Radios

1. Communications
2. Navigation
3. Satellite comms/GPS
4. Transponders, ADS-B

Lecture 9C: Aviation radios and communications

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In this lecture you will learn:

- Aircraft Communications
- UTM system

Aviation frequencies and radios

Radios
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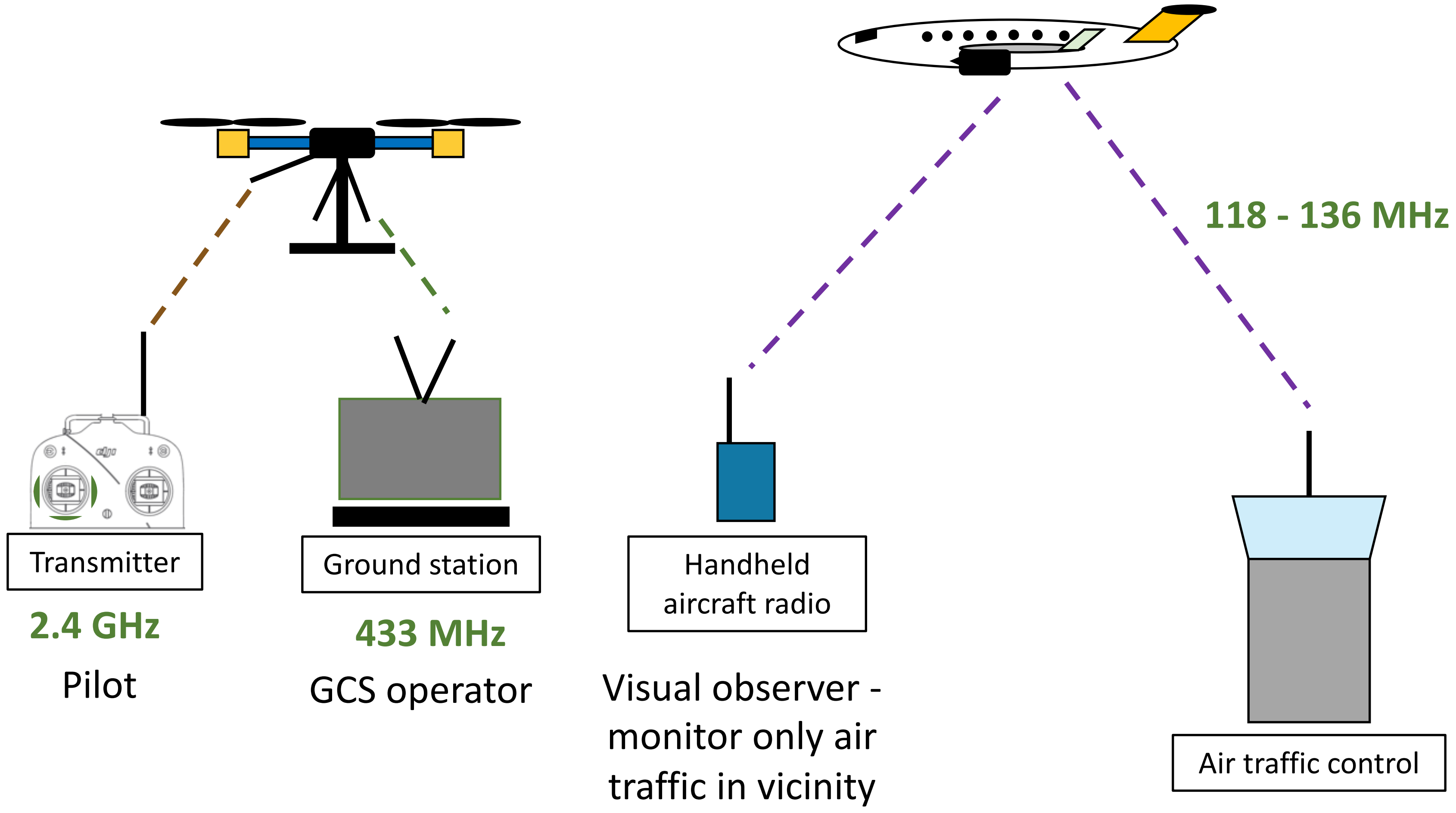

- Spectrum management is critical for safe and reliable operation
- Interference can originate from multiple sources and affect multiple points of communication

RC transmitter function

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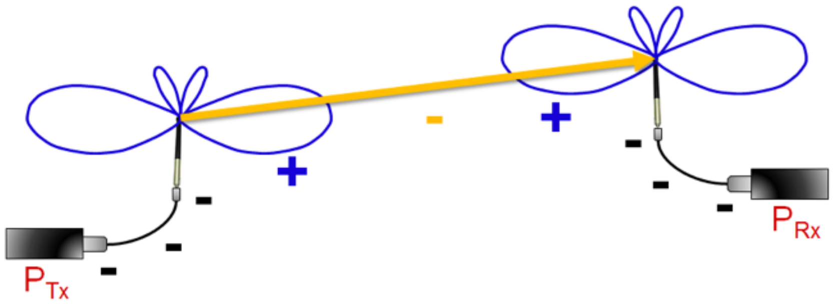
- The RC transmitter used for direct control to the aircraft operates on 2.4 GHz, internal channel hopping
  - The transmitter operates at a relatively low power of 100mW for line of sight operation
  - A frequency hopping, spread spectrum technology allows several transmitters to operate simultaneously without interference
  - The omni-directional antenna has characteristic lobes that favor a link that is **perpendicular** to the **antenna orientation**



Decibel Budget

$$P_{Rx} = P_{Tx} - L_{Conn_t} - L_{Cable_t} + G_t - L_{Path} + G_r - L_{Conn_r} - L_{Cable_r}$$

Ground link telemetry

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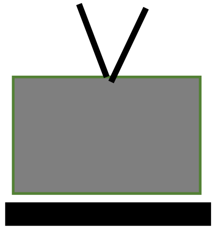
- A pair of 433 MHz radios are used to connect the computer or tablet to the aircraft
- This link is used to send flight commands to the aircraft when operating on a flight mission programmed in QGC
  - Similar to the 2.4GHz transmitter link, the telemetry link strength is affected by the omnidirectional antenna orientation
  - **Make sure your antennas are oriented nearly perpendicular to each other**
- A 433 MHz link will have superior range to a 2.4GHz link due to the higher energy, longer wavelength
  - While bandwidth will be less, the amount of data carried by either link is relatively small so bandwidth is not critical

Aircraft radio + Pixhawk



Ground station

Aviation radio frequencies

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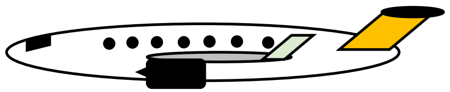
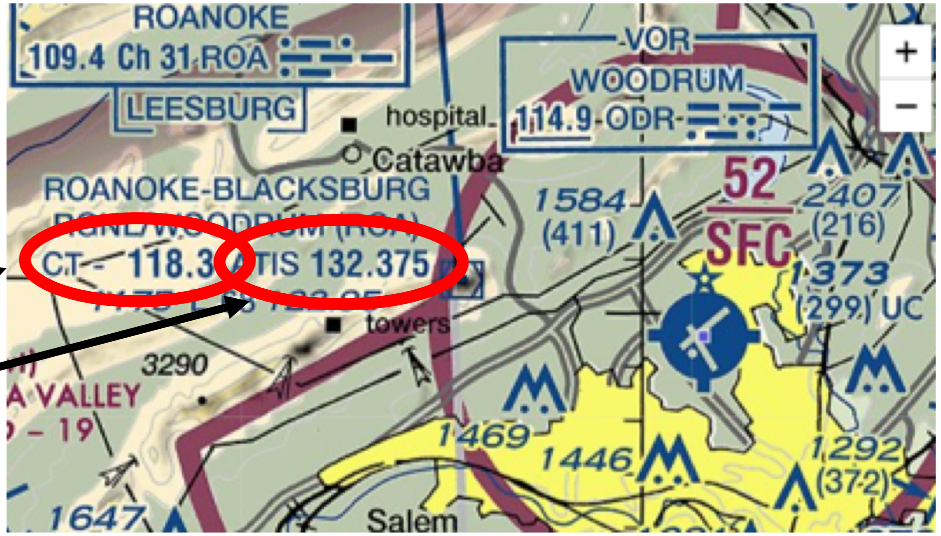


- Aircraft communications are on much lower frequencies since they are only sending audio (voice) signals
- Aircraft transceivers have 760 channels in a 118 MHz - 136MHz range
  - In most aeronautical charts, **airport-specific frequencies** are listed which are usually the best **frequencies to monitor** when operating in the vicinity of an airport
    - The control tower (CT) frequency should be monitored if operating near a controlled field
    - The automatic terminal information service (ATIS) frequency will broadcast current weather conditions



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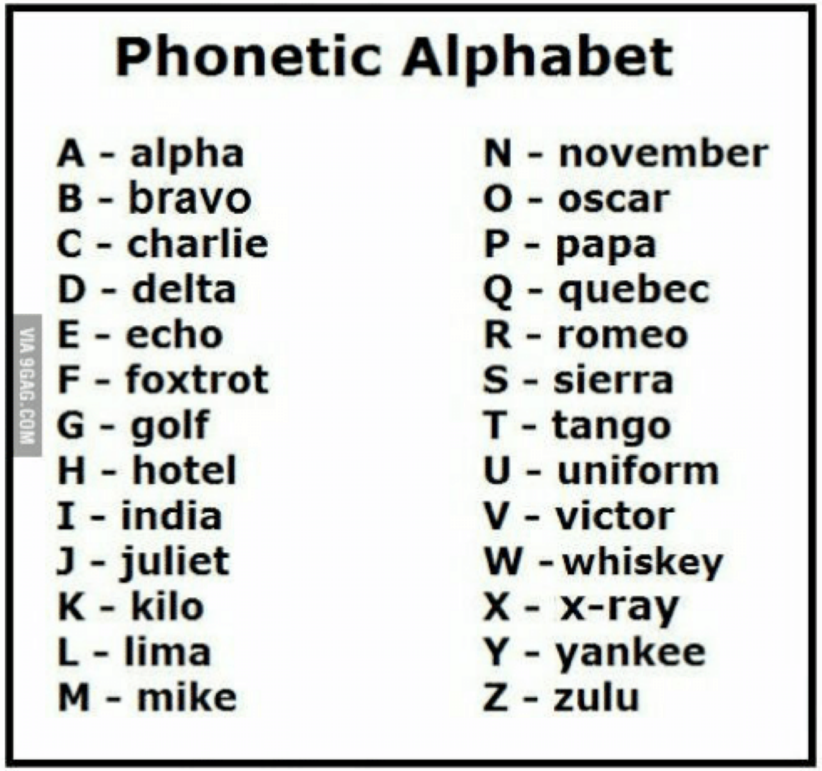
Aviation radio communications

- The Phonetic alphabet is used in radio communications to other aircraft
  - The purpose of the phonetic alphabet is to reduce errors in voice transmissions
- Acknowledging communications:
  - “affirmative” or “roger” = ”yes”
  - “negative” = “no”
- Requesting communications
  - State **who you are contacting** followed by **who you are**: “Lilongwe tower this is alpha delta delta alpha, over”



Phonetic Alphabet

A - alpha	N - november
B - bravo	O - oscar
C - charlie	P - papa
D - delta	Q - quebec
E - echo	R - romeo
F - foxtrot	S - sierra
G - golf	T - tango
H - hotel	U - uniform
I - india	V - victor
J - juliet	W - whiskey
K - kilo	X - x-ray
L - lima	Y - yankee
M - mike	Z - zulu

Air law related to radio communications

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Reference §41 DCA RPA regulations

41. 1) If operations are to be conducted within the 3 nautical miles boundary of an aerodrome, except for R-VLoS operations, no RPA shall be operated unless the pilot has a functioning air-band radio in his possession, tuned to the frequency or frequencies applicable to the Air Traffic Service Unit (ATSU) providing services or controlling such area or airspace or to aircraft in such area or airspace.

    2) The air-band radio shall have the required output and be configured in such a way that the range, strength of transmission and quality of communication extends beyond the furthest likely position of the RPA from the pilot.

Air law related to radio communications

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Reference §41 DCA RPA regulations

41. 3) For VLoS, E-VLoS and B-VLoS operations, the pilot shall, using the registration of the RPA as a call-sign, make the required radio calls, indicating the altitude, location and intended operation of the RPA in that area and at such intervals as are required in order to ensure adequate separation from other aircraft is maintained.

4) For approved RPA operations in controlled airspace, the pilot shall maintain radio contact, using the registration of the RPA as a call-sign, with the relevant ATSU, and acknowledge and execute such instructions as the ATSU may give at any time during the operation of the RPA.

Ground-based navigation systems

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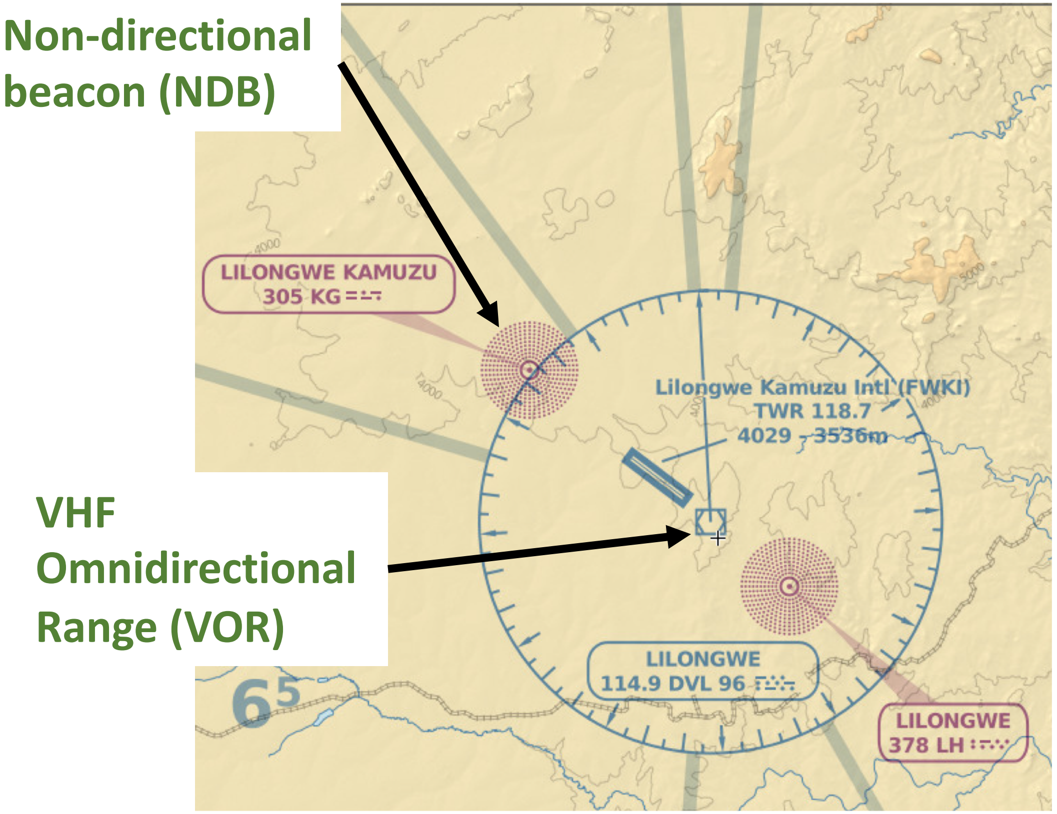
- Before satellite navigation existed, aircraft would use ground-based transmitters to reference their location
  - The **non-directional beacon** (NDB) or **automatic direction finder** (ADF) is a low-frequency AM transmitter that allows a receiver to identify the direction of the radio beacon
    - These transmitters are similar to AM radio stations and the receivers are subject to noise
  - The **VHF Omni Range** (VOR) system provides a magnetic heading indication directly to the receiver which is a more reliable means of localization
    - A VHF radio is subject to less noise than an AM radio



Aircraft that are following a particular navigational track will fly a corrected heading due to wind

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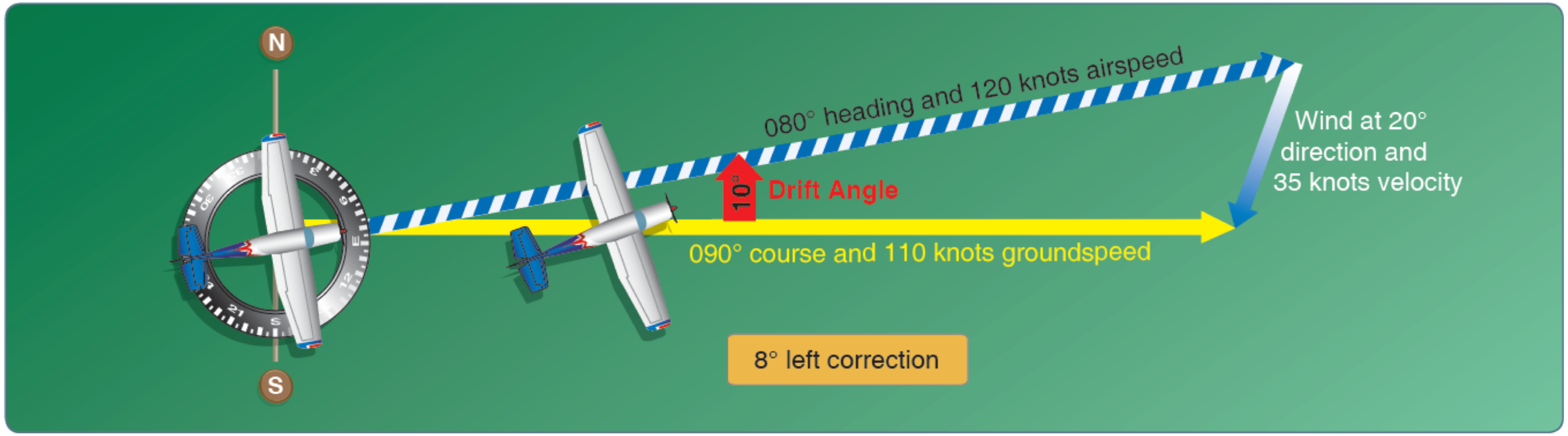
- With fixed wing aircraft that are traveling at a much higher speed at higher altitude, it is advisable to consider the winds aloft when determining how long the flight will take



An effective groundspeed is determined once a wind triangle has been drawn to find the drift component and the compensating flight heading to maintain course

Computing the crosstrack correction and groundspeed will provide accurate mission times to determine feasibility

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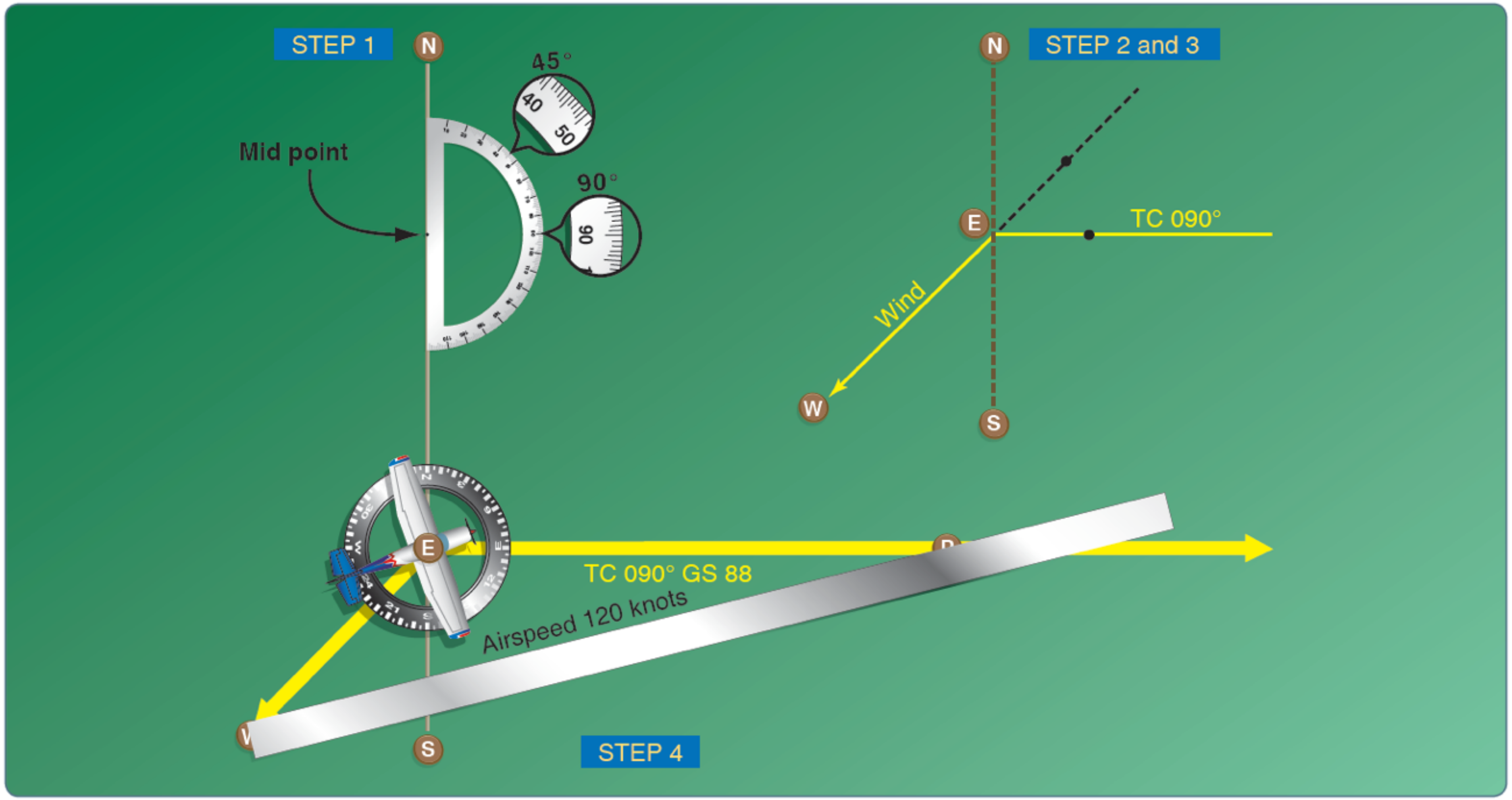

To determine aircraft groundspeed, plot the wind vector and the aircraft vector to find the flight heading + groundspeed over the desired track. Check endurance with battery capacity

Use of GPS in navigation

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- A global positioning system (GPS) is based on a global navigation satellite system (GNSS) consisting of multiple constellations representing multiple countries
- A GPS receiver determines global position through a time-based distance calculation from the satellite to the receiver
- Satellite positions are known precisely in relation to the Earth
- Distances to each satellite are computed based on a received signal time-of-flight calculation
  - These distances are in turn used to find the receiver's position

Use of GPS in navigation

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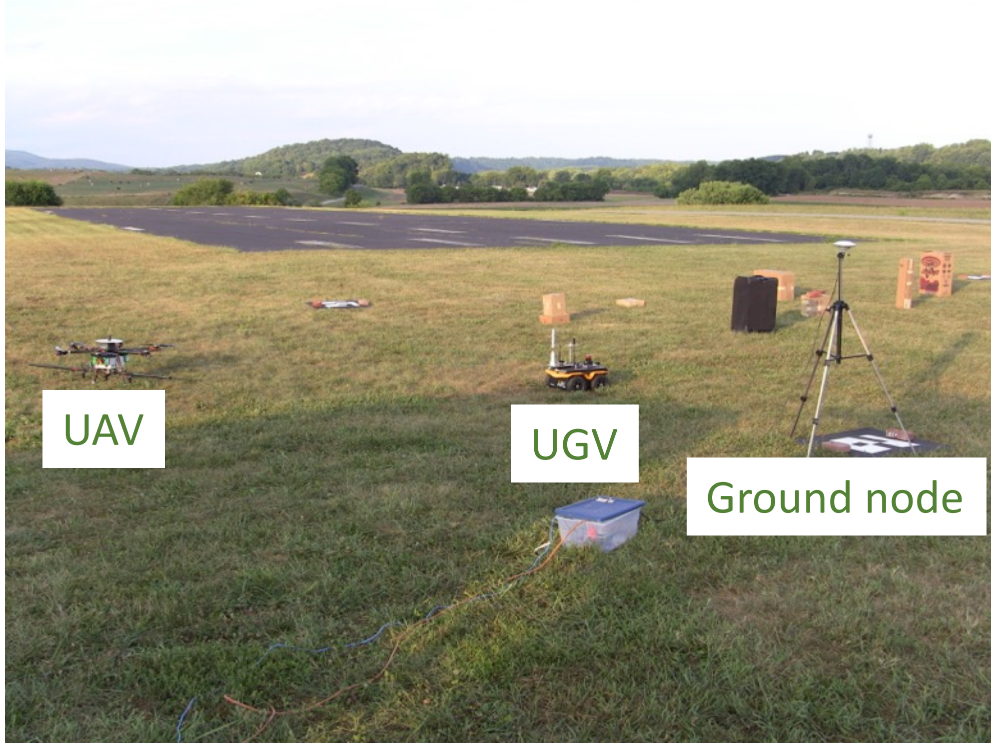
- GPS is the standard for RPA navigation and provides highly accurate information for precise positioning of the aircraft
  - Standard GPS will have an accuracy of a **1 - 2m RMS** while systems that use a ground-based reference node can achieve **centimeter-level accuracy**
    - Systems with ground-based systems use a stationary ground receiver to compute local position changes of the moving node, which is more accurate than using a global-scale reference
      - These systems are frequency called “RTK,” or **real time kinetic** systems
  - Altitude accuracy is usually less than lateral and longitudinal accuracy and may be $\pm 3m$



Use of GPS in navigation

- Most flight controllers use a combination of position, heading and velocity information from the GPS and inertial measurement unit (IMU) for navigation
- If the GPS signal is degraded, the IMU will still provide heading information and the aircraft will approximately fly its intended course
  - A flight controller may alarm if the number of satellites drops below a certain minimum number
    - A GPS nav system will have significantly more error when receiving 6 satellites as opposed to 12
    - If the GPS signal remains degraded, the aircraft will execute a return to launch (RTL) command

GPS errors will be bounded at a constant value, allowing an accurate review of flight track data

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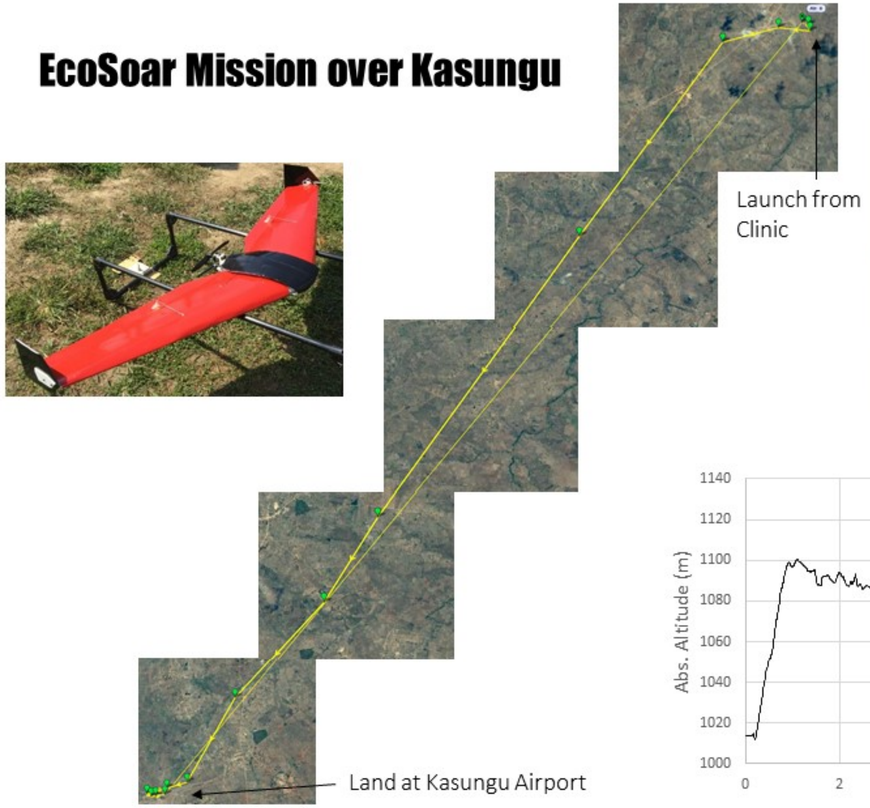
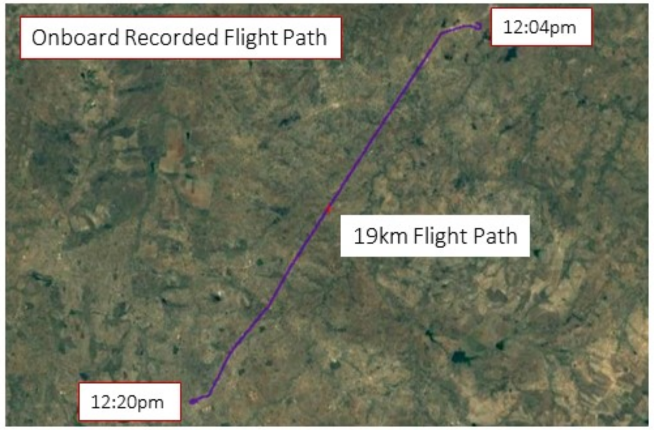
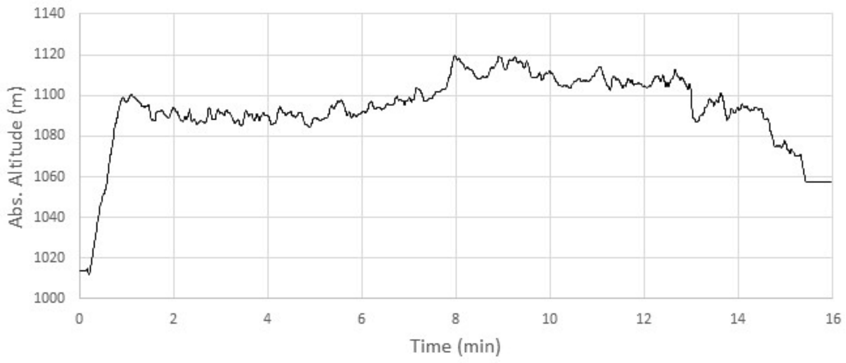
EcoSoar Mission over Kasungu



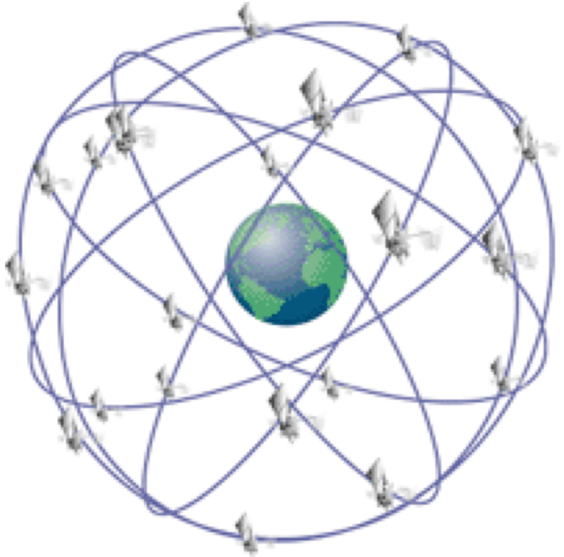




Flight logs provide a valuable source of information for analyzing flight performance or accident data

GPS position accuracy is a function of the number of satellites received and system integrity

- Receive Autonomous Integrity Monitoring (RAIM) is the capability of a GPS receiver to perform integrity monitoring based on satellite signals
  - A RAIM error indicates that accuracy has degraded to the point that GPS position is unreliable
- Although 4 satellites can theoretically be used to determine position, the accuracy will be low
- Typical aircraft GNSS (global navigation satellite system) will receive over 10 satellites which greatly improves positional accuracy



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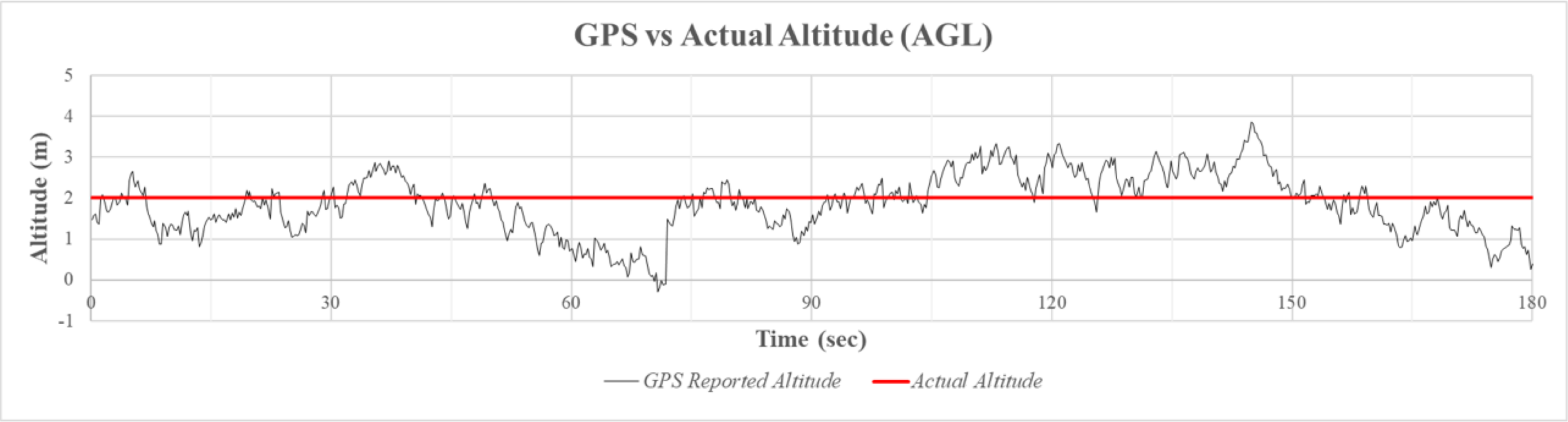
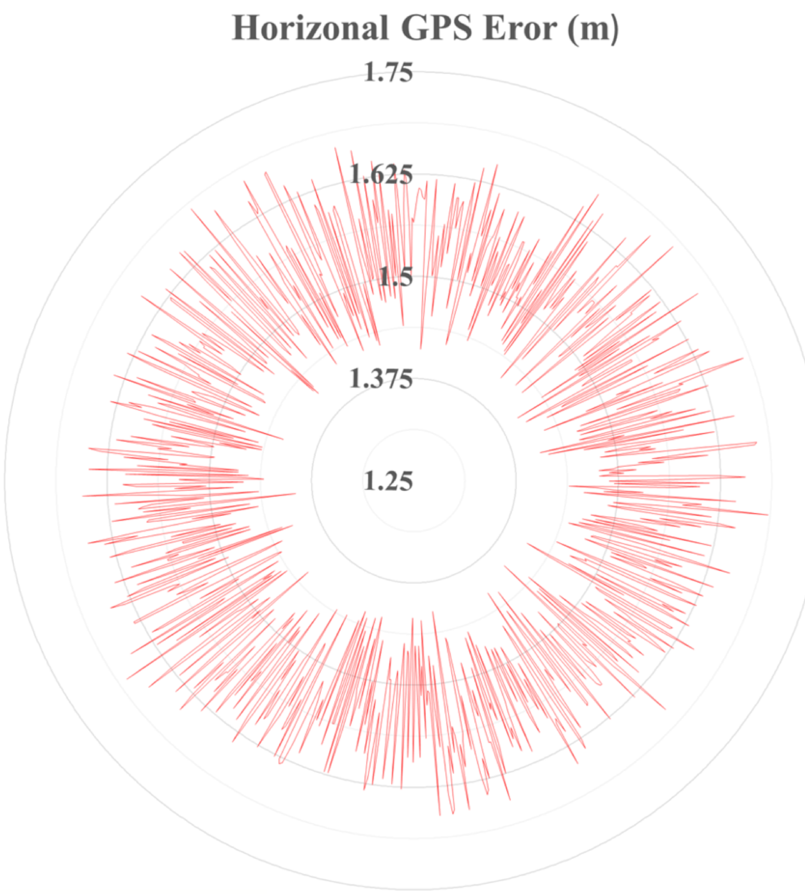
- In practice, local errors that result from GPS are typically acceptable for the precision required in most flight ops
- Errors shown here were determined for a Pixhawk-based flight controller in hover





Flight plans are typically created through waypoint navigation

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- Flight plans can be created using **waypoints** that are connected by straight flight legs, **or by defining areas** which are sub-divided into scan patterns
- In waypoint generation, the lat/long coordinates correspond to GPS nav points the aircraft will use for navigation
- Flight paths can be traced to examine the accuracy of the mission

Other satellite communications include telemetry for BVLOS flight

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- **Iridium** provides satellite communications options for RPA
- The Certus 9770 has an acceptable form factor for drones and is capable of L-band speeds of 22 Kbps to 88 Kbps
- Satellite comms are typically low bandwidth since they are usually meant for "heartbeat" monitoring or small dataset uploads

Iridium Certus™ 9770 Transceiver
Size of unit is approximately 14cm X 6cm X 1.6cm

iridium

Satellite communications usually occur within subsets of the L band

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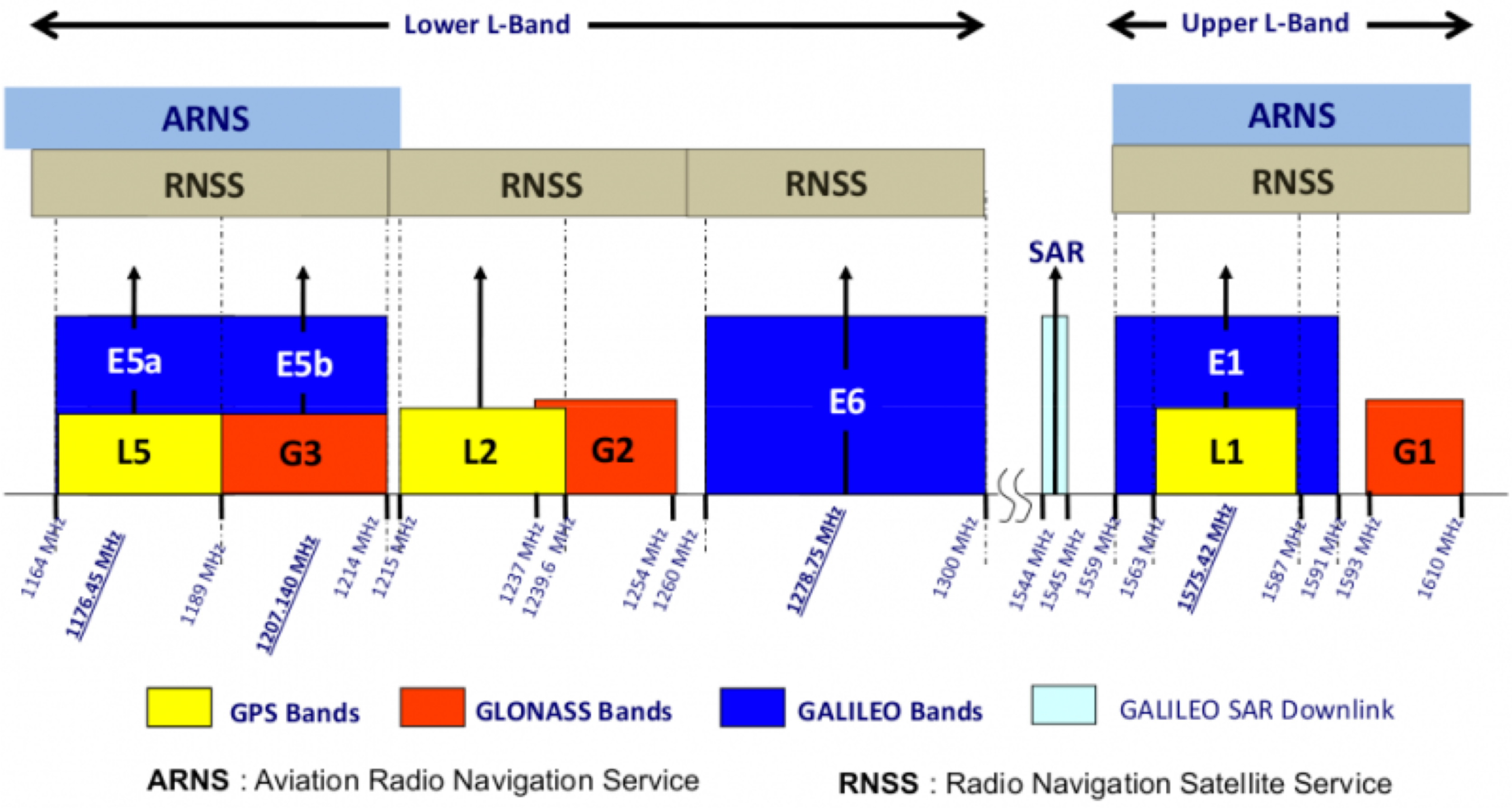
- Note that flights near cellular communications towers can result in GPS interference even though the frequencies are well separated!
- Flights near directional (yagi) antennas should be avoided as they concentrate RF energy



BVLOS flight aircraft are typically required to carry a transponder and/or ADS-B system

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- A **transponder** is an "on-demand" transmitter carried in the aircraft that reports a 4-digit code to a controlling authority
  - The code is assigned by air traffic control
  - The transponder "squawks" a code when a radar signal interrogates the aircraft
  - Each digit is a number from 0 – 7
- Mode C operation reports the altitude of the aircraft
- Mode S contains other information such as the 24-bit assigned ICAO code for the aircraft

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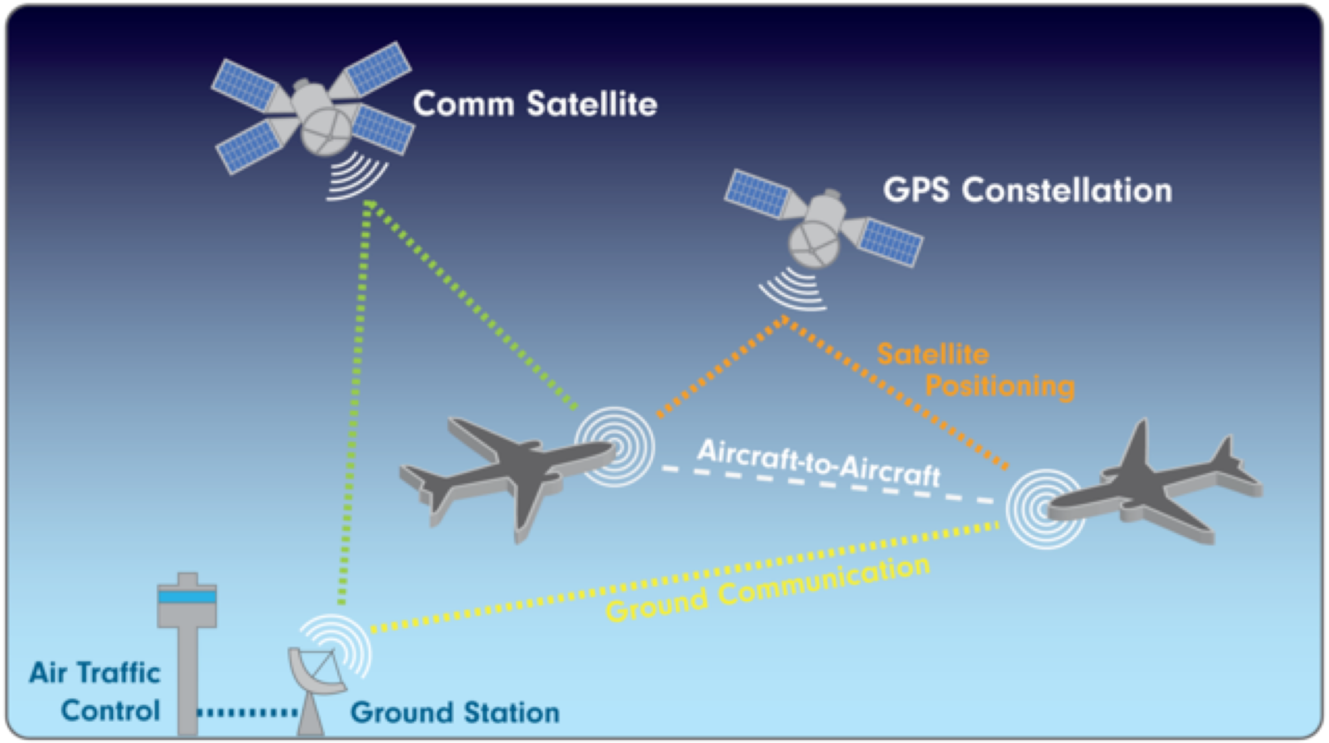
- **ADS-B** stands for **Automatic Dependent Surveillance – Broadcast**
  - ADS-B provides a GPS-based position reporting capability to air traffic control
  - In addition to a satellite constellation, ground-based receivers must have visibility to the aircraft to relay position information to air traffic control



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