Systems Engineering
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Lecture-20
Functional Flow Block Diagram

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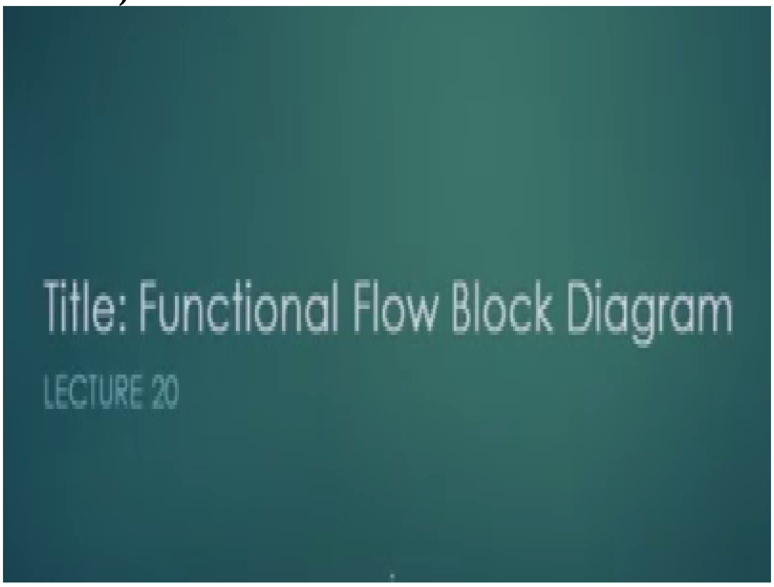

Good morning, today I will come you guys with the twentieth lecture of systems engineering, which we are going to discuss as a specific functional analysis tool called functional flow block diagram, it is an important tool. So the functional flow block diagram is a tool that is used to do conduct functional analysis which is an important step. If you remember again as a quick recap of this, we had a loop.

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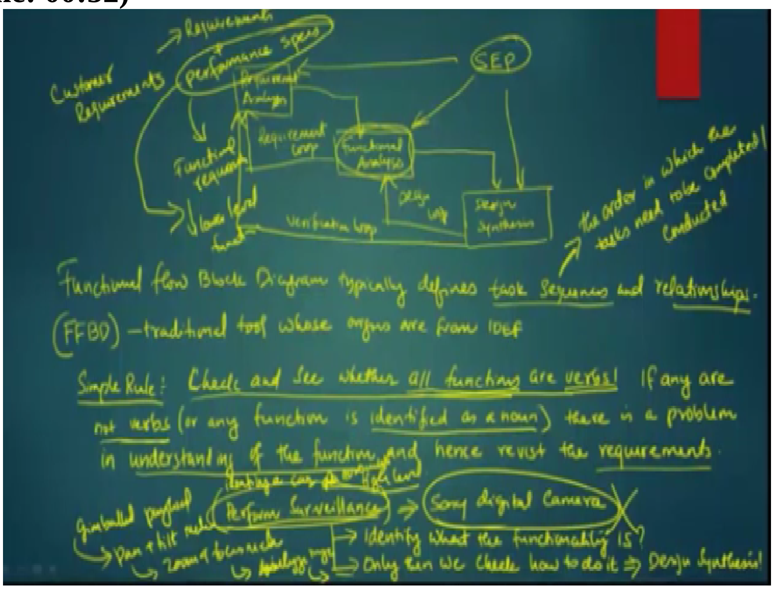

Systems engineering process loop had three things, the first loop is called as the requirement loop or the requirement, instead of the loop, we will call it as analysis. From here, we go to the next 1 which is called as functional analysis and then we have what we call as a design synthesis. So the requirement analysis gives rise to functional analysis, in this process you go back and check your requirement analysis and this is called as the requirement loop, okay.

Similarly, from functional analysis, once you have the output of the functional analysis, it becomes the input of the design synthesis and you keep on iterating between back, which we call as the design loop. You also have the loop with the requirement analysis, which we call as the verification loop, so and then you have the systems engineering process basically manning all the three, you have seen that.

This model we have been discussing, we have been going through different aspects of it, different though process of it, and stuff like that. So 1 of the tools in then we have been discussing the functional analysis in the previous classes and 1 of the tools that we mentioned there to conduct functional analysis in an efficient manner is functional flow block diagram. So what is a functional flow block diagram?

So in simple terms, a functional flow block diagram typically defines task sequences and relationships. So the task sequence is the most important thing and the relationship. So the task sequence implies the order in which the tasks need to be completed or conducted. So the order, the specific order within which you complete the; or you sequence the task, that is 1 and then also the relationship between the task, which task is related to who, that is also 1 thing, okay.

Another aspect also of the this is typically also known as FFBD, this is the abbreviation of functional flow block diagram, okay and this is also a; this is usually called as it is the traditional tool, is a traditional tool whose origins are from the IDEF system okay and also is that it also allows you to do, you know, help you to identify or in a way. What you can say is that, the simple rule that everybody follows in this.

The simple rule within which the functional flow FFBD works on it is, you check and see whether all functions are verbs. Earlier we also mention that these are actions, okay so you should be using verbs to do this, okay. If any are not verbs, okay or any function is identified as a noun then that means that there is a problem in understanding of the function. Hence revisit the requirements, it is almost impossible for any of us to really get the functions right at the first go.

As I said earlier, it is again an iterative process. So the first thing that you do is, in their functional flow block diagram is, you check and see whether all functions, each and every functions are expressed as verbs. If any or not verbs, if any of the functions are not as precise verbs, or you at see nouns in the form of verbs. Then you know that there is a problem in understanding of the function, okay.

You basically find that okay, the function, the understanding of the function is not clear to you and then you have to go back to the requirements. May be you may have to conduct the requirement analysis at some point of time, little bit again to get clarity on that. A typical example of this see if I say somewhere you know, write it as a, you know as like somebody says, if I say perform surveillance that is a verb actually, you are performing the surveillance, so you know what all things that need to perform the surveillance.

Instead of that, if I write, Sony digital camera, then this is a problem, this is not expected out of that. You supposed to express what function you are going to do? To perform surveillance, it does not, it is not mind to that do you need to use the Sony camera, you can use many other cameras, you can use infrared cameras. The aim is to identify what the functionality is? Or what function we need to finish?

That is the first thing what the functionality is, then only then we check how to do it? Remember, I mentioned earlier also that is the part of the design synthesis, so we are not designing a system yet, no system design as is going to happen at this point. We are just still working on the functional requirements, so the first part is the customer requirements, from there we got our requirements plus performance specs that gets translated into, what we call as functional requirements

These performance specs should filter down to lower level functions. So the surveillance, performance surveillance is a, this is a high level function usually. How would you do it? That is the like a gimbaled payload okay, you have a pan + tilt mechanism, so there is many options. So first is you require a gimbaled payload, from there a pan and tilt mechanism, then there is a zoom on focus mechanism, then from there image, analysis image; analyze image.

So keep on filtering it down and each time you move down from the performance surveillance, you might have a high level requirement of like somebody says, identify a car at from Thousand meters, then it boil down, how you get to do it at to the lower level of functions? So the performance specs which is usually attributed to the high level function gets boiled down to the lower level function.

That is primarily what the aspect of the functional analysis and functional flow block diagram is a tool that actually facilitates the analysis of breaking down of the higher level functions into lower level functions and as well as appropriately allocating the performance parameters that are associated with the higher level functions to the lower level functions. So let us see the also, let us see how does the FFBD looks like?

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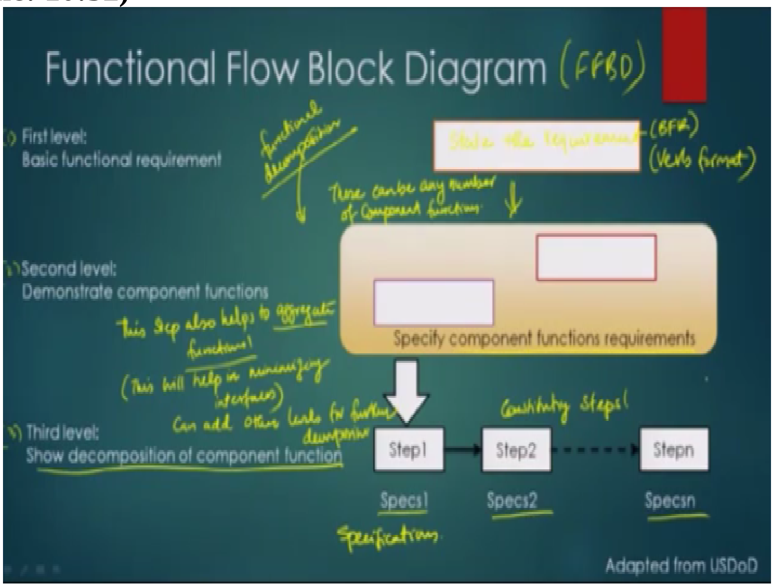

The functional flow block diagram has actually three, we can have multiple levels out of it also, typically you find it in three levels, the first level here, then the second level here and then the third level here, okay. So the first level is the basic functional requirement is what gets stated here. So you state the requirement here, the basic functional requirements gets stated there in the box, okay.

It will be something like perform mission or whatever it is, perform surveillance, conduct surveillance, so this will be a verb format. So conduct surveillance is a verb there, okay. From there, you basically break this down into its components functions. We just do as an example to components functions, there remember demonstrate the components functions, there can be any number of components functions.

So this is where, this step, this process is also called as functional decomposition, so you are decomposing the basic functional requirement into its components functions. The components function requirements are specified at this level, you are decomposing them into the components functions, okay. Also this is the time, this step also helps to aggregate functions, okay, this sounds counter and duty.

Because you are decomposing, you are at this point; you are decomposing the functions and you are also looking for aggregating them. First aim is to actually decompose them into components functions, the specific components, the constituting functions what are to achieve the basic functional requirement, this basic functional requirement is identified and from there the components functions are identified, so that the basic functionality can be achieved.

But then once it is done, you also look for opportunities to aggregate functions, why do you need to look for opportunities to aggregate functions? Because this will help in minimizing, minimizing what? To help in minimizing interfaces. Remember, 1 of the aspects of aggregating functions is; we can minimize interfaces. So that our aim is to ensure that the interfaces, the functional interfaces requires as part of this is minimized.

Then from there, once the components functions are identified, you go to the third level, we decomposition of the components functions, so the individual components functions are further decomposed into individual steps, what are the constituent? These are the constituting steps, you can always have a fourth level, I mean this can further brought it down, because this components function are further components, then you will have your further components in between and you move this whole thing 1 level down.

Here we assume that you can add other levels for further decomposition. But the last level is, where you basically decompose it in the constituting steps of the function and also at each constituting step, you also do the specifications, the specifications associated with each step is also part of this process. I hope you guys have a basic idea how the FFBD is designed and again as you can see this is a tool.

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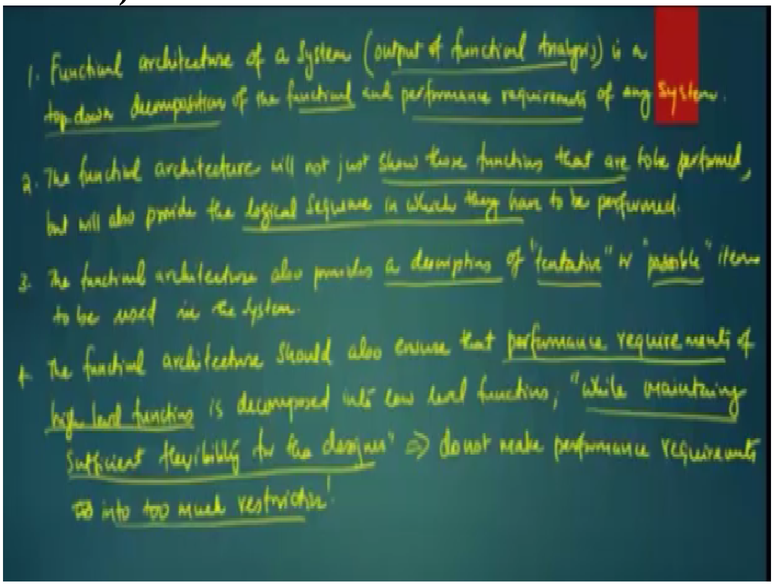

That allows the systems engineer to excise lot more flexibility, at the same time when he is doing the functional requirements. So let us do a; may be tried to do a simple example to see how this can be though through, so I will actually take an example of the, so again before doing this, just as a recap the functional architecture of a system, this is the output of functional analysis.

Okay, it is a top down decomposition is a down decomposition of the functional and performance requirements of any system. So this is the first point everybody need to clearly remember. The functional architecture of a system, which is the output of the functional analysis is a top down decomposition of the functional and performance requirements of any system.

So you are doing a top down decomposition of functional and performance requirements of any system. Number two, the functional architecture will not just show those functions that have to be performed but will also provide the logical sequencing or the logical sequence in which they have to be performed. This is important in a very complex system. Because it is not just show what functions have to be done.

But it also shows the logical sequence in which they have to be done. This is also an important aspect, okay. Third 1, the functional architecture also provides a description of

10tative, we called this as tentative or possible items to be used in the system, okay. So this is implies, where we provide a description of 10tative or possible items, they are in inverted commas.

Because in this process you are identifying alternatives, you are looking at whether it is a government provided item or a commercially of self-item or a specifically manufactured item, so but these are like your kind of giving clues to the designer, that okay. We thought through this, we think these items would be able to do, you know functional capabilities. Fourth 1 is the functional architecture should also ensure that performance requirements of high level functions is decomposed into lower level functions

But the important part is while maintaining sufficient flexibility for the designer. This is an important part. It is the duty of the functional analysis to breakdown the performance requirements of high level functions, the top level functions into the lower level functions, you have to bring them appropriately down, but ensure you have to make sure that maintain sufficient flexibility for the designer

If you make these performance requirements in a simple way to say it is do not make performance requirement as into too much restrictive. So this is 1 of the things that the systems engineers to ensure that the performance requirements should not be too much restrictive. So that the designer finds it extremely hard to design the system or the design the product, okay, fine.

With these kind of four points that are critically important to the functional analysis. We would now try to get into the example okay of, we will try to take an example of the UAV and then we will try to go from there, okay. So in the UAV, there is the 1 of the mission, let us talk about it is the UAV should always communicate with the ground control station providing live video feeds and telemetry okay, this was 1.

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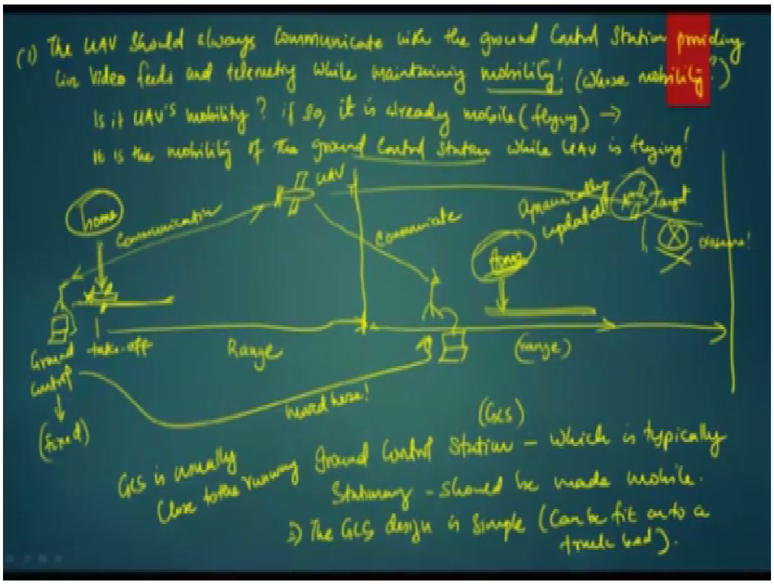

While maintaining mobility, this sounds like a tricky you are saying that the UAV should always communicate with the ground control station providing live video feeds and telemetry, while maintaining mobility, while the UAV is mobile, so whose mobility are we are talking about? So the mobility in this case, the user was talking about, is his question is like whose mobility?

The first question that we ended up asking his whose mobility? Then the user clarified is it UAV, is mobility, if so it is already mobile or in a way it is flying and so there is no point in asking for its mobility, then the user said "no, no", it is the mobility of the ground control station while UAV is flying, this was a tricky proposition for us. So think about this way, you have run way here, you have your ground control station with the antennae right here.

The ground control station computer and everything is connected here. The UAV takes off from here, it took off from here and it is flying supplies here, assuming that flying supplies here, okay flying around okay. It took off from here this was the take off. Ideally, you would have expect it will take off it will fly up to some level where this is, were its range okay, this is the range of the UAV.

We will assume that it will fly until this range, which is the range with the communication because it should be in communication, this is the communication, this is what we called as the ground control, okay the UAV. So then if that case, it should communicate back and forth between this sent videos and the UAV's mobile, this is the ground control is fixed. Now 1 of the things that user wanted was, okay once the UAV takes off, you can take this whole ground control and kind of move it here.

So let us say now you are ground control including the computer moved here. Now because a length you have a run way here, then the UAV should be able to still maintain this communication, okay, communicate and then come to this new area, so this was their way of enhancing the range, now the range is kind of like this, okay, so you might known how the capability to reach the target supplies here.

Oh, let us say instead of this range, we will say the range is supplies here and this was your let us say the target area, okay, by doing this, we can get the UAV to come over here. This was their thought process, okay and then observe the target. So that was the new challenge to this okay. Now we understand the functionality, the mobility is not a functionality of the UAV. The mobility is the functionality of a ground control station.

So the ground control station which is typically stationary should be made mobile, the reason is entire, why? Because the GCS design, the ground control station is also called as GCS. GCS design is simple, can be fit on to truck bed, so then we were like okay. One of the major aspect of it is when the UAV takes off, we set this as the home, so if anything happens, if the communication loses, the UAV is supposed to come by here.

But if we move the ground control station, then this will be the new home, it should come by here, where the run way is, you typically try to move your ground control station. The rule is that, the GCS is usually close to the run way, so that you can bring it back. So the home of the UAV, this need to be dynamically updated depending upon the location of the ground control station.

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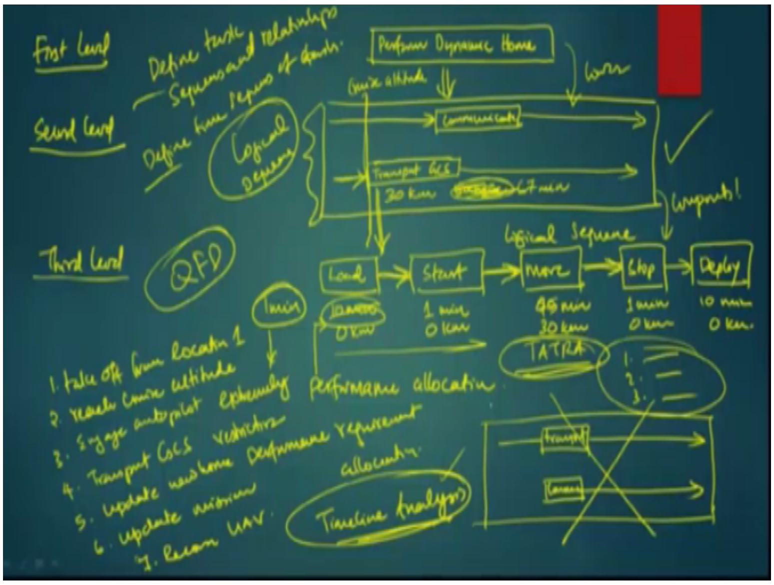

When this aspect was put forward we were like okay this is a new, completely new design challenge and new system approves that the requirement that the user has put in. We, how to change and create a new functionality, okay. So then for that, what we can think about is we wanted to do a functional diagram and always say the first level, we can say, think about as your first 1 say perform dynamic home.

You can say perform dynamic home as your first function and let us say for the time being. You can basically say that as your components functions, it is your second level, okay, where you can say is that it should communicate should always remain in communication, right throughout and in during these process, sometime you will probably have transport home or we will change it as transport GCS. This will also happen sometime, okay.

Usually, when we discuss with the customer, they said that okay once a UAV takes off it reaches the, let us we will assume this as these cruising altitude, they would like to shift the home, to this new location. So the aim is that, okay the UAV will continue to communicate throughout this process, but once it takes off after sometime into the takeoff and communicating. This is the point at which you can think about it has in the timeline.

This is where the another tool called the timeline is important because this is where the cruse altitude is reached, okay. Then, you transport the GCS. The UAV still remain in communication and you set up at the new location and the UAV continues to perform the mission, okay. So then, how much is the transportation? This we have to specify, so we said okay, the max it will do is something close to, we will said it as okay.

It will move to somewhere close to 30 km or 50 km and it would take somewhere close to 50 minutes to make this move or 30 minutes to make this move something like that. So we gave a 50 minutes as a time period and 30 km as a time for it to, distance for it to move, okay. So then 1 thing is this communicate function is 1 thing, but we can further see, that these transport GCS can be further broken down, it can be broken down into the third level, okay.

And we can say that okay it basically says once it is done, then we can say load, then you can say start, again say move, stop, deploy. So the transport GCS would accomplish these steps, where you start load, once the UAV is reach the altitude, then you load stuff onto the truck and then okay how much it time for it to take this? We can say 10 minutes and the distance travelled is 0 km, you just loading, you are not done anything.

Then start the truck and move we said okay it takes 1 minute. Then again you are not moved any distance and then move, we would basically say okay it is about 50 minutes or 45minutes. Then you travel somewhere close to 30 km, okay and then you stop which is like an another 1 minute and then 0 km and then you deploy, you will basically say another 10 minutes and 0 km.

So we think about it, this actually provides you that okay this total process is 10 +11, 11+1=12, 12+10=22+45 will be about 67 minutes we will be in this process. The ground control station will be mobile, so if you add to that okay fine then we say okay this 50 minutes was a lower estimate. This is only for this aspect, so we need to make this as 67 minutes and something like that.

So we will keep on editing, this we revise it, no to ensure that there is complete traceability or we can find out how it has done, okay and this is where this kind of a thing what we called as performance allocation. So if we loading, if we say instead of 10 minutes, somebody says I want to make it only just 1-minute loading. Then the problem is you are making it extremely, this will become an extremely restrictive performance requirement allocation.

So providing sufficient time okay, gives the time to the designer to design the system in such a way that he or she, the person who is utilizing the system as sufficient time to do the job and get it done without anything. So this is also what we call as the logical sequence, okay and this is also another logical sequence. Because you cannot do something like this, if you draw this diagram, this way wrong.

Instead of this, you draw this way, draw like this, let us say, transport ECS and then you would say communicate. It does not work. Because the reason is you first have to, the UAV has to do, or the sequence is this, take off from location 1, reach cruse altitude, auto pilot, sorry that's the wrong way of writing it.

Engaged auto pilot okay, 4; transport GCS, five; update new home, six; update mission, then 7 recover UAV. So if we go back to the previous diagram, the idea is that you take from this place. You reach the cruising altitude, engaged the autopilot, so this is where the auto pilot gets engaged, so it ensures that the UAV will stay in this area, that particular area that you are designated, then you pack and move, your GCS right here, okay.

The UAV will still remain in communication with the GCS, but the GCS is moving. "Excuse me" once you reached here, you engaged with ground control system and then this is where you update the new home, update home. So now the UAV knows that okay I don't want to go back here, I will come here only to land and then you tell UAV okay now this is your target so up to this point, this is where your communication problem was.

But because of this now you are able to moved your GCS, you are able get to this target. So this is another aspect that was, this is the way it has to be done, so you can say that the communication comes before the movement of the GCS, so that logic, if you write it this way, then it becomes wrong, instead this is where the right way to write it okay.

So this kind of a technique, what we just mentioned about how the functional flow block diagram can be used to break down a higher level function into a lower level function and lower level function into its components is an important thing because you will have for every function, you will have 1 functional FFBD, functional flow block diagram. By going through this documentation, you will be able to identify okay fine.

What all things, what we need to do to achieve this kind of a function? and ensuring that this traceability happen you said okay fine, this 50 minutes is wrong, it should be 67 minutes and you update that then totally find that because all the documents is in sink. Then you use this document to further study what is going on? and somebody says how this move happens and what type, somewhere you can say here that okay what type of it,

Somebody says okay we would choose the TATRA truck or something like this, then the idea is that okay then this whole base or we can say TATRA or some other 1, 2, 3, we will say these are the three trucks options that we think will do this trick as a mobile GCS. Then it allows the designer to choose an appropriate 1 from this and then design, may be make up a new choice completely all together by himself or herself, okay.

I think giving this all thing around, again the main summary point is that you know, this we have not discuss what we call as timeline analysis, which we will do sometime later down the road once we finish QFD. But this timeline somewhere here we can see that this timeline is there, and here also there is a timeline running in this process, okay, so the time taken to perform these activity is an important aspect of this whole system.

This is what we actually end up doing as part of the functional flow block diagram. So just to recap what we did today? The functional flow block diagram, it defines the task sequences and relationships that we have already seen and we also said define time sequence of task, these two we have seen, how it actually been taken care of today and we will also see the tool called QFD, quality function deploy that we mention briefly yesterday.

We will also see the tool and as well as we will also see the tool of timeline analysis and then we will move into what we called as the design synthesis, okay, where we will talk about requirement allocation sheet and another tools. So thank you for your patience listening and see you in the next class. Thank you.