Key Information and Communications Technology Trends for the Research & Education Community

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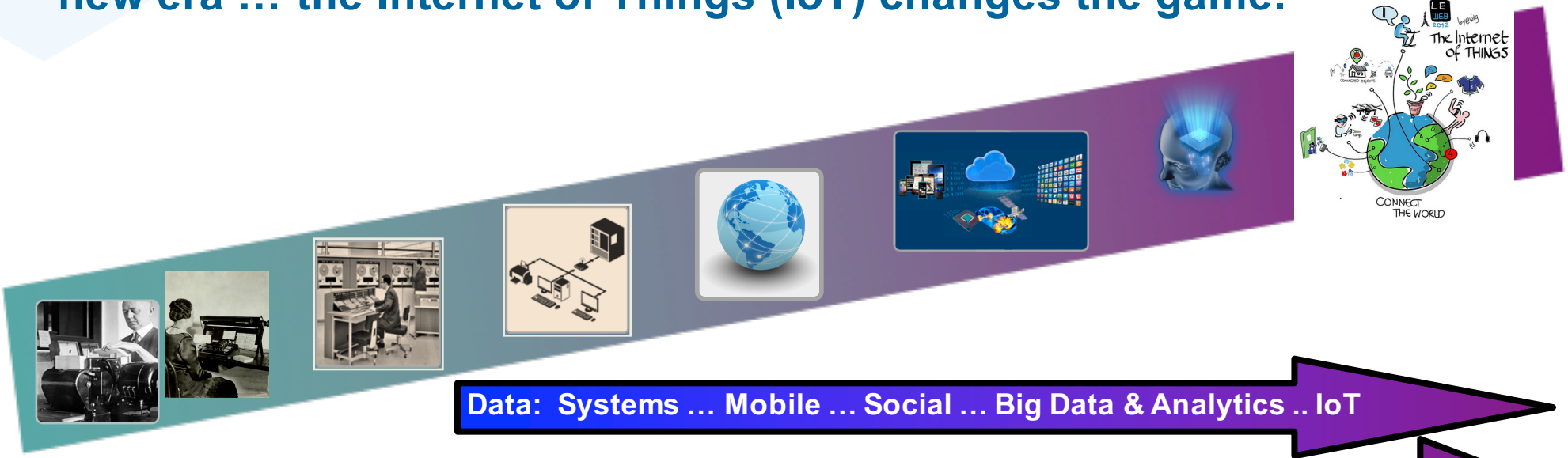
Advances in technology and cultural evolution are ushering in a new era … the Internet of Things (IoT) changes the game.



Data: Systems … Mobile … Social … Big Data & Analytics .. IoT

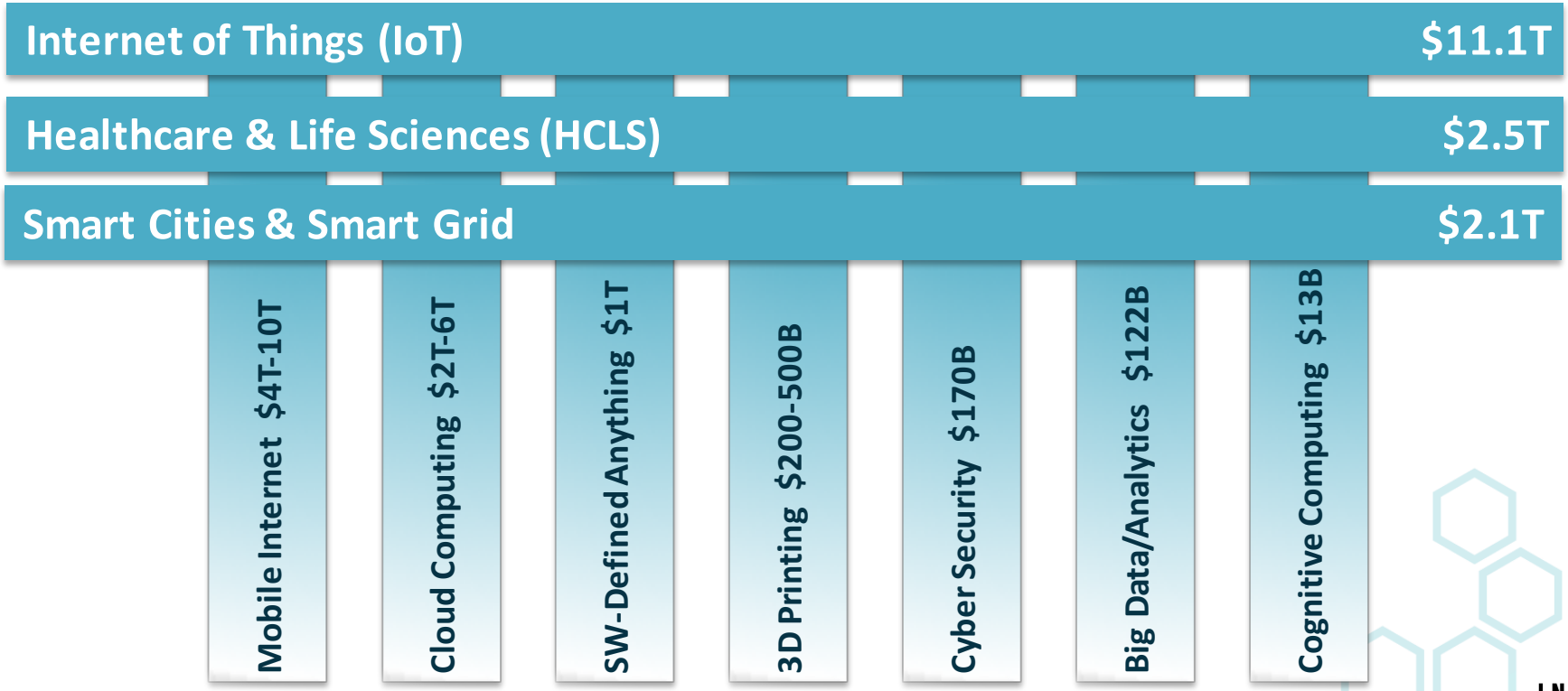
Computing: Centralized … Distributed … WWW … Personal … Cloud … Everywhere

Systems: Tabulating … Programmable … Cognitive

1900s 60s 80s 90s 2010s

INTERNET 2

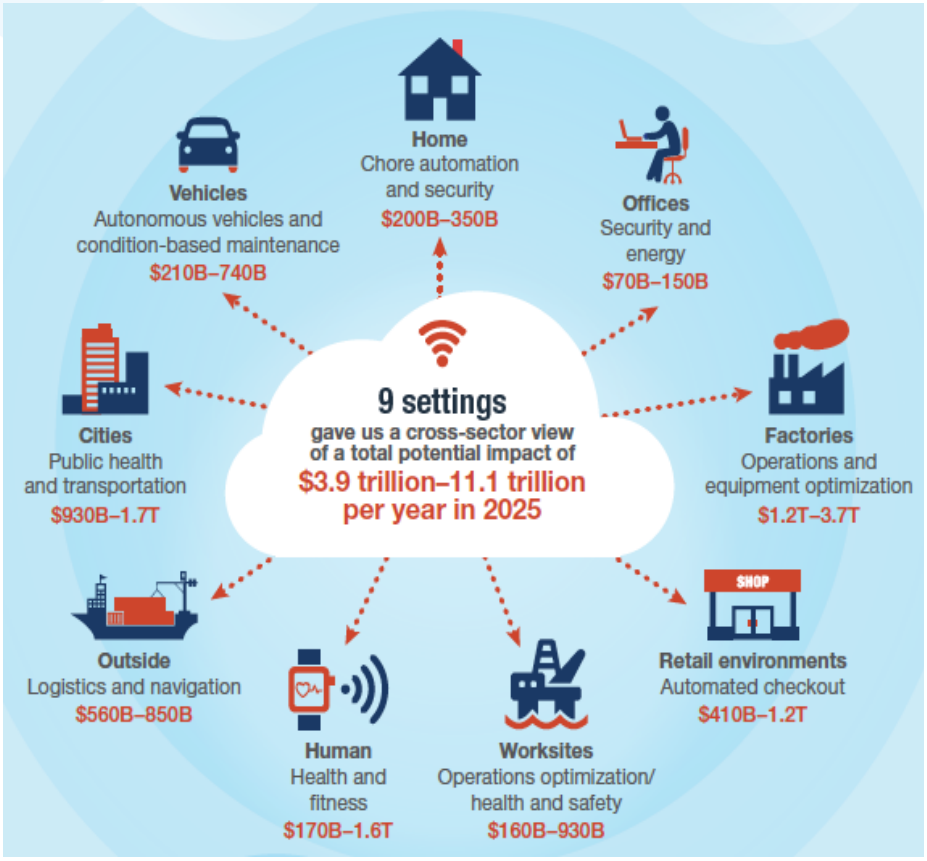
The Internet of Things, Healthcare & Life Sciences, and Smart Cities could represent $15T in global economic value in 2025.



Economic value includes revenues, cost reductions & service improvements achieved

Sources: Internet2 CINO analysis; BizTech; Deloitte; Consultantcy.uk; Forbes; Markets and Markets; McKinsey; US Department of Agriculture, Economic Research Services.

In 2025, the Internet of Things could contribute $11T of global economic value.

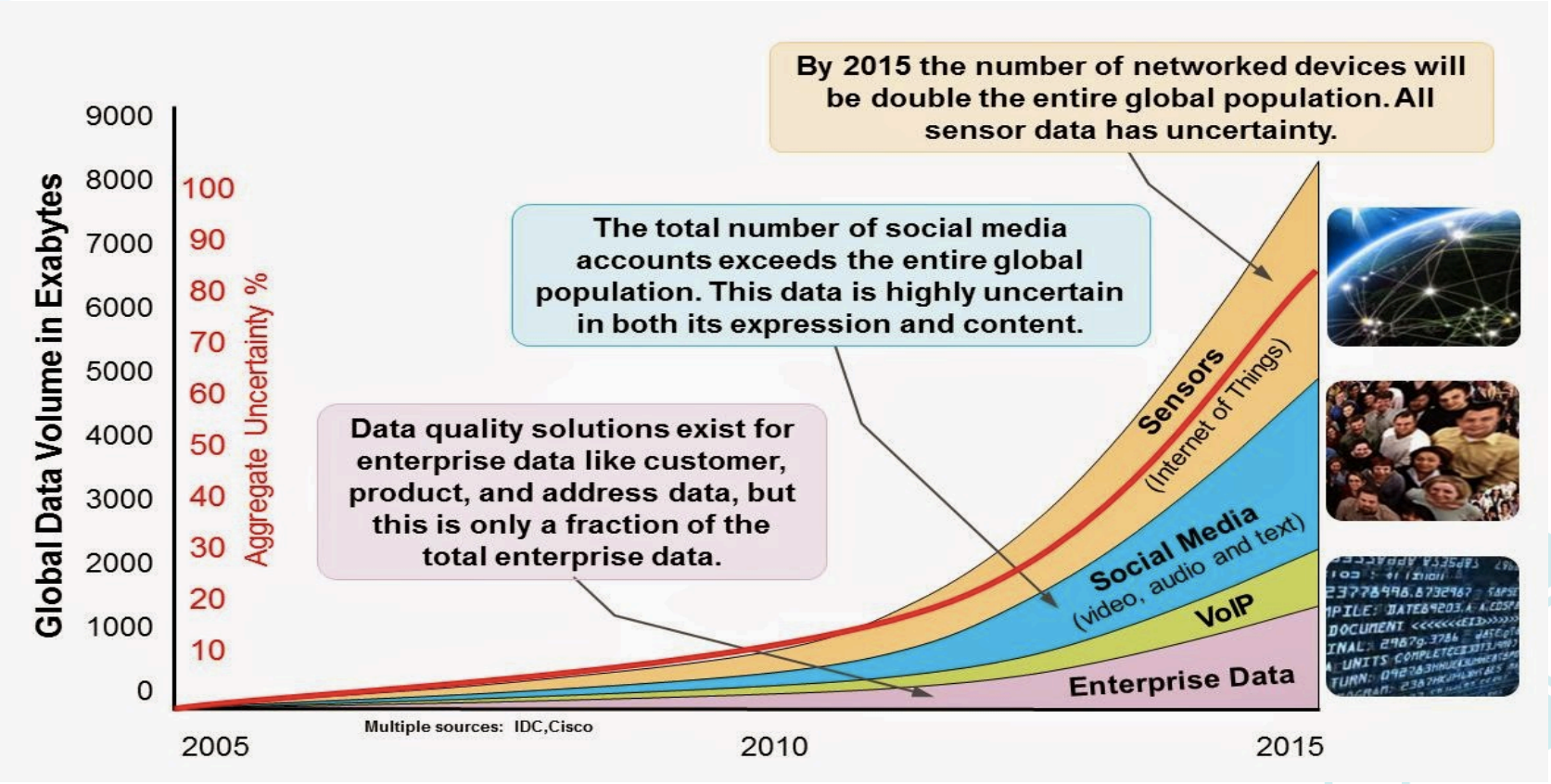


Internet of Things will connect billions of devices, generate large volumes of data, create transformational value, and need a secure network.

- IoT applies across many industries and use cases
- As the physical world becomes connected to the digital world, more "things" will be at play
  - 2014: 13B+ Internet of Things devices
  - By 2020: 25B to 200B "things" will be connected
- IoT is projected to deliver 2x IT economic value, representing 10% of global GDP
- Amount of IoT data will be ENORMOUS
  - Zettabytes (10^{21}) by 2020
  - Then Yottabytes (10^{24})
  - Then Brontobytes (10^{27})

Source: McKinsey "Unlocking the Potential of the Internet of Things." June 2015.

The Internet of Things and social media generate the majority of new data.



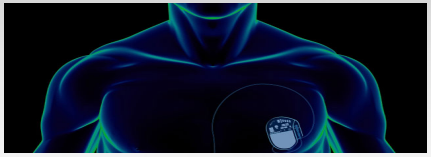
IoT risk and security awareness is increasing … and highlighting the need for security research and development.

Vehicle Hacking

http://www.infoworld.com/t/hacking/video-watch-what-happens-when-prius-gets-hacked-224270

https://www.youtube.com/watch?v=MK0SrxBC1xs

Global Positioning System Spoofing



Healthcare Device Hacking

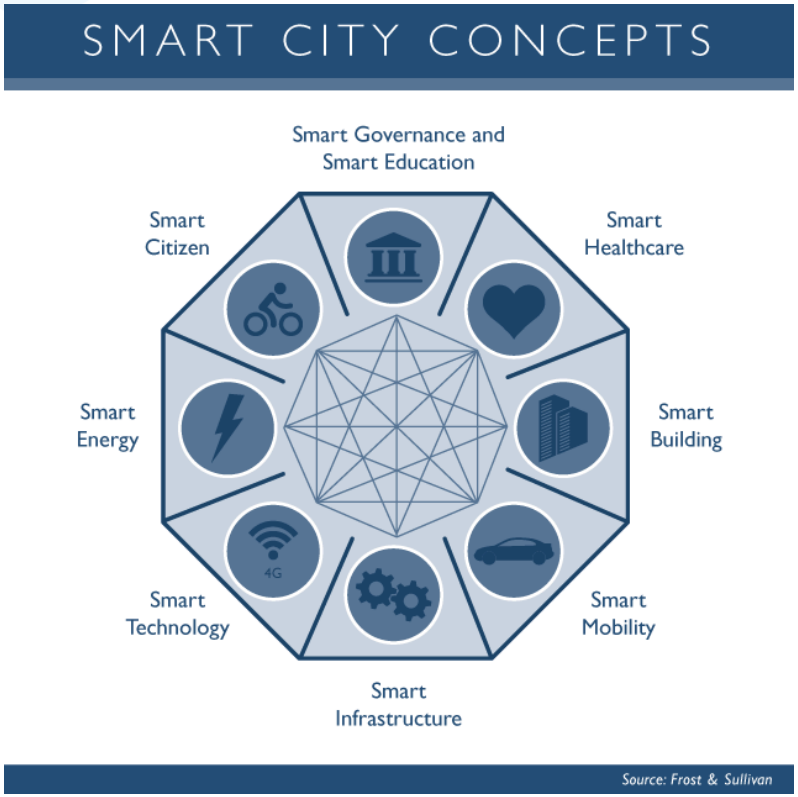
Industrial Hacking

Smart Home Hacking

National Transportation Safety Board Connected-Car Mandate

Sources: npr.org; thehackernews.com; spectrum.ieee.org; cnn.com; technologyreview.com; politico.com.

Smart Cities, Campuses, & Communities will be built on a foundation of Internet of Things technologies.



The White House "Smart Cities" initiative will help communities tackle key challenges.

- Projected $160M in new investment during fiscal year 2016
- 20+ cities and 25+ universities are named participants
  - 20+ Internet2 university members, e.g., Case Western, NYU, Rice, UCSD, University of Chicago, UWMadison
  - Industry members (Cisco, GE, IBM, Microsoft)
- Development of "Internet of Things" applications testbeds
- Developing multi-sector, intercity collaborative models

Smart Campus initiatives enable American College and University Presidents' Climate Commitment signees to deliver results.

Sources: Consultantcy.uk, "Smart City Market Revenues to Grow to 2 Trillion by 2020." 27 August 2015; Forbes, "Smart Cities – A $1.5 Trillion Market Opportunity." 19 June 2014; ACUPCC Reporting System; The White House, "FACT Sheet: Administration Announces New 'Smart Cities' Initiative to Help Communities Tackle Local Challenges and Improve City Services." September 2015.

Smart Grids are a first step in the development of Smart Cities/Campuses, and require end to end trust and security.

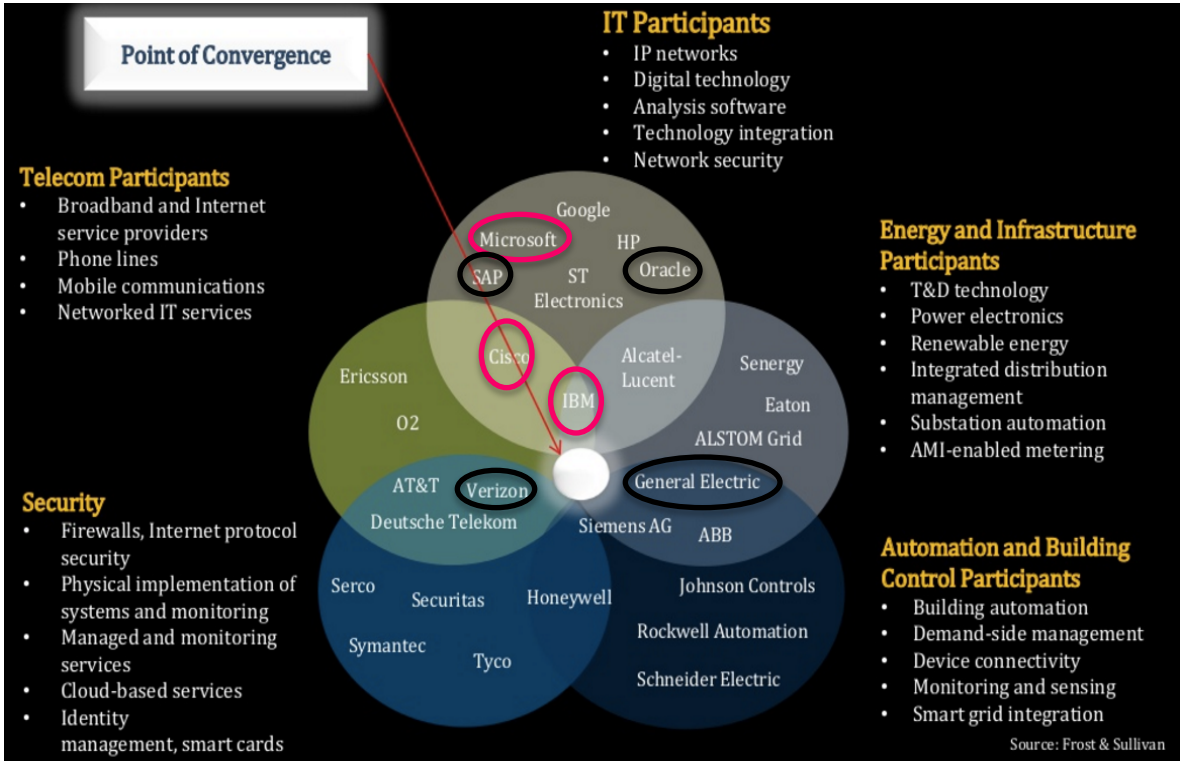
Smart Grid value is transformational and positively impacts:

- Transmission and network optimization
- Optimized renewables integration
- Distribution automation
- Advanced metering infrastructure
- Analytics for pattern recognition & optimization
- Cybersecurity for threat avoidance, identification and analysis

Internet2 is working with NIST, utilities, universities, and regional networks on a Smart Grid testbed.

Source: GreenTechMedia, "Smart Grid Market to Surpass $400 Billion Worldwide by 2020." 13 August 2013.

Internet2 has relationships with key players in the Smart Cities technology landscape.



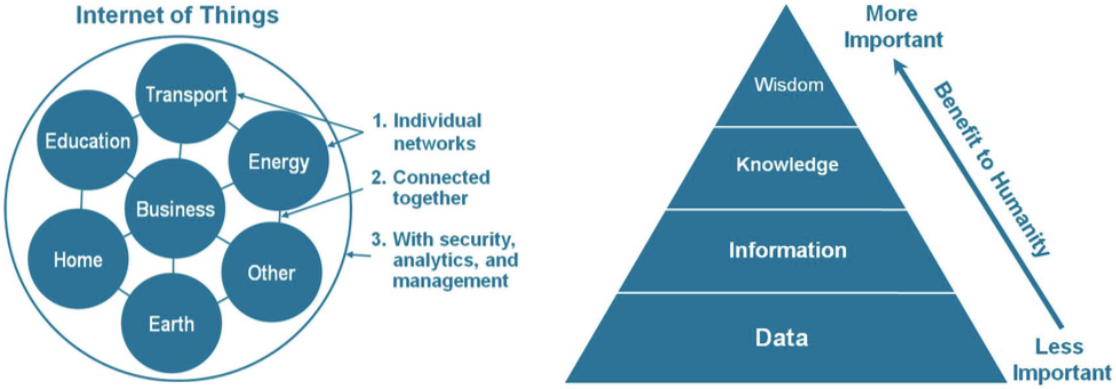
- Internet2 is working with the US IGNITE team and NIST in the development of both Smart Cities and Smart Grid
- Internet2 is creating a Smart Campus / Smart Cities Focus Group
  - Initial participants to potentially include Princeton, The Ohio State University, University of Pennsylvania, Virginia Tech, and University of Maryland-Baltimore County

= Internet2 IoT Working Group Industry Participant

= Internet2 Industry Partner Only

Source: Frost & Sullivan, "Strategic Opportunity Analysis of the Global Smart City Market." 30 August 2013.

IoT enables a System of Systems Approach that provides new insight and wisdom.



As systems become more interconnected, the data collected from each becomes even more important and can be leveraged across systems to improve outcomes.

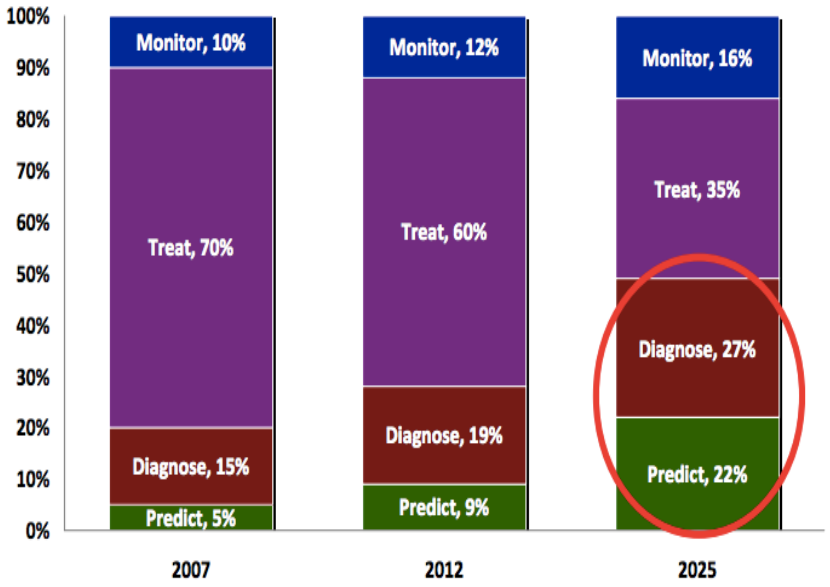
Consider a Smart City scenario:

- Surveillance cameras that detect real-time congested routes, providing data that then ….
- Incentivizes drivers to seek a different route through continually changing congested pricing models as pathways become clogged, and providing that data that feeds….
- Autonomous vehicles to inform of a better route.

Source: Cisco IBSG, "The Internet of Things: How the Next Evolution of the Internet Is Changing Everything," April 2011.

The Internet of Medical Things enhances monitoring, predicting, diagnosing, and management of health and wellness.

Healthcare Spending by Type of Activity



Remote monitoring, diagnosis and prediction becomes much more viable in an Internet of Medical Things environment.

- Connected personal biomedical devices
- Medical consultations via video
- Diagnostic insights via devices, video, and in person

Exponential value can be achieved for physicians, patients, and health outcomes.

Patient privacy concerns, security, and regulatory compliance are particularly important for a successful implementation.

Sources: Frost & Sullivan, "Strategic Opportunity Analysis of the Global Smart City Market." 30 August 2013; Deloitte, "Healthcare and Life Sciences Predictions 2020." November 2014.

Mobile Internet is an enabler of IoT, Smart Cities/Campuses, and Healthcare transformation.

Internet-enabled portable devices are now a way of life:

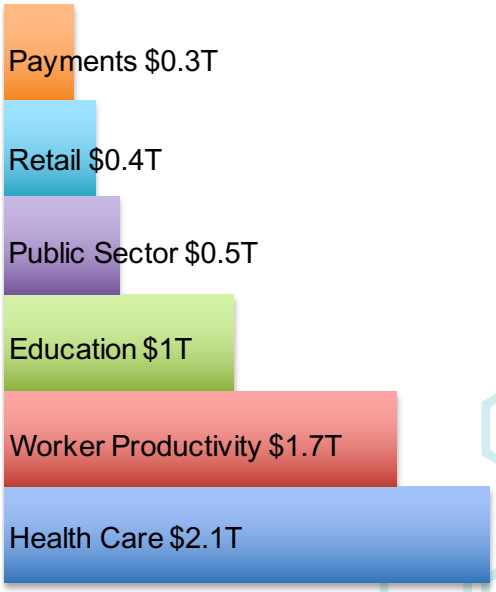
- Potential for 9.2B total mobile subscriptions by 2020
- Mobile computing devices, high-speed wireless connectivity, and applications

Healthcare could benefit the most from Mobile Internet.

Consider an aspirational Connected Healthcare scenario including IoT from Kaiser Permanente:
http://www.kp-itcomms.org/mm/digitalhealth/index.html

Connecting People to a Healthy Future (2012)

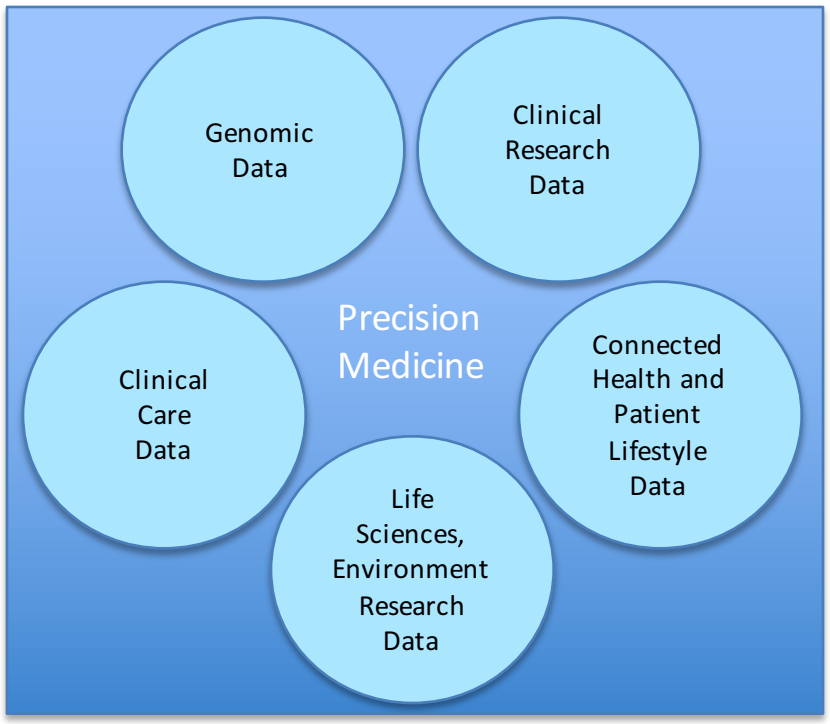
Healthcare Leads Mobile Internet Potential in 2025



Sources: McKinsey, "Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy." May 2013; TechCrunch, "6.1B Smartphone Users Globally by 2020, Overtaking Basic Fixed Phone Subscriptions." 2 June 2015.

Healthcare & Life Sciences will increasingly leverage technology for analysis of volumes of data, improving insights and outcomes.

Confluence of data to support Precision Medicine

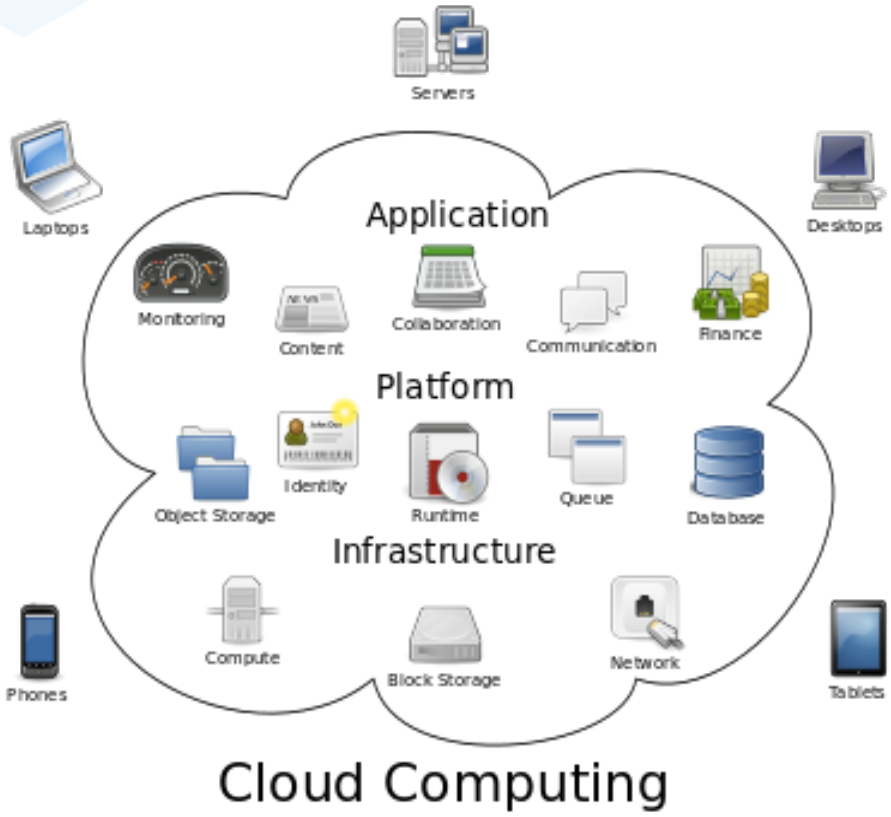


Large data volumes and analytics opportunity generated by:

- Genomic data
- Clinical and fundamental research data
- Clinical care data and observations
- Patient input including lifestyle, travel
- Environmental data (weather, geography)
- Wearable health and wellness devices
- EMR/EHR
- Images (tumors, MRIs, etc.)
- Biobank data
- Biotechnology, medical technology, pharma
- Cognitive computing opportunity

Source: National Institutes of Health, "The Precision Medicine Initiative Cohort Program - Building a Research Foundation for 21st Century Medicine." September 2015.

In 2025, Cloud Computing could contribute $6T in global economic value.



By 2025, most IT and Web applications/ services will be Cloud-based, driving the need for a secure and dependable network.

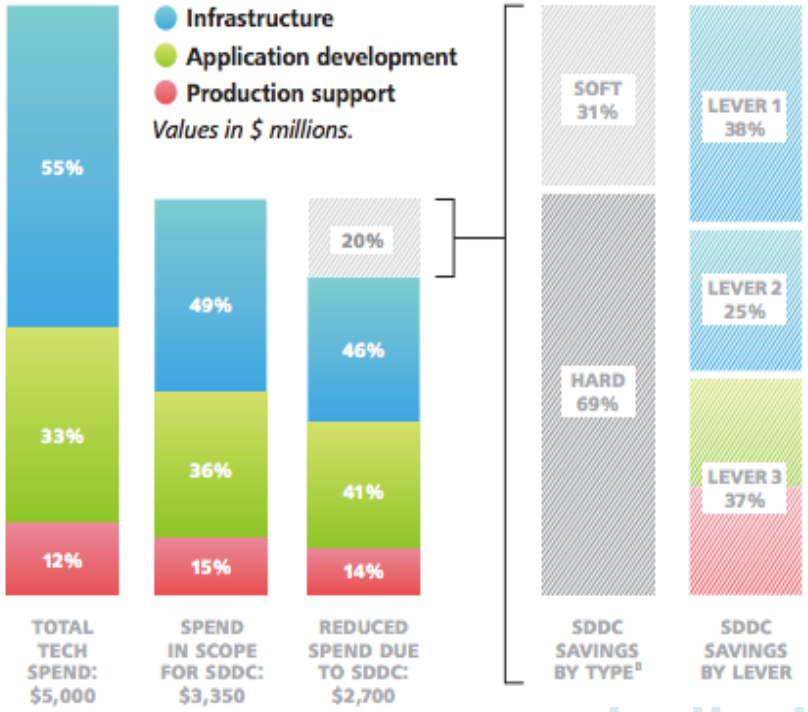
- Cloud Computing enables remote computational work
- Enables Internet-based services growth in on-demand environment
- Cloud computing capabilities become more important and pervasive in an IoT world

Sources: McKinsey, "Disruptive Technologies: Advances That Will Transform Life, Business, and the Global Economy." May 2013; Wikipedia, "Cloud Computing." 30 September 2015.

Software-Defined Anything can reduce IT costs up to 20%, representing up to $1T in reduced costs in 2025.

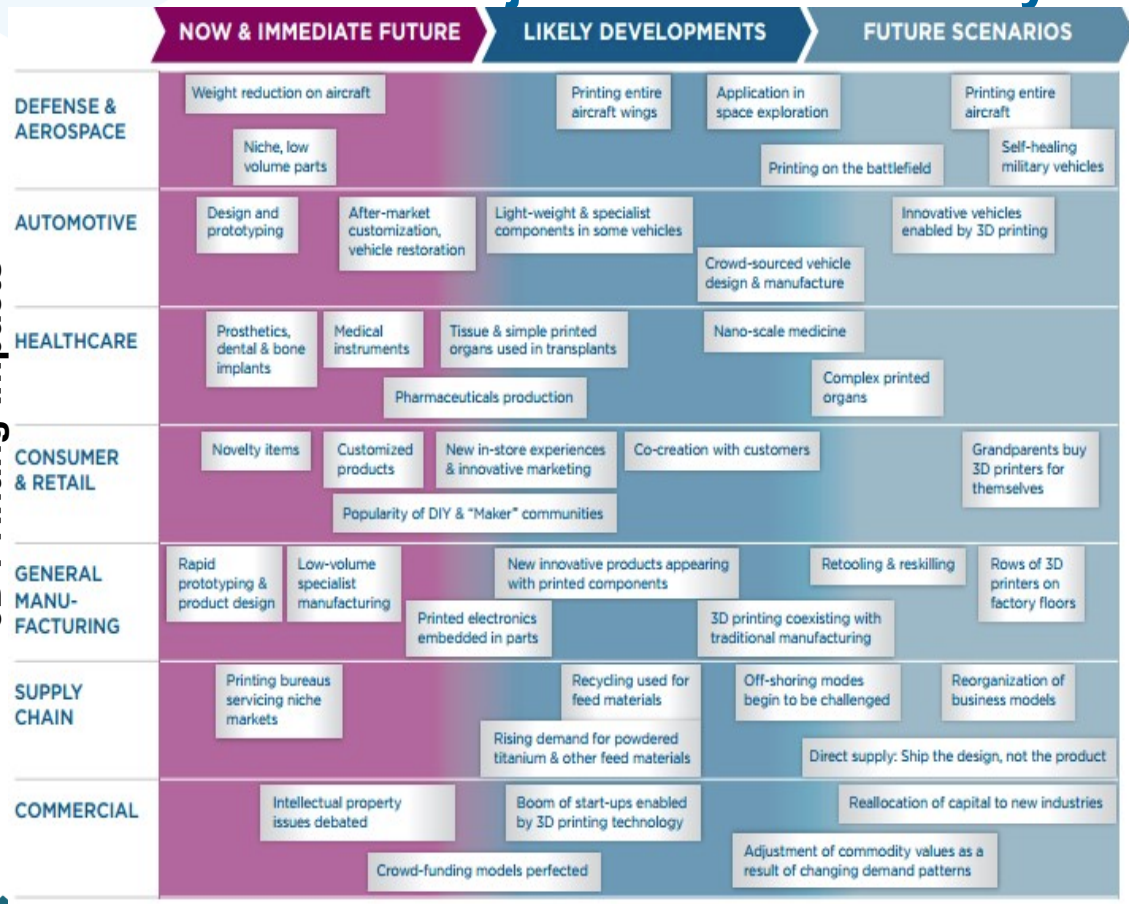
Software-Defined Anything enable efficiencies, reduced costs, and capabilities in a more consumable fashion:

- Rules, models, and code dynamically assemble and configure all needed elements
- Including security, e.g., Software Defined Perimeter (SDP)



Source: Deloitte, "Tech Trends 2015: The Fusion of Business and IT." 3 February 2015.

3D Printing creates physical objects that then become part of the IoT and each object – or collectively – can represent a lot of data.



3D Printing is expected to reach a "tipping point" in the next few years.

- 98% growth in 2015, doubling in 2016
- $1B market 2013, $6B 2017, $600B 2025

And its value can increase over time:

- Lower cost aircraft parts -> self healing aircraft
- Vehicle restoration -> crowd sourced vehicle design
- Dental implants -> printed human organs
- Supply chain business models -> Print on Demand

Sources: Forbes, "2015 Roundup of 3D Printing Market Forecasts and Estimates." 31 March 2015; 3dprintingindustry.com, "Trend Evolution: 3D Printing Trends (Part 1)." 24 February 2014.

Cybersecurity is required for IoT, HCLS, Smart Cities, and Smart Grid to be successful.

79% of organizations have experienced a Cybersecurity event in the past 12 months.

Within two years, 90% of all IT networks will have an IoT-based security breach, although many will be considered "*inconveniences.*" Chief Information Security Officers (CISOs) will be forced to adopt new IoT policies.

"There are two kinds of big companies in the US. There are those who've been hacked, and those who don't know they've been hacked."
- FBI Director, James Corney

Cyber Security is grabbing headlines and will become increasingly important with more connected IoT devices.

- Distributed Denial of Service (DDoS) attacks are increasingly more potent, and one of the most frequent types of incidents
- Key areas for innovation include: detection, response, defense, prediction, prevention
- End to end trust and security for IoT has multiple needs we call TIPPSS – Trust, Identify, Privacy, Protection, Safety, Security

Sources: IDG, "2015 US State of Cybercrime Infographic." 15 July 2015; IDC, "FutureScape: Worldwide Internet of Things 2015 Predictions." December 2014; IDC, "Thwarting Cyberthreats and Attacks Against Healthcare Organizations." November 2014; Internet2 CINO.

Cognitive Computing – combined with IoT – increases insights and the potential for perpetual optimization.

Cognitive Computing: the combination of humans, machine learning, and predictive modeling…

Vision: ingest and analyze many data types to provide insights for improved outcomes…

Enabling the opportunity for perpetual optimization.

Use cases would include healthcare and smart cities, leveraging tools such as:

- Natural language processing
- Visualization
- Input from text, images, data, including curated data from journals, clinical research, traditional sources, smart devices, sensors, wearables
- "Uncertain data" like social media
- Advanced and predictive data analytics

Sources: BizTech Reports, "Cognitive Computing Market is Expected to Reach $13.7 Billion By 2020, Allied Market Research Finds." 22 June 2015; IBM, "Your Cognitive Future: How Next Gen Computing Changes the Way We Live and Work." January 2015.

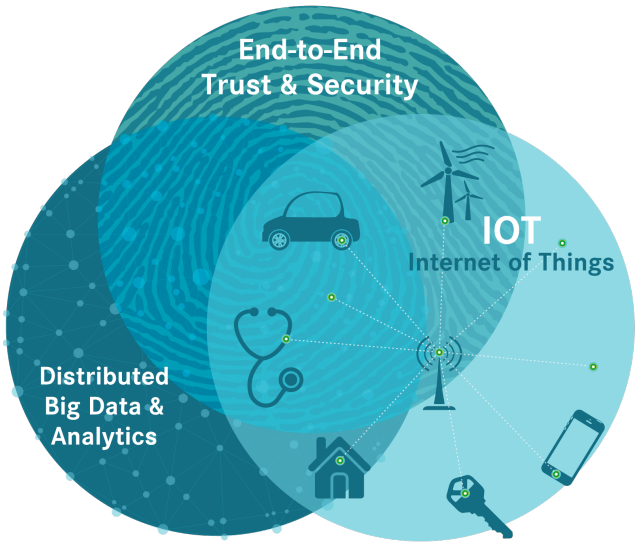
The strategic trends are reflected in the Internet2 Collaborative Innovation Program and Working Groups.

E2E Trust & Security:

- End to End Trust and Security for IoT
- TIPPSS – Trust, Identity, Privacy, Protection, Safety, Security
- SDP (Software Defined Perimeter), Network Segmentation

Distributed Big Data & Analytics:

- Genomics
- Smart Cities / Smart Campuses
- Digital Humanities



Internet of Things:

- IoT Sandbox
- Smart Cities / Smart Campuses
- Smart Grid Testbed

Strategic trends create opportunities that benefit members.

- **Research opportunities abound.**
  - Testbeds leveraging Internet2, NRENs and regional networks for applied research in IoT, Smart Cities/Smart Campus, the Internet of Medical Things
  - IoT Sandboxes (e.g., Internet of Medical Things, Smart Campuses) for collaborative research and application development, sharing of best practices
  - Innovations for device, chip, app, network, architecture, security, communications, etc.
- **Internet2 and its members can guide HCLS to the next frontier.**
  - Enable leverage of the confluence of various HCLS data sets: Genomic, Clinical Research, Clinical Care, Lifestyle, and Environment
  - Connect across multiple new technologies for strategic HCLS areas/use cases: IoT, big data and analytics, end to end trust and security, cognitive computing
- **Potential to positively impact culture and society.**
  - Educate future leaders of an IoT-led economy
  - Lead in addressing current and future challenges and opportunities

Strategic trends have implications specific to the R&E community.

- **Develop curricula to build the technical and business leaders of the future economy**
  - Curricula for Internet of Things, Healthcare and Life Sciences, Smart Cities / Campuses / Grids
  - Develop new business models, technologies, process
- **Create technology innovation through research and testbed programs**
  - Smart Grid, Smart Campus, Internet of Medical Things testbeds
  - IoT Labs – e.g. at UWMadison, Johns Hopkins Applied Physics Lab
- **Develop new models for improved operation and sustainability of a campus, city, community**
  - IoT to measure, monitor, model, and manage campus / city / community / health / safety operations
  - Cross-functional collaboration for improved outcomes, e.g., IT / facilities / administration / students
- **Attract funding to support member research in strategic domains**
  - Potential funding sources could include agencies, Industry, foundations
  - Opportunity for singular or multi-university funding proposals

Thank you

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