MINING COMPLEX GEOLOGY, MITIGATING FLOAT DUST, AND DEVELOPING AUTONOMOUS MACHINE CAPABILITY USING HORIZON SENSING TECHNOLOGY FOR COAL SEAM BOUNDARY DETECTION

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Why are Sensible Mining Machines so Senseless?

✅ FACT: Mining machinery extracts desired material from above, below, or between materials that are not wanted or needed. The contact of these various material layers is called the “horizon” or the “boundary”.

✅ FACT: Mining machinery is very advanced, globally pervasive and very well engineered ($$$$. And OEM’s make periodic advancements in machine “automation”. HOWEVER, mining machines lack sophisticated GEOLOGIC SENSORS. Can you image modern aviation without RADAR, or medicine without CAT scans or MRI?

✅ FACT: Mining machinery LACKS geologic boundary detection. A long-standing technology gap in mining.
Why Do We Need *Sensing* Mining Machinery?

Horizon Sensing is needed to navigate complex geology that undulates and varies in thickness.

Structural Variables Mitigated by Horizon Sensing:

- Fracture Zones
- Sand Levees
- Meandering Flows
- Paleochannels
- Variable Compaction
- Splay Deposits
- Faults and Voids

*Cross Section of the High-Energy Cutbank Region of a Paleochannel*
Can *Sensing* Machinery generate better product?

Horizon Sensing is needed to avoid cutting into the thin contaminated boundary layers. Leaving “un-cut” coal.

Contaminant Variables Mitigated by Horizon Sensing:

- The biochemical response of peat-coal during burial precipitates toxic chemicals in such as mercury, arsenic, cadmium, thorium, uranium, and potassium (K-37)
- These chemicals are concentrated in boundary layers by compaction
How Do We Make Sense of This Problem?

- This technology gap is the root cause of...
  - Excess “Float” dust generation, silica and coal
  - Methane ignition and coal dust explosions
  - Excessive toxic and radioactive elements in fly ash
  - Mine waste – low run-of-mine coal yield and quality
  - Roof control problems in complex geology
  - Additional prep-plant and power-plant cost and complexity

- Without “boundary detection” there can be NO transition from automated to autonomous machine control.

- **Working Solutions:** Near-field sensors for boundary detection. These are referred to as “Horizon Sensors”. Quick overview of Stolar’s **Horizon Sensor** technology.
Horizon Sensor Systems for Continuous Mining Machines

Measurement Electronics and Power Source within Drum (with wireless data)

Sensor Module on Cutter Drum

Machine and Operator Interfaces

Boom Arm Inclinometer

Typical continuous mining machine
Horizon Sensor Antenna Modules on Continuous Miners

HS on Joy 12CM (USA Mine)

HS on Joy HM31 (SA Mine)

HS on Joy 14CM (USA Mine after 1-yr operation)
Horizon Sensor Graphical User Interface

- Control and diagnostic algorithms
- Neural network for calibration
- Wireless communications to Smart Drum and remote control station
HS-3 Installation on Joy HM-31 (S.A.)

- Power Generator in Cutter Drum
- HS Sensor in Cutter Drum (inside and outside)
- Cutter Drum Module Preparation
- HS Sensor Mount in Cutter Drum (outside drum)
14CM Install for Coal Mine (U.S.)

- Cutter Arm Inclinometer
- Generator in Cutter Drum
- Miner Power Supply
- HS Sensor Mount during Welding
- Cutter Drum Preparation
Horizon Sensor Modules on Longwall Shearers

HS on Joy 7LS (Colorado Mine)  
HS on Joy 4LS (Ohio Mine)
Horizon Sensor Module on Bore Miner

Sensor and Battery Pack Combo

Graphics Display and Power

Display Module and Communication

Sensor Install

HS on Bore Miner Arm (Trona Mine)
Horizon Sensor Module on Highwall Miner

Install at Highwall Face (West Virginia Mine)

Original Concept

Sensor Frame Placement on Drum

Final Battery Install on Cutter Drum

Final Sensor Install on Cutter Drum
Horizon Sensor Accuracy on Continuous Miner

Joy 12CM12-10A at Illinois Coal Mine
Measurable benefits provided by use of Horizon Sensor (HS)

- Reduction in mine waste – yield improvement
- Improvement in run-of-mine coal quality (fewer fines)
- Improvement of roof and floor conditions
- Optimization of cut-ump-load cycle
- Increased bit/pick life (avoid cutting rock layers)
- Reduce operator’s exposure to airborne dust and noise
- Prevents mining into old works
- Improvement in coal preparation costs
- Improvement in power plant operation costs

While accuracy and endurance is still being evaluated, boundary sensing with HS may eventually enable **fully-autonomous** machine operations.
Next Generation HS-4: Update
Change Sensor from Passive RMPA Patch to Specialized “Focus-able” Radar

Double Sideband Gradiometric Ground Penetrating Radar (DSB-GPRg) with First Interface Spatial Clutter Geology Reflection Elimination (SCGRE)

Original Design
Evolutionary Design

Drum Mounted
Bit-Block Mounted

- DSB-GPRg has vastly deeper signal penetration than standard GPR
- SCARE Functionality eliminates RF noise, positional error, and sensitivity variation associated with rough and undulating surface (first interface suppression)
Next Generation HS-4: Update
Add functionality of bit-pick monitoring

- Crushed coal/rock under bit-tip creates “Float” dust
- “Float” dust minimized by next bit strike in radiating fracture from first strike
- 3D fracture vector determined by strain gauge assists in real-time monitoring of this critical “crushed zone” process
- Wet fractured and crushed coal creates first interface cluttering geology reflection
- Upgrade Drum-mounted electric power generation and data communications
- **Proven Historical Product-Line Status...** Withstands vibration, shock, and abrasion associated with drum cutting
Next Generation HS-4: Update
Surface Mining Sensor Installation