PRESS RELEASE

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11th International Symposium on Process Systems Engineering (PSE2012)

Eminent experts to discuss how Process Systems Engineering can address global issues of energy, sustainability and environment

1. **Singapore, 06 July 2012** – The Institute of Chemical and Engineering Sciences (ICES), an institute of the Agency for Science, Technology and Research (A*STAR) and the National University of Singapore (NUS) Faculty of Engineering are organising the 11th International Symposium on Process Systems Engineering (PSE2012), to be held in Singapore during July 15-19, 2012. The theme of the event is *Process Systems Engineering and Decision Support for the Flat World*, driven by the globalisation and global issues of energy, sustainability, and environment. A*STAR Chairman, Mr Lim Chuan Poh will give a welcome address at the event.

2. The International Symposia on Process Systems Engineering have been a triennial tradition since 1982. This series of symposia has been organised by the International Organisation for Process Systems Engineering with representations from the Asia Pacific Confederation of Chemical Engineering, the European Federation of Chemical Engineering, and the Inter-American Confederation of Chemical Engineering. It has proved to be an attractive global platform for the PSE academics, researchers, and practitioners from all corners of the world for sharing advances in PSE education, research, and application.

3. Chaired by Professor Iftekhar A. Karimi and Associate Professor Rajagopalan Srinivasan from the Department of Chemical and Biomolecular Engineering at NUS Faculty of Engineering, the symposium's technical programme will comprise invited and contributed

presentations on a wide range of PSE topics. Eminent PSE researchers and professionals are invited to present plenary and keynote lectures on topics related to the conference theme and Singapore. The contributed presentations will include both oral and poster sessions on topics of traditional and emerging interest. Nearly 350 participants are expected to attend this event.

4. Professor Karimi commented, "Process systems engineering (PSE) has had significant impact on chemicals and related industries. It is assuming even a greater role in addressing the global challenges of energy and climate change. We have a large and prominent group of PSE experts in the Department of Chemical & Biomolecular Engineering at NUS. Process engineers are much needed by the petroleum, chemicals, pharmaceuticals, and semiconductor industries, and specialisation in this area is the most popular among our chemical engineering graduates. Singapore is hosting this premier PSE conference for the first time, which offers an excellent opportunity to meet the world leaders in this area."

5. The technical programme will feature single-track plenary sessions or parallel oral sessions with keynote and contributed papers, and a poster session on the evening of July 18, 2012. Distinguished plenary speakers at this symposium represent an excellent mix from academia and industry and will focus on topics of direct relevance to Singapore. Please refer to attached annex for biographies of the plenary speakers. A list of keynote speakers is also available on http://www.pse2012.sg/program.html . The main topics will include, but are not limited to:

- Modelling and Optimisation
- Product and Process Design
- Operations and Control
- Biological and Biomedical Systems
- Business Decision Support
- Information Processing and Cyber Infrastructure
- Energy and Sustainability
- PSE Education
- Water, Oil and Gas, and Pharmaceuticals

About Institute of Chemical and Engineering Sciences (ICES)

Institute of Chemical and Engineering Sciences (ICES) is a member of the Agency for Science, Technology and Research (A*STAR). Established in 2002, its mission is to carry out world class scientific research, to develop novel technology and to nurture creative scientists and engineers to support economic growth in Singapore and to make a positive difference to society. The research area covers chemistry and chemical engineering science, combined with advanced analytical characterisation and measurement to develop state of the art technology for the petrochemical, general chemical, fine chemical and pharmaceutical industries.

For more information, visit www.ices.a-star.edu.sg

About National University of Singapore (NUS)

A leading global university centred in Asia, the National University of Singapore (NUS) is Singapore's flagship university which offers a global approach to education and research, with a focus on Asian perspectives and expertise.

NUS has 16 faculties and schools across three campuses. Over 36,000 students from 100 countries enrich the community with their diverse social and cultural perspectives.

NUS has three Research Centres of Excellence (RCE) and 22 university-level research institutes and centres. It is also a partner in Singapore's 5th RCE. NUS shares a close affiliation with 16 national-level research institutes and centres. Research activities are strategic and robust, and NUS is well-known for its research strengths in engineering, life sciences and biomedicine, social sciences and natural sciences. It also strives to create a supportive and innovative environment to promote creative enterprise within its community.

For more information, please visit www.nus.edu.sg

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Annex

Biographies and abstracts of the plenary speakers
11th International Symposium on Process Systems Engineering (PSE2012)

Prof. Lorenz Biegler

Carnegie Mellon University

Biography Lorenz T. (Larry) Biegler is the Bayer Professor of Chemical Engineering at Carnegie Mellon University. He joined the faculty at CMU after receiving his PhD from the University of Wisconsin in 1981. Prof. Biegler was appointed as the Bayer Professor in 1996. His research is computer aided process engineering (CAPE) including flowsheet optimization, optimization of systems of differential and algebraic equations, reactor network synthesis and algorithms for constrained, nonlinear process control.

Prof. Biegler has been a visiting scholar at Northwestern University, a scientist-in-residence at Argonne National Lab, a Distinguished Faculty Visitor at the University of Alberta, a Gambrinus Fellow at the University of Dortmund, a Fulbright Fellow at the University of Heidelberg and a Distinguished Jubilee Lecturer at IIT Bombay. He has authored or co-authored over 250 archival publications, authored or edited nine books and given numerous invited presentations at national and international conferences.The textbook "Systematic Methods of Chemical Process Design," co-authored with Ignacio Grossmann and Art Westerberg, is a landmark in process systems engineering education. Larry's latest book "Nonlinear Programming: Concepts, Algorithms and Applications to Chemical Processes." issued in 2010.

Multi-scale Optimization for Advanced Energy Processes Increasing pressures and awareness for critical energy systems demand powerful and systematic optimization strategies for their operation. This talk presents optimization advances for energy system design and operation their influence on a number of key applications. Recent breakthroughs in optimization technology are highlighted and a number of important investigation areas featured with multi-scale models.

The presentation highlights advances in several important application areas. First, detailed multi-scale modeling for optimal design of advanced energy processes is we essential to merge device-scale (e.g., CFD) models with flowsheet simulations - and optimize them together. This is illustrated using advanced power plant. optimization as a case study Second, we consider fast real-time optimization of dynamic systems under demand and price uncertainty, as illustrated in a case study for an air separation units. Third, we discuss powerful algorithms for optimal operation of energy distribution systems; this is featured through the real-time optimization of a pipeline network.

Finally, we consider advances in optimization methods and formulations for the integration of power plant modeling and operation along with the distribution network, and present an assessment of the capabilities of current technologies to fulfill this vision.

Dr. Brenda L Dietrich

IBM Research

Biography Brenda Dietrich is an IBM Fellow and the Vice President of Business Analytics and Mathematical Sciences, at the IBM Thomas J. Watson Research Center in Yorktown Heights, NY. She leads a worldwide a team of approximately 300 professionals, most with advanced training in mathematics, statistics, data mining, machine learning, operations research or related fields. She has contributed to IBM software products and to innovative methods that are used to manage IBM's business processes. She was instrumental in redirecting a significant portion of IBM's research division to support services planning and management. More recently she participated in formulating and executing IBM's business analytics strategy.

Dr. Dietrich serves on the board of advisors of the Institute for Computational and Experimental Research in Mathematics (Brown) and on the board of governors of the Institute for Math and its Applications. She has been the President of INFORMS, the conference program chair for several conferences, and is currently on the Board of Trustees of the Society for Industrial and Applied Mathematics (SIAM). She is also a member of the National Academies' Board on Mathematical Sciences and Applications. She is also an INFORMS Fellow and a recipient of the INFORMS Kimbell Medal.

Optimizing the end-to-end value chain through demand shaping and advanced customer analytics As supply chains become increasingly outsourced, the end-to-end supply network is often spread across multiple enterprises. In addition, increasing focus on lean inventory can often create significant supply/demand imbalances over a multi-enterprise supply chain. In this talk, we discuss a set of integrated analytics for supply/demand synchronization with a new emphasis on customer facing actions called demand shaping. Demand shaping is the ability to sense changing demand patterns, evaluate and optimize an enterprise supply plan to best support market demand and opportunity, and execute a number of demand shaping actions to "steer" demand to align with an optimized plan. Demand shaping can be accomplished through various business levers, including marketing actions, price management, portfolio management, new product introductions, promotions, sales incentives, order management, and, in a configure-to-order environment, configuration recommendations.

First, we describe a multi-enterprise cloud-based data model called the Demand Supply Signal Repository (DSSR) that includes a tightly linked end-to-end product dependency structure as well as a trusted source of demand and supply levels across the extended supply chain. Secondly, we present a suite of mathematical optimization models that enable on demand up-selling, alternative-selling and down-selling to better integrate the supply chain horizontally, connecting the interaction of customers, business partners and sales teams to procurement and manufacturing capabilities of a firm. And finally, we outline the business requirements for incorporating such a process into supply chain operations, and describe findings and managerial insights from real-life experiences with demand shaping in a server computer manufacturing environment.

Finally, we consider advances in optimization methods and formulations for the integration of power plant modeling and operation along with the distribution network, and present an assessment of the capabilities of current technologies to fulfill this vision.

Prof. Wolfgang Marquardt

RWTH, Aachen

Biography Prof. W. Marquardt is the Chair for Process Systems Engineering at RWTH Aachen University. Prof. Marquardt obtained his Dipl.-Ing. (1982) and Ph.D (1988) in Chemical Engineering from the University of Stuttgart. He has been visiting Professor at the University of Wisconsin, Madison (1999) and TU Delft, Nederland (2004). He is the Editor-in-Chief of the Journal of Process Control, an IFAC fellow, the recipient of the Leibniz award of the German Research Foundation 2001, the 2002 Roger Sargent Lecturer at Imperial College and the 2008 P. V. Danckwerts Memorial Lecturer of the American Institute of Chemical Engineers and the Institute of Chemical Engineers. He is a member of acatech, the German Academy of Engineering.

Prof Marquardt's research spans various areas of Process Systems Engineering including modeling and analysis, process synthesis, process operations and control, numerical methods for dynamic simulation and optimization, and information technology (methods and tools) for the support of model-based design processes. Advances in methods-oriented research areas are benchmarked and applied to various application problems including the product design, synthesis of bio-based process plants, operations and control of chemical reactors, polymerization processes and complete plants, modeling, analysis and control of seawater desalination and wastewater treatment plants, identification of meso-scale kinetics.

Bio-based Value Chains of the Future - an Opportunity for Process Systems Engineering

Different scenarios have been published recently which predict the depletion of fossil carbon resources for the production of fuels and chemicals in face of the increasing demand of a growing world population. Despite the uncertainty of such predictions, the switch from fossil to biorenewable carbon feedstock seems to be inevitable, if we aim at equilibrating global CO2 binding and release to stop the increasing trend of the average surface temperature on our planet. This switch of feedstock provides a unique opportunity to redesign the value chain from raw materials to new molecular products if we are willing to exploit the rich molecular structure of biomass to the extent possible.

Rather than breaking the molecular structure of the biomass into C1 building blocks either by gasification to synthesis gas (CO and H2) or by anaerobic fermentation to a methane-rich gas (CH4, CO2 and H2), the synthesis power of nature should be preserved by refunctionalizing the existing molecular structures in biorenewable feedstock into new chemicals, materials and fuels. Such future products should differ from current products by their oxygen content. Current molecular products contain little oxygen because the processing effort to oxygenate fossil carbon feedstock is avoided if possible. In contrast, future bio-based products will contain higher oxygen content. Surplus oxygen has to be released in biorenewables processing. Reduction of the highly oxygenated raw material can be either reached by releasing CO2 or H2O. While the former reduces the carbon efficiency and contributes to the climate problem, the latter requires large amounts of hydrogen, which has to be produced sustainably, e.g. by means of solar water splitting.

This presentation will concentrate on different aspects of designing bio-based value chains in a future bioeconomy. We will focus on four important issues, namely the screening and evaluation of promising reaction pathways linking raw materials to platform chemicals and fuels, chemical and biochemical catalysis, biomass pretreatment using green solvents, as well as the design of bio-based processes. The talk will not only highlight the power of PSE tools to contribute to the design of future bio-based value chains. Rather, it will also illustrate research opportunities at the interface between molecular science and process systems engineering.

The presentation will be put into the context of the strategic reorientation of RWTH Aachen University as part of the Excellence Initiative of the Federal and State Governments of Germany (ExIni). The general objectives and the structure of the Excellence Initiative will be outlined and illustrated by the particular measures introduced at RWTH Aachen University to shape its scientific profile.

Prof. Gintaras Reklaitis

Purdue University

Biography Professor Reklaitis is BS chemical engineering graduate of the Illinois Institute of Technology and received MS and PhD from Stanford University. After completing an NSF postdoctoral fellow at the Institute for Operations Research in Zurich, Switzerland, he joined the Purdue faculty in 1970. He served as Assistant Dean of Engineering for Graduate Education and Research for three years and then as Head of the School of Chemical Engineering for 16 years. Since January 2004, he has been appointed the Edward W. Comings Professor of Chemical Engineering. He is also co-director of the Pharmaceutical Technology and Education Center at Purdue and heads a multidisciplinary Purdue faculty team involved in the NSF Engineering Research Center on Structured Organic Composites.

Prof Reklaitis is an author/coauthor/co-editor of eight books and over 200 publications in the area of Process Systems Engineering. He has received several national awards, including the AICHE Computing in Chemical Engineering Award and ASEE ChE Lectureship. Besides the numerous academic and professional awards, he has also got biographical citations in American Men and

Women of Science, Personalities of America and Who's Who (in Engineering, Technology Today, and the Midwest and of Engineering Leaders in America). He has served as Editor-in-chief of Computers & Chemical Engineering since 1994 and on the editorial boards of several journals. A fellow of AICHE, he has served on the AICHE Board of Directors, as Annual Meeting Chair, Publications Committee chair and Executive Committee of the National Program Committee vice-chair and chair-elect. He is a trustee and the past president of the CACHE (Computer Aids for Chemical Engineering Education) Corporation and has served on the Governing Board and Executive Committee of the Council for Chemical Research. In February 2007, he was elected member of the US National Academy of Engineering and as of January 1, 2008, he was appointed Edward W Comings Distinguished Professor of Chemical Engineering.

Process Systems Engineering: Quo Vadis? Process systems engineering, which in content if not in title has a history almost as old as the chemical engineering discipline itself, can rightly be proud of having had a remarkable and sustained impact on the chemical and related industries. Model based methodologies for process design, process control and operations have become firmly imbedded in industrial practice world-wide, with focused teams regularly applying these approaches and tools in virtually all major CPI corporations (Stephanopoulos and Reklaitis, 2011). Within academic environments, instruction in process design and control likewise was firmly embedded as a core part of the chemical engineering curriculum, beginning in the mid 60's. However, in the 90's through the early years after the turn of the century, this core gradually eroded, especially in US universities. While the US ABET criteria continue to emphasize that the chemical engineering curriculum should" enable graduates to design, analyze, and control physical, chemical, and biological processes", many departments gradually lost the in-house capabilities to provide the appropriate process engineering educational experience, have relied on adjunct faculty to meet those critical needs, and in some cases have simply scaled-back in delivering this educational experience. This was on the one hand driven by exciting developments in nanoscale materials and applied biological sciences and growth in associated research funding which stimulated departments to add faculty who could contribute to such efforts. On the other hand, declines in available research funding for PSE methodology from US R&D funding agencies coupled with reduction of industrial support for academic research in PSE areas, at least in part as a result of reduced capital investments within the developed world, caused departments to see PSE faculty candidates as less attractive contributors to the departmental research funding portfolio. Accordingly, faculty numbers in PSE declined while industry demand for engineers trained in PSE was sustained in part as a result of the needs in associated industries such as semiconductors and pharmaceuticals.

However, in the past five years, the rising cost of petroleum and associated increasing cost of transportation fuels and core chemical building blocks, the mounting shortages of potable water in many parts of the world , and the concerns to at least restrain the growth of CO_2 in the atmosphere, have driven a resurgence of research in process innovations, such as in technologies to exploit renewable energy sources and in the invention of process pathways towards biologically sourced organic chemical building blocks. In parallel, the healthcare needs of the aging populations of the developed economies and burgeoning healthcare needs of developing economies that required cost-effective solutions, have stimulated research and developments in products and processes for meeting those needs. Most recently, the economic downturn and loss of manufacturing jobs in the developed countries have awakened governments to the importance of advanced manufacturing to their economies both in terms of economic output and in creation of good quality jobs. These factors have impacted demands for PSE trained graduates both from industry and increasingly to staff university departments. It thus seems that the scene has been set for a period of growth in the PSE discipline.

In parallel with these economic drivers, the enabling technologies on which the PSE discipline can build its model-based applications have also seen tremendous growth in capabilities and scope. Four major technology drivers of particular note are massive low cost data storage, cheap and powerful computing, near universal connectivity and innovative multimode man-machine interfaces. The PSE community is already exploiting this growth in power to address large scale process problems. We are seeing applications such as the dynamic grade change optimization of a chemical plant in which the optimization formulation involves some 6+ million differential algebraic equations (Hartwick and Marquardt, 2010) and integrated production planning and scheduling applications involving tens of thousands of discrete variables (Grossmann, 2012). An important and interesting question is where can and will these capabilities take us in the next decade?

It can be predicted with certainty that PSE algorithms and tools will be enhanced to take advantage of computing and data management capabilities. Global optimization and treatment of stochastic decision problems certainly are among the methodology domains of highest potential and need. For instance, such decision problems readily arise in product development pipeline management which involve large scale multi-stage stochastic decision problems of very challenging dimensions (Lainez et al., 2012). Certainly the capabilities to store, manage and access Big Data, developments in which science applications in biology and physics have dominated to date, will allow the PSE community to effectively exploit massive process and product historical data to better model process and product performance but also to better understand and mitigate abnormal process behavior along the lines advanced by Seider and coworkers to extract, characterize and learn from process near misses (Pariyani et al 2012). The management of the information, models and knowledge, which constitute the intellectual capital of an enterprise is another area of great potential. For instance, effective knowledge management over the life cycle of pharmaceuticals is recognized as central to the quality by design process promulgated by the FDA (Junker et al 2011). While the financial and commercial worlds are already exploiting wireless connectivity and highly intuitive graphical interfaces that use visual, tactile and audio inputs and outputs to support real time distributed decision making, there is tremendous promise for applications to real time process management, extending from the plant to the supply chain.

These technologies will also allow considerable expansion of the scope of PSE problems that it will be possible to attack, ranging from design and operation of smart manufacturing systems and enterprise-wide decision support systems to socio-technical systems such as regional power and water distribution grids. Such expansions in temporal and special dimensions will be matched by PSE support for modeling and design synthesis at micro and nano scales in biological and materials applications. It is interesting to speculate whether the PSE community can establish a valued role in these application domains where scientific discovery is the driver but PSE support tools and analysis are needed to support and guide that discovery process. Developments in the discovery, manufacture and delivery of medicines for personalized treatment and developments of innovative chemical pathways to the processing biologically derived feedstocks, both of which require multiscale approaches spanning the molecular to the process scale, seem to offer significant promise challenge.

In this paper we will offer speculations and predictions on such future directions along with opinions on prospects for success and impact. It certainly seems that the PSE area of chemical engineering is on an exciting path towards reestablishing its central role in chemical engineering.

Dr. Jeff Siirola

Eastman Chemical Company

Biography Dr. Jeff Siirola recently retired as a Technology Fellow in the Eastman Research Division of Eastman Chemical Company in Kingsport Tennesee where he was for 34 years. He received a BS in chemical engineering from University of Utah in 1967 and a PhD in chemical engineering from the University of Wisconsin-Madison in 1970. His areas of interest include chemical process synthesis, computer-aided conceptual process engineering, engineering design theory and methodology, chemical process development and technology assessment, resource conservation and recovery, sustainable development and growth, artificial intelligence, non-numeric computer programming, and chemical engineering education.

Dr. Siirola is an international program evaluater and past engineering accreditation commissioner for the Accreditation Board for Engineering and Technology. He is also a trustee and past president of CACHE (Computer Aids for Chemical Engineering Education), and a member of the American Chemical Society, the American Association for Artificial Intelligence, and the American Society for Engineering Education. He has served on numerous National Science Foundation and National Research Council panels, and on the advisory boards of several journals and chemical engineering departments.

Dr. Siirola is a member of the National Academy of Engineering and was the 2005 President of the American Institute of Chemical Engineers.

A Perspective on Energy and Sustainability There is much interest in concepts of sustainability within the chemical industry, especially related to health, safety, and environmental performance, product stewardship, value chain management, efficient use of resources, and mitigation of potential climate change. However, perhaps the greatest sustainability challenges are those associated with energy production and consumption. Energy consumption directly contributes to the majority of carbon dioxide emissions, and recent estimates of future economic growth indicate that global energy consumption may more than triple over the coming decades. Since at present carbon capture and sequestration technologies are very expensive, in difficult economic times emphasis is being given first to energy conservation and fuel switching as primary carbon management approaches. A number of current issues will be discussed including economic limitations to implementing energy conservation in retrofit situations, new approaches to the optimum control of energy during process operations, techniques to hasten the utilization of biomass energy sources, and the impacts of global shale gas development.

Mr. Yatin Tayalia

GE Power & Water

Biography Mr. Yatin Tayalia is the Regional Product Sales Leader for Asia Pacific for GE Water and Process Technologies based out of Singapore. He has diverse experience spanning Sales, Commercial and Technology development in Water Treatment including Desalination. His technical areas of interest are Water Treatment Technologies, Membranes, Polymer Engineering, Process Development, Process Modeling & optimization and Computational Fluid Dynamics (CFD).

He has been with GE for last 12 years and spend significant amount of time at GE R&D center in Bangalore before moving into business roles. There he led technology group developing solutions for Polymers, Water Treatment and Process Chemicals industries and involved in projects from "Concept to Commercialization". At GE Water Technology, he led the development of membrane based water treatment design platform, equipment health and performance monitoring tools and remote monitoring and diagnostics solutions. As part of his commercial role, he developed desalination and industrial water management projects in India and Middle East. Prior to joining GE, he worked for Fluent (now Ansys) specifically focused on CFD solutions for Chemical Process Industry. Currently, he leads the sales of broad portfolio of GE Water technology products like Pressurized membrane based separation systems and components (RO, NF, UF) and Electro-separation products in Asia Pacific region.

He received his Chemical Engineering degree (Integrated BS and MS) from Indian Institute of Technology Bombay in 1996. He has 5 patents, as many filed applications, and publications in peer-reviewed journals in the field of computational fluid dynamics and in novel water treatment technologies.

Process Intensification in Water and Wastewater Treatment: Key to Sustainable Development Water is one of the world's most valuable resources. As the gap between available clean water and demand widens, the current water and wastewater treatment technologies are challenged to treat tougher waters and meet stringent environmental regulations at affordable cost. Conventional treatment technologies have been successful within limits of feed water quality, contaminant removal efficiencies, recoveries and treatment cost. However, to manage this global crisis, a holistic approach to water treatment needs to be adopted to provide a robust and cost effective solution for lot more demanding requirements.

The paper explores key trends in water treatment at technology, equipment design and at system design level that significantly impacts the total solution and ability to meet the overall requirements.

Also specific developments in desalination and wastewater treatment technologies like Reverse Osmosis, Ultrafiltration, energy recovery devices and Membrane bioreactors are discussed that have significantly widened the capability envelope. An integrated multi-scale approach to system design leveraging various technologies can provide the viable alternatives and meet this global challenge in sustainable way.

Dr. Michael Thien

Merck & Co., Inc.

Biography Dr. Thien has worked in new product and process development at Merck for over 20 years. After receiving his B.S. in Chemical Engineering from Caltech (1982), an Sc.D. from MIT in biochemical engineering (1988) and a post doc at the Whitehead Institute of Biomedical Research, Mike joined the Merck Research Labs, working in vaccines and recombinant proteins. In 1991, Dr. Thien led a process development group for compounds made by organic synthesis, continuing in that capacity until 1997. During this time Dr. Thien was named a Merck Research Labs "Divisional Scientist" as a result of his development and plant start-up work on CRIXIVAN, one of the first HIV protease inhibitors in the marketplace. Between 1997 and 2003 Mike held roles of increasing responsibility including Senior Director of chemical pilot plant operations and Executive Director of chemical process development. Dr. Thien was named Vice President, Process R&D in 2003 covering analytical and engineering development of Merck's small molecules.

In 2005, Mike co-led a team to re-define the paradigm by which Merck brings new drugs to market. This effort resulted in the creation of a new function at Merck: the Global Pharmaceutical Commercialization organization. This group includes engineers and analysts from both R&D and manufacturing and reports up through manufacturing. In 2005 Mike was appointed to head this group and was made responsible for both late stage process development and the making of clinical and commercial launch supplies for all of Merck's new drugs, with responsibility for chemical and formulation development and manufacturing efforts at facilities in New Jersey, Pennsylvania and Ireland. In October of 2008 Mike took on the additional responsibilities of leading technical support for Merck's in-line small molecule and vaccine products. In April of 2009, Dr. Thien was appointed to Senior Vice President, Global Science, Technology and Commercialization where he became additionally responsible for the analytical sciences, statistics and packaging technology for manufacturing. Mike has made numerous invited conference presentations and guest lectures on the pharmaceutical industry and has served on advisory boards for MIT and the U.Texas at Austin and chairs a similar board for the Department of Chemical and Biomolecular Engineering at Tufts University.

Applications of Technology Roadmapping to Planning and Building Systems for Medicine and Vaccine Manufacturing Technology Roadmapping is a process that has been applied effectively to the identification, selection, acquisition, development, exploitation, and protection of technologies in a variety of industries. We explain how this process and framework can be adapted to the management of technologies used in the manufacture of medicines and vaccines from the raw materials to the use by the patient and customers. Considerations are offered on how to manage technologies that are product, process or infrastructural and whether the technologies are needed to maintain or grow an organization's business starting with the patient needs and strategic requirements in mind.