Systems Engineering
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Lecture- 11
System Interfaces and Interactions

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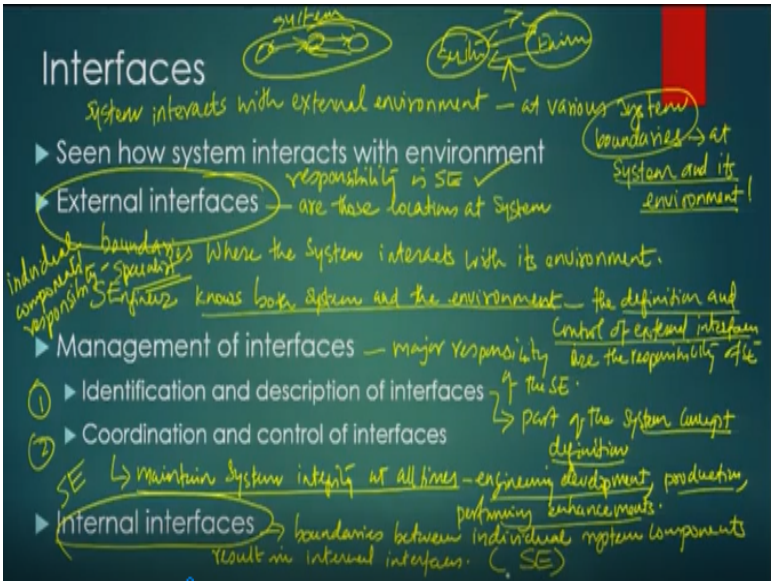

Good evening, so today, in continuing with the system boundaries and system interfaces and stuff like that. We are now looking into the todays components, system interfaces and interactions. And today, this is the 11th lecture of system engineering. And I am Dr. Deepu Philip from IIT, Kanpur. So, we talk about interfaces. And we have already been seeing this term, interfaces, interfaces, interfaces, and we also heard that interface is the responsibility of the systems engineer.

So, what are interfaces? So, let us define interfaces. So, the system, if we write it, the system interacts, interacts with external environment, we know, where does it interact? It interacts at various system boundaries. And where is this boundaries? It is at system and its environment. So, then these places, where the system and its environment, where it interacts, at the system boundaries. They are called as external interfaces.

So, the external interfaces are those locations at system boundaries, where the system interacts with its environment. So, the external interface is where he places where the system is being interacts the system interacts with this environment. So now the thing is the systems engineer, the SE, the systems engineer, is supposed to know or he knows or she knows both, system and the environment.

So, since the person knows and the system and the environment, hence the definition and control of external interfaces or interfaces, let us talk about external interfaces for the time being. Interfaces are the responsibility of SE. So, Since the systems engineer knows both system and its environment. And he knows the system and its environment or he is supposed to or she is supposed to manage the definition and control of these interfaces.

So, the system can interact properly with its environment. So, these interfaces can be managed and the management of these interfaces is the major responsibility of the systems engineer. So, this responsibility, the major responsibility of the systems engineer, it has two parts. The part one is identification and description of the interfaces and two is the coordination and control of interfaces. So, the identification of the identification and description of the interfaces

This is part of the system concept definition. So, what do we do here? So, when you have the systems concept definition this identification description of interfaces is one of the major part that the systems engineer is supposed to do. So, or the way he or she manages the interfaces. The second is the coordination and control of the interfaces. So, what is it amounts to is, is to maintain system integrity at all times.

Or the better way to say it is, when at the time of engineering development, the other one is also the production, or manufacturing of the system. Then is also the performing enhancements. So, the coordination and control of the interfaces is necessary because it helps the systems engineer to maintain the integrity of the system at all times. Whether it is the development phase of the system or the production phase of the system or performing enhancements or maintenance of the system.

That is also important to this. So, we just how the system interacts with the environment and we talked about what is external interfaces? So, then what are internal interfaces? Should be the interfaces within, inside the system. So, the internal interfaces are can be better defined as the boundaries between individual system components result in internal interfaces. So here the individual components of the system are interacting.

So, if we are, looking at here it is like the system and the environment is interacting, so doing different types of interactions. This is the environment, if you think about it. So, this is the external interfaces, where as we think about this, your system has multiple components in the system and when they interact, then that is called as the internal interfaces. So, this is the system and this is also the system.

So, the external interfaces are always with the environment, system environment where as the internal interfaces are always within the internal components or individual components of the system. So, whose responsibility is the internal interfaces? The internal interfaces is the responsibility of the systems engineer. External interface is the responsibility is systems engineer, for sure.

We already told that because he is the only person with that knowledge about both system and environment. Then whose responsibility is the internal interfaces? It is again systems engineer. The responsibility is with the systems engineer. Why? Because the individual components, if you look at it, I am just kind of writing it this side, the individual components responsibility, who has this responsibility?

It is a specialist. So, the specialist is responsible for the internal components. So, when two separate specialists are looking after two different components, then the interface is always responsibility of the systems engineer. Because individual components being the responsibility of the specialist engineer. And the internal interfaces become the responsibility of the systems engineer.

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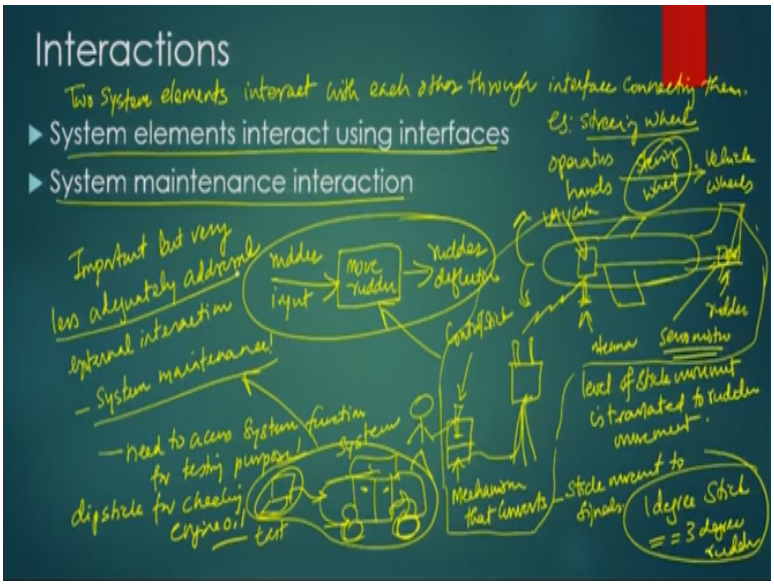

And then we now talk about stuff called interactions. And interactions are quite important in this case because system element interact using interfaces. And system also has what you call as systems maintenance interactions. So, let us talk about system interact how does a system elements interact using the interfaces? So, we can say that two system elements interact with each other. How do they interact with each other? Through interface connecting them.

An example of this is the way they you think about this example as a steering wheel. It is the interface between, what does it do? Here you have the operators hands and vehicle wheels. So, the hands and the wheels, operators hands interact with wheel using the steering wheel. So, this is the example of how two system elements interact with each other and you can assume that the steering wheel is the interface that is connecting them.

So, let me give you another example and this interaction through interface is quite complex can be depending upon the type of system that we are looking at so one example is less likely because you were talking about this UAV as an example so let me draw a simple UAV. It is kind of a box and I am giving an example of a tail, we are talking about a vertical fin, which is called as a rudder. So, we are talking about this. We are talking about the rudder of the UAV.

It has its wings and the stuff like flying around. Okay. And the rudder is controlled by it from the ground whether you have a human being who controls a stick which is mounted onto a box and it

is connected to an antenna which is mounted on a tripod. And the user moves the stick so let us call this as the control stick. Okay. And this movement is captured by, there is a computer within this or a mechanism that converts what does it converts.

It converts the stick movement to signals and that signals then goes to this base box and then the base box transmits the signal to the UAV and UAV has an antenna so here is the antenna and it captures the signal and it sends the signal to control and this is called a UAV control. Then this control has a connection to a motor. This is mounted here. A servo motor, this is the servo motor. So, depending upon the level of movement of the stick.

So, level of stick movement is translated to rudder movement so if the person moves the stick by, let us say one degree, one-degree stick might be equivalent to three-degree rudder. Three degree left rudder, three-degree right rudder. So somewhere it is calibrated accordingly so what I am trying to say here is that this interface, by moving the rudder three degree in one direction or other you will end up yoying the plane

The left or right depending upon which way the north is in the plane in the UAV. So, depending upon the rudder it will allow the system to move this way or that way. So, the control, the system diagram would probably look quite simple like this. It will look, this as the move rudder is the function and here what happens is rudder deflection is the output and this will be the rudder input. So, the control stick input happens here and this whole mechanism what we just saw.

Brought about all these thing up-to this box, kind of goes into this deflection of the rudder, so the one of the aspect is that you know it on one aspect of this whole interaction is that, it appears quite simple in a diagram but it is not really simple. It actually has quite a lot of parts that allows the system elements to interacting interfaces. So, the interface, design interface and studying the interactions is quite important for successfully engineering a system.

And also, another aspect of the interaction is the maintenance interaction that the system can have. So, it is an important interaction but very less or less adequately addressed external interaction. Interaction, what is that? The system maintenance, people does not really pay much

attention to this one when you are designing the system because at the time of maintenance, need to access system functions, for testing purpose.

People might have already seen that many vehicles like BMW, Mercedes and all, they typically have a mechanism where you have a car, you take the car into a workshop, you have the four wheels. So, you take them to the work shop and you have a computer here. You take a cable connect to the computer on the computer tells. What are the major issues with the car and then what all corrections need to be done.

And this diagram looks ugly but still you get the point across. So here this is where you are accessing the system, car is the system and this computer is used to conduct the, or test the vehicle functions to do maintenance. Another simple example of this is the dipstick for checking engine oil. So that is also one way of one interface through which you can interact with the condition of the engine oil of the system.

To figure out how good the condition of the oil is and you can change it or you can use an advanced system, where it can directly access this so some of the people, some people do consider that motor, motor vehicles that are capable of doing this, this particular case is, is well engineered systems because they are also taught through the system maintenance which is usually less adequately addressed system that lets adequately addressed feature in the interfaces and interactions design.

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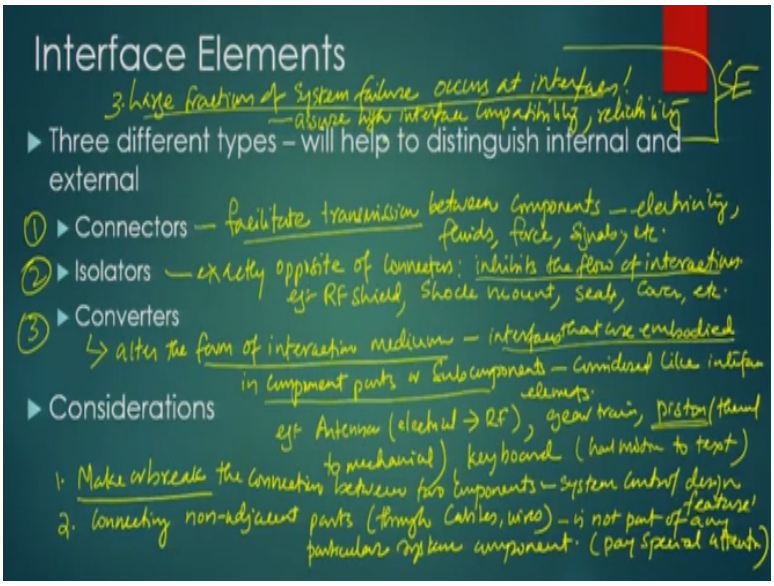

Now we talk about the elements of the interface so we know that the interface is that where the interactions happens and interface is something that is integral to the system and there are three different types or three different aspects that actually helps us to distinguish internal and external elements and internal and external interfaces. So, the first one is, the connectors. The second one is, the isolator and the third one is the converters.

So, what are these. So, the connectors in a simple definition is, if they are the ones that facilitate, facilitate transmission between components, whose component? system's component or can also be the external also. So here an example would be, some of the examples will be transmission of electricity which is the power it gives the transmission of fluid, which is material. It could be the transmission of force or could be transmission of signals.

These are all connectors etc. So, these are the examples, So, what it does is it facilitates transmission from between components, its moving stuff from one component to another. The second one is isolators. So, what do I say let us do, they do exactly the opposite of connectors or what is it is that inhibits the flow of interactions. So, some of the examples of this would be like, hour of shield. So, they stop the radio frequencies then shock mounts.

The aim is to isolate shocks then seals to isolate dust grim oil stuff like that cover or protective casing etc. These are examples of isolators and the idea is to inhibit the flow of interactions.

Third one is the converter and what are they? The converters. Converters alter the, the form of interactions interaction medium. So, they alter the form of interaction medium, what does that mean?

These are interfaces that are embodied in component parts or subcomponents and they are considered like interface elements. Some examples of them are antenna, this is where an electrical signal is converted to RF signal for an example, gear train, a motion in one direction is translated to motion in another piston. It converts thermal to mechanical energy keyboard, a hand motion to text something like this, these are all converters they alter the form of interaction medium.

So, you kind of start in one medium and then you end up with some other form. So, where it interfaces with the, it is usually embodied as the component part, like for example, piston is an integral part of the engine itself, which is actually used to convert the thermal energy of the fuel to a mechanical energy the harmonic motion of the engine. So, with these interface elements there are few considerations.

The one of the major consideration that we need to think about here is the make or break, the connection between two components. So, the interface elements either to make or break the connection, and this is very important because this is part of the system control design feature. So, if there is some issue you should have a mechanism to make or break the connection so like for example,

Clutch is an example where we make a connection between the engine and the transmission or break the connection between the engine and the transmission, that is one part. Then the another aspect of part two is that connecting non-adjacent parts. They are not next to each other, and these connections are through cables, wires etc., like insignificant components, usually, is not part of any particular system component.

So, if we have two computers in a place, you have computer 1 and computer 2, C1 and C2 and you are connecting each one with a LAN cable so then this would-be connection non-adjacent

we would say this is in one particular room and this is in another room, let us say we assume it in that way, we are connecting them. This interface is not really part of any system as such, and you do not really design that as the part of system but it is critical because we need to pay special attention.

Pay special attention because if this connection is not done properly then the interaction of the system then both the computers will be hampered. So exactly the same way, when you are connecting non-adjacent parts through cable or wires which does got any particular system component or does not been not been designed to the part of the system then you have to pay special attention. That is also one other consideration.

And the third one most important one that everybody should think about the point here is, I am writing on the top so that we can remember this as an important aspect of the system design. And the third one important one is that large fractions of system failure occurs at interfaces. This is quite important you know, then because of this you have to assure or ensure high interface compatibility you have to ensure that high interface compatibility is one aspect of this

And you have to have the liability also, and who, whose job is to do these ensurances system engineer. So, if a system fails at the interface and almost most the systems do actually fail large fractions of the system failure that everybody should remember it occurs at the interfaces, and to prevent that you should ensure that the system engineers should ensure and assure high interface compatibility and reliability of the interfaces.

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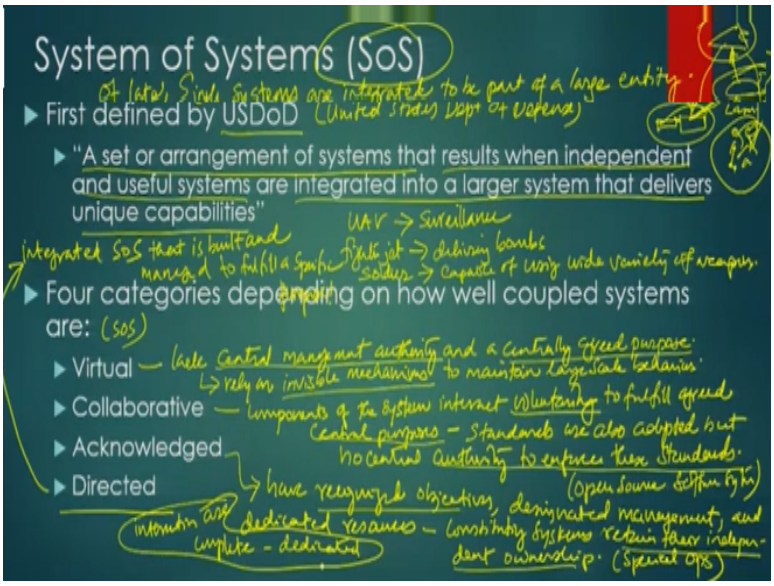

Now one of the things that we saw so far is the concept called systems assistance, I kind of briefly mentioned this in earlier presentation and we said we actually will see this later down the road. And the origin behind this system of systems or (SoS) usage is quite simple, of late, or lately, of late, single systems are integrated, to be part of a large entity. I kind of draw an example earlier in one of the presentation where you have avax controlling the UAV's fat ridges

And as well as the field guns, and surprisingly lot of the definitions actually came from this systems of system USDoD, this is United States Department of Defence. So, the DOD definition is quite simple. What it says is, it is set or arrangement of systems, so it is setup or arrangement of systems that results when independent and useful systems are integrated into a larger system that deliver unique capabilities.

So, you think about it in the previous example that I was talking to you. Let us think about the system where a UAV which is independently capable of surveillance and fighter jet which is capable of delivering bombs, payloads let us say it as bombs and let us say soldier, ok and what he do is capable of using wide variety of weapons, something like this. Let us say you are integrating this in a battlefield.

So, you could use UAV so let us say you have a UAV standing here and there is a tank sitting here, the enemy tank sitting here and you can use UAV to designate this using a laser targeting

and a fighter jet which can come from here, and then drop a bomb which will actually come and hit the target. So, for this the UAV need to communicate with the fighter jet and as well as this the ground force that is moving forward need to know that the fighter jet is coming to destroy the enemy tank.

So, they have to find cover to ensure that this explosion does not hamper them. It's kind of stuff that. So, everybody need to have information back and forth, these are the fighter system these are the surveillance system, there is a human base system there is an enemy tank system and a land bay system and all those things can be somewhere interact to deliver something that is larger than the current capabilities.

So that kind of a system usually originated from war field or battle fields and then it has been used in many capabilities. So, there are many ways we can discuss about when the system become a system assistance or when system integrated to be a systems assistance. Let us see this four of cases and how they work? The first one we will talk about the virtual one. Virtual is systems of systems we can also read as SOS.

Virtual SOS they lack central management authority and a centrally agreed purpose. So sometimes the few countries or few agencies within the countries might collaborate on to a specific enquiry of a case or a crime and they will come together informally, virtually at the time period. They will all work together to crack the case when the case is over then they go into their own way. So, what happens here is that self-system will rely on invisible mechanisms.

To maintain large scale behaviors. Because all these systems that we talk about they are independent and they do not have a, there is no central management authority and there is no centrally agreed purpose. But for some specific reason and for some invisible mechanism did exist and the system started collaborating with each other and then when the invisible mechanism goes away then the virtual system of system is typically seem to be collapsing.

So, the second one is collaborative system. So, what is the collaborative system? So here the components of the system interact voluntarily to fulfill agreed central purposes. So, in this case

usually, people agree on making something that is agreed central purposes is that components of system do interact voluntarily to fulfill their needs. But usually many cases standards are also adopted but no central authority to enforce these standards.

So, like an example of the season open source software system where people collaborate with each other and there is a common centrally agreed purpose. And everybody works voluntarily towards it to fulfill the centrally agreed purpose. And some standards are also agreed upon that we will do this and do that some standards are agreed upon. But there is no central authority to enforce those standards. So that is the collaborative system.

Then we talk about the acknowledged system. So, these acknowledged systems they have recognized objectives, designated management and dedicated resources. To do what? To fulfill the agreed central purpose. But the major aspect of this is that constituting systems retain their independent ownership. So classical examples of this is that special operations. People from different fields do collaborate in this.

Like people from air force will be the once will be those flying the operators from place A to place B. Operators may be drawn from different areas of army, navy, air force or other stuff like that. They collaborate together and there is a designated management and there are designated resources all those things are part of this. But at the end of the day they still maintain their independent ownership.

The air caste cell might belong to the air force; the soldier cell might belong to army or navy something like that. So, all those kinds of stuff. So, the acknowledged systems are to the large extent they do have recognized objectives and designated management and dedicated resources. But they still maintain their independent ownerships. So, this brings us to the last one called as directed systems. So, what is a directed system?

Because of lack of space, I am writing on top here, directed system is an integrated SOS system of systems that is built and managed, we are talking about this, built and managed to fulfill a specific purpose. So, the importance here is the directed system is that it is built and managed to

deal with a very specific purpose. So here the interactions are complete or dedicated. So, such systems are tightly coupled also or such systems are tightly coupled to create what we call as a system of systems.

So, with this we have come across the major accepts of system, its environment, its boundaries it interfaces the context diagram and how interaction happens and what are the ways in system of system get defines and other aspects of it. So now since we know how to define the environment of the system and the boundaries and as well as what are the different aspect that can create an input to the system and how do the input gets translated to the necessary output or a useful output.

That is the main aspect of the system design. The tools that will help us to define the system describe the system and as well as come up with other accepts that is necessary to do the design production and management of the system. You will start seeing them from the next classes. Thank you very much.