Lowell Institute for Mineral Resources

HARRY'S FATALGRAM SIMULATOR DESIGN EXHIBIT

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To demonstrate the capabilities of the Dynamic Safety™ software platform, we have created a short, modular serious game for fatality report training called *Harry's Fatalgram Simulator* (*HFS*). This serious game employs software and game design patterns that were motivated by extensive training field studies (Brown 2015). The application was designed in close consultation with mining industry experts, including safety trainers and members of the Lowell Institute for Mineral Resources Health & Safety Technical Advisory Committee (<https://minerals.arizona.edu/innovation/ishrc/>). It was originally developed as a test prototype for new technologies in "serious games." The origins of this game can be traced to the proof-of-concept presented to trainers and health and safety supervisors at the Western Region Mine Safety and Health Conference (Brown, Hill, & Poulton, 2011). In this white paper, I will discuss how specific game design patterns were mapped to users' "sensemaking" needs in support of the learning objectives for annual refresher fatality reports. A summary of this relationship is given in Table 1. I also summarize the formative user studies that were conducted with the game.

Prototype 1: Harry's Fatalgram Simulator. Fatalgrams are a mandatory component of the MSHA Part 48 annual refresher courses, which were covered in our field studies. A detailed discussion of existing media and pedagogy for fatalgrams may be found in Brown (2015). Using the Dynamic Safety™ platform, we developed a tool to reconstruct fatalgrams into interactive mini-games (Brown, Hill, & Poulton, 2011). Traditionally, fatalgrams are taught using slideshows, with minimal interactivity and tedious detail. This medium is often not adequate to illustrate causality relationships in a complicated story, as recommended by the Consequent

Table 1. Implementation of design patterns in prototype serious game.

Recommended Design Patterns	*Harry's Fatalgram Simulator*	
1. Unify work objects	Universal control console	✓
2. Manage complexity	Fixed / free camera Magic Lens (O+D)	✓
3. Improve tutorial Access	--	✗
4. Couple Discovery, Analysis, & Practicum	Story time slider Observe, then participate	✓
5. Couple learning, outcomes	Fork alternate timelines Try and watch	✓

theme of the **Design Guidelines for Training in Mine Safety (DGs)**, available at <https://miningsh.arizona.edu/resources/competency-models#asset-model>. In contrast, *HFS* can realize a fatalgram as a cinematic story in a 3D virtual environment (DG10), and allow learners to explore alternative timelines (DG11) where choices lead to visual consequences that are context-specific (DG12).

For the *HFS* game prototype, we make use of our Data-Driven Function Story (DDFS) scripting system to create modular story components that can be reassembled in different orders at run time. Some story elements may be tied to specific game state or to other story elements. Causality may be realized through the DDFS trigger mechanisms of the Dynamic Safety™ platform. We can then build interactive fatalgrams that play out as coherent 3D stories, based on the historical record of the accident. Significantly, users may fork off alternate timelines by taking control of the game and changing game state. These alternate timelines are only limited by the story elements available to the game. At a minimum, a fatalgram scenario should provide story elements to realize MSHA best practices, which are necessary to prevent the accident and achieve good outcomes. Additionally, the story may incorporate "dead end" outcomes where the accident repeats or a new accident is caused. Both positive and negative outcomes may be realized through visual story-telling in response to user decision-making in *HFS*.

The *Harry's Fatalgram Simulator* also offers a much greater level of presentation flexibility than is possible with traditional classroom media. In our field studies, spatial relationships were often unclear, and the learner's view of the accident scene was typically incomplete. Furthermore, a survey of the MSHA fatalgrams (<http:\\MSHA.gov\fatals>) suggests that visibility constraints play a major factor in many fatalities. Referring to the Design Guidelines for Training in Mine Safety, the Contextual theme provides insight on how to fix these problems. In particular, the accident scene can be carefully reconstructed as a 3D virtual environment (DG9), where users can explore the accident from different angles, and even

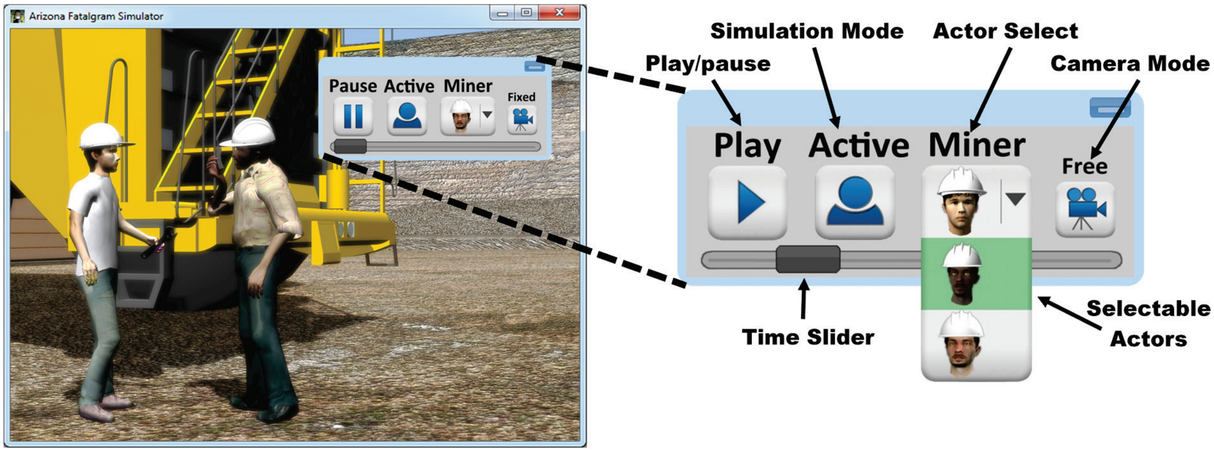

Figure 1. Control console for *Harry's Fatalgram Simulator*. Left: The console may be accessed at any time during gameplay; Right: The console affords access to simulation and camera parameters.

Table 2. Viewing and control schemes for *Harry's Fatalgram Simulator.*

Camera / Interface	Fixed	Free
Movie	Exocentric, constrained to cinematic view	Exocentric, unconstrained flying camera
Active	Egocentric, viewed through actor's eyes	Egocentric, constrained to sphere around actor

assume the viewpoints of actors in the scene through time and space, thus "seeing what they see" (DG8).

The game offers a control console (Fig. 1) to change the mode of interaction, alter camera constraints, and manage the progression of time. A summary of the camera and interaction modes is shown in Table 2. *HFS* offers “Fixed” and “Free” camera constraints for both “Active” and “Movie” interface modes, yielding four distinct camera metaphors. For example, the "Free" camera can be navigated at will, while the "Fixed" camera is attached to a staging location, which may be a cinematic vantage point or a specific character's point of view. Furthermore, a "Picture in Picture" window -- enabled by a Dynamic Safety™ Magic Lens -- can be used to show the accident scene from competing vantage points. The secondary viewport has its own camera, subject to the same "Fixed" and "Free" camera constraints that were defined above. The control console can be used to interface with both viewports; for instance, the last active window determines which state the control console is currently displaying.

The control console's interface mode determines the user's role in the unfolding story. The "Active" mode allows the user to change the story through the actions of a scene actor, while the "Movie" mode reverts the scene to the unaltered version of the accident sequence. The user

Figure 2. Sample interactive Fatalgram showing multiple views and interaction modes. Left: Picture-in-Picture allows the action to be seen from different angles at the same time; Right: The fixed camera, active mode allows a user to dive into the simulation and change its outcome.

can select any of the scene actors from a drop down menu and "dive" into that actor to become a part of the story. Furthermore, the console's timeline slider allows a user to skip forward and backward through time to select an “entry point” to fork the simulation.

To understand how these capabilities might be used in practice, consider a scenario where a trainer works with a group of learners to understand a haulage accident. According to the MSHA accident report, the accident was caused in part by a pickup truck driver's parking too closely to a much larger haul truck -- in the haul truck driver’s blind spot. To emphasize the blind spot, the trainer might invoke a flavor of O+D Magic Lens, called "Picture in Picture," to show a 3rd person “bird’s eye” view of the scene using a "Free" camera, with a 1st person "Fixed" view on the main display window illustrating that the haul truck driver's view (Fig. 2, left). From the haul truck driver's vantage point, the blind spot is obvious. As the movie played forward, the "bird's eye" view illustrates the pickup being shockingly crushed, while the driver is oblivious that he has just run over the pickup. Once the trainer feels that the visibility constraints are understood, she might rewind the time slider to a point before the fatal accident, enter an

Figure 3. Fatalgram reconstruction for serious games. The accident scene is shown at left and its game counterpart at right: (a,b) Haulage accident in surface metal; (c,d) Haulage accident in underground coal; (e,f) Fall of material accident in underground metal. (Photos courtesy MSHA)

"Active" mode, and ask one of the students to take control of an actor whose choices could oblivious that he has just run over the pickup. Once the trainer feels that the visibility constraints are understood, she might rewind the time slider to a point before the fatal accident, enter an "Active" mode, and ask one of the students to take control of an actor whose choices could prevent the accident (Fig. 2, right).

To demonstrate the *Harry's Fatalgram Simulator*, we have created three proofs-of-concept fatalgrams, covering a variety of mining methods. The fatalgrams are as follows:

1. Powered haulage, 1 fatality, surface metal (Ray, AZ 6/10)
2. Powered haulage, 1 fatality, underground coal (Delbarton, WV 5/10)
3. Debris fall, 1 fatality, underground metal (Galena, ID 6/10)

Figure 3 shows an accident scene reconstruction for each of these fatalgrams in the *HFS* game environment. As discussed, the game environment was constructed using the Dynamic Safety™ DDFS framework and Creation Toolkit. Furthermore, fatalgram #1 was fully developed into an interactive mini-game for testing with industry stakeholders. Fig. 4 presents a storyboard of this fatalgram, as realized through *HFS*.

In October, 2011, we conducted a formative study of the *Harry's Fatalgram Simulator* at the annual Mine Safety & Health Conference (MSHC) in Las Vegas, NV. During this study, a group of twenty industry trainers (approximately ten at a time) participated in one-hour focus group discussions. The *HFS* game was presented using a standard laptop computer, hooked to an external projection display. The projector had a native aspect ratio of 4:3 at a resolution of 1024 x 768 pixels. A mouse was used as an input device. During the session, the experimenter gave background on *HFS* and directed users in a walkthrough of the fatalgram prototypes. After

Figure 4. Event progression for a Fatalgram movie depicting a haulage accident. (a) Mechanics are instructed to test haultruck; (b) Truck is returned to tie-down area for testing; (c) Driver is paged to pilot the haultruck; (d) Mechanics mistakenly park too close; (e,f) Pickup truck is crushed by haultruck.

the play-through, the focus groups participated in a discussion on the gaming experience and its potential utility as a training tool. As this was our first test of a game developed using the Dynamic Safety™ framework, our questions were open-ended and meant to be discussion primers. Trainer feedback is summarized in Table 3.

Table 3. Sample user feedback for *Harry's Fatalgram Simulator.*

What would inhibit trainers from using *HFS*?	What would you suggest to improve *HFS*?
When will it be available?	More development needed.
Want to see more - keep at it.	Demo when finished product.
Timeline unknown for availability.	Hands-on use of simulator.
More development needed. Good idea.	Beginners need discussion of why.
Come back when available.	Make personal, give names to characters.
Interfacing was confusing.	Show rewards that are possible.
Software isn't ready yet.	Thought simulation would be more extensive.
Want more development of product.	Speed of operation. Timing is important.
Gamepad is a must for younger workers.	It has to be fun.
Hard to orient with mouse.	Could use more direction on what to do.

What was your "light bulb" moment?	What was your impression of *HFS*?
Interactive -- potential to change outcomes	Good idea and teaching tool.
The possibilities. Yes, this is the future.	It will be very useful for training.
Very interesting and enlightening concept.	Interesting idea.
Using tech my son uses - multi-generational.	This is how tech can & will help future.
Like control of vehicles & equipment.	Continue research and application.
Can play as multiple actors.	Want to see more - keep at it!
Outcomes & decisions prevent accidents.	Great potential.
Bad decisions are good to have.	Training has come a long way since slides.
Easy to point out issues.	Very interested in this type of training.
Can satisfy temptation for wrong answers.	Expected product, but concept is great.

The focus group participants thought that the *HFS* idea had great potential to improve their training courses. The game's emphasis on causality was a highlight, as was the ability to take control of different actors and equipment to change outcomes. Since no existing training products enabled this capability, many trainers were surprised by it. User comments included "great potential," "Good idea and teaching tool," and "this is how tech can and will help the future." Trainers thought that the "outcomes and decisions can prevent accidents" and the graphic consequences should help workers in "avoiding the scenario in the future." Trainers thought that "bad decisions are good to have," and that users might feel a "temptation for wrong answers" just to see the outcomes. Trainers felt that the presentation options gave them substantial flexibility to explore the scene and illustrate problems to audiences. The multi-view capability was good to "play as multiple actors" and "point out the issues" with spatial relationships and visibility.

One notable weakness of the prototype was that it lacked appropriate scaffolding. Recall that scaffolding involves a framework of hints and help on the training tasks (Yusoff, 2010, p. 35). Empirical analysis suggested that training workflows would benefit from better access to Tutorials during Discovery, Analysis, and Practicum (design pattern #3) (Brown, 2015, Ch. 6) . No scaffolding was implemented for *HFS*. Although the simulation allowed users to test different choices with observable outcomes, the simulation provided no hints as to *why* a choice was good or bad, or *which* choices reflected best practices. In the test implementation, it was the trainer's duty to provide help and hints to users as they need it. The lack of scaffolding was not a major factor in our focus group walkthroughs, but could be a problem in the field. As two trainers suggested, "Beginners need a discussion of why" and "Could use more direction on what to do."

The interaction and display capabilities were also areas for improvement. Several users commented that the mouse interface was challenging. A mode switch was necessary to toggle between cursor-mode, which was used to access the control console and secondary viewing windows, and navigation-mode, which was used to steer the viewport. Comments included "Interfacing was confusing," "Hard to orient with mouse," and "Gamepad is a must for younger workers." Note that a gamepad was subsequently used in future games, including *Harry's Hard Choices* (*HHC*) and *Harry's Hazardous Days* (*HHD*). Further usability discussion relating to the gamepad may be found in (Brown, 2015, Ch. 8). We also observed that the projector used for display at the conference limited the utility of *HFS* to illustrate spatial relationships and visibility constraints. Specifically, the projector's resolution (800 x 600) impacted the usability of the small "picture-in-picture" window, while the display aspect ratio (4:3) limited the field of view of the primary window. The game might benefit from an increased level of immersion, such as higher resolution and wider aspect ratio. We have subsequently addressed these display factors in *HFS*.

The most significant inhibiting factor was the current state of development of *HFS*. As a prototype, the simulator was not yet ready for classroom use, and only three fatalgram scenarios were in development at the time of testing. More than half of the comments related to the game's lack of availability. Trainers comments included, "want more development of product," "want to see more -- keep at it," "focus on practical end-use," and "When will it be available?" Most trainers were disappointed that *HFS* was not yet available as a product. We find their disappointment encouraging, as it suggests a high level of enthusiasm and high potential for acceptance among trainers. User acceptance was found to be a major concern in our field studies and is also reflected in the Design Guidelines for Training in Mine Safety (DG1). Indeed, additional studies have since examined many other aspects of user acceptance in serious games (Brown, 2015, Ch. 9-10).

References

[1] Brown, L.D. *Design, Evaluation, and Extension of Serious Games for Training in Mine Safety*. Ph.D. Dissertation, Dept. of Computer Science, University of Arizona, Tucson, AZ, 637 pgs., 2015.

[2] Brown, L.D., Hill, J.R., & Poulton, M.M. "A Platform for Interactive Fatalgram Simulation Using Commodity Gaming Hardware." *7th Annual Western Region Mine Safety & Health Conference*, Las Vegas, NV, Oct 24-26, 2011.