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June 1984

SHUTTLE CAR OPERATOR TRAINING SYSTEM

Contract H0272039
ORI, Inc.

Bureau of Mines Open File Report 59-85

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N. Seidle

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This report describes the design, development, and manufacture of a shuttle car operator training system. The training system, including a program of instruction, (1) is economically feasible; (2) addresses accident data and specific causes of accidents; (3) includes an aerospace quality simulator of sufficient fidelity to teach and develop manipulative skills, recognition of and response to hazards, and routine and emergency procedures; (4) is designed to significantly reduce the severity and frequency of accidents especially during the operator's first year; and (5) is designed to significantly improve the performance of the trainee as compared to the standard learning curve.

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FOREWORD

This report was prepared by ORI, Systems Development Division, 1400 Spring St., Silver Spring, MD 20910, under USBM Contract Number H0272039, under the Mining Research Program. It was administered under the technical direction of Bureau of Mines with James H. TaVoularis acting as Technical Project Officer. David J. Askin was the contract administrator for the Bureau of Mines. This is a summary of the work recently completed for the full contractual period. This report was submitted by the authors in final form in April, 1984.

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

ABSTRACT

Numerous studies conducted in the 1960's and 1970's concluded or implied (1) that a high accident rate in terms of severity and frequency exists among new (first year) operators of mine machinery equipment, and (2) that lack of experience and training is a major cause of this high accident rate. Further studies refined this premise to show that the major causes of accidents among first year operators are: (1) lack of manipulative skills; (2) failure to follow/adhere to routine procedures; and (3) failure to recognize and respond properly to hazards.

This report describes the design, development, and manufacture of a shuttle car operator training system, including a program of instruction which:

- Is economically feasible.
- Addresses accident data and specific causes of accidents.
- Includes an aerospace quality simulator of sufficient fidelity to teach and develop manipulative skills, recognition of and response to hazards, and routine and emergency procedures.
- Is designed to significantly reduce the severity and frequency of accidents especially during the operator's first year.
- Is designed to significantly improve the performance of the trainee as compared to the standard learning curve.

Development of the simulator produced several valuable by-products including a major state-of-the-art technological advance in visual systems for simulators, and a first-time application of (certain) advanced filming techniques to underground filming.

I. INTRODUCTION AND SUMMARY

BACKGROUND

Research in the late 1960's and early 1970's including the Theodore Barry study, subsequent MSHA (formerly MESA) studies, and industrial engineering studies demonstrated that first-year underground miners are more than eight times as likely to have an accident as five-to-ten-year veterans, that veteran miners operating a piece of machinery for the first time also have a high first-year accident rate, and that productivity is generally low during the first year an operator is assigned to a piece of machinery. These facts prompted several parallel efforts to improve productivity and safety, especially among first-year miners. The parallel efforts include generalized lighting, various roof control programs, various training programs, stricter laws and enforcement of the laws, and many other industry and government funded research programs to make it easier to operate machinery, to eliminate or reduce potential hazards, and to better prepare the miner for the work place.

Figure 1 depicts the history of the development of one of these training programs. As illustrated in Figure 1, the USBM funded a feasibility study (Contract Number SO-334179) to determine if aerospace-type simulators could be applied to mine machinery equipment operator training. The conclusions of that study were that simulators of the sophisticated aerospace variety are too costly to be applicable to coal mine training programs. However, the study went on to state that a major cause of accidents appeared to be lack of adherence to prescribed emergency and routine procedures and practices, and that training for adherence to prescribed procedures as well as most requisite skills could probably be accomplished within the cost constraints imposed by the mining industry via use of an integrated curriculum employing trainers or low-level sophistication simulators rather than sophisticated aerospace type simulators.

Based on this feasibility study, the Bureau of Mines funded an R&D contract (Contract Number H0242037) to (1) study specifically what needs to be taught for safe, efficient equipment operation; (2) determine the best method to teach the identified skills, procedures, knowledge, and attitudes; and (3) produce a prototype training system. The resultant training system included workbooks, handouts, an unpowered scale model of a shuttle car, a dynamic concepts trainer, a reaction trainer (mid-level sophistication simulator), and actual equipment exercises. The reaction trainer, or mid-level sophistication simulator, was designed and developed to satisfy specific training objectives. Preliminary field studies were conducted on this system. These studies indicated substantial success toward accomplishing the stated objectives with this prototype system as well as toward developing a viable simulator. During field testing, however, several potential hardware and software improvements which would enhance system effectiveness were noted as were software and hardware deficiencies. These improvements and deficiency corrections included courseware changes, major design changes to the unpowered model and dynamic concepts trainer, and improvement of the fidelity of the reaction trainer/simulator.

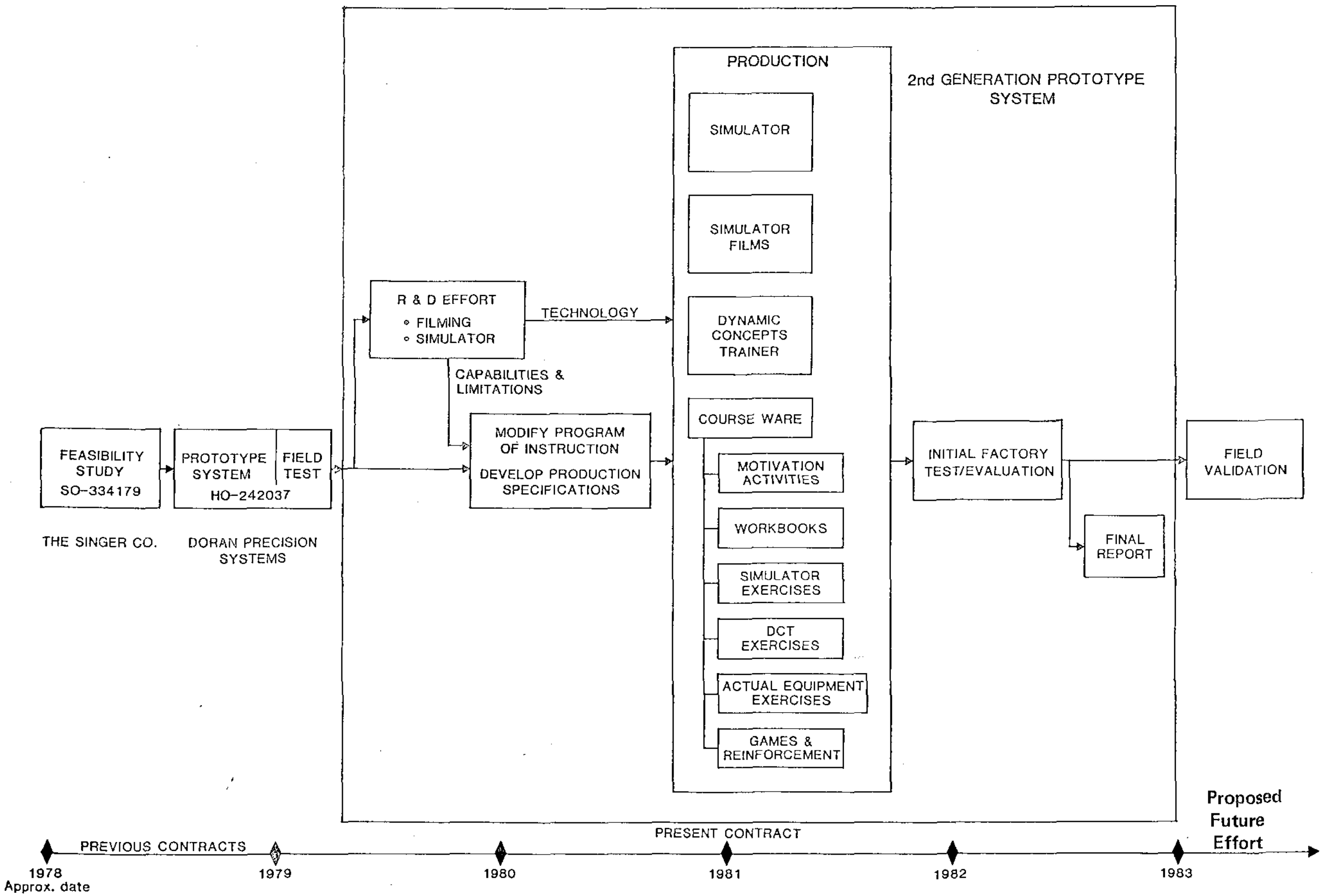


Figure 1: Development History
Shuttle Car Operations Training System (SCOTS)

The Bureau of Mines subsequently funded the present contract to produce a second generation prototype system. The second generation prototype system was to address the recommended improvements and noted discrepancies resulting from the aforementioned field tests, and upgrade the reaction trainer/simulator to a high fidelity, low cost simulator. This report describes the accomplishments of Contract H0272039 for the development and production of a second generation shuttle car operator training system.

OBJECTIVE AND PROGRAM OUTLINE

OBJECTIVE

The objective of this program was to fabricate and validate a second generation prototype of a shuttle car operator training system which will fulfill the requirements for implementation and ultimate utilization of this training technology.

PROGRAM OUTLINE

As depicted in Figure 1, the program began with two concurrent efforts. One of these efforts addressesed the simulator visual system fidelity objectives: picture quality, sufficient fidelity to accurately judge parallelism, and fidelity in turns. This was a high risk task in that the objectives had not been achieved previously with state-of-the-art simulation technology. Therefore, this was considered an R&D task, and successful completion was considered pivotal for the entire program. The program also addressed training system analysis objectives and cognitive activities objectives.

The program of instruction in combination with the simulator functional specifications defined the production tasks. The cognitive activities, the dynamic concepts trainer, the simulator film content, and the simulator specifications relative to training were all a subset of the program of instruction.

Upon completion of the course elements, the training system was tested at ORI facilities. The simulator and Dynamic Concepts Trainer (DCT) were shipped to USBM facilities, Bruceton, Pennsylvania, to await shipment to a field site for validation studies.

SUMMARY OF RESULTS, CONCLUSIONS, AND RECOMMENDATIONS

This project produced a second generation prototype training system, fulfilling program requirements. This system, depicted in Figure 2 and described in Appendix D, consists of an integrated curriculum comprised of workbooks, Dynamic Concepts Trainer, Simulator, actual equipment exercises, and game-type reinforcement activities. The trainee repeats the sequence workbook-DCT-Simulator several times, each time building and developing new skills and adding to old skills. Trainees participate in game-type reinforcement activities while waiting their turn in the simulator. The training system may be integrated into voc-tech school curricula and mine operator training programs.

General Improvements

The general improvements in each of five areas addressed in the development of this second generation prototype were:

Training System Analysis

1. Developed thorough, comprehensive procedures for every aspect of shuttle car operation.

2. Developed and structured training objectives which specifically address these procedures and the skill and knowledge required to execute the procedures.

Cognitive Activities

1. Reduced the time spent with workbooks.

2. Investigated and developed/utilized various methods and media to improve self motivation.

3. Provided reinforcement to improve retention.

Dynamic Concepts Trainer (DCT)

1. Replaced two devices, a 12 ft. scaled practice course, powered model to operate on this course, and duplicate operators pit from which the powered model was controlled, and a scaled unpowered model with a single five ft. scaled portion of entry/crosscut and unpowered, steerable model.

2. Utilized revised DCT to reinforce knowledge, illustrate concepts, vividly illustrate safety principles and documented accidents resulting from failure to adhere to safety procedures/practices, and demonstrate certain procedures such as turning or pulling under.

Simulator (Termed Reaction Trainer In Prototype System*)

1. Improved picture quality on screen.

2. Provided sufficient fidelity to accurately judge parallelism.

3. Improved fidelity in turns. Provided requisite fidelity to initiate turns and to straighten shuttle car as a turn is completed.

4. Reduced physical size of simulator. Developed a low profile motion base. Eliminate hazard generator.**

5. Redesigned electronics to improve hardware reliability.

6. Redesigned simulator exercises to enable students to develop and practice the various procedures associated with shuttle car operation (as opposed to other miner training program factors. Increased the time spent in the simulator (with a corresponding reduction in workbooks and DCT exercises).

Actual Equipment Exercises

1. Modified to remain compatible with the training system.

Specific Accomplishments

Specific accomplishments relative to the design, development, and production of this second generation prototype were:

1. Universally applicable techniques were developed for creating wide angle 16 mm film with the camera in motion in entries and crosscuts.

2. Techniques for creating a pseudo three dimensional (near field) effect in motion utilizing 16 mm film were developed for the simulator.

*Terminology changed from Reaction Trainer to Simulator consistent with change in fidelity, capability, and utilization.

**The hazard generator was a large device which simulated the roof - in motion - and would cause roof hazards such as protruding roof, bolts, multiple holy boards, curtains, etc. to physically protrude from the roof and contact the shuttle car and/or operator unless the operator took appropriate action to avoid the hazard.

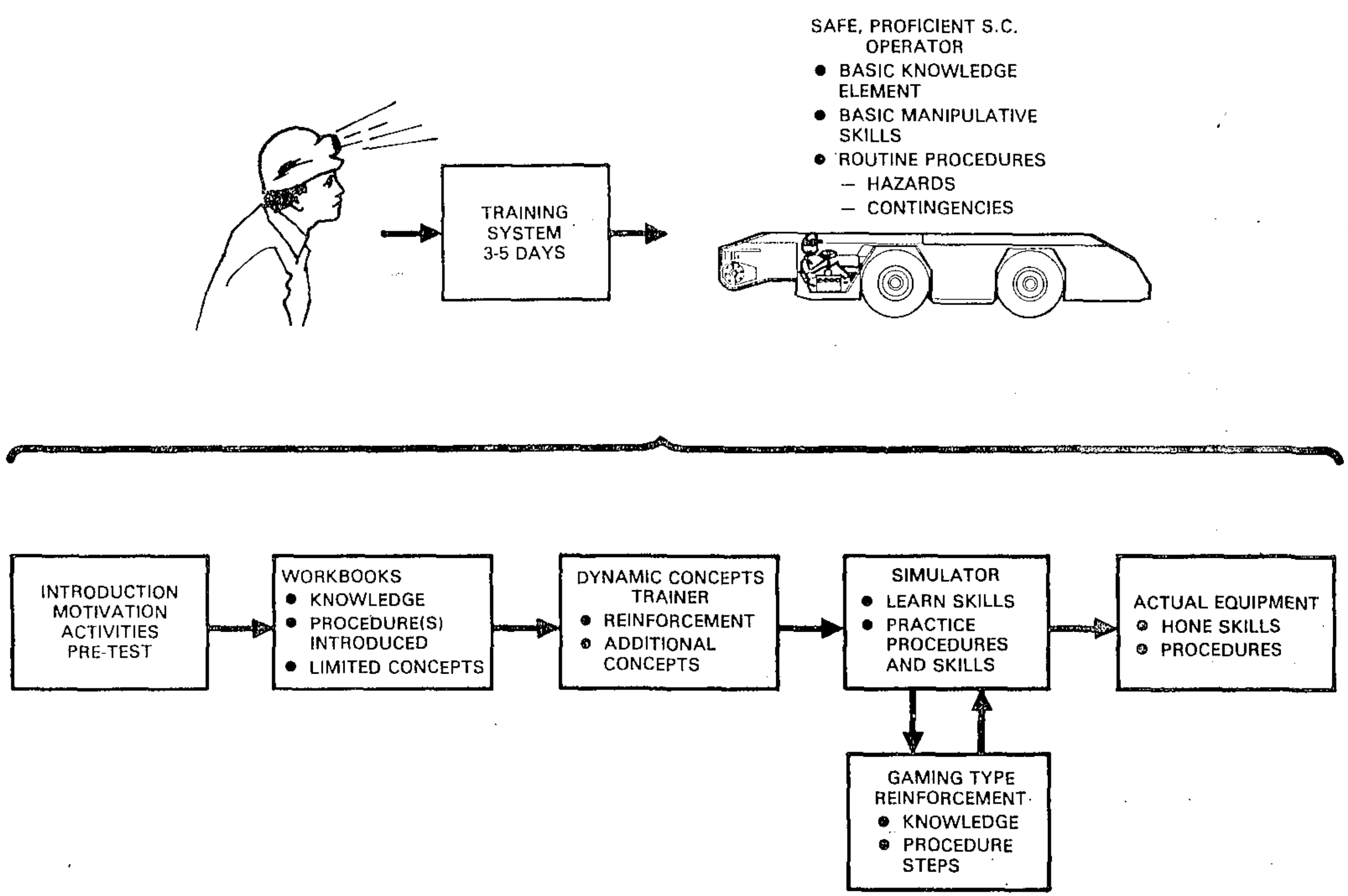


Figure 2: Training System Overview

3. During factory evaluation experienced shuttle car operators attested to the realism of the simulator, the ability to judge parallelism, the ability to initiate/recover from turns, and the picture quality/fidelity of the simulator.

4. The second generation prototype training system was produced. One element of this system is a smaller simulator which includes a low profile motion base.

5. As more operational use data is collected, the system may be shown to be cost effective to mine owners.

6. The following items were developed:

    a. Twenty-one procedures.

    b. Ninety-three training objectives.

    c. Cognitive activities including group and individual experiences, and reinforcement games.

    d. New Dynamic Concepts Trainer including new exercises.

    e. New Simulator (reaction trainer) including a new set of exercises and a demonstration program.

    f. Modified courseware.

Conclusions

The conclusions of the ORI's R&D effort, development phase, and production phase are:

1. A coal mine, mine machinery equipment, or ground vehicle simulator with the following salient features is technically feasible:

    a. Pseudo three-dimensional visual scene with adequate fidelity to learn, practice, and/or demonstrate precision maneuvering in, through, and around obstacles.

    b. Development, production, and yearly maintenance costs approximately one tenth the cost of comparable (fidelity) aerospace simulators.

    c. Rugged, reliable, easy to use, easy to maintain, and user friendly.

    d. Self administered learning with automatic remediation and positive reinforcement.

2. The training system may be shown to be economically feasible after operational use data is compiled.

3. The efficacy of the workbooks and DCT can be accurately estimated from professional knowledge and experience. Retention of knowledge by the trainers can be estimated but not as accurately. The efficacy of the simulator and simulator exercises as well as the estimated 6-8 hours of simulator time are professional estimates/opinions still to be verified. If this opinion is reasonably accurate, then, assuming some modification to the courseware will be warranted, the training objectives should be readily achievable.

4. The simulator has additional potential utilization in the following areas:

   a. Evaluation of work station designs

   b. Human factors design and evaluation

   c. Testing and licensing

   d. Surface mine vehicle operator training

The purposes of the program, to reduce the accident rate among new shuttle car operators, to produce an economically feasible training system, and the efficacy of the training system cannot be more fully assessed due to its current interim status.

Recommendations

ORI recommends that field tests, pilot classes and data analyses be conducted to:

1. Validate ability of graduates to satisfy Job Performance Requirements.

2. Compare accident rate (frequency and severity) of graduates with baseline accident rate (to be developed).

3. Identify specific changes or modifications which will enhance the training system.

4. Gather data to investigate the economic feasibility.

5. Gather hard long-term reliability data on hardware elements.

II. RESEARCH AND DEVELOPMENT

OVERVIEW

With reference to Figure 1, the program began with two concurrent tasks: a research task which addressed visual system/simulator fidelity and a development task which addressed training system and program of instruction design.

VISUAL SYSTEM/SIMULATOR FIDELITY RESEARCH

Learning to operate a shuttle car includes learning/developing psycho-motor, manipulative, and perceptual skills which can be learned, developed, and practiced only:

1. In the actual equipment in a real or high fidelity* simulated environment, or

2. In a high fidelity* simulator.

Previous contracts S0-334179 and H0242037 substantiated the economic and training benefits of a high fidelity simulator. However, a low cost simulator of requisite fidelity had never been developed.

The reaction trainer developed on contract H0242037 provided considerable insight into the development of a high fidelity simulator, but it was not of sufficient fidelity to develop manipulative skills. Further, the state-of-the-art in simulation at the onset of this contract did not include sufficient fidelity to develop manipulative skills involving the near field and far field simultaneously in an extremely wide angle (greater than 65°), dynamic situation involving a large vehicle passing within inches of fixed and moving objects. Additionally, at the onset of this contract cinematographic techniques had not been developed for dynamic, wide angle filming/projection underground (coal mines) relative to the requirements of the reaction trainer, or the envisioned simulator proposed for this contract. Likewise, corresponding staging, separation, and other techniques had not been previously developed.

Thus an extensive research effort was required to determine whether or not a high fidelity simulator would be technically and economically feasible, and if it appeared feasible, to develop:

*High fidelity is defined as a representation of the shuttle car and/or environment relative to the aggregate of skills and behaviors to be learned of such quality that the (coordinated) human senses cannot distinguish between the representation and the real world.

1. Simulation techniques

2. Filming techniques*

3. Staging, separation, and other techniques.

Also, utilization of the simulator, i.e., training system and program of instruction design/development, required a tabulation of capabilities and limitations plus a matrix of cost versus benefit(s).

The extensive research effort to accomplish these objectives is reported in detail in Appendix A.

TRAINING SYSTEM AND PROGRAM OF INSTRUCTION DEVELOPMENT

The objective of subject contract was to develop an operator training program which would train an experienced coal miner to operate a shuttle car proficiently and safely (i.e., satisfy the Job Performance Requirements as modified on this contract).

As depicted in Figure 3, developing the program of instruction (POI) began with verifying, and modifying as required, the job performance requirements (JPR's) developed on contract H0242037. Training objectives were then developed for each JPR. The training objectives were typically grouped and arranged in a hierarchy. Accomplishing the aggregrate of the training objectives necessarily resulted in the ability to satisfy the JPR's.

Next, the training objectives were sequenced based on difficulty, priority, importance, and prerequisite (hierarchical arrangement). Alternative methods and media were noted for accomplishing each training objective. Various training systems and POI's were configured from the noted method and media and tested for their ability to satisfy the sequenced training objectives. This process continued in an iterative fashion until an optimum training system was configured.

The corresponding POI and functional specifications for training devices were then prepared.

Job Performance Requirements

JPR's were Government Furnished Information (GFI) from contract H0242037. These JPR's were found to be slightly deficient, and were modified accordingly.

The GFI JPR's were reviewed with mine supervisory personnel, MSHA inspectors, and MSHA academy personnel for accuracy and thoroughness. Additionally, trained professional personnel conducted interviews with shuttle car operators, foremen, and superintendents to ascertain their perception of a shuttle car operator's job. The background and data provided with the GFI JPR's were studied as was the 1978 UMWA contract.

*Concurrent advances in holography, computer generated images, TV displays, and Link Division's (Singer, Co.) laser projector were considered as alternatives to the film-based simulator recommended by previous contracts.

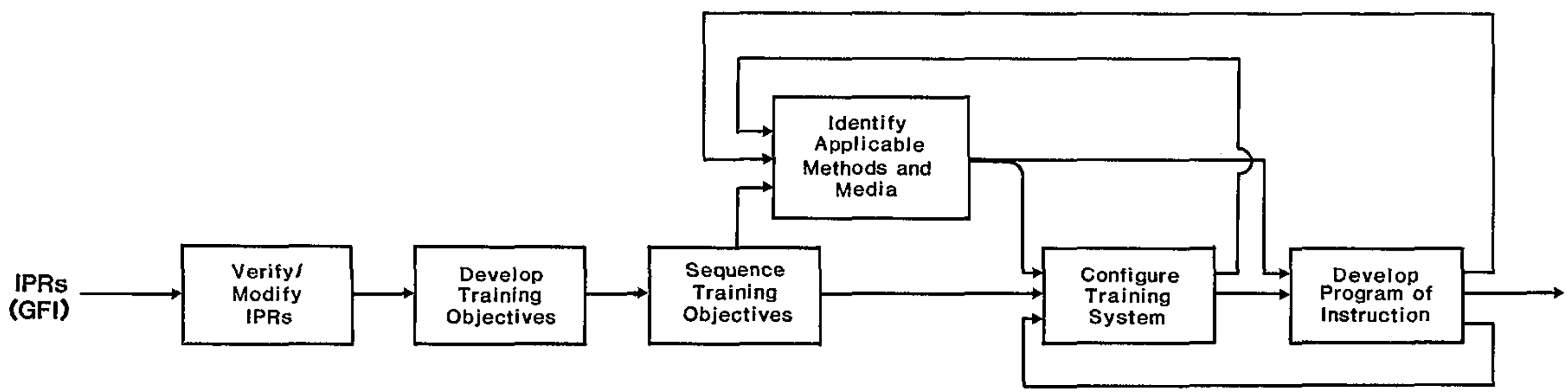


FIGURE 3: PROGRAM SEQUENCE FOR DEVELOPMENT OF TRAINING SYSTEM AND PROGRAM OF INSTRUCTION

The GFI JPR's were modified in accordance with the results of this study. The resultant JPR's were submitted to the USBM (TPO) in March, 1978. They are contained in Appendix B of this report for easy reference.

Training Objectives

Training objectives are concise statements of what a trainee must DO to demonstrate knowledge and skill related to the shuttle car and its environment. These are NOT teaching objectives (i.e., what an instructor will do), but rather the behaviors a trainee should be able to demonstrate as a result of completing the course. In developing the training objectives, emphasis was placed on the verb: describe vs demonstrate, state vs name vs identify, etc.

Training objectives were developed for each JPR. The training objectives were then compared, combined to eliminate redundanties, and arranged in a hierachy. The hierarchies focused directly on the main tasks and related subtasks of the JPR's. Hierarchical arrangements considered to be tangential to and supportive of other objectives were placed in a group termed "General Knowledge Requirements."

This effort resulted in 93 specific training objectives in seven hierarchical arrangements plus the General Knowledge Requirement. The number and content of objectives in each hierarchy, such as identify; name; match; describe; or demonstrate, typically vary among competent professionals. Nevertheless, the 93 objectives presented herein are believed to be a minimal set of training objectives which will enable a well structured POI leading to the ability to satisfy the JPR's. The 93 objectives and corresponding hierarchical arrangements are contained in Appendix C.

Training System and Program of Instruction

The training system and (POI) were derived and developed from the training objectives. In developing the training system, consideration was given to:

1. Experience gained in the prototype system.

2. Course design which would create a high degree of student interest and self motivation.

3. Student profile.

4. Instructor profile.

5. Probable facilities and equipment.

6. Various methods and media.

7. Content type (comic, graphical presentation, suspenseful dramatization, etc.).

8. Difficulty of learning (each objective) in terms of memory, conceptualization, and skill (coordination) development.

9. Priority or importance of each particular JPR.

10. Cost constraints and the ability of mine operators to integrate the training into their operations.

A discussion of the derivation and development of the training system and POI plus a description of the training system and POI are contained in Appendix D.

III. PRODUCTION

OVERVIEW

The training devices produced for this system are the simulator and dynamic concepts trainer. The media for this system include simulator films, simulator exercises, DCT exercises, workbooks, reinforcement activities, guides for group discussions, guides for instructor demonstrations, assessment, and actual equipment exercises.

SIMULATOR

As discussed in Appendix D, the simulator functional specifications, film scenarios, and exercises are in support of, and subordinate to, the program of instruction and the accomplishment of specific learning objectives. However, some compromises were necessary during the production phase to accommodate both filming limitations in the mine and hardware capabilities and limitations. These included limitations on scenarios involving other equipment, cables, roof bolts, and bottom conditions, and on automatic remediation imposed by available audio visual hardware.

Hardware

The simulator simulates shuttle car operation in a room and pillar section. As depicted in Figure 4, simulation, scoring, and executive functions are performed by the computer.

Once an exercise is initiated, the computer monitors the operator's or trainee actions (control position). The computer controls the visual system, motion system, sound system, and vibration system based on time and control position. These equations of motion have been developed to provide realistic high fidelity simulation of tramming in a room and pillar section.

The computer is also programmed to monitor and score the operator. At the discretion of the computer program, the operator may be remediated* and/or scored for the following:

Ribbing - Cockpit orientation is such that the shuttle car would hit the rib.

Parking - Failure to stop (and shutdown) in a safe parking area.

Shutdown - Failure to execute the shutdown procedure completely and properly within a prescribed period of time after stopping in a safe parking area.

Park Brake - Failure to set the park brake before exiting the shuttle car (to change seats).

Lights - Lights are not ON in the direction of travel.

*Remediation is discussed under "Exercises", p. 25.

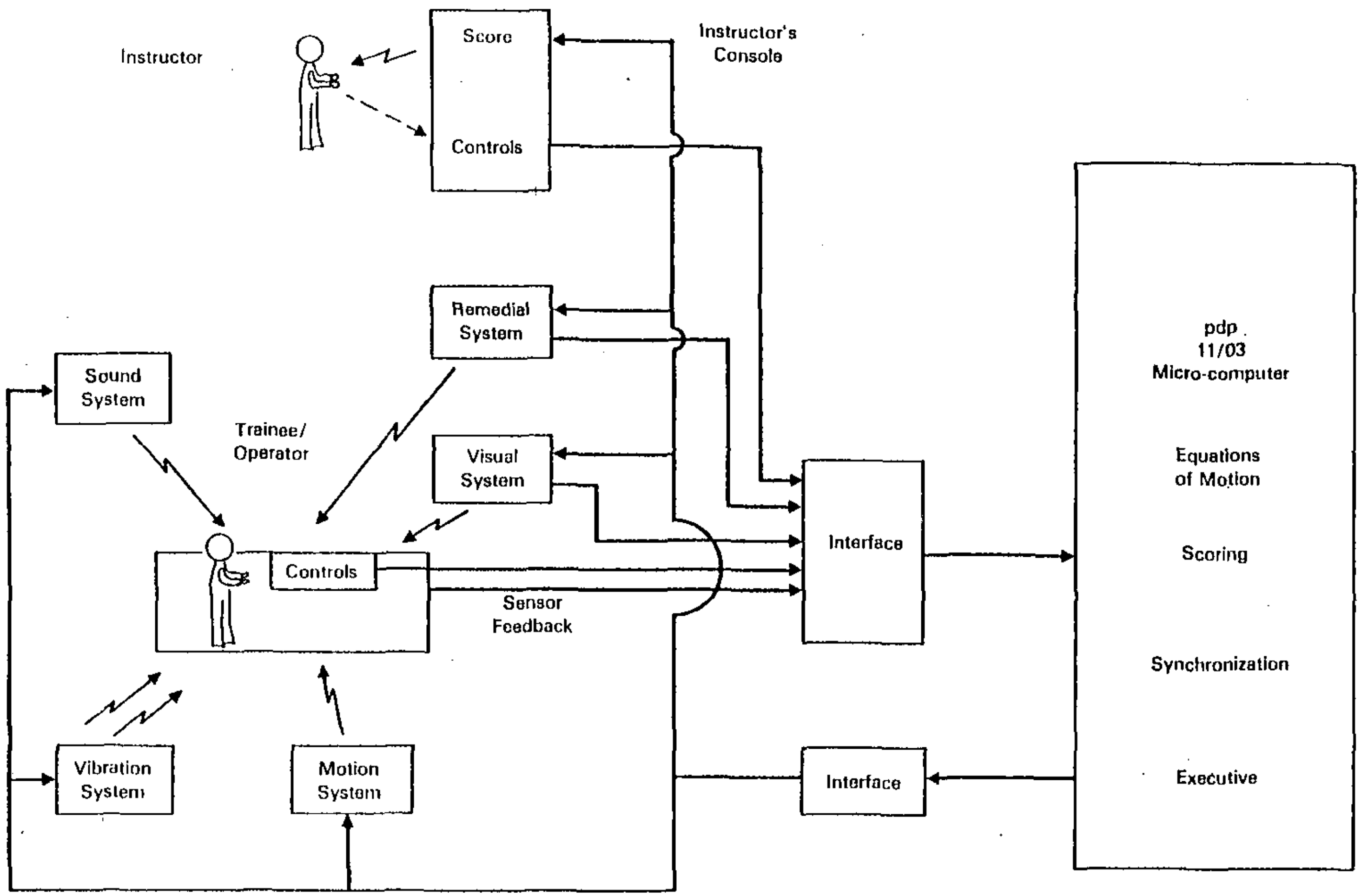


Figure 4: Simulator Functional Block Diagram

Bell - Failure to ring the bell.

Precision Steering -
Shuttle car position in the entry is not correct (for example, to go over a bridge).

Inappropriate Stop -
Operator stopped unnecessarily.

Contingencies (Fire, Roof Fall, Arcing Cable) -
Operator does/does not respond properly to contingency.

Hazards (Personnel, equipment, obstacles) -
Operator does/does not recognize and respond properly to hazard; operator fails to either correct the hazard (for example, remove debris) or wait for the hazard to be corrected (for example, personnel to move out of the way) as appropriate and in accordance with prescribed procedures.

Speed - Speed is inappropriate for conditions (for example, going through curtains, passing personnel, bad bottom, straight away, etc.)

Turns - Failure to negotiate/execute a turn.

Start-Up - Failure to execute the start-up procedure completely and properly.

End of Half Trip (Part of Loading/Dumping Procedure) -
Stopping distance is correct/incorrect at loading machine, dump point, etc.

The remediation system is a 150-channel audio tape unit (2 1/2 minute limit per channel) and random access slide projector (81 slide position/slides). This system can be programmed for audio only - continue, audio only - still frame, slide only, or sound-slide, as desired for each event.

Scoring consists of accumulating errors/correct responses by category (for example, Bell) for selected events. Remediation and scoring are independently programmable.

The simulator also contains an annunciator panel in the roof of the canopy. The annunciator panel provides positive reinforcement for correct responses, indicates a stalled condition, indicates a failure to set the park brake when not seated, and indicates proceed/don't proceed during certain portions of an exercise which may tend to be confusing to the operator. DON'T PROCEED, for example, is indicated during the introduction to an exercise or during focusing periods.

The simulator was designed to be rugged, reliable, relatively maintenance free, easy to use, and safe to operate.

Films

Films for the simulator were made at the Jenny mine, Auxier, Kentucky. Test films were generated in October 1978. Final films were made in December 1978, and January 1979.

Film Scenarios

An outline of requisite film scenarios was prepared compatible with the POI. Following an initial inspection trip to the mine, tentative scenarios were developed along with a tenative script of forty to fifty scenes which would be required to support the scenarios. Each scene was approximately one fourth trip; two scenes were required for each half trip (feeder to loader; loader to feeder). The juncture between scenes was a fake curtain near the mid point in the half trip.

A set of test films was then made to verify the viability of the scripts, to check timing relative to hazards, and to verify staging techniques and lighting.

After the test films wer reviewed and analyzed, the scripts were modified and 42 scenes/scripts were selected for final filming. Thirty-six of these 42 scenes were hazard scenes.

Filming

As discussed in Appendix A, lighting and staging techniques were developed and verified during the 1st, 2nd, and 3rd dynamic film tests. However, production (i.e., final filming) was to be accomplished at a third mine site and with a new filming crew. Therefore, the following events were completed as subtasks of the production filming task:

1. Initial inspection and planning.
2. Camera preparations, filming vehicle preparations, and filming crew rehersals.
3. Mine preparation.
4. Test film.
5. Mine preparation/modification.
6. Final filming (production films).

During the initial inspection it was determined that filming could be accomplished at the Jenny mine, that considerable staging would be required to accomplish the filming, that only one area was acceptable for filming, and that considerable preparation would be required to make this area acceptable for filming.

To facilitate panning as discussed in Appendix A, the camera eyepiece was opened and precision markings were added. Reddish-orange ribbons similar to those used by foreman were hung from the roof in a realistic setting but precisely placed for panning. Likewise, a seemingly random typical dirt smudge pattern was placed on the curtains; however, this pattern contained a number of precision markings for the cameraman.

In the Jenny mine, fifty to one hundred percent more light was required in each intersection than in the Bruceton mine (2nd and 3rd dynamic film tests)to obtain the requisite separation. This was due to the difference in physical size (20 ft. vs. 14 ft. entries). Also, it was discovered that a white, reflective rock dust would have to be located and selected from among the numerous variations in rock dust commonly used. Large quantities of burlap, black paint, white paint, rock dust, and coal dust were used in an artistic fashion to stage the films.

Considerable modification to staging and lighting was required between the test filming and final filming. Initial final films were verified within a few of days to prevent additional unacceptable filming in the event staging and lighting were still unsatisfactory.

ORI and the filming subcontractor, Kennedy-Lee, Inc., York, Pennsylvania, obtained 42 acceptable scenes. An additional four scenes which were simple turns were generated from these 42 scenes.

Exercises

Twelve film pairs were created from the 42 scenes. Each film contains 5 - 8 half trips; each film pair contains 5 - 7 complete trips. Six of the film pairs contain hazard scenes; six of the film pairs are intended for maneuvering skills and routine procedures only.

The second and third film pairs consist of turns only. There is a short straight away, the turn, and a short straight away. During factory evaluation tests, it was learned that a long straight away is required for the simulator to become oriented and aligned for a turn. Thus, film pairs two and three had to be refilmed or eliminated. Refilming could not be arranged, so they were eliminated. Film pairs four and five are used in their place for the turns module.

Each exercise is designed to teach the skills indicated in Appendices C and D, reinforce previously developed skills, and combine basic skills to form more complex skills. In addition to the film content, preprogrammed, automatic remediation is a major method of teaching. Remediation may be:

- A reminder (soft, gentle),
- Instructive (indicates the error, the consequences, and/or the correct method/procedure), or
- Punitive (punishes without alienating)

All three forms of remediation are used. Both the form of remediation and the remediation script (audio-visual presentation) were carefully selected and designed to accomplish the specific learning objectives for each exercise. Over one hundred and fifty remedial scripts were developed and programmed into the twelve exercises.

DYNAMIC CONCEPTS TRAINER (DCT)

As discussed in Appendix D, the DCT functional specifications and exercises are in support of, and subordinate to, the program of instruction and the accomplishment of specific learning objectives.

Hardware

The DCT consists of a scaled simulated working section, a scaled, unpowered steerable model, and miscellaneous ancillary pieces. In a cost-benefit trade-off analysis, it was decided (by USBM personnel) that the DCT would not include an operable conveyor in the model and the ancillary mechanisms to load and dump coal.

Construction details of the simulated working section include a wood base and fiberglass simulated ribs. The steerable model is the unpowered model supplied as GFE from contract H0242037 modified to include a canopy, fenders, and steering. Ancillary pieces (loading machine/continuous miner, miner, curtain, roof) were constructed primarily from wood. The dimensions of the simulated working section, including height above the floor, were human factor engineered for the 90th percentile.

Exercises

As the name implies, the primary function of the DCT is to teach concepts. From his involvement with the DCT, the trainee learns <u>why</u> certain procedures are the best or only workable procedure, and <u>why</u>, from a safety point of view, they should be followed. The DCT is an <u>interactive</u> device, the type of media coal miners appreciate and from which miners readily learn.

Ten DCT exercises were developed as indicated in Appendix D. The ten exercises generally support or help prepare the trainee for the imminent simulator exercise.

COGNITIVE ACTIVITIES

Cognitive activities, in support of the POI, training system, and class schedule, were designed to:

1. Introduce procedures, concepts, and knowledge elements.

2. Teach generic functions; teach the variations among shuttle cars and the impact of these variations on shuttle car operation.

3. Reinforce procedures and knowledge in a gaming environment.

4. Make productive use of the large amount of time each trainee spends waiting for his turn in the simulator.

5. Provide assessment and testing.

These cognitive activities include workbooks in programmed format, worksheets, and transparencies in gaming, problem solving, and quiz format, instructor demonstrations, structured informal group discussions, and group activities around the DCT and simulator which are not part of the DCT and simulator exercises. (Appendix D)

Testing combines written tests of knowledge and tests of skills.

ACTUAL EQUIPMENT EXERCISES

Actual equipment exercises were designed within the facility constraints discussed in Appendix D, and in accordance with the POI and training objectives. The actual equipment exercises consist of honing maneuvering skills: tramming straight, turning, and docking. Although an exercise for running coal is provided, little or no opportunity to run coal is expected in conjunction with actual equipment exercises.

Actual equipment exercises are executed under close supervision from the instructor. The trainee demonstrates the various skills in low tram before progressing to higher speeds. It is likely that some trainees will not progress to the higher speeds during these exercises.

INSTRUCTOR'S GUIDE

An Instructor's Guide was prepared following standard educational practices. The Instructor's Guide provides an explanation of the training system and POI, a description of the course and course elements, a discussion of each course element: what it is intended to accomplish and how it should be used, and a detailed class schedule including activities for trainee and instructor.

IV. COST-BENEFIT TRADE-OFF

OVERVIEW

Two cost-benefit analyses and trade-off studies were conducted: one to determine how to accomplish the objectives in the most cost effective manner, and one to determine if the benefit of accomplishing certain objectives warrants the cost of accomplishing that objective. This second set of cost-benefit analyses was conducted during the development and production phases to determine if certain objectives would be accomplished. The incremental cost of providing the functional capability (primarily in training devices) to achieve certain training objectives was weighed against the importance and criticality of these objectives. Major analyses resulting in either a compromise or a decision not to provide the requisite functional capability are discussed in this section.

LATERAL POSITION

The skills associated with tramming include positioning the shuttle car in the entry. This includes tramming in the center of an entry/cross cut, positioning for a turn, going over bridges, pulling under, positioning the boom with mine cars/feeders/conveyor belts, etc.

The simulator could be designed to include lateral position as part of the motion base. This would increase the cost of the simulator by tens of thousands of dollars, and the height by several inches. Without this feature, the simulator is always positioned correctly in the entry/cross cut.

Note: Because of the requisite screen geometry to judge parallelism as discussed in Appendix A, the picture cannot be moved on the screen to simulate position in the entry, except for docking when the simulated position is in an intersection and almost all of the visual information is directly ahead.

The decision to not include the ability to position the shuttle car (at a cost of tens of thousands of dollars) was based on the following rationale:

1. Trainees will become accustomed to proper visual cues because the cues are always where they should be in the trainer.
2. Positioning has little affect on teaching/learning parallelism.
3. The film content and simulator design can be such that docking and bridges are located in intersections and dead ahead, and the picture is positioned horizontally on the screen during these portions of the film.

HORIZONTAL FIELD OF VIEW

The desired horizontal field of view is 120-180 degrees in both directions. For a high fidelity diorama picture, 50-75 degrees is the maximum attainable per camera-projector. Therefore, to obtain the desired horizontal field of view, two or three synchronized (interlocked), edge matched camera (sets) and projector (sets) are required. The incremental cost of two or three cameras/projectors versus one camera/projector is tens of thousands of dollars, and the technical feasibility of acceptable edge matching is highly questionable.

Adequate fidelity was demonstrated via the mock-up to achieve the original program objectives relative to parallelism and turns with a single camera/projector and a compromise optical center of the field of view. Therefore, it was decided to develop the present system based on a single camera/projector. The validation study should include a determination of whether or not to pursue an increased horizontal field of view.

ROOF, FLOOR, AND DOCKING

The objectives of this program did not include a vertical field of view beyond that on the flat portion of the screeen in front of the shuttle car. With the radical improvement in fidelity between the prototype system (contract H0242037) and the dynamic film tests, it became obvious that the diorama concept should be extended to include the floor and roof, and that this would greatly improve the fidelity associated with docking and crossing bridges.

Provision of these features would require an R&D effort involving at least two test filming sessions plus potential refilming of the exercises. Due to cost and schedule impact, it was decided that this feature would not be provided pending the results of the validation study.

DCT: LOADING AND DUMPING

It is improbable that loading and dumping can be practiced during actual equipment exercises, and, as previously mentioned, this particular generation of the simulator will not include adequate fidelity to learn or practice the skills associated with loading and dumping. Therefore, the development of these skills must be accomplished on-the-job.

However, the burden of learning these skills on-the-job can be greatly reduced by expanding the DCT functional capability to include an operable conveyor in the model, simulated loading, and simulated dumping. The cost of adding this capability is several thousand dollars in development costs, and several hundred dollars in recurring costs. After reviewing the cost-benefit with USBM technical personnel, it was decided not to include this capability pending the results of the validation study.

V. ECONOMIC ANALYSIS

The economic acceptability of the training system is a function of investment magnitude, direct, immediate return on investment, indirect and future direct return on investment, and confidence in achieving expected return on investment. Confidence in achieving return on investment will necessarily follow validation studies and field experience.

The objectives of the program, a significant reduction in accident rate and severity, an improvement in the learning curve, and sufficient resulting increased revenues to more than pay the cost of training, are shown graphically in Figure 5. The estimated cost of training and increased revenues are:

Cost of Training

1. Purchase of Training System: $500,000		
÷ 5 yr. (amortization)	$100 K/yr	
2. Instructors, etc.	60	
3. Building, utilities, etc.	80	
4. Maintenance	7	
5. Expendables	3	
6. Fee, profit, etc.	30	
Total Cost	$280K/Yr.	
Per student cost @ 125 students/year		
(280,000 ÷ 125)	$2240	
Trainee Wages, etc.	450 - 500	
Total Cost Per Trainee		$2740

Incremental Revenues

Assumptions: 350 tons per section per shift.

$35 per ton at portal.

Two shuttle cars per section; one new operator and one experienced operator.

The difference in learning curves, Figure 5, results in a 10 percent increase in tonnage over the first 3 months - combined effect of one individual's productivity and his effect on the pace of the entire section.

During the first six months there will be, on the average of several graduates, a saving of one accident per section which would have resulted in a four hour work stoppage. (This may be the sum of several small accidents or one major accident.)

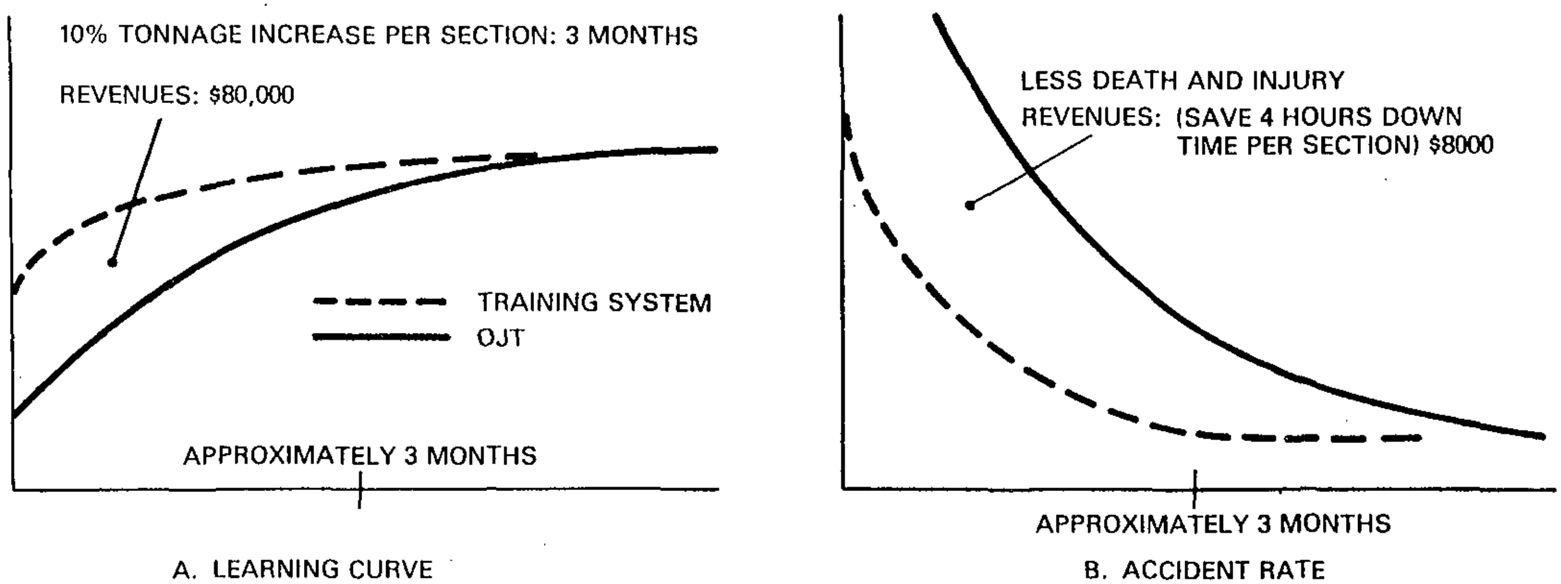


Figure 5: Anticipated Effect of Training On Learning Curve and On Accident Rate

1. Learning curve: 10% x 350 tons/shift

x 65 shifts (3 months) x $35/ton = $79,62
5

2. Reduced accident rate/severity: 350 tons/shift

x $35/ton = $12,250 revenue/shift . $12,250 revenue/shift ÷ 6 hours production/shift = $2,042 revenue per hour production.
$2,042 x 4 hours = $ 8,168

3. Total Increased Revenues $87,793

Alternative Analysis

If, because of this training program, six trips are completed for any reason - lack of accidents, reduced accident severity, learning curve, attitude, etc. - which would not have been completed otherwise, then the coal owner is slightly ahead financially. Beyond six incremental trips, the coal owner is substantially ahead. This conclusion is derived as follows:

Assumptions:
1. Cost of training is $2500 - $3000 as previously derived.
2. New shuttle car operator paces the section.
3. Payload is 7 tons per shuttle car.
4. Coal is valued at $35.00 per ton at the portal.
5. Each additional trip made by a new shuttle car operator represents two payloads. The new shuttle car operator is pacing the section and it is assumed there are two shuttle cars per section.

Dollar Value: 2 payloads x 7 tons/payload x 35 $/ton = $490 per additional trip
6 additional trips: $2940

VI. PROGRAM STATUS, CONCLUSIONS AND RECOMMENDATIONS

PROGRAM STATUS

The training system is in an interim status pending completion of arrangements for field testing within a voc-tech school frame work. The simulator and DCT have been shipped to USBM facilities for experimental and other non-training usage until arrangements for field testing are completed.

The training system design, the program of instruction, training device design, prototype training device manufacture, and prototype simulator films are complete. Courseware, workbooks, DCT exercises, simulator exercises including remediation, actual equipment exercises, reinforcement activities, trainee handouts, and Instructor's Guide, is in draft form. In accordance with an agreement between ORI, Wabash Community College, and USBM, Wabash and ORI personnel are to review and modify the courseware as appropriate prior to conducting pilot classes. The modified courseware are to be considered a final draft; courseware modified as a result of the pilot classes is to be considered the initial or preliminary prototype courseware.

The training devices were operated periodically at factory facilities during 1980-1982. The training devices proved to be extremely reliable in spite of a suspected lightning strike and discovery of minor latent design and manufacturing discrepancies.

CONCLUSIONS

The conclusions of the ORI's R&D effort, development phase, and production phase are:

1. A coal mine, mine machinery equipment, or ground vehicle simulator with the following salient features is technically feasible:

    a. Pseudo three-dimensional visual scene with adequate fidelity to learn, practice, and/or demonstrate precision maneuvering in, through, and around obstacles.

    b. Development, production, and yearly maintenance costs approximately one tenth the cost of comparable (fidelity) aerospace simulators.

    c. Rugged, reliable, easy to use, easy to maintain, and user friendly.

    d. Self administered learning with automatic remediation and positive reinforcement.

2. The training system is economically feasible.

3. The efficacy of the workbooks and DCT can be accurately estimated from professional knowledge and experience. Retention of knowledg by the trainers can be estimated but not as accurately. The efficacy of the simulator and simulator exercises as well as the estimated 6-8 hours of simulator time are professional estimates/opinions still to be verified. If this opinion is reasonably accurate, then, assuming some modification to the courseware will be warranted, the training objectives should be readily achievable.

4. The simulator has additional potential utilization in the following areas:

    a. Evaluation of work station designs

    b. Human factors design and evaluation

    c. Testing and licensing

    d. Surface mine vehicle operator training

The purposes of the program, to reduce the accident rate among new shuttle car operators, to produce an economically feasible training system, and the efficacy of the training system cannot be more fully assessed due to its current interim status.

RECOMMENDATIONS

ORI recommends that field tests, pilot classes and data analyses be conducted to:

1. Validate ability of graduates to satisfy Job Performance Requirements.

2. Compare accident rate (frequency and severity) of graduates with baseline accident rate (to be developed).

3. Identify specific changes or modifications which will enhanve the training system.

4. Gather data to substantiate claimed economic feasibility.

5. Gather hard long-term reliability data on hardware elements.

APPENDIX A

R&D EFFORT

OVERVIEW

The objectives of the visual system R&D effort were:

- o Determine optimum filming techniques and maximum attainable film quality level.
- o Determine optimum feasible staging techniques.
- o Determine optimum feasible screen material and geometry and projector lens for a diorama similar to the prototype system.
- o Determine feasibility of, and specifications for, planetarium type rib simulation.
- o Execute a cost-space-benefit trade-off analysis for less than optimal diorama and rib simulation. Select the final configuration based on this analysis.
- o Add manually operated yaw and lateral displacement to the final configuration. Establish the simulator fidelity level which will be achieved.

The reaction trainer films developed on previous USBM contract H0242037 were grossly underexposed when displayed on the large simulator screen; however, when the picture size on the screen was reduced by about 80 percent, exposure was barely adequate. Since these films were shot with the aperture wide open (on the order of f/2.8) and with the fastest (ASA rating) 16 mm film available, it was concluded that additional lighting would be required. Additionally, it was observed that a hand held camera appeared marginally acceptable. No other conclusions relative to filming techniques, diorama efficacy, etc. could be drawn from contract H0242037.

Thus, it was surmised that there were probably a large number of unforseeable problems, and that the lighting problem must be solved first. The program plan depicted in Figure A-1 was therefore adopted.

The static tests were designed to solve the lighting problem. Dynamic tests in conjunction with experimentation in a full scale mock-up were designed to evaluate test films and identify problems, and to analyze and develop solutions to problems. Because a large number of unforeseeable problems were anticipated, an unknown number of dynamic tests were also anticipated.

Four dynamic film tests were ultimately required to identify and solve the various problems. Thus, film testing and production involved the following filming sessions:

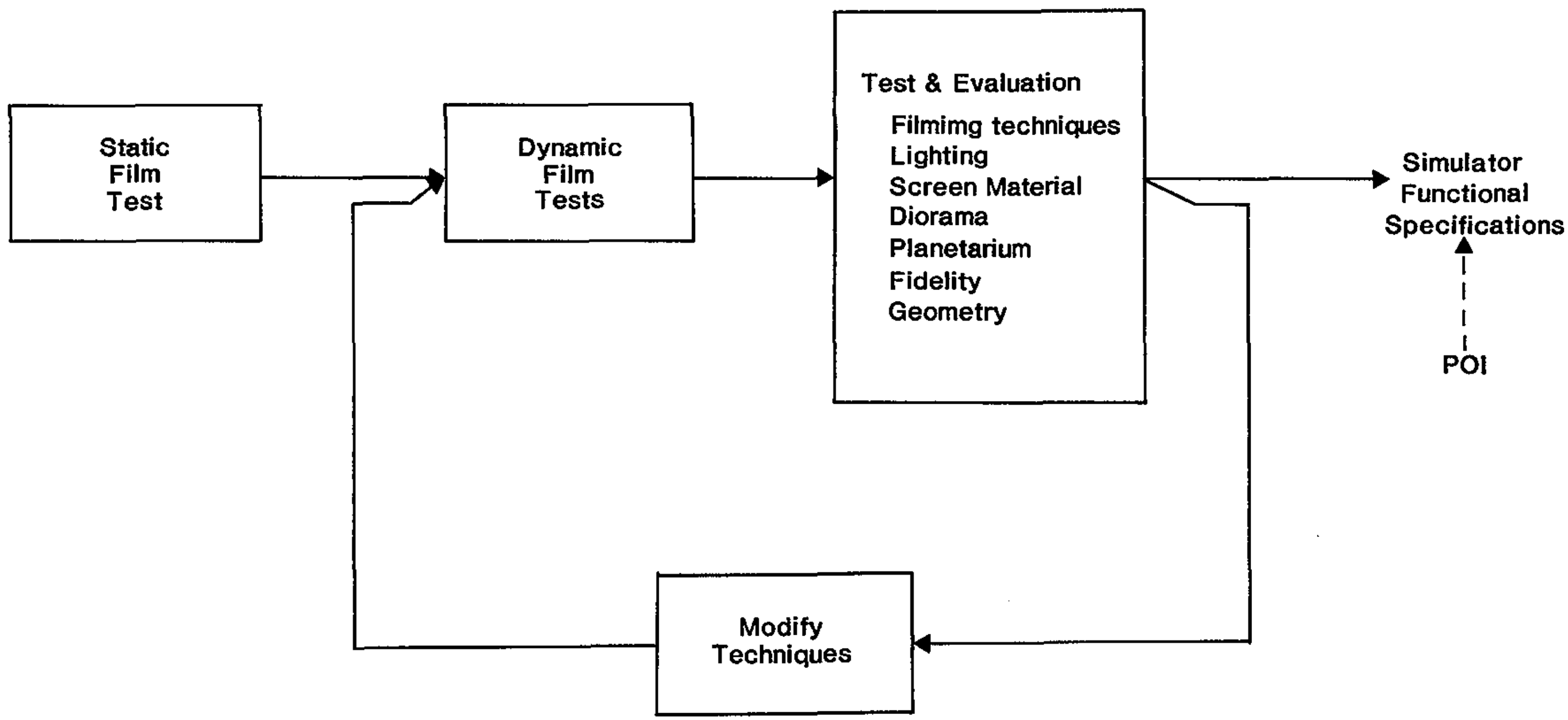


FIGURE A-1: VISUAL SYSTEM R & D

SESSION NO.	DATE	MINE	SESSION
1	Nov. 77	Island Creek No. 9	Static Film Test
2	Dec. 77	Island Creek No. 9	1st Dynamic Test
3	Feb. 78	Bruceton Research Mine	2nd Dynamic Test
4	May 78	Bruceton Research Mine	3rd Dynamic Test
5	Oct. 78	Jenny	4th Dynamic Test
6	Dec. 78 Jan. 79	Jenny	Final Footage

Following each filming session, experiments were conducted to determine and refine screen material, total visual system geometry, and filming techniques.

STATIC FILM TESTS

Purpose

The purpose of this task was to determine the lighting arrangement, film type, and camera settings which would be used for filming in motion underground. Thus the essence of this task was to shoot a number of test shots in a realistic underground setting. Motion during these tests was considered an unnecessary expense. The test film was to be projected onto a full scale rear projection screen for analysis.

Test Set-Up and Conditions

Test were conducted in the number 3 unit, Island Creek No. 9 mine, in the intake entries of a working section as depicted in Figures A-2 and A-3. Tests were conducted with the camera in the four locations shown in Figure 5. A variety of lighting arrangements were tested includeding up to 2000w located at the camera with and without cross lighting in the cross cuts. A reflective, silver check curtain as indicated in Figure A-3 was used in some tests to determine its effect on final quality.

Tests were conducted with Kodak 7247 negative stock, 7242 reversal stock, and commercial Ektachrome (ASA 25). Test were conducted with a 12 mm and 10 mm lens using an Eclair camera. Most of the tests were conducted with an f/2.8 setting; however, some test were conducted with an f/4, f/5.6, and f/8 setting. Various natural objects and special objects as noted on Figure A-3 were located for future analysis.

Test Summary

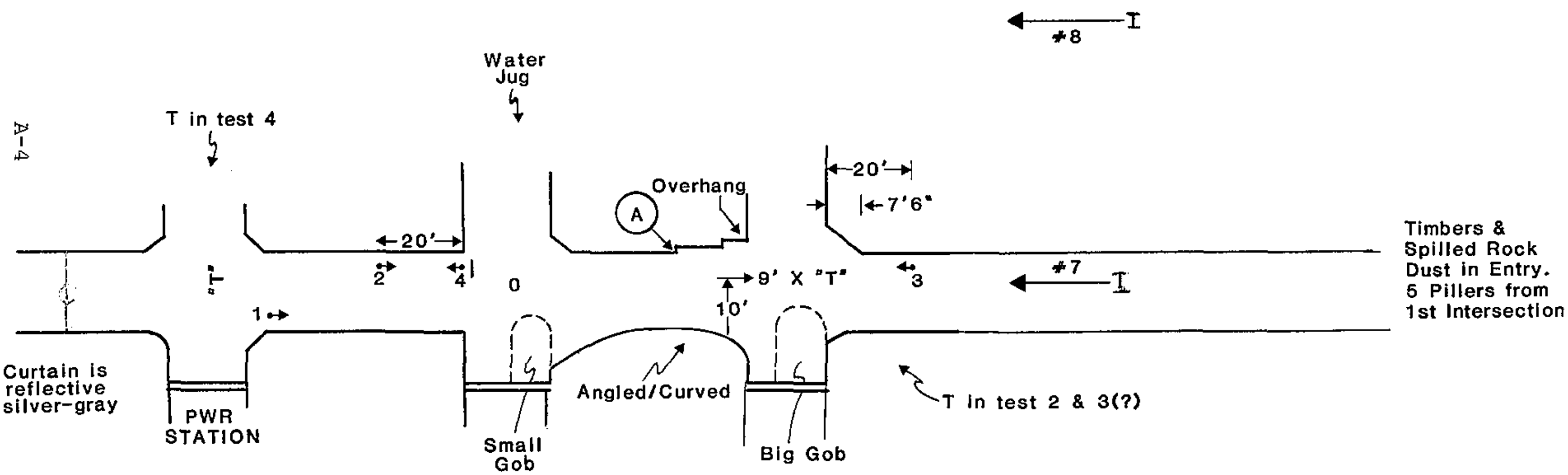
Table A-1 summarizes the results of the static film tests. The resultant picture quality and lighting were not adequate to accomplish the program objectives. However, it was obvious that the requisite quality could be achieved if a large number of lights could be placed along the filming route such that streaking, flair, shadows, etc. could be avoided, and the lights could be hidden from view.

Location 1: Corners on R hard to see.
Note overhang-2nd intersection on L
Corners by Gob at 2nd Int. on R
almost impossible to see.

Location 2- 2nd Intersection on L almost impossible to see-
Look for 1 3' up on far corner.
Can see A.

Location 3: Highly visible
Location 4: Highly visible

(not to scale)



Camera~3'6" from rib.
SEAM HEIGHT:~41/2'

Figure A-2: STATIC FILM TESTS:ISLAND CREEK NO. 9 NO. 3 UNIT:11-2-77

STATIC FILM TESTS

ISLAND CREEK NO. 9

NO. 3 Unit

11-2-77

Power obtained
from Transformer.
Power Cables passed
over opening along top
of permanent stoppage.

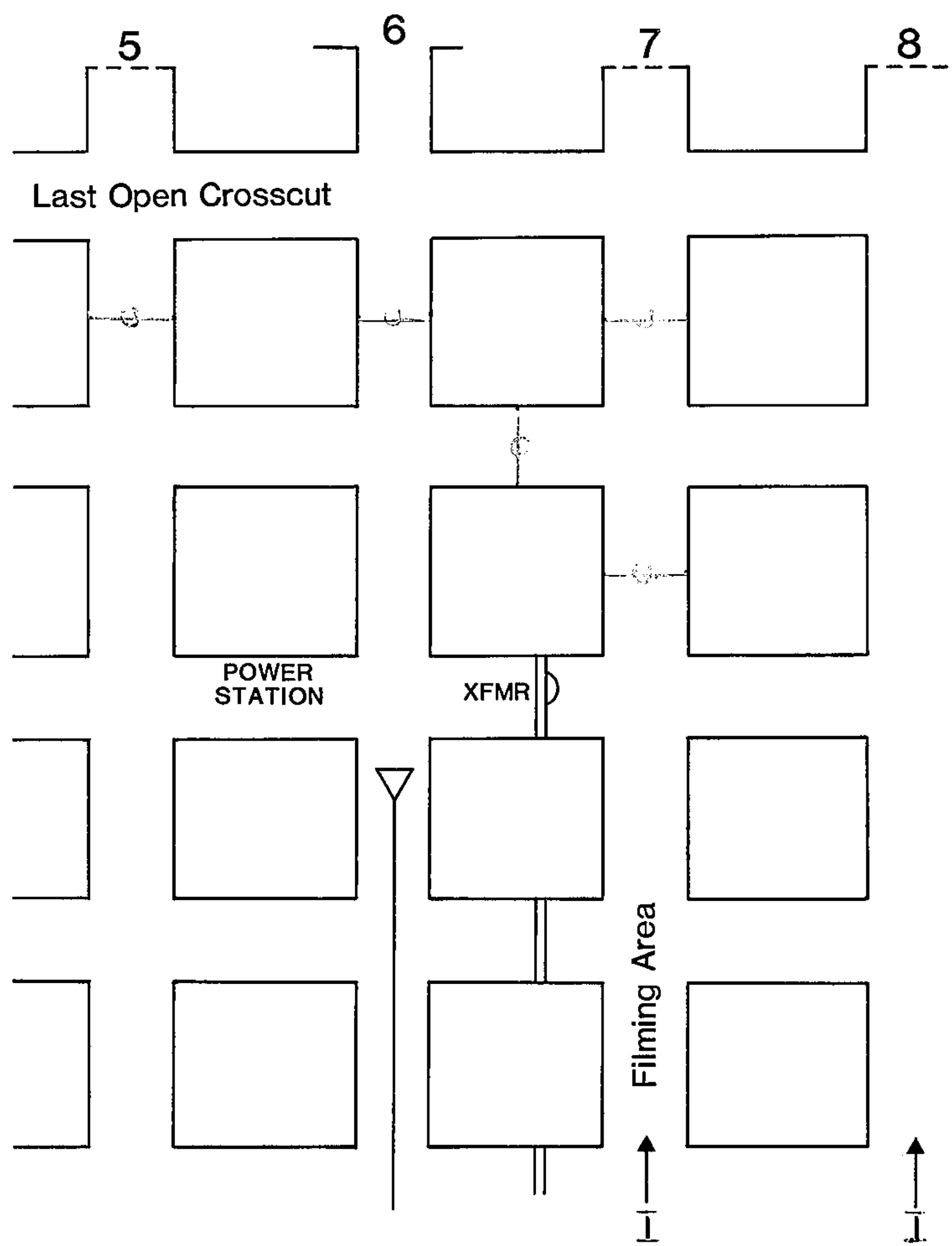


FIGURE A-3: TEST SITE FOR STATIC FILM TESTS AND DYNAMIC FILM TEST NO. 1

TABLE A-1: STATIC FILM TEST SUMMARY

OBJECTIVE	RESULT- CONCLUSION - RECOMMENDATION
Determine Film Type	Kodak 7427 Negative Film Stock - Normal Processing.
Determine Camera	Eclair
Determine Lens	Inconclusive: A 60° horizontal field of view (H-fov) is required. Tests were conducted with a 10mm and 12mm lens. The picture quality was satisfactory with both lenses, but the H-fov of the 10mm lens is only 50°.
Determine Camera Settings	f/2.8. To improve the depth of field, more lighting and a higher f/stop may be desirable.
Determine Optimum Lighting Arrangement	Inconclusive: Additional testing is required. This testing will be integrated with the dynamic film tests.

1st DYNAMIC FILM TEST

Purpose

The purpose of this task was to determine a feasible method for staging the simulator films, to generate a test film for the simulator mock-up, to conduct additional lighting tests, and to test additional film stock.

Test Set-Up and Conditions

Tests were conducted in the number 3 unit, Island Creek No. 9 mine in the normal working area. The test films were made a few days after the onset of the UMWA strike in December, 1977. Thus the area was relatively dust free and reasonably well rock dusted.

Figure A-4 depicts the filming route. Filming runs started and ended at check curtains, the loading machine, or the dump point. Segments ending/starting at check curtains could be spliced together for a complete run.

Lighting consisted of two (2) 1000 W lamps mounted on the filming vehicle plus 500 W lamps located along the filming vehicle path. A typical placement of these 500 W lamps for one segment is shown in Figure A-4.

The filming vehicle was a Jeep. The camera man sat slouched in the front of the Jeep. Tests were made with the camera three to five feet from the rib and with the camera in the center of the entry. The camera was twelve to eighteen inches from the roof.

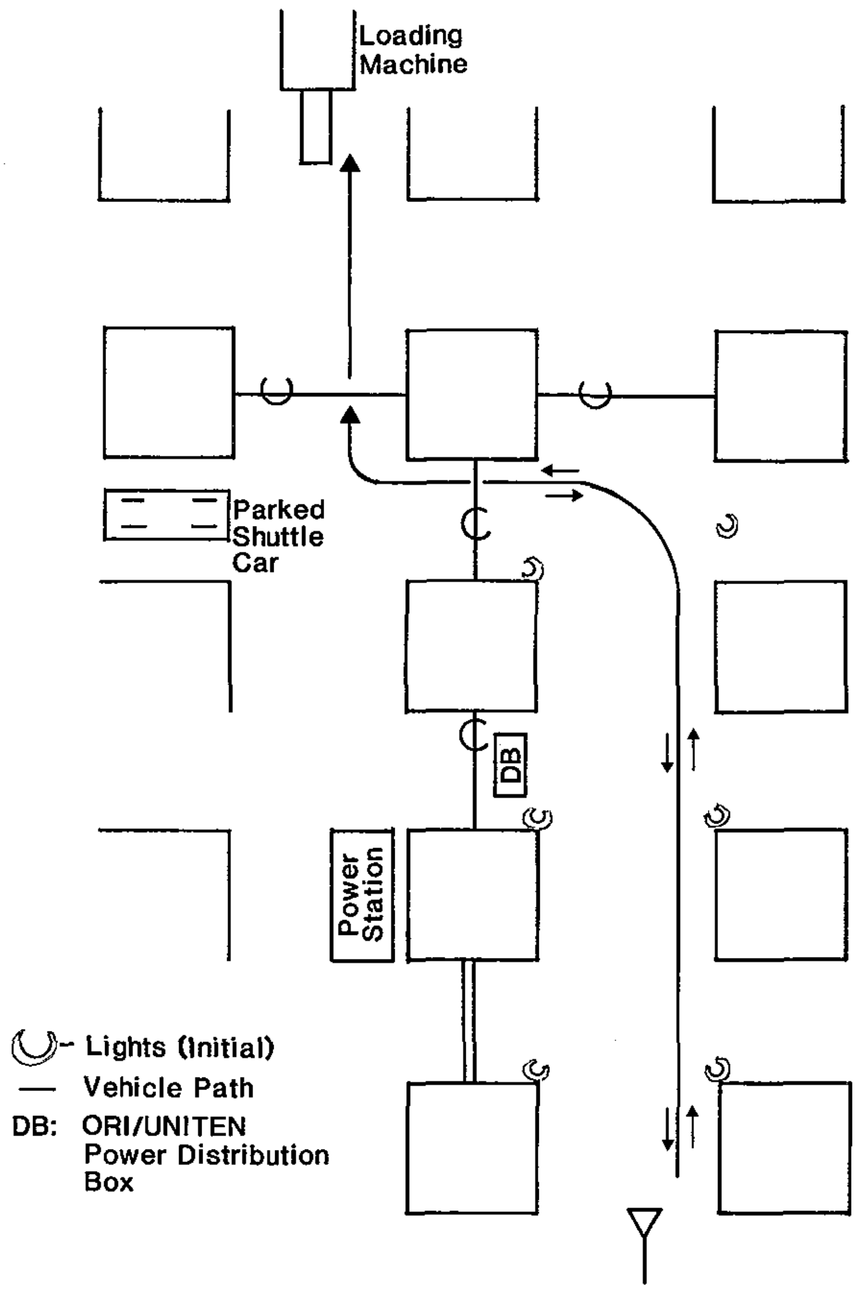


FIGURE A-4: DYNAMIC FILM TEST NO. 1

Flat orange, green, and brown material was used for check curtains. Various objects were placed in the entry and hung from the roof during different runs. These objects were selected on the basis of contrast and reflectivity. A parked, loaded shuttle car positioned as if waiting for the simulated shuttle car was also included in the test films.

Tests were conducted with Kodak 7247 negative film stock and 7242 reversal film stock.

Test Summary

The results of these tests were mixed. The objectives were accomplished and new unforseen problems became apparent. Specifically:

Lighting

The lighting was adequate to determine position in the entry, to see objects, to see tire tracks clearly and realistically, and to see one half pillar beyond the last set of lights. Intersections were not easily distinguishable and corners could not be distinguished even when near by. Also the inability to see further proved objectionable. Unnatural shadows caused by the placement of the lights were also observed.

It was concluded that adequate lighting without objectionable shadows could be obtained by placing lights along and beyond the filming path, that the amount of light would have to be doubled or quadrupled, and, due to almost nonexistent contrast, that techniques used by commercial entertainment film producers would be required to separate corners and intersections.

Curtains

Brown and green curtains were of too low a contrast. The orange curtain was excellent. It could be seen from a distance and it looks natural. There is no wash out as the filming vehicle with all of its light approaches the curtain. Thus a flat orange material was selected for staging check curtains.

Film Stock

Kodak 7427 negative Film stock was reconfirmed as both satisfactory and the best choice.

Filming Vehicle

The speed, inability to control speed, change in speed with battery drain and bottom conditions, cramped space for the camerman, and lack of maneuverability made the Jeep totally unacceptable as a filming vehicle. Additionally, the backwash problem and solution*, placed added demands on the filming vehicle for camerman mobility and vehicle maneuverability.

It was therefore concluded that the vehicle must satisfy the following requirements:

* Ref. Turns, p. A-9 and p. A-18

1. Low profile

2. Ability to travel at and maintain 2.67 MPH

3. Ability to maneuver so that the camera will follow the trajectory delineated on page A-18, and to maintain a straight trajectory with the camera 3-4 feet from the rib.

4. Comfortable seating for the cameraman which will allow him to rotate his torso consistent with the requirements indicated on page A-18.

5. Ability to mount requisite lights and to drag the resulting cable.

A modified golf cart was the only battery powered vehicle identified which satisfied these requirements; therefore it was concluded that such a golf cart would be required for future filming.

Loading Machine: Pulling Under

In the test films, pulling under was excellent in every respect. The loader boom did not flare, the loader-operator come-on signal was realistic, the loader cable was realistic, etc. Therefore, it was concluded that an actual loading machine or continuous miner should be used for the final films.

Dump Point

The dump point was marginally acceptable. In spite of added rock dust, the dump point lacked sufficient contrast to appear totally realistic and to provide high quality training. Therefore, it was concluded that Hollywood techniques would be required to stage an acceptable dump point.

Turns

The camera followed an approximate arc whose radius approximated the turning radius of a shuttle car (12 foot). The camera was pointed approximately tangent to the arc during the turn. The result, especially when viewed in the context of a diorama, was a totally unexpected and unacceptable backwash. This problem and solution are discussed on page A-18.

Test Film

An acceptable test film for simulator mock-up tests and visual system R&D was generated. The use of this film is discussed on page A-15.

Objects and Hazards

The ability to stage hazards involving personnel, equipment, and objects was verified. Techniques relative to contrast and timing were developed and verified.

Rock Dust

During the several days of filming, deterioration in rock dust reflectivity due to water seepage adversely affected the film quality. It was noted that extreme precautions would be required to maintain a consistent level of rock dusting throughout filming.

2nd and 3rd DYNAMIC FILM TEST

Purpose

Upon completion of the 1st Dynamic film test and evaluation in the mock up, several items were hypothesized but not proven. In addition to the final expected fidelity, these included techniques for eliminating backwash during turns and providing adequate fidelity in turns, lighting, separation, and selection of filming vehicle. Two filming tests were conducted, February, 1978, and May, 1978, to verify and refine the hypothesized solution and fidelity. The first test focused primarily on filming vehicle selection, techniques for obtaining adequate fidelity in turns, and evaluation of additional film stock. The second test was designed to verify that totally acceptable films could be produced and acceptable simulator fidelity could be obtained.

Test Set-Up and Conditions

Tests were conducted at the USBM research mine, Bruceton, Pennsylvania. The first test was conducted with the mine "as is" and with a lighting system similar to the lighting system employed for the 1st dynamic film test.

The second test was conducted with a new lighting system and a staged mine. A 25,000 watt lighting system was designed and produced. This 25,000 watts of lights could be distributed as desired throughout the filming area and on the filming vehicle. The extremely chamfered almost trapezoidal pillars were made to look realistically square/rounded/chamfered by adding specially textured burlap. The bottom was smoothed, puddles were eliminated, and excessive seepage was drained away from the filming path.

Both tests were conducted using a USBM Cushman golf cart as the filming vehicle. The camera trajectory, in accordance with the discussion on page A-18, was marked on the roof. A talented vehicle driver was selected and instructed to maintain a constant speed of two and two-thirds miles per hour and to maneuver such as to keep the camera directly under the roof markings at all times.

To generate proper panning, an eyepiece with numerous permanent markings was located. Test footage with the camera both straight and skewed was shot in a hallway with proper geometry. Objects in the hallway were aligned with the eyepiece markings and noted. This test footage was displayed in the simulator mock-up, and the preferable eyepiece markings for panning were selected. Thus, during filming, the camera was made to follow the trajectory and maintain the orientation dictated on page A-18.

During the second test two or three (as required) 1000W and/or 500W lights were placed in each intersection such as to provide contrast for corners and sufficient light for that intersection and the following pillar. Additional lights were placed along long pillars. Entries and crosscuts were illuminated as much as two hundred feet beyond the filming path. Four lamps totaling 3000W of light were mounted on the filming vehicle.

Kodak 7250, 7242, and 7247 film stock was tested.

Conclusions

From the aggregrate results of the 1st and 3rd dynamic film tests and experimentation in the simulator mock-up it ma be concluded that:

1. High fidelity simulation with high fidelity film is feasible and practical.

2. All details of the screen geometry, camera trajectory, camera pan, mine geometry, cockpit rotation geometry, and location of the picture on the screen are highly interrelated and extremely critical. The slighest deviation in any of these elements may result in unrealistic simulation, backwash, etc.

3. The staging techniques developed during the tests are essential for contrast, separation, timing of hazards (personnel and equipment), realism, and faithful generation of visual cues.

4. The USBM research mine, Bruceton, is not acceptable for generating simulation films because the entries are too narrow and inconsistent, the experimental material on the ribs is unrealistic, the roof is too high and unrealistic, excessive seepage fouls staging, and a reasonable route for training films could not be developed.

VISUAL SYSTEM MOCK-UP

Purpose

The purpose of the visual system mock-up was to conduct R&D studies which pertain to the ability to judge parallelism, initiate turns, and execute turns; to test the planetarium concept, and to demonstrate satisfactory visual system fidelity as prerequisite to completing the program. The mock-up was also used to evaluate test films, as a vehicle to help resolve the backwash problem uncovered during filming tests, and to refine the extremely critical visual system geometry. Various screen materials were tested in the mock-up to achieve a balance between screen gain, projection angles, and viewing angles. Finally, the mock-up was available to facilitate the cost benefit trade-off analysis discussed in Section IV of this report.

Description of Mock-Up

The visual system mock-up consisted of a cockpit, projection system, screen frame/screen, and roof.

Cockpit

The cockpit consisted of the operator's pit and shell-in-perspective from contract H0242037 (furnished as GFE) mounted on a base. The base was mounted on casters and anchored to a pivot point that the entire assembly could be manually rotated. The pivot point was selectable and changeable.

Projection System

The projection system was a standard 16 mm projector, a commerical continuous loop mechanism for long continuous loops, a specially designed continuous loop mechanism for short loops, and a variety of lenses including a zoom lens. The projector, etc., was placed on a table with casters that it could be easily positioned in any desired location.

Screen Frame/Screen

A structure was developed which permitted various flexible materials to be mounted via VELCRO. The angle of the diorama was easily and continuously variable, the radius of curvature could be easily changed, the width could be easily changed, and the relative position between the cockpit and screen could be easily changed. The structure was designed to accommodate semi-flexible material such as eighth inch plexiglass.

Roof

A home and office type suspended ceiling (2X4 tiles) was fabricated. White tiles covered with a thin coat of black paint provided a realistic roof effect.

Parallelism

Figure A-5 illustrates the general diorama geometry carried over from contract H0242037. Utilizing first the films generated in dynamic film test number one and later the films generated in dynamic test number three, dynamic, subjective tests were conducted as follows:

> Parallelism was subjectively judged by two (preliminary tests) and six (final tests) individuals who had operated shuttle cars in mines. One of the individuals was an accomplished industrial designer hired as a consultant to this job. Different combinations of screen angles, radii of curvature, projection angles, camera angles, projection throw distances, and relative location between cockpit and screen were tested.
>
> Parallelism was measured by measuring the amount of cockpit rotation required for the operator to preceive he was no longer parallel. The ability of the operator to perceive a lack of parallelism with less than three degrees of cockpit rotation was tentatively considered prerequisite for training (subject to later validation studies). The results of the subjective tests were:
>
> 1. A 15^{o} screen angle is the only angle which provides the desired three-dimensional effect.

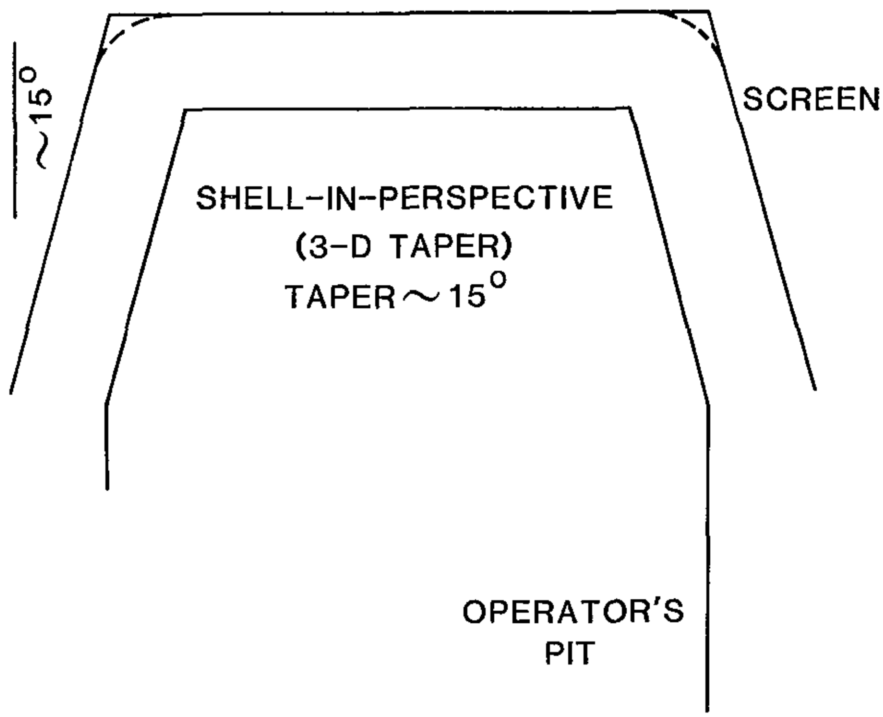


FIGURE A-5: GENERAL GEOMETRY OF DIORAMA

2. The closer the proximity of the cockpit to the screen, the greater the fidelity relative to parallelism. Fidelity is still good when the cockpit is three feet from the screen (side).

3. A curvature in the screen as opposed to a 15^{o} butt angle is preferable only in so far as it prevents a visible seam in the screen itself.

4. A forty foot throw distance in the inby direction provides the minimum acceptable depth of field. A sixty foot or greater throw is preferred. A twenty foot throw distance is the minimum acceptable outby.

5. Camera angle and projection angle have only a minute effect on parallelism in that the near side can be favored with a corresponding loss on the far side.

6. With the foregoing screen angle, proximity, and throw distance, lack of parallelism was readily perceived at a three degree (approximately) angle by the subjects tested.

Screen Material and Illumination

During evaluation of the test films, it was observed that the maximum attainable exposure when projected at standard illumination values (300-500 lumens through the lens) produced a marginally acceptable picture in terms of brightness level (3-5 ft. candles). Therefore, a screen material had to be selected which will transmit as much light to the trainee operator as possible as evenly as possible at all angles, and which can be economically produced in the desired "U" shape in small quantities. Rear projection screens typically have gains ranging from one (1) to ten (10) with gains as high as twenty (20) available on special order. Because of the extreme projection and viewing angles, a fresnel lens was considered in conjunction with the screen, and a Freen screen was investigated.

With reference to Figure A-5 and throw distances, projection angles in the inby direction range from 90^{o} to less than 10^{o}. The viewing angle ranges from 90^{o} to approximately 50^{o}. Therefore, screen gains greater than one (1) cause a darkening effect along the nearby ribs. Since a screen gain greater than one (1) is desired, techniques which would enable higher screen gains were sought. It was observed that when extra light added on the filming vehicle and aimed at the nearby ribs produced brighter nearby ribs on a flat screen, and could be made to produce equally bright ribs on the slanted diorama screen. The exposure of nearby ribs was/is substantially greater than were distant ribs. Through trial and error, a lighting arrangement was found whereby screens with a gain on the order of 1.7 to 2.1 yielded a flat picture (no perceptual variation in brightness level) for projector throw distances on the order of 60-80 feet (inby direction). This also produced an acceptably bright picture with standard projector illumination.

Thus, an acceptable and realistic picture was obtained using standard items via lighting techniques. This compared to the alternatives of a large, specially designed fresnel lens which would cost tens of thousands of dollars, and/or a xenon arc lamp projector which would cost several thousand dollars. A Freen screen was investigated and found technically not feasible because of the curvature in the screen.

The choices of substrates for the screen included glass and plexiglass of various thicknesses, and mylar. To avoid special forming, etc., a mylar substrate was choosen.

Suprisingly, an extreme variation in resolution and contrast (picture sharpness) and color distortion was observed among various manufacturers (screen gain 1.7 to 2.1; mylar substrate). Therefore, it is essential at the time of purchase to evaluate each vendor and select that vendor whose screen transmits the clearest, sharpest, truest color picture. (Specifications pertaining to resolution, contrast, distortion, and spectral transmission were not developed.)

Fidelity In Turns

The orginal objectives of this contract relative to fidelity in turns were to provide sufficient fidelity:

1. To judge the shuttle car position at any intersection required to accurately initiate a turn;

2. To judge when a turn is almost completed worder to straighten the shuttle car; and

3. To assure that the lack of fidelity during a turn does not have any negative training effects.

Initiating A Turn

The critical visual cues to cause the trainee to initiate a turn involve:

1. Ability to judge and position the shuttle car at a slight angle to the rib and about three feet from the rib as the shuttle car approaches the intersection.

2. Ability to judge when the left/right front wheel is adjacent to the corner.

Shuttle Car Position

The requisite "slight angle" can be judged compatible with judging parallelism. The distance from the rib can be simulated compatible with the "U" shaped screen only by a lateral displacement motion base. In the cost-benefit trade-off analysis, the operator's position will be fixed three feet from the rib.

Front Wheel Location - Inby

During evaluation of the dynamic test films, it was demonstrated via subjective tests that the position of either front wheel with respect to the corner could be accurately judged in the diorama. However, an approximate 100^{o} field of view (FOV) is required to simulate the relative location of both front wheels with respect to the rib/corner. Approximately 75^{o} is the maximum attainable FOV with a single projector/camera using rear projection techniques. In the cost benefit trade off analysis, page 79, a single projector/camera was choosen. The simulator in accordance with the trade-off, was designed so that the FOV is as illustrated in Figure A-6.

Front Wheel Location - Outby

Utilizing 35 mm slides to extend the picture created by the dynamic test films, it was demonstrated via subjective tests that the position of the operators pit and near side front wheel could be accurately judged in the diorama. However, the FOV from the loaded coal to the rib just behind the wheel is $130\text{-}150^{o}$. Similar to the inby direction, a single camera/projector was selected in the cost benefit trade off analysis with the FOV shown in Figure 8. This compromise FOV enables the operator to extropolate his position in an intersection and, from that judgement, initiate his turn.

Completing A Turn - Inby

Locating the shuttle car 3 feet from the rib with a 15^{o} screen angle as discussed previously places a mechanical cockpit rotation limit on the simulator of approximately $\pm 30^{o}$. Thus, just before completion of a turn, the cockpit is rotated 30^{o} and the shuttle car appears perfectly parallel in the new entry. At this point in the film, the camera pan angle must be equal to the skew angle minus the projection angle plus 30^{o} (or whatever the physical rotation limit is) minus the tangent of the trajectory. The camera must then pan at an angular velocity compatible with actual shuttle car rotational velocity corresponding to a shuttle car speed of "x" MPH, minus the trajectory tangent, while the camera proceeds along the trajectory at "x" MPH. ("X" was choosen as previously noted as 2 2/3 MPH.) The pan stops when the camera angle equals the skew angle.

If the operator straightens his wheels, the rotational velocity of the cockpit will correspond to the movement of the picture on the screen and the shuttle car will appear parallel to the new rib. Any deviation in this rotation will appear, instantaneously, as a lack of parallelism in a direction corresponding to incorrect (too soon; too late) recovery from the turn.

To accomplish this difficult panning maneuver, simultaneous multiple reference points corresponding to markings in the camera eyepiece were laid out. The cameraman, by maintaining proper alignment of these markings and transistion from one set to the next, would automatically generate a precision pan. Any deviation in this pan or in the projection alignment causes backwash as the trajectory becomes straight.

Completing A Turn - Outby

The physics of inby and outby turns are identical. However, the FOV Figure A-6 is such that just before completion of a turn there is very little visibility of the new entry.

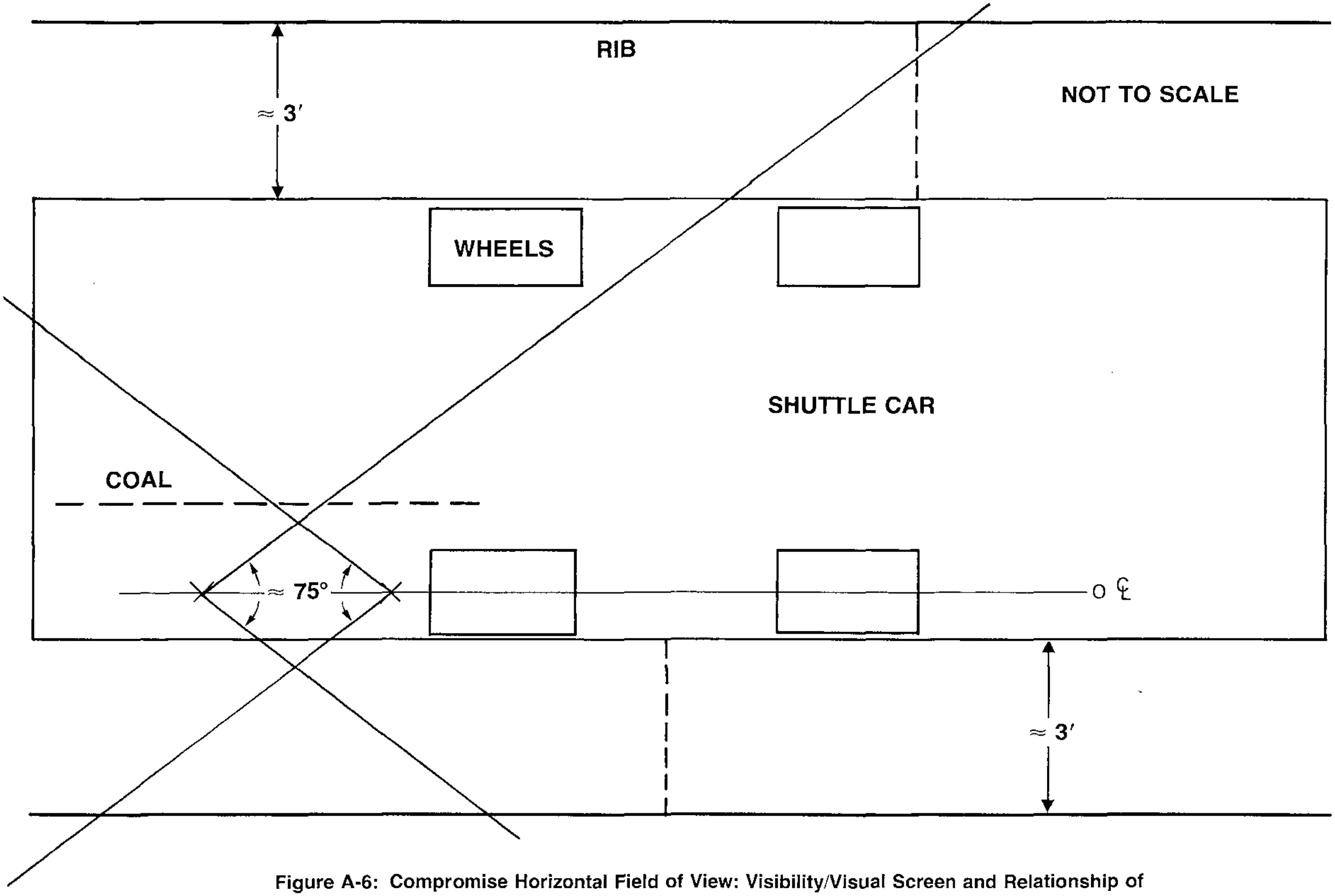


Figure A-6: Compromise Horizontal Field of View: Visibility/Visual Screen and Relationship of Forward Wheels (In By Direction) – Rib – FOV with 75° Field of View (FOV)

Fidelity During Turns

Filming of turns for the 1st dynamic film test consisted of a simple curvature trajectory which approximated the shuttle car operator position and pointing the camera tangent to the curve (i.e., straight ahead) during the turn. When the films were evaluated in the diorama setting, severe backwash and whipping appeared on the screen. This caused chronic vertigo.

After perusing the visual world during a turn, it was hypothesized and verified in the 2nd dynamic film tests that, since the shuttle car pivots about the corner in a turn, the camera would have to pan during a turn so that the focal plane of the camera pivots during the turn about the (extended/extrapolated) point in the focal plane of the camera where the corner is at the point in the mine where the shuttle car operator is located when the shuttle car first begins the turn, while the vertical axis of the camera optics traverses the precise trajectory of the shuttle car operators head. This pivot point is within the camera FOV for near side inby turns; it is outside the camera FOV for the other three turns. The combined geometry of the diorama (screen angle), cockpit rotation, this unique pan, and this trajectory yields a true, perfect perspective or simulation at every point in the turn. There is no backwash or whipping and resultant vertigo. However, to achieve this, extreme precision is required in each of the four elements.

To assure the correct trajectory, the camera position was marked by a low contrast string in the roof. As previously discussed, a filming vehicle capable of maneuvering the cameraman along the string was selected.

To accomplish the pan, markings were placed in the mine compatible with markings in the camera eyepeice. The cameraman, by aligning the markings in the eyepiece with the markings in the mine in the specified sequence and with the specified transition from one set of markings to another, automatically panned in the precise, requisite manner for each of the four turns.

Planetarium

The planetarium approach involves creating a forward view via film, TV, or etc., and creating a side view via projecting small, random, irregularily shapped, moving globs of light on a side view screen. The forward view and side view would be blended together so as not to create an objectionable discontinuity. This approach, however, was not pursued for two reasons. First, the diorama provides all of the rib simulation required relative to the capabilities and limitations of a planetarium approach to rib simulation; therefore the planetarium represents an unnecessary added cost. Second, based on the aforementioned problems relative to fidelity in turns, it is unlikely that the planetarium approach would permit adequate fidelity during turns.

SUMMARY: VISUAL SYTEM R&D

All of the technical objectives were accomplished through repeated experimentation and perusal. An economical visual system with more than adequate fidelity was demonstrated. This visual system includes a pseudo three dimensional near field blended with the far field so that maneuvering

APPENDIX B
SHUTTLE CAR: JOB PERFORMANCE REQUIREMENTS

Task 1. Pre-operation checkout

Perform the following steps in the order shown:

A. Demonstrate proper inspection and use of personnel clothing and safety equipment.

B. Obtain mine information from foreman.

C. Walk the shuttle car route and inspect it.

D. Locate other personnel and equipment (relative to start of production) in working area.

E. Inspect the shuttle car (non-operational).

F. Inspect the trailing cable.

B. Request foreman to energize the trailing cable - shuttle car operator should demonstrte that he knows how to energize/ deenergize the trailing cable.

H. Inspect the shuttle car (lights, boom, conveyor).

Task 2. Start shuttle car

Given instruction or intention to start machine:

A. Locate personnel and machinery in immediate area. Give vocal warning if appropriate.

B. Turn power ON.

C. Turn lights ON in direction of intended travel.

D. Turn pumps On.

Task 3. Tram - full and empty

Given instruction or intention to tram, and after performing Tasks 1 and 2:

A. Be seated facing direction of intended travel.

B. Sound warning device before depressing tram pedal.

C. Test brakes before tramming first time in each direction at start of shift and after breaks.

D. Tram total distance of 300 feet (including one right and one left turn) in each direction in approximately 1 1/2 minutes for each direction, without hitting roof, rib, or obstructions.

E. Slow down and ring bell before turning corner or penetrating curtains.

Conditions: bottom has 3-4" ruts that pitch shuttle car left and right while tramming; 1-2" of mud on bottom; entry width 18'; seam height 4' 6" ±6"; ribs vertical, parallel, with ±2 ft. perturbations.

F. Demonstrate ability to adjust speed and steering in response to mud, ruts, holes, bumps, etc.

G. Bridges: Be aware of, recognize at a distance of two shuttle car lengths, slow down when approaching, and tram over with wheels centered at ±2".

Task 4. Load

A. Given conditions of Task 3, tram shuttle car within 40 feet of the loader or miner, and approaching loader/miner in high tram: locate miner/loader operator helper, continue in high tram (conditions permitting) until front of shuttle car is within one shuttle car length of tip of conveyor, slow down and tram until loader conveyor boom is centered over shuttle car (±4"), and stop when front end of shuttle car is 8" ±4" from rear end of the loader or miner.

B. Maintain position under boom ±8" by coordinating shuttle car movement with loader (miner) movement.

C. Demonstrate proper use of cap lamp signals to operator for:

1. Movement of boom up or down, left or right.

2. Start and stop loading.

3. Move forward or back up.

D. Determine maximum height coal may be loaded in car as a function of the car, sideboards, bottom conditions, seam height, roof obstacles, and low points in roof between loader/miner and dump point.

E. Advance conveyor as loaded coal reaches height determined in D. Continue advancing as necessary until entire load is within ±4" of height determined in D and coal is within two flights of end of conveyor, without spilling more than 1/4 cubic yard.

Task 5. Dump

A. As shuttle car approaches feeder or mine car, begin raising boom so that neither feeder (car) nor roof is contacted by the boom as center of boom is positioned over appropriate point on feeder (car) ±6".

B. Set park brakes, operate conveyor at a rate that fills dump point as rapidly as possible without any spillage. Continue unloading until shuttle car is empty.

C. Stop conveyor, change seats, reverse lights, and release brake, all within 10 seconds.

D. Begin tramming away from dump point. As boom clears dump point, lower to tramming position without hitting dump point or roof.

Task 6. Park and Shutdown

A. Stop shuttle car in a legal parking place, turn wheels toward nearest rib, set parking brake, shut off power, all within 30 seconds.

B. Chock wheels (if on an incline or slope).

Task 7. Hazards and Contingencies

A. With reference to attached table, see and recognize each hazard/contingency at the specified distance.

B. With reference to attached table, react correctly to each hazard/contingency while tramming.

Task 8. General Knowledge Requirements

A. Demonstrate a knowledge of conventional and continuous mining cycles such as to predict the location and personnel and equipment during the shift.

B. Face machinery equipment

1. Recognize
2. Know intended usage

C. Describe the function and JPR's of shuttle car operator.

Task 9. Retreat Mining

A. Execute Task 4 except operator seated in direction facing away from loader or miner while loading.

B. Recognize imminent roof fall and cap lamp signal from miner/loader operator of imminent roof fall.

C. Execute emergency withdrawal in coordination with miner/loader operator and without spilling coal when a roof fall is imminent.

Task 10. Out of Section (Rock work; fall removal, etc.)

A. Knowledge of how rock/gob removal is accomplished

B. Relocate shuttle car to remote location.

C. Connect Power (energize trailing cable) at remote location.

1. Locate Power
2. Connect NIP
3. Know when to call mine electrician.

PREPARED: February 1978
SUBMITTED TO USBM: March 1978

HAZARD - CONTINGENCY	RECOGNITION DISTANCE	PROPER RESPONSE
Roof hazards such as low headers or roof bolts, multiple holey boards, and other fixed objects	During pre-op inspection.	Assure clearance. Do not pass under in high tram if clearance is minimal.
Roof hazards such as low hanging cables or water hose and other moveable objects.	1. During pre-op inspection. 2. 50 feet	Stop and correct hazard.
Personnel coming through curtains, around corners, out of holes, etc., into path of shuttle car.	0 - 50 feet	Emergency stop if close; slow down, sound warning device, give cap lamp signal, and prepare to stop if far away.
Machinery equipment coming through curtains, around corners, through intersections, etc., into path of shuttle car.	0 - 60 feet	Emergency stop if close; slow down, flash lights, and prepare to stop if far away. Via cap lamp signals, determine who will proceed or move out of the way. Do not shine head lights into other operators eyes.
Objects such as cinder blocks, timbers, bags of rock dust, equipment, cans, etc., lying in haulage way more than 1 1/2 feet from rib.	50 feet	Stop and remove object.

HAZARD - CONTINGENCY	RECOGNITION DISTANCE	PROPER RESPONSE
Fire in shuttle car.	N/A	Depress panic bar, turn lights off, brake hard to stop shuttle, set park brake, and release fire suppression device in one smooth, quick operation. Immediately notify foreman and prepare to extinguish fire with fire extinguisher.
Trailing cable begins sparking and arcing	N/A	Depress panic bar, turn lights off, brake hard to stop shuttle car, and set park brake in one smooth, quick operation. Immediately notify foreman, and prepare to extinguish fire with CO_2 or other class C fire extinguisher. (Foreman may direct shuttle car operator to trip circuit breaker and remove trailing cable from power station).
Roof Fall	N/A	Depress panic bar, turn lights off, brake hard for a stop, set park brake. If fall is in immediate area, stay in operator's pit under protection of canopy. Otherwise, follow foreman's instructions.

APPENDIX C

TRAINING OBJECTIVES

GENERAL KNOWLEDGE REQUIREMENTS

A1. Describe the physical features of a mine, including the proper definition of such terms as: conventional mine, continuous mine, entry, crossout, pillar, rib, roof, bottom, haulageway, face, etc.

A2. Describe conventional, continuous, and retreat mining cycles.

A3. Describe the general features of a "safe" mine.

A4. Describe the major functions, features, and operating principles of a shuttle car.

A5. Describe the function of a shuttle car operator.

A6. State the Job Performance Requirements (JPR's) for a shuttle car operator.

A7. Describe how a shuttle car gets its power, and the general procedures for energizing the shuttle car.

A8. Describe the different kinds of shuttle cars and how they vary in physical features (i.e., controls, wheels, operator's pit, etc.).

A9. Name and identify the other face machines used in conventional and continuous mining.

A10. State the functions and special features of each face machine.

A11. Describe the relationship of the other face machines to the shuttle car and its operator.

A12. Correctly identify imminent roof fall and cap lamp signal from miner/loader operator during retreat mining.

A13. Describe procedures for loading during retreat mining.

A14. Describe how emergency withdrawal is executed in coordination with miner/loader operator, without spilling coal when a roof fall is imminent during retreat mining.

A15. Describe how a shuttle car is relocated to a remote location out of section.

A16. Describe how rock/gob removal is accomplished.

A17. Describe how to energize a trailing cable (i.e., locate power, connect NIP, and know when to call mine electrician) at a remote location out of section.

PRE-OPERATION CHECK-OUT

B1. Name the function of hand tools which should be carried on the shuttle car.

B2. Describe the functions of hand tools which should be carried on the shuttle car.

B3. Name the clothing and safety items worn by a miner.

B4. Describe the clothing and safety items worn by a miner.

B5. State the kinds of information a miner should obtain from his foreman.

B6. Describe the normal route taken by shuttle cars, as well as the probable location of equipment, machines, personnel, etc. along or close to the route of travel.

B7. Describe the kinds of personnel and machines normally found in the working area, as well as their anticipated patterns of movement.

B8. State the shuttle car (non-operational) checks --including checks of operator pit cleanliness, fire fighting equipment, tools.

B9. State the steps for checking on the safe functioning of the trailing cable and appropriate parts of the electrical system.

B10. State the shuttle car (operational) check, including tires, control positions, lights, boom, conveyor.

B11. State the correct sequence of the pre-operation checkout as follows:

1. Inspect and use personnel clothing and safety equipment.
2. Obtain mine information from foreman.
3. Walk and inspect shuttle car route.
4. Locate other personnel and equipment (relative to start of production) in the working area.

5. Inspect the shuttle car (non-operational).

6. Inspect the trailing cable.

7. Request foreman to energize trailing cable.

8. Inspect shuttle car (operational).

B12. State the possible consequences of not conducting pre-operational checks.

B13. Perform the steps in the pre-operation checkout in the following order:

1. Inspect and use personnel clothing and safety equipment.

2. Obtain mine information from foreman.

3. Walk and inspect shuttle car route.

4. Locate other personnel and equipment (relative to start of production) in the working area.

5. Inspect the shuttle car (non-operational).

6. Inspect the trailing cable.

7. Request foreman to energize trailing cable.

8. Inspect shuttle car (operational).

STARTING THE SHUTTLE CAR

C1. Describe the hazards which could result from failure to perform the pre-tram procedure.

C2. Name in correct order the steps of the pre-tram procedure.

C3. Identify the controls of a shuttle car.

C4. Name the controls of a shuttle car.

C5. Match shuttle car reactions to operator control manipulations from lists of shuttle car reactions and control manipulations.

C6. Describe the function of each shuttle car control.

C7. Name in order the steps of the shuttle car start-up procedure.

C8. Describe the consequences which could result from failure to follow the steps of the shuttle car start-up procedures.

C9. Demonstrate in order the steps of the shuttle car start-up procedures.

TRAMMING - FULL AND EMPTY

D1. Describe procedures for tramming shuttle car straight ahead, in both directions, in a haulageway.

D2. Demonstrate procedures for tramming shuttle car straight ahead, in both directions, in a haulageway.

D3. Describe procedures for reversing directions of shuttle car.

D4. Demonstrate procedures for reversing direction of shuttle car.

D5. Describe procedures for tramming around a corner (from center adjacent and center opposite; or from rear adjacent, rear opposite, front adjacent, front opposite).

D6. Demonstrate procedures for tramming around a corner (from center adjacent and center opposite; or from rear adjacent, rear opposite, front adjacent, front opposite).

D7. Describe procedures for tramming through curtains.

D8. Demonstrate procedures for tramming through curtains.

D9. Describe procedures for tramming on wet and adverse bottom.

D10. Demonstrate procedures for tramming on wet and adverse bottom.

D11. Describe procedures for tramming near obstacles (e.g., low headers, roof bolts, multiple holey boards, low hanging cables, water hose, other moveable objects, and any objects lying in the haulageway).

D12. Demonstrate procedures for tramming near obstacles (e.g., low headers, roof bolts; multiple holey boards, low hanging cables, water hose, other moveable objects, and any objects lying in the haulageway).

D13. Describe procedures for tramming close to personnel and other machines coming through curtains, around corners, and out of holes or through intersections into the path of a shuttle car.

D14. Demonstrate procedures for tramming close to personnel and other machines coming through curtains, ground corners, and out of holes or through intersections into the path of the shuttle car.

D15. Describe the execution and meaning of cap lamp signals.

D16. Demonstrate ability to use and comprehend cap lamp signals.

D17. Describe the safety hazards (related to operator's pit, tramming, mine conditions, etc.) which can confront a shuttle car operator while tramming.

D18. Describe procedures to be followed in reacting correctly to hazardous situations encountered while tramming.

D19. Demonstrate ability to recognize and identify hazardous situations while tramming.

D20. Describe general safety precautions to be taken while tramming.

D21. Demonstrate general safety precautions to be taken while tramming.

D22. State the possible consequences of ignoring general safety precautions while tramming.

D23. Demonstrate ability to react correctly to hazardous situations encountered while tramming.

LOADING

E1. Describe procedure for safely pulling under a miner/loader with respect to all basic loading variations (i.e., straight, pinned, blind, on side-off side, turning crosscuts, sideways, manipulation of loading boom).

E2. Demonstrate procedure for safely pulling under a miner/loader with respect to all loading variations (i.e., straight, pinned, blind, on side-off side, turning crosscuts, sideways, manipulation of loading boom).

E3. Describe steps of procedure for safe operation of shuttle car conveyor and for jogging during loading (straight-on and sideways).

E4. Demonstrate steps of procedure for safe operation of shuttle car converyor and for jogging during loading (straight-on and sideways).

E5. Describe the execution and meaning of lamp signals.

E6. Demonstrate ability to use and comprehend lamp signals.

E7. Describe the safety hazards which can confront a shuttle car operator while loading.

E8. Describe procedures to be followed in reacting correctly to hazardous situations encountered while loading

E9. Demonstrate ability to recognize and identify hazardous situations while loading.

E10. Describe general safety precautions to be taken while loading.

E11. Demonstrate general safety precautions to be taken while loading.

E12. State the possible consequences of ignoring general safety precautions while loading.

E13. Demonstrate ability to react correctly to hazardous situations while loading.

DUMPING

F1. Describe procedure for safe pulling over a feeder or mine car (straight-on and sideways).

F2. Demonstrate procedure for safely pulling over a feeder or mine car (straight-on and sideways).

F3. Describe steps of safe dumping procedure (straight-on and sideways).

F4. Demonstrate steps of safe dumping procedure (straight-on and sideways).

F5. Describe the execution and meaning of lamp signals.

F6. Demonstrate ability to use and comprehend lamp signals.

F7. Describe the safety hazards a shuttle car operator can encounter while dumping.

F8. Describe procedures to be followed in reacting correctly to hazardous situations encountered while dumping.

F9. Demonstrate ability to recognize and identify hazardous situations while dumping.

F10. Describe the general safety precautions to be taken while dumping.

F11. Demonstrate the general safety precautions to be taken while dumping.

F12. State the possible consequences of ignoring general safety precautions while dumping.

F13. Demonstrate ability to react correctly to hazardous situations while dumping.

APPENDIX D

TRAINING SYSTEM AND PROGRAM OF INSTRUCTION DEVELOPMENT

As stated in the body of this report, the training sytem and POI were derived and developed from the training objectives with consideration given to ten specific factors (page). A discussion of the derivation and development of the training system and POI follows.

Constraints

The training system and POI were designed to satisfy the following constraints:

Class Size and Duration

The class size was set at 2 - 4 trainees and a minimum of 140 trainees per 45 week year*. The course is designed for one week maximum.

Note: A class size of 4 trainees and a one week class means each trainee will have only six (6) to eight (8) hours (approximately) to practice and demonstrate skills assuming a single simulator and that the class as a whole perform the actual equipment exercises.

Student Profile

The incoming student is a miner who has been underground at least 90 days, and who is expected to become a shuttle car operator within one month after graduation.

The majority of students are expected to possess at least an eighth grade reading level; however, some of the students will be illiterate. Likewise, some of the students will be at a 12th grade or higher reading and comprehension level.

Approximately 90-95 percent of the students will have previously operated cars, small trucks, and/or tractors. For the remaining 5-10 percent, this will be their first experience operating a powered vehicle.**

The attitude of incoming students is expected to vary radically. Some students will be eager to learn, some will be looking for a week's pay without going underground, some will have bid shuttle car operator jobs without learning for sure what they want or what they are getting into, and some will be coming to class because they were told to.

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*The economic analysis, Section IV, assumes 125 students per year. Four trainees in one week and 140 trainees per year represents a maximum student load; 125 trainees per year represent a worst case realistic financial base.

**This fact was discussed at length with the superintendent and foreman at Island Creek No. 9 mine in December, 1977.

Instructor Profile

The class is basically a one-week course which is repeated each week and which teaches only one thing -- shuttle car operation. Therefore, after a period of time, certain types of instructor personnel would be expected to tire of teaching this course.

ORI anticipates three broad situations, each conducive to a different type of instructor. One situation is where the course is offered in a voc-tech or similar school and the course is taught by the regular staff on a rotating basis.

Another situation is where the course is taught by the same instructor at the same or at varying locations throughout the year. In this situation medium quality instructors and moderately high turnover rates are expected.

The third situation is where the coal company provides the instructor from its training or PR department. Again, medium quality instructors and moderately high turnover rates are expected.

Probable Facilities and Equipment

Preferably, the training system should be conducive to trailer or fixed classroom installation. The trailers must be rugged, and standard commercial trailers are preferred to telescoping or collapsable military trailers. In classrooms, floor space should be minimized.

A survey of voc-tech schools revealed that reasonable and practical facilities for actual equipment exercises include (1) a reasonably good quality S.C. or (2) a stiff or non-responsive S.C. in:

1. An above ground simulated mine near the classroom.
2. An underground mine which does not not provide any opportunity to load or discharge coal.
3. An underground mine which provides the opportunity to run coal.
4. A parking lot.

The POI was developed for environments 1, 2, and 3 only. ORI does not believe satisfactory training will result in environment 4. Also, to achieve satisfactory training, the shuttle car steering, acceleration, and braking must not be sluggish; they must be reasonably responsive.

Practical Considerations

To be economically attractive, the total per student cost including student and instructor salary and benefits, facilities, course materials, profits, school funds, etc., must be under $5000 relative to 1978 wages and revenues-per-ton.

There has been much discussion and there are many opinions concerning the geographical location of training. ORI believes that to be successful the training program must be offered locally in such a manner that mine owners, superintendents, and foremen may send students without adversely affecting production.

A new shuttle car operator will usually come from a general labor position. Therefore, his absence from the mine prior to assuming the S.C. operator job will have minimal adverse effect on production. This would be the most advantageous time to train the operator.

Current practice is for the foreman to train the man on the job. This involves large amounts of the foreman's time during the first three shifts, very low productivity during the first 3-5 shifts, low productivity during the first three months, and a high accident rate during the first year.

New rules and regulations being instituted during the course of this contract require training prior to operation. However, the extent or quality of training is not specified.

Experience From Prototype System

Debriefing comments and an item analysis of test results from the prototype system indicate (reference final report, Contract No. H0242037):

1. The workbooks were an effective teaching media/method.
2. Retention of knowledge is questionable; therefore, reinforcement activities other than workbooks may be desirable.
3. 2-5 percent of the students were illiterate or semi-literate.
4. Students should not be required to spend more than 30 percent of their time studying the workbooks, and the class schedule should provide alternate activities after each half hour of studying workbooks.
5. With proper instructor guidance, the prototype DCT may be an effective teaching device.
6. The prototype reaction trainer, when it was used, appeared to teach and reinforce adherence to prescribed procedures and practices.
7. The prototype course tended to instill an awareness of safety and improve safety attitudes in students.

Evaluation of Objectives; Learning Sequence

The JPR's, Appendix B, are a complete job description. However, it is much more difficult to learn to tram straight than to learn how to turn the power on. It is also more time consuming to develop a concept such as the effect of four wheel steering than to learn mechanics of operation. Therefore, the training program was designed and scheduled to:

1. Provide instruction for all 93 training objectives with the constraints discussed on page D-1.

2. Provide the greatest number of units of instruction for the most difficult and important training objectives.

3. Introduce dynamic concepts related to safely operating the shuttle car as early as possible in the course, and provide extensive practice, remediation, and reinforcement of these concepts in simulated and real environments.

4. Introduce critical procedures related to safety and shuttle car operation as early as possible in the course, and provide extensive practice and reinforcement of these procedures in simulated and real environments.

5. Inject variety into the course, so that trainees do not become bored and demotivated.

6. Provide repeated but varied activities for reinforcing certain critical concepts, skills, and procedures.

7. Include both group and individual activities, the former, instruction which can be for an entire class; the latter, instruction which must be (or can be) for individual trainees.

8. Contain a sequence of skills instruction which, in the main, proceeds as follows:

   a. Introduction of skill concept
   b. Demonstration of skill in simulated environment
   c. Practice/remediation/reinforcement of skill in simulated environment
   d. Practice/remediation/reinforcement of skill in real environment
   e. Final performance of skill proficiency in real environment.

9. Concentrate on presenting information, demonstration, and simulation at the beginning of the course and on practice and performance in a real environment at the end of the course.

Methods and Media

The applicability of various instructional methods and media is discussed in this section. The content, comic, graphical presentation, suspenseful dramatization, and factual material to be studied, is another subject. The following methods and media were considered:

Media

1. Workbooks
   Programmed materials with illustrations and assessment tasks to teach most of the knowledge elements related to the shuttle car.

2. Worksheets
Brief printed materials in a gaming, problem-solving, or quiz format to provide the trainee with feedback and reinforcement with respect to the knowledge elements of the course.

3. Slide/Tape
Sound/Pictorial presentations may be employed to each content included in the General Knowledge Requirements, to enhance certain key concepts in the workbooks, and to provide a change-of-pace from workbook presentation.

4. Simulator
To provide simulated experiences in controlling the shuttle car, adhering to prescribed procedures, and in dealing with hazardous situations.

5. Dynamic Concepts Trainer
Table Top Model (DCT): to provide trainees with an understanding, through limited simulated experiences, of the essential concepts related to shuttle car steering and control, and to demonstrate the relationship between safety practices and accidents.

6. Motion Picture Film
Motion picture film, or "movies", may be employed to each content included in the General Knowledge Requirements, to enhance certain key concepts in the workbooks, to provide a change of pace from workbook and/or slide/tape presentation, and to enhance the orientation and/or motivation units at the beginning of the course.

7. Transparencies
May be used to provide correct responses to worksheet materials, for illustrations, and as a format for problem-solving activities.

8. Test Materials
To assess final cognitive performance.

Methods

1. Interpresonal Relations (trust building at beginning of course)
2. Instructor Presentation
3. Instructor Demonstration
4. Individual Trainee Study
5. Gaming and Problem-Solving
6. Instructor/Trainee Discussion

7. Group Discussion

8. Simulated Practice (of procedures and shuttle car skills)

9. Hands-on Practice (with actual equipment) in:

   A. An underground mine without the ability to load or discharge coal

   B. An underground mine with the ability to run coal, or

   C. An above ground simulated mine.

10. Assessment (of performance).

Selection Criteria

All of the standard methods and media were considered, and in general, several different methods and media could usually be employed for teaching any given objective or group of objectives. For example, the dynamic concepts could be taught via combinations of 16mm film, video tape, sound-slide (or film strip), lecture including blackboard and/or transparencies, the prototype DCT, the table top model (DCT), or demonstration with actual equipment in a parking lot.

In choosing the methods and media, ORI determined:

1. Availability of the instructor. As the program was originally envisioned, the instructor will spend large amounts of time in one-on-one or one-on-two situations in the simulator or at the table top model. During these periods the other students will need independent or self-administered studies such as sound-slide, film strip, workbooks, etc.

2. Availability of trainees and training devices, especially the simulator, actual equipment, and DCT.

3. Confidence in achieving the objectives of individual modules* via each method/media.

4. Motivational qualities including positive, negative, and neutral.

5. Variety and the overall efficacy of the POI.

6. Economic or cost factors including development costs (present contract and future ORI funded modifications), unit costs to industry, and facilities costs.

7. The student profile, instructor profile, facilities and equipment, and experience gained in the prototype system.

*A module is a unit of learning; it is not a workbook as used on the prototype system.

Selection of Methods and Media

ORI applied the foregoing criteria to varies combinations of methods and media. In general, it was concluded:

Workbooks - Workbooks similar to the prototype workbooks are an effective and economical method for teaching knowledge and introducing concepts. However, the total volume of workbooks must be reduced, the duration of any period with the workbooks must be less than one-half hour, only minimal reinforcement should be accomplished via workbooks, memorization of procedures should be introduced in the workbooks but not completed via the workbooks, and the workbooks should be less drudging than in the prototype system.

Sound-Picture - This area includes group and/or individual film strips and sound-slide. This particular form of instruction lends itself to reinforcement of knowledge and procedures, to teaching how to pull under in various orientations and conditions, and loading. It is particularly useful in the area of pulling under in various orientations and loading because a good program will enable the student to visualize what is happening, the rapid sequence of events, and what he should do when; but it will also enable the student or instructor to interrupt the program to elaborate or clarify any particular point.

This form of instruction is also excellent for introducing dynamic concepts.

Motion - This area includes video tape and film (8 or 16mm). Most first aid courses contain a 10-25 minute film as part of the first session. The film usually examplifies the concepts to be learned and helps motivate the students. In a similar fashion, a motivational film illustrating the job of the shuttle car operator and the location and movement of personnel and machinery relative to shuttle car operation shown during the first session would enhance the program.

Use of motion to teach and/or reinforce knowledge, procedures, concepts, docking, loading, and unloading is thought to be slightly inferior in terms of quality to sound-picture techniques previously discussed. Both the development and reproduction costs of motion are usually higher than sound-picture.

Learning Systems - These include group and individual systems such as the Lincoln Terminal System, various multimedia* systems with and without student responders, computer terminals, and various microfiche systems. Multimedia systems are a dynamic delivery system which are effectively used where attitude and motivation are a serious problem or where it is desirable to rapidly and dynamically switch delivery systems. The proposed program does not require this type of delivery system.

*A multimedia system is a dynamic system which automatically switches between motion, picture-slide, student response, and lecture forms of instruction.

Terminal systems do lend themselves to the same areas as the workbooks with added branching and remedial capability. For the shuttle car operator course only, the quality of training offered by a terminal and that offered by workbooks are approximately equal.

Transparencies and Worksheets - These provide a means to reinforce knowledge, procedures, and concepts in a relaxed and gaming environment. Properly designed units force a high degree of student response and action in a way which minimizes or eliminates the drudgery associated with memory work and motivates the students.

Lectures - The quality of instruction in lectures varies radically with instructors. In view of the instructor profile, ORI recommends minimal lecture.

Instructor Demonstrations - Instructor demonstrations using training devices such as the table top model and simulator are envisioned to provide benefits.

Instructor demonstrations on hardware devices can be used to teach and/or reinforce procedures, concepts, and skills. Instructor demonstrations followed by student exercises on the table top model will be particularly effective for teaching concepts and for remediation following reaction trainer exercises.

Table Top Model - The table top model, or dynamic concepts trainer, is a combination of the unpowered model and the combination powered model-operator's pit-situation generator developed on the prototype system. The table top model in conjunction with training aids may be used to demonstrate most of the concepts, procedures, hazards and hazard potential, and steering techniques associated with tramming and docking. It may also be use to vividly illustrate the relationship between safety practices and documented accidents.

Simulator - The simulator is a hardware device which partially simulates tramming in a room and pillar section. It may be used to teach and reinforce machine control in entries and crosscuts, initiating turns, recovering from turns, control familiarization, docking, hazard recognition, hazard avoidance, and reaction to contingencies.

Discussions - Properly designed and structured discussions involving two or more students, one student and the instructor, or two or more students and the instructor, may be used to reinforce knowledge, procedures, and concepts, to clarify or overcome isolated difficulty in learning specific concepts or skills, to increase motivation and improve attitude while learning, and to help convince the student to follow the procedures taught even though he may be the first in his mine to practice the prescribed procedures.

Training System

The training system is depicted in Figure 2 (page) and again in Figure D-1. The training system is designed to provide:

1. Initial information acquisition via workbooks.

2. Reinforcement of facts, concepts, and procedural steps via the dynamic concepts trainer.

3. Practice of procedures and skills via the simulator and actual equipment exercise.

4. Additional reinforcement via gaming activities.

5. Final performance of the terminal objectives.

The trainee will frequently repeat the sequence of workbooks, DCT, simulator plus additional cognitive activities while awaiting his turn on the simulator.

Cognitive Activities

Cognitive activities, as illustrated in Figure D-1, are individual and group activities involving workbooks, group activities around the DCT, gaming type reinforcement activities, group discussions, and group critiques.

Based on a class size of four (4) trainees, each trainee will spend approximately six hours per day outside the simulator, especially Tuesday, Wednesday, and Thursday. Initially, this time will be spent learning the prerequisite knowledge and concepts for the simulator exercises. Later, after all the knowledge and conceptual elements have been learned, waiting time for the simulator is a burden to the POI. Constructive, productive cognitive activities which will improve retention are required for this period.

Dynamic Concepts Trainer

The dynamic concepts trainer illustrated in Figure D-1 is a scale model. It is used to teach and reinforce concepts and procedures such as the quickness of four-wheel steering, the perception of four wheel steering and parallelism, turns, pulling under, and many more.

The DCT is also to be used to vividly demonstrate the need for safety procedures and to recreate documented accidents. For example, the lack of visibility in turns and the need to ring the bell can be vividly demonstrated by placing a scale model miner in the shuttle car path in a typical setting (turn) and asking the trainees to state when the shuttle car operator might first see the miner. As another example, the fact that numerous shuttle car operators crush their hands, legs, and head between the canopy/operators pit and rib each year can be stated and how this happens, and why it happens, can be vividly demonstrated. Thus the trainees both see and act out realistically how accidents actually happen, and how the shuttle car operator can prevent these accidents.

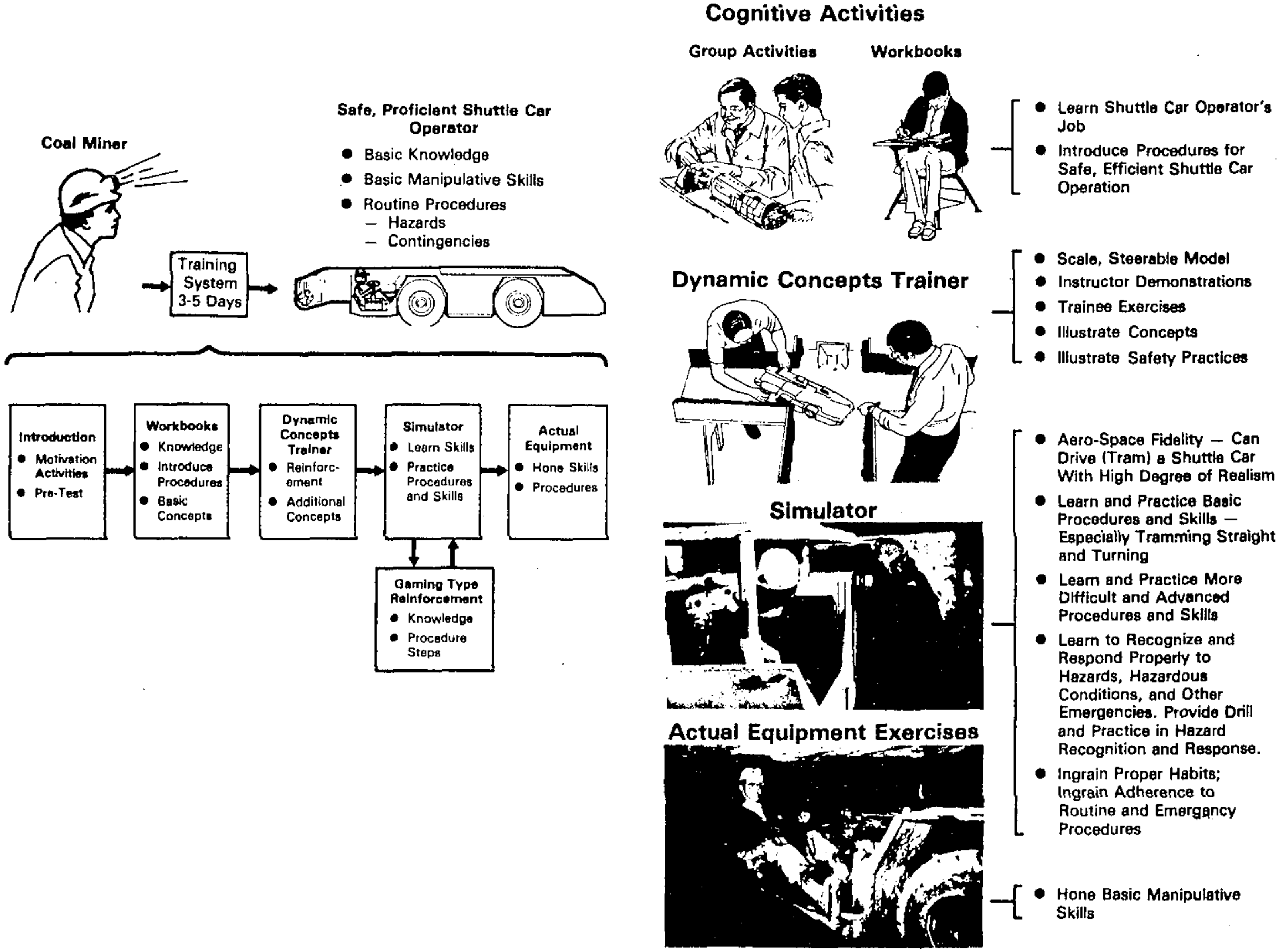

Figure D-1: Training System

Simulator

The simulator, illustrated in Figures D-1 and D-2, is, as discussed in Appendix A, a device with sufficient fidelity to learn, practice, and demonstrate skills relative to parallelism, turning, vehicle control, hazard/contingency recognition and response, and the several procedures associated with tramming, loading, and dumping.

Actual Equipment Practices

Notwithstanding the high quality, high fidelity simulator, one to two hours practice on actual equipment to hone the skills is considered essential for complete training. Most of this time will be spent tramming straight and turning. One or two trips running coal is considered highly desirable but not essential.

Program of Instruction

The detailed program of instruction is contained in the Instructors Guide which is considered part of the courseware for this program. This report contains an outline of the POI and a brief discussion of the POI relative to the outline.

Interium Status of POI

As stated in the introduction, the basic program plan was to develop the training system which includes running approximately four pilot classes in the field and modifying the POI accordingly, conducting validation studies on the training system, and modifying the training system and/or POI accordingly. However, this report is written prior to conducting the pilot class.

In addition to refining the POI and class schedule based on the pilot classes, ORI had planned to evaluate alternative plans for simulator utilization. The simulator exercises currently total approximately 12 hours for each trainee distributed as follows:

Control of Shuttle Car : 4 1/4 hours
Hazards : 3 3/4 hours
Hazards and Contingencies: 4 hours

Based on a class size of four (4) trainees and a limit of 40 hours class time available, only 6 - 8 hours (most likely 6 1/2) per trainee are available in the simulator.

The pilot classes are intended to verify four and one quarter hours as the amount of simulator time needed to learn control of the shuttle car (maneuvering skills), and to evaluate several alternative simulator exercise configurations. Although each of these alternative configurations has unique advantages and disadvantages relative to learning, they appear approximately equal in terms of overall efficacy and efficiency. Therefore, evaluation via the pilot class will be extremely helpful in selecting and refining a simulator exercise configuration for the validation studies. The resulting configuration could significantly affect the course outline and schedule presented in this report.

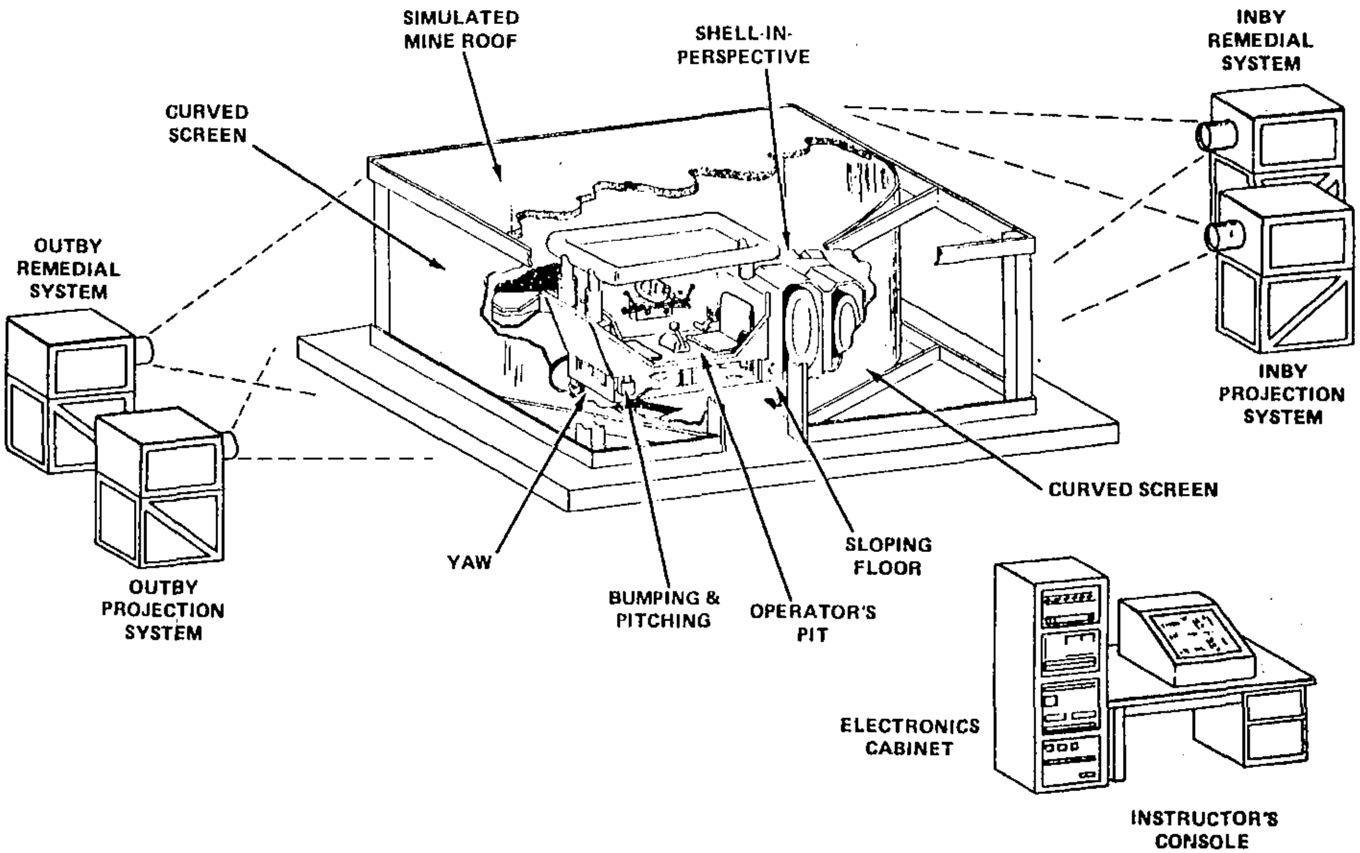

Figure D-2: Simulator Elements

Procedures

From the time a shuttle car operator arrives at his section until he leaves, excluding breaks, he is necessarily following, or should be following, one of the 21 procedures tabulated in Table D-1 at any instant. These procedures were derived from the JPR's based on observation of Shuttle Car operators. They were developed as an aid to the POI: the POI can be structured to accomplish the training objectives in the context of these procedures. The media content will present material in terms of, and in the context of, these procedures.

Course Modules*

Twelve modules have been developed based on the training system sequence, introduction via workbooks, reinforcement and concepts via the DCT, and learn/develop and practice procedures and skills via the simulator, the 93 training objectives, and the 21 procedures discussed previously. These twelve modules are tabulated in Table D-2 together with identification of the module media. Figure D-3 depicts the requisite sequencing of the modules in the course.

Class Schedule

Figure D-4 is the tentative class schedule Monday - Thursday pending final simulator exercise configuration. Actual equipment exercises are to be conducted Friday. Depending upon the arrangements for actual equipment exercises, additional simulator exercises may also be conducted on Friday.

Testing is provided via the simulator exercises. Table D-3 tabulates exercise number versus testing (subject to change with change in exercise configuration).

The class schedule is based on the module sequencing, simulator film content (which was determined based on original analysis of learning requirements and time), and verified time to complete simulator exercises. It may be observed that some of the course modules have necessarily been introduced before prerequisite modules are completed. This is to accommodate simulator exercises, and is done so that all prerequisite material is in fact completed. For example, simulator exercise S-4 is directed toward turns and alignment and stopping distance for loading and dumping; however, the trainee must tram through curtains as part of exercise 4. Therefore, he is briefly introduced to the procedure for tramming through curtains as a prerequisite for exercise 4. (Note: The original simulator films directed toward turns did not have any curtains, loading, or dumping. These films did no prove satisfactory during factory tests; therefore, an alternate film had to be adapted.)

Figure D-4 also suggests a workable track system. Several adjustments in this schedule are expected as a result of the pilot classes. This schedule is designed to maintain student motivation, provide interaction

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*A module is a unit of learning which typically includes several activities, media, and methods.

TABLE D-1: SHUTTLE CAR OPERATOR PROCEDURES

<u>Procedures related to operating and controlling the shuttle car</u>

1. Pre-operation check-out
2. Start-up procedure
3. Tramming procedure
4. Reverse directions procedure
5. Turning (a corner) procedure
6. Tramming through a curtain (brattice cloth) procedure
7. Tramming on wet and adverse bottom procedure
8. Loading (taking on coal) procedure
9. Dumping (coal in a feeder or mine car) procedure
10. Parking procedure
11. Shutdown (of the shuttle car) procedure

<u>Procedures related to responding to hazardous situations</u>

12. Tramming near a low fixed object in the roof
13. Tramming near a low moveable object in the roof
14. Tramming near a (discarded) object in the roadway
15. Tramming close to (other) miners (0-25 feet away)
16. Tramming close to (other) mine equipment (0-25 feet away)
17. Tramming close to (other) miners (26-50 feet away)
18. Tramming close to (other) mine equipment (26-50 feet away)

<u>Procedures related to responding to mine contingencies</u>

19. Fire in the shuttle car
20. Sparking or arcing trailing cable
21. Roof fall

Note: The detailed steps for each procedure are listed in Appendix B.

TABLE D-2: COURSE MODULES

No.	Topic(s)	Media/ Media Sequence	Exercises/ Pages *	Reinforcement
1	Controls	WB Simulator WB	B1 - B8* S - 00 (G) B16 - B21*	RA-5, RA-7,
2	Start Up Procedure	WB Simulator	C via S-00 (G)	RA-4, RA-8 S-6-S-12
3	Tramming Straight	WB DCT Simulator	D1-D7* D-1, D-8 S-1	S-4 - S-12 D-3
4	Tramming: Turns	WB DCT Simulator	D8-D11* D-2 S-4A & S-4B	S-5 - S-12 D-3 Misc DCT
5	Tramming: Curtains	WB DCT Simulator	D-12* D-6 S-5A	S-6 - S-12 D-7 Misc DCT
6	Tramming: Bad Bottom	WB DCT Simulator	D-13* D-3 S-6	
7	Loading and Dumping	WB DCT WB DCT Simulator	G D-4 H D-5 S-5B	RA-9 RA-10 RA-13 D-7 S-6 - S-12 DCT (G)
8	General knowledge	WB DCT GD	A D-3 -	RA-1, RA-2, DCT(G) D-7

TABLE D-2 (Cont'd)

No.	Topic(s)	Media/ Media Sequence	Exercises/ Pages *	Reinforcement
9	Pre-Operation	WB Simulator GD	F Demo -	RA-3 Morning Demo's
10	Park and Shutdown	WB Simulator	E S-5A	RA-12 S-5B - 5-12
11	Tramming: Hazards	WB DCT Simulator	I D-9	RA-6, RA-11 DCT (G) S-9 - 5-12
12	Tramming: Contingencies	WB DCT Simulator	I D-10 S-10	S-11 - S-12

* Page numbers are tentative and are expected to change.

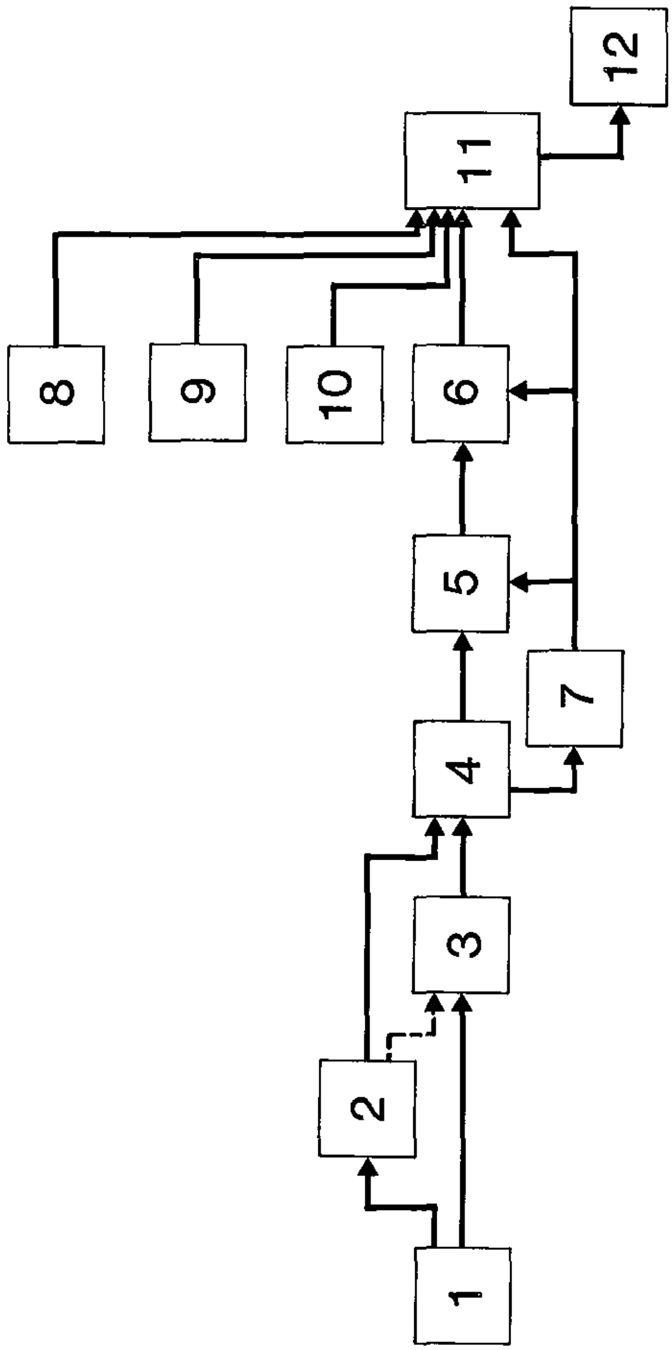

FIGURE D-3: MODULE SEQUENCING

MONDAY

	Student Number 1	2	3	4
1	Introduction DCT Demo			
1	Controls:	WB Simulator S-00 (Group & Ind) WB		
1/4	Break			
3/4	Start-Up Procedure:		WB DCT: D-1 (Group & Ind)	
3/4	Tramming Straight:		WB DCT: D-1 (Group & Ind)	
	Lunch			
1/2	S-1			Orientation WB
1½	Review Turns WB Curtains WB Bottom WB DCT D-2 Alignment - Load & Dump	S-1	S-1	Review Observe S-1
3/4	S-4A			
1½	Loading DCT D-4 Dumping DCT D-5 Orientation WB Review	S-4A	S-4A	
	RECAP			

Figure D-4: Class Schedule

TUESDAY

	Student Number 1	2	3	4
1/4	Demo: Pre-Op Inspection			
3/4	DCT D-3 Review			S-4A
3/4	S-4B			
	Review Pre-Op WB (Eq & Sect)	S-4B		
2¼	RA 4 Pre-Op WB (Eq & Sect)	(2 1/2)	S-4B	
	DCT D-6 (Curtains) Shutdown WB		(2 3/4)	S-4B
	Lunch			
1	S-5A			(3)
	Review Pre-Op (WB) RA 7	S-5A		
2¼	Tramming WB DCT D-7 (Running Coal)		S-5A	
	Review Pre-Op Eq Inspection			S-5A
	RECAP			

* Each trainee has a different waiting period between S-4B and S-5A; and between S-5A and S-5B.

Figure D-4 (Cont'd)

WEDNESDAY

	1	2	3	4
	Execute & Demonstrate Pre-Op Instpection			
¼	S-5B			
2½	Obstacles D14-19 DCT 8 H & C G RA 3	S-5B	S-5B	S-5B
	Lunch			
1	S-6			
2½	RA-1 RA 12 DCT 9	S-6	5-6	
½	RA 3 and Group Review & Discussion			

Figure D-4 (Cont'd)

THURSDAY

	1	2	3	4
¼	Execute & Demonstrate Pre-Op Instpection			
2	S - 9			
2	RA - 8 RA - 13 RA - 6 DCT 10		S - 9	
2	S - 12			
2	RA - 9 RA - 10 RA - 11 Review on DCT		S - 12	
	RECAP			

Figure D-4 (Cont'd)

Table D-3
SIMULATOR EXERCISE VS. SCORING

Exercise	Tested For	During Trips
1	Setting Park Brake	4,5
	Ribbing	4,5
4A	Ribbing	4,5
4B	Setting Park Brake	1-5
	Ribbing	4,5
	Turns Procedure	4,5
5A	Ribbing	1-5
	Turns Procedure	1-5
5B	Turns Procedure	1-5
6	Start-up Procedure	1
	Loading Procedure	1-5
	Dumping Procedure	1-5
7	No Testing	
8	Curtains Procedure	1-5
9	Lost Time Between Half-Trips	1-5
10	Curtains Procedure	1,3,5
	Hazards Procedure	1-7
	Travel At Max. Sale Speed	4-7
11	Inappropriate Stops	1-7
	Loading Procedure	1-7
	Dumping Procedure	1-7
12	Ribbing	1-7
	Turns Procedure	1-7
	Travel At Max. Safe Speed	1-7
	Hazards Procedure	1-7
	Contingency Procedure	1-7

among the trainees, guarantee only brief encounters with workbooks which are followed immediately by an interactive DCT or simulator or group activity, and provide reinforcement in a carefully thought out, timely manner. Thought has also been given to exchanging the reinforcement games and the workbook activity in areas that are considered a review of incoming trainee knowledge such as personnel safety equipment, general mining knowledge, etc. This has the advantage of spreading workbook activities over more days and, if the trainee misses items in the games, he will be more motivated toward the workbooks. Both approaches are planned for the pilot classes.

Media Content Summary

The general content of the media is:

Workbooks

Initially, nine workbooks are provided:

A. Orientation, Shuttle Cars, Job of A Shuttle Car Operator

B. Names, Functions, Locations, and Operation of Shuttle Car Controls

C. Shuttle Car Start-Up Procedures

D. Tramming Procedures

E. Shutdown and Parking: Procedure, Hazards, and Safety Precautions

F. Pre-Operation Check-Out

G. Loading: Procedure, Hazards, and Safety Precautions

H. Dumping: Procedure, Hazards, and Safety Precautions

I. Tramming Hazards and Contingencies: Safety Precautions and Consequences

Transparencies and Worksheets

Thirteen worksheets, answer sheets, and appropriate transparencies are planned for reinforcement activities.

Each worksheet, usually a single printed sheet, is in the form of a game, quiz, or problem. The correct solution is contained on a separate printed sheet or transparency.

The thirteen activities are:

RA-1 Coal Mine Crossword Puzzle

RA-2 The Case of the Lying Stranger

RA-3 Pre-Operation Check-Out

RA-4 Start-Up Procedure

RA-5 The Names of Shuttle Car Controls

RA-6 Spotting and Correcting Errors in Procedures to Avoid Injury and Damage from Hazards While Tramming a Shuttle Car: How Good Are You?

RA-7 The Shuttle Car Controls Game

RA-8 Start-Up Procedure

RA-9 The Loading Procedure Puzzle

RA-10 The Dumping Procedure Puzzle

RA-11 A Message on Avoiding Hazards

RA-12 Parking and Shutdown Procedure

RA-13 Loading/Dumping Errors and Possible Consequences

Dynamic Concepts Trainer

The ten DCT exercises are:

D-1 Tramming Straight: Parallelism and Safety Practices

D-2 Turns: Concepts, procedures, and safety practices

D-3 Review: Tramming procedures, concepts, and hazards

D-4 Loading

D-5 Dumping

D-6 Curtains: Steering, procedures, and safety practices

D-7 Review: D-1 through D-6 in context of running coal

D-8 Safe speed

D-9 How to overcome visibility problems: spoting hazards

D-10 Contingencies

Sound-Picture (Optional)*

Six sound-slide packages are suggested for future consideration. These packages are not considered necessary to accomplish the course

*The sound-picture packages, although recommended, were not developed under the current contract.

objectives; they will, however, enhance the quality of training and saleability of the system. The subject of each of the six packages is:

- Orientation to Mines, Mine Machines, and Shuttle Cars
- Shuttle Car Controls: Names, Locations, Functions
- Dynamic Concepts Related to Shuttle Car Operation
- Tramming: Hazards and Contingencies
- Loading: Hazards and Contingencies
- Dumping: Hazards and Contingencies

Simulator Exercises

Each succeeding simulator exercise introduces a new skill (or skills), provides practice/reinforcement of previous skills, and combines previous individual skills to form higher order, more complex skills. The new skill(s) or central topic introduced in each exercise is:

S-1	Tramming straight (parallelism); stopping distance
S-4A and S-4B	Turns; Alignment when approaching loader/miner and dump point
S-5A	Curtains; leaving loader/dump point; park and shutdown
S-5B	Complete loading and dumping procedure
S-6	Speed; Running coal
S-7	Objects In Path of Shuttle Car
S-8	Personnel and Equipment In Path of Shuttle Car
S-9	Random Hazards (No new skills introduced)
S-10	Contingencies; end of shift
S-11,12	Practice and reinforcement; No new skills introduced

Actual Equipment Exercises

Depending upon time and facilities availability, the following actual equipment exercises are considered part of the POI:

AE1: Pre-operational check-out

AE2: Tramming straight

AE3: Near Side Turns

AE4: Far Side Turns

AE5: Tramming: Dump Point To Face and Return