University of Wollongong

Engineering Manufacturing

Final Report
ACARP PROJECT C17018 – Stage 1

AUTOMATED BOLTING AND MESH HANDLING ON A CONTINUOUS MINER

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OPEN REPORT

Contents

List of Figures

List of Tables

Appendix 1

Appendix 2

1 ABSTRACT

Roadway development in underground coal mines is a unique process. The methods used to extract coal and support the exposed strata have evolved over the past century in a way that has taken the fundamentals of major machinery and incrementally modified the designs and processes to make limited improvement. As a result the process has become very restrictive for further innovation; especially in the areas of automatic operation and control. The existing machinery used to support operations has been specifically designed to accommodate the harsh and challenging environment that it operates within and any changes to their fundamental design can be counterproductive to increased output.

Subsequently, today's roadway development rates are failing to keep pace with modern longwall systems, and the methods currently used are proving to be inadequate if the industry is to progress to higher and more profitable production. Through a series of industry surveys, the bottlenecks which restrain improved production and safety of operators, have been identified and the manual strata support activities on a continuous miner have been acknowledged to be a major contributor to these constraints.

This project has developed prototype automatic machinery to be used in a set of laboratory surface trials that demonstrate a solution to automatic primary strata support on a continuous miner. A retrofit approach has been used to limit the amount of project risk in adversely affecting the fundamental operations of continuous miner equipment. The automation developed includes roof/rib bolt and mesh handling manipulators as well as plate handling equipment.

Successful results indicate that a satisfactory solution for automatic control and manipulation of roof and rib support materials has been achieved and that the designed machinery can be potentially used to support and improve cycle times in an underground production environment. Prototype designs and simulation have significantly reduced the technical risk in proceeding forward. When taken to full fruition, cycle times, and therefore overall development rates, are expected to be improved inline with the target of 10 metres per operating hour.

The results of this project have completed the first step of progressive stages whereby the next phase consists of full underground trial of automation equipment by end 2012.

2 EXECUTIVE SUMMARY

This project aims to contribute to the Australian underground coal Industry's vision to achieve rapid roadway development production rates from a continuous miner of at least 10 metres per operating hour and utilisation rates of 20 hours per day. A key enabler of this vision includes the automation of the primary roof and rib support activities associated with roadway development. This project draws together a system integrated into a continuous miner platform that when taken to production will fully automate the process of self loading and installing rib and roof bolts as well as steel mesh or other alternative roof confinement material, including the associated materials handling systems.

Result from a laboratory demonstration have confirmed that there is at least a solution for automated roof and rib support activities and that the achievable cycle times are consistent with higher development rates. The results now allow the laboratory test facility to be redesigned for a more substantial trial within an underground production environment.

2.1 Project Objectives

The overall objectives of this project are to improve roadway development rates in longwall mines by reducing primary roof and rib support cycle times whilst reducing the exposure of personnel to injury in the immediate face area by automating the primary roof and rib support process. Specifically, the project aims to find solutions which:

- adapt the Self Drilling Bolt (SDB) one shot drill and encapsulation process to the continuous miner bolting platform;
- further improve the cycle times achieved by SDB by automating the insertion of drilling/bolting consumables within the installation process at the drilling machine;
- automatically present, manipulate and fix steel mesh or alternative roof confinement material to the unsupported roof and ribs during the automated drilling/bolting process;
- provide sufficient automation that will remove the operator from the immediate face area;
- demonstrate the operation of such automation on a Laboratory Test Unit, representative of roadway development continuous mining machinery.

This project builds upon the recent advances of SDB technology by manipulating consumables on a continuous miner. The time saving benefits of a complete system will be realised from three distinct operations which include; 1) the transportation, storage and delivery of consumables to the development face and interface of the continuous miner with little or no disruption to the roadway development process; 2) the automatic retrieval and insertion of consumables by the drilling and meshing system during the roof support sequence; and 3) the integration of the manipulation sequences into other automation processes occurring on the continuous miner – such as coal cutting, CM steering and auto drill cycles.

The project also exploits existing technology from other industries to use the latest advances in industrial automation and robotic technology to deal with the specific challenges of the underground coal mine environment. Some of these challenges include:

- using sensors, actuators, manipulators and controllers that are compatible with vibration, gaseous, dusty and/or wet conditions;
- developing a cost-effective system within the confined space limitations of the continuous miner and the immediate area surrounding each drilling machine;
- creating a robust system whose component design ensures machine reliability and longevity;
- designing for easy operation and maintenance;
- integration of control systems into a common automation protocol.

2.2 Main Findings and Conclusions

The results of this project have identified a solution for automating several manual handling task performed on the continuous miner as part of the process of strata support. The engineering design and laboratory testing has significantly reduced the technical risks associated with bringing automation to fruition within the production process.

Through a series of preliminary site visits and industry forums, researchers of the project and participants from industry have been able to gain a better understanding of the constraints associated with the roadway development process, as well as a consideration for technologies used in other industries (many non mining).

This project has given the Roadway Development Task Group a better understanding of the requirements needed to automate the development process. It is anticipated that from the main findings of this project that further modification of the laboratory equipment can be confidently made so that more detailed underground trials can be carried out.

The results also define further constraints for a future automated system, such as the standardisation of consumables, the tight control of consumable condition and the preferred requirement of pneumatic services at the face. It also defines safety or no-go zones on the continuous miner that that would need to be controlled during a production environment.

The results have identified critical interface points at the rear of the continuous miner for where consumables are supplied to the onboard automation equipment. This constraint also affects how materials are handled and presented downstream of the cutting process and all the way to the mine surface.

Finally, this work has identified the potential time savings that can be achieved through automated repeatability. The cycle times for each modular section of the automation are well defined and further refinement can be made through future small incremental design changes.

This work concludes the objectives set for Stage 1 – Automated Bolting and Mesh Handling on a Continuous Miner, and creates a foundation for Stage 2 of this project which is described in the following section, Future Work.

2.3 Industrial Applications

This Stage 1 project has specifically designed automated equipment with the intent to apply the technology to the industrial process of Roadway Development. However, the systems developed and manufactured to date represent a prototype example of a potential solution, and in its current form does not satisfy the strict regulatory approval for underground use.

For the proposed future work (see Section 5) an underground trial has been planned to use the results of this report, and constructed hardware, to progress the concept to an industrial application. It is envisaged that the results of the underground trial will be sufficient for an independent Original Equipment Manufacturer/s to incorporate the findings into commercial equipment.

3 RECOMMENDATIONS

Because of the achievements of Stage 1 project C17018, it is recommended that the project be extended to an underground trial. The purpose of the underground trial is discussed in detail in Section 5 – Future Work. Secondly, it is recommended that the focus of the automation equipment should now extend beyond the immediate continuous miner and include the entire development panel, the required systems used to support the automation, and the integration of other automation technologies such as continuous miner self steering [3], and continuous haulage.

4 DESIGN FOR AUTOMATION AND CONTROL

4.1 Introduction

Historically, growing longwall production rates have not been matched by roadway development rates and attempts to introduce new roadway development technologies during this time have largely failed. In 2005 Australian Coal Association Research Program (ACARP) recognised the longwall continuity challenge and subsequently established a Roadway Development Task Group (RDTG) to develop a roadmap for targeted R&D to improve roadway development performance.

This project forms part of the overall plan and helps to recognise the issues relating to increased roadway development rates by identifying specific opportunities for new technologies, equipment and associated systems. Specifically, automation is thought to be key to alleviating several constrained manual handling tasks typically used in mines development.

As part of a cooperative research study involving seven mine companies, ACARP and the University of Wollongong, it was agreed that a preliminary scoping study should be undertaken from September 2007 to March 2008 to establish some of the technical risks and engineering barriers to the design of a fully automated bolt and mesh handling system.

Ten mine sites were identified to be of particular significance with regard to providing the best exposure of a range of mine conditions, machinery used and mine practice. Of the ten mines, six were in New South Wales and four in Queensland. Table 1 below lists the mines visited.

The visits were conducted over a three week period from 30th August to 20th September 2007. Each visit was carried out under the guidance of either frontline or middle management including Panel Deputies, Under-Managers or Development Coordinators/Superintendents.

In order to establish where (if any) technical risk may lie, each mine visit focused on targeting key observations. These included:

1. Strata and general mining conditions and specific mine challenges.
2. Method of material handling encompassing surface to face logistics and in-bye consumable storage and loading; including use of monorail, pods, racks etc.
3. Type of mining machinery, operational standards, robustness and reliability, and specialised modifications.
4. Roof and rib support standards for both mesh and bolts.
5. Perceived workforce culture including a willingness to engage and contribute to conversation, level of foresight, constructive feedback, individual ownership of the process, reactions to suggestions of change and improvement etc..

4.1.1 Mine Machinery and Process Variation

The selection of mine sites gave a cross section of the types of mining conditions, machinery and workforce culture. In many instances, there was high variability in mining conditions for the same process. This was mostly the result of geotechnical reasons. However, many of the mines visited with similar conditions also had differing machinery, standards, consumables, frontline management structure, workforce etc. All of these variables were identified as likely to influence the success of any automation developed within this project.

<u>Adverse Mining Conditions</u> - This was particularly the case for those mines having low coal strength, high horizontal stress or faults, water ingress etc. In these instances support standards and cutting cycles need to be continually adjusted to suit the changing conditions at any one time.

Specialist designed equipment was generally required to adapt to the unique conditions of these mines. Faults such as guttering, potting, rib slumping and cavities were difficult to predict and control and additional process operations, such as secondary auguring, spot bolting, tendon insertion, mesh forming etc. were often required during these fault zones.

Colliery	Company	Location	Entry	Miners	Strata Condition
Dendrobium	BHP Billiton	Mt Kembla NSW	highwall	ABM20	moderate
West Cliff	BHP Billiton	Appin NSW	trolley car	12CM30	moderate with gas
Beltana	XStrata	Hunter Valley NSW	highwall	12CM12	very good
Austar	Yancoal	Cessnock NSW	trolley car	ABM20 ABM25	very poor
Angus Place	Centennial	Lithgow NSW	trolley car	12CM30	poor
Springvale	Centennial	Lithgow NSW	drift	12CM30	poor
Crinum	BMA	Emerald QL	highwall	ABM25 12CM12	very Good
Grasstree	Anglo Coal Capcoal	Middlemount QL	shaft & cage	12CM32	good to very good
North Goonyella	Peabody	Nth Goonyella QL	drift	ABM25 ABM20	good
Northern Underground	XStrata	Newlands QL	highwall	12CM12	very good

Table 1 - List of mine sites observed.

For high gas and high water mines, it is likely that more stringent restrictions would be placed on the use of electrical equipment or sensors in an automated device. This would of course limit the possibilities of what types of automation equipment and services can be practically used.

Machinery Preferences - In all the ten mines visited, only JOY® and Sandvik® miners were used. However, several variants of these miners existed with some of the variations listed below:

- Vastly different frame sizes including platform layouts, machine height, machine length and consumable storage.
- Different cutting and sumping cycles depending if the machine was a Bolter Miner or Miner Bolter.
- Auto bolters or manual bolter control.
- Cram® or Hydramatic® type bolters with 90 degree or zero degree loading.
- Single or double roof bolters with static, traverse or forward tilt function.
- Temporary Roof Support (TRS) or no TRS.
- Proximity of the shovel in relation to the bolters.
- On board ducting.

Each mine appeared to have a preference for the make and model of miners used. This was usually dependant on the cutting conditions. In many instances the preference for machinery was purely subjective. Those mines that modified their machines for more automated functions, tended to modify Sandvik/Voest Alpine ABMs® (Alpine Bolter Miner). For more robust bolting functions, operators noted that JOY 12CM machines were preferred because of greater platform space, bolter placement and flitting ability. For many other sites, robustness and operation uptime was a serious concern for some older ABM machines. In most cases the geotechnical conditions and associated cutting cycles (discussed next) dictated the preference of machinery.

Other machinery preferences included the number and make of shuttle cars used and the sequencing of movement.

Cutting Cycle - The cutting cycle for most of the ten mines differed considerably depending on the type of machinery used and the mining conditions. The choice of miner is often determined by the process either being bolting or wheeling constrained. Those mines using ABMs and a Bolter Miner cycle were more likely to be restricted to 1.5 metre sump in cuts while JOY® miners were likely to cut several metres before flitting back and bolting. This cycle affected the logistics of material loading and storage on the machine. The ABMs were reportedly difficult to flit back and forth due to their physical size and mobility. The height of the machine and fixed onboard ducting often made it difficult to flit back past pre-installed rigid vent ducting.

From a survey conducted by Gibson and Associates [1] it was found that typical cutting rates for Australian underground roadway development are between 1.5 to 2.5 metres per operating hour, with best practice mines achieving average cutting rates of 5 metres per operating hour. Mines achieving lower rates were commonly bolting constrained whilst those higher developing rate mines, wheeling constrained issues dominated the cutting cycle.

<u>Bolt Pattern</u> – Almost every mine observed used a variation in the bolting pattern for both ribs and roof. For mines having adverse conditions and high density bolt patterns, it was common to install longer flexible tendon bolts using additional hand held machinery. For mines with poor rib structure, point anchors replaced fully encapsulated spin rib bolts.

The length of rib bolts differed from mine to mine depending on rib conditions. Those using longer bolts required telescoping drill bits with a two pass drilling process.

<u>Consumable Selection</u> – Several different types of roof support materials are used from one mine site to another. These include varying types of bolts used, mesh size and wire aperture, mesh orientation (strand up or strand down) and most notably, numerous designs of washer plates. In specific instances there are legitimate reasons for particular design to be used, but in most instances, the variation in consumables was a personal choice rather than for any engineering reasons.

<u>Logistics</u> - Most mines used Load Haul Dump Quick Detachable Systems (LHD-QDS) attachments to load consumable pods on the rear of the miners. For very high production mines, it was noted that materials are routinely loaded manually by hand in order to maintain production at higher rates.

Most storage containers of consumables were kept out-bye in the gate-roads or in the closest cut through. For mines using rigid ducting, it was common to see LHDs with a front end QDS bucket transporting stacks of ducting in-bye when the process permitted.

At one mine, small cut outs of approximately 3m deep and 5.8m wide were used to store the electrical transformer box and service cabling ready for the next panel extension. In most cases operators did not believe it would be in the best interest of productivity to be creating small cut-throughs to aid automation services and mass bulk material out-bye storage.

Currently, only one Australian mine is reportedly using continuous haulage for pillar extraction and no longwall mines are currently using this technology. When using continuous haulage, it is apparent there may be some opportunities in using the flexible conveyor system to store or convey bulk materials to the miner machine as well as providing other parallel services.

<u>Seam Height</u> - In most instances seam height was between 2.5 and 3.5m with some mines cutting more coal than was needed to suit the inherent design of the employed continuous miner. In some cases, the seam height and higher ABM machines made it difficult to load bolt and mesh materials. In at least three observed mines with lower roof heights, special QDS cantilevered jibs were used to load mesh and material pods to the miners.

In several observed instances, the slight reduction in roof height prevented the overhead mesh storage rack from being used at all. This meant that sheets of mesh are stored in the roadway against the ribs and had to be handled from the rear of the machine over to the bolter's timber jacks, one at a time. This appeared to place considerable strain on the operator's upper body and forced the operator to have to traverse along the length of the machine, disembark before re-embarking with a new mesh and returning to the front of the machine.

<u>Work Force Culture and Management Standards</u> - One of the major sources of variation observed between mine sites was workforce culture. In the limited time frame of the visits, there still appeared to be a direct connection between high morale, positive can-do attitude, process ownership, and a willingness to engage in constructive and hospitable conversation, with those mine sites that achieve

consistently good production rates. These mines also appeared to have well defined leadership with staff who could identify opportunities for improvement.

Mines that appeared to have good coherent coordination were also rewarded with higher production rates. This was reinforced by management personnel of good producing mines making the effort to involve the workforce in understanding and documenting all processes so they could be properly managed when faced with geotechnical and workforce variation.

4.1.2 Summary of Engineering Challenges

Several engineering technical challenges have been identified; initially from the mine site visits, and further during the course of the project. These include the following:

- There is very limited space available for attaching additional infrastructure to the continuous miners in their current configuration, particularly for mines with smaller roadway dimensions.
- Variation in continuous miner models, frame sizes, and specialised configured layouts make it difficult to design generic automation equipment across all platforms.
- The restricted use of materials, and non-approved electrical, servo-control, actuation and computer processing devices.
- The significant increase in supply rates for consumables required to service a rapid roadway development process, make it difficult to use onboard storage or buffered delivery system with the existing continuous miner design. This issue is compounded when accommodating any additional self drilling bolt infrastructure required.
- Adverse environment including rock falls, dusty conditions, corrosive water ingress and vibration pose a technical challenge for the robustness of any proposed manipulation equipment, sensors etc.
- Mines, whose strata support activities are routinely modified to adapt to challenging geotechnical conditions, have high variability or high density support in their process standards and are anticipated to be difficult to automate.
- Many existing onboard services such electrical supply, hydraulics etc. would need to be modified, and new services, such as pneumatics, are required to accommodate additional automation devices.
- Interacting parallel process machinery movement within a complex, and often varying, cutting and strata support cycles.
- Very limited space for logistical movement of consumables at both the face and out-bye storage.
- Monorail and vent tube extension is currently mostly a manual role within the process and consideration for an alternative ventilation system is specific to additional machinery support such as flexible conveyers and monorail systems.
- Restricted access to Original Equipment Manufacturer (OEM) control software and basic machine design and/or modification of this basic design.
- Reduced functionality risk associated with changing the fundamental major design of continuous miners.

4.2 Project Specifications and Methodology

This project has intentionally used a strategy of designing new equipment that will be adapted to existing mining machinery and processes using a *retro-fit* approach. This means that the fundamental design of a continuous miner and its operation have not been changed, but instead slightly modified to incorporate automation equipment.

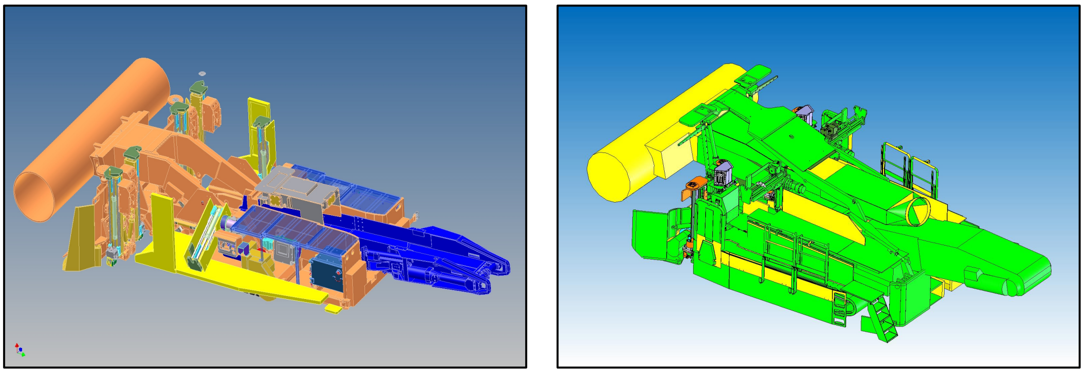
It was agreed that this retro-fit methodology would generate the least amount of technical risk to the overall roadway development process and therefore increased likelihood of technology take-up across the industry. The scope of the project could also be reduced to concentrate on a smaller set of designs for manipulation equipment that operates in parallel with other cutting cycle processes.

Due to the number of engineering challenges noted in Section 4.1.2, a series of technical specifications were developed that would control the amount of variation the automation was being designed for. This allows for a more focussed research effort towards the primary goals of the project. The automation equipment in this first instance is designed to suit the following constraints:

- mine roadway dimensions with a minimum roof height of 2.8m and minimum width of 5m;
- a strata support bolt density of 6 roof bolts and 4 rib bolts per advanced metre; and,
- the manipulation of either the Peter Gray® [2] or Hilti® style self drilling bolt (Figure 2),

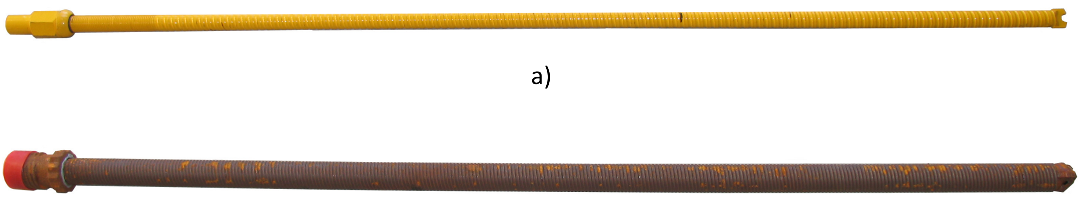
- the assumption that 6 minutes cutting and support cycles can be achieved that equate to cutting rates of 8 to 10 metres per operating hour, 20 hours per day.

For the purpose of this initial Stage 1 project, increased focus for conceptual designs was limited to two continuous mining frames; that being a JOY 12CM30/32 and Voest Alpine ABM25® continuous miner frames (See Figure 1). These frames were chosen as a result of their common use across Australia's cross section of underground coal mines.



a) b)

Figure 1. - a) JOY 12CM30, and b) Voest Alpine ABM25



a)

b)

Figure 2. – a) Peter Gray® SDB [2], and b) Hilti® SDB

To limit the scope of work of this project the design of the automation manipulation equipment has specifically been made to suit a JOY12CM30/32 frame. However, in principle each manipulator is designed to generically fit on any frame with the relevant modifications.

4.3 Machine Sequence

The machine sequence differs for the two types of continuous miner machines noted, depending if the continuous miner is designed for a bolter miner (simultaneous cut and bolt) or miner bolter (cut followed by bolt) configuration.

This difference is particularly relevant for cycle synchronisation whereby the sequence of the automation devices are required to work in parallel to other process operations. For instance, the loading of bolts and drilling sequence using the bolting rigs are tasks that can occur on a bolter miner during the cutting cycle, whereby the machine frame is stationary and rigid during this time. However, for miner bolter sequences, the cutting cycle prevents simultaneous bolting and the movement of the frame makes it more difficult to reload the drilling rigs or supporting material conveyance from the rear of the machine. Therefore, the time taken for the reloading of consumables becomes an important constraint when considering machine sequences.

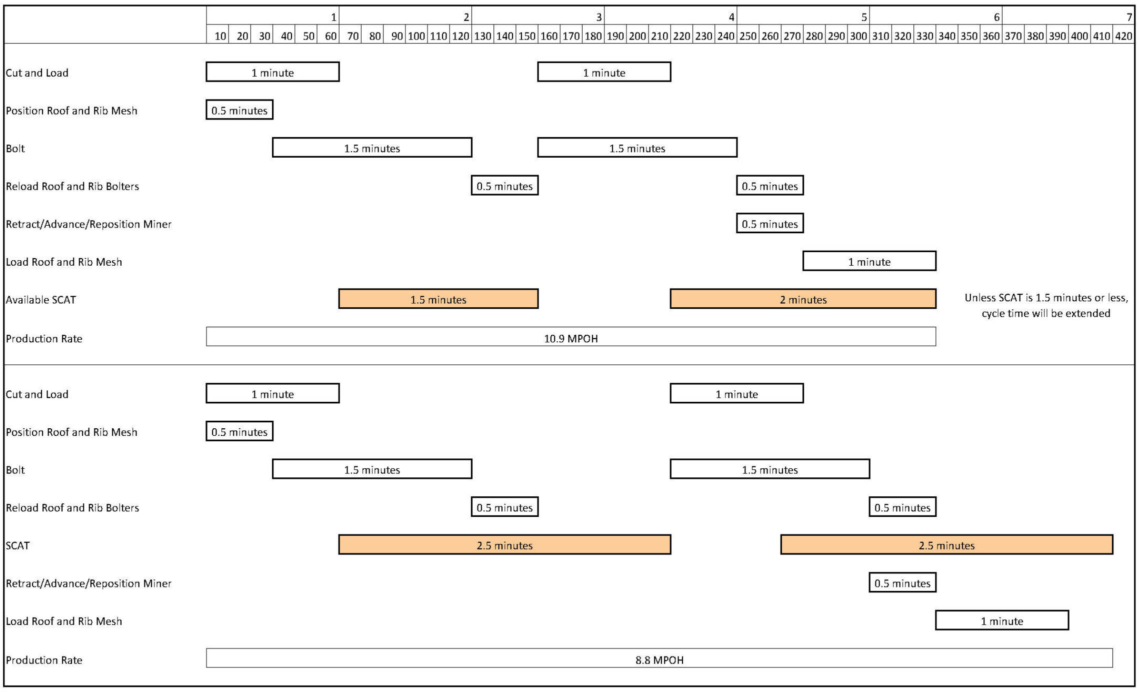


Figure 3. – Typical cutting cycle for one metre advance.

Figure 3 gives an analysis of the typical cycle time required to achieve the cutting rates for 8.8 MPOH and 10.9 MPOH. Depending on the cycle, the opportunity for reloading bolts, plates and mesh into drilling position are compressed into windows of time intervals which are discussed in Sections 4.5.2 and 4.6.3.

4.4 Materials Storage and Loading

Several issues are apparent when analysing the optimum method for storing and delivering consumable materials to the continuous miner. For those mines capable of achieving rapid roadway development rates in excess of 7 Metres Per Operating Hour (MPOH) and approaching the target rate of 10 MPOH, material delivery becomes a significant challenge. It is calculated that for 10 MPOH advance, more than 1.4 tonne of consumables is required per hour (see Table 2) using the Peter Gray® SDB. When using the Hilti® SDB, the weight of material for 10 MPOH exceeds 1.6 tonne. This equates to 40 tonnes of material required to complete a pillar cycle.

It is anticipated that the increased volume of materials to be handled requires new methods for loading the continuous miner. It becomes clear from a process point of view, that the numbers of bolts and mesh required to service the rapid roadway development process would deplete the capacity of existing onboard storage methods at too greater rate for them to remain practical.

When considering the use of the Hilti® SDB, this problem is compounded due to the increased diameter of each bolt, reducing the amount able to be stored in onboard pods. For the Peter Gray® type SDB, additional pumping infrastructure and possible resin storage remain issues for the competing availability of onboard space.

Finally, the addition of any automated manipulation equipment makes it difficult to fit onboard mass storage of consumables and any equipment used to automatically dispense these. This project consciously uses a concept of significantly limiting the onboard storage of materials and therefore relies on a lean material conveyance system whereby consumables are transferred from the rear of the continuous miner up to the respective automation equipment, employing a one-in one-out approach to complete a one metre advanced cycle. This provides greater work volume for automated materials manipulation as well as conventional manual operations in non-automatic mode. Removing onboard storage also eliminates the inefficient heavy reloading of large storage pods by potentially providing continuous support of consumable replenishment out-bye of the continuous mining process.

Roadway Advance									ACARP 2011			ACARP 2020		
Operating Hours(h)	1					8			12					20
Advance/Hour (m/h)	1	3	5	10	20	3	5	10	3	5	10	3	5	10
Total Advance (m)	1	3	5	10	20	24	40	80	36	60	120	60	100	200
Roof Support														
Sheets of mesh	1	3	5	10	20	24	40	80	36	60	120	60	100	200
Mass of Mesh(kg)	29	86	143	286	573	687	1146	2292	1031	1719	3437	1719	2864	5729
Mesh stack height(mm)	12	36	60	120	240	288	480	960	432	720	1440	720	1200	2400
6 Roof Bolt Pattern														
No of Bolts	6	18	30	60	120	144	240	480	216	360	720	360	600	1200
Mass of Bolts (kg)	48	144	240	480	960	1152	1920	3840	1728	2880	5760	2880	4800	9600
Resin (l)	7	22	36	72	144	173	288	576	259	432	864	432	720	1440
4 Roof bolt pattern														
No of Bolts	4	12	20	40	80	96	160	320	144	240	480	240	400	800
Mass of Bolts (kg)	32	96	160	320	640	768	1280	2560	1152	1920	3840	1920	3200	6400
Resin (l)	5	14	24	48	96	115	192	384	173	288	576	288	480	960
Rib Support														
Sheets of Mesh	2	6	10	20	40	48	80	160	72	120	240	120	200	400
Mass of Mesh (kg)	12	37	62	124	247	297	495	990	445	742	1485	742	1237	2474
No of Bolts	2	6	10	20	40	48	80	160	72	120	240	120	200	400
Mass of Bolts (kg)	12	36	60	120	240	288	480	960	432	720	1440	720	1200	2400
Resin (l)	2.4	7.2	12	24	48	57.6	96	192	86.4	144	288	144	240	480
Total for 6 Roof and 2 Rib Bolt Support														
Mass of Mesh (kg)	41	123	205	410	820	984	1641	3281	1477	2461	4922	2461	4102	8203
No of Bolts	8	24	40	80	160	192	320	640	288	480	960	480	800	1600
Mass of Bolts (kg)	60	180	300	600	1200	1440	2400	4800	2160	3600	7200	3600	6000	12000
Resin (l)	10	29	48	96	192	230	384	768	346	576	1152	576	960	1920
Mastic (l)	9	26	43	85	171	205	341	683	307	512	1024	512	853	1707
Cataylst (l)	1	3	5	11	21	26	43	85	38	64	128	64	107	213

Table 2 – List of consumables and associated mass

4.5 Fundamental Design

In the initial stages of this project, a concept design was produced which uses a singular reprogrammable device to manipulate all roof and rib, bots and mesh - this maximises the utilisation rates of introduced equipment, yet minimises the individual items of equipment needed and therefore the workspace required. Figure 4 illustrates the concept. The illustration shows two serial linked robots that are used to both transfer mesh forward from the rear of the machine and at other parts of the process, able to pick and place drilling consumables into the respective drill rigs from a consumable dispensing unit.

Several explosion proof articulated 6 Degree of Freedom robot manipulators are commercially available. However, the payload required to be handled, and in particular the roof mesh weight, suggested the process would require a robot manipulator whose dimensions exceeded what practically suited the continuous miner and average roadway dimension. This concept is therefore unlikely to succeed using the current space available on current continuous miner platforms.

Alternatively, a more traditional automation option was expected to be more practical. The Laboratory Test Unit developed within this project, and described in the proceeding sections, required detailed design of individual electromechanical manipulators which transfer and position consumables into the correct locations ready for drilling and anchoring. There are six major manipulators that, once integrated into the Continuous Miner operation, provide a complete automation system. These are described in detail in the proceeding sections and include the following:

1. Bolt delivery system
2. Washer delivery system
3. Roof bolt manipulator
4. Rib bolt manipulator
5. Roof mesh manipulator
6. Rib mesh manipulator

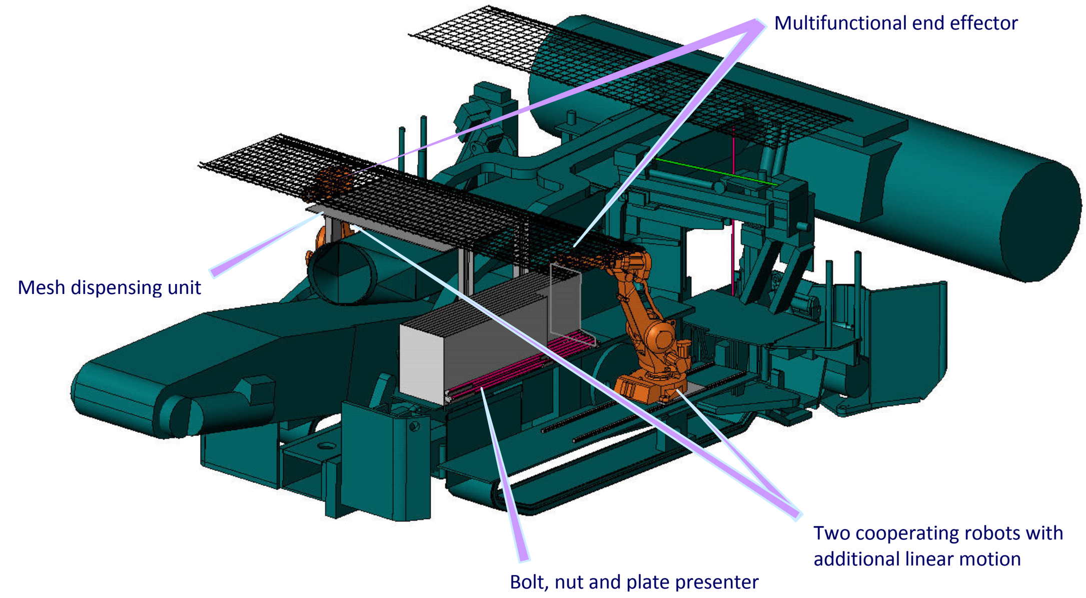


Figure 4. – Conceptual manipulation using two serial linked industrial robots.

4.6 Automated Bolt Delivery System

As discussed in Section 4.4, onboard storage of mass containment of consumables is physically not practical and an alternative approach has been taken. To assist in the controlled distribution of bolts, an automated bolt delivery system has been designed to selectively supply either roof or rib bolts to the respective bolt manipulators. The bolt delivery system also allows for a limited surge capacity of an additional two roof bolts for circumstances where additional spot bolting is required.

The bolt delivery system is top loaded with 7 bolts consisting of 5 roof bolts and 2 rib bolts. This number of bolts represents one metre advance cycle. Gravity and a series of controlled access points allow the bolts to fall onto a common centreline before being conveyed towards the front of the continuous miner. The system is positioned on either side of the continuous miner (LH and RH sides) as shown in Figure 5, and an image of the device is shown in Figure 6.

The control of the delivery system is via pneumatic cylinders for selective bolt dispensing whilst the conveyor is powered by a pneumatic rotary motor.

The supply of materials to the bolt delivery system is from a common interface point at the rear of the continuous miner. The detail of this design is covered in Stage 2 of this project and not discussed in this report.

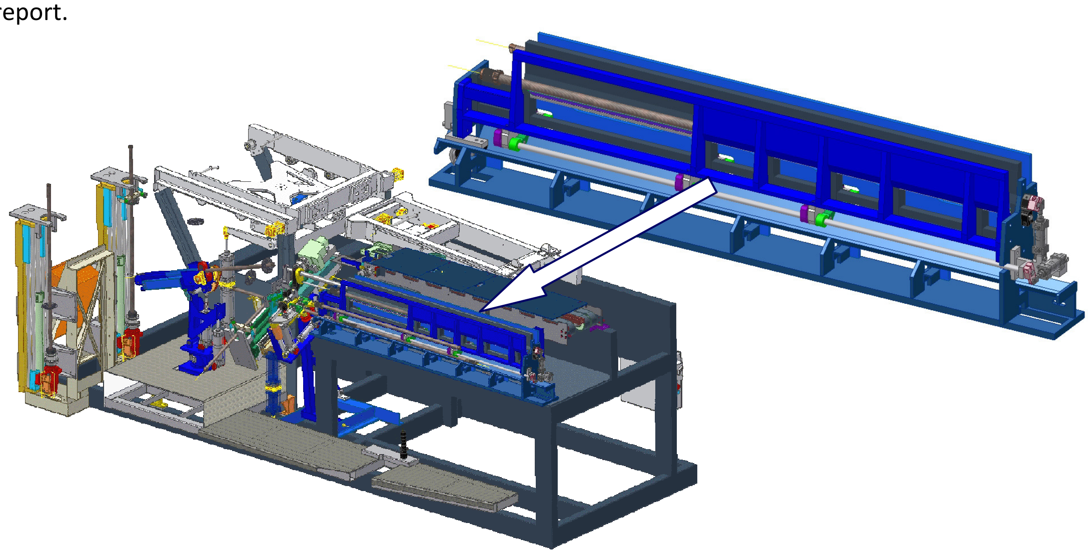


Figure 5. – Bolt delivery system location on the testing frame.

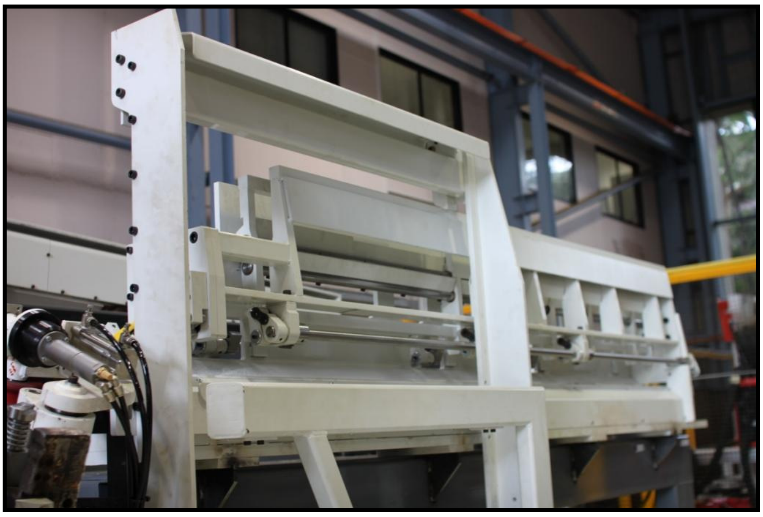


Figure 6. – Bolt delivery system

4.7 Automated Washer Delivery System

During one metre advance, several styles of washers are generally required. These include either a roof bolt washer, rib bolt washer and/or cut-able polymer washer. Furthermore, the industry currently uses several variations in style of washer and Figure 7 shows some of these. For standardisation, two steel washers adapted for the Hilti bolt were chosen for the delivery system design and one cut-table washer used.

The position of the delivery system is parallel to the bolt delivery system as shown in Figure 9. This location is in the vicinity of where historically, drill storage pods would have occupied. As shown in Figure 8 positioned height of the washer system allows onboard ventilation ducting to be designed into each side of the machine, below the washer conveyors.

Similar to bolt delivery system, the Washer Delivery System selectively dispenses the correct washer on demand. For this to occur, two conveyor lines are incorporated into the same unit which transfer washers from the interface point at the rear of the machine. One transfers a roof bolt washer, whilst the other a rib bolt washer. At the front of the delivery system (see Figure 10), a flip and grab mechanism selectively retrieves and positions each washer inline of the bolt centreline.

Once dispensed, the respective roof or rib bolt is conveyed from the Bolt Delivery System through the centre of the washer where it is captured and secured before the bolt is manipulated into the drilling rigs.

Figure 7. – Variation in washer designs used by the Australian Coal Industry

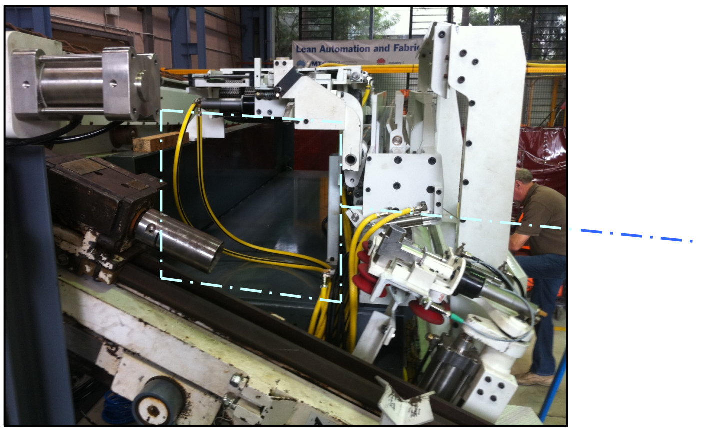


Figure 8. – Washer and bolt delivery systems located in the vicinity of existing consumable pods.

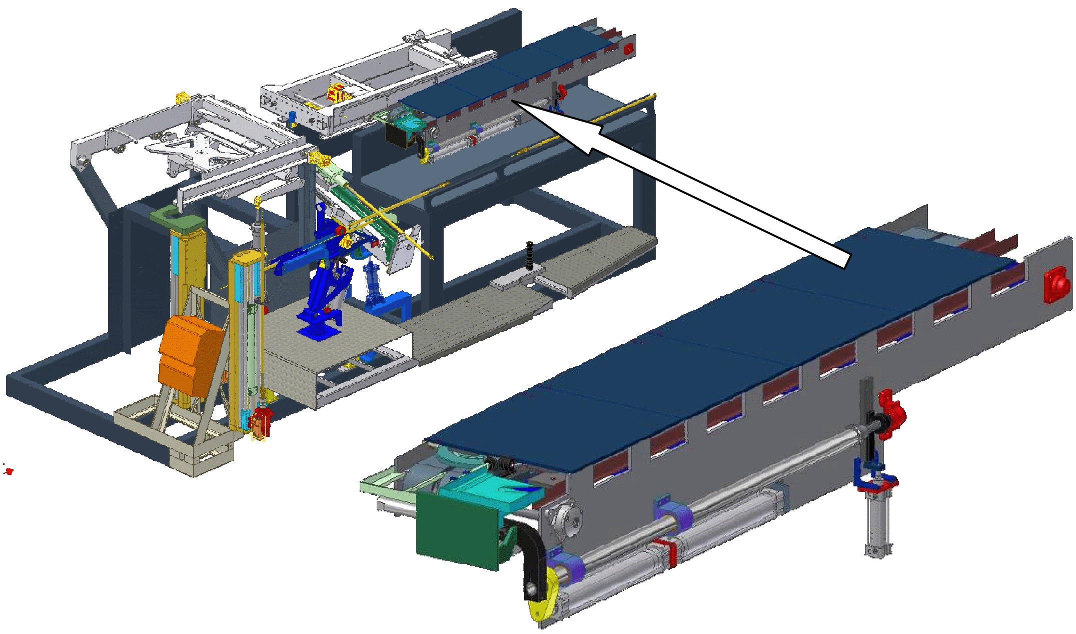


Figure 9. – Location of machine

Figure 10. – Washer Delivery System

4.8 Automated Roof Bolt Manipulator

The manual installation of roof bolts into onboard drilling rigs, represents a considerable portion of manual labour used to support the roadway development process. A skilled operator has the ability to efficiently follow a repetitious cycle of drilling and loading bolt and chemical consumables during a drill cycle. A typical drill cycle is comprised of the following steps:

1. Setting the drill rigs into position;
2. Loading the drill coupling with an adaptor dolly;
3. Loading the drill bit and collaring the hole;
4. Initiate auto drill and retract cycle;
5. Remove the drill bit and adaptor dolly;
6. Loading of a washer plate on the timber jack head plate;
7. Install a chemical resin sausage;
8. Loading of the bolt consumable into the drill chuck;
9. Initiate bolting advance and spin cycle;
10. Retract rigs.

By using a self drilling bolt, a number of these steps (2, 3, 5, 7) can be eliminated whilst the remainder of these steps can be automated and therefore relieve the operator of these tasks. The combined reduction in process steps and automation creates an opportunity to reduce drilling cycle times and eliminate operator exposure to high-powered machinery.

4.8.1 Self Drilling Bolts

Self drilling bolts provide a fundamental step in achieving high development rates. The design of the bolt allows it to be used as both the drill and roof anchor so that the drilling cycle becomes a one-shot process. This offers a time saving by eliminating the need to remove the drill from the hole before reinserting a separate bolt anchor. In reference to the Peter Gray® [2] and Hilti® bolt, a further step is removed by fully encapsulating the in-situ bolt by injecting a two part resin through an internal aperture in the bolt. This gives another time saving by eliminating the need to insert a chemical capsule. The removal of these two steps simplifies the roof support process and in doing so makes the self drilling bolt well suited to automation.

An earlier ACARP report (C15005 [1]) identified that there are five self drilling bolt systems that are currently in various stages of development for the underground coal industry. Other self-drilling bolts also exist for the civil sector that could easily be adapted - However, most are reportedly very expensive. At least three of the five bolts have been developed to a stage where they are ready to be commercially applied to current drilling practices and have been successfully demonstrated through existing ACARP projects and commercial mine site trials. The Hilti style bolt is rapidly being tested at various Australian underground coal mine sites, and several have incorporated the bolt into the mine site standards.

To reduce the risk of any competing SDB not been taken to fruition, this project has designed manipulation equipment to be as generic as possible and to accept either the Peter Gray® or Hilti® Style bolts. Although these two bolts are significantly different in diameter, the same manipulation principles can be used, as discussed later.

4.8.2 Roof Bolt Manipulator Design

Several considerations where identified as being important specifications for the design of a bolt manipulator. As mentioned, the manipulator is required to handle both the Hilti® and Peter Gray® SDB. Secondly, in the event where manual roof support installation is required, the mechanism designed is required to occupy as little volume as practical and can be removed or pushed aside from the work volume to allow uninterrupted access for operators during specific operational times. For example - manual operation may be required in difficult or high density bolting areas, such as intersections. In this example, it would be difficult to utilise automation as a result of high variability.

The design shown in Figure 12 illustrates a manipulator capable of accepting either SDB bolts one at a time. The roller feed system on the feed entry of the manipulator, allows this to occur and simplifies the linear actuation of the bolts. After a bolt is loaded, the mechanism is programmed to automatically place a bolt in either of the two vertical drilling rigs. Once the bolt is engaged in the drill rig mast, a rig mounted clamp supports the bolt whilst collaring and finally in-place drilling.

All actuation is pneumatic. This relieves the existing hydraulic system of the continuous miner of an additional demand. The pneumatic supply requires significantly less volume compared to hydraulic hosing, and the greatly reduced pressure limits the amount of force each actuator can produce in the event of unintentional movement and pinching. All components are FRAS (Fire Resistant Anti Static) rated.

Hard positioning of the manipulator is required for reproducible automatic operation. The hard stops are mounted securely in the base of the manipulator's slew rotational housing and eliminate the use of electrical sensors.

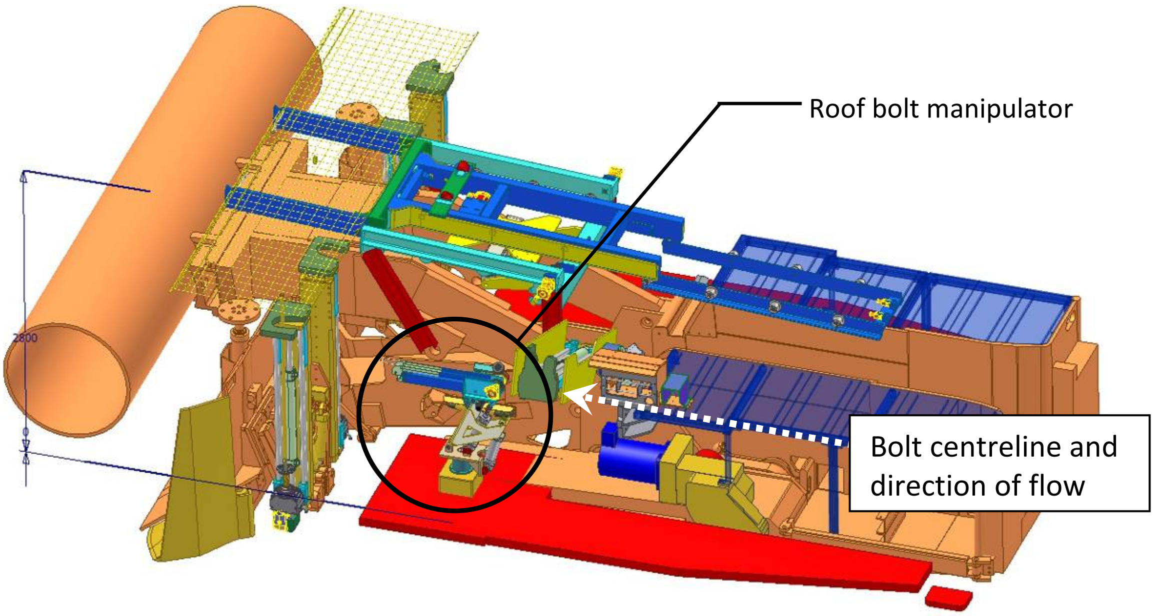


Figure 11. – Roof bolt manipulator positioned on a JOY 12CM30

The system is designed to consume as little volume as possible and is situated in an area on the continuous miner typically occupied by the bolting rig operator (See Figure 12). In the event that manual operation and loading of the drilling rigs is required, the design of the bolt manipulator allows it to be isolated, folded in on itself and pushed to the side of the work area.

For the bolt manipulator to function automatically, bolts are conveyed from the rear of the machine (Bolt Delivery System - see Section 4.6) The delivery of the bolt from the rear of the machine is expected to occur along a common centreline for both rib and roof bolts in order to reduce handling equipment. Figure 11 illustrates the bolt flow required. The cylindrical shape of a bolt allows them to be simply conveyed longitudinally using a compact polymer roller mechanism. The roller mechanism is located on the same centreline as the bolt delivery system. Figure 13 a) illustrates the roller mechanism.

For simplicity and compactness, pneumatic actuation was chosen. This reduces a number of return lines that would be required using a hydraulic system as well as preventing any additional demand on the continuous miner hydraulic pumping circuit. The simplicity of hosing and compressed air supply lends itself to quick change-outs and modification. And finally, in the unlikely event of human interaction, the injury caused by low pressure pneumatics is expected to be of a non-life threatening nature. However, the fundamental design of the roof bolt manipulators can be adapted to suite hydraulic actuation if necessary.

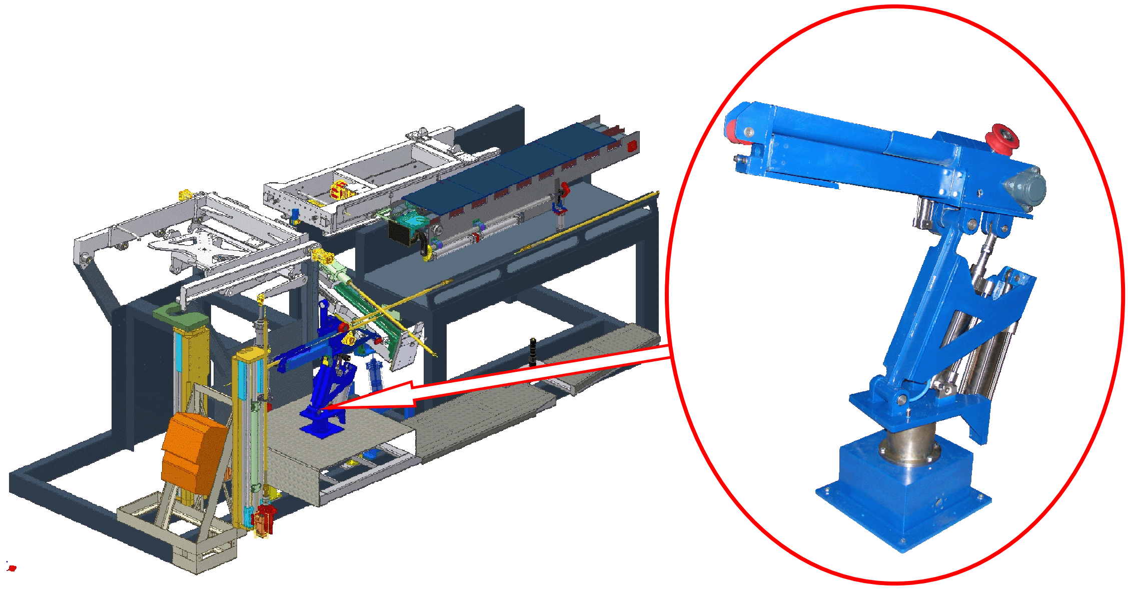
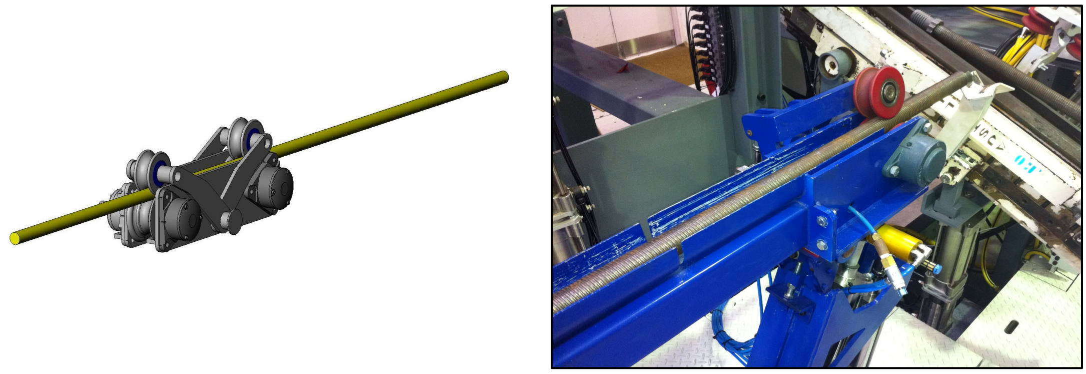


Figure 12. – Roof bolt manipulator and position on laboratory test unit.



a) b)

Figure 13. – a) Bolt roller transfer mechanism, and b) bolt being inserted into the hydraulic drilling rig.

4.8.3 Bolting Sequence

The operation of the roof bolt manipulator is simple. A single bolt is transferred from a horizontal position to a vertical position whilst simultaneously being placed into the drill chuck. For each bolt manipulator (one for each side of the continuous miner) a rotational movement of the manipulator is used to direct the bolt to each of the two bolters. Two hard stops for the rotation are used to repeatably line the end of the bolt with the drill chuck. A hard stop is also used to locate the rotation of the manipulator back to the home central position ready for the receiving of the next bolt to be installed. The loading is repeated for the adjacent bolting rig.

Operation of the roof bolt manipulator has been tested and results indicate that a single roof bolt, once conveyed into the rear of the manipulator, can be loaded into one of the two vertical roof bolting rigs as well as attaching a washer plate, within 20 - 25 seconds. This includes returning to the home position in preparation for reloading. Table 1 in Appendix 1 provides a time line for a cutting cycle required to achieve 10.9 MPOH. Each of the roof support activities have been allocated sufficient time in the cycle to achieve the desired rates.

The positioning of the vertical drill rigs can be either North-South or East-West. For loading of the rigs, the mast is returned to a home position (typically vertical) so that the bolt can be positively placed. Once located, the drill mast is titled to an angle required to drill the bolt into the correct aperture of the roof support mesh. Drilling trials using the self drilling bolts have demonstrated that fine adjustment of the drill masts to find the mesh aperture is unnecessary. Instead, the SDB is ploughed through the mesh and the spade drill bit either deflects any obstructing wire, or the drill mast deflects to an accommodating angle.

For the purpose of full automation of the drilling cycle, this project relies on recent developments of the *E-bolter* whereby both Sandvik and JOY mining have developed the next generation bolters which incorporate micro-controllers and servo actuated hydraulic valves onto the drill mast. This creates two innovations; 1) to fully automate the drilling cycle using independent and compact micro-control, and 2) replace cumbersome pedestal valves, manual valves and valve manifolds with compact mast mounted directional control and a flexible pendent controller attached by an electrical umbilical chord.

4.9 Automated Rib Bolt Manipulator

4.9.1 Rib Bolter Design

The rib bolt manipulator is designed to be as compact as possible and is located on the side of the hydraulic rib bolting rig as shown in Figure 14. The hydraulic rig requires at least a homing position for the bolt to be loaded. For this unit, the rib bolter has three positions for one bolt to be installed above horizontal and one below. The third position is the horizontal, and is used for loading the rig.

The design of the rib bolt manipulator also uses pneumatic control for all actuation. Similar to the roof bolt manipulator, the rib bolt manipulator uses a set of pneumatically controlled roller mechanisms to longitudinally convey a bolt from the common centreline.

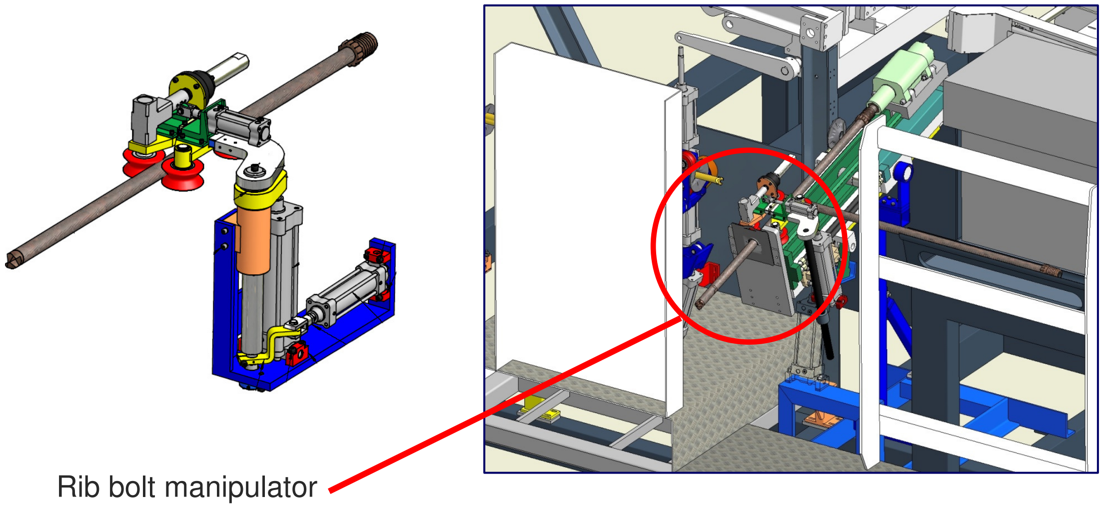


Figure 14. – Rib bolter schematic and location on the hydraulic rib bolting rig.

4.9.2 Bolting Sequence

Once a rib bolt is delivered to the rear of the manipulator, a set of rollers convey the bolt through a rib washer. The mechanism then extends horizontally upwards to swipe the washer out of a holder, before being rotated 90° inline with the hydraulic rib bolter. The bolt is then lowered into the centreline of the hydraulic rig and the roller mechanism, shown in Figure 15, feeds the bolt into the drill chuck. At this point the collected washer is simultaneously located onto a magnetic washer holding plate.

Drill clamps automatically hold and secure the bolt using a programmed movement of the hydraulic head plate. The clamps, shown in Figure 16, don't require any actuated control other than the hydraulic movement of the head plate. The clamps support the bolt during the drilling cycle and release as the drill chuck approaches the retracted position.

Each rib bolt can be loaded within 20 seconds before returning to its home position.

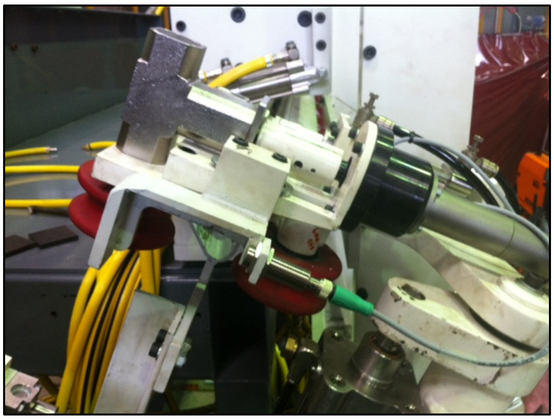
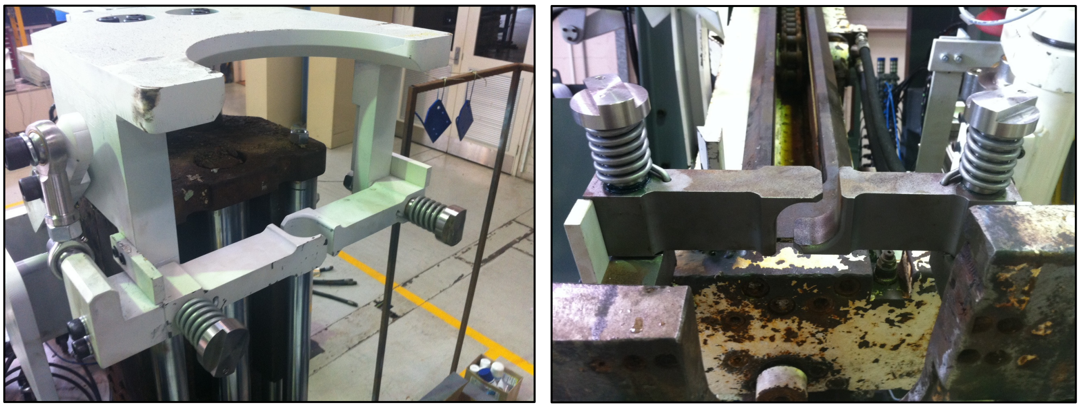


Figure 15. – Roller mechanism inline with bolt delivery centreline



a) b)

Figure 16. – Drill clamps: a) roof bolting rig, and b) rib bolting rig

4.10 Automated Roof Mesh Manipulator

Manual methods for roof mesh installation are a physically demanding and relatively constrained activity whereby mesh is typically man handled out-bye from the rear of the machine up over the centre conveyor before being rotated normal to the roadway and up onto the drill rig head plates. Alternatively for some frames, onboard storage requires mesh to be retrieved from a stack of mesh stored above the centre conveyor, rotated and placed upon the Temporary Roof Support (TRS).

Both of these processes are required to transverse the mesh forward to the drill rig operator's platform before rotating the mesh and placing it in a bolting position.

4.10.1 Process Restrictions

Several process restrictions were considered in the design of an automatic roof mesh installation manipulator.

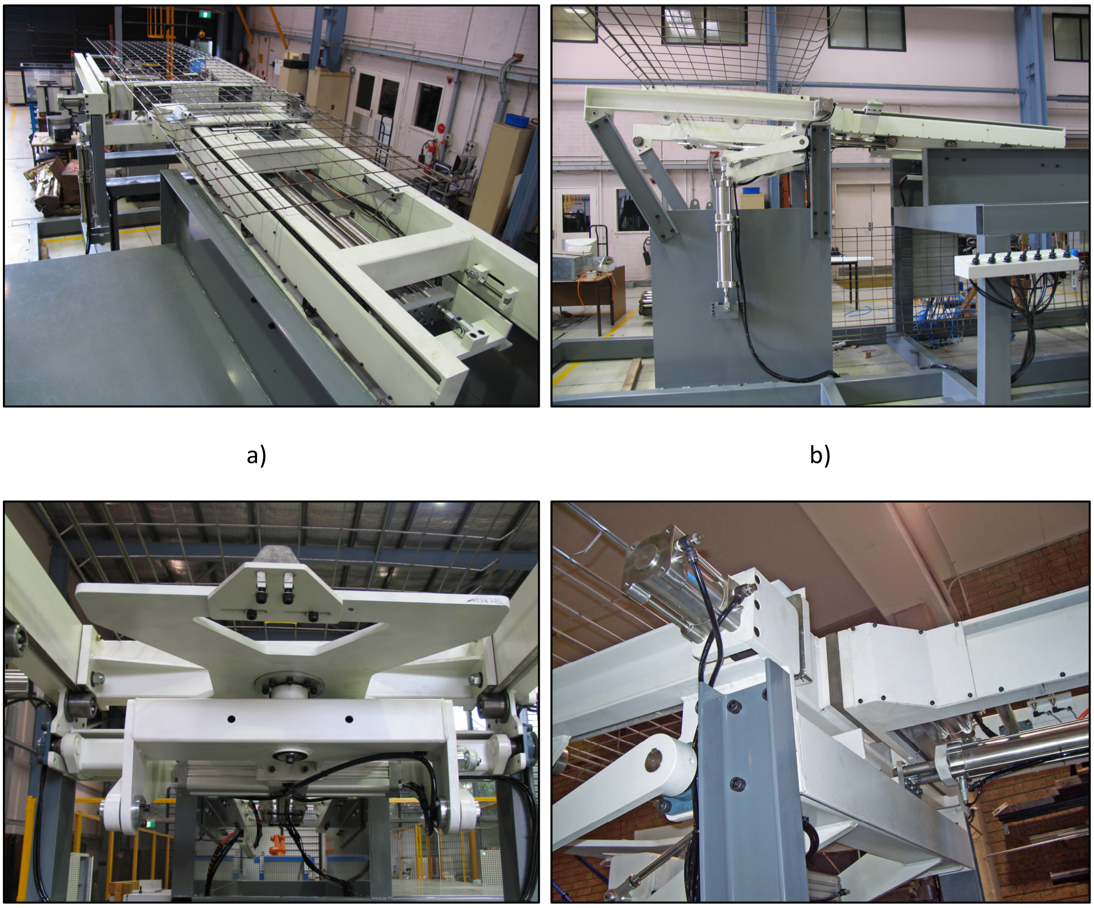
<u>On board ducting and hydraulic tanks</u> – both of these miner platform items significantly reduce the amount of available room for additional roof mesh manipulation equipment. Through consultation with industry monitors, it was decided to create additional space by modifying the central hydraulic tank (JOY 12CM30) with two saddle tanks, as well as placing on board ducting below a critical dimension.

<u>Onboard Mesh Storage</u> – early in the design it was deemed too difficult to complete a successful design solution in a cut roof height of 2.8m. The height required for a useful stack of mesh and the associated automated mechanical equipment that would dispense the mesh, far exceeds the available height. it

was therefore agreed that mesh would be transported from an interface point at the rear of the continuous miner whereby one mesh per cycle would be transferred to a roof mesh manipulator.

Rib Bolting Backslide – It was highlighted that in many mines, the capability of a rib bolter to perform a backslide operation to avoid two pass drilling would mean that some of the available room assigned to the roof mesh manipulator would interfere with backslide operations. As a result, the design of any roof manipulating equipment requires additional thought into how this space remains unobstructed during drilling.

Temporary Roof Support – For Voest Alpine simultaneous bolt and cut machines, the temporary roof support typically extends back to a pivot point approximately near the rib bolting rigs. This gives the temporary roof support additional stiffness to the mechanism but subsequently obstructs any additional equipment that can be designed around this area.



a) b)

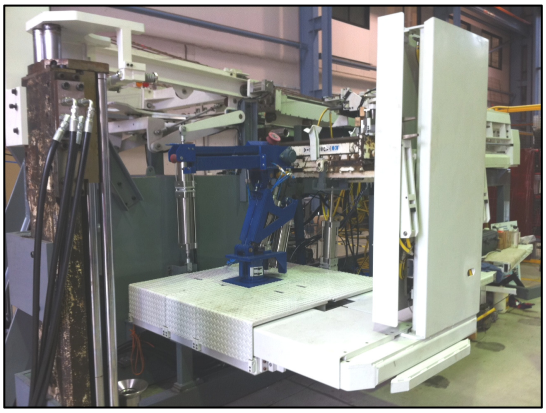
c) d)

Figure 17. – Roof Mesh Manipulator: a) top view of mesh and manipulator, b) side view of rotated mesh, c) rotational unit, and d) rear and front coupled section in closed position

4.10.2 Manipulator Design and Operation

Due to the above restrictions, the manipulator design only allows for one roof mesh sheet to be loaded and manipulated at any time. Figure 17 (a) shows a singular piece of mesh loaded but conveyed to a forward position by a chain conveyor. The manipulator is divided into two sections to allow space to avoid obstruction of the rib bolters during backslide operation. The rear section therefore simultaneously conveys the mesh forward whilst the supporting carriage extends to the front of the machine by approximately 700mm.

a)



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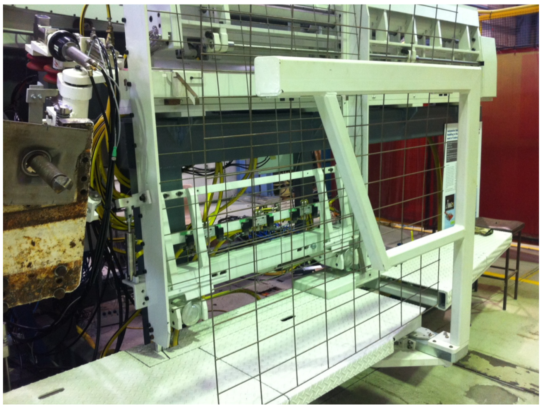


c)

d)

Figure 18. – Rib Mesh Manipulator: a) cassette dispensing unit and crash barrier, b) crash barrier in the extended out position, c) transfer arm, and d) conveyance system.

Once forward, the rear section securely couples to the front section (see Figure 17 (b) & (d)) using a pneumatically operated cam-locking and pin locating system. This allows the front section to freely move forward in latter operation.

A rotational turntable (see Figure 17 (c)) elevates and turns the mesh 90° whilst the front manipulator section transfers the mesh above the drilling rigs. Once in position, the roof bolting drilling rigs carry the mesh to the roof whilst the in-situ bolts locate through the known positions of the apertures of the held mesh. After drilling, the manipulator returns to the home position ready for the next cycle.

4.11 Automated Rib Mesh Manipulator

Similar to handling roof mesh, manual methods for rib mesh installation are a physically demanding and relatively constrained activity. Mesh is typically man handled out-bye from the rear of the machine along the side of the continuous miner before being held in place by an operator. The Rib Mesh Manipulator, replaces this manual activity using a series of integrated servomechanisms.

4.11.1 Manipulator Design

Typically, only one piece of mesh is required on each side of the miner for one metre advance. However, for the purpose of a demonstration and testing, the rib mesh manipulator has been designed to store up to 10 pieces in a storage unit. Each piece of mesh can be automatically dispensed on demand. The storage unit is shown in Figure 18 (a).

The storage unit separates a single piece of mesh onto a transfer arm (see Figure 18 (b)) whereby a set of chain conveyor located under the walkway (see Figure 18 (c)) conveys the mesh alongside the machine and in front of a modified rib crash barrier.

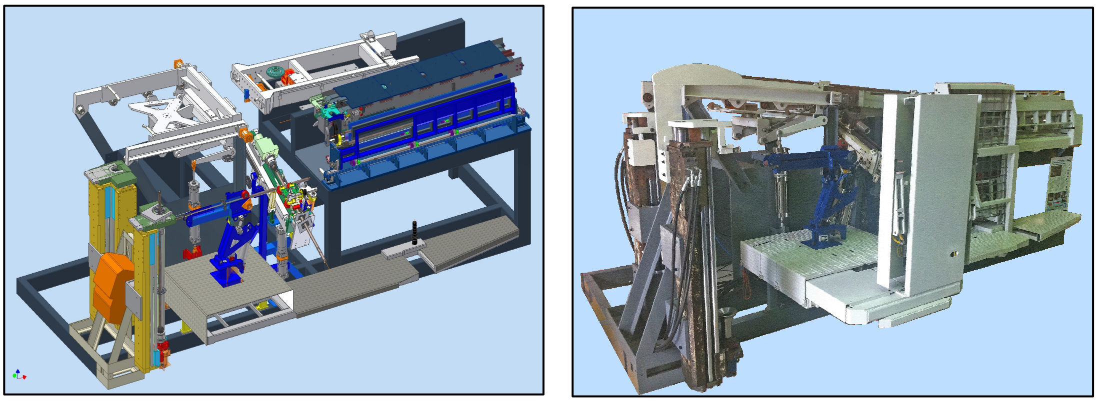
The rib crash barrier has pneumatic gripping cylinders that grab the mesh once the transfer arm has conveyed the mesh into position. Once secured, the mesh is linearly extended upwards whilst simultaneously the crash barrier extends towards the rib (see Figure 18 (d)). This allows the mesh to be positioned within the corner of the rib and roof, and prevents any fouling with existing roof and rib anchored bolts.

At this point the rib bolt is then positioned within the rib bolter and the drilling cycle commences.

4.12 System Integration

Each of the six manipulations systems described so far, are designed modular in order to function independently. However, the total system is designed to work interdependently so that a complete roof support cycle can be achieved in the most optimum time.

In some cases, each of the modular systems is required to cooperatively interact with the next. For example: - the operation of the rib bolt manipulator can only occur after the bolt and washer delivery systems have presented the consumables. Likewise, the rib bolt manipulator can only be rotated after the rib crash barrier has been extended out of the way. In other instances, many operations can occur in parallel in order to reduce the overall cycle times. The individual flow charts of each manipulator are included in Appendix 2 for reference.



a) b)

Figure 19. – Laboratory demonstration and testing unit a) CAD drawing, b) Laboratory unit

Figure 19 illustrates the integration of the complete system on a laboratory test frame for which the entire system was mounted and tested. The dimensions of the frame represent the major mounting points of a Joy 12CM30/32 continuous miner and allowed for the convenient experimentation in a laboratory setting. It also allows for easy modification of mounting points of key equipment during the course of the project. It is expected that the modular equipment can be removed and reattached to a real continuous miner platform for future underground trials.

The overall system has been designed to limit the number of sensors and interaction points with other equipment. This has been done for a number of reasons. Firstly, limiting the number of sensors reduces the risk of faulty operations. Secondly, because each system is run in a modular state, the internal operations of each other operation doesn’t require the state knowledge of individual devices and reduces the complexity of any programmed logic. Thirdly, in the event that a single module fails and makes the entire automation system inoperable, the materials and states of the other modules do not have to be reset. Instead the offending system can be individually addressed and reset.

4.13 Electrical Design and Control

In the present above ground laboratory trial, the system uses an overarching Allen Bradley SLC500 Program Logic Controller. At the time of this report, the electrical and control systems have not been designed for underground use, and will be focus activity for Stage 2 of this project.

Because all movement is pneumatic or hydraulically actuated, simple I/O is required to power a set of Direction Control Valves (DCVs).

4.14 Simulation

To assist in the understanding of how each modular system functions in respect to each other, as well as the entire continuous miner operation, Delmia V5® was used to simulate the automated process during the course of design.

Delmia® is both a graphical and time set function simulation package that allows the designer to embed 3 dimensional CAD drawings in a simulation environment. Figure 20 illustrates a model of a JOY 12CM32 continuous miner and shuttle car with the roof bolt and roof mesh manipulators operating within a cutting cycle.

Physical attributes, both static and dynamic, can be assigned to each manipulator and a series of complex movements and constraints can be tested in a time measured environment. This allows the designer to optimise interaction points, the timing of these and assesses if the overall cycle times can be achieved.

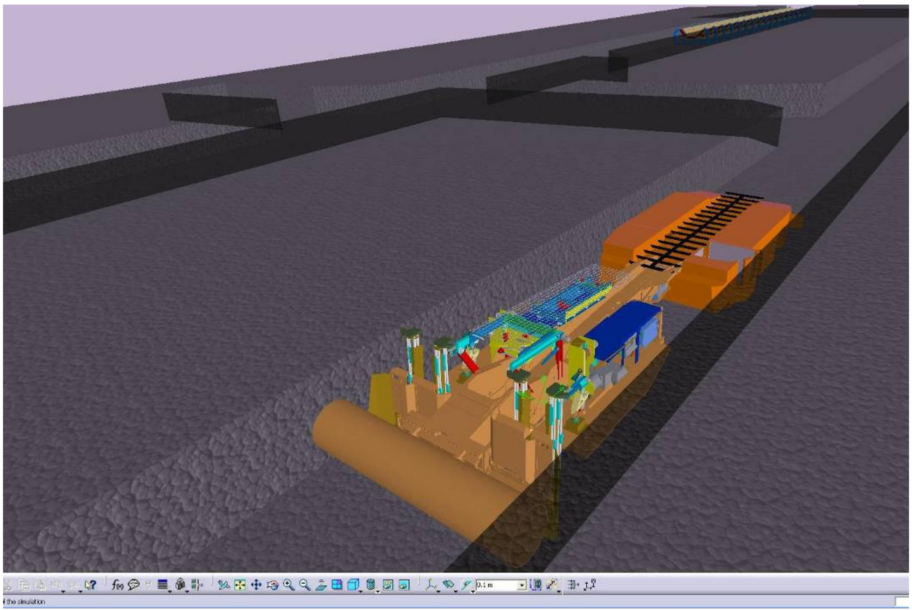


Figure 20. – Delmia V5® simulation model of the automated continuous miner and shuttle car in development panel

The simulation specifically offered the following benefits to the project:

1. At the design stage, simulated movement of the manipulators detected machinery clashes as a result of an unforeseen design faults and drawing revisions;
2. The operation of the machine was used as a valuable tool to illustrate and present to others the design concepts and scale of design; and finally;
3. Once constructed and tested, the real physic data and parameters of each manipulator and actuator could be updates to verify the model and perform further “what if” scenarios such as parallel and re-sequenced operations.

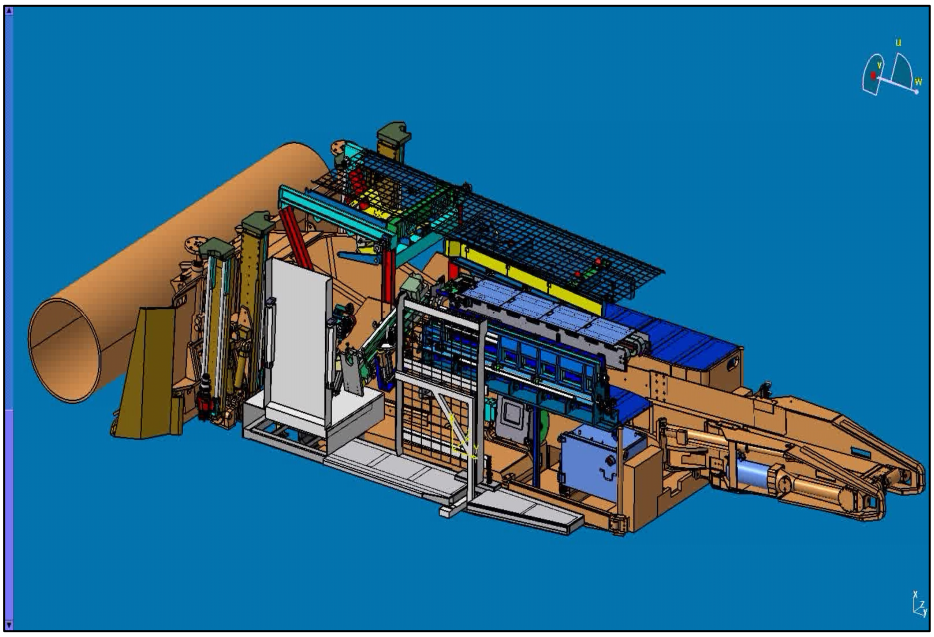


Figure 21. – Delmia V5® simulation model of the automated continuous miner
with automated manipulators

4.15 Laboratory Demonstration and Major Findings

The laboratory demonstration has shown that a solution for automated bolting and meshing is achievable. The demonstration also allowed several iterations and design revisions to be made so that a reliable and repeatable system could be developed.

Some major findings from the demonstration include:

- Automation of bolt and meshing activities is possible on a continuous miner without having to change the fundamental design of the miner platform and its operation.
- The cycle times achieved by the integrated automation are consistent with increased roadway development rates expected by the ACARP.
- An appreciation of the scale of mechanisms, actuation and control required to automate the process.
- The limitations of parallel and series operations.
- The modifications are required to suit the automation including:
    - The modification of hydraulic tanks to that of two saddle tanks.
    - The supply of compressed air to the continuous miner and coal face (although hydraulic actuation could easily be achieved with little modification to the current prototype design).
    - Interaction with cutting and bolting cycles of the continuous miner.
    - Standardisation of bolts, mesh and washers used.
    - The reorientation of the vertical hydraulic roof drilling rigs to north south.
    - Relocation of onboard ventilation ducting.
    - The use of E-Bolters for I/O control.
- An understanding of what challenges lie ahead for an underground trial.

4.16 Summary and Conclusions

The results of this project have demonstrated that the individual automation devices designed provide a solution to allow roof and rib support activities to be carried out automatically without human intervention for a one metre cycle advance.

The results also define further constraints for a future automated system, such as the standardisation of consumables, the tight control of consumable condition and the preferred requirement of pneumatic services at the face. It also defines safety or no-go zones on the continuous miner that that would need to be controlled during a production environment.

The results have identified critical interface points at the rear of the continuous miner for where consumables are supplied to the onboard automation equipment. This constraint also affects how materials are handled and presented downstream of the cutting process and all the way to the mine surface.

Finally, this work has identified the potential time savings that can be achieved through automated repeatability. The cycle times for each modular section of the automation are well defined and further refinement can be made through future small incremental design changes.

This work concludes the objectives set for Stage 1 – Automated Bolting and Mesh Handling on a Continuous Miner, and creates a foundation for Stage 2 of this project which is described in the following section, Future Work.

5 FUTURE WORK

The next stage proposes a further two year project that will expand the scope of the existing project to include further modification and improved design to allow underground trials of the system in a production environment.

This new proposed project is split into two distinct parts:

Task 1: Firstly, to build upon the outcomes of Project C17018 by further developing the prototype systems to conform to an underground production standard.

Task 2: Secondly, the design of a preferred integrated logistics system that will be used to take consumables from the mine surface to the continuous miner in a way that is conducive with high rate roadway development, and in particular, to facilitate automated bolt and mesh handling activities on the miner.

5.1 Task One

The proposed work within this part of an extended project will be conducted by the University of Wollongong as a continuance to Stage 1 - C17018.

Specifically, the objectives of this task will:

1. Define and agree upon preferred actuation and power source required for the final design of manipulation equipment.
2. Take existing prototype proof of concept bolt and mesh manipulation designs from Stage 1 and modify them to comply with safe underground intrinsically safe requirements.
    - Including the design and transfer of all control and electronics into flame proof enclosure.
    - Rewiring and installation of intrinsically safe DCV's, electric motors, FRAS rated materials etc.
3. Make any required modifications to a continuous miner platform and attach the new equipment for the purpose of underground trials.
    - SDB modifications.
    - Saddle tanks and removal of whole side platforms of the machine.
    - Automation or at least remote operation of hydraulic controls for drilling rigs.
    - Ruggedizing of high risk components, etc.
4. Integrate the control and operation of the automated bolt and mesh manipulators into the existing coal cutting process.
    - Develop a workable control operator interface.
    - Integrate automation permissives with miner operation.
5. Carry out a set of underground trials whereby the automation system is tested in conjunction with a continuous miner's operation;
6. Analyse options for batch or continuous materials delivery of roof support materials, which support automation activities on the continuous miner;
7. Design a logistics system including mechanical hardware, such as cassettes (if required), mining attachments or integrated conveyance, required to facilitate this system.

5.2 Task Two

The proposed work within this part of an extended project will be conducted by the Mining Attachments Pty. Ltd.

Task 2 is a three step process of providing concepts for a materials handling and supply logistics system that supports rapid roadway development and the automated bolt and mesh handing system. The specific activities include:

1. To clearly define the design scope of work;
2. To conduct a review of existing material handling systems in coal and civil tunnelling; and to,
3. Produce a final computer animation model to produce a conceptual design representation of the system and the interaction with the automation system.

5.3 Stage 2 Work Program

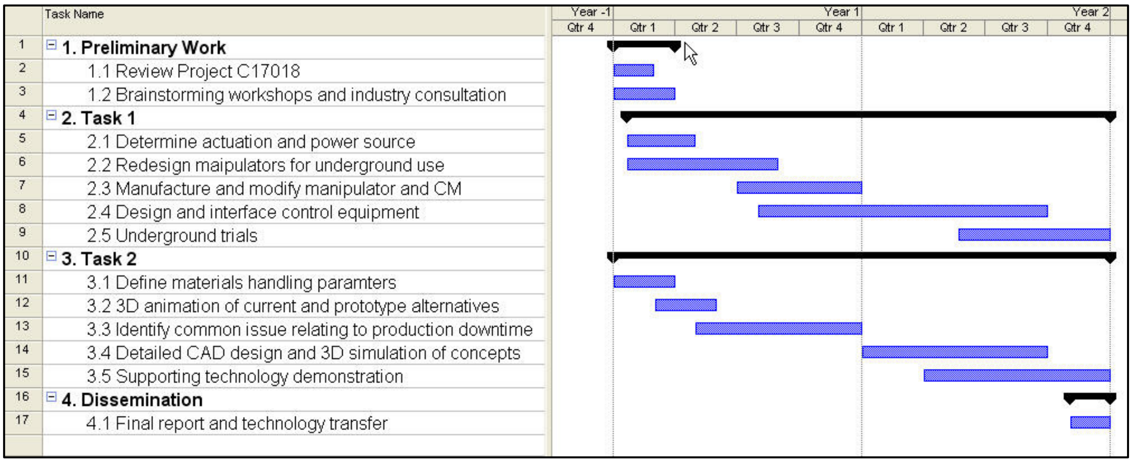


Figure 22. – Stage 2 work program.

6 Technology and Transfer Activities

As part of the requirements of ACARP funding, all research results from this project are available within the public domain. To assist in the transfer of technology and outcomes, this project has presented its findings at several industry workshops and conferences over the duration of the project.

To assist in demonstration of the technology, all industry representatives, including original equipment manufacturers, have been invited to view the Laboratory Test Unit situated within the University of Wollongong.

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Web: www.uow.edu.au		Web: www.uow.edu.au

7 Acknowledgements

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Particular acknowledgement and gratitude is given to Gary Gibson and Associates for his continued in-kind support and leadership.

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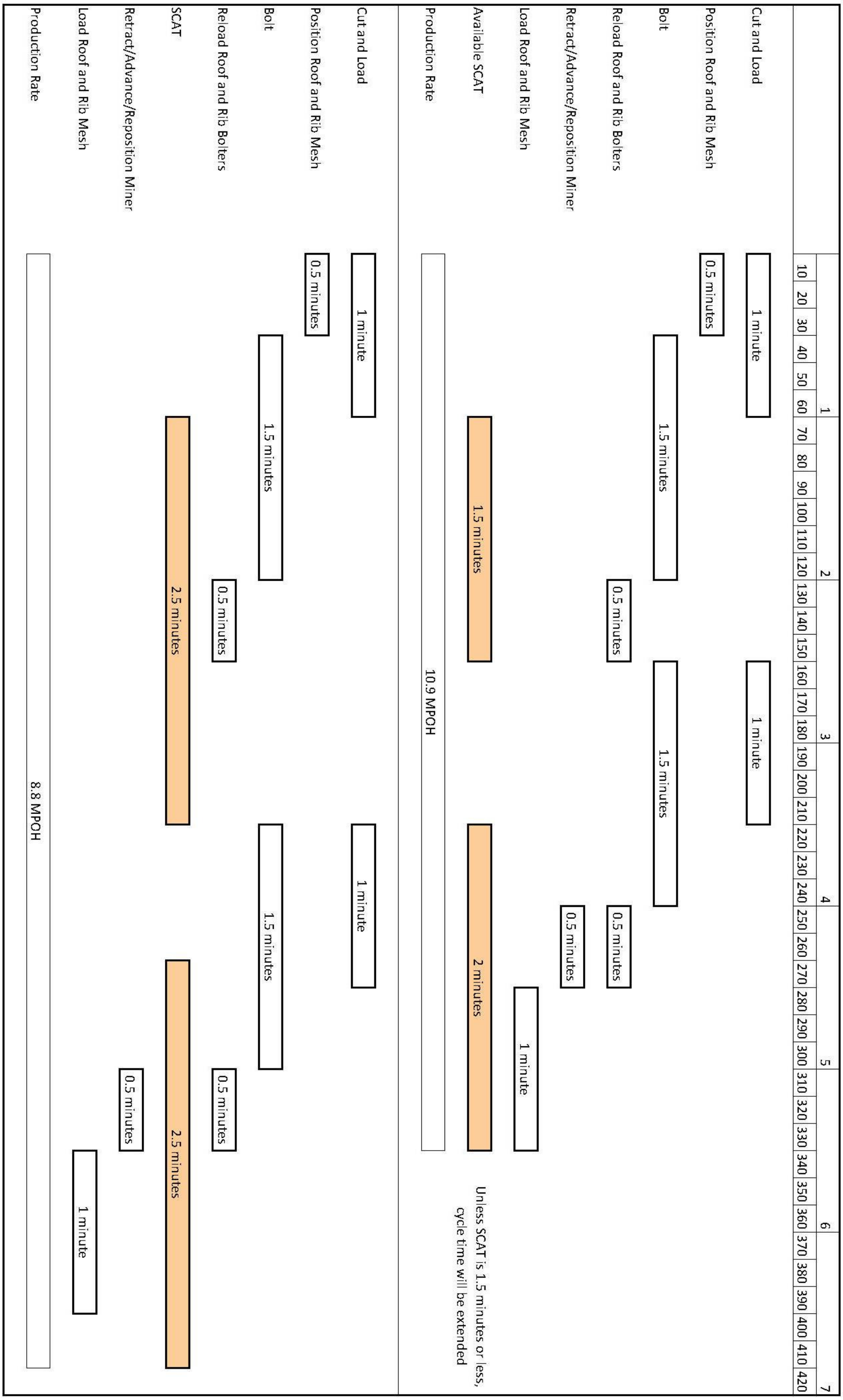
[3] Reid, D., Hargrave, C., Ralston, J., Strange, A., Reid, P., Malos, J., Dunn, M., "Interim Report – CM2010 Continuous Miner Automation", ACARP Report C18023, 2010.

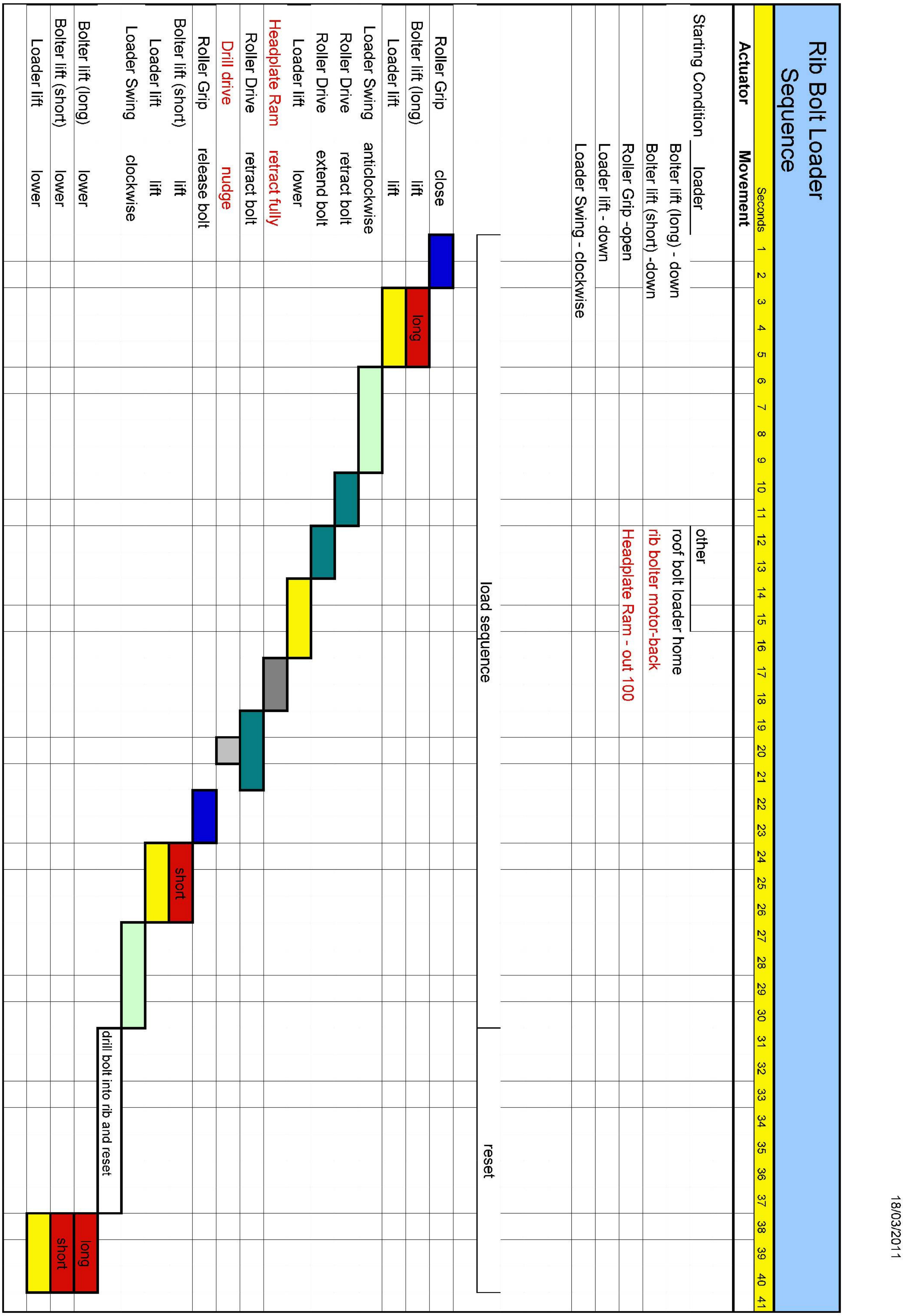
Appendix 1

Appendix 1 – Table 1.1

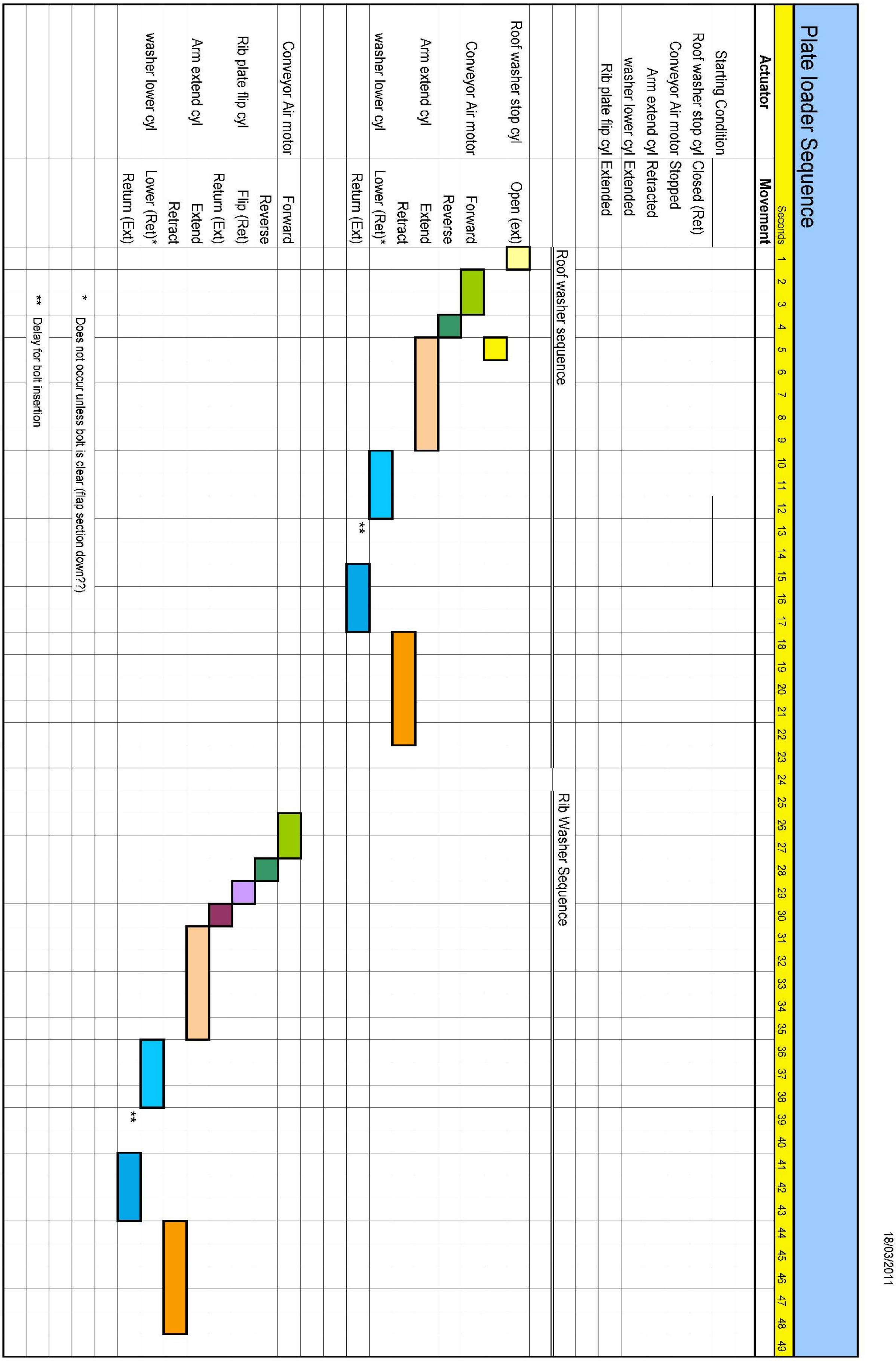


Appendix 2

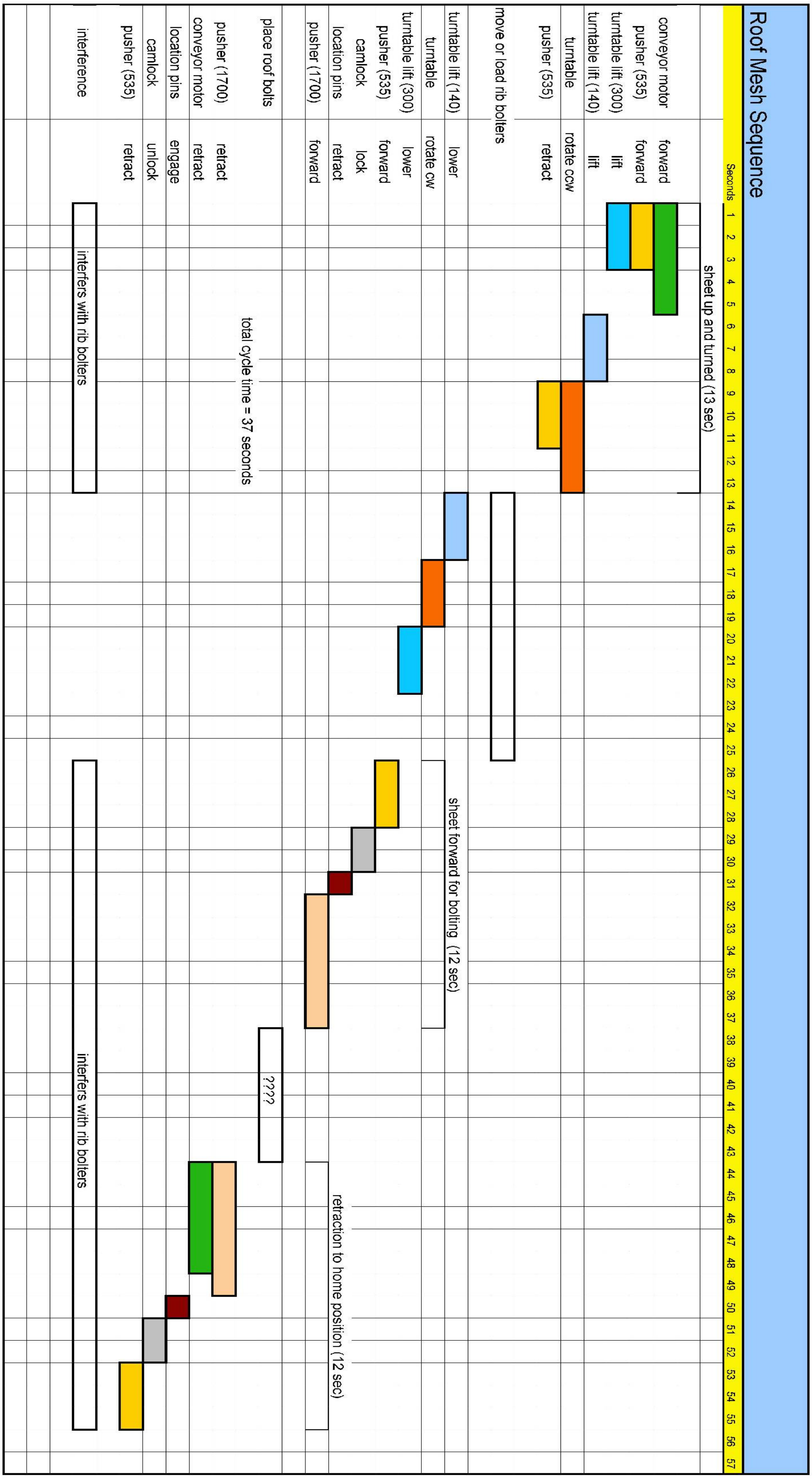
Appendix 2 – Table 2.1



Appendix 2 – Table 2.2

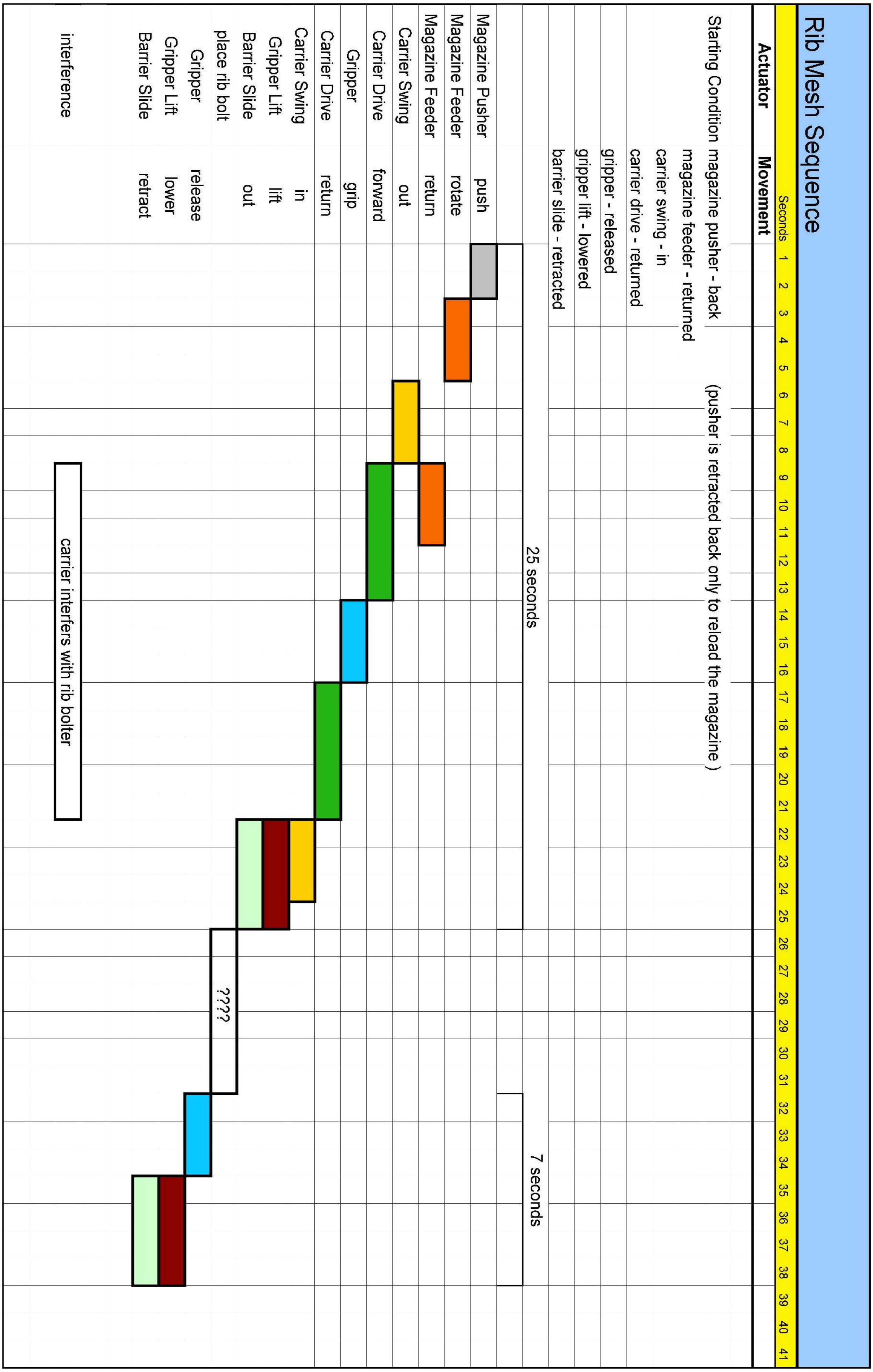


Appendix 2 – Table 2.3



18/03/2011

Appendix 2 – Table 2.4



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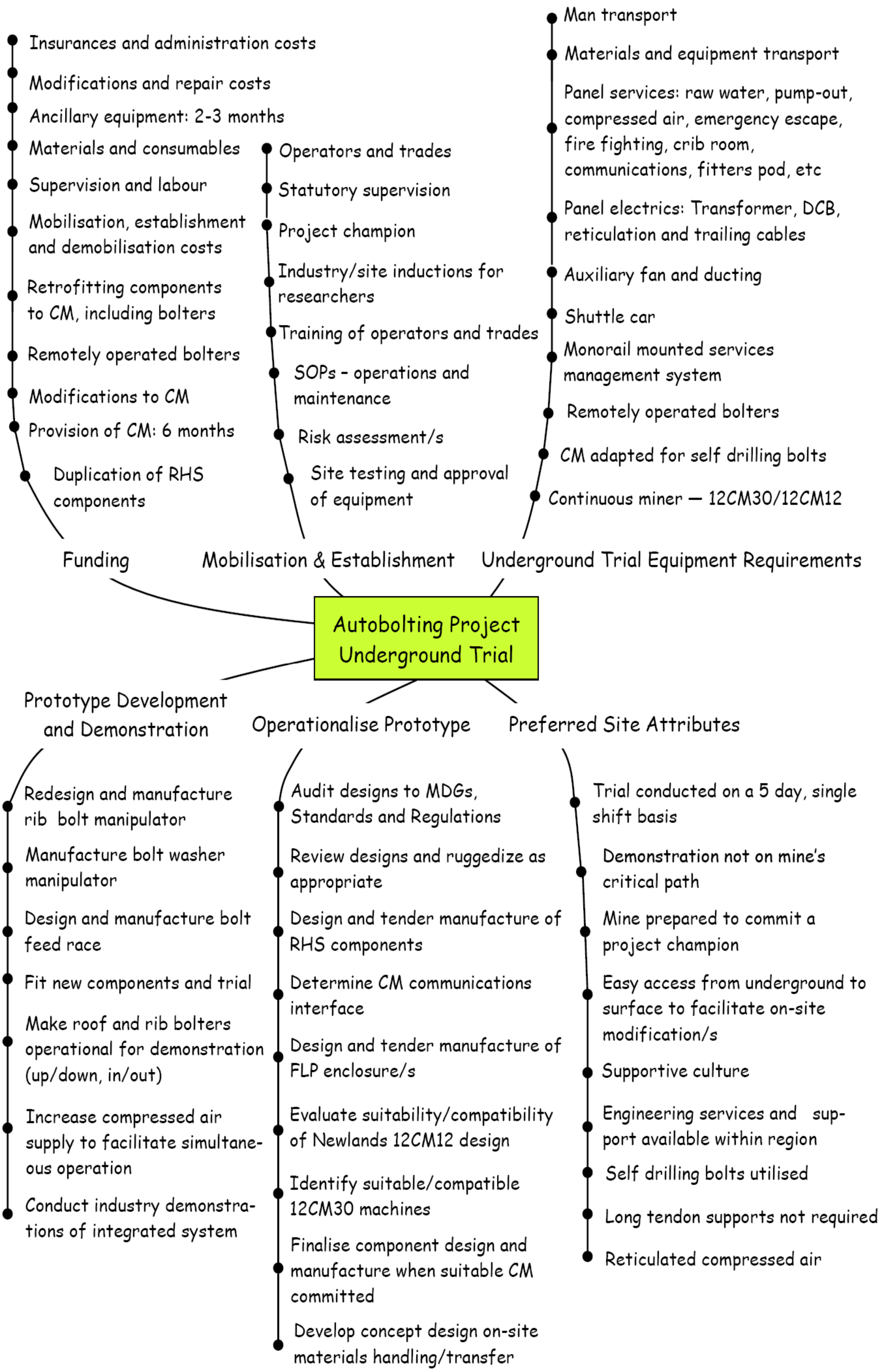
Autobolting Project Underground Trial
Funding
Insurances and administration costs
Modifications and repair costs
Ancillary equipment: 2-3 months
Materials and consumables
Supervision and labour
Mobilisation, establishment and demobilisation costs
Retrofitting components to CM, including bolters
Remotely operated bolters
Modifications to CM
Provision of CM: 6 months
Duplication of RHS components
Mobilisation & Establishment
Operators and trades
Statutory supervision
Project champion
Industry/site inductions for researchers
Training of operators and trades
SOPs - operations and maintenance
Risk assessment/s
Site testing and approval of equipment
Underground Trial Equipment Requirements
Man transport
Materials and equipment transport
Panel services: raw water, pump-out, compressed air, emergency escape, fire fighting, crib room, communications, fitters pod, etc
Panel electrics: Transformer, DCB, reticulation and trailing cables
Auxiliary fan and ducting
Shuttle car
Monorail mounted services management system
Remotely operated bolters
CM adapted for self drilling bolts
Continuous miner — 12CM30/12CM12
Prototype Development and Demonstration
Redesign and manufacture rib bolt manipulator
Manufacture bolt washer manipulator
Design and manufacture bolt feed race
Fit new components and trial
Make roof and rib bolters operational for demonstration (up/down, in/out)
Increase compressed air supply to facilitate simultaneous operation
Conduct industry demonstrations of integrated system
Operationalise Prototype
Audit designs to MDGs, Standards and Regulations
Review designs and ruggedize as appropriate
Design and tender manufacture of RHS components
Determine CM communications interface
Design and tender manufacture of FLP enclosure/s
Evaluate suitability/compatibility of Newlands 12CM12 design
Identify suitable/compatible 12CM30 machines
Finalise component design and manufacture when suitable CM committed
Develop concept design on-site materials handling/transfer
Preferred Site Attributes
Trial conducted on a 5 day, single shift basis
Demonstration not on mine's critical path
Mine prepared to commit a project champion
Easy access from underground to surface to facilitate on-site modification/s
Supportive culture
Engineering services and support available within region
Self drilling bolts utilised
Long tendon supports not required
Reticulated compressed air