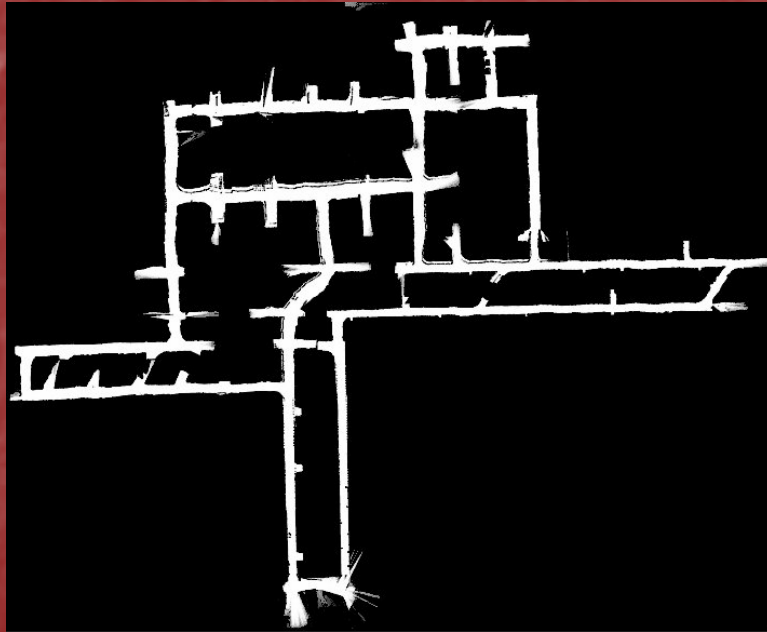
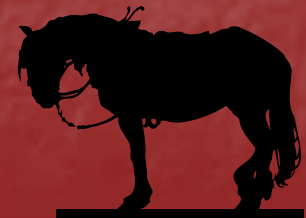


Workhorse Technologies, LLC

- Service Provider for Robotic Mapping of Underground Voids



Robotically Generated Mine Map



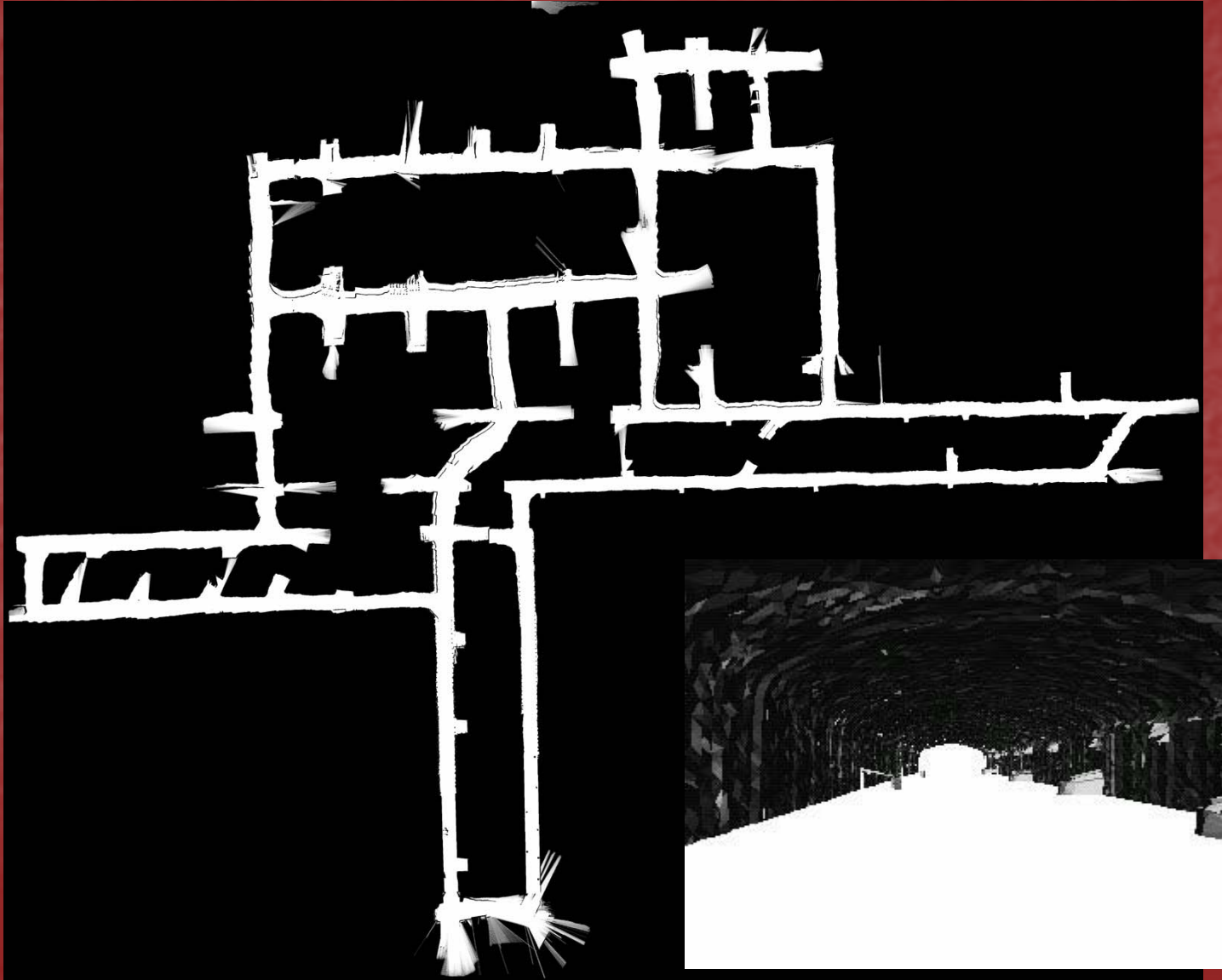
Agenda

- Introduce Workhorse to You
- Present Void Modeling Technology
- Discuss Void Modeling Technology
- Brainstorm Application of Void Modeling Technology for You
- Actions
- Adjourn

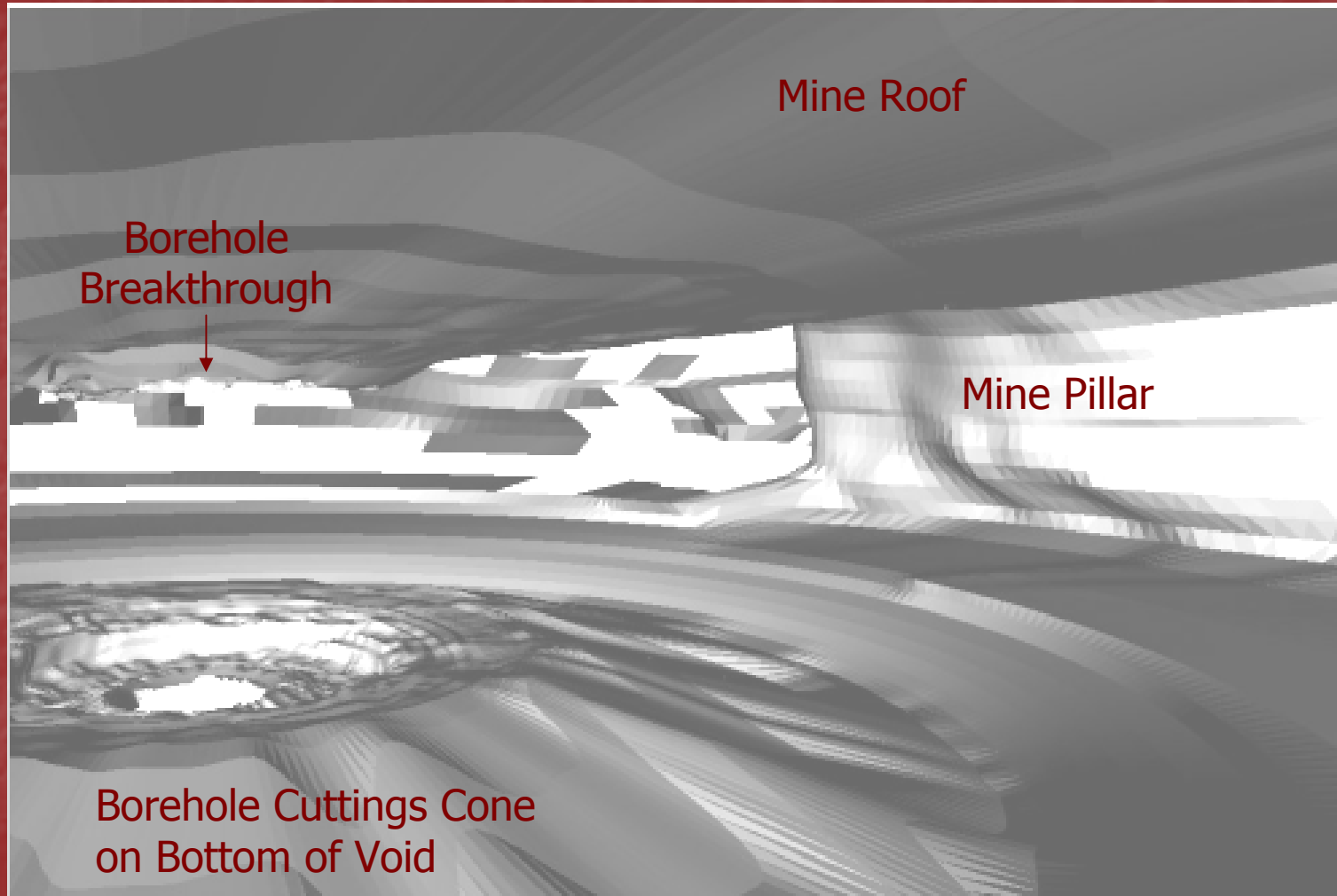
Services Provided

- Audit Mineral Reserves.
- Abandoned Mine Investigations
- Void Modeling
- Stabilization Planning and Verification
- Borehole Surveys - Wet or Dry
- Economizing Exploratory Plans

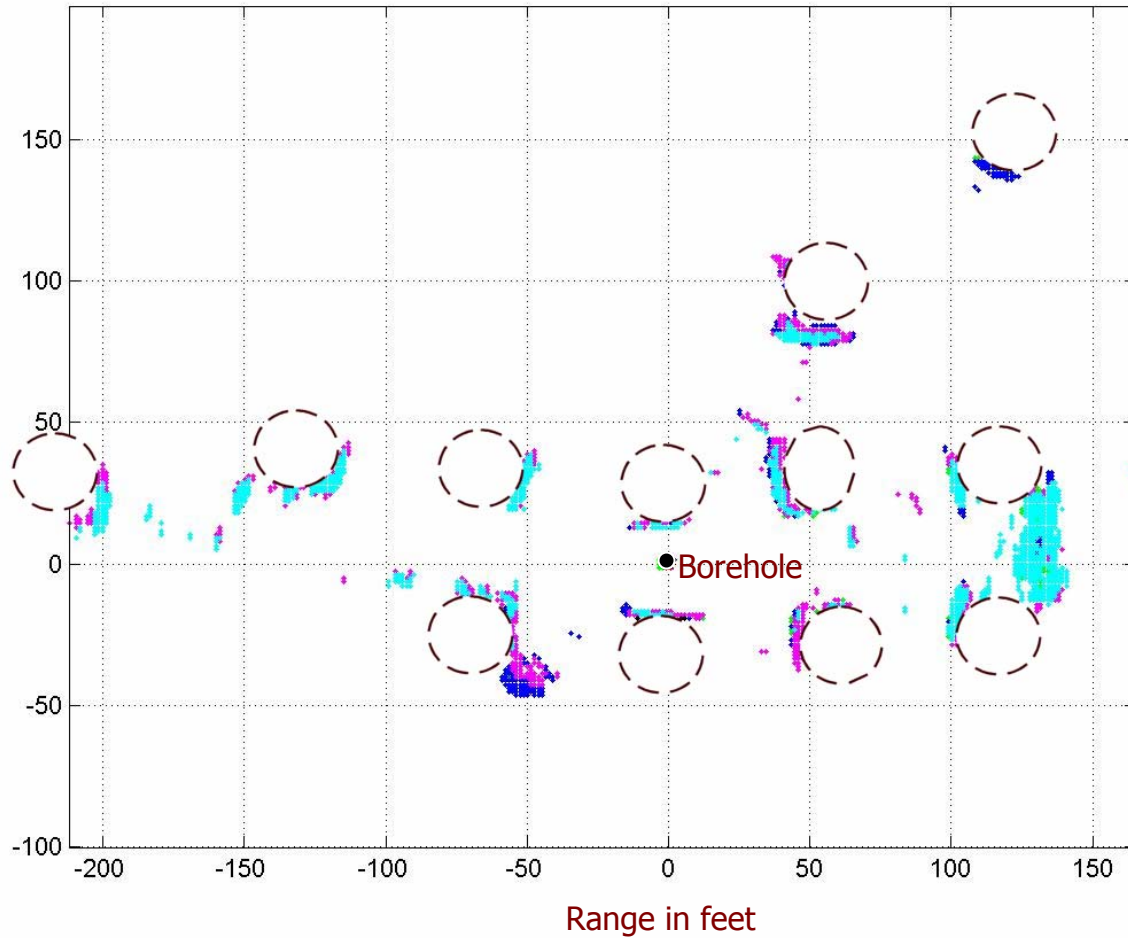
3 hr, 1 mile Mine Mapping



Mine Void View from Borehole



Map of Submerged Pillars



How do we Model Voids and Drive?

- No GPS
- No Wireless Communications
- No Sunlight, Dark Surfaces
- Inaccessible for retrieval
- Maps don't always exist
- Toxic/Explosive atmosphere possible
- Air filled, water filled, ponded

Workhorse solutions

Groundhog

- 4 wheel drive & steer
- 8' turning radius
- Laser Scanner mapping
- Hydraulics and electronics in an explosion proof enclosure



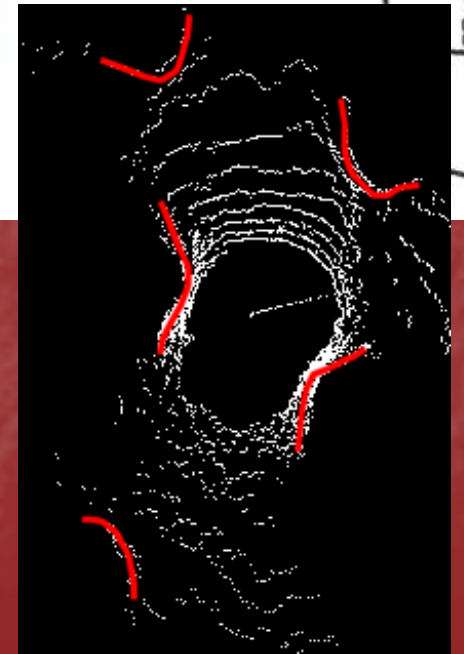
Abandoned Mine Mapping

- Uneven Floor, Deep Mud, and Water
- Environmental Sensing



Borehole Deployable Scanner

- Fit in 8" Borehole
- Lower hundreds of feet
- Laser Range Sensing
- Pan and Tilt Motion
- 3D model of void
- Correlation to prior map
- Video overlay on model



Ferret

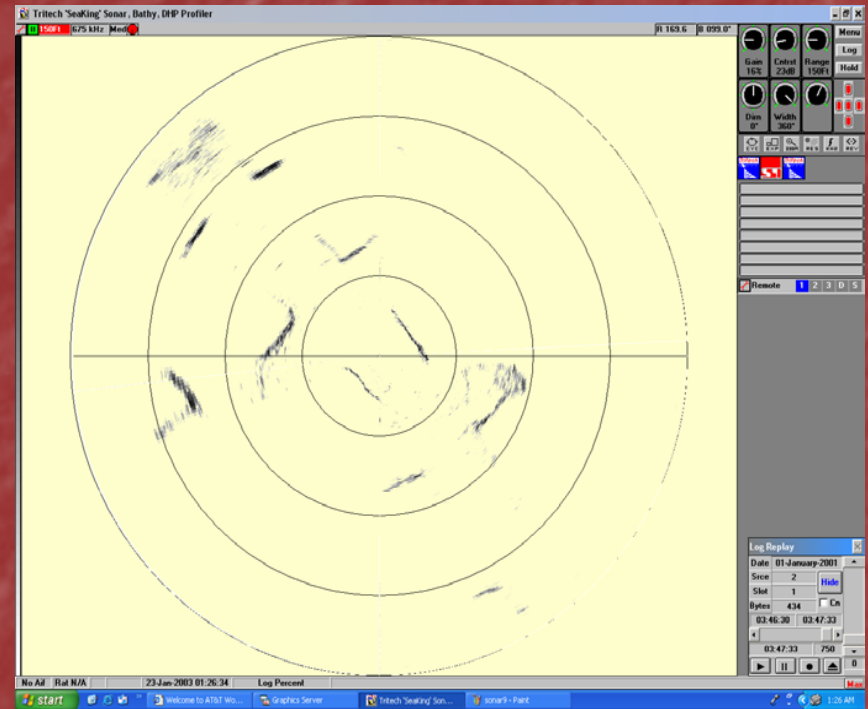
- Long Range – Low Reflectivity Laser
- Magnetic Compass
- Video Camera & Lights
- Deployment Apparatus
- Breach Detectors



Submersible Ferret

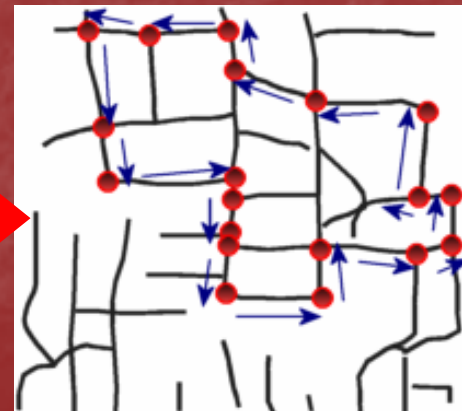


- 6" Borehole Deployable
- Scanning Sonar
- Readily Deployed
- Long Distance Ranging
- Magnetic Compass
- Submersible to Great Depths

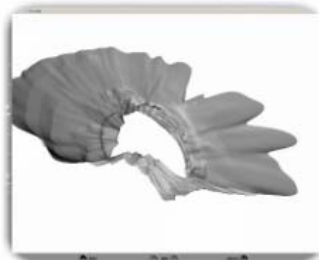


Software

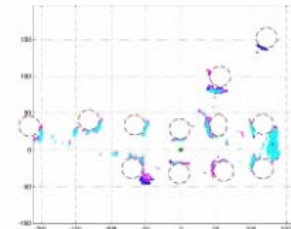
- SLAM (Simultaneous Localization and Mapping)
- Robot Control
- Scanning Control
- Void Modeling
- Volume Estimation
- Map Correlation
- User Interface



Map Registration



3D Void Modeling



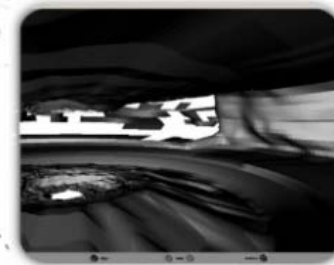
Visible Mine Structures



Profile of Mine Collapse



Mine Map Registration
With Surface
Coordinate System



Pillar & Debris Pile

Groundhog Day May 30



On Board Video



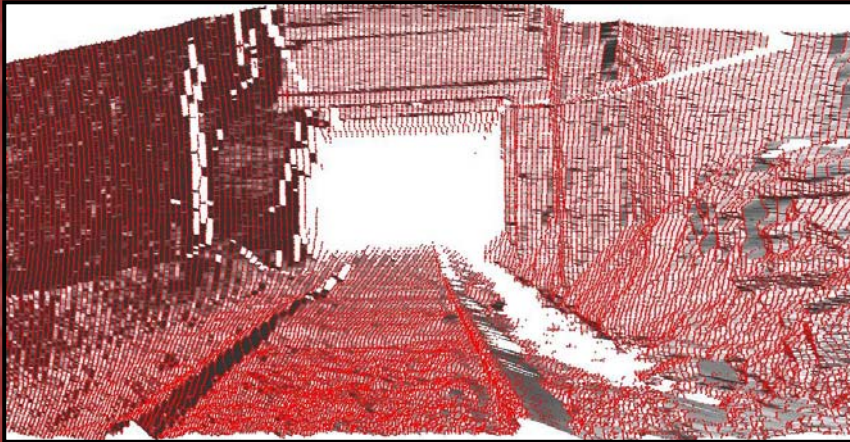
Entering the Mine

1500 ft Autonomous Driving
and Mapping at the Mathies Mine

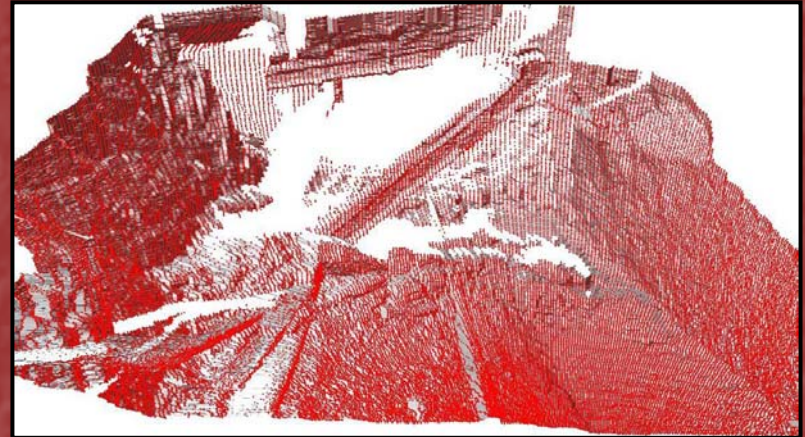


A great day

Groundhog Day Results



3-D Model – Navigable Passage



3-D Model - Fallen Roof
Timber Blocking the Passage



2-D Mine Map

Workhorse Could Answer

- What is the extent of prior mining?
- Is there remaining potential?
- What volume of material is needed to backfill a void?
- Was prior void stabilization backfilled properly?
- How close is an old mine to a residence or operation?
- What is an old mine layout?
- Have the pillars degraded?

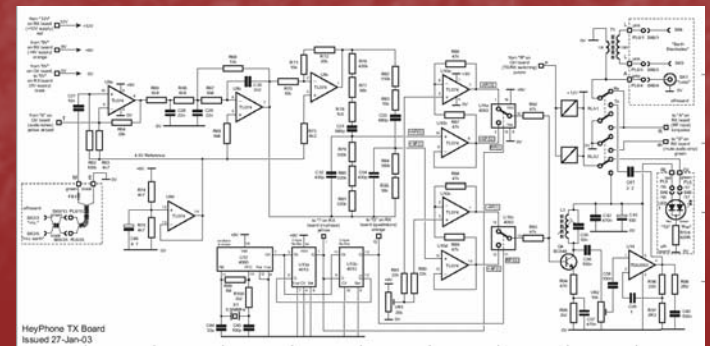
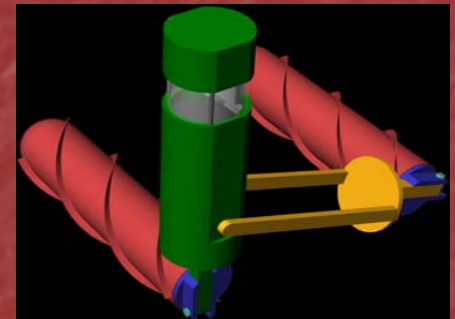
Subterranean Challenges

- Exploration Autonomy
- Communications
- Miniaturization
- Mobility
- Power
- Sensors
- Reliability

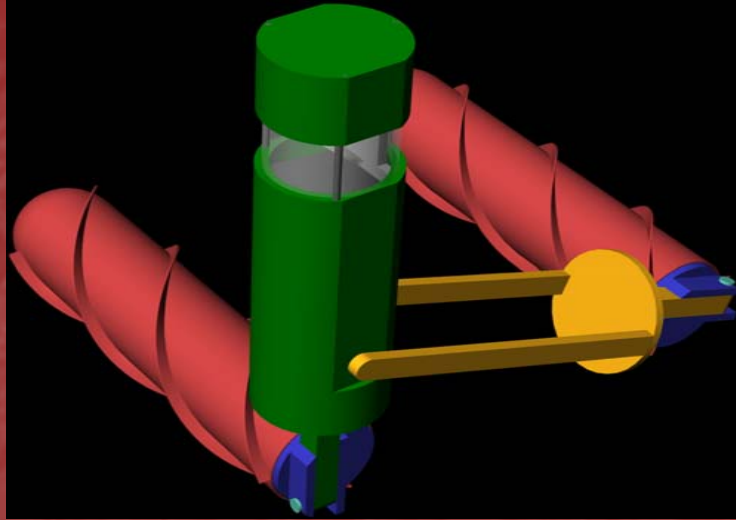


Future

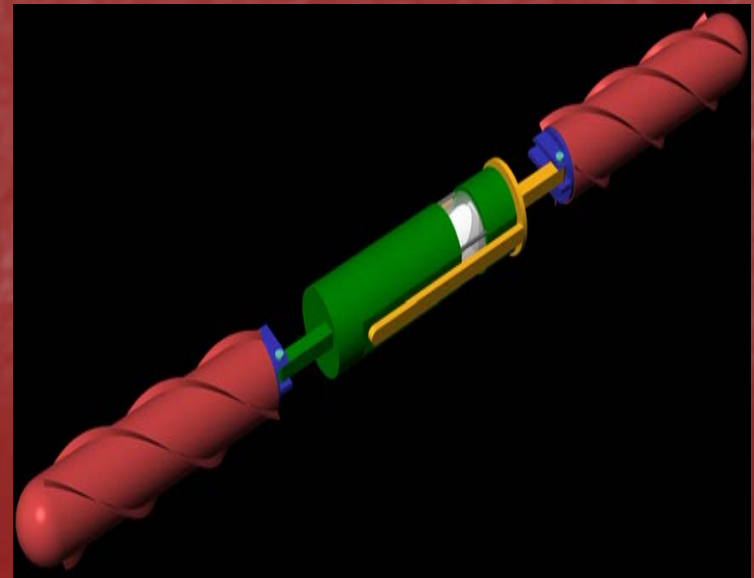
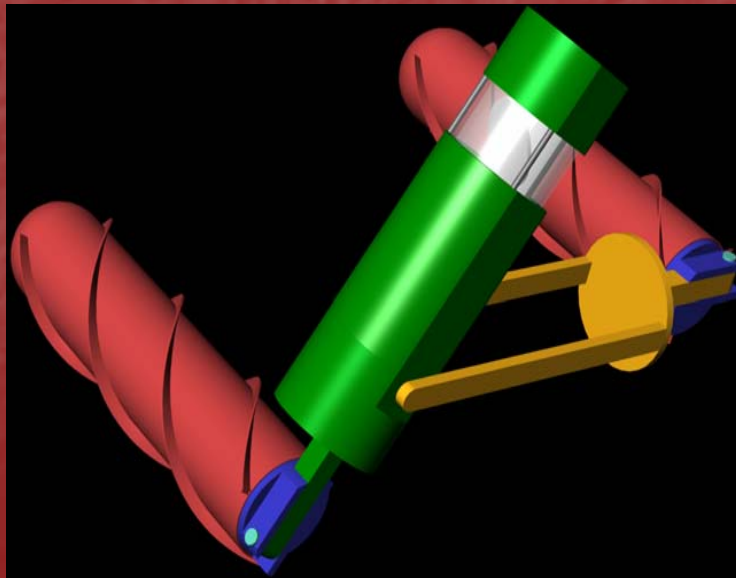
- Borehole deployable driving robot
- Boat for subterranean lakes.
- Submarine for submerged voids
- Wireless communications to surface
- Radio positioning
- Autonomous exploration
- Subterranean operations
- Guiding equipment
- Thin seam mining



Helix



- Borehole deployed robot
- Fluted drive cylinders
- Laser scanner
- Climbs obstacles
- Target design for a 6" borehole

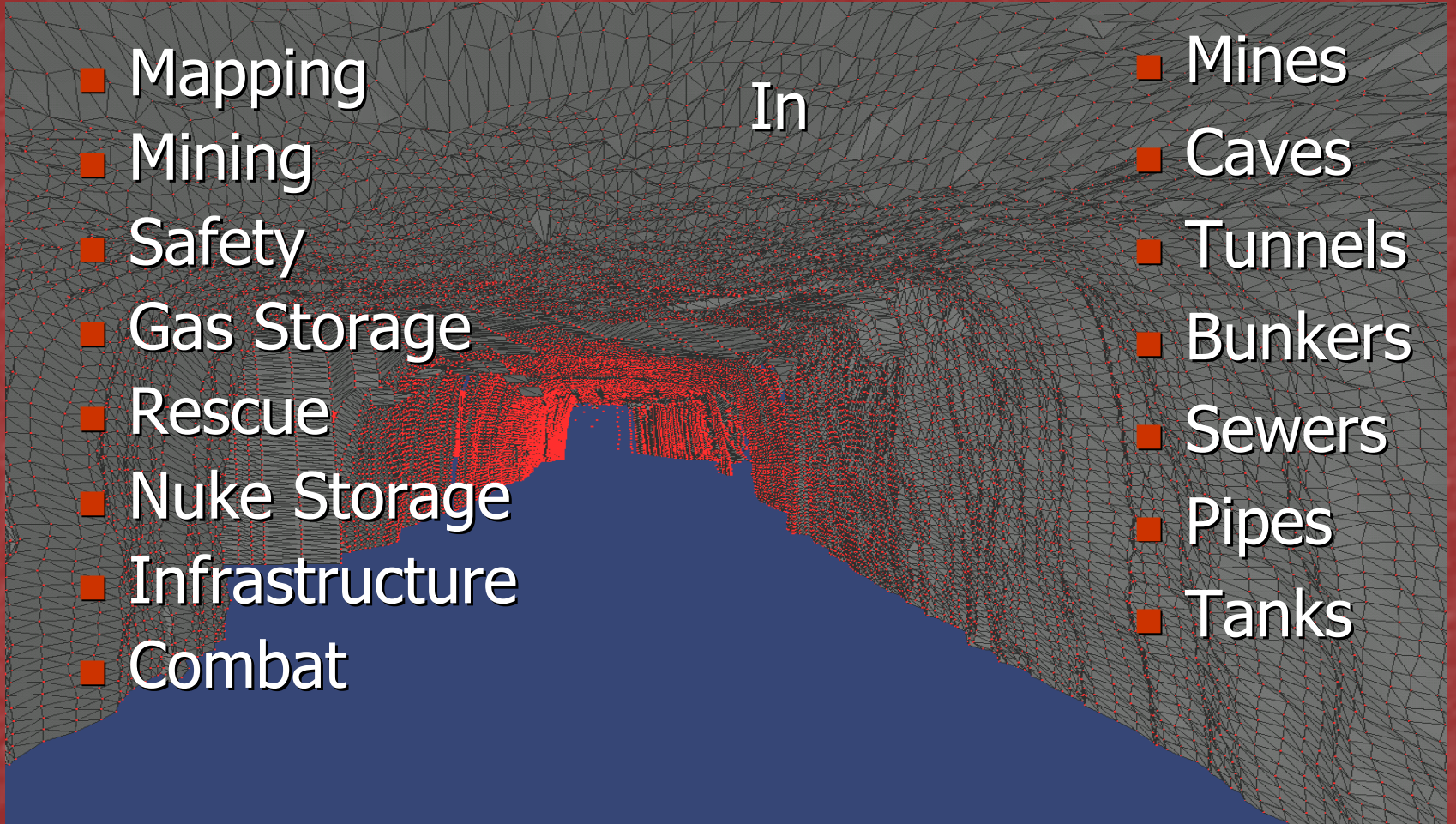


Subterranean Agenda

- Mapping
- Mining
- Safety
- Gas Storage
- Rescue
- Nuke Storage
- Infrastructure
- Combat

In

- Mines
- Caves
- Tunnels
- Bunkers
- Sewers
- Pipes
- Tanks



Next Steps Together

- Field work addressing an immediate need
- Visit Pittsburgh for live demonstration of the equipment
- Deepen government and business relationships
- Work toward a safer and more productive future in the mining industry.

Workhorse Thanks You

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