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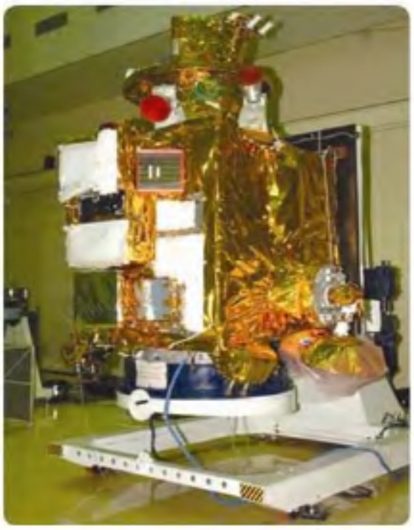
Chandrayaan-1

The launch of Chandrayaan-1 on 22 October 2008, was a landmark event in the history of India's space endeavour. A special section on 'Chandrayaan-1' in this issue covers the activities during the pre-launch stage of the mission leading to the realization of the Chandrayaan-1 spacecraft, successful development of the scientific payloads and establishment of facilities for communication, navigation and storage and archiving of data from this mission. J. N. Goswami and M. Annadurai (**page 486**) trace the events leading to the Chandrayaan-1 mission, its science objectives, the spacecraft, various payloads, mission sequence and operation plan over the mission life of two years and also highlight the international character of the mission. They note the plans to carry out remote sensing observations of the moon over a wide range of the electromagnetic spectrum, at spatial and spectral resolutions better than previous and currently planned missions to the Moon. They also point out that three of the Chandrayaan-1 payloads will employ novel methods for the first systematic study of volatile transport on the Moon, possible presence of water ice in the lunar polar region and solar wind–lunar surface interactions to identify localized lunar magnetic fields. They also note that Chandrayaan-1 will also carry a moon impact probe, equipped with a mass spectrometer, an imaging system and a radar altimeter, that will impact at a pre-designated area.

Mineralogy of the lunar surface provides idea of the different rock-types present in the moon and thus provides the basic information needed to reconstruct lunar evolution history. Identification of lunar minerals can be done by studying the reflected sunlight from the lunar surface in the UV-VIS-IR regions at high spectral resolution and looking for absorption features characteristics of different minerals. Chandrayaan-1 carries three spectral reflectance spectrometers capable of obtaining data at high spectral and spatial resolution over the wavelength range of 400–3000 nm. Kiran Kumar and colleagues (**page 496**) describe the various features of the Hyper-Spectral Imager (HySI) that covers the 400–950 nm range in 64 contiguous bands and characterized by a spectral resolution of ~15 nm and a spatial (pixel) resolution of 80 m. Carle Pieters and colleagues (**page 500**) present the



details of a very unique reflectance spectrometer Moon Mineral Mapper (MMM) that will cover the wavelength range of 700–3000 nm and will have spectral resolution of ~10 nm and pixel resolutions of 80 m. Finally, Urs Mall and colleagues (**page 506**) describe the Near Infrared Spectrometer (SIR-2), a compact, monolithic grating near infrared point spectrometer that covers the wavelength region of 0.9–2.4 micron with a spectral resolution of 6 nm and spatial (pixel) resolution of ~80 m. All the groups also discuss the various scientific issues that they will address by analysing the data obtained by these instruments. These instruments can also detect the mineral ilmenite, that acts as a host of helium, on the lunar surface.

While mineralogical data can be used to infer chemical characteristics of the lunar surface, direct determination of elemental abundance can be done only through the study of the intensity of characteristic X-ray fluorescence lines from the lunar surface produced by incident solar X-rays during occasional solar flares. Manuel Grande and his colleagues (**page 517**) describe the Chandrayaan-1 X-ray Spectrometer (C1XS), designed to measure absolute and relative abundances of major rock-forming elements (principally Mg, Al, Si, Ti, Ca and Fe) over the lunar surface. C1XS carries a ^{55}Fe calibration X-ray source for detector calibration and a X-ray Solar Monitor to record the incident solar X-ray flux.

The surface topography of a planetary body offers clues to unravel its evolutionary history. Chandrayaan-1 carries the Terrain Mapping Camera (TMC) designed to map the entire lunar surface and prepare a three-dimensional lunar atlas with 5 m sampled spatial and altitude data. Kiran Kumar and colleagues (**page 492**) describe the TMC that will image in the panchromatic spectral band of 0.5–0.75 μm with a stereo view in the fore, nadir and aft directions of the spacecraft movement. TMC will provide lunar images with highest resolution amongst the contemporary lunar missions. The data obtained by TMC will be complemented by another instrument onboard Chandrayaan-1, the Lunar Laser Ranging Instrument (LLRI) designed to generate data on lunar altimetry. J. A. Kamalakar and colleagues (**page 512**) describe the salient features of LLRI that will use a 10 mJ diode-pumped pulsed laser, operating at 10 Hz (5 ns pulse), together with 200 mm diameter telescope and a silicon avalanche photodiode to provide lunar altimetry accurate to within 5 m. Data from

LLRI will be used to generate a quantitative lunar gravity model.

The possibility of indigenous lunar resources, in particular, water-ice mixed with upper layers of lunar soil, in lunar polar region, is of paramount interest in planning future long duration missions to moon. P. Sreekumar and his colleagues (**page 520**) describe the High Energy X-ray Spectrometer (HEX) that will test the concept of volatile transport on moon on the lunar surface that can lead to enhancement in the concentration of volatiles (including water) in permanently shadowed lunar polar region. Solid-state pixilated cadmium–zinc–telluride (CZT) arrays will be used in HEX for detecting energetic photons in the energy range 30–270 keV from the lunar surface, and in particular, the 46.5 keV γ ray line from ^{210}Pb (a decay product of volatile ^{222}Rn) as tracer. They note that HEX will make the first attempt to detect low energy (<300 keV) γ rays from radioactive decay from a planetary surface. Another instrument, Miniature Synthetic Aperture Radar (Mini-SAR) will look for specific signal of water-ice mixed with top meter of lunar soil in the permanently shadowed lunar polar region. Paul Spudis and colleagues (**page 533**) describe the salient features of this payload operating at 2.5 GHz and how by transmitting and receiving polarized light and utilizing hybrid polarization architecture they will try to infer possible presence of water ice in the polar region.

Devoid of an atmosphere and global magnetic field, the moon offer free access to energetic particles of solar and galactic in origin. One of the instruments onboard Chandrayaan-1, Sub-keV Atom Reflecting Analyser (SARA) will use a novel approach to investigate solar-wind–lunar surface interaction to infer broad chemical characteristics of the lunar surface and identify regions of localized lunar magnetic field. Stas Barabash and colleagues (**page 526**) describe in detail the SARA payload consisting of the Chandrayaan-1 Low Energy Neutral Atom (CENA), and the Solar Wind Monitor (SWIM) and also the major scientific aims and objectives of this experiment. SARA represents the first study of its kind in planetary science context.

Any space mission needs to worry about potential hazards in space, particularly from energetic particle events that can lead to radiation damage and degradation of detectors used in various payloads and also of various spacecraft components and subsystems. T. Dachev and colleagues (**page 544**) describe the miniaturized Radiation Dose Monitor (RADOM) onboard Chandrayaan-1 that will continuously monitor energetic particle flux and radiation doses received by the spacecraft en-route to the moon and in lunar space.

The aim and objectives of the Moon Impact Probe (MIP) that will be released after Chandrayaan-1 reaches its designated lunar polar orbit are discussed by Ashok Kumar and colleagues (**page 540**). They describe the procedures to be adopted to ensure impact of the probe at a pre-designated area and also the details of the three instruments onboard MIP for lunar surface imaging, altimetry and detection of the tenuous lunar atmospheric component.

The articles for this special section were submitted prior to launch of Chandrayaan-1 on 22 October 2008 and do not contain any of the preliminary data obtained by the various payloads after their commissioning in the later part of November. A centrespread within the special section provide a glimpse of some of the preliminary data and images obtained by Chandrayaan-1. The MIP landed close to the South Pole as planned and all the other instruments have been commissioned successfully and voluminous data have been obtained by some of them at the time of going to press.

J. N. Goswami
Guest Editor

Indian White-backed vulture

The indiscriminate and widespread use of diclofenac has led to a decline of more than 95% of the *Gyps* vultures between 1988 and 1999 in the Indian subcontinent. However, there are reasons to believe that there are other causes for the decline of the

vulture population. For instance, Ajay Poharkar *et al.* (**page 553**) demonstrate that in a dense forest in Central India the decline in vulture population was not due to diclofenac but was due to a malarial parasite. The parasite was identified based on molecular markers and the presence of the parasite in the erythrocytes. Further, it is also demonstrated that two of the vultures with symptoms of malaria could be rescued using anti-malarials, thus implying that malaria could be an additional cause for the decline of the White-backed vulture.