



Introduction

1. Institute for Software Integrated Systems
2. Cyber-Physical Systems (CPS)
3. CPS Security

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Institute for Software Integrated Systems

- Established by the School of Engineering at Vanderbilt University in 1998
- Academic/professional research organization
- Mission: Advance the science and engineering of software-reliant systems
- Personnel:
 - 50 Research Scientists & Staff Engineers
 - 12 Faculty
 - 7 Admin Staff
 - 50 Graduate students/Postdocs



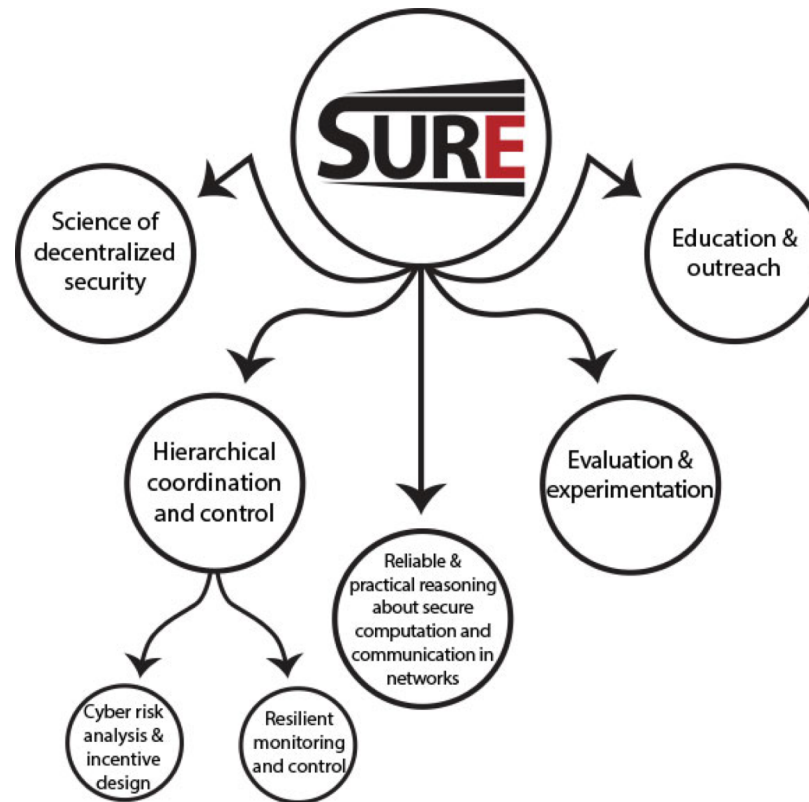


ISIS Delivers to Society

- People
 - Trained undergraduate/graduate students (BE/BS, MEng/MS, PhD) and postdoctoral scholars
 - Trained research scientists and engineers (ISIS alums are at the best research centers all over the world (MSR, IBM, Google,)
 - Educational activities for high school students in the science and engineering of software-reliant systems
- Science and Technology
 - Papers, reports and talks capturing and explaining new theory and technology
 - Major open-source and quality controlled software packages widely used in research and industry (many millions of line of code)



System Science of SecUrity and Resilience for Cyber-Physical Systems





CPS: Computing Perspective




- **Two types of computing systems**
 - Desktops, servers, PCs, and notebooks
 - Embedded
- **The next frontier**
 - Mainframe computing (60's-70's)
 - Large computers to execute big data processing applications
 - Desktop computing & Internet (80's-90's)
 - One computer at every desk to do business/personal activities
 - **Embedded computing (21st Century)**
 - “Invisible” part of the environment
 - Transformation of industry

- **Number of microprocessor units per year**
 - Millions in desktops
 - Billions in embedded processors
- **Applications:**
 - Automotive Systems
 - Light and heavy automobiles, trucks, buses
 - Aerospace Systems
 - Airplanes, space systems
 - Consumer electronics
 - Mobile phones, office electronics, digital appliances
 - Health/Medical Equipment
 - Patient monitoring, MRI, infusion pumps, artificial organs
 - Industrial Automation
 - Supervisory Control and Data Acquisition (SCADA) systems for chemical and power plants
 - Manufacturing systems
 - Defense
 - Source of superiority in all weapon systems





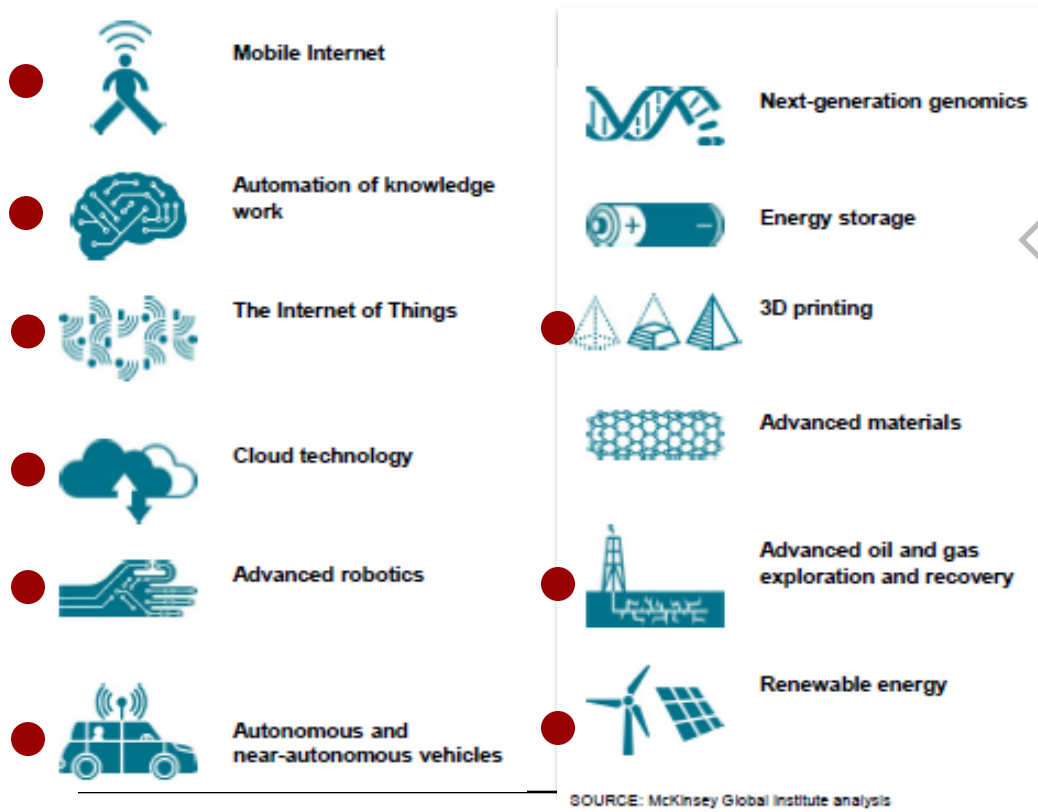
CPS: Systems Perspective

Sectors	Opportunities	
<i>Transportation</i>	Aircraft that fly faster and further on less energy. Air traffic control systems that make more efficient use of airspace. Automobiles that are more capable and safer but use less energy.	
<i>Defense</i>	More capable defense systems; defense systems that make better use of networked fleets of autonomous vehicles.	
<i>Energy and Industrial Automation</i>	New and renewable energy sources. Homes, office, buildings and vehicles that are more energy efficient and cheaper to operate.	



CPS is a big part of "The Future" (according to McKinsey)...

Top twelve economically disruptive technologies (by 2025)



McKinsey & Company

McKinsey Global Institute

May 2013



Disruptive technologies:
Advances that will transform life, business, and the global economy





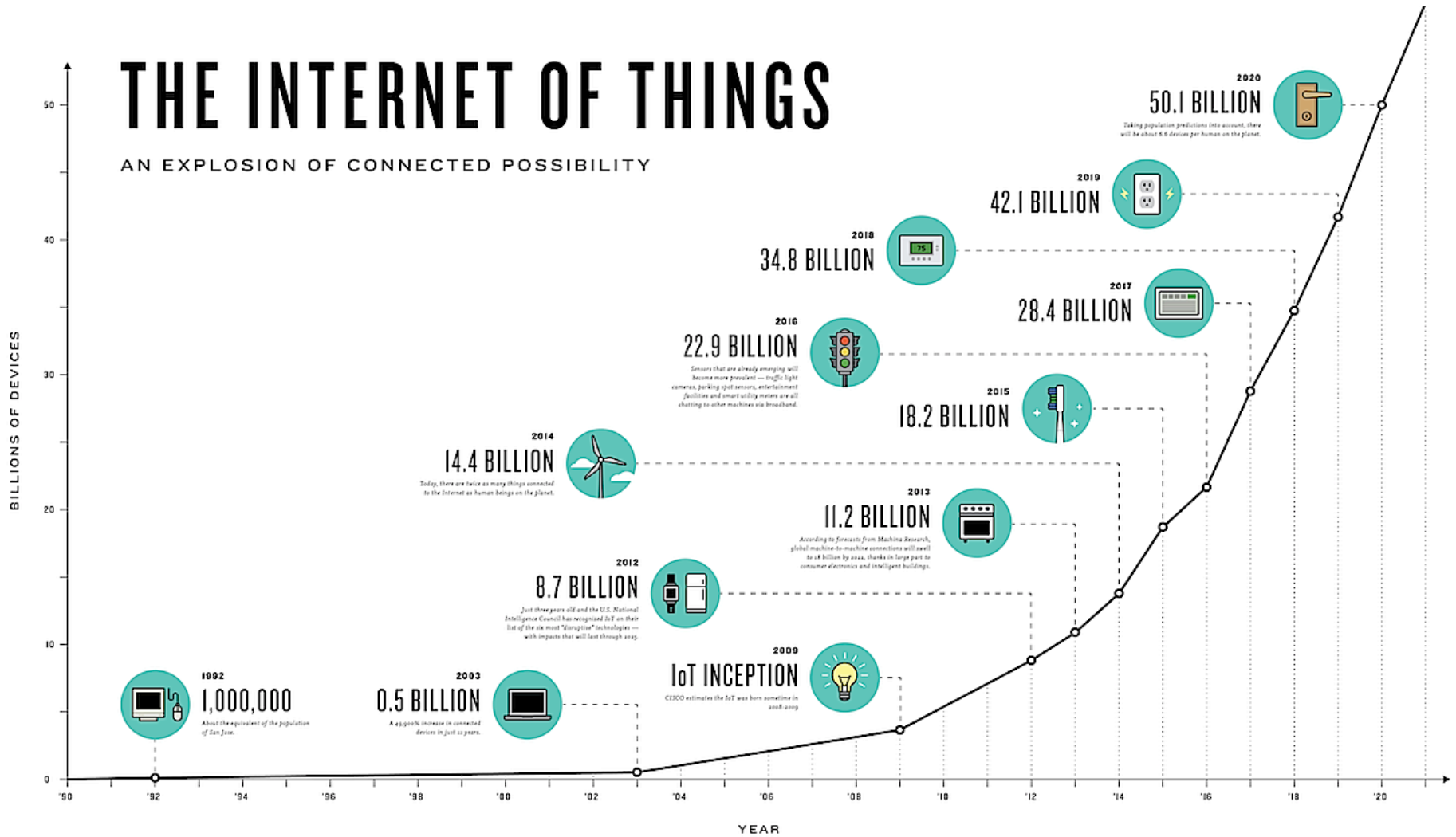
CPS Research is Fundamental to Smart and Connected Communities and Internet of Things





THE INTERNET OF THINGS

AN EXPLOSION OF CONNECTED POSSIBILITY





Transformation of Industries: Automotive

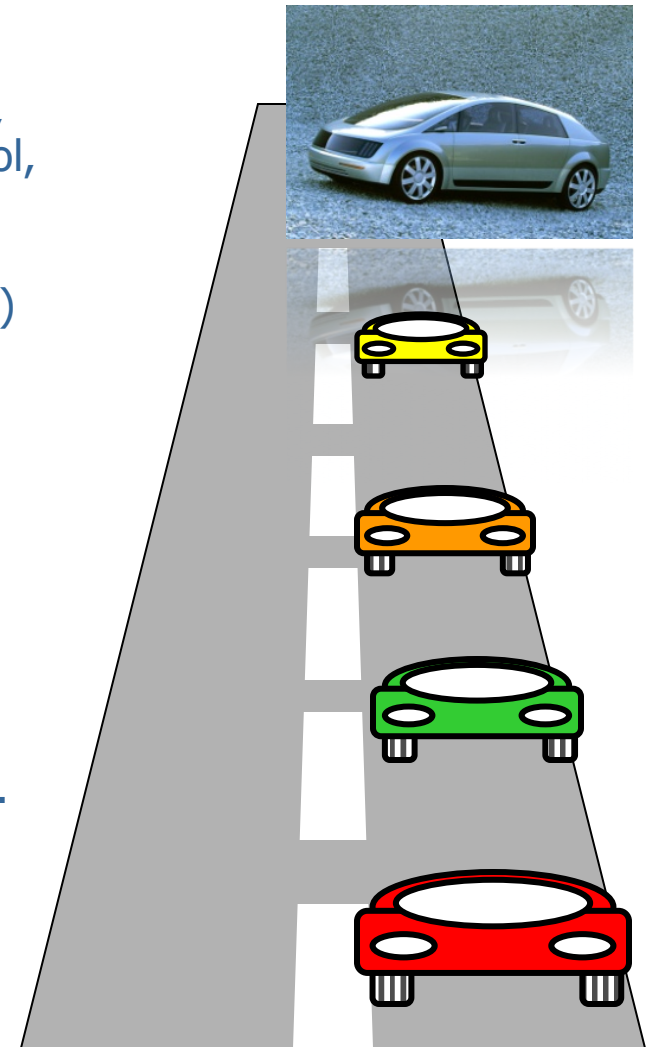
■ Current picture

- Largely single-vehicle focus
- Integrating safety and fuel economy (full hybrids, regenerative braking, adaptive transmission control, stability control)
- Safety and convenience “add-ons” (collision avoidance radar, complex airbag systems, GPS, ...)
- Cost of recalls, liability; growing safety culture

■ Better future?

- Multi-vehicle high-capacity cooperative control roadway technologies
- Vehicular networks
- Energy-absorbing “smart materials” for collision protection (cooperative crush zones?)
- Alternative fuel technologies, “smart skin” integrated photovoltaics and energy scavaging,
- Integrated operation of drivetrain, smart tires, active aerodynamic surfaces, ...
- Safety, security, privacy certification; regulatory enforcement

■ Time-to-market race



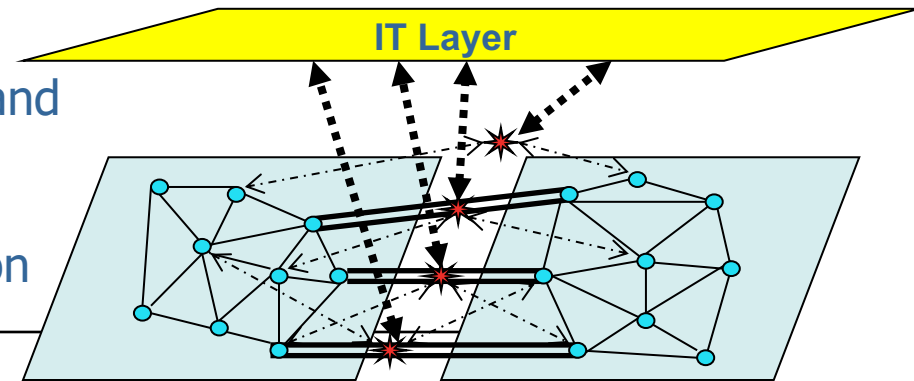
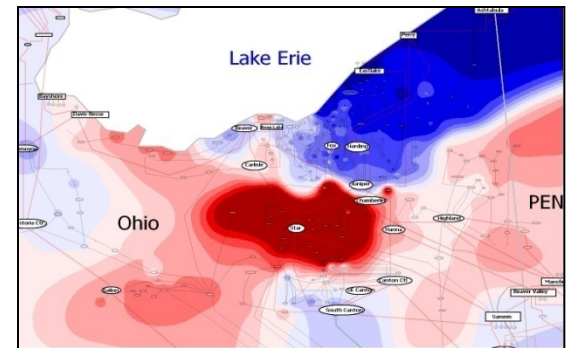
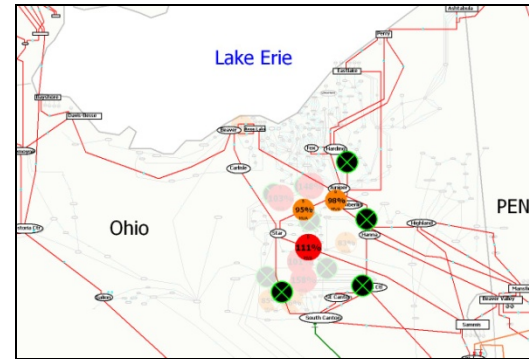
Transformation of Industries: Health Care and Medicine

- **National Health Information Network, Electronic Patient Record initiative**
 - Medical records at any point of service
 - Hospital, OR, ICU, ..., EMT?
- **Home care: monitoring and control**
 - Pulse oximeters (oxygen saturation), blood glucose monitors, infusion pumps (insulin), accelerometers (falling, immobility), wearable networks (gait analysis), ...
- **Operating Room of the Future**
 - Closed loop monitoring and control; multiple treatment stations, plug and play devices; robotic microsurgery (remotely guided?)
 - System coordination challenge
- **Progress in bioinformatics: gene, protein expression; systems biology; disease dynamics, control mechanisms**

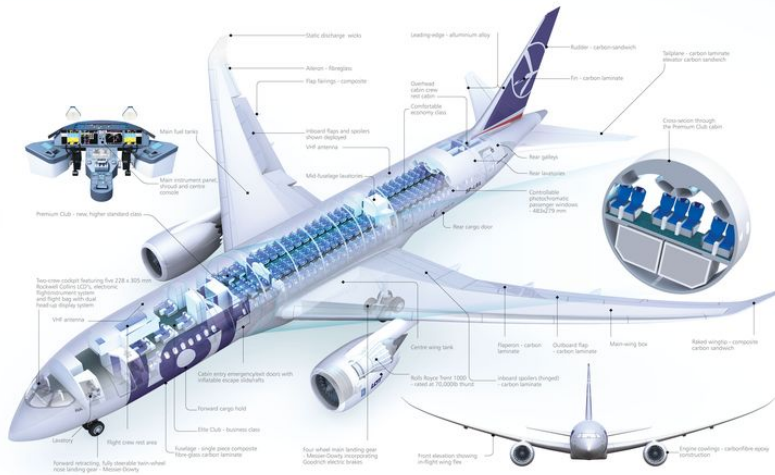


Transformation of Industries: Electric Power Grid

- **Current picture:**
 - Equipment protection devices trip locally, reactively
 - Cascading failure: August (US/Canada) and October (Europe), 2003
- **Better future?**
 - Real-time cooperative control of protection devices
 - Or -- self-healing -- (re-)aggregate islands of stable bulk power (protection, market motives)
 - Ubiquitous green technologies
 - Issue: standard operational control concerns exhibit wide-area characteristics (bulk power stability and quality, flow control, fault isolation)
 - Context: market (timing?) behavior, power routing transactions, regulation



Transformation of Industries: Manned and Unmanned Aerial Vehicles



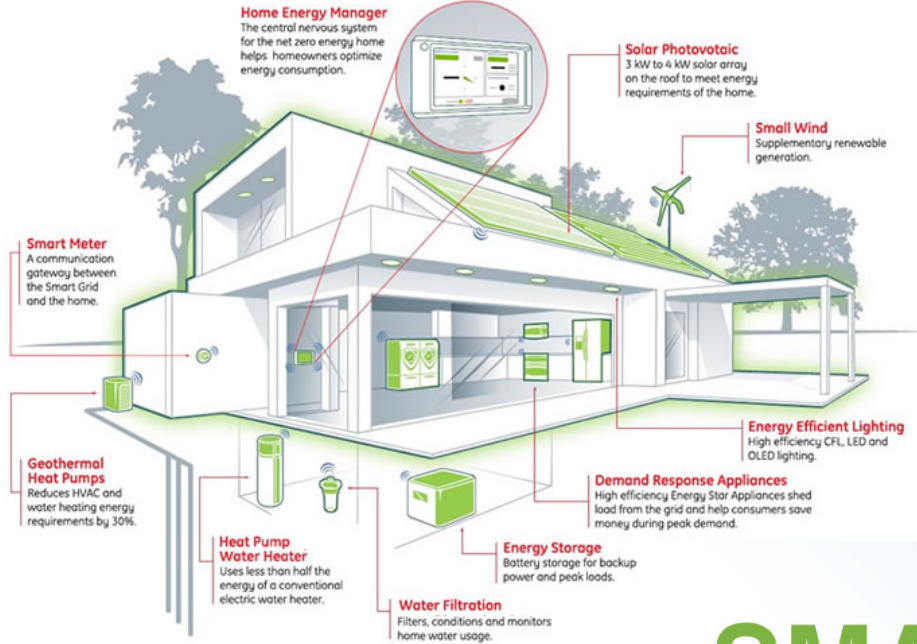
Google, Amazon, and Walmart want to deliver products to your doorstep nearly instantly by using drones

- Dreamliner
 - ~1330 networked microprocessors
 - 50% of design cost (\$ and time)
 - Correctness of software challenge
 - Cybersecurity (i.e., GPS spoofing)





Transformation of Industries: Smart Buildings



SMART BUILDINGS

An Intelligent Business Proposition

The structures that dot the skyline aren't just concrete and glass, static shells. It's time to put buildings to work. Make it easy for students to find the library on campus. (No more excuses.) Uncover new revenue streams in real estate.

Get **green**, **safe** and **productive**.





In a few words...

Cyber-physical systems are smart, complete systems of today and tomorrow;

Cyber-physical systems will enable ubiquitous technologies and applications for the future.

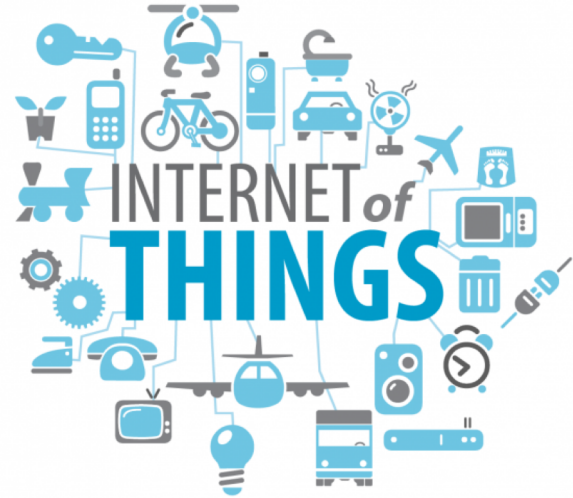
Advances in *cyber-physical systems* will reshape our world with more responsive, secure, and efficient systems that:

- ***Transform*** the way we live
- ***Drive*** economic prosperity
- ***Underpin*** national security
- ***Enhance*** societal well-being
- Users depend on and may ***bet their life on***



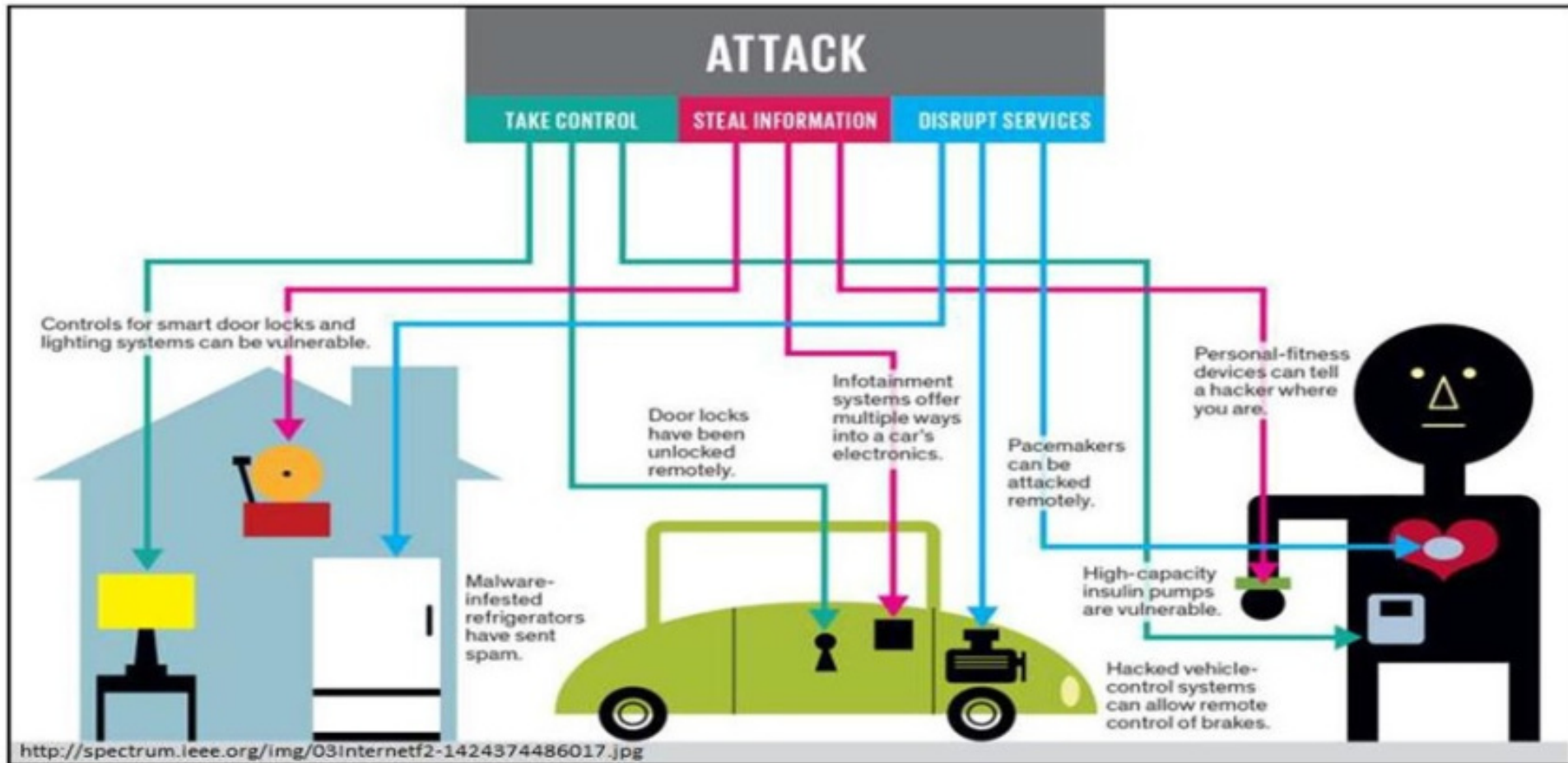
Software: The Great Enabler

- Good news: anything is possible in software!
- Bad news: anything is possible in software!



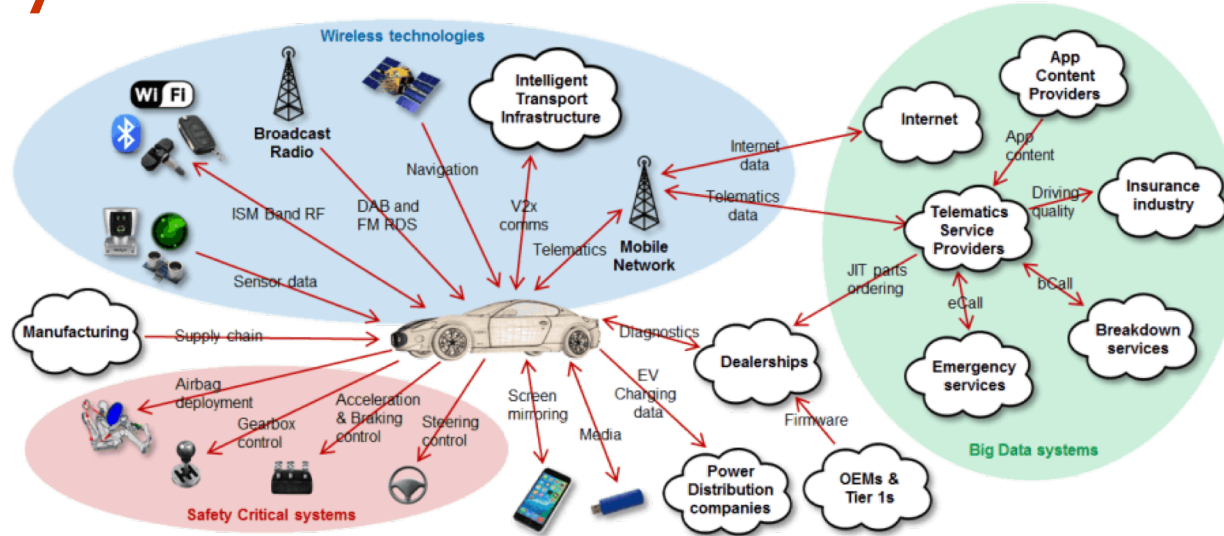


Internet of Things Cyberattacks





Cyber Attacks in Connected Cars

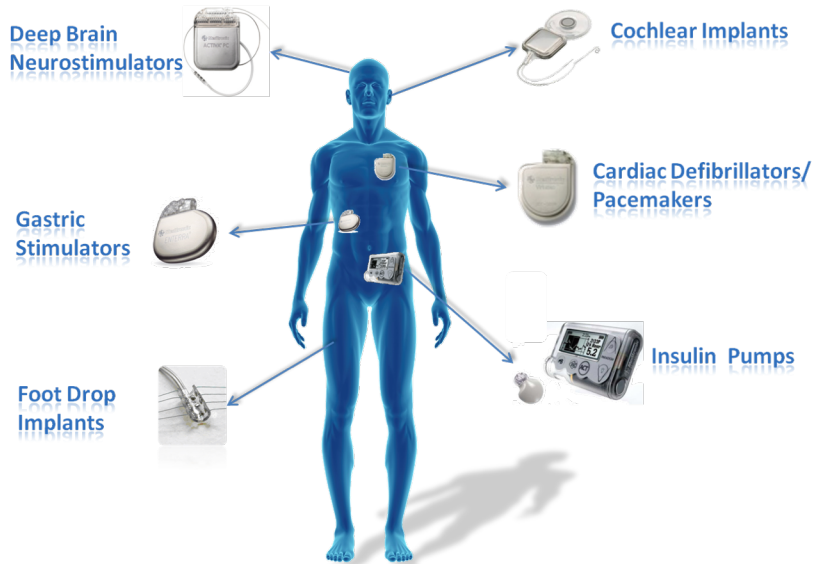


- **Fiat Chrysler recalled 1.4 million cars that were hacked**
 - The Jeep Cherokee is probably the only car that had to be recalled for a potential hack. 1.4 million cars including various models of the Dodge, Chrysler, and Jeep were recalled in a response to a potential hack that could affect the brakes, engine, steering, and other safety controls in the cars.
- **Tesla hacked by Chinese hackers**
 - A group of Chinese security researchers were able to hack a Tesla Model X, second time in a row since last year! The effect of the hack is that they found a way to turn on the brakes remotely and getting the doors and trunk to open and close while blinking the lights in time to music streamed from the car's radio — an effect they dubbed "the unauthorized Xmas show."



Medical Devices

WIRELESS IMPLANTABLE MEDICAL DEVICES



- TrapX, a deception-based cybersecurity firm, released a report about three real-world targeted hospital attacks which exploited an attack vector the researchers called MEDJACK for medical device hijack.
- In three separate hospitals, TrapX found “extensive compromise of a variety of medical devices which included X-ray equipment, picture archive and communications systems (PACS) and blood gas analyzers (BGA).”
- But “there are many other devices that present targets for MEDJACK. This includes diagnostic equipment (PET scanners, CT scanners, MRI machines, etc.), therapeutic equipment (infusion pumps, medical lasers and LASIK surgical machines), and life support equipment (heart - lung machines, medical ventilators, extracorporeal membrane oxygenation machines and dialysis machines) and much more.”



Ukrainian Power Outages



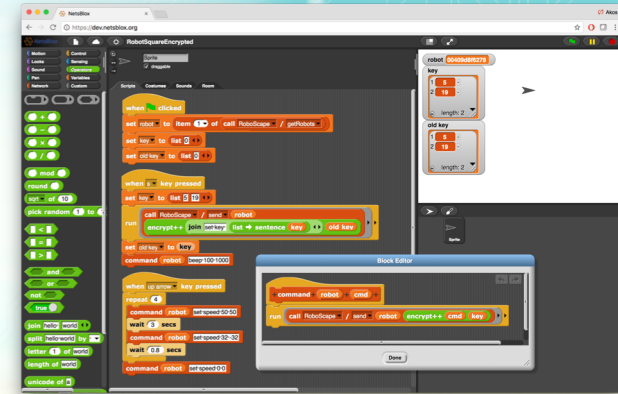
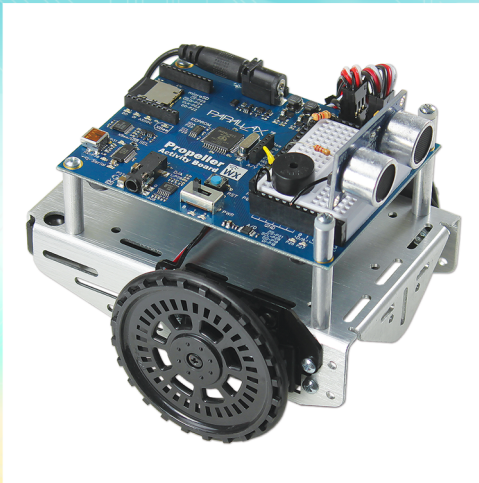
- In December 2015 a massive power outage hit the Ukraine, and it was found to be the result of a supervisory control and data acquisition (SCADA) cyber attack. This instance left around 230,000 people in the West of the country without power for hours.



CPS SECURITY

Summer Camps

- Learn to program, attack, and defend robots using **NetsBlox**, a networked, visual programming environment specifically targeted at introducing students to distributed computation and computer networking.



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