Beidou

China now has five navigation-and-positioning satellites, the launch of the fifth Beidou satellite took place in April. The system provides regional coverage of China and surrounds. It is named Beidou after the group of seven stars (Septentrio is Latin for ‘north') of the constellation Ursa Major, known in many cultures under different designations, in the UK ‘The Plough', ‘Big Dipper' in the US and ‘Big Mother Bear' in Russia. Others see the constellation as resembling a wagon. The first Beidou satellite (1A) was launched on 30th October 2000 followed by 1B on 20th December 2000. Since 2001 China's army and others have thus had access to a domestic satellite positioning system.

Estimate and Dual

Positioning by two satellites? Has satellite positioning with the turn of the millennium become no longer a trilateration problem for which at least three satellites are needed? From the known position of three satellites and the measured distances between them and the receiver the three coordinates of the receiver can be calculated. A fourth satellite is definitely necessary to eliminate the time bias. These are the basic principles of satellite positioning that every high-school pupil should know, and that is how GPS works. So by what magic does China make do with just two satellites? It's not magic. Beidou derives an approximation of one of the three coordinates from a digital elevation model (DEM) and eliminates time bias by dual-way transmission. Today DEMs can be accurately generated from a multitude of techniques, including InSAR, Lidar and digital photogrammetry, and are abundantly available. Time bias can be eliminated if the signal is shuttled back and forth from satellite to receiver and receiver to satellite. The satellite clock measures travel time, eliminating, most advantageously, the need for extremely accurate atomic clocks.

Iterative Positioning

How does Beidou accomplish this? Just as with GPS, each of the Chinese satellites broadcasts signals continuously. Once the user terminal has picked up signals it responds by transmitting them back to the satellite, which in turn forwards the received signals to a central control station. Here the range between terminal and satellite are inferred from travel time; principally by multiplying travel time by speed of light and dividing the result by two. From the ranges to the two satellites and an initial estimate of the elevation coordinate, perhaps taking sea level, a approximation is calculated of user's latitude and longitude. This approximate position is then used to extract an enhanced elevation from an existing DEM, which can then be used to obtain improved estimates of latitude and longitude. In the next round new time measurements are used, or the originals but now with the improved estimate of elevation. This iterative process ends with convergence, and the user receives his position within the Beijing 1954 Coordinate System, claimed accuracy of 100m and 20m when using calibration stations. Since the user terminal is not only a receiver but also communicates itself, network capacity limits to 150 the number of simultaneous users. Yet since the signals travel with the speed of light, over half a million users can be served per hour. Dual transmissions also mean a need for more space to accommodate devices, so Beidou terminals are bigger, heavier and more expensive than GPS receivers. China's army uses the two-way communication function to talk to units and monitor their position. However, two-way communication is strategically unfavourable: the enemy may also pick up processed signals and determine from them troop position and movement.

Regional Coverage

The third Beidou satellite (2A) was blasted into orbit two and a half years after launch of 1B, on 24th May 2003 to be precise. Nearly four years later, on 23rd February 2007, the fourth Beidou (3A) was put into orbit and operates as spare. The fifth Beidou, rocketed beyond earth's atmosphere on 12th April 2007, was not like the other four positioned in an approximately geostationary orbit 35,800km above earth's surface. Instead it is in an orbit of perigee 21,519km and Apogee 21,544 km. Beidou 1A is positioned north of Irian Jaya at longitude 140E, Beidou 1B south of Sri Lanka at 80E, and Beidou 2A rotates geo-synchronously with the western part of Borneo, Indonesia, at 110.5E. The advantage of geostationary satellites is ease of control. GPS is monitored by a master station at Falcon Air Force Base, Colorado Springs, USA, and remote stations in Hawaii, Ascension Island in the Southern Atlantic, Diego Garcia in the midst of the Indian Ocean and Kwajalein in the South-West Pacific. Six more National Geospatial Intelligence Agency monitoring stations were added in summer 2005. Beidou's ground segment includes the central control station and orbit-tracking stations at Jamushi, Kashi and Zhanjiang. However, the price paid for a system comprising so few satellites and limited ground control is regional coverage.

Compass

Regional coverage would seem to constitute something of a disgrace in the eyes of China's leaders, who want a doubling in Gross Domestic Product (GDP) this decade. They thus wish gradually to extend Beidou to become a real global satellite navigation system (GNSS), referred to as the Compass Navigation Satellite System. Ultimately scheduled for 2008, but definitely for 2010, the constellation will comprise five geostationary satellites and thirty medium-orbit satellites intended to provide positions with 10m accuracy, using, like GPS, the principle of trilateration.