Aging Guide-By-Wire Project

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Introduction

Northrop Grumman Corporation (NGC) utilizes a guide-by-wire system to direct the traffic of automated vehicles around their Bacchus West (*Figure 1*) plant. The guide path directs vehicles to various buildings around each plant to take rocket fuel through different stages of processing. This system has been used since the 1980's and is essential to regular business. Because of the importance of the regular operation of this system, Northrop Grumman is interested in determining the long-term viability of the guide-by-wire system.

Figure 1. An aerial view of the NGC Bacchus West campus in Magna. The covered road is where the guide-by-wire system is used to direct the automated vehicles across the plant

Problem

Northrop Grumman needs to determine the lifespan of their guide-by-wire system so they can make plans to upgrade or replace it in the future. To help them, our team has developed a testing fixture to simulate the conditions at the plant that will age wire samples to develop an aging model.

What is Guide-by-Wire Navigation?

Guide-by-wire is a system used to direct automated vehicle traffic via magnetic fields. A wire (typically installed into the floor) is given current which induces a magnetic field. The vehicle uses an antenna to sense the magnetic field and helps keep the vehicle centered on the wire.

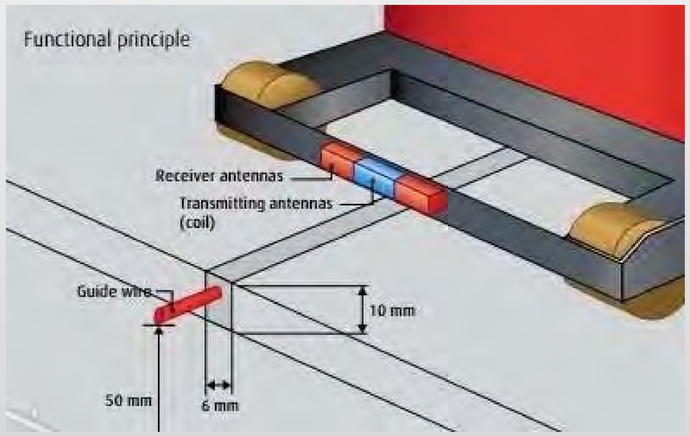

Figure 2. Diagram showing the typical layout of a guide-by-wire system. Wire installed in the floor induces a magnetic field which is picked up by antennas on the vehicle being guided. Image credit: OSIS Group

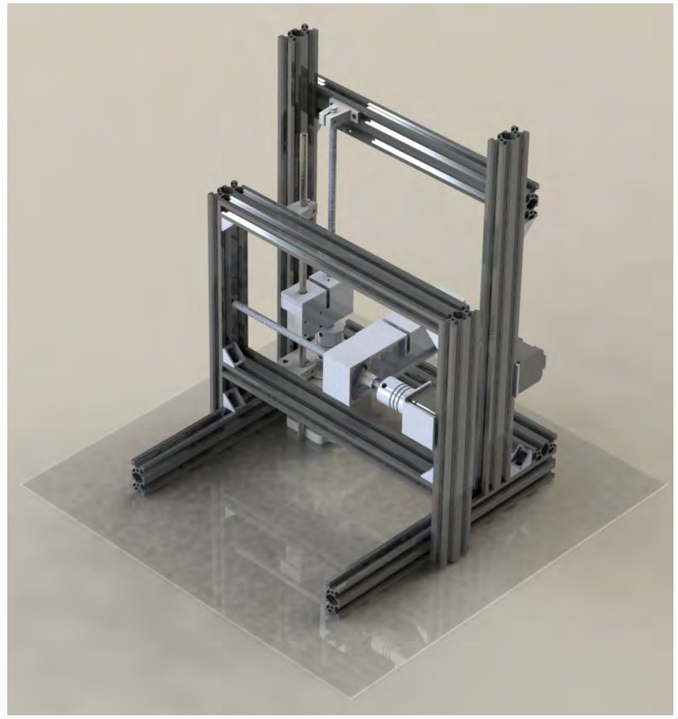

Figure 3. Full system rendering. The left sample plate moves vertically and the right sample plate moves horizontally.

Thermal Expansion

The guide-by-wire system is set in large slabs of concrete which are protected from outside weather. Because the areas with guide-by-wire equipment are not temperature controlled, there are small gaps between slabs to give space for thermal expansion. Table 1 shows how much the concrete expands based on averaged weather data in the plant area.

Table 1. Average change in length of concrete slabs based on the day/night temperature cycles. Note that warmer months have higher amounts of expansion/contraction.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ΔL [mm]	.3804	.4682	.5560	.6145	.6437	.7023	.7315	.7023	.6730	.6145	.4974	.3804

Dynamic Loading

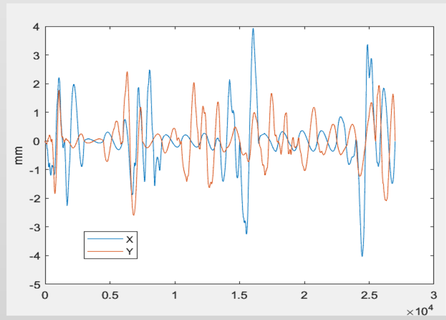

Figure 4. Graph showing the movement of a concrete slab over ~2.5 seconds as an automated vehicle drives over an expansion joint.

In addition to movement from thermal expansion, the expansion joints are also subject to sudden loads as vehicles pass over the gap. An accelerometer was placed at the joint to observe the acceleration of the slabs, which was later converted to an approximated displacement.

DAQ and Motor Control

The test fixture uses an Arduino and Raspberry Pi to send commands to motors which displace the sample plates both horizontally and vertically. Displacements mimic the regular movements from thermal expansion and dynamic loading.

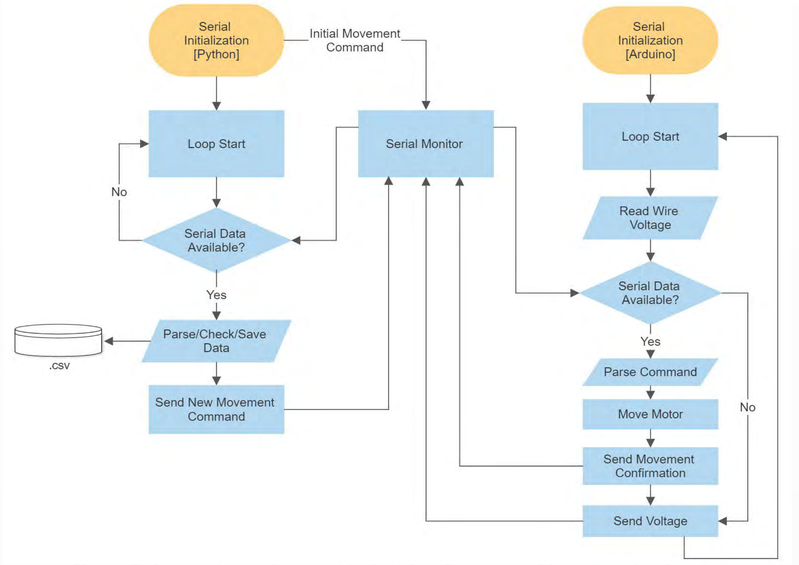

Figure 5. System flow diagram for Arduino-Raspberry Pi communication and interaction.

Test Sample

The sample plates moves horizontally and vertically to put stress on the wire which is buried in Sikaflex, a puddy-like substance used in the factory floors. The number of cycles is counted and the voltage through the wire is tracked to determine wire failure.

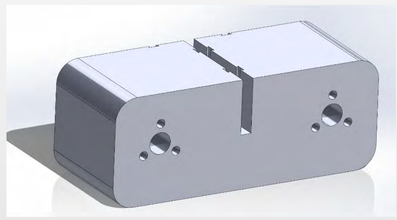

Figure 6. Horizontal sample plate. This plate allows for manipulation along x-axis.

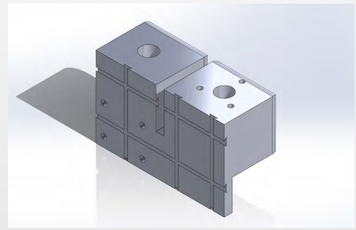

Figure 7. Vertical sample plate. This plate allows for manipulation along z-axis.

Test samples are built using a horizontal and vertical sample plate joined by Sikaflex. Wire is placed in between the plates per manufacturing specifications, see Figure 8. Sample is installed on fixture and tested until failure.

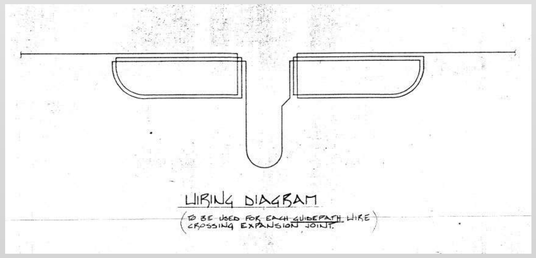

Figure 8. Manufacturers wiring diagram showing how wire installed at expansion joints.