CREATING VALUE

Automation and Productivity: Using Proximity/Object Detection to Increase Shovel Productivity in the Open Pit Mine

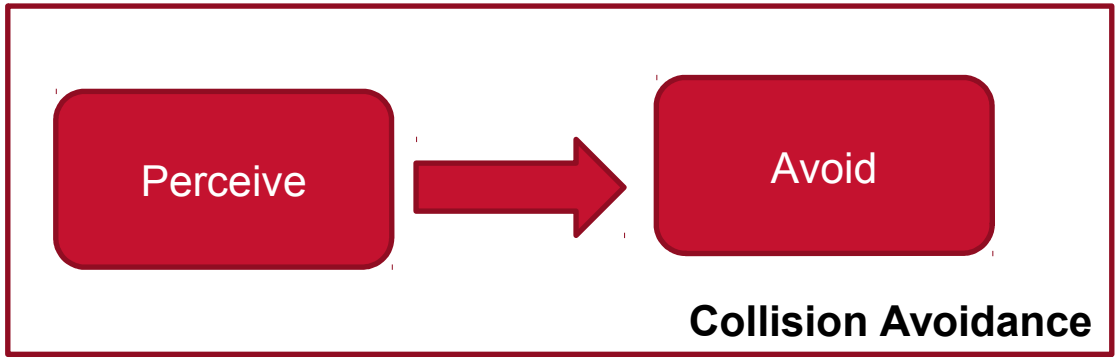
Eric K. Hsieh, Product Manager, Technology
Pat DeWitt, Shovel Operator Trainer, OME Training, Inc.

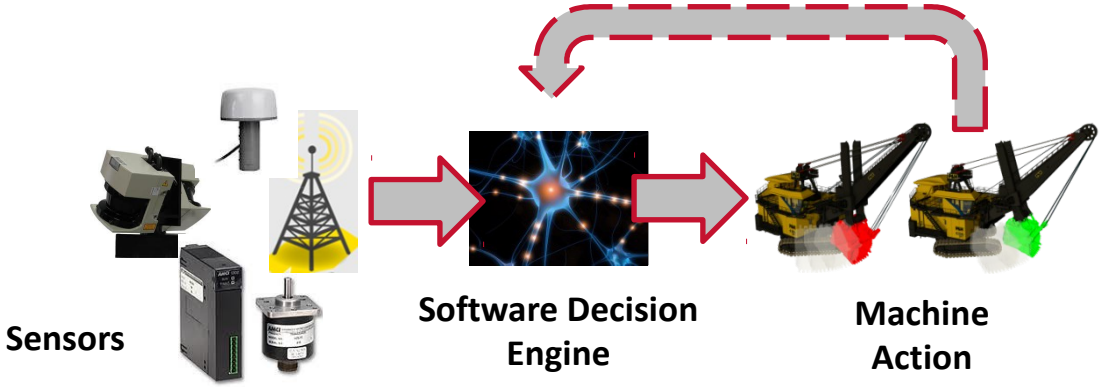
Haulage and Loading Conference, Phoenix, AZ
Wednesday, May 22, 2013

JOYGLOBAL

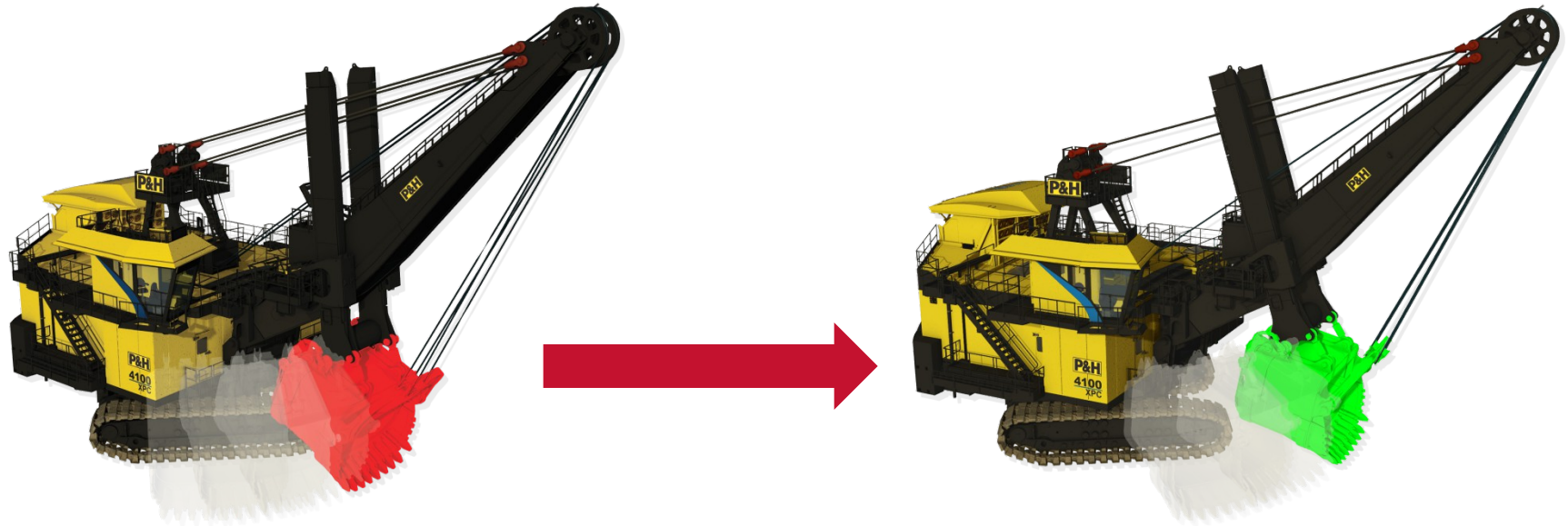
Perception and Avoidance

- Benefits of Proximity Detection and Avoidance
  - Increase Safety
  - Reduce maintenance costs
  - Increase digging production?!





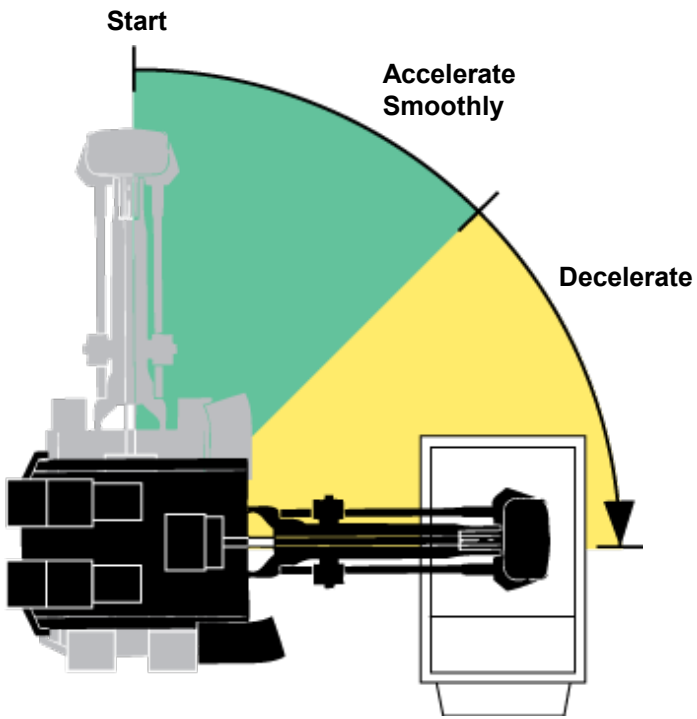
Single Machine Collision Detection



- Track Shield system: Integrated perception and avoidance
  - Pose estimation using Centurion control system data
  - Mitigation motions using Centurion controls

Shovel Production as Mathematical Optimization

- System Optimization: Standard Process Problem
  - Goldratt Theory of Constraints
- Using Supersizing as Production Improvement Strategy
- Law of Unintended Consequences: Bucket fill factors drop due to operator hesitance with bigger dippers and wider tracks
- Experienced Shovel Operator Trainers: Optimized Solutions Keepers



The weight in the dipper affects shovel stability as well as the rate of acceleration and deceleration.

Enforcing Shovel Best Practices

- The Track Shield system allows full-speed operations within the prescribed envelope
- Extension of boom limits concept
- Training tool so best practices are performed by muscle and visual memory

Best Practice 1:

Hoist Lowering to the Optimum Position

The shovel operator is performing the return phase to prepare for the next dig phase in the production cycle.

The Track Shield system does not detect any pending collision and does not attempt to override the operator's commands.

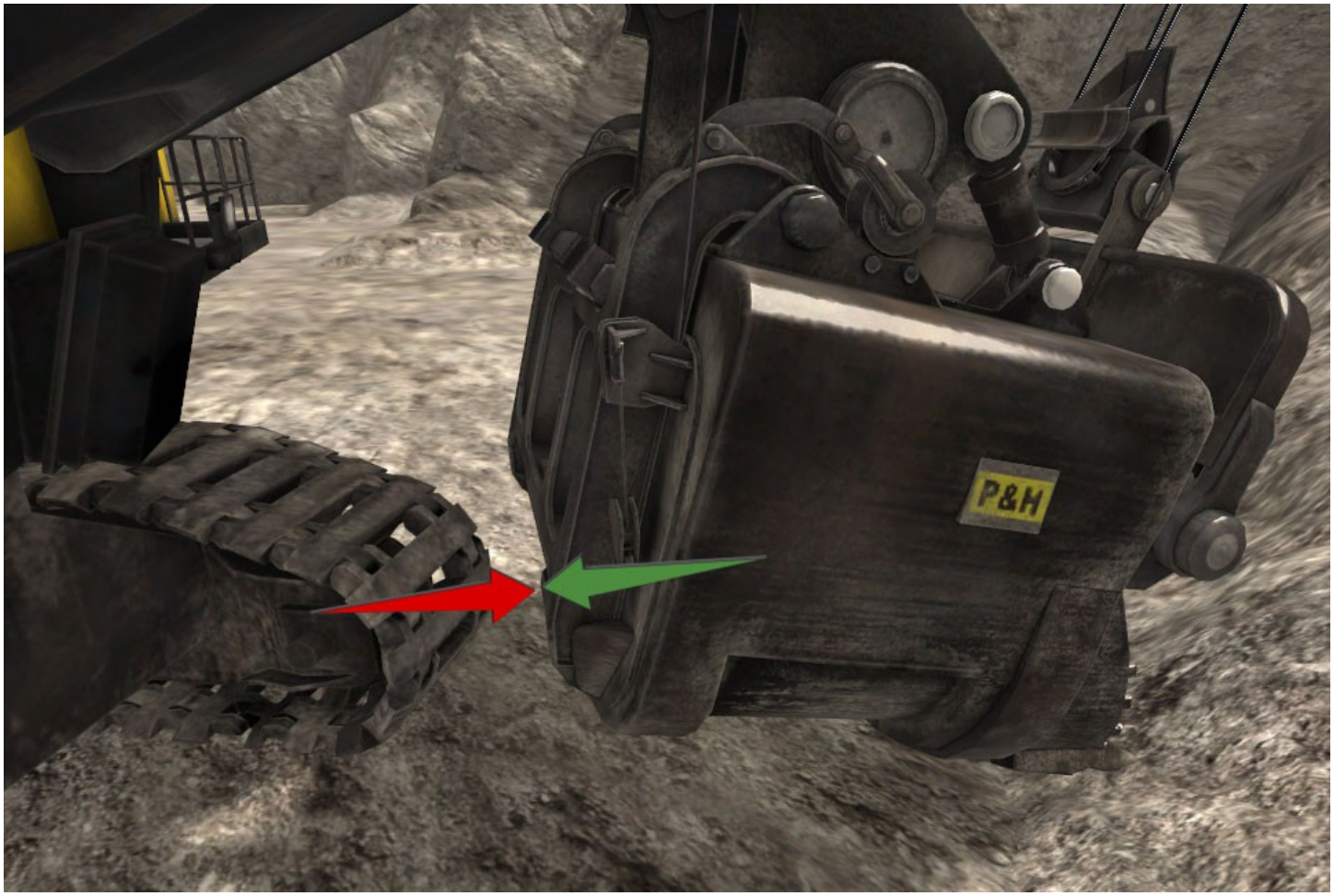
The shovel operator continues the return phase by continuing to apply a lowering command to the hoist motors.

The Track Shield system identifies that the current operator commands may cause a collision between the dipper and the tracks but still does not attempt to override the operator's commands because of the large distance between the dipper and tracks.

The shovel operator does not reduce the lower reference and the dipper is getting close to the tracks.

The Track Shield system identifies that the current operator commands may cause a collision between the dipper and tracks given the short distance between the dipper and tracks. The Track Shield system applies an overriding command that begins to reduce the hoist reference.

The shovel operator continues to not reduce or change direction of the hoist reference.



The Track Shield system identifies that the current operator continues to command a reference that may cause a collision between the dipper and tracks. The Track Shield system reduces the applied hoist reference to zero.

The shovel operator applies a hoist raise command.

Current operation will not cause a collision between the dipper and the tracks so the Track Shield system no longer overrides the operator's hoist reference. With the autonomous assist active, the operator is able to move to the maximum "limit" and gets used to the muscle and visual memory.

Best Practice 2:

Crowd Down to Optimum Bank Engagement Position

The shovel operator has positioned the dipper in a tuck position so that the tracks are directly below the dipper.

The Track Shield system does not detect any pending collision because the operator is not commanding any hoist, crowd or swing reference that may cause a collision. Therefore the Track Shield system does not override the operator's commands.

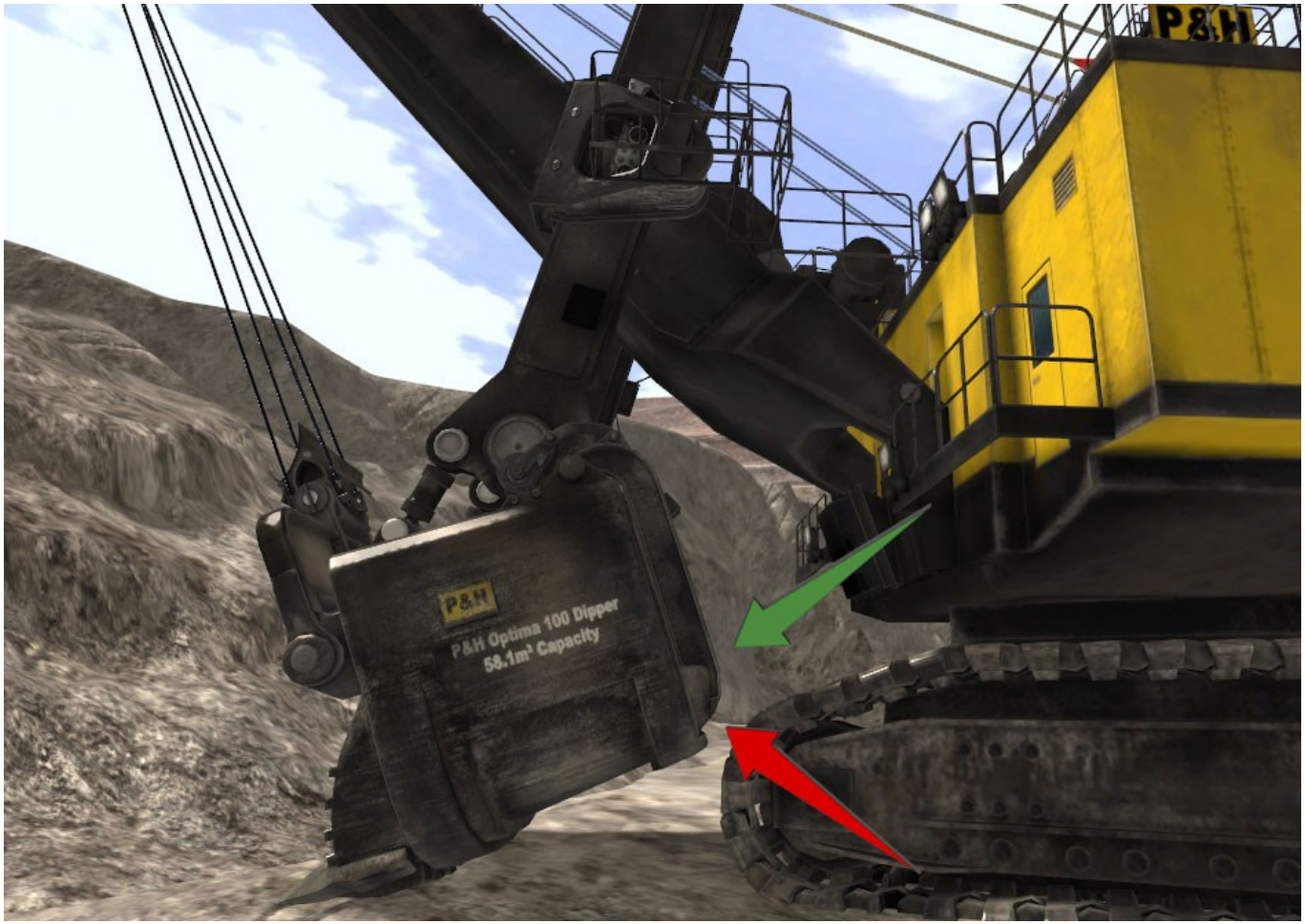
The shovel operator applies a slow crowd extension reference.

The Track Shield system identifies that the current operator commands may cause a collision between the dipper and the tracks but still does not attempt to override the operator's commands because of the slow speed being applied.

The shovel operator continues to apply a crowd extension reference.

The Track Shield system identifies that the current operator commands may cause a collision between the dipper and tracks given the short distance between the dipper and tracks. The Track Shield system reduces the applied crowd reference to zero.

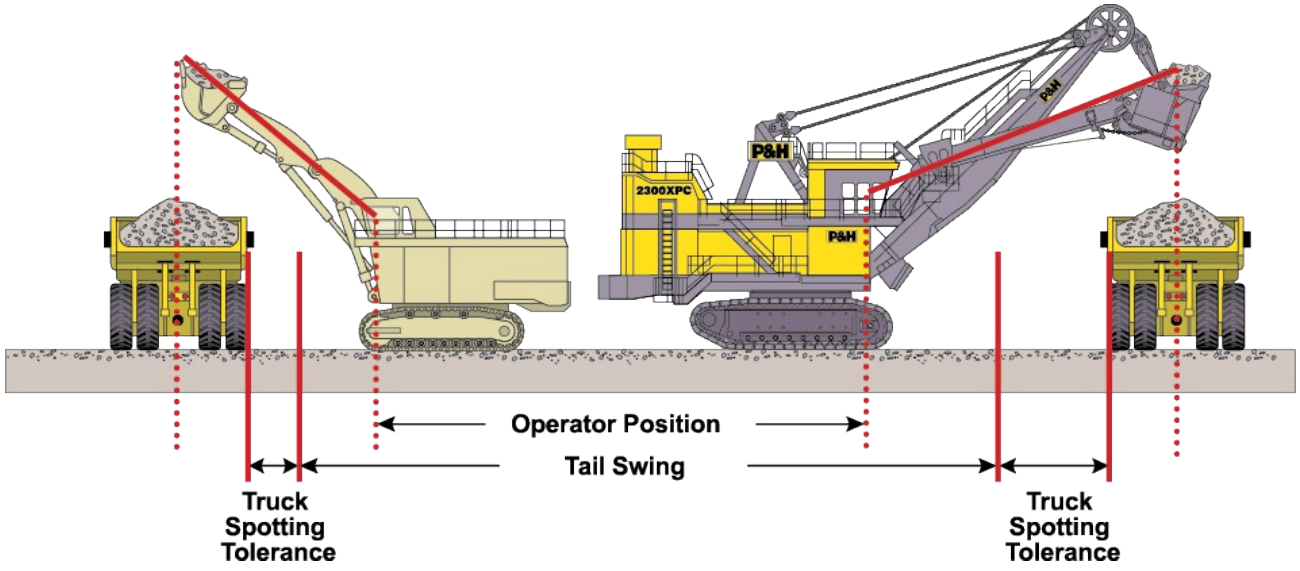
The shovel operator commands a hoist and crowd reference that is directed away from the tracks.



Operator is hoisting up (and away), so the Track Shield system no longer overrides the operator's crowd reference. With autonomous operator assist, the system enables the operator to quickly get to the optimum digging position relative to the bank.

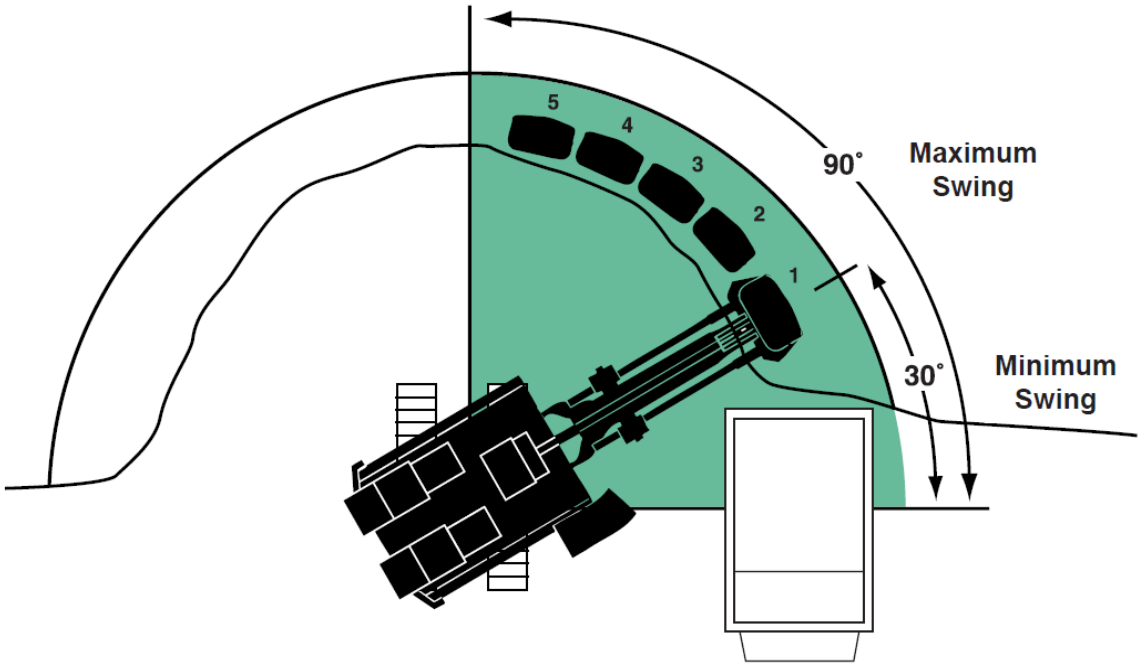
Best Practices Down the Line

- Machine-to-machine perception and avoidance requires integration of multiple pieces of equipment
- Options:
  - Full communication in “real world” reconstruction
  - Peer-to-peer-communication
  - Centered on individual pieces of equipment
- Complexity increases dramatically



Conclusion

- Proximity detection and collision avoidance can be production enhancers
- Fully autonomy may not be as helpful to a mine as assisting the operator in best practices



A typical digging sequence for the double back-up method of loading. Note that the maximum swing angle is 90° when digging on the same side as the truck being loaded.

Thank You

JOYGLOBAL