Gallelio in Seventeenth Century recognised the importance of relevant measurements to make paradigm shifts in evolution of civilization. He motivated generations to come, to do relevant measurements howsoever difficult these may be. Michelson, through the works of his lifetime, delivered the message that accuracy and reliability of an important measurement such as ‘velocity of light’ are the foundations on which science and technology of future is built. Over the years and through several dedicated workers, it has emerged that measurements (which and to what accuracy) is not trivial and requires analytical mind and collected expertise to correlate with diagnosis and predict performance. Health care has identified the importance of relevant measurements to a greater extent than engineering industries. However expanding frontiers of technologies (space, automobile, aerospace, nuclear, infrastructure, deep seas exploration and harvesting, deep mining, etc. etc.) put mega emphasis on new design, materials and performance in steady state and accidental conditions. Risks are difficult to assess even when we combine the best of analytical, experimental and evolutionary experiences. Challenges are further made complex due to lack of ability to predict ‘black swan’ and ‘fat tail’ scenarios resulting in catastrophic accidents of high adverse impact such as Gulf of Mexico, Fukushima, Bhopal, etc. The unpredictability is enhanced, by factors of magnitude, due to lack of safety culture (sometimes knowingly by management) and watching the slippery slopes by the teams without determined efforts to correct the culture of lack of ethics, safety, technology competence, etc. and acting in collusion with management for short term gains.

This paper focuses on health monitoring based on measurements combined with analysis and knowledge base harnessed through comprehensive asset management package. It is argued
that Project Management (PM) and Asset Management (AM) in synergy have the potency to deliver an effective life cycle management with high performance and low risks.

Health Monitoring (HM) is the process of implementing a damage detection and characterization strategy for critical engineering structures and components. HM is emerging as an inevitable technology to enable engineers, plant operators, bankers and insuring agencies to improve the safety, reliability, financial profitability, strategy and assess risks. The area has attracted immense attention especially in the sectors such as nuclear, aerospace, oil exploration, etc. in process industries such as petrochemical and steel and infrastructure such as bridges, high rise structures, stacks and towers. With the onset of globalization and liberalization, and increased stringency of codal specifications, extensive emphasis is being placed on continued plant operations, minimum of down times and avoidance of accidents. It is also being realized that failures especially in aging plants and structures can be catastrophic resulting in losses of personnel and assets. Managements prefer a steady state performance. However in practice such performances are seldom realized. Plants have planned and unplanned outages and in some cases catastrophic accidents. A glance at the history of accidents such as Challenger, space shuttle, USA, Concord aircraft, UK, Bhopal pesticide plant, India, Gulf of Mexico, USA, Fukushima Nuclear Plant, Japan, etc. clearly indicate that accidents are really not random but these have causative patterns and some common messages. These can be due to deficiencies in design, material, quality management, safety, etc. Plant outages and accidents are usually a forward chain of events starting from simple causative factors that are either overlooked or not known due to ignorance of existing experiences. In very few situations, accidents happen due to new damage mechanism and catch the organization by a major surprise. It is now well realized world over that a paradigm shift is necessary to reduce outages and prevent catastrophes that can prove to be disastrous and destroy companies in addition to causing major losses. It is in this context that performance life cycle assessment assumes predominance and importance.

In the present day world of advanced technologies, right from the stage of design through fabrication and operation, the concept of excellence and innovation is being attempted due to high degree of global competitiveness. However, grey areas that still persist in all industries and have been proved by the catastrophic failures such as the Gulf of Mexico or Fukushima nuclear accident, in recent times is the absence of a coherent team work, use of knowledge base and lack of competent motivated and ethical management and team. The R & D and Total
Quality Management teams need to be synergized with the operations and the inspections teams. A well thought of structured and integrated approach involving top management including finance is essential to reduce risks & derive the best out of costly assets. A paradigm shift in which performance life cycle is coupled with the asset and knowledge management and symbiotically integrated on a digital platform through a total quality management approach needs to be realised. This approach has been envisaged by us for an advanced sodium cooled fast reactor; a sustainable nuclear energy system. This presentation dwells on innovative health monitoring through advanced NDE coupled with asset and knowledge management to enhance the safety and reliability and also reduce plant down times and risks due to accidents.

Performance life cycle management tends to integrate the observations of the plant operators on the operating parameters with the results of the inservice inspection teams on the status of the defects and condition of the components. Probabilistic assessment using risk management analysis on the remnant life of the component and or plant is definitely being realised as complementary to deterministic approach especially in low probability high risk accidents. An important and inevitable aspect of life cycle management is health monitoring which provides the state of the component; be it unacceptable dimensions, leaks, stresses, degradation due to corrosion, growth of defect and in many circumstances, synergy of many of these combined with creep, fatigue etc. Conventionally, predictive condition management approaches have been primary means of health monitoring. With the advent of innovative and advanced sensors, instrumentation and electronics, online health monitoring has gained enhanced importance and confidence, in addition to inspections during shut downs. the motivation for the online health monitoring is to prevent routine maintenance from interrupting long-term continuous plant operation. The advent of advanced online monitoring coupled with analytical and numerical modeling has a broader impact, and amounts to a paradigm shift in maintenance strategy from outage-based maintenance to continuous real-time monitoring of operational and structural integrity. Indeed, monitoring data bases will provide a foundation for diagnostics and prognostics (i.e., predictive) capabilities that detect component degradation prior to failure, thus allowing for proactive rather that reactive maintenance strategies.

The heart of any condition management based approach is Non Destructive Evaluation. At the authors’ centre, a variety of innovative NDE sensors and techniques have been successfully developed and used for in service inspection and condition management. In special cases robotic devices and carriers have also been designed and developed for ensuring the
healthiness of critical welds and components. These are combined with in depth analysis of measurements, robust correlation with performance and risks of accidents.

In a complex technology like fast reactors (a technology for energy security of the world, in a sustainable manner) wherein the core and structural components are subjected to environments such as high temperatures and radiation fluences (gamma and neutron), ensuring the integrity especially when we need the reactors to operate for longer lives such as 60 years and above assumes importance and poses credible challenges. Health monitoring primarily combines a variety of sensing technologies for observing a structure / system over a time using periodical sample, dynamic response measurements through a variety of sensing technologies, extraction of characteristics pertaining to damage mechanisms from these measurements and analysis of these characteristics and comparing the same with the base line data or previous inspection data to determine the current health and predict the performance of the crucial safety structures.

Relevant essential pre-requisitions for a successful health monitoring process are the availability of an asset and infrastructure management system. Asset and infrastructure management system essentially involves the consolidation of all the inspection reports, testing reports, pre-NDT reports, data pertaining to pre-services of the qualifications which is forming the basis and base line for all future comparisons. It can be considered as a finger-print of a structure just before the plant or a structure is put into operation. Bharatiya Nabhikiya Vidyut Nigam Limited and Indira Gandhi Centre for Atomic Research which are close to completing 500 MWe sodium cooled fast spectrum reactor, have synthesized a comprehensive knowledge base and utilized innovative applications in concepts of HM and asset management. An asset and infrastructure management system based on an open platform has been successfully developed. Difference between conventional asset management system and our system is the integration of the knowledge heuristics during the project planning and implementation, analysis, rationale of decision making especially on deviations, etc. thus making this as a valuable knowledge management system for taking right decision at crucial junctures, important for enhancing performance, avoiding accidents and in worst scenario mitigating risk of catastrophic failure by flagging the concerns and providing choices of solutions in a graded fashion.

At IGCAR, a multi disciplinary approach, combining robotics with indigenously designed advanced sensors and transducers, wireless sensors, etc., integrated through a network of embedded measurements have been optimized for the health monitoring of critical components and structures of sodium cooled spectrum fast reactor. We give a few illustrative examples. A
fiber optic based bragg grating temperature sensor with instrumentation has been successfully developed in collaboration with Central Glass and Ceramics Research Institute and implemented for online monitoring in a sodium loop. Health Monitoring primarily consists of sensing and processing elements. We dwell on novel relevant measurements related to dimensions, structures, temperature gradients, evolution of deficiencies (leaks, corrosion, cracks etc., which are important for energy system namely sodium cooled fast reactor). A few examples are given to highlight the cross-fertilization of science based technology to other demanding applications in other sectors of industries, health care, cultural heritage etc. One of the main challenges in the reliable analysis of the measurements is the poor signal to noise ratio leading to inadequate assessment of performances. The signals can be corrupted by noises due to a variety of sources such as electromagnetic interferences, movement of other heavy machines, inherent fluctuations etc. At IGCAR, a variety of signal and image processing analysis and methodologies has already been developed for signal analysis, qualification and quantification from the sensors. The main challenges of HM, on such structures are demands placed on the sensors for robust and reliable performances over a long span of time in hostile environments.

This presentation would focus on the challenges faced during the development and implementation of a robust health monitoring system and unique asset and infrastructure management system. A few successful spin off applications in other industries and society are highlighted to give a message that rewards of science are in enhancing linkages with society to deliver better quality of life on this planet.