Thermal Hydraulics Division Newsletter
Spring 2002

MESSAGE FROM THE CHAIR
Cetin Unal, Thermal Hydraulics Division, Chair, 2001-2002

It is a great pleasure to serve as the chair of Thermal Hydraulics Division in 2001-2002, and would like to express my gratitude for electing me. Over the last ten years, the ANS Thermal Hydraulics division was committed to continue to support its own as well as ANS's mission in spite of the fact that the research funding in the thermal hydraulics area was declining. The recent energy crisis in California, the increase in the natural gas price, and widely discussed "green-house" effects of fossil fuels started the discussion to review energy policies. The nuclear energy with the development of advanced reactor technology will be significant part of the new energy policy in the coming years.

The terrible terrorist attack on our country last September changed all of our lives in some ways. We started to review our energy infrastructures to assess its vulnerabilities and ability to be able to provide reliable energy services that our industry and society depends upon. We expect that some changes in plant operations and regulations will take place. We need to find out means to ensure that the energy infrastructures are robust and almost free of all types of attacks. This will bring the ongoing discussion on the need for the distributed versus centralized energy infrastructures, the fuel type, and the modular small/large reactors/generators.

The thermal-hydraulics will remain a key discipline to design the types of reactors we need to make the energy infrastructures robust, reliable and less vulnerable in the new millennium. The thermal hydraulics research is already growing. The last 2-3 years, the number of papers in sessions organized by ANS THD was not as high as the number we used to have 10 years ago. In the last ANS Winter Meeting, we were able to organize six sessions including a total of 35 papers. Reasons for this are several. First of all, there are new funding and new programs. To give you an idea what is the status of present research activities in the area of thermal hydraulics, I asked several researchers and program managers to write us a summary of their program activities. You will find their review below.

Secondly, the program committee really worked hard to support the winter meeting. Session organizers did not only proposed general sessions, but called researchers to submit papers to our sessions. We definitely need to continue our efforts to raise the quality and number of the technical papers in our sessions so that we might be able to publish a Thermal Hydraulics Division Proceedings in the annual meetings. I want to remind our and ANS members that when your papers are accepted for a publication in our proceedings the papers can be forwarded to Nuclear Engineering and Design or Nuclear Science Journals without further review with the approval of the session chair. The success of the winter meeting also shows our commitment to support the ANS meetings and mission. I already heard that the headquarters noticed this improvement. I would like to encourage each of you to join us to continue to support THD sessions in the winter as well as summer annual meetings and want to thank you, in advance, for all of your efforts.

The last 2-3 years we have neglected to nominate our members for the ANS Fellow Award. This year we reinitiated this activity. I would like to remind particularly our ANS Fellow members that we need their involvement to promote our deserving members to not only Fellow Award but perhaps other ones. We need to promote dynamic individuals who can continue to work with the division. I will continue to support this type of activities during my term. Please contact me and chair or members of Honors and Award committee to give us ideas whom we should be considering to nominate. Your input is also needed in nomination individuals for technical achievement award.

I am very pleased that our membership increased to 782 from 753 in last two-years. I want to thank individuals who involved our recruitment activities for their efforts to bring new young people to our Division. We need to continue to recruit new people from emerging as well as traditional areas of thermal hydraulics. The well being of the Division depends on your efforts and dedication.

The 10th International Topical Meeting on Nuclear Reactor Thermal Hydraulics (NURETH-10) will be held in Seoul, Korea on October 5-9, 2003. Prof. Soon Heung Chang of KAIST and Dr. Won-Pil Baek of KAERI met with us at the ANS annual winter meeting and reported that they expect to provide a significant financial contribution to the THD. This is great news for our division. However, they need our help and participation in NURETH-10 committees, papers solicitation and in session organization, and in delivering plenary/keynote lectures. I am inviting all of you and other ANS members to involve with NUERTH-10 activities and give your best support to Korean organizers to make this meeting a great success.

In an attempt to review the status of thermal hydraulics research presently undergoing in different countries, I asked various investigators to share their goals and progresses with us. Of course it is impossible to review all of the thermal hydraulics research programs in a single newsletter. However, we can start this effort in this newsletter and continue in the future. In the last winter meeting, Dr. Madeline Feltus gave an overview of Nuclear Energy Research Initiative Projects that DOE supports. Below you will find the summary of her talk.

The some of the advance reactor concepts consider the use of liquid-metals such as lead or lead-bismuth as a coolant. The lead and lead-bismuth systems are studied 50 years ago in the U.S. and abandoned because of corrosion problems. Russians successfully use this technology. It will be interesting how the liquid-metal cooled systems will effect the development of the advance reactor design. I asked the project leader of Accelerator Transmutation of Waste, Dr. Kemal Pasamehmetoglu of Los Alamos National Laboratory and his collogues from Germany, Joachim Drs. U. Knebel, and Gerhard Heusener, to summarize their activity in this area. Finally, Dr. Martin Bertodano gives us his views on the status of computational fluid dynamics and code developments in thermal hydraulics research. I hope you find these short articles interesting and useful and wish you a new and successful year and hope to see you in 2002 at the ANS Annul Summer Meeting.

2001 ANS THD AWARDS

Professor Micheal Corradini was the recipient of the ANS-THD TECHNICAL ACHIEVEMENT AWARD for 2001, A plaque and a check of $1000.00 were presented to Prof. Corradini at the ANS Annual Winter Meeting before his award seminar on "In Search of Perfect Mixing: Studies in Liquid-Liquid Heat Transfer". Prof. Corradini is selected for this award by the ANS THD Honor and Awards Committee for his many unique scientific contributions in thermal hydraulics, severe accident phenomenology, and nuclear reactor safety technology, and his impact on the international technical community as a researcher, educator, and outstanding leader promoting deep physical understanding and technical excellence.

Prof. Corradini receives the 2001 Technical Achievement Award from Per Peterson.

Prof. Corradini gives his award seminar.

A group of THD members are enjoying the award dinner after the seminar.

THD Membership

Our membership considerably increased in 2001. In fact, it is increasing since 1998 as shown below. We have 782 members in 2001, and this number was 770 in 2000, showing a 1.5% yearly increase.

Year	Number
1997	808
1998	771
1999	753
2000	770
2001	782

The THD cordially invites you to become a member of the Division and participate in the Division's activities. Presently, our division activities include paper review, paper presentations, organizing and chairing technical sessions, sponsoring topical meetings, serving on our committees, and student conferences. If you are interested in becoming a member or if you are currently a member interesting in any of our activities, please contact me or any of the THD Officers.

Ongoing Thermal Hydraulics Research Programs

Thermal-Hydraulics Research Sponsored by the DOE Nuclear Energy Research Initiative Program, Madeline Anne Feltus

The Department of Energy Nuclear Energy Research Initiative (NERI) sponsors new and innovative scientific engineering research and development (R&D) to address the key issues affecting the future of nuclear energy and to preserve the Nation's nuclear science and technology research infrastructure. The current NERI areas are: (a) proliferation resistant reactors and next generation reactor design technology, (b) advanced nuclear fuel development, (c) new technologies for nuclear waste management, and (d) fundamental nuclear science and technology and materials R&D.

To date, 69 NERI projects have been awarded and represent approximately $79 million in R&D over the three-year project duration which involve 10 DOE laboratories, 24 universities, 20 industry and governmental research organizations, and 24 foreign research participants. Two NERI projects have been completed successfully thus far. Ten NERI projects that particularly focus on thermal-hydraulics R&D for innovative reactor designs and current reactors are listed In Table 1.

Three new reactor concept NERI FY 1999 projects are performing detailed thermal-hydraulic analyses as part of their design development. Dr. Carelli's team is performing fundamental neutronics and thermal-hydraulics evaluations as well as experimental tests for the passive safety system and novel steam generator performance demonstration for the Westinghouse IRIS Pressurized Water Reactor (PWR) design. A new modular and full-size simplified boiling water reactor (SBWR) is being designed by Dr. Ishii's (Purdue) team. This project focuses on natural circulation cooling mechanisms, providing a detailed stability analysis of the SBWR core, and modifying the Purdue PUMA facility for scaled integral experiments. The Multi-Application Small PWR concept is being designed by the INEEL lead team and will use newly designed full-system-pressure test facilities at the Oregon State University for demonstrating the passive features' performance for this PWR concept.

Three FY 1999 NERI projects focus on experimental and computational thermal-hydraulic methods development. Dr. Dhir (UCLA) is studying complete numerical simulation of subcooled flow boiling where chemical and thermal interactions occur, e.g., boric acid interactions during vapor generation at the fuel cladding surface. University of Wisconsin and Argonne are investigating stability and interfacial transport phenomena in systems that have multi-phase conditions, i.e., molten metal and water mixing together, during normal and transient conditions. Both experimental measurements and analytical modeling are being performed to determine the stability of liquid metal-water reactor concepts. Computational and experimental studies are being performed by the INEEL-lead team for high temperature fluid flow designs, e.g., gas reactors and supercritical LWRs, using the INEEL Matched-Index-of-Refraction flow test facility, and smaller scale separate effects test facilities at several universities. This FY 1999 NERI project will provide basic thermal data and fluid turbulence test data and information needed for computer simulations.

Dr. Catton (UCLA) is developing theoretical models and experimental test results to develop constitutive relationships for single and two-phase fluid flow in heat exchanger tube configurations and steam generator designs. This FY 2000 NERI project focuses on separate effects tests for heat exchanger tubes and will use various tube pitch-to-diameter ratios, tube bundle array designs, and fluid conditions in order to provide information needed to resolve flow induced structural vibration problems in current PWRs and future LWR reactor concepts.

Three FY 2001 NERI projects focus on thermal-hydraulics aspects of super-critical LWR concepts and one specific advanced LWR design. The Oregon State University APEX facility will be modified in Dr. Reyes' NERI project to be able to demonstrate the performance of the proposed Westinghouse AP1000 (3000 MW thermal) PWR design. This FY 2001 NERI project will develop the test facility scaling analysis and APEX facility modifications, and assess the AP1000 passive safety features during loss of coolant accidents and beyond-design-basis accident scenarios for the AP1000-specific passive residual heat removal and automatic depressurization systems, accumulators and core makeup tanks. Another FY 2001 NERI project (INEEL) will perform an overall feasibility study for a fast spectrum super-critical LWR that involves both reactor physics, neutronics and thermal-hydraulic analyses, as well as investigating fuel cladding and materials performance issues, plant engineering, and reactor system safety evaluations. The University of Wisconsin-lead team is investigating what innovations in materials, fuels, fuel cycle approaches will be needed for a super-critical reactor concept to be feasible. Both thermal-hydraulic and neutronics analyses will be performed as well as small scale experiments to demonstrate stability and heat transfer effects.

Table 1: NERI Thermal-Hydraulics Research and Development Projects
(Principal Investigator's Organization denoted by *)

1-The Secure Transportable Autonomous Light Water Reactor--STAR-LW (IRIS), *Westinghouse Electric Company*,* *University of California-Berkeley, Massachusetts Institute of Technology, Polytechnical Institute of Milan, British Nuclear Fuels, Commissariat a l'Energie Atomique, Japan Atomic Power Company, Mitsubishi Heavy Industries, Tokyo Institute of Technology, Bechtel Corp.*
2-Modular and Full Size Simplified Boiling Water Reactor Design with Fully Passive Safety Systems, *Purdue University*,* *Brookhaven National Laboratory, Toshiba Corporation*
3-Multi-Application Small LWR, *Idaho National Engineering Environmental Laboratory*,* *Bechtel Corporation, Oregon State University.*
4-Complete Numerical Simulation of Subcooled Flow Boiling in The Presence of Thermal and Chemical Interactions, *University of California, Los Angeles*.*
5-Interfacial Transport Phenomena and Stability in Molten Metal-Water Systems,
University of Wisconsin-Madison*, Argonne National Laboratory.
6-Fundamental Thermal Fluid Physics of High Temperature Flows in Advanced Reactor Systems, *Idaho National Engineering Environmental Laboratory*,* *Iowa State University, University of Maryland, General Atomics, University of Manchester UK, Tokai and Toyama Universities, Japan.*
7-Development of Design Criteria for Fluid Induced Structural Vibration in Steam Generators and Heat Exchangers, *University of California, Los Angeles*.*
8-Testing of Passive Safety System Performance for Higher Power Advanced Reactors, *Oregon State University*.*
9-Feasibility Study of Supercritical Light Water-Cooled Fast Reactors for Actinide Burning and Electric Power Production, *Idaho National Engineering Environmental Laboratory*,* *Westinghouse Electric Company, University of Michigan.*
10-Supercritical Water Nuclear Steam Supply System: Innovations in Materials, Neutronics, and Thermal-Hydraulics, *University of Wisconsin *,* *Argonne National Laboratory, Global Nuclear Fuel.*

Applications of CFD to nuclear reactor technology, Martin Bertodano, Purdue University

It may be said that multidimensional incompressible CFD began in the sixties with the seminal work from Los Alamos, so the nuclear community can be proud that it started it all. Since then CFD has moved to other industries where it has bloomed into countless applications, its origins mostly forgotten. Ironically, nowadays the commercial nuclear industry is lagging behind in the use of CFD.

Many single phase flow calculations in the reactor core and in primary components can and should be performed using CFD. In some cases CFD is already being used (e.g., boron mixing in the downcomer and cold ECCS injection in the hot leg of PWRs). However, single phase flow calculations in the core are still being done with quasi one-dimensional codes such as COBRA.

There are some issues about single phase flow CFD that will have to be addressed by the NRC before CFD methods can be certified. The two most significant issues are the choice of the computational grid and the turbulence modeling. The main concerns with the computational grid have to do with geometric fidelity and numerical convergence. Fortunately there are many tools available for mesh generation, and the commercial codes can use many different types of meshes. For example, it is now possible to use tetrahedral elements that can be adjusted to any configuration. The question of numerical convergence is resolved by mesh refinement. A simple rule is to double the mesh until the solution stops changing. However, in 3D calculations each doubling increases the number of mesh points by a factor of 8 and it is easy to overload even the most powerful computers.

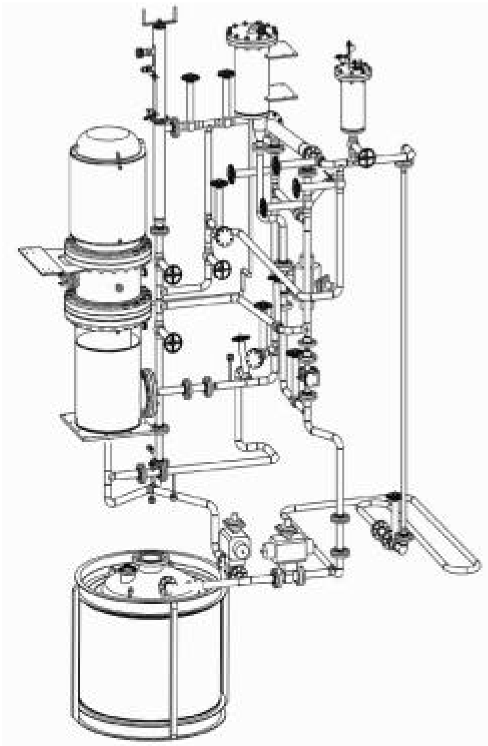
The selection of valid turbulence models is a little more delicate. Most CFD codes use some version of the k-ε model. However, even though this model is a considerable improvement over the mixing length models of the past, the k-ε model remains controversial. Perhaps the main issue from a practical point of view is that there is no general k-ε model, but there are several variations that work better for certain flow configurations. Therefore, the validation of specific turbulence models for different flow geometries, and the determination of the uncertainties are the key considerations.

The success of single phase flow CFD has raises the possibility of two-phase flow CFD. However, the presence of deformable interfaces makes this problem much more difficult. In addition the effect of the interfaces on the turbulence must be considered. Considerable progress has been made on dispersed flows (i.e., droplet and bubbly flows) but much work still remains to be done. The two-fluid model is the most practical approach although the Lagrangian-Eulerian method is also used. Both ways it is necessary to determine the interfacial area concentration, and this is the major source of uncertainties. However, recent transport models for the interfacial area concentration that consider various coalescence and breakup mechanisms are very promising.

The particle flow community has made remarkable progress predicting turbulent flows with small spherical particles. The two-fluid model Probability Distribution Function approach, which is similar to Boltzman's equation applied to the particles, provides very accurate phase distribution predictions for mono-disperse particles. The case for bubbly flows is more complicated because of the deformable bubble surfaces. Furthermore there are more significant forces acting on the bubbles (e.g. lift). Successful predictions of bubble distributions have been obtained for some cases but there is no general model yet that works for all bubble sizes and all flow conditions.
Bubbly flow CFD is an area of active current research where the nuclear technology community could make a significant contribution. One potential benefit is a more accurate prediction of critical heat flux based on mechanistic models.

Lead-Bismuth Eutectic Research Loop at LANL, Kemal Pasamehmetoglu, Los Alamos National Laboratory

As part of the Advanced Accelerator Applications (AAA) Program, researchers at Los Alamos National Laboratory built a lead-bismuth eutectic (LBE) materials loop aimed at developing LBE technology for spallation target and nuclear coolant applications. The DELTA loop is operational as of December 5, 2001, and will be used for extensive instrumentation, corrosion, and thermal-hydraulic testing in the coming years. A layout of the loop is shown in the figure. The total height of the loop is approximately 20 ft. The loop is designed for maximum experimental flexibility. The vertical layout allows for operating in natural circulation mode.



The primary mission of the AAA Program is to develop technologies for the transmutation of spent nuclear fuel. One primary candidate scenario for accomplishing the mission is to use a subcritical, fast-spectrum core containing nonfertile fuel (plutonium and minor actinides), along with long-lived fission product targets. LBE as a coolant has many advantages in such an application. Its low melting temperature and high boiling temperature offer a wide thermal operating range. It is practically transparent to neutrons and is chemically much less reactive than other liquid metals such as sodium. Also, it is a very efficient spallation material, so an additional solid target is not needed. On the other hand, LBE is very corrosive on commonly used structural steels and requires special corrosion-control schemes (such as active oxygen control). The LBE nuclear coolant technology is successfully used in the Russian submarine program, but experience in the west is quite limited. A number of strong research programs exist in Europe and Asia (Japan and South Korea) to develop this technology outside Russia. AAA Program activities are strongly tied to European activities through collaborative agreements.

To complement and supplement the international research, the DELTA loop is designed and built at Los Alamos National Laboratory. While initial testing will be tailored to the needs of spallation target development, the data will also be collected for nuclear coolant applications in critical and subcritical reactors. The testing will be aimed at instrument development (such as flow meters and oxygen sensors), corrosion behavior of different alloys with or without special surface treatment techniques, and thermal-hydraulic performance tests with emphasis on wetting characteristics of LBE and dependence of heat transfer on coolant chemistry.

The DELTA loop is capable of circulating over15 m^3/h of LBE. This corresponds to a flow velocity in excess of 4 m/s in the test section, which is considerably beyond the existing experience-base for LBE coolant applications. Continuous operation in natural circulation mode is possible, with velocities upward of 0.5 m/s in the test section. The loop is supplied with 100 kW of thermal power. The main components are a melt tank, a 25-hp mechanical sump pump, calibration and expansion tanks, a recuperator, and a variable-load LBE-to-LBE-to-water heat exchanger. The loop is equipped with an active oxygen control system with gas injection ports and multiple oxygen probes, in addition to other instrumentation (flow meter, pressure transducers, thermocouples). Research is ongoing in developing and installing online corrosion probes in the loop. Other than a few valves associated with the bypass piping and flow path configuration, all functions of the loop are automated and controlled through a data acquisition and control system. The loop is initially designed for three years of continuous operations. However, with periodic maintenance and upgrades, we expect a much longer lifetime, providing valuable technology data for the AAA Program and its international partners.

The Karlsruhe Lead LAboratory KALLA: A Technical Description, Joachim U. Knebel, Gerhard Heusener, Germany

Transmutation presents the possibility of closing the fuel cycle including the minor actinides. The objectives of the present research and development work is to assess whether transmutation is technically feasible and whether this technology provides advantages in comparison to direct disposal, especially as world-wide public acceptance of final repositories is low. The investigations are done in the frame work of a HGF Strategy Fund Project. All relevant experiments are performed in the KArlsruhe Lead Laboratory KALLA.

HGF Strategy Fund Project : In Forschungszentrum Karlsruhe an HGF Strategy Fund Project entitled "Thermalhydraulic and Material Specific Investigations into the Realisation of an Accelerator Driven System (ADS) to Transmute Minor Actinides" is performed which is funded by the Hermann von Helmholtz-Gemeinschaft Deutscher Forschungszentren (HGF) in the section "Energy Research and Energy Technology".The objectives of this HGF Strategy Fund Project are the development of new methods and technologies to design and to manufacture thin-walled, thermally highly-loaded surfaces which are cooled by a corrosive heavy liquid metal (lead-bismuth eutectic).

Karlsruhe Lead Laboratory KALLA: The KArlsruhe Lead LAboratory KALLA comprises all experimental activities in the field of Accelerator Driven Systems (ADS) in Forschungszentrum Karlsruhe which use the fluids lead or lead-bismuth eutectic.The research and development programme concentrates on the areas: heavy liquid metal technologies, materials, corrosion, thermal hydraulics, measurement techniques. The experimental activities are divided into two groups: Stagnant experiments, and Loop experiments.

Corrosion Experiment COSTA : The experiment COSTA (COrrosion test stand for STagnant liquid lead Alloys) is used to investigate the basic corrosion processes of steel in liquid, stagnant Pb or Pb-Bi under oxygen concentration control. The objective is the examination of the influence of: variation of oxygen concentration, surface conditioning including alloying, coatings which form protective layers, Bi in the liquid metal alloy.

Development of oxygen sensors KOSIMA : The availability of electrochemical oxygen sensors for the measurement of the oxygen activity in liquid Pb-Bi is an absolute prerequisite for the active oxygen control system (OCS).The major objectives of the development of oxygen sensors are: selection of suitable reference systems, Accuracy and reproducibility, Long-term stability.

Experiment KOCOS: Oxygen control system : The stagnant experiment KOCOS (Kinetics of Oxygen COntrol Systems) pursues three main objectives: Development of an oxygen control system (OCS), Measurement of the diffusion coefficient of oxygen in liquid Pb-Bi, Measurement of oxygen mass exchange rates between Pb-Bi and cover gas atmosphere.

Technology Loop THESYS : The Technology Loop THESYS (Technologies for HEavy metal SYStems) focuses on the de-velopment and application of fundamental lead-bismuth technologies: Oxygen measurement and control system (OCS) for loops, Thermal hydraulic measurement techniques, Heat transfer and turbulence. The experiments result in a thermal hydraulic data base which is used for the development of physical models and the validation of numerical codes.

Thermal Hydraulic Loop THEADES : The loop experiment THEADES (THErmal hydraulics and Ads DESign) concentrates on thermal-hydraulic single-effect investigations of ADS components which are of vital importance for the design work of ADS Systems: Beam window, Windowless target, Fuel element(s),- Pb-Bi/Pb-Bi heat exchanger, Steam generator, Air cooler. The experiments are used to set- up a thermal hydraulic data base for physical model and code validation.

Integral Experiment : The integral experiment K4T (Karlsruhe 4MW Target experiment) concentrates on thermal hydraulic integral investigations into the heat removal from a spallation target or a blanket for normal and decay heat removal conditions. The main objectives of K4T are: Heat transport within a closed spallation target module, Thermal hydraulic behavior of the heat removal system (spallation target or blanket, intermediate Pb-Bi loop, air cooler), Steady-state and transient behavior of the heat removal system.

2001 THD Candidates for THD Officers

New Thermal Hydraulics Division Officers and new additions to our Executive Committee are nominated. We congratulate all of them. Their term, when selection is finalized, of office begins at the close of the summer THD executive committee meeting. Following are our candidates for 2001 Election:

Chair, THD	**Vice-Chair/Chair Elect**	**Secretary**	**Treasurer**	**Executive Committee (3-Year Term)**
Jong H. Kim	Whee Choe	Shripad Revankar	Jovica Riznic	Per Peterson

UPCOMING MEETINGS

This summer there will be no National Heat Transfer Conference, so we will attend and meet at the ***ANS National Summer Meeting*** that will be held at Hollywood, Florida on June 9-13. The summer meeting includes an Embedded Topical Meeting entitled ***International Congress on Advanced Nuclear Power Plants (ICAPP).***

The ***2002 ANS National Winter Meeting*** will be held on November 17-21 at Washington DC including an Embedded Topical Meeting entitled ***8th Emergency Preparedness and Response.***

Information about the upcoming ANS Annual Summer and Winter meetings can be found at: ***http://www.ans.org/meetings/text.cgi?category=0*** .

THD 2001-2002 Officers

The following is the list of 2001-2002 THD Officers.

Cetin Unal	***Chair***
Jong H. Kim	***Vice-Chair***
Jovica R. Riznic	***Secretary***
Robert P. Martin	***Treasurer***

Executive Members

Cetin Unal	***2002***
David Bessette	***2002***
Alan E. Levin	***2002***
Jovica R. Riznic	***2002***
Robert P. Martin	***2002***
Jong H. Kim	***2002***
Yassin A. Hassan	***2003***
Mamura Ishii	***2004***
Larry Hochreiter	***2004***

Staff Liaison

Sharon S. Kerrick

Ex Officio

Donald R. Hoffman
Martin Pilch

Immediate Past Chair

Committee Chairs

Martin L. De Bertodano
Program Committee

Fan-Bill Cheung
Nominating Committee

Tom Larson
Membership Committee

Jose Reyes
Honors & Awards Committee