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software architecture; no model to predict how it might become unstable. Therefore, he invited the mathematicians to start work in order to formulate a model which can help analyse, understand and control its behaviour.

Enrique G. Reyes (USA) addressed some aspects of the modern geometrical study of different equations where formal differential geometry, moving frame techniques and integrable systems play an important role. T. T. That (USA) discussed some important theorems in Lie algebras and presented some generalized theorems in lie groups and lie algebras. B. P. Sinha (IIT, Kharagpur) presented an overview on high performance computing system. A. Sengupta (IIT, Kanpur) introduced a new mathematical approach to the understanding of chaos with the help of graphical convergence of a set of functions to a *maximally ill-posed problem*. He explained this concept to give a physical understanding of the nature of chaos and also to suggest a plausible explanation to the question of why a natural system tends to be chaotic.

Detailed algorithmic studies were presented by S. K. Dey (USA) to modify Perturbed Functional Iterations (PFI) and to make it suitable in a distributed computing environment. He also discussed the applications of the algorithm to large scale tridiagonal nonlinear systems which are frequently found in flow models. In another lecture, S. K. Dey presented in an interesting way the mathematical modelling of mind in mediation. Through mathematical modelling he showed that meditation could lead mind to a state where stress is absolutely zero. B. R. Sutherland (Canada) discussed the reflections and stability of large amplitude at which internal waves were in uniform shear and derived an analytic theory for predicting the amplitude for transmission through a reflecting level should occur. H. Taniguchi (Japan) put forward proofs of the existence of the d-embedding of an affine space into a projective space. R. Saigal (USA) presented a saddle point algorithm for solving Semi-Definite Programming (SDP) problems. D. K. Bhattacharya (Kolkata) discussed

some aspects of mathematical modelling of mercury poisoning and optimal therapeutic dose to control the effect of various diseases. He considered a mathematical model giving the growth equations of the fish and the fisherman and determined the optimal therapeutic dose from a control theoretic standpoint. S. K. Sen (IISc, Bangalore) discussed the accuracy of numerical solutions of linear differential equations and presented the inconsistency index and error bounds while obtaining numerical solutions of linear differential equations with the help of linear programming techniques.

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Storm-substorm relationship*

The conference on storm-substorm relationship was sponsored by The American Geophysical Union (AGU) and co-sponsored by many Indian and international organizations. About 100 scientists working in the field of geomagnetism, aeronomy, space physics, plasma physics and solar-terrestrial physics participated in this Conference. There were 44 foreign delegates from USA, Japan, Germany, China, Indonesia, Poland, Russia, Finland, United Kingdom and Sweden.

In his inaugural address, V. S. Ramamurthy (DST) emphasized the need for global cooperation and collaboration toward predictions of geomagnetic storms and substorms

resulting from solar disturbances. As one becomes increasingly dependent on the space-related technologies, awareness about the adverse effects of geomagnetic storms on the technological systems both in space and on earth has become an important issue. He urged the international space and earth scientific community to undertake collaborative projects to study the delicate balance between life on earth and forces of nature.

Geomagnetic storms are phenomena occurring in space, high in the upper atmosphere as opposed to the well-known thunderstorms that occur in the lower atmosphere. Eruptive processes, like coronal mass ejections (CMEs) and solar flares, occurring on the Sun can distort the earth's magnetosphere and cause geomagnetic storms. The magnetosphere is formed by the interaction of the solar wind, an ionized gas consisting essentially of electrons and protons, and the geomagnetic field. Substorms

are a process during which a significant amount of energy stored in the Earth's magnetotail is released primarily into the polar ionosphere and into the inner magnetosphere. This release of energy is known to occur in the form of plasma kinetic energy in an explosive manner. Broadly speaking, large perturbations of the Earth's space environment can be called geomagnetic or space storms.

The scientific program of the conference was organized into 10 oral sessions and 2 poster sessions and one panel discussion session. There were no parallel sessions. Various topics concerning storm-substorm relationships, such as interplanetary drivers, modelling the magnetosphere, plasma processes in the magnetosphere-ionosphere system related to storms and substorms, the response of the ionosphere and the atmosphere to geomagnetic storms and substorms, and prediction techniques for space weather were discussed extensively during these sessions.

*Indian Institute of Geomagnetism, Mumbai hosted an International Chapman Conference on 'Storm-Substorm Relationship' at Holiday Resort of Fariyas Hotel, Lonavala, from 12 to 16 March 2001.

A highlight of the conference was a special session at the Alibag Observatory (established in 1904 as a successor to Colaba Observatory started in 1826), one of the oldest geomagnetic observatories in the world. Together Colaba and Alibag Observatories have maintained an uninterrupted chain of magnetic data since 1841 till today, and their data have been used for the earliest studies of geomagnetic disturbances. A tour of the facilities left a deep impression of the depth and care with which the observatory facilities have been planned and built nearly 100 years ago and the extent of data and other contributions it has made to the international efforts for the understanding of geomagnetic disturbances. The session at Alibag was focussed on 'Ground and spacecraft-based observations: Experiences and future outlook'. Presentations by representatives of space research organizations in many countries, including the Living With a Star (LWS) and Solar Probe, two programmes of NASA on sun-earth connection theme, detailed the strategy for upcoming and future missions, and outlined the key issues that would be addressed directly. A brief summary of the important scientific outcomes of the Conference is given below.

The relationship between storms and substorms is one of the cornerstones of sun-earth connection. Significant advances in the understanding of the magnetosphere are expected when extensive *in situ* data from a large number of spacecrafts located in different regions of the coupled solar wind-magnetosphere system become available. At present the ISTP/GGS spacecraft located in the key regions of the magnetosphere, viz. solar wind, magnetotail, auroral regions and inner magnetosphere, have been giving many exciting results. Among these, the Energetic Neutral Atoms (ENA) imaging has clearly shown the potential of providing a new understanding. Studies of ion injections during storm-time substorms and isolated substorms using data from geosynchronous satellites and ENA imagers on Polar spacecraft have shown significant differences. The ring current is usually represented by the Dst index, which is expected to be influenced by other currents in the magnetosphere and is thus often considered not to be a very accurate measure of the

ring current. However, one of the new results presented at the conference showed that the ENA images, which are sensitive only to the ring current, show good agreement with the Dst index. Another study using ENA measurements by instruments aboard Geotail showed signatures consistent with substorm injections. The potential of ENA as an effective diagnostic tool for the magnetosphere is now quite compelling and the more extensive ENA measurements by the IMAGE spacecraft are bound to yield much more interesting data. These results have prompted some to suggest that a new index based on ENA data be used as a measure of the ring current.

The flow of energy, momentum and mass is the key to the understanding of sun-earth connection in general and storm-substorm relationship in particular. Often the flow from the magnetosphere to the interplanetary space, as opposed to the commonly recognized flow from the solar wind to the magnetosphere, is ignored. However, significant fractions of the particles injected on the night side magnetosphere during substorm expansions were shown to leave the magnetosphere before being trapped to form the ring current. These issues, in particular the important role of oxygen ions in the development of storm time ring current, were discussed in the conference. It is still a puzzle how the oxygen ions are extracted from the ionosphere, energized to few hundreds keV energies and then injected into the ring current. There is a strong need for multi-spacecraft measurements, along with ground-based techniques, for understanding the physical mechanism of extraction, energization and injection of ionospheric oxygen ions into the storm-time ring current, as well as of the decay of the ring current.

The ground-based measurements, such as all-sky camera images and magnetometer data, have been in the forefront of research in the storm-substorm relationship. These data continue to give new insights, especially with the use of the data from the worldwide chain of mid- and low-latitude stations. A study using these data indicates that the substorms lead to partial ring currents while the ring current develops in response to the solar wind induced electric field. It was also pointed out that substorms during the

initial phase of geomagnetic storms and those during the main phase are different in terms of the location where the corresponding auroral electrojets are most intense, indicating that the generation mechanisms differ between the two types of substorms. Empirical modeling of storm-substorm relationship using geomagnetic indices such as Dst and AL, and solar wind data have given many insights. A new model of the AL dependence on Dst, in which the nature of the dependence varies with the amplitude of AL, has given high correlations. Such models can be used to isolate the relative roles of the relevant physical processes.

The first evidence of storms without substorms was presented in the conference. Although this result is still being debated, it is a significant one in view of the long held view that there are no storms without substorms under steady solar wind conditions. Clearly more extensive and detailed studies are needed to reach the verdict on this key issue, and this result has provided the stimulus for such studies.

Storms and substorms are central to space weather, a topic of increasing interest to our technology-based society. Among the space weather effects of geomagnetic activity, the so-called killer electrons have been one of the leading issues. Studies using polar and sample data presented at the conference showed the hardening of the electron spectra, indicating *in situ* energization. A radial diffusion model of energetic electrons, in which the diffusion coefficients have been obtained by fitting to the past data, have shown good correlations with observations of these events, which occur mainly during the recovery phase of storms. Large-scale modeling efforts using empirical techniques, theory and simulations of the magnetosphere are needed to understand the different physical processes leading to the energization of electrons to MeV energies. This will lead to a proper assessment, and mitigation thereof, of the harmful effects of energetic particles on spacecraft charging, command anomalies, communication breakdowns, effects on astronauts and passengers on jet planes, and other damages during geomagnetically disturbed conditions.

The conference concluded with a panel discussion session co-chaired by Y. Kamide (Japan) with many well-

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known experts in the field, as panel members. The panelists presented their views on the important results and future outlook. There was clear consensus on many leading issues and at the same time significant divergence of views on some others. The most notable disagreement perhaps, is on the inter-relationship between convection, substorms and storms, in particular the key role of magnetospheric convection to storm development. Some felt that substorms are not essential to storm development but are merely incidental. There were, however, other strong

views that storms and substorms influence each other, especially considering the closeness of the locations where both of them originate and the efficient electrodynamic coupling among the different regions of the magnetosphere. The participants called for concerted efforts to determine the role of oxygen ions and wave-particle interactions on the ring current decay for a better understanding of the recovery phase of the geomagnetic storms. On space weather related issues, the evaluation of the performances of the current prediction techniques with high forecasting ability,

such as those based on neural network, nonlinear dynamics, etc. was recommended.

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IN CONVERSATION

An interview with Murli Manohar Joshi, Minister for Human Resource Development, Science and Technology and Ocean Development

An academic and a politician, Murli Manohar Joshi, retired Professor of Physics at Allahabad University, holds a unique position to fashion India's Science and Technology (S&T) policy for the future. Specialized in spectroscopy, he has authored nearly 100 research articles and a similar number of articles of general interest. He is a keen advocate for 'application of S&T as an equal-opportunity developmental strategy for all' in India.

Following are excerpts from an interview with the minister, held on 28 June 2001.

S&T in India and sustainable consumption

India is a developing country. India aspires to be counted on as a developed nation, though strictly neither third world nor first world. Also, India could have a population of about 1.7 billion people within the lifetime of our children. So, under your leadership, can India, having a cross-section of both ultrahigh technology sectors and the poorest of the poor, look forward to a S&T policy that is unique to our requirements. Do you feel the need for a

creative, unique S&T policy and not a 'copy-cat agenda'?

On the extent of my conceptualization of sustainable consumption, the latest example was the announcement of 'Simputer'. The Simputer combines two things; firstly, science in the service of the common man and secondly, making it affordable and available to the poor. What I am saying about sustainable consumption is that we should look to the poor as a market, rather than the rich. When you make unsustainable consumption or high-rise consumption, then you are primarily looking to the market of the rich people, the rich who can afford, who have surplus money and, who can purchase whatever goods are presented to them. My idea is, development, – 'yes', S&T, – 'yes'; but it must be used in the service of the common man. An example is of the Simputer, which is very affordable and it works for the common man, even for the illiterate. There are also differences, based on the concept that if it is a developing nation the fee (license fee) would be very small, while for a developed nation the fee would be very high. So, we are addressing the association of S&T with different layers of society in

a manner that those who can afford, get more, and those who cannot, get helped. In this way, an attempt is to create a scientific egalitarian society, a society that is both scientific and egalitarian, where technology is within the reach of everyone.

With reference to your speech delivered on 11 May 2000 entitled 'Sustainable consumption: A new paradigm', would your vision for the future (of S&T) integrate sustainable consumption into the basic weave and fabric of our society?

Now, the Planning Commission has formed a Committee on Sustainable Consumption with R. A. Mashelkar as the Chairman. This is the approach which is now being taken by a very large number of scientists. Last year, some eighty scientists from eighty countries gathered in Tokyo and discussed sustainable consumption. Scientists have now started adopting it. In biotechnology, I have been focusing on this for the past three years that we work on diseases primarily affecting the masses, such as malaria, kala azar, TB and also HIV. Again, giving more nutrition to the poor by introducing