



CAT® MINESTAR™

# COMMAND FOR DRILLING

START YOUR DRILLING  
OPERATION STRONG—  
AND FINISH STRONGER

PRODUCT BROCHURE



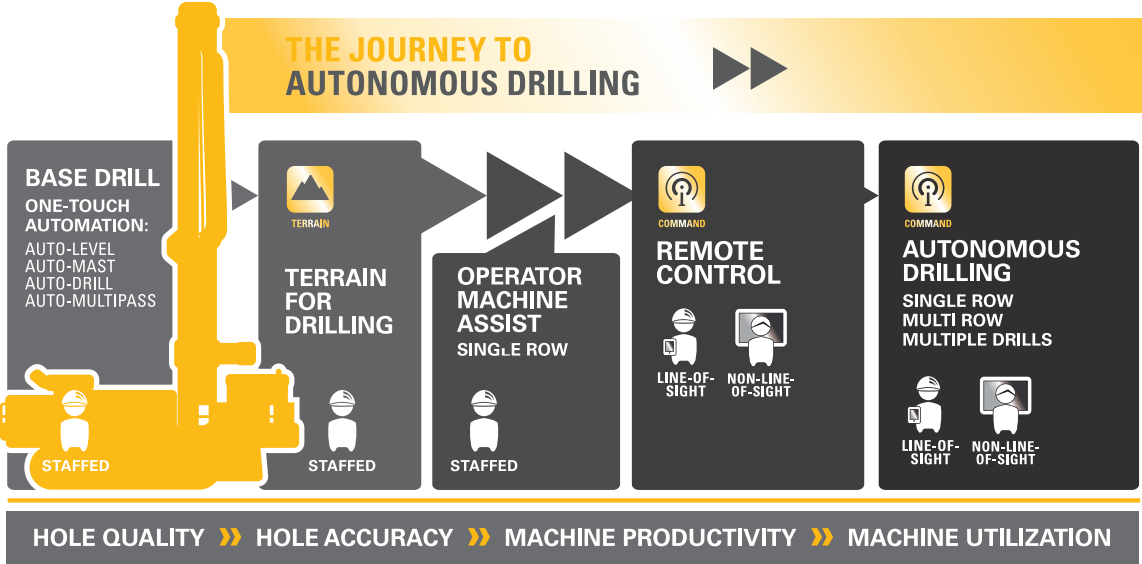


# BOOST SAFETY, PRODUCTIVITY, UTILIZATION & ACCURACY — THROUGH — DRILL AUTONOMY

Cost-effective, high-precision autonomous drilling impacts your entire mining value chain. Cat® MineStar™ Command for drilling enhances safety and improves drilling accuracy, productivity and utilization through drill automation — which will ultimately reduce your cost per ton. From pre-drill planning to blasting, Command impacts the bottom line all the way through the crusher and mill.

Command for drilling offers a range of capabilities, utilizing a building block approach that allows you to configure and automate the drilling system to meet your needs. The building blocks facilitate change enablement when moving an operator from onboard to off-board operation.

You can start your journey to autonomy with Operator Machine Assist—an operator assist technology—or begin with an off-site multi-row autonomous drilling system. Command also enables non-line-of-sight remote control of drills, with operators working either on- or off-site in a safe, comfortable Remote Operator Station (ROS). Command for drilling was designed for every step of your drill optimization journey.



Command for drilling takes advantage of the most sophisticated technologies available to deliver a next-generation drilling solution — one that boosts safety, productivity, and utilization at mine sites, especially those in difficult or remote locations.

#### ENHANCED SAFETY

Operator is removed from potentially hazardous environments

#### INCREASED PRODUCTIVITY

With reduction of non-drilling time from the drill cycle

#### HIGHER UTILIZATION

With the minutes and hours of delays turned into production time

#### REDUCED OPERATIONAL COSTS

Fewer re-drills, reduced drill wear and damage caused by the operator

## ENHANCED SAFETY

## GREATER ACCURACY

## INCREASED PRODUCTIVITY & PRODUCTION



### REMOTE OPERATOR STATION: SAFE, COMFORTABLE & PRODUCTIVE

- + Allows operator to control a single drill remotely or manage multiple drills while seated in a comfortable location on or off site
- + Line-of-sight remote control
- + Non-line-of-sight drilling
  - Remote control and non-line-of-sight operation
  - Autonomous assignments launched from a tablet interface or ROS controls
- + Removes operators from hazards and causes less mental and physical fatigue
- + Makes it possible for operators to extend their careers as drill controllers



### COLLISION AVOIDANCE SYSTEM: ESSENTIAL FOR SAFE AUTONOMOUS OPERATION

- + Enables automatic machine intervention controls when dangerous interactions are detected with other machines or objects and is an essential feature required for safe autonomous operation
- + Will safely bring the machine to a stop when objects are detected in the immediate path of travel of an autonomous drill
- + Makes calculated decisions on when to react to detected objects, as well as which objects should be filtered out
- + Continues drilling after object is detected, increasing productive time
- + Designed to keep uptime high and not disrupt autonomous drilling activities



# BUILDING BLOCKS TO SUCCESS

Command for drilling offers a range of capabilities, so you can configure and automate the drilling system to meet your budget and the needs of your site. Features and components serve as building blocks that allow you to easily grow and add features and capabilities at your own pace.

## THE JOURNEY TO AUTONOMOUS DRILLING >>>

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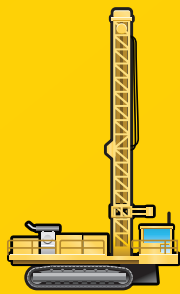
### DRILL ASSIST BASE MACHINE AUTOMATION

Enables One-Touch Automation

- + Auto Level with auto jack retract
- + Auto Mast—raise, lower and lock into place at proper angle
- + Auto Drill—single- or multi-pass automated drilling without operator intervention

#### Benefits

- + Reduced drill cycle time
- + Lower overall production costs
- + Improved hole consistency for higher quality blasts
- + Less stress on machine, which leads to reduced downtime
- + Error-free, technology-driven decision-making
- + Increased productivity for operators at any skill level



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### MINESTAR TERRAIN FOR DRILLING

Delivers State-of-the-Art Guidance

- + High-precision GPS guidance for operators
- + Patterns completed accurately and efficiently
- + Tracks drill consumables
- + Strata Recognition generates Blastability Index
- + Accurate Measurement While Drilling information aids in designing charge distributions
- + Drilling results database of measured improvements

#### Benefits

- + Improved safety
- + Improved drilling efficiency, accuracy and plan compliance
- + Less under- and over-drilling
- + Better blast planning and fragmentation
- + More consistent performance from inexperienced operators
- + Reduced survey work
- + Published drilling results via Terrain Database reporting



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### IN-CAB OPERATOR MACHINE ASSIST

Provides Operator-Assist Functionality to the Operator

- + Automates entire drill cycle
- + Operator can select a row of holes
- + Drill navigates from hole to hole, and auto-drills all holes in selected row
- + Operator ensures safe drill movement before authorizing auto-tram to the next hole

#### Benefits

- + Safer operations through multiple safety layers
- + Improved pattern accuracy and operational consistency
- + Increased productivity and fuel efficiency
- + Better compliance to plan
- + Equalized operator performance



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### NON-LINE-OF- SIGHT REMOTE CONTROL

Allows Operator to Remotely Manage Multiple Drills

- + Operator relocated to a ROS in an on-site or off-site location
- + Familiar and comfortable environment replicates the cab of the MD6250 and MD6310
- + Operators can control a single drill remotely or manage multiple autonomous drills
- + Maintains use of base drill auto-functions
- + Provides situational awareness with onboard vision and collision avoidance sensors

#### Benefits

- + Improved drill and blast safety
- + Accurate in-hole/bit positioning for every hole
- + Consistency in all functions of drill operation
- + Optimized asset utilization
- + Improved rock fragmentation
- + Higher productivity



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### AUTONOMOUS DRILLING SYSTEM

Automates the Entire Drilling Cycle

- + Single-row or multi-row solutions depending on drill model and application
- + Automates entire drilling cycle for a defined assignment
- + Autonomous tramming between holes and rows
- + Assignments launched from a tablet interface or ROS
- + One operator can manage drill operations across the mine site
- + ROS located on site or at off-site command center

#### Benefits

- + Higher machine utilization
- + Enhanced safety with operator removed from the cab
- + Increased pattern accuracy and operational consistency
- + Increased productivity
- + Fragmentation improvement that leads to downstream improvements for loading, hauling and crushing operations
- + Works on Cat and non Cat machines (semi-autonomy only)



# KEEPING PEOPLE AND MACHINERY SAFER

One of the most important benefits of autonomy is safety. Command for drilling contributes to a safer drilling operation in multiple ways—reducing risk to operators on the job, creating safer mine sites and protecting machines from damage.

## PROTECTING OPERATORS

Autonomy removes operators from the machine, which also removes them from exposure to things like noise, dust and vibration. There is less potential for injury related to the functionality of drill tools or drill deck activity, or to slips and falls when climbing on and off the machine.

Command for drilling also reduces risks in the event of a high wall collapse, machine roll-over or fall, and risks associated with operating near crests and voids. And by preventing drilling near previously drilled holes, Command minimizes the risk of drilling into bootlegs, which may contain undetonated explosive material from the previous blast.

Beyond safety risks, Command for drilling also protects operators from the stress on their bodies that comes from hours spent in the cab. Operators operating from the Remote Operator Station experience less wear and tear on their bodies as well as a decrease in mental fatigue after their shifts. With less mental and physical fatigue, operators are more able to extend their careers as drill controllers.

## IMPROVING SAFETY ACROSS THE SITE

In addition to protecting those who operate the machines, Command also contributes to a safer overall drilling operation for everyone on site.

- + Automated drilling results in quality holes, which leads to improved containment of explosive energy, reducing the occurrence of flying rock and face venting of energy.
- + The use of digital drill plans and remote operations reduces the number of survey and operating personnel required on the drill bench.

Command also helps ensure the safety of everyone working in the vicinity of autonomous equipment.

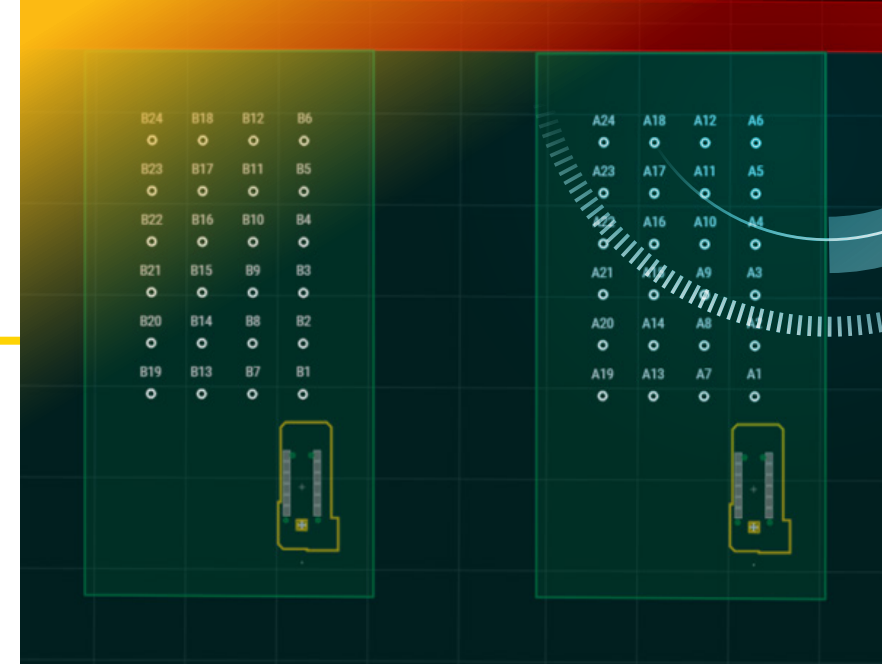
- + Command remotely monitors all mobile equipment equipped with MineStar Terrain working in the autonomous zone.
- + The handheld A-Stop device stops all autonomous vehicles equipped with Command within about 300 meters (984 feet) with the push of a button. Drills equipped with Command for drilling are fully compliant with the A-stop feature.

Command provides additional layers of safety beyond physical barriers to prevent non-essential personnel or machines from entering the work zone. This includes aligning electronic geo-fencing of the drills operating in autonomous mode to the site's physical markings and signage delineating drill benches. Command introduces Autonomous Operating Zones, Autonomous Exclusion Zones and Autonomous Inclusion Zones, enabling safer pattern design and drill segregation across the pattern.

### Collision Awareness & Avoidance

Command-equipped drills can take advantage of sophisticated technologies that help increase awareness of potential collisions, and in some cases prevent them by stopping machine operation when a hazard is detected.

- + Collision Awareness is compatible with Operator Machine Assist and Remote Control capabilities— notifying operators of the positions of nearby objects.
- + Collision Avoidance enables automatic machine intervention controls when dangerous interactions are detected with other machines or objects and is an essential feature required for safe autonomous operation.



### Virtual Boundaries

#### Autonomous Operating Zones

Autonomous Operating Zones (AOZ) segregate the Autonomous Drill Plan from staffed operations. All drills within the AOZ are autonomously or remotely operated machines.

- + Office personnel create the AOZ for the individual autonomous drill plans in Terrain Office.
- + The AOZ is visually displayed to the Drill Controllers on the autonomy user interface (UI) and to the Office personnel in Terrain Office.
- + Command for drilling will prevent autonomous drill operations outside of the AOZs.
- + Autonomous Exclusion Zones can also be created from Terrain Office to prevent autonomous or remote-controlled drills from entering keep out areas on the bench.

#### Autonomous Inclusion Zones

In conjunction with AOZs, Command for drilling offers Autonomous Inclusion Zones (AIZ). These are areas within the AOZ that are assigned to specific autonomous drills. The Drill Controller will manage individual drill AIZs, adding another layer of safety when there are multiple autonomous drills on the same bench. AIZs are automatically clipped to reside only within the AOZ. Drills equipped with Command can operate autonomously only within their individually assigned AIZ; the AIZs of other Command-equipped drills are treated as autonomous exclusion zones.

## PROTECTING MACHINES

Command for drilling incorporates features and functionalities that protect the drills themselves from potential risks of autonomous operation. Multiple, redundant features are built into Command for drilling to stop all motion should one of these events occur:

- + Any Emergency Stop or A-Stop is pressed
- + Extended loss of wireless communications is incurred
- + An object is detected in the immediate operating area
- + Any of the multitude of base machine interlocks are triggered
- + Detection of a fault where continued operation will result in machine damage
- + Machine enters an avoidance zone or tries to exit an inclusion zone
- + Operator presence detection is triggered from the operator station
- + Remote fire suppression is activated

Command for drilling is the only autonomous and remote-control solution that integrates directly with Cat machine electronic control systems. All Cat drills leave the factory ready for autonomy, saving installation time and speeding machine response time compared to aftermarket systems.

Command for drilling utilizes the base machine automation functions — Auto-Level/Retract, Auto-Mast, Auto Single-Pass Drilling and Auto Multi-Pass Drilling — to complete autonomous cycles. Tightly integrating with the base machine automation eliminates the need for additional control systems that require additional hardware, maintaining the integrity of the drill. Command also uses the base machine interlocks and controls, requiring no changes to existing site repair processes and enhancing existing drill diagnostics.

# WHAT CAN AUTONOMOUS DRILLING DO FOR YOUR OPERATION?

What if you could complete drilling precisely to plan, produce better quality holes and drive better blasting results? What if you could provide fragmented material of the right grade and size—increasing the efficiency of downstream operations? And what if you could achieve this while consuming less fuel and energy? MineStar Command for drilling can help make it possible.

The benefits of Command for drilling are extensive. Drilling automation:

- + Improves operator productivity and effectiveness, and increases safety by removing operators from dust, noise and vibration.
- + Boosts safety through:
  - Collision Awareness for Operator Machine Assist and Remote Control capabilities— notifying operators of the positions of nearby objects.
  - Collision Avoidance, which will safely bring the machine to a stop when objects are detected in the immediate path of travel of an autonomous drill—allowing essential tasks to be carried out safely on the same bench.
- + Delivers consistent and accurate drilling that pays off with better blasting outcomes, more productive loading and hauling, and more efficient final processing.
- + Delivers higher, more consistent drilling rates across varying geologies for all operators, resulting in an increase in overall fleet productivity.
- + Helps to ensure that every hole is accurately placed to plan and consistently drilled to the proper elevation and angle—improving final blasting results.
- + Reduces machine wear and tear by enabling optimized drill operation under OEM operational parameters.
- + Converts non-productive drilling hours into productive drilling hours.



## IMPROVED ACCURACY

High-precision Global Positioning System (GPS) guidance capabilities provided by Terrain for drilling ensure that every hole is autonomously drilled exactly to the designed coordinates and desired floor elevation. Autonomous drilling helps ensure the designed toe elevation is always on target so each shot produces a smooth, level bench—saving wear and tear on tires, undercarriages and other equipment. Terrain for drilling has been proven to boost pattern accuracy by 10 times compared to sites without a GPS guidance solution. Sites employing Command for drilling, starting with Operator Machine Assist, have seen compliance to plan up to 20% and higher than a Terrain-equipped machine.



## HIGHER UTILIZATION

Command for drilling automates the entire drilling cycle, including tramming between holes and rows of holes. The Autonomous Drilling System removes the operator from the cab of the machine, making it possible for each operator to manage up to five drills. The system facilitates short breaks and quick shift changes while autonomous drilling continues, giving mines more working time and less idle time during every shift. Utilization losses are recorded and studied using Terrain Reporting; analysis of this data has indicated at least 12.5% of utilization opportunity can be captured with Command for drilling.



## INCREASED CONSISTENCY

Automated drilling functions ensure consistent operations across the pattern and maintain operation within OEM recommended operating parameters — resulting in maximum bit life, reduced costs for consumables, longer machine life and lower maintenance costs. Command for drilling never has an off-day and can eliminate potential skill gaps between operators. Starting with Operator Machine Assist, Command reduces operator variability and increases consistency of drilling operations by up to 35% versus staffed operations, promoting advanced logistics planning and improving sequencing of the drill operation.



## REDUCED OPERATIONAL COSTS

Command for drilling helps reduce personnel costs across the operation. It allows one operator to manage multiple drills at once and enables remote operations that reduce or eliminate the costs associated with operator travel and onsite housing. Command for drilling can also contribute to lower fuel costs. It modulates the engine speed based on the activity being performed, decreasing the overall engine load and, in some cases, increasing fuel efficiency.



## INCREASED PRODUCTIVITY

Command for drilling improves cycle times by converting non-drilling time into drilling time. With Command, drill cycle activities such as leveling, un-leveling and tramming between holes are quicker. The drill arrives at target accuracy the first time and transitions between cycle activities without hesitation. This optimization removes typical inefficiencies seen during every drill cycle of a staffed operation. Command for drilling also leverages the base machine Auto Drill system, providing consistent quality drilling within OEM parameters. Sites utilizing Command for drilling have seen productivity increases of up to 17% or more across their drill fleet.



## BLASTHOLE AND FRAGMENTATION QUALITY

Command for drilling provides consistency to the planned design hole coordinates. Holes are always drilled to the designed elevation, which eliminates wasted tool wear from over-drilling. Matching the designed XYZ of hole collar and hole toes delivers high parallelism of holes at the designed spacing, which provides a consistent, specific fragmentation size as permitted by the rock strata. Drilling to plan and within optimal operating parameters results in quality holes with higher stand-up times. Targeted fragmentation improves diggability, which improves cycle times and fill factors — reducing the need for additional rock breaking and maximizing crusher and milling efficiencies.



## AUTONOMOUS DRILLING SYSTEM

The Command for drilling Autonomous Drilling System helps optimize the drilling process at mining operations. It enables multi-row autonomous drilling, empowering an operator to manage multiple autonomous drills across the mine. Drill controllers can safely manage autonomous drill assignments from a line-of-sight tablet or from a non-line-of-sight ROS located on site or off site. A line-of-sight tablet provides an opportunity to autonomously drill without the robust network requirements required for camera streaming to the ROS.



### THE AUTONOMOUS DRILLING SYSTEM:

- + Enhances safety by removing the operator from the cab—and potentially the mine—and by reducing people-to-machine interactions
- + Improves operational consistency
- + Increases productivity
- + Increases machine utilization — helping optimize how operators use their time by enabling one operator to manage multiple drills

### HOW IT WORKS

The Autonomous Drilling System (ADS) enables the drill to drill the complete pattern, with autonomous row change, as-designed—without operator intervention. ADS is designed to minimize the number of interactions an operator makes with the user interface. The drill controller is responsible for selecting the row change type and indicating which rows of holes are to be drilled during the autonomous assignment. From there the autonomous system will calculate the path of travel.

The multi-row autonomy solution will provide the drill controller with two selectable options for row changes. The operator will indicate the row to which the drill will be positioning, and then select between application-based row change method: a 180-degree turn to the next row, or a turn that will reverse the drill to the first hole in the next row. Once the assignments are set across the fleet of drills, the controller monitors the pattern progression and status of the drills from either the tablet or ROS. The controller's role then becomes exception-handling, where Command enables the operator to quickly handle an exception and then immediately resume the planned assignment with minimal interruption to productivity.

### MAINTAINING SAFETY: COLLISION AVOIDANCE SYSTEM

The Command for drilling Collision Avoidance System can be installed on Cat MD6250 and MD6310 drills, providing 3D detection capability around the entire footprint of the machine. The system is designed to maintain a safe area around autonomously operating drills, while ensuring productivity is not affected by conditions typically encountered during operations such as dust, inclement weather and known objects. As an additional safety layer, the system helps ensure the right objects are detected and protects the drill from unwanted operations.

The Collision Avoidance System is intended to display to the drill controller the relative (front, rear, left, right) location and severity of detection based on distance to the detected object in relation to the drill.

Designed to keep uptime high and not disrupt autonomous drilling activities, the Collision Avoidance System makes calculated decisions on when to react to detected objects, as well as which objects should be filtered out.

Upon detecting an object, Command will determine the correct reaction, based on distance to the object,

current machine activity, and the position of the object relative to the planned path of the drill. For example, if an object is located a distance behind the drill while the planned path is forward, the drill will continue to travel, as the object does not pose a risk of collision. For the same reason, object detections during drilling have no impact on autonomous operation.

Command for drilling utilizes an advanced algorithm for autonomous drills to work near known objects typical of a drill area, such as berms and cuttings piles, without interruption and while maintaining a safe distance from hazards. The algorithm also enables autonomous drills to operate efficiently without interruption due to dust or inclement weather conditions.

Caterpillar recommends the completion of a full risk assessment when the Collision Avoidance System is installed on an autonomous drill and recommends drill isolation administrative controls also be implemented in conjunction with Collision Avoidance.

- + Provides full coverage around the drill
- + Provides operator awareness for staffed and remote-control operations (Operator Machine Assist and Remote Control from the ROS)
- + Delivers easy-to-understand visual notifications
- + Continues drilling after object is detected, increasing productive time
- + Reacts only to objects detected in the direction of travel
- + Filters out larger turkey nests, reducing detection events
- + Hardened to withstand varying weather conditions (rain, snow, etc.)



# ONBOARD COMPONENTS: GET THE BENEFITS OF TIGHT INTEGRATION

Command for drilling is the ideal autonomy solution for Cat Rotary Drills. It is tightly integrated into the base machines and into the existing MineStar Terrain High-Precision GPS. Utilizing existing control systems enables less-invasive installations. Two models of Cat drills, the MD6250 and MD6310, come out of the factory autonomous-ready, with built-in attachment-ready options for all Command and Terrain installations. With harnessing and connections already built into the base machine and common components leveraged by the machine and technology, total installation time is greatly reduced compared to other aftermarket technology solutions. Tight integration minimizes interoperability issues and maintains the integrity of the base machine hardware and controls.

Command for drilling can be installed on Cat drills as well as those made by competitors. Retrofit kits are currently available for the Cat MD6640, P&H 320XPC and 120A, and Bucyrus 49R and 49HR. The package integrates with the base machine controls and does not hinder manual operation. Retrofit options reduce capital costs by allowing you to implement Command on existing machines rather than purchasing new.

## NOTES

### INDICATOR LIGHTS

- + High-intensity blue LED lights: Machine is in remote operation
- + Green lights: Machine is being controlled manually
- + Red lights: Machine has been stopped by the A-stop

### VISION SYSTEM

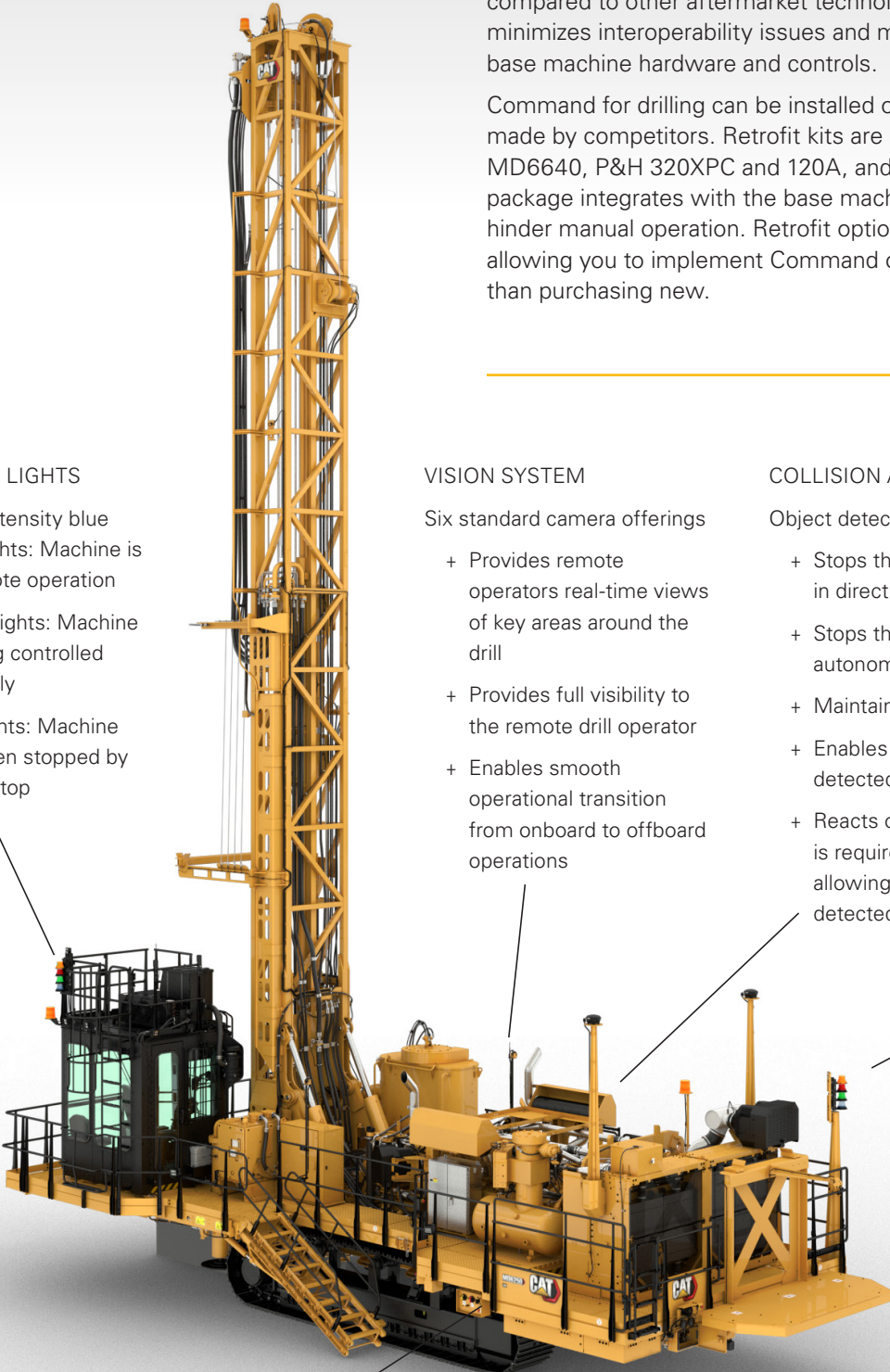
- Six standard camera offerings
- + Provides remote operators real-time views of key areas around the drill
  - + Provides full visibility to the remote drill operator
  - + Enables smooth operational transition from onboard to offboard operations

### COLLISION AVOIDANCE SYSTEM SENSORS

- Object detection capability:
- + Stops the drill when objects are detected in direction of travel
  - + Stops the machine only during autonomous operation
  - + Maintains a safe area around the drill
  - + Enables the drill to react to objects detected in the path of travel
  - + Reacts only if react if machine movement is required, increasing productivity by allowing drilling to continue if an object is detected

### A-STOP ANTENNAS

### MODE SWITCHES



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# COMMAND FOR DRILLING

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