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PERSPECTIVE

The genius of people like Norman, Gilbert, Faraday, Oersted, Ampere and Maxwell gave geomagnetism a strong footing to tackle fundamental problems related to Earth and interplanetary space. These discoveries whetted the curiosity of the inquisitive mind to unravel the causative agents and look for inter-relationships between the Earth, the Sun and other planets or satellites and use this knowledge to predictive purposes. Intricacies of changes in the geomagnetic field are studied because they change over several timescales from few million years to fraction of a second in several spectral bands. Each band of frequencies is a goldmine of information indicative of various causative mechanisms with sources in the Earth's interior, near space or far space environment as outlined in Chapters 1 to 8. Specifically, Chapters 5 to 8 list out applications of geomagnetic measurements to understand the chemical, physical and dynamical characteristics of the atmosphere and the interior of the planet Earth. In virtually every case presented in this book, there is considerable scope for further development in exploratory techniques, analysis, interpretation and application. Prospects for the future, lie in further extension and refinement of established approaches used in magnetic observatory, upper atmospheric and solid Earth studies.

I. The Observatory

Most of the Indian MOs are equipped with digital magnetometers from where the data are transported in real time to the central node and to the GINs. It is expected to increase density of MOs to cover more latitudes and longitudes of globe/India. Density of MO is to be particularly increased in the southern region for Sq, EEJ and CEJ studies and in the north for Sq focus and seismotectonics. The Shillong MO data are found sensitive to local earthquakes. This has offered clues to undertake the installation of seismometers at all other planned and existing MOs. This colocation of magnetic and seismic instruments will gainfully allow execution of timely response needed in earthquake monitoring studies. This would mandate inclusion of geomagnetism as a national programme. Ground-based data acquired at MOs together with data from magnetic survey satellites will provide ample opportunities for undertaking the investigations related to: (1) regional magnetic anomaly and reference field maps, (2) 'secondary effects' on Sq field, (3) induced currents associated with EEJ, (4) transient variations and (5) low-latitude 'bay' structure.

II. Antarctic Magnetic Data

After analysing the experiments carried out at Antarctica, the book can recommend widening of the scope of experiments to study: (1) magnetospheric influences on terrestrial magnetic field on a long-term basis and to record systematic magnetic field variation, (2) establish link between the magnetic field variation in the polar and equatorial regions, and (3) subsequently examine subsurface structures of the continent using magnetic field variations. Magnetic measurements at Maitri confirmed a decreasing trend in geomagnetic field, which needs to be incorporated in models depicting magnetic reversals. This will also have a bearing on the role octupoles and quadrupoles play during a reversal, since they are conjectured to maintain a semblance of geomagnetic field, when the dipole field is vanishing. The high latitude continent is an ideal place to study air-Earth Maxwell currents to extend understanding of the magnetosphere-ionosphere electrical coupling. Permanent GPS stations are setup for geodynamic meteorological and ionospheric studies. They also monitor glacier and iceberg migration. Study on Antarctic climate and environmental variability is initiated by conducting mineral magnetic studies on core samples collected from the basinal features of Antarctica and its adjoining regions. These can be correlated with subcontinental monsoon features for establishing teleconnections in weather patterns of these far off continents.

III. Space Environment

The entire range of phenomena in the field of equatorial aeronomy and its global connections between troposphere, stratosphere, magnetosphere and interplanetary space form a part of space environment research. Beginning with ground-based radio and optical probing of the upper atmosphere, the research has developed into an integrated programme that combines ground-based data with those obtained from balloons, rockets and satellites using a variety of payloads. Satellites carry onboard radio beacons to monitor and study ionospheric irregularities. Airglow measurements for wind and temperature parameters need to be continued. Recommended programmes include: the study of solar-terrestrial coupling, spread-F phenomena, EEJ/CEJ current systems, trace gases/minor constituents of the middle atmosphere, role of plasma in different interplanetary zones and space weather conditions. To learn about the mechanism/origin and development/decay of spread-F, ground-based magnetometers, ionosondes, Fabry-Perot interferometers (for 6300 Å airglow radiation) and beacon satellite scintillation studies, are recommended. The measurement of atmospheric electric fields/conductivities needs to be carried out using balloon and satellite-borne equipment to study stratospheric electrodynamics and global electric circuit.

Magnetosphere: Considerable work has been done on the exchange of energy between solar wind, magnetosphere and its subsequent transport to various parts of the magnetosphere-ionosphere system. The physical mechanism of many of these phenomena, however, remains elusive. The coupled magnetosphere-ionosphere system is highly complex/nonlinear and it is impossible to construct realistic analytical models for the various properties exhibited by this system. The advent of new generation fast computers and subsequent progress in numerical analysis methods has offered a powerful tool of computer simulation technique. Computer simulation techniques are now an integral part of space plasma research. It is recommended to do computer simulations to understand the: (1) role of ionosphere in substorm dynamics, (2) energy transfer, (3) substorm dynamics, (4) effect of energetic particles on spacecrafts, (5) auroral acceleration processes, (6) ionosphere, (7) ionospheric irregularities, (8) ionosphere-neutral atmosphere interaction and (9) simulation of geodynamo.

Sun, magnetic storms: The intricate picture of the connection between the Sun and the Earth's space environment has been uncovered in the last few decades. However, understanding of the physical processes, which drive and couple this complex plasma system, is still far from complete. Magnetospheric substorms and major geomagnetic storms produce intense surges in energetic particle populations that can adversely affect the functioning of modern satellites, GPS and power grids on the ground. An outstanding problem in solar-terrestrial physics pertains to predicting the evolution of physical processes within the magnetosphere and Earth's space environment. The space environment is a natural plasma centre, where accurate in situ measurements can be carried out. The validity of theoretical models and assumptions regarding plasma dynamics can be tested on time and spatial scales far greater than available in the laboratory. In fact, this knowledge can be applied to the study of magnetospheres of other celestial bodies like planets, comets, pulsars and the like.

Sun, interplanetary medium: Although it has long been suspected that sporadic geomagnetic disturbances are due to eruptive events on the Sun, it is only recently that research on the solar corona and interplanetary medium has indicated the mechanism by which it occurs. This knowledge poses a further challenge to understand the timing and location of solar eruptions and establish whether individual solar events are likely to cause geomagnetic storms. Success in forecasting a storm a day or more in advance will also depend on improved knowledge and better monitoring of the Sun and the interplanetary medium. A research project is proposed to study solar-terrestrial relationship as a comprehensively coupled system that starts from the Sun, goes through the interplanetary medium, magnetosphere, high/low latitude ionosphere, mesosphere, stratosphere, troposphere down to the boundary layer and the surface. This system also continues down into the shallow interior of the Earth, where induced currents are produced by electric currents, which come in handy for probes launched through electromagnetic induction studies.

10.1 SOLID EARTH GEOMAGNETISM

Improvements in instrumentation accelerated magnetic surveys: EM surveys became routine affair, proton magnetometers are towed behind ships (air/water) and satellites go to phenomenal heights with magnetometers. The sensitivity and accuracy of instruments needed to monitor and record magnetic field in the material domains of solid, liquid and gas (plasma) are getting better by the day. These days, geomagnetists have automated laboratory equipments at their disposal by virtue of which in a single day they can make more measurements of the absolute palaeointensity of magnetic materials such as ceramics and basaltic rocks than pioneer Thellier could do in a life time. Considerable emphasis needs to be put on developments of inversion techniques and models from the data gathered from MT, OBM, MOs, satellite data on plasma and EM field, etc. Joint inversion of gravity and magnetic satellite/ground anomaly data, incorporating constrains from laboratory density/susceptibility measurements should be undertaken to estimate depth of the source field. The satellite data will have to be inverted to better understand the lithospheric dynamics.

The recommended thrust areas are: (1) probing the lithosphere through the features of regional scale magnetic anomalies using ground, aeromagnetic and satellite data, (2) delineating subsurface electrical conductivity features using GDS and MT methods, (3) pool in all available MT-GDS survey data and conduct additional surveys wherever necessary to prepare a ‘conductance map’ for the country, (4) use OBM/OBE for MT/GDS studies on the ocean floor in the adjoining seas, (5) palaeomagnetic and petrographic studies, (6) reconstruct magnetostratigraphy of the sediment/rock sequences, (7) characterize geophysically the Indian terrain to model folds, faults, lineaments and suture zones, (8) develop methodology for identification of geomagnetic and geoelectric precursors associated with earthquakes, (9) use of GPS for precise baseline measurements in selected areas for monitoring crustal deformation, (10) take up challenging topics in emerging areas like environmental geomagnetism, archaeomagnetism, biomagnetism, and (11) take up EM (conductivity) study through laboratory scale experiments.

I. Lithosphere Study through Magnetic Anomalies

Potentiality of remote sensing through satellite in determining structure of geological significance and in identifying inhomogeneities in the lithosphere has been proved beyond doubt. Identification of seismically active zones, hotspots, rifts, tectonically active belts due to mantle convection and resultant stress changes that followed the collision of the Indian plate with the Eurasian plate from Magsat magnetization map is an excellent example of the importance of satellite magnetic data. Low magnetization is encountered under Indo-Gangetic plains and positive on either side of it. Inverse correspondence between high gravity and low magnetization over petroliferous basins like the Assam oil field, Bombay High and Cauvery basin, is also identified. Joint inversion of gravity and satellite/ground magnetic anomalies incorporating constrains from density/susceptibility laboratory measurements should be undertaken to estimate depth of the source field. The satellite data need to be inverted at both the global and regional (Indian subcontinent) level to be able to better understand the lithospheric dynamics. This will entail massive data matrix inversion requiring sophisticated computing facilities.

Recommendations to enhance the geologic utility of satellite geopotential anomalies include: (1) Magsat data with <2°> anomalies had limited resolution. Use of improved magnetic anomaly data may provide better anomaly maps for crustal analysis, (2) obtain additional geophysical data to establish better constraints on tectonic interpretations. This may include seismic or geothermal data or gravity data that reflects improved areal coverage, (3) correlation analysis conducted is qualitative. Quantitative correlations could be used to further constrain tectonics analysis and modelling. This could involve separating continental data from oceanic to compare the magnetization characteristics of both the crusts, (4) the effect of lithospheric cooling on oceanic magnetic anomalies, and (5) it is shown that the geopotential field anomalies are useful for tectonic analysis. Improved data coverage, especially for gravity and lower elevation magnetics, promises to provide more information for tectonic analysis, particularly for the tectonically rich, relatively little known regions of Antarctica. Combined gravity and magnetic data collected by NASA's proposed GRM satellite can provide such a data set. The Oersted and other satellite mission data can also be used for lithospheric and electrojet variations.

To resolve structural complexities of the Indian plate and to be able to map the source fields at different depths, magnetic anomalies at different levels need to be looked at. Thus as an extension of the ground magnetic surveys, the outings will be formulated to survey different tectonic blocks. This ground data can be coupled with available aeromagnetic and satellite data. The susceptibility of different rock types will provide the necessary constraints for modelling. The aeromagnetic method has given a coherent view by integrating surface and sub-surface features/tectonics of the major portions of the country. Aeromagnetic data have established that Chitradurga divides the eastern and western Dharwar, which has a bearing on prospecting ore and mineral deposits. Thus a plan needs to be formulated for covering the shield areas by systematic aerial surveys. This coverage can be complemented by ground magnetic data over different metamorphosed zones and regions rich in iron deposits, viz. Singbhum-Bastar area, Bababudan in Karnataka and Ratnagiri in Maharashtra.

II. Geoelectromagnetic Studies, MT/GDS/OBM

MT techniques are accepted as a useful tool in exploration studies, especially in the Deccan trap as well as the low velocity sediment covered regions. Further, they are inexpensive compared to their seismic counterparts. The efficacy of these techniques in the area of oil exploration should be consolidated by undertaking surveys in various unexplored sedimentary sequences of the Godavari and Assam region. The ability of MT techniques in identifying repository sites for nuclear waste can be used to demarcate places, where no active faults are connected to the water table.

Earthquake monitoring activity is still in its infancy. MT studies can identify active faults, which should be monitored for possible changes in seismotectonic activity using MT or other similar EM methods. Efforts will be made to develop inexpensive indigenous instrumentation for electrical tomography, which could be of importance in continuous monitoring of electrical resistivity and ground electric current and voltages, which are known to be useful earthquake precursors. MT studies undertaken in geothermal regions to estimate the possible extent of these resources, could be of importance in the future renewable energy resource programmes. Groundwater location could also be detected by suitable magnetic/electrical methods.

A model of the subcontinental conductosphere is planned to undertake with magnetic array and MT measurements, which can be combined with heat flow data and potential field measurements to target natural resources. MT studies in geothermal regions can supplement the conventional energy resources. They can also identify active faults that can be monitored for predictive changes in EM signatures. Extending the EM work to marine environment will throw light on the global dynamics of the lithosphere. In this light, OBM and OBE studies will be very useful. The subduction tectonics at the Andaman arc region have led to seismic and tsunamic activities in the past affecting the coastal areas in many ways. The monitoring and recording of magnetic field changes can forewarn the events. These studies can also map out hydrocarbon deposits. The theoretical and software development for inverting and interpreting 2D/3D EM structure, need augmenting, which would be suitably done in future. Efficient robust algorithms and tensor decomposition schemes are developed to minimize distortions in the response functions.

III. Earthquakes, GPS

Inexpensive indigenous instrumentation for electrical tomography is in different stages of development to monitor electrical resistivity and ground electric currents, which are useful earthquake precursors. At the same time, these precursors should be clubbed with non-seismological deformation field measurements—progressive and continuous stress field mapping, ULF/VLF EM studies, EM response of radio wave propagation, ionospheric perturbations, infrared emissions in upper atmosphere, geochemical signal monitoring by Rn, He, GEC/TEC measurements in ionosphere (electron contents) and others.

State-of-the-art GPS units monitor minute movement within the subcontinental intracratonic and intercratonic areas and margins. The inferred drift of different lithological units delineates earthquake prone regions. Repeat surveys keep an eye on the changes in the geomagnetic field prior to (and after) an earthquake forewarning a cataclysmic seismic event. New MOs at Kolhapur, Silchar, Andaman and Nicobar islands will monitor co-seismic signals. GPS is also used for detection of ionospheric perturbations (TEC) associated with earthquakes. Two seismological observatories are established at Rewa and Kolhapur, and multi-sensor geophysical observatories at Shillong (Assam) and Port Blair (Andaman and Nicobar islands). The data will be telemetered from these and other observatories either at a fixed timing or in continuous mode to a central location, where the complete history of local and regional changes of geomagnetic and geoelectric field will be continuously analysed and collated with other precursory data to arrive at medium and short-term forecasts of geomagnetic and earthquake activity.

Magnetic and petrological data will be collected over regions, where the GPS data depict maximum plate movements. Resistivity measurements can be taken in regions of maximum stress built up. Gravity and magnetic model will be constructed to evolve comprehensive lithospheric dynamics with ultimate objective of understanding earthquake processes. Areas thus covered will include not only the Himalayan region but also cover seismically interesting areas such as Bhadrachalam and Ongole/Bapatla regions of Andhra Pradesh, parts of Maharashtra, Gujarat, Madhya Pradesh and Karnataka.

Palaeoseismology is fast gaining importance. Continued seismic activity and loss to life and property has put strain on geoscientists and Government to garner short-term earthquake prediction. Apart from all the techniques enumerated above, prediction can be done by signatures left behind by the past earthquakes in lakes and other soft sediments. The dating of these events gives their cyclicity.

IV. Palaeomagnetism

The mechanism that causes ‘polarity reversal’ of the EMF needs considerable thinking. There is no *a priori* reason why the EMF should have a particular polarity and there is no fundamental reason why its polarity reversal should not change. Reversal has been explained in a number of ways, each of which lacks rigour. One amongst these suggests fluctuations in the distribution of the cyclic convection cells in the core to lead to an abrupt reversal. Such cells are randomly distributed and a reversal occurs when they attain a critical configuration. The retardation/acceleration of the convection due to the interaction at the core-mantle boundary leads to the observed secular changes in the magnetic field. Monitoring the secular change at several strategic locations on the globe can thus provide inputs to understand the electrodynamics of the Earth's interior, which is otherwise inaccessible. It is of paramount importance to make better use of the palaeomagnetic probe to understand magnetic properties of rocks. Special emphasis is envisaged to map details of the magnetic field during polarity transition, discover more excursions (aborted reversals), mapping systematic departures from the simple dipole structure, magnetic polarity stratigraphy and the acquisition of sedimentary magnetization, secular variation, palaeointensity and short-term geomagnetic field behaviour.

The Indian plate has migrated a phenomenal distance, whose journey can be redrafted from magnetic signatures retained in the magnetizable materials in rocks. The understanding of its tectonic history has considerably increased with the palaeomagnetic studies of south and central Indian dykes, Deccan basaltic rocks, and the Himalayan syntaxial sandstones/dolomites. The studies have placed the upper and lower limits on Deccan volcanic activity and established that the episode lasted for just about half a million years or so. Earlier it was conjectured that this volcanic exhalation continued for quite a long time. Some of the controversial problems on migratory path of the Indian plate will be taken up for definitive answers. Efforts are on to draw apparent polar wander path of India for better correlation with the one available internationally. Palaeomagnetism will also be applied to learn the history of microplates and other crustal fragments caught in evolving plate margins. There is a need to start research to get seafloor information on stratigraphy and tectonics.

The geomagnetic polarity record is central to the construction of geological timescale, and provides the principal tool for calibration of marine and terrestrial biozones. The polarity record continues to evolve with the recognition of brief polarity subchrons, and the limitations to this evolution may lie with sedimentary recording processes. In the Indian context, magnetostratigraphy of important sedimetary basins, e.g. intermontane Kashmir and petroliferous basins will be worked out, and a thorough comparison of biostratigraphic sequences made. Data-base will come from deep-sea piston cores from Bay of Bengal fans and neighbouring oceans. Rock samples from Tethys Himalayas and other regions will be investigated. Their chemical and radiometric analysis will be undertaken along with the preserved records of palaeomagnetic field.

V. Environmental Geomagnetism

Subtle changes in magnetic mineralogy, grain size, oxidation degree, stoichiometry and strain state will be interpreted in terms of changing provenance areas, climatic conditions, diagenetic regimes, and anthropogenic pollution. The interpretive value can be enhanced by utilizing several magnetic proxies together with a few geochemical proxies. Increased use of magnetic proxies is foreseen as a consequence of methodological advances in unravelling mixed magnetic mineralogy and further establishment of more quantitatively based parameters.

The ubiquity and environmental sensitivity of the magnetic mineralogies provide a record of past and present environmental and climate change process. Hence, most environmental magnetic studies aptly focus on environmental interpretations. The measurements are also routinely used because of importance of environmental magnetism to the range of palaeomagnetic application including tectonic, geochronological and geomagnetic investigations. Data-base will come from sediments and sedimentary rocks.

The value of mineral magnetic parameters derives both from the close links apparent between mineral magnetic assemblages and soil forming processes and from the relative ease with which these assemblages can be characterized and distinguished even in very low concentrations well beyond the reach of other techniques. Mineral magnetic studies of particulate flux between terrestrial and fresh-water systems will offer new insights into climatic variation and its bearing on erosion and sedimentation. A pattern underlying the Indian monsoon has been deciphered, the resolution of which needs datasets of longer-term, which can be provided by mineral magnetic studies. Most of the sediment-based studies has revealed LGM, YD and brought about an awareness of the climatic conditions prevailing over the Himalayan, western, eastern and central portions of India during the last 20 ka. Magnetomineralogical S-ratio is found to reflect monsoon quite well. Monsoonal changes can be predicted and planned for future. A new study is planned to know how climate change is magnetically reflected along the marine to continental (nonmarine) gradient in areas of India and its immediate surroundings. In addition, the need of making an inventory of existing magnetic methods and procedures, and selecting the most appropriate ones for SW Indian monsoon study is already underway for further optimization of mineral magnetic approach.

The apparent link between mineral magnetic properties and particulate pollution as a result of fossil-fuel combustion and other industrial processes, points the way to one urgent area of future study. The emphasis has been on the use of magnetic measurements in monitoring heavy metal deposition. Equally, the recent interest in the use of fly ash as a source of magnetite makes magnetic characterization especially important since a quantifiable relationship may be expected between magnetic susceptibility or SIRM and crystalline Fe concentration in any given fly ash. Heavy metal pollution correlates with magnetic enhancement, encouraging the use of magnetic measurements as a surrogate monitoring technique and suggesting that variations in heavy metal contents and mineral magnetic parameters indicative of changes in magnetic assemblages will be of value in identifying aerosol and sediment sources. Metropolitan areas like Mumbai, Navi Mumbai, Thane and Raigad districts, are screened for identification of pollution levels of contaminants in materials of roadside dusts, soils, lake sediments and mangroves using mineral magnetic techniques. This is now a fast emerging field and can be extended to other metropolises. Data-base will come from beach sands, roadside tree leaves, atmospheric dusts, fly ash, and mudflat and mangrove core samples.

10.2 CURRENT TRENDS/GEOMAGNETISM

Looking beyond the aforementioned themes, further applications in the influence of geomagnetic activity on weather and climate, archaeomagnetism, biomagnetism, medical and forensic science, are not difficult to envisage. Idenitification of inhaled particulate type and sources should be possible from lung tissue measurements as well as characterization of work environments in terms of aerosol loadings and types.

I. Geomagnetic Activity, Weather/Climate

One of enigmatic field of research is the influence of geomagnetic activity on weather and climate. Although most of the currents associated with the geomagnetic field flow at altitudes far above the regions which control the weather, intriguing results have emanated from studies of the solar features, geomagnetic activity and meteorological parameters like the atmospheric circulation patterns, drought conditions, rainfall, glaciations, etc. As it is unimaginable that solar activity can provide the requisite amount of energy for the meteorological changes, scientists are on the look out to identify some form of catalyst that can trigger large scale transfer of energy from the Sun and the interplanetary space through the upper atmosphere to the lower altitude regions.

II. Secular Variation/Archaeomagnetism

High-sedimentation-rate marine and lake sediments have revolutionized our understanding of the behaviour of the geomagnetic field. The presence of ubiquitous short-lived (~5 ka duration) polarity subchrons or excursions in the Brunhes and Matuyama chrons, coupled with high-quality relative palaeointensity frequently accompanied by short-lived perturbations of the direction of the geomagnetic field is now well established. The study of sub-Milankovitch-scale palaeoclimate changes requires approximate stratigraphic correlation at millennial-scale resolution. As correlation at this scale is not easily achieved through traditional isotopic methods, geomagnetic palaeointensity records and associated directional perturbations can well serve this purpose. In addition, understanding this short-term geomagnetic behaviour is important for constraining models of the geodynamo. There are two immediate prospects for improving the dating of lake sediments. The establishment of regional records of directions and intensities requires spatial corrections to be applied to individual determinations. Such ‘master curves’ for directional studies are now available for several areas, particularly in Europe, the Middle East, Japan, Australia and America. India does not have a SV master curve and needs to develop it from lake sediments and archaeological materials. The potential of mineral magnetism in archaeological studies has begun to emerge from sites in south India, hence archaeological dating of ancient sites in Maharashtra and Gujarat should be taken up. This development will permit dating of palaeomagnetic secular variation intensity records by matching with previously established SV time series.

III. Biomagnetism

Geomagnetic study over the years has been responsible for many innovative technologies in instrumentation to detect weaker and weakest magnetic fields. Today, magnetometers based on superconducting materials can detect fluctuations with astounding accuracy (one in a million). This has led to a new branch of application called 'biomagnetism'. Birds and animals use magnetic field for their direction finding, although little is known about their physical and biological skills in using this field. Many experimental studies are being carried out to understand this phenomenon. Developments in biomagnetism have also been significant even though a causal linkage still remains elusive. Association between number of heart attacks or epilepsy and condition of the Earth's magnetic environment; effect of geomagnetic storms on migratory birds do bring out association between man and his geomagnetic environment, though the linkage in quantitative terms is missing. Consequently biomagnetism has not attained the status of an exact science. Hence, biomagnetism will surely be the next big step in environmental geomagnetic studies. Specifically, there is a need to establish the quantitative significance of bacterial magnetite in depositional environments, to specify more fully the conditions under which authigenic and diagenetic processes are magnetically significant. In the course of time, it is hoped to have the health check and diagnosis of human ailments based only on passive magnetic measurements. Magnetotherapy is, nowadays, an accepted alternative for several physiological problems.

As the Earth is, but an ordinary planet of the solar system and as the Sun is, but an insignificant star in the milky way galaxy, it is the fond hope of geomagneticians that their scientific quest will pave way for a better understanding of the entire Universe, not just this planet Earth. The latest initiation of regional centres at places like Tirunelveli and Allahabad, dedicated to upper atmospheric studies and solid Earth geomagnetism respectively, can go a long way in planning and executing research pertaining to fundamental and applied aspects with the express aim of using the know-how for the overall betterment of the society we live in.