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Quasi-Zenith Satellite System
Combined services of communication, broadcasting and positioning

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This paper describes the overview of Quasi-Zenith Satellite System (QZSS) and examples of updated or emerging services using the QZSS.

The QZSS will enhance conventional services and create new services. We believe that the QZSS will effectively contribute to the infrastructures development which is inevitable to the progress of Japan's IT environment. In addition to that, the QZSS will play an important role in the utilization of IT in various fields in five to six years from now. Especially, with the provision of positioning function of the QZSS, the market for the positioning related services will expand more, and will be more widely demanded and more enthusiastically by the public. This, we believe, will ensure that life will be even more comfortable, affluent and safer than ever before.

We are aiming at providing services using the QZSS mainly within the Japanese territory but we will be able to expand our some services using the QZSS to East Asian countries such as South Korea, People's Republic of China which has big cities in the coastal and inland areas like Shanghai and Wuhan as well as Australia and New Zealand.

1. System Overview

1.1 Necessities and architecture

The current communication environment provided by conventional GEO satellites is not fully satisfactory to mobile users in the urban areas or in mountainous areas because Japan is located in mid-latitude with low elevation angles of about 45 degrees. Therefore signals from GEO satellites are being blocked by buildings and mountains.

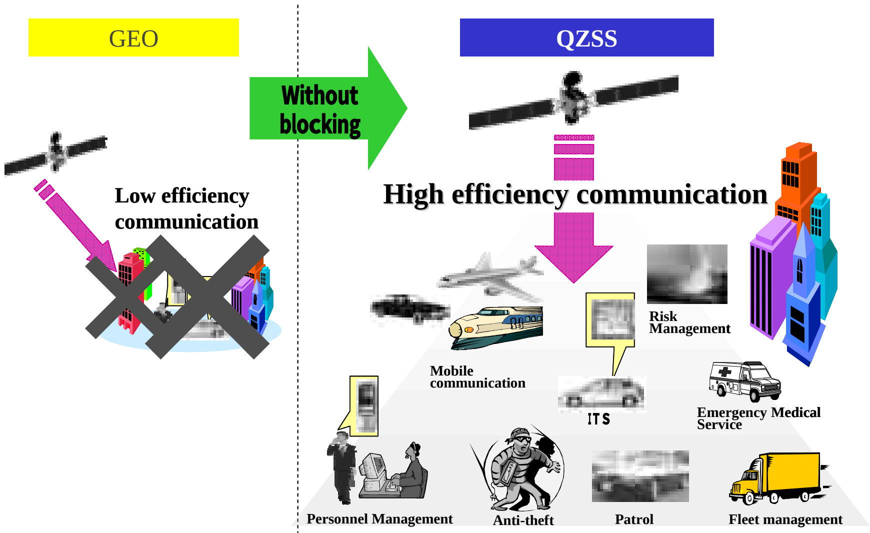

Fig. 1

The quasi-zenith satellites (QZSs) are a constellation of satellites which will orbit so called "figure of eight" formation looking from a particular region. Take the constellation of satellites whose orbit planes are about 45 degrees inclined from the equator. This constellation will be able to contribute to improve satellite communication environment for mobile users in urban and mountainous areas by offering high elevation angles of about 70 degrees (or more) in all over Japan.

If each one of the quasi-zenith satellite constellation's orbits is appropriately selected for one satellite, it will ensure 8 hours of high elevation angle for Japan and surrounding area due to the earth rotation. Therefore, in order to improve satellite communication environment based on 24-hour operation, at least one satellite will be in the orbit inclined from the equator, and each orbit plane set 120 degrees along the equator from the others, one satellite in each orbit will fly over Japan and surrounding areas alternately. At least 3 satellites are needed to be placed in the zenith to form this constellation. Each satellite of this constellation will be able to fly over Japan in the northern hemisphere, ensuring high elevation angles to mobile receivers in this region, and thus will provide signals to users in Japan and South Korea easily. Moreover, the each satellite of the QZSS will fly over the southern hemisphere, and will be able to provide signals to users in Australia and New Zealand in theory, although there are some restrictions of the elevation angles (less than 70 degrees if it covers Australia nationwide), the length of time each satellite fly over the area (In case of asymmetric eight figure orbit, the length of the arc that one satellite will need to fly over is longer than that of flying over Japan).

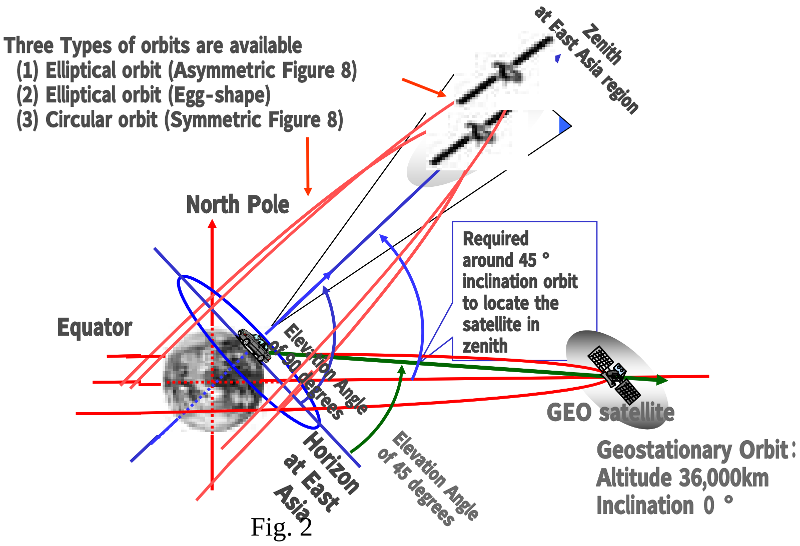

Fig. 2

1.2 Advantages

One of advantages that the QZSS could offer is the high elevation angle from earth stations. One of the proposed orbits (asymmetric eight-figure formation) will be able to provide elevation angle of about 70 degrees for users in and near Japan. Especially, for satellite communication and broadcasting services, an antenna only need to be installed directing towards overhead, which will enable easier installation of antennas than those of GEO satellites for mobile users. The QZSS will expand the market for the distribution of contents for passengers in cars. Furthermore, for those residents who are not able to receive signals from GEO satellites, satellite communication infrastructure will be improved dramatically by installing their antenna overhead for the QZSs if there is no obstacle above.

The second advantage is the ability to share the same frequencies with GEO satellites.

The International Telecommunication Union (ITU) regulates that newer satellites should not interrupt services of preceding GEO satellites. There are relatively large difference in elevation angles between the QZS and conventional GEO satellites. Therefore, it, in theory, is possible to reuse frequencies which are currently used by GEO satellites though interference evaluation processes are off course needed between the QZS and GEO satellites. By effectively using limited resources of frequencies, there is an extended possibility to promote a frequency related policy of separating ground communication networks from satellite communication network (especially for services using highly directional antenna).

1.3 Orbits

As of now, investigation is under way as to which orbit to be selected for the QZSs from several orbits. I would like to explain three options: asymmetric eight figure orbit, egg-shape orbit and symmetric eight figure orbit (perfect circular orbit).

(1) Asymmetric eight figure orbit

Let’s say when eccentricity is 0.099, apogee (Japan and its neighborhood countries) sets at 39,960 km, and perigee (around Australia) sets at 31,612 km, we will be able to minimize operational loop around Japan.

One of advantages of this orbit is that various services using three missions, communication, broadcasting, and positioning on the QZSs will be able to be served equally to users in Japan and neighboring countries. By choosing this orbit, two satellites in the constellation will be able to hand over at the contact point between the operational loop and non-operational loop, and will enable to simplify (or skip) hand over function on users’ terminals.

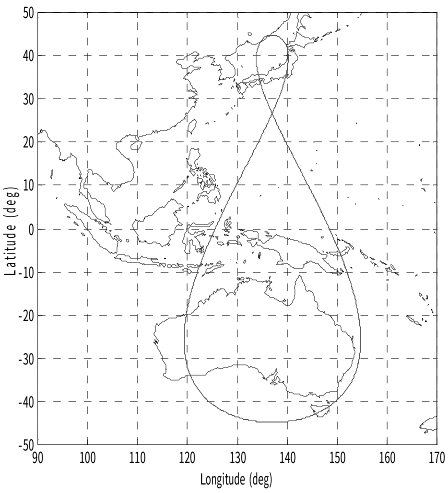

Fig. 3 Source: National Space Development Agency of Japan (NASDA)

(2) Egg-shape orbit

If we set eccentricity at 0.2, apogee (Japan and its neighboring countries) at 44,641 km, and perigee (around Australia) at 26,932 km, the elevation angle from Japan is from 1 to 2 degrees higher than that of asymmetric eight figure orbit described in (1).

The advantage of this orbit is that broadcasting related services will be provided a little bit effectively for users in Japan and its neighboring countries than other two orbits.

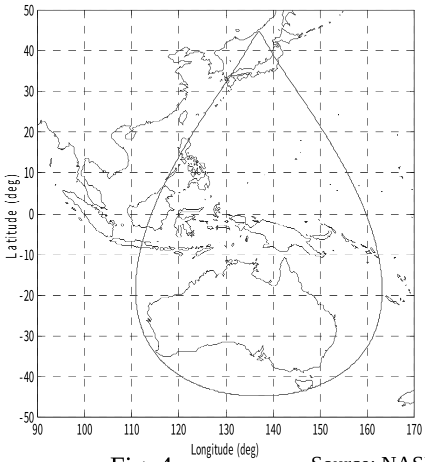

Fig. 4 Source: NASDA

(3) Symmetric eight figure orbit

If we set eccentricity 0.0, and choose apogee (around Japan) at 35, 786 km, and perigee (around Australia) at 35,786 km, the operational loop near Japan will become symmetric with the non-operational loop.

The advantage of this orbit is that positioning related services will be provided a little bit effectively for users in Japan and its neighboring countries than other two orbits.

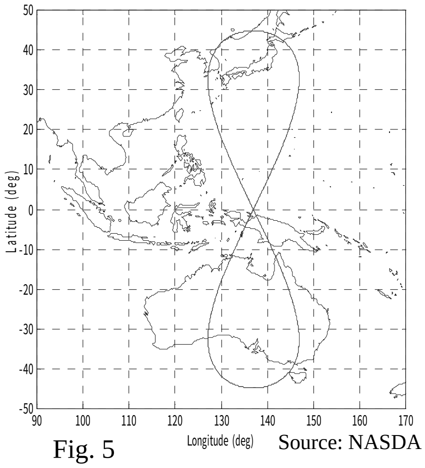

Fig. 5 Source: NASDA

1.4 Application Concept

The targeted market of the QZSS is mobile users as a whole. As I mentioned before, the QZSS will also complement services for urban and mountainous areas and remote islands where users find it difficult to receive satellite signals. Since various terrestrial networks including CATV have been implemented to solve reception problems of these areas, we would like to coexist with terrestrial service providers not pressing them.

The main targets of the QZSS will be mobile users in vehicles, aboard ships and aircraft, specifically, drivers and passengers of vehicles, operators of public transportation, buses, trains, and taxis, and their passengers, captains and passengers of ships and airplanes. Moreover, we will be able to help to establish ubiquitous network services by contributing to supplement the current communication services (roaming service in mountainous areas) or to expand location information based services using the positioning function for 70 million wireless phone users.

The application concept of the QZSS basically has the framework of combining communication, broadcast, and positioning missions in one satellite platform, which traditionally have been put on different satellites. The QZSS will try to expand each mission, and provide new services by combining “communication and positioning”, or “broadcasting and positioning.” The positioning function of the QZSS will be able to provide positioning services by itself and supplement and augment GPS functions. The QZSS will build common infrastructure which will make location survey more efficient and provide position related information services more conveniently for mobile users.

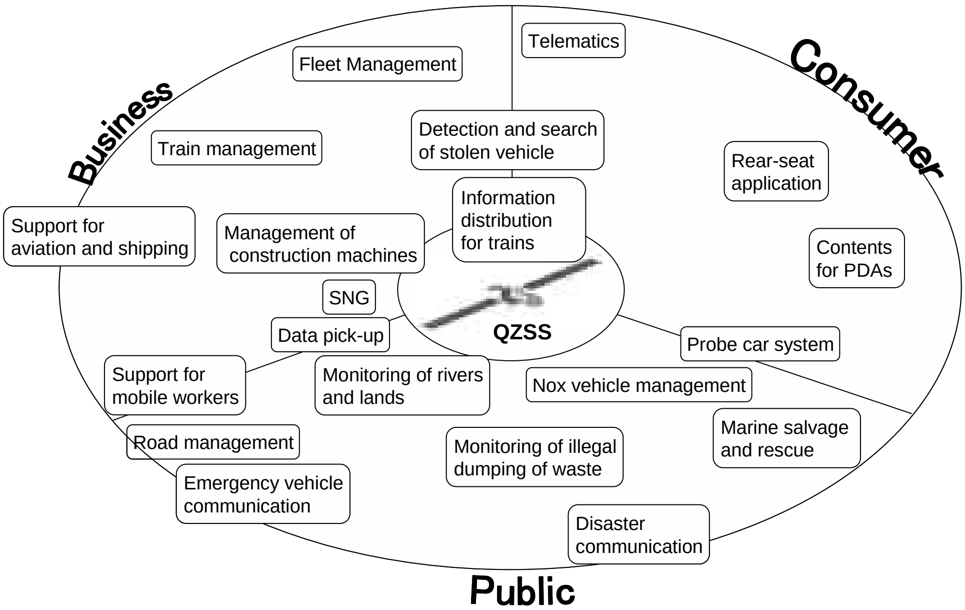

Fig. 6

The quasi-zenith satellite systems (QZSS) will enable and strengthen various kinds of existing or emerging services from one of advantages of the QZSS orbital characteristic: high elevation looking angles. The baseline of the systems we are now planning to carry forward comprise a satellite deployed near the zenith of Japan and gateways with the main target focused on user terminals anywhere in Japan (especially mobile user terminals), providing combined services of communication, broadcasting and positioning.

The QZSS’s big feature complements and reinforces the civilian function of the present U.S. operating GPS: the QZSS will broadcast highly precise positioning information which will at a stretch be able to decrease the positioning error level of about 10m (only by the present GPS) down to the level of 1cm to 10cm while it will increase the GPS visibility condition in an urban area or a mountain slope.

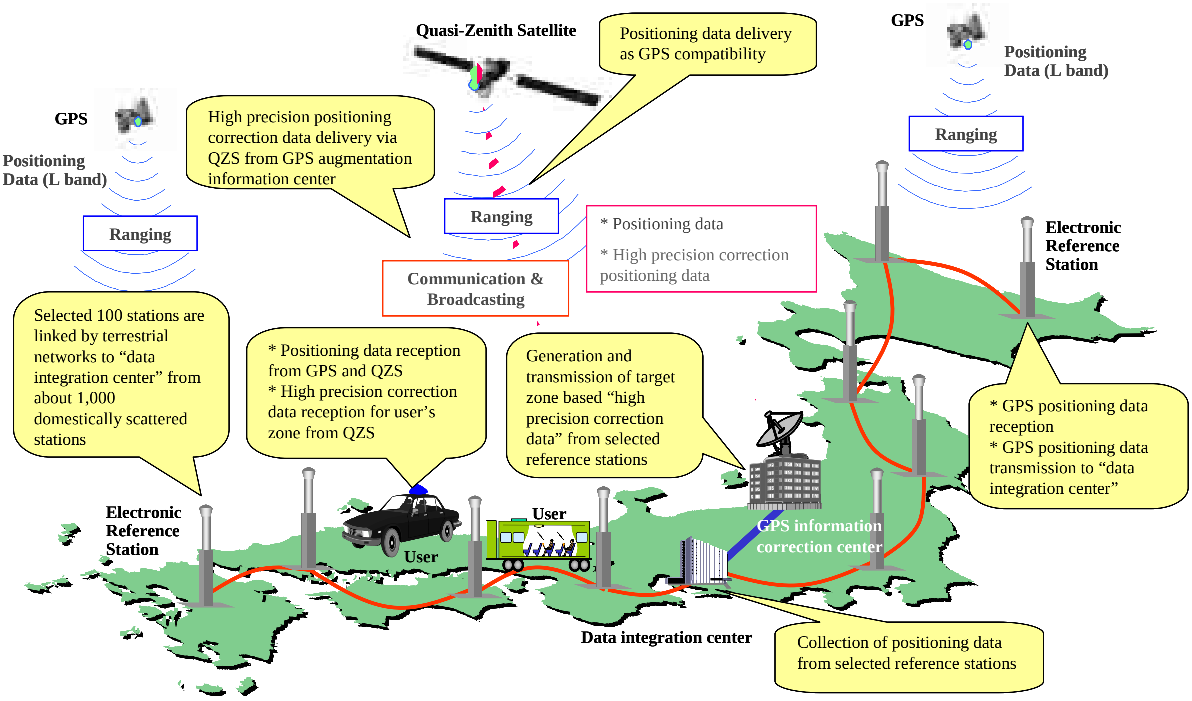

Fig. 7

In addition to this highly precise positioning information service, 24 hour service offering of communication and broadcasting will be an accelerator to produce the new kinds of services which have not been considered yet until now and may emerge and spread helping revolutionize a lifestyle of Japan.

2. Market Analyses

2.1 Increase of Internet users

The Ministry of Public Management, Home Affairs, Posts and Telecommunications estimated in 2001 that 87 million people will the Internet in 2005. Given the number of the Internet users in 2000 was 47 million, it is expected that the number of users will be nearly doubled within 5 years. The penetration rate of the Internet in middle size companies or big enterprises was nearly 95% in 2000, so from now on more and more SOHO and individuals are expected to use the Internet.

2.2 How the Internet is accessed

According to the 2001 white paper issued by the Ministry of Public Management, Home Affairs, Posts and Telecommunications, the Internet users through cell phones or PHS have increased more than five times in only one year from 3 million in 1999, and 15 million in 2000. These figures indicate that the number of mobile Internet users will rapidly grow in the near future.

2.3 Percentage of nationwide coverage

According to NTT Docomo's latest news, the FOMA's nationwide coverage (subscription rate) will achieve about 97 percent of Japan's population by the end of fiscal year 2004. Au and Vodafone are aiming to achieve same level of coverage as Docomo for their 3G services. On the other hand, these 3G services will cover only about 40 percent of the Japan's land surface. It seems that although mobile phone and PHS carriers play a role of public communication, it is difficult for them to cover the rest of 60 percent. It is too expensive for mobile phone carriers to invest their money to fill in the blanks in areas where there is mobile phone coverage gap. There are similar problems need to be solved in the ITS related infrastructure development in order to improve the nationwide coverage.

2.4 The role of QZSS

Above analyses indicate that one of the QZSS' advantages, high elevation angle from the ground to the satellites, will best serve mobile users (cell phone and PHS users as well as drivers, and passengers of cars with car navigation and other equipment). We also believe that QZSS will help to improve the percentage of nationwide coverage of wireless communication.

3. Application examples

Existing public services such as disaster monitoring, telemedicine and distance education are already using satellites communication links. The QZSS will help to improve the coverage of these services thanks to high elevation angles to the ground users.

Moreover, the QZSS will contribute to SNG (Satellite News Gathering) fro news stations or organizations. Because the QZSS has several advantages (the size of antennas in gateway stations are large, G/T is big in the satellite side, less interference with other satellites), it will be possible to send pictures from moving vehicles using smaller antennas than conventional ones, or on-the-spot coverage from newspaper reporters. These advantages will improve images broadcast at marathon races or will enable news stations to broadcast from the scene in mountainous areas or urban canyons.

The following sections describe six application examples which can be newly created or strengthened by using the QZSS.

3.1 Personal communication

The positioning function of the QZSS will improve the infrastructure for mobile users by providing highly accurate position information. The QZSS' positioning function will send out two types of data, GPS complementary data (the QZSS will send L1, L2, L5 bands ranging signals as another GPS), and GPS augmentation data (the QZSS will send out DGPS data, RTK-VRS data, and GPS capturing support data), thus it will be possible to provide more accurate position information (1 m class, 20 cm class or 2 cm class) than the current level (about 10 m).

There have already been related services in this filed but the QZSS will be able to offer one of infrastructures of accurate positioning. This accurate positioning infrastructure will become easily available for hand-held terminals (cell phones, PHS and car navigation system) by installing GPS chip into these terminals.

Various services, to provide the full-fledged counterpart of US E911 service in Japan, to advance store and event guide closely based on POI (Point of Interest), and strengthen reception of contents in the areas where signals are being interfered by mountains or high-rise buildings, will soon turn into reality using this accurate position information by coordinating various vendors and providers

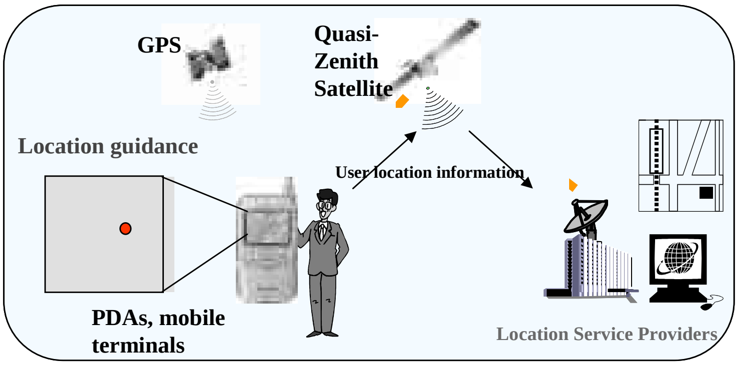

Fig. 8

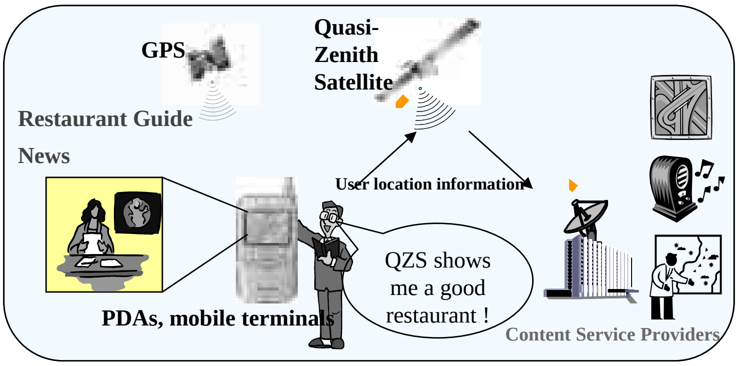

Fig. 9

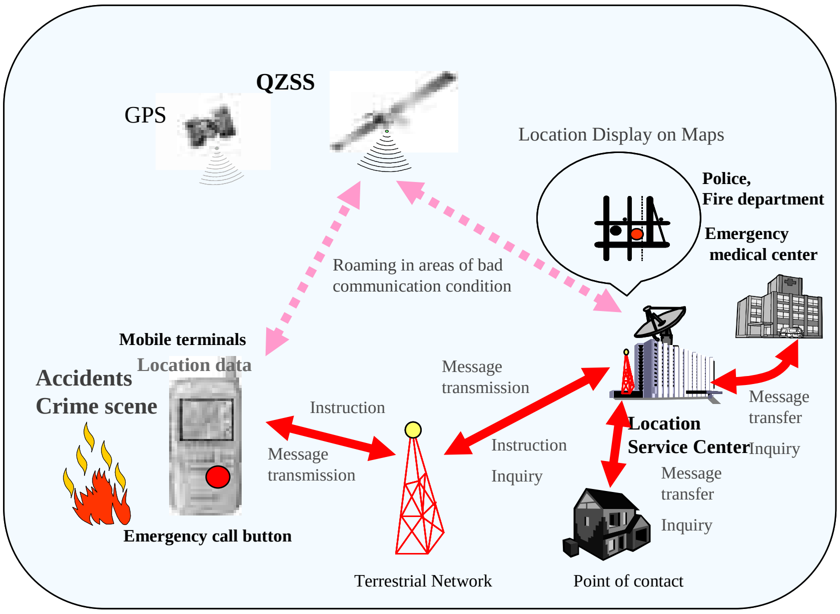

Fig. 10

3.2 Rear-seat infotainment

The broadcast function of the QZSS will enable to distribute various contents (music, video, news, and traffic and weather information) to passengers in moving vehicles or cars stuck in the traffic jam nationwide. Measures will need to be taken to receive clear signals in tunnels or under bridges but the QZSS will help to construct common infrastructure to distribute clear images for vehicles equipped with small antennas to receive signals from QZS, running between skyscrapers, mountainous areas, or near sound proof walls along expressways.

Rear-seat infotainment services will be based on conventional satellite multicast of content distribution, so passengers will be able to enjoy music or TV programs clearly without any blockage all over Japan.

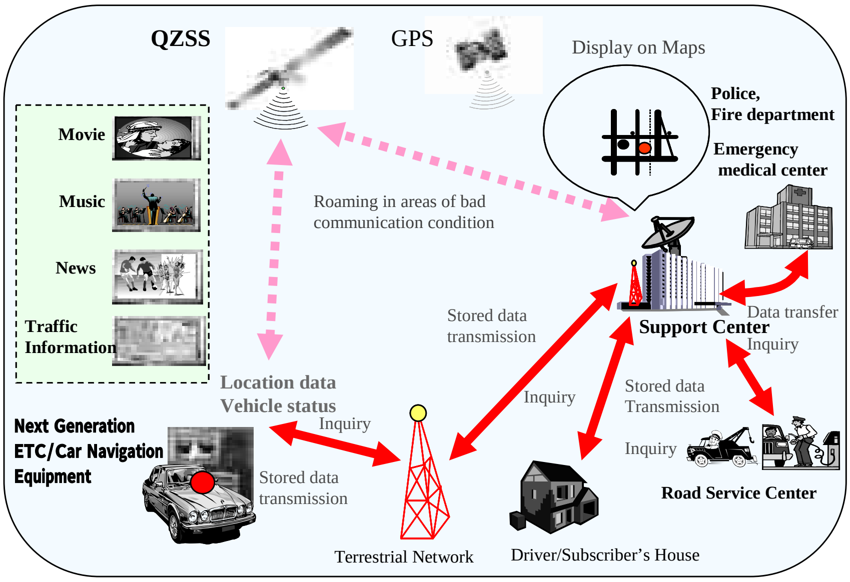

Fig. 11

The same technique can be applied to trains. The QZSS will transmit contents from broadcasting stations to antennas on trains, and distribute them via wireless LAN to passengers' handheld devices. It will be possible to offer programs that passengers want to watch continuously even on trains.

3.3 Telematics

There have been various telematics services including Toyota's G-BOOK. The highly accurate position information from of the QZSS will help to enhance functions of telematics services. Moreover, the high elevation angle from the ground to the QZS will improve communication environment of mountainous areas, urban canyons, accurate traffic information will be available through probe cars, and therefore moving by cars will become more efficient than ever.

In addition to the preceding services, the following services will become available:

(1) Remote maintenance

Condition of vehicles will be stored as sensor data while driving, and notify maintenance service providers such as dealers and contracted mechanics on regular or non regular basis. Usually these data will be sent via terrestrial network, and outside of this network, the QZSS will supplement collection of data by data roaming. In principle, the positioning function of the QZSS will enable to improve the effectiveness of remote maintenance by capturing location information of vehicles at the time of sensor data were stored. This will increase the effectiveness of remote maintenance according to drivers' operation characteristics.

Maintenance service providers will be able to support drivers through terrestrial network in case of emergency.

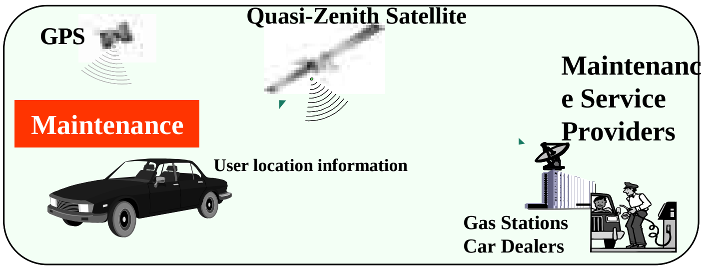

Fig. 12

(2) Upgrade of current services

As described in the section of personal communication, the positioning function of the QZSS, complementing GPS, will help to improve the current emergency services, accident assistance, and anti-theft measures.

By acquiring more detailed location information to detect emergency signals, and rescue operation can be performed promptly and accurately.

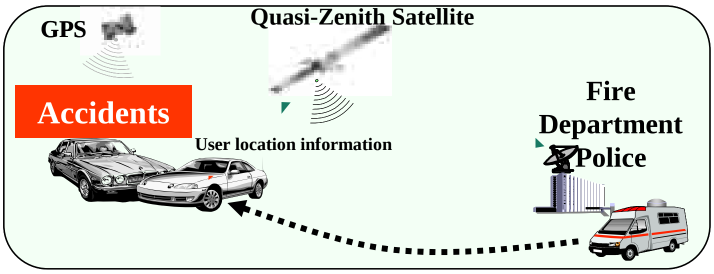

Fig. 13

3.4 Fleet management

There are various kinds of preceding services of fleet management. Some services use GPS and some services don't. Given the important role of logistics which corresponds with the development of e-commerce, we believe that the positioning mission of the QZSS will help to improve fleet management services by offering high-precision position information.

Specifically, delivery and fleet management based on detailed position information will become infrastructure to fit needs of e-commerce users, and will lead to the development of logistics related services.

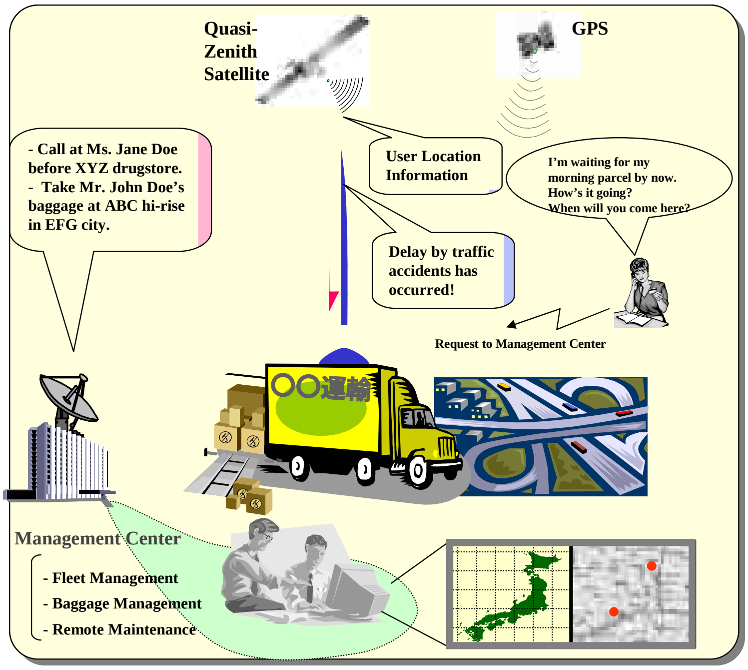

Fig. 14

In order to promote the use of the QZSS for fleet management based on high-precision position information, the development of Geographical Information System (GIS) and related information processing technologies are indispensable.

3.5 Emergency medical care services

According to the Ministry of Health, Labor, and Welfare’s Population Survey Report in 2001 (final), 45 thousand people died from acute myocardial infarction. It is said that half of them died within one or two hours after hit by strokes. If these patients are sent to emergency medical facilities within 30 minutes after hit by strokes, or proper treatment is conducted, the death rate due to acute myocardial infarction will decrease significantly.

Problems of traffic congestion need to be solved, however, appropriate primary care should be provided while patients are taken into hospitals. The communication function of the QZSS will be able to respond to these needs along with its high elevation angle feature. While keeping close contact with doctors of receiving hospitals, paramedics will send patients’ detailed conditions and pictures, and give proper treatment during the transportation. This, we believe, will contribute to the reduction death rate of emergency patients.

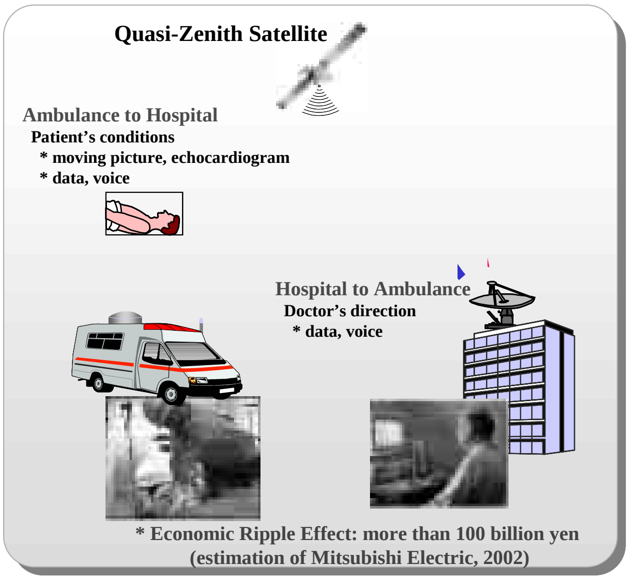

Fig. 15

3.6 Social risk management

It is reported that about 88 percent of more than 6 thousand victims from the 1996's Great Hanshin-Awaji Earthquake crushed to death by collapse of their houses. According to medical professionals, nearly 60 percent of hospitals in Hyogo prefecture were damaged and were unable to provide full medical treatment. And if the medical function in the disaster struck area remained intact, it is said that 2 to 3 percent of the victims would have been saved. At the same time, communication infrastructures were unavailable for the initial rescue operations, due to congestion, power outage and damage to the facilities. In addition to the devastation of terrestrial communication infrastructure, rescue operations in the Great Hanshin-Awaji Earthquake were extremely difficult because many buildings and houses had been collapsed.

While promoting countermeasures to disasters, we believe that the QZSS' positioning and communication missions along with its high elevation angle feature will help to assure rescue operations even if appropriate and prompt evacuation guidance by community wireless system does not work.

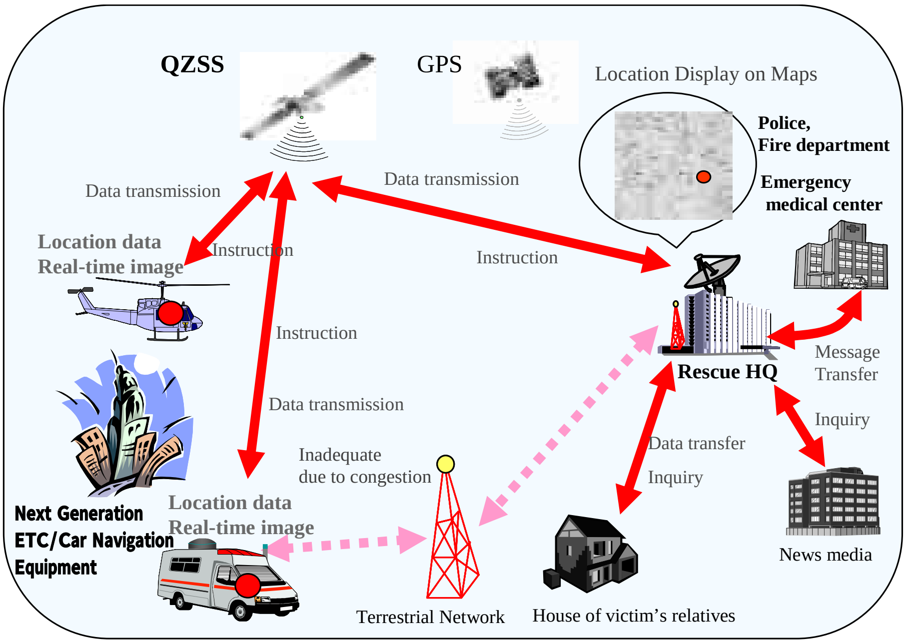

Fig. 16

4 Outlooks

The Japanese government approved funding for development of the QZSS project for the fiscal year 2003. We are planning to promote government and private sector joint research of the QZSS assigned by four ministries, the Ministry of Public Management, Home Affairs, Posts and Telecommunications, Ministry of Education, Culture, Sports, Science and Technology, Ministry of Land, Infrastructure and Transport, and Ministry of Economy, Trade and Industry, with the support from NASDA, CRL and other institutions and agencies. Advanced Space Business Corporation was established on November 1st, 2002, to conduct research and marketing of the QZSS by companies from the private sector. Launch of satellites is scheduled in the fiscal year 2008. We have started examining specific business plans by absorbing needs from users, service providers, and the related industries.

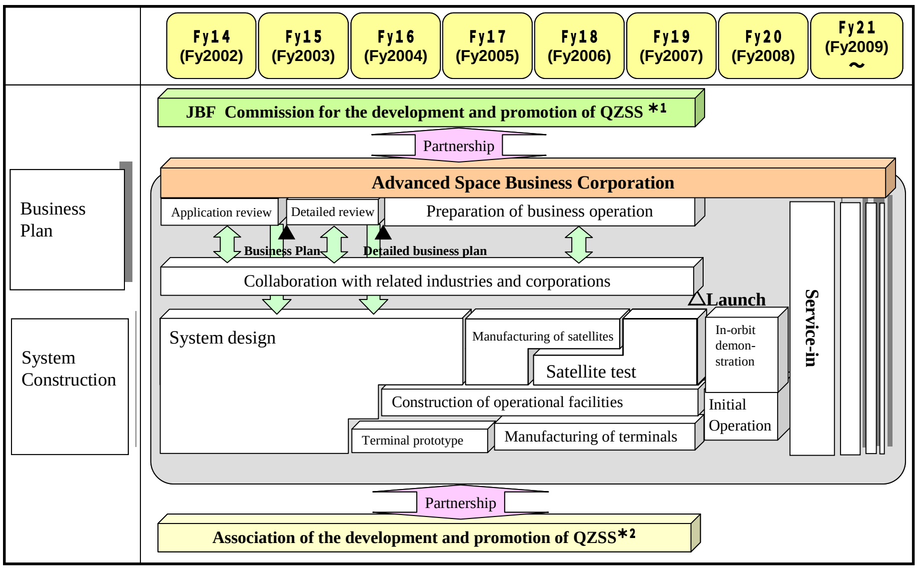

Fig. 17

This paper was prepared based on the oral presentation made at the APSCC-2002 Conference held in November 2002 at Seoul.