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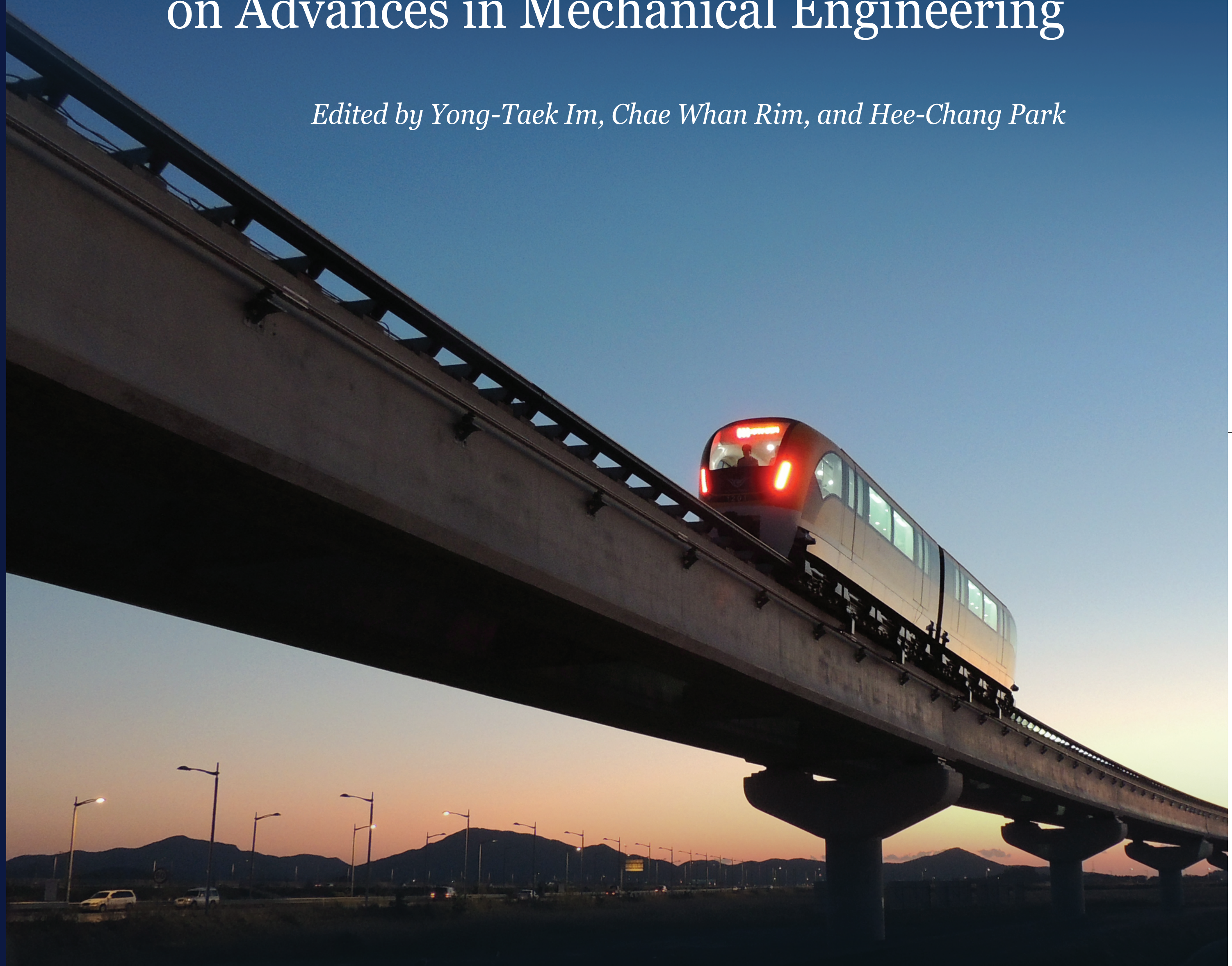
2015 International Forum Korea on Advances in Mechanical Engineering

Edited by Yong-Taek Im, Chae Whan Rim, and Hee-Chang Park



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KIMM KOREA INSTITUTE OF MACHINERY & MATERIALS

34103 대전광역시 유성구 가정북로 156
2015 IFAME 포럼사무국 T.042-868-7656

2015

International Forum Korea on Advances in Mechanical Engineering

Organized by

KIMM KOREA INSTITUTE OF MACHINERY & MATERIALS

Sponsored by

Ministry of Science, ICT and Future Planning

MOTIE MINISTRY OF TRADE, INDUSTRY & ENERGY

nst National Research Council of Science & Technology

대전광역시 DAEJEON METROPOLITAN CITY

UST UNIVERSITY OF SCIENCE & TECHNOLOGY

DIME Daejeon International Marketing Enterprise

NAEK The National Academy of Engineering of Korea

KAST 한국과학기술한림원 The Korean Academy of Science and Technology

Published by KIMM Press

156 Gajeongbuk-ro, Yuseong-gu
Daejeon 34104
Republic of Korea

First published in 2016

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2015 International Forum Korea on Advances in Mechanical Engineering

ISBN 979-11-86793-00-8 (93550)

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93550
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ISBN 979-11-86793-00-8

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PREFACE

Recently, the world economy was shaken by Greece, the origin of democracy and the Olympics. The main players coping with this crisis were Germany and France. Both countries are known for strong manufacturing and food technologies, especially transportation technology. It is well known that the first industrial revolution occurred in England in the textile industries and transportation sectors by the use of steam power in the 18th century. The second industrial revolution occurred with the automated assembly line introduced by Henry Ford in Detroit, Michigan in U.S.A in 1903. These two industrial revolutions focused on mass production to make the type of profits maximize for the companies. In sunset of the second industrial revolution, not only the aforesaid manufacturing leaders but also the emerging powers in Asia are trying to achieve game-changing technological breakthroughs.

According to the report by the Economist in 2012, there is going to be a paradigm shift in which advanced materials, digital manufacturing and additive processes increase the value-added in the third industrial revolution. The biggest key difference in this revolution is that the mass production is not the major element only to generate the types of profits anymore. This will also cause many changes in the manufacturing sectors such that we are going to see more on-shoring of manufacturers because companies will not be seeking lower-wage nations to pursue their manufacturing according to Dr. Mun Young Choi, Provost and Executive Vice President for Academic Affairs of the University of Connecticut. Therefore, innovation in manufacturing sectors through the advancement of science and technology is the key issue to maintain the growth of national economy and security.

Sequel to the 2014 International Forum Korea on Advances of Mechanical Engineering launched by the Korea Institute of Machinery and Materials (KIMM), advanced manufacturing technology was selected as the main theme of this year's Forum in 2015. Several countries set up the national initiatives such as Advanced Manufacturing Partnership of the United States of America, Factories of Future of the European Union, Industrie 4.0 of Germany, High Value Manufacturing of the United Kingdom, Industrial Structure Vision 2020 of Japan, Made in China 2025 of China, Manufacturing Innovation 3.0 of Korea and etc.

Invited speakers from the US, Japan, Taiwan, and Lichtenstein attended the Forum to share their valuable ideas and experiences on the topic. Dr. Mun Young Choi was talking about "Opportunities in Additive Manufacturing & Advanced Materials." In this talk, a survey on some of the exciting developments in advanced manufacturing and additive manufacturing in the U.S was presented. He showed that manufacturing is still considered to be very important in the U.S., despite the loss of jobs in the economic downturns for last half century since 1960s. In spite of such economic downturns companies have made investments in areas of advanced manufacturing and additive manufacturing that utilize digital techniques to innovate the process and product development for better sustainable productivity. The reason that manufacturing is considered to be so key by the federal government as well as individual states is that there is a multiplier effect in manufacturing. For every dollar of the value that is created by investment in manufacturing, there is 1.4 dollars of attained value. If we compare this with other areas of service industries like financials, that ratio is one dollar to 70 cents only. Therefore, every state and every leader want to see more manufacturing growth, done in a very smart way, in their regions. He also introduced the 3-D printing research activities at the University of the Connecticut sponsored by Pratt and Whitney including other industry partnerships such as General Electric Center for electrical-protection technologies, Fraunhofer Center for energy innovation, and United Technologies Institute for advanced systems engineering. He also pointed out the importance of investments in engineering and science education to pursue advanced manufacturing that leverages the third industrial revolution.

Dr. Chang-Jin Kim, Professor of Micro and Nano Manufacturing Laboratory in the Mechanical and Aerospace Engineering Department at the University of California at Los Angeles talked about "The Micro and Nano Fabrication Technologies of Micro-electro-mechanical systems (MEMS)." In his talk, not only the research but also the kinds of products applied in industries were introduced. Because of the perceived limitations of the original MEMS technologies, many research scientists tried to make more complex 3D structures. This can be achieved by employing a laser deposition technique. 3D printing technology today is merely the same technology available in the MEMS technologies almost 20 years ago, which was called by micro-scale lithography which can make 3D structures in nanometer scale. It is very beautiful but too expansive. That is why we do not see any of them in products yet. He believed that the next wave of MEMS commercial products is in bio and medicine. In bio and medicine areas of applications, it is important to make the products small because they are handheld or implanted in human bodies. When things are small, physical responses are faster. A lot of times, biomedical devices or systems are less sensitive to price. Even if they are relatively expensive, people tend to buy them. That is why biomedical products are the next wave. In biomedical products, simple fabrication is always desired not only because of the cost but also we do not want any complications in terms of biocompatibility, reliability, so they just want to make it simple. He just selected the superhydrophobic surface that repels the water to reduce the drag force. To really achieve this goal in reality, MEMS is the only solution he claims. With MEMS technology with perfect laboratory conditions, he can demonstrate at least 75% drag reduction in a boat under the water theoretically.

Dr. Zvi Karni, Vice President of Alion Science & Technology mentioned about paradigm shift of future manufacturing by applying 3D printing technology based on the advancement of Internet of Things in his talk on "Creative Economics through Hyper-local Manufacturing." The machine tools today are much larger than the components that they produce. This makes it very difficult to do rapid production, because we have to go back to wherever these big machines are located. But if we have such a robot that can assist the manufacturing in the 3D printing environment, it can create a large component with a small unit. As an example, he pointed out that a bridge is going to be printed in Amsterdam in two years. This new technology will bring in many socio-economic changes in the future.

Dr. Matthias Hänsel, Division Manager of ThyssenKrupp Presta Steering Group gave a presentation of "A Brief View into the Future of Precision Manufacturing by Cold Forging." He shared the thoughts and ideas that were gathered from a special initiative at the International Cold Forging Group (ICFG) and from the discussions with many experts inside and outside of ICFG as well as from relevant references. When members of the ICFG prepared the ICFG 2050, they found a very interesting article by Mr. Silverton of the U.K. published in 1977, describing what the metal forming industry will look like 50 years later in 2027 by sending an observer to some company visits. He reported what he has seen in his visit. His report included a digital factory as an engineering environment, data transfer by Internet, supply chain management, unmanned operation of automatic press transfer lines, flexible multifunctional presses with central hydraulic supply, energy recycling, solar power from the company's roof, energy recovery, recyclability of products, electric vehicles, etc. It was a time when the personal computer was not yet born. In his talk, Dr. Hänsel sent an observer to the future of maybe 2050 similar to the work by Mr. Silverton. It is quite impressive and interesting to learn more about the evolution of cold forming technologies for the future manufacturing environment.

Dr. Tae Won Lim, Vice President of Hyundai-Kia Motor Company addressed "Technology Innovations for Future Mobility." Original equipment manufacturers of automobiles have been listening to various voices and demands from customers and societies for a long time. They continuously ask the manufacturers to supply cleaner, more efficient, much safer, and more convenient vehicles. In order to have the secure position in the automotive market, most manufacturers have no choice but to focus their resources to develop green and smart cars. He was addressing the technology innovations at the Hyundai-Kia Motor Company in this regard. For the successful mass production of electric vehicles, we have to resolve some critical technical issues on driving range, cost, and charging time. For a longer driving range we have to develop high-energy batteries and improve the efficiency of power electronics. For the cost reduction, the research scientists are modifying electrode materials of the battery from very expensive material; such as cobalt to cheaper materials such as nickel and manganese. For the rapid and convenient charging, they are modifying the battery design and inductive charging system. Dr. Lim also addressed the issues on fuel cell. To reduce the cost, there are three key components: catalyst, membrane, and hydrogen storage tank. The innovative approaches to reduce the cost in these three areas were introduced as well. In addition, the system optimization should be considered for mass production of green cars. Multi-functional materials, i.e., the combination of steel, aluminum, carbon fiber-reinforced plastics, plastics, etc. are gaining more attention from the industries and academia because of weight reduction. To develop low-friction coating, adiabatic coating and nano-fluid coolant, nanotechnology is applied as well. Lastly, he talked about the advanced driver assistant system and the autonomous vehicle technologies for manufacturing smart cars.

Dr. Seung-Joo Choe, Executive Vice President and Chief Technical Officer of Doosan Heavy Industries and Construction talked about "Doosan's Efforts to develop Power-Gen Technology." He pointed out a survey made by IHS, a global market research company in Colorado. According to this survey, renewable energy will be expected to increase up to 27% in 2040 in the global power sector. The share of fossil fuels is expected to decline by approximately 10% from 63% to 52% in 2040. Fossil fuels are still expected to become an important energy source in order to meet the increasing power demands. The demand for gas is expected to increase. Domestic Korean power market will show a similar trend as the global trends. However, Michael W. Howard, CEO of Electric Power Research Institute (EPRI) mentioned a drastic technical innovation in electronics, communications and information in the last two decades. Electronic devices become smaller but show increased performance with decreased cost. Communications are easily made through the globally connected networks with increased speeds. Every day we meet an explosive amount of information as searchable and digitized data. This technical innovation drives the paradigm change in the power industry. He introduced the major industrial efforts and researches in coal-fired power plant, nuclear power plant, combined cycle power plant, renewable energy including wind turbine, and Doosan ultra-super-critical model.

Dr. Masahito Yamanaka, President of Yamanaka Engineering made a presentation of "Challenge for Sustainable Growth: Innovative R&D and Strategic International Sales Activities." He pointed out strong and weak points of the tooling business in Japan. Traditionally, dies and mold industry is known as the rise of the manufacturing system. 90% of the tooling businesses in Japan are family owned companies which have less than 20 employees. Due to their small size, the management, sales and R&D are usually weak. However, the profit ratio of dies and mold products is usually high. However, it is difficult to make companies large because of the weak management. After the economic crisis in 2008, Japanese government started supporting the dies and mold industry to revitalize the industry for maintaining quality. In addition, Japanese government selected six keywords for the growth strategy for the dies and mold industry. They are world class technology, expanding value of products, attractive human resource, robust trade practice, appeal to the world and globalization. 30 years ago, there is no need for any sales effort if the companies are making good products. However, it has changed now. He mentioned the importance of planning the strategies by adopting these keywords and flexibility concerning strong points and philosophy of Yamanaka Engineering. Its business strategy is composed of three divisions: the tooling business, parts business which is mainly for the outside of Japan including sales division, and solution business for process development. The solution business for process development is the most important division since high-level ability to develop new processes or products aerates new tooling business. If the tooling business is good, the parts business for the outside of Japan is also good. In order to motivate the people who are beginning their career in companies like small- and medium-sized companies, education or training from zero is also of importance.

Dr. Albert Pisano, Dean of Jacobs School of Engineering at the University of San Diego (UCSD) introduced the major research activities of the College of Engineering in the presentation of "Engineering as a Force for the Public Good." The UCSD launched a new institute in robotics and is trying to make an interdisciplinary working environment so that they can bring a broad view to engineering problems solving. Human learning experts will be guiding the robotics project. This is one example of a different approach that the UCSD is following for engineering. They have identified several industries that will experience exponential growth in the next decade; biotechnology and bioinformatics; medicine as increase in personal medicine; nano-materials and nanotechnology; networks and sensors; digital manufacturing (3D printing) and infinite computing; computational systems; artificial intelligence; and robotics. According to the recent prediction in sensors by experts, there will be 45 trillion network sensors in the next 20 years. There is a huge piece of mechanical engineering involved to make all of this happen. These sensors are too many to be fabricated from silicone only and are going to be manufactured by printing processes in the future. Several breakthroughs made by UCSD in the areas of elastic epidermal electronics, perinatal health, lifespan home care technologies, wireless sensing and diagnostics, whole body wearable sensors, non-invasive monitoring, harvesting energy from the skin, printable nano-electronics, precision delivery of drugs, manufacturing drugs in the body, sustainable energy technologies, computational mechanics, composite structures aviation safety, context-awareness in smart grid, and imaging atoms in a working battery are introduced in his talk.

Dr. Ching-Ming Chen, Vice President of Metal Industries Research & Development Center, Taiwan gave a talk on "The Effort put into Innovation and Globalization for Small & Medium Enterprises (SMEs) in Taiwan." The mission of the research center is to upgrade competencies of Taiwan's metal industry by advancing technologies for developing key components by applying an effective process design and establishing core laboratories. In addition to this, forging international cooperation, industrial clusters, collaboration with industry and academia, and technologies transfer to private sector is another part of the mission. It has six focused industries: high value equipment, automotive industry, medical devices and health care, mold and micro components, metal materials and fabricated metal products, and cross-field value added platform. He introduced the case studies on assisting small and medium enterprises for innovations; enhancement of industry value chain led by leading material factories; development of key technologies for bio-tech and food equipment; networking and promotion of the autonomy of motor industry; promotion of wind turbine industry. In conclusion, Taiwan government promotes a series of policies and applies a guidance system to assist the upgrading and transformation of SMEs. Also, MIRDC networks government policies and industrial needs and play an important role in the innovation and globalization process for Taiwan's SMEs.

Lastly I reviewed the national initiatives to revitalize the economy by boosting advanced manufacturing technologies in various forms and summarized my personal views and challenges KIMM is facing to overcome the global competition in the manuscript on "Raison d'être of Globalized Public Research Institutes." With this kind of effort, I would like to contribute to upgrade KIMM as the center for Knowledge, Innovation, Motivation, and Marketability to make the institution more sustainable in the international domain.

I sincerely hope that the proceedings will redirect the roles and responsibility of the globalized public research institute like KIMM, industry, and academia to achieve the sustainable economic growth to improve the quality of our lives for the future.

Yong-Taek Im
President
Korea Institute of Machinery and Materials

••• ACKNOWLEDGMENTS

It is the second IFAME. We believed the second would be easier, which means the first was too much burden to us. The Institute has 40 years of history and had hosted countless domestic and international conferences. Still, we are like a cat on a hot tin roof when faced with international affairs. We bowed we should do it with perfect this time at least. After the IFAME, some people say you are close to perfect in preparation. Others say they are still hungry. What can we say?

Well, let me say what we have done after the first IFAME. At that time nothing was decided, even the opening day and the subject of the forum. We organized a task force whose members are still fresh in good memory of the first one, except me who was an outsider of the main task in the first IFAME and still an outsider of the second IFAME. Everybody who is reading the acknowledgment is sure to be wondering who is writing the acknowledgement then. Mr. Jaeyun Song, in charge of organizing the Forum, was the head of Department of External Relations at that time. He had tried hard to steer the task force, even though he has very heavy load of public relationship. I am just doing final touch of the Forum.

The day the Forum took place fell on the day of the National Audit of the Institute which we want to avoid the disaster from the first and we have no control of. But Dr. Moon Jong Hong, the Chairperson of the National Assembly Standing Committee, generously allowed President Im to attend the Forum. What a relief!

Finally, we witnessed more than 200 audience assembled at the day of the opening successfully and could proudly announce the opening of the Forum.

Inviting speakers was never easy due to the schedule of their own. I would like to thank all the speakers for taking precious time and delivering fruitful contents of Advances in Mechanical Engineering. Dr. Hyun-Sil Kim, Dr. Jung-Hoon Chung and Dr. Seung Kook Ro deserve special acknowledgment for their contribution to inviting the speakers to the Forum.

Many thanks go to all the speakers and participants from all around the world whose contribution made the Forum extraordinary. Most of all, the steering and organizing committee did not spare their effort for the successful and meaningful Forum which is very much appreciated.

Gala dinner was held, thanks to Director Ji Ho Lee, at the garden of Lee Ungno Museum which was inaugurated in memory of artist Lee Ungno who lived in Paris his last 30 years till he died at the age of 86. He tried to balance the tradition and modern, Korean and Western by abstracts and collages which were advocates of Korean arts. That just like KIMM is trying to enter a new world based on the traditional manufacturing technology. The Gala Night would not have been possible without the support from Angeline Park and Se-hoon Oh of Daejeon International Marketing Enterprise.

I would like to specially thank Dr. Suk-Joon Lee, Vice Minister of MSIP; Mr. Taeseog Oh, Director-General of R&D Outcome Policy Bureau of Ministry of Science, ICT and Future Planning (MSIP); Dr. Sang Kee Suh, Dr. Byung Joo Min and Mr. Sang Min Lee, Members of the National Assembly; and Dr. Sang Chun Lee, Chairman of the National Research Council of Science and Technology (NST) for delivering their speeches and video presentations during the Forum, and Dr. Un Woo Lee;

President of UST; Mr. Jaok Koo, Chairman of Korea Federation of Machinery Industry Cooperatives; Dr. Hae Woong Hwang, Dr. Kyung-Hyun Whang, and Dr. Tae In Choi Former Presidents of KIMM; and Dr. Jong Hae Keum, President of Korea Institute for Advanced Study for contributing their valuable time and effort.

The generous support of Dr. Chun Hong Park, Dr. Byung-Chun Shin, Dr. Hyun-Sil Kim, Dr. Eui-Soo Yoon, Dr. Yongjin Kim, Dr. Joon Yub Song, Dr. Jae-Jong Lee, Dr. Hee-Chang Park, Dr. Sang Jin Park, and Dr. Dal Sik Kim is very much appreciated. The Forum was organized under the auspices of MSIP, the Ministry of Trade, Industry, and Energy, NST, Daejeon Metropolitan City, the University of Science and Technology, the Korea Academy of Science and Technology, the National Academy of Engineering of Korea, and the Daejeon International Marketing Enterprise.

The publication of the Proceedings of the Forum would not have been finished without the editorial support from Ms. Jinni Kang, Ms. Hyun Soo Sung, and Ms. Yoon Sun Heo who transcribed the manuscript.

Special thanks go to Mr. Myung Jun Oh for taking numerous photos and Ms. Min Jung Kim for designing fantastic banner and cover of the Forum. And I would like to thank Mr. Il Kwon Yang, Mr. Dong Eon Kim, Mr. Seung Mo Lee, Mr. Chang Won Lee, and Mr. Hee Joung Lee for preparing venue facilities, Mr. Jaeyun Song, Mr. Sung-Kyu Cho, Mr. Hyung Sun Na for the handling details of the Forum as well.

The outstanding administrative support from the organizing staff is too vast to mention in detail here but cannot be overemphasized.

I am confident that the next IFAME, which will take place in 2016, will be more exciting and stimulating. I am looking forward to seeing you all together next year.

Thank you very much.

Chae Whan Rim
Head
Department of External Relations
Korea Institute of Machinery and Materials

CONTENTS

SUMMARIES OF ABSTRACTS IN KOREAN (발표 내용의 국문 초록)

적층가공 및 첨단소재 분야에서의 가능성

Mun Y. Choi (미국 코네티컷주립대 부총장)

코네티컷은 제너럴 일렉트릭, 프랫앤휘트니, UTC 에어로스페이스 시스템, 제너럴 다이나믹스 등 세계에서 가장 큰 제조분야 대기업들의 본거지이다. 코네티컷 대학은 '넥스트 제너레이션 코네티컷'(Next Generation Connecticut)과 '테크 파크'(Tech Park)의 일환으로 새로운 과학·공학·교육 시설에 약 20억 달러를 투자함으로써 적층가공, 바이오제조, 복합소재 및 소재 유전체학을 통한 첨단소재 개발에 중대한 영향을 미칠 만반의 준비를 갖춘 상태이다. 본 발표에서는 미국에서 〈전미 제조혁신 네트워크〉, 〈소재 유전체학 이니셔티브〉 등 제조분야 파트너십을 지원하는 주요 취지를 개략적으로 소개할 것이다. 또한 코네티컷 대학에서 수행하는 구체적인 연구개발을 다룰 예정인데, 여기에는 프랫앤휘트니와 진행하는 가스터빈 부품 적층가공을 위한 전자빔 용해법(electron beam melting) 및 레이저소결 기술 연구개발, TE 커넥티비티와 진행하는 전자부품 적층가공 연구개발, 코네티컷 이노베이션 기금을 받는 재생의학 및 바이오프린팅 연구, 고전압 응용을 위해 제너럴 일렉트릭과 함께 진행하는 신소재 개발 및 테스트가 있다. 혁신적인 구리기판 금속산화물 박막코팅 접점은 차단기 내 전기접점의 모델로서 탁월한 접착력, 높은 열안정성, 우수한 도전율을 가진 것으로 드러났다.

MEMS의 마이크로 및 나노 제조기술

CJ Kim (미국 UCLA 기계항공우주공학과 교수)

미세전자기계시스템(MEMS, microelectromechanical systems)은 복잡한 3차원(3D) 형상을 미세규모로 만들어내는 능력으로 널리 알려져 있지만, 지금까지 거둔 상업적 성공의 대부분은 집적회로(IC)와의 호환성 덕분이었다고 봐야 한다. 복잡한 미세기계요소를 제조하는 능력은 거의 활용되지 않은 것이다. 바이오칩 같은 비-전자공학 응용이 곧이어 나오겠지만, 분명 그 성공은 복잡한 3D 기하학 구조를 만들어내는 능력보다는 소재와 시스템에 더 많이 좌우될 것이다. MEMS 제조가 가진 모든 역량과 실제 수요 사이에는 큰 괴리가 있다. 본 발표에서는 MEMS만의 독특한 제조기술을 개관하고, 그 기술의 결과물인 기기들을 예로 들며 그 효용성을 다룰 것이다. 또한 대량 생산에서 흔히 볼 수 있는 부정확하고 불규칙한 형상 및 패턴과 달리 정확한 형상과 패턴을 만들어내는 MEMS의 능력 및 과학적 연구와 공학 R&D에 필수불가결한 그 유용성이 강조될 것이다. 특히 초소수성 표면을 연구하고 흐르는 물의 항력(drag of water flows)을 감소시키는 표면을 고안하는 데 있어 MEMS 제조가 담당하는 역할을 소개할 것이다.

하이퍼로컬 제조를 통한 창조경제

Zvi Karni (미국 얼라이언사이언스앤테크놀러지 부사장)

1940년대의 얼라이언에게 골프공 인증기계는 하나의 글로벌한 문제였고, 우리는 그 문제에 대한 해답을 만들어낼 아이디어를 갖고 있었다. 오늘날 정부는 아이디어를 강화하는 여러 가지 프로그램들로 산업계, 학계, 연구소들을 독려하고 있다. 제조에 있어 아이디어의 창조성은 제품의 커스터마이제이션을 더욱더 필요로 해왔는데, 이는 제조공정과 제조기법이 국제적으로 배송되어야 할 물품들의 목록을 축소시키는 등 보다 기민해지도록 추동되고 있음을 의미한다. 창조경제에서 첨단제조는 누구나가 어떤 기기를 사용하든 어떤 네트워크를 이용하든 언제나 커스터마이제이션 제품을 주문할 수 있도록 하는 것, 그래서 어디서든 필요할 때 바로바로 이용할 수 있도록 하는 것을 의미한다. 얼라이언이 개발한 모바일 부품 병원(Mobile Parts Hospital)은 가장 혁신적인 첨단 현장 하이퍼로컬 제조기술 중 하나이다. 현재 우리는 대량 부품의 필요성을 줄이고 그것들을 운송하는 트럭과 보관하는 창고를 줄임으로써 공급망을 변화시키고자 소형공장 개발 과제를 다루고 있다. 나아가 지난 두 달 사이에 영국 해군과 대학 엔지니어들이 영국 해군 군함 내에서 하이퍼로컬 제조 100% 3D 프린트 무인항공기를 만들어 선두(船頭)에서 띄웠다. 로컬한 생산기계 설명에 따라 로컬한 방식으로 '프린트된' 스마트폰, 노트북, 옷, 보석, 음식 등, 디지털화와 매스 커스터마이제이션이 제조분야를 휩쓸고 있다. 그러나 하이퍼로컬 제조를 완전히 제대로 활용하기 위해서는 연구소들이 툴링 소형화(tooling miniaturization), 조립관리, 커스터마이제이션 비즈니스 모델 분야에서 검토를 계속해나가야 한다.

냉간단조 정밀가공의 미래에 대한 간략한 검토

Matthias Hänsel (리히텐슈타인 티센크루프 프레스타 스티어링 부장)

국제냉간단조그룹(International Cold Forging Group, ICFG)은 5년 전 냉간단조기술과 그 경제적 환경의 전망을 더욱 면밀히 살펴보기 시작했다. 본 논문은 ICFG 내부에서 이 기술의 전망에 대해 논의한 결과를 요약하며, 향후 10년 내 자동차 산업의 주요 시장 개발에 대해 간략하게 검토한다. 뿐만 아니라 냉간단조기술이 신기술과 신소재를 활용함으로써 그리고 정밀 냉간단조 기술에서 정밀 냉간성형 기술로 계속 나아감으로써, 이 기술의 지위를 앞으로 어떻게 성공적으로 주장할 것인가라는 문제를 통찰한다.

이러한 기술적 성과 외에도, 미래 글로벌 비즈니스 환경의 변화를 성공적으로 파악하기 위해서는 혁신기업 운영 및 조직형태의 기본 요소인 소위 인적 자본과 사회적 자본—직원들, 직원들의 지식, 네트워킹, 국제협력과 밀접한—이 앞으로 중요하다는 점을 지적하고자 한다.

미래의 이동성을 위한 기술혁신

임태원 (현대자동차 부사장)

자동차 기술은 최근 수십 년간 눈에 띄게 발전해왔다. 기술이 발전한 결과, BEV (Battery Electric Vehicle), HEV (Hybrid Electric Vehicle), PHEV (Plug-in HEV), FCEV (Fuel Cell Electric Vehicle) 같은 친환경 차와 첨단 운전자 지원시스템이 2000년대 초부터 상용화되었다.

그러나 보다 깨끗하고 안전하고 편리한 차를 요구하는 강한 목소리가 고객뿐만 아니라 사회로부터도 나오고 있어서, 자동차 산업은 친환경 차, 자율주행차, 커넥티드 카(connected vehicles)를 위한 첨단혁신기술을 개발해야 한다는 중압감을 느껴왔다.

본 발표에서는 앞서 언급한 자동차 산업 내 최신 과제들을 검토하고 그 해결을 위한 혁신적인 기술을 소개할 것이다.

발전(發電)기술 개발을 위한 두산의 노력

최승주 (두산중공업 부사장)

글로벌 경제 불황과 강화된 배출가스 규제로 인해 전력산업의 글로벌 비즈니스 환경이 변화하고 있다. 전기 수요가 급속하게 증가하고 있는 신흥 시장에서는 대규모 석탄 화력발전소나 원자력발전소가 선호되고 있다. 반면 엄격한 환경 규제가 적용되고 전기 수요가 포화상태인 선진 시장의 주요 발전원은 복합화력발전소(combined cycle power plant, CCPP)와 재생에너지이다.

석탄 화력발전소 부문에서는 고효율 초초임계압(ultra-supercritical, USC) 발전이나 저등급탄을 활용한 석탄 화력발전소가 주목을 끌고 있다. 원자력발전 부문에서는 최대 1400MW급 대규모 원자력발전소를 위한 기술이 확립되었는데, 증기발생기 같은 주요한 열화 부품 교체 및 노후 원자력발전소 폐로 조치와 관련된 기술이다. CCPP는 효율성을 향상시키고 강화된 환경 규제를 충족하는 대안으로 간주되고 있으며, 광범위한 R&D 노력을 촉진하는 자극제 역할을 하고 있다. CCPP 시장의 후발주자들은 선두주자들이 지배하고 있는 시장에 진입하기 위한 노력을 계속 하고 있다. 정부 정책과 규제는 재생에너지의 확대를 추진하고 있다. 재생에너지의 효율성 향상과 비용 감소가 설비의 증가를 낳는다. 재생에너지의 확대로 인한 전력 그리드 불안정을 제거하기 위해 에너지 저장장치(energy storage system, ESS)가 각광을 받아왔다. 미활용에너지 복구, 에너지 저장, 발전(發電)에서의 ICT 전환에 관한 R&D 역시 활발하게 진행되고 있다.

글로벌 시장의 변화에 따라, 두산중공업은 다양한 분야에서 신기술의 개발 및 상용화를 개시했다. 두산은 1000MW급 USC 화력발전소를 상용화했으며, 현재 극초임계압(hyper-supercritical, HSC) 기술을 개발하고 있다. 원자력발전 부문에서 두산은 폐로 기술을 개발 중이며, 증기발생기 교체에 관한 현장경험을 확보했다. 두산은 한국에서 최초로 석탄가스화 복합발전(integrated gasification combined cycle, IGCC)을 상용화 중이다. 또한 두산은 한국에서 해풍 터빈의 선두주자이기도 하다. 본 발표에서는 위에 언급된 분야에 관한 두산중공업의 R&D 활동이 소개된다.

지속가능한 성장을 위한 도전: 혁신적인 R&D와 전략적인 국제 활동

Masahito Yamanaka (일본 야마나카 엔지니어링 사장)

주식회사 야마나카 엔지니어링은 첨단기술지향 기업으로, 정밀냉간단조용 기구를 제조하고 금속성형공정에 특화된 CAE 소프트웨어를 포함한 엔지니어링 솔루션을 제공하며 해외에서 냉간단조제품을 생산한다.

일본 국내 자동차 생산량의 더딘 증가와 해외 제조·판매 역량의 보강은, 최근 수년간 주목할 만한 일본 자동차업계 추세였다. 고부가가치 제품을 증진시키는 독특한 기술—일본에서 '유일무이의 기술'이라 불리는—을 개발하는 것과 해외 비즈니스를 확장하기 위해 신흥 시장을 탐색하는 것은, 지속가능한 성장을 유지하기 위한 야마나카의 핵심 활동이다.

본 발표에서는 야마나카에서 진행한 최근 R&D 프로젝트에서 거둔 주요한 성과들을 소개할 것이다. 또한 해외에서 진행한 최근 활동을 소개함으로써 야마나카의 국제 비즈니스 촉진 전략을 설명할 것이다.

공학: 공익을 위한 힘

Albert Pisano (미국 UCSD 제이콥스 공과대학 학장)

본 발표는 캘리포니아에서 가장 큰 공대를 가지고 있는 UCSD가 공익의 관점에서 어떤 공학 연구를 수행하고 있는지를 소개한다. UCSD는 세계에서 15위 안에 드는 연구대학으로, 미국 안에서는 일곱 번째로 좋은 공과대학을 자랑한다. 공학, 인문학, 예술, 사회과학 등 다양한 분야의 인재들이 학제적 연구를 활발히 하고 있는 UCSD는 지구상의 주요 난제들이 30년 안에 해결될 것이라 예측하는 Abundance를 추구한다. 본 발표에서는 Abundance의 관점에서 UCSD가 수행하고 있는 생명공학, 생명정보학, 의학, 나노물질과 나노기술, 네트워크와 센서, 디지털 제조, 무한 컴퓨팅, 전산시스템, 인공지능, 로보틱스 등의 분야의 연구를 소개한다.

대만의 중소기업 혁신 및 글로벌화 노력

Ching-Ming Chen (대만 금속산업연구개발센터 부소장)

대만 경제발전기에 중소기업은 국가경제와 사회안정성에 큰 기여를 한다. 전 세계적인 산업발전과 경제발전이 있은 후, 대만 중소기업은 업그레이드와 변화의 어려움, R&D 역량 결여, 글로벌화 및 초국가적 혁신 연계의 부족에 직면해 있다. 그 결과 대만 정부는 작은 기업의 발전을 돕고 시장에서 살아남을 가능성을 높이는 등, 중소기업의 업그레이드와 변화를 지원하기 위한 일련의 정책을 촉진하고 지도체계를 가동한다. 대만 정부는 이러한 정책들을 실행하면서 산업구조의 다양화, 고성장 중소기업의 발굴, 중소기업 수출기여도를 높이기 위한 국제적 혁신 연계의 강화를 수행하고자 한다.

R&D 연구소인 MIRDC는 정부정책과 산업요건을 조율하며 대만 중소기업의 혁신 및 글로벌화 프로세스에서 지극히 중요한 역할을 수행한다. MIRDC는 중소기업이 혁신을 수행하고 제품의 가치를 끌어올리고 국제 경쟁력을 높일 수 있도록 오랜 기간 지속적으로 지원한다. 본 발표는 대만 중소기업과 정부 지도정책의 현주소를 소개하며, 나아가 MIRDC가 중소기업의 혁신 수행을 지원하기로 채택한 몇 가지 사례와 함께 그 전략을 설명한다.

세계화된 국가연구소의 존재 이유

임용택 (한국기계연구원 원장)

최근 민주주의와 올림픽의 발상지인 그리스의 디폴트 사태로 인해 세계 경제가 타격을 받았다. 앞장서서 이 위기에 대응하고 있는 주요 국가는 독일과 프랑스로, 두 국가 모두 운송과 농업을 필두로 한 강력한 제조 기술력으로 유명하다. 18세기 영국에서 산업혁명이 시작된 이래 과학기술, 특히 선진 제조기술의 발전은 국가 경제성장과 안보를 유지하는 데 중추적인 역할을 해왔다. 결과적으로 제조기술의 수준이 국가 경쟁력 유지의 핵심 요소가 된다. 이 논문에서는 선진 제조기술의 발전에 대한 각국의 새로운 정부정책으로서 선진제조 파트너십(미국), 미래의 공장(EU), 인더스트리 4.0(독일), 고가치 제조전략(영국), 산업구조 비전 2010(일본), 메이드 인 차이나 2025(중국), 제조업혁신 3.0(한국) 등을 검토한다. 이를 통해 한국기계연구원과 같은 국가연구소의 역할과 책임은 지속 가능한 경제성장을 꾸준히 지원하여 향후 국민 생활의 질을 향상시키는 것임을 재확인하고자 한다.

PRESENTER BIOGRAPHIES

Mun Y. Choi

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Dr. Choi received his B.S. in General Engineering in 1987 at the University of Illinois at Urbana-Champaign and his M.A. and Ph.D. in Mechanical & Aerospace Engineering at Princeton University in 1989 and 1992, respectively.

After completing the National Research Council Post-Doctoral Fellowship at the National Institute of Standards & Technology, he began his teaching and research career at the University of Illinois at Chicago (UIC) as an Assistant and Associate Professor. In 2000, he was selected as Associate Dean for Research & Graduate Studies at Drexel University and as a Full Professor in Mechanical Engineering & Mechanics. In 2008, Dr. Choi was appointed as the Dean of Engineering at the University of Connecticut (UConn) and in 2012 was selected as Provost. As the Chief Academic Officer, he is responsible for academic programs across 13 schools and colleges including the College of Liberal Arts & Sciences, Schools of Medicine, Law and Dental Medicine. At UConn, he has worked closely with administrators and faculty to develop significant programs through the $1.5B Next Generation Connecticut as well as the $172M Technology Park initiatives to grow programs of excellence in science, technology, engineering and mathematics.

Dr. Choi's research effort is focused on advancing the understanding of sooting and radiation on combustion and soot diagnostic techniques. His research has been funded by various federal and industrial sponsors including the National Science Foundation, Department of Energy, NASA, and the Department of Education. In addition, his NASA project on combustion efficiency and fire safety is currently being performed aboard the International Space Station.

He has received numerous recognitions for his contribution to research, education and outreach including the Society of Automotive Engineer Ralph R. Teetor Award, the University of Illinois System-Wide Scholar Award and Fellow status of the American Society of Mechanical Engineers. In 2007, he was elected President of the Pi Tau Sigma Int'l Honor Society for Mechanical Engineers.

PRESENTER BIOGRAPHIES

Chang-Jin (CJ) Kim
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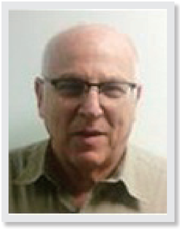
Professor CJ Kim received his B.S. from Seoul National University, M.S. from Iowa State University, and Ph.D. from the University of California at Berkeley, all in mechanical engineering, and joined the faculty at UCLA in 1993. Directing the Micro and Nano Manufacturing Laboratory, his research is in MEMS and Nanotechnology, including design and fabrication of micro/nano structures, actuators and systems, with a focus on the use of surface tension.

The recipient of the Research Excellence Award (Iowa State Univ.), TRW Outstanding Young Teacher Award (UCLA), NSF CAREER Award, ALA Achievement Award, Samueli Outstanding Teacher Award (UCLA), and Ho-Am Engineering Award, Prof. Kim has served on numerous professional and governmental committees and panels in MEMS and nanotechnology, including General Chair of the 2014 IEEE International Conference on MEMS. An ASME Fellow, he is currently serving as Senior Editor of the IEEE Journal of MEMS; on the Editorial Advisory Board for IEEJ Transactions on Electrical and Electronic Engineering; and on the International Steering Committee of IEEE MEMS. He has also been active in the commercial sector, as a scientific advisor, consultant, and founder of start-ups.

PRESENTER BIOGRAPHIES



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Alion Science and Technology
Alexandria, USA

Dr. Karni served as Chief Engineer of naval vessels reaching the position of the Head of the Marine Engineering Department within the Israeli Naval Service from 1965 to 1983. In 1986 Dr. Karni received his Ph.D. in Naval Architecture and Marine Engineering from the University of Michigan, Ann Arbor. Upon completion of his graduate studies, Dr. Karni joined John J. McMullen and Associates (later, Alion Science and Technology) as a Senior Project Engineer.

Dr. Karni has over 40 years of experience in various disciplines of Naval and Marine Engineering, Including experience as an onboard operator, designer, engineer and manager. He has lead multiple programs, studies and advanced analysis projects. Over the past ten years, Dr. Karni has dedicated much of his time to promoting and integrating advanced technologies, contributing to the international advancement of Total Ship Survivability, Propulsion Systems Integration and Design-Implementation Programs.

Dr. Karni currently manages the International Business Development for Alion and maintains customer relations in over 15 countries including South Korea, India, Israel, Greece, Turkey, Canada, Singapore, and others.

PRESENTER BIOGRAPHIES

Matthias Hänsel

Chairman International Cold Forging Group (ICFG)
Division Manager ThyssenKrupp Presta Steering Group
Liechtenstein

Dr. Matthias Hänsel was born 1962 in Essen/Germany. He is married, has two sons and is living in Vaduz, Principality of Liechtenstein.

Dr. Hänsel studied Manufacturing Technology at the University of Erlangen-Nuremburg from 1982 to 1988. During his master program he focused on cold forging technology and graduated with his Master Thesis in the field of numerical simulation of tool failure in 1988. Subsequently he became a research-assistant and co-worker of Prof. Manfred Geiger at the Institute of Manufacturing Technology at the same university. In spring 1993 he finished his academic research work with his PhD-thesis "FEM-Simulation of Fatigue Failure of Cold Forging Tools", which was part of a large national research program in collaboration with 7 other institutes, financed by the Volkswagen Foundation.

After leaving university he started his professional career as a profit center manager at Krupp Presta, an international leading company in the field of precision cold forging located in the Principality of Liechtenstein. After becoming vice director and head of the research and engineering department of the cold forging division in 1998, he took over the tool shop factory of the company as director in 2001. From 2004 until 2012 he additionally took over the responsibility for the departments of quality, purchasing and business process management of the cold forging division and in 2010 started to build up the company`s own education center at the headquarter in Liechtenstein, which today is training 100 young apprentices.

Apart from the tool shop factory and the education center, Dr. Hänsel today is responsible for the global laboratory organization of ThyssenKrupp Presta Steering Group, which meanwhile has developed to an international supplier of steering systems for the automotive industry with 7000 employees, 19 locations and an approximate turnover of 2 billion Euros per year.

Parallel to his professional career at ThyssenKrupp Presta, Dr. Hänsel always stayed closely related with the global community of academic research in the field of precision cold forging and tool life, publishing more than 50 papers and giving lectures at many international conferences. Already since he started to work for ThyssenKrupp Presta he was a member of the German Association of Engineers (VDI) in the Subgroup of Cold Forging, which later was renamed to the German Cold Forging Group (GCFG). He was contributing to prepare and to publish several technical documents and finally served as a board members of the GCFG from 2009 to 2011. In addition Dr. Hänsel is a member of the International Cold Forging Group (ICFG) since 1990. He was leading the subgroup Tool Life & Tool Quality for almost 10 years until 2011. From 2011 until today he is acting as the Chairman of the ICFG, actively promoting international technological cooperation in the community of cold forgers.

PRESENTER BIOGRAPHIES

Tae Won Lim

Vice President
Corporate R&D Division of Hyundai-Kia Motors
Korea

Dr. Tae Won Lim is responsible for the advanced research of Hyundai-Kia's R&D Division as head of Central Advanced Research and Engineering Institute.

After receiving his MS and Ph.D. degree in the Department of Mechanical & Aerospace Engineering, State University of New York at Buffalo, Dr. Lim joined Hyundai Motor Co. in 1991. He has been developing Materials for Powertrain as well as Environmentally Friendly Technologies including fuel cell, battery, three way catalyst, and recycle for 18 years. He had been the leader of Material Development Team for 3 years. In 2000, Lim took significant roles to establish the Fuel Cell development activities in Hyundai and served as the team leader of Fuel Cell Development team for 6 years. He was promoted to Director and Vice President in 2006 and 2013, respectively and has contributed to the development of the hydrogen Fuel Cell Electric Vehicle until 2013. After the world-first commercialization of Tucson ix 35 Fuel Cell Electric Vehicle in early 2013, Dr. Lim was transferred to Central Advanced Research and Engineering Institute to establish the advanced research activities inside of Hyundai-Kia as the Head of CAREI. Since 2013, Dr. Lim has been leading all research activities in the Next Generation Batteries, Solar Cell, SiC Power Module for EV and HEV, Autonomous Vehicle, Vehicle Ergonomics, Robots and New Materials and Surface Treatment.

PRESENTER BIOGRAPHIES

Seung Joo Choe
Executive Vice President & CTO
Doosan Heavy Industries and Construction
Korea

Seung Joo Choe received B.S. in Materials Engineering from Seoul National University, M.S. in Materials Science from Korea Advanced Institute of Science and Technology (KAIST) in 1978. Soon after the graduation, he began to work as Research Engineer in Korea Institute of Science and Technology (KIST) for three years. Then he received Ph.D. in Materials Engineering at Rensselaer Polytechnic Institute in 1985.

After the commencement, he had engaged in professional research field. He became Senior Materials Engineer at Textron Lycoming in USA and had worked from 1987 to 1993. Since he came back to Korea, he had worked at Korea Institute of Machinery and Materials as Principal Research Engineer from 1993 to 2000. After that he entered to Iljin Electric Co. as Managing Director of New Business Development for four years. From 2004, he joined Doosan Heavy Industries and Construction and finally acquired CTO (Chief Technology Officer) position, Head of Corporate R&D Institute in 2010. Currently, he is an executive vice president and CTO in Doosan Heavy Industries and Construction and a member of National Academy Engineering of Korea.

His major research interest is gas turbine hot section materials – alloy development and processing, and materials characterization and life prediction. He has had approximately 20 years' experience in superalloy. His R&D activities include computer aided alloy design of nickel base superalloy, creep fatigue interaction of turbine disk alloys, mechanical characterization of gas turbine materials, forming of cast & wrought and powder processed superalloys, casting processes, and component life prediction. After joining Doosan Heavy Industries and Construction, he has been involved in the development of gas turbine, power plant equipment such as boiler and steam turbine, renewables such as wind turbine and fuel cell. In his entire research life, he has proposed numerous scientific publications as well. He has made over 50 research publications and 40 presentations.

Masahito Yamanaka

President
Yamanaka Engineering
Japan

Masahito Yamanaka received B.S. in Mechanical Engineering from the college of Science and Technology, Nihon University in 1989 and M.S. in Mechanical Engineering under the guidance of Prof. Taylan Altan from the Ohio State University in 1994.

He joined Yamanaka Eng Co. since 1989 and has accumulated deep technical experiences in design and manufacturing of precision forging tools. From 1996 to 2010, he served as managing director for engineering and manufacturing departments. He became the president of Yamanaka Eng Co. in 2010.

He served as a board member of the Japan Society for Technology of Plasticity (JSTP) from 2009 to 2011. Also, he has been a board member of the Japan Forging Association (JFA) from 2010, a board member of Osaka Prefectural Manufacturing & Industrial Association from 2011, and a board member of Japan Die and Mold Industry Association from 2014.

From 2001, he has attended the International Cold Forging Group (ICFG) and actively contributed in promoting international technological exchange between academia and industries in the cold forging field. From 2009 to 2014, he served as one of co-chairmen for the Tool Life and Tool Quality subgroup of ICFG and made valuable progress in exchange of technical and practical information for the important issues in this field. He has been a member of Advisory Board from 2008 and inaugurated as Chairman of ICFG from this year.

PRESENTER BIOGRAPHIES

Albert Pisano

Dean
Jacobs School of Engineering
UCSD
USA

Albert Pisano is an elected member of the National Academy of Engineering for contributions to the design, fabrication, commercialization, and educational aspects of MEMS.

Prior to his appointment at UCSD, Pisano served on the UC Berkeley faculty for 30 years where he held the FANUC Endowed Chair of Mechanical Systems. Pisano was the senior co-director of the Berkeley Sensor & Actuator Center (an NSF Industry-University Cooperative Research Center), director of the Electronics Research Laboratory (UC Berkeley's largest organized research unit), and faculty head of the Program Office for Operational Excellence, among other leadership positions. Since 1983, Pisano has graduated over 40 Ph.D. and 75 M.S. students.

From 1997 to 1999, Pisano was a program manager for the MEMS Program at the Defense Advanced Research Projects Agency (DARPA).

Pisano earned his undergraduate ('76) and graduate degrees ('77, '80, '81) in mechanical engineering at Columbia University. Prior to joining the faculty at UC Berkeley, he held research positions with Xerox Palo Alto Research Center, Singer Sewing Machines Corporate R&D Center and General Motors Research Labs.

Pisano's research interests include: micro-electro-mechanical systems (MEMS) wireless sensors for harsh environments (600°C) such as gas turbines and geothermal wells; and additive, MEMS manufacturing techniques such as low-temperature, low-pressure nano-printing of nanoparticle inks and polymer solutions. Other research interests and activities include MEMS for a wide variety of applications, including RF components, power generation, drug delivery, strain sensors, biosensors, micro inertial instruments, disk-drive actuators and nanowire sensors. He is a co-inventor listed on more than 20 patents in MEMS and has co-authored more than 300 archival publications.

Pisano is a co-founder of ten start-up companies in the areas of transdermal drug delivery, transvascular drug delivery, sensorized catheters, MEMS manufacturing equipment, MEMS RF devices and MEMS motion sensors.

PRESENTER BIOGRAPHIES

Ching-Ming Chen
Vice President
Metal Industries Research and Development Centre
Taiwan

Ching-Ming Chen received his B.S., and M.S. in Mechanical Engineering from National Chung Hsing University and National Taiwan University respectively, and Ph.D. in Engineering Science and Technology from National Kaohsiung First University of Science and Technology. He also obtained the certification of project management from International Project Management Association in 2007.

He joined the Metal Industries Research and Development Centre (MIRDC)* in 1986 and was promoted from engineer, chief of Industrial Service Division, director of Taipei Branch, Regional R&D Service Department and Industrial Upgrading Service Department to vice president. During his 29 years with MIRDC, he is specialized in the management, metal forming, mold & die, testing and certification, business models, aviation, and medical device.

In the meantime, he also serves as chief project director of many key projects (supported by government) in the fields of heavy transportation industries, biotech & medical device industries cluster, the quality harmonization on cross-strait medical devices, industrial mold technology, DC brushless motor's drive & control technology, and the innovative service models, etc. He leads R&D teams to conduct the development of key technologies, products and industrialization in the related fields.

Additionally, he is appointed as director of Committee for Aviation Industry Development, Ministry of Economic Affairs. He is proactively engaged in interaction with the industrial associations and has been served as secretary general of Chinese Testing and Certification Association, director of Taiwan Aerospace Corp, PIHSIANG Machinery MFG. Co., Ltd, and Taiwan Implant Technology Co., Ltd. He also serves as vice chairman of Straits Technology Exchange Association, standing supervisor of Welfare Organization for the Elderly, Taiwan, R.O.C., as well as managing director of Asia Pacific IOT Association.

** Metal Industries Research and Development Centre (MIRDC) was established in 1963 by the United Nations and is one of major research institutes with focus on metal and its related technologies, including medical device and care, automotive mainly for chassis, mold & die micro machining for electronics products and micro parts, metal fabricated products, high value-added equipment for semi-conductor, energy and biotechnology. MIRDC implements 1,200 projects, trains 14,000 persons and also completes 18,000 cases of test and certification annually.*

PRESENTER BIOGRAPHIES

Yong-Taek Im
President
Korea Institute of Machinery and Materials
Korea

Yong-Taek Im received B.S. in Mechanics and Design and M.S. in Mechanical Engineering from Seoul National University, and 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 research 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 to be a Fellow of American Society of Mechanical Engineers and the Korean Academy of Science and Technology, and full member of National Academy of the Engineering of Korea. He is also a board member of Korea Polytechnic University.

Prof. Im received various awards such as F. Staub Award, Johnson Gold Medal, GCMM 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. Currently, he is President of Korea Institute of Machinery and Materials.

EDITOR BIOGRAPHIES

Chae Whan Rim
Head
Department of External Relations / Department of Technology Commercialization
Korea Institute of Machinery and Materials
Korea

Chae Whan Rim is the Head of Department of Department of External Relations and Department of Technology Commercialization, Korea Institutes of Machinery and Materials (KIMM)

He received B.S. in Naval Architecture and Marine Engineering in 1980 and M.S. Naval Architecture and Marine Engineering from Seoul National University, and Ph.D. in Naval Architecture and Marine Engineering at the University of Michigan in 1993. He received Distinguished Award at the graduation.

Before studying at University of Michigan in 1988, he worked as a researcher at KIMM in the field of analysis of structural behavior of various ships, and designing fishery boats and multipurpose containerships. After receiving Ph.D., he had participated projects such as ultra large containership, high speed ship, slamming load prediction, design of arctic going ship. He also performed many measurements on ship and on board tests. Recently, he is interested in renewable energy that he designed a floating wind turbine and developed a small wind turbine.

Now he is focusing on the transfer and commercialization of technology developed by KIMM. To fulfill the job, he got certificates of technology evaluation and technology management.

EDITOR BIOGRAPHIES

Hee-Chang Park

Director
Division for R&D Commercialization & Cooperation
Korea Institute of Machinery and Materials
Korea

Hee-Chang Park received M.S. in Electronics from Dongkuk University, and Doctorate in Electronics at Dongkuk University in 1988. He received Computer System training at CICC Japan during April until October of 1986 and Technical training at Illinois Institute of Technology(IIT) at 2007.

After receiving the master degree at Dongkuk University, he joined Korea Institute of Machinery and Materials at 1982. Starting form 1997 until now, he is the principal researcher in KIMM at the Robot-Mechatronics Research Group. He has accumulated research achievements from developing the Induction Heating Roll and the Cold Crucible Induction Melter System (CCIM).

At July of 2013, he served as Head of the Corporate Technology Support Department, making a technical support system for small and medium size enterprises and also achieved the royalty incentive goal of 5.5 billion Korean won. He served as the Director of the Technology Commercialization Center at June 2014, achieving 6.4 billion from the royalty, which was the greatest amount of royalty at that year.

Dr. Park has received the Development of merit from the Prime Minister at the 2009 Machine's Day. Currently, he is Principal researcher and the Director of the R&D Commercialization & Cooperation Division of KIMM managing technology commercialization and external affairs of the institute.

OPENING REMARKS

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

On behalf of the Korea Institute of Machinery and Materials (KIMM), I am pleased to welcome you all to the second International Forum Korea on Advances in Mechanical Engineering (IFAME 2015) at KIMM, Daejeon, Korea.

KIMM, one of the national research institutes in Korea sponsored by the Ministry of Science, ICT, and Future Planning, launched the Forum last year with the goal of setting up new directions for research, development, and business (R&DB) in mechanical engineering to spur creative economy through development of science and technology.

At the forefront of the national R&DB efforts in mechanical engineering, KIMM has always been committed and dedicated to enhancing the welfare of humanity by developing and commercializing cutting-edge technologies. KIMM has keen interest in advanced manufacturing technologies where energy/environment, safety, and nanotechnology converge.

After the 2008 global financial crisis, countries around the world focused once again on advanced manufacturing and launched manufacturing development strategies. A country without having an advanced manufacturing industry cannot evolve into a global player anymore.

This year's theme of the Forum is advanced manufacturing technologies in various fields of mechanical engineering from academia, public research institutes, and industry from the US, Germany, Lichtenstein, Japan, Taiwan, India, and Korea. Invited speakers and panelists are Provost M.Y. Choi from the University of Connecticut, USA; Dean A. Pisano from the University of California at San Diego, USA; Prof. C.J. Kim from the University of California at Los Angeles, USA; Vice President C.M. Chen from the Metal Industries Research & Development Center, Taiwan; Vice President T.W. Lim, Hyundai Motor Company, Korea; President M. Yamanaka from Yamanaka Engineering, Japan; Executive Vice President S.J. Choe from Doosan Heavy Industries and Construction, Korea; Vice President Z. Karni from Alion Science & Technology, USA; and Division Manager M. Hänsel from ThyssenKrupp Presta, Liechtenstein.

Special talks will cover "Opportunities in additive manufacturing & advanced materials"; "The micro and nano fabrication technologies of MEMS"; "Creative economics through hyper-local manufacturing"; "A brief view into the future of precision manufacturing by cold forging"; "Technology innovations for future mobility"; "Doosan's efforts to develop power-gen technology"; "Challenge for sustainable growth: Innovative R&D and strategic international sales activities"; "Engineering as a force for the public good"; "The effort for innovation and globalization for small and medium enterprises in Taiwan"; and "Raison d'être of globalized public research institutes." After the invited talks, panel discussions on the development of advanced manufacturing strategies and their impact on the national economy and security will follow.

With your valuable participation and contribution to the Forum in many ways, advanced manufacturing technologies will be promoted to make sustainable future for mankind through various challenges and innovation.

I sincerely hope that IFAME 2015 will be a place for fruitful discussions and intimate networking among all of you and that your experiences here at KIMM prove to be pleasant, illuminating and memorable.

Thank you for your support for the Forum and I look forward to meeting you next year as well.

CONGRATULATORY REMARKS

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

Ladies and gentlemen, welcome. I am Sang Chun Lee and I am the Chairman of the National Research Council of Science and Technology, Korea.

My congratulations go out to KIMM for the successful opening of the 2015 International Forum Korea on Advances in Mechanical Engineering.

As the paradigm of manufacturing changes rapidly, nations around the world are competing to seize the manufacturing sector of tomorrow. Hence, the importance of mechanical engineering is growing, as it forms the foundation of all manufacturing.

I hope today's forum will help present a direction for the future of mechanical technologies, so that we may seek paths to next-generation developments in manufacturing, through information communication technology and convergence.

Thank you.

CONGRATULATORY REMARKS

Dr. Suk-Joon Lee, 1st Vice Minister of Science, ICT and Future Planning

I am honored to celebrate the 2015 International Forum Korea on Advances in Mechanical Engineering, held by the Korea Institute of Machinery and Materials.

The Daedeok research complex of Daejeon Metropolitan City is proud of being a Korea's hub for science and technology to spur the creative economy through their convergence. Therefore, it is particularly meaningful to gather here to discuss the evolution of mechanical engineering for the future, the foundation of all industries, and seek directions for public research institutions together with world-renowned scholars and experts in the field. This 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 with ever-changing times, we need to take a step ahead in adjusting ourselves to the new era of the 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 such fields converge together.

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

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

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

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

CONGRATULATORY REMARKS

Dr. Sang Kee Suh, Member of National Assembly of Korea

Good Morning. I am Sang Kee Suh, Member of the National Assembly of Korea.

I would like to express my sincere congratulations on the successful opening of the 2015 International Forum Korea on Advances in Mechanical Engineering. I also apologize for not being able to attend in person due to National Assembly duties, and I am sending this video message instead.

As a former President of the Korea Institute of Machinery & Materials (KIMM), having served for 6 years, and a colleague who worked together for its development, it is truly gratifying to see today's international forum, marking how far KIMM has come.

Mechanical engineering is a fundamental technology upon which key national industries such as manufacturing are built, as well as a convergent technology that can be applied to all industries. As you well know, the core of President Park Geun-hye's creative economy drive is to generate future industries through convergence. Mechanical engineering plays a crucial role here.

I hope today's forum becomes an opportunity to promote awareness of the importance of mechanical engineering as well as exchange among industries, academia, and research institutes in the field.

I ask everyone present to keep up your diligent efforts to develop future-shaping technologies through continued innovation. I will do my part at the National Assembly, sparing no efforts to support the development of mechanical technologies.

I once again offer my heartfelt congratulations for the successful organization of the 2015 International Forum Korea on Advances in Mechanical Engineering.

Thank you.

CONGRATULATORY REMARKS

Mr. Sang Min Lee, Member of National Assembly of Korea

Good Morning, Ladies and Gentlemen, I am Representative Sang Min Lee.

I would like to welcome everyone here today and extend my congratulations upon the opening of the 2015 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 welcoming event for a city that is proud to be the national hub for convergent research, 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 entire 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. 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 paradigms.

I hope all participants in this forum will freely exchange their ideas and opinions to discover core elements to lead 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 would like to congratulate today's forum on mechanical engineering and hope you all spend meaningful time here.

Thank you.

CONGRATULATORY REMARKS

Dr. Byung Joo Min, Member of National Assembly of Korea

I am very pleased to congratulate the 2015 International Forum Korea on Advances in Mechanical Engineering promoting the creation and innovation of mechanical engineering.

Global industry makes every effort to address increasing demands to shift the R&D paradigm from the fast follower approach to a first mover one. In the face of this pressure, the 2015 International Forum Korea on Advances in Mechanical Engineering holds great significance in its leading efforts to explore the issues of future mechanical engineering, and realize a Creative Economy through continuing innovation.

'Mechanical engineering' has contributed to driving the growth of industrialization of Korea as a strong foundation of the manufacturing industry. Mechanical engineering has 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 technology by analyzing the current status of the technologies required for every sector of our society.

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

I 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 research sectors. It is my hope that through this forum, they will all come to have the right answers to promote future development.

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

Once again, congratulations on the 2015 International Forum Korea on Advances in Mechanical Engineering.

Session 1: Advanced Manufacturing Technologies I

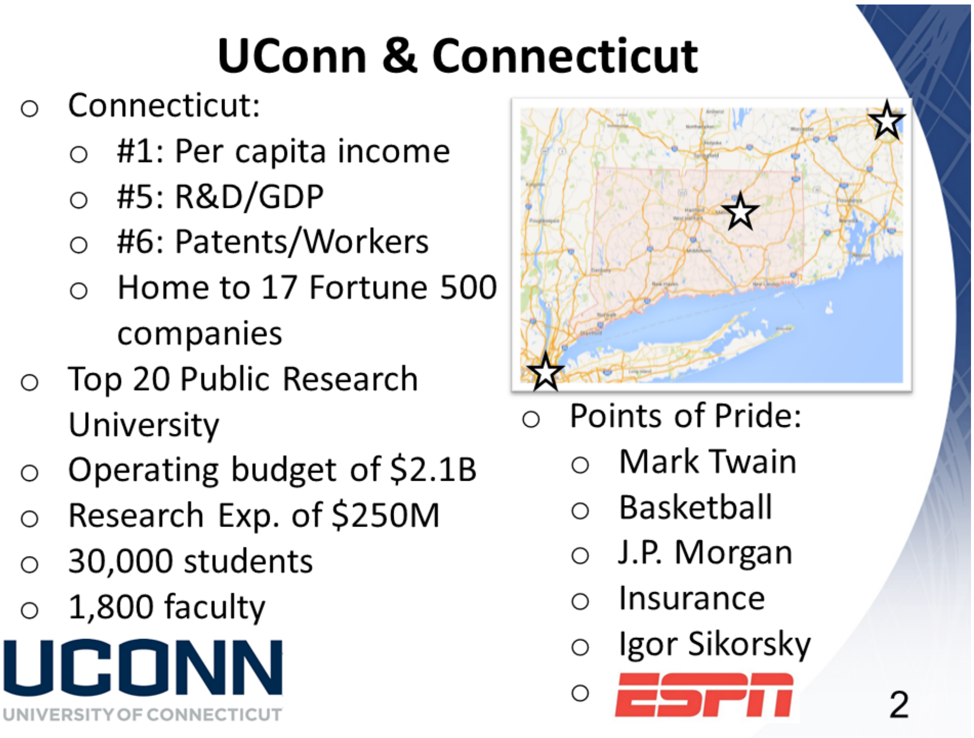
Opportunities in Additive Manufacturing & Advanced Materials

Mun Young Choi, Provost & Executive Vice President for Academic Affairs, University of Connecticut

Thank you, everyone. Good morning. My name is Mun Choi. I am from the University of Connecticut. I am a Korean-American, born in Korea in 1964. My family immigrated to the U.S. in 1973. Since then, I have been coming back on a number of occasions, and have been amazed by the progress that has been made in this country through the hard work of many individuals, especially those in the research institutes who made the technology implementation so useful. Congratulations.

As the introduction stated, I will be serving as the session chair for this session. This is the first of two sessions on advanced manufacturing technologies. We are going to hear some very exciting talks on topics ranging from additive manufacturing to advanced materials, MEMS development as well as cold forging and hyper-local manufacturing which are the topics that I think are going to be shaping a new paradigm in mechanical engineering. Before I start, I do want to recognize the fact that we have two former presidents of KIMM in the audience. First is Dr. Hae Woong Hwang. The other is Dr. Tae In Choi. Thank you very much for being here and your leadership throughout the years.

The first presentation that I will be making is a survey of some of the exciting developments in advanced manufacturing and additive manufacturing. It is a survey of some topics in which the U.S. has been making investments and that will open up some opportunities for us to develop very important international collaboration. I know that President Im has stated that globalization is a key for the types of activities that are being led by KIMM because collaboration and creativity will be developing the next generation of technologies that will benefit the society. We are very excited about that. My colleagues in this work are all materials scientists. I am a mechanical engineer. My job was to collect information from them and present it to you.



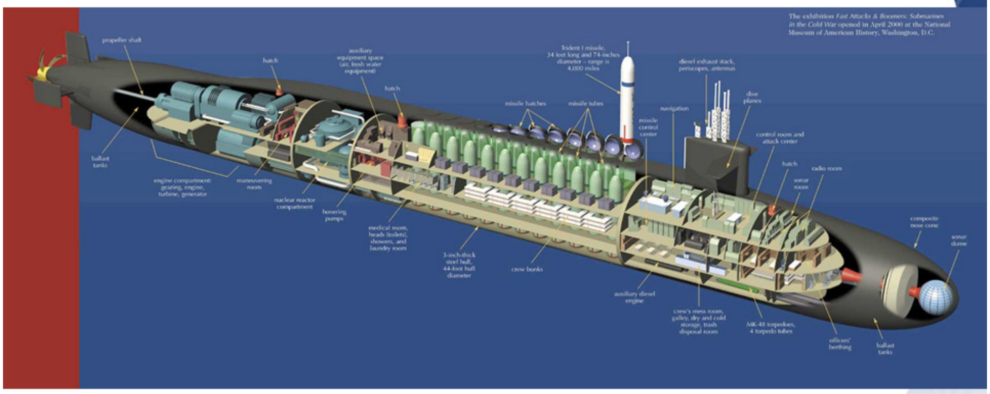
Many of you would probably want to ask, “Where is the University of Connecticut?” If you look at this slide, the University of Connecticut is located in the small state of Connecticut between New York and Boston. Our city is called Storrs. Even though Connecticut is a very small state, it is recognized as a state that has long been a leader in innovation in many ways. Back in the 1700s and 1800s, the Eli Whitney Gin was manufactured there. Since then, successive innovations including the helicopter, submarine, and the artificial heart were developed. On the cultural side, we also serve as the home to literary giants like Harriet Beecher Stowe and Mark Twain. For those of you who watch basketball and football, Connecticut is the home to the ESPN as well.

Our university is a top public research university that has ranked among some of the best universities including Purdue and Maryland. We have 30,000 students with an operating budget of 2.1 billion dollars. We have 12 schools ranging from Dental Medicine and Medicine to Law and Engineering. Our position is to grow STEM, i.e., science, technology, engineering, and math, through investments that are made by our very innovative Governor, Dannel Malloy.

When it comes to manufacturing, Connecticut serves as home to world headquarters of General Electric (GE). In Connecticut, their emphasis is on high-voltage transmission equipment as well as interconnect and charging station for electric vehicles.

You may also know Connecticut as the home of the United Technologies Corporation which operates Pratt & Whitney jet engines, Sikorsky, Otis Elevator, and Carrier.

Home to Manufacturing Innovations: General Dynamics



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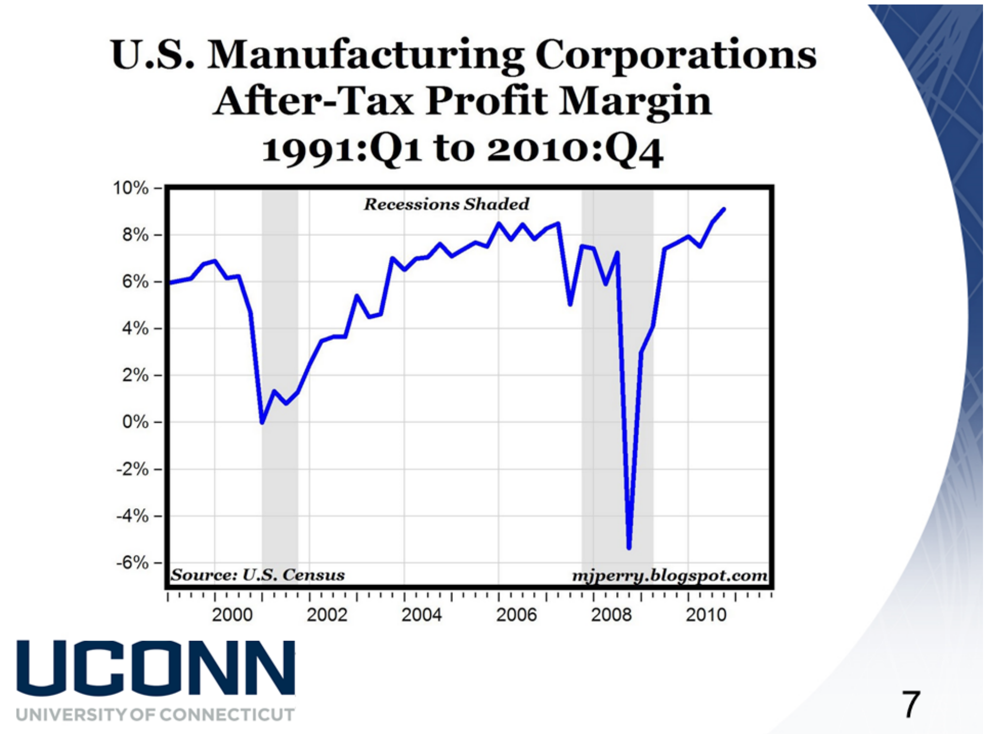
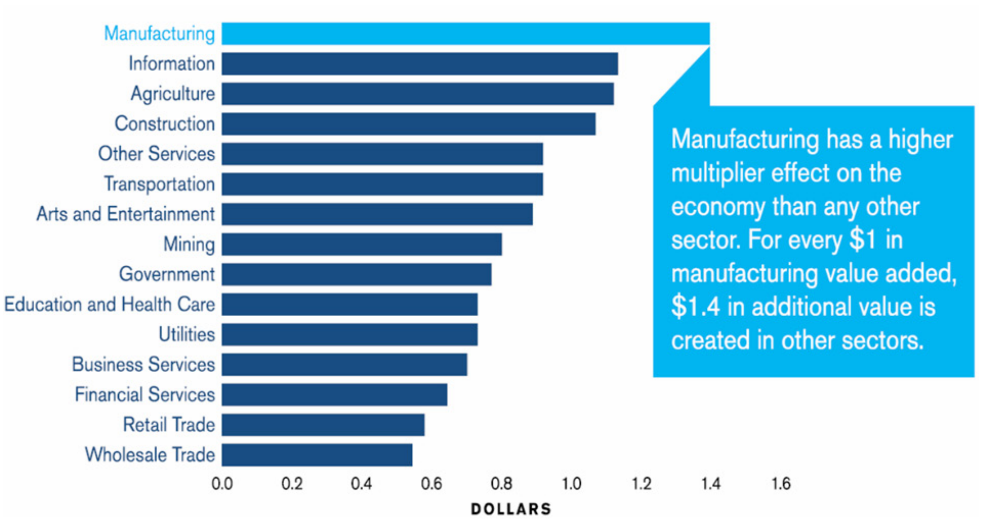
We also serve as one of two states in the U.S. that manufacture nuclear submarines. At General Dynamics Electric Boat, they manufacture both the Virginia-class attack submarines and the Ohio-class ballistic and guided missile submarines. The Ohio-class submarines are very complex pieces of equipment that cost about two billion dollars. That can manufacture two ships per year. Right now, General Dynamics working with the U.S. Navy and experts like Dr. Karni are developing the next generation of the Ohio-class replacement which will be in service by 2029. Being the only public university in Connecticut, we work closely with industries to develop not only workforce training but also research and development that make an impact in the marketplace.

The reason that manufacturing is still considered to be very important in the U.S., despite the loss of jobs, can be seen in the next few graphs. This graph shows manufacturing employment in the U.S. from the 1960s all the way to 2013. What you see in these gray bars is economic downturns, or 'recessions.' After each economic downturn, there is reduction, obviously, in employment in manufacturing. We see the most dramatic reduction at 2001. When politicians see graphs like these, they will immediately say that manufacturing is going away. However, that is not the case. If we look at where companies have made investments, it has been in areas like advanced manufacturing that utilize digital techniques and latest paradigms.



This graph shows after-tax profits of manufacturing firms that took a very big dip after the 2000 and 2008 recessions. They rebound. They are still making a profit despite the fact that the employment is going down, which means that productivity and the market share is going up.

Manufacturing's Economic Impact



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8

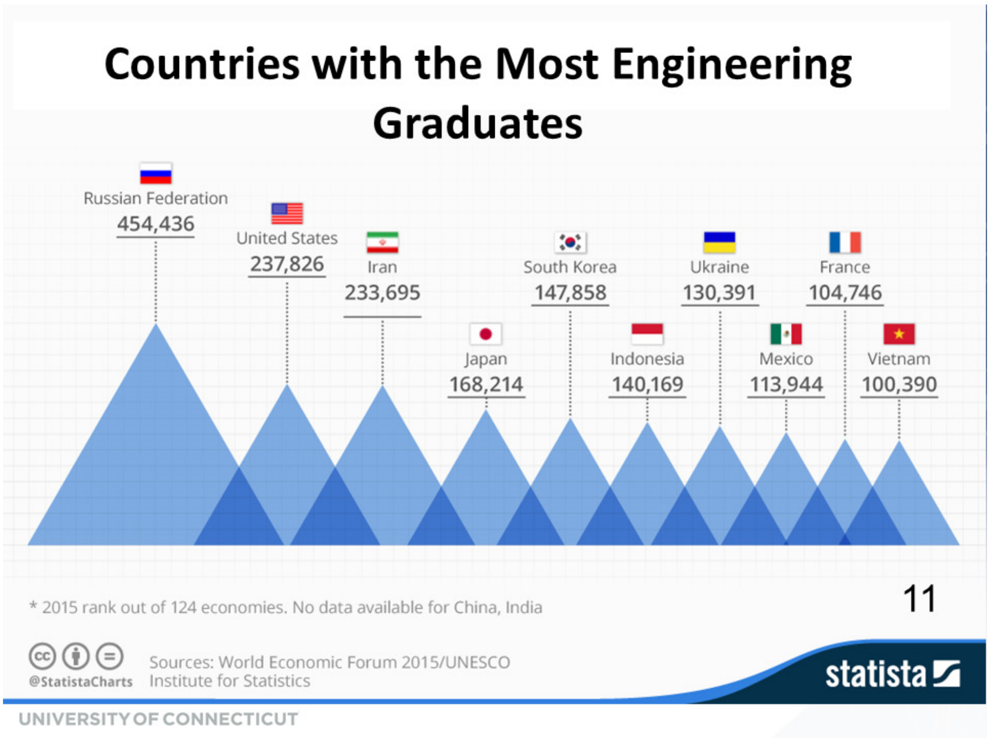
The reason that manufacturing is considered to be so key by the federal government as well as individual states is that there is a knowledge that there is a multiplier effect in manufacturing. What this chart shows is that, for every dollar of value that is created by investment in manufacturing, there is 1.4 dollars of attained value beyond that created value. If you compare this with other areas like service industries like financials, that ratio is one dollar to 70 cents. Therefore, every state and every leader wants to see more manufacturing growth, done in a very smart way, in their regions.

We also recognize that there are many dramatic changes that occurred. We all know about the First Industrial Revolution that occurred because of the advances made in the textile industries and the use of steam power for mining and transportation sectors. The Second Industrial Revolution occurred with the mechanization of the assembly line as perfected by Henry Ford. In each of these cases, the first and the second, there has been a focus on mass production to make the type of profits that companies were seeking.

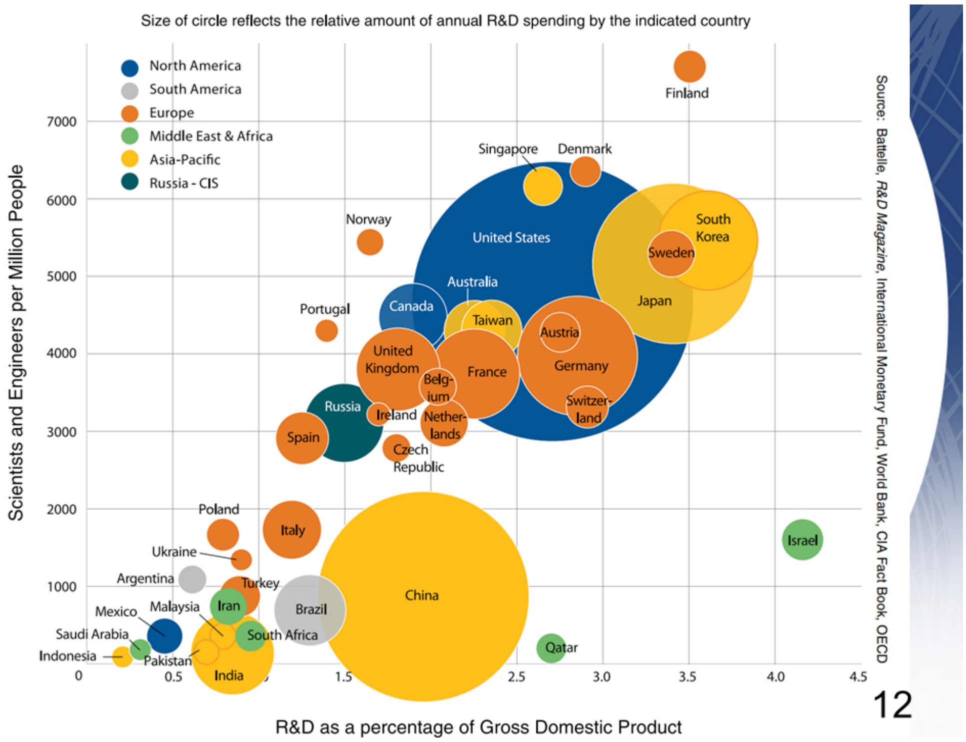
However, in the Third Industrial Revolution that is popularized by the 'Economist,' there is going to be a paradigm shift in which advanced materials, digital manufacturing and additive processes add greater value. The big key difference is that you do not need to have mass production to see those types of profits. In some cases, you will have the option of having one-to-one or buy-to-fly ratio which will be a dramatic paradigm shift. This will also cause many changes in the way we look at manufacturing. We are going to see more on-shoring of manufacturers because companies will not be seeking lower-wage nations to pursue their manufacturing.

Also, the idea that government will continue to pick winners and losers to subsidize industries that are important for national interest will eventually subside. We will also see many differences in which the companies that are going to be the new market-share leaders are going to be vying for that market-share leadership. Just like the dawn of the early automotive industry, there is going to be many losers and few big winners. Right now, that leveling of the playing field has not yet occurred. What is critical in all of this is creativity. Use of engineers, designers, marketing professionals, and so on all working in tandem is going to be the key.

Countries and states that make investments in engineering and science education will make a key difference in how they will pursue advanced manufacturing that leverages the industrial revolution.



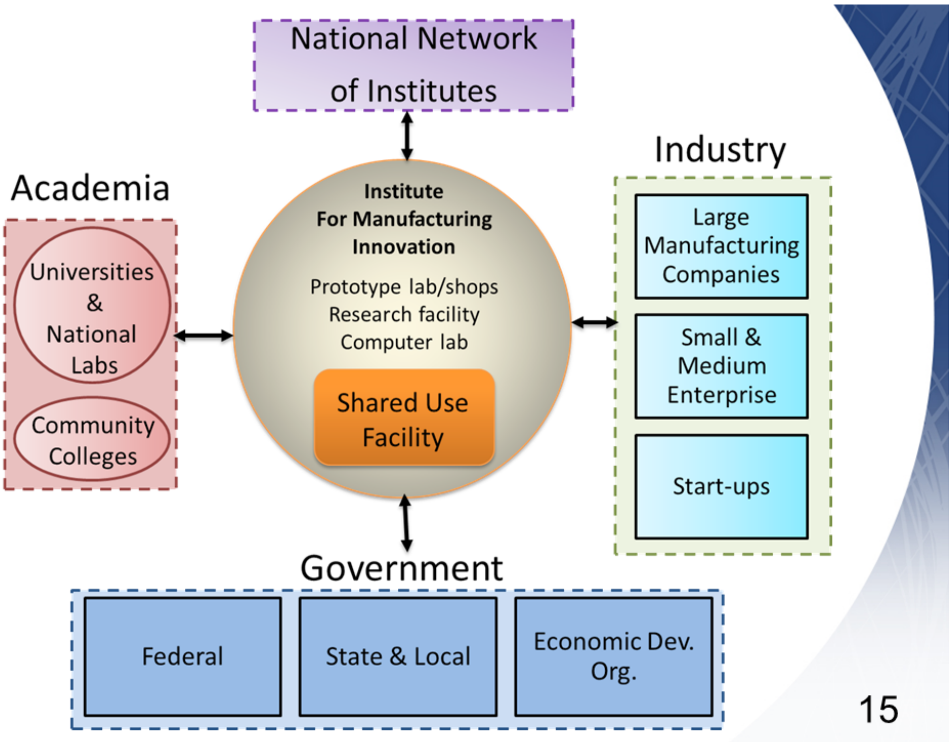
If you look at this slide, in 2015, the number of engineering graduates from these countries is shown. On this chart, it is very important to know that while the Russian Federation creates the highest number of engineers, Korea, based on the population, is second only to Iran in producing engineering graduates. Compare this with the U.S. where only one in 20 college students studies engineering. In Korea, it is one in four. However, just engineering is not enough. Continued investment and providing the opportunities for engineers and scientists to apply their craft is going to be very key.



Next slide shows the number of scientists per million people and R&D investment as a percentage of Gross Domestic Product. The size of the circles demonstrates the size of the investment that they are making. It shows here that with the exception of Israel, the percentage of investment is the highest for Korea, at 3.5%. This is really the envy of many countries around the world when they want to find out what has caused the Korean Miracle. It is this investment combined with the number of engineers that are graduating.

To leverage all these types of key investments that are needed in manufacturing, countries around the world are creating research centers. The most popular and most prominent are those that are in Germany: Fraunhofer and Helmholtz. In the U.K., they are also making investments through the Catapult Centers on topics that range from ceramics to high-value manufacturing. In the U.S., President Obama, early in his second term, developed plans for the National Network of Manufacturing Innovation (NNMI). Using Fraunhofer as a model, they are making investments that really carry new ways of manufacturing that can sustain the industries in the U.S.

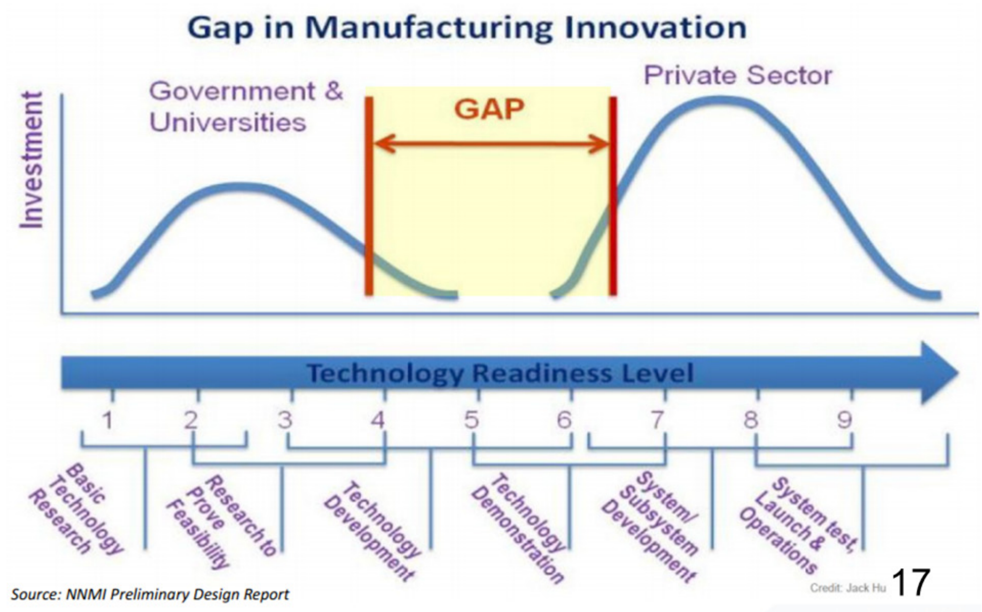
The goal of NNMI has many features, but, at the core, it is about advanced technology leveraging materials genomics, computation and design of materials, simulation of manufacturing processes as opposed to the Edisonian method and digital threading, especially of information that is generated throughout the process of manufacturing that can better leverage the time from design to actual launch. Last but not least, it is additive manufacturing of materials and components that is going to be the key. In order for this to succeed, we need to have policymakers, engineers, as well as marketing specialists all working in tandem, because their skills are going to be needed to overcome not only the technical challenges in finding new materials and new ways of manufacturing, but also societal changes. It is also because it is going to take a paradigm shift again for people to get used to additive or materials genomics that have not been practiced in mass quantities before.



The heart of the NNMI is collaboration with universities, government labs of both federal and state level and industries from large multinationals to small companies that serve the supply chain. The goal is to create new capabilities for manufacturing, help businesses that would otherwise not make that investment because of lack of resources and build a pipeline of talent. The core facilities are going to be the key because some of the equipment that is needed whether it is in digital manufacturing all the way to integrated photonics is going to require equipment-heavy investment. Therefore, to be able to share that facility as a consortium will make a key difference.

It also makes a big difference when you have federal agencies that are working in tandem with the White House and the Department of Commerce to make these investments together. Whether it is NASA, Department of Defense, Environmental Protection Agency, or National Science Foundation, each one of these organizations will co-invest in the institute so that they have their shares into the products and developments that come out of the institute.

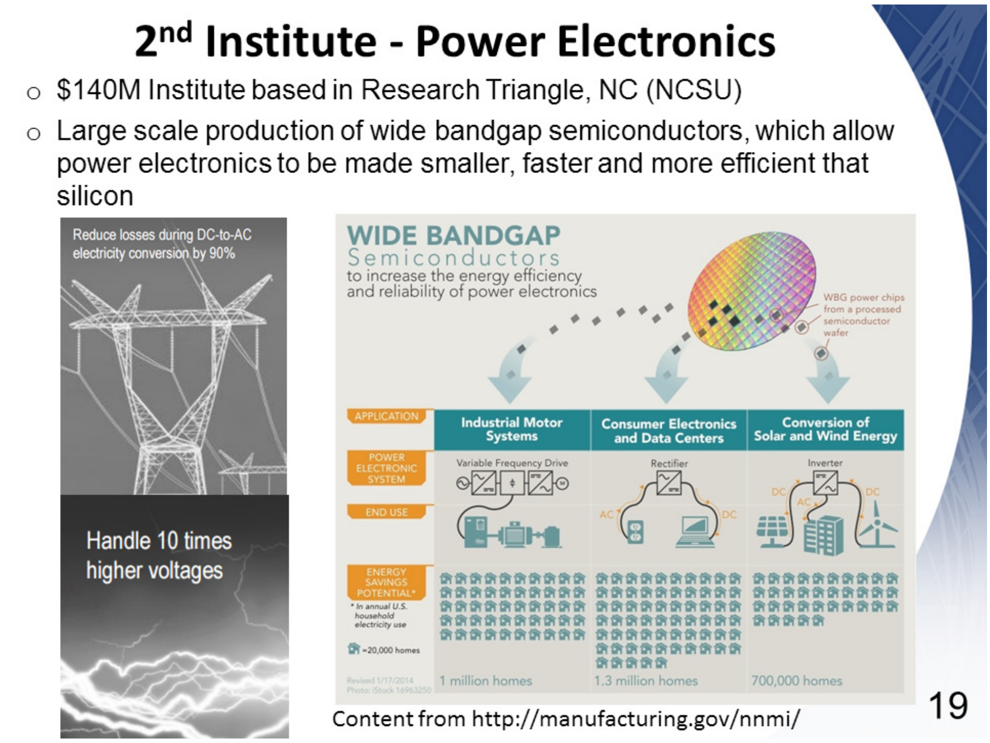
Manufacturing Scale-up Gap



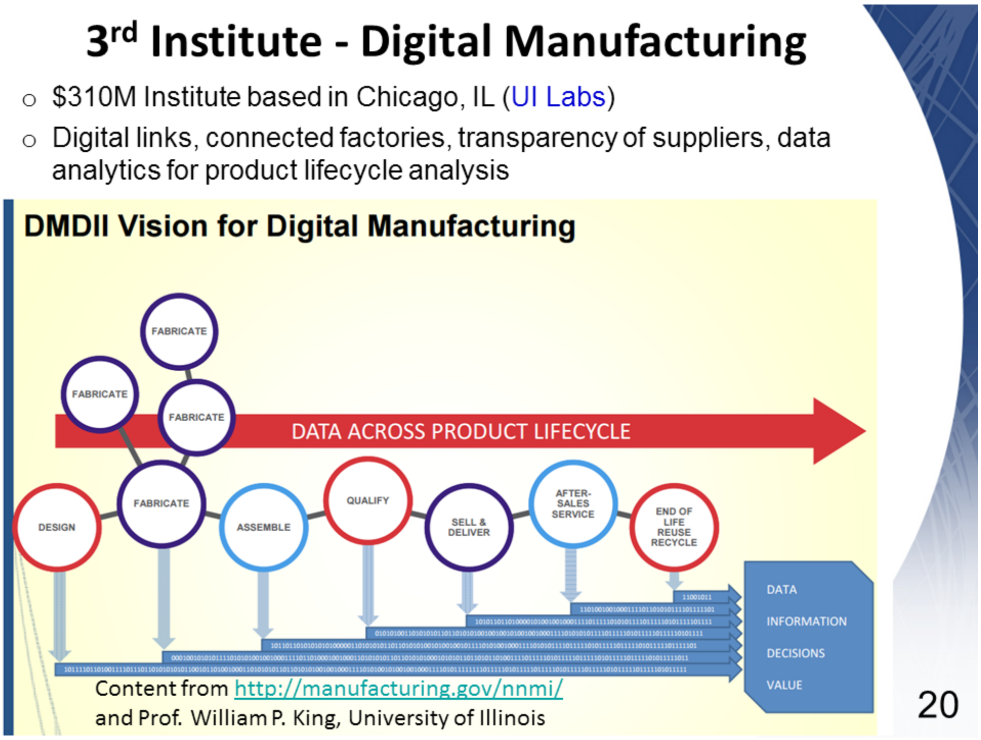
This chart shows the gap in manufacturing innovation. Governments and universities work in the early-stage development for the basic technology research at the low technology readiness levels (TRL), whereas private sector is great at product development using tested technologies at a higher TRL. The goal is to extend the government and university support for research in the TRLs from one to four and expand private support for TRLs of six and beyond to reach into the valley of death. The emphasis is to create advanced technologies for development to demonstration and to systems development, from which point the private sector will take over to the launch of products.

Let me share a few words about the institutes that have been selected. To date, there are seven institutes that have been established.

The first one is located in Youngstown, Ohio. It is called America Makes. It is a 110-million-dollar program that, at its core, is trying to determine the best ways to use metals-based additive manufacturing using modeling and simulation as well as developing new standards or certifying metal powders for use not only in powder metallurgy but also in additive technologies. The program also puts an emphasis on developing new standards and technology to assess the certification of the parts that are made. Imagine. When you have the same process that you use in a mass production part, you take samples to be able to certify and determine the certification of the products. However, in additive manufacturing, you are making up personalized one-offs in many cases. You do not have to test them each time to test that you have the right type of parts that you need.

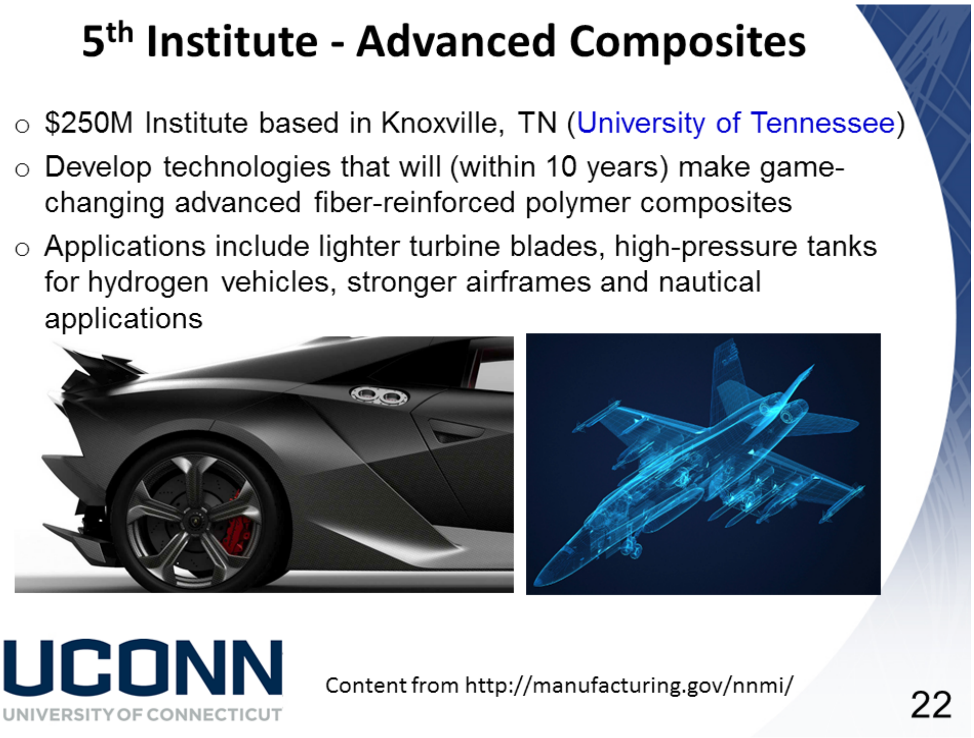


The second institute is based in Raleigh, North Carolina, as part of North Carolina State University. It is a 140-million-dollar institute that is focused on power electronics using wide-bandgap semiconductors. The goal is to develop these semiconductors that operate at much higher voltages, frequencies and temperatures. Some of the applications include reduction of losses from DC to AC conversion by 90% and handling higher voltages in the transmission lines by a factor of 10. The goal is to implement it in a variety ways of converting power from distributed generation like wind power and solar power and reducing the loss of that conversion. You can see, in that case, just by that conversion using the existing number of homes that are powered, we can increase the number of homes that are powered by 700,000.



The third institute is based in Chicago, Illinois. It is called the Digital Manufacturing Institute. They are looking at various ways in which data turns into information in which decisions can be made based on that information and value is created for the company. They take every single component of designing, fabricate using different components, assemble them and, throughout the lifecycle, use that data to be able to make an informed decision that leads to higher values. This project is a 310-million-dollar large activity based in manufacturing hub of Chicago.

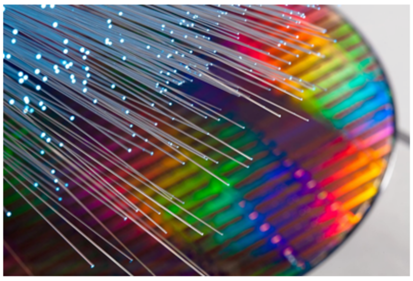
The fourth institute is based in Detroit, Michigan. It is an institute that will be looking at lightweight metals and how to use lightweight metals that can be improved in the process by selecting different powders, thermo-mechanical treatment of that metal. The goal is to use lighter metals that will have less impact on the environment, reduce the amount of materials used for that purpose as well as better understand how to reduce distortion and heat signatures that are created when you work with the lightweight metals.

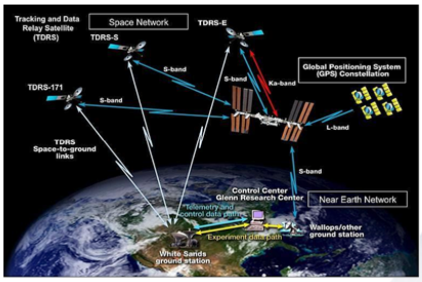


The fifth institute is based in the University of Tennessee. It has partnership primarily with the Department of Energy and Oak Ridge National Lab. The goal is to develop advanced composites that can be used in a variety of sectors including the energy sector, storing hydrogen and hydrogen vehicles all the way to vehicles that can be used in terms of better weight reduction and cost. The key goal by 2024 is to reduce the costs of manufacturing by 50%, the energy use by 75% and body structures and airframes by 60%. Now, imagine, for the aerospace industry in which the cost of fuel is so dependent on the weight of the aircraft, this could have a dramatic reduction.

6th Institute - Integrated Photonics NNMI

- $610M Institute based in Albany, NY (State University of NY)
- Ultra high-speed transmission of signals for the internet and telecommunications
- New high performance information-processing systems and computing
- Compact sensors for medical advances in diagnostics and treatments
- Multi-sensor applications for urban navigation to space communication and quantum information sciences





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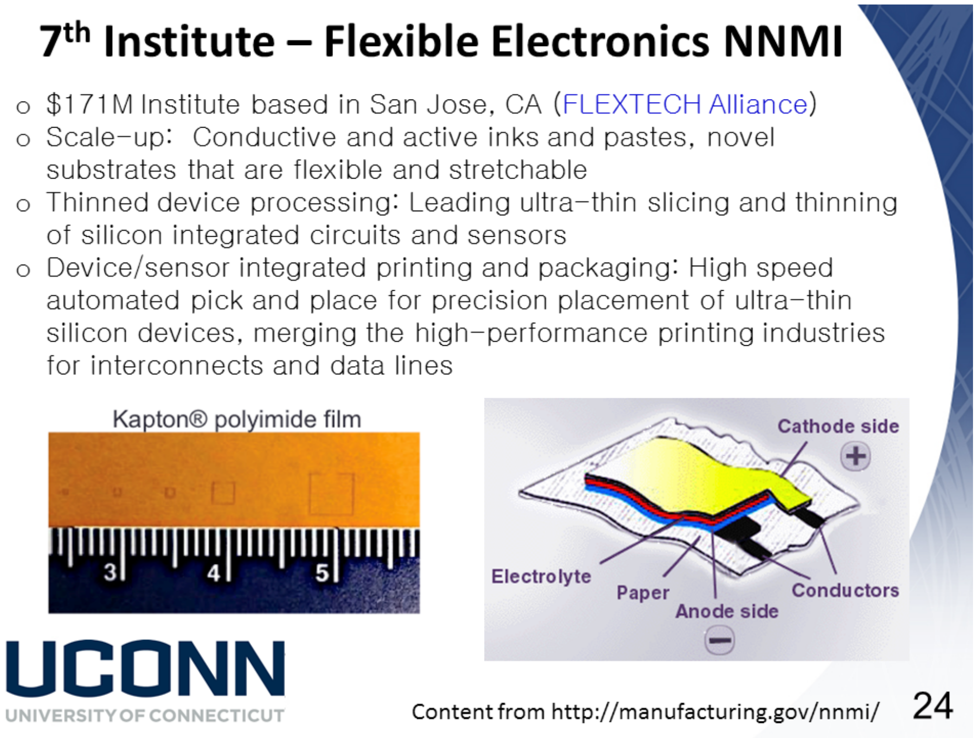
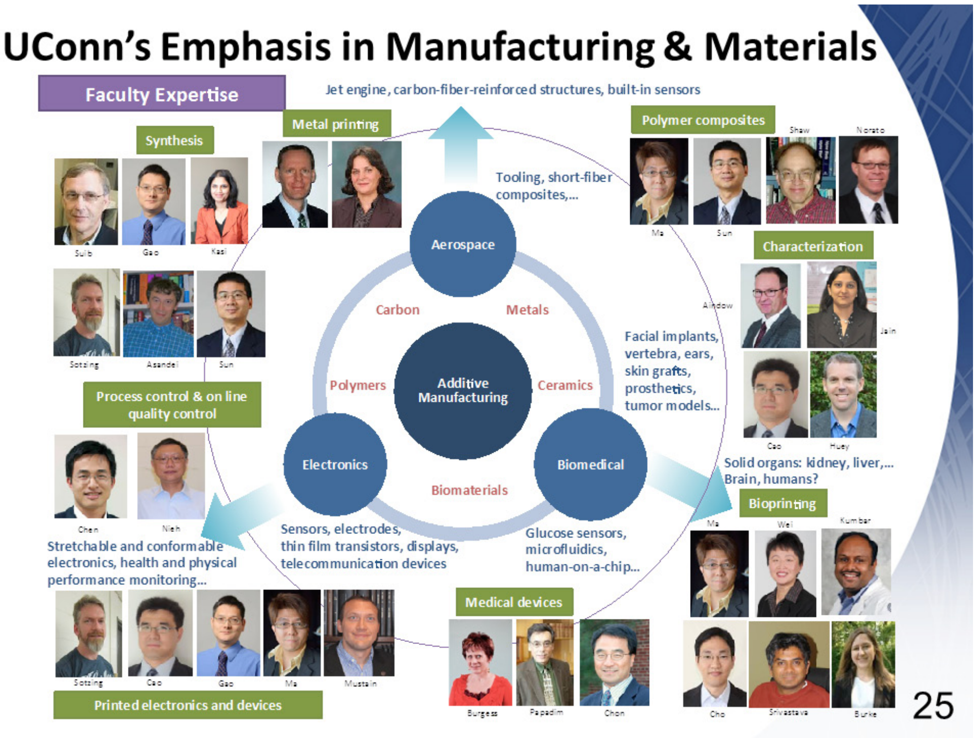
Content from http://manufacturing.gov/nnmi/

23

The sixth institute is based in the State University of New York at Albany. As you know, they have a very big SEMATECH research facility in that university. It is the largest of the NNMIs and is for integrated photonics. The goal is to take the photonics components such as lasers, detectors and waveguides and build that on a single platform that will reduce the number of interconnects and losses that occur through the interconnect. The goal for this is to enable high-speed transmission for telecommunications as well as Internet industry, and, eventually, use it for space communication. It is a very exciting topic.



The seventh institute, the latest one that has been formed, is based in San Jose, California. It is led by FlexTech Alliance. This has applications for additive manufacturing as well. The goal here is to develop very innovative novel pastes as well as adhesives and the type of flexible polymeric materials that can be printed on complex structures such as advanced batteries or capacitors that can be embedded into the thread or the fabric as well as metallic components that can be attached to complex geometries, e.g., an inlet for gas turbine blade. I am happy to report that this is a project that our university and the State of Connecticut will be partners on. Throughout the years by 2024, there will be a total of 45 different applications from different institutes throughout the U.S. The goal is that manufacturing will see a new renaissance because of this investment.

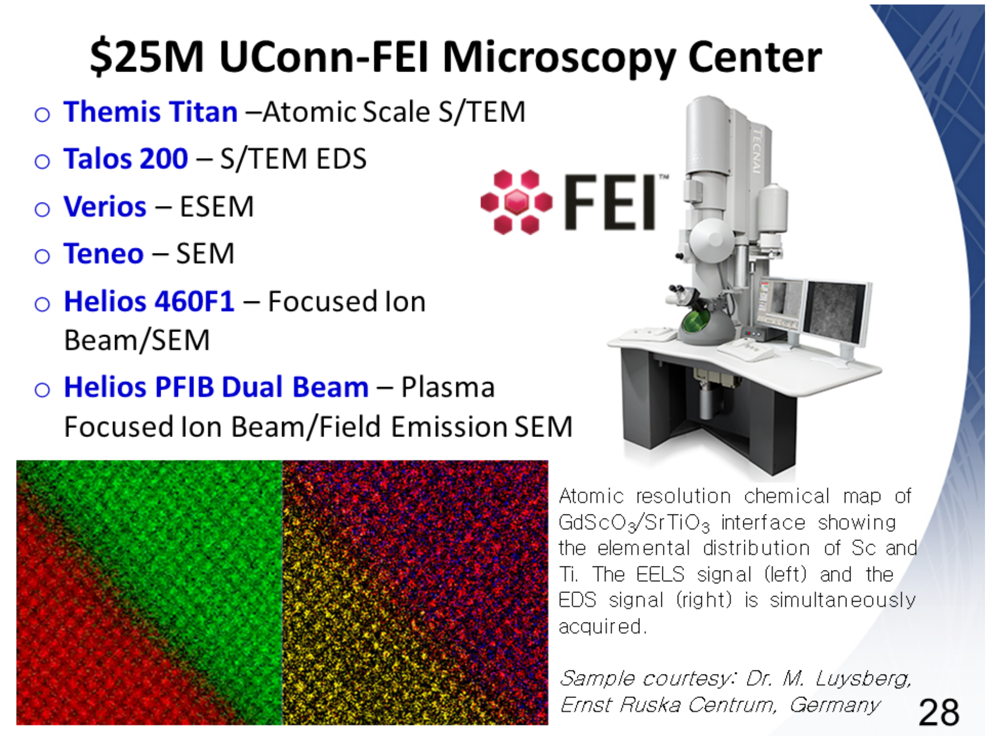


At our university, we have about 35 faculty members that are working on various areas of additive manufacturing and advanced materials. They are comprised of faculty from electrical engineering, mechanical engineering and materials science. The key goal is to develop the types of devices and components using carbon, polymers, metals-based materials as well as bio-materials to develop new inventions that can be used for gas turbine blades, actual tissue engineering, etc. We are very excited about the direction that we are taking.

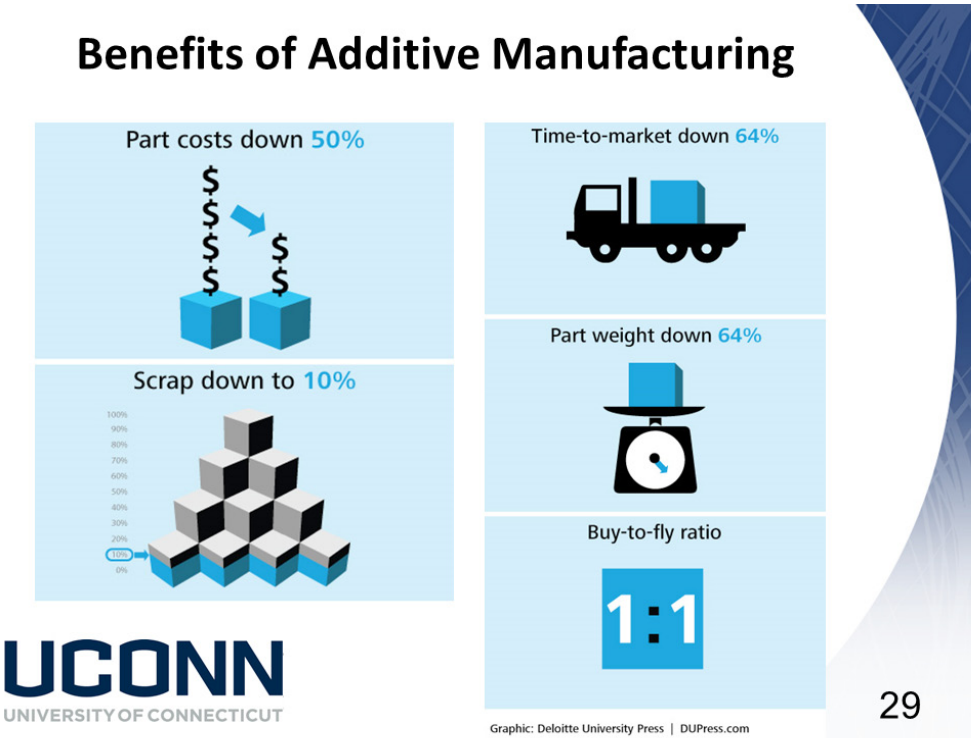
We also work with the Governor of Connecticut who is very innovative. During the past five years, he has invested three billion dollars in our university. Two key investments in facilities is the Innovation Partnership building and the Engineering and Science building. Using these facilities, we will be able to develop the types of partnership with industry.

Our industry partners have stepped forward. With GE, we are working on replacement for polymers that are used in high-voltage transmission line as well as circuit breakers. With United Technologies, we are developing advanced systems engineering that better aligns to design, analysis, testing and certification that can be used to reduce the design time of manufacturing systems. With the Fraunhofer Center, we are working closely with the two large fuel cell manufacturers that have Korean connection, Doosan Fuel Cell America and POSCO Energy, to develop advanced catalyst and reforming technologies. We also have an interest in developing advanced batteries as well as fuel cell catalyst.

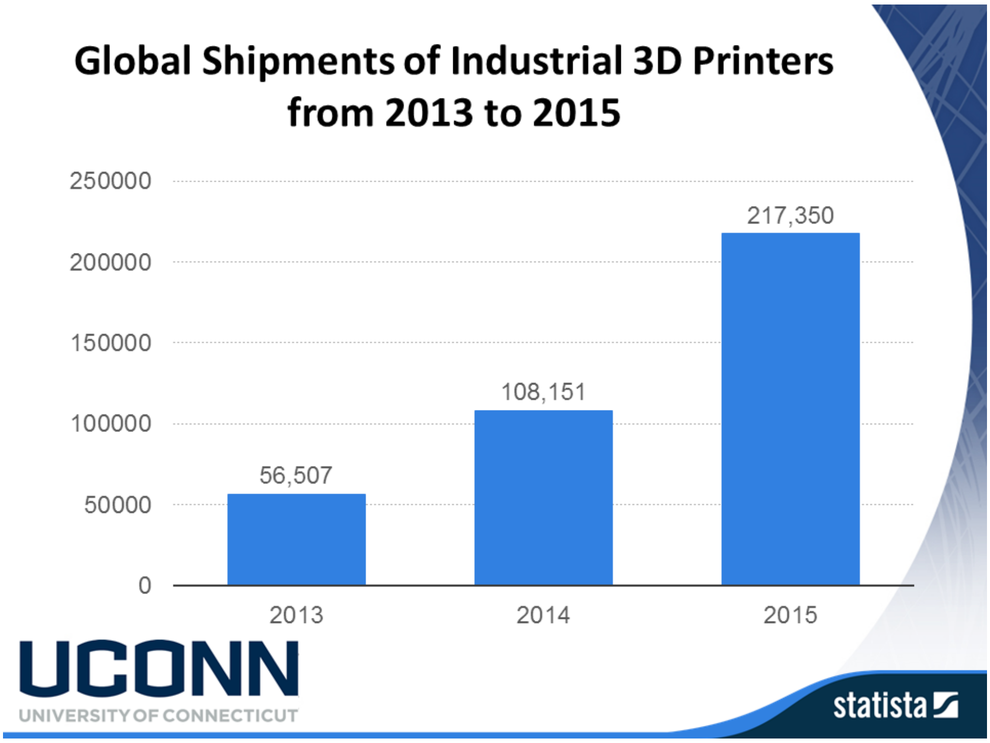
The most closely linked activity is the 7.5 million-dollar Pratt & Whitney Additive Manufacturing Innovation Center. As part of this, we are working with their engineers to better understand the role of sintering, melting and powder selection, and developing new types of metal powders that can be used to develop components such as the brackets that are shown here as well as stator components that can be used within a gas turbine engine. The ultimate goal is to take these components and assemble them or even make it as a single piece to replace the types of complex geometries that are required with an engine like this.



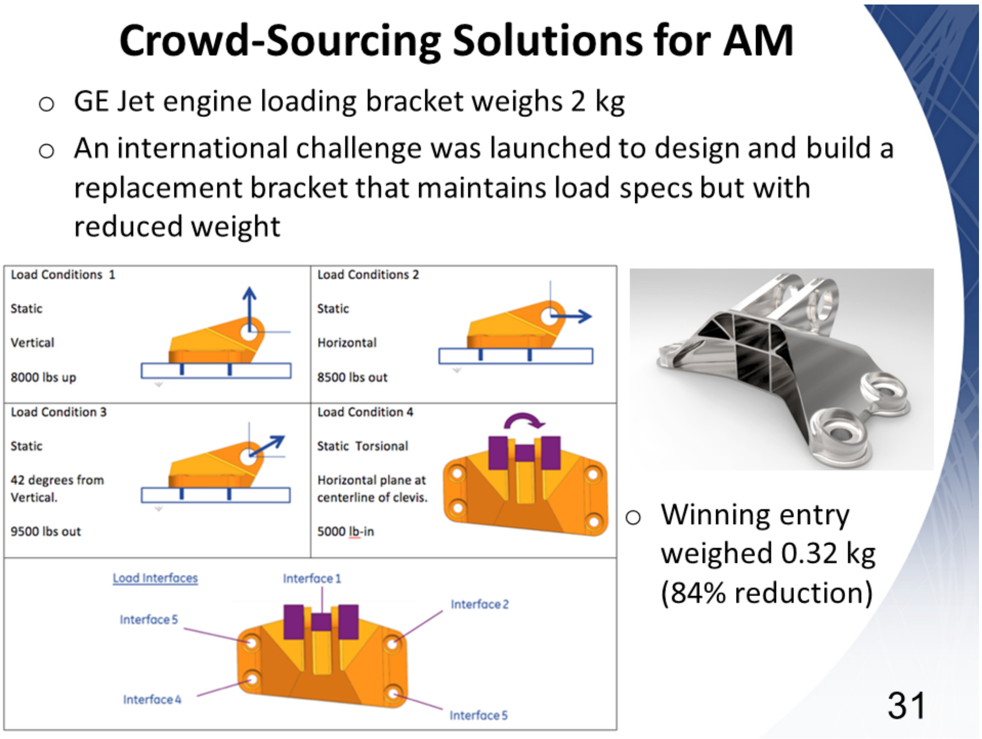
We are also very excited to hear the announcement that Pratt & Whitney formed an alliance with Field Emission Inc. (FEI), the world's largest manufacturer of electron microscope. We are going to purchase seven pieces of equipment ranging from scanning, electron microscopes all the way to Plasma Focused Ion Beams (PFIBs). The goal is to be able to measure material properties using both Electron Energy Loss Spectroscopy (EELS) and Energy Dispersive Spectroscopy (EDS) as well as picometer-level imaging to better understand how these parts are formed.



Although it sounds like it is a great idea, we need to quantify the benefit, the real advantage of additive manufacturing. Right now, the benefit is not understood fully by everyone. If we look at this chart from Deloitte Consulting, it shows that, by using additive techniques, we can reduce the number of parts by 50% and scrap metals, especially compared to a top-down, or subtractive approach, can be reduced by 10%. The time to market can be reduced by 64% because you can design and fabricate without mass retooling. All of these factors come into the value proposition of additive manufacturing.



If we look at the number of additive manufacturing equipment ranging from the low-end printers to high-end metal-based printers, that number has been skyrocketing. By 2018, it is estimated that the amount of investment and the market share that will be generated by additive manufacturers will top five billion dollars. That market is on its way to becoming a much larger market.

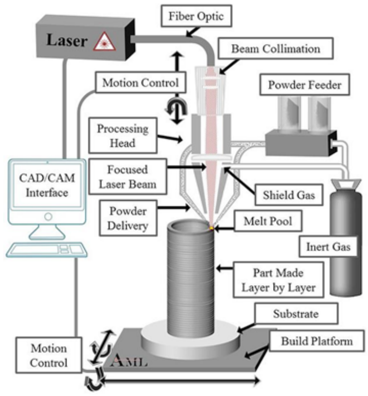


Since design can be done anywhere, it does not have to be done by specialists within that company, and the collaboration using crowd-sourcing approach can be very exciting. This is the case in which GE launched a challenge to redesign the bracket for one of their jet engines. The bracket looks similar to that and currently weighs two kilograms. It shows all the load conditions here. By making this available to crowd-sourcing, they received 640 submissions from throughout the world. The one that was selected was a young Indonesian engineer who was running a two-person design firm. Using his technology, he was able to design a bracket that meets all of the functional loads in the old design and reduce the weight by 84%. Once again, reducing weight of the aircraft is going to be a key metric for reducing the cost of operations.

In this slide, from GE, you will see that this is a housing for temperature as well as pressure measurement that leads to the high-pressure compressor of the GE engine. This is the first part that has been certified to actually fly in a commercial jet engine using additive technology. On the right hand side is the fuel injector for GE LEAP engine which used to be made by 20 separate components that had to be assembled. Now, it is manufactured as a single part using additive manufacturing.

Key Techniques in Additive Manufacturing

Directed Energy Deposition

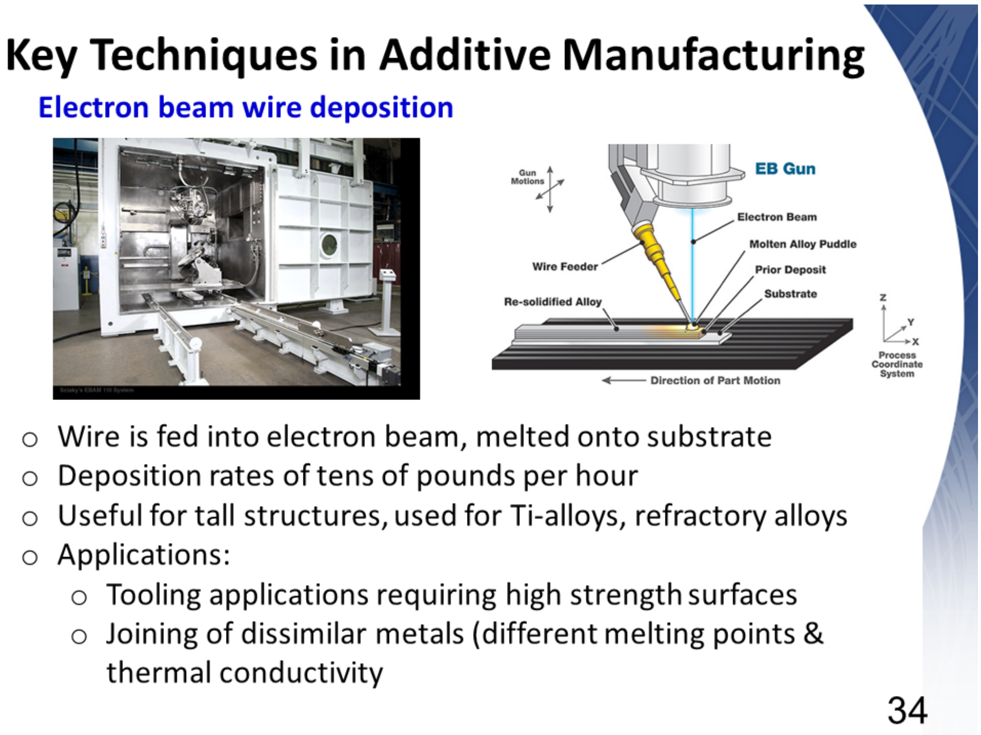


From Optomec and www.additivemanufacturinglaboratory.com/

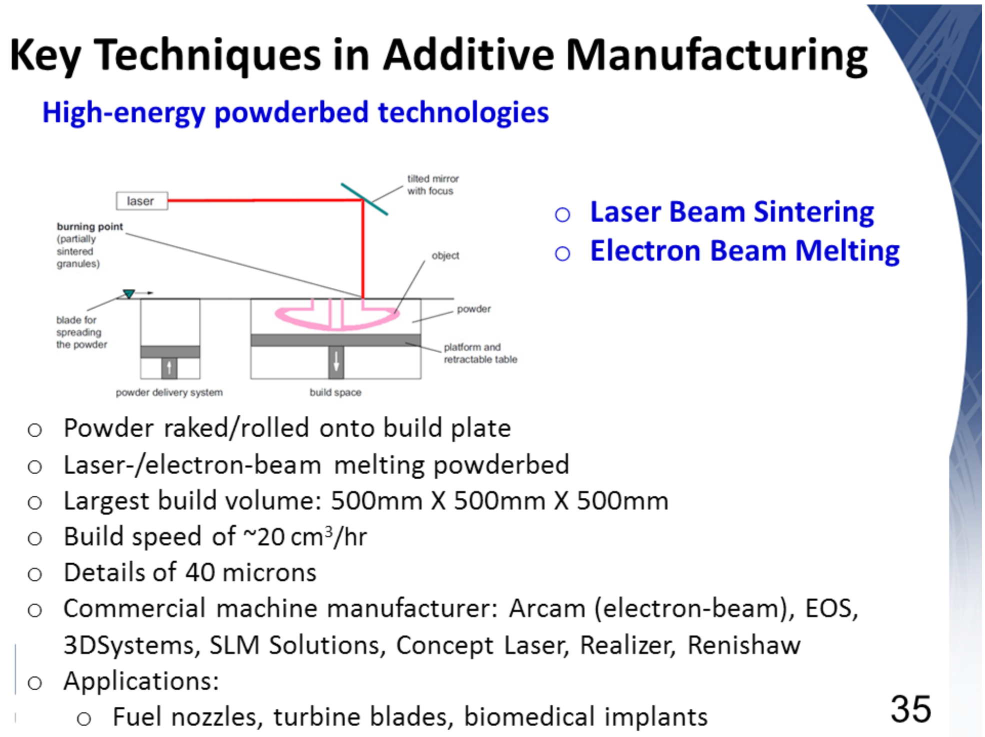
- Powder is fed into laser beam, melted onto substrate
- Deposition rates of pounds per hour (~70 cm^3/hr)
- Useful for tall/big structures
- Details of 500 microns
- Adding features to or repairing existing parts

33

Let me share a little bit of insight in some explanation of some of the techniques that are currently being used by industry in additive manufacturing. The common technique is what is called directed energy deposition. As you can see from this slide, we have a high-power laser with metal powders being fed from several sources that are joined together from the high-power laser. By having different axis of motion on the platform, you can create the materials or parts that are deposited at the rate of pounds per hour, and, therefore, it can be made for large parts. Since there is almost no limitation on how far to place the platform, one can make parts that are very tall or very wide. The limitation here is that we suffer from the low spatial resolution which is about 500 microns.



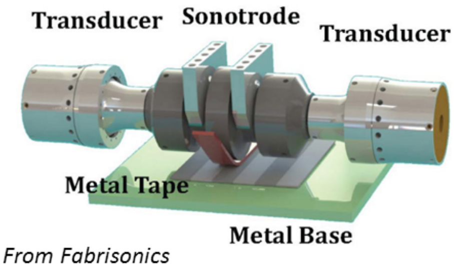
The next technique is called electron beam wire deposition. The world leader in the case is a company based in Chicago called Sciaky. In this technique, wires are fed through the wire feeder onto the surface. What you see on the bottom are the solidified parts. Obviously, this is an expensive technique because you are using electron beams, and, therefore, you have to operate in the vacuum. However, when you need to have a coating of very high-strength materials over lower-strength materials, this technique can be ideal.



The next technique that has gained a lot of attracting by using turnkey system is what we call high-energy powderbed technologies. There are two techniques that are very common. One is laser sintering in which we are not melting the metal powders, and the other is electron beam melting. They both come in turnkey systems. Basically, you have a powderbed here and a ray that brings in more powder as the parts are being either melted or sintered by laser electron beam. The working space is about half a meter across in a cube, and the amount of material that can be made is about a third of a pound. However, as you can see, compared to the directed energy technique, you actually have much better resolution of 40 microns. Applications are coming in with brackets, gas turbine on injectors and so forth. Opportunities are limitless based on the types of materials and manufacturing techniques.

Key Techniques in Additive Manufacturing

Ultrasonic additive manufacturing



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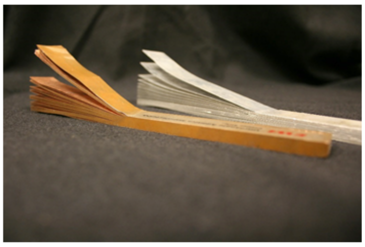
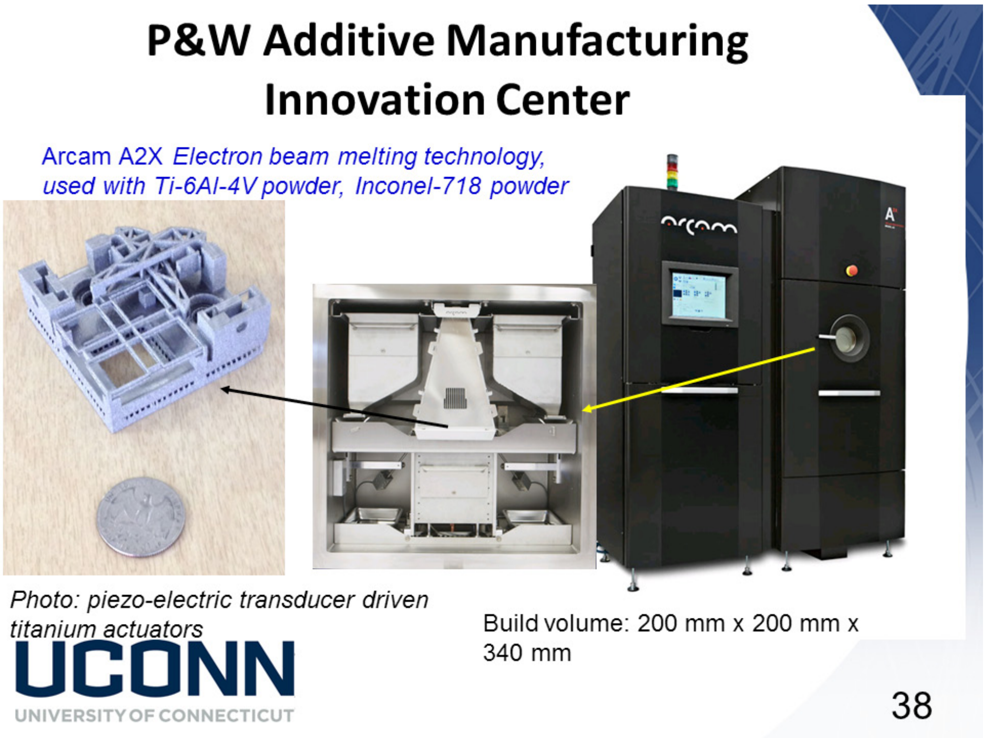


- Ultrasonically-driven (20,000 Hz), friction based bonding of foils
- Solid state only, no liquids involved
- Particularly useful for embedding thin foils/sensors
- Applications
  - Joining of materials at lower temperatures
  - Embedding of functional electronics to structural elements

36

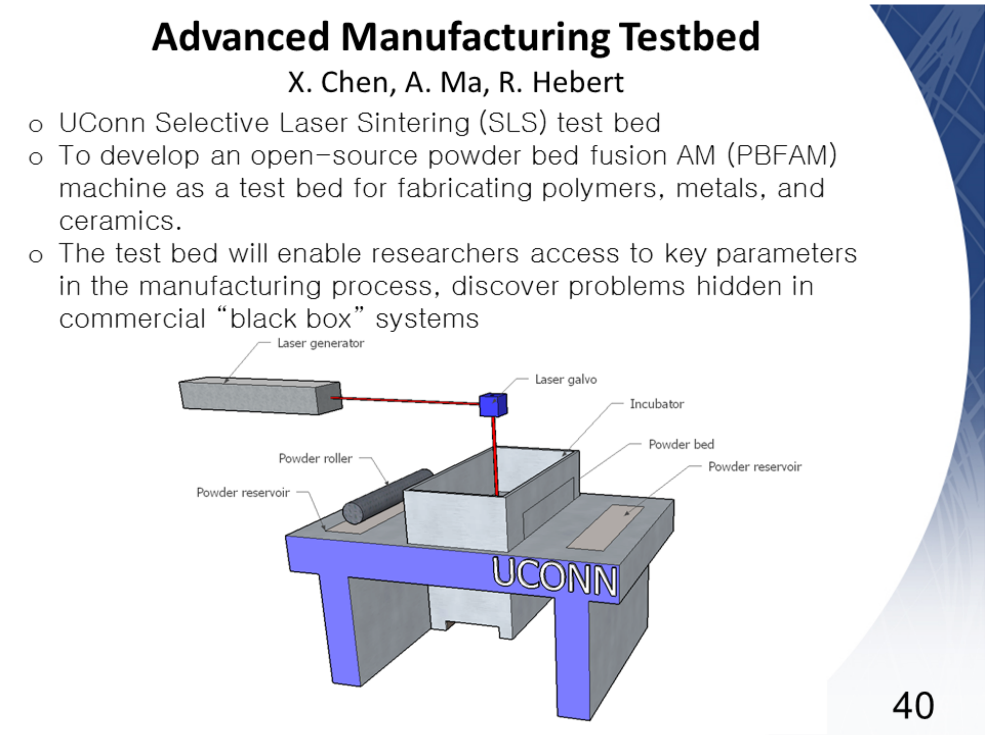
Other very exciting technique that was developed about 15 years ago is called ultrasonic additive manufacturing in which they use ultrasonic oscillation at about 20,000 Hertz. Using the friction that is created and the pressure, you break up the oxide layer between the metal parts and weld to pieces of very thin metal film at low temperatures. This is a great way to add on a film of metal that can be used for functional electronics. This is gaining a lot of support. However, obviously, this is not the type of experiment for equipment to use, when you are making parts like a gas turbine blade.

As part of our partnership with Pratt & Whitney, we purchased several machines for the direct metals laser sintering as well as electron beam melting. The first one was purchased from EOS which, I believe, is a company in Germany. Using Inconel, we made a nozzle-guide vane segment that has not been certified for flight, but we demonstrated that we can make that part to have the integrity of the original part.

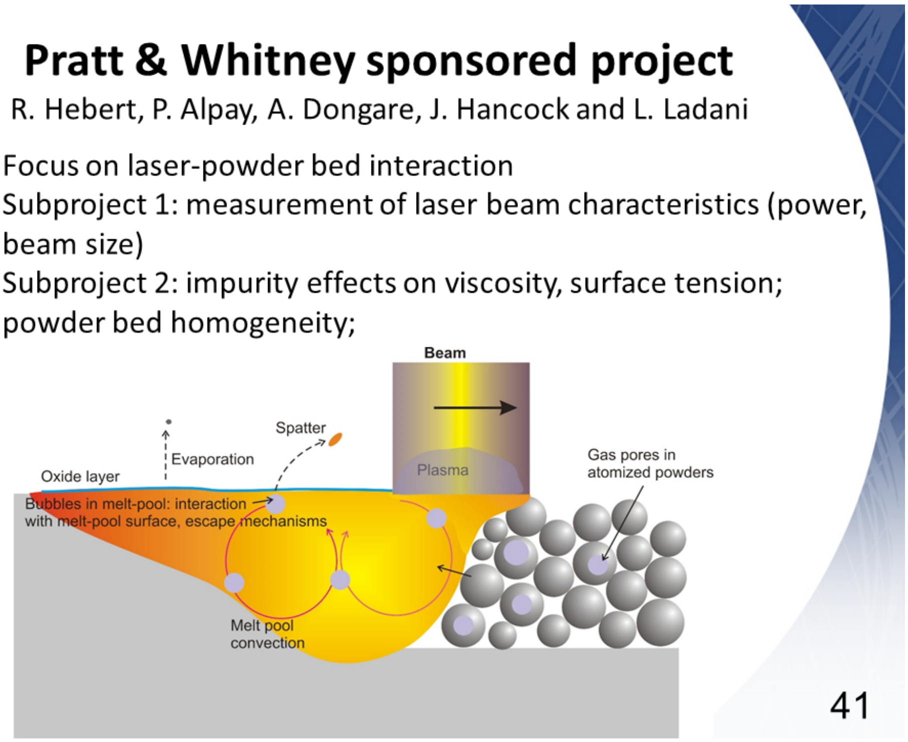


The next one that we have is from a company in Sweden called Arcam which really started to manufacture biomedical implants. By using that technology, we can melt metals so that you can have a much higher variety of types of metals that you can use for additive technology.

The last one is the 3D system, another laser sintering machine. Using this, we developed impellers that can be used for the compressor as well as using latticing to reduce the weight of the components within the jet engines.

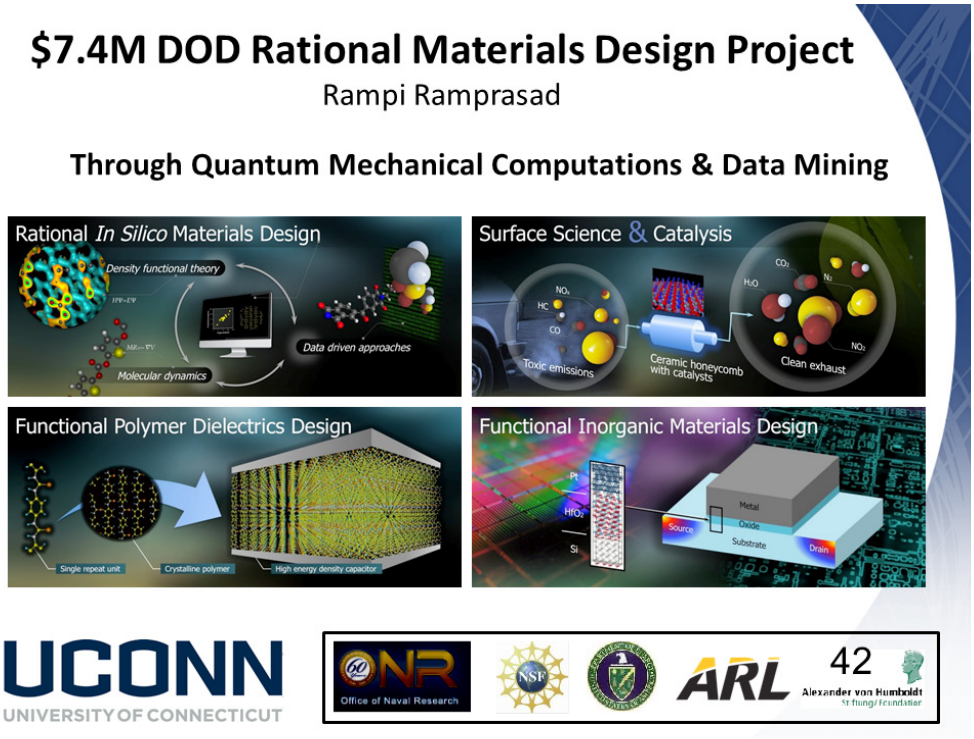


As we discovered in many of these technologies, we are seeing that it is a black box. We know that there is a high-power energy source; we know that we have powderbeds; and we get parts out of it. However, what occurs? What is the physical mechanism that occurs that we can manipulate to optimize our finished products? For that reason, we decided to manufacture our own laser sintering machine that can be used to change laser power, traversal, powder metallurgy and use different types of metal powder combination to understand what is happening by using in-situ measurements.



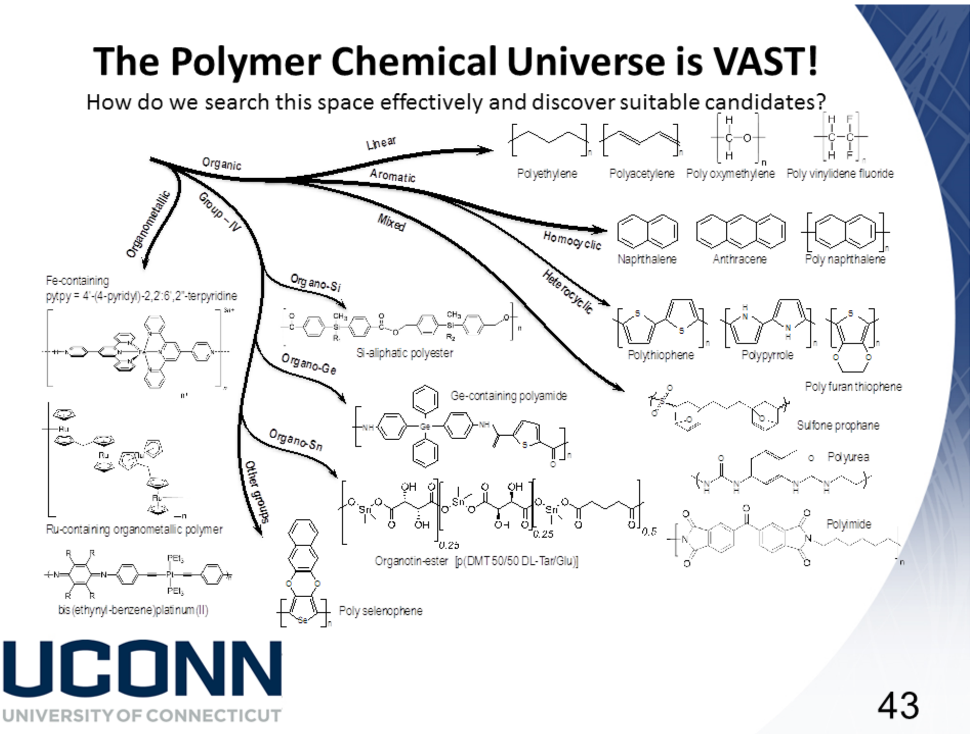
This is an experiment that is just beginning to get a start. The focus will be on better understanding the complex interactions that occur when a beam, whether it is a laser beam or an electron beam, interacts with the metal powder. What you have is a problem that is very rich in physics and chemistry, e.g., development of an oxide layer. How does that interact with the reflection of the laser energy or electron beam energy that comes through, evaporation of the material, spatter that occurs and the melt pool depth that eventually affects the heating of the unheated powders that are underneath here? Also, impurities, differences in the size and the presence of oxygen throughout the region can also affect the integrity of the parts that are created. This is a complex system in which we are going to be using in-situ measurements to better understand and isolate these types of processes to understand what is happening in the black boxes.

I would like to finish with two slides. I talked about the importance of additive manufacturing and the opportunities that they present. However, it is also important for all of us in the field of mechanical and materials engineering to think about how to develop the types of materials that will leverage the benefits of additive manufacturing.



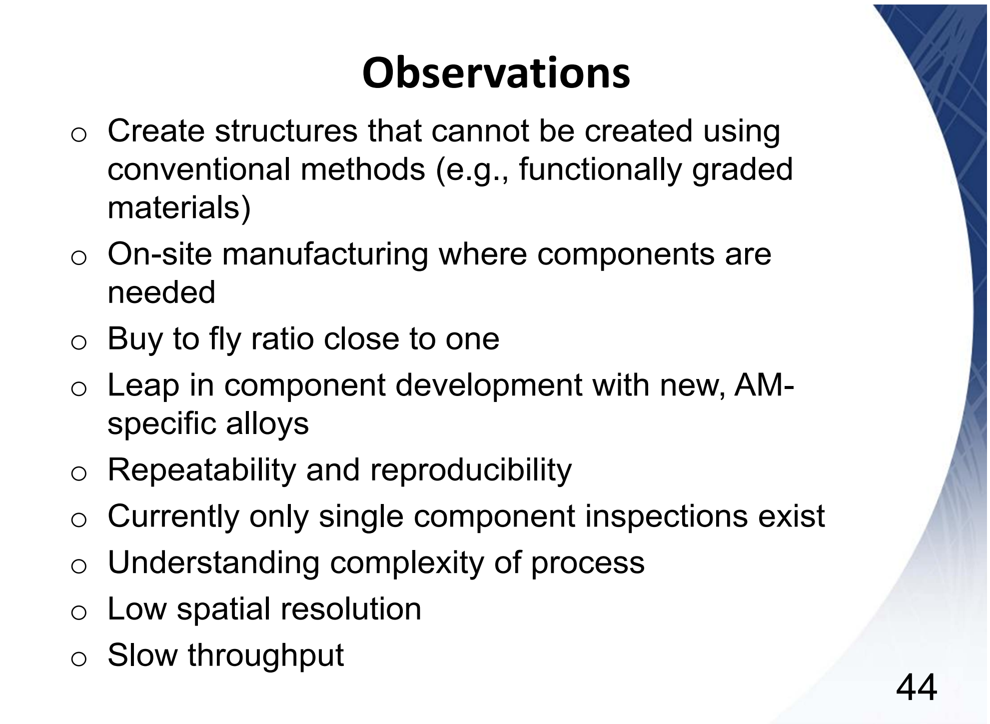
In this regard, one of our professors named Rampi Ramprasad is working with the Department of Defense on the rational computational-based evaluation of material properties using that technique as opposed to the Edisonian, i.e., trial-and-error, technique. The goal is to develop the types of polymers that can be used in a high dielectric super capacitor because the military is very interested in having soldiers have power packs that are embedded in their uniforms.

The goal is also to have better ways of creating the types of exhaust cleanup whether it is in a coal-fired plant or in a personal vehicle, by using different types of materials. However, the chemical space, i.e., chemical pathways, in the molecular interaction is so complicated that, without delving into computational mechanics, quantum mechanics and in silico, i.e., in-computer, computational assessment, it is going to be very difficult to do.



Let me give you one example. In evaluating different types of polymers that are possible for use as the base material for super capacitors, we can look at polypropylene.

When we look at polypropylene, there are so many different pathways in which you can have the chains match up and you can have different additives that can be combined. To be able to do this in a trial-and-error fashion will be nearly impossible. However, if we do it using a computational method, we can reduce the candidates that have been used for replacement of these parts.



Let me end my talk by sharing with you that I believe that opportunities in additive manufacturing are tremendous and that the ability to have creative designs that are no longer bound by subtractive machine technology is going to be a game changer. We also have some difficult challenges because we are not, at this stage, confident that we can use additive manufacturing to a degree that will replace traditional manufacturing in terms of cost, time that it takes for the design as well as manufacturing of the parts using techniques like electron beam melting. Nevertheless, the opportunities there are tremendous.

Let me end by sharing with you my colleagues as well as two colleagues from the Department of Commerce, Mike Molnar and Frank Gayle, who provided me with some of the insights and slides that are used in my presentation.

Thank you very much.

The Micro and Nano Fabrication Technologies of MEMS

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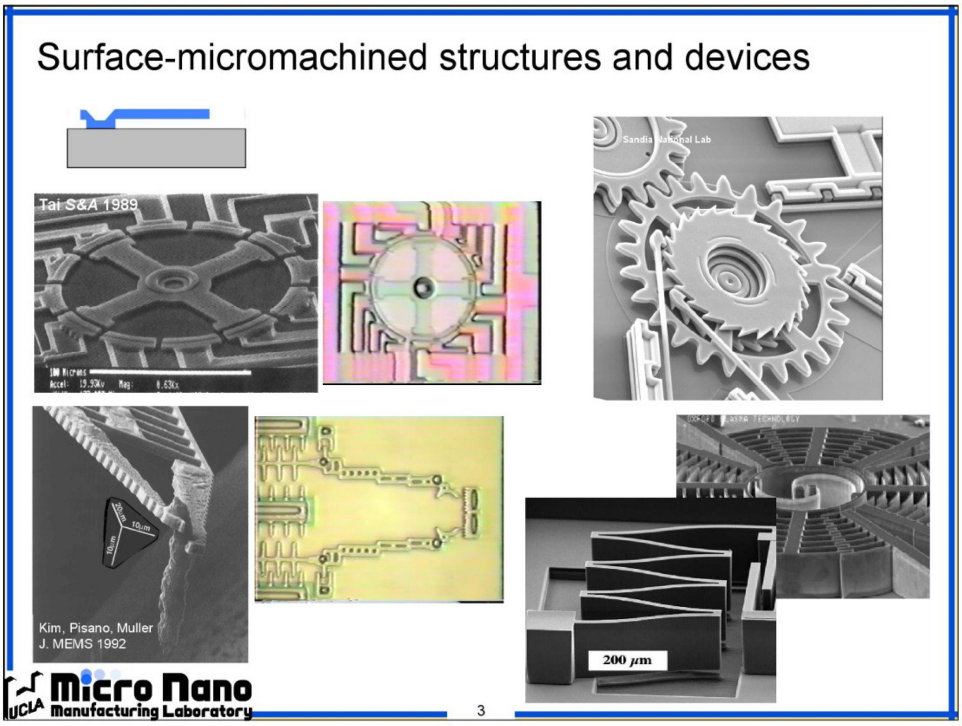
My name is CJ Kim or Kim Chang-Jin. I have worked with KIMM quite a few times, so it is not my first time being here in this institute, but I think this is the first time that I speak in this room. Today, I will talk about manufacturing, with focus on the microelectromechanical systems (MEMS) and nano technology. I will jump right into the technical part instead of giving you an overview of my presentation. Considering my position, I will not talk about policies. I am working at UCLA and my lab is called Micro and Nano Manufacturing Lab in the Mechanical and Aerospace Engineering Department. I also work for the California Nano Systems Institute at UCLA.

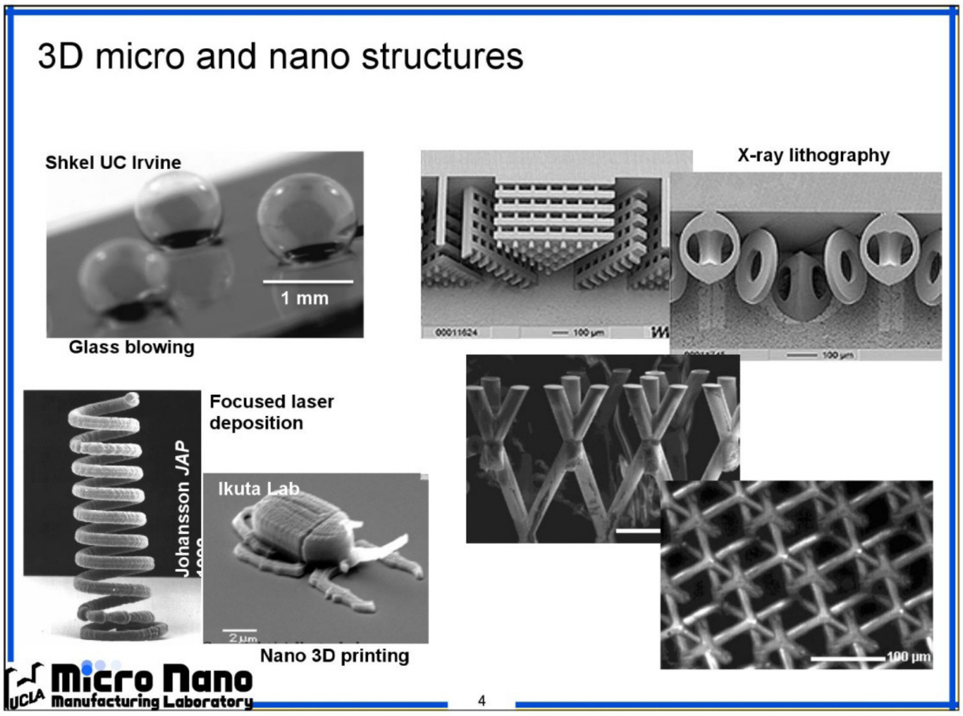
I will talk about micro and nano fabrication technologies that MEMS and nano technology are using. I will talk about not only research but also the kinds of products they end up making in industries as well as why we see what we see and why we do not see what we do not see. First, I will give you a very quick superficial overview and pictures of MEMS fabrication. What have they been making on the research side? You will find a lot of things. Then, I will move on to products. What manufacturing technologies have they used to make commercial products?



The birth of the MEMS synchronized with the introduction of the device called the micromotor which was developed in the late 1980s. This is called a surface micromachine where you make a thin film cross-section-wise and you remove the bottom so that you can fabricate them.

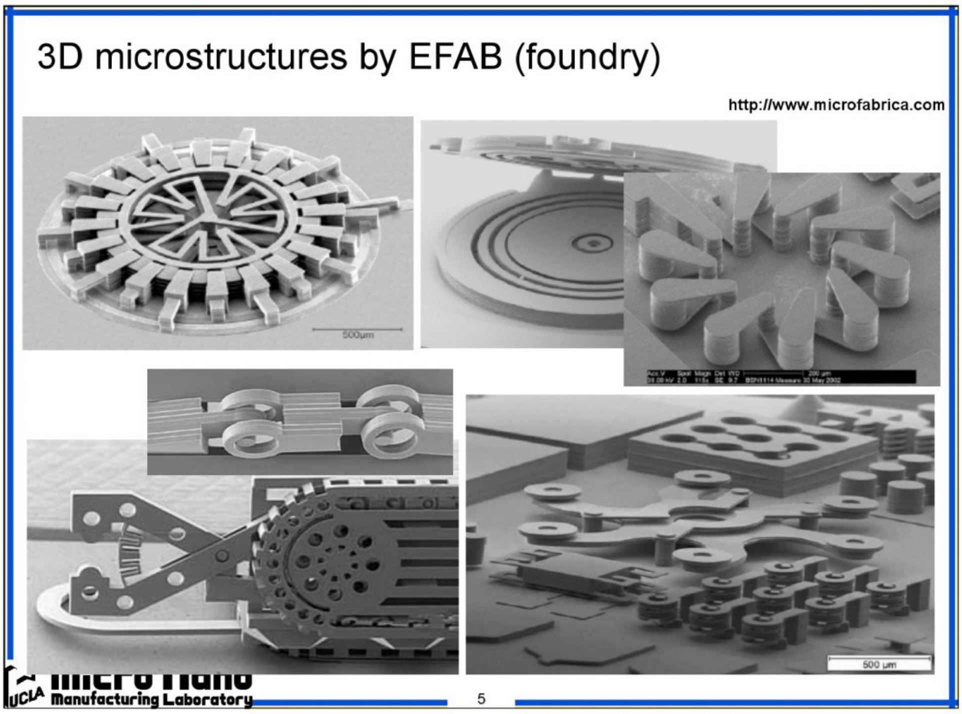
Based on this simple concept and using integrated circuit (IC) fabrication technologies, they are making many impressive objects and devices, some of which even move. As you can see, it is pretty impressive. That is why it sparked people's imagination and that is how micro machining started. Some of them became even thicker eventually. It looks beautiful. Did any of them turn into commercial products? No.

It looks pretty complex and complicated from the top, but looking at it from the side cross-section-wise, it looks pretty simple. Because of that limitation, people started to develop a lot of other different micro and nano manufacturing techniques, and they came up with different technologies which are much better in terms of the results.

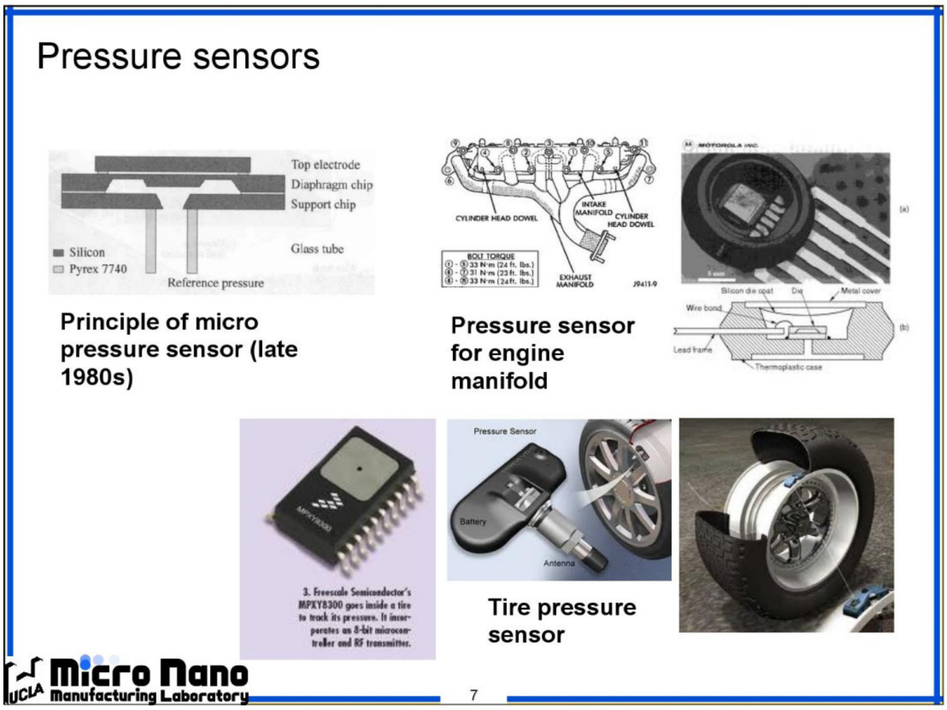


On the right side, you can see that it is not all vertical any more. Even if you look at it in cross section, it is complex. It is very well controlled, but is a very expensive process called x-ray lithography. On the left side is a bunch of creative techniques developed over the years. One of them shown here is relatively new. It is glass blowing. Basically, you blow glass in micrometer scale so that it makes a spherical hollow structure whose size is about 1mm. This has been used for radio frequency (RF) switches. It is a completely new kind of application that you could not even imagine before.

Because of the perceived limitations of the original MEMS technologies, people tried to make more complex 3D structures. On the lower left side, as you can see, you can make a coil. You can basically make any random 3D structures using a laser deposition technique. Today, 3D printing is very well known but this happened almost 20 years ago in MEMS. I named it 3D printing, but they used to call it micro-scale lithography. As you can see, they are making 3D structures in nanometer scale. It is beautiful, but too expensive. That is why you do not see any of them in products.

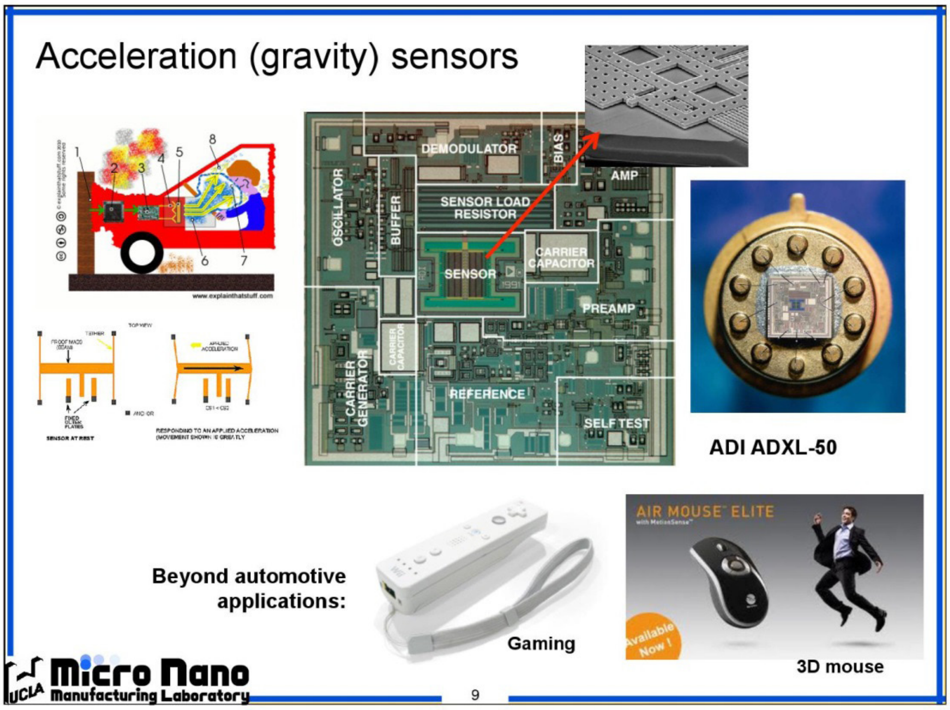


This is probably an extreme case. There is even a foundry service where you can submit your job, pay money and get these things done. Looking back, this is, in a way, a kind of 3D printing. Going layer by layer in literally micromini scale takes a long time, but a desktop production mechanism can make any 3D structure. EFAB is a company near LA. This is great, again, except the fact that it is very expensive. Therefore, you do not see any commercial products based on this.



I will move on to what kind of commercial products there are. I will show you several commercial MEMS products and analyze what kind of manufacturing technologies are used. They are very common. They are micro pressure sensors. They are more mature and the oldest MEMS devices. The principle is having a membrane that deflects based on pressure difference between one side and the other so that you measure the deflection angle. It is a relatively simple device. Today, it is used in cars and tires, and is mass-manufactured.

Another mature MEMS product is micro mirrors. Mirror arrays were developed and pioneered by Texas Instruments. There are a bunch of micro-scale mirrors there. This large optical chip has more than one million mirrors. You can use this to make a high-definition television (HD TV). This is a Mitsubishi 82” HD TV. However, even before that, almost two decades ago, we had projectors that had these chips inside. Recently, there are cellular phones that use nano projections. These are all based on this technique.



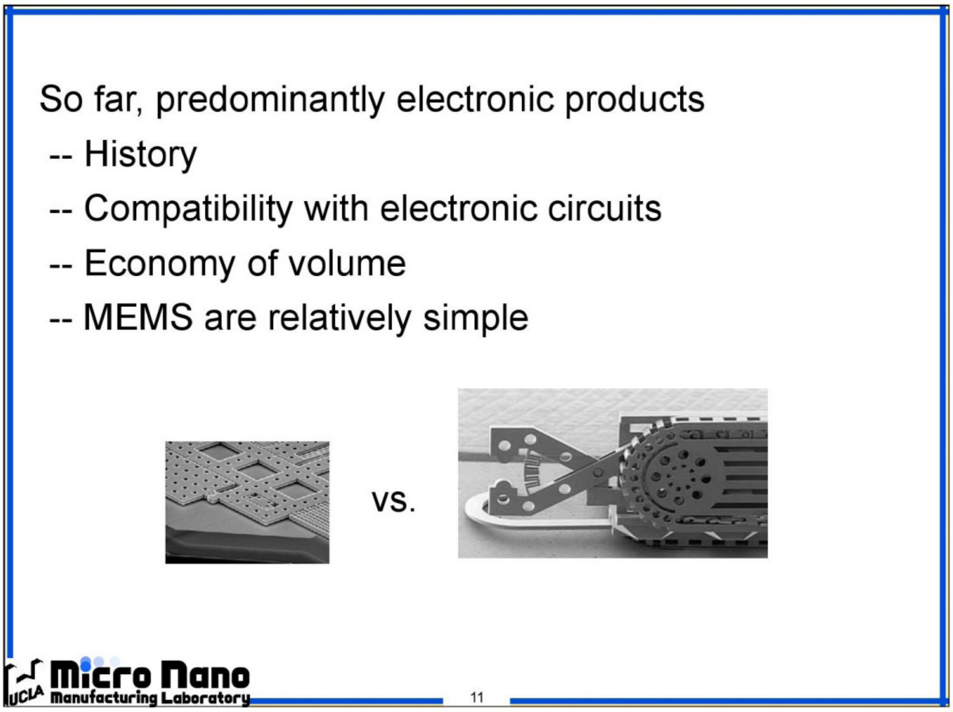
Another very well-known and common commercial MEMS product is an acceleration sensor. These are airbag deployment sensors, and, therefore, everyone is now experiencing this. On this chip, you have a simple beam which is flexible. These types of sensors are in almost every car these days.

About 10 years ago, this company entered the gaming industry with a 3D mouse. These are accelerometers or gravity sensors. As you can imagine, they are probably now in smartphones, too.

For the last five years, MEMS products have been highly leveraged by iPhones and smartphones. These days, all smartphones have MEMS products in them. Not only do they have gravity sensors so that your phone can sense the gravity, but they also have gyroscopes and microphones.

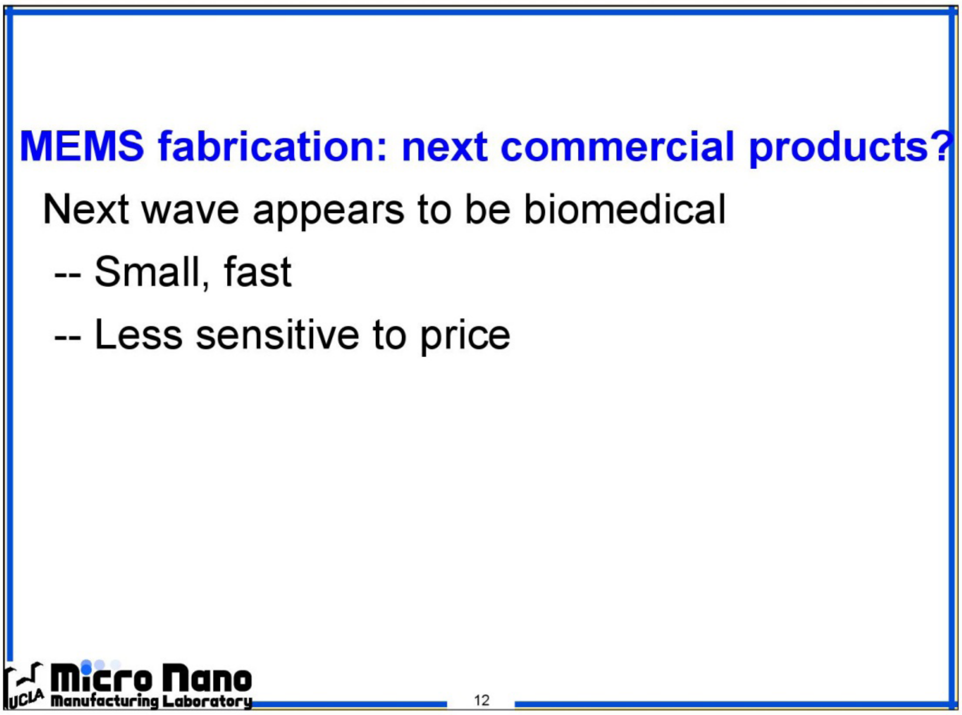
This is iPhone 6. This is about this thick and that is about half the thickness of iPhone. Part of the circuit is made with MEMS parts and they are made by two MEMS companies. Both have accelerometers. This has been fueling MEMS commercialization for the last several years. It is going to grow a lot more in the next several years.

This cartoon predicted smartphones two years ago. Of course, this is imagination, but some of it is true. The red parts are MEMS-based parts. However, these are not all. You can also sense humidity and more and more. As you can see, smartphone is right now the number one growth area for MEMS commercialization.



I am going to try to summarize. I showed a bunch of MEMS commercial products. What kind of manufacturing technique do they use? The answer is very simple. They do not really use that much. Partially, it is because of its history. MEMS had been studied by IC fabrication experts, and, therefore, it was natural to go to electronic products. Since all the manufactured techniques are based on IC manufacturing, it makes total sense not only from design but also from manufacturing to make them together with the circuit.

Also, MEMS manufacturing is often very expensive and it makes sense only if you have an economy of volume. Only if you sell a lot of IC chips can you also sell MEMS products. Because of that, MEMS products are relatively cheap. If you look at this part of an accelerometer, it is surface-micromachined. However complex it may look from the top, from the side, it is just one layer, typically. It is a very simple process. MEMS are relatively simple compared with what I will show you. They are very impressive products. They are manufactured, but not being used. They are heavily underused in terms of the true ability of MEMS manufacturing. Maybe it is because it is IC.



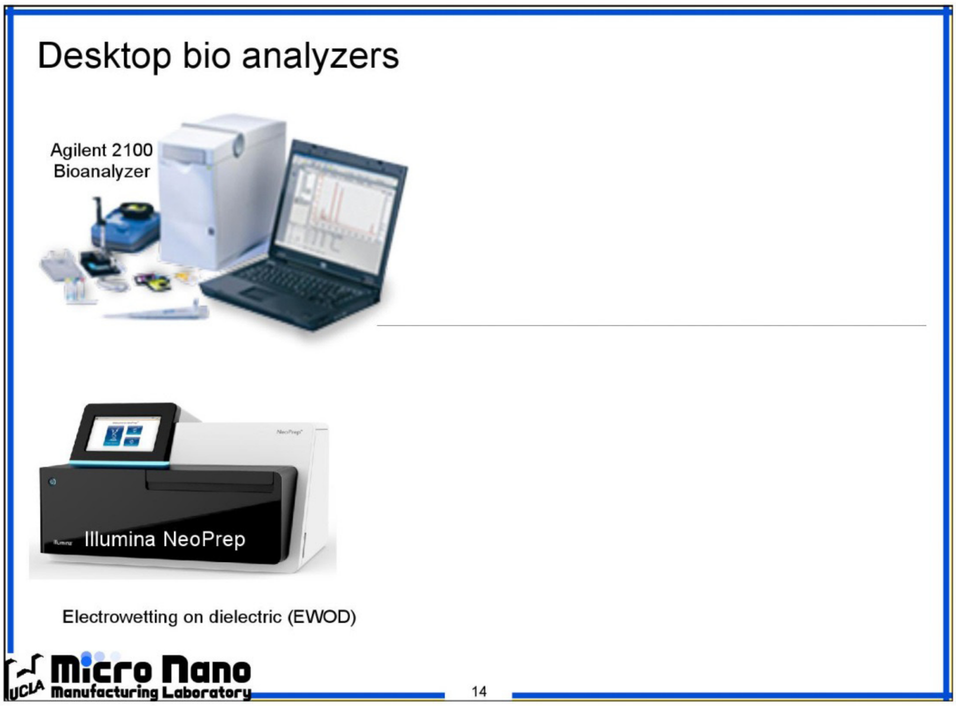
Let's look at what I believe is the next wave of MEMS commercial products. There are many commercial products being developed. I believe that the next wave of MEMS commercial products is in bio and medicine.

Why not in electronics? In biomedicine, it is important to make the products small because sometimes they are handheld or implanted in human bodies. Not only that, when things are small, physical reactions are faster. You might have heard about microfluidics, microtask, etc. one fundamental advantage of going small is that things become very fast. Diffusion length becomes very small, chemical reaction becomes very fast, and bioreaction becomes very fast. Being fast is very important.

A lot of times, biomedical devices or systems are less sensitive to price. Even if they are relatively expensive, people tend to buy them. That is why I think biomedical product is the next wave.

Let's look at next wave of commercial MEMS products. What kind of manufacturing technologies do they use? I threw in a lot of devices on the slide. These are small point-of-care systems based on microfluidics based on MEMS techniques. They are already on the market and there are probably ten times more products being developed or that are in the beta phase. These on the slide are all commercially available devices.

These are typically simple blood sensors based on simple fluid-moving mechanisms. Pregnancy sensors based on some wetting paper. They are relatively simple. That is why they were commercialized first. Whatever they do, if I fully and completely simplify what they make in terms of MEMS, they just make passive channels. They make all sorts of different channels and these become products because the rest of them are electronics. They exist because of MEMS, but in terms of manufacturing, again, they are extremely simple. They are not even as complicated as electronics. MEMS researchers are kind of disappointed that the manufacturing abilities of MEMS are not used.

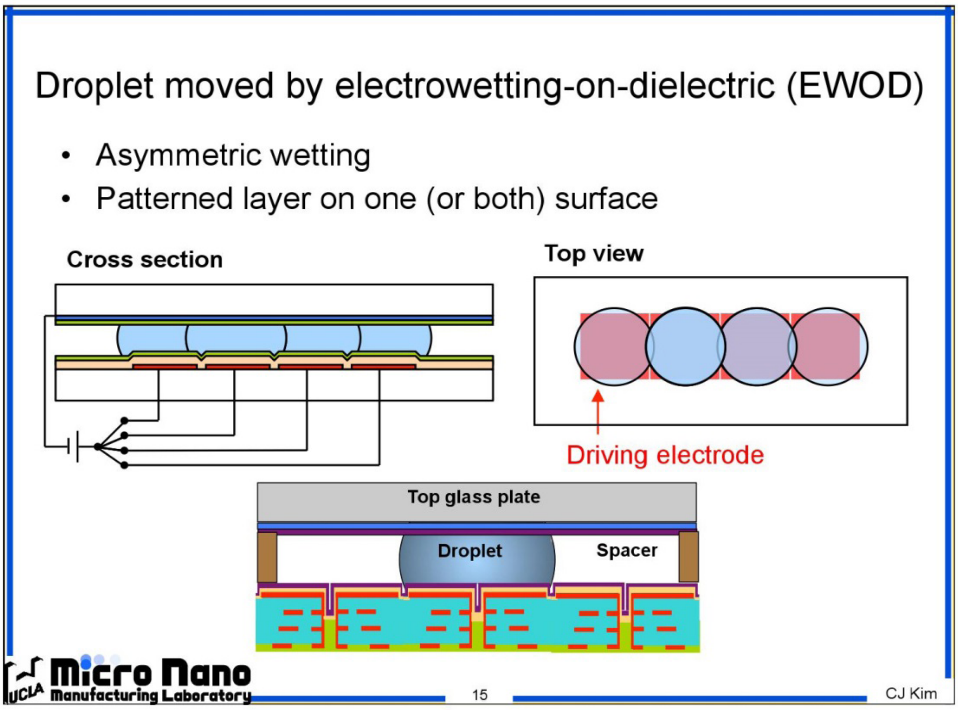


These are relatively simple small handheld devices for a blood analysis. More serious microfluidics products have been introduced over the past five years. One of the most well-known is Agilent Bioanalyzer. That has a system in it, pumps in it, electronics in it, but again, MEMS is just a simple channel. This is a brand-new one this year. This is probably one of the most sophisticated MEMS-based products because it does not use a pump any more. I know quite a lot about this product because this was commercialized based on research in our lab. We call it the electrowetting on dielectric (EWOD).

This is a complete system on desktop developed to make a DNA/RNA library preparation. This has sensors that have been commercialized. I have a video commercial here;

(The video clip is uploaded on the Forum website: forum.kimm.re.kr.)

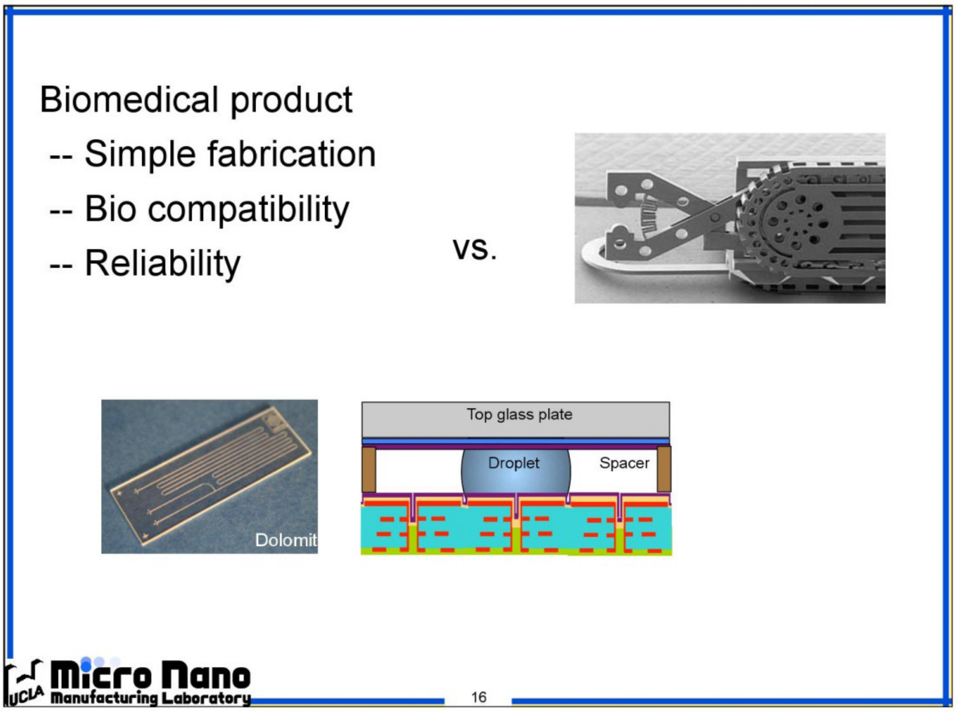
Imagine library prep with far fewer manual steps;
much less hands-on time;
virtually error proof;
imagine a library is prepared using nano-liter sized droplets;
enzymes, buffers, samples;
moved, merged, mixed;,
incubated, amplified, washed;
in a microfluidic digitally controlled environment;
imagine highly reproducible libraries prepared with unrivalled simplicity;
NeoPrep;
library prep;
reimagine.



This is one of the most sophisticated microfluidics-based products. Before, they were all passive. Once you move it, that was it. Now, you can actually control it. It looks pretty sophisticated but when you look at how the chips are manufactured, you would be surprised to see how simple it is. This was based on an EWOD device. We studied this about 15 years ago in our lab.

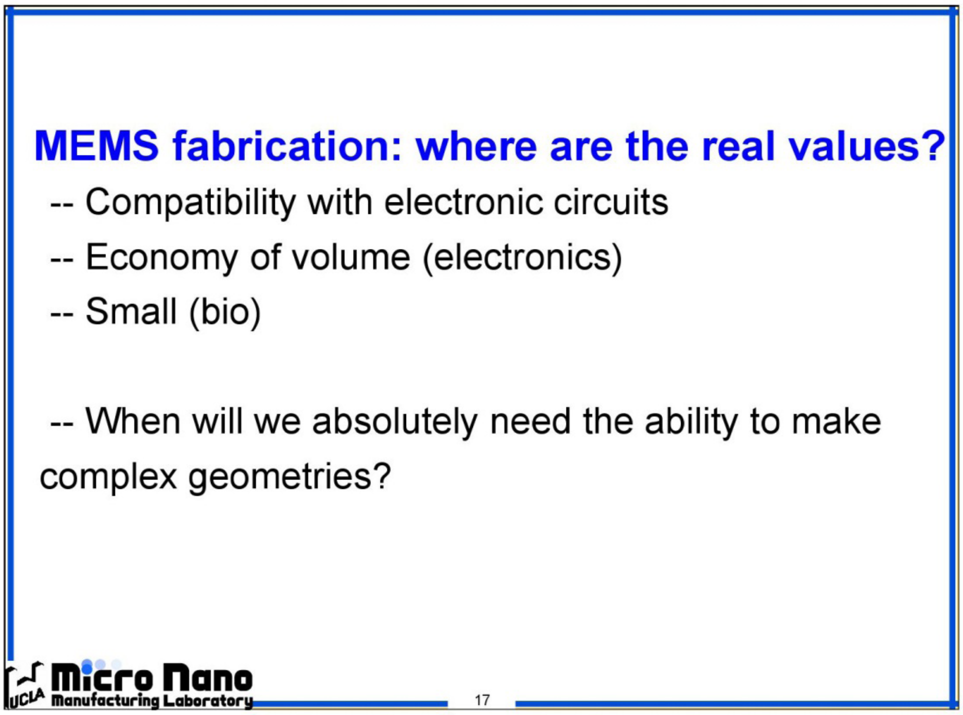
What you do is, instead of using pumps and valves and having micro channels, you have two plates. Between those, you have a droplet of water and by applying voltage locally, in this case on the right side, that side will become wetting and the contact angle will change. Because of that, there will be a net force to the right, so it will start to move. Just by applying voltage, you can move microfluidics.

Because it is so simple, it was commercialized earlier than other products that were studied earlier. This is the cross section of the actual device. It is very simple with just two plates. Looking from the top, in order to control different locations, you need multiple layers of electrodes. Instead of using MEMS, we just order from printed circuit board (PCB) manufacturers. This is a PCB plate, which is very cheap these days. The concept is very simple. The key is rather what kind of material is used, what kind of coating is done and biocompatibility issues. Again, it looks wonderful except MEMS is not actually used in terms of manufacturing.



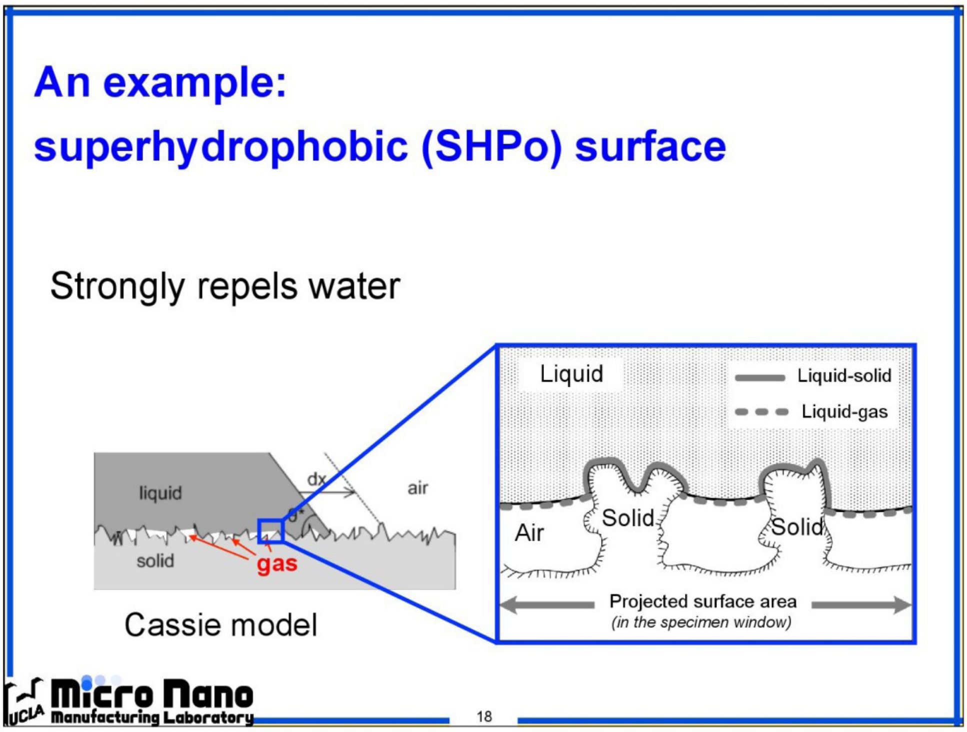
In summary, even the next wave of MEMS manufacturing does not seem to use much of MEMS manufacturing techniques. In biomedical products, simple fabrication is always desired not only because of the cost but also because you do not want any complications in terms of biocompatibility or reliability. Therefore, they just want to make it simple. It is also cheaper that way.

If you look at a typical biomedical MEMS device, it is just passive structures, or active but very simple structures. This sophisticated MEMS manufacturing technique is not being used.



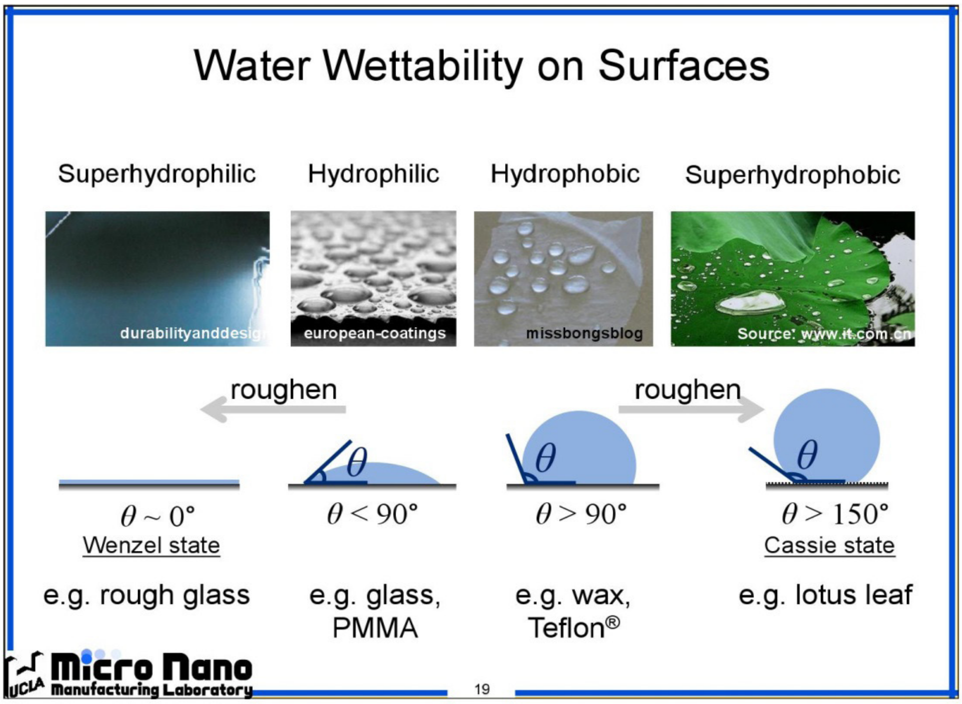
As a MEMS researcher, I always ask questions to myself. Why is MEMS valuable? How can we make MEMS more powerful, useful and utilized? Where are the real values of MEMS? That is always the main question I ask myself. Of course, the inherent advantage of MEMS should be always technical. Compatibility with electronic circuits is always good. In terms of the economy of volume, it is great if it is electronics. Even if there is not much volume, it is very valuable just by being small.

I want to push this even further. What kinds of applications will absolutely require MEMS manufacturing? What are areas where you can use only MEMS manufacturing and nothing else? I am searching for those applications.



I have several examples, but today I will just talk about one. That is what is called superhydrophobic (SHPo) surface. SHPo surface has been very popular. It has been around for about 15 years. These days, it is so popular that there are thousands of thousands of publications.

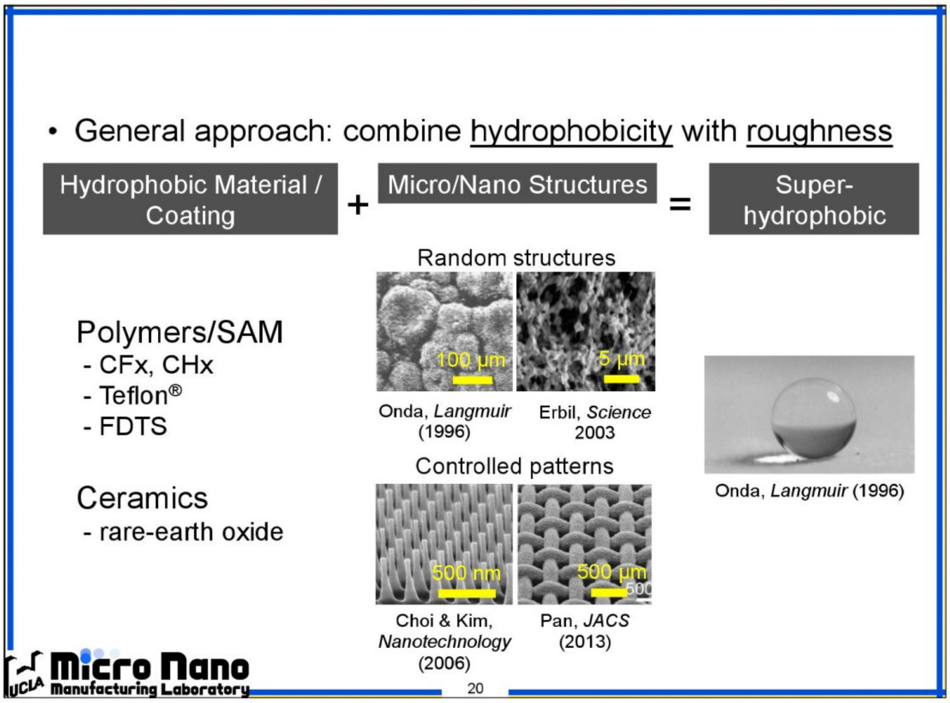
What is the SHPo surface? As the name suggests, it is hydrophobic and repels water but much more than hydrophobic. The essence of how it works is shown here. It has rough structures of micro and nano-scale roughness. If you somehow trap air in the roughness between the liquid and solid, it looks like this. Then, the contact angle will appear much larger than the actual contact angle. It will look like this. This is the solid area and this is the air, liquid contact. As you have more air fraction compared with the original, you will have more and more amplification of hydrophobicity.



Before I go much further, let me give you a quick background on wettability of the surface. Since water is most common, let us talk about water first. If the material is hydrophilic like glass or plexiglass, you have a contact angle smaller than 90°, typically 20° to 60°. If you make that surface rough, you will actually make it more wetted.

This is a superhydrophilic surface which will become completely wetted. However, if the material itself is hydrophobic like Teflon or wax, then it can trap gas like I showed earlier and that makes a contact angle that is larger than 150°. 150° is a big deal because if you did not have any roughness then there is no air trapped in between. Teflon is practically the most hydrophobic material and the contact angle is about 120°. In nature, there is no material that gives a contact angle of more than 120°. Anything more than 120° is not natural. It is artificial.

By convention, people define that if the contact angle is more than 150°, that material is called superhydrophobic. You know the surface roughness. The typical approach almost all the time is to use hydrophobic material, starting with maybe 90°~110° and make it rough so that it can trap air under the water. Then, this is the effect you get. You can get to a contact angle of almost 180° in the superhydrophobic surface.



In terms of materials, of course, you want to use hydrophobic materials. Those with chemistry background will probably recognize almost all of these materials. You can make the surface rough in many different ways. You can make it randomly rough. You can actually go home and scratch the cooking pan and you will find a hydrophobic surface. You can make it more regular as well. You can use MEMS to make it more regular.

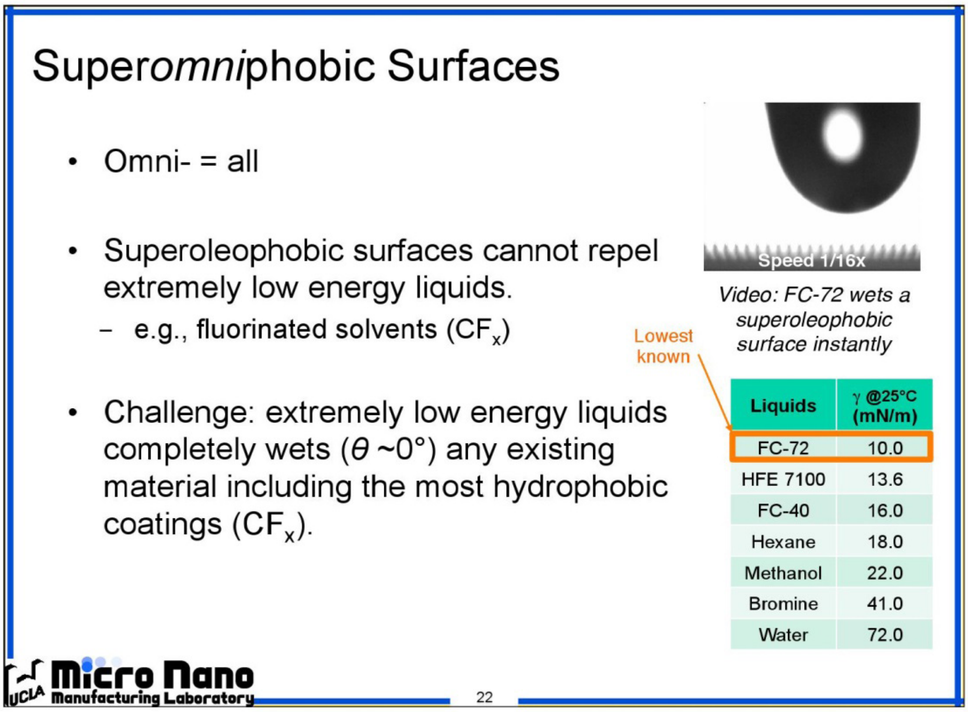
MEMS is good for making the surface regular because it has a reliable property. However, in this area, it is too expensive. It is true. You do not need any regular structure to make it superhydrophobic. Any random structure surface will make it superhydrophobic.

Where is the value in MEMS? I will move on to show you the value. Before I do that, this is one of the well-known commercials for a coating product called NeverWet. The name totally makes sense. They sell this coating unit with which you can coat any surface. The surface will look like this: randomly rough and hydrophobic. This is the 30-second commercial in the U.S:

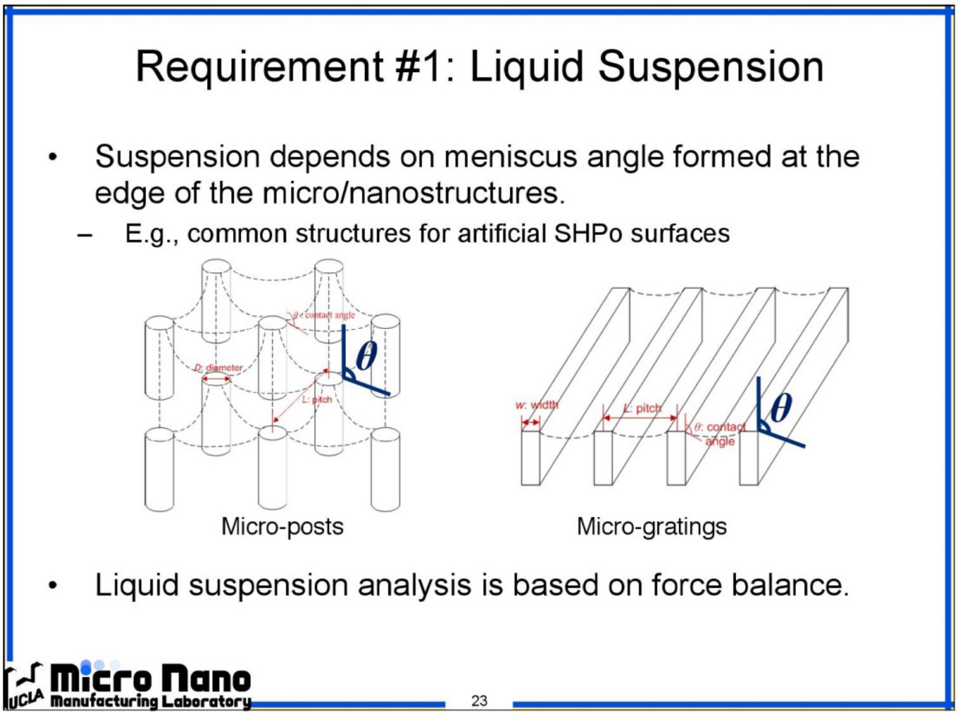
(The video clip is uploaded on the Forum website: forum.kimm.re.kr.)

Submerged but never wet;
experience Rust-Oleum NeverWet;
a revolutionary superhydrophobic treatment that causes liquids to fall in perfect spheres so they roll off surfaces like never before;
now available in a crystal clear fabric formula;
find out more at rustoleum.com/neverwet.

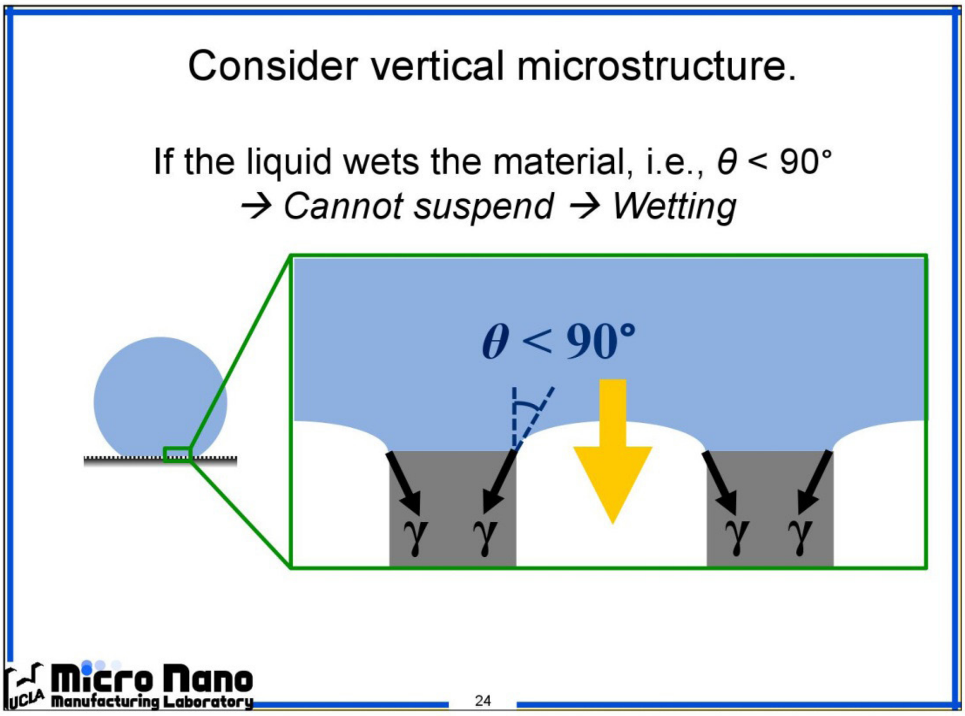
This is a commercial and you can see it is a little bit exaggerated. In reality, it is not as good as that but it is wonderful. Why do we need anything else? It is because there are many different liquids. First, I talked about water. Water is not the only liquid in the world. There are a lot of other liquids which are not water. Will this approach work if it is a non-water liquid? Water is a relatively unusual liquid that has a high surface tension. Most of the liquids other than mercury have much lower surface tension. Even if you have Teflon, which is very hydrophobic, you would know because you have a Teflon pan at home, water is okay but if you put oil on it, it will spread. You know even Teflon will not repel the oil. Contact angle is not larger than 90°. In that case, if you make it rougher, it will become even more wetted.



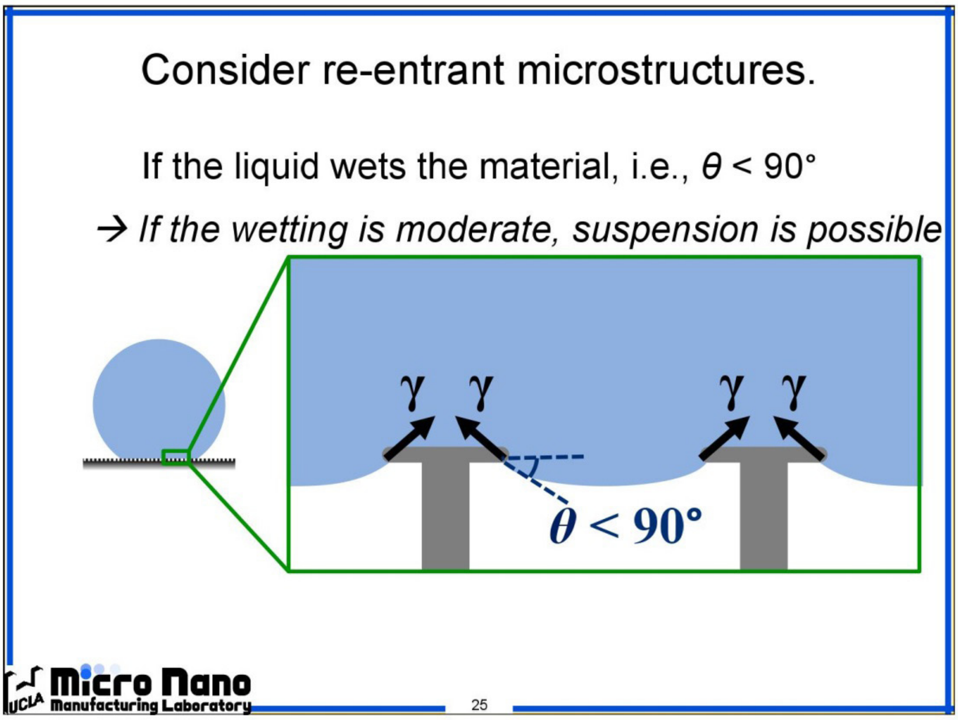
My question is whether we can make a surface roughness so that not only water but any liquid is repelled? My goal is shown here. There are people who have been developing surfaces that can repel many solvents and oil. This fluorocarbon liquid was not possible before. This shows an extreme case. It is FC-72. Unless you invent some other really weird liquid, FC-72 is the liquid with the lowest surface tension in the world. If you have a regular superhydrophobic surface like Teflon, and put FC-72 on it, it is going to spread right away. There is no surface in the world that can beat FC-72. However, if you look at things carefully and analyze them very well, you can come up with a dream or ideal structure that was not possible before.



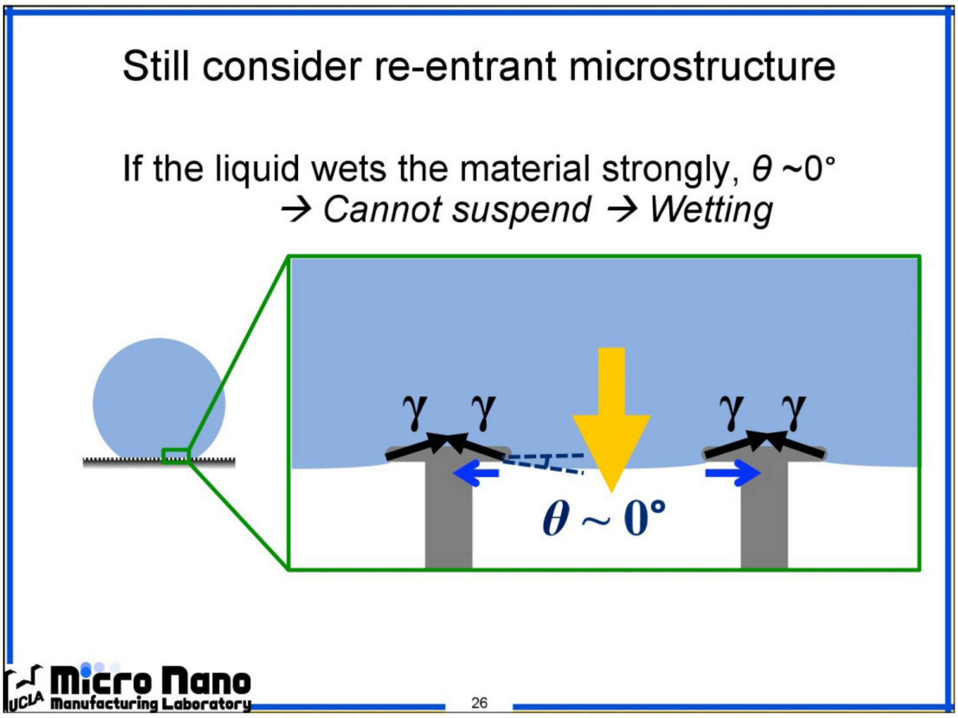
The next question is whether you can make it. That is where MEMS come in useful. Let us look at how superhydrophobic repelling occurs. If you have microstructures like these, or micro-posts or micro-gratings, first it has to repel.



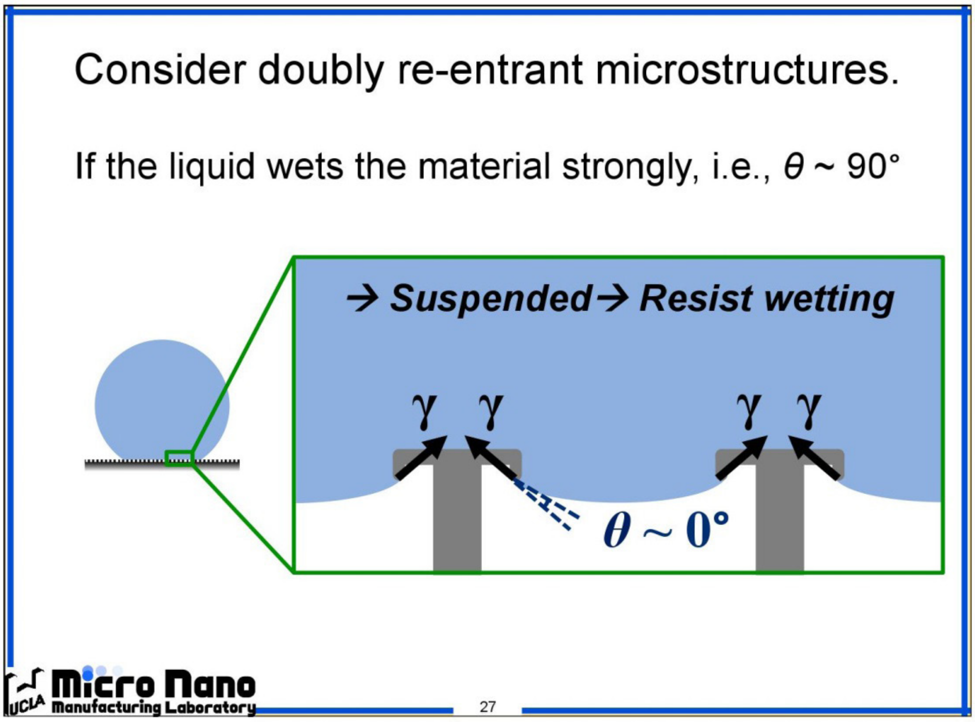
If you put liquid on these relatively simple microstructures and suppose the liquid wets the material, which means the contact angle is less than 90°, it is either water on glass or oil on Teflon. In that case, if you do a force analysis, you will find out that liquid is on this surface, on the structure, and the force is downward, meaning it will pull the liquid down and it will get wet. That is why everything gets wet if the contact angle is less than 90° in a microstructure.



Now, let us look at this kind of structure microscopically. This is called a re-entrant microstructure. In this case, even if the contact angle is less than 90°, you can make it so that net force or surface tension is pointing up, and so that the liquid can now suspend. Using this, people developed structures like Teflon that repels oil and solvents. That was possible.

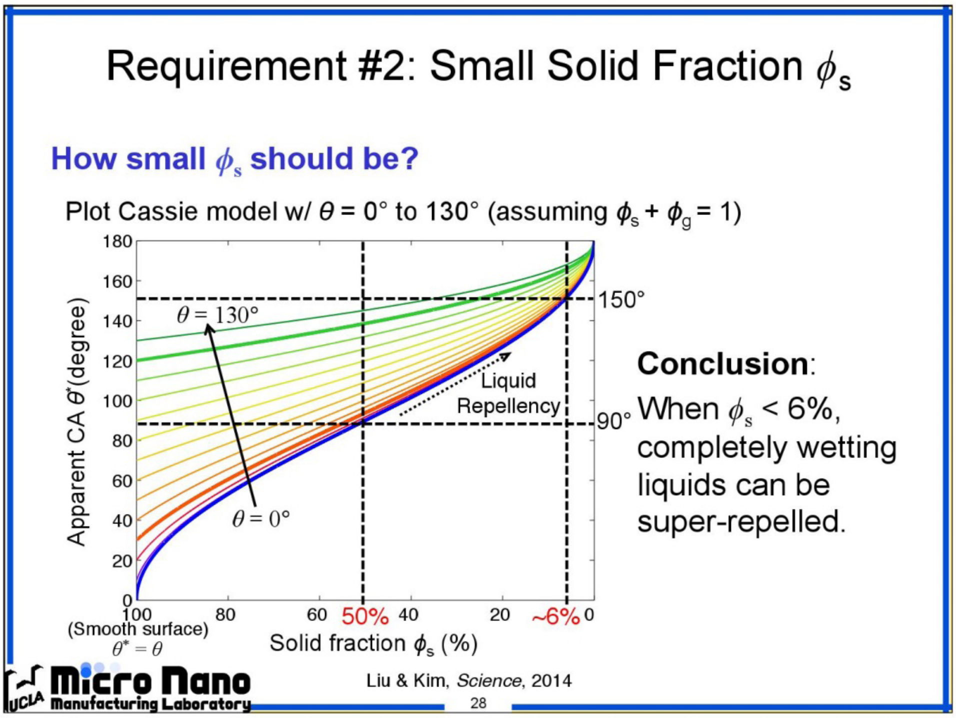


However, as I said at the beginning, I want a surface that repels all the liquids, not almost all the liquids. Is it possible? What if you go to extreme? You use the same regular re-entrant structure which repels oil, solvents and FC-72. The contact angle is almost 0°. Then, yes, there is a vertical force but the component is so small that any fluctuation in pressure would get it wet. That is why it never works.



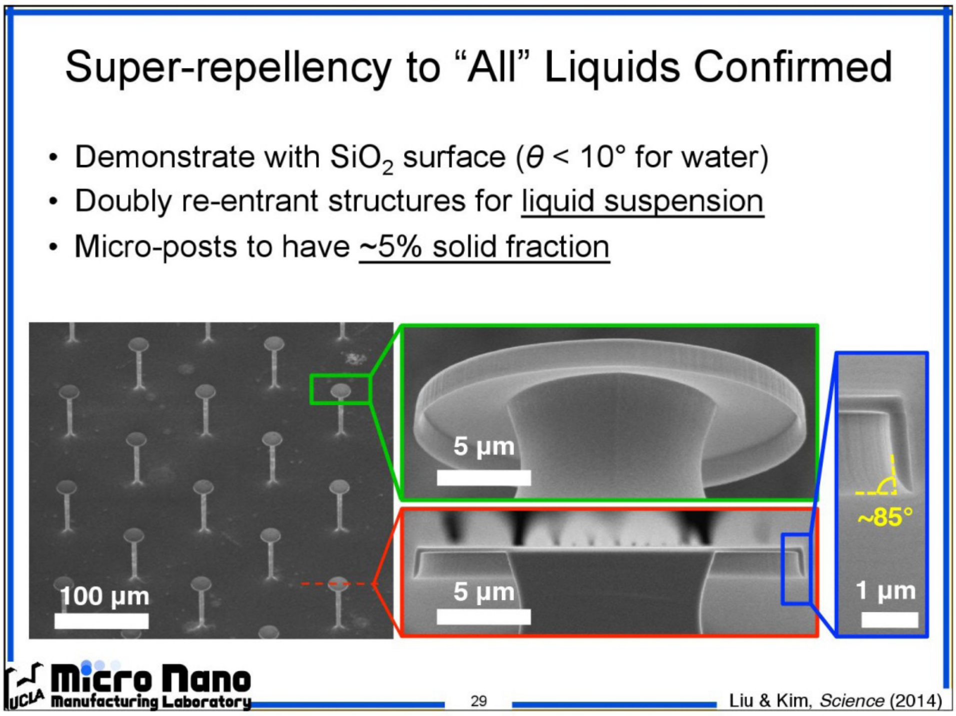
My idea was: why don't we make it more extreme? Why don't we do this? This is called doubly re-entrant microstructure. Even if the contact angle is 0°, you get a pretty significant positive vertical upward force. That makes sense. This was not a totally new idea. I had this idea around 30 years ago when I was doing my master's on heat transfer. This kind of structure existed then, but only in my mind. When I did my master's degree many years ago, I drew an ideal structure that can repel any liquid but that only God can make.

I did not study MEMS at the time. Therefore, it was in my thesis as an ideal structure. Only after I started MEMS did I think, 'Oh, maybe I can make it.' Imagining something is actually not that easy and developing it is not so easy, but once you develop it, it is not that difficult to go on.



Anyway, first, you have to repel. Second, you need a lot of air. I am not going to go into much detail, but the key is that there is a theory, an exact equation, predicting how much air volume underneath will make a contact angle of how much.

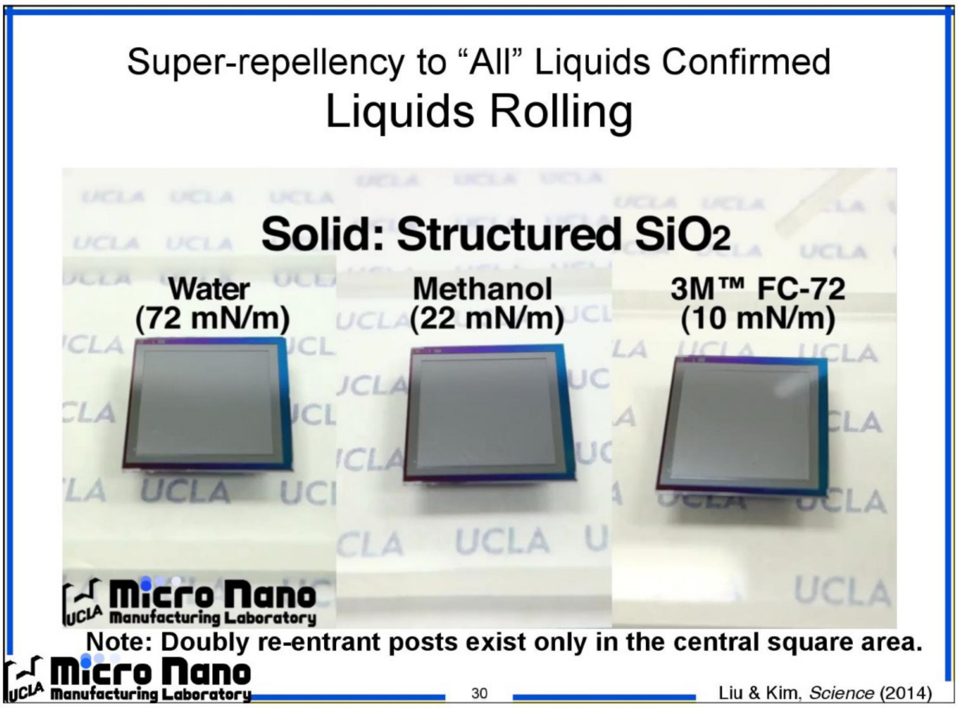
In this theory, which only exists and was never proven, we calculated that most of the surface should be air and less than 6% should be solid, meaning the solid fraction should be less than 6%. Obviously, unless you have MEMS, you do not even know if it is possible or not. We thought it was possible.



I am going to jump to the conclusion. We tried to make solid fraction of even less than 6%. 5% solid fraction was our result. In this case, as you can see, there are a lot of columns. At the top of the column, you have a nail head. As you can see, there is a lot of air. This solid part that actually touches the water or the liquid will be very small, less than 5%. However, a lot more details are needed. This shows what it looks like. It is not only head-shaped, which actually existed before, but it looks like a head with curtains around. Besides, according to the theory or equation, that curtain should be as short as possible, and its thickness should be as thin as possible, and it should be as vertical as possible. Unless you know MEMS, you would think this is impossible. We started the project because we thought it was possible. Again, as I said, developing something takes a long time, but once you develop it, doing it is not that difficult. Anyway, that was what I thought was the power of MEMS and how MEMS should be utilized. Other than MEMS, there is no way you can make a structure like this.

What was the result? The results were pretty shocking to us. The material was made with silicon dioxide, basically very clean glass made in the IC fabrication lab. The contact angle of even the water on glass was almost 0°, which was less than 10°. It is a very small contact angle.

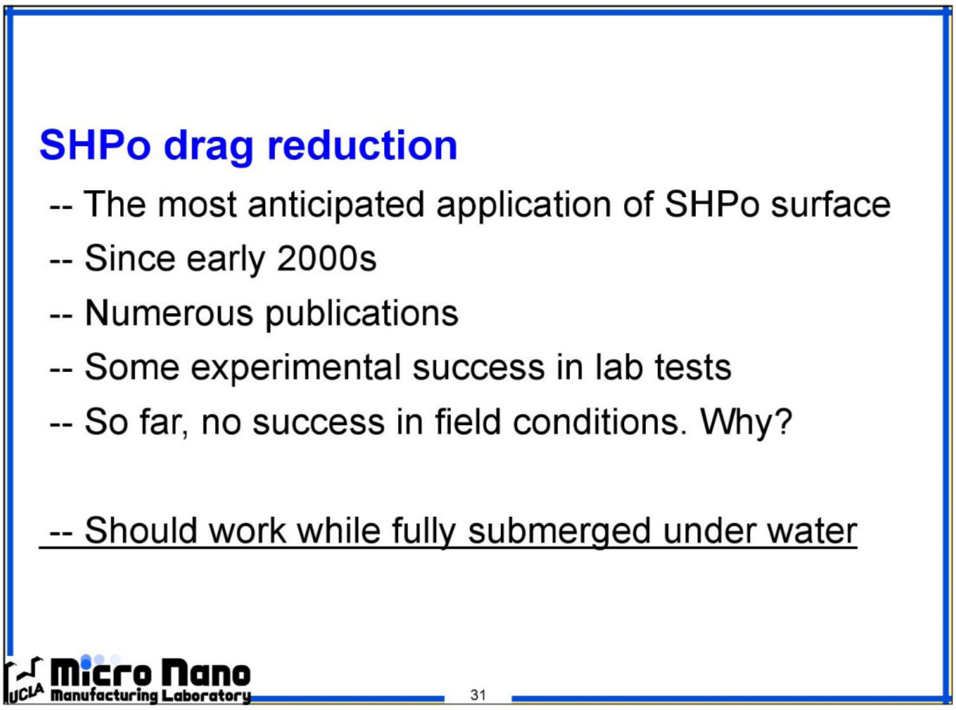
What about FC-72? It is also almost 0°. Contact angle for everything on glass made of this material was almost 0°, anyway. Suddenly, it does not matter what kind of substrate material you are talking about because the contact angle is 0° for water, FC-72 and everything else. As a mechanical engineer, this is what I call a mechanical surface. What kind of material it is made of does not make much of a difference. What kind of geometry it is made of determines the contact angle.



To show that, we had the same surfaces, but with water, methanol and FC-72 which have the lowest surface tension in the world. In the middle, we had the structure, and outside, we had the smooth same material, silicon dioxide. If I play this, you see, they behave the same. Water and FC-72 are two extreme cases. They behave in extremely different ways on regular surfaces, but on this mechanical structure, they behave the same because chemical energy does not make much difference any more. It is all mechanical.

Since you are the mechanical audience, I think you will love it. As you can see, water or any liquid goes to the side where there is no structure and it totally wets right away. Why is this important? It is because this new situation makes many impossible applications possible.

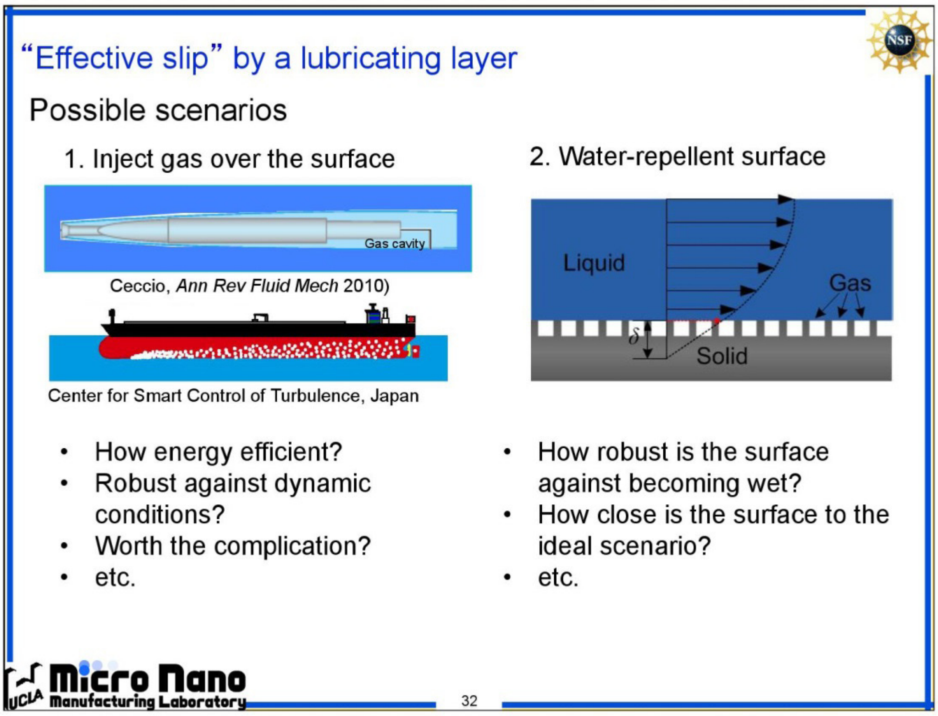
As you can see, in some cases, MEMS technologies are absolutely needed.



Let me go to the next example of superhydrophobic drag reduction. This is a much bigger scale. I will eventually show you its application in the boat. Why is superhydrophobic surface so popular these days? Among many applications, drag reduction is the most anticipated because of the large impact it has.

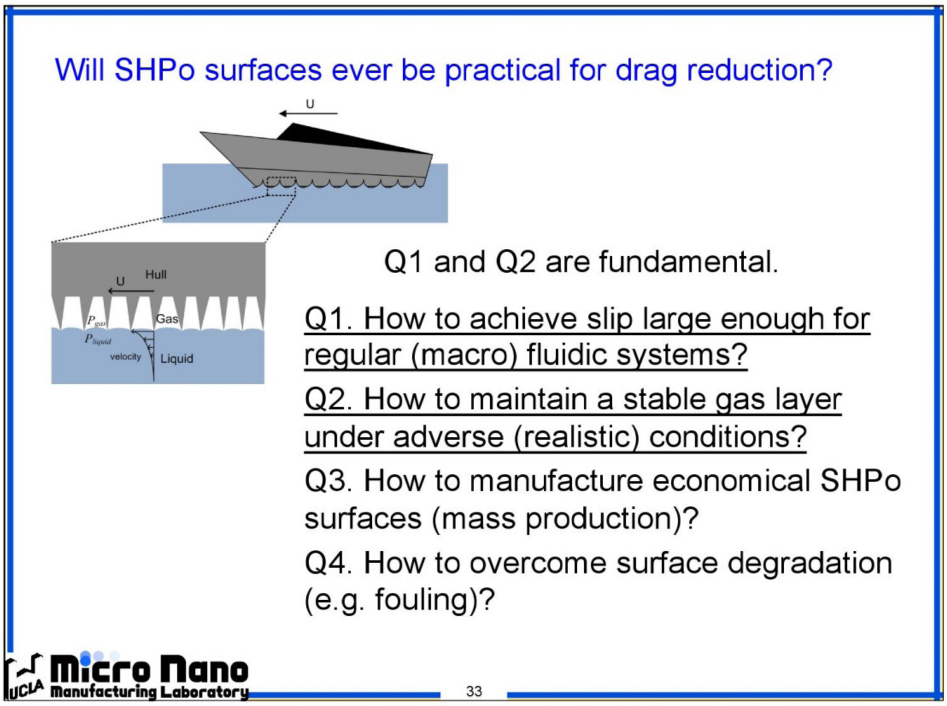
However, so far, although there are thousands and thousands of publications, almost every publication shows that, if this one works, eventually it is a drag. Nobody has showed that so far for the 15 years of research. Some experimental successes in labs have been published. However, even after 15 years of research and thousands and thousands of publications, nobody has been able to show drag reduction in field conditions outside the lab with the boat.

There are reasons. I will try to show you those reasons. To find out the reasons, you need MEMS. The main difference between MEMS drag reduction and NeverWet demonstration is that the regular hydrophobic surface demonstration is in air. To show drag reduction in boats, everything must be completely submerged under water and stay there for weeks. The boots in NeverWet advertisement were just being splashed outside the water. That is the main difference.

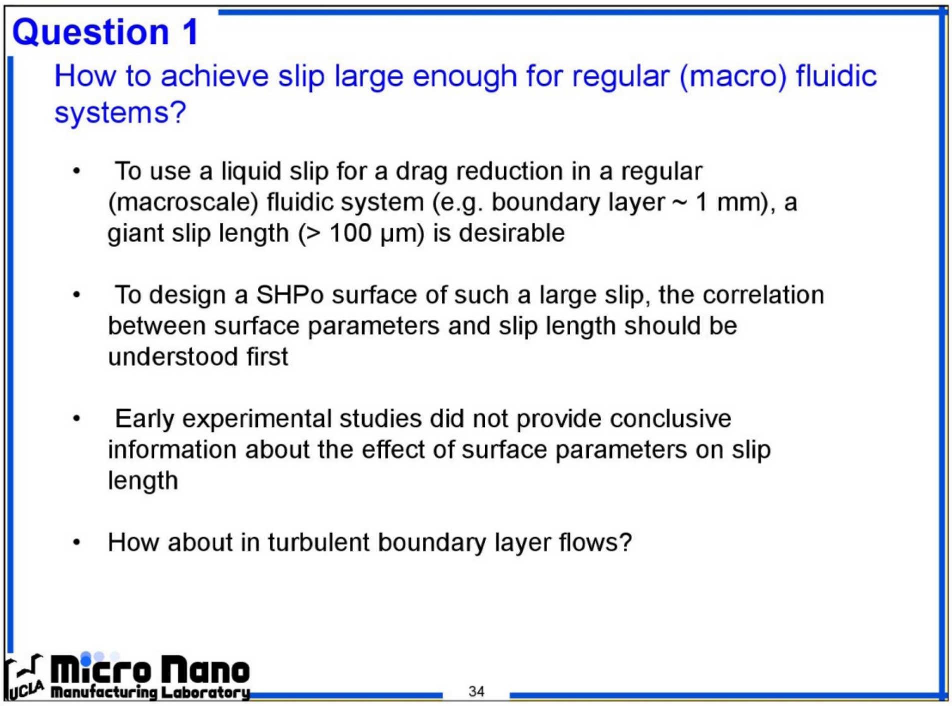


Now, can you keep the superhydrophobicity even when fully submerged in water for a long time? You need air to be able to reduce the drag. It is pretty well known in fluid mechanics that if you cover an object in the water with gas, you will reduce the drag, obviously because air has much less viscosity, i.e., one fifth the viscosity of the water. People already know this but they spend more energy creating and keeping the gas bubbles than what you save in energy using drag reduction. Therefore, it was never practical. That was the case for decades.

When the superhydrophobic surface came into the picture, people realized that maybe this surface is not all air, but most of it is air and that air is not leaving. You can reduce the drag quite a bit without putting any energy so that the drag reduction is a net gain for you. This is possible. That is why they were so excited 15 years ago and many people have been studying this for decades. However, again, as I said, nothing has worked so far. There are reasons.

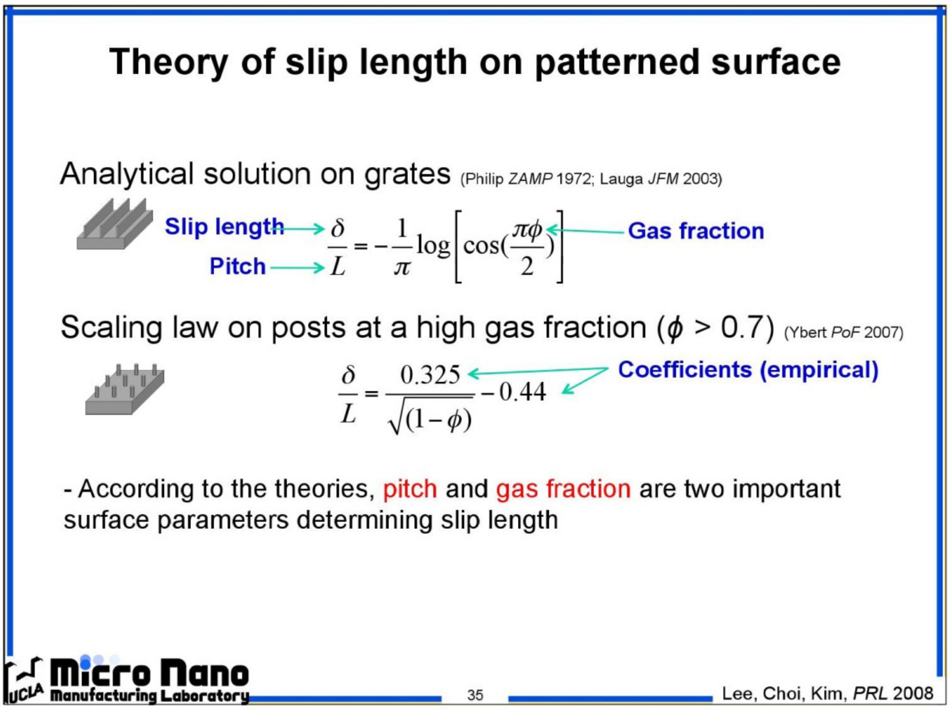


Now, I will summarize what we found. For this kind of surface to work under water in a boat for drag reduction, there are these two main scientific and fundamental questions to answer. Questions 3 and 4 are about making it cheap and practical. I will not go into details of Question 2 about how to maintain the air. Can the air be maintained? The answer is no. It does not get maintained. The air will be diffused away underwater after several hours. Therefore, the whole concept of superhydrophobic surface does not even work.



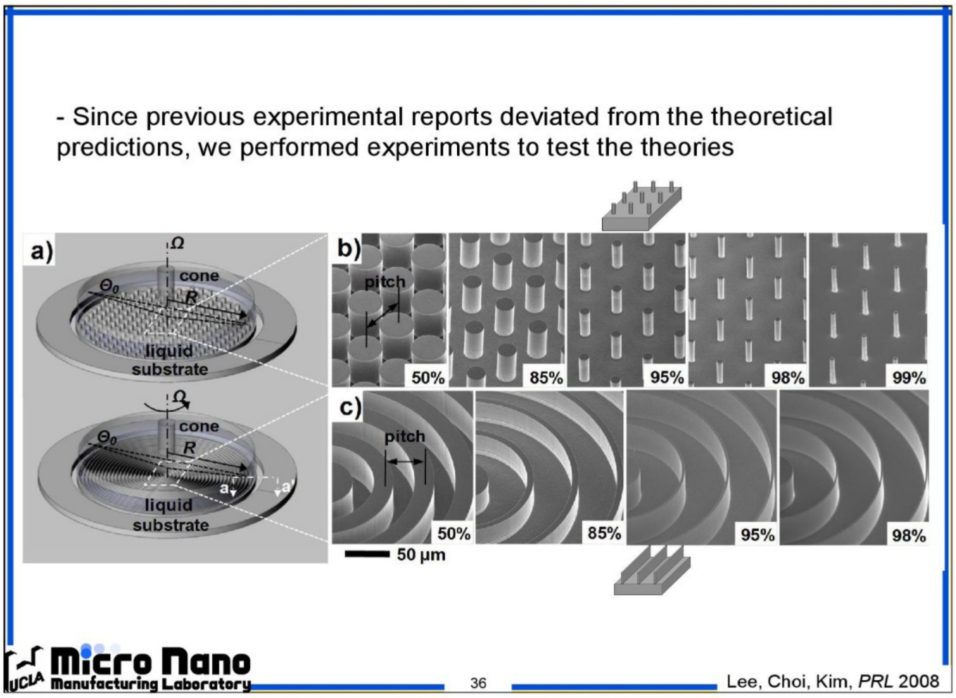
The answer to the first question is conceptually yes. There will be drag reduction, but how much? If it is only 1% drag reduction, it is not practical. Nobody was able to quantify how much. Let us look at the first question. How to achieve slip that is large enough to have an impact in a macro-scale application such as boats? To do that, you should have enough slip on the surface. Superhydrophobic surface is already known to have much larger slip than regular Teflon surface. However, nobody knew if it was enough.

How do you quantify this? How do you even design? Early experimental studies over the past two decades have produced a lot of publications showing that there is a drag reduction. Data was everywhere. Nobody could believe anything. Some studies showed a large drag reduction and others showed only a little drag reduction.



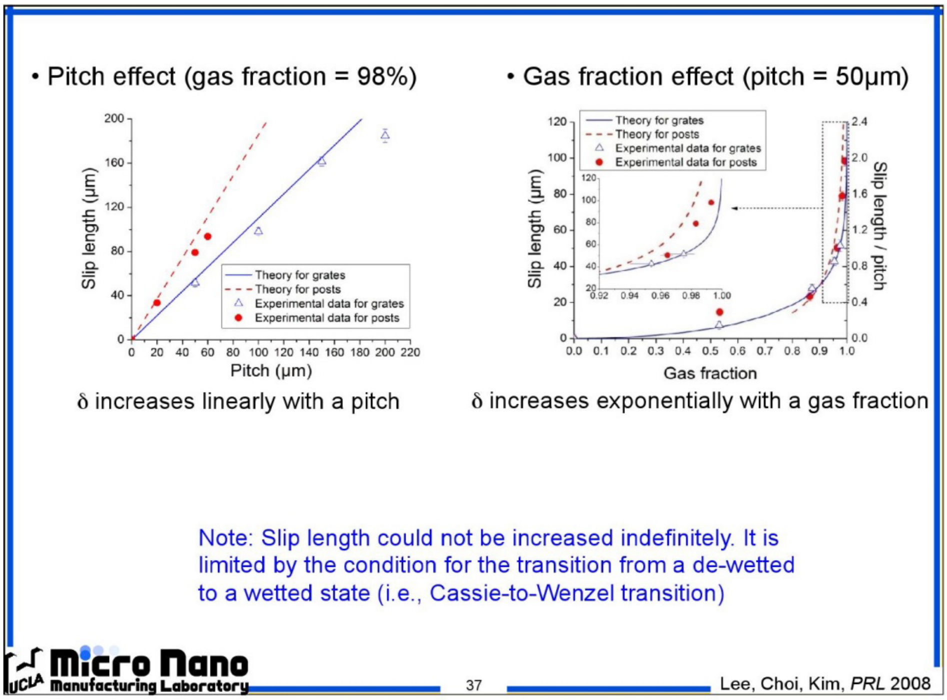
While this works okay for small laminar cases, the next question is whether it really works for turbulent cases. Does it work not only for turbulent cases but also for turbulent boundary layer flows in boats? Now, we know the equation. There are people who are publishing equations, but who knows which is correct? There were equations that described how much slip this kind of surface or that kind of surface would have. However, experimental verification was impossible because a random superhydrophobic surface cannot give you the parameters you need to solve the equations.

At least one thing that became clearer was as you pitch the distance between structures and gas fraction, meaning more and more air fraction, you get more slip. It makes sense qualitatively, but what about quantitatively? How do you know? This is where MEMS is needed.

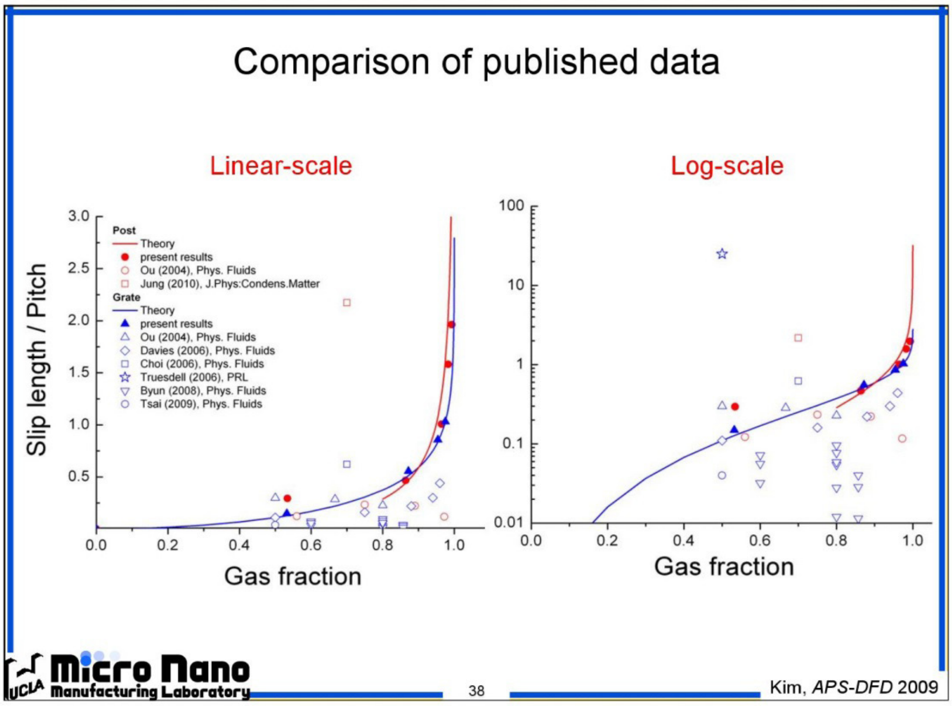


This is what we did several years ago. We made a surface that mimicked this or that structure. This one is about an inch in diameter. Under the rheometer, you measure the viscosity of the water. If the viscosity of the water is regular, you do not have any drag reduction. If the viscosity is measured to be lower than it should be, that means there is a drag reduction. It is very simple and that is why it was useful. Whether it is making it linear or concentric, MEMS can do it.

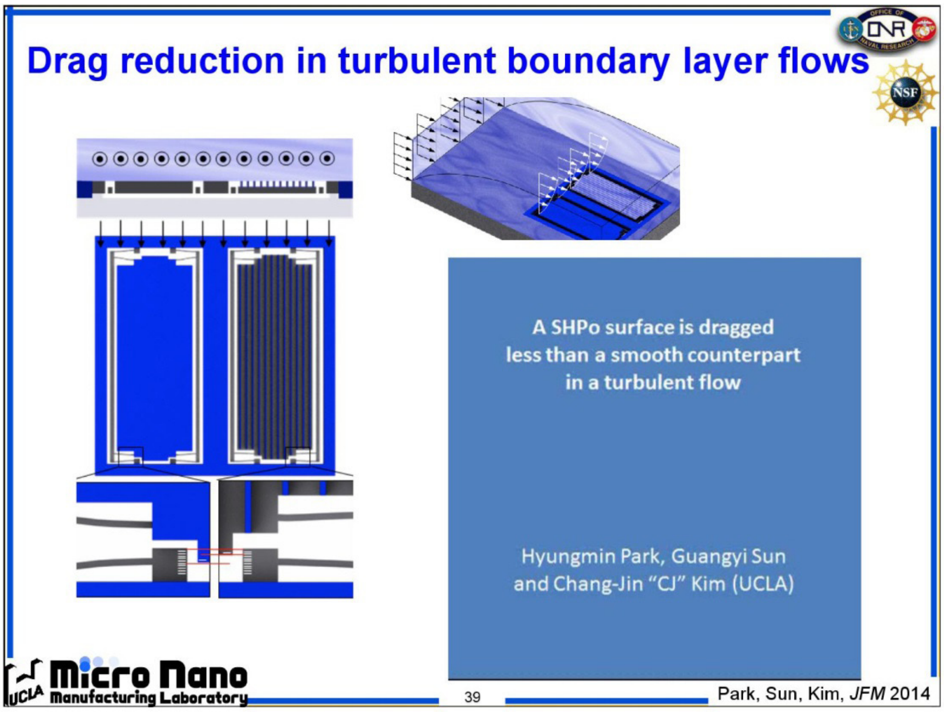
However, regular MEMS cannot do it because these are all based on instability issues. In other words, if any of these pins or posts is defective and water gets in, the entire surface gets wet. People will immediately think, 'it is not that practical.' Yes, it is not that practical. You have to make this small surface completely air-free. It has to be perfect. You have to go beyond regular IC manufacturing. That was our main research.



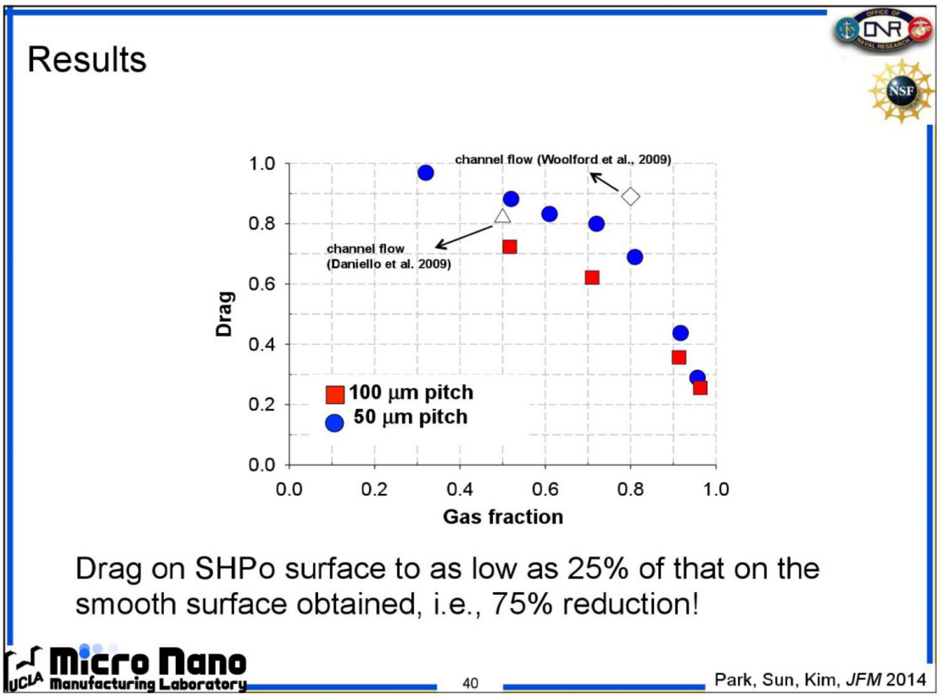
We developed conditions so that this surface would be completely air-free. Then, you can measure and get the data. The results were surprising because it turned out many of the equations were correct. We identified which equations were correct. They were those that completely matched our experimental results. Not only that, we found out that a lot of the data in the literature was dead wrong. Those with less drag make sense because experiments cannot be better than theories. However, some of them were even better than the theories. Obviously, something was wrong. Experiments were not that easy.



For the fun of it, I made these linear- and log-scale graphs with one data to prove how wrong it was. Until the experiments were done, a lot of people were in the dark. A lot of people were working hard but the data was very unreliable. Once we had that experiment done, we found out which equations were correct. These were actually very small and gentle laminar flow cases. Now, there is no more controversy. That was how MEMS was useful for settling down the entire field at least in the laminar case.



Nevertheless, eventually, drag reduction should work for turbulent cases as well. We made a surface like this, which is silicon-based, about an inch by inch. Two plates are suspended by exactly same beams made by MEMS. They are exactly the same springs, but with one difference: one surface is structured and the other surface is not. Both of them are Teflon coils. When there is a flow of water and if one surface shifts more than the other, that means there is a drag difference.

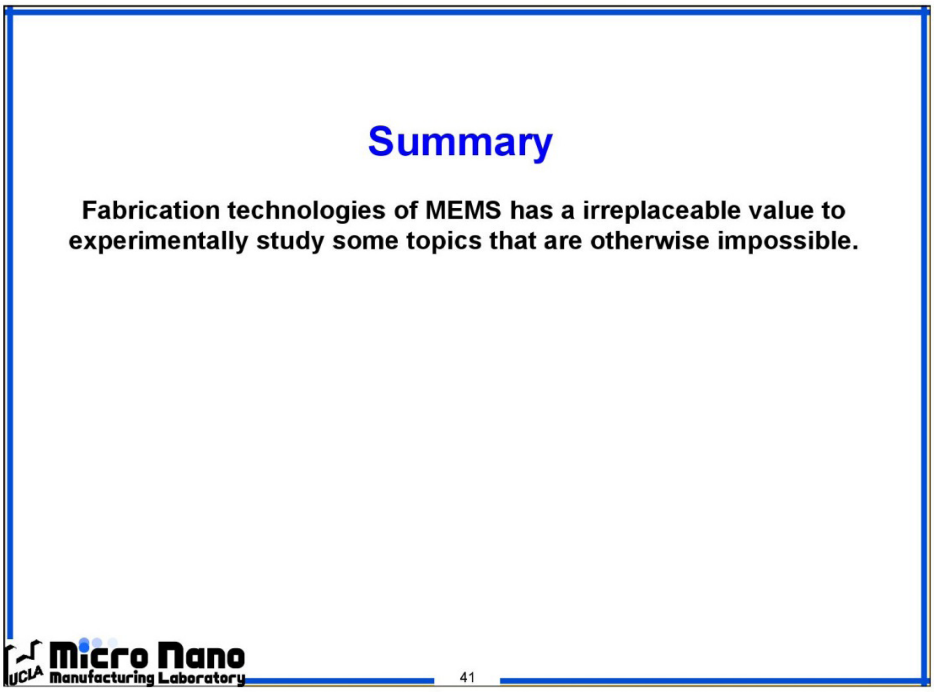


We were able to use a high-speed camera to see that. This was our scale. One plate is moving more than the other. This is how much it moves when the surface is smooth, and this is how much it moves when the surface is not smooth. There was no need to worry about the measurement error because we are comparing the two. Any error would be shared between the two. Whatever difference there is, it is due to superhydrophobicity.

The difference was strikingly large and this was the first data to show how much drag we had. 1 is drag of a smooth surface and 0 means no drag. As you go lower, you have more and more drag reduction. We found that, as you have more and more gas fraction, you have less and less drag.

In our experiment, we were able to get to only 25%, which means as much as 75% of drag was reduced. This would have been impossible unless you made samples with MEMS. That is another example of MEMS's value.

This is never to mean that you should expect 75% drag reduction in a boat. It will not happen. However, with MEMS in lab conditions where everything is perfect, you can at least predict theoretically what is possible.



My summary is very simple. I wanted to show you that the power of MEMS fabrication is not only in commercial and large volume. Fabrication technology is also very valuable in R&D.

Thank you.

Creative Economics through Hyper-local Manufacturing

Zvi Karni, Vice President, Alion Science & Technology

Good morning. I would like to thank the organizing committee and Dr. Im for inviting me. I feel like an odd presenter here since we are not a manufacturer and our work in this world is to develop solutions to problems that are presented to us. Problems that we see where there is a need to invent or develop either the science or engineering or to adopt science that is done in other places.

I saw from the previous presentations some elements that were immediately applicable to us. When there is any development in the world in terms of reduction of drag in ships, we will be one of the parties that will jump on it by either testing it or trying to apply it to our needs.

Alion Science and Technology is a pretty large company of about 3,000 people that is divided into half: one for ship designers and the other for scientists who came from the Illinois Institute of Technology Research Institute (IITRI). The presentation will cover both sides of our company.

We have been designing ships for many years. Actually, we have been supporting the Republic of Korea's Navy since 1978. I believe every ship of the Korean Navy has some parts that we designed. We did not do the full design but we contributed to special elements of the design.

When you look at ships, we have limitations because of manufacturing capabilities. For example, we cannot develop the optimal surface of ships in the water. We have to put the ship on the ground and develop it. This means that, in the shipyard, there is the capability to bend the metal not to have kinks and breaks so that it looks like a smooth surface. We are adopting our design to actual capabilities.

Another element is the piping inside. We are looking into manufacturing in order to develop lengths. Every shipyard has different diameters that they can bend and different lengths they can cut to produce. Our design is affected by these elements.

On the other hand, clients come to us with requests to develop something that does not exist. Then, we approach universities to find out what exists in the world, what are the state-of-art technologies and do the application from research into reality.

To give you an example of that, in the 80's, we got a request from the government of Israel to develop a ship that was stealthy. Their motivation was that they had missiles that were short-range while the enemies had longer-range missiles. They wanted to be able to keep the ship hidden until they could match the long-range missiles with their short-range missiles. In order to come up with a solution, we went to a few universities including the Georgia Institute of Technology, Atlanta for whatever they had developed at the time, which was reduction in radar signatures. We went to the navy labs where they developed reduction in infrared signatures.

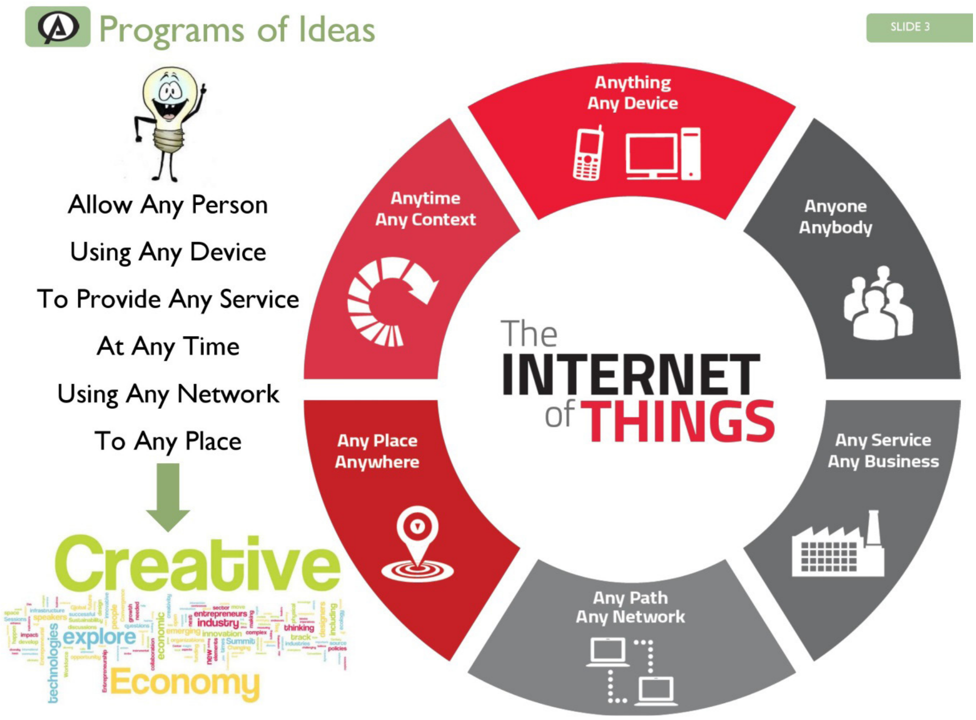
We took both technologies and applied them to a ship. By doing this, we developed the first stealth ship. Since then, if you look at ships, they have all the same designs because they follow our basic design from years ago.

The second part of our company initiated by Illinois Institute of Technology where major professors organized themselves, left the university, and created the institute to take advantage of their inventions.

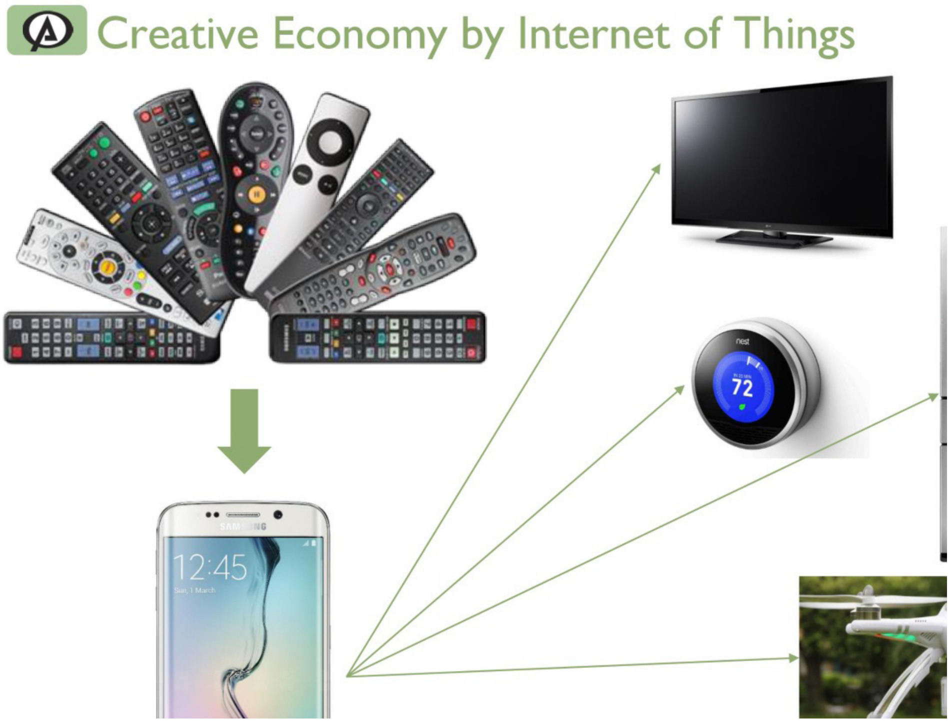
In the 40's, there was a need to standardize what a golf ball does and what the player actually contributes. In order to solve the problem, it was sent to the university. At that time, they were quite young, about 3 years in existence. They developed a standard machine that checks the golf ball. It is the standard of today's golf balls.

The idea was that someone came with a need and they developed applications to solve the problem. Most of the science part of the company was doing work in the maritime zone or in other fields such as this field. By the way, roughly the same machine operates today and before any official tournament, golf balls are checked with the same machine, which is about seventy years old.

This is the introduction of creative economy that every presenter today had a different name for.



From my viewpoint, it is the Internet of Things. You want to have an idea either coming to you as a request or you can come up with an idea. Now with the new technology, you can materialize it. You want to be able to provide any service at any time in any location as fast as possible. Movement from step to step is actually a creative economy. Today, it was called additive, creativity, etc. There seems to be different names for the same thing.



Let's look at the development of devices. When I was a child, I thought the only thing I had to turn to the right radio station was to turn a knob. This developed into remote controls. Now, you have remote controls for every device at home. You play with the devices and it helps every man. You can also use it to operate units. Children of today are going to have one device, and via the Internet, they can operate devices from any location at any time, any instrument either at home, at work, etc. There is a progression of ideas that can be materialized as soon as the technologies catch up. Or it is pushing the technologies to be developed.

When it comes to manufacturing, there is a need to product specific things as cheaply as possible. There is a need to do many things as rapidly as possible. It has to be rapid because there is competition that will take away your bread if you do not do it rapidly. It has to be rapid because it will cost you a lot if there is a delay.

Mobile Parts Hospital

SLIDE 6

A self self-contained, self self-sustaining, C-130 transportable mobile mini-manufacturing system that can efficiently fabricate standard and unique parts at or near the point of need.

Here we come to another product that our company developed that has gone through these stages. Majority or 90% of the company's works are for the U.S. government. When the U.S. deployed forces to Iraq and Afghanistan, they found that, because of conditions in the area, there was a lot of breakage and a lot of vehicles that have not been in operation for years. Started their life in this condition, things started to break. After a very short time, they found that they faced obsolescence in many parts. They were produced in the past and nobody produces them anymore.

Many elements are unique. This means you had to find who manufactured them, get them back to the U.S. or somewhere else in the world and find out who can supply them. If something else breaks in your vehicle, you had to wait for up to ten weeks to get the replacement. This meant many vehicles were out of service.

The company got a request to develop a rapid response unit. We do not produce. Rather, our job was to take whatever was available and package it under these restrictions. Here are the restrictions. It has to be in a single container, it has to be ai- transportable to an airbase near where it is needed, it has to be independent and it has to be able to produce whatever is needed with quick repairs.

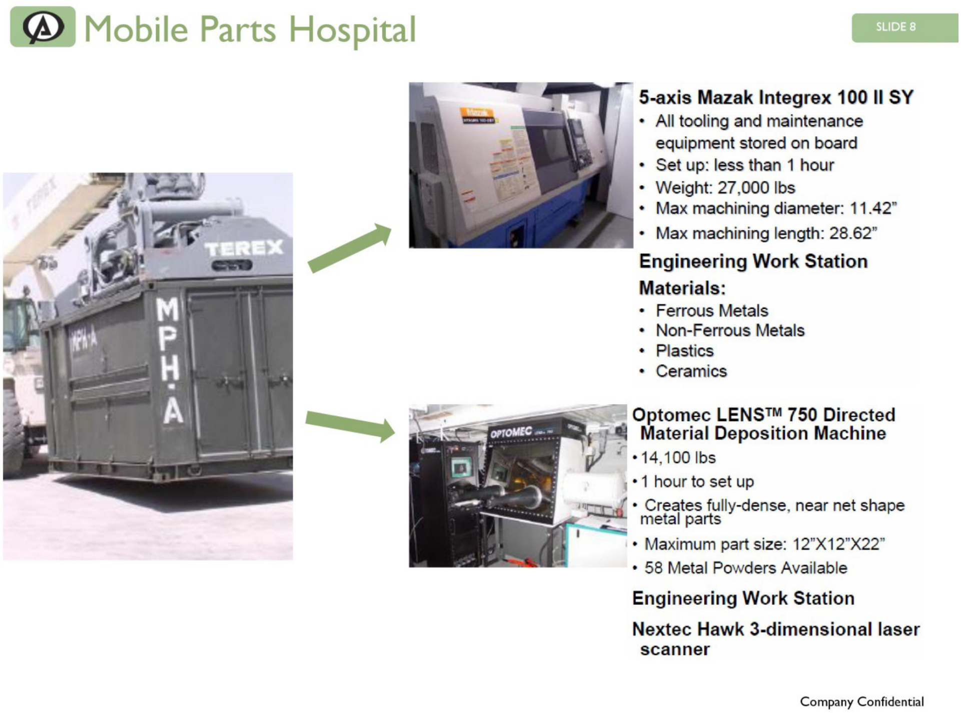
There are two views of the units. They are independent. They have their own power and their own machinery, which I will show you in a minute.

Mobile Parts Hospital

SLIDE 7

Company Confidential

What do we have in this mobile parts hospital? This was the name that was given to it. What we have is a complex cutting machine that initially did most of the work. We would have materials stored, coming with the container. When something breaks, the element would come to the hospital where they would measure it and try to find a component or a CAD drawing that exists. If it did not exist, based on the measurement, they would just put it into the machine and a machine will produce a component.



As time progressed, in the last generation of these machines, we now have 3D printer in this unit. This maybe one of the first applications where a live unit went to the field in the package with 58 metal powders that are available.

Today, because of the Internet, there is an easy connection to the base. There is time to find the original manufacturer or original drawings, send them back via the Internet to the unit and print it out whatever they can. You are using the machines for the accurate dimensions if needed. For many of the parts, there is no need to use the machine. There are many units like that deployed in different parts of the world. They support the army and the air force. Now we are starting to put smaller units in ships.

We found two videos on the Internet where the army talks about these units. Let me show you.

Basically, the unit that is broken reaches the factory or the hospital. It is checked and measured. A very complex and similar component from different powders are created to replace the original unit. This was done initially without lots of engineering because the idea was that it will not work for the full life like the original component. It was considered just a temporary unit.

However, some of the units lasted a long time and have never been replaced since they were put in the first time.

Another video shows the operation where a part comes into production and tens of thousands of parts are produced by this hospital for use.

The second video at the top says that we are not just doing repair any more. Any idea that comes in the field, a modification of a unit, if you want to have the foundation for guns, if you want to change some tools to operate in the battle, the request come to the hospital.

On the spot, they now make changes in the CAD drawing or they send it back and the change is made by the States. It is sent back via the Internet to the unit and improvement is manufactured on the spot. There is both repair and upgrade to the materials and components going on in the field.

There is an extremely wide application of 3D printing today. I selected just a few samples for the audience. These are items that are actually made using 3D printing. You can actually create full shoes of your own design and with your own colors and paints. This is manufacturing of bolts and mechanical parts. This part is printed and we are doing this part in our machine. Especially when the dimensions are not standard, when you do not have spare parts at all in the area, we just plug it in and create it, whether it be car parts, brakes, body parts, etc. Of course, tooth can be completely done today by printing.

The question is whether this will completely change manufacturing. Some people say, 'Let's wait and we will cross the bridge when we get there.' You have to look only a little further. The first bridge is going to be printed in two years. It's going to be in Amsterdam and they are going to print the bridge on the spot as a test to bridge a canal. Today, they are creating smaller-scale bridges.

The question of whether and how much will change in the future is a question of economics. Then, there are different mechanical or technical items that will need to be addressed. For example, the machine tools today are much larger than the components that they produce. This makes it very difficult to do rapid production, because you have to go back to wherever these big machines are.

But if you have this robot as you saw in the bridge, you can create a large component with a small unit. This is the kind of direction that we are going to. There are going to be many social changes. Every presenter today addressed the same subject from different viewpoints.

I will wrap up my presentation here.

A Brief View into the Future of Precision Manufacturing by Cold Forging

Matthias Hänsel, Division Manager, ThyssenKrupp Presta Steering Group

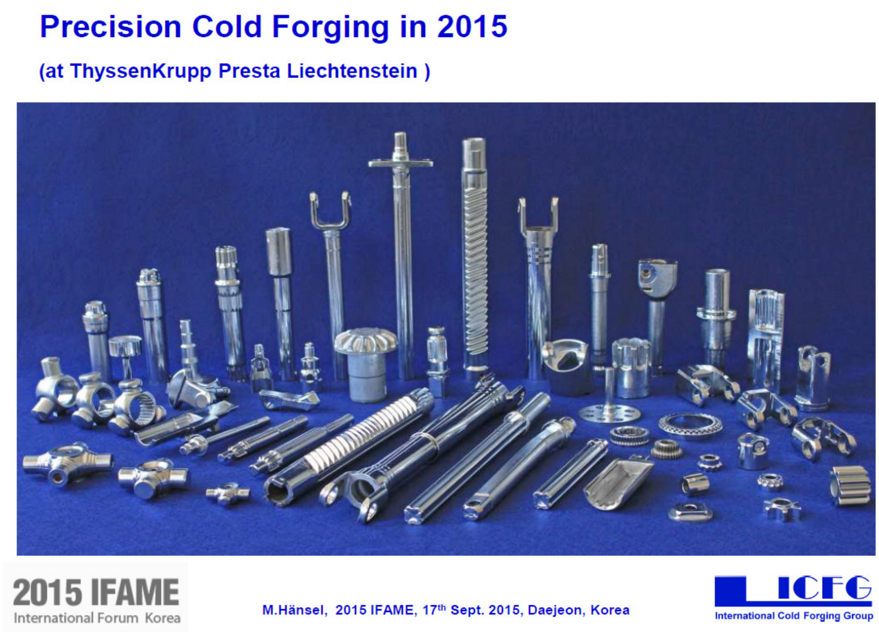
Note: The full paper of this presentation is attached in Appendix 1.

Ladies and gentlemen, good morning. Professor Choi, thank you for the introduction. I am very happy to be here. Thank you for the invitation to this prestigious international forum on advances in mechanical engineering. Thank you for giving me an opportunity to give you a brief view into the future of precision manufacturing by cold forging.

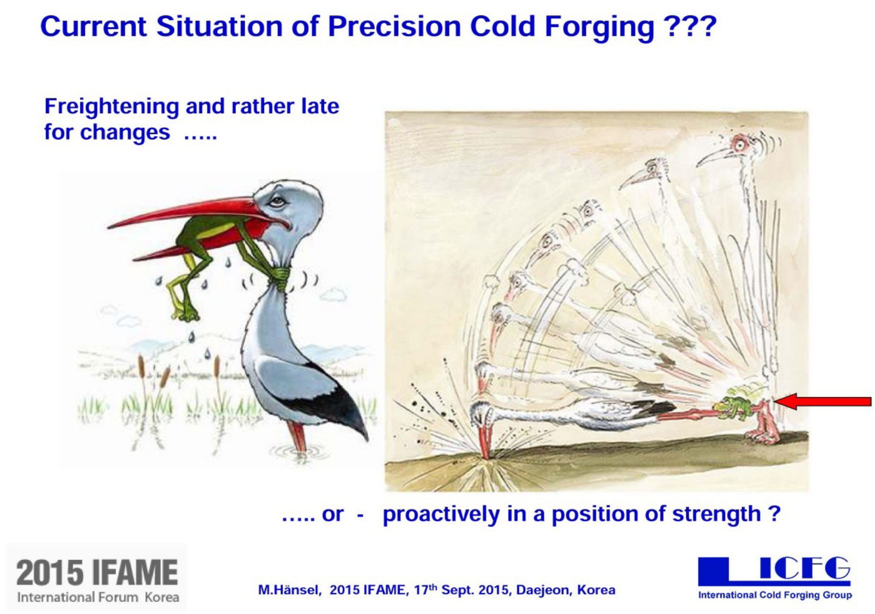
Since this is not a very easy topic, as you know, I am going to tell you a story, inviting you into a little trip into the future. Using this special way, I want to share with you the thoughts and ideas I gathered from a special initiative at the International Cold Forging Group (ICFG), and from discussions with many experts from inside and outside of ICFG, as well as from relevant literature. Since it is not possible to give all of these ideas now, please have a look at the proceedings. Luckily, my long paper was published and you can read all the ideas ICFG has gathered and collected.

My aim is not to give you a correct prediction of the future. This is not possible with scientific precision or economic relevance. If I were not the Chairman of the ICFG, I would actually pass this job to Mr. Yamanaka who will be speaking in the afternoon. However, I want to trigger your fantasy and your imagination because that is where our creativity and innovation start — in our dreams and visions. Maybe we will have a chance to discuss and share them afterwards, which I believe is one big purpose of this event.

A symbol of the power of vision to realize one of the biggest dreams of mankind is the dream of flying like birds in the sky and reaching for the stars. This dream made us make airplanes, jump around the moon, and it will bring astronauts to Mars very soon. Then, what are the smaller visions and dreams of cold forgers, which can bring future successes to our technologies, and which will let us jump around on our moon of technology, if you understand what I mean. I will give you the answer later. I want to stress the power of vision and imagination to push our technologies and our lives forward.



You can see some parts made by precision cold forging in our company. Since our company is making steering systems, most of them are related to steering systems and components. Some of them have complex gears and shapes used for other tier one suppliers in transportation business and automotive industry.

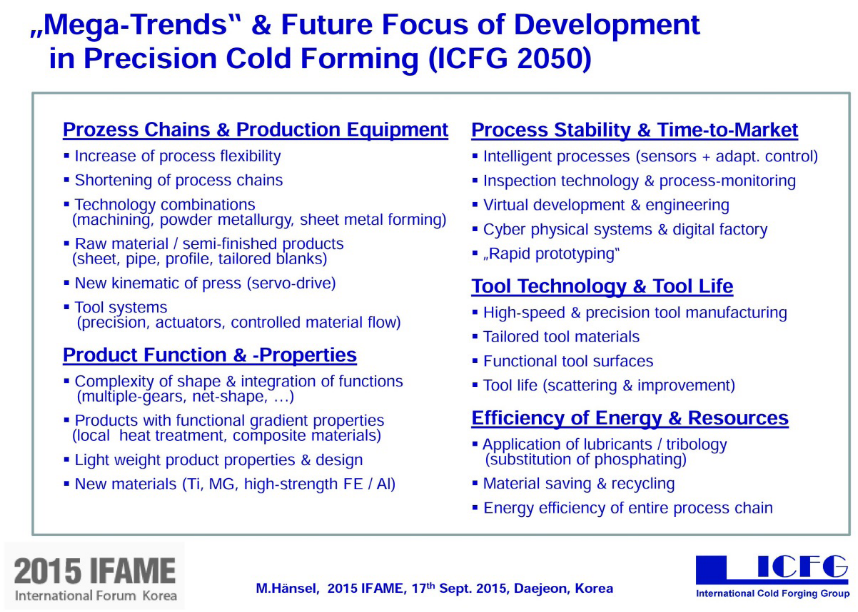


What is the advantage of precision cold forging? The word ‘precision’ in the name shows that we can reach a very high accuracy in shape and form. We can also do it with a less amount of materials or machines because it is very precise. It is also very fast, which means it is cost-effective. Unfortunately, we have to do it, as the word ‘cold’ suggests, at room temperature. Normally, you squeeze this part of the material using two tools at hot forging temperatures. It is very easy. Soft materials can be forged quickly.

In the case of cold forging, as you can imagine, the material has a high resistance against being squeezed into a desired form, requiring high press forces and high mechanical loads on the tools. There are 20,000 bars in such tools. Of course, there are a lot of technical problems. We have to take that into account and take this under control. This is very important for the future because we want to increase the precision. We want to increase the complexity of shapes, which means we may want to combine two or more parts in one forging part that will need to be assembled otherwise. We want to use new materials, light-weight materials for new applications, and we may also want to reduce the process chains to make them less costly. Those are some aspects of precision cold forging that I wanted to tell you before we go on.

Cold forging used to be a very booming technology for the past five decades. However, today, we have reached a certain level of stagnation. Striking and innovative developments are seldom and technologies mature. Implementation of these new technologies is difficult. Leading companies in this sector feel somehow threatened by emerging new suppliers from low-wage countries or they feel threatened by discussions about light-weight concepts and electro-mobility (e-mobility).

They ask themselves, ‘Will we survive?’ Maybe in this group, the situation is uncertain and uncomfortable and it can be compared to this little cartoon. The cold forging market has stopped growth. What can we do to turn this situation around and secure more striking and powerful positions? Following the vision of our friend before he came to this situation, we have to be innovative. We have to do things in different ways. You have to be early enough and do it in time. You have to be proactive from the position of strength. This vision is a little bit unrealistic but this was enough reason for the ICFG to search for the answer to this question.



We established a separate subgroup called ICFG 2050 to deal with aspects of future cold forging technologies. The subgroup was established in 2010 and held several workshops to gather ideas from ICFG members about future developments. We summarized the results in the technology report, which is given in the paper. We also put the results into a diagram and grouped them into different technology trends. We identified five mega technology trends that will be the focus of future technology developments.

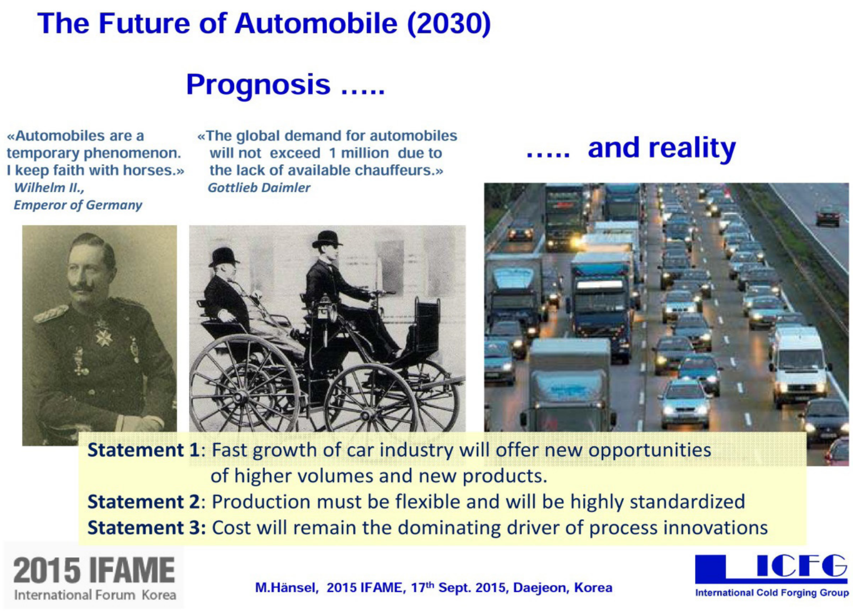
The first one has to do with processes and production. Here, you can find new presses with servo-drives, new tooling systems, new technology combinations and cold forging starting with centered pre-forms, sheet metals or with casting. There is also the increase in production flexibility and shortening of process chains.

Then you have product functions and properties. This is about the complexity of shapes and integration of functions. Yet, you also have products with functional gradient properties, which means that light-weight products using new materials like aluminum, magnesium, titanium and other high-strength steels.

You also have process stability using intelligent processes, sensors, adaptive control, virtual development environment, engineering the physical systems and rapid prototyping with additive manufacturing.

Then, you have tool technology and tool life. This is very important for cold forging.

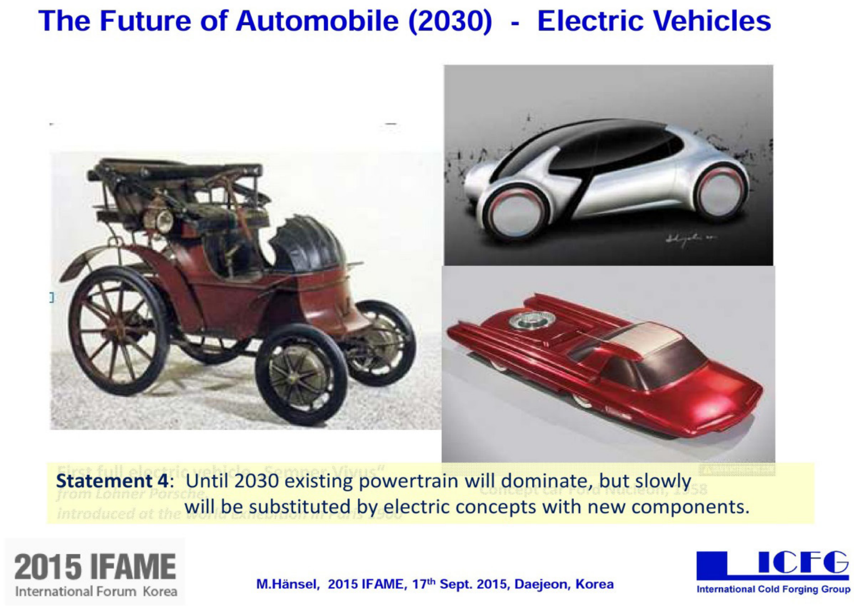
Another element is efficiency of energy and resources. This would include using environmentally friendly lubricants, for example, or saving more materials and recycling. It is also important to save energy along the entire process chain.



There are the many things we have to look at. Before I go into the future of cold forging, let's have a look at the future prospects of automobile and automotive industry, one of our biggest customers driving our development.

At the beginning of the last century, Gottlieb Daimler, one of the big fathers of automobiles said that the global demand for automobiles will not exceed one million due to the lack of available chauffeurs. Today, we know how wrong this vision was. What can we expect in 2030 when about 8.5 billion people are living on our planet with more than 50% living in big mega-cities with more than one million inhabitants? We will see that the number of cars will double to two billion units. The annual production volume will increase from 70 million passenger cars per year to 150 million per year. We will also see that there will be more variety of models in certain car segments. At the same time, we will see the trend towards modularization and standardization of global vehicle platforms.

What does it mean for us? The fast growth of car industry will offer new opportunities in terms of higher volumes and new products. This means that technologies will not die. Good news. Production must be flexible and highly standardized. Cost will remain the dominating driver of process innovations.



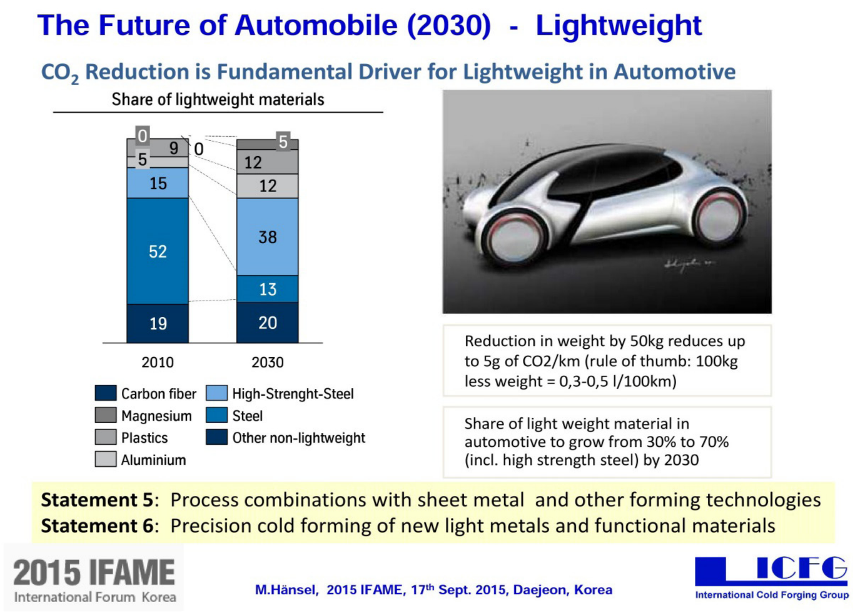
E-mobility, the dream of generations of automotive engineers will present another big challenge or change to the automotive industry in the next couple of years. Already in the 1900s, Ferdinand Porsche, another famous man from the automobile industry, developed this full electric car with two fully electric front wheel top engines instead of the central engine and mechanical transmission. It was a revolutionary concept at the time.

Today, more than 100 years later, this concept of front wheel top engine is considered again to be a very interesting system for mainly small electric cars. Due to the high cost and low performance of batteries at the time, these cars and other electric vehicle concepts were not successful, leaving combustion engines triumphant. They dominated the field for a long time and will dominate the field for the next several years until we see cars like this.

According to different studies predicting 2030, about 80% of cars will still have combustion engine, 16% will be hybrid cars with an additional e-engine, and only 20% will be fully electric, mainly small cars. Electric steering systems with the autonomous driving function, or self-driving cars will become a standard. The cost-efficiency and high performance of batteries and quick recharging stations will boost the use of electric vehicles in the city areas. However, full e-mobility will not come until 2050 when cheap renewable or fusion energy is available.

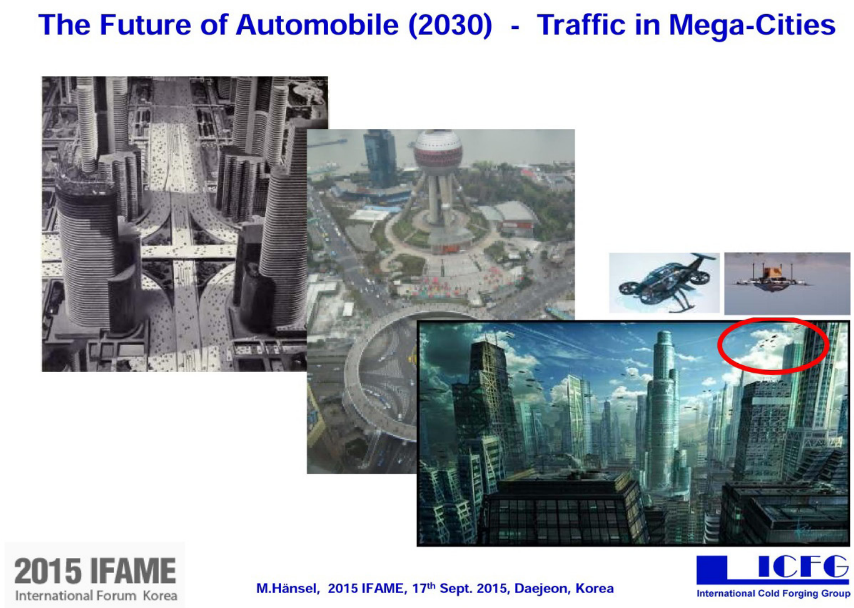
What does it mean for our technology? In 2030, power trains with our cold forging components will still be dominant, but they will slowly be substituted by electric concepts with new components. That means we still have time to act now as the cold forging community.

Please look at this funny car here. Fortunately, it remained to be a concept car. It is a Ford Nucleon. Developed in 1958, it had a small nuclear power reactor onboard to generate electricity for the car. Today, fortunately, fuel cells are considered a much better concept for onboard electric energy source and they will become available.

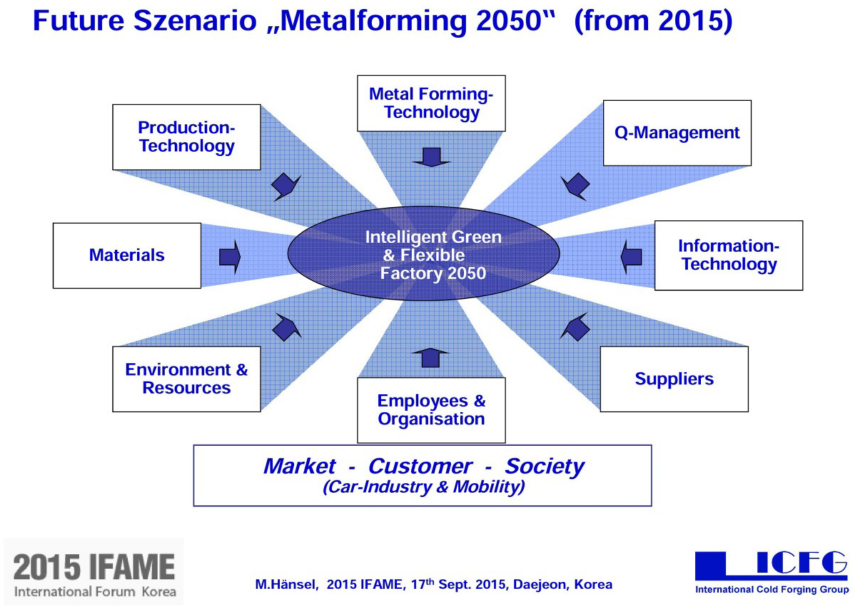


Light-weight is another big issue in the automotive industry due to the international requirement for CO2 reduction and it is the fundamental driver of light-weight design in the automotive industry. Until 2030, the share of light-weight materials will grow from 30% to 70%. As you see the blue color here, simple steel sheets will be replaced by aluminum and magnesium alloys and other high-strength steels because they can make thinner sheets, which means the cars will be lighter. 100kg weight reduction means a reduction of about 0.3 to 0.5 liter’s fuel consumption. It is very important.

What does it mean for our technology? Process combinations with sheet metal and other forming technologies will be necessary. Precision cold forming of new light metals and functional materials will be necessary.



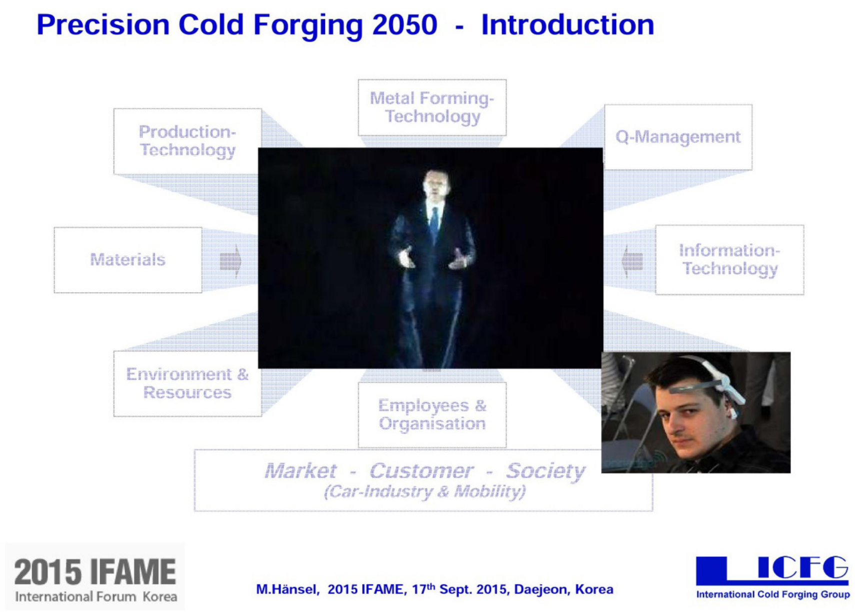
City traffic is another big challenge of tomorrow. It is not new. It is as old as the history of automobiles itself. Here, you can see the vision of future city traffic from a 1939 automotive show. Here, you see the Shanghai's city traffic today. There are similarities. Individual mobility behaviors in big cities of tomorrow will call for new urban traffic concepts. They will include car sharing, small light-weight cars, fully automatic driving, and electric engines. However, there are limitations in building new roads or metro lines. Infrastructure is very expensive.



What else can be done? Let's have a look at this future scenario of a future city, particularly at these little dots. Although it might sound like a science fiction, little aircrafts like these will conquer the sky of our megacities in the future.

Taxis will transport passengers and commercial goods from building to building. These private helicopters already carry VIPs in megacities like São Paulo. That is the reality. There are these multicopters of Amazon. This is already happening in reality. I personally believe we are witnessing a new technical revolution. We will soon have individual air mobility. This is one missing chapter of the mankind's dream of flying like birds in the sky. Who can stop us?

Remember how automotive mobility started more than 100 years ago. At that time, only rich people could afford cars, a symbol of a new age. Then, what do we see today? We see a big change. Maybe this change will bring us a new market of precision forging and ultra light-weight components made out of metal forms or metal fiber reinforced organic materials. Have you gathered enough visionary power now to follow me on a trip into the future?



Let's start our time machine. Before that, let me make another comment. When we started to think about ICFG 2050, we came around a very interesting article by Mr. Silverton of the Great Britain published in 1977, describing what the metal forming industry will look like 50 years later in 2027 by sending an observer to some company visits. He reported what he saw. It was an interesting concept.

What he reported was amazing. His report included, for example, a digital factory as an engineering environment, data transfer by the Internet, supply chain management, unmanned operation of automatic press transfer lines, flexible multifunctional presses with central hydraulic supply, energy recycling, solar power from the company's roof, energy recovery, recyclability of products, electric vehicles, etc. This was a time when the PC was not yet born. What vision can do is amazing.

While studying this article and thinking about what we have been doing at ICFG, I suddenly had an opportunity as the Chairman — sometimes, chairmen have this power — to reactivate the time travelling machine of Mr. Silverton and sent an observer to the future of maybe 2050. He had the task of reporting back to me what he saw and whether what we anticipated at ICFG was correct or not.

This company's visit started with a long welcome speech by the president of the company in the showroom. Unfortunately, the chairman was unable to come in person because he was on a business trip to India, a big mega-market for cold forging at that time. Therefore, his hologram was transmitted to the room in brilliant quality. That is how he gave his speech. He said, "Before starting the tour, please remember that you are not allowed to take any picture during the tour or my speech." So, unfortunately, I cannot show you any pictures from the future. However, he allowed my reporter to take some pictures from the museum which very well document the technical revolution of this company from 2015 to 2050. My reporter made some sketches as well.

I will read a little bit of this report. First, the president explained the company's history and its success stories. The company started exactly 100 years as a cold forger of simple automotive components, like most other companies in cold forging today. He said that this was the only company that survived the dramatic change in car industry that started in early 2020's, that means a few years from now, thanks to a complete reorganization of traditional cold forging section toward precision forming including integration of complementary manufacturing methods and new materials. The company did not just look at cold forging technology.

Ten years later, in 2030, the company joined an international collaboration network of cold forming companies, which developed into a very powerful international organization of complementing partners for flexible small quantity production of net-shape and net-function products. This was the foundation of the company's success.

In contrast, other companies developed into large international groups focused on standardized and large quantity production of selected product families with a global platform and highly specialized manufacturing technologies, but with impressive a global footprint and big subsidiaries in major markets.

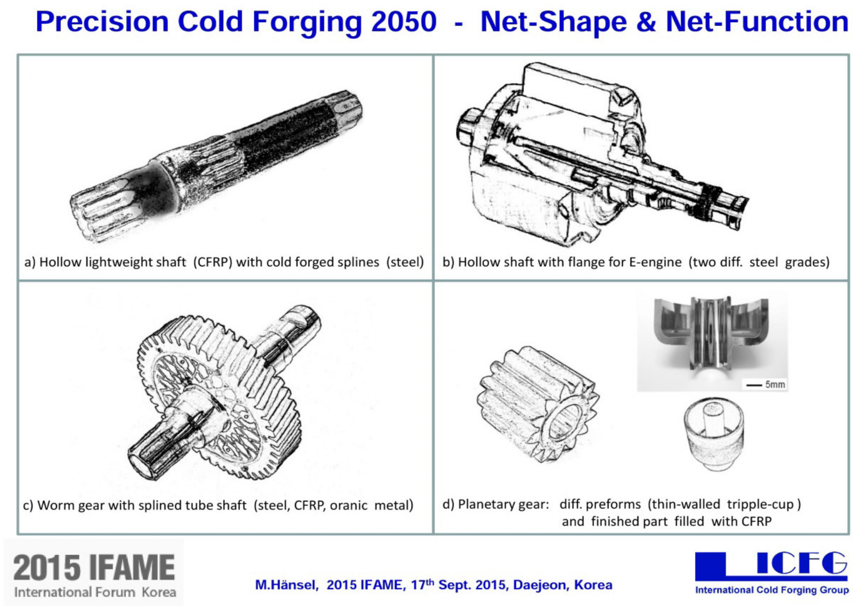
There were these two categories of companies. In both business models, however, the low-cost element was still the main market driver. He also mentioned that lightweight, which has been the focus for many years, had been replaced as the top issue of industrial research by efficient use of materials and design for recycling because energy was very cheap at that time, sadly.

Thanks to the company's rich experience in precision cold forming of lightweight components for small light cars, the company grew into a global leading supplier of such parts. In the fast growing sector of lightweight industry, bioengineers successfully copied the concept of light weight to technical ultra-light designs and manufacturing. Cold precision forming of fiber reinforced metal forms developed into one of the company's key technologies. Forming of these components was a big business.

He said that the first nuclear fusion reactor was successfully introduced that uses environmentally friendly sources of energy, leading to a long awaited boost to full electric vehicles. There was a boom in new net-shape and net-function components in electric engines and power trains, which account for a considerable part of the company's turnover. The president showed some examples, which I am not going to show now.

Later, I have some sketches that I want to show you. At the end of his speech, he wished the group to come again and have a nice day. After that, he disappeared and they were guided into the first highlight, a technical building with central engineering center and laboratories. Unfortunately, people were not able to enter the labs and offices, but they were led into a big room, a 3D vision center, which people called the big data room. There, they saw some very impressive 3D virtual reality shows about ongoing activities at the time.

The group had a very good impression of typical cyber-physical engineering lab, which was used regularly with customers. For full 3D design studies, numerical simulation of integrated manufacturing processes on nano-scale level, including resulting product properties, residual stresses and grade structure. In addition to virtual testing, for instance, they had lifecycle tests and crash tests and many assembly tests.



Following material scientists, process engineers gave other interesting insight into the activities of the material lab. They demonstrated a variety of materials and semi-finished parts that could be employed like special steels, light metals, aluminum and magnesium alloys, different tubes or tailored blanks for the final forming of net-shape or net-function parts. Also, many material composite billets with specific dissimilar material combinations or graded material properties are applied for integration of product functions: sintered preforms for special applications of bearings or filters, different steel grades, billets made of copper and aluminum combinations for electronic or solar industry, or different steel grades for hollow shafts.

You can see the different pre-shapes here. This shaft has two different materials with magnetic and non-magnetic iron alloys. They use a kind of a motor shaft as combined forming. They use organic metals with almost metallic properties, so-called organo-metals. New function hybrid materials recently developed in leading nano technology labs, proved to be ideal for cold forging of new lightweight applications. You can see this little thin shaped sheet metal forming in one stroke filled with organic materials, and then, this was formed into a net-shape component gear. It is very light.

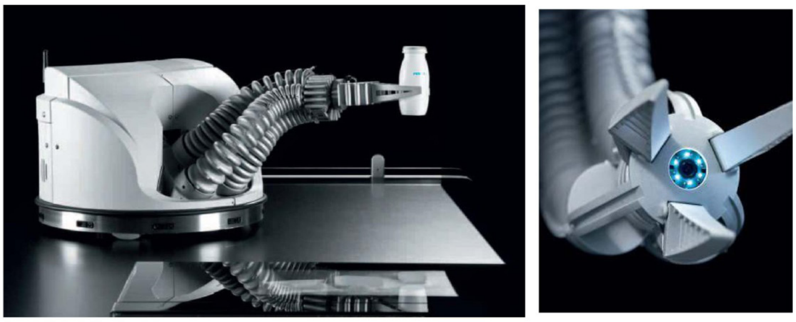
Net-shape cold forging in combination with other forming and primary shaping technologies, or so-called hybrid manufacturing, like precision forming of metal forms, made by laser assisted spraying. Final net-shaping, sizing of sintered or die cast components or even finish forming of injection-molded fiber-reinforced plastic, so-called real hybrid materials. It was a state-of-the-art company.

You can see the shafts with special materials based on organic substances calibrated by forming after this combined manufacturing. Technological boundaries between different forming and shaping technologies became overlapping and interacting for process engineers, using identical simulation tools and virtual engineering environment for the design of integrated process chains, and just applying different material properties on nano-scale level.

After the tour in the material lab, there was another tour to the chemical lab. I will skip those, but you can read some more about this in the document.

The visit continued with a guided tour through the forging plant. In general, intelligent production systems were assisted by the Internet of Things with smart human-machine interface or machine-to-machine communication. It was simple but rather complex artificial handling system, always following the modules with hands out like this. Collaboration between human and robot systems characterized the manufacturing environment of the press shop.

Precision Cold Forging 2050 - Flexible Automation 2

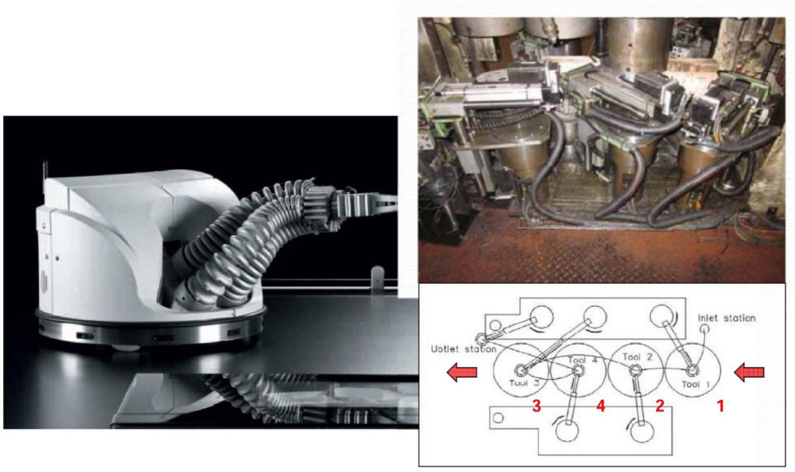


2015 IFAME International Forum Korea   M.Hänsel, 2015 IFAME, 17th Sept. 2015, Daejeon, Korea   ICFG International Cold Forging Group

It was very impressive to see how raw materials, which are very delicate parts because of precision, and finished parts were carefully loaded and unloaded piece by piece with the flexible high-speed handling system in the fully automated forging presses by smart pick-and-place grippers with integrated optic-tactile sensors for process automation.

The basis for the applied flexible handling system was ML robots, or mini light robots. Due to the new construction design by using extremely light and rigid components out of carbon composites and due to the intelligent local positioning system, fast and precise transport movements were possible. Equipped with intelligent grippers and measuring systems for different handling or in-line operations, they could become multi-purpose tools for a flexible automated production flow.

Precision Cold Forging 2050 - Flexible Automation 3



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The application of these ML robots allowed you to individually combine the forming stages of existing large multi-stage presses, which normally have material flow coming from here. First, second and third steps here. This is good for the machine, but not always good for the material process in the entire process chain. With this robot, the sequence can be changed because the robots are putting parts in different sequence lines, one, two, three and four. It is a very flexible solution for existing big presses because presses normally live for 50 years. This increased the possibility of using these presses considerably.

Precision Cold Forging 2050 - Flexible Press Shop

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The application of ML robots made it possible to have flexible press lines for multiple forging operations by simply linking several cost-efficient standard single-stroke presses of different sizes, mostly settable presses with new kinematics instead of large and complex multi-stage presses. It is very flexible and cost-efficient.

These so-called flexi-press lines offered a high degree of flexibility for many successful process combinations following the ideal use of material flow without restriction from presses. Flexi-press lines could be further combined with other operations like regular forming machines, joining of partial induction heating for functional integration of material properties in very economical process chains.

Precision Cold Forging 2050 - Flexible Press Shop

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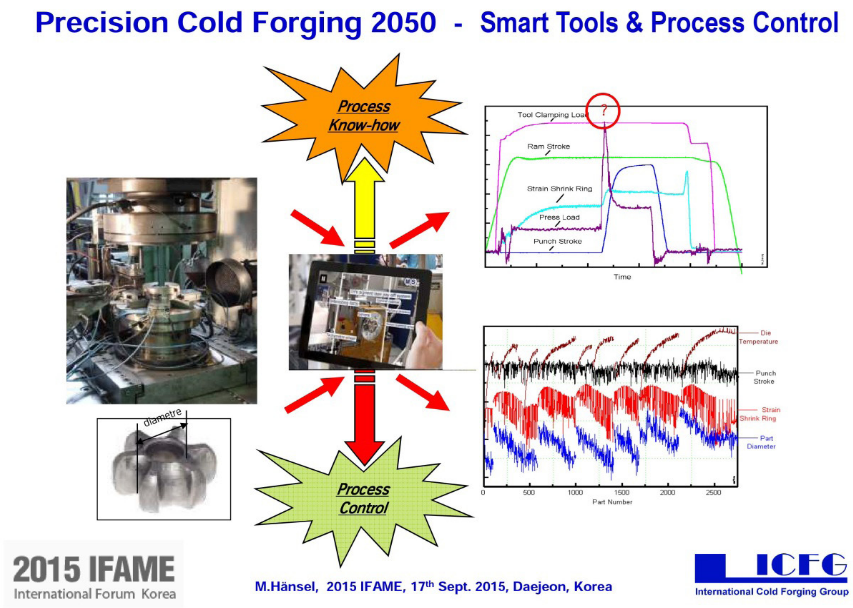
Another way that flexi-press lines increased the flexibility is that individual presses could be lined up in a new order easily with each product change by using the rail system behind the presses, which used to be employed in the old times for big transfer presses to change the tool system. They just push around the presses in the order they want and they can be easily aligned for new product manufacturing. It is 'plug and produce.' All you need is just cabling. Even for complex products, it became state of the art over the last two decades, showing high productivity and repeatability of product accuracy requirement.

Thanks to servo-drives of the presses, the computer-controlled actuators of tooling systems and these flexible ML robots, product-related adjustments could be booted from the server as a ready data set when the production starts so that the production can start immediately. Therefore, a complete change of press and tooling from one product to another was possible in a few minutes.

It is a huge benefit for flexibility. Flexi-production lines of this type could not be realized in 2015 because of lack in suitable robots and press concepts. Nevertheless, they eventually managed to develop it. They became very important alternatives to multi-stage presses for the realization of new integrated process chains. Thanks to continuous regulation of pre-stressing, so called active pre-stressing, during the forming process, I understand that the tool is cracking because of the strong mechanical load.

As I said, 20,000 bars need to be kept under control by the pre-stressing system. However, you can continuously manipulate this in order to keep constant the elastic deformation of the tools. This could be used and therefore, elastic deformation during the forging process could be compensated and reproduction accuracy of net-shape tools and tool life could be kept stable.



It is a very big advantage for precision manufacturing. Specific control of material flow by means of additional active tool elements served for a further reduction of press forces. That means one could combine the entire signals from the tool over the entire process to control and regulate the process with active tool elements and these servo presses.

The necessary sensor technology for temperature, ultrasonic measurements, inclusive wireless data transfer, which was necessary for process control of actuators for these tool systems was integrated directly in the tool construction. These are so-called smart tools. They are a major success factor for precision cold forming.

Precision Cold Forging 2050 - Flexible Press Shop

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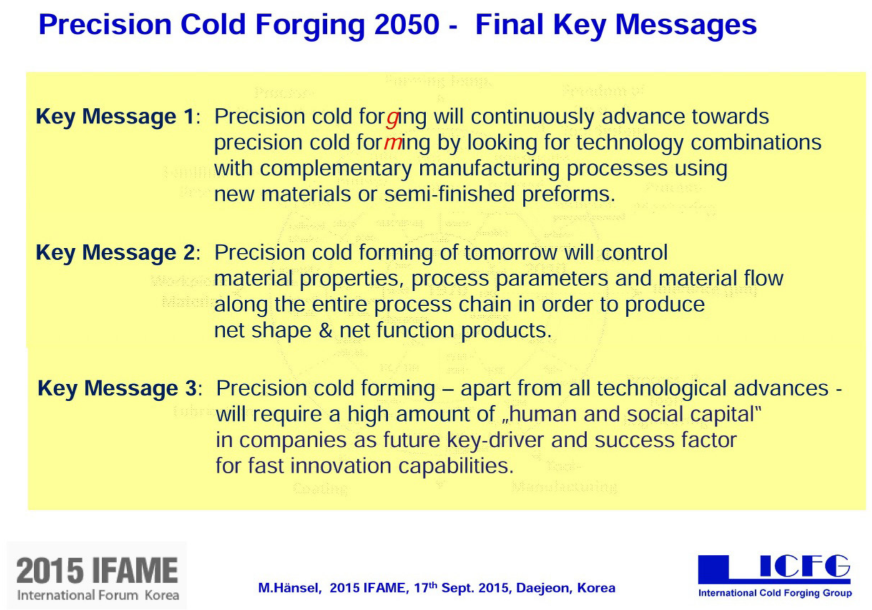
I want to skip the next part but automated tool production or tool shop was as interesting as what we have seen before. It could fill the entire conference. Dr. Im will have to invite me again.

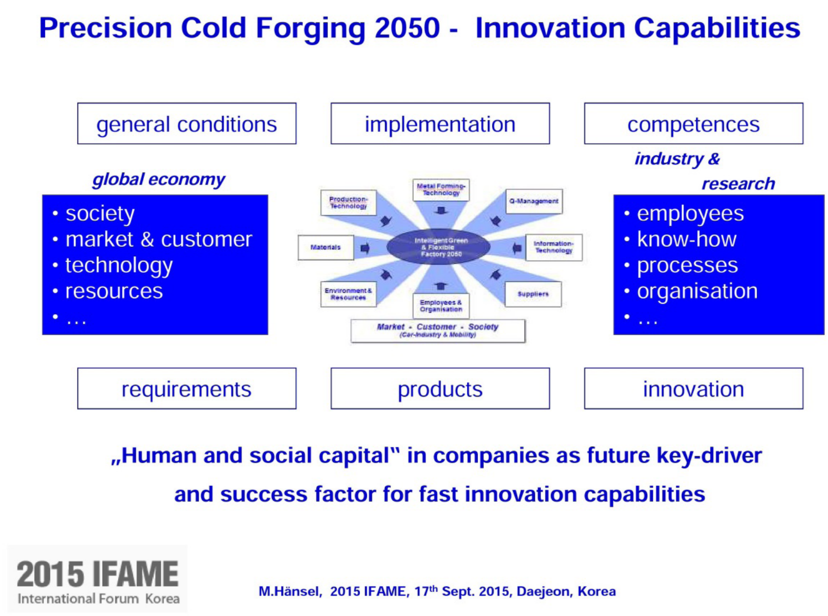
However, today, we will summarize and come back to the reality in 2015 in Daejeon. As a chairman, I was quite happy when I got the report because most of what we anticipated in the cold forging group seems to come true. This is a good sign.



Let me summarize with some important key messages. First, precision cold forging will continue to advance towards precision cold forming. Forging is just whoosh, but forming means including other processes by looking for technology combinations with complementary manufacturing processes using new materials or semi-finished preforms.

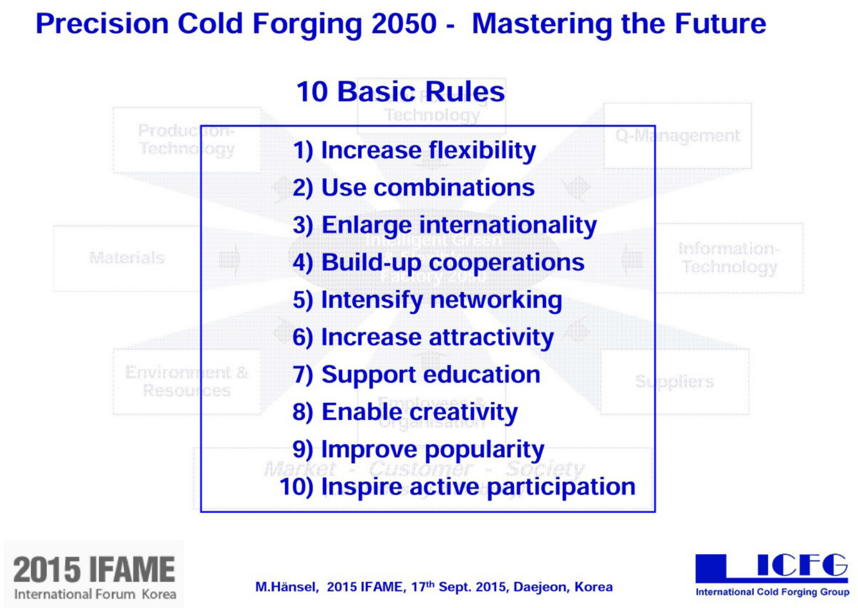
Second, precision cold forming of tomorrow will control material properties, process parameters and material flow along the entire process chain in order to produce net-shape and net-function products.

Third, Precision cold forming — apart from all technological advances — will require a high amount of human and social capital in companies as future key-driver and success factor for fast innovation capabilities.



Because it is so important, I will add another sentence. Human capital, which means employees and knowledge, and social capital, which means international networking and collaboration within companies as well as among international groups, are the most important for the management and organization of innovation in order to quickly master future changes of global business conditions.

Darwin said the biggest and the fast will win. That is not quite correct. The one who can most quickly adapt to changes will win. This is going to be the big challenge of the future.



I have summarized these ten rules about what we have to do to better survive; increase flexibility in production; use process combination; enlarge internationality; build up cooperation and networks; intensify networking; increase attractivity; support education of young people; enable creativity. Standardization is killing creativity. They are making papers but not thinking or dreaming visions or realizing them. Improve popularity of our technologies and our customers; inspire active participation of customers to create something together with us.

In this way, we will be on a good track as cold forgers to survive in the future and always we have to be creative. The vision I showed you today may seem too visionary, but it is the visions and dreams that push us to the next step every time. We have to be innovative. Innovation means doing things in different ways. Please always bear this list in mind and think about how you can achieve these. This is the way we have to live every day in our business.

Thank you.

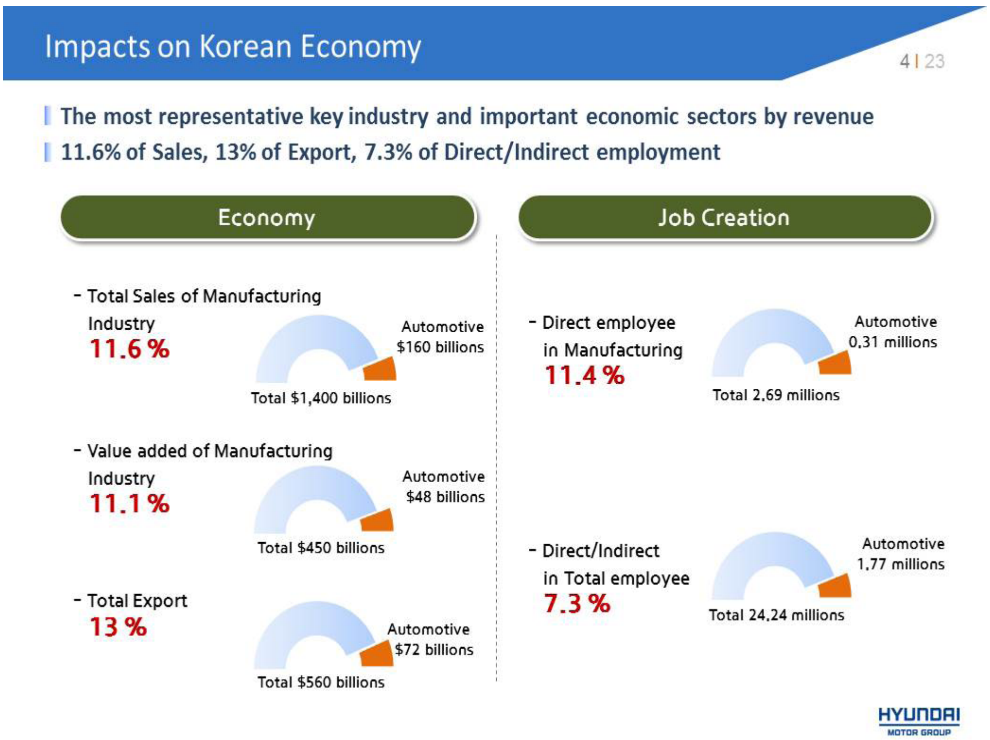
Session 2: Advanced Manufacturing Technologies II

Technology Innovations for Future Mobility

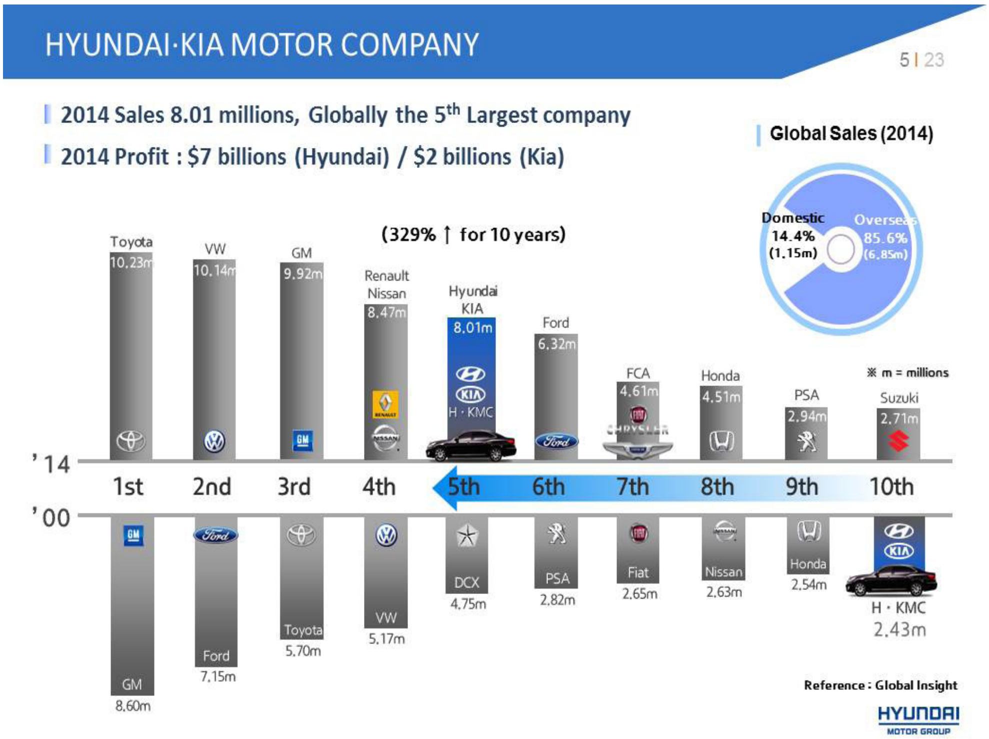
Tae Won Lim, Vice President, Hyundai-Kia Motor Company

Thank you, Mr. Chairman. Good afternoon. My name is Taewon Lim. I am the Vice President of the Central Advanced Research Institute of Hyundai Motor Company. I am sorry that Vice Chairman Dr. Woong Chul Yang could not join this Forum. As one of the busiest engineers in Korea, he is now at Frankfurt Motor Show. I hope you understand this kind of situation.

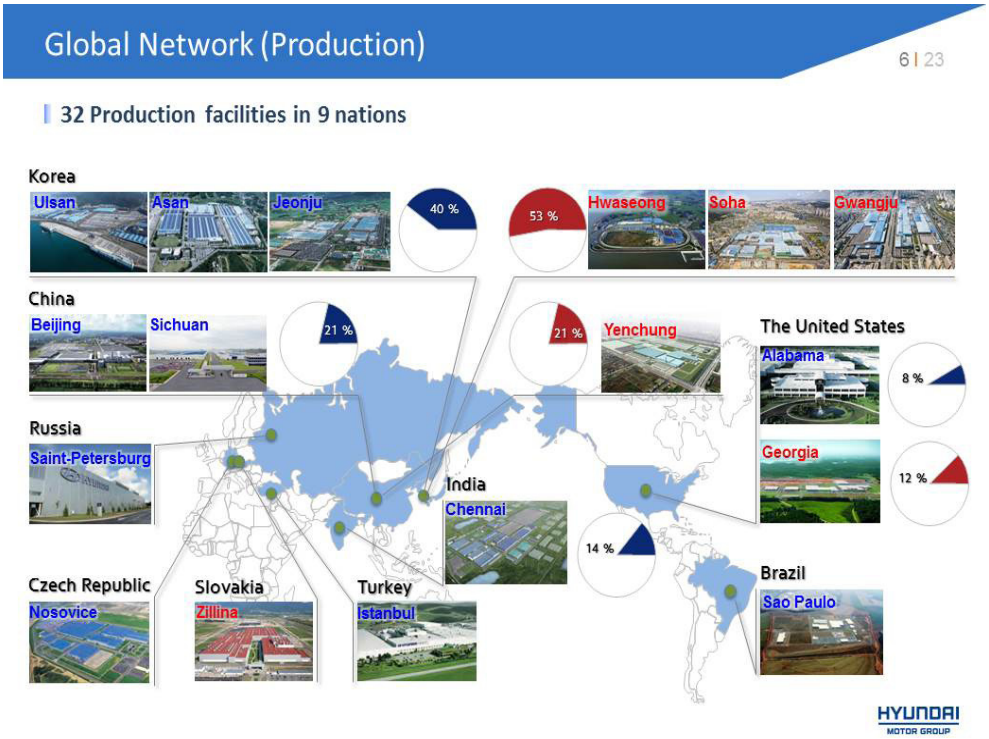
The topic of my presentation is technology innovations for future mobility. Future mobility covers all aspects of the engineering area. Therefore, I will not be able to talk about it in detail. Instead, I would like to introduce very briefly what is going on in the automotive sector. I am going to start by introducing the Korean automotive industry. Then, I am going to talk about Hyundai Motor Company and the innovations that are taking place in the Korean automotive industry.



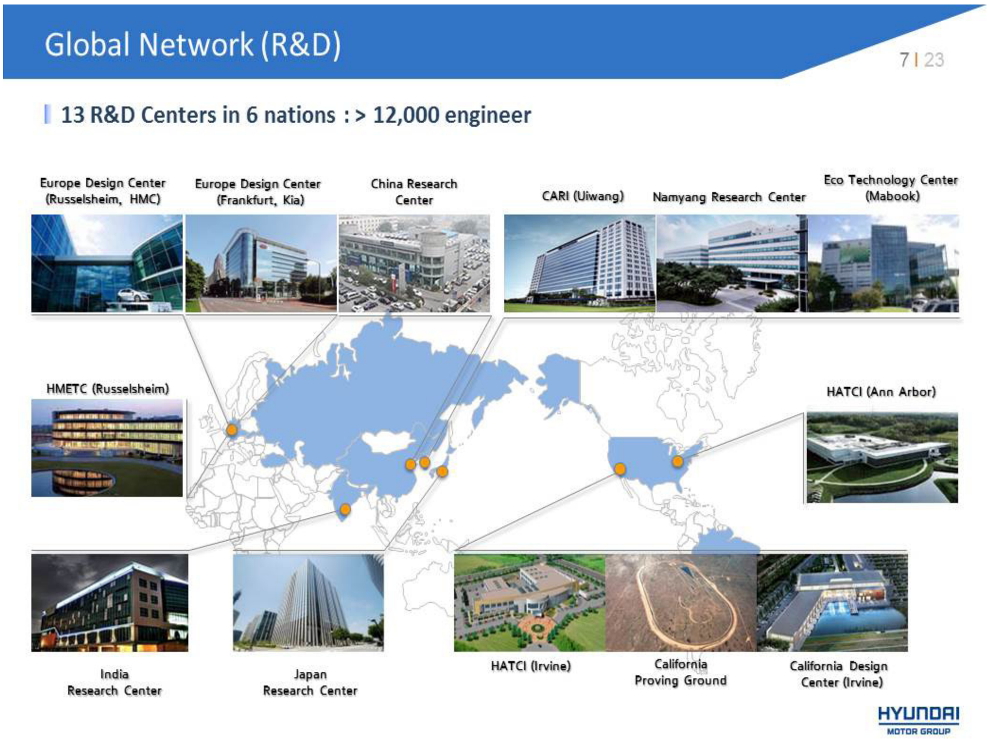
This slide shows the impact of automotive business on Korean economy. As the key industry in Korea, we have been playing a major role in the remarkable economic growth since 1980s. 11.6% of the total sales, 13% of the total export, and 7.3% of the direct employment come from the automotive business.



This is about Hyundai-Kia Motor Company. We are globally the fifth largest company since 2007. Number one is Toyota and the second is Volkswagen. In the year 2000, we were number ten, but, for seven years, we grew rapidly. Last year, we made a big footprint in our history by selling a little more than eight million vehicles. Our profit was seven billion US dollars for Hyundai and two billion dollars for Kia.



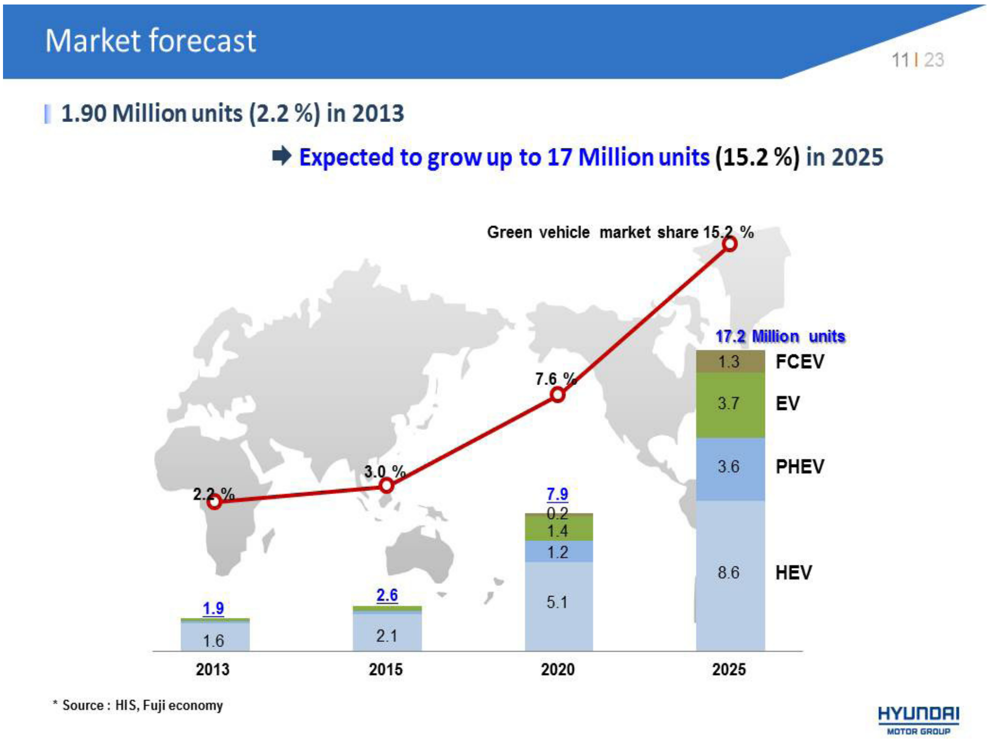
This is our worldwide production network. We have 32 production sites in nine nations: China, Russia, Czech Republic, Slovakia, Turkey, India, U.S., Brazil, and Korea.



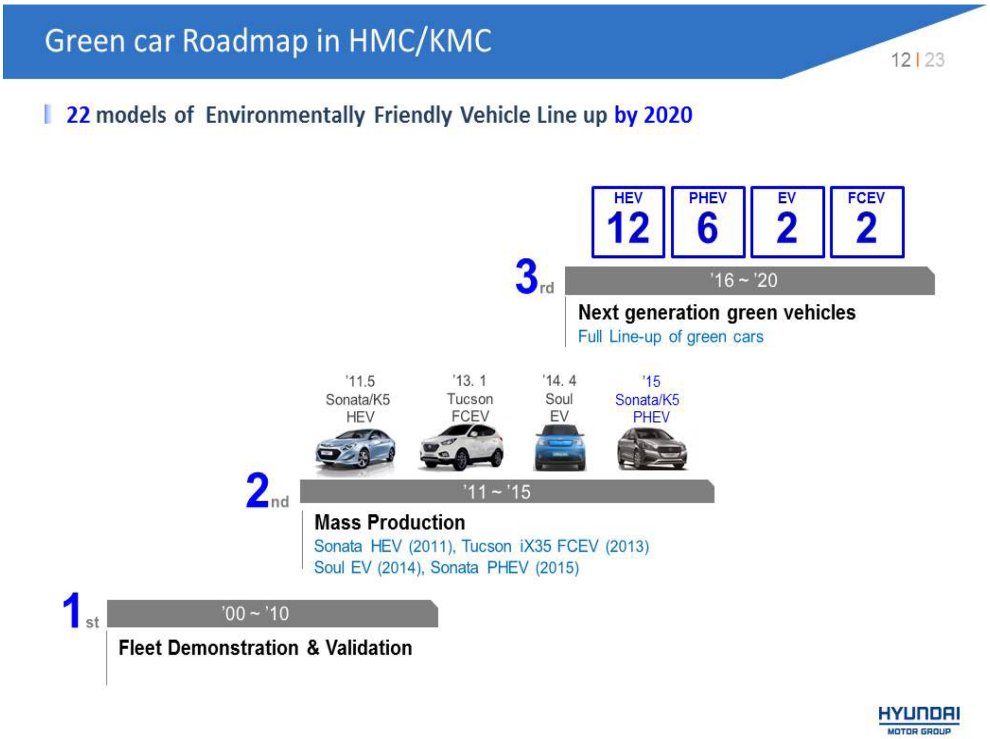
This is our global R&D network. More than 12,000 engineers are working at 13 different centers in six nations: Germany, China, India, Japan, U.S., and Korea. We have the European Design Centers in Russelsheim and Frankfurt, the Technical Center in Russelsheim, China Research Center, India Research Center, Japan Research Center, U.S. Research Center, California Proving Ground, and California Design Center. Near Seoul, we have three Research Centers. Namyang is the headquarter where we have more than 10,000 engineers. In Uiwang, we are working for advanced researches to develop the technologies for 10 to 20 years later. The Eco Technology Center in Mabook is dedicated to fuel cell research and development.

Let us begin the main story of my presentation which is about technology innovations.

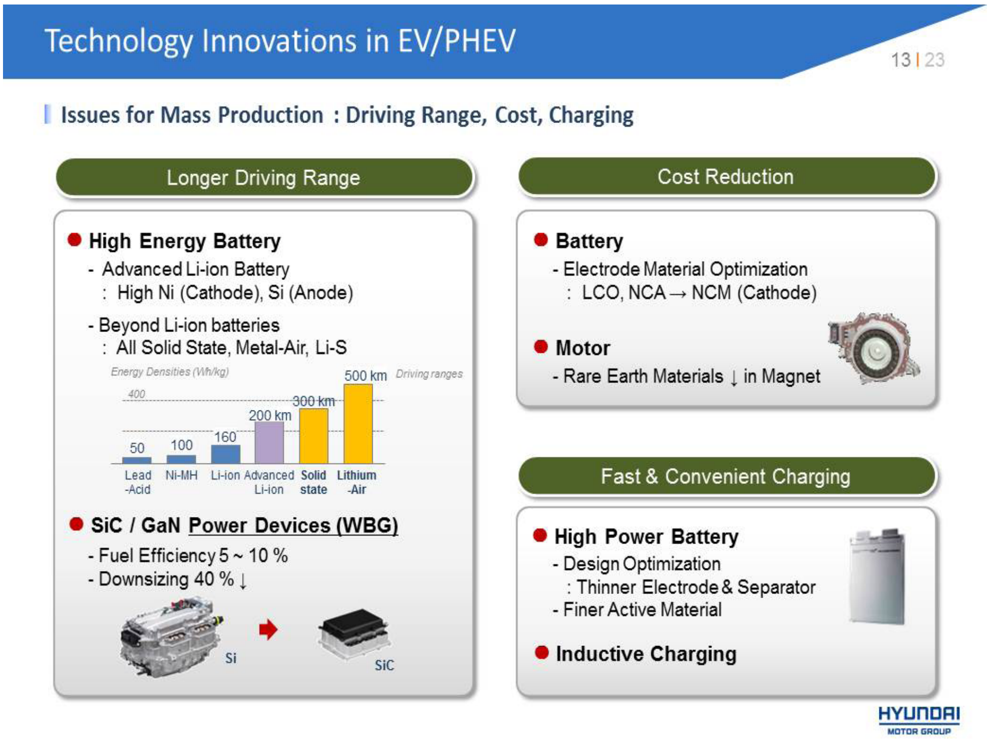
We, automotive Original Equipment Manufacturers (OEMs), have been listening to various voices and demands from customers and societies for a long time. They continuously ask us to supply cleaner, more efficient, much safer, and more convenient vehicles. In order to have the secure position in the automotive area, most automotive OEMs have no choice but to focus our resources as much as possible on the development of green cars and smart cars. In this presentation, I would like to briefly introduce about the technology innovations for green cars and smart cars.



Let me start with green cars first. What are your expectations of green cars after 10 years? Many people think that 10 years is enough time for widespread applications of green cars and that the market share will be over 30% or even 50%. However, in fact, according to some famous consulting firms such as Fuji Economy, the maximum number will be 15% at most. The market share right now is about 2%. Even though it is growing fast, 15% is actually still a big number. Everyone is talking about green cars such as electric vehicles (EV), fuel cell electric vehicles (FCEV), hybrid electric vehicles (HEV), plug-in hybrid electric vehicles (PHEV) and so on, but, in reality, green cars will be part of our powertrain supporter module, not the ones that dominate in all automobile powertrains.

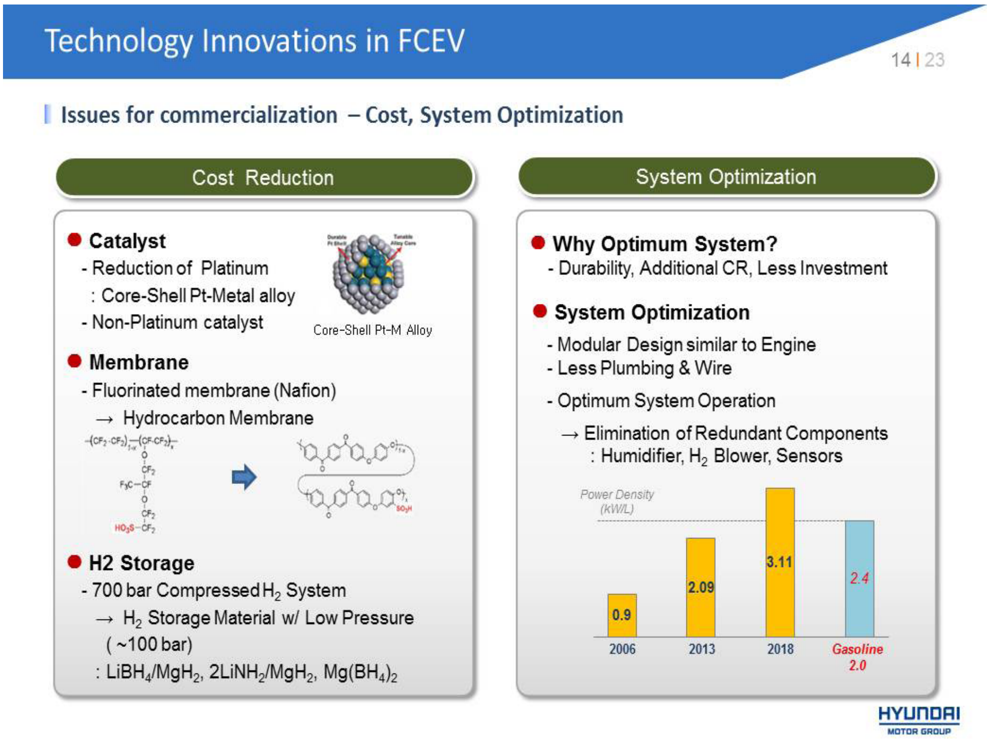


This is the green car roadmap of Hyundai and Kia. In 2000, we started the Fleet Demonstration with hybrid and fuel cell vehicles. At present, we are now producing HEVs, FCEVs, EVs and PHEVs. Specially, this year, we introduced Sonata PHEV. Two years ago, we introduced an FCEV for the first time in the world. By 2020, we are going to set up our full green car line-up of 22 models of environmentally friendly vehicles. For example, we are glad to introduce 12 HEVs, six PHEVs, two EVs, and two FCEVs.



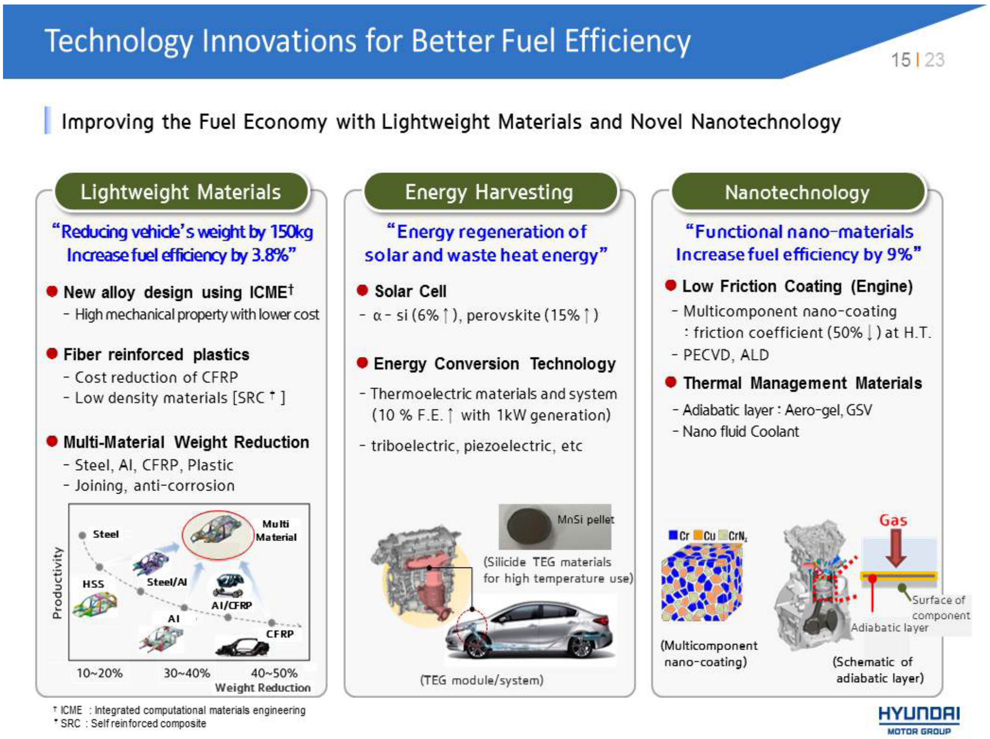
In this slide, I would like to share with you our ongoing technology innovations for EVs and PHEVs. As you know very well, for the successful mass production of EV, we have to resolve some critical issues regarding driving range, cost, and charging time. For a longer driving range, we have two main options. First one is developing high-energy batteries and the second is improving the power electronics efficiency. We are developing the advanced lithium-ion batteries as well as beyond lithium-ion batteries such as all-solid batteries and lithium-air batteries. Theoretically, the lithium-air battery is the only option for 500km of driving range. In order to improve the driving distance, we have to develop a more efficient inverter and convertor. For this kind of purpose, we are developing silicon-carbide and gallium-nitride power devices. Thanks to the silicon-carbide power device, we can improve the fuel efficiency by 5-10%. At the same time, we can reduce the volume of components by 40%.

For the cost reduction, we are modifying electrode materials of the battery from very expensive materials such as cobalt to cheaper materials such as nickel and manganese. In motors, we are trying to reduce the amount of rare earth materials, especially magnesite. For the rapid and convenient charging, we are modifying the battery design and inductive charging system.



Now, I would like to talk about the fuel cell. Many people wonder if mass production is possible for FCEVs. They mention issues of cost and system optimization. We are now developing how to reduce cost and optimize the system. I will not mention about the hydrogen infrastructure because it is not related to innovations. To reduce cost, we have three key components: catalyst, membrane, and hydrogen storage tank. Those three are the most expensive components in a fuel cell system and they cover more than 50% of the total system cost. We are developing the core-shell technology to reduce the amount of platinum. We are also studying how we can use non-platinum catalyst in a fuel cell system. For the membrane, hydrocarbon is getting attention from the academia and industry. We hope we can replace the current Nafion-based membrane with hydrocarbon membrane. Lastly, I would like to talk about the hydrogen storage. At this moment, Toyota, Honda and Hyundai-Kia are all using the 700-bar compressed hydrogen system. The development of new hydrogen storage materials for low-pressure conditions (~100-bar) is very important for cost reduction because we have to pay more for the pressurized vessel, valve, and regulator for the safety reason. Those materials include lithium boron hydride, magnesium hydride and so on.

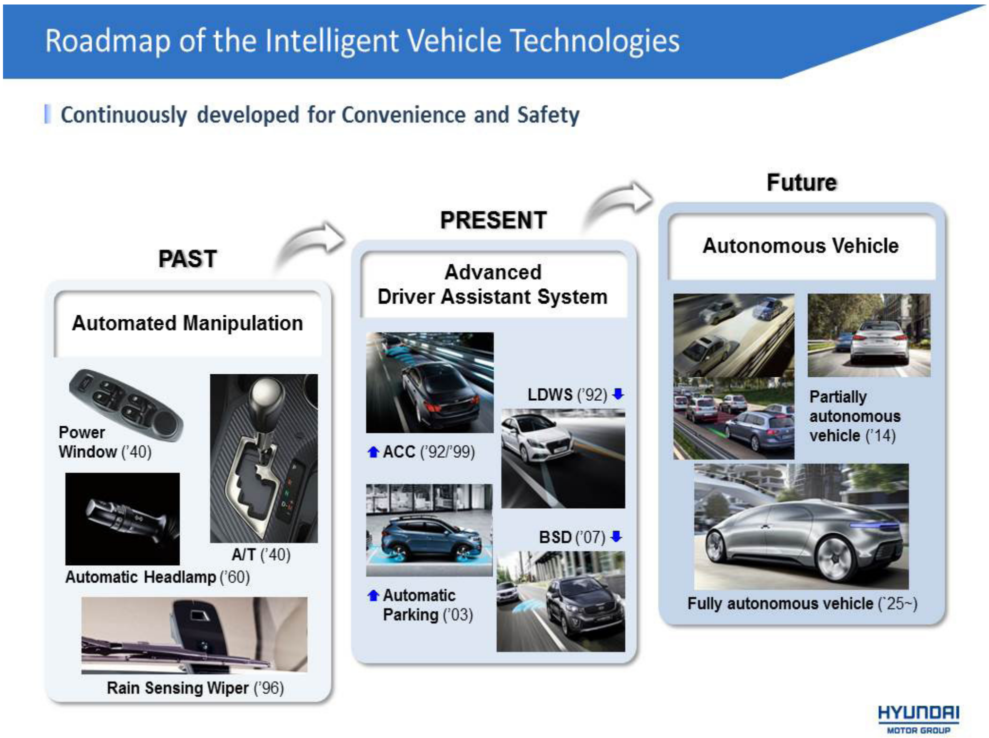
From the viewpoint of the automotive OEM, system optimization is also very critical for mass production. The power density of the fuel cell is important. About 10 years ago, the power density was less than half of the current internal combustion engine. When we started mass production in 2013, the power density of our fuel cell system was a little bit less than that of the internal combustion engine. We are now developing the next-generation fuel system and that will be much more than the internal combustion engine. One of the reasons that we have to have system optimization is that we can eliminate redundant components which can also lead to additional cost reduction. We can also use the current existing assembly line. If our fuel cell system is bulky and separated, it means we need another assembly line and the initial investment will be terribly high.



This slide shows the technology innovations for better fuel efficiency from the viewpoint of materials. Fuel efficiency can be improved by lightweight, energy harvesting and the functional nano-materials. For the weight reduction, automobile industries have been developing new light metal alloy using computational materials engineering and fiber-reinforced plastics such as carbon fiber-reinforced plastics (CFRP) and self-reinforced composites (SRC), so that we can attain higher stiffness and higher strength without cost increase. Multi-functional material, i.e., the combination of steel, aluminum, CFRP, plastic, etc., weight reduction is gaining more and more attention from industries and academia.

For energy harvesting, we are developing solar cell panel with amorphous silicon and perovskite and high temperature thermoelectric materials. With this kind of technologies, we can improve fuel efficiency by more than 10%.

We are also utilizing the nano-technology to develop low-friction coating, adiabatic coating and nano-fluid coolant.

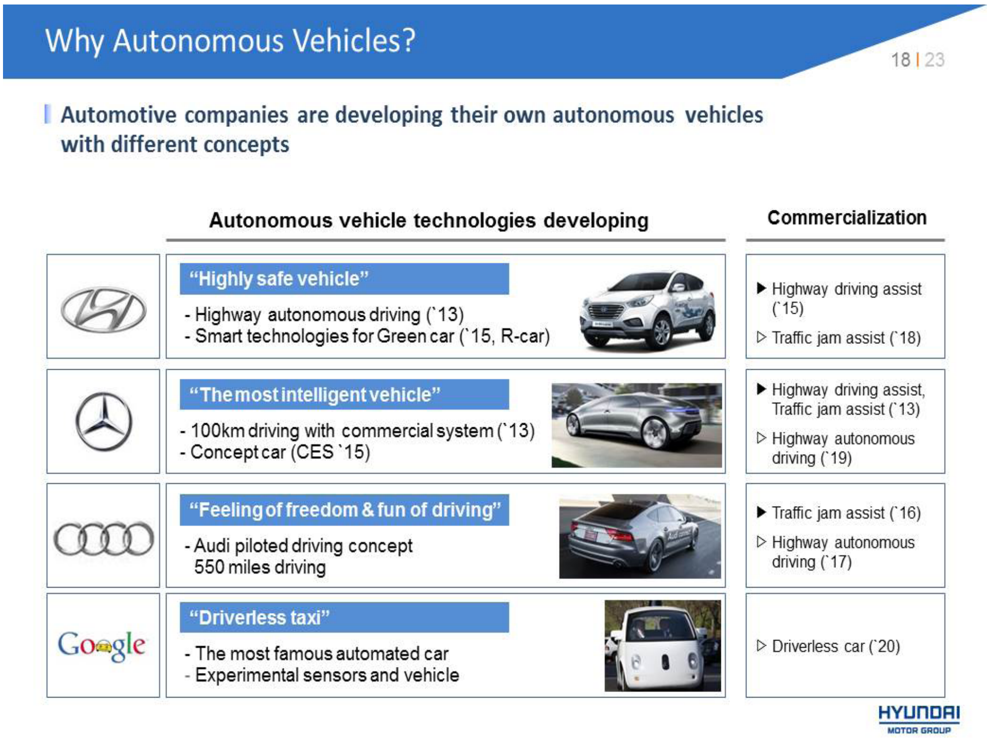


Now, I would like to talk about smart cars. This is the history and the future of intelligent vehicles. In the past, even in 1940, automotive companies were developing functional automation for driver convenience such as the power window and automatic transmission, which means we focused on the automated manipulation. Now, we are focusing on the advanced driver assistant system (ADAS). In the future, it will be autonomous vehicles. I would like to talk in detail about the ADAS and the autonomous vehicle technologies.

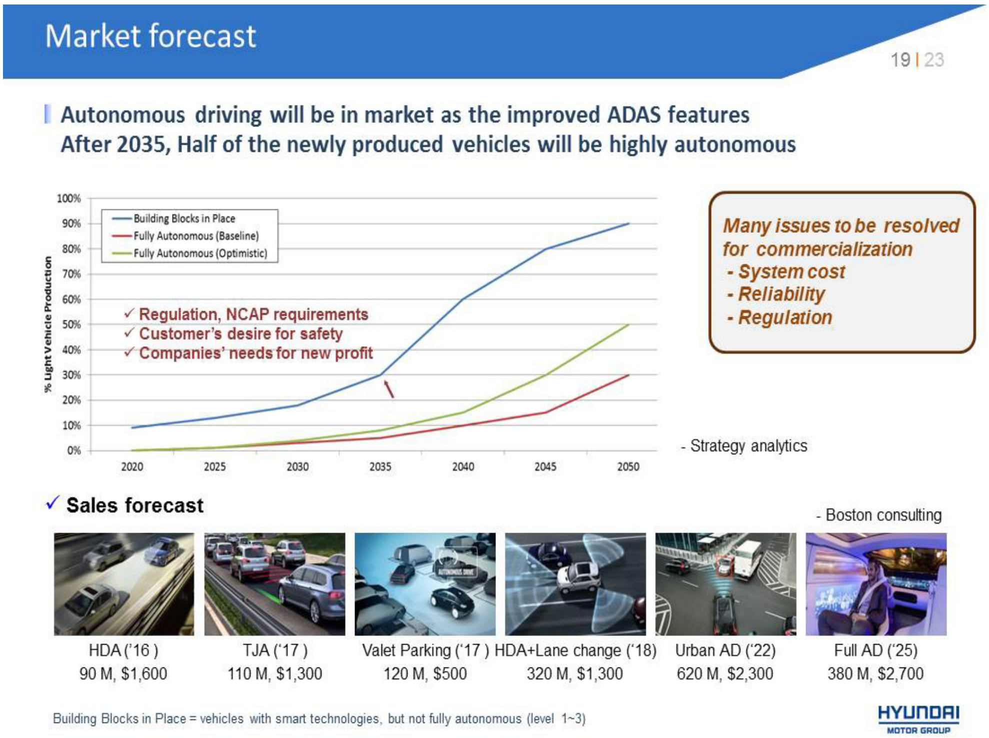
ADAS is developed to automate, adapt and enhance vehicle systems for safety and better driving experience. This shows ADAS which is already in the market: adaptive cruise control (ACC), autonomous emergency braking (AEB), high beam assist (HBA), traffic sign recognition (TSR), lane keeping assist system (LKAS), automatic parking (AP), lane change assist (LCA) and rear cross traffic alert (RCTA).

I would like to show a video clips on how Hyundai is doing on the ADAS development. This video clip was shown at the Consumer Electronics Show at Las Vegas this year.

(The video clips are uploaded on the Forum website: forum.kimm.re.kr)

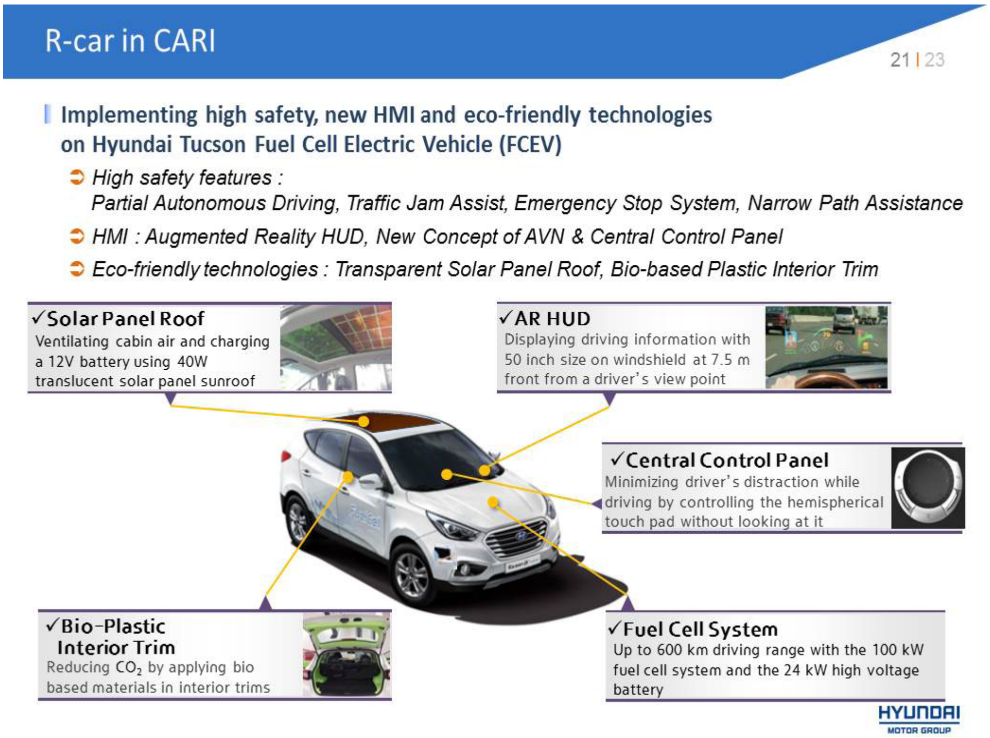


Why autonomous vehicles? As well as ADAS, every automotive company is developing its own autonomous vehicles with different concepts. Hyundai's concept is to develop highly safe vehicles through autonomous technologies. Our goal is to introduce the ultimate safe vehicle to our society. Daimler has a different idea. They prefer the most intelligent vehicles. Audi is focusing on the sense of freedom and fun. Google's concept is the driverless taxi.

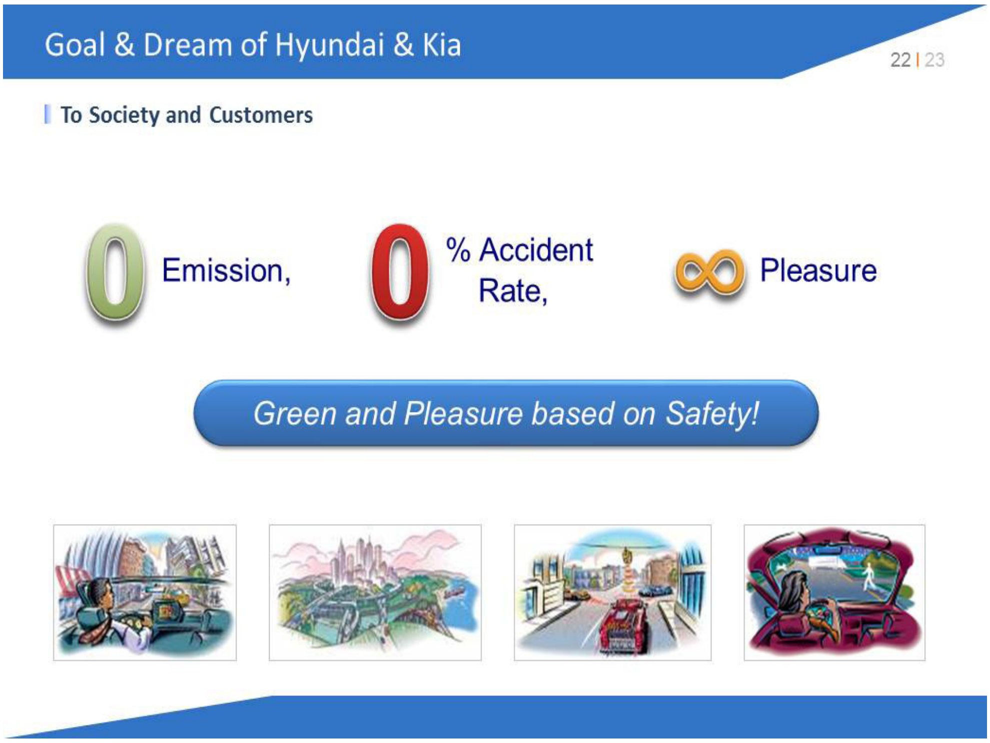


This slide shows the market forecast of autonomous vehicles. Autonomous vehicles will be in the market in the form of improved ADAS features. In 2035, half of the newly produced vehicles will be highly autonomous. However, unfortunately, the market share of the fully autonomous vehicles will be less than 10%. We have to resolve many issues regarding cost, reliability and regulations.

We have a sales forecast by Boston Consulting Group. The highway driving assist (HAD) will be available from 2016, traffic jam assist (TJA) and valet parking from 2017, urban autonomous driving from 2022, and full autonomous driving from 2025.



As a conclusion, I would like to introduce our research car project. We started the project two years ago. The target of the project is to guide the direction of advanced research by early applications of emerging technologies. In this project, we developed and evaluated many emerging technologies, e.g., partial autonomous driving, TJA, emergency stop system, narrow path assistance, augmented reality head-up display, new concept of audio-video navigation system, central control panel, solar penal, and bio materials.



This is my last slide. We, Hyundai-Kia Motor Company, have a dream for our societies and customers. Our dream is to be a zero-emission, accident-free, and maximum-pleasure vehicle supplier. We are going to make the best and every effort until our dream comes true.

Thank you for your listening.

Doosan's Efforts to Develop Power-Gen Technology

Seung-Joo Choe, Executive Vice President & CTO, Doosan Heavy Industries and Cnstruction

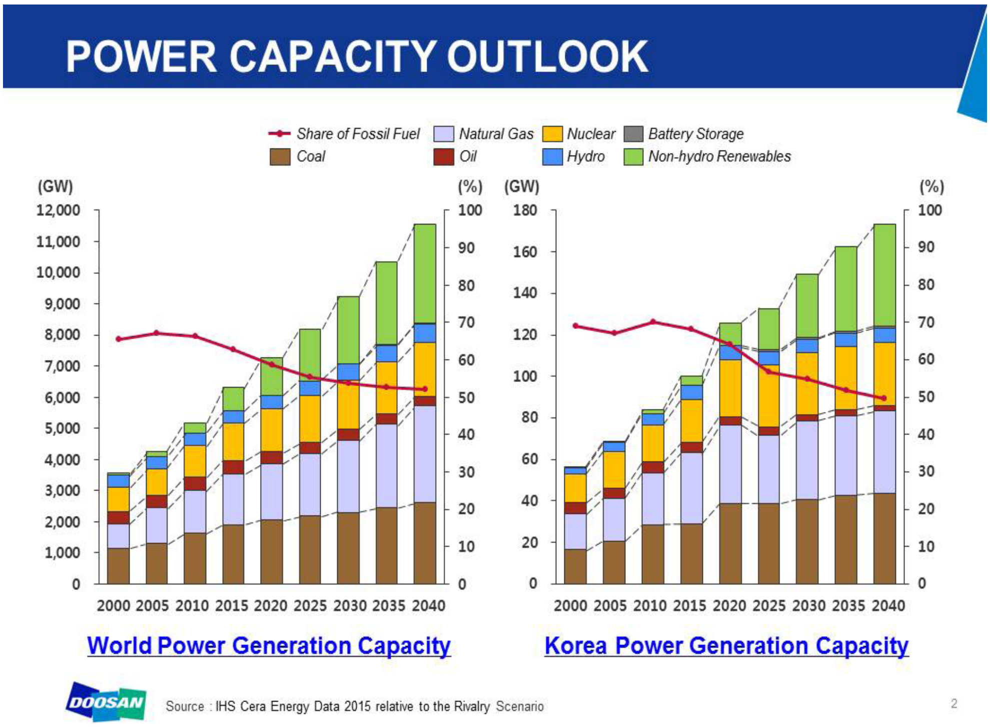
Thank you very much Mr. Chairman. Good afternoon ladies and gentleman.

First of all, I would like to congratulate the successful hosting of the 2015 International Forum Korea on Advances in Mechanical Engineering. Personally, it is my great honor to have a chance to talk in front of many distinguished experts and guests working in the field of mechanical engineering.

I wonder how many of you have heard about Doosan. Doosan has been in the power generation business since the 1970's, when no one in Korea knew how to build a power plant. Through the development of proprietary technology, Doosan has built power systems for both domestic use and for foreign export. After years of competing with global industry leaders in foreign markets, today, Doosan stands shoulder to shoulder with them.

Due to global economic recession, the global business environment related to the power industry has been changing. Today I would like to talk about Doosan's effort to keep pace with global market changes.

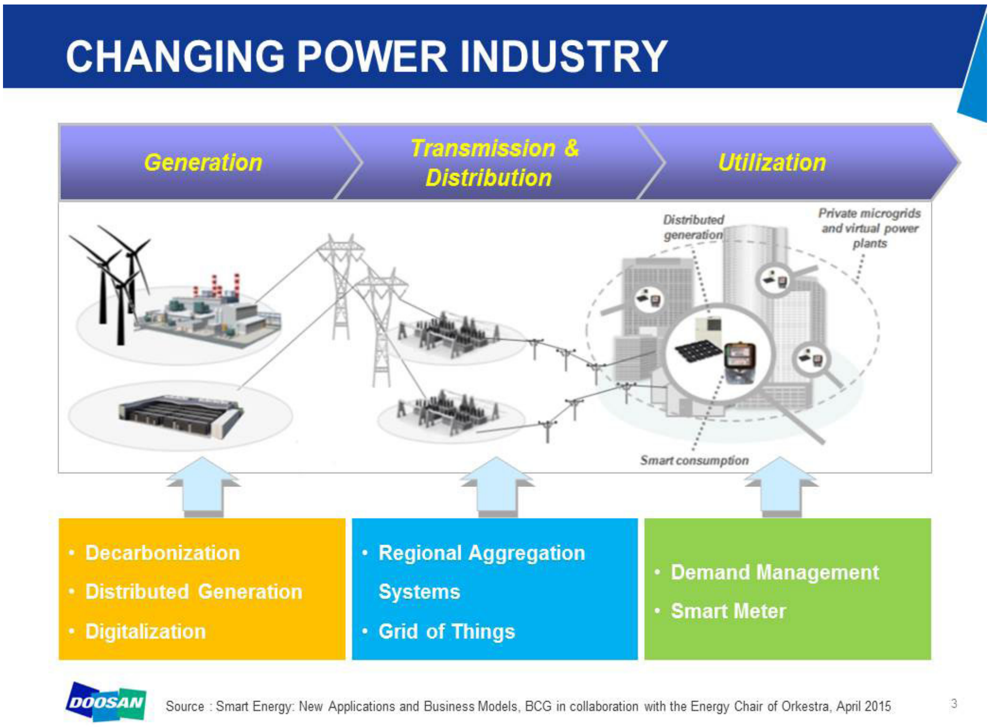
My talk is divided into three parts, introduction, technology megatrends, and Doosan's effort to meet markets. First, I would like to give an overview and introduction to the power industry; world power generation capacity outlook; current on-going changes in power industry and regional market trends.



As we know well there are many different methods of generating electricity. The most typical ones are coal fired power plant, hydro power plant, nuclear, and renewable such as wind and solar. Since we supply power plants and equipment for both domestic and foreign markets, it is important to understand the outlook of the power generation mix.

According to a study made by IHS, a global market research company in Colorado, renewable energy which has showed a robust growth will be expected to increase up to 27% in 2040 in the global power sector. The share of fossil fuels is expected to decline by approximately 10% from 63% to 52% in 2040. However, fossil fuels are still expected to become an important energy source in order to meet the increasing power demands. The demand for gas is expected to increase. Domestic power market will show a similar trend as the global trends.

World Energy Council predicts the coal power plant will play a central role in producing electricity even in 2050. Mike Duncan, president and CEO of the American Coalition for Clean Coal Electricity (ACCCE), mentioned last year that economics favor coal over natural gas for base load power generation. We keep an eye on the energy outlooks and correspondingly update the long-range plan on an annual basis.

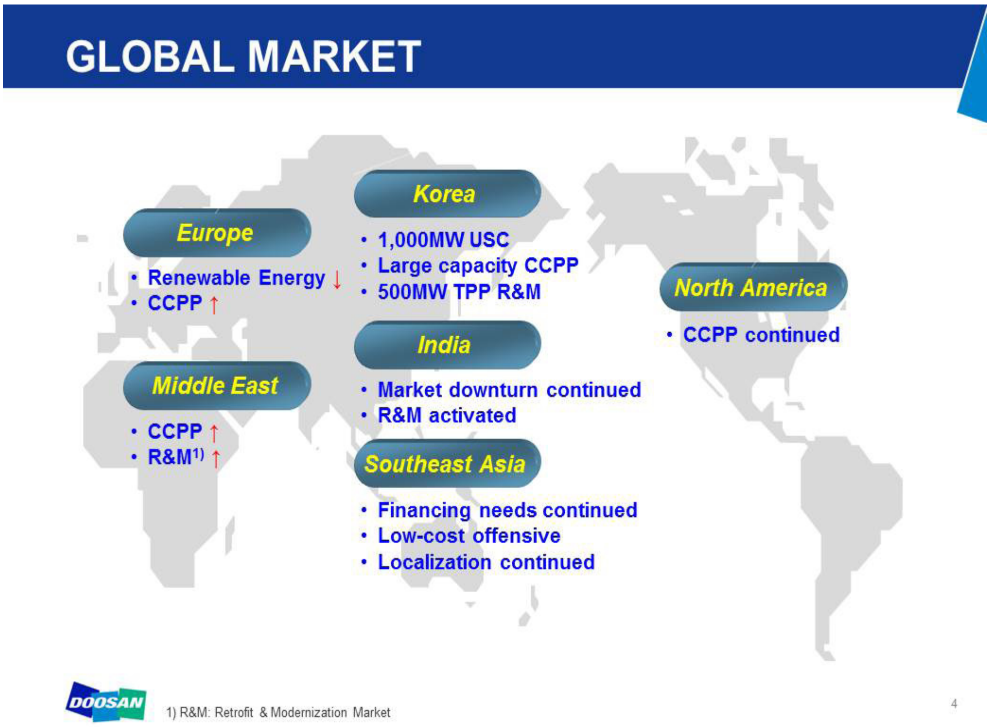


Michael W. Howard, CEO of Electric Power Research Institute (EPRI), pointed out in the 2015 EPRI summer seminar, a drastic technical innovation in electronics, communications and information in the last two decades. Electronic devices become smaller but show increased performance with decreased cost. Communications are easily made through the globally connected network with increased speed. Every day we meet explosive amount of information as searchable and digitized data. This technical innovation drives the paradigm change in the power industry.

In the power generation sector emission regulation requires CO_2 reduction. More distributed power generations such as wind and solar are connected to the grid.

The transmission and distribution sector requires optimized use of produced electricity.

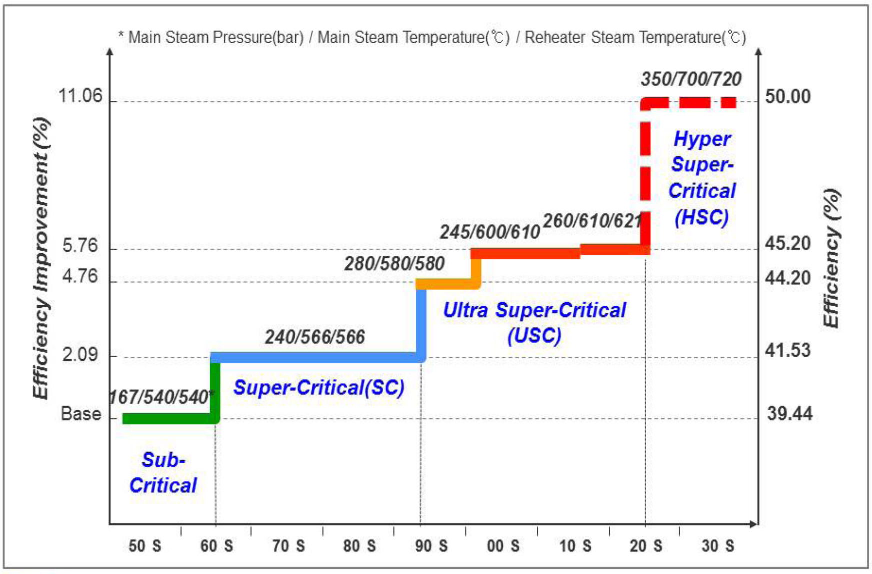
Consumers can produce electricity using rooftop solar and sell electricity to grid. Consumer has more choice and control since they are more informed due to integration of technical innovation. Utility has to redefine the relationship with the customer. This is the paradigm change in the power industry. Utilities have to develop a new business model.



We continually analyze the global market situation by region. In our targeted market such as India and Southeast Asia, market downturn will continue. Clients are steadily likely to favor large-capacity and high-efficiency power plants. TPP (Thermal Power Plant) business is decreasing, but CCPP (Combined Cycle Power Plant) opportunities are increasing. We expect high competition due to the shrinking order pool.

Next I will explain the technology megatrends in the power industry. Technology megatrend of coal fired, nuclear, combined cycle and renewable power plants are discussed.

COAL-FIRED POWER PLANT

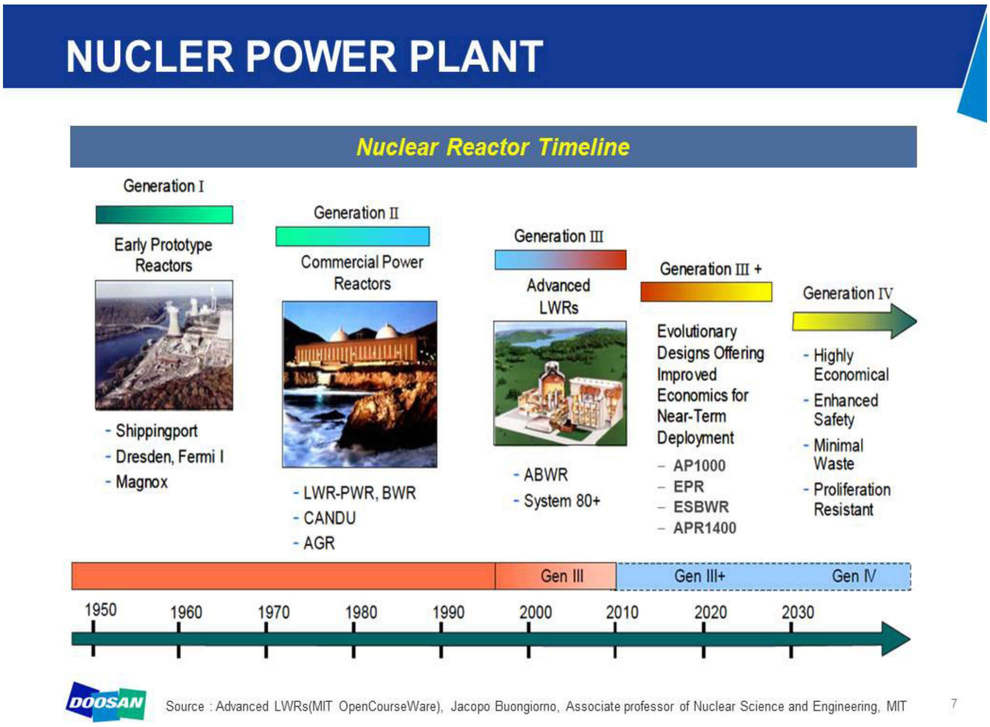


DOOSAN 6

The change of steam parameter with time in the coal fired power plant is displayed in the figure. The number indicates main steam pressure (bar) / main steam temperature (°C) / reheat steam temperature (°C).

The fundamental way of reducing environmental problems due to CO_2 emissions is to reduce fuel consumption significantly by boosting the efficiency of coal-fired power plant. By increasing the steam pressure and temperature, overall efficiency of coal-fired power plant is increased.

We have been developing technologies for Ultra Super-Critical (USC) plant and low NOx combustion in compliance with the technology megatrends.

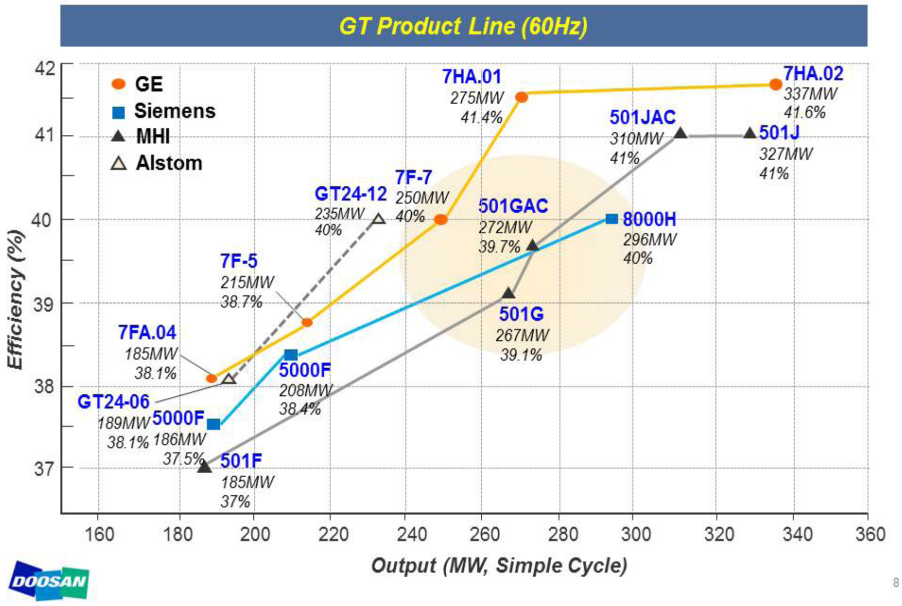


This slide shows the development history of nuclear power reactor. We are at the Gen III+ in this. Since the Fukushima disaster in 2011, Countries around the globe take every necessary measure to address the safety issues. Currently several types of the 4th-generation reactor are under development. Small-capacity modular reactors are also being actively developed.

In the short run, nuclear power business seems to have low growth potential in the wake of Fukushima crisis. However, quantitative impacts of new and renewable energy sources are still minimal at best; hence there are no definite alternative plans to replace nuclear power plants. These are the bases on which some countries will continue to build nuclear power plants, allowing for the nuclear industry to continually grow and develop.

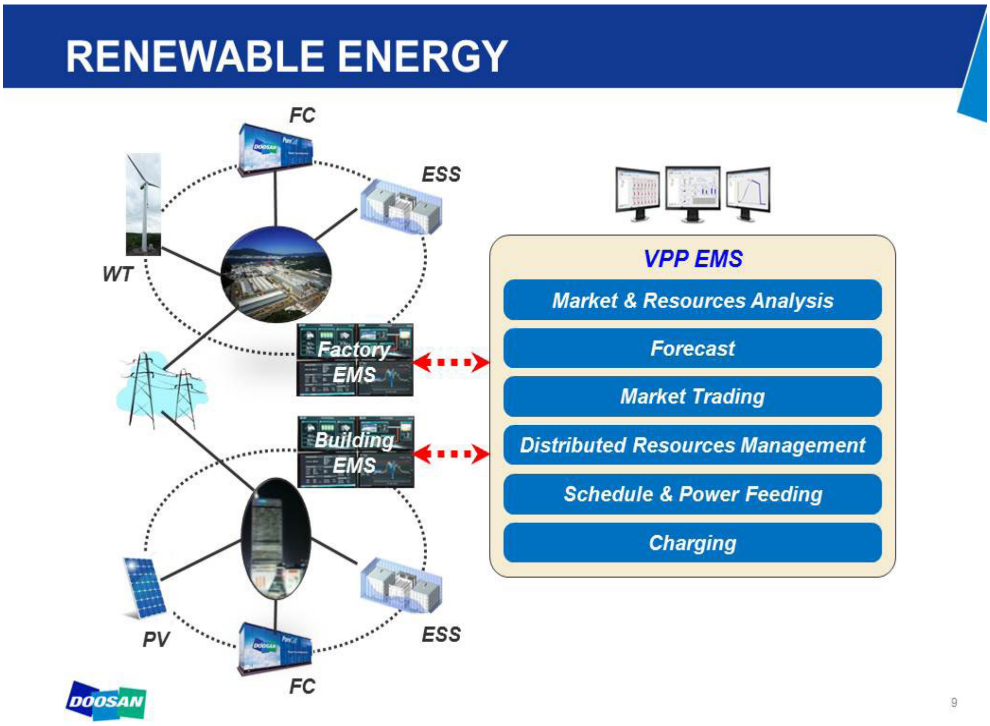
There are more than 400 nuclear power plants in the world (USA 104, France 58, Japan 50, Russia 50, Korea 23, India 20, China 16 but 26 under construction).

COMBINED CYCLE POWER PLANT



High-efficiency, low emissions and operation flexibility are the megatrend in the power generation gas turbine.

If we look at 60Hz gas turbine market, we see GE, Siemens and Alstom all release gas turbines of 40% efficiency. In particular, MHI and GE compete with J class and H class gas turbines which demonstrate more than 300MW power output with 41% efficiency.

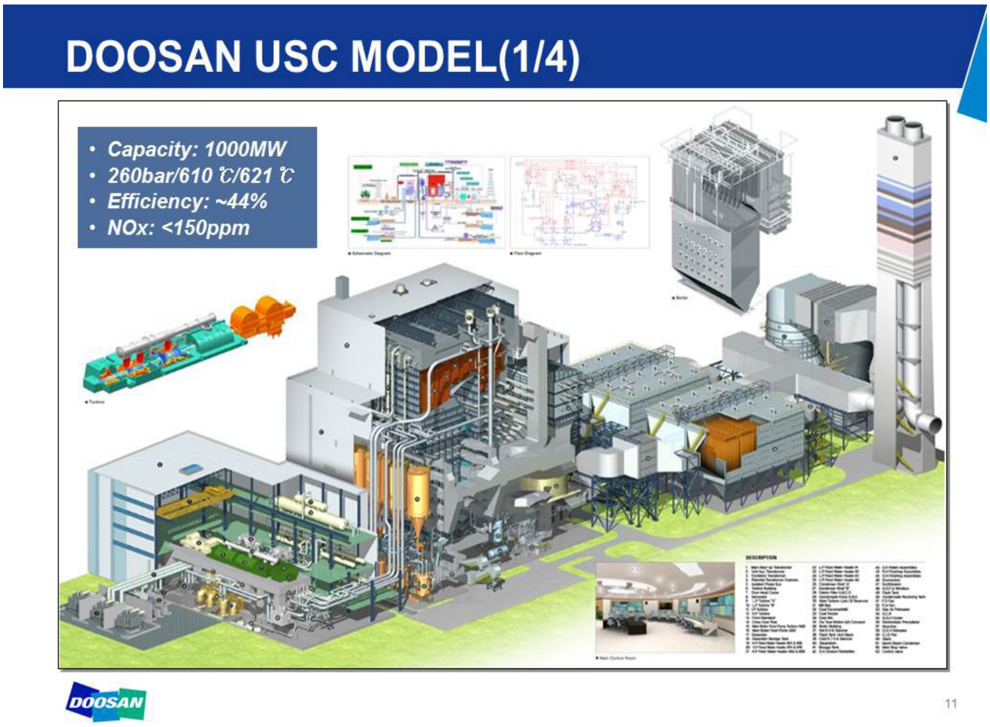


If we look at renewables, solar is achieving grid parity. As we know, the cost of solar panels has plunged from $4/W to $0.5/W. Energy Performance Certificate (EPC) cost was $5/W now $1.3/W. Efficiency is around 16%, which means fewer panel and less land.

Wind Turbine Generator (WTG) development focuses on low wind speed and off-shore WTG. EU targets 40GW by 2020, 150GW by 2030, and 460GW by 2050. This means more renewable connection to the grid in the future. Since photovoltaic (PV) and WTG are intermittent, Fuel Cell (FC) and Energy Storage System (ESS) are installed to control the uneven power variation.

International Energy Agency (IEA) predicts that the portion of electricity from renewable source will be 33% in 2040. In order to control various power sources, Virtual Power Plant (VPP), Energy Management System and ICT become more important in the future.

Next, I will give a talk on Doosan's effort to meet the market requirements.

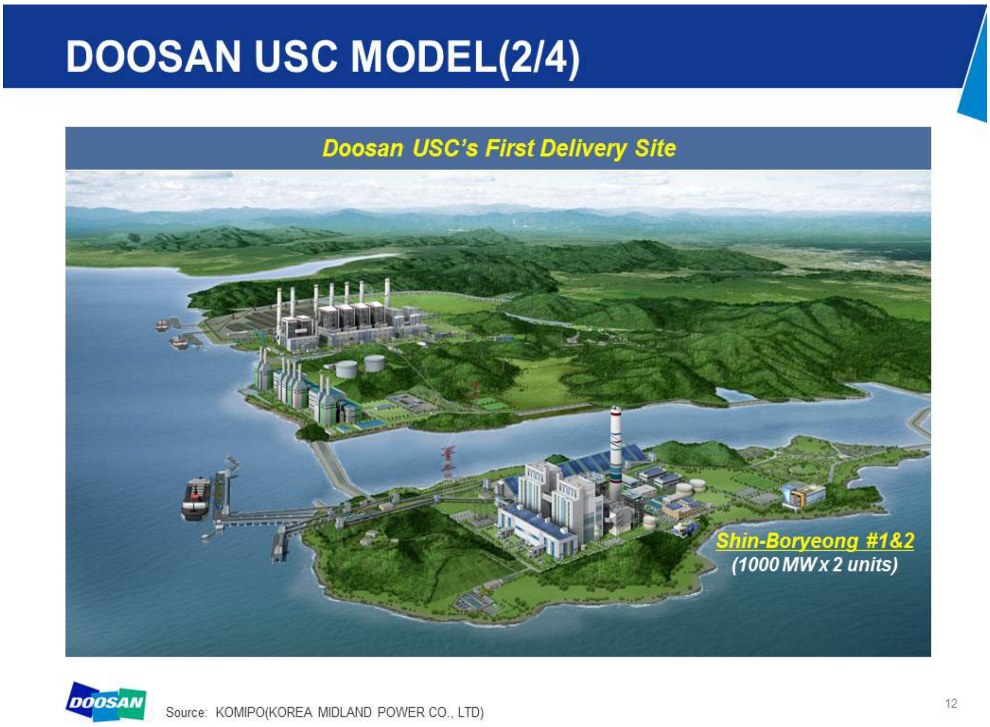


Doosan first started building power systems in 1976 by manufacturing heat recovery boiler for the Gunsan and Yeongwol combined cycle power plants with technology provided by Combustion Engineering (CE).

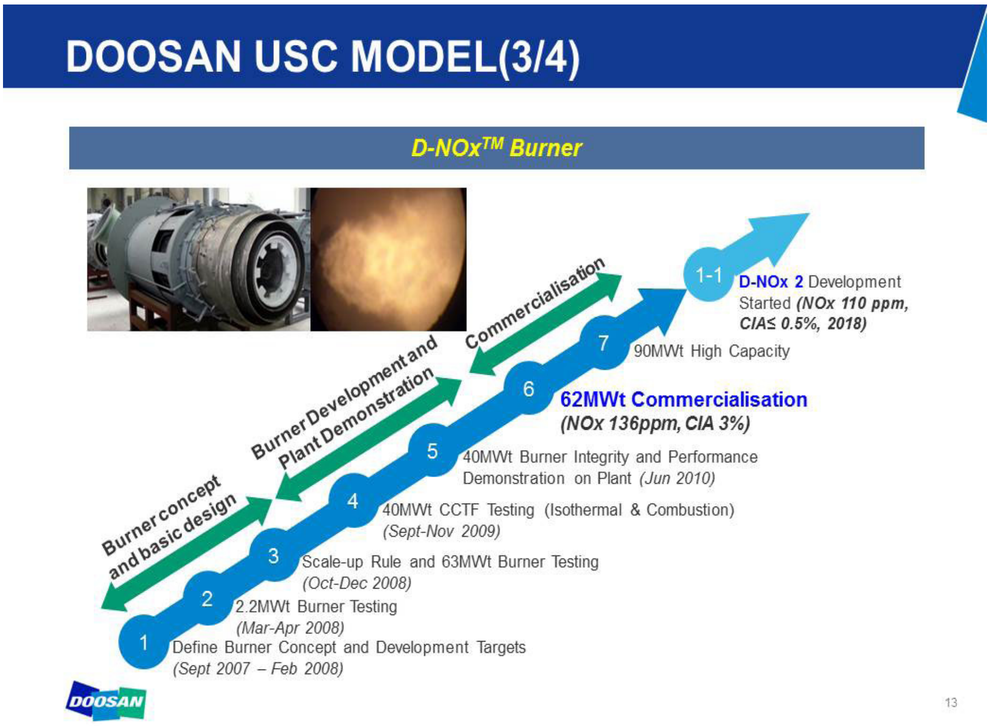
After many years of effort to develop independence in boiler, turbine and generator technology, and strategic acquisition of Babcock and Skoda Power for boiler and turbine OEM technology, Doosan becomes a global player for power plant EPC, engineering, procurement and construction. For this goal Doosan set up effective management strategies to become a global company and improve competitiveness in the main business of building power plants.

Doosan had developed the USC plant technology of boiler/turbine/generator for 610℃ steam temperature in 2008, and it will be demonstrated through the Shin-Boryeong #1 & 2 projects in Korea.

Doosan 1000MW USC coal power plant employs the highest steam temperature and pressure among the world USC coal power plant systems. The highest steam condition of 260 bar/610°C/620°C provides 3% higher efficiency than the conventional Super-Critical coal power plant with 10% less CO_2 emission.

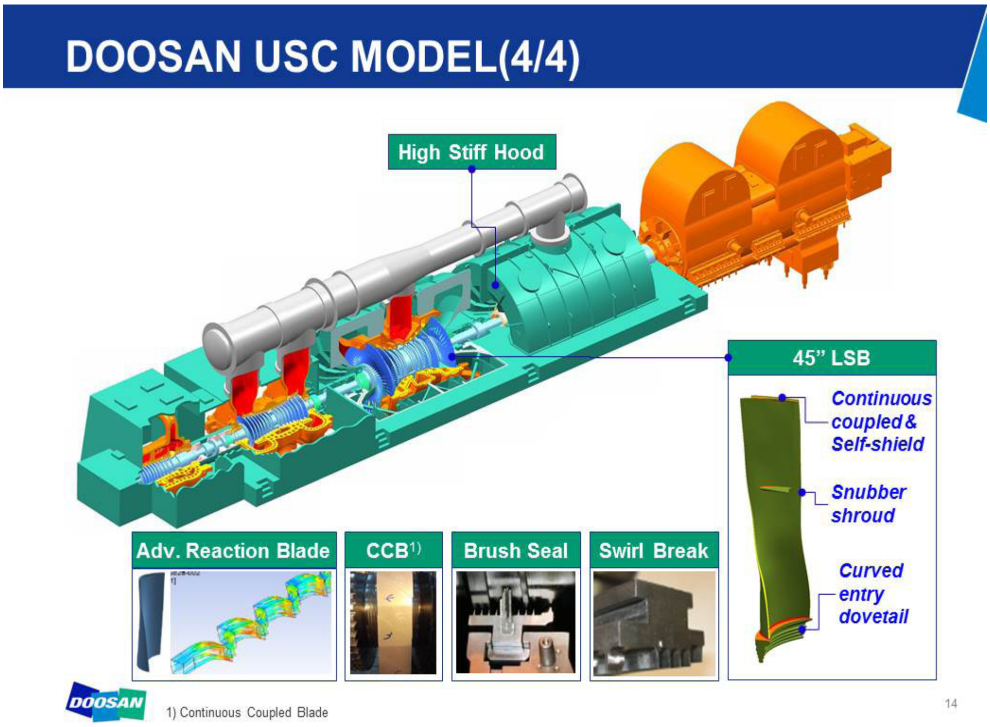


This is the bird's eye view of Shin-Boryeong site. Two units of 1000MW Doosan USC model are installed.



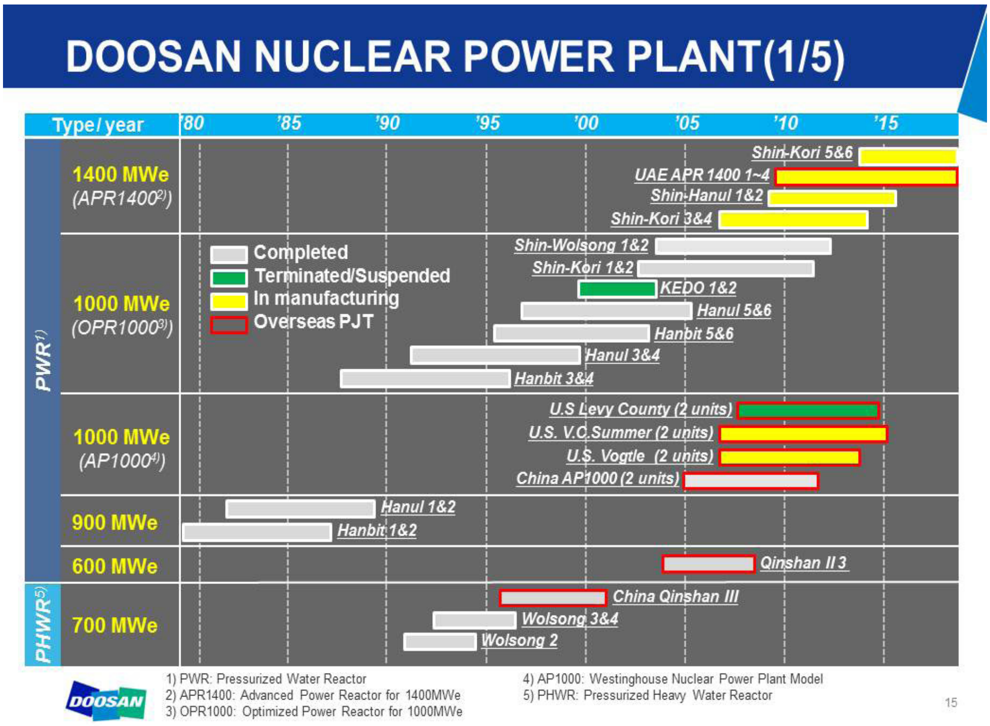
Doosan has been continuously developing the USC Boiler Technology to minimize pollution caused by coal combustion. D-NOx™ burners have been developed as a result, and have been successfully commercialized.

Further R&Ds are continued to develop the D-NOx 2 burner that can further reduce the NOx emissions significantly and can reduce the amount of carbon in ash to 0.5%.



The 1000MW USC Turbine has incorporated the efficiency and reliability enhancement technologies. By adopting the advanced reaction blade and continuous coupled blade design, turbine efficiency has been improved. Also by incorporating the advanced brush seal technology, leakage losses were reduced.

Improvement of rotor dynamics, stiffness improvement of low-pressure hood and adoption of 45” Ti last stage blades were also employed to enhance turbine reliability.

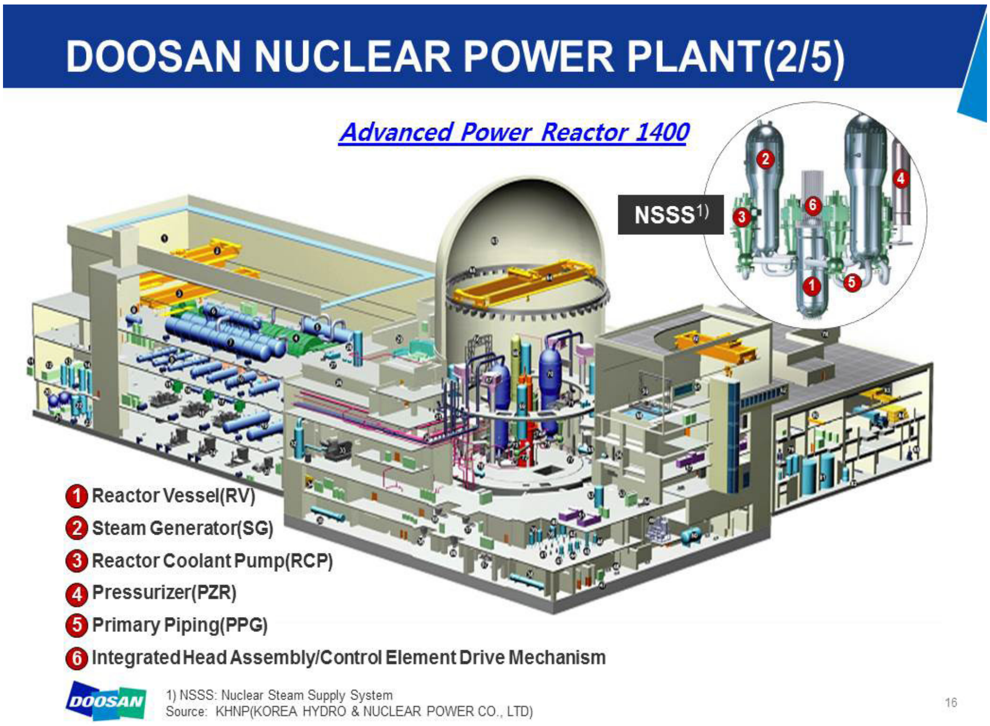


This slide summarizes Doosan's supply history of new nuclear power plants. Doosan has years of experience in building nuclear power plants in Korea and overseas.

Doosan has initiated its nuclear power equipment supply from Hanbit project #1 & 2, and participated as a main contractor of utility supplier in Hanbit project #3 & 4 in 1980.

In Hanbit project #3 & 4, Korean companies were selected as main contractors and foreign companies as sub-contractors so that they could learn technology more easily. Thanks to its effort, 72% of the parts were manufactured domestically in Hanbit project #3 & 4 compared to the past production of 35% in Hanbit project #1 & 2. By implementing additional plan for obtaining technological independence, Doosan acquired the capability to design and manufacture nuclear power systems of the same model as Hanbit project #3 & 4. This allowed the company to enhance its capacity in nuclear power plant construction during the construction of Hanul #3 & 4, which were the first Korean standard nuclear power station (1992-1999).

Also, Doosan has supplied domestic sector and USA with a variety of replacement nuclear steam generator, reactor head and pressurizer for extending the lifetime of nuclear power plant.



This shows the advanced power reactor (APR) 1400, a 1400MW nuclear power plant.

Nuclear power generation systems largely consist of a nuclear steam supply system, turbine generators, and auxiliary facilities. Only a small number of companies in the world are capable of making nuclear power systems, particularly the main systems because they require an extensive investment in facilities, extremely advanced technologies, and perfect quality assurance.

The APR1400 was a bold move Doosan took in 1995 (completed in 1999). The power output was drastically increased from 1000MW to 1400MW, and the power plant lifetime was extended from 40 years to 60 years, which in turn dramatically improve the cost effectiveness. It’s the most cost effective reactor among the third generation plus reactors of the same class made by France, Japan, and USA.

As for safety, it uses the hybrid safety system, which is regarded as the safest since it combines the advantage of the active safety system of France and the passive safety system adopted by USA.

The Korean standard APR1400 was installed at Shin-Kori unit #3 & 4 and Shin-Hanul #1 & 2.

DOOSAN NUCLEAR POWER PLANT(3/5)

Reactor Vessel

Height	14.8 m
Thickness	29.2cm
O.D	5.5m
Weight	553 ton

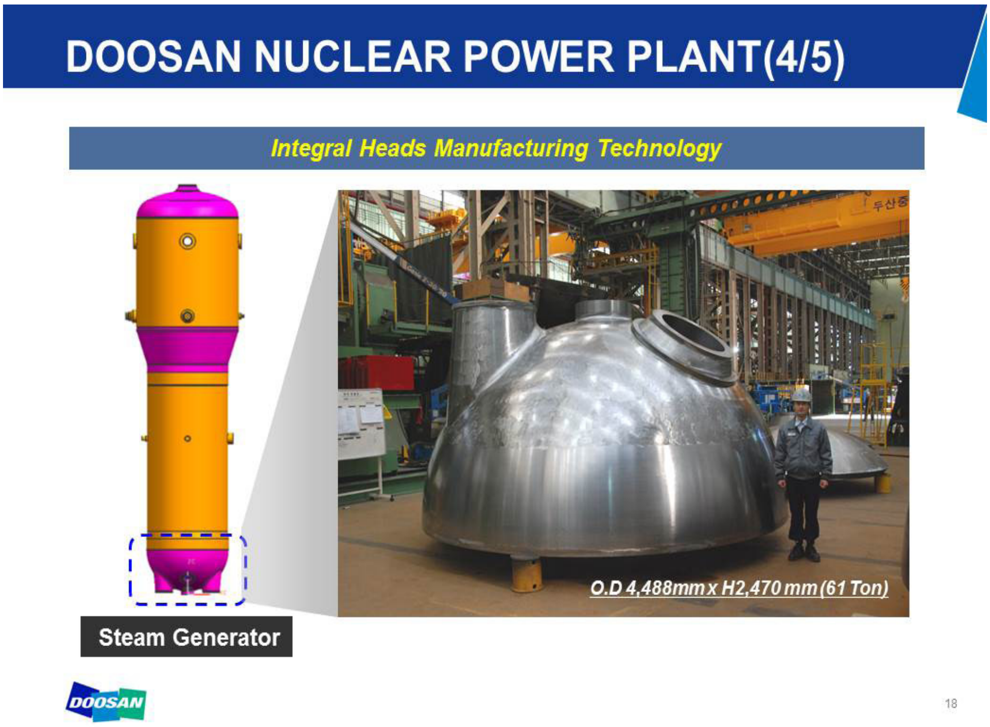
Steam Generator

Height	23 m
Thickness (Upper Shell)	14.3 cm
O.D (Upper Shell)	5.89 m
Weight	775 ton

17

This shows the reactor vessel of Shin-Hanul #1 & 2 in the left, and steam generator for APR 1400 supplied to UAE in the right.

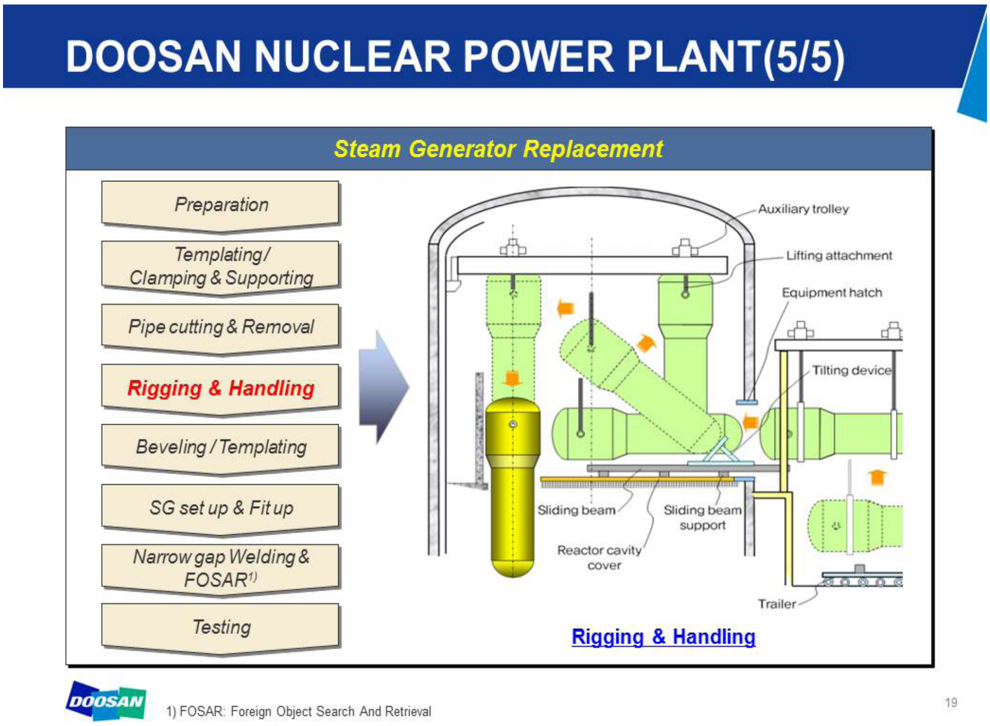
Doosan started exporting nuclear power generation equipment to USA, the foremost player in the industry, by winning a contract to replace steam generator for the Sequoyah nuclear power plant unit #1 in Tennessee (1999) just 30 years after Korea's first adoption of nuclear power plant technology.



Reactor vessel (RV) and steam generator (SG) which are the main equipment in the nuclear power plant are manufactured from separately forged steel components and welded together.

Doosan developed the integral head for the RV and SG of AP1000 for the first time in the world, and were successfully supplied it to overseas projects (China Shamen #1 & 2, Haiyang #1, USA V.C. Summer #2 & 3, Vogtle #3 & 4).

Integral head increases the lifetime of nuclear power plant and safety by removing the vulnerable welding and manufacturing the integrated component from the components manufactured separately previously.



Doosan has developed the steam generator replacement process and successfully implemented the technology by carrying out Hanul #3 & 4 steam generator.

For your better understanding a video clip is prepared.

(The video clip is uploaded on the Forum website: forum.kimm.re.kr.)

This is a bird's eye view of Korea's first net power 300MW IGCC plant.

Korea Western Power Company, Korea Electric Power Research Institute (KEPRI) and Doosan have developed the technology since 2006.

IGCC stands for Integrated Gasification Combined Cycle and is one of the major clean coal technologies.

IGCC technology is to convert coal and other carbon based fuel into fuel gas and then to make electricity using combined cycle. This converted fuel gas is called synthetic gas or syngas.

It has been gaining attention worldwide as the environmentally friendly and high efficiency power generation technology compared to the conventional coal power plant. The carbon dioxide capture and storage (CCS) treatment facility in an IGCC plant is smaller than in a traditional thermal power plant because it separates CO_2 before it burns the syngas

Furthermore, the gasification process to make syngas cannot only apply to power plant but also other chemical plant to produce fertilizers, hydrogen, synthetic natural gas and synthetic oil.

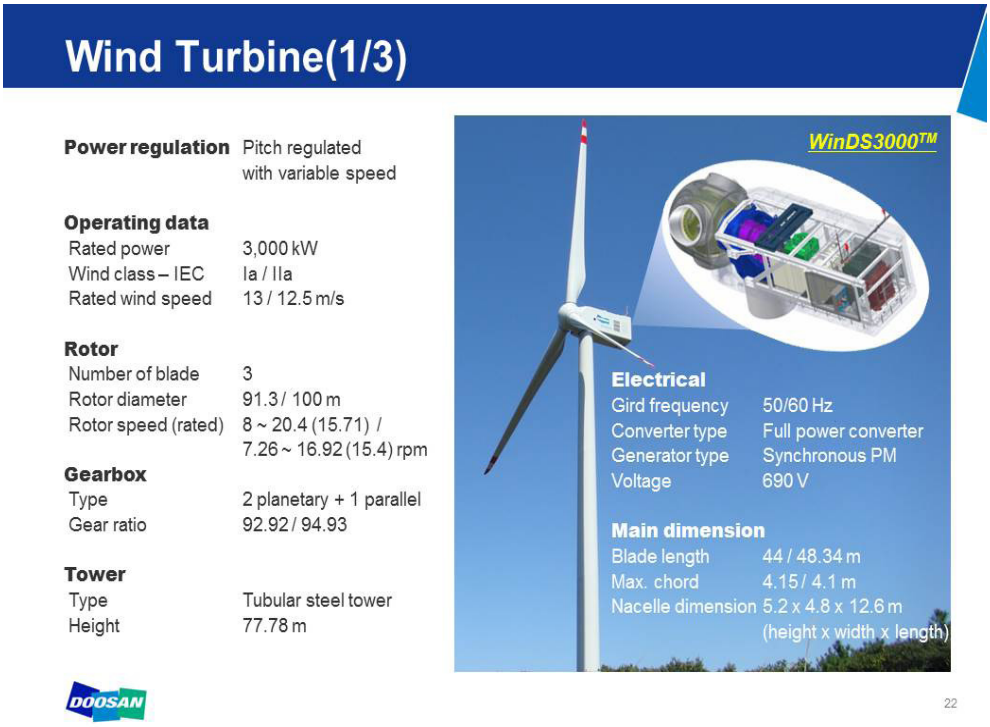
The global IGCC market is expected to grow to 400GW by 2030. Doosan has accumulated a comprehensive gasification plant design and engineering technology since 2006.

This slide shows Korea Western Power Company Taean IGCC construction site which is located at the west coast of Korean peninsula. The plant was designed to attain net efficiency of 42% and NOx emissions of less than 30ppm. So far approximately 95% of the constructions have been completed. Construction will be finished by the end of 2015. Commissioning is scheduled in early 2016.

IGCC plant is composed of four blocks. In gasification block, fuel is pulverized, dried, pressurized and fed into a gasifier. In a gasifier, the fuel is converted to syngas and heat, the heat is converted to medium and high pressure steam. In the gas cleaning system block, acid gas and particles in syngas are removed before syngas is combusted in the gas turbine combustor. In the air separation unit (ASU), oxygen is produced from the air, pressurized, and then, fed into a gasifier. Lastly, the power block is composed of gas turbine, heat recovery steam generator (HRSG) and steam turbine.

With the accumulated technologies, and subsequent IGCC project such as synthetic natural gas (SNG), coal to liquid (CTL), and hydrogen production expansion of business in various gasification plant applications is investigated.

Taean IGCC plant adopted shell coal gasification process. Shell gasifier has some distinctive characteristics compared to other gasifiers. Shell gasifier produces syngas using a dried coal so that the syngas heating value and coal conversion rate are higher than the slurry coal feeding types of gasifier. Also, the inner wall of the gasifier and syngas cooler is made of water tube, called membrane wall, so that thermal efficiency by heat absorption is higher than the others.



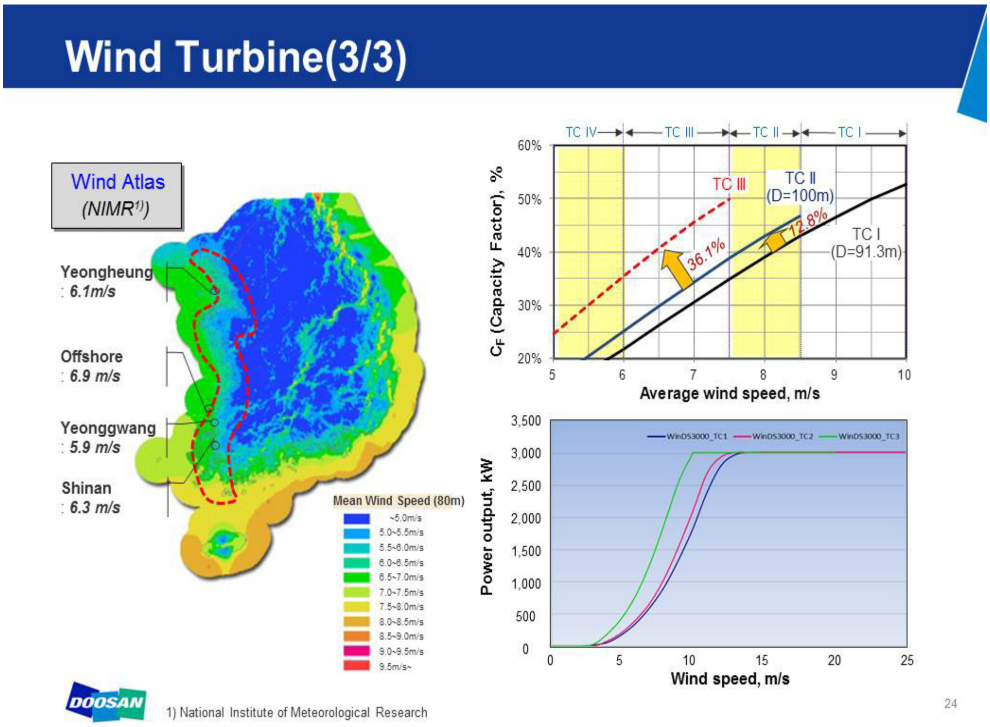
Doosan has developed the first 3MW wind turbine system in Asia. We named the product as WinDS3000™.

This product is applicable for both on-shore and off-shore installation. International certifications were obtained for both on-shore and off-shore models.

WinDS3000™-TC1 and TC2 products are used depending on the average wind speed of the installation area. The diameters of the rotor were 90m and 100m, respectively.

We used gearbox, and this product was applied to the robust system of full power converter and advanced control system.

WindDS3000™ has been selected for several on/offshore projects. So far 47 units were delivered for commercial operation and construction.



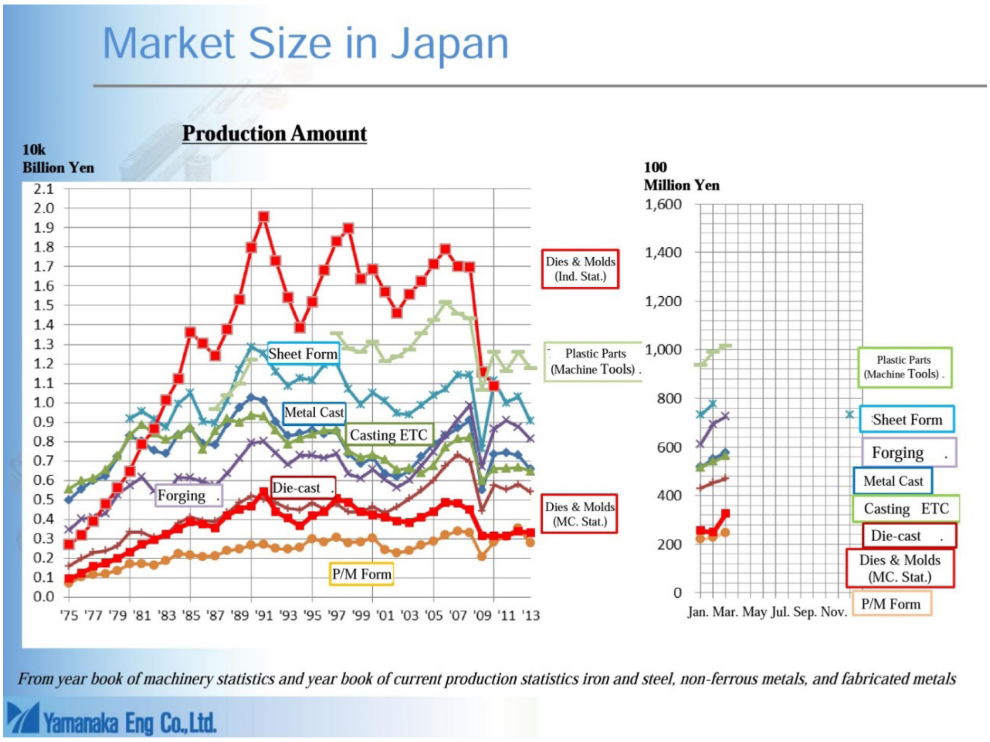
Doosan is currently developing a model for WindDS3000_TC3 which is favorable in low wind speed areas. If we look at the data provided by the National Institute of Meteorological Research, most west coast areas have been identified as TC3 suitable area with average wind speed area of 6~7 m/s or so. The TC3 model is expected to improve the capacity factor of 36.1% than the previous model TC2.

Thank you very much for your kind attention.

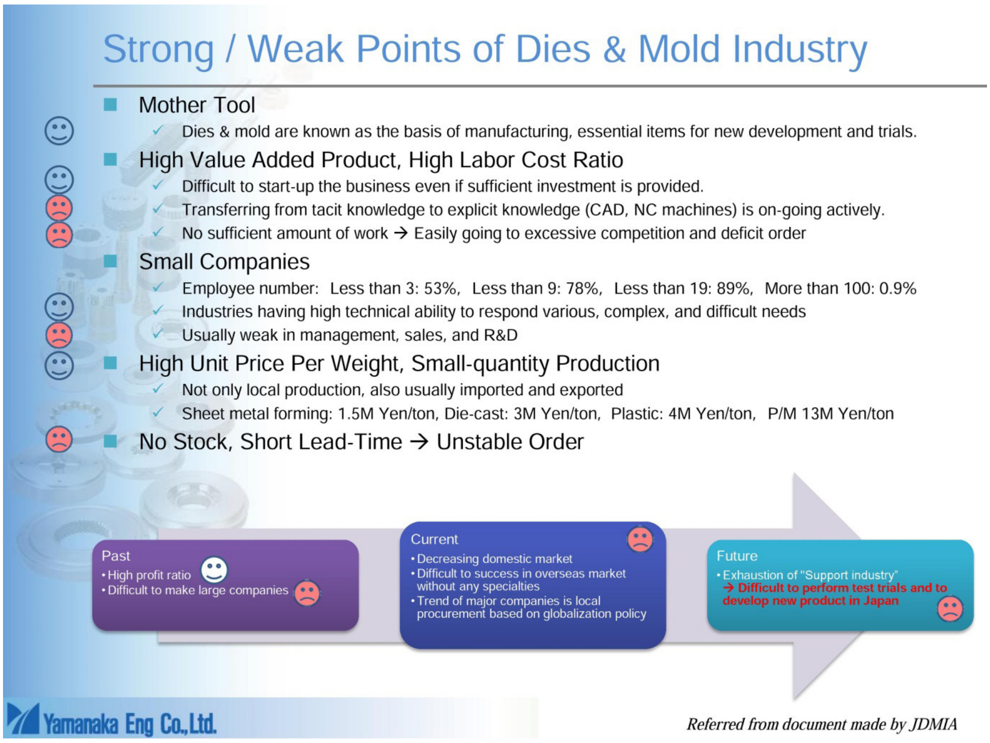
Challenge for Sustainable Growth: Innovative R&D and Strategic International Sales Activities

Masahito Yamanaka, President, Yamanaka Engineering

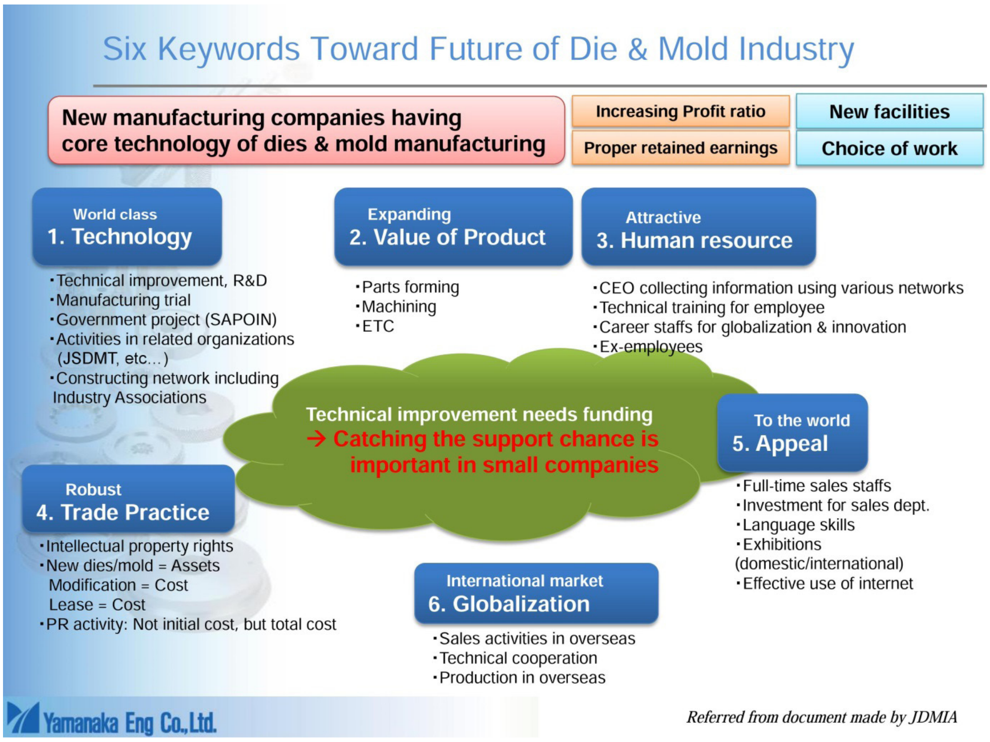
Thank you very much, Mr. Chairman. I am honored to be here in front of eminent professors, researchers, engineers and directors. I am from Yamanaka Engineering. Many of you may not know about this company. It is a family-owned company, and was selected as one of the leading small- and medium-sized companies in Japan. My father handed over the leadership to me five years ago. I am really enjoying this business. These days, we are facing many challenges and I will focus on a couple of them today. One is, of course, technologies, and the other is international sales activities. I would like to share those two things with you. Any feedback from the audience is welcome.



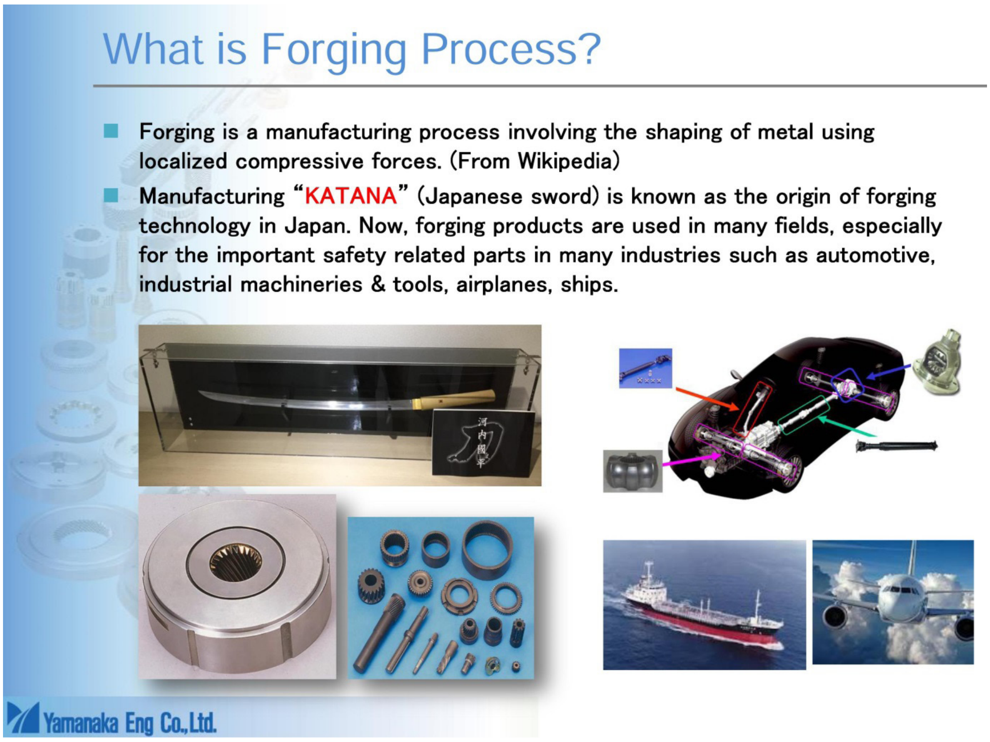
Before I talk about those challenges, I would like to mention dies and molds industry in Japan. This graph shows the tooling production amount in Japan for the past 40 years. It includes sheet form, metal cast, forging, die cast, etc. As you can see, in Japan, since 1970s, the motorization started and the amount has been rapidly growing. The bubble economy started in Japan in 1989 and fell in 1994. After that, our growth in this area has been stable for over 10 years with no growth at all. In Japan, we call it the Lost Decade. We had an economic crisis in 2008 due to Lehman Brothers' bankruptcy when the production went down sharply and then stabilized. This trend had a big impact on the tooling business.



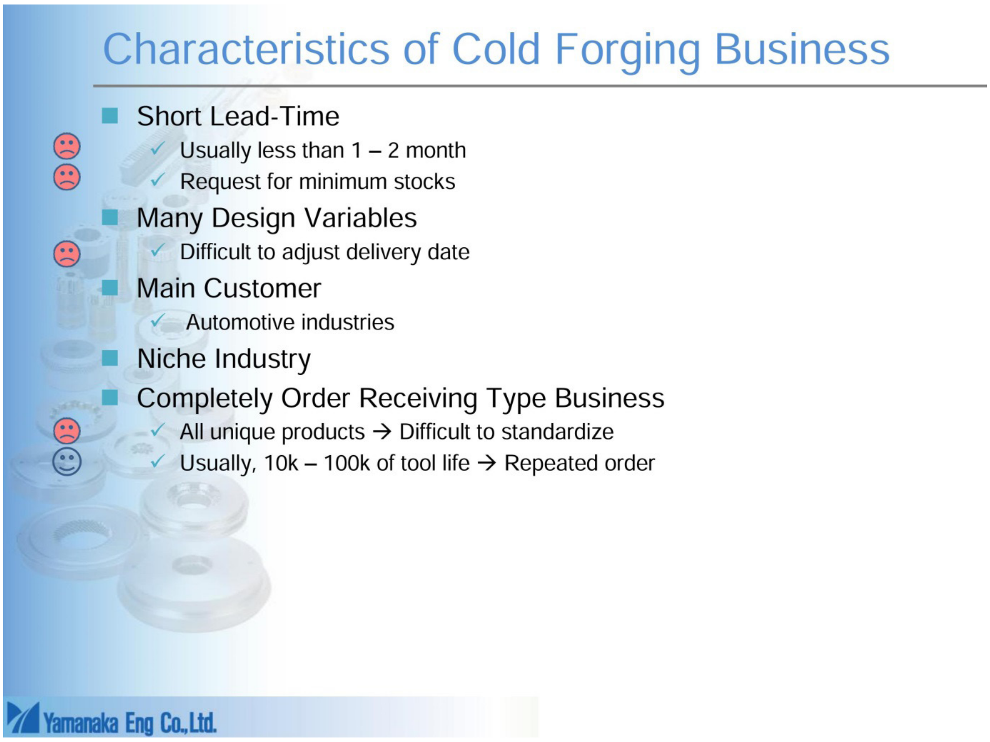
I would like to tell you about some strong and weak points of the tooling business in Japan. Traditionally, dies and molds industry is known as the rise of the manufacturing system. Many industrial products are manufactured using dies and molds. 90% of the tooling businesses are made up of family-owned companies which have less than 20 employees. Due to their small size, the management, sales and R&D are usually weak. The profit ratio of die and mold products is usually high. However, it is difficult to make companies large because of the weak management. After the economic crisis in 2008, the number of domestic die and mold companies has decreased steeply because of the effect of market tendency, and the concern about the declining competitiveness of the Japanese manufacturing industry. The Japanese government started supporting dies and molds industry actively. Recently, the Japanese dies and molds industry is reevaluated due to the high product quality.



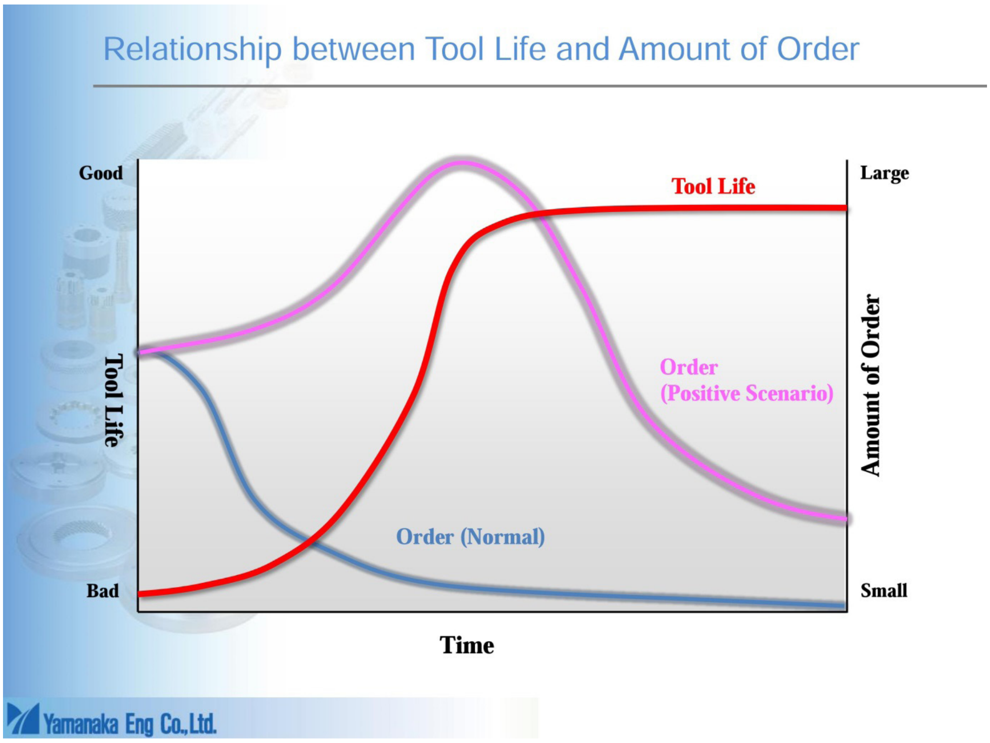
This slide introduces six keywords selected by the Japanese Die and Mold Industry Association as the growth strategy for the dies and molds industry. Those key words are world class technology, expanding value of products, attractive human resource, robust trade practice, appeal to the world and globalization. 30 years ago, it was said that you did not need any sales efforts if you manufacture good products. However, it has changed. We need sales marketing. I would like to mention the importance of planning the strategies by adopting these keywords and flexibility concerning strong points and philosophy of each company.



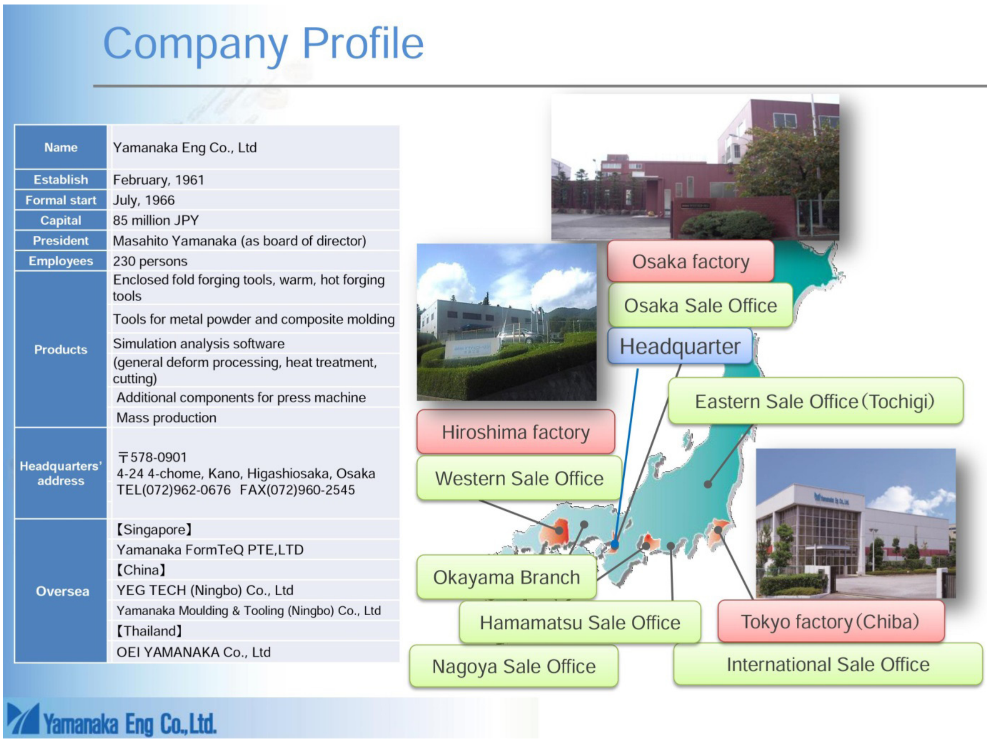
This slide tells you what the forging process is. According to Wikipedia, this is the definition: forging is a manufacturing process involving the shaping of metal using localized compressive forces. We produce this kind of tooling. This is an example of forging parts. Our major customer is automotive industry. Our products are mainly used inside the car where nobody can see: engine parts, axle shaft, differential gears and so on. Some of the forging parts are used in ships and airplanes. This is the Japanese sword, Katana, and its manufacturing caused the invention of forging. This Katana here in the picture is actually mine. It was manufactured three or four years ago by a very famous lifelong craftsman. I engraved my daughter's name here so that it can be passed down to her when I pass away.



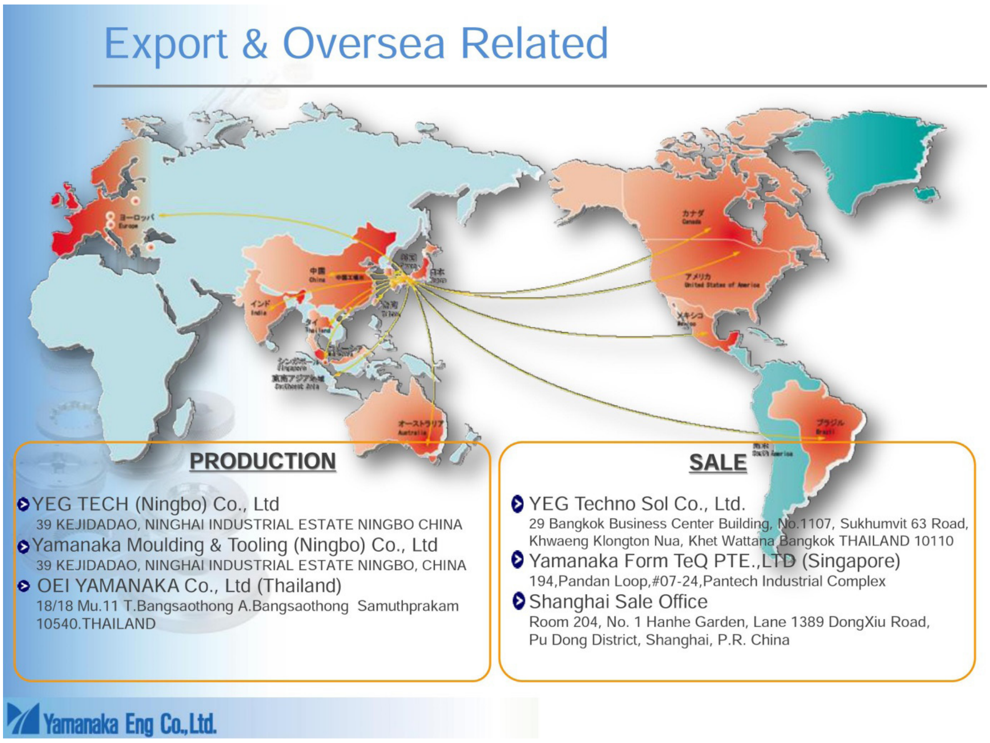
Now, I would like to talk about the general characteristics of cold forging business. We are mainly manufacturing dies through cold forging process under the room temperature condition. The most remarkable characteristics of this business are the short lead-time. The short lead-time is required especially for the cases where the lifetime of the products is short. On the other hand, the amount of repeated orders can be increased for the short tool life condition. Also, the competitiveness of a company can be increased with the improvement of tool life based on the technological strength. Our products are expensive compared to other manufacturers, but their quality is higher than that of any other competitors.



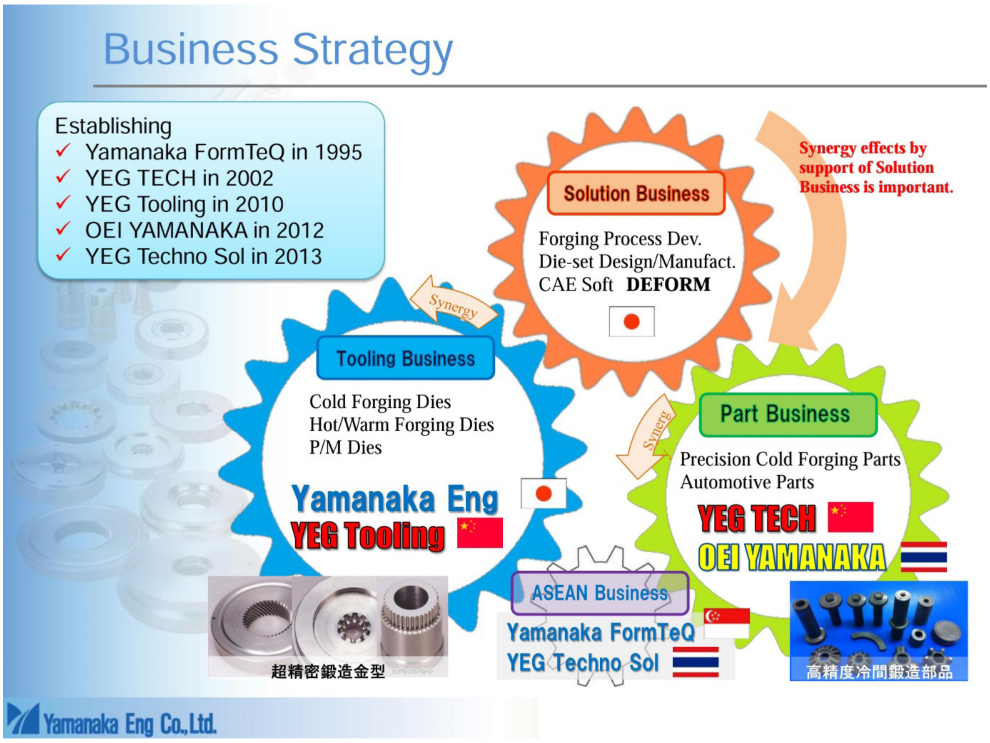
This graph shows the relationship between the tool life and the amount of orders. When the tool life gets better, orders decrease. That is normal economy. Therefore, companies like us, manufacturing cold forging tools should always look for new orders for the development. Otherwise we lose money.



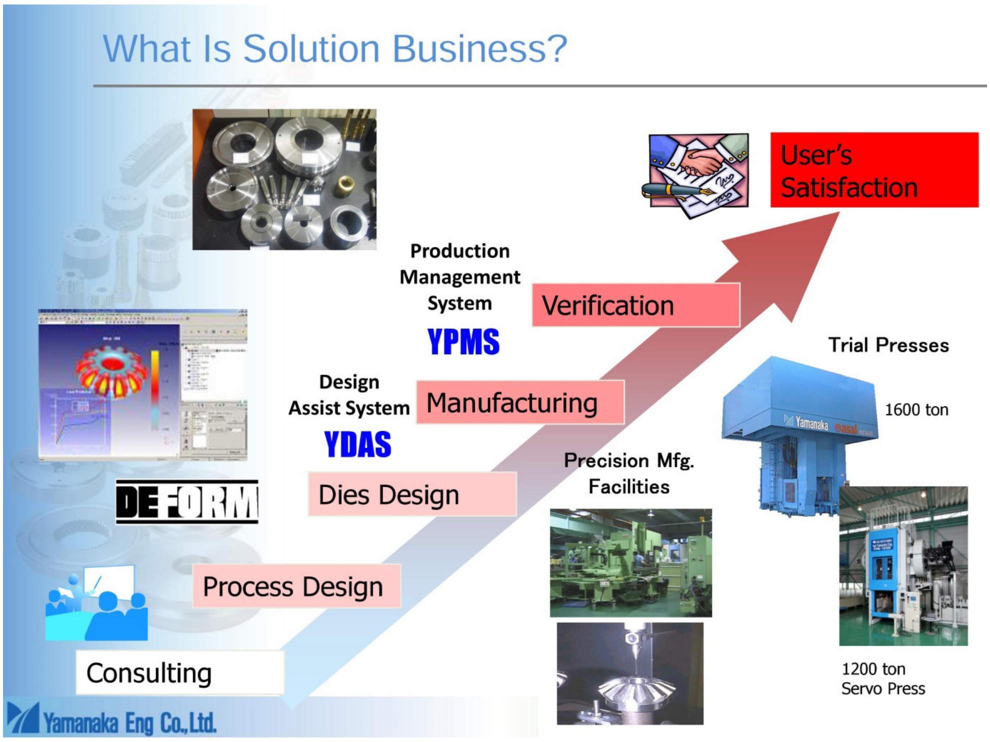
Next, I would like to talk about our company briefly. Our company is now 55 years old. The number of employees is 230. We have three plants each of which is located in Tokyo, Osaka and Hiroshima. The Tokyo plant, located very close to Narita Airport, specializes in high precision with complicated-shaped tooling.



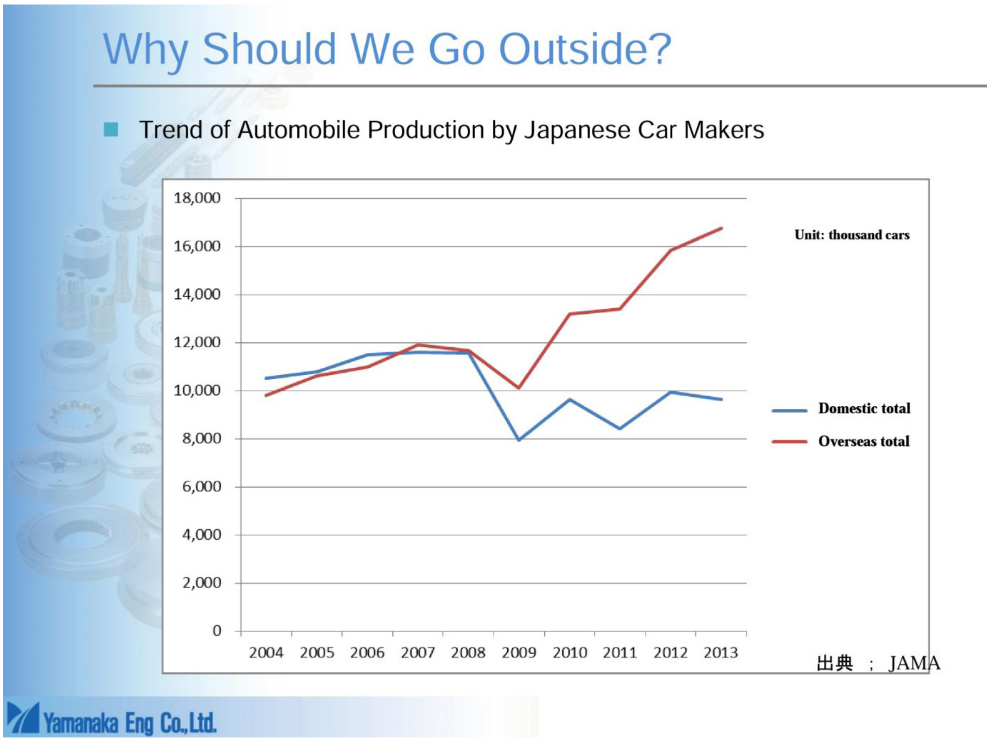
We are, of course, exporting tooling outside of Japan, nowadays mainly to China and Korea in East Asia and to Indonesia and India. We have three production plants: two tooling plants in Ningbo, China and a cold forging plant in Thailand.



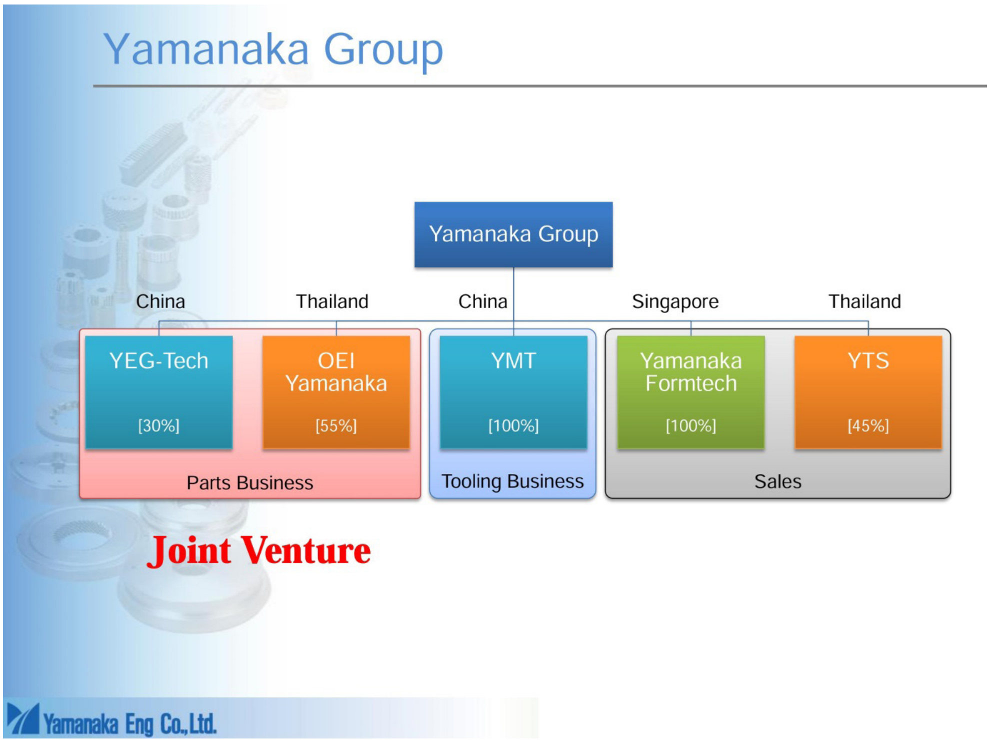
The business strategy of our company is composed of three divisions: the tooling business, parts business which is mainly for the outside of Japan and solution business for process development. As shown with the image of multiple gears here, we hope to propel our company forward by using the synergy effect. The growth of these three divisions is the main object of our management. The solution business for process development is the most important division since high-level ability to develop new processes creates new tooling business. If the tooling business is good, the parts business for the outside of Japan is also good.



Let me talk about the solution business in more detail. Engineering power boosted by the combination of accumulated know-how about tool, process design, and process simulation technology is one of the most strong points of our solution business to propose an innovative forging process and to satisfy our customers' needs. The solution business can provide the total solution for the development of a new cold forging process from the process and tool design to test forging trial for verification. Shaping and realizing the forging products from the customer's rough image is the motto of our solution business.



I would like to talk about the challenges in international sales activities. This slide shows the trend of automobile production by Japanese car makers. After the economic crisis in 2008, domestic production has been almost the same with no change or no growth. However, outside of Japan, Japanese car makers have produced more cars. There is one main motivation to try business outside of Japan.

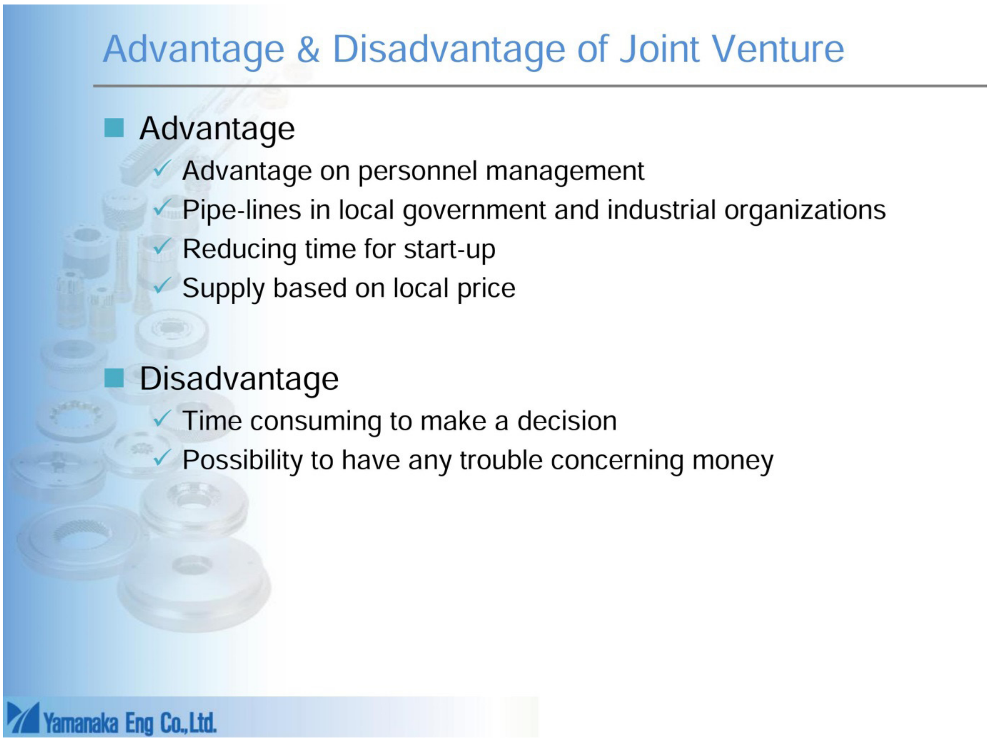


This diagram shows Yamanaka group. The parts business is a joint venture, not 100% owned by our company. The tooling business, on the other hand, is 100% owned by Yamanaka. Why? It is because we do not release these technologies to the third party. We regard the technologies for manufacturing tooling as core technologies. The main reason that we chose the joint venture was because we wanted to reduce the amount of investment.

These are the pictures of our plants in China and Thailand. I started my presidency this year at the time when the sales were almost domestic. Now, domestic sales are almost four times as big as the overseas sales. In the future, the total amount of overseas sales will reach the same level as the domestic sales amount or exceed it. The sales amount of domestic tooling business will increase along with the increase in the sales amount of parts business.

In this slide, I would like to explain about what the important points are for globalization. As I already mentioned about the spirits between business divisions with the gear image, the main philosophy is to grow overseas business that leads to the expansion of domestic business.

When considering going into the overseas market, the selection of a joint venture partner is seriously important. Visiting the factory and the country is the most effective way to understand the basic philosophy of a company considered as a partner. The building and the land should be leased to reduce the risk of withdrawal caused by any unexpected events.

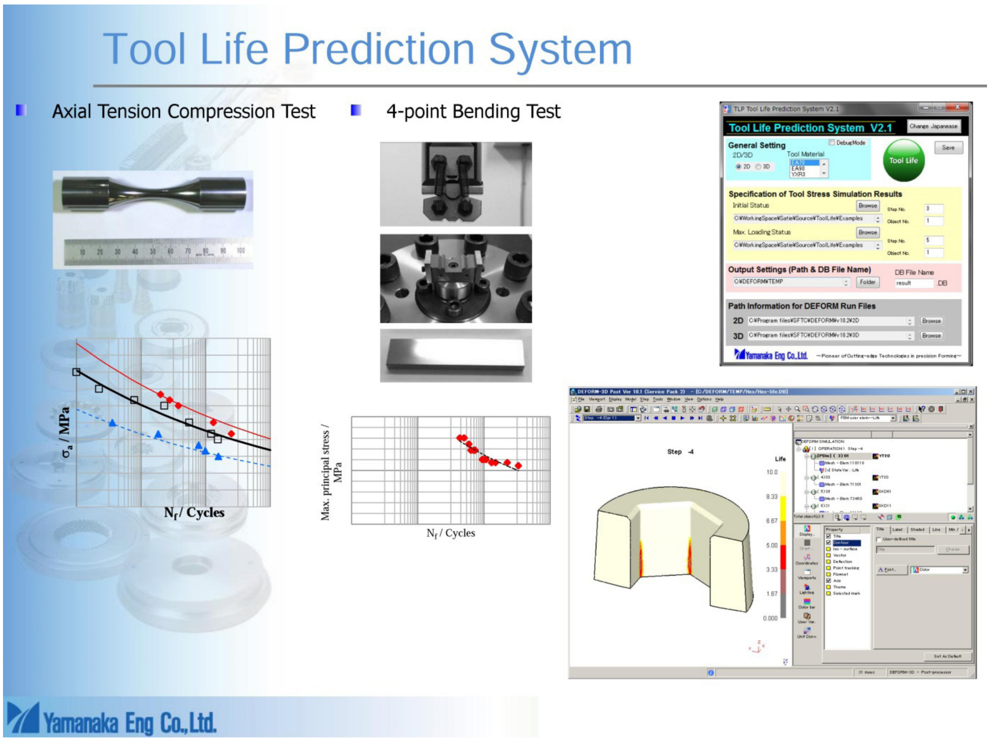


I'd like to talk about advantages and disadvantages of the joint venture. Troubles may occur between labor and management overseas. In such a case, the partner of the joint venture can be helpful to solve the problem effectively. In general, the ratio of manpower between labor and management is usually lower than that of local Japanese companies. Besides, making free use of pipe-lines in local government and industrial organization can help reduce time for startup to hire high skilled employees and to supply based on the local price.

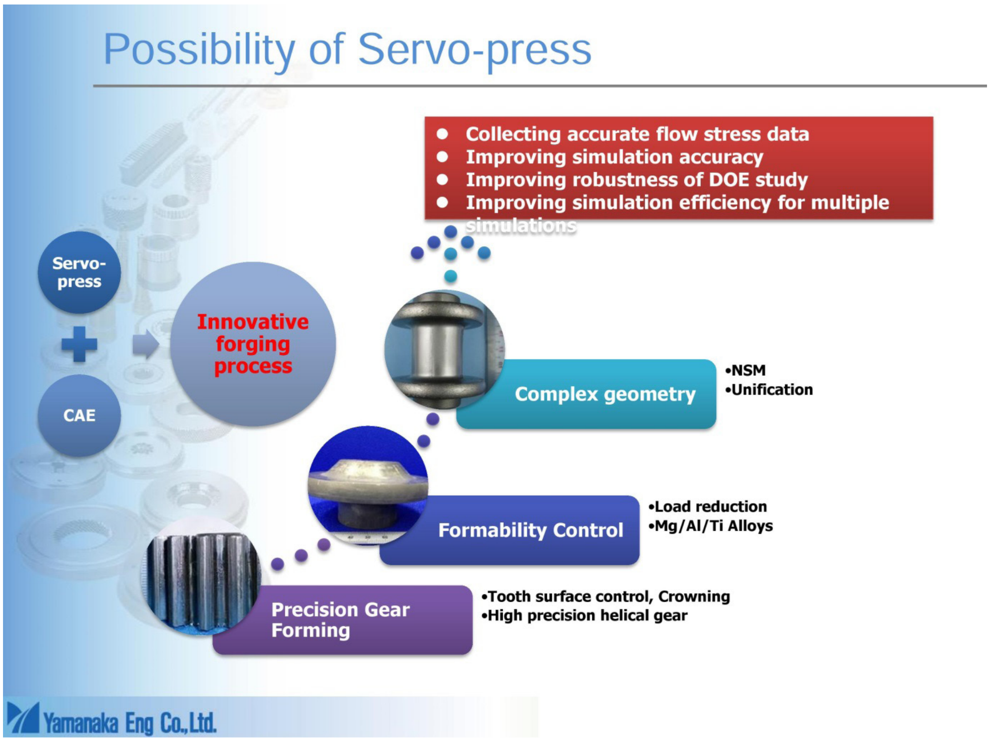
Of course, there are some disadvantages such as long negotiation time to determine the decision of investment. How to share information and communicate closely from both sides would be the key points to overcome such disadvantages.

What would be the most important issue for a successful joint venture business? Firstly, it is sharing the information of the management status such as key performance index (KPI). Sharing the recognition about current programs in sales production, quality and management is also important for the successful business. Making working groups composed of members from both sides to solve any important problems is one possible method to promote the understanding between both sides. A friendly relationship between owners is also important. I like playing golf with my Chinese and Thai partners in this picture. We hold a review meeting after a golf game and have a drink. This is very important for the success of the joint venture business. Making the environment for open discussions is the most important to cover all big issues. Communication is quite important. We need to get prepared to provide these environments.

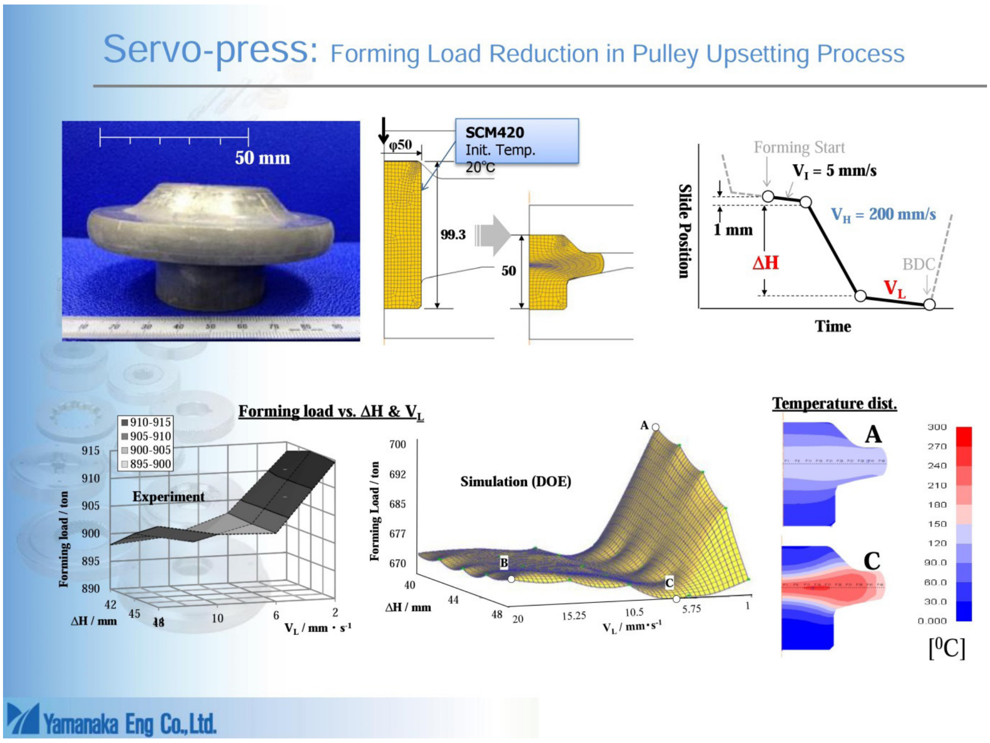
I would like to promote the overseas expansion more actively in the future. My philosophy about globalization, i.e., raising the domestic business based on the size of the overseas business would not change.



Now, I would like to talk about some developments done by us. Firstly, I would like to introduce our R&D activities for tool life prediction. Tool life, as I mentioned earlier, is a significant issue for designers since it is directly related to production cost and is usually difficult to predict accurately due to uncertain factors that make tool life unstable. We developed a tool life prediction system to predict fatigue tool life in ideal condition since this information can be used as a reference data for tool designers. Two types of fatigue test were carried out to find out fatigue characteristics of the tool materials: axial tension compression test and 4-point bending test. The tool life prediction system based on these fatigue tests was developed and linked with the simulation software. This shows some results. This is the actual tooling. The actual tool life was about 10,000 and the predicted tool life was about 7,000. The actual location of failure, i.e., cracking, was the same as shown in the simulation. It seems to work okay.



Next one is another development using servo press. It is obvious that servo press and the computer-aided engineering (CAE) technology is the key issue for the development of innovative forging processes opening new possibilities such as handling of complex geometry, realizing net shape manufacturing, improved production control of low-formability materials such as magnesium alloy, and developing high-precision gear forging and pressing machine gear parts. In the future, more work should be done for correcting accurate flow stress data concerning temperature, strength, weight and so on.



I would like to introduce an example where cold forging is applied to a servo press machine. The example here is forming of pulley upsetting by reducing forming load. We focused on the reduction of forming loads due to temperature increase or heat generation from the plastic deformation, and due to friction. We used our 4-axis press and the design of experiment (DOE) to have the optimum design so that we can get the lower load. CAE technology with servo press is very important for new developments. It is the double-flange part here. This was done by one simulation as shown here, down and up simultaneously. To get that one we have this lateral closing die equipment here. Close and open so that the deformation is complete. By using the DOE, we try to find the optimum closing force.

Finally, it is education. I would like to mention this one briefly. Are university students willing to enter a company of our size? I do not know about what it is like in Korea, but the answer is no in Japan. Everyone wants to enter a big-name company. Especially their parents want their children to work for a big company. Under this kind of situation, the key thing is to motivate the people who are beginning their career in companies like ours by training them, starting from the zero. Year by year, their motivation should get higher and higher.

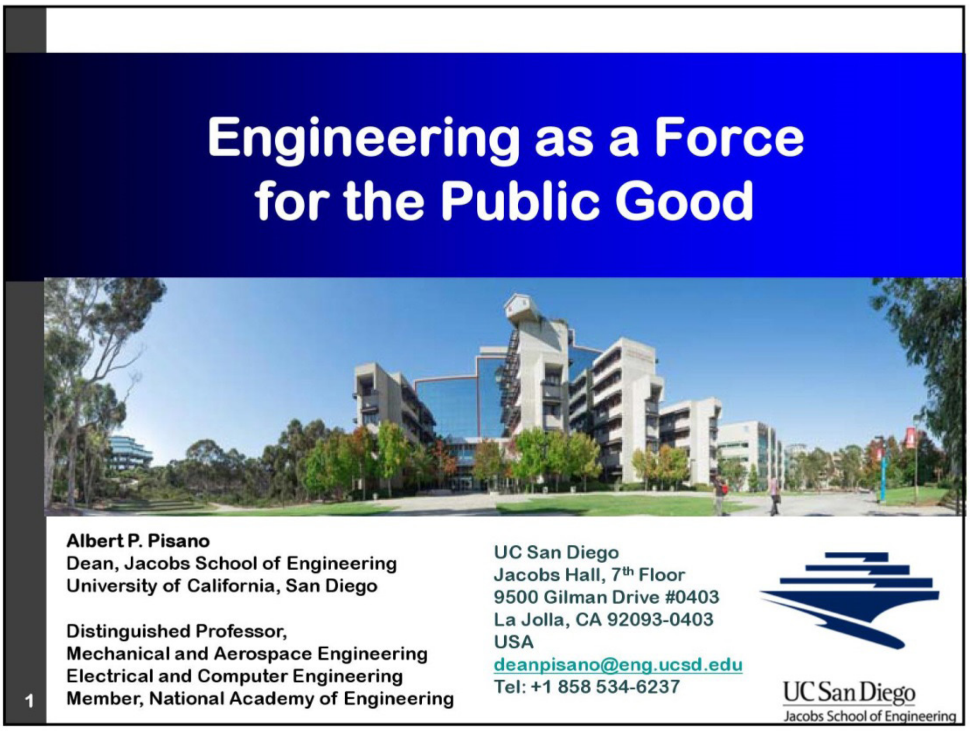
Thank you very much.

Engineering as a Force for the Public Good

Albert Pisano, Dean, Jacobs School of Engineering, UCSD

Thank you, gentlemen. Allow me just a moment to learn the operation of the equipment.

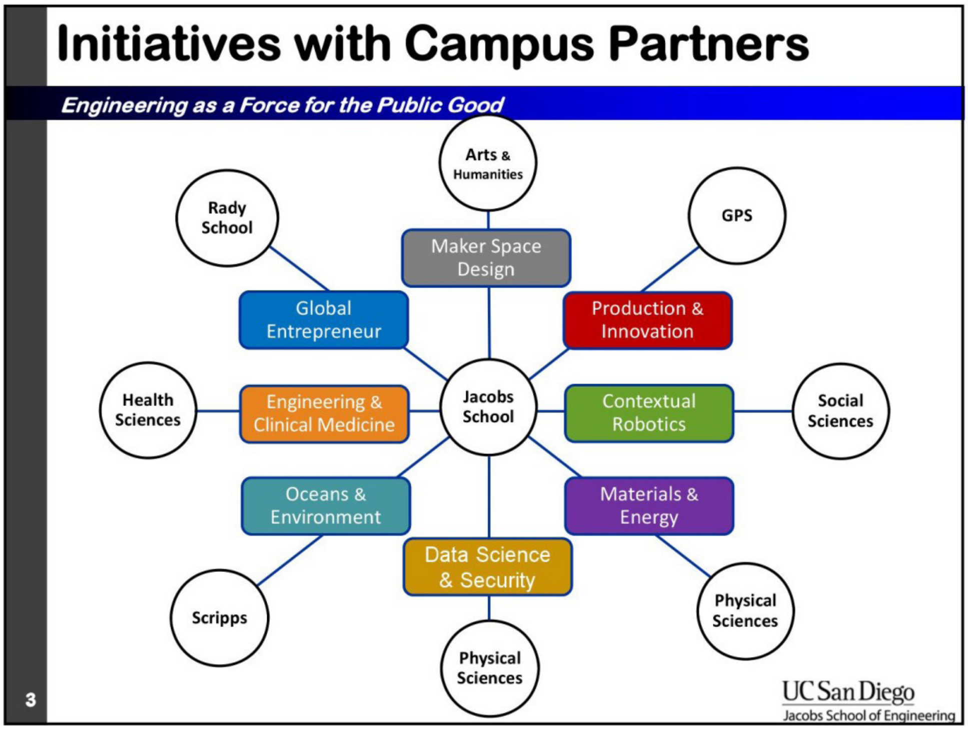
What I would like to do is to thank you all very much for your time and attention, and thank you very much for the organizers who are around, invited me here.



I am the dean of engineering of the largest school of engineering in the entire state of California. You may know the name Berkeley, you may know the name Stanford. My school is twice as big of those. I am bigger than the two. I have 8900 students, 7000 undergraduates and the charter for my school is to provide industrial talent for the industries in and around San Diego.

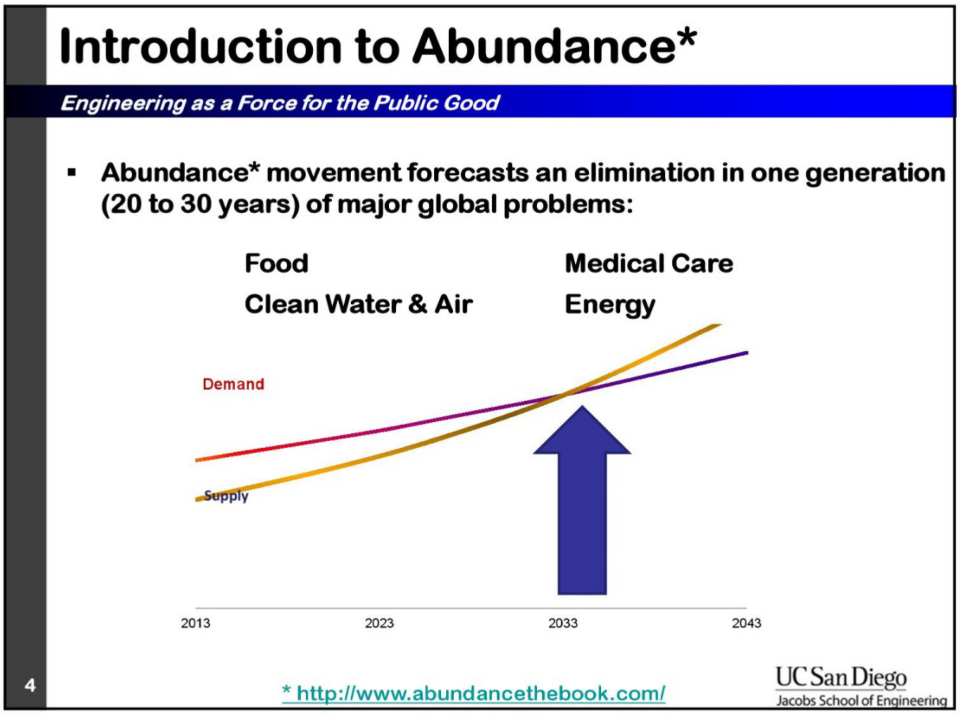
When I was at Berkeley, I ran the largest industrial consortium in the history of Berkeley, 48 companies at one time. I am the academic who has worked mostly within the industry rather than with the government.

When I hear some interesting presentations, especially one just before me, I said, “Okay. I think I understand some of these problems” and I am hoping in the next few minutes, I have to tell you a little bit about the way we are changing the education so that we can support engineering broadly, including manufacturing from our school.



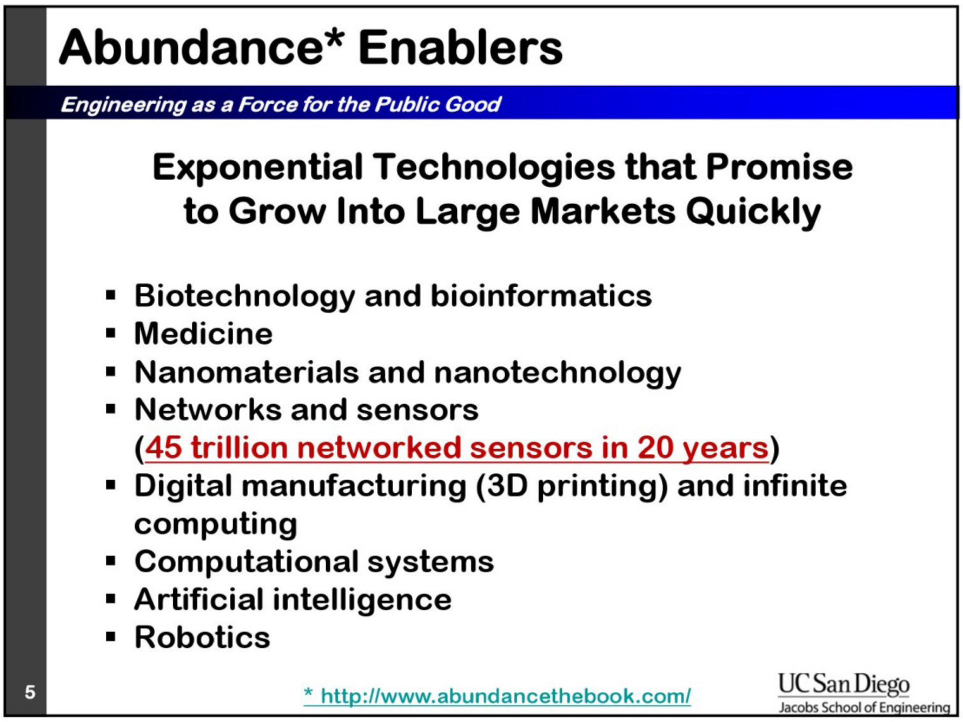
My school is ranked number seven among engineering schools in the United States according to the best school of the universities. As I mentioned, it is the largest school of engineering in California. The plan for the school is to partner with many of the portions of the campus so that we can bring a broad view to engineering problems. I will not go through all parts of this slide, but I will just offer that we are launching a new institute in robotics. That institute is in the area of context robots, robots that understand the situation around them. Engineering is a partner with social sciences because social science understands how humans learn. We want the robots to learn the same way humans learn.

Parts of our team are human learning experts, and they will be guiding that project. That is one example of a different approach we are tracking to engineering at UC San Diego.



I want to talk just a moment about the concept of 'Abundance'. There is no organization in the United States called 'Abundance'. It is working to increase the supply in excess of the demand for things like food, clean water, air, medical care, and energy.

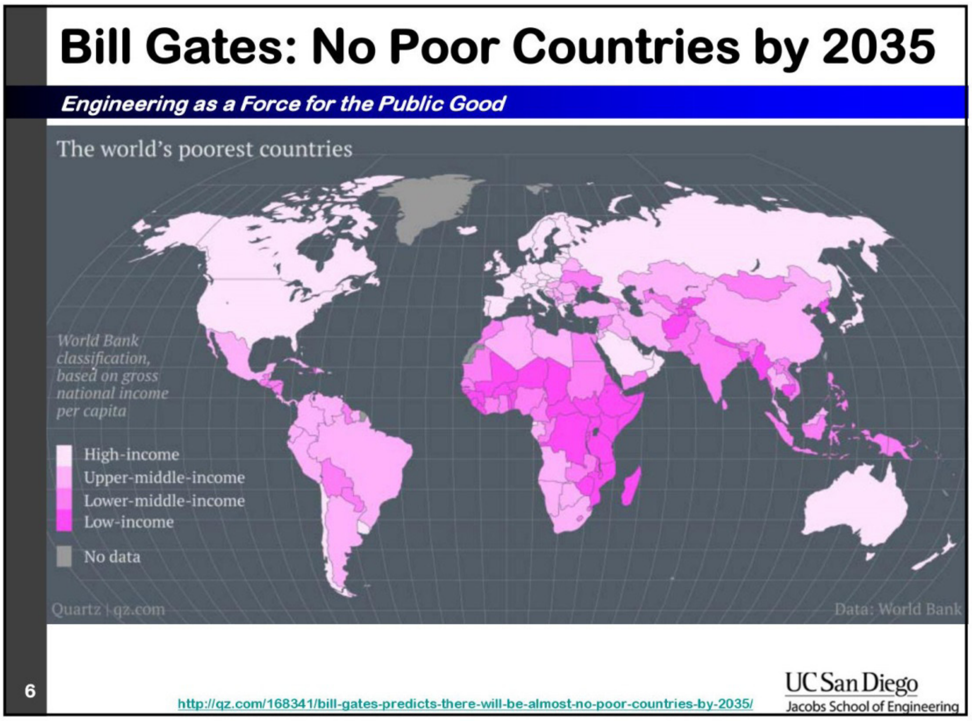
We all know this is a good thing to do for several reasons. One is the mandatory thing to do. Since my school is very practical, I also say it is good to do because you can sell more products to people who are economically better off.



We have identified several industries that we think will experience exponential growth in the next decade; industries that will double and double again. They are biotechnology and bioinformatics, medicine, as increase in personal medicine, nanomaterials and nanotechnology, networks and sensors, digital manufacturing, computational systems aims for robotics.

For an example, our robot institute is oriented toward consumer robots. Last year, one of the robots designed by our school became a toy. It sold by ‘WowWee.’ It is called the ‘MiP.’ In the first year, we sold two million pieces. This toy sells for 60 dollars. This year, I expected the limit of the volume. Most of the technology in that toy comes from the technology developed in my school, in an exclusive partnership with the ‘WowWee’ toy manufacturer. We are trying to duplicate the success by engaging in more industries.

I will focus a little bit on sensors here because there are experts who predict that, in the next 20 years, there will be 45 trillion network sensors. There is a huge piece of mechanical engineering involved, making all of that happen. Now 45 trillion sensors are a lot that you cannot make from silicone only. These are going to be manufactured by printing processes that make those many sensors.

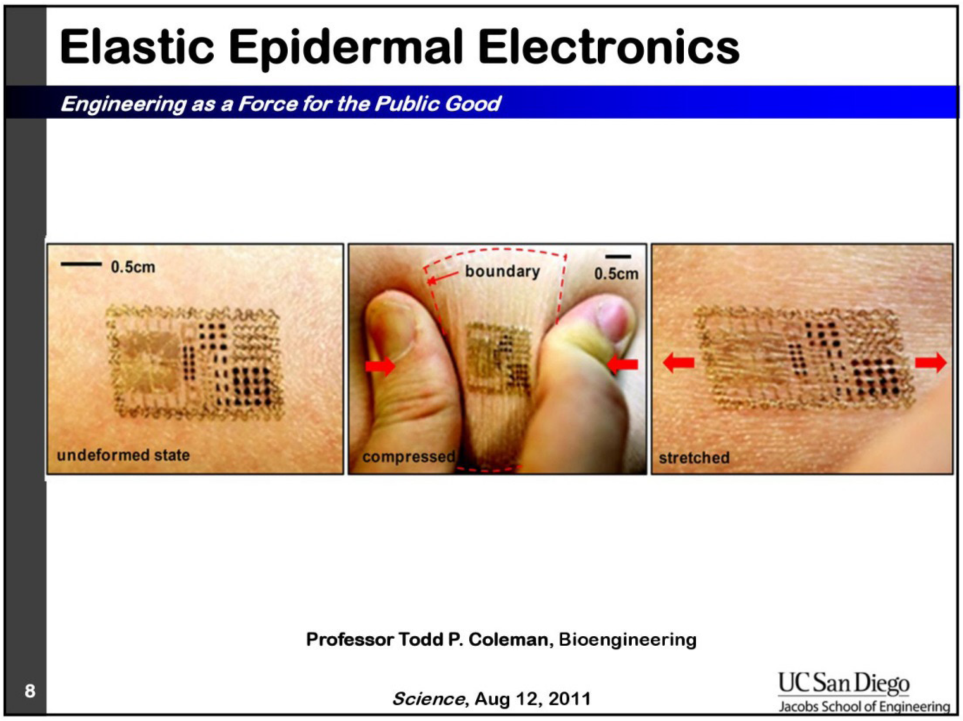


I will shift to the technical part of the top, and I will end on the social part of the top with this result from the Bill Gates Foundation.

Here is the link, and this is a public version of the presentation. It is available to the people who want. The Bill Gates Foundation made a study of what would happen if these high growth industries really did grow and generate the additional resources so that the world economy would expand enough to work on solving the problems. They are predicting that if we can organize the growth of these high growth industries, they think by 2035, there will be almost no more poor countries left in the world. Well, not everyone would be rich, but the definition of poverty will be exited in most of the countries of the world.

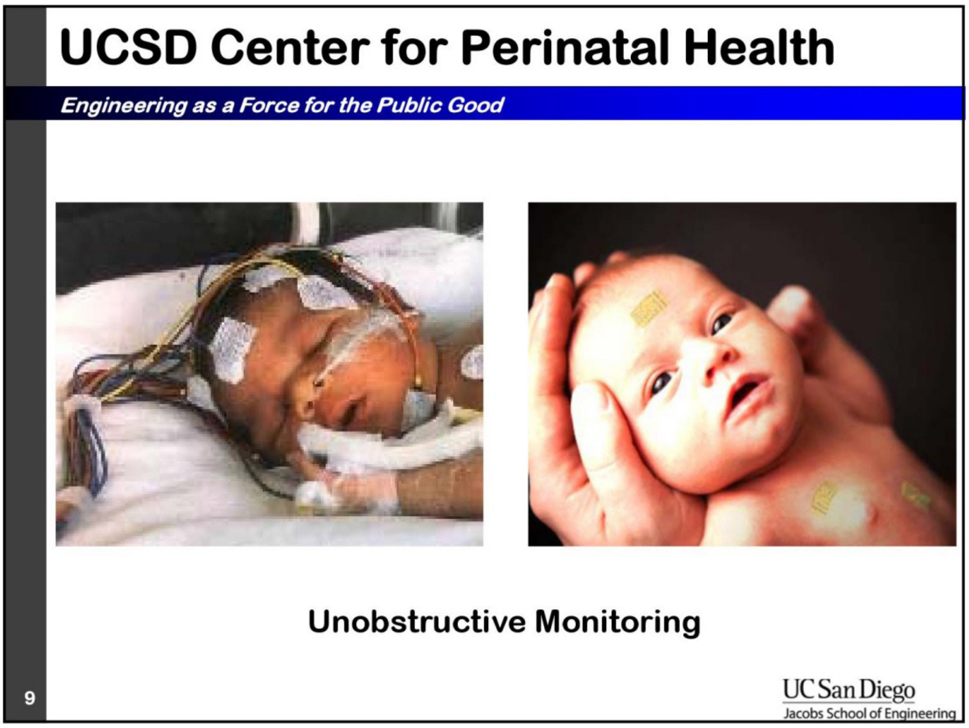
What is my school doing to make this happen?

I already explained that we work very tightly with the industry. I would like to share some of the projects that we are doing. We think these projects are all high-growth business projects.



First, you can make a radio, an antenna, a sensor, and an energy harvesting device using palmer electronics, and glue it to your skin the same way a Band-Aid glues to your skin. We use the same glue as the Band-Aid glue.

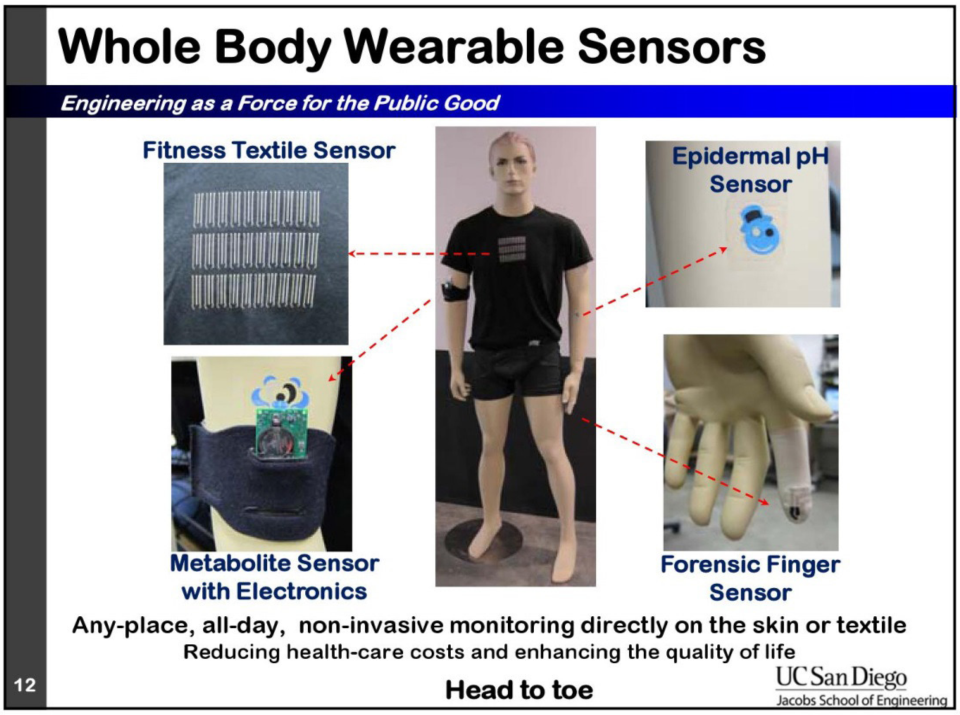
This is a functioning device. This device is used to get the metabolite rate of your body measure by measuring the lactic acid generated by your sweat. One vision is that the biological laboratory of the future is not a test to, and it is not a cartridge, and it is not a piece of plastic, it is you. You could image the volume of these sensors are going to be very high, because they will operate for some period of time and must be replaced from time to time for use on humans.



We have tested these sensors in the hospital. On the left is what happens to a baby if it's born prematurely with complications; an unhealthy baby on the right. Now few people realize that one of the big risks to the infant is a series of skin infections, because the pieces for these sensors has to be strong enough to take them to fall off, but they are replaced frequently so the infant will actually receive the wounds to the skin. If this wound gets infected, it gets another complication. On the right is an example of the sensor only measures one thing, not all the things to pick. The sensor on the right has been tested in four hospitals. This is a passive sensor that is interrogated to give a temperature of the baby for example.

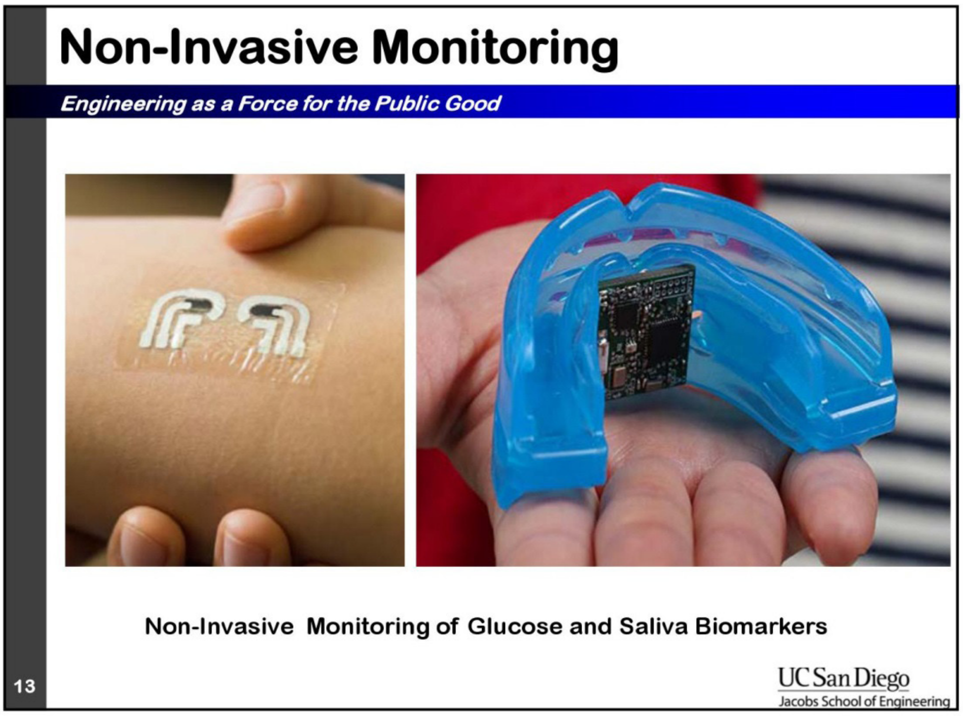
On our campus we have QI with the number of industries. QI stands for QUALCOMM Institute, the QUALCOMM funded institute for engineering invention. That is on our campus, center for wearable sensors that I just described one project, the hospital on the campus.

The logic of new program is called 'Center for mobile health systems and applications.' Now I think in Korea, probably Doctor M, which I think would be a Samsung product. This would be similar to Doctor M in the United States. The idea here is using a big data analytics and wireless communications. We get information about people before they go to the hospital, to intervene as early as possible with our remedy before it expands enough to cause a hospital bill. The part of this program includes sensors for air quality that go on your cell phone, and in fact, this is a cell phone centered technology where we leverage off the huge increase in cell phone manufacturer. There are 8 hundred million cell phones or more manufactured every year. Imagine this nearly one billion market, you are manufacturing a sensor module that eclipses the cell phone.



We have developed the series of sensors that actually work and measure a number of things on humans. For an example, this is an earlier version of metabolite sensors. This is the actual sensor. All sensors are designed in conjunction with the vision of arts and humanities, because many of these are for children. If the sensors look ugly, they won't wear it. So we are already addressing user update issues.

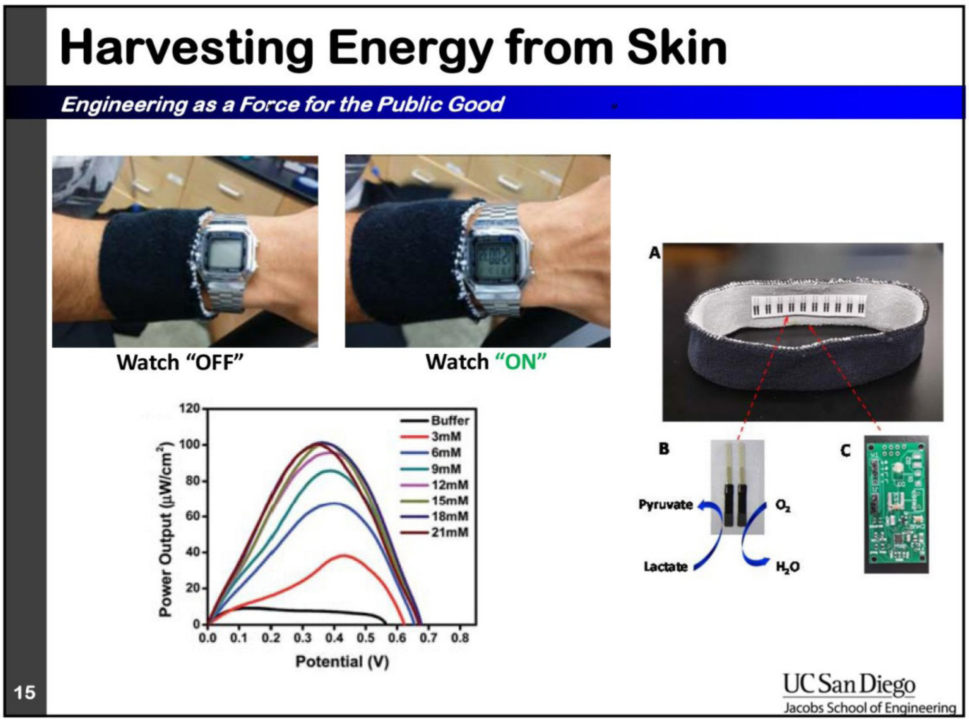
This sensor measures lactic in your sweat and this sensor measures activity by measuring the amount of salt that comes from the sweat from the chest. This sensor measures the PH of your body and this sensor actually measures the existence of dangerous chemicals. And it is part of a sensor that goes on with glove. We have at least five or six more sensors, but for the time, I will just describe these. You can see that all the sensors are in very thin film format, disposable once used, after a short period of time. Manufacturing volumes would be supported this way.



This is a blue coast sensor and a bio marker for the mouth piece for athletes or boxers. They frequently wear a tooth guard and a mouth guard. We had sensors that operate in the hot wet environment of the mouth, that determine chemicals in the saliva when the athletes are exhausted, that are chemical mark as appeared in the saliva, that we can receive a signal from that.

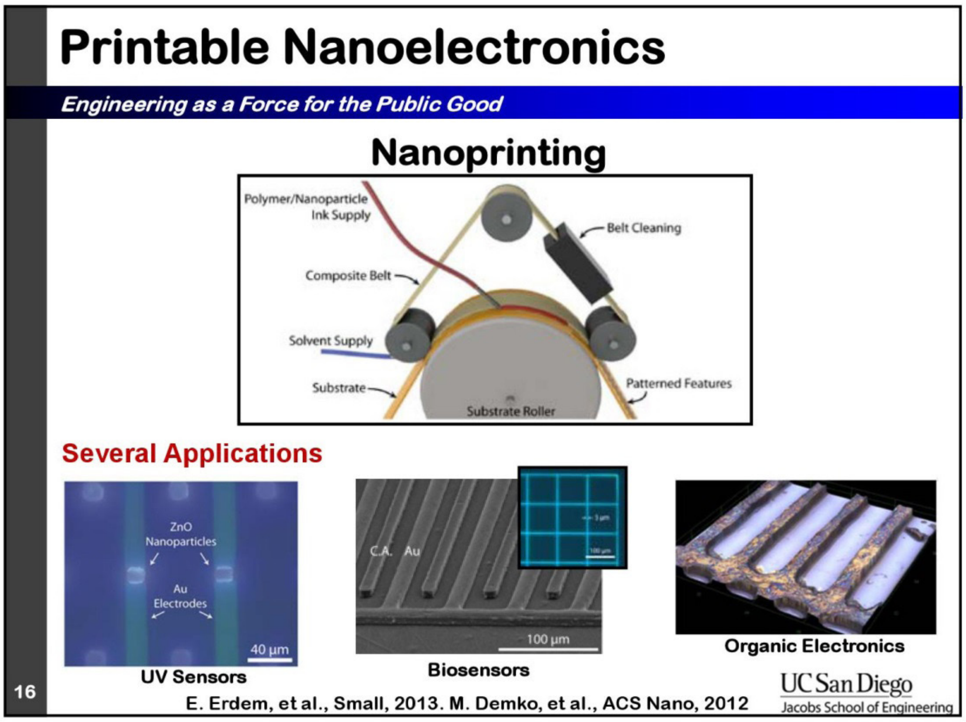
We have a large program in making a thin film solar cell. The thin film solar systems are quite interesting. There is a project in Africa called ‘White Africa.’ It is a thin film solar cell with an LED on it. You leave it on outside your house during the day, it charges up a small battery. At night you bring it in, and to study from a book, these are given to children.

Here I show different version of that. This is a completely flexible solar cell. Waterproof, sweatproof, you can wear on your skin, and basically it charges your cell phone. We know that there are solar power wrist watches already. The point is, this is powerful enough to operate a wireless sensor system for broadcast medical information from your skin.



Here is an example of how it really works. You will see that we can harvest as much as one hundred micro watts per square centimeter of the skin. Hundred micro watts sound small, right? One hundred millions of a watt.

Does anyone know how much electricity is a standard wrist watch required to operate? That is three micro watts. This sensor can run 30 wrist watches, or one smart watch operating at reduced power. How are we going to start making a trillion sensors a year, using various forms of organics? That we can drive down our costs and increase the manufacturing way?



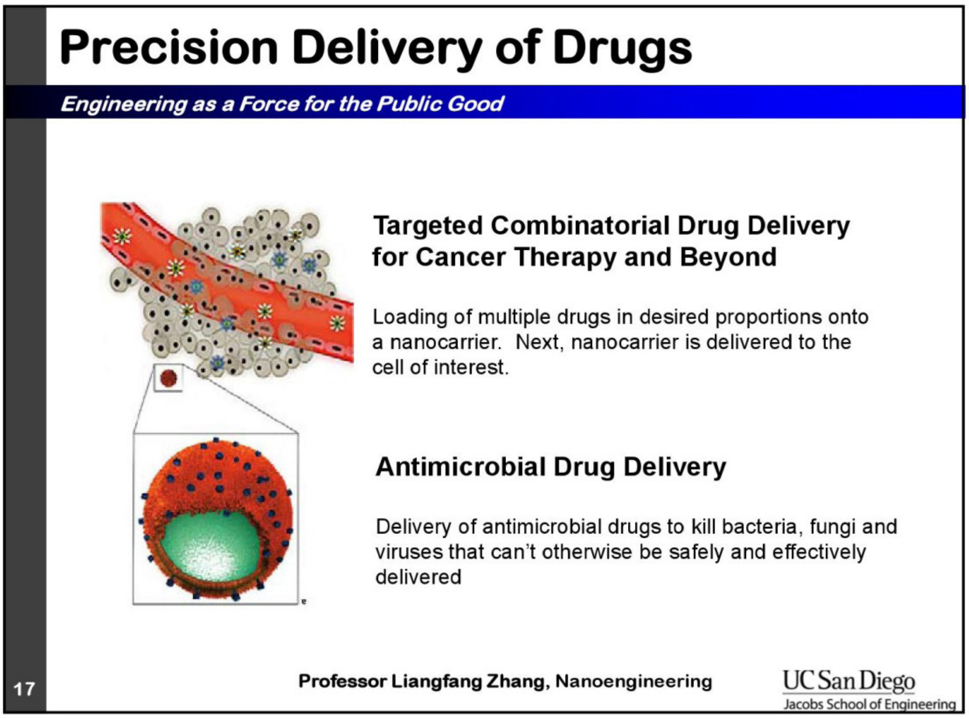
One of the ways to do it is, a new set of nano-printing technologies. We can imagine a reverse or traditional nano-printing technology, where we transfer the ink with the stamper, or you spread the ink on the substrate, press the stamper, and dry off the ink where you don't wanted. Each of these has fundamental disadvantages.

First, you cannot print thick ink. For many sensors, we need thick ink. The second thing is that if we use a reverse process, we need a very high pressure. We have to force the ink away from the undesired spot. No amount of pressure will do this perfectly.

Therefore, there is always a cleaning step. The cleaning step is where all the pollution is generated. That is where you generated effluent with unused ink. Now imagine you are going to use gold, or silver, or zinc oxide nano particle ink to make electronic devices, you don't want to throw away anything because the price of these devices has to be minimized. You don't want to dispose, or lose any of the value of the components of the being. Thus, this is a pure ink additive process.

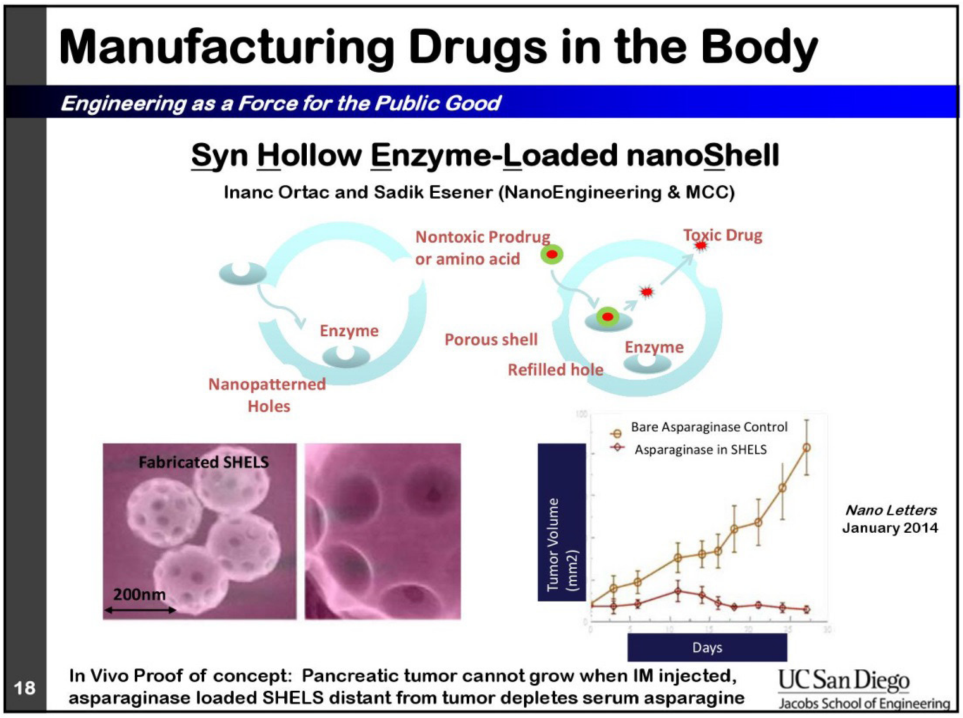
I will first show some of the results. This is an organic electronic. This is an old wet material that we print using this process. This is gold and some of those acetate on substrate, which is ink nano particles in gold, electrodes to make a UV sensor.

I will not go to all of the technical details on this process, but I will just say that the belt rolls slowly enough so that the ink dries before the belt is removed. And the sensors come off completely formed, so that there is no post drying process.



If you start looking at these very unusual ways of making things, what might you make?

One thing you can make is artificial blood cells, that perform useful biological functions in the body. This work has been done and we have proven this with mice and rats. This is the results that have already been achieved.

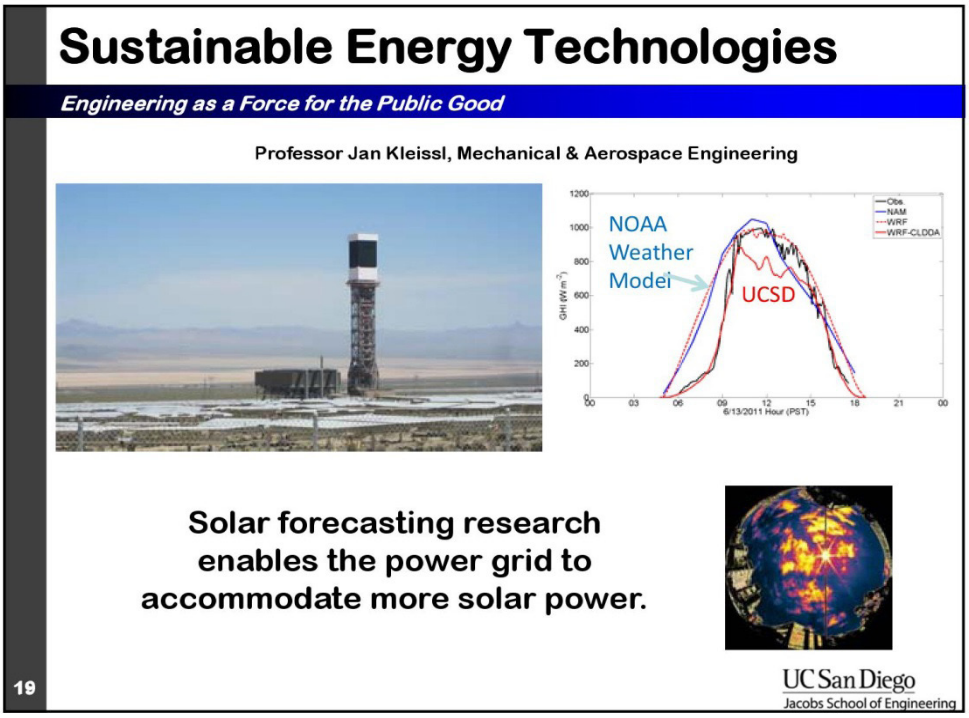


One interesting project is the drug manufacture in the blood stream. This is a micro fabricated sphere and the sphere's diameter is two hundred nanometers. A micron is one millionth of a meter or a thousand of millimeters. Two hundred nanometers is a fifth of a micron. Your hair is probably 30 or 40 microns. Therefore, this is extremely small compared to your hair.

These spears are fabricated with holes, so hollow spear, and they are preloaded with enzyme. This enzyme manufactures toxic drug to kill cancer cells, but your liver and your kidneys are adversely infected. So you cannot just take a large injection of this. The spears are decorated with a protein that sticks to cancer cells. What we do with the mice is, we inject the mice with the spheres, wait a few days, and eventually the spears start to get sticking to the cancer cells.

The second injection of a nontoxic drug precursor is given and it is distributed throughout the human body. Since it is nontoxic, it does not affect the kidney, the heart, or the liver. When that drug encounters a sphere and refuses it, the enzyme converts the drug from harmless to extremely toxic. Then the cells near the spheres are killed, but the cells have accumulated on the tumor. Therefore the poison is manufactured at the disease site.

Here is the experimental data from two unfortunate rats; they were infected with a tumor. In the first rat, we watched the tumor grow inside, and somewhere over here the rat dies. The second rat, the tumor starts growing, but slower. We inject the harmless material; the toxic drug starts to be manufactured so that the tumor never becomes very big and fat and starts to dissolve. Therefore we have a proof in animals such that this technique actually works.

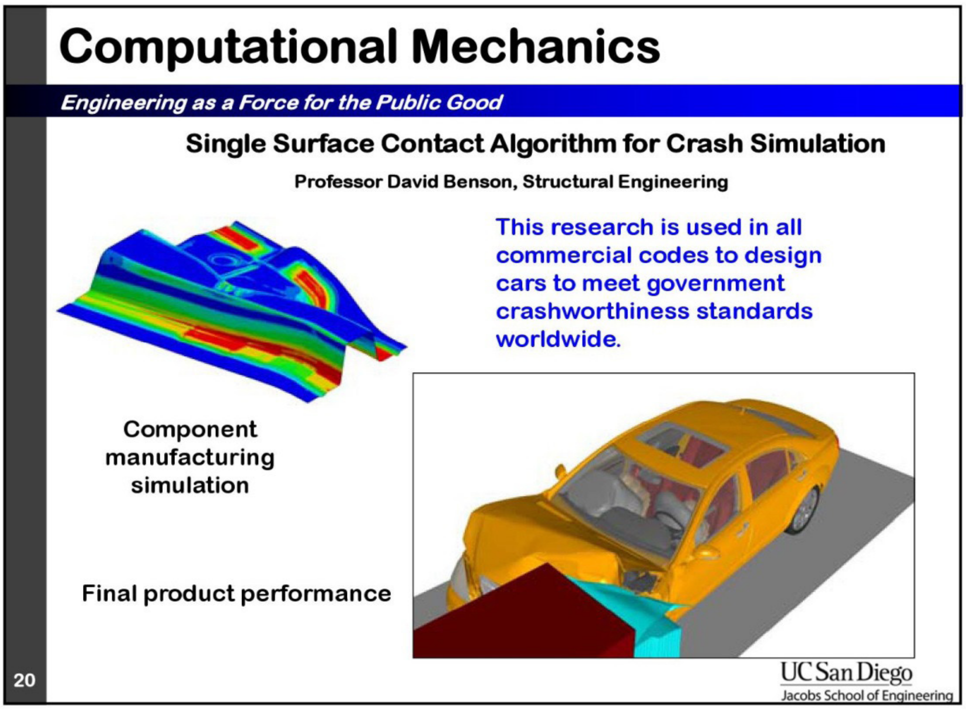


Now you can imagine that many people say, "Oh, we are going to build a lot more solar energy farms that harvest energy from the sun," and indeed many people do this. However, there are thirty little secrets. Clouds arrive, and near many solar farms, there is an array of gas turbines used to provide electrical energy if the solar farm cannot meet its quarter.

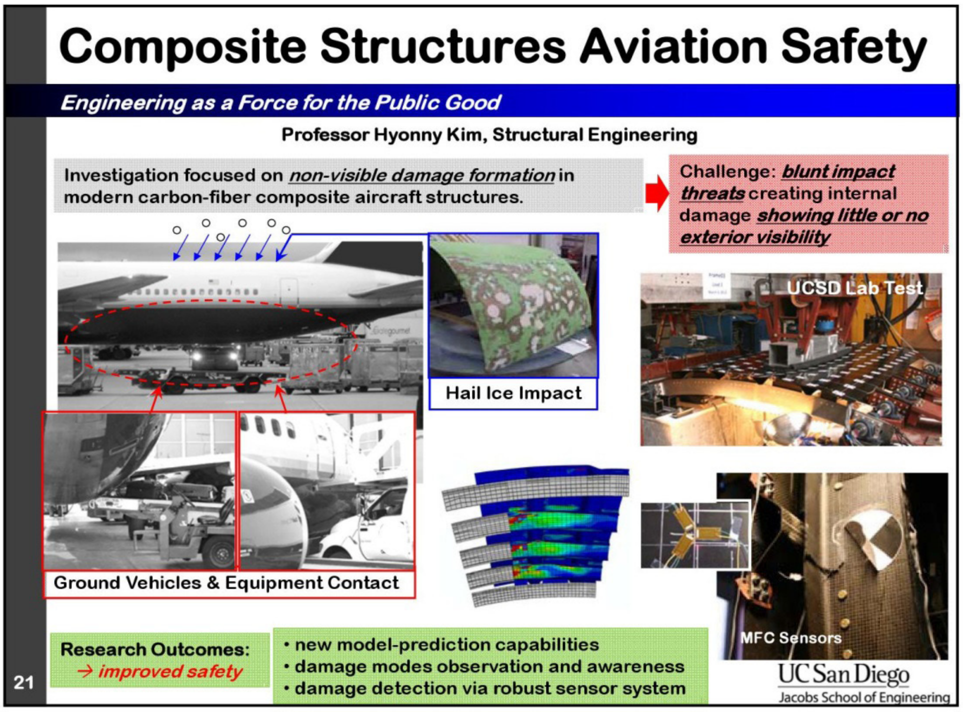
Now why would someone who has a green mentality, buy a gas turbine? The answer is the business model. If you provide unreliable source of electricity, your sell price is about 20 percent of a reliable source of electricity. Of course, if you are a wise business man, you will buy the gas turbine and the solar energy farm, and use both of them to provide reliable energy.

Now the trick is, how do you make more money than your competitor? You do that by turning the turbines off to the maximum amount possible, turning them on at the last possible minute. However, it takes twelve minutes to start a three hundred megawatt gas turbine. This research project shows we can predict the location of the clouds fourteen minutes in the future. We will predict where the shadows are on the ground, and this tool is actually in testing at a solar farm at California, where we are helping that solar farm burn the minimum possible metro gas. Since it knows fourteen minutes ahead of time that a cloud is going to go over the northwest side of the solar field, this is actually a computer composite of the sky. I will not go for a long explanation, but what this shows is, it predicts exactly where the clouds are going to be.

This is our prediction software, the outermost red line, we show that we can accurately tell this particular solar energy farm when they should start the turbines, and when is the first time estimated to turn them on.

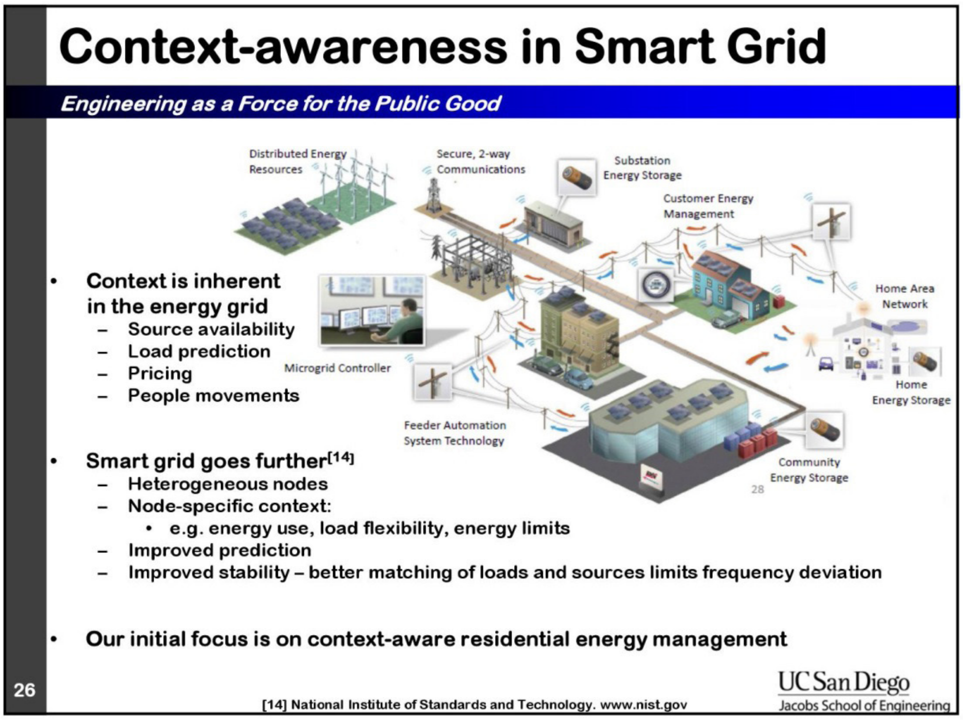


Many of us ride on automobiles today. What you might not know is that 85% of the cars on the road in the entire world were designed with correct software invented at the University of California of San Diego. We have a special team that develops CAD models, that allow large displacements and high strain rates in other words of crash, in a linear event. We modeled crash metal better than anybody, and that software has been licensed to most of the car manufacturers or better more accurately. Therefore we allow minimum amount of metal to be used for the car for the strength that you want.



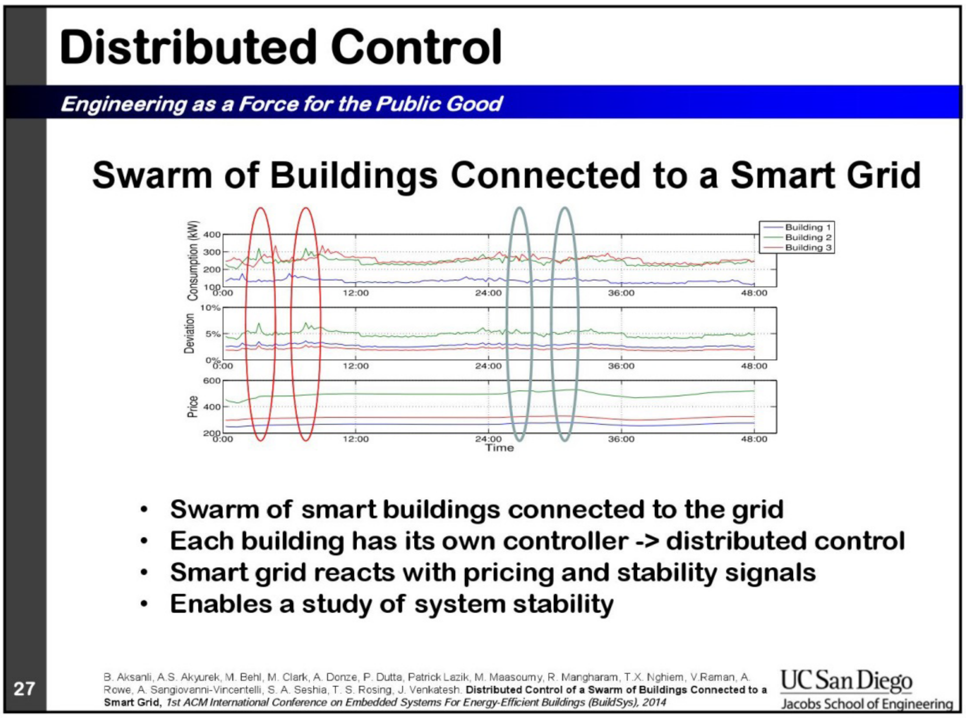
We are expanding that kind of work for aviation safety, and we have a number of experimental and computation tools used to predict some surface damage in composites due to ice hail falling from the sky. There are occasional collisions between ground vehicles and airplanes. Here's the example of a truck just about to bump into a side of an airplane, a view from the outside. You could imagine that composite materials are tough to evaluate for damage. The damage is always inside the lamination, no one wants to take an airplane at a service an x-ray, or ultra-sonically tested. We have the computer models that we are using with the aircraft safety people to be able to start predicting what we could apply before the plane has to become out of service.

I think I am running out of time, let me skip over a slide or two. I have described this one already, and let me move to this one.



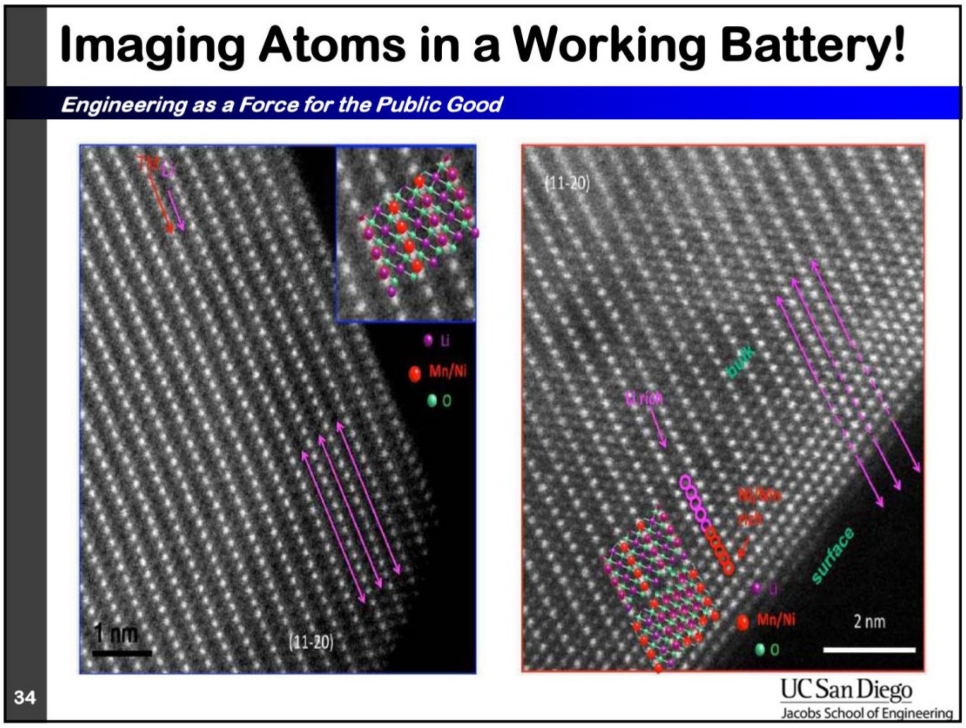
UC San Diego campus is 90% energy independent. We have 45 megawatts of solar energy installed, as well as our own gas turbine; we use our own cloud prediction software to minimize the amount of energy we have to buy from the grid.

One of the things that we are doing is looking at how to stabilize the micro grid. It is not well known that one problem with the micro grids for that some big unit comes online and absorbs a lot of electricity that starts in instability in the face, and that vibration can cause a search current and blow the interrupters.



For example, here is how we will use active monitoring to minimize the surges. Here, this is for two days. Day one from zero to 2400, and there's day two. On day one, the smart building starts consuming electricity, rather large spikes, a big deviation from the expected quote. We turn the software on day two, which is much lower spike, very low little way at the deviation. Part of what we have done is implementing a price model for electricity and programing that into the controllers, so that the building has to stand to avoid the surges.

I will not talk about the flow of the energy through the United States or what is out of solar energy. However, I will point out I think there are three kinds of batteries.



They are the high energy batteries used for storage in large micro grids of the high power batteries which provide a little energy of high rate for a flash. We actually took a hand at developing some of the three megawatt power battery storage system that we have at our own campus. We have a 45 megawatt grid, six megawatts of solar generation as stated before, three megawatt hours of energy storage and a gas turbine. And this is actually the gas turbine house to take care of that grid. This is the high and low and whatever.

I will close on this slide. Many of you may be interested in battery technology, when is battery going to have a higher capacity. We have the only research lab in the world that operates with the Li-ion batteries inside an x-ray imaging machine. We watch the ions move through the batteries. What you see here is a magnesium nickel pollutant that has gotten into the battery. These are actually the literal ion channels between the electrodes, along which the lithium ion will move. The lithium ion will go from the cathode to the anode, in charge and discharge. Here, you can see the presence of settle of the red atoms in this slide, which is a magnesium nickel. These are clogged channels. Everyone worries about battery failure at the cathode and anode, the anode particular, but they have overlooked this that there is significant battery failure in the ion channels. We are the first school in the world to image the ion channels as the ions move, and identify the source of the blockage.

Okay. Let me finish up. I think we took too long. Sorry about that. I apologize that so many robot slides were put into the presentation. That is my fault. Let me get pass the robots.

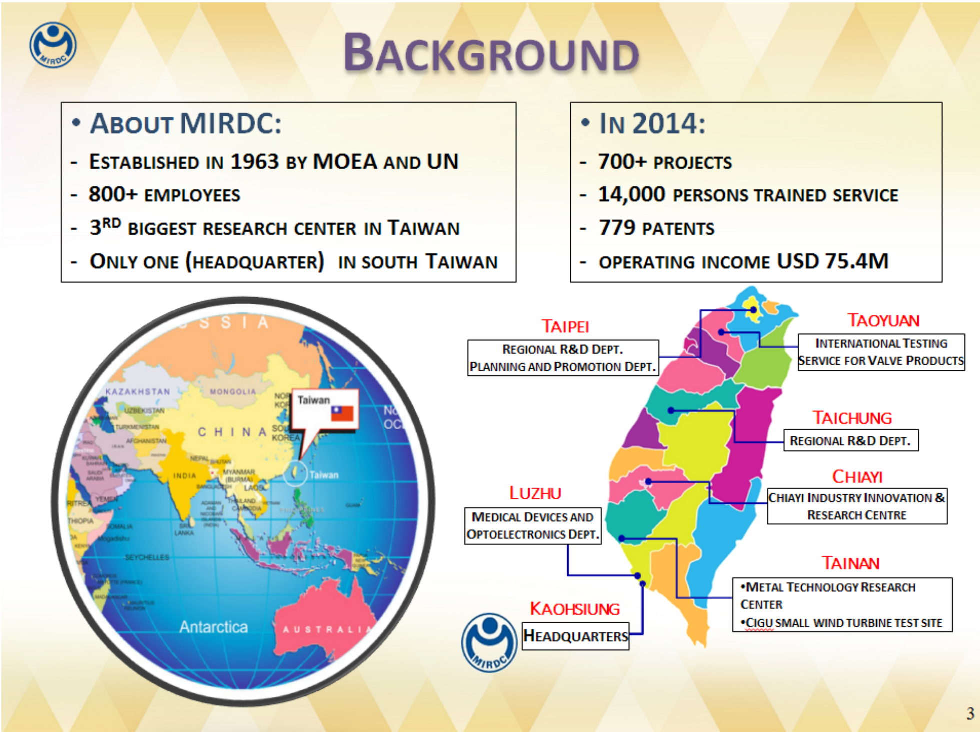
We summarize our research once a year for 450 members of the industry, you are all invited. This year, it is on April the 14th one half day, where we will have 450 industrial people and 250 research projects reunited in one day.

I want to thank you very much for your time and attention. I think I am just about on time. I am sorry that I have to skip over some slides. The closing point I want to make is that we are a large and growing school. We are very well connected with the local industries in and around San Diego. We are eager to make additional connections to industry all around the pacific.

Thank you very much for inviting me here today.

The Effort Put into Innovation and Globalization for Small & Medium Enterprises in Taiwan

Ching-Ming Chen, Vice President, Metal Industries Research & Development Center, Taiwan



Let me briefly introduce the MIRDC to you all. MIRDC was established in 1964 by MOEA and United Nation. We have more than 800 employees, and we are the third biggest research center in Taiwan. Also, we have one headquarter in South Taiwan. Last year, we completed about 700 projects. Also, we filled 779 patents while our operating income was 75.4 million US dollars. As you see in the map, we have 6 divisions located in Taiwan.

Mission

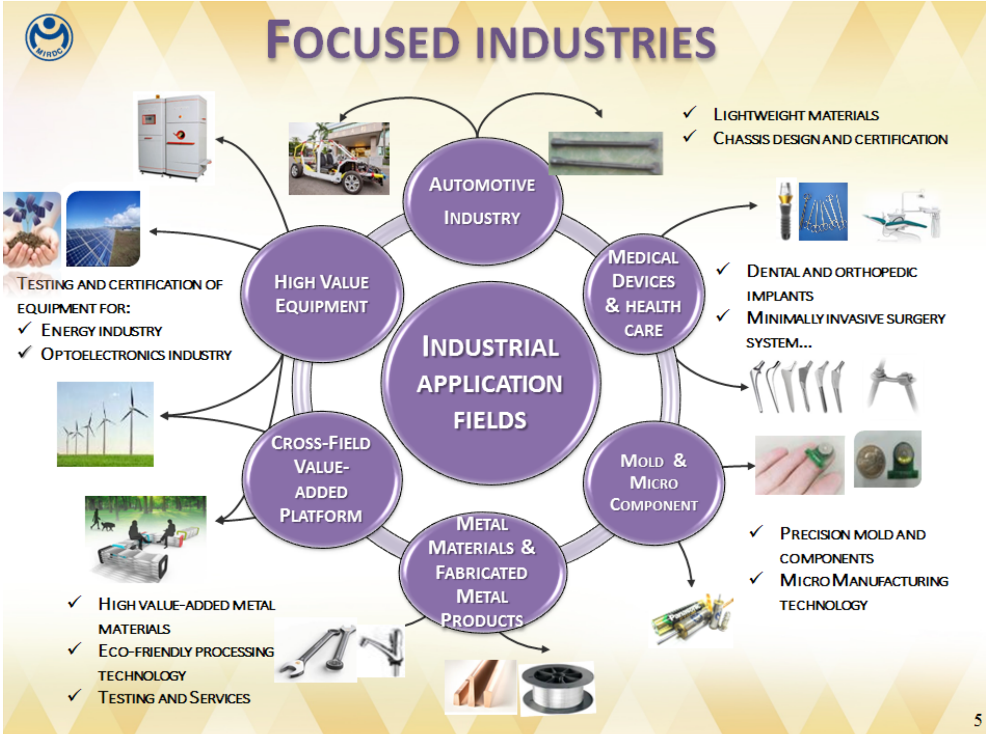
Upgrading Competencies of Taiwan Metal Industry

- **Internal Focuses**
  - ✓ Advanced technologies & key components / modules
  - ✓ Effective process design
  - ✓ Establishing core laboratories

- **External Focuses**
  - ✓ International cooperation
  - ✓ Industrial clusters
  - ✓ Collaborating with industrial, academic and research sectors
  - ✓ Technologies transferring

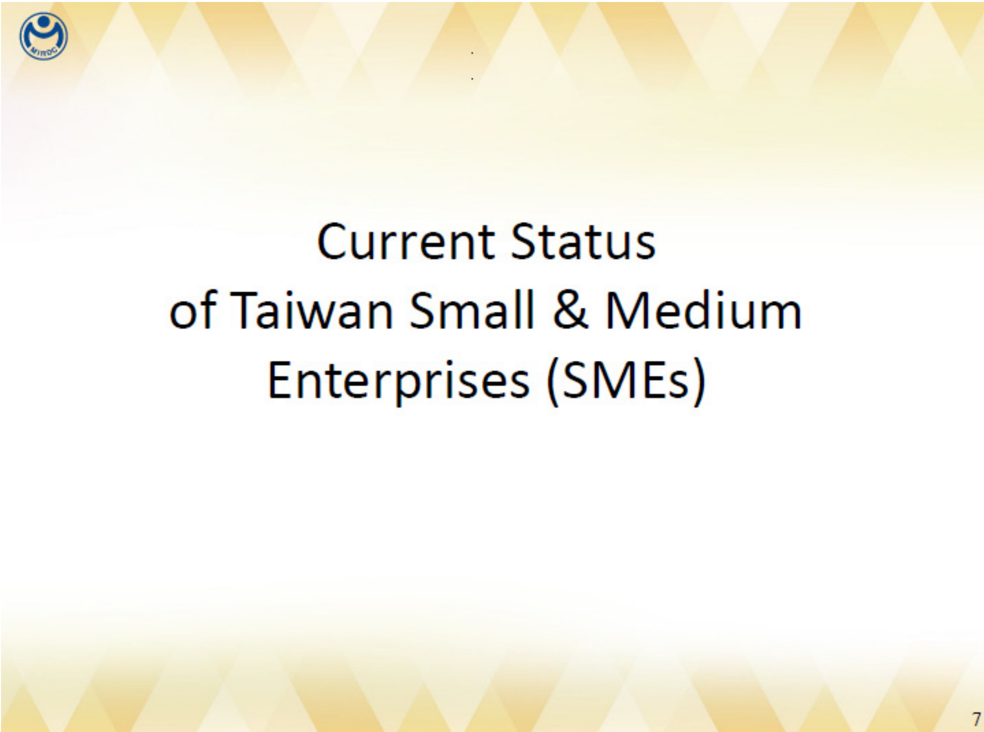
4

Our mission is to upgrade competencies of Taiwan metal industry. Our internal focuses are advancing technologies and key components or modules, emphasizing effective process design, and establishing core laboratories. Our external focuses are international cooperation, industrial clusters, collaboration with industrial, academic and research sectors, and promotion of technology transfer to private sector.

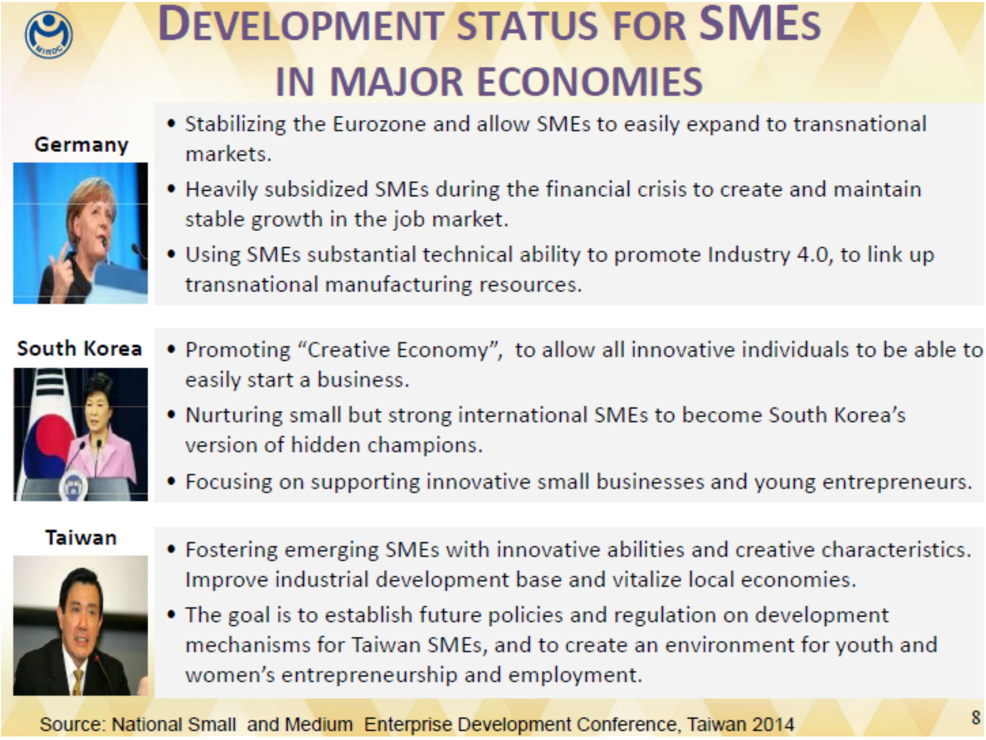


We have six focused industries: high value equipment, automotive industry, medical devices and health care, mold and micro components, metal materials and fabricated metal products, cross-field value added platform, and high value equipment. For automotive industry, our focus is on lightweight materials and chassis design and certification. For medical devices and health care, we hope to develop dental orthopedic implants and minimally invasive surgery system. For mold and micro components, we focus on precision mold and components and micro manufacturing technology.

We are doing international cooperation with countries all around the world including technology transfer and analysis.



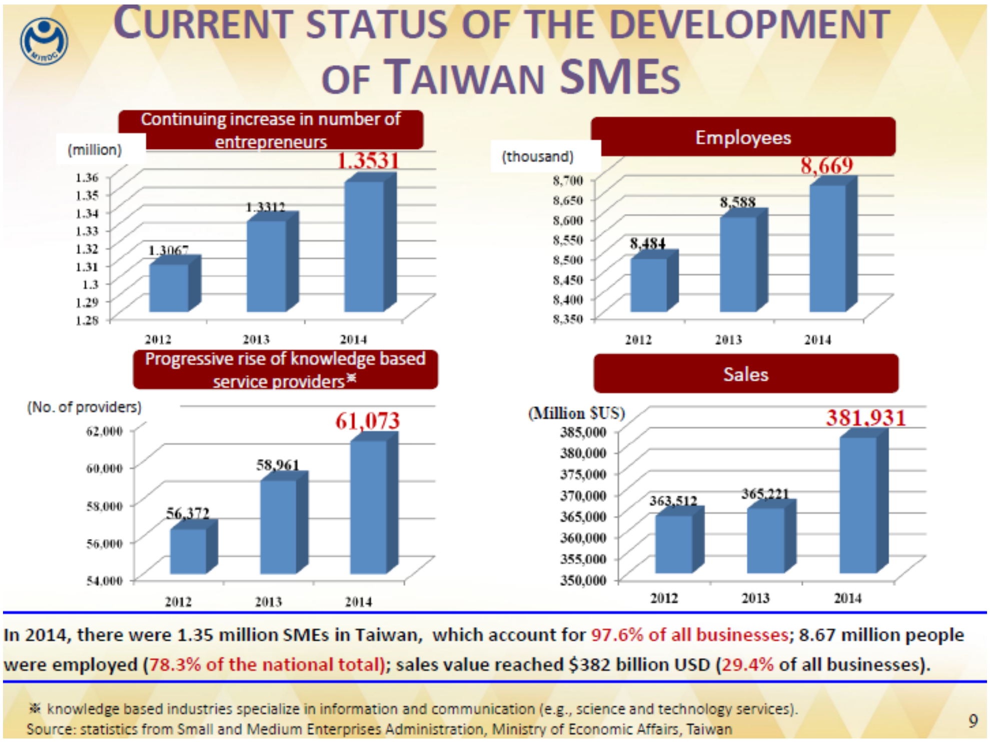
The second part of my presentation is about current status of Taiwan's small and medium enterprises. Let's look at development status for SMEs in three major economies.



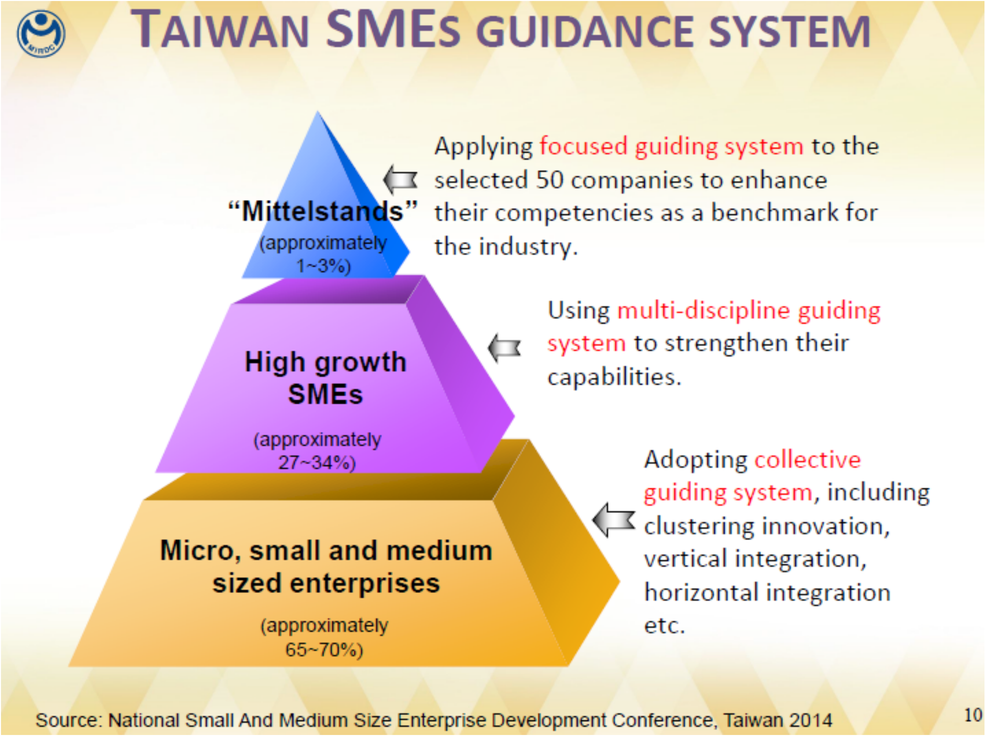
Germany stabilized the Eurozone and allowed SMEs to expand easily to transitional markets. They subsidized SMEs heavily during the financial crisis to create and maintain stable growth in the job market. Also, they used SME substantial technical ability to promote Industry 4.0 to link up transnational manufacturing resources.

In case of Korea, President Park promoted "Creative Economy" to allow all the innovative individuals to start a new business. Korea also nurtured small but strong international SMEs to make them Korea's version of hidden champions. Lastly, Korea focused on supporting innovative small businesses and young entrepreneurs.

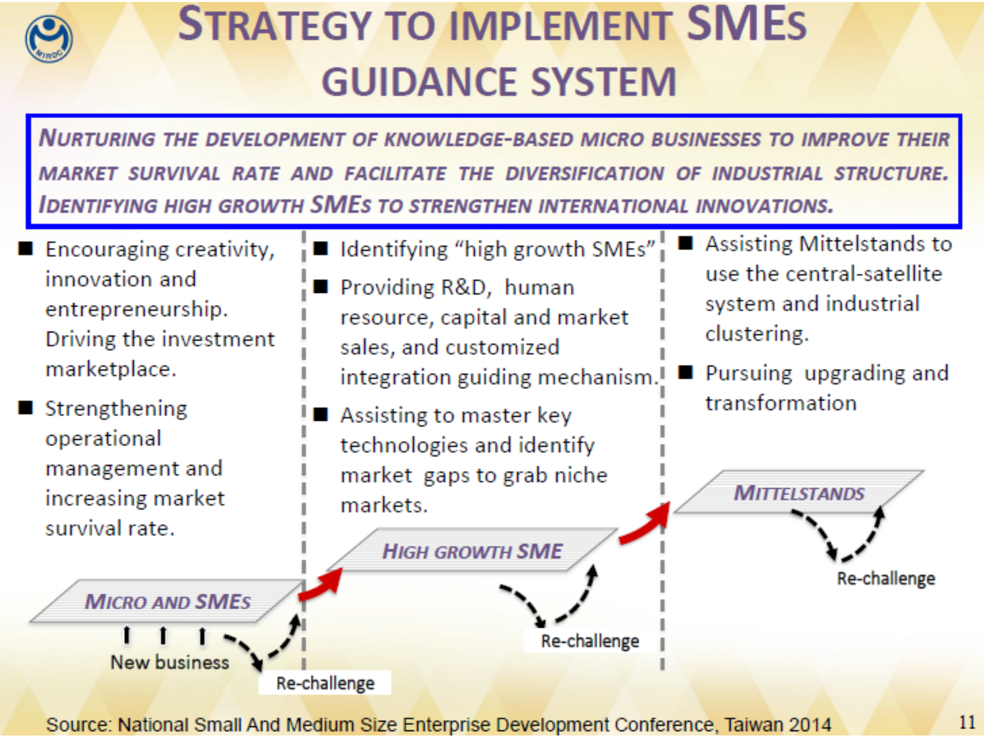
Taiwan also fostered emerging SMEs that had innovative abilities and creative characteristics.



Here is current status of the development of Taiwan SMEs. The number of entrepreneurs in Taiwan is continuously growing. Also, the knowledge based service providers are increasing as well. Currently, we have more than 800 employees working at SMEs. Also, our national sales reached 381,931 million US dollars last year (2014).



In Taiwan, we have the three guidance systems to help out SMEs. First, we have the focused guiding system for the selected 50 companies to enhance their competencies as a benchmark for the industry. We hope to have approximately 1 to 3 percent "mittelstands." Secondly, we have the multi-discipline guiding system to strengthen their capabilities. Through this system, we hope to have approximately 30 percent of high growth SMEs. Lastly, we have collective guiding system that includes clustering innovation, vertical integration, and horizontal integration. This system is built to help small and medium sized enterprises.



Now, I am going to talk about strategy to implement SMEs guidance system. Our strategy is to nurture the development of knowledge-based micro businesses to improve their market survival rate and facilitate the diversification of industrial structure. Also, we aim to identify fast growing SMEs in order to strengthen international innovations.

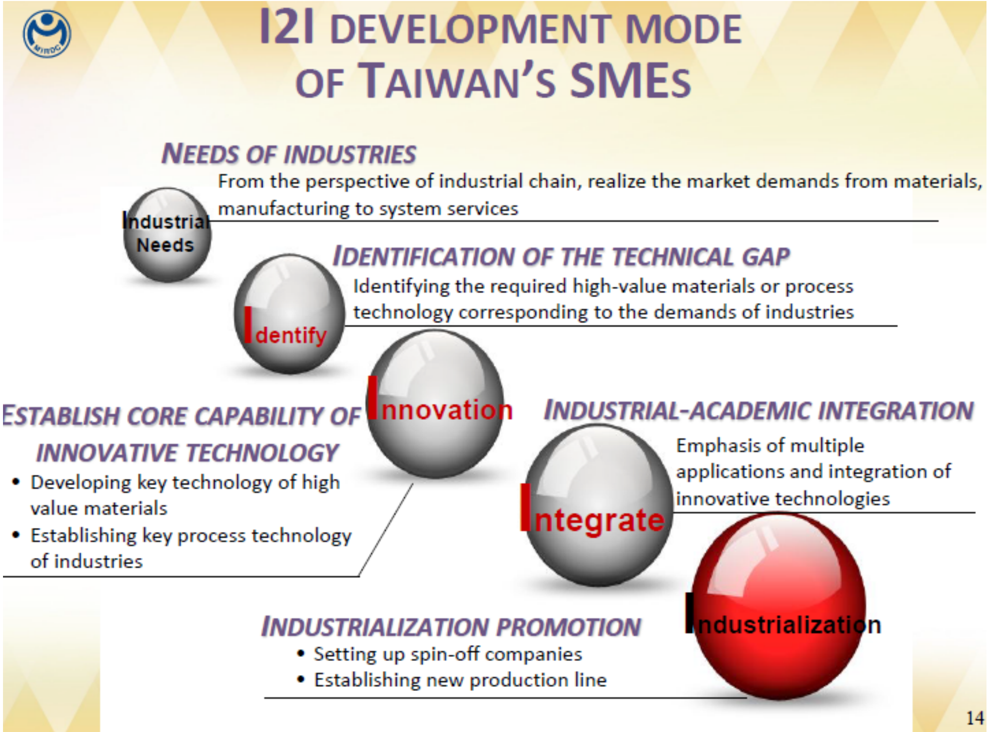
The first step of the strategy is to encourage creativity, innovation and entrepreneurship. Also, strengthening operational management and increasing market survival rate are necessary for this step.

The second step of the strategy is to identify "high growth SMEs," to provide R&D, human resource, capital and market sales, and customized integration guiding mechanism, and to assist to master key technologies and identify market gaps to grab niche markets.

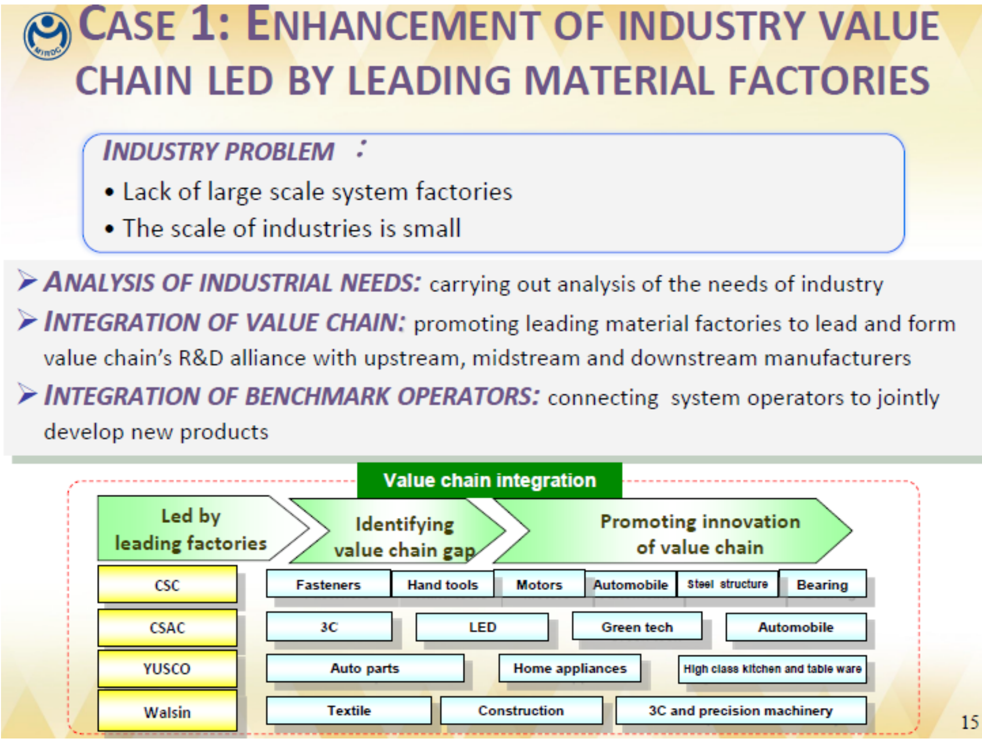
The final step for the strategy is to assist Mittelstands to use the central-satellite system and industrial clustering and to pursue upgrading and transformation.

Now, I am going to talk about how to use the guidance system to assist SMEs in Taiwan. For manufacturing, the guidance system is used for research development, production technology, and information management. For marketing, it is used for domestic and international marketing. For management, the guidance system is used to improve quality, business start-up and incubation, operational management. For finance, the system is used for sound finance. According to the guidance system, R&D institutes will assist SMEs for upgrade and transformation.

Now, I am going to talk about MIRDC's strategies and Case Studies on assisting small and medium enterprises for innovations.

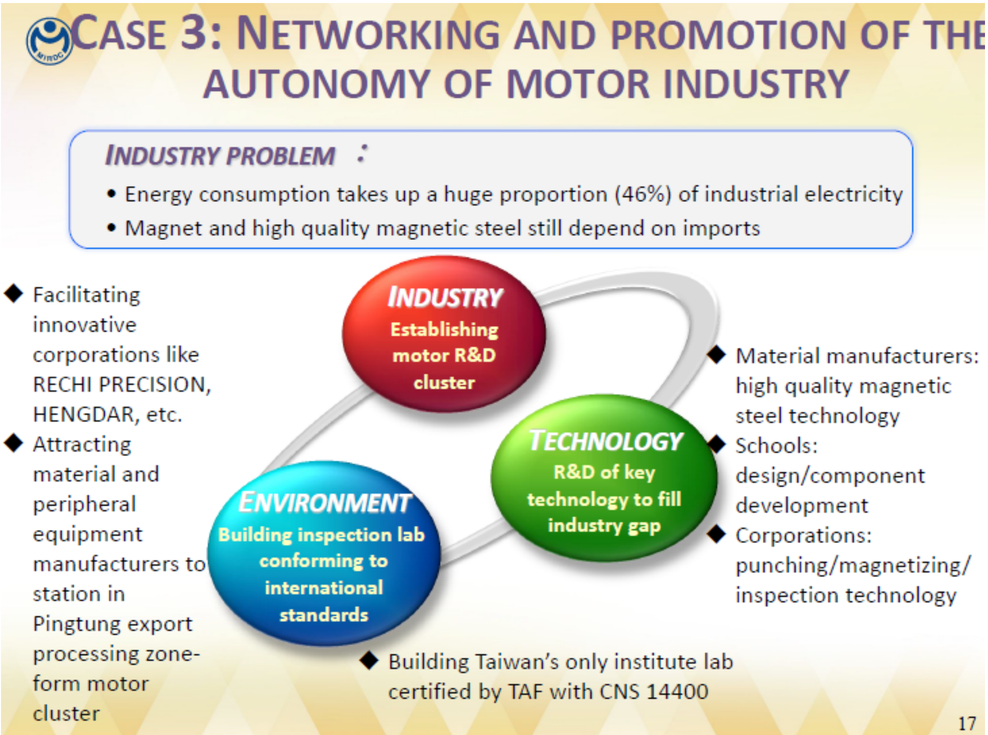


In this slide, there are 5 'I's in order to show the development model of Taiwan's SMEs. The first 'I' represents industrial needs from the perspective of industrial chain, the market demands from materials, and manufacturing to system services. The second 'I' represents identification of the technical gap. We identify the required high-value materials or process technology corresponding to the demands of industries. The third 'I' represents establishing core of innovative technology. We want to develop key technology of high value materials, and key process technology of industries. The fourth 'I' represents industrial academic integration. We emphasize multiple applications and integration of innovative technologies. The last 'I' represents industrialization promotion. We set up spin-off companies and also establish new product line.

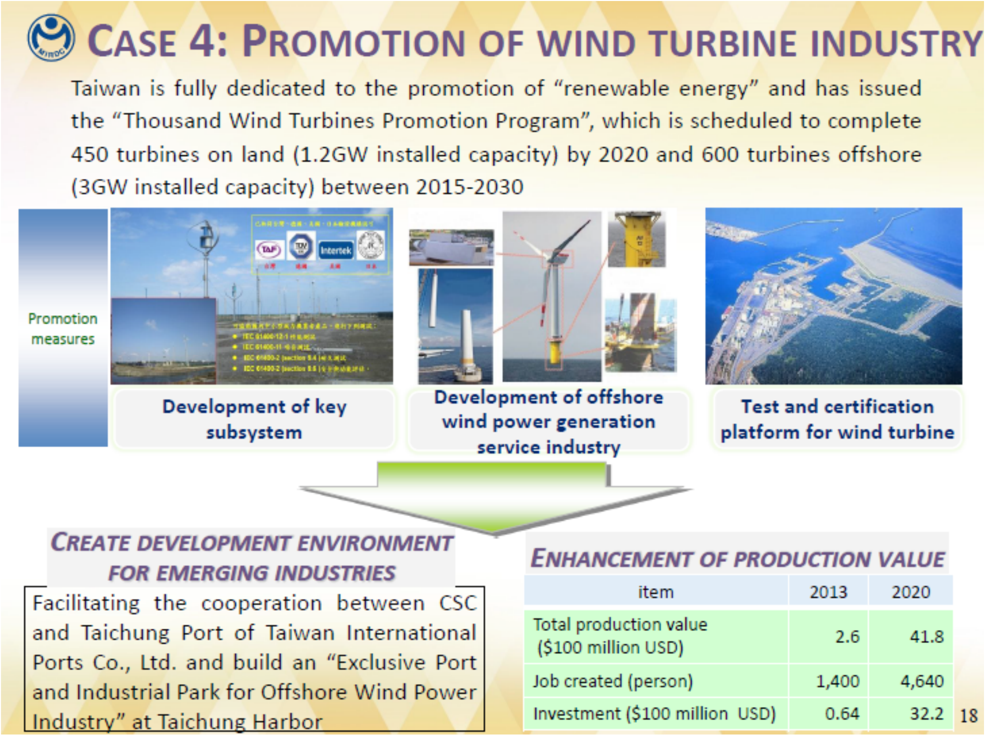


For case 1, I am going to talk about enhancement of industry value chain led by leading material factories. In Taiwan, we are lack of large scale system factories, and the scale of industries is small in general. In order to solve this problem, we first do analysis of industrial needs. Then, we do integration of value chain to promote leading material factories to lead and form value chain's R&D alliance with upstream, midstream, and downstream manufacturers. Lastly, we do integration of benchmark operators to connect system operators to jointly develop new products.

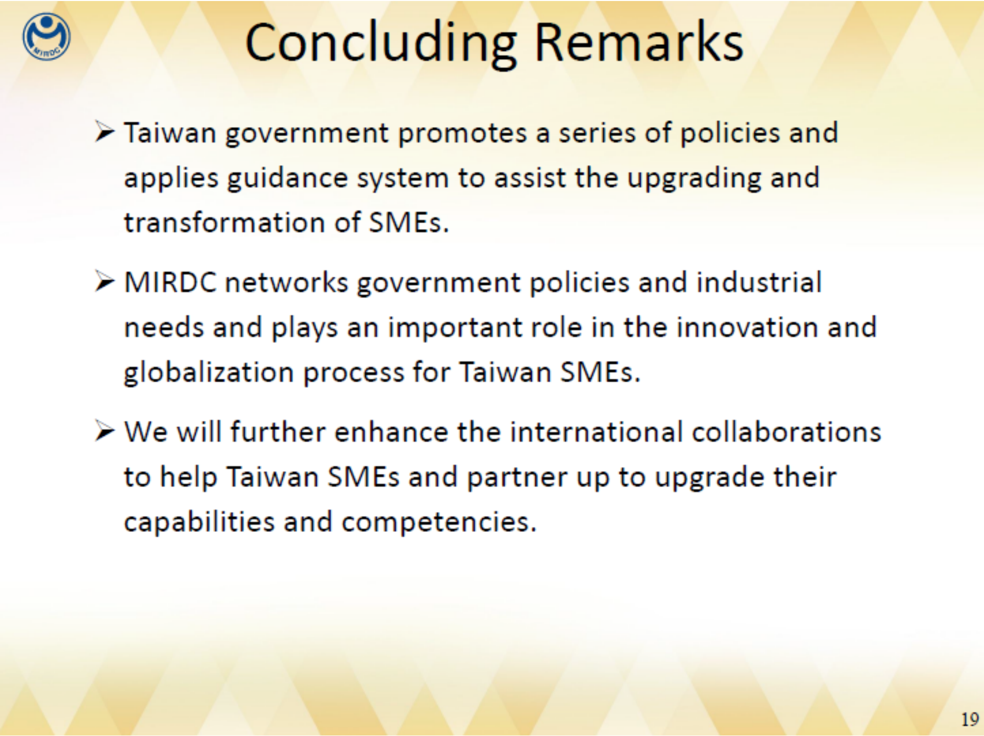
Case 2 is about development of key technologies for bio-tech and food equipment. The major technologies are as followings: biomass pre-treatment, supercritical fluid extraction, separation and purification, high pressure processing, powder and microencapsulation, automated solid-state fermentation, and inspection and analysis of natural compounds. We set up a pilot production line so that local materials can be adopted to develop high value-added products. MIRDC is equipped with developing bio-tech and food equipment to conduct customized development.



Case 3 is about networking and promotion of the autonomy of motor industry. One of Taiwan's industry problems is that energy consumption takes up a huge proportion such as 46% out of industrial electricity. Also, magnet and high quality magnetic steel still depend on imports. Therefore, we facilitate innovative corporations like Rechi Precision and Hengdar. Also, we attract material and peripheral equipment manufacturers to station in Pingtung export processing zone to form motor cluster. The function of material manufacturers is developing high quality magnetic steel technology. Also, the role of schools is to help design component development. Finally, the role of MIRDC corporation is punching, magnetizing, and inspection technology. MIRDC lab is Taiwan's only institute lab certified by TAF with CNS 14400.



The last case we are going to look at is about promotion of wind turbine industry. The government of Taiwan is fully dedicated to the promotion of "renewable energy" and has issued the "Thousand Wind Turbines Promotion Program," which is scheduled to complete 450 turbines on land by 2020 and 600 turbines offshore between 2015 and 2030. The promotion measures are as follow development of key subsystem, development of offshore wind power generation service industry, and test and certification of platform for wind turbine. These promotion measures created development environment for emerging industries by facilitating the cooperation between CSC and Taichung Port of Taiwan International Ports Co. Ltd. and building an "Exclusive Port and Industrial Park for Offshore Wind Power Industry at Taichung Harbor. Also, these promotion measures led enhancement of the production value.



Finally, Taiwan government promotes a series of policies and applies a guidance system to assist the upgrading and transformation of SMEs. Also, MIRDC networks government policies and industrial needs and plays an important role in the innovation and globalization process for Taiwan's SMEs.

Lastly, we will further enhance the international collaborations to help Taiwan's SMEs and partner up to upgrade their capabilities and competencies.

Thank you.

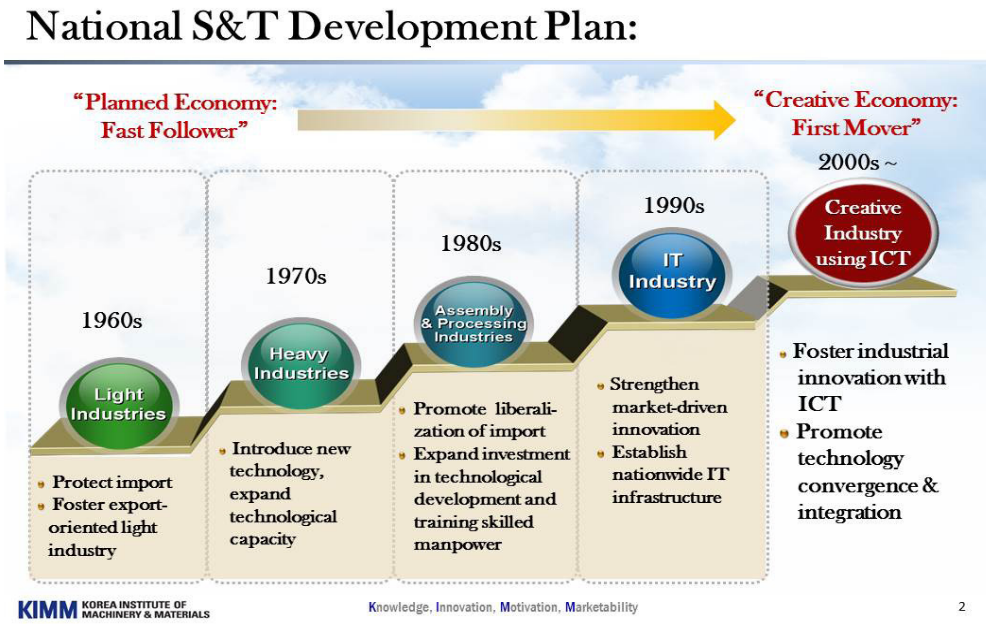
Raison d’être of Globalized Public Research Institutes

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

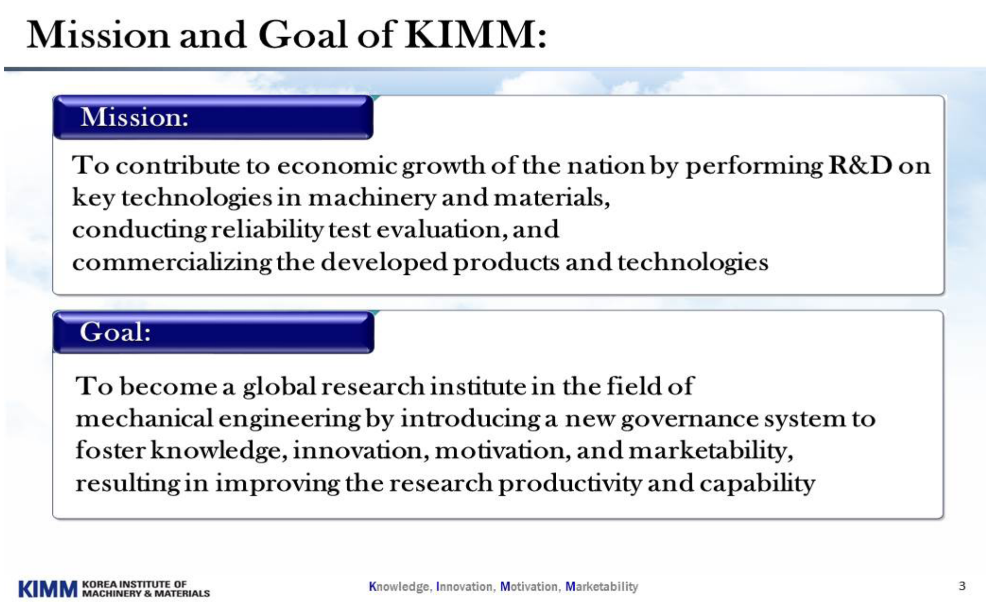
Note: The full paper of this presentation is attached in Appendix 2.

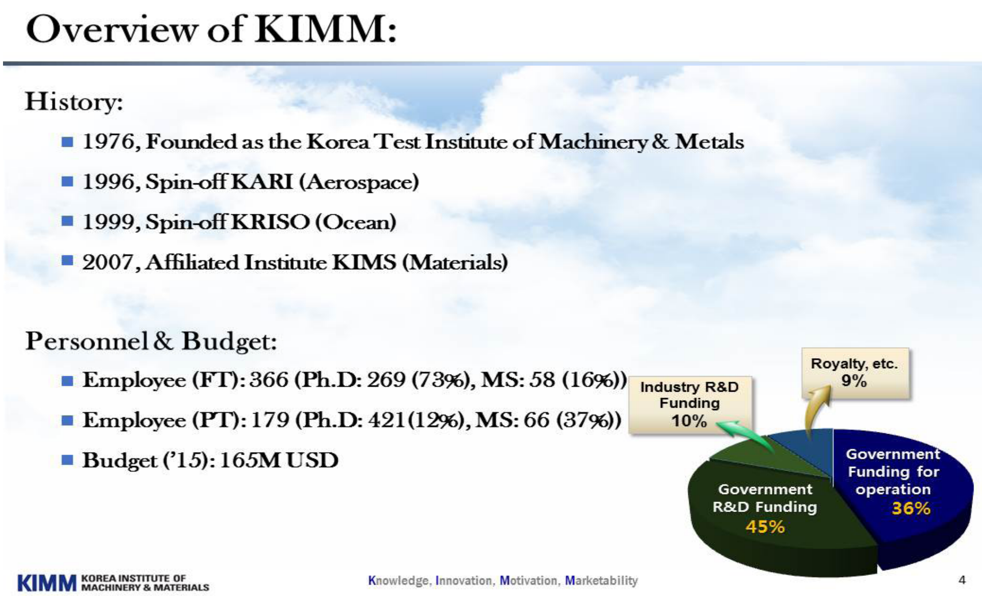
I will just talk for about five minutes to give you time for coffee.

This is what I am going to introduce today. Some of you may not know about my institute, so let me talk about it briefly. In addition to that, I am going to conclude with what we have to do at the public research institute in Korea, not in the U.S. or other advanced countries.



This is the overview of our industrial and economic growth. As you may know, in the 1960s, we had nothing, but we are now doing okay. The goal of my research institute was to restore the Korean economy through industrialization after the Second World War and the Korean War. At that time, the GDP per capita was about $60.

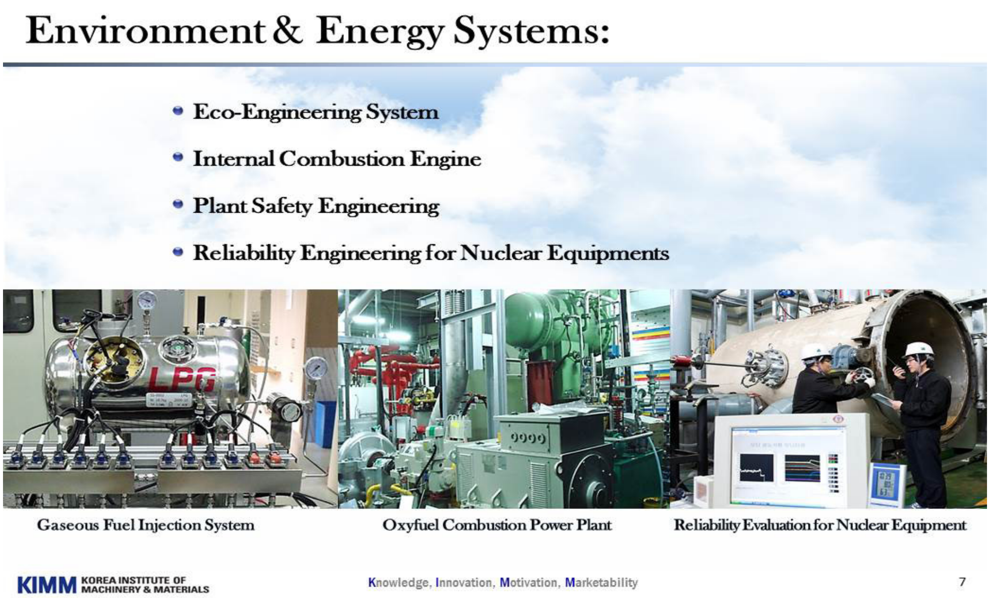




This is the current standing of my research institute. We have 335 full-time employees and 179 part-time employees. About 70% of our full-time employees have Ph.Ds.

KIMM has five research units. The oldest research unit is Advanced Manufacturing Systems headed by Director Joon Yeob Song. This unit typically develops ultra-precision machines and systems for various industries in Korea.

This is the second unit, Nano-Convergence Mechanical Systems headed by Director Jae-Jong Lee. In this image here, the lady, Dr. Hyuneui Lim sitting at the back is working with a lot of nanotechnologies. We really rely on her to improve our nanotechnologies and create royalty incomes in the future.



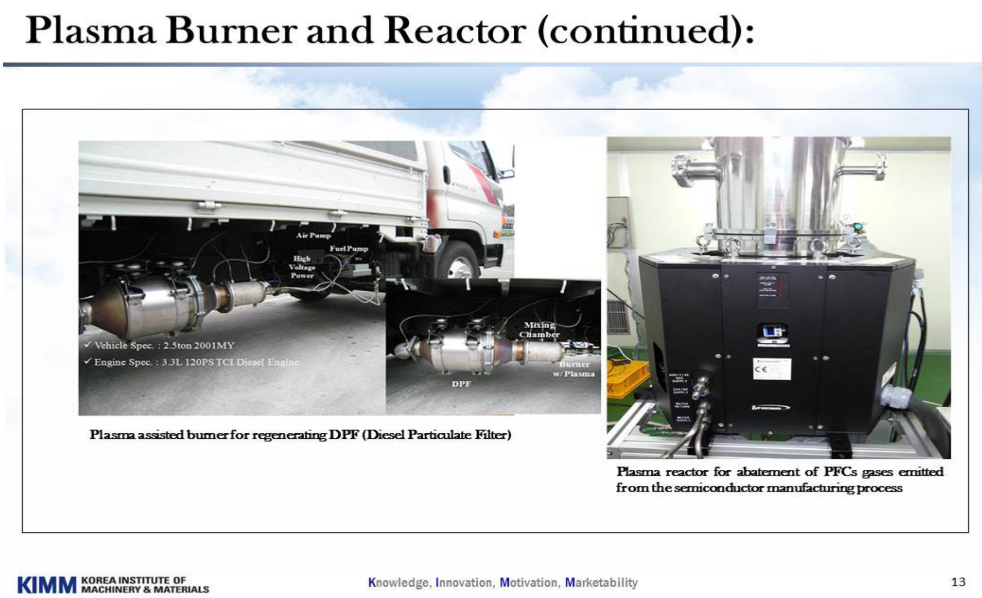
This is Environment and Energy Systems. I think you met the director who is here. He is also contributing to a lot of royalty incomes. Here, you can see some of the hardware that we developed.

This is Extreme Mechanical Systems Engineering where we support to develop nuclear engineering facilities in Korea like recycling coolant pump that we developed by Director Eui-Soo Yoon.

This is the last division called Mechanical Systems Safety division. Dr. Hyun-Sil Kim is the director.

We have three regional research centers, one in Busan, Gimhae and Daegu. This morning, I met the Director of the Daegu Center, but he had to leave. Dr. Kyung Taek Park is in charge of the Daegu Center where we develop medical assisted robots. Basically, we are working on robotics to help the handicapped and the elderly. In Busan, we have a laser technology research where we apply laser technologies for industrial applications. In Gimhae, we have an LNG research center to inspect components for their applications for LNG plants.

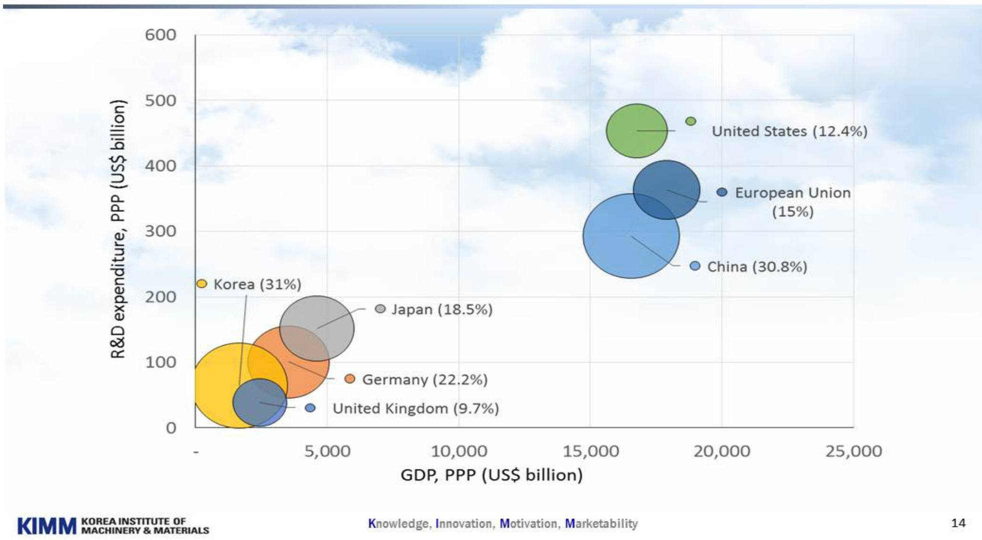
The royalty income at KIMM in 2014 was 5.6 M US$. Dr. Chae Whan Rim is responsible for technology transfer division. As you can see, our royalty income grew as we transferred technologies more. I really hope this happens this year too. We look forward to increase of the royalty income more than 2014 due to the extra effort of Director Hee Chang Park.



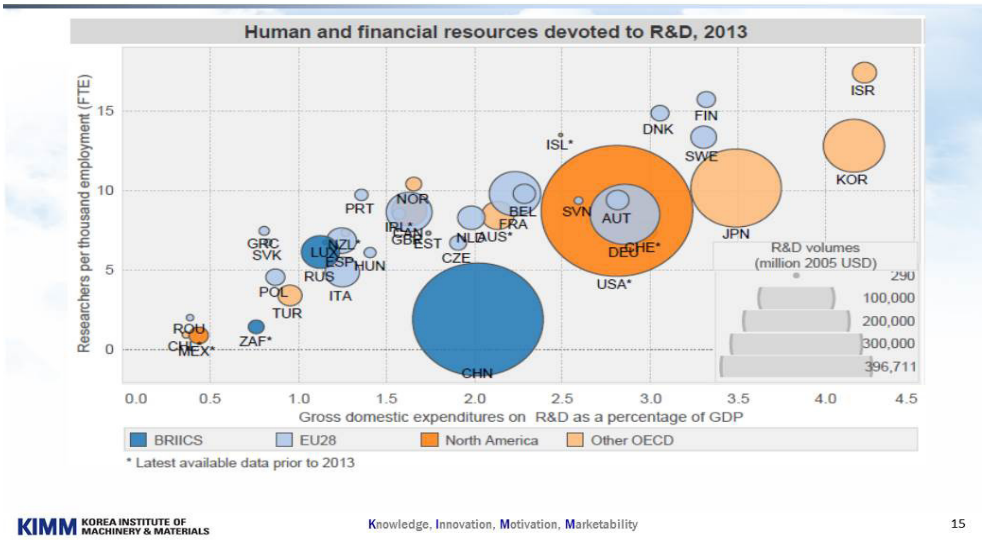
I would like to introduce just two of our major accomplishments. One is EcoBee. This is an actual photo of when the advertisement was displayed in Times Square in New York. Dr. Gordon and his company made investments to adopt this system in Russia. It is ongoing. It's not finalized yet.

This is the plasma burner and reactor installed at Samsung's semiconductor company. We installed it to solve the issue of chemical or pollutants generated from the process of semiconductor fabrication. After installing the plasma reactor, they were able to solve the problem and I think we got some royalty income there.

GDP, R&D and Manufacturing Share (2013):



Human and financial resources devoted to R&D:



We have heard today about the governmental and environmental factors that we have to concentrate on manufacturing. This is the GDP and R&D support in the manufacturing sector. This is the U.S., China and EU. They produce a lot of GDP, thanks to the manufacturing sector. I think we have to bring about advancements in the manufacturing industry. That is why I put up the statistics. All the statistics are available in the manuscript in the Appendix2.

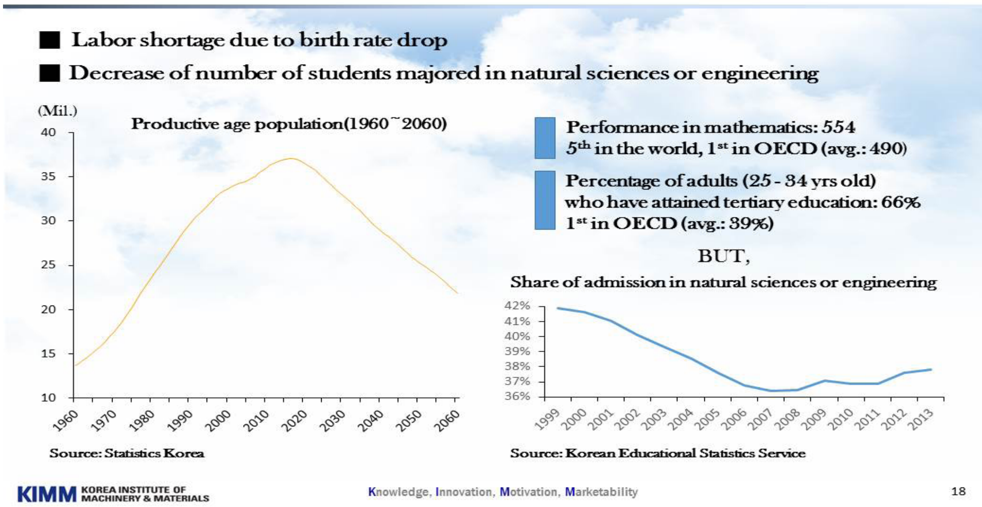
Here is President Obama of the United States. He announced the investment on the NNMI in the State of the Union and these are some of the research areas of NNMI established so far.

What do we have to do at KIMM? These are our challenges and tasks.

I mentioned only the achievements at my research institute, but what we lack the most is globalization. When I have visitors asking me how many foreign research scientists are working at my institute, I have to answer, “None.” That is the current status. Why? Because this is a public research institute funded fully by the government. In the future, we have to open up the door to international colleagues.

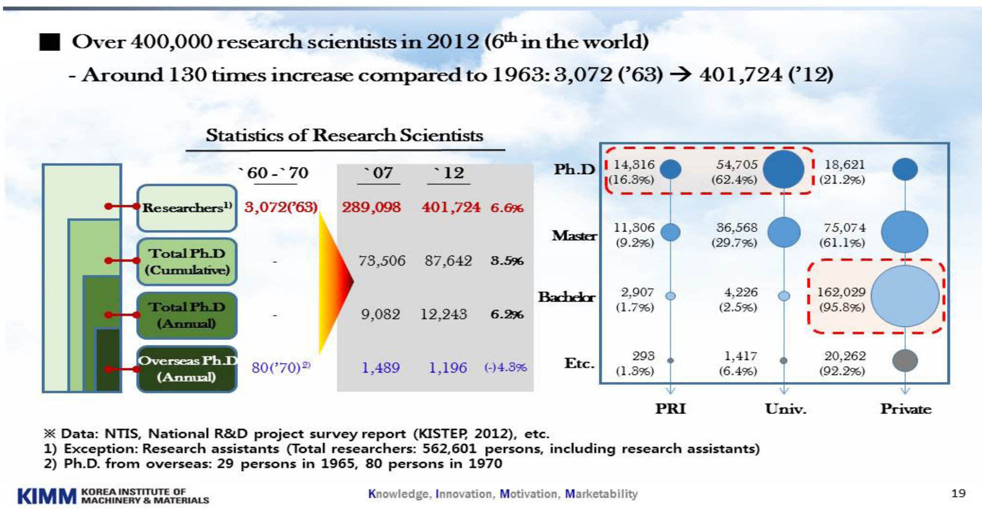
Another challenge is to increase research productivity. We set the goal of increasing productivity to about 7.5%. Currently, research productivity is around 6.6% depending on how to define it and we have to raise the productivity to 7.5%. Is it going to be easy? No.

Socio-economic Changes:

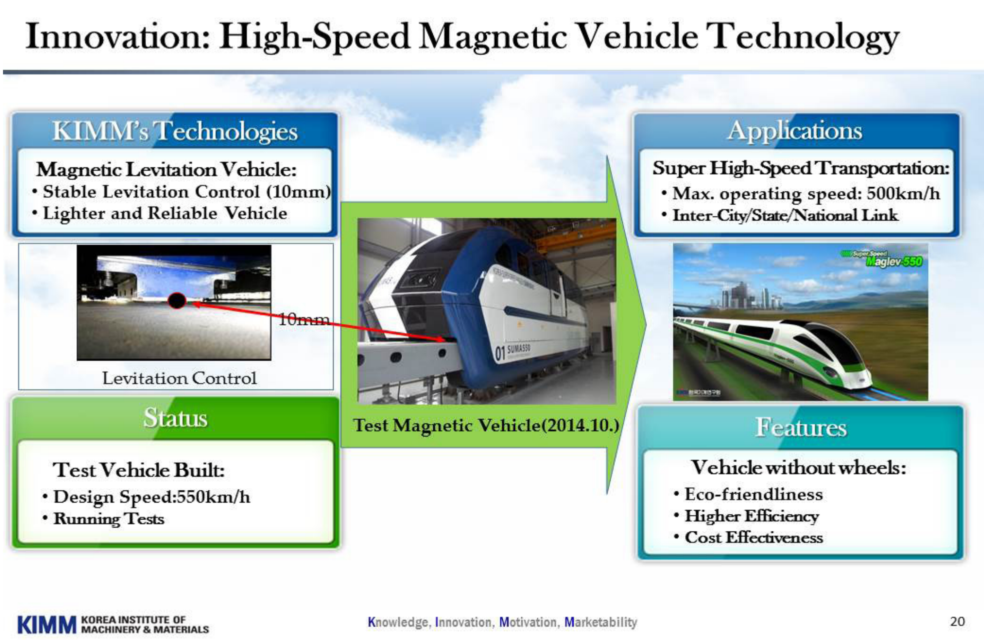


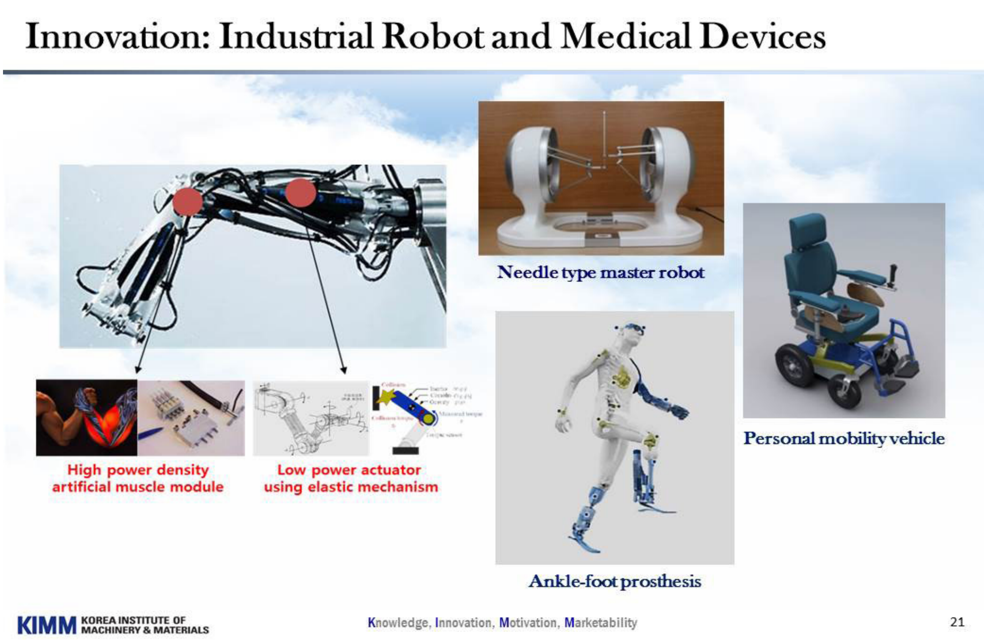
The productive population is going down. The peak is somewhere in 2016 and after 2016, the productive population who can contribute to GDP increase drops. How can we solve this problem? That is why when I give congratulatory speeches at weddings, I always tell the newlyweds to have a lot of children.

Change of R&D Manpower:

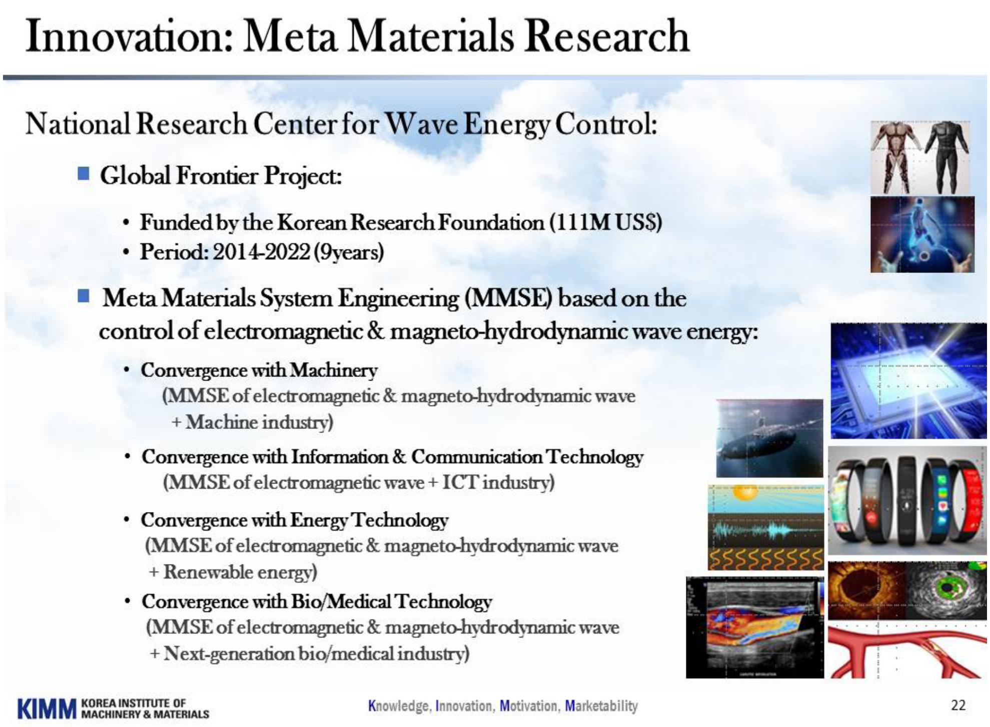


Here is another thing. The total R&D funding in the public sector is far less than that in the private sector. In the early 80s and 90s, the public sector's funding was larger than the private sector, but now it's just one third of the private sector. Then, how can we compete with private research institutes like the one at Hyundai Motors? They have more people, more funding, and we have to compete with them. That is the problem.

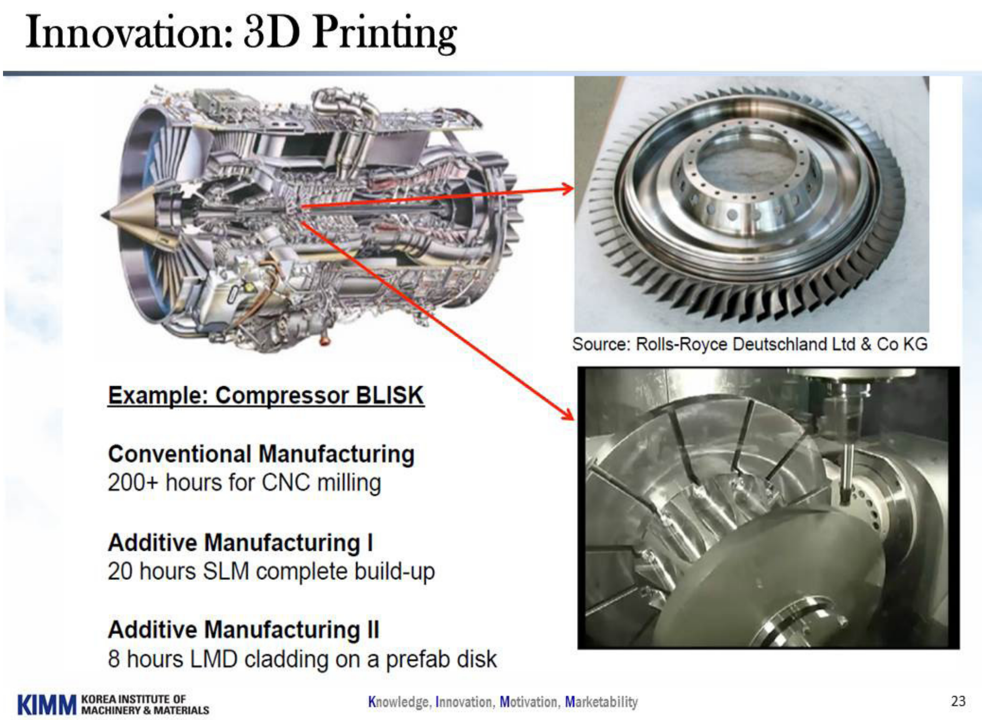




These are examples of our innovations, which I am going to skip. These are some of the medical devices.



Fortunately, last year, we secured a nine-year funding of 900 million US dollars on meta materials research. This is the outline of what we are going to do with the funding. I am sure it is not easy. That is what we have to do here.



Last Monday, we secured about $300 million over 3 years to develop 3D printing technologies. This morning, I heard some of you really emphasizing the 3D printing technology as a future technology. With this new funding, this is what we are going to do. We have a group of people working on nanotechnology and we have the major research center, so that's the item that I am going to push for the next few years. I hope that spirit will be transferred to my successor.

I am sure you received this bag from KIMM. KIMM here does not mean Korea Institute of Machinery and Materials. KIMM means knowledge, innovation, motivation and marketability. You all know that these words are important to make people's lives better and happier. I think we have to build up this institutional spirit and that's what I am going to do. I want to ask my colleagues to do everything to expand and contribute to KIMM.

I hope you love KIMM as well. That is the end of my talk.

To conclude my talk, I hope you take this booklet with you. This booklet has all the presentation materials. We are very happy to have this second version that reflects your hard work and contribution today. You can distribute these to your colleagues.

I really believe we have to work together. Instead of trying to solve the problems by ourselves, it is important to share the work and results. We have to share the knowledge and we have to save the globe. That's what we have to do for our future.

Thank you everyone for your participation. Thank you, Professor Choi, and Professor Kim for taking the session chairs. I am sorry I spoke for more than 10 minutes. Let me finish my talk here. Thank you.

PANEL DISCUSSION

Dr. Mun Y. Choi: Good afternoon. Welcome to the panel session that recaps some of our thoughts on manufacturing research. I really enjoyed the talks. I learned a great deal about cold forging, MEMS, superhydrophobic materials, and so on. As an educator, I was very interested in Dean Pisano's talk on using engineering for the public good. Studying engineering or studying a discipline with a mission, I think, is very important. I know that, in the U.S., with that kind of emphasis, we can address another very important social problem which is the lack of diversity in the STEM (science, technology, engineering, and math) disciplines. That is something that I want to share with my colleagues when I go back, to make sure that we have a similar focus as well.

From Dr. Hänsel's talk, he asked us, first of all, to dream, to have a vision, and to lead innovation. I think that is a call for all of us, as educators or researchers, to share with the next generation. In order to train the next generation of mechanical engineers, we have to move away from the traditional which is merely communicating ideas and theories. Instead, we have to instill them a sense of creativity, the role of globalization, professionalism, effective communication, empathy, and social and cultural competency. I think the very important element that we have to instill, in addition to an outstanding technical education, is a sense of confidence in our students. They need confidence to challenge the status quo, to challenge the conventional, and to challenge hierarchy and the power dynamics that typically occurs at many organizations.

I think, with that kind of an emphasis, we can have a trained workforce that could really take some of the great ideas that we have been thinking about and that we are dreaming about into action. From my perspective, I really enjoyed educational component that all of us shared in our presentations. As we go on, what I would like to ask each of you to do is to provide a very brief summary about what you feel are the most important developments that are needed, whether it is on the technical side or societal side, that will enable mechanical engineering discipline to really advance manufacturing engineering for the future. Let me start with Professor CJ Kim.

Dr. CJ Kim: Because of my position, my interest has always been in how MEMS can contribute to the society through commercialization. As I said in my talk, there is a big disconnect in MEMS between what engineers can do in their research and what are used in reality. The ultimate contribution of engineers is to make something commercially available. Even though we are able to perform so well in engineering for manufacturing, only less than one percent of the work is commercialized. I would like to hear what you think are some solutions for such disconnect between capabilities and utilizations.

Dr. Zvi Karni: I enjoyed very much hearing the discussions and presentations in so many different areas. I think everyone has some points in common. One of them is that there is a big change in the world. The big change is affecting manufacturers that used to be in a steady state for many years. I was also happy to hear the viewpoints from the social side because we are losing this side while placing much more emphasis on other things. I think it has been true for Korea as well in the past few years. Is there any need to do better education? Of course there is no question about it. New teaching is necessary so that the internal reeducation system for the preparation of the future manufacturing industries can be minimized. At industries, the research scientists need to find the practical solutions which were challenged by mechanical engineering. But coming here, I saw there is a way forward. This way forward is promising.

Dr. Matthias Hänsel: It was very interesting for me to see different aspects from what I normally do not see in my daily life: MEMS, gas turbines, power plants, energy saving, etc. Talking about education, universities in Europe are different from those in the U.S. For example, they have this kind of standard program in Europe to bring the fascination of new technologies into classically divided directions of DISCIPLINES: chemical engineers, mechanical engineers, chemists, etc. They all have their specialties. At the University of Zurich, they combine faculty members of various areas. Students get very fascinated by this. They understand what they are doing, and why they are doing. They are learning with more inspiration. They have visions and free thinking out of the books. This is one important thing.

The other thing is, as President Yamanaka mentioned, young people think that manufacturing is old style. They think of Industry 2.0, dirty fingers, etc. They think there is much better business in computer science, economics, etc. However, Industry 4.0 is actually about digitization. Anything can happen in a virtual space. I am also responsible for this training center for young apprentices in our company. We first teach them standards, and then, show them they can control a robot with their iPads. It makes them wake up, listen, and think about how they are really going to make it work. Like this, we have to market the possibilities of the cyber physical systems in manufacturing which is very interesting. Then, we get good people again coming back to manufacturing because, for them, manufacturing is not the main purpose. They are fascinated by the digitization.

Dr. Tae Won Lim: Manufacturing is not familiar to me because, since I joined Hyundai Motor Company, my job has been to take care of administration. I would just like to share my experience when I have a new engineer in my institute. When they first enter the institute, they are 25 to 30 years old and ambitious. They do not want to do labor-oriented work. However, in order to develop something good for commercialization, we have to do physical labor as well as intelligent work. I always say to them that, in order to be a successful engineer, they have to develop knowledge as well as mind. When your technology goes to the factory, you have to meet various levels of engineers or production workers, and then, you have to meet them with warm heart. One of my jobs is to teach engineers in my company the human touch.

Dr. Mun Y. Choi: As an administrator, I have to show my heart and mind to the faculty, too, to gain their trust. I think that is very important.

Dr. Seung Joo Choe: Because of advances in information and communication technology, we need innovations like Industry 4.0 of Germany and Internet of Things of GE. Otherwise, we fall behind. Companies in Korea, like Hyundai Motor Company, have to make cars in mass for many different models. I think we have to adopt those new technologies into our manufacturing. We are doing mass production. We are doing business order-based. We are familiar with them, but instead, we are trying to accommodate those kinds of new technologies and integrate them to our production.

We tried to put the smart sensors to all the intermediate products during the process, put together all the information, and analyze all the big data.

The first thing we have to do is to digitize all the production data. That should be done first. We need more software-oriented engineers, not the hardware type of engineers. While hardware can be commodities soon, without software, it is just a very low-value-added product. Unless hardware is tied to certain application software, you cannot sell hardware. We have to catch up very fast because there is a big gap.

When new graduates are hired, they have chances to learn and earn their credit. However, they do not like to learn difficult and traditional mechanical engineering. We have to train them in the company, which is a loss. We also have to train software for them in-house. These are the important changes we have to make in the future to be competitive in the world.

Dr. Masahito Yamanaka: Thank you very much. I saw many things through today's presentations. I will focus on the human because they are humans that create, innovate, and manufacture. Education is the most important. As Dr. Choi said at the beginning of the Forum about decrease in the number of engineers in the U.S., the same problem is occurring in Japan. Students tend to go to the service industry.

What we do in our company, among other things, is letting many people experience what manufacturing is. We offer various internship opportunities. We also invite 70 to 80 elementary school children to our company every year to show our production system. They find it very interesting, although they do not know about manufacturing. They want to touch the tools and find out more. Giving motivation through education is the most important thing.

Dr. Albert Pisano: I want to emphasize the familiarity of students with actually building and making things. Let us talk about high school students who are about to enter college. Many of them do not make anything anymore. This may have been true for us when we were younger when we had all sorts of hobbies in which you used your hands to work. However, the number of electrical engineering students who actually build the circuit before they go to college is very low.

We have taken some very extreme steps to crack this problem in our school. We announced the program called 'Experience Engineering.' They set courses for freshmen. In the first month they arrive, they have to start building things in their declared disciplines. For example, mechanical engineering students build robots since they need to know electromechanics; bioengineering students actually build a thought-controlled switch. They put two electrodes on their head and turn the light switch on and off by thinking the correct way.

I agree with many of the comments that were made today. I will just integrate some of them together by saying we are trying to restore a pleasure of designing in making things by running all the students through this new curriculum. Surely, a third of the students will love it, a third will hate it, and the rest third will be questioning. I have 7,000 undergraduates. If a third like it, I am generating a little over than 2,300 students who will go on to these industries.

Dr. Mun Y. Choi: Thank you very much for your opinions. Today, we did not allow the audience to ask questions during the presentations. Now is your opportunity to ask some of the world experts about their thoughts on a variety of topics.

Dr. Hyun Sil Kim (Director, Research Division for Mechanical Systems Safety, KIMM): I would like to ask a question to Dr. Ching-Ming Chen from Taiwan. I learned a lot about small- and medium-sized companies in Taiwan through your presentation. I wonder how large companies in Taiwan are doing in terms of innovation and globalization.

Dr. Ching-Ming Chen: Actually, it is our problem in Taiwan. Taiwan has no large companies like Samsung and Hyundai in Korea.

Dr. Jae Jong Lee (Director, Research Division for Nano-Convergence Mechanical Systems, KIMM): I have a question for Professor Pisano. I know you have a lot of experience in nanotechnology. I would first like to hear some of your ideas on the vision of the nanotechnology-based bio industry. Secondly, you showed some academic electronics. What kind of mechanism or fabrication do you use to make the tools to work in electronics?

Dr. Albert Pisano: Thank you very much for your questions. First one is nanotech and medicine or nanotech and bio. I will offer three directions that our school is following. These are not chosen by me. These are where the faculty decided to go. The first direction is direct nanotechnology within the body. That is why I showed two kinds of nanoparticles that can be used to spot and treat diseases and take care of a number of things. There are a large number of people going in that direction. The second group is using nanotech in terms of special thin films. Particles or pieces are attached or applied to the films. Maybe I will call the first approach one-dimensional.

The second approach is two-dimensional like patterned surfaces, printed devices, and so on. The third one is a mix. It is not the direct use of nanotechnology on the body, but it is the use of nanotechnology in the machines that we use to understand about the body. For example, they are hyper-miniaturized imaging systems or very-high-speed DNA sequencers which use micro or nanotechnology, i.e., 'off-the-human' nanotech. These are three general directions of my faculty.

I will try to answer to the second question. All the epidermal sensors which are stretchable sensors are actually engineered using two new approaches. The first approach is functionalized stretchable polymer, i.e., chemically treated stretchable polymer. That is one invention. The second one is extremely innovative. We had several materials that we engineered from the molecular level to be intrinsically stretchable and electronically functioning. Many people think, "To make a copper wire elastic, you can make a curl and it will be easy to stretch." That is how we make a steel wire stretchable.

However, what if I told you that we could take carbon chain molecules of certain length that do not, at the molecular level, have extreme amount of pliancy? When you build a polymer out of these, it looks just like rubber, but it retains its electric properties. I showed one example of the stretchable solar cell. If you take just a simple elastic polymer to put the solar material on, it cracks as soon as you get above a few percent strain, whereas the stretchable solar cells will take eight- or nine-percent strain because the solar material itself is molecularly elastic. These are the two new technological directions that we are taking. There are several startup companies that are trying to commercialize this technology.

Dr. Matthias Haase: My name is Matthias. I am from the Institute of Forming Technology and Lightweight Construction at TU Dortmund, Germany. I have two questions, one general and one specific. I would like to start with the general question to President Im. There are Fraunhofer Institutes in Germany, and we have heard today that the U.S. is also coming up with a similar approach. Do you think this kind of approach will also fit for Korea, i.e., a mixture of academic research and research directly related to the industry?

Dr. Yong Taek Im: Yes, of course, but the environment is a little bit different. In the U.S. and Germany, there are very strong small- and medium-sized enterprises that are really anxious to develop their technologies, whereas, in Korea, most small- and medium-sized enterprises do not have the capability to do so. Some of them do, but not many. The problem lies in the lack of interest in investment. Funding is very limited. What I am going to do is to ask some small- and medium-sized enterprises to make a type of consortium through which they can share research benefits. That is what I am pushing for. What we can try at this stage is to educate small- and medium-sized enterprises how they can get benefit out of doing research.

Another thing is the structural problem. Conglomerates like Samsung and Hyundai have their own hierarchy. Second-, third-tier, or smaller companies have to work intimately within the hierarchical relationships. That is an obstacle to fair competitions in a free environment. I hope this answers to your question.

Dr. Matthias Haase: Thank you very much. My second question is for Professor Kim. You showed us one approach of producing a new kind of a hydrophobic material. Do you see specific benefits or specific application of your approach compared to already existing approaches?

Dr. CJ Kim: I spent time on one major application of superhydrophobic surface, which was to apply on the bottom of the yachts or naval ships. It has a somewhat different need to perform than most of other superhydrophobic surfaces. I also talked about another superhydrophobic surface -- the glass-based superomniphobic surface but did not have a chance to talk about its antibiofouling property. Because microstructured glass surface is fragile you cannot use it for many promising applications in biomedical. Still, many medical doctors have come to me after seeing my paper on the antibiofouling surface and asked about their particular applications. For them, even if the surface is expensive, it is okay.

Dr. Yoshinori Yoshida: My name is Yoshinori Yoshida. I am a professor at Gifu University, Japan. I am studying manufacturing technology and metallurgy. Let me go back to the comment of Dr. Yamanaka. You said that you invite children to your company, and they said they liked it very much. I would like to know if their parents also like it.

Dr. Masahito Yamanaka: I have not opened our company to parents yet, but I would like to. Parents these days tell their children where to go and what to do. After students join our company, I would like to invite their parents and tell them about the philosophy of our company.

Dr. Yoshinori Yoshida: I believe that parents and students should be educated. Manufacturing and mechanical engineering are very interesting. They contribute to the human life and we should educate students and parents about this. Parents sometimes stop their children's dreams, even if children want to be an engineer. Can you share ideas on how to educate the importance of engineering?

Dr. Matthias Hänsel: In Germany, we invite students and their parents but also with their teachers. How could we possibly make fascination out of technology when teachers do not have any clue about technology? We have to bring fascination to technology in parents first, pupils, and then, teachers. In Liechtenstein, there is a big competition between technology-driven educational positions and the banking business. Everybody goes to the banking business and I am competing against it.

Dr. Chae Whan Rim: My name is Chae Whan Rim of KIMM. I have a question for any panel here. When teaching students engineering, modern tools such as robots are used to get them interested. In that case, most students get interested only in application, not in the basic knowledge. People get bored immediately when you try to teach them the basic knowledge. I would like to ask what your strategies are for the engineering education that does not make people bored.

Dr. Albert Pisano: The first thing we do is to require the students to take a course in which they actually have to make something. I can assure you that most of the students are not successful in making it work. I showed some wonderful examples, but that is for the lucky few that got forward. Most people did not. They are a little bit frustrated by this especially when their colleagues make it work and they do not. Then, they set up this understanding that they need to know something in order to make it work.

When we write a catalogue that describes projects, each project has a list of courses. We say, "to do this project correctly, you need to take these courses, but these courses are a year, six months, or eighteen months in the future. Therefore, if you like this kind of project, this is why you must take these particular courses." That is, we lead with the doing, and then come the fundamentals and the understanding. Later in the curriculum, they go and make things again. This time, they have a much higher level of success.

Dr. CJ Kim: I think the question here is not how to keep them from getting bored. They may get frustrated but they do not get bored. They come to engineering school because they like engineering. To speak policy-wise, the key to make engineering successful is to pay them well, not to make them curious. They come to engineering school because they are very interested, work hard, and do great, but later find out they do not make as much money as their friends in banking business. I never had the solution or answer. It is the only answer for their parents since parents want their children to go to a school where they can make money.

Dr. Tae Won Lim: Hyundai as well as Doosan pay very well. Our factory workers earn 90,000 dollars annually which is far above average. Nevertheless, whenever I ask university students, especially engineers, they never go to the factory. They consider the research centers only. We need engineers for quality control, manufacturing processes, and so on, but it is very difficult to recruit them. Money is very important, but social culture is the more important factor, especially in Korea.

Dr. Masahito Yamanaka: Money is most important, of course. There is no question. However, the key is to let as many people as possible know what manufacturing is. As you may remember from my presentation, when I see how the Japanese sword is made, it is incredible. It makes me think that manufacturing is great. Likewise, I believe, seeing something changes something. It is very important to show people what manufacturing is.

Dr. Mun Y. Choi: In the U.S., I think there is some truth to what Professor Kim was saying. At our university, when we hire a Ph.D. in engineering for the assistant professorship, we start at about 90,000 dollars for a nine-year contract. For a finance Ph.D., on the other hand, we pay 190,000. That is just one example that we see in our society.

Dr. John Sajdak: I am John Sajdak from Alion Science and Technology, U.S. Thanks to everybody on the panel for coming and talking. It is really interesting to hear. Many of those talks discussed the future technologies and where we are going five years, ten years, or fifteen years from now. It would be interesting to hear what the panels think is the critical breakthrough technology or process that is needed today, say, in the next twelve months, that engineers, students, or scientists should be thinking about working on in order to enable the five-, ten-, or fifteen-year solution.

Dr. Mun Y. Choi: Dr. Choe, we talked about the integrated gasification combined cycle (IGCC) being important. One of the things that Korea is very concerned about is the capture of partners. In that regard, what do you think is needed in that industry to really capture more of the market share?

Dr. Seung Joo Choe: IGCC is considered to be an old technology. Climate control is the key driver to revive the technology because the IGCC technology is now almost dead. In order to be competitive as the alternative power-producing technology, maybe by 2030, we have to reduce the carbon capture cost. Even though you use oxygen to burn coal, you still need to separate carbon dioxide and others. We should come up with a cheaper way to separate and capture. Another problem is storage. We do not have enough storage space. There are many other issues like who is going to own the stored carbon dioxide and if it comes out suddenly, who is going to be responsible for that. Many things are involved in that simple IGCC technology.

Dr. Mun Y. Choi: Let me ask Dr. Pisano a question. President Im talked about the need for institutional spirit to break down cultural barriers or cultural resistance. From your presentation, you talked a lot about design-based learning, practiced-based learning, and experience for learning that many Korean universities want to implement. You were able to do that in a very short time period. How were you able to get your faculty, staff, and students around this vision and get it implemented?

Dr. Albert Pisano: I had to find six champions first before I could get anything to go. I have six partners. I had to identify at least one person within departments that really wanted to do. I offered that to three of the departments that were already doing something similar, but in a very small scale. The three of the champions were eager to see a big growth. First, I identified the champions. The second is, I had to find a million dollars. I went fundraising and put together one million dollars. Then, I offered to pay for solutions to the problem. All of a sudden, now you have a champion within departments who is talking to his colleagues, "you know, the dean has a million dollars." He told every single six department, "if we get our shares, it is only a hundred and sixty thousand, but if we successfully cooperate, we are going to get three hundred thousand!" As you see, the resources were the second. I think the competition was the third. That was the real thing that really moved it forward. Everyone understood that it was good to do.

Dr. Mun Y. Choi: Great idea. Champions and resources. Are there any closing comments that the members would like to make?

Dr. Yong Taek Im: What would happen if you did not have those resources? Do you think it would still work?

Dr. Albert Pisano: No. Every department is trying to find resources for its teaching mission. I asked the department to add more to that mission. I know that they are asking for a little bit more money than they really need to do the mission. I turned a blind eye and asked for a few percent extra bonuses in something else. Their interest was also aligned with my idea.

Dr. Yong Taek Im: Thank you for your answer. Thank you, Professor Choi, for the wonderful job running the panel session. I think we are about to close the long forum.

Dr. Mun Y. Choi: Before we close, let me thank all the speakers again. Today was a terrific day. I learned a lot. I think we all did well. I want to thank president Im and the staff for organizing a terrific conference. Thank you.

CLOSING REMARKS

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

I believe that today has been a great experience and another important step in building up R&D directions of mechanical engineering. We all acknowledged that, with a third industrial revolution under way, the whole community of research scientists, industries, and educational side, should cooperate to solve global challenges.

I would like to thank all the speakers and session chairs for their contribution, and the steering and organizing committees for their sincere dedication to planning and coordinating the Forum. Your professionalism, strong commitment, and excellent collaboration resulted in an illuminating event.

I hope you will continue this conversation at the Gala Dinner tonight with other participants and with your colleagues when you go back to your own environments. I look forward to seeing all of you again at next year's IFAME which will take place here in Daejeon!

MEMORIES OF THE FORUM

Friendly conversation between the host, President Yong-Taek Im, and the speakers

Mr. Taeseog Oh, Director-General of the Ministry of Science, ICT and Future Planning (MSIP) giving congratulatory remarks on behalf of Dr. Suk-Joon Lee, 1st Vice Minister of MSIP

At the opening ceremony: host, speakers, two former Presidents of KIMM (Dr. Tae In Choi and Dr. Hae Woong Hwang, 3rd and 4th from the right), President of University of Science and Technology (President Un Woo Lee, 2nd from the right) and Division Director of R&D Commercialization & Cooperation of KIMM (Director Hee-Chang Park, rightmost)

Congratulatory remarks by Dr. Sang Chun Lee, Chairman of the National Research Council of Science and Technology of Korea

Congratulatory remarks by Dr. Sang Kee Suh, Member of the National Assembly of Korea

Congratulatory remarks by Mr. Sang Min Lee, Member of the National Assembly of Korea

Congratulatory remarks by Dr. Byung Joo Min, Member of the National Assembly of Korea

Dr. Mun Y. Choi, Provost & Executive VP of the University of Connecticut,
chairing Session 1: Advanced Manufacturing Technologies I

Dr. Mun Y. Choi, Provost & Executive VP of the University of Connecticut, giving a talk entitled “Opportunities in Additive Manufacturing & Advanced Materials”

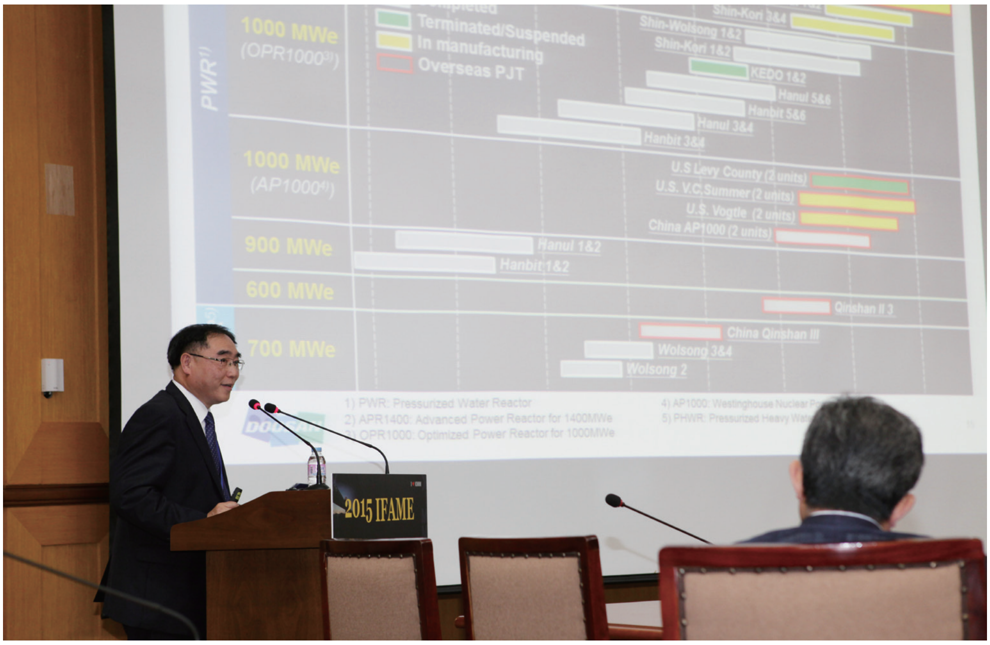
Professor Chang-Jin (CJ) Kim of Mechanical and Aerospace Engineering at UCLA, giving a talk entitled “The Micro and Nano Fabrication Technologies of MEMS”

Dr. Zvi Karni, VP of Alion Science and Technology, giving a talk
entitled "Creative Economics through Hyper-local Manufacturing"

Dr. Matthias Hänsel, Division Manager of ThyssenKrupp Presta, giving a talk
entitled "A Brief View into the Future of Precision Manufacturing by Cold Forging"

Professor Chang-Jin (CJ) Kim of Mechanical and Aerospace Engineering at UCLA, chairing Session 2: Advanced Manufacturing Technologies II

Dr. Tae Won Lim, VP of Hyundai-Kia Motor Company, giving a talk entitled “Technology Innovations for Future Mobility”



Dr. Seung-Joo Choe, Executive Vice President & CTO of Doosan Heavy Industries and Construction, giving a talk entitled "Doosan's Efforts to Develop Power-Gen Technology"

Dr. Masahito Yamanaka, President of Yamanaka Engineering, giving a talk entitled "Challenge for Sustainable Growth: Innovative R&D and Strategic International Sales Activities"

Dr. Albert Pisano, Dean of Jacobs School of Engineering of UCSD, giving a talk entitled "Engineering as a Force for the Public Good"

Dr. Ching-Ming Chen, Vice President of Metal Industries Research & Development Center, Taiwan, giving a talk entitled "The Effort Put into Innovation and Globalization for Small & Medium Enterprises in Taiwan"

Dr. Yong-Taek Im, President of KIMM, giving a talk
entitled “Raison d’être of Globalized Public Research Institutes”

Dr. Albert Pisano, Dean of Jacobs School of Engineering of UCSD, speaking about the importance of system-based engineering education during panel discussion

Dr. Matthias Hänsel, Division Manager of ThyssenKrupp Presta, emphasizing collaboration among experts

Speakers and participants seeing exhibits at Lee Ungno Museum before gala dinner

Opera singing before gala dinner at Lee Ungno Museum

Dr. Yong-Taek Im, President of KIMM, hosting the gala night at Lee Ungno Museum

Participants enjoying dinner

Group photo of the speakers and participants after dinner

Organizing Committee

Appendix 1

A Brief View into the Future of Precision Manufacturing by Cold Forging

Dr.-Ing. ***M.Hänsel,***
Chairman International Cold Forging Group, Fürstentum Liechtenstein

Summary
Five years ago the International Cold Forging Group ICFG started to look more carefully at the future perspectives of cold forging technology and its economic environment. The paper summarizes results of the discussion about future perspectives of this technology from inside the ICFG and gives a brief view on the expected development of the important market of automotive industry in the next decade. In addition the author takes a visionary look at the question of how cold forging technology will successfully assert its position in future by employing new technologies and materials and by continuously advancing towards precision cold forming technology. Apart from these technological achievements the authors wants to point out the future importance of human and social capital (employees and their knowledge, networking and international collaboration) as basic factors of management and company organisation in order to successfully master the change of global business environment.

1. Introduction

In the late sixties of the last century, when the International Cold Forging Group (ICFG) was founded — cold forging was a young, fast-developing technology. Thanks to a great number of unresolved issues related to new application possibilities or process problems on the shopfloor and the beginning of systematic research in these pioneer years of cold forging, there was enough space for interesting discussions and active information exchange on an international level between members from science and industry. Future was just happening.

Today, approximately 50 years later, cold forging has matured into an established, globally used production technique. Decades of process optimization and standardization in large quantity production result in a very good mastering of the technology. Due to the complexity level of the technology and the high degree of product and process standardization, which has been achieved today, innovation steps are only possible to a small extent and often time-demanding in their practical implementation. Moreover many topics are no longer pre-competitive and open for inspiring discussions between experts from industry and research institutions, because they are considered as know-how critical. Room for improvements and creativity of cold forging engineers has suffered considerably in comparison to the early days of cold forging. We have been experiencing some kind of technology saturation at the beginning of this century.

Additional factors from the market-side like

- growing competition due to new players on the market from low-wage countries,
- too small awareness level at the customers, which are not aware of the potentials of the technology and often still think in terms of conventional machining,
- threatening substitution through alternative processes and materials, lightweight design or electro-mobility,
- decreasing market significance - cold forging possibly will be pushed away into niche applications with high complexity and low volumes - and therefore low interest for public funded research projects,

burden the willingness and the interest for international cooperation within the global cold forging community, which however is very important for future innovations, leaving some kind of irritation about the future perspectives of cold forging.
Enough of a challenge and motivation for the International Cold Forging Group to deal intensively with future development trends and perspectives of this technology.

2. Precision cold forging advancing towards precision cold forming - future development trends

Despite the above mentioned apprehensions, the future of cold forging looks rather promising on closer inspection. Recent technological developments with clever process combinations of cold and warm forging respectively sheet metal forming, successful applications of servo presses in combination with online process monitoring for the purpose of controlled material flow or successful application of new lubricants and materials show the enormous potential of cold forging as a successful technology for industrial production of tomorrow.

Chapter 2 will highlight some of these possible future technological innovations and development trends, which can be expected from the point of view of the ICFG. They reflect the output of many discussions during the annual ICFG Plenary Meetings of the last 5 years (especially the Subgroup ICFG 2050) [1]-[6], completed by some statements of the author. Figure 1 tries to summarize these results in form of a technology radar.
It shows the most important, currently visible engineering activities and technological innovations for the main influencing process factors of precision cold forging - so-called technology fields, represented by different axis on the radar – which are illustrated through examples of decisive milestones and innovation steps from 1970 until today, in a review of the last 40 years since the founding of the ICFG, and further into future until 2050, as a preview on the next 40 years. (Remark: the chronological sequence of the innovation steps is rather schematical and is possibly not expressed correctly in all cases).

In the technology field "Workpiece-Material" for example development started from simple low carbon steels and aluminium, followed by high alloyed steels, as we see it today, leading towards magnesium and titanium (light-metals) and further to innovative composites (and hybrid materials) for combined forming of different materials out of one blank, such as aluminium & copper or different steel grades, as it will be employed tomorrow.
The required billets for cold forging can be produced by either mechanical joining, combined rod extrusion or rolling - or even sintering with functional graded powder compositions. In all cases the main driving forces for these technological innovations are products with new requirements calling for lightweight designs, specific material properties or functional materials.

In future so-called tailored blanks – pre-produced blanks using material composites mentioned above or preformed sheet metal plates - will enlarge the choice of available billet shapes and preforms made out of bar stock, wire, tubes or extruded profiles considerably, setting a new main trend in the technology field "Semi-finished-Products".
Tailored blanks, made out of sheet metal stampings for instance with specific preformed material distribution (thickness), will allow to form elevated shapes at flat parts, like gears or thin-walled elements with high accuracy, due to improved die filling and material flow.
Analogous activities can be observed in every field of the technology radar, illustrating the enormous innovation power of that technology in future, on its way towards advanced precision cold forming.

The following illustrations now will look at some of the main market and customer oriented development trends (written in the cloud symbols in figure 2 & 3). In case of automotive industry for instance, as the main customer of precision cold forging, these trends are determined by the all-decisive market forces *cost reduction, CO2-emmission and safety*, significantly driving the engineering activities and technological innovations of the technology fields, shown in figure 1. In conclusion, the development trends can be resumed to five important strategic "mega-trends" of precision cold forming, representing the focus of future development activities from the point of view of the International Cold Forging Group, displayed in figure 4.

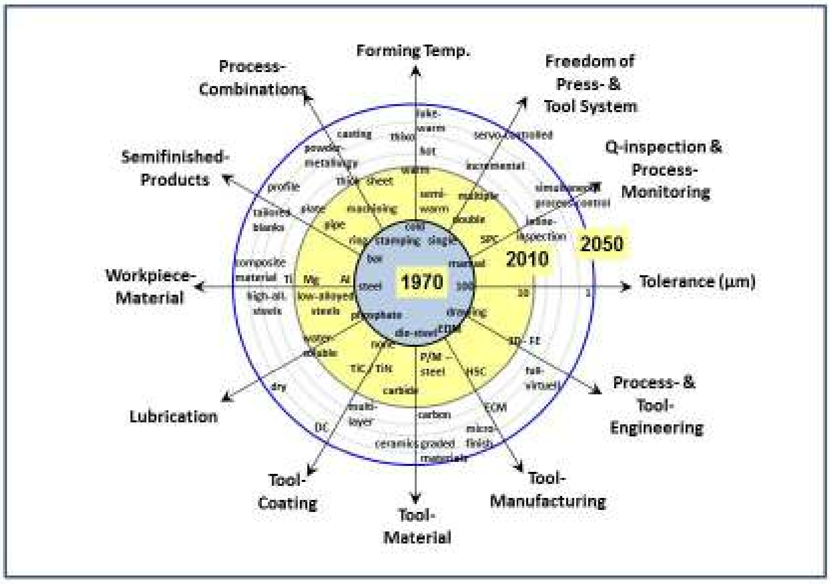


Figure 1: Currently visible technological trends in precision cold forging / forming (Hänsel/Osakada)

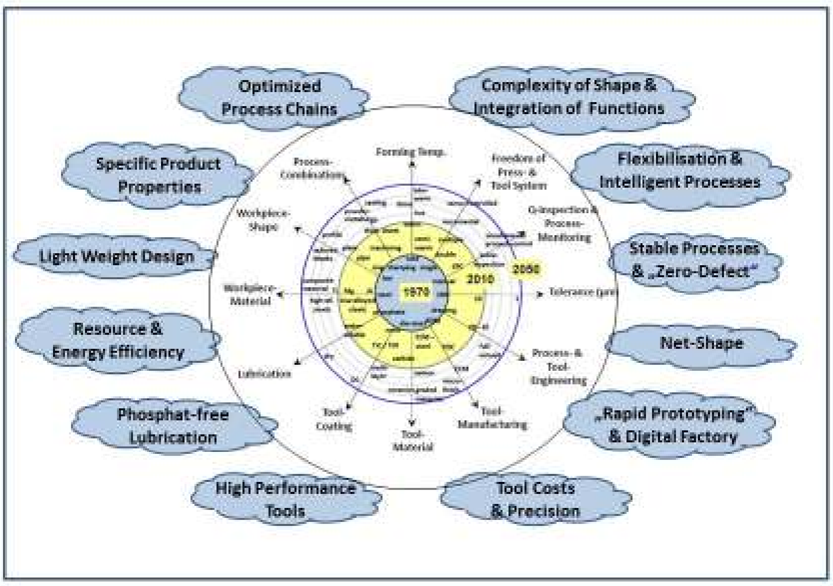


Figure 2: Development trends & strategic topics of precision cold forming

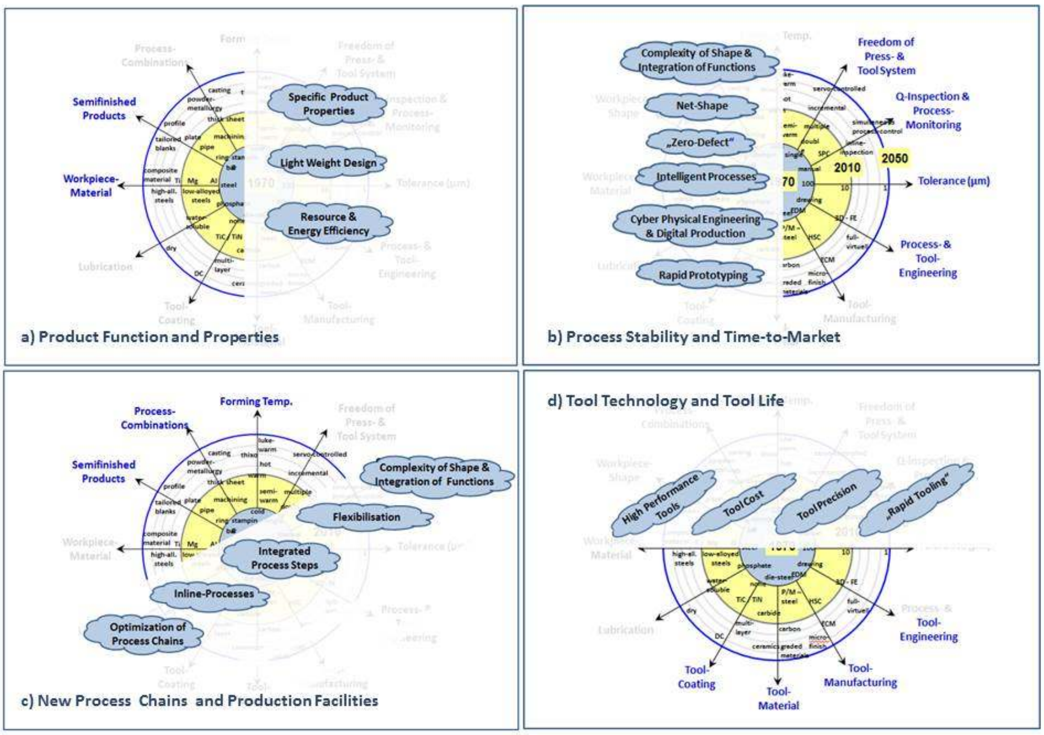


Figure 3: Future main development trends of precision cold forming

1) Product function & properties

Looking for cost-saving solutions to manufacture new products with specific functional material properties or lightweight designs or just for more efficient use of resources, engineers will learn to apply and combine materials in more intelligent ways, figure 3a. Composite materials or light metals as well as specific profiled preforms and tailored blanks will deliver new impulses for engineering activities and product & process innovations in the future.

2) Process stability and time-to-market

Trying to increase the accuracy and complexity of net-shape parts, engineers will succeed to precisely control material flow and reduce excessive tool loading in future, attempting to achieve zero-defect and high process stability in production, figure 3b. This will be facilitated by so-called cyber-physical systems, connecting computer and information systems with the physical world of manufacturing, often referred to as *Industry 4.0* [13]. Typical elements are:

- advanced numerical simulation of complete process chains, considering production equipment as well as material properties and micro structure of the product, including virtual testing,
- servo presses and active tool systems (motion control and flexible prestressing) will allow to compensate and correct drifting temperature or pressure conditions,
- integrated sensor systems for inline inspection and adaptive process control in cooperation with active tool elements.

Virtual engineering, assisted by 3D-printing, will help to speed up rapid prototyping and time-to-market of new products. 3D-printing, however, although very successfully applied as well for prototyping of metal components, will never replace real cold formed parts due to the lack of specific material properties like strain hardening.

3) Process chains and production facilities

In order to increase cost-efficiency, flexibility and applicability of precision cold forming technology, engineers will learn to think in terms of flow production and integrated process chains, starting from the raw-material up to the finished part, figure 3c. They will manage to design cost-saving process sequences with combined forming operations and they will know how to deliberately influence all relevant process parameters like forming temperature, local pressure, local friction conditions or material properties in order to better control the forming process. Servo presses in combination with multi-action tool systems will provide defined material flow conditions (e.g. by divided flow method or incremental forming) through programmable motion control of corresponding tool elements, similar to flexible CNC-machines.

In addition process engineers will learn to combine the benefits of precision cold forming much better with the merits of other manufacturing processes like machining, rolling, warm-forging, sheet-metal forming or sintering, thus generating new cost-efficient technology combinations. Hybrid manufacturing, resulting from clever combinations of precision cold forming with other primary-shaping technologies, like thixo-forming, die casting or even injection moulding in one integrated process chain or even in combined tooling systems (hybrid forming), will be a real innovation and will open up new opportunities of manufacturing and application.

In-house integration of new manufacturing technologies and combination with existing forging processes is a must for successful precision forging companies in future and will help to sustain or even increase the companies` value added opportunities. Vice versa, precision cold forming will become more attractive for other companies and will successfully be integrated in their production flows as interesting complementary manufacturing technology together with sintering, injection moulding or assembly operations.

4) Tool technology and tool life

In particular in precision cold forging operational costs and product accuracy are very much influenced by tool life and tool quality. Therefore, improvement of tool life including better tool management as well as innovative tool manufacturing processes are in the focus of research & development activities, eventually aiming at the goal of “indestructible” tools with high precision and low manufacturing cost, figure 3d. Flexible manufacturing cells for combined high-speed machining will ensure cost-efficient production of high precision tools. Load-adopted tool designs in combination with new tailored tool materials and micro-structured functional tool surfaces will increase tool life and tool performance.

5) Efficiency of energy and resources

This fifth mega-trend will gain more and more significance for total production cost in future. It represents a clear advantage of advanced precision cold forming, compared to other competing manufacturing technologies, and is an important contribution to environmental sustainability. Major topics will be reduction of total energy demand along the entire process chain - amongst others focusing on energy saving production equipment -, application of environmental-friendly lubricants and development of new lightweight designs, which will replace heavy bulk metal components through less material demanding constructions. However, it must be pointed out in this context that future use of composite and in particular hybrid materials for lightweight applications has to be critically reviewed from case to case with respect to later recycling possibilities and resulting total life-cycle costs.

Figure 4 briefly summarizes the five above described “mega-trends” of precision cold forming, representing the focus of future development activities from the point of view of the International Cold Forging Group.

Chapter 5 will outline some “examples” of these development trends.

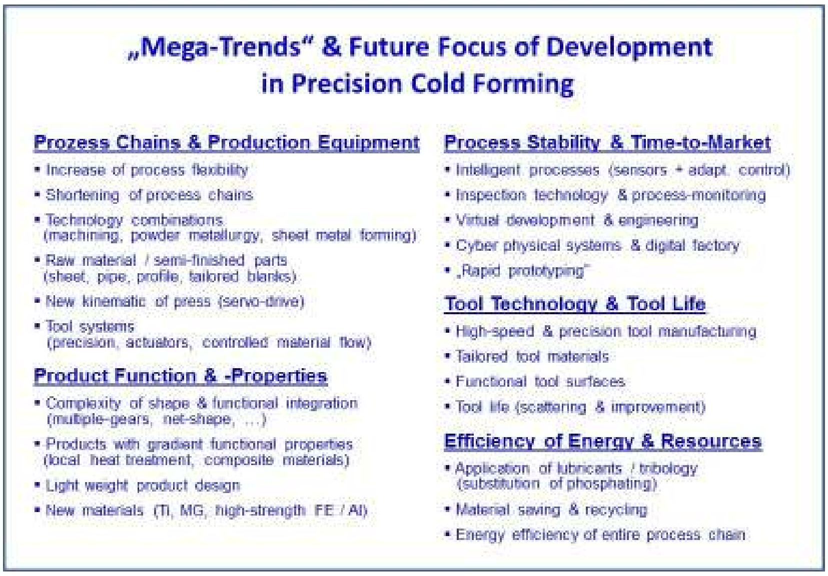


Figure 4: Summary of „Mega-Trends“ & future focus of development in precision cold forming

Figure 5: Future scenario of 1977 – „Metalforming twenty-twenty seven“ [7].

3. “Metal forming 2027” – A brief view into the future of metal forming from 1977

For a realistic estimation how technology trends will develop in the future it may be helpful to look back in the past and compare previous technical visions with modern state of technology – sometimes with big surprise how precisely future trends could be anticipated and described some years ago. This retrospective view gives a better feeling for the speed of certain innovation processes and helps to estimate what can be expected realistically in the future.

In this respect the article “Metal forming twenty-twenty seven“ of A.C.Silverton from Schuler Group is a rather interesting and remarkable view into the future of metalforming from the year 1977 [7]. The author describes in form of a visitor report the impressions of a fictive visitor’s tour through the manufacturing areas of three different metalforming companies of the automotive industry in Great Britain in 2027. In this context he expresses himself partly very precisely and detailed about different technical and organizational aspects, like it should be expected from his point of view, describing the green and intelligent factory of 2027, figure 5. Rather remarkable, taking into account that in 1977 the PC was just on its way to be born.

Very modern seeming aspects, like the digital factory as R&D platform, data exchange via Internet, supply-chain-management, lean-production or control systems for material flow with chip codification, belong to the production day-to-day in 2027, as well as laser-welding, unmanned operation of transfer press lines with full automation, flexible multi-functional presses with central hydraulic supply, fully automated tool exchange systems, press and tool monitoring systems or automated 100%-inline quality inspections. In 2027, solar power from the own company roof, energy recovery and recyclability of the products will be as self-evident for a Licenced Green Factory, as electric or hydrogen powered cars on the roads, assisted by traffic navigation plus autonomous driving systems, so-called Family Transportation Modules - highly standardized vehicles with modular lightweight concepts, governed by strict EU-norms - will be naturally for automotive industry at that time.

The fictitious time travel taking a big leap-in-time of 50 years into the year 2027 allowed an interesting, still very up-to-date and worth reading consideration of possible future trends in metal forming industry - although it had one decisive error, which the author couldn’t have foreseen. Metal forming, once one of the showpieces of the British industry, is nowadays barely present in England. After the British automotive industry has almost disappeared, it hasn’t survived the change in this area of the market, nor in technology, except for a few exceptions.
A bad omen for the entire global cold forging technology, facing a similar radical change of automotive industry today and tomorrow?
And what can be done?
The following chapters will try to give an answer to that question.

But before going on, a concluding remark with regard to „Metalforming twenty-twenty seven“:
To take a *leap-in-time* of several years is an adequate mean to provoke real innovative and possibly, even daring ideas, in a very creative and inspiring way – free of current problems in production or engineering daily-business, according to the motto „Think out of the Box“. However, only in case these ideas and visions are shared with others, if they are clearly articulated and brought into focus of many people, they can contribute to build the future. In particular in a small community, like the cold forging and precision forming group of experts, ideas and visions can be shared between the members very easily and that way can create considerable impact on future development of the considered technology - a major goal of the ISPF-seminar. Therefore it is the primary intention of the author to stimulate the imaginative power of the readers of this paper by inviting them to join him on a time travel and a visionary trip into the future in chapter 5.

4. Future development trends of automotive industry until 2030

In his article Mr. Silverton outlined just a few interesting details about the advancements of automobiles and automotive industry in 2027 - not enough for a real visionary insight into the future of the biggest market and technological trend-setter of cold forging technology. So, which are the trends dominating mobility behaviour and automotive industry in 2030, 15 years from now? Threat or opportunity?
The following chapter gives a brief overview in bullet points to partly answer that question, summarizing the most important facts of different up-to-date studies dealing with the future of mobility and the automobile in 2030 [8]-[12].

Population and society

- World population will grow to approx. 8,5 billion people in 2030.
- More than 50% of the world population will live in cities >1 million inhabitants.
- The number of mega-cities will grow rapidly, with a corresponding impact on mobility.
- Average population in Asia & BRIC-countries with fast growing economies will be much younger (32) but less prosperous, than in the classic industrialized countries of North-America/Japan/EU (44), demanding for different car concepts with regard to price, flexibility, comfort etc..
  At any case high safety standards and environment-friendliness will belong to the top expectations.

Mobility behavior and vehicle concepts

- Mobility behavior of people in mega-cities and agglomerations will be very individual, depending on the actual situation. Mobility must be fast, flexible and cheap.
- In cities areas a strong trend towards car-sharing (flexibility), e-mobility (air-pollution), small vehicles (space saving) can be expected.
- In 2030 autonomous driving will be self-evident for special areas and applications by means of smart cars & traffic infrastructure (city-shuttles, slow or stop&go traffic, parking areas, highways etc.).
- Researchers have identified three main scenarios of living environment in 2030 (population density, mobility behavior, available infrastructure, prosperity, average age) with special needs for corresponding vehicle concepts.
- Region 1: mega-cities -> urban cars
  Small & flexible vehicles for short distances, full-electric (due to available recharging infrastructure), environmental-friendly and cheap mobility. New light-vehicle concepts, using standard OEM-system modules with individual customizing of car options and accessories.
- Region 2: growing regions -> low-cost cars
  Cheap all-round vehicles for medium distances in mixed rural areas.
  Low diversity of car models, very much standardized / modular vehicle platforms, weight optimized, simple hybrid concept with small combustion engine.
- Region 3: prosperity region-> high-tech cars
  Comfortable luxury cars for medium to long distances in industrialized regions, as well for wealthy population in region 1 or 2.
  High diversity of car models and options, maximum lightweight construction, considerable part with e-engines and range-extenders.

Automotive market and powertrain concepts

- Global vehicle population will double to 2 billion units until 2030.
- Annual production volume of passenger cars will increase from approx. 70 million units in 2015 to approx. 115 million units in 2030.
- Mega-trends of automotive industry will be standardization, safety, functionality, lightweight.
- Average weight of cars will be reduced by 30% through consequent use of lightweight materials and designs. The share of lightweight materials will reach 70%, incl. high-strength steels for warm-forming. (Rule of thumb: 100kg less in weight is equivalent to minus 0.3-0.5 l/100km)

- Engine efficiency of internal-combustion engines (ICEs) will be forced up to 50% by improved „Dies-Otto"-technology.
- CO_2-emmission of cars can be reduced to 70g/100km in 2030 (~50% of value from 2000).
- Cheaper high-performance batteries with high energy density (500Wh/kg = factor 3-5 of 2015) and quick re-charging stations will boost the use of small full-electric cars mainly in urban areas.
- However, total energy balance shows, that full e-mobility will not be reasonable unless cheap, renewable energy is available. ("Tank-to-Wheel" efficiency of e-engines is only 22.5% compared to 40% of Diesel-ICEs, due to high losses during generation and distribution of electric power.)
- In 2030 2 out of 3 cars will use additional electro-engine mainly for hybrid technology, but 3 out of 4 vehicles will still be powered by ICEs. Only 20% of all new cars are using electric powertrains with range extender (ICEs, fuel cells).
- Fuel cells will develop fast and will have a good chance in 2030 as electric power source for larger cars in regions with sufficient hydrogen supply infrastructure.
- Wheel hub motors, which are threatening to replace standard powertrains and transmissions, will only be employed for urban cars with low max. city-speed.

Manufacturing technology

- By 2030, the market for components of electric vehicles will be almost twice of the market of components of internal-combustion engines, with focus on electric motors and batteries.
- Demand for new automotive components is expected to increase rather fast and will slowly replace mainly heavier, conventional cold and warm forged products, driven by implementation of lightweight concepts, electric motors or new powertrain concepts. Until 2030 gradual substitution of conventional forgings will be compensated by continuous growth of annual car production, still demanding for those parts. Thereafter their market-share will shrink quickly until 2050, when the electric powertrain will dominate, with only pure electric cars and hybrids on the roads.
- Manufacturing in 2030 will be characterized by intelligent cyber-physical systems with high degree of flexible automation, smart machine-to-machine-communication and human-robot-collaboration. Internet-of-things will expand into many new applications of the modern digital factory. Manufacturing technology in precision forming has to blend into these world of cyber-physical systems and will find new technical solutions.
- Simultaneous engineering will be carried out together with competence partners by means of internet-based Social Knowledge Networks and knowledge management tools. Augmented reality and digital consistency of data throughout the development process will be self-evident.
- 3D-printing will be often applied for functional prototypes and even small quantity production using all kind of materials (- but cannot substitute cold forged parts as mentioned before).
- Innovations in sheet and tube forming in combination with advanced joining technologies such as clinching, industrial origami, friction stir spot welding or adhesive bonding will offer new opportunities for lightweight constructions of car body and chassis components.
- In addition a new mix of available materials like magnesium, metal-foams, metallic glasses or composite-materials will trigger innovative lightweight applications and will create new manufacturing technologies.

And what is the position of precision cold forming in industry in 2030? Future production environment will be completely different - with precision cold forming still as a key-technology. New products will emerge using new materials and offering new opportunities for technology enhancement. Market will expand and conventional forged parts will be substituted. Until 2030 precision cold forming has time to react but has to take that chance!

5. Precision cold forming in 2050

In his exploration into the year 2027, which he started in 1977, Mr. A.C.Silverton had the unique opportunity to get to know the current state of the art in metal forming by visiting three different sheet metal forming companies (see his visit report *Metal forming 2027* [7]).

At the beginning of 2015, while preparing for the 7th ISPF seminar, the author and Chairman of the International Cold Forging Group surprisingly had a second opportunity to re-activate Mr. Silverton's time machine. He could send an observer "back in the future" to the year 2050 on an excursion through a modern precision forming company and its tool shop and R&D-centre. The visit probably took place during the 25th ISPF seminar, which became very popular over the years and was organized much more frequently than at the beginning of the century. His task was to carry out an evaluation of up-to-date technologic development trends, which were already visible in 2015. In this context comes a short summary of his impressions from his visit report.

Introduction and welcome

The company visit started with an introduction in the show room of the visitor centre.

At the beginning the president gave a warm welcome speech telling some details about the company`s history. It had a long tradition in precision metal forming of more than 75 years, starting out previously as a simple cold forging factory manufacturing lateral extruded parts, shafts and screws for automotive industry. He was very proud that his company received the international certificate for energy efficient manufacturing already 20 years ago.

The president pointed out some aspects of the success story of the enterprise. It only survived the dramatic change in car industry, starting in the early twenty-twenties, due to a complete re-organisation of its traditional cold forging section towards precision forming, including integration of complementary manufacturing methods and new materials. He mentioned that cost-efficient hybrid-forming of functional hybrid-materials was the "dernier-cri" of metal forming at that time and one of the highlights of research in science and industry.

He mentioned as well that *lightweight*, which was in the focus for many years, was replaced as the top-issue of industrial research by *efficient use of materials* and *design for recycling*. He told that first nuclear fusion reactors were successfully introduced as a new, environmental friendly source of energy, leading to the long expected boost of full-electric vehicles. The following boom of electric cars offered many new net-shape & net-function components in the area of electric drive and powertrain, where the company generated a considerable part of its turn-over.

The big experience of the company in precision cold forming of lightweight components for small but extremely high-loaded mechanical transmission components of electric drives in road-vehicles made the company as well to one of the worldwide leading suppliers of such parts for the fast growing sector of air-vehicles. In particular in mega-cities autonomous flying Individual-Air-Vehicles (called IAVs) became very popular as fast and flexible air-taxis. Bio-engineers had successfully solved another dream of mankind already some years ago by copying the concept of bird-bones to technical ultra-lightweight designs. Cold precision forming of fibre-reinforced metal-foams developed to one of the key-technologies.

Smart buildings with new concepts of energy generation and temperature regulation developed to another important market for precision forming. They offered many new applications in the field of tubes & joints or pumps for solar heating and cooling systems or fuel cells stacks.

As a final example for the successful transition of the company, the president showed some examples of hollow shafts and lightweight micro-gears. The finished gears were produced out of very thin-walled, triple-cup formed metal parts filled e.g. by carbon fibre laminates for increased stiffness. They were made for mechatronic drives of various forms of small and large robots, an extremely developing market of the last two decades [12].

Before finishing his speech, he unfortunately reminded the visitor group again that it was strictly forbidden to take any photos during the visiting tour. However our observer managed to make some sketches of several innovative products, shown in figure 6.

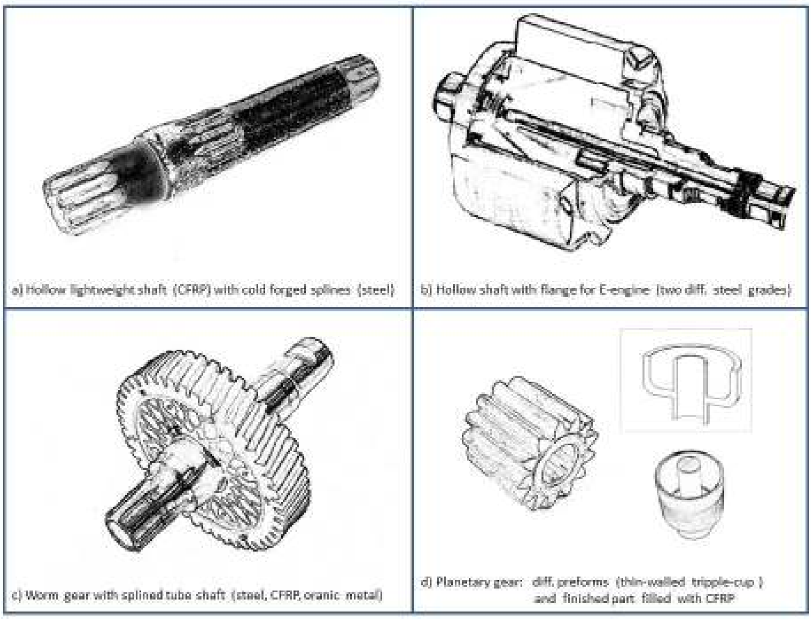


Figure 6: Examples of hybrid manufacturing and net-shape / net-function cold forming in 2050.

<u>Production plant</u>

The visit continued with a guided tour through the forging plant. The guide explained that the manufacturing areas of mass production and small-quantity production were clearly separated spatially and organizationally some years ago. In mass production area, which seemed to be organized rather similar to former factories, a rather high degree in automation of material flow and tool handling with only few operators on the shop-floor was noticeable. Precision wires, prepared by online surface-treatment and 100% defect-inspection before forging, were dominating in this area and had almost completely replaced the usual bar stock material for reasons of optimized production flow.

In contrast to that, in small-quantity production area mainly preforms and tailored blanks of various types were employed, resulting from the large variety of products supplied to many different customers.

This production department had been organizationally and technologically reorganized in 2020, following the strict market requirements for high flexibility in manufacturing. Already long before 2050 it had evolved with about 50% of all produced parts to the most important economic success factor of the company. The tour focussed on this part of the factory.

In general, intelligent production systems, assisted by the "Internet of Things", with smart human-machine-interfaces, machine-to-machine communication and collaborating humanoid robot systems characterized the manufacturing environment of the press-shop. Apart from this striking sight, in particular the air-conditioning was the most surprising characteristic in the production building, together with the extreme cleanliness and the low noise level. The main argument was that without air-conditioning of the hall and temperature-regulation of the tools net-shape production with closest tolerances would not have been possible anymore for a long time. The lack of bulk material production, which also is not compatible with net-shape-production e.g. of gears, was one explanation for the low noise level. Very impressive to see, how raw-materials and finished parts were carefully loaded and unloaded piece by piece with flexible

high-speed handling systems in the fully automated forging presses.
It was reported that the development of a significantly more effective 3D-camera technique in combination with higher processing power of computers, starting around 2010, was followed by big advancements in image procession and consequently also in the field of "pick-and-place" grippers with integrated optic-tactile sensors for process automation.
The basis for the applied very flexible handling systems were small ML-robots (ML=mini-light) - some of them resembling flexible elephant trunks. Due to their new construction design by using extreme light and rigid components out of carbon composites and due to their intelligent Local Positioning Systems (LPS) fast and precise transport movements were possible. They were equipped with intelligent grippers and measuring systems for different handling or inline operations and had therefore become a „multi-purpose-tool" for flexible automated production flow. ML-robots were available reasonable-priced in various standard sizes.

The application of ML-robots for instance made possible to build up flexible press lines for multiple operations by simply linking several cost-efficient standard single-stroke presses of different sizes (mostly servo-presses between 50-250to) instead of large and expensive multi-stage presses. The idea to replace those inflexible multi-stage presses by "Flexi-Press-Lines" (FPL) was adopted from the assembly departments in the early twenty-twenties, where this solution was state-of-the-art already for a long time.
Flexi-Press-Lines allowed to individually combine the forming stages and adapt it to the ideal engineered forming sequence of the products. They also offered the possibility for many successful process combinations, like for instance hollow forward-backward extrusion in combination with lateral extrusion, for the manufacturing of interesting preforms of lightweight gears. Flexi-Press-Lines further could be combined with other operations, like radial forming, machining, joining or partial induction heating for functional gradation of material properties, in very economical process chains. Process combinations and integrated process chains were a big success characteristic of precision forging in 2050.
In order to even further increase the flexibility of Flexi-Press-Lines, individual presses could be „joined together" and newly combined in an arbitrary order with each product change. A rail system behind the press line, like it was used previously at tool exchange systems of big presses, served for it.
A complete changeover of press and tooling from one product to another was possible in less than one hour. All tool systems with high guiding accuracy between upper and lower tool block were pre-set precisely in the tool management centre. Thanks to servo-drives of the presses, computer controlled actuators of the tooling systems and the flexible ML-robots, product related adjustments could be booted via internet-link from the cell server as a ready dataset at production start. "Plug-and-Produce"-philosophy, even for complex products, became very state-of-the-art over the last two decades, assuring high productivity and repeatable product accuracy during re-start of production.

Flexible production lines of this type still could not be realized in 2015 because of lacking or unappropriated robots and press concepts. But due to high flexibility and combination ability they had developed into a formula for success for the survival of precision forging technique already some time ago. They became a very important alternative to multi-stage presses, which however, mostly equipped with energy efficient servo-drives and servo-transfers, were still dominating in mass production in 2050.

Engineering Centre and Central Laboratories

The next highlight of the tour was the technical building of the central engineering and laboratory departments. Unfortunately the visitors were not allowed to enter the labs and offices for the reasons of know-how protection. Instead the guests were guided to a special room, the 3D-Design-Studio & Conference-Centre, where some very interesting and fascinating 3D virtual reality shows about current R&D activities were presented.
The group got a very good live impression of a typical **cyber-physical engineering lab**, which was used regularly together with customers for

full 3D design studies and numerical simulations of integrated manufacturing processes and resulting product properties. Even virtual testing, for instance assembly tests, life-cycle tests, crash tests or – latest development – chemical corrosion tests, could be carried out with astonishing precision.

In the following a material scientist and a process engineer gave a rather interesting insight in the activities of the **material lab**. They demonstrated the wide variety of materials and semi-finished parts that could be employed, like special steels and light-metals (a lot of Al or Mg alloys), different tubes or tailored blanks.
By means of flexible roller spinning for instance a precise material distribution was adjusted on stamping blanks for later forging of flat teethed geometries. Also many material composites, billets with specific dissimilar material combinations and graded material-properties, were applied. Sintered preforms for special applications of bearings or filters, or billets made out of copper/aluminium combinations for the electronic or solar industry or different steel grades for hollow shafts in electric motors, were typical examples used in the factory. Organic metals, new functional hybrid materials recently developed in leading nano-technology labs, e.g. had interesting electric and magnetic properties and proved to be ideal for cold forging and new lightweight applications. The lab engineer mentioned that even FEM-simulation of material characteristics on micro-scale level was solved.
Net-shape and net-function cold forming of composite and hybrid materials had gained access of many new products on the market, figure 6.
Net-shape cold forging in combinations with other forming and primary-shaping technologies (hybrid-manufacturing) like precision forming of metal foams, final geometrical shaping (sizing) of sintered or die-cast components or even finish-extrusion of injection-moulded fibre-reinforced plastics (real hybrid materials), was state-of-the-art of the company at another sister-plant. Technologic boundaries between different forming/shaping technologies became overlapping and interacting for process engineers, using the same expert-system and virtual development tools for similar problems.

Next station of the tour was the **measuring lab**. It was striking to see that 3D measurements were carried out mostly by means of optical methods in 2050 – conventional tactile 3D coordinate measuring machines (CMM) couldn't keep up with the measuring speed and resolution accuracy of the Laser-Grid-Scan-technology (LGS). In this process the part for inspection was positioned in a measuring chamber and the surface was scanned in one setting from all six sides (thanks to a transparent mounting table) by a high-resolution grid of laser interferometers without any movement of machine axes. All required values of part dimensions, shape & positional tolerances and surface characteristics were generated out of the scan-data. Furthermore it was confirmed by the quality department manager that thanks to the advancements in image processing (already mentioned before in the production area), a strong development of optic measuring devices suitable for inline inspection tasks had taken place as well.
Apart from those optical inspection methods, inline process control by means of smart tooling systems and "Plug-and-Produce"-philosophy were state-of-the-art to ensure high process stability. The introduction of a 100% hot-wire-inspection in the rolling mills of the steel suppliers, first starting around 2020, had contributed as well since then to the high quality level of net-shape cold forming. However the overall target of "zero defect" could not be achieved and remained a vision still in 2050.

After the measuring lab, the group went on to the **chemical lab**, which amongst others was responsible for all R&D activities in the field of tribology & lubrication and surface technology.
Modern precision forming 2050 got along in most cases with minimized lubrication, either by inline surface-treatment or direct in-process application of lubricants, due to an optimized interaction between surface topography, tool coating and motion of tools. Adjustable kinematics of servo presses and ultrasonic excitation of tools played a big role, as well as active coatings adapting individually to local tribo conditions – the latest achievements of nano-technology in the field of functional surfaces.
The chief-chemist reported that the basis for this powerful step towards environment protection

and cost reduction was a fundamental re-thinking of the process layout, many years ago. The sequence of forging operations was now orientated on requirements and limitations of the tribo-system, which were assessed using FEM-simulation with an integrated tribo-model, and not necessarily on the number of available forming steps of the press. Amongst other things, Flexi-Press-Lines with a variable number of forming steps represented a big advantage for these kind of process innovations, because the sequence of forming stages could be ideally adapted to the tribological conditions.
However, up to this date phosphate-coating of raw-material could not be eliminated completely. Especially in case of more critical net-shape production with high deformation degrees, electrochemical surface treatment of calcium-phosphate in connection with polymer-based lubricants, had been still very extended for both wire or blanks.

Tooling Competence Centre

The tour continued with a visit of the near-by tooling centre, which belonged to the company already for a long time, but still served some customers at the external market.
In 2050, a modern tool shop played a much bigger key role for the success of precision forming than it already used at the beginning of the 21th century. It has developed increasingly into a technology and service centre for tool engineering, tool management and express deliveries (rapid tooling). Thanks to successful projects for added value optimization in tool shops in 2015 and after subsequent reconstruction the companies of tool making industry were strongly specialized and involved into nationally and internationally linked supplier networks. Japan and Central Europe were still the centres for global precision tool fabrication and development.
Tools for prototype manufacturing could be ordered today and were usually delivered within 48 hours. Prefabricated hardened material blanks in different hardness/toughness classes were employed in standard dimensions, which were machined to nearly final dimensions out of a full material block through ECM-process (Electro-Chemical-Machining), which had experienced a true revolution since 2010. The final machining of remaining surface material and surface-finish-treatment was realized very fast and flexible through combined hard & laser milling and fully automatized polishing, by means of high-precision ML-robots.
Specialised supplier companies provided individually manufactured tool blanks with graded material characteristics - adapted to existing tool strains - for the manufacturing of highly stressed dies and punches of mass production. Desired material composition and distribution was determined by FEM-simulation in the fully virtual development area of the tool engineering centre, applying the digital transmitted simulation data of the customer`s forming process and the resulting tool loads. The data were subsequently transmitted online to the processing machine of the sub-supplier for production of the tailored material block.
New hard materials on ceramic and metallic basis with superior material properties were applied, whose development was introduced already in 2010 with newly tungsten-free hard composite materials on TiCN-basis.
The tool preforms were fabricated very precisely by standard Laser-Metal-Build-process (LMB), which had been developed continuously since 2005. They were built up, with the desired individual distribution of material properties and were finished in a following process step without distortion by laser-supported heat treatment. In unfavorable load situations of the tool, segmented tool preforms were still employed with special carbid or ceramic-inlays even in 2050.
Final machining was achieved with the help of further developed high-precision machining centres for hard-milling or spark-erosion, which was completed by the above described finishing processes in a fully automatized manufacturing cell. The reached accuracy of complex free form surfaces were reliable at ±2µm. It was interesting to see that profile grinding, which around 2010 was usual for example for machining of punches with gears, could often be replaced through 5-axes simultaneous high-speed cutting and subsequent super-polishing on the same machining centre in the following years.
Smooth tool surfaces with very low roughness-values contributed significantly to the stabilization of tool life on a high level. In specific cases they were refined through active nano-coatings

(ANC), as well as local laser structuring. The tools could be recoated regularly in order to protect them from early abrasion.

For protecting the tools of fatigue and overload fractures special systems of prestressing were employed. The outer stress-ring often consisted of CFRP material, which due to its high stiffness guaranteed a significantly reduced tool deflection and due to its high tensile strength enabled also significantly thinner, space-saving reinforcements for smaller tooling spaces on the presses than it was thought around 2010.

Above all, thanks to active prestress regulation, which was employed very often, cyclic tool deformations during forging process could be well compensated and therefore high reproduction accuracy of the tools, as well as durability at precision forming, could be kept rather stable. Specific control of material flow by means of additional active tool elements served for further reduction of press forces. The necessary sensor technology for tension, temperature and ultrasonic measurements, inclusive wireless data transfer, which was necessary for the process control and for the actuators of these tool systems, was integrated directly into the tool construction. So-called “Smart Tools” were one of the major success factors of precision cold forming, as the visitor group already had seen in production of the forging shop.

Thereafter the group was guided back to the visitor`s centre for final discussion and farewell, which is the right moment to finish our excursion into precision forming technology of 2050 and the extract of the visit report and return from our time travel back to the year 2015.

6. Changing business environment of cold forging technology – future key factors

Not only the operative excellence of processes, as they were described above for selected examples of 2050, but also the remaining factors in the business environment must fit in order to master the required change process, figure 7.

Market and clients’ expectations change continuously and are very difficult to predict. Industry and science in close collaboration must try very quickly to implement these expectations into concrete products or services within predetermined frame conditions or limiting factors, like laws, consumer behaviour, technical possibilities or resources. The overall decisive financial requirement of profitable business should only be mentioned here, but will not be emphasized on.

For this purpose, companies can build on employees, knowledge and certain business or manufacturing processes, which are available in different organizational forms. Besides the factor human capital (employees and their knowledge), the level of national and international networking between organizations and employees, the so-called social capital, will become very important in the future.

The changing frame conditions and its consequences on the direct business environment, like for instance the use of new media, work-life-balance expectations of employees or the need for international cooperation in networks or with partners, must also be well observed in precision cold forging in future. An „exclusive“ concentration on technological innovation will not be sufficient.

A main focus must be put on the potential for innovation of the company, so that it can adapt as soon as possible to changing frame conditions, figure 7. According to the statement of Charles Darwin - „survival of the fittest“ -, in the end not the strongest or fastest will survive, but the one who can adapt most rapidly to changing conditions.

In order to be inventive, two preconditions are required for the company: willingness and the ability for it. Willingness is a question of leadership. Potential for innovation strongly depends on education, training and knowledge. That is why it cannot be stressed often enough that education and qualification of employees, but also the attractiveness of the workplaces and employees’ satisfaction play a central key role to ensure the future survival of the company.

Additional central points are the already above mentioned, sustainable handling of knowledge in the company, as well as the biggest possible international network of the organisation and its employees with suppliers or cooperation- and research partners.

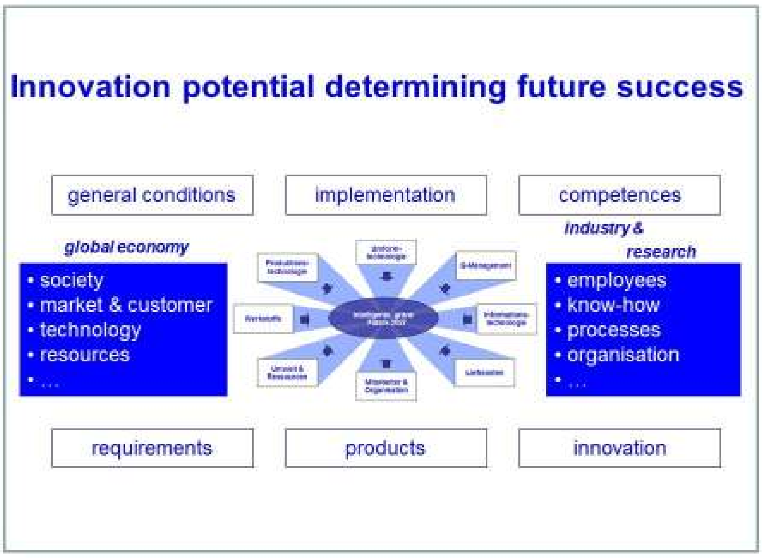


Figure 7: Key factors for future development trends in the business environment of cold forging technology

7. Conclusion

The paper was looking at the question, whether precision cold forging would survive the year 2050 in view of the forthcoming dramatic change in automotive industry, the ensuing boom of new technologies in the area of lightweight design or electro-mobility and the emergence of new global competitors.
In contrary, it seems that medium term market perspectives for precision cold forging can be assessed as rather positive, offering many new opportunities, which however must not be missed. The previous chapters outlined some examples of possible technical approaches and innovations.
The author tried to point out that precision cold forging, which is steadily moving towards precision cold forming by combining different forming processes and new materials, has a big potential to stay in the market as a key technology. In future product and process engineers must extend their know-how about complementary manufacturing technologies, must think in terms of integrated process chains and must look at possibilities for combined (hybrid) manufacturing processes. Computer systems, knowledge-networks and team work will support them.

In order to defend the high level of precision cold forming technology in the future, the "cold forming community" should – above all efforts to watch the market, improve the technology and identify new product applications - also take into account the following "10 basic rules" as recommendations for successfully mastering the future, which are very much related to management and organisation:

<u>1) Increase **flexibility**</u>, to react faster on new products or changing boundary conditions in adjusting manufacturing processes and company organisation in future.
<u>2) Use **combinations**</u>, to complement virtuosicly the abilities of cold forming in innovative integrated process chains with the merits of other manufacturing technologies and new materials in future. Hereby required process know-how and new engineering skills must be build up.

3) Enlarge internationality, to reinforce international sales, production and acquisition in future and if necessary be present locally as well.
4) Build-up cooperations, to get support of national and international cooperation with partner companies, customers, suppliers or university partners in future.
5) Intensify networking, to recognize earlier future challenges and to develop innovative solutions commonly through active national and international information exchange – either bilateral or in associations.
6) Support education, to develop employees in the best possible way in future so that they can master the increasing complexity of precision cold forming processes.
7) Increase attractivity, to inspire good and motivated employees for this field of metal forming through excellent workplaces.
8) Enable creativity, so that employees do not lose their abilities and stay innovative (innovation potential of the company) despite of the constant tendency to standardization.
9) Improve popularity, to interest customers increasingly through technology advertisements and public relations for the advantages of cold forming technology and its potentials for future applications.
10) Inspire active participation, to increase influence on new product requirements and designs by means of closer cooperation with customers` pre-development teams in order to employ more efficiently the strengths of cold forming. In this manner it is possible to shape proactively new product requirements and the market.

The challenges which are in front of us cannot be resolved exclusively by us alone due to the enormous speed of change, which characterises our world. On the other hand this world would also have sufficient answers and solutions for our problems and questions – we just need to discover them. International experience exchange and active discussions make it possible for us to participate very easyly all the time and enable us to innovatively design the future through commonly shared ideas, visions and dreams. Sometimes those dreams and visions may appear too far away – or need a good sense of humour - , but they help us "to think out of the box" according to the motto: Innovation means to do things in a different way – pro-actively and from a position of strength! (Figure 8)

Figure 8: Innovation means – to do things in a different way! Pro-active and from a position of strength!

8 Literature

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••• Appendix 2

Raison d'etre of Globalized Public Research Institutes

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Abstract

Recently, the world economy was shaken by Greece, the origin of democracy and the Olympics. The main players coping with this crisis were Germany and France. Both countries are known for strong manufacturing technologies, especially transportation and agriculture. Since the industrial revolution in England in the 18th century, evolution of science and technology, especially advanced manufacturing is the key issue to maintain the growth of national economy and security. In result, the level of manufacturing technology becomes the key element for maintaining the strength of the country. In this paper, new government policies of several countries on development of advanced manufacturing technologies such as Advanced Manufacturing Partnership (U.S.), Factories of the Future (EU), Industrie 4.0 (Germany), High Value Manufacturing (U.K.), Industrial Structure Vision 2010 (Japan), Made in China 2025 (China), and Manufacturing Industry Innovation 3.0 (Korea) will be reviewed to redirect the roles and responsibility of the public research institute like KIMM to steadily support the sustainable economic growth to improve the quality of our lives for the future.

1. Introduction

Manufacturing is the process of converting raw materials into products; it encompasses the design and manufacturing goods using various production methods and techniques. Manufacturing began about 5000 to 4000 B.C. with the production of various articles of wood, ceramic, stone, and metal. The word manufacturing is derived from the Latin manu factus, meaning "made by hand"; the word manufacture first appeared in 1567, and the word manufacturing, in 1683 [1]. Because a manufactured item has undergone a number of changes in which raw materials have become useful products, it has added value, defined as monetary worth. Manufacturing is a matter of fundamental importance to the economic strength and national security of the country, as shown in Figure 1, which depicts the Gross Domestic Product (GDP) in a country as a function of manufacturing activity within that country.

Faced with slowing economic growth rates, rising wage costs, and growing competition from the developed and developing countries, Korea is entering a critical stage for upgrading the country's manufacturing sector and setting up a better public R&D strategy that can sustain steady economic growth of the country.

After the 2008 global financial crisis, countries around the world focused once again on manufacturing and launched manufacturing development strategies. More efforts will be made to boost the integrated growth of manufacturing and product services, and improve the levels and core competition of the manufacturing sector in global markets. A country without having an advanced manufacturing industry cannot evolve into a global player anymore.

More than any other industry, a globally competitive manufacturing sector translates inventions, research discoveries, and new ideas into better or novel products and processes. To be sure, there are many interrelated factors of an innovation ecosystem - entrepreneurs, workers, tax policies, to name a few.

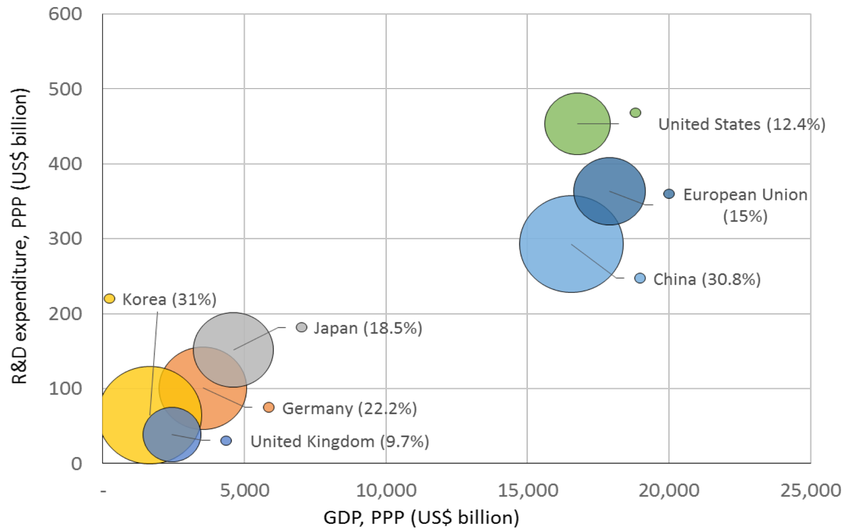

Figure 1 GDP, R&D and Manufacturing Share in 2013 (PPP (Purchase Power Parity) and Circle size represents the value added created by manufacturing in percent of GDP in 2013) Source: World Development Indicator in OECD Statistics

But without manufacturing, the economy-building, job-creating power of innovation fades, considering that manufacturing firms are known to be almost three times to more likely than service industry to introduce a new or significantly improved product or service. With regard to production, distribution, technical-support, a similar disparity in innovation performance separates manufacturing firms from on-manufacturing businesses [2].

American high-technology manufacturing industries lead the world in total output, but the U.S. global share has fallen from 34 percent in 1998 to 28 percent in 2010. Over the same period, the U.S. share of global high-technology exports declined from 22 percent to about 15 percent [2]. The U.S. manufacturing sector now faces enormous challenges. American leadership in manufacturing and, as a consequence, innovation performance is at risk.

There is a broad agreement that, for the United States to prosper in the 21^{st} century, it must have a high-performing manufacturing sector. In a recent survey, 85 percent of Americans agreed that manufacturing is important to their standard of living and 77 percent say it is very important to national security. Consistent with this majority view, 79 percent of Americans said a strong manufacturing base should be a national priority [3].

In this paper, new government policies of several countries on development of advanced manufacturing technologies such as Advanced Manufacturing Partnership (U.S.), Factories of the Future (EU), Industrie 4.0 (Germany), High Value Manufacturing (U.K.), Industrial Structure Vision

2010 (Japan), Made in China 2025 (China), and Manufacturing Industry Innovation 3.0 (Korea) will be reviewed to redirect the roles and responsibility of the public research institute like KIMM to steadily support the sustainable economic growth to improve the quality of our lives for the future.

2. Why Advanced Manufacturing Technologies?

Manufacturing stands on the threshold of a major transformation. From the digitization of equipment, processes, and organizations to three-dimensional printing (or additive manufacturing) to materials with custom-designed properties, a new design, production, and business capabilities are opening the way to new types of advanced manufacturing technologies [4].

Owing to the report provided by the President's Council of Advisors on Science and Technology (PCAST) [5], advanced manufacturing is defined as a family of activities that (a) depend on the use and coordination of information, automation, computation, software, sensing, and networking, and/or (b) make use of cutting-edge materials and emerging capabilities enabled by the physical and biological sciences, for example, nanotechnology, chemistry, and biology. This leads to manufacture of new products emerging from advanced manufacturing technologies.

According to the same report [5], advanced manufacturing entails more than making high-tech products. It also includes using new, often leading-edge machines and processes to make products that are unique, better, or even cheaper. Advanced manufacturing technologies also facilitate rapid integration of process improvements, readily permit changes in design, such as new part features or substitute materials, and accommodate customization and cost-effective low-volume production.

Product innovation and process innovation are different sides of the same token in advanced manufacturing. Scientific discoveries, new ideas, and novel engineering approaches can be converted quickly into the seeds of new products and processes. Technology-intensive and dynamic, advanced manufacturing enterprises require high-skilled workers to perform at high levels and compete globally.

Advanced manufacturing provides the path forward to revitalizing global leadership in manufacturing, and will support economic productivity and ongoing knowledge production and innovation in the country. The nation's long-term ability to innovate and compete in the global economy greatly benefits from the cohort of manufacturing and manufacturing-related R&D activities in the country. The loss of these activities will undermine the nation's capacity to invent, innovate, and compete in the global markets. It cannot be overemphasized based on the recent economic crisis in Greece.

3. Strategic Initiatives of Several Countries in the World

3.1 US

Since 2011, a series of significant policy documents and initiatives has raised the profile of advanced manufacturing and underscored its importance in the United States economy [5-7].

The reports addressing shortcomings of America's advanced manufacturing environment were presented by the PCAST in June 2011 [5] and July 2012 [7]. Three major issues of enabling innovation, securing the talent pipelines, and improving the business climate were commented by the Advanced Manufacturing Partnership (AMP) Steering Committee. The proposed national strategic plan for advanced manufacturing [6] and the National Network for Manufacturing Innovation (NNMI) design [8] and pilot institute were other landmark recommendations for capturing the domestic competitive advantage in American manufacturing. The importance of these proposals and activities to transform and profoundly impact the economy and well-being of the entire nation cannot be overstated.

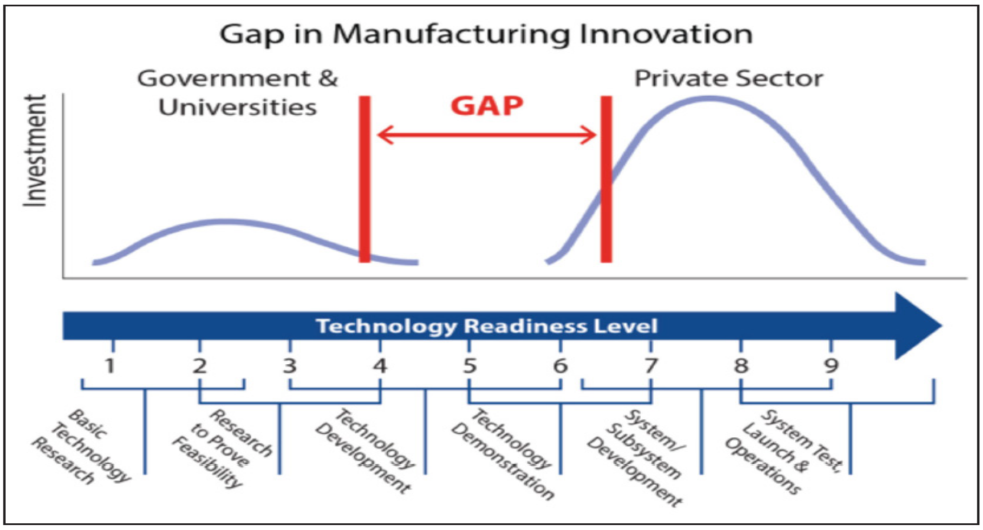

Figure 2 Distribution of investment in technology development in the United States summarized in the position paper by the NAMRI/SME [9]

The June 2011 PCAST report [5], "Report to the President on Ensuring American Leadership in Advanced Manufacturing," indicated that the environment for research in the U.S. is very healthy, with fundamental research leading to life-changing technologies that continue to astound the public. Flat-screen displays, lithium-ion batteries, solar panels, and so on, are fruits of American research. However, these American technologies are not manufactured domestically, even though labor is a small portion of the production cost.

One of the reasons for this situation can be understood from Figure 2, which illustrates the distribution of investment compared with the level of development in a product [9]. In the U.S., government-sponsored research is predominantly done in the early stages of product development, and industry concentrates on the very late stages. The gap in between is a space that is owned by neither entity - the so called "valley of death."

From the funding point of view, significant funds are made available in several countries for manufacturing infrastructure, research and demonstration to promote the manufacture of products invented everywhere, including in the U.S. If a product has developed to a prototype, it is relatively easy to locate manufacturing scale-up and demonstration activities anywhere in the world; once these tasks have been performed; there is an impetus to keep manufacturing near the pilot production facilities. This has been the practice and experience of the German Fraunhofer Institutes [10], where the establishment of a new institute leads quickly to industrial development.

In a free-trade world, manufacturing infrastructure provides a competitive advantage to a nation; this is recognized by most advanced and developing economies. Established programs directed toward advanced manufacturing are summarized in Table 1 [9]. For comparison, the U.S. invests roughly US$ 0.15 billion annually in the Hollings Manufacturing Extension Partnership program, US$ 0.15 billion in the Advanced Composite Manufacturing, US$ 0.61 billion in the Integrated Photonics and US$ 0.37 billion in manufacturing through the National Science Foundation (NSF) [11]. NSF funds fundamental research, including the Materials Genome Initiative and the National Robotics Initiative, neither of which have strong ties to manufacturing. Regardless, even with NSF funding that is nominally relevant; the U.S. lags behind the world in its support of manufacturing research. This is a dangerous condition and one that needs to be corrected immediately according to the position paper printed by the NAMRI/SME [9].

Table 1. Comparison of levels of investment in manufacturing research [9]

Country	Program and Summary	Investment in U.S. dollars[1] (billions)	Equivalent U.S. investment[2] (billions)
Germany	**Fraunhofer Program.** World's most established and premier manufacturing research program: complements Max Plank Institutes (German analog to National Science Foundation).	1.0	3.0
	Spitzencluster. Supports the best or 'leading-edge' German industrial clusters.	0.25	0.75
	Central Innovation Program. Provides grants to small and medium enterprises to finance research and innovation projects.	0.64	1.92
United Kingdom	**The Catapult Program.** Established seven centers in advanced manufacturing.	0.264	1.6
Australia	**Industry and Innovation Program**. Collaborations between academic, government and industry researchers to commercialize discoveries; $500 million over four years	0.50	5.0
Japan	**New Energy and Industrial Technology Development Organization.** Promotes R&D for energy and industrial technologies.	1.64	4.89
	Other programs (Kohsetsushi Centers, Technology advanced Metropolitan area Association, Kawasaki Business Incubation Center)	0.51	1.45
Taiwan	**Industrial Technology Research Institute(ITRI)**	0.60	18.9
Finland	**Finland Science and Technology Council**	0.63	35.5
South Korea	**Ministry of Education Science and Technology.** Research programs in the 577 initiative target semiconductors, automobiles, machinery, health care and software.	12.8	175.0
Singapore	**Future of Manufacturing Program**	0.5	25.5
	Other programs (Satellite Industry Development, Collaborative Industry Projects)	0.19	9.7
France	**Competitiveness Clusters.** Similar to the German Fraunhofer program: 71 competitive clusters in cutting edge and key technology sectors	0.75	4.9
China	No government figures. Estimates are 1.7% of GDP, 82.7% of which support manufacturing sector.	108	222

Notes: 1. Investment by federal government only; often matched by local governments.
2. Scaled by size of GDP.
3. Annual investment.

2012 - President Obama announces new National Network of Manufacturing Innovation

Original plan - $1B invested in a network of 16 institutes of manufacturing innovation.

Carnegie Mellon 2012

National Network of Institutes of Manufacturing Innovation

2012 America Makes – 3D Additive Manufacturing, Youngstown Ohio,$70M
2013 DMDII Digital Manufacturing & Design, Chicago, Ilinois, $150M
2013 LIFT Lightwieght Metal Manufacturing, Ohio, Michigan, $150M
2014 Power America -Wide-Bandgap Semiconductors North Caroline, $150M
2014 IACMI –Advanced Composite Manufacturing, Purdue, Indiana, $150M
2015 IP – Integrated Photonics, Rochester, NY $610M,
2015 Institute of Flexible Hybrid Electronics Manufacturing , $200M
Clean Energy
Revolutionary Fibers and Textiles

Figure 3 Obama's presentation in the State of the Union [13]

In the 2014 State of the Union address, therefore, President Barack Obama declared that the United States is well-positioned for economic growth and announced additional manufacturing initiatives, as shown in Figure 3 [12, 13]. Numerous economic indicators suggest a strong resurgence of domestic advanced manufacturing, as long as a proper environment can be secured and maintained.

Through various administrative, legislative and private-sector actions, there is a momentum on several key PCAST/AMP recommendations, including an additional three announced and four projected institute in the NNMI, support for community college-industry workforce development collaboration and a sustained policy of investment in advanced manufacturing R&D emphasizing the accelerated launch of technologies from laboratory to market [13].

3.2 EU

Manufacturing accounts for about 15% of European Union's GDP and employment [14, 15]. European manufacturing is also a dominant element in international trade, leading the world in sectors such as automobile, machinery and agricultural engineering. However, Europe's position as a global industrial leader is fading and the leadership in many areas is being threatened by the lower-wage economies and other high-tech competitors, leading to a decline in employment recently.

Europe needs a strategic shift from cost-based competition to an approach based on the high added value for recovering growth and gaining sustainability. And, there are demands for more eco-friendly, customized and multi-functional products. Manufacturing has to tackle the challenge of producing more with less energy, material, and waste. These are in fact the basic directions of the research and innovation in advanced manufacturing technologies stimulated by the FP7-NMP programme and Horizon 2020 [16].

After the downturn with financial crisis in 2008, the Public Private Partnership - Factories of the Future (FoF) were established. This partnership is a EUR 1.2 billion programme in which the European Commission and industry are collaborating in research to support the development and innovation of new enabling technologies for the EU manufacturing [16].

The FoF initiative aims at helping EU manufacturing firms (especially Small- and Medium-sized Enterprises (SMEs)) to settle in the competitive global market and to meet the global consumer demand by developing the key enabling technologies. The FoF concentrates on increasing the technological basis of EU manufacturing through the development and integration of enabling technologies, such as innovative technologies for adaptable machines, ICT for manufacturing and novel industrial handling of advanced materials. Under this initiative, 150 R&D projects were launched involving top industrial companies and research institutions. These projects covered the wide range of manufacturing: supply chain configurations, virtual factories, material processing and handling, programming and planning, customer-driven design, energy efficiency, emissions reduction, new processing technologies, new materials, and upgrading of existing machines and technologies [16].

3.3 Germany

It is well known that Germany is a global leader in manufacturing. Based on Germany's continued role as one of the world's most innovative and competitive manufacturing industries and technological leadership in industrial production research and development, a pioneering new world of decentralized and autonomous real-time production, a new type of industrialization; Industrie 4.0 is planned and implemented [17].

Industrie 4.0 means the coming industrial revolution on the way to an Internet of Things, Data and Services. It refers to the technological evolution from embedded systems to cyber-physical systems. Decentralized intelligence helps create intelligent object networking and independent process management, with the interaction of the real and virtual worlds.

The German government passed the "High-Tech Strategy Action Plan" in March 2012, which identifies 10 Future Projects including Industrie 4.0, for which funding of up to EUR 200 million was allocated. And the government identifies the Industrie 4.0 future project as a main measure in securing Germany's technological leadership in the mechanical engineering sector, and plans to carry forward with the digitalization of traditional industry with expansion into the area of "Smart Services" foreseen, as well as the strengthening of projects and activities in the "Green IT" sector [17].

And, there are several relevant projects; Cyber Physical-Systems 2020, ICT 2020, Autonomy for Industrie 4.0, CYPROS, and RES-COM [17]. Agenda CPS aims to be the lead provider of cyber-physical systems by 2020. ICT 2020 is focused on the area of ICT in complex systems (e.g. embedded systems), new business processes and production methods as well as the Internet of Things and Services. Autonomy for Industrie 4.0 contributes to further development of the next evolutionary steps for machines, service robots and other systems to deal with complex tasks autonomously owing to the transition from ICT-based control mechanisms to autonomously acting components and systems. CYPROS aims to develop a representative spectrum of cyber-physical system modules for production and logistics systems for industrial use. And RES-COM project addresses automated conservation of resources through highly interconnected and integrated sensor-actuator systems in an Industrie 4.0 context.

3.4 UK

The U.K. is a major competitor in the manufacturing sector. In terms of manufacturing Gross Value Added (GVA), it is 8th in the world, generating 10% of the U.K. GVA [18]. The U.K. ranks second only to the U.S. in the aerospace industry [19], and two out of the top six pharmaceutical companies are headquartered in the U.K. [20], where they also support significant manufacturing assets. Despite these strengths, globalization has continued to drive production activities towards countries with lower labor costs and/or larger markets. The financial crisis in 2008 highlighted the U.K. economy's heavy reliance on service sectors. Developed countries have seen roughly the same change in composition with a gradual decline in production and manufacturing as a proportion of GDP, but the U.K. manufacturing industry has declined at very fast pace, resulting in the U.K. moving from having one of the largest shares in 1948 to the lowest in 2012 [21].

The U.K. government formulates a strategy, "High Value Manufacturing (HVM)," to increase the role that manufacturing plays in the growth of the economy. HVM is the application of leading edge technical knowledge and expertise to the creation of products, production processes, and associated services which have strong potential to bring sustainable growth and high economic value to the U.K. [22].

It aims to ensure that HVM is a key driver of the U.K. economic success and to help accelerate firms on their innovation activities from concept to commercialization by doubling the direct investment in HVM innovation to around £50 million. It also focuses on the investment in the most attractive technologies and manufacturing sectors where the U.K. can become a major player in the global markets, making investment choices using a set of 22 manufacturing competencies [23] with the greatest potential to create high-value economic impact across multiple global market sectors. The U.K. decided to invest in the High Value Manufacturing Catapult to provide the cutting-edge equipment and the skilled resources to firms to commercialize their world-class technologies, and to provide open access to the most effective platforms for knowledge exchange such as the Knowledge Transfer Networks, Knowledge Transfer Partnerships, Special Interest Groups and HVM Catapult [22]. The U.K. firmly believes that such a national strategy helps firms combine the best manufacturing innovations to create world-beating products, processes and services [22].

The HVM Catapult combines the strengths of 7 existing centers (located in Glasgow, Sheffield (2), Sedgefield, Ansty, Bristol and Coventry) across key manufacturing processes, with over £140 million of government investment planned over a six-year period, and investment matched by private industries. It enables innovation to cut across sectors by bringing together firms from diverse industries and giving access to a pool of world-class expertise, equipment and processes invested and supported by the U.K. government. This was a benchmark for the Creative Economy Innovation Center in Korea.

3.5 Japan

Japan is also known to be one of the global leading economies in manufacturing sectors. The "Monozukuri" is a representative word of Japanese manufacturing. The Monozukuri literally means the process of making or creating things, but it has more intense meaning: the Japanese External Trade

Organization (JETRO) describes the Monozukuri as ‘having the spirit of producing excellent products and the ability to constantly improve a production system and its process’ [24]. It symbolizes strong manufacturing base and manufacturing-oriented feature of Japanese economy.

However, Japan recognizes modestly the “deadlocked position” of her industries that they are lagging behind the world’s major players and market changes. Japan tries to formulate and implement a strategy to maintain the leadership by crossing the boundary between the government and firms, between ministries and between the national and local governments. It is the “Industrial Structure Vision 2020,” a nationwide effort to strengthen industrial competitiveness [25].

The strategy presents 5 strategic industrial fields as a direction of future industrial structure adjustment: Infrastructure-related/system export (nuclear power, water, railways, etc.), environment/ energy problem solving industry, creative industry, medical/ health service and advanced areas (robots, space, etc.). And it offers 9 cross-sectional measures for the future including comprehensive strategy to make Japan Asia’s industrial center, corporate tax reform, promotion of R&D to produce new values, “IT” to support advancement of overall industry and so on [25].

3.6 China

As a major driver of Chinese economic growth, manufacturing has contributed more than 40 percent of China’s GDP. During the past three decades since society reform and market opening began, manufacturing in China has grown faster than the overall economy. In result, the share of capital- and technology-intensive production has risen, but labor- and resource-intensive have declined. The average growth of manufacturing output was about 20 percent per annum between 2005 and 2013. In 2012 China’s manufacturing added values reached US$ 2,080 billion, or about 20 percent of the global total, making China a manufacturing giant [26].

On March 5, 2015, Premier Li Keqiang said China’s State Council pledged to boost the implementation of the “Made in China 2025” strategy to transform China from a manufacturing giant into a world manufacturing power [27]. Based on this announcement, digitalization and industrialization will be unified and priority will be given to the development of ten particular fields, including robotics, aerospace, railways, electric vehicles, information technology, new materials, agricultural machinery, and etc. To achieve this, Beijing plans to continue a state-directed innovation and propose to establish 15 manufacturing innovation centers by 2020, which would be expanded to 40 by 2025. Behind this new vision is the Chinese leadership’s realization that China needs to transform the country’s manufacturing industry to enable it to keep up or stay ahead of that of other countries [28].

The Made in China 2025 strategy offers three key drivers of China’s hope of becoming a manufacturing world power owing to Mr. Dan Zhang [26].

Firstly, China must focus on research for common technology especially in strategically emerging industries. Through innovation, China can realize a leap forward in their economic development. To speed up such development, China will need to enhance independent innovation in traditional industries, boosting core and key technology research that takes full advantage of available resources. In this way, innovation will promote the transform and upgrade of all traditional industries.

Secondly, China should focus on high-end equipment manufacturing, an industry that plays a key role in economic growth. China must accelerate structural reform in key industries sector. China’s equipment manufacturing industry is developing a solid foundation with some notable achievements like manned space flight, the lunar exploration project and manned deep-sea submersible craft named after a mythical sea dragon. Intelligent manufacturing equipment, marine engineering equipment, advanced rail transportation equipment and new energy vehicles have been developed fast so far. However, the international competitiveness of such companies should have been significantly enhanced.

Thirdly, China makes standardization of intelligent manufacturing a top priority. China must accelerate integration of domestic standardization resources and establish an intelligent manufacturing standardization system. China must standardize according to the characteristics of intelligent manufacturing development and absorb ideas from the advanced countries like German Industrie 4.0 and advanced U.S. manufacturing.

3.7 Korea

For the past five decades, Korea is also known for successful transformation of the country into a democratic society and remarkable economic growth. Gross national income per capita was just $ 67 in 1962 when the national industrialization has started. It has grown to be 420 times ($ 28,180 in 2014) and trade value is 9th in the world. The success was based on manufacturing-centered economic revamp led by the late president Park Chung Hee.

Korea is now one of the global leading countries of manufacturing in the areas of memory semiconductor (world market share: 67%), shipbuilding (34%), mobile phone (23.9%), automobile (9%), steel (4.3%) and so on. Continuous manufacturing promotion policies and export-driven development plan have contributed to reach a current stage. The government R&D expenditure for the manufacturing area is approximately KRW 3.7 trillion, and public research institutes takes part in the R&D activity with 33.6% of budget (firms' share: 48.1%) [29].

Established as government-sponsored research institute in 1976 in Changwon, Korea, the Korea Institute of Machinery and Materials (KIMM) played an important role to achieve this economic revolution in the machinery and materials development and contributed to make the total production of general machinery industry from US$ 0.3 billion in 1977 to US$ 104 billion in 2014 (370 times).

The Korean government accelerates convergence in the manufacturing sector and sets the new stage for innovation of the manufacturing industry. The Ministry of Trade, Industry & Energy submitted a business report to the Trade, Industry & Energy Committee of the National Assembly on July 2, 2014. It suggested the Creative Economy Industrial Engine Project and the Manufacturing Industry Innovation (MII) 3.0 strategy. MII 3.0 strategy that focused on productivity improvement in the manufacturing sector under the five-year plan (2013-2017) is implemented now. The MII 3.0 strategy has the three key elements of the creation of new manufacturing oriented toward industrial convergence, the enhancement of the major segments, and the advancement of the industrial infrastructure for innovation.

The Ministry of Science, ICT & Future Planning and the Ministry of Trade, Industry & Energy together released action plans for the 19 projects constituting the Future Growth Drivers and Industrial Engines Strategy including wearable smart device, manufacturing system for advanced material, safety & health robot and offshore plant in extreme environment, etc. According to this plan, a budget of approximately US$ 5.1 billion will be invested by 2020 for the projects so that the industry sectors can export up to at least US$ 100 billion by 2024 [30]. Thus, Korean government and industries pay more attention to the core material and component development, engineering, design and software segments for the enhancement of industrial competitiveness of manufacturing sector according to this plan.

In addition, productivity improvement of SMEs is essential for making sustainable economic growth of Korea. According to the statistical data, the productivity level of SMEs was merely 28 percent of that of large companies in 2011. The basic principles of MII 3.0 are: 1) embracing the whole business ecosystem to include lowest-tier vendors to forge the innovation network, 2) encouraging the voluntary participation of SMEs with innovative spirits, 3) motivating businesses to participate in innovation activities through benefit sharing; 4) ensuring openness in project implementation using standard methodology, with room for flexibility at the industry and corporate levels; and 5) fostering innovative mindsets among participating CEOs for continuation of improvements [31].

Large, medium-sized, and public companies funded (US$ 200 million over five years) MII 3.0 to provide consulting on manufacturing process innovation and replace old facilities of SMEs. The main analysis and consulting tool is the Korea Production System developed by the Korea Productivity Center. The target of MII 3.0 is to establish an advanced industrial ecosystem by supporting 2,000 second- and third-tier SME vendors yearly from 2013, reaching 10,000 over five years [31].

About 75 percent of the fund is allocated to the SMEs supplying products to large, medium-sized, and public companies that participated fully in MII 3.0 funding. The remaining 25 percent of the fund is allocated to SMEs with no linkage to contributing companies.

4. Challenges of Public Research Institutes like KIMM

Based on the literature survey on the strategic national initiatives on advanced manufacturing technologies as described in the earlier section, a global leadership in the advanced manufacturing technologies cannot be overstated. As can be seen in Table 1, the research funding on manufacturing in Korea is relatively abundant compared to other developed or developing countries except for China. However, the human resources and public funding are, respectively, rather limited as shown in Figure 4 and Table 2 and 3 compared to the private sector now.

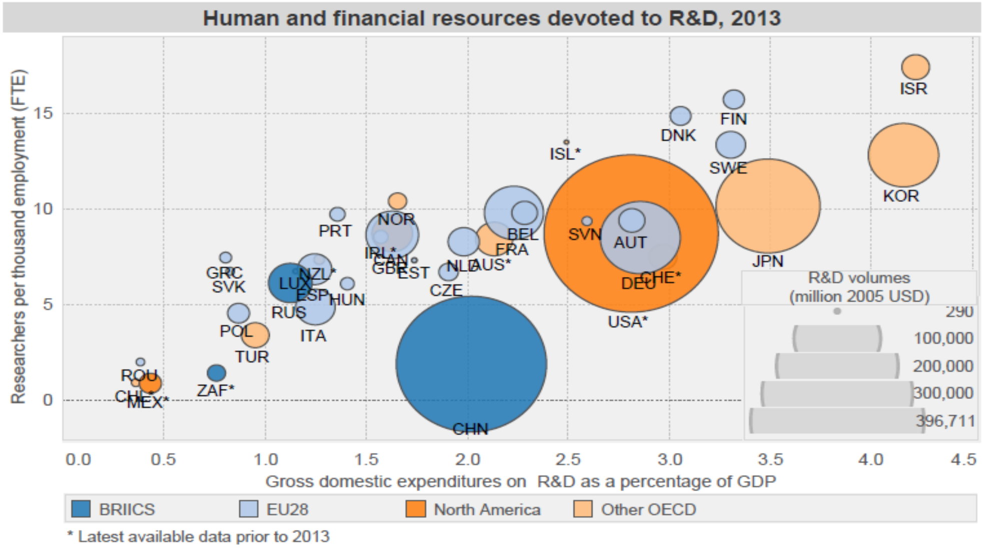

Figure 4 Comparison of the human and financial resources devoted to R&D in 2013 (Source: www.oecd.org/sti/rds [32])

Table 2. Total R&D expenditure in million US$ (Source: World Development Indicator [33] for European Union and OECD Statistics [32] for other countries)

Country Name	1990	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
China	..	32,647	85,714	104,324	122,922	144,685	184,379	213,010	247,808	293,065	336,495
Germany	35,347	52,375	64,299	70,229	74,023	81,971	82,822	87,822	96,282	100,699	100,991
Japan	69,134	98,758	128,695	138,565	147,602	148,719	136,954	140,607	148,389	151,810	160,247
Korea, Rep.	..	18,542	30,618	35,413	40,640	43,906	45,987	52,173	58,380	64,458	68,937
United Kingdom	20,053	27,873	34,081	37,046	38,735	39,397	39,433	38,139	39,133	38,852	39,859
United States	152,389	269,513	328,128	353,328	380,316	407,238	406,000	409,599	429,143	453,544	..
European Union		198,852	249,798	275,171	292,806	322,012	331,600	339,478	356,528	363,485	

Table 3. Government sponsored R&D expenditure in million US$ [32]

Country Name	1990	2000	2005	2006	2007	2008	2009	2010	2011	2012	2013
China	..	10,906	22,581	25,781	30,264	34,130	43,163	51,161	53,714	63,215	71,027
Germany	11,950	16,445	18,251	19,331	20,366	23,282	24,652	26,606	28,725	29,418	..
Japan	12,479	19,339	21,569	22,426	23,070	23,230	24,195	24,146	24,347	25,565	27,720
Korea, Rep.	..	4,439	7,050	8,171	10,077	11,156	12,598	13,955	14,538	15,373	15,740
United Kingdom	7,127	8,426	11,154	11,806	11,978	12,081	12,837	12,311	11,917	11,141	10,760
United States	63,405	70,716	101,044	105,501	110,931	123,757	132,545	133,497	133,767	139,665	..

In order to overcome such problems, KIMM has to find a better solution and set up a right strategy to support the sustainability of the national economy by boosting the Korean manufacturing sector to survive in the global markets. With this kind of challenging effort, we can reduce the valley of death, as shown in Figure 1.

To partly cope with such problems, KIMM introduced long-term flagship projects to better contribute to the development of advanced manufacturing technologies within the limited funding and manpower. Collaborations with other public research institutes like Korea Institute of Materials Science, Korea Research Institute of Bio-Science and Bio-technology, Korea Research Institute of Chemical Technology, Electronics and Telecommunication Research Institutes and etc. were actively promoted internally. The research funding for such collaborations has increased from 8.5% of the internal main research program in 2014 to 11.6% in 2015, even though the annual R&D budget has stagnated for the last several years, as shown in Figure 5.

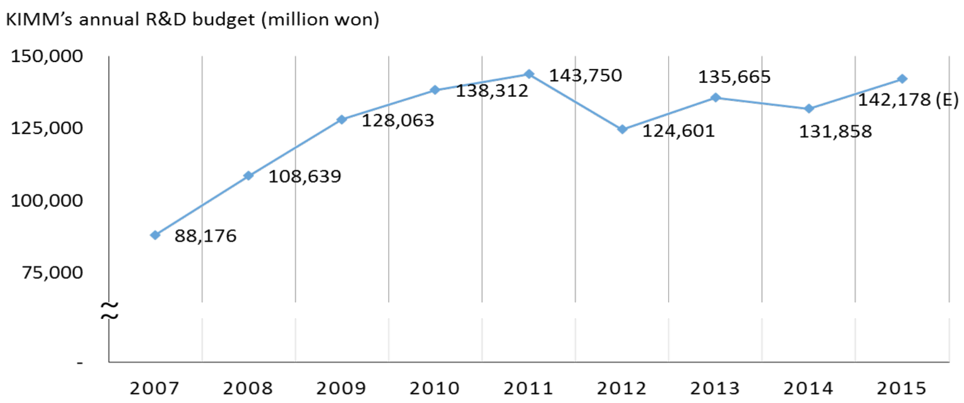

Figure 5 KIMM's annual R&D budget (in million Korean won)

Recently, KIMM secured the 3-year government research funding of US$ 30 million on 3D printing technology. In combination with the planned long-term 9-year funding of US$ 90 million on the Meta Materials research starting from 2014 and the existing research outcomes on nanotechnology, etc., KIMM can really create new research environment for additive manufacturing as demonstrated in Figure 6 [13]. I strongly encourage to my colleagues at KIMM the formation of collaborative working environment locally and globally. In order to easily achieve the convergence of existing technologies and introduce a new frontier spirit to making innovation more efficiently, such changes are indispensable to the public research institute like KIMM to become more globalized research institute in the end. If we can successfully make such innovations at the public research institutes, then, the Korean economy will be stably sustained and the leadership of Korean industry will be fortified.

Figure 6(a) Additive manufacturing – accomplishments and challenges [13]

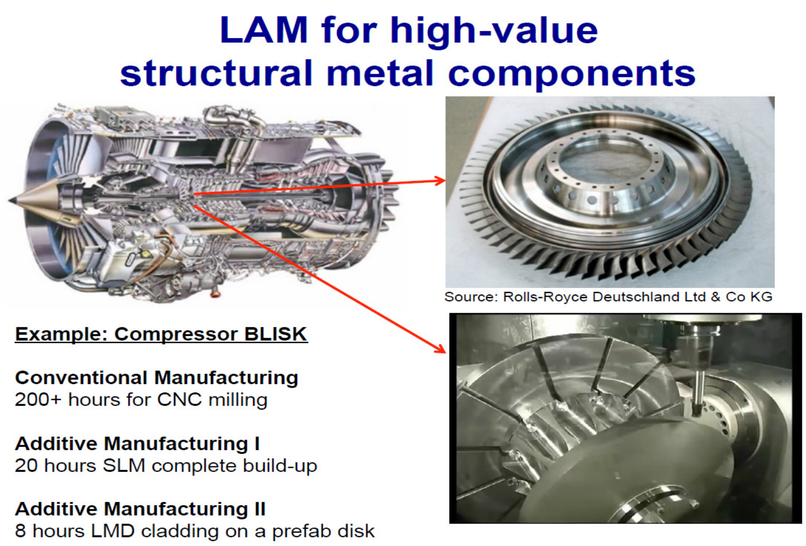

Figure 6(b) Examples of additive manufacturing [13]

Opening start-up companies established by the research scientists should be encouraged as well to advocate the technology transfer developed at the Institute and shorten the time from the laboratory to the market. The systematic technical support and consultation program led by the research institute should be redesigned to satisfy the market needs from the SMEs as well.

Lastly, increase of the research productivity and opening a branch office of the internationally well-established research institute at KIMM or other research institutes on a specific research field might be beneficial in order to save the development time and effort. Thus, long-term government support for making this happen should be encouraged further.

5. Conclusions

Despite the statistical rapid growth of the national GDP of Korea, there is still some gap for Korea to become a manufacturing powerhouse that can compete with industrialized countries like the U.S., Japan, and Germany according to the present review. Korea still lacks capacity in terms of fundamental knowledge, independent innovation, core technology, industrial structure, and value chain.

Through global economic structural reformation, developed countries have launched reindustrialization and return-to-manufacturing strategies that fiercely compete with each other in the global markets. Facing competition from both developed and developing countries, Korea urgently needs to implement an efficient manufacturing development strategy to survive in the market.

Knowledge-intensive manufacturing service refers not only to the development of new technologies and products but also the value-added services promoting a transformation of technological management chain. Manufacturing services can improve the market environment and provide new technological R&D, logistics, technical support and technology transfer, consulting, finances to manufacturing processes and products in a globalized network. A comprehensive set of intellectual property laws, a sound social security system, and strict regulatory system should be well-prepared as safeguards.

In conclusion, the public research institutions like KIMM need to support Korean Industry by pursuing knowledge, innovation, motivation, and marketability to enhance control of the industrial value chain in the global markets. We have to acknowledge that the human and technological resources are very much limited to make the world economy more sustainable to make everybody's life happier and healthier through development of advanced manufacturing technologies after all.

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