General Electric

Resilient-Sustainable Infrastructure (RSI)

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The National Academies
Roundtable on Science and Technology for Sustainability

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Defining the Energy Eras

Every era has its defining trend

Oil Shocks→
Energy Security

Reagan/Thatcher→
Deregulation

Climate Change→
Carbon control

1970s **1980s** **1990s** **2000s**

Source: GE Energy, Global Strategy and Planning, 2012

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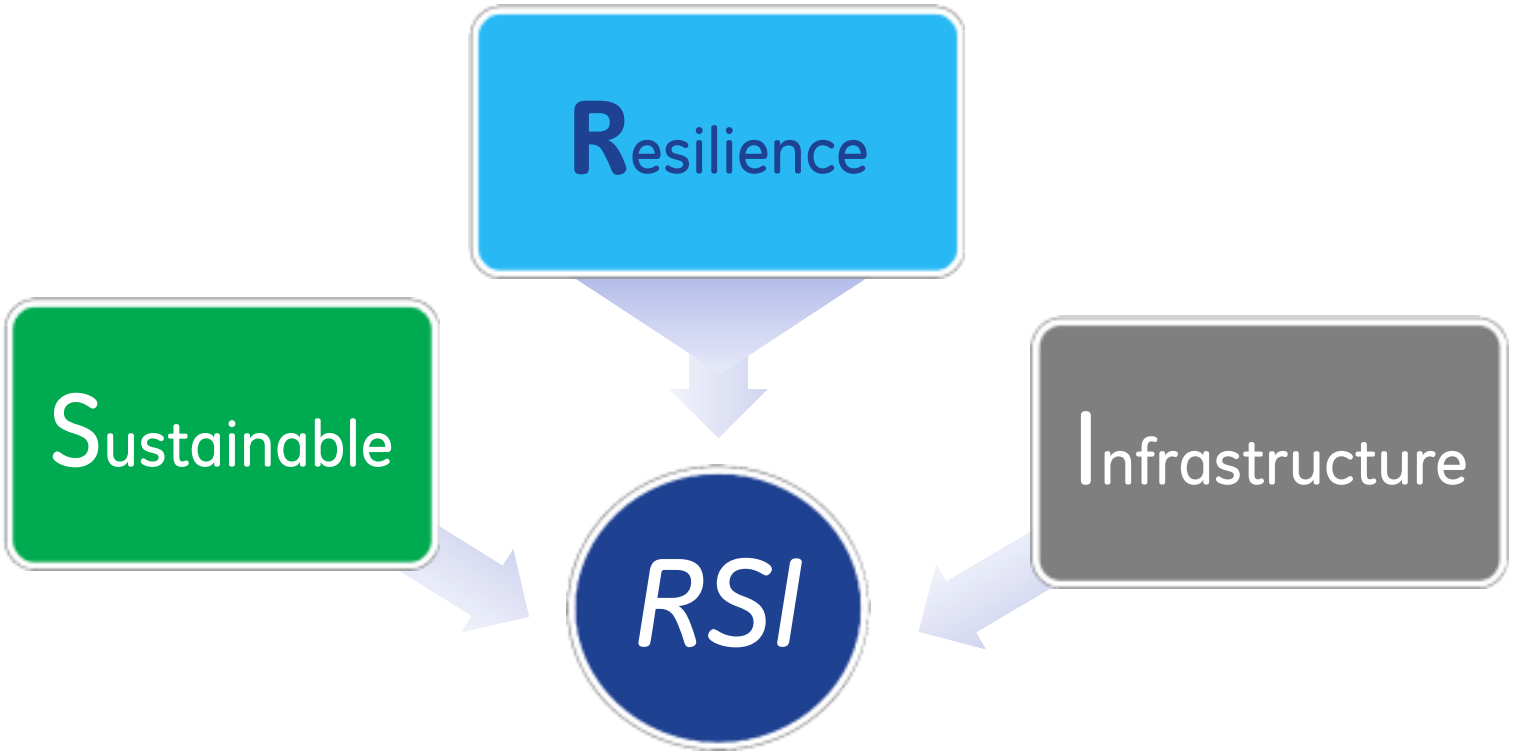
Macro trend… global shift to *RSI*

Next generation infrastructure



Source: General Electric, 2012

US Natural Disasters - Energy Impacts

Hurricane Sandy

October 2012

Category 1 hurricane.
Second-costliest hurricane in US history

55%

Key East Coast oil refining capacity shutdown

- 0.6 million barrels per day production loss through refinery shut downs or reduced runs.
- Two refineries were shutdown, and one refinery reduced runs due to hurricane Sandy.

>10 Million

Customers lost power

- 8,511,251 combined total peak outages in 21 states.
- New Jersey was the most badly impacted with 10% of customers without power – while other states saw less than 3% of their customers suffer electricity outages.

>$50 Billion

In total estimated damages

Other impacts:

- More than 600,000 cars could be damaged.
- According to IHS Global Insight. Sandy could cause about $20 billion in property damages and between $10 billion and $30 billion in lost business.

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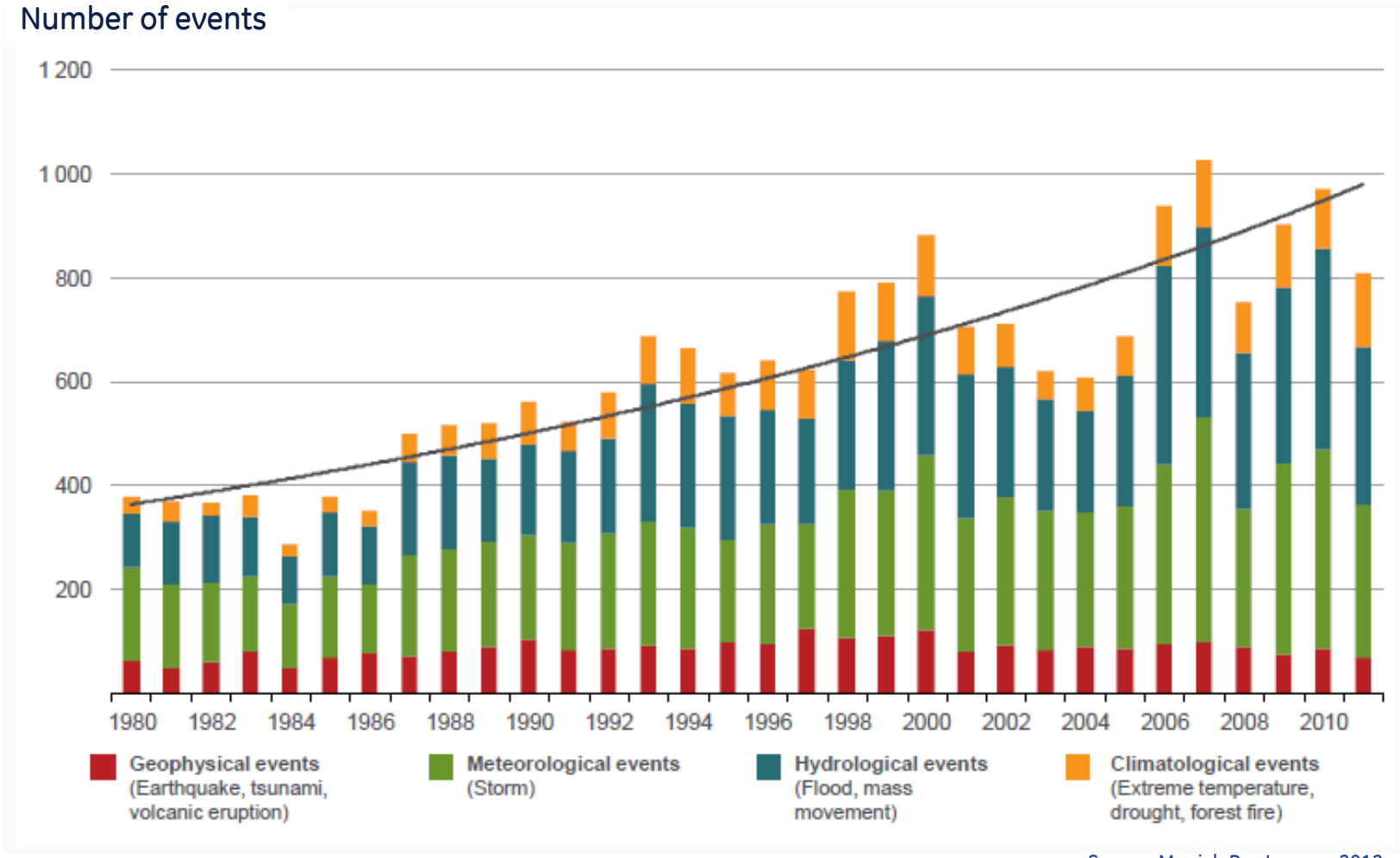
Source: U.S. Department of Energy; EIA and Edison Electric Institute, 2012

World-wide natural disaster trend



Source: Munich Re, January 2012

Expect 12,000 disasters over next 15 years*

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*Assuming a future trend rate of 800 disasters a year.

Forces driving rise of resilience

Complex interlinked issues arising from global change

Rapidly expanding human built environment

- The human built environment is growing globally at a rapid rate
- In the next 15 years, global output will grow between $40 and $65 trillion dollars.
- The growth of the built environment enhances livelihoods but it also increases the exposure to naturally occurring hazards ranging from earthquakes to tropical storms.

Dependence on critical infrastructure

- Technological change is increasing prosperity but it is also increasing dependence.
- As economies become more advanced they have become more dependent on critical supporting infrastructure including:
  - energy
  - information technologies
  - transportation networks
  - supply chains

Rising economic damage from chronic and acute shocks

- Growing global concern about ecosystem dynamics and the potential for thresholds and tipping points.
- Rising economic damage associated with the impact of natural disasters, which climbed to an all time high of $380 billion in 2011.

Source: GE Energy, 2012; Munich Re, 2012

Shifting landscape

Growing demand for footprint reduction and resilience

Resilience

Planning + Asset Hardening → Emergency management → Backup and recovery

Reduced environmental footprint

Carbon

Water

Efficiency

Waste

Networks

Fleets

Facilities

Machines

Source: General Electric, 2012

Industrial Internet

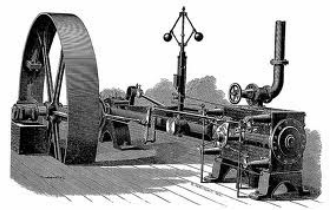
Setting the stage
1750-present

2012-and beyond: Expansion of the Internet across industrial enterprises

Intelligent devices

Intelligent networks

Intelligent automation

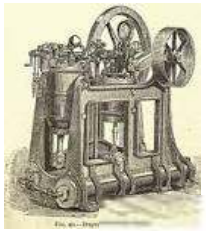


1750-1950: Rise industrial machines, fleets and networks

1965-1980 Creation of ArpaNet and other precursors to the Internet

Big data and the cloud emerge

1750	1950	1960	2010	Future
Industrial Revolution		Internet Revolution		Industrial Internet



continuous combustion engine that is the basis for the gas turbine

1950s: Rise of Mainframe computers

1990-2010: Rise of personal computers; World Wide Web, private networks; e-commerce and eventually social media

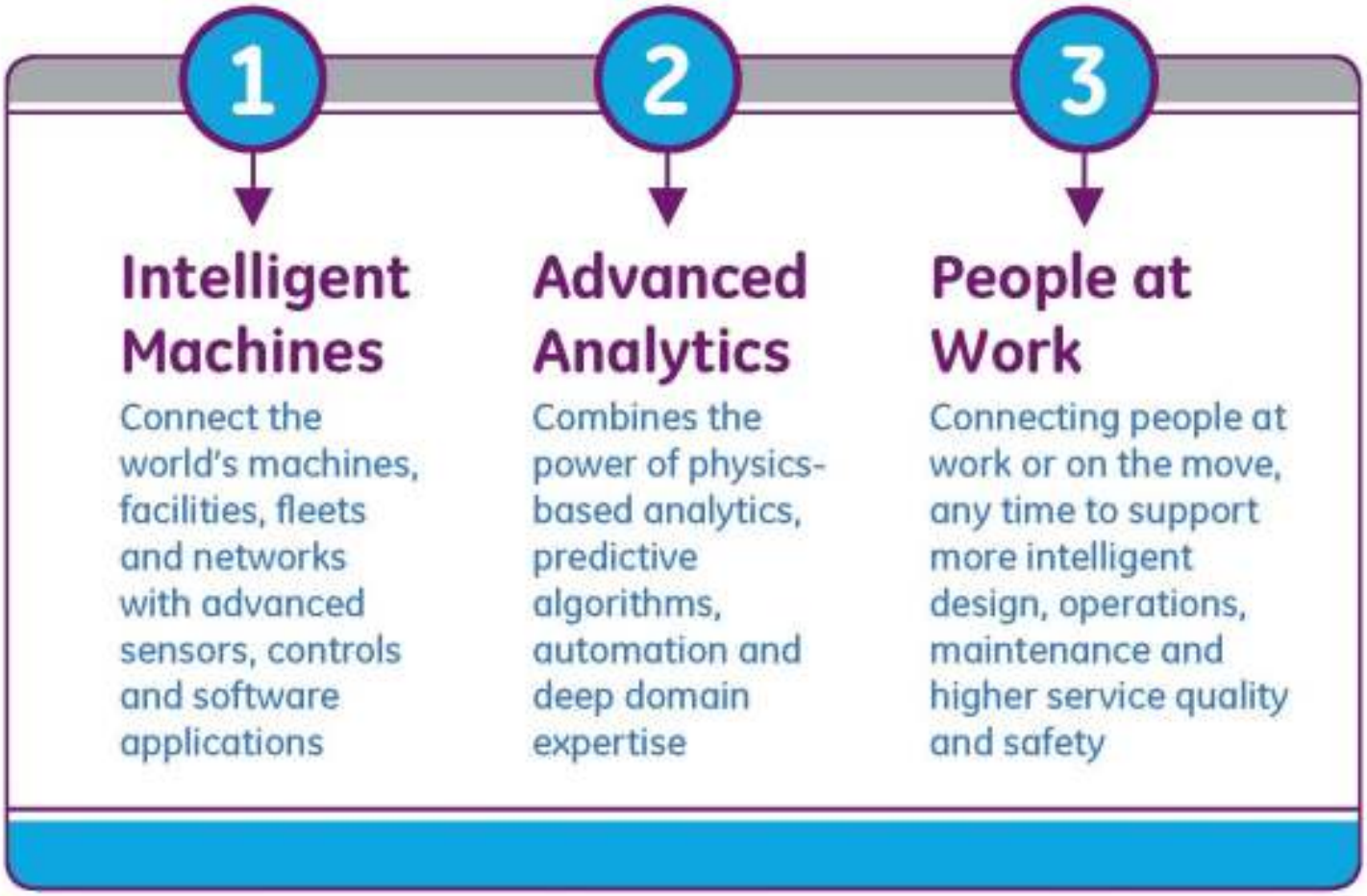
Advanced machines

Fleets

networks

Historic Waves of innovation and productivity

Industrial Internet building blocks



Source: Peter C. Evans and Marco Annunziata, *Industrial Internet: Pushing the Boundaries of Minds and Machines*, General Electric, November 2012

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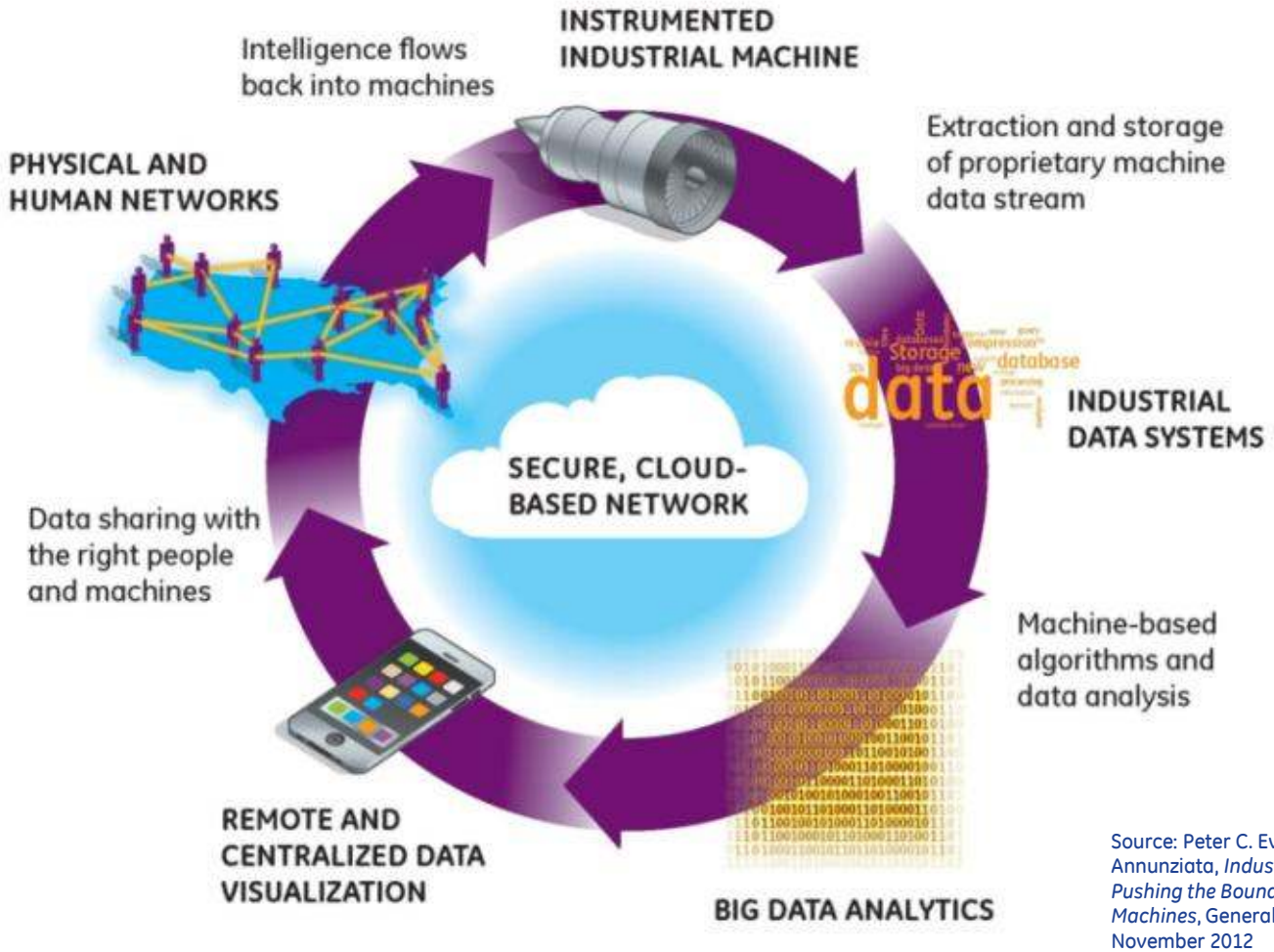
Industrial Internet

From instrumentation to intelligence and back



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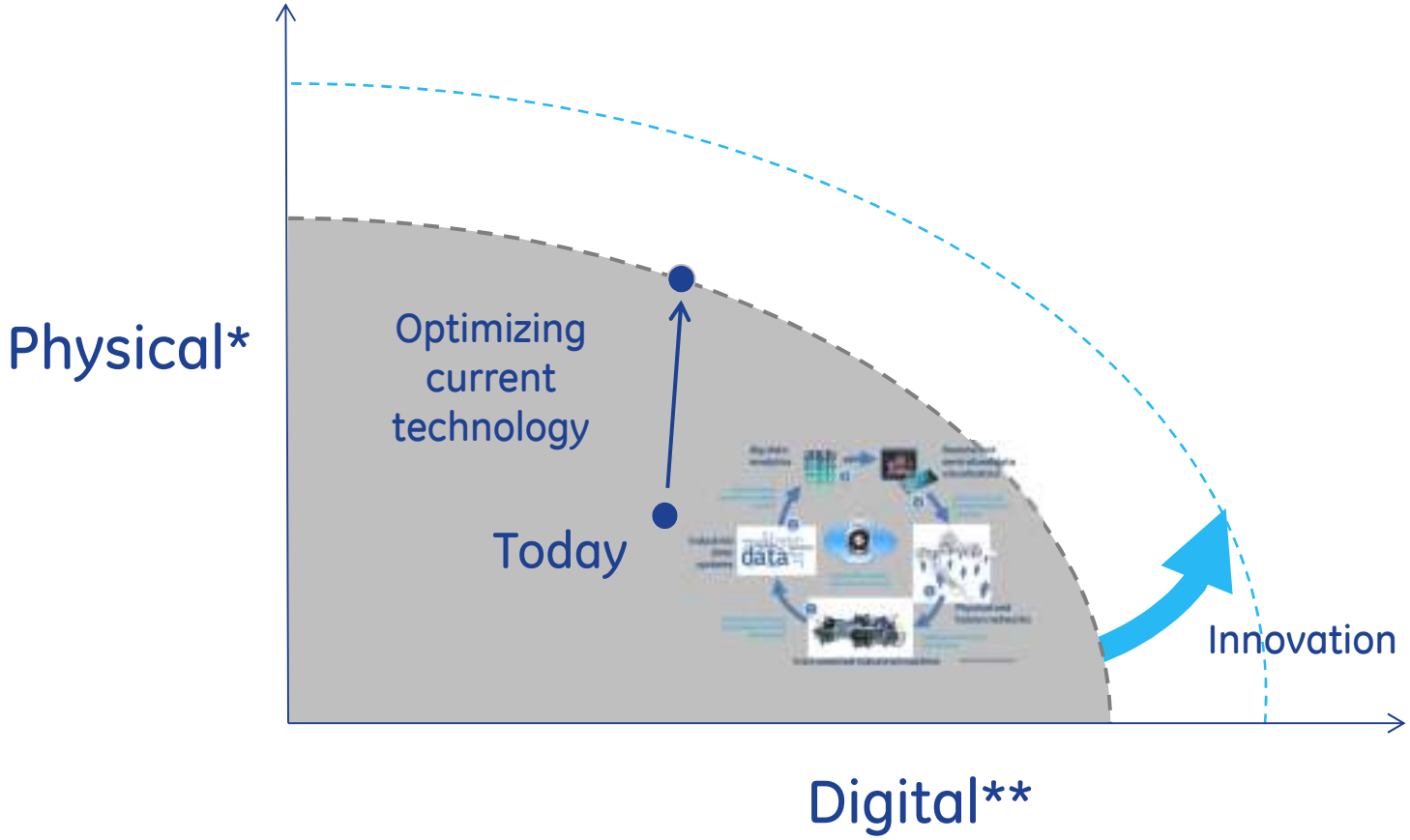
Possibility frontiers

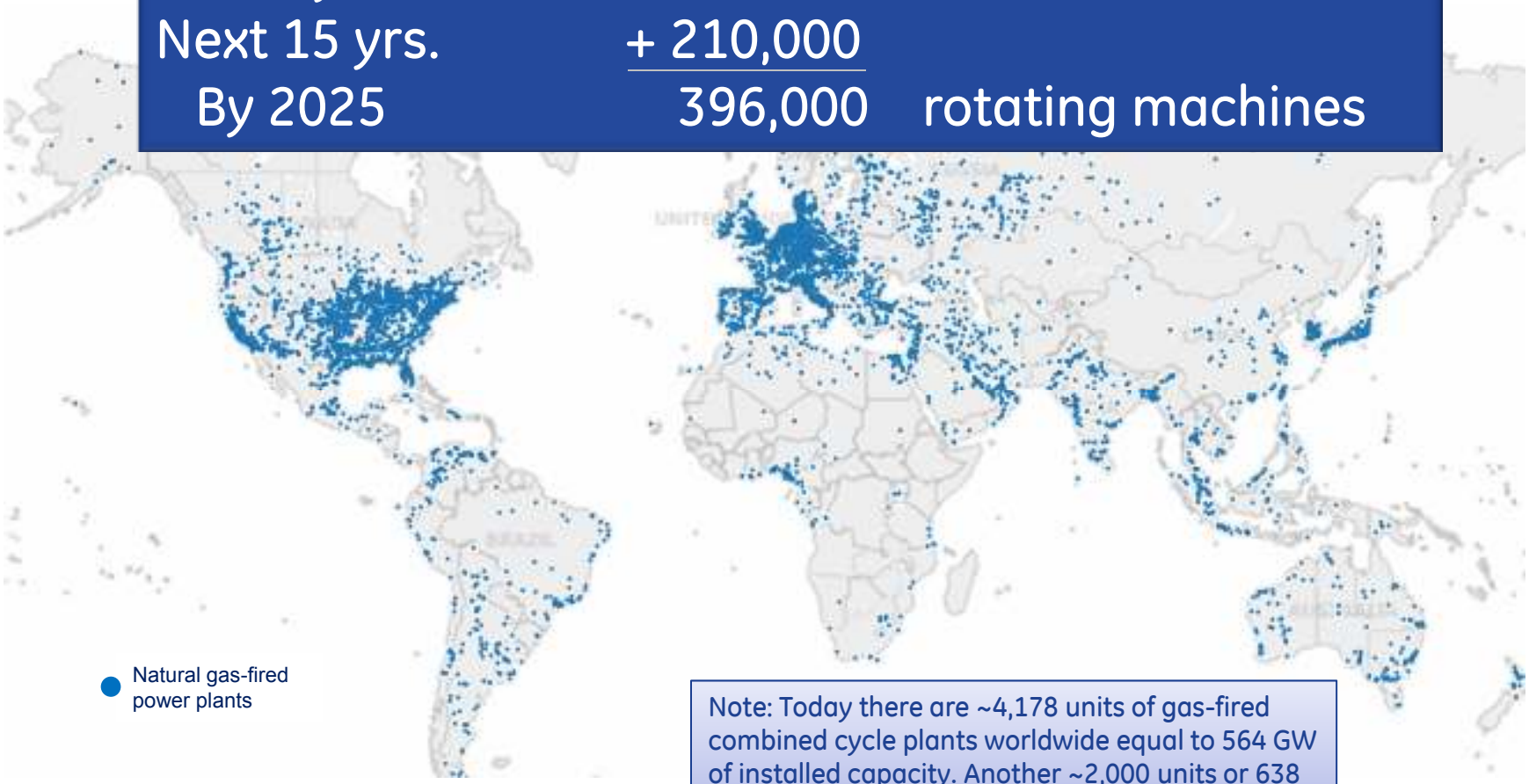


* Machines, facilities, fleets and networks
**Intelligent devices, intelligent systems, intelligent automation

Things that spin…

Combined cycle gas-fired electricity generation segment

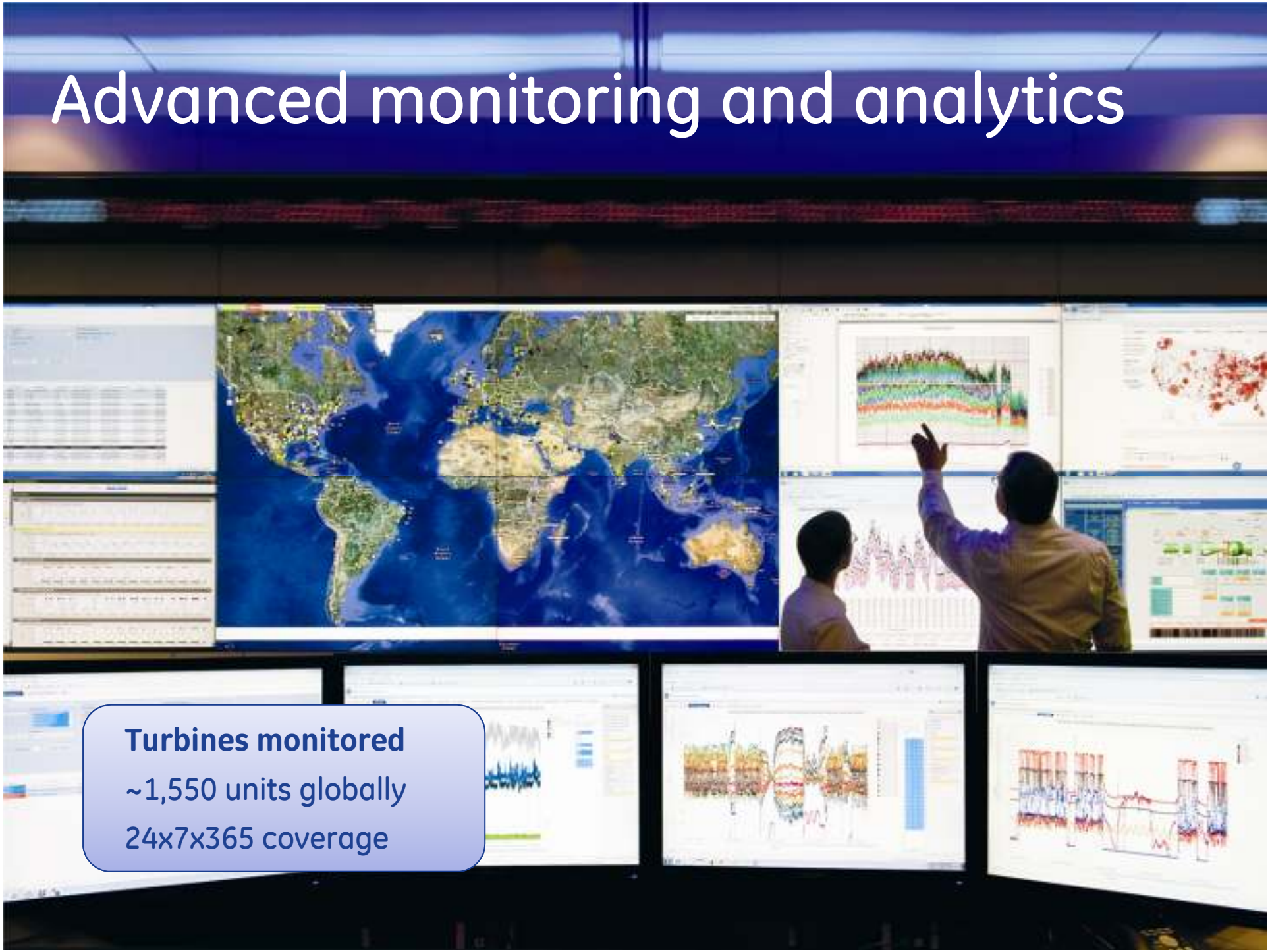
Today	186,000	
Next 15 yrs.	+ 210,000	
By 2025	396,000	rotating machines



Source: UDI Platts data and General Electric, 2012

Note: Today there are ~4,178 units of gas-fired combined cycle plants worldwide equal to 564 GW of installed capacity. Another ~2,000 units or 638 GW will be added between 2011 and 2025.

Advanced monitoring and analytics



Turbines monitored

~1,550 units globally

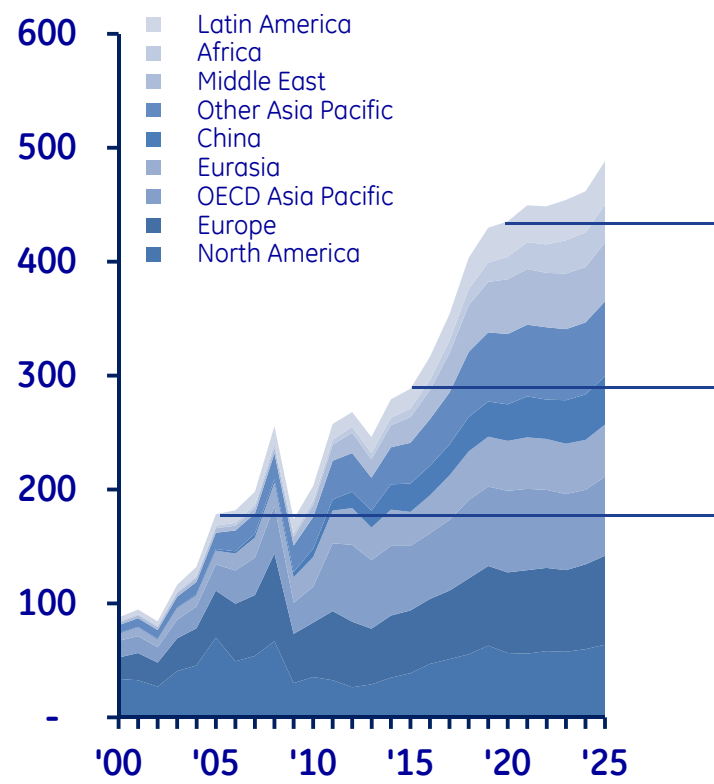
24x7x365 coverage

Energy industry benefits

Potential fuel savings for gas-fired power plants

Global power sector fuel spending on NG

Billions of constant 2010 Dollars –Reference case



Sources: GE Energy calculations based on Fuel COE Aug 2012 country generator gas demand and NG price outlook. Historic data from IEA, BP Stat report, EIA, CERA, BMI.
Notes: Fuel savings estimates assume a 1% improvement in country level system average btu/kwh generation efficiency by 15.

Efficiency gains from software and network optimization driving better dispatch optimization & improved gas/power system harmonization

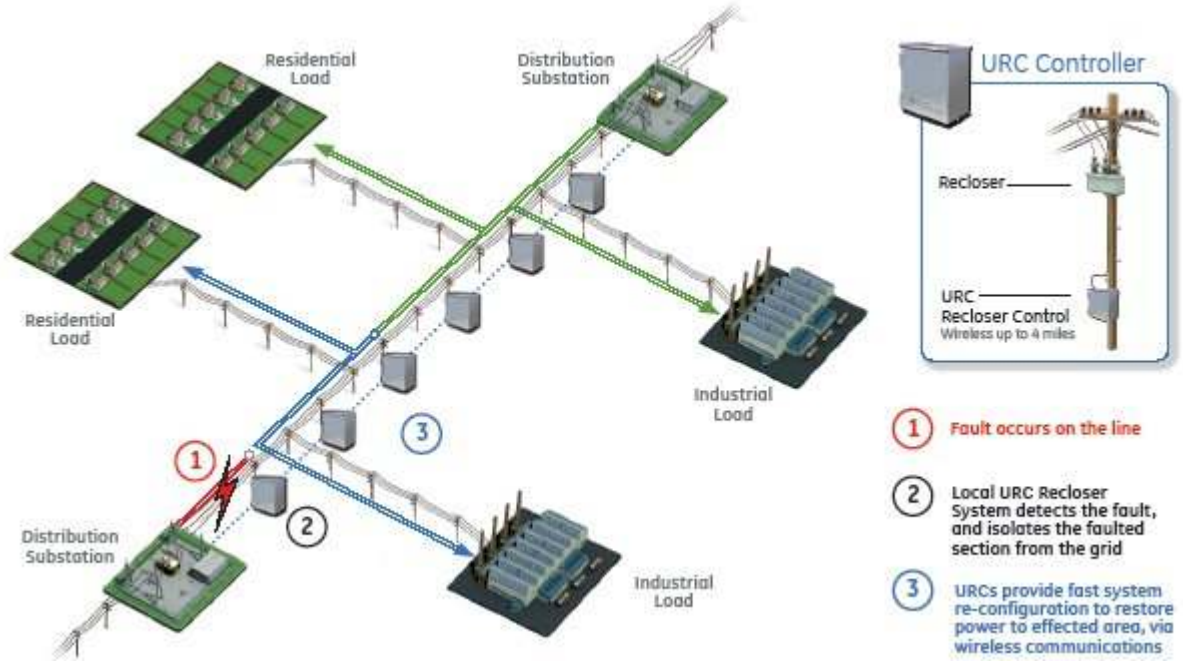
$66 Billion = Cumulative savings over 15 years

imagination at work

Advancing Resilience

Distribution automation… Recloser Control System (URC) enables the efficient recovery of distribution system networks

- Fault isolation, sectionalization and power system restoration schemes
- Intelligent, high speed and reliable DAS solution reduces customer outages
- Secure wireless capability provides peer to peer communications



1. Fault occurs on the line
2. Local URC Recloser System detects the fault, and isolates the faulted section from the grid
3. URCs provide fast system re-configuration to restore power to effected area, via wireless communications

Source: General Electric, 2012

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Disaster recovery:

Rapid deploy and integration technologies add or replace energy assets anywhere

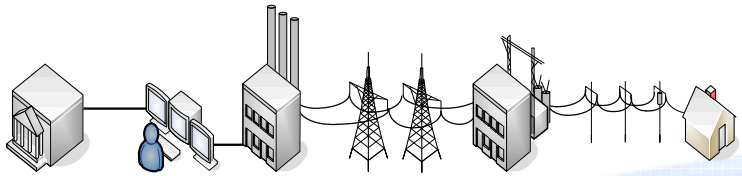
Fast backup power:

GE's FastPower delivers a fully functional, onsite power plant

RSI requires technology integration

Building next generation resilient-sustainable infrastructure

Traditional infrastructure



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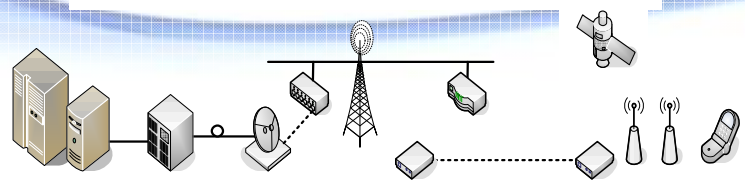
Industrial Internet



Resilient

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Sustainable infrastructure

Joining capabilities through innovation

What's next.. the missing pieces

- **Expand speed and scope of technology deployment**
  Incentivize more rapid deployment of technology and services across the spectrum of resilience: prior to, during and after disruptions.

- **Close governance and policy gaps**
  Enhance coordination across government bodies responsibility for sustainability on the one hand and natural hazards preparedness on the other at the local, state and international levels.

- **Send the right market signals**
  Take measures to encourage innovation around resilience. Devise new policy architecture and incentives to advance resilient-sustainable energy infrastructure in the US and globally.

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