GLOBAL POSITIONING SYSTEM (GPS)

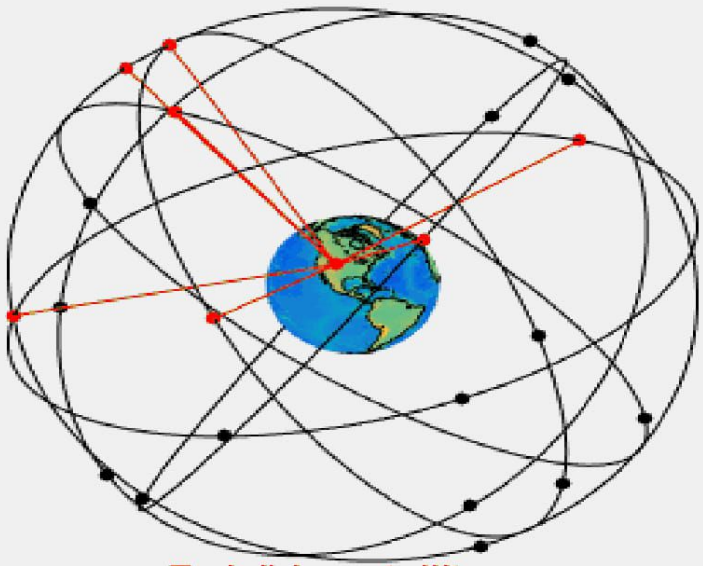
The Global Positioning System (GPS) is a satellite-based navigation system made up of at least 24 satellites.

➢ GLOBAL POSITIONING SYSTEM (GPS)

- ✓ The global positioning system is a space-based navigation system that was launched by the U.S. Department of Defense in the early 1990's, and has since become very popular commercially, not only for aircraft navigation, but for maritime, automotive and personal applications as well.
- ✓ It provides position data, velocity rate, and system time to GPS receivers all around the world.
- ✓ GPS consists of three segments: a space system segment, a control system segment, and a user system segment.
- ✓ The space system segment consists of 6 planes of satellites, each plane containing 4 satellites, in precise 10898 mile geostationary orbits.
- ✓ The control system segment has several monitoring stations located in U.S. controlled territory that track all satellites in view and accumulates ranging data to

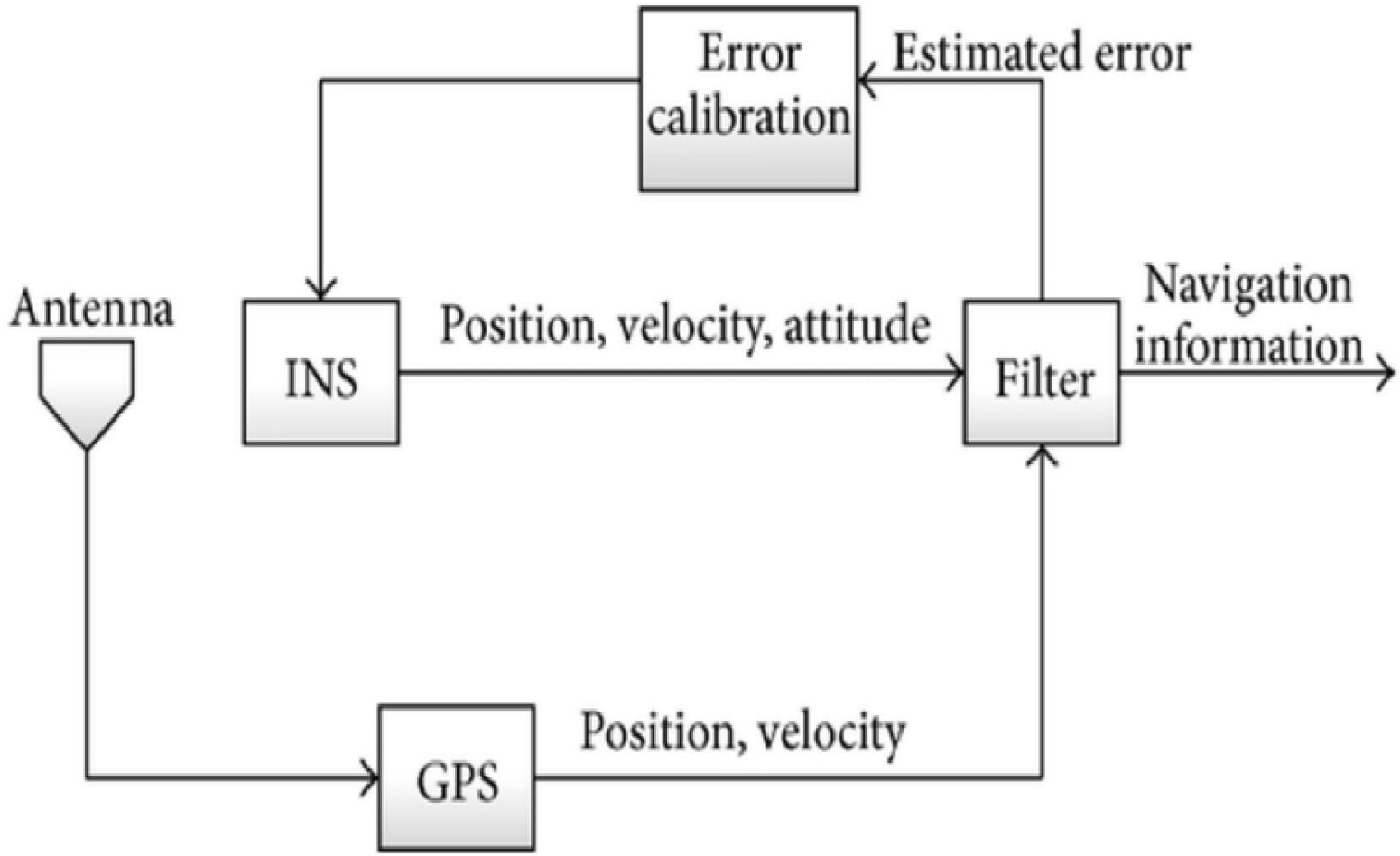
➢ GLOBAL POSITIONING SYSTEM (GPS)

- ✓ The user's GPS receiver computes its distance from the satellites by measuring the travel time of the satellite's signal.
- ✓ By using the distances from at least three satellites, the GPS receiver can triangulate the user's current position.
- ✓ With measurements from four satellites, the GPS receiver can determine elevati



7 visible satellites

➢ GLOBAL POSITIONING SYSTEM (GPS)



➢ GLOBAL POSITIONING SYSTEM (GPS)

- ✓ The INS system only measures acceleration and angular rates and mathematically integrates these into velocity and position.
- ✓ However, since the inertial system outputs are obtained through integration, they drift at a very low frequency.
- ✓ The GPS is an ideal reference for realigning and recalibrating the INS during light.
- ✓ An algorithm, known as a Kalman Filter, is used to provide error correction to the INS.
- ✓ In addition, the INS provides prepositioning data for re-acquiring the GPS signal should the signal be lost.

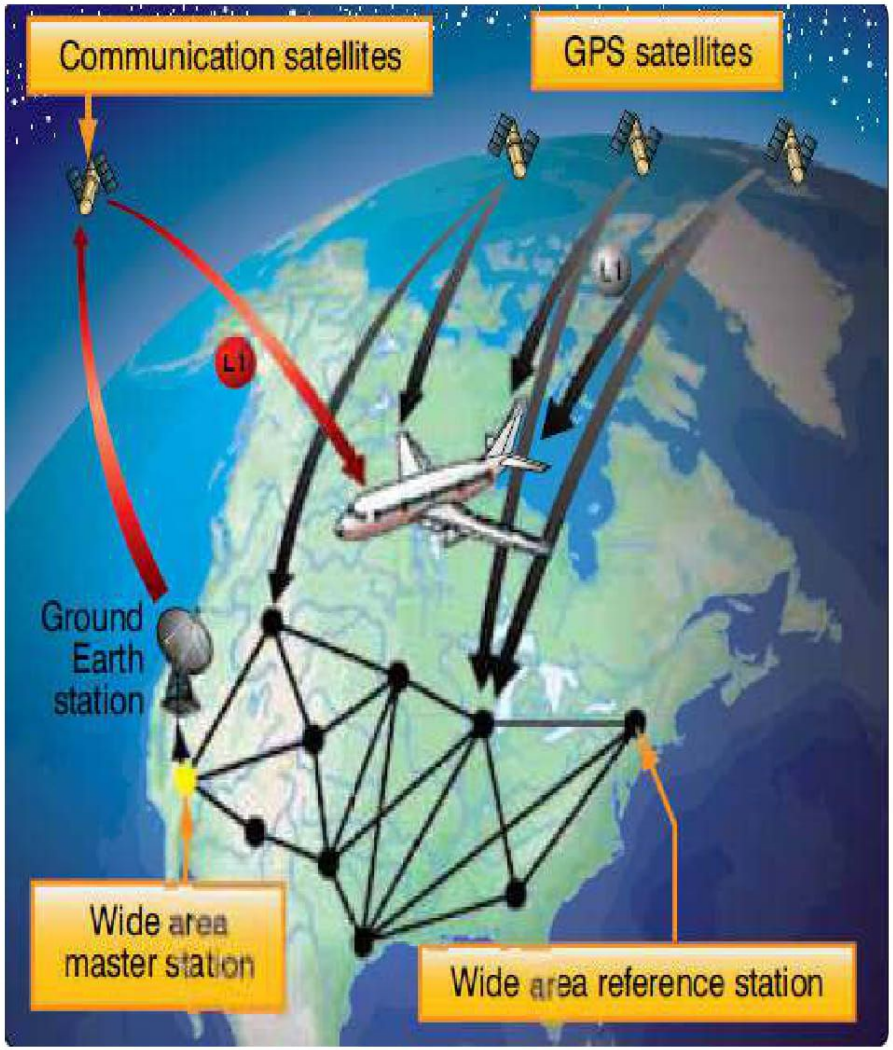
➢ GLOBAL POSITIONING SYSTEM (GPS)

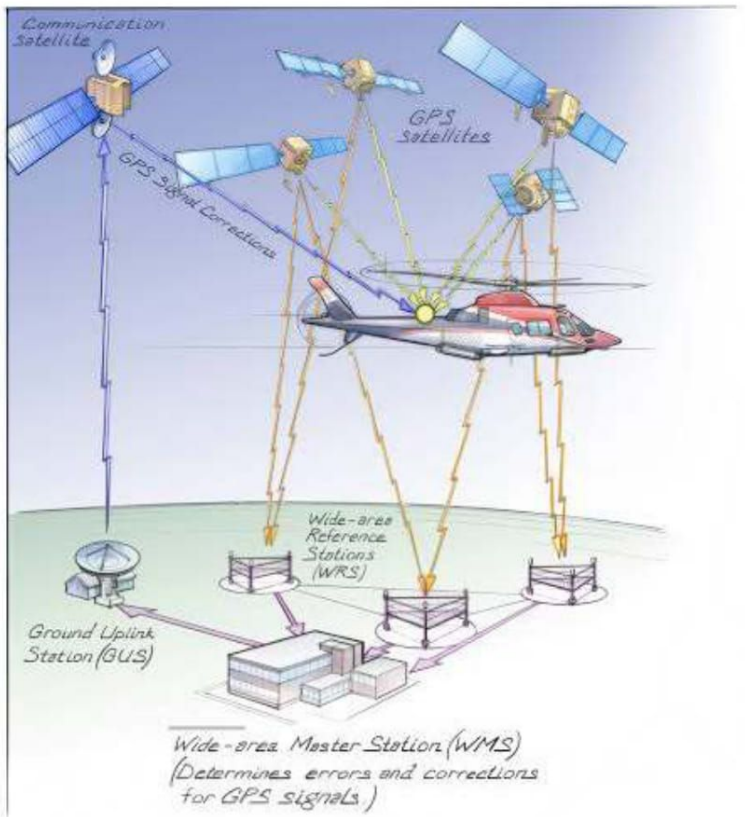
○ WIDE AREA AUGMENTATION SYSTEM (WAAS)

- ✓ Unlike traditional ground-based navigation aids, the WAAS covers nearly all of the National Airspace System (NAS).
- ✓ The WAAS provides augmentation information to GPS receivers to enhance the accuracy and reliability of position estimates.
- ✓ The signals from GPS satellites are received across the NAS at many widely-spaced Wide Area Reference Stations (WRS) sites.
- ✓ The WRS locations are precisely surveyed so that any errors in the received GPS signals can be detected.
- ✓ The GPS information collected by the WRS sites is forwarded to the WAAS Master Station (WMS) via a terrestrial communications network.
- ✓ At the WMS, the WAAS augmentation messages are

➢ GLOBAL POSITIONING SYSTEM (GPS)

○ WIDE AREA AUGMENTATION SYSTEM (WAAS)





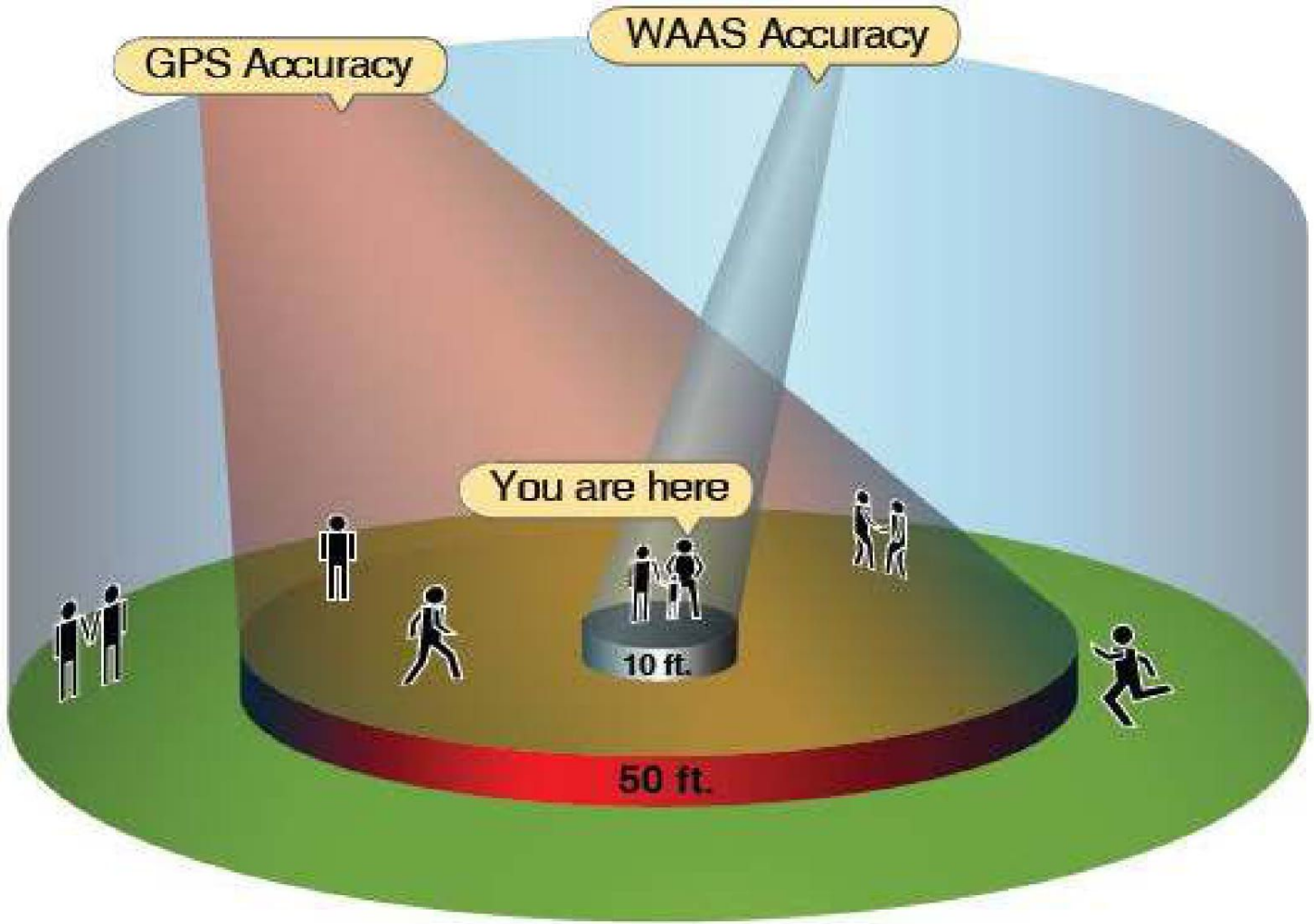
➢ GLOBAL POSITIONING SYSTEM (GPS)

○ WIDE AREA AUGMENTATION SYSTEM (WAAS)

- ✓ These messages contain information that allows GPS receivers to remove errors in the GPS signal, al lowing for a significant increase in location accuracy and reliability.
- ✓ The augmentation messages are sent from the WMS to uplink stations to be transmitted to navigation payloads on geo-stationary communications satellites.
- ✓ The geo-satellite navigation transponders broadcast the augmentation messages on a GPS-like signal.
- ✓ The aircraft's GPS/WAAS receiver processes the WAAS augmentation message as part of estimating position.

➢ GLOBAL POSITIONING SYSTEM (GPS)

○ WIDE AREA AUGMENTATION SYSTEM (WAAS)



➢ GLOBAL POSITIONING SYSTEM (GPS)

○ WIDE AREA AUGMENTATION SYSTEM (WAAS)

- ✓ The GPS-like signal from the satellite navigation transponder can also be used by the receiver as an additional source for calculation of the user's position.
- ✓ WAAS also provides indications to GPS/ WAAS receivers of where the GPS system is unusable due to system errors or other effects.
- ✓ Further, the WAA S system was designed to the strictest of safety standards hazardously misleading information that would cause an error in the GPS position estimate.

GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

GNSS and GPS work together, but the main difference between GPS and GNSS is that GNSS-compatible equipment can use navigational satellites from other networks beyond the GPS system, and more satellites means increased receiver accuracy and reliability.

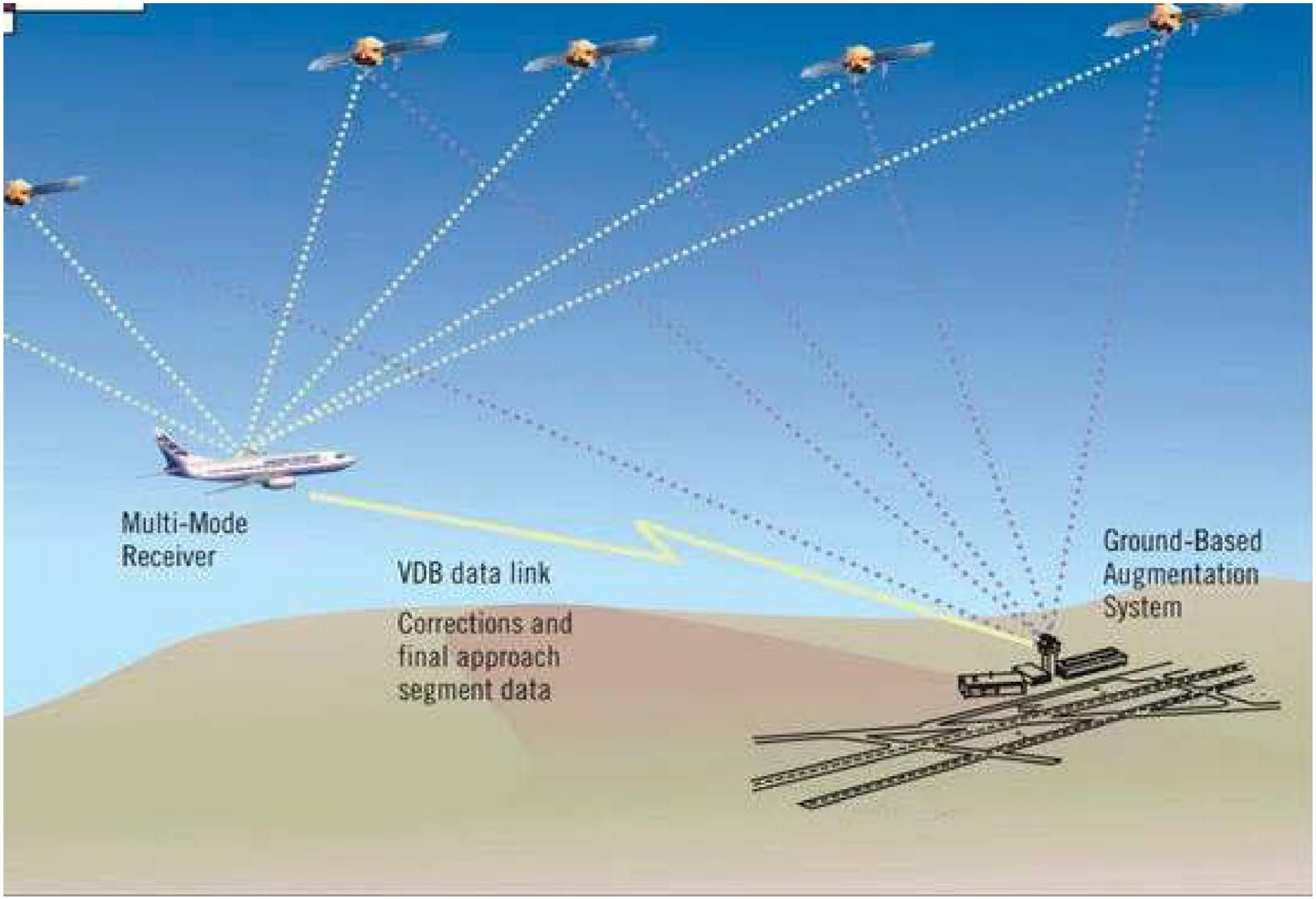
➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

- ✓ In 2001, the International Civil Aviation Organization (ICAO) approved an international standard for a landing system based on local correction of GNSS data to a level that would support instrument approaches.
- ✓ The ICAO Standards and Recommended Practices (SARPS) define the characteristics of a Ground-Based Augmentation System (GBAS) service that can be provided by an airport authority or an Air Traffic Service provider.
- ✓ The GBAS service provides the radiated signal in space that can be used by suitably equipped airplanes as the basis of a GNSS Landing System (GLS).
- ✓ The initial SARPS support an approach service.
- ✓ Future refinements should lead to full low-visibility service (i.e., takeoff, approach, and landing) and low-

➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

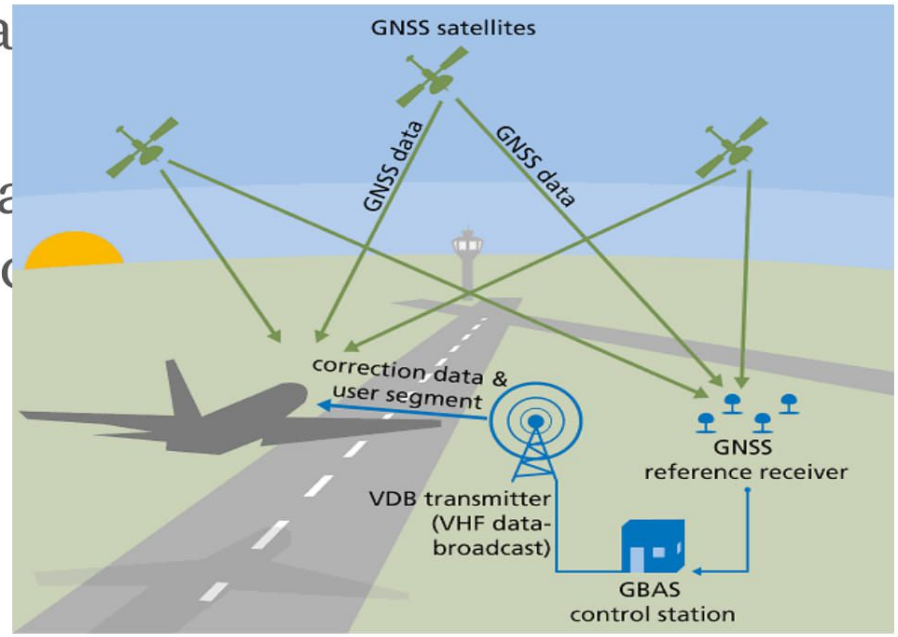
- ✓ The GLS consists of three major elements- a global satellite constellation that supports worldwide navigation position fixing, a GBAS facility at each equipped airport that provides local navigation satellite correction signals, and avionics in each airplane that process and provide guidance and control based on the satellite and GBAS signals.
- ✓ The GLS uses a navigation satellite constellation which include the U. S. Global Positioning System (GPS), and the European Galileo System for the basic positioning service.
- ✓ The G P S constellation already is in place and improvements are planned over the coming decades.
- ✓ Galileo is the global navigation satellite system (GNSS) that is currently being created by the European Union

➢ GLOBAL NAVIGATION SATELLITE



➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

- ✓ One of the aims of Galileo is to provide an indigenous alternative high-precision positioning system upon which European nations can rely, independently from the Russian GLONA SS and US GPS systems.
- ✓ Galileo is intended to provide horizontal and vertical position measurements within 1-metre precision, and better positioning services a positioning systems.
- ✓ The complete 30-satellite Ga and 6 active spares) is expec

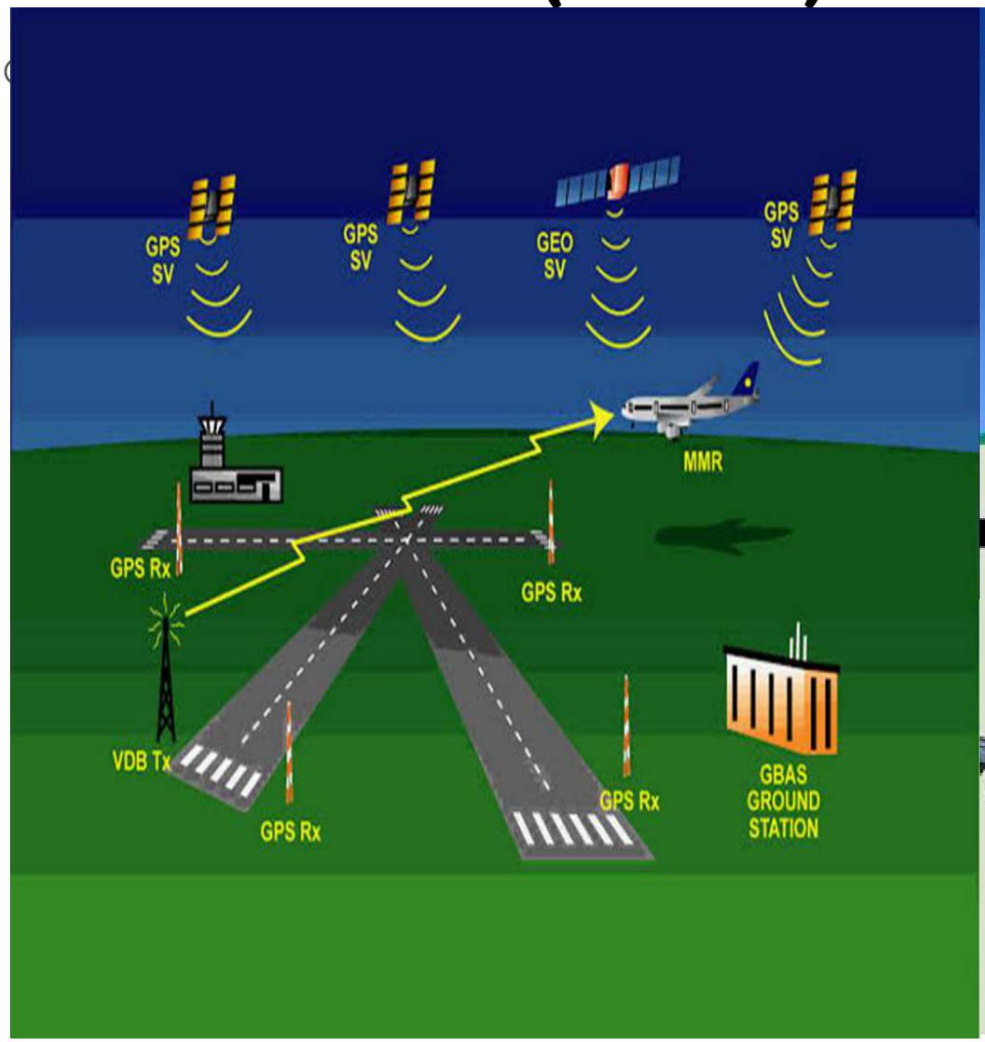


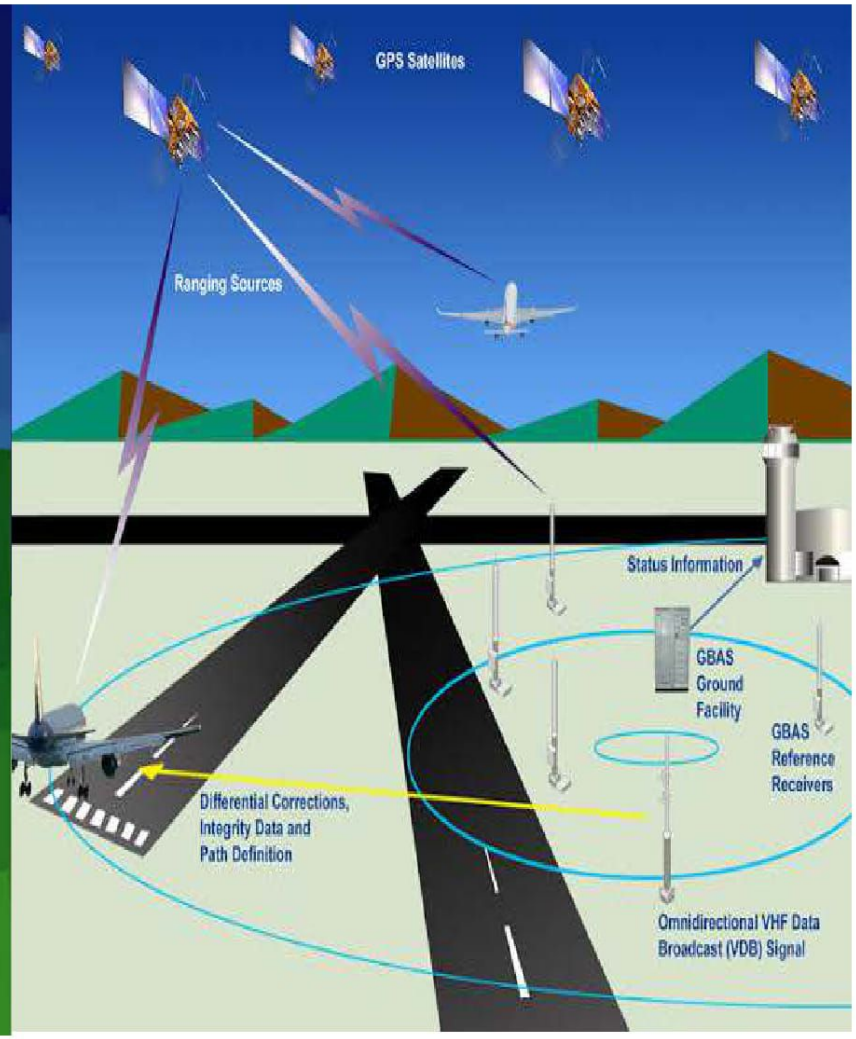
➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

○ GNSS OPERATIONAL ELEMENTS

- ✓ The basic positioning service is augmented locally- at or near the airport- through a GBAS radio transmitter facility.
- ✓ Because the ground facility is located at a known surveyed point, the GBAS can estimate the errors contained in the basic positioning data.
- ✓ Reference receivers in the GBAS compare the basic positioning data with the known position of the facility and compute corrections on a satellite-by-satellite basis.
- ✓ The corrections are called pseudo-range corrections because the primary parameter of interest is the distance between the GBAS facility and individual satellites.

➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)





➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

○ GNSS OPERATIONAL ELEMENTS

- ✓ The satellite constellation is continuously in motion, and satellites ascend and descend over the horizon when observed from any point on Earth.
- ✓ The GBAS calculates corrections for all the satellites that meet the specified in-view criteria and transmits that information to the nearby airplanes over a VHF Data Broadcast (VDB) data link.
- ✓ Boeing airplanes that are currently being produced contain Multi-Mode Receivers (MMR) that support Instrument Landing System (ILS) and basic GPS operations.
- ✓ These MMRs can be modified to support GLS and potentially Microwave Landing System operations.
- ✓ The GLS capability is supported through the addition of a

➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

○ GNSS OPERATIONAL ELEMENTS

- ✓ The MMRs apply the local correction data received from the GBAS to each satellite that the airplane and GBAS share in common.
- ✓ Because of position and altitude differences and local terrain effects, the GBAS and the airplane may not necessarily be observing the same combination of satellites.
- ✓ The airplane systems only use satellite information that is supported by correction data received from the GBAS.
- ✓ When the airplane is relatively close to the GBAS station, the corrections are most effective, and the MMRs can compute a very accurate position. Typical lateral accuracy should be ≤1 m.
- ✓ A single GBAS ground station typically provides approach and landing service to all runways at the airport where it is installed.

➢ GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

○ GNSS OPERATIONAL ELEMENTS

- ✓ The GBAS may even provide limited approach service to nearby airports.
- ✓ Each runway approach direction requires the definition of a final approach segment (FAS) to establish the desired reference path for an approach, landing, and rollout.
- ✓ The FAS data for each approach are determined by the GBAS service provider and typically are verified after installation of the GBAS ground station.
- ✓ One feature that differentiates the G LS from a traditional landing system such as the ILS is the potential for multiple final approach paths, glideslope angles, and missed approach paths for a given runway.
- ✓ Each approach is given a unique identifier for a particular FAS, glideslope, and missed approach combination.