Mine Automation and Data Analytics

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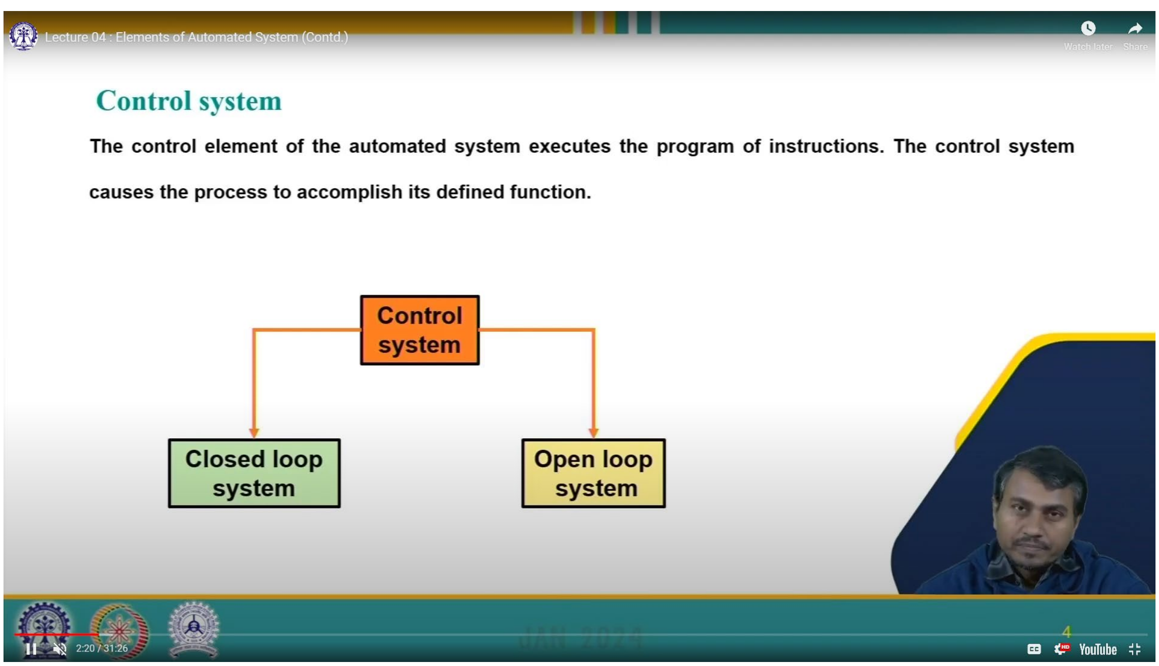
Week-1

Lecture-4

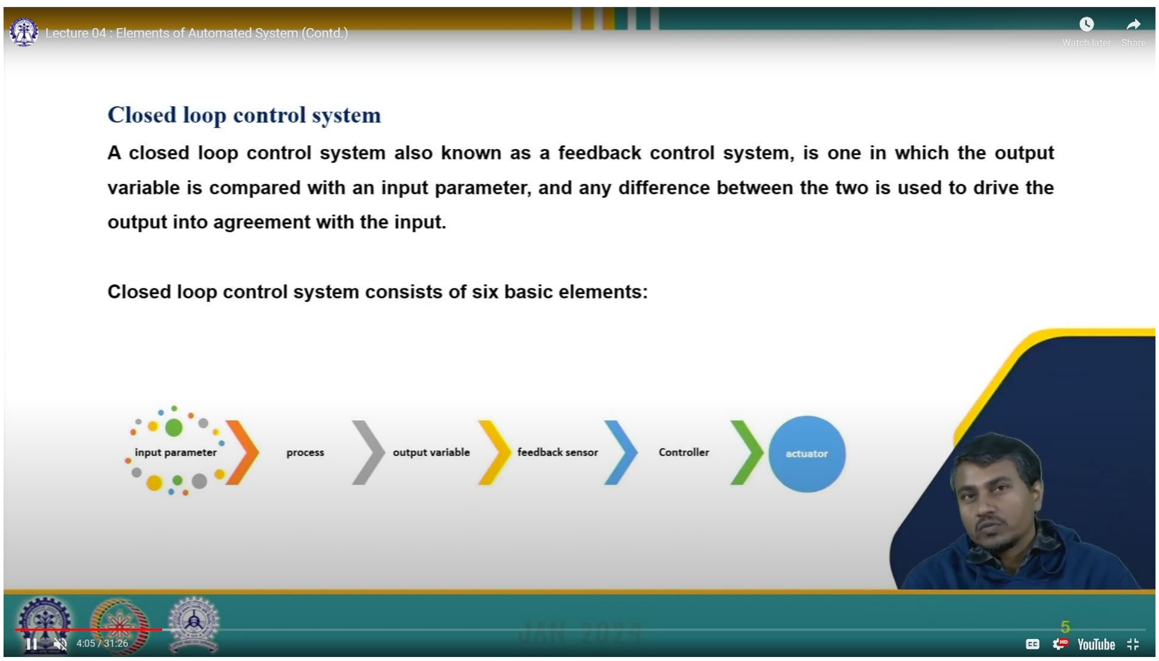
Elements of an Automated System (Contd.)

Welcome back to my course, mine automation and data analytics. In this course, we are going to cover the remaining parts of the elements of an automated system. So, in this lecture, we are going to cover the following: We will discuss the control system, the open loop control system, and the closed loop control system because, for an automated system, the control system plays a vital role and we will see the different parts of a closed-loop and open-loop system, their advantages and disadvantages. Then we will discuss the positive impact of automation in the mining industry and the operational readiness and deployment of automation systems in mining.

So let us discuss the control system: The control element of the automated system executes the program of instructions. It executes the defined set of rules that have already been defined for a designated area. So, the control system causes the process to accomplish its defined function. So, this can be done in two ways: using the closed-loop system or the open-loop system.

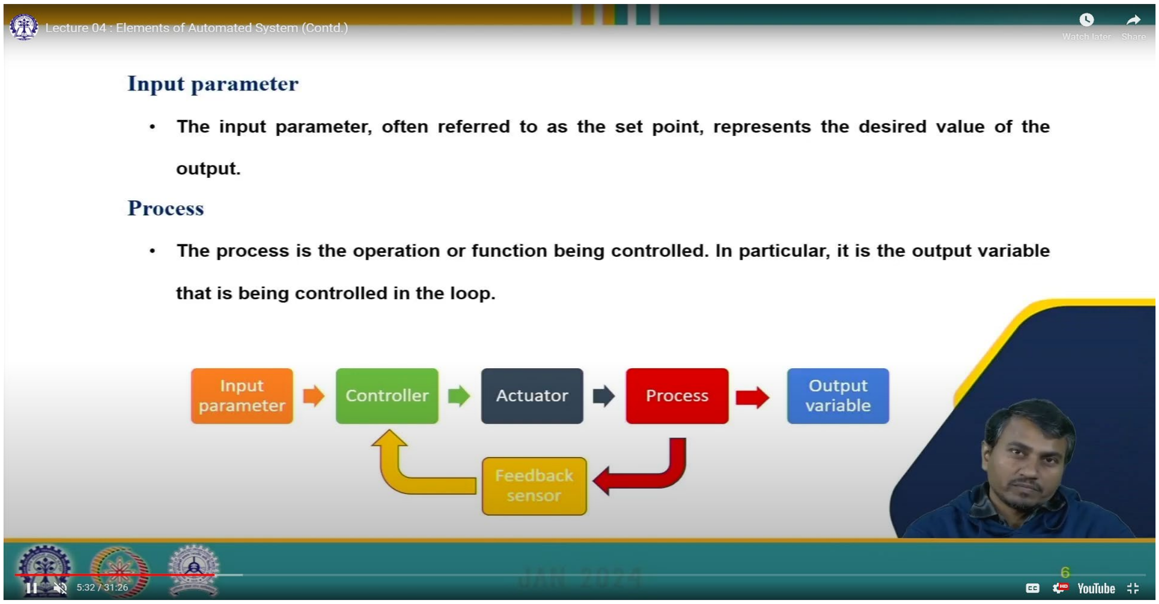


Closed-loop control system: The closed loop control system, also known as feedback control system, because the feedback is associated with the system, it works on the feedback, is one in which output variables are compared with an input parameter and any difference between the two is used to drive the output into agreement with the input. So, it means the difference between the value that is coming at the output level and the desired value. The difference is basically driving the system to rerun the system so that the desired value is achieved. A closed-loop control system consists of six basic elements. It is composed of input parameters, then it basically participates in the process, it has output variables, it has a feedback sensing system based on this feedback sensing system, it basically compares the value in the output. Then the controller, and this is basically, finally, it goes to the actuator. So, these are the components of the control system in a closed-loop system.



Input parameter: The input parameter, often referred to as the set point, represents the desired value of the output. So, this is a very important point here because based on this value and the output value, it will compare, and based on that, the closed loop system basically reruns the system.

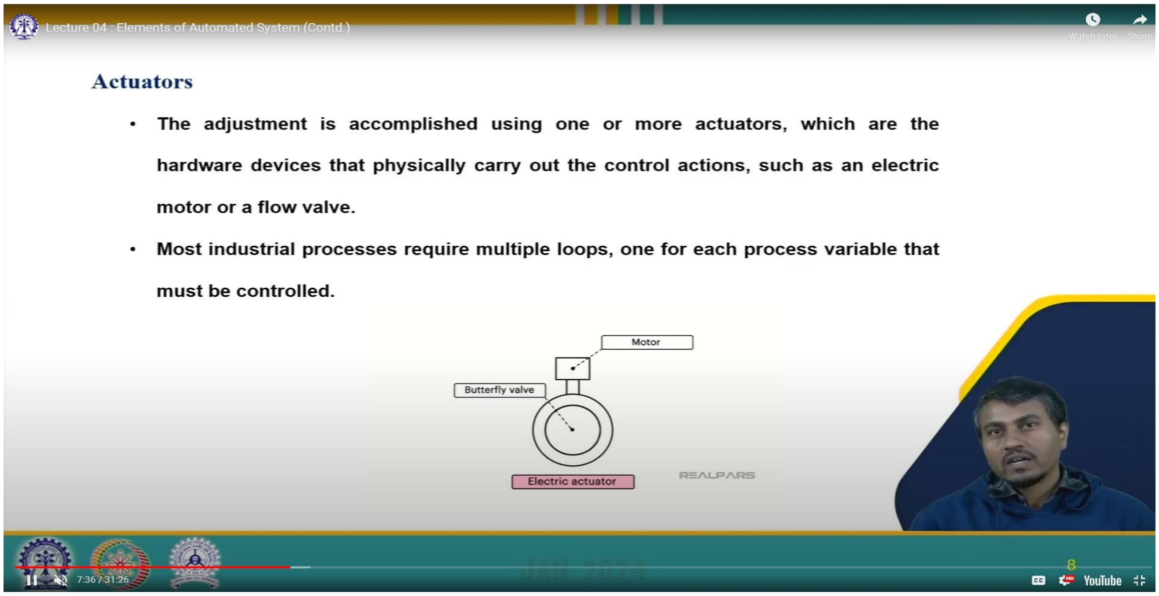
Process: Process is the operation or function being controlled. In particular, it is the output variable that is being controlled in the loop. Input parameter. Then it goes to the controller, then to the actuator, then to the process, and here the feedback sensing system is attached and if any value difference is found, it instructs the controller to act on it, and again, the actuator performs the work and finally outputs the value. So here, the role of the feedback sensing system is very important. The feedback sensing system gets the data, compares it, and, based on the difference, orders the controller and then actuator to the final process.



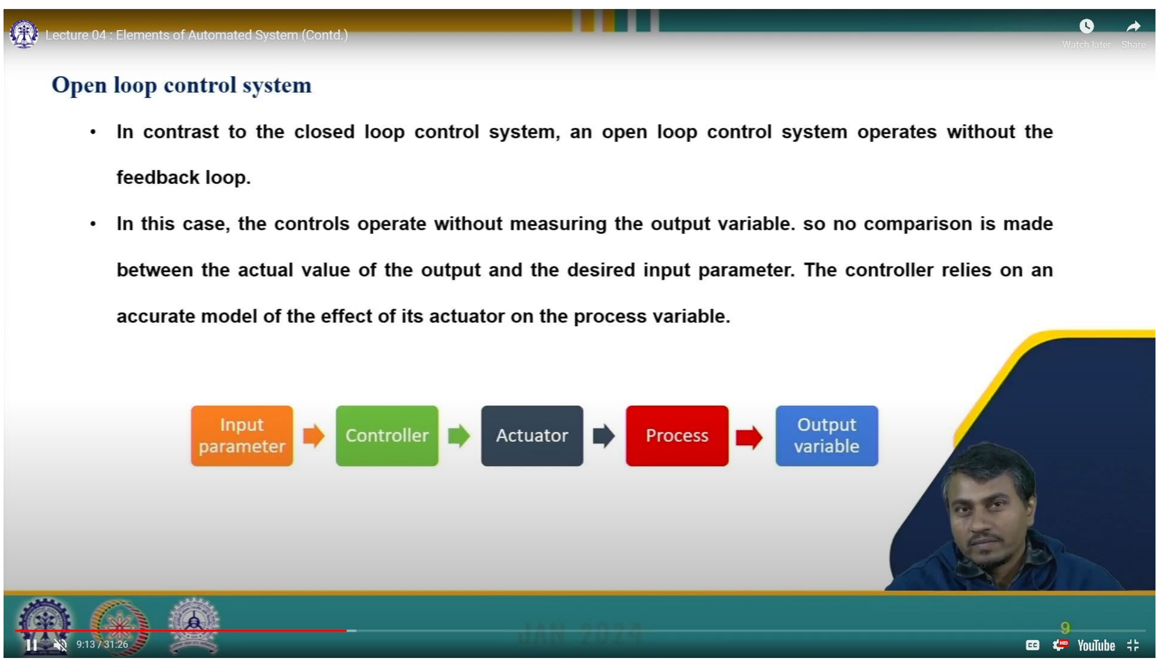
Output variable: The output variable is some process variable, perhaps a critical performance measure in the process such as temperature, force, or flow rate. A sensor is used to measure the output variable and close the loop between input and output. Sensors perform the feedback function in a closed-loop control system.

Controller: The controller compares the output with the input and makes the required adjustments in the process to reduce the difference between them.

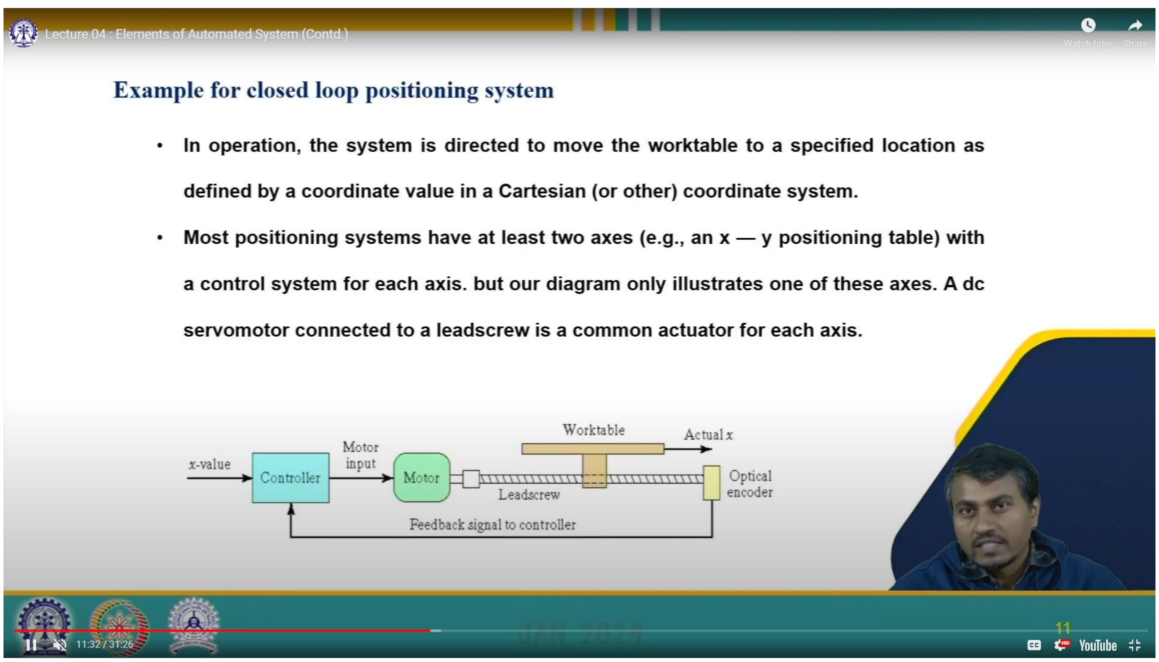
Actuator: The adjustment is accomplished using one or more actuators, which are the hardware devices that physically carry out the control action, such as an electrical motor or a flow valve. Most industrial processes require multiple loops. One for each process variable that must be controlled. An example of an electrical actuator, it basically acts on necessity and basically executes the work on the set of defined rules.



Open-loop control system: In contrast to a closed-loop control system, an open-loop control system operates without a feedback loop. The feedback loop is absent here. So as a result, it's basically a simple control system. So, in this control system, control operates without measuring the output variable. There is a difference between the closed loop and the open loop. So, no comparison is made between the actual value of the output and the desired input parameter. The difference between the closed loop and open loop is that in the closed loop, we compare these two values.



Here, we are not making any comparison between the actual value of the output and the desired input parameter. The controller relies on an accurate model of the effect of its actuator on the process variable. So, input parameter comes first, followed by controller, actuator, process, and output variable. So according to the model, it will deliver the final value, but it will not compare with the desired input parameter. So, the efficiency of this system might not be feasible for complex systems or this kind of system might not be very suitable for a complex system, because here we do not have much control over the process. So, with an open-loop system, there is always the risk that the actuator will not have the intended effect on the process and that is the disadvantage of an open-loop system. Its advantage is that it is generally simpler and less expensive than the closed-loop system. Open-loop systems are usually appropriate when the following conditions apply: The actions performed by the control system are simple. The actuating function is very reliable and any reaction forces opposing the actuation are small enough to have no effect on it. If these characteristics are not applicable, then a closed-loop control system may be more appropriate. So open-loop control systems have very little space or less accommodating capacity to be useful in industrial control systems.



An example of a closed-loop positioning system. Here it is basically a movable work table. It is moved in the x-axis and it can move both the both the x and y axis. But here, due to the 2D dimension, we are only showing that it is moving only in one direction. So here the movement is controlled and monitored with the optical encoder, and there is a motor. In the motor, there is an input and if we want to move the work table to a particular location, it is basically measured by the optical encoder and based on that, the controller basically controls the speed of the motor, and by doing so, it basically executes that work. So, the movement of the work table is actuated by this controller and the motor. The optical encoder monitors how much work is achieved by this system. So, a DC servo motor connected to this lead screw is basically the common actuator for each axis. So, if a y-axis movement is required, then along the y-axis we can also fit a DC servo motor with the lead screw. So, by this method, basically this kind of system is working in a closed-loop positioning system. So, a signal, including the coordinate value and how much it goes, is sent from the controller to the motor that drives the lead screw, whose rotation is converted into a linear motion of the positioning table. As the table moves closer to the desired x coordinate value, the difference between the actual position and the input x value is reduced. The actual x position is measured by a feedback sensor, here an optical encoder. The controller continues to drive the motor until the actual table position matches the input position value.

An example of an open-loop positioning system: For the open-loop case, no feedback loop is present, and a steeper motor is used in place of the DC servo motor. A steeper motor is designed to rotate a precise fraction of a turn for each pulse received from the controller. Since the motor shaft is connected to the lead screw and the lead screw drives the work table, each pulse converts into a small, constant linear motion of the table. So, to move a table, the number of pulses that correspond to that distance is sent to the motor.

Question number 1: In a closed-loop control system, why is the comparison between the output variable and the input parameter essential? to generate input parameters, to control the process, to drive the output into agreement with the input. The correct answer is, to drive the output into agreement with the input.

Question number 2. Why is the actuator considered a crucial element in a closed-loop control system? It generates input parameters, it controls the process, it measures the output variables, it drives the output into agreement with the input. The right answer is, it controls the process.

Question number 3. In terms of complexity and cost, how does an open-loop control system generally compare to a closed system? More complex and expensive, more complex but less expensive, less complex and less expensive. The right answer is less expensive and less complex.

So let us discuss the positive impacts of automation in the mining industry. Why is the mining industry looking for a higher and higher degree of automation in mines? So companies are undertaking projects in automation and computer-integrated manufacturing for good reasons, some of which are as follows: First, it basically increases labor productivity. That is the major reason why major companies are focusing on this domain. So, it automates the manufacturing operation and increases the production rate. Automation leads to higher labor productivity. It basically leads to higher output achieved per hour of labor input.

Reduces the labor cost: So increasing labor costs has been and continues to be a trend in industrialized societies around the world. Consequently, high investment in automation has become economically justifiable to replace manual operations. Machines are increasingly being substituted for human labor to reduce unit production costs.

Mitigate the effect of the labor shortage: The shortage of labor has prompted the development of automated operations. Automation is considered a substitute for insufficient labor in advanced nations, and this is particularly true for developed nations and this kind of automation strategy is coming from these countries.

Reduce or eliminate routine manual or clerical tasks: So, an argument can be put forth here that there is a social value in automating operations that are routine, boring, fatiguing, and possibly irksome. So, automating such tasks improves the general level of working conditions.

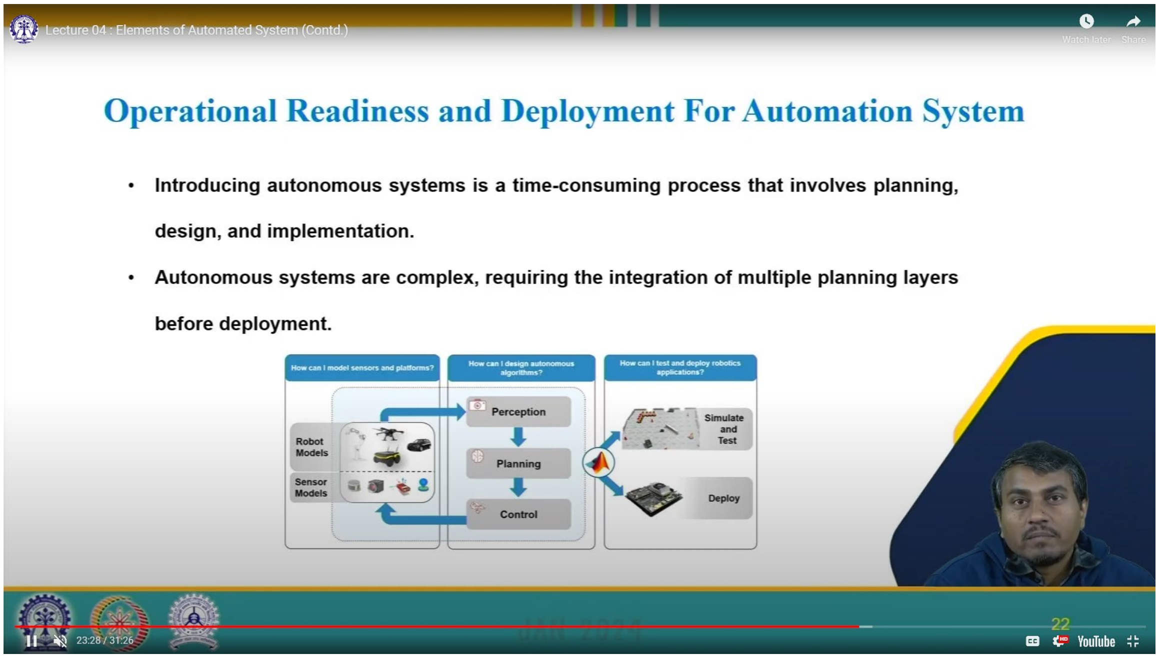
Improve product quality: Automation not only results in higher production rates than manual operation, but it also performs the manufacturing process with greater consistency and conformity to quality specifications.

Improve worker safety: Automating a given operation involves transferring the worker to a monitoring role or removing them from the operation. So, this transition enhances safety by reducing the worker's active participation in the process. The occupational Safety and Health Act, OSHA, of 1970 underscores the national objective of ensuring the safety and physical well-being of workers. Here in our country, the DGMS stresses the safety and physical well-being of the workers from time to time. OSHA has acted as an impetus for the adoption of automation to improve workplace safety. So, it is also another reason or an impetus for adopting more and more automation in the mining industry to ensure worker safety. So, we are basically avoiding sending labor into dangerous conditions, and those operations are being thought of and those operations are being done by the machines, automatic machines, and that is why there is increasing demand for moving in this direction.

Reducing manufacturing lead time: Automation helps reduce the elapsed time between customer orders and product delivery, providing a competitive advantage to the manufacturer for future orders. So, by reducing manufacturing lead time, the manufacturer also reduces work-in-progress inventory.

Accomplish process that cannot be done manually: Certain operations cannot be accomplished without the aid of machines. So, these processes require precision, miniaturizations, or complexity of geometry that cannot be achieved manually.

Operational readiness and deployment of the automation system: So, introducing an automated, autonomous system is a time-consuming process that involves planning, design, and implementation. We have already shown you in the first lecture the impediments in a mining project. Autonomous systems are very complex, requiring the



integration of multiple planning layers before deployment. So here, this figure is basically three blocks. So, these three blocks are basically looking at the first block, looking at how I can model the sensor and the platform. So, robot models and sensor models are being devised according to necessity. For example, if we are looking at the monitoring of the mine site, we can open the mine site remotely using drones or other UAV vehicles. So, for a specific mine site, the wind conditions may not be optimal. So, we have to design a kind of UAV vehicle that can fly and operate in difficult, conditions. So that basically is the first building block to model the sensors, and we have to fit a particular kind of sensor that is very suitable to monitor, to capture that data, which is required for basically helping in the mining, so for example, it can be fitted with the optical sensor; it can be fitted with the IR sensor, as the requirement prevails. So based on that, it will basically prepare a perception model and based on that, it will plan its execution, and there should also be some control. So how can I design the autonomous algorithm in a given situation in a mine condition? For example, the robot is designed or a robotic UAV is designed, that robotic UAVs operate autonomously in the mine. So, it will collect the data, for example, where are the locations of different machines, or maybe it is basically mapping the whole mines for the 3D reconstruction, or maybe mapping the whole mines in terms of measuring the temperature in the vicinity of the mines with the IR sensor, so maybe there are different tasks that it can accomplish. So, the next stage is how I can test and deploy these systems and these robotic applications in mine. So, they can be put into the mines, and they will be sent to collect the data and based on the data, their collection of the data will simulate it, maybe in real time or may not be in real time and based on the preliminary data, future deployment can be thought of, and future deployment may be done with higher accuracy and precision based on the preliminary data found. So, there are different stages of operational readiness in this kind of system. So, for this kind of application, most people nowadays are looking for remote monitoring of the mines. So, this is a good operation, and this is a good example of building a perception model, then planning and executing that thing in the mine in the context of monitoring something at the mine site. So, the implementation of an autonomous system necessitates meticulous planning. Planning is very, very important here, but plans must also be adaptable to ongoing technological challenges or changes. So, this section addresses fundamental principles and considerations for implementing autonomous systems, covering mine planning, engineering design, and architecture. Additionally, it includes information on essential deployment and commissioning activities.

Several key factors must be established in advance: The organization has reasons for automating a mine site, this is very, very important. Why is the mine site thinking of automating some part of it? The next important step is the determination of project scope and scale, including what components to automate. This required a justification, and it also required a good amount of thought about which part of the process should be automated. The level of autonomous system or equipment we are looking at is semi-autonomous, hybrid, or fully autonomous. We have to plan the autonomous operational maturity and their interconnection at the overall enterprise level so that this kind of autonomous system will be adaptable to the existing processes. So, we have to plan, and we have to think about it in detail before planning the implementation of automation at a particular mine site. So, these choices influence the required changes to the mine design and plan. So, the adoption of an implementation approach is very, very important. So, this requires the involvement of the skilled think tank of the mining company, which has already worked extensively for that mine. So, they should congregate their opinion together, they should think over it, and they should plan for the implementation approach for that particular mine site. What kind of autonomous system and what kind of automation can be good for this particular mine site? Then the selection of a technological approach, which may involve the integration of supplying a mature technology or a new technology, so this is also very important in the context of thinking about implementing some automation in the existing mining project.

So, these are the references. So let us summarize what we have covered in this lecture. So, we have explored the fundamentals of control systems, highlighting their pivotal role in regulating and managing processes. We have discussed the concepts of open-loop control systems as well as closed-loop control systems. So, we have discussed the motivation behind automating systems, considering factors such as efficiency, precision, labor reduction, and improved safety as driving forces for the adoption of automation. We have also discussed the challenges of deployment automation in existing mining conditions. Thank you.