Global Navigation Satellite Systems and Applications

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Lecture - 13
Satellite Based Augmentation System (SBAS)

Hello everyone and welcome to new lecture on Satellite Based Augmentation System of Global Navigation Satellite Systems and Applications course. And in this, we are going to discuss how the augmentation that means ultimately how accuracy can be improved by employing a satellite which is generally a geostationary satellite to increase the accuracy rather than having you know, typical arrangement like in DGNSS as we have discussed in earlier lecture.

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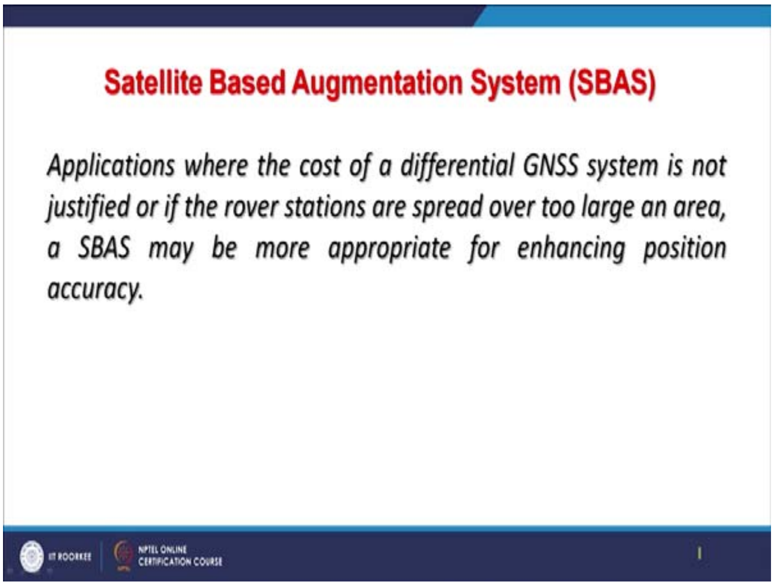

So, in those applications where the cost of a differential GNSS system is not justified or it is very expensive and if rover stations are spread over a large area then SBAS may be a more appropriate for enhancing position accuracy. That means, that if we have to get the high accurate data using a single unit that is only the rover and we want that in the entire country or at a continental scale, these differential signals should also be available then this is the best technique which is becoming available now.

So, even if our smart mobiles are capable of, you know getting data from these SBAS techniques and also they are having the algorithms to incorporate those error signals and if it is possible which is becoming possible then our accuracy will improve say from 3 meter to few centimetres and this is what SBAS is indicating.

Now, this SBAS as I mentioned that every time it is not easy for everyone to have a differential GNSS system in which a lot of arrangements are required and equipment's are, you know these receivers are also expensive plus do not get accuracy estimates or position estimates in the field generally then through post processing you achieve better results.

So, that can also be avoided if SBAS becomes a reality and second thing is of course, the accuracy. So, there are many applications and the most upcoming application is automated vehicles where driverless vehicles are being developed and in such applications definitely we require very high accuracy, also in some constructions and construction industry where this GNSS are being implemented.

Maybe for large field agriculture, again such applications are required and high accurate positioning data is also required and that can be achieved by SBAS. So, let us go in the detail about this.

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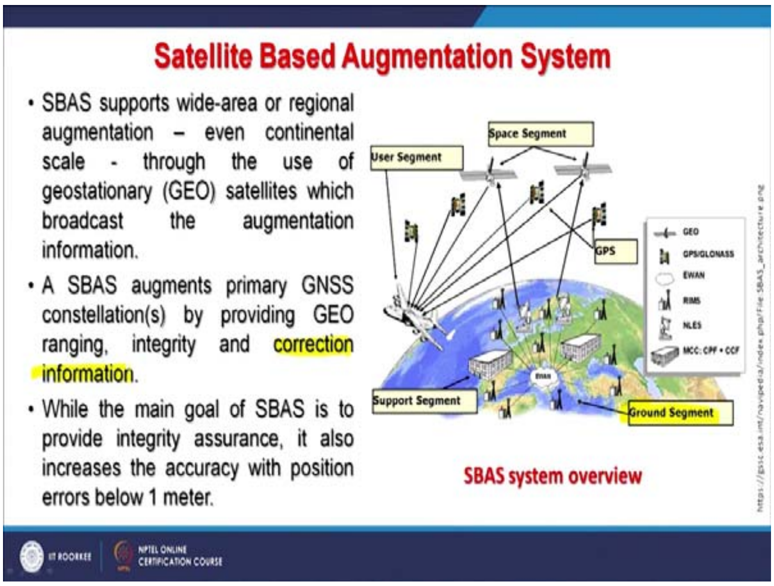

When we go in this as mentioned that it can be achieved by geostationary satellites which basically broadcast the augmentation information. How they broadcast the augmentation system because on the ground, we will have many base stations which are receiving signals from many GNSS networks and then they will broadcast the errors to the geostationary satellite which might be focusing over a country or a continent like for India.

If we are having several such ground stations in case of SBAS and these stations are receiving signals from various GNSS systems maybe like GPS, NAVIC, BeiDou and GLONASS and using these signals at certain fixed locations where we are having a highly accurate positioning then errors can be estimated and these errors can be transmitted back to the geostationary satellite and these geostationary satellite will again transmit back to India.

Because the footprint of these satellites are generally very large like in case of some geostationary satellites of India like INSAT-1D or 3D and other series.These geostationary satellites not only covers the entire India but Indian subcontinent. So, in the neighbouring countries are also covered; it is a kind of, you can imagine a disk say which large disk. So, anywhere if somebody is having appropriate receiver which is capable of receiving signals from SBAS or means from these geostationary satellites and that application or software in built or inside in that receiver.

If it can remove the error part then our accuracy improves immediately in real time. So, generally if you are having good signals from various GNSS systems say when you are using a smart mobile then maximum accuracy which we get is or GDOP we get about 3 meter but if we imply this SBAS then it is highly likely that we will get the position accuracy within 10-20 centimetre. So, that is the biggest advantage and individuals do not have to have their own system like a base station and other things. So, the data to the geostationary satellite will be supplied by various base stations to a single satellite and then that satellite will transmit back.

So, this is the concept behind the SBAS. Now SBAS segments basically primary GNSS constellations by providing GEO ranging because these are the geostationary satellites as you know that these satellites are in a space somewhere around 36,000 kilometres away from the surface of the earth and their footprint is very large. And so, these augmentation basically provided by these GNSS constellations is a GEO ranging, data integrity and correction information. And what we are interested most here is the correction information.

So, that we can improve the position estimation using even a single receiver and while main goal of SBAS is to provide integrity assurance, it is also increases the accuracy and position error below 1 meter. As I have been mentioning that a normal operation when we are using multiple GNSS without differential, without RTK (Refer Time: 7:51) or any other concept then maximum accuracy we get around 3 meter. But using SBAS concept, we will be able to get the accuracy less than 1 meter or a few centimetres.

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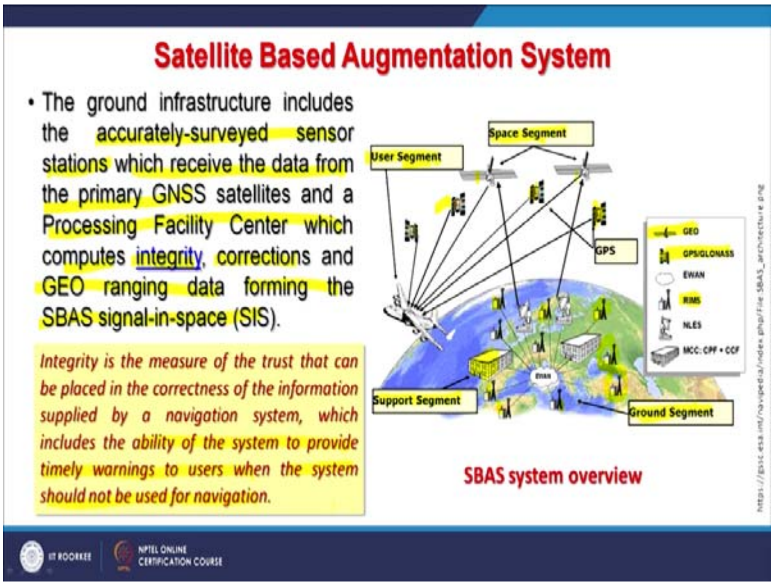

So, we are having ground stations; there will be various ground stations which are shown here as you can see and these can transmit the data. There will be a support segment. There will be of course, user segment and space segment in which you are having geostationary satellites. So, these geostationary satellite as shown in this schematic tool and there are other GNSS systems in here; they are shown as GPS or GLONASS and then you are having a central processing unit and these you know, base stations are also there and further processing units are there. So, that makes the SBAS system.

Now, as shown through this schematic or a diagram that this infrastructure for SBAS includes accurately surveyed sensor stations. These are the stations which are accurately surveyed and they become basically base stations which receives the data from primary GNSS satellites, maybe from GPS, GLONASS, BeiDou, IRNSS or NAVIC and processing facilities centres; they collect this data, computes integrity, computes corrections that means comparing with the average position value of each stations and then finding the corrections and then GEO ranging data which is coming from these satellites.

Basically, the geostationary satellite forming the SBAS Signal In Space that is SIS. So, this will make our standalone receivers much more accurate compared to this conventional differential technique. And here the integrity word, I would like to further discuss on this that the integrity is the measure of the trust that can be placed in the correctness of the information supplied by the navigation system. And this integrity also includes ability of the system to provide timely warnings to users when the system should not be used for navigation.

So, there will be information that currently there is a corrections data and other data is not available and therefore the system should be used knowing that it is not very accurate but it is just for there but once a complete set up is ready, this integrity issue will not be very common; it would be definitely going to be rare. Because the best advantage with geostationary satellites that they are very stable platform relatively compared to other orbital objects or satellites and therefore in the issue of integrity are going to be less.

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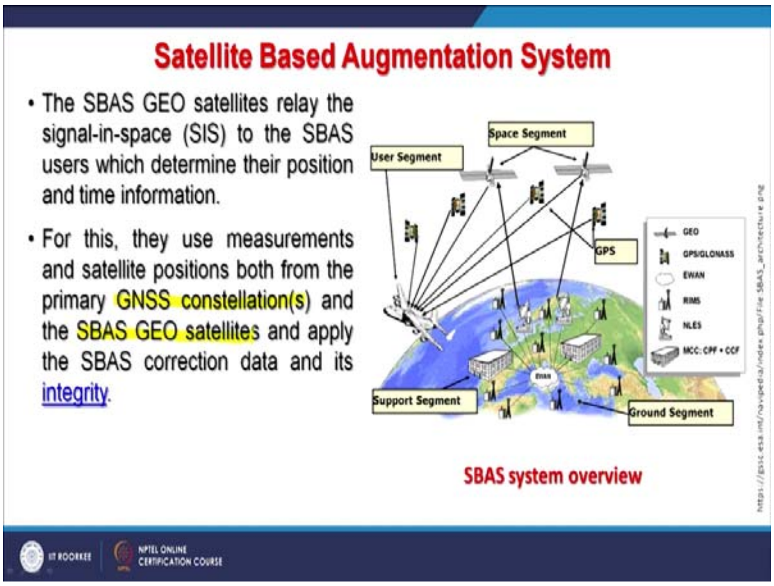

Now this SBAS GEO or geostationary satellites basically relay the signal in a space that is SIS to the SBAS users; an SBAS user as I have mentioned that even a smart mobile if capable of processing the errors data then that can also be used and which determine their position and time information.

Currently at least I have not seen any mobile which is capable of calculating or estimating position using SBAS data as well and giving a 20 centimetre accuracy but there are separate systems by established companies which are demonstrating through their own signals for correction signals, not exactly. The fully SBAS operational at least over India is not yet available but this is definitely under construction and very soon it is going to be implemented. And for this, they use the measurement and satellite positions both from primary GNSS constellations and SBAS GEO satellite; that means that SBAS is not independent of these GNSS constellations.

It is exploiting the convention one or the primary GNSS systems and adding these error signals. So, we can make more accurate position estimations by employing a satellite instead of Ground Based Augmentation System. So, as you can understand that the advantage with the Space Based Augmentation System is that the error correction signals can be made available to a continental scale rather than for a very small area and there in conventional DGNSS or RTK, the baseline or length of baseline is also a problem. But here that is not going to be a problem at all. So, that is real future for very accurate positioning information.

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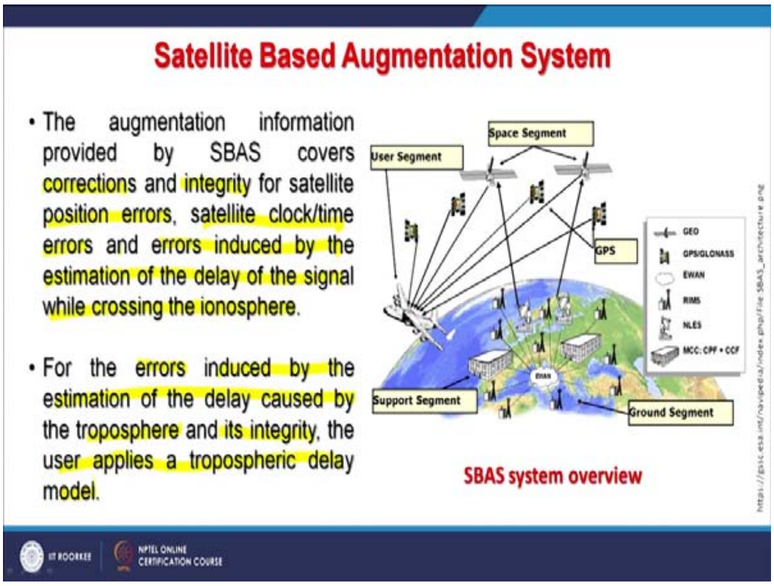

The augmentation information which will be provided by SBAS will cover the corrections as I have already mentioned, an integrity of the satellite position errors, satellite clock time errors that is very-2 important because that is the basis of getting position and errors induced by the estimation of the delay of signals by crossing the ionosphere. So, these ionospheric delays; that information will also be carried by SBAS signals which will be used by the software within these receivers and high position estimations can be achieved.

And for the errors induced by this estimation of delay caused by the troposphere and its integrity, the user applies a tropospheric delay to the model to get more accurate information.

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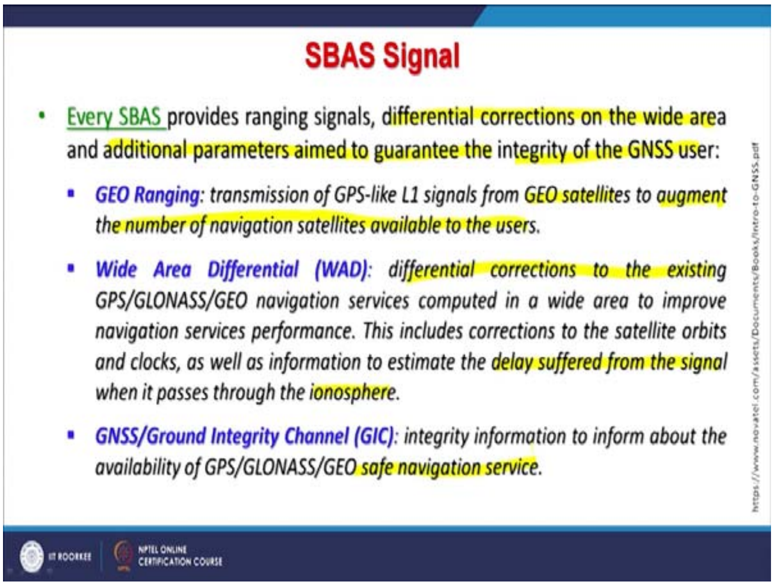

So, every SBAS provides ranging signals as GEO ranging you know so, because they are geostationary satellites. So, every SBAS provides ranging signals, differential corrections on wide area; wide area means at continental scale, it will cover a not only entire India but a surrounding countries and additional parameters aim to guarantee the integrity of the GNSS users which are these signals: the GEO ranging that is the transmission of GPS-like L1 signals, GPS or GLONASS or BeiDou or IRNSS from these geostationary satellites, basically to augment the number of navigation satellites available to the users.

So, these GEO ranging will be available. The signals will carry the 3 types of information: one is GEO ranging, second one is Wide Area Differential; for a large area this differential information would be available to make your position estimates more accurate. So, thus the differential corrections to the existing GPS, GLONASS, GEO navigation services computed in a wide area to improve navigation services performance and this will include corrections to satellite orbits and clocks as well as information to estimate delays suffered from signal when it passes through the ionosphere.

So, these ionospheric delays information will also be carried by SBAS signals. And the last one which will be carried by SBAS signals or being carried is the GNSS Ground Integrity Channel that is GIC; the integrity information to inform about the availability of GPS, GLONASS, BeiDou, IRNSS (NAVIC), GEO safe navigation service whether it is safe or not, currently it is providing better accuracy or not that information will also be available through SBAS.

Now, reference stations; how these reference stations will be established which are geographically distributed as you have also seen in the previous diagram.

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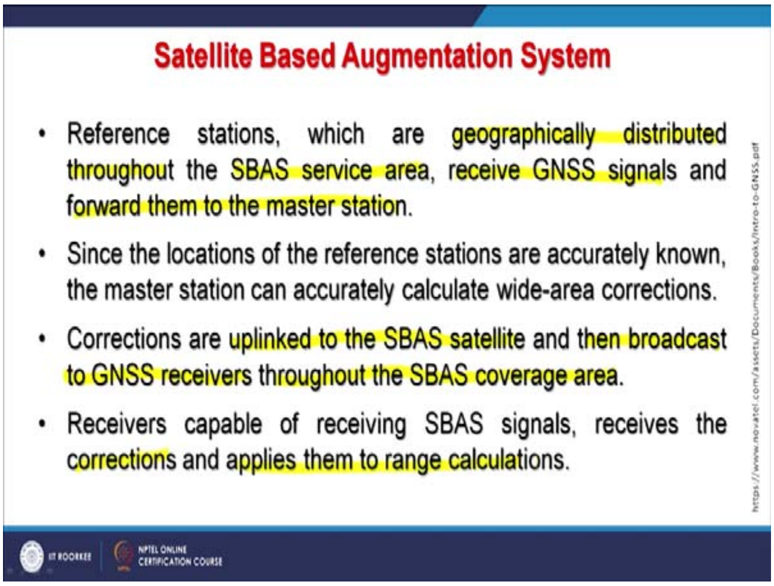

So, over India there might be 10-20 such reference stations which will be providing service to this SBAS or geostationary satellite which will receive signals from GNSS systems like GPS, BeiDou and GLONASS. And then forward them to a master station for further processing. And this master station not only further process and will provide the accuracy estimates but also it will transmit this error data to the geostationary satellites so that it can back transfer the data to the users.

So, since the location of these reference stations are accurately known, the master station can accurately calculate wide-area corrections and this is how it is going to work. So, when these reference station will be established or are being established, their positions is very accurately being measured and once that is there then comparisons can be done with the current data and through that average value and then you get the error. So, how much error are being phased currently and that information will go to the geostationary satellite only to transmit back to the users. And the corrections are up linked to the SBAS geostationary satellite then broadcasted back to the GNSS receivers throughout the SBAS coverage area.

So, entire continent will have the benefits of SBAS and the receivers capable of receiving SBAS signals receives the corrections and applies them to range calculations. Now we will have an overview of some of the SBAS services which are being implemented or have already been implemented all over the world.

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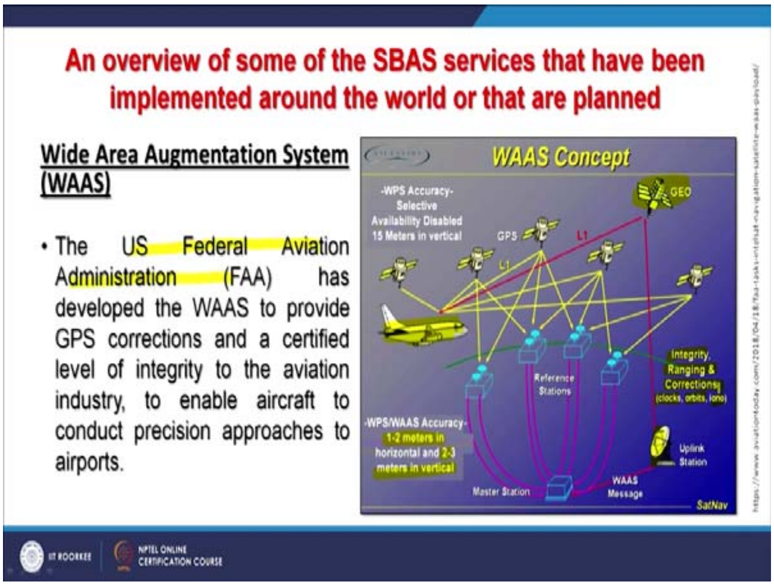

Including, we will also discuss the SBAS services of India and some upcoming SBAS services. So, this Wide Area Augmentation System that is WAAS, it has been implemented by the US Federal Aviation Administration (FAA) which developed this one and the concept wise or component wise is same that you are having reference stations.

Those reference stations are receiving signals from GNSS navigation systems and then error is being estimated and this error is getting transmitted back to the geostationary satellite as shown here and then these geostationary satellites are also providing signals to the users; the user might be a flying aircraft or may be a vehicle or any other object or any other receiver which is installed or handheld by the human. So, this WAAS; Wide Area Augmentation System has already been implemented which is quite accurate and this WAAS provides 1 to 2 meter horizontal and 2 to 3 meter vertical accuracy, also it provides the information about integrity, ranging and corrections.

So, clock orbits and ionospheric delays, all those information are up linked first to the geostationary satellite and then get transmitted back to the users or receivers.

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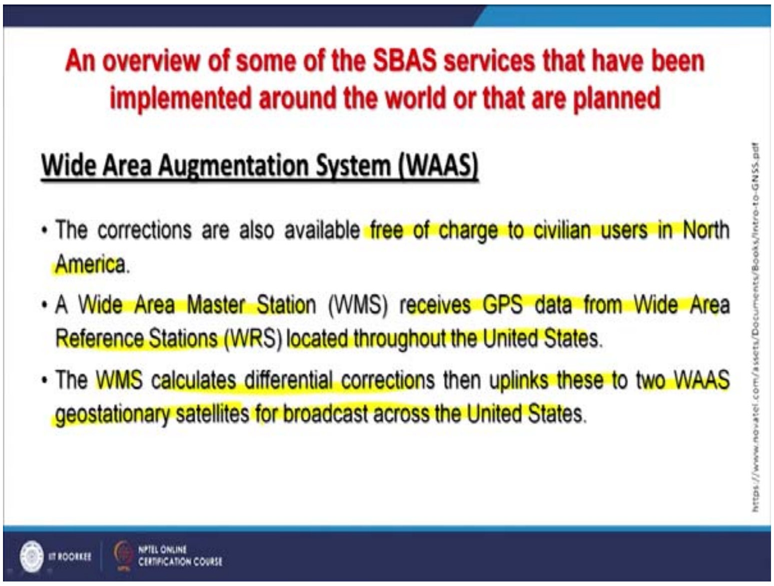

Now this WAAS system; the corrections are also available free of charge to civilian users in North America because some private companies, though they are providing these corrections but they are charging money. It is subscription based or if you buy a particular company receiver then the service provided by that company might be free or might be included in the cost.

So, that kind of situation is there but if it is developed by a country or a federal agency then free of charge service all these corrections can be provided as being done in US. Now there are other segments or parts of this; that Wide Area Master Station receives the GPS data from Wide Area Reference Stations located throughout the United States because this WAAS is mainly focused for US. So, it has been planned or established like this and these Wide Area Master Stations basically calculates the differential corrections then uplink to two WAAS geostationary satellite because US being a large country.

So, just one geostationary satellite may not cover the entire country. So, they are employing two WAAS geostationary satellites. Also every country is also trying not only to cover their country even if it is large but surroundings as well. So, it is very useful for some military or strategic purposes and then that corrections are broadcasted back to the users of United States.

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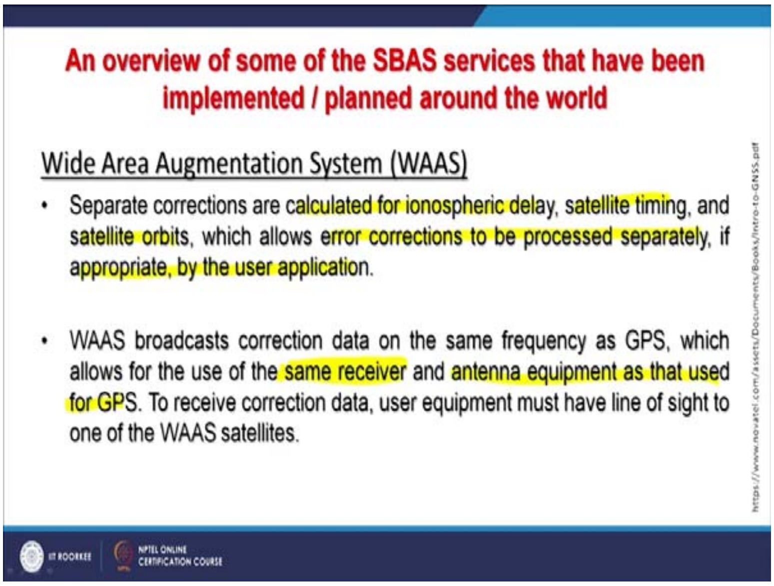

Now in this WAAS; wide area network of US that separate corrections are calculated for ionospheric delay, satellite timing and satellite orbits and which allows error corrections to be processed separately if appropriate by the user applications.

So, if one needs more then it is possible. And these WAAS also broadcast correction data on the same frequency as GPS which allows for use of the same receiver. So, you need not to have some special receiver or separate receiver because the frequency is the same. So, that is another advantage with that; an antenna equipment that used for GPS. So, the same receiver can also receive signals or WAAS and can calculate better position estimations, can incorporate the correction data and then information can be provided to the user.

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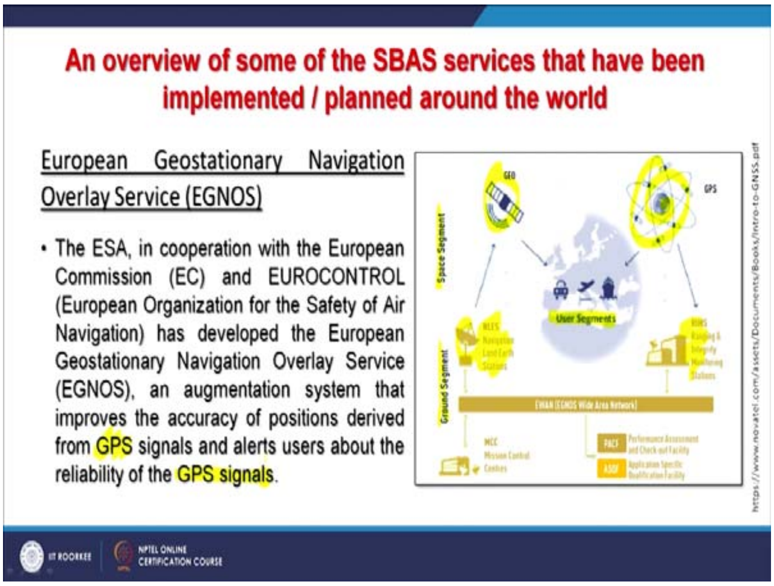

Now let us look another system which is being developed by European agency that is called EGNOS. Europe is already having their GNSS system that is your GALILEO but employing the SBAS, Satellite Based Augmentation System will definitely improve the accuracy.

So, they have already implemented EGNOS. EGNOS also will have the same architect or same arrangements; same type of segments that you are having a space segment and in two parts; one is the conventional you know GNSS constellations then geo geostationary satellites then you are having a ground stations and then you are of course, having user. So, a space segment is here then ground segment is here and then user segments are there. So, they are providing all that information to the corrections to the geostationary satellite and geostationary satellite is broadcasting back to the users.

So, European Space Agency in cooperation with the European commission that is EC and EUROCONTROL that is European Organisation for Safety of Air Navigation because these SBAS signals are also being used by the aviation industry for accurate landing and navigation. So, that is why they are also partner to that, has developed the European Geostationary Navigation Overlay Service which is called EGNOS, an augmentation system that improves the accuracy of positions derived from GPS signals or any GNSS systems like GALILEO or GLONASS, BeiDou because these are also global.

So, these signals from these GNSS systems are also available for Europe. So, not only GPS but other GNSS systems and alert users about the reliability of the GPS signal. So, once when you are using and if the EGNOS signals are also being received then your position estimations will become much more accurate.

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So, European EGNOS has the three satellites being used, it has to cover a large continent. So, it is having three geostationary satellites which cover all members of European nations and several other countries in Europe. And EGNOS transmits differential corrections data for public use and has been certified for safety-of-life applications. So in case of any disaster or even simple car navigation or for aircraft navigation, this EGNOS can also be used only in Europe and EGNOS satellites have also been placed over the eastern Atlantic Ocean, the Indian Ocean and the African mid-continent.

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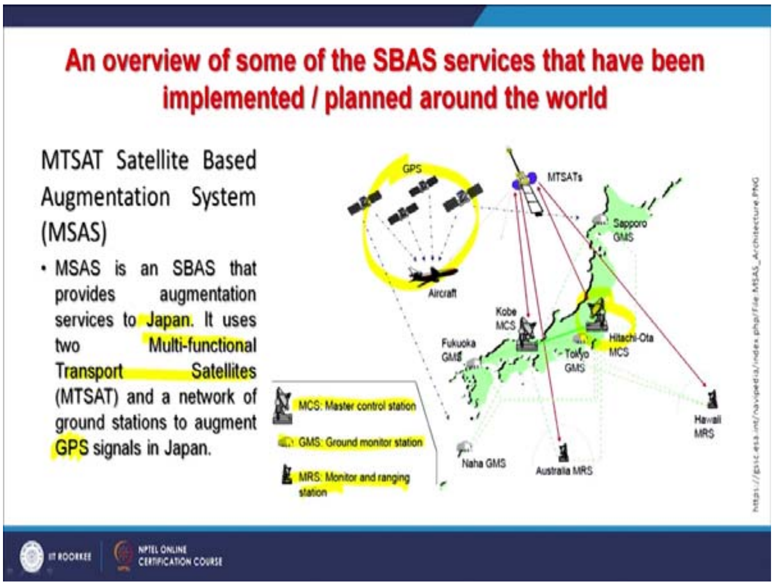

So, it covers a very large area. And then there is another system which is called MTSAT that is Satellite Based Augmentation System or MSAS. And that is also there which has been developed by Japan. Though Japan is having relatively small geographic area but nonetheless they too have developed this augmentation system which is called MSAS. And again you are having a Control Station, same way you will have a Space Segment, you would have Ground Segments, Control Segments and then you are having User Segment as well.

So, then you are having Ground Monitoring Stations and then monitoring and ranging. So, the overall concept of all these augmentation systems whether it is a WAAS or EGNOS or MTSAT or MSAS, they are have same concept except geographically they are located at different part of the world.

So, MSAS is an again SBAS system that provides augmentation services to Japan. It uses 2 Multifunctional Transport Satellite, MTSAT. And a network of Ground Stations to augment GPS signals in Japan. So, it is not only GPS as I have been mentioning in case of EGNOS of European, that many other constellations can also be used to get better position estimations.

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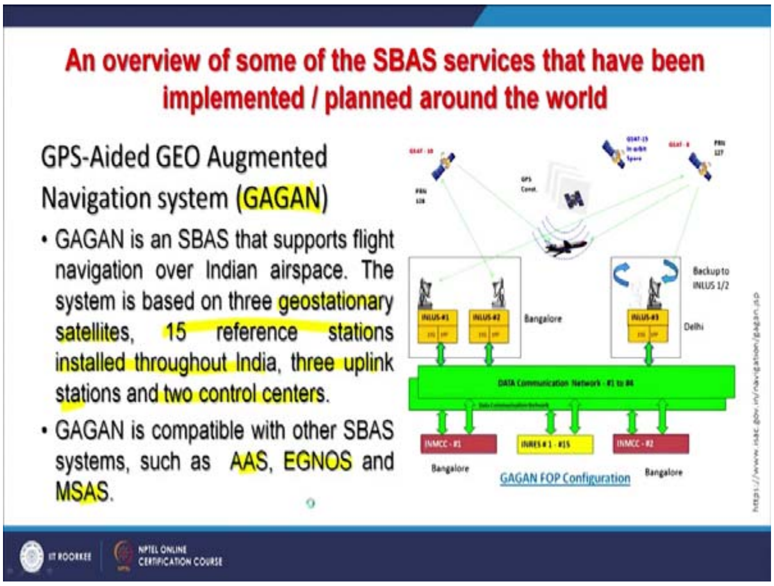

Now, let us come to our own system which is GAGAN which is GPS-Aided because when we did not have our own IRNSS or NAVIC system and at that time, other systems were not available. The same time India also developed a GPS aided Geo Augmentation Navigation System which is called GAGAN and this is again a GPS based. So, GAGAN is an SBAS again that supports flight navigation over Indian airspace. The system is based on three geostationary satellites and 15 Reference Stations installed throughout the India, 3 Up-Link Stations and 2 Control Stations.

So, GAGAN is there which is in SBAS category and there are three geo stationary satellites are being employed for these correction signals and of course, there are 15 Reference Stations spread all over the India and 3 Up-Link Stations and 2 Control Centres. So, likewise this GAGAN signals can also be received. The only problem is that the receivers which we are using are whether capable of receiving signals from these SBAS systems or not, that is the mainly main point. If they are not receiving signals then no matter whether SBAS exist for a country or in a continent, we will not be able to use it.

So, GAGAN is compatible with the other SBAS systems such as WAAS, EGNOS and MSAS system because otherwise concept is same except geographically located at different places.

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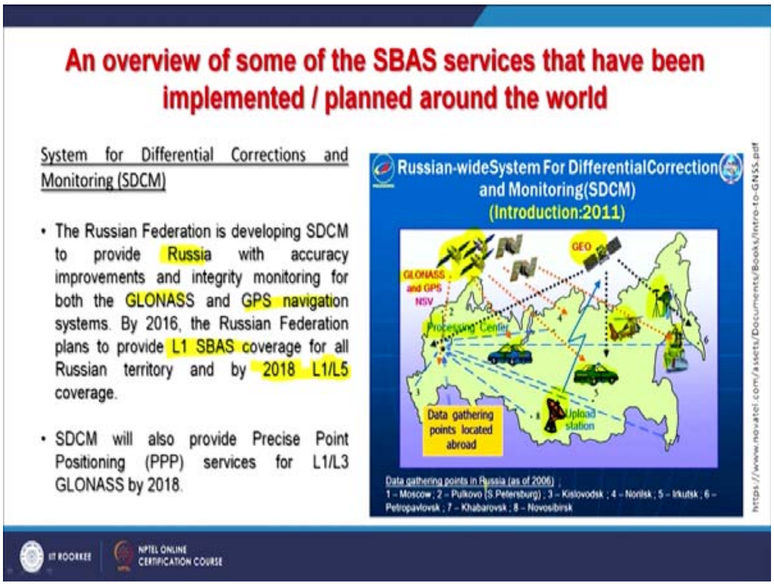

And some other systems are there like a System for Differential Corrections and Monitoring that is SDCM and that is Russian system, they have developed. So, it provides the accuracy improvements and integrity monitoring of with both GLONASS and GPS navigation systems. So, in 2016 they have developed and the transmission of this SDCM is also in the L1 frequency. So, it is compatible with other signals and hope they have also started transmitting in L5 as well.

So, this is again architecture of this SDCM of Russia where segment are same; you are having a Space Segment geostationary satellite, some other GNSS system like GLONASS and GPS. And you are having then Control Stations, Up-Link Stations, Processing Centre and then Users are there for standalone or for air navigation, car navigation or ship navigation, there it can be used. So, they are having 8 Reference Stations all over the Russia which is Moscow, Pulkova and Kislovodsk, Norilsk and Irkutsk and other places. SDCM will also provide Precise Point Positioning that is PPP mode and which will be broadcasted in the L1 and L3 frequency.

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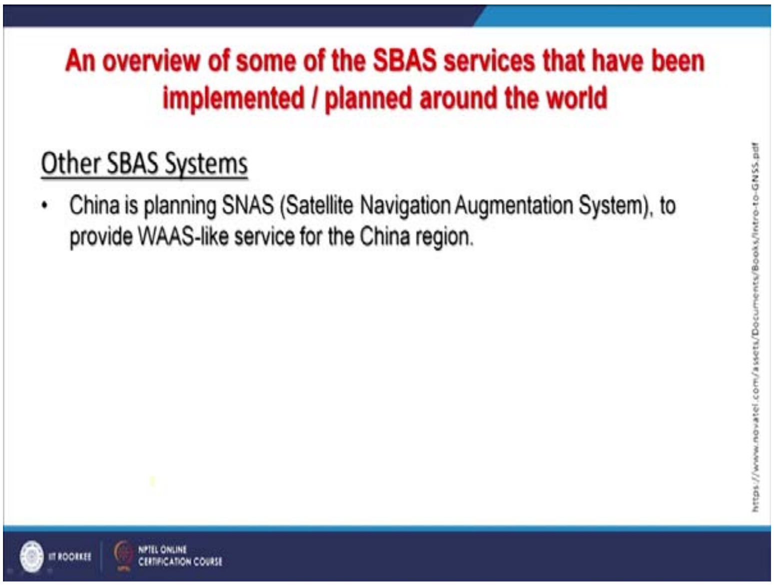

Some other SBAS systems are also there. China is also planning the SBAS system which is going to be called as SNAS that is Satellite Navigation Augmentations System to provide WAAS like service for the Chinese region.

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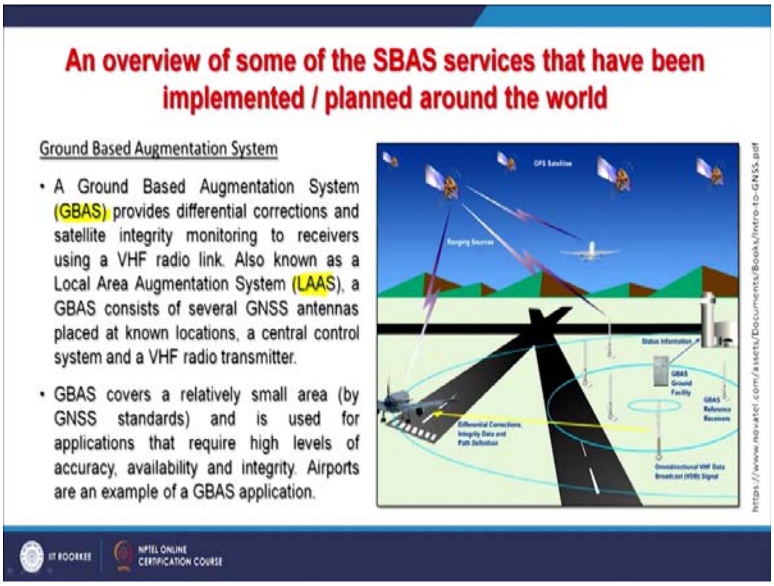

And their Ground Based Augmentation Systems are also there, local area that is LAAS is there or Ground Based GBAS is there but once this concept of SBAS that is Satellite Based Augmentation System has come then compared to these Ground Based Augmentation Systems are having very limited applications.

But nonetheless they have been developed in past, they are being used for a very specific purposes especially for a air navigation; for the aircraft landing and takeoff and so on in a poor visibility conditions. So, Ground Based Augmentation Systems can also be employed for very specific purposes, but the wide applicability which can be achieved only by SBAS not by Ground Based but for specific purposes, these can definitely be employed.

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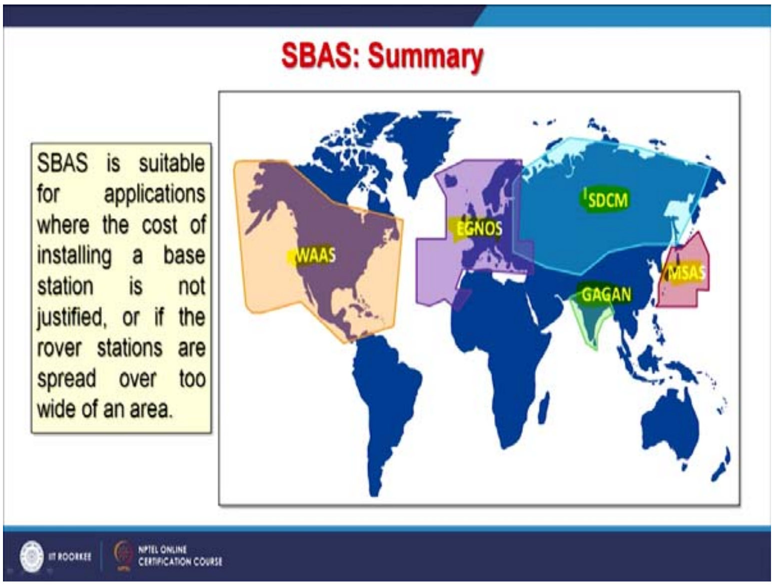

So, in summary what we see that different countries are having their own SBAS, a Satellite Based Augmentation System. We first discussed the American one which is WAAS then also we discussed the European that is EGNOS, we also discussed Japanese one that is MSAS, we also touched upon GAGAN system and then SDCM which is a Russian system is there, China as I have already mentioned in this figure it is not shown but it is also going to bring.

So, SBAS is suitable for applications where the cost of installing a base station for in case of differential GPS or GNSS is not justified or if the rover stations are spread over too wide of an area. So, if we have to cover a large area or a continent then these Ground Based arrangements like in differential GPS or RTK is not going to work. So, the best solution currently available is the SBAS.

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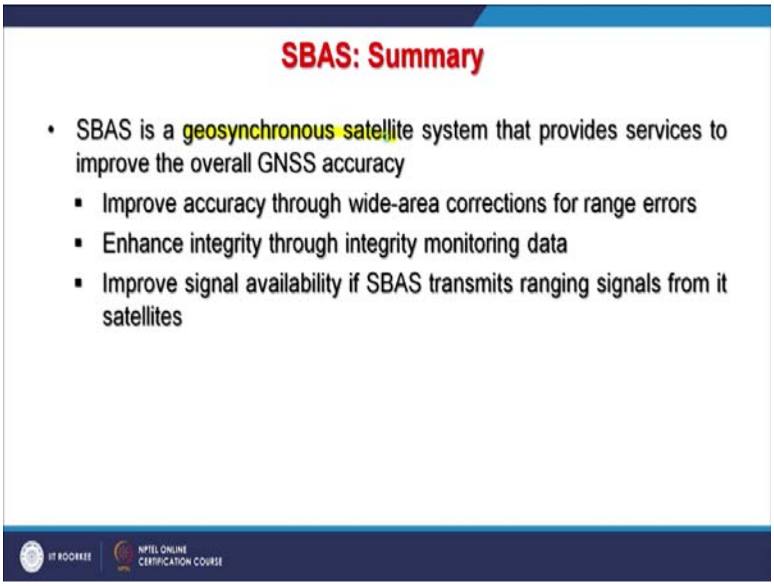

Further SBAS as you know, it uses at least one geostationary satellite if continent is big, country is big they may employee two or three satellites and provide service to improve the overall GNSS accuracy and improve accuracy through wide area corrections for range errors because the corrections data is being collected from various stations; in India there are 12 Reference Stations. Enhance integrity through integrity monitoring data. So, we know that how the quality of data is being transmitted to the geostationary satellite which will of course, will transmit back to the user and improve signal availability if SBAS transmits ranging signals from its satellite.

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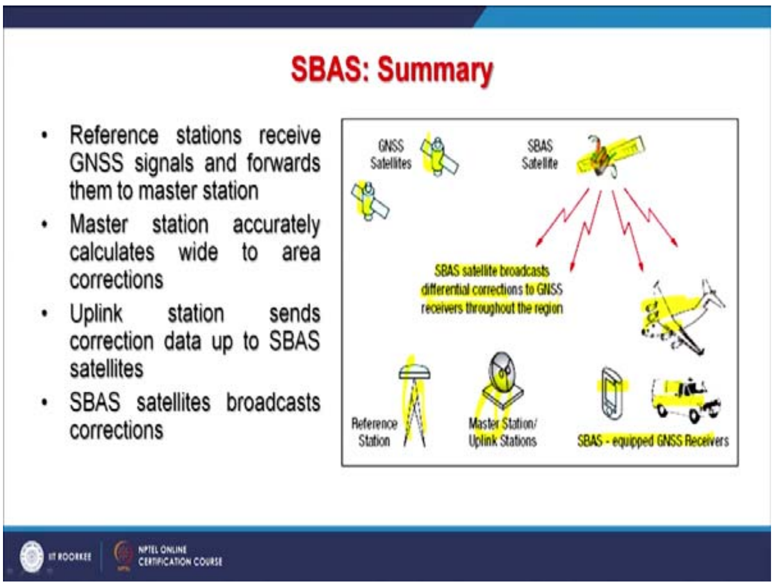

So, these Reference Stations receive signals and forward them to the master station. We are just you know, recapping the entire discussion here through this summary slides that Master Station accurately calculates wide to area corrections. As we have seen that there are SBAS geostationary satellites, GNSS satellites, receivers are there Master Control Stations there and other equipment which are just users of that.

So, SBAS satellites broadcast differential corrections to GNSS receiver throughout the region, to GNSS receivers because generally they are using the same L1 frequency. And in this setup, the Up-Link Station sends correction data up to the SBAS satellite that is geostationary satellites and these satellites broadcasts back to the users.

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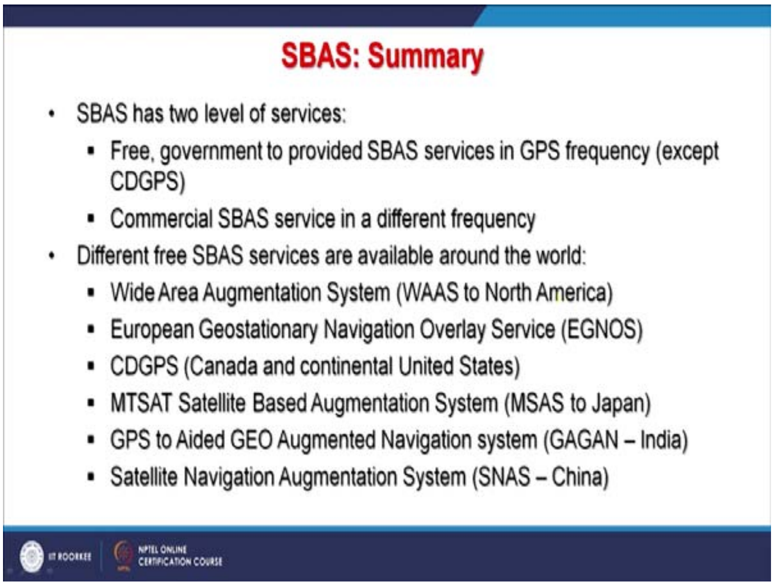

Finally that SBAS has two levels of services; one is the free government to provide SBAS services in GPS frequency except in CDGPS. So, when government is involved generally the SBAS service or correction data is free. There are commercial services are also available but they are in different frequency and different free SBAS services are also available around the world which are like for Europe EGNOS and WAAS for North America and then CDGPS that is Canada and continental US, MTSAT which is for Japan and then GAGAN for India and this SNAS for the China.

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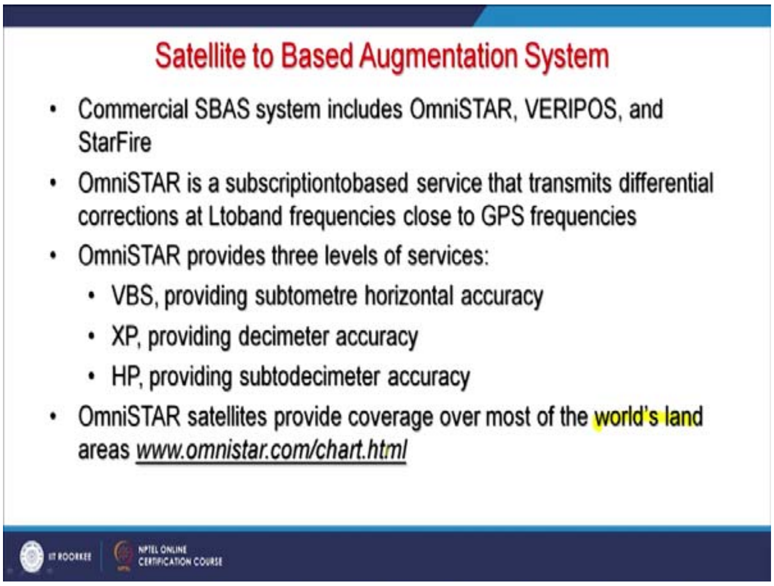

And these commercial services includes like OmniSTAR, VERIPOS and StarFire. Basically these services are being provided by the manufactures of different GNSS receivers. So, that if you buy that receiver and if you want to augment your signals or get the position estimations more accurately then you can also subscribe to these services. An OmniSTAR is a subscription based service that transmits differential corrections at L1 band frequencies close to the GPS frequency. OmniSTAR provides 3 levels of services that are VBS provide to sub-metre horizontal accuracy, XP provide decimetre accuracy and HP providing sub decimetre accuracy.

An OmniSTAR provides coverage over most of the world land and this can be accessed through this site. So, this brings to the end of the discussion on SBAS which is very important and going to come and the accuracy which we are getting currently which is around 3 meter in the standalone GPS like in your smart mobile, will have if they become capable of calculating or using these corrections data then they will provide the position accuracy in few centimetres. So, this brings to end of this discussion as usual I am leaving with a cartoon to enjoy.

Thank you very much.