MineSAFE: A New Software Architecture for Mine Safety Education

Leonard D. Brown

John Ros Hill

Mary M Poulton

THE UNIVERSITY OF ARIZONA

Motivation

- The mining workplace
  - Multimodal, dynamic, and often hazardous
  - Timing, space, norms, customs, relationships, languages (Billet, Fenwick, & Somerville 06; Rose 03)
- Workplace learning
  - Practical, physical, problem focused (Barton & Hamilton 05)
  - Instruction usually takes a mentoring style (Waibel et al 12)
- Existing safety training materials: often decontextualized (Wallerstien '92, Waibel et al '12)
  - Not reflective of task or workplace conditions, ambiances
  - Can be dry with limited ability to engage

Motivation

- Allow for more "situated" learning
  - Similar to mentoring style
  - Critical thinking in context of real situation, workplace
- Address the diverse demographics of the workforce
  - Differing cultural backgrounds, norms, first languages
  - Varying degrees of literacy (computer, language, etc)
  - Varying ages, levels of experience
- Fit into established pedagogical systems
  - Variety of teaching models, situations, environments
  - Classroom, one-on-one mentoring, independent
  - Enhance, don't revolutionize

Video games as vehicles of learning

- Entertainment value may enhance learning: Games can be contextually relevant, realistic, & **memorable**
- Provide urgency, motivation, excitement to improve score, outcomes (Gee '07, '08)
- Lesson from game industry: good games are addictive!
- Address many challenges to learning process at same time
  - Workplace literacy
  - Second languages

Objectives

- Findings of needs assessment
- Overview of Arizona MineSAFE
- Example: Harry's Hard Choices Interactive
- Preliminary feedback

Needs assessment

- Goal: gain a better understanding of training needs, ways to improve upon existing materials
- Surveyed existing digital media
  - Training games by CTS, Inc
  - NIOSH-published game materials (Map reading; Evac beta)
  - CSM mine rescue simulation
  - MSHA video training materials
- Conducted informal user study
  - Target apps: NIOSH Map reading; Evac Beta (c/o Tim Orr)
  - Representative and/or freely accessible
  - 9 UA students participated

Initial findings and indications

- Limited (or no) consequences for actions
  - Subjects exploited lack of consequences (e.g. walking in fire)
  - "What's the point if I can't die or lose?"
  - Graphic expressions of consequences can be memorable
  - Solution: enforce positive and negative consequences
- Limited (or no) social interaction, teamwork
  - Going it alone: representative of a real work/crisis situation?
  - Game experience described as being "lonely"
  - Character backstory can provide motivation, emotional investment
  - Solution: Enhance interaction with other story characters

Initial findings and indications

- Decontextualized learning
  - Users disoriented, difficulty understanding objectives
  - MRB: completed quiz successfully, still got lost
  - Subjects wandered aimlessly looking for clues
  - Non-native speaker: difficulty w/ verbal instructions
  - Solution: couple learning w/ realistic multimodal context
- Slow paced, unchanging environment
  - Limited options to interact with world, restricted movements
  - Game experience described as sometimes "boring"
  - Solution: More engaging, more immersive, more suspenseful
  - Solution: More open-ended interaction (sandbox analogy)

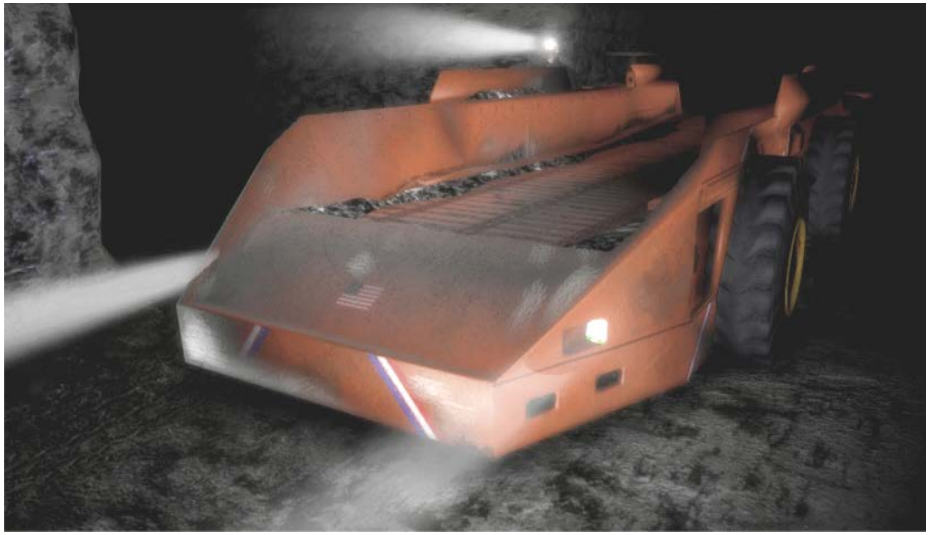
The Arizona MineSAFE Platform

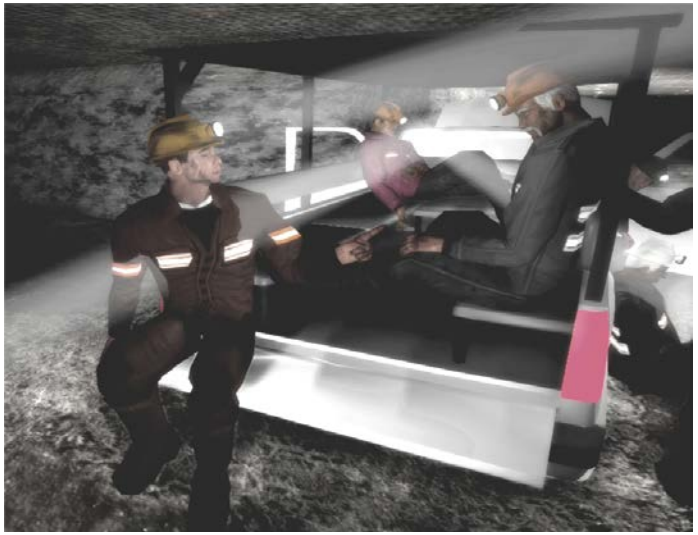
- Software Architecture for Mine SAFEty Education
  - Provides contextualized "sandbox" for critical thinking
  - Emulates sights, sounds, distraction of a real situation
  - Supports workplace literacy & second language learning
  - Enables rapid-prototyping of training applications
- Use to create, customize many games for safety education

- Examples discussed today
  - Interactive Fatalgram Simulator
  - Harry's Hard Choices Interactive

Open, Richly Interactive Environments

- Dynamic above ground & underground environments
- Usable equipment & haulage: use arbitrarily anytime
- Crew interactions: dialogue, decisions, leadership
- Consequences and persistent world state
  - Rewards & penalties reinforce learning





Authentic Mine Workplaces

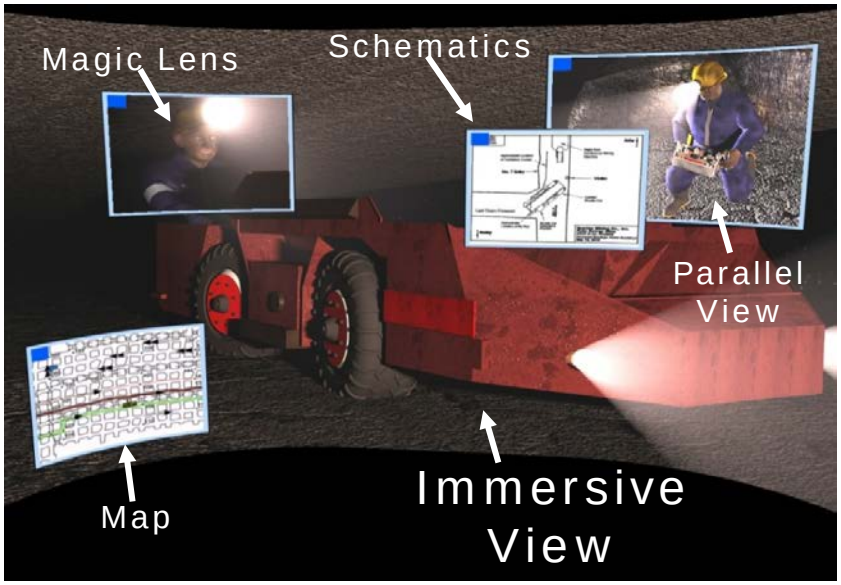
- Serve as backdrop for many different safety training games
- Recreate the sights, sounds, & distractions of real mine workplaces
- Represent a variety of methods, practices
- Include metal & coal, surface & underground mine sites

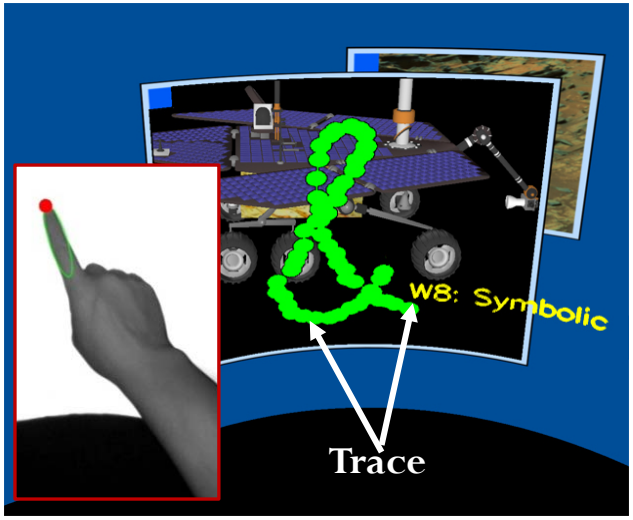
Learn Safety Equipment & Procedures

- Adhere to MSHA safety, self rescue guidelines, best practices
- English & Spanish dialogue, subtitles
- Examples: SCSR, SRLD, gas meter, refuge chamber, safety lines, goggles

Emerging Interfaces & View Paradigms

- Scalable: Increase level of immersion, reduce seams between reality and virtuality
- Correlate information, provide assistance for workplace & second language learning
- Touch, hand gestures, and tangible objects





Content Creation Toolkit

Fear

MineSAFE training initiatives

- Prevention: *Interactive Fatalgram Simulators*
  - Reconstruct MSHA Fatalgrams as 3D worlds
  - Working toward a suite of mini-games (5-10 min)

- Preparedness: *Harry's Hard Choices Interactive*
  - Extends NIOSH paper activity
  - Emergent storyline (30-60 min)

Harry's Hard Choices Interactive

- Based on NIOSH paper activity (Vaught, Hall, & Klein 09)
- Play role of section foreman as he tries to get crew out of mine
- Reconstructed paper activity into dynamic storyline
  - De-serialized, randomized, and emergent events
  - "Replayability": Each play-through is slightly different

Demo: A normal day interrupted

Rich team interaction

- Characters have personalities, predispositions, morale
- Communicate through speech, body language, expressions
- Emergent behavior illustrates human factors
  - Conversational topics depend on context
  - Opportunities for situated decision-making
  - Teamwork: Assist injured, manage SCSRs

Choices have consequences

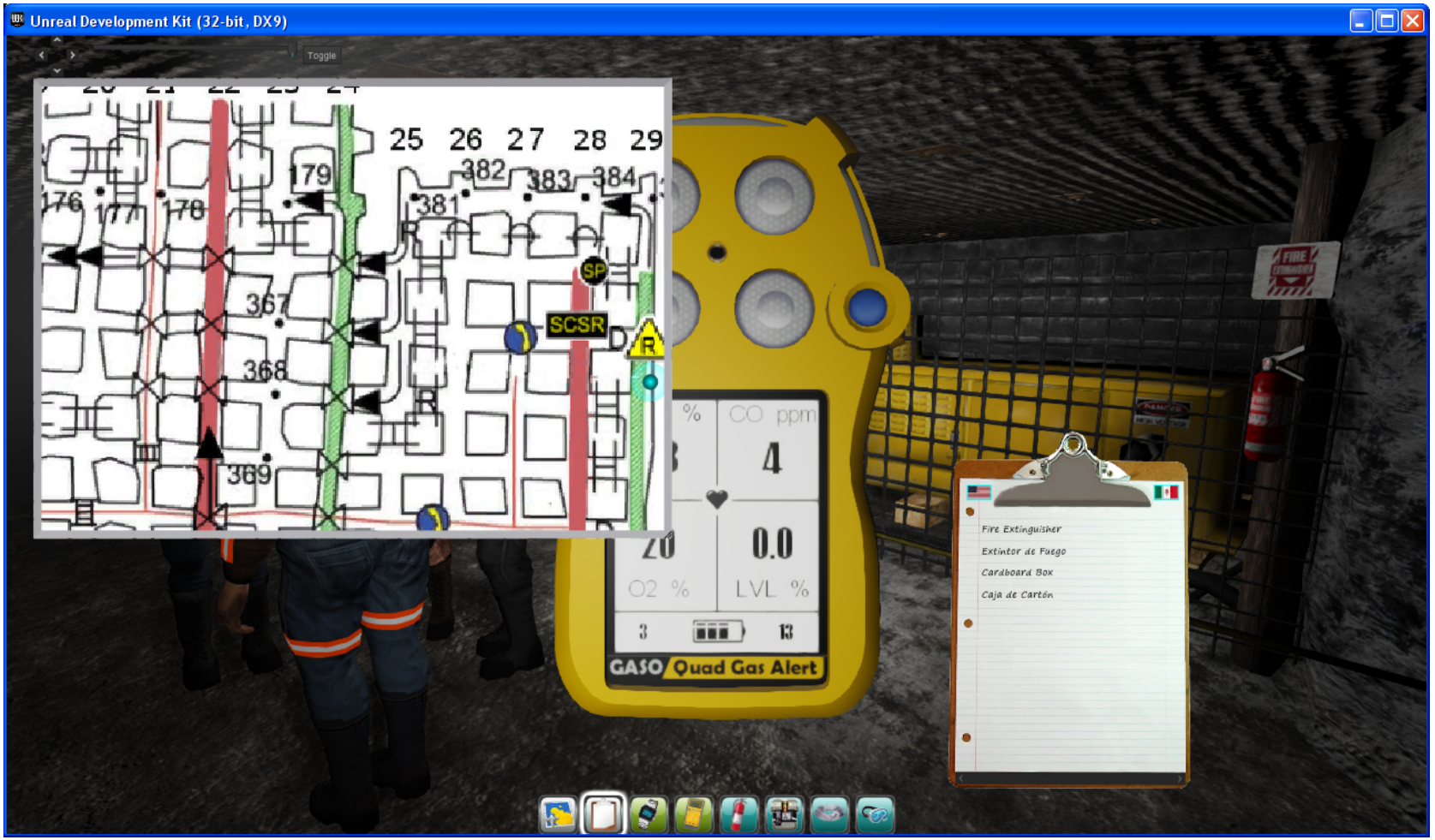
- Outcomes affecting **both** player and crew members
- Injury & death: Asphyxiation, burns, sprains, fatigue
- Crew demeanor and morale impacted by choices
- Time is your enemy! No-win conditions possible.

Demo: Making choices

Enabling workplace learning

- Integrated tools to facilitate learning
  - Customizable presentation, visual aids
  - Personalize the learning process for audience
- Example: Workplace literacy
  - Interactive maps, on-screen annotations
  - Terminology references, cross-linking
- Example: Second language literacy
  - Second language audio tracks, subtitling
  - Language references, cross-linking
  - See and hear both languages in context

Demo: User interface



Pilot Study

- Objective: Preliminary feedback on content, game design
- Focus groups approach
  - TAC: Industry experts, 25+ yrs in mining safety & health
  - About a dozen participants, 2 or 3 at a time
  - 10 minute overview & guided demo
  - Organic discussions
- Design dimensions explored
  - Equipment & procedures
  - User interface capabilities
  - Applicability to current training line-ups
  - Dialogue & crew interaction
  - Game play & pace

Select Feedback

- Game Equipment & Procedures
  - Accuracy of environment details
  - Examples: include proper vent tubes, chocking, airflow patterns
  - Usage patterns for safety equipment
  - Examples: Cache usage, 1 hour breathing apparatus, modern communication systems, lifeline orientation
- User Interface Capabilities
  - Interface can impact user acceptance
  - Keyboard+mouse: challenging for some groups
  - Gamepad: universally desirable; also engages younger gen

Select Feedback

- Training Line-up
  - Possible usage: inexperienced miners, new hire orientation, annual refresher, mine rescue, evacuation drills
  - Trainer-led: Trainer can play through as group watches
  - Acceptance: Will industry, MSHA approve?
- Dialogue & Crew Interaction
  - Multilingual context: Crew may revert to native languages in pressure situations, model potential communication issues
  - Help & prompts in second language: Spanish, Navajo
  - Accents & vocabulary usage: vary by region

Select Feedback

- Game Play
  - Multiplayer: potential for small group/team training
  - Surface control: Add supervisory roll, where trainer can direct Harry's escape
  - Spot Training: Focus on different particular aspects
- Pace and Timing
  - Time constraints a factor: <60 min simulation is desirable
  - Timing: Selectively compress time, fast forward
  - Visible ticking clock adds pressure

Future Work: Classroom Assessment

- Formative tests of game design & user interface
  - Is the interface accessible and easy to use?
  - Qualitative: evaluate with questionnaires & feedback
  - Iterative tests provide incremental improvements
- Efficacy of approach
  - Does the simulator achieve results? Trainers will decide.
  - Test group: Training with fatalgram simulator
  - Control group: Training using "traditional" approach

Conclusions

- MineSAFE: An emerging platform for mine safety training
  - Accessible, highly interactive training tools
  - Contextualized learning, critical thinking
- Games for Mine emergency prevention & preparedness
  - Harry's Hard Choices Interactive
  - Others: Interactive Fatalgram Simulators
- Ongoing work will address games in practice
  - Usability and efficacy analysis
  - Extensions: increase collaboration; enhance immersion
- Looking for more industry collaboration, involvement

Research Sponsors

- National Inst. for Occupational Safety & Health

  "Western Mining Safety& Health Resource Center"

  1U60OH010014-01

- Mine Safety & Health Administration

  "Improving Mine Emergency Prevention using Computer Software Simulations"

  BS-22468-11-60-R-4 (Brookwood-Sago)

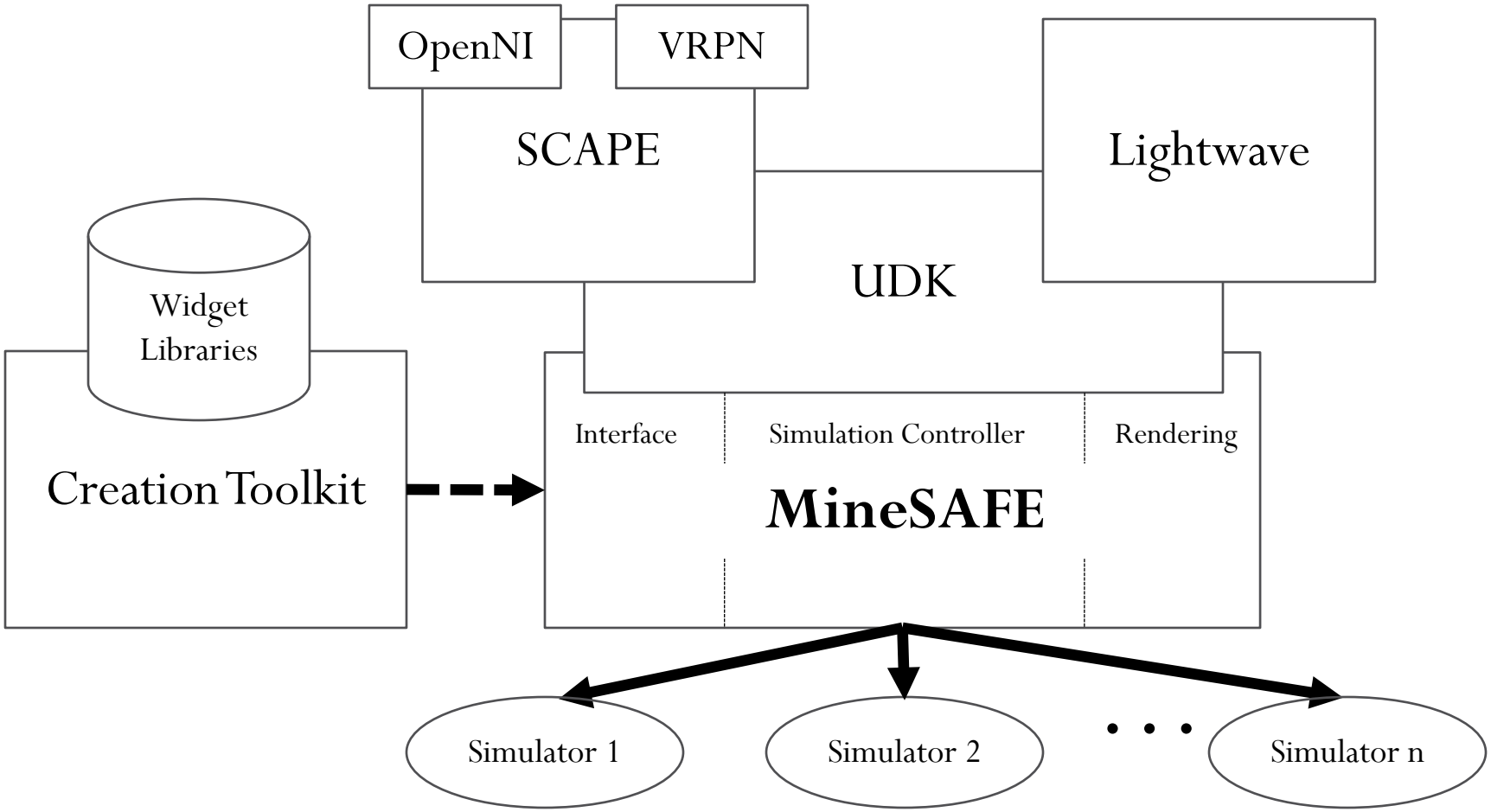
Acknowledgements

- Contacts (@email.arizona.edu)
  - Leonard D Brown -- ldbrown
  - John R.M. Hill -- jrhill
  - Mary M. Poulton – mpoulton

- Acknowledgements
  - Michael Peltier
  - Dr. Hong Hua

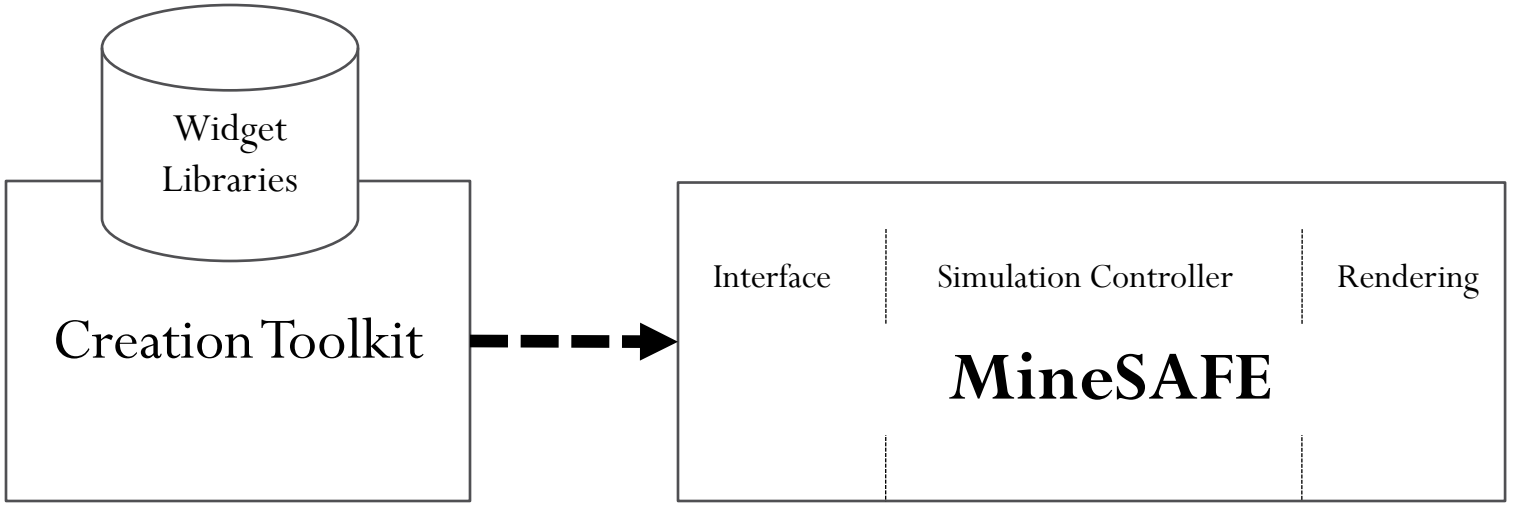
MineSAFE: Software architecture

- Using our platform, we can program a host of safety games.



Content Creation in MineSAFE

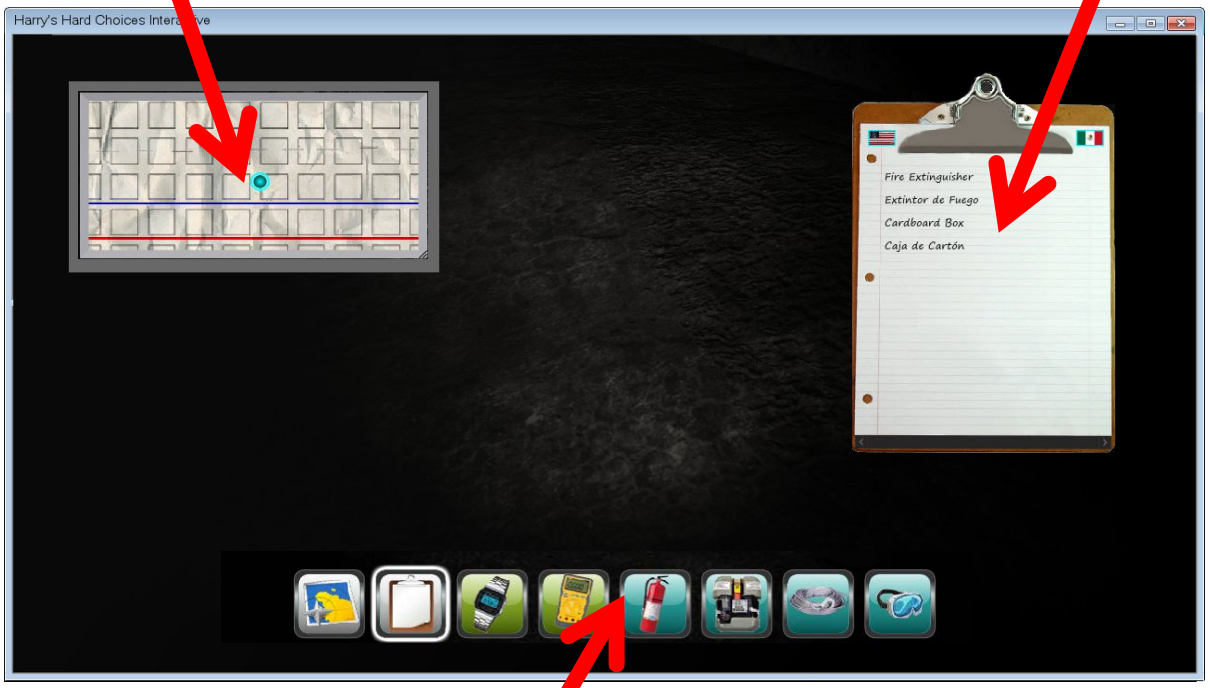
- Commonalities may be abstracted programmatically
- We can develop a generic "toolkit" to speed the creation
- Libraries of construction elements – "widgets"
- Toolkit works within the platform to streamline creation of games (e.g. MEP, fatalgrams) of specific classes
- Eases adaptation to specific sites and scenarios w/ similar methods



Customizable User Interface

Annotated
Mini Map

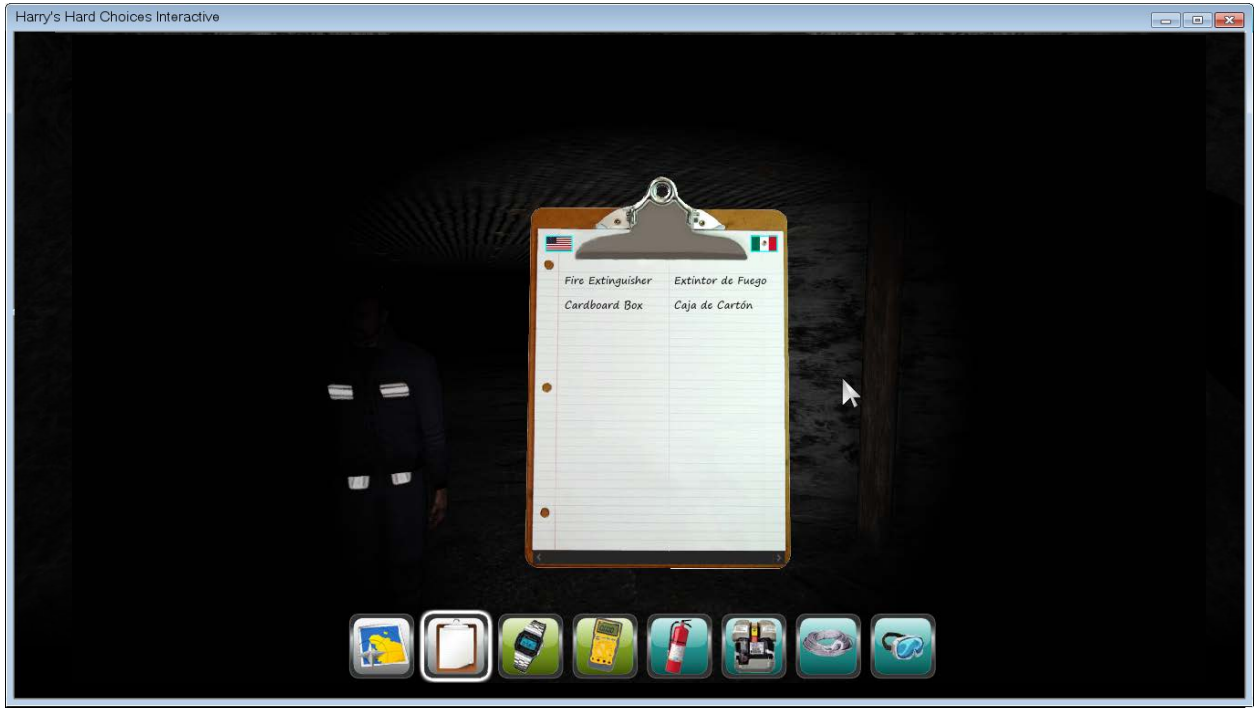
Multilingual
Clipboard



Help Console
with Tooltips

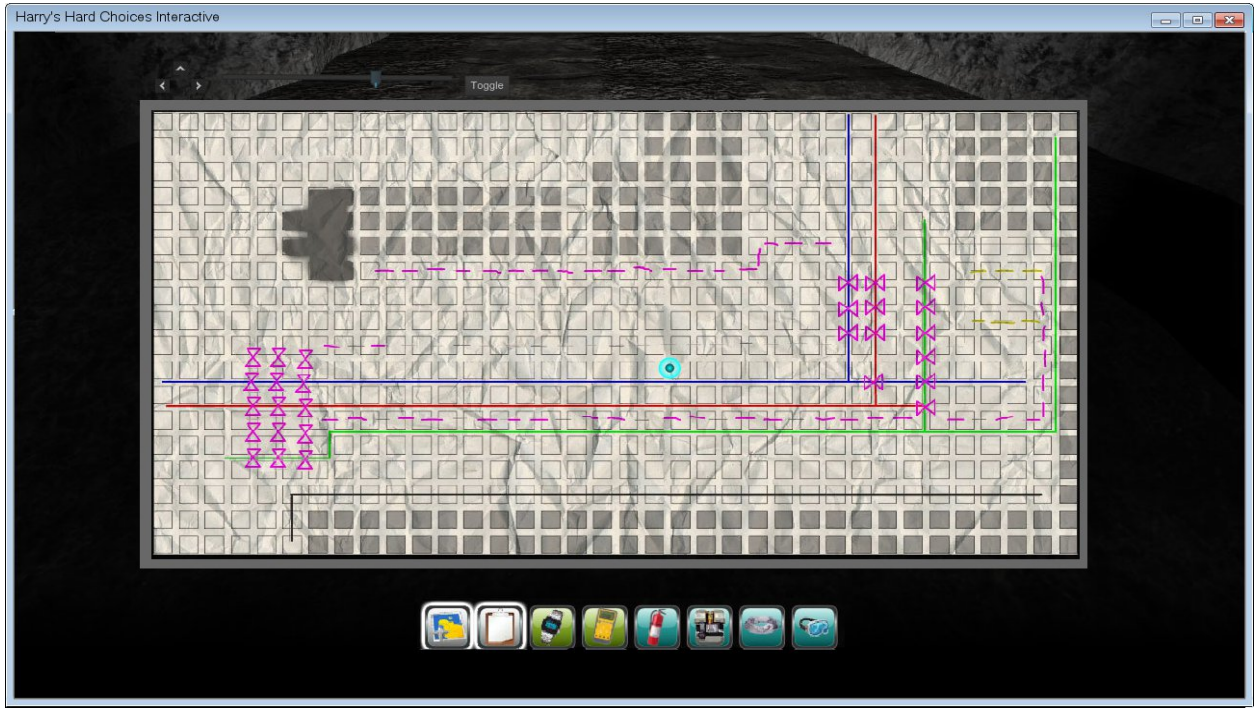
Multilingual clipboard

- Workplace terminology reference
- Record of event & dialog history
- Cross-linked to spoken words



Annotated mini map

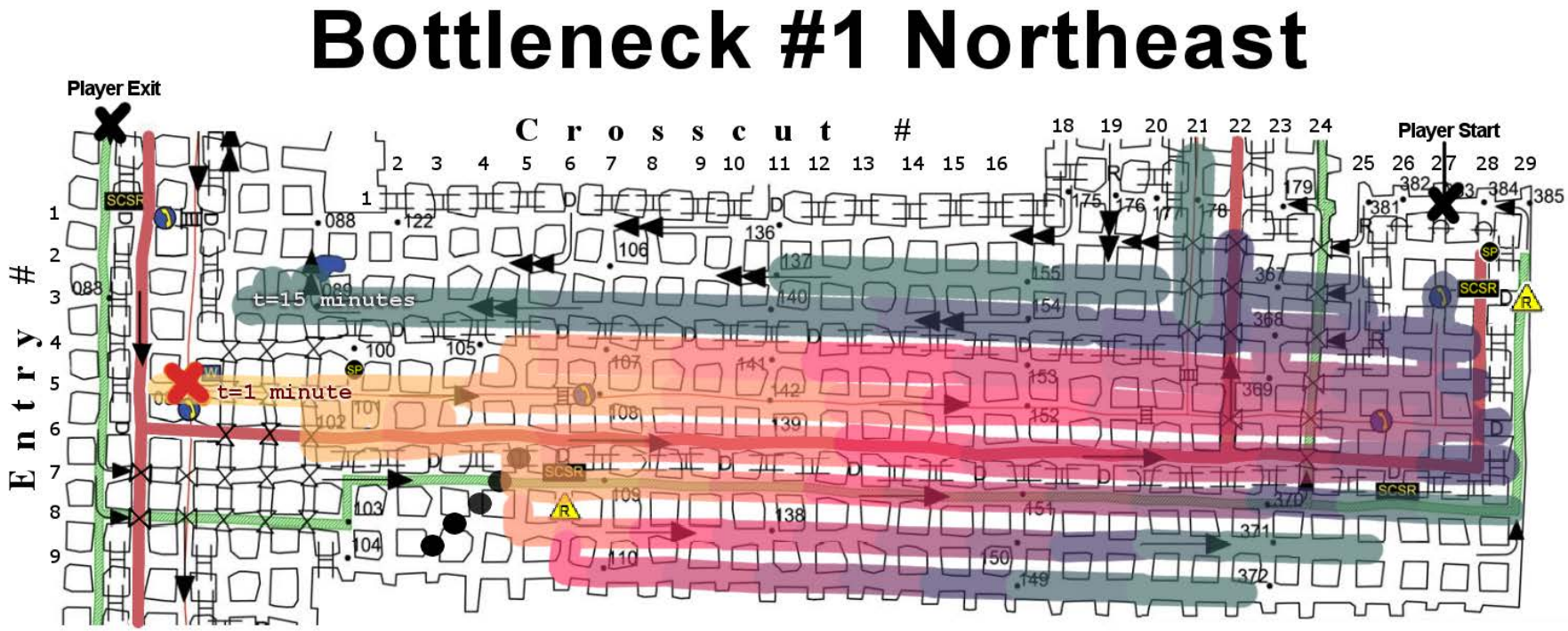
- Real-time navigation aids (user, objectives, hazards, crew)
- Magic Lens: multiple layers with pan, zoom
- Terminology cross referenced to clipboard



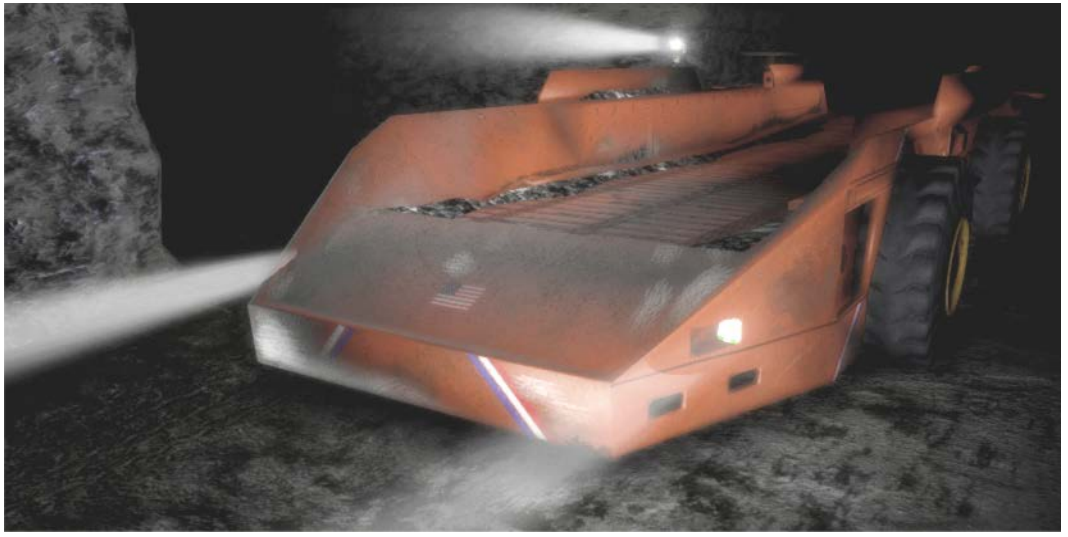
Mine fire, smoke effects

Smoke propagation patterns

- Smoke rapidly fills all areas of the section
- Dangerous gases propagate (CO; methane build up possible)
- Fire rapidly doubles in size, may block off the section (Tim Orr,

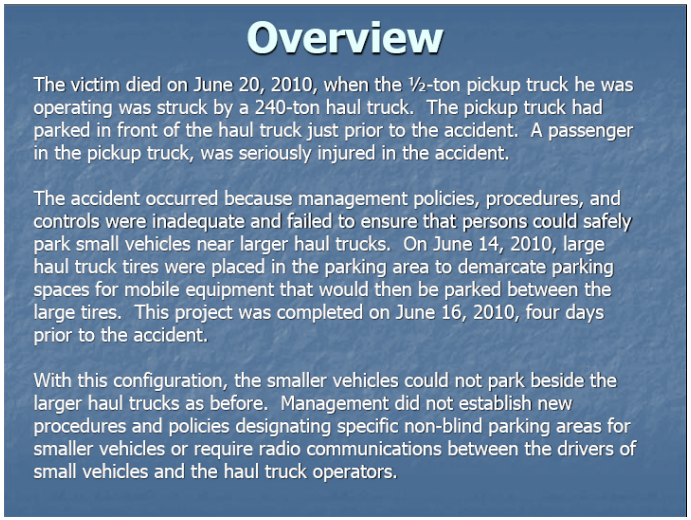


Lighting: A new attention to detail



Interactive Fatalgram Simulator

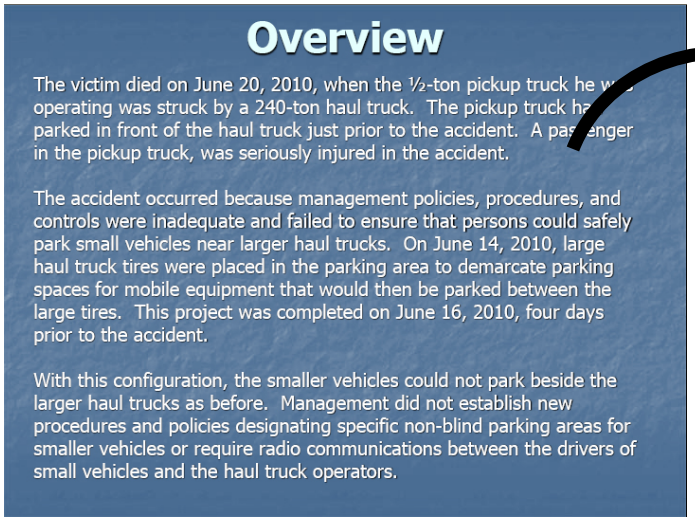
- Get beyond write-ups, diagrams, slides
- Suitable for annual refresher courses
- Tells story of accident, allows alternate endings
  - Capture sights, sounds, and distractions of workplace
  - Emphasis on freedom of choice with clear outcomes



[www.msha.gov]

Interactive Fatalgram Simulator

- Beyond write-ups, diagrams, slides
- Mini-games suitable for annual refresher courses
- Games that tell story of accident, let user alter outcome
  - Capture sights, sounds, and distractions of workplace
  - Emphasis on freedom of choice with clear outcomes

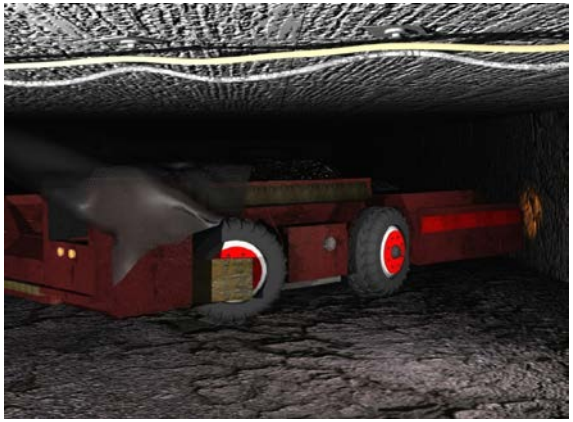


[www.msha.gov]

Scenarios Under Development

- Haulage, surface metal (Ray, AZ)
- Haulage, underground coal (Delbarton, WV)
- Debris fall, undergrnd metal, Galena, ID)

- Yields infrastructure for creating others



Fatalgram Simulator Capabilities

- Controls over flow of time
  - Move back and forth through time
  - Replay events from different angles
- Watch 3D "movie," dive in, change outcome
  - Make mistakes, view consequences
  - Implement best practices, avoid accident

Initial feedback

- Presented Ray haulage fatalgram at 7th Western Mine Safety Conference, Las Vegas, NV, Oct 2011
- Presenter showed demo, led discussion on capabilities
- Feedback: positive, but tempered enthusiasm
  - I want this now, where can I get it? (Not available yet)
  - Limited computer experience, unfamiliarity with games
- Suggestions for improvement:
  - Make simulation more open-ended, with more possibilities
  - Allow site-specific, method-specific adaptation
  - Provide more robust rewards system
  - Further enhance access to MSHA-approved training materials

Partnership Opportunities

- References needed for Creation Toolkit
  - Sites: authentic look and feel of a real workplace
  - Equipment: mine methods-specific safety training
  - Pictures, photos, diagrams, descriptions

- Play testing of interactive betas
  - Informal tests & feedback (try it out)
  - Classroom testing and evaluation