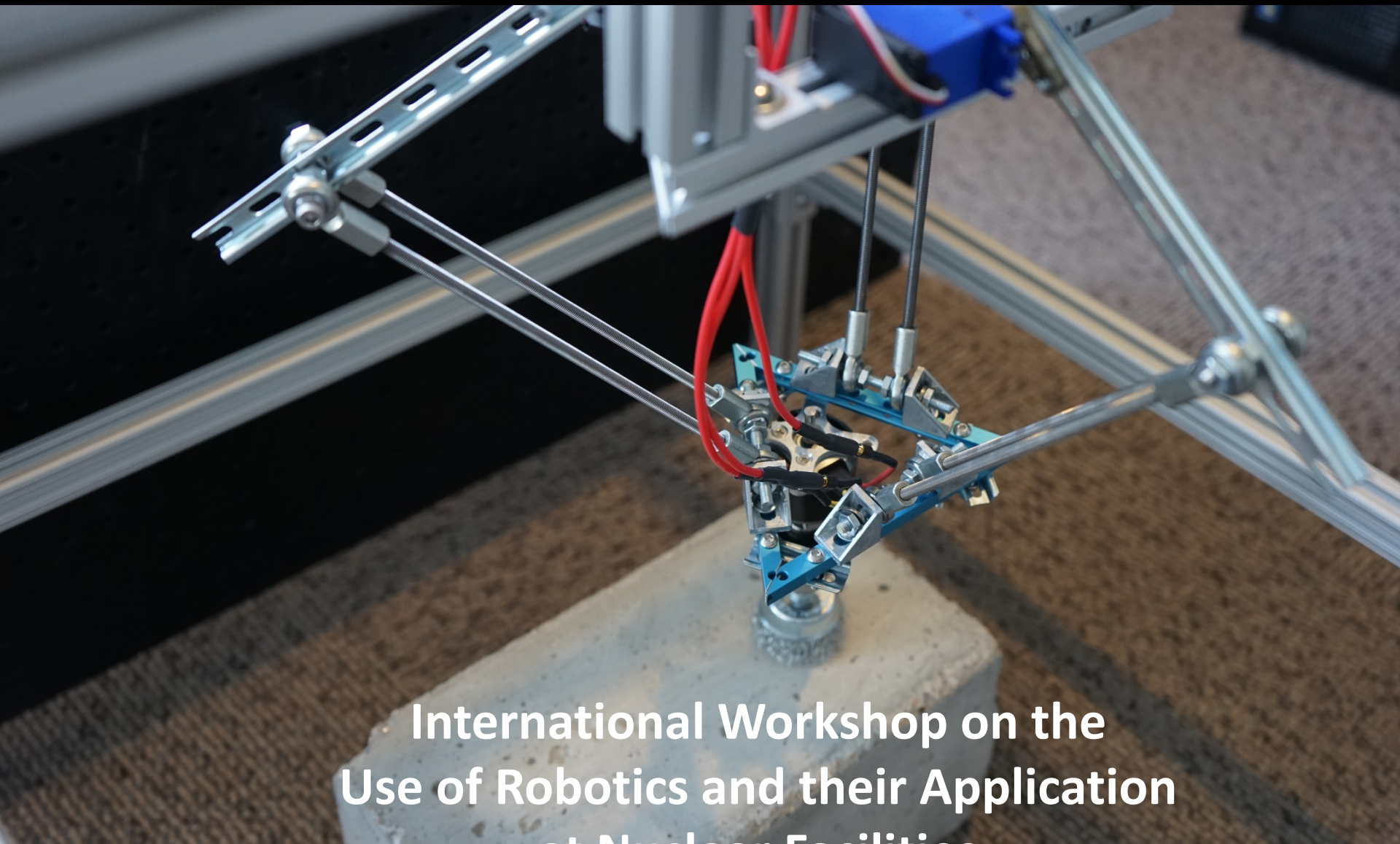
Robotic Research at the LANL Engineering Institute

David Mascarenas



International Workshop on the Use of Robotics and their Application

LANL Research related to Remote Sensor Deployment with Aerial Robots

- Ability to fly indoors to collect samples and data
  - Silicon-Retina based transparent barrier detection
  - NaI detector code written for flight.

- Robotic Inspection and repair of Nuclear Infrastructure
  - Tap-testing on aerial robotic platforms
  - Ultrasonic excitation for the Remote sensor deployment device
  - Extending Human Proprioception to robotic manipulators
  - Prototype delta-machine underway to enable repair using aerial robots

- Robot Teaming / Human Machine Interface
  - Artificial Personality Synthesis for diverse, robust teams of robots
  - Besso Project (National Academy of Engineering Keck Conference 2015)
- Extracting Dynamics from video

Silicon–Retina based system for transparent barrier detection

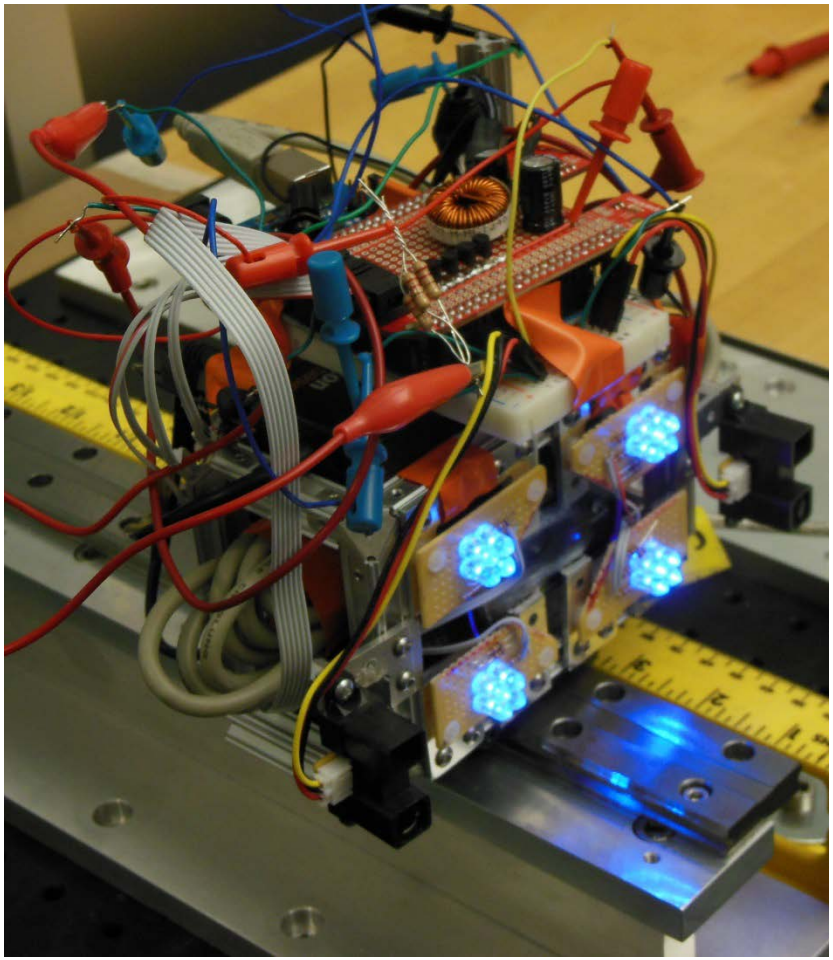
Birds have both high-quality vision as well as high-performance flight capabilities.

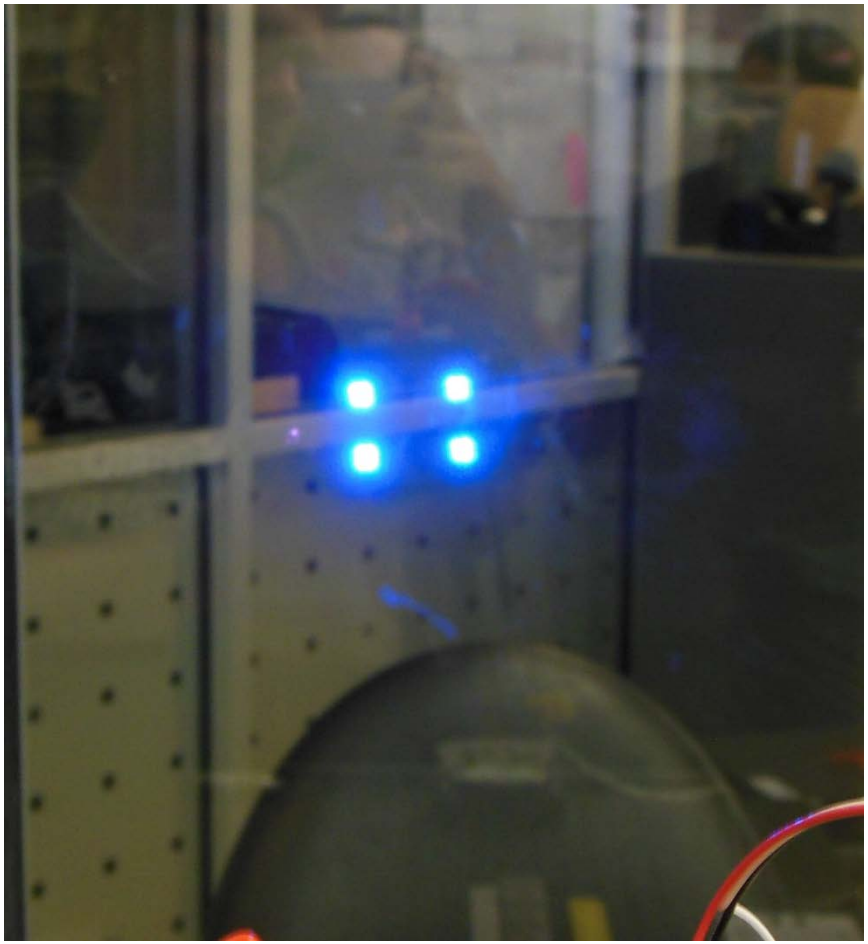
However it is estimated that 100s of millions of birds die each year impacting transparent barriers.

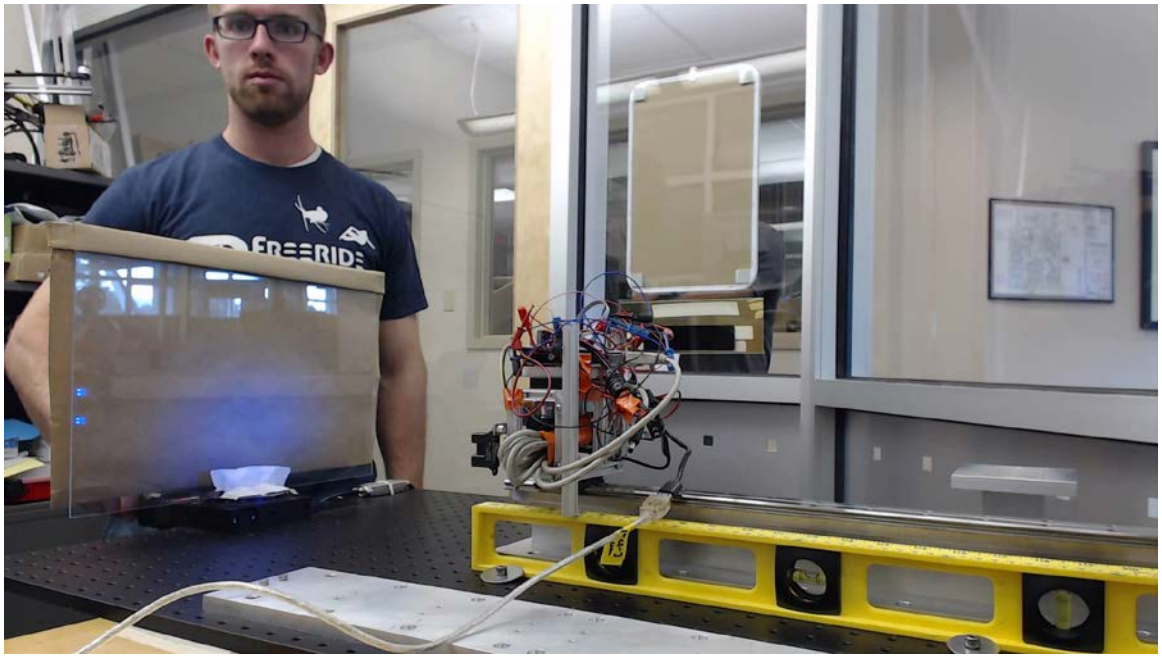
https://en.wikipedia.org/wiki/Peregrine_falcon#/media/File:Peregrine_Falcon_head_shot.jpg

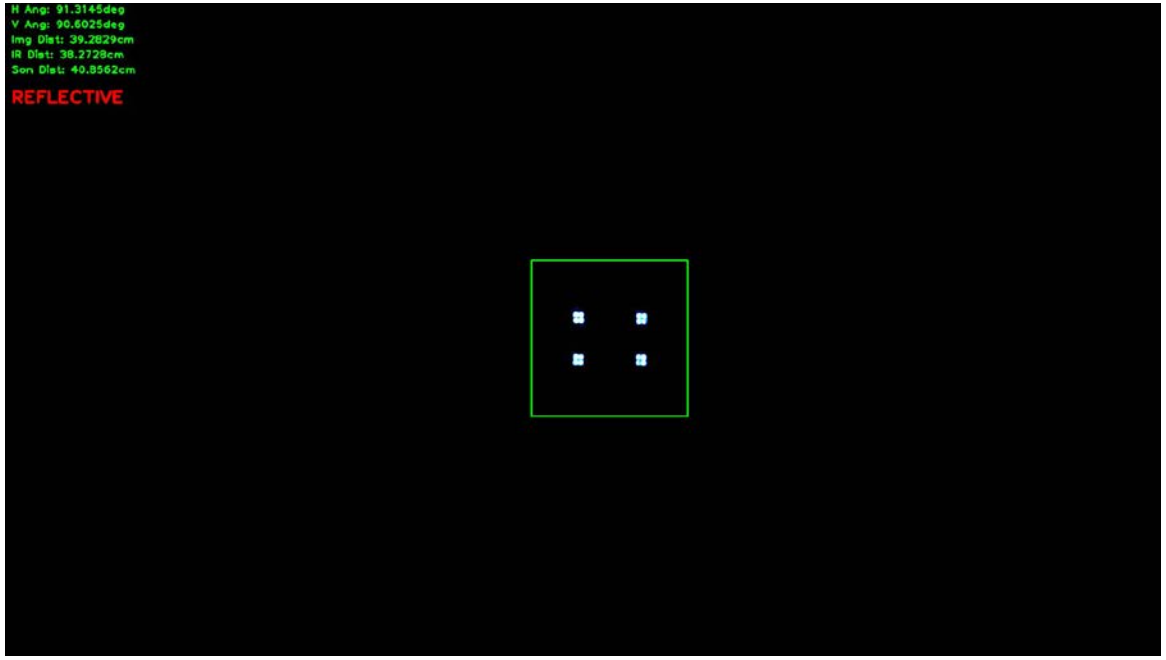
Transparent Barriers are a common obstacle when navigating indoor environments

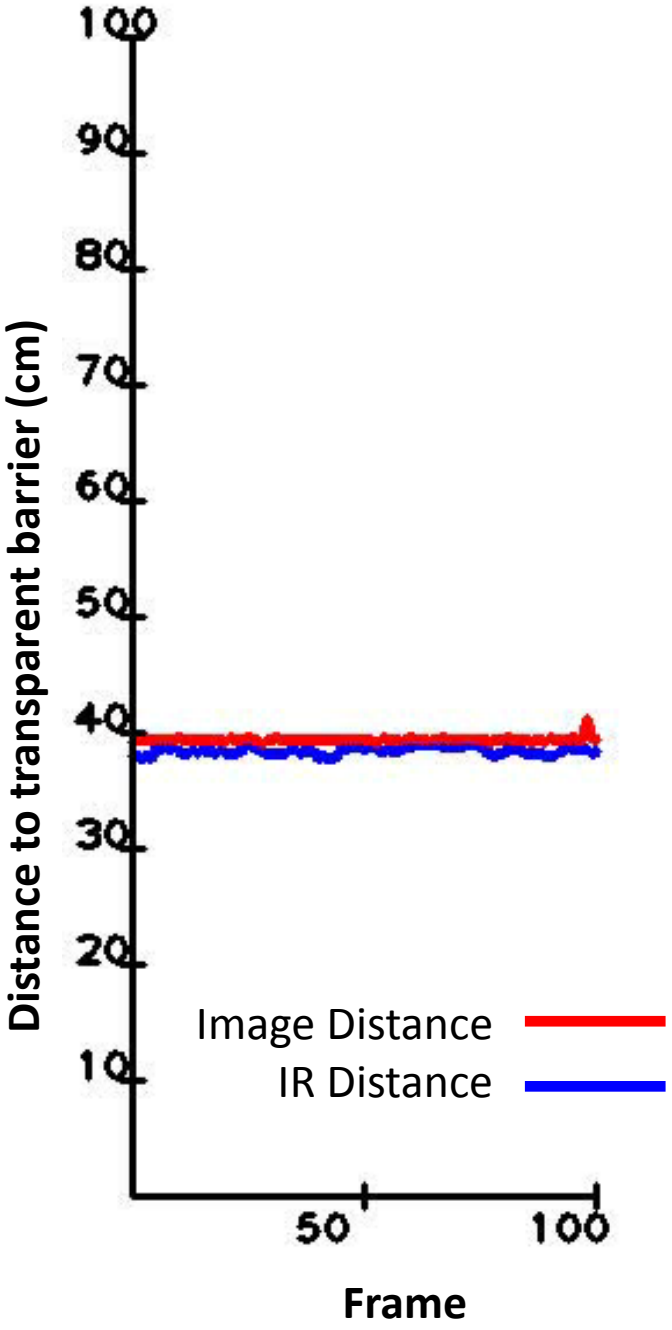
General Concept – DSS 2014



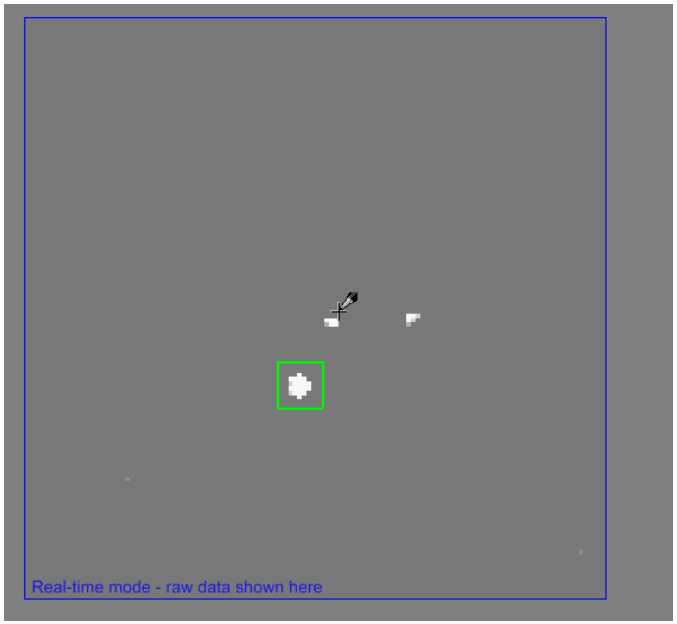


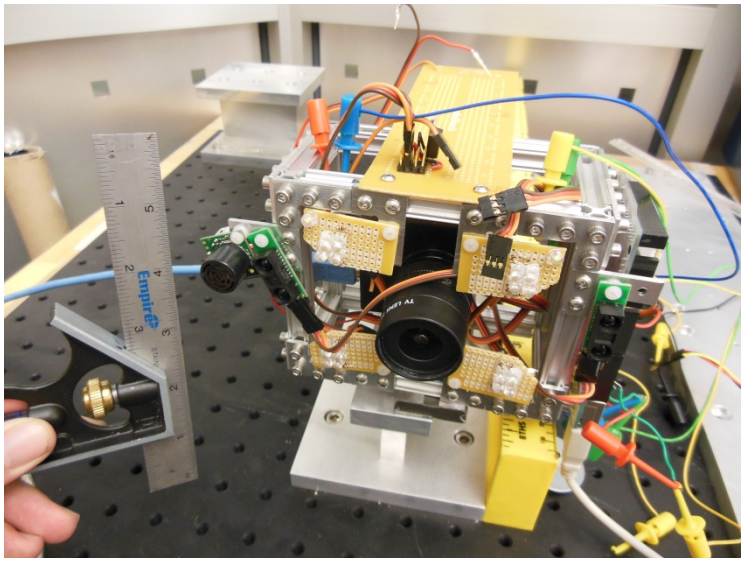


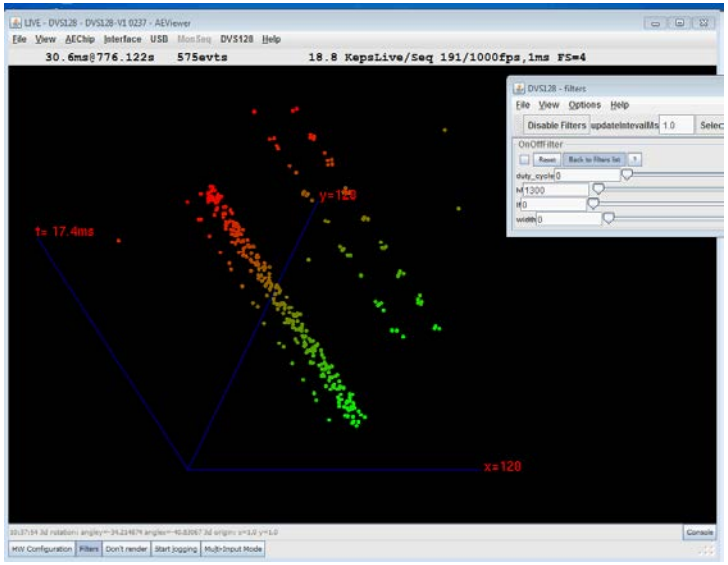

H Ang: 91.3145deg
V Ang: 90.6025deg
Img Dist: 39.2829cm
IR Dist: 38.2728cm
Son Dist: 40.8562cm
REFLECTIVE

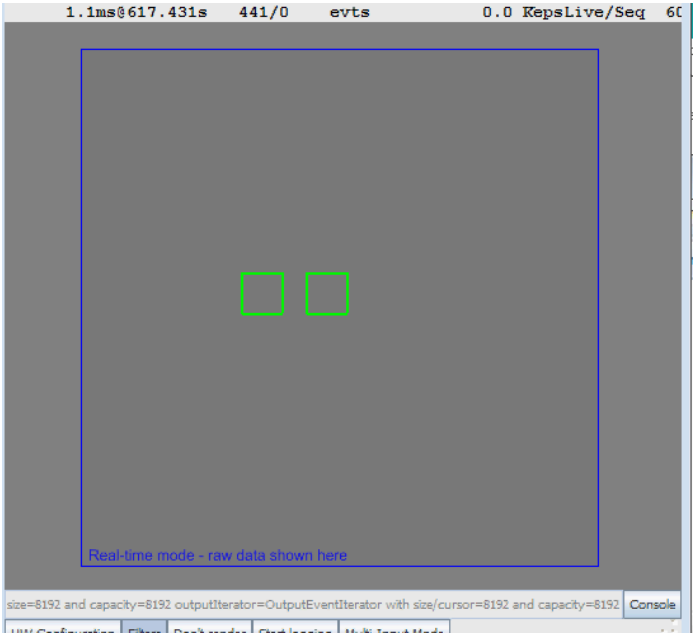

Distance to transparent barrier (cm)
100
90
80
70
60
50
40
30
20
10
Image Distance
IR Distance
50
100
Frame

Highly responsive silicon retina enabled transparent barrier detection



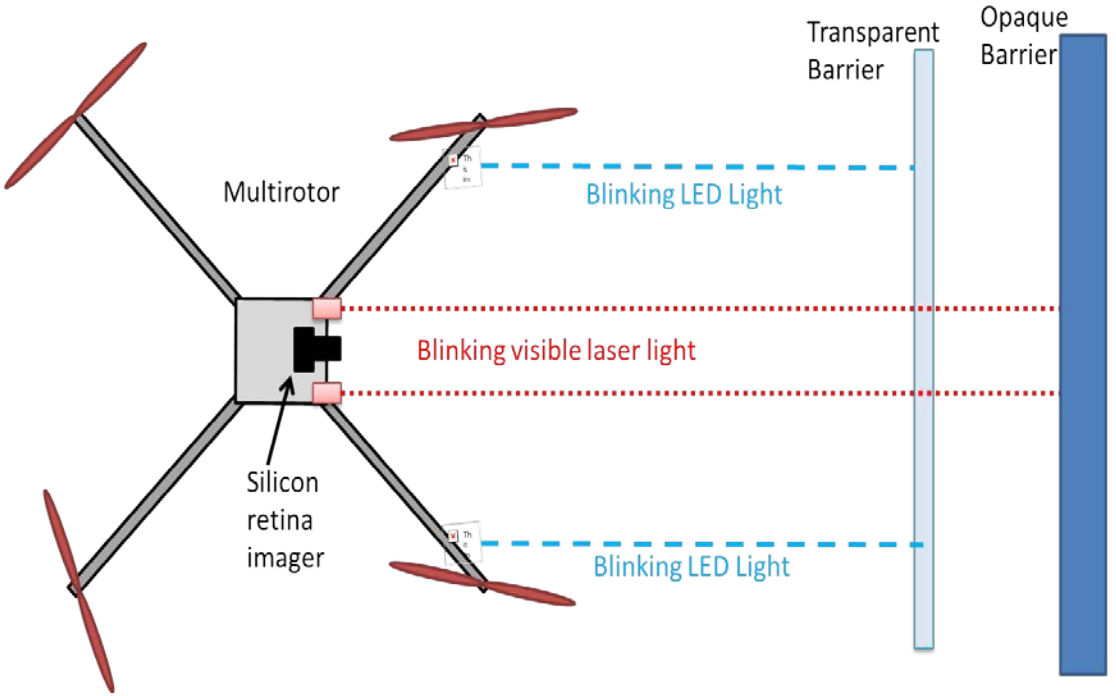




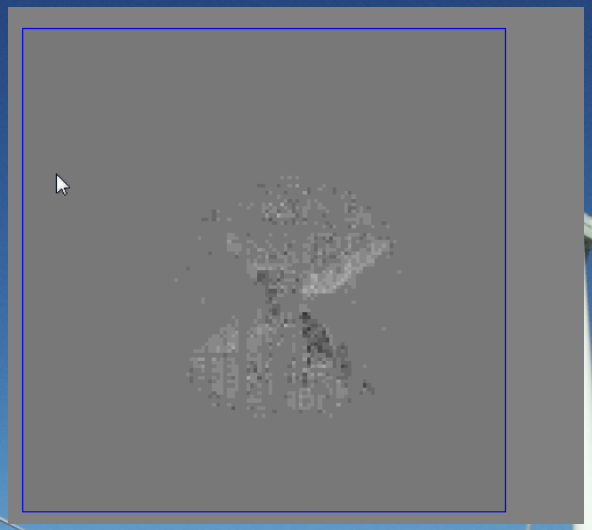


Silicon–Retina based system for transparent barrier detection

Solving this problem requires developing a mult-modal sensing strategy that is also highly responsive

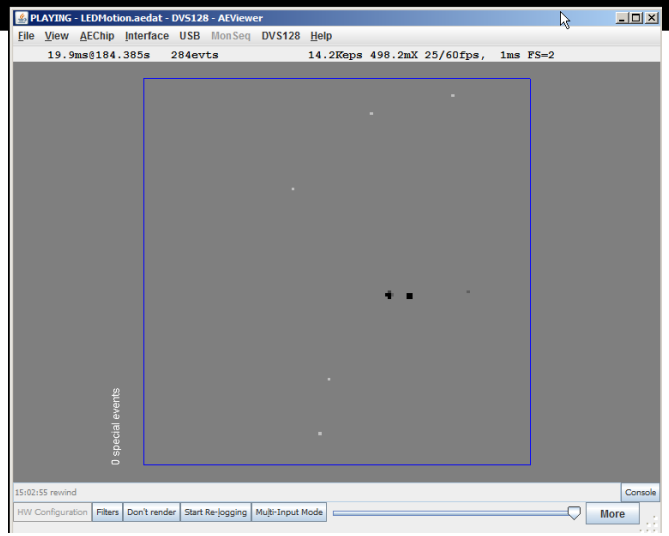


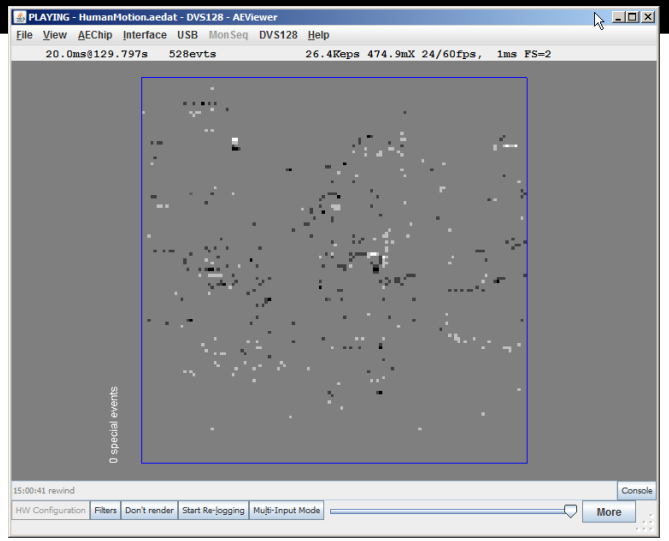
Infrastructure Health Monitoring with the silicon retina

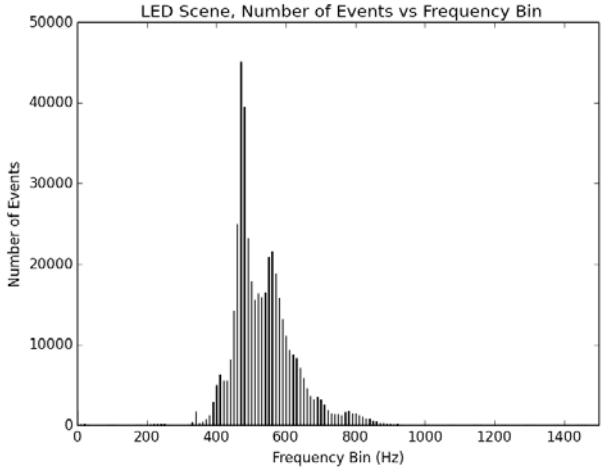


Event domain signal processing theory we learn will help us reduce power, memory and bandwidth considerations for conventional sensor networks.

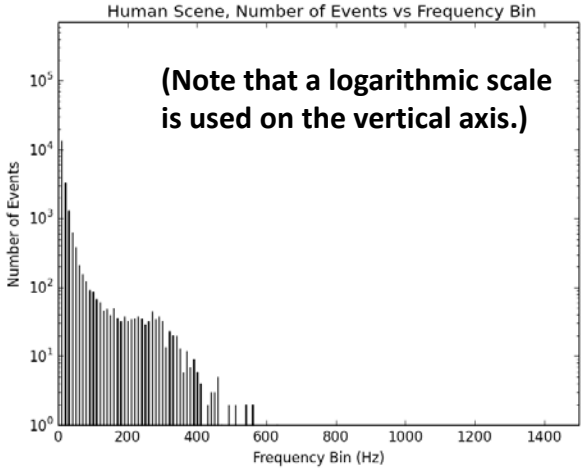
Silicon Retina Measurements at the human timescale and the LED blink timescale





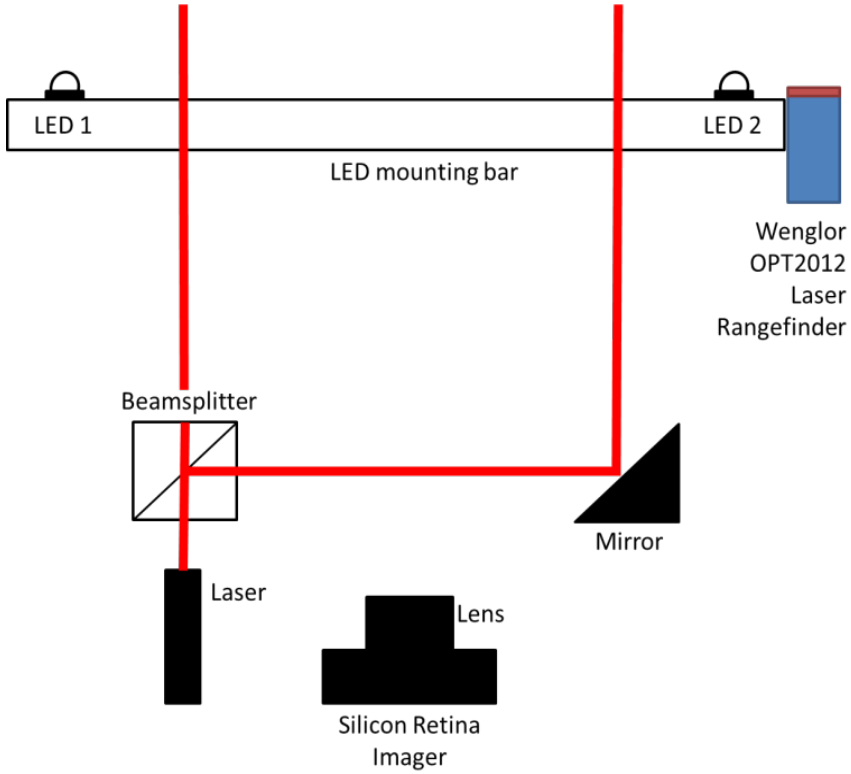


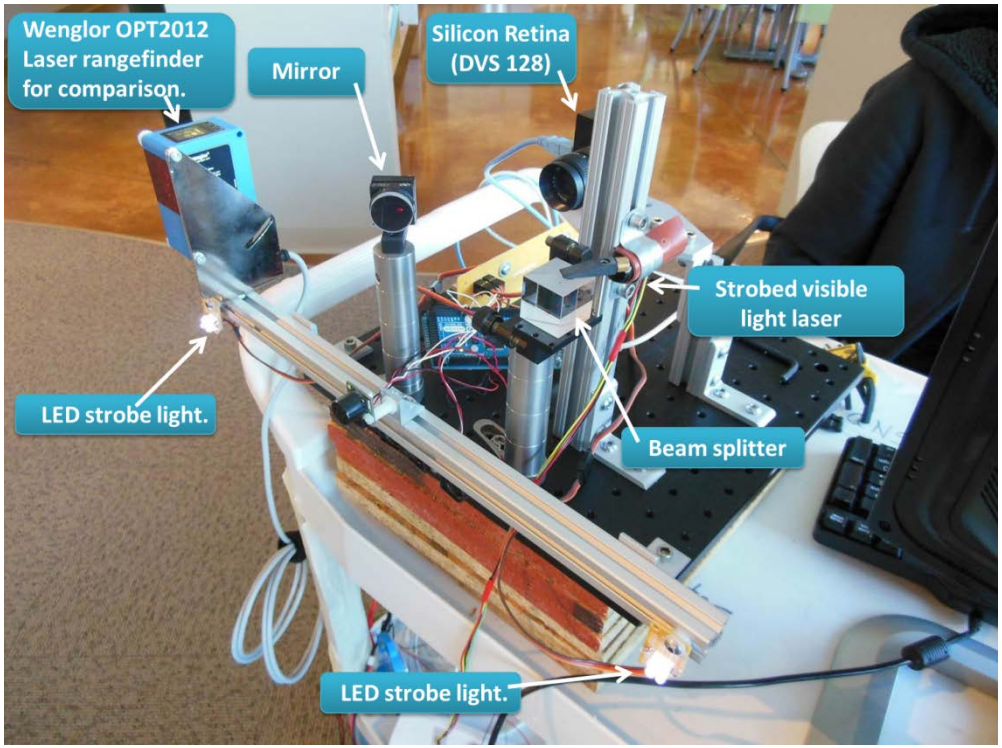
A frequency histogram that was generated from a scene wherein everything was completely still except for two pulsing LEDs at 500 Hz. The recording was roughly 20 seconds long.



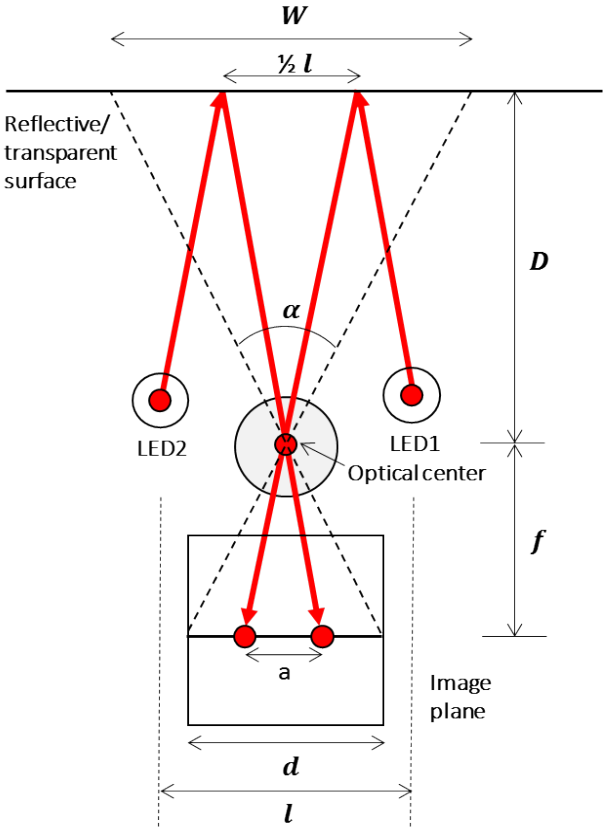
A frequency histogram generated by viewing a scene featuring a human performing jumping jacks and other calisthenics in an office environment. The recording was roughly 20 seconds long.

Multi-modal transparent barrier detection prototype

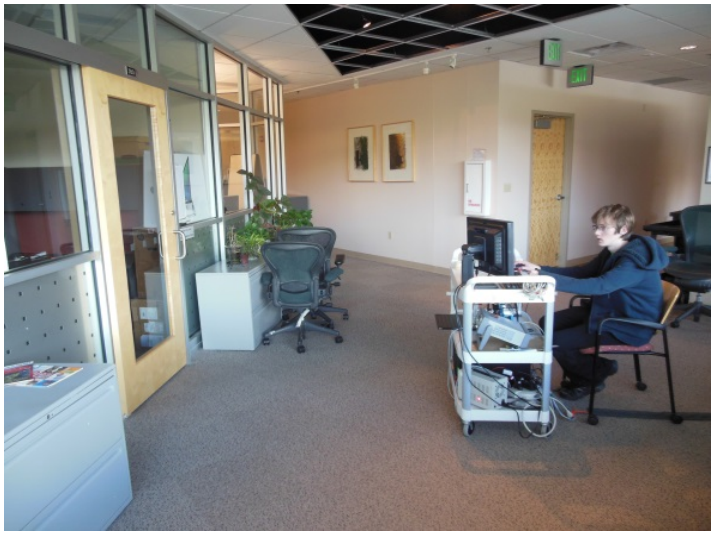




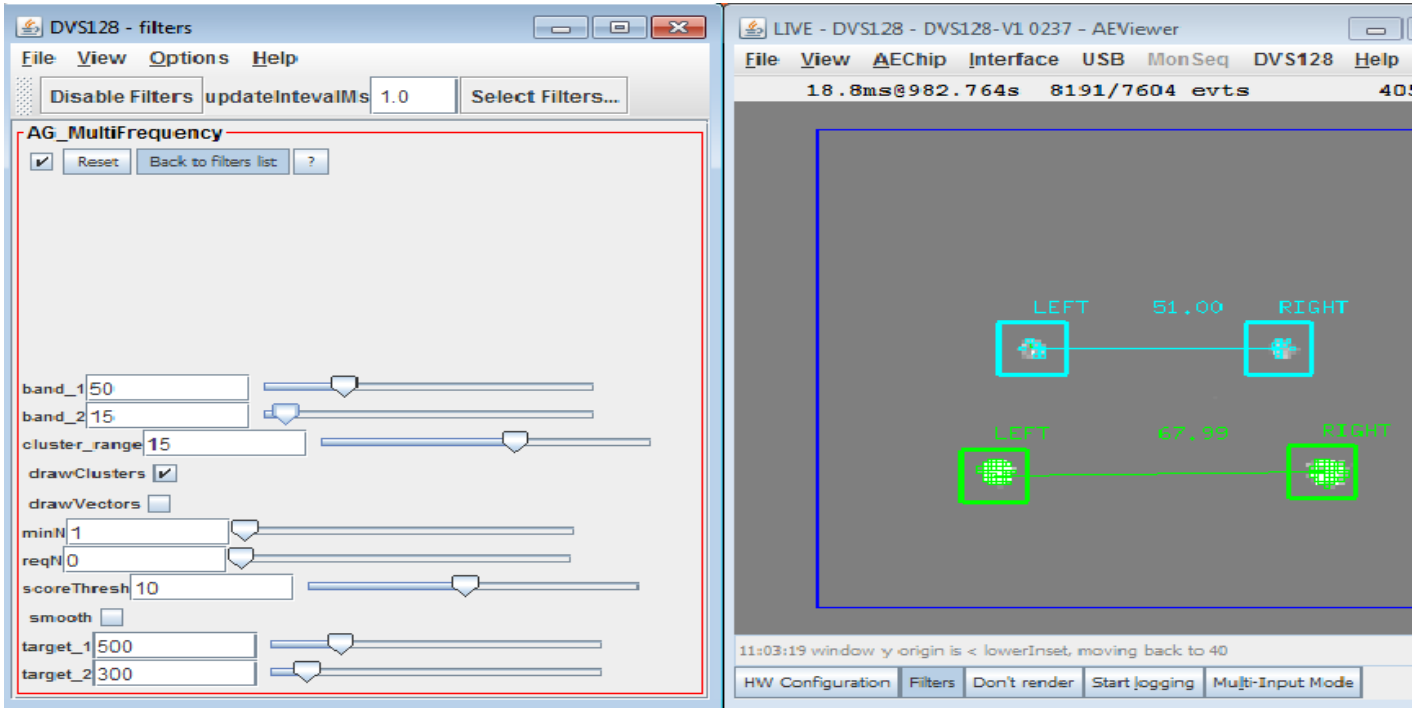
Distance to a transparent barrier can be measured using the blinking LEDs



$$D = \frac{1}{4 * tan\left(\frac{\alpha}{2}\right)} \frac{d_{pixels} * l}{a_{pixels}}$$

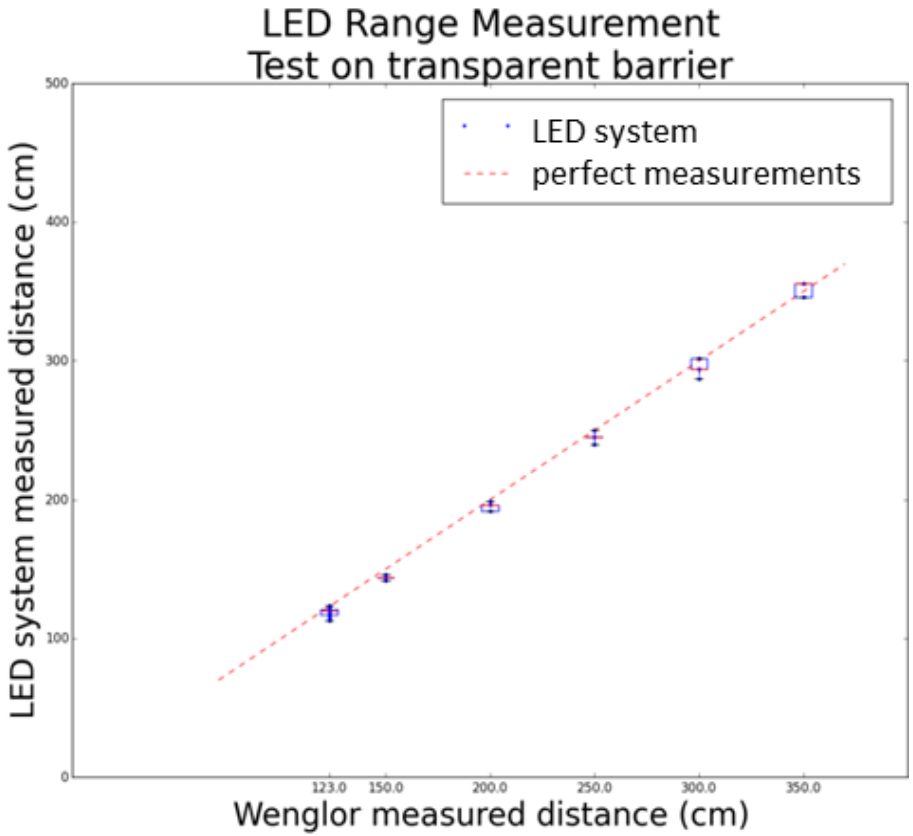


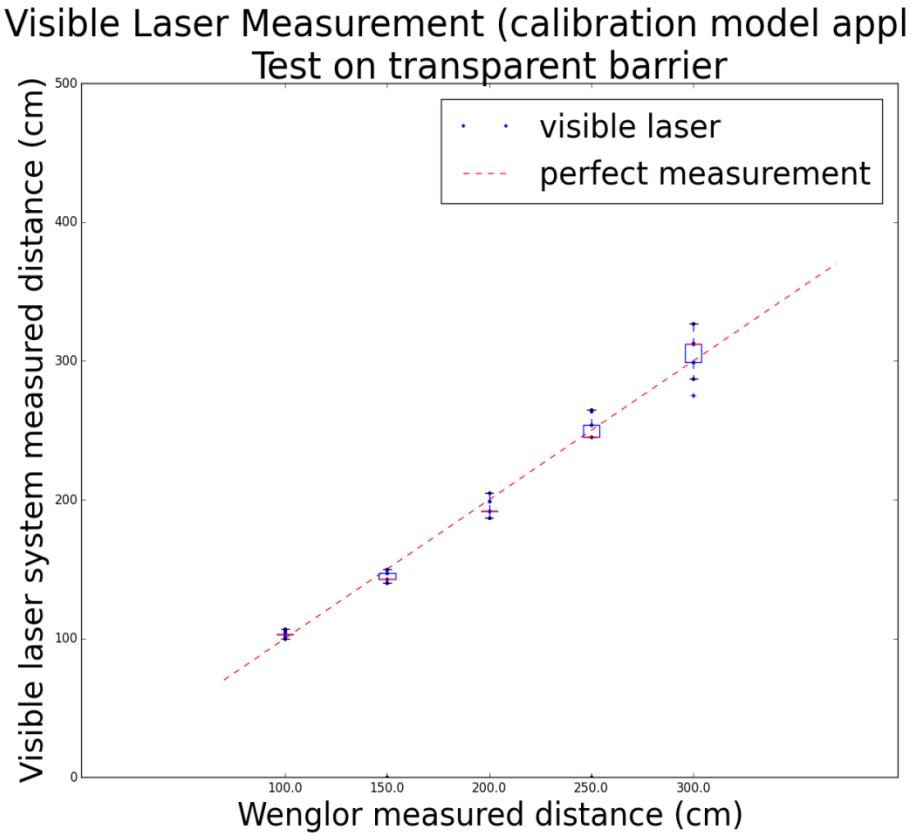
Multi-modal transparent barrier detection prototype



Successful isolation of LED/visible laser reflections blinking at two different frequencies. The reflections are then sorted into clusters. A pair of LEDs are blinking at 500 Hz (green). A visible-light laser is passed through a beam-splitter and blinked at 300 Hz (cyan). (Numbers between clusters are the pixel distance)

Distance to a transparent barrier can be measured using the blinking LEDs





Transparent and Reflective barriers can also be distinguished from one another

Opaque barrier

Distance (m)	Opaque (%)	Transparent (%)	Reflective (%)	False data (%)	No clusters (%)
1.25	100	0	0	0	4.632
2	100	0	0	0	5.504
2.25	100	0	0	0	2.744
3	100	0	0	0	2.364

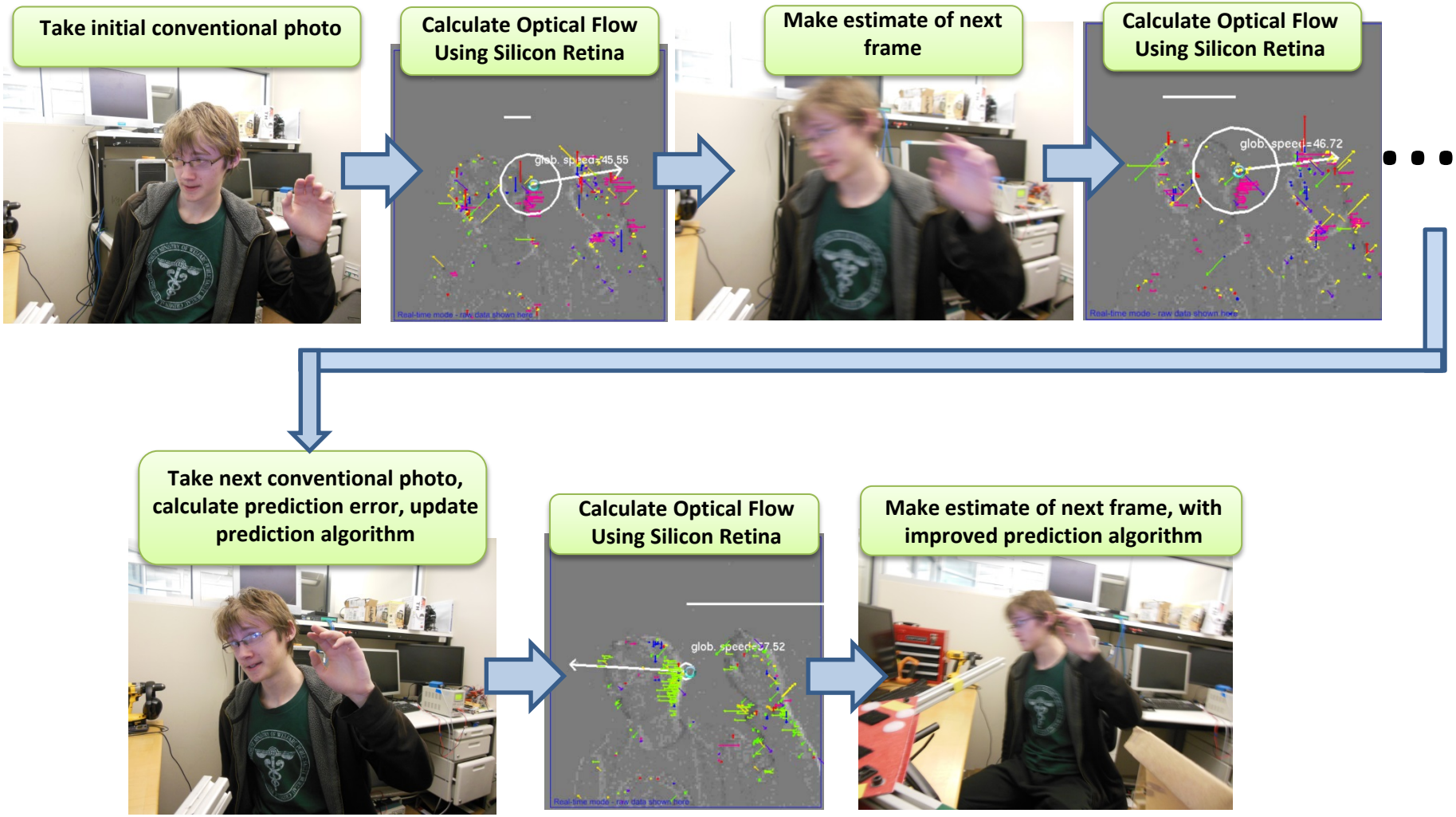
Transparent barrier

Distance (m)	Opaque (%)	Transparent (%)	Reflective (%)	False data (%)	No clusters (%)
1.25, 2.25	0	100	0	0	0
2, 3	0.216	99.756	0	0.028	0
3, 4	1.348	98.652	0	0	0

Reflective barrier

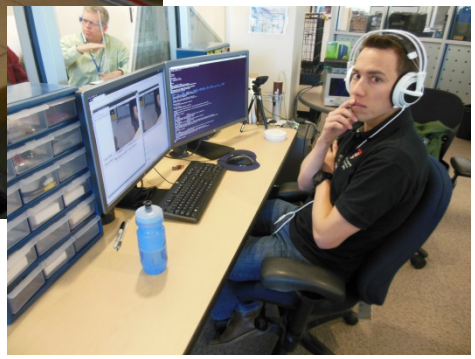
Distance (m)	Opaque (%)	Transparent (%)	Reflective (%)	False data (%)	No clusters (%)
1.25	24.24	0	73.936	1.824	1.18
2	0.36	0.404	99.008	0.228	0
3	0.08	31.128	68.512	0.28	0

High-Framerate, Low-Bandwidth Video Streams



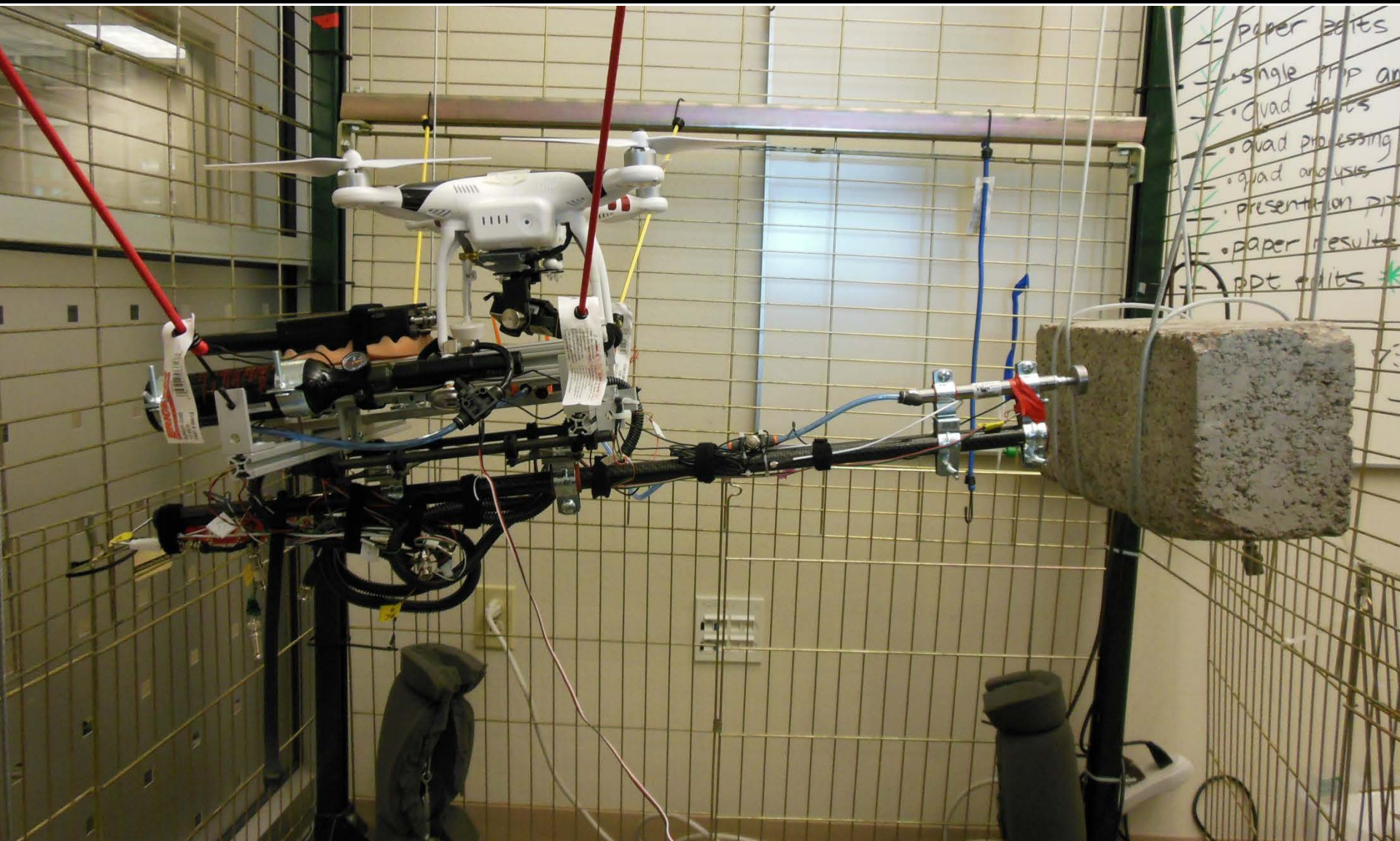
This high-framerate, low-bandwidth imager has great potential for collecting video in caves, tunnels, pipelines, undersea, subways, confined spaces, emergency operations in rubble/near-collapse buildings as well as safeguarding infrastructure

Embedded control of a NaI detector for deployment on an S1000 octocopter.

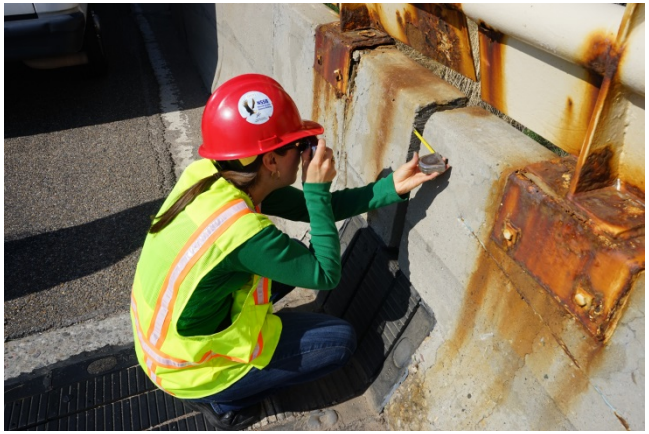


Tyler Trombetta (USN) and Alex Marchi (LANL-EI)

A multirotor-based approach for tap-testing difficult-to-access structures



“I don’t trust SHM systems, when I inspect a bridge I do a visual inspection and I hit it with a hammer”
-Scott Snelling, P.E. (to paraphrase)



The hammer is not only used to evaluate the acoustic response, it also facilitates the visual inspection by removing mud, corrosion and other debris.

"The biggest problem for me is getting access to the structure so I can do an inspection."
-Scott Snelling, P.E. (Paraphrased)

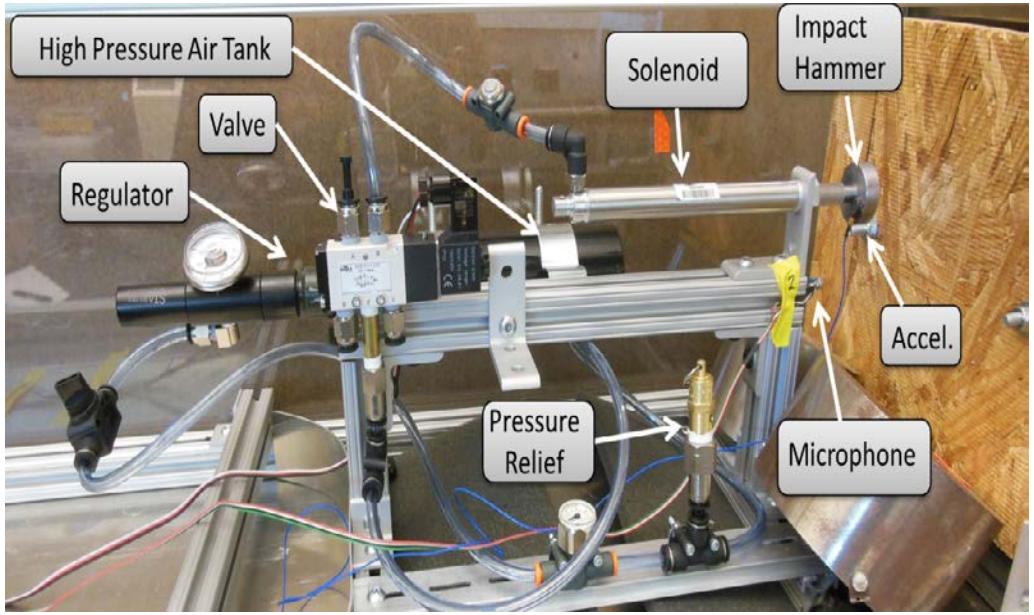
- Inspections and repair require that a technician must scale wind turbine (Blades may be moving on the order of a meter in wind.)
- To inspect extent of damage to the wind turbine, a tap test is performed by the technician.
- During repairs the technician must wear respirator and Tyvek suit (exposure to composite dust)
- Working in ropes for multiple hours is ergonomically unfriendly
- (Based on conversation with Tony Bergin, wind turbine inspector.)

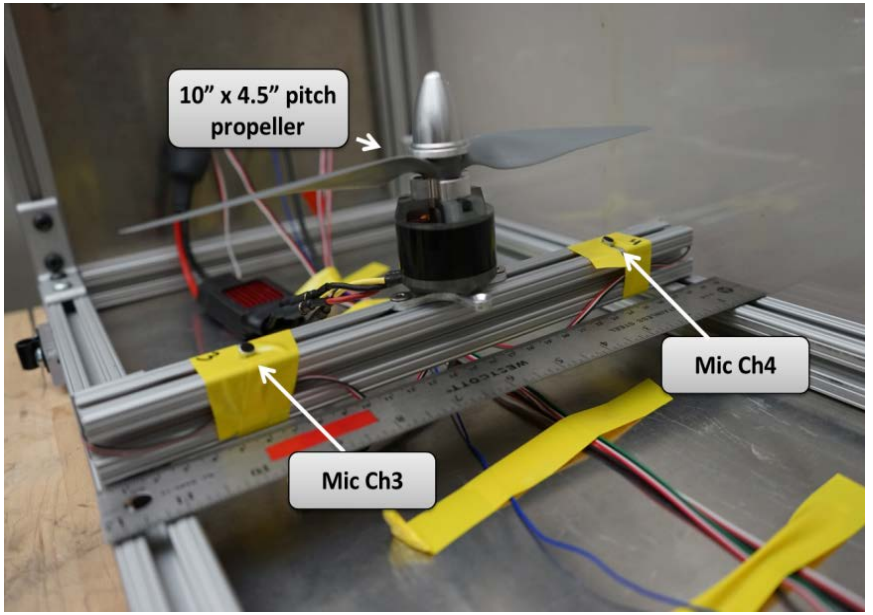
“I think we can do something about that…”
-David Mascareñas

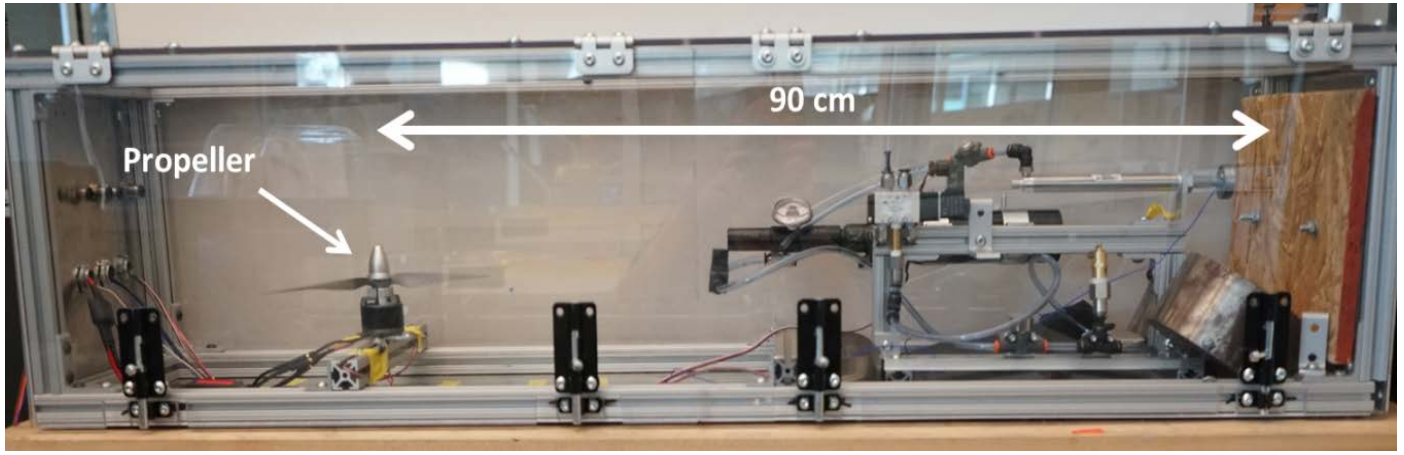
-A concept was born-

Aerial Robotics
+
Novel Tap Testing Device
+
Expert Human Judgement
=
Better Structural Inspections

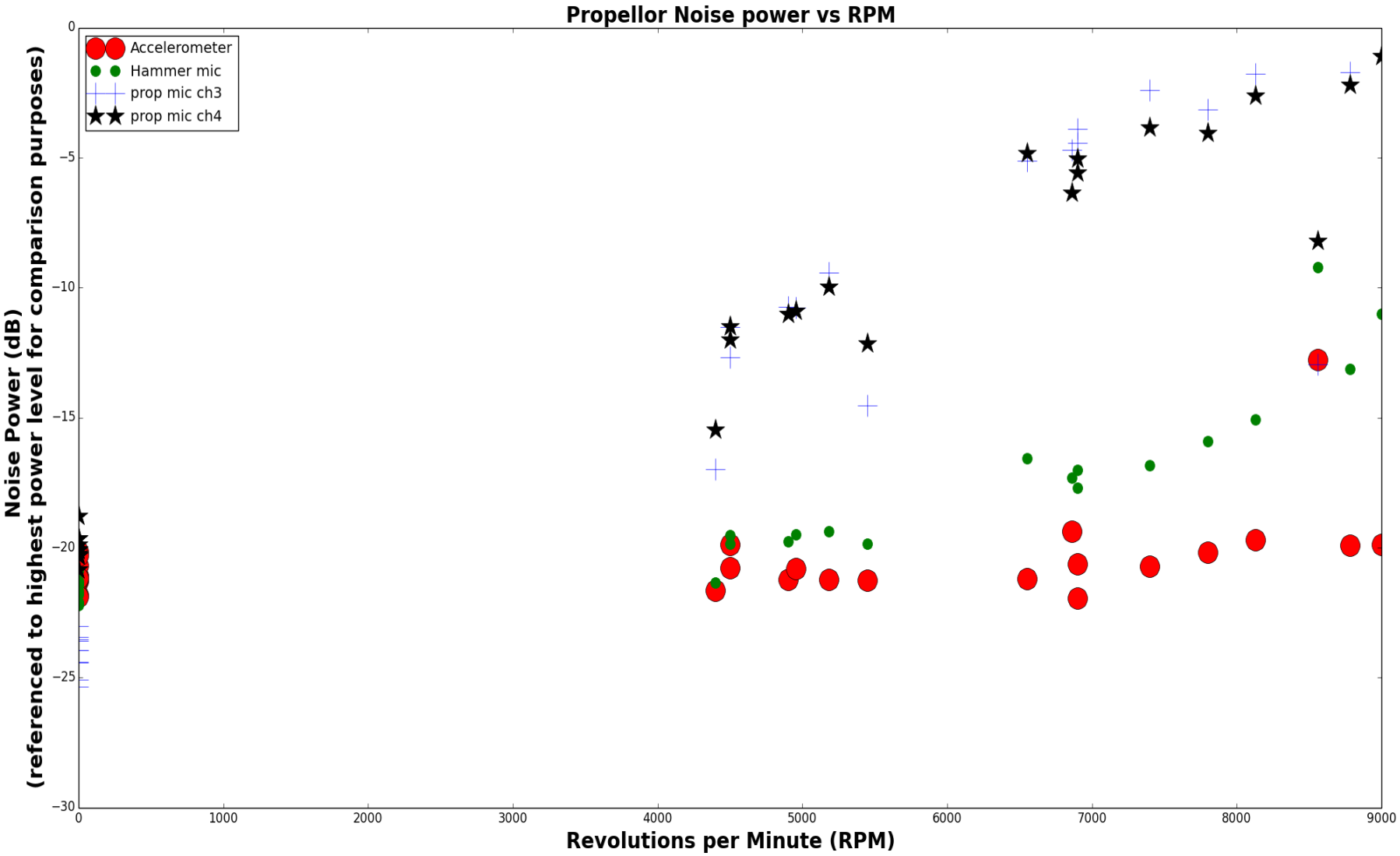
Pneumatic tap-testing prototype





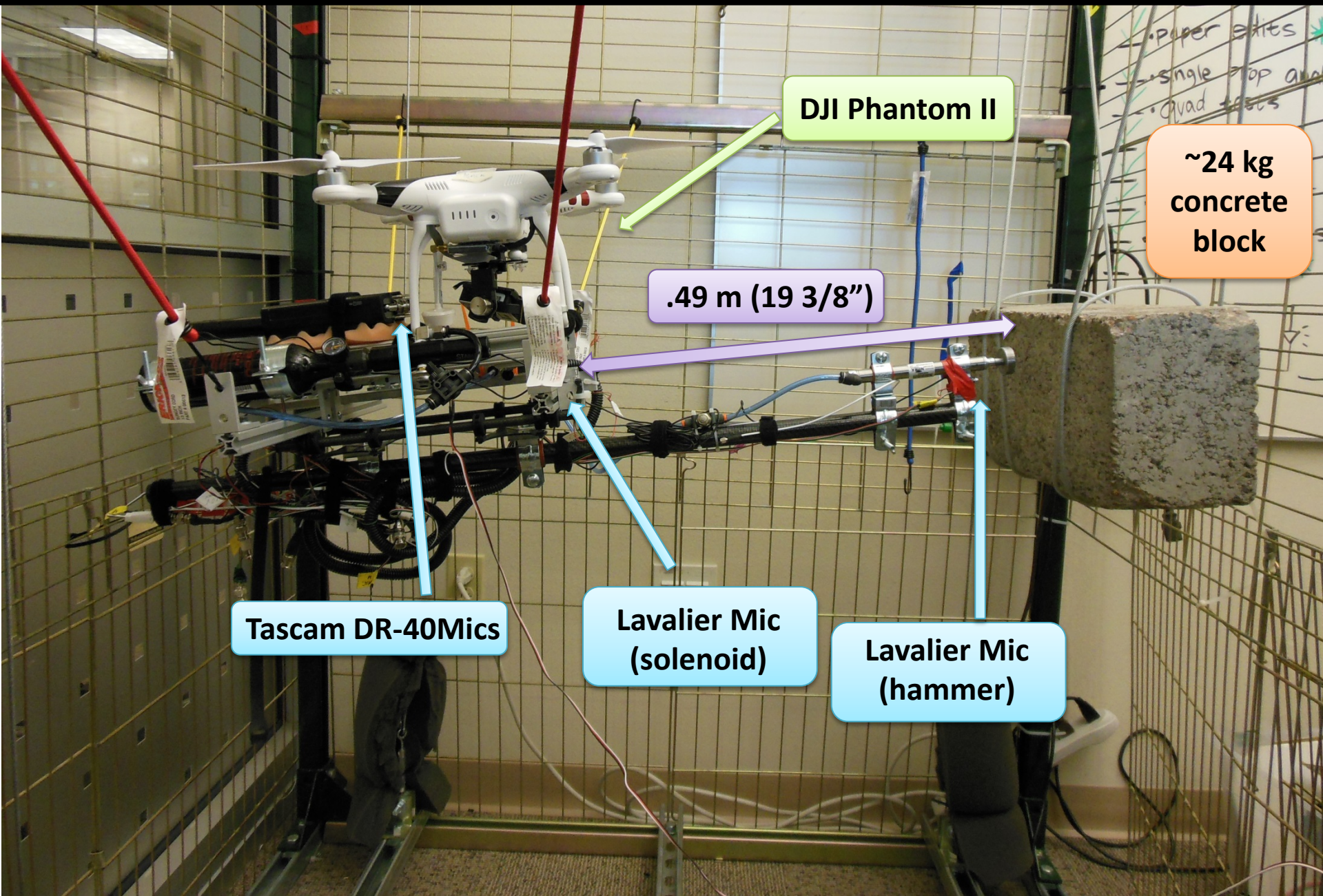


Initial Measurements from the prototype

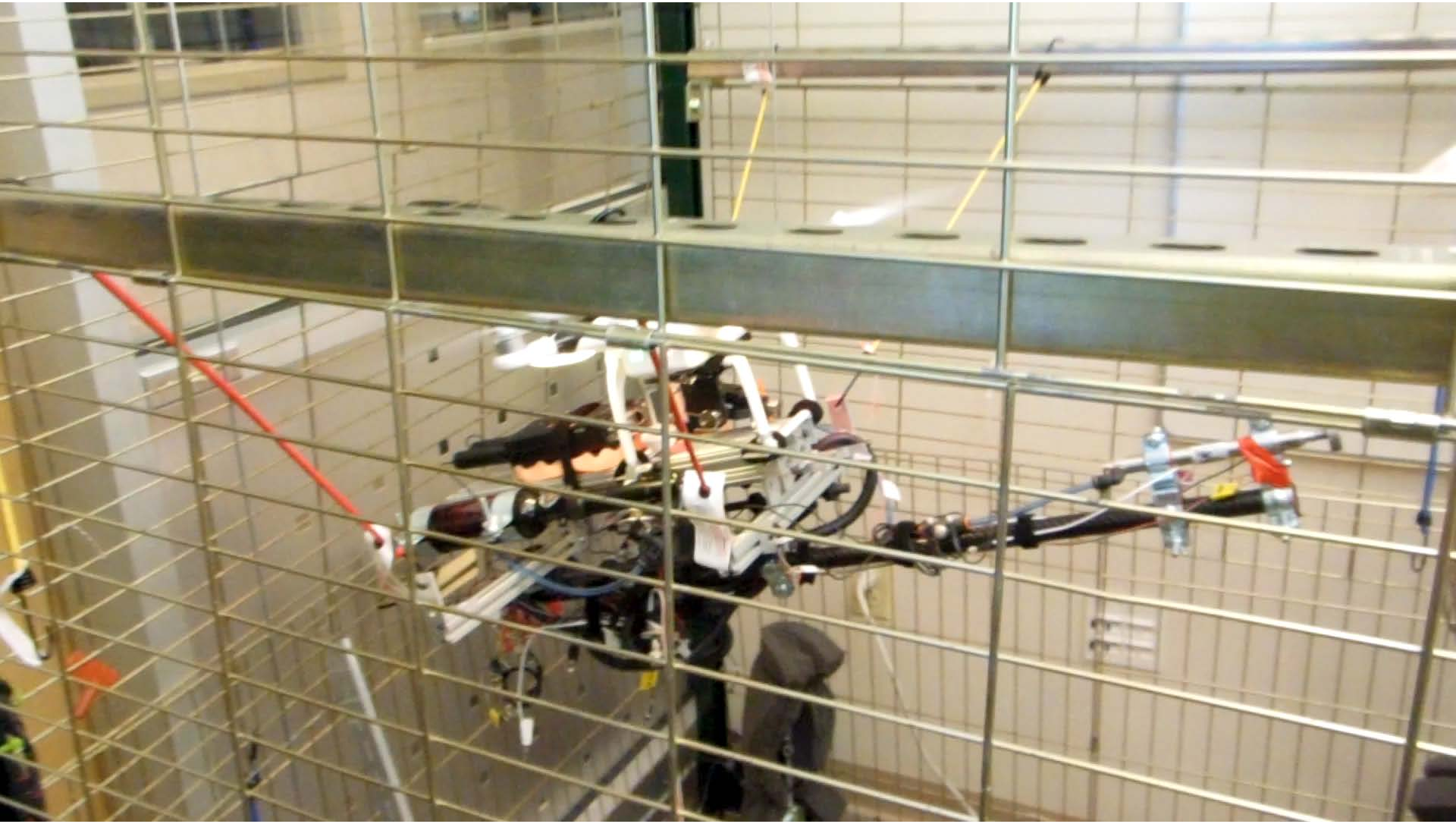


Relative propeller noise power measured from inside the testing chamber at varying RPM.

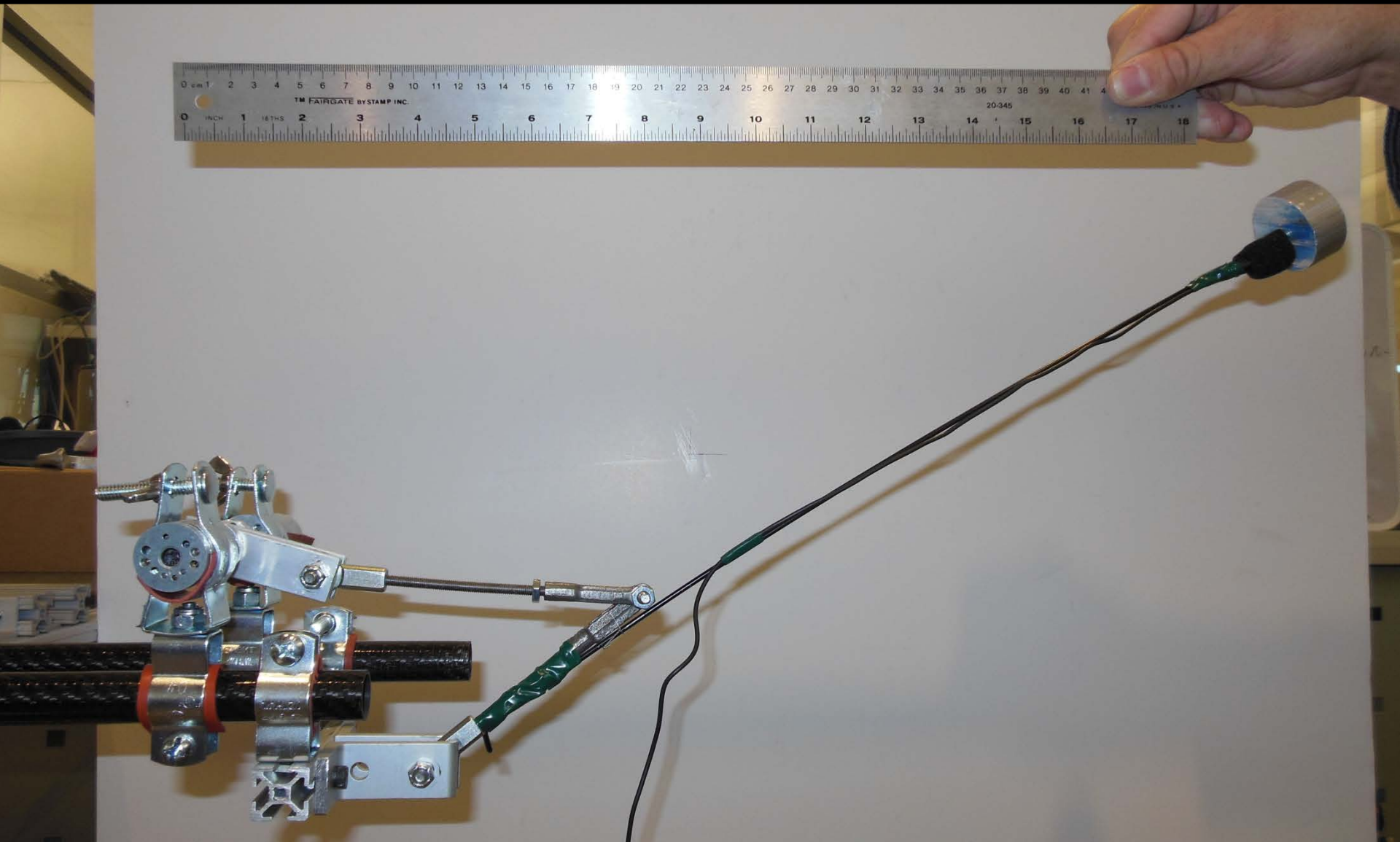
Suspended version of the system



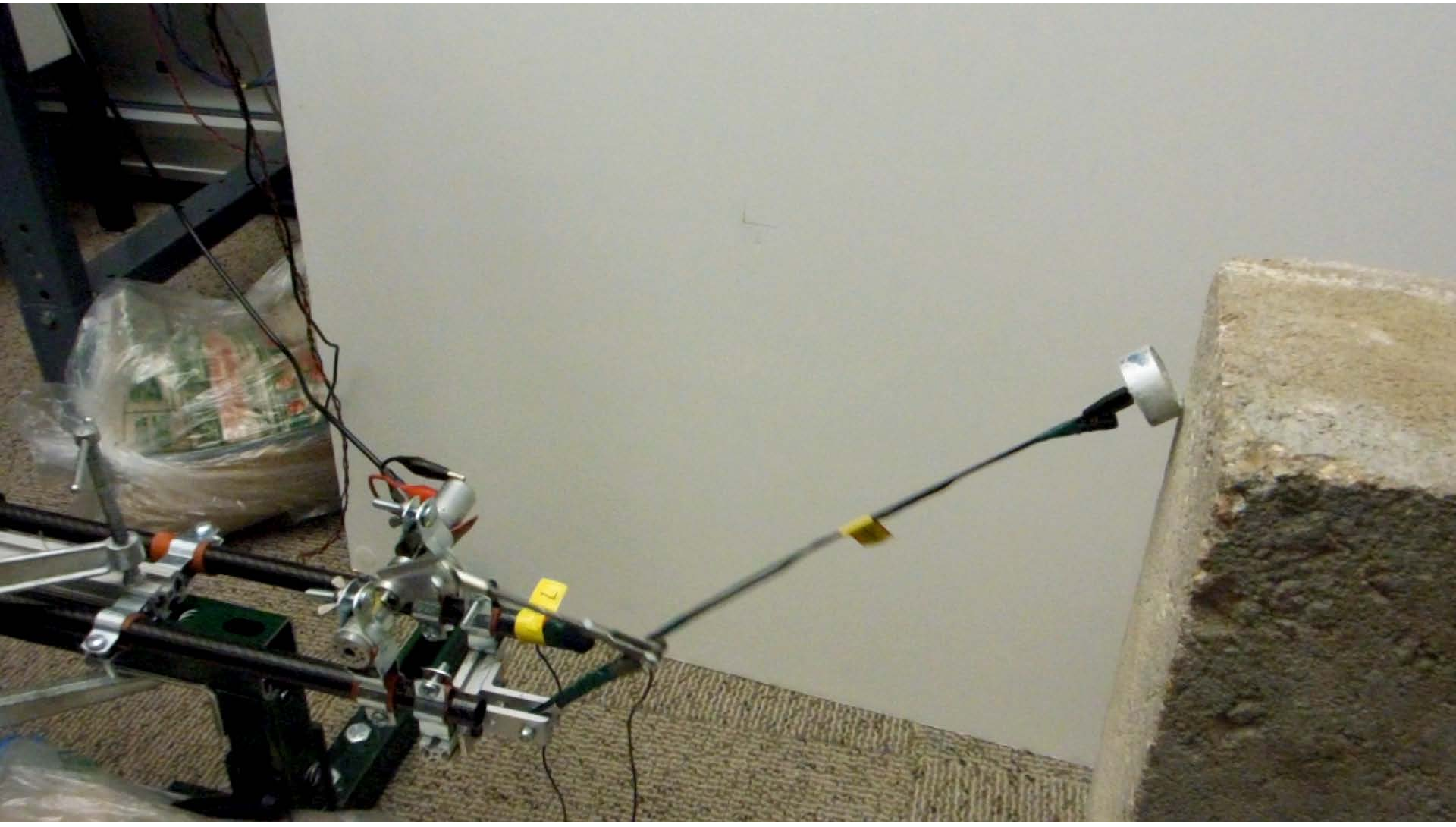
Suspeded Tap test with propellors



A motor-driven, four-bar, crank-rocker, tap-testing linkage

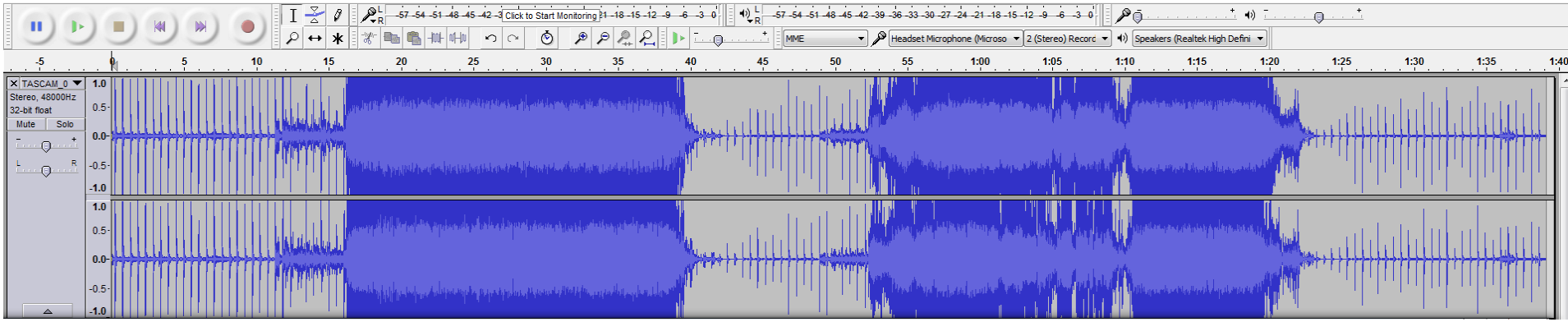


Tap Test Linkage With Concrete Block

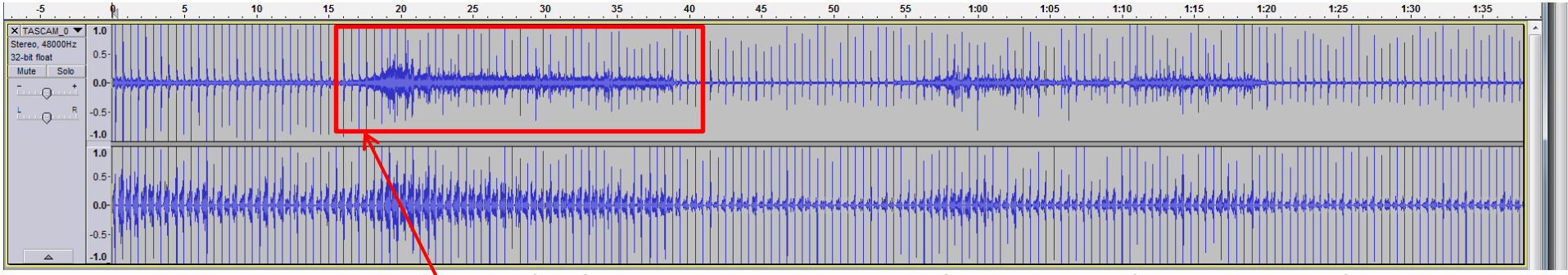


Sound Recorded by the Microphones

Propeller Microphones

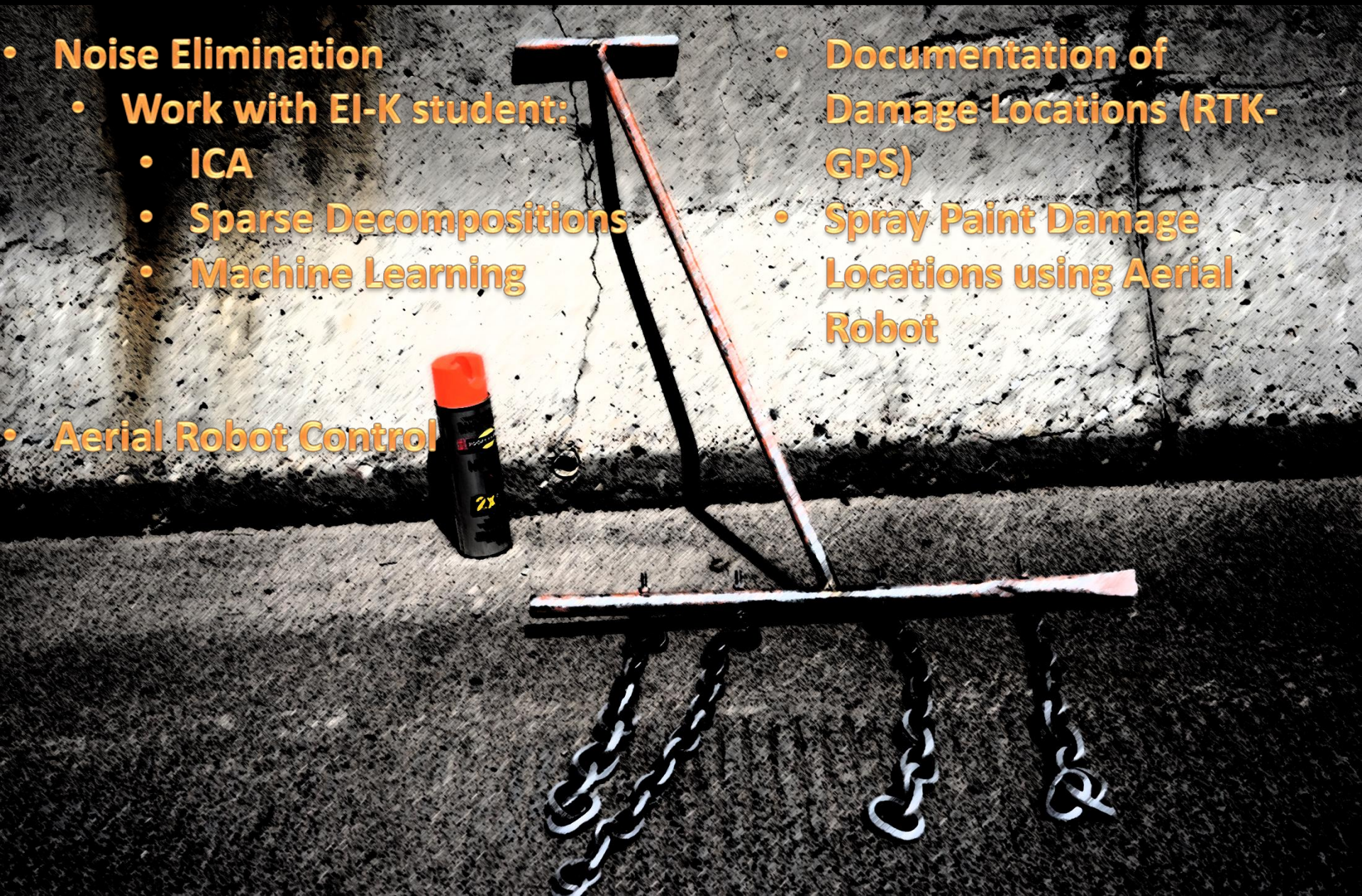


Hammer Microphones



Blind source separation techniques such as Low-Rank Sparse Decompositions are looking promising for denoising this signal. We will also try ICA, and CP

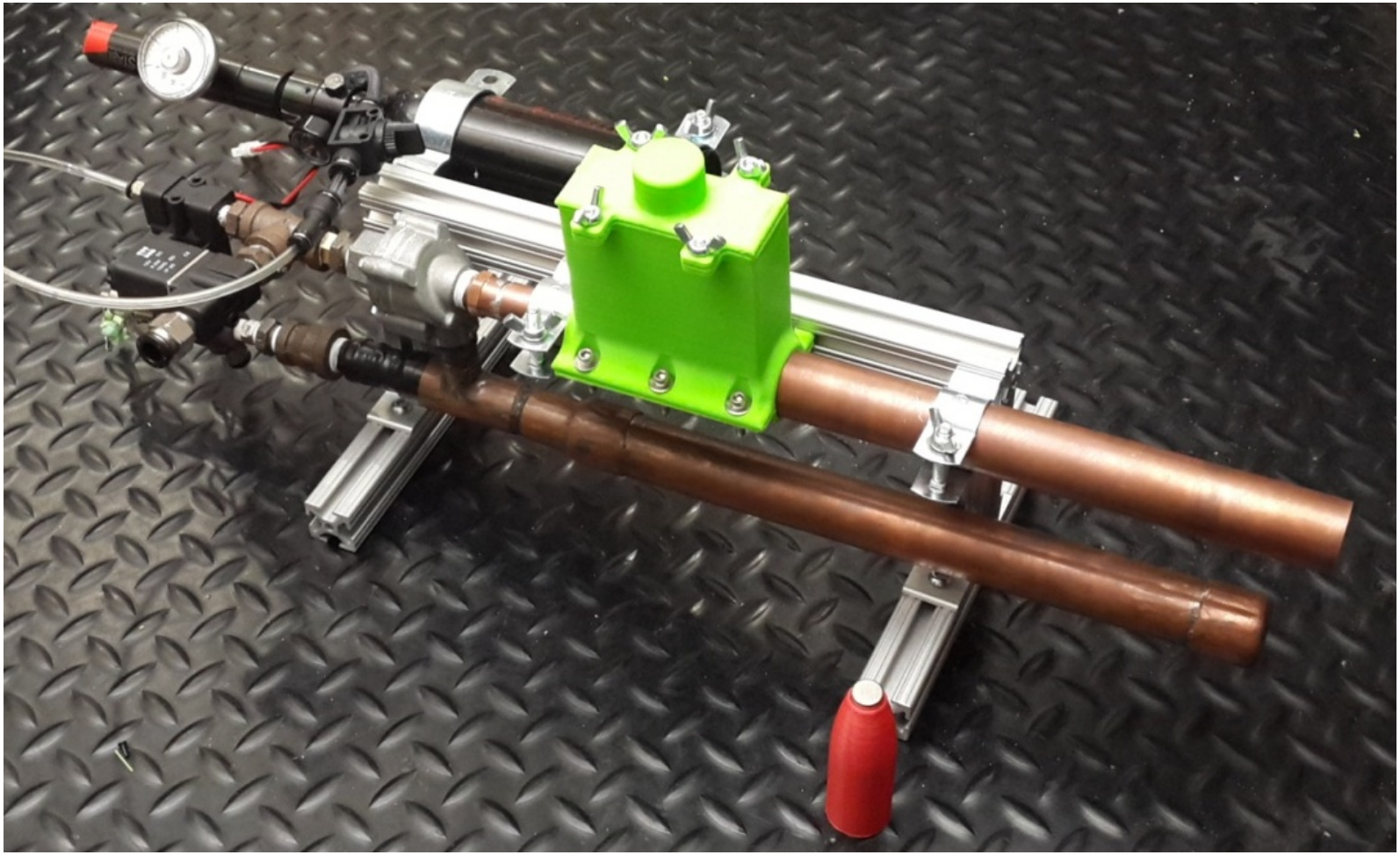
Future Work



- Noise Elimination
  - Work with EI-K student:
    - ICA
    - Sparse Decompositions
    - Machine Learning
- Aerial Robot Control
- Documentation of Damage Locations (RTK-GPS)
- Spray Paint Damage Locations using Aerial Robot

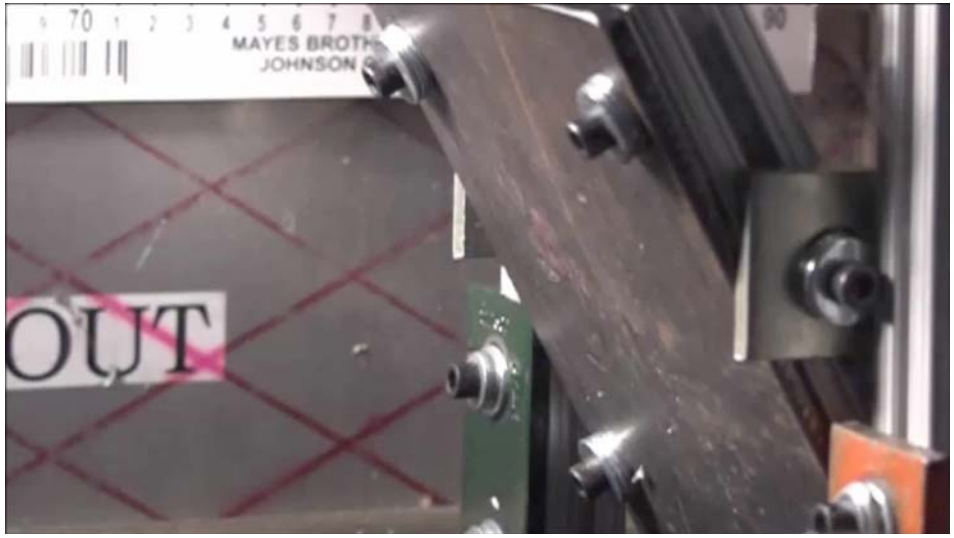
Remote Sensor Deployment

Rapid, precise deployment of sensor nodes from aerial robots



Remote Sensor Deployment

Rapid, precise deployment of sensor nodes from aerial robots

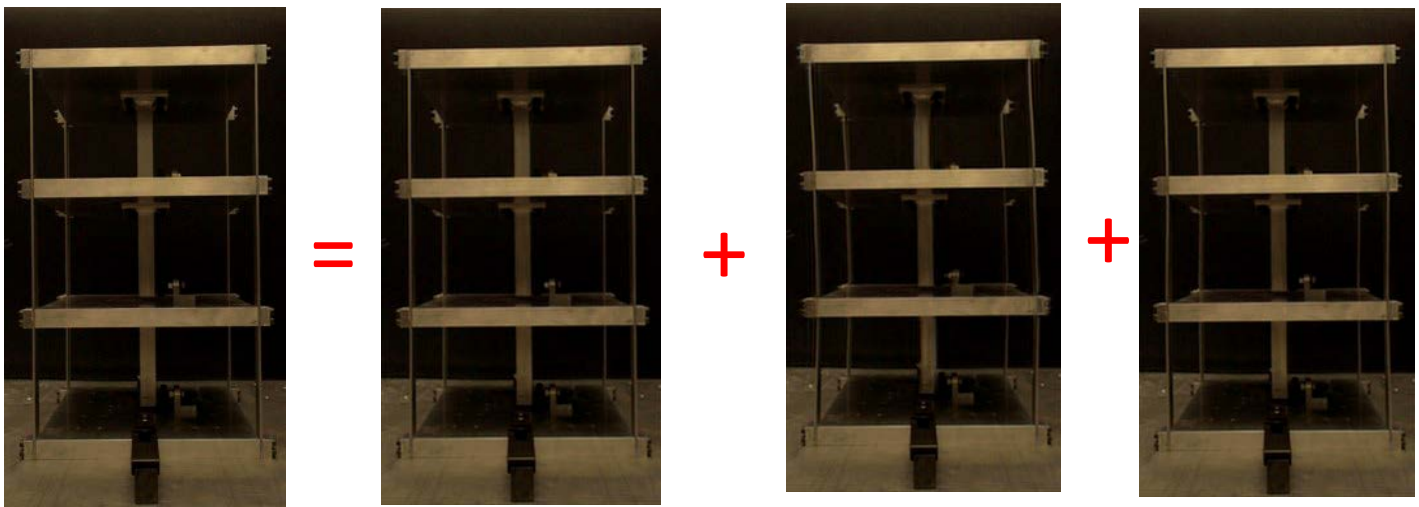


Work With Fernando (UNM)

This type of technology may also be of interest to the State Department for Sustainable Development Applications.

Railroad bridge displacement at the field
(Moreu et al. 2014, 2015)
$10K installation Costs

Original video Mode 1 – 6.34 Hz Mode 2 – 17.96 Hz Mode 3 – 25.89 Hz

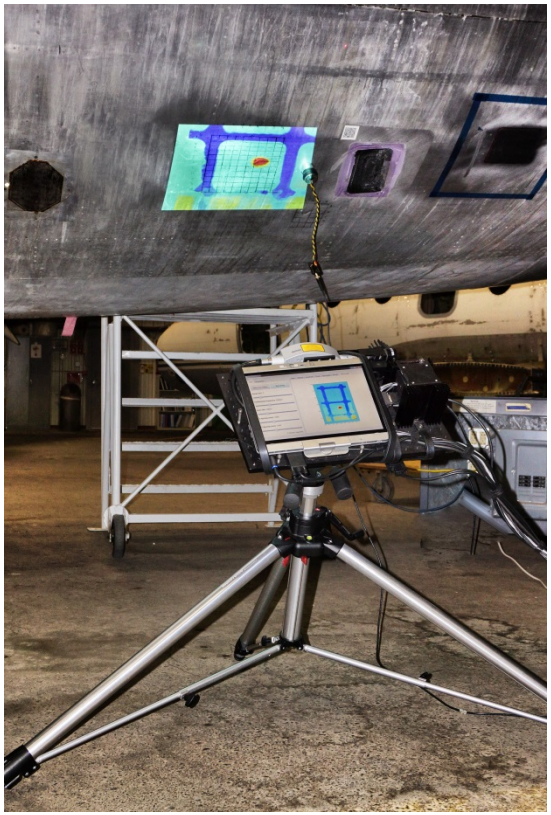


Y. Yang and D. Masca-renas 2015

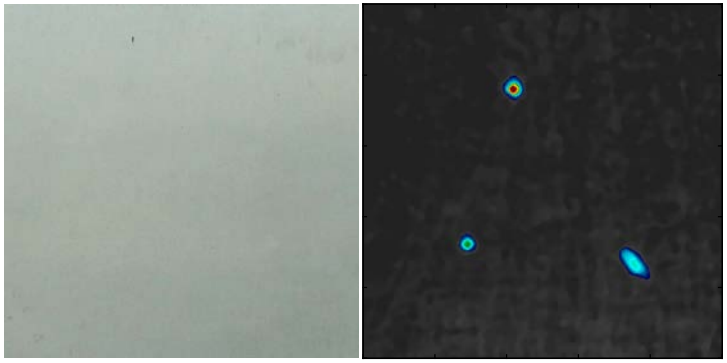
Laser Ultrasound

Damage & Defect Detection

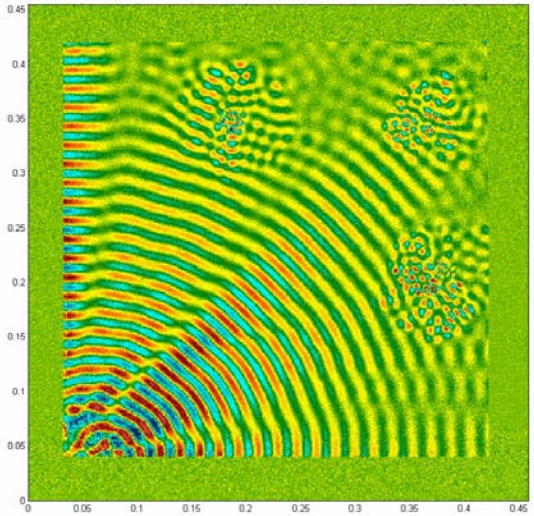
Eric Flynn, LANL-EI

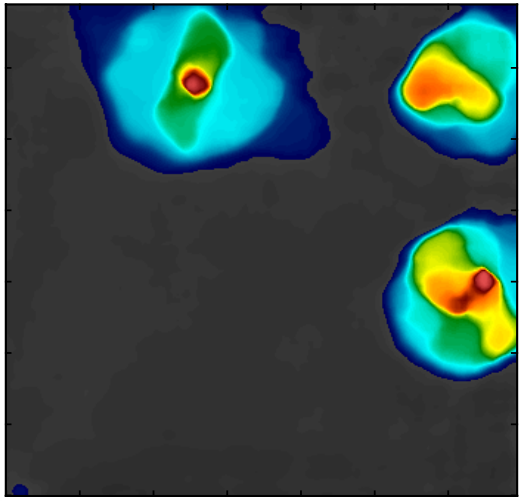


Corrosion

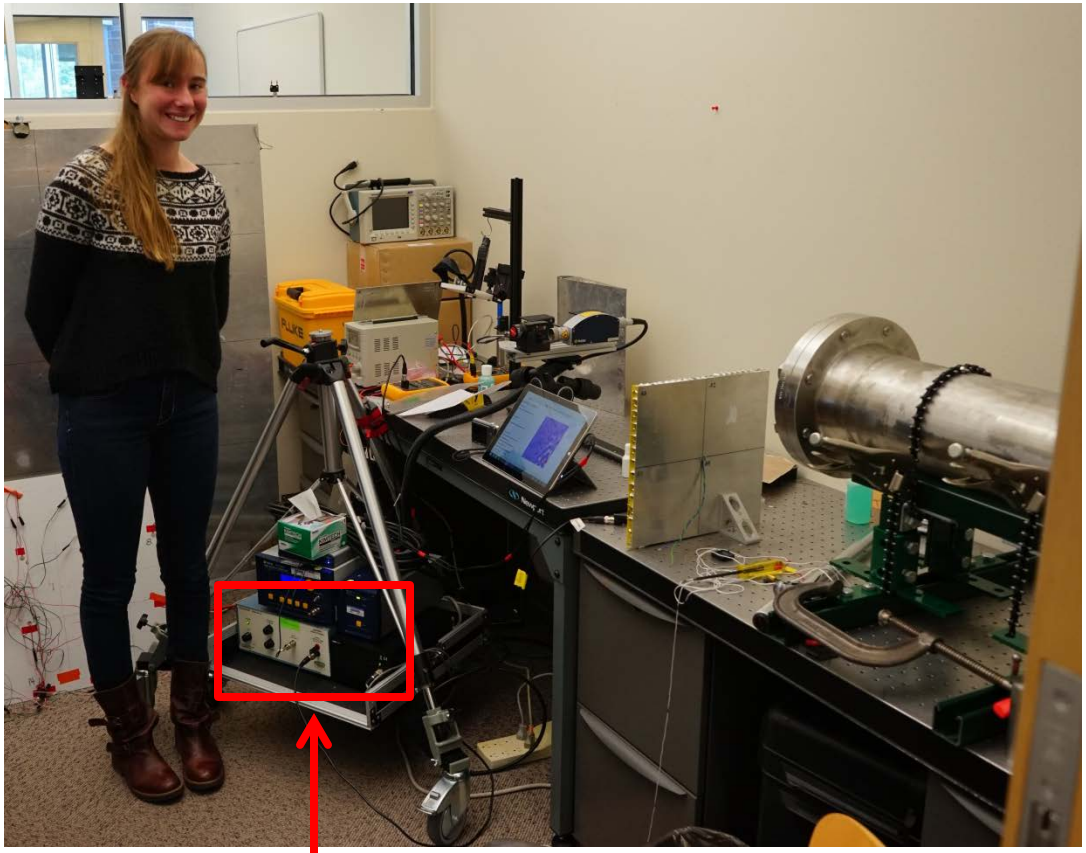


Delamination



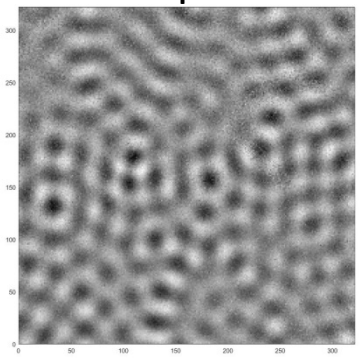


Towards Laser ultrasound deployed from an aerial robot

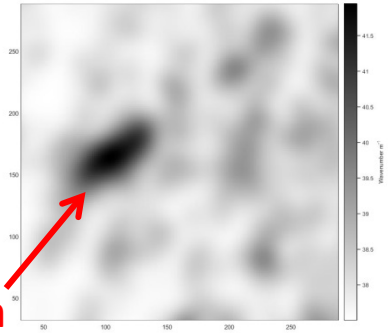


The size of this excitation source must be reduced before this can be deployed on an aerial robot.

Real Response



Wavenumber



Corrosion

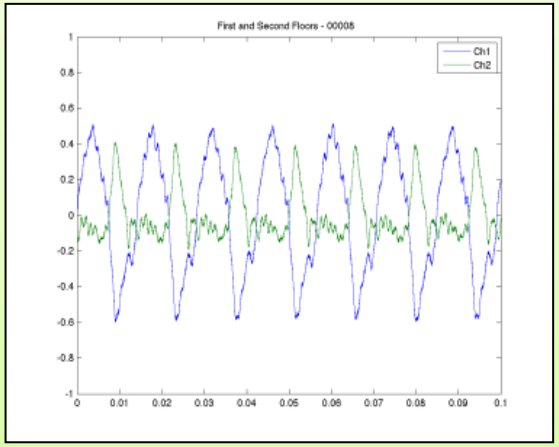
Promising Architecture

A Structural Nervous System

We are exploring non-invasively interfacing a health monitoring sensor network with a human nervous system.

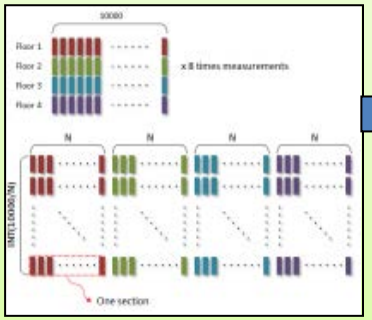
The Haptic Paradigm

Raw
Sensor Data

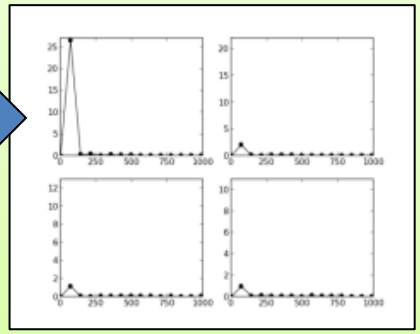


Pre-processing

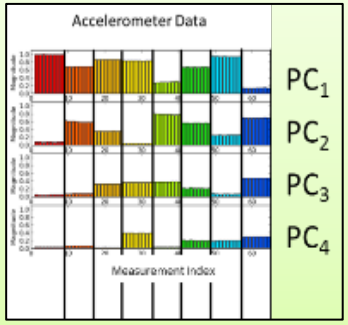
Principle Component
Analysis



Fast Fourier Transform



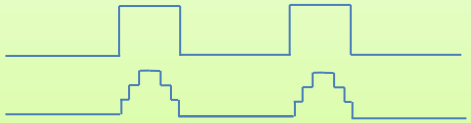
Haptic Code



Physical modulation

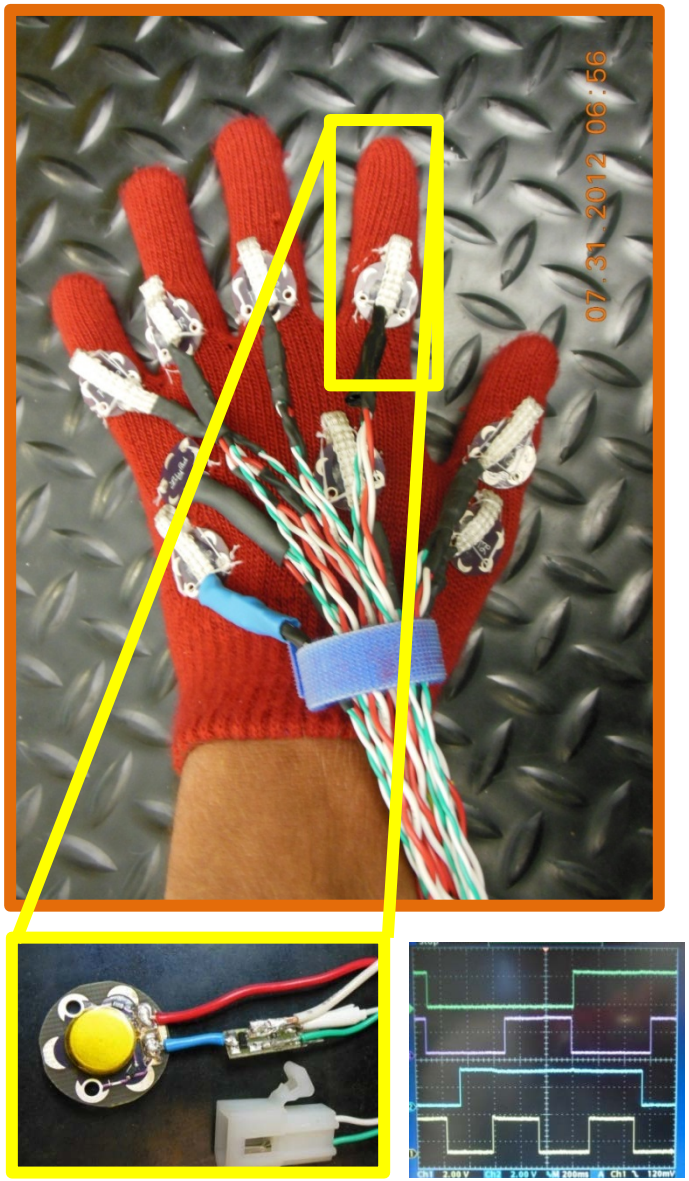
Example:
The higher the magnitude of data:

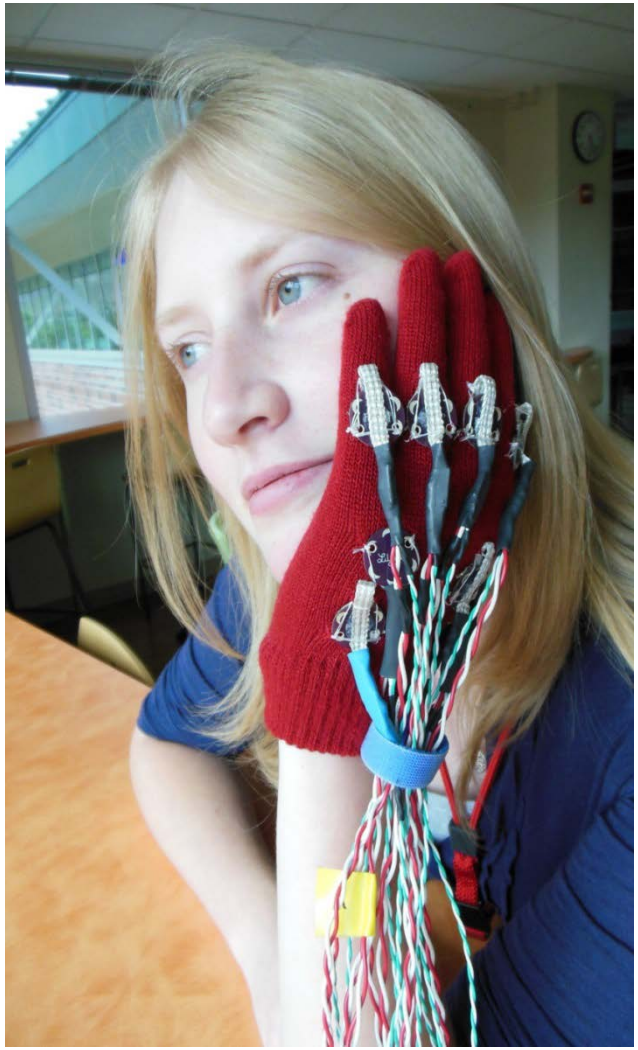
- The higher the frequency
- The higher the amplitude
- The higher the duty cycle for pulse-width modulation



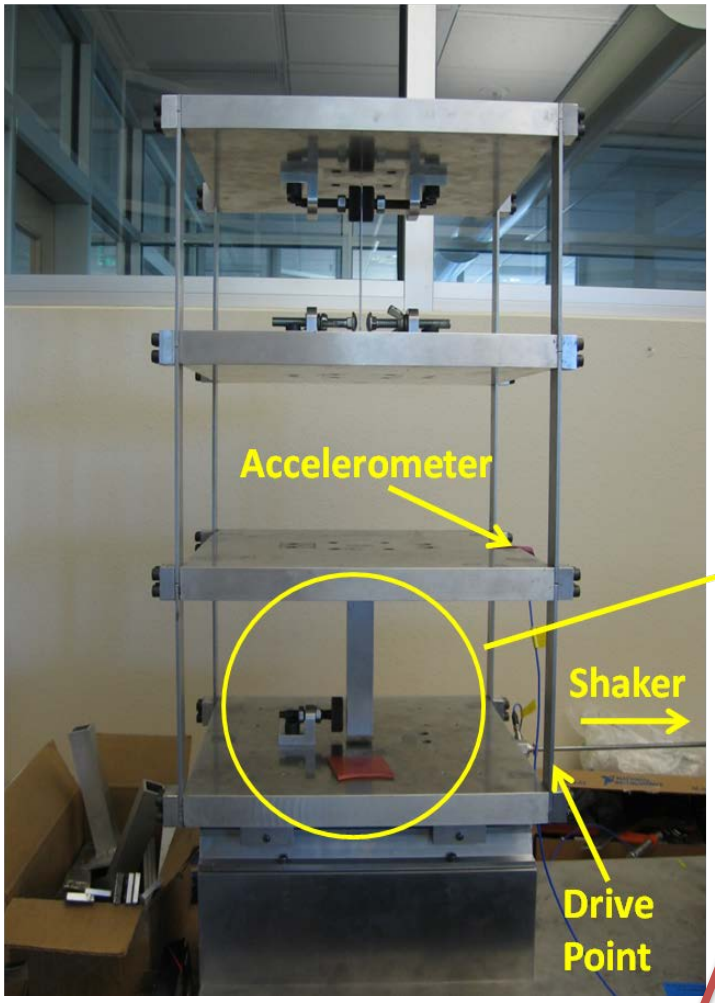
Actuators

The Vibrohaptic Device

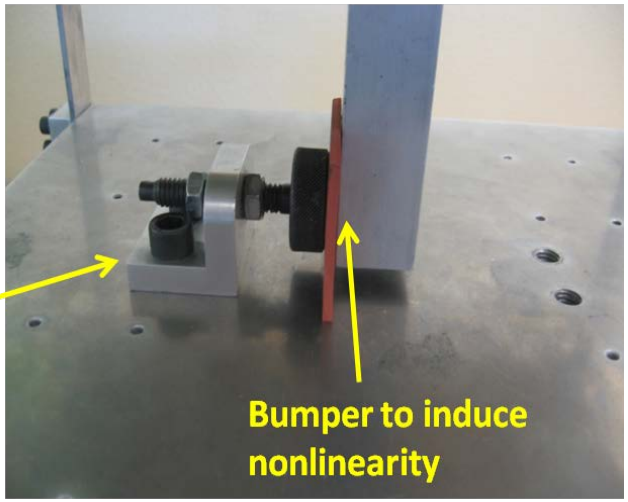




Initial Experiment



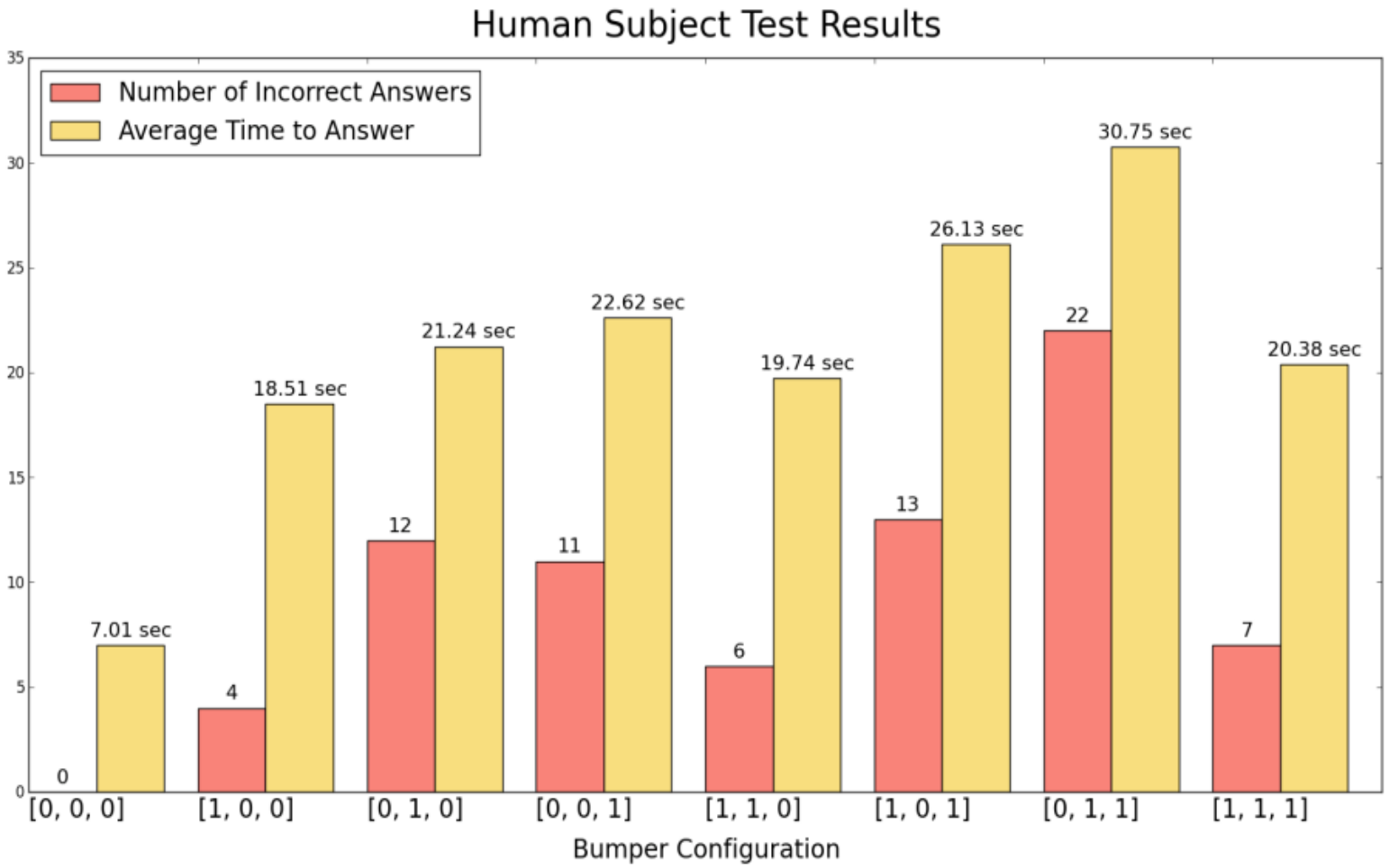
DSS Idea – Given three possible nonlinearities can a human use a haptic interface to "feel" and localize the damage in the structure. Can a human identify which nonlinearities are active and which are not simply by haptically enhanced perception?



1. Feed data into a computer, perhaps do some preliminary crude data normalization and feature extraction, then send excitaiton to haptic interface
2. Outfit blindfolded human with haptic Human-to-Machine Interface and see if they can identify which structural nonlinearities are present simply by feel/sense.

Consider both Human-Machine Supervised and Unsupervised learning cases for different humans.
Eventually make use of apprenticeship learning.

Initial Results



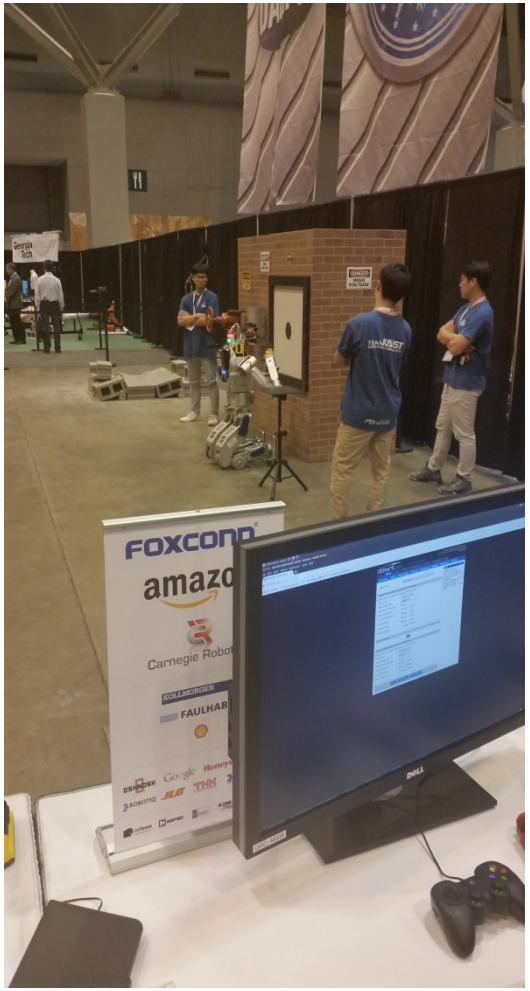
Initial Results

		Participant Response								
		[0,0,0]	[0,0,1]	[0,1,0]	[1,0,0]	[1,1,0]	[1,0,1]	[0,1,1]	[1,1,1]	Miss Rate
Bumper Configuration	[0,0,0]	28	0	0	0	0	0	0	0	0 out of 28
	[0,0,1]	0	17	1	0	2	3	4	1	11 out of 28
	[0,1,0]	0	0	16	3	9	0	0	0	12 out of 28
	[1,0,0]	0	0	2	24	1	0	1	0	4 out of 28
	[1,1,0]	0	0	3	1	22	0	2	0	6 out of 28
	[1,0,1]	0	0	1	0	0	15	2	10	13 out of 28
	[0,1,1]	4	1	0	10	1	6	6	0	22 out of 28
	[1,1,1]	0	1	0	0	2	1	3	21	7 out of 28

Confusion Matrix

Participant	Number Correct (32 possible)	Took Notes?
A	24	yes
B	8	no
C	28	yes
D	26	yes
E	26	yes
F	24	yes
G	13	yes

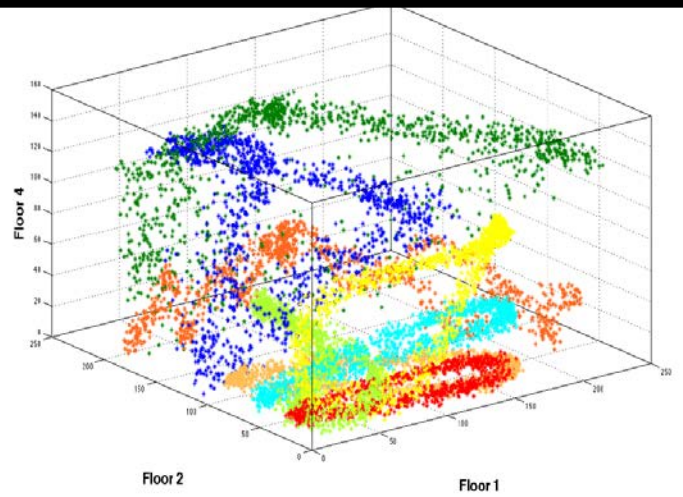
State-of-the-art in robotic tool usage



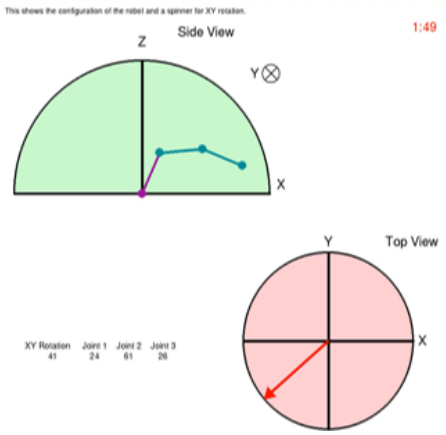
About 2 minutes to cut this hole.

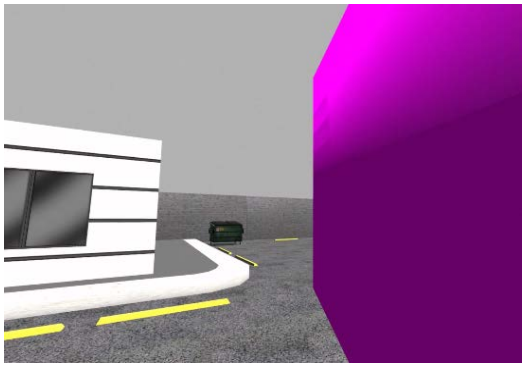
Robots Prepared for DARPA Robotic Challenge 2015
Captured at DARPA Wait What workshop August 2015

Haptic Proprioception



Haptic Proprioception





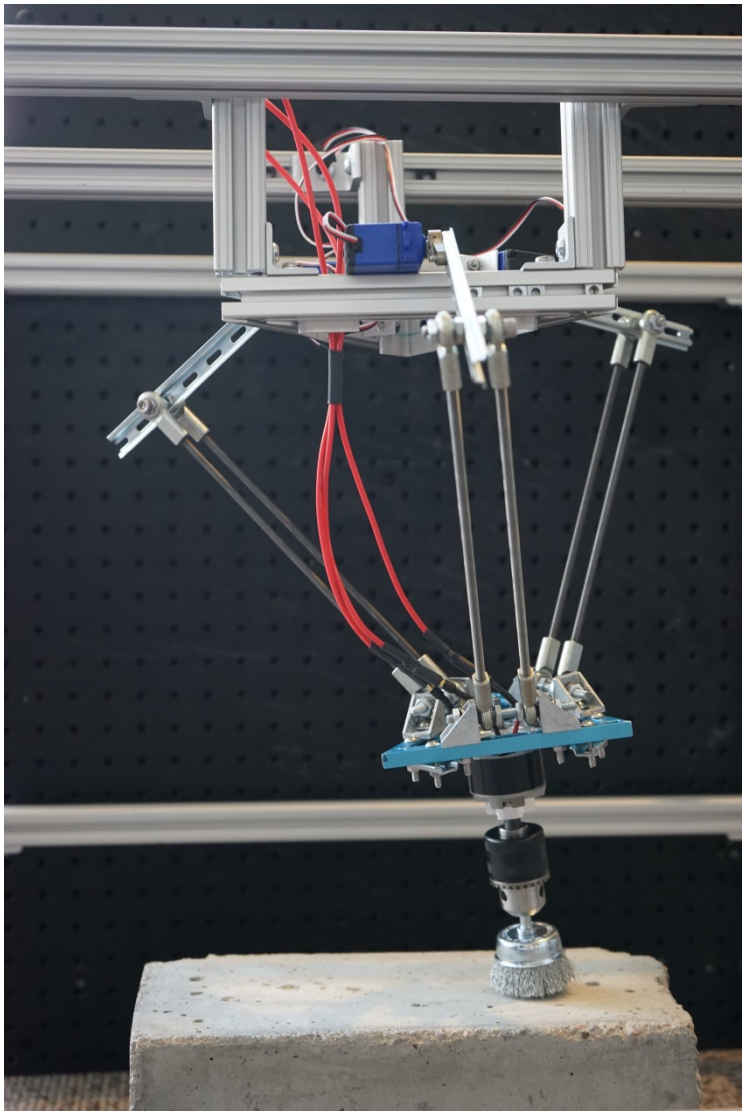
Simulation

Knob Setup

Vibro-haptic Sleeve

Haptic Proprioception Setup

Delta Machine for Aerial Robotic Applications



- Lightweight
- Stiff

Adaptable to a wide variety of tools:

- Drills
- Grinding wheels
- Saws
- Wire brush

Artificial Personality Synthesis: Leveraging Diversity to enable robust robotic teams.

Current computational personality research is dangerously homogenous.

The Big 5

Openness, Conscientiousness, Extroversion, Agreeableness, and Neuroticism.

"Trait based models are widely accepted in the computing community as well. All of the works surveyed in this article adopt personality traits (the BF in 76 cases out of 81) and, to the best of our knowledge, no other theories were ever adopted in computing oriented research. On one hand, this barely reflects the dominant position of trait based models in personality psychology. On the other hand, trait models represent personality in terms of numerical values, a form particularly suitable for computer processing. [1]."

A. Vinciarelli and G. Mohammadi, "A Survey of Persoanlity Computing," *IEEE Transactions on Affective Computing,* vol. 5, no. 3, pp. 273-291, June 2014.

The problem with this is that experience and research have shown that solving problems is generally aided by being able to combine diverse ways of approaching the problem.

This is how the Netflix prize was won.

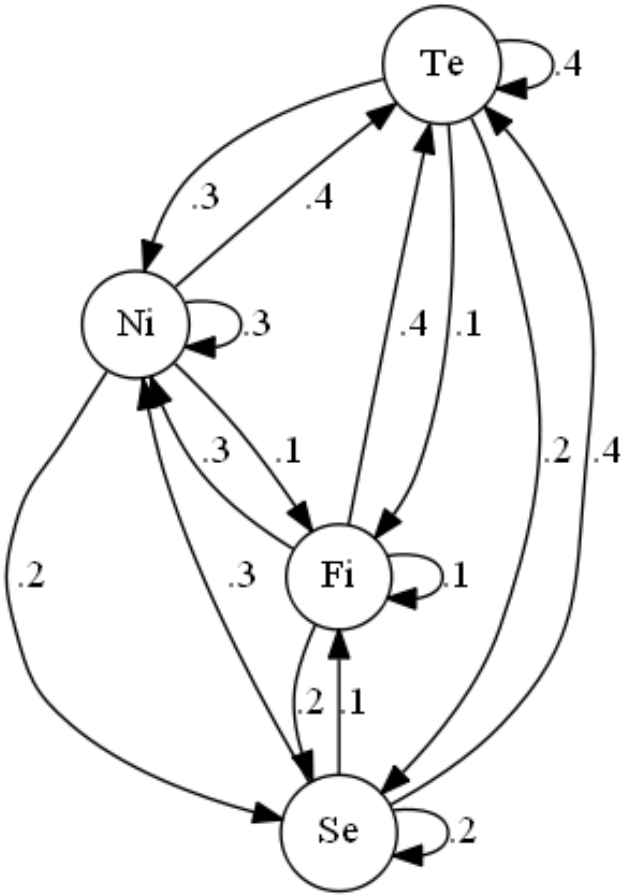
Artificial Personality Synthesis: Leveraging Diversity to enable robust robotic teams.

Over the course of the last 4 years I have been developing an alternative approach to the computational personality problem.

My approach incorporates a "type-based" personality model as opposed to being purely "trait-based."

My approach is inspired by Jungian, type-based personality theory.

- **Personality is modelled in terms of 8 cognitive functions. All people have access to all 8 functions, however different "types," of people have different orders of preference to use the functions. A person can only use one cognitive function at a time and there are constraints on the preference order of the functions.**
- **The key insight is that the cognitive functions can be implemented using known algorithms.**
- **Cognitive functions can be combined in the form of a state machine.**



Algorithms map to Jungian cognitive functions

Extroverted Thinking ()

Contingency planning, scheduling, and quantifying utilize the process of extraverted Thinking.

POMDP, A*, Kalman Filter, Model Updating?

Introverted Thinking ()

Using introverted Thinking is like having an internal sense of the essential qualities of something, noticing the fine distinctions that make it what it is and then naming it.

PCA, ICA, Hierarchical Deep Learning, Auto-Associative Neural Nets

Extroverted Sensing ()

An active seeking of more and more input to get the whole picture may occur until all sources of input have been exhausted or something else captures our attention.

Active Sensing Algorithms, (Consider the active learning algorithms from Cornell), Maximize Information Gain, Active SLAM, Online Learning, Unsupervised Learning (Maybe)

Introverted Sensing ()

Introverted Sensing often involves storing data and information, then comparing and contrasting the current situation with similar ones.

Pattern Matching and Classification Algorithms. Supervised Learning. It is kind of like taking previously stored data and replaying it through the system to determine the reaction.

Algorithms map to Jungian cognitive functions

Extroverted Feeling ()

The process of extraverted Feeling often involves a desire to connect with (or disconnect from) others and is often evidenced by expressions of warmth (or displeasure) and self-disclosure.

State-of-health monitoring, NDE, Affective Computing

Introverted Feeling()

As a cognitive process, it often serves as a filter for information that matches what is valued, wanted, or worth believing in.

Neural Networks?

Extroverted Intuition()

Using this process we can really appreciate brainstorming and trust what emerges, enjoying imaginative play with scenarios and combining possibilities, using a kind of cross-contextual thinking.

Search Engines do this . They bring varieties of ideas together that are somewhat loosely related.

Introverted Intuition ()

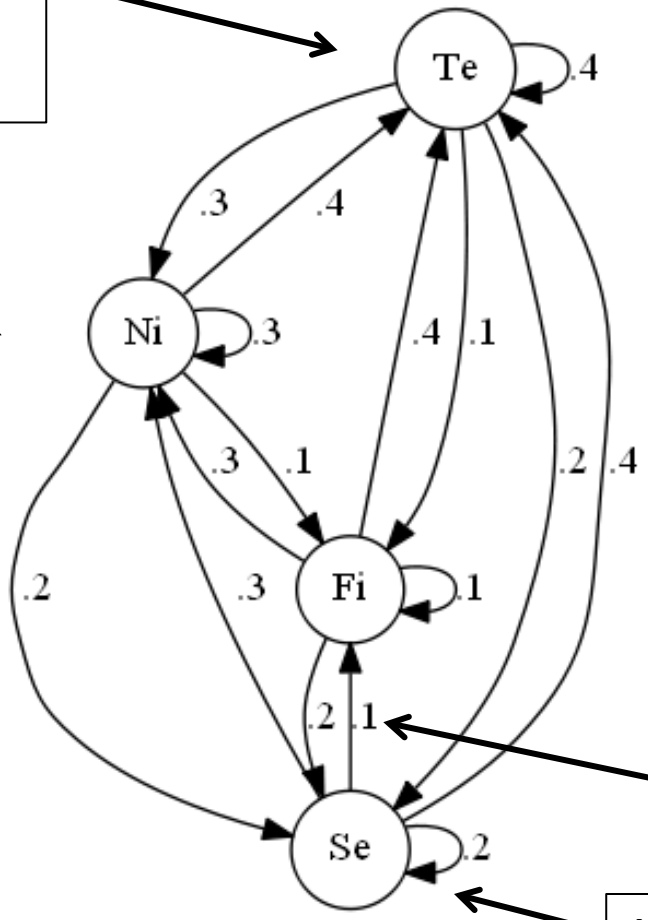
This process can involve working out complex concepts or systems of thinking o conceiving of symbolic or novel ways to understand things that are universal.

I think this is executed by nearly all simulations and possibly optimization algorithms and genetic algorithms. Design of experiment as well. People who are strong Ni users tend to fall prey to "Analysis Paralysis", Autocomplete,

So to build David Mascareñas:

Partially Observable Markov Decision Process

Simulation/Prediction



I am smiling ☺

State of health monitoring

Active Learning

Mascareñas, David, "A Jungian Type-Based Framework for Artificial Personality Synthesis,"
Feedback from NIPS reviewers was that they would like to see an experiment.

The Besso project:

In addition to my being used to characterize and synthesize personalities, my approach also gave me insight into the development of an augmented creativity machine to help generate innovative ideas for proposals.

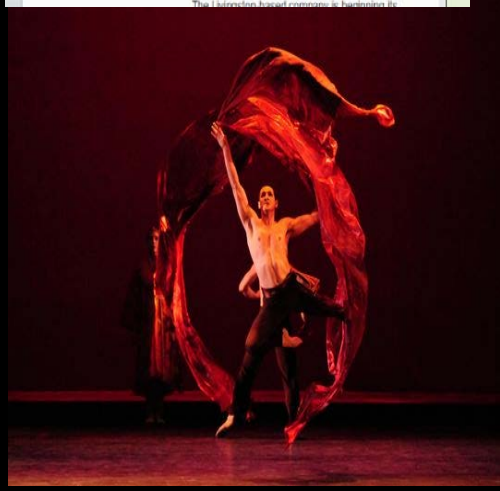
I attended the 2015 NAE KECK Conference on the integration of Science Medicine and Art. I joined the Creativity, Innovation and Action group. I told them about my interest in augmented creativity and the idea resonated with the group.

Misau Landau, Science Writer, Harvard Wyss Institute
Roger F Malina, Art and Technology Distinguished Chair, UT Dallas
Daniel Keefe, Virtual Reality, Computer Science, U of Minnesota
Adam Leeb, Cofounder Astrohaus
Fermi Niveditha, Visualization, Texas A&M
Christina Patrick, Science Writer, John Hopkins

Contributor:
Lise Autogena, Cultural Communication and computing research Institute, Sheffield Hallam University.

Besso is…

- A virtual companion for us, for kids, …
- Integrated within your natural environment.
- That provides creativity-supporting imagery, data, suggestions, links, …
- At a time and place when you are ready for creative thinking - **taking a walk**.
- Built on computer vision, augmented reality, data mining, artificial intelligence, ***and*** visual art, storytelling, character development.
- Bessos link together to form a community.
- Bessos also try to create real-world links between their real-world companions.
- At night, Bessos get together and make new connections (at the Besso Bar and Grill).



NJ Ballet kicks off season at Mayo PAC
BILL NUTT, CORRESPONDENT
9:35 a.m. EST November 13, 2015
The organizers of the New Jersey Ballet want audiences to know that classical ballet involves more than nutcrackers, swans and sleeping beauties.
Their solution? They are sending their dancers to war.
(Photo: Courtesy of V&M Productions)

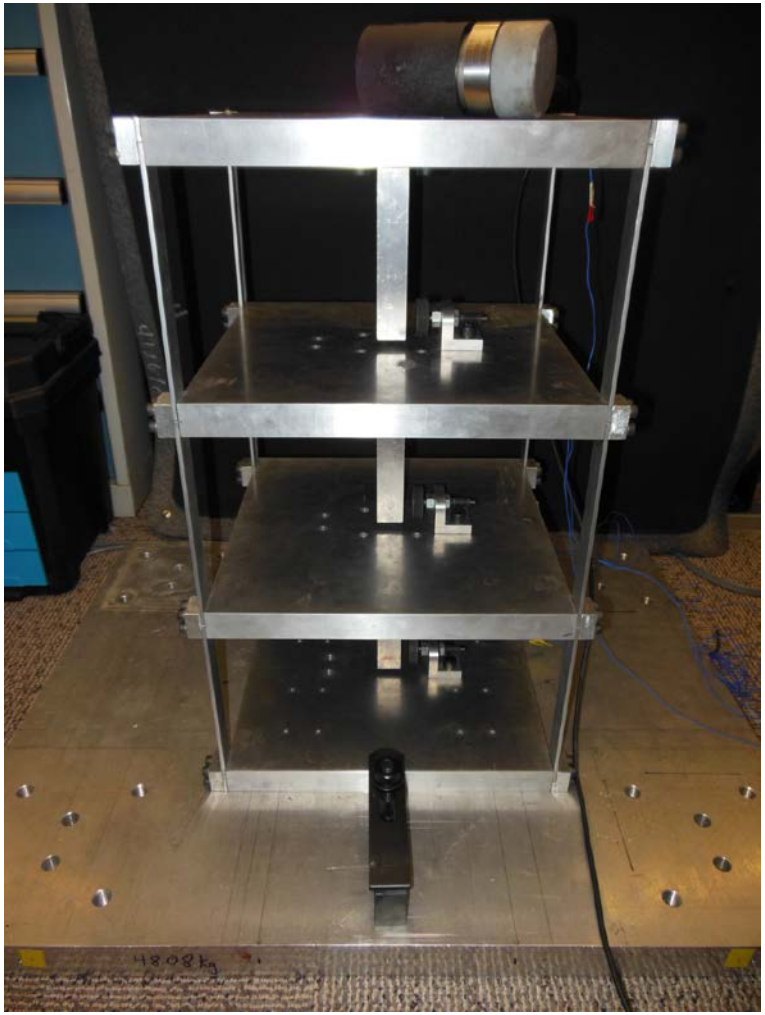
BREITBART
BIG GOVERNMENT
BIG JOURNALISM
BIG HOLLYWOOD
NATIONAL SECURITY
TECH
VIDEO
BREITBART LONDON
BREITBART TEXAS
BREITBART CALIFORNIA
SUICIDE BY COBRA: TEXAS TEEN LETS DEADLY SNAKE BITE HIM REPEATEDLY, SAYS REPORT
SHARE
EMAIL
TWEET
AP File Photo/Mustafa Quraishi

One of the biggest breakthroughs of this workshop was that we came up with a plan for a minimum testable hypothesis for Besso. We are currently working on a proposal to further Besso Development

Measuring Dynamics in Video

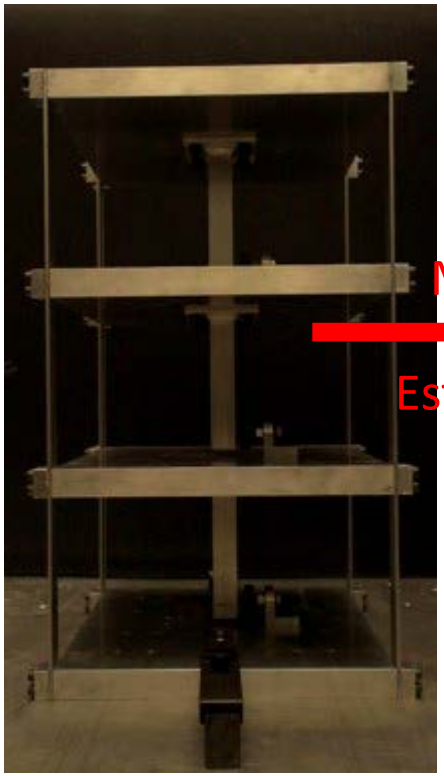
Impact Hammer

Sony Exmor Super 35 CMOS with Zeiss ALC-SH114 Lens



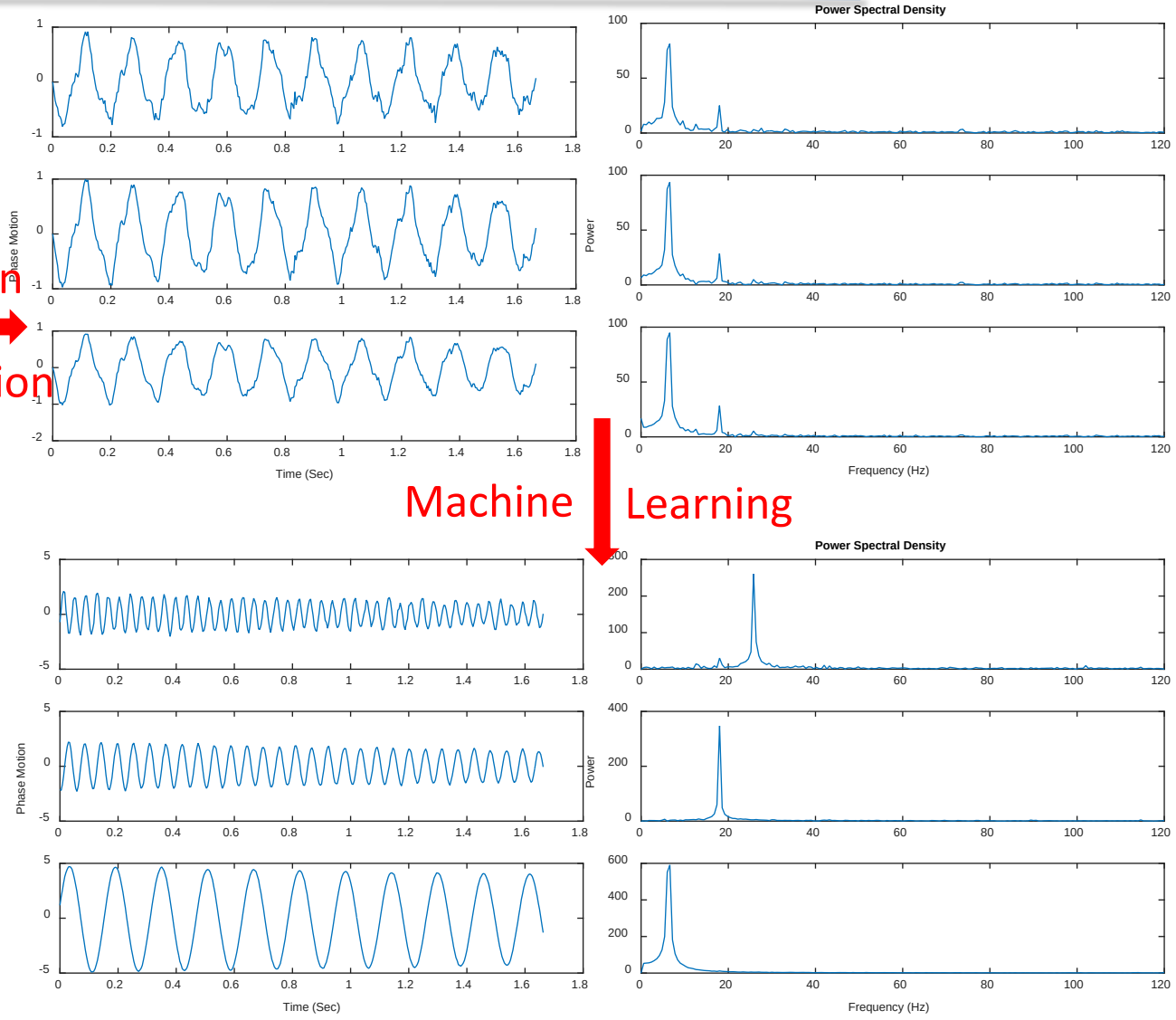
- Fixed Base
- Impact Excitation
- 1080p Resolution
- 240 fps Video

Motion estimation & machine learning



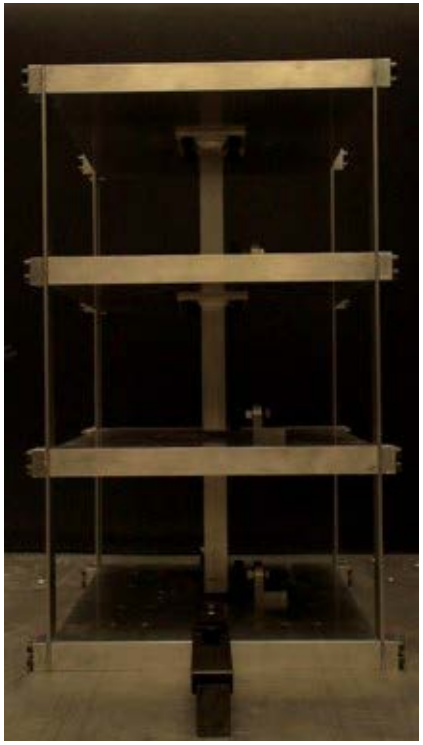
Motion Estimation

Machine Learning



Mode visualization of vibration

Original video



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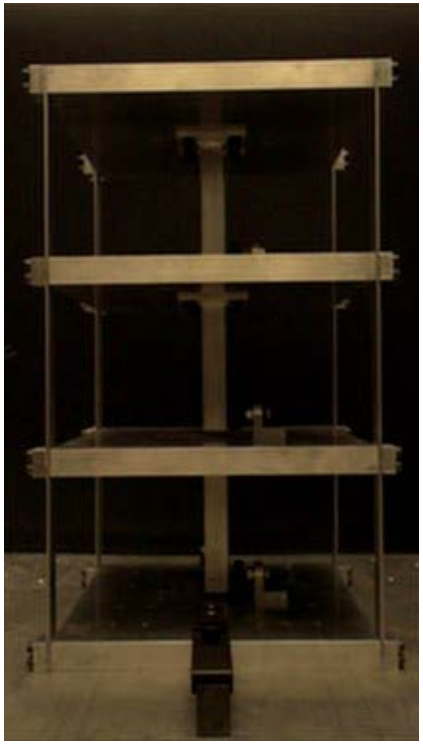
Mode 1 – 6.34 Hz



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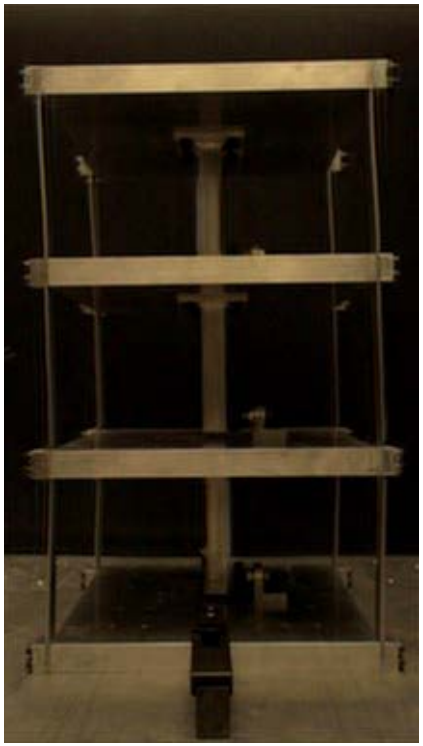
Mode 2 – 17.96 Hz



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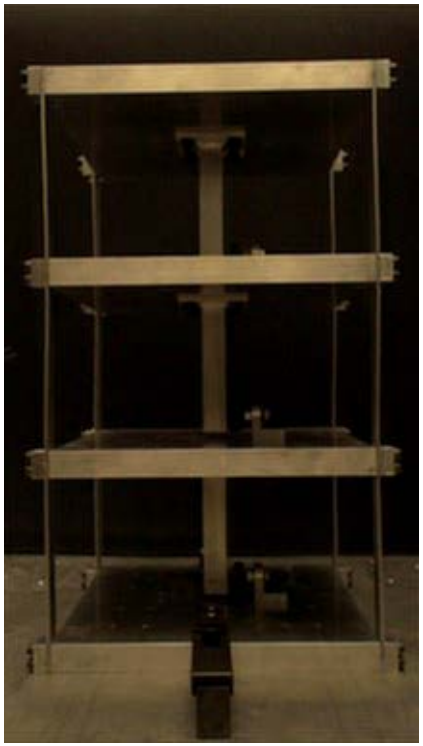
Mode 3 – 25.89 Hz



Appendix

Pros and Cons

	Pneumatic Hammer	Mechanical Linkage
Pros	Significant energy can be applied with pneumatic solenoids.	Lightweight components, only 6 V needed to run motors, noise associated with the motor running is much lower than the pneumatic solution.
Cons	Many components, heavy acoustic noise from the pneumatics corrupts measurement, 24 V DC needed to run the solenoid.	Linkage has a number of moving mechanical parts. Some fear that the weight associated with the system CG will throw the aerial robot off-balance.