

Cat[®] Command for Hauling



Autonomous Control for Your Mining Operation

- *Autonomous trucks work safely with other manned and light vehicles on the site*
- *Multiple, redundant safety features ensures the system functions in a safe, predictable manner*
- *High productivity through near continuous machine utilization*
- *Reduction in process variability and better planning of maintenance and downtime improves operational efficiency*



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Cat MineStar System is the industry's broadest suite of integrated mine operations and mobile equipment management technologies configurable to suit your operation's needs.

Combining the Fleet, Terrain, Detect and Health capabilities of Cat MineStar System, Command enables you to implement remote control, semi-autonomous or fully autonomous mining equipment systems – offering unprecedented improvements in operator safety, equipment availability and site productivity.

Command for hauling takes advantage of sophisticated technologies to enable Cat autonomous haul trucks to work safely and productively on busy mine sites. More than just an operator-free equipment system, Command for hauling is a complete, autonomous solution that delivers solid, bottom-line benefits for miners who need to work in challenging and remote locations. Highly advanced safety systems enable Cat autonomous haul trucks to operate reliably around other mining equipment, light vehicles and site employees.

Automation Addresses Mining Challenges

More miners are looking to automation for answers.



Partnering to Achieve Success

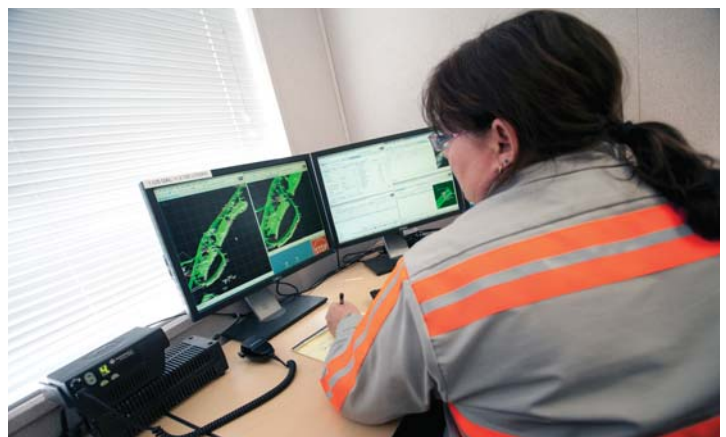
Command for hauling is part of an integrated mining solution tailored specifically for your operational needs. Caterpillar and your local Cat dealer will partner with you to meet production requirements, plan equipment maintenance and monitoring, ensure safe operating procedures and collectively look for areas to improve operations via the comprehensive technology suite. This long term agreement benefits all involved parties by utilizing the knowledge of Caterpillar and its dealers to focus on the machine, technology and product support, while relying on your expertise of the mining application and processes to collectively make your operations more profitable.



Autonomy is rapidly emerging in the mining industry as an imperative to achieving safety and expansion strategies. Command for hauling enables total autonomous operation of mining trucks, interaction with other equipment and integration with customer mining processes and systems, all managed by Cat MineStar System. Autonomous trucks respond to calls to the shovel, move into loading position, haul loads to the designated dump points and even report to the maintenance bay without an operator on-board.

Automation solves many problems faced by miners in today's competitive environment. With reserves being mined in more remote locations than ever, infrastructure requirements and labor shortages pose challenges that are difficult to overcome with manned mining operations. Automation resolves some of these challenges while making mines more safe, efficient and productive.

- Provides productivity improvements through significantly improved utilization
- Reduction in process variability positively impacting plant throughput
- Supports your sustainability efforts by lessening infrastructure needs and operating the equipment as designed, reducing fuel burn, machine downtime and wear part replacement
- Enables majority of workforce to remain in developed areas, improving employee retention and engagement while lowering travel costs
- Reduced manpower on site and on machines enhances site safety and lowers human resource costs



Improve Productivity

- Increases utilization and eliminates downtime caused by shift change, operator breaks or absence
- Ability to alter or redesign mine maps to meet changing operational needs without stopping production
- Orderly truck queuing, faster spotting and reliable tracking of haul times and distance aids in fleet optimization
- Utilizes proven Fleet mine management software to efficiently assign machines, track material flow, reduce misroutes and track production statistics to continuously improve operations

Enhance Safety

- Controlled access to pit reduces the number of people and vehicles exposed to mining hazards
- Positional awareness accurately displays machines and light vehicles on a digital mine map to help manage traffic flow and vehicle interactions
- Predictable operation has the potential to reduce accidents caused by unintended machine movements
- Safely navigates complex haul roads and mine site traffic through advanced sensing technology

Reduce Maintenance Intervals and Cost

- Virtually eliminates the potential for machine damage from misuse and overloading because the machine is always operated as intended
- Monitoring equipment health conditions alert maintenance personnel of machine faults and upcoming service intervals to enable repair before failure



Improve Productivity, Safety, and Availability

Continuous, predictable operations enhance efficiency.



Command for hauling is one piece of an integrated mine automation system. Machines, technologies, processes and knowledgeable personnel combine to help you improve productivity, enhance safety and reduce maintenance costs.

Command for Hauling Operation

Advanced technologies control complex machines.



Command for hauling utilizes a suite of technologies, wireless communications and global positioning to automate Cat mining trucks. Advanced perception and sensing technologies enable it to work safely and productively alongside manually operated equipment, such as loading tools, cleanup and maintenance machines, and mine site personnel. A communication and data network is required with bandwidth to reach every point in the autonomous operating zone. This includes a control center that houses office software, while support vehicles are equipped with interface panels that allow data input and limited truck control from the field. Key operational features include:

- Operating in either autonomous or manual mode. Cat autonomous trucks have the same performance and functionality of the standard truck model when operated in manual mode.
- Processing data from on-board sources such as electronic control modules and sensors, as well as off-board sources like satellite positioning and operation updates from the mine office.
- Autonomous operating zone defines the specific area where automated operations occur and controlled access is needed. A more refined autonomous inclusion zone limits automated truck activity to a specific, controlled area such as load and dump points, fueling and maintenance bays.
- The system, configured by the Command Operator, generates lane assignments to destinations such as load, dump or maintenance stations. Assignments are also optimized by rerouting to avoid bunching, sending the nearest available truck, and managing intersections to keep traffic moving smoothly.
- Interaction between autonomous trucks and manned mine support vehicles are managed through the system. For example, loading tool operators set the spot point for autonomous trucks. Operators of manned vehicles can view nearby autonomous machines on their in-cab display to know the location and proximity of automated machines in the working area.
- Creates and maintains the virtual mine map, including status of load and dump areas and road conditions.

- Tracks the location of all mobile equipment and obstacles or hazards in the autonomous zone and distributes positions continuously so all mobile equipment and other assets appear on the mine map.
- Monitors machine health, modifying truck operation to optimize performance and avoid downtime.
- Compiles operations data and generates detailed, real-time production analysis.
- Autonomous stop devices, carried by each person that enters the autonomous operating zone, enable an immediate stoppage of all autonomous machines in the area.
- Sophisticated sensors allow safe edge dumping to be performed, reducing the need for auxiliary equipment at the dump point. All traditional dumps can be performed including paddock, highwall and crusher among others.
- Obey mine Ground Control Plans including speed limits, queuing protocol, signaling and executing predetermined intersection priorities.
- Utilize proven Cat Detect technologies to prevent collisions with unexpected objects in the truck's path. When obstacles are detected the truck will slow to a stop and await further instruction from the office before proceeding.
- Dynamically create new paths of travel in the load and dump areas. Dynamic lane creation by the autonomous truck prevents the operator from manually reestablishing the lane, freeing them up for more productive work.
- Maintain stability by controlling steering, braking and traction.
- Limit mine support staff intervention to exceptional circumstances such as maintenance or refueling.

Loading Tool Interaction

Terrain provides high precision management of drilling, draglines, grading and loading operations. Loading tools on an autonomous site are equipped with a Terrain on-board display that communicates key functions to the autonomous truck.

- Set Spot: records the location the truck should stop for most efficient loading
- Call Truck: available trucks assigned to pass the queue point and enter the loading area
- Send Truck: after the truck is loaded it is released to continue to its next destination
- Area Stop: loading tool operator has the ability to stop all autonomous trucks in the immediate working area around the loading tool with the push of a button.

Updates to the mine map are transferred between the loading tool and office software. As the mine plan progresses, automated trucks can adjust their path of travel to the changing conditions of the site.

Auxiliary Machine Interaction

Auxiliary machines, such as tracked dozers, motor graders, water trucks or other light vehicles play critical roles in autonomous mining operations. Each is fitted with sensors, software and on-board displays that allow the vehicles to interact with autonomous mining trucks, the office software and other Cat MineStar System equipped machines. All must have positioning and Proximity Awareness capabilities, the ability to lock/unlock zones and to capture and submit terrain survey data.



Safety is Our Top Priority, and Yours

Multiple, redundant systems aid safe operating practices.



Controlled Access to the Pit

Mining can be hazardous work, and keeping your operation safe is a top priority for Caterpillar. All autonomous mine sites must have several layers of protection, beginning with the security and boundary fencing found at most mines. Within the mine site is the autonomous operating zone, in which autonomous vehicles may be used. Entering the zone requires special training and security authorization. In addition, each person is issued a remote A-Stop device, which can bring to a stop any nearby autonomous vehicle. Reducing the number of personnel working around any type of large, moving equipment lessens the potential for injuries.



Autonomous System Stop

There are several primary methods for stopping an autonomous truck in the unlikely event that an unsafe condition arises.

A system A-Stop device is provided to all personnel and machine operators in the pit working area. With the press of a button, the A-Stop command is transmitted direct to the trucks, independent of any radio network, to enable all autonomous trucks in the area to make an emergency stop. The office system receives notification that an A-stop command has been activated and must clear the activity before operations can begin again.

The other option to stop operations is for the office system operator to issue a site-wide stop. This operation broadcasts an immediate stop command to all autonomous equipment.

One of the other safety features built into the Command for Hauling system is the ability for the trucks to stop in the event there is a loss of wireless communications. Because autonomous trucks are in continuous communication with the office, when communication is unavailable, the trucks automatically come to a safe stop using the service braking system, while maintaining position in the center of the lane. They resume operation when communication is restored.



Proximity Awareness

All machines in the autonomous operating zone are tracked and monitored through the Detect capabilities of Cat MineStar System. Positioning and Proximity Awareness technologies display the location of all mine site assets in the office software. If an obstacle is detected within the assigned path of the truck, on-board sensors will enable the machine to come to a controlled stop a safe distance from the object.

In addition, manned machines equipped with Fleet, Terrain and Detect on-board systems can view equipment in the near vicinity on the in-cab display. Enhancing operator awareness of the conditions surrounding their vehicle can significantly improve accident avoidance.

Autonomous Mode Change

Changing a truck from autonomous to manual mode is a multi-step process conducted by the field technician near the truck. Mode indicator lights on the truck tell nearby personnel whether the truck is in autonomous mode, autonomous-ready mode, or manual mode. These lights are an important safety feature in communicating the current mode of the truck and whether it can be safely approached.



Integration with Cat MineStar System

A comprehensive mine management system.



Cat autonomous mining trucks are part of an integrated site system. Interaction and communication with other Cat MineStar System capability sets is what makes the Caterpillar solution unique. More than just autonomous trucks, the system brings together the management of critical functions within a mining cycle to provide new levels of control, monitoring and access to information.

Each of the Cat MineStar System capability sets outlined below is available for manned fleets. In an autonomous mine, these proven systems are utilized with an additional set of features specific for automated trucks.

- Fleet is a trusted system with proven productivity improvements at mining operations around the world. The Command office system builds on the current Fleet software to add additional levels of safety and control for autonomous machines.
- Terrain is utilized on manned loading tools and dozers to communicate commands to the autonomous truck such as queuing, spotting and capturing terrain survey data.
- Detect is the positioning and sensing system, giving the autonomous trucks information about their location and proximity to other equipment and mine site assets.
- Health provides critical event-based information to the office for proactive maintenance management of the autonomous trucks.



Office Software

Utilizing Cat Fleet's full feature set, automation and Proximity Awareness capabilities have been added for safe autonomous control of equipped trucks. The Command office software is managed by four key roles: Shift Lead, Command Operator, Command Builder and Command Technician. Each role has visibility to the screens within the software that are necessary to perform that particular job, putting relevant and timely information at their fingertips.

Shift Lead

The Shift Lead is responsible for all activities in the assigned shift which includes staffing requirements/scheduling, productivity objectives, and equipment management and assignment to meet the daily mine planning production and operations goals.

Command Operator

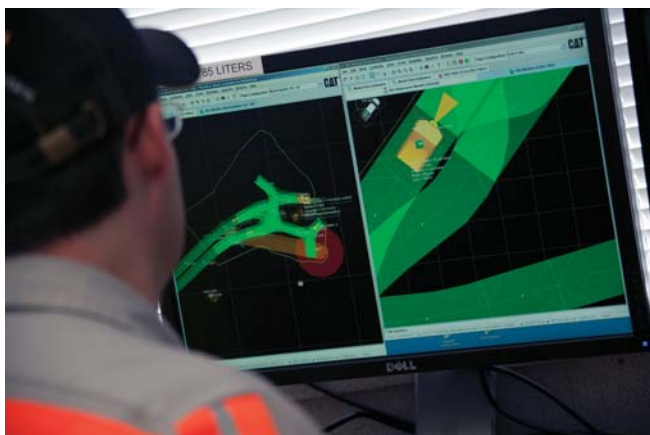
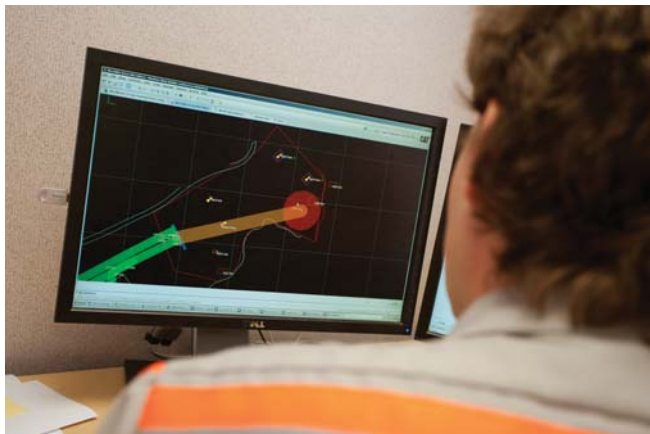
The Command Staff Operator's duties and responsibilities include the pre-shift and shift change functions, observation and management of load, dump and mine site activities, monitors and manages autonomous operating zone access, coordinates site wide activities for equipment operators, water trucks, graders, maintenance equipment movement on site and duties associated with configuring the application to meet mine productivity goals.

Command Builder

The Command Staff Builder is responsible for creation and maintenance of the site survey and surfaces for autonomous truck operations in load, dump and haul road areas and well as integrating planning activity with the overall mine plan to meet short and long terms planning and productivity goals.

Command Technician

Command Technician duties involve direct interaction with the autonomous trucks, including pre-start, starting and coordinating truck movement in the autonomous operation zone with the Command Operator and Builder to meet mine planning and operations goals.



On-Board Components

Rugged and reliable for your harshest mining applications.



On-Board Components

Each mining truck intended for autonomous operations is equipped with specific components and software that allow the truck to work autonomously.

- Multiple perception sensors for obstacle detection and proximity awareness.
- Complete machine health monitoring sensors and software.
- Integrated positioning system, including dual GNSS receivers, for precise position, speed and orientation reporting.
- Wireless communications equipment for exchanging data and positioning information with Cat MineStar System and other machines in the autonomous area.

Positioning

Knowing the precise location of autonomous trucks, loading tools, auxiliary machines, light vehicles and stationary equipment, is critical to proper system operation. The Command for Hauling system depends upon a GPS Base Station, and global positions translated to a local coordinate system with sub-centimeter accuracy. Once the entire autonomous operations area is surveyed and a virtual map is created, the location of each vehicle or piece of mobile equipment must be tracked.

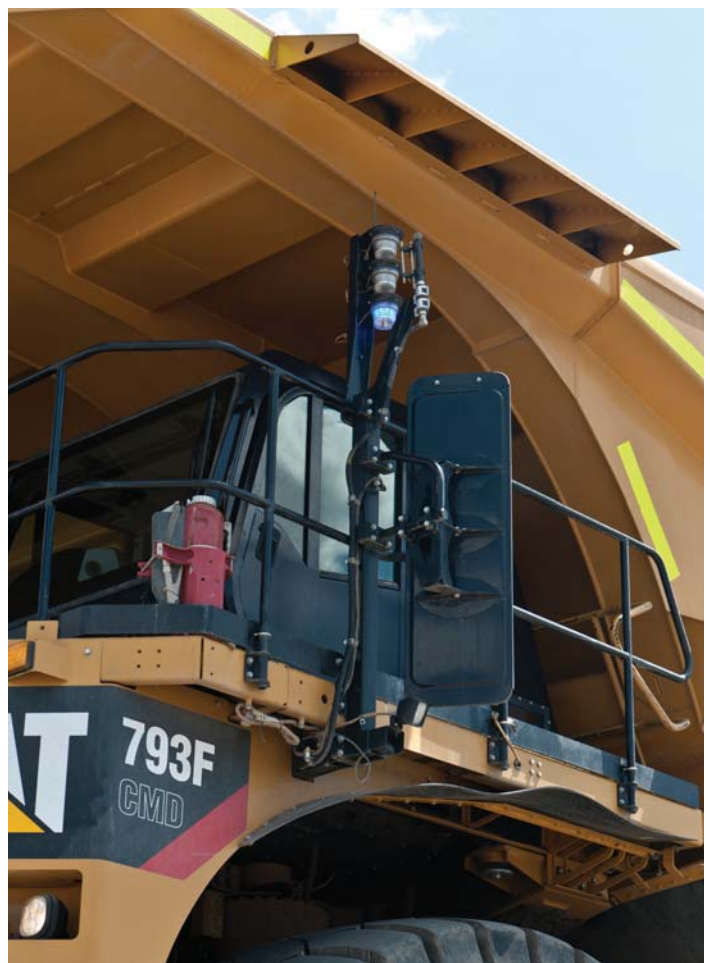
Each autonomous truck is equipped with two GNSS antennae. A single GNSS receiver can reveal the truck's position and speed, but two receivers show the truck's orientation even at rest. Plus, the second mast provides a backup positioning system. Despite redundant systems, should a truck lose the ability to determine its position, it will come to a complete stop and await instructions.

Machine Diagnostics

- On-board diagnostics monitor system health and protect from problems that could result in machine damage or autonomous system failure.
- Additional sensors monitor the performance and health of the on-board network, object detection system, GNSS signals, communications and other systems. Any issues are sent to the Command Operator.
- Payload monitoring provides the truck's current payload to the office software. Overloaded trucks (based on mine site and 10/10/20 rules) should not leave the loading area.
- Tire pressures are monitored for possible leaks or sudden depressurization.

Object Detection

Command for Hauling uses object detection to prevent autonomous trucks from contacting people, vehicles or other objects. Each autonomous truck uses radars and sensors to monitor the immediate work area, identify obstacles and hazards, and determine an appropriate response without human intervention, such as bringing the truck to a stop upon object identification.



Network Infrastructure

Caterpillar partners with you on your infrastructure needs.

Data Systems

The central office and all mine assets must be in constant contact with each other to maintain accurate positioning, monitor machine health and manage autonomous assignments. The configuration of the communications system depends upon the bandwidth needed, the size of the site and other factors. Caterpillar and your Cat dealer can help you spec out a system for your site needs.

Positioning Systems

Continuous line of sight to GNSS satellites is critical for safe, reliable autonomous operation. Command for hauling uses global positions translated to a local coordinate system, a base station and reference stations to track machine and object locations.

Selection

Individual site infrastructure requirements will vary. Caterpillar will partner with you for site planning and infrastructure needs as well as vendor selection.





Support

Caterpillar is with you every step of the way.

Caterpillar will maintain the autonomy components of the Command for hauling system, both on the trucks and in the mine control center. This includes the sensors, in-cab displays and related hardware on machines with site awareness, as well as related software. Caterpillar will also provide trained system specialists who will work with you to define your production goals and establish a plan for your fleet.

Customers are responsible for the maintenance of the autonomous trucks and the Command for hauling infrastructure. Your Cat dealer can help with both, providing the same world-class support you've come to expect with all Cat products, including:

- Preventive maintenance programs
- Diagnostic programs, such as Scheduled Oil Sampling and technical analysis
- Customer Support Agreements
- Rebuild and Reman options

Caterpillar and your Cat dealer will consult with you to maintain optimum system functionality and maximum mine production.

Command for Hauling Specifications

Touch Screen Display

Display screen	165 mm (6.5 in) LCD display, 640 × 480 transfective color VGA	
Electrical input	9 to 32V DC	
Operator switches	Four illuminated push buttons with tactile feedback one 4-way rocker switch	
Video input	Four video inputs, support NTSC video inputs	
Audible alarm	Integral audible alarm located on the front face. Two outputs for external alarm.	
Operating temperature	-20° C to 70° C -4° F to 158° F	
Storage temperature	-40° C to 85° C -40° F to 185° F	
Humidity	100%	
Height	157 mm	6.18 in
Width	229 mm	9.02 in
Depth	80 mm	3.15 in
Weight	1.81 kg	3.99 lb

Radars

Electrically scanning radar		
Operating frequency	76.5 GHz	
Dimensions	173.7 mm × 90.2 mm × 49.2 mm	6.84 in × 3.55 in × 1.94 in
Weight	575 g	20.28 oz
Power	1A @ 12V	

GNSS Receivers

Accuracy	< 1 m*	
Connector	One 12-pin Deutsch, one antenna TNC	
Electrical input	9 to 32V DC 120 mA @ 24V DC	
Operating temperature	-40° C to 70° C -40° F to 158° F	
Storage temperature	-50° C to 85° C -58° F to 185° F	
Humidity	100%	
Height	187 mm	7.36 in
Width	86 mm	3.38 in
Depth	57 mm	2.24 in
Weight	0.8 kg	1.76 lb

*With base station corrections.

Lidar

Number of lasers	64 Class 1 – eye safe 905 N·m wavelength	
EMC capability	to EC-42 version	
Sealing	Rated to IP67 (± 35 kPa)	
Storage temperature	-50° C to 90° C -58° F to 194° F	
Spin rate	300 rpm-1,200 rpm	
Weight	13.6 kg	30 lb
Dimension	283 mm × 223.5 mm × 231.1 mm	11.14 in × 8.80 in × 9.10 in
Power	2A @ 24V	
Input voltage range	10V to 32V	

A-Stop Transmitter

Maximum operating temperature	-18° C to 65° C -0.4° F to 149° F	
Maximum storage temperature	-50° C to 85° C -58° F to 185° F	
Transmit range	>180 m	
Operating frequency	919 MHz	
Charger input	100-240 V AC (50-60 Hz)	
Charger output	2A @ 5V	

Onboard A-Stop Receiver

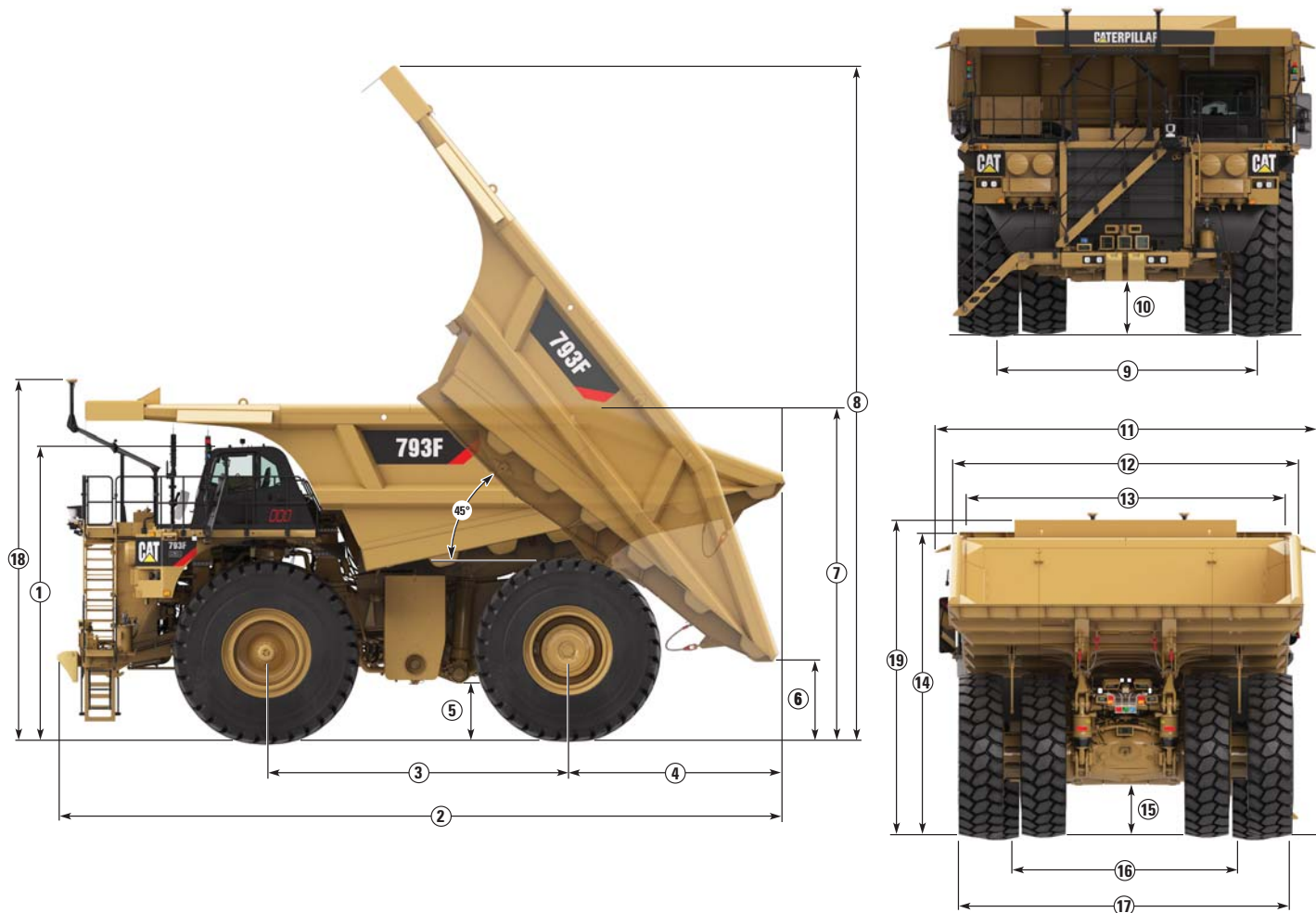
Maximum operating temperature	-40° C to 85° C -40° F to 185° F	
Maximum storage temperature	-50° C to 85° C -58° F to 185° F	

- The Receiver will accept power from a 9 to 32-volt source.

Command for Hauling Specifications

Dimensions

All dimensions are approximate. Shown with 176 m³ (230 yd³) MSD II Body.



1 Height to Top of ROPS	5597 mm	18 ft 4 in
2 Overall Length	14 258 mm	46 ft 9 in
3 Wheelbase	5905 mm	19 ft 5 in
4 Rear Axle to Tail	4257 mm	13 ft 11 in
5 Ground Clearance	990 mm	3 ft 3 in
6 Dump Clearance	1263 mm	4 ft 2 in
7 Loading Height – Empty	6559 mm	21 ft 6 in
8 Overall Height – Body Raised	13 628 mm	44 ft 9 in
9 Centerline Front Tire Width	5630 mm	18 ft 6 in
10 Engine Guard Clearance	1217 mm	4 ft 0 in
11 Overall Canopy Width	8297 mm	27 ft 3 in
12 Outside Body Width	7778 mm	25 ft 6 in
13 Inside Body Width	6946 mm	22 ft 9 in
14 Front Canopy Height	6603 mm	21 ft 8 in
15 Rear Axle Clearance	1006 mm	3 ft 4 in
16 Centerline Rear Dual Tire Width	4963 mm	16 ft 3 in
17 Overall Tire Width	7605 mm	24 ft 11 in
18 Height to Top of Masts	6900 mm	22 ft 8 in
19 Height to Top of Rock Guard	6826 mm	22 ft 5 in

For more complete information on Cat products, dealer services, and industry solutions, visit us on the web at www.cat.com

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