Workshop Report: Executive Summary

Workshop on Industry-Academe research partnerships to enable the human-technology frontier for next generation smarter service systems

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The two-day workshop[1] brought together US-based and international thought leaders from a variety of disciplines in industry and academia to outline a long-term human-technology research agenda that will enable smart service systems of the future.

Service systems contribute to more than 75% of the U.S. GDP and provide close to 80% of employment. It has been demonstrated that the integration of technology as an aid to the human worker can result in dramatic improvements in productivity by augmenting human capabilities in the workplace. Hence, in the next few decades technology-based innovations in service systems can have enormous economic importance for the United States. Smart service systems also have the potential to become the conduit and drivers of social innovations addressing major societal problems.

The agenda of the workshop can have transformative impact on the US economy and beyond by identifying the grand challenges that industry faces, not only for today's service systems, but for the service systems envisioned in 20-30 years. The ultimate objective is to bring attention to academic research on technologies that neither industry nor academia are working on at the moment but that are necessary to enable this next generation of service systems.

[1] Workshop Website: http://www.servicescienceprojects.org/ISSIPNSF/

These futuristic services are likely to be enabled by the automation of the built environment capable of providing innovative services by teaming with humans for the benefit of individuals and society. Examples are those enabled by ambient intelligence, cognitive environments, virtual assistants, service robots, intelligent vehicles, smart infrastructure, autonomous systems, and intelligent devices of all sorts, networked by the Internet-of-Things (IoT) and other communication paradigms. The departments from which academic researchers will be drawn to work on these challenges will be diverse. Participants were selected based on a broad range of expertise across a variety of research fields, including engineering, information technology, computer science, operations research, optimization, and social and behavioral sciences. In particular, researchers who were already interested in transdisciplinary collaborations were invited. Industry researchers from Fortune 500 companies in the smart services space were also invited. With more than a 1200 members with diverse backgrounds representing industry, academia, and government, ISSIP (the International Society of Service Innovation Professionals) was uniquely positioned to convene such workshops.

In the 2-day workshop, 58 experts from industry, academia, and government foundations came together and identifies 8 themes for future long-term research. The eight themes are:

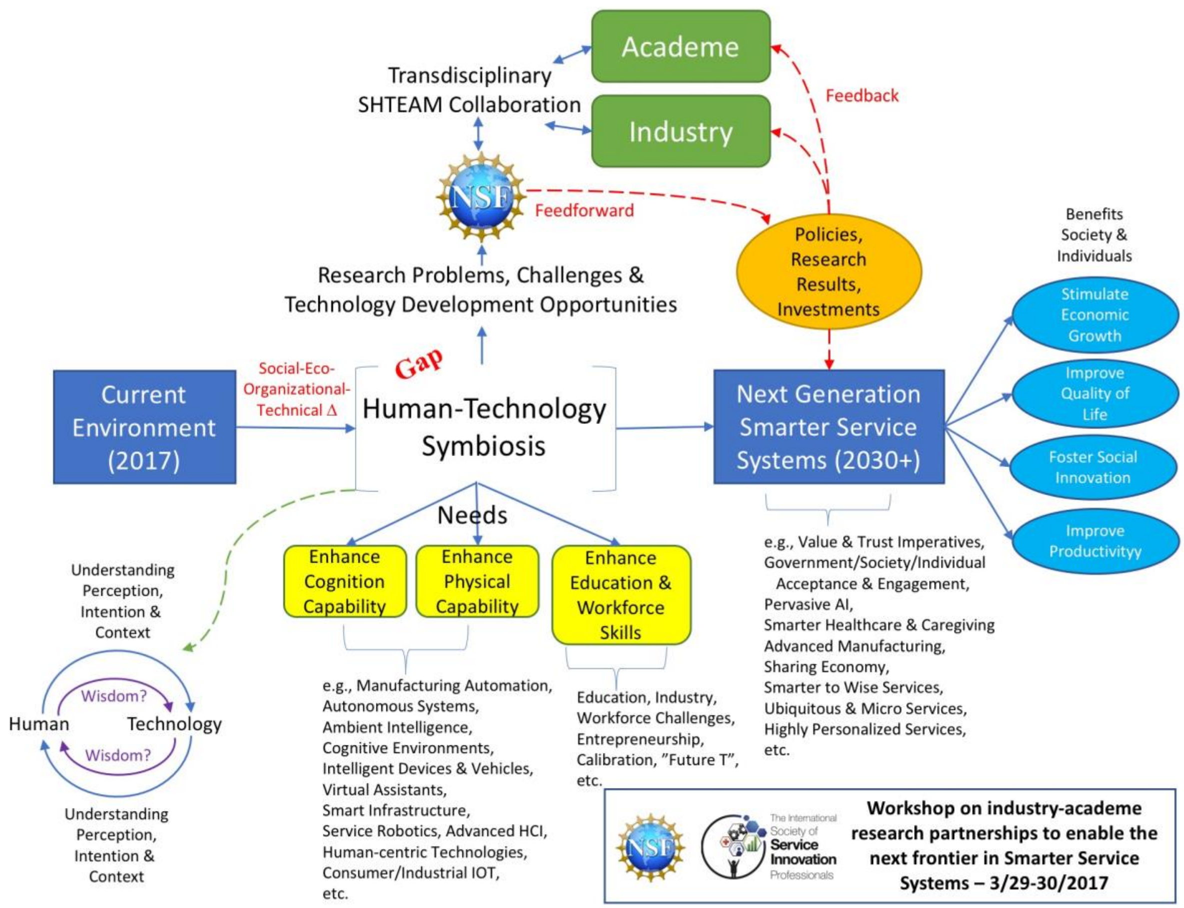
1. People and Technology (symbiosis):
2. People + Technology (restore/augment/enhance physical capabilities)
3. People + Technology (augment/enhance cognitive capabilities)
4. Healthcare and Technology
5. Future Workforce Challenges (technology & learning, skills gap, curriculum, job displacement/replacement, lifelong learning, etc.)
6. Working with Industry Challenges (e.g., IP, Open Innovation, open source, open collaboration, breaking the silos, etc.)
7. Advanced Manufacturing/Maker Collaboration (e.g., manufacturing on demand, etc.), Sharing Economy/Excess Capacity Utilization
8. Consumer/industrial IOT - internet of people vs internet of things

The following is a summary of recommendations that came out of the 2-day talks and discussions on where to focus foster research collaborations with federal as well as public-private funding for more impactful academe-industry partnerships:

- On people-technology symbiosis, foster research collaborations that study “wisdom computing” and interdisciplinary research to study a network of robots with humans at the periphery, or part of the network - swarm intelligence - with command and control, and emergent peer-peer scenarios.
- On People-Technology symbiosis to restore/augment/enhance physical human capabilities, foster human-centric research and education in cross-cutting disciplines.
- On People-Technology symbiosis to augment/enhance cognitive human capabilities, drive Citizen Science projects - Consider university funding to build “charter city” testbeds, requiring academia-industry collaboration with a long term research horizon (10-15 years).

- On Healthcare and Technology, develop a program to study and invite stakeholders to address the grand challenges for prevention of chronic diseases using crowdsourcing to scale.
- On Future Workforce Challenges, support development of pilot ecosystems of fluid work, workers, and learners and sponsor research to explore new paradigms of work and labor and training.
- On working with Industry Challenges, foster research collaborations to study university-industry collaboration as a service system, and potentially fund the development of a people-cyber infrastructure to support industry-university collaboration, and startups, angels, and VC ecosystems.
- On Advanced Manufacturing/Maker Collaboration (e.g., manufacturing on demand, etc.), Sharing Economy/Excess Capacity Utilization, foster research collaboration that could help provide seed funding that encourages industry/university engagement.
- On IoT services, foster research collaborations that could act as an accelerator to provide research funding for industry-academe interdisciplinary research of IoT elements, systems and services to drive proliferation of use cases and scalability.

The figure below summarizes the theme, discussion, and recommendations produced at the workshop.



Summary of Workshop

Final Report

Workshop on Industry-Academe research partnerships to enable the human-technology frontier for next generation smarter service systems

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1 Background

Service systems contribute to more than 75% of the U.S. GDP and provide close to 80% of employment. It has been demonstrated that the integration of technology as an aid to the human worker can result in dramatic improvements in productivity by augmenting human capabilities in the workplace. Hence, in the coming decades service ecosystems enabled by digital innovation (smart service systems) will be increasingly the drivers of economic and job growth in the US economy. Smart service systems also have the potential to become the conduit and driver of social innovations addressing major societal problems.

Smart service systems are complex sociotechnical systems (enabled by sensors, communication, computation, and intelligence – embedded around, on, and in us to improve quality of life) that hold tremendous promise especially where human capabilities are augmented with those of engineered systems further increasing the potential for innovation, growth and prosperity. Any engineered system or artifact that interacts with, and provides a benefit to humans, is de facto providing a "service" - a metaphor for value-added interactions of humans with technology. Innovation in complex smart service systems, however, requires closer collaboration between multiple stakeholders including industry and academia from many different disciplines.

To this end, NSF, in the last four years, had invested in translational research through the Partnerships for Innovation: Building Innovation Capacity (PFI:BIC) program solicitation focused for the first time on the integration of smart technologies such as Artificial Intelligence, Machine Learning, Internet-of-Things, into service systems (2015 solicitation NSF 15-610; 2014 Solicitation: NSF 14-610; 2013 solicitation: NSF 13-587).

In May 2016, the Director of The National Science Foundation, Dr. France Córdova, unveiled ten big ideas[2], for the type of basic research that NSF funds that could help answer pressing societal problems in the coming decades (NSF 2016). These ten big ideas are:

1. Harnessing data for 21st century science and engineering
2. Shaping the human-technology work frontier
3. Understanding the rules of life (i.e., predicting phenotypes from genotypes)
4. The next quantum revolution (physics)
5. Navigating the new Arctic (including a fixed and mobile observing network)
6. Windows on the universe: multimessenger astrophysics
7. More convergent research
8. Support for mid-scale infrastructure (costing tens of millions of dollars)
9. NSF 2050 (i.e., a common fund to seed large, ambitious projects)
10. NSF INCLUDES: Enhancing Science and Engineering through Diversity

Of the ten big ideas #'s 1 and 2 are all about innovation of smart service systems.

The International Society of Service Innovation Professionals, ISSIP, proposed and ran a workshop to bring together industry researchers and academic researchers who are thought leaders from a variety of related areas for a two-day meeting in Silicon Valley to craft a research agenda for the smart service systems of the future. This report is the result of that meeting.

2 The Workshop

2.1 Rationale and Goals

On March 29-30, 2017, 58 representatives from academia, industry, and government who are thought leaders from a variety of related area assembled in a two-day meeting in Silicon Valley to propose a research agenda for the human-technology frontier for next generation smarter service systems. For the workshop agenda, participant list and presentations slides, see www.servicescienceprojects.org/ISSIPNSF/.

[2] NSF Ten Big Ideas: www.nsf.gov/news/special_reports/big_ideas/

The objective was to identify research opportunities for technologies that neither industry nor academia are working on at the moment but that are necessary to enable the service systems of 2030 and beyond. The goal of the workshop was to identify some research questions/problems/themes that require attention (that industry and academe are not yet addressing) to move us towards a more genuine human-technology partnership, and to that end identify the technologies that need to be developed.

Based on a combination of presentations and discussion during day 1, the participants identified eight major themes that became the focus of day 2. These themes were:

1. People and Technology (symbiosis)
2. People + Technology (restore/augment/enhance physical capabilities, robotics, etc.), DIY Services, and microservices
3. People + Technology (augment/enhance cognitive capabilities, semantic models, etc.)
4. Healthcare and Technology
5. Future Workforce Challenges (technology & learning, skills gap, curriculum, job displacement/replacement, lifelong learning, etc.)
6. Working with Industry Challenges (e.g., IP, Open Innovation, open source, open collaboration, breaking the silos, etc.)
7. Advanced Manufacturing/Maker Collaboration (e.g., manufacturing on demand, etc.), Sharing Economy/Excess Capacity Utilization
8. Consumer/industrial IOT - internet of people vs internet of things. Smart vs. Wise, task automation to value creation.

In the morning of day 2, 8 groups were announced based on these themes and each participant was asked to join one of these groups. Then groups were asked to hold a discussion in order to answer the following questions for each theme:

1. What we know now?
2. What is possible/needed/hoped for/critical success factors in the future?
3. What is the gap?
4. How to fill the gap?
5. Opportunities for academe/industry research partnership?
6. Challenges, risks and mitigation?
7. What is the possible roles of the NSF in this?

In the ensuing sections, we first provide a summary of talks on day 1, and then a summary of the group discussions on day 2. The summary for day 2 is formatted according to each of the question discussed in that group.

Day 1

Welcome

Yassi Moghaddam, Executive Director, ISSIP, and Professor Stephen Kwan, Associate Dean, Lucas College and Graduate School of Business, San Jose State University, opened the session and welcomed and thanked the participants. Yassi explained how ISSIP catalyzes industry-academia-government collaboration in cutting edge research, best industry practices, innovative educational models, and policies that promote advancement of smart service systems by fostering professional thought leadership of its members through joint conferences, workshops, publications, members mentorship, and awards globally. She then went over the agenda for the 2 days, and introduced Alexandra Medina Borja, NSF Program Director.

Goals & Rationales of the Workshop

Alexandra Medina Borja, Program Director, NSF: NSF-funded technologies are already changing the US workplace for the better. NSF is primarily focused on funding basic research in science and engineering. Division of Industrial Innovation and Partnerships (IIP), within the Engineering Directorate, is responsible for the agency's Innovation (Translational & Commercialization) efforts. CISE is the main ENG partner in IIP. There is a funding gap between fundamental/translational research and commercialization (Valley of Death). IIP tries to address this gap. Smart Service Systems fits in this area. The first generation of smart service systems are those that people use machines to automate structured routine tasks (machines are not data aware). Second generation are Smart Machines (data aware and sensing). The 3rd generation are human-centered cognitive engineered system. The latter is the focus of the workshop.

Examples include:

- 3D-printing,
- Driverless cars,
- Next gen manufacturing,
- Smart healthcare.

Partnership for Innovation started 2012, the last 4 years, NSF has focused on human-centered smart service system, supporting research with interdisciplinary goal, marrying technology and social sciences, and brining academia, industry, students to collaborate.

Going forward, of the ten "big ideas," two are related to smart service systems: 1) Harnessing data for 21st century science and engineering; 2) Shaping the human-technology work frontier. Both of these are at the forefront of research and have the potential to create millions of new jobs[3]. Proposing to include the following themes:

- Human technology Symbiosis (Augmenting the individual (note: Accenture calls this Making Humans "Super"; IBM calls "Cognitive systems augmenting human intelligence")
- Fostering lifelong and pervasive learning with Technology

Therefore, we need to ask what research questions/problems/themes require attention (that industry and academe are not yet doing) to move us towards a more genuine human-technology partnership? What technologies need to be developed?

Keynote 1: Industrial Internet of Things: Adoption, Roadmap and Impact on Workforce

Edy Liongosari, Chief Research Scientist and Managing Director, Accenture:

Arguably the biggest driver of productivity and growth in the next decade, the Industrial Internet of Things (IIoT) will accelerate the reinvention of sectors that account for almost two-thirds of world output. While most of current efforts in IIoT focus on operational efficiencies, the next wave of disruption is expected to come from the creation of entirely new products, services, and markets. Such a transformation will also have dramatic implications for the workforce.

This keynote drew from the results of a study Accenture conducted in collaboration with the World Economic Forum on the Industrial Internet[4]. There evolution of IIoT is expected to take place in four "waves":

1. Improved Operational Efficiency
2. New Products and Services -
3. Outcome-based Economy - IoT Is about outcome not things, it is about the value
4. Autonomous Pull-Economy

In the first wave, known as the "Industrial Internet" or "Industry 4.0", we should expect vastly improved operational efficiency (e.g., improved uptime, asset utilization) through predictive maintenance and remote management. Over time, in the second wave, we will see more new connected ecosystems built around platforms that cross through traditional industry boundaries and enable new products, services and business models. IoT at the end of the day is all about outcomes. So, In the 3rd wave, we will see the emergence of outcome based economy, enabled through visibility into customers and partners' products, made possible through data aware product and services. And, finally in the 4th wave, we will see work environments that are self-organizing, dynamic, demand driven with

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[3] Wilson, H. J., Daugherty, P. R., Morini-Bianzino, N. "The Jobs That Artificial Intelligence Will Create". *MIT Sloan Management Review*, Summer 2017, sloanreview.mit.edu/article/will-ai-create-as-many-jobs-as-it-eliminates/

[4] "Industrial Internet of Things: Unleashing the Potential of Connected Products and Services", World Economic Forum, 2015, www3.weforum.org/docs/WEFUSA_IndustrialInternet_Report2015.pdf

collaboration between humans and machines, which will result in unprecedented levels of productivity and more engaging work experiences.

However, charting these waves will not be easy and will have its business and societal challenges. The technology for smart systems is here, or will be here, but putting it all together is hard. Businesses, educational institutions, and policy makers must address the challenges regarding the human side of these coming waves. Millions of new jobs will be created, but millions will be lost[5]. Therefore policies to address this including, reskilling and upskilling will be crucial.

Industry Panel I - Visions of the Next Frontier (Moderator: Rahul Basole, Georgia Tech, Panel Speakers: Prashant Tyagi, GE; David DeMilo, Cisco; Rama Akkiraju, IBM; Tim Chou, Stanford University)

Prashant Tyagi, General Electric:
The number of devices with sensors that collect critical data is increasing exponentially every year and is expected to exceed 20 B by 2020[6]. While more devices are predicted for the consumer market, the value derived from the this market will be smaller than industrial and government markets - which is why GE has been concentrating on Industrial Internet, with its Predix platform. As IoT moves from hype to reality over the next couple of years, it is evident that the value derived from this new internet will be proportional to the way we collect, analyze and utilize the massive amounts of data being generated. Therefore, every organization needs to spend efforts to re-think their data strategy and identify gaps or improvements that will help prepare for the upcoming "data tsunami". Current data strategies as we know them are apt for handling the data generated in today's environments which is limited in terms of the six V's (volume, variety, velocity, veracity, variability and value). As these dimensions expand, organizations need to create a data strategy that can keep up with these changes. GE's approach to industrial internet is to leverage IoT and Big data in the form Digital Twins - "the ability to make a virtual representation of the physical elements and the dynamics of how an Internet of Things device operates and works[7]" - to create at least 1 % of efficiency for customers which translates into billions of dollars. The two challenges for the next decade are:

1) How do we go from Data Analytics and Predictive Analytics (mostly today) to Decision Analytics to Prescriptive Analytics, where is the greatest opportunity for advancements lies in the next 10 years?
2) How do we provide the right data sets for the right users in different industries (different personas require different data patterns and technology stack)?

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[5] CGP Grey, Humans Need Not Apply, August 2014, www.youtube.com/watch?v=7Pq-S557XQU
[6] "Gartner Says 6.4 Billion Connected 'Things' Will Be in Use in 2016, Up 30 Percent From 2015", Gartner Press Release, November 10, 2015, www.gartner.com/newsroom/id/3165317
[7] IBM Watson Internet of Things: Introducing Digital Twin, June 19, 2017, www.slideshare.net/IBMIoT/ibm-watson-internet-of-things-introducing-digital-twin

Rama Akkiraju, IBM:
Driven by the proliferation of consumer facing conversational agents such as Apple's Siri, Amazon's Alexa and Microsoft's Cortana, research on Conversational Systems is in vogue again. To enable natural, personalized and compassionate conversations, conversational systems must be equipped with User Models. “User Models are models of people/users, who use computer systems, that capture users' context, preferences, personality, emotions, intentions etc. While User Modeling has been an area of research in the field of Human-Computer Interaction (HCI) for quite some time, the emergence and rise of social media platforms such as Twitter, Facebook and Instagram, where users share/broadcast their daily activities and have social conversations with friends, is providing increased access to user data that can be analyzed (with users' permission) for personalization.

IBM Research is using user models in psycho-linguistic, natural language processing and machine learning approaches to enable human-machine natural, personalized and compassionate conversations. “Many interesting questions arise when we consider human-technology frontiers for next generation service systems: should automated computer systems pretend to be compassionate? How far should they go in their language and actions in personalizing conversations? Where are the boundaries? What about privacy and ownership issues around creating, sharing and managing user models?”

Major technologies enabling next generation of smart service systems include:

1. AI/Cognitive assistants/bots/robots everywhere and for everyone
    - Conversational
    - Highly Personalized
    - Contextual
    - Services delivered through multiple devices, multiple modalities
    - Always connected
    - Doing the research for you to enable decision support
    - Making you aware of alternate possibilities to enable discourse
2. Blockchain (distributed ledger)
3. Sharing Economy/Capacity Utilization (Uber, AirBnb)
4. Internet of Things, instrumented worlds (Smarter homes, Smarter Cities, Smarter Workplaces, Smarter Cars)
5. AI-based Automation (Autonomous vehicles/Assisted driving, Drones)
6. Micro Services (Uber, Netflix, Twitter, Paypal, Bluemix, SoundCloud)
7. Server-less Computing (Function-as-a-Service)
8. Continuous Delivery Tools (Docker, Jenkins)
9. AI in Industries
    - Healthcare (Doctor assistant, Radiologist assistant)
    - Legal Assistant, Brand Manager assistant,
    - New Business Opportunity Identification Assistant
    - Security and Surveillance
10. 3D Printing

11. Cyber Security/Privacy
12. Augmented Reality, Immersive Experiences and User Interfaces
    - Entertainment (gaming)

David DeMilo, Cisco:
Machine Learning algorithms (especially Bayesian and Support Vector Machine (SVM)) have been used for a few years to derive business insights from transactional data regarding renewals of subscription and contract-based business models, customer usage of product features, cross-sell and upsell opportunities, and other aspects of sales and servicing motions. What's new and intriguing now is the prospect of using AI/Cognitive technology to transform the user experience so that sellers, technical support engineers and customers can get answers to complex questions faster, navigate complex business processes quickly with less human assistance, and generally simplify the customer selling and servicing experience. Understanding the nature of these new commercial technology offerings, how they integrate with existing CRM systems and business architectures, assessing the risk involved against the real business value has been challenging and at times overwhelming. Cisco IT has been working with its business stakeholders to take an architecture-led approach to determine how we can navigate the cognitive landscape to identify the best near-term opportunities for experimentation, as well as leverage Cisco's own collaboration and customer care products to deliver a cognitive enabled service experience for our customers in the longer term.
The culture today is much more ready to accept suggestions by AI. Smart services with automated bots and virtual assistants are here today, and conversation is the new UI. This is challenging for IT people. Designing dialogue is a new skill that IT needs to acquire.

Opportunities:
- Opportunities to allow employees to experiment with their own ideas and to experiment with new vendor platforms and technologies:
    - Hackathons
    - Emerging Teams
    - Customer Pilots
    - Career Development Programs

Risks and Challenges:
- Getting off the ground without an architectural vision:
    - Consistent endpoint experience and behaviors
    - Approach to identity federation and authorization
    - Bot orchestration and control
    - Curation of semantic databases and models
- Hype vs. Realism... and Ethics
    - Focus on Labor Replacement Cases vs. Value/Growth Cases
    - Hype: Remember the ATM
    - Developing virtual agents consistent with ethics of artificial intelligence

Learn to ask the right question, stop talking about task automation, start talking about how to improve value chain. Stop talking about labor replacement, start talking about value growth. Collaboration is no longer a platform, it is a service.

Tim Chou, Stanford University:
Two challenges stand in the way of adoption. First on the business side, most companies that build machines sell just the product, and not services. "Few companies are like GE, where 60% is product (e.g. jet engines, MRI scanners, gas turbines) and 40% is service revenue. CEOs of other machine manufacturers need to start to shift their business models to recurring, high margin service." The second challenge is that the Internet was built for people ("Internet of People", IoP) and not things. Things can be where people can't. Things can now spew massive amount of data about themselves and do it very frequently enabling whole new classes of services in every industry [8].

The skills gap is a big issue from two perspectives. One is that how consumers and users of smart service systems will have to adopt new perspectives, learn new skills, understand new innovations. The other is what kinds of skills are needed for the workforce of companies such as Cisco, IBM, Accenture, GE and other that create smart service innovations? How should academia educate people for these skills?

Academe Panel I - Human-Centered Technology Enablers (Moderator: David Lindeman, UC Berkeley, Panel Speakers: Bérénice Mettler, U of Minnesota; Eric Seibel, University of Washington; William J. Clancey, Florida Institute for Human and Machine Cognition; Wolfgang Fink, U of Arizona)

Bérénice Mettler, U of Minnesota:
Automation and robotics are making their way into specialized areas of human skills, such as surgery. Human motor skills are complex behaviors, which are constrained by the power law of learning. This law implies that highly skilled operators, pilots, athletes, and surgeons require thousands of hours of dedicated training to achieve their expertise.

"In my research, I have been interested in the system integration of perceptual, control, and planning mechanisms supporting versatile performance in complex spatial environments and tasks. The work has, in particular, focused on formal modeling methods based on principles of dynamics and controls. The detailed understanding of human skilled motor behaviors opens opportunities to use technology for human augmentation; rather than focusing entirely on replacing human skills. Technology can also assist humans in acquiring their skills more efficiently and operating more safely."

[8] Chou, T. *Precision: Principles, Practices and Solutions for the Internet of Things.* CloudBook, 2016.

Human-machine systems have been evolving from manual control to automation today (e.g. autopilot, laparoscopic surgery), to augmentation in the future (e.g. Robotic surgery using the DaVinci tool).

- Automation (1940-1990):
  - Reduce workload
  - Augment mechanical system
  - Relies on structure
- Classic AI/Robotics (1990-2020):
  - Take human out of the control loop, e.g. autopilots, autonomous driving, etc.
  - Builds on/extends traditional human-machine architecture (aviation, healthcare, vehicle operation)
- Human Augmentation (2020-2050):
  - Reduce workload, improve safety, help humans learn skills
  - Builds on ecological relation between human and task environment
  - Takes advantage of communication, control, computing (3Cs)
  - Allows unconstrained interactions

Human augmentation can accelerate training or rehabilitation of human motor skills. This is the focus of her research. Her research approach has been to generate feedback across multiple levels of human information processing hierarchy. The research challenges include:

- What information to collect? And when?
- How to communicate [with the human] Conscious/Unconscious?
- Multidisciplinary complexity - the nature of research requires the convergence of other siloed disciplines including Human Factors, System Physiology, and Behavioral Sciences
- Agent-Environment Dynamics - agents that are embedded in the environment with behaviors that are responses to dynamic state changes
- System complexity - Spatial skill rely on a broad range of coupled processes including sensory-motor, visuomotor, and visuospatial skills, and perception, planning, and reasoning.
- Challenging to pinpoint mode of actions, and organization principles
- Effect of control on perception and effect of perception on control

Eric Seibel, University of Washington:

The dental service model is antiquated and is not meeting the needs of millions of Americans. The greatest disparity is travel distance from a dentist or expenses, as shown in Alaska Native Tribal Health Consortium studies[9], where there is 2.5x prevalence of caries (tooth decay) compared to the same aged children in the USA. With the advent of topical medicinal therapies, mini-optical sensors and mobile computing, we are taking on the challenge of testing a community-based Dental Health Aid model.

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[9] Willard, M. E. “Alaska Tribal Health System - Oral Health”, 2013 dhss.alaska.gov/ahcc/Documents/meetings/201303/AlaskaTribalHealth-OralHealth-Williard.pdf

Three new concepts of managing oral health outside a dentist office is being tested in cooperation with the local community dental health aid and managing dentist.

1. Screening: optical imaging plaque loading that accumulates on teeth for quantitative feedback
2. Therapy Monitoring: fluorescence spectral analysis to measure the process of healing enamel
3. Caries Prediction: ranking the activity of the plaque deposits to locate sites for active prevention

Fundamental technologies exist today. Major challenge is the interface design in providing low cost solutions with high level of engagement without a high burden for the various users (child, parent, local/distant caregivers). These pilot studies of delivering oral health services can be extended to gum disease for adult users and internationally for all users, such as China, India, and Mexico where there are 6x fewer dentists per capita than USA.

William J. Clancey, Florida Institute for Human and Machine Cognition:
Technology that has come into common usage in the past decade—including mobile computing, interoperable and reconfigurable system architectures, miniaturized biomedical sensors, voice commanding and touch interfaces—has fundamentally changed what automated systems can do and, more importantly, how they need to be designed and developed. Because of the interactivity and adaptability that today's technology enables, computerized devices and tools are best conceived and designed as total systems, which includes the people and their environment. This is accomplished by developing systems iteratively in the context of use through partnerships with vendors, institutions, and people who use the technology and whose lives may rely upon it. Such a systems design methodology is facilitated by Brahms[10], a multi-agent modeling and simulation tool for designing and evaluating total work systems, relating people, technology, and the environment. Chronological behaviors, called activities—including perceiving, reasoning, communicating, using tools, and moving. Activities are conceived socially in terms of roles and modes of participation by which we distinguish coordination, cooperation, and collaboration. Brahms simulations relate how people's mental models change through interaction and how monitoring and interpreting the environment using tools is conceptually organized by activities (i.e., cognition is situated and practices are located). Brahms has been applied to design and deploy automation for a variety of space science, medical, office, and commercial flight work systems.

Wolfgang Fink, University of Arizona:
"Human-Centric Smart Service Systems for Artificial Vision, Tele-Ophthalmology, and Space Exploration"

[10] W.J. Clancey, C. Seah, C. Linde, M.G. Shafto, N.S. Rungta, "Work Practice Simulation of Complex Human-Automation Systems: The Brahms Generalized Überlingen Model," in *Formal Verification and Modeling in Human-Machine Systems*, Papers from the 2014 AAAI Spring Symposium**,** Mercer, E. G., Goodrich, M. A., Rungta, N. and Bass, E. J., ed., AAAI Press, 2014.

NSF defines a "smart" service system as: "a system capable of learning, dynamic adaptation, and decision making based upon data received, transmitted, and/or processed to improve its response to a future situation. […] These capabilities are the result of the incorporation of technologies for sensing, actuation, coordination, communication, control, etc. The system may exhibit a sequence of features such as detection, classification, and localization that lead to an outcome occurring within a reasonable time." [11].

The presentation touched upon three examples from research in multiple synergistically connected areas: Biomedical Engineering & Biotronics for Healthcare, Tele-Health and Mobile Health, Autonomous Multi-agent Robotic Exploration and Synthetic Reasoning Systems, Multi-dimensional Optimization and Computer-optimized Design in Support of Brain-Machine Interfaces, and Reverse Engineering of Complex (Biological) Systems.

1. Artificial Vision Implants (Neural Prostheses) to restore vision to the blind via visual prostheses. The majority of these efforts are based on the electric stimulation of the retina, the optic nerve, the lateral geniculate nucleus, or the visual cortex. These devices require non-trivial mapping of video inputs to appropriate electric stimulation patterns. The research includes: 1) real-time image processing systems; (2) blind subject-in-the-loop stochastic optimization of electric stimulation patterns; and (3) novel electrical stimulation strategies to improve the resolution of vision afforded by visual prostheses.
2. "Smart Ophthalmics", an Innovation Platform for Smart Mobile Health and Tele-Health. Mobile Health is an emerging field characterized by the use of portable, mobile devices capable of collecting, storing, retrieving, and transmitting data over wireless networks in real time for the purpose of improving health and quality of care. In particular, "Smart Ophthalmics" aims at extending ophthalmic healthcare to people who operate/live in austere environments, or are geographically dispersed, where time, cost, and the possibility of travel/transportation make access to even adequate medical care difficult if at all possible. The framework includes smartphone-based ophthalmic examination devices that, in conjunction with custom apps and smart remote server backends, perform comprehensive examinations of the eye, to greatly improve remote patient screening and triage in a timely manner to prevent permanent eye or vision damage.

3. Autonomous Robotic Exploration Systems - Robotic agents are called for in the extreme environment of space, as well as in potentially hazardous or inaccessible operational areas on Earth. As such, future robotic missions/operations will require increasing degrees of operational autonomy, especially when following up on transient events. Our research is a patented and NASA award winning disruptive mission paradigm, termed "Tier-scalable Reconnaissance", as the foundation for autonomous C^4ISR (Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance) systems of the future.

[11] Partnerships for Innovation: Building Innovation Capacity (PFI:BIC) Program Solicitation, NSF 15-610, 2015.

Industry Panel II - Cognitive Systems and Learning (Moderator: Tony Boccanfuso, University Industry Demonstration Partnership, Panel Speakers: Alex Kass, Accenture; Saurabh Thapliyal, General Electric; Steve Ritter, Carnegie Learning; Jim Spohrer, IBM)

Alex Kass, Accenture:

It seems clear that the ways the service workforce of the future acquires, organizes, and applies knowledge must continue to undergo dramatic change. Technology has already made exciting new channels and techniques available for helping individuals learn. However, we need to rethink much more than how learning is delivered because the challenges of this era are much broader than how we make individuals knowledgeable.

- First, the breadth of information that an individual may need as they carry out modern service jobs demands that we think of learning as something that goes on largely at the point of need, rather than in dedicated, just-in-case learning sessions. We can no longer pretend that we're creating capable workers by teaching them everything they need to know in preparation for their opportunities to perform; instead, we need to think about the capable worker as someone who goes into performance situations with two things: 1) Enough knowledge to bootstrap their performance, which is to say to determine what knowledge is needed, what their gaps may be, and how those gaps can be quickly addressed through learning or collaboration. 2) The tools (technological or otherwise) to find the people or knowledge resources needed to provide the needed service. It's less about an individual being smart about all the situations he or she might face, and more about that individual being able to get smart quickly.
- And increasingly, when we think about having the knowledge needed to provide top quality service, we need to think at three distinct levels: 1) the individual level, the team level and the organizational level. The real question is how does the organization get the best thinking on every project and problem. Some of this can be addressed by training members of one's team to handle the next project, but much will be about re-imagining what a team is: We need to move beyond the notion of a static organization in which the org chart determines what team is asked to attack a problem, to a dynamic organization in which the needs of the problem – rather than organizational boundaries - determine what people and resources are assembled to attack the problem. An effective manager will be one who can put together and orchestrate ad-hoc teams of people and systems, sourced on demand, with the right knowledge and skills to succeed in each project.

Digital Service Innovation is about using technology to make working smarter. Accenture has been researching this area for the last several year, and sees Digital service Innovation happening at three levels: 1) Individual, 2) Team, 3) Organization (workforce transformation).

At the individual level, where worker needs just-in-time access to knowledge, intelligent assistants will play a pivotal role. At the team level, new collaboration technologies, especially for distributed teams will be crucial. And, at the organizational level static hierarchical organization must give way to dynamic labor market, leveraging internal and external crowdsourcing.

Saurabh Thapliyal, General Electric:
Leveraging the contextual information around our assets (building and managing a knowledge graph of assets) is very important. Given the same IoT device, system, and subsystem could be used in different context, developing a unified framework for managing machine learning models across the cloud and edge for different applications is very important to us (GE).

Steve Ritter, Carnegie Learning:
AI-based instructional systems have proven to be educationally effective and are starting to be more widely used in mainstream educational environments. A typical goal for these systems was to duplicate the effectiveness of a personal human tutor. Many researchers in the area assumed that, as intelligent systems approached the effectiveness of a personal instructor, the role of the instructor would diminish. We are now at the point where Intelligent Tutoring Systems (ITS) approach the effectiveness of a personal human tutor but, instead of replacing teachers, the use of such systems has served to amplify the importance of teachers. While intelligent instructional systems have a role in helping to personalize instruction for students and to scaffold complex problem solving, they need to be seen as part of an instructional system that includes both automated and human sources of instruction. Our work now focuses on ways that we can help students make best and most efficient use of their teachers and ways that intelligent systems can help teachers make the most of the limited amount of time that they spend with students.

The more we understand about how the student learns, the better we can help the student to learn. ITSs are very effective, but they will not replace teachers. Learning requires both information and affirmation. Teachers can offer both, ITSs cannot. More research to better understand what leads students to ask for assistance and about what ITSs can tell teachers will improve the teacher/ITS instructional system.

Jim Spohrer, IBM:
"Engineering Robots To Live In and Learn With: Towards Smarter/Wiser Service Systems"

The engineering of smart service systems will benefit from rapidly advancing technologies from four main areas: (1) material/energy systems, (2) artificial intelligence/augmented intelligence (aka cognitive systems), (3) virtual reality/augmented reality, and (4) blockchain/open technologies. Because of these advancing technologies, clothing will serve many more functions, including exoskeletons that allow learning of physical, mental, and social interactions in news ways. These advances will especially benefit the elderly, disabled, and young. Vehicles and houses can also be viewed as robots that we will live in. Engineering these advanced smart service systems will require T-shaped professionals, with depth and breadth.

Academe Panel II - Research for Future Infrastructure (Moderator: Stephen Kwan, San Jose State University, Panel Speakers: Paul Oh, University of Las Vegas; Thomas Kurfess, Georgia Tech; Anuj Sharma, Iowa State University; Karthik Ramani, Purdue University; Burford Furman, San José State University)

Paul Oh, University of Las Vegas:
Consumer Robotics in the Age of Acceleration - The lines between consumer electronics and consumer robotics grow blurry each year. For example, over 400 robotics companies exhibited at the 2016 Consumer Electronics Show (CES). Devices like drones, virtual reality headsets, 3D printers, driverless cars, and bionics – are essentially robots and/or were developed upon foundational knowledge in robotics. Projections like those by the Japanese Robotics Association see an annual $30B+ market for household robots by 2025 – and surpassing industrial robot sales. Beyond the Roomba, consumer robots like DJI quadcopters, Jibo and Pepper personal robots, and Tesla driverless cars and related technologies like Oculus Rift headsets demonstrate this growing area. Observations suggest that the product adoption rate for a consumer robot hovers around 7-years.

We believe Vegas Hotels are suitable testbeds and ripe for creating the ecosystem of consumer robotics. Areas where we believe consumer robotics can help:

- Hotel Operations - Check-in, Housekeeping, Guest Engagement
- Food-and-Beverage - Show intermission, Banquets
- Entertainment - Theatre excess capacity, Shows past expiration date
- Gaming - Changing demographic, Monetizing E-Sports
- Retail - Skilled workforce, Theft prevention

Thomas Kurfess, Georgia Tech:
"Emerging manufacturing services enabled by sensors, HPC"

Sensors are prevalent in modern society. They are present in our homes, in appliances such as ovens, washers and refrigerators. They are on the streets monitoring traffic flow and weather. More importantly, the connectivity makes the data from these sensors available at our fingertips. For example, it is commonplace to check the weather radar before heading out to determine if an umbrella is needed for an impending storm. Monitoring traffic and determining the quickest route home from work based on current traffic patterns is another way that we use these sensors in our daily life. A similar scenario is evolving in the manufacturing sector, where sensors are used throughout manufacturing operations and on virtually all manufacturing systems and equipment.

Major directions in the cyber physical manufacturing workspace include:

- Distributed manufacturing
- Tools will morph to leverage new workforce
- Security / Safety / Privacy

- Embedded low cost systems (processing, memory, connectivity)
- Web and Desktop as a Service will be commonplace
- Flexibility / customization will grow
- Not just OEMs, but suppliers as well
- Open source / repurposed hardware will rule

Anuj Sharma, Iowa State University:
"TIMELI: Traffic Incident Management Enabled by Large Data Innovation"

TIMELI aims to use emerging large-scale data analytics to reduce the number of road incidents through proactive traffic control and to minimize the impact of individual incidents that do occur through early detection, response, and traffic management and control. This will be achieved using end-to-end machine learning for situational awareness, the design and rapid solution of geo-temporally-aware traffic models using partial differential equations, stochastic model predictive control, and user-centric advanced visualization techniques for decision assistance. New algorithmic approaches, machine learning, and a stochastic framework are used to detect anomalous outliers and implement context-sensitive traffic models. An advanced human machine interface provides information visualization and decisions recommendations in an intuitive format to minimize any cognitive bottlenecks.

- Future applications include:
- Connected vehicles
- Autonomous Cars
- High-performance Computing
- Workforce Development
- Theoretical Development
- Non-profit Motives

Current technology gaps exist in data handling and archiving, analysis for decision support, and the design of output formats using big data technologies.

Karthik Ramani, Purdue University:
"MakerPAD: Intuitive Design Interfaces and Fabrication Network for STEM Robotics"

Currently, product design and manufacturing are the purview of enterprises and professionals such as engineers and artists. Everyone has ideas, but only a select few can bring them to reality. This is a tremendous waste of untapped human creative resources and economic potential to the society and world Economy. MakerPAD will address these issues and will be supported by intelligent manufacturing-aware computational fabrication network including smart services using computer vision and artificial intelligence algorithms. Our partnership will enable smart STEM robotics services through the cloud and includes leaders such as ZeroUI, augmented reality and computer vision companies, educational research with children and museums for informal education.

Burford Furman, San José State University :
The Transportation Research Board recently identified a set of hot topics that they consider to be transformational technologies for transportation[12]:

- Connected–automated vehicles
- Shared-use services
- Unmanned aerial systems (UASs)
- IoT
- Cybersecurity
- Smart cities
- NextGen (aviation operations)
- 3-D printing
- Big data

While these are having and will continue to have some transformational impact in transportation, they are fundamentally not sufficient to address the herd of ‘elephants in the room' when it comes to a bright future for mobility in urban areas: finite fossil fuel resources, pollution, congestion, safety, and quality of life. A new paradigm for truly sustainable urban transportation is needed. Researchers at San José State University and others have propose Solar Powered Automated Rapid Transit Ascendant Networks (SPARTAN) as the way forward.

SPARTAN mobility effectively addresses inherent fundamental problems, and will significantly change how urban transportation is done. It:

- is exclusive, grade-separated guideway with solar PV panels
- utilizes existing vehicular rights-of-ways (ROWs)
- uses suspended driverless vehicles
- uses off-line stations
- has non-stop origin to destination
- has on demand scheduling
- Is a taxi-like service
- facilitates transit oriented development (TOD)
- Is truly sustainable

[12] Mohaddes, A., & Sweatman, P. “Transformational Technologies in Transportation: State of the Activities”. Transportation Research E-Circular, (E-C208). 2016.

Keynote 2: Enabling Human-Technology Improvement for next generation smart service systems

Henry Chesbrough, Faculty Director, Center for Corporate Innovation, Haas School of Business, University of California, Berkeley:

Today Open Innovation[13], is a widely accepted method of innovation by organizations. In April of 2003, the term "open innovation" yielded ~200 Google pages, before I published the book, in April 2013, a search on the same term yielded 483 million pages (6 orders of magnitude in 10 years)!

There are two kinds of Open Innovation: 1) Inside-out, 2) Outside-in.

Outside-in innovation is when a company makes greater use of external ideas and technologies in its own business to achieve "economies of scope" (e.g. Amazon third party merchants). This is typically resisted by "Not invented here" syndrome.

Inside-out innovation is when a company allows some of its own ideas, technologies or processes be used by other businesses to achieve economies of scale (e.g. Amazon Web Services). This is typically resisted by "not sold here" syndrome.)

Platforms are critical to success of open innovation. New IoT Platform Business Models can transform remote poor villages to better standard of living through open innovation.

"Charity doesn't scale, while appropriate business models can scale."

Closing Remarks Day 1

Ralph Badinelli, Virginia Tech:

Our purpose for the workshop is to help guide federal funding and public-private funding in areas where research collaboration can be fostered and can propel innovations to "Cross the Valley of Death." The mission of ISSIP is to "promote service innovation for our interconnected world." So, we are happy to partner with everyone here to recommend a research agenda toward this goal.

Themes that emerged throughout today were: Human-technology symbiosis with a focus on healthcare, transportation, advanced manufacturing, education, financial services, retail, and high tech verticals. Technology alone cannot address future challenges, human Factors/Effects and business models have to be considered. Public Policy has to be factored in. Science and engineering is important, but so is soft sciences. That is why innovation in the context Smart Service Systems and Value Co-Creation must be studied. Technologies that enable Smart Service Systems include:

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[13] Chesbrough, H. W. (2003) Open Innovation: The New Imperative for Creating and Profiting from Technology, Harvard Business School Press.

- Moving (Robotics)
- Sensing (IoT)
- Communicating/Connecting (networking)
- Data managing/Interpreting/ Analyzing/Deciding (Descriptive, Predictive, and Prescriptive analytics)
- Conversing
- Learning/Adapting/Cognition
- Empathizing
- Creating

Day 2

Group 1 - People and Technology (symbiosis)

Contributors: Ralph Badinelli, Kazuo Iwano

What do we know?

A symbiotic mutualistic relationship exists when two organisms of different species, develop a cooperative relationship in which each organism benefits from the activity of the other and they co-evolve. To allow for stronger people-technology symbiosis, we need new technologies, systems, modeling tools, and disciplines for machines to better understand people and for people to build machines with perception, intent and understanding of context.

People and Technology symbiosis is about making interactions natural, which not only includes machine's understanding of the user, but also includes user's understanding of the machine. This goes beyond traditional Human-Computer Interface, HCI, and includes human position, mood, attitude, body language, and more.

Today, advanced sensors are enabling us to build machines that can, not only perceive a human's (and other objects') position, and its non-verbal cues, but also are able to collect and process massive amount of data that combined with advances in big data and context based analytics are giving them the intelligence to determine human moods and attitudes. These machines can further perform predictive analytics to predict human intent resulting in creative collaboration between human and machine.

Technologies today that can improve a human's ability to perceive a machine's position, mood, attitude, intent and context include machine-to-human communication systems, standards, protocols, in addition to error trapping, diagnosis and translation, human factors, and affective computing.

What is possible/needed/hoped for/critical success factors in the future?

Group 1 identified eight major areas of possibilities for further long-term research where it comes to people/technology symbioses. They included:

1. Architectures and systems to maintain control of a network of robots (e.g., a network of autonomous Machine-To-Machine (M2M) interactions with humans on the periphery)
    - Command and control systems?
    - How can a large network of autonomous machines produce a desired emergent outcome without a command and control system?
2. Swarm intelligence (of network of robots, and network of robots and humans)
3. Robots fighting
4. In a large network of machines and humans, how can stability be achieved? Given limitations on context awareness, intent awareness, command and control?
    - How can systems science help with models of emergent phenomena.
5. How can technology help people become wiser (Wisdom Computing[14])?
    - Wisdom is "the ability to make good judgments based on what you have learned from [our] experience, or the knowledge and understanding that gives [us] this ability[15]" (Data > Information > Knowledge > Wisdom), In other words, Wisdom is the power of knowledge, intuition, ethics, culture on decision making.
        - How can wisdom be transferred to machines?
        - How can machines develop their own wisdom?
        - How can machines be controlled by human wisdom?
6. Maturity level of society with regards to AI, Ubiquitous Service Systems
    - How can humans adapt to the rapid and relentless introduction of AI applications?
        - Design of education in technology, AI
        - Design of programs for popularizing Service Science[16] and Service Innovation
            - Design of innovative campaigns to instigate and control the debate about the implications of new technologies and systems
            - STEM to STEAM to SHTEAM (Science, Humanities, Technology, Engineering, Arts, and Math)
            - Popularizing T-Shaped learning (deep plus broad learning)
            - Education, Marketing
            - The right time for humans to take over (e.g., avoiding The 3 Deadly D's of cockpit automation: Distraction, Dependency, Daring)
            - System design/engineering for fail-safe, fault-tolerance, resilience
            - Standards engineering for safety, recovery
7. Challenges of the New Human Identity

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[14] Iwano, K., Tsuyoshi, M., Wisdom Computing, Toward Creative Collaboration Between Humans and Machined, Center for Research and Development Strategy (CRD), Japan Science and Technology Agency (JST), 2015

[15] Cambridge Dictionary

[16] Service Science is the study of value-co-creating systems that benefits all (individuals, institutions and society). Service science as a framework for people-technology symbiosis that integrates the well-being of individuals and society into the implementation of technology.

- Human and Non-Human identity - How can humans control their identities when connected to technology and service systems that augment their abilities? Will the technologies that we use determine our sense of identity?
- How can governments or society manage the adaptation of individuals to sudden power, enablement, competition – legal restrictions or comprehensive entitlement?
- Individual identity blending into network identity
    - When actions, decisions and performance are managed at a network level, how should resources and value be distributed? (e.g., driverless cars)
    - What cultural norms may need to be adjusted to live in a world of controlled networks?
- What governmental structures will need to be changed or created to align more accurately with the new class and community identities?
    - Discipline to help study these: Big Data Analytics, Sociology, Psychology, Economics

8. Social Complexity
    - What changes will take place in society and in economies as people-machine networks form, change and die?
    - How can societies and governments address the phenomenon of narrowing of political views as a result of the leveraging of networking?
    - When and how should technology be forced on humans? How can individuals maintain a right to “go native”?
    - How can societies and governments manage the class effects that will come from the adoption of empowering technologies (legal restrictions or comprehensive entitlement)?
    - How can individuals adapt sudden power, enablement, competitive advantage that comes from technology adoption?
    - Disciplines to study these: Political science, Economics, Sociology, Psychology
9. How can NSF help?
   Foster industry-academe interdisciplinary research collaborations to study the topics above.

Group 2: People + Technology (restore/augment/enhance physical capabilities, robotics, etc.), DIY Services, micro-services

Contributors: Berenice Mettler, Heidi Korhonen, Veronica Martinez, Ron Swenson, Rama Akkiraju, Nassrin Naaseh, Stephen Kwan, Wolfgang Fink.

What we know now?

Automation and robotics have made their way into manufacturing and are making their way into specialized areas of human skills, such as surgery. Advanced technologies are providing opportunities to use technology to make up for lost capabilities in people (e.g., disabled, elderly, etc.).

Human factors, the scientific discipline concerned with the understanding of interactions among humans and other elements of a system, played a key role in development of technology in the 20th century. Design requirements were conceived by people who were invested in augmenting human capabilities and supporting the operator or worker.   In contrast, today's engineers in both industry and research often approach human factors as an afterthought. For example the new electrical steering systems in cars decouple the driver from the driving experience. Human response time is estimated to be between 100-200 ms, however dynamic response characteristics of many technologies do not take these limitation into consideration thus compromising human safety.

One of the areas where machines have been augmenting human capabilities most efficiently has been in automation of, and not autonomy in, manufacturing. While automation has been successful for routine tasks in factories, manufacturing is still best suited for mass-production and far from individualized. Today, economics and societal needs drive technology development (mass production) and oppose customization (considered too expensive), and purpose-driven manufacturing (e.g., or cleaner environment).

Automation is a set of related functions, processes, or procedures, performed automatically by equipment. Automation assumes that the operator performs some requirements before or after the automated sequence in order to complete the task. Autonomy is a state of a system in which it can perform the programmed operations under a set of conditions without human intervention. Automation is successful in areas with structure and routine tasks (e.g., factory). Autonomy is successful in situations where there is a degree of self-governance and self-directed behavior and must be adaptive to and/or learn from an ever-changing environment. Automation is here today, autonomy is not; and primarily research on autonomy of machines has been the focus of computer science departments, emphasizing only computational perspective.

Similar to personalized medicine that would yield significant health care cost reduction, improve personal health outcomes, and reduce hospital readmission rates, personalized manufacturing could result in cost-efficient individualized experiences that is also good for the environment.

What is possible/needed/hoped for/critical success factors in the future?

Critical success factors that would further the field in people-machine physical symbiosis include:

- Climate change in research environments
- Human-centric Technologies in unstructured/uncertain environments
- Scalability of Technology for Services
- Value of Entrepreneurship in Academia

Climate change in research environments: In order to take the next leap into people-machine physical symbiosis, we need a climate change in research environments that encourages openness within the research community and between industry and academia. While supporting the traditional research facilities and tools, we need to also tap more into crowdsourcing, i.e., experimental trial and error approaches, which are inherently different from those traditionally pursued by funding agencies. The research community needs new approach towards innovation that is more collaborative, experimental, and open. For example, companies like Neuralink[17], that are developing new/next generation technologies behind closed doors, need to ensure public dissemination of information in line with NSF's charter for the purposes of Public-Private-Partnerships.

Human-centric Technologies in unstructured/uncertain environments: Machines need to work successfully and safely with humans in uncertain, non-structured environments. In such environments, implications of time and space need to be considered, i.e., action/reaction times of humans need to be aligned with action/reaction times of machines. Designing with human-centric principles, must consider also scaling for multi-agents macroscopic structures, infrastructures that carry through organic properties at a larger scale while preserving and enhancing the human-centric properties. Such human-machine service systems must build capabilities in emergent and adaptive fashion as properties of systems rather than programming them into the system.
Value of Entrepreneurship in Academia: Emphasizing the importance of entrepreneurial activities (IP, patents, start-up companies) as part of the faculty promotion & tenure process is important to create an environment where faculty are encouraged to take a long-term applied research view needed for people-technology symbiosis, otherwise faculty are forced to leave academia (see editor's note[18]).

What is the gap?

For successful physical augmentation of human capabilities, several gaps were identified by this group including:

- Funding for translational research would be needed (beyond fundamental research to address the "Valley of Death" (i.e. Technology Readiness Level, TRL[19], 4-6))
- The design of human-centric people-machine interfaces requires team of experts with diverse backgrounds including social sciences research which forces and dimension have not historically been considered "serious research." This is ironic since a lot of technology development is indeed driven by social interaction.
- Significant amount of work has been done by academic research in understanding people; however, for seamless human-machine interaction, people in real-world situations/environments must be studied to ensure accuracy/veracity/validity.
- Often academic solutions work well in well-controlled research environments (e.g., labs) but fail in realistic real-world environments which is necessary for commercialization and scaling.
- Lack of enabling ecological interactions with the natural environment (it should work in natural environments and not in just constrained environments)
- Human-centric factors ignored or lost, especially at larger scale

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[17] https://www.neuralink.com/

[18] Editor's Note: Many universities still do not have in their promotion and tenure process an effective way of valuing entrepreneurship as described here. Most are still adhering to the Teaching, Research and Service model.

[19] Technology readiness levels (TRL) are a method of estimating technology maturity of a program, defined by several agencies including Department of Defense, NASA. See more: en.wikipedia.org/wiki/Technology_readiness_level

- Academia is encouraged to be entrepreneurial, but when they are, they might risk financial conflict of interest (FCOI) issues at their university and/or government research labs (with and without federal funding).
- Absence of an institution that would facilitate the handshake between academic low TRL and industrial high TRL (to bridge the Valley of Death).

How to fill the gap?

- Create degrees in new fields of human factors (similar to field of Biomedicine) to better study human-machine symbiosis.
- Academia and industry have to work more closely to bring in "realism", "practicality", and "veracity" to research, to bridge the gap between invention and innovation, and properly adjustment for real-world applications.
- Encourage more academe/industry collaboratories - Explore/expand/revisit existing NSF programs such as I/UCRC, ERC, STC strategies and look also at some European models (e.g., Steinbeis-Centers as a role model for US-based academic commercial research).
- Advocate Entrepreneurship (IP, patents, startup companies) as part of the promotion and tenure process in academia

Opportunities for academe/industry research partnership (see 2nd and 3rd bullet item for Q4)

Challenges, risks and mitigation

- The stage of research considered "Valley of Death" is too risky for industry to invest. Issuing some incentives to industry might potentially mitigate this risk.
- Engineering/Scientific Principles, Policies and Market - How can we emphasize certain scientific/engineering design principles to create core values, which in turn will change policies, which in turn will generate economic incentives, which in turn will influence market forces and corporate strategies (e.g., scientific principles in human factors: human-centered designs, ergonomics, biology of humans, quality of life, health).
- Health implications, and long term effect of augmentation on health must be considered.
- Ethical questions of using augmentation (unfair advantages) must also be researched.

What is the possible roles of the NSF in this?

NSF can help create awareness in:

- Cross-cutting disciplines such systems engineering and systems-of-systems research, data sciences (statistics, machine learning, etc.), material sciences, human factors, etc.
- Encourage future curriculum development: NSF PMs can influence academic institutions to teach students in these areas since they fund research in these areas
- Focus on/reemphasize more the human-centric aspect: do not design in the absence of the human requirements

NSF can also develop novel research themes:

- For examples, around mobility, personal transportation, human factors, aspects of health that are influenced by behavioral and human factors, human-compatible prosthetics/robotics, and bi-directional brain-computer interfaces (e.g., along the lines of "Neuralink")
- Pick up on general market forces (e.g., need for public transportation to relieve cities).
- Encourage emergent, experimental approaches to building the ecosystem of innovation, combining/merging bottom-up and top- down engineering.

Group 3: People + Technology (augment/enhance cognitive capabilities, semantic models, etc.)

Contributors: Jim Spohrer, Jimmy Xu, Bill Clancey, Burford Furman, Anuj Sharma, Jack Park, Matthias Herterich, Gerhard Gundergan, Heidi Korhonen, Stephen Kwan, Kartik Gada

What we know now?

(3) Enhance: are all the opportunities to use technology to make the average person far more capable than they naturally are - night vision, augmented reality for perception, exoskeletons for safely lifting heavy loads, etc.

For number 3, the topic of testbeds came up - like building new Cities from scratch (Paul Romer's Charter Cities). Some of the debate was about trying to fix a broken design (incremental, band-aid fixes) versus throwing everything out and starting tabula rasa (with a blank slate) so you could rebuild from scratch. So the debate was which is a better way to develop smarter service systems - incremental fixes to broken systems, or starting from scratch.

Data is crucial to people-technology symbiosis research. People-technology symbiosis to augment cognitive capabilities research requires 4 types of data:

1. Hidden/internal to the human body (e.g., data about saliva, melatonin, etc.)
2. Observable/external (e.g., videos of traffic)
3. Hidden/perception (e.g., conception of social, person's life narrative)
4. Public debate - Redesign imagination - Testbeds (Buff Furman – don't band-aid bad designs, new testbeds needed; Gerhard Gudergan, Bill Clancey; Kartik Gada – ATOM; technology progress dividend that goes to all adult citizens)

Some of the common ways today data are being collected include:

- Citizen Science (e.g., project such as Eyewire)
- Companies open it (e.g., Uber, Google, etc.)
- Simulations generated content

The data are being used in science, business and society to improve existing service systems (smart service systems), or design new service systems (wise service systems).

What is possible/needed/hoped for/critical success factors in the future?
Gather more of all types of data, text, audio, video, in all languages, and with as much diversity as possible.

What is the gap?
Testbeds to test diverse applications related to various service systems (healthcare, Energy, Waste Management, Education, and more).

How to fill the gap?
Build university testbeds from scratch. A good model is Paul Romer's "Charter City"[20], which in effect is a test bed with living people, open technologies, and an ecosystem that supports its many organisms.

Opportunity for academe/industry research partnership:
Industry and academia can collaborate on open technologies to build solutions on the test bed. Then generate and collect data, and simulate many scenarios that enhance life and work conditions and help the service system thrive.

Challenges, risks, mitigation:
A major risk for such a test bed is privacy. Security practices and data governance become key to mitigating the risk of privacy.

What is possible role for NSF in this?
- Drive Citizen Science project that result in generation and collection of relevant data.
- Foster university-industry translational research collaborations to build "charter city" testbeds, requiring academia-industry collaboration with a long term research horizon (10-15 years).

Group 4: Healthcare and Technology
Contributors: Yasunori Kimura, David Lindeman, Eric Seibel, Zami Temesgen

What we know?
The group discussed the prevailing **trends** in Healthcare:

Challenges

[20] paulromer.net/tag/charter-cities/

The U.S. population is aging rapidly. Every day, 10,000 baby boomers are turning 65, according to Pew Research[21]. By 2030, 71 million Americans (about 20% of the U.S. population) will be 65 and older. These individuals are at high risk for chronic illness and complex chronic conditions. Chronic disease accounts for 75% of the $2.5 trillion in annual US health care costs, and this growing population will continue to be, the heaviest users of health care. As a result, our nation is facing critical challenges, including shortage of caregivers including in geriatrics; primary care, nursing, and social work.

To address these challenges, many institutions are shifting health care delivery and reimbursement to the "Triple Aim" framework[22] which takes a systemic approach to care delivery and leverages technology to improve access, improve quality, and reduce costs.

With more than 80% of physicians using smartphones and 90% of hospitals having EMR systems[23], technology is already demonstrating improvements.

What is possible/needed/hoped for/critical success factors in the future?
Solutions

Advances in biomedical engineering, precision medicine[24], cloud computing, mobile computing, wearables, Internet of Things, AI/Machine Learning, predictive analytics, and access to experimental data are introducing new possibilities in personalized innovative healthcare services that will improve healthcare access, quality and will reduce cost.

What is the gap?
These will however require significant patient-caregiver engagement behavioral changes. Today, there is substantial gap in the number caregivers, and quality of workforce skills necessary for the new era of healthcare.

How to fill the gap:
The following were recommended to help to close the gap:

- Workforce Expansion
    - Educating health care professionals to use technology and engineering to impact health, healthcare delivery, medical education, service science
    - Engineers, informatics, and others
- Workforce Training & Retraining

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[21] Baby Boomers Approach 65 – Glumly, 2010, www.pewsocialtrends.org/2010/12/20/baby-boomers-approach-65-glumly/

[22] Institute for Healthcare Improvement, Triple Aim Framework: www.ihi.org/Engage/Initiatives/TripleAim/Pages/default.aspx

[23] Heath IT Dashboard: dashboard.healthit.gov/help/dashboard-catalog.php

[24] The tailoring of medical treatment to the individual characteristics of each patient; the ability to classify individuals into subpopulations that differ in their susceptibility to a particular disease or their response to a specific treatment.

    - Educating medical professionals about the potential of technology and engineering to impact health care
- Developing Workforce Pipeline
    - Addressing the future healthcare workforce K-12

How can NSF help?
NSF could develop a program to study and invite stakeholders to address the grand challenge for prevention of chronic diseases (Goal is to study and test crowdsourcing as a viable means to deliver smart service).

Examples of such grand Challenges could include:
- Keeping elderly people independent, functional, and connected to tele-healthcare although they may be isolated (rural and/or not web proficient). Evaluate challenges and compare outcome measures (incl. cost) to current services.
- Maintaining support system for the disabled (medical, sensory, cognitive, physical) – again compare outcome measures to current social service delivery.
- Examining drug interactions by self-reporting from tracking a nationwide crowd – compare to typical survey and other current practices.
- Local Crowdsourcing for Health - Form, organize, and manage a local crowd or community around the person or group or healthcare mystery/challenge for monitoring health and supporting wellness

Today NSF has a citizen science program in engineering: www.nsf.gov/pubs/2016/nsf16059/nsf16059.jsp. This group recommends a similar program for healthcare.

Challenges the program must address (when working with crowd data):

- Lack of confidentiality
- No control of IP (sender and receiver)
- Difficulties in clear communication
- Risk of low-quality and false information and misinterpretation
- Inefficiencies, like answering basic questions of many participants
- Disparities in tools (web, smartphone, experience)

Consideration for Grand Challenges include:

- Technology/science - Sensors, human-computer connectivity, cognitive, survey accuracy, health/companion bots, big data and real-time analytics
- Industry – cable/telecom/web/social-media, survey companies, assistive/sensor/computer, telehealth/assistive tech, health bots
- Society – crowd/local communities, governments, NGOs (health)

- Education – health/environmental science, family/community health, nursing/geriatric care, social engineering/management, computer science/engineering

Cross cutting Issues that must be addressed in the study include:

- Disparities
- Patient engagement
- Privacy
- Confidentiality
- Data security
- Alignment with clinical practice
- Interoperability
- Open source
- IP
- Lack of clear business model

Potential partners to establish a distributed testbed include:

- Health systems (Mayo, UC, UW)
- Corporate (Boeing, Fujitsu)
- Agencies/Government (AHRQ, WHO)
- Foundations (Gates)
- NGOs (AARP)

NSF Mechanics that might help:

- Seed grants
- Center grants
- Graduate research fellowships
- Foundation/NSF partnerships
- Industry/NSF partnerships

Group 5: Future Workforce Challenges (technology & learning, skills gap, curriculum, job displacement/replacement, lifelong learning, etc.)

Contributors: Alex Kass et al

What we know now?

Big changes coming. Socio-eco-technical systems are shifting the center of gravity for employment. High volume, mass-production structured processes, which are central engines of employment today, are going to be increasingly automated. While large scale businesses and processes will continue to play an important role in the economy, their role as sources of employment will diminish. The center of employment gravity will shift to a more complex ecosystem of many smaller-scale processes that emphasize niche markets, customization, and small runs.

Organizations themselves will becomes much more fluid. They become more like small nodes in a networked ecosystem that organize talent in ad-hoc ways, constantly reconfiguring on demand. Liquid work patterns and labor market changes will require flexible, specialized knowledge and skills on-demand. Ability to cope with and accommodate changes will be inequitably distributed, and these changes will transcend national borders.

What is possible/needed/hopes for critical success factors in the future?

- A dynamic ecosystem platform that re-imagines how people organize to provide service.
- A platform that can support education as a smart, agile service system.
- A platform that supports resource ecosystem (marketplaces) transparency.
- Inclusion and second chances in the system (i.e., opportunities for lifelong and life-wide learning).
- New models, concepts and measures for productivity and satisfaction.
- More thought leadership in academe, industry, and from policy makers.

What is the gap?

Many of our current service systems are designed to serve the old, large- organization models of employment rather than the coming dynamic ecosystem model. We lack the platforms to help form and reform dynamic employment ecosystems. We lack models to help equip people for the new work ecosystems, or to evolve as the ecosystems evolve. In addition, people with potential value are being excluded.

Socio-economic models for education are inadequately focused on linear concepts. Formal educational systems are (relatively) resistant to the needs of the current and future workforce. Current worker/learner evaluation criteria are oriented to short term output/content rather than longer term/effort/process.

How to fill the gap?

- Develop ecosystem models for businesses that includes workforce, labor, human resources, and training.
- Develop platforms to promote the desire for continued learning and growth mindset.
- Articulate agile career pathways and career re-entries.
- Develop business models and best practices for just-in-time education.
- Build bridges among workforce advocates, human resources and formal education.

Opportunities for academe/industry research partnership?

Industry and academe could partner together to:

- Offer micro credentials and continually update to stay relevant to industry.
- Co-create competency definitions for work & skills
- Industry to sponsor pilot studies to propose compensation, evaluations, continued training, internships, and cooperative educational models.

- Universities to give students credit for participation in industry training programs.

Challenges, risks and mitigating factors:

- **Risks to society:** A truly disruptive change is coming. Automation is eliminating so many jobs, and the jobs it creates requires more advanced skills that are in short supply. This raises the prospect of a society with high unemployment and a labor shortage at the same time. The disruption can be forestalled only a bit, and doing so may actually make the eventual impact more jarring. Making the change without undue pain is going to be difficult: We need to get the platforms and processes in place now, before crisis levels are reached.
- **Risks to business:** Companies lack the platforms and mindset to make the transition from durable/static organization to dynamic ecosystem.
- **Research challenges :** Sustainable changes require 10+ years of program support while the interval for research funding support today is more short term (3~4 years). Also lack of publication opportunities in this area undermines participation of elite academic thought leaders.

Possible roles for NSF?

- Support development of pilot ecosystems – with platforms for organizing work, workers, learners.
- Foster research collaborations to explore new paradigms of work and labor and training – focused on digital futures.
- Support research in the wild – promote inclusivity, understand needs.
- Foster development of data-driven simulations of future workforce and training scenarios.
- Create centers of excellence (similar to NSF Science of Learning Centers[25]) to promote interdisciplinary development of workforce, oriented to PhD studies, with industry involvement:
    - Sponsor PhD studies in workforce futures.
    - Support industry involvement in academe for scenario & vision development.
    - Build bridges, such as GOALI program[26].
    - Support creation of journal that publishes interdisciplinary studies of workforce.

Group 6: Working with Industry Challenges (e.g., IP, Open Innovation, open source, open collaboration, breaking the silos, etc.)

Contributors: Kaisa Stills, Ming C. Lin, Jyoti Sarin, Maurice Sharp, Yassi Moghaddam

What do we know now?

[25] www.nsf.gov/pubs/2005/nsf05509/nsf05509.htm
[26] www.nsf.gov/pubs/2012/nsf12513/nsf12513.htm

While there are models for industry-academia collaboration[27], higher education institutions face many challenges when working with industry including Intellectual Property issues, continuity challenges, and time line mismatch between industry and academia.

Intellectual Property rights and expectations present a major hurdle to collaboration between industry and academia. In general university administration views IP as valuable but not only does not facilitate its transfer to increase the chances of commercialization, and return on investment, it also often hinders such transition. For many universities, the IP and tech transfer is a loss, which makes the university lose interest in research collaboration with industry. Furthermore, university tech transfer offices often create a bottleneck to transfer of IP. For these reasons industry, mainly interested in IP for commercialization is discouraged to collaborate with academia[28].

Another challenge for collaboration between industry and academia is the time horizon mismatch between the two. Given the rapid rate of change, industry time horizon is getting shorter and shorter, but academic research time horizon is long. A typical research grant interval is 3 years which for industry is considered several product iteration, or technology generation iteration.

Continuity is another issue hindering long-term collaboration. Often when an industry sponsor changes jobs, or companies her/his interest in the research fades or vanishes, and it is difficult or impossible for the research faculty to fill the gap.

NSF, with its various programs, including ICORE, IURC, BIC, AIR, and SBIR has been trying to address these challenges, however, the funding for these program is relatively small, the chances of win is low, and the effort to apply is significant.

What is possible/needed/hoped for/critical success factors in the future?

More than ever before, academia and industry need to collaborate, and we need new model for collaboration. To be able to respond to rapid rate of change, industry needs to tap into the invention and innovation capabilities that otherwise would staying dormant. To stay relevant, universities have to find ways to co-create more value for students, businesses, and society.

Both universities and industry culture needs to change to foster successful industry-academia collaboration. One way to foster collaboration is to consider Co-Op programs not only for graduate students, but also for faculty, both nationally and internationally.

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[27] Examples: University of Waterloo International Collaboration: https://uwaterloo.ca/institute-nanotechnology/partnership-and-collaboration, and University-Industry Development Partnership, UIDP, https://www.uidp.org/

[28] Editor's Note: some industry partners prefer to work with faculty members under contract, i.e. "work for hire", with very clear and defensible IP rights ownership for the hiring party. The university is usually reimbursed for the percentage of time a faculty member works on the contract. Government agencies can also enter interagency agreements with universities for work on research.

Matching market problem—what are the different ways that those matches can be made? People and knowledge flows?

What is the gap?

Universities and industry have different purposes, goals, offerings, concerns, capabilities and core competences. One is not for profit, the one strives to maximize profits. One has to answer to shareholders every quarter, the other doesn't. One operates with longer horizon timelines, the other one doesn't. Universities have open environments that encourages the free exchange of information and ideas. Companies have closed environments that controls access to information crucial for their business success.

These present challenges to industry-academia collaboration, but also create opportunities.

How to fill this gap?

Innovative models of collaboration need to be examined to bridge this gap. Looking at industry-academia as a service system, this group asked: "how would we fill the gaps if we were to design the relationship as smart service system?" It is important to make both parties more conscious about each other's goals, concerns, what they value, what value they offer, and to whom, design and validate the two-way knowledge transfer to nurture the relationship where they match, create more alignment where possible, and grow the ecosystem.

For example, professors are encouraged to do consulting (20% of their time, summer time, and sabbatical). Companies like to work with faculty with market savvy and understanding of their business. Also students like to work with companies, and companies like to hire student interns. Faculty level and graduate level Co-Op's can strengthen industry-academia research (learn from successes: IBM-faculty rotations).

Increasingly companies are co-creating in the form of "open innovation" projects. This presents a great opportunity for co-creation where companies bring real challenges, and universities offer their core competency in research and talent.

The role of IP is different for companies and universities. Companies look for return on the IP investment, professors want to publish papers. While these are different, they are not competing and can be leveraged in a complementary fashion (as some universities such as Stanford do).

Recommendation to NSF:

1. University-industry offer, concerns, capabilities, possibilities, hindrances for alignment, and successes factors need to be studied as an interconnected service system - NSF to potentially fund a study/workshop with a goal to build innovation capacity and create jobs (i.e. Innovation Matching Market study with impact to jobs, community, and society).

2. NSF could possibly facilitate a study to understand the flow of university IP revenue, ROI, and opportunity cost[29].
3. NSF could catalyze faculty level and graduate level C0-Op's (learn from successes, IBM-faculty rotations) to scale innovation and jobs through entrepreneurship.
4. NSF could catalyze industry-challenges-focused university incubation.
5. NSF could potentially facilitate the development of a people-cyber infrastructure to support industry- university collaboration, and startups, angels, and VC ecosystems.

Group 7: Advanced Manufacturing/Maker Collaboration (e.g., manufacturing on demand, etc.), Sharing Economy/Excess Capacity Utilization

Contributors: Francis Quek, Karthik Ramani, Stephen Kwan, Tom Kurfess

What We know

With advances in material science, lower cost of fabrication, and innovative processes for rapid prototyping, design ideation is increasing becoming physical. The lines between designer, manufacturer, and customers are blurring as seen by the rise of the maker culture[30]. Lower barriers to accessing new computational & fabrication tools such as IoT, data analytics, AI, cloud computing, 3D printing, and other new technologies are further accelerating this trend to "democratize" manufacturing and reinvigorate small-batch production and sales giving rise to a decentralized manufacturing infrastructure over time.

Success Factors

Critical success factor for such adoption will require a change in mindset from maker to manufacturer. Entrepreneurs have to make the leap from Individual makers to small startups to small manufacturer. They have to collaborate not only with each other but also with large industrial firms, universities, and governments to build or be part of an ecosystem and scale.

Being part of a distributed manufacturing ecosystem will require resilience, flexibility, and logistics know-how to rapidly customize/individual and scale. It also requires access to capital and partnership with large industrial firms.

Filling the Gap

To make this leap, we need:

- AI systems for makers to offload the cognitive design details to augment their capabilities - Design Aided by Computers (DAC) rather than CAD.
- A new generation of workforce training to grow entrepreneurship, and makers to manufacturing mindset.

[29] A similar study on the patent system was done by the National Academies, 2004 - www.nap.edu/catalog/10976/a-patent-system-for-the-21st-century

[30] Maker Culture definition: en.wikipedia.org/wiki/Maker_culture

- Integrated cloud computing/storage to handle the distributed nature of manufacturing
- Intuitive tools for collaborative design and manufacture (similar to G-Suite)
- Long tail market innovation - in a distributed manufacturing environment there is more opportunity for maker/manufacturer to focus on its own sweet spot and niche market.

Academe / Industry Partnership Possibilities

Ideas for industry and academe partnership to close these gaps include:

- Industry could provide CAD/CAM tools As-a-Service to students to encourage makers culture
- Community Colleges and universities could offer design courses that encourage the maker movement
- Both industry and academe could build maker spaces that encourages entrepreneurship
- Industry could offer open plug and play systems and make it available for co-creation between students and industry (e.g., Hackathons, app stores, etc).
- Preparing the workforce

Challenges / Risks / Mitigation

The risk of going from maker to manufacturer include:

- Deployment – how do you go from making one or small number of something to mass production. It requires capital, partnership, distribution channels.
- Validation – testing and validation for manufacturing is much more stringent than when making a small numbers of something.
- Business models - going from proof of concept (maker) to commercialization and mass production is a challenge.
- Funding – is needed to scale, but is a barrier to entry.

Role of NSF

Areas where NSF could help:

- Encourages industry-university engagements, where industry could provide a means for scaling and wide deployment.
- Look for opportunities where this effort could be integrated into ongoing projects such as I-Core.
- Consider an ECR that brings the various aspect of this public-private partnership together, researches the long-term implications decentralized manufacturing, and focuses on the workforce development.

Group 8: Consumer/industrial IOT - internet of people vs internet of things. Smart vs Wise, task automation to value creation.

Contributors: Haluk Demirkan, Paul Oh, Selcuk Candan, Lasse Mitronen, Rahul Basole

What we know now?

The number of connected “things” are increasing. International Data Corporation, IDC, predicts that worldwide spending on the Internet of Things (IoT) will be surpassing the $1 trillion mark in 2020[31]. IoT is all about interconnection of smart service systems that are fundamentally changing the infrastructure of the planet — power, transportation, healthcare, agriculture, and more. — and how we co-create value.

Key enabler of wide adoption of IoT are standards that allow safe interconnectivity, platforms that allow collaboration and service ecosystems that bring stakeholders, technologies, and processes together to co-create value in very rapid, efficient, and scalable fashion.

IoT is creating tremendous opportunities for growth in business and society, but there are three main challenges that stand in the way of adoption.

1. The first challenge is in workforce upskilling for IoT.
2. The second challenge is on the business side, most companies that build machines sell just products. Where most of the value is in the services enabled by IoT, few companies are focusing on its service growth potentials.
3. The third challenge is that most software has been built for the Internet of People (IoP), with people as end point, not things. Internet of things introduce a whole set of new requirements that have implications in standards, security, vulnerability, data governance, data privacy, and liabilities,

How to fill the gap?
To address these challenges, there is a need for:

- Professional training and education with the goal of skilling of new graduates and upskilling of mid-career professionals.
- An open repository of use cases that would identify applications and services, where the real value of IoT resides (a national/international repository).
- (Open) test beds that encourage collaboration and co-creation.
- Pilot projects that encourage, explore, and test collaboration, alliances, and co-creation.

Additionally, opportunities for academe/industry research partnership to address these gap include:

- Use the academic ecosystem as a test bed to develop and pilot new IoT solutions and services that benefit individuals, institutions and society. This is not without risks. Convincing the

[31] Internet of Things Spending Forecast to Grow 17.9% in 2016 Led by Manufacturing, Transportation, and Utilities Investments, According to New IDC Spending Guide, https://www.businesswire.com/news/home/20170104005270/en/Internet-Things-Spending-Forecast-Grow-17.9-2016

institutions to open up their ecosystem would have privacy and security implications. Also the value proposition for such partnerships have to be clearly defined.

- Using third-party non-profits to play the orchestrator role between different academic institutions and between industry and academia might mitigate these risk.

What is the possible role of the NSF?

NSF could act as an accelerator to:

- Drive scalability through university-industry collaborations.
- Foster programs for development of innovative
  - Individual elements
  - Integration of elements
  - Smart services

NSF might design such programs as multi-stage grant program tied to certain milestones, for example:

- 1st stage = $500k
- 2nd stage = $2million + (for multiple collaborators)

Also NSF could design a set of enhanced programs across directorates to encourage interdisciplinarity.

Concluding Remarks and Future Directions

This report summarizes the March 29-20, 2017 ISSIP-NSF sponsored workshop that took place in Santa Clara, CA, entitled: *Workshop on Industry-Academe research partnerships to enable the human-technology frontier for next generation smarter service systems*.

This report summarizes the motivation and call to action for the participants:

(1) Economic and Technological Motivations: Service systems dominate the economy, from finance to healthcare, and well-engineered, data-driven service systems incorporating advance technologies are becoming smarter and more integrated with each other, as well as manufacturing and agricultural systems, in complex value chains and supply chains.

(2) NSF Motivations: Of the ten big ideas identified in May 2016 by NSF shaping their future program directions, the first two provided motivation for this workshop, namely (a) Harnessing data for 21st century science and engineering and (b) Shaping the human-technology work frontier (NSF 2016).

(3) Call to Action: NSF also wanted the assembled and balanced industry and academia participants to provide insights on set of topics, including: (A) identify what research

questions/problems/themes require attention (that industry and academe are not yet addressing) to move us towards a more genuine human-technology partnership? (B) And to that end what technologies need to be developed? (C) what role can NSF play to catalyze new types of academic-industry-government collaborations to develop the advanced technologies need to make smarter service systems with genuine human-technology partnerships emerge.

The participants identified eight themes to explore in parallel with teams composed of industry and academic experts, namely (1) People and Technology (symbiosis), (2) People + Technology (restore), (3) People + Technology (enhance), (4) Healthcare and Technology, (5) Future Workforce Challenges (effects of automation and lifelong learning), (6) Working with Industry (models and challenges), (7) Advanced Manufacturing (better building blocks and collaboration models), (8) Internet of Things (at home and in work places). To prepare to report out to the larger group, each parallel team addressed the same six questions: (1) What we know now? (2) What is possible/needed/hoped for/critical success factors in the future? (2) What is the gap? (4) How to fill the gap? (5) Opportunities for academe/industry research partnership? (6) Challenges, risks and mitigation? (7) What is the possible roles of the NSF in this?

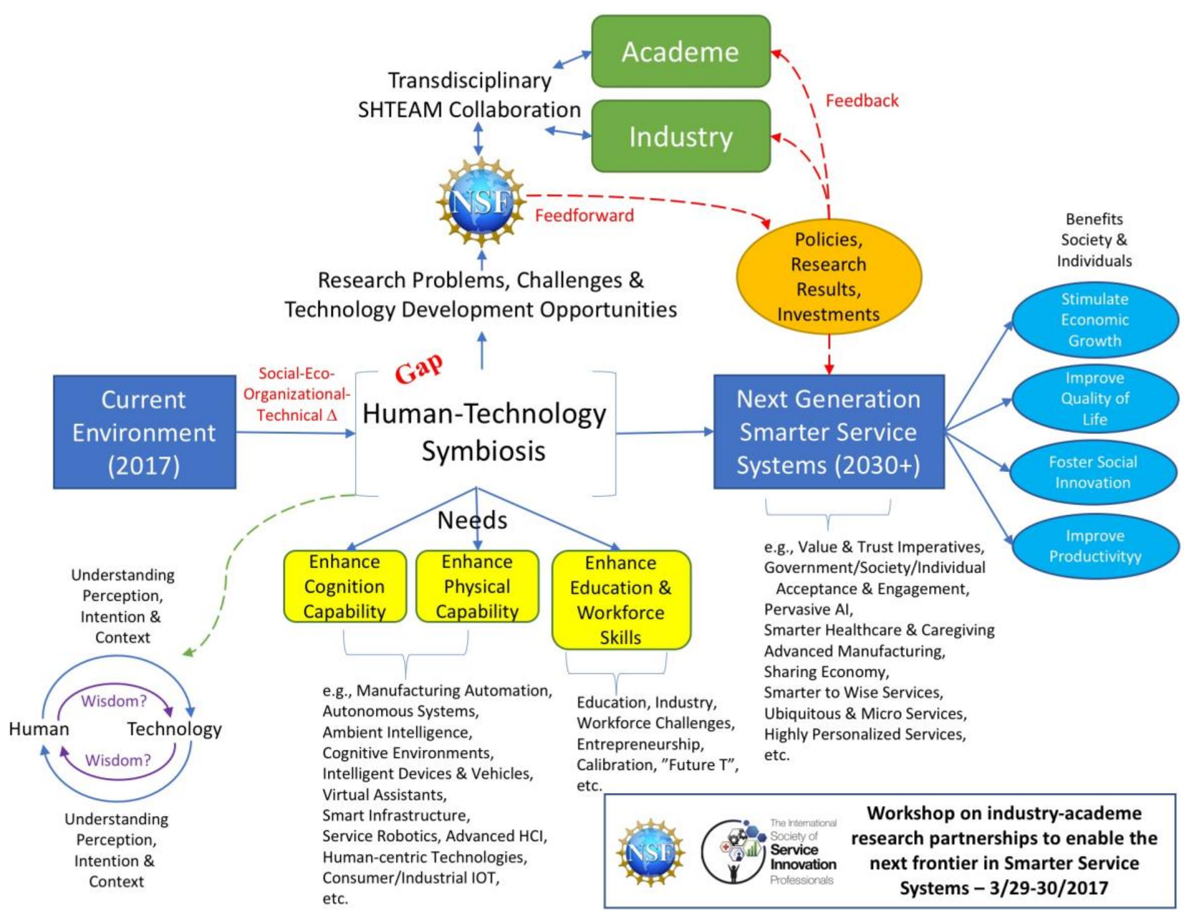

Figure 1. Summary of workshop

The bulk of this report summarizes the outcome of the 8 groups working on the 7 questions and the major elements of the discussion are shown in Figure 1. The following table summarizes technology areas with the most promise for the future industry-university collaborations, based on the recommendations of the attendees:

Technology and Capability Areas	**Defining Characteristic or Focus**
People-Technology Symbiosis Technologies	Tech that understands working with people
Restore/Augment/Enhance Physical Capabilities	Expand human physical capabilities with tech
Augment/Enhance Cognitive Capabilities	Expand human cognitive capabilities with tech
Healthcare Technologies	Focus on chronic diseases
Workforce Technologies	Focus on training/simulations of future workforce
Social-Cyber-Physcial Infrastructure Capabilities	Expand social capabilities with platform tech
Advanced Manufacturing/Maker Technologies	Focus on scaling up and down (local)
IoT (Internet of Things) Technologies	Focus on security and trust

In the remainder of this sections we summarizes recommendations from the workshop on some possible future directions where federal funding and public-private funding can influence long-term research:

- On people-technology symbiosis, NSF could catalyze fundamental research in “wisdom computing,” i.e. research technologies that help people become wiser (Wisdom Computing) and to go beyond smart service systems (efficiency) toward wise service systems (sustainable innovation). Study emergent phenomena in a network of robots and network of robots and humans.)? Study a network of robots with humans at the periphery, or part of the network - swarm intelligence - with command and control, and emergent peer-peer scenarios. Study scenarios of conflict. How can wisdom be transferred to machines? How can machines develop their own wisdom? How can machines be controlled by human wisdom? Research to study human identity when technology is augmenting human capability.
- On People-Technology symbiosis to restore/augment/enhance physical human capabilities, NSF could foster human-centric research and education in cross-cutting disciplines such as systems engineering and systems-of-systems research, data sciences, material sciences, human factors, etc. around themes such as mobility, personal transportation, human factors, aspects of health that are influenced by behavioral and human factors, human-compatible prosthetics/robotics, and bi-directional brain-computer interfaces, encourage emergent, experimental approaches to building ecosystems of innovation.

- On People-Technology symbiosis to augment/enhance cognitive human capabilities, NSF can drive Citizen Science projects that result in generation and collection of relevant data. Consider university funding to build “charter city” testbeds, requiring academia-industry collaboration with a long term research horizon (10-15 years).

- On Healthcare and Technology, NSF could develop a program to study and invite stakeholders to address the grand challenges for prevention of chronic diseases using crowdsourcing to scale. NSF Mechanics that might help include Seed grants, Center grants, Graduate research fellowships, Foundation/NSF partnerships, and Industry/NSF partnerships.

- On Future Workforce Challenges, NSF can support development of pilot ecosystems – with platforms for organizing work, workers, learners. Sponsor research to explore new paradigms of work and labor and training – focused on digital futures. Support research in the wild – promote inclusivity, understand needs. Sponsor development of data-driven simulations of future workforce and training scenarios. Create centers of excellence (similar to NSF Science of Learning Centers) to promote interdisciplinary development of workforce, oriented to PhD studies, with industry involvement: Sponsor PhD studies in workforce futures. Support industry involvement in academe for scenario & vision development. Build bridges, such as GOALI program. Support creation of journal that publishes interdisciplinary studies of workforce.

- On working with Industry Challenges, social-cyber-physical infrastructure and platform technologies can be used to expand social capabilities, and enhance university-industry collaborations, concerns, capabilities, possibilities, hindrances for alignment, and successes factors need to be studied as an interconnected service system - NSF could facilitate such a study/workshop with a goal to build innovation capacity and create jobs (i.e. Innovation Matching Market study with impact to jobs, community, and society). NSF could also potentially facilitate a study to understand the flow of university IP revenue, ROI, and opportunity cost[32]. NSF could catalyze faculty level and graduate level C0-Ops to scale innovation and jobs through entrepreneurship. NSF could catalyze university incubation focused on industry-challenges. NSF could potentially fund the development of a people-cyber infrastructure to support industry-university collaboration, and startups, angels, and VC ecosystems.

- On Advanced Manufacturing/Maker Collaboration (e.g., manufacturing on demand, etc.), Sharing Economy/Excess Capacity Utilization, NSF could drive a program that encourages industry engagement, where industry could provide a means for scaling and wide deployment. Look for opportunities where this effort could be integrated into ongoing projects such as I-Core. Consider an ECR that brings the various aspect of this public-private partnership together, researches the long-term implications decentralized manufacturing, and focuses on the workforce development.

- On IoT services, NSF could act as an accelerator to:
    - Drive industry-university translational research toward proliferation of use cases and scalability, and especially security and trust.

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[32] A similar study on the patent system was done by the National Academies, 2004 - www.nap.edu/catalog/10976/a-patent-system-for-the-21st-century

- Foster programs for development of innovative individual IoT elements, Integration of elements, and smart services. NSF might design such programs as multi-stage grant program tied to certain milestones. Also it could design a set of enhanced programs across directorates to encourage interdisciplinarity.

Appendix A. Participants

Last Name	First Name	Institution
Akkiraju	Rama	IBM
Attia	Naguib	IBM
Badinelli	Ralph	Virginia Tech
Basole	Rahul	Georgia Tech
Boccanfuso	Tony	University Industry Demonstration Partnership
Boscovic	Daragan	Arizona State U
Candan	Selcuk	Arizona State U
Chesbrough	Henry	UC Berkeley
Chou	Tim	Stanford U
Clancey	Bill	The Institute for Human & Machine Cognition
DeMilo	David	Cisco
Demirkan	Haluk	U Washington
Fink	Wolfgang	U Arizona
Furman	Burford	SJSU

Gada	Kartik	Woodside Capital Partners
Gudergan	Gerhard	Aachen U, Germany
Heitz	Christoph	ZHAW, Switzerland
Iwano	Kazuo	Mitsubishi Chemical Holdings
Kass	Alex	Accenture
Kimura	Yasunori	Fujitsu Laboratories, Japan Science and Technology Agency
Korhonen	Heidi	VTT, Finland
Kundel	Kristen	Cisco
Kurfess	Thomas	Georgia Tech
Kwan	Stephen	SJSU
Lin	Ming	UNC Chapel Hill
Lindeman	David	UC Berkeley
Liongosari	Edy	Accenture
Locke	Robert	Johnson Controls
Malik	Naresh	SJSU
Manduchi	Roberto	UC Santa Cruz
Martinez	Veronica	Cambridge University
Maull	Roger	U of Surrey

Medina Borja	Alexandra	NSF
Mettler	Bérénice	U Minnesota
Mitronen	Lasse	Aalto U
Moghaddam	Yassi	ISSIP
Naaseh	Nasrin	Silicon Valley Leadership Group Foundation
Oh	Paul	U Nevada, Las Vegas
Quek	Francis	Texas A&M
Ramani	Karthik	Purdue U
Rayes	Ammar	Cisco
Ritter	Steve	CarnegieLearning.com
Russell	Matha	Stanford U
Sarin	Jyoti	Cisco
Seibel	Eric	U Washington
Sharma	Anuj	Iowa State
Sharp	Maurice	Apple
Sheet-Davis	Lubab	Lam Research Corporation
Spohrer	Jim	IBM
Stills	Kaisa	VTT, Finland

Sullivan	Kevin	U Virginia
Swenson	Ron	International Institute of Sustainable Transportation
Temesgen	Zami	Mayo Clinic
Thapliyal	Saurabh	GE
Tyagi	Prashant	GE
Xu	Jimmy	Brown U
Yin	Jane	Fujitsu

Appendix B. Agenda

Wednesday, March 29th, 2017	
8:00-8:30	Check-in, and breakfast
8:30-8:45	Welcome - Introduction and Context Yassi Moghaddam - ISSIP Executive Director, Workshop co-Chair Stephen Kwan, Associate Dean, SJSU
8:45-9:15	Goal of the Workshop - Alexandra Medina-Borja, NSF
9:15- 9:45	Keynote I - Edy Liongosari, Chief Research Scientist and Managing Director, Accenture
9:45-10:45	Industry Panel I - Moderator: Basole Rahul, GA Tech Prashant Tyagi, GE, David DeMilo, Cisco, Rama Akkiraju, IBM, Tim Chou, Stanford University
10:45- 11:00	Break
11:00 -12:00	Academe Panel I - Moderator: David Lindemann, UC Berkeley Bernice Mettle, U of Minnesota, Bill Clancy, IHMC, Eric Seibel, UW, Wolfgang Fink, U of Arizona
12:00 - 1:00	Grab Lunch and Birds-of-a-Feather tables (laptops will be provided to show introduction slides)
1:00 - 2:45	Industry Panel II - Moderator: Tony Boccanfuso, University Industry Demonstration Partnership, Panel Speakers: Alex Kass, Accenture; Saurabh Thapliyal, General Electric; Steve Ritter, Carnegie Learning; Jim Spohrer, IBM
2:45-3:00	Break
3:00-4:00	Academe Panel II - Moderator: Stephen Kwan, SJSU Paul Oh, UNLV, Karthik Ramani, Purdue, Thomas Kurfess, GA Tech, Burford Furman, SJSU, Karthik Ramani, Purdue, Anuj Sharma, Iowa State U
4:00-4:30	Keynote II - Henry Chesbrough, UC Berkeley

4:30-5:00	Day 1 Closing remark and wrap Up, Ralph Badinelli, President, ISSIP, Professor, Virginia Tech
5:00-7:00	Poster Session
Thursday, March 30th, 2017	
8:30-9:00	Check-in, breakfast, and networking
9:00-9:20	Summary of Day 1, instructions for breakout sessions Yassi Moghaddam, ISSIP
9:20-10:20	Breakout I
10:20-10:40	Break
10:40-11:45	Breakout II
11:45-1:30	Grab Lunch and Prepare Presentation
1:30-2:50	Groups 1-4 Reports (20 min. each) - Heather Yurko, Cisco
2:50-3:10	Break
3:10-4:30	Groups 5-8 Reports (20 min. each) - Haluk Demirkan, U of Washington
4:30-5:00	Summary and Next Steps - Workshop co-Chairs Adjourn

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