ACHIEVEMENT

Another land-mark in space: Recovery of spent rocket stage

Space missions will no longer be an expensive affair.

■ by Wg Cdr DP Sabharwal

SpaceX organisation, on 8 April this year created the fourth marvel in the history of space exploration when it landed its Falcon 9 rocket on a drone ship at sea thus retrieving the rocket after it had put the satellites into the orbit. This phenomenal feat was in fact a step better than its earlier successful attempt when a similar Falcon-9 rocket had touched-down in December last year at a ground-based landing site in Cape Canaveral, Florida, after putting a satellite into space.

Both the achievements put together would allow the recovered rocket to be reused thus reducing the launch-costs and the launch time-frames drastically can be compared to other three land-marks of space exploration:

- The launch of Sputnik-I by the then USSR on 4 October 1957 which sent shock-waves throughout the world and more so in the USA where the American public openly displayed their anger and sense of fear that they were woefully behind the Russian in the space-age. The 58 cm diameter polished metal sphere, with four external radio antennae to broadcast radio pulses that was Sputnik-I, became the precursor for the launch of hundreds of satellites that have proved to be so beneficial to mankind in the areas of telecommunications and weather forecasts amongst many others.



A replica of Sputnik 1 at the NASA Museum.

- Moon landing by American Neil Armstrong and Edwin Aldrin on 20 July 1969 through Apollo-11. This event opened the floodgates for exploration of other planets resulting in landing of probes and vehicles on other planets at regular intervals to explore the possibility of life over there.
- Launch of first manned space-station Skylab by the Russians on 19 April 1971. Though the first crew

faced trouble while docking and could not enter the station, the second crew of three remained on board for 23 days, though died during re-entry into the Earth orbit. This mission paved the way for many more space-station leading to the present International Space Station (ISS) which houses a crew of seven throughout the year.

Importance of the mission

Anything in space such as the probes, satellites and space stations are launched through Satellite Launch Vehicles commonly known as rockets which are huge in size and massive in weight. Just for example, Indian Polar Satellite Launch Vehicle (PSLV) is 44 meters tall and weighs almost 3,25,000 kg at the time of launch to put a satellite that would just be about one meter in height and would weigh about 3,000 kg in weight (less than 100 times the overall weight of the rocket).

The fuel in the first stage of the all the space application rockets burns at an exceedingly high rate. In case of PSLV, the rate is some 1,314 kg/sec (1,38,000 kg burns in 105 seconds). As stated earlier, once the fuel in the first stage is exhausted, the complete stage is jettisoned, while the remaining rocket with the satellites keeps moving up for its intended mission.

Each launch vehicle is made in multi-stages, generally 2-4 to improve overall efficiency. After first stage fuel is over, the first stage rocket consisting of outer casing and the rocket-engine is jettisoned; the remaining rocket becomes lighter and thus accelerates faster. The same thing is repeated after second and third stages in case it is a four state rocket like the Indian PSLV.

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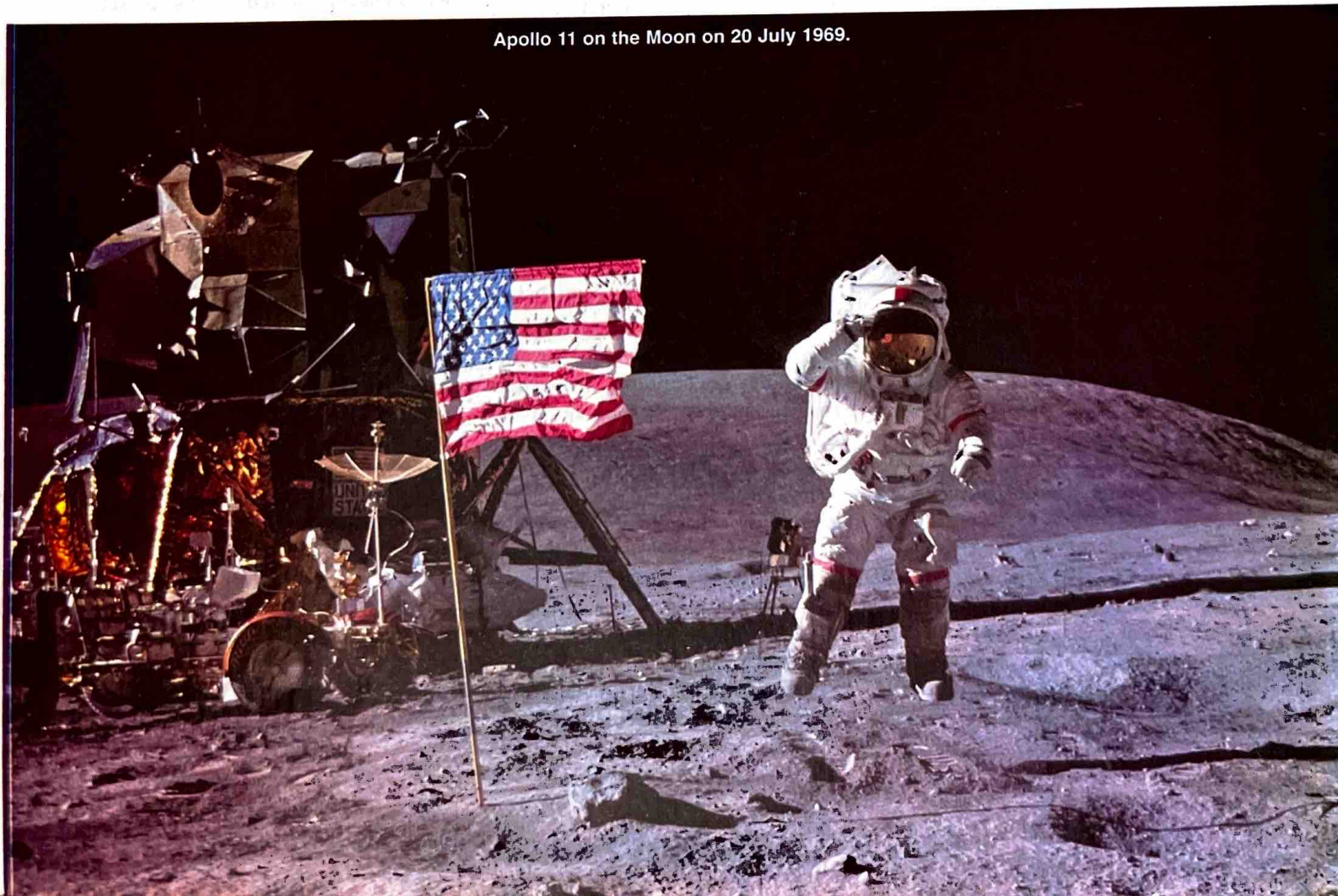
This first stage of the rocket, which is made of extremely high strength and special managing steel, in the case of Indian PSLV is 2.8 meters in diameter (one-and-a-half times the height of an average Indian at 5'8"), it is 20 meters long (6 times as long as Maruti-800) and weighs almost 13,000 Kg. This case as it falls to the Earth gets destroyed; hence these rockets are termed as 'expandable rockets.'

Making the external casing of the first stage of any satellite launch



Apollo 11 on the Moon on 20 July 1969.

SpaceX company



SpaceX is a private company founded in 2002 and is owned by management and employees with minority investments from few organisations including Google. It designs, manufactures, and launches the world's most advanced rockets and spacecraft. The stated goal of the company is to revolutionise space transportation, with the ultimate goal of enabling people to live on other planets. Within a short span of less than 15 years, SpaceX is already advancing the boundaries of space technology through its state-of-the-art launch vehicles (Falcon) and spacecraft (Dragon).

Falcon 9 is a two-stage rocket designed and manufactured by SpaceX for the reliable and safe transport of satellites and the Dragon spacecraft into orbit. Falcon 9 has the distinction of being the first massive rocket designed and developed in the 21st century, with maximum reliability. It's rather simple design with only two-stage configuration minimises the number of separation events.

It has nine engines in the recoverable first stage of the rocket. What is really impressive is that it can safely complete its mission even in the event of one or even two engine failures and subsequent shutdown.

Falcon 9 had made history in 2012 when it delivered Dragon into the correct orbit for rendezvous with the International Space Station, making SpaceX the first commercial company ever to visit the station. Since then SpaceX has made a total of three flights to the space station, both delivering and returning cargo for NASA.

vehicle is not only costly but is a time consuming affair. Thus efforts have been going on for decades to retrieve and recover this casing with associated engines for re-use so that there is no need to build new first stage rocket casing for each mission. It is in this context that the achievement of SpaceX can be considered as another landmark in the history of space exploration.

It is reported that the Falcon 9 rocket costs $60 million to make, and the fuel costs a meagre $2,00,000. After a good where the recovered rocket doesn't need too much updating and refurbishment, reusability could eliminate a good amount of manufacturing cost. As per SpaceX president, reusable rockets are likely to bring down launch costs by about 30 percent, which is quite appreciable.

Methods of recovery

Parachute recovery: NASA and many other organisations including SpaceX have considered and experimented landing the spent rocket stage using parachutes. However, the problems encountered have been insurmountable. Since there have to be three stages of parachutes (pilot, drogue and main chutes), the overall complexity tends to be high thus increasing chances of something going wrong. The weight and volume required to store parachutes is exceptionally large.

Such huge parachutes present problems with descent control since strong winds will swing and sway the parachutes. Since the recoverable rocket stage has engines at the base, so its centre-of-gravity is low and hence sways and swing of parachute will cause tremendous lateral loads for which the rocket casings are not designed, hence they would tend to crack or even break under severe gust conditions.

Landing on the Land: Vertical landing of the first stage of the rocket using rocket engine thrust is another concept that has been tried successfully. In this case as the rocket casing descends towards the Earth, its speed increases every second due to the gravitational pull of the Earth. To reduce this speed, engine rockets are fired so that the upward reaction (due to the action of the engine exhaust ejected downwards) arrests this rapid fall and acts the same way as parachute would do.

Sea landing: Landing rocket stage on ground may appear to be simpler than doing so at sea. But it is not so because making the rocket stage at land poses many additional problems. During the launch, the rocket first ascends vertically (invariably from the east coast of any country) and then follows a parabolic arc up and away from the launch pad further towards the east over the sea, so that the spent pieces fall over the sea.

Because of this, making the spent rocket casing to land on the sea would mean first slowing it down then, completely turn it around towards the land, and then retread the vertical and horizontal distance it has covered to get back to the landing site. That requires a lot of maneuvering and extra fuel. In sea-landing most of these phases are avoided and the rocket can be made to land wherever its trajectory ends.

The main disadvantage for recovering the rocket stage on a recovery platform floating on the ocean is that it offers a very small area for it to land as compared to vast land territory. Moreover, the recovery platform is not stationary and is floating on moving water. However, the advantages it offers are far more than this disadvantages.

First the retrieval rocket need not be maneuvered from its natural trajectory as the recovery drone ship can be positioned in an ideal place to 'catch' the vehicle on its more natural path back to Earth. Secondly it would decreases the distance the rocket needs to travel, and hence would require much less amount of fuel which is the most important element since it has to be taken-up in the first place!

For many missions, in particular using large launch vehicles for putting bigger satellites, exceptionally large quantities of fuel are required. In such cases performing a ground landing may not even be possible. Such launch vehicles would either launch heavy payloads or go to a high orbit would need extra speed during the initial ascent.

This would demand extra speed and hence more fuel. In such launch vehicles, there would never be enough leftover fuel to execute a landing on the ground and thus recovery platform floating on the seabed would be the best, if not the only option for recovery.

The remarkable recovery of the first stage rocket on 8 April was associated with another first to its credit. Stored in the trunk of the Dragon spacecraft that went further up in the space and attached itself with the International Space Station was the Bigelow Expandable Activity Module (BEAM). This module was packed up like a parachute and will be made to expand to more than five times its compressed volume subsequently. Later, BEAM will be attached to the Tranquility Node of the station, and will become the first expandable habitat occupied by humans in space.

The future

SpaceX is preparing to launch a much bigger and heavier 'Falcon Heavy' rocket for the lift-off sometime in the last quarter of this year, which would be the most powerful operational rocket in the world. The rocket with a height of 73 meters will be able to lift into orbit a payload of over 53 metric tons. Just to get a feel of the size, the Gateway of India is a mere 26 meters high, Buland Darwaza at Fatehpur Sikri is only 40 meters high, while India Gate is 42 meters high.



Falcon 9 rocket's launch and landing shot in one frame.

When operational, Falcon Heavy rocket will lift more than twice the payload of the next closest operational vehicle, the Delta IV Heavy, but at one-third the cost. Falcon Heavy has been designed to carry humans into space and restores the possibility of flying missions with crew to the Moon or even to Mars.

Just imaging a tall structure like Kutab Minar which is also 73 meters tall, getting lifted into the air! As regards weight, well it will be close to 4,00,000 kg; equivalent to a Boeing-737 jetliner fully loaded with passengers, crew, luggage and fuel.

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SpaceX is also planning to recover the Falcon 9's payload fairing, another specially designed and costly part of the overall rocket structure that protects the satellites when they are launched into orbit. Presently, the company has over 60 missions on its manifest representing over $7 billion under contract.

Final words

Recovery and reusability of spent rocket motor, at least of the first stage is not only time and cost-effective, it is important as well for the space missions. The big advantage that would be visible in the future would be the regularity of missions.

As per SpaceX Director, they are aiming to increase the total number of yearly launches. There are two more scheduled launches during the next two months. Such close and literally back-to-back launches have never happened in the past. What is further promised can be seen from this part of the press statement by the company Chairman: 'we hope we're going to be able to launch basically every other week by the end of the year.'

A tall statement by a person who had delivered what was said earlier. In the light of such a thing happening, the future of space travel looks really bright. ■