FINAL TECHNICAL REPORT
September 1, 2006, through April 30, 2008

Project Title: **REMOTE UNDERGROUND COAL MINING – PHASE 2**

ICCI Project Number: 06-1/1.1B-1
Principal Investigator: E. Bane Kroeger, Southern Illinois University
Project Manager: Joseph C. Hirschi, Illinois Clean Coal Institute

ABSTRACT

The research conducted on the remote underground coal miner (RUCM) during Phase 1 proved the equipment and process was technically feasible and had favorable economics over traditional room and pillar mining techniques. During Phase 2 of the project, the design of the equipment making up the RUCM system was refined. Alternative coal transfer systems were discussed and the project team recommended the chain haulage system proposed during Phase 1 of the project be replaced by a flexible conveyor belt system. The flexible belt system requires fewer workers and should speed movement of the system outby to a new cut or to the next crosscut.

During this phase, the process was presented to MSHA and four different coal companies for their comments. All had positive comments about the process. The biggest concerns raised by MSHA were ventilation of the cuts during mining and performing gas checks in the cut before mining. Issues regarding electrical and fire suppression systems were also addressed.

The Phase 1 economic analysis was also updated to reflect increases in equipment and supply costs over the last two years. These higher costs have widened the gap in cost per month between RUCM mining and standard room and pillar mining making the RUCM approach more advantageous. The RUCM mining plan involved developing panels with three continuous miners and the room and pillar mining plan used six continuous miners. Both plans produced 1.7 million clean tons per year. Operating costs calculated for the two mining plans included costs for labor, supplies, power, preparation, and waste disposal. All were estimated on a monthly basis. After updating the economics to 2008 dollars, the monthly cost for the room and pillar mining plan was $2,474,873 and the cost of the RUCM plan was $1,821,577. On a cost per ton basis, the room and pillar mining plan had raw and clean production costs of $10.10 and $16.84 per ton, respectively. The RUCM plan had raw and clean production costs of $8.57 and $12.60 per ton, respectively. The largest cost differences between the two plans were in the categories of labor and supplies. This was due to the reduced number of workers and the lower amount of roof bolting supplies consumed per month by the RUCM plan.

EXECUTIVE SUMMARY

The objectives of this research were to develop detailed designs for RUCM subsystems and equipment, develop a detailed list of equipment for the mine plan and locate vendors for those pieces, develop detailed plans to move the RUCM and its associated equipment from panel to panel, and locate a coal industry partner willing to commit to purchasing and demonstrating the RUCM at a mine in Illinois.

A team of individuals from academia, coal companies, consultants, and equipment manufacturers assembled during Phase 1 of the project focused on adapting the Superior highwall mining system for underground use. Subsystems of the highwall mining system were examined in detail to determine suitability for underground use or to design required changes necessary for underground applications. Subsystems evaluated included the cutterhead module, push beams, auger power head, base frame, push beam mover, chain transfer conveyor, and ventilation.

Additionally, the Phase 1 economic analysis was updated to reflect increases in equipment and supply costs over the last two years. These higher costs have widened the gap in cost per month between the RUCM mining technique and room and pillar mining techniques. The RUCM mining plan involved developing panels with three continuous miners and the room and pillar mining plan used six continuous miners. Both plans produced 1.7 million clean tons per year. Operating costs calculated for the two mining plans included costs for labor, supplies, power, preparation, and waste disposal. All were estimated on a monthly basis. After updating the economics to 2008 dollars, the monthly cost for the room and pillar mining plan was $2,474,873 and the cost of the RUCM plan was $1,821,577. On a cost per ton basis, the room and pillar mining plan had raw and clean production costs of $10.10 and $16.84 per ton, respectively. The RUCM plan had raw and clean production costs of $8.57 and $12.60 per ton, respectively. The largest cost differences between the two plans were in the categories of labor and supplies. This was due to the reduced number of workers and the lower amount of roof bolting supplies consumed per month by the RUCM plan.

For existing mines in Illinois that have continuous mining equipment available, the roughly $8.9 million investment in a RUCM system will be recovered in about 14 months. Personnel and some equipment can be reassigned to the RUCM section. Larger mines in Illinois operating six or more continuous miners may be able to support two RUCM units with their existing equipment and personnel. One or two continuous miners could be shut down and personnel moved to two RUCM units. This could nearly double annual production from a single large mine (from 1.7 million clean tons using traditional room and pillar mining to 3.3 million clean tons using RUCM) and should reduce production costs at the mine by over 35%.

OBJECTIVES

The objectives of this project were to utilize data generated in Phase 1 of this project to develop detailed designs for RUCM subsystems and equipment, develop a detailed list of equipment for the mine plan and locate vendors for those pieces, develop detailed plans to move the RUCM and its associated equipment from panel to panel, and locate a coal industry partner willing to commit to purchasing and demonstrating the RUCM at a mine in Illinois.

INTRODUCTION AND BACKGROUND

There are two distinct methods for underground coal mining: longwall and room-and-pillar. The choice between these two mining methods is typically dependent on geology, property limits, and subsidence rights. If a mine property has favorable geology, a large block of coal reserves, and subsidence rights, then the mining method of choice is most often longwall mining because a higher percentage of coal can be extracted. In situations where the geology or mine property is not suitable for longwall mining or the mine does not have subsidence rights, then room-and-pillar mining techniques are used. Both types of mining are used in Illinois, but more than two-thirds of Illinois' annual production (which exceeds 30 million tons) comes from room-and-pillar mining.

In underground room-and-pillar coal mining, the three highest operating costs are labor, supplies (including roof control), and electricity. Any reduction in one of these cost areas could substantially decrease the cost of coal production. One technology that has great potential for cost reduction in two of the three cost areas is the remote underground coal mining (RUCM) process developed during Phase 1 of this project. In the proposed process, coal is mined using an adaptation of a highly successful surface mining technique, the highwall miner.

Major components of the RUCM include a base frame, auger power head, push beams, and a cutterhead. The cutterhead is pushed forward from a base frame that is anchored in an entry using hydraulic cylinders. Coal is mined in 10- to 14-foot wide cuts that are 500 feet long. Workers do not enter these cuts so roof supports do not need to be installed. A long rib pillar is left between the cuts, the width of which is based on several factors including mine depth and strength of coal pillars.

The mining process consists of pushing the cutterhead forward by the length of a push beam (10 feet is proposed for the RUCM), cutting coal as it is pushed. The pushing force is supplied by hydraulics on the base frame. Coal is transported from the cutterhead to a conveyor system by means of augers housed in push beams. The augers are powered by a power head mounted on the base frame. After each 10-foot mining increment, another push beam is mounted on the base frame and the cycle is repeated.

Phase 1 research determined the advance rate of the cutterhead to be 3 feet per minute. For a 6-foot mining height and a cut width of 10 feet, the production rate would be 8.1 tons/minute. For a 500-foot long cut, 50 10-foot long push beams would be needed and

167 minutes of cutting time would be required. In addition to cutting time, at least two additional minutes per push beam would be required for insertion and coupling for a total of 267 minutes per cut under ideal conditions.

After cutting the full width of a panel, the base frame retracts the push beams at approximately 20 feet per minute, or about 0.5 minutes per push beam. Once again, approximately two minutes per push beam are required for uncoupling and removal from the base frame resulting in a total retract time of 125 minutes. In addition to cutting and retracting time, an estimated 45 minutes will be needed to service equipment and move the base frame to the next cut resulting in a total cycle time of 437 minutes per cut. This leaves 43 minutes in an 8-hour shift for unexpected delays.

Using these parameters and production rates, Phase 1 studies indicated the RUCM would make one cut per shift and produce 1,350 raw tons. Because the cutterhead can be kept in the coal seam, there is no need to cut into the roof or floor in most mining applications. Thus, run-of-mine coal from the RUM should be cleaner with only about 20% reject as compared to 35-40% from a typical continuous miner unit.

Phase 1 identified mine conditions suitable for RUCM mining. The most important requirements were a flat lying seam at least 6 feet thick with a competent roof. These restrictions limit the choices to five or six current mines in Illinois, but if production costs are reduced by the amount anticipated, the technology may open coal deposits in Illinois that have been considered economically unmineable to date.

EXPERIMENTAL PROCEDURES

In this Phase 2 project, conceptual plans developed in Phase 1 were used as a basis for detailed equipment designs. Another goal for Phase 2 was to locate a coal industry partner willing to commit to purchasing and demonstrating a prototype RUCM at a mining operation in Illinois. Detailed equipment designs from this phase will feed into a final Phase 3 and will be the basis for much of the fabrication and permitting work. It is anticipated that Phase 3 will include equipment fabrication, mine installation and demonstration. Equipment design and operating issues addressed in this project include:

- Machine Design:
  - Cutterhead module
    - Reducing length
    - Increasing cutting height
    - Cross-hole drilling capability
  - Push beams
    - Reducing length
    - Ventilation allowances
  - Power head (auger drives)
    - Reducing length
  - Base frame
    - Anchoring system

- Thrust system
- Hydraulics system
- Push beam mover
- Transfer conveyor
- Operating Issues:
  - Move plans
    - From cut to cut
    - From panel to panel
  - Ventilation
    - Fan and controls
    - Tubing connection to power unit
    - Air flow through cutterhead module

The research team for this project was composed of individuals from academia, coal companies, consultants, and equipment manufacturers. The team members and their affiliations are listed in Table 1.

Table 1. Remote Underground Coal Mining Project Team Members

Team Member	Affiliation
E. Bane Kroeger	Southern Illinois University
Michael McGolden	CoalTec Energy
Gary Hartsog	Alpha Engineering
Steve Antoline	Superior Highwall Miners
J.D. Fairchild	Superior Highwall Miners
Bob Henry	Superior Highwall Miners
Stewart Myers	Superior Highwall Miners
Tom Cushman	Phillips Machine

RESULTS AND DISCUSSION

During Phase 1, different highwall mining systems were evaluated for their ability to be adapted for use underground. Since it is likely a prototype unit would be deployed in Illinois, the project team selected a system that would be most compatible with conditions encountered in the Illinois Basin. In the Illinois Basin, the Herrin (Illinois #6) and Springfield (Illinois #5) seams are the most widely mined seams. They vary in thickness from 4 to 7 feet and are mainly underlain by clay that can range from hard and blocky to saturated and soft. Roof strata can also be highly variable between hard sandstone and limestone to soft, thinly laminated shale, with the latter being most common. Given these conditions, the enclosed coal transfer system in the push beams offered by Superior Highwall Miner (SHM) seemed to be the logical choice. In addition to selecting the SHM mining system, their proprietary cutterhead was also chosen by the team for use in this research because it would be easiest to modify for fitting onto the limited space available on the base frame.

To complete the overall research project, ten different tasks were undertaken. In addition, background information was also compiled to make the report more complete and costs generated in Phase 1 of the project were updated to 2008 dollars.

Task 1 – Cutterhead Module Design

Three major subtasks for redesign of the current SHM cutterhead module were reducing module length, increasing cutting height (the current module can only cut seams up to 64 inches), and design of a cross-hole drill to mount on the cutterhead module.

SHM uses three different cutterheads based on the thickness of the coal seam being mined. For coal seams with thicknesses up to 15 feet, a modified Joy 14CM15 cutterhead is used. For seams with thicknesses up to 7 feet, a modified Joy 14CM10AA cutterhead is used. For seams with thicknesses below 64 inches, a proprietary SHM cutterhead is used. All three cutterheads use the same 995 voltage as SHM units running on the surface.

The proprietary cutterhead for thin seams was chosen for this project because the research team felt it would be the easiest to modify to fit into the limited space available on the base frame. Since the cutterhead is ground based, it has to fit on the base frame when starting a cut. The auger drive motors are located at the back of the base frame and can only be shortened to about 7 feet, which limits the length of the cutterhead to about 12 feet. In its current configuration, the SHM cutterhead is approximately 20 feet long. As part of Phase 1, conceptual changes suggested for shortening the cutterhead involved moving drive motors from behind the cutterhead to the top of the module as shown in Figure 1 with the top panel removed. Those changes need to be refined and detailed designs need to be developed.

In its current configuration, the SHM cutterhead can cut coal up to a height of 64 inches and is capable of cutting up to 6 inches below grade. To increase the cutting height of the head, the stroke of the lift cylinders will be increased. This change will allow the head to cut only about 3 inches below grade, which should not be a problem for the shorter lengths of the push beams. This change should allow the cutterhead to cut seams up to 72 inches thick. If necessary, the diameter of the cutting drum or the length of the lift arms could be changed to gain additional cutting height.

Another design factor discussed by the project team was to accommodate the need to ventilate a cut that has been stopped short. The team discussed the option of mounting a drill to the top of the cutterhead to drill through the coal web to the previous cut. This will allow some air to pass through the short cut and into the adjacent cut. Another option discussed by the team was to retract the cutterhead by 40 to 50 feet and turn the cutterhead to cut through the coal web and into the previous cut. An additional option would be to retract the cutterhead and reenter the hole. This would likely be the least desirable option but the most effective under certain conditions.

To better keep the cutterhead in the coal seam, SHM has installed gamma sensors on the cutterhead to detect the top and bottom. This provides a direct reading to the operator where there are distinct differences between the roof, coal seam, and floor. They allow the machine operator to better judge the position of the cutterhead in the coal seam and reduce out-of-seam dilution. Using this system has allowed machine operators to stay within 1% of the inherent seam ash in certain mining operations. This drastically reduces coal cleaning costs and in some instances has allowed run-of-mine coal to be sold as a raw product, avoiding preparation and disposal costs entirely.

Since MSHA requires gas checks to be made prior to any mining in normal room and pillar operations, they would likely require methane monitors on the cutterhead to determine if methane levels are within safe operating limits before operation of the RUCM commences.

MSHA also suggested the need for a fire suppression system on the cutterhead. It may be possible to use the water line feeding dust suppression sprays on the cutterhead as the feed for a fire suppression system. The cutterhead could also have a self-contained fire suppression system that could be remotely activated by the machine operator.

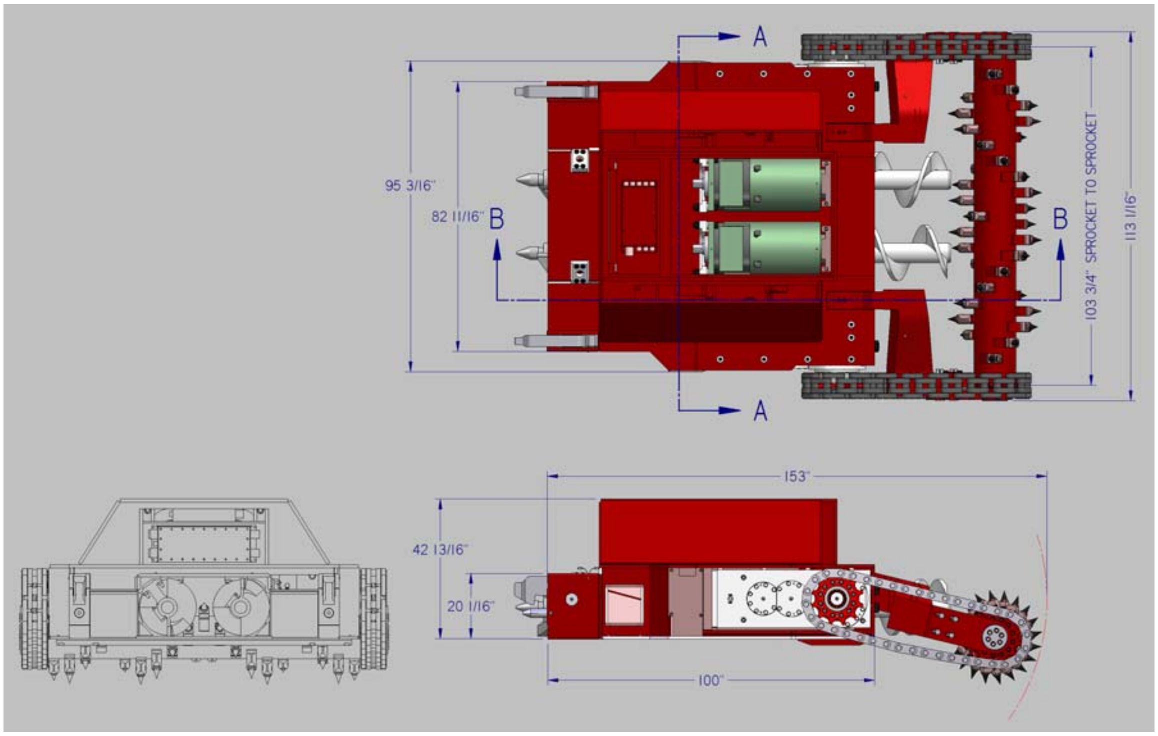

Figure 1. Conceptual Design for RUCM Cutterhead.

<u>Task 2 – Push Beam Design</u>

Standard SHM push beams are 7 feet wide and 20 inches high with two 17.75-inch augers on 22.44-inch centers. These augers are turned by a drive unit (power head) mounted on the base frame. The standard 20-foot push beam weighs 12,000 pounds. For the RUCM system, push beams must be shortened to 10 feet to fit on the base frame. A 10-foot beam would weigh approximately 6,000 pounds. The operating plan recommends stacking two push beams together and moving them with a scoop or small shield mover to and from the base frame. The 40-inch height and 12,000 pounds of two push beams should be easily moved by a scoop or small shield mover.

The current SHM push beams have two square structural steel tubes each 14 inches wide on either side of the augers as shown in Figure 2. At least one, and possibly both, of these structural tubes must be opened to allow ventilation air to be pushed from the base frame to the cutterhead. Some type of union between the push beams will also have to be developed to minimize air leakage and pressure loss between push beams.

In surface applications, the trough above the structural tubes is used to accommodate a flexible duct called a Bretby. The Bretby keeps hoses and cables from becoming tangled or damaged when in a cut. On the surface, the Bretby is rolled up on a reel that is approximately 16 feet in diameter. In an underground application, the Bretby reel would be too large, so the project team decided to separate cables and hoses placing them on individual reels that will likely be mounted on skids. These skids would be located adjacent to longwall shields pushing the base frame. The project team also recommended that a hinged cover be added to the cable tray on the inby side of the push beams. This cover would protect hoses and cables from falling debris and would eliminate or reduce the need to shovel debris out of the tray while push beams are being retracted.

Figure 2. Push Beam with Possible Ventilation Duct Identified.

Task 3 – Auger Power Head Design

Another major change that needs to be made to the current SHM design is shortening the power head that drives the augers. The current power head design has a length of 15 feet. It needs to be shortened to about 7 feet to fit into the designed 22-foot wide underground entries. As part of Phase 1, conceptual changes to the power head involved moving the drive motors from in-line with the augers to a position that is higher on the frame as shown in Figure 3. Those changes need to be refined and detailed designs need to be developed.

SHM created designs for a new gear box to allow the auger drives to be mounted above the augers. This will allow coal to flow from the augers through slots below the drive motors onto the chain conveyor in the bed of the base frame. The redesigned gear box will allow the auger drive unit to be shortened to about 81 inches.

Another key design component discussed by the project team was flexible tubing to connect the ventilation fan to the auger drive unit. The tubing needs to be flexible enough to accommodate 10 feet of travel needed during cutting cycles.

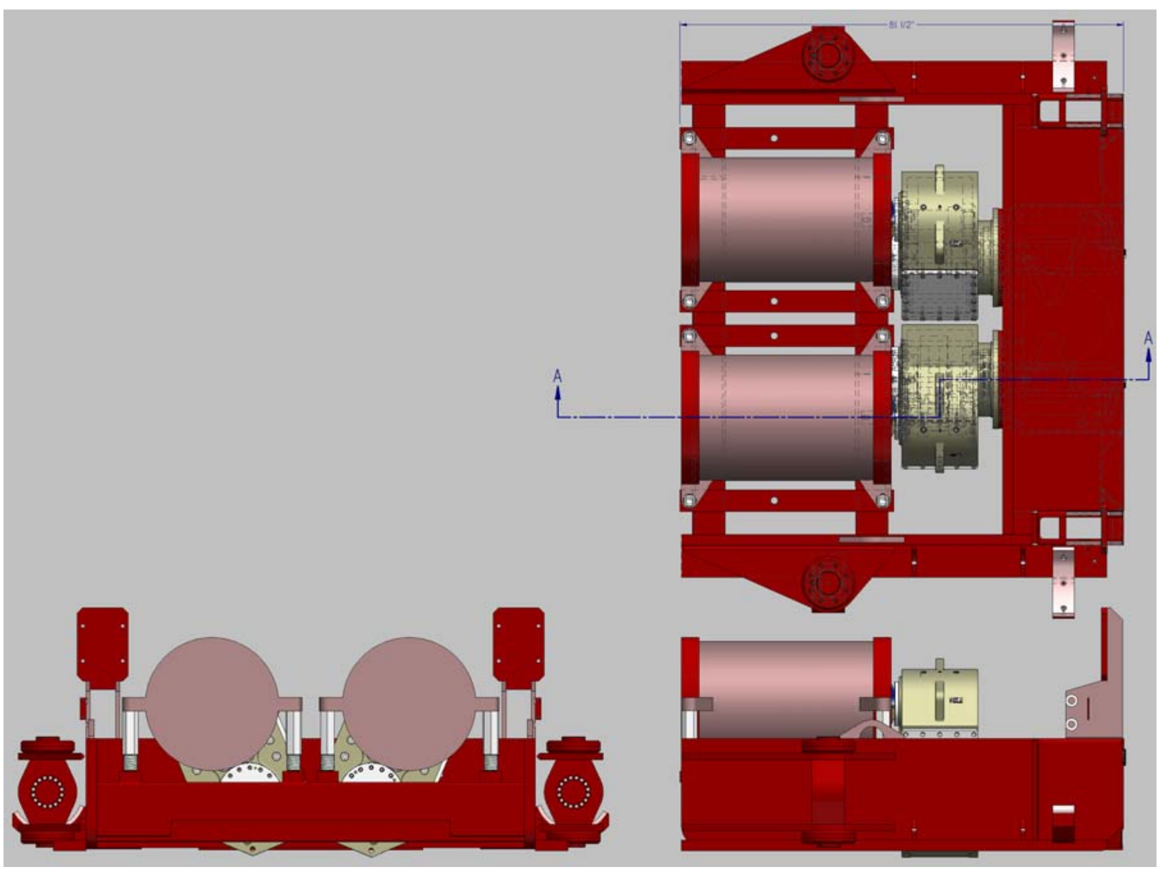

Figure 3. Conceptual Design for RUCM Auger Power Head.

Task 4 – Ventilation System Design

To ventilate cuts as they are being mined, air will be blown through one or both of the 14-inch square structural tubes on each side of the push beam auger box shown in Figure 2. This will be accomplished with a centrifugal fan mounted inby the base frame. The fan will require a single 100 horsepower motor to move 15,000 cubic feet per minute (CFM) at 30 inches of water pressure (WG) to deliver 6,000 CFM to the cutter drum area. A damper will be used to direct the air flow inby the fan when push beams are being added during the cutting cycle. Detailed designs for the fan, cutterhead ductwork, push beam connections, and controls need to be developed.

If a cut needs to be stopped short of cutting through to the bleeder entry, a drill mounted on top of the cutterhead module will drill through the web pillar allowing ventilation air to flow through the cut and exit to the adjacent cut. Detailed designs for the drill and mounting hardware need to be developed.

To ventilate completed cuts, airflow will be created using controls similar to longwall mining where air from the active headgate panel is forced through the mined out area because of a pressure differential from the headgate (development entries) to the tailgate (bleeder entry). Depending on the size of openings being mined and the amount of methane liberated, airflow requirements are estimated to be between 40,000 to 70,000 cubic feet per minute. This will require a ventilation pressure differential from the mouth of the headgate to the back of the tailgate panel of about 1.5 to 2.0 inches WG. Typically, this pressure differential is easily created in areas designed for secondary mining. As in longwall mining, regulators on the headgate and tailgate will create the pressure differential and there will be an evaluation point in the tailgate. There will also be a stopping line between entries 1 and 2 of the panel development headgate. Entry 1 will become the tailgate or bleeder for the next panel and will be separated from the remaining headgate entries by the stopping line.

Task 5 – Base Frame Design

As part of Phase 1, design of the base frame and thrust system involved using pairs of push-pull cylinders working together with traveling clamps, as shown in Figure 4, to generate the thrust needed to sump the cutterhead into the coal. Those changes need to be refined and detailed plans need to be developed.

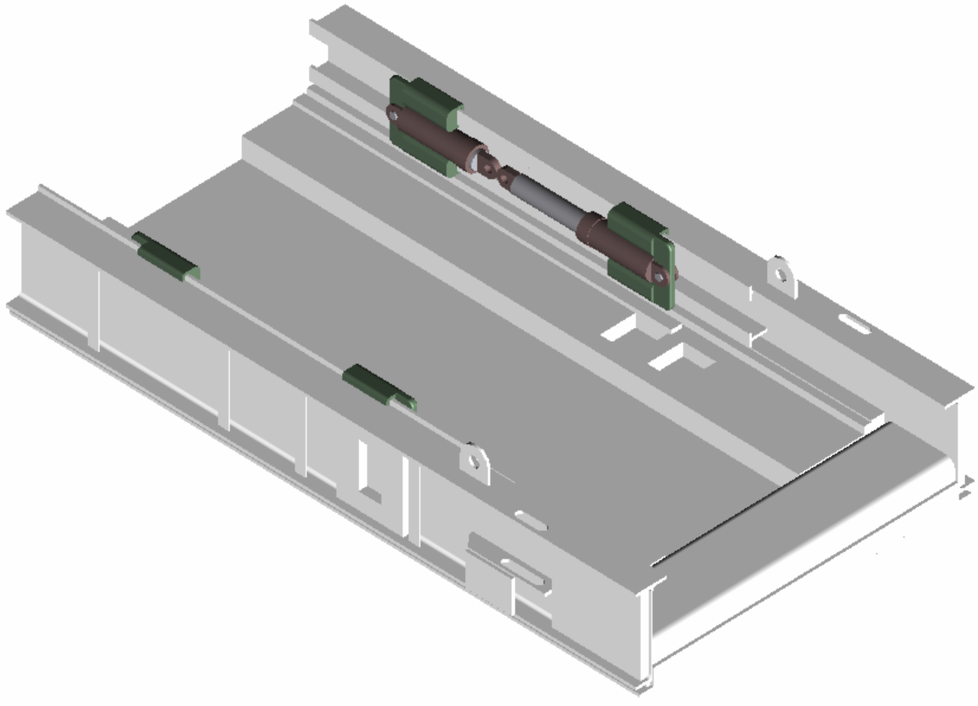

Figure 4. Conceptual Design for the RUCM Base Frame.

A major aspect of the base frame design is the anchoring system, needed to hold the base frame in place while the cutterhead is being thrust forward and also during retraction of the cutterhead from each cut. The current thrust system has a capacity of 380,000 pounds and is designed to push the cutterhead to a cut depth of 1,000 feet. The highwall system used on the surface relies on the weight of the machine and two anchoring pins 6 inches in diameter that are inserted in holes ten feet deep on the front corners of the base frame as shown in Figure 5.

Figure 5. Anchoring Pins Used to Stabilize the Base Frame (Photo courtesy of SHM website).

Because the final width of panels is unknown at this time, the same 380,000 pound thrust capacity was used to design the RUCM. The conceptual design of the anchoring system was to have vertical anchoring cylinders pushing against the roof and floor. In areas where roof material is not sufficiently strong, there is a danger of causing roof falls around the base frame. In the RUCM entry, primary roofbolts will likely be on a pattern of 4 feet by 4 feet. If the bolts are 5 feet long, they can be expected to hold about 4 feet of rock. Assuming the rock has a unit weight of 140 pounds per cubic foot, each bolt would be holding about 9,000 pounds of rock. To avoid damaging the roof or roof bolts, about 4,500 pounds of load over the 16 square foot area each bolt is holding, or 280 pounds per square foot should not be exceeded. Since the conceptual base frame is 10 feet wide and 20 feet long, a canopy designed to cover the entire base frame would have an area of 200 square feet. This canopy should be able to exert 56,000 pounds of load onto the roof, which is only about 30% of the load needed at a cutting depth of 500 feet. To overcome this deficiency, the project team proposed using horizontal cylinders to push off the front and back of the base frame against coal pillars. The remaining 324,000 pounds of thrust required to push the cutterhead forward will be generated by these horizontal cylinders.

Using horizontal cylinders requires a specifically designed mine plan because the cylinders do not have coal pillars to push against when the base frame is sitting in an intersection. When the highwall miner is operating on the surface, MSHA prefers that every tenth cut is skipped. This essentially adds a small barrier pillar between sets of ten adjacent cuts in the case there is a chain reaction pillar failure in the cuts. Using this concept, development entry pillar sizes can be designed so that a particular cut in a series (e.g. the eleventh cut) will coincide with an intersection and that cut can be skipped to form a small barrier pillar between sets of cuts (ten in this case). An optimum pillar size will have to be determined for each specific application because pillar size affects the logistics of getting push beams to and from the base frame. An alternative to skipping cuts in intersections would be to place steel beams behind the base frame to bridge the intersection. The base frame could then push off these beams to generate the necessary thrust force. Care would have to be taken to make sure that beams extend far enough into the pillar in order to avoid damaging pillar corners.

Another design change to the SHM base frame is eliminating the side discharge belt conveyor at the back of the base frame. The chain conveyor in the bottom of the RUCM base frame will discharge onto a chain conveyor (mother line) under the back of the base frame. In Phase 1, the concept was to have the mother line behind the base frame, but this would require the base frame to be shortened an additional 30 inches. During this phase, it was determined to design a notch in the base frame and locate the mother line beneath the base frame. By locating the mother line beneath the base frame, the length of the base frame can be the full width of the entry or 20 feet long.

Since the base frame will be within 150 feet of the gob area, all electronics will have to be permissible. Permissible components will be given highest priority to minimize the amount of permitting needed.

Task 6 – Push Beam Mover Design

A key component to making the RUCM process feasible is developing a quick, reliable, and safe method of transferring push beams from the platform where shield movers or scoops leave them to the bed of the base frame. The current SHM system uses a rail-type system mounted above the base frame as shown in Figure 6. The beam mover latches on to the top of a push beam, raises it and then moves the beam into position above the base frame. When ready, the beam mover lowers the push beam into place and unlatches from it. Detailed designs need to be developed to insure that the beam mover fits with the 8-foot height of an underground entry.

Figure 6. Push Beam Mover.

During this phase it was determined to mount the push beam mover on the underside of the base frame canopy. This would provide protection to the mover from debris falling from the roof and it would also provide a level surface to which the mover can be mounted. The canopy will be lowered when the base frame is moved to the next cut or the next panel, so there should be no problems when moving the base frame. The key design element here is to ensure there is enough height for the push beam mover to operate properly. Eight feet of height should not be a problem for most mines in the Illinois Basin. If extra height is needed, it would be best to remove it from the floor. For most of the mines in the Illinois Basin, some floor material is already removed during the mining process for various reasons.

Task 7 – Chain Transfer Conveyor Design

Coal cut by the cutterhead will be transported by push beam augers to the bottom of the base frame where a chain conveyor takes it to the back of the base frame. The Phase 1 design of the base frame had a chain transfer conveyor placed against the coal rib under the power head drive motors at a right angle to the base frame. Notches cut into the bottom of the base frame allow it to move independently of the chain transfer conveyor. The outby end of the chain transfer conveyor will require a goose-neck arrangement to transfer the coal to a continuous haulage unit. The inby end of the chain transfer conveyor will extend past the longwall shields creating a situation where equipment is located in an area that MSHA may classify as "gob". Having workers enter this gob area to repair equipment could be problematic.

A second option for transferring the coal from the RUCM to the section belt is to utilize a flexible conveyor such as the Joy FCT. A flexible conveyor would eliminate the use of the transfer conveyor behind the RUCM. The capital cost of a flexible conveyor will be higher than a chain conveyor system and most likely will be more expensive to operate, but it should significantly reduce the move time of conveyor systems and eliminate the need for a transfer conveyor that extends into a gob area.

Another option is to use cascading chain conveyors with lengths matching the distance from the center of one cut to the next. Before the base frame is moved to the next cut, one segment of the chain conveyor is removed and the remaining conveyors are moved forward as a unit.

Task 8 – Detailed Equipment Selection

In addition to RUCM components described in detail in previous tasks, a detailed list of ancillary equipment needs and possible vendors was compiled as shown in Table 2. In addition to the listed manufacturers of new equipment, there are regional equipment rebuilders that can supply most of the listed equipment. Most rebuilt equipment will be in excellent shape and have a significantly lower price tag reducing equipment costs by as much as half in many instances. This may also reduce shipping costs for the equipment.

Table 2. Ancillary Equipment and Potential Manufacturers

Item	**Manufacturer**
Articulating Chain Haulage System	DBT America
	Long-Airdox
Coal Hauler	DBT America
	Sandvik
	Stamler
Continuous Miner	DBT America
	Joy Mining Equipment
	Sandvik
Feeder-Breaker	McLanahan
	Stamler
Flexible Belt Conveyor	Joy Mining Equipment
Longwall Shield	Joy Mining Equipment
	DBT America
Mini Trac	DBT America
	Eimco
Scoop	DBT America
	Stamler
Shield Mover	DBT America
Transfer Conveyor	DBT America
	Eagle Iron Works

Task 9 – Move Plans for RUCM

Another key aspect of a successful RUCM will be minimizing the time required to move the RUCM and its associated equipment from panel to panel. In Phase 1 of the research, it was assumed that the RUCM and all of its associated equipment could be moved from panel to panel in two weeks. For equipment that is solely used for production, any time the equipment is not producing coal is very costly to the mine. It is imperative that good move plans are developed and followed to ensure that tools and equipment are in place when the RUCM needs to be moved.

The layout for the RUCM operation resembles a longwall operation in many respects. Transferring the system from one panel to the next is very similar. The success of the system and the cost structure of the mine are dependent on a quick and efficient transfer of the system from panel to panel. This requires specific equipment, good planning, trained people, and a mine layout designed to facilitate such moves. Longwall operations have developed procedures over the past 25 years that have continued to improve and lower the cost associated with moves and the amount of time the longwall is out of production. This same process needs to be done with the RUCM.

While the system consists of many components, there are very few that actually present a problem when moving the unit. The major components of the system consist of:

- Power box
- Operator's control station
- Belt tailpiece section for continuous haulage
- Continuous haulage system or FCT
- Chain transfer conveyor (if not using FCT)
- Longwall shields (2)
- Push beams (55)
- Base frame and cutterhead
- Cables, hoses, and reels
- Ventilation fan, damper, and tubing
- Scoops and/or shield haulers (3)

Moving the majority of this equipment is a very simple process. These components can be easily handled by scoops making several trips to carry them from one panel to the next. The move can be expedited by utilizing cars that will hold more than one component. For example, the ability to carry two push beams at once will eliminate 27 trips and speed up the move.

As with most moves, developing a comprehensive plan before starting is critical. While the push beams and other small equipment may be the easiest to move, they need to be moved last, as there will not be enough room for them at the new panel until the main equipment components are in place.

The most critical portion of the move plan is handling the base frame and continuous haulage system. The key to a quick move is being able to handle and move these components without breaking them down into smaller components. Many companies that operate continuous haulage already have plans in place that allow them to transfer their systems without separating components. There are a few key items to these plans:

- Main entry development must include designated crosscuts to transport the system. Typically, these will be 45-degree angled entries to allow the equipment to be easily maneuvered around turns.
- The path of travel must also include enough room and proper turns to not only keep the system intact, but keep the orientation correct making sure the inby end of the system stays on the inby end.
- Ideally, a diesel generator set needs to be utilized to allow the haulage system to tram itself without excessive cable handling.
- The outby end of the system, or "dolly" which rides on the belt system, can be carried by a scoop in conjunction with tramming the system.
- The entire move is dependent on good roadway conditions. Proper height, drainage control, and grading must be maintained to ensure that the move is not delayed.
- The launch vehicles on surface operations use a series of bogeys to set under the vehicle and allow the system to be pulled into place. It would be easy to

also employ this technique underground. The only issue is the height required, as any additional height for the bogey will require additional height in the entry.

There are several other issues that will improve any panel transfer. As with longwall moves, it makes sense to examine components that will need repair or replacement at the end of a panel. Those components can have spares bought and already in place, thus taking them out of the critical path of the move. The most obvious component is the belt tailpiece section. This is relatively inexpensive and can already be in place. It may also be worthwhile to investigate a spare power center. Most mines typically have spares in their systems, and this simply involves specifying a unit that can serve different functions, but also can supply power for the RUCM. The cutting element of the system is another component that should be examined for the value in maintaining a spare unit. The overall maintenance strategy may be best if the system is replaced after every panel and undergoes a partial rebuild.

The final component in the move plan is site preparation for both the end of one panel and the start of the next. The transfer will involve some dismantling of components and reinstallation. The design of start and end points of panels can accelerate this process. Having areas to turn equipment around or gain access to various areas is critical. Also, having lifting bolts or beams suspended can make jobs much easier and quicker.

Thirty years ago, a typical longwall move was a 4-week process. Now, with much more complicated equipment, the moves are completed in a week. The RUCM move is much simpler, but involves the same level of importance and should be given the same level of detailed planning and resources. The RUCM system should be moved from panel to panel and resume operations in two to three days with good planning and proper resources.

Task 10 – Find a Coal Industry Partner

In an effort to find an industry sponsor, presentations of the results of Phase 1 of the project were made to four coal companies. The presentations were made to over 50 engineers and mine managers representing 30 different mines in Illinois, Indiana, Kentucky, and West Virginia.

Although all of the companies were interested in the project, most felt the project needs to be driven by Superior Highwall Miners. The most logical next step would be to build a prototype system and find a mine that would be a test site. Waivers from MSHA for an experimental unit should not have a significant cost or pose significant problems to obtain. Based on results from the test site, a decision to go forward with permitting for use underground would be made by Superior.

CONCLUSIONS AND RECOMMENDATIONS

The remote underground coal mining process presented in this report does have advantages over a typical room and pillar mining process. Updated economics show the RUCM's advantage has grown even larger as the cost of equipment, supplies and labor have increased. Labor costs have increased but not the 30% to 50% increase of equipment and supplies. The advantages of the RUCM system need to be explored more rigorously and any drawbacks of using the system need to be addressed by a mining company that intends on utilizing this type of system. A comprehensive mining plan needs to be created to fit the mine where the system will be deployed.

The recommendation of the project team is to have Superior collaborate with a mining company to build a prototype unit and deploy it underground in a test panel. This will provide the data needed to convince the underground mining community that the process has merit. Once proven, the market for the underground systems should be as large as it is for surface highwall systems.

With recent tragic events in coal mining, MSHA is taking a more rigorous stance on mining safety. Because of this, any potential mining plan will be given more scrutiny and any experimental waivers that may be needed to test this process will be more difficult to obtain.

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DISCLAIMER STATEMENT

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APPENDIX

Updated Economic Analysis

Capital costs

A list of major equipment needed at the face and their costs was compiled for the RUCM plan and a comparable room and pillar mining plant. Capital costs for the two plans were then estimated and compared based on identical annual production rates for the two plans. Capital costs for the RUCM plan were estimated at $18,590,993. Capital costs for the continuous mining plan were estimated at $22,266,000. Costs for each individual piece of equipment along with the number required for each plan are provided in Tables A1 and A2. These costs have increased approximately 33% from the previous economic analysis conducted in 2006.

For the RUCM plan, if the width of panels could be extended to 600 feet, the number of push beams required to make the cut would need to increase to 60 and it would be prudent to have six spares. This would increase capital costs for the RUCM plan by an additional $550,000. It should be noted that most existing room and pillar mines have continuous miners and coal haulers available that can be shifted from primary production to development. If enough equipment is already available at a mine, then capital costs to deploy a RUCM could drop to less than $7 million.

Table A1. Capital Costs for the RUCM Plan.
(Assumes 500-foot wide panel and 3 continuous miner development units)

Equipment	**Number Required**	**Cost of Each**	**Total**
Remote Miner	1	$1,200,000	$1,200,000
Push beams (10-foot length)	55 (50 + 5 spares)	$59,100	$3,250,500
Shield mover	2	$550,000	$1,100,000
Scoop	1	$300,000	$300,000
Tail dolly	1	$3,000,000	$3,000,000
			$8,850,500
Continuous miner	3	$1,800,000	$5,400,000
Battery ram car	9	$550,000	$4,950,000
Roofbolter	3	$450,000	$1,350,000
Feeder/breaker	3	$400,000	$1,200,000
Scoop	3	$300,000	$900,000
Rock duster	3	$34,000	$102,000
			$13,902,000
		Total:	**$22,752,500**

Table A2. Capital Costs for Room and Pillar Mining Plan.
(Assumes equivalent production capacity as RUCM plan).

Equipment	Number Required	Cost of Each	Total
Continuous miner	6	$1,800,000	$10,800,000
Battery ram cars	18	$550,000	$9,900,000
Roofbolter	6	$450,000	$2,700,000
Feeder/breaker	6	$300,000	$1,800,000
Scoop	3	$400,000	$1,200,000
Rock duster	3	$34,000	$102,000
			$26,502,000

Operating costs

Operating costs for both the RUCM plan and the room and pillar plan were estimated in terms of labor, supplies, power, preparation, and waste disposal. The research team determined these costs were most important in the economic analysis. The outby costs should be nearly the same for both mining methods, so they were not included in the economic analysis and should be added to these costs if determining the overall project economics. A summary of the costs examined for both mine plans on a monthly as well as a per ton basis are provided in Table A3. As with the equipment costs, supply costs have increased up to 50%since the previous economic analysis conducted in 2006, mostly due to increases in the price of steel.

Table A3. Summary of Operating Costs.

Remote Underground Mining	Monthly Costs	$/raw ton	$/clean ton
Labor	$588,546	$2.77	$4.07
Supplies	$439,968	$2.07	$3.04
Power	$91,327	$0.43	$0.63
Preparation cost	$531,615	$2.50	$3.68
Disposal of waste	$170,121	$0.80	$1.18
Total:	**$1,821,577**	**$8.57**	**$12.60**
Monthly Production (tons)		212,646	144,598

Room and Pillar Mining			
Labor	$788,981	$3.22	$5.37
Supplies	$718,545	$2.93	$4.89
Power	$110,044	$0.45	$0.75
Preparation cost	$612,360	$2.50	$4.17
Disposal of waste	$244,944	$1.00	$1.67
Total:	**$2,474,873**	**$10.10**	**$16.84**
Monthly Production (tons)		244,944	146,966

Labor

The hourly workforce required to operate the equipment each shift was estimated. For the RUCM unit, seven people would be needed for each production shift. These are typical manpower requirements for surface operations as well. To staff the three continuous miners and associated equipment performing development work, 29 workers would be needed for each production shift and seven workers would be needed for the maintenance shift. The total number of people needed at the face to run the mine would be 86 workers per day. Using 63 production shifts per month for the RUCM unit and 42 production and 21 maintenance shifts per month for the continuous miner units, the monthly labor cost to operate the RUCM plan totaled $588,546.

For the room and pillar mining plan, 56 workers would be needed on each production shift and seven workers on the maintenance shift for a total of 119 people needed at the face per day. Using 42 production and 21 maintenance shifts per month, the monthly labor cost to operate the room and pillar mining plan totaled $788,981.

Dividing monthly costs by clean tons produced per month provided labor costs of $4.07 per clean ton for the RUCM plan and $5.37 per clean ton for the room and pillar mining plan. Detailed labor cost estimates for each mining plan are provided in Tables A4 through A6.

Table A4. Hourly Workforce Labor Costs Required to Operate the RUCM.

RUCM Unit:	**Number of Workers**	**Hourly Rate**	**Benefits Rate**	**Hours Worked per Shift**	**Cost per Shift per Worker**	**Cost per Shift**
RUCM operator	1	$25.00	50%	9	$337.50	$337.50
Shield mover operator	2	$23.00	50%	9	$310.50	$621.00
Scoop operator	1	$22.00	50%	9	$297.00	$297.00
Laborer	1	$20.00	50%	9	$270.00	$270.00
Mechanic	1	$25.00	50%	9	$337.50	$337.50
Foreman	1	$35.00	50%	9	$472.50	$472.50
Total:	7					$2,335.50
Number of shifts per month:						63
Labor cost per month:						**$147,137**

Table A5. Hourly Workforce Labor Costs to Operate RUCM Development Units.

Development Units:	**Number of Workers**	**Hourly Rate**	**Benefits Rate**	**Hours Worked per Shift**	**Cost per Shift per Worker**	**Cost per Shift**
Development Shifts:						
CM operator	3	$25.00	50%	9	$337.50	$1,012.50
Battery ram car operator	9	$23.00	50%	9	$310.50	$2,794.50
Roofbolter operators	6	$23.00	50%	9	$310.50	$1,863.00
Laborer	3	$20.00	50%	9	$270.00	$810.00
Scoop operator	3	$22.00	50%	9	$297.00	$891.00
Mechanic	2	$25.00	50%	9	$337.50	$675.00
Electrician	1	$25.00	50%	9	$337.50	$337.50
Foreman	2	$35.00	50%	9	$472.50	$945.00
Total:	29					$9,328.50
Number of shifts per month:						42
Labor cost per month:						**$391,797**
Maintenance shifts:						
Roofbolter operators	2	$23.00	50%	9	$310.50	$621.00
Scoop operator	2	$22.00	50%	9	$297.00	$594.00
Mechanic	1	$25.00	50%	9	$337.50	$337.50
Electrician	1	$25.00	50%	9	$337.50	$337.50
Foreman	1	$35.00	50%	9	$472.50	$472.50
Total:	7					$2,362.50
Number of shifts per month:						21
Labor cost per month:						**$49,613**
Total labor cost per month:						**$441,410**

Table A6. Hourly Workforce Labor Costs to Operate the Room and Pillar Mining Plan.

	Number of Workers	**Hourly Rate**	**Benefits Rate**	**Hours Worked per Shift**	**Cost per Shift per Worker**	**Cost per Shift**
CM Production Shifts:						
CM operator	6	$25.00	50%	9	$337.50	$2,025.00
Battery ram car operator	18	$22.00	50%	9	$297.00	$5,346.00
Roofbolter operator	12	$23.00	50%	9	$310.50	$3,726.00
Laborer	6	$20.00	50%	9	$270.00	$1,620.00
Scoop operator	6	$22.00	50%	9	$297.00	$1,782.00
Mechanic	4	$25.00	50%	9	$337.50	$1,350.00
Electrician	1	$25.00	50%	9	$337.50	$337.50
Foreman	3	$35.00	50%	9	$472.50	$1,417.50
Total:	56					$17,604.00
Number of shifts per month:						42
Labor cost per month:						**$739,368**
Maintenance Shifts:						
Roofbolter operator	2	$23.00	50%	9	$310.50	$621.00
Scoop operator	2	$22.00	50%	9	$297.00	$594.00
Mechanic	1	$25.00	50%	9	$337.50	$337.50
Electrician	1	$25.00	50%	9	$337.50	$337.50
Foreman	1	$35.00	50%	9	$472.50	$472.50
Total:	7					$2,362.50
Number of shifts per month:						21
Labor cost per month:						**$49,613**
Total labor cost per month:						**$788,981**

Supplies

Supply costs for each mining plan were estimated for roofbolts, stoppings, ventilation curtains, bits, replacement parts, lubricants and hydraulic oil, rock dust, cables, and miscellaneous supplies. These costs were totaled on a per shift basis using historical cost figures. For the RUCM plan, the monthly cost of supplies was calculated to be $439,968. For the room and pillar plan, the monthly cost of supplies was calculated to be $718,545. Dividing these monthly costs by clean tons produced per month provided supply costs of $3.04 per clean ton for the RUCM plan and $4.89 per clean ton for the room and pillar mining plan. Detailed supply cost estimates for each mining plan are provided in Tables A7 and A8.

Table A7. Supply Costs for the RUCM Plan.

Item:	**Cost per Shift**	**Number of Shifts per Month**	**Monthly Cost**
Roofbolts	$6,801.25	42	$285,653
Stoppings	$390.18	42	$16,388
Ventilation Curtain	$212.00	42	$8,904
Continuous Miner Bits	$481.50	42	$20,223
Remote Miner Bits	$240.00	63	$15,120
Replacement Parts for Face Equipment	$798.00	42	$33,516
Replacement Parts for RUCM Equipment	$266.00	63	$16,758
Lubricants and Oils for Face Equipment	$315.00	42	$13,230
Lubricants and Oils for RUCM	$105.00	63	$6,615
Rock dust	$165.00	42	$6,930
Cables and Electricals for Face Equipment	$75.00	42	$3,150
Cables and Electricals for RUCM	$25.00	63	$1,575
Miscellaneous for Face	$189.00	42	$7,938
Miscellaneous for RUCM	$63.00	63	$3,969
			$439,968
Roof bolt costs:			
Single miner unit developing panels:			
Number of bolts per row:	6		
Distance between rows (feet):	4		
Number of bolts per foot of advance:		1.5	
Cost per bolt:	$8.30		
Bolt cost per foot of advance:		$12.45	
Feet of advance per shift:		225	
Bolt cost per shift:			**$2,801.25**
Super units developing mains and submains:			
Number of bolts per row:	5		
Distance between rows (feet):	4		
Number of bolts per foot of advance:		1.25	
Cost per bolt:	$8.00		
Bolt cost per foot of advance:		$10.00	
Feet of advance per shift:		400	
Bolt cost per shift:			**$4,000.00**
Stoppings costs:			
Blocks, 8"x8"x16", dry stacked	$1.65		
Number of blocks per stopping:	125	$206.25	
Sealant (cost per stopping)	$13.50	$13.50	
Total Cost per stopping:		$219.75	
Feet of advance per stopping (average):		352	
Feet of advance per shift:		625	
Stopping cost per shift:			**$390.18**
Ventilation Curtain:			
Clear, 10 oz., rip stop (per yd²)	$2.65		
Number of yd² used per shift:		80	**$212.00**
Continuous Miner Bits:			
Bit, steel body with carbide insert	$5.35		
Number of bits replaced per shift:		90	**$481.50**
Remote Miner Bits:			
Bit, steel body with carbide insert	$4.00		

Number of bits replaced per shift:		60	**$240.00**
Estimated cost of replacement parts per shift			
Continuous miners doing development			**$798.00**
RUCM equipment			**$266.00**
Lubricants and Hydraulic Oils consumed per shift			
Continuous miners doing development			**$315.00**
RUCM equipment			**$105.00**
Rock dust used per shift			
Continuous miners doing development			**$165.00**
Cables and other electricals used per shift			
Continuous miners doing development			**$75.00**
RUCM equipment			**$25.00**
Miscellaneous			
Continuous miners doing development			**$189.00**
RUCM equipment			**$63.00**

Table A8. Supply Costs for the Room and Pillar Mining Plan.

Item:	**Cost per Shift**	**Number of Shifts per Month**	**Monthly Cost**
Roofbolts	$12,000.00	42	$504,000
Stoppings	$737.22	42	$30,963
Ventilation Curtain	$318.00	42	$13,356
Continuous Miner Bits	$963.00	42	$40,446
Replacement Parts for Face Equipment	$1,596.00	42	$67,032
Lubricants and Hydraulic Oils	$636.00	42	$26,712
Rock dust	$330.00	42	$13,860
Cables and Other Electricals	$150.00	42	$6,300
Miscellaneous	$378.00	42	$15,876
			$718,545
Roof bolt costs:			
Number of bolts per row:	5		
Distance between rows (feet):	4		
Number of bolts per foot of advance:		1.25	
Cost per bolt:	$8.00		
Bolt cost per foot of advance:		$10.00	
Feet of advance per shift:		1200	
Roof bolt cost per shift:			**$12,000.00**
Stoppings costs:			
Blocks, 8"x8"x16", dry stacked	$1.65		
Number of blocks per stopping:	125	$206.25	
Sealant	$13.50	$10.00	
Total Cost per stopping:		$216.25	
Feet of advance per stopping (average):		352	
Feet of advance per shift:		1200	
Stopping cost per shift:			**$737.22**
Ventilation Curtain:			
Clear, 10 oz., rip stop (per yd²)	$2.65		
Number of yd² used per shift:		120	**$318.00**
Continuous Miner Bits:			
Bit, steel body with carbide insert	$5.35		
Number of bits replaced per shift:		180	**$963.00**
Estimated cost of replacement parts per shift			**$1,596.00**
Lubricants and Hydraulic Oils consumed per shift			**$636.00**
Rock dust used per shift			**$330.00**
Cables and other electricals used per shift			**$150.00**
Miscellaneous			**$378.00**

Power

Power costs for each mining plan were estimated by totaling the horsepower requirements for face equipment. This number was then converted to kilowatts. The number of kW was multiplied by the number of hours utilized per shift and the number of shifts worked per month. The number kW-hours used per month was multiplied by a power cost of $0.06 per kW-hour to determine the monthly power cost for each mining method. The monthly power cost was estimated at $91,327 for the RUCM plan and $110,044 for the room and pillar mining plan. Dividing these monthly costs by the clean tons produced per month provided power costs of $0.63 per clean ton for the RUCM plan and $0.75 per clean ton for the room and pillar mining plan. Detailed power cost estimates for each mining plan are provided in Tables A9 and A10.

Table A9. Power Costs for the RUCM Plan.

Equipment	Number Required	Horsepower Required	kWatt Demand
RUCM Unit			
Remote Miner	1	750	750
Shield mover	2	150	300
Scoop	1	100	100
Chain transfer conveyor	2	100	200
Mobile Bridge Carrier	3	30	90
Bridge Conveyor	3	20	60
			1,500
Number of Hours per Month			**504**
Number of kW-hours used per Month			**563,749**
Continuous Miner Units			
Continuous miner	3	435	1,305
Battery ram cars	9	150	1,350
Roofbolter	3	100	300
Feeder/breaker	3	180	540
Scoop	3	100	300
Rock duster	3	10	30
			3,825
Number of Hours per Month			**336**
Number of kW-hours used per Month			**958,374**
Total Number of kW-hours used per Month			**1,522,123**
Power Cost per kW-hour			$0.060
Power Cost per Month			**$91,327**

Table A10. Power Costs for the Room and Pillar Mining Plan.

Equipment	Number Required	Horsepower Required	kWatt Demand
Continuous miner	6	435	2,610
Battery ram cars	18	150	2,700
Roofbolter	6	100	600
Scoop	6	180	1,080
Feeder/breaker	3	100	300
Rock duster	3	10	30
			7,320
Number of Hours per Month			**336**
Number of kW-hours used per Month			**1,834,064**
Power Cost per kW-hour			$0.060
Power Cost per Month			**$110,044**

Preparation Costs

It was determined that the RUCM should have a reject rate of 20% by being better able to stay in seam during mining. This is a historical reject rate from Superior machines working on the surface. Due to out-of-seam dilution, the room and pillar mining plan was assumed to have a reject rate of 40%, which is the average for room and pillar mines in the Illinois Basin. Thus, the RUCM plan will only have to produce 212,646 raw tons to obtain 144,598 clean tons per month while the room and pillar mining plan would need to produce 244,944 raw tons to obtain 146,966 clean tons per month. A preparation cost of $2.50 per raw ton was used to calculate the monthly preparation cost of $531,615 for the RUCM plan and $612,360 for the room and pillar mining plan. Dividing these monthly costs by the clean tons produced per month provided preparation costs of $3.68 per clean ton for the RUCM plan and $4.17 per clean ton for the room and pillar mining plan.

Disposal Costs

Costs to dispose of preparation plant wastes for both mining plans were estimated. Given the different reject rates, the RUCM plan should produce 68,048 tons of processing waste per month while the room and pillar mining plan should produce 97,978 tons of processing waste per month. A disposal cost of $2.50 per ton was used to calculate the monthly disposal cost of $170,121 for the RUCM plan and $244,944 for the room and pillar mining plan. Dividing these monthly costs by the clean tons produced per month provided waste disposal costs of $1.18 per clean ton for the RUCM plan and $1.67 per clean ton for the room and pillar mining plan.

Results of Cost Comparison

A mine plan was developed using the RUCM to mine 85,000 raw tons per month and three continuous miners to develop mains and RUCM panels mining an additional 127,596 raw tons per month. This RUCM mining plan would require a total of 86 workers at the face each day, working five days a week. Because the RUCM unit requires fewer workers than the development units, worker productivity was determined separately as 21.4 raw tons per miner hour for the RUCM unit as compared to 5.5 raw tons per miner hour for the continuous miner development units.

Monthly clean coal production from four mining machines in the RUCM plan was then compared to production from a typical room and pillar mining plan. The room and pillar mining plan needed six continuous miners to produce an equivalent amount of clean tons. When this amount of clean tons was converted to raw tons at the lower yield expected from the room and pillar mining plan with just continuous miners, 245,000 raw tons per month was required from the room and pillar plan. This plan would require 119 workers at the face each day, working five days a week. Productivity was 5.6 raw tons per miner hour.

The economic analysis indicates the RUCM plan will save more than $650,000 per month over the room and pillar mining plan for the conditions described in this report. The bulk of this savings comes from labor and supplies, with smaller amounts being realized in the other cost categories as shown in Figure A1.

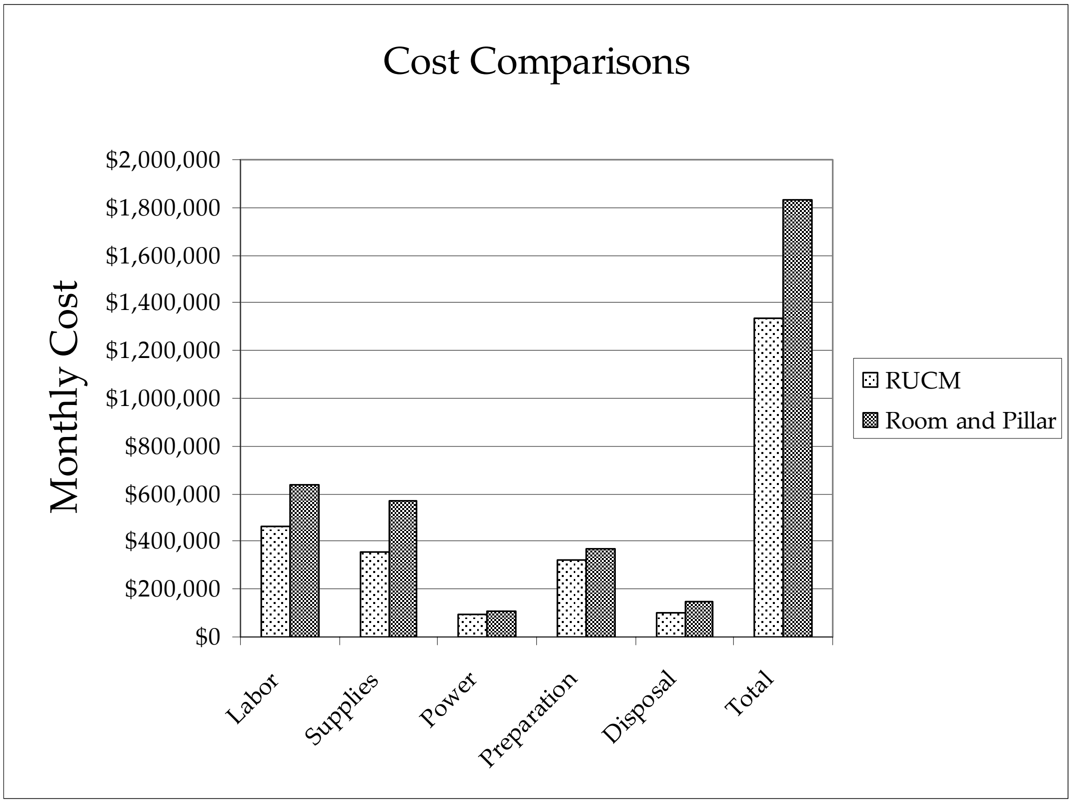

Figure A1. Monthly Costs by Category for Two Mining Plans