[Monitoring our environment is necessary for an understanding of the processes and phenomena that occur in the oceans, in the atmosphere and on the surface of the earth, in forecasting the weather and in assessing the impact man's activities have on the environment. The development and manufacture of instruments required for this purpose and for the exploration of gas, oil and mineral resources should therefore have a high priority. In view of the revolutionary developments in recent years in geoscientific instruments brought about by advances in electronics and computer sciences and the advent of a variety of instrument platforms on earth and in space, and recognizing the need for co-ordinating the development within the country of geoscientific instruments for monitoring the environment and for geophysical prospecting, the Government of India appointed a series of committees in the seventies to review the position and identify various existing lacunae. The main findings were that while adequate technical competence exists in the country for the requisite R & D effort required for the development of the latest instruments and techniques, their translation into equipment and systems required for exploration and non-exploration purposes remains unfulfilled. The author, who was the chairman of the CoST and NCST committees and expert groups on geoscientific instruments, summarizes the work done in the country in the development and manufacture of geoscientific instruments, surveys the recent trends in geoscientific instrumentation, identifies the technological gaps that exist in the country and suggests future courses of action. Ed.]

GEOSCIENTIFIC INSTRUMENTATION

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1. Introduction

WHEN we speak of our environment, we usually refer to the earth, its atmosphere and the oceans, the lithosphere, the atmosphere and the hydrosphere. The geoscientific parameters that define them vary from one domain to the other. A study of the solid earth parameters such as its size, shape, mass and moment of inertia, the gravitational and magnetic fields and various local anomalies and other properties enables us not only in understanding the structure of the earth but in the possible prediction of earthquakes and in the exploration of gas, oil and mineral resources. A study of the land surface, the oceans and the atmosphere enables us to understand the processes and phenomena that occur in them and in forecasting the weather. The complexity and wide distribution of meteorological elements in various scales of motion make the complete measurement of the atmosphere an impossibility, and it becomes necessary to resort to sampling techniques. Similar problems exist in studying the hydrosphere parameters in the oceans, lakes, rivers, underground waters and in the atmosphere.

The measurement of geoscientific elements involves recording data in large quantities, at high rates over long periods of time with high precision or a combination of these. Furthermore, it may be necessary to analyse data quickly so that adjustments can be made to obtain optimal response to current conditions. Meteorological information is in addition highly perishable and has a useful life time of 12 hours at the longest, except for climatological purposes, with a time period as short as ten minutes for tornado sightings.

2. Recent Trends in Instrumentation

Our knowledge of the earth and its environment was and in many areas is still dangerously inadequate. Data gathered in the past provided only the most rudimentary notions of the atmosphere, the earth and the undersea world. We knew very little of the dynamics of the atmosphere and the sea in motion, although our ability to predict the motions of the atmosphere, the sea and the solid earth affects our daily lives and the success and failure of almost all our daily activities.

The advent of the earth satellites and their use as observation platforms and the spectacular developments in electronics and computer sciences in the last two decades in measurement, data gathering and processing, have revolutionized the entire field of geoscientific measurements. It is not only possible now to monitor the entire earth and its environment from instrument platforms on earth and in space continuously, but the process has been incredibly simplified by the use of a single sensor mounted on a satellite which needs neither routine maintenance nor periodic attention. The danger of degradation of the sensor, however, exists, with the instrument out of reach for repair or replacement.

Satellites have also been used for data collection from multiple earth platforms. One of the major problems in large area coverage of *in-situ* measurements involving many unmanned sensor carrying platforms, located on land, the oceans or the atmosphere, fixed in position or moving, is communication and the key component of such a data collecting system is the satellite, which also serves as the navigator for moving platforms.

For the interpretation of the data obtained from space platforms, ground truth information is however, necessary. Demand for the whole range of geoscientific instruments used at the earth's surface and below therefore continues to grow.

As a result of these remarkable advances in techniques of measurement and data processing, the growth rate of the instrument, computer and data processing industry during the last two decades and particularly during the last five years has been startling, on any scale of comparison and continues to exceed the growth rate of the technically oriented industries of the world.

3. Present State of the Art

The present state of the art in geoscientific instrumentation can be most clearly demonstrated by examples of measurement on land, sea and air and from space.

3.1. *Automation in meteorological observations*

Because of the complexity and wide distribution of meteorological elements, it is necessary to consider the measuring instrument, the parameter measured, the environment in which the instrument must function, the exposure of the instrument, network spacing and the frequency of sampling in a system, if useful and representative data are to be obtained; also the operator of the instrument and user of the data. In all this, automation and the use of electronic computers, large, medium and small, play an important role and have speeded up the rapid transition of meteorological measurements from a descriptive and inexact science to an exact physical science based on mathematical physics. Meteorological measurements have been considerably simplified by the extensive use of

(a) automatic weather stations on land and sea, reporting by landline and radio to data collecting centres,
(b) automation of upper air measurements by the introduction of minicomputers for reduction of radiosonde and radio-wind data;
(c) automation of weather radar data by the use of minicomputers to process video information from weather radars; and
(d) automatic collection and processing of hydrologic data such as precipitation and water level, from river catchment areas, using telemetering rain and river gauges and minicomputers.

Thus data acquisition and initial data processing has been considerably simplified by the extensive use of microprocessors and minicomputers. The latest development in handling the large amount of highly perishable surface and upper air information which pour in continuously from thousands of stations around the world is an integrated approach to information handling and management problems in meteorology. The Automation of Field Operations and Services, being tried out in the USA, will communicate the data faster with fewer errors, sort out data, alert the forecaster to special warnings and provide different presentations for his use, simplify the mechanics of forecast preparation and speed up dissemination of the forecast.

3.2. *Instrument platforms*

Ground platforms are most commonly used both for *in-situ* and remote measurements. Airborne platforms include balloons, rockets and aircraft and fill the gap between the ground platforms and space platforms. Ocean platforms range from submarines and surface ships, deep diving research vehicles such as bathyscaphes, ocean buoys, both anchored and free-floating, submerged experimental laboratories, location marked submerged instruments and special-purpose oceanographic research vessels. Space platforms are unique in geoscientific measurements and have been used for nearly two decades now as invaluable tools for remote sensing of the earth and its environment, weather forecating, space studies and communications.

Instrument platforms normally carry a number of auxiliary systems with which the instrument must interface, and which provide information, signals and controls essential to the conduct of the experiment. These include communications and telemetry systems for remotely operated platforms, power supplies and positioning systems, including propulsion, navigation, guidance and control.

Almost all meteorological and hydrological parameters that can be remotely sensed are now measured as a routine by orbiting and geostationary satellites. The satellites use scanning radiometers in the visible, infrared and microwave regions and provide not only cloud imagery but vertical profiles of temperature, humidity, ozone and other trace gases, winds, electrical activity etc.

Specially instrumented aircraft can serve just as well as satellites in data gathering and processing for all geoscientific investigations and have been extensively used as such for both *in-situ* and remote measurements and in exploration surveys. Aircraft are valuable research platforms in view of their mobility and altitude capability.

Instrumented special purpose ships are completely floating laboratories like instrumented aircraft. Buoys are equally fundamental to measuring programmes and a variety of anchored and drifting instrumented buoys has entered the main stream of ocean measurement programmes. The need of global weather and estuarine pollution observations will make buoys even more common. Buoys being unmanned are free of overhead costs, legal requirements and acoustic backgrounds normally associated with manned ships and propelled devices. Although buoys usually float on the surface, they can rest on the bottom or float at mid-depth. Free falling and free ascending sondebuoys provide new types of measurements.

In the early days of geoscientific instrumentation, attention was focussed mainly on the development of sensors. Today with observation platforms like aircraft and satellite which can generate millions of bits of information in a very short period of time, the instrument designer has to consider not only the sensor but the user and the problem of data processing before he builds an instrument, if a user is to be able to interpret the data collected within his life time.

4. Technological Gaps

The examples given above illustrate graphically the state of the art in the world today in geoscientific measurement techniques and instruments. India does not use automation in meteorological observation systems except in the current weather instrument systems used at airports and in telemetering raingauges installed in a few river catchment areas on an experimental basis to telemeter rainfall information. A beginning has been made in the use of automation in processing radar and upper air data. India receives satellite data collected by USA and USSR satellites and obtains television and microwave information from its own satellite Bhaskara, launched in 1980 for earth observations. The National Remote Sensing Agency operates instrumented aircraft for remote and *in situ* measurements in the atmosphere and for extensive geophysical prospecting. India has one oceanographic ship Gaveshini of limited range and has used naval ships for international oceanographic and meteorological observation programmes. The Ocean Science and Technology Agency has plans to obtain two more research ships in the near future. Meteorological and oceanographic buoys with tide and wave telemetering systems and multi-signal data acquisition systems, have been developed and used near the west coast by oceanographic and fisheries research institutes. Ocean buoys have also been used in off-shore drilling and estuarine pollution studies off Bombay.

A variety of geophysical prospecting instruments, both ground-based and airborne, from analogue and digital seismic systems and advanced logging systems and airborne mineral survey instrument systems have been developed and some used in routine surveys. Environmental pollution monitoring instruments have also been developed for network use. The India Meteorological Department and many national survey organisations manufacture in their workshops most of the instruments required for routine observations. Considerable R & D work on geoscientific instrumentation is also done in various educational institutions and universities.

The technological gaps in the country in the latest techniques of measurement and instrumentation are, however, considerable. The technological gaps in the technique of manufacture of less sophisticated instrumentation required in large numbers for routine measurements are unfortunately equally large.

A survey conducted by an Expert Group on Geoscientific Instruments appointed in 1971 by the Committee on Science and Technology (CoST) had identified the various lacunae in the development and manufacture of geoscientific instruments for exploration and non-exploration purposes. The requirements for the next decade had then been estimated as about Rs. 15 crores and the Committee had recommended that, since the country has adequate technical competence for the requisite research and development effort for the design of instruments for monitoring the environment and for geophysical prospecting:—

(1) all development programmes should be supported and encouraged in an integrated manner so that progress in all areas moves forward simultaneously

(2) the instruments developed by various R & D institutions in India and which are needed in large numbers should be passed on to a suitable organization, either in the public or private sector, for the purpose of engineering and manufacturing in the most efficient manner, conforming to the best professional standards.

Accepting the recommendations of the Expert Group, CoST appointed in 1972 a high level Committee for co-ordinating the developmental activities of various geophysical institutions in the country in the field of instrumentation. It consisted of scientists from the Geologial Survey of India (GSI), the India Meteorological Department (IMD), the Oil and Natural Gas Commission (ONGC), the Atomic Minerals Division (AMD) of the Department of Atomic Energy, the Airborne Mineral Survey and Exploration (AMSE), the National Geophysical Research Institute (NGRI), the Centre for Exploration Geophysics of the Osmania University, the Electronics Commission and the Department of Science and Technology. The Committee prepared a detailed assessment of the overall needs of the country for geoscientific instruments in the light of the exploration and exploitation programmes of the AMD, AMSE GSI, ONGC, the Survey of India, the Central Water and Power Commission, the Central Ground Water Board, the National Institute of Oceanography, State Geological Surveys and other agencies and identified areas of related R & D efforts as they existed in various organizations. But its attempts to co-ordinate these efforts and promote them on an objective basis so as to hasten the consolidation of overall instrument development and manufacturing programmes did not unfortunately succeed.

A Planning Group on Survey Instruments appointed by the NCST Panel on Marine Resources in 1972 prepared a report on marine instrumentation required for monitoring the oceans, lakes and rivers. The Development Council for Instrument Industry of the Ministry of Industry also appointed in 1974 a sub-committee on Geoscientific Instruments, which again prepared a report on the various types of geoscientific instruments required in the country during the next ten years.

So, while a considerable amount of work has been done by a series of committees to assess the national requirements for geoscientific instruments and plan their development and manufacture in an organized manner and the development of geoscientific instruments continues in various R & D organizations a considerable part of the requirements of instruments are still met by import either directly or under various aid programmes.

5. Future Course of Action

The future course of action is very clear. If we are to be independent in this vital area, we have to improve and extend the existing development capability by co-ordinating and harnessing in an effective manner the scientific and technical competence already available in the country. If development plans are governed by time-bound schedules, it should be possible to reach a stage within four to five years, wherein the import of instruments for geoscientific investigations can be eliminated. There is thus an overwhelming need to initiate a crash development programme which should involve the import of the most crucial mechanical or electronic components and special raw materials which are not at present available in the country for complex instruments which are needed in large numbers. R & D effort should aim at reducing progressively the dependence on imports through an adaptive design which would facilitate a quick change over to indigenous substitutes of these elements as and when they become available.

A major lacuna is the lack of adequate field data regarding the performance of instruments already developed by various institutions. With a captive market, excellence in instrumentation tends to be a major casualty.

This is particularly true of instruments made in departmental or in-house workshops. Instruments which are needed in large numbers and which have been developed and engineered to the required level of performance should be handed over, after adequate field trials, to a suitable organization for the purpose of mass production. Once the time-bound development and manufacturing schedule becomes operative, it should be mandatory on the different user organizations to use only instruments made in the country, wherever such instruments are available.

HEALTH HAZARD ALERT ON 2-NITRO PROPANE (2-NP) AS A SUSPECT CAUSE OF CANCER

International Occupational Safety and Health Hazard Alert System has alerted that 2-Nitro propane (CH_3–$CN(NO_2)$–CH_3) [other names: *Dimethyl* nitromethane, Isonitropropene, Nitro isopropane, Nl-Par-5-20 TM, Ni-Par-3-3-0-TM] is a hazardous chemical—a confirmed animal carcinogen and a suspect cause of cancer in humans. The permissible limit for exposure is 25 ppm which cannot be detected by odour since its detecting power by odour is 83-160 ppm and hence greater danger for exposure by the following users/processors:

Coating vynyl and epoxy paints and resins, nitrocellulose paints, chlorinated rubber paints, printing (Rotogravure and Flexographic) inks. Ship building and maintenance (Marine coatings), Furniture painting, plastic products, Adhesives, Highway Maintenance (Traffic markings), etc.

Symptoms of acute exposure are reported to be nausea, vomiting, diarrhoea, anorvexis, severe head-ache, etc. Liver and kidney systems may be affected from prolonged exposures. Symptoms of toxic hepatitis have been reported.

For guidelines of health and safety measures and further details can be had from Dr. R. P. Dambal Secretary, Electro-chemical Society of India, Indian Institute of Science, Bangalore 560 012.