REMOTE-CONTROLLED MOBILE EQUIPMENT IMPLEMENTATION

Steve Naglack, Edw. C. Levy

JC Pierce, Hexagon

NSA Annual Meeting

2024 Goals and Objectives

Experiment on remotely controlled mobile equipment to isolate the operator from job hazards and improve overall safety.

PROJECT #1
973 TRACK LOADERS

Fully functional loader undergoing minor repairs to be used in hot slag operations

PROJECT #2

Caterpillar 980M Steel Mill with Full Cat Remote Operation

ETA- Oct 2024

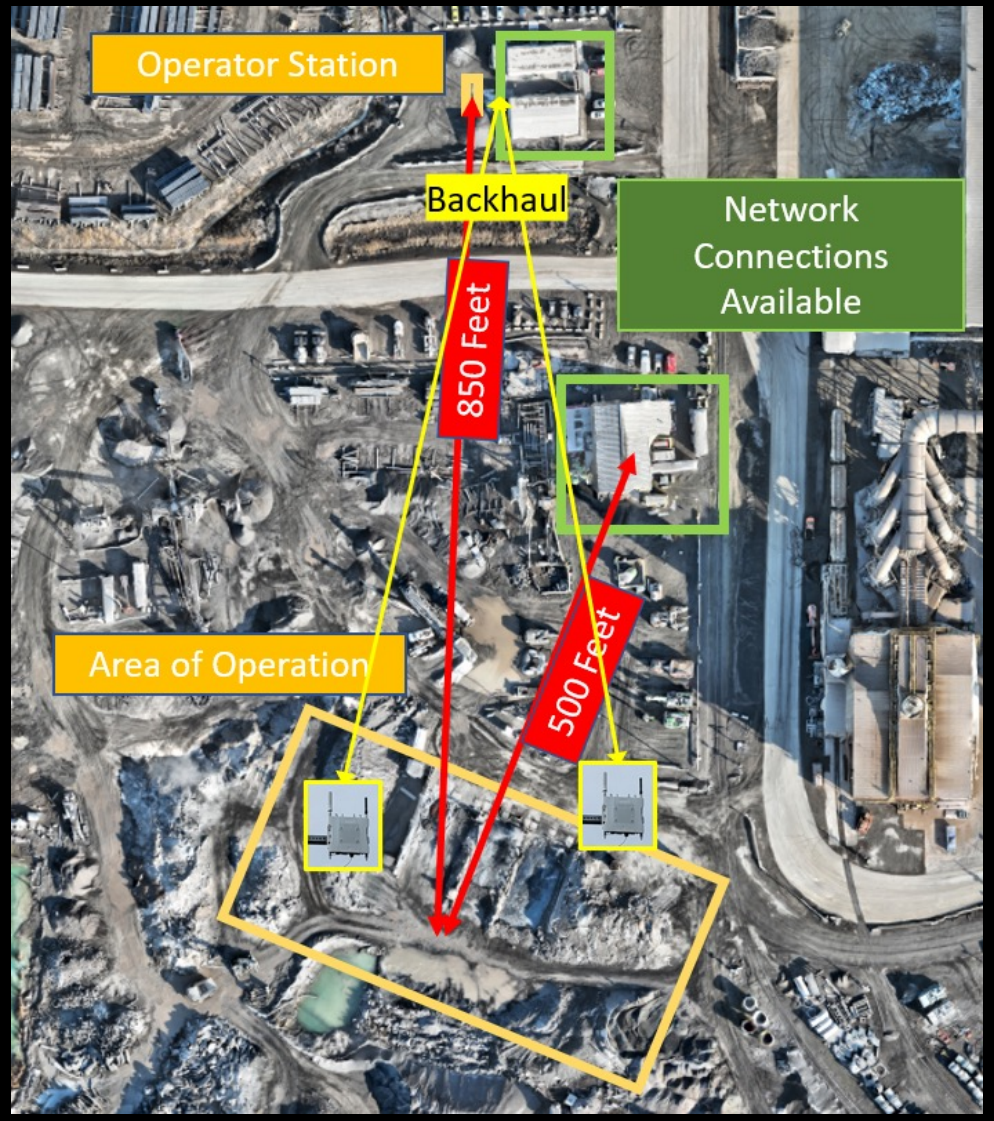
NATIONAL SLAG ASSOCIATION • NATIONAL SLAG ASSOCIATION •
NSA
NATIONAL SLAG ASSOCIATION
Proudly Serving The Industry For Over 100 Years

Command Console and Command Station
Safety Enhancements

- Control the machine from a safe distance
- Eliminate safety risks in potentially dangerous situations including stockpiles, steep slopes, unstable surfaces and areas with hazardous materials or the possibility of falling debris
- Less potential for injury while climbing on/off the machine
- Remove operator risk from machine rollover or sliding

Command Console and Command Station
Efficiency Improvements

- Single user can quickly and easily switch between Cat Command installed machines, and change jobsite locations, with no downtime
- Select and activate machine features from the Command Station and Command Console as though the operator was in the machine
- Control the machine with the same response time as sitting in the cab
- Maintain smooth, precise control from a safe location
- Ergonomic layout, universal controls and familiar machine displays allow for easy access to machine functions
- Reduce operator fatigue and improve productivity by eliminating the effects of machine vibration, machine sound and excessive site conditions
- Allow operators who have had medical concerns to return to work and operate machines earlier


Operator Station
Backhaul
Network Connections Available
850 Feet
500 Feet
Area of Operation

Site Layout

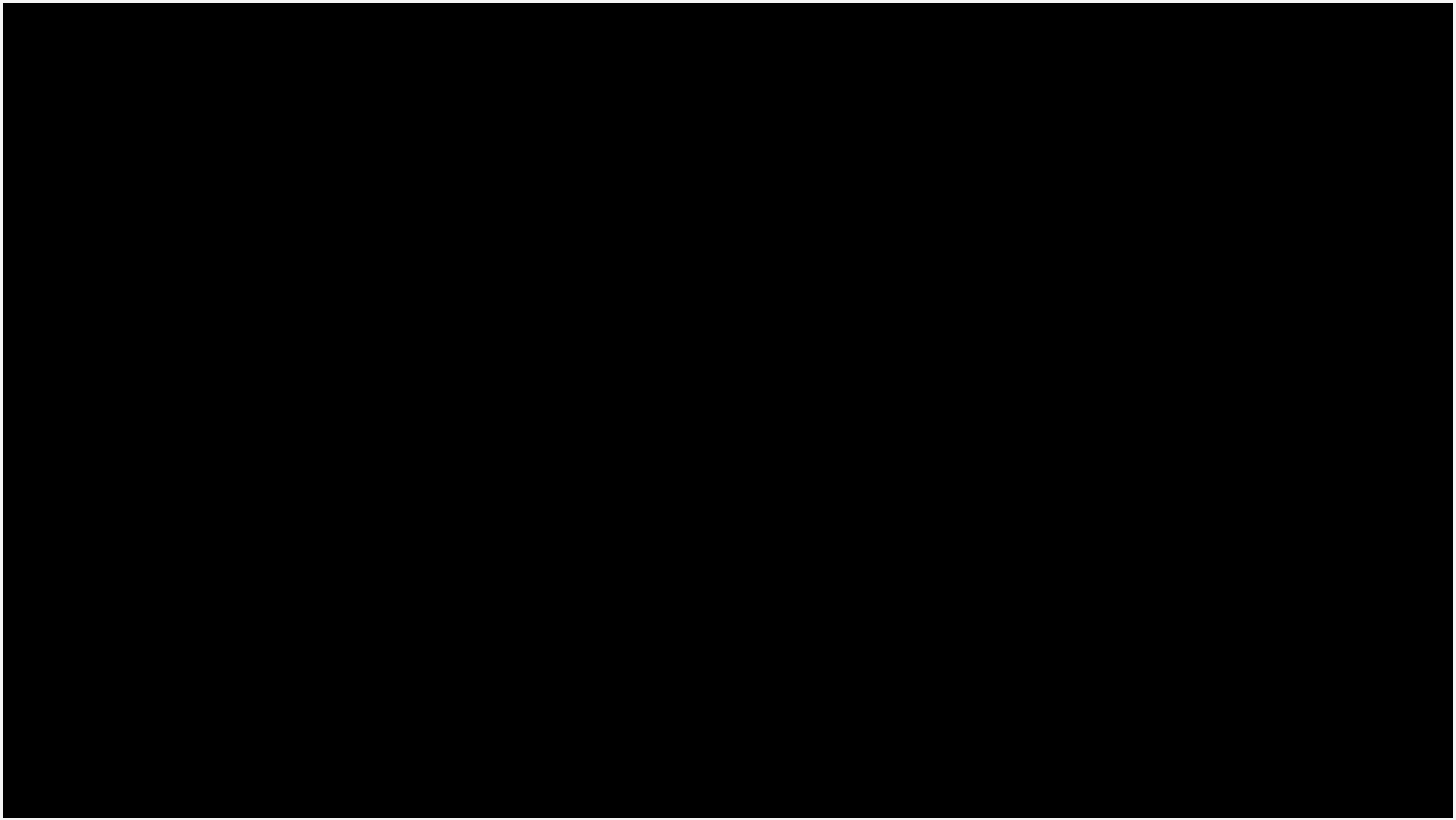
Project #3

Sennebogen 870E Drop Ball Machine with Hexagon Remote

Currently Fully Operational

HEXAGON | HARD-LINE

NATIONAL SLAG ASSOCIATION
Proudly Serving The Industry For Over 100 Years



HEXAGON | HARD-LINE

For nearly three decades, Hexagon has been at the forefront of providing remote control solutions for the mining industry. Over the past six years, we have collaborated with prominent industry partners in the slag and steel sector to enhance safety by enabling hazardous tasks without operators in the cab.

NATIONAL SLAG ASSOCIATION
NSA
NATIONAL SLAG ASSOCIATION
Proudly Serving The Industry For Over 100 Years

TELEOP™ STATION COMPONENTS (MAY VARY)

The Teleop™ station is the control center for the system. It is set up in a remote location outside of the working area, allowing the operator to be totally out of the proximity of danger. Several remote control stations may be set up and able to choose from a network of machinery under the Teleop Multi™ system.

Teleop™ Client Computer

Runs the TeleAi Client software and communicates commands from the touchscreen to the TeleAi server, which then forwards them to the remote location over the network.

Monitor

Displays camera views and telemetry data from the machine.

Touchscreen

TeleAi Client software is controlled using the touchscreen. It is used to select the desired machine and work zone, controle the machine, and change what is being displayed on the main monitor.

M22 Module

Converts signals from the Teleop chair's controls (switches, joysticks, pedals, etc) into a format that can be used by the system to control machine functions.

Disconnect Switch

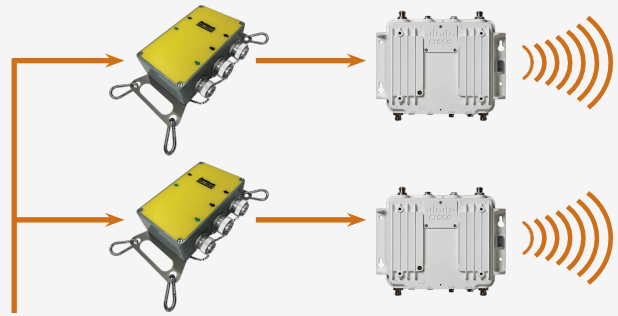
Supplies main power to the control chair. When *ON the* control chair is operational, when *OFF* the control chair is disabled. It may be locked-out to prevent operation from the Teleop station.

Teleop™ Control Chair

Controls are communicated to the TeleAi server and then sent to the remote location over the network.

BACKBONE NETWORK COMPONENTS (MAY VARY)

The BackBone network components are mounted throughout the working area to create a WiFi network that communicates with the machinery under Tele-operation. The number of network components present will vary depending on the size and shape of the area requiring network coverage.



Network/fibre to remote Teleop station.

Network Panel

The network panel is powered by 120VAC (supplied by site) and supplies 24VDC and network connection to all components down the line. Network from the remote Teleop station is brought here.

Network Switch(es)

In addition to boosting the signal over long runs, each switch provides a connection point for cameras, access points, and barriers. It is the number of these items desired and then length or shape of the run that dictates the number of network switches that will be needed.

Access Point

Access points are mounted throughout the remote operating area. They are responsible for wireless communication between the machine and the BackBone Network. The AP receives a signal from the Network Switch and transmits it wirelessly, to be picked up by the Bridge on the machine. Access points transmit audio, video, telemetry and other necessary signals from the machine back to the Network Switch.

AUXILIARY CONTROL KIT (OPTIONAL)

Standard I/O Module(s)

When used as standard I/O modules these devices can accept a variety of inputs and outputs for control of auxiliary processes (chute doors, lights, atomizers, PLC's, etc.). Any devices plugged into these modules can be controlled directly from the Teleop touchscreen.

MACHINE COMPONENTS FOR BASIC TELEOP (MAY VARY)

The machine components are mounted on the machine itself. They control the machine based on the commands received from the Teleop™ station over WiFi. They also transmit important signals from the machine back to the remote Teleop™ station.

Network Module

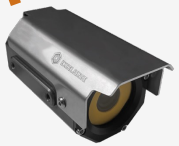
Receives a signal from the Bridge and sends commands to vehicle unit. It also provides power to the bridge, cameras, microphone, and LiDAR sensors. It forwards audio, video, telemetry and other necessary signals back to the Bridge.

Bridge

A Work Group Bridge is mounted on the machine. It is responsible for wireless communication between the machine and the BackBone Network. It receives a signal from the access points and passes it on to the Network Module. It transmits audio, video, telemetry and other necessary signals from the machine back to the Teleop station.

Microphone Module

Picks up audio from machine and sends the signal to the Network Module.



Camera

Outdoor camera with 720p resolution. Cameras are mounted on machine and send a video signal to the Network Module.

Vehicle Unit

The Vehicle Unit controls all machine functions based on the signals received from either the Network Module (in Teleop mode) or via radio signal (in Line of Sight mode).

Teleop Antenna

Transmits Wifi signal to the Work Group Bridge.

Controle Module

Receives a control input from the vehicle unit and generates a variable output for control of proportional functions.

MACHINE COMPONENTS FOR OPTIONAL ADD-ONS (MAY VARY)

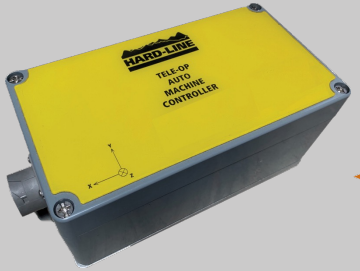
The machine components are mounted on the machine itself. They control the machine based on the commands received from the Teleop™ station over WiFi. They also transmit important signals from the machine back to the remote Teleop™ station.

IMU Sensors (Bucket Assist Only)

Multiple IMU sensors are mounted to the machine to track angles for the Bucket Assist feedback system.

teleop ASSIST

teleop AUTO



Auto Machine Controller (AMC) (Assist / Auto Only)

Processes the data from the LiDAR and other sensors needed for Assist & Auto driving.

LiDAR (Assist / Auto only)

Scans the machine's surroundings to either localize the machine in the drift (Auto) or to center the machine in the drift (Assist).

Line of Sight Unit

Sends commands to the vehicle unit, which then controls the machine. Uses 900MHz radio signal.

900MHz Antenna (Line of Sight)

Transmits radio signal between vehicle unit and Line of Sight unit. A clear path between this antenna and the Line of Sight unit must be maintained for proper operation. (Antenna only present on models operating in Line of Sight)

BARRIER COMPONENTS (MAY VARY)

Barriers are the primary safety feature of the Teleop system and shut down the machine when opened. The barrier components are mounted at all entrances to an area where there are machines under Tele-operation. The number of barriers required will depend on the number of entry points that allow access to the machine under remote control.

Barrier Strobe

Alerts personnel of the presence of machines operating under remote control. Flashes when the barrier is closed and remote operation is enabled.

Camera

Outdoor camera with 720p resolution. Security camera mounted for monitoring of the barrier area. Sends video signal to the Network Switch.

Steel Strut

Attaches to zone wall on either side of the barrier. Provides a place to tie, support, open and close gates.

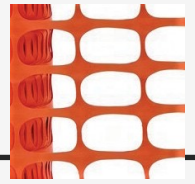
Barrier (Gate) Module

Disables Tele-operation when personnel must cross a barrier and enter a remote workzone. The switch is pulled out to enable Tele-operation and pushed in to disable Tele-operation. Placed at all barrier gates.

Network Switch (Network Component)

Gate Connector

Gate connectors plug in at the top and bottom of all gates. Gate connectors must be plugged to complete the electrical path back to the barrier module. This arms the barrier and creates a fail-safe design that shuts down the machine when the gate is opened.



Orange Fence

Placed at all points of entry to a workzone where a remote operated machine is/can be used. Acts as a physical and visual barrier for mine user safety.

Barrier Detection Interface Module

Used to connect the two laser module outputs in series, ensuring a fail-safe design that shuts down the machine when either laser is broken. Interfaces signal to barrier module. Installed near barrier module.

Component for laser equiped barriers only.

Laser Modules

Two laser modules for activating a laser beam on both sides of the fencing. Unsafe worksone notice sent to Teleop operator when laser signal is broken.

Component for laser equiped barriers only.

973 Track Loader

Sennebogen 870

Barrier Module for LOTO

Tele Op Control Station

NATIONAL SLAG ASSOCIATION • NATIONAL SLAG ASSOCIATION •

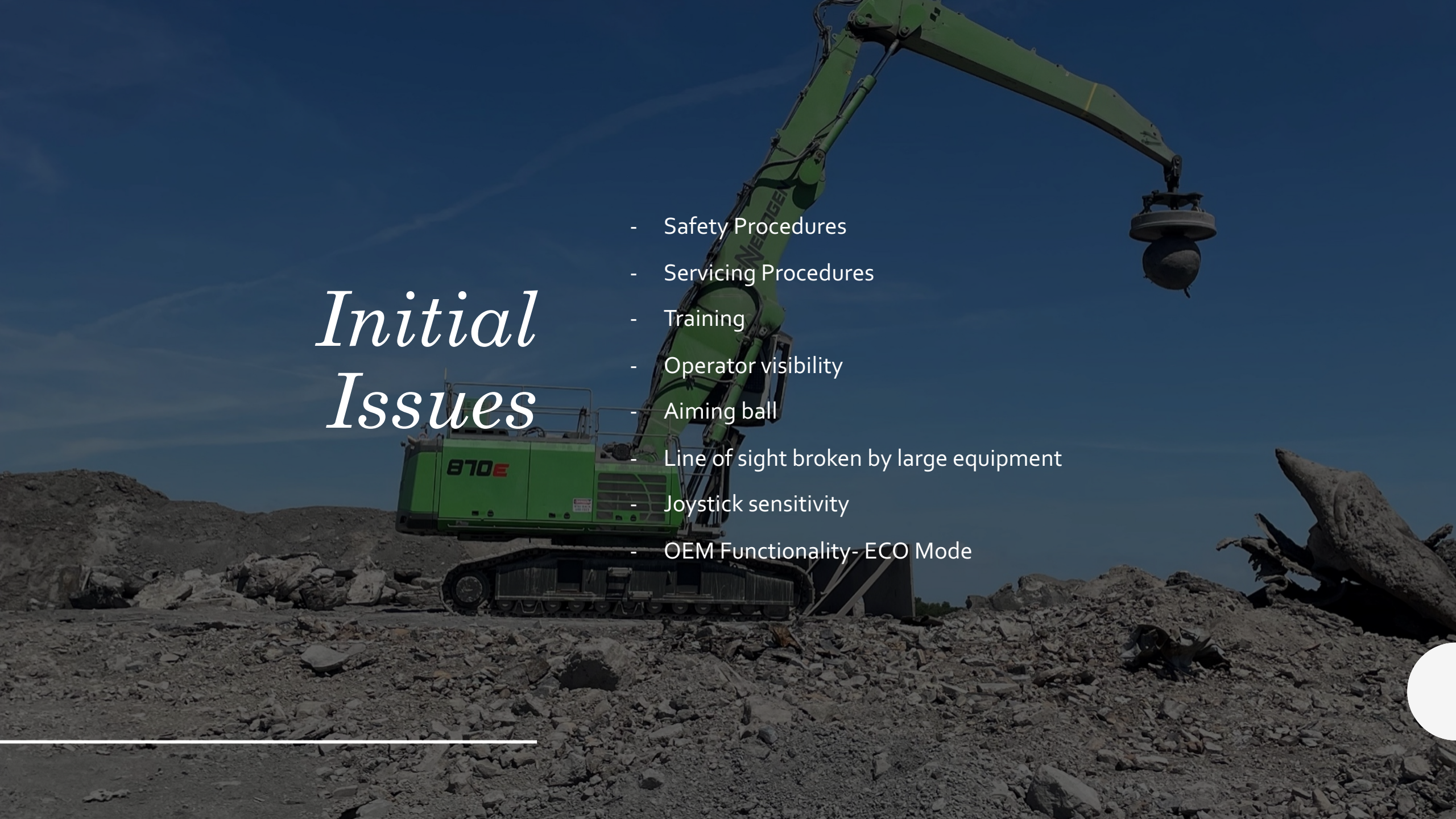
NSA

NATIONAL SLAG ASSOCIATION

Proudly Serving The Industry For Over 100 Years

LINE OF SIGHT

369 FT

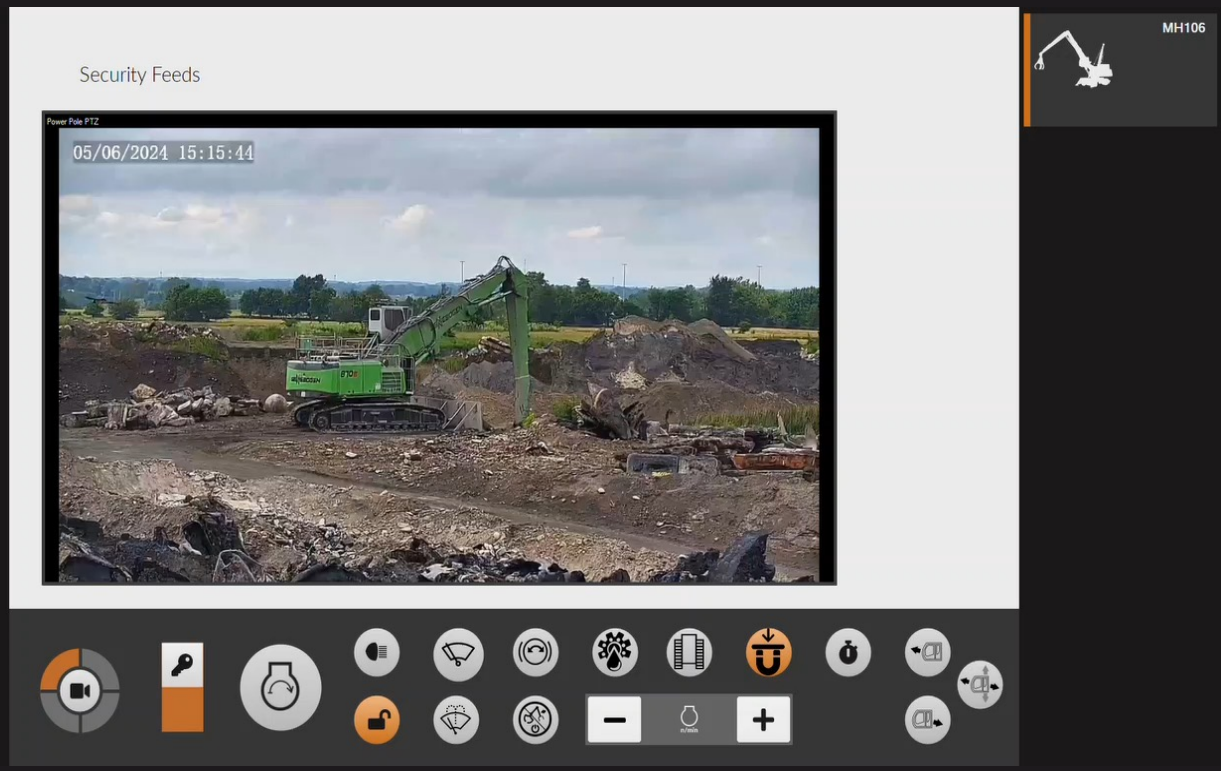


Initial Issues

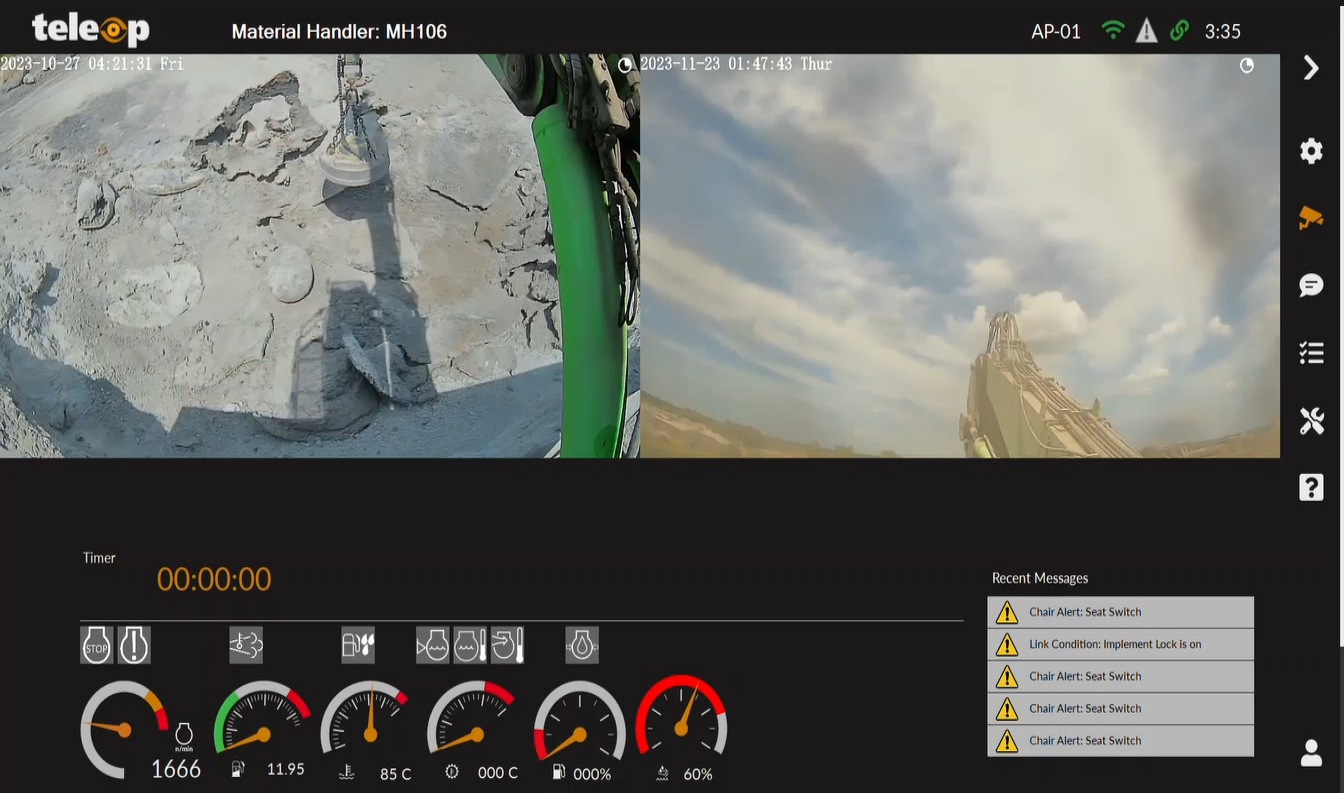
- Safety Procedures
- Servicing Procedures
- Training
- Operator visibility
- Aiming ball
- Line of sight broken by large equipment
- Joystick sensitivity
- OEM Functionality- ECO Mode

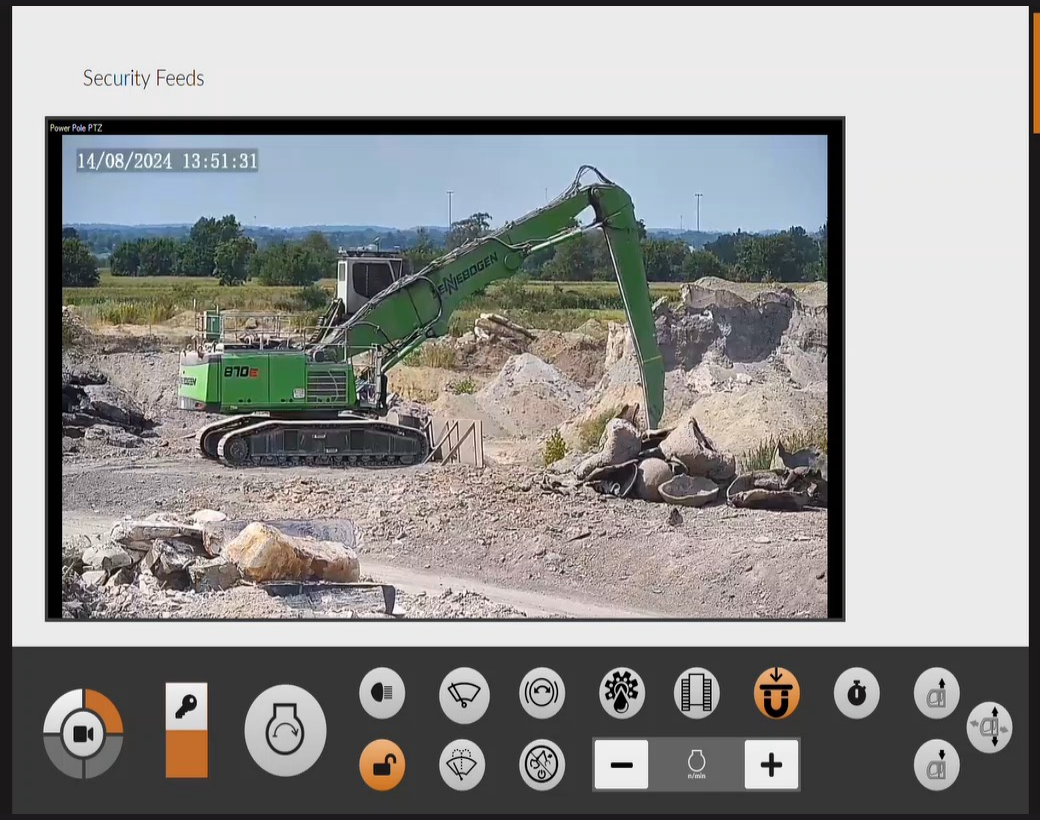
- Safety Procedures

Servicing Procedures



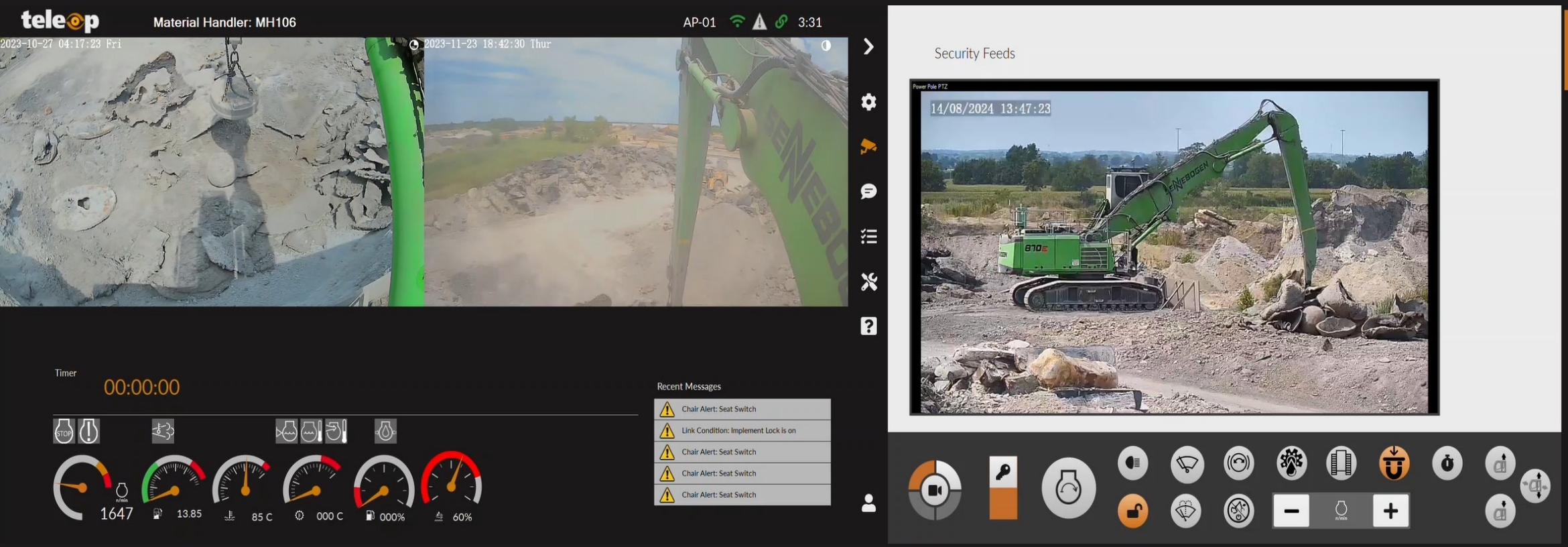
- Operator Visibility





- Aiming Drop Ball

NATIONAL SLAG ASSOCIATION
Proudly Serving The Industry For Over 100 Years



- Joystick Sensitivity

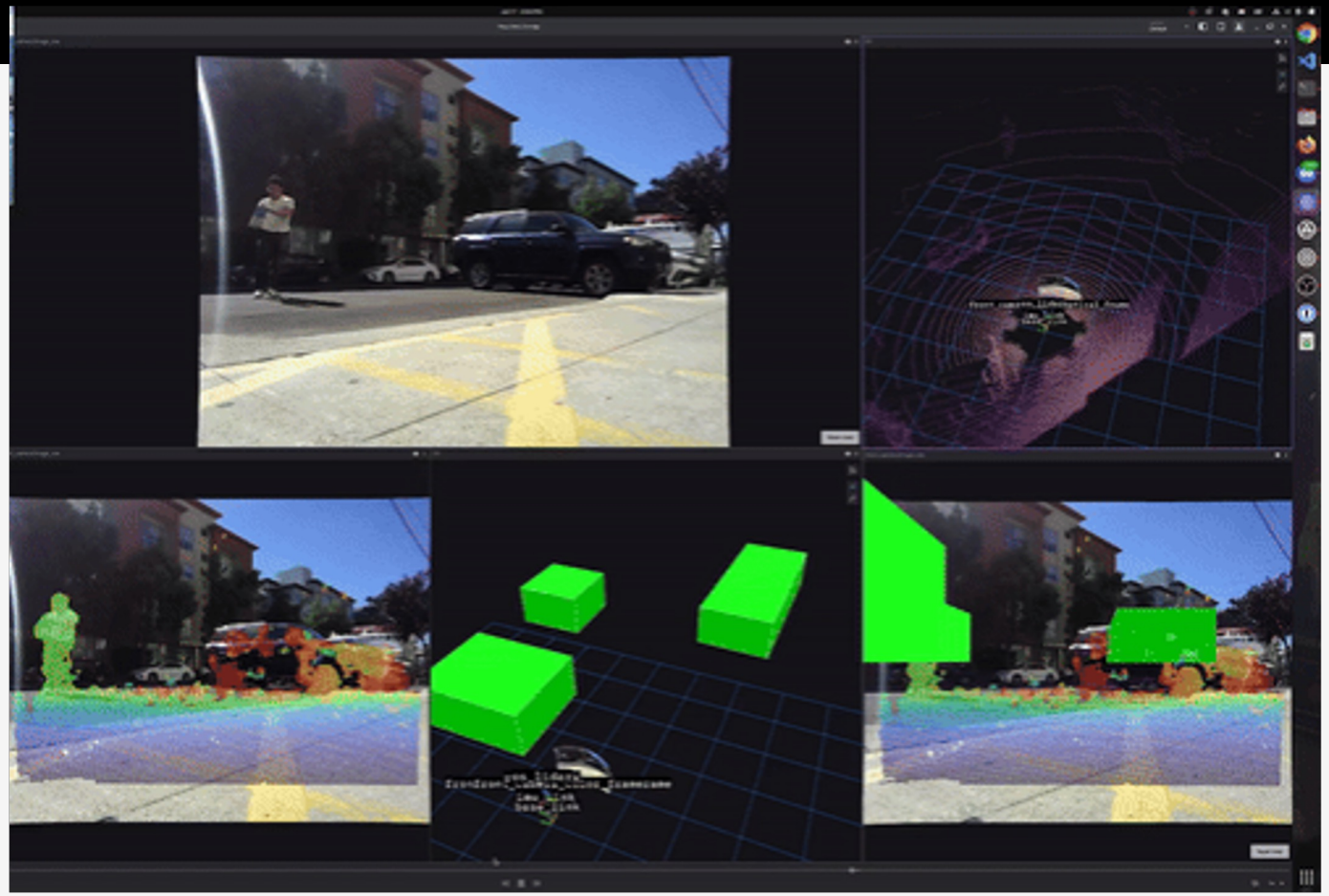
SINCE 1918
SOLUTIONS FOR YOUR ENVIRONMENT®
What's Next?
HEXAGON
HARD-LINE
NATIONAL SLAG ASSOCIATION
Proudly Serving The Industry For Over 100 Years

POLYMATH ROBOTICS

Additional Goals:

- Polymath proposes a phased approach to implementation of autonomy on top of the HARD-LINE teleop system with optionality for Levy at each phase
  - Phase I - add an aiming reticle to the operator view
  - Phase II - operator input drop pattern – **with focus on downstroke swingback / impact**
  - Phase III - full drop operation autonomy
  - Phase IV - full drop and movement autonomy

POLYMATH ROBOTICS



2024 Annual Meeting

Questions / Comments?