

*REPORT*

**Manufacturing for the 21<sup>st</sup> Century Committee**

*March 19, 2012*

**Committee Members:**

Professors Bahram Ravani (Chair), Diran Apelian (Co-Chair), Richard Dorf, David Horsley, M. Saif Islam, Subhash Mahajan, Alexander Rezvin, and Kazuo Yamazaki

Executive Director Martha Kerbs of Office of Research, and President Adam Hansel of DTL (Digital Technology Laboratory) Corporation.

**Charge to the Committee:**

The college of Engineering at UC-Davis established the Manufacturing for the 21<sup>st</sup> Century Committee in March of 2011 to address and make recommendations on the following three issues:

- *What is the current state-of-the-art in manufacturing excellence in the College of Engineering at UC-Davis and who are the faculty leaders?*
- *Are there obvious weaknesses in areas (related to Manufacturing) that are considered vital to the future of the College and Campus?*
- *How can we leverage existing and future excellence in manufacturing to take advantage of forthcoming state and federal initiatives, for example, in terms of externally funded centers?*

Each of these three points is addressed in this report, followed with specific recommendations.

**Background:**

The importance of Manufacturing in job and wealth creation and economic growth of the country has recently been well publicized in both political and technical circles. President Obama launched the Advanced Manufacturing Partnership (AMP) on June of 2011 as a national effort for developing partnerships between industry, federal government, and universities for addressing emerging technologies that can create high quality manufacturing jobs and can enhance the global competitiveness of the United States. The key elements of the AMP program include the following:

- Manufacturing in Security Industries with an initial investment goal of \$300 million by Department of Defense, Homeland Security, Energy, Agriculture, Commerce and other agencies as co-investment with industry in manufacturing of small high-powered batteries, advanced composites, metal fabrication, bio-manufacturing, and alternative energy.

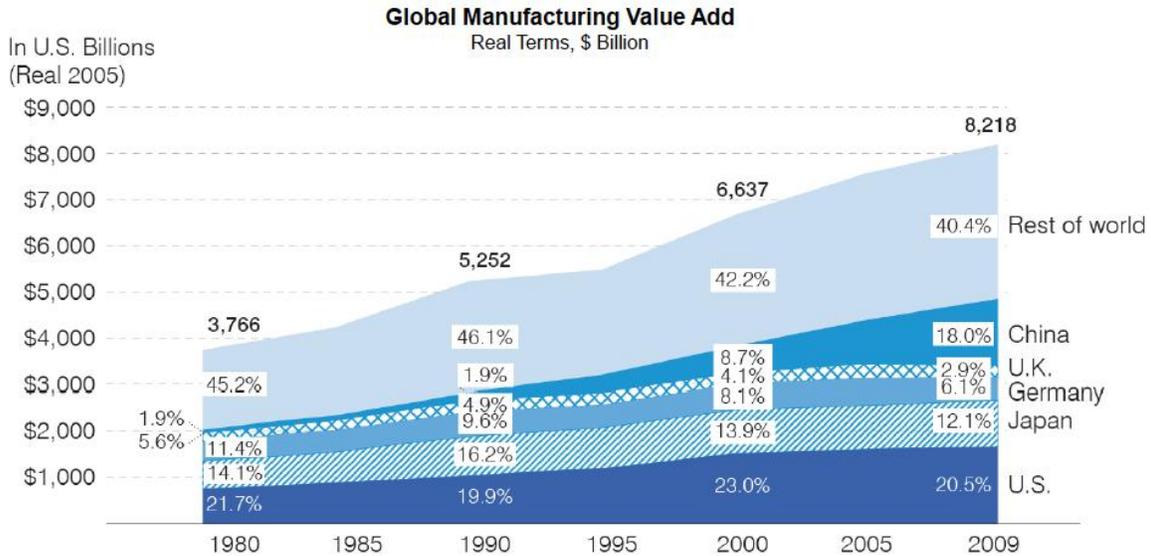
- Efficient Development and Deployment of Advanced Materials with an investment of \$100 million in the Material Genome Initiative as an enabler for US companies to double the speed of new material development and deployment.
- Next Generation Robotics with an investment of \$70 million by The National Science Foundation, National Aeronautics and Space Administration, National Institute of health and the Department of Agriculture for development of next generation of robots that can work with human operators adding new capabilities to factory workers, healthcare providers and surgeons and soldiers.
- Energy Efficient Manufacturing Processes and Materials with an initial investment of \$120 million by the Department of Energy as an enabler for companies to reduce manufacturing costs while increasing energy efficiency.

In addition, President Obama's budget is proposing to invest \$1 billion to create a new National Network for Manufacturing Innovation with an initial pilot funding of \$45 million using existing resources from the Department of Defense, Energy, Commerce and the National Science Foundation through a competitive application process.

The AMP program is intended to provide a boost to manufacturing industry in the United States since this industry has been in decline since 2000. Even before the economic downturns of 2008, the employment in the manufacturing sector had dropped by 20% since 2000. The percentage drop has even been worse since 2007. In California, the drop has been slightly more than the national trend. In 2007, manufacturing contributed to 12.8% of California's GDP and the state had the largest share of manufacturing employment in the nation.

The 2011 Directory of California Manufacturer lists 27,552 industrial companies involved in Manufacturing. This is in contrast to approximately 48,500 of such firms in California in 1991. The University of California had a system wide attempt in helping maintain the mid size manufacturing industry in California in the early 1990's through providing seed funding for a manufacturing extension program. This program, however, was not very successful due to various reasons including lack of grass root involvements of the faculty and unrealistic restrictions on providing funding for this program. From a global context, while US share of global production has fallen, U.S. manufacturing continues to grow and outperforms Europe and Japan – see Figure 1. From a strategic perspective, UC Davis is well poised to build and grow its manufacturing activities as the nation and the world needs the knowledge base and human resources.

At present due to the need to revive US manufacturing industry and the existence of the new initiatives such as those described in the AMP program or the newly announced Network of Manufacturing Innovation, there is a tremendous opportunity for academic institutions to become important enablers in developing the research, innovations, and the workforce that can shape the landscape of future of manufacturing in the next decade and beyond. This opportunity is even more prevalent for the University of California since California has been and remains to be a leader in high technology manufacturing and innovation attracting a larger share of venture capital among all the states in the nation.



Source: UN National Accounts Main Aggregates Database, Booz & Company analysis

Figure 1: Global manufacturing in US billions (\$) over almost a three decade span [1].

1. Mayor, T., “The Future of Manufacturing”, Booz&Co. Power Point presented at U.S. Manufacturing Competitiveness Initiative: Dialogue on Next Generation Supply Networks and Logistics, Georgia Institute of Technology, February, 2012.

### Analyses:

- *What is the current state-of-the-art in manufacturing excellence in the College of Engineering at UC-Davis and who are the faculty leaders?*

There are two major research laboratories that signify the state of Manufacturing Excellence with the College of Engineering. One is the Intelligent Manufacturing Systems (IMS) laboratories of Professor Kazuo Yamazaki of the Department of Mechanical and Aerospace Engineering and the other is the Northern California Nanotechnology Center (NC<sup>2</sup>) facility of the College of Engineering.

The IMS laboratories consists of two major research laboratories one devoted to conventional machining and the other to non-conventional machining and nano-machining operations. Both of these are machine tool research laboratories and are equipped with state of the art equipment valued at more than \$4 million. They are by far the best-equipped research laboratories in the area of machine tools among any Universities in the US.

The (NC<sup>2</sup>) facility is a shared research laboratory consisting of approximately 10,000 square foot class 100 cleanroom for micro and nano-fabrication and technology development. This facility is available as a re-charge facility to the faculty at UC-Davis as well as industry. The (NC<sup>2</sup>) facility is equipped with advanced equipment for the deposition of materials, lithography,

etching, and inspection for micro- and nano-system research and characterization which can also be used for advanced additive type manufacturing and micro/nano fabrication. In the lithography area, the equipment in the facility includes systems for pattern generation and mask aligners, NanoImprint systems, and NanoSem Electron Beam Lithography systems. In the thin film area, the laboratory is equipped with Furnaces, Electroplating systems, and Electron-Beam Evaporators. In the Dry Etching area, the equipment in the laboratory includes Plasma and Thermal etching systems as well as Wafer Handling devices. Finally in the Metrology area, the laboratory is equipped with advanced Profilometers, Nano-spec film thickness monitors, and Zeiss surface Microscope as well as other Electron Scanning Microscopes.

In terms of faculty research, the only single faculty in the College of Engineering who has had his/her main area of research and professional activities focused in the area of manufacturing has been Professor Yamazaki of the Department of Mechanical and Aerospace Engineering.

Professor Yamazaki has developed a fully funded research program in the area of manufacturing with industrial funding exceeding \$1 million per year as well as major (worth several million dollars) equipment donations and loans establishing some of the best equipped machine tool laboratories at UC-Davis to support his research. In addition, Yamazaki has been graduating MS and PhD students in the field of manufacturing who are sought out by the manufacturing industry. He has also been receiving post-doctoral and visiting scholars from other Universities working in his laboratories for training and research in manufacturing.

In addition to the above accomplishments, Professor Yamazaki established the MTTRF (Machine Tool Technologies Research Foundation), a non-profit public charity foundation. MTRF has established a worldwide network to promote and collaborate on education and research focused on machine tool system technologies. As President of MTTRF, Yamazaki created a mechanism to provide state-of-the-art CNC machine tool systems to esteemed universities around the world. Today, MTTRF is supporting 18 universities in the world including MIT, UC Berkeley, University of Wisconsin-Madison, University of British Columbia (Canada), Coci University (Turkey), University of Firenze (Italy), ETH-Zurich (Switzerland), KU Leuven (Belgium), Bremen University (Germany), University College Dublin (Ireland), National University of Singapore, Keio University (Japan), Kyoto University (Japan), etc.

The UC Davis IMS Laboratory has been acting as the MTTRF collaboration center of the manufacturing education and research by cooperating with these MTTRF supported renowned university professors. Over the last decade, MTTRF has provided UC Davis with more than 4 million dollars worth of manufacturing equipment for education and research.

Prof. Yamazaki along with his former students has founded DTL (Digital Technology Laboratory) Corporation in Davis as a subsidiary of a major machine tool company – namely Mori Seiki Inc. The synergy from Professor Yamazaki's research activities, the work of DTL and other factors have convinced Mori Seiki corporation of Japan to build its first US nano-machining manufacturing facility in Davis adjacent to DTL Corporation. This facility is scheduled to become operational in June of 2012 and will have a significant impact on the local economy. This is an opportunity for further collaboration with UC-Davis.

In addition, there are several other key faculty members in the College of Engineering whose areas of research and professional activities, are relevant and complement the above two Centers – **IMS** and **NC<sup>2</sup>**; these include in no particular order:

- Professors Joanna R. Groza and Enrique J. Lavernia of Chemical Engineering and Material Science who have worked, respectively, on plasma sintering and spray atomization and deposition technology and they have recently teamed up with researchers at LLNL (Lawrence Livermore National Laboratory) in a joint proposal on “Rapid Manufacturing”.
- Faculty in the area of physical electronics in Electrical and Computer Engineering including Professors Saif Islam and Richard A. Kiehl who are working respectively on nano-scale electronic/photonic design and fabrication and self-assembly of nano-meter scale electronics.
- In Mechanical Engineering, in addition to Professor Yamazaki, Professor David A. Horsley has been working in design and manufacturing of Micro-Fabricated Sensors and Micro-Mechanical (MEMS) devices. Furthermore, Professors Rida Farouki and Bahram Ravani have worked in the area of Computer Aided Design and Manufacturing. Recently Professor Ravani, jointly with Professor Bernd Hamann of Computer Science Department, has teamed up with faculty at the Technical University of Kaiserslautern of Germany on a major multiyear International Research Training Proposal to the German National Science Foundation on “Physical Modeling for Virtual Manufacturing Systems and Processes”.
- In addition to the faculty in the College of Engineering, Professors Richard C. Dorf and Andrew B. Hargadon of the Graduate School of Management have been working on entrepreneurship and technology ventures, which are very relevant to Manufacturing.

It should also be pointed out that since the present national agenda in manufacturing, as defined in the AMP program, includes other key elements such as advanced materials, robotics, and energy efficiency including manufacturing of batteries for hybrid vehicles, one needs to also mention activities relevant to these key areas within the College of Engineering as follows:

- In relationship to the key element of the AMP program dealing with manufacturing of small high-powered batteries, composite materials, and alternative energy as well as the one from Department of Energy dealing with energy efficiency, there are several faculty members and groups in the College of Engineering who have relevant activities. These include some of the activities in the Institute of Transportation Studies (ITS) under leadership of Professor Daniel Sperling on Hybrid Vehicles (some jointly with Mechanical Engineering Professor Andrew Frank), Energy and Transportation, and Sustainable Transportation Energy Pathway as well as more recent work on effect of Green House gases. In addition, the work at ITS in conjunction with several faculty members in the Department of Chemical Engineering and Materials Science (including Professors Bruce Gates, Joanna Groza, Sangtae Kim, Alexandra Navrosky, Pieter Stroeve, Ahmet Palazoglou, Philip Power) in the area of fuel cells and hydrogen storage can impact energy efficiency and can possibly be aimed at developing better manufacturing techniques for fuel cells as a key component of the future energy storage and retrieval. In the Department of Mechanical and Aerospace Engineering the work of Professors Case van Dam and

Bruce White have focused on wind energy and can benefit from the initiatives on alternative energy as well as energy efficiency. Furthermore, Professors Paul Erickson and Valeria La Saponara have been working, respectively, on fuel cells and composite materials that are included in the first key element of the AMP program and can benefit from it.

- Several faculty members in the Department of Chemical Engineering and Materials Science have been active in the areas of Advanced Materials dealing with both syntheses as well as processing issues and can participate in various initiatives in manufacturing including the Material Genome, and the Energy Efficient Manufacturing Processes and Materials initiatives of the Department of Energy. These include Professors Joanna Groza, Enrique Lavernia, Subhash Mahajan, and Subhash Risbud.
- In the Department of Mechanical and Aerospace Engineering, several faculty members have been active in robotics research and can contribute or benefit from the key element of AMP dealing with Advanced Robotics. These include Professor Harry Cheng whose work in the development of iMobot (an intelligent reconfigurable modular robot) is being commercialized and those of Professors Bahram Ravani and Steven Velinsky on developing human-centric robotic systems for highway maintenance and construction which is directly related to AMP program element dealing with the next generation of robots that can work with human operators.

Much of the emerging manufacturing technologies is interdisciplinary in nature, and will require an environment and a culture where departmental barriers are erased. At UC Davis the graduate program vehicle is a huge advantage in that such interdisciplinary initiatives are easier to execute; this is a strength that ought to be leveraged.

➤ *Are there obvious weaknesses in areas (related to Manufacturing) that are considered vital to the future of the College and Campus?*

There is a clear lack of a coherent center of mass or inertia in terms of number of active faculty members who are directly involved in research and professional activities in the area of manufacturing. Only one faculty member was identified that was directly working and professionally active in this area while there are many others for whom part of their work can fit into some of the related areas. This means that the campus and the college can clearly benefit from allocation of a cluster of faculty positions in different aspects of manufacturing that can go across several departments or even colleges and connect to other programs and initiatives on campus such as the energy initiative or the Graduate School of Management (GSM). The GSM can be an effective player, for example, in activities related to Manufacturing Innovation and Supply Chain aspects of the manufacturing enterprise.

Furthermore, there is a clear need to make sure that the existing state of the art facilities of **IMS** laboratories and the **NC<sup>2</sup>** facility are kept up to date. This may require development of personnel and business models that can make these facilities sustainable.

Prof. Yamazaki's activities via the IMS, MTTRF, and the relationships with DTL and Mori Seiki are dependent and centric to Yamazaki, which puts UC Davis in a vulnerable position. Succession planning needs to be implemented at once and the needed resources must be available to carry this out.

The College of Engineering does not have any ongoing industry university alliances via consortia that are sustainable; no NSF I/UCRCs; nor any ERCs in the area of manufacturing. Prof. Apelian who is a Distinguished Visiting Professor (2010-2013) has noted that there is a lack of sustainable industrial collaborations in the area of materials processing or manufacturing. See: [www.wpi.edu/+mpi](http://www.wpi.edu/+mpi) as a reference of how an Institute with over 80 corporations can sustain the activities in the arena of manufacturing. Such consortia at Davis within our core strengths as well as in emerging areas should be considered and executed.

The national Laboratories have embarked on a major initiative in manufacturing sciences (LLNL, Los Alamos, etc.), and these initiatives are an opportunity for UC Davis. At the present there are no established alliances in manufacturing with our national laboratories.

- *How can we leverage existing and future excellence in manufacturing to take advantage of forthcoming state and federal initiatives, for example, in terms of externally funded centers?*

The committee strongly feels that any progress in developing national dominance in manufacturing and becoming a bigger player in some of the on-coming initiatives in this area can be most successful if is built on our existing strengths and broadening from there. The committee recommends a three-prong approach:

**1. An institutional commitment to manufacturing with allocation of resources that can include:**

- a. Providing funding for a distinguished seminar series in manufacturing innovation for the 21<sup>st</sup> century. This can be a good way of bringing top researcher in the field to UC-Davis for exchange of ideas and potential collaboration with the faculty and can help develop a momentum in this area at UC-Davis. This seminar series can also provide some national exposure for the university and help in the recruitment of top faculty members in this area to the campus. The seminar series can also serve as a prelude for the development of a workshop on the subject at UC-Davis.
- b. Allocation of faculty positions in a cluster format that would include proper succession plans for existing senior faculty in Manufacturing and hiring of new faculty who could maintain and enhance the two existing unique facilities.
- c. Formation of a Manufacturing Research Group with the appointment of a faculty coordinator and staff support to work with various faculty groups identified earlier to pursue funding opportunities and fostering more directly related manufacturing research. This effort should have the goal

of leading to a graduate group in Manufacturing, with focus in Manufacturing Innovation as an example.

- d. Staff allocation and support for upkeep of main research laboratories in manufacturing. Reduce or eliminate recharge of these facilities for attracting faculty and industry and form the alliances that are needed to launch consortia and new partnerships.
- e. Supporting and building on the existing strengths. For example, providing institutional support for the establishment of the center proposed by Professor Yamazaki for Precision Manufacturing as outlined in his power point presentation provided in the appendix of this report. Ultra Precision Manufacturing can be considered as an initial area of emphasis that can be broadened to other areas such as the interface of manufacturing and energy, advanced material processing, manufacturing innovation and other areas.
- f. UC Davis has made a commitment to Sustainable Development. There is a need to focus on Manufacturing for Sustainable Development. This includes energy, mobility – transportation, housing, food and water, and materials recovery and recycling. Faculty positions and recruitment is needed to be able to execute this vision.

2. **Develop a strong alliance with industry and the national laboratories.** This can be achieved through building on our existing strengths and relationships; we need to form alliances and provide incentives for industry to utilize our facilities and for our faculty to develop collaborations with industry. The college of Engineering has special relationships with some of the National Laboratories and we should leverage with them in the area of Manufacturing. We should also take advantage of the unique opportunity provided by the existence of DTL Corporation and the very soon nano-machining manufacturing plant of Mori Seiki USA in Davis by starting an industrial alliance and broadening it to the national level and development of an industrial consortium in this area.
3. **Develop strong alliances with extension programs and junior colleges** for training of the workforce. Much can be learned (and emulated) from the German system with their strong programs for the development of human capital that supports their industrial base. Such alliances with junior colleges and community schools will pay dividends as it will position UC Davis as an institution where the manufacturing industry can view it as a “one stop shop”.

## **Appendix A**

### **Professor Yamazaki's Presentation on How to Boost Manufacturing Initiative at UC-Davis**

# **STRATEGY TO BOOST UP MANUFACTURING INITIATIVE PROGRAM AT UC DAVIS**

**Kazuo Yamazaki, Dr. Eng.**

**Professor**

**University of California  
Davis**

**President & CEO**

**Machine Tool Technologies  
Research Foundation**

## OUTLINE

- **How to promote manufacturing at UC Davis**
- **Proposing CPM: Center for Precision Manufacturing**
- **Technical Emphasis of CPM**
- **What will CPM do?**
- **Mechanism of CPM**

## HOW TO PROMOTE MANUFACTURING AT UC DAVIS

- **Promotion Plan Concepts**
  - **Matching the needs of the nation and industries**
    - Transportation, Energy, Health
    - Keys: High productivity and High Precision
  - **Plan should be based on the current activity strength**
    - **Our Strength: Manufacturing equipment and process (Software and Hardware)**
      - Equipment: Machine Tool System (Machine tool and CNC Controllers)
      - Process: Traditional Machining (Metal Cutting) & Nontraditional Machining (EDM, EBM and Laser cutting)
  - **Plan should be based on the feasibility and sustainability from human and physical resources availability and procurement and cooperation points of view**
    - Faculty and research staff: Yamazaki and post doctoral fellows, graduate students.
    - Equipment and Facility: heavy collaboration with several key manufacturing industries and non-profit supporting organization

**PROPOSING CPM:**  
**CENTER FOR PRECISION MANUFACTURING**

By recognizing that the key manufacturing attributes of national and industrial needs are:

**High Productivity**

**High precision**

And,

More than 15 years of very active manufacturing research and education activities at UC Davis with high reputation in the nation and strong support by various international industries

I would like to propose :

**The Center for Precision Manufacturing (CPM) at UC Davis**

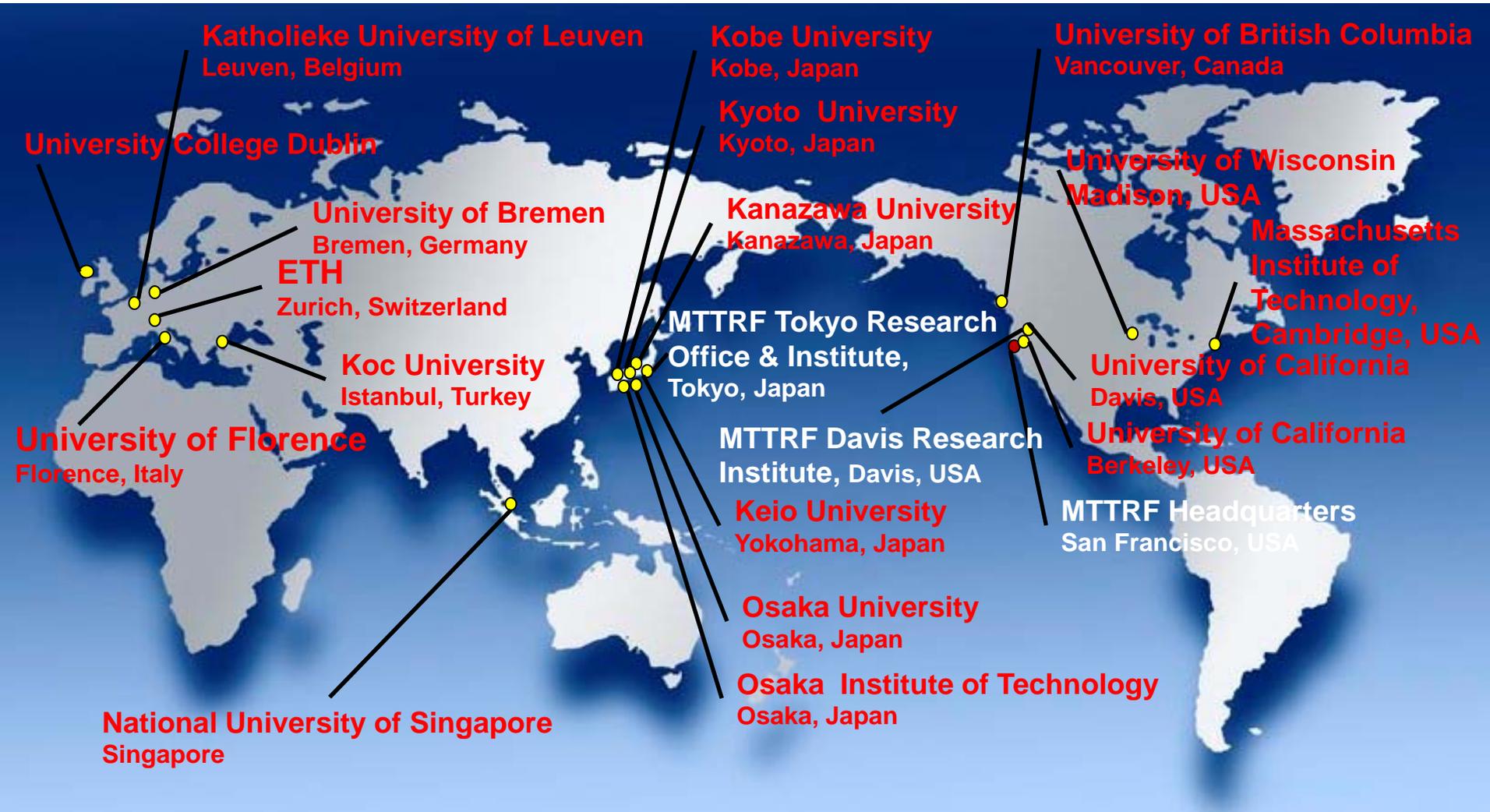
## TECHNICAL EMPHASIS OF CPM

- **Technology Focus:**  
**Machining of parts made of novel materials for US superior products, such as medical devices, energy systems, aerospace equipment , etc.**
- 1. **Productive machining of large components made of difficult-to-machine materials such as titanium, nickel-based alloys for aircraft structure and engine --- high power and high speed machining equipment and process development.**
- 2. **Productive and ultra-precision machining of miniature components made of difficult-to-machine materials such as single crystal silicone, silicon carbide, tungsten carbide --- nano and micro machining equipment and process development**

## WHAT WILL CPM DO?

- **Provide the manufacturing education for students in the real-world atmosphere**
- **Conduct the research projects on CPM focused technology areas by heavy collaboration with industry**
- **Accept in-service engineers for upgrading their manufacturing knowledge and skills utilizing the well equipped facility of CPM**
- **Carrying out the technology exchange programs with world top rated universities under the support by the non-profit public charity foundation entitled MTTRF (Machine Tool Technologies Research Foundation)**

## OUR WORLD WIDE RESEARCH NETWORK



## MECHANISM OF CPM

- **How to find the people to be educated and trained**

Students (undergraduate and graduate students) and industry engineers

Students of California residents and Students from growing economy countries, who plan or want to take over the family owned manufacturing business.

- **How to bring up the manufacturing professionals**

- Beginner to intermediate

- Undergraduate education and internship

- Intermediate to senior

- Graduate education and research and collaboration with industry

- **How to acquire the physical resources ( Facility, equipment and accessories)**

- **How to acquire the financial resources**

Gift funds raising through research and development collaboration with industries coupled with government research contract