

▶ Tipping the scales at over 1,361 and 7,257 tonnes respectively, Cat's 7495 electric mining shovel and 8750 walking dragline are not only two of the largest machines on the planet, but two of the largest vehicles to have ever moved over the surface of the Earth. These are industrial vehicles on a titanic scale, deceptively toy-like when seen from a distance, yet astonishingly immense once up close and personal, especially when in the operator's cab.

Each is designed to do a very specific surface-mining job. In the case of the electric mining shovel, it is to remove, every 30 seconds or so, up to 109 tonnes of overburden, oil sands, coal or minerals in a single pass, rotate to the side, and deposit the load in the back of a haul truck. After a few more passes, and with its bed full, the haul truck moves off to be replaced by another that has been waiting in the wings. When necessary, the shovel operator will activate the tracks, drive the machine to a slightly new position, and continue digging. And that is pretty much it, day and night, week after week and month after month.

The value of a single shovel's output – the eventual value of the material it removes – often exceeds US\$160,000 per hour or US\$2,666 per minute. Sliced even further, that is US\$44 per second, a figure giving new meaning to the phrase 'every second counts'.

As far as the walking dragline is concerned, its primary function is to remove overburden, and then replace it after the minerals have

been removed (often by an electric mining shovel). A walking dragline literally walks, albeit slowly, to its operating position on two side 'shoes' that move in parallel about massive side-mounted cams. The dragline rotates, as well as changes direction, during a pause in a walk, by lifting the shoes and spinning about the plate-like circular tub beneath its enormous 'house' and the centre of gravity of the whole machine.

The entire vehicle easily exceeds the dimensions of an entire city block. The Cat 8750 can dig down to depths of 66.7m and dump a single load of 129m<sup>3</sup> at a height of more than 50m. Just like the electric mining shovel, a dragline is designed to operate around the clock, year after year, keeping in tow a reel of thick electric cable that runs through the mine and is linked to a power grid.

#### Getting better with age

These vehicles are the product of more than 130 years of rich history, innovation and engineering prowess by a company that built the machines instrumental in the construction of the Panama Canal. Bucyrus, founded in 1880 in Bucyrus, Ohio, joined the Cat family in 2011, making Cat the largest full-service mine vehicle provider in the world.

Shortly before the acquisition, Bucyrus had undertaken development of an entirely new cab for installation on its largest electric mining shovels and draglines. It was intended to be an operator-centric cab, one meeting the functional needs of the operator during actual work as well as the more



# DATA MINING

TO ENSURE THE NEW CAB FOR ITS SHOVELS AND DRAGLINES WAS TRULY 'OPERATOR-CENTRIC', CATERPILLAR'S DESIGN TEAM CONDUCTED 83 INTERVIEWS ON 50 MACHINES WORLDWIDE, GATHERING FASCINATING INSIGHTS INTO THE NEEDS OF THE PEOPLE WHO 'LIVE' IN THEM



**MAIN IMAGE:** With 12-hour shifts the norm in mining shovels and draglines, a brand-new cab design that met the functional needs of the operator, as well as his 'habitational' needs, was a key requirement

**BELOW FROM LEFT:** The new cab in action on a 7495 electric rope shovel; early basic cab layout concept showing second entry door to the rear; and operator station modelling



## CASE STUDY

'habitation' or comfort-orientated needs associated with operating a complex machine over a long shift in a harsh and remote operating environment. The cab also needed to address the somewhat different requirements of draglines and shovels, as well as integrate state-of-the-art technology and design.

So, with an operator-centric cab in their sights, the cab engineering group and product planners in South Milwaukee, Wisconsin, USA enlisted the expertise of Santa Barbara, California-based Ergonomic Systems Design, and Formation Design Group of Atlanta, Georgia. The two research and design consultancies have worked together for over 20 years, engaged in the development of numerous industrial vehicles, aircraft interiors, medical devices and other products.

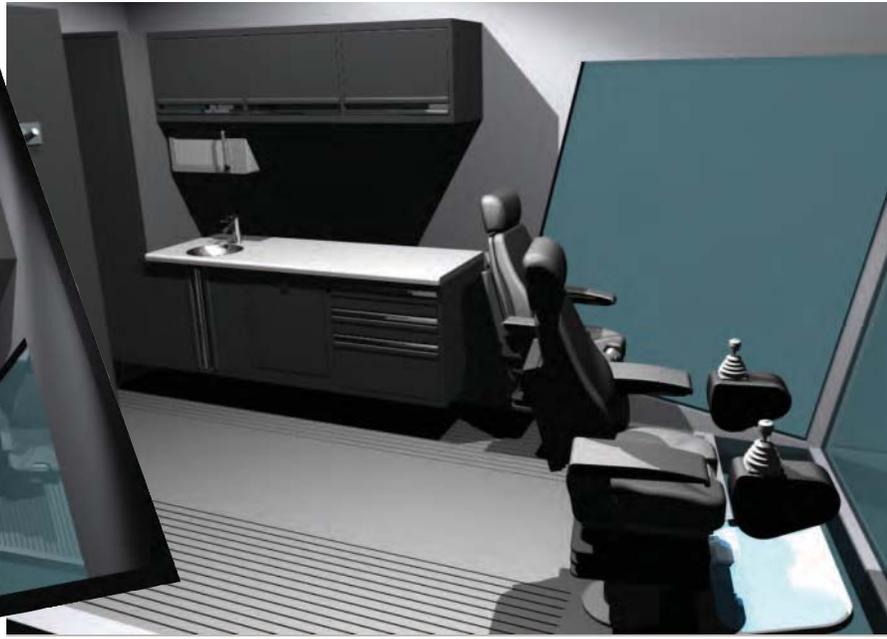
The team quickly set about devising and implementing an extensive worldwide research plan to determine and define the new cab. This was followed by intensive design activities and evaluation and testing with operators.

### Operator-centric field research

The keystone of the undertaking was a plan to visit mine sites, to see and board as many existing machines as possible, and interview a considerable number of individual operators as they went about their work.

The first stop in this multinational trek was in the Canadian oil sands north of Fort McMurray, Alberta. Electric mining shovels are used extensively in the region both for the removal of overburden and the extraction of oil sands. Arrangements were made ahead of time to meet up with a number of major mine owners. One, sometimes two, team members were transported, often dozens of miles, out to the electric shovels.

The operator would cease digging for less than a minute in preparation for boarding. We visitors quickly approached the shovel and tugged on a hanging rope to pull down the retracted stairway. Once on board,



ABOVE: The importance of a comfortable trainer's seat was stressed early on, as was the need for plenty of storage space

the stairway was raised as quickly as possible and digging was resumed. The climb continued, three storeys up, to the cab.

Aside from the sheer size of the machine, the first thing one realises after boarding a working electric mining shovel is that there is a great deal of motion in all axes. There may be in excess of 3,000,000 lb of mass under your feet, but it nonetheless spins, decelerates, lurches, jerks and vibrates as it engages the high wall, lifts and fills the bucket, rotates towards the haul truck, and releases

the load out of the bottom of the bucket. A touch of motion sickness is not uncommon for a first-time visitor to an electric mining shovel. You also find yourself looking for things to hold on to!

Our technique was to let the operators continue to dig while we peppered them with questions covering all conceivable aspects of the machine: visibility and lighting, push button locations and joystick forces, display design and camera locations, radios and communication links, and seat comfort and ride

quality. All answers and other comments were written down, and particularly insightful observations on the part of the operator were explored and discussed. We also made an inventory of everything that was inside the cab. As well as all control, display and communication gear, this typically included a coffee pot, microwave oven, portable radios, helmets and safety gear, coats, tools, documents, seats and chairs, window cleaning equipment, vacuum cleaner, brooms and much, much more.

**Each to their own**

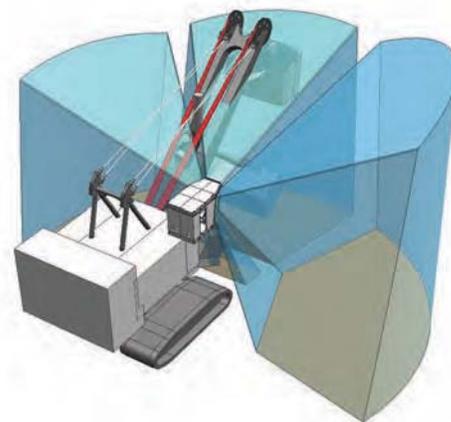
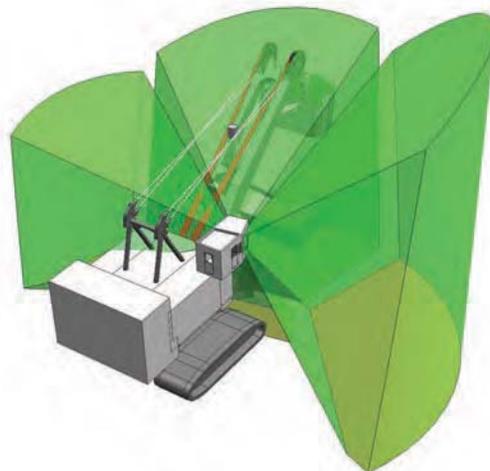
It is important to understand that, when employing an operator-centric approach to design, the designer, not the operator, still does the designing. Operators are trained to operate, and designers and engineers are trained to design and engineer.

The operator, however, based on his or her extensive experience with the product, is in an excellent position to point out strengths and weaknesses to the designer, identify features that work well and those that do not, and discern needs and requirements that can be the inspiration for new and improved designs.

During our interviews, for example, a number of skilled shovel

operators who also conduct training noted the importance of addressing the requirements of the trainer, not just the operator. This eventually led to a number of cab features that directly support real-world training, including the trainer and observer seats and a separate emergency stop switch accessible by the trainer.

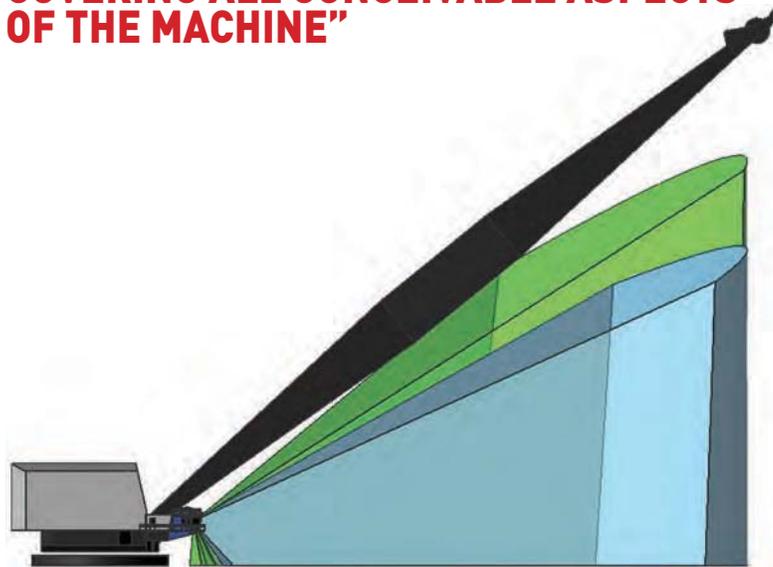
Operators of different makes and models of shovels and draglines were interviewed, although most of them were operators of vehicles previously manufactured by Bucyrus or Marion, a company acquired by Bucyrus in 1997. Our interviews lasted anywhere from one to four hours and depended somewhat on the availability of



TOP AND BOTTOM: **Visibility improvements on the shovel and dragline (green) relative to previous model (blue)**

ABOVE: **Watching out for the power cable when in propel mode is a vital part of shovel operation – superb visibility is therefore essential**

**“OUR TECHNIQUE WAS TO LET THE OPERATORS CONTINUE TO DIG WHILE WE PEPPERED THEM WITH QUESTIONS COVERING ALL CONCEIVABLE ASPECTS OF THE MACHINE”**



transportation in particularly distant corners of some mines. Personal safety was also of importance and of particular concern when attempting to board or leave a shovel with haul trucks moving about nearby.

Although some shovel activities involve a single individual working alone, many times they are assisted by a tender in a dozer whose job is to keep the working floor flat and clear of debris for access by the shovel as well as arriving haul trucks. The tender might also monitor and position the power cable during travel manoeuvres, as well as operate the shovel when the main operator takes a break for a meal. Most surface mines usually operate on 12-hour shifts, with shift changes in the morning and evening.

From the Alberta oil sands, the research team moved on to Wyoming and the Powder River Basin, a region supplying about 40% of all power plant coal consumed in the USA.

Once again, shovels were visited and operators interviewed. Visits to various draglines and their operators were made here as well. But unlike shovels, draglines typically have an anteroom behind the cab. Although their designs and layouts can differ considerably, anterooms are usually about the size of a large travel trailer and can contain cooking facilities, dining tables, refrigerators and considerable additional storage.

And, again unlike shovels, draglines may frequently be staffed with a number of individuals who are employed as tenders, as well as maintaining equipment inside the massive ‘house’.

## CASE STUDY

After moving on to Queensland, Australia, and two weeks visiting various mines (primarily coking coal) in the vicinity of Moranbah and Emerald in the outback, the team eventually racked up a total of 83 (3 women, 80 men) operator interviews on 50 machines in the USA, Canada and Australia. Taken together, the interviewed operators represented a collective machine operation experience of upwards of one million hours, an impressive number by any measure.

### Electronic research outreach

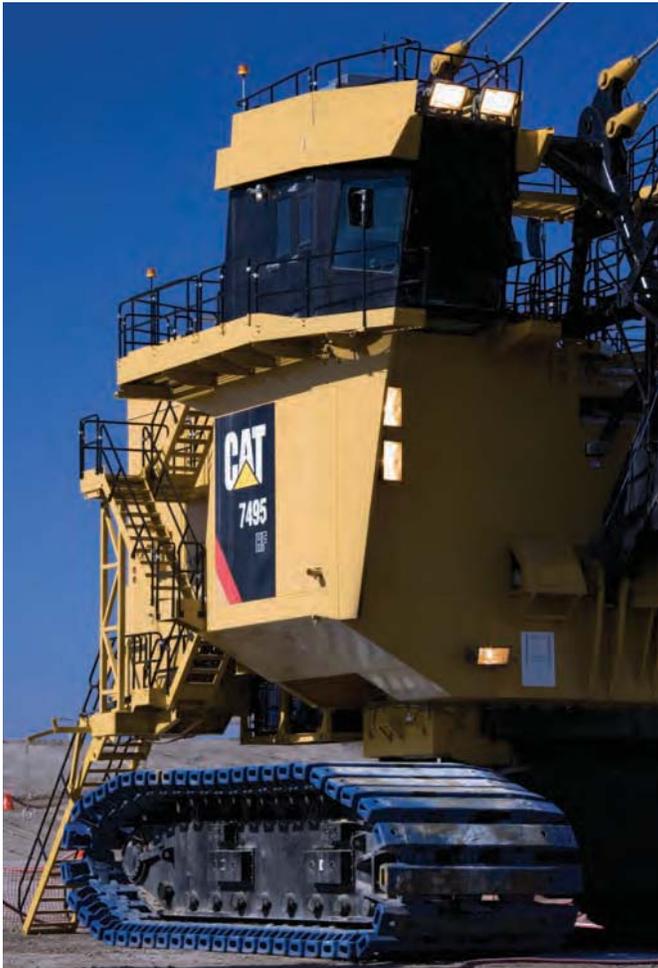
Despite our interest in understanding all markets, it was recognised that not all markets around the world could be visited by the research team. Accordingly, shovel and dragline operators worldwide were sent an electronic questionnaire to further extend the research outreach.

A total of 66 machine surveys containing complete descriptive and photographic records of cab interiors and exteriors were received from



ABOVE: The rather cramped toilet doesn't quite share the same feeling of luxury and space as the cab

BELOW: Optimum window and pillar placement and sizing was achieved after numerous studies had been carried out



### A VIEW FROM THE OPERATOR

▶ *IVT's* editor recently had the pleasure of clambering around this new cab, not just as a self-contained unit exhibited at Minexpo, but on an actual 7495 electric rope shovel at Caterpillar's training facility in Tinaja Hills, Arizona, USA.

Having climbed up the 44 steps to the cab on a very warm day indeed, while musing on the possibility of simplifying access with a Stairmaster, a luxurious seat was a welcome sight in itself.

Sitting across from me in the operator's chair was demo instructor Jim Shanklin, who left me in no doubt as to how much he loved the new, bigger design.

"The seat is comfortable, and it handles like a champ," was his succinct appraisal. "I grew up using traditionally positioned controls, but the kids nowadays like to run them right here," he said, deftly drawing them together in front of his stomach. "You can just about set them up any way you like, and the armrests' indents to rest your forearms in are really comfortable too.

"The older machines just didn't have this level of visibility. Now it's incredible – you can see round the sides, to the back and straight down to the ground," he enthused, lifting up the grate and angling it to brace his feet against. "There's good lighting, and the electric shades come in really handy too, when you're working all night and the sun suddenly pops up over the horizon.

"What I love about it is that it's super quiet," he continued. "It's not exactly soundproof, but those doors are heavy – so for all the noise that's going on back there, it's pretty amazing!"

He also highlighted the refrigerator and microwave as bonuses, which means he no longer has to bring a sandwich toaster to work(!) From my point of view, I was highly impressed, but couldn't quite shake the feeling that some of that space – and more pertinently, luxuriousness – should have been allocated to the rather poky downstairs toilet (see left)...

mines in Asia, Africa, North America, South America and Europe.

Shovel and dragline operators can be surprisingly devoted to their unusual machines and take great pleasure in providing detailed information when an interest is expressed. Whereas oriental carpets and curtains might hang from the walls of a dragline cab in North Africa – and rice cookers often take the place of a microwave oven in cabs in Mongolia and China – there were certainly more similarities than differences in regards to operator requirements for the next-generation cab and control system.

The results from this expedition proved to be invaluable, and were added to the eyewitness data that was collected during the team's actual mine visits.

### Design development

More than 1,000 user comments and observations were computer analysed to identify important themes and, ultimately, design objectives. This information, taken together with the team's personal observations and ideas, resulted in a cab specification that would serve as a roadmap to development.

Initially, particular attention was paid to the basic size, structure and layout of the cab. Numerous layout, as well as styling, concepts were developed using 3D computer models.

The final design incorporated an operator-forward arrangement, trainer's station, observer's station, an entry door on the side, and a second entry door at the rear – the latter serving as the entrance from the anteroom in the case of a dragline. Another reason for having the back door was that it provided a straight-on path to facilitate moving a stretcher into and out of the cab in the case of a medical emergency; an issue we had occasionally heard about during our interviews.

Storage, cabinets and counter tops lined the central fore-aft aisle, providing an efficient and functional arrangement for the cab as a whole. Particular attention was given to ensuring that all of the gear that had been previously inventoried in the 50 visited machines could be stowed within the new layout.

Seating comfort, ride quality, fatigue reduction, communication, remote viewing and camera systems, emergency systems, noise, ingress and egress, control adjustability, glare control, operator reach zones and hand holds are just a few of the topics addressed during the cab design phase.

Visibility was deemed to be of particular importance, so numerous visibility studies were therefore performed for optimal window and pillar placement and sizing – the result being notable improvements



Designing the operator's station was a major undertaking in its own right. Special emphasis was given to having a fully adjustable seating and armrest system to accommodate the full range of operators as they ran controls while experiencing a considerable amount of motion.

Touchscreen control systems have been employed extensively due to the large number of elements requiring control as well as the design flexibility that is provided by touchscreens. For example, not only do shovel and dragline controls operate somewhat differently, but individual mines can have preferred control-response mapping. The use of touchscreens was therefore important in meeting these and other control and display reconfiguration needs without the need to have entirely different sets of hardware.

Military human factors interface design specifications were used in the design of touchscreen control and display elements to help ensure operability in a rugged and moving environment. Custom, patented joystick controllers were developed and incorporated into the fully



ABOVE: Future operators evaluate the cab design mock-up in Wisconsin as the author listens in

adjustable and supporting armrests. Camera views from inside the 'house' as well as all around the vehicle are provided by displays mounted above the front cab window, along with a rearview mirror that provides the operator with a view of the cab behind him or her without the need to turn around.

Prior to the construction and extensive field testing of the final cab in mines, two-dozen shovel and dragline operators from all around the world were brought to South Milwaukee for a week-long test and evaluation of the new cab concept.

These miners systematically evaluated all aspects of the cab, helped in the selection of seating and other elements benefiting from their final input, and by comparing the new design with the one it has replaced, helped to quantify the improvements of the new cab.

The new, super cab has met with great success since its introduction, and is now in operation on dozens of new machines all around the world. The product is a testament to the value of an operator-centric approach to design. **IVT**

in the upward views of the boom, downward views of the ground, and views out of the side – something of particular importance with a shovel that is constantly co-ordinating its movements with the comings and goings of haul trucks.



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