Mine Automation and Data Analytics

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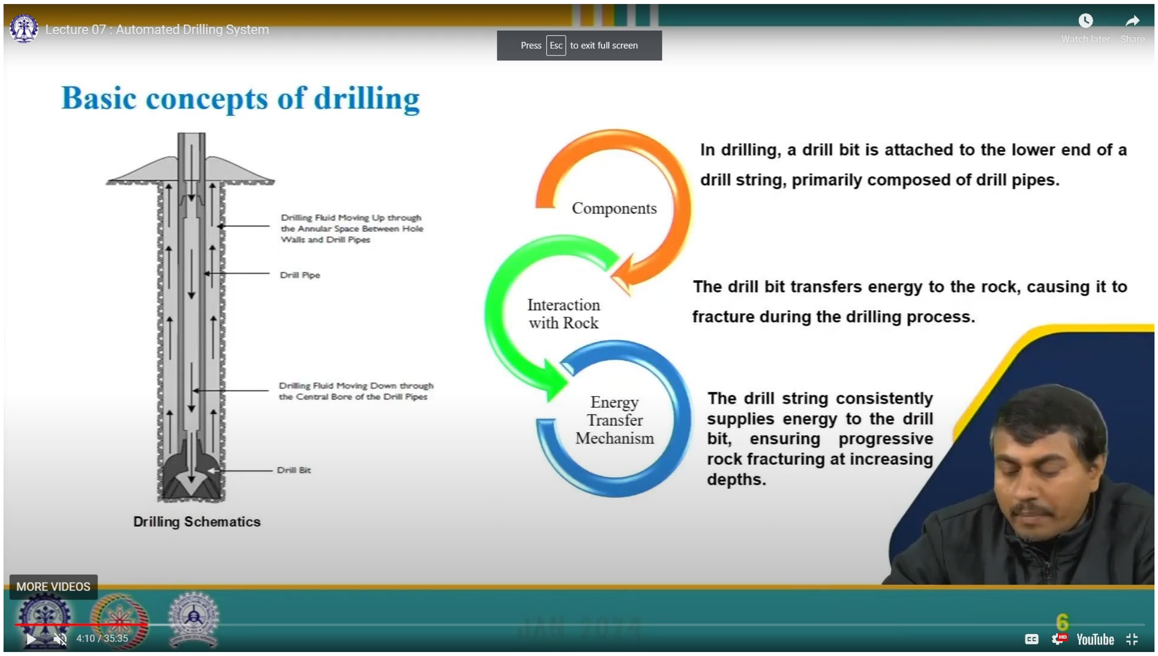
Week-2

Lecture-7

Automated Drilling System

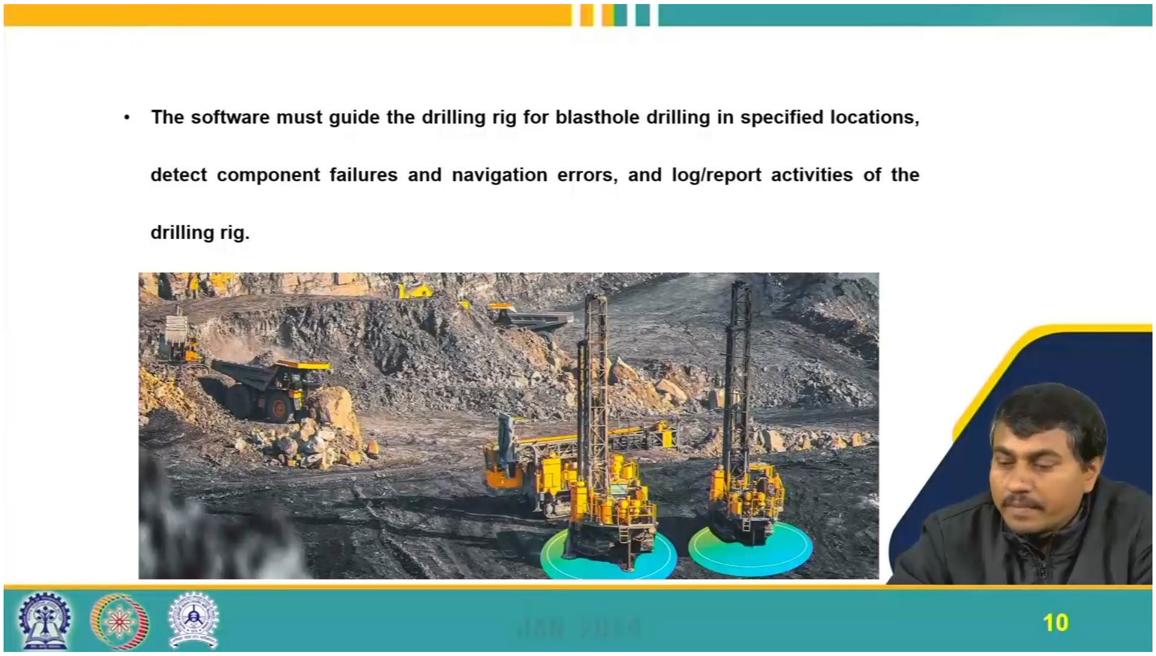
Welcome back to my course, Mine Automation and Data Analytics. So, in this lesson, we will discuss the automated drilling system used in open-pit mines. So in this lesson, the following concepts will be covered: We will discuss the introduction to drilling, then the basic concept of drilling, the overview of the autonomous drilling system, the main system of autonomous drilling, the benefits of autonomous drilling systems, the basic sensors used in automated drilling systems, the disadvantages of drill automation, the whole navigation system concept, the concept of measuring while drilling, the role of autonomous drilling systems in the mining industry, automation-driven drilling processes, and the challenges of autonomous drilling systems.

Let us discuss what drill is all about, so it is about the large rotary drill that is commonly used in the mining industry to drill holes in ore bodies and strata, primarily for the removal of the overburden and the removal of ore. Large earth boring machines are commonly known as blast hole drilling rigs. It involves the mapping process for a specific drill pattern, drilling a blast hole, and finally filling the blast hole with explosive and exploding it. So, an individual blast hole pattern may typically consist of 50 or more holes. Each hole contains a measured quantity of explosive required to fracture the strata as intended. So, this is a common drill machine used in open-pit mines. The basic concept of drilling, here in this schematic, we have shown you the drill pipes, and through these drill pipes, fluid goes down, and here it is the drilling rigs, and the fluid goes up in the annular space between the pipe and the borehole wall. So here the drill rigs cut the rock and advance the drill process. So, these are the following components: in drilling, a drill bit is attached to the lower end of the drill string, which is primarily composed of drill pipes, as I have shown here. Then, through interaction with the rock, the drill bit transfers



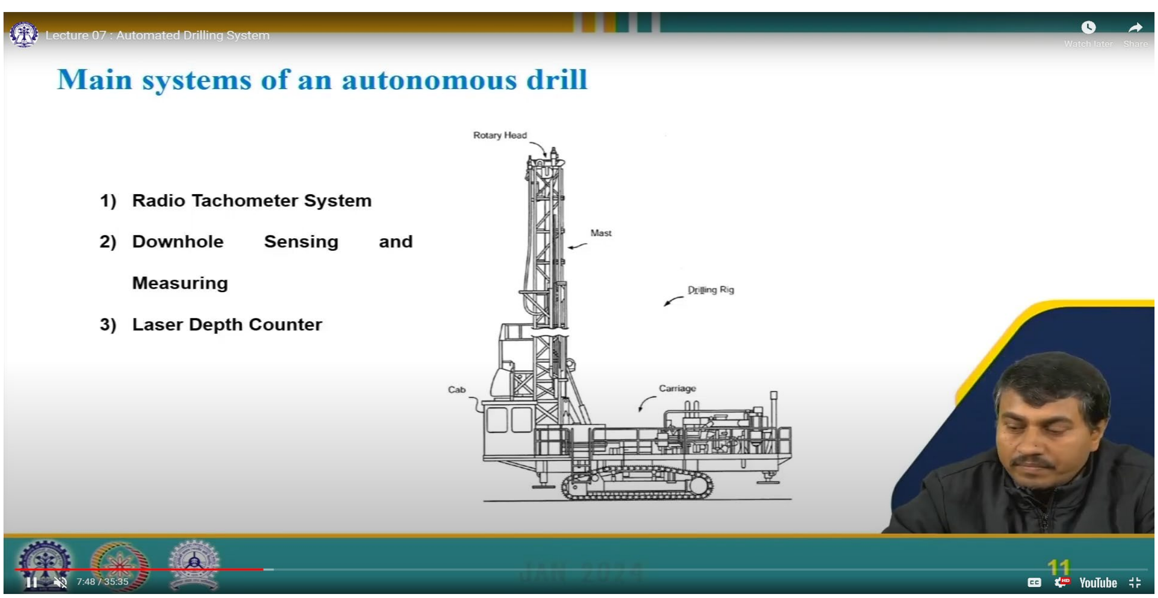
energy to the rock, causing it to fracture during the drilling process. Then there is the there is the energy transfer mechanism. The drill string consistently supplies energy to the drill bit, ensuring progressive rock fracturing at increasing depth.

The overview of autonomous drilling systems-Autonomous drilling involves unmanned drilling rigs controlled remotely, known as teleoperated rock drilling apparatus. Autonomous mining operations encompass the collective use of unmanned drilling rigs, loading vehicles, and other mining vehicles. These can be controlled externally from an overground control room. This is a typical image of an automated drill machine operating in an open-pit mine. Due to the absence of human involvement in autonomous drilling systems, data must be sensed and transmitted to a remote computing device for monitoring, analysis, and optimization of the drilling process. Autonomous drilling rigs may feature navigation systems, marking for remote control, collision avoidance capabilities, and other features enabling operation without a human on board. Unmanned drilling rigs need high reliability to avoid human intervention and have the ability to recover from problems, replace used parts, and perform regular upkeep. Inexpensive and efficient solutions are required for collecting and transmitting data to the remote operator, necessitating software to control the hardware components of the drilling rigs. The software must guide the drilling rig for blast hole drilling in specified locations, detect

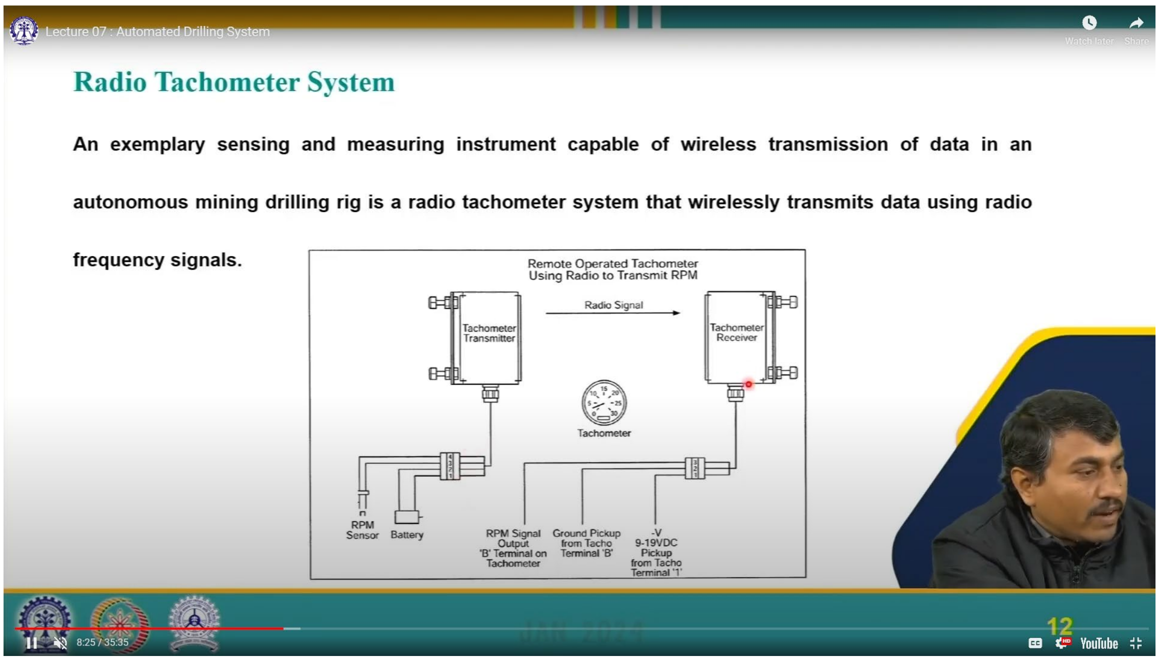


component failures and navigation errors, and log the activities of the drilling rig. This is an example of how simultaneously two drill machines operate on an open pit mine while collaborating with other machinery and vehicles in the vicinity of the mine.

Main system of an autonomous drill-This is a typical example and schematic figure of a drill machine. Here on top, there is the rotary head, there is a mast, here is the cabin, and here are the drill rigs. It comprises a radio tachometer system, a downhole sensing and measuring system, and a laser depth counter.

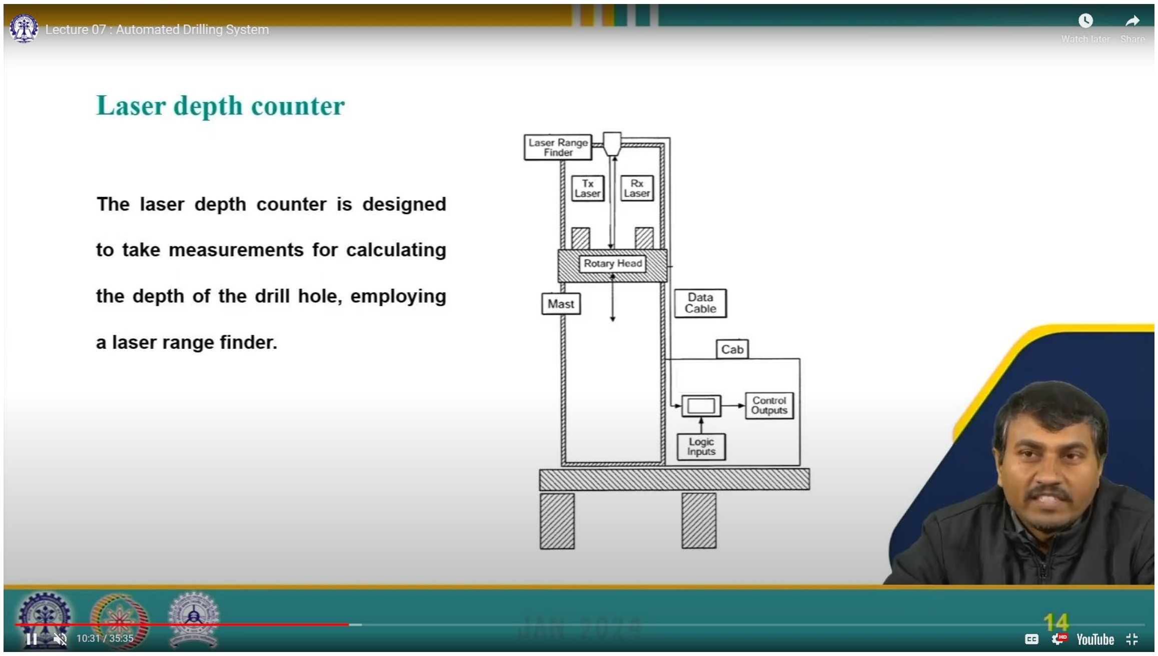


Radio tachometer system-An exemplary sensing and measuring instrument capable of wireless transmission of data in an autonomous mining drilling rig is a radio tachometer system that wirelessly transmits data using radio frequency signals. This is a typical example. The left side of this figure is the tachometer transmitter that transmits the data, and on the right side is the tachometer receiver that receives the data. The following components of the data basically measure the terminal RPMs, the battery source, and how the drill machine performs. These are the data that basically communicates between the tachometer transmitter and the receiver.



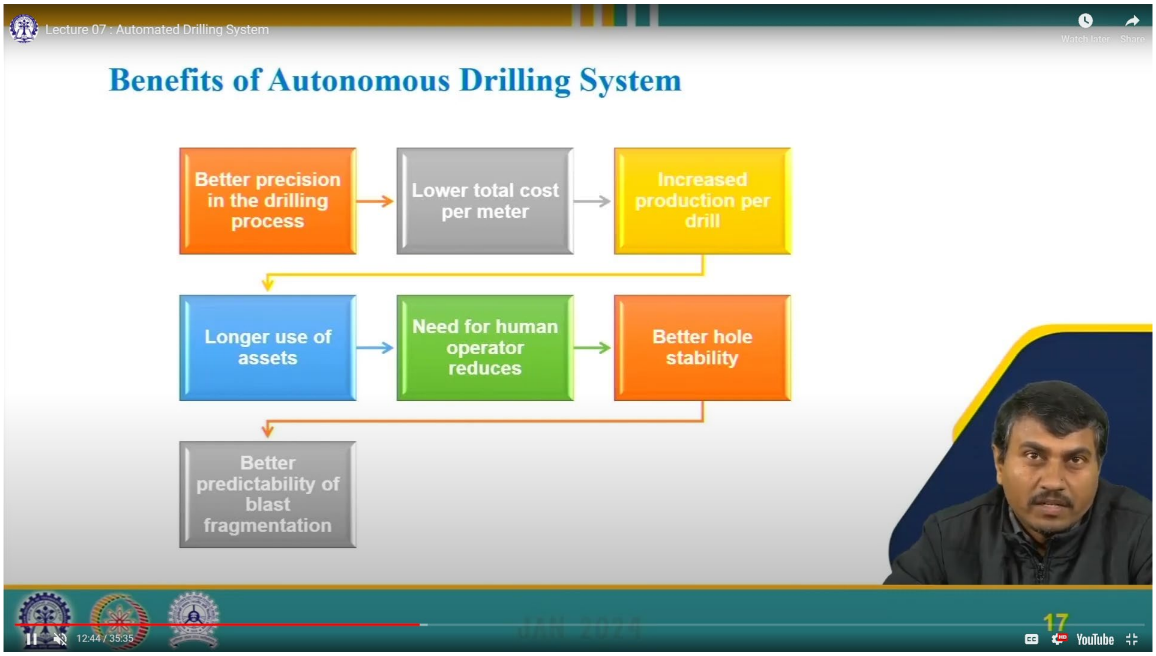
Downhole sensing and measuring-In mining drilling rigs, which are mobile rigs placed on a moving track, sensor information from tools and components obtained downhole can be processed and displayed in semi-real-time. Because of the nature of mining operations, where numerous holes are drilled in a short period of time, drill pipes are rapidly inserted and withdrawn from the earth. So due to the quick drilling and extraction process, surface and downhole measurements such as vibration, pressure, and temperature can be relayed in semi-real-time.

Laser depth counter-This component consists of the laser rangefinder at the top that basically sends the pulse from the top, and on the rotor rigs and drilling rigs, it reflects, and by that, it measures the depth. So that laser depth counter functions like this. It is

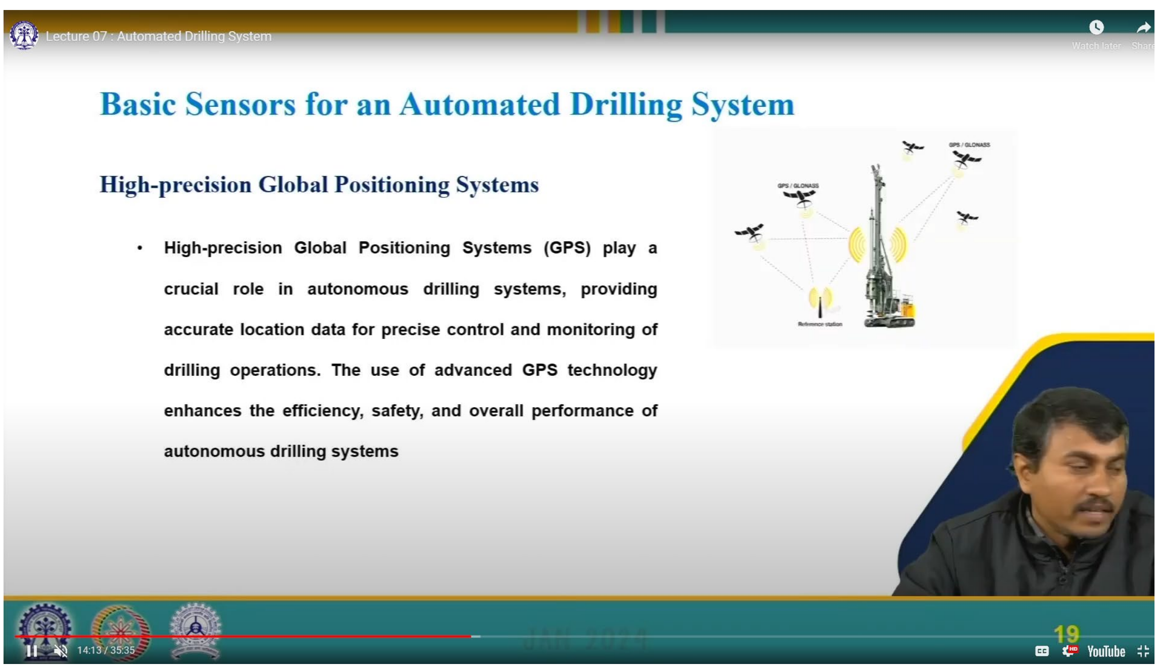


fitted at the top of the mast. The laser depth counter is designed to take measurements for calculating the depth of the drill hole employing a laser rangefinder. The laser rangefinder uses a laser beam to determine the distance to a reflective object, such as a rotary head. The laser operates on a time-of-flight principle. The laser is measuring a laser pulse in a narrow beam towards the object and measuring the time taken for the pulse to be reflected off the target and return to the sender. The displacement of the object is calculated based on real-time measurements. The laser rangefinder position at the top of the mast, aimed at the rotary head, measures the displacement of the rotary head as it travels up and down the mast. The raw data collected by the laser rangefinder includes the range of distances between the laser mounted at the top of the mast and the distance to the rotary head as it travels the mast. The raw data can be relayed using a wireless transmission system on the drilling rigs. The relayed data is subsequently used to compute the depth of the drill hole and the penetration rate of the drill over time.

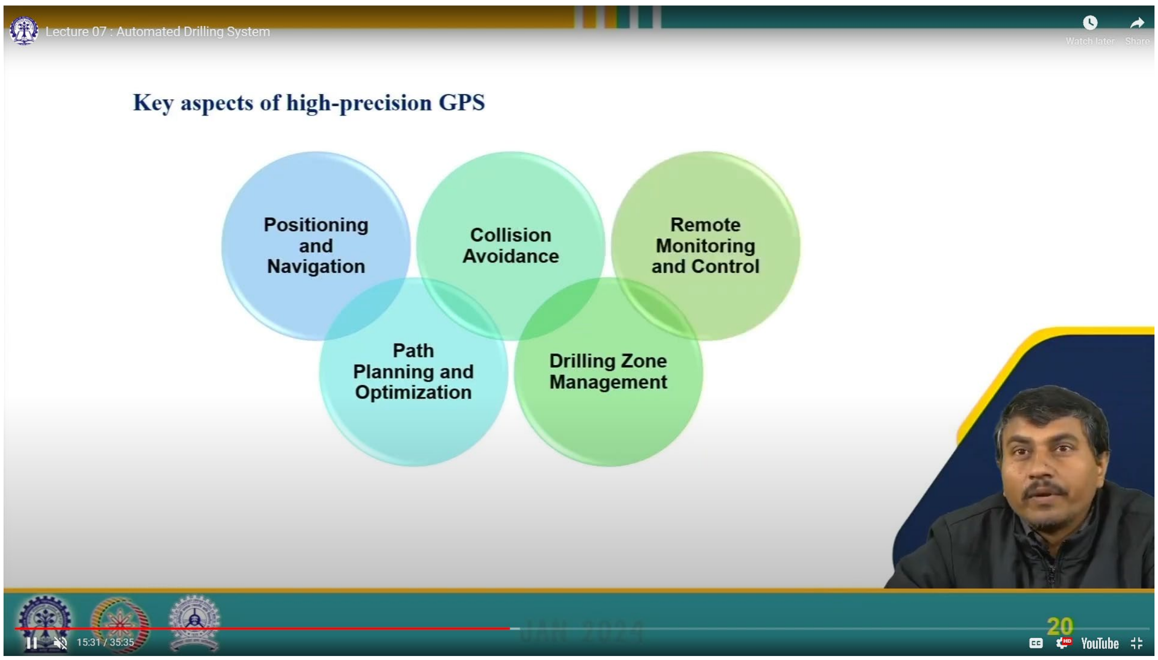
Benefits of autonomous drilling system-Better precision in drilling process, lower total cost per meter of drill hole depth, increase production per drill, longer use of assets, reduced need for human operators, better hole stability, and better predictability of blast fragmentation. So, in totality, it basically enhances the drilling process and optimizes the drilling process, and by that, it basically enhances productivity as well as lowers the cost



substantially. Basic sensors for an automated drilling system, drill rig position, high-precision global positioning system are used, inertial measurement units are used, and laser technology finds the depth of the drill rigs in real time.



Basic sensors for an automated drilling system: here we use the high-precision global positioning system that is GPS plays a crucial role in autonomous drilling systems, providing accurate location data for precise control and monitoring of drilling operations. The use of advanced GPS technology enhances the efficiency, safety, and overall performance of autonomous drilling systems. Here is an example: the drill machine basically establishes connections with different GPS and GLONASS satellite systems. Sometimes a local base station is settled on the mine site for enhanced connectivity and better precision mapping of the system. So, it is always connected to the GPS so that the drill patterns can be accurately mapped and the drilling process can be established and carried out as planned.



Key aspects of high-precision-GPS, position, and navigation accuracy are enhanced, ensures collision avoidance with other vehicles flying in the vicinity of the mine site, optimizes path planning, drilling zone management is efficiently managed with remote monitoring and control. So, in totality, the GPS system basically helps to enhance the accuracy of the position of the drill rigs. It ensures the mapping of other vehicles that are plying in the vicinity of the mine site so that drill operations can safely run without any collisions with other vehicles. it basically establishes the real location time of the drill rigs so that real monitoring and control over the system are easier from the control tower or the control room.

Drill hole depth: we use laser technology for measuring the drill hole depth, string encoders, wheel, and we use other encoders as well. We use the magnetic pulse for drill rig roll and pitch measurement. We use the digital tilt meters just like this on the right side of this slide. This is a digital tilt meter used on the drill rigs, measuring its roll and pitch. For track speed measurement, we use track encoders. Drill rotation velocity: we use a magnetic pickup on the drill drive gearbox and a flow meter on the rotation hydraulic circuit.

Disadvantages of Drill Automation: We have a substantial number of good points and advantages over the automated drilling system, but there are some challenges as well. So, we will discuss those aspects here. The automated drill is best suited to stable geology, where geology is stable and the strata strength is known or the strata behavior is more or less known. So, the rate of penetration and its overall optimization are good. On an unstable geology, maintaining or controlling the automated drilling system can sometimes become very, very difficult. It can be slower than certain parts of the drill cycle as it maintains the level of accuracy required. It is also some of the limitations for achieving higher accuracy; sometimes drill bits or drill machines operate slowly rather than the planned ones for achieving higher accuracy. The sensor failure on the drill is common and could stop the whole process. The overall system of an automated drill machine or drilling system operates basically on a sensing system. So, if the sensor fails, drill rigs will be jammed, and the whole system will be locked. So, that could stop the whole operation. So, these are basically some of the glitches in the automated drilling system. Detection of worn bits or drill string failure can be difficult. It is one of the major challenges in an autonomous drilling system for detecting worn-out bits in real time so that, in due time, the replacement time for these parts is reduced and the drill machine performs efficiently. So, this is one aspect that, in future automated drilling systems, must be addressed. High-precision GPS might make it difficult to get signals in deep, open pits. So, for those kinds of situations, an augmented ground-based satellite or pseudo-lights may be required for the functioning of the automated drilling system. So, that will enhance or increase the cost of operation of the automated drilling system.

Let us discuss a few questions

Question 1

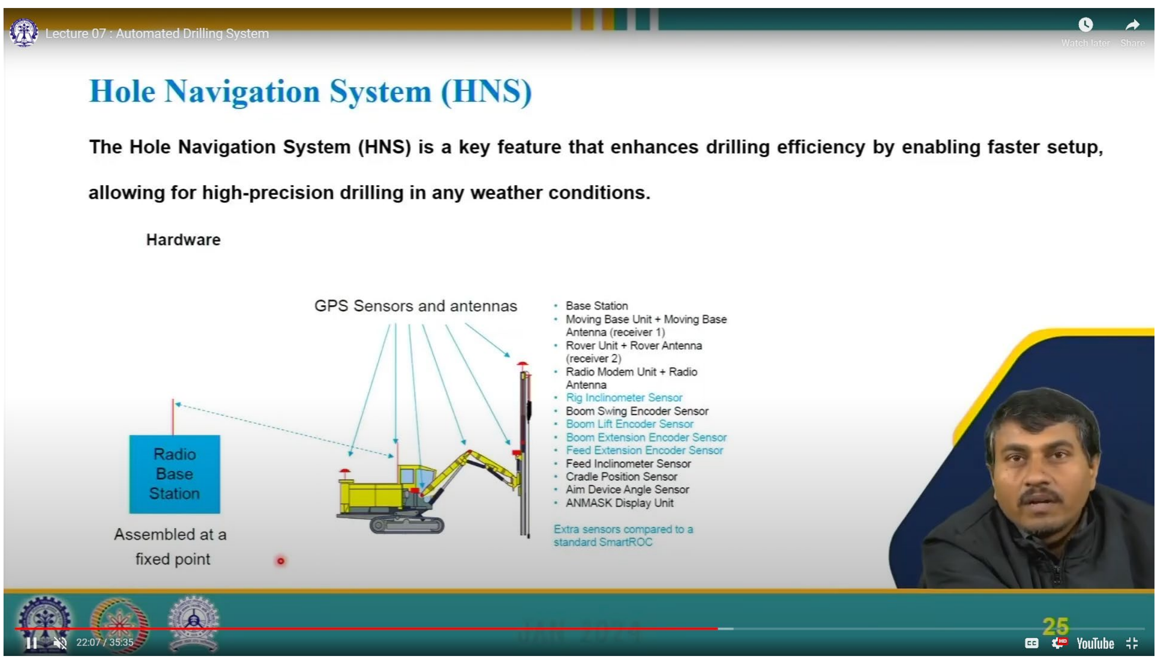
What is a key advantage of automation in surface blast hole drill rigs compared to manual operation? lower productivity rates, increase accuracy and repeatability, greater manual control, limited operational efficiency.

The right answer is increase accuracy and repeatability.

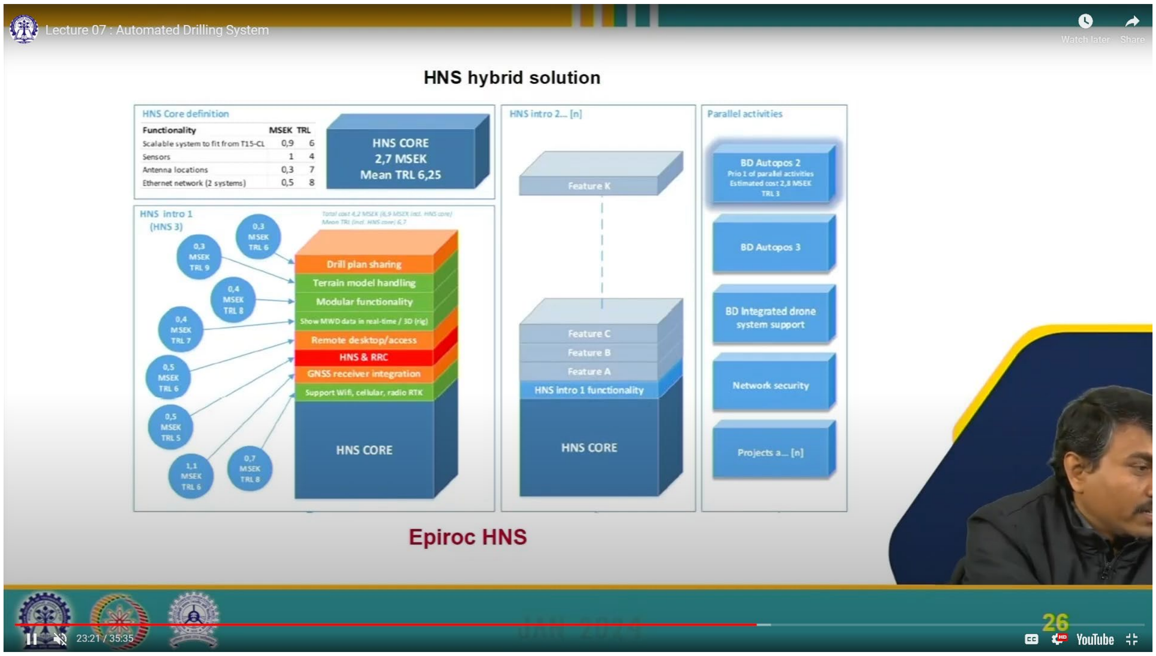
Question 2

What is essential for effective supervision of a drill rig when operated remotely? inadequate vision coverage, limited use of prior geological knowledge, adequate vision coverage, complex movement path planning.

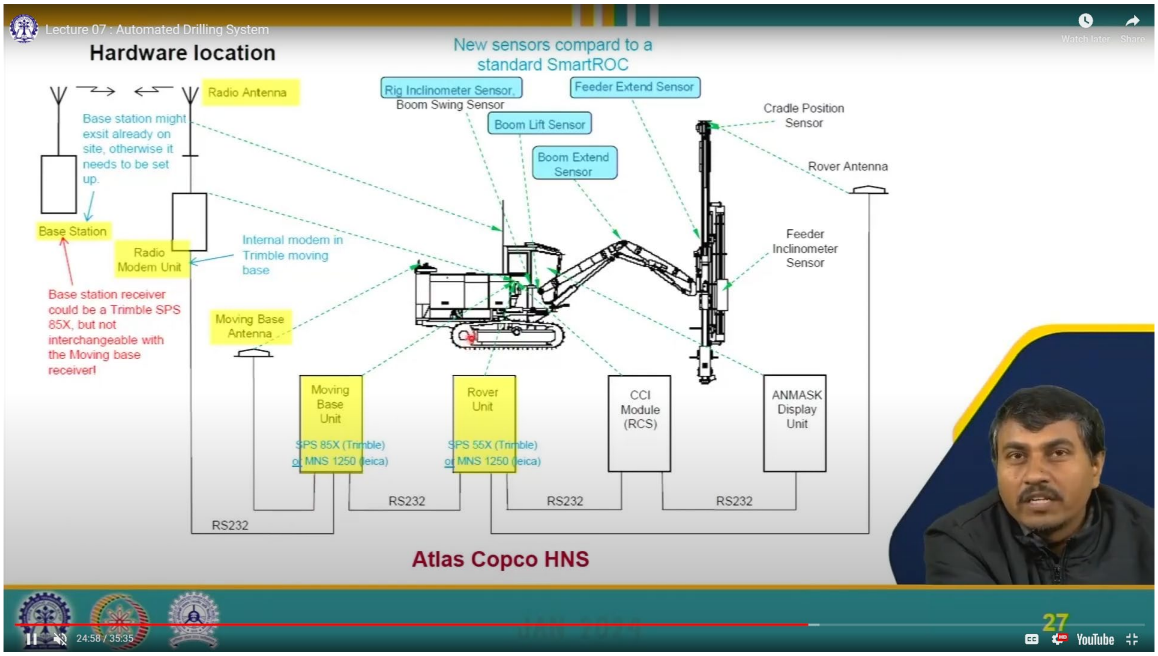
The right answer is adequate vision coverage.



Let us discuss the hole navigation system-Currently, all automated drilling systems use these hole navigation systems for optimization of drilling operations. So, the hole navigation system is a key feature that enhances drilling efficiency by enabling faster setup, allowing for high precision drilling in any weather condition. So, this is a typical example of a hole navigation system. We have collected this data from an iron ore mine operated by Tata in Noamundi, so here is the automated drilling system with the hole navigation system, attached with the extra sensor, which is the rig inclinometer sensor, the boom lift encoder sensor, the boom extension encoder sensor, and the feed encoder feed extension encoder sensor. So, these are the extra sensors that are fitted on an automated drilling machine compared to the other smart ROCs that operate on the mine field. It is always in connection with the GPS sensor and antennas and transmits the data through the radio frequency to the nearby control station. Here is a diagram of how the hybrid hole navigation system works in the mine.

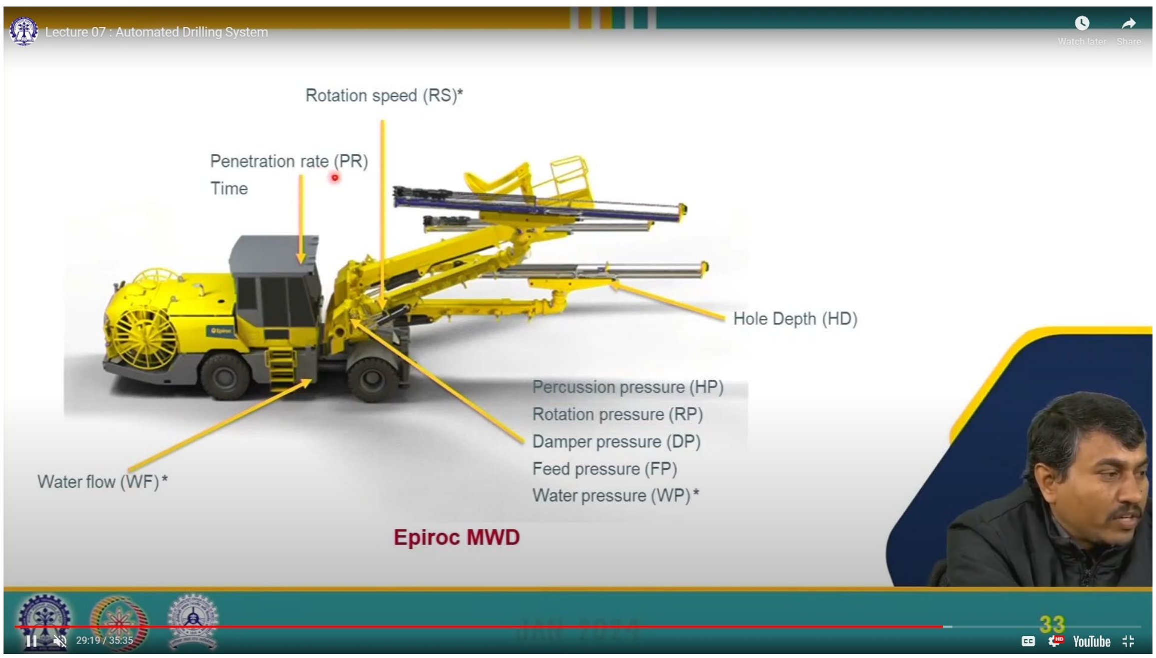


This is the solution practiced by the EPIROC drilling system, on the first block of the core system, they have a drill plan, then the terrain modeling handling, then the modular functionality, then the saw drilling while measuring in real time or measuring while drilling, the remote desktop access, then the hole navigation system, and the GNSS receiver integration and support with Wi-Fi and cellular and radio RTK. So, these modules are the core of the HNS hole navigation system. There are several layers of operation in the HNS core of the EPIROC system, as well as other parallel activities going on in the system and also here, they have worked on network security because now the data is transmitted in real time. So, the cybersecurity aspect of the system is also taken into consideration.



It is another example of the hole navigation system developed by Atlas-Copco. Here they are using some extra radio modules, rover antennas, and moving base antennas to balance the connectivity of the drill machine with the base station and the control room and here the extra sensor uses a rig inclinometer, boom lift sensor, boom extended sensor, and feeder extend sensor to get real data about the hole in real time, which is basically transmitted in real time through the rover antenna to the nearby base station and efficiently operates on the mine site. As required.

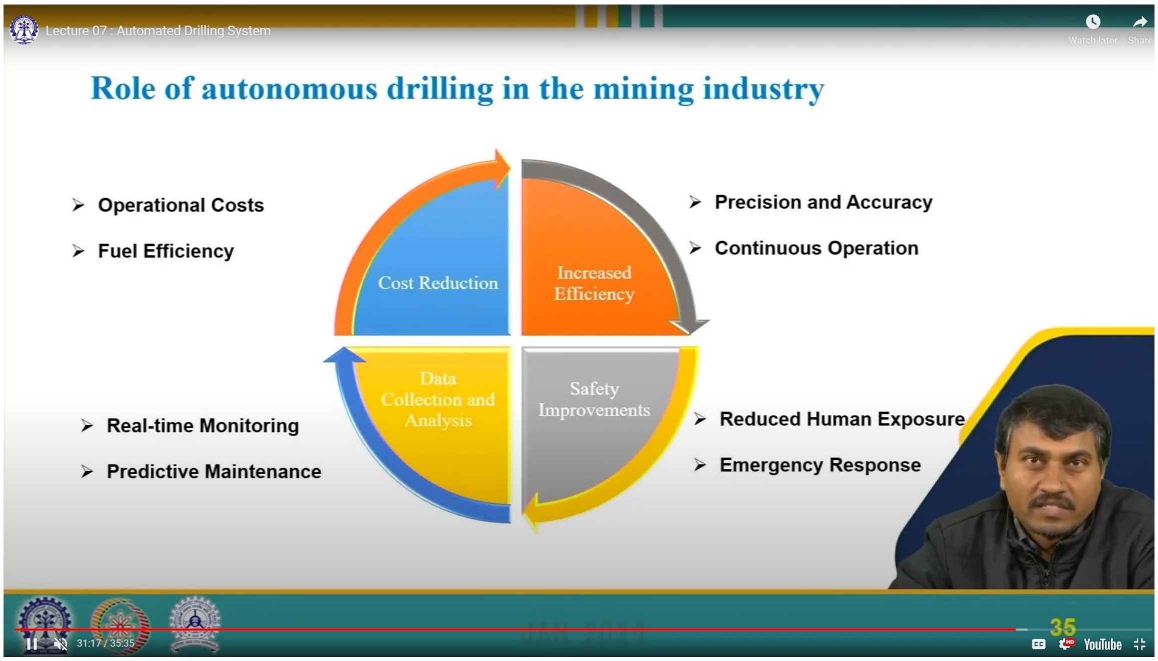
Base station: the base station is placed within the coordinate system and serves as a reference position for the rig to correct its positions, also known as the RTK real-time kinematic fix. The base station is comprised basically of a GPS receiver and radio module unit. Working principle: during operation, the base station sends out RTK data to the radio modem on the rig in order to correct the bit position by adjusting the carrier phase frequency sent from the satellites. Sensor calibration can be performed with the HNS system offline. If a baseline error shows up during operation, it can serve as an indication that calibration is needed. Possible causes: sensor not calibrated, different coordinate systems in the receivers, sensor error, measurement error in the link model. Calibration is also needed if the feed or boom has been exposed to heavy movements. Calibration of boom swing for Volvo cabin. Set the boom swing straight forward in the longitudinal direction of the rig. Measure with a roll-up measuring tape between the boom swing and cab until parallelity is achieved. For the bosal cabin, use the boom pillar to make sure the alignment is right. Use the digital spirit level, put it against the pillar, and measure towards the boom, making sure it is straight. Calibration of feed tilt and feed return. Set the feeder in vertical position by positioning the feed tilt and feed turn to vertical position 0 using the electronic spirit level. Calibrate feed turn and feed tilt to 0 by pressing the calibration button for feed turn and feed tilt, respectively, in the calibration menu. This is a typical example of how calibration of the feed tilt and feed return is done in the field.



Measured while drilling analysis (MWD)-Measured while drilling is a method for identifying the properties of the rock by continuously recording all drilling parameters of importance during drilling. By means of analysis, where operating variations due to the operator or control system are removed, a detailed description of the mechanical properties of the rock mass can be made. So this is a typical example of epiroc measured while drilling. So sensors are fitted for measuring the water flow, the penetration rate and time, rotary speed, hold depth measurement sensor, percussion pressure sensor, rotary pressure sensor, damper pressure sensor, feed pressure sensor, and water pressure sensor.

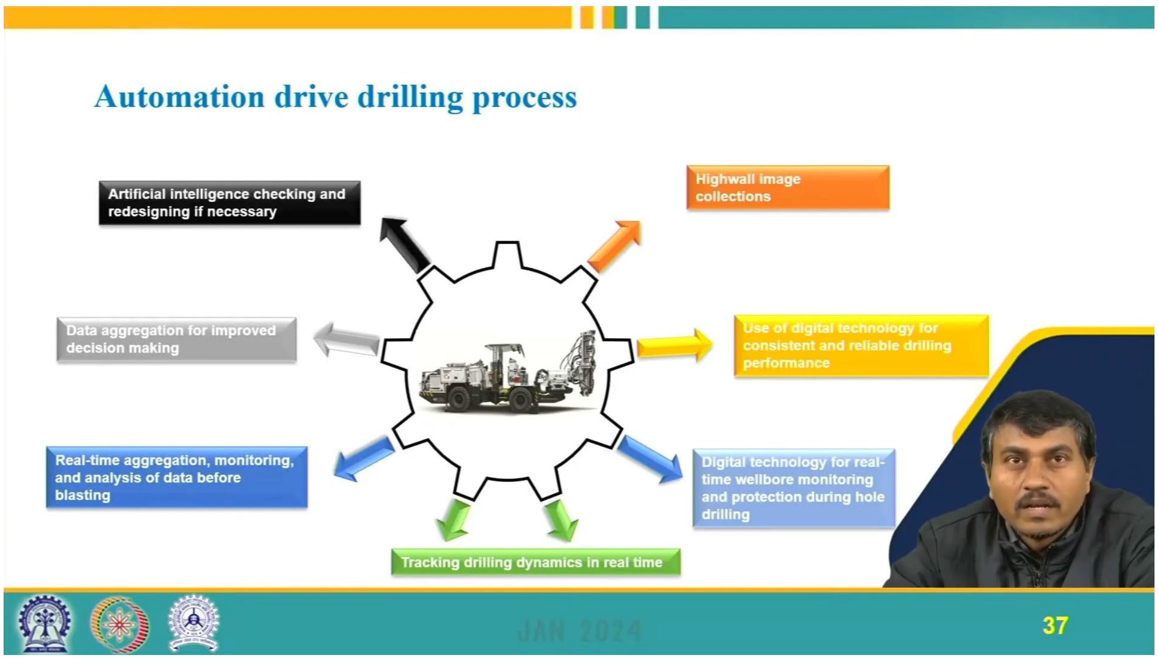
All these data are measured in real time without the intervention of the process, and thereby it makes a good amount of database for future analysis of the system.

The advantages of measuring while drilling-Very high degree of detail as data are recorded in all production holes; very low cost as recording takes place automatically during normal production drilling; very high data security as the recording takes place at the same time as drilling the hole and not afterward; minimal disruption of production.



The role of automation drilling in the mining industry- First is to increase efficiency; it basically increases precision and accuracy; and it enables continuous operation of the drill machine. Safety improvement basically reduces human exposure to hazardous work and has an emergency response system. Data collection and analysis, real-time monitoring is possible, and it collects the data in real time, and Predictive maintenance are also possible using the data, which reduces the cost. Operational costs are reduced, and fuel efficiency is also increased. Automation drive drilling process, the impact of digital technology on the entire drilling process, from high wall image collection to pre-blasting activity, real-time monitoring of oil bores using digital technology during drilling for protection, utilization of artificial intelligence for tracking drilling dynamics in real time and for verification and redesign as needed. Input decision-making during the drilling process through data aggregation and thorough analysis before blasting.

Automation drives the drilling process; it basically collects high wall images; it uses digital technology for consistent and reliable drilling performance; it uses digital technology for real-time oil bore monitoring and protection during hole drilling; and it tracks drilling dynamics in real time. In real-time aggregation, monitoring and analysis of the data before blasting are possible. Data aggregation for improved decision-making is ensured, and artificial intelligence checking and resident is necessary.



Challenges in autonomous drilling systems-We need a very reliable sensing system for extreme weather conditions and extreme geo-mining conditions. We need a very robust and flexible wireless communication system for the remote operation of this machine in remote locations in difficult terrain. We need adequate vision coverage to supervise the rig remotely. We need complex movement path planning in challenging geomining conditions, and integration with other mine equipment, such as explosive trucks, is also essential for achieving higher efficiency in the whole drilling operation.

So, these are the references, and here we want to acknowledge Tata-Noamundi, iron ore mines management for sharing some of the information used, and we also acknowledge the help provided by the executives of EPIROC working at the Tata- Noamundi site.

So, let us brief in a few sentences what we have covered in this lesson. We have discussed the foundation, or the fundamentals of the drilling process. We have explored the fundamental concept underlying the drilling process. We have introduced the concept of drilling systems and emphasized technological advancement. We have discussed the main system of autonomous drilling. We have examined the advantages, such as efficiency and safety, of adopting autonomous drilling systems. We have explored the essential sensor integral to an automated drilling system. We have introduced the whole navigation system, emphasizing its role in guiding the drilling process. We have explored major oil drilling analyses, highlighting their significance in real-time data collection during drilling operations. We have explored the pivotal role of autonomous drilling in enhancing mining operations. We have discussed how automation drives the drilling process and optimizes efficiency. We have also addressed the obstacles and challenges of implementing an autonomous drilling system. Thank you.