China GNSS 101

Compass in the Rearview Mirror

Japan National Institute of Informatics

In 2006, China built and sold 7.2 million cars, almost all of them to that country's domestic market. Only 100,000 of the vehicles had GPS-based navigation systems on board. This tells us two things: China can build a lot of stuff. And the country has a huge untapped market for GNSS.

GLEN GIBBONS

Late last year, I attended China's only government-sanctioned international conference on GNSS and visited a number of local companies. I came to one conclusion: The world of GNSS is about to change, and China will have a lot to do with that.

Consider this: China has launched its own GNSS system, Compass/Beidou. It has liberalized policies on GNSS receivers and navigable digital maps. It is already one of the world's largest economies with enormous capital reserves and steadily-growing disposable income in the hands of millions of citizens.

As a GNSS player, the People's Republic of China (PRC) arouses interest and concern on at least four levels: as a service provider (compatible or incompatible?), as an equipment manufacturer (competitor or partner?), as a product designer and technology distributor (re-engineering or innovation?), and as an enormous market of largely untapped potential (closed or open?).

In their own fashion, of course, every other GNSS provider brings the same set of questions and, like China, a distinct way of answering them.

The real questions are what lessons has China learned from the world's 30-year experience with GNSS and how will it apply those lessons to the nation's emerging role of GNSS provider, designer, manufacturer, and marketplace.

One measure of that can be taken from increasingly public, though still carefully scripted statements on the subject from Chinese public officials and industry leaders.

NaviForum: Beidou's Debut

The Shanghai Navigation Forum (NaviForum) bills itself as the only international GNSS exhibition and conference officially approved by the Chinese government, which is also deeply involved with the organization of the event. (Sponsors included the Department of High & New Technology Development and Industrialization, Ministry of Science & Technology (MOST); Department of Map Management, State Bureau of Surveying & Mapping (SBSM); and the Science & Technology Commission of the, Shanghai Municipal People's Government.)

Its fourth annual staging in December 2007 drew more than 700 attendees, with 29 percent coming from outside China, according to conference organizers. And it was, in many respects, a coming out party for Compass, which is

also widely known by its Chinese pinyin (alphabetized) name, Beidou.

As with GPS and Russia's GLONASS systems, Compass began as a military program operated by China's defense mapping agency and, as with those other two GNSSes, will continue to have a military component. Several geostationary satellites were launched beginning in 2000, broadcasting on a center frequency of 2491.75 MHz in a small slice of spectrum allocated for radiodetermination/mobile satellite.

Until late in 2006, it appeared that Compass/Beidou would remain a regional system, augmenting full-fledged GNSSes. A 2003 agreement committed China to investing €200 million ($290 million) in cooperative development of the European Union's Galileo system.

In October 2006, however, China announced that it would build a full-fledged GNSS system that would transmit signals in the L1 band where GPS and Galileo military and public safety services are located. Then, last April 14 China launched a middle-earth orbiting (MEO) satellite and quickly began broadcasting signals.

The Compass signals were soon analyzed by researchers at Stanford University and Belgian GNSS receiver manufacturer Septentrio, who published articles in the July/August 2007 issue of *Inside GNSS* describing their findings.

Subsequently, in a break with a previously restrained public posture on the subject, several representatives from the China Satellite Navigation Engineering Center described the program in some detail at NaviForum 2007. In another session, "New Positioning System," European and Chinese public and industry panelists focused on Compass. And throughout the conference, Chinese speakers referred repeatedly and favorably to the domestic GNSS system.

"New Positioning System" panel members (from left): Yang Qiangwen, CSNPC; Chuang Shi, Wuhan University; Roger Pagny, French Ministry of Communications; Jean Chenebault, Pole Star SARL, and technical expert for GNSS Supervisory Authority; Zhao Yaosheng, Beijing BDStar Navigation; Zhan Xingqun, China Galileo Industries; Jing Guifei, National Remote Sensing Center of China.

Something Old, Something New

Much of the information revealed in the Shanghai meeting merely confirmed what had already been published by outside researchers: L-band signals centered at 1561.098 MHz ± 2.046 MHz (Beidou 1 or B1, overlaying the Galileo E2 band and part of the GPS L1) and 1589.742 MHz (B1-2 on Galileo E1 and the upper portion of GPS L1); 1207.14 MHz ±12 MHz (B2, E5b), and 1268.52 ±12 MHz (B3, on the lower portion of E6).

B1/B1-2 signals would use quadrature phase shift keying (QPSK) and binary offset carrier (BOC) modulations similar to those employed by GPS and Galileo on those frequencies, according to Yang Qiangwen, senior engineer, China Satellite Navigation Project Center (CSNPC, also sometimes referred to as the engineering center) in the Beijing region. The signals will have a pseudorandom noise (PRN) code chipping rate of 2.046 Mcps and a minimum received power level of -163 dBW.

Several of the speakers, however, also provided further insight into Compass and China's ambitious plans for the system. Ran Chengqi, the CSNPC deputy director speaking in place of the center's director, Yang Changfeng, told the NaviForum audience that open services would be operated at L1 and L5.

He also emphasized the need for compatibility and interoperability with other GNSS systems, saying, "China will work with the other GNSS providers under UN International Committee on GNSS (ICG) rules."

"Beidou is a huge investment," Ran said. "We need to be very careful in its implementation and look at the risks in the market. Our goal is a long-term commitment to users.

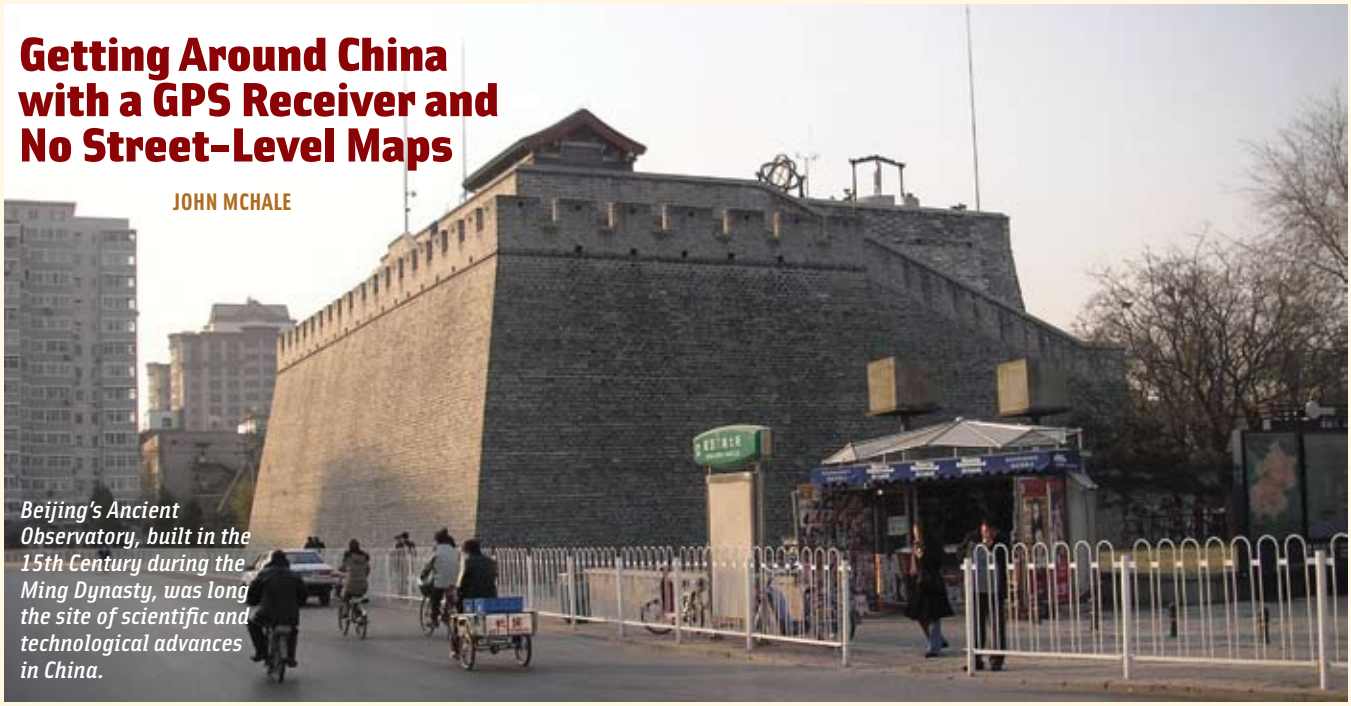
He underlined the system's "strategic role," adding, "although Beidou has made a fast start, we still need to commit our resources to make sure. We need more open industrial policies," alluding to the promised publication of a public Interface Control Document (ICD) that would specify Compass's technical parameters so that receiver manufacturers could build user equipment confidently.

"We have to build up [Compass/Beidou] awareness and our own brand in the world," Ran concluded. "An open, prosperous, and strong China will develop based on an open, strong, and healthy navigation system."

In a plenary session speech, Liao Xiao-han, deputy director of High & New Technology Development and Industry, Ministry of Science and Technology (MOST), said, "After completion of Compass, we believe it will be the major supplier of positioning, navigation, and timing [PNT] in China and also a significant supplier of PNT in the world."

Getting Around China with a GPS Receiver and No Street-Level Maps

JOHN MCHALE



Beijing's Ancient Observatory, built in the 15th Century during the Ming Dynasty, was long the site of scientific and technological advances in China.

I have always wanted to go to certain places in China that weren't on any standard tour. These included such sites as the Ancient Observatory in Beijing, Qianling Park in Guiyang, the Maritime Museum in Shanghai, and the walkway around Victoria Peak in Hong Kong.

Recently, on my first trip to and through China —21,889 miles in all, I used a GPS receiver to find my way through Beijing, Guiyang, Shanghai, and Hong Kong. As a navigator for the past 50 years, I always try to have an alternative means of knowing where I am and where I want to go.

Using Google Earth, I undertook some pre-trip planning, viewing pictures that are available on the Internet to do a virtual tour before ever leaving the good old US of A. With Google maps, I located the latitude and longitude of all of the tour sites my wife and I planned to visit and the position of each of the four hotels and airports that we would be using. I inserted most of the position data into my Garmin etrek Vista receiver before I left home.

Temple of Heaven in Beijing

I also own a Garmin NUVI 660 that I use in my automobiles and RV, but I took the etrek Vista with me because it looks like a cell phone and is less intrusive in crowds.

As a back up to the information in my GPS receiver, I printed a picture of the Google Earth map area around each of locale of interest and downloaded other maps off the Internet, especially public transportation maps.

Off the Map

In recent years, I have used a GPS receiver to navigate in England, Wales, Italy, Spain, Portugal, the Danube River area, and Greece where street-level map data is available. Unfortunately, I could find no detailed map databases of China that are compatible with my receiver. The China map on my Garmin CD, for example, includes only the main roads in the larger cities.

I compensated for the lack of street level detail by establishing a grid of sites of interest on the Garmin display for the four cities.

Mobile phones are a familiar sight in the hands of many Chinese. So, my GPS receiver and I faded into the background because, except for my facial features, I looked like any other person with a cell phone.

I used subways, buses and my feet to get around. Most signs were in Chinese and English. In the four cities I visited, the subways and buses also had audio cues in Chinese and English.

Initializing my GPS receiver in my first stop of Beijing was no problem. I used the menu for initialization to the world map and vectored to Beijing as a new location from Maryland. In about two minutes, I was ready to navigate. The receiver took about a minute to restart in the other three cities.

On our first afternoon in Beijing, my wife, Carolyn, and I hopped on the blue line of the subway near the Swissotel where we were staying. We traveled four stops south to a transfer station and then went two subway stops west on the red line to the beginning of a walking street that I had noted in tour literature. (Beijing's subway system is very easy to use despite what tour guides tell you.)

We got off near Wangfujing, a rather upscale walking street with stores and restaurants and many Chinese shoppers. Using GPS, we conducted a circle tour that took us through the Dongchang hutong area of ancient alleys and narrow lanes with one-story homes. As we meandered through the mostly residential area, I used the GPS position of the hotel as a reference.

We were probably the first "tourists" to see this hutong from the ground level. As the Chinese people achieve a better standard of living, hutongs are rapidly being torn down and replaced with skyscrapers. A few years from now, they will only be retained as tourist attractions.

My next destination was to find the Ancient Observatory that was built around 1410 during the Ming Dynasty. The Observatory was in continuous use until 1922. Halley's Comet was first detected at this venerable observatory.

Leaving the hotel and traveling south again, I exited the subway at a major road intersection. However, I could see no nearby building and no sign of the observatory. I turned on the GPS and in less than two minutes saw my position on the map display and inserted a "go to" command relative to the observatory location I had stored at home before the trip.

The GPS receiver has a built in compass and, as I aligned the display with north, it indicated that the observatory was only 454 feet to the north-

east. Following these directions, I crossed under the major Second Ring Road and saw the observatory building. This is another example of navigation and stress reduction in a strange land.

Shortcuts to Heaven

After visiting the observatory and its informative museum, I noted that TianAnMen (Gate of Heavenly Peace) Square and the Forbidden City were only four subway stops to the east. To conserve time, I used the subway to get there. Upon leaving the subway and turning on the GPS, I again orientated my location relative to the Forbidden City, the National Museum, and the Great Hall of the People.

The square is the largest open area in any city in the world. Once you know where you are, you know how to get where you want to go. No problem!! I returned to the Forbidden City several days later with the organized tour.

Author John McHale at the Great Wall of China with a sign promoting he 2008 Olympics in Beijing

The third use of GPS in Beijing occurred during a tour with a local guide at the Temple of Heaven, a few miles south of the Forbidden City. This complex is several miles square and has a north-south axis.

As we entered the area, a number of police and soldiers were shooing visitors away. Our guide told us a VIP was also visiting that day. I had previously saved the location of the major temple in the complex, using Google Earth. I showed the guide where we were on my GPS receiver map display relative to where he wanted to take us, which was about a half mile away.

Could we get around the VIP incursion by going cross-country through the mature woods where the Chinese were exercising? Our guide had never deviated from the normal tour route, but he said, "Let's try." Our group of four got to the temple before the official entourage and saw much more of the complex. GPS saved the day for us!


Tai-chi exercises in a Guiyang park

GPS Height at Great Wall

My next use of the GPS on this trip was on our two-hour hike on the Great Wall. On this excursion we used the altimeter function of the GPS to determine how high we climbed up the ridge on the top of the Great Wall.

Starting from the Badaling or Juyongguan Pass at 2,150 feet above sea level, about 490 feet was all we could manage while observing the surrounding grandeur on this blue-sky crisp temperature day. We were only 32 miles from our hotel, as the crow flies, and a thousand years away from the reason for the expenditure of so much human effort.

About 1,077 miles south of Beijing is the city of Guiyang. This was the second city on our tour and the city reminded us of Pittsburgh nestled in this hilly country. I used my GPS on day excursions with a guided tour to an ancient village located south of Guiyang.

Primarily I employed the GPS receiver for orientation here. However, I showed some of the village children and even the mayor of the village how far they were from Guiyang and Beijing. I found the villagers to be knowledgeable about GPS, but this was the first receiver they had ever seen. Apparently, you do not need GPS to steer a water buffalo!

Shanghai, another stop on our tour, is a magnificent city is on the Huangpu River, which flows into the Yangtze River and is about 60 miles from the Pacific Ocean. It takes about two hours to drive all the way across the city without traffic.

Sea Exploration before GPS

One of my objectives in Shanghai, besides walking down glittering Nanjing Street, the famous shopping boulevard, was to visit the C.Y. Tung Maritime Museum on the campus of Shanghai Jiao Tong University. After my tour guide dropped me off at the entrance to this large campus, I turned on my GPS and entered a "go to" for the location of the museum. I was only about 900 feet away and walked directly to the building without getting lost among all of the students.

The museum has a history gallery with ship models on the first floor. In particular, the gallery contains displays of the seven ocean voyages of the Ming Dynasty admiral, Zheng He. One end of the gallery is dominated by a large model of a 400-foot long ship with six masts and a crew of 1,000 men and women.

An unusual feature of the ship design was the port and starboard masts that augmented the other four-centerline masts. The off center masts were apparently used to augment the rudder for steerage for such a large vessel.

After leaving the Maritime Museum, I backtracked my way out of the campus to Hua Shan Road. I had the previously saved the coordinates for the closest red line subway station (Xujiahui) in the GPS. The "go to" function indicated the direction, and I walked a few blocks and saw the subway signs. Five stops later, I was back at the hotel on Nanjing Road.

The last city to visit on this trip was Hong Kong. Our major use of the GPS was on our one and a half hour circumnavigation of Victoria Peak for which I had previously loaded the position of the top of the peak tram station.

GPS greatly enhanced my first trip to China – made it easier in some cases and possible in others. Because of the wide streets in all of the cities and parks, I encountered little of the "urban canyon" effect that blocks satellite signals and prevents the receiver from establishing a position fix. My brother has eight deer stands on his 60-acre property in upper New York State. Over the years I've saved all of the positions into my GPS receiver. Using GPS in China was similar to the navigating I have done in the dark as I deployed to one deer stand or another early in the morning. If you know the position of where you are and you know the position of where you want to go, implementation is only a matter of not walking into the trees.

In China, I was not navigating in the dark and there were plenty of Chinese to bump into. In addition to trip planning with the Internet and Google Earth, all we needed for a successful tour was common sense and courtesy.

Author

John McHale is retired from NAVAIRSYSCOM and the Institute for Defense Analyses and has held many offices with the Institute of Navigation. He accompanied his wife, Carolyn McHale, as her guest when she attended meetings of Women in Technology in China as a delegate with People to People.


Liao Xiaohan


Ran Chengqi


Chen Kehong

Liao emphasized the need to make Compass "compatible and interoperable with GPS and Galileo" by working to share common frequencies and avoid interference on limited GNSS bandwidth.

Meanwhile, he added, "We are working with Galileo to create synergy," he said, "We want to expand the PNT footprint."

According to several speakers, Beidou will be providing a regional service over the east Asia region by 2009 and a global service later at an indeterminate date. Beidou's open services will be offered without "entrance or authorization fees."

In the New Positioning System session, Yang reported that the CSNPC would provide an open and free ICD on its website "in the very near future," admitting, however, that the website was still under development. Compass operators have a "very detailed plan for future beyond 2009," which would be released along with a launch schedule – also "in the very near future," he said.

In tests of Beidou's signals conducted August 21–30, 2007, the CSNPC found an average 0.5 meter residual ranging error and a one-meter sequential error in the MEO satellite's orbital positions based on comparisons with satellite laser ranging to the satellite. (See Table 1 and Figure 1.) The on-board clock error was 5 nanoseconds over 3 hours, and 11 nanoseconds in the course of 24 hours.

Station	Data	Residual (m)
Shanghai	79244	0.529
Changchun	64690	0.411
Xi'an	82843	0.494
Kunming	38420	06.59
Urumqi	61612	0.443
Total	326809	0.501

TABLE 1. Compass MEO-1 residual ranging errors

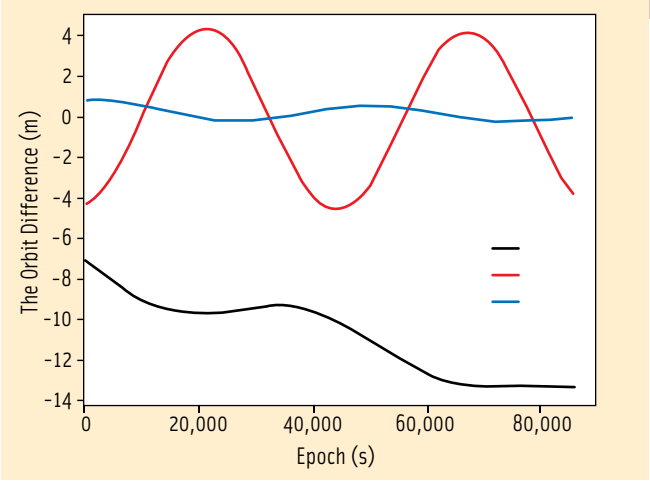


FIGURE 1 Compass MEO-1 orbit prediction errors

Industry on Parade

A well-attended exhibition accompanying the conference drew a couple of dozen Chinese and foreign companies and public agencies. These included the country's first GNSS company to issue public shares of stock (and the provider of services for the first phase of Beidou), Beijing BDStar Navigation Co., Ltd. Although organizations representing the automotive, portable navigation, and telecom sectors dominated the exhibit, Beijing UniStrong, which plans on entering the U.S. survey market, also was represented.

Underlining the Shanghai region's generally accepted status as the economic center of China, Chen Kehong, vice-chairman of the Shanghai Municipality's Science and Technology Commission, described the region's 14-station differential GPS network.

"In the future, would like to see incorporate multiple [GNSS] systems [into the DGPS network], including Beidou." Chen said that the regional government would like to see such services based on market rather than planned economy.

"The Shanghai municipal government will move Beidou into the application industry chain," he added. "We will spare no effort to implement Beidou services and technology development."

In a corresponding show of bureaucratic support for commercial development, Li Yongxiong, director general of the Department of Map Management, State Bureau of Surveying and Mapping (SBSM), described efforts to liberalize China's regulatory policies on access to data with which create navigable map databases.

Eleven companies approved by central government to product digital maps with maps currently available from six Chinese companies. These cover every city in China except two, and 95 percent of all of highways, according to Li.

Available mapbase incorporate 5 million points of interest and 1.8 million miles of highways and expressways at 1:10,000 scale. The SBSM is "working very hard on 1:2,000 scale databases in urban areas," for which the agency would like to create a system to real-time updates.

(Articles in future issues of Inside GNSS *will return to the subject of China's domestic GNSS design and manufacturing sector as well as the effect of Compass/Beidou's development on the world's other GNSS systems.)*