USING THE CAVITY MONITORING SYSTEM AT MOUNT ISA, NW QLD.

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ABSTRACT: Mount Isa Mines Ltd (MIM) purchased its first Optech Cavity Monitoring System (CMS) in 1993 following a successful trial at the Olympic Dam Operations in S.A. This trial followed an earlier unsuccessful underground assessment at MIM's X41 Copper Mine, where typical stopes are 40 metres square and range from 75 to 300m high. The immediate benefits were seen to be the rapid, mass data collection by fewer people and a "complete" void survey for each stope. Other benefits to be later quantified include accurate stope reconciliation and fill volumes, measurement of ore dilution by monitoring stope firings with the cms, and optimising stope designs through better knowledge of adjacent stope boundaries.

This paper describes nearly a decade of CMS use at Mount Isa.

INTRODUCTION:

An outcrop of silver-lead-zinc ore at Mount Isa was discovered in 1923 and copper ore was found in 1927. Open cut mining commenced in 1931, and underground operations followed soon after. MIM currently produces 1.2 million tonnes of silver-lead-zinc ore per year from the Isa Lead Mine, and 2.0 million tonnes of silver-lead-zinc ore per year from the George Fisher Mine, 20 km north of the city of Mount Isa. It also produces 5.7 million tonnes of copper ore from the two Isa Copper Mines.

Sub-level open stoping has been the predominant underground mining method for copper ore-bodies and wide silver-lead-zinc ore-bodies. The narrower lens type silver-lead-zinc ore-bodies at Isa and George Fisher are currently mined by variations of the benching method.

MIM has operated base metal underground mines in NW QLD for 75 years. During this long period, mining methods and machinery have evolved to create a safe and economic working environment, though in the last decade, low metal prices and unfavourable exchange rates have eroded profits considerably. Surveying instruments, techniques and methodology have also changed dramatically during this same period, giving us a situation today where never before in history has a surveyor been able to collect so much useful data in such a short space of time with relative ease and safety.

DEVELOPMENTAL HISTORY OF THE CMS:

The CMS was developed out of a joint venture between Noranda Technology Centre (NTC) in Quebec, Canada and Optech Systems, a Canadian laser rangefinder manufacturer. NTC, the research and development arm for the Noranda Mining Group, responded to the mining group's need for "a mining instrument to assess the dimensions of unsafe or inaccessible cavities" (CMS User Manual). The economic climate at the time also applied significant pressure on the industry in general to reduce mining costs. One of several ways to achieve this outcome was to measure the dilution of ore that occurs in most mines. (Dilution is loosely described as the ore that is left behind (under-break) or the waste taken with the ore (over-

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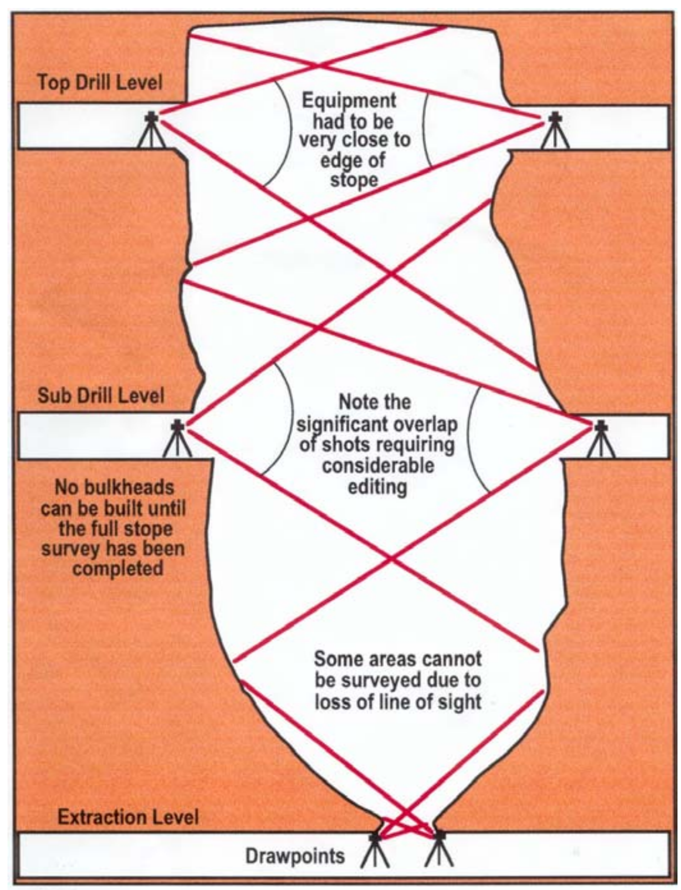
break)). The principle that “what gets measured gets managed” was the key driver. Miller et al (1992) describes the situation at this time- “1991 was again a difficult year for the mining industry in Canada (and Australia). The Northern Miner Journal (April 1992) reported that ore depletion, low metal prices and depressed market conditions forced the closure of 33 mines, resulting in a net loss of 2000 jobs or a reduction of 12.7% in employment……. With severe economic conditions like this, one of the main objectives of each mining operation is the reduction of production costs. Dilution is one of the factors that directly affect operation profitability. This new tool, initially called the Laser Stope Survey System, then (later) named Cavity Monitoring System, “allows for a rapid, precise and efficient measurement of underground excavation volumes. By comparing the excavation planned with the volume excavated, it becomes possible to determine the “real” amount of mining dilution as well as the amount of ore left in place. This system may also allow for early detection of a dilution problem. As with other diseases, early detection provides the best chance for a fast and total recovery.” (Miller et al, 1991). It was in this environment that the CMS was conceived, and the “war against dilution” began in earnest when Optech’s CMS became commercially available.

In his paper “Measuring to Inaccessible Points, a Stope Surveying Problem”, (Campbell, J.A.,1981) Campbell reveals the frustration of the Isa surveyors at not having a reflector-less type instrument with which to survey stope voids, when such an instrument had clearly already been conceived in the minds and even the laboratories of the instrument makers. After describing six methods which have been used at Mount Isa for surveying stope voids, he concludes by saying that “an instrument is required which can, without the use of reflectors, cycle off rough, dirty walls or rock giving a three dimensional read out of a specific point or points, enabling a plot to be made up of the absolute shape of the stope, or rill, with hopefully a minimal labour requirement.” This situation in our underground mines was no doubt mirrored elsewhere. The CMS was the long awaited instrument, after several reflector-less mount-on EDMs filled the gap.



TYPICAL SET UP
USING TOTAL STATION METHODS

Floyde and Campbell (1989) again describe the situation at Mount Isa up to 1990: “For more than twenty years, there has been a requirement for surveying open stopes at Mount Isa, ranging from one-off situations in the early days, to a basic requirement for all copper stopes to be surveyed prior to filling of the void and with lead stopes being surveyed as required." Various techniques and methods pertaining to the era prior to Optech's CMS are described in this paper. Makkai (1988) also describes various historical methods used for surveying stopes at Mount Isa, with the remainder of his paper devoted to the use of the new Wild DIOR 3002 Reflector-less Distomat for surveying stopes and stockpiles. This latter combination was used at Isa from 1987 to 1993.

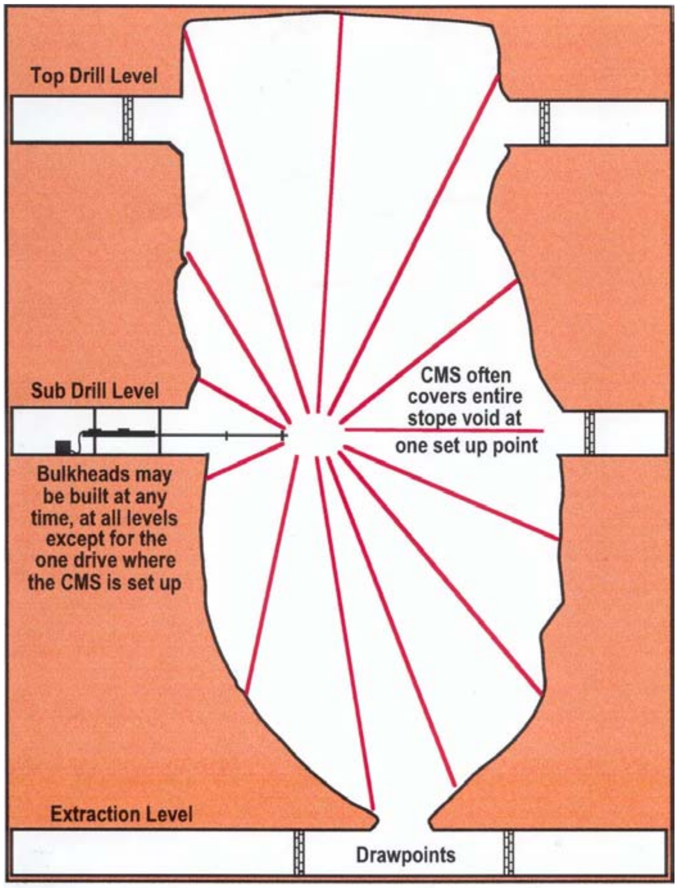
FIRST CMS AT MT ISA:

MIM purchased its first CMS (serial number 002) in late 1993 for about $76,000 (AUS). The CMS is a fairly simple instrument to operate, and after a brief period of in-house training, our surveyors were able to achieve an acceptable level of competency very quickly. From a surveying perspective, the major achievement with the CMS was being able to obtain a complete three-dimensional model (a B spline mesh as opposed to a triangulation) of the stope void with the survey having been performed by only two people, in approximately one hour. Complete void surveys were previously possible in only a few of the copper mine stopes where there was access from several sides on several mine levels. The lead mine at Isa and Hilton (now George Fisher) however, with their distinct hangingwall (HW) and footwall (FW), often only had an access to the stope from one side. If the access was on the HW, only a small portion of the FW could be surveyed, and if there was an access on the FW, the surveyor could survey only a small quantity of points on the HW. Stope surveys before the CMS therefore often provided only sketchy information about the void. Probe drilling from nearby development also provided useful but scanty information on void proximity, with additional cost. The introduction of the CMS at Mount Isa a decade ago has totally revolutionised cavity/stope surveying. Our constant use of the CMS has made it possible during the intervening time, to survey every subsequent lead and copper mine stope, thus providing complete stope graphics within the database. This has in turn allowed each stope to be accurately reconciled in terms of actual tonnes and ore grade compared with design.

This instrument has "revolutionised stope measuring methods, and has the capacity to save many millions of dollars because of its performance accuracy". (Jones, 1995).

INTEGRATED MINE PLANNING SYSTEM DEVELOPMENT:

During the late eighties, Mount Isa Mines embarked on a program to develop in-house, an integrated mine planning system (IMPS) which used Microstation™ 3D software coupled with an Oracle database. To populate the graphical database, over 900 survey plans (at 1:250 scale) covering the whole mine (over sixty years of mining at this point) had to be scanned, then converted to the correct reduced level. In excess of 30,000 survey stations, thousands of vertical openings, and stope outlines were also added to the database. With this across the board move to a graphical representation of objects, it made sense to capture digital data wherever possible. Our first CMS was purchased around this time, enabling us to collect the necessary field data to build more accurate models of our stope voids and incorporate them into the graphical database where the information was available to many users over the vast computer network.

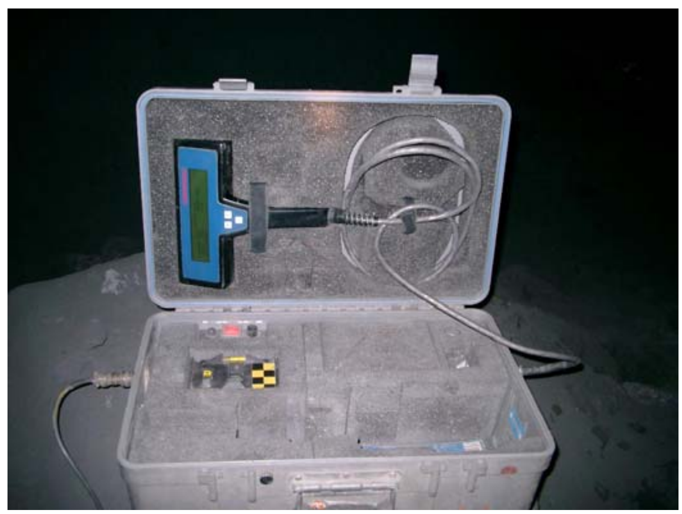


TYPICAL SET UP
FOR SURVEY USING THE CMS

FINANCIAL JUSTIFICATION:

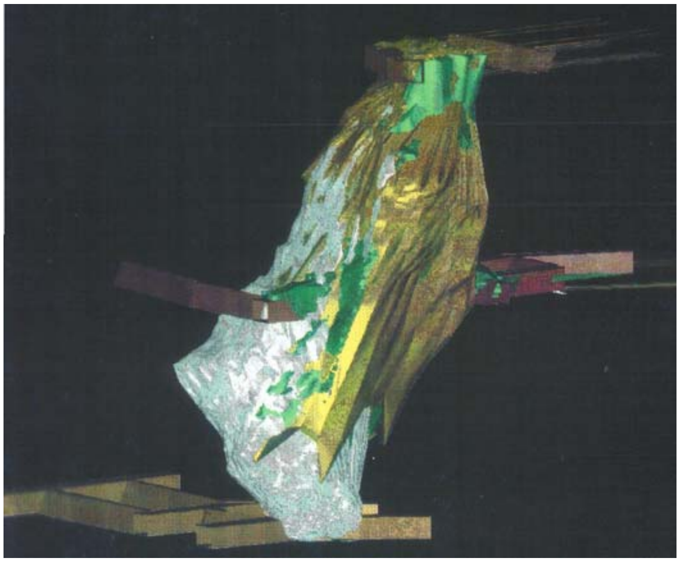
The traditional method of justifying the purchase of a new surveying instrument or piece of equipment has generally been to carry out a detailed cost/benefit analysis. This must provide significant savings in man-hours both on the job and in the office, to help produce a satisfactory internal rate of return to meet return on investment criteria. A different approach was used with the justifications for the CMS purchases, yet with the same result. An emphasis was placed on both the quality and quantity of useful data able to be collected. There was mention also made of the time savings that the CMS would contribute to both the field work and the processing. Clearly, the additional information provided by the CMS has helped our mine engineers and geologists to make more informed decisions, and provide answers for the following sorts of basic questions (plus a host of others):

- How much ore has been left behind (under-break)
- What is the value of that ore and can it be recovered economically?
- How much over-break is there and where is it?
- Did firing that last diaphragm ring expose any of the adjacent fill mass
- What is the overall dilution in this stope
- How much fill is required to fill the stope (fill is budgeted for between the three Isa mines)
- How much solid ground remains between the actual stope back and development above.



Optech CMS case with hand controller

The first CMS purchase coincided with the then new Enterprise Mine coming on stream, with the opportunity "to record the total stoping experience of this new mine."(Burns, 1993). He also noted the following: "Furthermore, stope geometries (especially in the ore-bodies hangingwall) will also impact on conventional surveying. For example the second stope R602 will not have the final hangingwall position recorded. As this will be our first experience in the hangingwall of the ore-bodies all performance data must be recorded. These stopes are above 6 percent copper and learning experiences for subsequent stopes will be crucial." It is difficult to place a dollar value on this sort of information, but the value is certainly there, and this was recognised by management.



"Rendered" stope model from three CMS surveys, with mine development

MIM bought a second CMS "during a period of strong focus on dilution control in the Lead Mine in late 1995." (Hall, 1998). The second CMS also alleviated the problems arising from increased usage of the existing unit between its four mines. The second justification focussed on major benefits that were real, yet difficult to quantify. The lead mine's contribution to the financial justification included the following: "The budget assumes ten percent dilution from which we can say that a one percent improvement (ten percent absolute) in dilution will save $760,000 annually. A realistic assumption is that the Optech CMS can contribute up to half this amount, i.e., 5 percent absolute reduction in dilution, which equates to annual savings of $380,000 in the first year. Frequent CMS surveys will provide progressive feedback on stope/benching status and allow for corrective action to be implemented before the stope is completed, rather than being an 'after the fact' measurement of the void." (Hall, 1995).

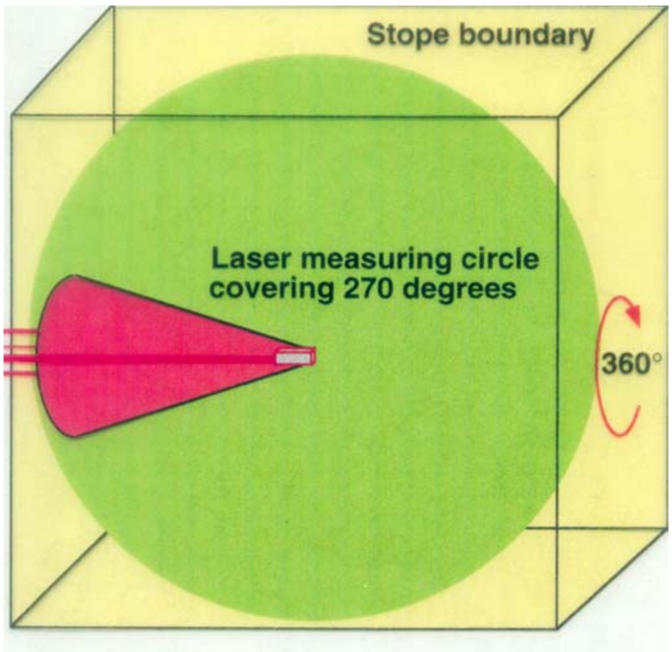
The work order to purchase the second CMS passed through the justification process more easily than the first, largely because there was now widespread knowledge about the quality and quantity of the information collected with each survey. The CMS was an instrument the mines could no longer live without.

MIM has since retired its first CMS and purchased additional two systems, leaving three working CMSs for the mines at Mount Isa.

CMS in operation (Courtesy Optech Web site)

DESCRIPTION OF THE CMS:

The CMS consists of a motorised scanning head containing an infrared laser EDM with visible red laser pointer, mounted on one end of a set of five interlocking carbon fibre extensions making up a ten metre boom. The scanning head is powered and controlled via a cable link to the data logger. The scanning head rotates about the boom axis through 360°, then the head inclination increases by a nominated amount, and another rotation takes place. Up to 376 points are collected for each 360° rotation, with each rotation taking 30 seconds. The scanning head elevates to 135° (146° on later models) from horizontal at the increment nominated by the operator (usually 1 to 3°). This process is repeated until the survey is complete. For a full survey with 1° increment, around 50,000 points can be surveyed in one hour. This is a quantum leap forward from earlier stope surveying methods that yielded 60 to 80 points in an hour of continuous observing.



CMS Scanning Coverage

The CMS produces a binary type .cms file of 262 kb, no matter how large the scan. From this raw data file, the CMS conversion software produces a choice of three files (dxf, xyz and ascii). Our preference has always been the data exchange format (dxf) file, which easily imported to Microstation™. By the time our in-house developed IMPS was replaced the commercially available MineSight™, our surveyors had begun using Surpac™ software at all our mines. The "old" dxf converter in the CMS reduction software would not work with MineSight™, so the CMS generated dxf file was imported to Surpac™, where a new dxf was created, and imported to MineSight™ to produce the required triangulation. Typical CMS generated dxf files range from about one megabyte (Mb) up to 6 Mb in size.

CMS scanning head- (Courtesy Optech Web site)

PERFORMING A CMS SURVEY:

The CMS User Manual describes in plenty of detail, how a survey is to be performed. This process is also well documented by Gilbertson (1993) hence this process will not be described here.

Four significant improvements the CMS has brought about for the mines at Mount Isa are:

1. the number of personnel required to carry out a stope survey has been reduced to a minimum of two people;
2. the time required to complete a survey, and process the same is significantly less than before;
3. the amount of vital data that can be collected in a relatively short period of time has made a quantum leap forward;
4. the safety risk due to less exposure (time wise) to any potentially dangerous

conditions around the opening into the void is much lower.

CMS OFFICE PROCEDURE:

While the reduction software that comes with each CMS has largely remained unchanged since the first production model in 1993, computer hardware has made considerable progress in terms of processor speed and screen graphic capabilities. The software packages in use at Mount Isa have also been continually upgraded with improvements.

When the surveyor has completed a cavity survey, the usual priority is to "submit" the graphics (generally a triangulation or DTM representing the void, with text and appropriately attributed elements) to the mine graphics database where the mine personnel have access to the data. Reconciliations can then be carried out to obtain the relevant statistics on how well the stope has performed. At Mount Isa, the surveyors' involvement is generally finished at this point, whereas at other mines, the surveying department is responsible for providing fill volumes and calculating stope dilution statistics.

SAFETY CONSIDERATIONS:

The last decade has seen our mines implement new safety standards in response to government legislation. Standard work instructions (SWIs) have been written to protect mine personnel working near vertical openings, and the surveyor and assistant using the CMS to carry out a stope survey operate in line with that standard.

The surveyor wears a full body harness, with a suitable length lanyard, attached to a one tonne (one metre cube) concrete block placed at the stope edge. In the early days at Mount Isa, it was standard practice to attach a heavy rope to the operator's safety belt, and to secure the other end to the nearest rock-bolt.

Prior to using the CMS for stope/cavity surveys at Mount Isa, a survey team could typically be standing at the edge of a stope on one mine level for up to two or three hours, then move to another mine level for several more hours to obtain additional information. The amount of exposure in man-hours, for a large stope with several accesses on several mine levels becomes quite considerable. The widespread use of the CMS at Mount Isa has generally meant that fewer surveys are required for each stope and this in itself has reduced the exposure to the inherent dangers for surveyors working near large underground voids.

Ground conditions throughout our mines vary, and it is not uncommon for additional material to fall off within stopes.

It is worth noting that there has not been any physical injury to survey personnel in the course of carrying out a stope survey, both before and after CMS.

CALIBRATION:

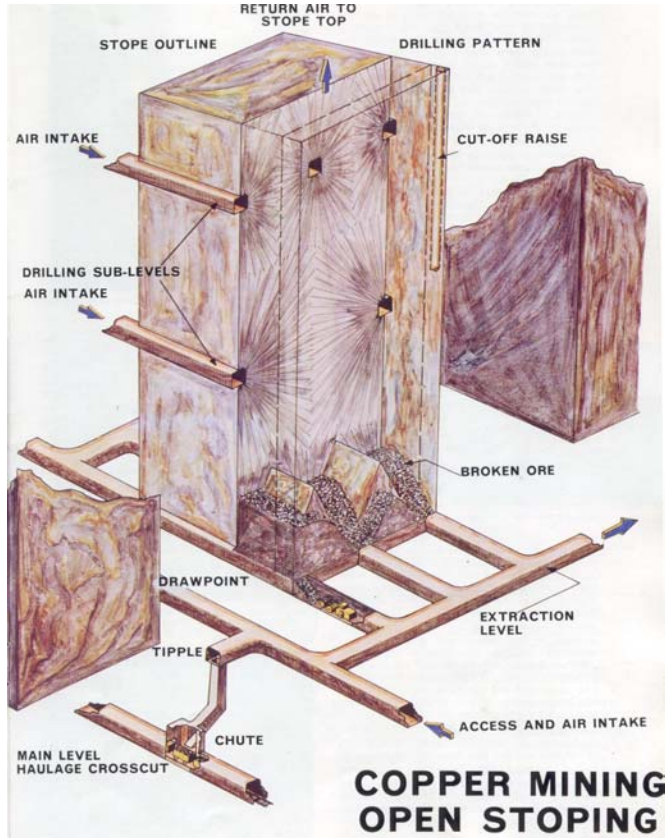
Our early CMS surveys at Mount Isa were invariably accurate due to the units being new, with no wear in the joints of the booms, and overall, being in good calibration. The first indication of there being calibration type errors is when a stope survey appears out of position in relation to the design shape, or when it does not align correctly with elements of the mine workings, typically development headings which often form the perimeter or some part of the stope. To correct any apparent rotation or elevation error, the survey graphics would be rotated about the "head" position so as to "fit" the mine workings or another CMS survey performed from another level with graphics in the same file. When there was perceived to be a lull in the amount of CMS work required, the CMS would be sent to the supplier for calibration and servicing. It was only recently that a calibration room (as described by Jarosz and Shepherd (2002)) was set up at our George Fisher Mine, allowing calibration constants to be derived on site for each CMS, and applied to the respective instrument. Regardless of the fact that the instrument may have recently been calibrated, it is always good practice to sight along the boom to ensure the two targets (which are surveyed to coordinate the CMS survey) on the boom are co-linear with the red laser spot on the opposite wall. This little check should be carried out before pressing the "RUN" button to start the scan.

Our experience has been that the five interlocking carbon-fibre extensions forming the boom need to be well maintained otherwise alignment errors are introduced due to misalignment from sloppy joints.

CMS APPLICATIONS AT MOUNT ISA:

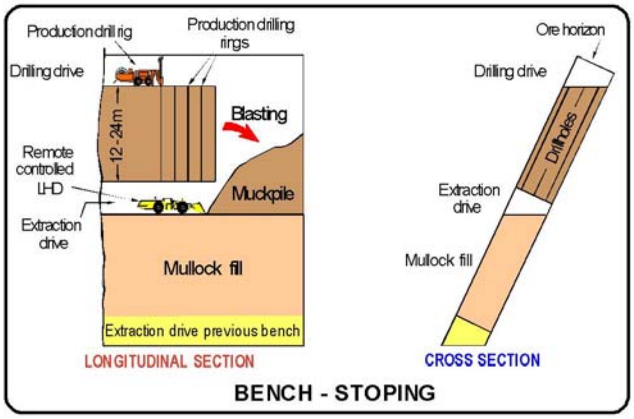
Our CMS units have been used for a number of less conventional tasks in addition to underground stope surveys. The following list, however, highlights some of the more common situations where we have used the CMS:

- Large Copper mine stope voids (long hole open stoping) to determine final stope shape, amount of dilution, quantity of fill required, and stope performance calculations- actual tonnes extracted versus "bogged" tonnes versus design tonnes. There is generally no urgency for CMS surveys to be completed as soon as the stope is empty because the copper stopes are generally very stable, (as opposed to the situation in the lead mine stopes where hanging wall stability is an issue) allowing some to be left empty for up to a year before filling.



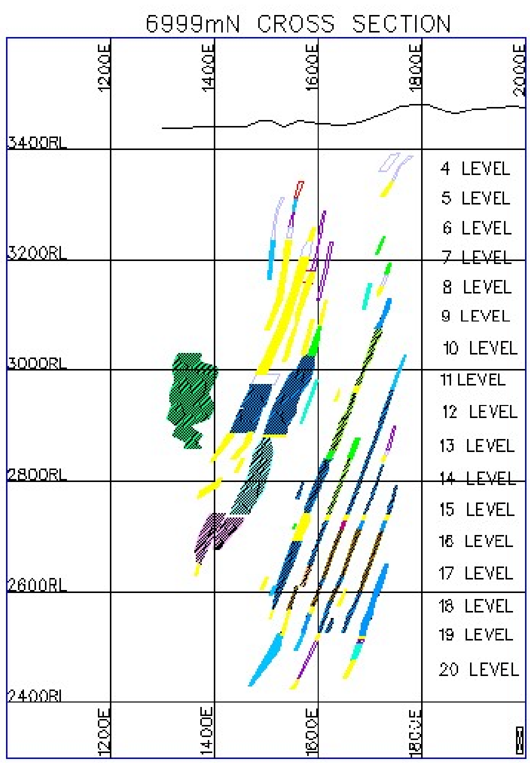
Typical large stopes in the Copper Mine

- Lead mine "lens" type ore-bodies- open stope and bench stope surveys as per large copper stopes. CMS surveys were often performed after firing two or three closely spaced blast rings, to monitor any over-break and under-break, thus providing an opportunity to modify the firing of subsequent rings. The up-hole bench method began to be used at the top of the ore-body or where a crown pillar was required. CMS surveys of the up-hole benches were performed for the usual reasons (stope performance data and volumes), plus optimising the fill hole target design and providing graphics for the database.



Schematic showing bench/panel stope mining method

- Filling of the bench stopes at the George Fisher mine and the Lead mine at Isa is usually commenced immediately the stope has been bogged empty because of stability issues.



Lead Mine X-Section showing lens type ore-bodies

- Panel stopes – similar to bench stopes in the lead mine. These stopes are generally up to 10 metres wide, and up to fifty metres tall, and are mined without leaving pillars of ore behind. Filling is carried out from the top (drilling) horizon, while the bogging is from the bottom or mucking horizon. CMS surveys were performed on a regular basis from the top sub-level to monitor the blast design and check on dilution from over-break. The hanging- wall often had varying amounts of fall off, and because the CMS surveys were progressive, it was possible for the relevant engineer to alter the blast design or firing sequence to control any dilution which was highlighted by the CMS. These CMS surveys in the bench and panel stopes were usually very rewarding in this regard.
- CMS surveys before and after firing several production rings to determine blasting damage and muck profile statistics. This application took place in the lead mine panel stopes and benches.
- Fill hole (typically 140mm to 600mm diameters for use with "liquid" fill) and fill pass (greater than 1 metre diameter and loaded by truck or conveyor belt) design for stopes in all mines- stope voids are filled with a variety of materials. Voids which are designed to be tight filled will generally be filled with either paste fill, cemented hydraulic fill (CHF) or aggregate material, or a combination of these. Where a combination of fill material is used, the engineer needs to consider where the dry fill will land relative to future exposures when designing the fill system for that stope. There should not be any dry fill up against future exposures- a "ring" of CHF or paste fill should contain the dry fill core. The fill hole or pass should ideally break into the void at the highest point to ensure the void can be completely filled. Prior to CMS, the design of the target point for the pass/hole was usually based on design parameters. A "dtm" or triangulation from the CMS survey

of the void allows accurate positioning of the fill hole/pass target to optimise the filling of stope voids.

- Ore-pass surveys to determine the amount of wear. In a number of instances, some of our passes wore to such an extent that they "broke through" into existing development. There are obvious limitations with using the CMS to survey ore-passes, as this is an application for which it was not designed in its standard form. It does, however, provide much useful information about the first twenty of thirty metres of the pass. Optech subsequently produced a vertical insertion kit which was specifically designed to allow the CMS to be lowered down vertical openings such as ore-passes and holes with a minimum diameter of approximately 150mm. This kit was not purchased by MIM.
- Underground ore-bin surveys- Most of our ore storage bins and large excavations were mined prior to the CMS development, but there have been opportunities to use the CMS to determine wear characteristics and check on the storage volume of these chambers.
- Development heading profiles. A two metre long aluminium boom was manufactured to replace the carbon fibre booms, allowing us to mount it directly on a survey tripod and profile underground headings and excavations. The CMS was used for a brief period for this type of survey, but the method was discontinued with the advent of reflector-less total stations.

Short Aluminium boom for tripod surveys

- Chute recesses to determine if any additional mining or stripping is required. Our CMS has been sent to the MIM McArthur River Zinc-Lead-Silver mine in the NT to carry out stope surveys, ore-pass surveys and final survey of their underground crusher station chamber prior to the construction of the crusher.
- Surveys of old unfilled stope voids in the lead mine, from nearly half a century ago. Not a bad effort considering the thousands of stopes mined over the years. There remains a number still not done due to these voids being in very old areas of the mine and now bulk-headed off. Incidentally, this is one area requiring much diligence and appropriate risk assessment prior to the planned super-pit.
- Copper smelter furnace to determine the wear pattern in the refractory bricks. While the CMS accuracy is ±5 centimetres, the results from the above surveys gave a good indication of where the wear had occurred.

A NEW GENERATION CMS?

Our experience in using the CMS for almost a decade now has led us to compile a "wish list" of modifications we would like to see incorporated into any new model. These ideas were communicated to Optech personnel, and include the following:

- New case with wheels and retractable handle like airport travel case.
- Reduce weight from the present 18kg, perhaps by using different construction material.
- Improve data cable- currently uses 21 pin canon type connector. The cable is acknowledged to be the weak link with the system.
- Booms- currently 5 carbon-fibre extensions interconnected with external catches which are susceptible to damage if not treated with due care and a little maintenance. (No suggestions on how to improve)
- A battery status indicator would be useful in CMS case. Currently, battery status is displayed on the hand controller when the system is in operation.
- Scan control filter selection to be finer than 1 degree of arc, or operator should be able to specify a distance between consecutive surveyed points (preferably the latter).
- Hard-wired hand controller to avoid having to plug in each time it is used- potential fault area with broken wires in 21 pin connector (same as long data cable).
- Difficulty obtaining an adequate return signal in dusty conditions and high humidity- new 24 volt model has increased distance measurement range and better capability in this area.
- DOS based software is now very dated- suggest move to windows/interactive software.
- Display job name for job being processed.
- Increase the number of surveys able to be stored in the onboard computer from the present four surveys to say ten surveys.
- Use a flash/data card to store data and to save lugging heavy unit around.
- Increase down-load speed/baud rate if continuing with on board data storage.

SUPPLIER COMMITMENT:

The CMS is a very repairable instrument. (There are fewer and different problems with the newer 24-volt model, which is identified by the yellow case). The Australian distributor carries a stock of the most commonly required parts, which means that most repairs are effected relatively quickly. We have found that our CMS units have become less reliable as they have aged. The weakest link with each system has been the fifteen metres long, 20-core cable. We now receive a comprehensive service report with each repaired instrument.

CONCLUSIONS:

The use of the Optech CMS at Mount Isa has revolutionised the surveying of underground cavities and openings that would not otherwise be able to be surveyed in their entirety. This has had a direct impact on profitability, production and safety, to name just three areas. In summary, the automation of stope surveying through the use of the Optech CMS has resulted in significant gains for Mount Isa Mines.

The CMS has been a relatively simple instrument to incorporate into the mine surveyors' toolbox, but our experience has shown that maintenance and downtime become more frequent as the age of the instrument increases.

Approximately 60 Optech CMSs have been sold in Australia since 1993 and nearly 300 worldwide. The mines that have begun to use these instruments regularly have positioned themselves well to attack the dilution problem by measuring what they are trying to manage. Mount Isa Mines has, for nearly a decade now, been reaping the benefit of their investment in this technology.

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