Global Navigation Satellite Systems and Applications

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Lecture – 18
Global Navigation Satellite Systems (GNSS) Applications - II

Hello everyone and welcome to Global Navigation Satellite Systems and Applications. In previous lecture, we have discussed some applications of GNSS systems or constellations; how these signals can be used in surveying mapping, GIS and in a sciences field.

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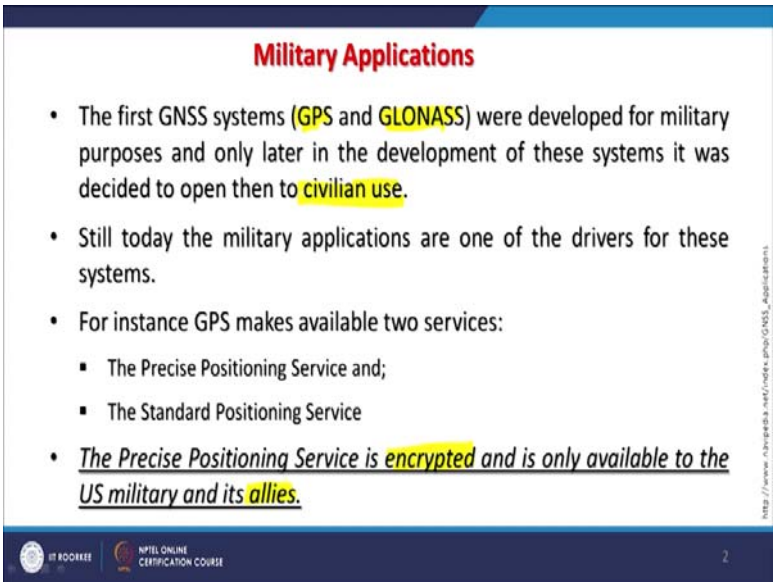

In this discussion, we are going to have some discussion on how in military applications where basically the main original purpose of all these GNSS systems were to employ in military applications but as we know that later on, their civilian applications have become very normal and expensive and extensive in that sense. So, first GPS and GNSS these were parallely developed by two countries who had cold war in between them that is USA and former USSR

And the main purpose was to put on missile so that you know the guided missiles can be employed in case of a war. And, then these countries; initially first US and then Russia started thought that they can be opened for civilian use and then various applications in civilian domain started coming. Still today as we know the military applications are one

of the drivers of this system so the lot of investment or money which is coming towards the development of these GNSS systems by different countries. The main purpose has always been the military purpose whether it is BeiDou, whether it is a GLONASS or GALILEO or even IRNSS in that case.

For instance as we know that GPS available in two services which we have already discussed. So, we are not going to discuss in detail about these two services but just very briefly I will mention here that the PP service that is Precise Positioning Service not available to the civilian domain and mainly available for military domain and then SPS that is the Standard Positioning Service which is available to civilian domain. So, most of these GNSS operators; they almost all of them are having these two type of services. One for military purpose that is very precise, another one for standalone or maybe in employing DGNSS or other systems but that is Standard Positioning Service.

And as we also know that these PP service in case of particularly about GPS, it is encrypted. So, one cannot unless you are having permission or proper hardware, then only you can receive this signals in PPS, otherwise SPS signals will be coming. So, PPS service is completely encrypted in only available to US militaries and its allies. When we were been discussing the BeiDou system at that time, the similar kind of discussion also came and just to give analogy or relate with this discussion is that the Precise Positioning Service in case of Beidou is available only to military uses of China and Pakistan.

So, they have opened only to Pakistan and whereas US has opened its Precise Positioning Service to US and its allies like United Kingdom and many other countries.

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Different types of military applications are there; for military navigations, of course that is main than target acquisition that is again for missiles and other things, for car navigation.

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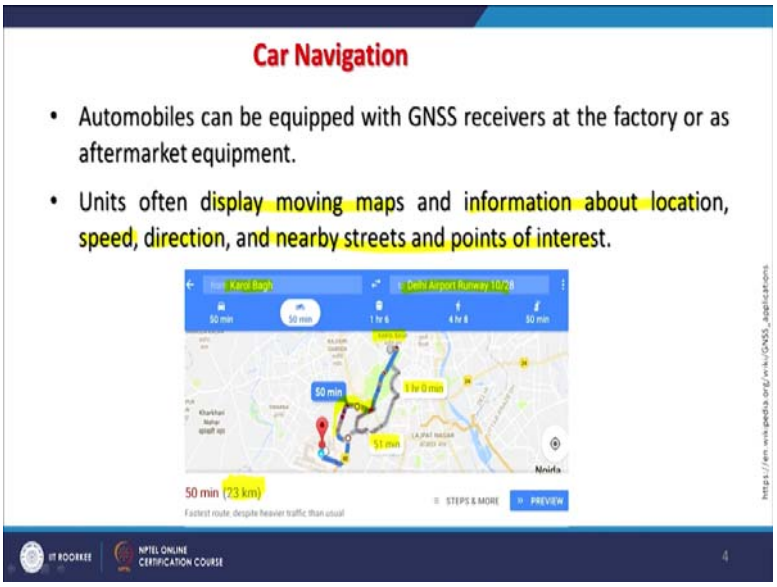

Now after this military navigation, we come to car navigation which is now the most common and very upcoming application of GNSS for automobiles applications and mainly for automated movement of vehicles that is what being targeted now. So in car

navigation, these are being used even nowadays putting a smart mobile near the dashboard of a car we can also use these car navigation system.

So, there are cars which are being built along with navigation systems but there are having some updating and other issues are there and cost also involves. There is a mobile based so the same mobile can be use for card navigation as well. And there are units often display moving maps, information about the location, speed, direction and nearby street and point of interest. So, like in Google map, when you use for this car navigation if you put that I am looking for petrol pump or gas station or a restaurant or a hotel and immediately it will start showing on the map. So, where you are and where these facilities are there that distance can also be estimated quite quickly.

So, these units are available like for example here I have just put a scenario that if one has to move from Karol Bagh to Delhi Airport, then what are the ways there and which route options are there and how much time it will take. So, estimated time there is a roughly 9 minutes difference and this one is the least which is just 50 minute time which has been chosen in default And so, here is the Karol Bagh and this is the route which we will be followed. However, as you can also see that through crowd sourcing of mobile locations of different people along these roads; these 3 kinds of a colors or patches are shown along this route of 50 minutes between these 2 locations.

One is blue patch which says that movement or traffic is moving normally, another one is the yellow one which says that traffic is moving slowly and the red patch is where for at that moment of time; the traffic has almost stopped or moving very-2 slowly. So, that kind of information is also being made available through communication networks as well. So, it becomes very convenient for anybody to use these car navigation systems and then decide that which route to follow and how much time it will take, what distance one has to be covering and so on so forth. So, that is why in car navigation, these GNSS based systems like Google map or others have really become very-2 popular.

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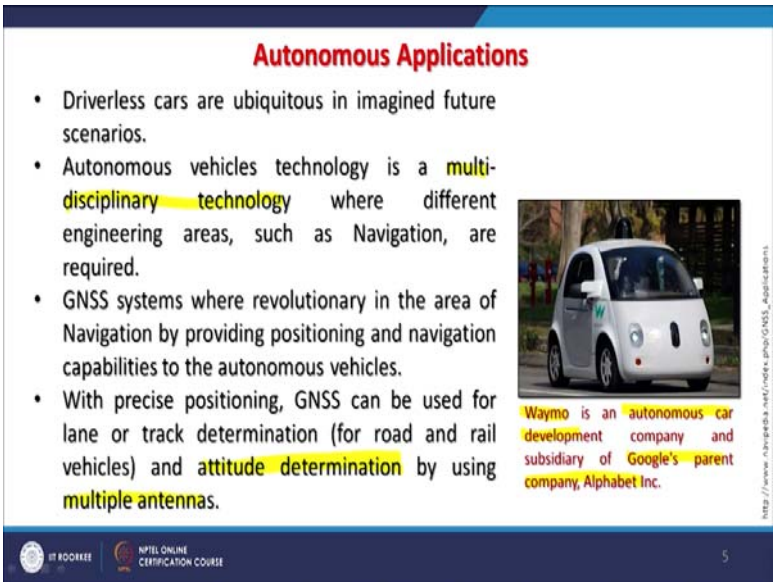

Autonomous applications; driverless cars has been I have already mention. This is what the most common application is going to be in near future that wherever the good road network is there and all everything is organized then autonomous car can be used like prototype cars, similar cars which are using these navigation device, GNSS and others have been developed like Waymo is one of the Google's product which is there on the street which is driverless and many more similar applications are being developed. So, autonomous vehicles technology is a multidisciplinary technology as we know where different engineering areas such as navigation are required.

GNSS systems were revolutionary in the area of navigation by providing positioning and navigation capabilities for autonomous vehicles. Near future, maybe in 4-5 year time, maybe not be we will be seeing these cars in India because of lot of traffic but where those parts of India or areas where less traffic is there. And, once these navigation autonomous car becomes reliable even in a crowded areas or where more traffic is there still these will be seen in future.

So, for this purpose definitely you one require a precise positioning GNSS system and in real time. So not even near real time but in real time because it's a moving vehicle. So, you require a precise positioning and that too in real time. And there are technologies currently even available to do this and this is possible. Vehicles have already been developed, they are being used but to a very limited extent currently.

And, then these options that which route has to be followed and these things, that information has also to go to the computer which would be inside these cars to decide the optimum route as per the passengers requirements. And of course, attitude determination because these are moving vehicles so, in which how they are moving and what rules and regulations have to be followed, every information have to go inside these autonomous cars. And there might be requirements of multiple antennas are there. That is why mentioned that it is a multidisciplinary technology which is being developed, being made a prudent and very soon we will be seeing very commonly such things also.

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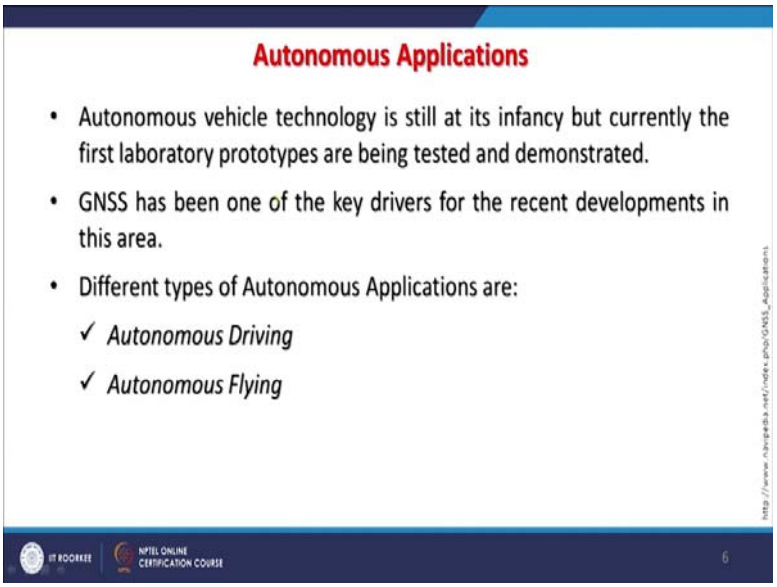

Autonomous vehicle technology still at infancy but currently the prototypes are being demonstrated, tested all over the world. And GNSS signals available from multi constellations are one of the key drivers, a key input for these recent developments in autonomous applications. There are different other autonomous applications like one which we have just discuss this autonomous driving. Another one is autonomous flying that is autonomous flying will add more complications.

Because this driving is on the flat surface or road or little uneven but when flying is involved that is really a 3 D. And a wind direction, wind speed, all kinds of information and these constraints, objects which are present are going to be there, but anyway. Once these technologies become more reliable especially the GNSS technologies then these things will also come in future.

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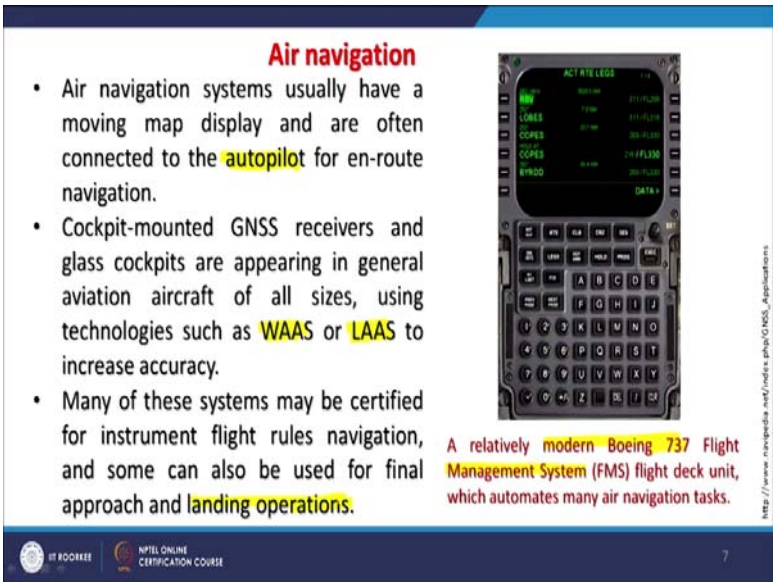

Air navigation which is already being there and nowadays in almost all modern aircrafts which are equipped with the GNSS receivers, they are using navigation systems and not only inside the cockpit but even for passengers; the position is plotted about where the aircraft is flying, what is the speed of the aircraft, over which country it is flying and so on so forth. So, all that information is also available and for air navigation, autopilot possibilities is also there that again is a multidisciplinary but one of the key inputs is the positioning. So, this is one of the inside view of part of this modern Boeing 737 flight management system is there.

And different parameters are displayed here, which can be controlled and aircraft after takeoff can be put on autopilot for long routes where not much disturbances are there from atmosphere or any other thing, these things can be employed. So, cockpit - mounted GNSS receivers and glass cockpits are appearing in almost in these general aviation aircraft of all sizes, using technologies such as WAAS; this Wide Area Augmentations Systems or Land Area Augmentations Systems to increase the accuracy.

Accuracy is the key and that too in real time because for such applications whether it is an autonomous application of vehicle movement or air, these 2 things are the key and development is coming in that direction already, systems are there. And many systems have to be certified which fulfilled all these navigation rules so that these can be employed, maybe for even landing operations such systems can be employed for that.

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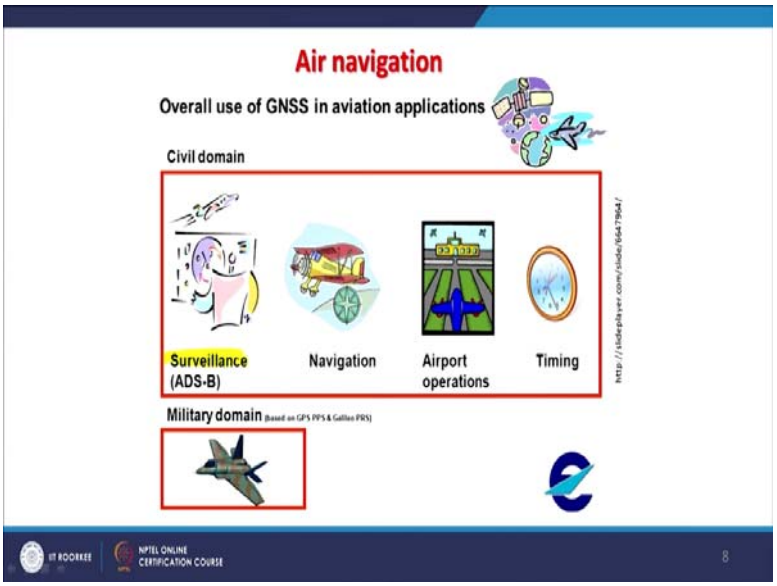

Air navigation in brief what we see that for surveillance, this is being used even in now drones are being employed which are having their own navigation systems and you can design everything, all sorties can be designed at what height, at what coordinates it should go there or stay there, what kind of track it will follow, all those things can be done, it is being done so, that also comes under this air navigation. Air navigation in case of your aircrafts is there and normal aircrafts, in airport operations also navigation systems are being employed.

Of course very important component GNSS because they are all having atomic clock; many constellations are having synchronize atomic clock systems are there which can use these accurate timings. And there are requirements of using accurate timings especially in air navigations and in military purposes. So, the timing is another parameter or data which comes through GNSS and of course, military domain is there we have already discuss some very briefly because many military applications are not in civilian world for our details.

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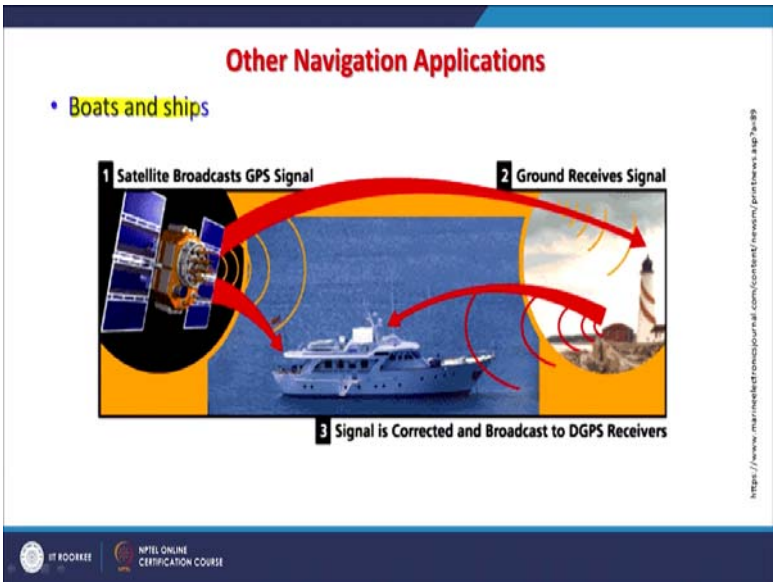

Now other navigation applications which are in water are boats and ships. Extensively they are using these GNSS systems whether it is a large ship or submarine or wherever but for submarines of course, under water sometimes it become difficult but there are ways they have invented to use the navigations there and some earlier as you can see here that these lighthouse here being used.

But now, the lighthouses are being not only used for the conventional purpose but they are also being used for ground receiving signals as well. And of course, the satellite based GNSS systems are there and finally these signals are corrected using this ground receiver signals and satellite based signals. And then DGNSS signals are transmitted through these lighthouses to the ship or boats for very accurate positioning. So that is a Ground Based you can say Augmentation System in coastal areas. One of the Indian system, which was developed like Gagan or in US the WAAS that was the main purpose to provide accurate navigation for boats and ships in the sea or in river systems.

There are lot of other applications are coming which are in this domain of a navigation like heavy equipments.

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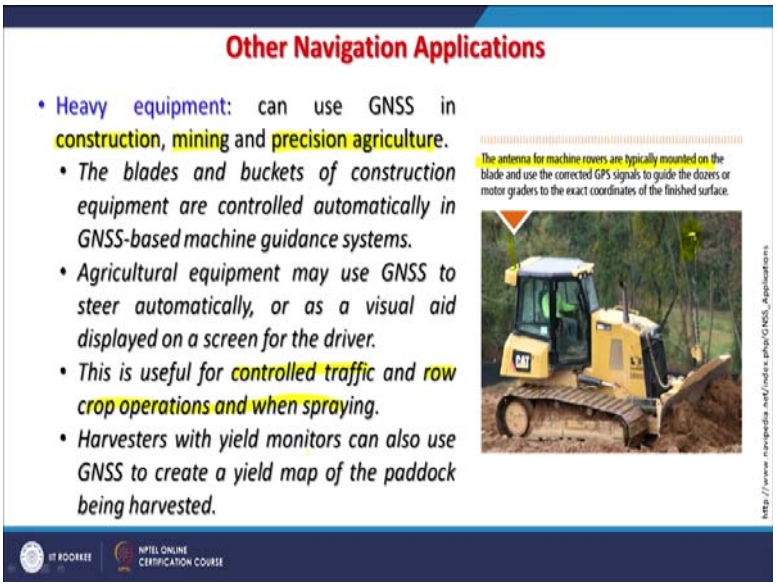

So, for heavy equipments also like here, the example is shown that antenna is there for this machine and that can be controlled. So, that exactly one knows that what kind of location at that location which is that machine is working. And for many other applications, these machines in future can also be programmed and so, that more accurate things can be done. There is heavy equipment which is used in constructions so which is using navigations systems, also in the mining, mining output and other things. And the precision agriculture that is for large farms where very precise irrigation is required or fertilizers are required to be put in the field or maybe harvesting time.

So for that, this precise agricultural is one of the areas where GNSS systems are being employed. There are like in constructions; the blades and buckets of construction equipments are controlled automatically in GNSS based machine guidance systems. So, that the optimum energy is used, optimum resource is used and output is much better. So, that machine should work very efficiently including the humans who are controlling these machines. So, if these navigation systems are employed then these things can become possible.

Agriculture equipment as I have said that precise agriculture may use GNSS to steer automatically as a visual aid displayed on a screen for the driver. This is also useful for control traffic and row crop operations and when spraying fertilizers or some insecticides and other things. Harvesters with yield monitoring can also be done through the GNSS.

For large farming, it has already been implemented so that we know that which parts of farm have more output or harvest is coming from which part is less so that a farmer can later on analyze that what deficiency was there at that particular location where less harvester has come. So, this is what all comes under precise agriculture and it is being employed in large farms.

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There are other applications of GNSS; maybe in leaser, maybe in sports. One of the applications like here the cyclist have started using when they go for areas which are unknown, they can use these navigation systems or maybe in some cycle racings also.

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Hikers can use like because sometimes you may lose the track if you are in a dense forest or in some barren areas so hikers are also employing.

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Climbers are also using.

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And then pedestrians are also using navigation systems for different kind of purposes.

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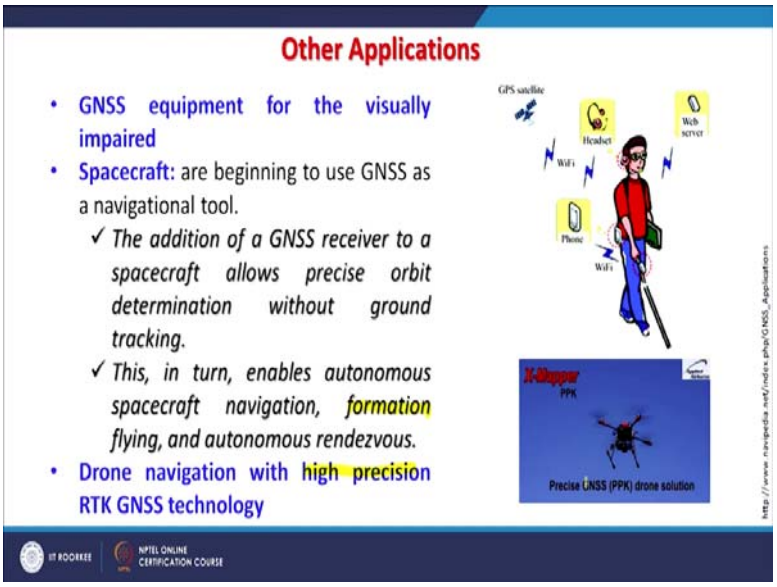

And there are some other applications like equipment for visually impaired or blind people that also are being used. So, that they can get the correct navigation signals, can move and have a normal life. So, lot of a development is also taking place in this area for physically challenged people, especially visually impaired people. Spacecraft say normal now to use the GNSS for navigation.

Addition to GNSS receiver, spacecraft allows precise orbit determination without ground tracking. Especially in the Atlantic oceans and other water bodies, when aircrafts are flying you do not have the Ground Stations to support the navigation or location, then GNSS receivers becomes very handy and that is why all now modern aircrafts are equipped with this kind of facilities.

And in turn, which enables autonomous aircraft navigation that is autopilot mode and formation flying, autonomous rendezvous and so on that is all becoming possible through these GNSS systems. Drone navigation which I touched earlier little bit and drone are becoming now very common for various kind of surveying, applications in emergency services and so on so forth.

So, drones are also using navigation facilities or equipment or this GNSS technology so that they can be sent to a precise location and can deliver the things or can take a photograph or video graphs and can transmit that information to a controlled station or can record while flying and then come back and recordings can be retrieve. And for that Real Time Kinematics GNSS technology is being employed, depends on for what purpose the drones are being used.

But you require generally a very high precise this GNSS technology for a drone navigation but this is becoming very-2 common nowadays for drone to use this navigation technology even military have started extensively using these drones with very high precision GNSS technology.

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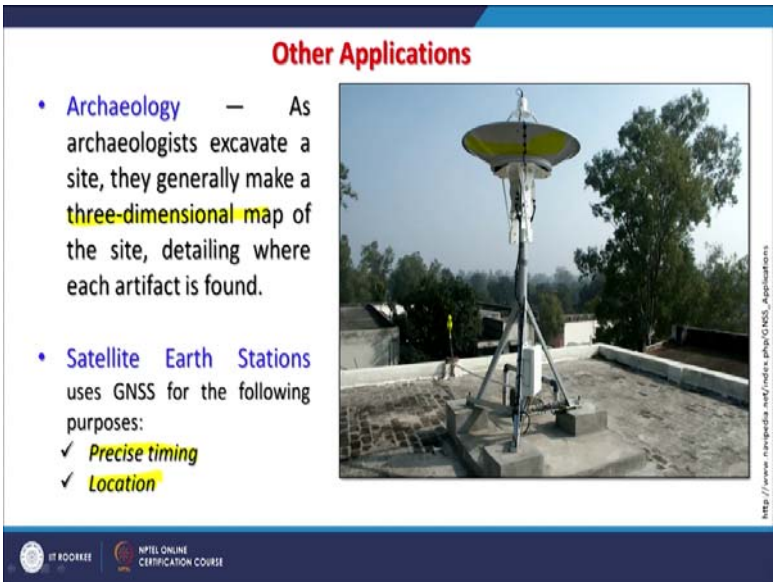

There are some other applications like in archaeology; for archaeologist excavation, they not only for finding a new site but when these things say the site has been identified, how to map a creative 3 dimensional map. And other thing details where artifacts have found and their exact very precise location. So for that purpose archaeology or archaeologist have started using GNSS also.

One of the examples which I will now narrate here is about how in satellite earth stations, a GNSS technology can be used. There are two purposes here and since 2002 myself have been operating this NOAA HRPT satellite earth station in our department that is department of earth sciences IIT Roorkee. And our satellite earth station is equipped with a GPS antenna or now you can say GNSS antenna for two purposes; one is precise timing, another one is the location of the earth station. So, this is the outside view of course, the larger antenna which you see here parabolic is mainly to receive the signals from NOAA series of satellites.

But there is a small antenna which you can see here which is a GPS antenna or GNSS antenna so, the purpose of this antenna to provide the precise timing to the system which is a controlling system which is inside in lab. Because as you know that the desktop computers for clock, they are having some backup battery, after sometime may be 5 years, 6 years time the battery becomes weak and then timing of your system may become slow and in that case, how to keep very accurate timing of the system because

very precise timing is required whenever they are over passes of saying this particular example NOAA satellites.

Then the system must know that when that satellite will be coming and that is through the orbital parameters that are determined. If system clock is off by say 2-3 minutes then when satellite will come then antenna will be looking in different direction and satellite will be going in different directions because these are the automated data acquisition system. So, they work in day time and night time so not every time somebody is sitting and it is not possible when the satellites are flying at about 850 kilometer away from earth station to CN track.

So, this works on a prediction system but the key component in the prediction software or system is that the time has to be very precise and that is fed through this GPS and updated that GPS, at every 10 seconds it checks the system clock and if there is some deviation in supersedes. And another one is of course, the location because the location is very important to know that which satellite will come in the range of this antenna. So, for these two purposes also, this is other kind of applications or GNS systems which have been implemented long back since 2002, we have been using such things for operating a satellite earth station.

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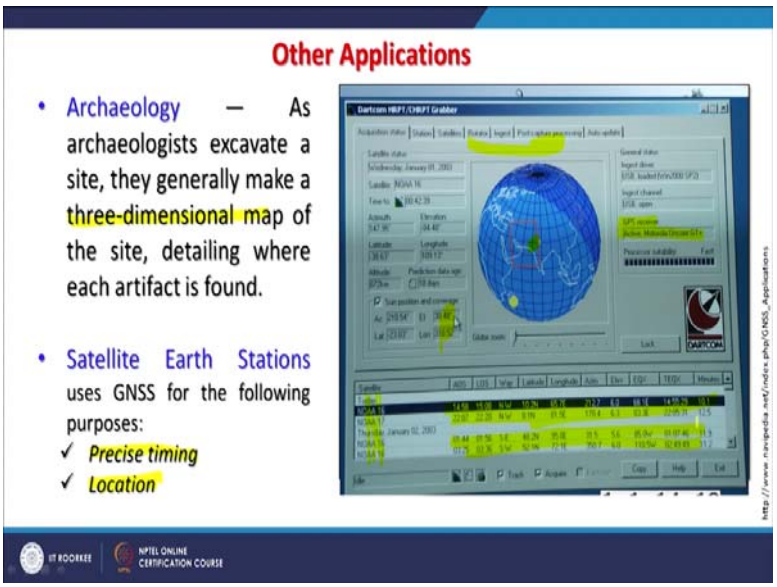

This is what you see that GPS receiver and when you change the system time, in few seconds time it will update or when system time get slow, it can be again updated so, this

is how things works. So, it is very important not only for timing but for the location because location here like in this screenshot that is location is coming through the GPS antenna that is showing location of the antenna. So, based on this prediction which you are seeing here, one week prediction for different types of satellites coming and their overpasses time; how much time they will stay in the range of antenna, every information is being estimated through these 2 key parameter that is precise timing and location.

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In marketing nowadays lot of people have started applying these GNSS systems for market research companies are also using these systems along with the GIS to decide where to open new branches and using GIS, they also use the source economic data, requirement of the people may be based on certain surveys and so on. But the location becomes very important and location information is nowadays being collected through GNSS system. Also the target advertising accordingly based on the patterns of the road. And I have already mentioned the socio-demographic attributes or data within the residential zones. So in marketing also, people have started using extensively these GNSS.

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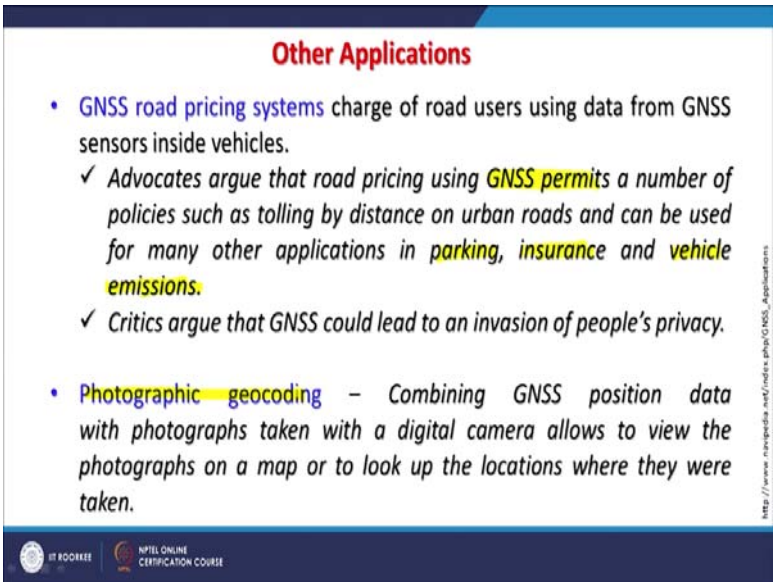

A road pricing systems that is the toll; how much toll is required and how much one has used the toll road and future that may be decided based on GNSS. So whenever you enter, there is some code has been fed and when you exit from a toll road, that is also checked and then how much distance you have been in the toll road can be calculated and accordingly it can be charged to the users.

So, there are such applications also and road pricing can be based on the GNSS systems. So, it requires definitely lot of other works to do before we go. Maybe applications in parking, maybe few applications in insurance, vehicle emissions and so on so forth, these will come. Now some critics argue that GNSS could lead to an invasion of people privacy; some people are always having this kind of view that my location should not be revealed. And therefore, they feel that is a breach of individuals privacy but that is different discussion altogether.

Photographic geocoding is one of the again common even if using a smart mobile and GNSS system, this can be done very easily. There are apps when you install and use the camera, recoding is done automatically. So, once when you use these photographs on GIS platform then the location of these photographs is directly attached instead manually it is fed to the system. So, combining GNSS position data with photographs taken with the digital camera which is most common now is allows viewing the photographs on a map or looking up at the location where they were taken.

This photographic geocoding is very-2 useful in many kind of service including in geological service or facility management or you know building service for various purposes. So that the photograph is having geographic coordinates and then the location specific information is there along with the photographs. So, that becomes a very-2 useful application of this.

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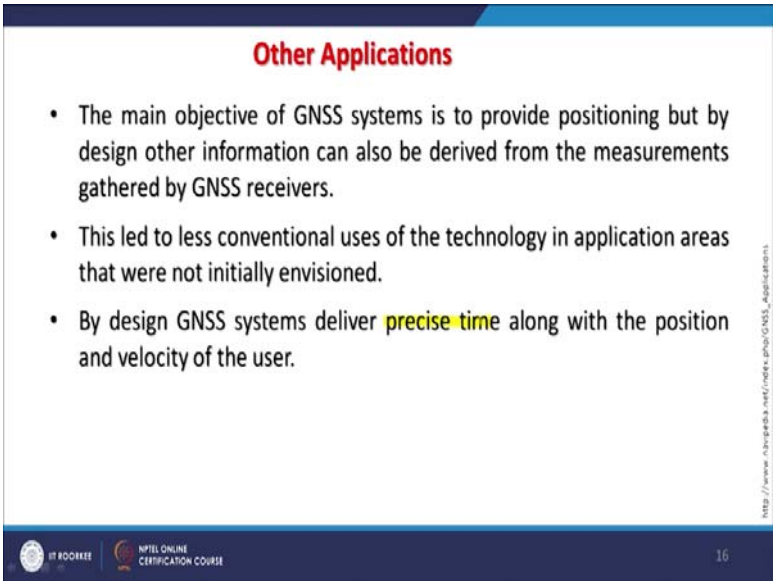

So, as you know that the main objective of GNSS system is to provide positioning but by design other information can also be derived from measurements gathered by GNSS receivers. And basically this has led to less conventional uses of technology in application areas that we are not initially envisioned. When these systems were developed, people did not think at that time that one day we will be having autonomous vehicles or people will be implying GNSS in precise agriculture and other things.

So, a technology when it is developed of course, the main purpose at that time in the beginning was military but now we know that in various domains of our lives, GNSS systems have already intruded and are being used directly or indirectly by many of us, whoever are even using a smart mobile definitely they are using these systems because they deliver not only the position but GNSS systems also deliver the precise time along with the velocity of the user and that is also of course, coming through the positioning and time so that is also there.

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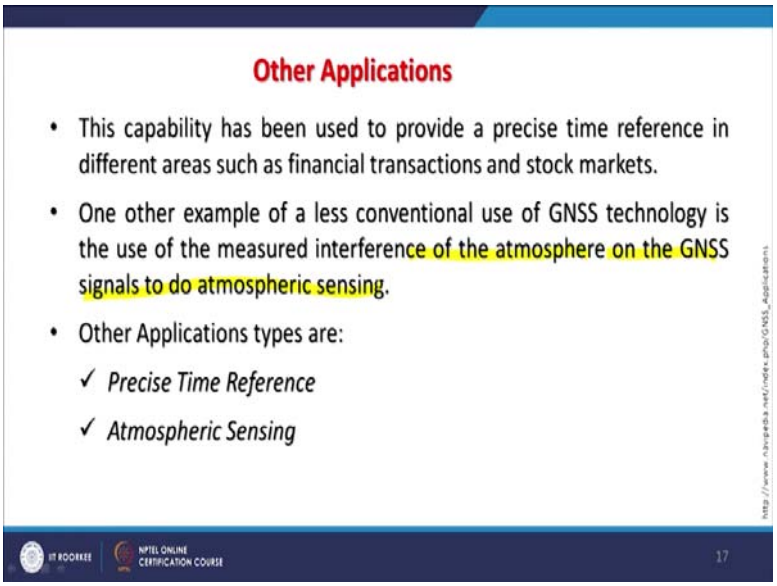

In other applications the capability has been used to provide a precise time reference in different areas such as financial transactions and stock markets. You know that because of stock market, one country influences the other one and therefore precise timing matters and if everyone is using these GNSS timings and they are synchronized then lot of problems related with this stock markets can be solved and it is being done so these are the some other applications where GNSS timings are being used.

And some other less conventional use of GNSS technology is to use the major interference of the atmosphere on the GNSS signals to do atmospheric sensing. This I have already mentioned earlier also that when GNSS signals pass through these ionospheric and tropospheric layers, they are delays. Some can be modeled easily, some cannot be modeled easily because the nature is very dynamic. So, for atmospheric sensing these signals are being used.

And of course, other applications type; the Precise Time Reference that is there, Atmospheric Sensing is there and this brings to the end of both application part 1 and 2. As this technology is still under development and I hope that it will be keep developing. So, what we will be having more precise location, we will be having more precise timing and highly reliable services and in real time lot of precise applications can rely on GNSS technologies. And once these becomes more reliable and prudent, more applications will be innovated, more applications will come and even in our normal day to day life, we

will be using such facilities or such technologies to improve our lives. So, thank you very much. I am again leaving with a cartoon for you to smile.

Thank you very much.