

Building a Holistic System Demonstrator

Holistic Energy Harvesting Demonstrator

Alex Weddell
11 February 2013

Overview

- Vibration data: a resource for the community
- Introducing the application
- System requirements
- Detail of prototype design
- Test results
- The finished prototype in operation



Why?

- Nobody has deployed a tuneable energy harvester!
- Little data on real vibration dynamics
- By defining a real application, we find out what the real challenges are! Addressed by other themes
- Demands a 'holistic' view of the whole system...



Vibration Data

- No repository for long-term vibration data
- Only tables of 'typical' values
- Are they consistent?

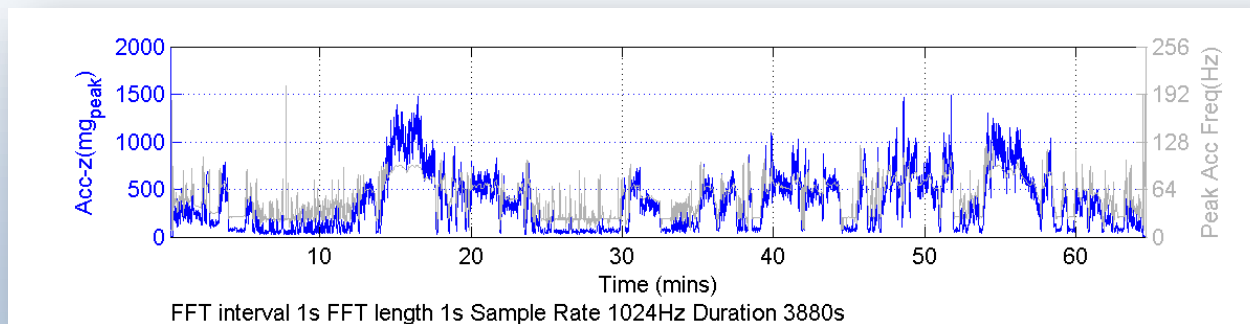
Vibration source	A (m/s ²)	F_{peak}
Car engine compartment	12	200
Base of 3-axis machine tool	10	70
Blender casing	6.4	121
Clothes dryer	3.5	121
Person nervously tapping their heel	3	1
Car instrument panel	3	13
Door frame just after door closes	3	125
Small microwave oven	2.5	121
HVAC vents in office building	0.2–1.5	60
Windows next to a busy road	0.7	100
CD on notebook computer	0.6	75
Second story floor of busy office	0.2	100

Vibration Data

- First steps: looking at real, long-term vibration...

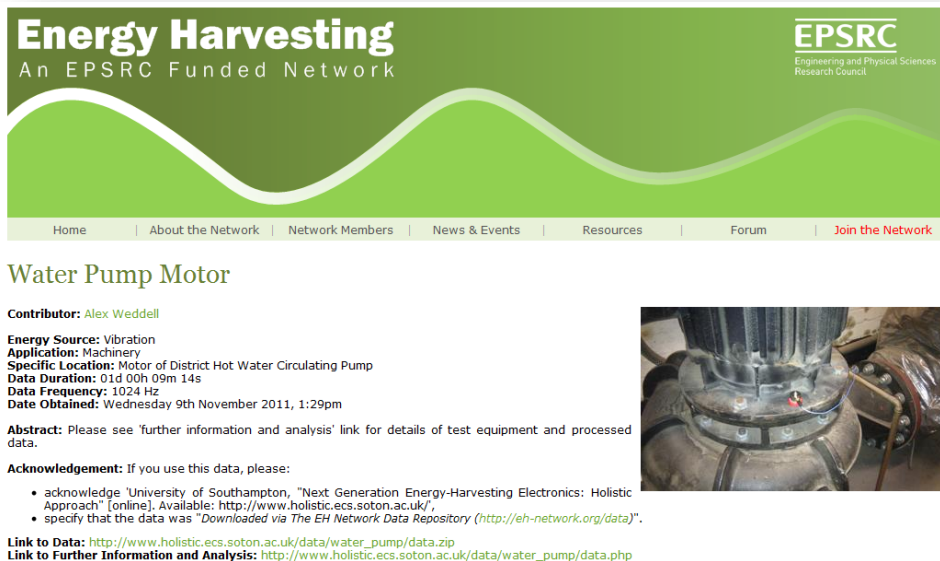


- Looking at *dynamics* of vibration aids design process



Vibration Data

- An important resource for the community
- Available free of charge for download from the “Energy Harvesting Network” resources page



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Water Pump Motor

Contributor: Alex Weddell


Energy Source: Vibration
Application: Machinery
Specific Location: Motor of District Hot Water Circulating Pump
Data Duration: 01d 00h 09m 14s
Data Frequency: 1024 Hz
Date Obtained: Wednesday 9th November 2011, 1:29pm

Abstract: Please see 'further information and analysis' link for details of test equipment and processed data.

Acknowledgement: If you use this data, please:

- acknowledge 'University of Southampton, "Next Generation Energy-Harvesting Electronics: Holistic Approach" [online]. Available: <http://www.holistic.ecs.soton.ac.uk/>,
- specify that the data was "Downloaded via The EH Network Data Repository (<http://eh-network.org/data/>)".

Link to Data: http://www.holistic.ecs.soton.ac.uk/data/water_pump/data.zip
Link to Further Information and Analysis: http://www.holistic.ecs.soton.ac.uk/data/water_pump/data.php




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Shock Absorber Casing

Contributor: Alex Weddell

Energy Source: Vibration
Application: Machinery
Specific Location: Shock Absorber Casing (Front LHS) on 1999 Ford Focus 1.6 Petrol
Data Duration: 01d 00h 09m 14s
Data Frequency: 1024 Hz
Date Obtained: Wednesday 9th November 2011, 9:31am

Abstract: Please see 'further information and analysis' link for details of test equipment and processed data.

Acknowledgement: If you use this data, please:

- acknowledge 'University of Southampton, "Next Generation Energy-Harvesting Electronics: Holistic Approach" [online]. Available: <http://www.holistic.ecs.soton.ac.uk/>,
- specify that the data was "Downloaded via The EH Network Data Repository (<http://eh-network.org/data/>)".

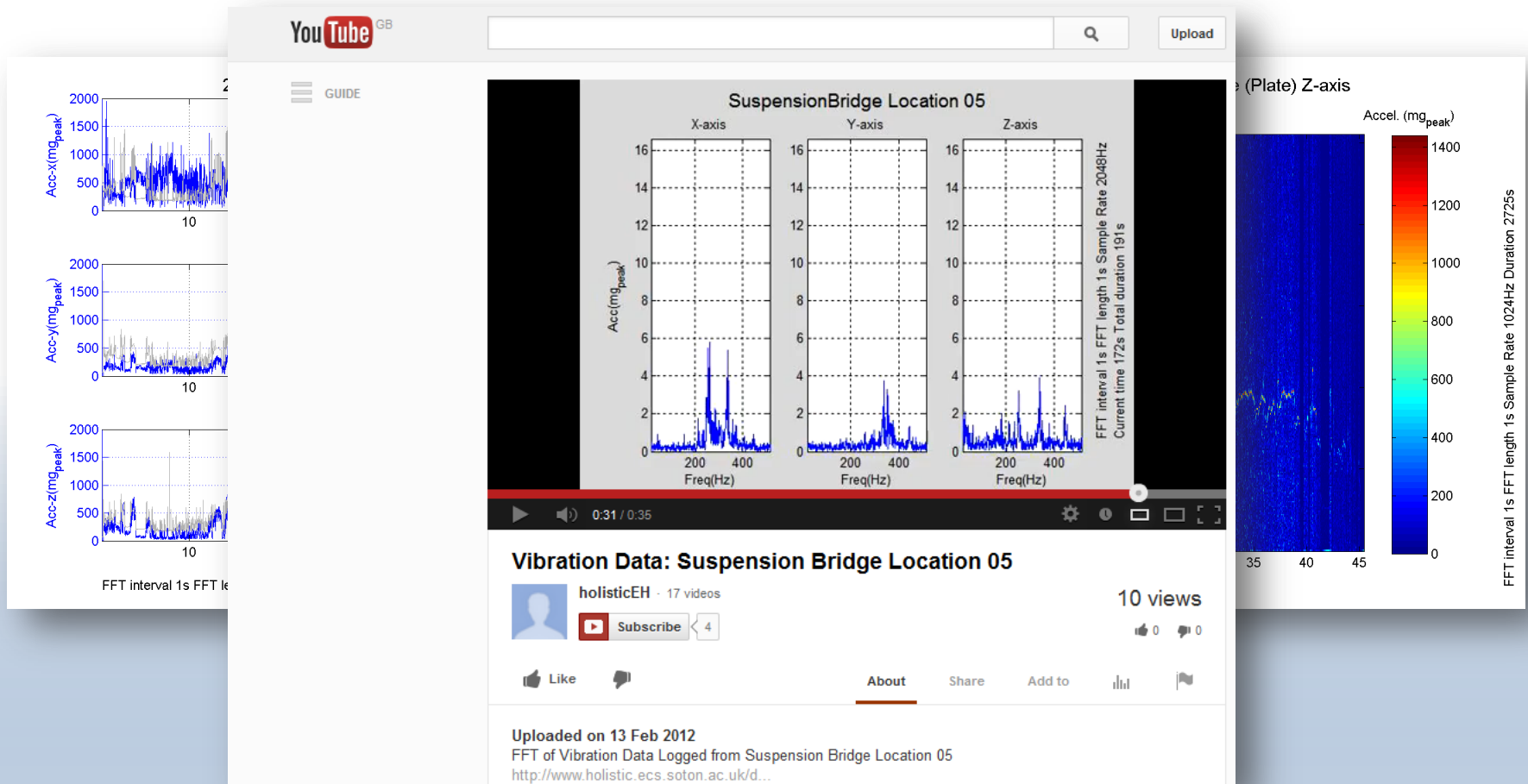
Link to Data: http://www.holistic.ecs.soton.ac.uk/data/focus_shock_absorber/data.zip
Link to Further Information and Analysis: http://www.holistic.ecs.soton.ac.uk/data/focus_shock_absorber/data.php



www.eh-network.org

Vibration Data

- Data available raw, and...



The image shows a YouTube video player with the following content:

- Video Title:** Vibration Data: Suspension Bridge Location 05
- Channel:** holisticEH - 17 videos
- Views:** 10 views
- Upload Date:** 13 Feb 2012
- Description:** FFT of Vibration Data Logged from Suspension Bridge Location 05
<http://www.holistic.ecs.soton.ac.uk/d...>

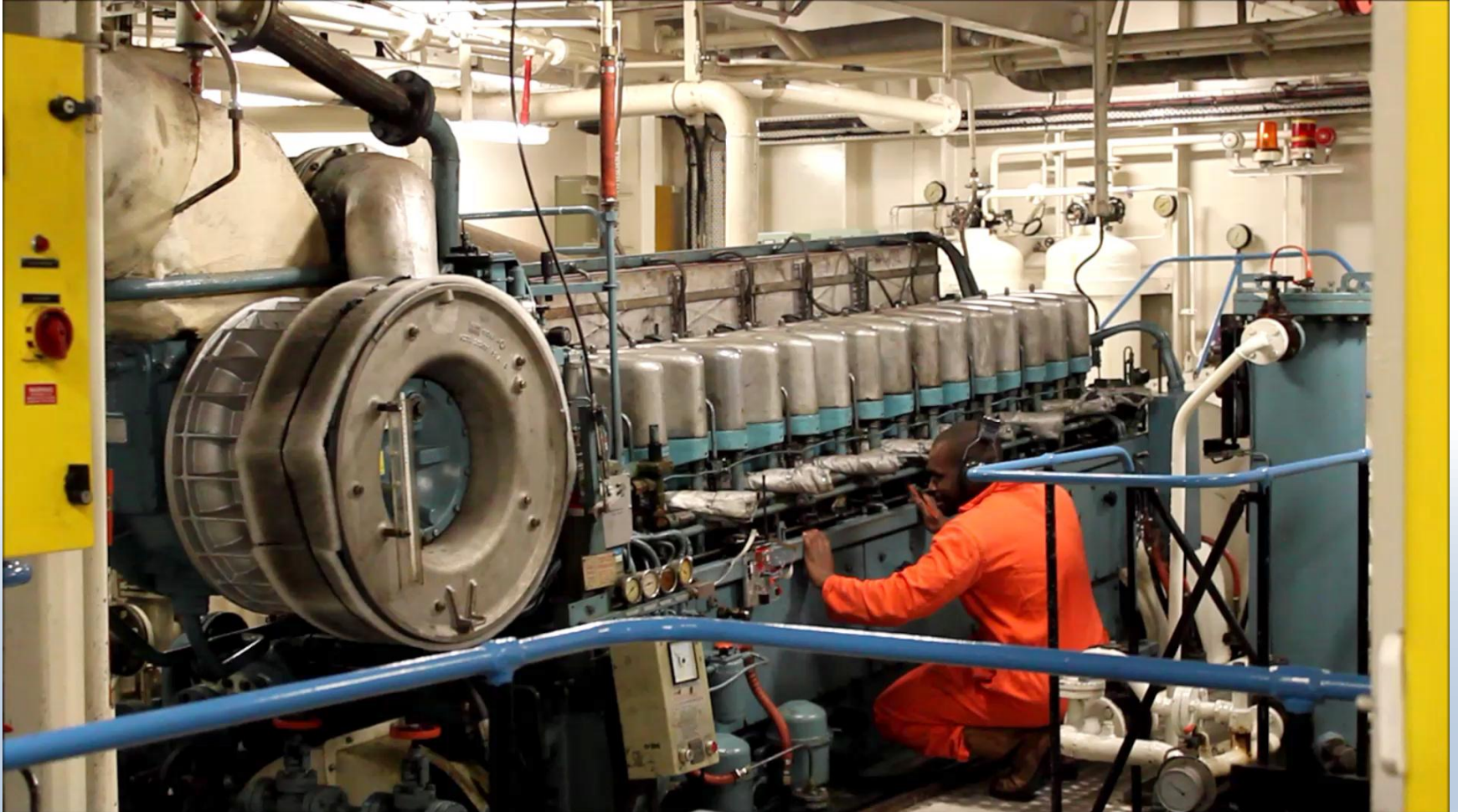
The video content includes:

- Time-Domain Plots:** Three plots showing acceleration (Acc) in mg_{peak} over time (0 to 10 seconds) for the X-axis, Y-axis, and Z-axis.
- Frequency-Domain Plots (FFT):** Three plots showing acceleration (Acc) in mg_{peak} versus frequency (Freq) in Hz (0 to 400 Hz) for the X-axis, Y-axis, and Z-axis.
- Color Scale:** A vertical color scale for acceleration (mg_{peak}) ranging from 0 (blue) to 1400 (red).
- Technical Parameters:** FFT interval 1s, FFT length 1024Hz, Duration 2725s.

Application



Application

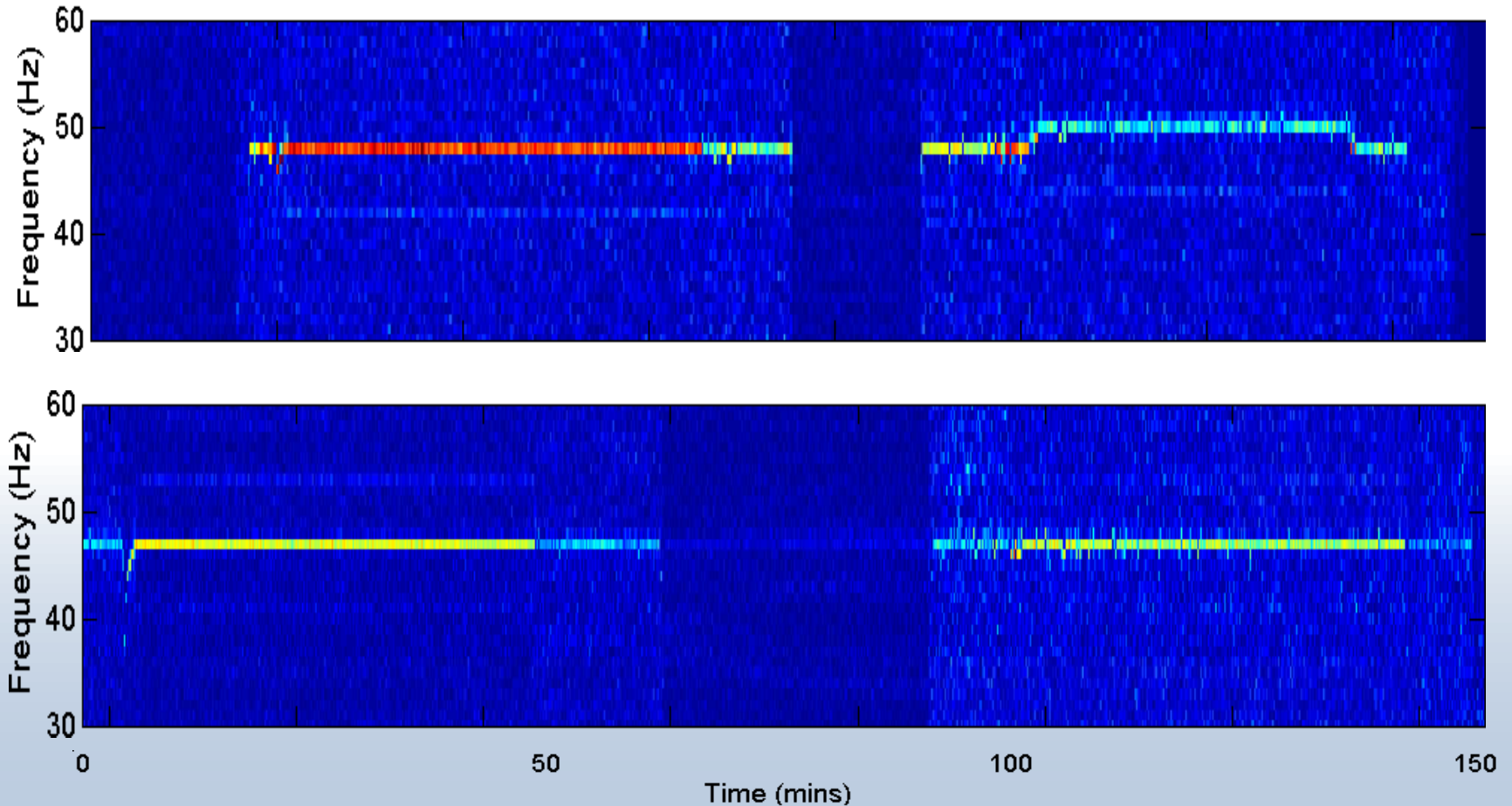


Application

- Condition monitoring of a main engine
 - Voith-Schneider propulsion
 - 4 'fixed' engine speeds
 - Speeds drift over time, mechanically set
- Engine condition monitoring
 - Monitor vibration and temperature
 - e.g. detect bearing wear, imbalance
- Transmit wirelessly – no cabling to install
- Harvest energy from vibration at various frequencies



Data from Two Ferries



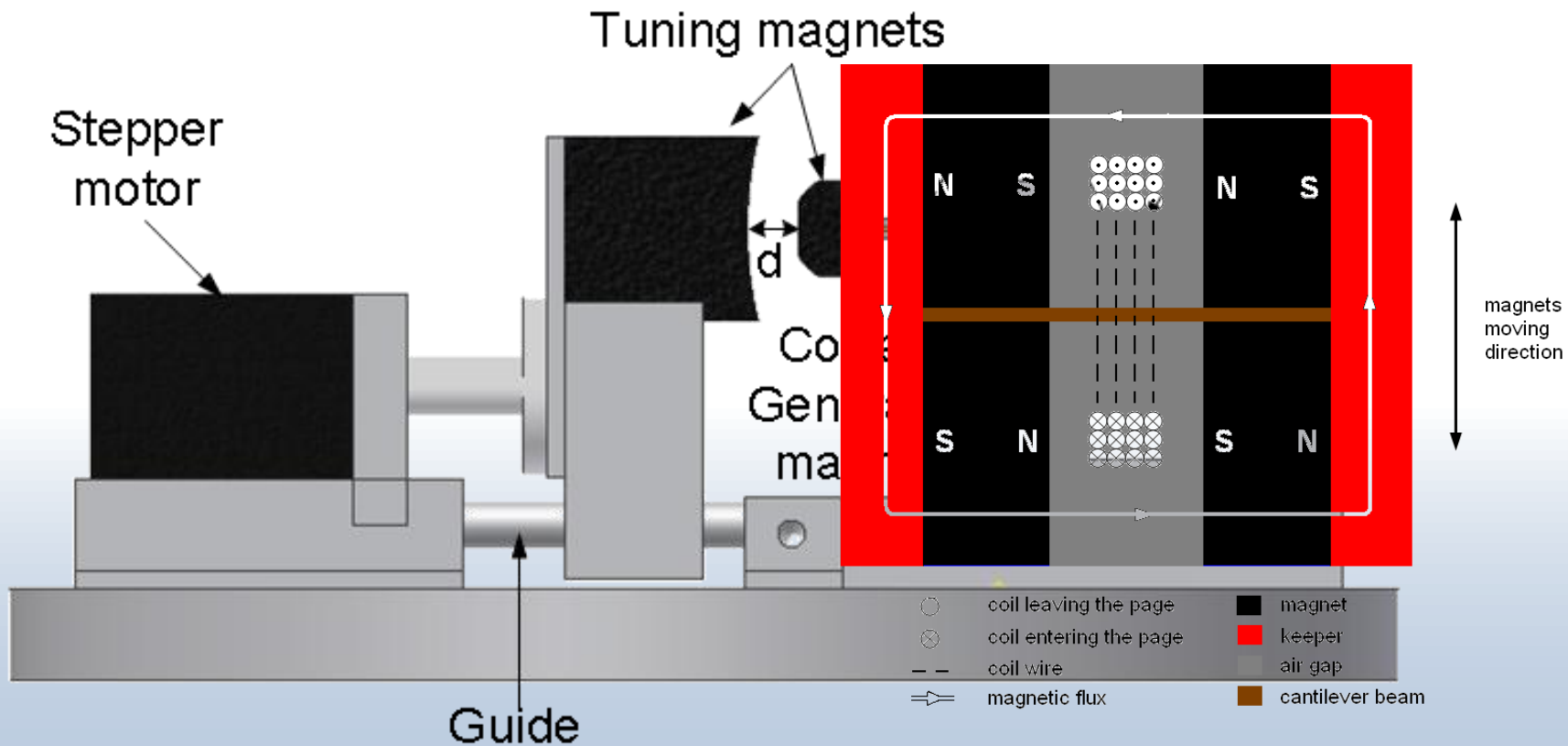
Red = 1000 mg_{pk}

System Requirements

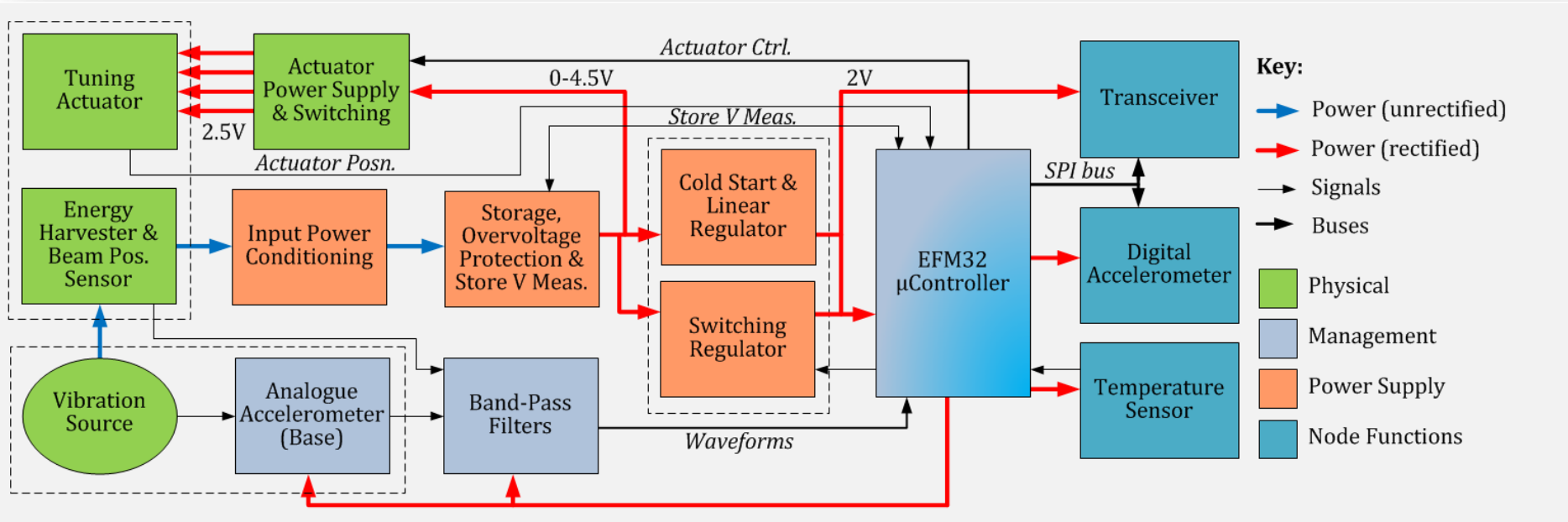
- Wireless sensor to operate on a ferry engine
 - Able to sense vibration/temperature and transmit
- Tuneable harvester
 - Frequency range: 42-55Hz
 - Max Amplitude $1.5 g_{pk}$
- Approx. energy budget: 1mW
- Able to cold-start
- Adaptive operation



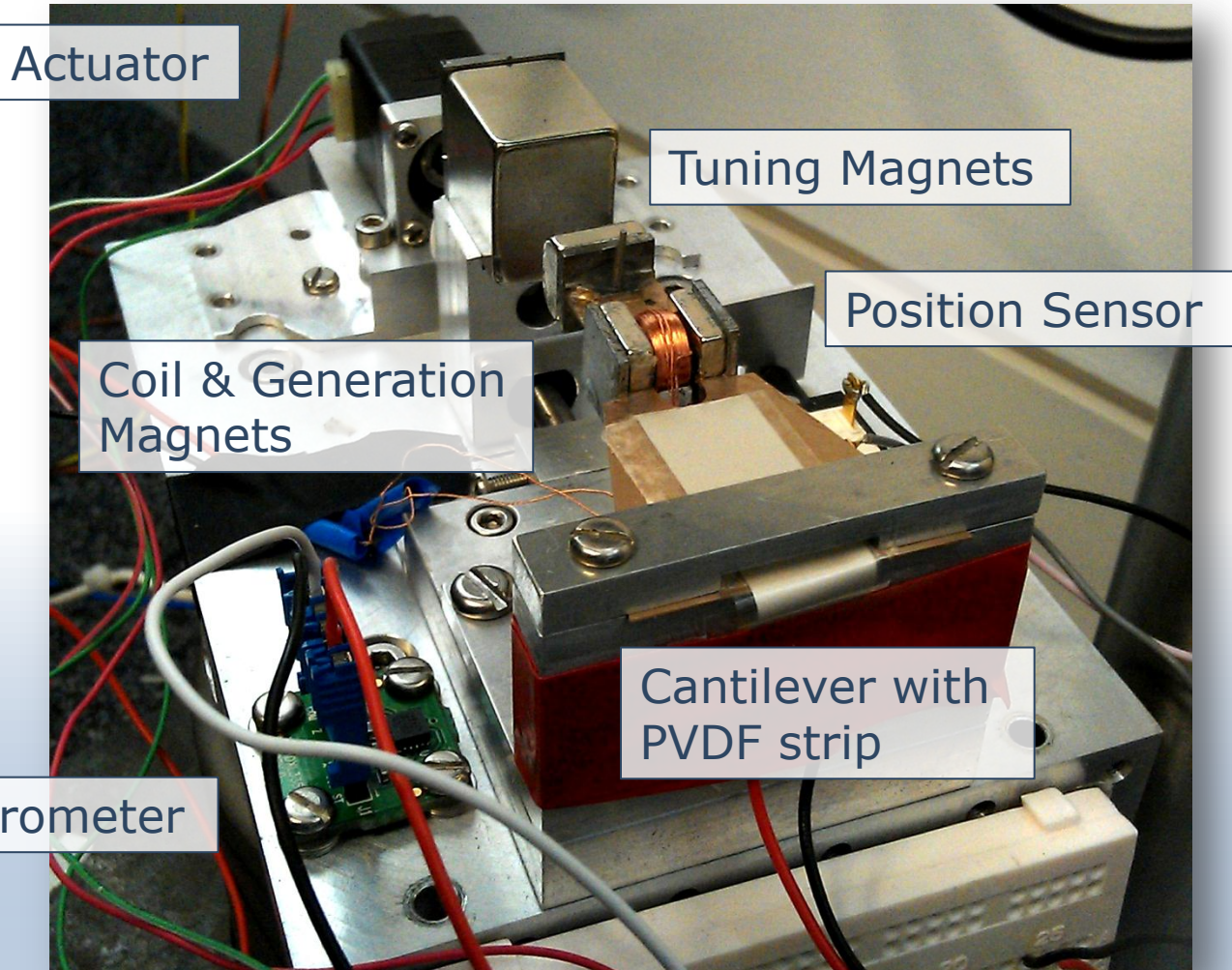
Tuneable Generator Design



System Topology

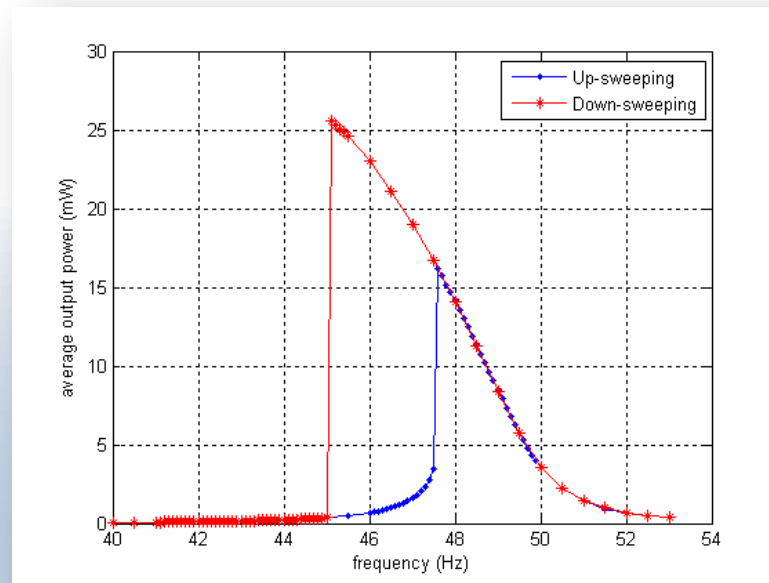


Tuneable Generator



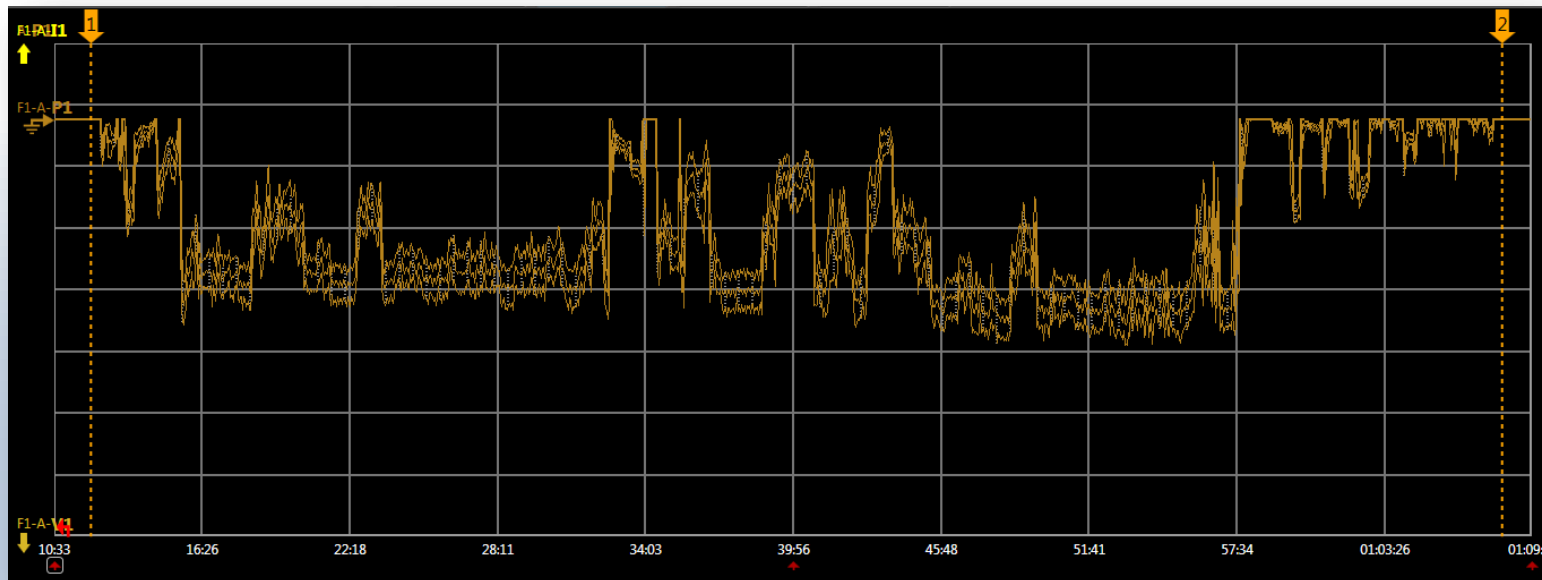
Challenges

- Amplitude and frequency changes
- Tuning – the 'cliff edge'
- Resilience to high vibration levels

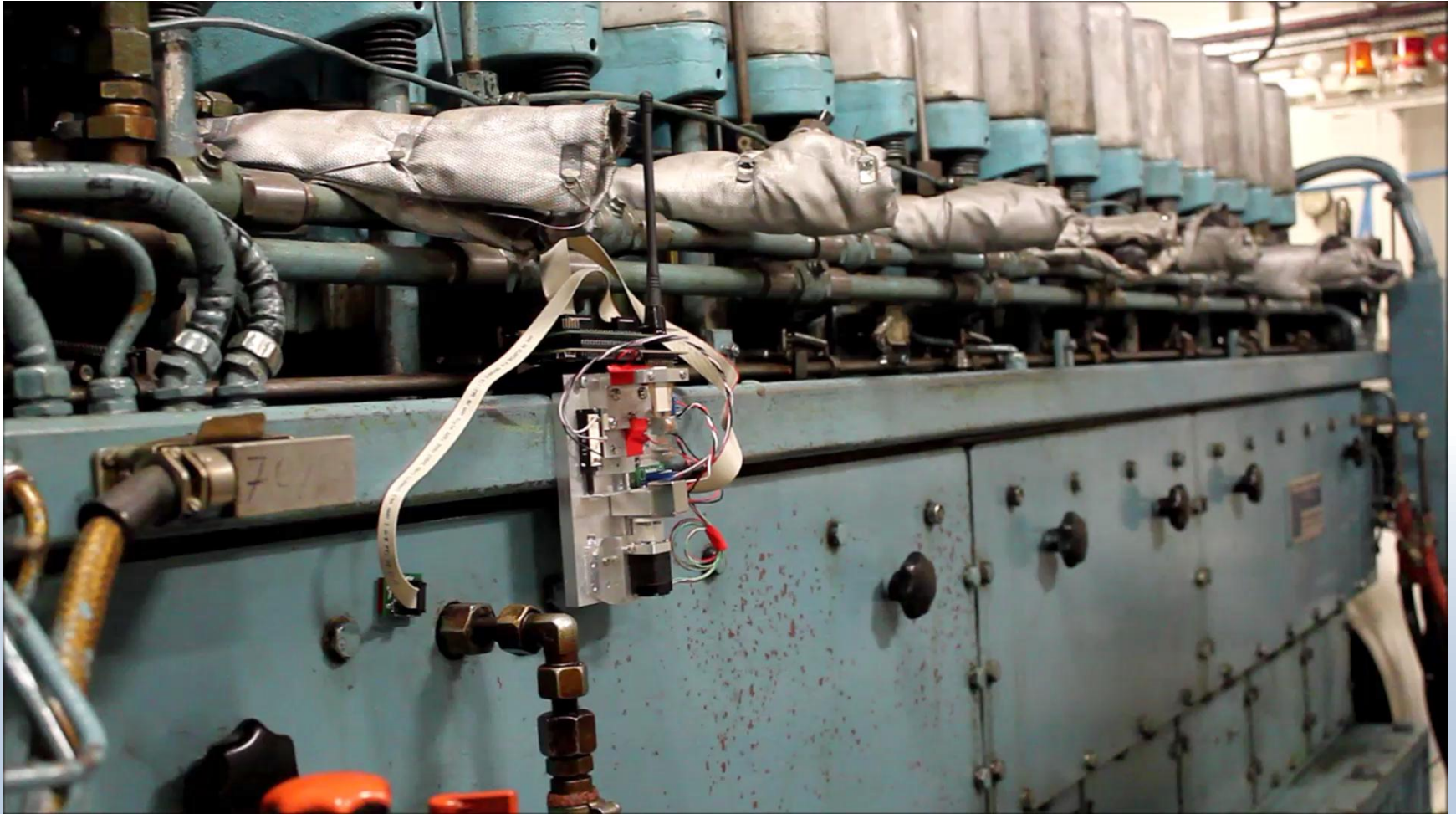


Results

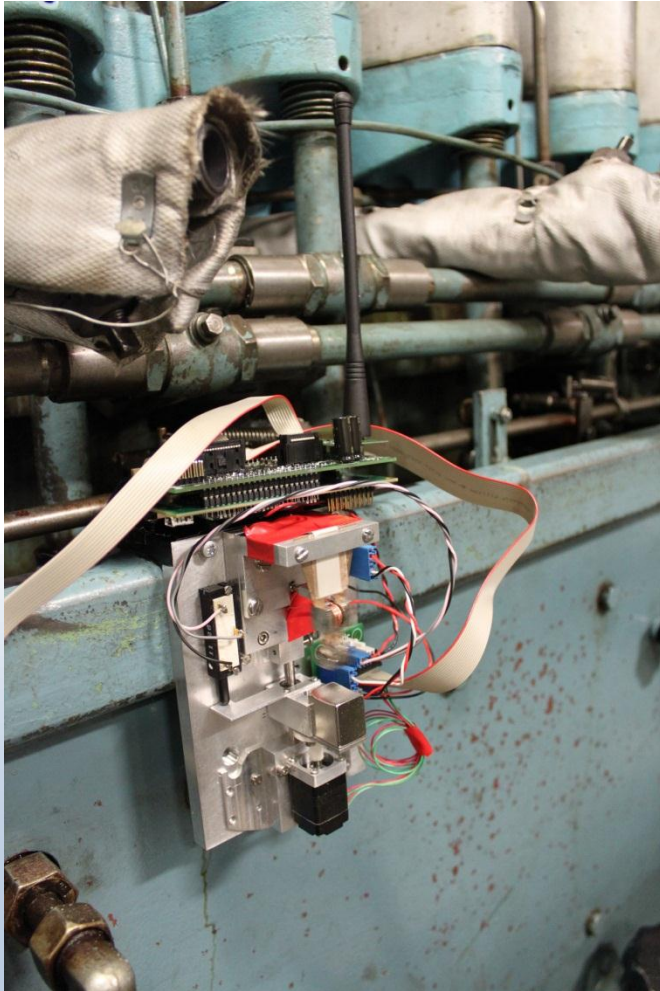
- Automatically tuned (update every 30 s)
- Bridge rectifier into 3.0 V load (SMU)
- Power: average 3.8 mW, peak 7.9 mW
- Against average 2.2 mW, peak 8.1 mW (no tuning)



The Finished Prototype



The Finished Prototype



- Tuneable energy harvester
- Able to cold-start and control its own operation
- Able to sense and transmit wirelessly
- Harvests $\sim 3.8\text{mW}$
- Adaptive operation
- First deployment of a tuneable energy harvester!

Acknowledgment



Questions?

