



**Extreme (-302F to 3732F) Passive Wireless Resonant Sensors:
Ground Test to Commercial Flight Instrumentation**

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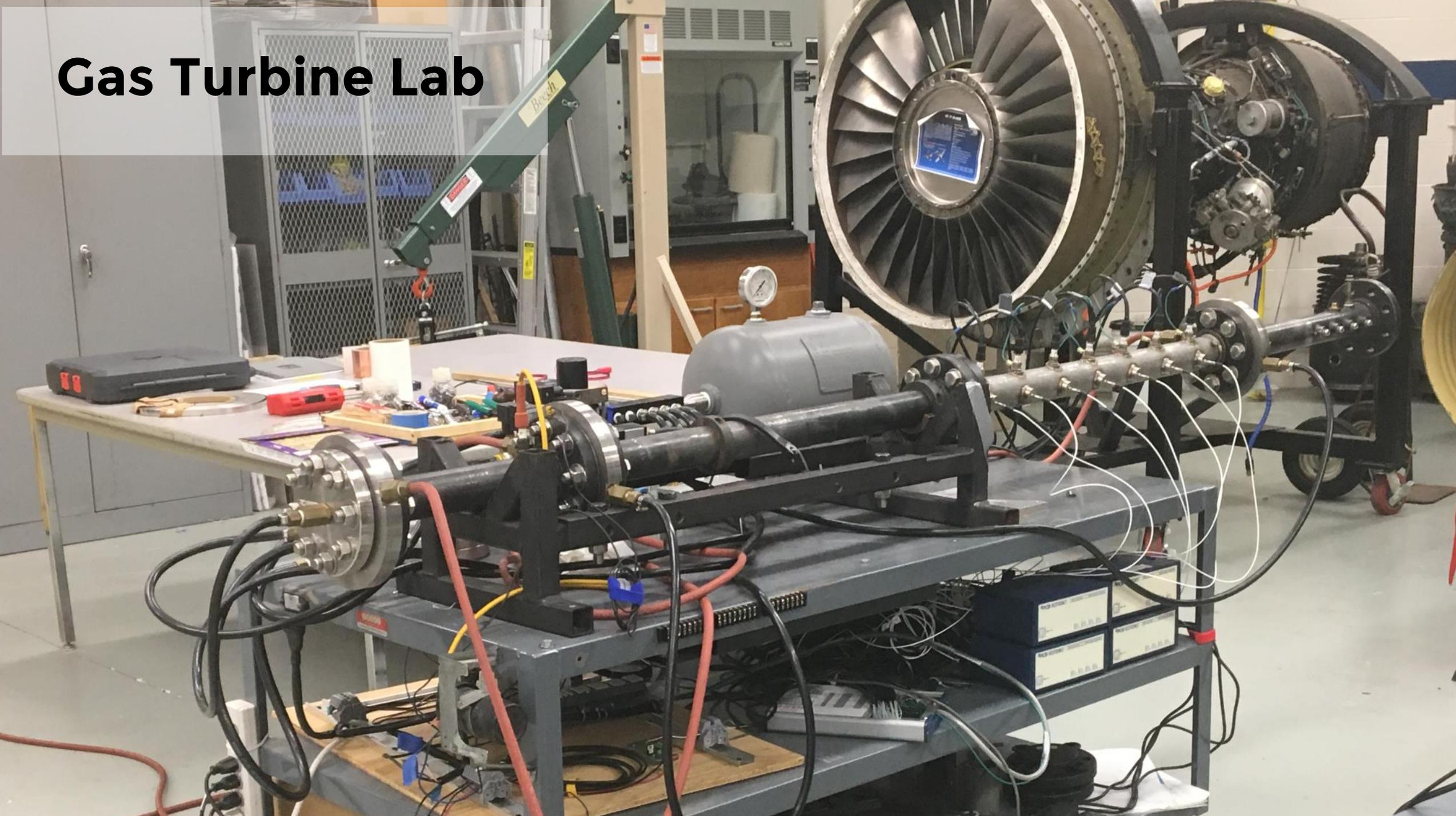
Who I am?





EMBRY-RIDDLE
Aeronautical University

Gas Turbine Lab



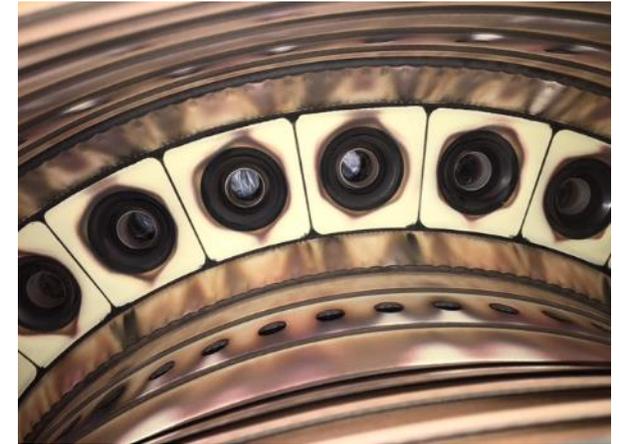
Overheated Components



PDE Rings



Blades



Combustion Chamber





I WANT YOU

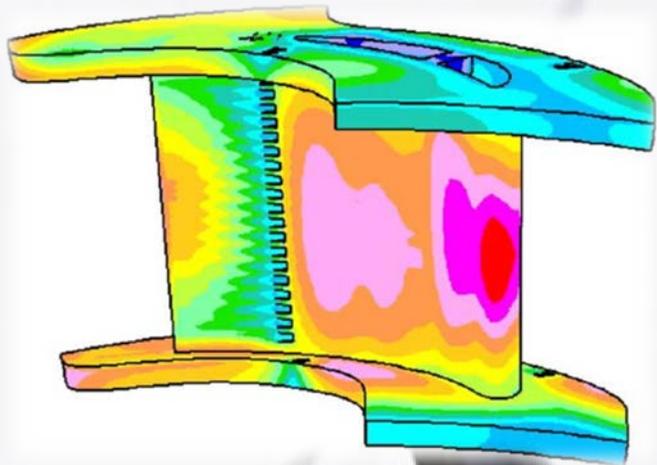
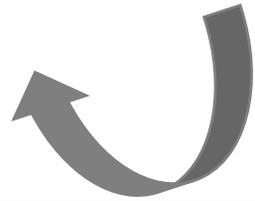
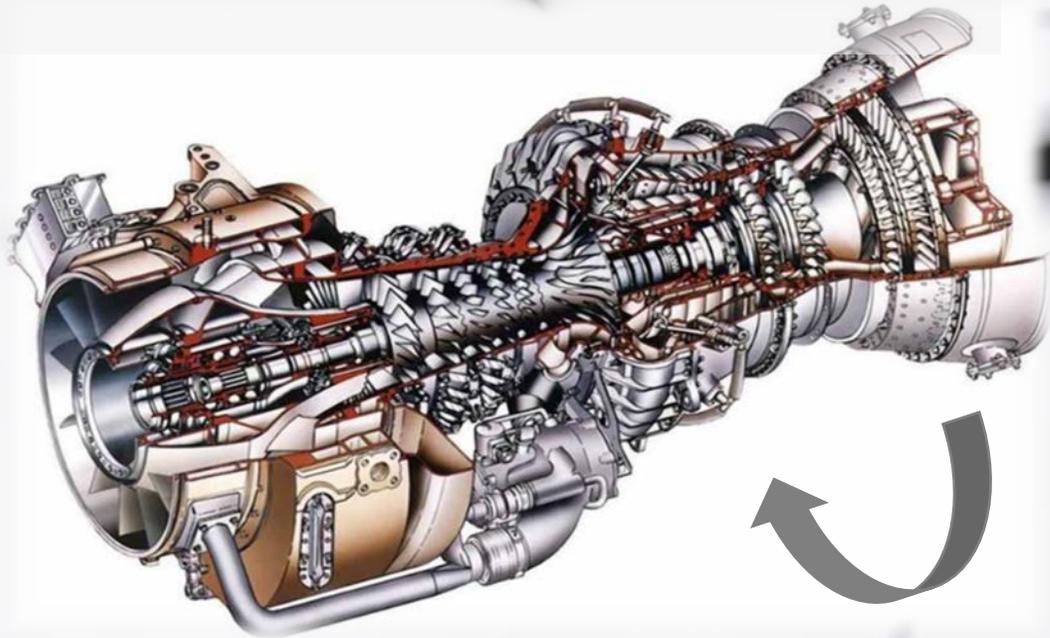
FOR  **CORPS**
NSF Innovation Corps

NEAREST RECRUITING STATION

Get out of the building!



Life Cycle Costs



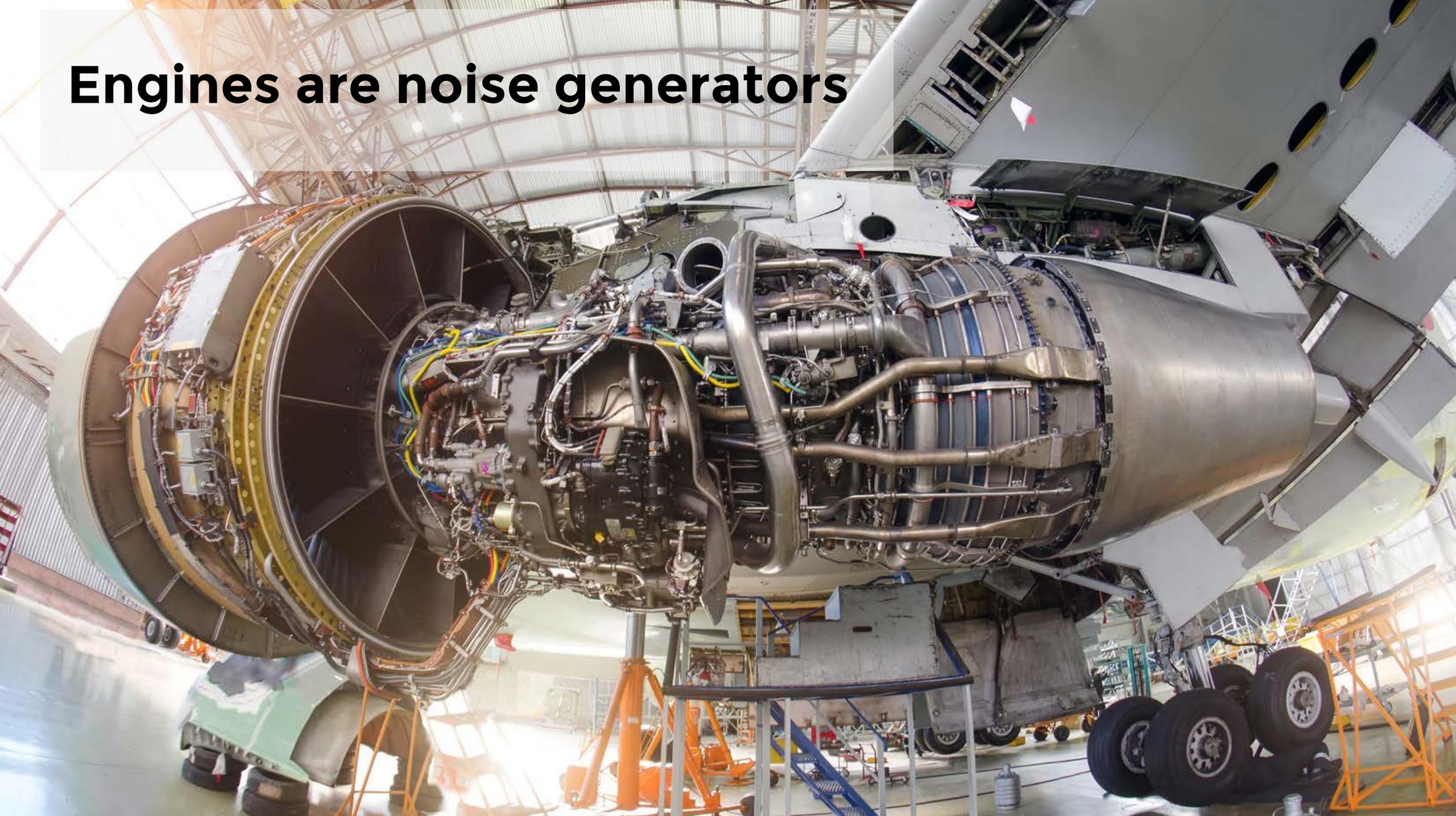
Lengthy Lead Times



Airline Performance



Engines are noise generators



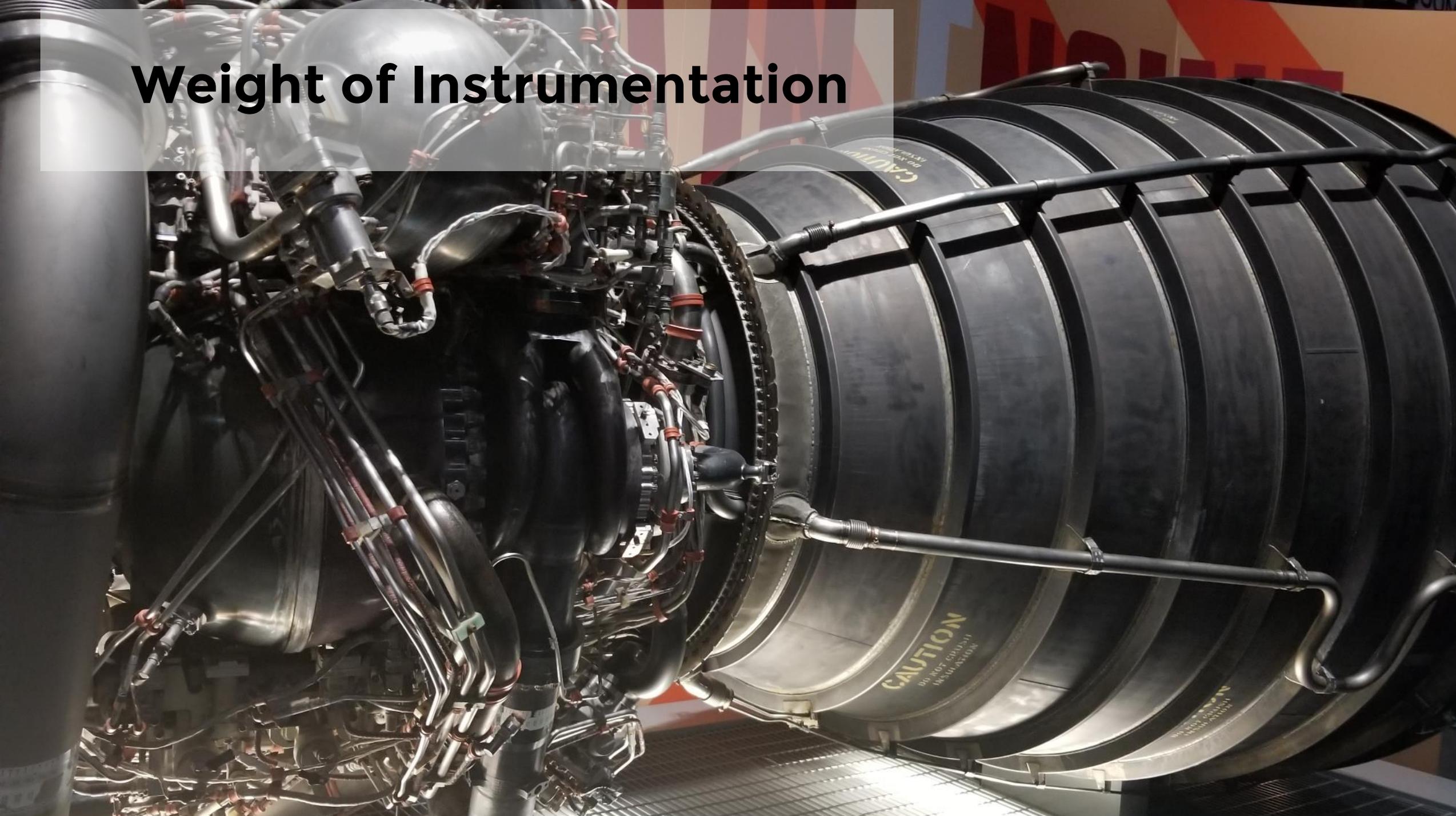
Engines are shrinking



Rocket Test Stand



Weight of Instrumentation



PATENTS AND PUBLICATIONS

(11) **United States Patent**
Gong et al.



US8558705B2

(10) Patent No.: **US 8,558,705 B2**
(45) Date of Patent: **Oct. 15, 2013**

(54) **CERAMIC SENSORS FOR WIRELESS SENSING**

(75) Inventor: Xun Gong, Orlando, FL (US); Lian An, Orlando, FL (US)
(73) Assignor: University of Central Florida Research Foundation, Inc., Orlando, FL (US)
(*) Notice: Subject to any disclaimer, the terms of this patent are extended or adjusted under 35 U.S.C. 154(b) by 557 days.
(21) Appl. No.: 12821309
(22) Filed: Jun. 23, 2010
(45) Pub. Publication: US 2010/021181 A1 Dec. 23, 2010
Related U.S. Application: Provisional application No. 61/217,731, 2009
(54) **INTEGRATED CAVITY FILTER/ANTENNA SYSTEM**
(75) Inventor: Xun Gong, Orlando, FL (US); Yuhai Yan, Orlando, FL (US)
(73) Assignor: University of Central Florida Research Foundation, Inc., Orlando, FL (US)
(21) Appl. No.: 13/012309
(22) Filed: May 28, 2011
Publication Classification:
(51) Int. Cl. H01P 1/20 (2006.01)

(56) **References Cited**
U.S. PATENT DOCUMENTS
2,338,202 A1 * 2/2006 Kane et al. 276
2007/0075319 A1 * 4/2007 Cook et al. 375
2008/0102111 A1 * 4/2008 Morgan et al. 374
* cited by examiner
Primary Examiner—Therese Malkin
(74) Attorney, Agent, or Firm—Jensen & Associates, P.A.

(11) **United States Patent Application Publication**
Gong et al.

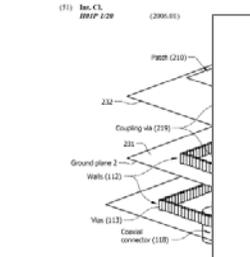
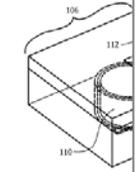


US 2012/0203279 A1

(10) Pub. No.: **US 2012/0203279 A1**
(45) Pub. Date: **Nov. 22, 2012**

(54) **INTEGRATED CAVITY FILTER/ANTENNA SYSTEM**
(75) Inventor: Xun Gong, Orlando, FL (US); Yuhai Yan, Orlando, FL (US)
(73) Assignor: University of Central Florida Research Foundation, Inc., Orlando, FL (US)
(21) Appl. No.: 13/012309
(22) Filed: May 28, 2011
Publication Classification:
(51) Int. Cl. H01P 1/20 (2006.01)

(52) U.S. CL. 333/202; 343/00 MS
(57) **ABSTRACT**
An integrated cavity filter/antenna system includes a substrate, a cavity filter formed in or on the substrate, a first cavity resonator in or on the substrate that is coupled by metal walls, at least a second cavity resonator is formed in or on the substrate that is enclosed by metal walls. An inter-resonator coupling resonator is coupled between the first cavity resonator and the second cavity resonator. An antenna is integrated with one of the cavity resonators on the substrate and is used as a part of the cavity filter and as a radiating element for the filter/antenna system. A connector is coupled to one of the cavity resonators for coupling energy into the

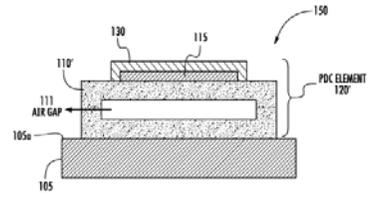


US 2015/002889 A1

(11) **United States Patent Application Publication**
GONG et al.

(10) Pub. No.: **US 2015/002889 A1**
(45) Pub. Date: **Jan. 29, 2015**

(54) **LOW-PROFILE WIRELESS PASSIVE RESONATORS FOR SENSING**
(75) Applicant: University of Central Florida Research Foundation, Inc., Orlando, FL (US)
(72) Inventor: XUN GONG, ORLANDO, FL (US); LIAN AN, ORLANDO, FL (US)
(21) Appl. No.: 14/539,489
(22) Filed: Jul. 24, 2014
Related U.S. Application Data:
(96) Provisional application No. 61/875,384, filed on Jul. 24, 2013.
Publication Classification:
(51) Int. Cl. G01N 27/04 (2006.01); G01N 27/02 (2006.01)



Wireless Passive Temperature Sensors Using Integrated Cylindrical Resonator/Antenna for Harsh-Environment Applications

Haitao Cheng, Student Member, IEEE, Xinhua Ren, Member, IEEE, Siamak Ebadi, Member, IEEE, Yuhai Chen, Lian An, and Xun Gong, Senior Member, IEEE

Abstract—Wireless passive temperature sensors for harsh-environment applications based on cylindrical microwave cavity resonators are presented herein. Such antennas are in sensors with zero additional volume. The resonant frequency of the sensors are determined by the dielectric ceramic materials, which monotonically increase per se. Silicon nitride (SiN) ceramic, which is very robust inside harsh environment high temperatures and corrosive gases, are split paper to reduce dielectric losses and increase accuracy. A robust interrogation antenna is widely used to measure the sensors up to 1300 °C. Tests on SiN and SiN₂ ceramics are measured up to 1300 °C, respectively, with a sensitivity of ~ 0.75 1000 °C. This type of wireless, passive, and robust is used for many harsh-environment applications, including:

Index Terms—Cavity resonators, high-temperature microwave sensors, and antennas, temperature wire



Evanescent-mode-resonator-based and antenna-integrated wireless passive pressure sensors for harsh-environment applications

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Abstract—A novel wireless passive temperature sensor based on a reflective patch is demonstrated up to 1050 °C. This reflective patch acts as a patch resonator (temperature sensor) and an integrated antenna at the same time. The temperature sensing mechanism is the monotonic increase of the dielectric constant of alumina versus temperature, which reduces the resonant frequency of a patch resonator formed on such an alumina substrate. By properly designing the shape and dimensions of the patch, it can also act as a transmissive antenna for wireless passive sensing. Therefore, temperatures can be wirelessly sensed by measuring the resonant frequency of the temperature sensor using an interrogation antenna. This temperature sensor uses robust alumina and platinum materials for high-temperature applications. In addition, this wireless passive temperature sensor is simple in mechanical structure and low in profile, with the potential to be in a conformal shape. A temperature sensor using this reflective patch was designed, fabricated and tested from 50 to 1050 °C in air. The resonant frequency of the sensor decreases from 5.07 to 4.58 GHz, which corresponds to a dielectric constant change from 7 to 11.4 for the alumina substrate. The temperature measurement sensitivity is found to be 0.3 MHz/°C at 100 °C. Being wireless, passive and low profile, the proposed high-temperature sensor can be used for various harsh-environment applications.

1. Introduction
Real-time pressure monitoring is essential for many environment applications, such as gas turbines for power generation. During turbine operations, there is an option rate to achieve the maximum thermal efficiency for temperature [1]. Pressures beyond or below the optimal result in reduced thermal efficiency. Additionally, cooling of pressure inside a gas turbine is necessary for safe operation. Higher pressure ratios than the designed value could lead to compressor surge which results in flameout, or even serious compressor blades.

1. Introduction
Accurate online monitoring of temperatures as well as other physical parameters in highly deleterious inside various harsh environments such as gas turbines [1], turbine engines [2] and nuclear reactors [3]. However, these harsh environments are typically characterized by high temperatures (>1000 °C), corrosive gases (containing sodium, vanadium and sulfur), high pressures or nuclear radiations. Currently, there are no commercially available sensors which can survive these harsh environments and provide continuous monitoring. Novel sensor architectures and sensing mechanisms are necessary to achieve the aforementioned goal. Particularly, wireless sensors are highly desirable since they do not need failure-prone wire interconnections. In addition, they provide a lot of flexibility in measuring sensors at different locations.

The authors reported wireless passive sensing mechanisms using dielectrically loaded resonators [1], [2]. When temperature rises, the dielectric constant of the material inside the sensor

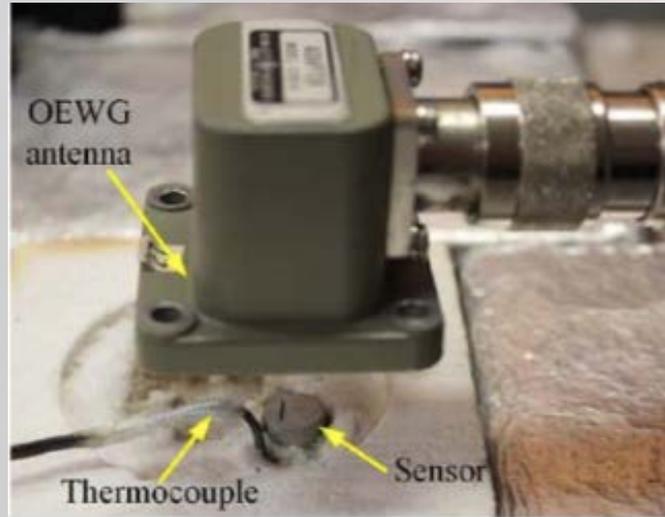
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http://dx.doi.org/10.1109/JSEN.2014.1318100
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http://dx.doi.org/10.1109/JSEN.2014.1318100
0018-4242/15/0301493-08 © 2014 IEEE. All rights reserved.

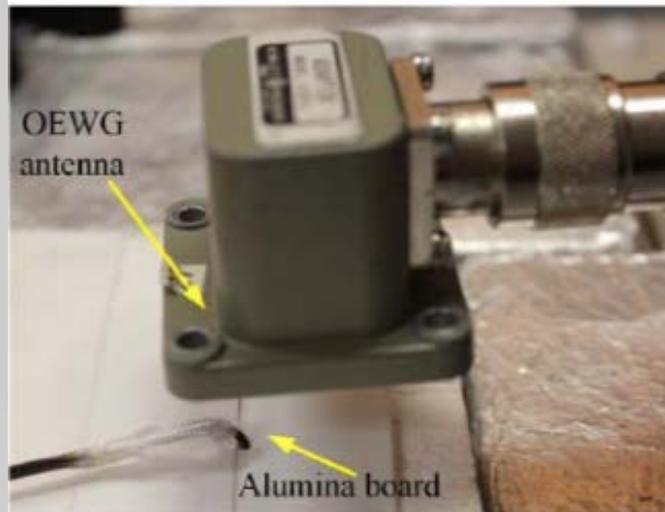
WIRELESS HIGH-TEMPERATURE CERAMIC SENSOR

Published in IEEE Sensors Journal March 2015

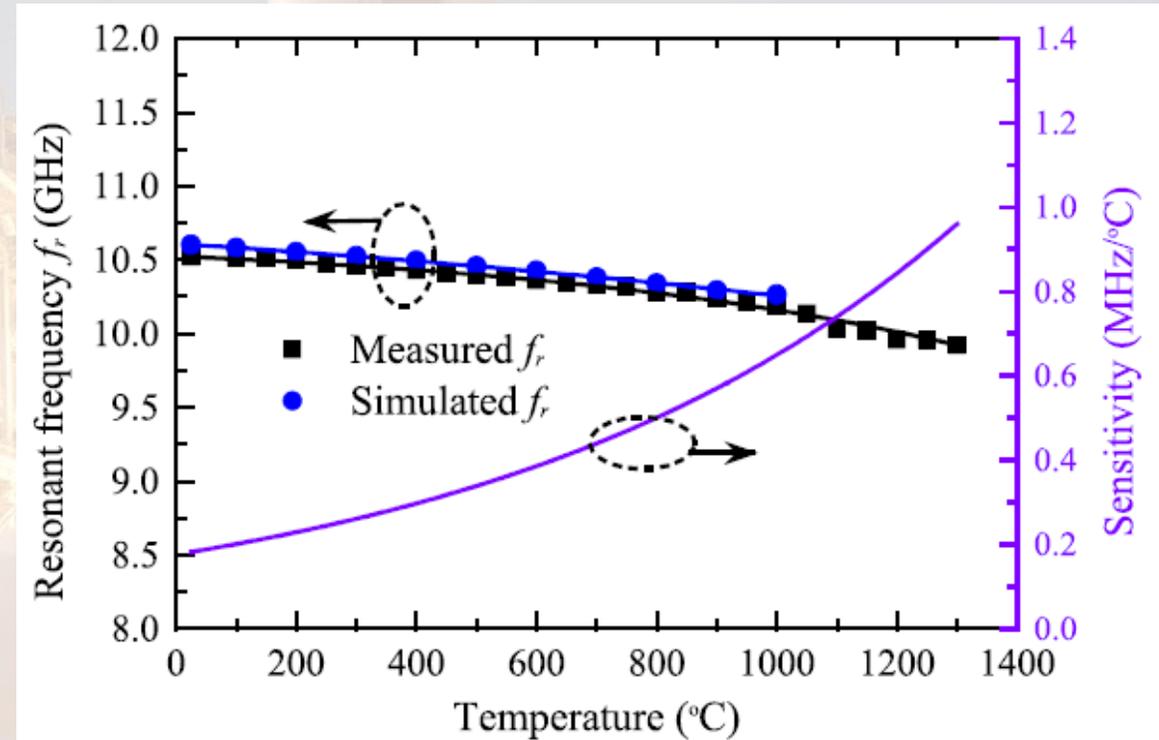
High-Temperature measurement using heat pad and X-band OEWG antenna



(a)



(b)



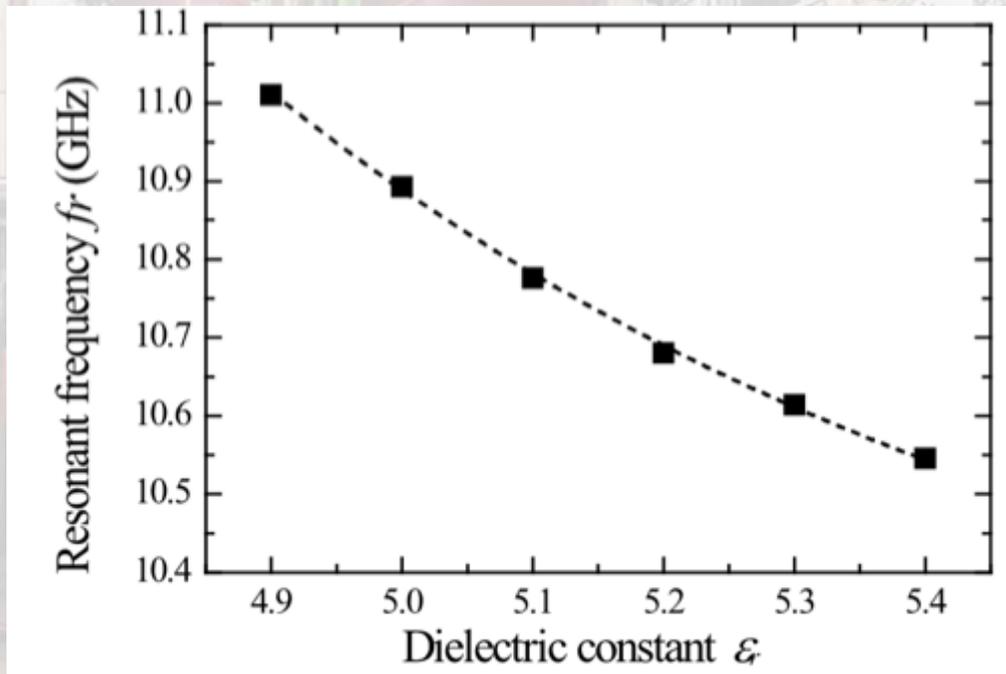
WIRELESS HIGH-TEMPERATURE CERAMIC SENSOR

Published in IEEE Sensors Journal March 2015

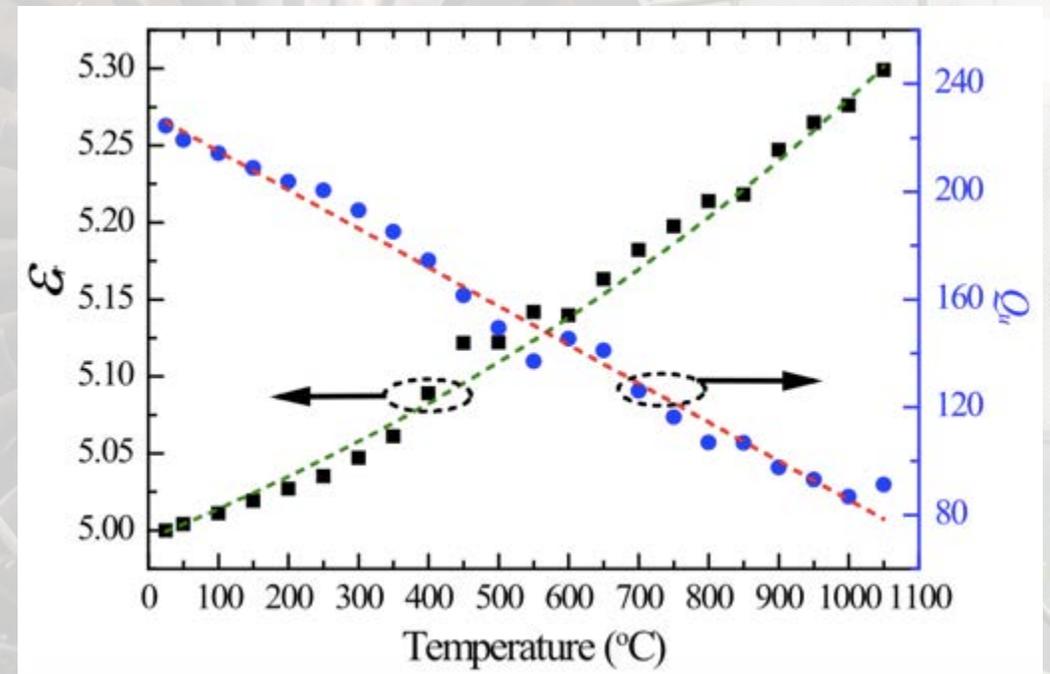
Step 1 → Detects Resonant Frequency, RF

Step 2 → Compares RF to Characterized Data

Measured RF Versus Dielectric Constant



Characterization of Ceramics at High Temperatures



Step 3 → Determines Temperature

Resonant Frequency is inversely proportional to Dielectric Constant, ϵ_r



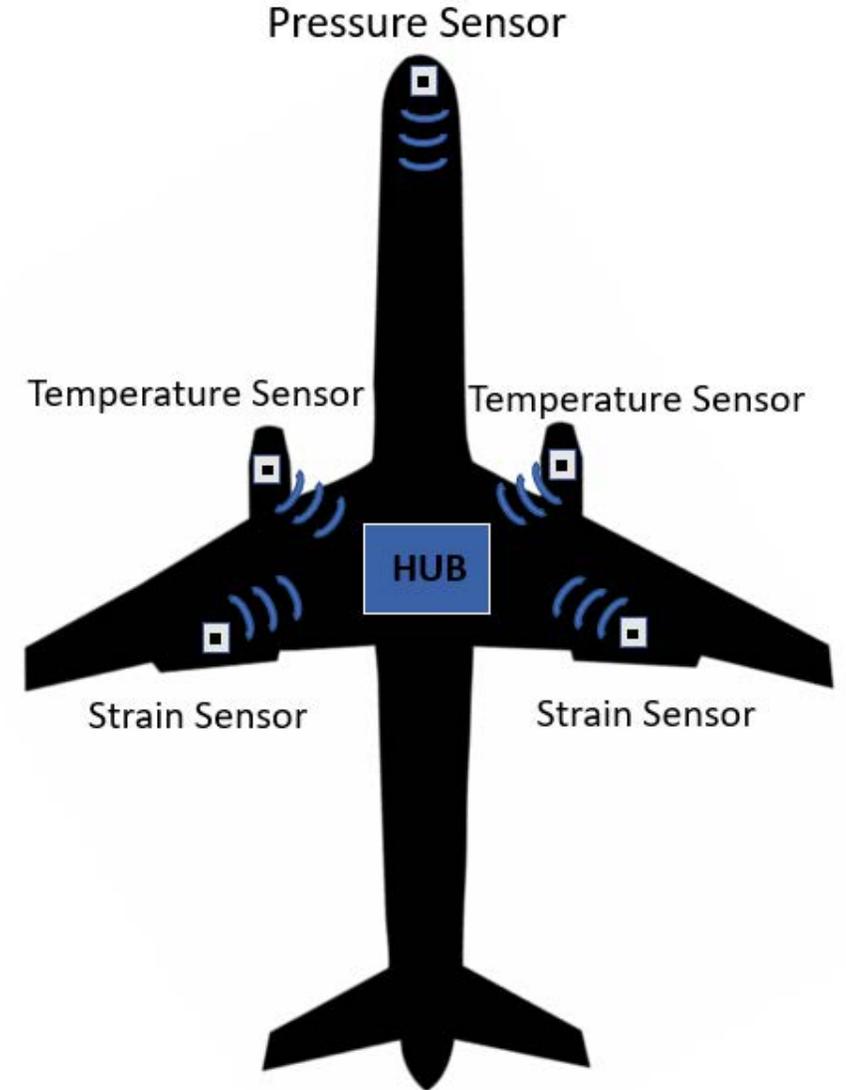
$$f_{TM010} = \frac{cp_{01}}{2\pi a \sqrt{\epsilon_r}}$$

Wireless Aviation Intra-Communications (WAIC)

- Local Radio communication between avionics components and systems on-board the same aircraft.
- Only safety and flight operations related applications, not for passenger communication.
- Low Transmission Power (10 dBm)

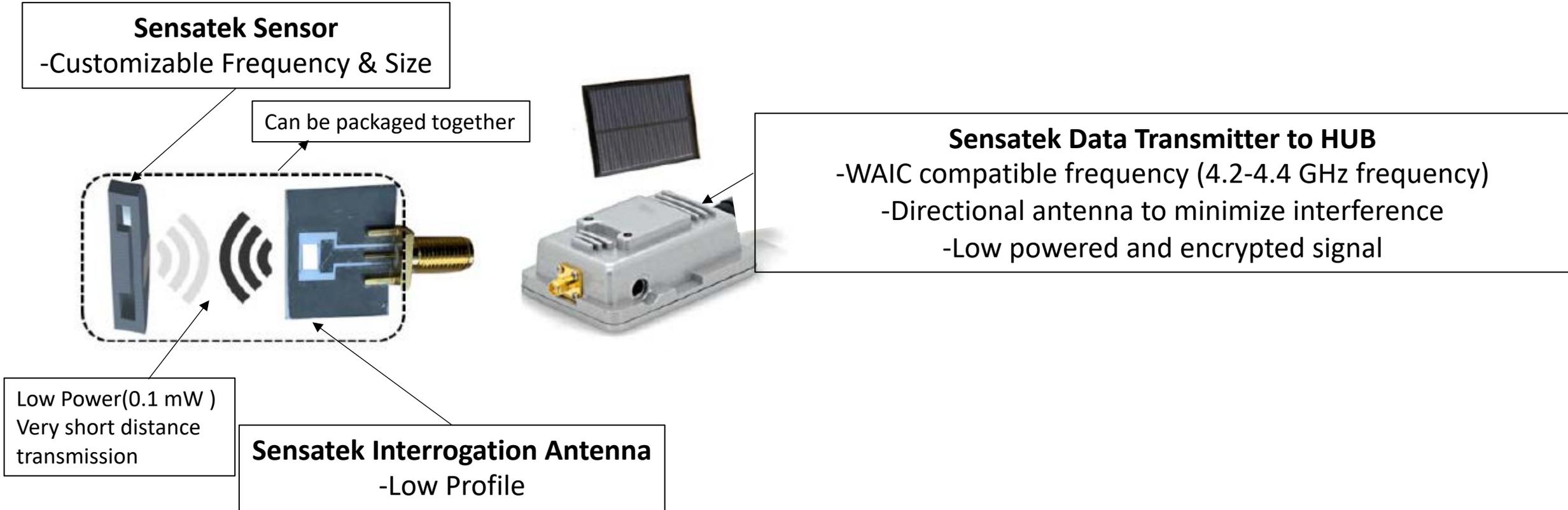
Motivation & Advantages:

- 30 % of wires are potential candidates for replacement.
- Aircraft wiring usually features double, triple redundancy through different route.
- Having wireless communication enables redundancy while mitigating risk of single point of failure.
- For space missions, increases useful payload capacity, improves economy for commercial aviation applications.



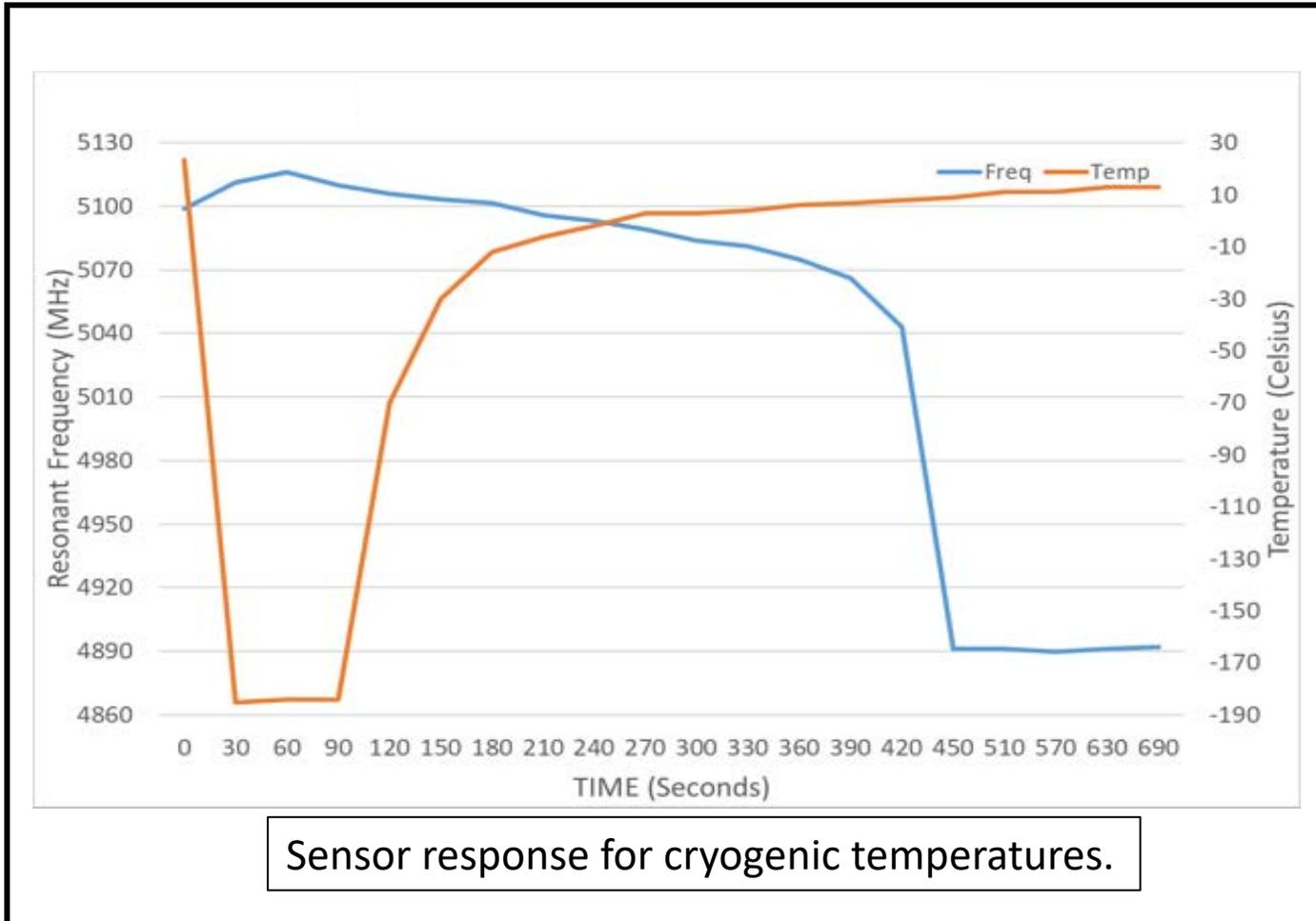
Sensatek Sensors Suite enabling WAIC

Sensatek Sensor System for WAIC applications



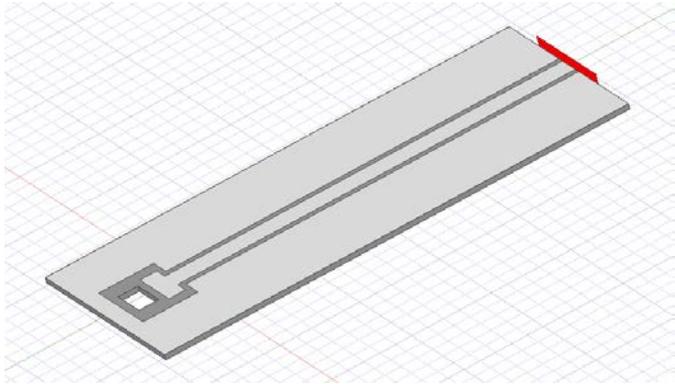
Cryogenic Testing

- Quick Proof-of-concept test using Liquid Nitrogen
- Liquid Nitrogen Poured over sensor placed on an Inconel component in a Pyrex Container
- Temperature recorded wirelessly for sensors using waveguide and independently using K-type thermocouple attached to DAQ
- Test duration was 12 minutes, readings recorded every 30 secs.



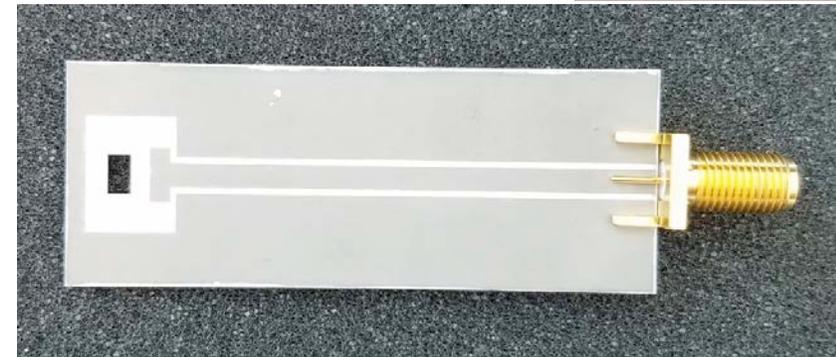
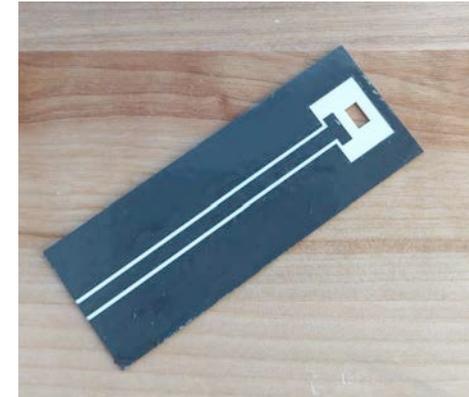
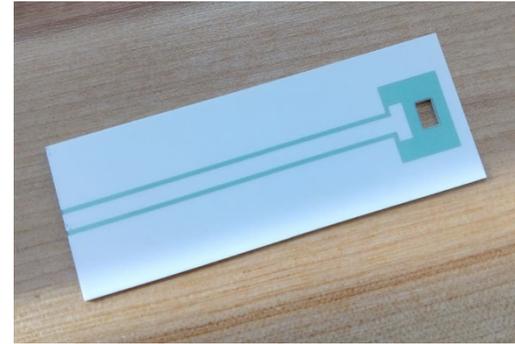
Harsh Environment Antenna Design and Manufacturing

(1)



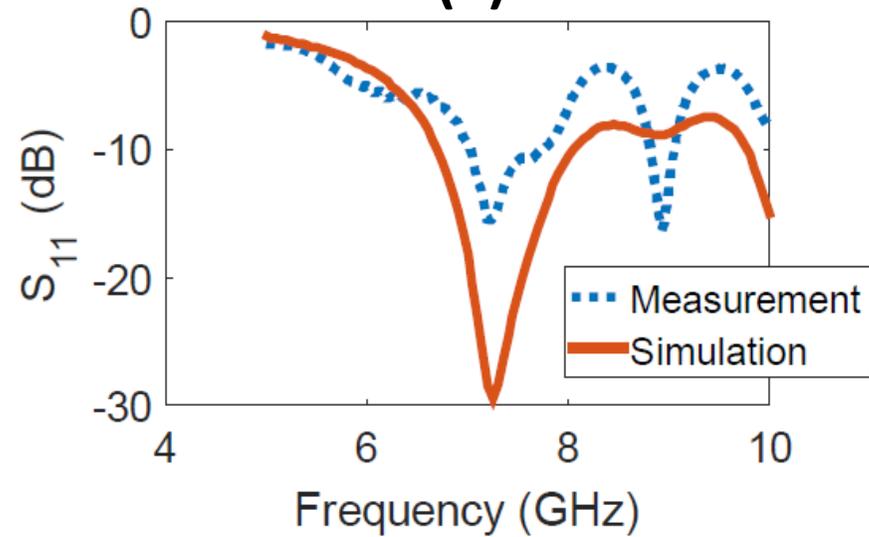
CAD Model of the antenna

(2)



Manufacturing Process of the antenna

(3)



Simulated Vs Manufactured

Proof of Demonstration: Survivability on Rotating Microturbine Wheel





Meet The Team



Reamonn Soto
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B.S. Physics
M.S. Aeronautics



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OFFICER



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Lord™**

GT GreenbergTraurig

JAMESON & COMPANY

James Moore
Certified Public Accountants and Consultants

What's next?

