Seeking & Evaluating Applications of SAWs (SEASAWs)

LaRC RD Tech Catalog ID:

Surface Acoustic Wave (SAW) Sensors - RF powered passive, wireless, wave based Sensor, a Systems Analysis

BACKGROUND & MOTIVATION

SAW Sensors are a promising alternative to some sensors in aerospace, but have not been assessed

- *SAWs are Batteryless, Wireless*
- *Wires in Spacecraft and Aircraft have structural considerations, maintenance / reliability needs, and inherent complexity*

Onboard sensors during flight, Ground testing, Experimental setups

- *Placed incognito (with low form factor)*
- *interrogated from afar*
- *Multiple at a time*

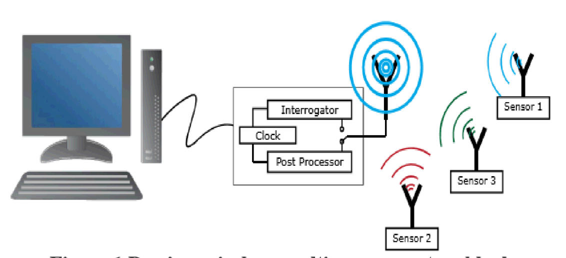


Figure 1 Passive, wireless, multisensory system block diagram.

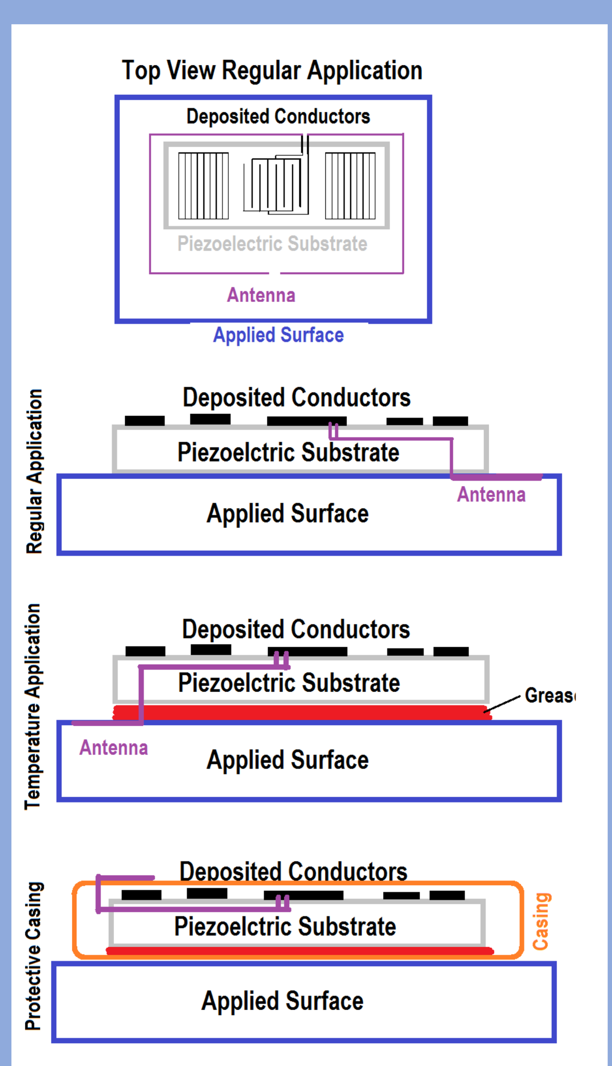
INNOVATIONS

Beyond wireless sensing, Multiple operating parameters are being pushed with basic research

New Approaches in Works:

- *Interrogation Schemes*
  - *Orthogonal Frequency Coded*
  - *Time Division Multiplexing*
- *New Materials*
  - *Heat resistant conductors*
  - *Different piezoelectrics*
- *Fabrication Techniques*
  - *Flexible Substrates*
  - *Mass production*
- *Hardware Improvements*
  - *UCF Transceiver box*
- *Software Development*
  - *Software Defined Radio*

SAW Sensor Operating parameters		
Property	**Value**	**Units**
Max Op temperatures	910	Celcius
Therroritical Max temp	1470	Celcius
Min Op Temp	-200	Celcius
Therr Min Temp	-	Celcius
Min Op Pressure	Vaccum	
Max Op Pressure	15000	psi



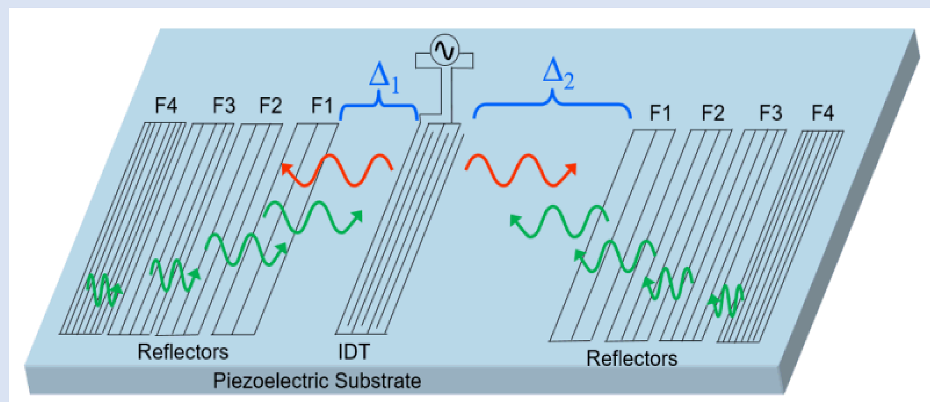
The Casing – per use

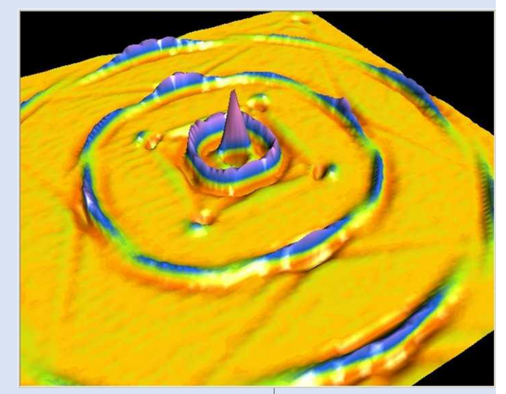
- *Effects many aspects, should be customized per application*
- *Antenna Size*
- *Data Collection*
- *Structural Integrity (Both the system where installed, and sensor itself)*
- *Reliability, Installation, & Mounting*

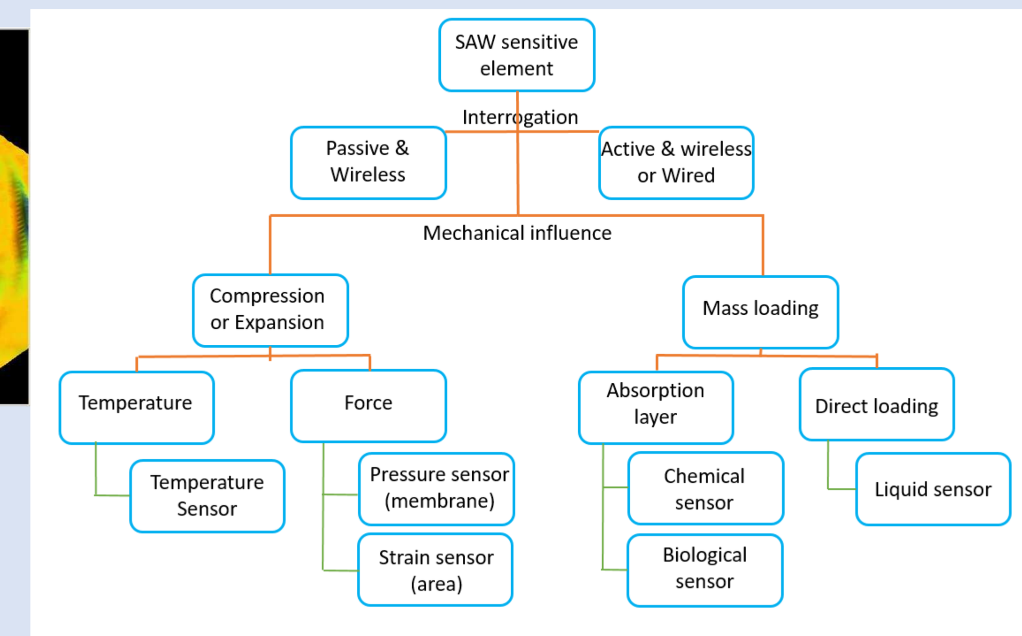
DESCRIPTION

General Principles

- *Operates by turning Electromagnetic waves into a mechanical SAW(s) on a crystal piezoelectric substrate, using deposited conductors (Interdigitated Transducer, and Reflectors) to generate and conversely re-emit EM waves*
- *The SAWs are affected by things like temperature and strain, and reading these effects back allows for their measurement in the time and frequency domains*







Pros:

- *Propagation (wave speed) and reflection (frequency reflection change) characteristics are the varying parameters*
- *Delay times allow for transmitted signals to dissipate before response*
- *Durable, Low Maintenance, Environmentally Friendly, Security Encodable, Radiation resistant*
- *SAW Market and capabilities are growing*

Cons:

- *SAWs can be scrambled because of jamming in EM Warfare.*
- *SNR goes down with more Sensors per interrogator*
- *Currently, individual sensors must be calibrated in lab*

Metrics 'knobs' to be improved:

- *Signal to Noise Ratio (dB)*
- *Sensitivity (g/Hz, C/Hz)*
- *Range (meters)*
- *Sample Rate (Samples/Sec)*
- *Calibration longevity (time)*
- *# of Sensors per interrogator*
- *Hardware limitations*

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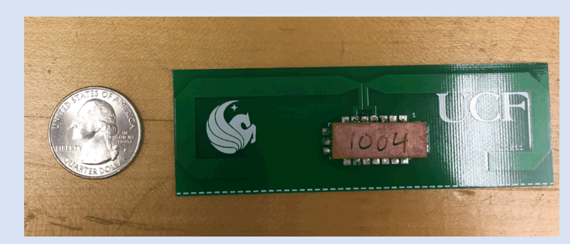
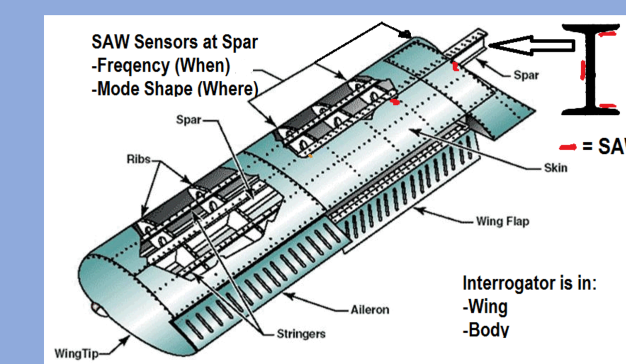


ANTICIPATED IMPACT

Simplify design, while getting information. 2 Cases

ASHM – Strain for Maintenance

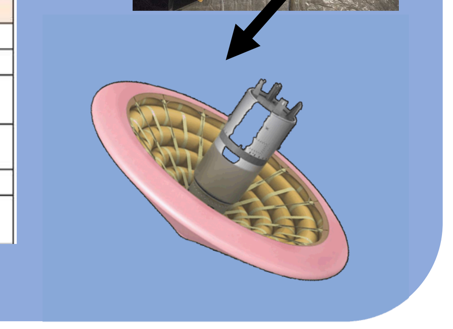
- *On Aircraft wings to track fatigue*
- *From full look-over to check engine light*
- *Individual parts tracking / fatigue measurements*



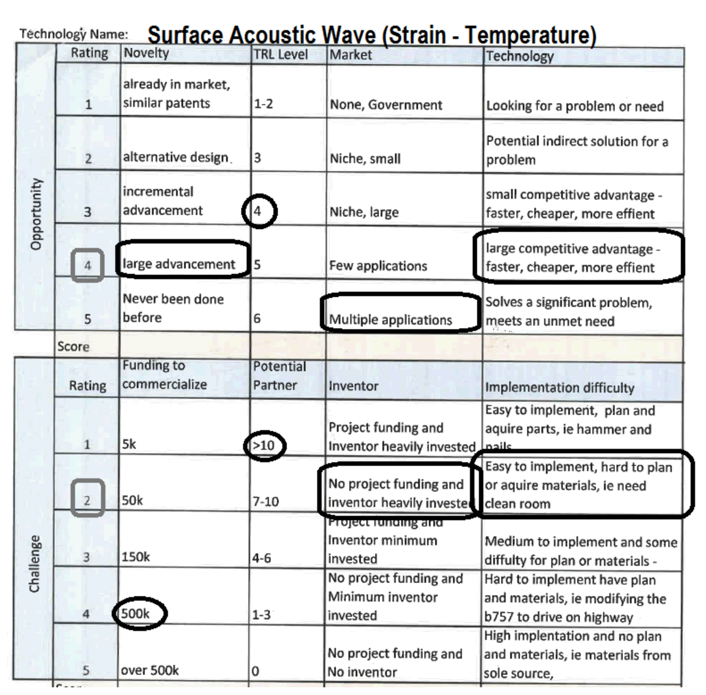
HIAD – Heat flux sensing

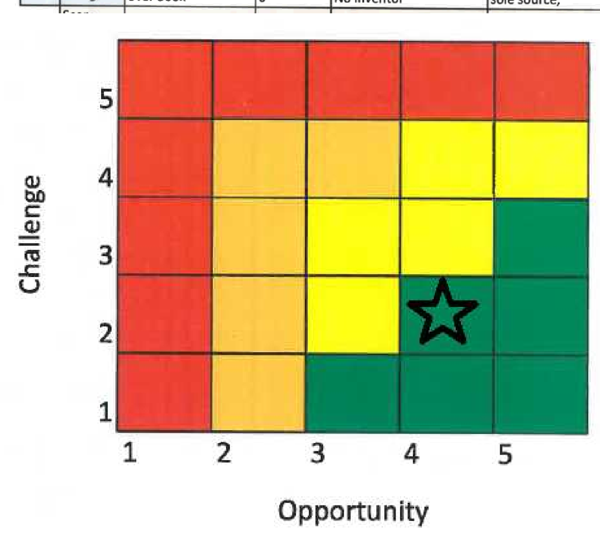
- *Flexible sensors for packaged inflatable heat shield*
- *Measure Heat flux for software validation*
- *Thermocouple wires break on folding*

Technical Objectives	Quantity/Measurement	Accuracy Goal
Aerothermal Environment and Thermal Protection System (TPS)		
Aerodynamic heating	Heat Flux – Forebody	±5%
	Heat Flux – Afterbody	±10%
Reduced TPS and vehicle mass, reduced subsystem risk for future missions	In-Depth Temperatures, as a function of time at multiple locations	±15%
	Recession in Flight (multiple locations)	±2 mm
	Final Recession (if recovered)	±1 mm
Demonstrate adequate bonding and bondline integrity	TPS-to-structure bondline visualization (before and after flight)	±0.5 mm



Tech - Adoption Waterfall Chart





Maturity Metrics

Current Technology Readiness Level (TRL) 4.5

- *Technology is well understood and how to produce, implementation into aerospace vehicles not tested, but tech demonstrator easily doable*

Advancement Degree of Difficulty (AD2) 4

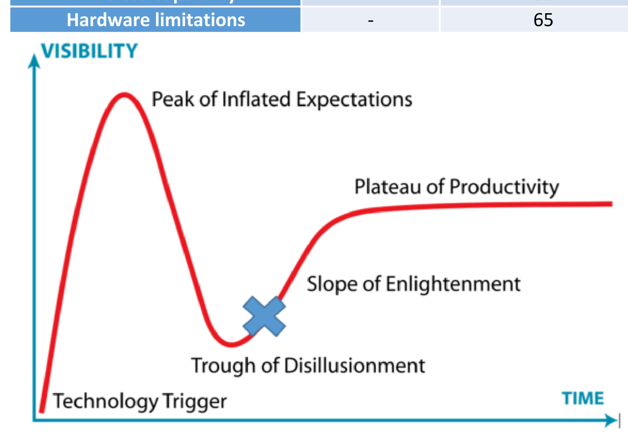
- *Its well understood at 40%. Casing / Configuration would be specialized per aerospace application (small scale being easier with COTS units, others need flight validation and design)*

Research and Development Degree of Difficulty (RD3) II

- *SAWs have a good chance of implementation into the aerospace industry, however funding to get it through flight qualification of electronics*
- *# of sensors and form factor are constraints*

Technology Survey Responses

Knob	Units	Rating (1 not important - 100 impactful)
Signal to Noise Ratio	dB	70
Sensitivity	g/Hz, C/Hz	76
Range	Meters	60
Sample Rate	Samples/sec	76
Calibration longevity	time	86
# of Sensors per interrogator	#	66
Wireless Capability	-	90
Hardware limitations	-	65



Application Area	Rating (0 not much use - 100 full use)
Entry Decent and Landing (EDL) Heat Flux	86
Aircraft Structural Health Monitoring	93
Wind tunnel instrumentation	85
Vibration and Shake tables	65
Mass sensing on Satellites or Rovers	70
Space Test Vehicles for ground testing	90
Chemical Sensing	90
Shock and impact testing	70
Small Scale lab experiments	83
Interplanetary Missions	100
Hypersonic Testing	70
Pressure Vessels	75
Spacecraft Electronics onboard management	35
Microgravity Structural Sensing	55
Inflatable Structures	86
Mechanical Structural Testing	90
Nondestructive Evaluation	70

PATH FORWARD

What should be done with SAWs in the Future?

- *Technology Demonstrations*
  - *Raise the TRL level by placing them on ground tests (like wind tunnel instrumentation, TPS testing, etc.*
  - *Then put on SAWs on Flight Hardware like the two above*
- *Conferences*
  - *Like the Wireless in Extreme environments (WISEE)*
  - *Mixes private, Research and customers to find points of application, as there are many*
- *Basic Research*
  - *New advancements are occurring continuously and there is a healthy community of SMEs in the field*
    - *Many subfields of SAWs (Biosensing, filters, delay lines, sensors)*
  - *Work with international partners to advance field*
    - *Europe is 10 years ahead in research*

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