WALKING ON THE MOON

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This is the story of a private Indian company, TeamIndus, that is competing in the Google Lunar XPRIZE challenge to land a rover on the moon.

Ek Chotisi Asha — one small hope, that is what I am named: ECA for short. But the hope I represent is anything but small. I represent the hopes of 1.3 billion people of India as they make giant strides across all facets of science and I represent the hope of humanity to spread wings, move out of the security of mother Earth and settle on distant planets. I am a small but giant step in that direction. You see, I am a small rover (refer **Fig.1**) that is designed to travel from the Earth to the Moon, land there and drive around on the moon. By the time you read this story, I will be on my way to the moon or would have already landed there.

I was conceived and built in the office of the young start-up company, TeamIndus, in Bengaluru, India. It all started when Google announced the Lunar XPRIZE (GLXP for short), a global competition. It is a $30M

Fig. 1. ECA (Short for Ek Chotisi Asha- one small hope) is the moon rover designed by TeamIndus.
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Fig. 2. ECA along with the spacecraft, photographed at the TeamIndus facility in Bangalore.
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competition to challenge and inspire engineers, entrepreneurs and innovators from around the world to develop low-cost methods of robotic space exploration. To win the Google Lunar XPRIZE, a privately funded team must be the first to a) successfully place a spacecraft (refer **Fig.2**) on the moon's surface, b) have it travel 500m, and c) transmit high definition images and video back to the Earth.

Initially when the prize was announced, no Indian teams were participating and this motivated my makers to come together, form a team and register for GLXP. I believe they signed up for the competition on the very last day, 31st December, 2010. Phew! I may not even have been conceived, let alone be born if they had missed that deadline!! And you know what? It was just five people who formed the initial team of TeamIndus. Today, there are over one hundred and twenty people in the team (refer **Fig.3**), including about two-dozen experienced space experts from ISRO and a whole lot of young engineers, pretty much fresh out of college. Imagine the excitement for them — sending a rover to the moon within five years of coming out of college!

I believe this challenge is only for privately funded companies, and the participants had to acheive the mile-stones set by Google Lunar XPRIZE. Our turning point came in 2014.There was an interim Milestone Prize announced by GLXP to check the progress of the competition. Three prizes were announced for showcasing robust hardware and software to overcome key technical risks in the areas of imaging, mobility and lander systems. TeamIndus won the $1M prize for demonstrating its landing technology.

My launch will happen from Sriharikota. I will be travelling inside a spacecraft that was also designed by TeamIndus. The spacecraft in turn will be carried on the nose of an Indian Space Research Organization (ISRO) rocket, the Polar Satellite Launch Vehicle (PSLV). We collaborate extensively with ISRO; and, also, PSLV has an amazing record of thirty nine consecutive successful launches. Only the very best for me!

There are specific days that are ideal for lift off — this is when the moon is crossing the Earth's ecliptic plane — that is, when it crosses the Earth's orbital plane around the sun. This occurs every fifteen days. Hence the window for launch would be that day or maybe a day before or after. This window repeats up every fifteen days and we could catch any of these windows after 28th December, 2017.

I won't be travelling alone, though. My spacecraft will be shared by my competitor! HAKUTO is a team from Japan which is one of the five final teams still in the competition, and their rover, Sorato, will be making the journey along with me on TeamIndus' spacecraft. I can see you are speechless with wonder — why should we help our competitors? But let me tell you, in science, there is no competition. We are all working towards widening the horizons for humanity and there is only collaboration among scientists. In fact, that is the only way in which we can understand the universe.

The spacecraft itself will be designed to be able to carry the payloads — both my friend Sorato and I along with some experiments we will be carrying, all adding up to around 20kg. You must appreciate that it is really important to keep the weight as low as possible and my own design has been changed many times to finally reach a weight of just 7kg. Imagine if one of you guys have to reduce so much weight just how much dieting you have to do! But to carry this payload mass of just 20kg, there is a whole paraphernalia that is required, all together adding up to a whopping 600kgs!! Let me explain the details.

First of all, when the spacecraft starts its descent on to the moon surface, it would be falling at a speed of about 1.7km/s. This has to be decelerated using a propulsion system to almost zero speed as it touches down. This propulsion system will be about 60kg in mass. Mind you, this is just the propulsion system — without any propellant. The whole housing for the payload and the thrusters will add up to another 60kg (here again, after multiple design iterations, we brought down the mass from 90kg to 60kg). Then there would be a guidance navigation system, communications system, computer, battery, solar panel etc. — all together another 60kg. So the total dry mass — without fuel — would be about 200kg. The fuel required for the above deceleration for soft touchdown is another 200kg. But that is not all: we also need propellant to get us to the moon. That will be another 200kg. Altogether, that makes 600kg for the spacecraft for carrying 20kg payload. Talk about the tail wagging the dog!

The distance from the Earth to the moon is all of 3,84,400km. The journey starts with a series of four stages of propulsion by PSVL. The first stage will take us up to 150km altitude, outside the Earth's atmosphere; the second stage will take it to about 400km and the third stage to almost 800km. At the end of all four stages, the spacecraft will be placed at a highly elliptical orbit of 880km X 70,000km (perigee of 880km and apogee of 70,000km) around the Earth. The spacecraft that carries me will initially make a few manoeuvres while going around the Earth, finally reaching a speed of 10.4km/s. This is forty times the speed of a normal commercial aircraft! I hope I don't get dizzy with all that speed! Once this maximum speed is reached, the propulsion system shuts off and we continue to go towards the moon, losing some of our speed due to continued gravitational pull from the Earth (refer **Fig.4**).

Throughout this journey, the spacecraft will be communicating back to the Earth and also getting instructions from the Earth using a particular band of micro-wave frequency called the S-Band.

There is also a guidance and navigation system on-board the spacecraft, consisting of a star-sensor and sun-sensor that ensures the position and the orientation of the spacecraft — referred to as the attitude of the spacecraft — is right (it

Fig. 3. Members of TeamIndus.

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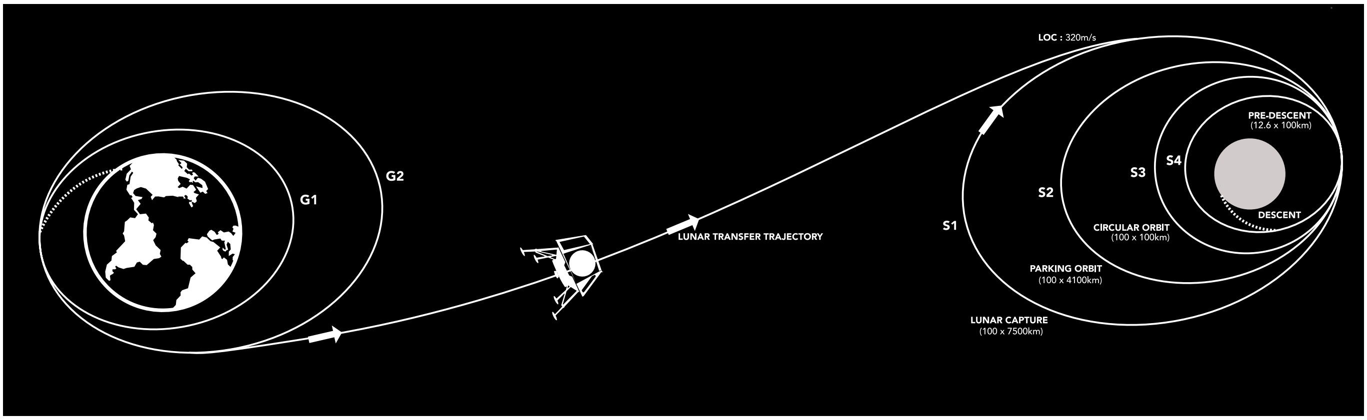

Fig. 4. The trajectory of the spacecraft.

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is not only in life that you need to have the right attitude to succeed!!) Once the craft has the proper attitude, direction can be changed accurately using the data from the inertial measurement unit — consisting of a gyroscope and accelerometer. Imagine the precision required to exactly position, orient, and direct a spacecraft freely hanging in space using just the thrust of propellants! My digital mind boggles!

Once the spacecraft nears the moon, it has to decelerate, though. Otherwise it will be travelling too fast to be grasped by moon's gravity. For this, some more propellant fuel has to be used. After this, we take some orbits around the moon and then the spacecraft starts its descent to the surface. During this phase, it requires terrain relative information — i.e. the information regarding the distance to the moon and where exactly it is heading on the moon. This is done using the laser range finders, the laser altimeters and the cameras on board the craft.

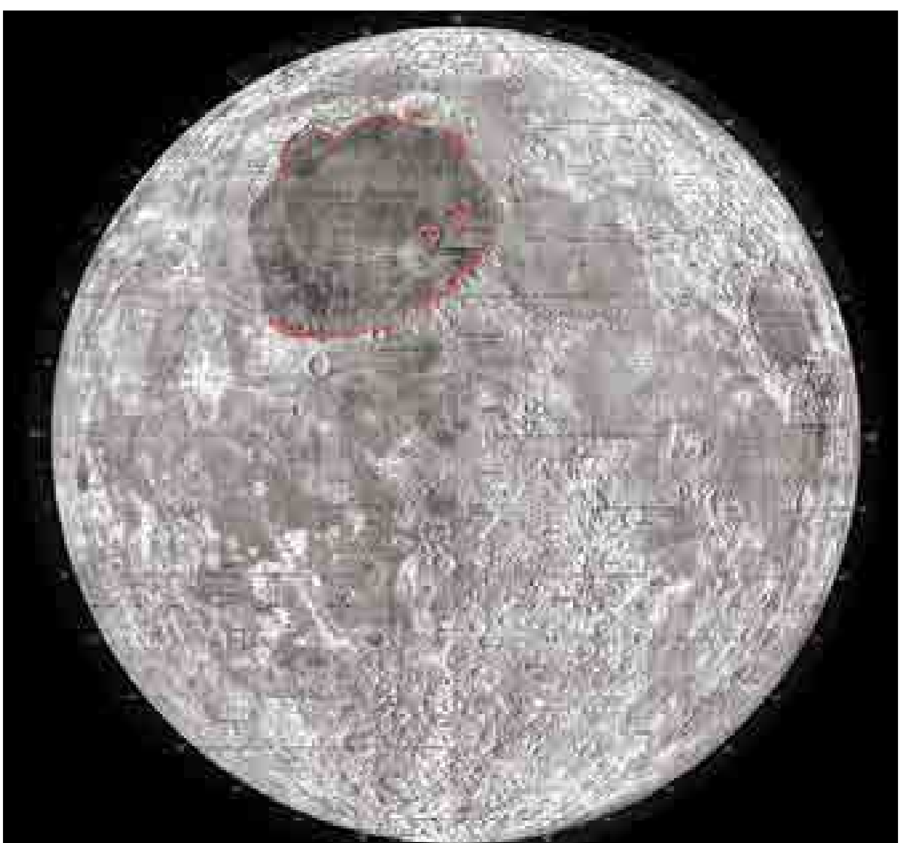


Fig. 5. Mare Imbrium.

Credits: Srbauer, Wikimedia Commons. URL: https://commons.wikimedia.org/wiki/File:Imbrium_location.jpg. License: CC-BY-SA.

All these different gizmos on the craft are powered by the battery on board, which in turn is recharged using the solar cells.

The four legs of the craft and the touch down velocity are designed, taking into account the type and hardness of the terrain it will be landing on. This information is available from previous missions to the moon. Again, as I said, it is all the information from so much of past scientific work that will help us to succeed. That is how science works.

Once the craft (now called the lander) lands, it is time for me to act. You recall of course that my primary goal is to travel 500m on the lunar surface, take pictures and videos, and send them back to the Earth. To navigate through lunar terrain, I have specially designed wheels. They all have independent suspension and movement. They are all fitted with these special fittings called grousers that increase the contact area with the ground and increases traction. I am also built to be flat and low in shape so that my centre of gravity is very low. This ensures that I don't topple. Also, knowing the exact kind of terrain I am going to be landing on has helped my designers cut out unnecessary features to reduce my mass. For example, I cannot climb up slopes that are greater than 40° incline. But we do know beforehand that where I will be landing on — Mare Imbrium (refer **Fig.5**) — will not have such steep inclines. It is a vast lava plane.

Even though I have a lot of artificial intelligence algorithms built into me, till I travel the first 500m, I will be controlled remotely from the Earth. This can be done because the two cameras that serve as my eyes continuously send images and video back to the Earth through the lander. I will send images to the Earth, they will analyse these images and send me simple text instructions such as move three steps forward and one to the right etc. Of course, I will be making only one move at a time. One just cant be too careful when letting a baby walk — and I am a baby for all practical purposes.

Once the initial milestone is achieved, like a growing baby, I will be allowed to wander around a little more on my own, since my algorithms will be continuously learning and would have learned how to better navigate the terrain on my own.

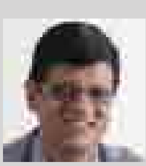
In the meanwhile, the experimental setups in the lander would have started their work. These were identified through an outreach program launched in 2016 called Lab2Moon, specifically targeting young minds across the globe. In the quest to catalyse humankind as a multi-planetary species, TeamIndus invited youth under twenty-five years to imagine, design and build an experiment that will help humanity build sustainable life on the Moon. Three thousand entries from fifteen countries and over three hundred cities across the globe were received in the first round.

After Phase 2 — the shortlisting process, Team Space4life from Italy won this competition and their experiment will be flying to the moon. They are working on developing a radiation shield using bacteria. Other on-going projects include Team Zoi (India) which works on photosynthesis on the moon by extremophile cyanobacteria, Team Ears (India) which works on an Electrostatic radiation shield experiment, Team Kalpana (India) which works on Instrument for Lunar dust analysis, and Team Callisto (India) which works on a Lunar dust accumulation analyser.

The whole program is so exciting. But my life will be a short-lived in all probability. Daylight lasts only for fourteen days on the moon. To maximise our mission, we will be landing at dawn. So I have fourteen days of sunlight to complete the 500m, then to do my wandering around. After that darkness will descent. Since there is no atmosphere on the moon, the heat doesn't get trapped and stay on the surface. By the next sunrise, fourteen days away, the temperature will reach about -200°C. If you think that is bad, remember that during the first fourteen days of daylight, the temperature would have reached over 100°C! I might look small and frail, but I am tough. My creators have designed me to be functional at temperatures at which water will vaporise. But it is very much doubtful if I will survive the intense cold. Of course, I know my friends at TeamIndus will be waiting with bated breath to see if I will pop back into life and start transmitting after fourteen days of night when the sun rises again. But for me, it doesn't really matter. I would have given my life for the progress of humanity.

Note:

1. According to the latest news reports (Jan 10th, 2018), the official contract between TeamIndus and ISRO has fallen through because TeamIndus has not been able to raise the funds required to pay for the use of ISRO's launch services. Hence, inspite of their technological readiness, TeamIndus may not be able to meet the deadline set by GLXP. Even so, we have decided to carry this article, because our account of their attempt reveals important aspects of this multidisciplinary scientific effort. It also illustrates how the history of science is filled with ambitious leaps of faith, many of which do not succeed. Nevertheless, without these risks, science wouldn't be where it is today.
2. Credits for the image used in the background of the article title: A historic extraterrestrial sky—the Earth viewed from the Moon, Apollo 8 mission, Lunar orbit, 24th December, 1968. URL: https://upload.wikimedia.org/wikipedia/commons/a/a8/NASA-Apollo8-Dec24-Earthrise.jpg.



Ramgopal (RamG) Vallath is a bestselling author and motivational speaker. He has conducted dozens of science workshops in schools based on the story of his children's sci-fi book, Oops the Mighty Gurgle. He also delivers motivational talks to students on how to find success.