ECS455: Chapter 4

Multiple Access

4.9 Async. CDMA: Gold codes and GPS

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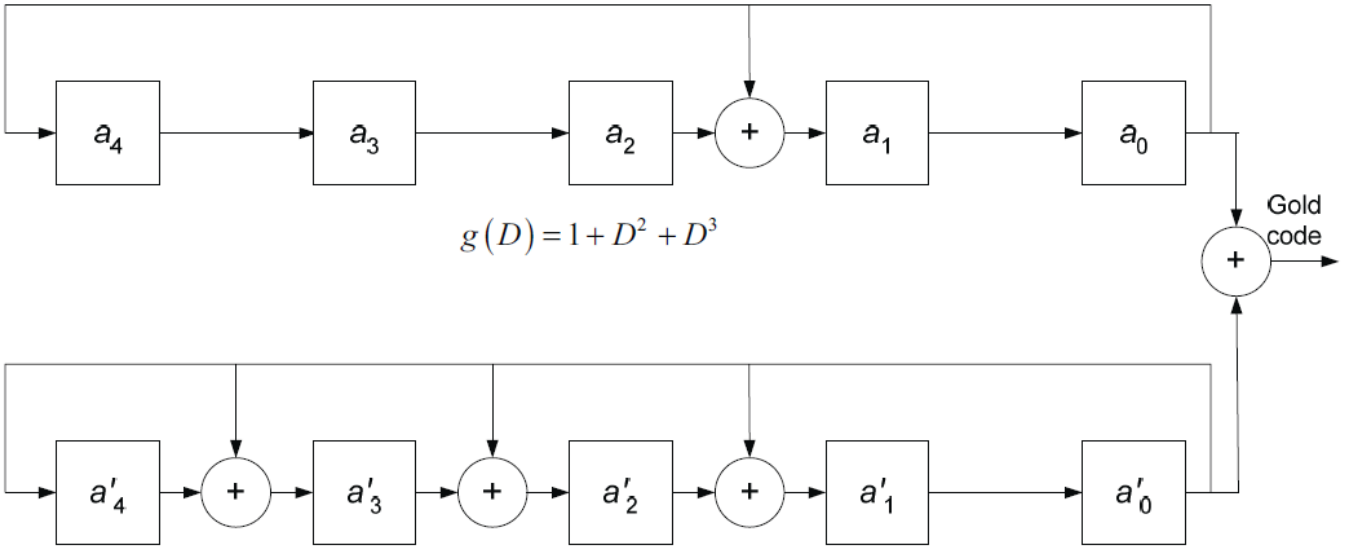
Asynchronous CDMA Model

- In cellular systems, the design of the **reverse link** (mobile-to-base station) is considerably simplified if the users need not be synchronized.
- It is possible to let the users transmit asynchronously in CDMA.
- Codes assigned to different users need to have **low cross correlation** with each other **independent of the relative delays**
- **Gold codes**

Gold codes

- Gold codes have **worse autocorrelation** properties than maximal-length codes, but **better cross-correlation** properties if properly designed.
- The chip sequences associated with a Gold code are produced by addition of two m-sequences.



[Ziemer, 2007, Fig. 9]

Orthogonality (a revisit)

- **Downlinks**
  - May use **orthogonal** spreading codes such as Walsh-Hadamard codes
  - Orthogonality can be degraded by multipath fading.
- **Uplinks**
  - Generally use **non-orthogonal** codes due to the **difficulty of user synchronization** and the complexity of maintaining code orthogonality in uplinks with multipath.
  - Little dynamic coordination of users in time or frequency is required
    - Users can be separated by the code properties alone.
- There is a hard limit on how many orthogonal channels (orthogonal codes) can be obtained.
  - For non-orthogonal codes, there is no hard limit.
  - Non-orthogonal codes cause mutual interference between users.
    - The more users, the higher the level of interference
      - Degrade the performance of all the users.
- Non-orthogonal CDMA scheme also requires power control in the uplink to compensate for the near-far effect.

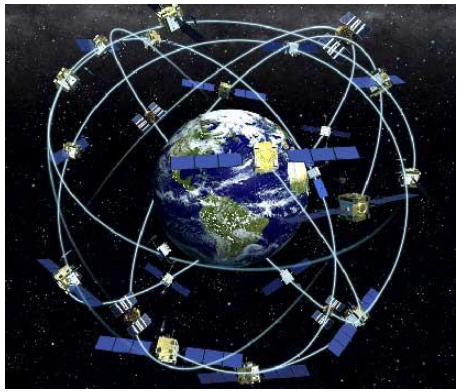
[Goldsmith, p 458]

Review: Near-far Effect

- Arise in the **uplink** because the channel gain between a user's transmitter and the receiver is different for different users.
- Suppose that one user is very **close** to his **base station** or access point, and another user very far away.
  - If both users transmit *at the same power level*, then the **interference from the close user will swamp the signal from the far user**.
- **Power control**
  - Make the *received* signal power of all users to be roughly the same
  - Essentially inverts any attenuation and/or fading on the channel
  - Each interferer must **contribute an equal amount of power**
  - Eliminating the near-far effect

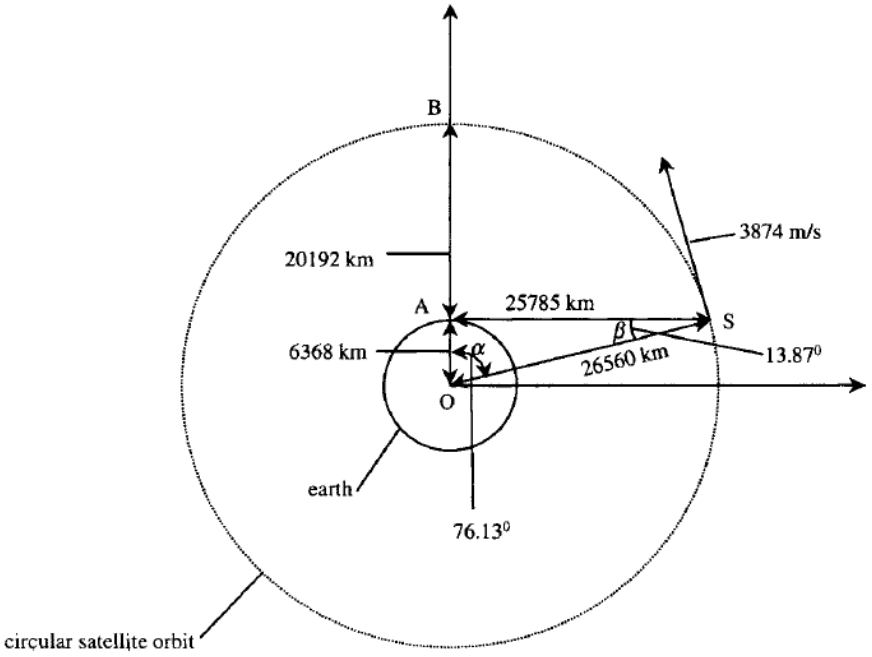
Global Positioning System (GPS)

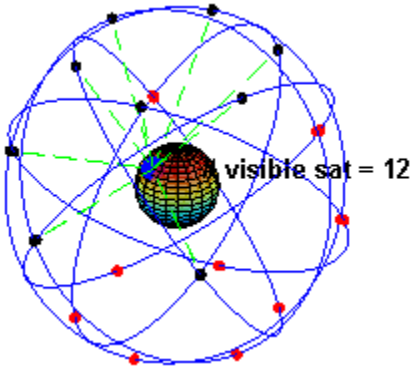
- Original application in the **military**
- Allow a person to determine the **time** and the person's precise **location** (latitude, longitude, and altitude) anywhere on earth.
- The potential applications of GPS are so vast that it has been called (with some exaggeration) **the next utility** (similar to gas, water, and electricity).



GPS Satellite

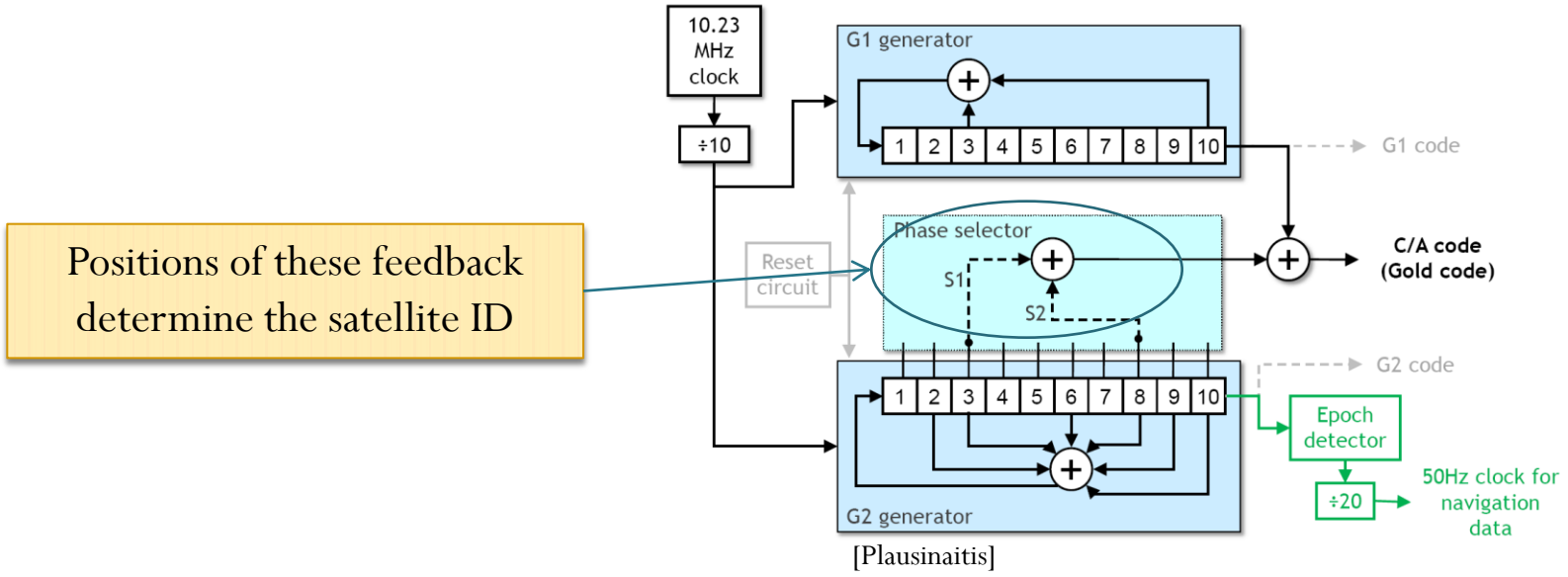
- A minimum of 24 GPS satellites are in orbit at 20,200 kilometers (12,600 miles) above the Earth.
- The satellites are spaced so that from any point on Earth, **at least four satellites** will be above the horizon.





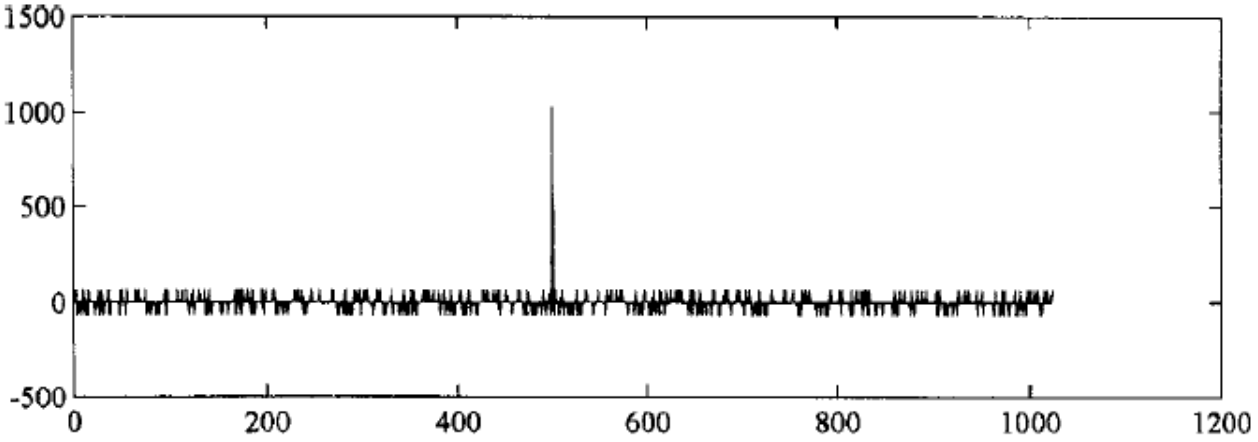
GPS and Gold codes

- Gold codes are used to distinguish the signals from different satellites
  - Coarse Acquisition Code (C/A)
  - Standard Positioning Service (SPS)
- The message data is transmitted at 50 bits per second.
- 1023 bits with a period of one millisecond.

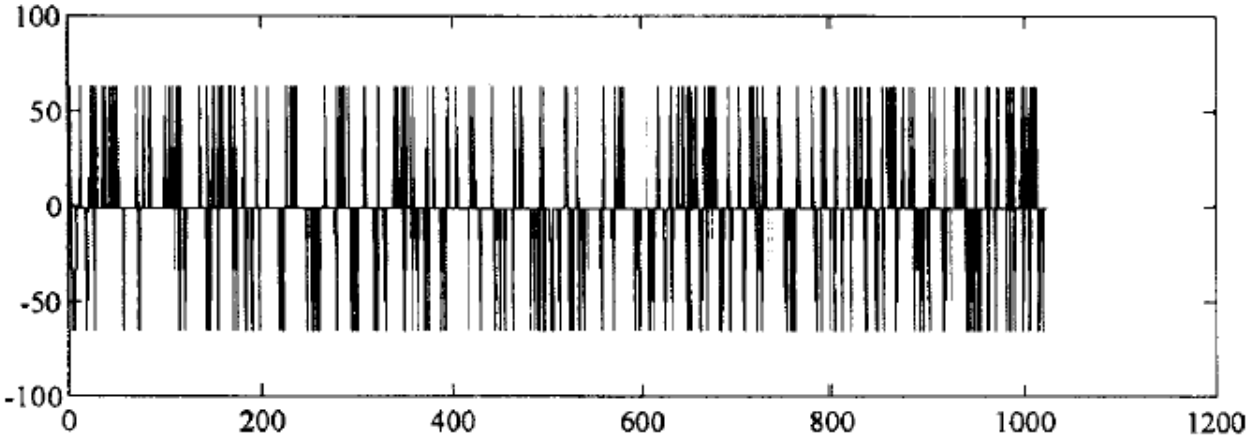


[Plausinaitis]

Auto and cross correlation of C/A code



(a) Autocorrelation of satellite 19.



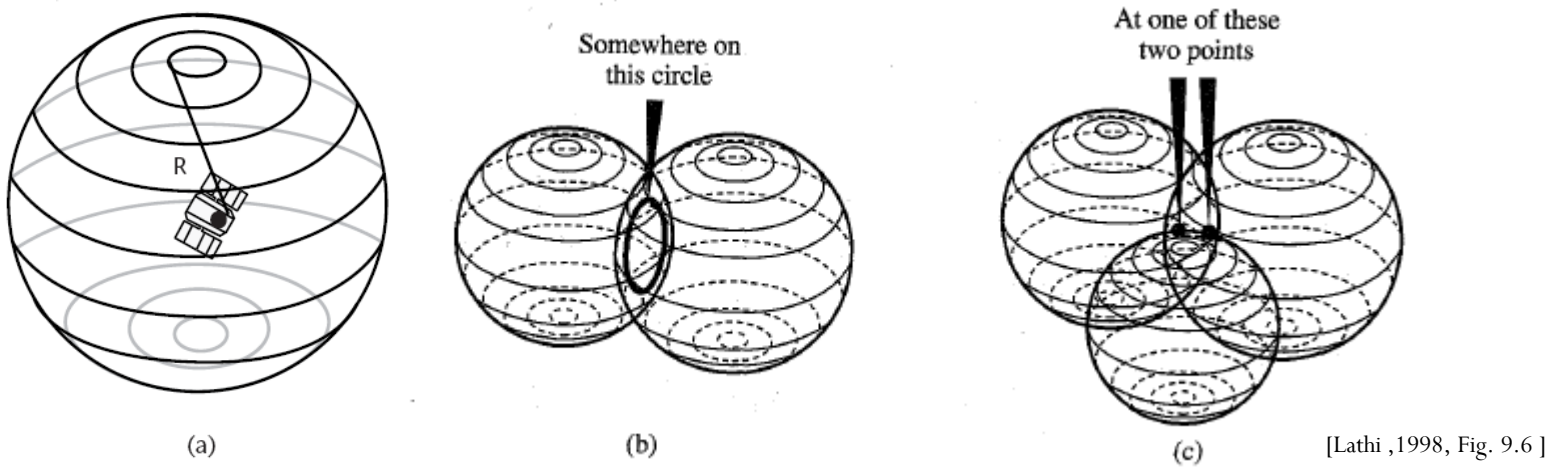
(b) Cross correlation of satellites 19 and 31.

How GPS Works?

- A GPS receiver measuring its **distance from a group of satellites** in space which are acting as precise **reference points**.
- All the satellites have **atomic clocks** of unbelievable precision on board and are synchronized.
- The satellite are continuously transmitting the information about their location and time.
- GPS receiver on the ground is in synchronism with the satellites.
  - Off by an (unknown) amount τ.
  - For now, assume $\tau = 0$.
- By measuring the propagation time, the receiver can compute distance d from that satellite.

GPS-Trilateration

- Intersection of three sphere narrows down the location to just two points.



[Lathi ,1998, Fig. 9.6]

- In practice, there are four unknowns, the coordinates in the three-dimensional space of the user along with τ within the user's receiver.
  - Need a distance measurement from a fourth satellite.

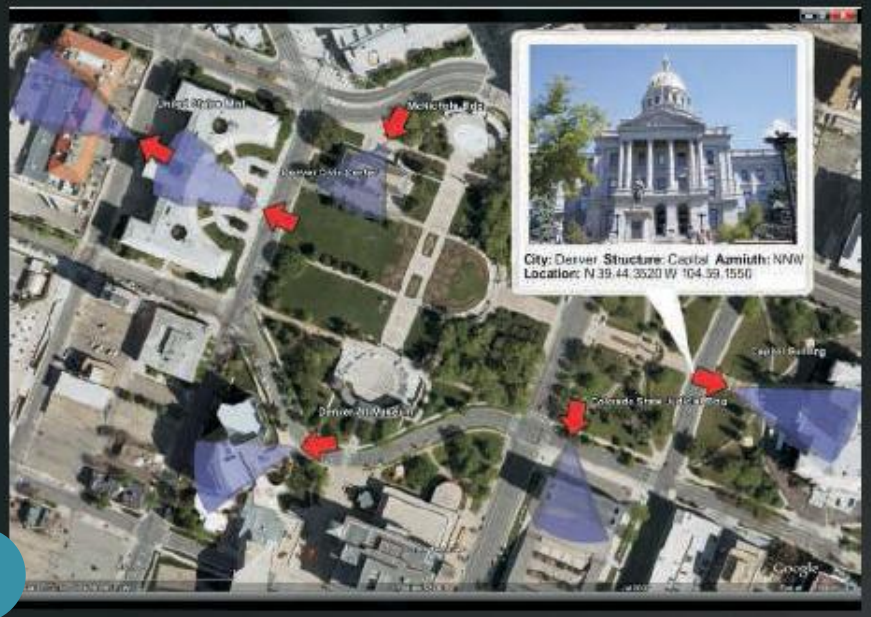

Keep left on I-90 E
S Western Ave
45
mph
0.1
Church St
W Broadway
Hudson St
TRIBECA, NY
Chambers St
350
yards
13 M
25 min
2:00 pm
2:26 pm
30 mph
Broadway
TOMTOM
NOKIA
WASHINGTON
BETHESDA
MCLEAN
ARLINGTON
ALEXANDRIA
JEFFERSON
CAMP SPRINGS
FORESTVILLE
Fn
Ctrl

Geo-Imaging Optimized

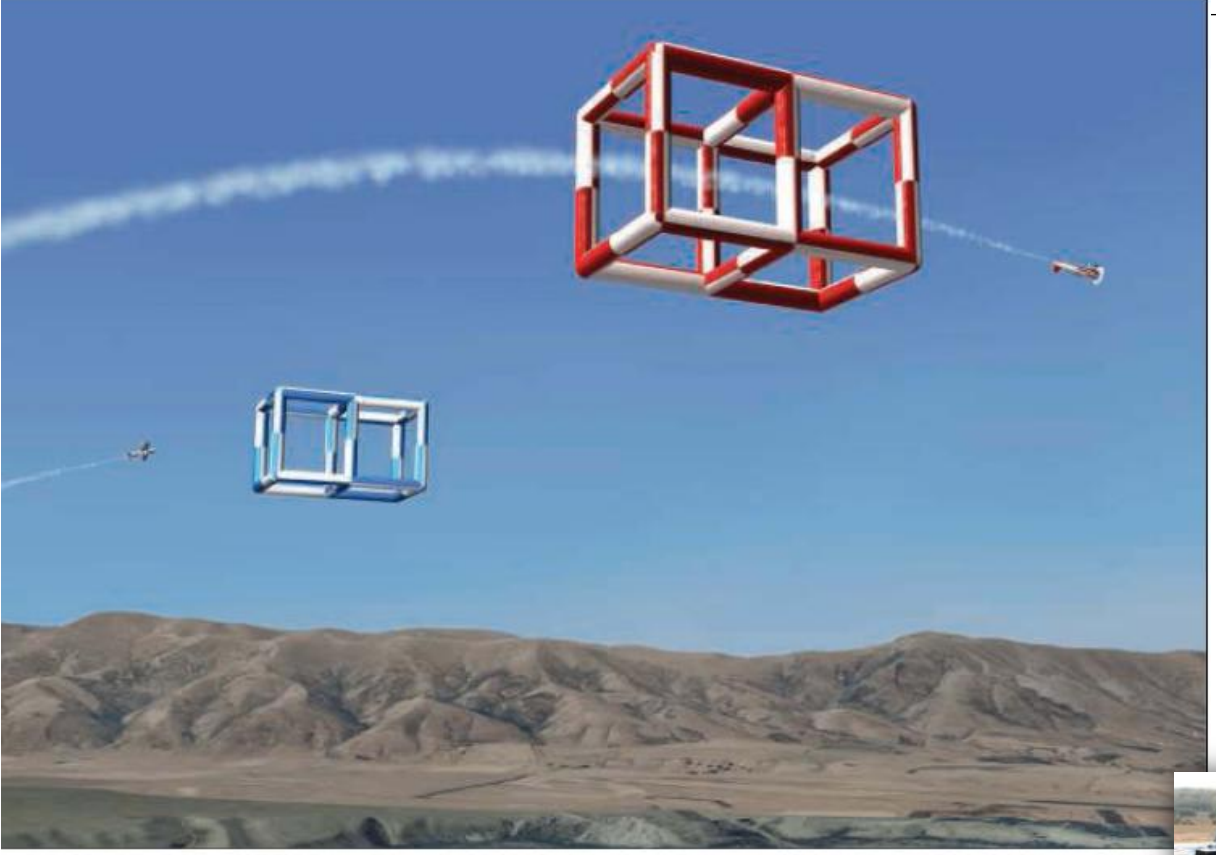
Simple, Durable, Proven.

The Ricoh 500SE GPS-enabled digital camera continues to provide the definitive ruggedized solution for integrating high quality images and video into GIS mapping applications. As easy to use as a point-and-shoot camera, the on-board GPS and data-dictionary tag images with position and workflow-related attribute data. Enhanced capabilities such as available compass and handheld GPS integration ensures the 500SE solution will deliver whenever pictures are a priority.

500SE GPS Camera
with integrated **GPS module**




"Thanks to Septentrio GPS technology, we can run 24/7 operation with 0 misplaced containers."
Stephan Gosiau,
Technical Director
PSA HNN
HESSE-NOORD NATIE
PSA

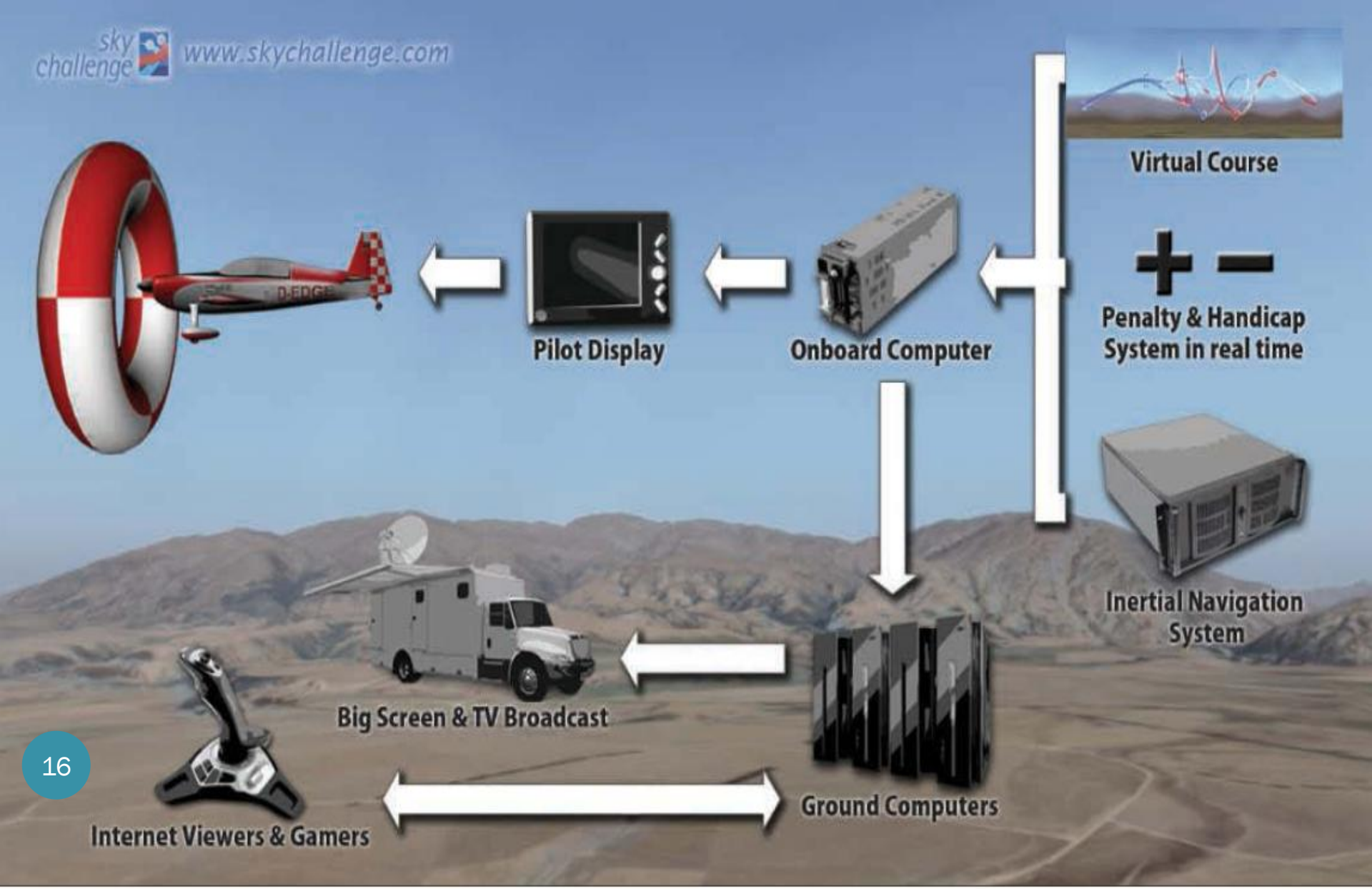


Sky-High Twists and Turns

Aerobatic racing between real and virtual aircraft poses steep positioning requirements. Real-time accuracy must reach at least 1 to 3 meters to score pilots through the course, and position must incude pitch, yaw, and roll in a high-g environment with dynamic flying maneuvers that frequently disrupt GPS signal reception.

Sky Challenge, a real-time race between real and virtual aircraft. Pilots race actual aerobatics planes through a virtual course made up of 3-D objects that do not physically exist.

Loading the course into a flight simulator on the ground and geographically linking it with the real world and simulated planes enables virtual pilots to race against real-world pilots in real time or after the race.



▲ **SKY CHALLENGE SYSTEM** (www.skychallenge.com) links a real-world air race through virtual objects with a live video game. Race spectators see the virtual course combined with the real world on giant outdoor TV screens. The **SKY CHALLENGE COURSE** is made up of a number of differently shaped virtual objects. Volumetric models compare the real aircraft position with the obstacles — in real time. Subsequent obstacles move away from the pilot as a penalty in the event of a collision.

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4.10 Other Remarks

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FDMA never dies!

- Any CDMA or TDMA system will normally include an FDMA component, and can therefore be considered as a hybrid CDMA/FDMA or TDMA/FDMA system.
- In the relatively narrowband TDMA-based 2G systems with a small number of slots per frame
  - D-AMPS: 30 kHz carrier, three users per carrier
  - GSM: 200 kHz carrier, eight full-rate users per carrier
- FDMA still fulfills a role in providing multiple access, although not down to individual channels.

Space Division Multiple Access (SDMA)

- Control the radiated energy for each user in space.
- Use spot beam antennas.
- Sectorized antennas may be thought of as a primitive application of SDMA.