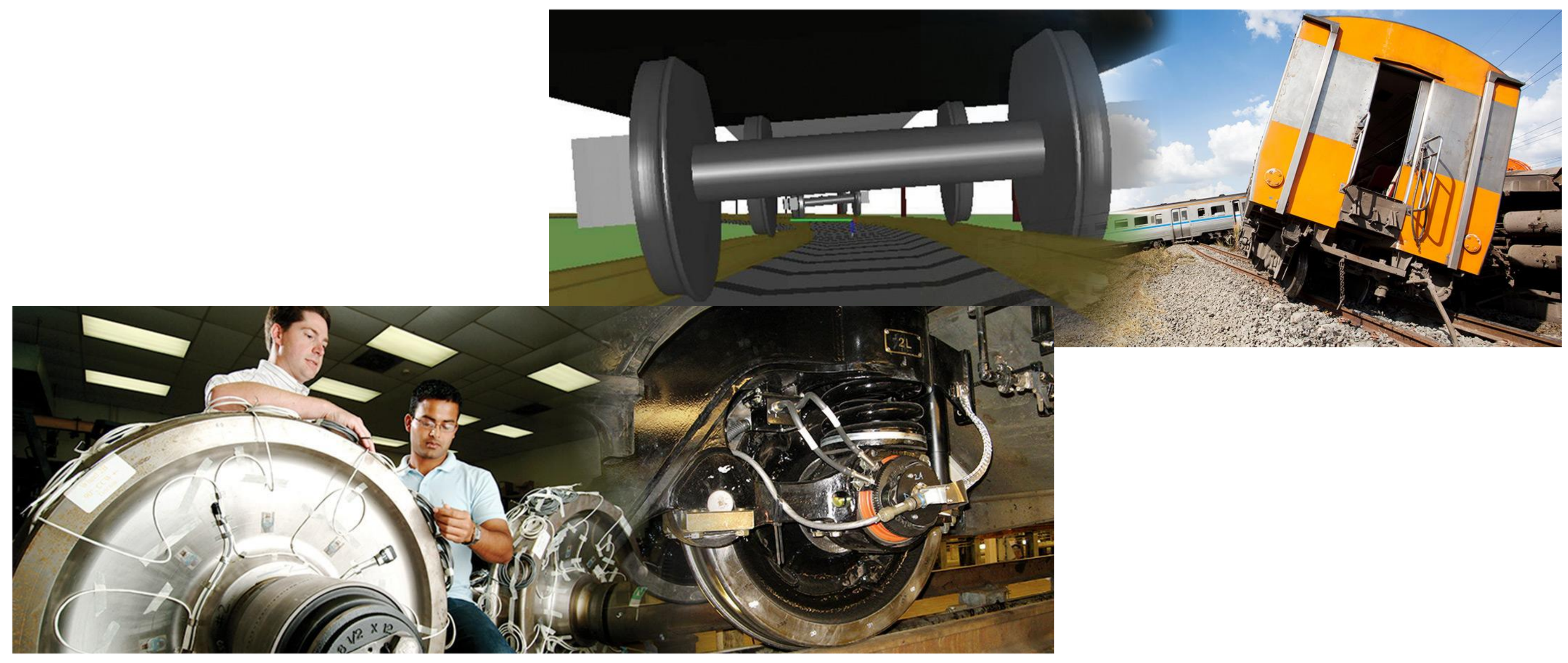
Instrumented Wheel Set Redesign

Objectives

Redesign an Instrumented Wheel Set (IWS)

Grove City College has partnered with ENSCO Rail to assist them in redesigning their instrumented wheelset. ENSCO Rail operates a large rail test facility in Pueblo, Colorado where one of their tasks is to perform test that will help prevent rail car derailments. To do this, ENSCO uses an instrumented wheelset, or IWS, which is a fully calibrated strain gauge array that produces vertical, lateral, and longitudinal wheel/rail force measurements. The GCC new and improved instrumented wheelset design will enable ENSCO to better understand the forces acting on the rail car wheels and rail tracks, which can help them identify issues that may lead to derailments.

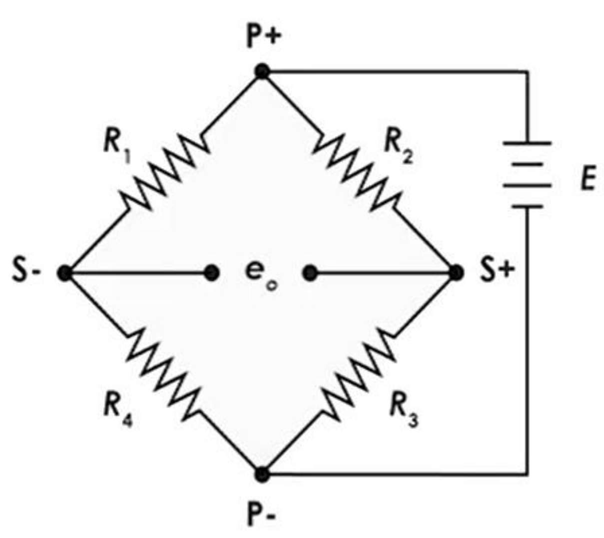


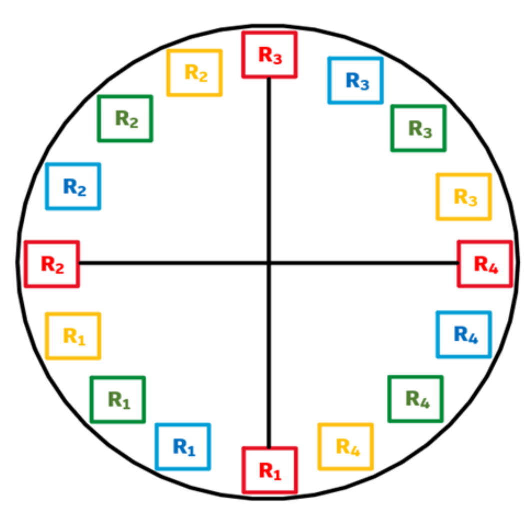
Background

Strain Gauges
Wheatstone Bridges
Radius of Sensitivity

Strain Gauges and Wheatstone Bridges

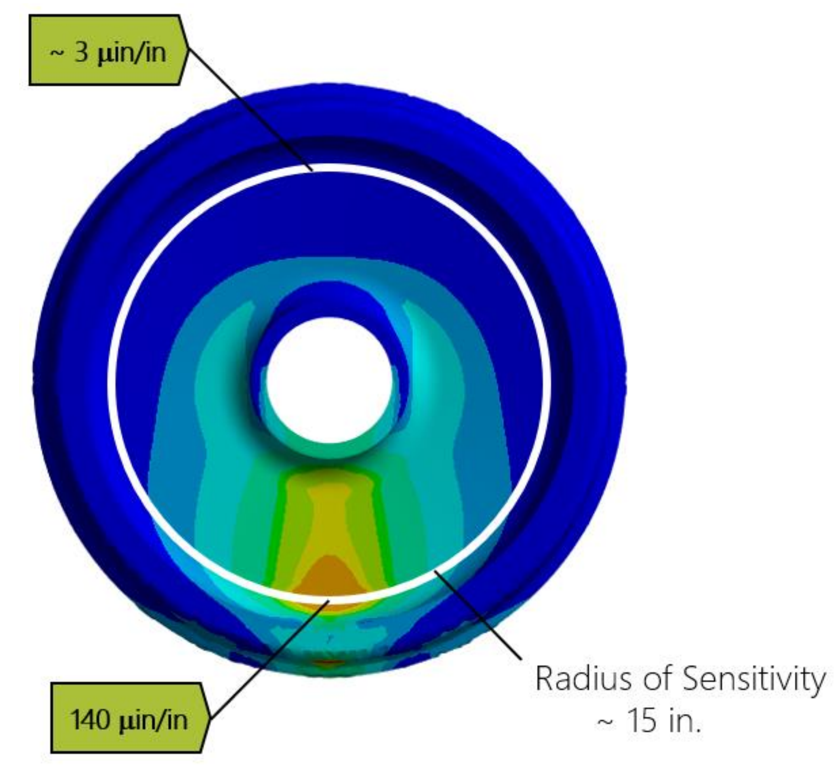
Because of the small output signals of strain gauges and the low strain produced in the wheel, the IWS must read extremely small signals, which are highly susceptible to electrical noise. ENSCO wires the gauges in a Wheatstone bridge configuration (shown in the lower left), which increases the sensitivity of the measurement and additionally allows for four strain gauge outputs to be replaced by one Wheatstone bridge output. The four gauges in a given bridge are laid out symmetrically around the wheel, with multiple bridges installed on the face of the wheel. The lower right figure illustrates this layout with four bridges on the face of the wheel, each color representing a separate bridge.





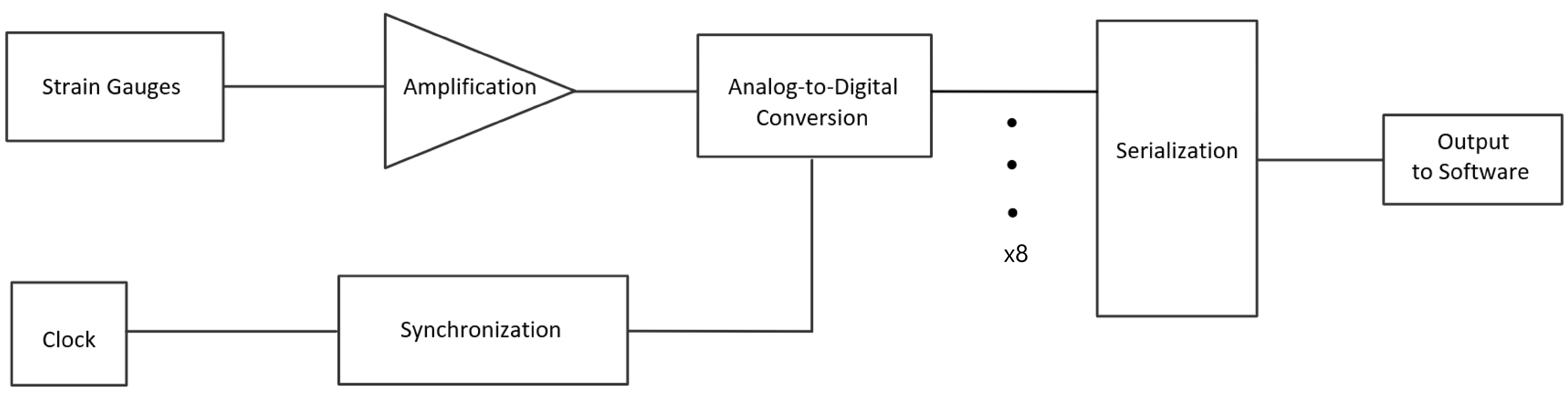
Radius of Sensitivity

In order for an IWS to function properly, the forces applied to the wheel must be accurately determined from the strain gauge measurements. It is therefore best to place the gauges in areas where the strain is the highest, since the strain gauge signal strength is proportional to the strain. Stronger signals will be less susceptible to noise and most easily handled by the circuity. The location of maximum strain on a rail wheel is known as the radius of sensitivity. The team performed Finite Element Analyses (FEA) analyses in ANSYS in order to determine where the radius of sensitivity would be and how much strain the circuit should be expected to measure at that location. The figure to the right shows an FEA color plot of a rail wheel, with the radius of sensitivity indicated in white, and key measurements shown.



Circuit Design

Amplification
ADC
Serialization



Amplification

The amplification portion of the circuit was designed to amplify the Wheatstone bridge output voltage from 0.48mV (the bridge output at 148uin/in strain as predicted in the FEA analysis) to 3.3V in order to be handled easily by the Analog to Digital Converter (ADC).

ADC/Serialization

The Wheatstone bridges were each paired with their own 12-bit resolution ADC, incorporating sample and hold functionality to enable synchronous polling by a Field Programmable Gate Array (FPGA) and allow the data from all 8 bridges to be accessed at the correct time.

Test Unit Design

Scaled Rail Wheel
Force App. Wheel
Drivetrain
Safety Brake
Frame

Main Shaft Assembly

The main shaft assembly holds the 1/3 scale rail wheel. It attached to the frame via two bearing blocks, which hold Timken tapered roller bearings. The main shaft is hollow to allow the wires to run from the circuit (mounted on the wheel), through the main shaft, and off the test unit via an end of shaft slip ring to a data acquisition (DAQ) unit.

Force Application Assembly

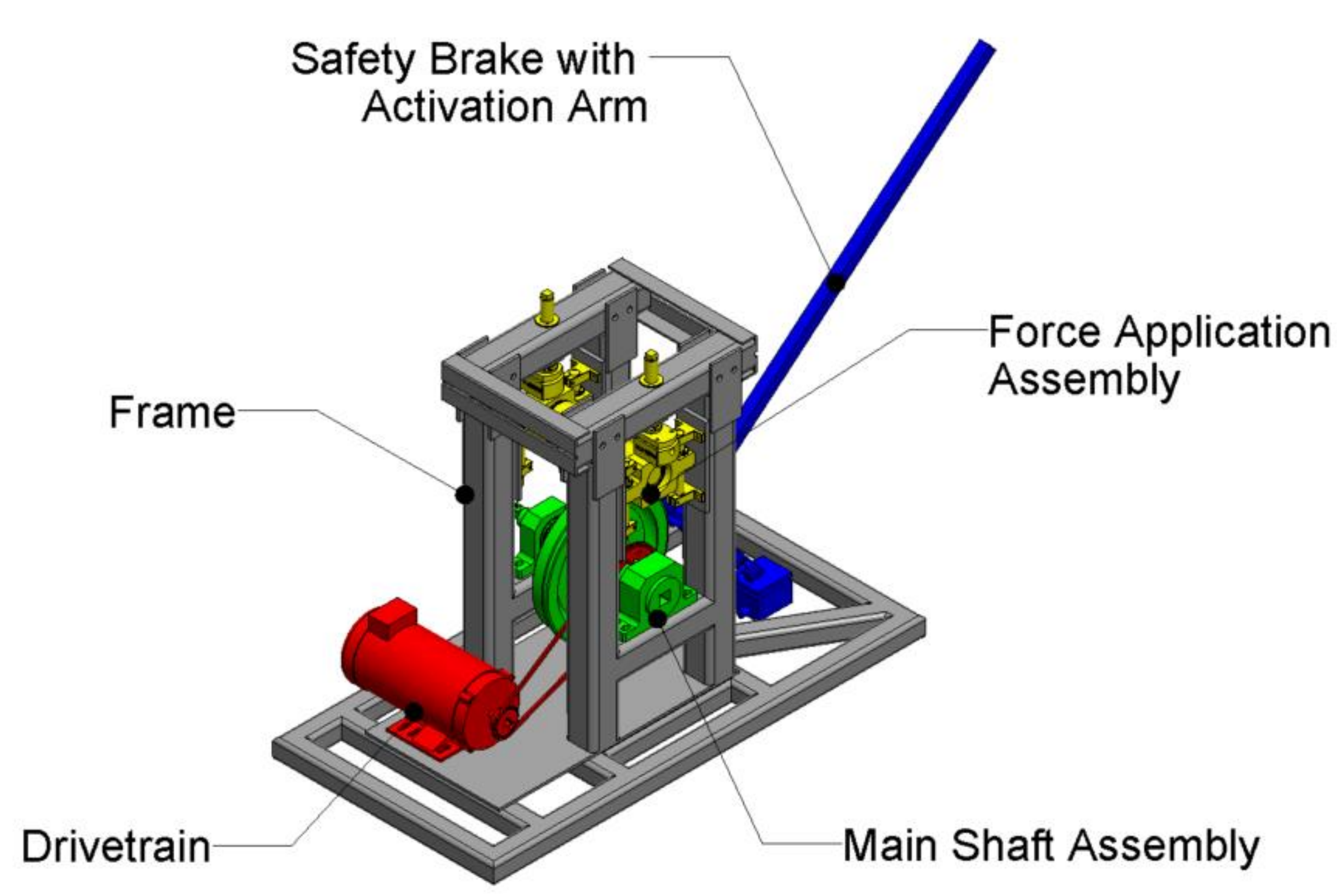
The force application assembly sits directly above the main shaft and is held in place by four linear motion shafts. This allows the shaft to move in response to the forces applied by the hydraulic pistons, which contact the shafts' bearing blocks. The assembly applies force to the scaled rail wheel by means of separate idler wheel, which has the outer profile of a rail (also scaled by 1/3).

Drivetrain

The main shaft is driven by a 1hp electric motor that sits on the base of the frame. The sprockets have a 2.25:1 great ratio, which provides added torque to drive the wheel and a sufficient maximum speed to test the circuit design.

Safety Brake

The safety brake consists of a spring-loaded lever arm with a brake pad on the end that contacts the wheel. The lever is held in place by an electromagnet and when power is cut from the system the electromagnet releases the lever and the springs force the brake pad against the wheel. The brake is able to bring the wheel from its full speed of approximately 600rpm to a full stop in ¼ of a second.



Back Row: Joshua Thomson, Levi Marasco, Bergen Weiner (Team Lead)
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Special thanks to our advisor Dr. Ulrich, sponsor Ron Lang, and shop manager Luke Johnson for their support and guidance on this project.