IJCRT.ORG ISSN : 2320-2882

INTERNATIONAL JOURNAL OF CREATIVE RESEARCH THOUGHTS (IJCRT)

An International Open Access, Peer-reviewed, Refereed Journal

LAUNCHING AND LAUNCH SYSTEM: A REVIEW

[1] Sindhu Sujata Kandu, [2] Prof. Y.K. Mishra
[1]Research Scholar, [2]Associate Professor
[1]Department of Electronics Engineering,
[1]KNIT Sultanpur, India

Abstract: Humans are very impatient species among all species on earth. They always try to know everything not only about earth but also about space and the universe. For space exploration, firstly they need to reach into space. Launch vehicle is the only medium to reach into space. A powerful, cost efficient and reliable launch vehicle is required for this purpose. This review paper reveals the technological evolution of launch vehicles and type of propellants are being used. The cost of launching and the problem associated with designing the launch vehicle is also outlined in this paper.

Index Terms **- Launch vehicles, ELV, EELV, RLV, Propellant, FALCON 9, SSTO.**

I. Introduction

Space activities are expensive, risky and hazardous but it is only global commons which spans every nation, providing a unique potential bond of economic, social, and military power [4]. Launch vehicles play a vital role in space activities.

It is quite difficult to tell that when the first true rocket had appeared. But Chinese fire-arrows were considered as the 1st one. By the 16th century, rockets were categorized as one of weapon during war [1]. The word rocket was first used in 1611, derived from “rocchetta” which is an Italian word that has meaning distaff – a rod used in spinning or weaving [9].

In the 19th century, after the launch of Sputnik-1, there was a revolution in the field of space activities [9]. And this revolutionary act was called “The Beginning of Space Age”. From that time to till now, launch vehicles passed through various technological evolutions like- high altitude from sub-orbit to LEO & GTO, RLV, Robust fuel tank, less hazardous propellants, etc. Actually, technological evolution is not same as biological evolution but it linked with biological evolution. The needs emerging from biological evolution set the path for technological progress. There are two main purposes to analyze the successive development of spacecraft systems: **(a)** To give technical guidance for future spacecraft designs and **(b)** Establish a system to evaluate which technologies are worth investing in, depending on their overall technology maturity [8]. The launch vehicle could either be ELV or RLV. ELV (Expendable Launch Vehicle) are that type of vehicle which shed it first stage after reaching to a certain altitude in space. It is expensive because it cannot be reuse. In case of RLV (Reusable Launch Vehicle), either few parts of vehicle or complete vehicle can be reuse for several missions. RLV fly into orbit, after completing the mission it return to the landing site [13].

The propulsion system is an essential part of launch vehicles that provide thrust so that rocket moves through air and space [7]. There are three categories for propulsion system: deep space propulsion, in- space propulsion, escape propulsion. Depending upon category and application there are various propulsion technologies like chemical, non-chemical, propellantless etc. [15].

Launching cost should be considered very carefully while exercising space activity. Launch vehicles should be designed in such a way that it imposes less cost for launching [17]. Though in the beginning cost was not primary factor and at that time main target is to reach into space. But in current scenario we need frequent launch for various purposes such as to send cargo and human to ISS, Interplanetary survey etc. If launching cost will be high, it would not possible. Technical evolution shows a drastic change in launch vehicle not only in performance but also in cost factor. Launching cost has been reduced by the factor of 20 approximately using new technology [20].

We know that the design problem is a multi-parameter optimization task. For efficient launch vehicle design there must be a balance between performance and programmatic drivers. Performance parameters are mass efficiency, managing losses and propulsion efficiency while programmatic drivers include operability, reliability, affordability, safety/abort and reusability. All these parameter is sub-optimized under certain constraints that are again coupled with non-ideal effects (management of losses). The degree of coupling between solutions of sub-optimize problem and non-ideal effects determines the success or failure of the program. New technology development, including structures/materials, manufacturing, propulsion, avionics, thermal protection system (TPS) and health monitoring, is one key to the success of future aerospace programs [22].

II. LAUNCH VEHICLES

- **The era of modern rocketry, ideas and experiments**

Father of modern astronautics Konstantin Tsiolkovsky (1857-1935) had proposed the idea of space exploration by rocket. To achieve greater range, he suggested the use of liquid propellants for rockets, in a report published in 1903[2]. Practical experiments in rocketry were conducted by Robert H. Goddard (1882-1945). He concluded that a rocket operates efficiently in a vacuum than air. He also told that multistage rockets can provide enough thrust and velocity to reach target orbit. First successful flight flew for only two and a half seconds on March 16, 1926 that was fueled with a liquid propellant (liquid oxygen and gasoline). It climbed 12.5 meters, and landed 56 meters away. Third great space pioneer Hermann Oberth (1894-1989) had published a book in 1923 about travel into outer space by rocket. The V-2 rocket cum missile used for 1st time to achieve long range during war and it gets thrust by burning a mixture of liquid oxygen and alcohol. It was developed by German engineers and scientists, including H. Oberth [1, 2 & 9].

First artificial satellite Sputnik I was launched on October 4, 1957, by R-7 ICMB technology (Fuel-Kerosene T-1, Oxidizer-Liquid Oxygen)[1,2,5]. Launching of Sputnik I open a way to reach into the space for various purposes like: space exploration, scientific investigation and experiments, instantaneous worldwide communication, weather forecasting and so on [9].

In order to improve altitude, range and accuracy, multistage rocket is being used [1, 9]. Multistage rocket may consist of either only solid rocket booster, or liquid propellants or the combination of both. Example of Multistage rocket: DELTA, SCOUT, SATURN V, Space Shuttle, ASLV, PSLV, FALCON 9 etc. Among all these vehicles some are Expendable types i.e. DELTA, PSLV etc. and some are Reusable types i.e. Space Shuttle, Falcon 9[1, 6, 10, 11 & 12].

- **The era of future rocket, ideas and demonstration**

In space programs, each step is subject to five coupled criteria; size, cost, technical performance, weight and risk of failure. Technical performance, safety and the cost are major factor that being considered while designing the launch vehicles [9]. Reusability of launch vehicles could bring down the cost of launching. This idea was being studied since the early 1960's and the result was world's 1st RLV i.e. Space Shuttle [7, 13]. After the accident of Columbia and Challenger, NASA moves towards the ELV and EELV [11] technology [7]. NASA had also invested into the new programme single-stage-to-orbit (SSTO) i.e. X-33, X-34 but the program never progressed to orbit; it did complete several successful suborbital test flights. But after a crash and subsequent fire that destroyed the Vehicle and due to rising cost funding was ultimately canceled [3, 13]. After that SSTO programme was closed forever.

Elon Musk, founder of SpaceX, gave the idea of recovering 1st stage. First Grasshopper test rig demonstrated for Vertical takeoff and vertical landing in 2013. On December 21, 2015, Falcon 9 was successfully landed vertically on land. SpaceX is now working on the project "STARSHIP" with ultimate goal of sending human to the Mars at reasonable cost [14]. Robust design and advanced technologies ensures the round trip from earth to mars.

III. PROPULSION TECHNOLOGIES

The propulsion system of a rocket includes pumps, tanks, propellants, power head and rocket nozzles. Rocket moves when it gets thrust from propulsion system. Propulsion Technologies are categorized as **A)** Escape Propulsion i.e. from earth to space **B)** In-Space i.e. in orbit **C)** Deep Space Propulsion i.e. from orbit to outer space [15]. Flow diagram of Propulsion Technologies is shown in figure 1[16]:

In this paper our main focus is on escape propulsion technologies i.e. Solid, Liquid, Hybrid and Green Propellants.

- **Solid Propellants:** A solid-propellant rocket has the simplest form of engine. It has a nozzle, a case, insulation, propellant, and an igniter. Solid rocket fuel grains (a grain is a solid mass that is molded by mixing fuel and oxidizer) are packed inside the cylinder and an igniter is used to start combustion. When combustion starts, the fuel grain burns energetically, releasing a large volume of hot gases that provide thrust. The purpose of the nozzle is to increase the acceleration of the gases as they leave the rocket and thereby maximize the thrust e. g. SLV, Delta, scout, Pegasus etc. [1, 15]. Solid propellant rockets are cheaper than others and used as booster [2, 16].
- **Liquid Propellants:** Liquid propellants have separate tanks for fuel and oxidizer. It also has a combustion chamber and a nozzle [1]. The fuel of a liquid-propellant rocket is usually kerosene or liquid hydrogen; the oxidizer is usually liquid oxygen. They are combined inside the combustion chamber to provide high thrust compare to solid propellant rocket. It is suitable for space applications because it provide superior performance and precise controlling capability [15].
- **Hybrid propulsion:** Solid and liquid both technique are combined to overcome the complexities of liquid bipropellant engines and the lack of controllability of solid rocket motor. The gaseous propellants, stored in oxidizer tank are injected into the solid fuel. Advantage of such engine is high performance and combustion can be easily regulated. But the main issue in these engines is that it cannot provide large thrust so they are rarely built [15, 16].
- **Green propellants:** Toxic and carcinogenic hydrazine propellants which is currently used in spacecraft propulsion imposes hazardous effect on environment. Green Propellants is being used in liquid, solid, hybrid, monopropellant or bipropellant engines that provide good performance, good storability, wide material compatibility as well as low pollution and toxicity [15, 16].

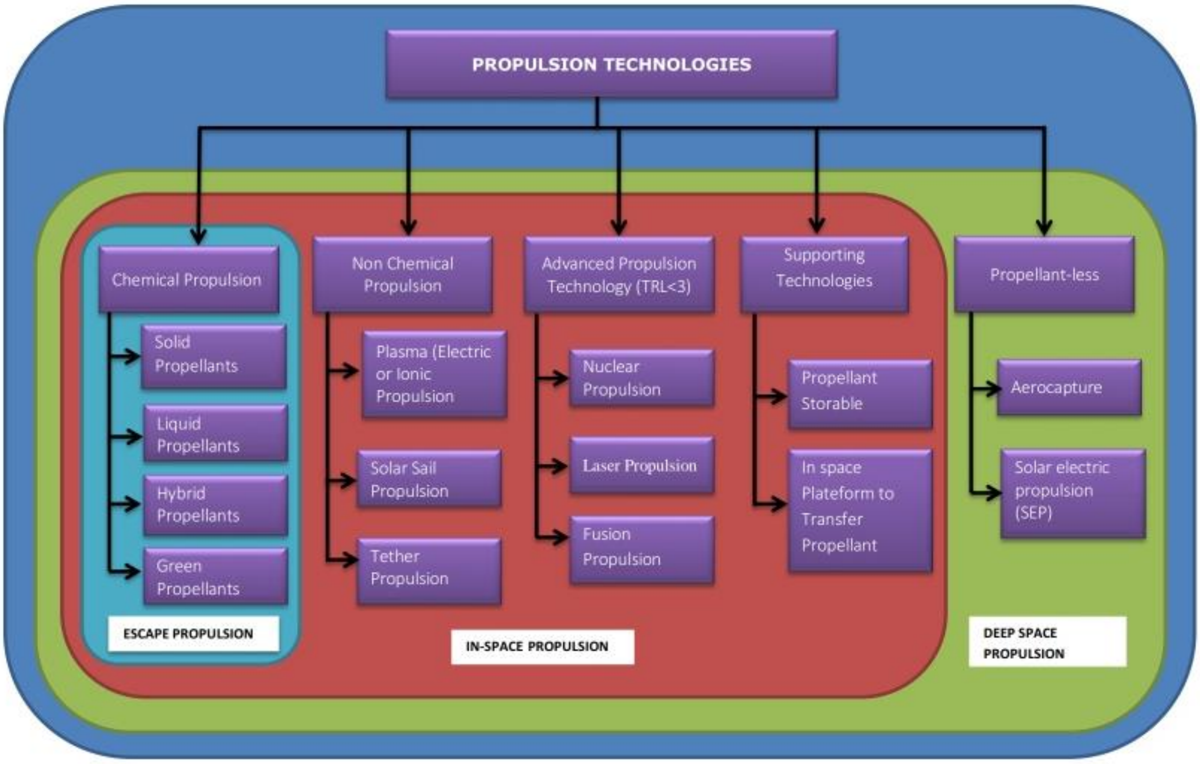

figure1: propulsion technologies

IV. COST OF LAUNCHING

To expand the space research and exploration, low cost access to space is essential. All space research agencies having two main goals regarding cost reduction are: **A)** The total cost required for launching from launch stage to final propulsive stage used in orbital transfer must be reduced and **B)** the cost of developing for – reaching space transportation technologies should be minimized, that enables new deep space missions [17].

Standardized launch cost for ELV and RLV are categorized as vehicle production cost, direct operation cost, indirect operation cost, and insurance. Vehicle production cost includes vehicle recurring cost and refurbishment cost and spares. Direct operation cost includes launch and ground operations cost, propellant and gases cost, mission operations cost, transportation cost, launch site user fee per launch, launch failure implications and mission abort. Indirect operation cost includes program administration and system management cast, marketing. Customer relations and contract cost, technical support and improvement cost, taxes, fee, profit etc. Insurance includes insurance against launch failure and payload loss [18].

The main cost drives are engines (40-52%) and vehicle structure (20-38%) which are primary area of cost reduction [18]. By using technically advanced engine and monocoque structure (SSTO), launching cost can be cut by a large factor [19].
During initial period of 1950-70, the launch cost was very expensive i.e. $ 1000K/Kg to LEO. Average launch cost during 1970-2000 do not change much and remain constant through these year i.e. $ 18.5K/Kg to LEO. Launch cost drastically reduced to $ 2.7K/Kg to LEO for the first time when Falcon 9, RLV, was launched [20].

V. FUNDAMENTALS AND ISSUES IN DESIGINING

The main function of a launch vehicle is to place an object into the specific orbit. To reach into final orbit, the main function that are range of achievable orbit and payloads, quality of the final orbit should determine in terms of velocity change. There need to notice that the main function having certain technical criteria. The secondary function is associated with the payload handling. It means the launcher is able to cope up with mechanical interference, protect from induced environments, data handling, air-conditioning etc. [22].
The designing of an STS is a very complex process and several challenges/problems associated with it. Solution of the problems can be achieved by design equations. Design equation includes performance, cost, and operation. Basically performance and programmatic drivers are strongly coupled that makes the designing complex. There are few constraints that restrict us to design fully ideal launch vehicles. The main designing constraints are-

- **Thrust to weight ratio at lift-off:** Typically it must not be lower than 1.1 and preferred to 1.2. Actually initial acceleration is very important during launching. If it significantly less, vehicle may drift from desire path due to ground wind, aerodynamics and thrust alignments. Higher initial acceleration reduces the gravity losses.
- **Manned/unmanned mission:** we cannot increase acceleration beyond certain limits in manned mission because human endurance limit is within 3g to 5g. A trained astronaut can bear up to 5g while a normal citizen endurance limit is 3g.
- **Payload accommodation:** these constraints are the part of vehicle design. For example: fairing should be kept on the nose of rocket to protect the launch vehicle payload from dynamic pressure and aerodynamics heat when it crosses atmosphere. It includes weight, length, diameter attachment approach etc.
- **Cost constraints:** it shows a dominant effect on designing. Though cost is incorporated with various factors such as weight, performance and designing etc. Reusability can lower the launch cost. But Reusability leads to complexity in designing. Re-entry and landing is a complex process and required constant observation. Landing can be any form like: parachute landing (e.g. SRB), horizontal landing (e.g. space shuttle) and vertical landing (e.g. Falcon 9).
- Other constraints are stage separation and ascent rate. Both affect the performance of Launch vehicle [21].

- Three sets of constraints i.e. reliability, availability and maintainability ensure the success of mission.
- Development constraints express the frame in which the development is carried out and cover constraints.
- Production constraints are expressed by the operator; that includes maximum mission cost, the launch frequency and the exchangeability between payloads [22].

Vehicle designing carried out under these constraints. Efficient design ensures compatibility and proper trade among various factors. It involves material selection, manufacturing process, assembling methodology, testing and advanced technologies for better result [21].

VI. CONCLUSION

This paper is a brief summary about the launch vehicles and launching. It shows that how the idea of launch vehicle comes to human and how it evolves with the time. The main target of launch vehicle is to reliable delivery of payloads into space in specified orbit for various purposes. Different types of propellant are being used according to the exigency. Although researchers are intended towards the successful operation but they wish to reduce the launch cost by improving current technology. The best example is Falcon 9 that has cut the launch cost significantly. When improvement in technology is taken into account, researchers face various designing challenges. By overcoming these issues reliable launch vehicle can be manufactured.

VII. ACKNOWLEDGMENT

I would like to extend my gratitude and sincere thanks to my supervisor Prof. Y. K. Mishra Department of Electronics Engineering for his constant motivation and support. I truly appreciate and value their esteemed guidance and encouragement from the beginning to the end.

VIII. ABBREVIATION

EELV: Evolved Expendable Launch Vehicle
ELV : Expendable Launch Vehicle
GTO : Geo Transfer Orbit
ISS : International Space Station
LEO : Low Earth Orbit
RLV : Reusable Launch Vehicle
SSTO: Single-stage-to-orbit
SRB : Solid Rocket Booster

REFERENCES

[1] Gregory L. Vogt, Ed.D, Deborah A. Shearer, “ROCKETS”, NASA.

[2] James J. Harford.1997. Korolev's Triple Play: Sputniks 1, 2, and 3, adapted from James J. Harford, Korolev: How One Man Masterminded the Soviet Drive to Beat America to the Moon (John Wiley: New York, 1997). [Online]: https://history.nasa.gov/sputnik/harford.html. [Available on]: 11/02/2021.

[3] Michael Joseph Policelli. 2014. Vertical Takeoff Vertical Landing Spacecraft Trajectory Optimization via Direct Collocation and Nonlinear Programming. M.S. Thesis, Department of Aerospace Engineering. The Pennsylvania State University, 2014.

[4] Henry R. Hertzfeld, Nicolas Peter. 2007. Developing new launch vehicle technology: The case for multi-national private sector cooperation”, Space Policy, vol. 23, pg. no. 81–89, may 2007.

[5] Korolev and Freedom of Space: February 14, 1955–October 4, 1957. [Online]: https://history.nasa.gov/monograph10/korspace.html. [Available on]: 11/02/2021

[6] Ilcev St. D. 2016. Spacecraft Launching Technique and System, International Conference on Electrical, Electronics, and Optimization Techniques (ICEEOT) – 2016

[7] Launch System. [Available on]: 12/02/2020, https://history.nasa.gov/SP-4012v7ch2.pdf

[8] Svenja Stellmann, Daniel Schubert, Andre Weiss. Historical Evolution of Space Systems. IAC-09-E4.2.4

[9] Proc. Mtgs. Acoust. 31, 040004 (2017). doi: 10.1121/2.0000704

[10] [Online]: https://history.nasa.gov/SP-4402/ch1.htm. [Available on]: 15/02/2021.

[11] AA Vicario, SM Shanmuga Ramanan, S Arun. Composites in Missiles and Launch Vehicles, Comprehensive Composite Materials II, Volume 3. doi:10.1016/B978-0-12803581-8.03960-6.

[12] Falcon 9. [Online] https://www.spacex.com/falcon9. [Available on]: 15/02/2021.

[13] Bhavana Y, Mani Shankar N and Prarthana BK. 2013. Reusable Launch Vehicles: Evolution Redefined. Bhavana et al., J Aeronaut Aerospace Eng 2013, 2:2, DOI: 10.4172/2168-9792.1000107

[14] Elon Musk. 2016. Making Humans A Multi-Planetary Species”, International Astronautical Congress in Guadalajara, Mexico, September 26–30, 2016, DOI: 10.1089/space.2017.29009.emu

[15] Salgado, Maria Cristina Vilela, Belderrain, Mischel Carmen Neyra, & Devezas, Tessaleno Campos. 2018. Space Propulsion: a Survey Study about Current and Future Technologies”, Journal of Aerospace Technology and Management, 10, e1118. Epub February 26, 2018. https://doi.org/10.5028/jatm.v10.829

[16] DRAFT Launch Propulsion System Roadmap Technology Area01. [online]. http://www.nasa.gov/pdf/501329main_TA02-InspaceProp-DRAFT-NOV2010A.pdf&ved=2ahUKEwjyvfLph8PrAhUc7XMBHY3cBVKQFjABegQIDRAG&usg=AovVaw01j8Ai6Rj8wrQKCcPFMrXX. [Available on]: 15/02/2021.

[17] Space Transportation Technology, chapter 5. The National Academies Open Book. Online: https://www.nap.edu/read/6293/chapter/7. [Available on]: 18/02/2021.

[18] Dietrich E. KOELLE. 1992. Launch Cost Assessment of Operational Winged Launch Vehicles. AlAA Fourth International Aerospace Planes Conference, 1 - 4 December 1992/0rlando, Fl. doi: 10.2514/6.1992-5021

[19] J. P. Henneberry, F.J. Stoddard, A.L. Gu. 1992. Low-Cost Expendable Launch Vehicles. AIAA/SAE/ASME/ASEE, 28th Joint Propulsion, Conference and Exhibit, July 6-8, 1992 / Nashville, TN. DOI: 10.2514/6.1992-3433.

[20] Harry W. Jones. 2018. The Recent Large Reduction in Space Launch Cost, 48th International Conference on Environmental Systems, 8-12 July 2018, Albuquerque, New Mexico. Online website: https://ntrs.nasa.gov/search.jsp?R=20200001093%20

[21] Robert S. Ryan & John S. Townsend. 1997. Fundamentals and Issues in Launch Vehicle Design. Journal Of Spacecraft And Rockets. Vol. 34, No. 2, March–April 1997. DOI: 10.2514/2.3209.

[22] Bonnal, C., Ciucci, A., Obersteiner, M. H., & Haidn, O. 2014. Launch Systems. The International Handbook of Space Technology, 165–195. Doi:10.1007/978-3-642-41101-4_8.