



Passive Wireless Sensing

From Research to Reality

Outline

- GE Global Research
- GE passive sensing needs
- GE current passive sensing efforts
- Passive sensing challenges for industry
- Collaboration opportunities



GE Global Research

1,100 Scientists
and Engineers,
600+ PhDs

United States Niskayuna



~3,000
patents
per year
across GE

India Bangalore



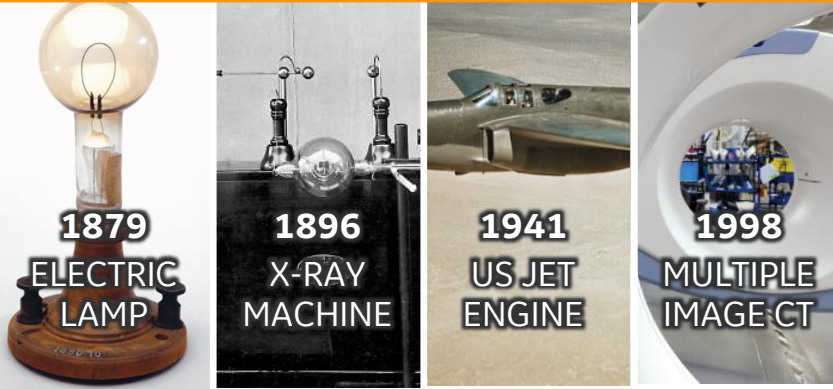
~60,000
visitors
globally/year

11 technical
disciplines

A more focused, competitive R&D organization

GE ... unmatched innovation legacy & scale

Discovery ... world's firsts






Portfolio ... differentiated IP

- ✓ **Top 10 global patents ...**
63,000+
- ✓ **Broad applicability ...**
cross disciplinary
- ✓ **Market tested ...**
product deployed



Prosperity ... ecosystem impact



-  **Generating**
1/3 of world's electricity
-  **Powering**
Takeoff every 2 seconds
-  **Curing**
16,000+ scans every minute

Building on a century of breakthroughs

Focusing portfolio for growth & shareholder value creation

The New GE



AVIATION | **\$27B**



RENEWABLE ENERGY | **\$9B**



POWER | **\$35B**



Healthcare

+

**BAKER
HUGHES**
a GE company

+

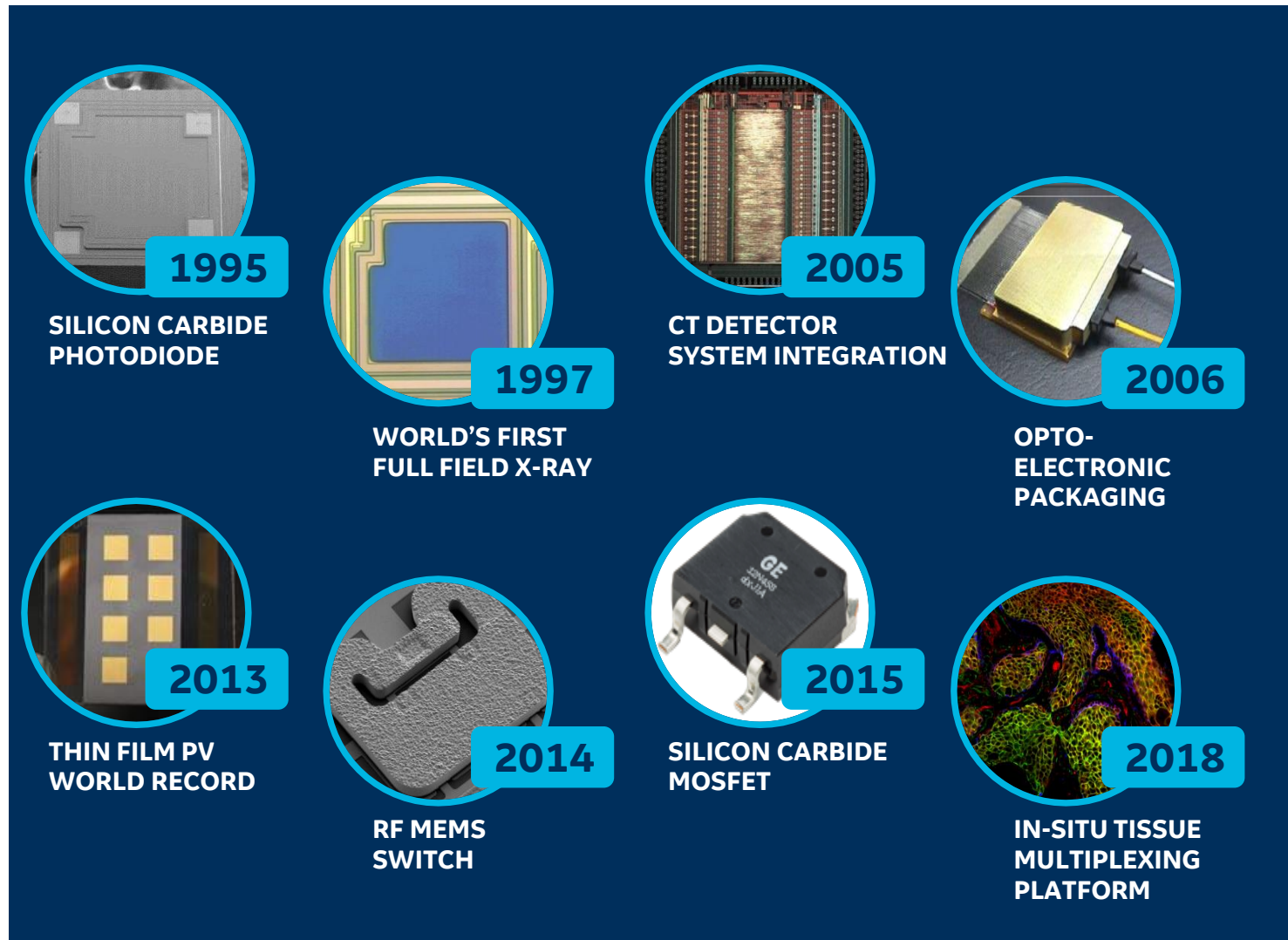
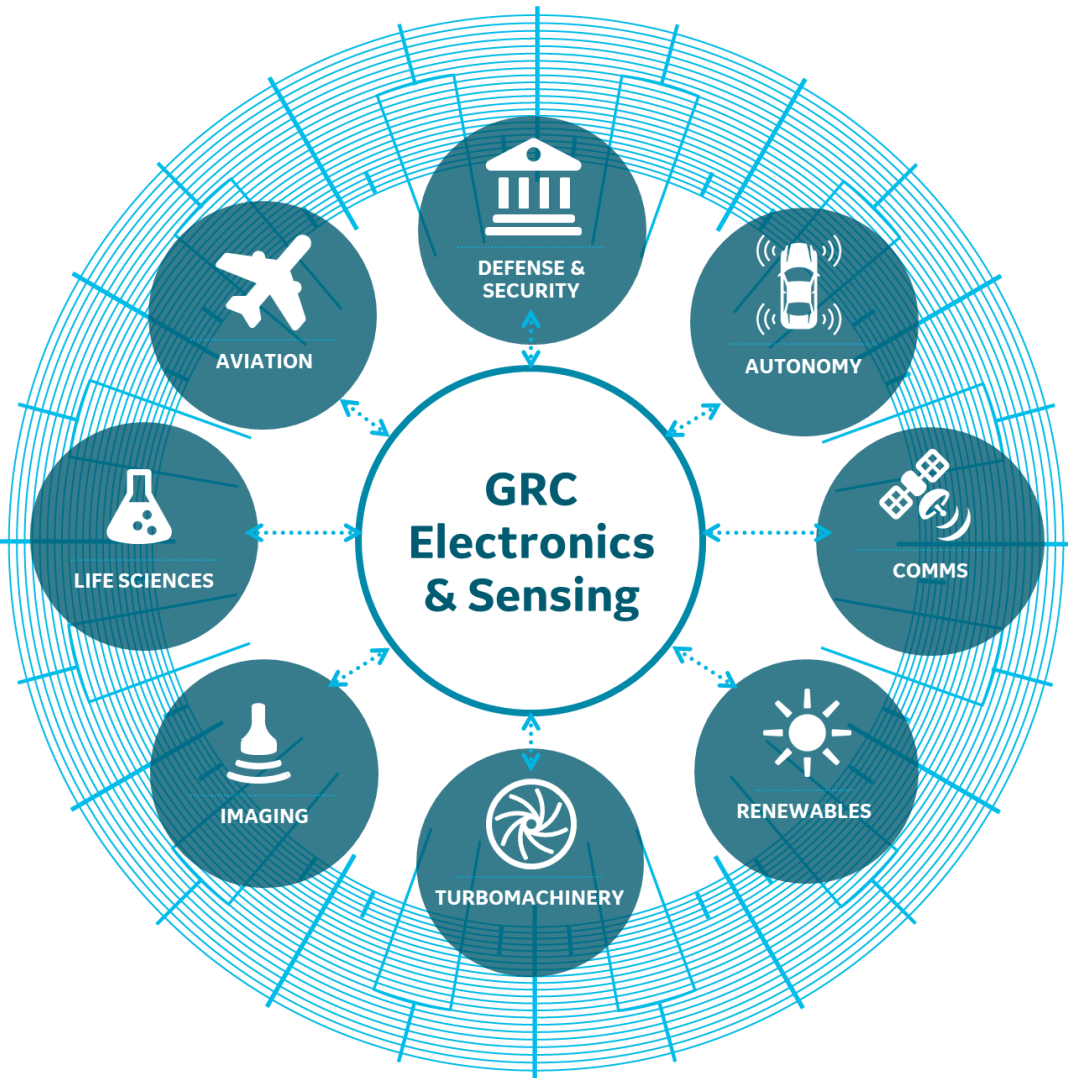


GE Locomotives

*Three valuable stand
alone companies with a
more focused GE,
positioned for growth*

Leading franchises solving tough problems w/ advanced technology

Track record of **innovation to production**



Ideas, Expertise, Speed, Scale ... Our unique competitive advantage

Passive Sensing Needs



Horizontal Tech Multipliers ... differentiation across GE

Industrial Focus

Technology adoption at GE

✓ Innovators & early adopters

✓ Fast follower

							
	Aviation	Healthcare	Power	Renewables	BHGE	Trans.	Current
 SIC Faster	✓	✓	✓	✓	✓	✓	✓
 ADDITIVE Transform	✓	✓	✓	✓	✓	✓	
 DIGITAL TWIN Precognitive	✓	✓	✓	✓	✓	✓	
 EDGE/CONTROLS Smarter	✓	✓	✓	✓	✓	✓	✓
 ROBOTICS Productive	✓	✓	✓	✓	✓	✓	
 AI “No laws”	✓	✓	✓	✓	✓	✓	✓
 CMC Hotter	✓		✓		✓		

Efficiently deploying R&D capital

Uses for Industrial Sensors

Three key GE product uses for Sensors

- 1) Instrumentation- Validation of product models and provide fundamental understanding of generic unit operating conditions (1000's of sensors)
- 2) Condition Based Monitoring- Used on every unit shipped to provide real-time information on stresses and aid in determining useful remaining life (100's of sensors)
- 3) Control of GE Products to maximize efficiency and/or lifetime and/or capability (10's of sensors)

Type	Lifetime	Criticality	Accuracy	Cost	Number Of sensors on Product	Value (Customer Benefit/ Cost)
Ins	Weeks	High	High	1000's	1000's	Low
CBM	Years	Low	Low	10's	100's	Med
Control	Years	High	High	100's	10's	High

Sensors serve different needs that drive different requirements

Key attributes for Industrial Sensors

Location of measurement (Fixed, Rotating?)

Accuracy and Lifetime over Temperature Range

- 30 to 60C for some benign industrial applications

- 40 to 85C for standard industrial

- 55 to 125C for military grade industrial hardware

- Much Higher temperatures for OEM integrated items on assets with combustion (250, 500, ...1500C)

Measurement bandwidth

Data quality indicator (no data is better than wrong data)

Digital Data Output (CAN, Fieldbus, Profinet, etc.....)

Integration method of sensor

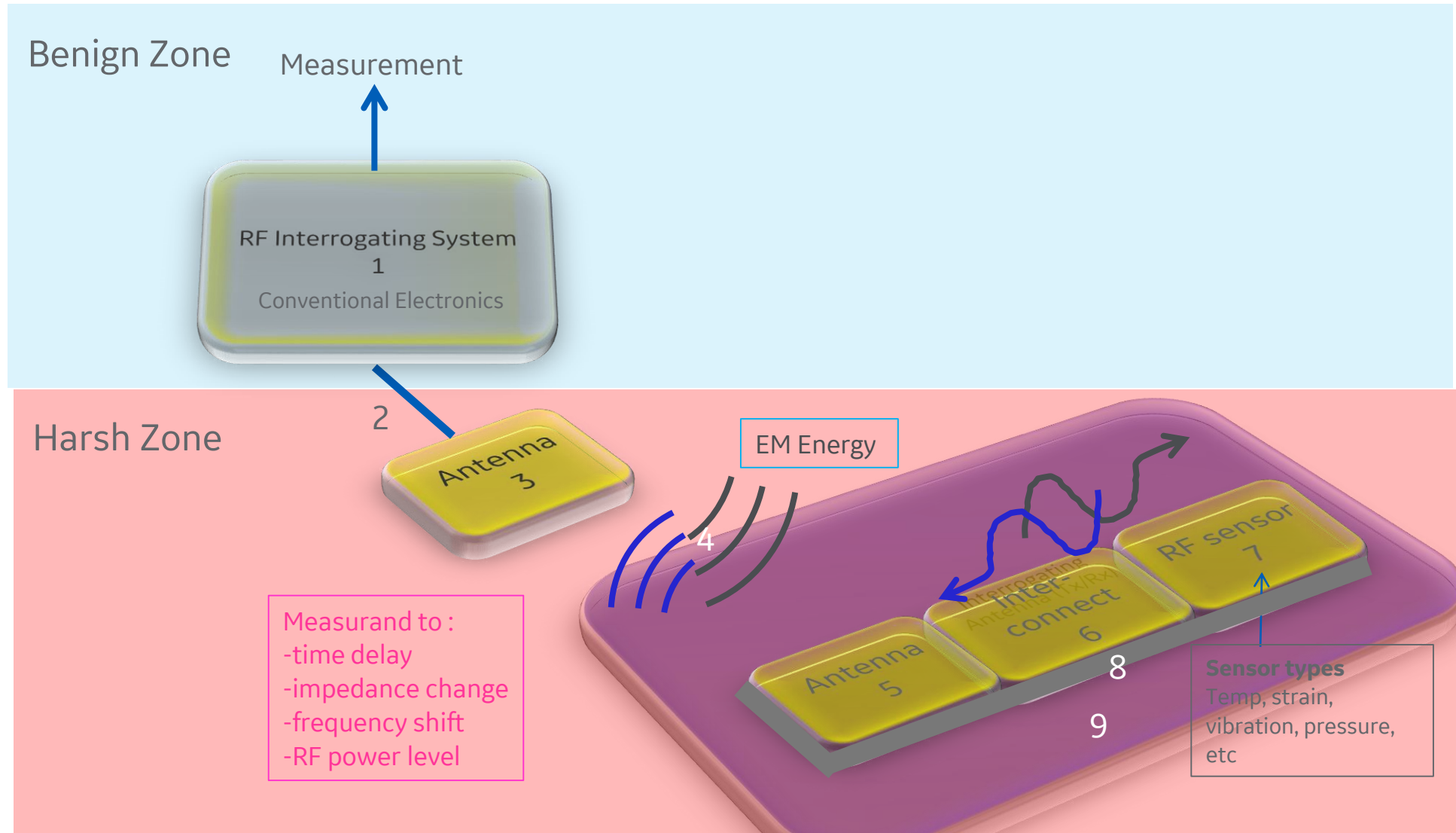
- Bolt On (can be easily add onto and off of an asset)

- OEM Integrated Sensing systems within an asset

- OEM Integrated “Spray-On” (integral on a component of an asset)

Each sensor application will have unique set of requirements!

Simplified RF Sensing Systems (SAW)



Simplistic view of passive sensing system

Passive Sensing Attributes

Key Measurands

Temperature

Strain/Vibration

Distance/Gap

Key Attributes

Powerless: No batteries, electronics or P-N junctions

Able to function in hot environments ($>125^{\circ}\text{C}$)

Contactless interrogation for Rotating (& Stationary) applications

Multiple Sensor Locations (for redundancy as well as multipoint sensing)

Vibration/Strain up to 5KHz Measurement Bandwidth

Short (<3 Meter) Interrogation Range

Passive sensing enables direct measurement of currently inferred measurands

Passive Sensing Systems at GE Global Research



General Challenges for Passive Sensing for Industry

1. Need to identify key high value sensing needs (Controls has been GE's focus to date)
2. Need holistic system level solution, a transducer (i.e. strain to frequency shift) is not enough
3. Need to critique sensing solution to needs (Is the solution the best choice and why)
4. Need assessment of TRL/MRL to sensing need (what is cost/risk exists for New Product Introduction (NPI) Team)
5. What data already exists wrt TRL/MRL (The more that is available the more likely the effort will get funded)
6. A realistic supply chain needs to be defined, GE Global Research has experience in doing this and getting agreements in place with multiple parties.
7. The overall solution needs to be a Win/Win for both the Sensor System user and Sensor System provider (They may not be the same entity, sometime GE spins off a company, sometime it creates a strategic relationship with a commercial entity)

The more performance and endurance data that exists the better!

Technical Challenges for Passive Sensing for Industry

1. Demonstrated reliability in pertinent environment
 2. Demonstrated performance in pertinent environment
 3. EMI/EMC
 4. Security
- Fundamental models and subsystem testing and analysis is acceptable
 - Need to define and follow a methodical development approach
 - All this requires a goods amount of investment, the value story must be clear and strong.

We need science not just a “cool demo” to go from Research to Reality

GE Success Story: Surface Acoustic Wave Torque measurement solutions



Die



Shaft Assembly



System

Wireless direct torque measurement for superior control

Surface Acoustic Wave technology provides excellent direct strain measurements without creep impacts over time for torque and linear applications. Passive measurement, non P-N junction technique with simultaneous temperature readings provide higher reliability and accuracy than typical torque measurement systems.

GE Global Research works with our Commercial Partners from the device fabrication through the system integration to differentiate the application solutions.

SAW TECHNOLOGY

- ✓ Increased controllability provided by direct torque output monitoring
- ✓ **±2% accuracy** for improved output capacity and operational efficiency
- ✓ Reliability testing at 150C for 20,000 hours
- ✓ Shaft assembly testing up to 40,000g's
- ✓ 1k to 100k Ft-Lbs
- ✓ OEM Integrated Scalable Solutions for <200C



Collaboration with GE Global Research



GE Global Research ... innovation DNA

Capabilities



600+ PhDs

*Unmatched
interdisciplinary
expertise*

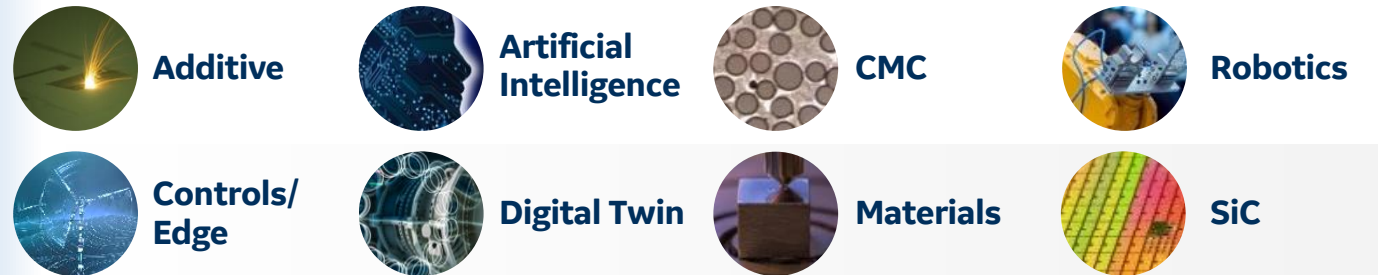
Research to Reality

Breakouts

SHAPE BUSINESSES



SPAN INDUSTRIES



CREATE THE FUTURE



How can passive sensing impact the future of GE products?

Exponential Ideas ... platforms for future GE businesses

Imaging & Therapy Platforms



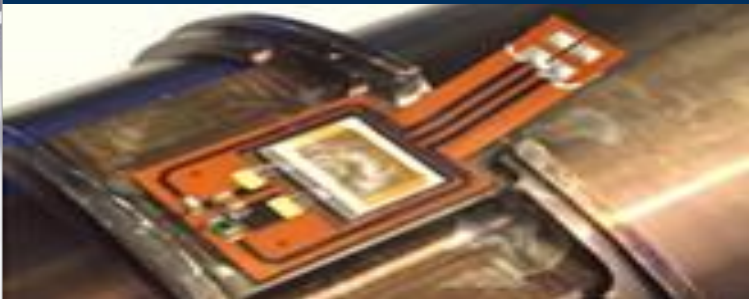
Disrupting \$B markets

Digitally Transformed Services



Leveraging network effect multipliers

Microsystems



Enabling 10X differentiated products

Secure Forever



100X more secure at 1/10th the cost

FORGE

Show What's Possible



Connect and Partner



How can we work together to provide something valuable?

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Look forward to hearing from you!

Questions?



