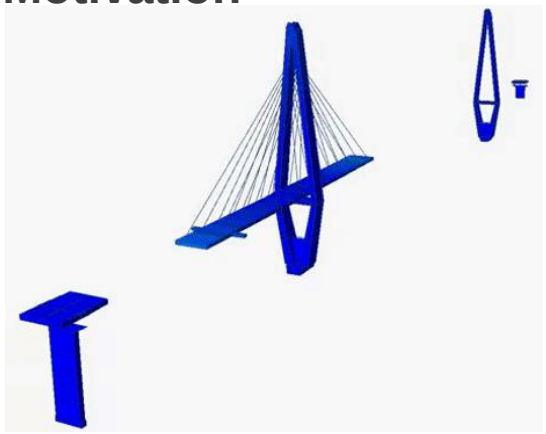
IoT-integrated Edge Computing Device and ML-SVM Classifier for Damage Detection in Metallic Structure

Shanker Malla and Amit Shakya

Undergraduate Creative Group

Enablers

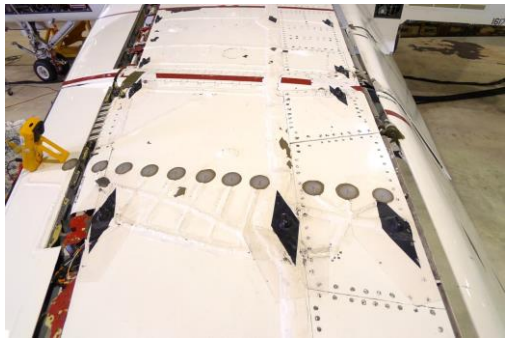
Motivation



Rapid development of Infrastructure

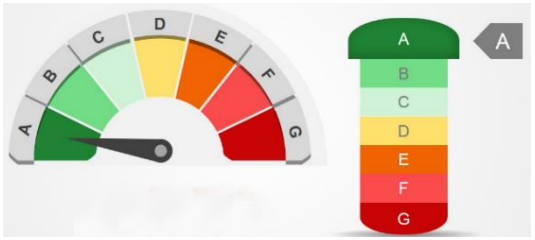
Prevent structure catastrophe

Why wireless?



Why intelligent?

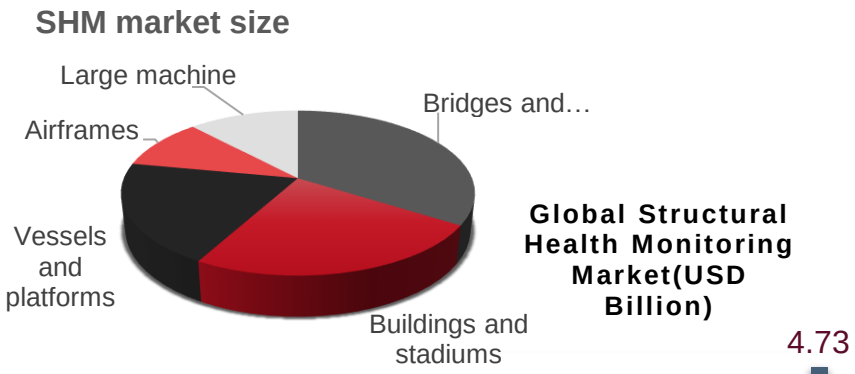
- Edge Computing
- Energy Efficient
- Alert System

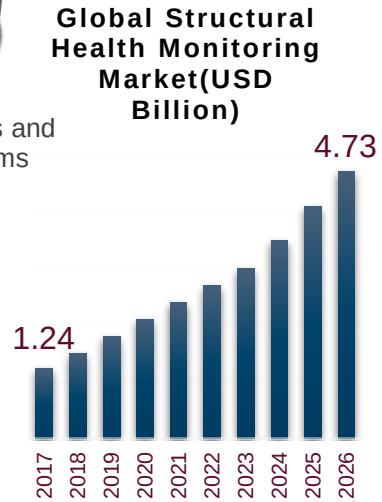


Market Prospects

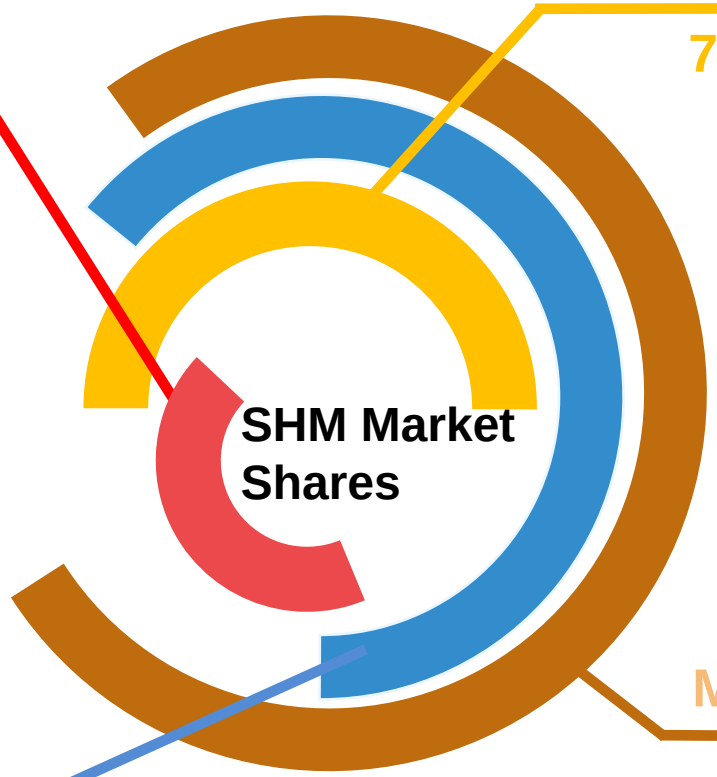
01 SHM Market Size

4.73 Billion





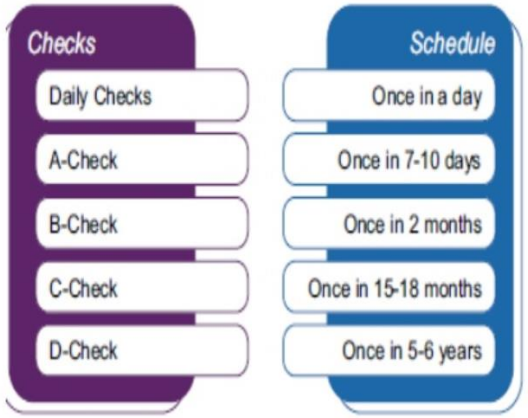
- Market size to reach 4.73 billion in 2026
- Aircraft industry to witness largest growth
- Scope in other fields



02 Inspection Required

70 Million Man Hour

70 million man hour inspection is required by an aircraft in a year and 80 percent is visual inspection



03 Global Fleet Size

39,000 Global Fleet size to reach this number by 2029

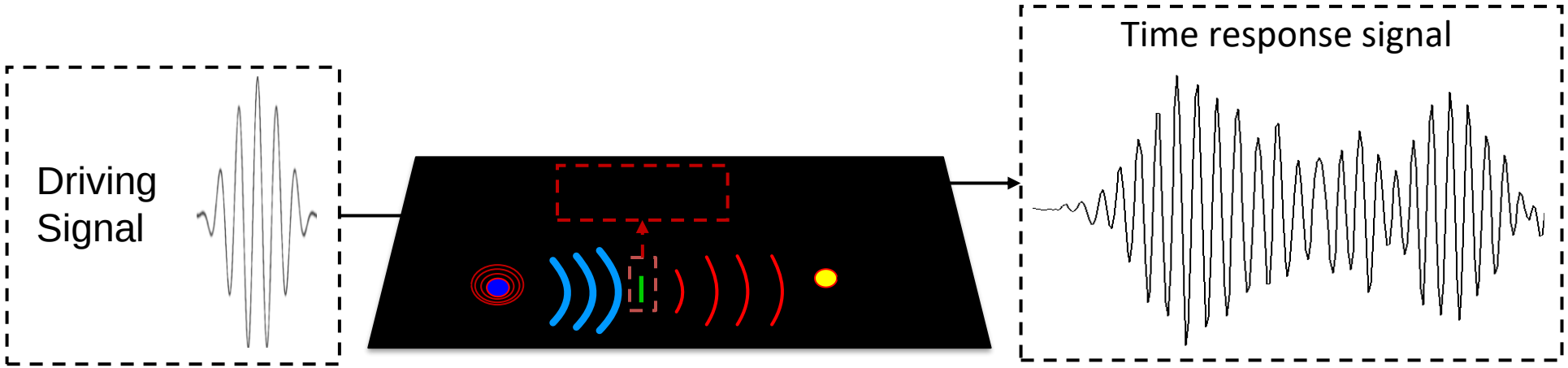
04 Maintenance Expenditure

$116 billion

- Total global Maintenance Repair and Overhaul (MRO) expenditure to rise to $116 billion by 2029, up from $81.9 billion in 2019

Core Technology

- By analyzing lamb wave we can detect damage in the structure
- PZT converts lamb wave to electric signal and vice versa

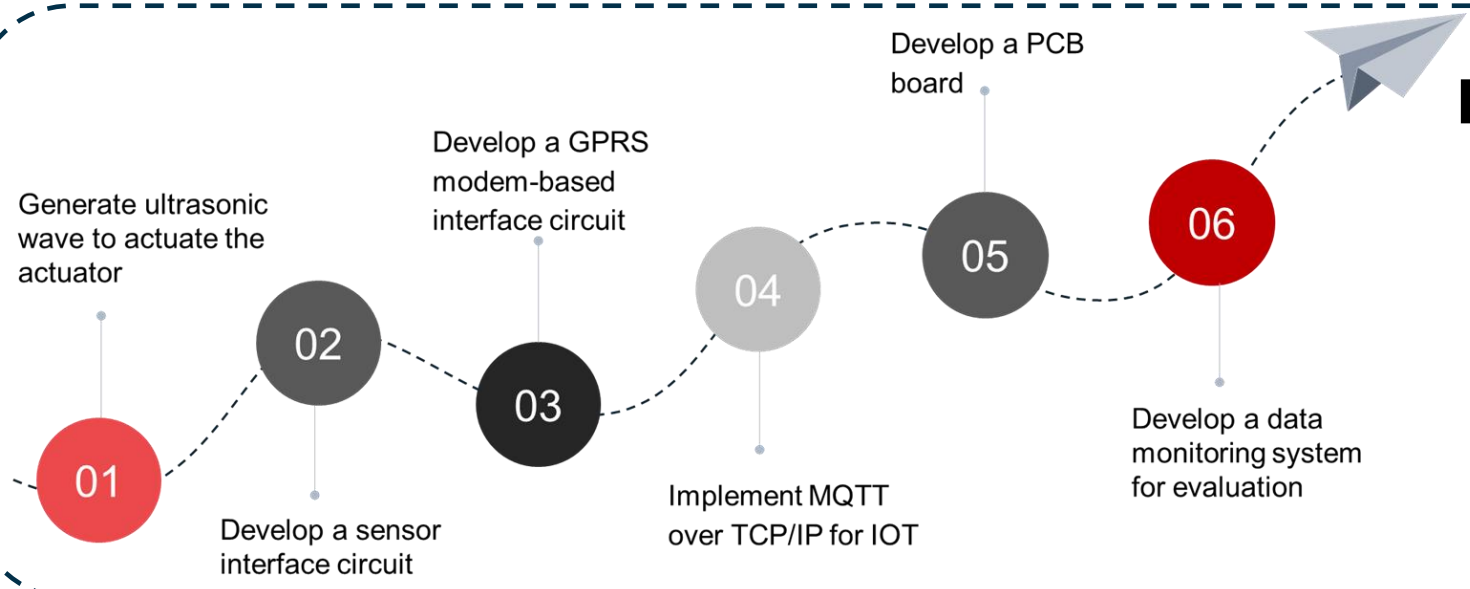


TD RMS (Time Domain Root Mean Square)

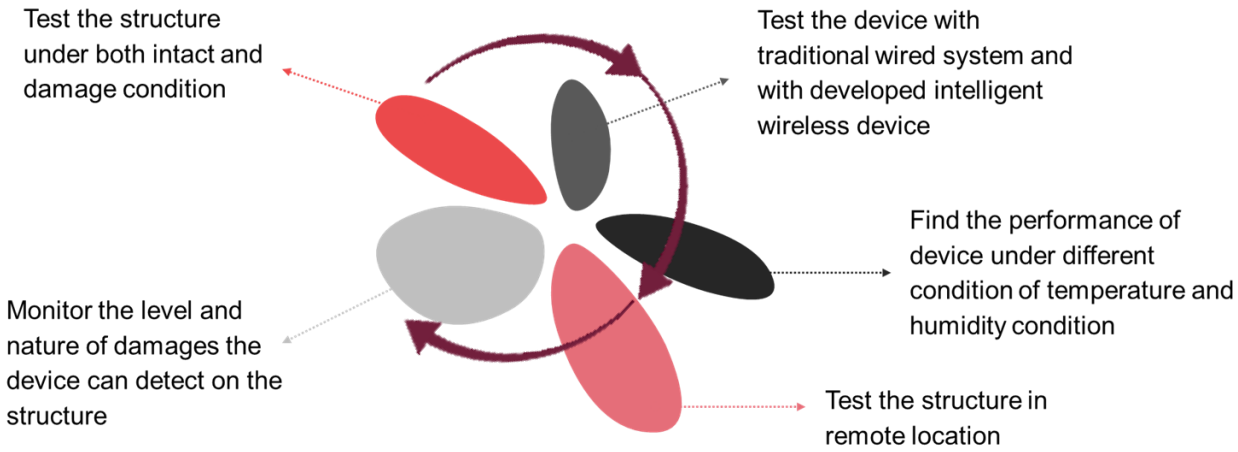
$$DI_{TDRMS} = \frac{\int_{t_1}^{t_2} \left| S_m(t) - S_b(t) \right|^2 dt}{\int_{t_1}^{t_2} \left| S_b(t) \right|^2 dt}$$

Procedures

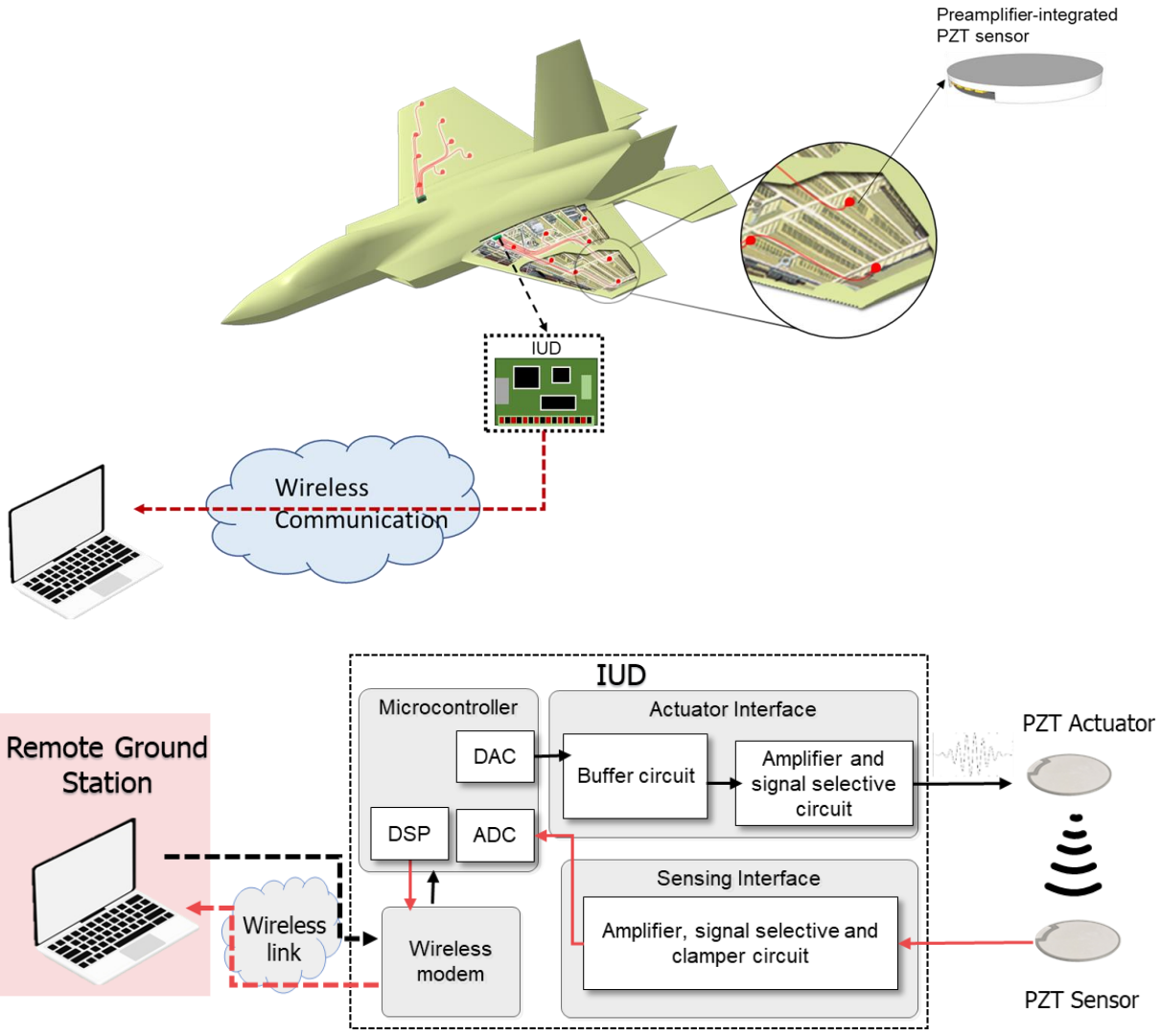
Development Procedure



Testing Procedure



Overview



01 Actuates the actuator to generate ultrasonic wave

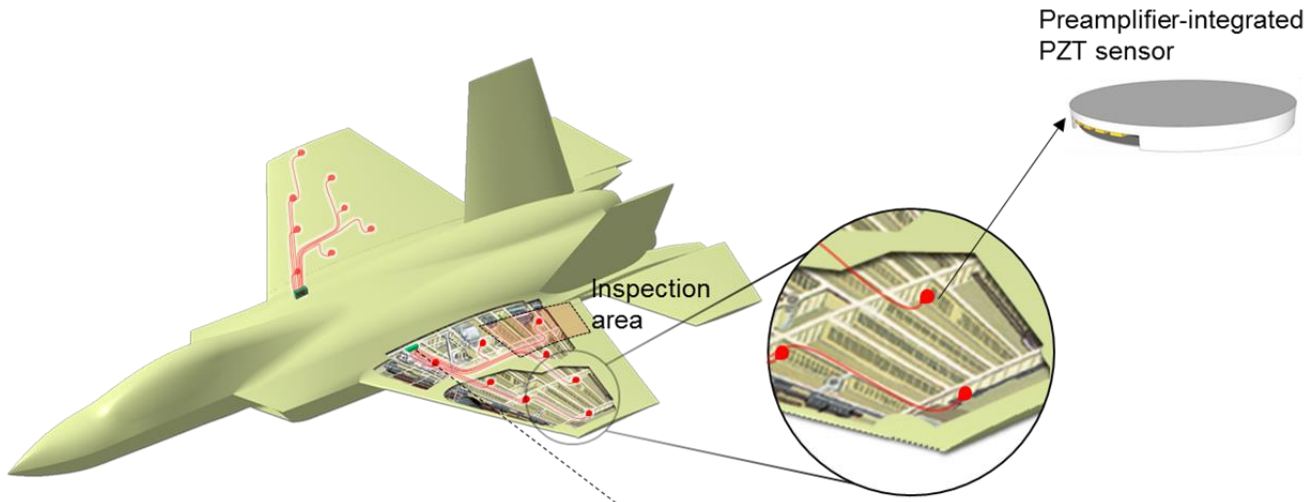
02 Selects the required sensors

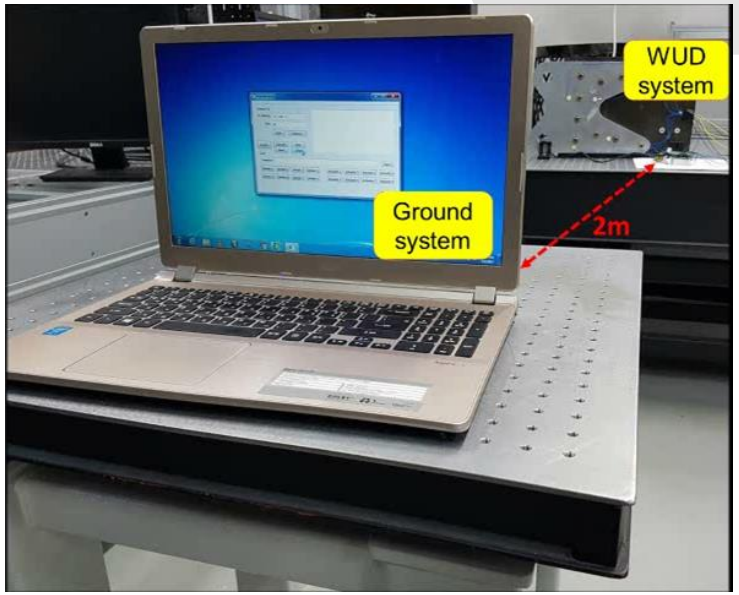
03 Collects sensed ultrasonic wave from the PZT sensor

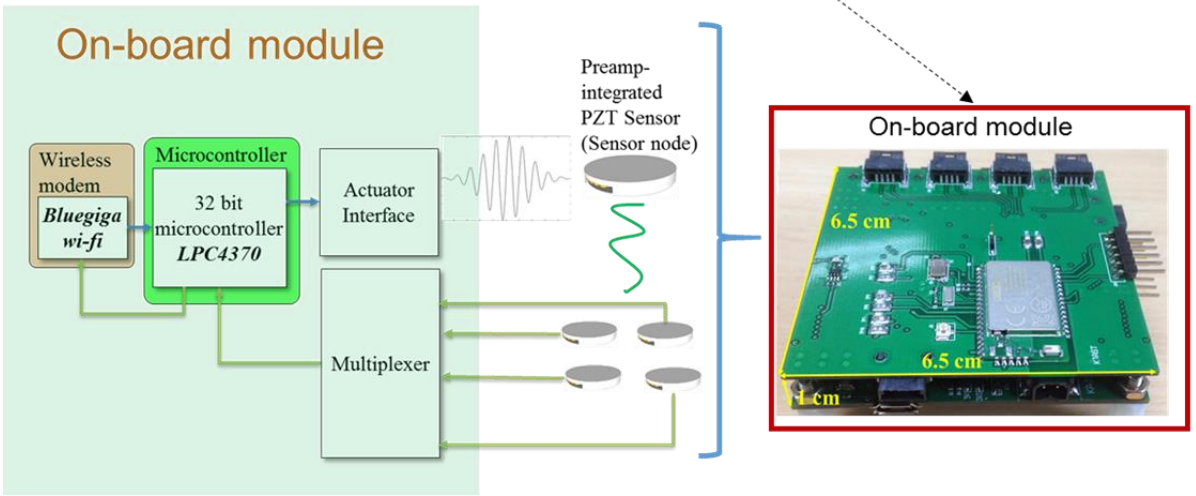
04 Calculates the damage index from the collected wave data

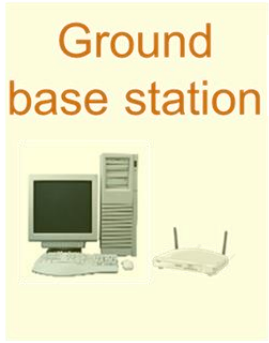
05 If damage is severe, send damage index to the Laptop

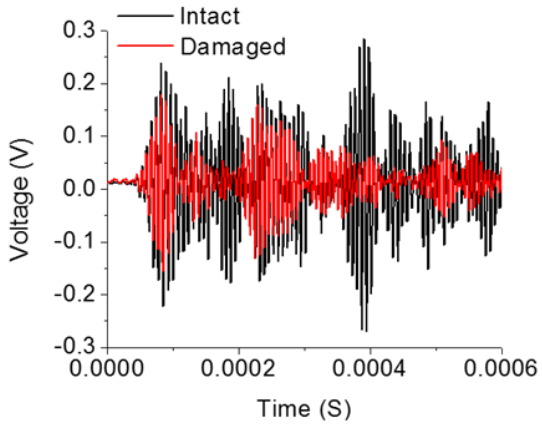
Foundational/Preliminary work (1)

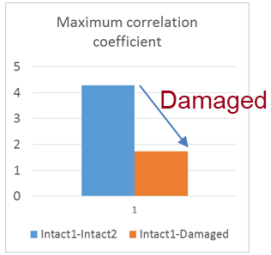






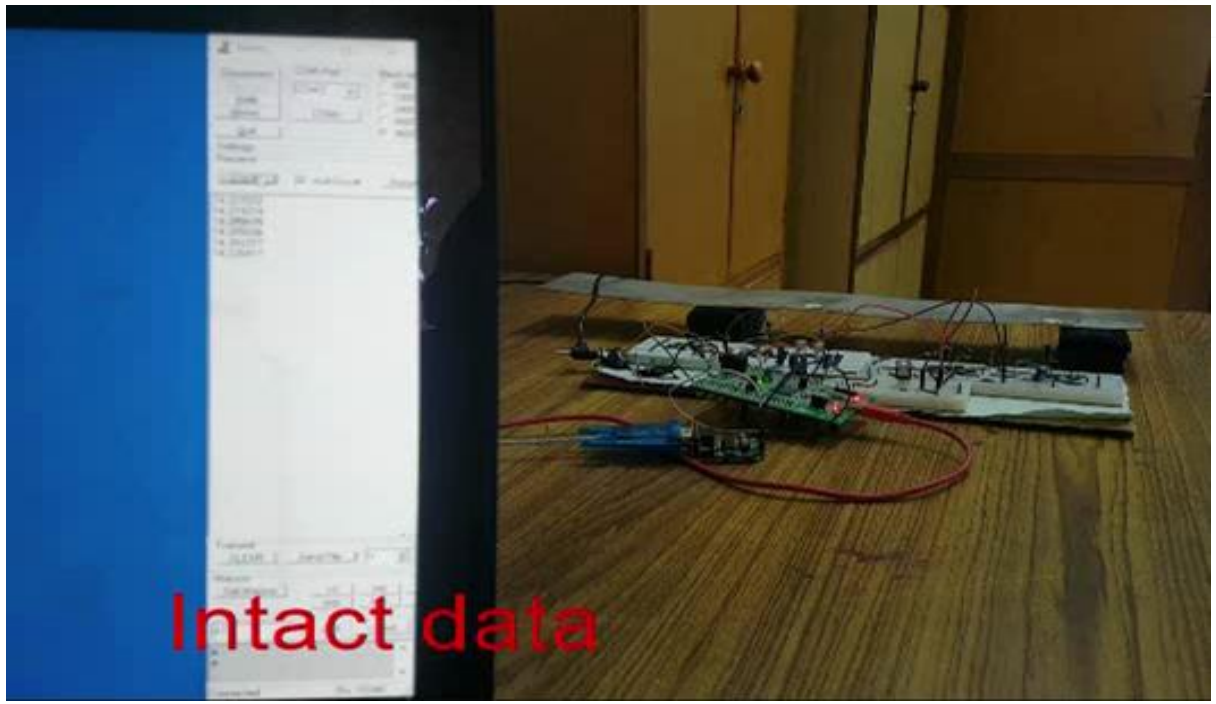






Foundational/Preliminary work (2)

Intact data: ~14
Impact data: ~17



Foundational/Preliminary work (3)

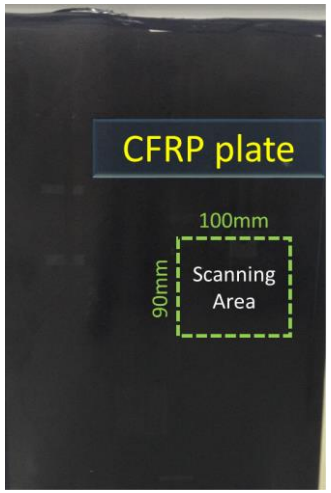


Figure: Scanning Area

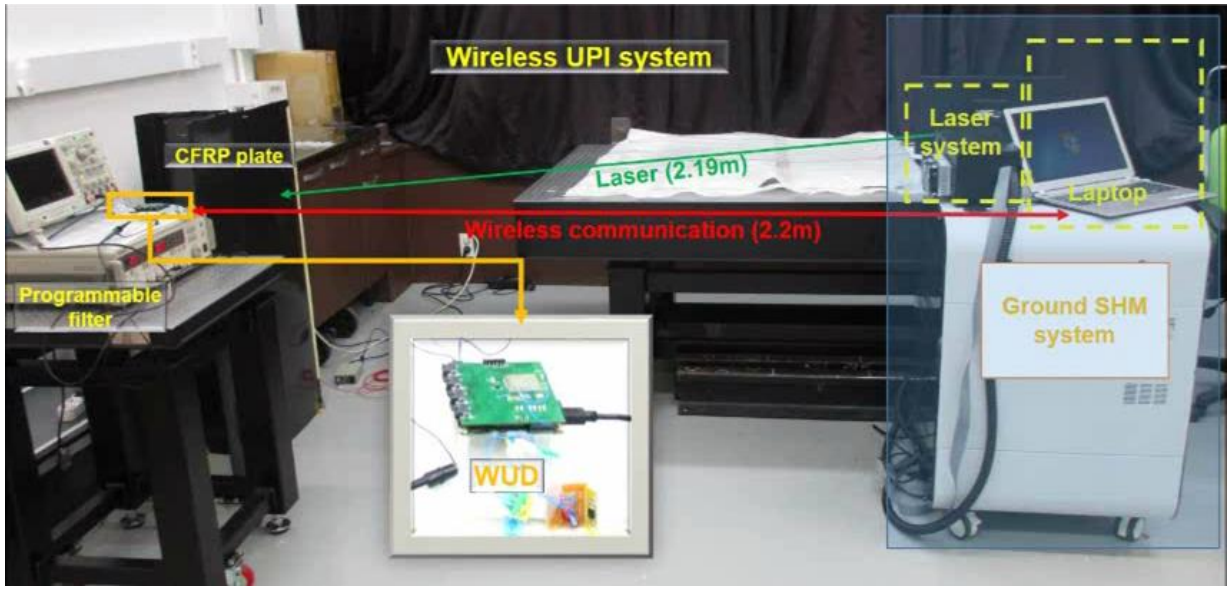


Figure: Video of Wireless UPI experiment

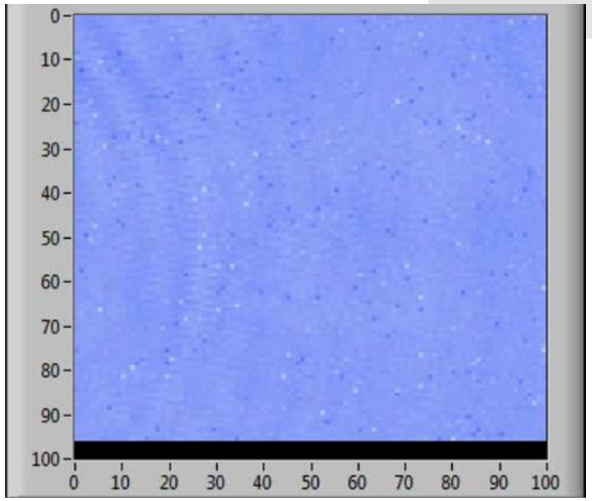


Figure: Reference video for UPI system

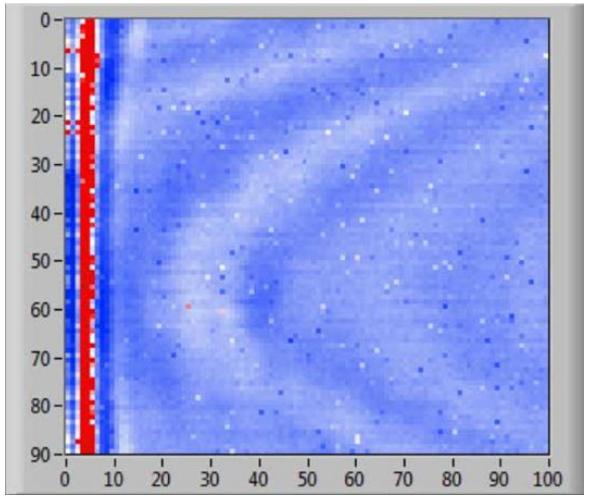


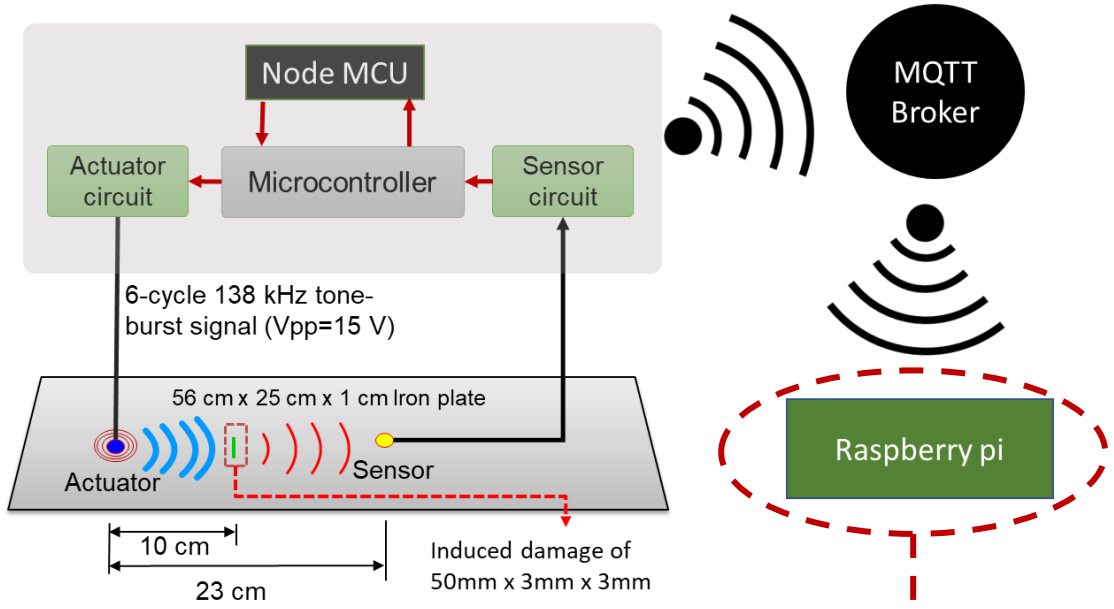
Figure: Video from wireless UPI system

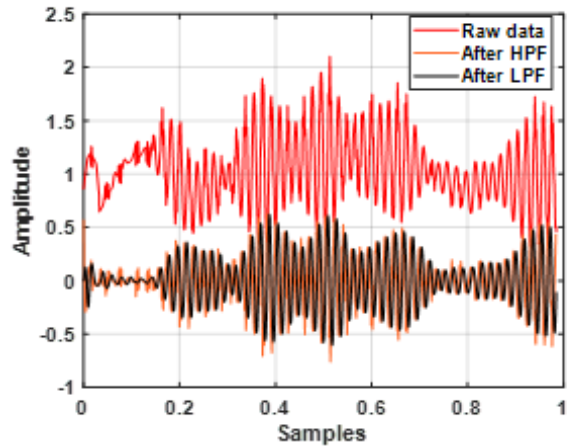
The acquired ultrasounds were processed for damage detection and evaluation

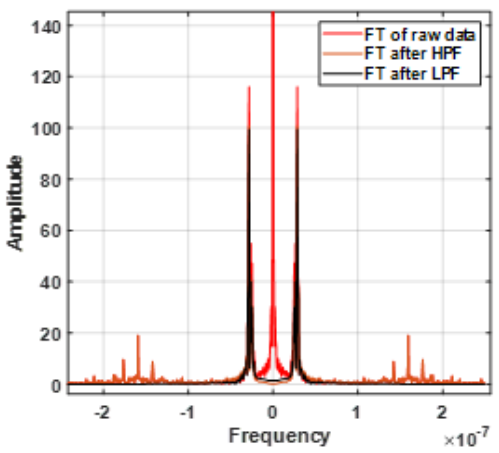
- Mismatch of movie is due to mismatch of the signal while triggering LMS and Wireless Ultrasonic Device (WUD)

Sensor circuit and controller circuit was successfully used to capture the ultrasonic wave generated by laser and send it to Laptop to generate Video to visualize damage

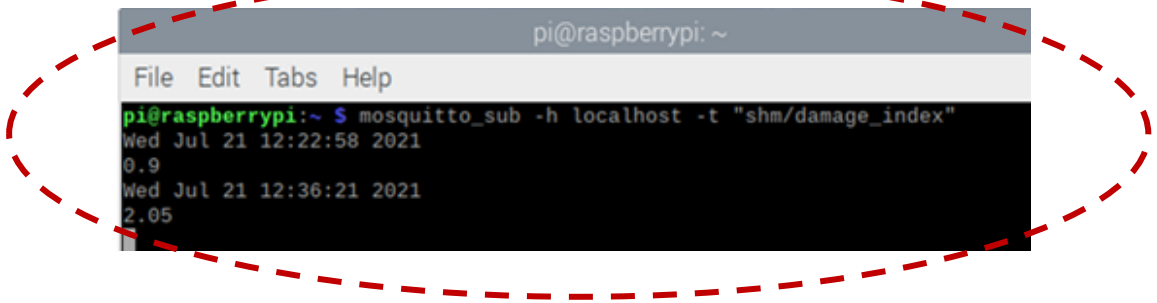
Foundational/Preliminary work (4)





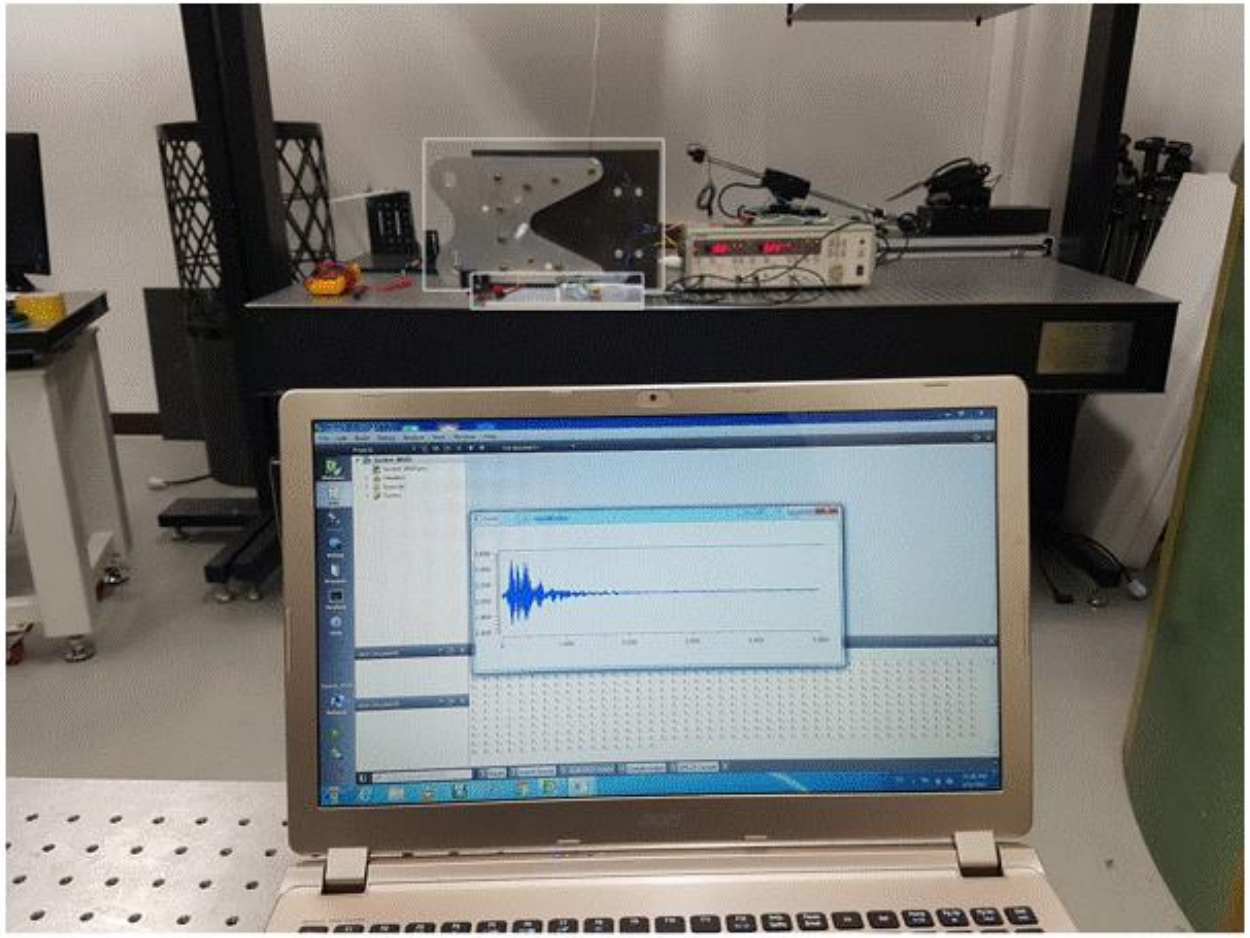


Wave sampled from microcontroller to check processed and unprocessed signal



Damage index captured at the Raspberry pi. Damage index was calculated in the Microcontroller itself, showcasing the edge computing capability of the microcontroller

Product prototype



Final product

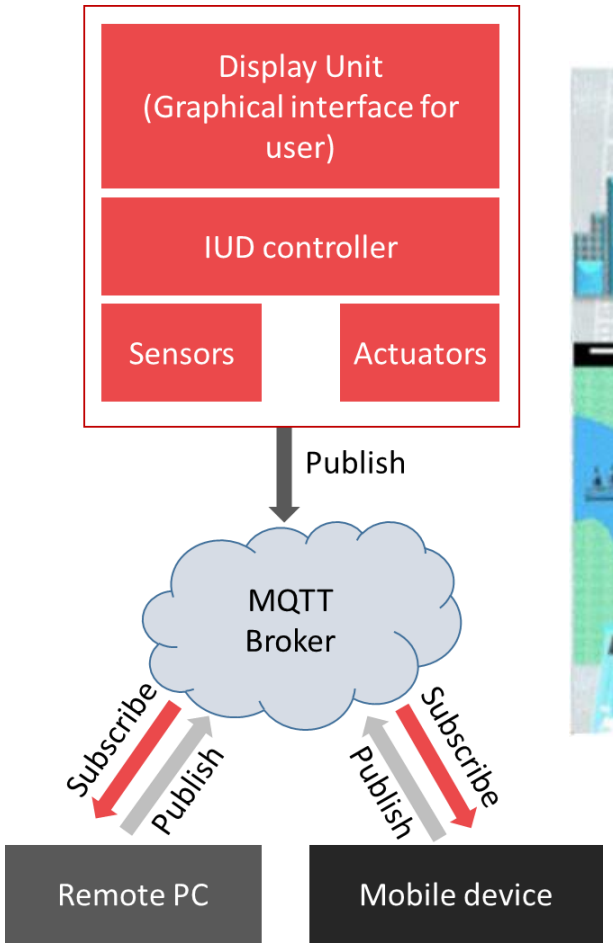
- IOT based ultrasonic device with edge computing capability that can monitor damage of the structure at the early stage

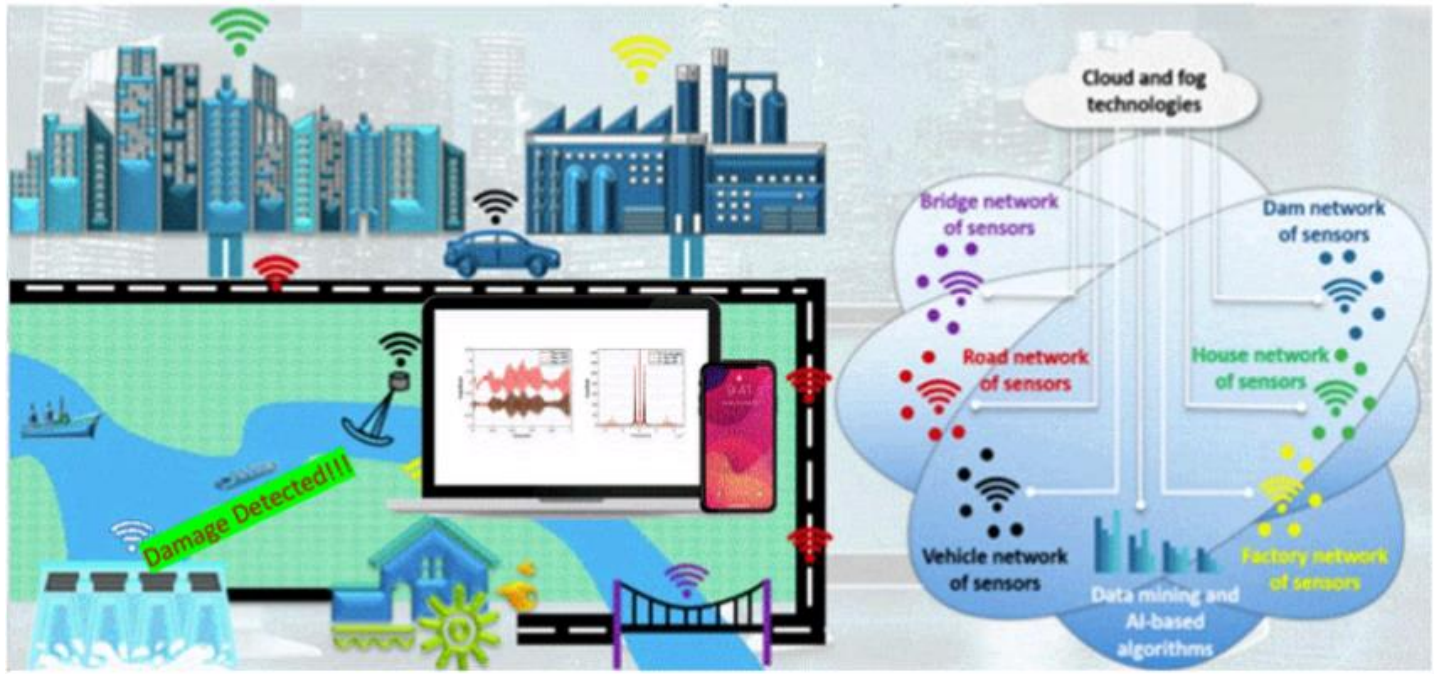
Features

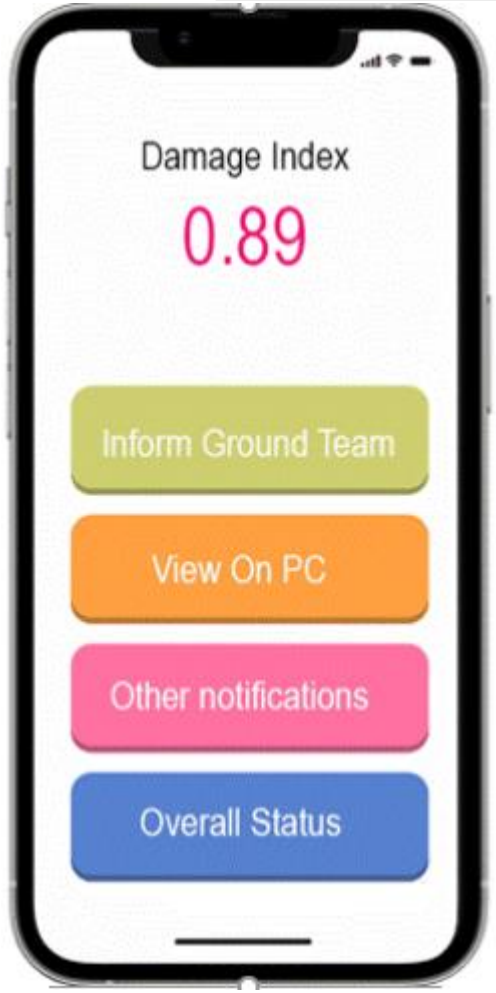
- The ability to perform spatial SHM over large structural areas without a need to deploy hundreds of sensing nodes
- On-board computation algorithms
- Reliable wireless communication techniques
- Reducing the deployment cost via material design, optimal sensor placement strategies, etc.
- Enhancing sensitivity to various damage types
- Integrating the sensor with different plug-in functionalities

Specification	Performance
Power supply	15 V
Microcontroller	168 MHz, ADC: 10 bit, 2.5 MSPS, FPU
Actuator signal	138 kHz, 15 Vp-p, 6 cycle
Communication	Wireless

Final Product







Our Team

Members

Amit Shakya

Cosmos College of Management and Technology,
Pokhara University
Nepal

Undergraduate, Final year student
Electronics and Communication,

Shanker Malla

Pulchowk Engineering Campus
Tribhuvan University
Nepal

Undergraduate, Final year student
Aerospace Engineering

Our Team (Technical Mentor and Advisors)

Mentors

Manish Man Shrestha
Professor,
Cosmos College of Management and Technology;
Pokhara University

CTO, Electronics
Samadhan Engineering

Mr. Srijan Rajbamshi
CTO, Mechanical
Samadhan Engineering

Master in Mechanical Design
Designer for Honda
Research for autonomous Vehicles

Mr. Rupak Aryal
MBA
Faculty Member, International Business
Isilington College

Marketing Manager,
Samadhan Engineering
Winner of Innovation awards in National competition

Advisor

Prof. Bikash Nakarmi
Professor,
Nanjing University of Aeronautics and Astronautics
Jiangsu, Nanjing, China

Feedback

- Professor Dr. Tri Ratna Bajracharya
- Former dean of Tribhuvan University, Institute of Engineering
- Director, Center for Energy Studies

"It is an innovative and unique piece of equipment with immense business potential. Recently it was used in the university for the testing and laboratory Use in our newly opened Aerospace program"

Feedback

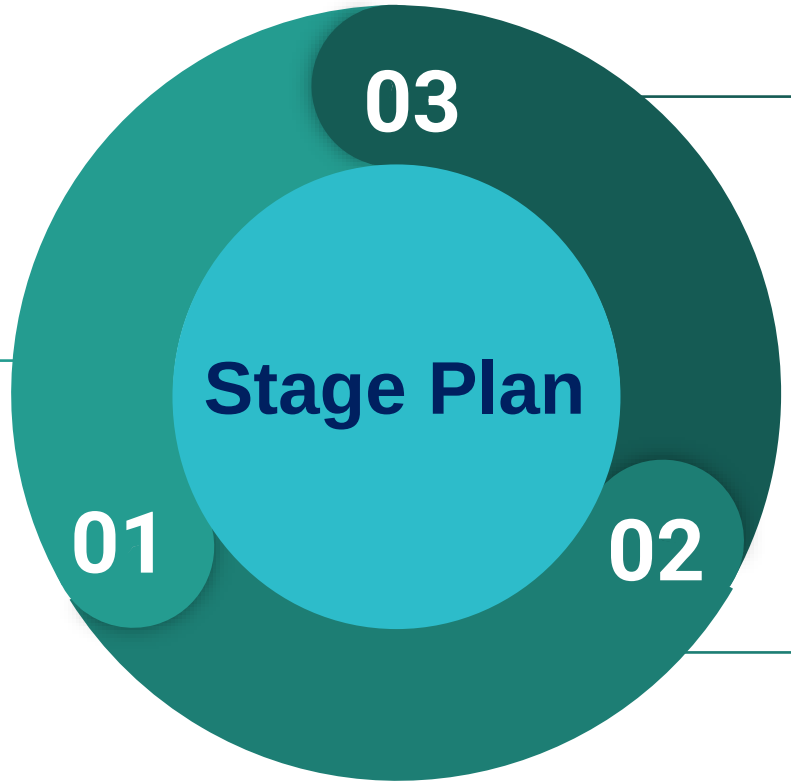
- Vijay Lal Nyachhyon
- Director, MULTI Disciplinary Consultants (P) Ltd.

"It is a novel device and I am looking forward to using it in our heritage conservation project."

Business Plan

Survive-
Initial Product

1. Niche Market
2. Customer Satisfaction



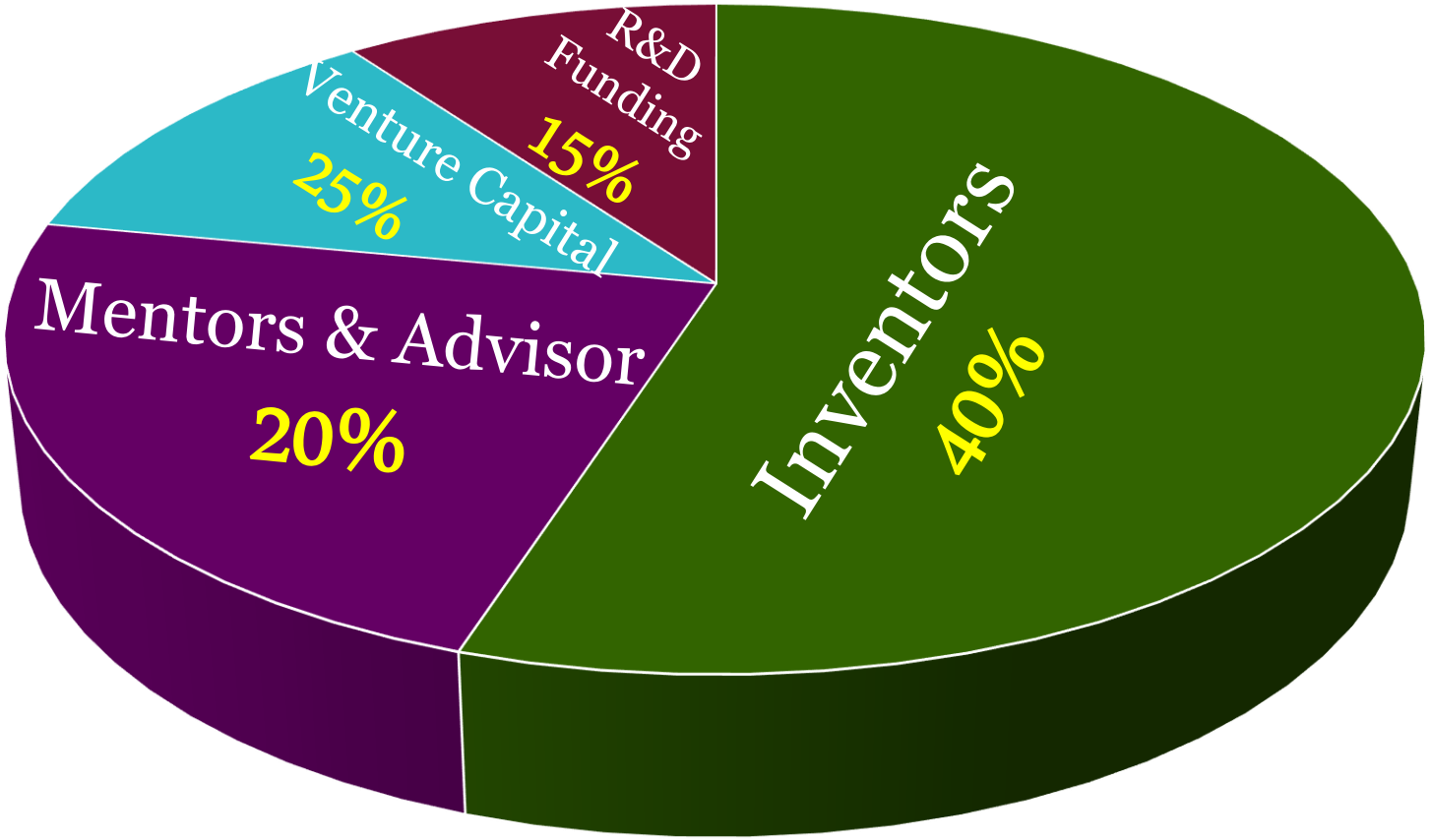
Transform-
Commercialization

1. Mass Production
2. Global Market partnership/Distributorship
3. Adaptation and aggregation

Expand- Incremental Innovation

1. Product Improvement
2. Add new features
3. Target to new markets
4. New Product Development

Capital Investment



Capital Investment

Capital Overview (Unit: USD $)

Lender	Use of capital (Managing cost / Investment in equipment, etc.)	Size of loan	Loan interest	Loan repayment period
Equity	252,000			
Loan	105,000	25%	15%	3 years
Grant	63,000			
Total	**420,000**	26,250		

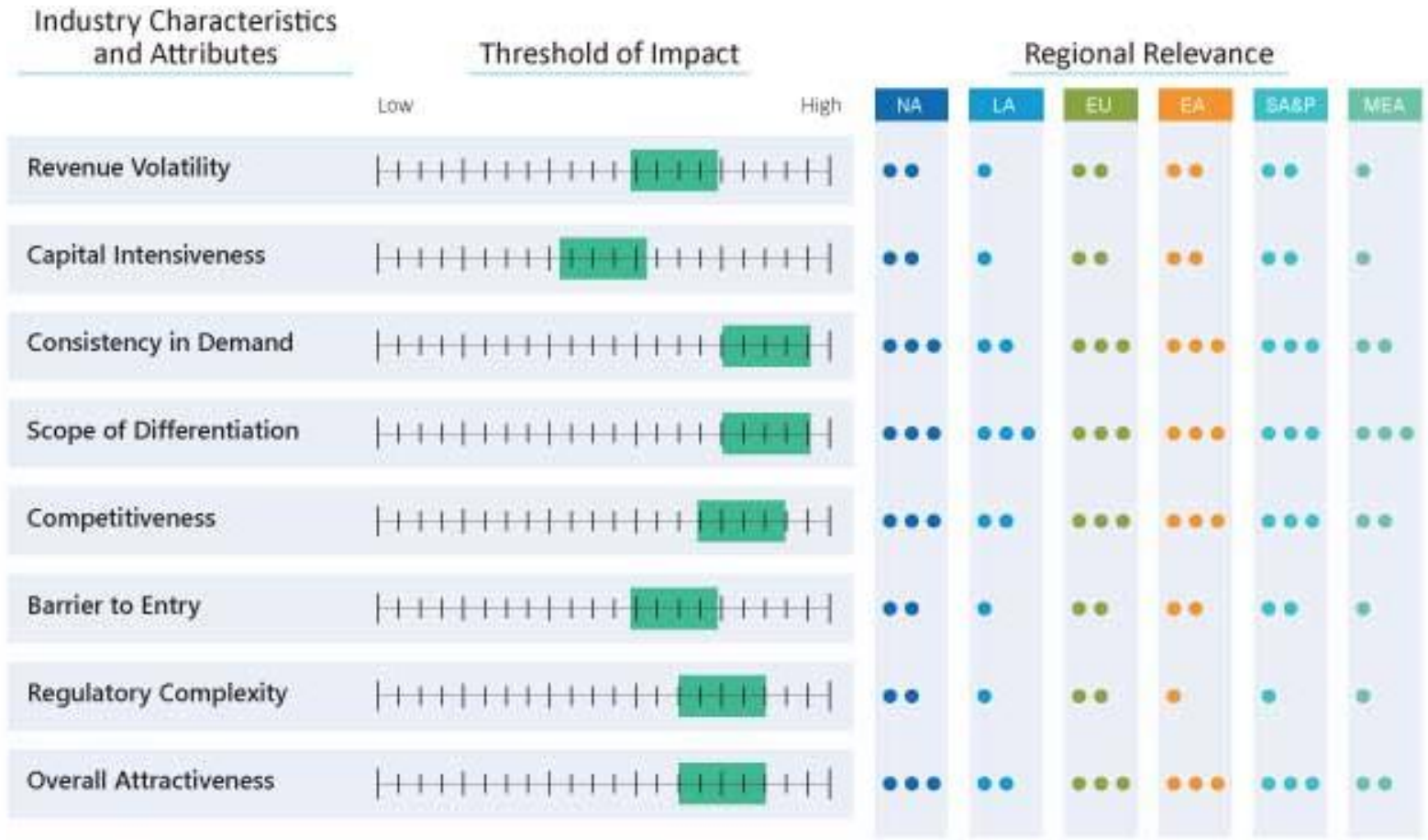
Capital & Financing Plan (Next 3 Years, Unit: USD $)

	Total capital	Financing plan		Major Contribution Source
		Equity capital	Outside capital	
Working capital	**130,000**	**83,000**	**47,000**	**Equity**
Equipment capital	**290,000**	**169,000**	**121,000**	**Loan+Grant+Equity**
Total	**420,000**	**252,000**	**$168,000**	

Performance Plan

Year	Product	Implementation plan Sale Plan			Main Market/Customer
		Number of Units	Per unit price	Total Sales	
1st year 2022	IoT- based Edge computing SHM	10	$5000	$50,000	Heritage Conservation units universities+ construction consultants (**Nepal**)
2nd year	IoT- based Edge computing SHM + Laser-based SHM	40 + 10	$5,000 + $12,000	$200,000 + $120,000	Heritage Conservation units universities+ construction consultants+ Hydropower +oilfield (**Nepal+Bhutan+UAE**)
3rd year	IoT- based Edge computing SHM + Laser-based SHM Restaurant	75 + 30	$6,000 + $14,000	$450,000 + $420,000	Heritage Conservation units universities+ construction consultants+ Hydropower+oilfield+Aeronautics (**Nepal+Bhutan+UAE+ Africa+South East Asia)**

Market Characteristics



SHM market characteristics and attributes with regional relevance, 2021

Source: Future market insights

Target Market

Micro Hydro Plants of Nepal

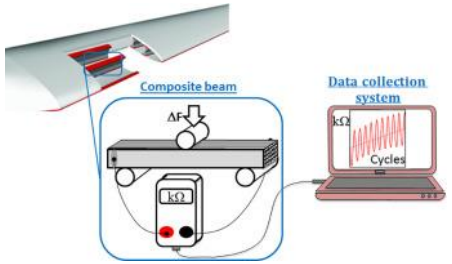
University Laboratory collaboration for Testing Equipment

Oilfield

Heritage Conservation Sites

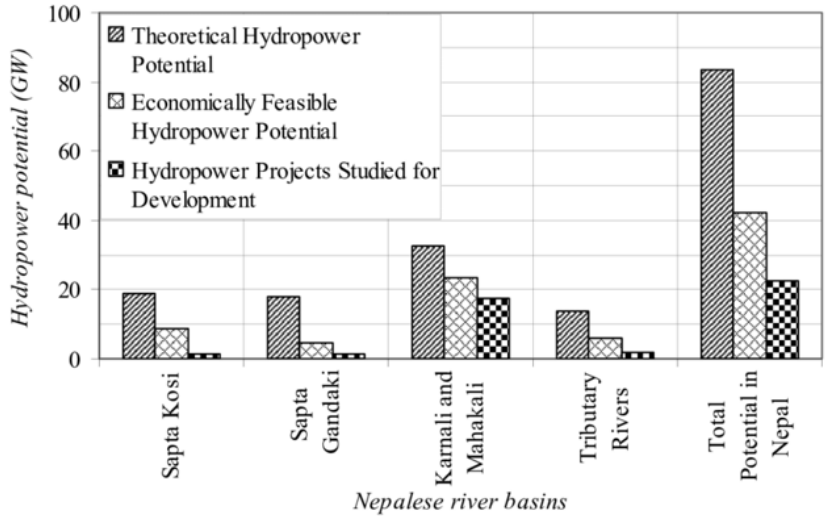
Turbines

Builders and Consultants

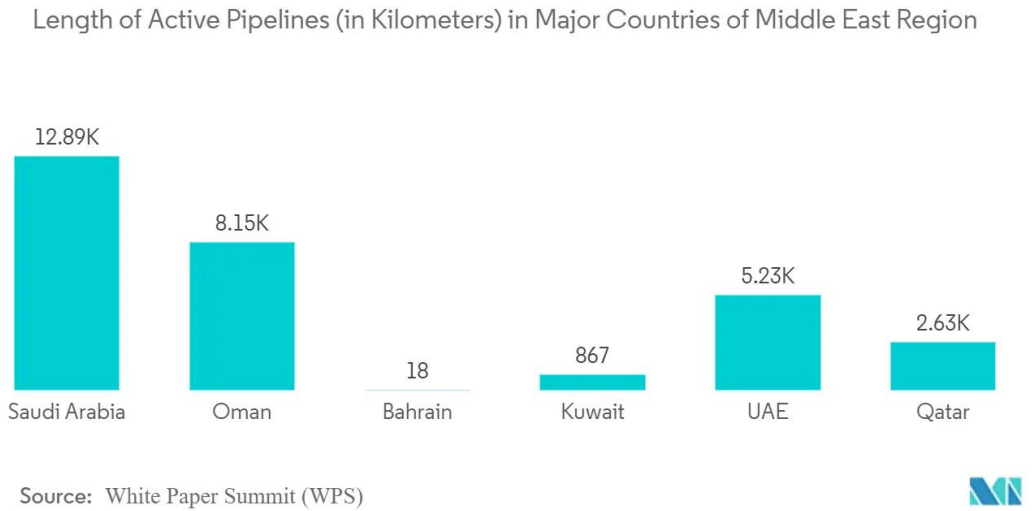


Aeronautical Fields

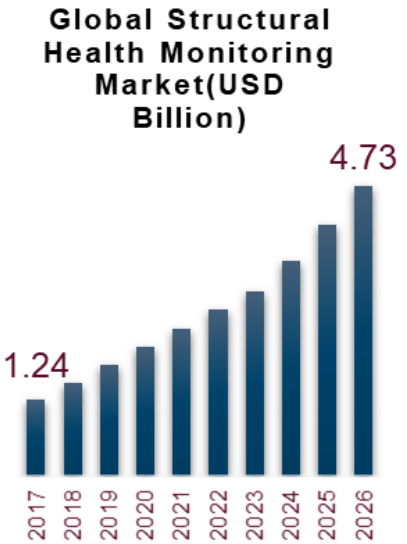
Market Size



Hydro plants capacity in Nepal

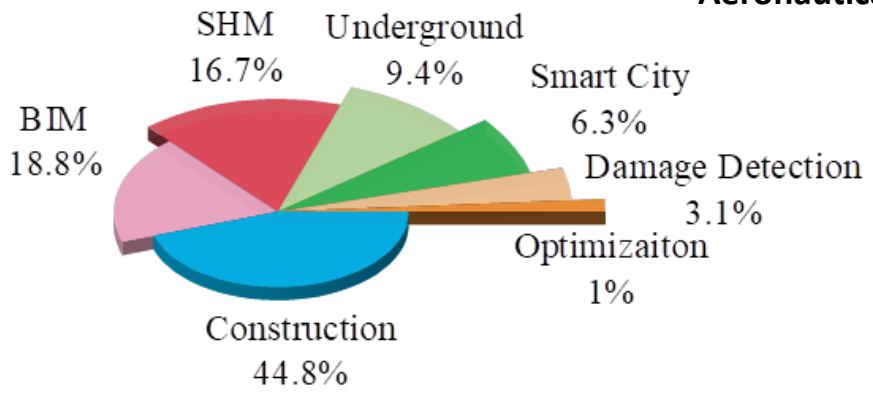


Length of active pipelines in Arab countries especially for oil and gas



Aeronautical Market Size

Turbines Operation and Maintenance market. Source: Data Bridge market Research



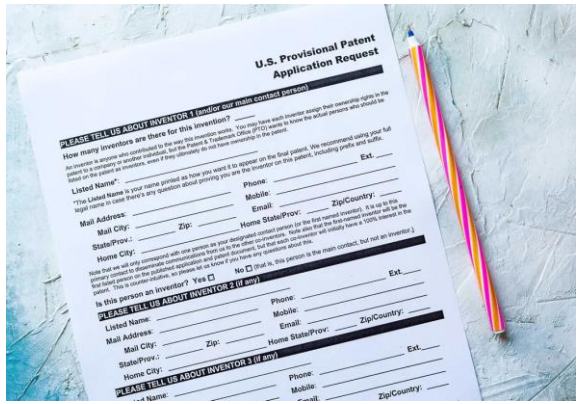
SHM in Construction works source: The university of Mexico research report

Entry Strategy

Exhibition

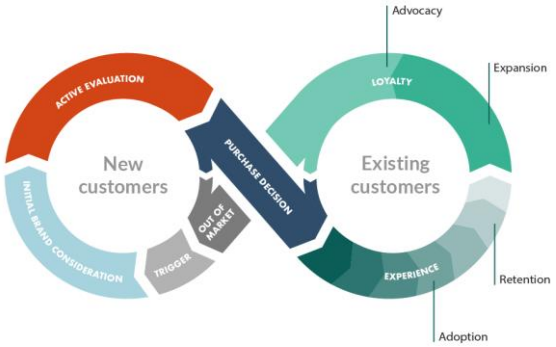
Secure funding

expertreviews
RECOMMENDED



Patent Application

Expansion Strategy



PATENT

2022

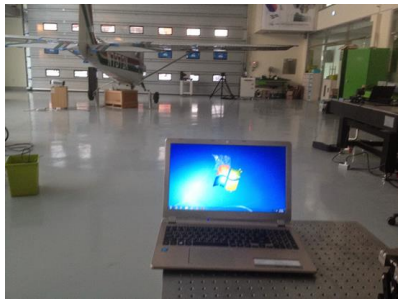
- Patent Filling
- Application for the Industry Standardization
- Secure Financing
- Product showcase, delivery, and customer feedback

2023

- Expanding customer base outside Nepal
- First product delivery of laser-based SHM

2024

- Expand on the capacity
- Upgrade the system with AI and the laser control



Market Penetration → **Technology Maturation** → **Expansion**

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