Message from the Chair

Ram D. Sriram

Welcome to the 2012–2013–summer edition of the CIE Division newsletter. In addition to reviewing our activities over the past year, the newsletter is also a forum for our members to express their views. Here are some highlights that I would like to share.

A strategic plan was put in place with four major goals: 1) Ensure that the division has considerable impact on engineering; 2) Improve the participation by technical committees; 3) Increase membership; and 4) Develop outreach activities. To successfully achieve these goals we will need your active participation in various CIE activities. To realize our third goal, in addition to recruiting new members, we would like you to go to the ASME website and ensure that your primary division is CIE. The Division is willing to support activities related to the above goals. Please feel free to contact either the Executive Committee members or Technical Committee leaders for any suggestions you may have in helping us achieve our goals.

The yearly award program has been very successful with a backlog for several of the awards. This year we introduced a new award for the best doctoral dissertation and the response has been overwhelming. I am pleased to inform you that two of our past awardees namely the 2011 Life Time Achievement Winner Charbel Farhat and 2012 Leadership Award Winner Paul Adams have been elected as the members of the prestigious U.S. National Academy of Engineering.

I would like to thank the CIE community for being very responsive to the various deadlines for this year’s conference. We have accepted 117 papers, with several panels planned. Jon Hirschtick, founder of Solid Works, will be our keynote speaker. Our technical committees will meet on Monday during lunchtime. Please contact the technical committee chairs if you plan on attending these meetings. One of the highlights of the conference will be the student poster session, which will be held on the Tuesday evening. This will be followed by the CIE awards ceremony and reception.

There will be a few changes in the Executive Committee. Effective July 1st, Ashok Kumar, University of Florida, Gainesville, will be the Division chair and I will take over as the chair of the Honors and Awards Committee from John Michopoulos, who has made invaluable
contributions to the success of CIE over the past 6 years. Bipin Chadha, who has been helping us in our outreach activities with the industry, will finish his term as our Industry Executive. Marc Halpern, Vice President, Research, Manufacturing Advisory Services, Gartner Inc, will be our new Industry Executive. We thank both John and Bipin for their excellent service, and we welcome Marc aboard. Our new Member–at–Large will be selected before July 1st.

Honors and Awards
Our division’s honors and awards were awarded, as usual, during our annual conference, the 32nd CIE conference that took place August 12–15, 2012 in Chicago, Illinois.

This year the CIE Lifetime Achievement Award supported by Infotech Enterprises was awarded to Dr. Jami Shah, Arizona State University, Professor, Founding Editor of JCISE, “In recognition of his outstanding contributions to furthering the discipline of computers and information in engineering.”

The CIE Leadership Award was given to Mr. Paul R. Adams, Senior Vice President, Operations & Engineering, at Pratt & Whitney, “in recognition of his outstanding leadership in furthering the discipline of computers and information in engineering.”

The CIE Excellence in Research Award was awarded to Dr. David W. Rosen, Professor, Georgia Tech, School of Mechanical Engineering, Associate Chair for Administration in the School of Mechanical Engineering, Director of the Rapid Prototyping & Manufacturing Institute at Georgia Tech, “in recognition of his research excellence in the discipline of computers and information in engineering.”

This year the CIE Young Engineer Award went to Dr. Gregory Michael Mocko, Associate Professor in the Department of Mechanical Engineering at Clemson University, “in recognition of his ability and potential for making significant contributions to the discipline of computers and information in engineering.”

The Distinguished Service Award was given to Mr. Fred Proctor, NIST, “for his distinguished leadership of the CIE division.” The 2012 Service Award was given recognizing Dr. Mahesh Mani “for his sustained contributions to the CIE division newsletter.”
The Best of Conference Paper Award was awarded to Sujal Bista, Sagar Chowdhury, Satyandra Gupta, Amitabh Varshney, University of Maryland, College Park for the paper, "Using GPUs for Realtime Prediction of Optical Forces on Microsphere Ensemble" and Fnu Vinayak, Sundar Murugappan, Cecil Piya, Karthik Ramani, Purdue University for their paper, “Handy-Potter: Rapid 3D Shape Exploration Through Natural Hand Motions.”

More information on these awards, and how to nominate candidates, can be found on the CIE Division web page under “Honors and Awards.”

The Year in Perspective
John Michopoulos

This year I have had the honor to graduate to the role of the past chair of the division and have passed the leadership to the Ram D. Sriram as the new CIE Division Chair. In reflecting over the past year I cannot help extending my view over the past five years of my participation in the CIE Executive Committee (ExComm), as I feel compelled to share the most important lessons learned and some of the most important achievements that I was lucky enough to experience.

The most important lesson was that nothing could be accomplished relevant to the goals and objectives of the division without the brilliant and hard work from all members of the ExComm. I have been very fortunate to work side by side with adroit, self-motivated and benevolent individuals who enabled and supported my proposals and initiatives in a manner that transforms all sweaty aspects of volunteer work to a very joyful endeavor. For that alone, I wish to express my deepest appreciation to all members of the ExComm before and after my arrival. In addition, Imre Hovarth, Chris Paredis, Ravi Rangan, Fred Proctor, Shuichi Fukuda, Ram D. Sriram, Ashok Kumar, Josh Summers, Krishnan Suresh, Monica Bordegoni, and all members of the Technical Committees leadership, all deserve the huge appreciation of all members of CIE, as they have really been the engine under the hood of CIE.

The second important and disappointing lesson I learned is that the mechanics of institutional inertia are stronger than the strongest efforts of the ExComm members within a single ExComm cycle. Specifically, proposed changes relative to methods and procedures or revisions to web tools relevant to the operational support of the divisional activities, including the web page of the division and the paper management system for the CIE conference, take much longer time that we would like them to take and sometimes never get done within one single ExComm cycle.

On the positive side, some of the most notable achievements during my tenure in the ExComm have been the following:

Attendance in the CIE conference not only has reached the highest levels ever observed, but also has remained in sustainably high levels.

In addition to the annual conference, the division has decided to initiate a new book series, containing peer-reviewed chapters, aiming to capture the cutting-edge research topics across all disciplines of CIE. Each volume in the series, is designed to cover advancements for the past five years. The first volume of the series is planned for 2014 (book series update on Page 17).

We have established and maintained a tradition of honoring excellence via the expansion of our awards program. New awards (Lifetime Achievement,
Leadership, Excellence in Research and Young Engineer) have been established mainly via the ingenious initiative by Dr. Ram D. Sriram. Even this year we have expanded the awards to include a Best Dissertation/Thesis award suggested by our international incoming member Monica Bordegoni and will be awarded for the first time at the 2013 conference.

Our technical committees have remained active, have maintained the highest levels of excellence and have provided considerable support to the ExComm for all projects that required their support.

In addition to the division bylaws, we all worked together to formulate the first division strategic plan for the next five years.

The custodial account of the division has reached its maximum balance ever. Although this is very good news, it also presents the challenge and a responsibility for the best utilization of the funds for expanding CIE membership, community reach, training and other innovative programs and activities.

Computers and Information in Engineering is not just a division of ASME. It is a constructive composition of technological areas that are shaping the interdisciplinary synergism of all engineering activities now and in the future way beyond what mechanical engineering was even five years ago. I strongly believe that the CIE division is a vibrant organization that has enabled and fueled the advancement and progress across all these areas and has the potential to shape the future of research and development everywhere. I have been honored and blessed to have experienced the transformative power of collaboration with colleagues, who all share the same convictions on excellence and progress.

Despite the fact that mechanical engineers are expected to be naturally pragmatic, and therefore know that wishes do not carry weight, instead of wishing you, I would like to salute you all with a thought from Protagoras: "Human is the measure of all things."

Therefore, evaluation of Advanced Modeling and Simulation, or Computer–Aided Product and Process Development, or Systems Engineering, Information, and Knowledge Management, or Virtual Environments and Systems, still implies that your actions are based on your knowledge and beliefs. May you all work on the automation of re–examining and re–establishing your beliefs, the same way your creativity generates models of reality on all computational substrates.

CIE 2011 Conference Report

Ram D. Sriram, Ashok Kumar, and John Michopoulos

The 32nd CIE conference was held in Chicago, August 12–15, 2012. We received over 200 papers for review, out of which 157 papers were accepted and organized into 40 sessions. The conference provided an excellent platform for exchanging ideas. We truly appreciate the hard work of our technical committees, various topic and symposia organizers, and our referees.
Keeping tradition, there were several excellent tutorials and workshops on Sunday. Our CIE members were involved in organizing several workshops: Shuichi Fukuda on Brain–Body–Emotion, Dan Negrut on Parallel Computing on GPUs, and Paul Witherell and Rachuri Sudarasan on Sustainability. This year, there was a significant change in our luncheon and award ceremony. The general conference chairs decided to have a common luncheon for the entire conference. Hence, we did not have a CIE luncheon, keynote, and award ceremony as a single unit. Instead, the CIE keynote was held before the conference luncheon on Tuesday and the awards ceremony was held in the evening, along with the student poster session. Light refreshments were provided for the award ceremony, and we thank our ASME staff for ensuring we were all well taken care of. The CIE division general meeting was held after the award ceremony. The four technical committee meetings: Advanced Modeling and Simulation (AMS), Computer–Aided Product and Process Development (CAPPD), Systems Engineering, Information and Knowledge Management (SEIKM), Virtual Environments and Systems (VES) were held during the lunch break on Monday, as is the normal practice.

Mr. Randall W. Huber

Mr. Randall Huber, division manager of the Advanced Virtual Product Development team at Caterpillar Technical Center, was our keynote speaker. Randall’s talk entitled “Helping Shape Future Caterpillar Products,” discussed the role of simulation in Caterpillar’s product life-cycle. We also had a special lecture on Wednesday (August 15th) by Dr. James Warren, who heads the Material Genome Initiative at the National Institute of Standards and Technology, provided an overview of the Material Genome Initiative, which was announced by President Obama in June 2011.

Dr. James Warren

Our awards ceremony on Tuesday evening recognized contributions to CIE in several categories: Lifetime Achievement, Excellence in Research, Young Investigator, Leadership, Distinguished Service, Fellows elected in the July 2012–July 2013 time period, and Best Paper awards. Infotech Enterprises made a five year commitment to support the Lifetime Achievement award. We thank Infotech Enterprises for its support. The first recipient of this award was Prof. Jami Shah, Arizona State University. The various award winners and their citations are provided later in the newsletter. The awards ceremony was preceded by the student poster display. 16 posters were displayed. We thank NIST’s yearly support of this program.

The 33rd CIE conference will be held in Portland, Oregon, from August 4–7, 2013. We look forward to meeting you there.
Division Members Elected to Fellow Grade

This year there were several division members elected as Fellows.

Prof. Richard Crawford, Department of Mechanical Engineering, University of Texas at Austin (Elected Fellow 2011, award received 2012)

Prof. Imre Horváth, Department of Design Engineering, Delft University of Technology

Prof. Stephen C–Y Lu, David Packard Chair in Manufacturing Engineering, University of Southern California

Prof. Cho Solomon To, Mechanical & Materials Engineering, University of Nebraska–Lincoln

Prof. Uma Jayaram, School of Mechanical and Materials Engineering, Washington State University, Pullman, WA

Dr. Sudarsan Rachuri, Program Manager, Sustainable Manufacturing, Engineering Laboratory, National Institute of Standards and Technology
Technical Committee Reports

Advanced Modeling and Simulation (AM&S)

Brian Dennis

The goal of AM&S is to promote the use of advanced modeling and simulation in solution of engineering problems and to encourage the development of new algorithms and software that lead to fast and more accurate simulation tools. This year 66 papers were accepted among the various topics in Advanced Modeling & Simulation. The presented topics ranged from new numerical methods for solving differential equations to applied engineering analysis with commercial modeling software. Two new topics were added this year: High Performance Computing and Topology Optimization. The complete list of AM&S topics presented at the Chicago conference is detailed below.

1. AMS General: A broad range of topics on modeling of simulation, especially those not included in the special sessions below.

2. Inverse Problems in Science and Engineering: Papers focused on the solution to inverse problems including shape design, material properties determination, boundary values/initial value identification, force & source determination, and governing equation determination were presented.

3. Material Characterization: This symposium included a wide range of material characterization issues including the development of methods and their applications and advancing material characterization for high-performance simulation.

4. High Performance Computing: This topic incorporates the developments and applications in GPU computing and has been expanded to include other areas of high performance computing including heterogeneous GPU/CPU computing and cloud computing. The organizers hosted contributions that demonstrated high performance computing in various fields including CAD, CAE, CAM, CFD, and Life-sciences.

5. Topology Optimization:
This topic involved the various aspects of topology optimization applied to advanced material and structural systems. Papers involving recent advances in topology optimization were presented.

AMS GPU Workshop
This workshop provided a GPU computing how-to tutorial that was augmented with a hands-on GPU programming session. The participants had the opportunity to use their laptops to remotely log into a GPU cluster and understand through concrete hands-on examples some of the concepts covered in the first part of the workshop. The workshop concluded with a discussion of optimization techniques for effective GPU computing and an overview of research that has benefited from the computational power available on today's commodity GPU cards.

AMS Paper Award:
We awarded the AMS Best Paper to: DETC2012-71050 “High dimensional full inverse characterization of fractal volumes,” by John Michopoulos and Athanasios Iliopoulos.

AMS TC Leadership
Chair: Brian Dennis, University of Texas, Arlington, dennisb@uta.edu
Co-Chair: Krishnan Suresh, University of Wisconsin, Madison, suresh@engr.wisc.edu
Vice Chair: Yan Wang, Georgia Institute of Technology, yan.wang@me.gatech.edu
Secretary: Mahesh Mani, University of Maryland, mmani@umd.edu
Computer-aided Product and Process Development (CAPPD)

Charlie C. L. Wang

At this year’s conference, five tracks are organized by the CAPPD technical committee. Topics included traditional areas of interest in CAPPD such as Geometric Modeling, CAD, Manufacturing and Process Planning, Modeling, Analysis and Optimization in Design/Manufacturing plus those recent trends about Emotional Engineering, Engineering Applications of Brain Science and Human Models as well as Modeling Tools and Metrics for Sustainable Manufacturing. Each submission is reviewed by 2–3 reviewers, where a few marginal papers are reviewed in two rounds. Finally, 52 papers are accepted to form 12 technical sessions, where 5 sessions are under the general CAPPD track (CIE–2), 3 sessions are under the track of Emotional Engineering (CIE–16), 2 sessions are under the track of Engineering Applications of Brain Science and Human Models (CIE–19), and other two sessions for Sustainable Manufacturing (CIE–18–1) and Tolerance Allocation (CIE–20–1).

**Awards**: This year’s Prakash Krishnaswami Computer-Aided Product and Process Development Technical Committee Best Paper Award was from “Direct Geometry Processing for Tele–Fabrication,” (DETC2012–71483) by Xiaoping Qian (Illinois Institute of Technology), Yong Chen (University of Southern California), and Kang Li (Illinois Institute of Technology). In addition, a CAPPD Best Paper Award was presented to “Robust Optimization of Mixed–Integer Problems Using NURBS–Based Metamodels,” (DETC2012–70573) by John C. Steuben and Cameron J. Turner (Colorado School of Mines).

This year’s CAPPD Leadership and Service award was presented to Dr. Derek Yip–Hoi from Western Washington University for recognizing his continuous service and contribution to the technical committee.

Graduate Student Poster Session

This year’s CIE Division Graduate Student Poster Session continued to be organized by the CAPPD technical committee. A total of 16 posters were submitted from 6 different universities. The Manufacturing Systems Integration Division at National Institute of Standards and Technology was again able to provide travel awards of $1000 a piece to five students selected for the excellent quality of the work they submitted. Three additional stipends of $600 each were also sponsored from the operating budget of the CAPPD committee. A full listing of the award recipients and their research poster titles is as follows:

**NIST Awards**
- Bryan O’Halloran (Oregon State University): A Framework to Generate Fault-Based Behavior Models for Complex Systems Design
- James Mathieson (Clemson University): Design Project State Prediction
- Essam Z. Namouz (Clemson University): Automated Assembly Time Estimation Method
- Matthew G. McIntire (Oregon State University): Automated Data Collection through Text Mining for Consumer Choice Modeling in Engineering Design
- Ryan Arlitt (Oregon State University): Discovery of Cognitive References used for Analogy Formation in Function–Based Design

**CIE–CAPPD Stipends**
- Dani George (Clemson University): Concept Generation Through Functional Combinations and Options Matrices
- Akshay Agrawal (Vanderbilt University): Verification Workflow for Model-based Development
- Yang Hu (Washington State University): Estimating Selective Disassembly Time through Disassembly Graph based Connective Complexity Metrics
Current TC Leaders
Chair: Jitesh Panchal, Purdue University, panchal@purdue.edu
Vice Chair: Gaurav Ameta, Washington State University, gameta@wsu.edu

Secretary: Caterina Rizzi, University of Bergamo, caterina.rizzi@unibg.it
Past Chair: Charlie C. L. Wang, The Chinese University of Hong Kong, cwang@mae.cuhk.edu.hk

Virtual Environments & Systems (VES)
Monica Bordegoni

The Virtual Environments & System (VES) technical area hosted 26 presentations that were organized into 6 sessions. Four sessions addressed general issues regarding virtual reality and systems, including virtual reality technologies for assembling, training, maintenance and robotic applications.

A key trend was the study of new interaction techniques based on 3D interaction, tracking systems, haptics for industrial applications in various domains. In particular, a specific session on 3D interaction techniques has been successfully launched in this conference edition. Besides, an additional session has been organized on VR in Product Conceptualization & Design.

The VES community has shown a growing interest towards the use of Virtual and Augmented Reality technologies, where the various technologies find their application in several industrial domains, as aerospace, automotive, manufacturing, as well as non-industrial domains, as the medical field.

The VES best paper award was assigned to the paper by Erik Bonner and Jan Berssenbrüegge entitled "GPU-Based Local Tone Mapping in the Context of Virtual Night Driving."

TC Leadership
Chair: Abhishek Seth (abhishekseth@gmail.com)
Co-Chairs: Monica Bordegoni (monica.bordegoni@polimi.it), Sven Kreft (sven.kreft@hni.uni-paderborn.de)
Secretary: Hai Jun Su (su.298@osu.edu)
Past Chair: Jan Berssenbrüegge (jan.berssenbruegge@hni.uni–paderborn.de)

Systems Engineering, Information and Knowledge Management (SEIKM)
Ying Liu

An observation of fast-rising interests shown in the Systems Engineering, Information, and Knowledge Management (SEIKM) activities is related to design and engineering problems centered on their complexity, large size, uncertainty and the big data simultaneously generated. To help the community and industrial folks coping with such challenges, several efforts have been advanced at SEIKM Technical Committee (TC).

Since 2009, Design Informatics (DI) has emerged as a Special Session, then a Special Symposium, and now starting from the 2012 CIE conference in Chicago, IL it is elevated as a permanent topic under SEIKM TC. DI is particularly interested in how design information and knowledge are being generated, represented, perceived, interacted – stored, searched and retrieved, and reused from conceptual design to the end of product lifecycle. It has its very own nature of multidisciplinary study and harnessed the latest advancements in machine learning, data/text/multimedia mining, information retrieval, semantic technology, ontology engineering and so on. Several crucial aspects that DI emphasizes include data analytics, handling of big data, information retrieval and knowledge management, semantic-based applications.
and so on in design and engineering. Seven papers were presented in the 2012 Chicago Conference.

Meanwhile, the advances in the Complex and Large Scale Engineering Systems have successfully maintained its momentum in attracting significant interests in the community. SEIKM TC has continued to sponsor the Special Symposium on Model–based Design and Verification of Complex and Large–Scale Systems. This symposium was successfully marketed as a venue for works and topics related to 1) Principles and methodologies for designing systems of systems, 2) Formal verification methods for platform–based complex systems design, 3) Pre–verification of design patterns for hardware/software co–design, 4) Integration of cyber–physical systems design across multiple abstraction levels through meta–modeling, 5) Trading complexity as a quantifiable systems engineering design parameter, and so on. The year 2012 has witnessed a well–attended symposium with 14 papers presented.

In cognition of significant research progress achieved, the 2012 SEIKM Best Paper Award was given to:

Several workshops were hosted by SEIKM contributors in 2012, and this trend will continue in Portland, OR. Furthermore, for the coming year 2013 conference in Portland, the CAPPD Poster Session has been rebranded as the CIE Poster Session. SEIKM TC will work closely with other TCs to identify and select those promising research efforts, which are led by postgraduate students and are still at their early stages to be reviewed and appreciated by the SEIKM, and CIE community at large. After the SEIKM TC annual meeting held at Chicago, the following leadership team was elected. Please feel free to contact anyone of us if you would like to learn how to become more involved with SEIKM activities.

TC Leadership
Chair: Ying Liu, National University of Singapore (mpeliuy@nus.edu.sg)
TC CIE Program Chair: Matt Bohm, University of Louisville (matt.bohm@louisville.edu)
Secretary: Chris Hoyle, Oregon State University (Chris.Hoyle@oregonstate.edu)
TC Past Chair/Award Chair: Richard Malak, Texas A&M University (rmalak@tamu.edu)
Large, engineered systems have undergone a major transformation over the past 50 years. They have grown in size, autonomy, and complexity. Much of that growth can be attributed to the large infusion of cyber technologies into heretofore physical systems. This is not about adding cyber technologies "on top of" conventional physical systems where both sides maintain separate identities. This is about marrying cyber technologies with physical systems, at multiple temporal and spatial scales, to create new kinds of systems. Clearly, the technological advantages brought about by such a marriage can have broad benefits on the economy and the society. We call the resulting marriage, Cyber–Physical Systems (CPS).

Cyber–physical systems are not simply the connection of different kinds of components. They are rather a new system category, which is simultaneously physical and computational. Graphically, CPS can be viewed as a multi-layered network of strongly interacting physical, computational, and human components. The nature of the interactions between system components continues to evolve. Components are inextricably intertwined, such that the impact of a change in any component can propagate to distant parts of the system. The impacts of that change are often unpredictable and neither fully traceable nor path independent. The interactions between components are not stable and may change over time. Consequently, total system behavior is often rife with surprises and unintended consequences.

The result is that cyber–physical systems exhibit evolutionary behaviors that are (1) increasingly dynamic, unpredictable, and complex, (2) the results of the structural interactions among the various components, and (3) whose cause and effects are often highly unpredictable and separated in time and space [1]. It is not possible, however, to determine whether these evolutionary behaviors are the result of components acting alone or their interactions with other components. How to engineer these cyber–physical systems, therefore, is a question of both theoretical and practical importance. Currently, engineering of any physical system is based largely on a top–down, three–step approach commonly called reductionism. Its fundamental premise that physical systems can be decomposed into separately addressed components; and, more importantly, that a total understanding of every component in isolation leads directly to a total understanding of the overall system.

Inferring system behavior from its components' behavior is possible only if two critical assumptions are valid: compositionality and composability. Compositionality means that system–level properties can be computed directly from component–level properties. Composability means that component properties are not changing in any fundamental way as a result of any interactions with other components. Because of the strong influence of component interactions on system behavior, the compositionality and composability assumptions are not valid for cyber–physical systems. Therefore, a fundamental rethinking of engineering theories, methodologies, and, practices is needed. In the following sections, we summarize a number of those theories, methodologies, and, practices and propose a new approach called consilience–based engineering.

Systems Engineering

The classic reductionist approach to systems engineering is embodied in the 'V' shape. The V shape comprises a set of methods starting from requirements, hierarchical decomposition, component design (down

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the left-hand side of the V) and component testing, subsystem composition test, and finally, systems testing (up the right-hand side). This approach works extremely well when there are clear definitions of functional boundaries. This clarity was present even when there were numerous possible choices (say n) for the requirements–to–functions decompositions. Further, for each such decomposition there may be many possible realizations (say m) of the physical corresponding physical components. This means that there are n*m possibilities to realize a given system design; at each level of the decomposition.

However, with the introduction of cyber components, the functional boundaries of components have become more ambiguous. Ambiguity arises because of the potential for computationally efficient choices (say r) for replacing some or all of the functions of, and the interfaces between, physical components with cyber components. Such choices add to the complexity of both the design process and the result products. They change the original functional–to–physical mapping into a functional–technology–realization mapping. The resulting complexity goes from n*m (order n squared) to n*r*m (order n cubed) for each subsystem in the system network [2]. In addition, the specification of interface requirements has become dramatically more difficult. This happens because of the constant change in the boundaries between the physical and cyber components. As the authors in [3] have observed most failures in systems design happen at the interfaces, which presents significant design challenges.

**Software Engineering**

One can observe that the field of software engineering has changed from the earlier approaches of waterfall model of software development to more flexible model represented by Spiral model of development [4]. Currently software engineering is moving away from value-neutral approaches (requirements to product without any analysis of the intrinsic and explicit value of software products) to value-based approaches that advocate concurrent engineering, justification of choices, evaluation of real options in terms of strategy and evolution and issues of ethical production of software [5, 6]. These efforts not only address the issue of the tangible and intangible value of these systems but also the fact that to avoid failure, concurrent engineering must focus on the interfaces between different systems [7].

**Concurrent Engineering**

Concurrent engineering is another approach that originated in the 1980’s in the design of complex engineered systems like cars, aircraft and other products [8]. The main focus of this approach has been to bring the variety of functional perspectives and disciplines in the context of design and manufacture of systems. These approaches focus on ensuring that identification potential mismatches between the different subsystem and the interfaces early in the process of design. It is well known that the cost of mismatch when caught early in the process is less than when the mismatch is identified at the later stages of product development and manufacturing process. To facilitate concurrent engineering, considerable effort was placed on developing collaborative engineering tools some of which have evolved over time and entered the main stream in engineering [9].

**Cognitive Systems Engineering**

Another discipline that has made an impact on the design of physical systems over the last 25 years is cognitive systems engineering. Cognitive systems engineering has focused on the match between the human cognitive ability and the interface to the physical system. Originally, started from the design of operator rooms for nuclear power plants, this effort has moved to the area of cockpit design for aircraft and other interfaces where the criticality of reaction of the human in the loop to respond to the state of system [10]. In this view of systems design, the combination of operators and machines constitutes the system. Operators here are not users in the sense of human–computer interaction but of humans, machines, and systems that constitute the workplace.
Cognitive systems engineering is distinguished from the study of human computer interaction (HCI). HCI has evolved into the new discipline of Interaction Design. The history of this evolution is recounted in [11]. Here, the human is considered a user with a free range of operations – examples include the mouse and the smartphone. The underlying principles of interaction design still have limitations in the sense of treating the process of interaction as purely an information processing task [pg. 17–19, 10]. As more of these devices become part of the work environment, the necessity to incorporate the lessons of cognitive systems engineering will become critical, since users will no longer have complete freedom. Instead, they will become operators in the work environment with specified functions to perform.

Model–based Engineering

In systems engineering a new trend is to increase the use of computer–interpretable models especially in the specification and design stages. This approach is generally known as model–based engineering. Model–based engineering is an attempt to codify the underlying information models that characterize the different aspects of designed product. The model–based effort has always existed in the form of modeling physical systems through differential equations and other mathematical and graphical formalisms in systems engineering. What is new in the recent effort is to create models that represent software in languages such as UML [12]. In the systems engineering domain, the extension and adaptation of UML to systems design has resulted in intuitive modeling tools such as SysML [13].

Social Aspects of Engineering

For the most part, the social aspects of systems engineered using the aforementioned approaches are neglected. That is, the role that humans play in the operation and maintenance of such systems is rarely included in their design. The famous sociologist, Charles Perrow, in his analysis of the accidents at Three Mile Island and other complex engineered systems, points out that it is impossible to identify all the paths and dependencies in such a system. He concluded, therefore, that many of these catastrophic accidents are what he called “normal” [14]. What he meant by this term is that such accidents are a part of the systems design that often remain unknown to the designers. He and others recently refined this theory of “Normal Accidents” to make the case that as the complexity of the engineered system increases, the humans, organizations that interact with and manage these systems often contribute to their failure. He also argues that if the system is monolithic and tightly integrated the potential for dire consequences of such failures can be catastrophic as was the case in Fukushima, recent financial crisis and other disasters [15, 16]. In his essay on complexity, catastrophe and modularity [17], he argues such systems should be linearized and modularized to ensure that any failure remains local and poses minimum vulnerability both to the systems themselves and to the surrounding societal and environmental systems. This thesis is based on the idea that events with very low probability but very high consequences cannot be ignored when designing and building systems whose complexity is not fathomable. Recent experiences of Fukushima and the financial crises, among others, certainly lend credence to this thesis [18].

A new consilience–based approach to Engineering

Consilience, according to the famous entomologist, E.O. Wilson is the synthesis of inductions from more than one discipline [19]. From this perspective, consilience in design is to draw upon all disciplines that can inform the design of a system in ways that transcend these disciplines themselves. As noted above, the V-structured systems engineering approach of the past is no longer viable. The rising complexity of engineered systems, the growing infusion of cyber components into these systems, and proactive role of humans and other social institutions in these systems makes the need for a new approach imperative. This new approach is what we call a “consilience based approach” [20]. This approach relies on integrating the product characterization in terms of complexity and the societal
characterization in terms of its associated disciplinary perspectives. These disciplinary perspectives come with their own inductions on the structure and behavior of complex systems as we have observed in the previous section. The question then is how do we integrate these inductions and perspectives?

Engineers model every physical and cyber component of the cyber physical system. Without these models, they could not achieve either a comprehension of, or a valid design of, that system. Each model, by its nature, is limited in scope. Each model attempts to replicate the behavior of the corresponding component. Therefore, multiple models are needed to capture every aspect of the system and to predict its overall performance under different operating conditions. Moreover, these models are refined continually to deal with anomalies that arise in the system over time. A very nice example is from aircraft design, where computational fluid dynamics models, wind tunnel experiments with physical models, and inflight testing of prototype models are all used to understand different aspects of the performance of a new aircraft.

Since each of these models is developed and tested using different technical disciplines, there is the need for additional models that serve as interfaces between the disciplines and the models that participate in the design. These additional models capture the information exchanges that represent the interfaces between the disciplines and the models. UML for software engineering and SysML for recording the interactions during the requirements stage among software, hardware and physical systems are used to represent those information exchanges.

Following the traditional V structure, these component cyber, physical, and information models would be developed and tested separately before attempting to integrate them into a system model. However, this approach fails to account for the potential, unintended, emergent behaviors that arise from the integrated system. Moreover, the additional post–hoc integration of separate societal models will only increase the likelihood of those behaviors. Hence, we need an approach that takes into account the financial and social value of engineering in CPS as they are highly integrated heterogeneous components and systems that need to be failure proofed by design. In doing so, we argue that the resulting systems must maximize safety and reliability, and minimize the potential consequences of their failures.

To address this need we advocate the extension and propose that a model–based approach that characterizes all aspects of the Cyber Physical Social System (CPSS) be undertaken. This approach not only models the Cyber–physical part but also includes models of human–CPS interactions and organization–CPS interactions. This approach necessarily borrows modeling methods from the traditional scientific and engineering disciplines described above. Additionally, it requires the creation of new modeling paradigms to represent (1) the temporal/spatial interfaces among all components, (2) the behaviors of the human and societal components, and (3) their interfaces with the CPS components. For example, there is a need for time encoded programming languages as proposed in [18] for cyber physical systems. On the other hand, understanding the interactions between humans and machines and developing high fidelity models of those interactions is a relatively new cross–disciplinary effort. Similarly, we would require network models of human behaviors – both individual and collective – and organizational behaviors of relevant societal systems. More importantly, we need cross–disciplinary models that can be used to evaluate vulnerabilities arising from the interactions and dependencies between human, organizational, and CPS components.

The advocated model–based approach specifically addresses the dynamic relationships between the system’s structure and its behavior. This approach starts with a complete and computer–interpretable representation of the system’s behavioral requirements. Traditional reductionist techniques are then used to identify all of the components, their desired material and behavioral properties, their relationships to one another, and their associated interfaces. This results in a multi–layered, highly integrated structure with the
components within and across each layer forming complex networks of physical and social systems. The third step involves the development and testing of numerous mathematical and computational models of the individual components, their behaviors, and their properties. New synergistic techniques are needed to integrate these component models together layer by layer until the system model is generated. At every step, the behaviors, and where relevant the material properties, of these models are checked against the requirements. The real-world system will be constructed, or modified if it exists already, only after meeting all of the requirements.

To ensure that such modeling efforts are carried out consistently to address the problem of integrating the different disciplines new metrics and measurement methods will be needed. Beyond measurements there would be an explicit need to develop standards for the different modeling paradigms that will be encountered in the design of these complex interlinked networks. We will also need standards for modeling and designing these network topologies of the socio–technical organizations that will ensure linearization properties that can minimize the scope and consequences of failures. Scale-free networks provide such possibilities but they are also vulnerable to catastrophes under certain design conditions [21, 22]. The need for modeling and designing such networks is still a nascent field. In all of these domains of enquiry, the timely availability of models for testing conformance to specified behavior and standards will be critical.

**Summary**

Technology life cycles are becoming shorter as is the time for those technologies to become ubiquitous in the society. In [23], the authors estimate that the Industrial Revolution took about 150 years; but the computer revolution took only 50 years. Cell phones, which hit the market in the early 1980s took only 25 years to become a global phenomenon. Computers and cell phones are two examples of a growing number of products that marry hardware, software, communications, and physical components into what are called cyber physical systems. We discussed a number of approaches to engineering these cyber–physical systems and concluded that they are inadequate for this purpose. Finally, we propose a new, consilience–based approach that draws on the disciplines and practices that can inform and help resolve those inadequacies. This new approach would critically depend on the development of new measurements and standards for the design and performance of these systems at varied interfaces between these systems.

**References**


CIE and ASME sponsored Book Series on the Advances of Computers and Information in Engineering Research (ACIER).

John Michopoulos, David Rosen, Chris Paredis, Judy Vance,
Editorial Board of the “Advances in Computers and Information in Engineering Research” (ACIER) series.

As the ACIER book series reflects the division’s second most important outreach project after the annual conference, and as it is in the inaugural stage, we felt that we needed to update the members of the CIE on its current status.

After the call for chapter proposals, the editorial board, has successfully deployed a custom created website for the series at URL http://cie-advances.asme.org that was used to solicit a total 69 chapter proposals. Based on criteria of excellence in research and relevance to CIE, the chapter proposal review cycle yielded 29 proposals that were invited to submit drafts of the chapters for peer-review.

In order to guarantee the uniformity of the typographical aesthetics and facilitate the authoring process, the editorial board decided to develop a custom set of LaTeX templates for the book series and invite the authors to use them. Furthermore, in order to enable the author teams to produce their drafts in a collaborative and efficient manner, a unique web-based distributed LaTeX document production resource was developed (by CIE members Drs. Iliopoulos of GMU/NRL and Michopoulos of NRL) named LaTeXpad. Instances of this tool were deployed for each of the 29 author teams and associated links were distributed. Subsequently, the author teams were invited to use the tool for authoring their chapters. This was another way CIE demonstrated leadership in remaining true to the commitment of the division to computers and information in engineering.

As of May 15, 2013, out of the 29 accepted chapter proposals, 22 draft chapters have been submitted.

The peer-review cycle will begin by the end of May 2013 keeping the project on course and on schedule relative to the originally created plan. The editorial board plans to utilize the resources of the division for the review cycle.

As the editorial board, we want to assure all members of the CIE Division, that we remain committed to producing the first volume of the series, with the utmost criteria of excellence in terms of both form and content. Our ultimate goal is to establish the beginning, of a hopefully long lasting series, that will document CIE’s contributions to the field and stimulate more to come.

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