

Greens Creek Automated Loader

FOCUS ON HEALTH AND SAFETY ASPECTS

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NIOSH Mine Automation and Emerging Technologies Health and Safety Partnership

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Promoting productive workplaces
through safety and health research



RESPONSIBLE. SAFE. INNOVATIVE.

OUTLINE FOR TODAY

Loader automation with focus on health and safety aspects

- Hecla
- The Issues to Be Resolved
- The Automated Solution
- Implementation
- System Operation
- Takeaways and Advice

HECLA MINING COMPANY



As a corporation

2019 Production	
Silver	12.6 Moz
Gold	273 koz
Zinc	58.9 ktons
Lead	24.2 ktons

- Founded in 1891; oldest NYSE-listed precious metals producer in North America
- Largest primary silver producer in the USA
- About 1,700 employees total across all operations
- 5 producing mines at present

HECLA MINING COMPANY

North America

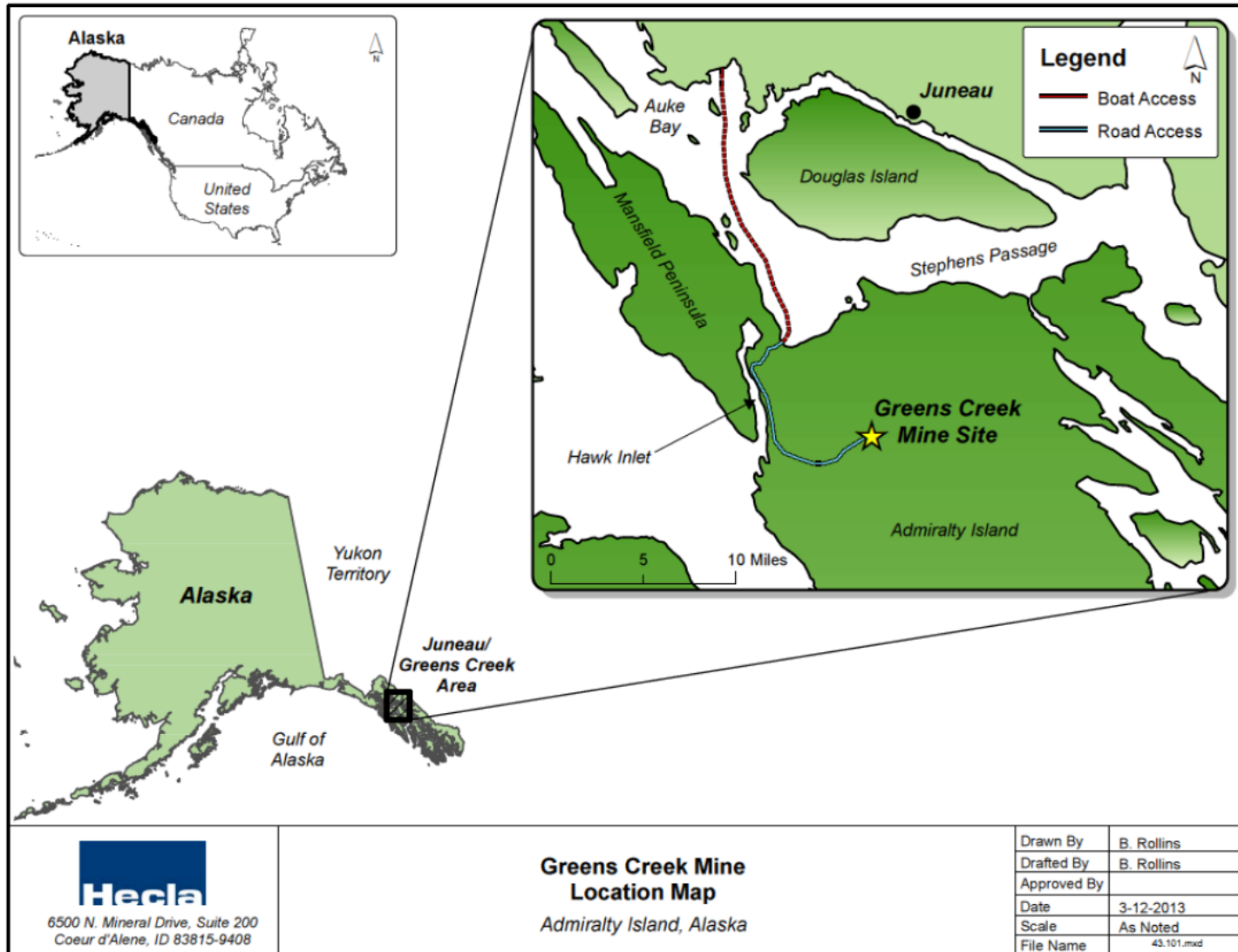


The Issues to Be Resolved

GREENS CREEK MINE

Hecla's flagship operation in SE Alaska

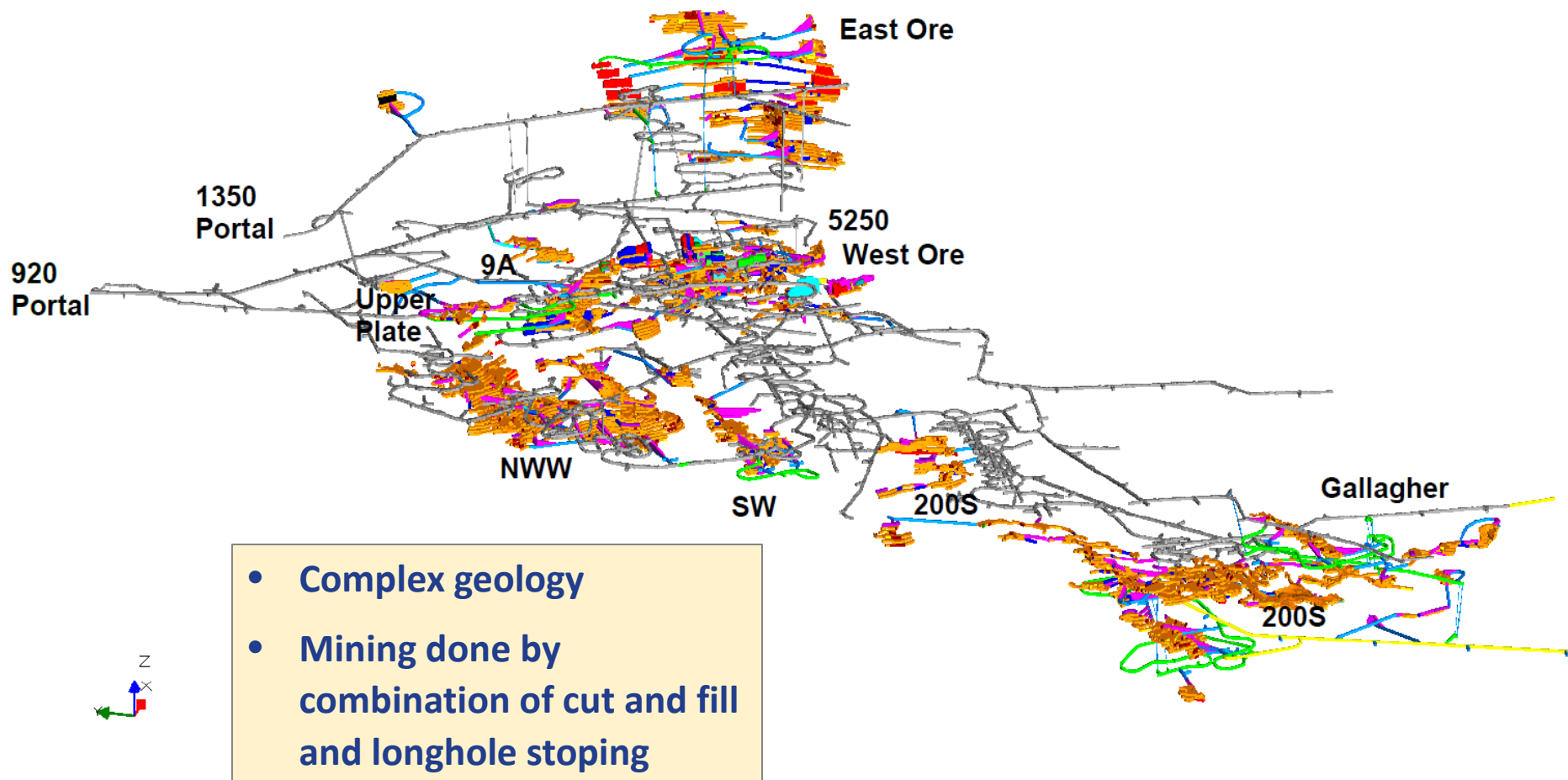
Figure 1-1: Project Location



GREENS CREEK MINE

Mine layout per NI 43-101 Report (filed April 1, 2019)

Figure 1-2: Existing and Planned Mine Development including Mineral Reserves – 3D View



THE ISSUES TO BE RESOLVED: THE 'WHY'

Mainly, exposure to unsupported ground and unutilized time

- Time is unutilized for the loader fleet at end/start of shift when the mining cycle is paused for blast time and for miner transit from/to working face for shift change; how can we keep advancing the mining cycle?
- In longhole stopes, which are inherently unsupported ground workplaces, is there a better option than conventional line-of-sight radio-based remote-control (RC) mucking? The process is inefficient by its nature, needing regular switching between remote operation (tram and load bucket at face) and manual (tram and dump bucket); it also needs ancillary excavation (cutouts for mucking stands).
- If unconstrained by limitations of radio RC system, can we gain more flexibility toward optimization of stope layout?
- **Health and Safety Aspect:** during conventional RC mucking, the loader operator is required to be near the loader and its workplace hazards
- Key constraint – any growth in headcount is problematic, as infrastructure is constrained (capacity of commuter ferry for workforce and island camp accommodations)

OTHER POTENTIAL BENEFITS

Numerous dimensions of upside

- Potential for decrease in mine operating costs, if able to leverage system capability of 1 operator controlling up to 3 automated machines
- Potential for decrease in mine maintenance costs (automated operation vs. human: consistent operation within vehicle design parameters and without damage)
- Potential for increase in availability of loader fleet (consistent automated operation within vehicle design parameters)
- Potential for reduction in capital with realized higher availability and higher utilization of automated loader fleet
- Potential for increase in development advance rate (ft/man-shift)
- Potential as an entry point into automated equipment operation; next stage (automated haulage) could be based on this foundation

The Automated Solution

Project description

- Key pieces of solution
 - Automation control system (hardware and software) including
 - Remote operator station and vehicle onboard automation system
 - Automation operating zone perimeter control system
 - Underground communication network expansion
- The specifics at Greens Creek
 - Sandvik AutoMine Loading - Lite Single system (later upgraded to AutoMine Multi-Lite)
 - 7 cy LHD – Sandvik LH514 (3 units in initial phase: 1 factory-equipped and 2 retrofits)
- Installation in Q1 2017

THE AUTOMATED SOLUTION

Project description

- **Health and Safety Aspects**
 - Management of Change process at introduction
 - Initial application of vehicle automation at site / within corporation
 - Sandvik's use of IEC 61508, IEC 62061, and IEC 13849 standards to maximize design quality and corresponding system safety integrity level
 - Known unknowns vs. *unknown unknowns*
 - Difficult to project extent of effects introduced by this technology in the early stages of understanding and evaluation

HECLA GREENS CREEK MINING COMPANY

FORM
VEHICLE & EQUIPMENT RISK ASSESSMENT

THE AUTOMATED SOLUTION

New hardware arrived in 2017



New 7 cy loader equipped for automation

Remote operator
station in mine office

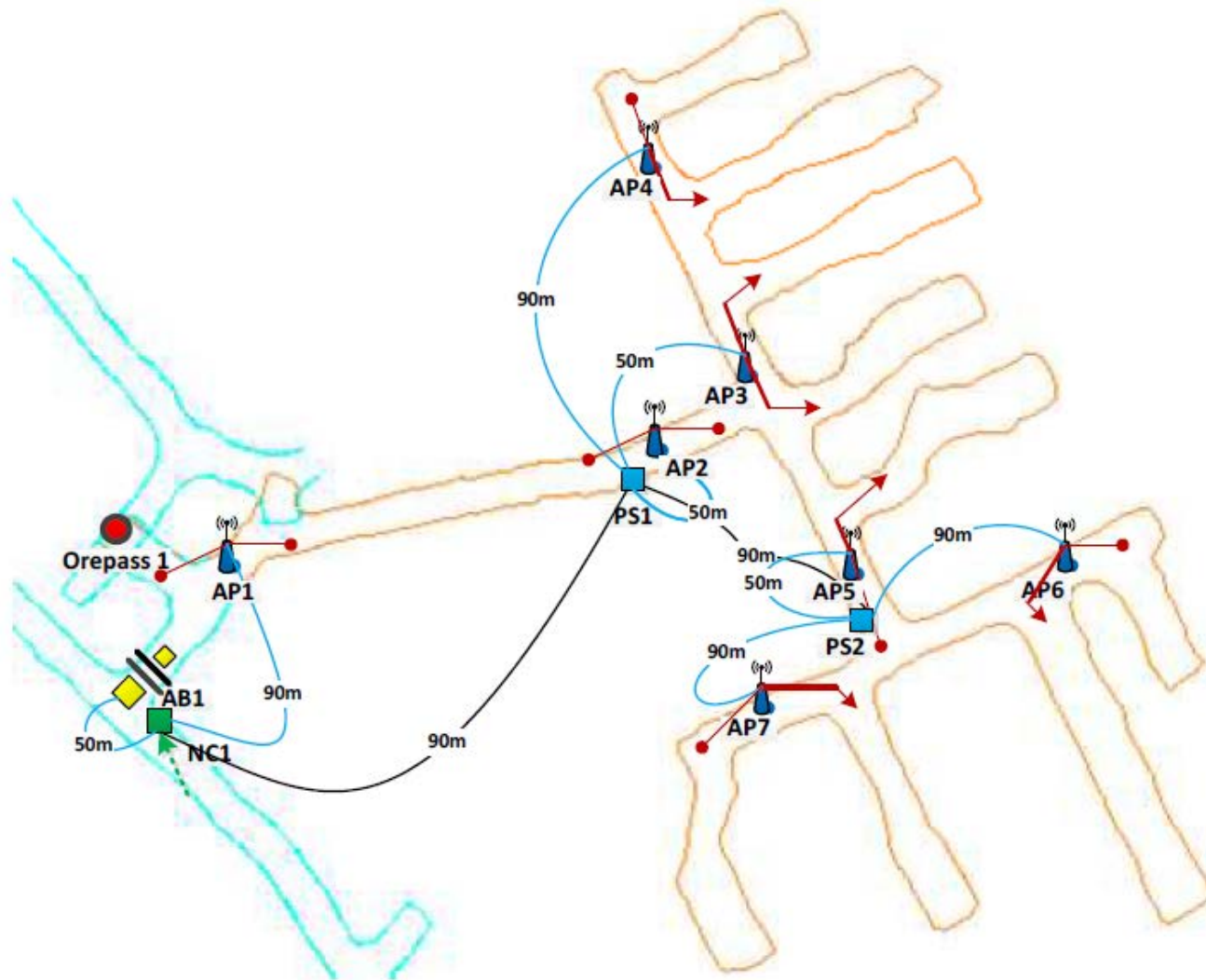


Implementation



INITIAL INSTALLATION

Isolated work zone for rehandling ore

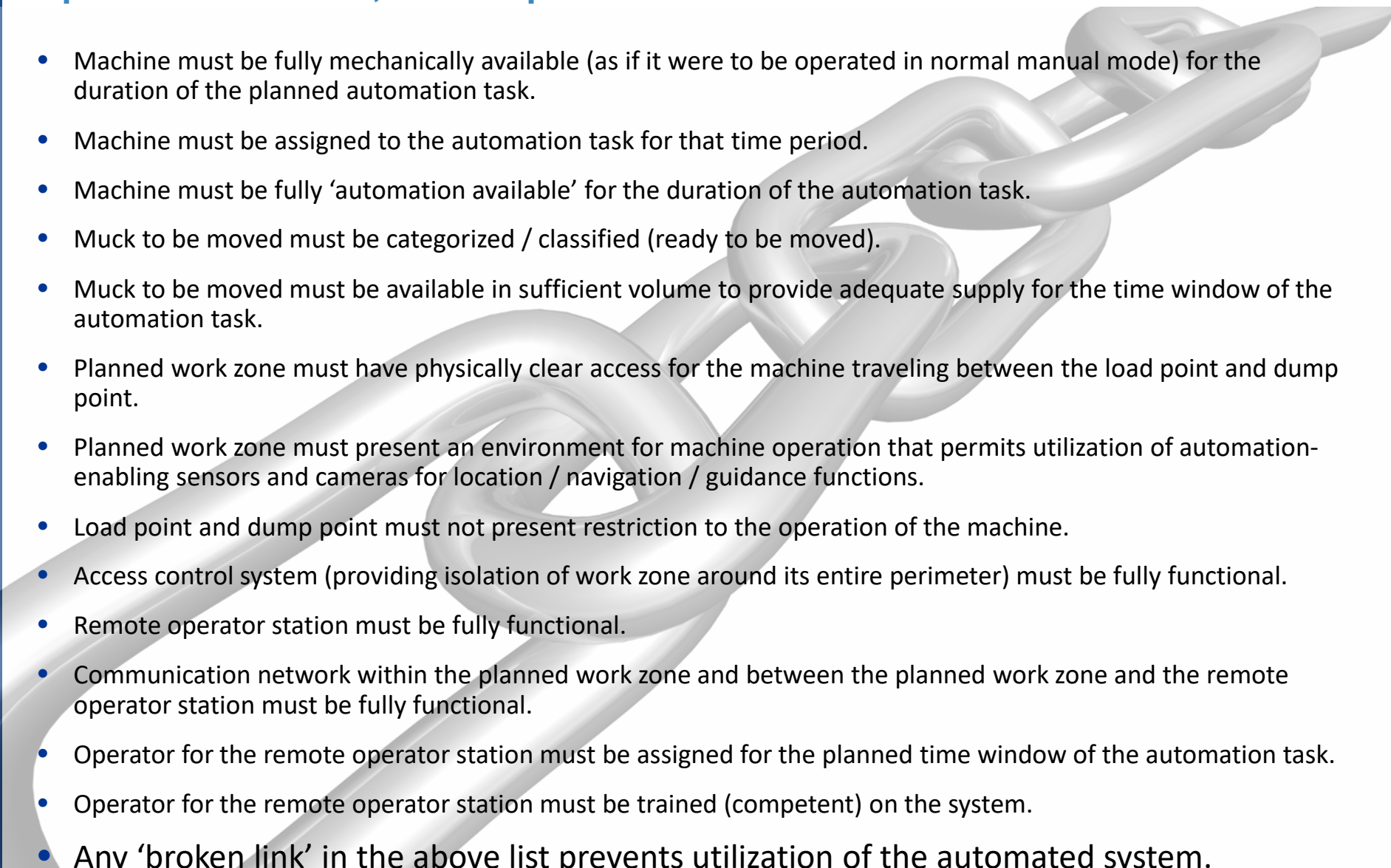


Automated loader system

- Project benefited from prior installation of underground digital communications network backbone
- New system was required to fit into the existing operating environment, not the other way around
- Much time was spent in learning and troubleshooting mode
- Automation-equipped loaders were periodically operated manually per decision made by mine operations: situational ‘manual-mode availability’ vs. ‘automated-mode unavailability’
- Some challenges included:
 - small project team with knowledge gained from this project known within limited group
 - shift schedule (employee workday vs. shift-end / shift-start opportunity window)
 - 24/7 mine operations with expertise less accessible on nights and weekends
 - new duties / role evolution for some employees (e.g., mine electrician, mine engineer, equipment operator, maintenance technician)
 - keeping up with 3-D mapping of routes for future loader missions
 - some individuals were slower to accept new technology
 - training of remote operators to ensure skills across all crews

CHALLENGES RE: THE 'AUTOMATION CHAIN'

All items below must occur *at the same time* for automated operations to occur; list is representative but not all-inclusive

- 
- Machine must be fully mechanically available (as if it were to be operated in normal manual mode) for the duration of the planned automation task.
 - Machine must be assigned to the automation task for that time period.
 - Machine must be fully 'automation available' for the duration of the automation task.
 - Muck to be moved must be categorized / classified (ready to be moved).
 - Muck to be moved must be available in sufficient volume to provide adequate supply for the time window of the automation task.
 - Planned work zone must have physically clear access for the machine traveling between the load point and dump point.
 - Planned work zone must present an environment for machine operation that permits utilization of automation-enabling sensors and cameras for location / navigation / guidance functions.
 - Load point and dump point must not present restriction to the operation of the machine.
 - Access control system (providing isolation of work zone around its entire perimeter) must be fully functional.
 - Remote operator station must be fully functional.
 - Communication network within the planned work zone and between the planned work zone and the remote operator station must be fully functional.
 - Operator for the remote operator station must be assigned for the planned time window of the automation task.
 - Operator for the remote operator station must be trained (competent) on the system.
 - Any 'broken link' in the above list prevents utilization of the automated system.

- **Health and Safety Aspects**

- Potential top-line safety risk: vehicle / human interaction
- Managing operational urgency to provide or restore availability (fix 'automation chain links')
- Engineering controls: Sandvik technology – comprehensive system design
 - Onboard sensors, laser scanners, cameras
 - Barriers to isolate automation zone: Access Control System, gates, switches
 - Interlocks in control software to block / slow some system functions
 - Vital knowledgeable vendor assistance
- Mine administrative controls
 - Signs, inspections, creation of new step-by-step SOPs (checklists)
 - Training: remote operators, electricians, supervisors, trainers, others in the loop
 - Site location tracking system for personnel and vehicles
- Communication to all involved: clear, complete, constant

System Operation



The journey from a *project* to a *process*

- Acceptance was gained over time by mine operations team; system provides another option (complementary, not full replacement)
- Integration of technology was helped by management's target for daily production contribution from automated fleet
- Site added the AutoMine Tele-Remote system in 2018 (with second operator station); now have automation systems for 4 loaders and 2 haul trucks
- Team learned 'sweet spot' for deployment: high loader fleet availability + significant bulk tonnage to handle + preferred alternative to conventional RC loading
- Loader maintenance has evolved (parts stocking, automation system check-out, tasks and responsibilities)
- Future designs consider requirements of automated equipment: drift width, broader curve radius, shallower angle for access into muck bays, etc.
- Path forward includes planning for targeted automated haulage opportunities
- **Health and Safety Aspects:**
 - Training needs: system updates, personnel changes, new hires
 - Update and addition of SOPs as procedures change

Takeaways and Advice

Integrating automation into a mining operation

- Be able to learn **fast**
- Document problems and solutions along the way to help deepen and broaden the learning
- Take advantage of manufacturer's specific expertise as you develop your own in-house knowledge base; let the supplier help you be successful
- Communicate the coming change and what it will look like to all who will be affected; make the reasons for the change intuitive and show that its success matters, including the basis of the value proposition
- Assign responsibilities from the outset; reconsider and reassign over time to assist in fully operationalizing the technology
- Understand the concept of the "automation chain" from the start of the technology adoption process
- Designate an 'automation specialist' role; perhaps even have an expert on each crew
- If you can, when you automate a piece of mining equipment, dedicate it to use within that system
- If you have a choice to either buy a technology system factory-installed on a machine or add it on later... buy it installed

TAKEAWAYS AND ADVICE

Focus on **health and safety** aspects

- Be as comprehensive as you can in evaluating potential impacts during the technology evaluation stage, starting with safety and health risks. It is helpful to develop a feel for what changes will happen around all edges of the project.
- Conservatively plan (don't underestimate) time required for training all affected parties to provide the knowledge they will need for the tasks that will be modified by the new technology. Training is a commitment for the full life of the technology.
- Support use of field risk assessment process to guide decision-making through changes in circumstances and conditions.
- Don't overcomplicate the automation zone perimeter controls when communicating about them. Miners know what barriers are, and they must always be respected.



- 3. Automate**
- 2. Standardize**
- 1. Simplify**
- 0. Stabilize**
- Survive*

GREENS CREEK AUTOMATED LOADER

Focus on safety and health aspects



Questions?



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GREENS CREEK AUTOMATED LOADER

Focus on safety and health aspects



Thank you!