



DRILLING AUTOMATION PACKAGES DEVELOPMENT / TUNNELING RIGS

TECHNICAL SPECIFICATION

Sandvik intelligent drilling jumbo fleet (DD422i, DT922i, DT912D, DT1132i and DT1232i) represents an advanced control system based electro- and diesel hydraulic jumbo technology to provide top-level performance, accuracy and reliability for underground development drilling and tunneling. These rigs have the widest range of automatic drilling functions to give increased productivity with reduced costs, top-level product safety and access to the future of underground mine development and tunneling.

This document outlines the technical content of various automation levels Sandvik offers along with the units as well as practical steps to bring such technology into usage and to gain all the potential benefits out from it.

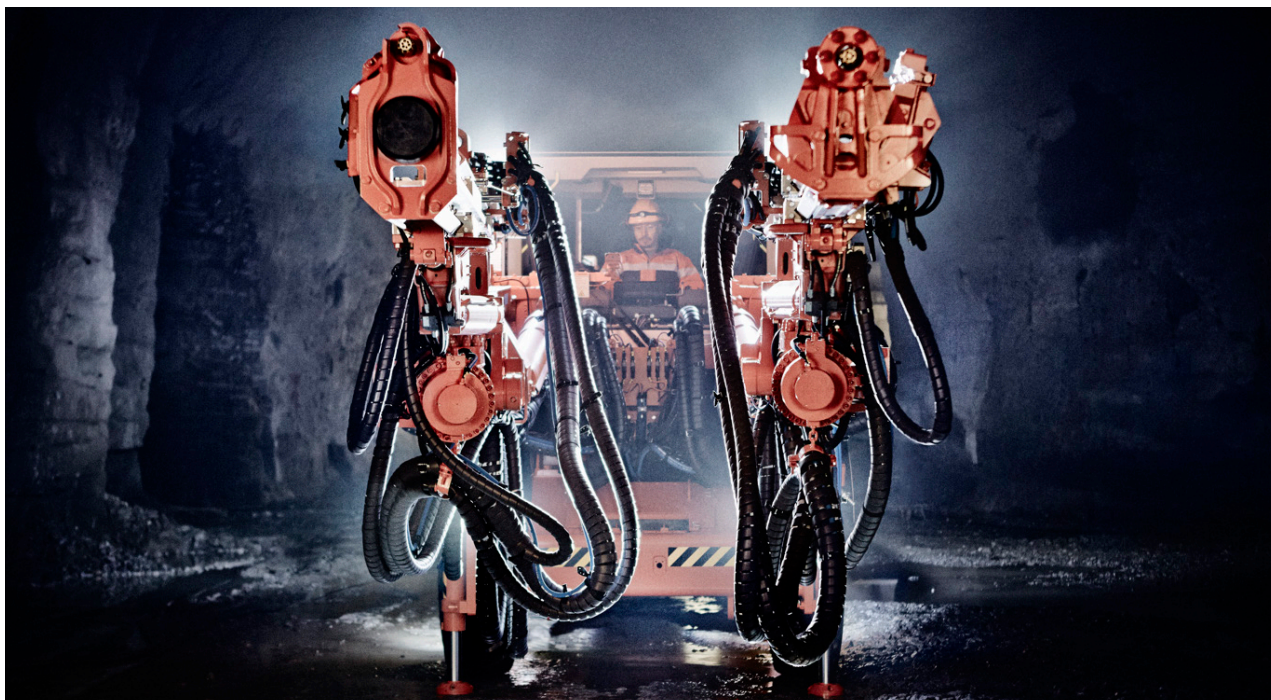
Available automation level varies based on selected equipment model as follows:

AUTOMATION LEVEL & UNIT MODELS

	Standard	Silver	Gold	Platinum
DD422i	•	•	•	•
DD422iE	•	•	•	•
DT912D	•	•	•	•
DT922i	N/A	N/A	•	•
DT1132i	N/A	N/A	•	•
DT1232i	N/A	N/A	•	•

• Available - N/A Not available

Suitable automation level depends on end user needs and vision on how to gain the most optimized results from the underground mine development or tunneling.



1. SANDVIK DRILLING AUTOMATION PACKAGES - DEVELOPMENT / TUNNELING RIGS

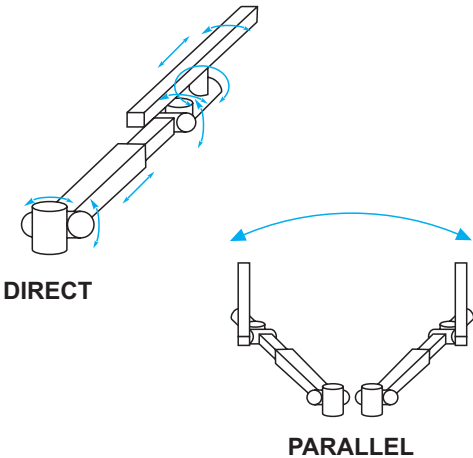
OVERVIEW OF THE AUTOMATION LEVELS

Sandvik drilling jumbo automation levels are available in following four main categories:

AUTOMATION LEVEL				
	Standard	Silver	Gold	Platinum
Control system	SICA	SICA	SICA	SICA
Boom parallel holding	Hydraulic	Hydraulic	Electronic	Electronic
15' touch screen display and electric joysticks for boom and drilling controls	•	•	•	•
Torque optimized drilling control system	•	•	•	•
Display of feed angles, drilling depth and penetrate rate		•	•	•
Pre-settable angle and depth indication for reference hole		•	•	•
Counters and recommended change levels for bits and tools		•	•	•
Drill pattern and bit visualization via on-board touch screen			•	•
iSURE- office tool for design of drilling pattern with charging and blasting simulation			•	•
Round analysis and MWD information			•	•
Drill rig suitable with various navigation methods			•	•
Hole end correction from different start point vs. plan				•
Semi-automatic boom control				•
Automatic boom control				•

STANDARD LEVEL

- In this level the boom auto- parallel holding is done hydraulically. This means that no additional instrumentation or sensors are installed onto the drilling modules. System has two various operating modes for the boom control:
 - In standard and Silver the hydraulic parallelism moves always tilt and swing if lift and turn cylinders are used. So only the front joints and boom zoom can be moved individually. This could be needed during corrections to feed angles in autoparallel holding (see point 2 below).
 - Autoparallel mode, where booms can be operated while system maintains feed alignment automatically to ensure the holes are aligned with each other (see picture below).



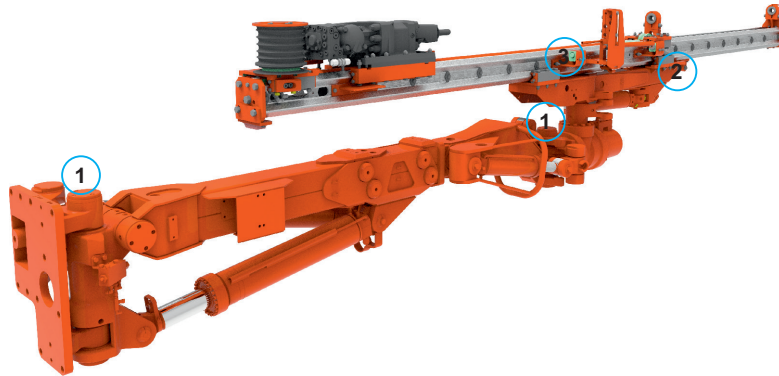
When running the boom with the positioning control joystick, the control system ensures that the direction of the feed remains unchanged. In addition, the control system keeps the drill bit on a plane parallel to the drill plan by controlling the boom zoom and feed extension joints (platinum only). This feature enables the drilling of parallel holes in the entire cover area of the boom. Torque optimized drilling control system plays important role in achieving good results with regard to drilling penetration rate, minimum dilution of holes and high service life for both rock drill and the consumables (i.e. shank, rod and drill bit). The drill rig can be configured with various drilling control modes depending on the local rock conditions. Torque optimized drilling control methods keeps rotation pressure at its optimum level by adjusting the feed & percussion pressures. This way the drill rig is capable to adapt the drilling power to changing rock conditions within the shortest response time and highest level of precision. Through various measurements (e.g. flushing water flow, rotation pressure) the drilling control system is able to make determinations from the rock conditions encountered at the bottom of the holes and adjust the drilling parameters accordingly to avoid various types of jams that typically contribute to the overall cycle time of drilling the face. On top of these, the system allows creation of various drilling parameters datasets (i.e. drilling recipes) for different hole types, such as lifter holes, contour holes, bolt holes, reamer holes etc. Once defined, these settings help end user to achieve the best possible results in drilling precision, speed and tool life.

SILVER LEVEL

Boom auto-parallel holding is done hydraulically also in Silver level.

This level provides basic instrumentation to visualize feed alignment (both vertical and horizontal angles) with drilling depth and penetration rate information as defined in picture below:

1. Angle sensors: Boom swing and feed swing
2. Feed Inclinator
3. Linear measurement for rock drill position



Presettable angle and depth indication for reference holes allows drilling various holes with same angle and depth settings. This is a reference information against which all other holes can be compared with to gain consistent angles and drilling depth in both center holes of the face but and also at the contour to achieve better control in over breaking and pull out.

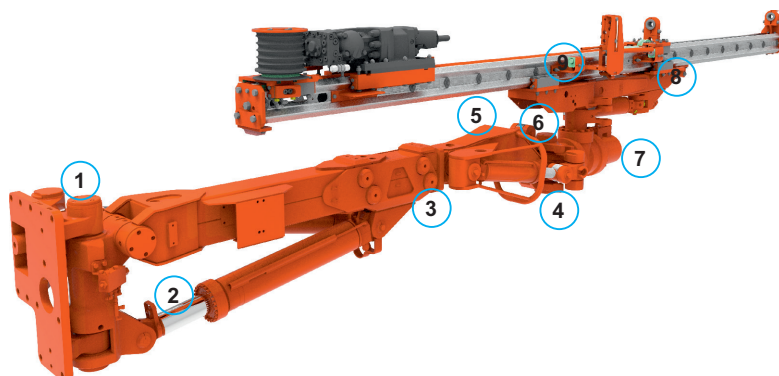
Counters and recommended change levels for bits and tools will help gaining optimized amount of drill meters out from the consumables. Also the change of tools can be done in predictable and controlled intervals to avoid unnecessary breakdowns at the heading.

GOLD LEVEL

Gold level allows the design of drill pattern for each heading, download of the pattern onto the unit and visualization of the design with on board touch screen display.

Gold level takes the concept to gain consistent drilling results, minimized over breaking with good pull out to a new level through instrumented drilling concept. The boom auto parallel- holding is done electronically and the boom has following sensors attached:

- | | |
|-----------------------------------|--|
| 1. Boom swing (angle sensor) | 6. Bolting joint (angle sensor) |
| 2. Boom lift (angle sensor) | 7. Roll-over (angle sensor) |
| 3. Boom extension (linear sensor) | 8. Feed extension (linear sensor) |
| 4. Feed tilt (angle sensor) | 9. Rock drill position (linear sensor) |
| 5. Feed swing (angle sensor) | |



Also the cylinders for boom lift and swing and feed lift and swing are different. This is because Standard & Silver level uses three chamber- cylinders for the areas mentioned above to maintain the parallel holding of the feed. For Gold & Platinum level the feed parallel holding is based on information received from the angle sensors.

Drill pattern and bit visualization via onboard touch screen provides further assistance for the operator to drill the face as per predefined drill pattern designed with iSURE (see further information below). The drill shows the exact location (i.e. x, y, z coordinates) of the drill bit in reference to the drill plan. The drilling boom movements are to be done manually by the operator.

iSURE office tool for design of drilling pattern with charging and blasting simulation offers easy ways to create target profile (i.e. shape and key dimensions) for the tunnel, create dedicated drill pattern to achieve the given target profile with given rock conditions and explosives used. The tool runs in a normal office pc or laptop. iSURE can automatically calculate the relational factors between the explosives used (i.e. kg equivalent with TNT per drill meters), burden (radius of the fragmentation caused by the explosive) and the spacing of the holes. Once two of the factors are known, the tool calculates the third missing parameter on behalf of the user. For example by knowing the type of explosive and corresponding burden within local rock conditions, the tool can suggest the most optimum hole spacing and pattern for the user to achieve given target profile for the tunnel.

iSURE offers also capability to plan the optimum drilling pattern at the bottom of each hole. This is to achieve the best results in rock breakage during blasting where the hole bottom is the most critical area to achieve good pull out and minimum over break.

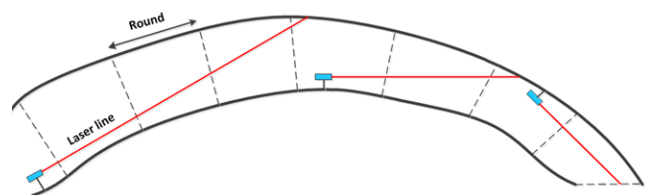
Also tunnel and mine layout design can be done with the tool, different drift and tunnel profiles with dedicated drill plans can be linked onto specific areas and this way handle to whole mine development / tunneling project with a single tool. iSURE provides also IREDES interface to any third party mine planning tool to allow import and export of various data sets, e.g. tunnel lines, drill patterns etc.

Round analysis and MWD information ensures that once the cut has been drilled, various type of information can be collected from the unit and reported via iSURE, e.g. x, y, z location of the holes vs. given plan, MWD (Measure While Drilling) information, timing related data, various counters and other maintenance data. This whole philosophy of designing the drilling pattern and verifying the results for further adjustments plays key role to optimize the quality of the excavation, improving the productivity and reducing the costs of excavation.

Drill rig suitable with various navigation methods ensures the drill plan can be drilled within right location in the mine coordinate system. Therefore a dedicated navigation procedure is needed to find this location and orientation for the drill pattern at the heading.

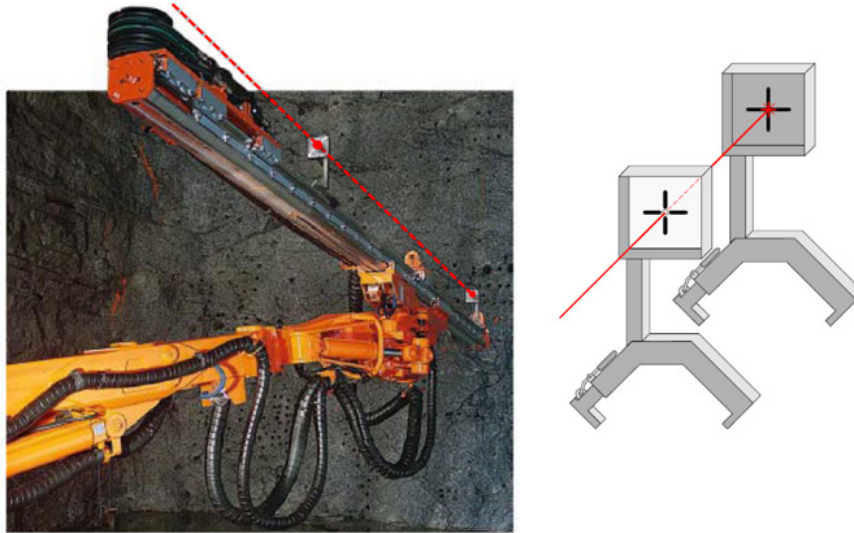
GOLD level offers three following navigation methods to setup the rig:

1. Laser line navigation is a method to navigate the drill rig by using fixed laser line within the drifts that intersects the face within a predefined x, y, z location. Once the feed is aligned with the laser line and tunnel distance (i.e. PEG number) is known the unit can determine the location and orientation of the drill pattern vs. its own location. iSURE offers tools to create drift / tunnel layouts and predefined laser sets (straight lines) can be linked with these layouts (see picture below).



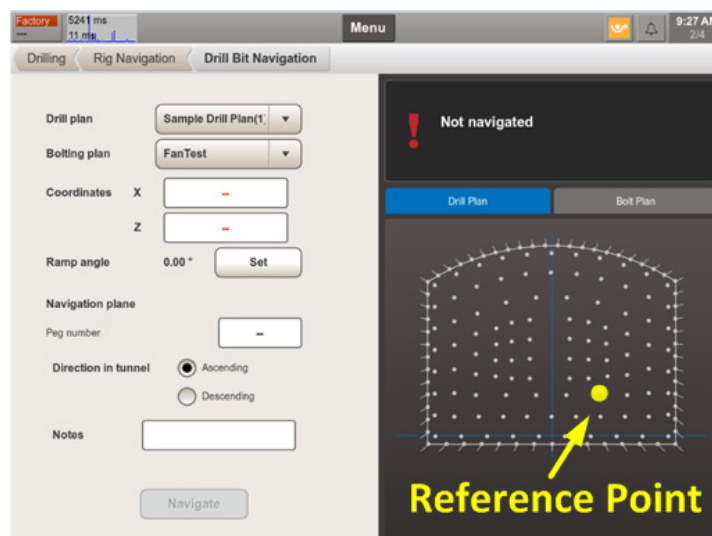
Dedicated surveying team should be used to mount fixed points in the tunnel where the laser can be attached during navigation to point towards the face. For each cut to be drilled the unit calculates x, y, z location and angle on where the laser line intersects the drill pattern.

During navigation the operator attach the laser onto the installation post at the wall to point the laser onto the face with predefined angle. Then operator can install laser intersection points onto the feed rail to indicate when feed is aligned with the laser line. By moving the feed to a position where laser line intersects both of these points at the feed rail (see picture below) the operator ensures the unit knows the direction of laser line and from there can calculate the direction of the tunnel.



Then operator inserts the tunnel distance information (eg. 135m) onto the user interface and presses "Navigate" button. The tunnel distance information can be measured manually from predefined fixed point / wall marking that should be delivered by the mine surveying team. Once all the information above is given (feed alignment, distance in the tunnel line), the drill rig knows its location at the tunnel and can locate the drill plan accordingly.

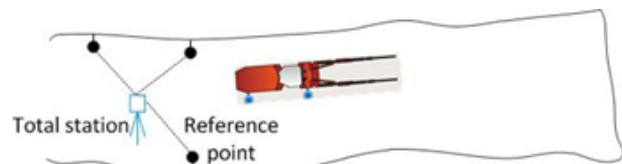
2. Drill bit navigation works similar principle as laser line but there are no physical laser line involved within the navigation. In this case the mine surveying team marks up a reference point (ie. imaginary laser line intersection point or tunnel center line) onto the face with a spray can. This point represents predefined hole or x,y coordinate within a drill plan (see picture below).



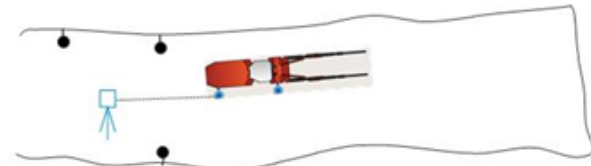
Also the tunnel direction (vertical ramp angle, horizontal direction) info is needed. The ramp angle can be inserted onto the user interface of the unit. The horizontal direction of the next round is measured from the angle of the feed.

3. Total station navigation is based on triangular measurement where location can be determined by measuring its distance and angle to known points. These known points should be marked by the surveying team and minimum amount of points that can be seen simultaneously should be three. In practice the points are marked at the wall of the drift / tunnel and they have predefined x, y, z location from where the location of the total station can be calculated. The first step in navigation is to calculate the location of a portable total station by pointing the device to three known points at the tunnel. From there the total station calculates its own location (i.e. x, y, z points). Next step is to point the total station onto prism or reflector attached to the fixed known point at the drill rig. In total the unit needs to be mounted with two prisms to calculate both location and orientation of the unit. The rig is then moved to the face ensuring that the total station has continuous line of sight available for the prism attached to the unit. Depending on which model and brand is being used, the total station can follow the rig automatically while is moving to the face as long as the unit remains in the line of sight for the total station. Once arrived to the face, the operator can set down the jacks and select suitable drill plan for the round. Also some brands in total station (eg. Leica 1200 series) can be wireless radio link with the unit. In this case the operator requests the total station to calculate the unit location and orientation. The total station searches another prism, calculates the details and to send all the data onto the unit via radio link. The rig is now navigated and ready to drill the face as per given plan. The picture below illustrates the principle defined above.

1. Calculate the location of total station from the reference points.



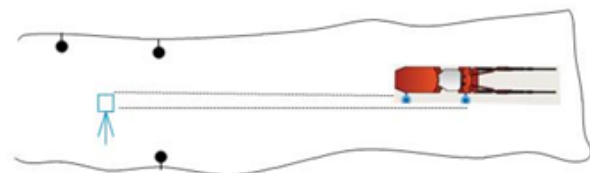
2. Point total station onto the prism mounted at the unit.



3. Move the unit to the face.



4. Calculate the location and orientation of the unit, send navigation details to the unit.



PLATINUM LEVEL

On a Platinum level the rig has some additional automatic drilling functions available. The boom instrumentation is identical with Gold level which means that the only difference between the levels of Gold and Platinum is the rig control system software.

Hole end correction from different start point vs. plan allows to deviate the starting point of the hole without compromising the ending point that matters the most from blasting perspective. iSURE drill planning and analyses tool available in Gold and Platinum levels offers capability to plan the optimum drilling pattern at the bottom of each hole. This is to achieve the best results in rock breakage during blasting where the hole bottom is the most critical area to achieve good pull out and minimum over break.

In practice there are cases where drilling cannot be started within the point at the heading as defined in given plan. This may be because of uneven rock surfaces, near proximity of a hanging wall / roof or under break from the previous round. Hole end correction will allow the hole collaring taken from different starting point (e.g. 150mm left from planned location) but still to achieve hole end as per given plan. Once moved onto the new location the system can automatically aligns the feed to achieve planned hole end.

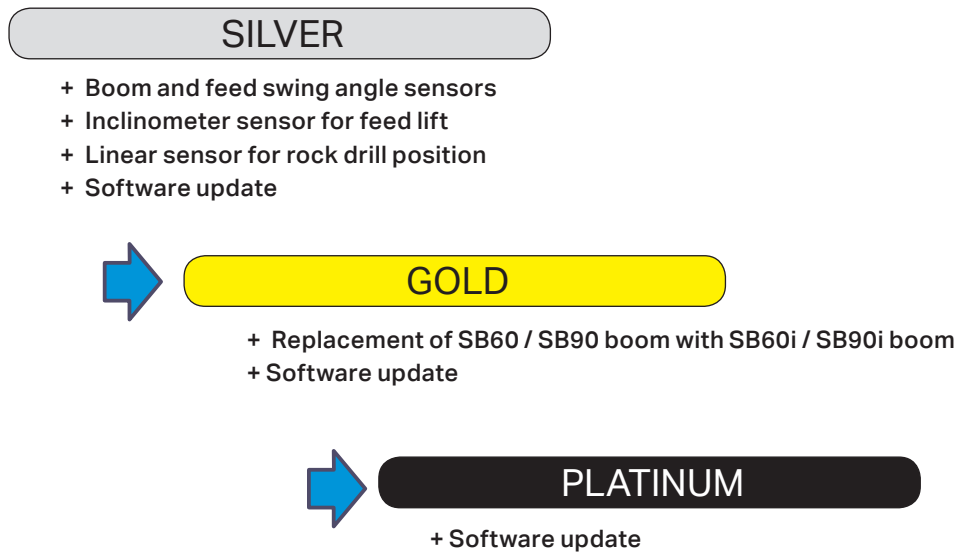
Semi- automatic boom control is usable feature when changing the underground face drilling methods from manual assisted to automatic boom movements. This allows a gradual and controlled increase of automated boom movements by manually selecting the holes the operator wants the system to drill allowing the operator simultaneously focus on one boom while the other is drilling autonomously.

The operator can operate the booms manually and the system assists by dynamically selecting the closest hole to the drill bit even when the boom is moving. When the system picks up the hole as per operator preference, the controls can be passed to the drill rig (i.e. pressing "play" button). From there the system takes over by moving the boom to the hole, aligns the feed as per given plan, drills the hole all the way to the toe and retains back to wait further instructions from the operator.

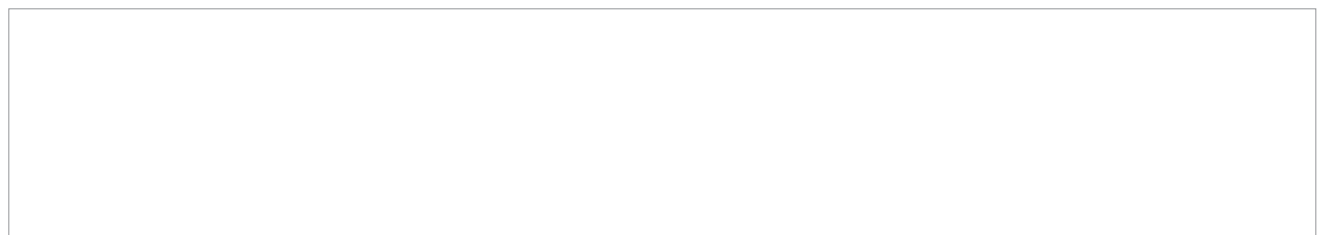
Automatic boom control allows drilling of multiple holes automatically by the unit according to predefined order or sequence. In practise the unit moves automatically the boom onto given hole as per the sequence, aligns the feed accordingly and starts the drilling. Once the hole is finished the boom moves to the next hole automatically without any involvement from the operator. The drilling sequences can be created with iSURE and downloaded onto the drill rig together with the drill plans by using an USB stick or optional wireless connection. Also there are often need to change given plans (e.g. uneven rock surfaces, limitations in space to move the boom between the holes etc.) at the face by the operator. Therefore the sequences can be modified and created created via on board touch screen display at the unit.

LEVEL UPGRADES

Upgrades between various automation levels are possible. However the scope of work depends on from which to where in levels the upgrade is needed, see following picture for more details.



Please contact your nearest Sandvik representative for further information about the upgrades of your unit.



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