Slide 1: Title (Keith Marzullo)

Good afternoon. My name is Keith Marzullo, and I am the Division Director for the Division of Computer and Network Systems within the Directorate for Computer and Information Science and Engineering at the National Science Foundation. Welcome to today's webinar on the 2014 Cyber-Physical Systems Program.

It is my pleasure to introduce my boss, Dr. Farnam Jahanian, the head of the CISE Directorate.

Slide 2 (Farnam Jahanian)

Good afternoon! On behalf of my colleagues at the National Science Foundation, it is my great pleasure to welcome you to this webinar to learn about the 2014 joint Cyber-Physical Systems (CPS) solicitation.

As automation and information technology pervade new platforms, cyber-physical systems have become ubiquitous in our everyday lives and grow increasingly complex each year. They fly our planes, control our nuclear power plants, run our medical devices, and so much more. The question we are asking today is, "How can we build and verify systems upon which people can – and will – bet their lives?"

Advances in cyber-physical systems hold the potential to reshape our world with more responsive, precise, reliable and efficient systems that:

- Augment human capabilities;
- Work in dangerous or inaccessible environments;
- Contribute to a sustainable future;
- Provide large-scale, distributed coordination; and
- Enhance societal well-being.

These advances in CPS are closely intertwined with, and will have pervasive impact upon, many of our societal priorities, including:

- Smart systems for manufacturing and robotics;
- Environment and sustainability, including emergency response;
- Healthcare, through the development of innovative medical devices; and
- Transportation and energy networks and infrastructure.

Since its inception in 2009, the NSF CPS program has sought to deeply integrate *computation, communication, and control into physical systems*, enabling "smart" systems with cyber technologies – both hardware and software –

a) That are deeply embedded in, and interacting with, physical components; and

b) That sense AND change the state of the real world.

In the last year, the NSF CISE and Engineering Directorates worked together to fund about 30 new projects (approximately 60 total awards) with an investment of over $35 million. And since 2009, the CPS program has supported over 250 awards, accounting for over $170 million in investment and spanning over 350 PIs and co-PIs across over 35 states.

Within NSF, our investment in CPS has continued to build upon our Core programs in the CISE and Engineering Directorates (for example, Computer Systems Research), and complements several closely related cross-cutting programs, notably the National Robotics Initiative, or NRI, Smart and Connected Health, and Secure and Trustworthy Cyberspace.

At the same time, we also recognize that achieving next-generation cyber-physical systems requires bringing together experts from many different sectors and disciplines – which is why we have worked across the government over the last year to build a partnership to advance U.S. leadership in CPS.

For the 2014 CPS solicitation, NSF is working closely with the Department of Homeland Security's Science and Technology Directorate as well as two parts of the Department of Transportation – the Federal Highway Administration (FHWA) and the Intelligent Transportation Systems (ITS) Joint Program Office (JPO).

Now let me turn it over to my colleague, Dr. Pramod Khargonekar, NSF Assistant Director for Engineering, to say a few words.

Slide 2 (Pramod Khargonekar)

Thank you, Farnam. I'd just like to speak briefly at a higher level about the importance of the CPS program.

CPS as a national imperative has been noted in several reports by the President's Council of Advisors on Science and Technology, or PCAST, over the last few years. For example:

- A *2007 PCAST report* recommended that Federal R&D agencies strengthen existing programs or create new, cross-disciplinary ones to accelerate work in this area.
- The *2010 PCAST report on Networking and Information Technology Research and Development, or NITRD,* expanded on this recommendation, particularly as it applied to energy, transportation, healthcare, and homeland security.
- And a *2011 PCAST report on Advanced Manufacturing* called for focused investments in advanced manufacturing to "strengthen U.S. leadership in the areas of robotics, cyber-physical systems, and flexible manufacturing" as a means to promote sustainable economic growth and job creation.

These recommendations, consistent with the *President's Innovation Strategy* of 2011, all arise from accelerated demand and the associated technical challenges for new capabilities and services deemed to be intelligent or "smart," including *smart* transportation systems, medical technologies, buildings, and manufacturing.

This joint solicitation – and more specifically, the research that we anticipate funding through it – furthers our longstanding commitment toward fundamental research in CPS that spans multiple application domains, while at the same time identifying early-stage CPS research that addresses the important needs in emerging areas covered by our partnering agencies, including transportation CPS and security of CPS.

Through this partnership, we believe the CPS program will continue to play a catalytic role in the development of smart technologies that advance societal grand challenges and enhance our nation's productivity.

We are pleased by this new interagency solicitation, and we look forward to seeing the exciting proposals that will result.

Let me now turn things back over to Keith who will continue the webinar and offer more detail.

Slide 3 (Keith Marzullo)

Thank you, Farnam and Pramod, for this inspiring introduction of our CPS program and its importance to the Nation. Today we will be providing an overview of the NSF CPS program and will be giving details on our latest solicitation.

We will also present some FAQs, and will provide you the opportunity to ask questions to any of us.

Slide 4 (Keith Marzullo)

As Farnam described, cyber-physical systems are pervasive in our life. CPS exist in many domains that we interact with daily. They tightly integrate sensors, computing, real-time control and the physical environment. CPS are found in the automobiles we drive, the airplanes we fly in, and in many of today's medical devices. The applications of cyber physical systems are endless. Several of these are listed here. This diagram has its beginning in the early days of the CPS program; it was developed by Dr. Jeannette Wing when she served as Assistant Director at CISE when the CPS program was created. We call this affectionately our "Daisy Diagram". The figure shows the diversity of CPS applications and illustrates an inner core that identifies many of the technology elements that are common across these applications. The inner core includes: Safety, Control, Verification, Real-time, Networking, and Security. The CPS program focuses on creating discoveries inside this core, and applying these principles to solve important and challenging problems that affect multiple CPS applications. Our researchers are making important progress in core areas, such as verification, which is fundamental to designing safe autonomous vehicles and medical devices. Security is a central principle in CPS in many sectors, and has unique attributes that distinguish it from "enterprise" security.

The CPS community is large and is growing. We hold an annual Principal Investigators Meeting that brings together our program grantees. Last year attendance was nearly 300. We have a thriving Virtual Organization that helps to establish connections between our researchers. Indeed, we recently held a community discussion on future challenges of the CPS community and directions of the VO to meet these challenges; the enthusiasm of the participants was palpable.

Slide 5 (Keith Marzullo)

This slide shows many of the important characteristics of CPS. These systems exist at a wide diversity of scales ranging from ultra-small to systems such as automobiles or airplanes consisting of hundreds of integrated processors to systems of systems. The time scales can vary from very fast (milliseconds for control loops of several hundred KHZ) to very slow (in excess of several seconds). CPS can have variety of substrates including biological or nano-scale. Many CPS are those that "you can bet your life on" with high criticality, and thus require certification. In all our systems we look to close the loop – in real-time rates including some with mixed initiative operations.

Slide 6 (Keith Marzullo)

These are goals that underlie the CPS program. We have already touched on the need to develop the core science that underlies complex cyber physical systems. We are committed to building a research community. In addition, we have a degree of impatience. We are looking to see how our research can accelerate the development, design, and verification of CPS. These are pressing challenges that are critical for our National economy. Creation of prototypes and utilization of realistic test-beds enable a greater degree of experimentation and a more rapid transition into practice. In addition, the use of test-beds lower the bar for the research community to focus their effort on core CPS challenges.

Let me now introduce Dr. David Corman, who is the lead Program Director in Cyber Physical Systems.

Slide 7 (David Corman)

Thank you Keith. I wanted to mention several recent CPS activities that have occurred and are relevant to the Solicitation. Information on these including videos and presentations can be retrieved from the CPS Virtual Organization. We hosted a set of workshops designed to help NSF build a research agenda in the domains of Energy (including Smart Grid), Transportation (Aerospace and Automotive), and Medical. We also conducted workshops for aspiring CPS researchers (individuals who have been unsuccessful in obtaining CPS grants) as well as early career researchers (senior graduate students, Post Docs, and others starting academic positions in the field).

Slide 8 (David Corman)

The biggest news and the principal reason for the webcast are to introduce you to the 2014 CPS Program solicitation. The solicitation was released on March 5. The submission window is May 19 – June 2. This is later than past solicitations. However, many in the community have been able to take advantage of the increased time to formulate ideas and have attended several of the CPS program workshops. There are important changes in the solicitation and I will walk you through them in the following chart.

Slide 9 (David Corman)

As was mentioned by Farnam, 2014 is the first CPS joint solicitation. We are excited to bring both the Department of Homeland Security – Science and Technology Directorate (HSARPA) Cyber Security program, and the Department of Transportation Federal Highway Administration and Intelligent Transportation Systems Program Office into the solicitation.

The basic mission of the solicitation to identify early stage foundational CPS research will continue. We are also looking here for research that addresses mission agency needs, and has potential for acceleration and maturation.

David Kuehn is here from DOT FHWA, and Tammi Fisher is here from DHS S&T, and they will speak briefly later about their programs.

We are also very enthusiastic about the transition to practice option for CPS. This will provide the research community greater opportunity to demonstrate usability and maturation of the work. CPS technologies are critical to future economic growth, and CPS research results can be leveraged by industry.

Finally, Breakthrough and Synergy Proposals are 15 pages. Frontier proposals remain at 20 pages.

Slide 10 (David Corman)

This chart (first of two) illustrates some of the foundational issues that the solicitation addresses. These are cross disciplinary and applicable to a multitude of domains. Other central themes are welcome.

System design continues to be of great interest. Cyber Physical Systems need to be designed to be safe, secure, and resilient. They must operate in wide diversity of environments that are dynamic and may require resiliency in the face of extreme and rapid physical disturbances and cyber attack. Integration of privacy and security into their design is of importance.

System verification technologies are also a critical area to many of our CPS. CPS are becoming ever more complex and we need tools and techniques that will enable rapid and complete verification. Techniques in formal methods are of interest, but they must scale to system size. We are also interested in compositionality and ideas on incremental certification. We need technologies that can provide safety yet enable us to shrink the size of “Test spaces” for these systems. This is important in driving system affordability for future competitiveness. Mixed authority systems in which the human interacts with CPS present many verification challenges.

Slide 11 (David Corman)

Cyber-physical systems must be able to operate in a variety of physical environments. The networking environment may range from clouds to network challenged. In addition, the system may have energy management constraints that require deep trades in processing and networking to prolong system life. Big data is prevalent in many cyber-physical systems. How do integrate big data into real-time control?

Finally, CPS will integrate software and hardware capabilities. There is a need to explore how core CPS technologies can developed to enable dramatic reductions in timelines for design, build, test and verification of complex systems. Do these foundational capabilities scale to support globally distributed integrated hardware and software design and production challenges in real-world systems?

These are but a few of the foundational issues that we are interested in. We await your ideas.

Slide 12 (David Corman)

This chart outlines the "research target areas" for the CPS Program. In formulating the research idea, proposers must ensure that the research addresses challenges in at least one of the three target areas as follows.

First is science of CPS. The CPS Program seeks research that enables next generation of CPS to move beyond the classical fundamental models of computation and physics. New models and theories that unify perspectives, capable of expressing the interacting dynamics of the computational and physical components a dynamic environment; support composition, bridge the computational versus physical notions of time and space, cope with uncertainty, and enable cyber-physical systems to interoperate and evolve.

Second is Technology for CPS. The CPS program seeks new design, analysis, and verification tools that embody the scientific principles of CPS and incorporate measurement, dynamics, and control are needed. New building blocks are also needed, including hardware computing platforms, operating systems, and middleware.

And finally, Engineering for CPS. CPS researchers should rethink the principles and methods of systems engineering that are built on the foundations of CPS science and technology. Researchers should pay attention to system architectures, designs, and integrations as well as the exploration of design spaces that will produce certifiably dependable systems.

Slide 13 (David Corman)

David Kuehn from DOT / FHWA will present the next chart that provides additional insight into DOT program interests.

Slide 13 (David Kuehn)

The Department of Transportation is pleased to be working with the National Science Foundation on cyber-physical systems. The Department has been supporting research on connected vehicle and highway systems. We believe that deployment of such systems could lead to dramatic improvements in safety and reliability in the highway transportation system. Examples of such research include cooperative adaptive cruise control for more stable vehicle platooning, merge assist, and signal phase and timing applications to improve traffic flow and safety on arterial roadways. More recently, the Department has been working on a path for leveraging the benefits from technologies that allow for increased vehicle automation. For both connected vehicle and highway systems and for vehicle automation systems there is much that still needs to take place on both fundamental scientific questions and large scale systems engineering. In particular, the Federal Highway Administration is seeking new methods for understanding the system level impacts of increased connectivity and automation and for testing the introduction of these systems into a roadway system environment where there is and will continue to be a mix of current and past technologies.

Slide 14 (David Corman)

Tammi Fisher will briefly now describe specific areas of interest to DHS S&T HSARPA.

Slide 14 (Tammi Fisher)

DHS S&T is very happy to be participating in this solicitation. We have particular interest in CPS security technologies relevant in multiple domains as shown on the chart. Our interest includes technologies for guarding against malicious attacks on CPS including technologies for identifying, predicting, preventing, and recovery from faults. Further information on DHS S&T interests in cyber security can be found at the website provided on the chart.

Slide 15 (David Corman)

The CPS solicitation will utilize the same three proposal types as before – Breakthrough, Synergy, and Frontier. CAREER CPS grants will be considered as part of the CAREER solicitation.

Breakthroughs are looking for significant advances that can change the field. We also look for new approaches to bridge the fields of computing, communication, and control. Funding for these projects is up to $500,000 and up to three years. Breakthroughs typically are single PI, high risk, and high reward projects. We anticipate approximately 10 projects to be awarded.

Synergy projects are at the intersection of multiple disciplines to accomplish a clear goal. They aren't two separate projects stapled together. Funding is up to $1,000,000 and for a period of 3-4 years. Approximately 20 projects may be awarded. A larger number were awarded last year.

Frontier projects are our largest single investment. They have a value of up to $7,000,000 for up to 5 years. Frontier projects require careful development to create a well-integrated and orchestrated program. The project goals cannot be accomplished by simply splitting it into multiple and independent single awards. One – two projects may be awarded.

Transition to practice options is available for each of the award classes. Finally, it is important to point out the importance of foundational research for each of the award class.

Slide 16 (David Corman)

This chart highlights special review criteria for transition to practice. Projects with a transition to practice option must include a supplemental document (up to five pages) that describes how the research results are to be further developed, matured, and experimentally deployed. It should also include a budget (no larger than $167,000 for breakthrough, $400,000 for synergy, and $1,000,000 for Frontiers). Proposals will be reviewed based on expected impact, extent to which value proposition is described, feasibility and utility, plan, metrics for assessing success, and appropriateness of budget, i.e. is the budget commensurate with the activity and impact.

Slide 17 (David Corman)

We have included some things to consider as you formulate your proposal.

Am I proposing just a (cool) application or am I proposing the fundamental science that cuts across multiple application domains?

Am I touching the major elements of CPS (Computing, Sensing, and Control)? Also, consider where the Physical element is.

How am I closing the loop?

Read the solicitation carefully.

Slide 18 and 19 (David Corman)

The CPS program website provides access to information about recent CPS awards. The information is accessible from the CPS program page under the Directorate for Computer & Information Science and Engineering. The website allows the user to search for "What Has Been Funded (Recent Awards Made Through This Program, with Abstracts). The information can also be finding searching the awards data base under the home page nsf.gov.

The following two charts show screen shots of how to pull information. The information can also be retrieved through "search awards" on the NSF home page.

Slide 20 (David Corman)

Thank you for listening.

Questions may be addressed to CPSquestions@nsf.gov

Slide 21 - 24 (David Corman)

We have collected FAQs over the next several charts.

1. **Question**: How can industry participate in a CPS proposal?

   Answer: Industry frequently participates through letters of support and hosting internships or through industry advisory boards. While proposals may only be submitted by Universities and

Colleges, and non-profit non-academic organizations, industry may participate in a proposal as a sub-awardee.

2. **Question**: Can my proposal fund international collaborators?

   Answer: Under most circumstances, no. Please contact Program Director for additional information.

3. **Question**: How does joint solicitation change proposal review process?

   Answer. Agencies will contribute panelists. Proposal review process will be unchanged. We will use interagency transfer of funds.

4. **Question**: Can we submit a domain specific proposal? E.g. Smart Grid?

   Answer: Proposals need to consider holistic, integrative approaches to cyber-physical systems that are applicable to more than one application domain. Smart grid, can of course, be one of the applications that stimulates the research and will use the technology.

Thank you again.