Engineering vis-à-vis science: India's missed discovery of water on the Moon

Most Indians are justly proud of their country's missile, space and nuclear programmes. Of all the Indian civilian science initiatives, the Indian Space Research Organization (ISRO) has been the most successful. In space exploration, there is no room for excuses or rationalizations. The difference between success and failure is obvious. Either a satellite remains in orbit or falls down. The principles and procedures in science management that ISRO has developed over the years need to be carefully studied with a view to examining the possibility of their wider applicability in other science organizations.

India's space programme is extremely good value for money from even by international standards; ISRO's rocket launching facilities are being commercially used by other countries. Perhaps the best testimony to India's cost-effective space programme comes from the fact that it had such confidence in its own capabilities that *Chandrayaan-1* was not insured.

Chandrayaan-1 was successfully launched on 22 October 2008. On 14 November, it entered its final operational orbit at a height of 100 km from the lunar surface. The same day, the Moon Impact Probe (MIP) was released to hit the southern pole of the Moon at a predetermined location. In a mildly jingoistic exercise, the probe deposited India's national flag on the Moon. The choice of the date was significant; 14 November is the birthday of India's first prime minister Jawaharlal Nehru, well known for his fascination and support for science.

The term 'science' is often used variously, but it will be useful to give it a precise meaning. Science proper or basic science gives new ideas and makes new findings. Technology prepares prescriptions for making new things or making things in a better manner, while engineering actually makes things using already established prescriptions. Although the distinction between technology and engineering is hazy, the separation of science is clear cut.

Let us make a distinction between a rising technology and a flat technology. As the name suggests a rising technology is one which is currently undergoing rapid phases of development whereas a flat technology is one which has been more or less standardized. Clearly, a rising technology of today is a flat technology of tomorrow.

USA focuses its attention on the rising technologies of the day. Once they are standardized, it parcels them off to lesser countries, e.g. car manufacture. (This is certainly not a good philosophy, as USA seems to be realizing now. Focus on rising technology should go hand in hand with production of wealth through flat technologies for the sake of the country's economy and mindset.)

If lunar missions have now been left to the likes of Japan, China and India, it is because the missions now constitute standard technologies. If tomorrow colonization and mining of celestial bodies become a possibility, you would see the initiative being grabbed back by the US and to a lesser extent by the European Space Agency (ESA).

Indian space programme in itself (as also the missile and the nuclear) is not science but an exercise in engineering. It can of course be a tool for carrying out scientific research. *Chandrayaan* carried 11 thematically integrated scientific payloads, five from India, three from ESA, two from USA and one from Bulgaria. All the experiments aimed at creating a high-resolution map of the lunar surface and the minerals beneath it. Although the mission was originally planned to last two years, it had to be aborted on 30 August 2009, once the craft lost radio contact with the earth. It however did provide valuable data while it lasted.

The most spectacular early scientific results from the mission came from the two US payloads: Moon Mineralogy Mapper (M3) and Miniature Synthetic Aperture Radar (mini-SAR). They provided first direct confirmation of presence of water in the form of ice on the side of the Moon perpetually away from the Sun. The M3 paper, with Carle Pieters as the lead author, was published in *Science*[1] on 23 October 2009. The mini-SAR paper, with Spudis as the first author, which was submitted to *Geophysical Research Letters*[2] on 22 December 2009, accepted on 22 February 2010 and published on 31 March 2010. The Americans handsomely acknowledged the contribution of Indian space technologists. Referring to the M3 paper, Jim Green, director of the Planetary Science Division at NASA Headquarters in Washington declared on the NASA website that 'This surprising finding has come about through the ingenuity, perseverance and international cooperation between NASA and the India Space Research Organization'. Echoing the same sentiment, Pieters went on record on her University website that 'If it were not for them [ISRO engineers], we would not have been able to make the discovery'.

As it has turned out, India became a cheap vehicle for USA to do lunar science.

The MIP which deposited Indian national flag on the Moon also carried a scientific payload, CHACE (Chandra's Altitudinal Composition Explorer), comprising a mass spectrometer. During the 25 min of fall on to the lunar surface, CHACE obtained data confirming the presence of water on the Moon. A team of Indian scientists sent their paper to *Science* in December 2008, which however rejected it in March 2009. The Indian authors then sent the paper to *Nature* in April 2009, which also rejected it, in July 2010. Finally, in November 2009, the paper, with R. Sridharan as the first author, was sent to a lesser journal *Planetary and Space Science*[3]. The paper was revised on 22 January and accepted on 24 February. It became available online on 6 March and in print in May 2010. The Sridharan paper dutifully refers to 'the most sensational finding' reported by Pieters and collaborators. The Indian paper using *Chandrayaan* data could have been a discovery announcement; instead it ended up being a me-too paper. India had the opportunity to be the first past the post, but it chose to be an also-ran.

A recent newspaper[4] report on the missed opportunity is titled 'NASA sidelining India's moon men?'. It has not

spelt out what India expected from NASA. Nothing gives the India of today greater satisfaction than complaining about being abandoned by the West.

The data obtained by a NASA experiment aboard *Chandrayaan* is NASA's property. NASA hands it over to the project leader who along with their collaborators analyse it and publish their findings in a journal of their choice. The published paper in fact duly records that the apparatus was flown onboard *Chandrayaan*. Pieters' team includes three India-based authors, one each from Physical Research Laboratory, Ahmedabad; National Remote Sensing Agency, Hyderabad and even ISRO, Bangalore. Similarly, Spudis team includes Indians. Interestingly, some Indian authors are common to M3 and mini-SAR papers.

Similarly, the data obtained by CHACE payload belonged exclusively to ISRO. Its analysis was complete by December 2008. The paper should have been immediately published in a journal like *Current Science*, where the authors would have got the benefit of referees' comments. They could even have published in *ISRO Newsletter*. Once their results were in print, all subsequent researchers would have been duty bound to take note. ISRO itself is guilty of failing to realize the significance of its findings. That is why it kept on chasing international journals. (It would be instructive to see what arguments were proffered by the editors of *Science* and *Nature* while rejecting the ISRO paper.) If a path-breaking paper is published in a national journal, the journal would automatically become international.

It is noteworthy that the analysis of NASA data was carried out outside the NASA system, whereas ISRO data was handled from within. ISRO is a hierarchical system, with a line of command and annual confidential report writing powers. We do not know whether the decision to run after international journals was taken by the authors themselves or whether the suggestion came from above.

Indian science has never been self-assessing. When senior scientists and science managers evaluate a person's performance for bestowing an award or recommending a promotion, they are more likely to read the name of the journal where the paper is published rather than the title of the paper. Our universities and institutions ask national and international papers to be listed separately, with the former being given short shrift. (This has produced the ridiculous situation where academics have published their papers in Bangladesh!).

It is not the first time that India missed making an important discovery in the solar system. The predicted occultation of a distant star by Uranus on 10 March 1977 was independently observed by astronomers of the Indian Institute of Astrophysics, Bangalore, and Uttar Pradesh State Observatory, using their ground-based 1 m telescope at Kavalur and Nainital respecively. The event was also seen by an American team which used a 91 cm telescope aboard an airborne observatory. Interpreting their data correctly, the Americans telegraphically announced the discovery of a ring system around Uranus on 21 March 1977 in an International Astronomical Union Circular[5]. The Kavalur astronomers failed to grasp the full significance of the data before them and could spot only the densest part of the system (since designated epsilon ring) which they dubbed a new satellite of Uranus. This announcement was published in the same Circular mentioned above. To be on the safe side, they next submitted a short communication to the quarterly *Bulletin of the Astronomical Society of India*[6] which published it in its March 1977 issue. The communication carried a note added in proof which referring to the work of 'other observing teams' and 'further detailed analysis' stated that 'It appears that the planet is encircled by belts of varying dimensions'. At the same time, a paper announcing the discovery of a satellite of Uranus was submitted to *Nature* which received it on 30 March, accepted it on 20 April and published[7] it on 26 May 1977. The paper was preceded by the American discovery paper[8]. At least, the Kavalur astronomers had made an attempt to analyse the data they had obtained. Nainital observers on the other hand dutifully observed the event and promptly forgot about it. Two years later Kavalur and Nainital pooled their data and published a detailed we-too paper in a lesser journal[9].

Making scientific discoveries requires a certain amount of boldness and defiance. In the absence of these attributes, a country can only belong to the also-ran category.

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