MEETING REPORTS

SUMMARY OF THE 14TH IEEE INTERNATIONAL CONFERENCE ON PLASMA SCIENCE, ARLINGTON, VIRGINIA, JUNE 1-3, 1987

INTRODUCTION

The 1987 Institute of Electrical and Electronics Engineers (IEEE) International Conference on Plasma Science was the 14th in a series of annual conferences that began in 1974. Total attendance at the conference was 453, including 37 attendees from 11 foreign countries. National laboratories (40%), universities (40%), and industry (20%) were represented at this 3-day conference.

Each day the technical program began with a plenary session review talk followed by parallel poster and oral sessions. A total of 335 abstracts, including 8 postdeadline, from 17 countries were submitted. These included 178 oral sessions, of which 51 were invited, and 157 poster presentations.

The plenary sessions focused on fusion, plasma accelerators, and plasma chemistry. The status of the U.S. magnetic fusion program was reviewed by J. F. Clarke [Office of Fusion Energy, U.S. Department of Energy (DOE)]. A review of plasma-based high-energy accelerators was presented by T. C. Katsouleas [University of California, Los Angeles (UCLA)]. A review talk on chemical and physical reactions under thermal plasma conditions was given by P. Fauchais (University of Limoges, France).

A broad spectrum of plasma science and application topics was included in the technical program. For this report, the program is divided into seven general topics: basic plasma science, fusion, space plasmas, magnetohydrodynamics (MHD), plasma chemistry, plasma diagnostics, and plasma applications. A variety of diverse applications enhanced the program. New technical areas include free electron lasers, plasma chemistry and processing, X-ray lasers, and plasma-based accelerators.

BASIC PLASMA SCIENCE

This topic includes basic plasma phenomena, waves and instabilities, solid-state plasmas, and gaseous electronics and its application to arc technology.

Basic plasma phenomena papers discussed discharge and sheath effects in plasmas, plasma/magnetic field interactions, and high-frequency wave/plasma interactions. For discharges, the concept of dynamic chaos was applied successfully in modeling parallel plate and magnetron discharges. It was shown that the electrical resistance of a diffuse discharge can be changed by illuminating the discharge with a pulsed infrared laser. For sheaths, numerical simulations were used to show that Kelvin-Helmholtz vortices become destabilized in the sheath set up when a magnetized plasma is adjacent to a wall. For plasma/magnetic field interactions, experiments were described where the tearing of a thin current sheet into magnetic islands is observed; the nonlinear dependence of the plasma conductivity tensor on current is observed, and plasmoids injected across magnetic fields are sometimes stopped by plasmas confined by the magnetic field. Another paper described how some features of magnetic helicity injection can be interpreted in terms of the canonical momentum of a single particle. For wave/plasma interactions, the breakdown of the atmosphere by high-power microwaves and the creation of anomalous friction on plasma particles by electrostatic turbulence were discussed.

Papers concerning plasma waves and instabilities were in three general areas:

1. wave/bounded plasma interactions
2. solitons in plasmas
3. instabilities and turbulence.

In area 1, the transient reflection of a wave from a suddenly created plasma was studied, and control theory was applied to problems of electromagnetic wave/bounded plasma interactions. In area 2, the behavior of solitons in an inhomogeneous plasma was considered, and experimental results on spherical ion acoustic solitons were presented. In area 3, various topics, such as magnetic fluctuations and resistive drift instabilities in tokamaks, diffusion in drift-wave turbulence, and fluctuation diagnostics, were discussed. Finally, a variational method of a cross-field amplifier was derived.

A tutorial session of five invited talks on solid-state plasmas was arranged to introduce this topic to plasma physicists. These talks presented the theory of solid-state plasmas and the elements of the topic that underlie state-of-the-art microelectronics and optoelectronics.

Gaseous electronics deals with fundamental processes in electrical discharges, while arc technology focuses on the application of these discharges to switching, plasma processing, etc. The technological potential for plasma physics in this low-energy area was evaluated in an invited talk by K. U. Riemann (University of Bochum, Federal Republic of Germany). Papers in this area reflected an increasing interest in diffuse discharges, in electrode phenomena in glow and arc discharges, and in effects not in local thermodynamic equilibrium (LTE) and nonlinear effects in arc discharges. For diffuse discharges, transient phenomena, steady-state characteristics, and discharge kinetics were discussed. Other papers included cathode fall modeling in glow discharges, erosion phenomena in high-current arc discharges, and electrode-affected recovery effects in gas-blown spark gaps.

FUSION

Tokamak and stellarator research was highlighted by two invited papers—"Progress in Tokamak Research" by H. P. Furth [Princeton University (PU)] and "Review of Stellarator Research World Wide" by J. L. Shohet (University of Wisconsin). These talks provided comprehensive overviews of progress in their respective approaches to fusion.

Additional tokamak papers presented device design studies of super-high-field tokamaks, a fusion ignition experiment based on a single-turn-coil tokamak, and a university-level design for a small low-aspect-ratio tokamak. Other papers discussed nonlinear MHD stability theory and a comparison of experiment to theory on pellet ablation for fueling. Experiments on the Tokamak Fusion Test Reactor (TFTR) described the determination of burnup fraction, delayed neutron counting systems, and low-voltage startup. Neutral beam injection experiments on the TFTR were described by L. R. Grisham (PU). Four separate beam lines inject up to 20 MW of deuterium beam energy at 120 keV in 0.5-s pulses. Central electron and ion temperatures of 20 keV and 6 to 7 keV, respectively, and total neutron yields of 10^6 were demonstrated.

For stellarators, a variety of papers from the Wisconsin Stellarator-Torsatron Laboratory discussed transport coefficients and plasma fluctuations. Also, the theory of a tokamak-stellarator hybrid plasma was described.

For light-ion-beam fusion, there is interest in developing intense high-purity Li^+ beams. The production of 60 to 90% pure Li^+ beams from lithium and lithium nitrate surfaces was reported for a magnetically insulated ion diode operating at ~ 700 kV and 30 kA. However, the mechanism for ion production in this source is not understood. Two experimental approaches to vaporize and ionize a thin lithium layer were reported. A dye laser tuned to the 670.8-nm resonance line of lithium produced 10^{16} lithium ion/cm^2 for 500 mJ/cm^2 of dye laser energy in a 1.8-μs pulse. Alternatively, a 400-ns pulsed surface discharge source producing ~150 MW of soft X rays (10 to 100 eV) was described. A system of these discharges could illuminate lithium at 1 MW/cm^2 and 250 mJ/cm^2.

There were several papers on spheromaks and reversed-field pinches (RFPs). Spheromak plasmas show a surprising tendency to act as objects having a structural integrity. Measurements and theory relating to the injection and decay of magnetic helicity (a measure of linking of field lines) and to the overall energy balance in spheromaks were reported. Attempts to accelerate such plasmas were described along with numerical modeling of the acceleration process. Results from RFP experiments at Culham Laboratory and at GA Technologies were presented. Progress in experiments with an unconventional (segmented shell, noncircular) RFP was reported. Stabilization and heating of compact toroids by energetic electrons have been suggested, and work on producing such hot electron rings was reported.

SPACE PLASMAS

Our understanding of space plasmas has changed considerably during the last decade as a result of *in situ* measurements of plasmas in the earth's ionosphere, cometary plasmas, planetary magnetospheres, and recent discoveries of helical and filamentary plasma structures in the galaxy and in extragalactic objects. In particular, Birkeland (field-aligned) currents, double layers, and field-aligned electric fields are now known to play a far more important role in the evolution of plasma in space, including the acceleration of charged particles to high energies. Because the properties of plasmas in space are found to differ little from those in the laboratory, empirical knowledge gained from earthbound experiments has suddenly found application in situations orders of magnitude greater in dimension. Kirchoff's laws for currents in circuits appear equally valid regardless of whether the plasma has its dimensions measured in centimetres, kilometres, parsecs, kiloparsecs, or megaparsecs.

The papers in this session represent an update of the knowledge gathered about our plasma universe. Approximately half the papers report data measured in the solar system, which by 1983, had become the primary laboratory in which plasma processes of great generality could be studied. This research includes measurements of electric fields and currents in the ionosphere, plasma MHD effects in the magnetosphere, multisatellite observations of magnetic fields in space plasmas, and the generation of magnetospheric power from planetary spin. The other papers are generally concerned with extrapolating these data to plasmas not accessible to *in situ* measurement, i.e., plasmas having the dimensions of galaxies, clusters of galaxies, voids, and the Hubble distance. This research includes the relation of laboratory plasmas and near-space plasmas as a key to understanding the plasma universe (as well as the key to a better understanding of laboratory experiments from the unprecedented data bank represented by space plasmas) and new insights on the highly isotropic microwave background radiation that pervades all space.

MHD

The MHD sessions focused on space-based MHD power, studies of MHD generator phenomena, and the application of magnetic fusion reactors to MHD energy conversion.

Space-based power was highlighted by two invited talks. G. E. Staats (DOE) described the Strategic Defense Initiative/MHD assessment program whose objective is to determine the feasibility of employing multimegawatt MHD power systems (10^2 to 10^3 MW) for space-based burst power (10^2 to 10^3 s) applications. The effluent interactions of space-based power systems were discussed by J. K. Koester (Space Power, Inc.). He indicated that large effluent rates (tens of kilograms per second) produce a cloud that can strongly modify the space environment. For example, number densities of 10^{19}/cm^3 extending tens of kilometres from a spacecraft and charged particles with velocities of 7500 m/s can be produced. In other papers, two space-based MHD power-generating systems were described: a gas-core nuclear system with a fissioning plasma disk and a closed loop magnetoplasmadynamic generator operating in conjunction with a jet compressor.

Several studies of MHD generator phenomena were presented. A joint United States–People's Republic of China research program reported results from the Mark II Faraday generator in Beijing. A peak power of 2 MW (electric) was achieved, and wideband data were recorded on flow rates, combustor pressure, plasma emission, electrode currents, Faraday voltages, and cathode-to-ground voltages. Other papers investigated the effect of external fluctuations on nonequalibrium disk MHD generators and the heat transfer in two-phase flow of an MHD duct. Because arcing is a major current transfer mechanism in an open cycle MHD channel, an experimental study of arcing phenomena for several configurations of slagged and "clean" electrodes in combustion gases was reported. Papers on plasma guns for MHD generators included a hybrid gun concept that utilized a much larger than conventional powder charge, and an analytic solution of the time evolution of an ideal coaxial plasma gun operating in the snowplow mode in the weak coupling limit. Finally, two novel uses of MHD technology were described: the electromagnetic sounding of the earth's crust using an MHD generator, and a simulation analysis of the effects of an explosion on the geomagnetic environment.

A series of three papers described the application of magnetic fusion reactors to MHD energy conversion. Two papers emphasized the use of microwave radiation to superheat gas or vapor *in situ* to high temperatures suitable for MHD conversion. Studies of superheating with microwaves using one- and two-dimensional hydrodynamic codes gave temperatures of 3000 K at pressures of 0.1 atm with existing microwave sources operating at 56 GHz. Higher frequency synchrotron radiation (1000 to 2000 GHz) produced similar temperatures at several atmospheres pressure. Another paper investigated a cesium-seeded mercury vapor Rankine cycle disk-type generator, attractive for installation in a fusion reactor. Due to the higher atomic weight of the working fluid and larger collision cross sections, the Hall parameter in the mercury-cesium system is higher than for a noble gas counterpart. As a result, the circumferential velocity is critical to high enthalpy extraction. For a new disk-type generator geometry with separated channels, calculations gave enthalpy extractions of 43.5% for a single-electrode pair and 48.5% for multielectrode pairs.

PLASMA CHEMISTRY AND PROCESSING

The papers in this area span the spectrum of high- and low-pressure plasmas and their applications to plasma chemistry and processing. In an invited paper, R. A. Gottscho (AT&T Bell Laboratories) addressed space-time resolved glow discharge electric fields. He described nonintrusive spectroscopic measurement techniques with high sensitivity and excellent spatial and temporal resolution, and pointed out some serious disagreements between these measurements and existing theories. In another invited paper, G. L. Rogoff (GTE Laboratories) considered the electrical aspects of plasma/particle interactions. In the usual modeling of heterogeneous thermal plasma synthesis and processing, the electrical effects of particle/plasma interactions are ignored. Rogoff identified conditions where this is a serious limitation.

Low-pressure papers included the following: a correlation of plasma characteristics with polymer properties in the production of tetrafluoroethylene films; modeling of low-pressure microwave discharges and comparison with experimental processing results; a low-power (<150-W) microwave ion source; measurements of transient sheaths and radio-frequency affected plasma potential using emissive probes; a novel toroidal dc discharge for materials processing; the optimization of polysilicon etching by a chlorine-argon plasma; and a theory of plasma ion implantation for hardening of metals.

In the high-pressure area, the synthesis of nitrides was discussed. A simulation calculation examined the effect of reactor operating conditions on the flow, temperature, and species fields in a new type of thermal plasma reactor. An experimental study reported on the synthesis of aluminum nitride in a free-burning nitrogen arc. Other papers described the application of high-pressure (100 Torr to 2 atm), high-temperature microwave discharges to chemical processing and the use of an electron beam to enhance gaseous combustion reactions.

PLASMA DIAGNOSTICS WORKSHOP

A workshop on plasma diagnostic methods for industrial applications was organized to enhance communication among users of plasmas from industry, universities, and national laboratories. This workshop was prompted by the observation that industrial users of arc furnaces, plasma etching, welding, flame spraying, and other materials processing applications tend to lack formal training in plasma science and to regard a plasma as a black box containing mysterious physical processes from which one gets a desired product by adjusting knobs. These applications have billions of dollars per year of industrial cash flow ($500 million in flame spraying alone), are important to the future competitiveness of major industries, and apparently have inadequate contact either with advances in plasma physics made in academic institutions in the past 30 yr or with advances in plasma diagnostics made in the DOE fusion program.

The centerpiece of the workshop was a series of eight invited talks. "Plasma Diagnostics: Motivations and New Directions" by A. Garscadden (Wright-Patterson AFB) emphasized the possibilities of laser-based techniques to diagnose plasmas of industrial interest. The application of diagnostic techniques developed in the DOE fusion program for industrial plasmas, with emphasis on Thomson scattering, was discussed by D. A. Rasmussen (Oak Ridge National Laboratory). An example of a highly sophisticated data analysis method for determining three-dimensional current paths in plasmas of industrial interest was presented by W. Gekelman (UCLA). Diagnosing arc furnace plasmas to minimize the production of electrical noise was described by T. L. Ochs (U.S. Bureau of Mines). The National Science Foundation program activities in industrial plasma processing were presented by L. S. Goldberg. Processes using plasmas for melting and refining metals, and the needed diagnostic tools, were discussed by R. C. Eschenbach (Retech, Inc.). The use of heavy-ion-beam probes to diagnose low-pressure arcs and other low-temperature plasmas of industrial interest was presented by R. L. Hickok (Rensselaer Polytechnic Institute). Applications of this technique were described in three contributed papers. M. E. McIlwain (Idaho National Engineering Laboratory) discussed a new diagnostic technique using holographic interferometry on high-pressure plasma jets of a kind used in welding, smelting, melting, and coating fabrication processes.

Additional contributions covered a range of topics with many potential applications to industrial plasmas. These topics included a new method for measuring the effective collision frequency using the full-width at half-maximum of the electron cyclotron resonance (ECR) absorption curve; the use of water vapor for spectroscopic measurements of heavy particle temperatures; a new secondary emissive capacitive probing technique and its application to low-pressure plasmas; and spectroscopic methods to measure *in situ* erosion yield and density fluctuations in a nonperturbing way (using neutral lithium beams). Also, the diagnosis of flames by the analysis of charge loss of a macroscopic projectile as it moves through the flame was presented. Several papers described the use of X-ray diagnostics to measure ion and neutral beam parameters. A group of papers devoted to tokamak plasmas described the tomographic reconstruction of density contours and far infrared interferometry and scattering measurements. Finally, the application of a pulsed ionization chamber diagnostic to fissioning plasmas in a pulsed nuclear environment was discussed.

PLASMA APPLICATIONS

Pulsed Power

Significant advancements in pulsed power applications were reported in technical sessions on intense electron and ion beams, fast opening switches, and ultrafast Z-pinches.

Intense Electron and Ion Beams

The papers on intense electron beams emphasized beam generation and transport. Beam emittance, beam head erosion, and beam/air interactions were discussed. Calculations and experimental results were presented for electron beam injection into a transport channel, into partial pressure gas fills, and across magnetic boundaries. The intense ion beam papers described the characterization of cryogenic and conventional diode sources, transport in multistage accelerators and final-focus geometries, and beam/plasma interactions.

Fast Opening Switches

Inductive energy storage has always held the tantalizing possibility of higher power, more compact, lower cost pulsed power generators than are available with capacitive energy storage. The major impediment has been the lack of fast opening switches. A number of developments in opening switches have occurred in the past few years that make inductive energy storage accessible. The different switches discussed in this session included the plasma erosion opening switch (PEOS), the reflex switch, and gas or plasma discharge switches. Advances with the PEOS were reported in extending its operation to higher power, to longer conduction time, and to repetitive pulsing. Several fluid and particle simulations of these different switches using one- and two-dimensional codes were presented.

Ultrafast Z-Pinches

Z-pinches were described in several contexts, ranging from X-ray radiation sources and X-ray laser media to megagauss field generation and controlled fusion. Theoretical studies of non-LTE radiation hydrodynamics of ultrafast gas-puff pinches were reviewed by J. Davis [Naval Research Laboratory (NRL)]. The group from Sandia National Laboratories presented an experimental study of axial nonuniformities of imploding gas-puff pinches. Also, two-dimensional simulations of gas-puff implosions onto central targets were described and compared with measurements. In addition, some papers addressed pinch stability, the influence of preionization on pinch dynamics in a microchannel (needle plasma), and the role of inelastic collisions in determining electron energy distributions in Z-pinches. Finally, encouraging progress was reported toward making a plasma of fusion interest by creating a high-current discharge along a frozen deuterium fiber.

X-Ray Lasers

The desire to generate coherent radiation at X-ray wavelengths is driven in part by the desire to see and write smaller features. Such developments would permit new studies in many areas, e.g., biodynamics, chemical kinetics, material sciences, and lithography. Several efforts to extend lasing to shorter wavelength were reported. A continuation of the successful experiments with neon-like ions on the NOVA laser at Lawrence Livermore National Laboratory (LLNL) to nickel-like ions was described. Evidence for gain on nickel-like europium $4d$-$4p$ transitions from 10.1 to 6.6 nm was reported. Examination of three-body recombination schemes involving hydrogen-like, helium-like, and lithium-like ions was also discussed. To extend experiments at PU to below 10 nm, a picosec 1-TW KrF laser is being developed. The status of engineering these new experiments was reported. Finally, a new class of short-wavelength lasers using photoionization followed by Auger decay was described. This simple pumping scheme circumvents complex collisional pumping kinetics. Fluorescence and gain were reported for xenon at 108.9 nm.

New results for lasing of neon-like systems focused attention on the need to understand the physical processes in these hot dense plasmas. Lasing was reported for neon-like copper in an experiment at NRL similar to the neon-like selenium experiment at LLNL. However, the gains measured for the $J = 1$ and $J = 0$ lines were large and comparable, in contrast to the immeasurably small gain for the $J = 0$ line in the LLNL experiment.

Three papers addressed the preparation of plasmas for X-ray laser experiments. Progress in producing a neon lasant plasma for a pulsed-power-driven sodium-neon photopumped experiment was reported. Properties of the plasma from a NaF capillary discharge to be used in this sodium-neon experiment were described. A capillary discharge was combined with a high-power laser to produce an 8-mm-long, 0.2-mm-diam fluorine plasma, attractive for X-ray laser experiments.

Plasma Focus

The plasma focus is basically a linear pinch formed near the end of a simple coaxial plasma accelerator. The electrostatic energy initially stored in a capacitor bank is converted into magnetic-field energy as the discharge current peaks prior to an MHD instability. The high plasma densities and temperatures that result from radial compression of the plasma lead to many interesting phenomena, which were reported in this session. Among these were ion and neutron emissions, X-ray radiation, and magnetic-field compression. The operation of plasma focus devices ranging from 500 to <1 kJ was reported. Of particular interest were studies of the structure and dynamics of the current sheath and repetitive pulsed operation. Applications of the plasma focus as an ion or X-ray source for laser pumping and for projectile acceleration were discussed.

Mirror Device Plasmas

The basic mirror device is the simplest machine offering a useful degree of hot plasma confinement. In particular, the good confinement of high-energy particles makes the device useful in ECR heated and neutral beam applications. The simplicity of the mirror makes it attractive in practical nonfusion applications. This session included papers that described the application of mirrors to accelerators, high-charge-state ion and X-ray sources, neutron sources for fusion materials research, and wave-plasma research involving cyclotron heating, pondermotive force, and potential control studies.

Electromagnetic Launchers

This session considered accelerators or "guns" designed to use electrical energy to accelerate or launch either solid projectiles or well-organized plasmas at hypervelocities for target impact or appropriate equation-of-state studies. The session contained discussions of railgun operation in fairly standard configurations including experimental studies of several different railgun systems; experimental and theoretical analysis of plasma armature driving the sabot and projectile down the gun bore; measurement and analysis of erosion of the rail electrodes or insulator materials; design and use of specially configured diagnostic probes to measure the drive current profile; and a discussion of problems of plasma restrike in undesirable locations, which tend to limit performance to no more than 8 km/s. Additional papers described approaches planned or under study to reduce or eliminate troublesome rail and insulator erosion problems, e.g., use of a gas gun for first-stage high-velocity injection into a high-speed railgun bore, or use of a conductor configuration tending to magnetically shield critical surfaces. Also, several very different gun configurations were discussed. The limit of railgun performance with only a plasma armature was explored. In an invited paper, J. E. Osher (LLNL) reported on an "electric gun" that uses an exploding metal foil and $J \times B$ forces in a very short gun configuration to drive thin plastic solid flyers up to 20 km/s. Proposals to use electrothermal expansion or coaxial magnetic compression to drive projectiles to hypervelocities were presented. Finally, the theory and operation of a coaxial plasma gun driving high-energy density magnetized plasma to extremely high velocities was described.

Free Electron Lasers

The theoretical modeling of free electron laser (FEL) physics is becoming more sophisticated, and the number of experiments is increasing. A major advance in FEL theory is in the area of radiation self-focusing. Radiation focusing plays a central role in the practical utilization of the FEL since in many proposed experiments the radiation beam is not confined by the waveguide structure. Correct use of the self-focusing property can enhance the FEL gain and efficiency. For the first time, algebraic expressions were reported for guiding the beam in the small-signal, exponential growth regime. This was reported in an invited paper by P. Sprangle (NRL). Simple expressions for the growth rate, intrinsic efficiency, radiation spot size, and wave-front curvature were obtained. The analytic expressions are in good agreement with fully nonlinear three-dimensional simulations.

Many FEL experiments were proposed, and two experimental results were reported. The Mark II FEL at Hughes Research Laboratories provided stable, single-mode, linearly polarized emission for 10 μs at 35 GHz with a linewidth of 200 kHz. Recent experiments on the Electron Laser Facility at LLNL, which uses the Experimental Test Accelerator (3.5 MeV, 1 kA) and an electromagnetic wiggler (4.0 m, 4 kG), were described. Operation was extended from 35 to 140 GHz by using a 250-W extended interaction oscillator as the source and operating at reduced wiggler fields. The radiation grew exponentially in the wiggler and was observed to saturate at 100 MW near the end of the wiggler (3.4 m). No significant gains were obtained by tapering the wiggler after saturation, due to lack of wiggler interaction length. The measured output powers and gain were in good agreement with simulations.

CONCLUSION

The technical program of the conference was promoted and arranged by the session organizers who provided the conference chairman with technical summaries of their session topics. These were edited by the chairman to prepare this conference report. The session organizers are identified in the conference record. Presentations to the conference are documented in the Conference Record—Abstracts of the 1987 IEEE International Conference on Plasma Science, which is available from the Director, Publishing Services, IEEE, 345 East 47th Street, New York, New York 10017.

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SUMMARY OF THE 13TH INTERNATIONAL SYMPOSIUM OF EFFECTS OF RADIATION ON MATERIALS, SEATTLE, WASHINGTON, JUNE 23–25, 1986

This biennial symposium series is sponsored by the American Society for Testing and Materials (ASTM) Committee E10 on Nuclear Technology and Applications. The series began in 1960 and has become a major international forum for the exchange and discussion of both fundamental and technological aspects of behavior change in materials exposed to radiation environments. The data presented at this meeting were primarily concerned with the response of metals to neutron or charged-particle irradiation although there were a number of papers directed toward nonmetallic materials. As in the past, the performance of nuclear fuels was not included since this topic receives adequate treatment in other forums.

The thirteenth symposium reached a record level of participation, necessitating its publication in two separate proceedings. This report is organized in the order that was used to compile the proceedings.