Overview of the Educational Activities of the COE

Tetsuo Sawaragi

Project Leader and Professor at Department of Mechanical Engineering and Science, Graduate School of Engineering

1. Philosophy for Establishing the Center

A complex mechanical system is “a system with a complex structure that exhibits a variety of behaviors, which are influenced by its environment, and realizes beneficial functions for human beings through these behaviors.” The purpose for establishing our Center has been to understand the governing laws behind these behaviors and to derive mathematical models as well as to analyze their control principles and functional design methodology, thereby creating a new mechanical engineering field of **complex mechanical system engineering**. In addition, we have been conducting a variety of educational activities, which are consistent with Kyoto University’s tradition of *On-the-Research Training*, in order to produce highly specialized young researchers with broad perspectives, who are capable of pioneering new research fields. Contrary to conventional project-oriented collaborative research where participants work on the design and analysis of an assigned single segmented region, we have strived to build a self-organizing research organization by making our Center activities focus on **collaborative works on the fundamental basic research**. Our educational activities have been carried out based on the following operational principles.

(1) To ensure that Center members share and have the same visions on issues related to complex mechanical engineering

(2) To openly exchange one's own expertise and to impart a variety of research and ideas

(3) To promote autonomous and spontaneous research and academic freedom

(4) To build a global organic network of researchers

This report will summarize these activities at the Center and provide an overview of the graduate school reform that is in progress and implemented at the Graduate School of Engineering of Kyoto University under the encouragement of the outcome gained at our Center.

2. Educational Programs for Young Researchers

(1) Frontier Seminars

One of the purposes of our Center is to pioneer new research fields by ensuring that both engineering and science researchers rethink the concept of traditional mechanical engineering from the common viewpoint of "complexity." To conduct such collaborative works on the fundamental basic research, it is particularly important for participants to openly exchange one's own expertise/ideas and have daily discussions so that a common perspective of issues and research methodology is shared. To this end, in addition to the many seminars presented by invited visiting researchers through our enhanced visiting researcher program, we have been actively holding seminars and research meetings among the Center members. In fiscal 2004, 2005, and 2006, we hosted 50, 40, and 56 international visiting researchers, respectively. Moreover, the number of seminars that we have hosted in and out of Kyoto University was 45 in fiscal year 2003, 58 in 2004, 43 in 2005, 70 in 2006, and 60 in 2007.

(2) Frontier Research Program

We have implemented the Frontier Research Program to provide research grants for young researchers, including doctoral course students, in order for them to conduct independent and autonomous research projects. In this program, recipients are selected via a competitive application process evaluated at the program steering committee. Unlike other grant programs such as *Kakenhi* (Grants-in-Aid for Scientific Research), which solicit any type of research project, we think that this program provides opportunities for applicants to recapture their research projects from a new point of view by considering the synergy between our Center's research programs and their own research projects. Some successful applicants, mainly doctoral course students, may treat their grants as young researchers' activity expenditures, and all grant recipients must submit reports on their research activities and results. In fiscal 2003, 2004, 2005, and 2006, there were 43, 37, 52, and 47 grant recipients, respectively.

(3) Research Assistant (RA) Program

We have implemented the Research Assistant (RA) Program for doctoral course students working on research projects, which match the Center's objectives and are supervised by a professor belonging to our Center, by providing monthly salaries for their research activity expenditures. This program aims to encourage our doctoral course students to take the initiative in their research activities by engaging in activities such as participating in academic conferences and collecting materials. However, eligibility is limited to the qualified students belonging to our Center; students from industry, international students on governmental assistance, students and postdoctoral fellows on the Japan Society for the Promotion of Science's Research Fellowship for Young

Scientists are excluded because of the restrictions on their positions. Moreover, students in their fifth year of the doctoral course or later are ineligible. As an overall qualification for RA, recipients of this research assistant are obligated to participate in the seminar of the 21st Century COE Complex Systems Mechanical Engineering as well as to submit reports on their progress and results of their research projects. These requirements are designed to ensure that in addition to their independent research, students in the RA program are aware of their obligation and responsibility to support the Center's research projects. There were 31 RA recipients in fiscal 2003, 39 in 2004, 34 in 2005, 34 in 2006, and 31 in 2007. Besides these RA recipients, the number of students receiving a Research Fellowship for Young Scientists of the Japan Society for the Promotion of Science has increased annually. In fiscal 2003, there were only 4 fellowship recipients, but there were 7 in 2004, 8 in 2005, 11 in 2006, and 7 in 2007. Although these individuals are ineligible for the RA program, this increase of the recipients of Research Fellowship is a manifest outcome of the education of the Center.

(4) International Apprenticeship Program

As part of our continuing efforts to train international caliber, young researchers, we have implemented the International Apprenticeship Program. This program provides opportunities for young researchers to receive instruction directly from the world's most prominent researchers. Although conventional students' international visits are primarily to present their research works at the conferences and/or symposia, this new program aims to nurture the habit of leaving Japan to present as well as to solicit opinions about our research projects at research institutes abroad. To achieve this, participants must conduct a joint research project with a single supervisor as well as partake in a

collaborative research project that is beyond their specific specialty at locations, including overseas satellite centers, for a sufficient time to allow the exchange of ideas and a joint research project in a different field to be conducted. This program has already provided abundant opportunities to debate and discuss in English because students must participate in seminars held at their apprenticeship location, build a strong research network for long-term studies abroad, and more. Hence, we feel that this program is worthwhile. Each participant must select the place to visit, find lodging, apply for permission to visit, convince the host that he or she is capable of contributing to the host's organization during his or her stay, negotiate conditions of the visit, etc., on his or her own. There were four young researchers who participated in this program in fiscal 2003, 11 in 2004, eight in 2005, and six in 2006.

3. Interdisciplinary International Activities

We highly value research exchanges in and out of our Center.

Internally, our interdisciplinary collaborative research projects within our Center or other faculties and departments within Kyoto University were conducted through our shared interdisciplinary research facilities, Katsura Int'tech Center, namely its Fluid Dynamics Advanced Research Center (Pic. 1), Nano-Engineering Advanced Research Center, and Smart Materials Laboratory.

Pic.1 Katsura Int'tech Center, namely its Fluid Dynamics Advanced Research Center

Externally, we started to build our international collaborative research network (Fig. 1). When we began our COE, we exchanged a memorandum of agreement (MOU) between Kyoto University and IIASA (International Institute of Applied Systems Analysis), Austria, as our base for international information dissemination in fiscal 2003. Since then, we have hosted an annual international seminar with prominent invited speakers from around the globe as well as presented our achievements at IIASA as our international satellite center. To present our activities, we hosted the First Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2004) in 2004 at IIASA. The proceedings of this seminar were published as an official technical report, which has been distributed to the eighteen member countries of IIASA as well as to the rest of the world. Then in fiscal 2005, upon invitation from Professor Martin Buss of the Technical University of Munich (TUM), who serves as a member of our international evaluation committee, we held the Second Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2005) at the Technical University of Munich jointly with IIASA and TUM. The Third Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2006) was held again at the IIASA, and the Fourth Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2007) was held on June 28 and 29, 2007 at IIASA.

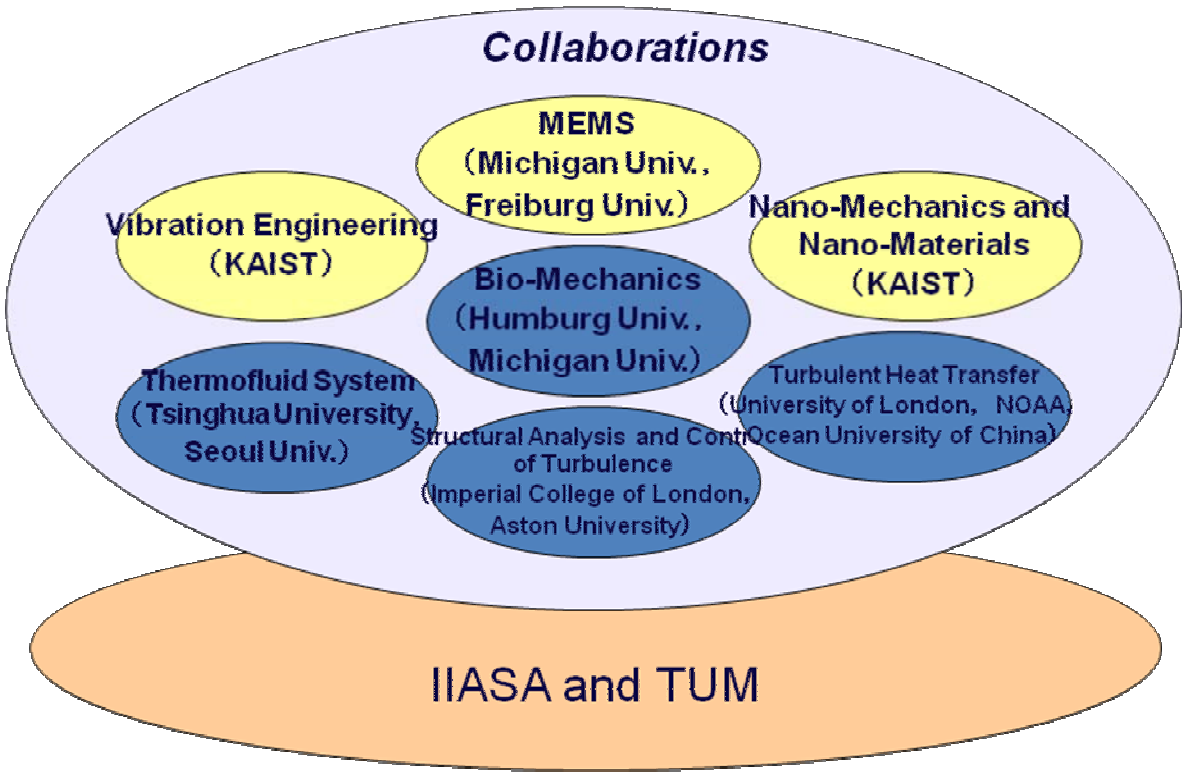
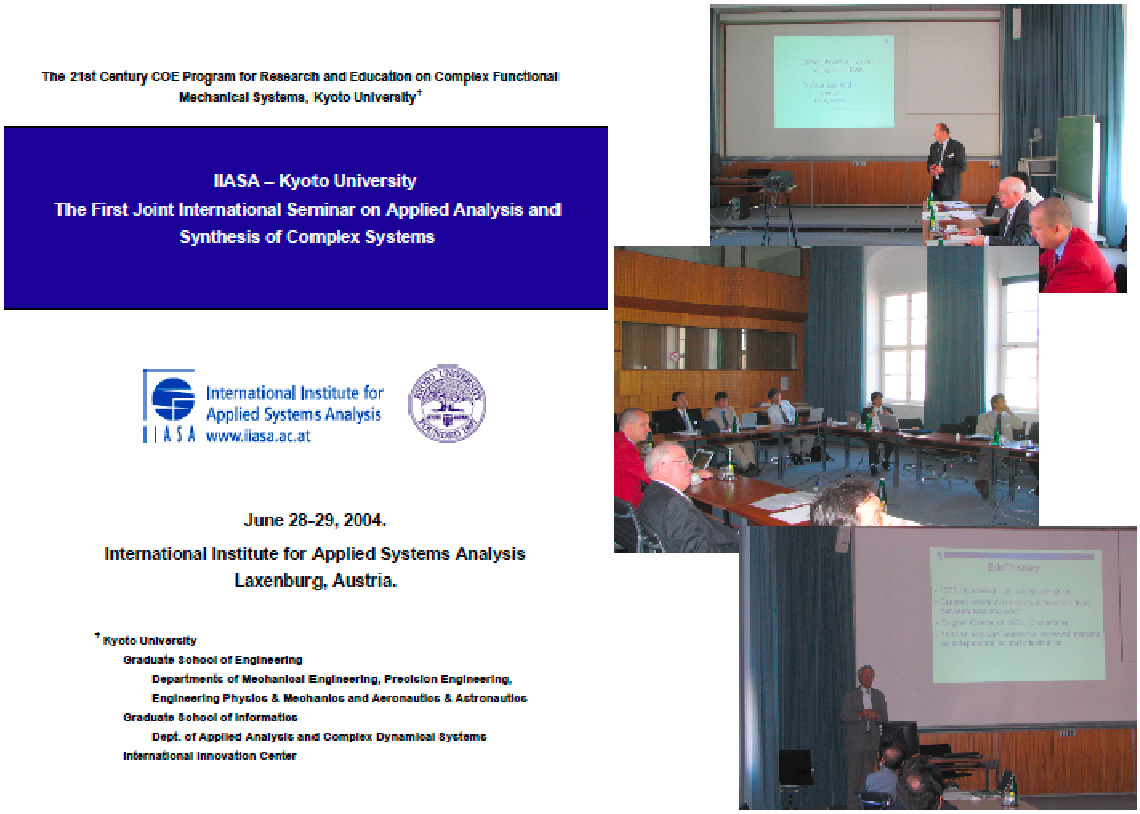


Fig.1 Networks of International Collaborations



Pic.2 The First Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2004) in 2004 at IIASA

Pic.3 The Second Joint International Seminar on Analysis and Synthesis of Complex Systems (ASCS2005) at the Technical University of Munich jointly with IIASA and TUM.

IIASA is an international research organization, which emphasizes systems science on a global scale, which was conceived by an initiative by then U.S. President Johnson in 1966 when he called for the establishment of “an international research organization with participation from major countries from East and West apart from their political standpoints for the purpose of researching various issues shared by mature societies.” IIASA was subsequently established in October 1972 at Laxenburg, Austria. It has been engaging in interdisciplinary and scientific research on issues of the environment, economics, technology, and society from the perspective of human activity on global

change. IIASA operates on the financial contributions from the NMOs (National Member Organizations), which include countries in North America, Europe, and Asia. The three main areas of IIASA's activities are energy and technology, environment and resources, and population and society. Encompassing these areas, IIASA is analyzing the sustainability of society and effect of changes on a global scale from a variety of viewpoints such as the environment, economics, technology, and social development as well as studying the process of the interactions between humans and the environment. Various researchers from around world gather at IIASA, and provide beneficial insight to policy makers and academic societies from a scientific point of view based on the most recent application system analysis method. IIASA's research results are published in books, academic journals, official publications of IIASA (such as research reports) as well as on electronic media such as the Internet and CD-ROMs. With more than 50 conferences and workshops annually, IIASA is a research organization of the highest order that encompasses innovative research, interdisciplinary and international collaborations, and networking with groups of scientists, including Nobel laureates around the world.

Another internationally notable research organization in the complex systems research is Santa Fe Institute (SFI) of the United States. This not-for-profit organization, which is located in New Mexico, U.S.A., was established in 1984 with the Los Alamos National Laboratory as its parent body. Since then, SFI has been engaging in research of complex adaptive systems. W. Brian Arthur, who was instrumental in its establishment, is noted for his law of increasing returns in complex system economics. Dr. Arthur's research was conducted at IIASA from 1977 until 1983 when his decision to leave IIASA was influenced by the détente during the Regain era. Our Center had the honor of having the

President of SFI, Geoffrey West, visit on September 7, 2005. On that occasion, I, the then sub-leader of the Center, briefed him on the research activities at our Center in the presence of Toshio Yokoyama, Director-General of the Organization for the Promotion of International Relations and Vice President of Kyoto University, and Mitsuhiko Araki, Dean of Faculty of Engineering and then Vice President of Kyoto University.

Furthermore, we have signed a collaborative research agreement with the Ocean University of China on phenomena analyses and modeling of complex flow. Moreover, each group within our Center is actively pursuing an international collaboration. These collaborations include turbulent transportation research (with the University of London, Columbia University, NOAA, the University of California, and the Ocean University of China), complex flow modeling (with the University of Toulouse III, the University of Bordeaux I, and Aix-Marseille University I), biological materials research (with the University of Hamburg, and the University of Michigan), structural analysis and control of turbulent flow (with Imperial College, the University of Madrid, and Aston University), complex systems research (with the Technical University of Munich and Linkoping University), and micro-structural machine system research (with the University of Michigan and the University of Freiburg).

We are leveraging these international collaborations to actively hold international symposia and workshops in order to increase our visibility in the international arena and to publish our results at international conferences and international academic journals.

The Complex System Materials Group hosted MEMS lectures to commemorate the academic exchange agreement between the University of Michigan, the University of Freiburg, and Kyoto University with invited researchers from each university. In 2004,

these three universities authorized an academic exchange by each signing an inter-faculty academic exchange agreement of the Faculty of Engineering. Later, student exchange agreements, which include tuition waivers, were signed between Kyoto University and the University of Freiburg, and between the University of Michigan and the University of Freiburg (an inter-faculty student exchange agreement between Kyoto University and the University of Michigan has yet to be signed). According to the agreement, these three universities take turns hosting symposia. In addition to sending young professors to these symposia, we also encourage master's and doctoral students to attend because these symposia provide valuable opportunities for students to participate in poster sessions and lectures at the host university. Furthermore, this academic exchange agreement has created opportunities for long-term student exchanges between universities as Kyoto University now accepts students from the University of Freiburg.

The Complex System Materials Group organized The Kyoto – Birmingham University International Symposium on Recent Advances in Fluid Mechanics on September 3 through 5, 2006 at the University of Birmingham, UK. This symposium was spearheaded by Professor J. R. Blake of Department of Mathematics, the University of Birmingham, and Professor Masato Nagata of Kyoto University, and was jointly sponsored by our COE and the University of Birmingham. There were 15 speakers from Kyoto University, nine from the University of Birmingham, six from other universities in the UK, and one from Italy. This symposium had lively discussions, and doctoral course students from the Department of Mathematics of the University of Birmingham and Kyoto University introduced their works through poster sessions. Furthermore, Kyoto University has been holding Three Asian Universities Thermal Engineering

Conferences in other areas of study, namely thermal radiation, thermal transfer in solids, and micro-scale thermal fluid phenomena, on a regular basis with Seoul National University, South Korea, and Tsinghua University, China.

The Complex System Control and Design Group held the Third International Symposium on Adaptive Motion in Animals and Machines (AMAM 2005) in Germany on September 25 through 30, 2005, while the Joint Workshop on the Frontier of Complex Mechanical Systems for and with Humans was held on October 6 and 7, 2005 at Kyoto University in conjunction with the Technical University of Munich (Pic.4).

Pic.4 The Joint Workshop on the Frontier of Complex Mechanical Systems for and with Humans was held on October 6 and 7, 2005 at Kyoto University in conjunction with the Technical University of Munich.

Twenty presentations, including eight from our Center, ten from Technical University of

Munich, one from University of Tokyo, and one from Nara Institute of Science and Technology were given. Young researchers, mainly from the two hosting universities, engaged lively research exchanges, which involved postdoctoral fellows and doctoral course students. These exchanges led to the signing of agreements between Kyoto University and Technical University of Munich, namely the Inter-University Academic Exchange Agreement (2006) and Student Exchange Agreement (2007), which are the first such university-wide agreements between Kyoto University and a technical university.

In addition to the abovementioned symposia, each group has been actively hosting or jointly hosting international symposia and conferences, which included one in fiscal 2003, 14 in 2004, five in 2005, four in 2006, and four in 2007.

4. New Lectures for Graduate Students

(1) Newly offered seminars for doctoral course students: "21st Century COE Seminar on Complex Systems Mechanical Engineering"

Since 2004, we have been offering new lectures for doctoral students in the Department of Mechanical Engineering and Science, Department of Micro Engineering and Department of Aeronautics and Astronautics entitled, "21st Century COE Seminars A – F on Complex Systems Mechanical Engineering" (one unit for each semester). The purpose of these seminars is to train our doctoral course students to present and discuss their research results in English as well as to describe their work to researchers in different fields. Additionally, our faculty members are present and participate in these discussions. Hence, the seminars are venues where our students acquire the ability to explain and discuss their work to auditors from different fields. We ask students to

introduce their works based on a minimum level of common understanding on the subject matter, and then they discuss, “what they have done, what issues were faced, and how this issues were overcome.” Furthermore, we provide occasions for students to attend lectures and discussions offered by faculty members of our COE as well as those by invited experts and researchers in the COE programs. These programs allow students to acquire a broad knowledge and many different perspectives, which are beyond their specialty to deepen their understanding of complex systems mechanical engineering. Moreover, we strongly encourage RA recipients, mentioned above, to participate in these initiatives.

Compared to Ph.D. training in the West, Ph.D. training in Japan has generally been regarded as inferior in its ability to nurture students to take the initiative to take leaderships in their research project and to discuss their work in comprehensive terms with researchers in different fields. Moreover, Ph.D. training in Japan has been regarded as weak in its ability to communicate with other researchers by leveraging on what they have in common. However, all of these abilities are essential in pursuing collaborations. Although our students accumulate practical experience by participating in our internship program with industries in Japan and abroad, education must also provide similar opportunities to students on a daily basis to ensure that students are not confined to a narrow specialty and viewpoint.

In light of these concerns, in 2006, we implemented a new initiative to the 21st Century COE Seminar on Complex Systems Mechanical Engineering. We redefined the seminars so that they are no longer a place to present already obtained research results, but are now a place to tackle new issues by a team of several students, who must work

cooperatively and combine their individual knowledge. We let all doctoral course students, whether they are international students, students from indistries, regardless of their specialty and age, form a team of several students. Each team must come up with a project proposal on a significant, given theme. These teams, which are lead by the students themselves, must develop a plan and progress according to a predetermined timeline. Typically, each team works together for about a year, and each member uses his or her expertise to contribute to the project so that their chosen subject matter can be discussed in a seminar format in English. Two times of meetings for announcing the results are organized every year, one in the summer and the other in the winter, and these are open in and out of the university. Although team members assess each other, the team as a whole is evaluated by other teams, and it is typical that each team naturally becomes interdisciplinary all by itself, and interestingly, each group always has a student who takes a leadership role.

For example, if we take a seminar held in fiscal 2006, we asked students to propose a liberal and grand research project on the “harmonious coexistence in the global community,” which is one of the mission statements of Kyoto University. We let them compete and evaluate each other according to how “impressive” their proposals were, and presented the “Impressive Awards for Enterprise” at the end. As the report in the first semester, we held a mid-term presentation entitled, "Young Investigator’s Free Talk on Harmonious Coexistence within the Human and Ecological Community on this Planet,” at the Inamori Hall within Shiran Kaikan on July 28, 2006. During the second semester, the students’ proposals were refined through discussions and debates between teams, and the final presentations were given on December 21 at the AV Hall on the third floor of the Kyoto University Library. These presentations were widely publicized

to the Kyoto University community, including its President. Unlike a formal academic conference, which we often attend, we saw a number of unique ideas that the students came up with on their own that we would have never thought of. Thus, we feel that this program provides valuable experiences for students to reconsider their regular research activities from the viewpoint of what each student can contribute under a common theme and what enables the understanding of their research to members from different specialties.

Pic.5 The 21st Century COE Seminar on Complex Systems Mechanical Engineering.

(2) Establishing a New Lecture for Graduate Students: "Complex Systems Mechanical Engineering"

Building upon the results from the past four years, our departments have began to offer a new lecture for graduate students in order to introduce cutting-edge research achievements in this new mechanical engineering field of *Complex Systems Mechanical Engineering*. Besides the Fundamental Theories of the Complex Systems Mechanical

Engineering Group, each of the three research groups, namely the Complex Systems Fluid Dynamics Group, Complex Systems Materials Mechanics, and the Complex Systems System Engineering Group, offers four units.

1) Fundamental Theories (2 units)

2) Complex Systems Fluid Dynamics (4 units)

    Turbulence Theory in Dynamics System

    Environmental Fluid Engineering

3) Complex Systems Materials Mechanics (4 units)

    Materials Mechanics based on the First Principle

    Nano Biomechanics

4) Complex Systems System Engineering (4 units)

    Human-Machine System

    System Biomechanics

These courses are designed for doctoral course students, but master's students are allowed to enroll. Moreover, these courses are part of initiatives in the Mechanical Engineering departments for a new curriculum to enhance graduate level education by encompassing different fields with multiple majors ("interdisciplinary engineering courses"), and will be applied to the Five-Year Integrated Masters-Doctoral Program (discussed later), which is currently being planned.

5. International Research Conferences Organized and Hosted by Young Researchers, including Doctoral Course Students

As part of our training program, we actively held international research conferences organized and hosted by young researchers, including doctoral course students, in addition to those led by faculty members. The following are major international conferences in this category.

(1) Collaboration with the University of Michigan and the University of Freiburg

In November 2004, the Complex Systems Materials Mechanics Group signed an academic exchange agreement among three universities – Kyoto University, the University of Michigan, and the University of Freiburg – for the purpose of systematic development of fundamental technologies for the next generation micro electronics – machine integrated systems (MEMS: Micro Electro Mechanical Systems). This academic exchange agreement is known as the MicRO Alliance, which is derived from the three universities names（Michigan, fReibuRg, kyOtO). The MicRo Alliance aims to systematically and comprehensively establish a framework to develop fundamental technologies of the next generation MEMS field by organically combining the strengths of each university.

In this Alliance, training of young researchers is an important element for achieving our goals. Hence, we are actively encouraging interactions among young faculty members such as associate professors and assistant professors as well as doctoral course students and master course students. Through these interactions, young researchers become familiar with the infrastructures of each other’s universities such as micro-machining, micro analysis, and ultra high sensitivity analysis, which helps develop a system where

researchers make use of each other’s research infrastructures. In addition, we are actively engaging in a recurrent education for young researchers and engineers in industry. Each of the three universities, Kyoto University, the University of Michigan, and the University of Freiburg, has been active in academia-industry collaborations. Currently, we are developing a system where young researchers and engineers from our industry partners are accepted as graduate students so that this system serves as a venue for recurrent education of the next generation MEMS field. Furthermore, we are considering an internship program at various geographical areas through our alliance partner universities in order to nurture ability for the doctoral course students and master course students at Kyoto University, the University of Michigan, and the University of Freiburg, to conduct the next generation MEMS research with industry applications in mind and from a global point of view.

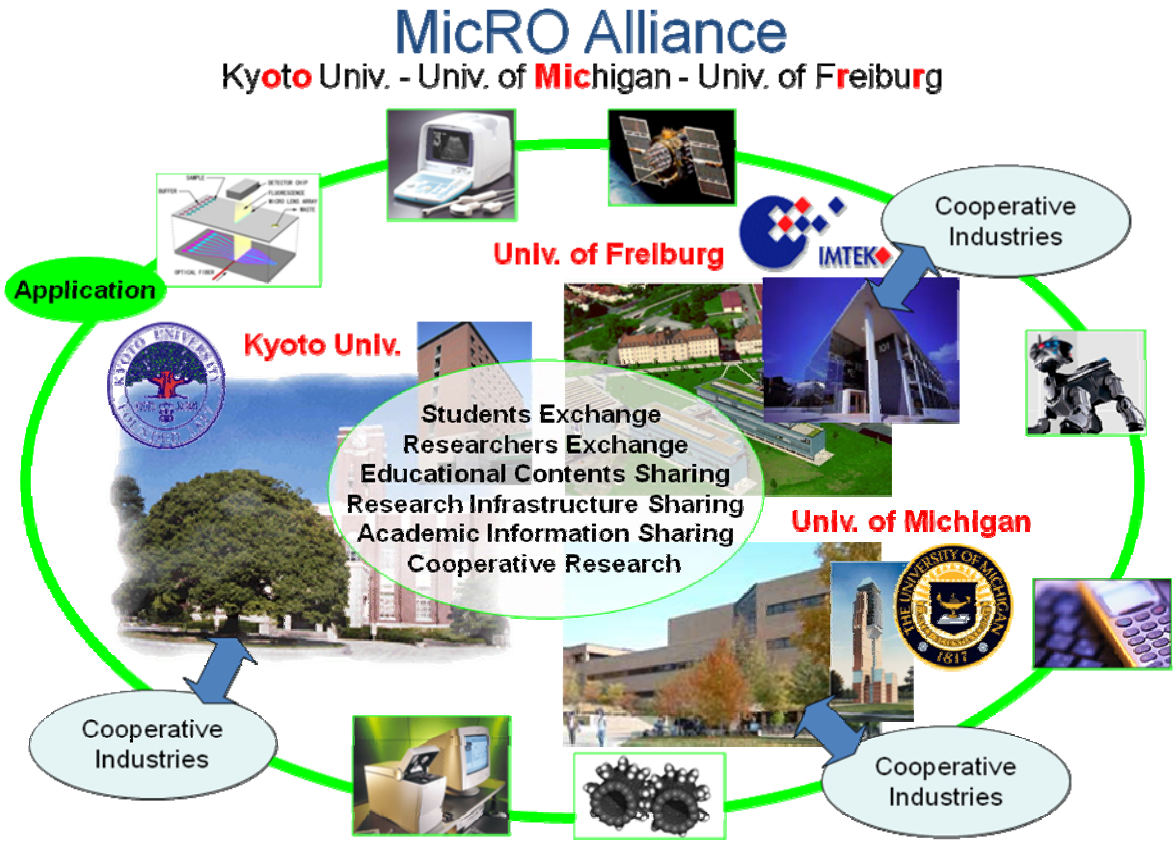


Fig.2 The MicRO Alliance: Kyoto University, the University of Michigan, and the University of Freiburg

(2) Academic exchanges with the Technical University of Munich

The Complex Systems Control and Design Group jointly hosted an international workshop with Technical University of Munich on October 6 and 7, 2005 at Kyoto University as part of a university-wide event, which was geared mainly toward young researchers. 19 young researchers from Technical University of Munich visited our Center, including six doctoral course students. Our young faculty members and doctoral course students of the Control and Design Group held research exchange events with these visitors.

This workshop was planned jointly by Prof. Tetsuo Sawaragi, who then served as the

group leader, and Professor Martin Buss of Technical University of Munich, who also serves as an international research advisor to our COE. The workshop was held as part of an exchange program between Kyoto University and Technical University of Munich entitled, “Deutschlandjahr 2005/2006”. This exchange program was initiated by the Deutschland in Japan 2005/2006, which was sponsored by both the Japanese and German governments and by the appointment of Kyoto University by Technical University of Munich. This workshop aimed to introduce scientific frontiers from Japan and Germany to Japan’s academia, industry, and foundations in order to further academic and research exchanges between the two countries and the two universities.

On the first day of the workshop, a total of 151 people, including Professor Hannemor Keidel, Vice-President of Technical University of Munich, and Professor Kazuo Oike, President of Kyoto University, at Rohm Plaza on our Katsura Campus, attended. Technical University of Munich gave a presentation on the status of frontier science in Germany and Technical University of Munich’s roles and contributions there. Then Kyoto University introduced its five 21st COE Programs currently underway in the science and engineering fields. Our COE leader, Professor Kazuo Tsuchiya, presented an overview of our research activities. On the second day, six frontier science workshops, which were on a sustainable society, computational mechanical physics, foods and environment, architecture, bio-materials, and complex systems mechanical engineering, were held at three campuses of Kyoto University, namely Yoshida, North, and Katsura campuses. One of these was the “Joint Workshop on the Frontier of Complex Mechanical Systems for and with Humans”, which was held jointly by our group and Technical University of Munich. We had a lively research discussion with 20 presentations, mainly by young researchers, postdoctoral fellows, and doctoral course

students from both universities. All workshops were centered on the theme of robots and humans. From the human side, presentations were made from the viewpoint as a system to bridge humans and machines on a wide range of topics from co-adaptive human-machine system dynamics to experimental analysis on entrainment during pedestrians' walking on a bridge. On the other hand, from the viewpoint of designers of autonomous robots, presentations were made on two-legged robots, aero robots, power-assist equipment, and learning algorithms of environmentally adaptive machinery. Furthermore, a variety of presentations were made on interface systems to bridge humans and machines such as the architecture of virtual reality, extended reality, and mixed reality work space to remotely control robots and the usability design of equipment.

(3) Kyoto University - KAIST Joint Workshop on Nano-Mechanics & Nano-Technology

The Complex System Materials Mechanics Group held the First Kyoto University and KAIST Joint Workshop in conjunction with the Korea Advanced Institute of Science and Technology (KAIST) on May 20 through 23, 2006. The purpose of this workshop was to present research projects, to exchange opinions, and to have international interchanges among doctoral course students of mechanical engineering from both universities.

The workshop was initiated by Professor Takayuki Kitamura of our Center and Professor Seyoung Im of KAIST, and was sponsored by the Center for Nano Scale Mechatronics & Manufacturing BK21 KAIST Valufacture Institute of Mechanical Engineering (on the KAIST side), which is dubbed a Korean 21st Century COE Program.

Doctoral course students from both universities mainly organized the workshop through active discussions to determine the schedule. The two-day workshop had nine participants from Kyoto University and eight from the KAIST.

Pic.6 The First Kyoto University and KAIST Joint Workshop in conjunction with the Korea Advanced Institute of Science and Technology (KAIST) on May 20 through 23, 2006

During the workshop, participants from both universities presented their works on macroscopic strength evaluation based on continuum dynamics (simulation), fracture mechanics of anisotropic materials, and fracture mechanics of three-dimensional cracks as well as projects in the areas of more microscopic strength evaluation, evaluation of mechanical properties and strength, and the physical properties using quantum mechanics. These approaches from different points of view gathered much interest as was evidenced from the fruitful question and answer discussions. Hence, this workshop project has had a significant impact because it has stimulated the students' future international research activities not only due to the presentations during the workshop, but also the dialogue with the other students during the preparation phase to ensure the

workshop was well organized. The student organizers also conducted a questionnaire survey to all the participants in order to make the next workshop even better. The second workshop is planned for this fall.

(4) Kyoto University - KAIST Joint Workshop on Vibration Control Engineering

The Complex Systems Control and Design Group had the First Joint Workshop, mainly with doctoral course students, at our Center and the Vibration Engineering Laboratory at the Korea Advanced Institute of Science and Technology (KAIST) at KAIST (Daejeon, Korea) on August 31 and September 1, 2006. The purpose of this workshop was to exchange opinions on research and to have dialogues among the students between the two universities. In addition to students of Kyoto University, we invited students from other universities in Kyoto Prefecture to attend. This invitation resulted in the participation of one doctoral course student from Doshisha University. This workshop was initiated by Professor Hiroshi Matsuhisa and Associate Professor Hideo Utsuno of Kyoto University and Professor Chong-Won Lee of the KAIST, but was planned and operated by a collaborative effort of doctoral course students from both universities. Each university had six participants present their research results, which lead to discussions in English. The purpose of this Joint Workshop was not only to exchange ideas about research in both countries and to practice presenting in English, but also to gain an experience in planning and operating a workshop. Through these organizational activities, students from both countries have had interchanges as well as have learned about each other’s cultures.

Pic.7 The First Joint Workshop, mainly with doctoral course students, at our Center and the Vibration Engineering Laboratory at the Korea Advanced Institute of Science and Technology (KAIST) at KAIST (Daejeon, Korea) on August 31 and September 1, 2006

Although the main topics in the workshop presentations were vibration analysis and control of dampers, boards, beams and axial structures, there were a variety of other presentations. Our students witnessed the attitude of KAIST students, and found common ground on all the presentations, not just the ones in their specialty field, which resulted in interesting discussions and valuable lessons in nurturing their international mindset. In addition, we were invited to visit their research groups, students' residences, laboratories, and a reception to meet faculty members and all students hosted by the KAIST department. This invitation yielded an excellent opportunity to discuss education, international students, and initiatives for internationalization at each university.

Students who participated, especially the ones who lacked experience studying abroad, strongly felt the importance of being able to communicate in English in order to conduct

research internationally. In addition, the students felt that the workshop was a great opportunity to practice viewing issues from a variety of different perspectives, and learned that receiving opinions and questions from different points of view is really beneficial. This workshop provided our students a chance to not only give presentations, but also create new friendships and deepen their understanding of students from a different country as peers through lunches and a reception after the presentations. These experiences have expanded our students' global views and have built the foundation of an international network for their future research careers.

6. Collaborative Education Program with Industries and Universities

(1) Academic-Industrial Cooperative Seminars and Recurrent Lectures

There is a growing desire in industry to collaborate with universities on their fundamental research needs due to a paradigm shift in the mechanical technologies. Accordingly, the importance of continuing education has been increasing, while evaluations and requests from industry have simultaneously impacted the concept of mechanical engineering in the university's research and education. In response to this situation, our Center has teamed up with our alumni association from the mechanical engineering departments of Kyoto University (abbreviated as Keikikai) to offer recurrent seminars and academic-industrial cooperative seminars as collaborative educational programs with the industrial community.

These recurrent seminars are an easy-to-understand discussion of the latest achievements in mechanical science and engineering. The purpose of these seminars is twofold. First, they provide reeducation for industry engineers seeking new methodology to resolve issues. Second, they help engineers looking for ways to

commercialize core technologies of their companies.

On the other hand, academic-industrial cooperative seminars are offered as part of our academic-industrial collaboration initiatives, and these are courses for industry engineers and researchers on complex systems mechanical engineering and advanced technologies. The topic of each course is related to our Center's activities. The seminars, which discuss the latest research findings in complex systems mechanical engineering as well as industry's research needs, are presented by a faculty member of our Center. The comprehensive discussions are aimed to discover academia-industry collaboration topics. At the conclusion of each course, we have the Salon of Excellence (SOE) where people freely discuss matters related to the lectures and academia-industry collaboration. These seminars are supposed to nurture people's general knowledge, not necessarily limited to engineering, in a relaxed and enjoyable atmosphere as well as provide a forum to exchange views and build networks. The purpose of this initiative is to discover and train people who can influence society both in Japan and abroad for the next generation.

In 2004, we held five academic-industrial cooperative seminars in Tokyo (with a total attendance of 142), and one recurrent seminar (in Tokyo with 53 attendants). In 2005, we held six academic-industrial cooperative seminars in Tokyo (with a total attendance of 158) and two recurrent seminars in Tokyo and Nagoya (with a total attendance of 94). Similarly, in 2006, we held six academic-industrial cooperative seminars in Tokyo and Fukuoka (with a total attendance of 127), and two recurrent seminars in Tokyo and Nagoya (with a total attendance of 110). Thus, in the last three years, we have held 17 seminars with 684 people in attendance.

Pic. 8: Academic-Industrial Cooperative Seminars and Recurrent Lectures

(2) 21st Century COE Program Open Symposium

This open symposium was first held when this Center was established in 2003. Since 2004, it has been held annually in May. The symposia introduce the objectives of our Center as well as specific research projects, and show people our research and experiment facilities. The main purpose of these symposia is to report the research results of the Center during each fiscal year. We consider these symposia as prime occasions to widely publicize complex systems mechanical engineering to the public, and therefore, we publicize the symposia through such channels as the alumni association and a mailing list of academic associations that our faculty members belong. Furthermore, to obtain an external evaluation of our research results, we are commissioning an evaluation to an external advisory committee, which is comprised of five prominent intellectuals outside of Kyoto University who are highly regarded in applied mathematics, statistical physics, fluid dynamics, materials dynamics, and system engineering. The committee's evaluation is reflected in the planning of subsequent fiscal years.

Pic. 9 21st Century COE Program Open Symposium

The second symposium, which was held in 2004 (at the International Hall, Kyoto University Clock Tower Centennial Hall), attracted 174 participants. The third one held in 2005 (at the Inamori Hall, Kyoto University Shibaran Kaikan) had 178 participants. In addition to the fourth one in 2006, which was held at the Katsura Hall, B Cluster, Kyoto University Katsura Campus, we had an open house to showcase the experimental facilities at the Katsura Int'tech Center.

7. Reorganization and Reform of Graduate School

Mechanical engineering is a mature discipline with a long, rich history, and each one of its research fields has its own well-established concepts and methodology. However, upon the establishment of this Center, a movement started to reconsider the conventional concept of mechanical engineering in order to pioneer new research fields. In 2005, this movement motivated the reorganization of four mechanical engineering departments (mechanical engineering, mechanical engineering and physics, precision engineering, and aeronautics and astronautics), and consequently, three mechanical engineering departments, i.e. mechanical engineering and science, micro engineering,

and aeronautics and astronautics, now operate as one coordinated mechanical engineering group to provide a master's program with the same curriculum. This unified curriculum offers eight core courses, which include three in the dynamics of mechanical engineering (fluid, materials, and thermal), computation, system control, design and manufacturing, quantum physics, engineering ethics, and technology management. Each student must take five of these eight courses as compulsory courses in addition to the seven or more applied courses. The applied courses include ones in fields such as bio, information, environment, nano as well as interdisciplinary courses with mechanical engineering, but each student chooses which courses to take.

For the doctoral course program, in addition to the training with common doctoral courses for the mechanical engineering group and under each department's curriculum, we also provide training on interdisciplinary and advanced or fundamental topics at the Advanced Research Centers at the Katsura Int'tech Center. The five Advanced Research Centers encompass fluid dynamics, nano engineering, micro chemical systems, interface science, and environmental materials control. These topics are being expanded to cover even more diverse interdisciplinary fields in order to respond to the changing needs of society. Infrastructures for interdisciplinary research beyond the boundary of each specialty are being established. Our Center has been making a significant contribution, particularly through our research at the Fluid Dynamics Advanced Research Center, the Nano Engineering Advanced Research Center, and the Smart Materials Laboratory. Our contributions are highly regarded as solidifying the foundation of this new Katsura Int'tech Center as shared interdisciplinary facilities within Kyoto University.

The common philosophy in education for graduate students is to achieve a balance

between a high degree of specialization and a broad knowledge base. At our doctoral course program, our responsibilities are to produce university professors and people with an ability to pursue research in the international arena who can lead society and the world. Our approach to fulfill our responsibilities is not to provide a standardized education, but to provide the students with choices. By showing what direction each choice may lead a student, we are providing a flexible education system, which can be tailored to each student's needs.

(2) On-Going Reform of Graduate School: Master's – Integrated Masters-Doctoral Program

Graduate school education system reform currently underway at Graduate School of Engineering includes an initiative to implement an Integrated masters-doctoral program, which consolidates the master's and doctoral course programs. Under this new system, the following two programs will be offered.

A. Interdisciplinary Engineering Course (Inter-sectorial education program)

This program aims to train students who can contribute to the pursuit of truth and development of their chosen fields of study, including existing specializations and academic fields, and related interdisciplinary areas. This program will be offered at the Advanced Education Center, which will be implemented along with the Advanced Research Center at the Katsura Int'tech Center mentioned above.

B. Advanced Engineering Course (Single specialty type education program)

This program will replace our existing doctoral course program. This program strives to train students who can contribute to the pursuit of truth and development

of their chosen fields of study from existing specializations and academic fields.

The educational objectives of each course are (1) to unify the master's and doctoral course programs, (2) to provide three options of study, which are three to five years in duration, and (3) to help our students systematically design their curriculum for their course work and research so that their time at our Center prepares them for their long-term objectives. Students will not only study a plethora of existing courses in each of our departments, but also acquire broad academic knowledge and international perspectives through experiments, laboratory work, and seminars, as well as On-the-Research Training at the Advanced Research Centers, industry partners, and international institutes. Our goal is to produce researchers who can take a leadership role and organize a research team in a new or emerging research field.

We are planning for five units within the Advanced Education Center to comprise the Interdisciplinary Engineering course mentioned above. Our Center is taking the lead in two of these units; *Applied Dynamics Unit* and *Bio-medical Engineering Unit*. The achievements we have obtained through our Center activities will be organized and realized as new graduate programs[1].

8. Philosophy in Education at the Center and the Future Prospects

(1) Philosophy for Education at the Center

To implement the aforementioned educational programs at our Center and graduate school reform, we must extract issues relevant to the university and graduate school

[1] As of April 2007, other units being considered to join the Interdisciplinary Engineering course of Graduate School of Engineering, besides the two mentioned, are *Evolutionary and Sustainable Social Infrastructure Engineering*, *Materials Functionality and Conversion Science*, and *Human, Environment and Design*.

education. Currently the primary issue appears to be something like cramming system of education, which is a mode of education based on the idea that what is taught is predetermined and exist independently, and educator teach only this material, has reached its limit. A problem with this paradigm is that as academic fields mature, the degree of specialization in the content of what we teach becomes even higher, and each specialization becomes disconnected from other specializations in many ways. Consequently, students cannot acquire the comprehensive knowledge, which each specialty was originally founded on. Hence, a true *learning experience* is not provided. To resolve this issue, we have proposed a new, common concept of *Complex Systems Mechanical Engineering*. This program unifies all of traditional mechanical engineering, and we have used this program to conduct our research and education activities. Our philosophy of education can be summarized as follows.

Our first change has been to reconstruct our *view of knowledge* that the education in mechanical engineering stands upon. In the mechanical engineering, particularly in fields involving synthesis, an education methodology that strictly crams knowledge and principles into students, and operates only on these specific principles is not suitable. Thus, we adopted a methodology where knowledge can be easily pragmatized and conceptualized. On the other hand, mechanical engineers must be able to “investigate the relationship between each piece of knowledge” in individual fields, which are becoming increasingly segmented. This is the standpoint of viewing knowledge from relations among different disciplines, and this is knowledge gained through addressing real world issues. Much of this type of knowledge can be applied to a new phenomenon only when a person can theorize the phenomena of a particular event through abstraction and essentialization. What our Center has strived to achieve, first and

foremost, is to train our students so that they can obtain knowledge by combining experimental research and mathematical analysis in order to bridge abstraction and concretion.

The second part of our philosophy in education is to practice collaborative research methods of the fundamental basic research. Unlike education for collaborative research of the project type, it is difficult for a faculty to clearly show the goals of each stage. Even if the goals are set higher throughout the education process, it is difficult to take a step-by-step approach where a student aims to achieve the next higher goal by starting with lower level goals. Hence, the goals of education in the fundamental basic research will be qualitative and spiral where an over-all model, which is structured to some extent at the beginning, but is expanded and improved as the faculties understands the students' learning processes and is able to incorporate knowledge that the faculties have gained through their experiences. This new philosophy conflicts with the existing curriculum-based educational system where instructions are given efficiently within a limited amount of time. As such, the success of our new philosophy hinges heavily upon the students' efforts of interpretation.

For this reason, although the educational program at our Center has strived to further students' ability to look for similarities rather than differences among issues that encompass multiple fields and to thoroughly consider individual approaches, our goal has been to nurture students' ability to theorize these issues as they are abstracted and generalized by grasping their essence, thereby discovering potential relationships with new and different needs.

Our third philosophy pertains to a difficulty due to the fact that educational activities in

complex systems mechanical engineering must have an open world instead of a closed one as a target. To date, Natural Science has made great achievements by objectifying experiences and events as if they were “things”. The power of natural science has been exhibited by applying itself to the objective world. On the contrary, the world that a mechanical engineer faces cannot be isolated from human being, wherein humans need useful and easy-to-use knowledge. This is the reason that the fundamental knowledge of mechanical engineering has to be arranged and systematized as an empirical science supported by a good pragmatism. Therefore, our Center has emphasized the importance of producing people with the abilities to raise and extract issues as well as the ability to structure technologies to resolve these issues. In other words, our Center strives to train engineers who make good use of their knowledge.

(2) To Create New Applied Dynamics

One aspect of education in complex systems mechanical engineering is its form of elemental engineering that places objects at its core as a fundamental science specializing in a particular field; in other words, it is an analytical process. The other aspect is its form of system engineering for designing artifacts with practical applications; in other words, it is a synthetic process. These two components are indispensable to educate researchers and engineers in mechanical engineering. The original motivation for proposing the concept of complex systems mechanical engineering at our Center was that mechanical engineering has become a rather mature and highly developed academic field, resulting in divisiveness among narrowly defined specialties, which made it difficult to share the same concepts. We felt that this situation was one that needed to be resolved, and thus, our educational objective is to produce

people who are conversant with a common language between analysis and synthesis.

If mechanical engineering of the 20th century is considered to be an academic field based on “dynamics,” then mechanical engineering of the 21st century is the systematization of applied dynamics based on the fundamental concept of “dynamics, complexity, and information”. This type of mechanical engineering would naturally result in the development of a new academic field. Thus, complex systems mechanical engineering aims to understand the relational existence that is created between the interaction of individual functions and the whole system as well as time and space by focusing on all the dynamics within a system. This is the very motivation in naming our Center as “dynamic mechanical system”.

In addition to continuing conventional studies on mechanical systems based on traditional dynamics, thermal fluids, and control fields, our future plans are to include global environmental systems, which are characterized by diversity and natural purification, biological systems, which are characterized by self preservation and evolution, and social systems, which are characterized by organization and interrelationship, into our research topics. By focusing on the complex adaptive principle as a universal principle among these systems with different functions, we will be venturing into the future activities of our Center by pursing functions that unify and maintain whole systems, while simultaneously maintaining interrelationships among systems in harmony with the environment.