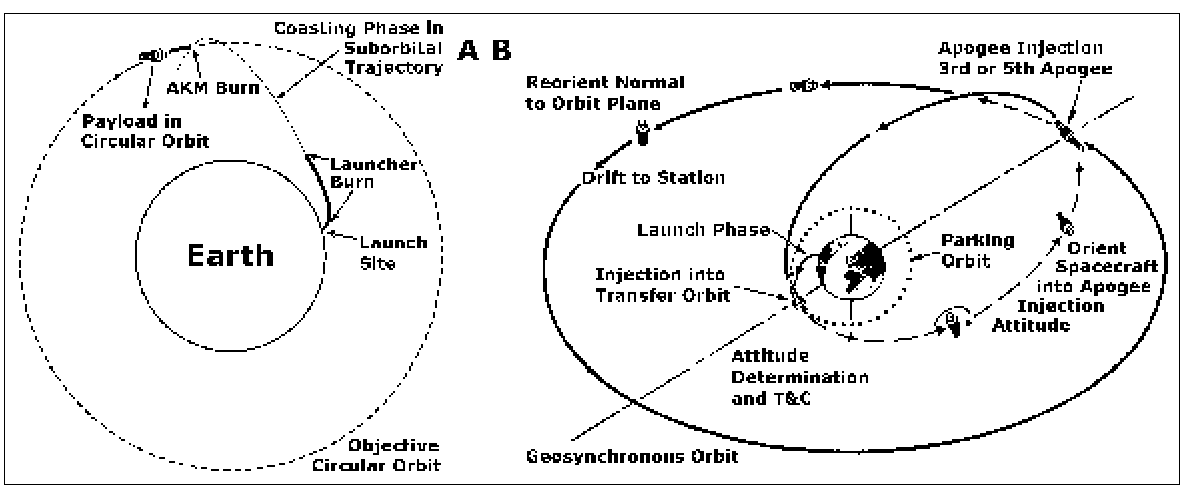

Figure 1. Satellite Installation in Circular and Synchronous Orbit – Courtesy of Book: by Pascall/Withers **[2]**

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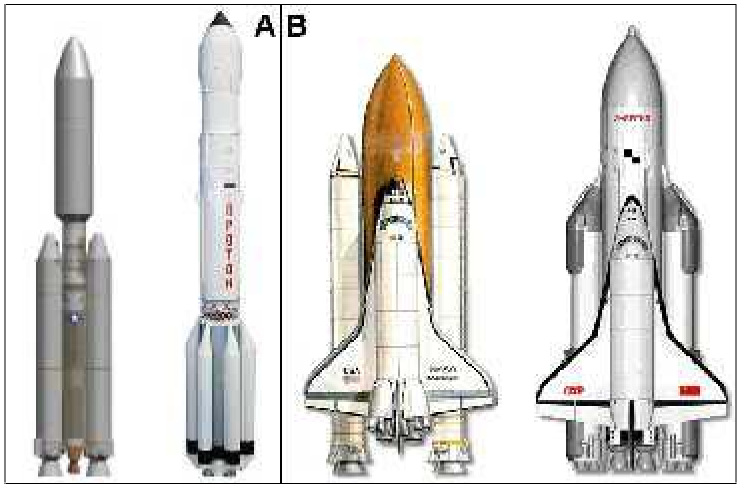

Figure 2. Types of Launch Vehicles - Courtesy of Book: by Ilcev **[3]**

A satellite may be launched into an elliptical or synchronous orbit by using the successive or indirect ascent sequences, known as the Hohmann transfer ellipse method, shown in **Figure 1 (B).** This method enables a satellite to be placed in an orbit at the desired altitude using the trajectory that requires the least energy. At the first sequence the launch vehicle propels the satellite into a low parking orbit by the direct ascent method **[3]**.

3. Expendable Launching Vehicles

The great majority of communication satellites have been launched by expendable vehicles and this is likely to continue to be the case for many years to come. There are two types of these vehicles: expendable three-stage vehicles and expendable direct-injection vehicles.

1. Expendable Three-Stage Vehicles – Typical series of three-stage vehicles are Delta and Atlas (USA), Ariane (Europe), Long March (China) and H-II (Japan). In addition, new generations of launchers have already been developed with two-stages such as Delta III and Ariane 5. Both stages are propellant systems using cryogenic liquid fuel, while the first stage is assisted by nine strap-on solid-fuel motors.

At this point, the first and second stages of three-stage expandable launch vehicles are usually designed to lift it clear of the Earth's atmosphere, to accelerate horizontally to a velocity of about 8,000 m/s and enter a parking orbit at a height of about 200 km. The plane of the parking orbit will be inclined to the equator at an angle not less than the latitude of the launch site. The most efficient way of getting from the parking orbit to a circular equatorial orbit is to convert the parking orbit into an elliptical orbit in the same plane, with the perigee at the height of the parking orbit and the apogee at about 36,000 km and then to convert the transfer ellipse to the GEO.

Thus, the third stage is fired as the satellite crosses the equator, which ensures that the apogee of the Geostationary Transfer Orbit (GTO) is in the equatorial plane. When the satellite is placed in the GTO, the third stage has completed its mission and is jettisoned.

2. Expendable Direct-Injection Vehicles – Typical models of direct-injection launchers are the USA-based 60 m Titan IV and the Russian-based 62 m Proton, illustrated **in Figure 2 (A Left)** and **(A Right)**, respectively and also Zenit (Ukraine). Otherwise, these types of vehicles do not need an AKM because direct-injection launchers have a fourth stage, which converts directly from GTO to GEO constellation.

The Proton rocket is one of the most capable and reliable heavy lift launch vehicles in operation today. Proton D-1 and D-1-E launcher variants have three and four stages, respectively. At lift-off the total weight of Proton is about 688 tons and this vehicle has the capability of placing a maximum of 4,500 and 2,600 kg into GTO and GEO, respectively **[3, 4, 5]**.

4. Reusable Launch Vehicles

Reusable launch vehicles have already been developed in the USA (Space Shuttle), illustrated in **Figure (B Left)** and Russia (former-USSR) Energia/Buran, shown in **Figure (B Right)**, which has as their aim the development of vehicles that could journey into space and return, all or much of their structure being reusable and thus, the satellite launching will cost less. Moreover, in using these launchers there will be less burnt-out upper stages than with expendable vehicles. In space remain the small pieces in transfer orbits for many years and much small debris, remains in LEO for a long time, adding to the growing space junk hazard for operational satellites and future space operations **[3, 6]**.

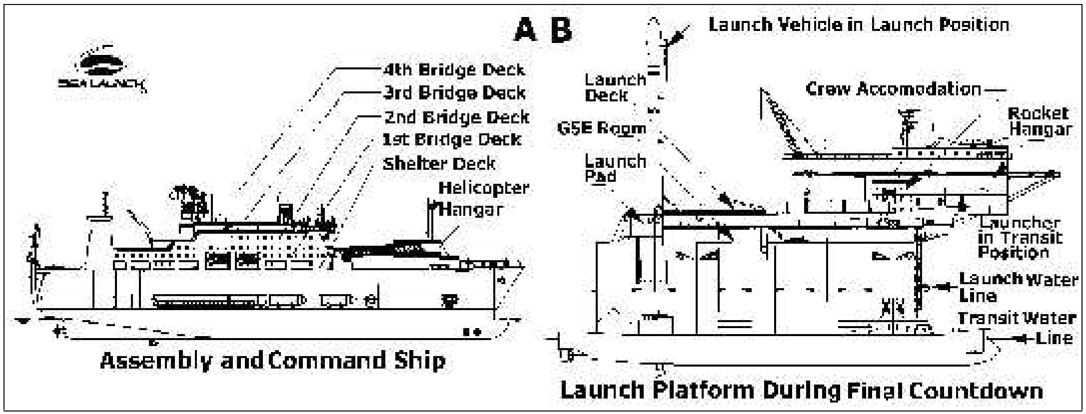

Figure 3. Sea Launch Modules – Courtesy of Manual: by Sea Launch Company **[7]**

1. Space Shuttle – The US NASA developed a fleet of manned reusable vehicles known as Space Shuttle, which are capable of lifting a satellite of up to 29.5 tons into a parking orbit, inclined at 28.5°, with an altitude of up to 431 km, shown in **Figure 2 (B Left)**. This space plane is 37.2 m long (with rocket 56.02 m), the fuselage is 4.5 m in diameter, the wingspan is 23.8 m and the mass is about 84.8 tons. It is designed to accommodate seven crewmembers and passengers on board plane. The system came into service in 1981 and made over twenty successful operational flights until January 1986, when the Shuttle Challenger was destroyed by a fault in the solid-propellant booster and all the crew were killed in a tragic accident. Therefore, following this huge disaster, NASA redesigned the booster and decided to use Space Shuttle only for regular launches program without crew. However, the final shuttle mission was completed with the landing of Atlantis on 21 July 2011, bringing about the end of the 30-year Space Shuttle program.

2. Energia/Buran Space Plane – The Russian space launcher Energia was the most powerful operational vehicle ever made, capable of carrying about 100 tons into space, whose four first-stage booster units are recoverable for reuse. Thus, in particular, it can launch the Buran space plane, enabling it to acquire a LEO and to land with the aid of its own rocket engine, shown in **Figure 2 (B Right)**. The main purpose for which those very heavy lift vehicles were developed was to ferry personnel and supplies for the Russian space station Mir, and also to retrieve or repair satellites already in orbit. However, the Energia launching vehicle could also carry into space a side-mounted canister containing an upper stage and a payload compartment suitable for a large heavy spacecraft or group of communication satellites to be placed in orbit. Thus, Energia flew for the first time on 15 May 1987, carrying a spacecraft mock-up and later on 18 November 1988 carrying an unmanned version of Buran space plane. The reusable Buran space plane is 36.3 m long (with rocket Energia 58.70 m), the fuselage is 5.6 m in diameter, the wingspan is 24 m and the mass is about 100 tons. It can be flown in automatic configuration or under the control of a pilot to place satellites in LEO or to retrieve them and come back to base for the next use. Up to ten people, crew and passengers, can be accommodated and it can carry in the cargo bay up to 30 tons into an orbit of 200 km altitude and 51.6° inclination. It enables large satellites to be put into orbit and construction of space stations to be considered for both the scientific and telecommunication missions.

The Russian space agency Roscosmos decided in 1992 to terminate the Energia/Buran Program due to the economic difficulties after disintegration of Soviet Union. Besides, consideration is being given in Russia to the development of a more compact winged space plane designed to ferry personnel and their luggage into space. This compact shuttlecraft could be placed on the top of a Proton or Soyuz current launchers **[3, 8]**.

3.3. Land-Based Launching Systems

Most satellite launches have taken place from the following launch facilities:

1. US-Based Launch Centres – It launches satellites from two main locations, in Florida Cape Canaveral, suitable for direct equatorial orbit and the Vandenberg Air Force Base in California, suitable for polar orbits.

2. Russian Launch Centres – Russian satellites are launched from two main launch centres named Baikonur and Northern Cosmodrome. Baikonur lies north of Tyuratam in Kazakhstan, with the all launching support infrastructure for launching Proton and Energia heavy launching rockets and vehicles. The Northern Cosmodrome is located near Plesetsk, south of the town Archangelsk, suitable for launching satellites for all purposes in high inclination orbits. This Cosmodrome is the world's busiest launch site.

3. European Launch Centres – The European launch centre is Cosmodrome in French Guiana Space Centre, which is using Ariane launching vehicles. The position of this Cosmodrome enables the best advantage to be taken of the Earth's rotation for direct equatorial orbit.
4. Chinese Launch Centres – The principal launch sites in China are Jiuquan and Xi Chang, for launching Long March vehicles. In the meantime, the Xi Chang launch centre has also become most used for launches into the GEO for the international market.
5. Japanese Launch Centres – The launching Tanegashima Space centre is situated in the prefecture of Kagashima. The facilities include the Takesaki Range for small rockets and the Osaki Range was used for the launch of H-I vehicles until the termination of program in 1992. After renovation the Osaki Range will be used as the launching for next generation of J-I Japanese vehicles. The new Yoshinobu launch complex has been constructed next to the Osaki centre to satisfy the requirements of the new H-II launcher.
6. Indian Space Research Organization (ISRO) – India has four launch sites: ISRO Satellite Centre in Bangalore, Satish Dhawan Space Centre in Andhra Pradesh, Thumba Equatorial Rocket Launching Station in Thumba and Vikram Space Centre in Thiruvanthapuram **[3, 9]**.

3.4. Sea-Based Launch Systems

The Sea Launch Multinational Organization was developed in March 1996 to overcome the cost of land-based launch infrastructure duplication around the world. The newly formed Sea Launch system is owned by the Sea Launch Partnership Limited in collaboration with four international partners such as US Boeing Commercial Space Company for designing and manufacturing the payload, Russian RSC Energia for developing and qualifying Block DM-SL design modifications, Ukrainian KB Yuzhnoye/PO and Yuzhmash for developing and qualifying Zenit-2S launcher, and Shipping Anglo-Norwegian Kvaerner Group and Sea Launch Company, LLC for designing and modifying the Assembly and Command Ship (ACS).
The Sea Launch Company, partner locations and operating centres, has US-based headquarters in Long Beach, California and is manned by selected representatives of each of the partner companies. The Sea Launch Partners have the following responsibilities and tasks:
The partner team of contractors has developed an innovative approach to establishing Sea Launch as a reliable, cost-effective and flexible commercial launch system. Each partner is also a supplier to the venture, capitalizing on the strengths of these industry leaders. The System consists in two main modules: Assembly (Command and Control Ship) and Launch Platform, both illustrated in **Figure 3. (A)** and **(B)**, respectively. However, transit for the ACS and the LP from Home Port in Long Beach to the launch site on the equator takes 10 to 12 days, based on a speed of 10.1 knots.
The Sea Launch Home Port complex is located in Long Beach, California. The Home Port provides the facilities, equipment, supplies, personnel and many other procedures necessary to receive, transport, process, test and integrate the spacecraft and its associated support equipment with the Sea Launch system. The Home Port also serves as the marine base of operations for both of the Sea Launch vessels. The personnel providing the day-to-day support and service during pre-launch processing and launch conduct to Sea Launch and its customers are located at the Home Port **[3, 7]**.

5. Conclusion

The most considerable launching problem is risk of unsuccessful operations during launch stages, what is doubling the cost of the space segment project. Thus, it is very important to find out the most secure launch vehicle and to avoid the situation that NASDA mission failed to put the MTSAT spacecraft into the GEO at 140° E from the Japanese Tanegashima Space Centre in city Kagoshima in 1999 on an H-2 rocket. The similar samples of launcher disasters occurred with and without crew onboard such as rockets of Ariane program, Space Shuttle reusable plane Challenger and other vehicles. As stated earlier the Russian Proton rocket is one of the most capable and reliable heavy lift launch vehicles in operation today, and Sea Launch together with abandoned Energia project, if may return to launch service, could decrease the unsuccessful launches.

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