

LA-UR-16-26204

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Title: Tap Testing Hammer using Unmanned Aerial Systems (UASs)

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Intended for: final poster for Student Symposium at Los Alamos

Issued: 2016-08-11

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Introduction

- There are 100,000 railroad bridges in North America.
- More than half are over 100 years old.
- Maintenance is prioritized by inspection.
- Inspections cost money which we don't have.

Infrastructure spending is a large component of the railroad annual budget that must be prioritized to ensure safety.

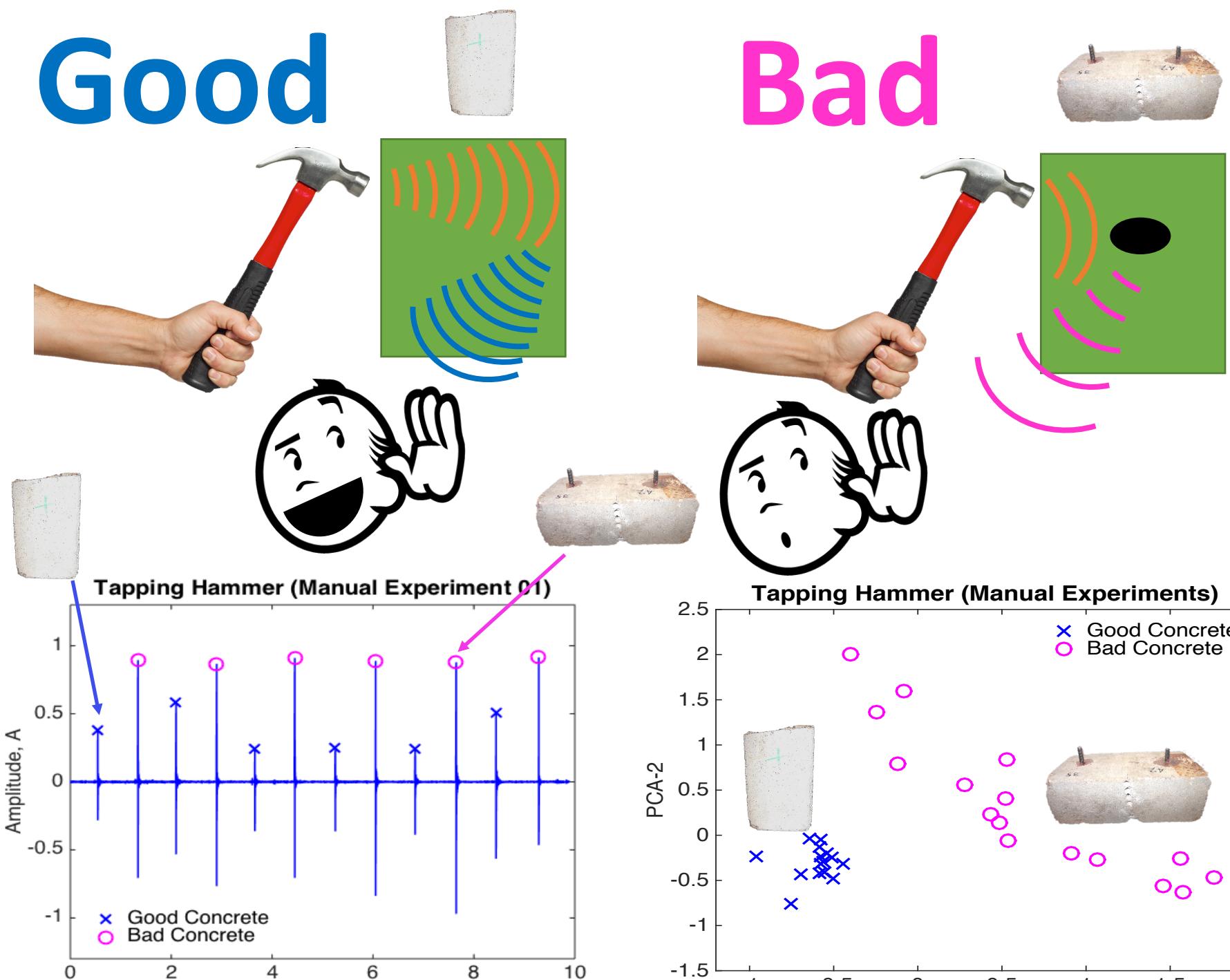
Report Card for America's Infrastructure (American Society of Civil Engineers)						
Category	1988*	1998	2001	2005	2009	2013
Aviation	B-	C-	D	D+	D	D
Bridges	-	C-	C	C	C	C+
Dams	-	D	D	D+	D	D
Drinking Water	B-	D	D	D-	D-	D
Energy	-	-	D+	D	D+	D+
Hazardous Waste	D	D-	D+	D	D	D
Inland Waterways	B-	-	D+	D-	D-	D-
Levees	-	-	-	D-	D-	D-
Public Parks and Recreation	-	-	-	C-	C-	C-
Rail	-	-	-	C-	C-	C+
Roads	C+	D-	D+	D	D-	D
Schools	D	F	D-	D	D	D
Solid Waste	C-	C-	C+	C+	C+	B-
Transit	C-	C-	C-	D+	D	D
Wastewater	C	C+	D	D-	D-	D
Ports	-	-	-	-	-	C
America's Infrastructure GPA	C	D	D+	D	D	D+
Cost to Improve	-	-	\$1.3 trillion	\$1.6 trillion	\$2.2 trillion	\$3.6 trillion



Current inspection priorities include early detection of concrete deterioration, caused by the recent increase of car load capacities.

Railroad bridge inspectors conduct concrete tapping to acoustically detect deterioration of concrete by sound.

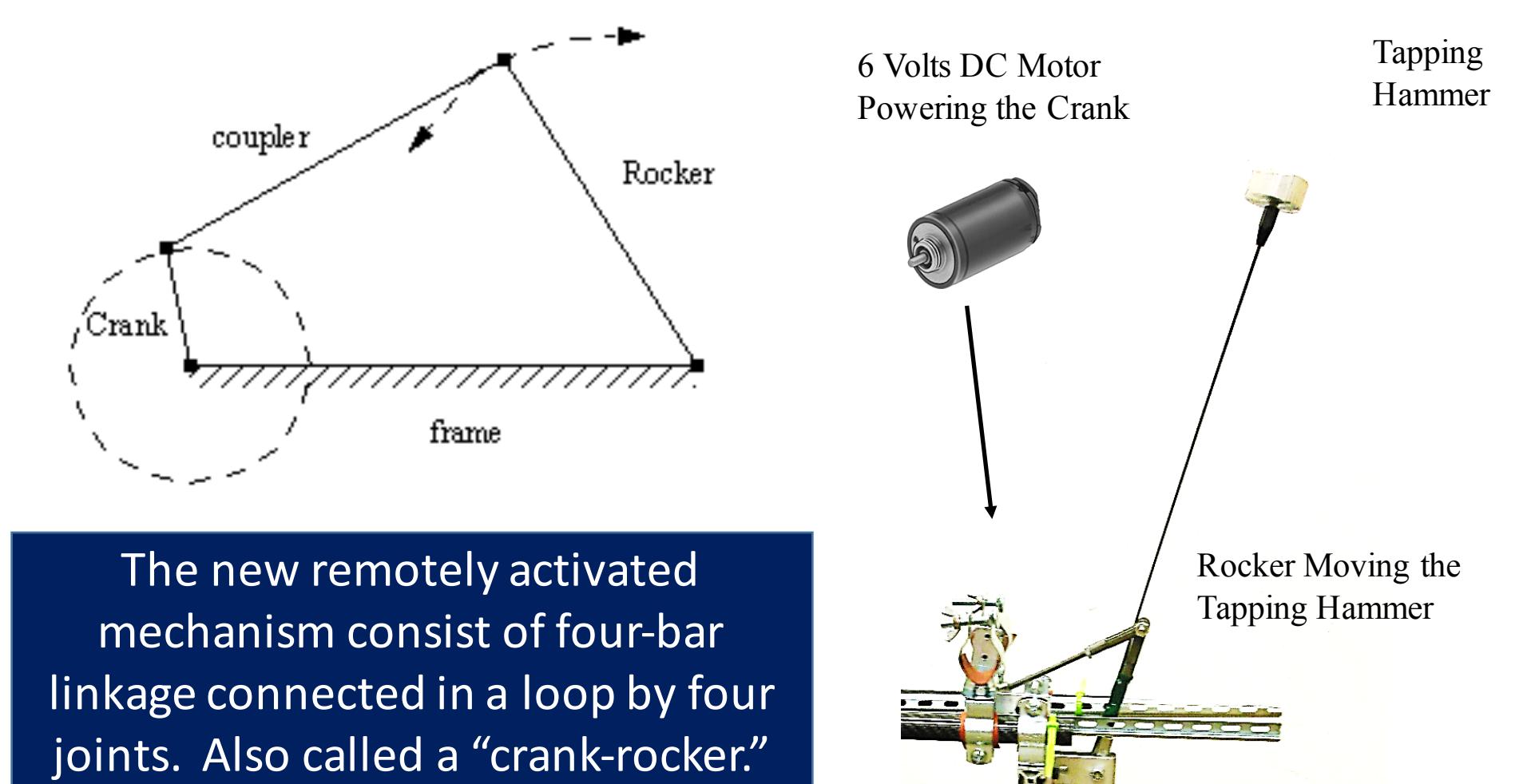
Non destructive Testing (NDT) Theory



Project Description

Creating a tapping mechanism
Collecting the tapping sound
Analyzing the sound data
Implementing for flight

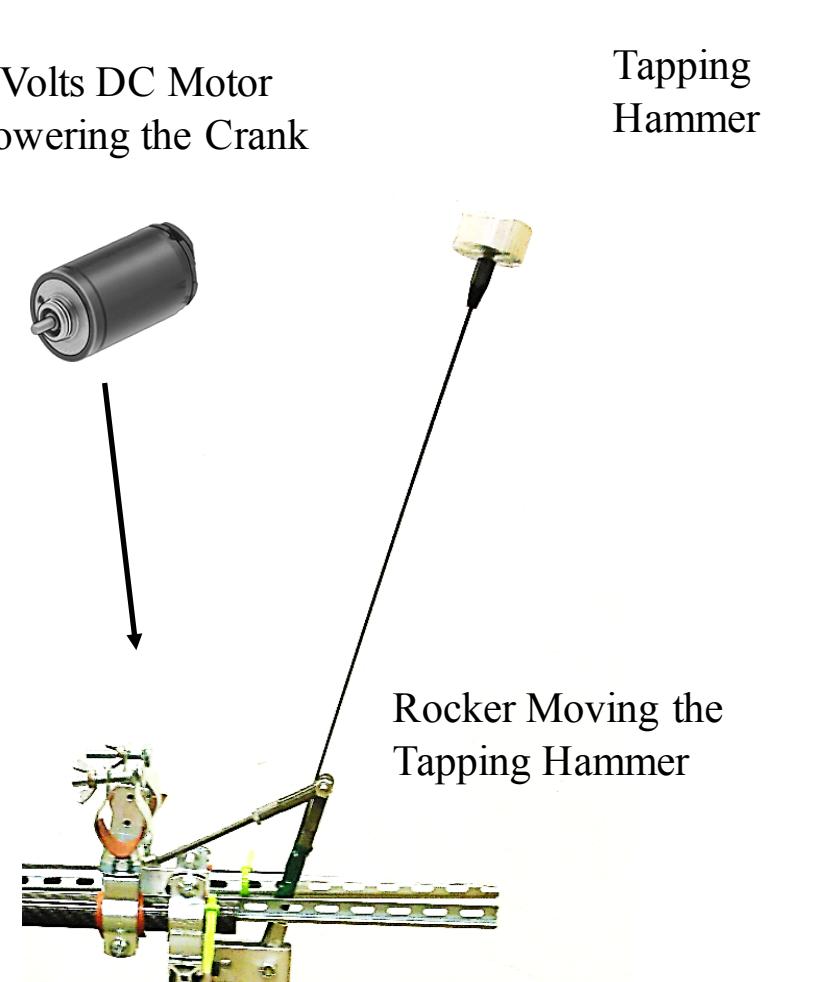
Crank-Rocker Mechanism



The new remotely activated mechanism consists of four-bar linkage connected in a loop by four joints. Also called a "crank-rocker."

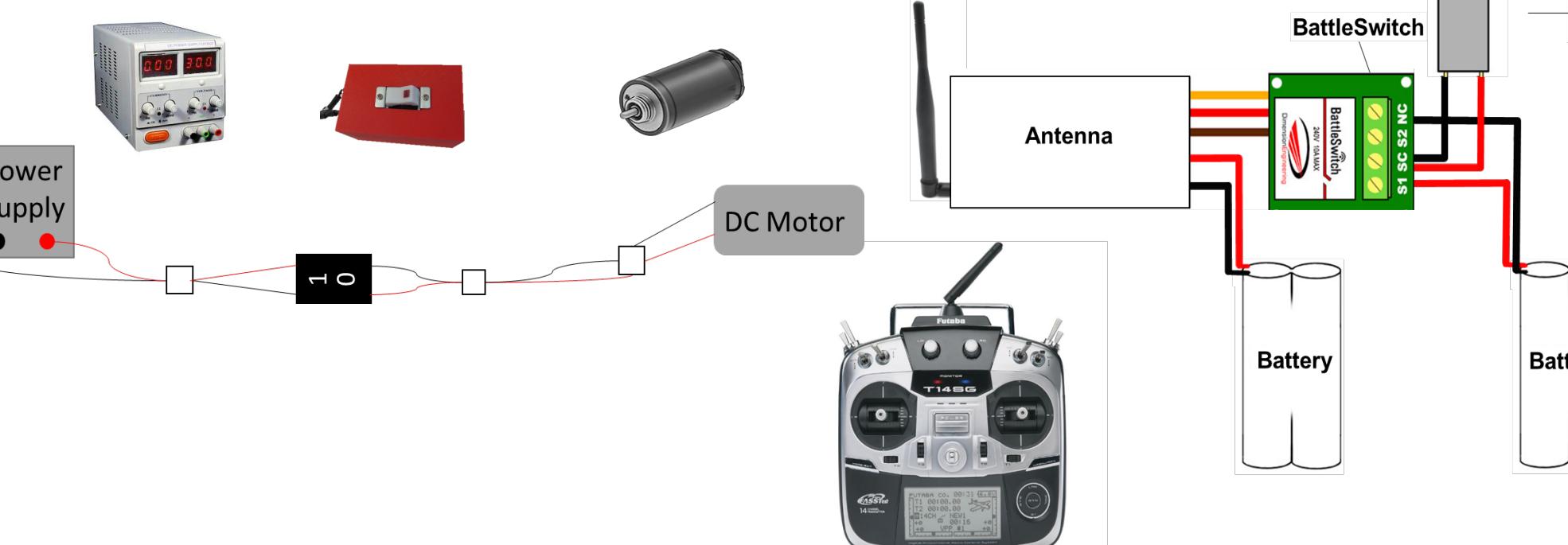
The crank rotates 360 degrees and the rocker that can rotate through a limited range of angles between 0 and 180 degrees.

Tapping Hammer



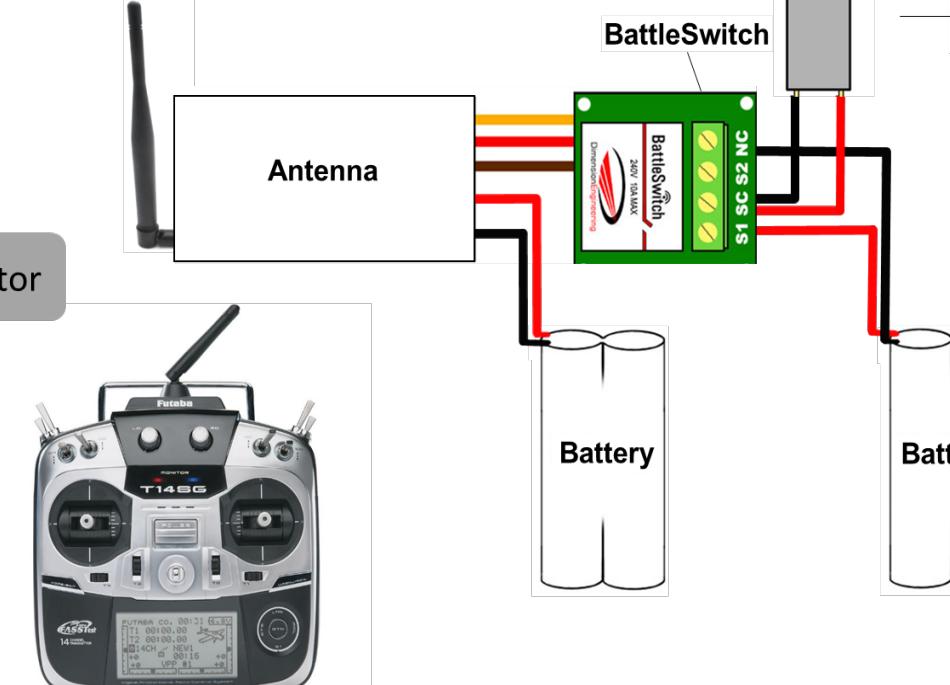
For this tapping mechanism, the crank is powered by a 6 Volt compact DC motor.

Indoor Validation



For the indoor validation, a remote actuation was first tested with a wired mechanism powered by a 5 Volt signal.

Wireless Validation



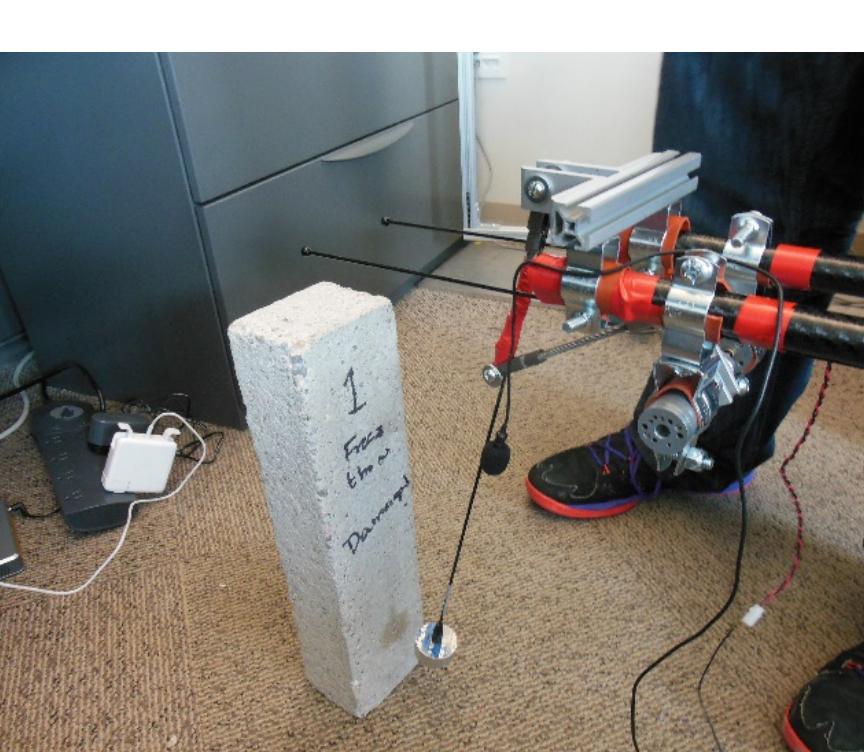
For the UAS operation, the remote mechanism can be turned on and off using a wireless connection.

Before Rotation



Hammer is rotated to avoid collision with the drone propellers.

After Rotation

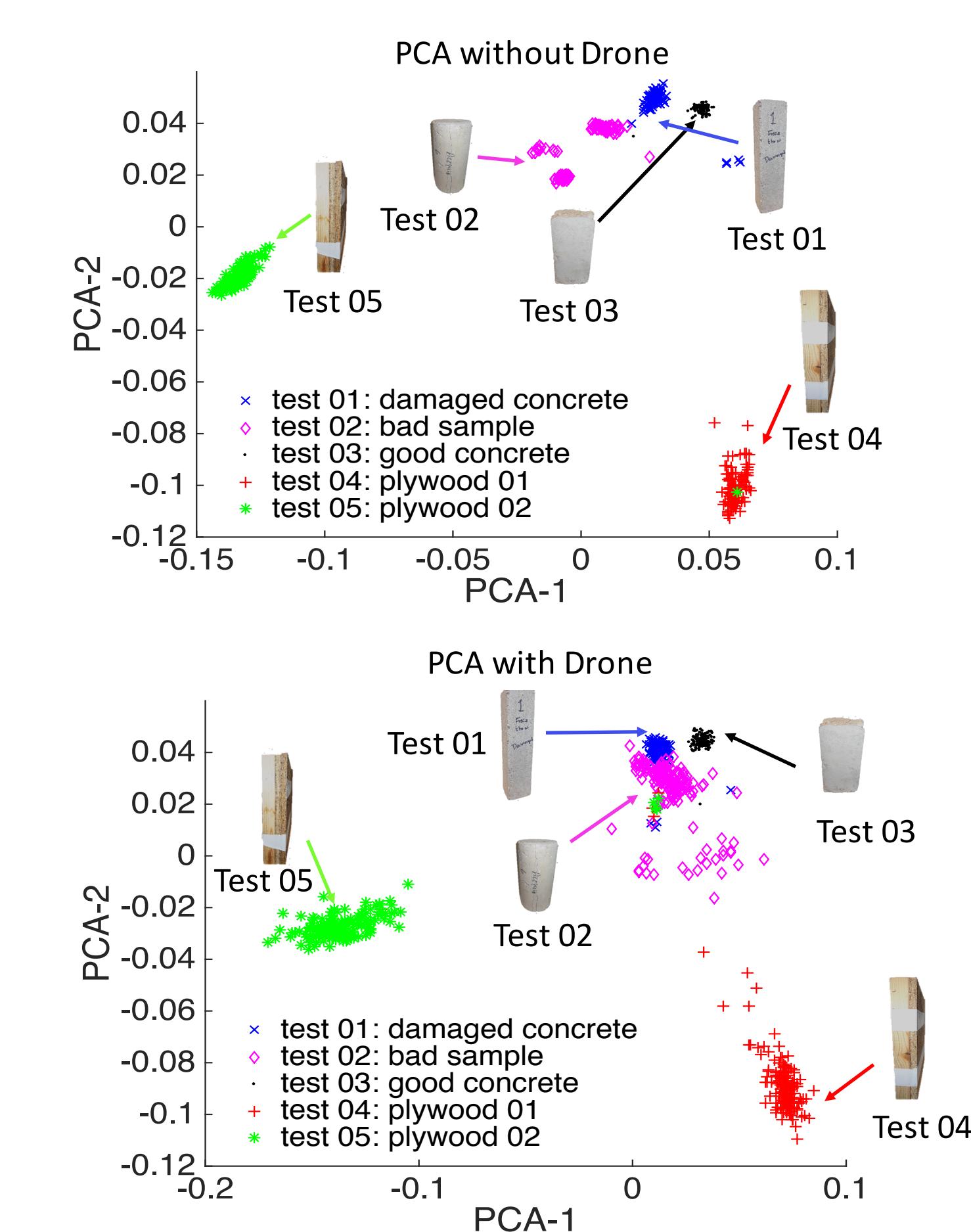


This research describes the development, validation, and testing of a remote concrete tapping mechanism enabled by UAS

Results

- The new tapping mechanism can remotely impact the surface, record the sounds of the impacts, and post-process the data to inform replacement prioritization.
- Principal Component Analysis (PCA) of the data enabled the clustering of the different sets of data.

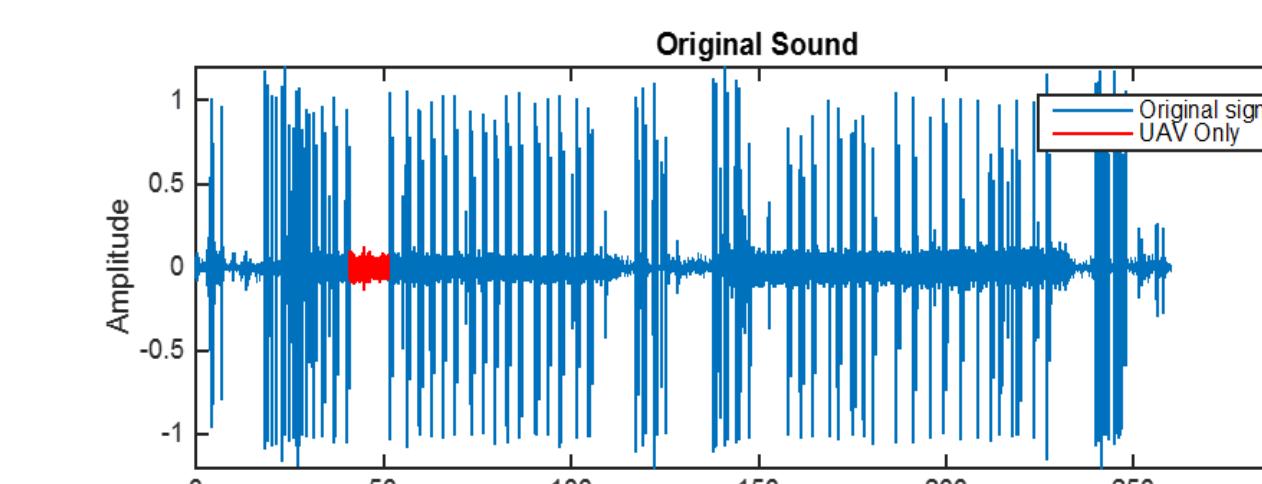
Data Clustering



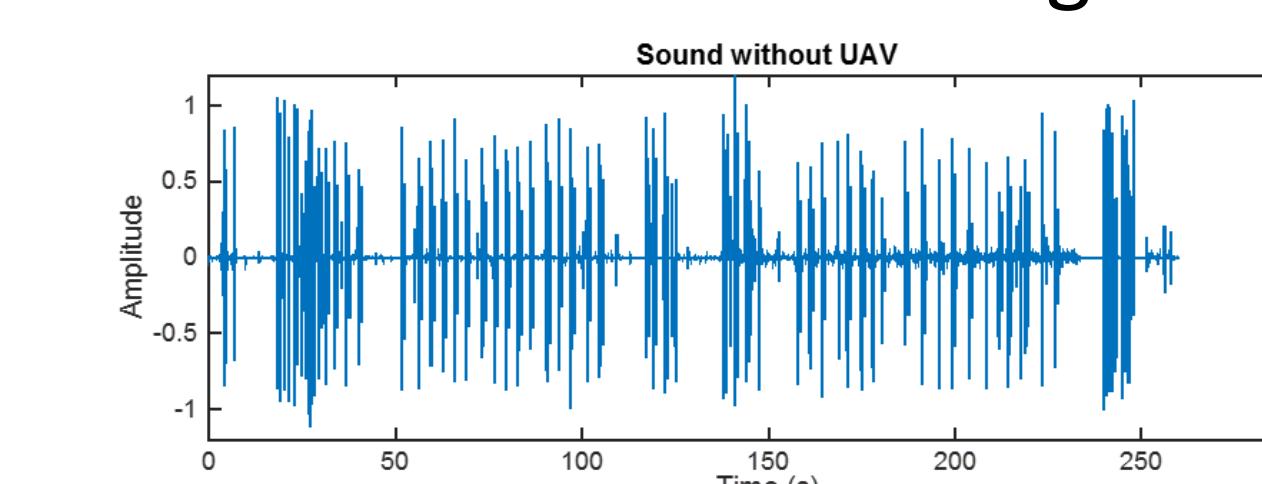
- The clustering of the five different experiments is shown without drone and with drone.
- The clustering of the five experiments is consistent under both experiments.

Denoising Process

Before Denoising

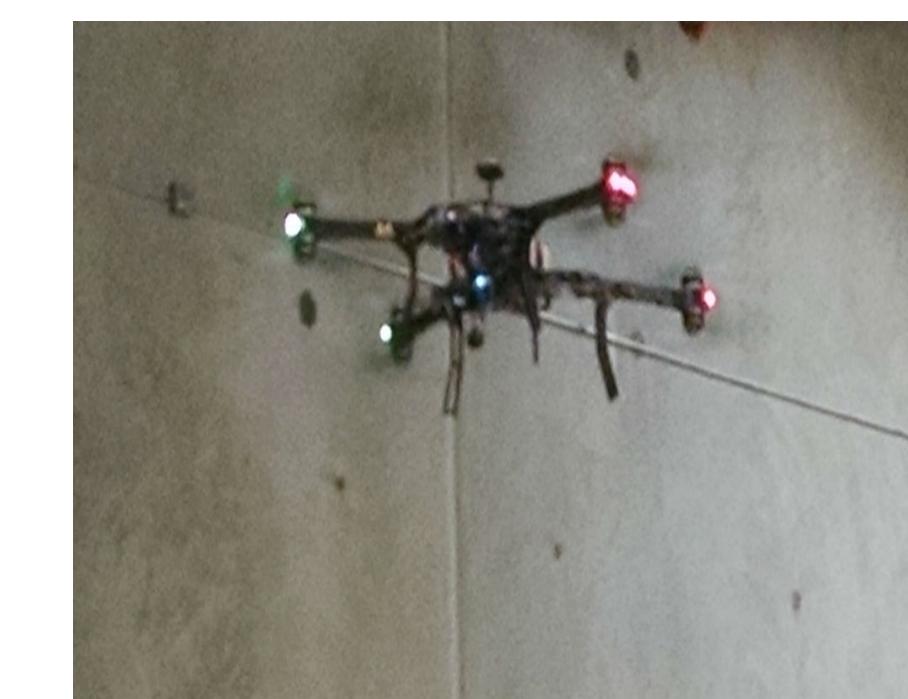


After Denoising



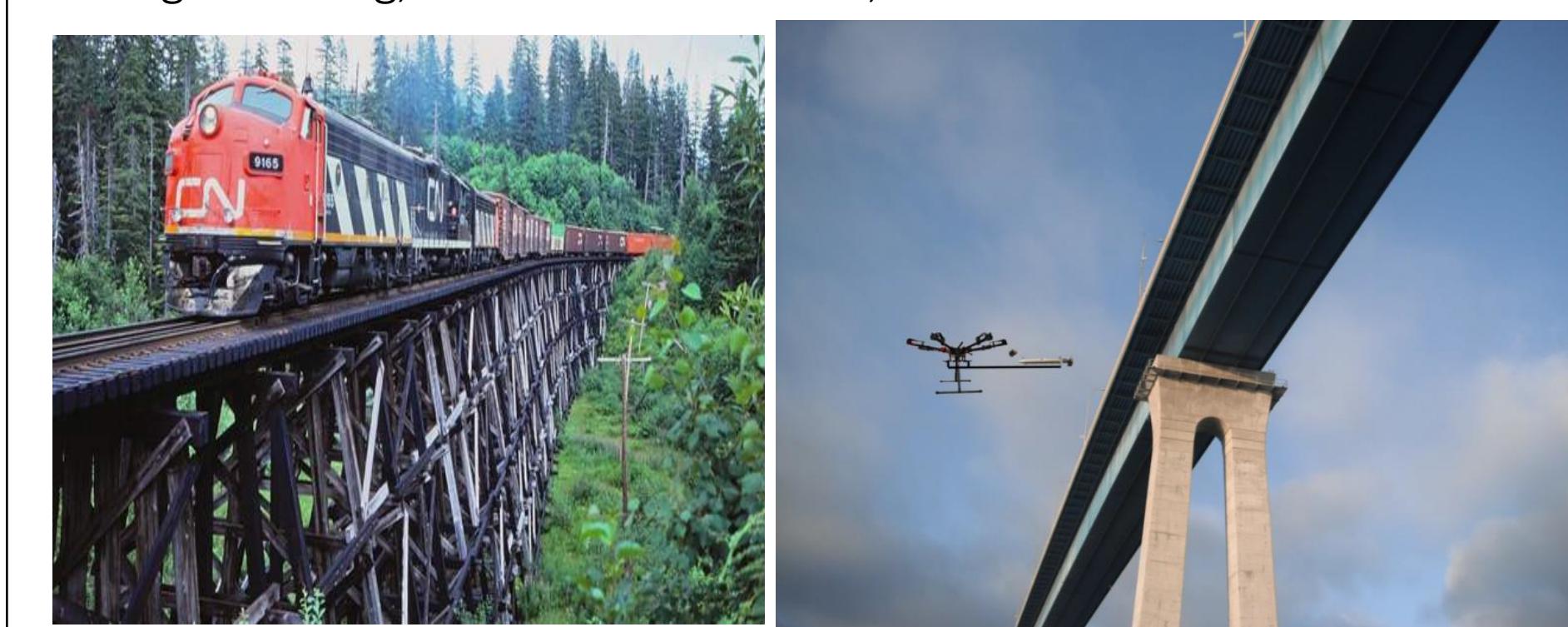
- The spectral subtraction is performed by selecting a portion of the signal without concrete tapping.
- After the sound of the propellers is removed from the entire recording, the new file can be played in the sound software.

Future Work



- In-door flight and outdoor inspection are scheduled for final validation
- Robots can assist railroad bridge crews to safely carry their inspection
- Final stages of this research include remote sensor deployment
- cyber-physical systems and embedded mechanisms will enable the smart management infrastructure.

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Conclusion

The results quantify for the first time concrete tapping data collected remotely with UAS, enabling cost-effective, safer and sustainable upgrade prioritization of railroad bridges inventories.

Acknowledgments

- Canadian National University of New Mexico
- New Mexico Consortium
- Mountain View College

