Global Navigation Satellite Systems and Applications
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Lecture – 10
Quasi-Zenith Satellite System (QZSS)

Hello everyone and welcome to 10th lecture of Global Navigation Satellite Systems and Applications. And in this discussion, we are going to discuss Japanese System which is called Quasi-Zenith Satellite System for navigation that is QZSS. And it has been developed by Japanese Aerospace Exploration Agency like in US, we are in NASA, in India, we are having ISRO. So, this JAXA, Agency of Japan has developed this regional system.

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So, in Japanese, it is called the Michibiki and that means to guide; to show the way and this is regional navigation satellite system, it is not global. Japan is being a very small country in sense of geographic area and they wanted to develop for their own purposes. But the interesting part from navigation systems point of view, we are also sometimes getting signals from QZSS in India as well. But not from many satellites because we will see that the constellation is different, but anyway maybe from one or two satellites, if our receivers are capable of receiving those number of channels then we are also getting QZSS signals in our receivers.

So at the beginning, the system was basically developed by the Advanced Space Business Corporation, team of JAXA and in 2007, the work taken over by the JAXA together and the Satellite Positioning Rresearch and Application Centre of JAXA is now in full command.

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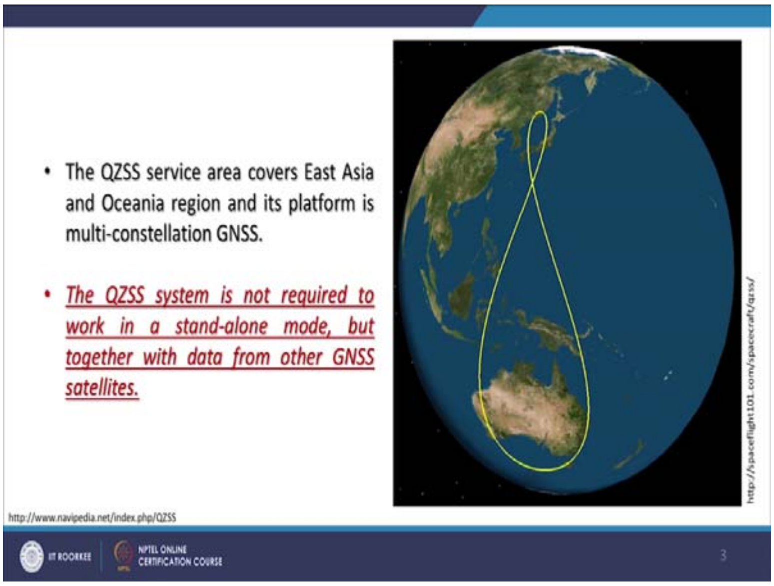

As you can see that this orbit is completely different that is why it is quasi kind of arrangement. This QZSS service area covers East Asia and Oceania region. And its platform is multi-constellation GNSS system. So, this QZSS system is not required to work in a stand-alone mode, but it depends; it is not completely independent but together with data from other GNSS satellites.

So, it is a kind of Augmentation Systems and this Augmentation is mainly focus for Japan. It is not exactly as SBAS but of course, because it is not independent systems. It depends on other GNSS systems which we will be see very soon that …

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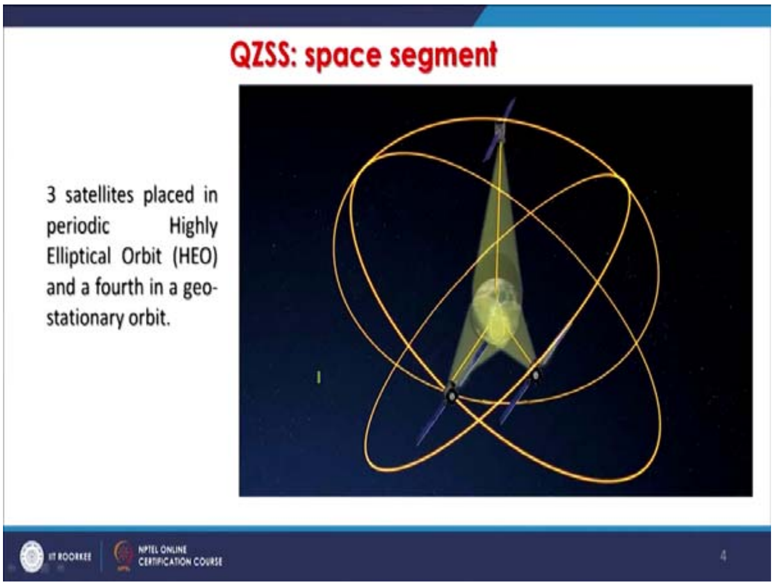

There are three satellites placed in periodic Highly Elliptical Orbit which we can see here that these three orbits are there and three satellites; one satellite, another one and third one and if fourth is in a geostationary. So, that it keeps looking or it is synchronized with the speed of earth and the satellite will always keep focusing over Japan.

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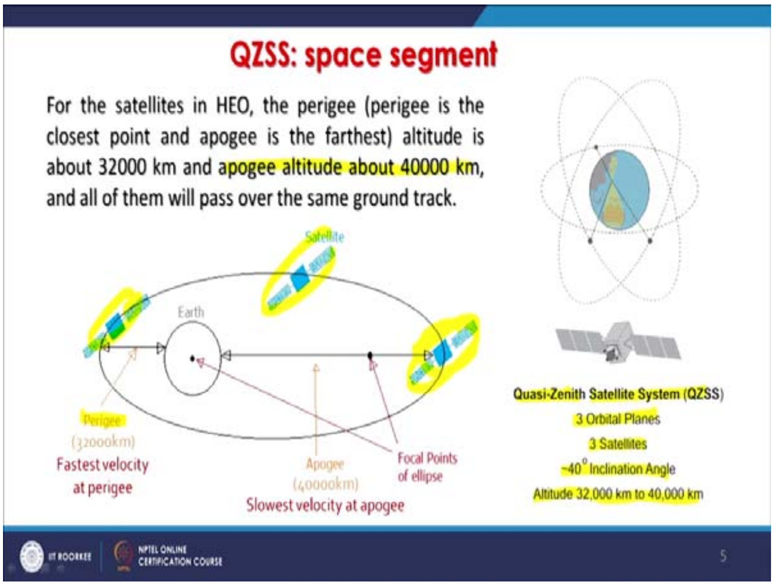

So, this is what we see that one satellite is here, another one is here. It is also here and the main focus, it is not completely circular and that is why it is called Quasi-Zenith Satellite System. 3 orbital planes as you can see here and there are 3 satellites; 40 degree inclination angle and the altitude are relatively very high as compared to GPS or GLONASS or other systems are there.

So, this is how the constellation is there and for this Highly Elliptical Orbit of QZSS; the perigee which you see here is 32,000 kilometres, where you will have the fastest velocity and that is the closest point to the earth and apogee is the farthest point of the earth. So, basically apogee is there and this altitude or the distance of apogee is about 40,000 kilometres.

And all of them will pass over the same ground track and that is why here what do you was seeing that orbit is not a regular one. So, it's a different kind of orbit which you are saying here.

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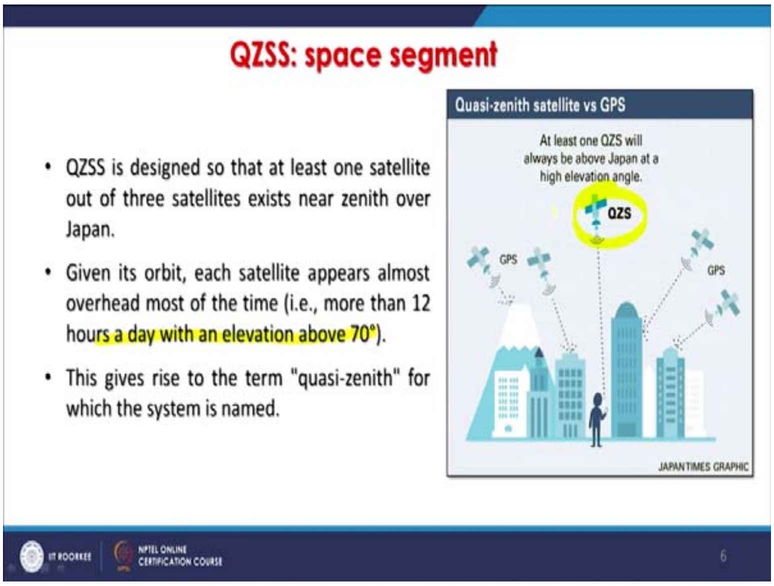

It's not independent system; it will be using other GNSS signals along with QZSS to improve the positional accuracy basically over the Japan and maybe in neighbouring country. QZSS is designed so, that at least one satellite out of 3 satellite exist near zenith over Japan. And not many satellites have been intended because other satellite signals will be available from other GNSS systems which are global. So, in this orbit, each satellite will appear almost over head most of the time.

And this is the same advantages being taken as in case of IRNSS systems that most of the satellites are overhead us because of geostationary in nature and more than 12 hours a day with an elevation above 70 degree. So, that is the biggest advantage that these satellite like it, will be on overhead, few will be here in other inclined position, but nonetheless hope they will be providing good signals for a geographically small country. So, this gives rise to the term Quasi-Zenith for which the system is named.

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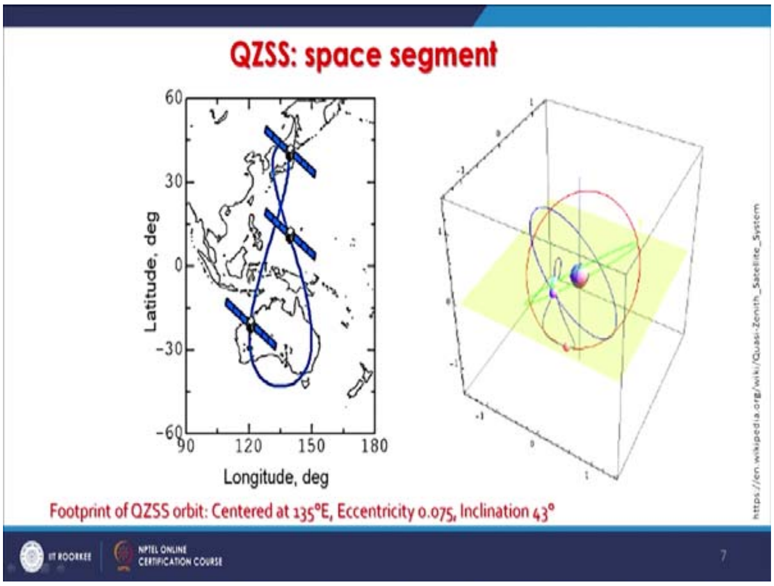

And as you can see here in this animation that how from any location in Japan; how these access to the satellites are available as you can see there all 3 satellites are moving And in there designed orbit. And this is how, they will be getting at least one satellite will always be there and another one is of course, geostationary which is all the time focusing and signals from other GNSS system will allow to estimate accurate position within Japan.

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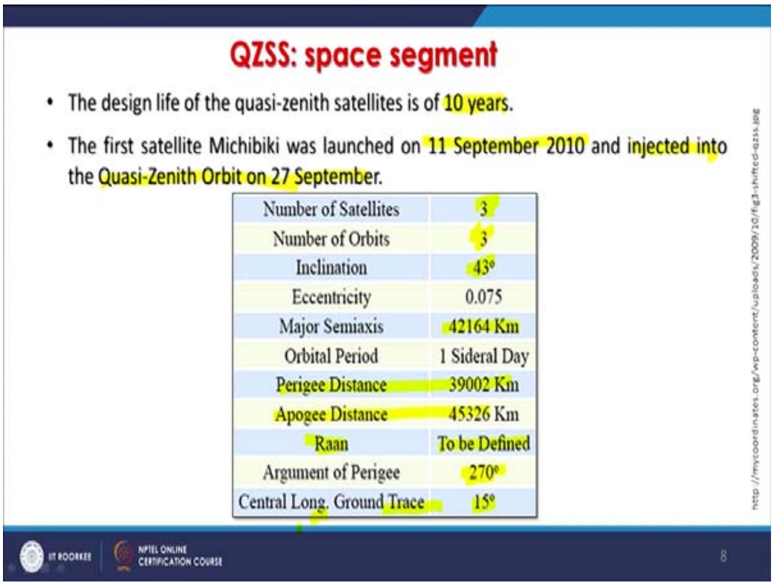

And as number of satellites 3, number of orbits 3, as you have seen the inclination is 43 degree and eccentricity is 0.075, major semi-axis is 42164 kilometre and orbital period is one sidereal day and perigee distance is 39002 kilometre, apogee distance is 45326 kilometre. And some other parameters yet to be defined that is Raan, argument of perigee is a 270 degree and Central Longitude Ground Trace at 15 degree.

So, this design life of Quasi-Zenith satellite or QZ system for each satellite is 10 years and this is almost true in most of the satellites which are very far deep in space, much more away from the earth. We have already discussed this point that satellite is very close to the earth; Low Earth Orbit, the life of such satellite would be less than if satellite is very deep in the space generally life of the satellites may go up to 10 years or sometimes even 15 years. And first satellite of this Michibiki or QZSS was launched on 11th September, 2010 and injected into the Quasi-Zenith orbit on 27th September, 2010.

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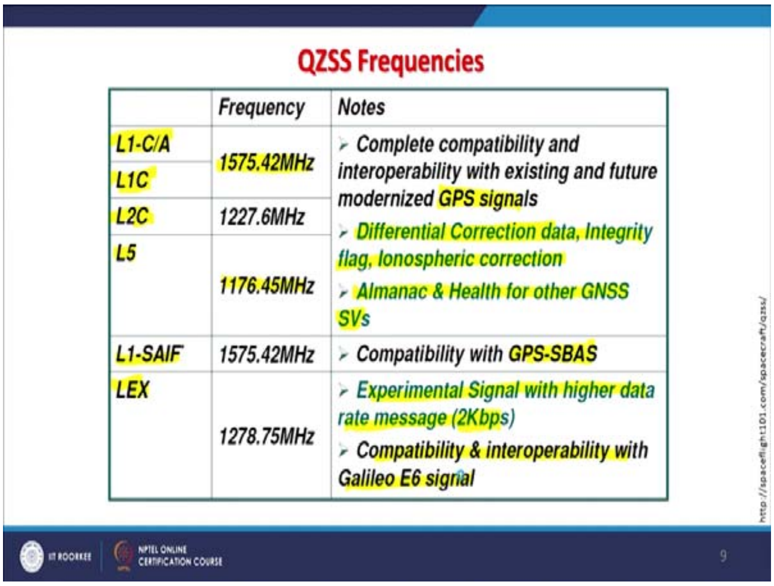

So, these are the frequencies which are being used by QZSS; L1 frequency this is Coarse Acquisition and L1C and L2C, L5 and L1-SAIF and LEX. And one by one we will see that L1-C/A and L1-C that is 1575.42 Mega Hertz which is complete compatibility and interoperability with existing in future modernize GPS signals because it will be using signals from other GNSS systems for example, GPS. So, the same frequencies have also been incorporated so, that in receiver, these things are there.

Then for L2, L5; the differential correction data, integrity flag and ionospheric corrections will also be done through these frequencies. Almanac and health of other GNSS Space Vehicles will also be coming through these frequencies. And L1-SAIF is the compatibility with GPS and SBAS. SBAS that is Satellite Based Augmentation System which is now becoming a very popular and almost every country is trying to have their own geostationary satellite. So, that they can have Satellite Based Augmentation and what the advantage of them; of course, we will be having a full discussion one lecture on this SBAS, but at this stage, the advantage of SBAS because these differential corrections can come through this SBAS. Because this SBAS which is geostationary orbit and the signals from SBAS will always be available for that country which has planned or launched these SBAS.

So, India is also having this SBAS our system. Many countries are have already have their own SBAS (Refer Time: 11:20) or planning to have their SBAS system. And this

LEX that is the experimental signal with high data rate message 2 Kilo-Bytes per second, compatibility and interoperability with E6 signals are there. So, as mentioned already the QZSS is not complete independent system; only 4 satellites, 3 in Quasi-Zenith orbit, one is geostationary and rest of these things are being from other GNSS system. So, you know probably, they are not intending from that kind of military operations or other things. But for civilian, these numbers of satellites and available accuracy hopefully will be sufficient.

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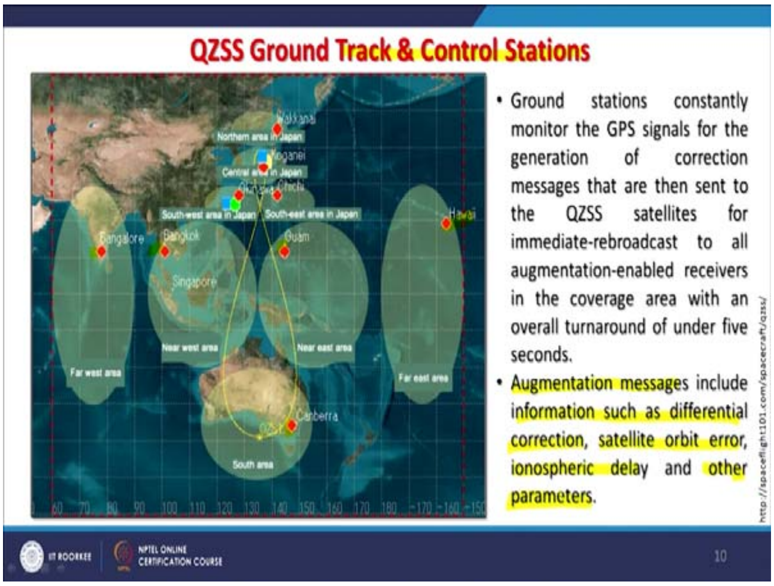

And of course, they are not looking in that sense of complete independence or independent system of their own, but using other GNSS systems which are already available. Now, as you can see that these ground track and control stations how they are spread. So, they are having these Ground Stations which are in these red dots; which are spread all over the world and of course, in Japan or near Japan.

So, Ground Stations basically constantly monitors the GPS signals. Sometimes we also call them as Monitoring Stations for generation of correction message and then they send these to QZSS satellites for immediate rebroadcast to all augmentation-enabled receivers in coverage area with an overall turnaround of under 5 seconds.

So, very quickly, the corrections are sent to the satellites from these Grounds or Monitoring Stations and then these are also passed to the user or to the receiver where signals are being used for position estimation or for recording. And these augmentation messages; the purpose here is to improve the accuracy, include information such as differential correction that is the error which is being recorded and communicated to the receiver ultimately. So, you get the more accurate position.

As if there are some errors in the satellite orbit, these Monitoring Stations keep monitoring and then they transmit ionospheric delay that is always incorporated in the signals. And other essential parameters may also be sent through these Monitoring Stations to Master Controls Stations or other Up-Linking Stations.

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So, the benefits of this QZSS; there are many that there are Mobile Mapping Systems which can utilise convoy truck systems, in for Fluid Management. Of course, this is the future this is the Automated Driving which is coming now; which is going to be completely based on GNSS system, some prototype vehicles have already been developed.

In the end of this course, we will be of course, discussing those things as well. Then Smart Driving Support System, in maybe Smart Intersections and all these systems are also focusing on Disaster Prevention and in case of Emergencies; availability of signals and distress signals also. And then efficiency of Infrastructure Maintenance for that purpose also. Tunnel Surface Management, if there are large civil structures maybe a reservoir; dam, may be a tunnel, are there any deformations are happening then if accurately, the data is measured on regular basis then such things can be estimated and it is being done. Then Landside Protection also there these signals can be used. Railway Management, Area Surveillance, High Precision Navigation, Road Pricing, Information Controll Centres. All kinds of applications will be there using this QZSS signals.

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System	BeiDuo	Galileo	GLONASS	GPS	NAVIC	QZSS
Owner	China	EU	Russia	United States	India	Japan
Coverage	Regional (Global by 2020)	Global by 2020	Global	Global	Regional	Regional
Coding	CDMA	CDMA	FDMA	CDMA	CDMA	CDMA
Orbital altitude	21,150 km (13,140 mi)	23,222 km (14,429 mi)	19,130 km (11,890 mi)	20,180 km (12,540 mi)	36,000 km (22,000 mi)	32,000 km (20,000 mi)
Period	12.63 h (12 h 38 min)	14.08 h (14 h 5 min)	11.26 h (11 h 16 min)	11.97 h (11 h 58 min)	1436.0m (IRNSS-1A) 1436.1m (IRNSS-1B) 1436.1m (IRNSS-1C) 1436.1m (IRNSS-1D) 1436.1m (IRNSS-1E) 1436.0m (IRNSS-1F) 1436.1m (IRNSS-1G)	
Revolutions per sidereal day	17/9	17/10	17/8	2		
Number of satellites	5 geostationary orbit (GEO) satellites, 30 medium Earth orbit (MEO) satellites	24 by design, 14 operational, 4 commissioning, 30 operational satellites budgeted	28 (at least 24 by design) including:[17] 24 operational 2 under check by the satellite prime contractor 2 in flight tests phase	31 (at least 24 by design)[18]	3 geostationary orbit (GEO) satellites, 5 geosynchronous (GSO) medium Earth orbit (MEO) satellites	In 2011 the Government of Japan has decided to accelerate the QZSS deployment in order to reach a 4-satellite constellation by the late 2010s, while aiming at a final 7-satellite constellation in the future
Frequency	1.561098 GHz (B1) 1.589742 GHz (B1-2) 1.20714 GHz (B2) 1.26852 GHz (B3)	1.164–1.215 GHz (E5a and E5b) 1.260–1.300 GHz (E6) 1.559–1.592 GHz (E2-L1-E11)	Around 1.602 GHz (SP) Around 1.246 GHz (SP)	1.57542 GHz (L1 signal) 1.2276 GHz (L2 signal)	1176.45 MHz(L5 Band) 2492.028 MHz (S Band)	
Status	22 satellites operational, 40 additional satellites 2016-2020	18 satellites operational 12 additional satellites 2017-2020	Operational	Operational	7 satellites fully operational	
Precision	10m (Public) 0.1m (Encrypted)	1m (Public) 0.01m (Encrypted)	4.5m – 7.4m	15m (Without DGPS or WAAS)	10m (Public) 0.1m (Encrypted)	1m (Public) 0.1m (Encrypted)

https://en.wikipedia.org/wiki/Satellite_navigation#Positioning_calculation

And this is one comparative chart of so far of different GNSS systems which we have discussed; starting here with the GPS which is of United States, then we have also discuss GLONASS of Russia and then we have also discuss the BeiDou China system, and then we have also discuss the NAVIC or IRNSS which is our India system and in this particular lecture we have also discuss the Japanese one.

As you can see that Chinese one, though originally it started regional but it is now global; it is already global, at least in India we are getting good quality signals from BeiDou. GALILEO is ultimately intended for global operations. GLONASS and GPS anyway, they were designed for global, Indian system is regional and this QZSS that is Japanese system is also regional.

The coding system; some are using CDMA, some are like GLONASS is using FDMA and rest of the systems are using CDMA. And we have also discussed about the orbital altitude that is the distance of these satellites or constellation from the earth. So, that in, this GLONASS are the closest satellites relatively and whereas the NAVIC are at the farthest because we are also using geostationary orbits as well. So, they are very far in a space or very deep in a space and the period; that means how they complete one cycle or one orbit of the earth. So, this BeiDou; 12 hours, our Indian systems is also depending on different satellites and then 11 hours, GPS and so on so forth.

Revolution per sidereal so 17/9 out of in 17/10 then 17/8, 2 and this information is not available for next systems in table. And now number of satellites as we know that in case of GPS which we started 31, in case of a GLONASS 28 total, in case of GALILEO 24 and 6 are in spheres. So, basically 30 satellites and in case of BeiDou, 5 Geostationary Orbits, 30 Medium Earth Orbits and in case of Indian system, 3 Geostationary Orbit, 5 Geo-Synchronous Orbit. And QZSS also as you have seen that 3 in the Quasi-Zenith orbit and 1 in Geostationary Orbit. And these are the frequencies which are being used by different navigation systems and the status is that BeiDou is working. GALILEO is working though we do not get signals in India but it is known that it is working, GLONASS is working and GPS is of course, it is working. GLONASS signals also, we receive in India.

So, we know that it is working and IRNSS as mentioned when we kept our focus on the discussion of IRNSS that only for military purpose, it is open but for civilian; Standard Positioning Services that is not available yet to civilians. But hopefully very soon these things would also be available for normal people. And the most important part is the precision without using SBAS. So, there are 4 Standard Services or Precision Services in case of Standard Services; BeiDou 10 metre, in case of GALILEO, it is just 1 metre. So, it is highly accurate relatively.

In case of GLONASS, 4.5 to 7.4 metre, in case of GPS of course, without differential GPS or WAAS that is a Wide Area Augmentation System and then India; for public, we will be having not yet that is in going to be 10 metre but encrypted for military purposes, it is going to be 0.1 metre. And QZSS, we get 1 or 2 satellite; mainly 1 satellite signals from QZSS and that is 1 metre for public and of course, for special services or encrypted services for which one has to pay is 0.1 metre.

So, this gives a comparative study or comparative chart of all the navigation systems which so far we have discuss belonging to different countries or union like European Union in case of GALILEO.

So, this brings to the end of this discussion on QZSS which is Japanese system and this also completes all GNSS system so far which have been developed by different countries. And in future we will be discussing the differential GPS, SBAS and other things. As usual I am leaving again with a cartoon to enjoy.

Thank you very much.