



Passive Wireless SAW Sensors, Microsystems & Applications

October 9, 2019

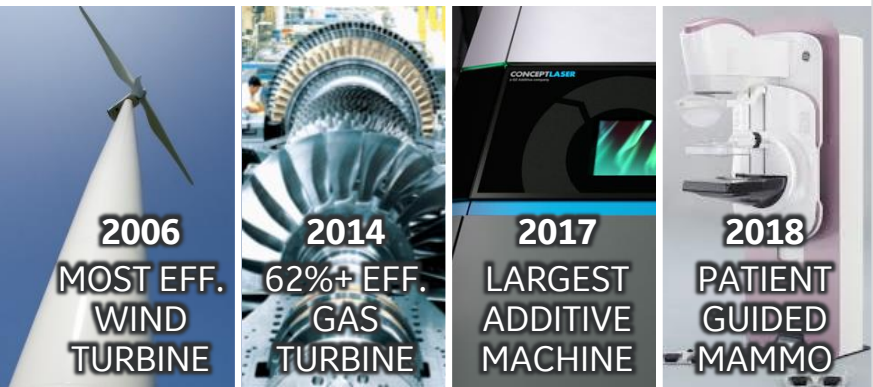
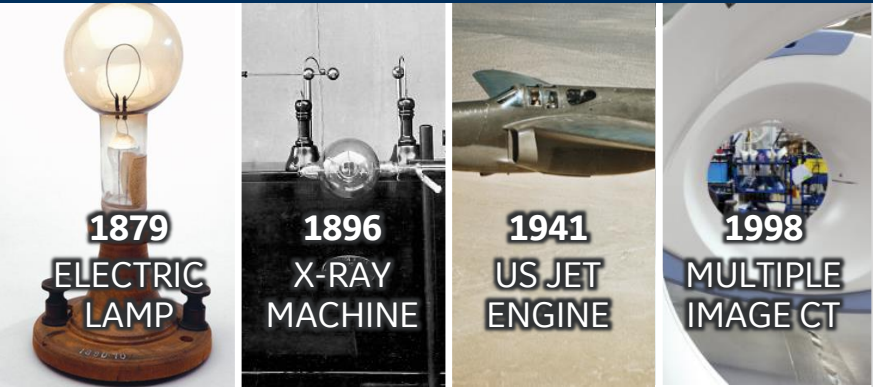
Outline

- Industrial needs for Sensing Solutions
- Strain and Torque Sensing requirements
- First SAW Torque Implementation
- Expansion into new spaces
- Developments for larger systems and lower costs
- Future needs



Contemporary research ... GE's innovation legacy & scale

Discovery ... world's firsts



Foreground IP

Portfolio ... differentiated tech

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

Building background IP

Prosperity ... ecosystem impact



 **Generating**
1/3 of world's electricity

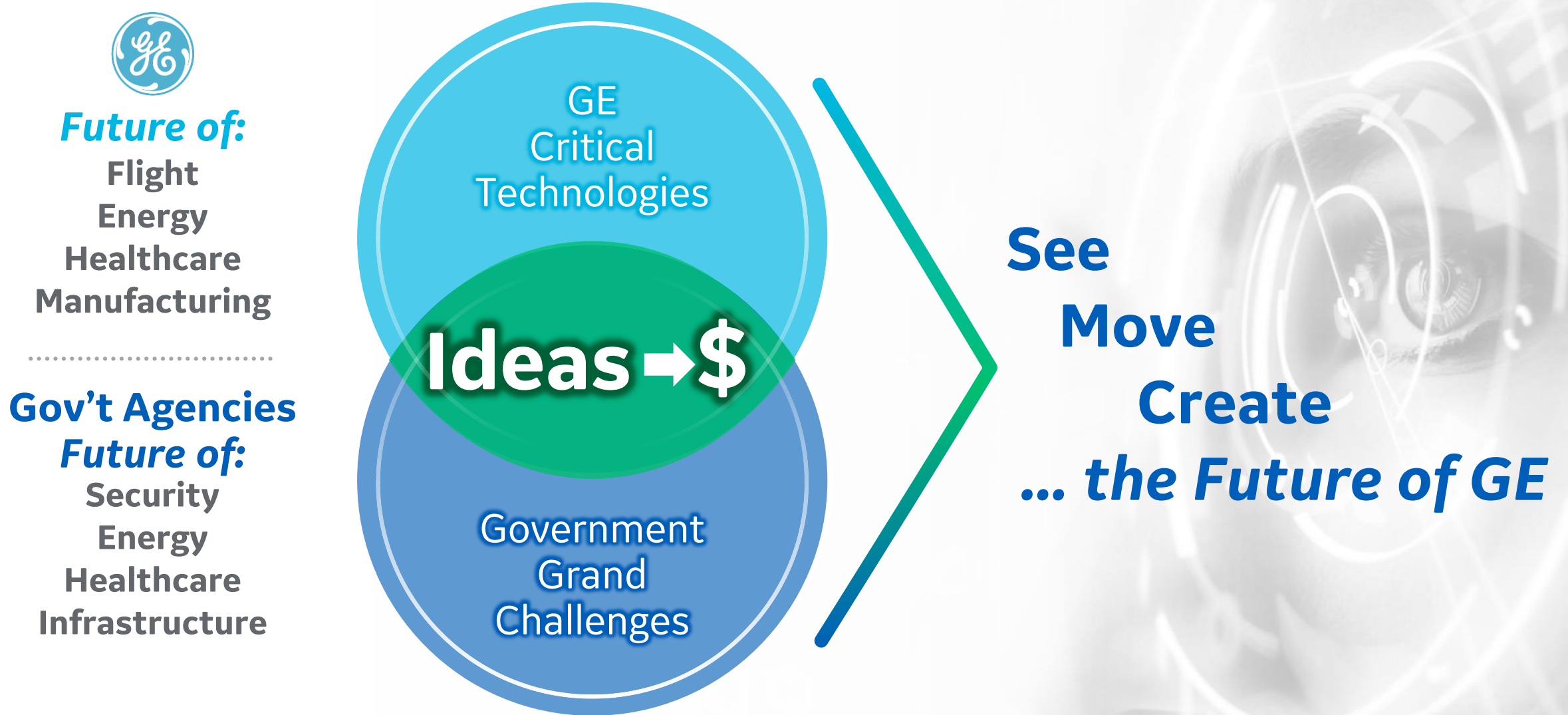
 **Powering**
Takeoff every 2 seconds

 **Curing**
16,000+ scans every minute

GE Businesses “+”

IP+IQ is the key to unlock the world's most valuable problems

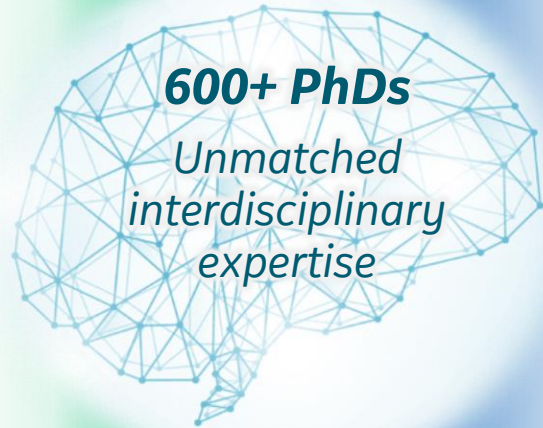
Contemporizing our Innovation Engine



Accelerating GE innovation through Government Partnerships

GE Research ... unique value proposition

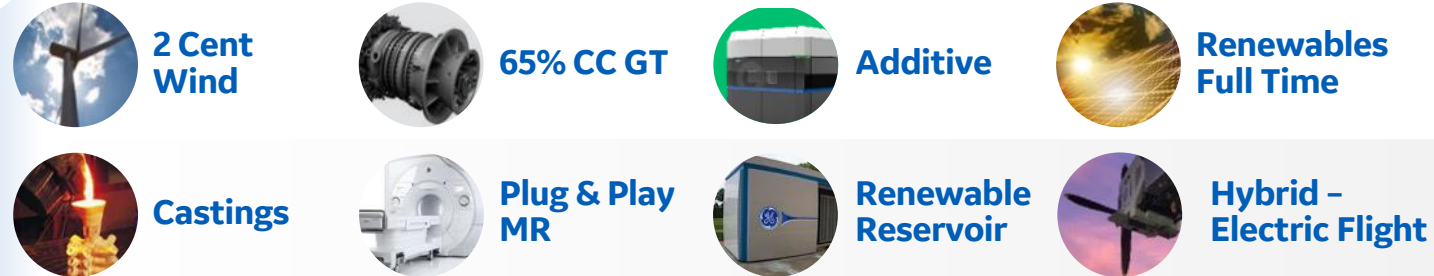
Capabilities



Research to Reality

Breakouts

VERTICAL



HORIZONTAL



EXPONENTIAL



Scientific depth & breadth ... delivering real economics

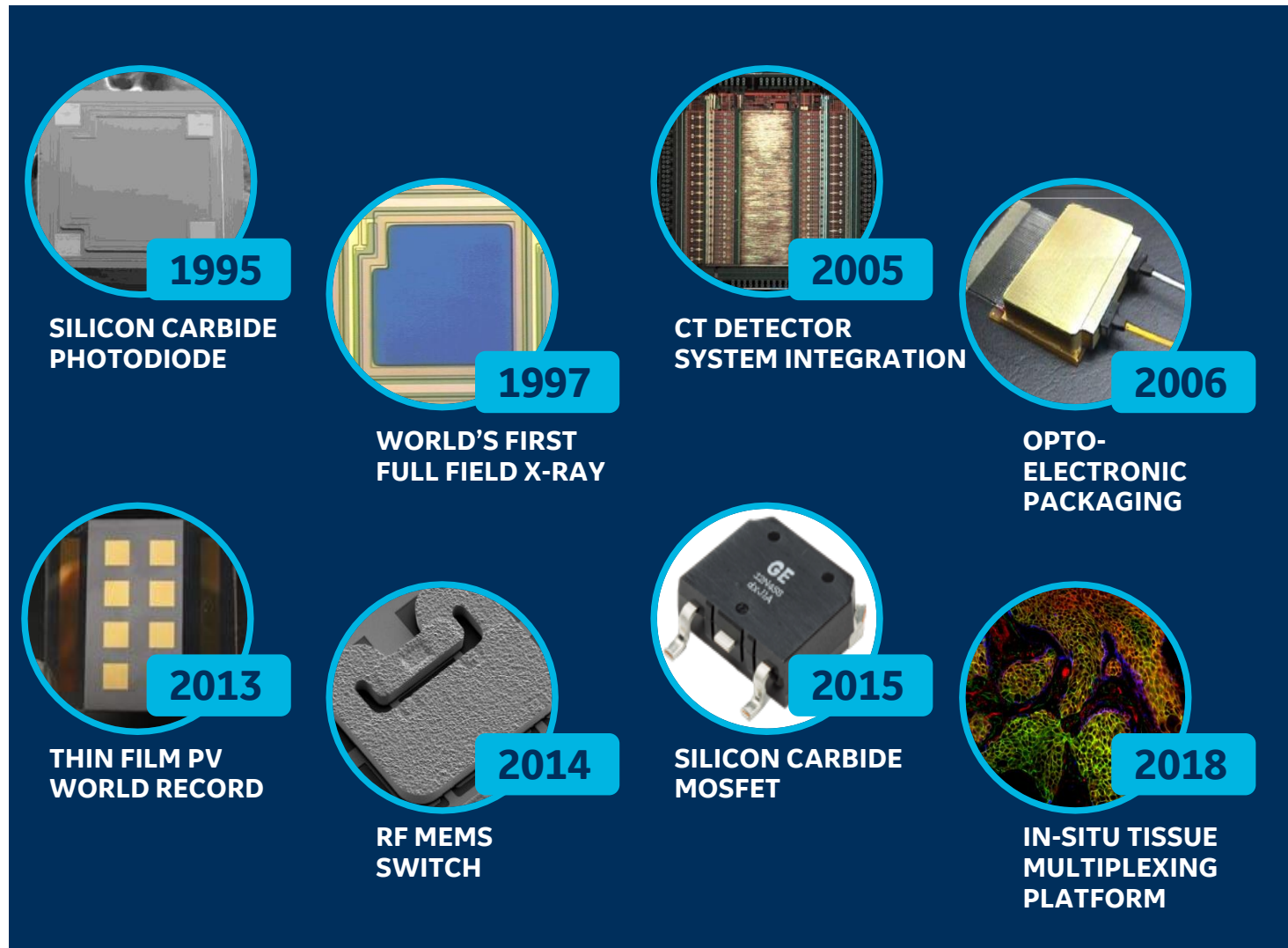
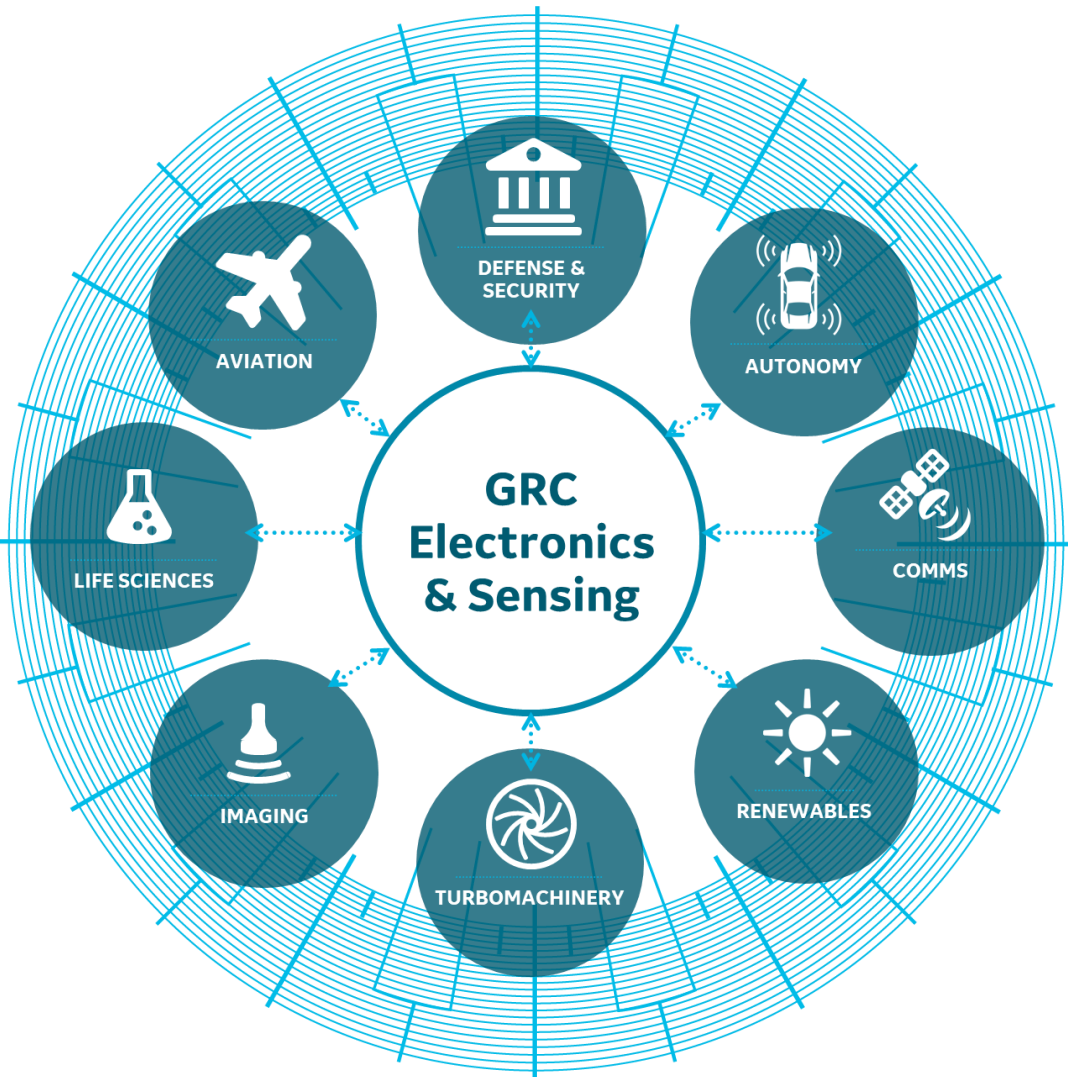
GRC inside ... an innovation engine for today's GE

- **Larger innovation network**
- **Knowledge sharing**
- **Technical depth & breadth**



Connecting to GE businesses, government agencies & strategic partners

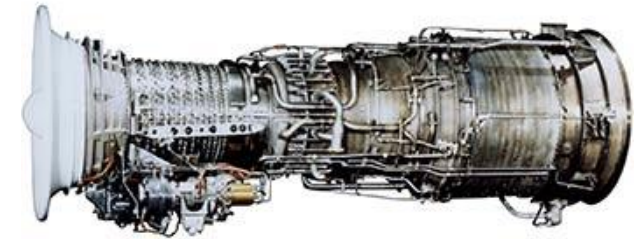
Track record of innovation to production



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

Torque Sensing Needs

- Engine torque measurement
 - Increased controllability provided by direct torque output monitoring
 - $\pm 2\%$ accuracy for improved output capacity and operation efficiency
 - Reliability testing at 150C for 20,000 hours
 - Shaft assembly testing up to 40,000g's
 - Axial length of $< 1"$ for dual redundant system

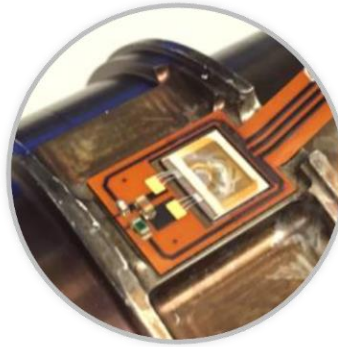


First GE Implementation (SAW)

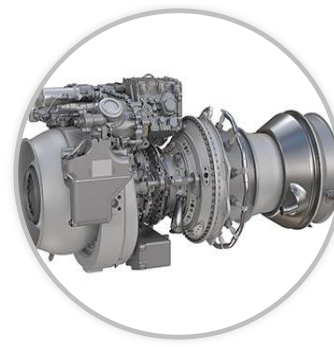
Integrated Surface Acoustic Wave (SAW) torque measurements



Die



Shaft Assembly



System

SAW technology provides

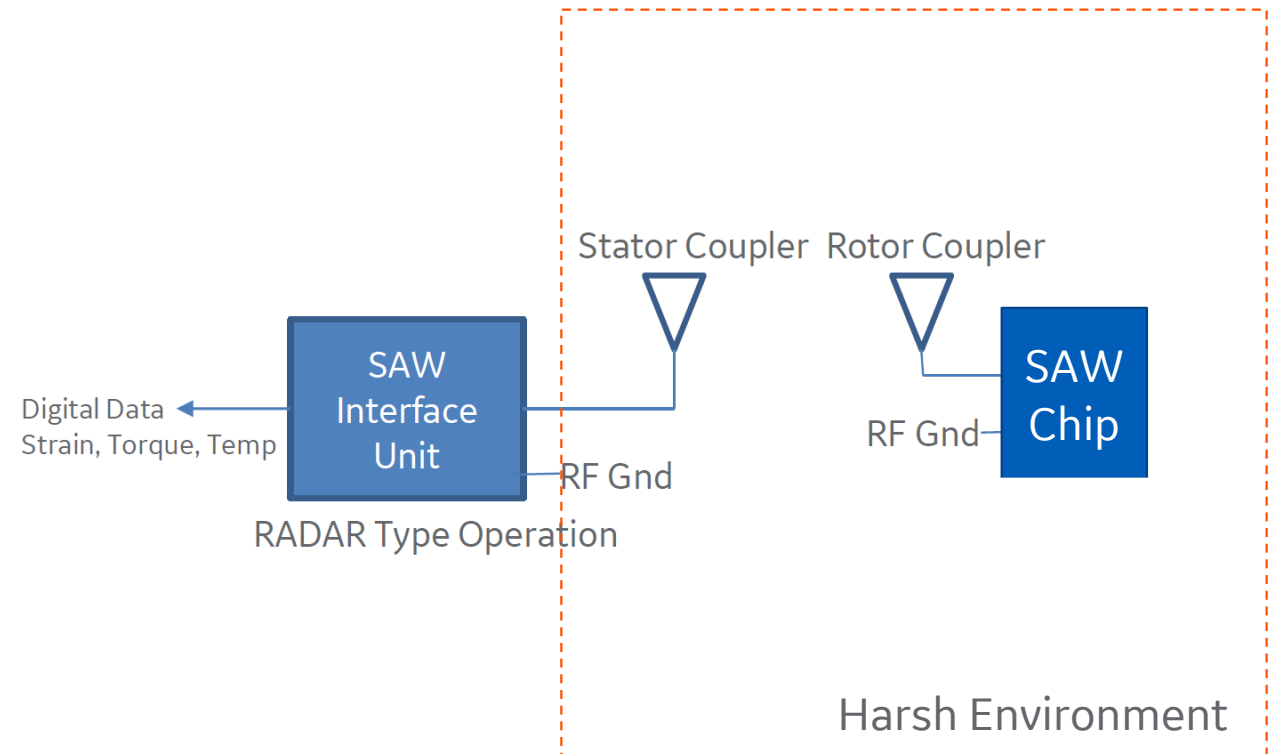
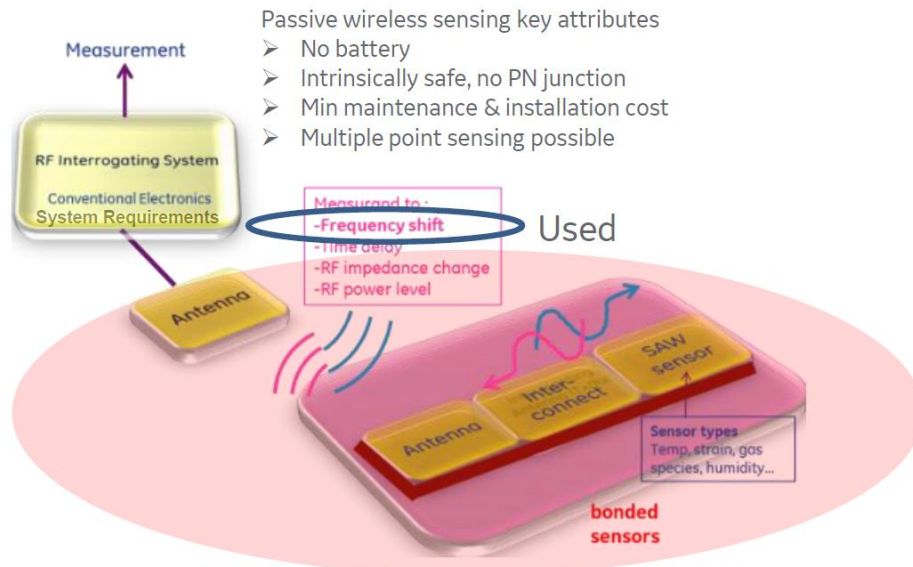
- Excellent direct strain measurements without creep impacts over time for torque and linear applications
- Passive measurement, non P-N junction technique with simultaneous temperature readings (higher reliability and accuracy)

GE Research works with the GE Businesses and Transense Technologies Plc to develop SAW solutions for GE systems and applications.

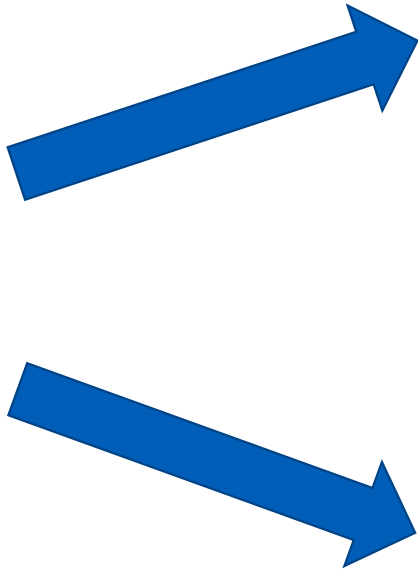


SAW Operation

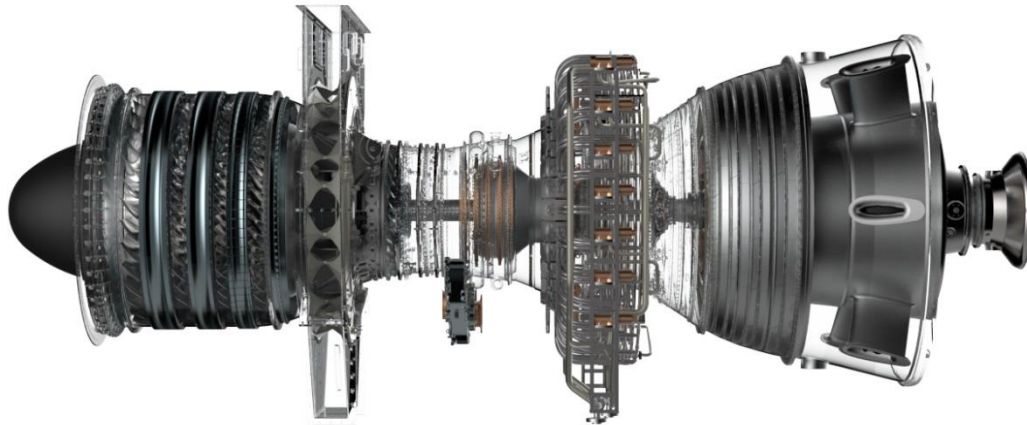
All Passive components in Harsh Zone



Continued Evaluations in new spaces



Strain: Wired

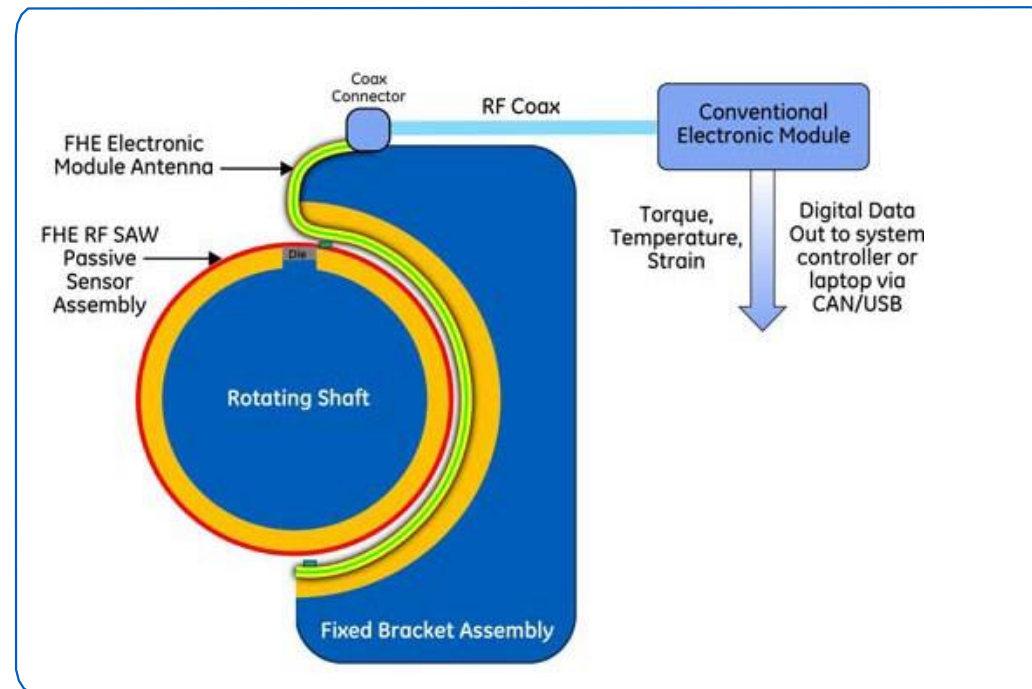


Large diameter: Wireless



Need for scalable solutions with low complexity

Need solution from 3 inch to 3 foot diameter shaft



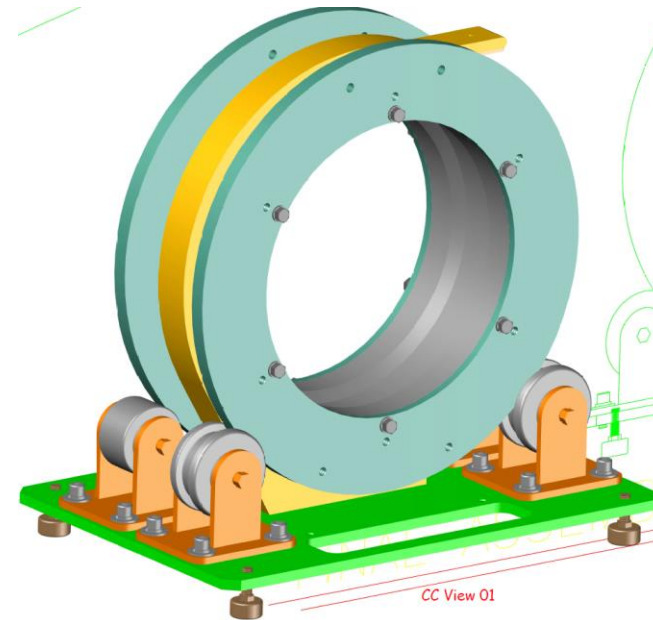
Generalized problem

- Large format Flexible Electronics with high reliability and low cost with pre-assembly capability



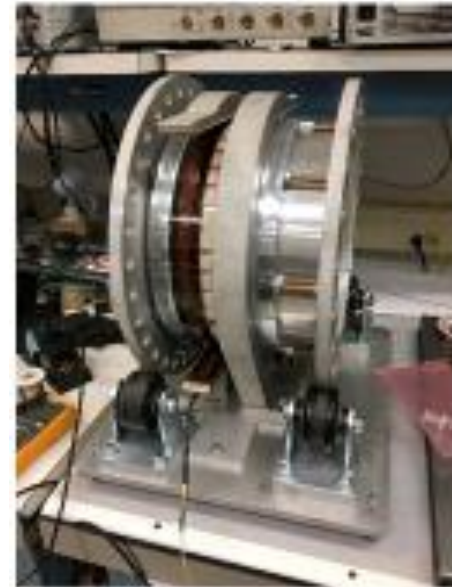
Developments

- ✓ Printed Conductors
- ✓ Wirebond free attachment
- Reliability testing
 - ✓ Adhesion
 - ✓ High G
 - ✓ Bend testing
 - ✓ Tensile testing
 - ✓ Humidity
 - ✓ Thermal Stability
 - ✓ RF and breakdown



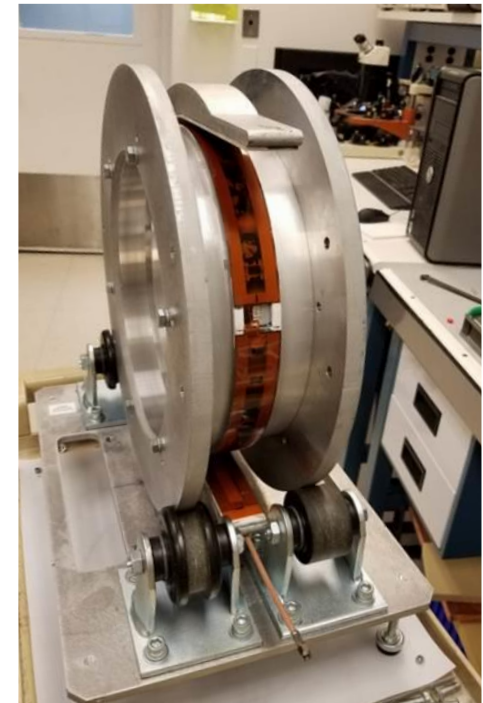
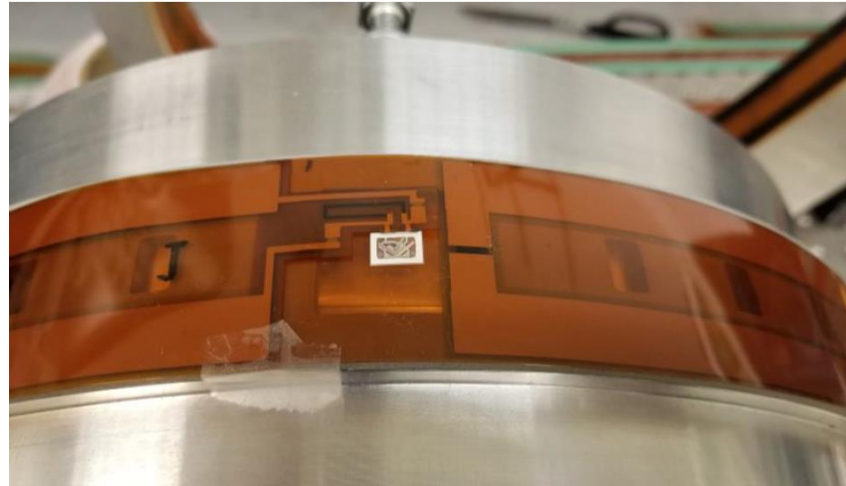
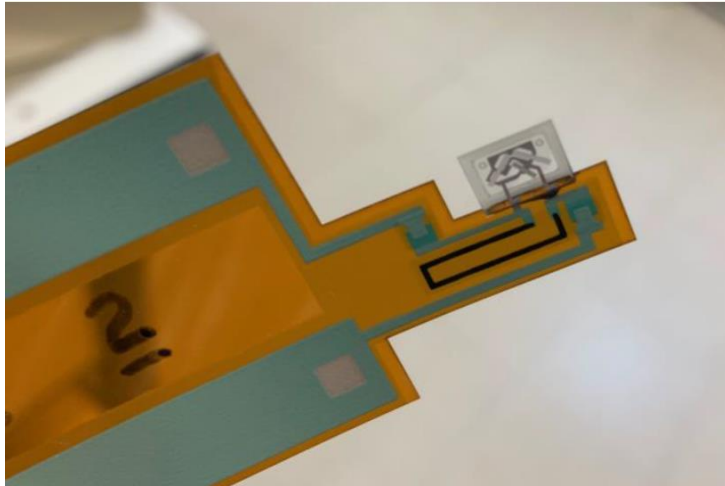
TMS Platform

Printed Conductors & Integral passives



Fully Integrated solution

- Sub-Assemblies
- Low temp die attach



Future needs

- Higher Temperature capability (Sensor, Package & System)
- Identify further high value applications
- EMI/EMC
- Security



- **Acknowledgement:**

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