

# 2014

## International Forum Korea on Advances in Mechanical Engineering

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Organized by

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**KIMM** 한국기계연구원  
KOREA INSTITUTE OF MACHINERY & MATERIALS

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*Published by KIMM Press*

*156 Gajeongbuk-Ro, Yuseong-Gu  
Daejeon 305-343  
Republic of Korea*

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*First published in 2015*

*Edited by Yong-Taek Im & Sang-Rok Lee  
2014 International Forum Korea on Advances in Mechanical Engineering*

*ISBN 979-11-954565-0-5 (93550)*

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## International Forum Korea on Advances in Mechanical Engineering

*Edited by Yong-Taek Im & Sang-Rok Lee*



KIMM PRESS

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## PREFACE

According to the statistics on the volume of the trade, Korea ranked 10th in the world. Korea's rapid economic rise is often referred to as "the miracle on the Han river." Many visitors to my research institute are very curious to know how this miracle was achieved over the last half century. I think the major success was due to the target-oriented economic planning of the late President Park Chung Hee, who really created a blueprint for national industrialization starting in 1962.

The first big decision of his economic planning team was to build POSCO, the steel mill at Pohang in 1965. In 1966, he decided to build up the second research institute, Korea Institute of Science and Technology (KIST), in Hongneung with the help of the then President of the U.S., L.B. Johnson, similar to the Battelle Research Institute in Columbus, Ohio. In 1971, the graduate school of the Korea Advanced Institute of Science (now the Korea Advanced Institute of Science and Technology) was launched in Hongneung next to KIST to produce research scientists and engineers for revamping domestic industry. The whole series of investment plans was very daunting because the gross national income per capita was less than 100 US\$ in the early 60s.

As part of such economic plans, the industrial complex for mechanical engineering was introduced in the Changwon area, where the Korea Institute of Machinery and Materials (KIMM) was established in 1976 to inspect the materials, machine parts, and products. In 1992, KIMM moved to the Daedeok Science town, where around 20,000 research scientists are working at the 30 national research institutes, 2 national universities, and countless technology-based corporations and startups. The total number of companies in the Daedeok Valley reached 1300 as of 2012, and their sales volume was around 13B US\$.

Recently, Korea's research and socio-economic environment has become more challenging because of the rapid growth of private research institutes and international competition. In order to cope with such challenges, R&D strategy needs to be changed to improve the research throughput and technology transfer to industry, especially to the small- and mid-sized companies. In addition, KIMM should encourage research scientists to form more spin-off companies and engage in more domestic and international collaborations because the world market is becoming more dynamic and global.

Thus, a plan was made to hold the International Forum Korea on Advances in Mechanical Engineering (IFAME), hosted by the Korea Institute of Machinery and Materials (KIMM) in Daejeon, Korea, on October 24, 2014. With 237 participants, the Forum had fruitful presentations and discussions by renowned speakers from industry, academia, and research institutions around the world on new initiatives, plans of action, and the best practices concerning spearheading technological advances in the field of mechanical engineering, in

particular, for next-generation manufacturing technologies including bio nanotechnology, energy, and the environment, as well as the roles and perspectives of public research institutions.

In this Forum, we sought promising future technologies in mechanical engineering and measures to strengthen national competitiveness. In the “Next-generation Manufacturing Technologies” session, Professor and Director Taylan Altan of the Engineering Research Center for Net Shape Manufacturing at the Ohio State University, Vice President Guenther Klopsch of Siemens Ltd. Seoul, Vice President Sangwhui Cho of Hyundai-Rotem Company, Managing Director Stephen Roth of Bayerisches Laserzentrum GmbH, and Distinguished Professor Luke P. Lee of UC Berkeley presented on next-generation metal forming, laser processing along with *Industrie 4.0*, modular manufacturing, and development of molecular diagnostic systems, respectively. They shared the view that manufacturing technologies will evolve in ways that ensure the following outcomes: improvements in both productivity and precision, energy saving, enhanced lifecycles of products, flexible production, and reduced costs. We also explored bio-inspired medical technology, which requires not only basic science but also an understanding of various areas in mechanical engineering such as nanoscale manufacturing processes, optics, and microfluidics.

In “Energy and the Environment” session, Senior Executive Vice President Kenji Ando of Mitsubishi Hitachi Power Systems (MHPS) introduced endeavors in gas turbine development and current research activities of MHPS. The President Jong-Soo Woo of the Research Institute of Industrial Science & Technology (RIST) presented on energy efficiency improvement and emission reduction. We learned that MHPS’s gas turbine technology is a result of the Japanese government’s mid/long-term R&D support as well as the company’s effort. We also explored the R&D activities of RIST, which have focused on areas including energy efficiency improvement, carbon capture and utilization, smart grid, clean coal, and fuel cells.

In Session 3, the roles and perspectives of public research institutions with respect to the current global environments were discussed. Engineering Director David Korsmeyer of NASA Ames Research Center introduced Ames’s efforts in improving research output through modular design in spacecraft. Furthermore, Ames is investing in promoting manufacturing competitiveness and commercializing its technologies, leading to job creation. I reaffirmed that government research institutes in Korea should contribute to the creative economy by improving research productivity and developing key technologies. KIMM’s new visions and management strategies were introduced to accommodate changes in the research environment and national R&D governance system.

With this kind of new effort, I would like to rebrand KIMM as the center for Knowledge, Innovation, Motivation, and Marketability to make the institution more sustainable for the

future.

I thank all the speakers and participants from around the world who contributed to embarking on this journey to explore the future of mechanical engineering. I would like to express my deep gratitude to all the members of steering and organizing committees for helping make this Forum a success. I am confident that the next IFAME, which will take place in 2015, will be even more exciting and stimulating. I am looking forward to seeing you all together next year.

Yong-Taek Im  
President  
Korea Institute of Machinery and Materials



## ACKNOWLEDGMENTS

Were it not for the leadership of Dr. Yong-Taek Im, President of the Korea Institute of Machinery and Materials (KIMM), and the support of the international and domestic colleagues from the U.S., Germany, Japan, and Korea, the 2014 International Forum Korea on Advances in Mechanical Engineering in Daejeon would not have been possible. As a co-organizer of the Forum, I would like to express my heartfelt appreciation to all the participants who travelled from places distant and near to share their valuable time and expertise to make the Forum a resounding success.

I would not have been able to finish the publication of the Proceedings of the Forum without the editorial support for transcribing the manuscript from Ms. Jinni Kang, Ji Hyeon Seo, Heeyun Kang, and Hyun Soo Sung, and editing the manuscript from Professor Mik Fanguy. The endless support from Mr. Sung-Kyu Cho, Mr. Jaeyun Song, Mr. Byong Joo Yoo, Ms. Eun Hee Soh, Ms. Eunjin Lee, Mr. Myung Jun Oh, Mr. Seung Hun Oh, and Dr. Chang Ju Kim to handle details of the Forum was very much appreciated as well. Professor Hyun Dong Shin, Drs. Jeong Lak Sohn, and Sung-Hak Cho deserve special acknowledgment for their contribution to inviting the speakers to the Forum. The outstanding administrative support from the organizing staff is too vast to mention in detail here but cannot be overemphasized.

The generous support of Drs. Eung Sug Lee, Byung-Chun Shin, Hyun-Sil Kim, Eui-Soo Yoon, Yongjin Kim, Chun Hong Park, Jae-Jong Lee, Hak Joo Lee, Hee-Chang Park, Sang Jin Park, Chae Whan Rim, and Mr. Hong-Bae Kim was very much appreciated. The Forum was organized under the auspices of the Ministry of Science, ICT and Future Planning, the Ministry of Trade, Industry, and Energy, the National Research Council of Science and Technology (NST), Daejeon Metropolitan City, the University of Science and Technology, the Korea Academy of Science and Technology, and the National Academy of Engineering of Korea.

Also, I would like to specially thank Vice Minister Suk-Joon Lee, Assistant Minister Dr. Jae Moon Park, Mayor Dr. Sun-taik Kwon, Members of National Assembly, Dr. Sang Kee Suh, Byung Joo Min, Sang Min Lee, Chairman of NST, Dr. Sang Chun Lee, and former Chairman of POSCO, Mr. Joon Yang Chung for delivering their speeches and video presentations during the Forum, and Presidents Kwanghwa Chung, Inwoo Han, Dae Im Kang, Sung-Mo "Steve" Kang, Heung Nam Kim, Jong Kyung Kim, Kwang Ho Kim, Kyu Han Kim, Kyu Ho Lee, Un Woo Lee, Tae Kwang Oh, Ro Kwang Park, Yong Seop Ryu, Eun Sup Sim, and Chairman of the Daejeon Chamber of Commerce & Industry, Jong Hyeon Son for contributing their valuable time and effort.

Lastly, the support for designing the promotional materials from Ms. Minjung Kim and printing the manuscript from the SIMBOOKS and the special assistance from Mr. Jaeyool Sim are very much appreciated.

Thank you very much.

Sang-Rok Lee  
Director of External Affairs & PR  
Korea Institute of Machinery and Materials

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# 발표 국문 요약문 (Presentation Abstracts in Korean)

## 세션 1 : 차세대 제조 기술

### <차세대 제조업에서의 금속 성형의 역할>, 타일란 알탄

※ 발표 전문은 23 쪽을 참고

미국 오하이오주립대 준정형가공연구센터 소장인 타일란 알탄 명예교수는 차세대 제조업에서의 금속 성형의 역할에 대해 설명하며 점성력을 이용한 벌지 시험(Viscous Pressure Bulge Test)과 이를 통한 재료의 특성 분석, 마찰과 윤활 특성 파악을 위한 컵 드로잉 테스트(Cup Draw Test), 서보 프레스(servo press)의 특성, 서보 유압 쿠션(Servo-Hydraulic Cushion)의 특성 등을 소개한다. 알탄 교수는 초고장력 강판(advanced high strength steel; AHSS), 알루미늄 합금(Al alloys) 및 이들 소재 성형을 위한 서보 프레스 개발 및 응용이 제조업의 향후 해결과제 또는 연구 방향이라고 강조한다.

### <제조업의 미래>, 귄터 클롭쉬

※ 발표 전문은 41 쪽을 참고

지멘스코리아 귄터 클롭쉬 총괄대표는 최근 외환 경제 위기 이후 중요성이 부각되고 있는 제조업의 미래와 제조업 강화를 위한 세계 주요 국가들의 정책적 노력에 대해 논한다. 또한 클롭쉬 대표는 전주기 개발과 생산 프로세스에 사이버 설계 시스템(cyber-physical system) 개념을 도입한 독일의 제조업 정책인 Industrie 4.0 을 설명하면서 Industrie 4.0 에 부응하기 위해 지멘스가 약 10 년간 기울인 디지털 매뉴팩처링 관련 R&D 노력을 소개한다.

### <철도차량의 모듈기반 설계 및 제조>, 조상휘

※ 발표 전문은 51 쪽을 참고

현대로템 조상휘 기술연구소장은 세계 철도 시장의 확대에 따라 다양한 혁신을 추구하고 있는 현대로템의 생산 전략을 설명한다. 세계 시장 성장 둔화와 노동비용 증가, 단기 공급 대응 능력 요구, 고객 수요의 다양화 및 전문화 요구 등에 대응하기 위해 생산기술 혁신이 필요한 상황 속에서 현대로템은 모듈화 생산 시스템을 통해 생산성 향상, 파트너십 확대, 글로벌화 도모, 원가 절감 등의 혁신을 달성할 수 있었다고 밝힌다.

### **<레이저 가공의 새로운 트렌드>, 스테판 로쓰**

※ 발표 전문은 57 쪽을 참고

독일 바이에른 레이저센터 스테판 로쓰 상무이사는 레이저 가공의 새로운 트렌드를 설명하며 이를 통해 창출 가능한 다양한 이익에 대해 소개하고 있다. 로쓰 상무이사는 고부가가치 제조업에 광범위하게 적용되는 레이저 가공은 유연성, 자동화 등의 측면에서 각광받고 있으며 빔 직경 (beam diameter)의 소형화가 레이저 소스 개발 트렌드의 핵심으로 자리하고 있다고 말한다. 또한 그는 레이저 가공은 앞으로 재료 활용의 효율성, 에너지 효율성, 공정 효율성, 고정밀성 및 적층 가공성의 관점에서 발전해야 한다고 주장한다.

### **<혁신적인 글로벌 보건의료를 위한 바이오-나노 과학>, 루크 리**

※ 발표 전문은 69 쪽을 참고

미국 캘리포니아주립 버클리대 루크 리 교수가 혁신적 보건의료를 위한 바이오나노광학을 주제로 이야기한다. 하나의 진단 플랫폼 상에서 다양한 생물학적 시료의 특성을 분석하여 의학적 상태를 사전에 진단하는 ‘통합적 분자 진단 시스템 (iMDx)’의 개발에 주력하는 루크 리 교수는 혈액 분리를 통해 생물학적 시료를 진단할 수 있는 iMDx 개발을 위해서는 기초과학뿐만 아니라 나노, 모바일 IT, 광학, 미세유체역학 등 다양한 지식이 필요하다고 강조하고 있다.

## **세션 2 : 에너지와 환경**

### **<미래 발전산업의 과제>, 겐지 안도**

※ 발표 전문은 93 쪽을 참고

미츠비시 히타치 파워시스템즈 겐지 안도 부사장은 미래 발전 산업의 과제를 설명하면서 가스터빈 사업에 주력하고 있는 거대 에너지 기업 미츠비시 히타치 파워시스템즈를 소개한다. 미츠비시 히타치 파워시스템즈의 가스터빈 분야 기술 경쟁력은 정부의 R&D 투자 및 자사의 노력과 함께 실증 시험 전용 설비 구축의 결과이며, 이미 소형에서 초대형에 이르는 제품 라인업 구축에 성공하였다. 미츠비시 히타치 파워시스템즈는 최근 후쿠시마 원자력 발전소 사고로 인해 석탄가스화복합화력 (integrated gasification of combined cycle; IGCC) 기술 개발을 본격 추진하고 있으며, 일본 주고쿠 전력과 개발된 기술의 실증을 추진 중이다.

### **<에너지 및 환경 기술 개발의 전망>, 우종수**

※ 발표 전문은 105 쪽을 참고

포항산업과학연구원 우종수 원장은 에너지 및 환경 분야의 당면 과제는 인구 증가로 인한 에너지 소비 증가, 지구 온난화 및 경제난 해결에 필요한 안정된 전력 공급이라고 강조한다. 이에 에너지 효율 향상과 신재생에너지원 확대가 중요한 역할을 하게 됨에 따라 포항산업과학연구원이 에너지 효율 향상, 이산화탄소 포집·활용, 스마트 그리드, 청정 석탄, 연료 전지 등의 기술 개발을 위해 기울이고 있는 노력을 소개한다.

### **세션 3 : 정부 출연(연)의 역할과 전망**

#### **<NASA 에임스연구소의 주요 R&D 성과와 과제>, 데이비드 코즈마이어**

※ 발표 전문은 127 쪽을 참고

미항공우주국(NASA) 에임스연구소 데이비드 코즈마이어 기술국장은 정부출연연구기관으로서의 에임스연구소의 역할, 기능, 운영 방침 등을 소개한다. 에임스연구소는 2.5 억 달러 이하의 소형 인공위성 및 달탐사선 개발에 주력하고 있으며 비용 절감을 위해 모듈라 설계 방식을 채택하고 있다. 또한 소형인공위성(nanosat) 프로젝트를 통해 우주의 다양한 중력과 강한 자외선이 생물체 성장과 유전자 발현 및 기능 형성에 미치는 영향을 연구하고 있다. 또한, 최근에는 R&D 예산의 일부를 제조업 경쟁력 강화에 투자하고 있으며 이의 상업적 활용에도 많은 관심을 기울이고 있다고 밝힌다.

#### **<한국기계연구원의 도전과 혁신>, 임용택**

※ 발표 전문은 139 쪽을 참고

한국기계연구원 임용택 원장은 대한민국이 무역 대국으로 성장하였고 제조업과 R&D 투자에 기반한 경제 발전을 달성하였으나 70%를 상회하는 민간 R&D 투자 비중과 출산율 저하에 따른 생산 인구 감소 추세를 고려했을 때 출연(연)의 임무와 역할을 다시 설정해야 한다고 말한다. 그는 새로운 출연(연) 거버넌스 출범, 국가 R&D 사업 투자의 효율적 집행 등을 강조하며 변화하는 외부 환경에 따라 한국기계연구원이 새로 정립한 비전, 경영목표 및 추진전략 체계를 소개한다. 또한 부유식 복합 화력 발전, 초고속 자기부상열차 및 의료용 로봇 기술 개발 등과 같은 중장기 기술 개발의 필요성을 강조한다.



## PRESENTER BIOGRAPHIES



**Yong-Taek Im**

President

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Korea

Yong-Taek Im received a B.S. in Mechanics and Design and an M.S. in Mechanical Engineering from Seoul National University, and a Ph.D. in Mechanical Engineering at the University of California, Berkeley in 1985.

After one year of post-doctoral experience at Berkeley, he began teaching and researching at the Industrial and Systems Engineering Department of the Ohio State University until 1989. After that, he joined the faculty of the Department of Mechanical Engineering, Korea Advanced Institute of Science and Technology (KAIST), where he served as Associate Dean of University Planning and Coordination in 1991 and established the Office of International Relations in 1993. From 2007 to 2011, he served as Dean of the Office of External Affairs and Associate Vice President of the Office of Special Projects and Institutional Relations. Since 2008, he launched and coorganized the International Presidential Forum on Global Research Universities four times. He served as Chairman of the Asian Science and Technology Pioneering of Research and Education League in 2011, Director of the Mechanical Engineering Division of the Korea Institute of Science and Technology Evaluation and Planning, and Editor-in-Chief of the *Journal of Mechanical Science and Technology* of the Korean Society of Mechanical Engineers (KSME).

He received Humboldt Research Fellowship from Germany and Australia-Korea International Education Policy Exchange Program Fellowship from Australia. He was elected as a Fellow of American Society of Mechanical Engineers and the Korean Academy of Science and Technology and is a member of the National Academy of Engineering of Korea.

Prof. Im has received various awards such as the F. Staub Award, Johnson Gold Medal, GCMC Outstanding Research and Scholarship Award, SDPS Award, Presidential Commendation Award from the Korean Government, the first Academic Excellence Award from the Korean Society of Technology for Plasticity, and Designated Affiliate Professorship of POSCO. He has published 210 domestic and international refereed papers and has registered 23 patents. Currently, he is the president of the Korea Institute of Machinery and Materials.



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**Taylan Altan**

Professor Emeritus, Director  
Center for Precision Forming  
The Ohio State University  
USA

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Taylan Altan joined the Ohio State University (OSU) as a full professor in 1985 after working 2 years at Dupont, and 19 years at Battelle Columbus Laboratories in metal forming and manufacturing research.

Professor Altan conducts and supervises R&D in various metal forming and manufacturing projects for government and industry. He advised more than 130 Master and 40 PhD students and developed several courses in forging and sheet metal forming for OSU and industry.

His education includes the following: Diplom Ingenieur, Technical University, Hannover, Germany, 1962; MS, Mech. Engineering, University of California, Berkeley, 1964; PhD, Mech. Engineering, University of California, Berkeley, 1966.

Professor Altan has published several books on metal forming, forging, and sheet metal forming and more than 600 technical papers. He is a member of the following organizations: the North American Manufacturing Research Institute (NAMRI), the American Society of Mechanical Engineers (ASME), the International Academy for Production Engineering (CIRP), the Society of Manufacturing Engineers (SME), and the Japan Society of Technology of Plasticity (JSTP). He is a recipient of the following awards: S.M. Wu Research Award presented by NAMRI, William T. Ennor Manufacturing Technology Award by ASME, Gold Medal and Frederick W. Taylor Research Medal by SME, and Gold Medal by JSTP.



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**Guenther Klopsch**

Head of Digital Factory Division and Process Industries & Drives Division  
Siemens Ltd. Seoul, Korea  
Korea

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Guenther Klopsch is the head of both the Digital Factory Division and Process Industries & Drives Division at Siemens Ltd. Seoul. As a trusted industrial partner, the Divisions offer a comprehensive portfolio of seamlessly integrated software, hardware and technology-based services in order to support manufacturing companies in improving their productivity, efficiency, and reliability.

Mr. Klopsch graduated in electronics at the University of the German Army, Munich in 1977, and he joined Siemens AG, Industry Sector as a trainer at Automation Systems & Products in 1985 after serving as a military officer in Landsberg. He was appointed as Regional Manager for Business Development Europe of Automation Systems at Siemens AG in Nuremberg, Germany in 1988. He started to serve as Marketing Services Manager for Automation Systems in 1990 and became Head of Business Development Germany at Automation Systems in 1994. He served as Director and Head of Business Development Overseas in Automation Systems at Siemens AG in Nuremberg from 1997 to 2004.

Guenther Klopsch came to Korea as Vice President and Division Leader of Industry Automation & Drive Technology in 2004. After four years in Korea, he was appointed as Vice President and Head of Regional Development of Sales & Marketing in the Industry Automation Division at Siemens AG in Nuremberg in 2008. Before his return to Korea, he worked as Vice President and Sector Lead of Industry Sector for North Region in Germany from 2010 to 2013.



**Sangwhui Cho**

Vice President  
Hyundai-Rotem Company  
Korea

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Sangwhui Cho began his tenure as Vice President of Hyundai-Rotem in January 2014. He joined the Hyundai-Rotem from 1992. Since then, he has sought to advance the railway system industry. He has also served as President of Hyundai-Rotem USA until 2012 and maintains a leading position in the industry by keeping up with international market trends.

He received a Ph.D. in Industrial Engineering from Lehigh University, Pennsylvania USA and earned bachelor's and master's degrees in mechanics & production engineering from Seoul National University, Korea.



**Stephan Roth**

Managing Director  
Bayerisches Laserzentrum  
Germany

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Dr.-Ing. Stephan Roth studied production technology at the University of Erlangen-Nuremberg. From 1996 until 2001, he worked as a staff scientist at the Institute of Manufacturing Technology in the field of laser material processing. At the Bayerisches Laserzentrum in 2001, he started as a division manager, and in 2008, he became authorized signatory. Since March 2010, he has led the BLZ as a managing director.

He is a member of the following organizations: Advisory Board “Laser Demonstration Center (LDC)”, Saint Petersburg, Russia; Board (bursar) of Förder- und Freundeskreis für den Ausbau der Lasertechnologie an der Friedrich-Alexander-Universität Erlangen-Nürnberg e. V., Germany; and Conference Chair of LAMOM Laser Applications in Microelectronics and Optoelectronics Manufacturing of the SPIE conference Photonics West, USA.



**Luke P. Lee**

Arnold and Barbara Silverman Distinguished Professor  
UC Berkeley  
USA

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Luke P. Lee is a 2010 Ho-Am Laureate. He is the Arnold and Barbara Silverman Distinguished Professor of Bioengineering, Electrical Engineering & Computer Science, and Biophysics at UC Berkeley, the Director of the Biomedical Institute of Global Healthcare Research & Technology (BIGHEART), and a Co-Director of the Berkeley Sensor & Actuator Center. He was Chair Professor in Systems Nanobiology at the Swiss Federal Institute of Technology (ETH, Zurich). He received both his B.A. and Ph.D. from UC Berkeley. Prof. Lee has more than ten years of industrial experience. His current research interests are precision medicine and preventive personalized medicine. Prof. Lee has authored and co-authored over 300 papers on bioinspired system integrations, biophotonics, quantitative life sciences via integrated optical microfluidics SQUIDs, and medical devices. <http://biopoets.berkeley.edu>



**Kenji Ando**

Senior Executive Vice President  
Mitsubishi Hitachi Power Systems  
Japan

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Kenji Ando was inaugurated as Director, Senior Executive Vice President of Mitsubishi Hitachi Power Systems (MHPS) as of February 1, 2014.

Mr. Ando received his bachelor's degree in mechanical engineering at Tokyo University in 1976. He joined Mitsubishi Heavy Industry Takasago Machinery Works as the plant start-up engineer in 1976. He was involved in the latest nuclear power plants, fossil steam power plants, and gas turbine power plants. From 1997, he took leadership of the Plant Design Engineering Department.

From 2003, he took charge of the gas turbine service business as the Deputy Head of Takasago Machinery Works in 2006 and Head of Takasago in 2010.

He became Deputy Head of MHI power systems division in 2012 and Senior Vice President, Deputy Head of the Energy & Environment domain in October 2013. He is working toward the development of high efficiency gas turbines, steam turbines, integrated gasification of combined cycle (IGCC) units, and the establishment of a worldwide network of MHPS service.



**Jong-Soo Woo**

President  
Research Institute of Industrial Science & Technology  
Korea

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Jong-Soo Woo was inaugurated as the 9th president of the Research Institute of Industrial Science and Technology (RIST) as of March 26, 2014. President Woo received his B.S. in Metallurgical Engineering at Seoul National University, M.S. in Materials Science & Engineering at the Korea Advanced Institute of Science and Technology (KAIST), and Ph.D. in Materials Science & Engineering at the Massachusetts Institute of Technology (MIT) in 1987.

He has been an employee of POSCO, a multinational steel-making company, since 1980, where he was General Manager of the Electrical Steel Sheet Research Department (1987 to 2008), Deputy General Superintendent of the Technical Research Laboratories (2008 to 2009), and Head of the EU Office (2009 to 2011). Prior to his move to RIST, he was Head of the Technical Research Laboratories of POSCO (2011 to 2014).

He served as General Affairs Manager, Commissioner of the Steel Committee, and Pohang Branch Office Head of the Korean Institute of Metals and Materials from 2000 to 2009.

Currently, he is also Chairman of the Steel Committee of the Korean Institute of Metals and Materials, Regular Member of the National Academy of Engineering of Korea, Technology Director of the Korean Society for Technology of Plasticity.

He is the author of more than 100 domestic and international refereed papers and has registered 74 patents.

He played a pivotal role in developing high magnetic induction grain-oriented electrical sheet steel by low-temperature heating method, plate-accelerated cooling technology, and temporary/permanent magnetic refining technology.



**David Korsmeyer**

Director of Engineering  
NASA Ames Research Center  
USA

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David Korsmeyer is the Director of Engineering at NASA Ames Research Center. He has over 50 technical publications and is active in several professional organizations. Dr. Korsmeyer was the lead of the NEO (Near-earth Object) mission concepts study for NASA in 2006, directly supported President Obama's 2009 Human Space Flight Review. He is an advocate for small spacecraft to support NASA missions. Dr. Korsmeyer received his B.S. in Aerospace Engineering from Penn State, his M.S. and Ph.D. from the University of Texas at Austin, and is a Sloan Fellow with a Master's in Business Management from the Stanford Graduate School of Business.

## OPENING REMARKS

### **Yong-Taek Im, Chair of IFAME and President, Korea Institute of Machinery and Materials**

Good morning, ladies and gentlemen. I am Yong-Taek Im, President of the Korea Institute of Machinery and Materials (KIMM).

I would like to take this opportunity to welcome everyone who is with us today at the first International Forum Korea on Advances in Mechanical Engineering. I thank you all for kindly accepting my invitation and attending this event to share your expertise and insights. My special thanks go to Dr. Taylan Altan, Dr. David Korsmeyer, Dr. Luke P. Lee, Dr. Stephan Roth, Mr. Kenji Ando, Mr. Guenther Klopsch, Dr. Sangwhui Cho, and Dr. Jong-Soo Woo for your precious contributions to the Forum. I also extend my sincerest gratitude to all the participants from Korea and overseas for honoring today's special occasion on this beautiful autumn day.

We considered carefully before deciding the themes of the three sessions as "Next-generation Manufacturing Technologies," "Energy and the Environment," and "Roles and Perspectives of Public Research Institutions." To revive the competitiveness of the U.S. manufacturing industry, the Obama administration has been promoting a policy focusing on R&DB efforts in state-of-the-art manufacturing technologies. To this end, the U.S. government is investing in emerging digital manufacturing technologies and encouraging public-private partnerships to support small- and mid-sized enterprises. Against this backdrop, I believe it is imperative for Korea and other nations to share their visions regarding the efforts that we must make to invigorate our manufacturing industries and what sectors within the industries have promising potential. Some predict that unconventional energies such as shale gas will reduce production costs and consequently revive the industry. While anticipating an industrial renaissance created through the convergence of the unconventional and the conventional, I hope public research institutes in the developed nations will offer valuable insights that can be applied to research institutes in Korea.

This is the first international event since my inauguration as President of KIMM, and the largest since the foundation of the Institute. This, I am sure, is also the only occasion where the future of mechanical engineering can be discussed from the perspectives of encouraging not only global creative economy but also job creation.

I hope this occasion will be a precious asset to every participant here today.

I am also confident that your attendance and contributions today will lay a solid foundation for this forum's future in the years to come.

Once again, I would like to extend a very warm welcome to you all.

Thank you very much.

## CONGRATULATORY REMARKS

**Sun-taik Kwon, Mayor, Daejeon Metropolitan City, Korea**

Good morning, I am Sun-taik Kwon, Mayor of Daejeon Metropolitan City. As the mayor of a scientific stronghold in Korea, it is indeed my pleasure to attend the 2014 International Forum Korea on Advances in Mechanical Engineering with renowned scholars from around the world in mechanical engineering.

I am also honored to meet and communicate with world-class specialists in the field at this forum. I hope this occasion will serve as a venue to broaden our knowledge and perspectives through lectures to be delivered by distinguished speakers.

I hope every participant here today will enjoy the forum, with in-depth discussions on manufacturing technologies representing mechanical engineering, energy, and the environment for our future society, as well as on the missions of government-funded research institutes.

Established in Daejeon in the 1970s, the Korea Institute of Machinery and Materials and other government-funded research institutes in the Daedeok research complex have dedicated efforts to a wide range of research and development projects for nearly four decades.

I express my sincere gratitude for their contribution to the development of our city to become an acclaimed powerhouse of science and technology in the nation.

I believe communication and mutual understanding are the most important elements in ensuring the continued cooperation and prosperity of Daejeon and the Daedeok science and technology complex.

I wish today's forum will provide an opportunity for local businesses and research institutes to interact with each other and strengthen mutual exchange, and to solidify our city's identity as a science and technology hub.

Once again, I extend my congratulations on the opening of this forum today, and I hope mechanical engineering will become a field of new pioneers in this ever-changing era, based on communication and mutual understanding among industries, academic fields, and other related organizations. As Mayor of Daejeon, I pledge to provide full cooperation in the course.

Thank you.

## CONGRATULATORY REMARKS

**Sang Min Lee, Member of the National Assembly of Korea**

I would like to extend my welcome and congratulations upon the opening of the 2014 International Forum Korea on Advances in Mechanical Engineering.

This Daedeok research complex in Daejeon Metropolitan City is a highly distinguished place that accommodates a number of research institutes in all fields of science and technology, from basic science to application technology.

This forum is a welcome event for a city that is proud to be the national hub for research convergence, and I hope all participating researchers will engage in vigorous discussions.

In the coming era, technologies are expected to evolve from mass production to customization. Therefore, everything required by end users must be factored in during each stage of production, including processing, distribution, and services.

Technology that works not for its own sake, but for all of humanity -- This, I believe, is one of the directions we should pursue in the years to come.

At the same time, we have to foresee several decades ahead, predict how our society will change, and develop major technologies to prepare ourselves for future challenges. Living environments change; technologies progress. In a society like this, I believe that the researchers who are gathered here today will have to raise questions and topics to shift the current paradigm to that of a first-mover.

I hope all participants in this forum will freely exchange their ideas and opinions to discover core elements to lead R&D in mechanical engineering in the future and identify what roles mechanical engineering will play within our respective societies.

Developing sustainable technologies and conducting groundbreaking research require an environment with guaranteed autonomy in research. As a member of the National Assembly, I promise to continue my efforts to ensure an environment where all scientists and engineers can focus on research and development benefitting our society.

Once again, I applaud today's forum on mechanical engineering and hope you all spend meaningful time here.

## CONGRATULATORY REMARKS

**Suk-Joon Lee, Vice Minister, Ministry of Science, ICT and Future Planning, Korea**

I am honored to be here today to celebrate the 2014 International Forum Korea on Advances in Mechanical Engineering, organized by the Korea Institute of Machinery and Materials.

The Daedeok research complex of Daejeon Metropolitan City proudly serves as Korea's hub for science and technology to advance convergent research efforts. Therefore, it is particularly meaningful to gather here to discuss the future of mechanical engineering, the foundation of all industries, and seek directions for public research institutions together with world-renowned scholars in the field. This event also coincides with the Korean government's endeavors to reinforce the "control tower" function of Korea's creative economy.

At this juncture of great transformation in these ever-changing times, we need to take a step ahead in adjusting ourselves to the new era of a creative economy.

We are witnessing how a high level of creativity and abundant ideas are invigorating global industries.

In addition, the boundaries between different technological areas are disappearing as fields converge.

Korea is maintaining its global leadership in a number of areas including smartphones, LCD televisions, semiconductors, shipbuilding, and automobile industries, based on its solid reputation as a powerhouse of science and technology.

Despite an unfavorable economic environment, discourses revolving around creation and convergence, as well as on societies and technologies that promote well-being, are adding a diversity of new sectors in the science and technology scene in Korea.

I hope this forum will serve as a venue where all participants actively share diverse and creative ideas regarding mechanical engineering of the future.

Again, I would like to applaud today's forum and hope you all have a meaningful time.

## CONGRATULATORY REMARKS

**Joon Yang Chung, President, National Academy of Engineering of Korea**

Good morning, ladies and gentlemen. I am honored to extend my congratulations on the opening of the 2014 International Forum Korea on Advances in Mechanical Engineering. I would like to congratulate this very meaningful forum for opening a new chapter in the field of advanced R&D.

As we all know, the advancement of industrial technology depends on the ceaseless pursuit of innovation built upon fundamental capabilities. However, we also have to go beyond that and consider the environment, daring to invest in sustainable development. We also have to pour our efforts into fostering shared growth between large corporations and small and medium enterprises through collaboration and cooperation. This is the only way that the labor of today in industrial development can create happiness for the generations of tomorrow.

I believe each and every individual gathered at this forum shares passion for the future of mechanical engineering. This is the true objective of this forum. Experts in the mechanical engineering field from industry, academia, and research institutes will discuss such pertinent topics as the current status of manufacturing, energy and the environment, and the roles and perspectives of public research institutions. From our discussions, we will map out a path for the future of manufacturing technology from the standpoint of innovation and overcoming challenges.

I cannot stress enough the importance of this forum and believe that it has to be sustained into the future to deal with various social issues and advance national happiness.

I extend my sincerest wishes for the success of this forum and truly hope it will be a productive and enjoyable day for all.

Thank you.

## CONGRATULATORY REMARKS

**Sang Kee Suh, Member of the National Assembly of Korea**

Good morning, I am Sang Kee Suh, a member of the National Assembly of Korea. First of all, let me offer my sincere congratulations on the opening of the 2014 International Forum Korea on Advances in Mechanical Engineering.

I regret that I am not able to attend the forum in person due to the schedule of the National Assembly's annual audit, but I am pleased to express my congratulations through video on this meaningful occasion.

Mechanical engineering serves as a strong foundation for all industries and has a special strength in that it can be applied to all industries.

Nevertheless, it is a shame that the importance of mechanical engineering is not as widely recognized as that of IT, communications, and so on.

I hope that 2014 IFAME will be a good starting point in promoting the significance of mechanical engineering and that it will be a place for networking and exchanging ideas and opinions.

This forum is all the more meaningful to me as I served as the president of the Korea Institute of Machinery and Materials in the 1990s, with many great engineers to develop KIMM into a truly advanced and competitive research institute. The forum brings back good memories from those days.

I wish you all every success in what you do. As a member of the National Assembly, I will do my best to support all scientists and engineers.

Once again, congratulations on launching the IFAME, and I wish everyone happiness and good health. I look forward to seeing your persistent efforts for the development of mechanical engineering. I believe the participants here can make the world a better place. I wish you good luck.

Thank you.

## CONGRATULATORY REMARKS

### **Byung Joo Min, Member of the National Assembly of Korea**

Good morning, I am Byung Joo Min, Head of the Yuseong District Chapter of the Saenuri Party.

First of all, I would like to express my regret for extending my congratulations through this video message. I am very sorry that my schedule at the National Assembly does not allow me to join the Forum.

I am very pleased to express my congratulations for opening of the “2014 International Forum Korea on Advances in Mechanical Engineering,” promoting new directions and innovations in mechanical engineering.

Global industry makes every effort to address increasing demands to shift the R&D paradigm from a fast follower to a first mover.

In the face of this pressure, the 2014 International Forum Korea on Advances in Mechanical Engineering holds great significance in its leading efforts to explore the issues of future mechanical engineering and to realize a creative economy through continuing innovation.

I anticipate that the distinguished scholars and industry experts in mechanical engineering around the world will have very informative and productive discussions at today’s forum.

As a member of the National Assembly, I also will do my utmost for the development of mechanical engineering and will spare no effort to make every possible policy work for this development.

Thank you.

## **CONGRATULATORY REMARKS**

**Sang Chun Lee, Chairman, National Research Council of Science and Technology**

Good morning, I am Sang Chun Lee, Chairman of National Research Council of Science and Technology.

I am very pleased to extend my congratulations for the “2014 International Forum Korea on Advances in Mechanical Engineering.” I would also like to express my gratitude to all the guests here, both from Korea and from abroad, for taking the time to participate in this forum.

Mechanical engineering has contributed to driving the growth of industrialization of Korea as a strong foundation of the manufacturing industry.

Mechanical engineering has also emerged as an instrumental part of our lives in addressing social problems and promoting the welfare of citizens, from the construction of public infrastructure to the application of disaster response technology.

I believe that this forum will serve as an opportunity to examine the future direction of mechanical engineering by analyzing the current status of the technologies required for every sector of our society.

As Chairman of the National Research Council of Science and Technology, I really hope this forum will bring an opportunity to redefine the role and responsibility of government-funded research institutes, by reflecting the ideal direction of government R&D projects and the roles of individual researchers.

Once again, congratulations for launching the 2014 International Forum Korea on Advances in Mechanical Engineering.

Thank you.



## **Session 1: Next-generation Manufacturing Technologies**



# THE ROLE OF METAL FORMING IN NEXT-GENERATION MANUFACTURING

**Taylan Altan, Emeritus Professor and Director, Engineering Research Center for Net Shape Manufacturing, the Ohio State University, USA**

Thank you very much, Mr. Chairman. I am very honored and happy to be here. I am also very humbled among all the distinguished guests.

I have been working for more than 40 years in metal forming and manufacturing. You can see my websites here. If you would like to have more information about this topic, you can always go there. We have all the information.

I am a very practical person. I work a lot with industry, as seen in this figure. Just to give you an idea, these are the industries that support my research. As a result, a lot of what I do is relatively practical. However, being practical does not mean you do not have to think about the future. I will try to discuss some of the new things that are happening in my field, especially in the next three to five years, or maybe ten years. After that, I really do not know how things are going to develop.

**THE OHIO STATE UNIVERSITY** ERC/NSM and Center for Precision Forming - CPF **CPF**

CPF is supported by NSF and several companies interested in metal forming.

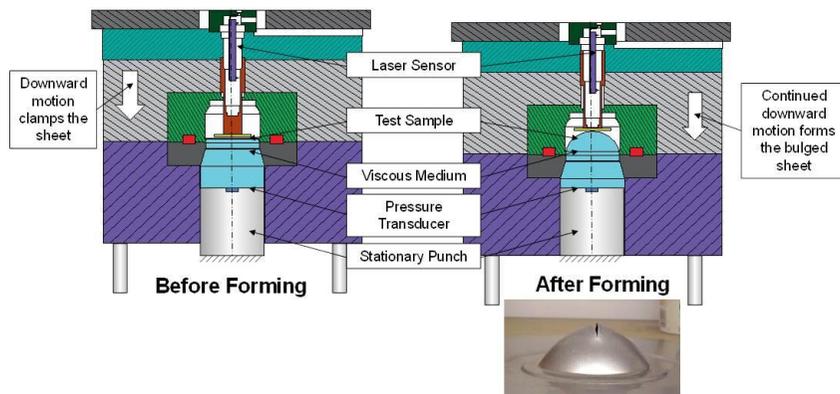
**HONDA** **tyco**  
**CHRYSLER** **NUCOR**  
**ITC** **Quaker** **Scientific Forming Technologies Corporation** **posco**  
**Interlaken Technology Corporation** **IMRA**  
**Altair** **AIDA America** **N**  
**esi** **EWI** **National Manufacturing Co., Inc.** **SHILOH**  
**get it right** **THE MATERIALS JOINING EXPERTS** *Specialists in Deep and Shallow Drawn Enclosures*

What I would like to talk a little bit about is materials. As many of you may know, materials are changing. When materials change, the characterization of materials also changes. As we have more complex materials, e.g., advanced high-strength steels (AHSS), transformation-induced plasticity (TRIP) steels, they require much more precise characterization. Friction and lubrication in manufacturing as well as in metal forming are very important. As you all know, there is process simulation which I will talk a little bit about. The new development in my field is servo drive presses, which I believe are also being introduced in Korea as well. There is also hot stamping, which is already well-known. The future of these technologies is very important for the industry.

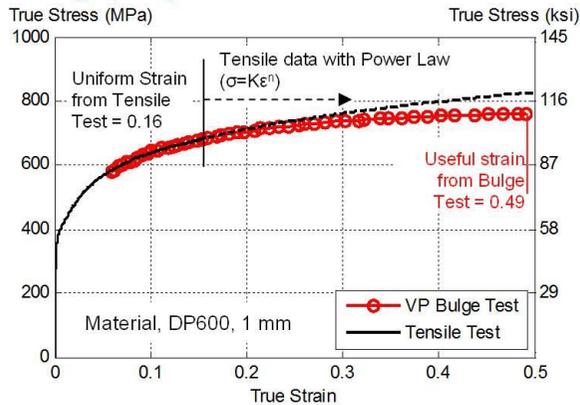
This is a viscous pressure bulge (VPB) test in more detail. I just want to show you that this is an interesting observation. I believe when most mechanical engineers talk about material characterization, they think about the tensile test. The tensile test is uniaxial; it has limited strength. When we work with new materials, we use what we call a bulge test. As you see here, you have a tooling where you can measure with a laser the height of the bulge. You can also measure the pressure, from which you can obtain the direct stress-strain diagram of the material. That is much more accurate and useful for simulation.

**Material Characterization, Viscous Pressure Bulge (VPB) test**

**The flow stress data is determined from the pressure and dome height**



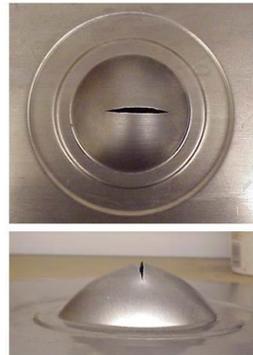
**Viscous Pressure Bulge (VPB) Test**



**Test sample**



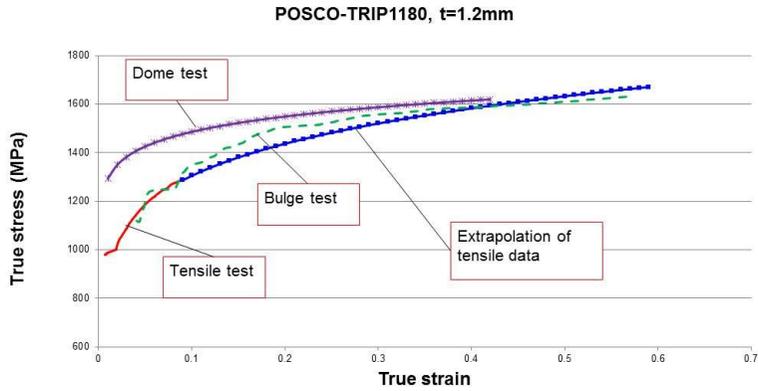
**Before bursting**



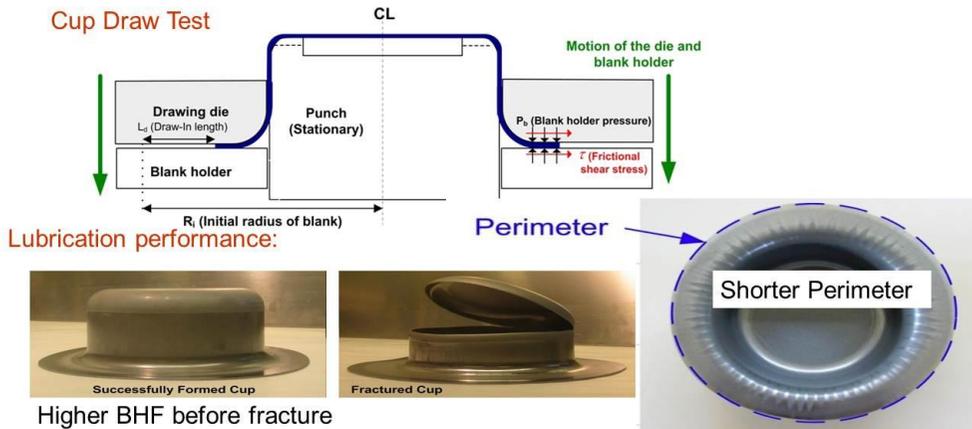
**After bursting**

You see here the red lines. These are from the bulge test. The black lines are from the tensile test. The tensile test stops at strains over 0.15 ~ 0.16 because the tensile specimen cracks. The reason I am showing this is that, all industries around the world use the tensile test as material characterization, which is OK at the beginning. However, as the materials become more complex, we have to use more sophisticated testing methods.

This shows you the example of how the crack, i.e., part fracture, opens at the apex. That is because there is no friction between the sheet metal and the material.

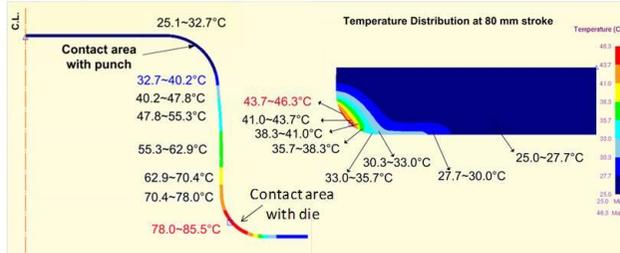


I will show you this. This was done by POSCO, which is, in my opinion, one of the top-notch steel companies in the world, and I am delighted that I have been working with them for the last 15 years. So, you can see here the test results from the tensile test and bulge test and how they may differ. Since bulge test is biaxial, that is more useful, in my opinion, for the application in the practical world for determining the material characterization because, in actual stamping, the deformation is biaxial.



Lubrication is another issue. We developed various tests to evaluate the friction and found out something. This is a so-called cup draw test, where we start with a blank and, for a given blank holder pressure and lubrication, we measure how much the blank pulls in. When we draw the cup always to the same height, we can evaluate and compare lubricants. Now you might think this is not a big deal, but if you are an automobile company or steel supplier and you have to make parts from new alloys that you have not formed before, lubrication is a very important issue.

Temperatures in Cup Draw Test – DP 600

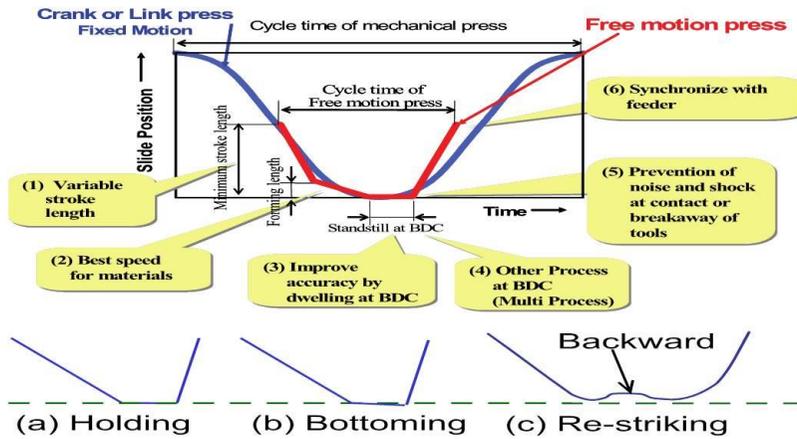


Challenges:

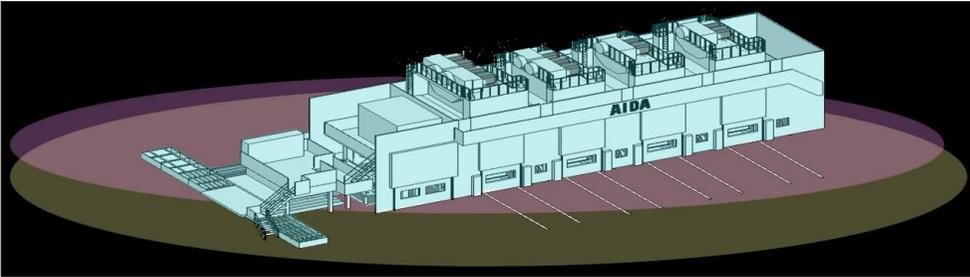
- 1) Higher contact pressure and higher temperature are detrimental for lubricants,
- 2) Temperature and pressure additives are needed

Ref. Kim et al 2009

This is the slide that shows the temperatures that are generated. In this case, this is a relatively low-level AHSS, i.e., 600 MPa tensile strength, dual-phase alloy. Of course, as you know, steels are 980 ~ 1200 MPa, and what this slide is supposed to show is that, in the deformation, the temperature increases. When most people today make computer simulations of stamping operations, they do not worry about the temperature. However, temperature is extremely important. As the strength of the materials goes up, then the temperature becomes more important. Why does the strength of the material that we use go up continuously? That is because we want to save weight. The question is, “What do you do about it?” One thing you do about it is to use high-strength and low-weight materials. The other is, of course, using aluminum.



Now, many of you may be familiar with this and some of you may not be. Servo drive presses came to the industry 10 years ago, but we do not know how to use them properly yet, I think. Most people use servo presses as a mechanical press just to increase productivity. However, just to give you an idea, companies like BMW, Honda, Chrysler, etc. already have decided, and I am sure Hyundai in Korea is also thinking along those lines, that the new press lines are going to be servo press lines because they increase productivity and offer the possibility of changing the speed-stroke characteristics. The blue one is a mechanical press, and the red one in the figure is a servo press. You can change the speed at the forming stage, you can have dwell, and you can even go back and forth, as you can see here, which is so-called re-striking. By the way, I have taken this picture from Komatsu, who is one of the leaders in this field.



Improved  
Formability

· System with optimized press forming requirements for each product

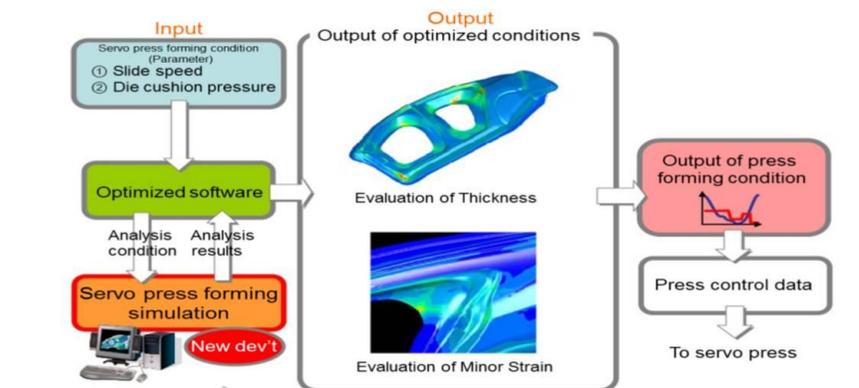
Improved  
Productivity

· Press-to-Press Loading Motion: System is optimized for each product.

Energy-Saving

· Die cushions have an energy regeneration system

This is a schematic of an Aida press, 2,500 ton, and several of these presses are installed around the world. There are two of them in North America by Honda. The results are summarized here. Here you have improved formability, and improved productivity. This is the most important thing. Energy-saving is also extremely important in Europe, Korea and Japan. However, unfortunately, in the US, it is important of course, but we do not emphasize it as much as you do, partly because energy is relatively inexpensive there. That is the reality. But energy issue is important. These presses are now becoming the standard presses in forming.



The question is, “What is happening in the future, how we can obtain from FE simulation and optimize results of what we obtain?” Then, we can just integrate that into the operation of the servo press, which gives us a lot of flexibility. This is the output of this kind of integration. The development is being done at this point by Honda. We can obtain the output in the optimum conditions of strength and thickness. The idea is to get the optimized speed profile directly to the press so that the press would be running to give you the optimum conditions. They do not sound like very heavy research issues, but if you are in the industry and have to compete in the world, you really have to worry about these things.

- Existing manufacturing process (Mechanical press)



Crack occurrence  
10 locations

- This development mfg process (Servo press + Optimized forming condition setting system)



Crack occurrence  
None

- One drawing press + 5 presses for follow-up operations



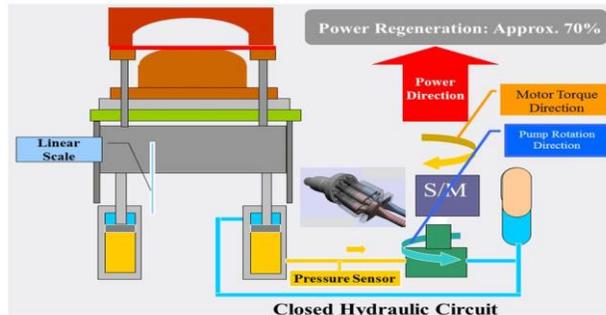
Technical Data:	
Total press force:	10,300 tons
Drawing press force:	2,500 tons
Total length of press line:	98 meters
Length of press:	34 meters
Strokes per minute:	17

Source:BMWarchive.de

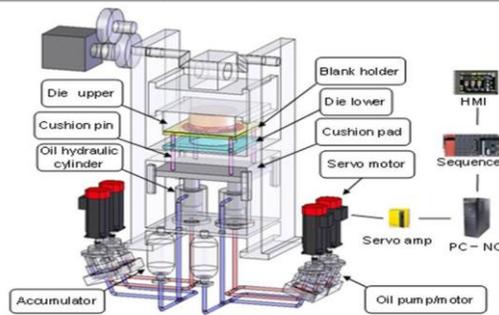
Source:Schulergroup.com

Here, you see the advantage you can obtain. These are actual parts in the mechanical press that you can obtain in some cases. This is the whole side panel of a car. You have cracks in several locations for the case of a mechanical press, and if it uses a servo press and the optimum forming conditions, you can eliminate the cracks. That is, of course, a tremendous amount of savings in material, effort, and cost.

Obviously, Japanese manufacturers are not the only one. This is the Schuler press, and there are several of them, e.g., BMW and Volkswagen. All the automobile manufacturers are using this line.



During Down Stroke, Cushion Pressure Generates Power

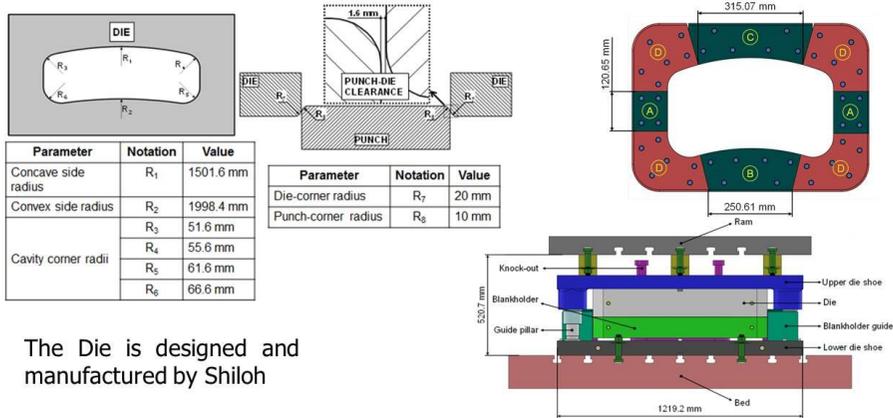


Elimination of Pressure Surge in the Die Cushion

This is an interesting design of a hydraulic cushion, which saves energy. As you see here, it uses several servo presses, servo drives, schematically. Then, you see the die and the hydraulic cushion underneath. This hydraulic pressure that is exerted with the cushion is used, through the hydraulic motors, to generate electricity, which is then reused to run the machine. As a result, 70% of cushion energy is saved. This is very interesting – at least in my opinion – one of the first designs in the press technology. Hydraulic cushions are used and will be used in the future because they have several applications and capabilities. One of them is so-called pre-acceleration. That is to say, you move the cushion before you hit the parts. As a result, you reduce vibration and the adverse effects of the deformation. You can change the pressure in the cushion, and this improves your flexibility to control the blank holder force and pressure. As a result, you can control the metal flow better. The cushion can also control the reverse and does not kick out the part immediately.

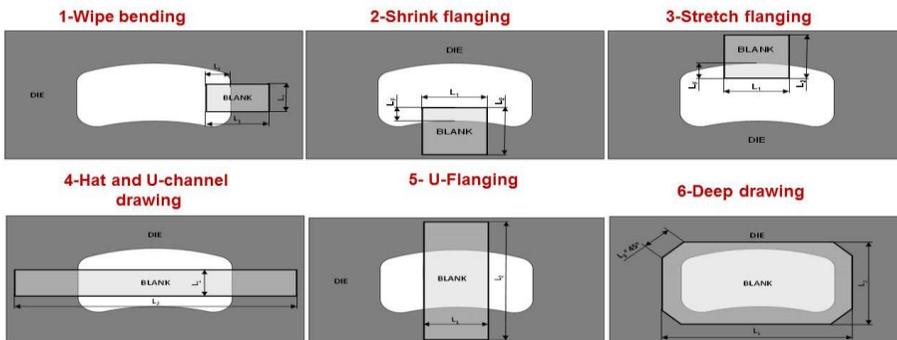
Here, you see again the cushion design very schematically. Here is the pressure. This pressure drives hydraulic motors that generate power.

## Forming of AHSS and Al5182-O in servo press



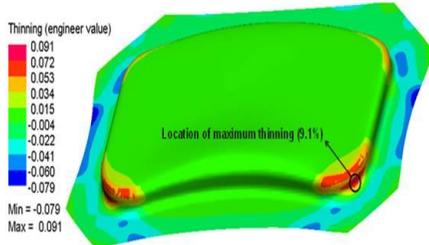
The Die is designed and manufactured by Shiloh

## Forming of AHSS in a Servo press



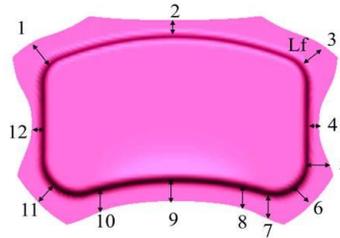
We are conducting tests. How can we use the servo press to improve the formability of parts made from AHSS? This is a very important issue for the press builder as well as for the press user. And we work with industry. This is a die designed and manufactured by the company Shiloh. These are inserts that we can change from different materials and different coatings and so on.

One issue is springback. How can we predict springback in forming AHSS? What can we do in the press kinematics to be able to reduce springback? You see examples such as shrink flanging, bending, U-flanging, and of course, deep drawing. The die in the previous slide is designed to conduct all these tests as well as the simulations.

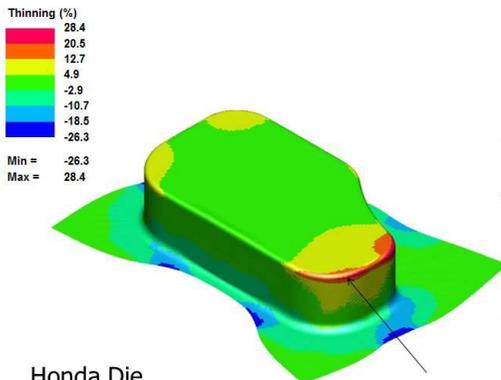


**DP980 with 1.4mm thickness**

**Shiloh Die**

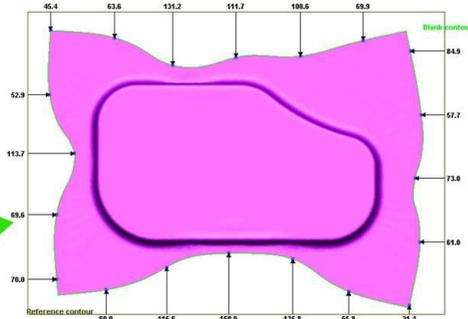


Flange length at different locations is measure from experimental samples and compared with simulation results



**Honda Die**

**Material draw-in**

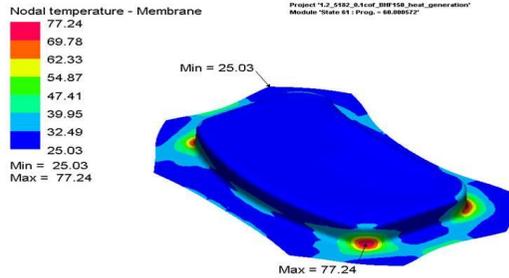


Maximum thinning ~28%  
Draw depth = 155 mm

So, you can see an example in these tests we conducted. This is a relatively simple die, but, still, we can form DP 980, which is a relatively high strength material. We can also predict how the flange pulls in so that we can evaluate simulations.

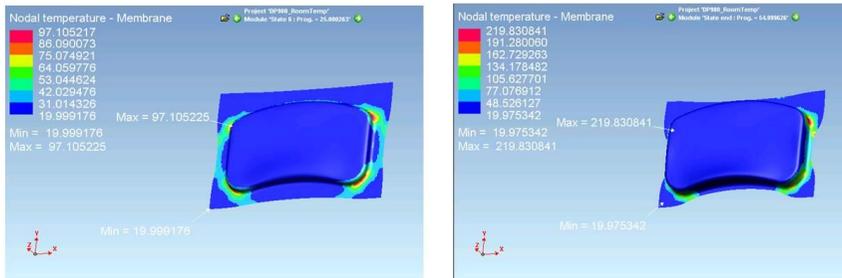
We also work with servo presses to deform aluminum. Honda is interested in that, which is no secret. The forming of an aluminum is an important issue because it is cost-effective, relatively speaking. You also want to save weight.

Deep drawing of Al5182-O shows the maximum temperature observed on blank is about 77 °C for 60mm stroke



Surface heat transfer is between blank and tooling is not considered      Room temperature is 20 °C

Deep drawing of DP980 shows the maximum temperature observed on blank is about 97 °C for 25mm stroke and 219 °C for 55mm stroke.

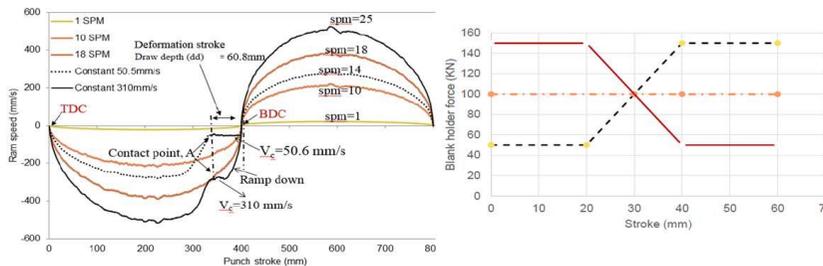


Surface heat transfer is between blank and tooling is not considered      Room temperature is 20 °C

Again, simulation helps us. One of the issues that we have to be careful of both in aluminum as well as in AHSS is that we have to estimate temperature. This is a relatively new approach, I believe, where we can calculate the temperature during the deformation in stamping. In the past, we neglected temperatures. We always assumed room temperature. Well, that is not the case, especially with materials that have high strength. Temperatures can be very high, and, therefore, they affect lubrication. They affect the properties of the materials and forces, so we have to know more about the temperature increases.

These are examples for DP 980. As you see, you can have temperatures up to about 200°C. 200°C can change the properties of the material, but, also, more importantly, change the behavior of the lubricants.

Different ram speed and BHF profiles were used in the tryouts.



Note: 1) These speed vs stroke curves were obtained from press.

2) These blank holder force curves are input to the press.

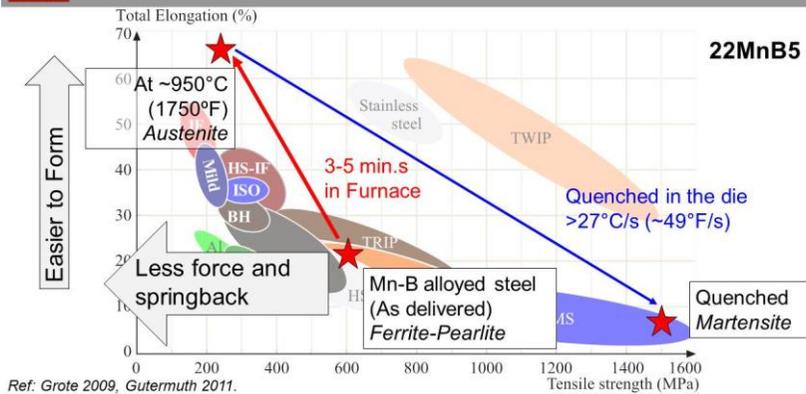
Blank holder force: 250KN

Draw depth: 75.8mm

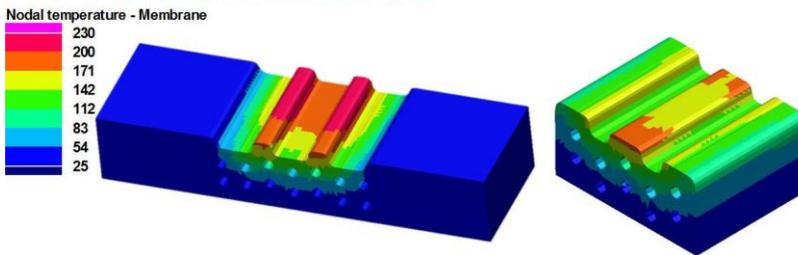


This illustrates very briefly the speed versus stroke of a servo press for different velocity settings. The issue here is how we can modify the velocity during the deformation because that velocity may affect the formability and the performance of the lubrication. We are doing research in this area and are hoping that we can come up with some ideas on optimum operations for the press so that you can have, for a given material and thickness, the best, optimum conditions. Similarly, you do the same thing with the blank holder pressure here. This is, in the vertical direction, the blank holder force and how it changes in stroke. By changing this, you can improve the formability of the material.

Here are some actual samples. Unfortunately, as many of my results are confidential, I cannot show them to you, but, at least, you have the general idea.



**FE Simulation of cooling channel analysis**

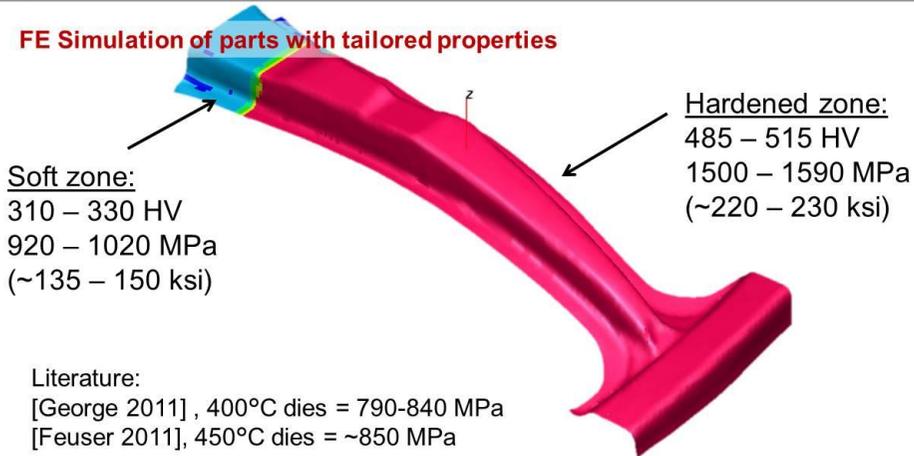


1.3 mm roof rail die, After 10 stampings.

Hot stamping is well-known. This is the famous “Banana Curve” that shows you the properties of the material and total elongation. Here, it is the tensile strength. The idea is that you heat the material to austenizing temperature and quench it very quickly. This is the manganese-boron alloyed steel and you obtain up to 1,600 MPa strength. This is well-known. In fact, it is used very well also in Korea and Japan. It was developed initially in Europe, but everybody is using it now. It is a big technology, but it requires a lot of investment. The idea is, “What are we researching, and what are the alternatives for this technology? Can we do this cheaper and better?”

We can also calculate the cooling of the dies because the dies must be chilled to be able to quench the material during the deformation very quickly so that we can obtain high strength as well as reduced springback. However, since it is not a cheap process, people who make new investments are worried whether they should build a hot stamping line or build a servo press line.

**FE Simulation of parts with tailored properties**



FE simulation has been developed so that we can even optimize the process nowadays. This is also used for production design, actually. Deep colors have different properties so that they are quenched in different ways, so you have a hardened zone and a softer zone, which makes assembly easier.

Let me go to the summary of this whole activity. First, I talked about challenges in forming AHSS. That is a very important issue, in my opinion, and it is going to be like that for the next five years, at least, or maybe more. Since they have low formability and high probability of fracture, we have to design techniques to increase the formability. Of course, the steel companies work very hard to develop materials that are high-strength and high-formability. However, it is also expensive because of alloying elements. The big problem in the industry is that mechanical properties vary from batch to batch.

Most of my colleagues are not aware of this, but industry deals with this all the time. What do we have to do to differentiate the properties of the materials from coil to coil? The interface pressures and temperatures require that we pay attention to lubrication. Tool wear is, of course, increasing; we have to use better tool materials and coatings. Finally, springback is a very important issue because we have to control the dimensions of the parts we make.

People have been working on springback for years. It is a very difficult issue to solve because material properties are very important as well as the shape of the part. Aluminum alloys have different challenges. As you know, in the aerospace industry, the aluminum alloys of 2,000 and 7,000 series are extensively used. The question is whether they can be used also in the automotive industry. They are lighter in weight, but they are expensive and

difficult to form. Therefore, we have to do a lot of research with these alloys to apply them to mass production. The use of servo presses right now is only for increasing productivity because they can go fast, slow down, and then go fast. You can have it large, e.g., 2,500, 3,000 ton presses, and there is an increase in productivity by 50 ~ 60%. The question is if we can also increase formability so that we can form the materials better. As you see, there are a number of challenges in using servo presses as well.

I believe that is all I have. I have a little commercial here. I have summarized all this work on sheet metal forming in a book with my colleagues. If any of you are specifically interested in metal forming or stamping, this is my contact information. You can send me an e-mail, and I will be happy to send you some more information if you need it. Thank you very much for listening to my story.

Thank you.



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[www.ercnsm.org](http://www.ercnsm.org)



# THE FUTURE OF MANUFACTURING

**Guenther Klopsch, Head, Digital Factory Division and Process Industries & Drives Division, Siemens Ltd. Seoul, Korea**

Distinguished guests and the organizers, thank you for giving me the chance to talk here about what our ideas are for the future of manufacturing. You may have heard that, in many countries, the governments have been strengthening ideas: in Korea, for example, it is creative economy; in Germany, it is called *Industrie 4.0*, which means Industry 4.0; and in America, they call it the Internet of Things (IoT). Secondly, I want to thank Professor Altan. Some of your examples are equipped with our machines, products, and systems.

You can see that Siemens definitely has quite a long history in the industry automation field. Now, coming to my topic which is future of manufacturing, before I start to talk about what our ideas are about that, I would like to talk a little about challenges which are in front of the manufacturing industry.

## Korea into the top ranks of global manufacturing



- Manufacturing output continues to grow by about 2.7 percent annually in advanced economies and 7.4 percent in large developing countries (between 2000 and 2007)
- South Korea's economy has risen steadily in global manufacturing, ranked 11<sup>th</sup> in 1990, 8<sup>th</sup> in 2000 and 7<sup>th</sup> in 2010.
- South Korea's manufacturing share of GDP is 28% ranked in the world's 2<sup>nd</sup> place.



Source: McKinsey Global Institute, IHS Global Insight, United Nations Statistics Division, BEA (Nov., 2012)

First of all, let's look at the global changes. Look at the importance of manufacturing in the various countries all over the world. If you look at the left-hand side of the slide, you can see the ranking of the different nations over the last 30 years. If you look a little bit more in detail, you can see that there are many changes. There are many countries, for example, like China, getting more and more important over the years. Other countries, especially, some European countries, I would like to take a great example there. They are getting less

## Manufacturing is getting more and more important all around the world



important in the manufacturing ranking all over the world. Then, let's have a look at the right-hand side of the slide. There you can see the manufacturing share of the total GDP of a country. If you look there, you can see that, for example, in China, the manufacturing stands for 33 percent of the total GDP, and in South Korea, ranking number two in this chart, 28 percent, i.e., the same importance of manufacturing in South Korea, China, Indonesia, Japan, and Germany. Then, some others are coming. If you look at the importance of manufacturing, for example, in countries like Great Britain, France, Canada, and the US, the importance is only about 10 ~ 13 percent nowadays. Exactly this picture has given many governments all around the world the idea to strengthen the competitiveness of their manufacturing again.

Again, I have three examples. I have talked about *Industrie 4.0* already, the German idea of the future of manufacturing, but as well, the second initiative the German government took is the smart services world, where we are talking about not only the manufacturing itself, but the whole lifecycle of a product. In the US, we know that the new initiative for the national network for manufacturing innovation and the research center "Digital Manufacturing and Design Innovation" also started there in order to make sure that these are so-called "re-industrialization" starting in the US, strengthening again the manufacturing there. Even in China, the government is now strengthening the integration of IT into the industrial processes. China, as well, is making a lot of efforts in creating more energy efficiency. In all of these, the initiative is finally to strengthen the manufacturing industry in the country.

What does it mean for a single company? At the end, for a single company, it means to get more competitiveness in the global arena. In a European or Asian perspective, Germany, Japan, and Korea, for example, we know that our energy prices are much higher than, like Professor Altan as well mentioned, for example, in the US. This competitiveness has to be

gained again if you want to be successful in the world. There are three key elements to do that – the first one is to increase efficiency.

I took one example of energy saving out of our own factories. Maybe you've heard of it. This is the picture of our quite famous Amberg factory, where we introduced most of our ideas of the future of manufacturing. The latest initiative we took there was installing energy analysis out of the energy-saving systems. There are two examples. One is the energy consumption at the machine level during Christmas time, i.e., one week. By using this technology, we could reduce, in this factory, the energy consumption by 200,000 kWh during one week only through utilizing this energy analysis and, finally, develop energy-saving programs. We can also save 100,000 liters of liquid nitrogen per year out of that. Finally, it comes up with the quality of 12 DPM (defects per minute), which is a quality of 99.9988%. This high quality is one result of the integration of software and hardware in that factory.

The next topic is to shorten time-to-markets. Look especially at consumer goods, and let's talk about televisions. Every year in the famous fairs in the world for that kind of product, they show new products. The innovation circle in this product is getting faster and faster. Even worse, from a production point of view, the products get more and more functionalities. It means they get more and more complex. This means, finally, that for production, you create much larger databases.

**Siemens Electronics Factory Amberg –  
Increased productivity and energy efficiency through Plant Data Services**

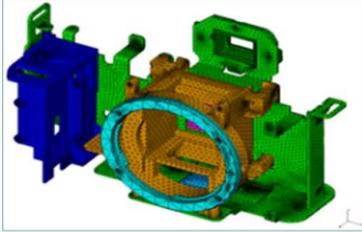
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- At a glance: Automatically updated consumption values for electricity, gas, water and other resources on the factory or site level
- Reduction of energy consumption on machine level: Savings in Christmas time of ~200,000 kWh (vs. previous year)
- Identification of unnecessary resource input in non-production times: Annual savings of 100,000 liters liquid nitrogen

**Energy Analytics –  
Intelligent reports and dashboards**

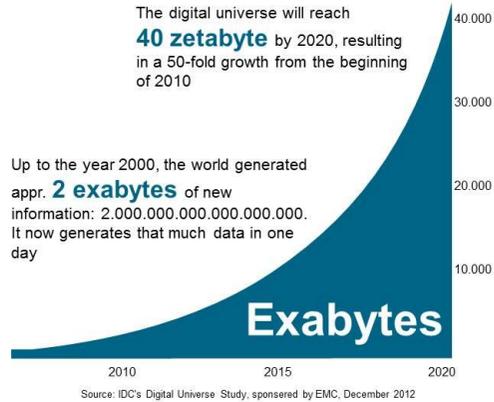
The image shows a factory floor with various machines and workers. A semi-transparent box is overlaid on the right side of the image, containing the text and bullet points. The Siemens logo is in the top right corner of the image area.

## Big Data – Data is growing exponentially



### Product development

Product data of one camera increased from 1.8 terabytes to 296 terabytes



Take the camera, for example. Ten years back, one camera created a database of roughly 1.8 terabytes. Nowadays, it is roughly 300 terabytes, i.e., 150 times larger compared with ten years before. If you look at the speed, i.e., how fast the databases all over the world are increasing with the usage of, for example, smartphones and the Internet, you have to have in mind that up to the year 2000, from the beginning, the world generated 2 exabytes of new information. This speed is increasing much faster nowadays, day by day, through the usage of, for example, the Internet, the extensive usage of PCs, smartphones, and cloud computing.

Coming back to competitiveness, if you want to be competitive in the future, you have to enhance your flexibility. I want to use one example to show you why this is so important. I have chosen a car model as one example, which is probably one of the most sold automobiles in the world, i.e., Volkswagen Golf. We could speak easily about mass production in this arena. I think nobody in this room would say “No, this is not mass production.” This is definitely mass production. Please have a look at the order book of this car. If I want to buy a Volkswagen Golf, nowadays I can choose from 11 different types of engines, e.g., diesel, normal gas, hybrids, and e-motors. They have three gear types you can choose from, two body panels, and four different chassis. Even the combination of tire rim, you can choose 10 of them, and 45 colors, and so on and so on. Finally, the question is if we have the heated seats or not. If you add all these options up, you come to several trillion possible configurations in this car. Then, we cannot talk about mass production anymore. This is an individualized mass production. You have to remember that whenever I order one of these cars, for example, black, with a black interior, with a specific tire, with a specific rim, of course, with a heated system, with automatic gear, the data, out of the shop where I buy that, has to flow finally to the factory where it will be produced, whether this factory is in the US, in Germany, or wherever. At the time when my black chassis is running around the assembly line, the right tire has to be there. The robot has to understand how to fix these

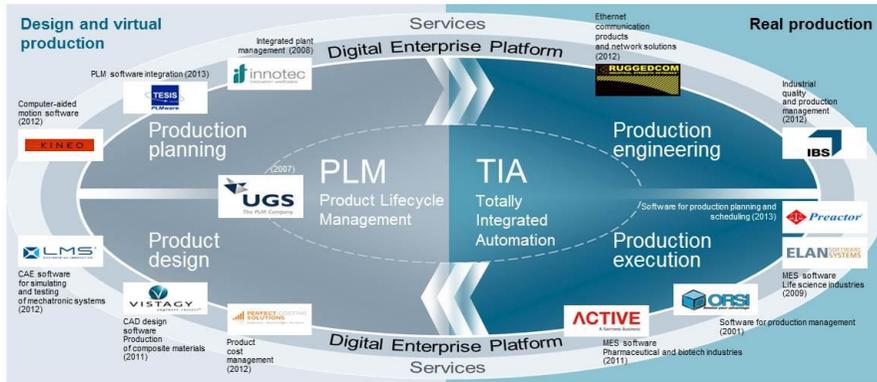
tires on my car. At the end of the day, I want to have exactly the same car which I have ordered delivered. It was just a simple example to make you understand how much data has to be served all around that process from my order to the delivery.

Now, I would like to come to my main topic, the way to *Industrie 4.0*. Let's have a look very quickly at the history of manufacturing. We know that, at the end of the 18th century, we started with the so-called First Industrial Revolution when we introduced mechanical production plants, where we used water and steam power to start with the First Industrial Revolution in manufacturing. At the end of the 19th century, I am very happy to say that, at that time, Siemens was already in that game. We introduced the mass production by dividing the labor using electrical energy. The first example was the conveyor belts in a slaughterhouse house in Cincinnati. Maybe more famous is the automation in the manufacturing of Henry Ford in America as well. The Third Industrial Revolution popped up in the 1970s when we introduced so-called Programmable Logic Controllers (PLCs). At that time, for the first time, electronics and IT came into the manufacturing arena. Now, we are on the way to *Industrie 4.0*, to the Fourth Industrial Revolution, which will take some time. However, we are on the way.

What does it finally mean? It finally means that we are combining the virtual world using software in the design of a product in production planning. Here, the real world means production itself, where we have to do the production engineering and the production at execution. If you bring this combination between the software (the IT world) and the hardware world together, this is what we are talking about when we talk about future of manufacturing, e.g., *Industrie 4.0*, IoT, or whatsoever.

**Siemens is linking digital product planning with physical production: 4 billion EUR invested since 2007**

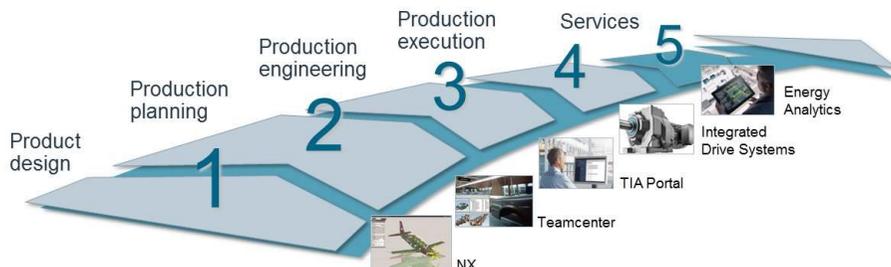
SIEMENS



This is the picture to show you where we are. You can see if you start on the left-hand side of the slide again, a product always starts with the design and the development. There, you are using software products, i.e., software tools. You are already creating data. Actually, you are already using market data and bring it into the product design. The next step in the product lifecycle is the production planning. Once you know how your product should look, you start with the planning of the production. What do I need to produce this exact product? Once you know that one, the next step is production engineering. Once you know how you want to produce that product, you have to do the engineering for your machines. You have to tell the program controller, i.e., the automation system, what it has to do. You have to tell the robot what it has to do in each step. This is the production engineering, and finally, the production runs. The nice thing is in this picture is that you now understand that using one single database in all the products' lifecycle here is very important. The communication in the various steps here gets more and more important. We have shown here the software products that we have at Siemens. We use this slide especially to show that we are quite far already. However, if you think about the future of manufacturing, there are still some things to do in order to complete the whole picture.

**The answer for the future of manufacturing –  
Covering the entire product development and production process**

SIEMENS



**Verify design and manufacturing processes virtually – validate and optimize real production**

To make it a little bit different, if you look at the production lifecycle, you always talk about various steps starting with the product design. For example, if you are using our software product, then, next, you can design your product. What is even more important is that you can even, already at that phase, simulate how the product will work. Let's talk about one simple example which everybody understands, maybe. If you think about a windmill, you may know that, when the windmill is generating power, it always makes some noise. In order to optimize their noise, they can already simulate at the product design stage and change the design of the plate a little bit in order to get less noise out of the product at the end of the day. After that, the data out of that software tool is automatically, with the common database, transferred to the next step of the production planning at Teamcenter, for example. You are then planning your production. Even before you have touched the first product, you can already simulate the production itself. You can check whether, if I put some steel at the beginning, at the end a car is falling out. Even more importantly, you can always check whether the capacity that you have been planning can be reached or not without doing anything.

The next step, then, is transferring the data out of here into the engineering software. It engineers the production, which means you are going from the virtual world into the real world. Then, you go to the program of the automation system where you tell the conveyor when it should start and when it should stop and how long or when you tell the robot what it has to do. The next step is product execution. It goes to the firmware of the product of the hardware into the firmware of the automation system. The automation system itself knows, then, when it has to start with the center and when to stop. Finally, you will create some centers in your production area that are analyzing your energy consumption, telling you exactly, during a lunchtime break, for example, that you do not need to run that machine, how to go in a safe way down, and, just before the break ends, how to bring it up to speed

again. So, this is the whole lifecycle, and this has to be done when we are talking about manufacturing of the future.

Just to summarize where we are, I have been talking about the product lifecycle management. I have been talking about what certain governments have been doing in order to strengthen their manufacturing in industry again, starting with creative economy here in Korea down to *Industrie 4.0* or, in China, the IT revolution. The idea behind that is automation becomes more and more complex, and we should strengthen the competitiveness of the industry in the global environment. Secondly, when we are talking about smart factories, digital enterprises, their categories are coming from yesterday, when all the steps in a product lifecycle management from product design down to production have been done seriously. First of all, we have to finish your design; once you finish your design, you start with the production planning; once you finish the production planning, you do your production engineering; once you finish production engineering, finally, you start with the production. The process in total is like that. Now, we are trying to do it in more of a serial manner, starting already with the production engineering even when the design is not finished yet. Of course, it means certain risk for a company, if you are designing a new car and you start with your production planning already and the design is changed, you may have to change your production planning. The idea is to put in a more overlapping time periods. The benefit out of this is, if you do it in a series, you can reduce the time to market from the first idea about the product to the production, and this is what we are talking about. Competitiveness by shortened time to market includes improving the productivity, improving the efficiency, and getting more competitiveness out of that.

We know now what has to be done in order to come to the next step. First of all, what are the key elements of the idea of the future of manufacturing? First, it is the production network. We have to have a flexible chain through all the various parts of a factory. Think about the situation where I have ordered my Volkswagen Golf four weeks ago. The production is already prepared, not started, and I change my mind, saying, "Oh, sorry. I do not want to have a black one. I want to have a red one." This information has to go finally into the place where they color my car. This is the meaning of the flexible value chain, which has to be built in all around the factory. The next one that I have been talking about is the fusion of the virtual world and the real world. We have to integrate product design and production engineering in order to shorten time to market because the first one who is at the market gets the most money out of the product. The second one is already one of the losers. This is the meaning for shortening time to market. Finally, this will be the final step there: the so-called cyber physical systems where we are not talking anymore about the production of a car in the same way, always starting with their chassis, starting with the body, combining, and finally, bringing it to someone for the final check. The production has to be much more flexible in the future, thinking about which part of my factory is less in workload and which one is overloaded so that I can change my production capacity.

In a nutshell, coming from local controls nowadays, we have to go to dynamic networks of local controls. Coming from run-time communication and real-time communication, nowadays, we have to extend that. Think about the number of data created in a single product. We have to extend communication possibilities, and we have to standardize them. We are using nowadays so-called copies of products and production, and we have to come to digital models all over the factory over all the various processes and all the various functions in the processes. We are using nowadays so-called manufacturing and execution systems (MES). We have to optimize our processes through more dynamic networks. We are starting to have these industrial security concepts. We have very safe internal software. However, only by using the Internet, problems can appear already. So, industrial security will be very important in the future so that we are thinking about how we can do self-configuring security concepts, not only for global and general purposes, but also for temporary requirements. Finally, we have to think about the people, execution, and decision-making. This is nowadays the main topic of humans. In the future, it has to be the decision-making. Look for strong partnerships, strengthen R&D, and, finally, do not forget your people and train your employees. These are the main topics on the way to *Industrie 4.0* from my point of view. I hope I could bring some ideas within the last 30 minutes over to you.

Thank you.



# MODULE-BASED DESIGN & MANUFACTURING IN ROLLING STOCK

**Sangwhui Cho, Vice President, Hyundai-Rotem Company, Korea**

Good morning, ladies and gentlemen. Thank you, Dr. Lee, for introducing me. I am very grateful to KIMM and President Im for inviting Hyundai-Rotem to present our production method. So, this is the 2014 International Forum on Advances in Mechanical Engineering. I am also a mechanical engineer, and as a mechanical engineer, I am very pleased to discuss future technologies from the mechanical side in Korea. As you see in the banner in each side of the front stage, we have pictures of the Maglev. I think that is a very good example of R&D cooperation between industry and a research institute. Hyundai-Rotem and KIMM have a long history of cooperation in this kind of development. For the Maglev, we cooperated with KIMM, and, finally, we manufactured this car and are going to commercialize it at Incheon International Airport soon. I am very proud of this cooperation and thankful to KIMM and President Im.

I am going to introduce how we make trains in Korea. The topic “Modular-based design and manufacturing in rolling stock” is not fancy nowadays, but that is how we succeed in our business. I am sure many of you are familiar with taking trains but not many of you are familiar with the word “rolling stock.” A rolling stock means a kind of a vehicle operating on a rail, but nowadays, it has an expanded definition; even though Maglev does not have wheels, it is called a rolling stock. From now on, I will not use the word “train.” Instead, I will use “rolling stock.”

For half of the section, I will introduce what the rolling stock business situation is in the world and in Korea. Then, I will talk about what the modular concept is in Hyundai-Rotem. Hyundai-Rotem belongs to Hyundai Motor Group. Hyundai Motor Group has 47 members. We have some sister companies. They are actually bigger than us, including Hyundai Motor, KIA Motors, Mobis, Hyundai Steel Company, Hyundai Construction, etc. Hyundai-Rotem is a member of the heavy industry area in Hyundai Motor Group. We had 3.3 billion turnover last year, and we have more than 4,000 employees. Our business has three major distinguished divisions. One is railway, which I will explain later. Another is defense where we make some military tanks. The last one is the plant and machinery division, where we produce facilities to assemble automobiles and provide steel-making facilities.

# Corporate Information



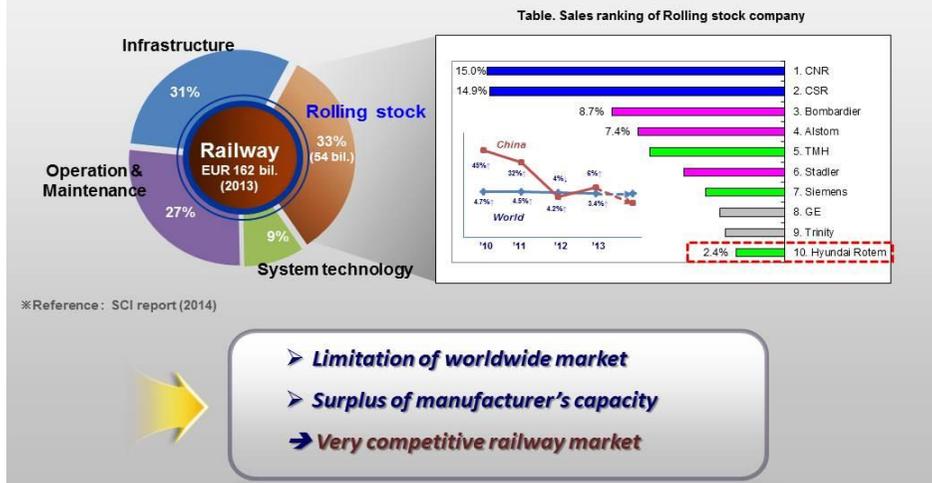
Hyundai Rotem, a Member of Hyundai Motor Group(HMG)



I will explain a little bit more specifically Hyundai-Rotem's products in the rolling stock area. We have high-speed train products, e.g., KTX-Sancheon and –Honam. Also, our major product is electric multiple units. Some metro cars and commuter cars are equipped with an electric motor. We have already delivered some driverless vehicles in Korea, Brazil, Canada, and other countries. We also make locomotives, including diesel locomotives, diesel electric locomotives, and diesel hydro-electric locomotives. We have lots of experience in this area. Another one is diesel multiple units. We use these cars on unelectrified rails. We use diesel engines for coaches. We have already provided several passenger coaches like double-deck coaches in LA and Boston. The last product area is light rail vehicles including the maglev and trams. We already have good experience in the maglev system, which we delivered at Incheon International Airport. We also have a wireless hybrid low floor tram, which we delivered in the Turkish city of Izmir.

We started manufacturing in 1965. Thus far, we have produced almost 40,000 cars and exported them to more than 40 countries. I will tell you a little bit more about Rotem. Rotem Headquarters is in Seoul, and we have a Changwon plant, a Dangjin Plant, and an R&D center very near Seoul. We also have overseas assembly facilities. They are called Eurotem in Turkey, and Rotem USA in Philadelphia. Turkey, America, India, and Brazil are our major overseas markets. In India, we have partner companies for assembly, and, in Brazil, we are going to make our own factory next year.

## Status of World Railway Market



With this basic information on Rotem, I will introduce the worldwide market. 2014 statistics say the railway market, including infrastructure, operation, maintenance, system technology, and rolling stock, is equivalent to 126 billion euros. Vehicles, i.e., the rolling stock itself, represent 33% of this volume. However, we think about who the manufacturers are in the world. Before 2000, there were three major players in European countries and Canada, but nowadays, major manufacturers are in north China and south China. They get almost 30% turnover from the worldwide market. This kind of volume does not dramatically increase. They increase by as much as an interest rate. However, in China, in 2000, their market was saturated, but, at that time, they had huge capacity. Nowadays, they want to come out because there is some surplus manufacturing capacity. Even in this situation, Rotem has the tenth position in the world with 2.4% sales volume. Some people think this is very good, but we still want to jump up and make some more increase in the market. However, our market size is almost the same every year, which is also true for manufacturing capacity and surplus. I think people just think about that as a kind of a crisis for manufacturers. Because of this, we think about lots of ways to survive and to enlarge our market. What is the reason? What is the way?

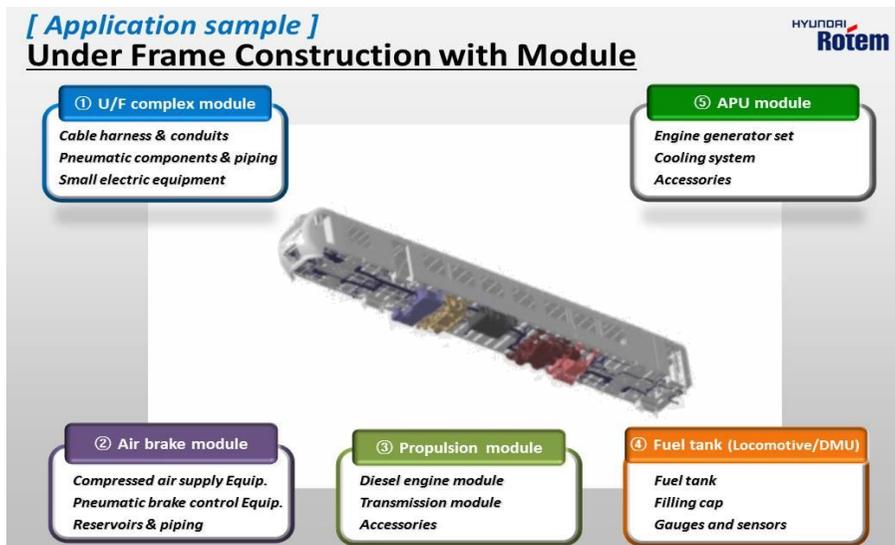
I simply explain what the situation is. First of all, as I told you, it is “not large scale” and “surplus of manufacturer’s capacity” and “customer size.” This kind of business is always financially supported by the government. The government asks an operator like Korean Railway or Deutsch Bahn, “Why spend money outside? You should spend money inside.” It means you should assemble or buy items in your country. America and Brazilian regulations, for example, say 60% of the materials should be bought in their country. It means an increase in localization in every country, even in Korea. Regarding lifecycle cost, most of

the operators want us to save maintenance cost and operation cost. They always ask us, at the bidding stage, about the lifecycle. This is a mass transportation system. Because of that, they want a higher level of safety, higher level of availability, good maintenance, and reliability. Those are RAMS (reliability, availability, maintenance, and safety) targets. Then, when it comes to resources, we think about the manufacturing side. There is an increase in labor cost, not only in Korea, but everywhere. As there is a surplus of manufacturing capacity; other manufacturers want to come to Korea, America, and everywhere. Customers want a short delivery time. There are also needs for global manufacturing plants. Many manufacturers have global manufacturing sites like Rotem. Lastly, there is no killer technology. In China, companies like Bombardier, Alstom, Siemens, and even Hyundai-Rotem can produce high-speed trains. There is no killer technology to make us go to the top position nowadays. Because of that, we need to overcome this situation and expand our market.

We should think about new products, how we can save manufacturing cost, and how we can create new markets. We do it everywhere, but, today, I will explain and show what we do now on the manufacturing side. The tasks are productivity improvement, competitive cost, and local manufacturing.

As I listened to previous speakers, we are the user of the metal forming, ideas of the complex products, and automation. This is the real situation. We think about lots of things. First of all, we want modular manufacturing, platform-based design, and new technology. We do everything like that. However, today, we talk about modular manufacturing. The worldwide trend is that rolling stock manufacturers use platform-based designs, especially in European countries. They make the same platform for trains from low-speed to high-speed. They have brand names. In Japan, there are more functionalized modular concepts. However, in the Korean case, we try more production-wise modular concepts. In the beginning of the manufacturing in Rotem, we assembled everything, more than 20,000 parts. It means very low productivity. Then, we thought about making modular, functional items like the seat, heater, cab desk kit, even luggage racks, and draft screens. That is what we did in the 1990s. After that, we tried a system-level module. It means that a cab is kind of a system: function plus operation. The toilet and power pack are also a kind of a system.

As you know, we make more modules outside. That means more materials, and material costs increased. However, with a reduced number of parts, we save lots of money inside. That is, even though we spend lots of money outside, we save lots of money in-house. That is why we try this kind of system-based module. Nowadays, in 2010, we are still fighting about this concept. Now, we make a module system plus chassis. It is very simple. They are the cab, roof, and the side of the frame with six elements. Just six elements make a vehicle. However, it is not easy. Sometimes, it is impossible. We realized some of the parts in metro cars, but they are not perfect. However, we try. There is a way to innovate our production line. Because of that, we always try this kind of complex module.



This is an example of how we can make a module: a driver’s cab; ceiling components including some insulation, air products, interior panel, grilles, etc.; ceiling cable trays; and electric wiring connection, which is also a module system we have. Usually, the air brake system is installed in the under frame. We have equipment, air piping, and electric wires working together. In the end cubicle, we also have a module.

I can show the under frame module as an example. This is how we install it. Usually, we do not have this kind of module. Every worker sees the upside and assembles. But nowadays, it is just a module and assembly. It is very easy. However, we cannot make it automated. This is the 3D simulation model. We already have a 3D design using, e.g., CATIA version 5, which is very good for us. We can change the module area, automatically changing in the body side. There is so much data we need, as Mr. Klopsch said. I introduced our own way. As you see, this kind of module is very big, so we need very specific logistics problems. It is not only one company or one supplier that makes this kind of module. There are a series of suppliers. They get together and make the module. There are very long supply chains. It is not an easy method to implement. There are conventional things, but we should think about how to integrate them. We need standardization of interface, and we also control the tolerance and stock of materials. We do not need a new concept. Every automobile company says “just in time.” However, we need the concept “just in sequence,” because we also produce in a series production. Because of that, in every station, we need materials. We cannot have materials that we cannot produce. We have concepts like “direct in sequence” and “just in sequence,” which are beyond “just in time.”

Everybody knows some advantages, I think. Customers - we can make that module that is easy for maintenance. If there is something wrong, they just take out the module and change it. Availability is good. Car builders - there are so many advantages, e.g., shorter lead time. I will explain this one. We have lots of facilities overseas. Our policy is to design in Korea and manufacture outside. How can we easily manufacture outside? Making some module brings the very difficult task of handling and controlling a global plant outside. That is why flexible manufacturing is important. Thus, our production line should be more flexible. It is the same with suppliers. They have very flexible capacity, and they also deliver equipment, not piece by piece, but in package form, which is a very good way for a better logistics. Suppliers also increase their business chance. That is the situation in Korea nowadays. Very small- and medium-sized companies cannot overcome the situation because of the high technology and the low labor costs of China. However, with this concept, we can make a good chance for our medium-sized companies. It means win-win technology for customers, car builders and suppliers.

I will summarize my talk. Modular manufacturing, as I told you, increases our productivity and allows us to have a good partnership with customers. We cannot survive in the domestic market. We have to go outside, as we already have examples in our plants in Turkey, North America, etc. We should globalize the production of rolling stocks. Modular manufacturing is not only the way to survive or overcome the situation, but also our new manufacturing paradigm.

Thank you very much.

# NEW TRENDS IN LASER MATERIAL PROCESSING

**Stephan Roth, Managing Director, Bayerisches Laserzentrum, Germany**

Thank you very much, Mr. Chairman, for the kind introduction. Thank you very much to the organizers of this forum for inviting me to give a presentation. I will talk about new trends in laser material processing. I will not talk too much about technical details, but I will try to give you an idea of what is becoming possible because of new developments in the field of laser sources of the tool, the usage of materials, and new processes. I want to show you what is necessary to benefit from these new possibilities and why research and development (R&D) is a very important part in the successful usage of these new possibilities. The Bayerisches Laserzentrum (BLZ) was founded 20 years ago for the transfer of knowledge and the experience gained by R&D into industrial applications. It was R&D work done by the center itself but also done at the University of Erlangen, i.e., the cooperation of a privately owned nonprofit research company with a university, which is very important. The goal of the center is to inspire the companies for new products and new processes, as well as to generate experts in laser material processing.

Today, we are mainly working for the automotive industry, electronics production, and mechanical engineering. In this slide, you can see key technologies we are doing R&D on currently, mainly the joining, welding, soldering, brazing of metals, plastics, and glass, and then working on the laser cutting of different materials. What is becoming more and more important is the two topics below. One is precision manufacturing because of availability of new tools that can be also used for industrial applications. The other is additive manufacturing, which is a hot topic at the moment. All these topics are accompanied by process analysis because getting an understanding of the interaction between the tool and the laser beam together with the material of the work piece is very important.

**Key process technologies at blz**

The image displays six key process technologies at BLZ, arranged in a 2x3 grid. Each technology is represented by a vertical panel with a title and a corresponding image. The top row includes Laser Beam Welding, Laser Beam Soldering/Brazing, and Laser Beam Cutting. The bottom row includes Additive Manufacturing, Precision Manufacturing, and Process Analysis. The BLZ logo is visible in the top right corner of the grid.

**blz** BAYERISCHES LASERZENTRUM

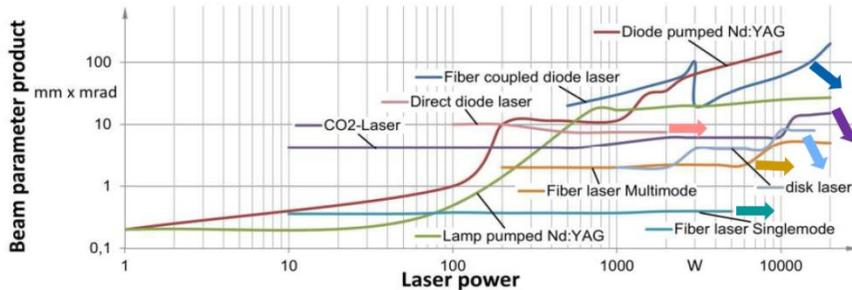
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Dr. Stephan Roth 24.10.2014 | 3

When we ask ourselves if we should use laser technology in production, there are some advantages that have been well known for a couple of decades. A laser is always used if you need high flexibility and small and various sizes of the work piece. Another advantage is that we have a tool that is not in contact with the work piece, so there is no wear; thus, you can have long working distance. This non-contact treatment leads to another advantage, namely, the high precision you can gain. It only depends on the type and size of the tool used for this. And of course you can easily integrate this technology into the process chain. I think most of your companies are using this laser marking. I am not talking about laser marking today, but it is a good example of the integration of the process into process chains.

Just to give you an overview of what was possible so far by using laser technologies in the next two slides, it is the joining of different metal parts for the aerospace industry, production technology, and automotive industry. By using a laser you can change the properties of the surface of the work piece. One example is hardening a tool in the automotive industry. Or you can even drill the filter paper of cigarettes by using laser technology. The advantage is high speed of the treatment and non-contact between the tool and material.

There was one example to change the properties of the treated surface when you cut thin metal parts or sheets. Normally, you don't want to change the material properties. You can see one example from medical technology, which is the cutting of stems, or cutting some parts for precision industries, especially, in Switzerland. There, by the treatment, you don't want to change the properties of the metal parts. Also, in electronics production, you can treat plastics for airtight housings. Or you can again join some electronic connections. There are still a lot of applications and solutions available. So what are the key factors for the future?

## Recent development of laser sources



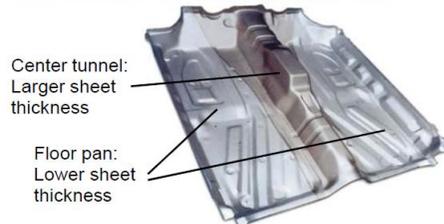
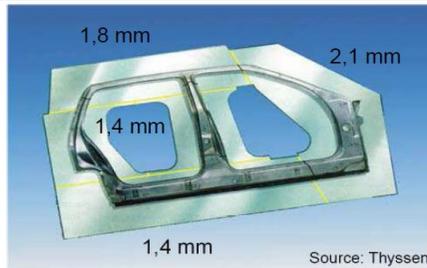
Sources: IPG Laser, Trumpf, Rofin, Direct Photonics

- Higher laser power
- Better beam quality ► smaller beam diameter

In particular, manufacturers of laser sources are constantly working on generating or producing better sources. What does “better” mean? Better laser sources are, firstly, to reach higher power because power means speed in production. There are high-power sources available for longer time already, but the problem is they are not good enough because the beam quality gets worse, which means your tool size is getting larger. Therefore, you have more influence on the work piece, and the precision is going down. So, what they want to do is to reach higher power and higher processing speed together with small tool size and, therefore, gain better precision. These new tools are used in the future with different motivations. We have already heard something about efficiency. Efficiency, of course, is also a key trend for laser technology in different areas. We already heard about one of these areas where we want to get better efficiency. Another very important part is different materials. We have already heard about high-strength steels by Professor Altan, which I will address later on, and the higher efficiency of the whole process by automation but also by parallelization. Other trends are smaller tools and higher precision, and laser technology is increasingly used in additive manufacturing. It has already been used for a couple of years, but I think now is the right time to increase these applications.

## Material efficiency: Tailored parts

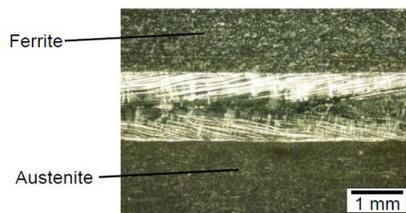
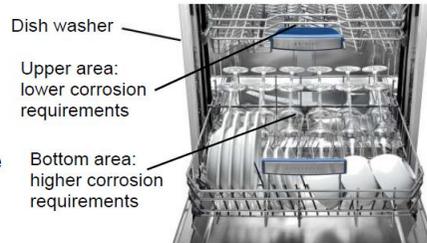
- **Tailored Blanks**
  - Laser welded blanks with different materials and coatings
  - Locally different sheet thicknesses possible
    - ▶ Lightweight construction
- **Tailored component properties**
  - Narrow weld seams with small heat affected zones
  - Formability is retained after laser beam welding
    - ▶ Most flexible production chain



I will start with material efficiency and will just give you some examples of what has turned R&D into application at the moment on laser technology to give you some ideas about what is possible. The tailored parts or tailored blanks using laser sources used here have already been known for years. However, it is combining sheets with different thicknesses and is getting more and more to combine different materials. Aluminum alloys, for example, are used in order to have the right material with the right thickness at the right place inside a car, for example. By doing this, you can save weight and expensive materials when you produce parts. Having tools available with a small tool size makes it possible to influence the parts. Even the properties of the materials are reduced. With this, you have no bad influence on the following processing steps; for example, if you have forming afterwards, you have a very small heat-affected zone and that offers extra advantage.

## Material efficiency: Dissimilar metal joints

- **Ferritic and austenitic stainless steel**
  - Laser beam welding of dissimilar materials
  - Selection of materials due to the local corrosion requirements
- **Preservation of corrosion resistance**
  - Laser welding with low heat input, thus no concentration of alloying elements
  - Substitution of nickel
    - ▶ Increase in corrosion resistance of tailored welded stainless blanks

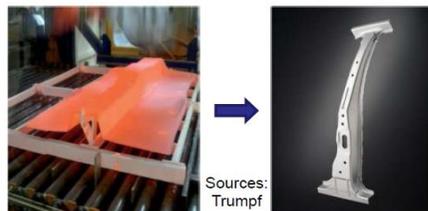
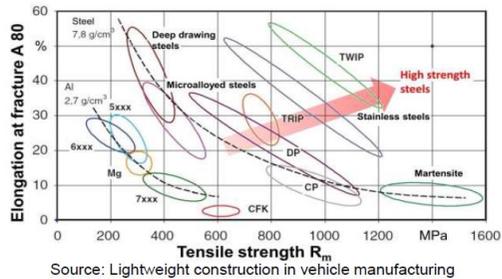


Something similar, but not to reduce weight but to save costly materials, is achieved if you join different materials, for example, white goods, not to avoid corrosion but to have it on the right place. Again, we can have the parts with good corrosion resistance at the right place combined with less expensive materials, so that we can, for example, substitute some alloy elements like nickel that are increasing the costs for this. This is an example of reducing costly materials by using different materials, making it possible to join these materials by laser technology, which was not possible so far.

## Material efficiency: High strength steels



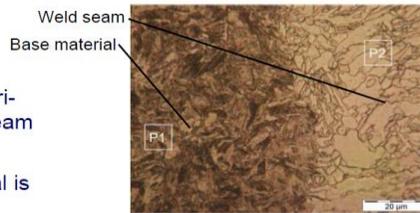
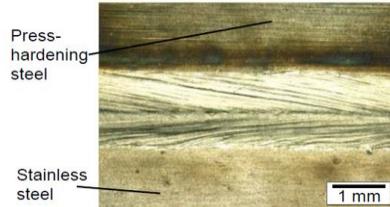
- **Lightweight construction**
  - Higher tensile strengths enhance crash-behavior performance
  - Lower sheet thicknesses possible
- **Cold and hot forming possible**
  - Different hardening mechanisms
  - Increase in tensile strength during production process achievable
- ▶ **Enhanced safety**



Coming back to the high-strength steels, it is another possibility. Just to have the same performance of a part, for example, in the car body, and to have good strength for crash cases, you can have lower sheet thickness of these metals by combing or joining them with laser technology. Again, you have a very small heat-affected zone. You can even adjust the hardness by controlling the process parameters on the joining zone so that you have no influence later on. A welding seam is not a weak point in your car body.

## Material efficiency: High strength steels

- **Laser welding of high strength steels**
  - Reduction of heat input and heat affected zone with laser beam welding
  - Homogeneous strength in weld zone due to low heat input
- **Strategies for welding high strength steels**
  - Welding with filler material
  - Modelling the temperature distribution after welding through beam oscillation
    - ▶ Hardness of base material is reached

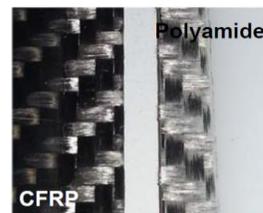


## Material efficiency: Dissimilar plastic joints

- **Laser-based joining of dissimilar materials**
  - Challenge for common joining techniques
  - Structuring of surfaces leads to strong connections
- **Multi-material lightweight design**
  - Joining thermoplastics with metals or fiber-reinforced plastics
  - Transmission and heat-conduction joining possible



*Fracture behavior*



Just to give you some examples of these kinds of welding seams, you see a very smooth surface and a very small heat-affected zone because the tool is not too large and there is not too much energy going into the surrounding materials. This also makes new strategies for welding possible by using filler materials or even by adapting the temperature you want to reach in order to get the hardness inside the seam to the same level as in the surrounding sheets.

What I am telling you on the metals is similar for plastics. Light-weight construction is a very important part, especially for the automotive industry, and reducing the weight of metals is one solution. However, if we think of a totally new mobility, I think reducing the weight of metal parts will not be sufficient. You have to make it possible to use the plastic inside a car body or other parts to reduce the weight of mobile cars and other rolling stocks in the future. With this technology, you have to make it possible to combine metals with plastics or different plastic parts. Laser technology is a suitable solution for this. There can be some pre-treatment necessary to have a rougher surface of the metal, but by laser technology, it is possible to join metals and plastics, also with good quality.

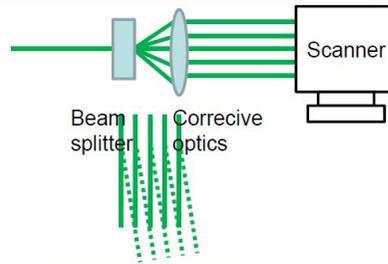
The new welding strategy that I am always talking about is moving this small tool of the laser beam. Here is an example of a car. These kinds of beam oscillation are used to get better results, so we have laser sources enabling a very small tool size and, of course, new system technology fast scanning to provide the possibility of moving the beam very fast. With this, you can make the process more stable and robust for variations of the patch, properties of the steels, or the materials used. By employing this, you can get better properties. This is also used for the Golf Model 7 for the roof.

Coming to the energy efficiency, the new laser sources have two directions. One, of course, is to increase the wall block efficiency of the sources. A laser is well known for heating the surrounding area and destroying energy because the conversion from electricity to optical power is relatively low. The manufacturers are constantly working to increase this. Another important point is to get a better efficiency of the radiation. You generate it, and you put it into the process to get better results out of this. One very important example for this is the treatment of copper. If you treat copper with a laser, there is high reflection for the infrared radiation normally used, so you are losing energy out of the process. By using a shorter wavelength, a green wavelength, and the visible range of the spectrum, we can put more energy into the process and can get better results. As you can see on the right side, using the green radiation of the weld seams is much better than using infrared radiation. There are also some solutions combining infrared and green radiations. The green radiation is a door opener for the process and will get some more energy inside the infrared because the wall block efficiency of these green lasers at the moment is relatively low. However, I think manufacturers will be able to increase this in the future and the sources are not as powerful as infrared sources today. But this will also change in the future.

Coming to process efficiency, there are two main topics. One is the automation. It is already available for laser sources. But to have these new sources with good beam quality, you can enlarge the distance between the source and the work piece and, by doing this, you can have large facilities and a higher degree of automation. However, this also makes it necessary to have cracking systems to make sure that the results are the same during the whole process, i.e., no variations from patch to patch or from part to part.

## Process efficiency: parallelization

- **Multi spot scanning**
  - Splitting the beam to achieve numerous parallel sub-beams
  - Use of special optical element to split beam
  - Fixed number of sub-beams, depending on splitting element
  - enable the use of fiber-guided systems
  - Optical setup designed for
    - Aberration correcture
    - Parallelization
- **Arbitrary beam splitter**



If the power your source is offering is sufficient, you can also make some parallelization of the process, not only generating one structure but also generating more by beam splitting. So you just have optical elements, just divide the beam into several beams and reach the same result for every beam. If the distance and the number of your beams are fixed, you can use optical elements. By using the optical elements, you can also make some corrections to avoid failures. If you want to have more flexibility in the distance of the beam and in the number of beams, you need some more complicated optical elements.

Another trend is higher precision. One development responsible for this is the so-called ultra-short pulsed (USP) lasers. What does it mean to have USP lasers? This means that the pulse duration is so short that you change the mechanism of interaction between the beam and the work piece. By doing this, you can avoid too much heat being put inside the work piece. It is, together with plasma, going out of the process again, and, by this, you can have smaller structure sizes, even smaller than the tool size. It also makes it possible to treat difficult materials, i.e., ones in the form of optical, transparent, very dissimilar material mixes, or even temperature-sensitive materials.

The lasers were used in micro-processing in the past. However, this was always the problem: the size of the beam was too large and the processing time was too long, so the output was too low. However, by using these USP lasers, this is changing, totally. The first industrial result was the drilling of the fuel injection nozzle by Bosch in Germany. There are many

## Additive Manufacturing of Metal Components

*Gear Wheel*  
(1.2709, 1.4542)



Source: Rapidobject

*Dental Prostheses*  
(Cobalt-Chromium)



Source: EOS



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*Mold Insert*  
(1.2709)



Source: Jell

*LEAP engine*  
*fuel nozzle*



Source: GE Aviation

**blz** BAYERISCHES  
LASERZENTRUM

Dr. Stephan Roth

24.10.2014 | 22

other applications occurring at the moment, and I think this will be the future of precision manufacturing by using laser technology with these USP lasers. If I was asked three years ago, I would not have been so sure about this. But now, the sources are available for industrial use, and that's the main thing. We have the processes and knowledge developed for years by many researchers all the around the world. Now the sources are available to bring this technology into production.

Some other examples of structuring metal forming tools include small structures inside lubricants and the treatment of difficult materials, in this case, hard materials such as diamonds and ceramics. By using these tools, it is possible to treat these hard materials.

Coming to the last trend, it is additive manufacturing. Everybody is talking about additive manufacturing, which is good for us production engineers. The estimations, I think, were the same 20 years ago, but now, the technology is prepared for industrial use, and I will tell you why. When you look at additive manufacturing so far, it is well known for prototypes for some medical products, inserts, implants, etc. However, it is now coming to the real world. The first parts will be aircraft parts in the near future, which will be produced by additive manufacturing by laser beam melting. Now we are prepared for this because it was developed in the end of the 90's already, and it was used for some functional prototypes, metal powder, layer, etc., using the laser. But the challenges for materials available were no wide range and the process stability was too low. Today, we are able to treat different materials by modified powder systems. We can combine materials and can even make an alloy during the process. That is possible for metals, and the process is getting more and

more stable. We have monitoring systems available. So we can increase productivity, accuracy, and process stability. Additive manufacturing using laser technology is prepared to become a serial production technology.

What is the role for all these trends of R&D institutions and companies in this development in the future? Just to give you an example from the BLZ, these institutions and companies offer flexibility, knowledge, and experience, and they can be a platform for interdisciplinary work. That is most important. The production is becoming more and more complex due to the process, materials, and tools. Therefore, knowledge and experience are becoming more and more important. You should not use R&D institutions as suppliers of solutions only. If you really want to change, if you really want to shorten your process of production and development time, you need knowledge and experience. R&D partners are the chance for the industry to gain this knowledge and experience, and you have to support them. It is a chance to get knowledge and experts who can handle problems within your companies, and that is one of the key factors to shorten the time from the idea to the product. We did this for two examples in the past, and I just wanted to show you what was possible. Here, in the brazing process for the automotive industry, you can reduce and can make the process simpler, can make it more stable, and make it cheaper. For the plastic welding, etc., the process is getting more stable and more flexible. The properties of the work pieces and the parts you produce are getting better. This is only possible by real cooperation and willingness to learn from R&D partners. That is my main message to you. Strengthen R&D partners and cooperation with real active support.

Thank you very much for your attention.



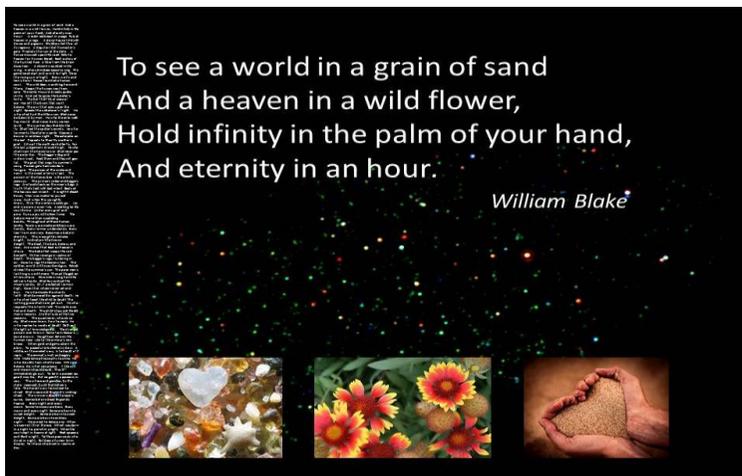
# MANUFACTURING SOLUTIONS FOR DIGITAL HEALTHCARE WITH BIGHEART\*

\*Bionanoscience for Innovative Global Healthcare Research & Technology

**Luke Lee, Professor, Bioengineering, Electrical Engineering & Computer Science, and Biophysics, UC Berkeley, USA**

It is my honor and joy to share what I have been doing at Berkeley after many years in industry. I worked in the industry called TRW, as well as a small startup company called Conductors. Therefore, I have a quite different experience compared to typical academic professors. Today, I would like to show you the importance of manufacturing solutions for digital healthcare with BIGHEART. It is bionanoscience for innovative global healthcare research & technology. This is greetings from our department. I named our group as BIOPOET: Bio-inspired Photonics Optofluidics Electronics Technology & science. As you can see, due to my industrial and academic experience, I am trying to integrate all science and technology for the purpose of global health.

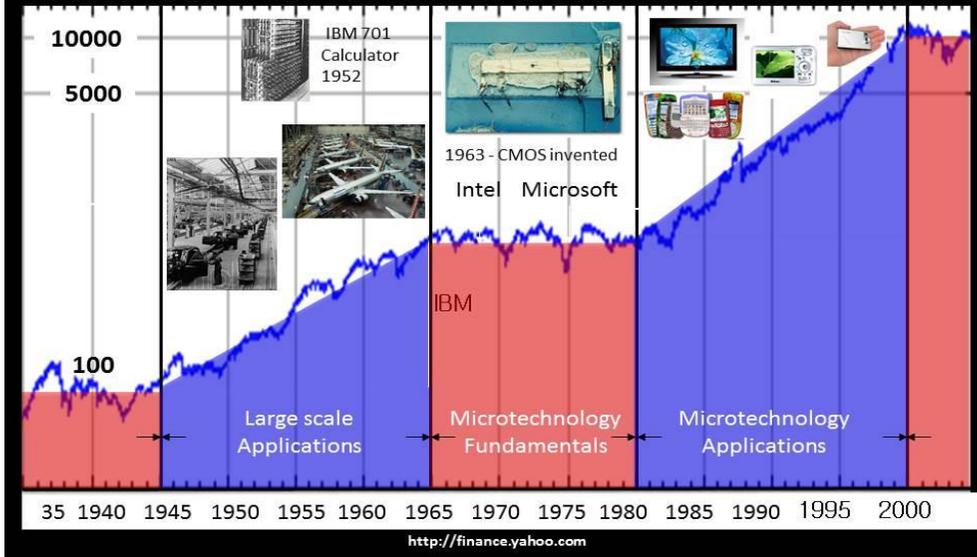
Before we start, I would like to introduce to you one of my favorite poems, “Auguries of Innocence.” How many of you know this poem? I guess it is very difficult to see because I intentionally wrote it in small letters. I would like to highlight a few lines by William Blake. He even predicted in the 19<sup>th</sup> century the importance of the industrial revolution, the danger as well as blessing. What we need to learn from this lesson is very important, as engineers and scientists. If we ignore the importance of the industry as well as manufacturing, we might destroy our prosperity. That is how he predicted, even in the 19<sup>th</sup> century, when he was looking at England.



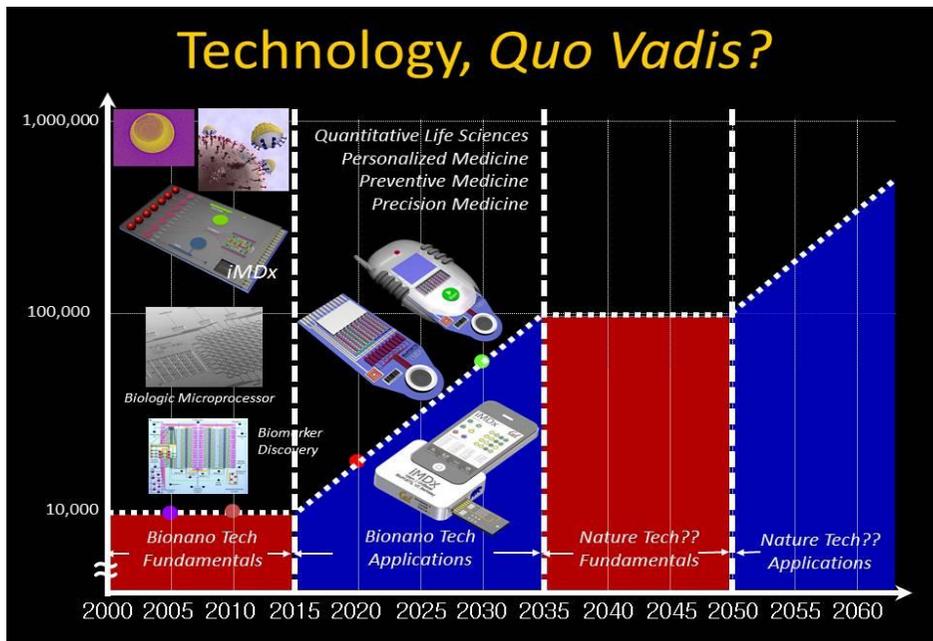
This is a really important lesson for my students, current engineers, and scientists in the US as well as other countries because we have to learn how to see the world in a grain of sand. Inside a grain, there is a beautiful crystal structure. We have to learn from it “a heaven in a wild flower.” How does a flower generate patterns? While we are fabricating nano-, micro-, or millimeter-structures, we have to learn how nature can create this multi-scale dimensions by patterning from gene coding. I like the third line: “Hold infinity in the palm of your hand.” Currently, many students in engineering or science try to avoid the “hand.” It is very important to think about using our hands. It is our hand that innovates science as well as engineering. We can have infinite number of inventions as well as innovations in science and technology. “Eternity in an hour” -- we think that we enjoy prosperity forever, but, as you know from the lesson of England, even though the Industrial Revolution was initiated in England, think about the situation in England or even in America. We have to watch out with our behavior. We have limited time. We have to balance things in basic science as well as real manufacturing science.

After I introduce the motivation, I will talk about innovative manufacturing for personalized medicine while introducing how we create integrated molecular diagnostic systems (iMDx), integrative microphysiological analysis platforms (iMAPs), as well as quantum nanoscopes. It is not just for science. We have to create new technology to create new science. If time permits, I will talk about creativity in precision manufacturing and healthcare, especially integrative arts, culture, technology, and science (iACTS). We have to act on it. Otherwise, if you sit there and rely on banking industry, our country can collapse. If time permits, I will talk about integrative translational engineering, arts, medicine, and science (iTEAMS) as well.

# Dow Jones Industrial Index



If you look at the Dow Jones Industrial Index in this slide, the x-axis is the year and the y-axis is this index. Until 1945 from the early 1900's, nothing happened because of the World Wars I and II. Suddenly, there is an increase in the Dow Jones industrial index which was created on Wall Street. You can see that, from 1945 to 1965, they enjoyed large-scale application in industry. Nothing happened from 1965 to 1980. Many people were skeptical that there was no way to recover the economy. However, during this period, some people invented CMOS, transistors, etc. It looks ugly, but this is the initiation of transistors as well as CMOS, and many new micro-electronic fundamentals were discovered. You have to remember that, during this discovery, there was the transistor. This was done by engineers, but they got the Nobel Prize in Physics. Remember, the engineers got a Physics Nobel Prize, even for this integrated transistor. Then, from 1980 to 2000, because of this fundamental period of micro-technology, we enjoyed applications of micro-technology for 20 years. This is the history from which we have to learn a lesson.



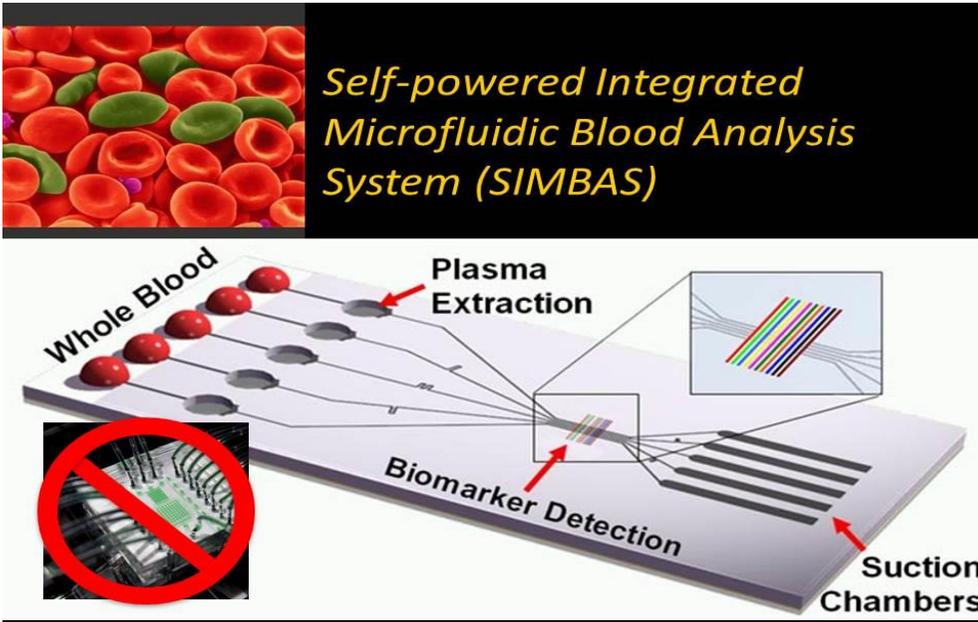
From 2000, people wondered, “What is next?” This is my own interpretation. You do not have to believe me. But I have been focusing on bionanotechnology fundamentals from 2000. You might say, “Look, you have only two more years to go.” However, due to the history of 20 years of application and 15 years of a fundamental period, I can predict that we might have a bionanotechnology application from 2015 to 2035, for developing new personalized medicine, preventive medicine, and precision medicine. We will have different gadgets that you cannot even expect. After 2035, I might die. So it is up to the new generation. You have to prepare for it. There is a dark period; however, do not worry. There are things on which we have to make fundamental research and of which we have to think about for future application.

Within that motivation, we can think about having personalized medicine by using patient samples or blood and having this nice system at home so that it can accumulate a kinetic model of our cellular or metabolic activities. All this information at home is very weak, so we can have a nice way of handling large experimental data at home. At the end, by integrating all different disciplines, e.g., optics, IT, NT, BT, physics, and chemistry, we can think about generating creative disruption using this kind of integrated iMDx for future new medicine. We developed this prototype. However, why is there no industry? The problem is that there is no mass production of this multi-scale system integration from nano-, micro- to the millimeter-scale. Why? There is no industry because people are afraid to create this kind of industry. However, without industry, it is impossible to make new medicine. We really need innovative precision manufacturing for multi-scale system integration for personalized medicine.

In my view, the role of precision manufacturing is not only creating jobs but also establishing healthy economy as well as a healthy mind. Without the job, without using our hands, if you try to just do everything with only software, there is a limitation. Then, you create new science. For example, this year's Nobel Prize in Chemistry is a microscope. It is an engineering job. Actually, the person who got the prize helped his father's manufacturing facilities. In Physics, it was LED. If you look at these wonderful Japanese electrical engineers who got the Nobel Prize in Physics, they really spent time for doing engineering, perfect engineering. Without precision engineering, there is no new science. You need to use new tools to make new science. If you use old tools, you cannot make new science. It becomes the best defense mechanism against global economic power. You have to remember manufacturing will help us.

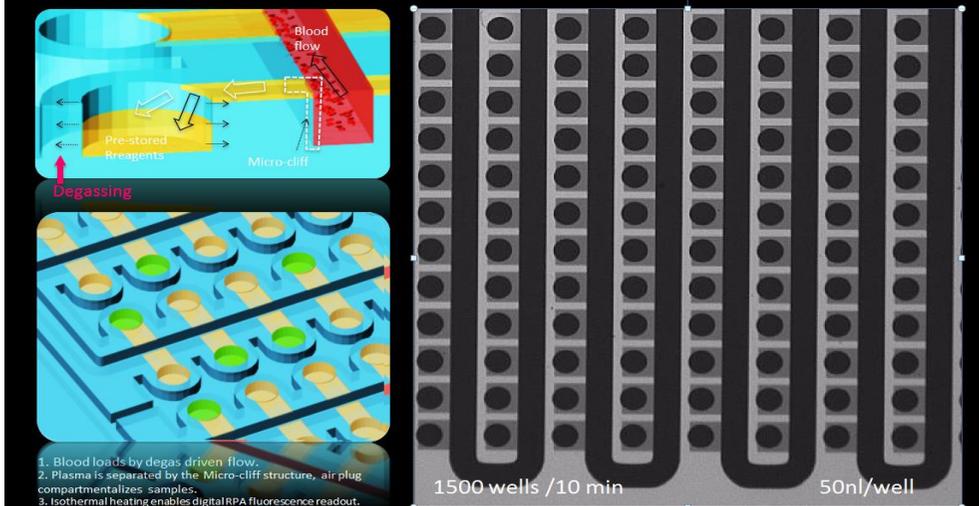
I will talk about our example of iMDx first. In order to make additive manufacturing for personalized medicine, you have to think about how to make biological application specific integrated circuits (BASiCS), which allow us to integrate many different samples as well as cell cultures and detection all together. So, BASiC for quantitative biomedicine (QB) is creating new science, i.e., QB on a chip for digital healthcare systems. You have to remember if we can measure biological science quantitatively, it is not a science. That is why there is a lot of temptation to fabricate the data by fabricating the pictures because they couldn't make quantitative measurement. So, it is important to think about design. But our philosophy is "Simplicity is the ultimate sophistication." If you follow the design rule for electrode and high- and low-fluidic resistance, you can add all different components of different functions of the sample prep, detection, capturing cells, and so on. These are some examples. Due to the time, I will highlight only a few examples. We developed a new way of capturing a single cell as well as studying ion channels and then moving solution using light and so on.

I would like to introduce to you the integrated iMDs for global health. When I say global health, I do not mean only the third world, but also developed countries in Europe or America. The emphasis is "sample-to-answer" at low cost. For example, in global health, HIV, TB, etc. are a serious problem, but in San Francisco, we have the same problem. Whether you are in a developing or developed country, we have to address this global healthcare problem. This simultaneous detection of DNAs, RNAs, and proteins can be done by dropping the blood. Is it possible to create a chip that processes everything including separation, detection, and amplification? I would like to show you an example. It is very important to make iMDx with an ASSURED condition, which is affordable, sensitive, specific, user-friendly, robust/rapid, equipment-free, and deliverable. How can we accomplish this in a university lab? Even if we create innovative creative design, it is impossible to make this ASSURED iMDx in a university. We can demonstrate this, but we cannot mass-produce millions of chips like this. Why do we need millions of chips? It is because we have to test clinically over and over until we have assured data. Otherwise, it is a useless platform.



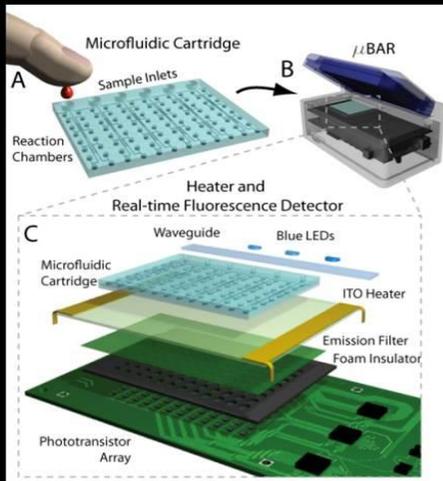
So, we made this device. I would like to show you the importance of this integration. First, it is a self-powered integrated microfluidic blood analysis system (SIMBAS). The whole idea is “no external pump.” You draw out the blood. By knowing this porosity of the polymer, we can design the chip that can pull out the blood in separate plasma. You can see that the blood is dropped, and then there is a trench where the cell is basically separated. Then, plasma is extracted in two minutes. You can do fast blood separation and do protein and DNA analysis downstream.

## Self-digitization of *Blood Plasma*



Here, it is showing that we can do a self-digitization of blood separation. This design allows very fast self-digitization of plasma, but we have to remember that, before we fabricate, we also immobilize the region in this well. We can have thousands of wells for many different probes to detect different cancers. So you can detect many different diseases at once using this kind of self-digitization chip because everything is integrated in this well. We can amplify the signal of nucleic acid. So, by knowing this possibility of integration, we can see also the detection of the PCR on the chip right away in 30 minutes. We are now pushing this 30 minutes to 30 seconds. So, we can make a 2-minute separation and 30-second DNA detection.

## Mobile Healthcare: POC Genomic Diagnostic System for Global Healthcare



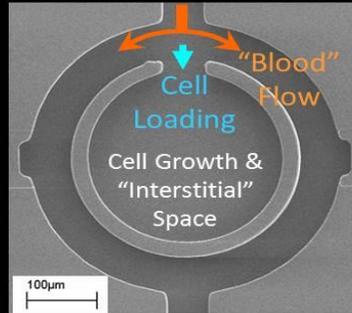
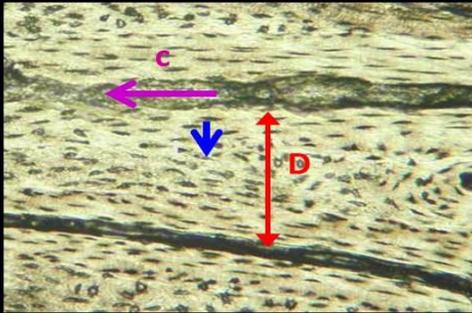
- Rapid detection & identification of ID pathogens
- Genomic analysis of pathogen infectivity and drug resistance
- Battery-powered (3.7 V)
- Blue LED (472 nm)
- Phototransistors (515 nm)
- Automation via microcontroller & USB interface
- SD Flash memory card reader
- GSM cell phone module
- GPS module

Myers et al., PLOS ONE 2013

We also integrate this system using a new detection system so that we can drop this blood, and this is disposable. This reader has a GPS module so you can have all this information wherever you are. Then we are making a smartphone iMDx to make a nice web application so that we can transmit this information to a needed place.

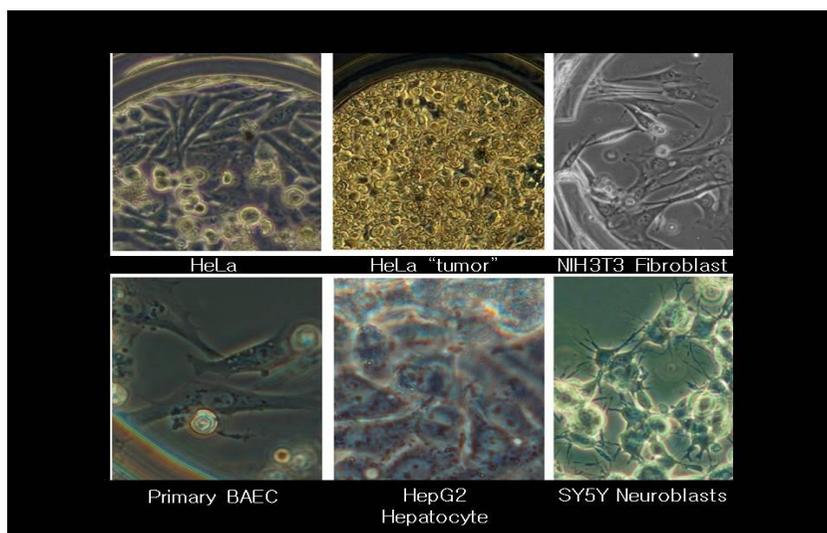
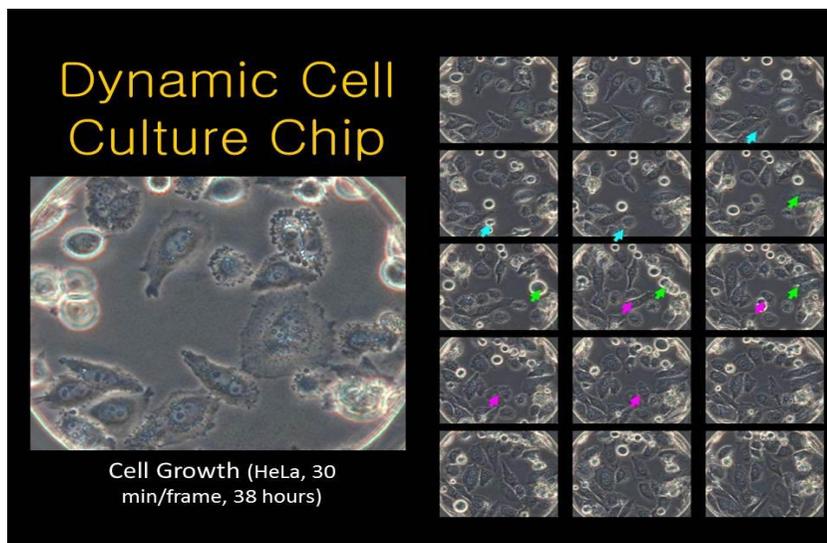
The next one is integrative microphysiological analysis platforms (iMAPs). This is for using the patient-specific induced pluripotent stem cells (iPSCs). We have been developing this dynamic cell culture as well as liver-on-a-chip and now a Harvard group is following this lung-on-a-chip. The history of the organ-on-a-chip allows us to create this nice movement in the US for the organ-on-a-chip. I have to go back to the history of the cell culture. Professor Koch did a wonderful job using this Petri dish. His assistant invented this Petri dish. We have been using Petri dishes for many years, and then he got the Nobel Prize for his accomplishment in bacteriology. In real life, our tissue in the body is not steady. Our body is in dynamic condition, so we have to think about how to create new dynamics of cell culture.

## Recapitulating Physiology: Physiologically Relevant *m*-Environment



	Tissue	Microfluidic
Size (D)	100-300 $\mu\text{m}$	50-1000 $\mu\text{m}$
Circulatory Flow (c)	700 $\mu\text{m/s}$	80-4,000 $\mu\text{m/s}$
Interstitial Flow (i)	0.1 $\mu\text{m/s}$	0.08-4 $\mu\text{m/s}$
Extracellular Matrix	Complex	Surface Coating

This is a real tissue sample. There are circulatory flows. In between circulatory flows, there is an interstitial flow. We have to think about all dynamic flows and make a physiologically relevant micro-environment to culture the cell. Then we can recapitulate the physiology. By designing these different flow rates for the different organs, we can create this nice organ-on-a-chip or dynamic cell culture chip so that we can have different injections of nutrient gradient and as well as flow of the nutrients so that you can combine quantitative cell biology.

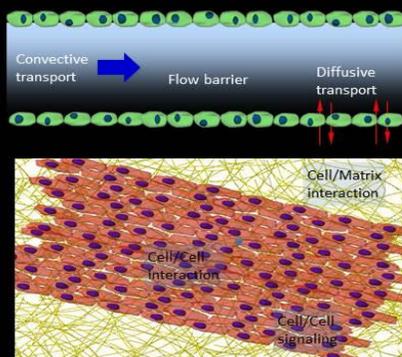


You can see that each cell generates different dynamic cell growth culture depending on the flow rate.

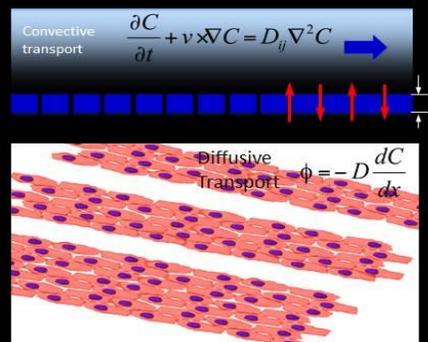
You have to think about that this cell has the same conditions except one variable. One looks like a tumor, and one looks normal. The only difference here is the flow rate. It is showing the importance of the flow rate. If you do not control the flow rate, if you culture it in a steady condition, you do not have any idea of how a tumor cell can be created even though it is an identical cell. It is very important to have precision engineering, even for stem cell biology. Otherwise, how dare we claim that, using a Petri dish, we can use cell to make a

nerve cell, endothelial cell, cardiac cell, etc.? The reason why there are temptations to fabricate the picture is because they probably saw but couldn't repeat the experiment. They could not measure quantitative data. Why? It is because they did not have a tool. It is time to listen. Engineers can provide precision biological tools instead of using a 100-year-old Petri dish for steady cell cultures. It is time to change dynamic cell cultures for real physiological conditions.

## Physiologically Relevant Dynamic Cell Culture for Precision Medicine



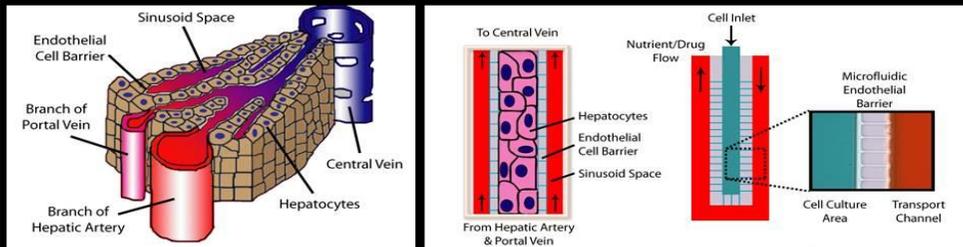
In vivo



Cultured Cells

1. Understand physiologically relevant microenvironments
2. Use precision microengineering to create better cell environments
3. Precision biological perturbations, real time and continuous monitoring

# Physiologically-inspired Liver Architecture on Chip

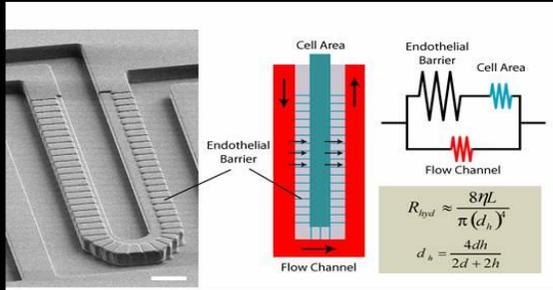


- Sinusoid space transports blood to hepatocytes
- Lined with fenestrated endothelial barrier
- Hepatocytes form extensive cell-cell contact

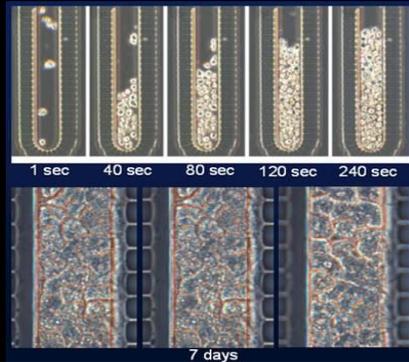
This is an example of a physiologically-inspired artificial liver. People thought that it was impossible to culture the primum cell, but by knowing the basic physiology, there is a convective flow as well as diffusive flow. By knowing this, you can mimic this architecture of the liver and then fabricate this device using micro fabrication by controlling the flow rate, etc. You can make this simple fluidic circuit model and control the flow rate.

You can see how this primum cell can be maintained for many days without dying away. This is the first demonstration of the primum cell culture for a long-term cell culture in dynamic condition.

# Physiologically-inspired Artificial Liver Sinusoid

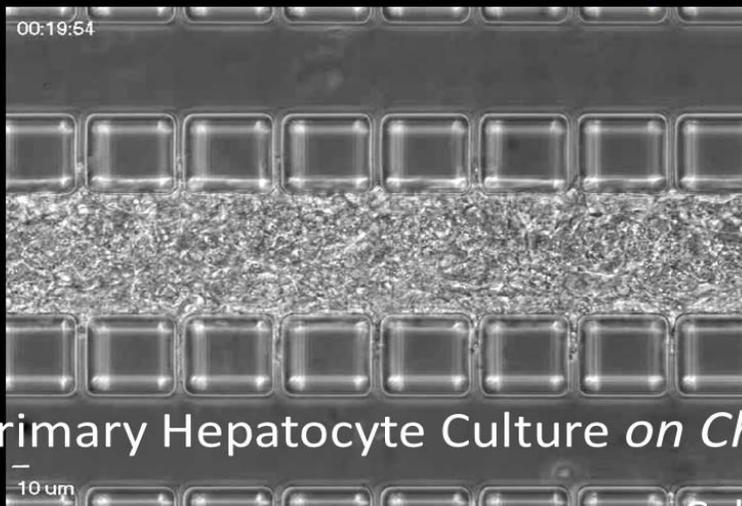


## Precision Control of Hepatocyte Loading



- Microfluidic endothelial barrier
- High density hepatocyte culture
- Continuous flow mass transport

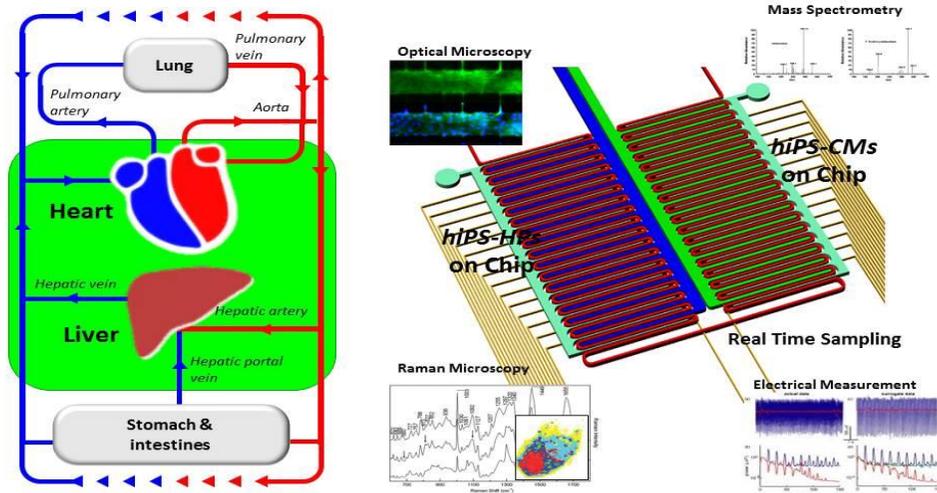
# Physiologically-inspired Liver Architecture on Chip



Primary Hepatocyte Culture *on Chip*

CellASIC

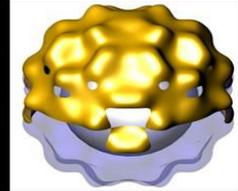
## Patient-Specific iPSCs-based Integrative Microphysiological Analysis Platforms (iMAPs)



Now we are expanding this to make an integrated micro-physiological analysis platform using iPSC to make hepatocyte and cardiomyocyte so that we can study patient-specific drug discovery and drug analysis tests. Then, we expand this to many different organs so that we can fabricate this fluidic chip that allows to capture this differentiation as well as maintaining different organ functions and to analyze all different activities of human metabolic activity for drug discovery and toxicology studies.

Creative precision manufacturing can create precision medicine. It is very important. If we want to create precision medicine with old tools, it is too late. We will waste a lot of research funding. So it is important to have large-scale multi-scale convergence of BT, NT, and IT. It is because we have to integrate protein patterning, fluid dynamics, optical detection, as well as optical amplification or chemical amplification, and so on. With this kind of integrated system, we can contribute to medical innovation for different diagnostics for different diseases. You can check down to nucleic acid detection.

# *Nanoscale Additive Precision Manufacturing for Nano-Satellites*



## *Exploring the Living Cells: Cellular Galaxy*

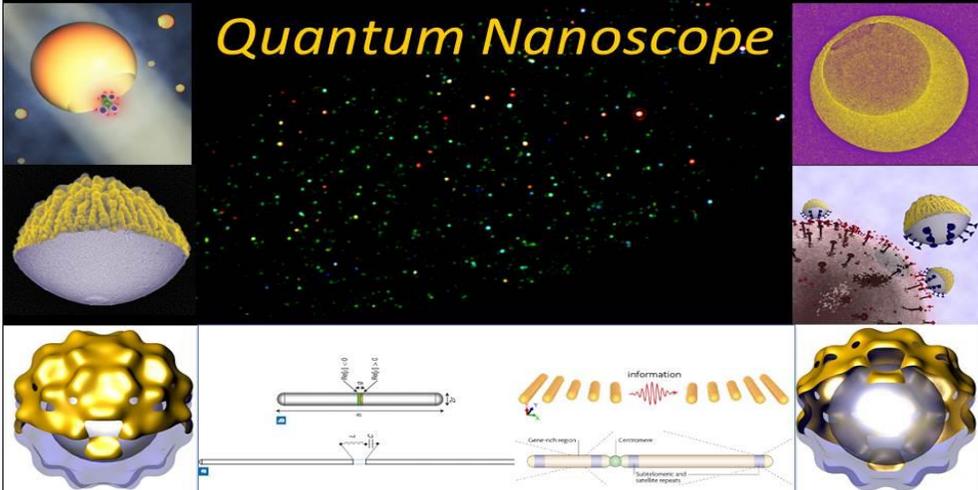
For the remaining time, I would like to highlight nanoscale additive precision manufacturing for nanosatellites. This is nothing but a nanoscale integrated system for optics. This is a plasmonic structure. Inside is a magnetic particle and on the outside, you can add a gene so that it can explore a living cell as a cellular galaxy exploration. My question is, “Can we capture e-motions in living cells?” When I say *e-motion*, it means electronic motion. Is there any tool to capture e-motion in a living cell? We do not have any tool to capture e-motion or transfer information in a living cell. Why, then, do we need to understand this electronic transfer information? It is to monitor and regulate cellular signaling pathways as well as to understand electronic transfer mechanisms of enzymes or proteins as well as nucleic acids.

So I would like to make an analogy. I was in TRW, and I was involved with satellite integration. This is all meter-scale or centimeter-scale, but you have to think about this galaxy. People thought that the galaxy was something like a nuclear plant from the USSR. We have to think about making new observations in a cell. Instead of fear or bias, we have to explore a cellular galaxy with new platforms.

# Nanoscale Satellite

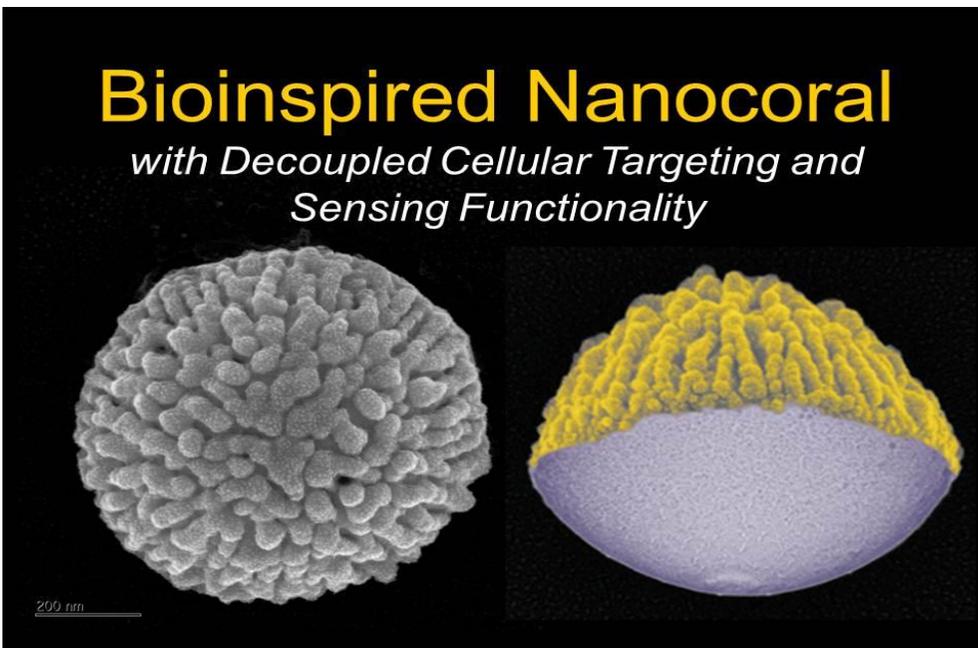
*Capturing electron transfer dynamics and molecular imaging in living cells*

## Quantum Nanoscope



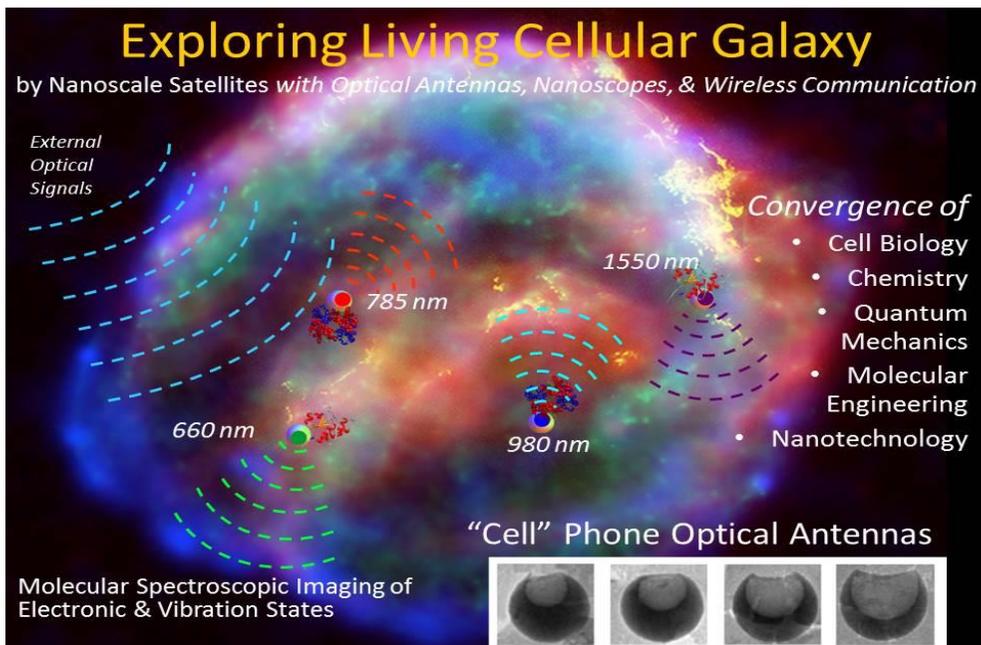
# Bioinspired Nanocoral

*with Decoupled Cellular Targeting and Sensing Functionality*

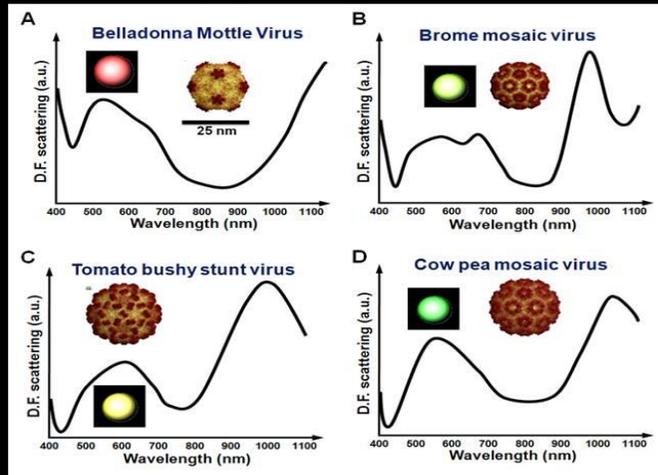


This is a nanoscale satellite. This is a crescent shape. You can generate different colors. It also provides fingerprint information as well as an optical antenna so that you can target a specific cell and sense the molecule within the cell or within the membrane area.

This is one example of bio-inspired nanocoral with a half-sized nanostructure for sensing. The other side is for cellular targeting so that we can target a specific receptor molecule. If there is a cancer cell, we can use this system to target the cancer cell and gene delivery for treatment. You can think about manufacturing this kind of structure and then the targeting of a specific cancer. But the principle for this antenna uses a surface plasmon polariton. By knowing this boundary between the metal and dielectric layers, we can generate coherent charge oscillation when you shine the light. We can use this system as a new optical antenna system. Another advantage is that, even though you shine the near-IR, even if this plasmonic satellite is ten nanometers, you can focus by resonating the electron. This is the advantage of this kind of structure.



# *Eu.virus Optical Antennas*

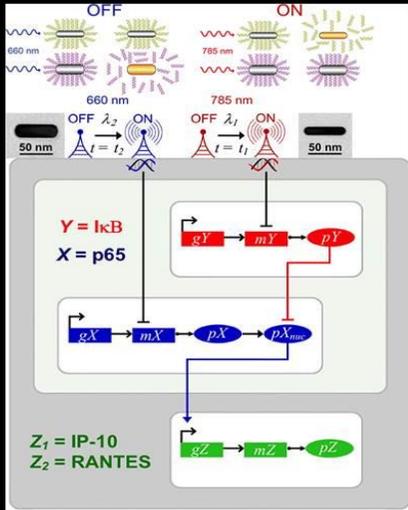


We can insert the system inside the cell and call from the outside. By shining a specific wavelength, you can liberate the attached genes or peptide from outside the cell. This is the true “cell” phone because you can communicate with this antenna, which is inside the cell from the outside.

We can create new viruses and good viruses for the same purpose, and then we can see this function for targeting, sensing, imaging, and drug delivery. The advantage is, again, optical enhancement through this plasmonic structure, and then we can get different specific optical resonant peaks.

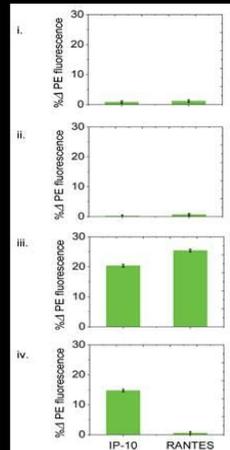
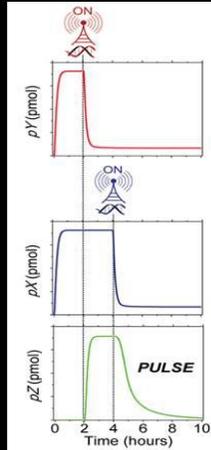
# Photonic Gene Circuits

Two NF- $\kappa$ B regulated genes: IP-10 & RANTES



Lee et al., (ACS Nano 2012)

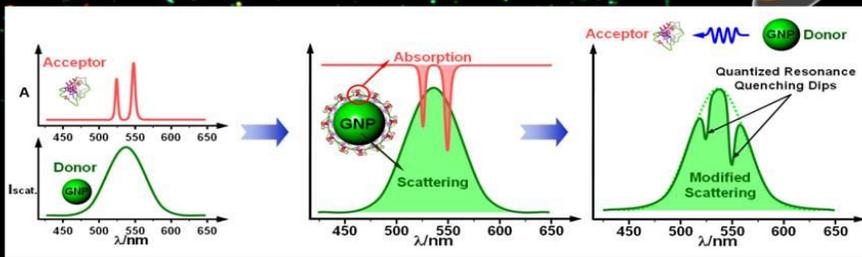
	ON	ON	Output IP-10 early gene	Output RANTES late gene
i.	0	0	0	0
ii.	0	1	0	0
iii.	1	0	1	1
iv.	1 ( $t_1 = 0$ hr)	1 ( $t_2 = 2$ hr)	1	0



# Quantized Nanoplasmonic Dip Spectroscopy by PRET

Quantum Nanoscope

*Fiat Lux!*



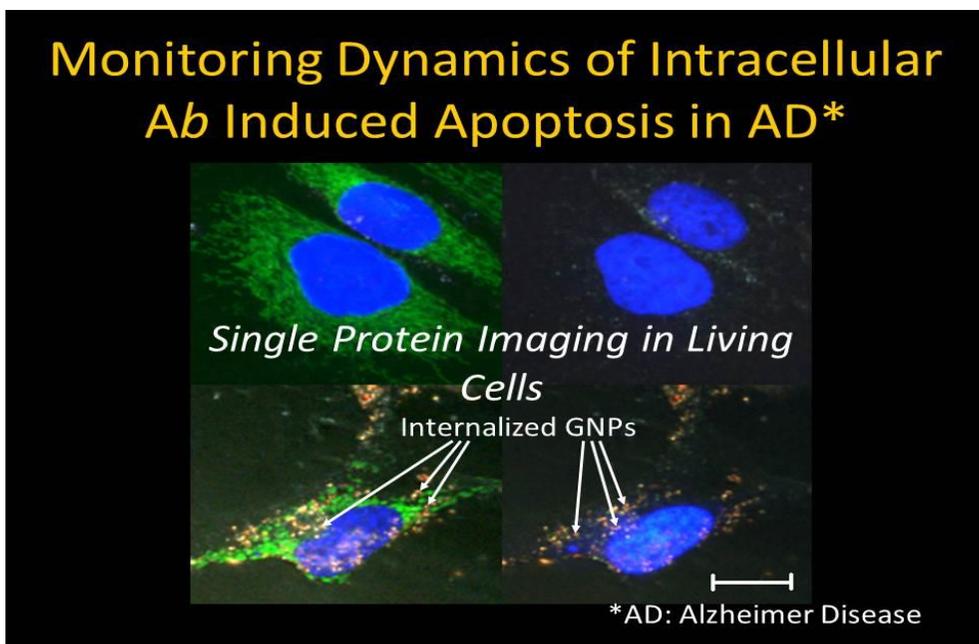
I would like to highlight the advantage of this optical antenna. You can attach it and then shine the specific wavelength to turn it on and off at different times so that you can make genetic pulses. This is the first demonstration of gene circuits in a living cell. Why is it important? This is very important for gene therapy. Instead of using toxic chemicals, we can

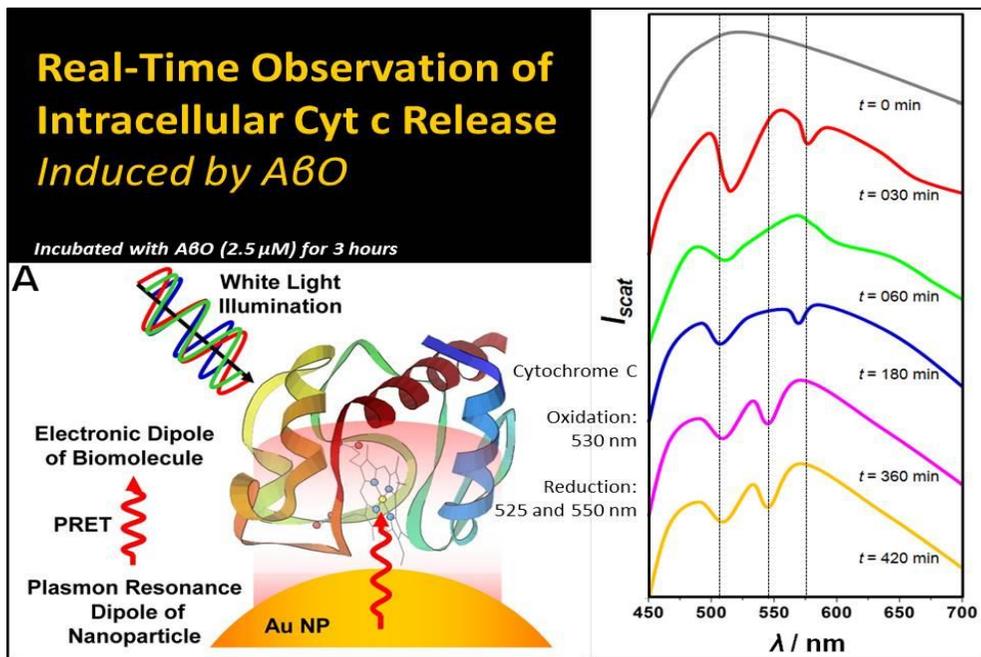
regulate gene circuits for NF- $\kappa$ B for biological circuits.

We can also use this plasmonic structure nanosatellite as a sensor of an optical spectroscopy sensor. If we have a protein around this antenna, we can capture this identical absorption peak, as you can see here in quantized resonant quenching dips. So why do we want to do this? It is because, for example, regarding Alzheimer disease, people argue that it is due to the problem of electron transfer (ET). Is it true? How do you know whether it is an ET problem of mitochondria or not? So, we have to study quantum biophotonic ET (QuBE) in living cells. There is no tool, so we have to deliver inside the cell and challenge whether it is important to study QuBE. QuBE, or not QuBE, that is the question. Otherwise, we do not have the exact observation. Nobody has really observed true ET in living cells. This is the hypothesis learned in the textbook, but there is no one who has observed it directly.

So we can deliver inside the Alzheimer disease cell and see whether we can capture this optical information through the ET.

Without poking with a wire, we cannot get this spectroscopic information from the outside because this optical antenna transmits this information to the outside so that we can get an idea of whether it is reduction of oxidation or you get the idea through the ET information.





I hope I gave you an idea of importance of the nanoscale satellite manufacturing for capturing new information that we do not see, not only outside of the world using satellites, but also inside our cells all the way down to the ET level in cells.

In a few minutes I would like to highlight iACTS. It is for stewardship, sustainability, and social responsibility by creating convergence. By looking at art, we might say “How does it relate to technology?” If you look at Bio-active matter for an air detoxification wall, you can make a new wall that allows detoxicating all the air in many different countries. We can come up with a new way of making air detoxification using creative art as well as this new wall.

For obstacles of creativity, we have to remember that there is a huge political and educational boundary. We learn a lesson from *Demian* by Herman Hesse: “The bird struggles out of the egg. The egg is the world. Whoever wants to be born must destroy a world.” We have to remove the boundaries to make creativity.

Here are my conclusions. Integrated molecular diagnostic systems (iMDx), integrative microphysiological analysis platforms (iMAP), and nanoscale satellites are developed for precision personalized medicine. Precision manufacturing for new medicine will create a healthy economy and new sciences. Creative convergence of integrative art, culture, technology, and science (iACTS) can generate a healing ecosystem. Innovative scale-up manufacturing through the convergence of life science, engineering, and medicine is the solution for global healthcare and healthy economy.

I would like to finish my presentation with one quotation by Goethe.

*Knowing is not enough;  
We must apply.  
Willing is not enough;  
We must do.  
In the realm of ideas  
Everything depends on enthusiasm...  
In the real world  
All rests on perseverance.*

Johann Wolfgang von Goethe

## **Session 2: Energy and the Environment**



# The Challenge for Future Power Generation

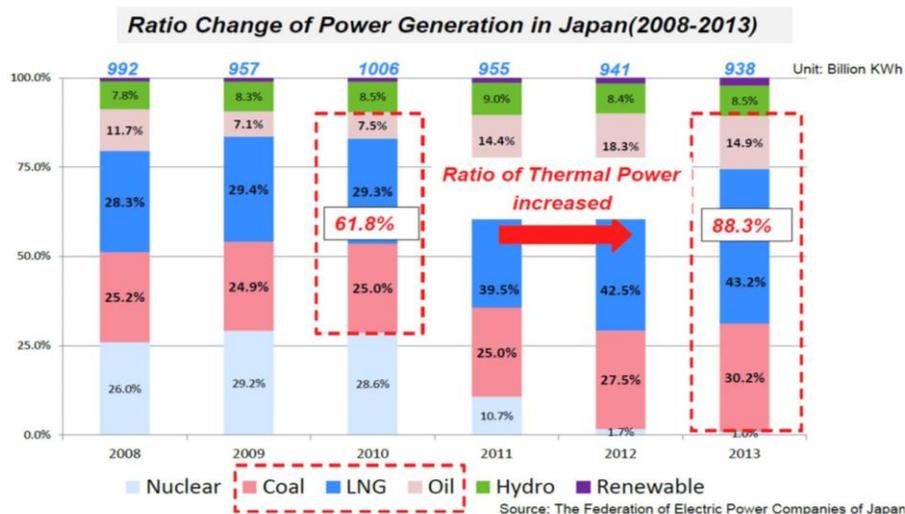
**Kenji Ando, Senior Executive Vice President, Mitsubishi Hitachi Power Systems, Ltd., Japan**

Dr. Yong-Taek Im, thank you very much for your arrangement of such a wonderful session today. I would like to introduce what company we are. I will mainly focus on gas turbine technology. Thirty minutes will be given to me, so please stay calm and listen to my presentation. Thank you.

Today, I will firstly talk about what the most required energy is these days and what kind of energy is environmentally safe. Secondly, I will explain how Mitsubishi Hitachi Power Systems was established. Thirdly, I will focus on the high efficiency of gas turbines and integrated gasification of combined cycle (IGCC), which is the most advanced technology in the world. Lastly, I will talk about air quality control systems.

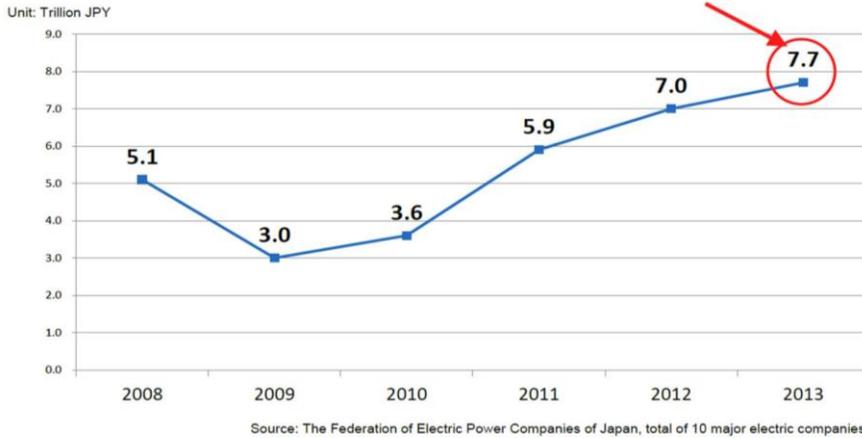
Here, we can see the power generation ratio change from 2008 to 2013 in Japan. At this moment in Japan, we completely shut down all of the nuclear plant stations. As you can see here, blue color is liquefied natural gas (LNG) and red color is coal. Nowadays, LNG consumption is jumping up.

## 1-1. Power Generation in Japan



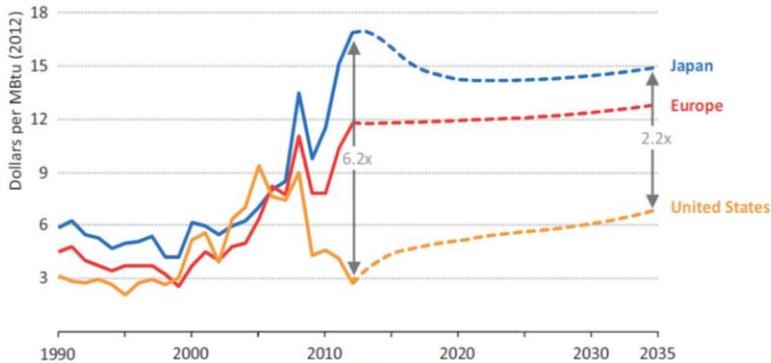
## 1-2. Energy Cost for Power Generation in Japan

### The highest energy cost for power generation in Japan



## 1-3. Forecast of Natural Gas(LNG) Price

Source: International Energy Agency, World Energy Outlook2013



**Increasing fuel price requests high efficient equipment**

This slide shows energy cost for power generation in Japan. The highest energy cost for power generation in Japan is ¥7.7 trillion, and it is gradually increasing. Mostly, we consume natural gas in order to supply electricity power in Japan.

This slide shows a forecast of LNG prices. Here, we see the LNG prices of the United States,

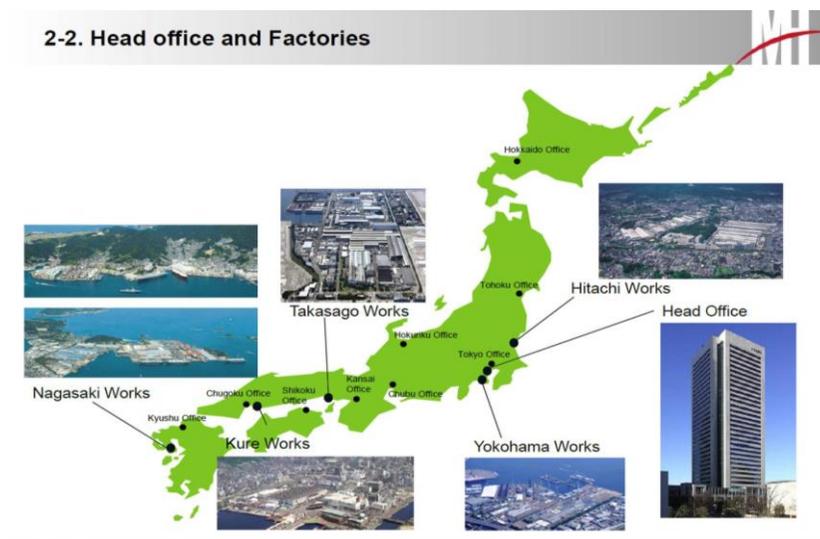
Europe, and Japan. The Japanese natural gas price is 17 US dollars per MBtu. We have to import 100% of our LNG from overseas. Even in the States, because of some kind of fee for developing shale gas, such cost will slowly increase. Also, in Japan, lots of fuel cost will keep going up. So, what should we do? One typical thing to solve this problem is to develop environment-friendly and higher energy efficiency gas turbine systems.

Mitsubishi Hitachi Power Systems (MHPS) was established last February by Mitsubishi and Hitachi. The majority of the capital is taken by Mitsubishi. Only 35% of the capital is taken by Hitachi. However, both companies have the same policy: develop environment-friendly systems for the future.

Let me introduce our company's head office and factories. Our head office is located in Yokohama, just across Tokyo. We have several factories and facilities in Hitachi, Takasago, Yokohama, Kure, and Nagasaki. We are dedicated to large-scale gas turbine facilities in Takasago. In Hitachi, they put more focus on smaller gas turbines. Both facilities are dedicated to gas turbine development and manufacturing.

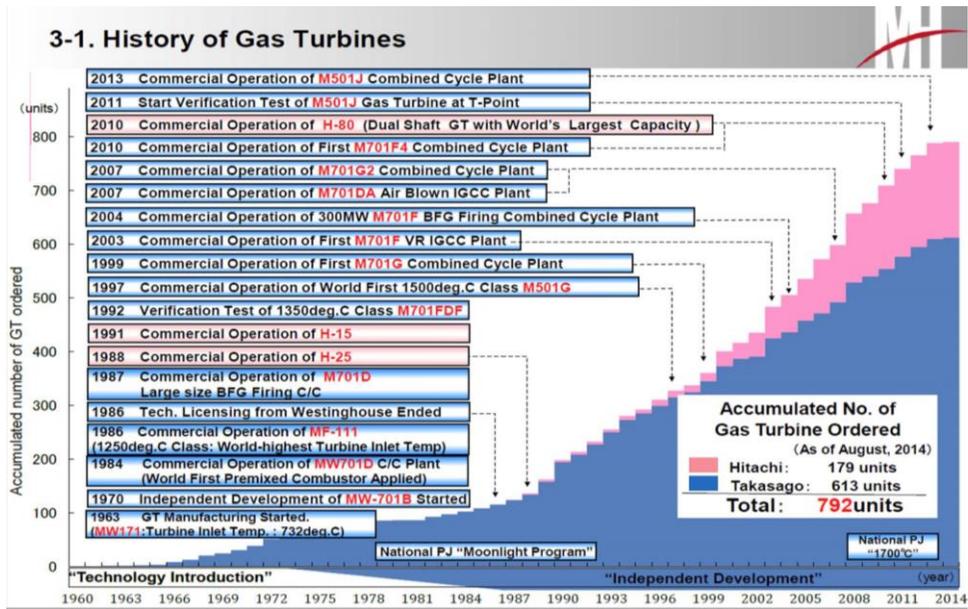
Also, we have several subsidiary companies in the world. We have companies in the States, Europe, and Korea. Korea's electricity demand is jumping up. Our company is providing several gas turbines to Korea and Korean customers. However, we have to compete with our two major competitors, GE and Siemens. One typical subsidiary company, MHPS Americas, is located in Orlando, Florida, USA. MHPS Europe is located in Duisburg, Germany. The biggest subsidiary office in East Asia is located in Korea.

We mainly produce gas turbines, steam turbine generators, and combined cycles.

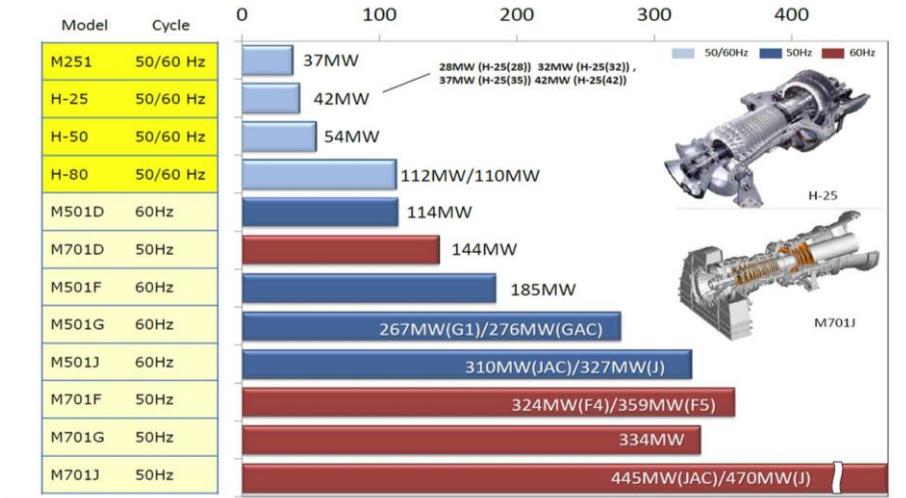


Our company's vision is maximizing the potential ability of Mitsubishi and Hitachi. Our business scale is \$12 billion in 2014. However, by 2020, we expect to reach \$20 billion.

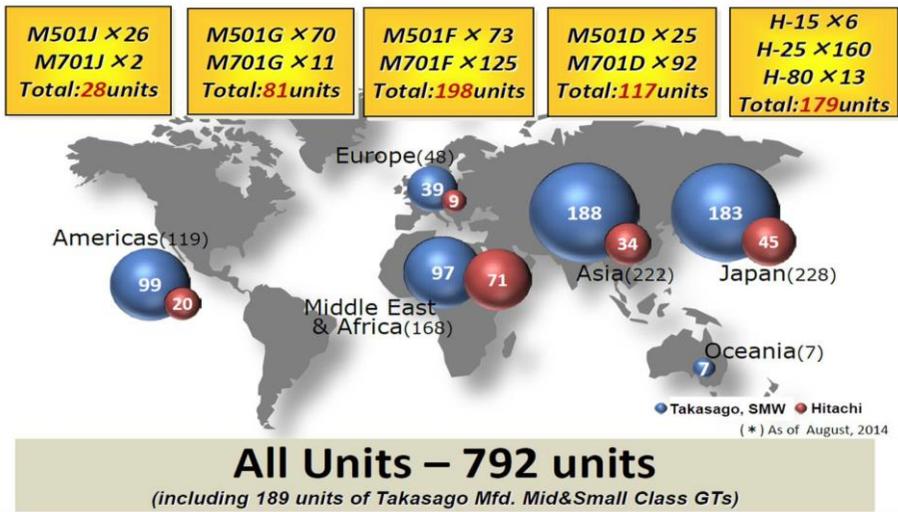
Here, we have a history of the gas turbine development of our company. We commenced manufacturing and producing gas turbines in 1960s. At first, our teacher was the States. However, gradually, our technology has grown up. Even though gas turbines were not the key business for us, we developed gas turbines by ourselves. Then, combined cycles were developed. Combined cycle means the exhaust energy of gas turbines to be utilized for steam generation. Steam turbines and gas turbines both produce electricity. That means those are high efficiency power plants. The gas turbine business will smoothly increase, not only in Japan, but also in the worldwide business in Korea, in Asia, in the States, and in Europe. In the future, more of such kinds of high efficiency power plants will be installed, so we have to develop much more. At the moment, the latest version of gas turbine development is type J. A temperature just out of the combustor is 1600°C. Our goal in the future is reaching 1700°C and increasing energy efficiency. We have to develop much higher efficiency gas turbines.



### 3-2. Gas Turbine Line up



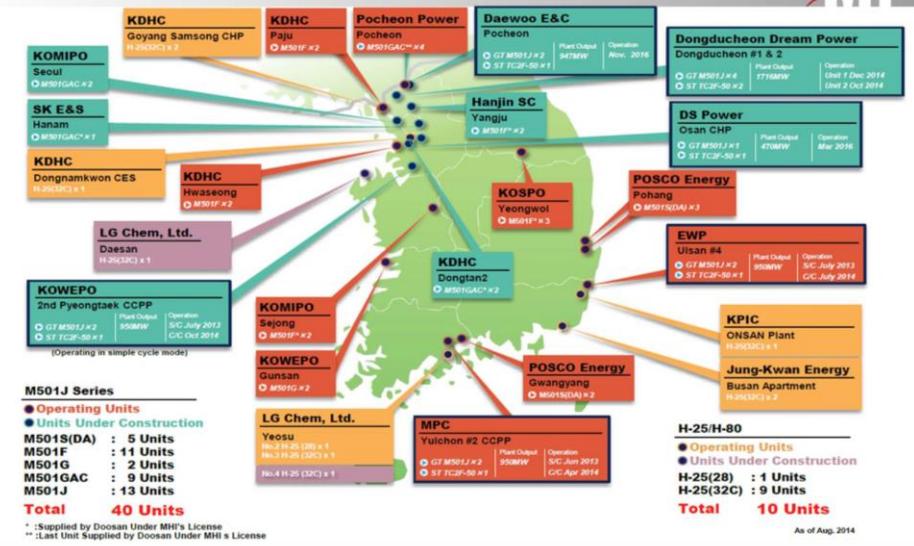
### 3-3. MHPS Gas Turbine Global Experience



This slide shows our gas turbine line up. From small ones to big ones, we have a wide ranging line up for providing gas turbines to worldwide customers. Specifically, the small ones are made by Hitachi, and the big gas turbines are made by Mitsubishi. So, depending on the customers' needs, we can provide any size of gas turbine.

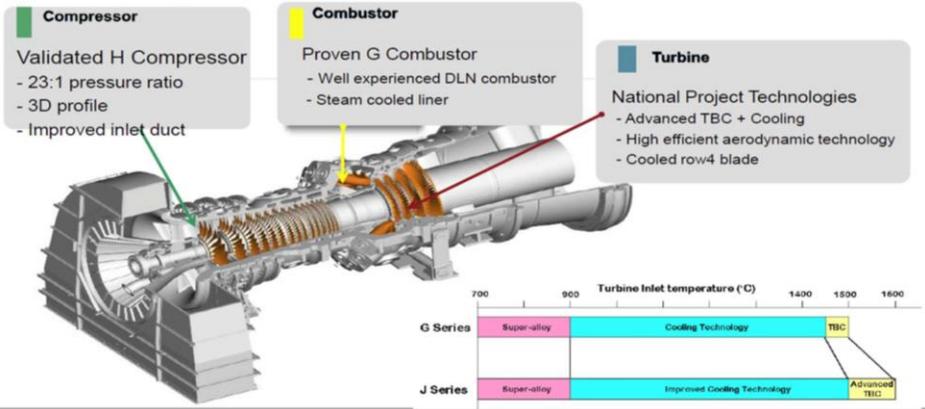
Here, we can see the latest worldwide production quantity. These days, higher efficiency gas turbines are very popular for the purpose of environment-friendly strategies.

### 3-4. MHPs Gas Turbine Award Record in Republic of Korea



### 3-5. J Series Gas Turbine Features

- C/C efficiency > 61%
- High Pressure Ratio Compressor Experience from H Engine
- Steam Cooled Combustor Experience from G Engine
- Turbine Technologies from National Project



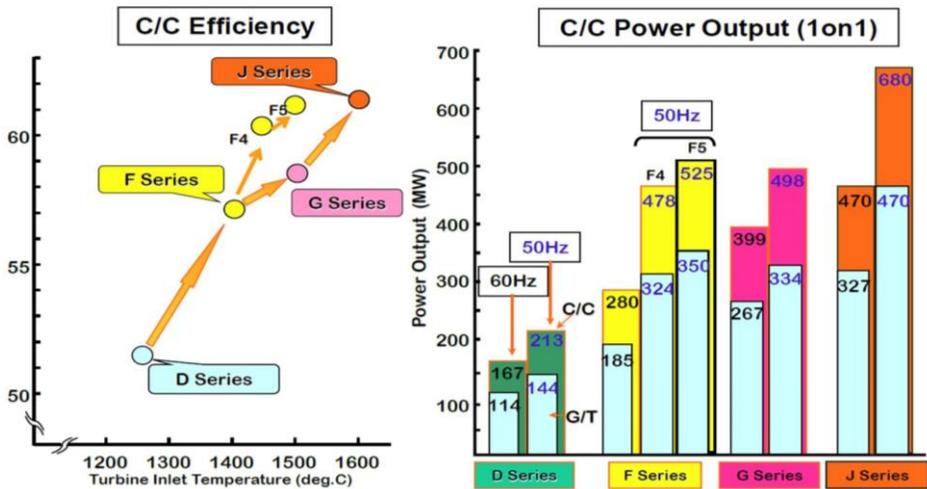
We have already provided such kind of gas turbines to Korean customers. We have to make our best effort to contribute to the Korean customers for huge business development.

The J series gas turbine is the very latest version. The concepts of a gas turbine's compressor, combustor, and turbine mechanism are almost the same as those of a jet engine. All the

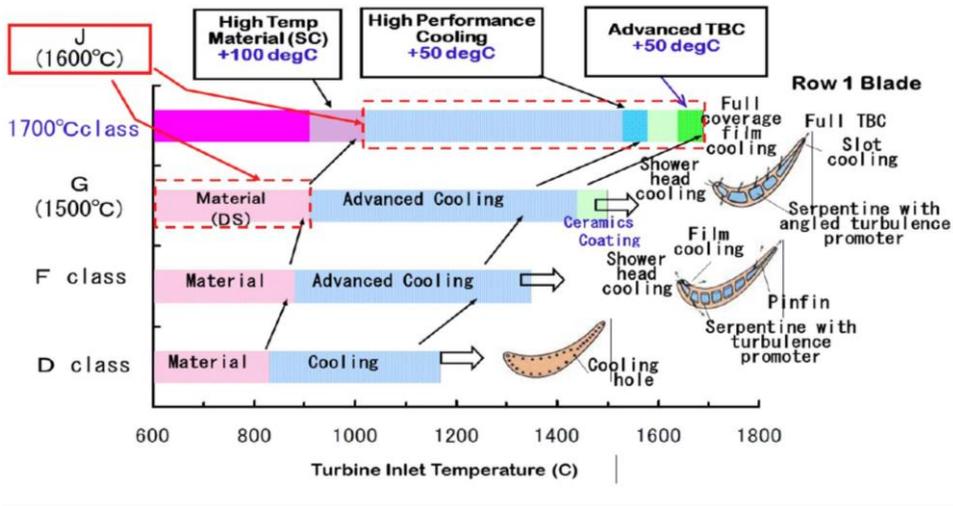
power of the compressor, combustor, and turbine is produced in the turbine state. At the compressor state, only consuming occurs. Sixty percent out of 100% power is to be consumed in the compressor state. It means gas turbine efficiency is 40%. So, we have to minimize loss of thermal efficiency.

Nowadays, the temperature efficiency of our combined cycle is more than 61%. At the moment, our goal of thermal efficiency of a combined cycle is 63%. On this slide, we can see a lineup of electricity power output. The biggest output is shown in the mixture of a gas turbine and steam turbine. This big scale combined cycle output is almost 700MW.

### 3-6. Performance Enhancement



### 3-7. The role of each technology for 1600C J-series GT



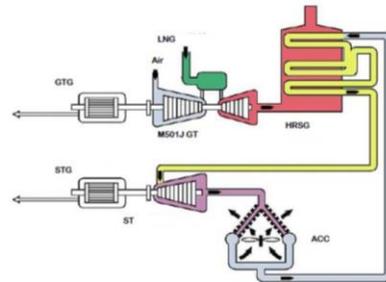
We have three key features in our gas turbine business. Those are high temperature material, high cooling performance, and advanced TBC. These are important for the future development of gas turbine technology. Such kind of development is already carried out at GE and Siemens. Every gas turbine manufacture is focusing on these developments of technologies.

### 3-8. Development and Verification in Takasago



	Takasago Machinery Works	R&D Center
Site Area	216 acres	35.4 acres
Building Area	2,677,974 ft <sup>2</sup>	657,018 ft <sup>2</sup>
Employees	4,027	406

### 3-9. T-Point Verification Plant at Takasago



18,466AOH / 175starts (by end of Sep. 2014)



	2010			2011								
	10	11	12	1	2	3	4	5	6	7	8	9
Manufacturing	█											
Installation	█			█								
Commissioning				█								
Demand Operation											█ →	

I would like to introduce one of the facilities in Japan. The Takasago facility is dedicated to gas turbine manufacturing. At these facilities, there are an R&D center, huge manufacturing

works and a verification system. Before developing new gas turbine production, we put the new gas turbine into some kind of system. Then, we operate it, for the time being, for 3 months, 6 months, and 1 year in order to check the efficiency and reliability of the parts. Takasago is a newly developed gas turbine center. This R&D center and shops develop new gas turbines. This R&D center, 45 shops, and verification areas are on one site, and that is the strength of our business.

IGCC means integrated gasification of combined cycle. Coal is to be changed to gas. In Korea, the same development is going on. In Japan, as you can see here, we have a 250MW IGCC plant that is smoothly running right now. We have to use the coal and change it to gas. That is a key point.

The point is, as I told you, in Japan, we have to import 100% of our natural gas from overseas by \$17 per MBtu. It is very expensive. We lose much money for power generation now. So, we like to utilize coal. Why? Coal is very cheap. So, Japan likes to utilize coal. Then, how can we utilize coal? That is a key point. For the next step, we would like to develop high efficiency gas turbines. Next, we like to utilize coal, especially in an environment-friendly way. How? We developed such kind of system, IGCC. IGCC energy efficiency is higher than normal super critical steam turbine power plants. And also, we can produced pavement materials or concrete aggregate from the residue of combustibles. That means IGCC is an advantageous one.

As you can see here, another IGCC plant is now under construction.

### 4-3. Oxygen-Blown Gasification Technology

**Oxygen Blown IGCC Demonstration (Osaki CoolGen Project)**

- J-Power and The Chugoku Electric Power Co., Inc. jointly established Osaki Cool Gen Corporation on July 2009.
- Osaki CoolGen constructs a 170-MW-class IGCC demonstration plant supported by Ministry of Economy, Trade and Industry and then plans to conduct trials utilizing the latest CO<sub>2</sub> separation and capture technology and fuel cell technologies.

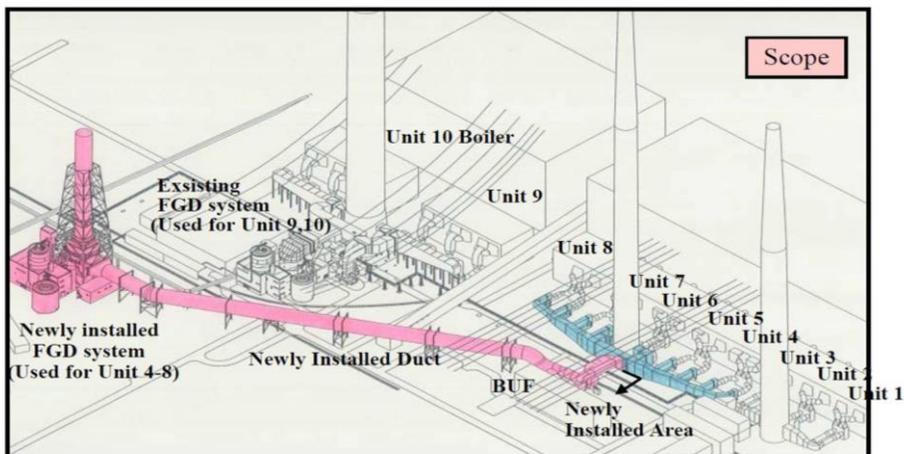
(Under construction)

<b>Output</b>	<b>166 MW</b>
<b>Gasifier</b>	<b>O. blown, single-chamber two-stage spiral-flow entrained type</b>
<b>Gas Cleanup</b>	<b>Methyldiethanolamine (MDEA)</b>
<b>Gas Turbine</b>	<b>H-80 (1,300°C Class)</b>
<b>Operation Start(Scheduled)</b>	<b>March 2017</b>

One big 500MW unit is to be installed in Nosan, Tokyo. The Japanese government has already decided to install two 500MW IGCC power plants in the Nosan area of Tokyo. By 2020, these IGCC power plants will be in service. MHPS established one company. Through this new established company, we can provide environment-friendly equipment widely. For example, we can provide gas desulfurization systems, selective catalytic reduction (SCR), or flue gas desulfurization (FGD) to anywhere. The point is that our different experience in providing supply systems is well-known. We have provided several kinds of FGD and SCR to Korean customers. Nowadays, in order to provide the better environment strategy, we have already developed a high efficiency particulate matter (PM) removal system. Due to customers' needs, we added FGD supplement to the existing power plants. We can provide such kind of additional FGD or SCR for environment-friendly strategy without any problems.

Here is one example. This experience shows how we added FGD to the existing power plant in Poland. If, in Korea, any customers will be interested in such a kind of additional supplement of new FGD to the existing power plant, you can contact us at any time.

#### 5-4. FGD Retrofit to existing units : Reference in Poland (2/2)



## 5-5. Sea Water FGD for Asian Market : Reference in Indonesia

Client : PT. Paiton Energy  
Plant : Paiton #3, Indonesia  
Fuel : Coal  
Generating Power : 856MW  
Gas Flow Rate : 2,859,500 Nm<sup>3</sup>/h(w)  
Desulfurization : 92.0 %  
Efficiency  
Start up : April 2012  
Absorber Type : DCFS  
Absorbent Type : Sea water



**Flue gas for 856MW is treated by single module absorber**

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Here is one example of sea water FGD for an Asian market. Anyway, at last, I can say in Korea, in Asia, in Europe, and in the States, the customers will need something in order to improve their environmental issue for the future strategy.

Mitsubishi Hitachi Power Systems would like to know customers' needs and customers' opinions. So, if you need to get further explanation of our strategy, please let us know. I will visit your office. Thank you very much.

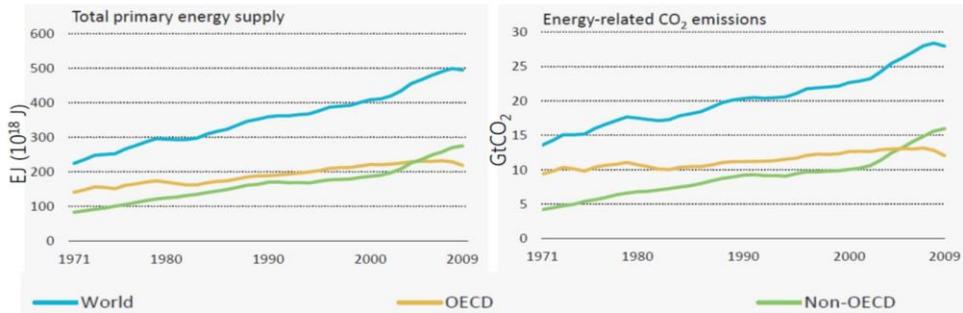
# Perspectives on the Development of Energy & Environmental Technology

**Jong-Soo Woo, President, Research Institute of Industrial Science and Technology, Pohang, Korea**

Thank you very much, Chairman. Good morning, ladies and gentlemen. As introduced, my name is Jong-Soo Woo. I am the president of Research Institute of industrial Science and Technology, called RIST, an affiliated research organization of POSCO, which is the largest integrated steel company in Korea, having produced about 37 million tons of crude steel, last year. First of all, I would like to congratulate this successful hosting of the 2014 International Forum Korea on Advances in Mechanical Engineering. Personally, it is my great honor to have a chance to talk in front of the distinguished experts and guests working in the field of mechanical engineering. I remember it was sometime in April or May this year when Dr. Im, the host of this forum and the president of KIMM, asked me for a talk on this occasion and also told me that any subject would be okay as long as that was related to energy. Although, energy is one of the major research areas of RIST, his offer was kind of trouble to me because it had been a really short period of time since I moved to RIST from POSCO, and most of my career with POSCO is about steel. Therefore, I did not think that I could give a talk as an expert. Instead, I decided to talk what I have learned on research activities at RIST concerning energy and environment. In this regard, today, I would like to introduce the technologies RIST has been trying to develop in the field of energy and environment. Before that, I would like to mention global issues on energy and environment as a background of such technology development.

Let me start with global issues on energy and environment. With increase in population and economic growth, the need for food, water, and energy has increased inevitably and explosively. As a result, we have come to the state where we have to worry about the mega problems of resource depletion and environmental pollution on a global scale. Due to the concern on what the mega problems will bring to a vanishing future, the UN has addressed sustainable development as the underlying principle of economic growth. The core concept of this sustainable development is that the development should be environmentally bearable, economically viable, and socially equitable at the same time.

## World Energy Demand And Emissions



- From 6,000 Mtoe to 12,000 Mtoe
- Rapid growth outside OECD after 2000 is remarkable

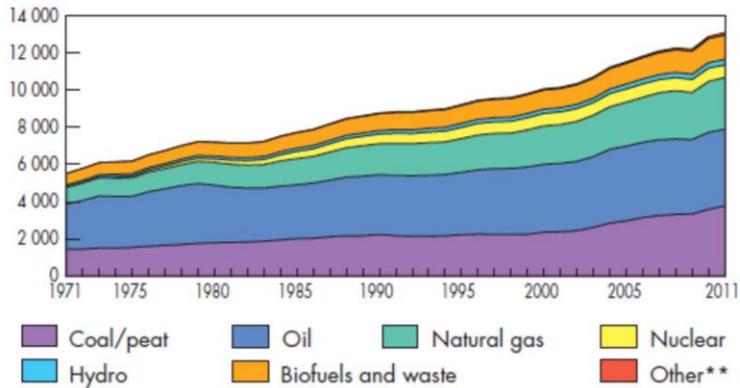
- CO<sub>2</sub> emissions from 14Gt to 30Gt
- Since 2005, non-OECD countries emit more than OECD

Source: IEA , ETP 2012

I would like to mention world energy demand and CO<sub>2</sub> emissions with this slide. In the world energy consumption, CO<sub>2</sub> emissions have doubled in the past 40 years. The energy consumption has increased from 220 to 500EJ, and the CO<sub>2</sub> emissions have increased from 14 to 30GT. One thing we can notice in this graph is that the growth of energy consumption outside the OECD has been very remarkable since 2000. As a consequence non-OECD countries began to release more CO<sub>2</sub> than OECD countries since 2005. The growth rate in energy consumption and CO<sub>2</sub> emissions in non-OECD countries is very steep, while the rate is flattened in OECD countries.

## World Energy Supply by Fuel

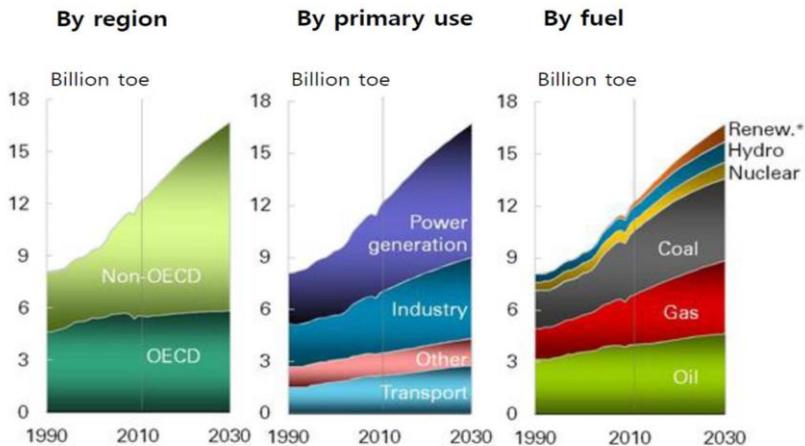
World total primary energy supply from 1971 to 2011 by fuel (Mtoe)



Source: IEA, 2013 Key world energy statistics

This slide shows the history of the world energy supply by fuel. For the past four decades, what we can notice in this slide is that the consumption of fossil fuel has increased steadily and the contribution of each fuel has changed considerably. The amount of oil has not changed very much. On the other hand, the supply of all other fuels is found to have increased remarkably. As a result, the share of oil has decreased from 46 to 32% while the portion of coal has increased from 25 to 29%, natural gas from 16 to 21%, and nuclear from 1 to 5%. However, the portion of hydro and biofuels seems to remain constant. The portion of renewable energy such as geothermal, solar, and wind has increased from 0.1 to 1% during the same period.

## Energy Outlook 2030

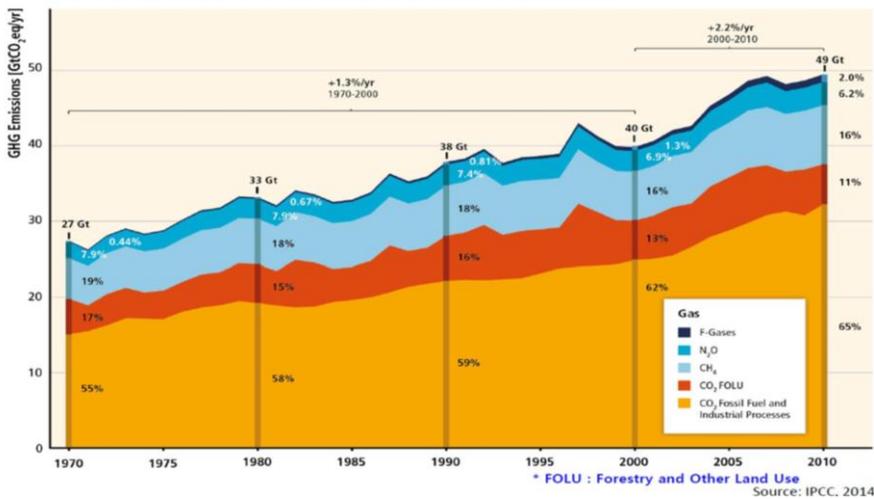


Source: Energy Outlook 2030, BP 2013

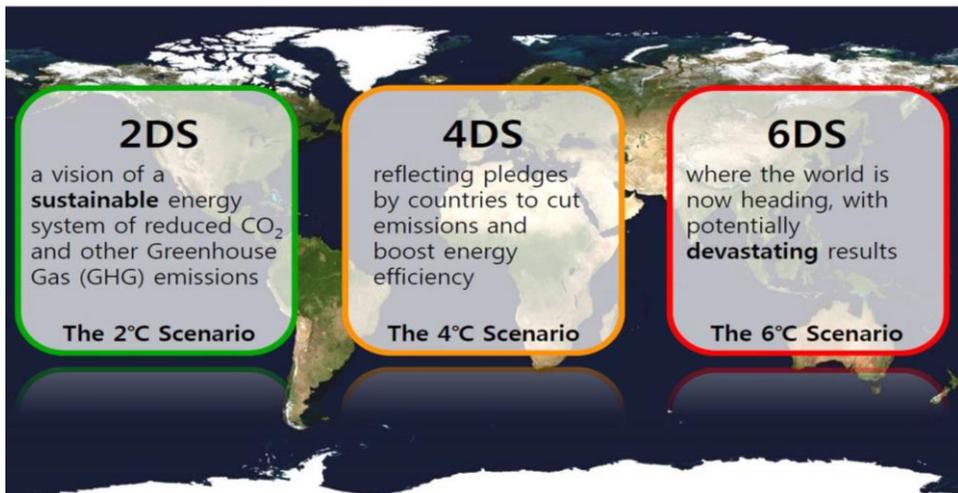
Now, let us look at the energy forecast of 2030 in this slide. Most of the energy consumption growth will come from non-OECD countries. Their energy consumption in 2030 is expected to increase by about 60% as compared to that of 2011. And this number will account for 65% of the total world consumption. In the second graph, you can see that the energy use for power generation will grow faster and industry and the transformation sector are following suit. I think this means that the main driver of the world energy consumption is the population growth in non-OECD countries and their quest for a better standard of living. However, this simple fact brings us direct consequence to the environment. Based on the forecast shown at the third graph, the consumption of fossil fuels will be ever-increasing and will become a never-ending story, despite of so much effort to reduce it.

# Greenhouse Gas Emissions

Total Annual Anthropogenic GHG Emissions by Groups of Gases 1970-2010



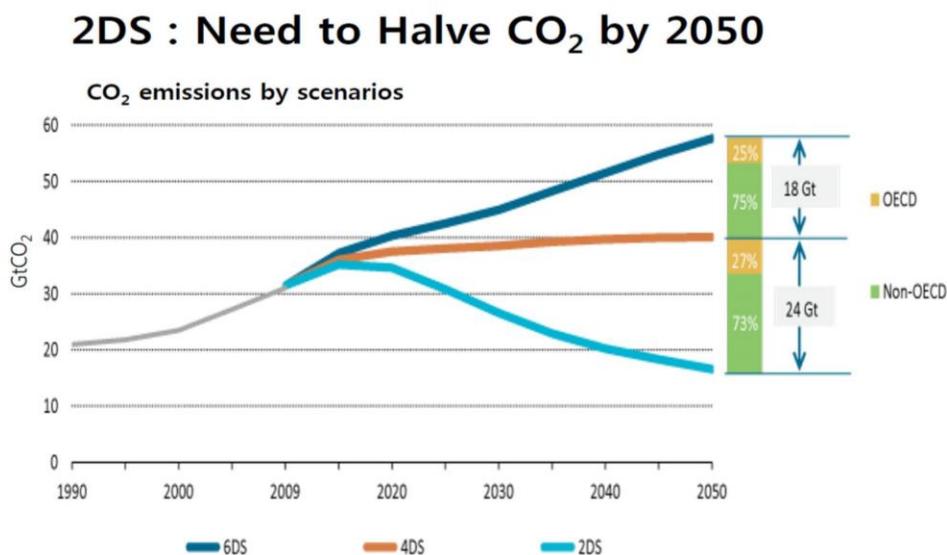
## ETP 2012 – Choice of 3 Futures



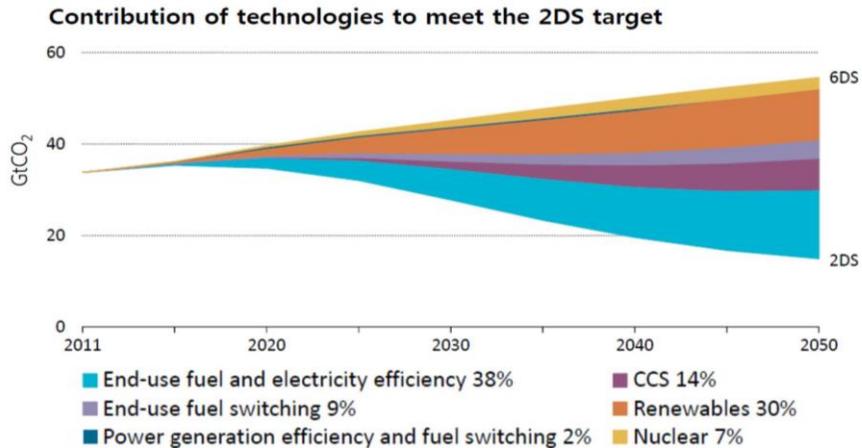
This graph shows the painful consequence from ever-increasing fossil fuel consumption I mentioned just before. According to the graph, the greenhouse gas emission keeps increasing in spite of all those reduction efforts. Most emission growth is in CO<sub>2</sub> from the fossil fuel combustion and industrial processes, which account for 65% of the total greenhouse gas emissions followed by methane, forestry and other land use, nitro oxygen, and Freon gases.

Here are the famous climate change scenarios prepared by International Energy Agency (IEA) in 2012. The report, Energy Technology Perspectives (ETP) 2012 suggests three possible energy futures to 2050, a 6°C scenario, a 4°C scenario, and a 2°C scenario. The 6°C scenario assumes that the world continues down the path it is now heading. The 4°C scenario reflects the stated intentions by the countries to cut emissions and boost energy efficiency. And finally the 2°C scenario offers a vision of a sustainable energy system of the future. There must be many in the audience who already know the scenarios very well. I would like to mention a little bit more on the 2°C scenario. The ETP 2012 2°C scenario explores the technology options needed to realize a sustainable future, based on greater energy efficiency and more balanced energy systems, featuring renewable energy sources and lower emissions. The 2°C scenario tries to identify possible technology innovations and political options that ensure an 80% chance of limiting the long-term global temperature rise to 2°C.

In terms of CO<sub>2</sub> emissions, the message from the ETP 2012 is clear. To have a chance to limit the global temperature increase to within 2°C, the world needs to cut its CO<sub>2</sub> emissions by 50% from today's level by 2050. It should be brought down to roughly 15 GT from today's over 31 GT. Based on the graph in this slide until 2050, we need to fill the gap between 24 to 42 GT of CO<sub>2</sub> emissions by means of various clean technologies.



# A Transformation Is Needed

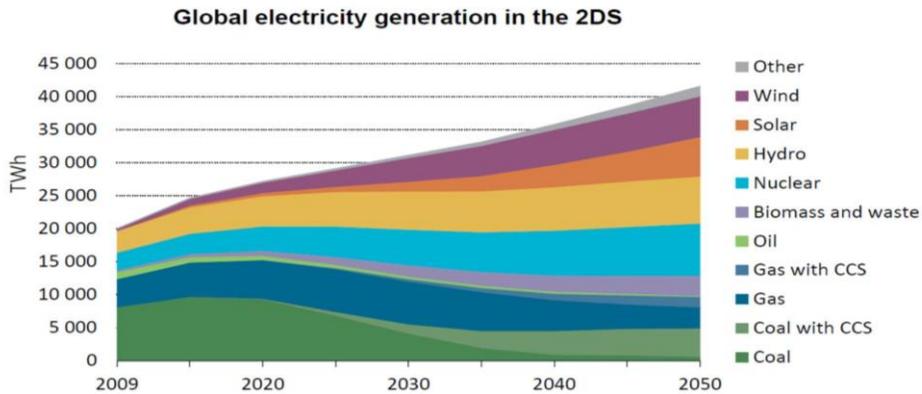


Source: IEA, ETP 2014

The ETP 2012 suggests that in the 2°C scenario, energy efficiency should make the largest reduction in the global greenhouse gas emissions. However, relying on energy efficiency is not enough. And we need to combine with other technologies to meet long-term targets. According to this slide, between the 6°C scenario and 2°C scenario until 2050, energy efficiency accounts for 38% of the cumulative emission reductions, renewables for 30%, and carbon capture and storage (CCS) for 15%, with the balance filled by nuclear energy and fuel switching.

It is difficult to overstate the importance of energy efficiency, which is nearly always cost-effective in the long run. It helps not only cut harmful emissions but also enhances energy security. As most of the industries are stationary resources of greenhouse gas emissions, a significant potential for the enhancement of energy efficiency exists in the industrial sectors. And this needs to be pursued through technological innovations.

## Low-Carbon Electricity : a clean core

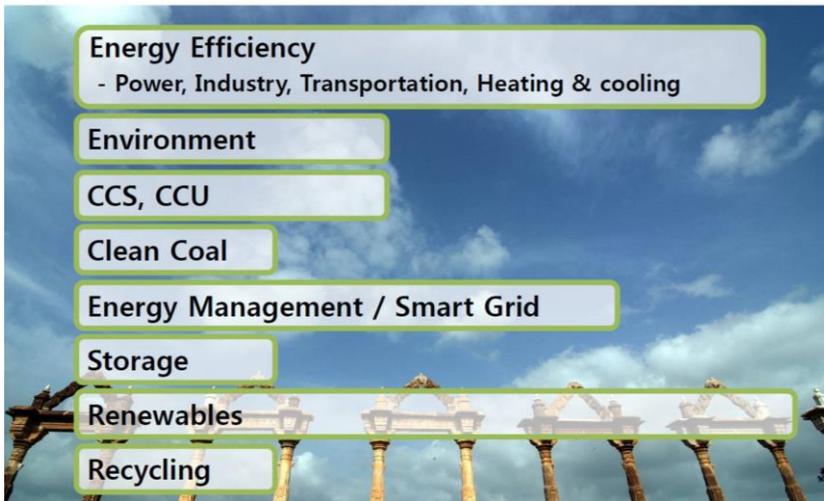


Source: IEA, ETP 2012

In the 2°C scenario, the power generation sector will take over 15% of the total primary energy consumption, which means that electricity dominates the whole energy system. Therefore, low carbon electricity is believed to be at the core of a sustainable energy system. Although it is too challenging to realize the 2°C scenario, renewable energy sources need to produce more than half of the world electricity in 2050. Reducing the use of coal and improving the efficiency of coal fired power generation are considered to be important next steps. Natural gas and oil will remain important for the global energy system for decades to come, and CCS is to remain critical in the long term.

As you can see in the slide, the target in the 2°C scenario is too ambitious to achieve. I do not think we can reach the target. Today's energy system paradigm is based on uni-directional delivery of energy. Therefore, in order to meet the target, we need to realize a sustainable energy system that is multi-directional and integrated even smarter than before. This sustainable energy system will feature more diverse energy sources and provide a better balance between the sources than today's system. Besides that, the new system will be more integrated, complex, and rely more heavily on distributed power generation. This already entails increased efficiency, decreased system cost, and less burden to the environment by incorporating a broader range of technology and fuel.

## To get on track to a sustainable future



## Energy & Environmental Research at RIST



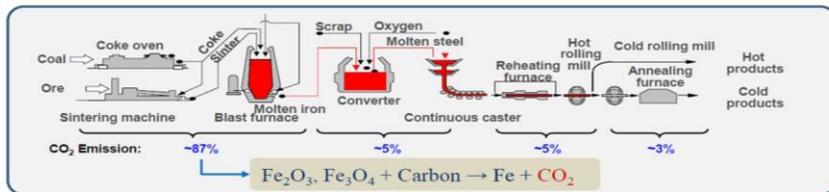
Up to now, I have reviewed the global issues, energy and environment, and how to get on the right path for a sustainable future. The integration of existing key technologies and continuing innovations will accelerate our efforts to achieve a sustainable future. For technology innovation, we need to deal with various aspects of energy and environment such as energy efficiency, CCS, energy storage, renewable energies, smart grids, and so on, as shown in the slide. The utmost test we are facing right now is how to speed up and integrate our efforts in order not to hand a devastating future over to the following generations.

From now on, I would like to introduce the R&D activities RIST is carrying out in the field

of energy and environment. We are dealing with a somewhat broad range of subjects, as described in this slide. However, by doing so, we think we are also contributing to the global effort to realize this sustainable future. Today, I will briefly explain some of the representative R&D projects we are currently performing.

RIST is committed to developing necessary technologies on energy and environment for POSCO, more specifically for the iron and steel production process. This slide gives a general overview of the iron and steel making process. The reduction of iron oxygen to make iron and steel requires a reducing agent that can also produce energy. The iron and steel making process consumes a huge amount of energy, as shown on this slide. Not only consuming energy, the world iron and steel industry also generates a fairly large amount of CO<sub>2</sub>, corresponding to about 5% of global CO<sub>2</sub> emissions. Therefore, the iron and steel industry concentrates its efforts on reducing energy consumption and CO<sub>2</sub> emissions together. As many R&D programs are on the way globally by various steel companies, RIST is carrying out research projects on energy saving and carbon capture utilization in collaboration with POSCO.

## Energy and CO<sub>2</sub> in the Iron & Steel Industry



### ✓ Features of iron & steel-making

- energy-intensive: ~ 25 GJ/t-steel
- high burden: ~ 2t-CO<sub>2</sub>/t-steel (~5% of global emissions: 6.5Mt-CO<sub>2</sub>/yr)

### ✓ Activities for CO<sub>2</sub> Reduction

- Routes for CO<sub>2</sub> reduction at iron and steel industry

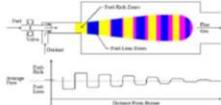


### Regional programs:

- ✓ ULCOS (Europe)
- ✓ AISI CO<sub>2</sub> BP (US)
- ✓ COURSE50 (Japan)
- ✓ POSCO CO<sub>2</sub> BP (Korea)
- ...

# Energy Efficiency

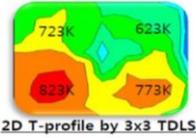
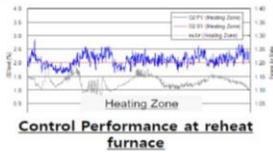
- **Oscillating Combustion : Control fuel lean & rich to induce mild combustion**



**Major Achievements**

- Application to radiant tube burners for indirect heating furnace ('09~'10) ~30% NO<sub>x</sub> reduction & 3% fuel saving
- Demonstration for large scale direct heating burners ('12~)

- **Oxygen control using TDLS (tunable diode laser spectroscopy)**



**Major Achievements**

- Automatic combustion control was enabled by using TDLS oxygen sensing
- Application : Reheat & forge furnaces ~5% energy saving and prevention of ~ 20% scale loss

Improving energy efficiency can be considered as the first step for energy saving. Since the steel industry is operating various kinds of industrial furnaces, energy saving from the furnace is a crucial research area. This slide shows two R&D projects concerning improving the energy efficiency. One is an oscillating combustion, and the other is a laser-based combustion control. The purpose of these projects is to save fuel consumption and to reduce NO<sub>x</sub> emissions. The application of this technology is underway in the POSCO steel plant.

# Waste Heat Recovery

- Waste heat

The recovery of waste heat below 300°C is very restricted by lack of technology.  
 Total amount of world-wide waste heat being able to recover is 1,109GW ('11, Wasabi co.).  
 Market forecasts of power generation using waste heat ('17) : 65.0 billion won/yr

- Waste heat power recovery

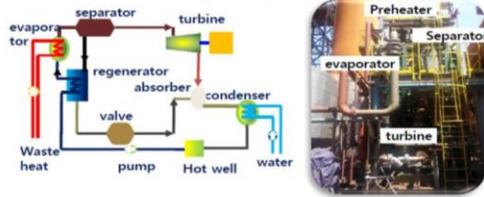
<b>ORC</b>	<ul style="list-style-type: none"> <li>•Technically mature</li> <li>•Commercially available</li> </ul>
<b>Kalina cycle</b>	<ul style="list-style-type: none"> <li>•R&amp;D in progress (long term run-test)</li> <li>•Commercially available</li> </ul>
<b>TPG</b> <small>(Thermoelectric power generation)</small>	<ul style="list-style-type: none"> <li>•R&amp;D in progress</li> <li>•Modular/Compact</li> </ul>

## Kalina cycle power generation

### Characteristics

- Working fluid is NH<sub>3</sub>/water mixture with low boiling point

### Kalina cycle & pilot plant



### Major Achievements

- Pilot-plant(600kW) operation and process optimization ('13)
- Demo plant underway for geothermal generation (Pohang, '15~)

The conversion of waste heat into electricity has been considered to be a promising route for improving energy efficiency. Especially when the temperature is below 300°C, there has been no commercially available technology so far. As shown in this slide, we are working on two commercialized Kalina cycle systems with higher efficiency and compact design. The system uses an ammonia/water mixture as a working fluid, which is adequate to recover low-temperature waste heat. A 600kW-scale pilot plant is under testing at POSCO's Gwangyang plant to optimize the design and operating conditions. Application to geothermal power generation is also scheduled for development as a national project.

- **Thermoelectric power generation**

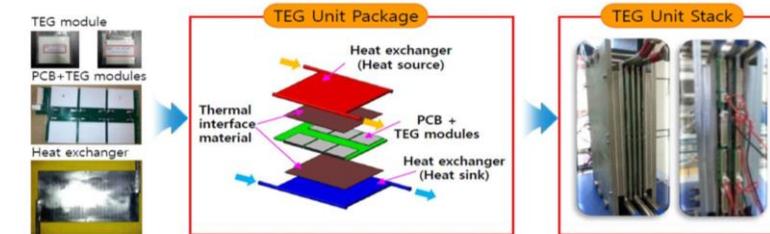
Thermoelectric generator produces electricity using semiconductors through a temperature difference (Seebeck effect)



<Thermoelectric Generator Schematic>

### Development of TEG system

**Characteristics** ➢ To enhance power output with compact design → stacking technology



**Major Achievements**

- Development of TEG unit stack: 235W with 4 packages stacked ( $\Delta T=150^\circ\text{C}$ )
- Power density > 23.5kW/m<sup>3</sup>, Net power ratio > 50%
- Field test of pilot scale (5kW) system using furnace exhaust gas ('14.12~)

## CO<sub>2</sub> Capture Using Aqueous Ammonia

- **CO<sub>2</sub> Capture**

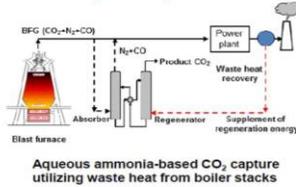
CO<sub>2</sub> capture is the term of technologies aimed at capturing carbon dioxide emitted from industrial and energy-related sources before it enters the atmosphere



- **Type of CO<sub>2</sub> Capture**

<b>Absorption</b>	<ul style="list-style-type: none"> <li>• Amine, ammonia, ...</li> <li>• Technically mature</li> </ul>
<b>Adsorption</b>	<ul style="list-style-type: none"> <li>• Pressure/Temp swing</li> <li>• Limited application</li> </ul>
<b>Membrane</b>	<ul style="list-style-type: none"> <li>• Polymeric, inorganic, ...</li> <li>• R&amp;D at early stage</li> </ul>

### RIST capture process



Aqueous ammonia-based CO<sub>2</sub> capture utilizing waste heat from boiler stacks



CO<sub>2</sub> Capture Pilot Plant (10 t-CO<sub>2</sub>/d) @ POSCO-Pohang Works

**Major Achievements**

- Absorbent regeneration at low temp (~80 °C) utilizing waste heat (~150°C)
- CO<sub>2</sub> capture pilot operation at 90% removal w/ 99.8% purity
- Commercial design (1kt/d) completed

A thermoelectric power generator converts heat into electricity by using the well-known Seebeck effect. This slide describes the laboratory-scale thermoelectric power stack developed at RIST. The power density of this stack is found to be well over 20kW for a cubic metal. A 5kW scale pilot test is underway using the exhaust gas from a furnace in the POSCO steel plant. We expect that this kind of thermoelectric power generation can be utilized as distributed waste in a recycling system.

This slide explains the CO<sub>2</sub> capturing technology RIST is currently developing for POSCO.

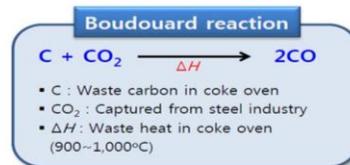
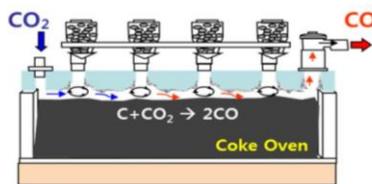
Among many possible technologies, absorption is regarded as the most technologically mature and economically feasible. We are developing aqueous ammonia-based CO<sub>2</sub> capturing technology. This technology has an advantage in using energy because this absorbent regeneration temperature is as low as about 80°C. Therefore, the regeneration energy can be provided from low-temperature resources of 150°C. We have built a pilot plant in POSCO's Pohang plant and successfully tested it with a production capacity of 10 tons of CO<sub>2</sub> per day.

Now I would like to introduce a unique technology utilizing CO<sub>2</sub> to produce a valuable substance, carbon monoxide, a reducing agent in this case. This technology is very specific to the steel industry and is considered to be the world's first CO<sub>2</sub> utilization technology of its kind. In this technology, when CO<sub>2</sub> is injected into a coke oven during the coke-making process, it is converted into carbon monoxide by reacting with carbon that is deposited in the coke oven wall. By injecting CO<sub>2</sub> gases into the coking chamber, carbon monoxide can be produced through the well-known Boudouard reaction. We are currently building pilot facilities at POSCO's Pohang plant and expecting that carbon monoxide in the coke oven gas will be amplified by 10%.

## CO<sub>2</sub> Utilization : Conversion into CO

- CO<sub>2</sub> conversion using coke oven: steel-industry specific CO<sub>2</sub> utilization tech.

CO<sub>2</sub> utilization means the conversion of CO<sub>2</sub> into CO, fuel, other valuable chemicals. We develop the conversion technology of CO<sub>2</sub> into CO via Boudouard reaction utilizing waste carbon and heat in the coke-making process.



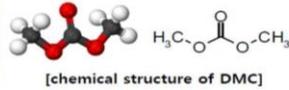
**Major Achievements**

- CO<sub>2</sub> conversion to CO: ~65%
- COG (Coke Oven Gas) production amplification: 10%
- Pilot testing at POSCO: optimization & long-term operation

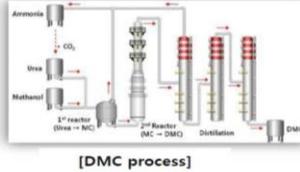
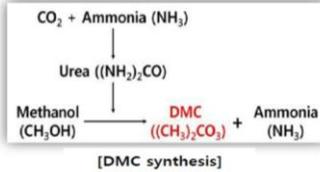
# CO<sub>2</sub> utilization : DMC Synthesis

## • DMC(dimethyl carbonate)

DMC is used for  
 - Raw material for engineering plastic (Polycarbonate): 1 Mt/yr  
 - Potential fuel additive for MTBE substitute : 7~8 Mt/yr



### RIST DMC process

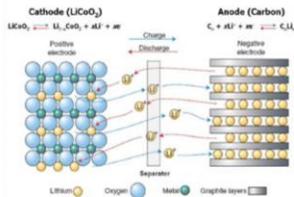


- Major Achievements**
- Lab ('11~'12): feasibility study for a new catalytic synthesis system
  - Pilot ('12.7~present): pilot-scale (30 ton/yr) operation and process optimization
    - Continuous operation: 600 hrs
    - DMC Yield: 85%, Purity: 99.9%
  - Chemical utilization of CO<sub>2</sub> : 0.5 t-CO<sub>2</sub>/t-DMC

# Energy Storage : Lithium-ion Battery

## • Lithium-ion battery (LIB)

LIB is a rechargeable battery based on Li intercalation reaction. It has much higher energy density and longer life cycle compared to the conventional Pb or Ni batteries. LIB will be used for next generation EV and/or mobile devices



<Schematic reaction diagram of LIB>

### • Cathode development



- Major Achievements**
- High capacity & high stability cathode materials (Ni-rich Gradient NMC)
  - Enhanced the life cycle of cathode materials through coating method

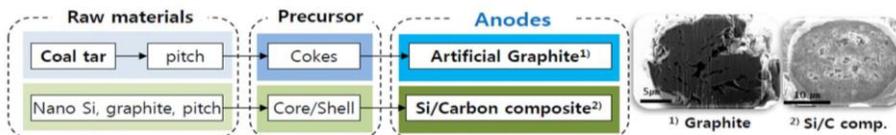
This slide shows another example of utilizing carbon dioxide to produce valuable chemical compounds, dimethyl carbonate (DMC), in this case. In our process, urea and methanol are combined to produce DMC, where urea is produced by the reaction between carbon dioxide and ammonia. We have developed necessary technology, such as the catalyst and reactor design. In the pilot plant, with 30-ton-per-year capacity, continuous operation has been achieved with 85% DMC yield and 99.9% purity.

A lithium-ion battery is a rechargeable battery, which is a so-called secondary cell based on

a lithium intercalation reaction. It is known to have much higher energy density and a longer life cycle compared to the conventional Pb or nickel batteries. RIST is currently developing a wide range of materials necessary for a Li-ion battery comprising various cathode and anode materials. This slide introduces two examples of cathode materials containing key elements such as Li, Ni, Mn, and Co. Quite recently, we have developed a unique cathode material showing higher capacity and more stable characteristics than existing materials. Its unique feature is a Ni-rich gradient layer in nickel manganese cobalt oxide (NMC) type materials.

This slide shows another example of our development, an anode material. We are developing artificial graphite anodic materials utilizing the coal tar from steel plants as a byproduct, which exhibit high capacity and long life cycle compared to other graphite-based materials. Silicon carbon composite is considered to be a candidate for advanced anodic materials as well. Due to the coal and share structure it has, we expect to control the volume expansion of silicon to enhance the cyclic life of the materials. We are also working on this material.

● **Anode development**



**Major Achievements**

- High capacity and cyclic life of artificial graphite anode
- Si-carbon composite anode with higher capacity than natural/artificial graphite

● **Performance comparison of developed materials**

<Posco Gradient-NMC vs conventional NCA>

Cathode Mat'ls	Discharge capacity (0.1C)	Cap. retention @ 50 cycles
PG-NMC (Ni 80%)	209 mAh/g	98 %
NCA (Ni 80%)	194 mAh/g	95.8 %

Higher performance than conventional one

<Artificial graphite vs commercial one>

Anode Mat'ls	Discharge capacity (0.1C)	Efficiency(%)
Developed	357 mAh/g	92 %
Commercial	355 mAh/g	94 %

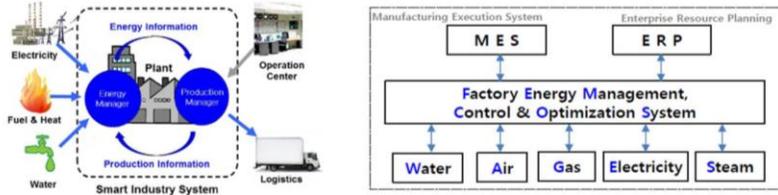
Similar performance with lower price

# Smart Industry

- **Smart industry**

System-wide energy efficiency improvement by optimizing energy and production process with sensor network and IT system based on the smart grid methodology

- **Technology progress of Smart Industry**



**Major Achievements**

- **Demo stage research and application**
  - New concepts establishment for the industrial system(POSCO)
  - Energy demand prediction & efficiency evaluation of energy facilities
  - Application of energy saving solutions
  - Achievement of 2 million \$/year energy cost reduction

We have developed a system-wide improvement method of energy efficiency focusing more on industrial plants or building complexes called “smart industry.” In developing this concept, we adopted the smart grid methodology established for a nationwide power grid. As you know well, a smart grid or smart industry incorporates every possible primary and secondary energy source, energy storage, and saving device. The role of a smart grid or smart industry is to integrate all of these options with a network of sensors and IT technology. By doing so, the energy efficiency is optimized. RIST has established a new smart industry concept for industrial processes and demonstrated the technology as an option in steel work plants.

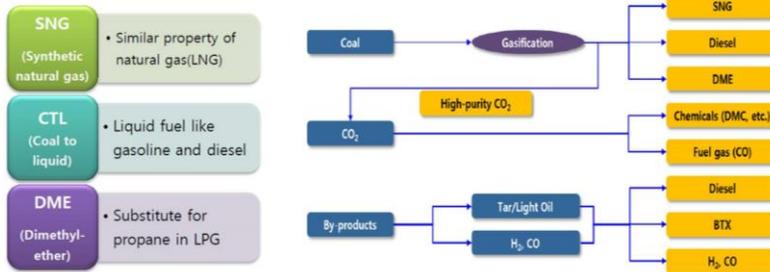
# Clean Coal Technology

- Coal to Fuel and Chemicals

Coal to SNG(Synthetic Natural Gas), Diesel & DME  
 CO<sub>2</sub> to Chemicals and Fuel Gas  
 Steel By-products (Tar, Light Oil, By-product Gases) to Diesel & Chemicals



- Type of Coal to Fuel / Chemicals



Coal is considered to be the most abundant energy resource on earth. Therefore, it is very important to utilize coal as cleanly as possible for a more sustainable future. As shown in this slide, there are many clean coal technologies in various kinds of coal conversion methods such as coal to synthetic natural gas (SNG), coal to various petroleum liquids and chemicals, and even the utilization of coking coal as a byproduct from the steel plant.

POSCO is now constructing the first SNG plant in Korea, which is in the final stage of installation. The plant is located close to POSCO's Gwangyang steel plant and plans to produce 500,000 ton of SNG synthesis natural gas annually. In relation to the commercial operation of the SNG plant, RIST has been developing new technologies such as high-performance catalyst and reactors.

Now I would like to move to our R&D activities for environmental protection. We have been focusing on the improvement of air and water qualities. The main air pollutants from the steel work are particulates, NOx, Sox, and odors, not to mention CO<sub>2</sub>. Quite recently, we have developed and successfully demonstrated an odor treating technology by removing hydrogen sulfide with an oxidizing agent. We plan to extend our R&D to the treatment of five particulates, which is becoming a more serious issue in the industrial sector.

Water recycling has always been an important environmental issue in the industry, just like other industrial sectors. Recently, we have developed a desalination technology with improved energy saving and a higher recovery rate. This technology has been applied to the commercial seawater desalination plant constructed near Gwangyang steel works. Another successful R&D application is a nitric-acid-free pickling process for stainless steel. We have developed a new pickling solution containing no nitro acid to make zero emissions of nitrogen compounds into the air and waste water.

## Environment : By-product Reuse

- Slag from steel industry

Slag is a by-product from blast furnace and steel-making process.  
It is composed of silicon/calcium/aluminum and other metal oxides.

- Type of Slag and Its Application



A typical blast furnace converts around 62 to 65% of the charging materials into iron, and the remaining 35 to 40% becomes a byproduct, so-called slag, made of complex metal oxides compounds. Considering POSCO's steel production in a year, it also produces an enormous amount of slag every year. In this slide, the typical applications of various slags from the steel plant are shown: cement, road base, artificial fish-reef, silicate fertilizer, and so on.

We have developed a new type of cement, called PosMent, containing an increased amount of slag powder and showing the same quality. The ordinary slag cement in Korea contains 40% slag powder, but PosMent contains up to 70% slag powder. In 2013, 530kT of PosMent was used in Korea for various applications. Another example of slag utilization is for the improvement of marine ecology, such as the concept of a sea forest. The slag-based artificial fishing reefs developed by RIST have been acknowledged by the Korean government.

The fuel cell is a device that produces electricity using the electro-chemical reaction of fuel gases. Among various kinds of fuel cells, RIST has been focusing on developing high-performance solid oxide fuel cells (SOFCs) since 2001. Due to more than 10 years of R&D, RIST has accumulated the SOFC technology capability up to building cell stacks, not to mention cell units and their components. So far, RIST has achieved the world's top-class cell unit, whose size is 1,100cm<sup>2</sup> and power density is 0.44W/cm<sup>2</sup>. A stack made of this cell unit is found to generate over certain kW and its electrical efficiency turned out to be well over 50%. Right now, we are building a 10kW demonstration SOFC system for a building application, and we intend to commercialize the SOFC system as early as possible.

Now let me conclude my presentation. I really appreciate your kind attention. Thank you very much.



## **Session 3: Roles and Perspectives of Public Research Institutions**



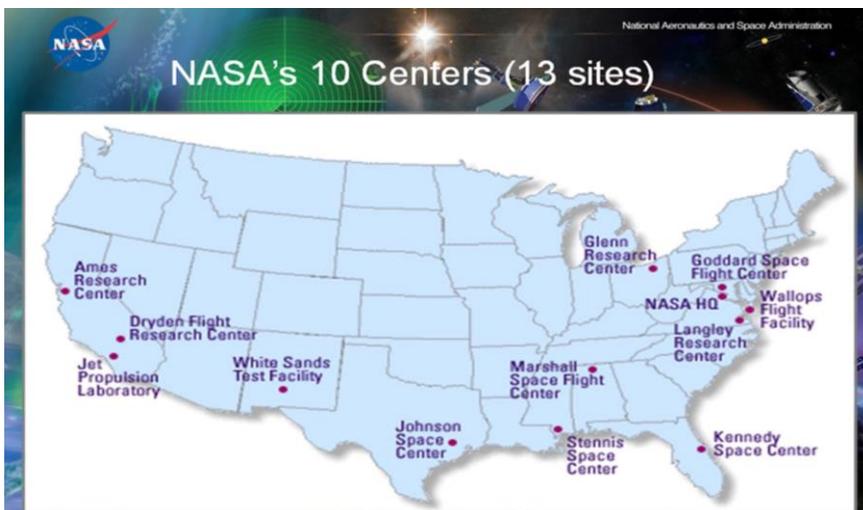
## Missions of NASA Ames Research Center

**David Korsmeyer, Director of Engineering, NASA Ames Research Center, USA**

Thank you, Dr. Im. It was a great pleasure for you to invite NASA Ames. I cannot tell you what a pleasure it is to be here and to enjoy the interesting talks so far. I have been asked to talk about the roles and perspectives of public research institutions and how that works. I would like to give you a little bit of background about NASA Ames, its history, innovation, and its most current interesting missions.

First, I want to introduce NASA, which is the National Aeronautics and Space Administration. NASA actually has 10 different NASA centers at 30 sites throughout the United States. The NASA Ames research center is on the West Coast of the United States. Many of you are familiar with the Johnson Space Center, where the main mission is controlled, and Kennedy Space Center, where the launch vehicles blast off into space, and, of course, NASA Headquarters, which has all the money.

NASA Ames research center is actually part of the original NASA, which was the National Advisory Council or National Advisory Committee for Aeronautics (NACA) that was created back in 1915. So, NASA itself is coming up on its 100 anniversary. NASA Ames is actually the second-oldest NASA center, which was founded in 1939. So, we are 75 years old this year, and we are enjoying a great anniversary. NASA itself was founded in 1958 after the Sputnik launch and with the invention of advanced rocketry, and its mission has been to explore aeronautics and space for the United States government.





## NASA Ames Today



• **2480 employees\***  
 • **≈\$900M+ of yearly revenue**  
 (including reimbursable)  
 \*in addition, 900 students, summer 2014

- **Science**
  - Space, Earth, Biological Sciences
  - Astrobiology, Lunar Science
- **Affordable Small Spacecraft**
  - Lunar Missions
  - Nanosatellites
- **Exploration Systems**
  - Exploration Technology Development
  - Entry System Technology
  - Supercomputing
- **Aeronautics & Aviation**
  - NextGen Airspace Systems
  - Fundamental Aeronautics
  - Aviation Safety
  - Green Aviation
- **Innovation, Education, & Entrepreneurial Collaborations**
  - NASA Research Park

You can see a picture overview of NASA Ames here. It is actually one of the smaller NASA centers, but it is still quite a large institution with 2,500 employees and almost a \$900-million budget every year. We also have a very large student population that comes every summer. There are about 900 students. Prof. Im has provided several tens of students to us over the past years. Our field of expertise is very broad, and I found that synergy between various disciplines has made NASA Ames an excellent place to work and made our innovations quite unique for NASA. We focus on particular areas of the sciences, space and earth science, and the biological sciences. So, even though you think of NASA as a big hardware and engineering organization, we are getting into very small and biological engineering systems, which I will talk about a little bit. We are also doing some very innovative small spacecraft. I will discuss several of those missions later on in my presentation. And we have a very large exploration technology area focused on advanced materials for thermal protection, nanotechnology, supercomputing, intelligent, and artificial intelligence (AI) systems. In our aeronautics and aviation, we focus mostly on the next-generation aerospace and air traffic management for the United States. We have well over 4,500 flights in the US every day, and managing all those flights safely is part of our purview. One of the other issues we are most focused on for the NASA center is on collaborating with education, international partners, and entrepreneurial companies.

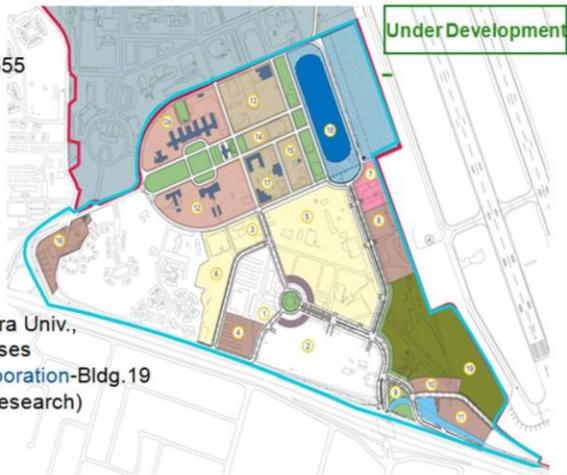


## NASA Research Park

Innovative Collaboration in Science, Engineering & Education

### 90+ Partners Today

- University Associates
- Google-North East Section
- University of California/UARC-Bldg. 555
- M2MI Corporation-Bldg.19
- Carnegie Mellon University-Bldg. 23
- San Jose State University
- Metropolitan Technology Center in Bldg. 583C
- Foothill-De Anza Community College
- United Negro College Fund Special Programs Corporation-Bldg.19
- Space Technology Center
- San Jose State, Stanford, Santa Clara Univ., Utah State Univ. /Micro Satellite Classes
- Kentucky Science & Technology Corporation-Bldg.19
- Bloom Energy-Bldg. 543 (Fuel Cell Research)
- Industry Partners-Bldg. 566 & 19
- UAV Center-Bldg.18
- International Space University
- Singularity University



A good example of that is that NASA Ames has a 70-acre research park that is right off the main portion of our campus here to the top of the page. We have over 90 different small university, academic, and industrial partners in our University Research Park. This allows tremendous vibrant innovation. Many of these are actually associated with startups that have come out of NASA employees taking their intellectual ideas, going out, and forming a startup in Silicon Valley and then finding a way to commercialize their technologies.

Some of the unique capabilities that NASA brings to the US federal institutions are a lot of our facilities. These are facilities that cannot be found anywhere else in the world. We have the world's largest wind tunnel with an 80-ft × 120-ft cross-section so large that you can put a full-size aircraft inside and test it up to 250 mph. We have the full-motion six-story-tall vertical motion simulator, which allows us to test everything from lunar landing systems and aircraft to harbor test facilities. We have a developmental system for small spacecraft and many other systems including our onsite machines and manufacturing facilities for the very unique system we build.

One of the key areas that we found that keeps us most innovative is adopting new technologies and new approaches to collaboration that have come along with the change and increase of information technology. NASA Ames hosts three virtual research institutes, but people in the institute do not actually live or work at NASA Ames. Instead, we manage the

central location and provide the IT infrastructure for several institutes that are virtually connected across the globe and complete with various universities' participation both in the US and internationally. We found this to be a tremendously valued and valuable model of getting large-scale collaboration between researchers and communities that are otherwise very far apart, and it helped to minimize a lot of the travel cost.

In particular, NASA Ames, in our 75 years of innovation, we found that no idea is a bad idea. Innovation for innovation actually has turned out to be an incredibly valuable activity for a federal research institutions to focus on. Back in the 1950s before NASA was formerly NACA, which was still the Advisory Committee for Aeronautics, we discovered what was called the blunt body concept, which is why the reentry vehicle that NASA and the other governments of the world use is actually a small squat flat system. Based on the aeronautics and compression heating, it turns out to be the best shape to allow us to reenter safely into the atmosphere. It was developed in several papers in the 1950s but was not implemented well until the 60s. Similarly, we focused on novel technologies leading to tiltroters and tiltcraft, as well as very high altitude planes sampling the atmosphere. We have a proud history of a number of missions back in the 70s. We were the center in charge of the pioneering 10 or 11 missions. When we moved into the 80s, we became the center of excellence and high-end computing information systems and human-centered technologies. Then, later in the 2000s, we started a series of small satellite programs that I am going to describe to you here in a few minutes.

At NASA Ames, we have several family missions. That is going to be the remainder of the focus for my talk today. We have large astronomy missions. One is SOFIA, which is with the German space agency (Deutschen Zentrums für Luft- und Raumfahrt; DLR), which provides a large telescope on the back of a 747. The second is the Kepler mission, which was a planet-finding mission.

Kepler was launched in 2009. It was one of the last great observatories that NASA put together. It stared at 145,000 fixed stars for four years, and over the course of four years, it found 3,500 planetary candidates. Before Kepler, there were only 10 confirmed planets outside of the solar system. Now, after four years, looking at basically a post stamp size of the sky, we found another 3,500 planetary candidates. Each candidate has been validated by another astronomical observatory. If you take these results and propagate that across the whole of our Milky Way Galaxy, there are well over 100,000 earth-size planets in a habitable zone in our galaxy alone. This has huge implications for humanity: what it means to be only one planet in a very large neighborhood of systems.

SOFIA is another novel interesting technology. As I mentioned, it was developed with the German space agency that provided an infrared telescope. One of the interesting things about manufacturing and mechanical engineering with NASA is that we tend not to do the

same thing twice. We are certainly not doing production manufacturing or production systems. No one prior to us cut a hole in the back of a 747 and installed a large door that you open at altitude of 4,000 feet and stuck the telescope out, but we did. And it was tremendous engineering effort in conjunction with the DLR. This aircraft has become operational and made a flight all around the world to get very interesting observations of infrared space technology or space astronomy.

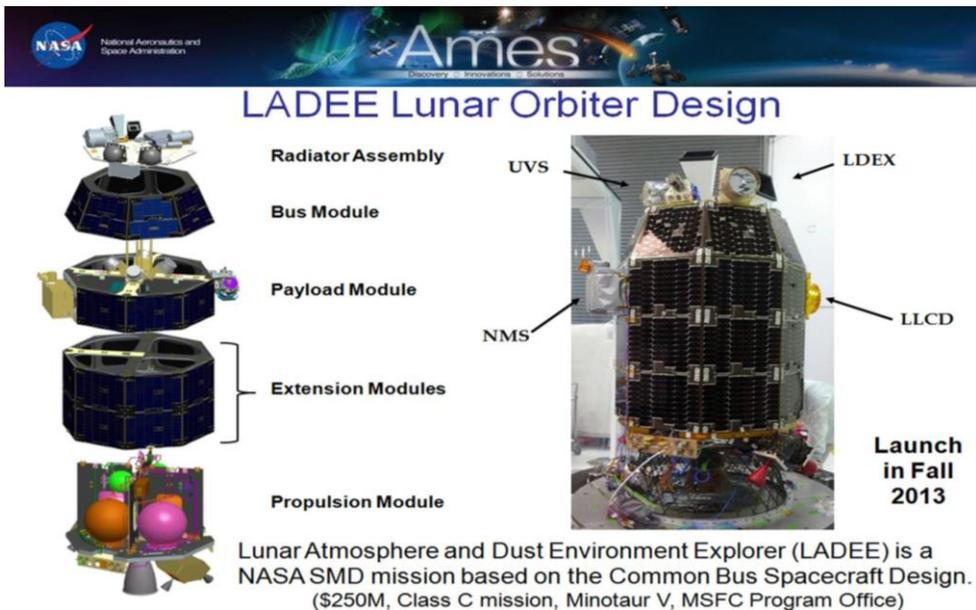
The second area that NASA Ames has been focusing on for the past 10 years or so is small spacecrafts, which are less than 500 kg or under \$250 million. I understand that sounds like a lot, but if you have seen many of the spacecrafts we have launched, it is as large as the whole platform I am standing on right now, and the budget was a billion to two billion dollars. So, when I am talking about 500 kg and \$250 million, by NASA's terminology, that is small. One of the things we have been able to focus on at Ames is a series of lunar missions. Back in 2007, we were awarded a mission called LCROSS that went to the moon and impacted on the Saturn Craters. We just finished the mission called LADEE, and we are working on a resource prospector mission. We have a series of other missions that are mostly earth orbiters using a small satellite system.

LCROSS, as I said, was actually a lunar impactor that was launched using the remainder pieces of another NASA mission. This launch vehicle actually was purchased to launch a single satellite called the Lunar Reconnaissance Orbiter around the moon, and NASA Ames proposed an alternate to throwing away or disposing of the remaining components of the rocket. Instead, we instrumented the upper stage and created another small spacecraft called the Shepherding Satellite, where we took the large upper stage of the rocket after it has been used to boost the Lunar Reconnaissance Orbiter to the moon. We retargeted it to land on the south pole of the moon on a permanently shadowed crater that impacted at about 4 km/sec through several tons of lunar soil. We were able to validate that there are significant volatiles, i.e., water ice, carbon dioxide ice, nitrogen, and even sulfur compounds trapped in the shadow crater of the lunar surface. This was a real innovative find because, up to that date, many had assumed that the moon was a really dry place. It turned out that it is not so true after all.

Just this past summer, we launched another mission called the Interface Region Imaging Spectrograph, which is a small satellite that stares at the chromospheres of the sun. There is an interesting region where the temperature goes from several tens of thousands of degrees up to several tens of millions of degrees centigrade over the course of 10,000 miles. We do not understand why that physics occurs. We do not understand the means of the mechanisms that make this happen. But it is the whole reason for doing research and understanding this. And building the system has to do a lot with the magnetic fluxes in the plasma reactions of the solar atmosphere. This mission was launched in June of 2013 on the Pegasus spacecraft.

Most recently, we developed the LADEE lunar orbiter system. One of the most novel things about the LADEE lunar orbiter is that we developed the first modular design that allowed us to take several different preforms to find structural components and functional components and put them together in different modular fashions. You can see this is what we call a four-stack. There are four layers. The LADEE system uses what we call the Ames Common Bus Spacecraft Design, which is a fully composite spacecraft design. This is the first fully composite spacecraft that NASA has ever flown, and it worked tremendously well. Its job was basically to explore the dust and atmospheric environment of the moon.

In particular, we were trying to understand how the lunar dust responded to the sun and how the dust was thrown up into a very high, what we called an exosphere, every time the day-night terminator moved across the surface of the moon. It was launched on September 6<sup>th</sup>, 2013. It had eight months of operational work in orbit around the moon prior to impacting on the far side. We did that deliberately as we were flying only 15 km above the moon. We were very close. At the very end, we got down to 5 km above the moon and actually impacted a mountain that happened to be 6 km tall.



The image shows the LADEE Lunar Orbiter Design. On the left is a 3D exploded view of the spacecraft, showing five main sections: Radiator Assembly, Bus Module, Payload Module, Extension Modules (indicated by a bracket), and Propulsion Module. On the right is a photograph of the assembled spacecraft with labels: UVS, LDEX, NMS, and LLCD. Below the photograph, it says "Launch in Fall 2013". At the top of the slide is the NASA logo and the Ames Research Center logo with the tagline "Discovery Innovation Inspiration".

**LADEE Lunar Orbiter Design**

Radiator Assembly  
 Bus Module  
 Payload Module  
 Extension Modules  
 Propulsion Module

UVS  
 LDEX  
 NMS  
 LLCD

Launch in Fall 2013

Lunar Atmosphere and Dust Environment Explorer (LADEE) is a NASA SMD mission based on the Common Bus Spacecraft Design. (\$250M, Class C mission, Minotaur V, MSFC Program Office)



## Ames Common Spacecraft Bus – Modular Approach



The Ames’s common spacecraft bus is a modular component system where each of these is structurally independent but can be coupled together. We actually developed a lander concept first in 2007, and when we proposed that to NASA for a mission, they actually came back and said, “No. We would rather you do a lunar orbiter.” We actually did a three stack, but because we needed larger fuel tanks, we increased to the final four stacks and the LADEE spacecraft began.

NASA National Aeronautics and Space Administration

# Ames

## Resource Prospector (RP) Mission - 2019

**Mission:**

- Characterize the constituents and distribution of water/volatiles in lunar polar surface materials
- Demonstrate ISRU oxygen extraction from lunar regolith

**RPM Flight Project Office (NASA-ARC)**

- ✓ FY13: Pre-Phase A: MCR (Pre-Formulation)
- FY14-15: Phase A (Formulation)
- FY16: Phase B: SRR, PDR (Prelim Design)
- CY19: RPM launch
- \$250M LCCE Cost Cap, HEOMD
- Class D<sub>2</sub> Category 3 (<\$250M)
- LV: Falcon 9 v1.1 class

**RP Mission Design**

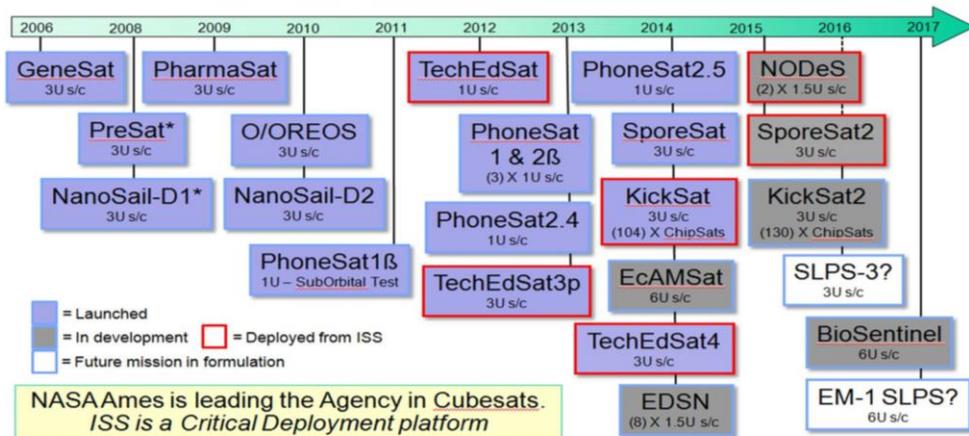
- Nom. Mission Life: 10+ Cycles
- Rover + Payload Mass: ~325 kg
- Lander Dry Mass: ~900 kg
- Lander Dimensions (w/rover): 3.7m x 3.7m x 1m
- Rover Power (nom): ~150 W

The next big mission for us is going to be a mission called the Resource Prospector. In 2009, building on the information with the LCROSS impact on the south pole of the moon, we discovered all that water. Now we want to figure it out what we can do with it, how we can extract it, whether we can get it into a pure form to be valued for NASA or other agencies for future exploration. The role of this is to land a small rover on the south pole of the moon near a permanently shadowed crater and traverse to where we would know there would be some cold traps which would largely hold the water ice. Then, we get an auger here, drill in and bring up the material, validate its makeup with the new transpectrometer, bring it into an internal oven on the rover, and bake out oxygen from the lunar regolith, distill out any water or water ices, and get down to a pure form of water to validate that we can make use of this in the future. This mission has recently been approved.

I am going to talk next about a form factor for satellites, nanosat. These are not small cells to explore living systems in the body. However, these are what we call nano, meaning very small satellites. We use them in terms of units, so one unit of nanosatellite is  $10 \times 10 \times 10 \text{ cm}^3$  for about a 4-inch cube. A 3U system is  $30 \times 10 \times 10 \text{ cm}^3$ . We are flying up to 6U systems. These are very small, and with the fixed interface, we found that these canisterized satellites are very innovative because we can use them in the interstitial pieces of launch vehicles that are deploying other large satellites. So with the leftover room that exists in every launch vehicle that NASA sends up into space when launching a large satellite, we can fit many tens of these nanosats. In December of 2013, we launched a single large satellite and 28 nanosats. Then, in December, a month later, we actually launched a single satellite and 39 nanosats. So there is a tremendous multiplier effect that can be used by leveraging up of this form factor for small spacecrafts.



## Ames Nanosat Missions



It turns out the NASA Ames leads NASA within our space agency for making use of these. We first started flying nanosatellite back in 2006, where we were actually doing gene expression or space biology missions. It turns out that one of the tricky activities for us is developing micro fluidic systems that are working in zero G. As we were trying to do so with cell growth in mediums and also doing ceromotograph and spector analysis of the cell growth over a long period of time in space, we developed a series of missions. Recently in 2012, we started deploying this international space station as another potential means to get them into the space.

We have three themes that we use on our nanosats to investigate, in particular, testing, life, and space, which are validating and enhancing the already existing international space station biological testing. We have a number of satellite systems that have been deployed. O/OREOS was actually deployed in 2010. It has been 4.5 years, and it is still operating today. We have a number of systems, EcAMSat and BioSentinel, that are going up into space next year. And then in 2018, the second version of the system called SporeSat, which is a 3U system, will be deployed off the space station in the fall of 2015. One of the most interesting ones we are doing is exploring deep space by using this form factor.

So, the next large mission NASA is doing is launching its space launch system, which will take the manned system vehicles into orbit. As I said, there is always extra room and volume on a launch vehicle, and we have actually arranged to deploy one of twelve small nanosats off the first SLS launch. The one that NASA Ames is going to develop is called Biosentinel. We are actually sending up each to grow over an 18 months period to validate how it behaves in zero G and with a high radiation environment. So, we want to see how things



behave outside of the safe, protective environment of the earth.

One of the other themes we are working on for nanosatellites is looking at how to bring down small NASA from the international space station, including biological payload, medical issues, and small crystals that are growing up in the station. We have been exploring, in cooperation with the Japan Aerospace Exploration Agency (JAXA), deploying small CubeSat off of the international space station. We were the first US CubeSat, right after the first JAXA's spacecraft, to be deployed in 2012. Subsequently, we have a small family of satellites, called TechEdSat, that are understanding how we can use all these form factors to bring systems down to the earth. We are actually deploying a cell called Exobrake, which is a large cell that helps slow down the vehicle so it can land at a particular point on the earth.

Here is a great picture of one of my favorites. It shows the TechEdSat that was launched in 2012. It passes in front of one of the space station solar panels. So, again if you want to talk about the value of mechanical engineering, someone had to design these solar panels, which are one quarter of a soccer field in size and are on the international space station and in orbit. Similarly, we were able to engineer a very small, very inexpensive, and very cheap nanosat that could also make use of the international space station. We deployed these as well.

The third area that we are exploring is COTS, which are consumer-grade commercial off-the-shelf technologies. One of the quick demonstrations we did was looking at Nexus S phones. We wanted to validate whether or not the commercial consumer-grade avionics or electronics could be used for the spacecraft system in a productive fashion. So, we built a

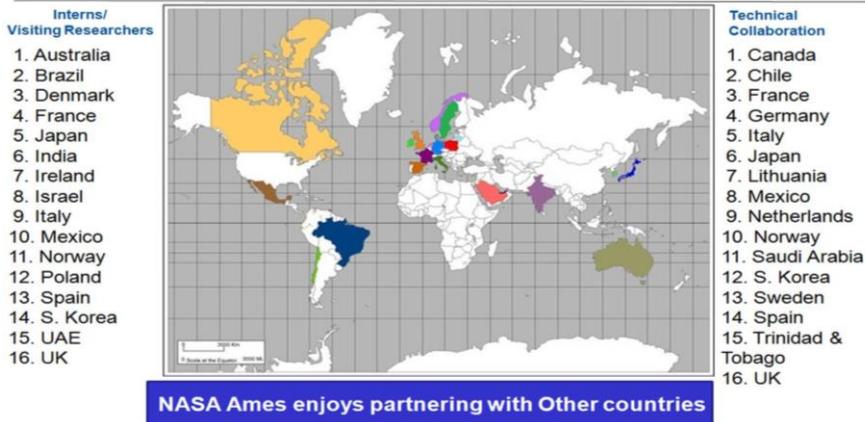
very small PhoneSat right here. We developed them over a year and got them deployed and then built several iterations based on that. This validated to us that in some specific areas consumer-grade technologies, which are very inexpensive but very high reliability and manufactured at high mass or high numbers, are very useful for small-scale space missions such that we developed a series of multiple satellite missions called Swarms that we are going to use that technology on.

The first system is called EDSN, and it is going to be launched in January of 2015. We just held our final review on it yesterday and validated it to be on a flight already. This is going to be the first true Swarm in space of eight satellites. By that, instead of the ground talking to all eight spacecrafts individually and giving the command to control necessary to make them do what we need to have them do, they are going to talk to one satellite and that one satellite will talk to the others and then that one satellite will collect all the data and beam it to the ground. We call that the captain satellite. This captain will rotate amongst all the different satellites. So, we have shown a dynamic adaptive Swarm system for spacecraft that is very novel and unique.





## International Partnerships



This is a perfect example of very small-scale manufacturing that NASA Ames does: building up all the components and then doing a very small but intense assembly of a total of 14 of these systems. You can see 12 of them are here, 8 in the foreground and 4 of the background, all at the same time, all duplicate, and all highly integrated, and most of the materials and systems were manufactured specially at NASA Ames.

With that, I want to tell you a little bit of about the other and last piece of innovation that NASA Ames is proud of, which is working, in particular, with international partners. We have more. There are actually 16 here, but I found out recently that we have 4 more mistakenly not listed. International visiting researchers that come and work at NASA Ames for a year or more are proven to be highly productive and a highly valuable partnership. In addition, we have now started a technical collaboration on future space missions. Similarly, with a number of different countries, sometimes they are the same, but sometimes they are different. We have, for example, many Brazilian researchers visiting us, but we don't have any official Brazil missions in the work. You can see that South Korea is proud of entering both of these lists. We are very proud to be partnering with South Korea and KARI, KIMM, KAIST, and many other organizations. We are looking for more opportunities to do that.

So, to summarize, NASA Ames is one of the oldest NASA centers at 75 years old. However, we have a pleasure and benefit of being one of the more innovative NASA centers. Our mission is to be a research center to push the forefront of technology and engineering utilization. NASA Ames also is the focus within NASA for partnering international organizations in space.

I thank you very much for your attention.

# Challenges and Innovation of KIMM

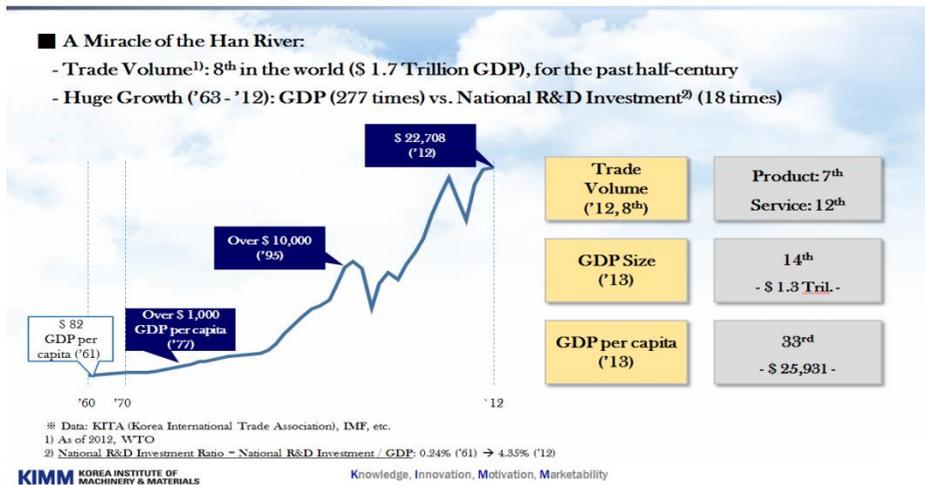
**Yong-Taek Im, President, Korea Institution of Machinery and Materials, Daejeon, Korea**

Good afternoon, ladies and gentlemen. I am sure you have been hearing wonderful talks in various fields of mechanical engineering from the morning until now. What I am going to share with you today is a general overview on the challenges and innovation of my research institute, Korea Institute of Machinery and Materials (KIMM).

As you can see here, the trade volume of Korea increased tremendously since the 1960s. For the last half century, Korea made tremendous economic growth, as shown in this slide, owing to the target-oriented, planned economic policy of late President Park Chung Hee, who really made a blueprint of the national industrialization since 1962. From the naked country, Korea ranked 8<sup>th</sup> in the world in terms of the trade volume in 2012. Many visitors from the world are curious about this so-called “Miracle of the Han River.”

The first big decision of his economic planning team was to build the steel mill at Pohang, POSCO, in 1965. In 1966, late President Park decided to build up the second research institute in Hongneung, the Korea Institute of Science and Technology (KIST), with the help of then President L.B. Johnson of the US, similar to the Batelle Research Institute in Columbus, Ohio in the States. In 1971, the graduate school of the Korea Advanced Institute of Science (now the Korea Advanced Institute of Science and Technology) was launched in Hongneung next to KIST to produce research scientists and engineers for revamping Korean industry. The whole series of investment plans was very daunting at that time because the gross national income per capita in the 1960s was about \$62.

## Economic Growth of Korea:



Right now, the GDP per capita of Korea is around \$24,000. Thus, we made tremendous progress through this industrialization plan.

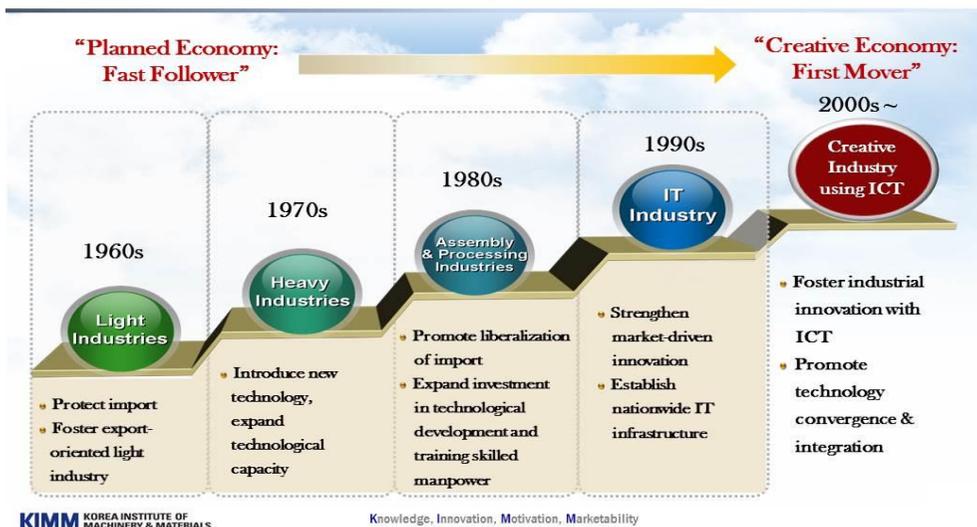
Although the economic growth was eye-catching for the last three decades, its rate slowed down since 1997, when the financial crisis occurred in the United States. In order to cope with such an economic problem, the current government is trying to change the science & technology development plan from “the fast follower” to “the first mover” model under the theme of a creative economy plan by fostering industrial innovation with the use of information and communication technology (ICT) and promoting technology convergence and integration.

## Evolutions of Korean Industries:



Share of General Machinery & Equipment: (1999) 5.5% → (2012) 6.8%

## National S&T Development Plan:



How could we still boost up the growth rate and get it back on the right track? You can see that, during the last couple of decades, public research institutes are getting smaller and smaller compared to the size of the private research institutes in Korea like Samsung Electronics and POSCO. Now, almost everybody, including some of you, is using Samsung Electronics cellular phones, I guess. I think that is where we are. In terms of national R&D investment, it is almost \$55 billion in total in 2012. Out of \$55 billion, the public R&D budget is only around \$14 million and the private R&D budget is \$36 billion, resulting in most of the innovations in the private sector.

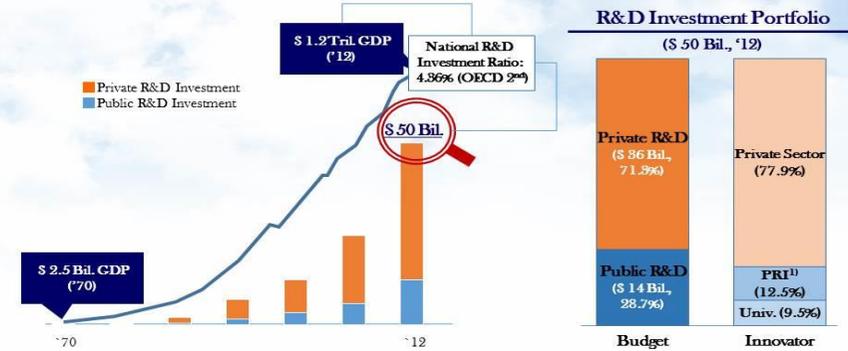
In terms of R&D human resources, however, 401,724 research scientists and engineers were working for R&D in 2012, which is around a 130-fold increase from 3,072 compared to 1963. Most Ph.Ds and MSs are still working either in the universities or the public research institutes. Thus, missions and goals of the public research institutes should be redefined and redirected in order to boost up the economic growth rate for the country under such a new research environment.

Another big issue is the socio-economic demographic change. Right now, young people do not want to have babies. I think the birth rate of Korea is one of the lowest in the OECD countries. Productive workers in their 30s and 40s are in short supply, increasing the labor cost. We have to think about this problem and overcome it by developing technology like *Industrie 4.0* or IoT, as mentioned by Mr. Klopsch. That is the only way we can survive in this competitive market. As you can also see here, another problem is that some of these young people's parents do not want to send their children to an engineering college anymore. Many parents want to send their brilliant children to law, business, or medical schools. So,

all these people entering law or medical schools are possible top candidates to the colleges, the cream of the crop. The rest are those who we must educate for science and engineering. That is the challenge.

## National R&D Investment:

- Economic growth by industrialization through R&Ds
- New roles and mission of the public research institutes (PRI)



※ National R&D project survey report (KISTEP, 2012), etc.

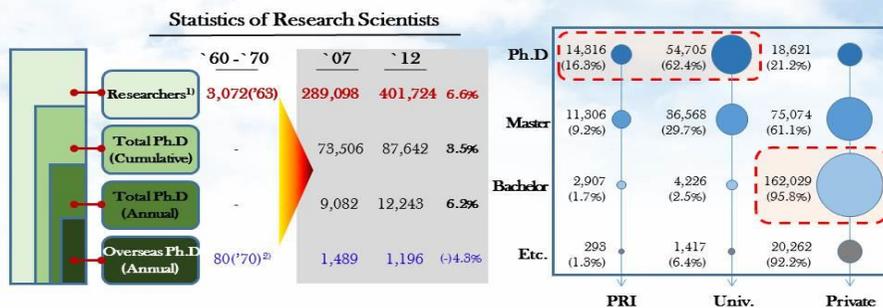
1) PRI: Public Research Institute (PRI), composed of GRI (Government Research Institute) 92% and NRI (National Research Institute) 8%

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## Change of R&D Manpower:

- Over 400,000 research scientists in 2012 (6<sup>th</sup> in the world)
- Around 130 times increase compared to 1963: 3,072 ('63) → 401,724 ('12)



※ Data: NTIS, National R&D project survey report (KISTEP, 2012), etc.

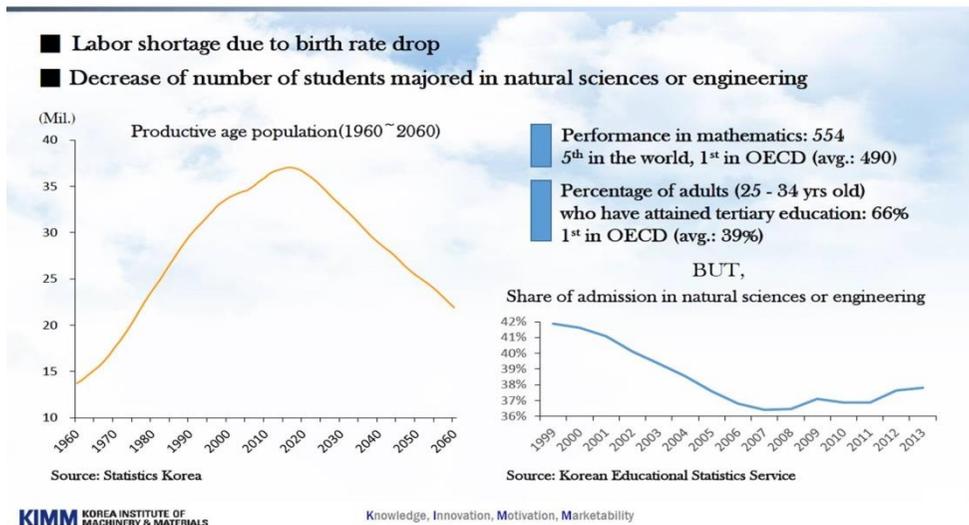
1) Exception: Research assistants (Total researchers: 562,601 persons, including research assistants)

2) Ph.D. from overseas: 29 persons in 1965, 80 persons in 1970

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## Socio-economic Changes:



The Korean government is trying to change the paradigms of public research institutes. They are looking into some of other advanced countries' strategies, e.g., Fraunhofer in Germany and some research institutes of the United States. According to a recent study by the Center for American Progress and Heritage Foundation in 2013, the mission and roles of the government research institutes have shifted to develop a specific capability or meet national interests for defense, public health, energy, and environment, etc. As a result, they have to carry out long-term, complex, and multidisciplinary research for leading national science initiatives that the private sector is unwilling to engage with and universities are often incapable of undertaking.

Thus, the Korean government decided to merge the Korea Research Councils for Fundamental Science & Technology and Industrial Science & Technology into the National Research Council of Science & Technology in July of 2014 under the Ministry of Science, ICT, and Future Planning. This unified research council governs 25 government research institutes whose budget was \$4,428 M and whose employees totaled 16,457.

Then, the biggest challenge is how to compete with the private research institutes or other international research institutes, such as Fraunhofer or NASA Ames, with only a small budget and a handful of human resources, as I mentioned earlier.

Now, I just want to localize my angle to the challenges and innovation of the research institution, KIMM. Here is an overview of KIMM. In 1976, it was established as the Korea Test Institute of Machinery and Metals to contribute to the economic growth of the nation by testing the metals, parts, and products for machinery and materials development. In 1996

# Overview of KIMM:

## History:

- 1976, Founded as the Korea Test Institute of Machinery & Metals
- 1996, Spin-off: KARI (Aerospace)
- 1999, Spin-off: KRISO (Ocean)
- 2007, Subsidiary: KIMS (Materials)

## Personnel & Budget:

- Employee (FT): 344 (Ph.D: 255 (74%), MS: 55 (16%))
- Employee (PT): 230 (Ph.D: 42 (18%), MS: 77 (33%))
- Budget ('14): 149M USD



and 1999, it spun off the Korea Aerospace Research Institute and the Korea Research Institute of Ships & Ocean Engineering, respectively. It still has an affiliated institution, the Korea Institute of Materials Science (KIMS) as a subsidiary.

KIMM's total budget is about \$150 million. The total employees are about 700, of whom half are full-time and the other half are part-time. Ph.D holders take up about 60% and the rest are Bachelors or Masters. We have about 45% government R&D funding and 10% private sector funding. If you compare it with the Fraunhofer model, the private funding should be around 40% in addition to the basic funding from the government. We need to increase the industry funding. However, the problem is that the research power in the private sector is not behind us anymore. That is another challenge we have to struggle with now.

In the beginning of the establishment of KIMM, its mission was trying to help industrialization of Korea domestically. Right now, due to economic growth and globalization of the market, this mission must be changed. As Dr. Friedman mentioned, "The world is flat." We must collaborate in the international domain, as pointed out by Director Korsmeyer. Thus, the new goal of the institution is to become a global research institute in the field of mechanical engineering by introducing a new governance system to foster knowledge, innovation, motivation, and marketability, resulting in improving the research productivity and capability. Because of the shortage of our budget and human resources compared to other private and international institutes, I ask my staff to collaborate intellectually and wisely with partners domestically and internationally. That is what we are trying to do and partly why we are hosting this International Forum today.

Now, I am going to introduce the research divisions at KIMM. We have five research divisions: advanced manufacturing systems, nanoconvergence mechanical systems, environment and energy systems, extreme mechanical systems, and mechanical systems safety engineering.

The advanced manufacturing systems engineering is one of the oldest and strongest research areas at KIMM. In this division, we develop ultra-precision machines and systems, laser & electron beam applications, printed electronics, and robotics and mechatronics. I think this is part of the field where we can work together with the NASA Ames in the near future.

The next one is nanotechnology, where research on nanomanufacturing technology, nanomechanics, and biomimetics are carried out. From 2003 to 2012, KIMM carried out the national frontier project in the nanotechnology area. Thus, the infrastructure to do research on the application of nanotechnology is excellent. The research scientists in this field are also from various disciplines of physics, chemistry and biology, electronics, and materials sciences.

The third area is environment and energy systems engineering. We develop internal combustion engines, including the LPGi engine, and ecofriendly engineering systems, and we run tests and inspections on plant safety engineering and nuclear engineering.

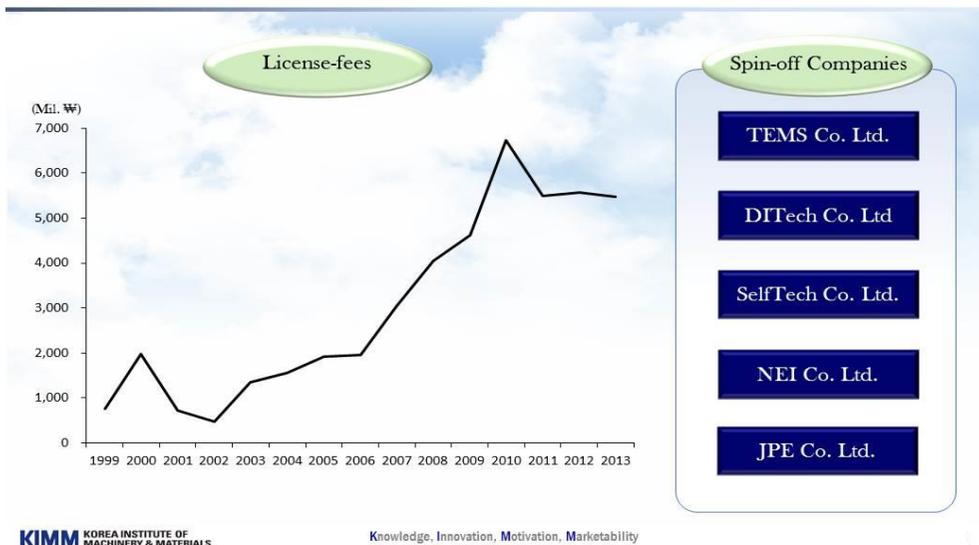
The next one is extreme mechanical systems engineering where we handle extremely low and high pressures or temperatures. We try to develop technologies for extreme environments. What we are trying to do here is to try to develop a recycling coolant pump for nuclear applications and also some other hydraulic pumps including design technologies, etc.

The last one is the mechanical systems safety engineering. We have developed the fundamentals of a magnetic levitation train that was installed at Incheon International Airport. We started this research project 25 years ago and transferred the technology to Hyundai-Rotem. Also, we are developing systems dynamics and working on reliability issues for naval shipbuilding and wind power systems.

We have three regional R&D centers in Daegu, Busan, and Gimhae. In Daegu, we are trying to develop medical devices for disabled people including the elderly. Robotics engineers are working with rehabilitation research scientists and medical doctors in the hospital. In Gimhae, we are trying to develop testing facilities of valves and parts for LNG applications under extreme conditions. In Busan, we recently tried to develop laser technology, engine, and nuclear safety research centers. Busan is close to Changwon and Pohang, where many machinery plants and shipbuilders are located. So, I think the research centers in this area will grow in the near future.

Many people are talking about the importance of the technology transfer from the research institutes to measure the performance of the research capabilities. Now, I am going to introduce this aspect. The total amount of technology transfer is not much in terms of royalties at present, but we are trying to push this further to especially help R&D activities for the small- and medium-sized enterprises and industries. Through this, we are trying to create jobs for young people.

## Technology Transfer:



# Major Accomplishment: EcoBee

## World's 2nd Commercialized Urban Maglev:

- Commercial Service at the Incheon Int'l Airport (6.1km) to be expected soon
- MOU with Gordon Atlantic Co. for the service in the State of Leningrad in Russia



- Eco-friendliness with low noise, low vibration and no pollutants
- No risk of derailment or electromagnetic hazard
- Low maintenance and operation costs

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As I mentioned earlier, we had a major accomplishment in terms of the technology transfer of levitation technology to Hyundai-Rotem, a subsidiary of the Hyundai Motor Group. Now, we are discussing with Indonesia and Russia, especially with St. Petersburg, Russia for the possible installation of this new maglev system (namely, EcoBee, developed by KIMM) in these regions. The city government of St. Petersburg is trying to develop a new commercial and residential area for the World Cup Soccer Games in 2018. They are trying to build up a public transportation system to link the current metropolitan subway system with this new maglev system to provide environment-friendly transportation for the users. Also, in Indonesia, they are trying to build a new airport, where they are trying to install the maglev train for a circular line. Right now, Gordon Company on Wall Street, in this photo, is very much interested in implementing this technology to Montreal in Canada and Austin, Texas in the US as well. We are very hopeful to export this technology in near future.

## Plasma Burner and Reactor (continued):



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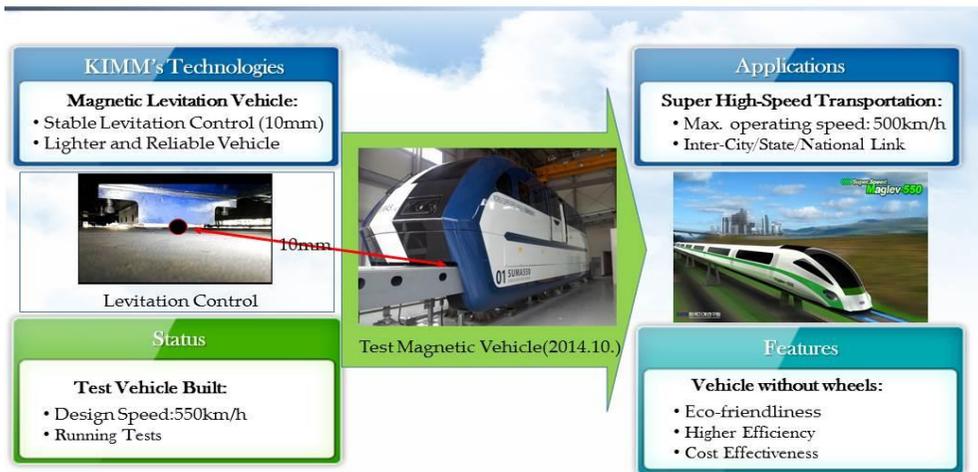
Dr. Young Hoon Song and his colleagues from the Plasma Engineering research team were working with a small spin-off vacuum company, LOT Vacuum. They started working together and developed plasma technology that could burn off toxic pollutants from the semiconductor industry. They transferred the technology to the LOT Vacuum, which is a small-sized company. Then, Lot Vacuum sold a hundred of these plasma reactors to Samsung Electronics. Next year, Samsung Electronics is expanding the second line of the semiconductor factory and its application. This was another great success of technology transfer from the Institution. I am sure there are many such cases of technology transfer. I heard about 140 cases per year were assisted and transferred to small- and medium-sized companies as well as large companies in Korea in various ways. In terms of technology transfer, KIMM is doing reasonably well.

However, I have some challenges to make KIMM better and more global at the current stage. The first thing is how we can change its operating system. I have to find out good solutions for this R&D operation system. I am not sure of the answer at this moment, but we have to improve the R&D environment through revamping the current operation system. Otherwise, it is very difficult to survive in the global research market. The second one is globalization. The reason why I am hosting this International Forum is that I wanted to make some kind of globalization of my research institute and introduce it to the international domain, i.e., introduce what we do and who we are more extensively. That is what I am trying to achieve through this International Forum. We have very good research scientists, most of whom are Korean. Still, I think we have to try to recruit international research scientists. Although I am not sure whether I can do it during my term, it is my goal. It is obvious that we have to work together with international researchers because we cannot solve everything by ourselves,

only to cope with the Ebola virus and bird flu problems, etc. In terms of research productivity, we have almost 6% research output as defined by royalty income divided by the total of R&D budget invested. Fraunhofer has around 7% research productivity. My goal is to make par to 7%.

The next one is about technology innovation that KIMM is undertaking. I would like to talk about EcoBee again. EcoBee runs at 110km/h. Right now, we are trying to develop a rapid levitation train which runs at around 500km/h. Our research teams are also working on medical devices and industrial robots to support small- and medium-sized enterprises. We got around \$100 million in June of 2014 for carrying out a national global frontier project for the next nine years on meta-materials research. Because of the recent discovery of the shale gas and due to national safety reasons, the idea of a floating power plant is interesting to pursue as innovation of a new technology. These are the biggest long-term areas of research thrust of KIMM for the next stage of development in the future.

## Innovation: High-Speed Magnetic Vehicle Technology



# Innovation: Industrial Robot and Medical Devices

**High power density artificial muscle module**

**Low power actuator using elastic mechanism**

**Needle type master robot**

**Ankle-foot prosthesis**

**Personal mobility vehicle**

**KIMM** KOREA INSTITUTE OF MACHINERY & MATERIALS

Knowledge, Innovation, Motivation, Marketability

# Innovation: Meta Materials Research

## National Research Center for Wave Energy Control:

- **Global Frontier Project:**
  - Funded by the Korean Research Foundation (111M US\$)
  - Period: 2014-2022 (9years)
- **Meta Materials System Engineering (MMSE) based on the control of electromagnetic & magneto-hydrodynamic wave energy:**
  - **Convergence with Machinery**  
(MMSE of electromagnetic & magneto-hydrodynamic wave + Machine industry)
  - **Convergence with Information & Communication Technology**  
(MMSE of electromagnetic wave + ICT industry)
  - **Convergence with Energy Technology**  
(MMSE of electromagnetic & magneto-hydrodynamic wave + Renewable energy)
  - **Convergence with Bio/Medical Technology**  
(MMSE of electromagnetic & magneto-hydrodynamic wave + Next-generation bio/medical industry)



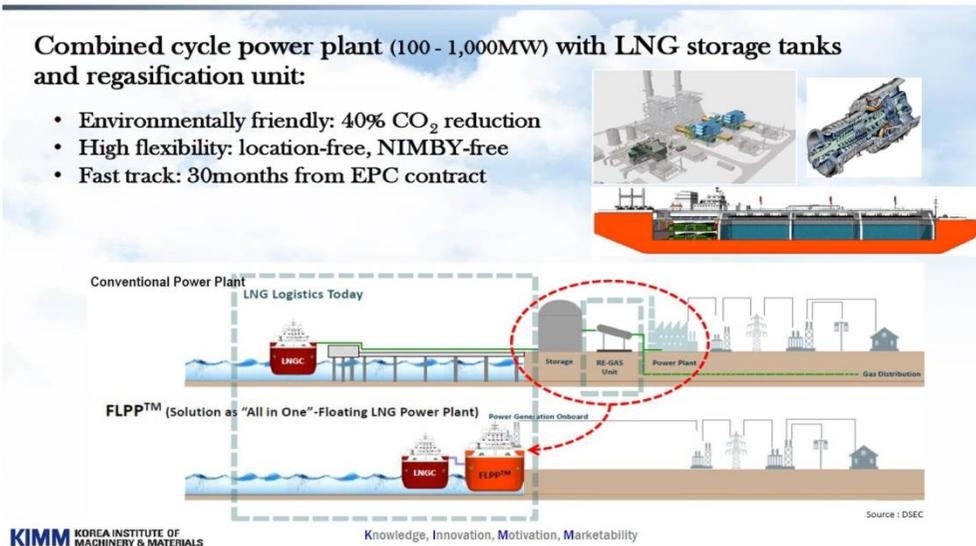
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# Innovation: Floating Power Plant

Combined cycle power plant (100 - 1,000MW) with LNG storage tanks and regasification unit:

- Environmentally friendly: 40% CO<sub>2</sub> reduction
- High flexibility: location-free, NIMBY-free
- Fast track: 30months from EPC contract



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As Senior Executive Vice President Ando mentioned about the energy costs in Japan and Korea, it is extremely important to reduce them in both countries compared to the United States. Another problem is that we cannot find the right place to put a nuclear power plant in Korea or Japan because of the Fukushima accident. That is the biggest challenge now in Korea. If we try to build this power plant on a ship and put this ship in the sea, we do not have to worry about the land to put this new nuclear power plant on. That might be a good alternative. Another thing is, because of the usage of shale gas, energy costs will go down. As Senior Executive Vice President Ando mentioned earlier, if we develop a 1700°C gas turbine, the cost will go down even further. By utilizing this kind of idea, Korea can even assist the strong ship building industry and material suppliers like POSCO. Hybridization of all these technologies together to make this idea more feasible and economical might be beneficial in solving the sustainability issue of energy for the world. That is what we are continuously trying to do at KIMM.

I rephrased KIMM as the center for knowledge, innovation, motivation, and marketability during my tenure. That is my new governance philosophy to share with my staff to make the institution better for sustainable growth of the nation and the world.

That brings me to the end of my talk. I appreciate your listening. Thank you very much.



## PANEL DISCUSSION

**Dr. Yong-Taek Im:** This morning, we had beautiful talks on next-generation manufacturing technologies. In the afternoon, we also heard about energy and environment issues and the roles and perspectives of government research institutes. If any of you on the floor have any questions on these issues, please raise your hand and we will welcome your questions first. Do you have any questions or comments for any of the speakers?

I will first ask a question to all of our speakers. We just talked about several issues on the advances of mechanical engineering including next-generation manufacturing technologies. This morning, some of the speakers mentioned a national network for manufacturing institutes in the States that was announced by President Obama in 2013. They are trying to build a manufacturing hub in the United States to create new jobs. May I ask Dr. Altan, Dr. Korsmeyer, and Dr. Lee to comment on this in the order named?

**Dr. Taylan Altan:** As you all know, there was big publicity in the United States because, in the United States, the Obama administration realizes that it should reduce the country's trade deficit, which is about 500 billion dollars a year. To reduce that, and also to increase employment, manufacturing is a key issue. Unfortunately, it is my perspective that there is a big gap in this critical issue, and critical discussion is not stabilized in the United States right now. The Republicans are very much against whatever Obama proposes, so funding for these issues or the suggestions is very difficult to obtain. Again, they are establishing four or five institutes right now for taking funds from the Department of Energy, Department of Defense, and so on, and maybe some from NASA. I am not sure yet. So I think something is happening. I think the best part of its initiative, I believe, is that the universities and the research centers are much more aware of manufacturing as an issue, and now we have to wait and see how it is going to end up. The big problem, I believe, is that we do not have many people in universities who understand manufacturing because, for many years, they did not pay attention to it. So, to bring this up all of a sudden can be difficult.

**Dr. David Korsmeyer:** From the NASA perspective, we are aware of the national network of manufacturing issues and have actually been asked to put in a portion of our funding. It has not been taken but it has been redirected. So, we have been asked to participate with other federal research labs, such as those in the DoE and within the DoD, to collaborate together to find ways to work with regional centers of excellence in manufacturing. One very good thing that has come out of that is there has been a number of valuable workshops, at least in the regional sense, in the Southwest of California, where we've got together with the labs and the larger academic institutions and share what we are currently working on or what are the challenges in manufacturing in mechanical engineering and materials sciences. I agree with you that this is something that the U.S. had largely stopped paying a lot of serious attention to. As you know, that has proven to be a problem because

we feel behind on what a lot of the rest of the world was focusing on, and actually, with the advance of some of the new additive manufacturing technologies, there is enough change that we can re-enter. Now, hopefully, it will lower the cost point and gain some of the valuable synergies from working together. I think KARI, KIMM, and all the other Korean research institutes have not taken their eyes off of manufacturing to the extent that the United States did, but I think that is to your advantages. So we are working to catch up now to where some of you already are.

**Dr. Luke P. Lee:** I think that it is really a good time to think about this manufacturing effort in the United States. In a way, it is kind of late, but better than nothing. I am glad that the Obama administration got good advice and built this up, even educational effort in manufacturing. As I mentioned, it is too late, but I am hoping that it is a good wake-up call for American academia to establish this discipline again. I remember my advisor told me that if you do manufacturing in the university, you become a second-class professor, so I did not do that. But as I shared with you, I was in industry, but I always worried about the economy because if we focus on the service economy and try to make money out of the banking industry or only the software industry, it has limitations. And you create actually a big hole in the middle class. We are human beings, and we have to work with our hands. If we forget about producing real products, we are following the wrong model of England. Guess what happened. Even though England initiated the Industrial Revolution, but what is made in England that is the best product right now? This is a very critical issue. When I grew up, I used to see that the best products were made in the USA. If I do not see this, what is the best product in the United States at this moment? There are good products, yet we lost a competitive edge. So I hope there are things to follow, things to learn from the United States, but there are things not to learn. It is very important to follow some good examples that balance between engineering and pure science in Germany through the Max Planck Institutes as well as the companion institute, Fraunhofer. They are really emphasizing on training engineering students to be real engineers. So, if we forget about this basic component of education to train engineers to be engineers, they become pseudo-engineers, and it loses manufacturing capabilities. And if you lose manufacturing capability, you lose economy. So this is the most important thing that Obama's administrative staff recognize. So, I am glad that it started and hopefully we will catch up soon and make a better correction for this time.

**Dr. Yong-Taek Im:** I want to say something. This is so wonderful. I wish Obama would hire you as a consultant. Professor Lee mentioned the balance between theory and practice. He mentioned Fraunhofer and Max Planck Research Institutes. Do you have any comments on that, Dr. Roth from Germany?

**Dr. Stephan Roth:** I think that the model of Fraunhofer is successful. That is why they want to export it to all over the world. But as we also see, different countries have different boundaries and thinking. And therefore, there is a limitation from it. But I think the Fraunhofer can be a good example of cooperation, and, of course, also to foster institutes

to cooperate. They are forced to make income, they are forced to be in contact with industry. Of course, you have to take care of my opinion a little bit about the size of the Fraunhofer institutes because it is the same for all: it becomes larger and larger. You lose something. You lose flexibility. You lose communication within. And therefore, the Fraunhofer model has some limitations. Sometimes this can be a real limit for industries to use because what they want is, of course, knowledge, experience, and systems they want to pay for. That is very easy and very good. But, of course, what they really need is flexibility because they have no time. That is the main problem. In Germany, we have so many funding models, especially for small and medium enterprises to bring them close to R&D. But all the people have no time to really deal with the problem and to look at what is going on. They just come, they put their problem to your institute, and then they leave. After two years, they come back with research projects and look for the solution and the outcome. And that is not enough. Even if we think Fraunhofer is a good example of knowledge transfer and cooperation between R&D and industry, thinking about R&D has to change. Even Germany does. Germany is not ever perfect, and this must be changed. That is the same all over the world.

**Dr. Yong-Taek Im:** In Japan, manufacturing is so strong. Senior Executive Vice President Ando, do you have any comments on this?

**Mr. Kenji Ando:** Thank you very much. First of all, Japan is not so strong in manufacturing now, by the way. What Japan should do for the future when we develop and when we contribute to worldwide development strategy? That is the point. Maybe in Korea, hundreds of Korean companies will think about something. That is how we do. How can we contribute to worldwide development? As I told you, as a company, what should we do? That is the point. So the dedication of the people and the development mentors of technology or, of course, development for the environmental friendliness are the issues that we will continue to work on. However, on the other hand, as humankind, we have to grow our next younger generations. That is the key point. This is not enough to reply to your question. I do not know what we should do to contribute to the worldwide development. First, development of hardware at the moment.

**Dr. Yong-Taek Im:** President Woo, I am sure you have so many experiences in Korean industry, especially in steel-making, concerning the importance of manufacturing in the modern economy.

**Dr. Jong-Soo Woo:** Actually, I got his question before I came here. One of the possible questions in the panel is “What could be the role of mechanical engineering in addressing the upcoming problems that humankind is facing?” Actually, I have thought about such questions before I came here. I have not thought about this question before specifically about mechanical engineering, but I have thought about the matter in general terms. As I said in my presentation, I think there are three big challenges that humankind is facing in the coming decades. One is energy, the other one is water, and the third one could be food.

So, I think the utmost challenge will be energy, as before. I think one of the roles of mechanical engineering is that it plays an important role in converting all those energies into one other. So, it has a role in converting electrical energy into kinetic energy, and it also has a role in converting resources into electrical energy or other types of energy. So, in making the sustainable future or in contributing to the distribution of resources, the most important thing is how to improve efficiency in converting all those kinds of energy. So the challenge of mechanical engineering or the role of mechanical engineering is how to improve the efficiency of all those processes converting one energy into another energy or natural resources into energy. That is my answer.

**Dr. Yong-Taek Im:** Thank you. The first question that I have raised is President Obama's mentioning this plan for NNMI. That was not on my questionnaire. That is the question: "Why did President Obama bring out this kind of initiative?" President Woo mentioned the importance of manufacturing, especially. But, anyway, you just answered my question. He mentioned the importance of the energy issue. I think that is the area of Senior Executive Vice President Ando. Please share your thoughts on this issue and energy problems that we are facing.

**Mr. Kenji Ando:** First of all, on the future of energy issues, all of the countries would have to investigate it, finally. The first one is the nuclear problem. That is the first issue. The second one is renewable energy: solar and wind, as I told you. And third is coal and LNG. That finally means, totally speaking, that the best mixed strategy should be required. That is my idea: nuclear, renewable, and coal and LNG. That kind of best mix is required. That is the basic idea. Then, it is how to develop new technology based on this fundamental idea. That is the key point. So we are struggling now.

**Dr. Taylan Altan:** If I may, I would like to add a few more comments about the issue. I think it is good to remember that Obama does not want centers to belong to universities. He wants them to be run by independent research organizations. That is one point. I attended many of those meetings, plannings, and so on. The second issue is that he wants to give funding to support small local colleges, i.e., community colleges, because his advisors apparently told him that universities do not produce students who can be active in manufacturing. So, it seems that, in summary, all evidence from Germany and also from Japan shows that, number one, good research is done in cooperation with industry so that one knows what real problems are, and number two, we need qualified trained people. Otherwise, all the research does not happen.

**Dr. Yong-Taek Im:** Then, naturally that brings the next question: how to improve the productivity of research. I think that is a kind of a question you just pointed out.

**Dr. Taylan Altan:** I want to ask you about this because I work with SIMTECH in Singapore. You may want to work with them because they have this problem all the time. How do you measure productivity? In my opinion, if you measure just by the royalties divided by the

input, you are wrong, in my opinion. I think you should increase the amount of industry contribution to your center. Admittedly, the large companies are not going to come to you because they have their own. But there are a number of Korean medium-sized companies. I am sure they need research. Now, you could do many things. For example, you could say, "Okay, for a given size, you pay 50 cents, and I pay 50 cents. For a larger size, you pay 60 cents, and I pay 40 cents, etc." So, you can find innovative formulas to encourage small business to put cash in the research. Even if they put 20 cents on the dollar, that is good. That shows commitment. We make a mistake in the States, and we have something called "in-kind". Companies say, "We put in-kind." Actually, it is funny because they do not do it. It is something to consider.

**Dr. Yong-Taek Im:** Thank you, again. And Dr. Roth? Do you just want to share your experience regarding improvement of productivity of R&D?

**Dr. Stephan Roth:** First of all, I would support the suggestions of Prof. Altan. Productivities in the R&Ds of research institutes are valuable, and his suggestions could be a good solution for achieving this because this is exactly what we want. We want contribution. We do not want to get only the problems or the challenges. We want real contributions because industries must understand that this is a chance for them, not only providing solutions, but, as manufacturing becomes more and more complex in the future, we need more and more complex solutions because the challenges are becoming increasingly complex. Therefore, if you want to keep the development time short, or even shorter in the future, knowledge and experience must be everywhere, not only at research institutes, but at universities. And the only way to gain this knowledge is by contributing to people who are experts in knowledge and experience already. That is what we have to transfer to industry to indicate that it is a chance to take. Of course, it will cost money. R&D in industry also generates no direct income. They have the same problem. All is productivity. The R&D of a company only costs, but it is a chance, because in the future, you will need this. You have to start earlier. Otherwise, you have the same problem like the U.S. with additive manufacturing; then, you see, there is a problem. There is a big point that you cannot resolve within a year just by spending money and just with willingness to build up a new institute.

**Dr. Jong-Soo Woo:** Can I comment on that a little bit? About ten years ago, I actually managed product and plant development in POSCO, Pohang. At that time, the productivity meant how much you can produce for a given time. So if you produce as much as possible in a given time, you can reduce your cost a lot. This means you can make a lot of money. So, in the production plant, the product means cost. However, when I return to my research institute as a researcher, I felt that the same notion is very negative because in the R&D sector, being productive means, to most people, how much you invest in your R&D projects, how many R&D projects you are doing based on that money, and how good of a result you can make out of your research project. This is the R&D productivity that many people think about. Maybe you can increase the productivity of your R&D based on such kind of notion. But you cannot get innovation or you cannot get the technology

development by managing your R&D just with productivity only. When I look at Dr. Im's presentation, he defined the productivity as the royalty divided by R&D budget. In a sense, it is okay. But my opinion is that when you increase the royalty of intellectual property with your R&D investment, you need to define your R&D projects very well, and you need to carefully evaluate the result of your R&D projects. I think that is all. If you are doing well in defining your R&D projects and if you are very good at evaluating R&D projects, then the productivity will follow. That is my opinion. And another point is carrying out your R&D projects is not for the customer in some cases. Who are going to need your R&D projects or the result of your R&D projects? As long as you think about your customers and who are going to need your project and whom you are really working for, that will increase your productivity. That is my additional opinion or comment.

**Dr. Luke P. Lee:** In terms of the productivity, let's say manufacturing R&D, to me, it is time to think about how to communicate failures. A lot of scientists and engineers, especially in Asia, they want to avoid sharing failures because it is a shame to share failures. But we have to encourage ways of discovering mechanisms of failures in precision engineering or even in science. It is very critical to communicate and document all the failures. So, it is time to think about how to "publish to cherish" instead of "publish or perish." A lot of people think that manufacturing R&D should not worry about publication, but we have to also publish the mechanism of failures. If we knew the mechanisms of lots of failures, that would be a successful case and you can build a foundation of making a robot system. This is because if you already failed so many times, with your documentation, other people would not have to repeat it. Otherwise, the next generation would make the same mistakes because they did not even hear about it and they did not even know about it. So it is time to publish to share the failure mechanisms in order to make a successful case. And we have to encourage many young people who make a lot of mistakes instead of awarding only so-called successful cases. In any difficult precision manufacturing engineering, R&D, or science, if the student never experiences failures, it is questionable whether he or she really did a real job or not. So we have to encourage all young scientists or engineers to enjoy the accumulation of the failures and mistakes.

**Dr. Stephan Roth:** I think that is the perfect thesis for this question and answer: increasing the productivity of R&D by selling failures. That is what we have to do.

**Dr. David Korsmeyer:** I tend to very much agree with that. Especially when you are doing innovation, trying something new for the first time, you are going to find activities you cannot do. And that does not mean that you actually fail. That is a successful research outcome. It means you did not know enough, or you needed to take different approach. I think that is something that needs to be recognized and re-emphasized in the teaching of engineering communities, that getting it right for the first time means you may have been too conservative and may have not taken the risks and may have not actually tried hard enough to do the job in the right way. So, there is a lot that could be learned from pushing through failures and then taking one step back. But you do not know where the failure is

until you get there. So there is a lot of benefit out of that. And, then, I want to make one more comment on the manufacturing ability. As I mentioned, NASA does not make a lot of the same products, so I would say there is a skilled ability factor of manufacturing capability that needs to be addressed. It is not just making the most of the product. To maximize your R&D and get your profitability by having tens of millions of your product, it is actually manufacturing at the proper scale. If you can make extremely high quality inexpensively and very quickly, that is equally as valuable as building hundreds of millions of courses of R&D at a very low cost. And it depends on the actual product that you are going to create.

**Mr. Kenji Ando:** To improve R&D business productivity is easy because I am a member of a private company. First, carefully define the purpose of R&D. Next, as Dr. Im explained in his presentation, marketability and the market-oriented R&D. Third, speed, that is, controlling speed and the progress of the R&D at every right interval. That's all.

**Dr. Yong-Taek Im:** Well, we just covered some of the issues. And, finally, I think that we just want to know what the most important issues are that we are facing at in the field of mechanical engineering. Somebody has mentioned the energy, water, and food. If you want to share some of your thoughts, that might be interesting.

**Dr. Taylan Altan:** Of course, I concur with the water, food, and energy. These are well-known issues that we have to deal with. The question is how you go about dealing it. So, I would like to address two issues that, at least in the States, are considered worldwide problems. First, engineering education is a very important issue. In my opinion, although maybe not too many people would agree with me, what I call Anglo-Saxon navigation that we have in the States, England, and maybe also in Korea, is not sufficient to generate and to educate good engineers. The Northern European countries would do the better job because the training of engineers is project-based. You need to learn fundamentals, and then you also make the projects successful that implement huge fundamentals together. I always say to my students, "You guys build GM cars, and the German engineers are going to build BMW. Which one do you want to buy?" So that is one issue. It is a very important issue in my opinion. The second issue is publications. All researchers would like to publish. And I fully concur with you. You also wish to publish your result. It is the cheapest way to learn from someone else's mistake. But the publication issue in last 10 years has gone too far. For example, many universities and research centers measure productivity by publications, which is nonsense, by citation and so on. One has to keep new roles as a director of laboratory, and you have to keep a balance. On the one hand, you want to encourage young people that they have to publish. On the other hand, you do not want publication to take the role, which should be related to research, and be used for some companies and industries.

**Dr. Stephan Roth:** Besides, the cooperation between R&D institutes and industries is a very important challenge for the future, especially for interdisciplinary cooperation. As

mentioned earlier, the complexity of the problems increasingly requires that we find solutions together in a harmonious way giving mutual benefits to every participant for the R&D projects.

**Dr. Luke P. Lee:** I guess the most challenging thing to me is whether mechanical engineering can manufacture multi-scale healthcare monitoring systems or healthcare systems that allow more efficient treatment of patients using the new multi-disciplinary concept of an integrated approach. For example, if we need to make an automated biochip that you drop only on blood, and let this system process everything, it requires the integrating of protein patterning as well as nuclear asset patterning. And we have to add the mechanical component, which is mixing the solutions as well as controlling the volume, etc., the precision control of the authentic solution, as well as amplifying the biological solution for detection. It also requires optical and electrical detection. So, it requires the integration of so many different disciplines. Furthermore, the scale varies from the nanoscale to the micro- and millimeter-scale. So, it is challenging. However, I realize that it has a lot of reward in return. If we solve the challenging issue of precision manufacturing that needs to add the value from biological to optical and electrical control, we can really make an impact on this current society in solving problems of aging in developed countries as well as problems of the young people in developing countries due to the infectious diseases. If we do not have this monitoring system, we cannot prevent infectious diseases or virus can attack even other parts of the world, as you can see now. So, it is a serious problem. However, if we create a preventive medicine by developing a monitoring system, we can capture this information down to a molecular level, and we can definitely contribute as an engineer to make a new preventive medicine, as well as precision medicine, that provides us better information for improving the quality of daily life for humankind.

**Dr. Yong-Taek Im:** Then, let me try to conclude this panel discussion. I really appreciate your frank opinions and thoughts on several issues discussed so far. Research productivity is not easy to define as a single line for various cases. All of us came to a conclusion that collaborations with industries and the international domain should be actively sought and the mechanisms for failures should not be ignored as well. In addition, precision engineering is imperative to make a sustainable progress in science. Because of the interests of the participants in the Forum, it will be continuously organized by KIMM for the next year.

## **CLOSING REMARKS**

**Yong-Taek Im, Chair of IFAME and President, Korea Institute of Machinery and Materials, Korea**

Ladies and gentlemen, we come to the close of what has been a very productive day. I believe that the topics we have discussed today gave us both practical and inspiring benefits. They also gave us a greater insight into building up R&D directions of mechanical engineering and revamping the missions of public research institutions.

I want to thank all the speakers for their contribution, and the steering and organizing committees and the rest of the staff for their sincere dedication to planning, coordinating, and facilitating the Forum. My thanks goes to every single person here, but the most special acknowledgment goes to Ms. Minjung Kim, who designed all the promotional materials including booklets, posters, banners, etc. Your deep commitment made this event even more memorable.

I am already committed to figuring out how I can best keep up the momentum of these discussions. All the contributors have agreed to hold the next IFAME in Daejeon on September 17, 2015. Let's continue this conversation next year in Daejeon!



## MEMORIES OF THE FORUM



<Opening Ceremony>



<Welcoming Remarks: Dr. Yong-Taek Im, President, KIMM>



<Congratulatory Remarks: Dr. Sun-taik Kwon, Mayor, Daejeon Metropolitan City>



<Congratulatory Remarks: Dr. Jae-Moon Park, Assistant Minister, Ministry of Science, ICT and Future Planning>



<Congratulatory Remark: Mr. Joon Yang Chung, President, National Academy of Engineering of Korea, Ex-Chairman of POSCO>



<Congratulatory Remarks: Dr. Sang Kee Suh, Member of National Assembly of Korea>



<Congratulatory Remarks: Dr. Byung Joo Min, Member of National Assembly of Korea>



<Congratulatory Remarks: Dr. Sang Chun Lee, Chairman, National Research Council of Science and Technology>



<Photos Session of VIPs and distinguished guests>



<MC: Ms. Ji Hyeon Seo, External Relations Officer, KIMM>



<Session Chair: Dr. Luke P. Lee, Arnold and Barbara Silverman Distinguished Professor, U.C. Berkeley>



<Speaker: Dr. Taylan Altan, Emeritus Professor, Director, Engineering Research Center for Net Shape Manufacturing, Ohio State University>



<Speaker: Mr. Guenther Klopsch, Head of Digital Factory Division and Process Industries & Drives Division, Siemens Korea>



<Speaker: Dr. Sangwhui Cho, Vice President, Hyundai-Rotem Company>



<Speaker: Dr. Stephan Roth, Managing Director, Bavarian Laser Center (Bayerisches Laserzentrum GmbH)>



<Speaker: Dr. Luke P. Lee, Arnold and Barbara Silverman Distinguished Professor, U.C. Berkeley>



<Speaker: Mr. Kenji Ando, Senior Executive Vice President, Mitsubishi Hitachi Power Systems>



<Speaker: Dr. Jong-Soo Woo, President, Research Institute of Industrial Science & Technology>



<Speaker: Dr. David Korsmeyer, Engineering Director, NASA Ames Research Center>



<Speaker: Dr. Yong-Taek Im, President, KIMM>



<Session Chair: Dr. Yong-Taek Im, President, KIMM>



<Panel Discussion>



<Panel Discussion>



<Panel Discussion>



<Panel Discussion>



<Dr. Yong-Taek Im presents a flower bouquet to Dr. Sang-Rok Lee, Director of External Affairs & PR and Chairman of the Organizing Committee of the 2014 IFAME>



<Dr. Yong-Taek Im presents a flower bouquet to Ms. Ji Hyeon Seo, External Relations Officer, KIMM >



<Dr. Yong-Taek Im presents a flower bouquet to Ms. Jinni Kang, External Relations Officer, KIMM >



<The Audience>



<The Audience>



<Coffee Break>



<Press Interview: Dr. David Korsmeyer, Engineering Director, NASA Ames Research Center>



<Press Interview: Dr. Yong-Taek Im, President, KIMM>



<Casual Luncheon Meeting>



<Casual Luncheon Meeting>



<Participants tour the Dae Cheong Ho (Lake)>



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<Participants tour Cheong Nam Dae>



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<Participants tour Cheong Nam Dae>



<Participants tour Gyeryongsan Pottery Village>



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