GNSS INTRODUCTION

and Location Technology overview

GNSS Group: Zhicheng Li

2014-8-4

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

Agenda

Innovation changes the future

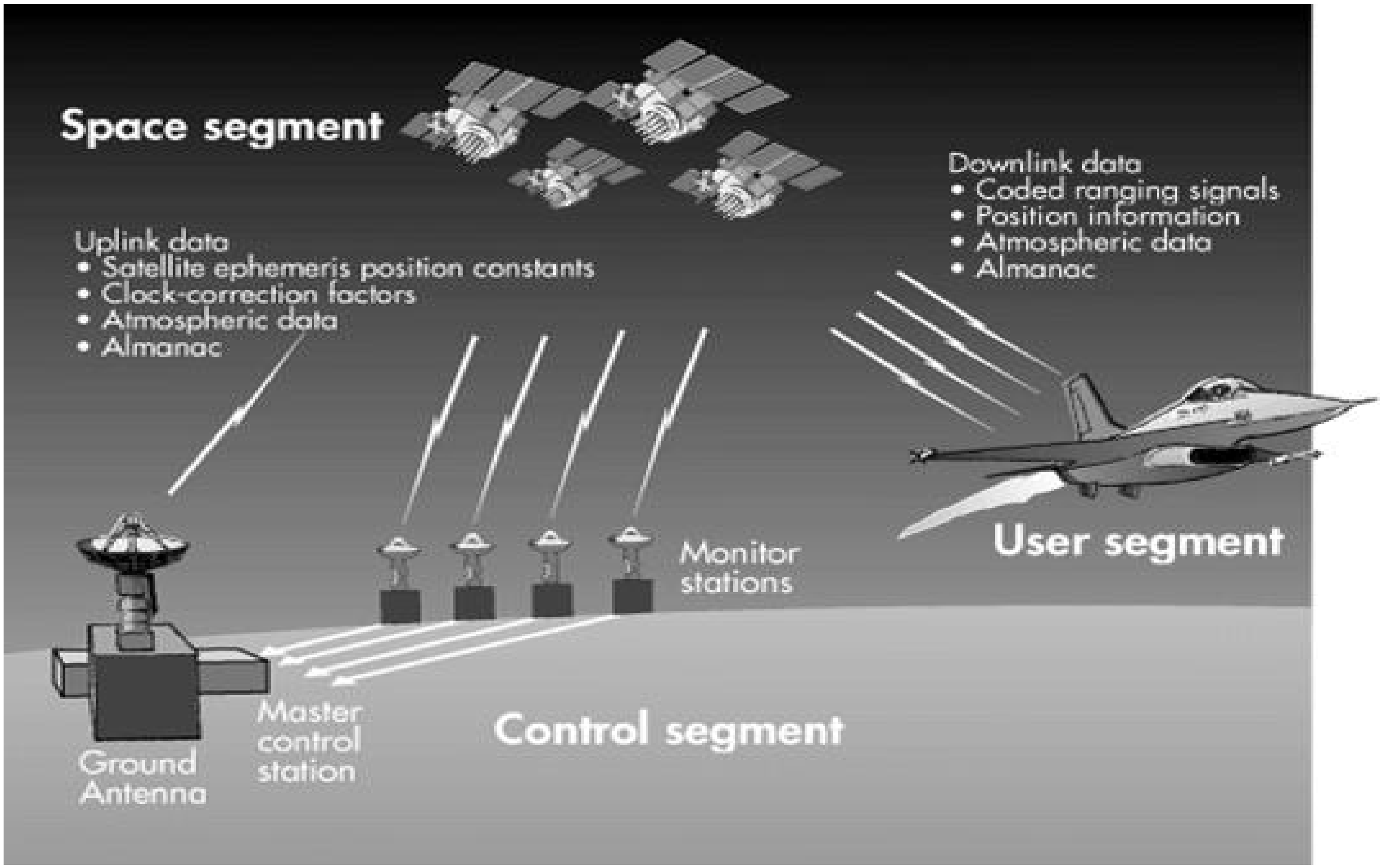
- Ø Section1: Understanding GNSS
- Ø Section2: GNSS Augmentation
- Ø Section3: GNSS Aiding
- Ø Section4: Location Based Service(LBS)
- Ø Section5: Indoor Positioning

Understanding GNSS

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

- GPS
- GLONASS (Russia)
- BDS (China)
- GALILEO (E.U)
- QZSS (Japan, regional)
- Navigation Conception

GPS System Segment

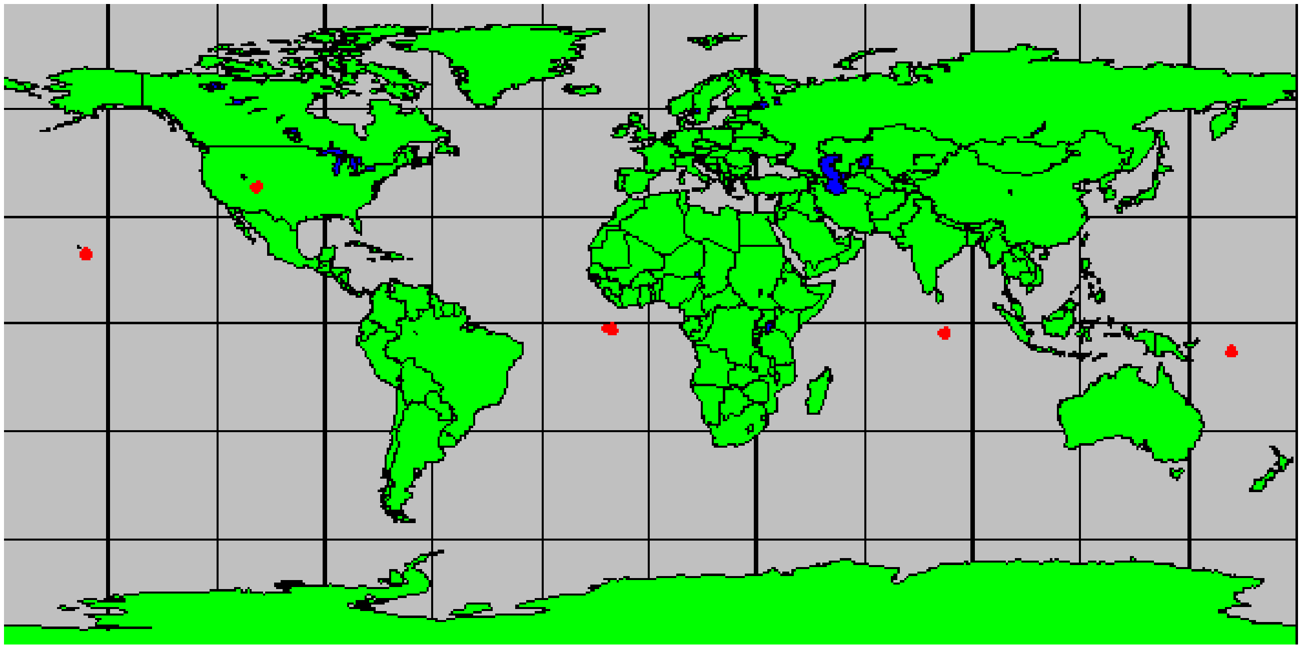


GPS Navigation Conception

System Segments:

- Control Segment
  - Master Control Station and Backup
  - Monitoring and Uplink Stations
- Space Segment
  - 27 to 32 Satellites
- User Segment
  - No Organization – Consists of all receivers
  - User Segment is Passive – Receive Only

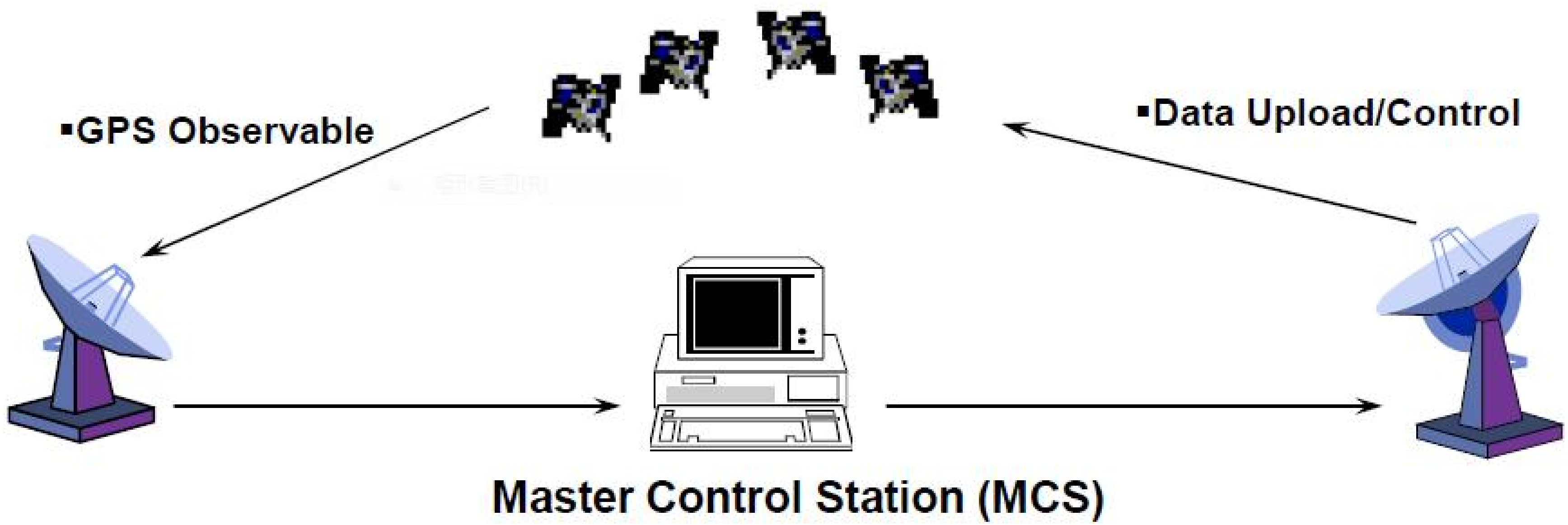
GPS Control Segment



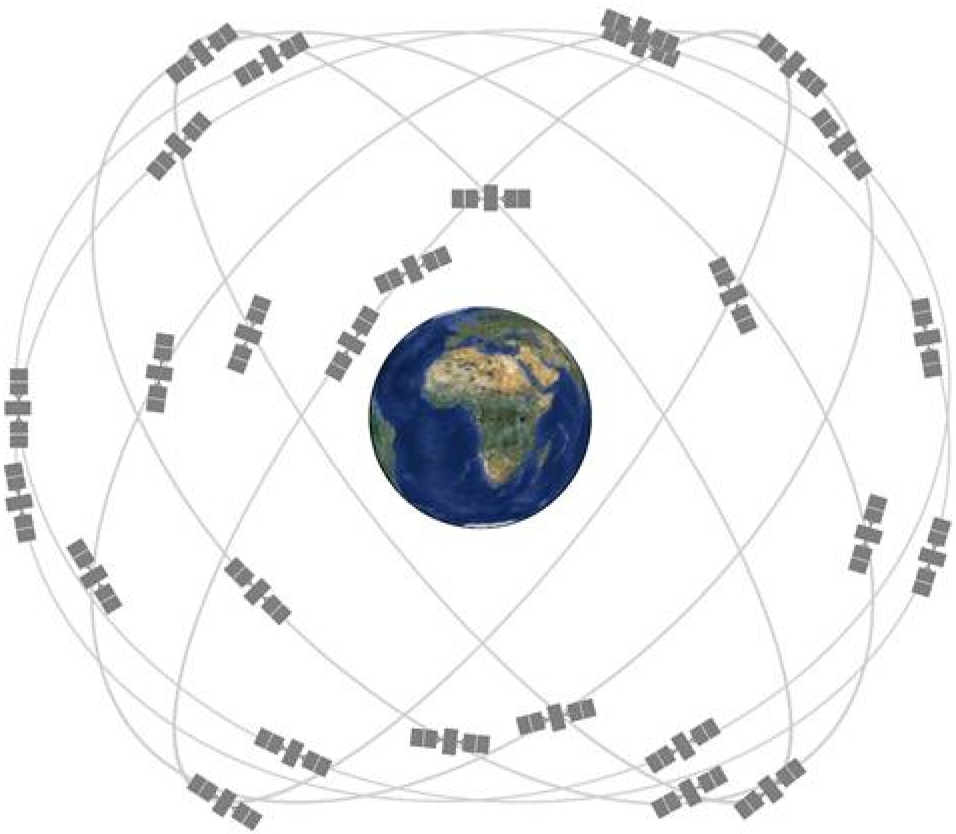
Control Segment

Master Control Station: Schreiver AFB, Colorado Springs, Colorado
Backup: Moffet AFB, Sunnyvale, California
Monitor sites: Ascension Island*, Diego Garcia*, Kwajalein*, Hawaii
* These sites can upload data to the satellites

GPS Control Segment



GPS Space Segment



- Altitude 20,200 km
- Six orbital planes
- 24 satellites + 3 to 8 active spares
- Worldwide coverage

GPS User Segment

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Anyone or Anything Requiring Location or Timing Information

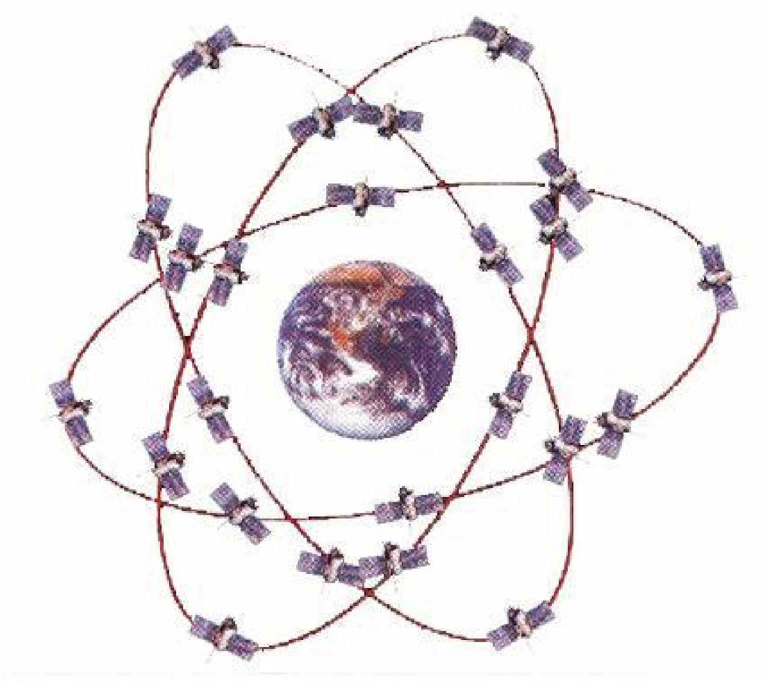
Other GNSS Systems

GLONASS

- 24 SVs (full constellation), set healthy on December 8, 2011
- 3 orbital planes, spaced 120º apart, inclined 64.8º with up to 8 SVs per plane
- Orbital period ~11 hours, 15 minutes
- Like original GPS, GLONASS is considered a first generation GNSS
- FDMA
  - L1 Center frequency = 1602 MHz   L2 Center frequency = 1246 MHz
  - Frequencies are 562.5 kHz offset in L1, 437.5 kHz in L2

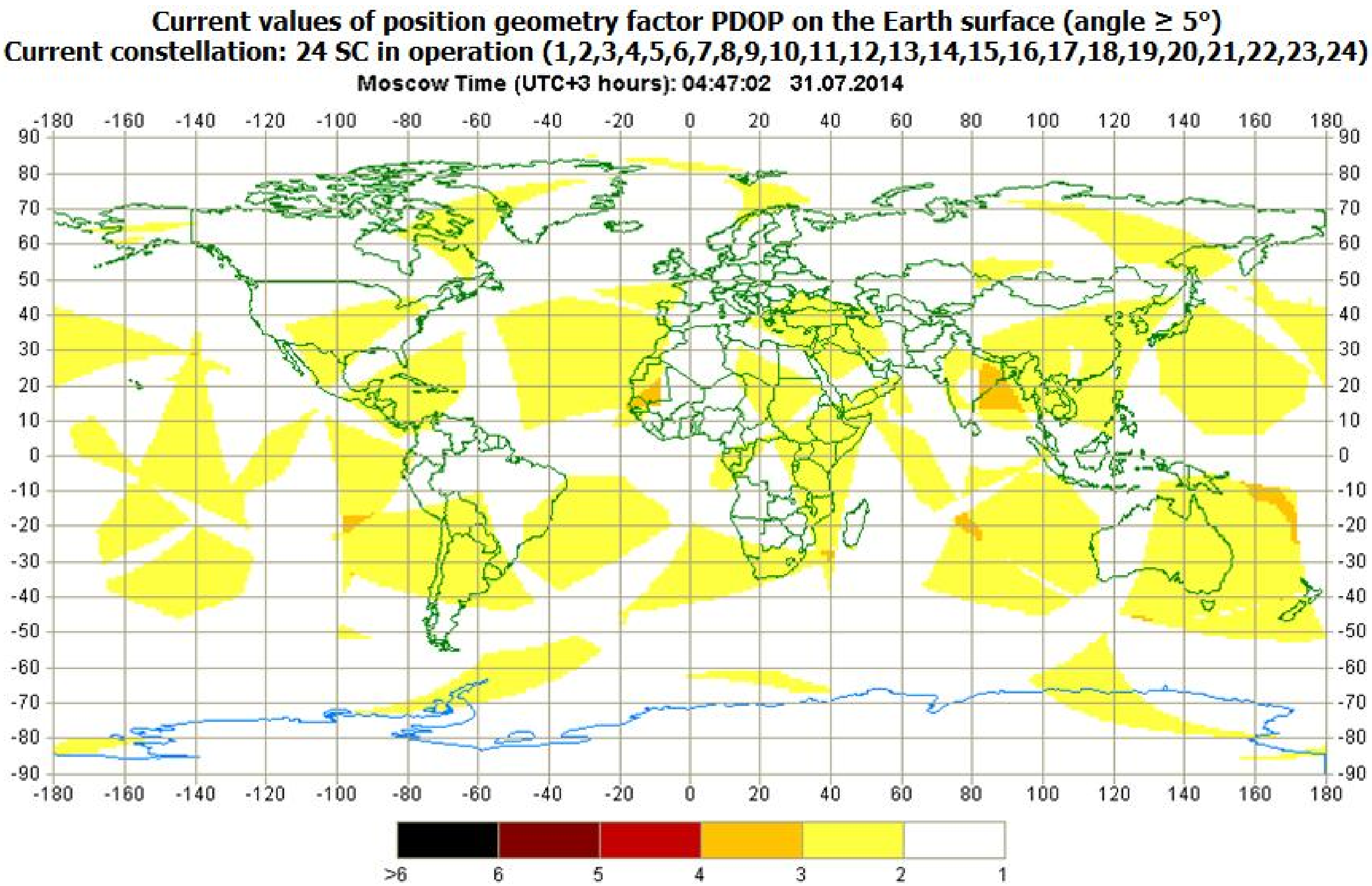
Constellation Status

Total satellites in constellation	29 SC
Operational	24 SC
In commissioning phase	1 SC
In maintenance	-
Under check by the Satellite Prime Contractor	1 SC
Spares	2 SC
In flight tests phase	1 SC



GLONASS constellation

GLONASS Availability



GLONASS Accuracy

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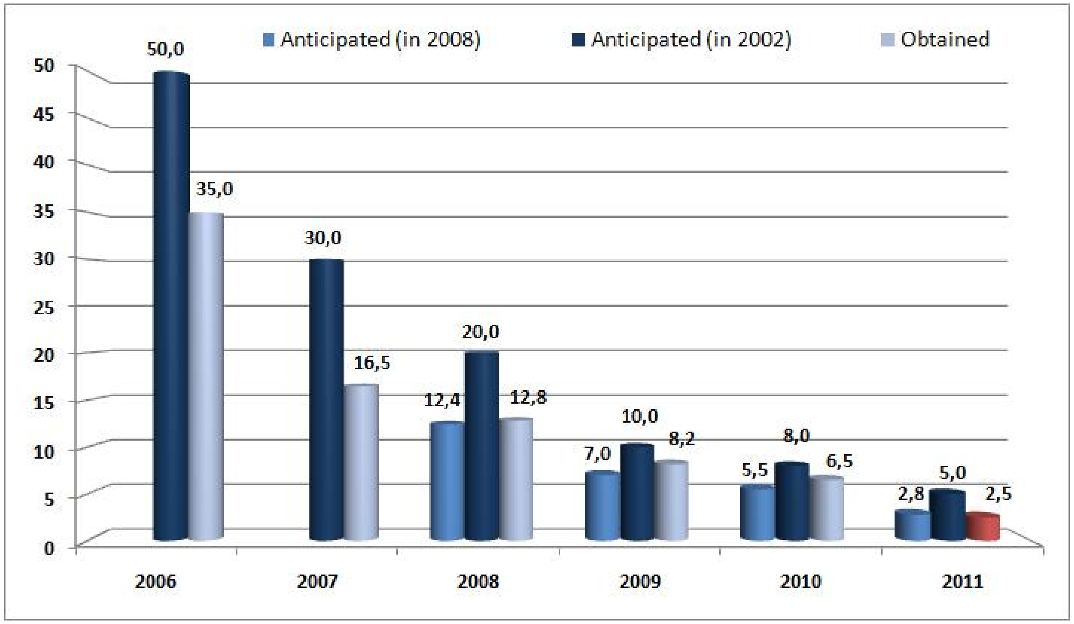

BDS

- 35 SVs (full constellation,2020), currently 5 GEO, 5 IGSO and 4 MEO
- Nominal frequency of B1I signal is 1561.098MHz

BDS Development Roadmap

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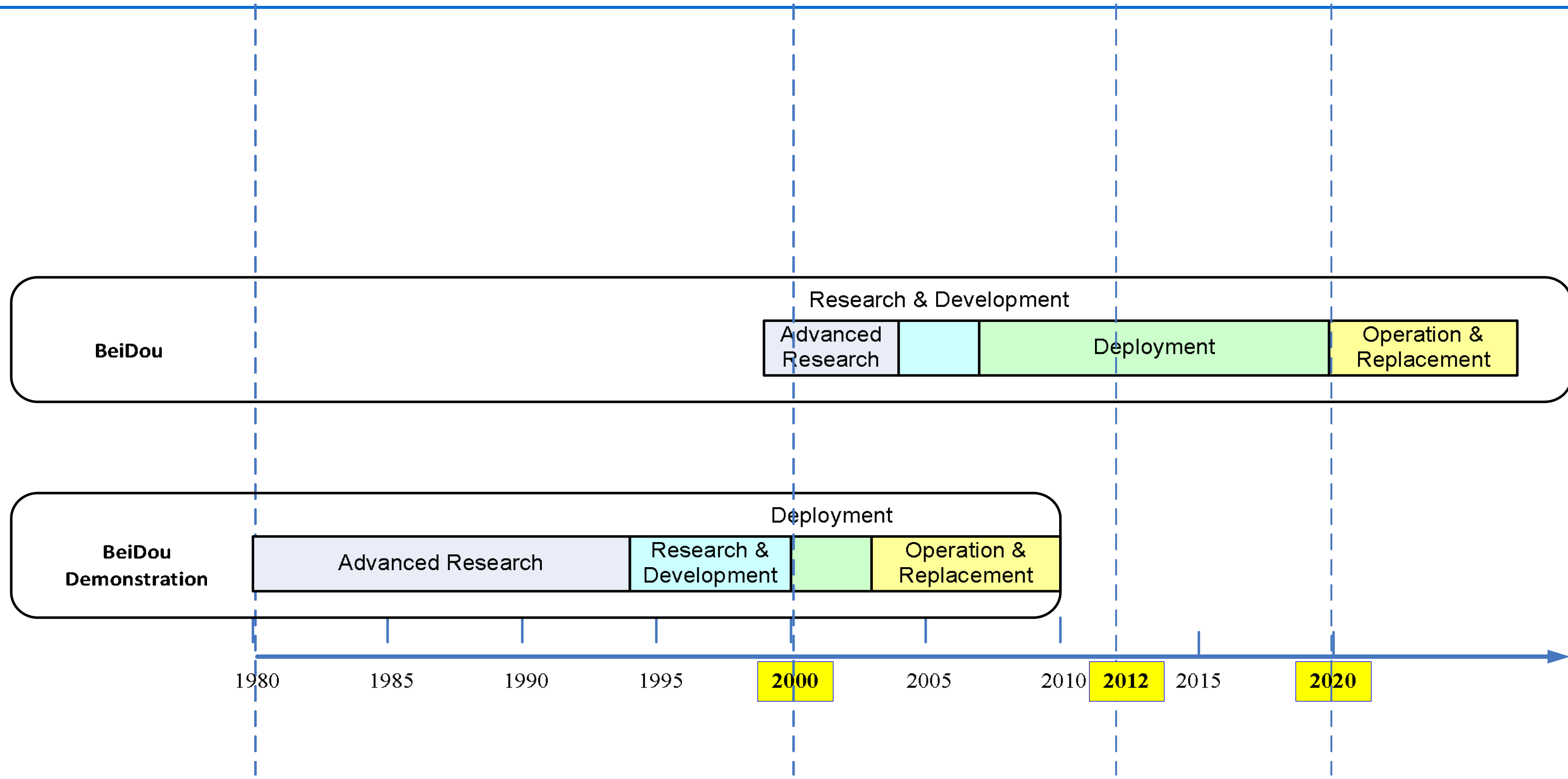

*BeiDou-Demonstration ——BeiDou Navigation Demonstration System
BeiDou——BeiDou Navigation Satellite System

Services and Performance

The system can provide four types of services, including authorized service, open service, wide range differential service and position report service.

authorized service	
open service	
wide range differential service	
position report service	

positioning accuracy <10m
timing accuracy <20ns
velocity accuracy <0.2m/s

BDS Coverage

BeiDou will gradually extend from China to the Asia-Pacific region, and further extend to all over the world by 2020.

Galileo

- Contains a total of 30 satellites; 27 are operational
- 3 spare satellites
- Satellites are in 3 different planes, equally spaced around the plane.
- Altitude = 23, 600 km
- Satellites are in Medium Earth Orbit (MEO)

Galileo Constellation

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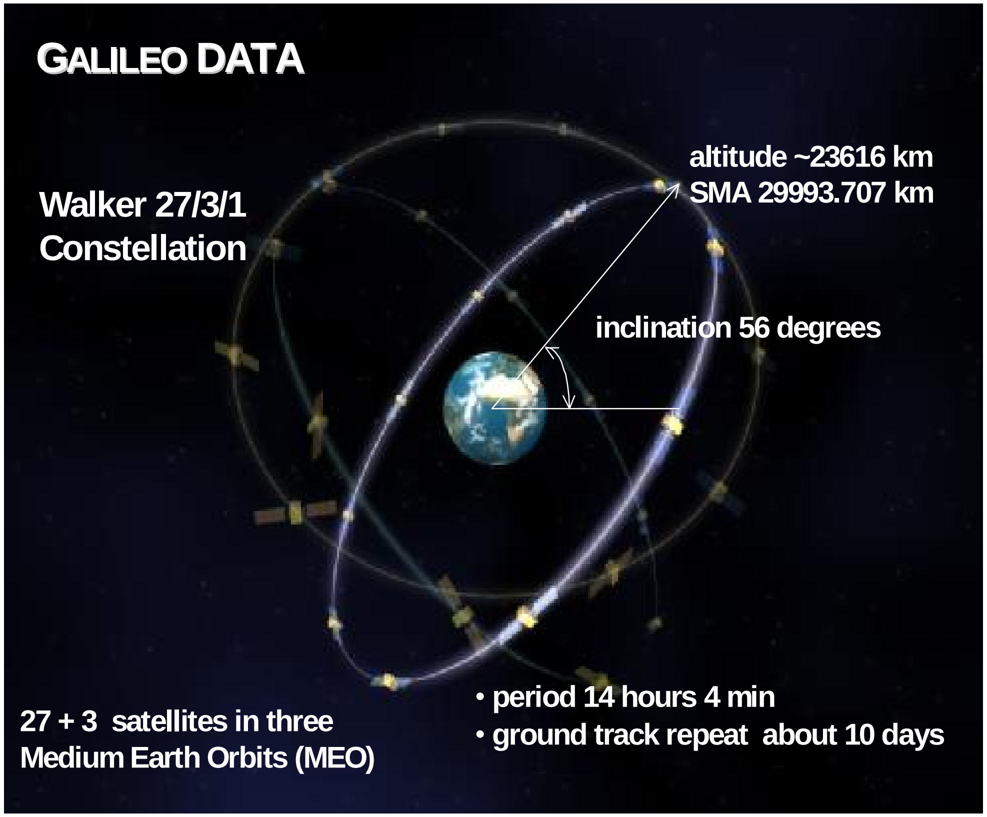
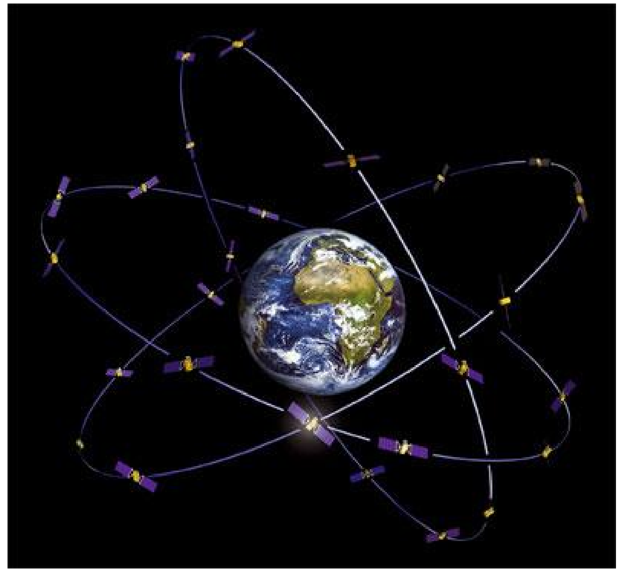
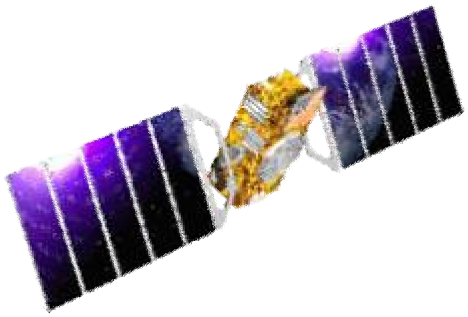


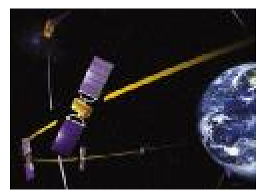


Galileo Implementation Plan



Full Operational Capability
27 (+3) Galileo satellites
2013

In-Orbit Validation
4 IOV satellites plus
ground segment
2010



Galileo System Testbed v2
2 initial test satellites

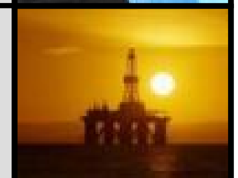
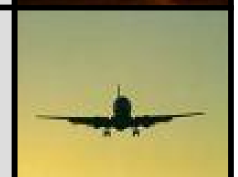
2005

GALILEO
GIOVE

Galileo System Testbed v1
Validation of critical algorithms

2003

Galileo Services

Open Service	Free to air; Mass market; Simple positioning	
Commercial Service	Encrypted; High accuracy; Guaranteed service	
Safety of Life Service	Open Service + Integrity and Authentication of signal	
Public Regulated Service	Encrypted; Integrity; Continuous availability	
Search and Rescue Service	Near real-time; Precise; Return link feasible	

Galileo Performance Requirements (Dual Frequency)

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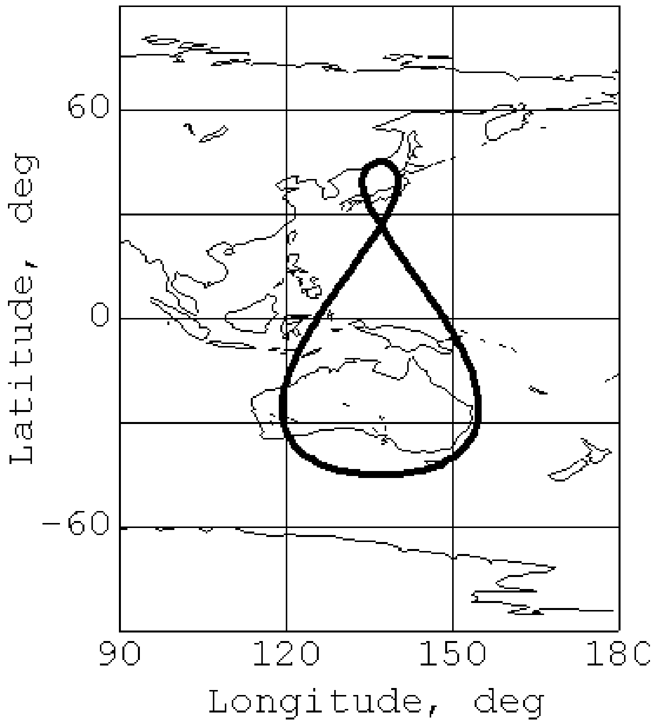
Service	Horizontal Accuracy (95%) (incl. system margins)	Vertical Accuracy (95%) (incl. system margins)	Availability for global coverage	Integrity
Open Service	4 m	8 m	> 99.5%	NO
Commercial Service	Detailed performance requirements under elaboration			
Safety of Life Service	4 m	8 m	> 99.5%	YES (LPV200)
Public Regulated Service	4 m	8 m	> 99.5%	YES

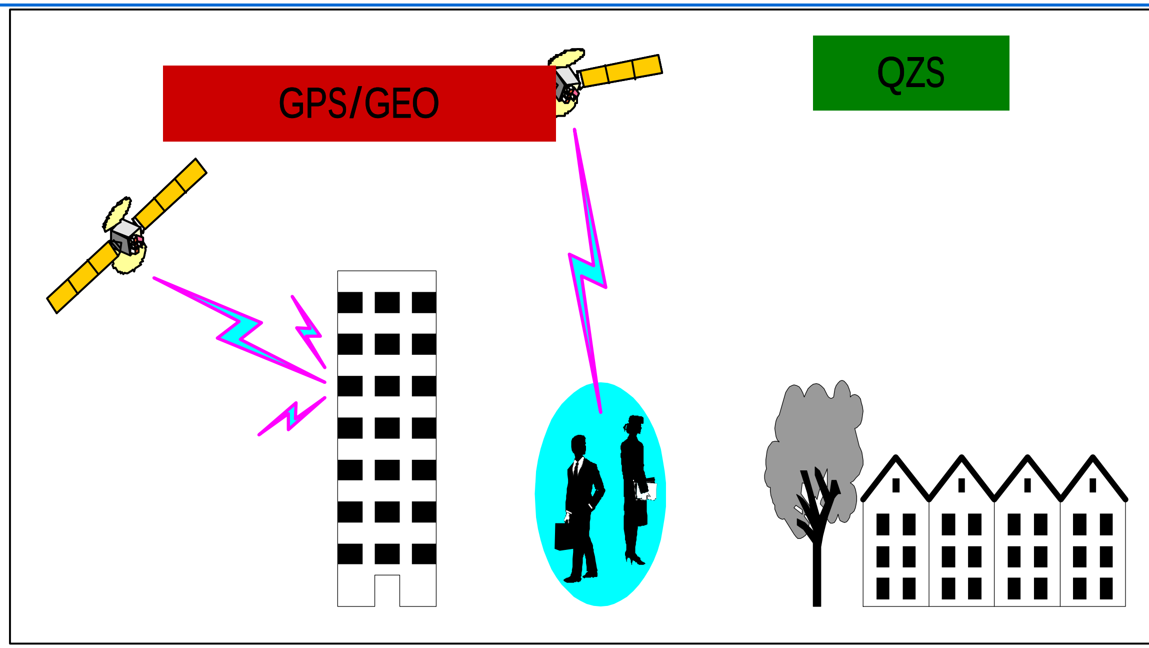
QZSS

Innovation changes the future

- Regional navigation service broadcast from high-elevation angle by three satellites on the inclined geosynchronous (quasi-zenith) orbit;
- Broadcast GPS-compatible supplemental signals on three frequencies and two augmentation signals, L1-SAIF and LEX;
- The first QZS satellite successfully launched on Sept. 11, 2010.

QZSS Concept





- Footprint of QZS orbit;
- Centered 137E;
- Eccentricity 0.1, Inclination 45deg.

- Broadcast signal from high elevation angle;
- Applicable to navigation services for mountain area and urban canyon;
- Augmentation signal from the zenith could help users to acquire other GPS satellites all the time.

Combining Multiple GNSS - Advantages

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- Number of Satellites Available Increases
- Improves DOP
- Increases likelihood of finding a signal with partial blockages
- Increases Integrity
- Less likely to be affected by 1 bad SV
- Systems are no longer subject to one control system
- Shorten TTFF

Navigation Conception

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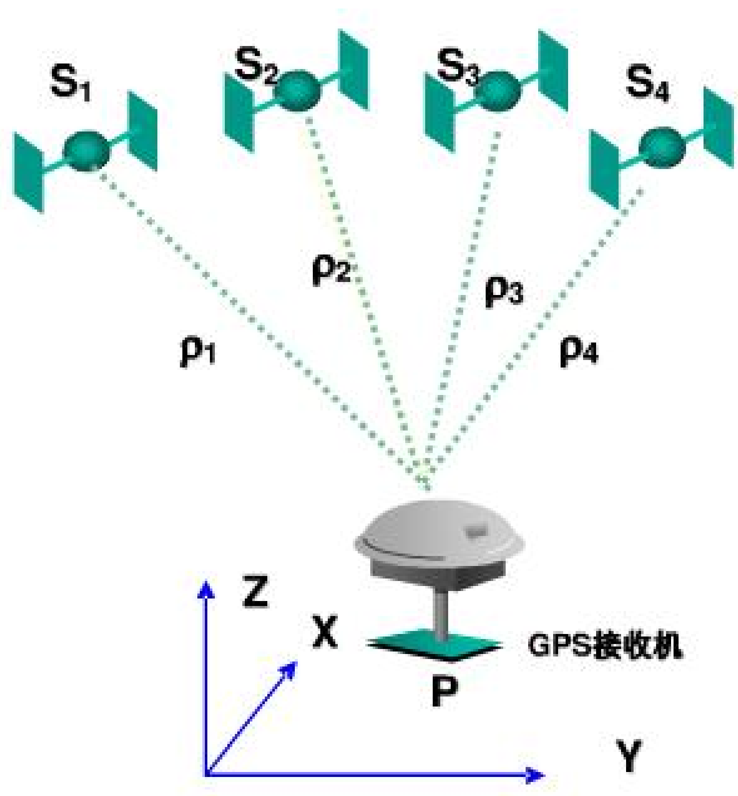
- To make a fix, a receiver must:
  - Find satellite signals and lock onto them
  - Get the ephemeris for each satellite
  - Measure the pseudorange to each satellite
  - Determine the precise time
  - Solve the navigation equations

- The time this takes, called Time To First Fix (TTFF) depends on how long each step takes

GPS Positioning Methodology



- Ø Navigation Message Contains SV Position With Respect to Time
- Ø Receiver Computes Relative Time of Receipt of Signals
- Ø Solving 4 Simultaneous Equations Gives Receiver's Position and tR, the Time Offset

$$(X - x_1)^2 + (Y - y_1)^2 + (Z - z_1)^2 = [(\rho_1 + CB) \cdot c]^2$$
$$(X - x_2)^2 + (Y - y_2)^2 + (Z - z_2)^2 = [(\rho_2 + CB) \cdot c]^2$$
$$(X - x_3)^2 + (Y - y_3)^2 + (Z - z_3)^2 = [(\rho_3 + CB) \cdot c]^2$$
$$(X - x_4)^2 + (Y - y_4)^2 + (Z - z_4)^2 = [(\rho_4 + CB) \cdot c]^2$$

Where: (XYZ) = receiver's position

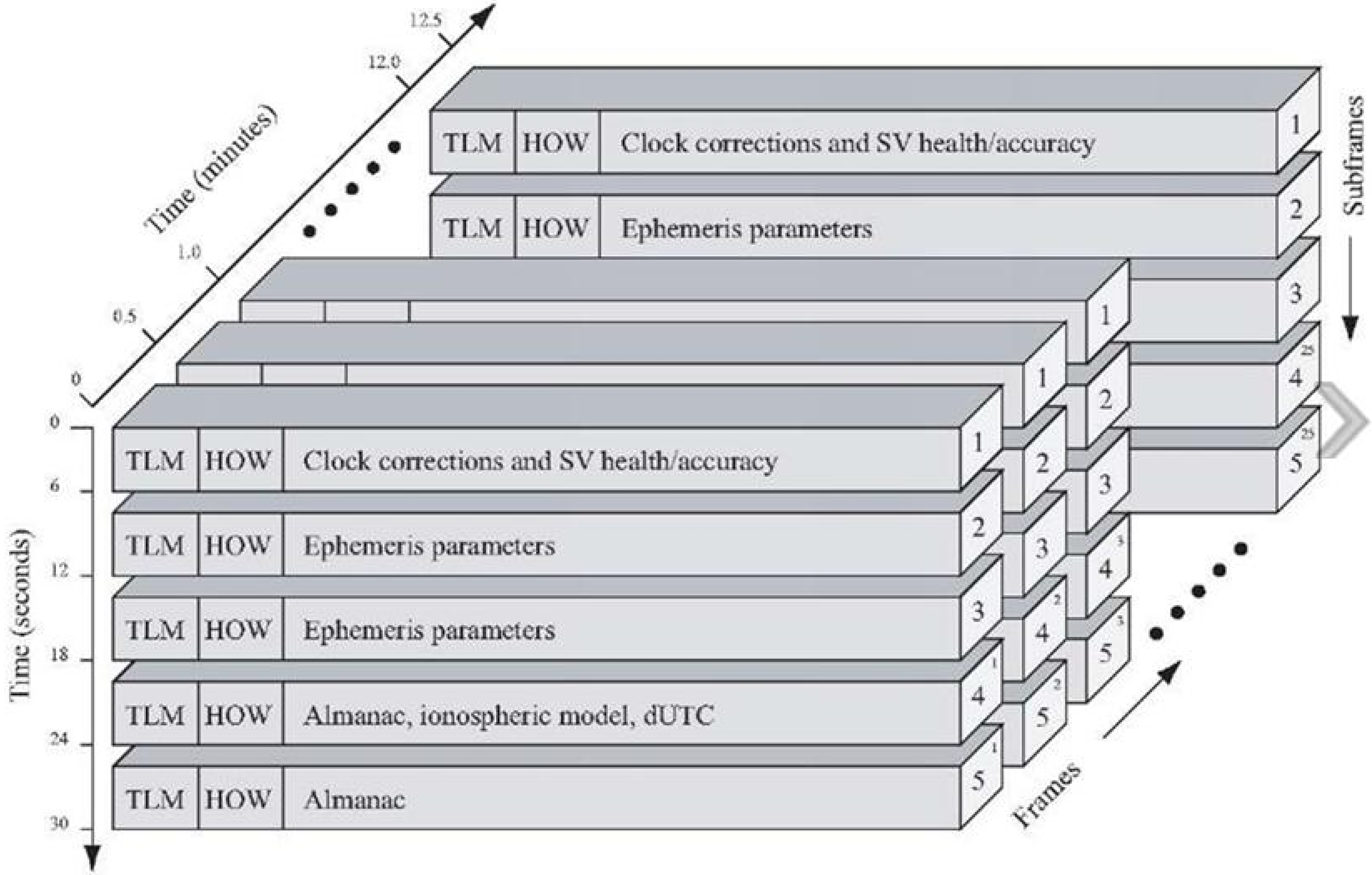
$(x_i y_i z_i)$ = position of SV_i calculated from ephemeris

ρ_i = pseudorange measurement to SV_i

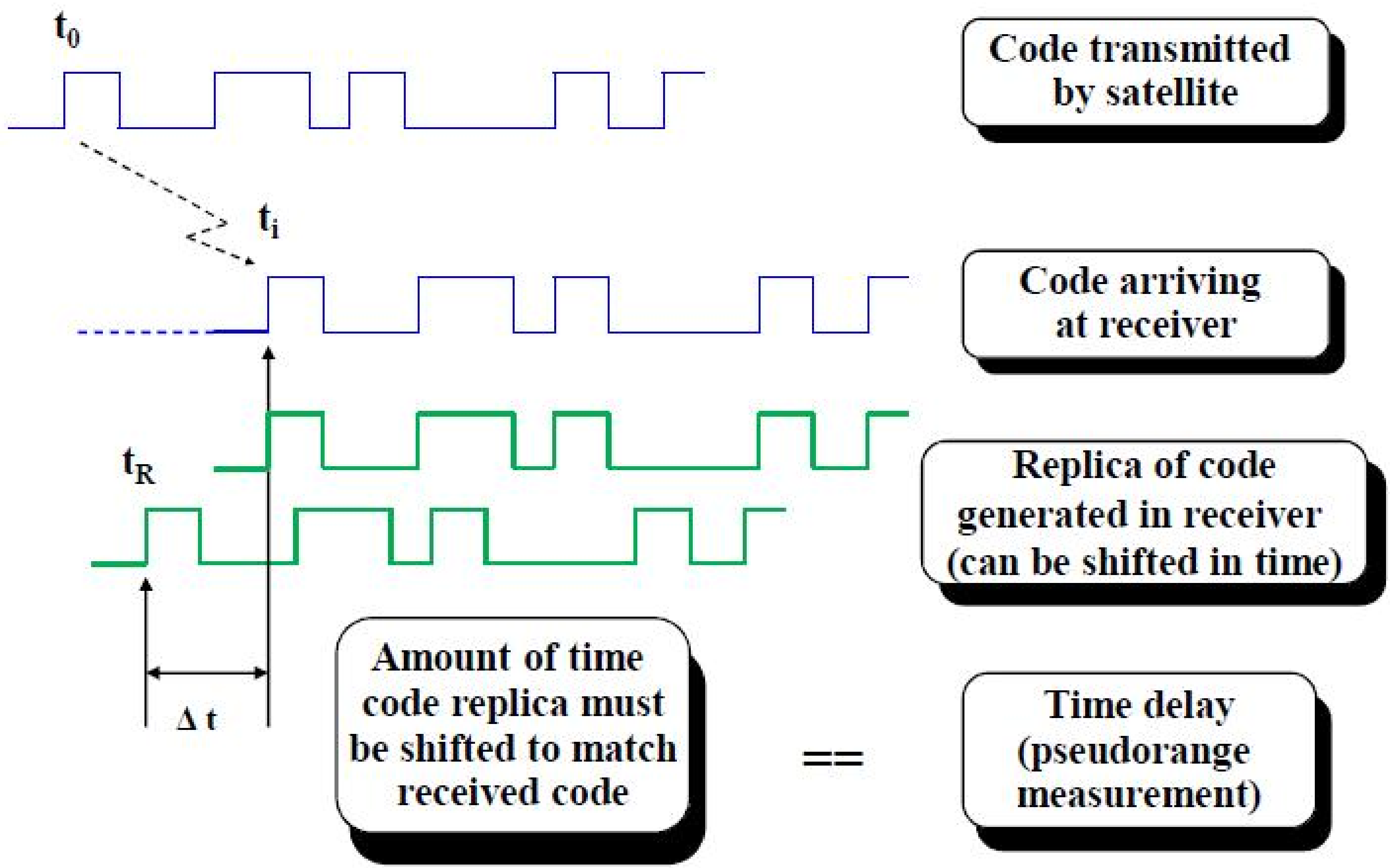
CB = Clock Bias ($t_R - t_0$, error in Rcvr Clk)

c = speed of light, 299,792,458 m/s

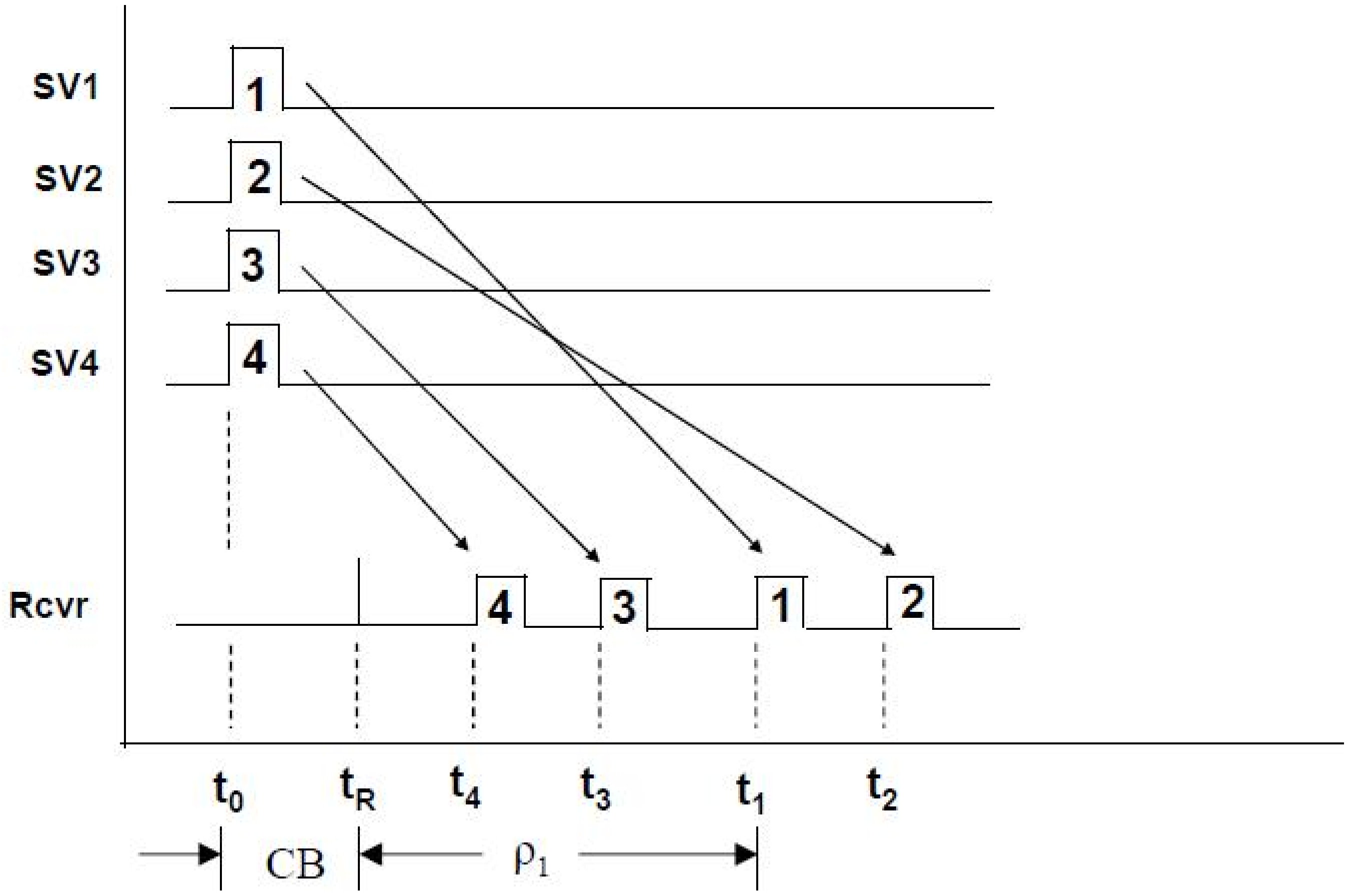
GPS Frame Structure



Pseudorange Measurements



Pseudorange



GPS Error Source

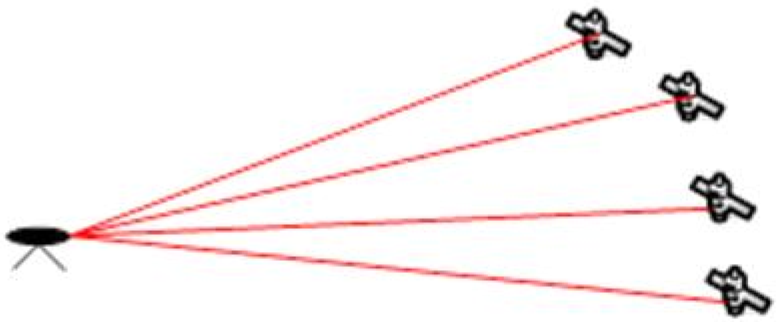
- Satellite Clock Error
- SV Ephemeris Error
- Ionospheric Refraction
- Tropospheric Refraction
- Receiver Noise
- Multipath
- Dilution Precision

Note: Earth Rotation Effect should be take into consideration

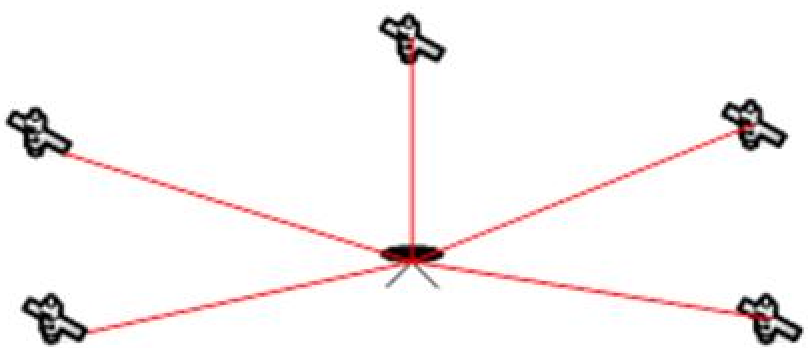
Satellite Geometry and Dilution of Precision (DOP)

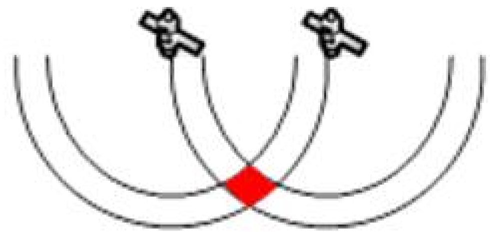
Acronym	Type	Position Component(s)
GDOP	Geometrical	3D Position and Time
PDOP	Position	3D Position
TDOP	Time	Time
HDOP	Horizontal	2D Horizontal Position
VDOP	Vertical	1D Height

Poor GDOP

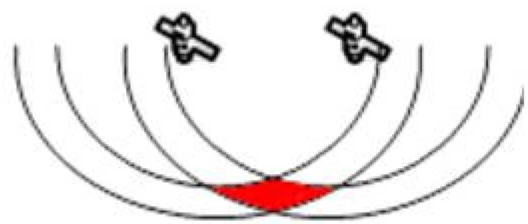


Good GDOP





Well spaced satellites- low uncertainty of position



Poorly spaced satellites – high uncertainty of position

Geometry in 2-D (GPS Basics, 2000)

Accuracv Estimation

Dimension	Measure	% Probability	Typical Usage	Definition
1	RMS	68	Vertical	Square root of the average of the squared errors
2	CEP	50	Horizontal	Radius of a circle centered at the true location which encloses 50 % of the measured points
2	RMS	63 – 68	Horizontal	Square root of the average of the squared errors
2	2dRMS	95 – 98	Horizontal	Twice the RMS of the horizontal errors
3	SEP	50	3-D	Radius of a sphere centered at the true location which encloses 50 % of the measured points
3	RMS	61 – 68	3-D	Square root of the average of the squared errors

GPS Performance Index

- TTFF
- Accuracy

Question:

- How to Shorten TTFF
- How to Improve Accuracy?

Agenda

Innovation changes the future

- Section1: Understanding GNSS
- Section2: GNSS Augmentation
- Section3: GNSS Aiding
- Section4: Location Based Service(LBS)
- Section5: Indoor Positioning

GNSS Augmentation

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

GNSS Augmentation

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- GPS needs "augment" to remove errors and add availability and integrity

- Two basic concepts –

  Space based Augmentation System (SBAS)

  Ground based Augmentation System (GBAS)

SBAS

–Designed to identify and correct for specific errors, *valid over wide area*:

- Satellite Clock
- Satellite Ephemeris
- Ionosphere

Operational Overview

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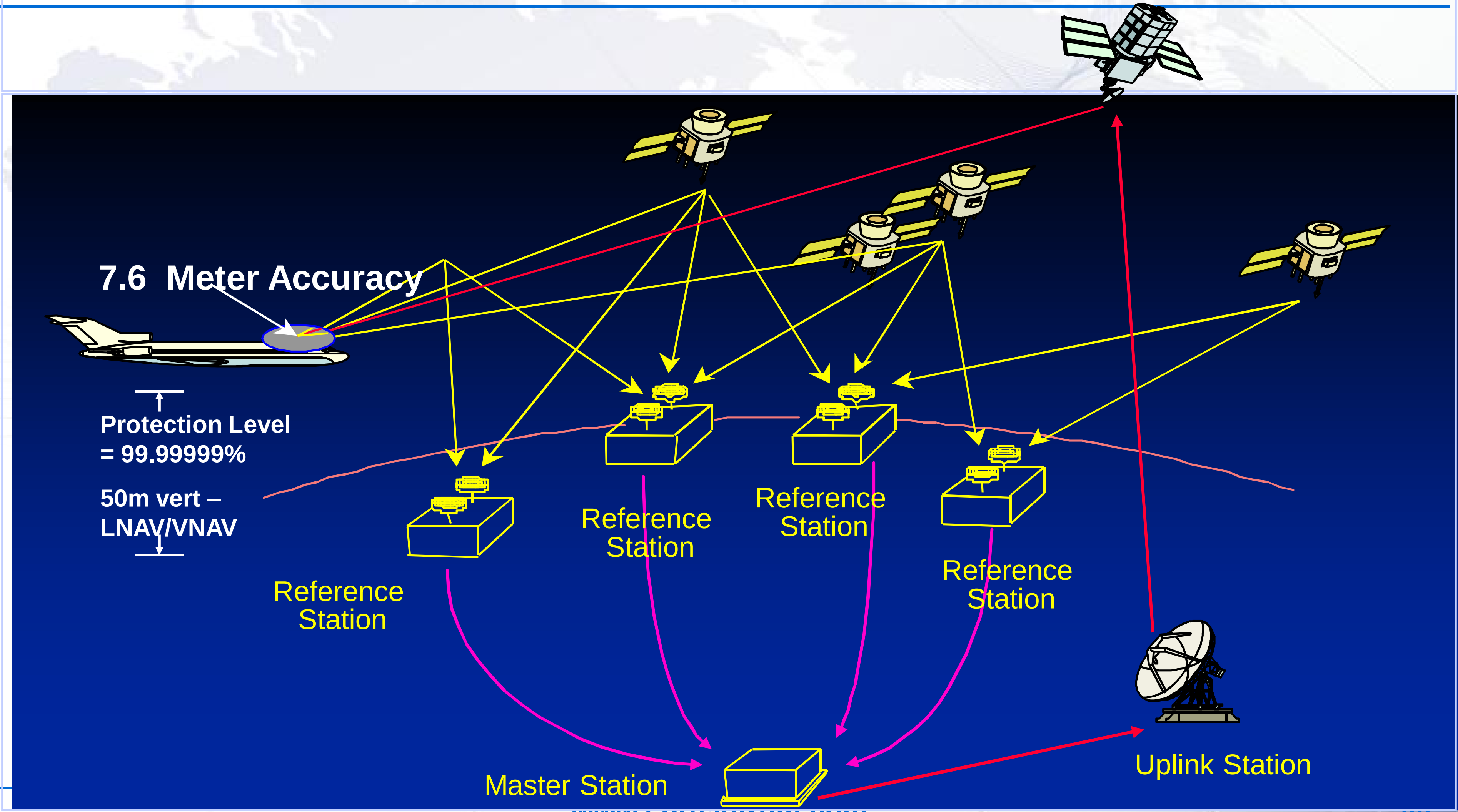

SBAS

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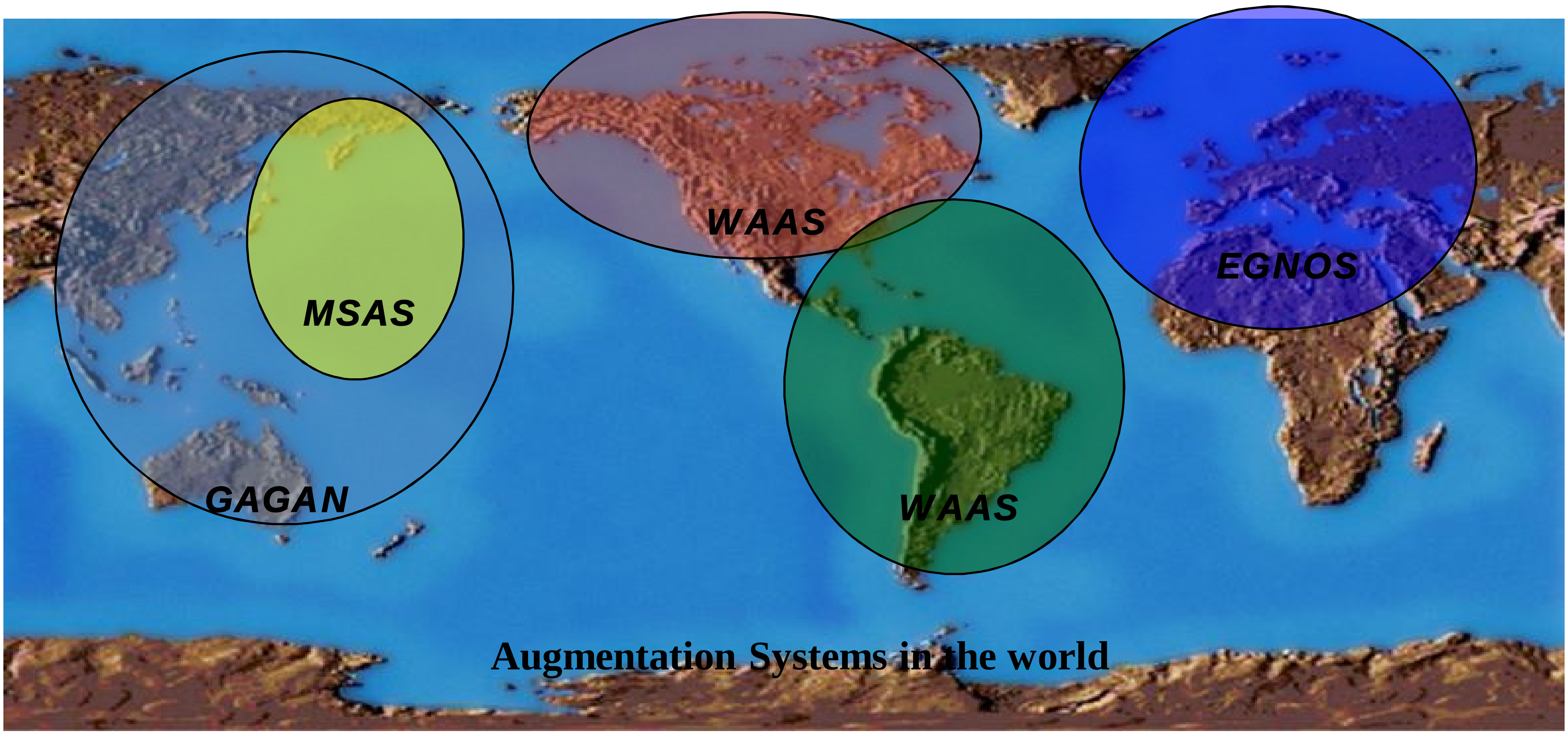
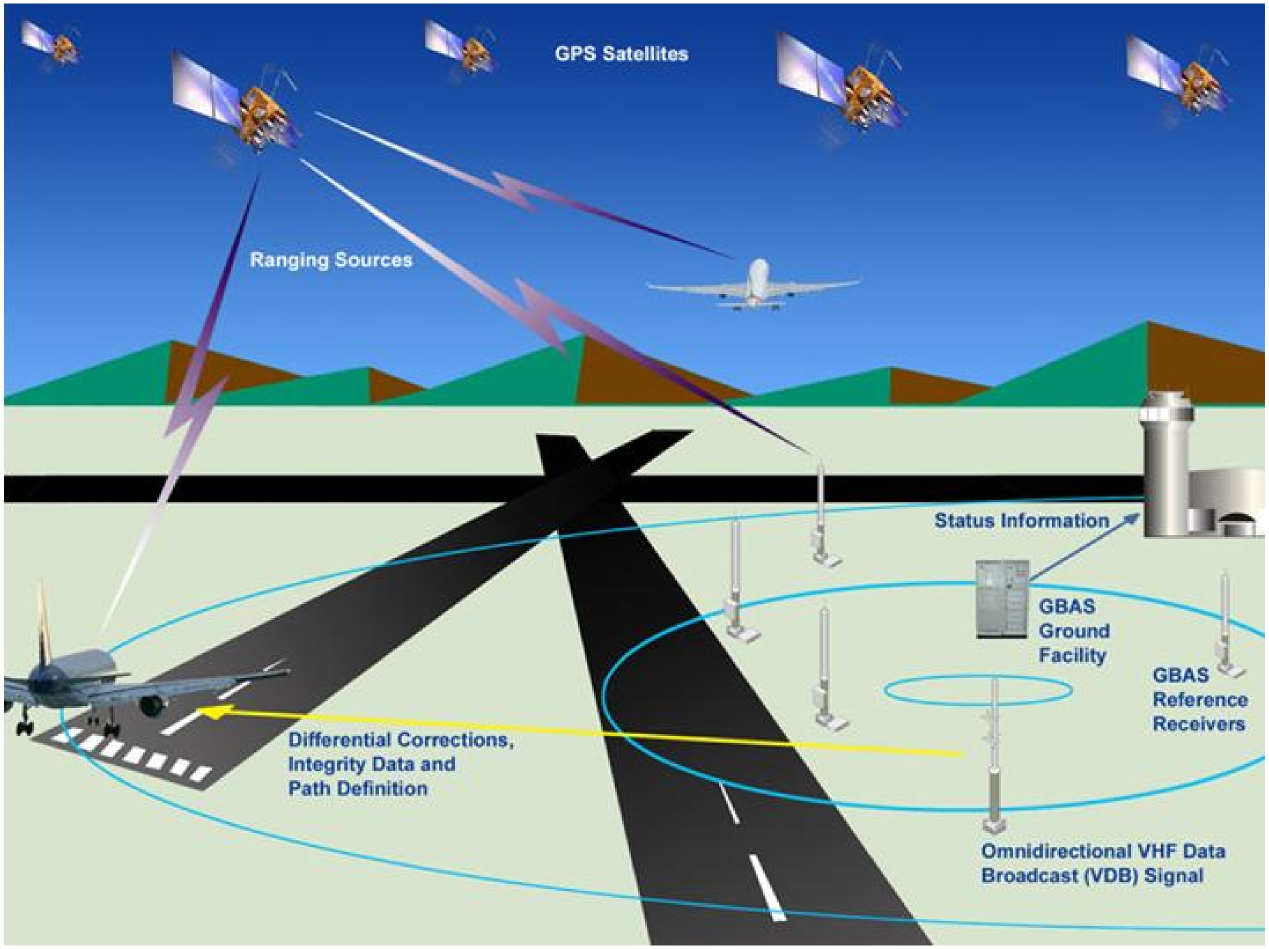


GBAS

- Ground-Based Augmentation System (GBAS) is a system that provides differential corrections and integrity monitoring of Global Navigation Satellite Systems (GNSS). -DGPS

GBAS Architecture



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GNSS Aiding

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

Aiding Source

Innovation changes the future

- AGPS
- Predicted Ephemeris
- DR

AGPS

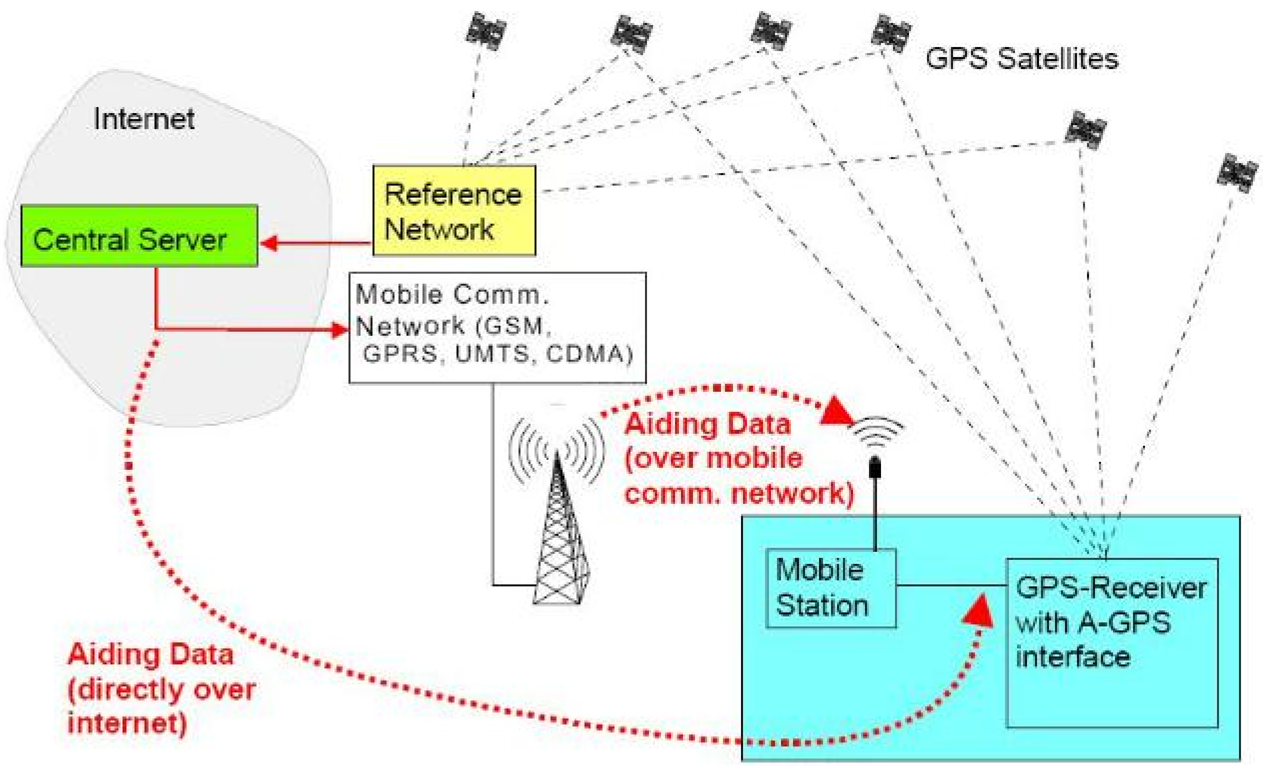
Innovation changes the future

- What is AGPS?

  Assisted GPS (abbreviated generally as A-GPS and less commonly as aGPS) is a system that can:

- Ø Improve the startup performance or time-to-first-fix (TTFF)
- Ø Improve the Sensitivity
- Ø It is used extensively with GPS-capable cellular phones, as its development was accelerated by the U.S. FCC's 911 requirement to make the location of a cell phone available to emergency call dispatchers

AGPS System



GPS Satellites
Internet
Central Server
Reference Network
Mobile Comm. Network (GSM, GPRS, UMTS, CDMA)
Aiding Data (over mobile comm. network)
Mobile Station
GPS-Receiver with A-GPS interface
Aiding Data (directly over internet)

How AGPS shorten the TTFF performance

Spreadtrum
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- Ephemeris
  - No need ephemeris download, saving 18s+ at lest.
- Almanac
- Coarse position
- Time
- Doppler

From the above information, we could:

- Know which satellite in view
- Narrow satellite search range (frequency and Doppler)

AGPS Assistance Type

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- Mobile Station Based (MSB): Information used to acquire satellites more quickly
- Mobile Station Assisted (MSA): Calculation of position by the server using information from the GPS receiver
  - The device captures a snapshot of the GPS signal, with approximate time, for the server to later process into a position.
  - Iono Correction

AGPS **Standards**

Innovation changes the future

- Control Plane

  ü RRLP – 3gpp defined RRLP or Radio resource location protocol to support positioning protocol on GSM networks.

  ü TIA 801 – CDMA2000 family defined this protocol for CDMA 2000 networks.

  ü RRC position protocol – 3gpp defined this protocol as part of the RRC standard for UMTS network.

  ü LPP – 3gpp defined LPP or LTE positioning protocol for LTE Networks.

- User Plane Protocol

  SUPL V1.0

  SUPL V2.0

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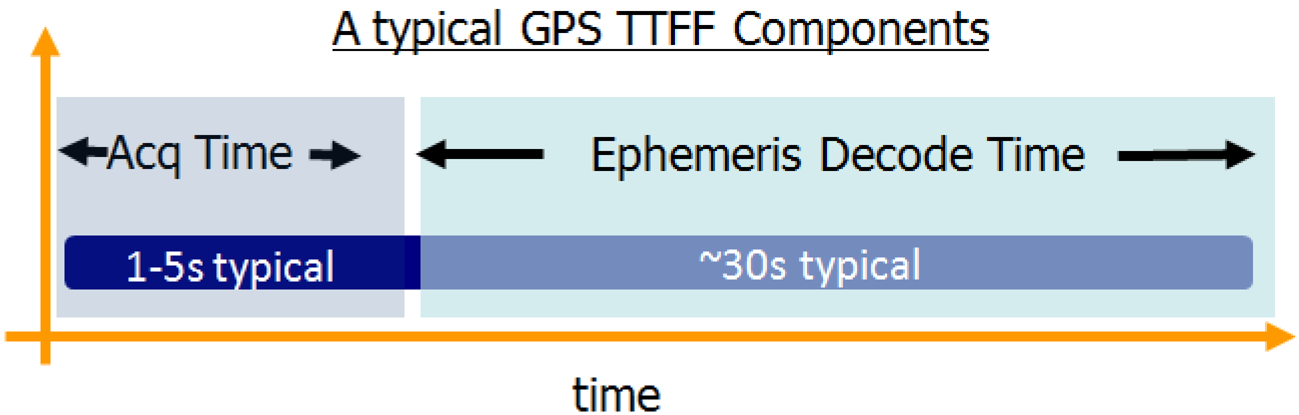
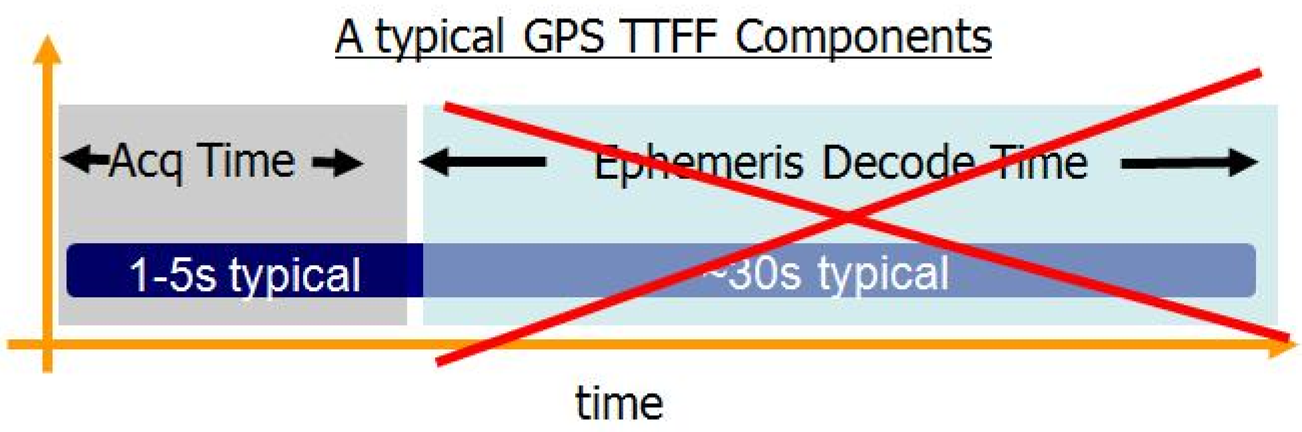
- Components of TTFF



GPS TTFF (warm and cold starts) consist of:

1. Acquisition time: Time required to acquire individual satellites
2. Navigation data (Ephemeris) download time: Time required to download navigation data from at least 3-4 satellites
   - Decoding of the navigation data from the satellite data stream

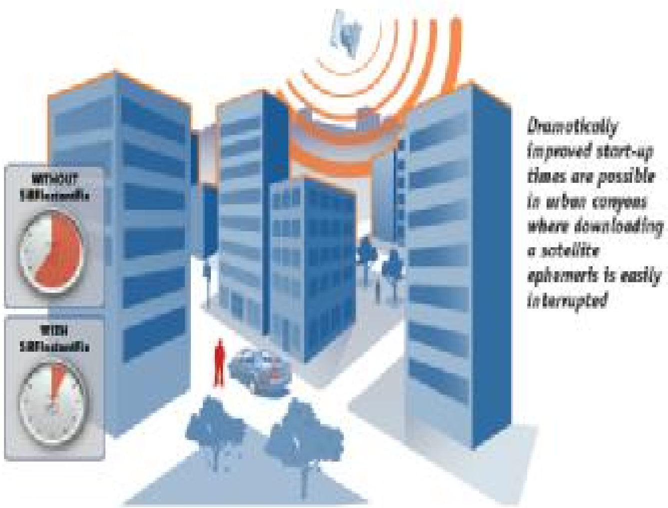
- Benefit of Predicted Ephemeris

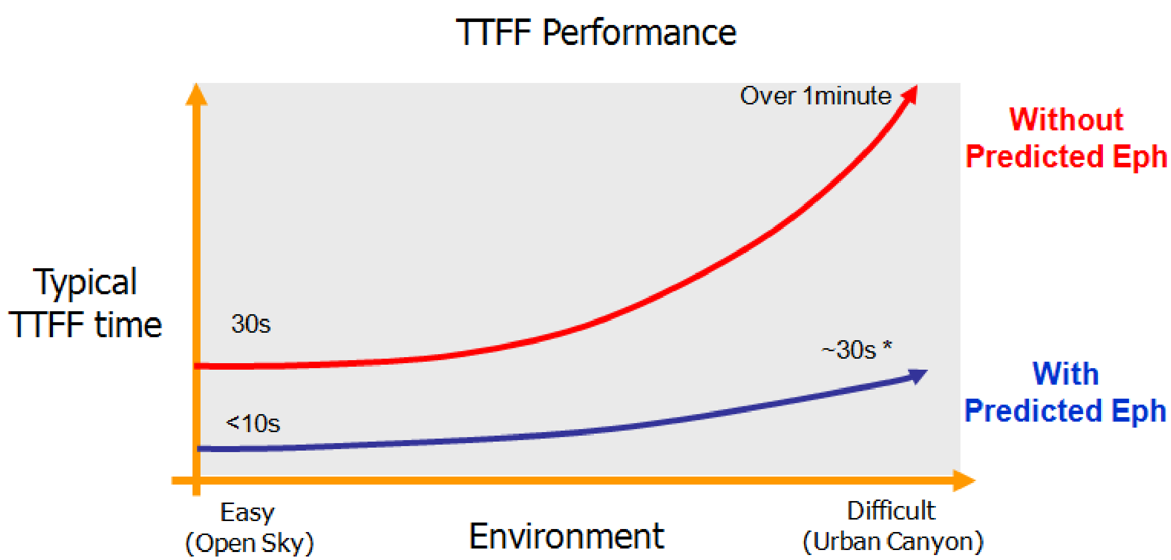


Predicted Ephemeris eliminates the need for the ephemeris download to achieve a fix:

- The receiver is able to acquire a fix much more quickly

Typical Results





Predicted Ephemeris Types

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- Client Based

Download broadcast ephemeris:

  - ü Received from GPS signal or
  - ü Received from aiding

Typically 3~7 days prediction

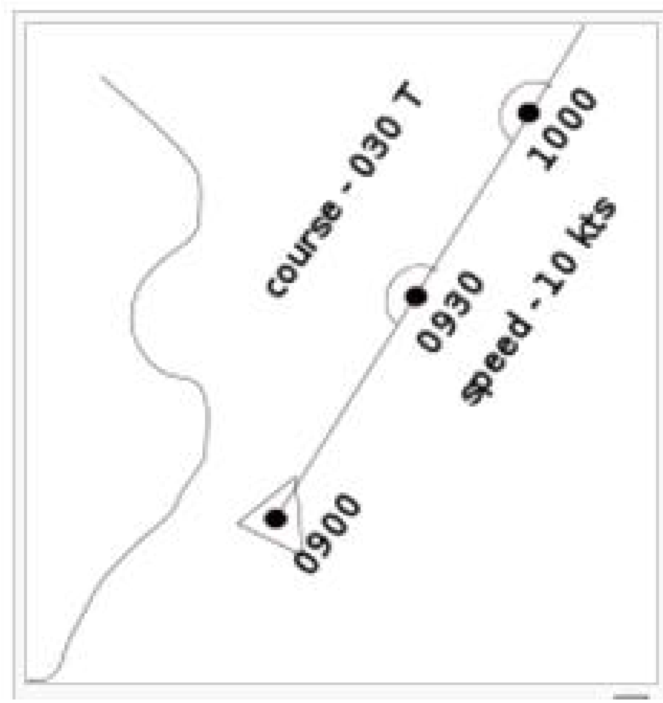
- Server Based

Download precise ephemeris from JPL (Jet Propulsion Laboratory)

  - ü More accurate
  - ü Typically 7~14 days prediction

Dead Reckoning(DR)

- Dead Reckoning Navigation involved knowing where you are by:
  1. Start from a know position
  2. Then keeping track of direction travelled, speed, and time elapsed
  3. As direction or speed changed, plots were made on a chart and the current estimated position



Vehicle DR

- In Vehicle DR, position fixes come from GPS
- In between GPS fixes, Sensor inputs help smooth out GPS “noise”
- When GPS is lost (tunnels, parking garages, etc.) sensors fill in the gaps

Pedestrian dead reckoning

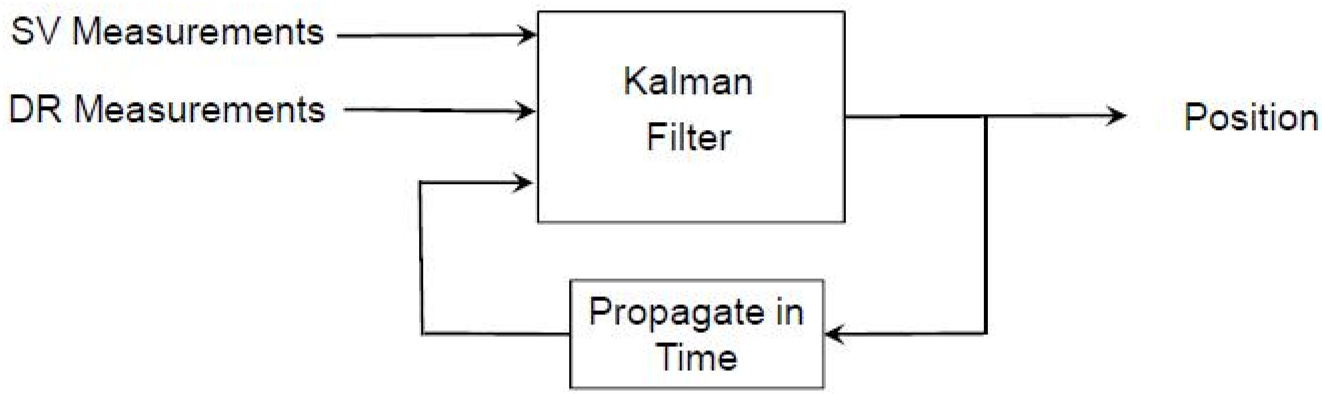
Increased sensor in Smartphone:

- Built-in accelerometers can be used as a pedometer
- Built-in magnetometer as a compass heading provider.

Pedestrian dead reckoning can be used to supplement other navigation methods in a similar way to automotive navigation, or to extend navigation into areas where other navigation systems are unavailable

Tightly Coupled DR

- All inputs to the Position Fix go into the same Kalman Filter
- The Kf assesses the quality and weights each input in accordance with the quality
- Based on quality of inputs, output quality is computed and used to rate its weight on next solution



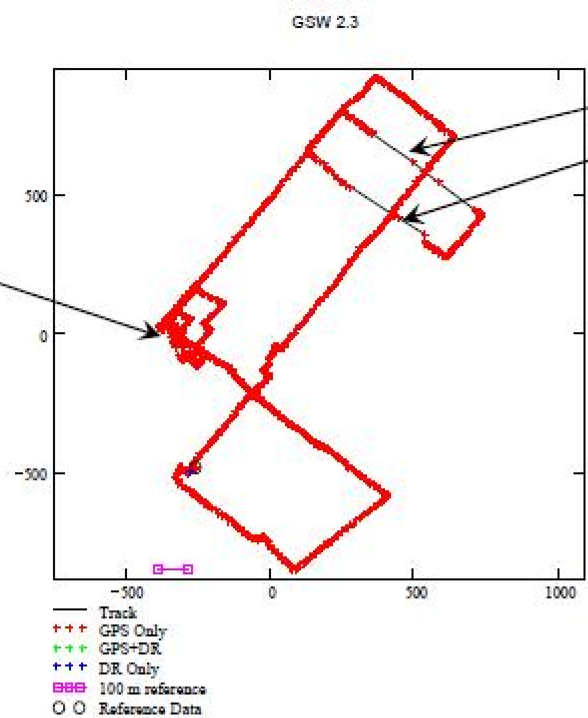
DR Test Results-01

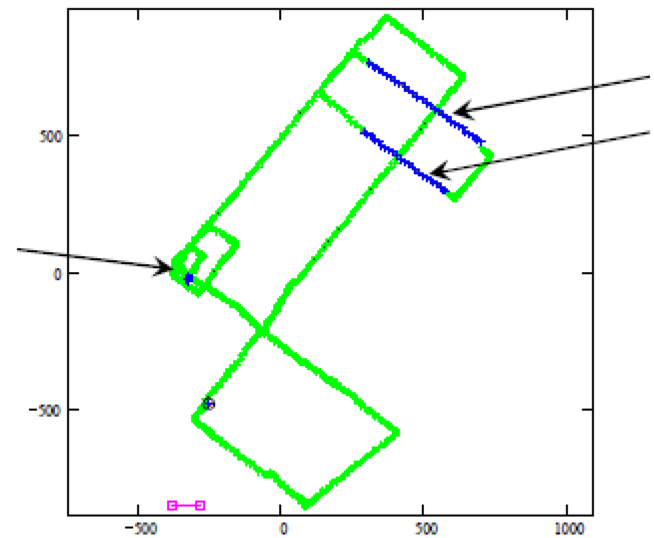
GPS only (Image courtesy of u-blox) GPS & Dead Reckoni

DR Test Results-02

Loss of tracking
In tunnels

Noise in
Urban Canyon





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Location Based Service (LBS)

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

What is location-based service?

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- Location services, wireless location services, mobile location-based services
- Allow that mobile users (MUs) use services based in their position or geographic location

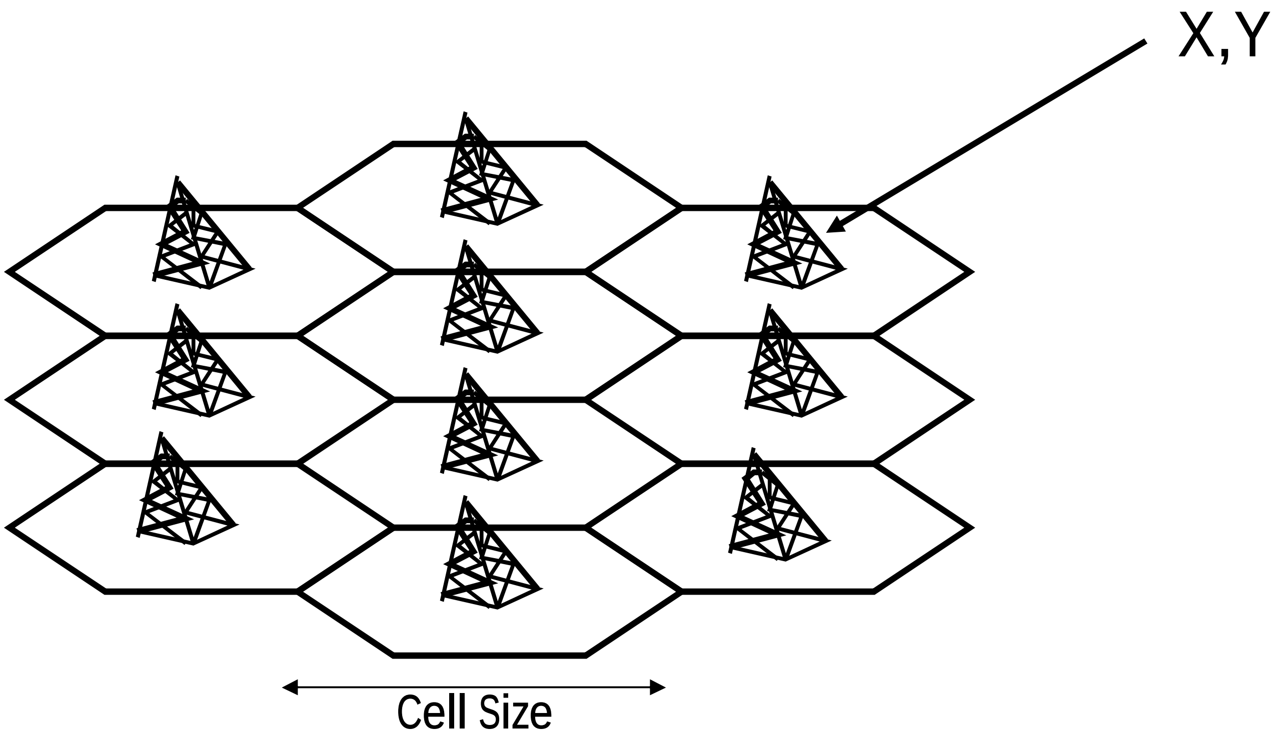
Location Technologies

- Network-based
  - –Technologies that exploit the cellular infrastructure to obtain geo-location information.
- Handset-based
  - –Location intelligence is stored within terminal
- Each of these groups may be divided into:
  - –The MU uses signal transmitted by the base stations to calculate its own position
  - –The base stations measure the signals transmitted by the MU and relay them to a central site for processing.

Location Technologies: network-based

Spreadtrum
Innovation changes the future

- CGI+TA (Cell Global Identity + Timing Advance)



Location Technologies: network-based

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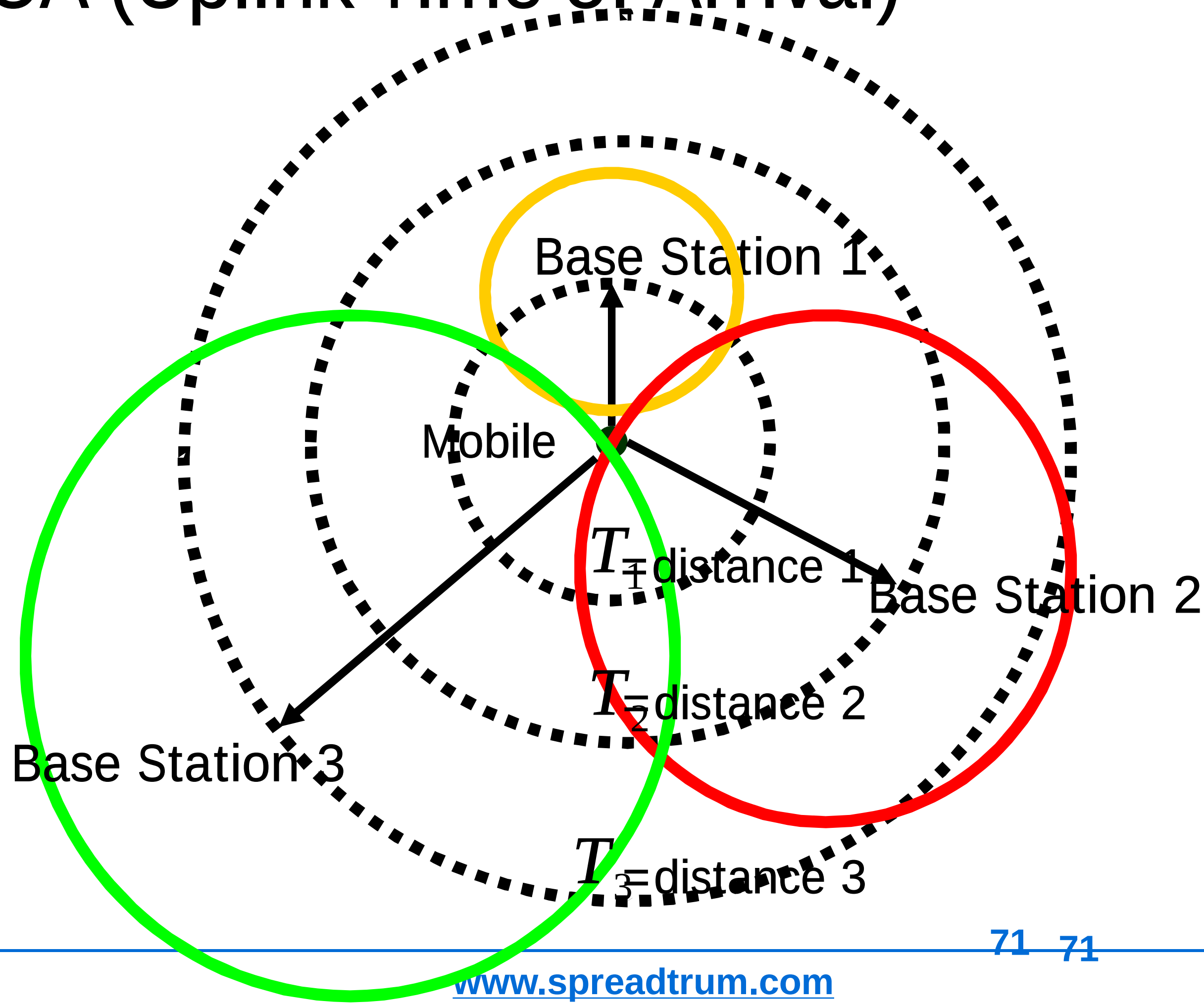
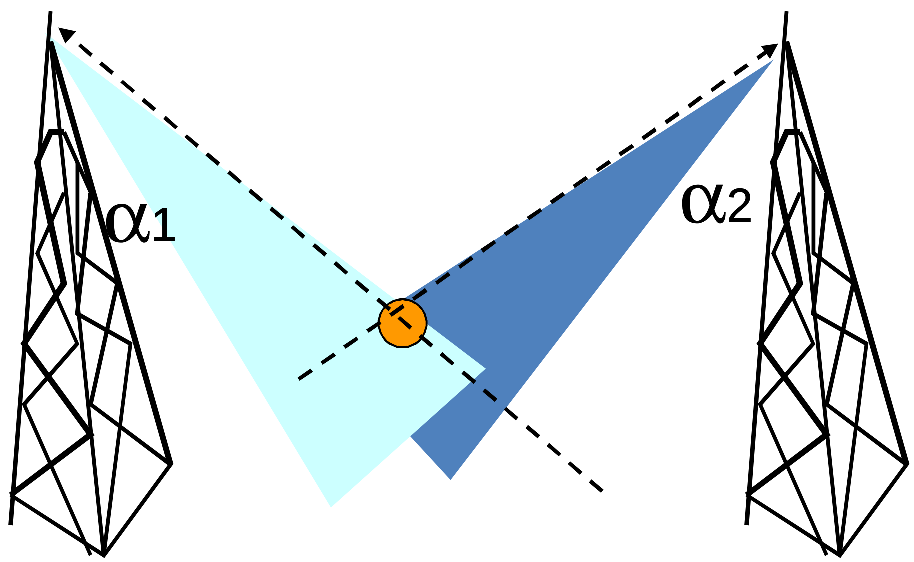
- UL-TOA (Uplink Time of Arrival)



71 71

- AOA (Angle of Arrival)

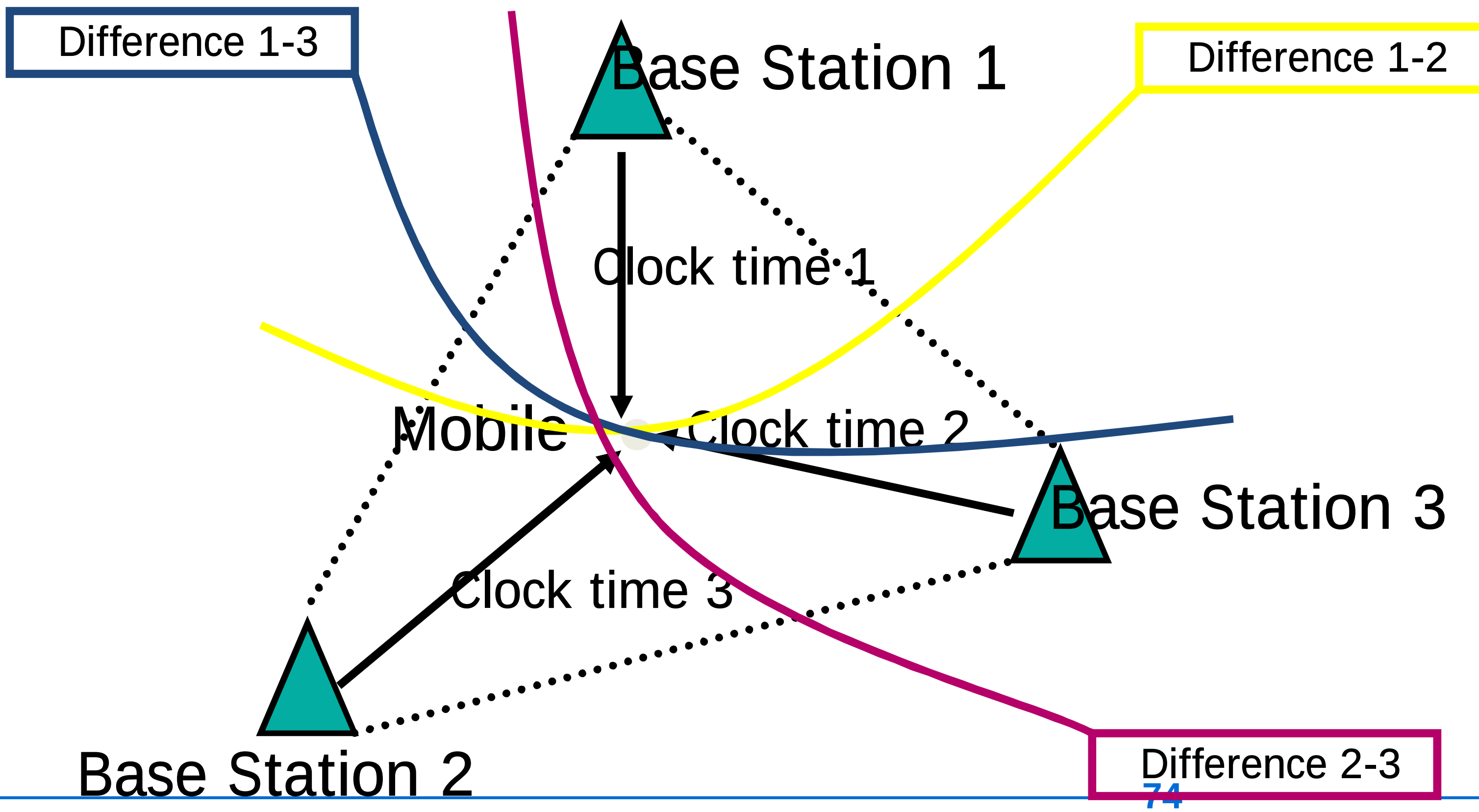


Location Technologies: handset-based

- GPS (Global Positioning System)
- AGPS (Network Assisted GPS)

Location Technologies: handset-based

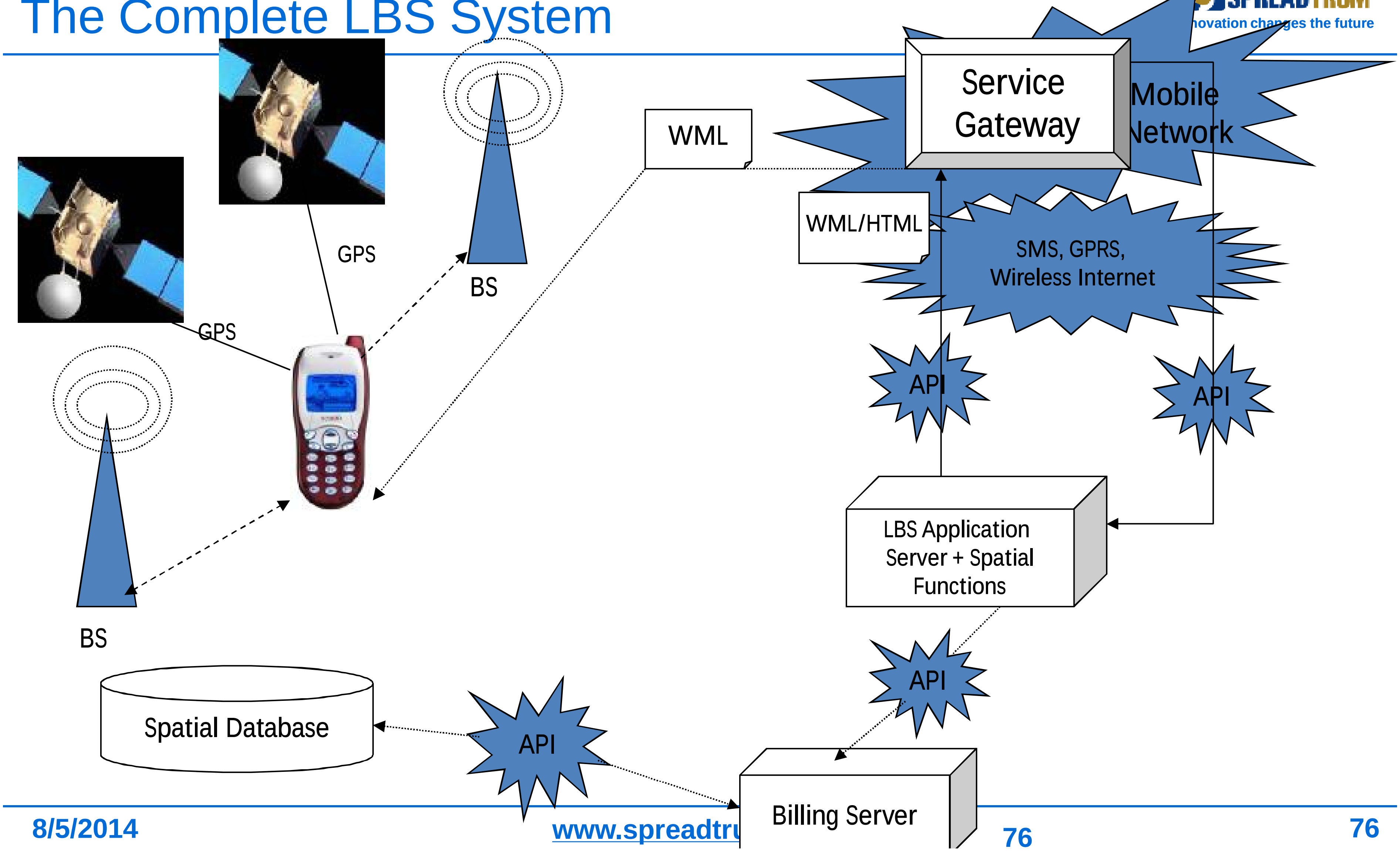
- EOTD (Enhanced Observed Time Difference)



Spatial Data

- Essential component of LBS architecture
  - –Storing and analysing spatial data
- Geographical Information System (GIS)
  - –Refers to the computer-based capability to manipulate geographic data
- Maps or images can be stored in vector or raster format.
- A spatial object must have:
  - –Location: a known point
  - –Form: a geometric representation
  - –Attribute: the nature of the object
  - –Spatial relationship: the boundary of an area

The Complete LBS System



LBS is a Daily Experience

LBS used for search, maps, navigation, check-in, fitness, tracking, etc.

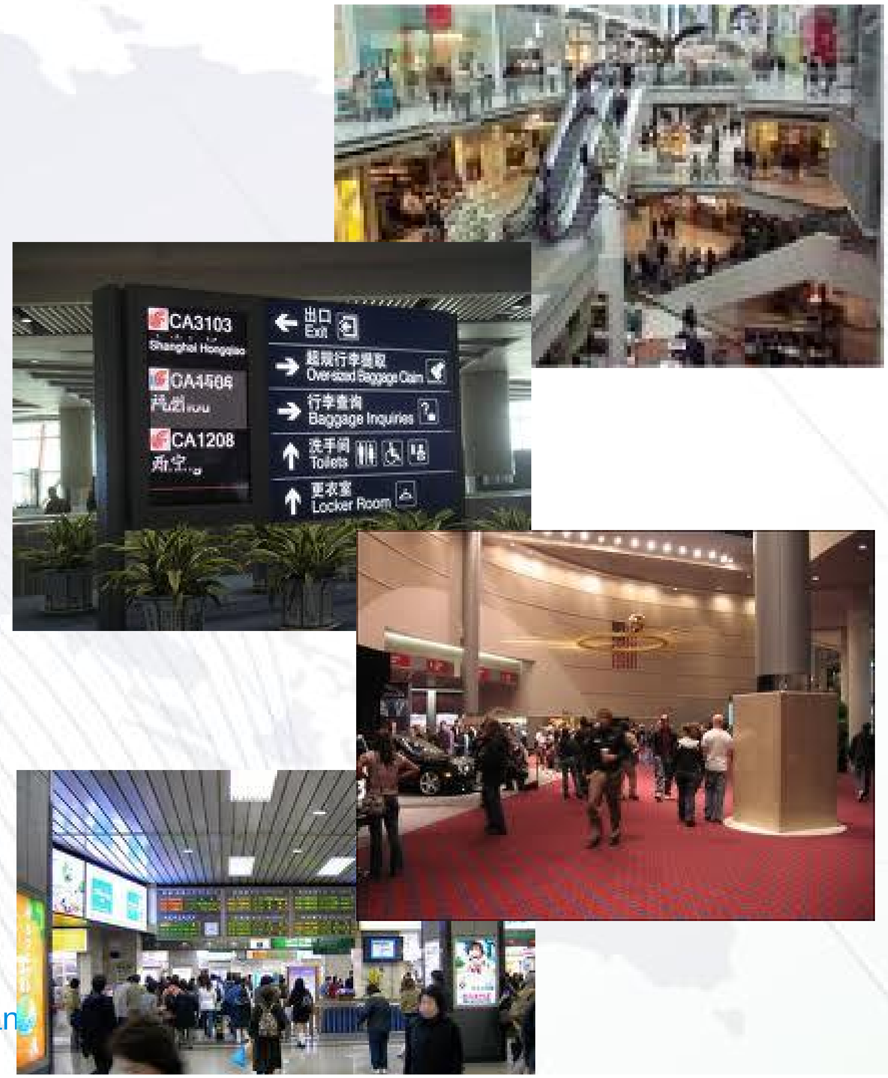
But… LBS is Not Indoors

Consumers...

- Have come to rely on their favorite LBS applications
- Expect functionality anywhere anytime
- Indoors a very high percentage of the time
- Require indoor LBS that works in smartphones to provide maps, search, directions, check-in and much more

GNSS helps improve some outdoor scenarios, but does not help indoors.

Additional solutions are needed.



Agenda

- Section1: Understanding GNSS
- Section2: GNSS Augmentation
- Section3: GNSS Aiding
- Section4: Location Based Service(LBS)
- Section5: Indoor Positioning

Indoor Positioning

Shanghai· Beijing· Shenzhen· San Diego· Korea· India

Why is this important ?

- Smart phones require an excellent location experience, even indoors
- Location is key to delivering useful, relevant content

Challenge for Indoor-Positioning

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- Dynamic Resource Allocation – allocate best resources to calculate position

- Continuous Positioning– ability to keep system hot and ready to deliver instantaneous position information for minimum power

- Measurement Fusing– ability to dynamically choose, combine and predict the best sources of positioning information

Indoor Positioning Sources

- RSSI based Wi-Fi
  - –Self-learning
  - –RSSI method
  - –Update DB with more accurate Wi-Fi learning data
- Cellular data
  - –Solution reliability
  - –Reduce GNSS uncertainty
- MEMS
  - –Navigation enhancements for vehicle and pedestrian mode
  - –Power saving with motion detection
  - –Optimizations through understanding platform dynamics
- Others
  - –Pseudolite
  - –Blue tooth

Some Results in SiRFusion: Wifi-Only

- Illustrative example in Encore hotel, casino, and meeting rooms
- Once GPS is lost indoors, the locations of Wi-Fi access points are used to determine approximate position once every 20s
- The uncertainty illustrated by the size of the ellipses makes most indoor use cases impractical
- Once outdoors, a more accurate GPS position is obtained and the uncertainty shrinks

Some Results in SiRFusion: PDR-Only

- Once GPS is lost indoors, the PDR is used to keep track of position
- The MEMS sensors drift and the error accumulates at a growth rate of 5% of distance travelled
- Soon the position track is not representative of the actual path
- The uncertainty illustrated by the size of the ellipses makes most indoor use cases impractical

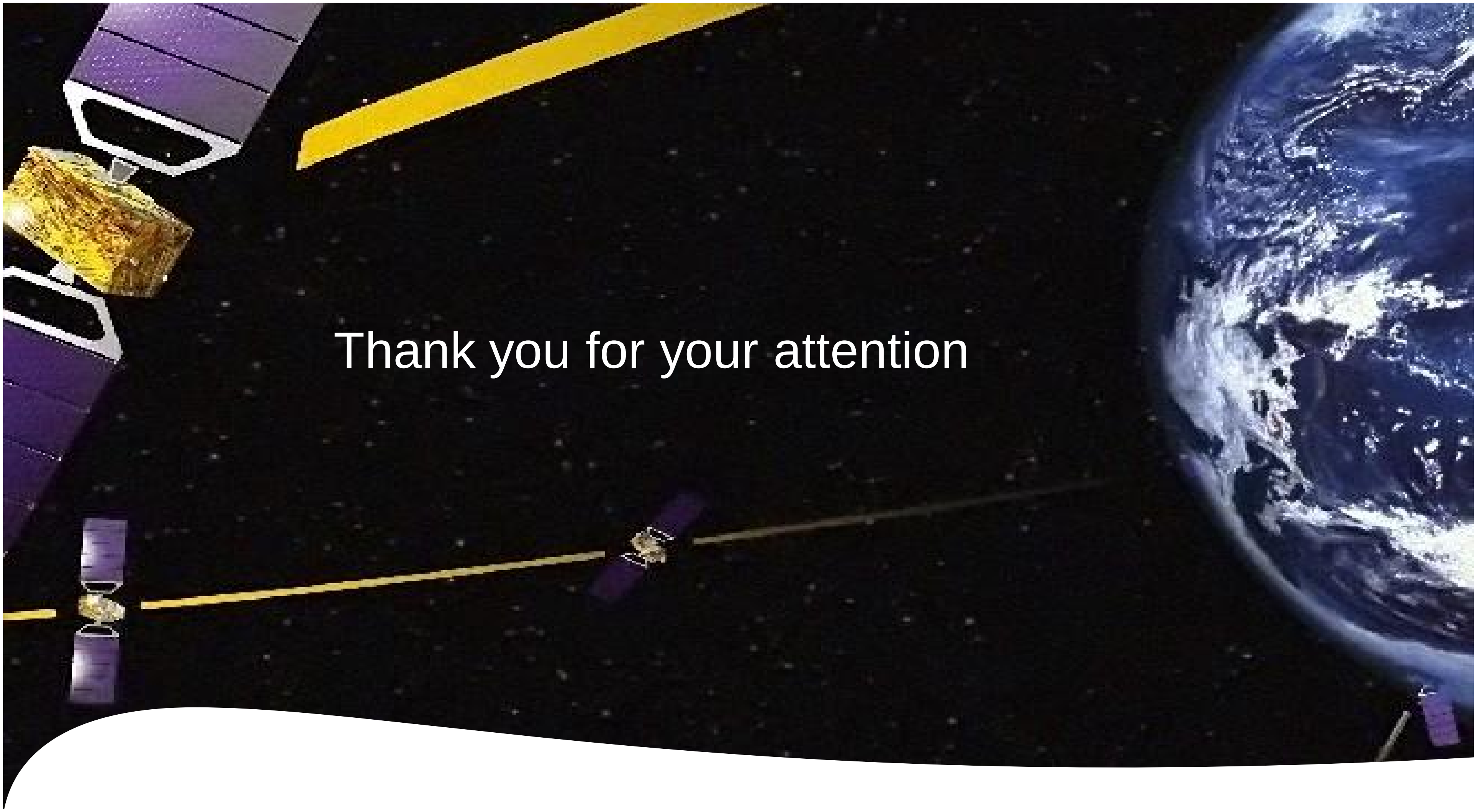
Some Results in SiRFusion: Fusion of Wifi and PDR

SPREADTRUM
Innovation changes the future

- Once GPS is lost indoors, the MEMS sensor output is used for dead reckoning as the user moves
- PDR is very accurate short term, so the user path is clearly shown
- The error grows about 5% of distance traveled, so in 200m, the error grows only 10m
- Wi-Fi positioning keeps the error from growing too large
- Learning: the better accuracy allows the indoor Wi-Fi access point locations to be determined more precisely

“Indoor location-based navigation nears reality”

--USA Today


Thank you for your attention