CPS Summer School 2017
Designing Cyber-Physical Systems – From concepts to implementation
September 25-29, Alghero, Italy

How CPS applications in biomedicine came to reality

a journey through US federally funded schemes for stimulating research and industry

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Let's start with a commentary

"What my 90yo mom taught me about the future of AI in health care"

Let's start with a commentary

"What my 90yo mom taught me about the future of AI in health care"

The Context

" ….My mother has **moderate heart dysfunction**, and her physician has her on all the right medications, including a daily dose of Lasix, a "**water pill**" that makes you urinate more and thereby **eliminate some of the salt** in your blood. Yet last year, over several weeks, her legs became increasingly **swollen with fluid**…. Her physician sent her to the **emergency room**……By the time she left the hospital, her legs had not returned to normal but **were visibly thinner**….

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The Action

…. The plan was to have her **watch her weight daily**, and every time there was **any sign of increased fluid**, to recommend an extra dose — **an extra pill** — of Lasix, to restore her fluid balance….. I decided to purchase an **internet-enabled scale from Fitbit** that allowed me to check my mother's weight via Fitbit's web application.

I asked my mother to **weigh herself every morning** before eating. In the first few weeks, **if she forgot to weigh herself** I could see that and **would call** her to nudge her.

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The Algorithm

1. *If* $w_i - w_{i-1} > 1$ lb (Δi= 24hrs), *then* recommend 1 extra pill.
2. *If* $w_i - w_{i-1} = 1$ lb, *then* wait

   if $w_{i+2} - w_i > 1$ lb, *then* recommend 1 extra pill.

   If she took the extra pill, *then:*
3. *If the* $w_{i+4} > w_{i-1}$, *then* give 1 extra pill on i+5.

   If $w_{i+6} > w_{i-1}$, *then* go visit her in her apartment and see if her legs are swollen or if her breathing has changed.

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The Outcome

.... Through the miracle of the **internet and smartphones**, I was able to run the algorithm even when **I was in a distant part of the globe** to give a talk or on a family vacation.

Best of all, my mother **hasn't even come close** to needing to **go back to the hospital**. Her legs remain completely unswollen. Also, I never called her doctor about persistent fluid gain because that [third] part of the algorithm was never triggered.

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The Conclusions (1)

- **….** A frail, elderly patient's health may be influenced by single or multiple **perturbations** that span the full spectrum of human experience: How much salt was in yesterday's food, the appearance of a **skin infection** on a leg, change in **thyroid hormone levels**, increased fluid loss due to **apartment heat** after an air conditioner failure, sad news causing **mood changes** causing decreased exercise..

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The Conclusions (2)

- **….** Even more challenging: How does a **computer program** obtain **trust and persuasive powers** so that skeptics like my mother will **comply** with recommendations? What discussions, diagrams, pressures or **incentives will be sufficient** to convince someone who may **not be feeling well at all** to change a behavior, a medication or diet?

Let's start with a commentary

"What my 90yo mom taught me about the future of AI in health care"

….**AI** does not do well at understanding the **wide world**, at picking up mood or subtle signs of distress, at convincing a resistant human to listen to the doctor. **We don't need AI for that; we need a caring village**.

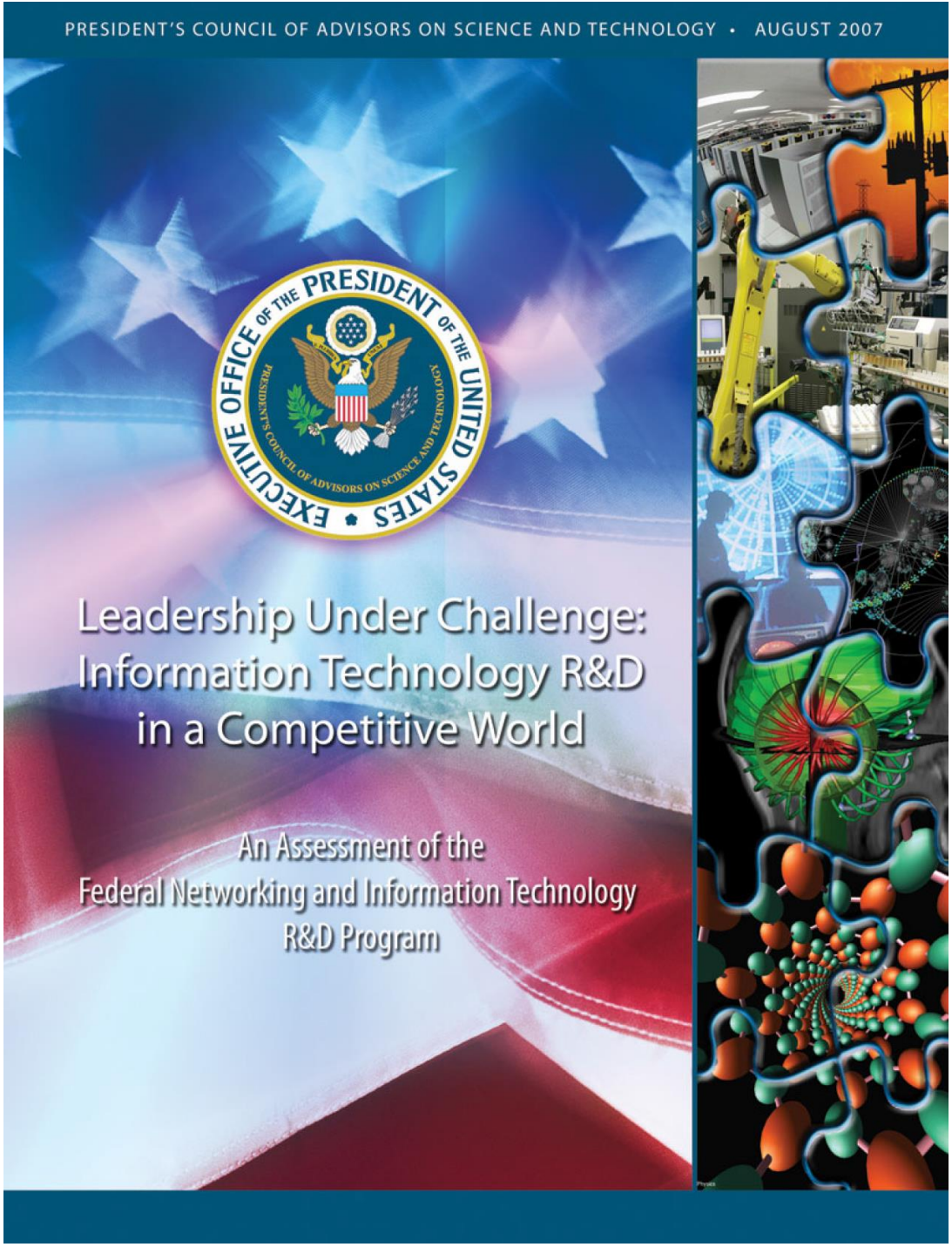
Dr. Isaac Kohane *is the inaugural chair of the* ***Department of Biomedical Informatics*** *at* ***Harvard Medical School****.*

Commentary aired on WBUR Boston, an NPR radio on June 16th 2017

Research
in
CPS-based
biomedical applications

…….in the US

a bit of history



08/2007 report of the President's Council of Advisors on Science and Technology (PCAST)

Subcommittee on Networking and Information Technology

Leadership Under Challenge: Information Technology R&D in a Competitive World

09/2008

Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 08-611

National Science Foundation

Directorate for Computer & Information Science & Engineering

Directorate for Engineering

$30,000,000

Full Proposal Deadline(s) (due by 5 p.m. proposer's local time):

February 27, 2009

Last Friday in February, Annually Thereafter

Foundations: new scientific and engineering principles, algorithms, models, and theories for the analysis and design of CPS.

Methods and Tools: to bridge the gaps between approaches to the cyber and physical elements of systems through innovations such as novel support for multiple views, new programming languages, and algorithms for reasoning about and formally verifying properties of complex integrations of cyber and physical resources

Components, Run-time Substrates, and Systems: new hardware and software *Components, Run-time Substrates* (infrastructure and platforms), *and* (engineered) *Systems* motivated by grand challenge applications.

Cyber-Physical Systems (CPS)

Cyber-Physical Systems (CPS)

Cyber-Physical Systems (CPS)

Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 13-502

REPLACES DOCUMENT(S):
NSF 12-520

National Science Foundation

Directorate for Computer & Information Science & Engineering
Division of Computer and Network Systems
Division of Computing and Communication Foundations
Division of Information & Intelligent Systems

Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 14-542

REPLACES DOCUMENT(S):
NSF 13-502

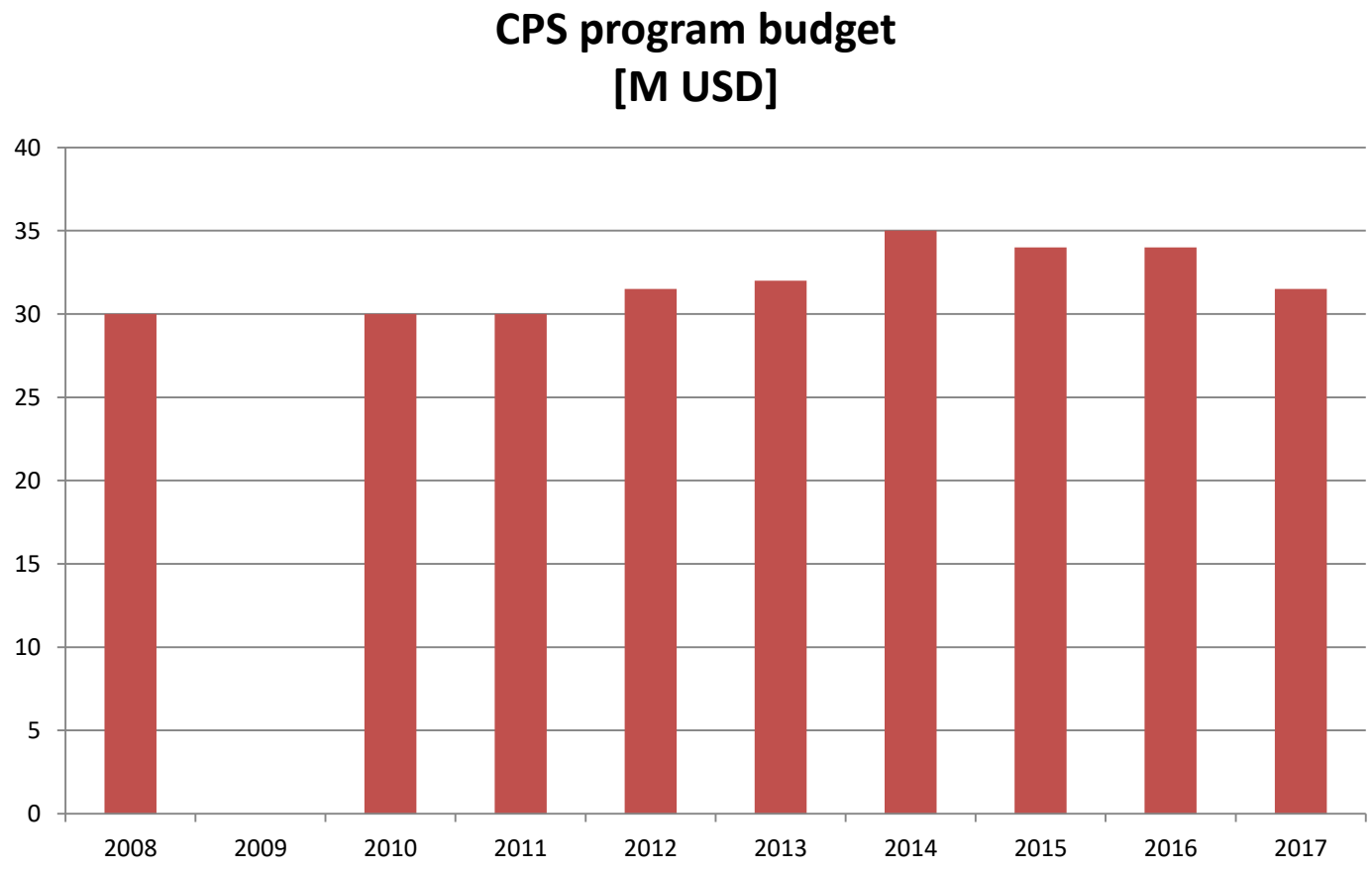
National Science Foundation

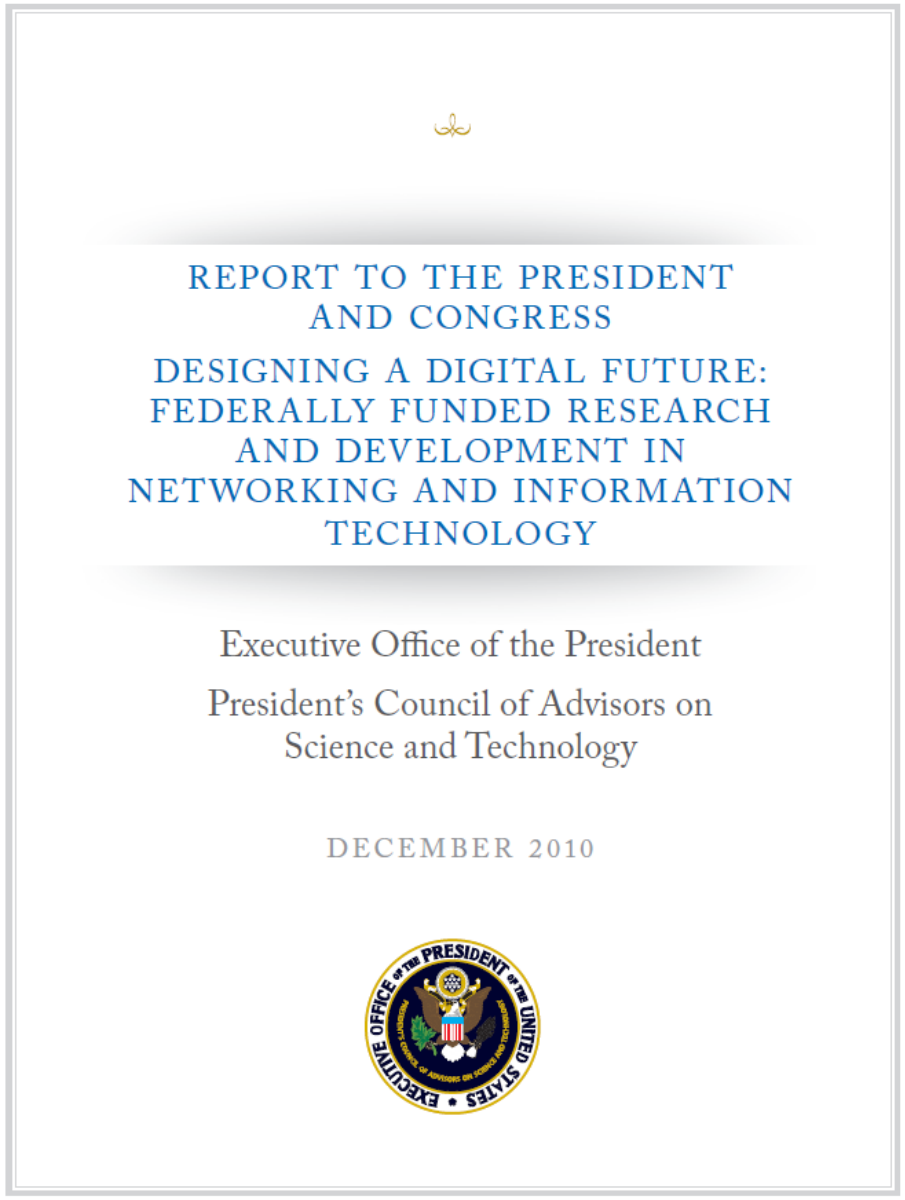
Directorate for Computer & Information Science & Engineering
Division of Computer and Network Systems
Division of Computing and Communication Foundations
Division of Information & Intelligent Systems
Division of Advanced Cyberinfrastructure

Directorate for Engineering
Division of Electrical, Communications and Cyber Systems
Division of Civil, Mechanical and Manufacturing Innovation
Division of Chemical, Bioengineering, Environmental, and Transport Systems

Department of Homeland Security, Science & Technology Directorate

U.S. Department of Transportation, Federal Highway Administration


CPS program budget
[M USD]
40
35
30
25
20
15
10
5
0
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017



Calls for

continued investment in CPS research because of its scientific and technological importance as well as its potential impact on grand challenges in a number of sectors critical to U.S. security and competitiveness such as the ones noted above

Senior Steering Group

The Networking and Information Technology Research and Development

CPS Vision Statement - Dec 2012

Definition

Cyber Physical Systems (CPS) are smart networked systems with embedded sensors, processors and actuators that **are designed to sense and interact with the physical world** (including the human users), and support real-time, guaranteed performance in safety-critical applications. In CPS systems, the joint behavior of the "cyber" and "physical" elements of the system is critical - computing, control, sensing and networking can be deeply integrated into every component, and the actions of components and systems must be safe and interoperable.

Agriculture…..
Building Controls…..
Defense…..
Emergency Response….
Energy…..
Healthcare challenges arising from our aging population combined with the opportunities provided by inexpensive sensing, ubiquitous communication and computation and the demand for 24/7 care will lead to an **explosion of cyber-physical medical products**.
Manufacturing and Industry….
Society….
Transportation…..

Crosscutting Strategic Challenges that are Essential to Success in all Sectors
Cybersecurity….
Economics….
Interoperability Challenge…..
Privacy….. Safety and Reliability……

The CPS initiative

In 2015, **NSF** is working closely with multiple agencies of the federal government, including the

DHS - U.S. Department of Homeland Security, Science and Technology Directorate (S&T);

DOT - U.S. Department of Transportation: Federal Highway Administration (FHWA), Intelligent Transportation Systems (ITS) Joint Program Office (JPO);

NASA - National Aeronautics and Space Administration: Aeronautics Research Mission Directorate (ARMD);

several **NIH** - National Institutes of Health Institutes and Centers [National Institute of Biomedical Imaging and Bioengineering (NIBIB), Office of Behavioral and Social Sciences Research (OBSSR), National Cancer Institute (NCI), and National Center for Advancing Translational Sciences (NCATS)];

to **identify basic research needs** in CPS common across multiple application domains, along with opportunities for accelerated transition to practice.

PROGRA
NSF 15-

REPLAC
NSF 14-

Cyber-Physical Systems (CPS)

PROGRA
NSF 16-

REPLAC
NSF 15-

Cyber-Physical Systems (CPS)

PROGRAM SOLICITATION
NSF 17-529

REPLACES DOCUMENT(S):
NSF 16-549

National Science Foundation

Directorate for Computer & Information Science & Engineering
- Division of Computer and Network Systems
- Division of Computing and Communication Foundations
- Division of Information & Intelligent Systems
- Division of Advanced Cyberinfrastructure

Directorate for Engineering
- Division of Electrical, Communications and Cyber Systems
- Division of Civil, Mechanical and Manufacturing Innovation
- Division of Chemical, Bioengineering, Environmental and Transport Systems

Department of Homeland Security, Science & Technology Directorate

U.S. Department of Transportation, Federal Highway Administration

National Aeronautics and Space Administration

National Institutes of Health
- National Institute of Biomedical Imaging and Bioengineering
- National Cancer Institute

National Center for Advancing Translational Sciences

U.S. Dept. of Agriculture

National Institute of Food and Agriculture

GCN NIH dives into cyber-phy ×

Secure | https://gcn.com/articles/2015/02/27/nih-cyber-physical-systems.aspx

NIH dives into cyber-physical systems research

By Mark Pomerleau | Feb 27, 2015

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7 security projects worth watching

National Institutes of Health

Notice of NIH Participation in the Cyber-Physical Systems Initiative (CPS)

- The NIH encourages CPS research and technology development ……. to
  - *achieve **functional independence** in humans,*
  - *improve **quality of life**,*
  - *assist with **behavioral therapy** and **personalized care**,*
  - ***monitor** or generate efficacious **readouts of therapeutic effects of therapies**, and*
  - *promote **wellness/health**.*

- Advances in sensors, wearable devices, and patient-facing technologies hold great promise in improving healthcare ….. **Little is known, however, about how advances in CPS can integrate these technologies and interfaces to increase patient engagement and activation**……

- One vision of medical CPS could be **the development of personalized patient-care systems** which are tightly knit with other non-medical CPS systems. Such a closed-loop environment could enable **optimal and timely delivery of healthcare improvements at a significant cost reduction**.

Notice Number: NOT-EB-15-003

Release Date: February 19, 2015

National Institutes of Health

Notice of NIH Participation in the Cyber-Physical Systems Initiative (CPS)

Examples of medical CPS research and technology development:

- Pursuing approaches to **enhance interoperability** between various **medical devices** and/or systems;
- Implementing CPS technology to
  - **reduce medical errors** in intensive care units (ICUs);
  - for **real-time monitoring and analysis** of complex biomedical research systems …..;
- Developing
  - **prototypical closed-loop CPS for medical systems**
  - **human-system integration (HSI) applications** designed to optimize the role of human cognition in relation to CPS support within the context of either clinical or consumer health environments;
  - applications to **monitor physiologic, motor, and cognitive functioning** across environments to inform treatment and facilitate research;
  - approaches to understand the **behavioral and social aspects of medical CPS implementations**;
  - **real-time patient-specific clinical decision-making** approaches;
  - **real-time data analytic techniques for medical CPS systems**;
  - CPS applications **to improve access, utility, and management of biomedical big data** for basic research;
  - hospital-wide applications to decrease fragmentation, improve quality of care, and conserve costs by tracking medical assets and conjoining informatics data flows to enable a "learning healthcare system."

Notice Number: NOT-EB-15-003
Release Date: February 19, 2015

The CPS initiative

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USDA - U.S. Department of Agriculture-National Institute of Food and Agriculture (USDA-NIFA);

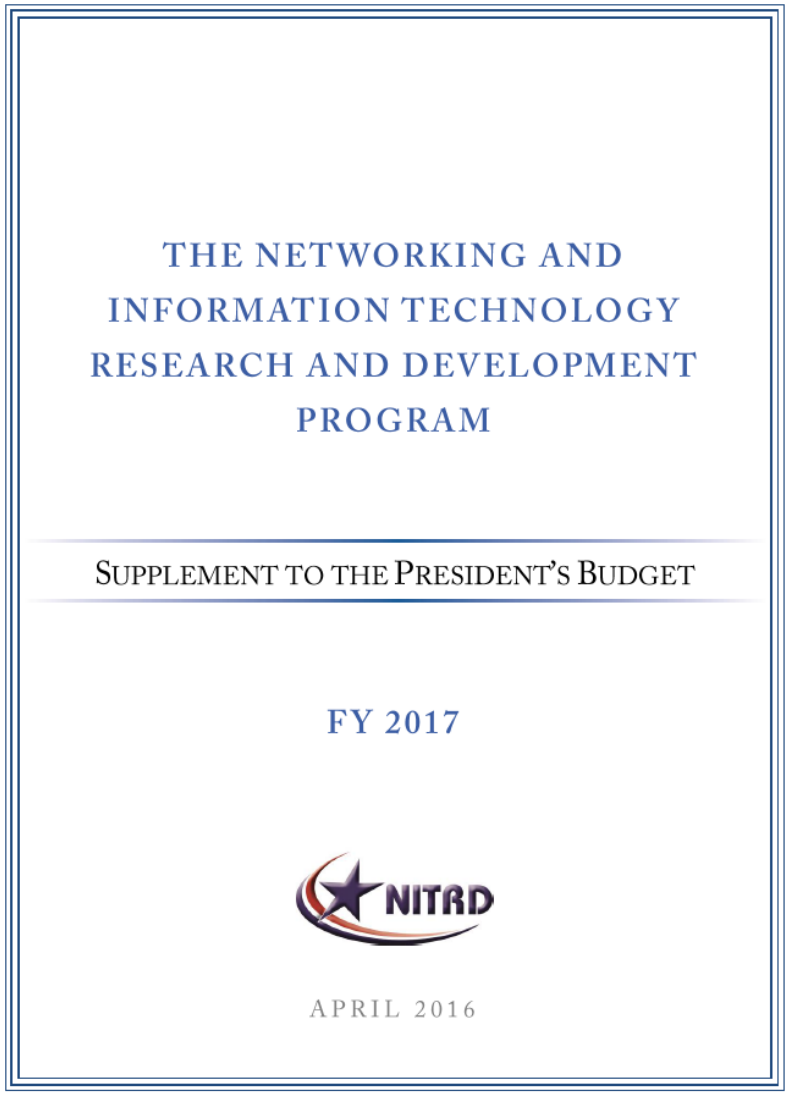
to **identify basic research needs** in CPS common across multiple application domains, along with opportunities for accelerated transition to practice.

THE NETWORKING AND INFORMATION TECHNOLOGY RESEARCH AND DEVELOPMENT PROGRAM

SUPPLEMENT TO THE PRESIDENT'S BUDGET

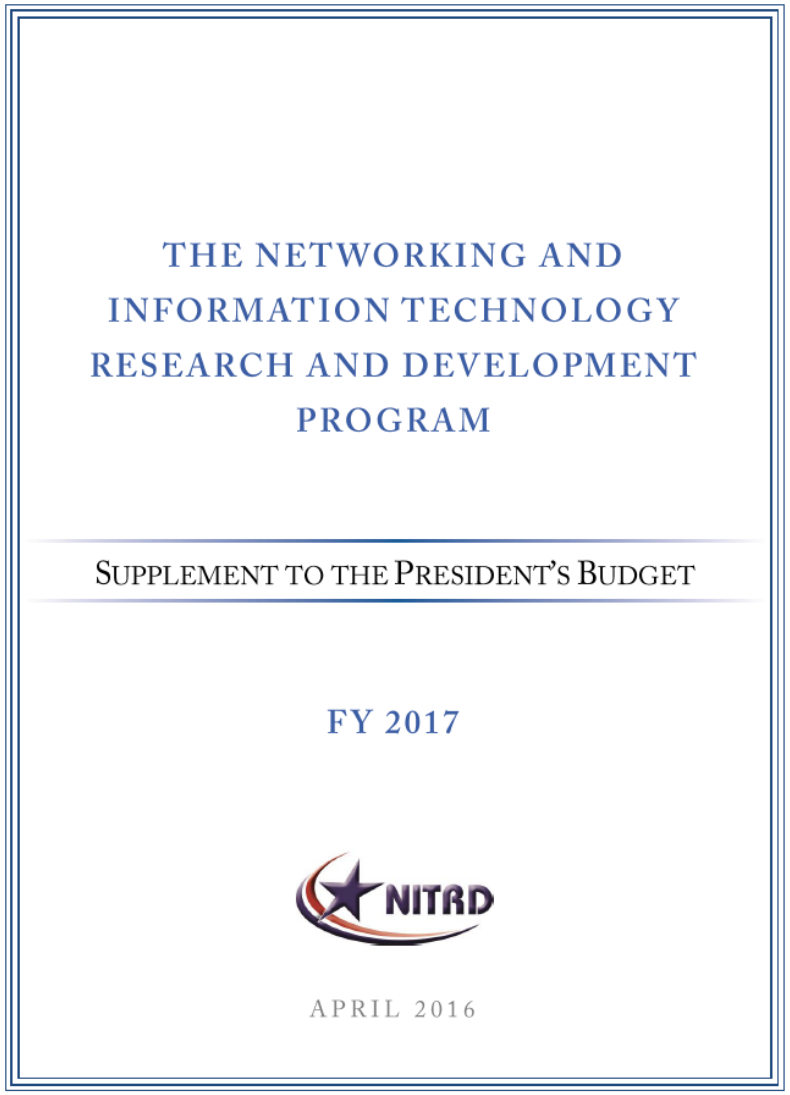
FY 2017

APRIL 2016



Program Component Areas (PCAs)

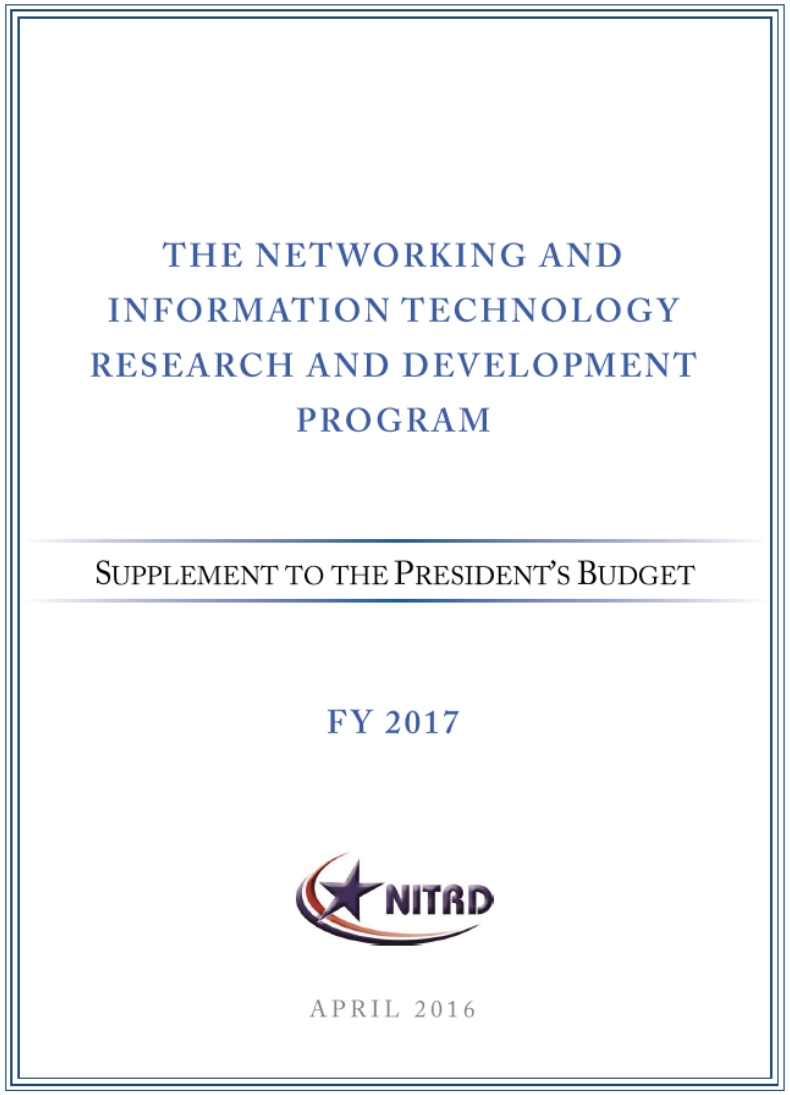
- Enabling-R&D for High-Capability Computing Systems (EHCS)
- High-Capability Computing Systems Infrastructure and Applications (HCSIA)
- Large-Scale Data Management and Analysis (LSDMA)
- Robotics and Intelligent Systems (RIS)
- Human Computer Interaction and Information Management (HCI&IM)
- **High Confidence Software and Systems (HCSS)**
- Large Scale Networking (LSN)
- Cyber Security and Information Assurance (CSIA)
- Social, Economic, and Workforce Implications of IT and IT Workforce Development (SEW)
- Software Design and Productivity (SDP)



High Confidence Software and Systems (HCSS)

Strategic Priorities

- Science and technology for building CPSs:
- Management of complex and autonomous systems
- Assurance technology
- High-confidence real-time software and systems
- Translation into mission-oriented research
- CPS education
- Secure, dependable Internet of Things (IoT)



High Confidence Software and Systems (HCSS)

Highlights of the Request

The HCSS agencies report the following topical areas as highlights of their planned R&D investments for FY 2017:

- Cyber-physical systems
- Complex systems
- High-confidence systems and foundations of assured computing
- Information assurance requirements
- Aviation safety
- Assurance of Flight-Critical Systems

President's Budget FY 2017

Agency/ Program Component Area	Cyber Security & Information Assurance CSIA	Enabling-R&D for High-Capability Computing Systems EHCS	Human Computer Interaction & Information Management HCI&IM	High-Capability Computing Systems Infrastructure & Applications HCSIA	High Confidence Software & Systems HCSS	Large-Scale Data Management & Analysis LSDMA	Large Scale Networking LSN	Robotics & Intelligent Systems RIS	Software Design & Productivity SDP	Social, Economic, & Workforce Implications of IT SEW	Total [a]
NSF	111.0	131.0	182.8	183.2	86.5	111.3	139.0	43.5	82.7	127.1	1,198.0
DoD [b]	145.1	216.4	170.0	81.9	12.9	38.2	108.0	102.9	10.2	3.1	888.7
DOE [c]	30.0	208.3		393.6	17.5		88.0	11.7		10.0	759.1
NIH [d]	3.0	23.1	313.0	194.6	30.0		8.0		129.0	54.0	754.7
DARPA	300.1	6.0				106.6	27.6				440.4
NIST	70.2	18.0	8.2	8.1	15.7	15.8	10.8	7.9	1.8	4.0	160.5
NASA		11.0	14.0	60.9	4.9	5.4	0.8	53.5	6.6		157.0
DHS	66.8		2.0			5.0					73.8
NOAA			0.2	36.0			3.3		3.7		43.2
NNSA		30.0								3.5	33.5
AHRQ			22.9								22.9
EPA		3.7	3.1								6.8
NIJ	1.5						1.0	1.0			3.5
NARA			0.2								0.2
Total [a, d]	727.7	647.5	716.4	958.3	167.5	282.3	386.4	220.5	234.0	201.7	4,542.4

High Confidence Software and Systems (HCSS)

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HCSS R&D supports development of scientific foundations and innovative and enabling software and hardware technologies for the engineering, verification and validation, assurance, standardization, and certification of complex, networked, distributed computing systems and **cyber-physical systems**.

President's Budget FY 2017

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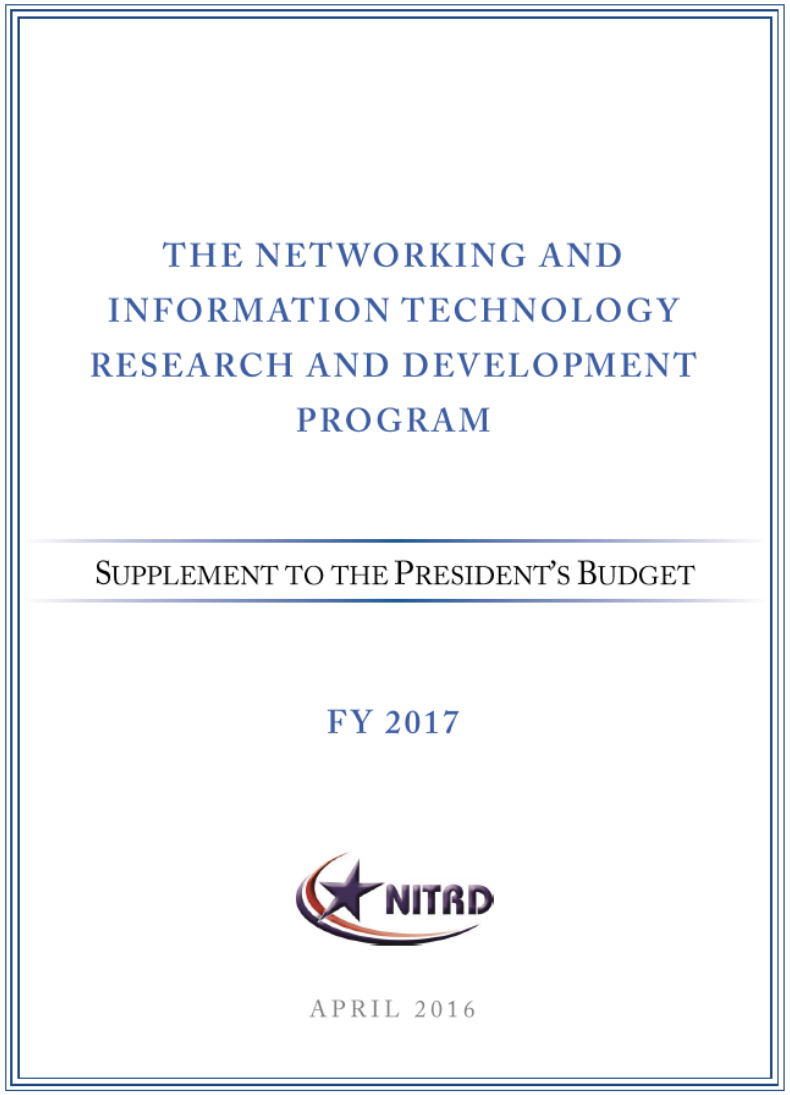
18%

of HCSS R&D goes to **biomedical applications**



NIH National Institutes of Health

- translational research in biomedical technology to **enhance development, testing, and implementation of diagnostics and therapeutics** that require advanced CPS innovations;
- assurance in **medical devices**;
- **telemedicine**;
- computer-aided **detection and diagnosis**;
- computer-aided **surgery and treatment**;
- **neural interface** technologies.


Medical-CPS | CPS-VO
Secure | https://cps-vo.org/group/medical-cps
CPS-VO
MY GROUPS
username
Log in
Search
Not a member?
Click here to register!
Forgot username or password?
Medical-CPS
CPS-VO » MEDICAL-CPS
Medical-CPS
Home
Calendar
Recent Activity
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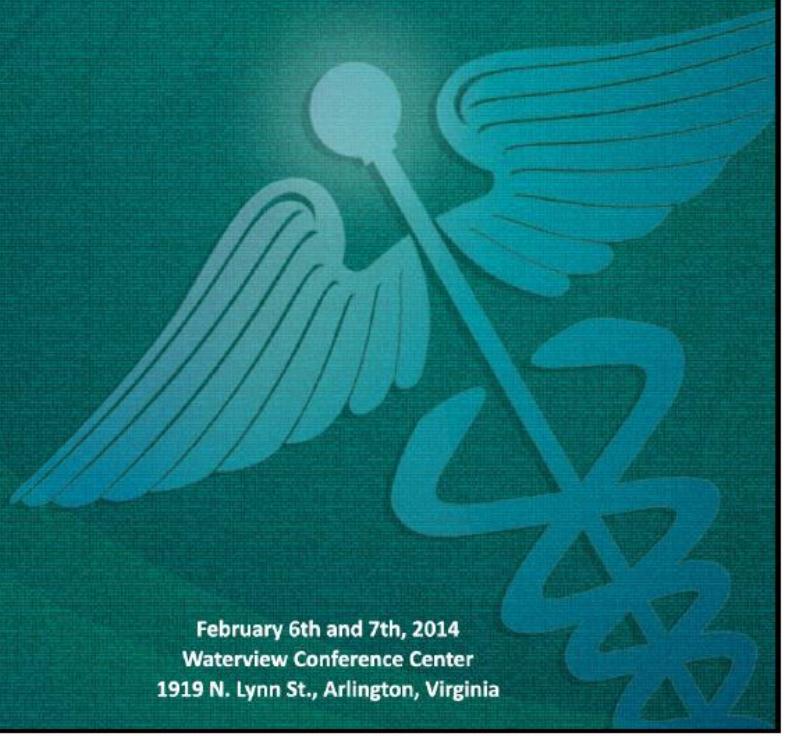
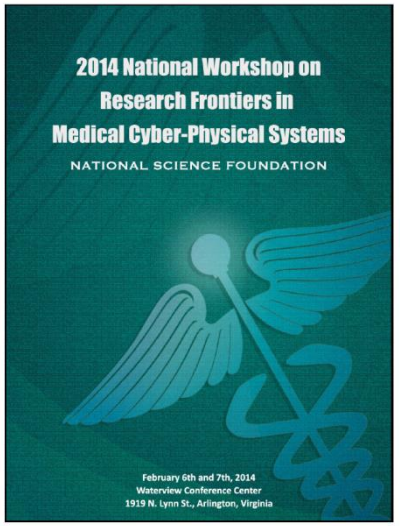
Forums
Files
SUBGROUPS
MEMBER INFO
Medical cyber-physical systems (MCPS) are life-critical, context-aware, networked systems of medical devices and medical systems infrastructure. These CPS systems and infrastructure are increasingly the foundations for providing high quality continuous care for patients. The need to design complex MCPS that are both safe and effective has presented numerous challenges, including achieving high assurance in system software, interoperability, context-aware intelligence, autonomy, security and privacy, and device certifiability.

2014 National Workshop on Research Frontiers in Medical Cyber-Physical Systems

NATIONAL SCIENCE FOUNDATION



February 6th and 7th, 2014
Waterview Conference Center
1919 N. Lynn St., Arlington, Virginia



Future Directions in Monitoring and Diagnosis:

- New, better domain specific languages for automated biology.
- Automation in preparation and use of wet lab tools.
- Distributed control systems over the Internet with timing constraints and QoS guarantees.
- Individualization- custom monitoring and diagnosis for each individual patient.

Future Directions in Modeling, Verification and Trustworthiness:

- Further innovation in mobile- and cloud-computing systems. Must be ensured private, verified correct.
- Nationally shared comprehensive logging and analysis.
- Efforts to open and crowd-source existing platforms.
- Diagnosis and treatment of cardiac disorders using controllers based on formally verified models.
- Proving correctness of combinations of verified components, especially with regards to emergent behaviors and properties of the combined system.

Future Directions in Intervention, Control and Prosthetics:

- Integration of existing epilepsy monitoring technologies to improve interoperability and customize solutions for patients.
- Architectures for human/machine combined operations in telesurgery and other semi-autonomous fields.
- Paradigms for switching control between humans and robots.
- Detailed modeling of soft-tissue interaction.
- Safety-aware controller engineering and design.

CPS-VO Medical Group

The group brings together researchers and developers working on CPS in the medical domain,

- medical device interoperability
- high-confidence development of medical devices
- medical robotics.

Several large-scale projects in the medical CPS domain have been funded by both NSF and NIH.

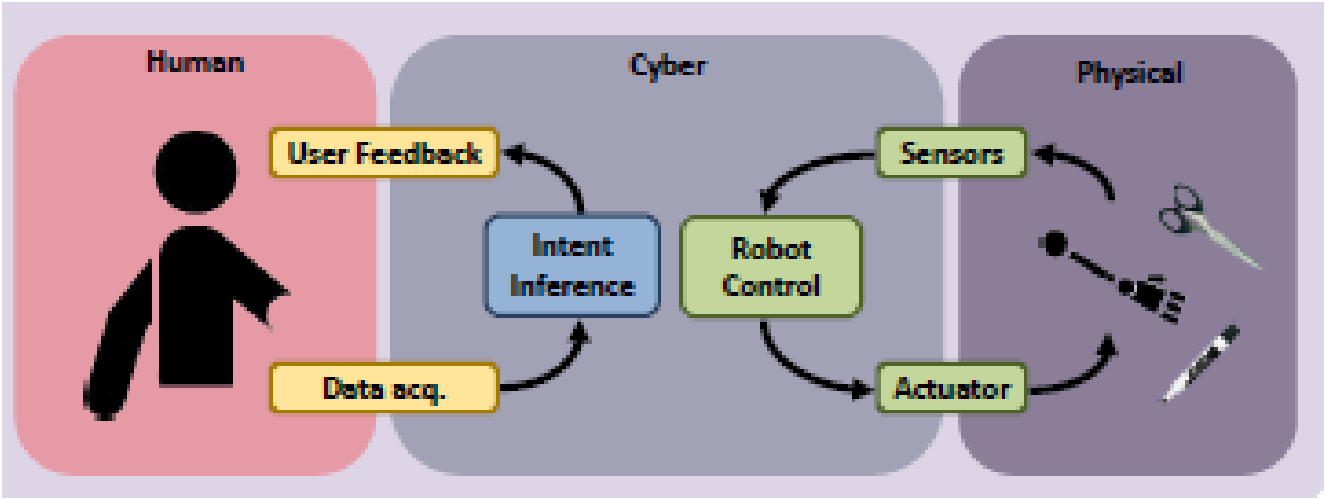
The group hosts discussions that go beyond the scope of any individual projects, planning future projects, and general exchange of ideas.

The group **is open to all researchers who are involved in medical CPS research** or are interested in learning more about it.

Granted studies from NSF database

Nested Control of Assistive Robots through Human Intent Inference

…..to create a unified engineering, biomechanical and physiological framework for designing and evaluating patient-in-the-loop



NEU – WPI – SRH

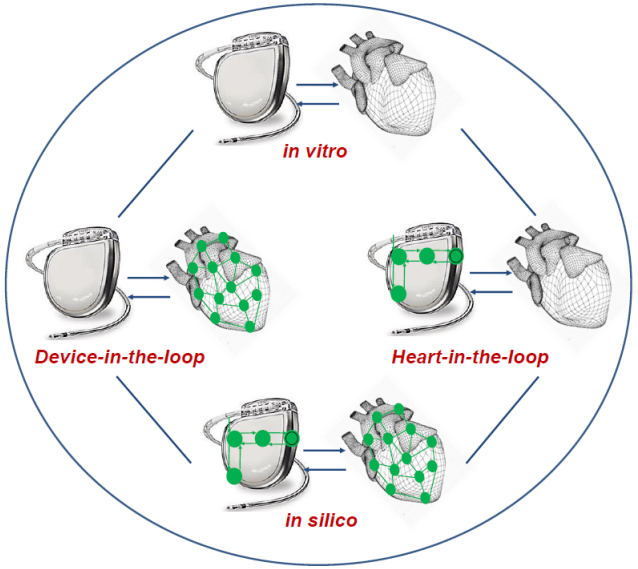
Design and build an EEG-EMG-context fusion approach for human intent inference that tightly integrates with an intelligent physical interface to allow users to control a robotic hand prosthesis.

https://cps-vo.org/node/29324

Granted studies from NSF database

Compositional, Approximate, and Quantitative Reasoning for Medical CPSs

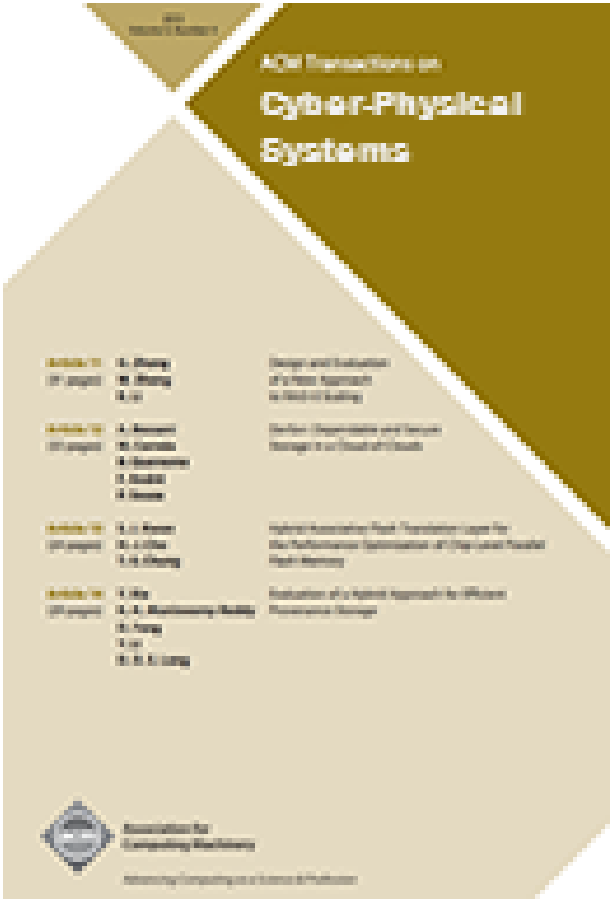
….. to enable the development of a true in silico design methodology for medical devices that can be used to speed the development of new devices and to provide greater assurance that their behavior matches designer intentions, and to pass regulatory muster more quickly so that they can be used on patients needing their care



Stony Brook University – Upenn – UMD – Carnegie Mellon – Georgia Tech - etc

https://cps-vo.org/node/29427

Publications



A special issue on
Medical Cyber-Physical Systems

…. evidence of contributions to
medical cyber-physical systems applications and systems in practice

Expected publication: Fall, 2017

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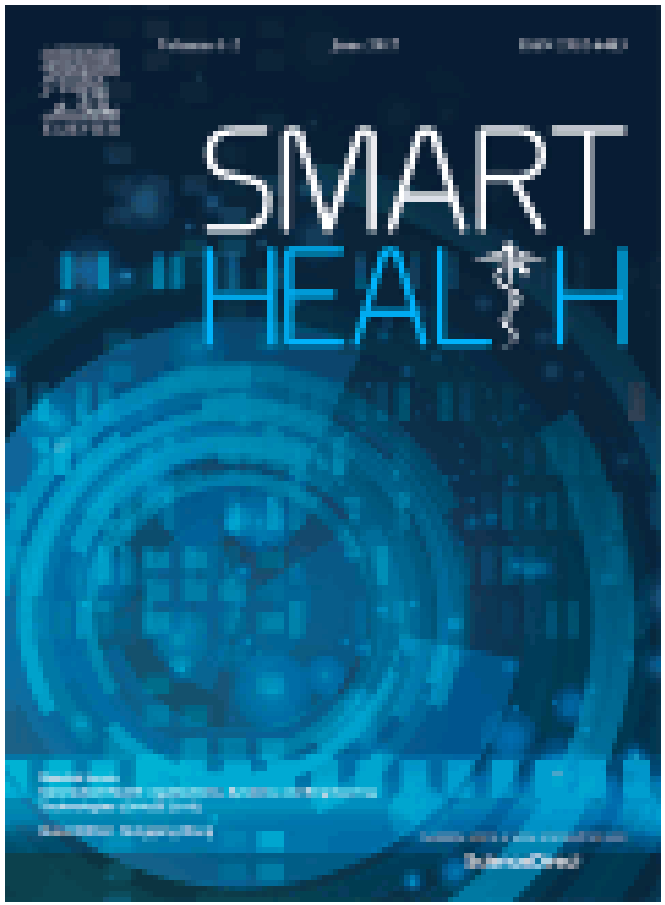
Publications



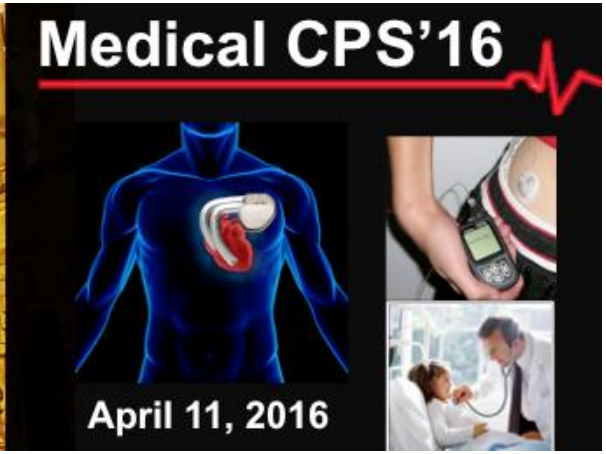
A special issue on theoretical and experimental research for security, privacy and trust solutions in the context of medical cyber physical systems.

Submission deadline: Sept. 30th 2017

ELSEVIER

Workshops

Berlin, Germany April 14, 2014

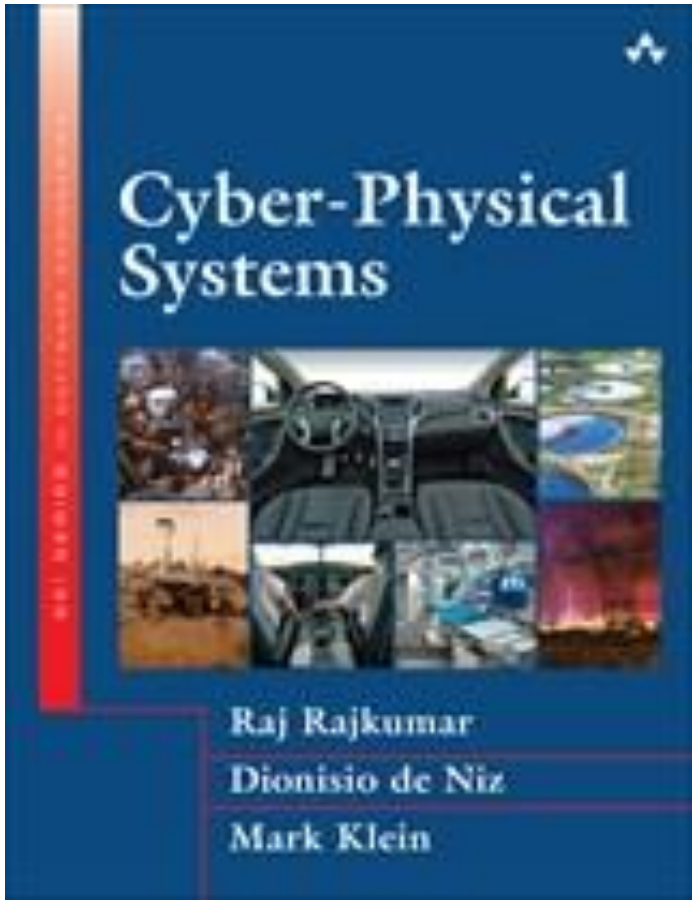


Workshops

International Workshop on Security, Privacy, and Trustworthiness in Medical Cyber-Physical Systems

Philadelphia July 17-19, 2017

Books

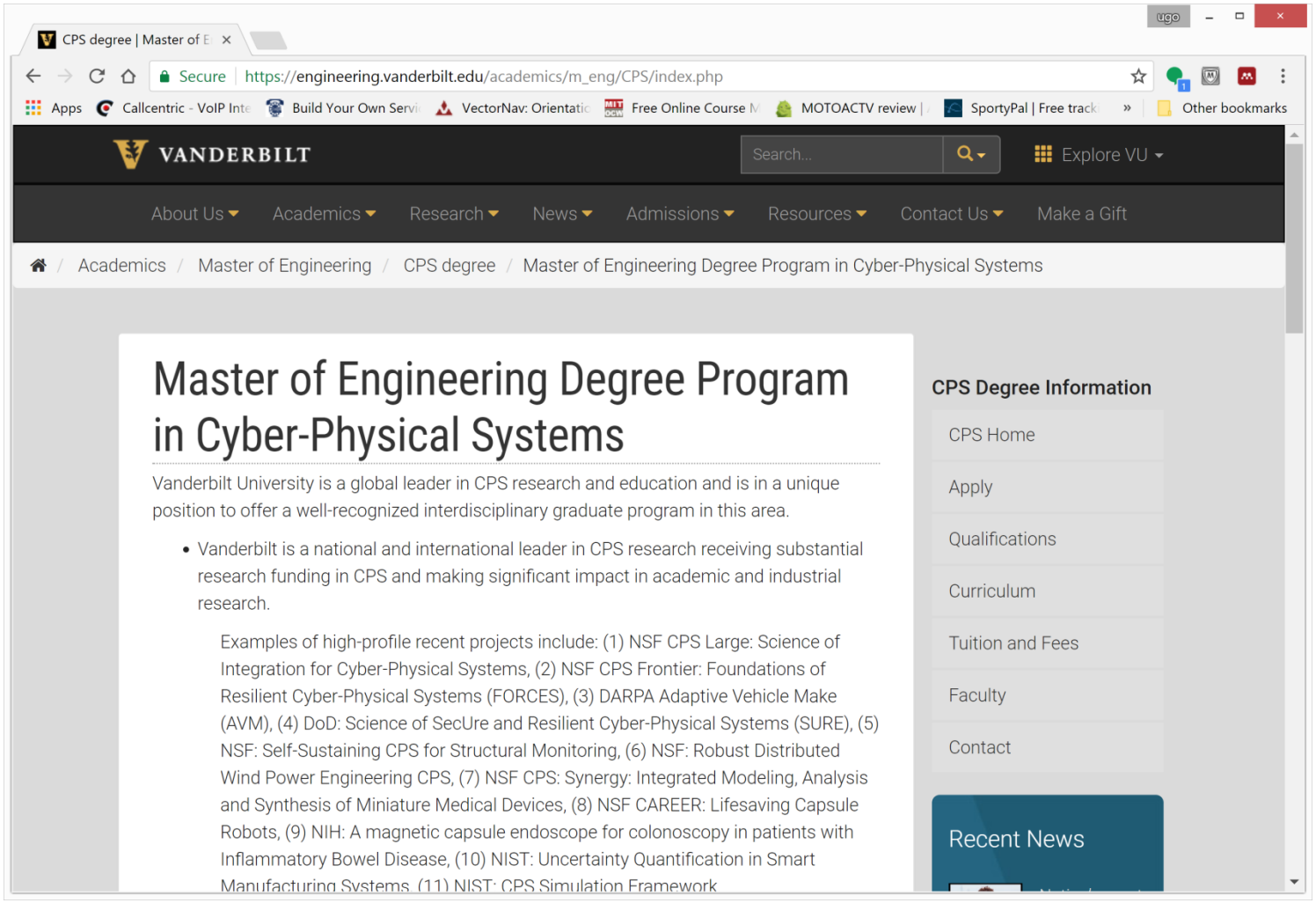


Medical Cyber-Physical Systems

by:
Raj Rajkumar,
Dionisio de Niz,
Mark Klein

Feb 16, 2017

Education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Academics / Master of Engineering / CPS degree / Master of Engineering Degree Program in Cyber-Physical Systems
Master of Engineering Degree Program in Cyber-Physical Systems
Vanderbilt University is a global leader in CPS research and education and is in a unique position to offer a well-recognized interdisciplinary graduate program in this area.
Vanderbilt is a national and international leader in CPS research receiving substantial research funding in CPS and making significant impact in academic and industrial research.
Examples of high-profile recent projects include: (1) NSF CPS Large: Science of Integration for Cyber-Physical Systems, (2) NSF CPS Frontier: Foundations of Resilient Cyber-Physical Systems (FORCES), (3) DARPA Adaptive Vehicle Make (AVM), (4) DoD: Science of SecUre and Resilient Cyber-Physical Systems (SURE), (5) NSF: Self-Sustaining CPS for Structural Monitoring, (6) NSF: Robust Distributed Wind Power Engineering CPS, (7) NSF CPS: Synergy: Integrated Modeling, Analysis and Synthesis of Miniature Medical Devices, (8) NSF CAREER: Lifesaving Capsule Robots, (9) NIH: A magnetic capsule endoscope for colonoscopy in patients with Inflammatory Bowel Disease, (10) NIST: Uncertainty Quantification in Smart Manufacturing Systems, (11) NIST: CPS Simulation Framework
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Shift towards industry

- SBIR
- STTR

Shift towards industry

- SBIR
- STTR

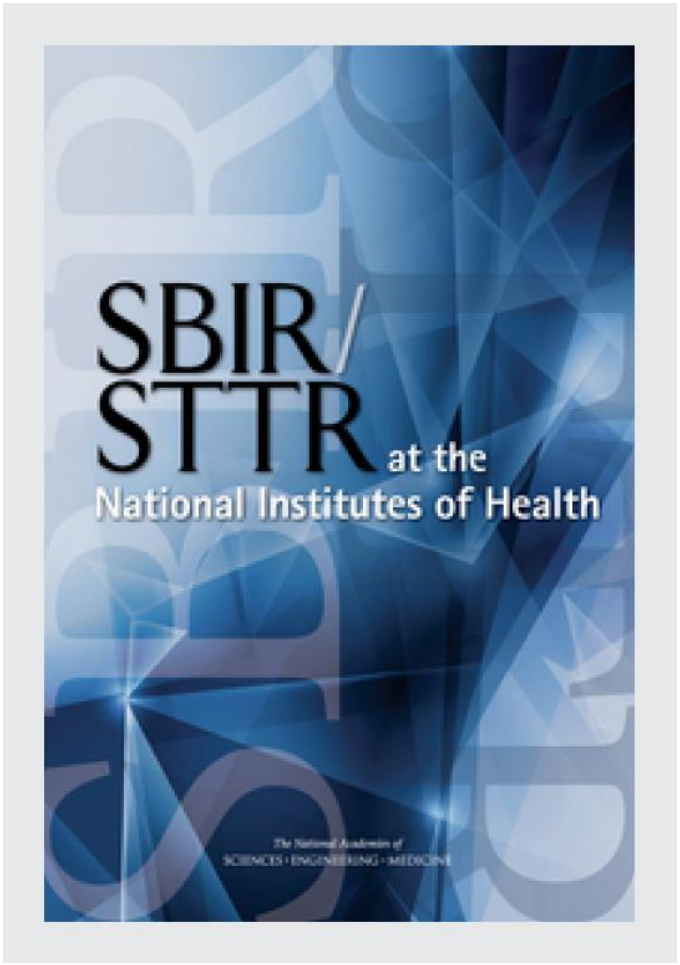
The Small Business Innovation Research (SBIR) program is a **highly competitive** program that encourages **domestic small businesses** to engage in Federal Research/Research and Development (R/R&D) that has the **potential for commercialization**. Through a competitive awards-based program, SBIR enables small businesses to explore their technological potential and **provides the incentive to profit from its commercialization**. By including qualified small businesses in the nation's R&D arena, high-tech innovation is stimulated and the **United States gains entrepreneurial spirit** as it meets its specific research and development needs.

Shift towards industry

- SBIR
- STTR

The Small Business Technology Transfer (STTR) is another program that expands funding opportunities in the federal innovation research and development (R&D) arena. Central to the program is **expansion of the public/private sector partnership** to include the **joint venture opportunities for small businesses and nonprofit research institutions**. The unique feature of the STTR program is the requirement for the small business to formally collaborate with a research institution in Phase I and Phase II. STTR's most important role is to bridge the gap between performance of basic science and commercialization of resulting innovations.

Shift towards industry



Published by the National Academy of Sciences, Engineering and Medicine

Shift towards industry

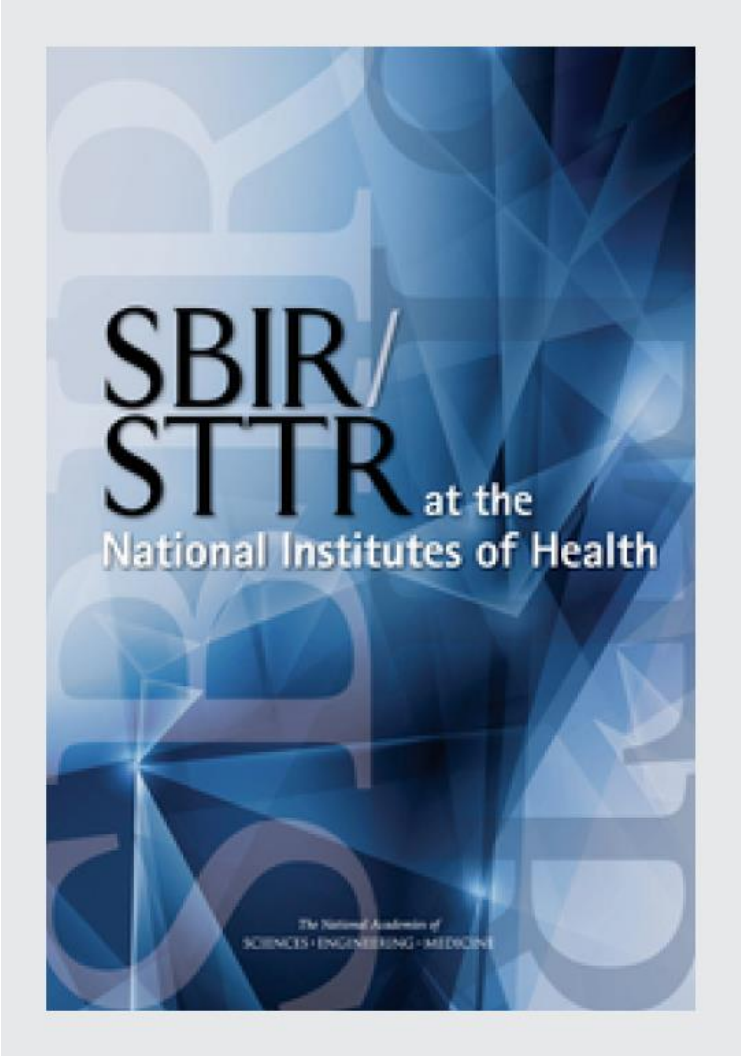
The **National Academy of Sciences was established in 1863 by Act of Congress** signed by President Lincoln, as a **private non governmental institution** to advise the nation on issues related to science and technology. Members are elected by their peers for outstanding contributions to research.

The **National Academy of Engineering was established in 1964** under the charter of the National Academy of Sciences to bring the practices of engineering to advising the nation. Members are elected by their peers for extraordinary contributions to engineering.

The **National Academy of Medicine (formerly the Institute of Medicine) was established in 1970** under the charter of the National Academy of Sciences to advise the nation on medical and health issues. Members are elected by their peers for distinguished contributions to medicine and health.

The three Academies work together as the **National Academies of Sciences, Engineering and Medicine** to provide independent, objective analysis and advice to the nation and conduct other activities to solve complex problems and inform public policy decisions. The Academies also encourage education and research, recognize outstanding contributions to knowledge, and increase public understanding in matters of science, engineering, and medicine.

Shift towards industry



- Phase I provides limited funding up to $150,000) for feasibility studies.
- Phase II provides more substantial funding for further research and development (typically up to $1 million).
- Phase III reflects commercialization without providing access to any additional SBIR/STTR funding, although funding from other federal government accounts and other sources is permitted and encouraged.

Start ups

- telemedicine,
- biosensor technologies,
- implantable devices,
- energy harvesting and remote powering devices,
- medical ultrasound systems,
- robotic surgery,
- physiologic signal QoS (Quality of Service)

enterprises

IoT Healthcare Solutions

Secure | https://www.kaaproject.org/healthcare/

Apps | Callcentric - VoIP Inte | Build Your Own Servi | VectorNav: Orientatic | Free Online Course M | MOTOACTV review | | SportyPal | Free tracki | Other bookmarks

What you can do with Kaa

Ability to manage virtually any number of devices

Automated device-to-analytics data flow

Remote monitoring of patient's health statistics

Hospital asset management

Remote device configuration and tuning

Data analytics applications for clinicians and patients

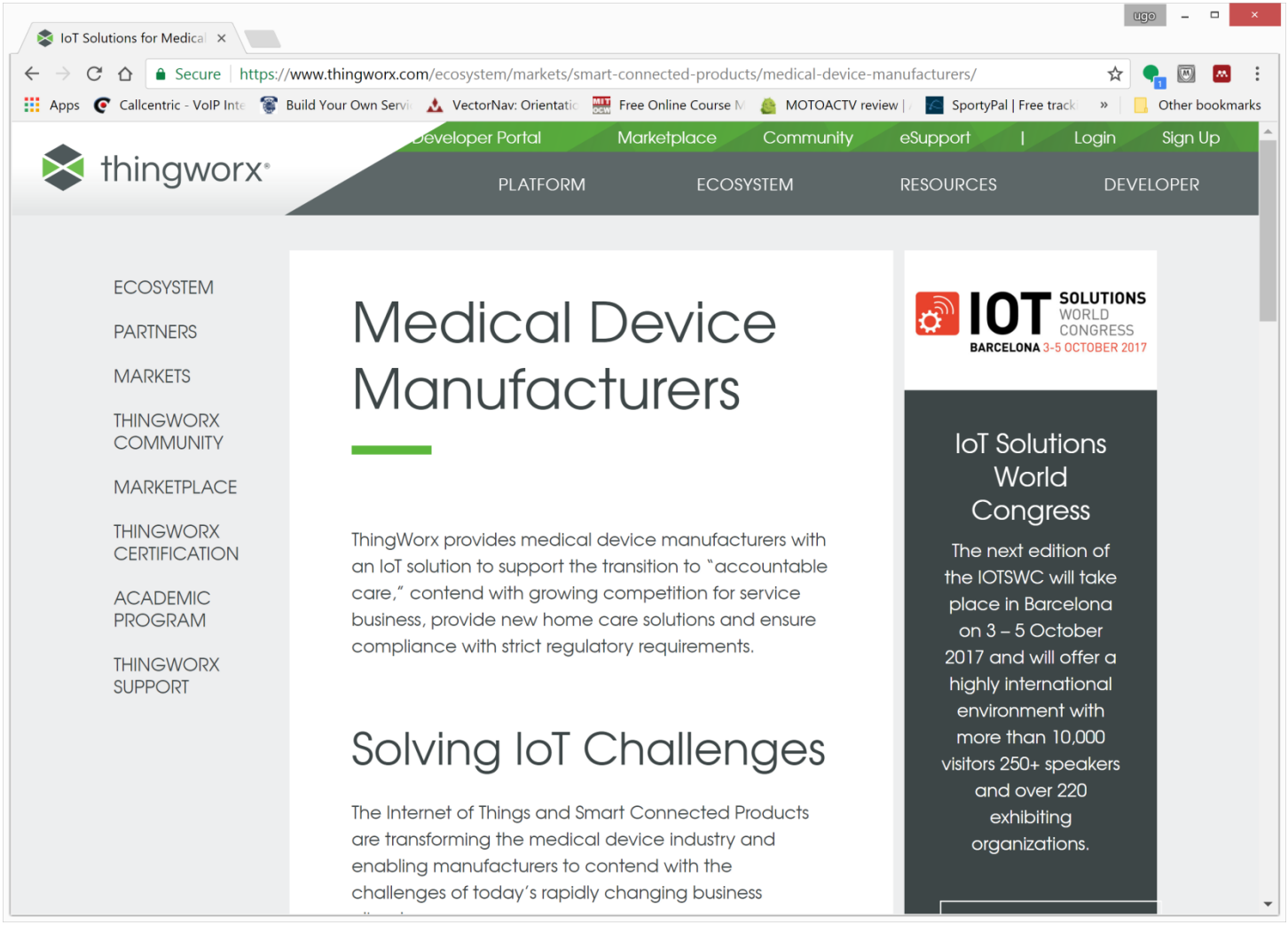
Predictive device maintenance

HIPAA-compliant data security

At the convergence of Healthcare and the IoT, an abundance of new life-giving opportunities is getting unhidden. Kaa gives access to the most incredible ones.

DUP_1163_IoT-Me....pdf | CPS-WorkshopRe....pdf | Show all

enterprises



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New Tech Uses Hardware, Software to Train Dogs More Efficiently

For Immediate Release

May 2, 2016

- Dog trainer

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- Dog trainer

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