

Wireless Sensor Networks for Aerospace Applications

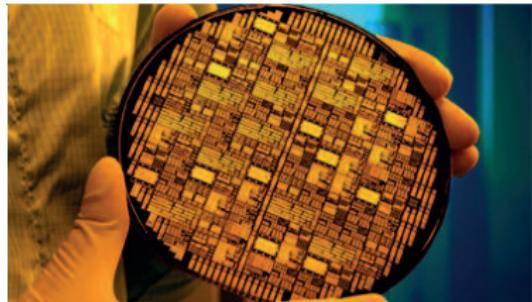
Dr. Bahareh Zaghari

University of Southampton, UK

June 9, 2017



In 1961, the University of Southampton made aviation history with the first human-powered flight.



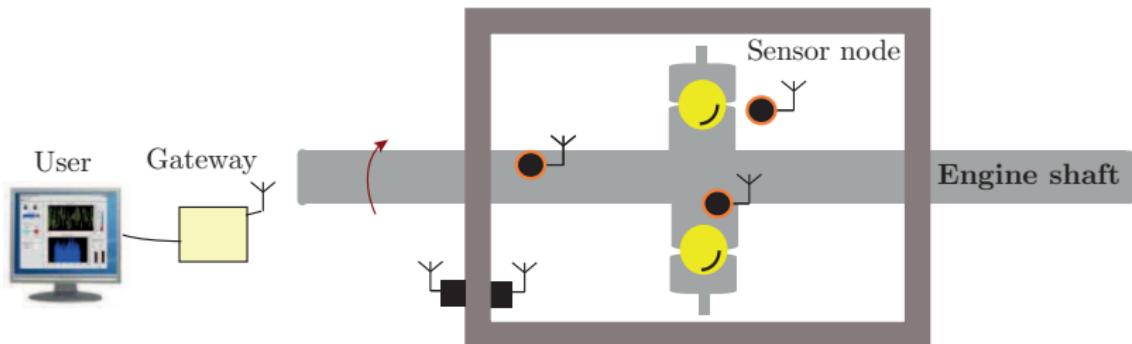
Introduction

- ▶ General challenges for wireless communication in aero-engines
- ▶ Motivation
- ▶ Solution overview
- ▶ Addressing the challenges (with practical examples)

Challenges

- ▶ **Regulations and standards for radio transmission**
- ▶ **Energy consumption of a sensor node**
 - ▶ Supplying power
 - ▶ Manage power requirements
 - ▶ Scheduling of sleep-wake up patterns for sensors
- ▶ **Security, reliability, and robustness of the wireless sensor network**
 - ▶ Metal blocks RF signals
 - ▶ Harsh environment (high temperature, pressure, and vibration)
 - ▶ Interference with other systems

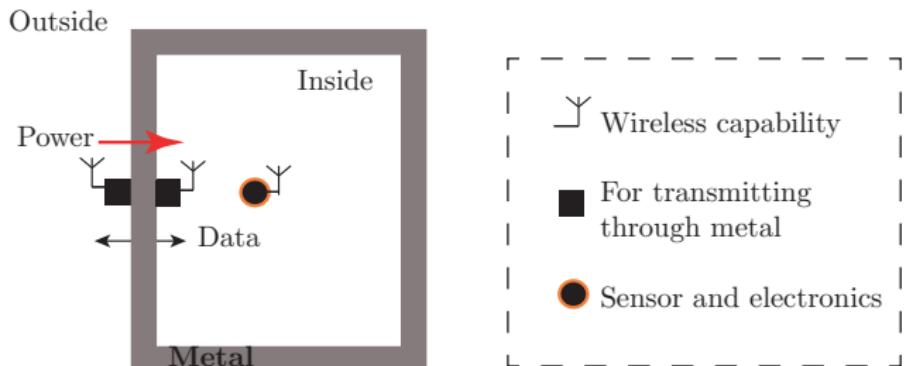
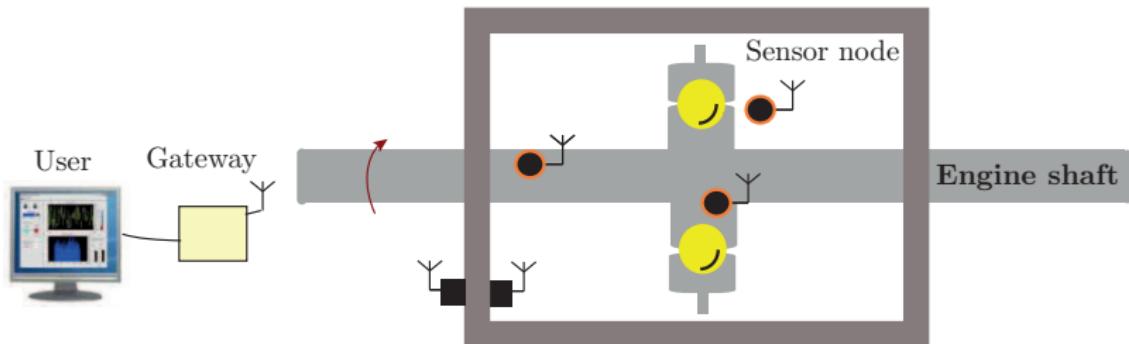
Future of Aerospace Wireless Sensor Network (AWSN)



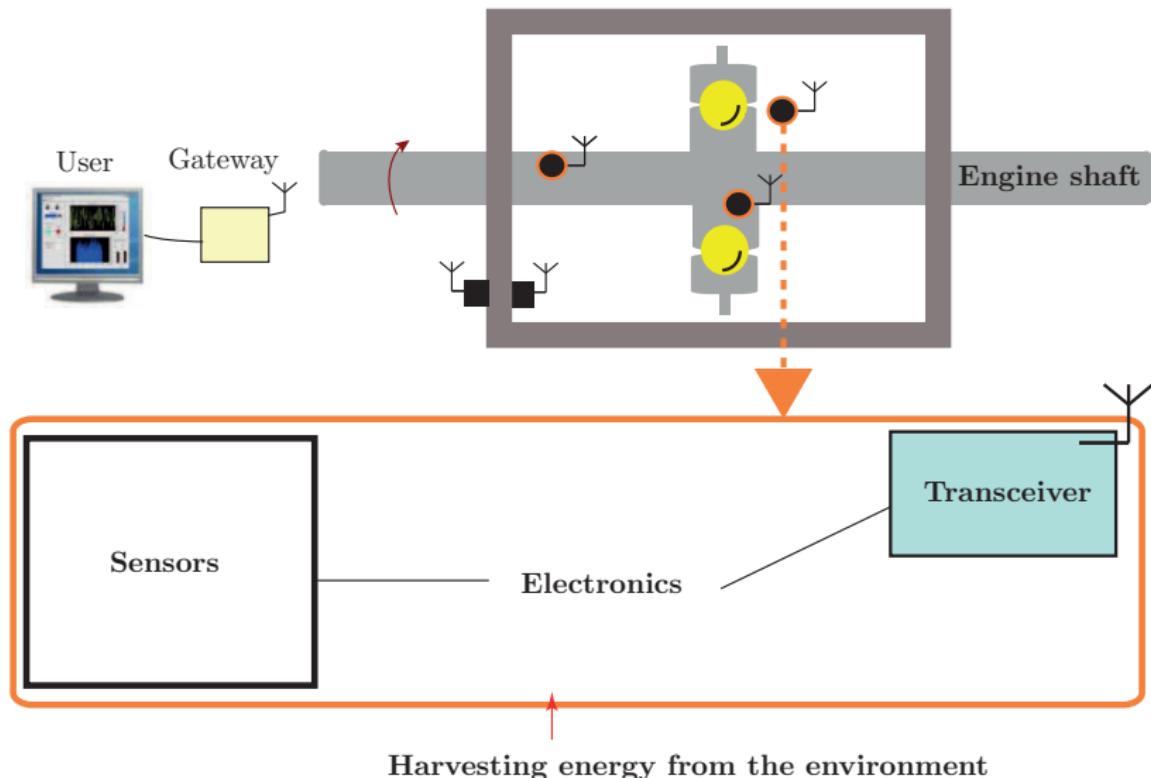
Ball bearing schematic as
part of the jet engine

Objective: To develop a **smart system** incorporating
multiple sensors, energy harvesting, wireless communications, and data analytics
for **intelligent monitoring** of aero-engines.

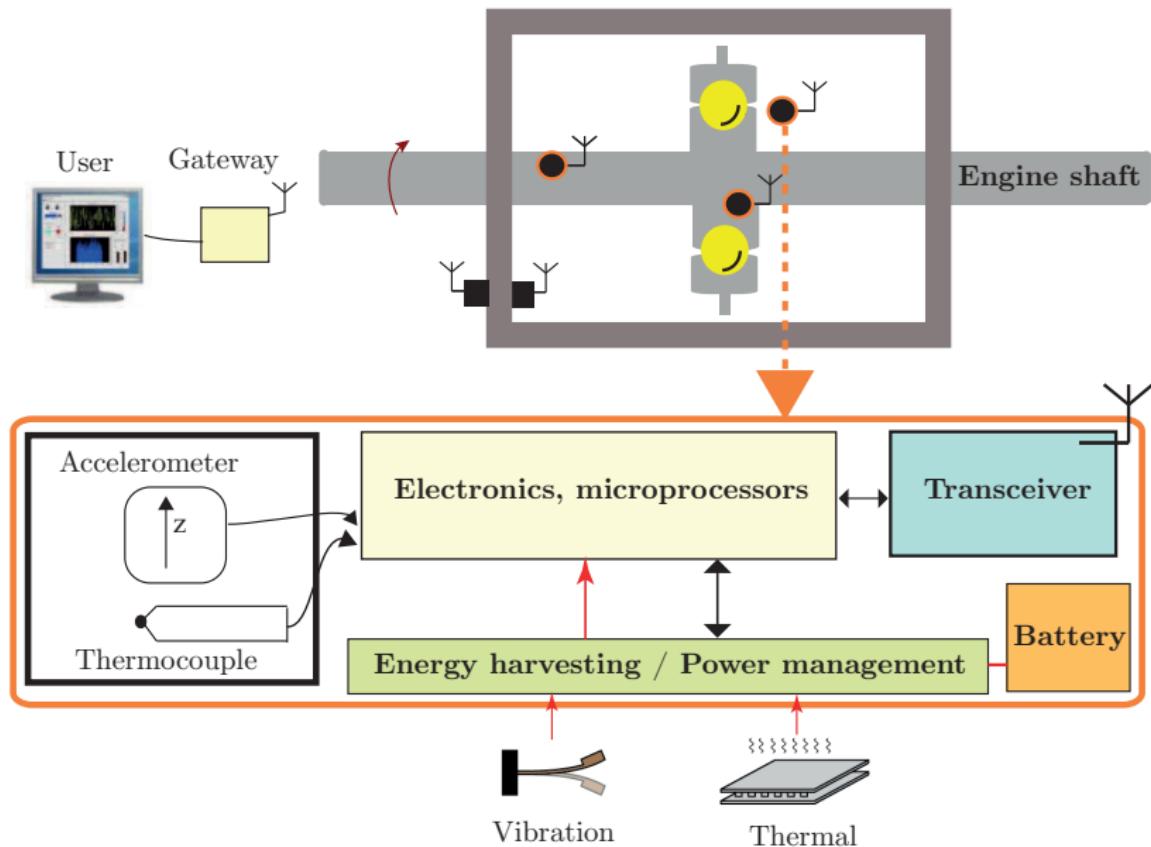
Future of Aerospace Wireless Sensor Network (AWSN)



Future of Aerospace Wireless Sensor Network (AWSN)



Future of Aerospace Wireless Sensor Network (AWSN)



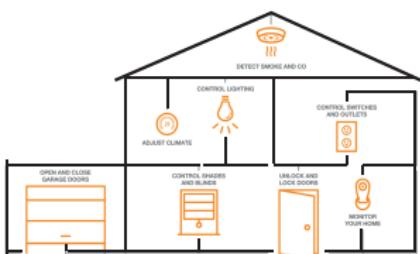
2000s

- Wireless internet widespread
- ISM band comms commonplace, wireless sensor deployed, Bluetooth widely used for simple tasks
- ZigBee alliance announced availability of specifications



1980s

- ISM band regulation free for use without license.
- Cellular radio
- GPS navigation, early wireless internet



1970s

- Almost everything wired
- Radio was used by military, space,...
- Low power, short range wireless

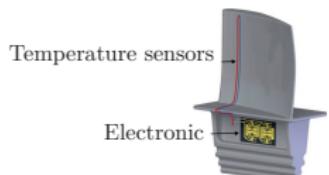


1990s

- Wireless internet starts to be deployed, mobile phone
- ZigBee was conceived
- Bluetooth standards begins drafting

Future

- Opportunity for energy harvesting
- Smaller device size
- Higher bit rate available
- Lower costs of system-on-a-chip
- Electronics for harsh environments



2010s

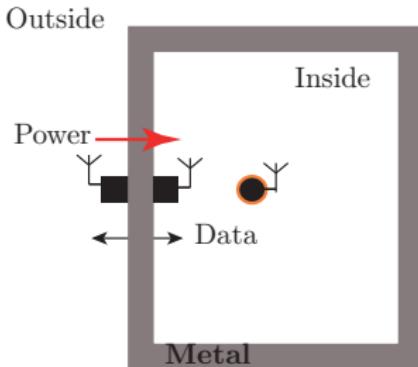
- DSSS modems cost reduction
- Semiconductor's size and cost reduction (microelectronics)
- The Internet of things (IoT)

Existing Technologies

Wireless transmissions for AWSN:

- ▶ **IEEE 802.15.4 standard** - Frequency 2394-2507 MHz - For short range communications (<100 m)
 - ▶ Low power - average power consumption is 100 mW in the 2.4 GHz ISM band.
 - ▶ IEEE 802.15.4 has 16 channels in the 2.4 GHz ISM band.
- ▶ **Standards based on IEEE 802.15.4, such as ZigBee, WirelessHART, and 6loWPAN.**
- ▶ **Ultra Wide Band (UWB) radio systems** - Frequency 3100-10600 MHz - For short range communications (<10 m)
 - ▶ Low power - average power consumption is 30 mW.
 - ▶ Thousands of channels can be used.
 - ▶ Smaller size antenna can be designed for higher frequency transmission.
 - ▶ Interferences can be reduced.

Data Communication Through Metals



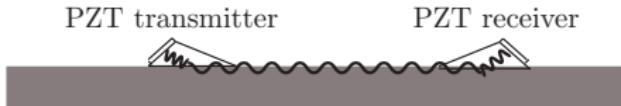
Generating shear or longitudinal wave



Generating shear wave



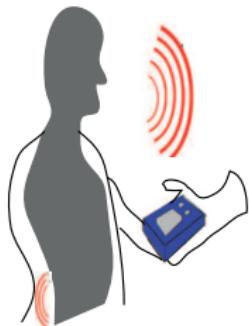
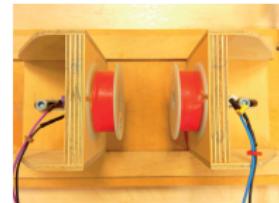
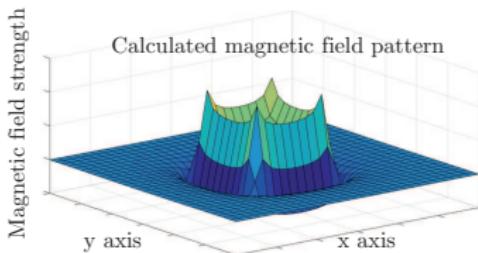
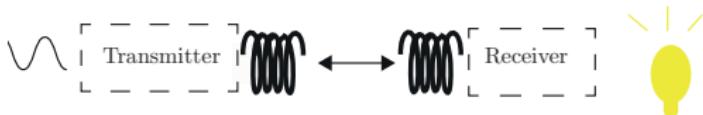
Generating surface acoustic wave



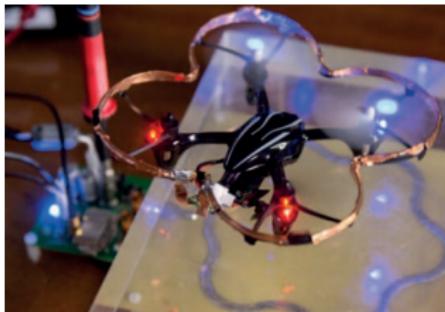
- Wireless capability
- For transmitting through metal
- Sensor and electronics

Power Delivery

Inductive coupling



Wireless sensing and monitoring
of biomedical applications
(NASA Technology Transfer Program)



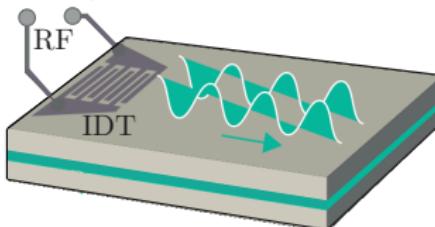
In-flight wireless power transfer for drones
(Imperial College London)



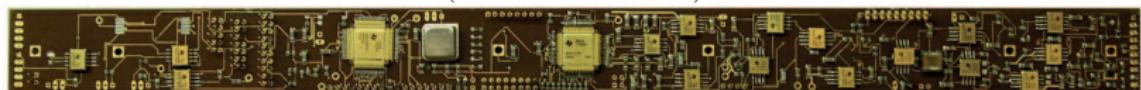
Wireless charging module
(from Cobalt aerospace)

Electronics for Harsh Environment

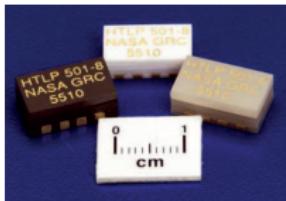
High Temperature (800°C) Interdigital transducer (IDT) devices
(University of Southampton)



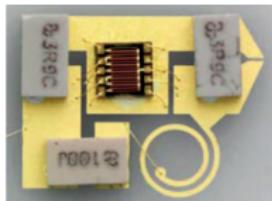
Harsh Environment Acquisition Terminal (H.E.A.T) up to 210°C with RS485 transceiver
(Texas Instruments)



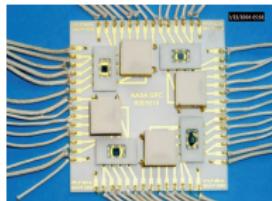
Wireless sensor operating at high temperature (500°C) (NASA Glenn Research Center)



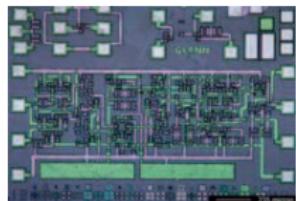
Harsh environment
packaging



High temperature RF
components



AC amplifier based on
SiC MESFET and
ceramic packaging



High temperature
signal processing and
wireless
(2.4 GHz Rectenna)

Summary

- ▶ **Wireless communication solves many problems for aero-engines.**
 - ▶ Cabling
 - ▶ Maintenance
 - ▶ Health monitoring and problem diagnosis
- ▶ **But it comes with other challenges.**
 - ▶ Wireless communication through metals
 - ▶ Powering remote sensors, and managing power
 - ▶ Electronics in a harsh environment
- ▶ **These other challenges can be solved.**
 - ▶ Communication: Wave propagations
 - ▶ Power: Inductive coupling method, solution architecture
 - ▶ Environment: Electronics for harsh environment

Thank you