



# FORCES: Digital Transformation of Societal Systems

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Joint work with Tom Siebel, CEO C3 IoT  
PI Meeting, August 2017



# Fusion of Computing & Communication



# Societal Scale Cyber Physical Systems (CPS)

## \* Characteristics

- \* Ubiquitous, Pervasive, Disappearing, Perceptive, Ambient
- \* Always Connectable, Reliable, Scalable, Adaptive, Flexible

## \* The Emerging Service Models

- \* Environmental control, energy management and safety in “high-performance” homes
- \* Avionic safety and control UAVs
- \* Management of traffic flows: UGVs, on-demand transport, ..
- \* Distributed Health monitoring
- \* Smart Grid
- \* Smart Cities
  - \* Water
  - \* Oil and Gas

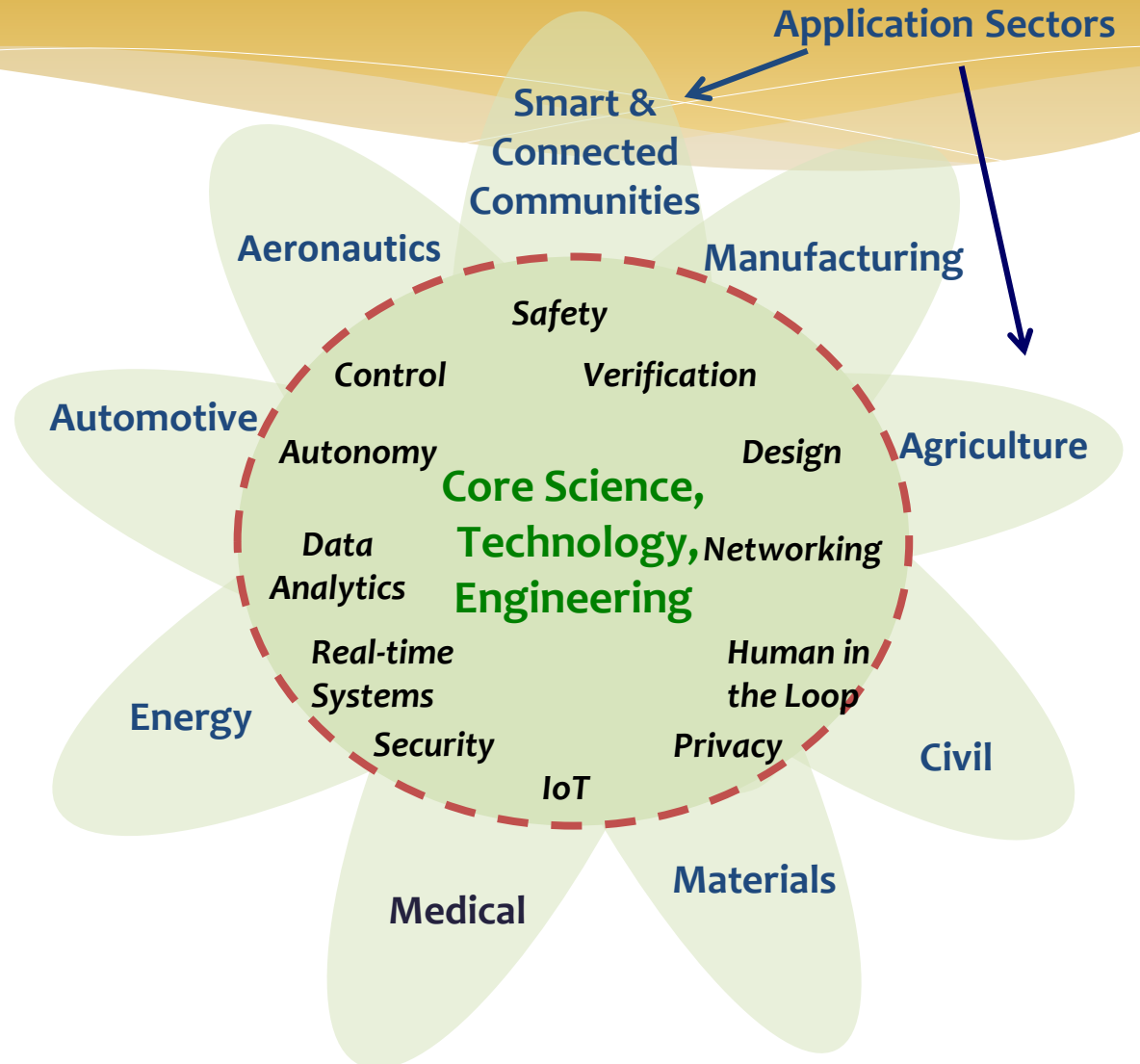
# Resilient CPS Systems

- \* Domains

- \* Energy
- \* Ground transportation
- \* Air transportation
- \* Smart communities

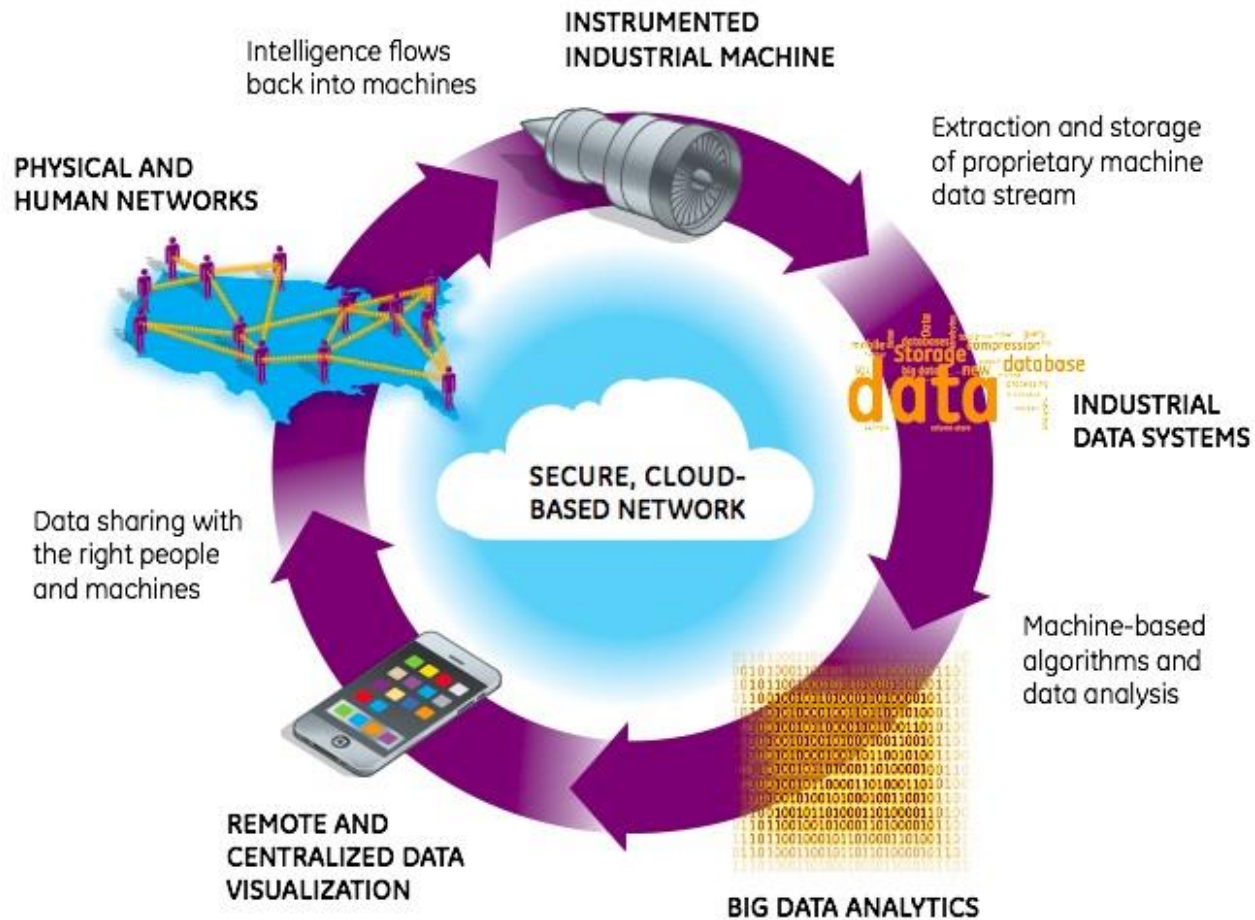
- \* Science

- \* Robust control
- \* Reliability & safety
- \* Human-CPS
- \* Security & privacy



# Industry 4.0, Industrial Internet, Fog, Swarms, ...

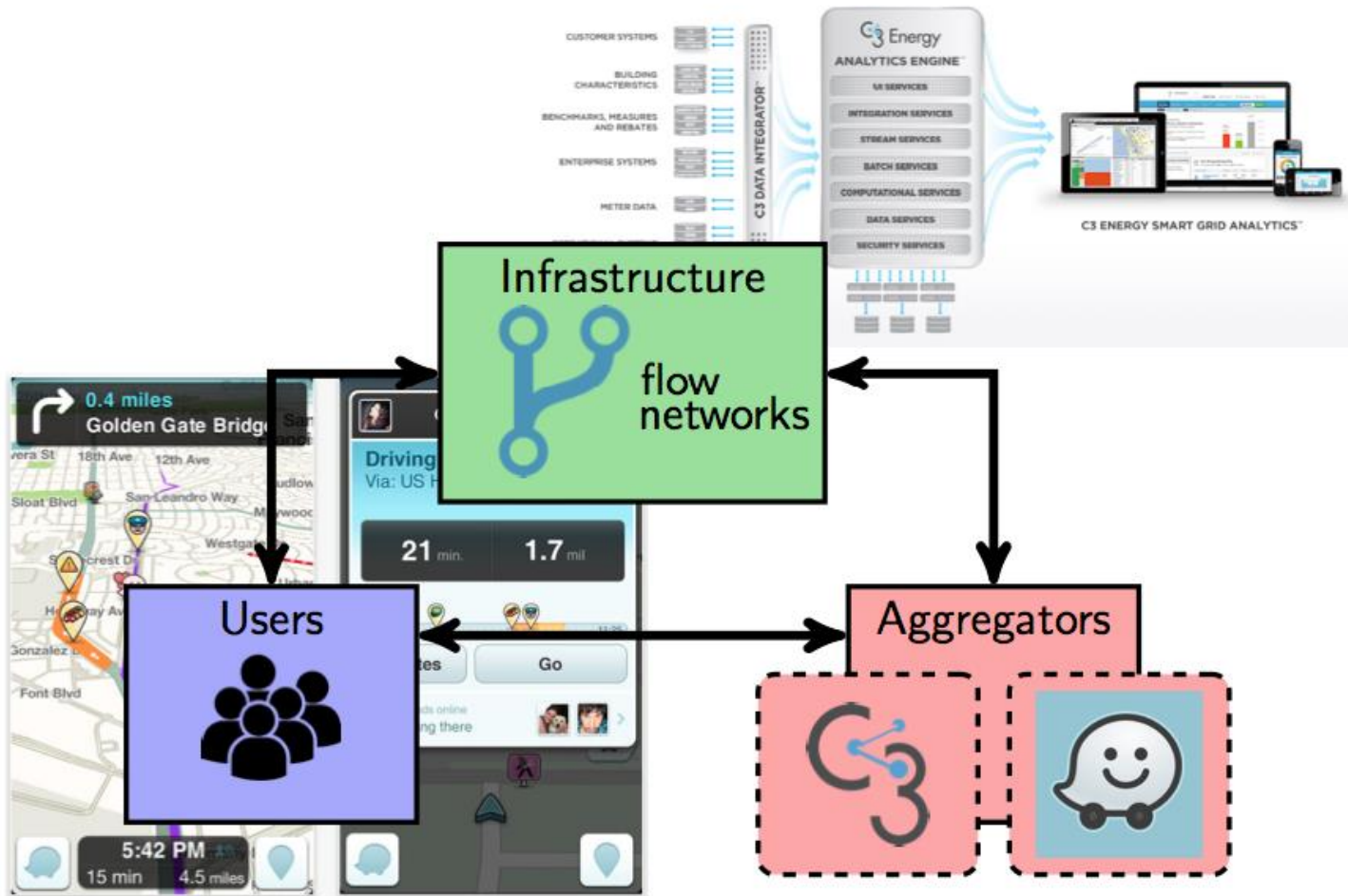
Figure 4. Industrial Internet Data Loop



# CPS continue to be on [rapid] ascent!



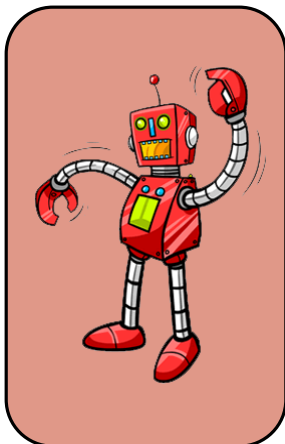
# Sharing Economy: Data as a Commodity



# Provably Correct Mixed Initiative Systems

- \* **Proofs** of correctness, **tools** for synthesis
- \* Hierarchical Decision Making and Controller Synthesis: Scaling Up
  - \* reinforcement learning operates on-line but often makes *myopic* decisions
  - \* model-based planning leverages known structure to ensure high-quality decisions
- \* Learning by Doing
  - \* learn from rich instruction; provide advice & reward to human
  - \* robust to inconsistency; respects neuronal learning speed in human sensori-motor loop





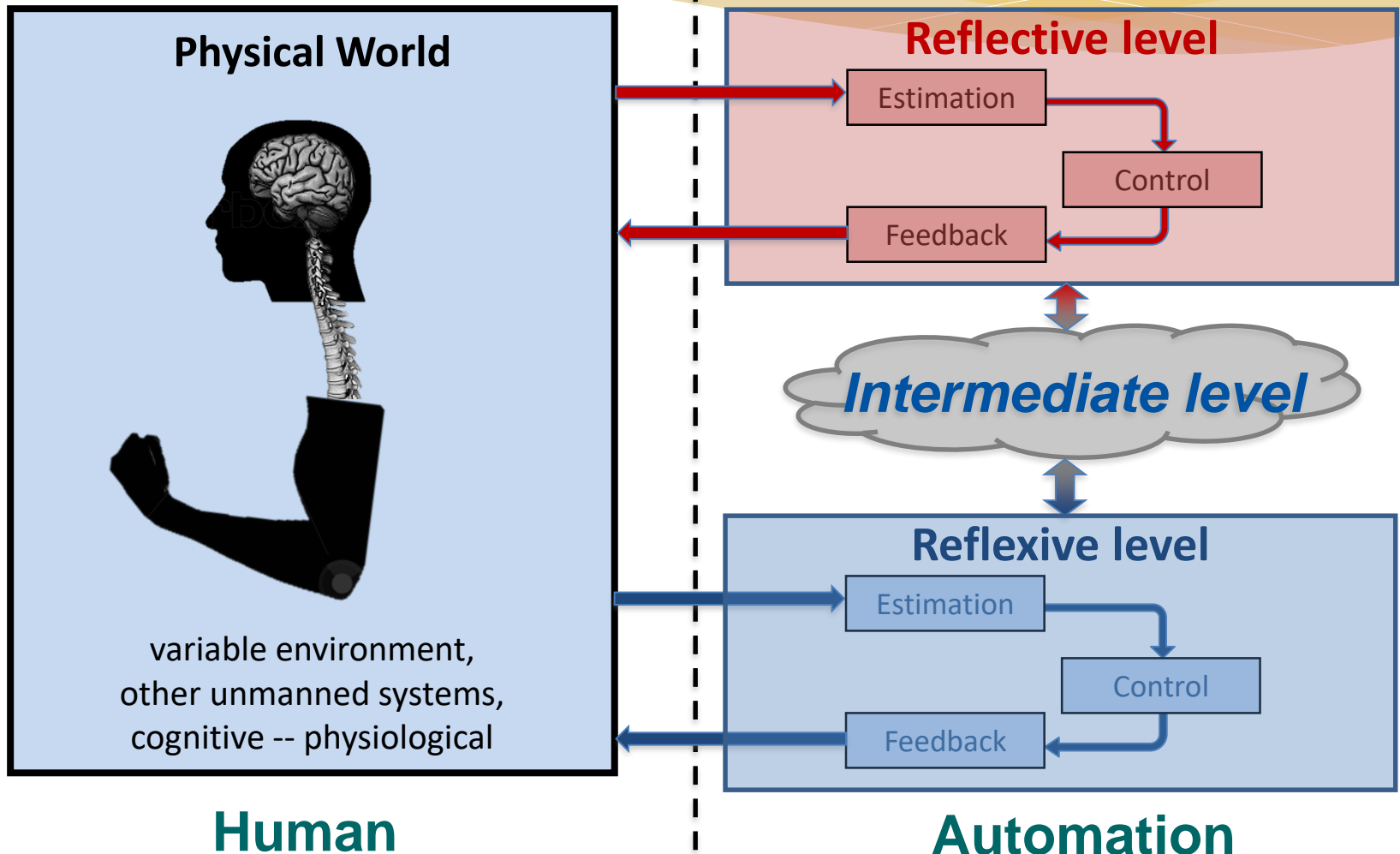
## Human-Aware Control

- Closed-Loop Human Modeling
- Planning to Leverage Effects on Humans

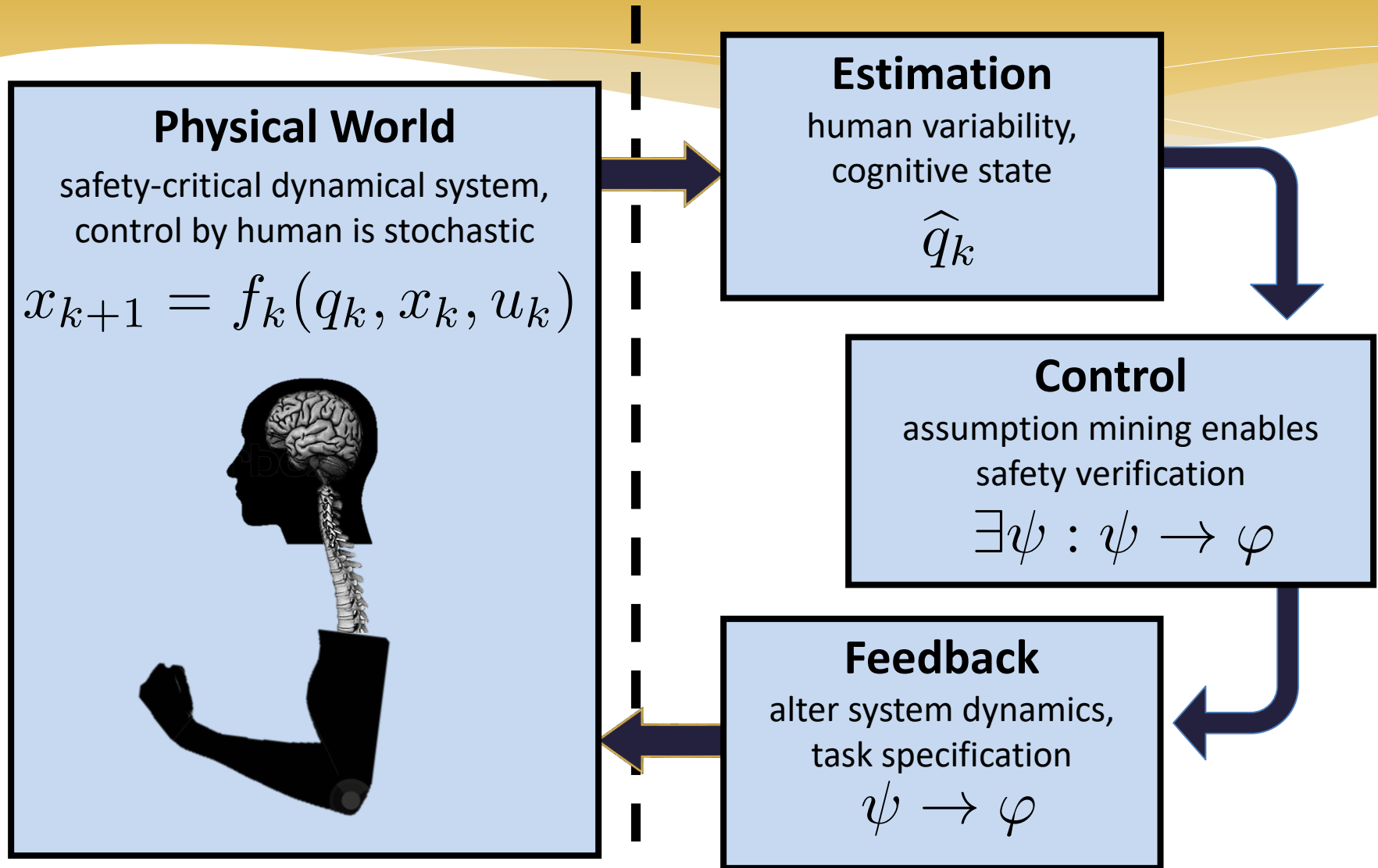
## Controller Synthesis from Formal Specifications

- Systematic Human-Intervention
- Control under Uncertainty

# Reflexive Interacts with Reflective

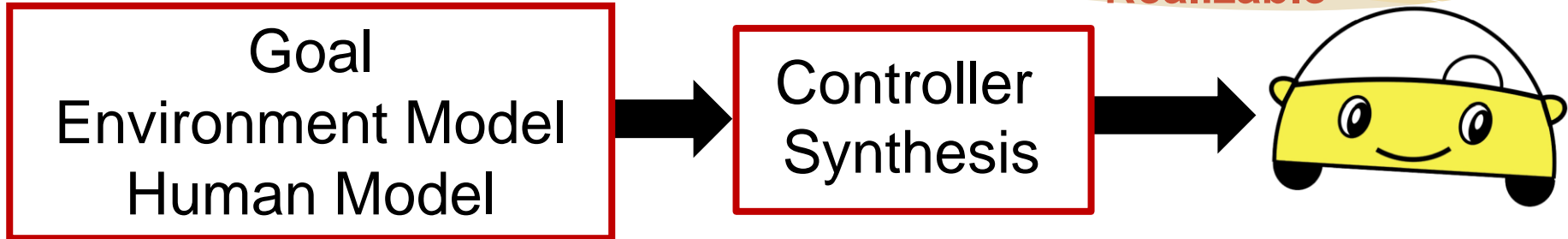


# Interaction as a Stochastic Hybrid System



# Controller Synthesis from Logic Specifications

## LOGIC SPECIFICATION



Given a **formal specification**, encoding the

- objective,
- environment model,
- **human model**,

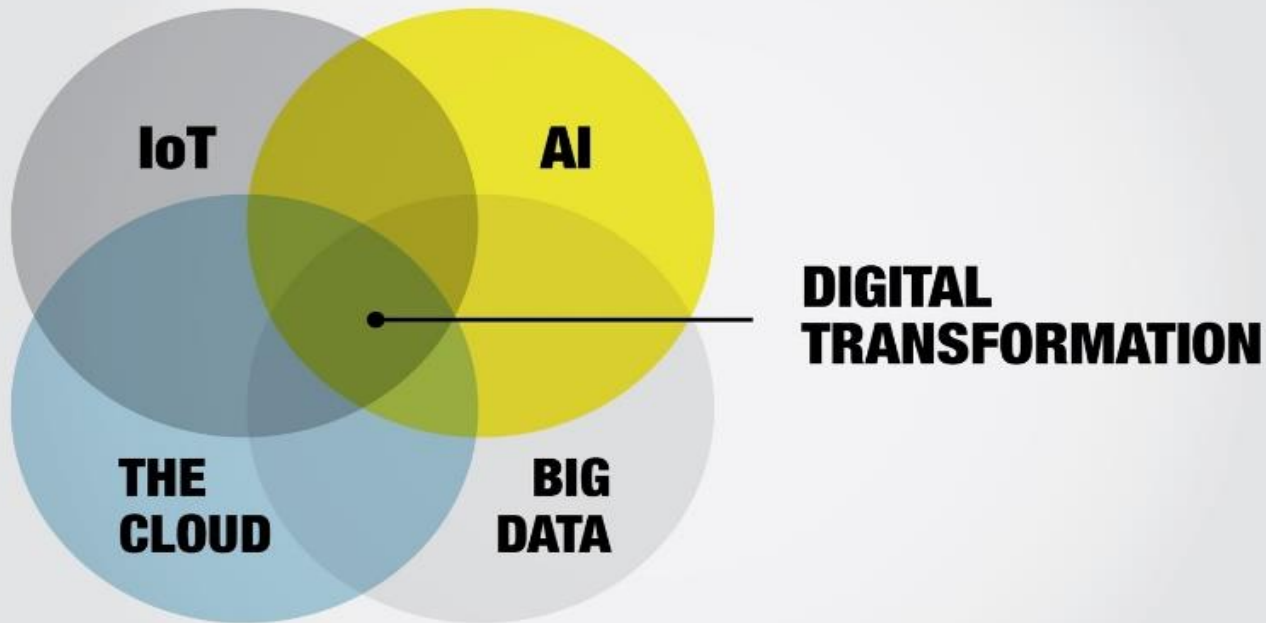
**synthesize a controller** that is **guaranteed** to satisfy the **specification**.

# Digital Transformation: Post-Industrial Redux

- \* Digital Transformation is a concept that is increasingly appearing on corporate board agendas and rising to the top of CEOs' strategic plans.
- \* In 1973, Harvard sociologist Daniel Bell in *The Coming of Post-Industrial Society: A Venture in Social Forecasting*, predicted the Information Age.
- \* At the pinnacle of the industrial era – before the ubiquity of the minicomputer and prior to the personal computer, the Internet, the iPhone, Facebook, and Snapchat – Bell predicted the advance of information technology would drive nothing less than a restructuring of the global economy.
- \* Bell theorized the emergence of a new social order – driven by information technology – dramatically altering the way social and economic interactions are conducted, the way in which knowledge is promulgated and retrieved, and the very nature of the livelihood and avocation of mankind.

# Digital Transformation of Societal Systems

Figure 1: Convergence of disruptive technologies are driving Digital Transformation.

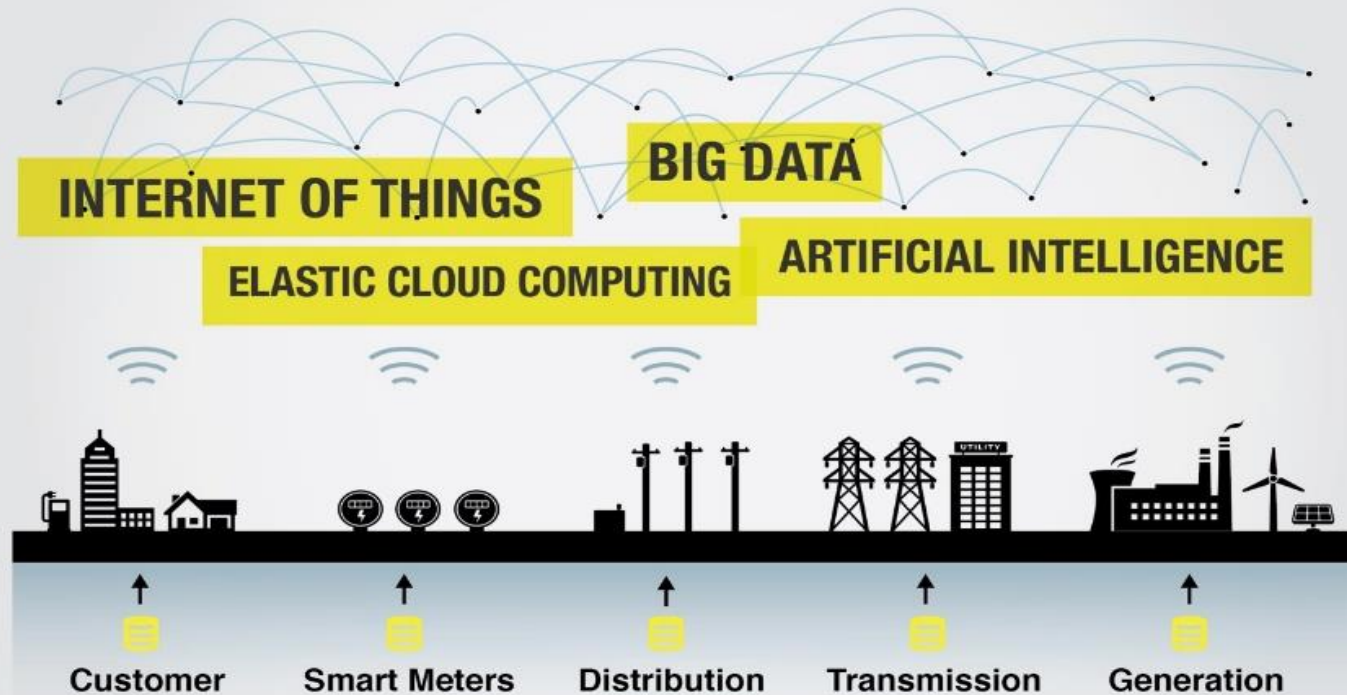


# The Power Grid Example

- \* The electric power grid, as it existed at the end of the 20th century, was largely as originally designed by Thomas Edison and George Westinghouse a hundred years earlier: power generation, power transmission over long distances at high voltage (115kv or greater), distribution over medium distances at stepped-down voltage (typically 2kv-35kv), and delivery to electric meters at low voltage (typically 440v for commercial or residential consumption).
- \* Composed of billions of electric meters, transformers, capacitors, phasor measurement units, power lines, etc., the power grid is the largest and most complex machine ever developed and, as noted by the National Academy of Engineering, “*Century of Innovation: Twenty Engineering Achievements That Transformed Our Lives*,” 2003 is the most important engineering achievement of the 20th century.
- \* The 21st century development of the smart grid is the result of the sensing of the electric utility value chain – essentially, IoT meets the grid. It is estimated that \$2 trillion is being spent this decade to sensor this value chain by upgrading or replacing the multitude of devices in the grid infrastructure so that all the devices emit telemetry and are remotely machine addressable. Derived from “*Estimating the Costs and Benefits of the Smart Grid*,” Electric Power Research Institute (EPRI), March 2011.

# New CPS Technology Stack for Smart Grid

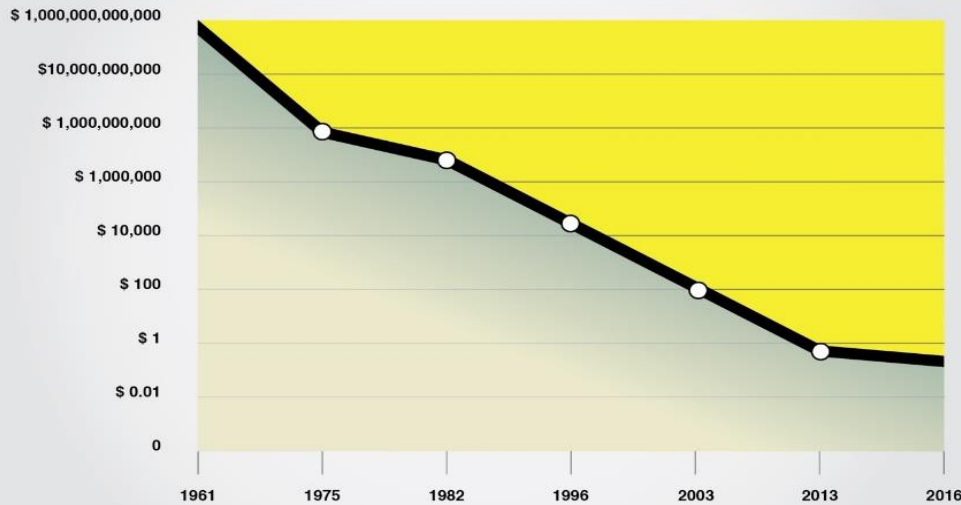
Figure 2: Fully connected sensor networks such as the Smart Grid require a new technology stack.





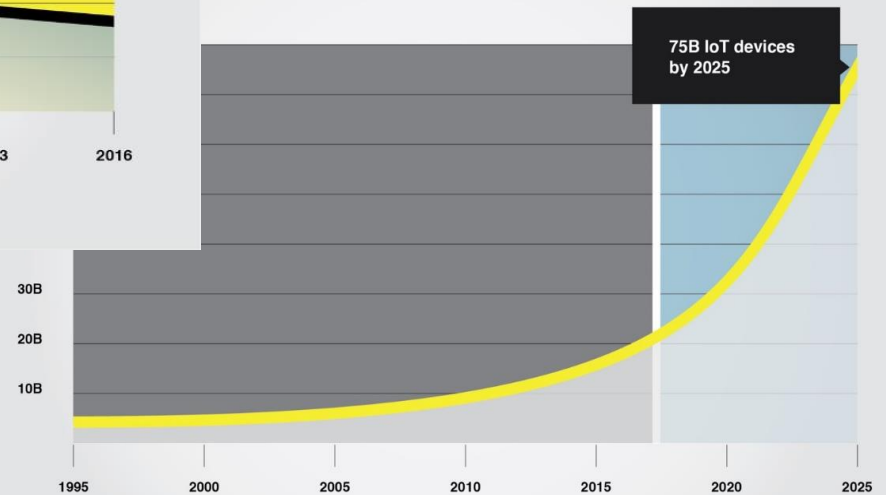
# Trends in Storage and Devices

**Figure 3: The cost of cloud-based data storage and compute has decreased dramatically over time.**



SOURCE: Goldman Sachs, "Profiles in Innovation: Artificial Intelligence," November 2016

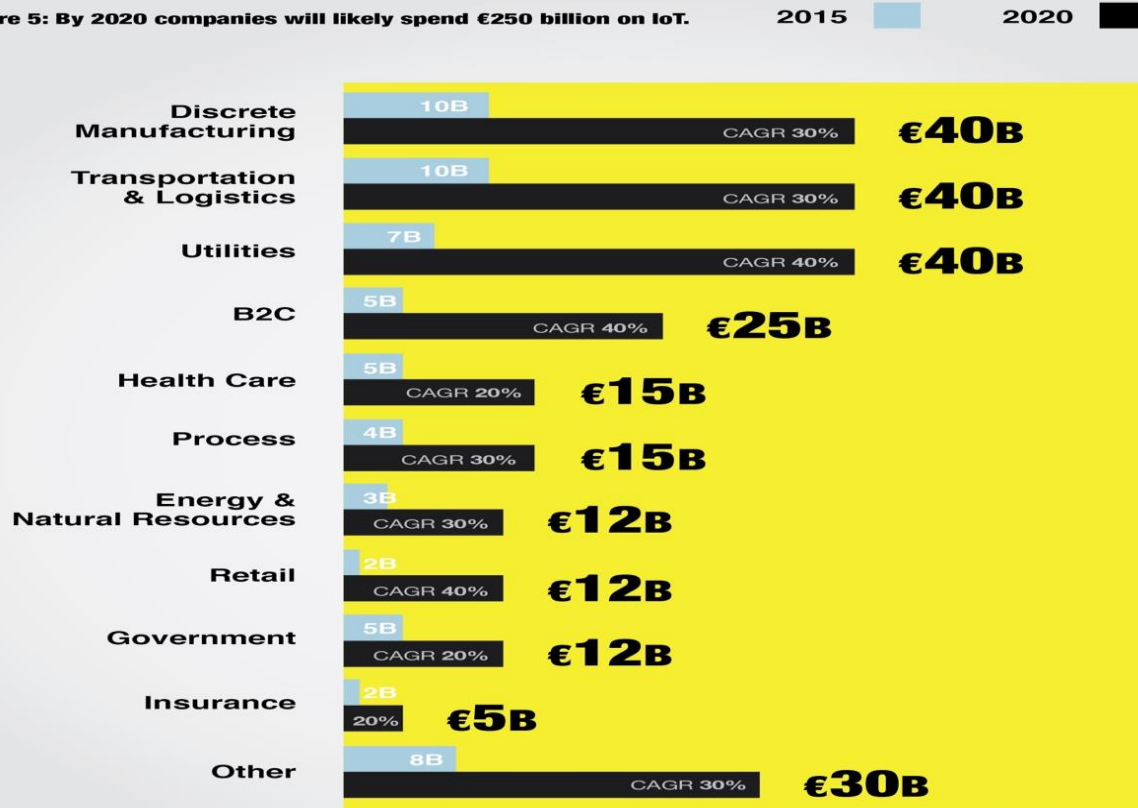
years, the number of connected devices will grow at more than twice the rate of the last 20 years.



SOURCE: IHS Technology, "Tech Companies Creating Strategic Platforms to Support the Internet of Things," April 2016

# Spending on IoT

Figure 5: By 2020 companies will likely spend €250 billion on IoT.



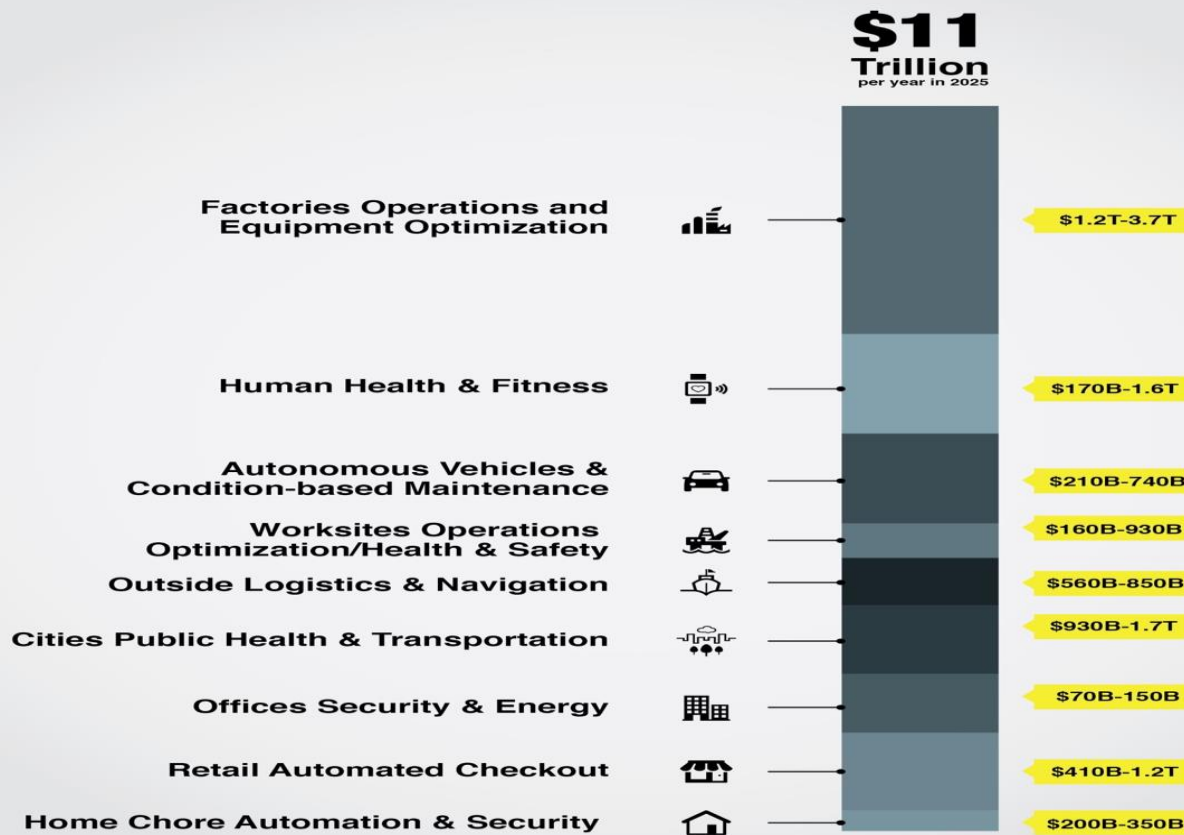
SOURCE: BCG, "Winning in IoT: It's All About the Business Processes," January 2017

# This is Much Much More than Big Data!!

- \* The concept of “Big Data” is a commonly misunderstood consequence of these technology trends. With big data, we perform calculations on all the data; there is no sampling error. This brings a renaissance to the promise of AI to evolve a new kind of CPS science, enabling a class of computation previously unattainable using machine learning and deep learning to perform precise predictive analytics.
- \* At the convergence of IoT, Cloud Computing, Data Analytics, and AI is Digital Transformation. The benefits are breathtaking. McKinsey Global Institute estimates the value that industries and governments will create from IoT Digital Transformation will range from \$3 trillion to \$11 trillion per year in 2025. No industry will remain untouched. “*The Internet of Things: Mapping the Value Beyond the Hype*,” McKinsey Global Institute, June 2015.

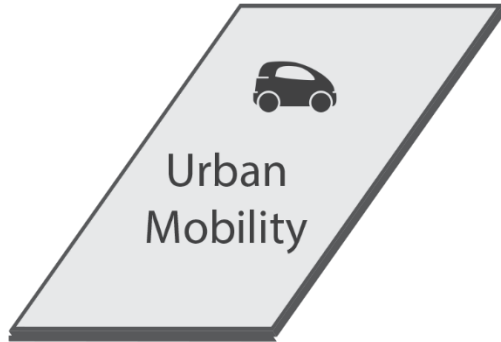
# Economic Impact: Off the Charts!

Figure 6: The potential economic impact of IoT is a staggering \$11 trillion per year in 2025.

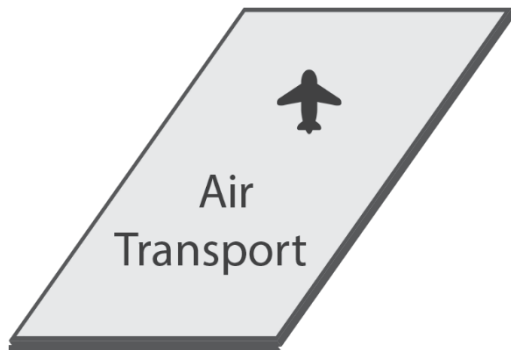
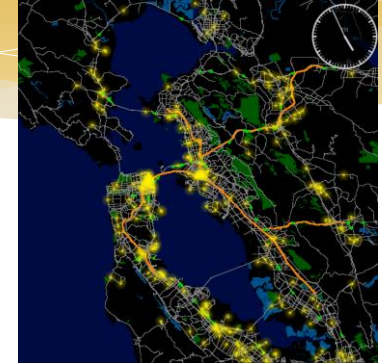


SOURCE: McKinsey Global Institute: "The Internet of Things: Mapping the Value Beyond the Hype," June 2015

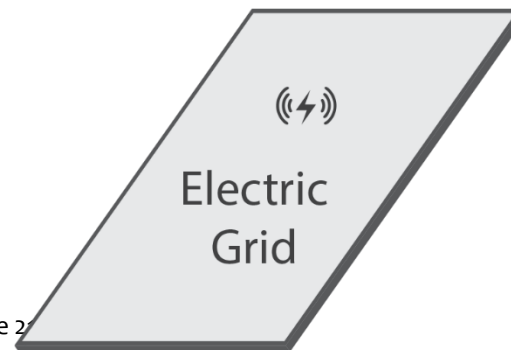
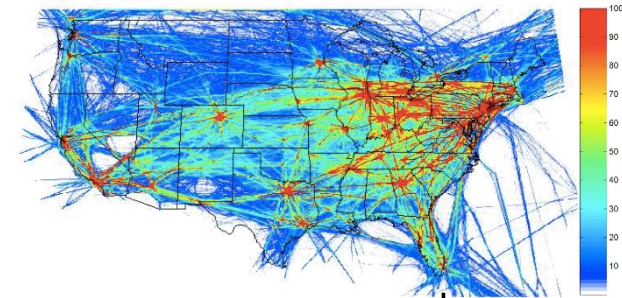
# Smart Cities



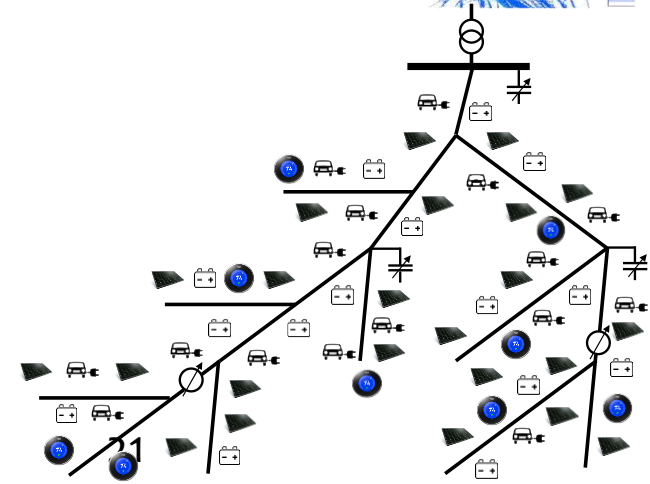
- \* Vehicles/ride sharing/mass transit/cyclists/pedestrians
- \* **Traffic jams, ineffective control**



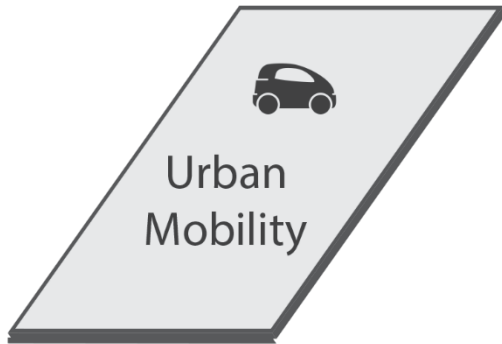
- \* Air traffic infrastructure
- \* **Fragile network susceptible to crippling delays**



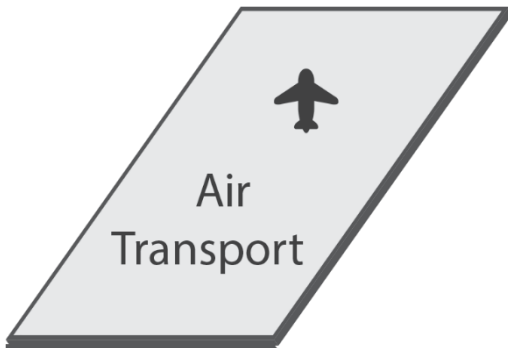
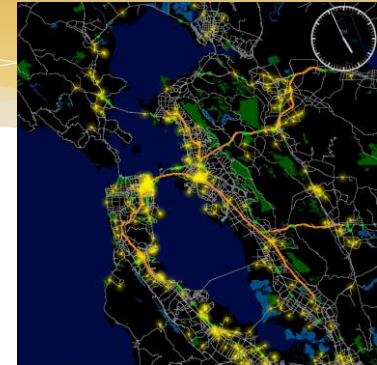
- \* Distribution system, control infrastructure
- \* **Fluctuation from renewables**



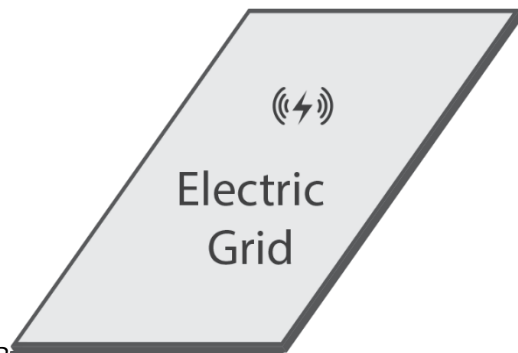
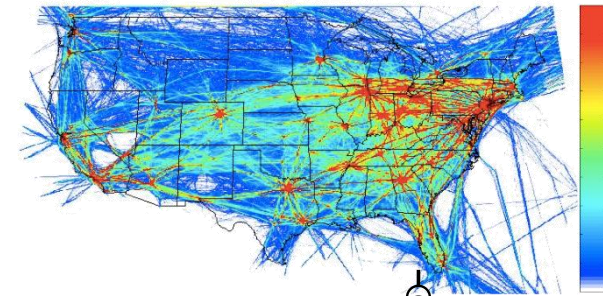
# Societal Scale Infrastructure Systems



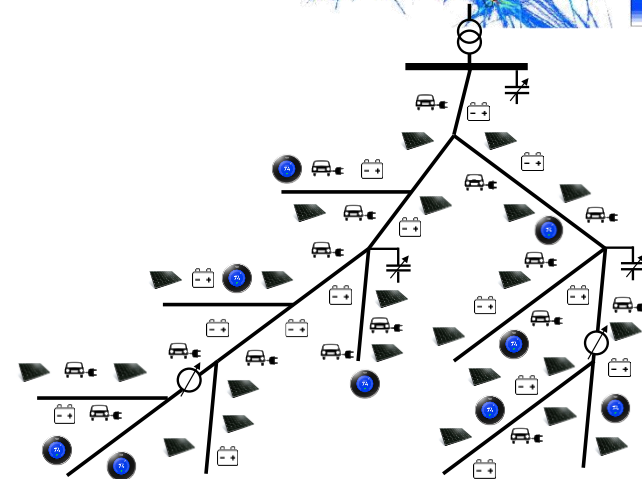
- \* A resilient traffic system responsive to demand
- \* Reduce energy footprint of individual consumer



- \* A decentralized architecture with strategic allocation of capacity-constrained resources
- \* UAV Traffic Management



- \* Resilient grid operation with increased visibility
- \* Incorporation of local, clean and carbon neutral resources



# Innovation Being Driven Top Down

Perhaps the most unique aspect of this technology trend is that Digital Transformation is being driven from the top. The Digital Transformation mandate is being driven personally by the CEO. This is something new.

- \* Heinrich Hiesinger at ThyssenKrupp
- \* Volkmar Denner at Bosch
- \* Isabelle Kocher at ENGIE
- \* Francesco Starace at Enel
- \* Darius Adamczyk at Honeywell
- \* Samuel Allen at John Deere
- \* Fabrice Brégier at Airbus
- \* Larry Renfro at Optum/United HealthCare
- \* Michael Burke at Louis Vuitton
- \* Li Yue at China Mobile

# Transforming Health Care: United Health Care

- \* Soon all medical devices will be sensed. Healthcare records and genome sequences will be digitized. Human populations will be sensed with wearable and implanted devices that remotely monitor pulse, blood chemistry, hormone levels, blood pressure, temperature, and brain waves.
- \* With AI and ML, disease onset will be accurately predicted and prevented. Best medical practices will be more uniformly applied. Physician-augmented AI will attain increasingly accurate diagnoses and optimally efficacious treatment protocols. Pharmaceutical treatments will be patient and disease specific.
- \* United Healthcare insures more than 100 million people. Driven by the CEO of its Optum division, it is developing more than 1000 AI predictive analytic healthcare applications and micro-services to transform the healthcare industry.



# Digital Transformation of Societal Systems

- \* Digital Transformation, enabled by CPS, IoT and AI, changes everything about the way products are designed, manufactured, sold, delivered, and serviced.
- \* It ushers in new economic models in the “sharing economy.” It changes everything about the underlying business processes, management practices, and information systems.
- \* As shown by Amazon and Uber, it changes everything about the nature of customer relationships, customer expectations, the supply chain, pricing models, and customer service.
- \* It changes the nature of work.
- \* The next step in the Information Age is a giant leap forward. It is happening now. Many new and unanticipated enterprises will emerge; new business models are and will be created; many enterprises will be transformed; and the many that fail to transform will cease to exist.

# Disruption!!

- \* Tesla's market capitalization exceeds General Motors' even though its revenue is less than 1/20th of GM's. Tesla collects terabytes of data from its vehicles and uses machine learning to continuously improve predictive maintenance, self-driving capabilities, and the driving experience of its cars. Tesla is digitally transforming the automobile industry.
- \* Amazon's market cap is almost twice that of Walmart's even though its revenue is 1/4th of Walmart's. Amazon's share of the U.S. e-commerce market is 33 percent and could increase to 50 percent by 2021. Its buyer and seller data and network effect create a virtuous cycle for the company and the consumer. Sears, Gymboree, RadioShack, J.C. Penney, Macy's, Kmart, Guess – more than 8,600 brick-and-mortar stores will close their doors in 2017. Amazon has digitally transformed retailing.
- \* Uber and Lyft have created an entirely new mode of transportation, the sharing economy, using IoT and the cloud. These companies have a combined value of more than \$60 billion, and between them have disintermediated the traditional taxi and limo industries. San Francisco's largest taxicab company declared bankruptcy in 2016. In Los Angeles, the number of taxicab rides declined by nearly 30 percent between 2013 and 2015, resulting in a net loss of 2.4 million trips per year. The ride sharing companies are digitally transforming transportation.

# A Call to Invent the Future!

We need to invent the future under this digital transformation:

- \* New business models
- \* Pricing Privacy
- \* Learning Utility and Prospects of Consumers
- \* New Security Concerns and Resilience to Attacks
- \* The Gig Economy and the Changing Nature of Work

This is to be enabled by the grand fusion implicit in CPS: IoT, Big Data, Machine Learning, Cyber Human with the overlays of privacy, Resilience, social justice and social welfare.

# Accelerating innovation and maximizing impact

## HUB for Inventing the Future

Bringing an ecosystem of world-class experts and partners to create innovative solutions for pressing global problems.

