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Message from Director, BARC, on the occasion of 50 years of DAE

Dear Colleagues,

It is with immense satisfaction and great pride I take this opportunity to convey my warm wishes to all of you in these glorious moments of golden jubilee celebrations of the Department of Atomic Energy (DAE). From the day of its inception, the growth of the DAE during the past five decades has been phenomenal. The country has attained self-reliance in the fields of nuclear science and technology through the relentless commitments and unstinting contributions made by the dedicated scientists and engineers of the family belonging to DAE. At this juncture, in my capacity as Director, Bhabha Atomic Research Centre, it is my proud privilege to remember the finest contributions made by BARC, the cradle of creative ideas and nurturer of science and technology in the nation, in the growth of country's nuclear energy programme in particular and also the enormous responsibilities lying ahead of us. Starting from a small R&D centre known as the Atomic Energy Establishment Trombay (AEET) which was formally established in the year 1957 under the leadership of legendary Dr.Homi J. Bhabha, in whose name the centre has been renamed since 1967, BARC is presently the premier institute in science and technology in India and perhaps the largest R&D centre under a common roof in the world where widest spectrum of activities in the nuclear science and technology is being pursued.

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We are aware, Water along with 3 Es, viz., Energy, Environment and Education, are the essential pillars of the structure that support quality of life in the society in any country, particularly in the developing countries with large population like ours. The linkage between availability of sufficient primary energy in general (and that of electricity in particular) and the economic growth of the country is established beyond doubt.

India is the world's fourth largest producer of electricity (with 1,30,000 MWe installed capacity of electrical power generation). But we are the world's second largest population of one billion plus as a result of which our per capita electricity consumption is ~ 600 KWhr/yr (which is less than one-fourth of even the world average value of 2500 KWhr/yr) compared to the figure of about 10,000 – 12,000 KWhr/yr in Organisation for Economic Cooperation and Development (OECD) countries. India's population could rise to 1.5 billion by year 2050 from the present level of 1 billion plus. Even if we have the modest target for per capita electricity consumption of about 5000-7000 KWhr/yr - which is the bare minimum required for an acceptable quality of life in a society - India has to generate electricity ~12 times more than what was produced in the year 2001-2002 (i.e., about 7500 billion KWhr in the year 2050 from the level of about 635 billion KWhr in 2001-2002).

If we have a close look at the fuel resource position in India, it is clear that we have no other option but to increase progressively the share of nuclear energy in the overall energy mix in India. So the ground reality is that for all other developing countries with large population like China, South Korea, etc., where there is a wide gap between the prevailing per capita electricity consumption and the certain minimum recommended for an acceptable quality of life in society, the growth of nuclear energy is inevitable. However, the success or otherwise of nuclear energy programme in any country does not necessarily depend on its merits – it also needs certain basic conditions to be co-existant, viz., (i) high demand of electricity to bridge the gap between the prevailing per capita electricity consumption and certain minimum per capita consumption of electricity needed for a reasonable quality of life in the society; (ii) absence of better alternate option of electricity generation to meet the energy gap; (iii) availability of advanced in-house technological base to exploit nuclear energy; and finally (iv) support from the people/Government to cope with the energy demand in the country through nuclear energy programme.

We, at the Department of Atomic Energy (DAE) in general and Bhabha Atomic Research Centre (BARC) in particular, are committed to exploit nuclear science and technology for :

- *(a) improving the quality of life of our 1 billion plus population,*
- *(b) staying at the forefront of nuclear science and technology in order to retain the place of honour and dignity for India amongst the world community; and*
- *(c) of course, the task of enhancing the national security.*

For improving the quality of life in the society, our primary mandates are to:

- *(i) provide energy security by way of generation of nuclear power that is safe, reliable and economical in addition to its eco-friendliness; and*
- *(ii) enhance use of radioisotopes and radiation technology in non-power sector for health care (which also includes nuclear desalination), agriculture and food preservation, isotope hydrology and industrial applications.*

It has been recognized since our independence that India's national development would have to be driven by science and technology. As Dr Bhabha said, "what the developed countries have and the under developed countries lack is modern science and an economy based on modern technology".

It has also been recognized that it is not possible to transform the economy of a *country on the basis of the modern technology that has been developed elsewhere without establishing at the same time modern science and technology in the country. Right from the beginning, therefore, dependence on indigenous nuclear resources and self-reliance have been assigned highest priority in our R&D programme for both power and non-power generation sectors.*

But, harnessing nuclear energy for its utilization either in nuclear power sector or non-power sector calls for development of a host of technologies which demands high level of excellence in both basic sciences and engineering sciences to address various issues involved in complex and multi-disciplinary nature of nuclear science and technology.

To enable the scientists and engineers at BARC to pursue excellence in the areas of nuclear science and nuclear technology, we have built a series of research reactors/critical facilities and established all the relevant technologies required at the front-end as well as the back-end of nuclear fuel cycle needed to support the research reactors/critical facilities including the facilities for production of radioisotopes and application of radiation technology.

Our research reactors APSARA, CIRUS AND DHRUVA are all being extensively utilized for basic and applied research, isotope production, material testing and training for human resource development (which has been one of the strongest pillars of our success story).

During the process of establishing these reactors and other multidisciplinary technologies, we have succeeded in establishing various groups of professional excellence or what we call 'centres of excellence' in all major areas of basic sciences of physics, chemistry as well as bio-sciences and engineering sciences under the competent and dynamic leadership of various Group Directors.

As you are aware, the actual list of achievements in BARC is too long to be covered in totality and it would not be proper to single out a few amongst these accomplishments. However, it would be most appropriate to say that the entire spectrum of technologies required to harness nuclear energy for improving the quality of life in our society was given birth to at BARC and subsequently nurtured by utilizing its multi-disciplinary strength to bring these technologies to their maturity before being handed over for exploitation on industrial scale by various PSUs/Industrial Organizations of DAE like NPCIL, NFC, HWB, UCIL, ECIL, BRIT etc.

After decades of dedicated R&D efforts, we have succeeded in establishing our indigenous PHWR technology on a firm footing. Our 12 units of PHWRs (in addition to the first two BWRs) are operating at world class level both in terms of capacity factor (~90% average) as well as safety record. Presently, 8 more reactors are in different phases of construction in the country. We are amongst a very few countries in the world who have succeeded in achieving the comparative level of excellence in all the technologies involved in the nuclear fuel cycle, including the most complex gas centrifuge technology at the front-end and the technology for "vitrification of high level nuclear wastes" (which is needed to allay the apprehensions of common people on management of nuclear wastes) on the back-end.

Parallel to the world class performances of our indigenous PHWR system, the growth of applications of radioisotopes and radiation technology in non-power sectors in India has also been remarkable, covering a wide spectrum starting from nuclear agriculture and preservation of food on one end, to health care and industrial applications on the other end. In nuclear agriculture, in addition to earlier 23 varieties, our groundnut variety TG-37A has been identified by ICAR for commercial release recently and cultivation of groundnut varieties TAG-24 and TG-26 at North Eastern Hill State and Leh have shown encouraging results. Similarly, for food preservation, we have established recently KRUSHAK – a demo-plant at Lasalgaon, Nasik, for low dose irradiation of onion and other agricultural products, in addition to our earlier medium dose spice irradiator at Navi

Mumbai. In the area of health care, some of our latest contributions are I-125 based miniature brachy therapy source, indigenously developed state-of-the-art Co-60 based Teletherapy Unit, Medical Cyclotron – PET facility, Radiation Processed Sterile HYDROGEL for burn injuries, Digital Medical Imaging System based on Charge Coupled Device (CCD), Hygienisation of Municipal waste with Co-60 based Irradiator, induction of Nisargruna (biogas) plants etc.

India is the lead country in industrial applications of radioisotopes in Asia and Pacific Region because of our excellence in all three areas of applications : (i) use of sealed sources (γ-radiography, computer aided tomography, γ-scanning and nucleonic gauging); (ii) use of open sources as Radiotracers (e.g., for RTD measurements for process optimization in chemical, petroleum and petrochemical industry); (iii) radiation processing (using Electron Beam Accelerator, 2 MeV-20 KW-DC type) for a host of applications out of which radiation cross linked polymers/co-polymers for electrical cables/wires with improved electrical and mechanical properties (which are not possible to achieve otherwise). Very soon, we are going to add the entire range of EB-accelerators (500 KeV – 10 KW DC; 3 MeV-30 KW DC; 10 MeV-10 KW(RF) to cover the entire need of the industries.

Because of the remarkable progress in our most comprehensive programmes both in nuclear power generation sector as well as non-power sector, India is acknowledged as an advanced country as far as nuclear science and technology is concerned.

Being members of the most respected BARC family, we need to scale progressively higher heights of excellence in nuclear science and technology in order to meet the growing expectations of the people of India. While we need to develop new technologies based on creative design and innovative ideas, we also need to always stay at the forefront of all the areas of basic sciences by utilizing not only the upgraded/newly created advanced facilities being installed for this purpose at BARC, Mumbai; CAT, Indore; VECC, Kolkata; TIFR, Mumbai; but also through our participation in all major international mega projects created to pursue high levels of basic sciences on "equal partner basis" (and not any longer on "donor-recipient basis" that was prevailing earlier). In this context, I am extremely happy to make a special reference to the fact that India has been given "observer status" in the most prestigious international mega project at CERN, Geneva, where the most advanced basic sciences are planned to be pursued with facilities built on the most advanced technologies in the world. I take this opportunity to compliment the entire DAE family in general and all my colleagues from BARC in particular (whose contributions towards implementation of this mega project have been appreciated most). It is indeed heartening to note that CERN is showing progressively more and more keenness to expand the existing collaboration with BARC, especially in the area of grid computation.

Pillars of Success

Some of the important pillars behind our success story in nuclear science and technology are:

- *(i) Strong HRD programme with ever expanding linkages with academia and research institutes.*
- *(ii) Persistent policy of pursuing excellence in Basic Sciences while we pursue excellence in Engineering Sciences for Technology development work in mission mode.*
- *(iii) Highest priority to continuous upgradation of the technologies involved in the future nuclear fuel cycle for improved plant capacity factor, uprating of the plant capacity and life extension.*
- *(iv) Strong emphasis towards Research & Development activities in the areas of health, safety and environmental science in general and that of reactor safety in particular.*
- *(v) Sustained upgradation of the R&D base for advanced instrumentation and electronics to build state-of-the-art control and instrumentation systems.*

(vi) The premium we pay for the development of high performance parallel processing supercomputers (mainly for meeting in-house demands) which can be claimed to be the best in the country. ANUPAM Parallel Processing Supercomputer (ANUPAM-ARUNA with 128 processors) has already attained 360 Gigaflops of computing power on high performance Linpack benchmark. BARC Parallel Processing Supercomputers (16 different models of ANUPAM series have so far been developed) are now working at 25 different organizations outside DAE. Our supercomputer is running the operational weather codes faster at the National Centre for Monsoon Research and Weather Forecasting of DST, New Delhi, at almost one-tenth of the cost of the Cray-XMP supercomputer. We have a target to reach 1.5 Teraflops computing capacity by 2005 using about 1000 nodes of PCs available at that time.

But, we have a long way to fulfill our commitments to provide energy security to the nation on a sustainable basis. We have plans to increase the share of nuclear power from the present level of about 2.5% to about 5% by the year 2008 and then to about 10% by the year 2020 through systematic induction of about 20,000 MWe of nuclear power.

Our present generation of PHWR utilizes only about 0.5% of the total uranium fuel and our modest uranium reserves may not support more than 15,000 MWe installed capacity through existing PHWR route. That is why, our committed nuclear power of about 20,000 MWe by the year 2020 calls for induction of Fast Breeder Reactors (FBRs) to contribute about 2000 MWe and Advanced Heavy Water Reactor (to contribute about 300 MWe). In the long run, our goal is to contribute about 25% share of India's electricity generation capacity through nuclear power programme by the year 2050.

Obviously, therefore, Indian nuclear energy programme has reached a stage where the scientists and engineers of BARC, by utilizing its multi-disciplinary technological strength, must continue to stay focused for developing a host of technologies through innovate ideas and creative design in three broad areas, viz. (i) to stay tuned to the horizontal needs of our expanding PHWR/LWR programmes to take care of the much needed technology uprates, aging management, life extension, and fitness for service analyses; (ii) to shoulder substantial responsibilities for the success of our next generation PFBR by way of providing the entire requirement of necessary MOX fuel along with the fuel fabrication technology, waste management facilities, inclined nuclear fuel transfer machines, cell transfer machines and shipping cask, high temperature special sensors, validation of seismic design for reactor containment and major equipment/machineries to mention some of the major tasks. The success of our next generation Prototype Fast Breeder Reactor (PFBR) would provide the country an access to about 130 times more nuclear power from our limited uranium reserves; (iii) to develop technologies for the vertical needs of our nuclear energy programme, i.e., the technologies that are needed in the future for our nuclear energy programme based on India's vast thorium reserves (amounting to ~ one-third of world's total thorium reserve).

Keeping in mind that India has to fall back on its thorium reserves for energy security on a sustainable basis, we have the road map for introducing thorium (as ThO_2) in place of UO_2 in the blanket zone of FBRs at an appropriate growth level of installed nuclear power capacity in the second stage (because early induction of ThO_2 to replace UO_2 in the blanket zone of second stage FBR based on PuO_2 – UO_2 MOX fuel would retard the growth of nuclear power programme). However, we need to master well in advance all the technologies involved at the front-end as well as back-end of Th-233 fuel cycle at plant scale (from our existing experience at pilot scale). Accordingly, as all of you are aware, one of our major tasks in hand is to start construction of a thorium fuel based 300 MWe Advanced Heavy Water Reactor (AHWR) within two years time. Designed for 100 years of plant life, AHWR will generate

65% of the power from ThO based fuel. This reactor system (first of its kind in the world) has not only the most attractive feature of primary heat removal by natural circulation but it also incorporates host of other passive safety features that are in line with the approach being pursued world over for development of inherently safe reactor system by incorporating safety features that do not call for any human intervention or any active control devices for reactor safety. I am sure, from regulatory point of view, this reactor concept would be equally exciting because such reactors eliminate the need for any exclusion / sterilization zone and hence do not call for any planning for emergency-evacuation.

At the national level, the peer review of the Detailed Project Report (DPR) of AHWR by NPCIL Expert Committees is over and at international level AHWR has been selected for a case study at IAEA for its acceptance as per international standards for next generation advanced reactors.

In parallel, we have already taken actions to complete the R&D task involved in development of technologies needed at the front-end as well as back-end of Th-U-233 fuel cycle. In fact, from our existing position of being recognized as an advanced country in terms of our achievement in nuclear science and technology, we aspire to be the world leader in the area of utilization of thorium for harnessing nuclear energy for the benefit of mankind.

We have also plans to induct nuclear energy as primary energy source in the near future, viz., nuclear energy as source of heat for a variety of applications. For this, another innovative reactor being developed in BARC is a small capacity (~100 KW(th)) Compact High Temperature Reactor for addressing the needs of some specific applications like the need for small unattended power packs for electricity generation in remote areas that are not connected to the grid system or for production of hydrogen from H_2O *using thermo-chemical means as an environment friendly alternative to hydrocarbon fuels for our transportation sector (which has a huge burden on our import bill, in addition to the environmental concern associated with hydrocarbon fuels) or even for refinement of low grade coal and oil deposits to high grade fossil fuel. The physics design of this small vertical natural circulation type totally passive CHTR (1m D x 1m H) has been finalised with 19 fuel assemblies/channels with TRISO type coated particle fuels (where Th-U233 carbide kernel is encased by multi-layers of pyrolytic carbon and silicon carbide) with liquid metal like molten Pb or Pb/Bi eutectic, as coolant. Detailed design of various reactor systems like simulation and modeling of passive power regulation system, heat pipes, etc. are in progress.*

As our nuclear programme is expanding, our programme at the back-end of the fuel cycle deserves special attention to cope with the increasing demand from reprocessing as well as waste management facilities. Enhancing the availability factor of the existing plants at the back-end of nuclear fuel cycle (all of which are otherwise performing extremely well), through systematic induction of better technologies, capacity - uprating by way of improved process design and remote handling equipment and life extension through induction of components and control systems with better reliability have been some of our major technological challenges.

To meet this objective, reliability of certain critical equipments/components like spent fuel chopper, master slave manipulator, and servo manipulator have been improved through better design with full participation of Indian industries.

Similarly, while the Waste Immobilisation Plant (WIP), Trombay, has been operated to vitrify the high level waste (HLW) from PP, the construction of Advanced Vitrification System (AVS) at Tarapur for immobilization of high level waste using advanced Joule Melter Technology is nearing completion. After commissioning of this system by the end of the year, India would establish yet another advanced technology for vitrification of HLLW.

While we can continue for few more decades by storing the vitrified high level waste in the *interim Solid Storage Surveillance Facilities (S3F), we have accelerated our development efforts for locating a permanent storage facility for the vitrified waste in a deep geological repository.*

In this context, we have also initiated a long term programme to develop Accelerator Driven Sub-critical System (ADSS) – yet another reactor concept for future – that could be used for either (a) power generation from Thorium; or (b) production of U-233 for our third phase FBR based on ThO_2 / U-233 O_2 fuel; or (c) more importantly incineration of long-lived actinides and transmutation of long-lived fission products of present generation PHWRs to short-lived products with, say, few 100 years of half-life, thereby drastically reducing the long term activity burden of HLLWs which will go a long way to enable us to store them in near-surface burial under surveillance or make their disposal in geological repository at much reduced technological complexities depending on the half-life of the finally achieved incinerated /transmuted products. R&D work for development of special solvents and for inducting the process for partitioning of minor actinides during reprocessing operation are in progress.

We do realize the ground reality that the success or otherwise of our multidisciplinary nuclear energy programmes for taking the benefits of nuclear science and technology to the Indian society depends mainly on the availability of sufficient number of high quality trained manpower. Accordingly, we have assigned top priority to our HRD programmes. To meet our needs in terms of quality human resource, we have devised a variety of programmes for training, some at the various levels of entry to the organisation and some during the service period to tackle obsolescence. Presently, the growth of knowledge is so fast that in the field of science and technology, the half-life of knowledge base of a scientist or an engineer is about 5 years, unless it is updated regularly in order to stay at the forefront of science and technology. We are fully aware of the availability of young talents and wisdom of the faculty in the academia. We are, therefore, continuously strengthening the linkage between the DAE and academia in various ways. Through the DAE-Inter University Consortium we have opened up many of our major research facilities such as nuclear reactor, accelerator and synchrotron radiation sources for utilization by students and faculty members from the University system. Further, through the wings of our Board of Research in Nuclear Sciences (BRNS), we constantly pursue various collaborative research programmes in the most cost effective way with Universities and research institutions, which also includes setting up of major research facilities for undertaking experimental validation work that are of importance to our programme, e.g., the Department of Atomic Energy is setting up 'advanced centres of excellence' like Centre for Thermal Hydraulics for AHWR at IIT Mumbai; Centre of Knowledge base Engineering at UICT, Mumbai; National Centre for Free Radical Research, Pune etc. that are dedicated to DAE programmes. These centres not only enable DAE programmes to benefit from the expertise available with the University faculty but also provide an excellent training ground to the university students in the areas which are of interest to DAE.

On the happy moments of the Golden Jubilee Year of the Department of Atomic Energy, as a mark of our collective salutation, admiration and paying homage to our founder Dr. Homi J. Bhabha, let us rededicate ourselves to take this great R&D Centre to an enviable height of international eminence by committing ourselves to improve the quality of life in our society through progressively more and more induction of nuclear science and technology in the areas of power generation as well as non-power generation. As a part of the legacy we have inherited from Dr.Bhabha, let us accept these challenges for taking India into a position of super power through the road of vibrant economy based on sustained energy security, food security and health care.

B. Bhattacharjee
Director

REMOTE SURVEY, INSPECTION AND OPERATION WITH A MOBILE ROBOT

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Introduction

In the X-th plan, Division of Remote Handling & Robotics has taken up a project on the development of mobile robots. The urgency to build a mobile robot is felt whenever we confront a situation that requires a human being to be sent to investigate the nature, degree and cause of an actual or potential accident, and if possible, to recover, repair or defuse the situation at considerable risk to his life. It could be a radioactive spillage from a leaky valve in a reactor hall, a suspected bomb in an aircraft or a biological or chemical weapon planted in an office building. The single most important reason why we need robots is that they can be deployed in such situations to save precious human lives.

We can send a mobile robot to a remote corner of an inaccessible location for viewing, mapping, a close visual inspection (for example, looking for suspected cracks or leaks in a pipe), or even manipulation of objects (opening or closing a valve, tightening a bolt, picking up an object) in the remote environment. The inspection may also be instrumented, like measuring the temperature or the radiation level at a point, or getting an X-ray or ultrasonograph image of an object. The robots in all these cases are usually teleoperated and monitored remotely from a workstation.

A mobile robot may be wheeled, tracked, legged or a combination of some of these. While a wheeled robot can move only on relatively smooth terrain, a tracked robot can climb curbs and staircases, and a legged robot can walk over highly irregular terrain although that requires very complex coordinated control of leg motions. Wheeled robots are simple to make and ideal for indoor applications. That is why we initiated the development of a wheeled mobile robot with help from IIT Kanpur. The prototype, named SmartNav (Smart Navigator) has been completed and is shown in Figure 1. The software for its application in remote survey and inspection has also been developed.

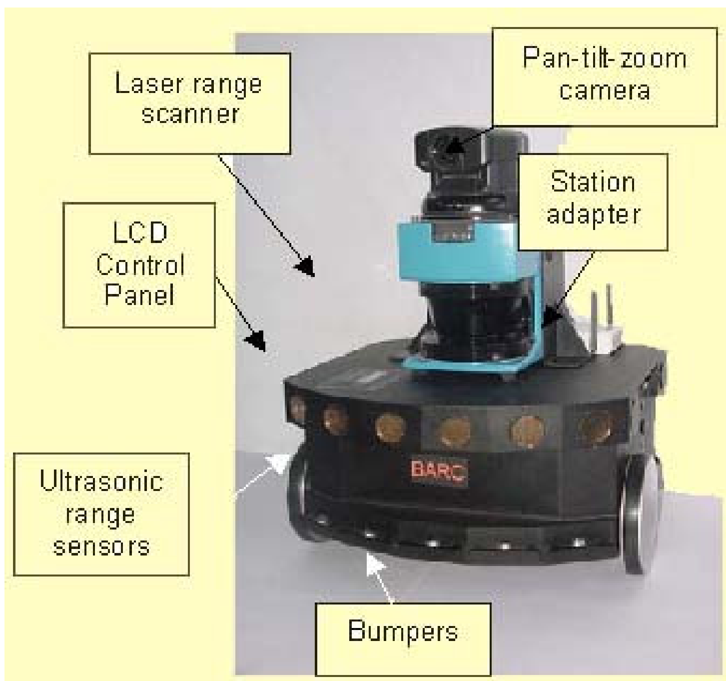

Fig. 1 Components of a mobile robot

Remote handling of radioactive materials, explosives (Explosive Ordnance Disposal) and hazardous materials forms important application areas for mobile robots. They require mounting a task specific manipulator on the mobile platform. Recently the Centre of Environment and

Explosive Safety (CEES), Delhi, approached us for the development of a suitable mobile robot that can be used remotely for removing boxes containing expired explosive fuzes from a storage room to a location where they can be safely disposed. Since this application falls in line with our projected course of development in mobile robots in the X-th plan, we agreed to build the robot for them. Design of the manipulator and the automated vehicle for this purpose is already underway.

In this article, we give a brief description of the technologies that go into building and controlling a mobile robot. First, we list the components. Then, we describe the computing architecture that is typically used in mobile robots. Next, we explain the major concerns in safe and intelligent navigation of mobile robots and outline algorithms that we have implemented to provide necessary solutions. Building a convenient and effective user interface for teleoperation is an important aspect of a mobile robot application. We describe the Graphical User Interface that we have developed for remote survey, mapping and inspection. We describe briefly the mobile robot that we are developing for CEES. In conclusion, we summarize our achievements and ongoing activities.

Components of a Mobile Robot

1. ***Drive configuration:*** A small mobile robot (see Fig.1) typically has two drive wheels for differential steering and one castor wheel for support. Depending on the ratio of the speeds of the drive wheels, the robot executes trajectories of varying curvatures – from a straight path to turn-in-place. Two DC motors with gearbox and encoders drive the wheels. Bigger mobile robots with higher payloads usually employ four or more drive wheels. For rough terrain locomotion or for climbing curbs and staircases, tracks substitute the wheels.
2. ***Motion control:*** An electronic drive circuitry provides power to the motors. A microcontroller regulates the wheel speeds by controlling the set-point voltages of the drives. Often there is also an on-board computer that runs intelligent programs to guide the robot autonomously.
3. ***Power source:*** Although they contribute significantly to the weight of the cart, rechargeable sealed batteries are preferred over an umbilical power cord for ease of operation.
4. ***Sensors:*** a) Sonar : Ultrasonic range sensors operating at a frequency of 40 kHz on time-of-flight technique measure the extent of free space around the mobile robot. Because of wide beams, the collected range data have poor angular resolution. For the same reason they have sensitivity over a larger solid angle. However, because of mirror-like reflections, sometimes sonars fail to detect even nearby inclined plane surfaces.
   b) Laser range scanner: This shoots a laser beam to measure the distance to the nearest object by measuring phase shift or time-of-flight. Because of its narrow beam, the laser-range-data has good angular resolution. With dense range data (at least one per degree), accurate to a cm, available from a scanner, one can build a fairly accurate 2-D map of the remote environment.
   c) Bumpers: Mounted all around the periphery of the vehicle, these microswitches detect physical contact of the robot with an object in the environment.
   d) Gyro/compass: Optionally used to determine the orientation of the robot.
5. ***Remote viewing & inspection***: A pan-tilt-zoom (PTZ) camera is used for this purpose. Depending on the application, there may be several such cameras mounted strategically at selected points on the mobile robot.
6. ***Wireless communication:*** The on-board computer connects to the Local-Area-Network through wireless station adapter and access point pair. In absence of an on-board computer, the microcontroller communicates

directly with a remote client computer through a radio modem. The video from the PTZ camera is also transmitted wireless. It can be received at a distance by a matching receiver and displayed live on a monitor.

Computing Architecture

Figure 2 shows a typical computing architecture in a mobile robot. The microcontroller is the heart and sometimes the sole computing element in a mobile robot. It maintains:

- Desired velocities of drive wheels in a tight control loop
- Current wheel positions from encoder signals
- Collision status from bumper micro-switches
- Sonar range data by periodically firing them and measuring the times of flight of the reflected beams.Apart from the above, an important function of a microcontroller is to receive instructions from a client computer - either the on-board PC through a serial line or a remote computer through radio modem. Most of these instructions relate to the motion of the mobile robot. Some request status information from the microcontroller.

A client computer runs high-level programs to guide the mobile robot intelligently by issuing appropriate instructions to the microcontroller. The client computer may be sitting in the mobile robot itself. This allows the Laser range scanner and pan-tilt-zoom camera to be interfaced to this computer for on-board real time processing of laser range data and video images for possible autonomous operation of the mobile robot. In this case the on-board client computer connects to the Local-Area-Network through a station adapter and makes itself available from any workstation on the LAN for monitor and control of the mobile robot. Most commercially available mobile robots meant for actual deployment however do not carry any on-board computer. The client computer in this case is a remote control console for the operator. It communicates with the microcontroller through a radio modem. Video images from the cameras on the mobile robot are received through video transmitter-receiver pairs and displayed on the control console.

For SmartNav, with a client computer sitting in the mobile robot, following are the components of the computing architecture that we have implemented for remote control and monitoring of the mobile robot:

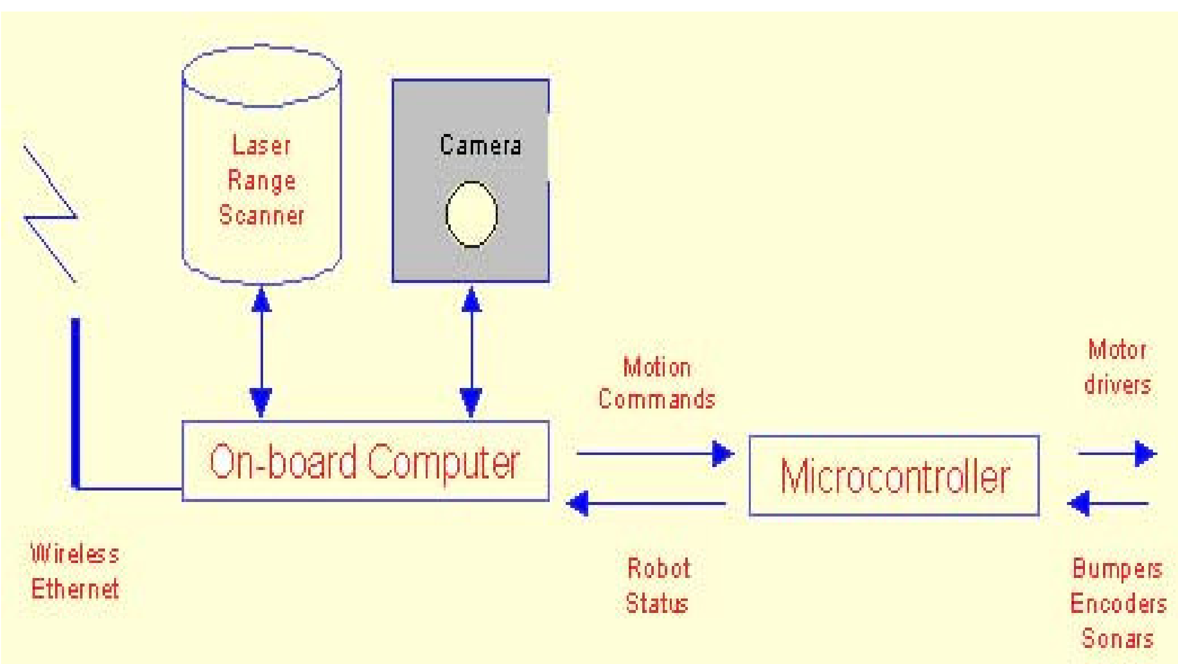

Fig. 2 Computing architecture of a mobile robot

1. A high-level robot control program (SmartNavCtl) runs on the on-board computer. It implements obstacle avoidance, path planning, localization and map building for intelligent navigation in an unknown and changing environment. It decides the appropriate course of motion of the mobile robot and issues motion commands to the microcontroller accordingly. It also receives periodic updates of the status of the robot as its commands are executed by the microcontroller.
2. The operator controls and monitors the mobile robot from a remote computer (not shown in the diagram) on the LAN transparently through a convenient graphical interface program ReNaVCon (Remote Navigation and Viewing Console). This program communicates with the on-board control program SmartNavCtl through program sockets to convey operator's commands, as also to receive the current status of the mobile robot and its environment at regular intervals to refresh the displays of the graphical interface.

Problems of Navigation

Whatever be the mechanism of locomotion of a mobile robot, the nature of problems it faces in navigating in a remote and unknown environment are more or less the same. The major solution components for reliable navigation are listed below. They form part of SmartNavCtl.

Localisation and Map Building

In order to control the robot reliably, it helps if the operator gets an online map or layout of the remote environment. The robot itself should be able to incrementally build the map using the laser range data and locate itself at every instant on that map. This is difficult in view of the fact that the position and orientation of the mobile robot, as computed from its wheel encoders, accumulate error because of wheel slippage and unevenness of the floor. This error grows indefinitely without any bounds. The resulting map, obtained by superimposing the range scans collected at each of these computed positions, soon starts looking chaotic (see Figure 3a).

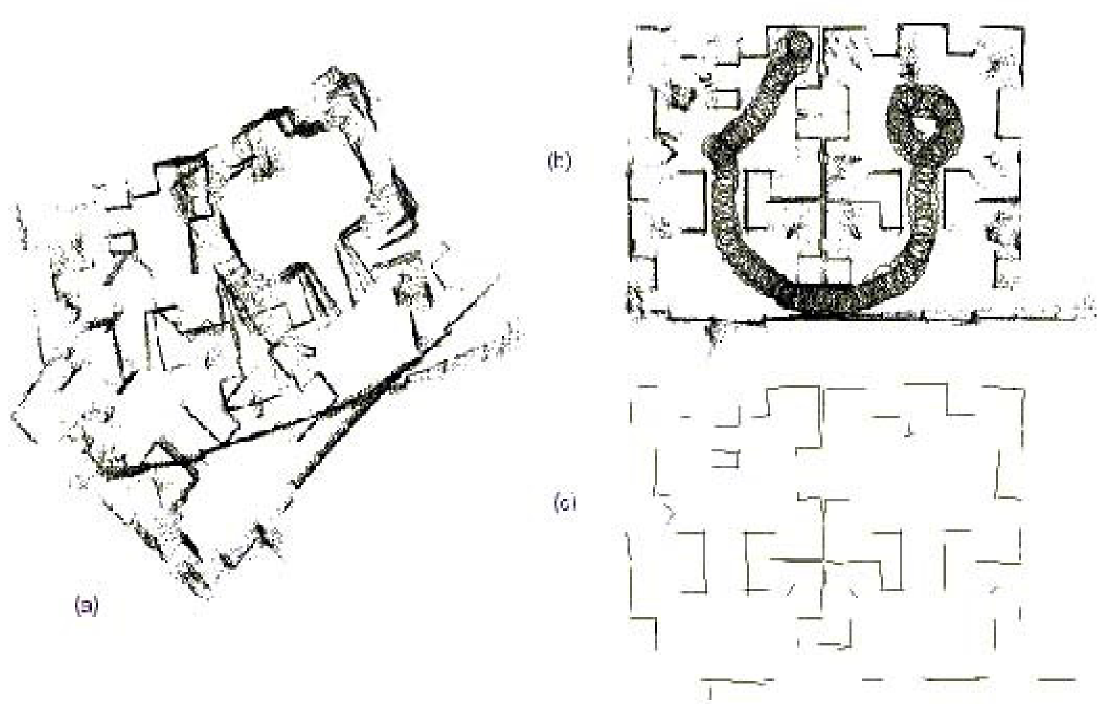

Fig. 3 (a) Map without localization, (b) Map with localization, (c) Line map used as reference for localization.

To obtain the correct map, the correct position of the mobile robot for each range scan has to be ascertained. This is achieved by matching the range scan at an unknown position with a reference map built from earlier scans. The translation and rotation needed to align the range scan with the reference map determines the change in position and orientation that the mobile robot has undergone since it moved out of the last known position. This process is called localization. By superimposing the range scans at these corrected positions, the correct map (Figure 3b) is now obtained. Figure 3c shows the corresponding line-map of the robot's environment. It serves as a reference map for matching further range scans for the purpose of localisation.

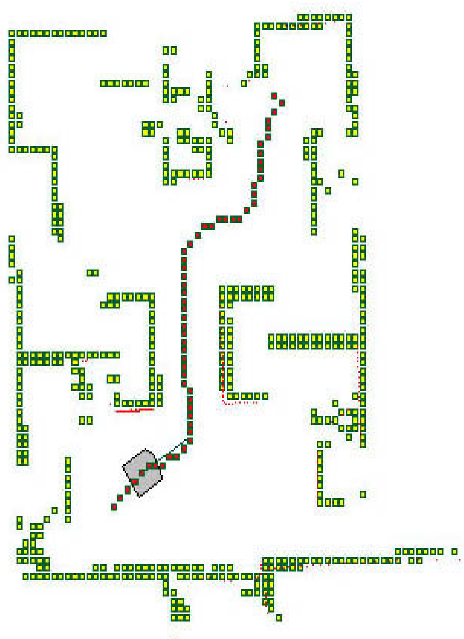

Fig. 4 Robot following a path planned on a grid map

Matching range scans with an incrementally growing reference map is the simplest approach for real-time concurrent mapping and localization. We have implemented this algorithm and it works well in office-like environments with sufficient line features. However for navigation over a larger area with diverse features, inaccuracies may creep in. There is a robust method for map-building that considers a number of scans together. It adjusts their positions and orientations in such a way as to minimize their total error. The resulting map is much better in quality, though it requires a lot more computation. We have acquired this map-building package named Scanstudio [1] and have used it to build accurate maps of the remote environment.

Path Planning

As the robot builds a map of its environment, it is in a position to plan its path for moving from one point to another within the map avoiding obstacles on the way. We have implemented the gradient navigation algorithm [2] for this purpose. In this method, the entire map area is divided into a grid of square cells. Cells that contain laser range data are declared as occupied. Others are assumed to be free. The method computes a navigation function for each cell in such a way that starting from any cell, if one just keeps following the neighboring cell with the lowest value of the function, one would eventually reach the goal cell along the lowest cost path. Computing such a navigation function is of course not trivial. It starts by assigning a zero value to the goal cell and then spreads out to reach all the cells on the grid following a wavefront algorithm. The navigation function can be made sensitive both to the intrinsic cost of a cell as well as its distance to the goal. The intrinsic cost reflects our resistance to include the cell in the path – in view of being very close to an obstacle or some other reason (e.g., the cell may be slippery, uneven or on an edge and hence less preferred). Figure 4 shows the path planned by the gradient navigation algorithm at an instant during navigation. While the robot follows this trajectory, it must localize itself intermittently and plan fresh paths to respond to any changes in the environment.

Reactive Navigation

Although path planning methods compute an efficient path to the destination, they are computation intensive and cannot be run in real time. So they are not applicable in a changing environment. Also, the planned paths are not suitable for smooth and fast tracking by a robot. In contrast, a reactive navigation system outputs motion commands directly from the current range data of the robot satisfying the robot's motion constraints. As a result, the robot systematically closes in on the destination while avoiding collision with objects in the environment. This kind of reflexive action can be learnt through examples into a back-propagation neural net [3] or encoded into a function [4] such that at any instant the robot knows what curvature to follow and at what speed. Since this function is executed many times over in a second, the robot can respond to dynamic changes in the environment very effectively. However, reactive navigation alone often results in an inefficient and unnatural path to the destination because of its lack of perspective. It can be best used to track the currently planned path as a sequence of intermediate destinations. While it follows the planned path, it remains geared to respond reflexively to any sudden changes in the environment. We have implemented and tested reactive navigation using a novel curvature activation function. Figure 3b shows the robot's trajectory under reactive navigation while it is busy building a map of the environment.

Operator's Console

Figure 5 shows the graphical interface presented by Remote Navigation and Viewing Console (ReNaVCon) program, which works as a client to SmartNavCtl. It is through this interface that the operator controls and monitors the mobile robot remotely. It has two windows – the left one shows a 2-D layout or map of the robot's environment explored so far and the other one shows the video image from the PTZ camera on the mobile robot. Below the map, there are buttons to drive the robot forward, backward, turn left, turn right etc. The robot can of course be commanded to move to a certain location on the map by left-clicking the mouse with the cursor on that location. This is by far the most convenient way of driving the robot. Once asked to move, the robot plans a path to the goal location and then keeps following the path until it reaches very close to the goal. On the way, every time it undergoes a prespecified translation or rotation, it localizes itself with respect to the map. It also updates the map in the process. The map window can be enlarged and zoomed-in to check minute details.

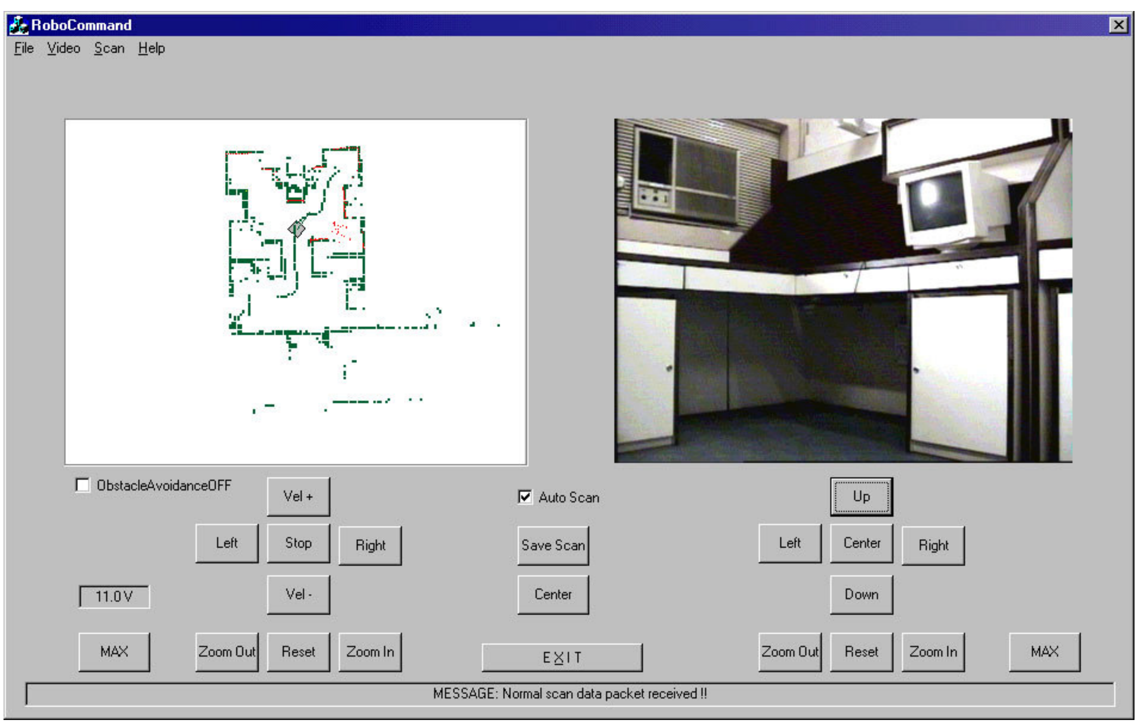

Fig. 5 User interface for remote survey and inspection

The window in the right half of the GUI displays the video image from the on-board PTZ camera. Apart from seeing the objects in front of the robot while driving, the operator can pan and tilt the camera through buttons positioned under the window to see the objects on the sides of the robot and below. Simultaneously, the map window shows with a short line from the center of the robot the direction where the camera is turned at the moment, so that the operator can relate the video image with the corresponding part of the map. This correspondence is useful for the operator to understand the spatial arrangements of the objects he sees through the camera in the remote environment. The video window also can be enlarged and its content zoomed-in for a close visual inspection of an object in the remote environment.

Experiments

We have two versions of our application program for remote survey, mapping and inspection. One of them uses the ScanStudio library, the other does not. In the first, we are exploring what all ScanStudio has to offer for map-building and localization. In the other one, we are trying to build our own routines, which run much faster and perform reasonably well in office environments. We hope, eventually our own version will work robustly in diverse environments and over larger areas.

So far our experiments have remained confined to a small area around our office. We find that with our GUI it is easy and fun to drive the robot and inspect its environment remotely. With laser range data alone to guide, the robot sometimes misses low-lying objects, like the bases of rolling chairs and hits them. The laser range finder also misses clean glass surfaces. Although that may temporarily mess up the map, the sonars prevent any collisions.

One important aspect of this application is the quality of the wireless communication between the robot and the control console. Its effectiveness over long distances depends very much on the geometry of the location, the nature of partitions and walls etc. Both our programs have been run many times over continuously for more than an hour on each occasion to test their robustness in teleoperating the robot. But for occasional snags in communication because of robot going out of range or access point needing a reset, our programs were found to be stable.

Remote Handling of Explosives

About 300 boxes containing rejected fuzes of anti-tank mines are stacked in a room at Ordnance Factory Khamaria, Jabalpur. Each box measures about 600 mm x 250 mm x 250 mm and weighs about 20 kg. These boxes have to be taken out of the room, one by one, to a location where they can be safely disposed. We are developing a remote controlled vehicle carrying a manipulator for this purpose (see Figure 6).

Fig. 6 Mobile robot for removal of boxes containing explosive fuzes.

The vehicle will be driven remotely through a RF link from a control desk primarily by watching on TV monitors the video images received from the PTZ camera units mounted on the vehicle and the manipulator. The vehicle will also have ultrasonic range sensors mounted all around its periphery to warn of potential collision situations.

With an approximate straight line map of the room prepared in advance by measurements, the vehicle will be able to locate itself with respect to this map at any point during its motion by matching the ultrasonic range data with the map [5]. Once the vehicle is positioned approximately at the desired location with the right orientation, the wheels will lock in position. The manipulator can now be used remotely to pick up a box and place it on the vehicle. The vehicle can then carry the box out of the room to a safe location for disposal.

The manipulator arm mounted on the vehicle has 4 degrees of freedom and a gripper for holding the box. The gripper is mechanically constrained to remain vertical so that the box doesn't get tilted during movement. The manipulator design is such that it can be fully accommodated within the length of the vehicle, but can reach a point 2m away from its base. The gripper and the joints of the manipulator are actuated by DC motors.

Summary and Conclusion

We have developed an application program for remote survey, mapping and inspection using a mobile robot. This application rests on several specialized software components performing map-building and localization, path planning and reactive navigation. We have also developed a mobile robot named SmartNav with help from IIT Kanpur. Recently we have taken up a project with the Centre for Environment and Explosive Safety, Delhi for the development of a mobile robot for removing boxes containing expired explosive fuzes from a storage room to a location where they can be safely disposed. We are keen to show our present systems to potential users and find out if these can be used with or without modifications in some of their applications.

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DIRECTOR, BARC, LAUNCHES A NEW RADIATION PROCESSED HYDROGEL WOUND AND INJURY DRESSING (HI-ZEL)

A function was organised by M/s ABS Medicare Pvt. Ltd., at Hotel Surya Palace, Vadodara, on 21st February 2003, to launch its maiden product HI-ZEL, a new hydrogel burn and wound dressing. The license to manufacture the dressings was granted to the company in November 2002 by Board of Radiation and Isotope Technology. The dressings produced

From left to right, Dr. Lalit Varshney, Dr Hina Hotchandani, Dr A.A Majmudar, Mr B. Bhattacharjee, Dr J.P. Mittal, Dr N. Ramamoorthy and Mr B.A Majmudar

using the radiation processing technology developed by Dr Lalit Varshney of Chemistry and Isotope Group, BARC, are getting wide acceptance in treating burns, ulcers and other difficult to heal wounds.

Mr B. Bhattacharjee, Director, BARC, was the chief guest and he released the first boxes of HI-ZEL to the dealer. Dr J.P. Mittal and Dr N. Ramamoorthy were among BARC/ BRIT luminaries present. About 125 surgeons and other prominent citizens of Baroda attended the function. Senior officers from BARC/BRIT including Mr J.K. Ghosh, Mr P. Madhusoodanan, Dr A.K.Kohli and Dr Sunil Sabharwal, graced the occasion.

Dr Lalit Varshney gave an introductory talk on HI-ZEL and its applications to the audience. Prof. Pilloo Patel, H.O.D, Surgery Department, SSG Hospital, Vadodara, presented findings about clinical trials on non-healing ulcers carried out in his department.

The Directors of ABS Medicare Pvt. Ltd, Mr B.A. Majmudar, Dr (Ms) Hina Hotchandani and Dr A.A. Majmudar talked about different aspects of the company. Mr Bhattacharjee, Dr Mittal and Dr Ramamoorthy addressed the gathering and assured M/s ABS Medicare Pvt. Ltd. of all support in the venture and asked the company to keep social objectives in mind.

"KILBIL" - A DAY CARE CENTRE FOR CHILDREN INAUGURATED

KILBIL, a day care centre for children and the first project of Anushakti Community Welfare Society(ACWS), was inaugurated on March 25, 2003 by Dr Anil Kakodkar, Chairman, AEC and Secretary, DAE. It was presided over by Mr B. Bhattacharjee, Director, BARC. The guests of honour were Dr (Ms) A.M. Samuel, Ex-Director, Bio-medical Group, BARC, and Ex-Chairperson, BARC Women's Cell, and Ms Sudha Bhave, Joint Secretary, DAE. The welcome address was given by Mr Anthony de Sa, Controller, BARC, and Chairman, Ad-Hoc Committee, ACWS.

Dr Anil Kadkokar, Chairman, Atomic Energy Commission, and Secretary to Government of India, exchanges pleasantries with a little girl during the inauguration of KILBIL

Anushakti Community Welfare Society (ACWS) is a non-governmental organization established with the approval and support of the Department of Atomic Energy for the welfare of 'Anushakti Community' which includes DAE employees and their family members.

It is in the process of being registered as a Society, and will be run by a Governing Council, in accordance with approved by-laws. It will undertake various activities and projects in the furtherance of its aims and objectives. Separate Managing Committees, under the overall supervision of the Governing Council, will manage the project.

DAE had provided an initial grant, but the mandate is for the society to be self-sufficient, and run on a no-profit-no-loss basis in the future.

KILBIL is a unique centre catering to the needs of 150 children – infants, toddlers and school-going children. It aims at providing quality care, based on modern, scientific and professional principles, to children of the families of DAE employees, especially those in which both parents are working.

Innovative features

- Planned infrastructure for developing sensori-motor coordination and related activities for infants.
- Modern educational aids, child friendly toys, interesting indoor and outdoor games to stimulate and recreate the body and mind of the nursery kids.
- Carefully planned facilities for school-going children to make their stay in the centre proactive, productive and pleasurable.
- A well equipped library, educative multimedia kits and scientific experiment kits to convey the young to far horizons.
- Qualified staff to cater to a holistic development of the child which aims to foster social skills for adaptation, communication, innovation and creativity.

Dr Anil Kakodkar, Chairman, AEC, Mr B. Bhattacharjee, Director, BARC, Mr Anthony de Sa and other dignitaries have a look at the facilities at KILBIL

- The centre will function through an interactive approach among parents, experts and management.

IAEA/RCA REGIONAL TRAINING WORKSHOP

IAEA/RCA Regional Training Workshop on "Tracers in Oil Field Investigations" was organised by the Isotope Applications Division (IAD), BARC, in collaboration with Oil and Natural Gas Commission (ONGC), Ahmedabad, during March 3-14, 2003. During the first week, the Workshop was organised at Hotel Parle International, Mumbai, and during the second week, at Hotel Fortune Landmark, Ahmedabad and Institute of Reservoir Studies, Ahmedabad. Dr Gursharan Singh, Head, Isotope Applications Division, BARC, was the Workshop Director and Dr Prabuddha Jain from ONGC was the Workshop Coordinator.

Dr Gursharan Singh, Director of the Workshop and Head, IAD, BARC addressing the audience. Others on the dais are (from left to right) : Mr Y.B. Sinha, Director (Exploration), ONGC, Mr B. Bhattacharjee, Director, BARC, Dr K. Raghuraman, RCA National Representative and Dr Prabuddha Jain, Course Co-ordinator, ONGC

The Workshop was formally inaugurated by Mr B. Bhattacharjee, Director, BARC, on March 3, 2003 at Hotel Parle International, Mumbai. The Workshop was attended by 12 overseas participants, two each from Bangladesh, China, Vietnam and Thailand, one each from Indonesia, Malaysia, Philippines and Myanmar, and four from India. In addition, there were 3 observers from India. Dr Tor Bjornstad from Norway and Dr Joseph Shekhung Tang from Australia were the IAEA experts who delivered lectures in the Workshop.

Dr Tor Bjornstad delivered lectures on tracer technology, basic principles of radioactivity and their applications in oil field investigations. Dr Joseph Shekhung Tang delivered lectures on various applications of radiotracer techniques in oil fields and modelling of tracer data. The Workshop gave a good overview of tracer applications in oil field investigations.

The Workshop also included a visit to Institute of Reservoir Studies, Ahmedabad, where laboratory experiments were conducted. Participants presented the status of the tracer technology as applied in Oil Field Investigations in their respective countries. During the presentation, the participants shared their experience and extensive discussions took place. The course was formally closed on March 14, 2003. This was followed by distribution of participation certificates by the course Director to all the participants.

FORTHCOMING CONFERENCE

India's limited natural uranium reserves (in contrast to its vast thorium resources) necessitates a three stage nuclear power programme. In the first stage, natural uranium oxide is used to fuel indigenously designed and constructed PHWRs to produce power. The plutonium extracted from PHWR spent fuel would be used in the second stage of the programme to fuel Fast Breeder Reactors (FBR) which could convert depleted uranium (and later thorium) into more plutonium (or U-233). The third stage of the programme would be based on utilization of U-233 and thorium. The whole programme has been envisaged based on spent fuel reprocessing and closing the fuel cycle by recycling the fissile material.

IGCAR has completed the design and technology development for the 500 MWe Prototype Fast Breeder Reactor and obtained the necessary clearances to launch this project. The facilities to reprocess the high burnup mixed carbide fuel from FBTR are ready for operation. Thus, it emerges as appropriate place to review the status of the work in the country on Nuclear Fuel Cycle Technologies with emphasis on Closing the Fuel Cycle.

The three-day conference, beginning from December 17, 2003, will consist of invited talks by experts and specialists in the field. In addition, it is planned to have contributed papers to be presented in Poster Sessions. The contributed papers will be accepted after peer review.

Duiring the conference, a session devoted to the INS Awards scheme and presentations by the award winners has been planned.

The INSAC-2003 & BRNS : Nuclear Fuel Cycle-1 conference has the theme "Nuclear Fuel Cycle Technologies : Closing the Fuel Cycle".

The conference would cover the whole gamut of technologies associated with the nuclear fuel cycle. The areas to be covered include :

- Uranium and thorium exploration
- Ore mining and processing
- Nuclear fuel production
- Fuel performance
- Fuel reprocessing
- Nuclear waste management
- Alternative fuel cycle
- Fuel cycle innovations
- Safety and regulation
- Fuel cycle economics

Further details are available on the link "seminars" at the website http://www.igcar.ernet.in and from Secretary, Technical Programme Committee, INSAC-2003 & BRNS : Nuclear Fuel Cycle-1, Dr P.R. Vasudeva Rao, AD, CG, Indira Gandhi Centre for Atomic Research, Kalpakkam 603 102 Ph : +91-4114 - 280229; Fax : +91-4114 - 280065
Email : vasu@igcar.ernet.in

Satellite Conference

A satellite conference on "Materials and Technologies for Nuclear Fuel Cycle" is being organised by Kalpakkam and Chennai Chapters of Indian Institute of Metals and Kalpakkam Chapter of INS. The conference would have significant participation from the Industry and would cover areas such as materials, robotics, instrumentation etc. The conference aims to strengthen academia, research and industry participation on topics related to nuclear fuel cycle. To enable interested participants to attend both events, the conference will be held at Chennai during December 15-16, 2003, just before INSAC-2003 & BRNS: Nuclear Fuel Cycle -1.

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भा.प. अ. केंद्र के वैज्ञानिकों को सम्मान / BARC SCIENTISTS HONOURED

- डॉ. जय पाल मित्तल, प्रतिष्ठित वैज्ञानिक तथा अध्यक्ष, रासायनिक एवं आइसोटोप वर्ग, भाभा परमाणु अनुसंधान केंद्र को विज्ञान तथा प्रौद्योगिकी के क्षेत्र में उत्कृष्ट उपलब्धियों पर कॉउसिल ऑफ साइन्स एन्ड टेक्नॉलोजी, उत्तर प्रदेश के द्वारा "विज्ञान गौरव सम्मान "

(2002-03) से सम्मानित किया गया। विज्ञान गौरव सम्मान पुरस्कार में एक लाख रुपये की राशि, स्मारिका, शाल तथा प्रशस्ति-पत्र निहित है। यह पुरस्कार डॉ. मित्तल को लखनऊ, में 16 अगस्त 2003 को कॉउंसिल ऑफ साइन्स एन्ड टेक्नॉलोजी के कार्यालय में उत्तर प्रदेश के कॉउंसिल ऑफ साइन्स एन्ड टेक्नॉलोजी के माननीय मंत्री के द्वारा प्रदान किया गया।

Dr Jai Pal Mittal, Distinguished Scientist and Director, Chemistry & Isotope Group, BARC was conferred the VIGYAN GAURAV SAMMAN Award (2002-03) by Council of Science & Technology, U.P., on his outstanding achievements in the field of Science and Technology. The Vigyan Gaurav Samman consists of Rs 1 lakh in cash, a memento, a shawl and a citation. The award was given by Honourable Minister, Science & Technology, Government of U.P., on August 16, 2003 at the Office of Council of Science and Technology, at Lucknow, U.P.

- श्रीमती बिरजालक्ष्मी दास, अल्प सक्रिय विकिरण अध्ययन अनुभाग, भाभा परमाणु अनुसंधान केंद्र, को जीव विकिरण क्षेत्र में प्रमुख योगदान को मान्यता देने के लिए वर्ष 2002 का इन्डियन एसोसियेशन ऑफ रेडियेशन प्रोटेक्शन (IARP) के द्वारा संस्थापित प्रतिष्ठित डॉ. गोपाल-अयंगर युवा वैज्ञानिक पुरस्कार से सम्मानित किया गया। यह पुरस्कार इन्हें एक पदक तथा प्रशस्ति-पत्र के रूप में भाभा परमाणु अनुसंधान केंद्र के आदरणीय निदेशक श्री. बी. भट्टाचारजी के द्वारा मार्च 5-7, 2003 के दौरान IGCAR, कलपक्कम में आयोजित 26वें (IARP) सम्मेलन में प्रदान किया गया। पिछले एक दशक से श्रीमती दास अल्प-स्तर आयनों में परिवर्तित विकिरण का जीव विज्ञान सम्बंधी मानव जाति पर प्रभाव, जो केरल तट के उच्च-स्तरीय मोनोज़ाइट विकिरण क्षेत्र में स्थित हैं, का अन्वेषण करने में व्यस्त रहीं। इनके श्रेय में कई प्रसिद्व राष्ट्रीय तथा अन्तर्राष्ट्रीय पत्रिकाओं में प्रकाशित लेख भी हैं।

Ms Birajalaxmi Das of Low Level Radiation Studies Section, BARC, has been awarded the Dr Gopal-Ayengar Young Scientist award for the year 2002, instituted by Indian Association of Radiation Protection (IARP), in recognition of her outstanding contribution in the field of Radiation Biology. This award carries a medal and a citation and was presented by Mr B. Bhattacharjee, Director, BARC, during the 26th IARP Conference held at IGCAR, Kalpakkam, during March 5-7, 2003. For the past one decade, she has been involved in investigating the biological effects of low-level ionizing radiation on human population living in monazite bearing High Background Radiation areas of Kerala Coast. She has to her credit several publications in reputed national and international journals.

- डॉ. संगीता, क्रिस्टल प्रोद्योगिकी अनुभाग, TPPED, को एकांकी क्रिस्टल की वृद्धि एवं विकास के चरित्रीकरण में प्रमुख योगदान के लिए "काउंसल ऑफ साइन्स एन्ड टेक्नॉलोजी " उत्तर प्रदेश की ओर से राष्ट्रीय स्तर पर "विज्ञान रत्न सम्मान " पुरस्कार से सम्मानित किया गया । पुरस्कार में इन्हें 50,000/ रुपये की राशि, एक स्मारिका तथा एक प्रशस्ति-पत्र दिया गया।

Dr Sangeeta of Crystal Technology Section, TPPED, BARC, has been awarded the VIGYAN RATNA SAMMAN award of Council of Science & Technology, U.P., for her outstanding contributions to the development of technology for the single crystal growth and characterization of optical crystals on national level. The award consists of cash amount of Rs. 50,000/-, a memento and a citation.

- श्रीमती ए.ए.बेनर्जी एवं श्री आर.प्रसाद, ईंधन रसायनिकी प्रभाग, भाभा परमाणु अनुसंधान केंद्र ने गोरखपुर विश्वविद्यालय के रसायनिक विभाग में मार्च 23-25 के दौरान आयोजित पोस्टर अधिवेशन के राष्ट्रीय सम्मेलन में थरमोडाइनामिक्स एन्ड रियक्शन डाइनामिक्स पर " गिब्ज़ फ्री एनर्जी ऑफ केल्शियम रोडाइट बाइ सोलिड स्टेट गाल्वेनिक सेल " शीर्षक का शोध-पत्र प्रस्तुत किया, जिसको सम्मेलन में पुरस्कार के लिये तीसरे स्थान पर घोषित किया गया।

Ms A.A. Banerjee and Mr R. Prasad of Fuel Chemistry Division, BARC, presented a paper entitled, "Gibbs Free Energy of Calcium Rhodite by Solid State Galvanic Cell" in the poster session of the National Seminar on Thermodynamics and Reaction Dynamics held at Department of Chemistry, Gorakhpur University, during March 23-25, 2003, and the poster has been adjudged for the third position in the seminar.

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