Drones Demystified!

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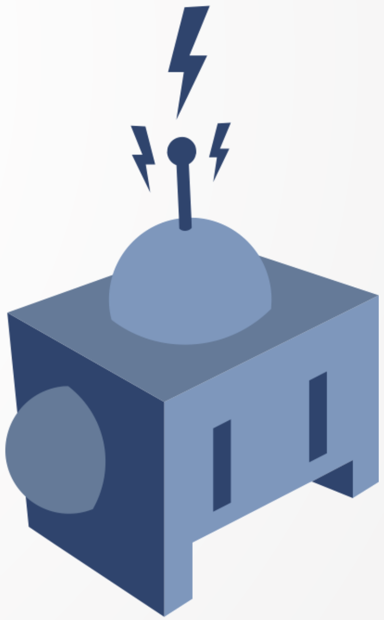
Drones Demystified!

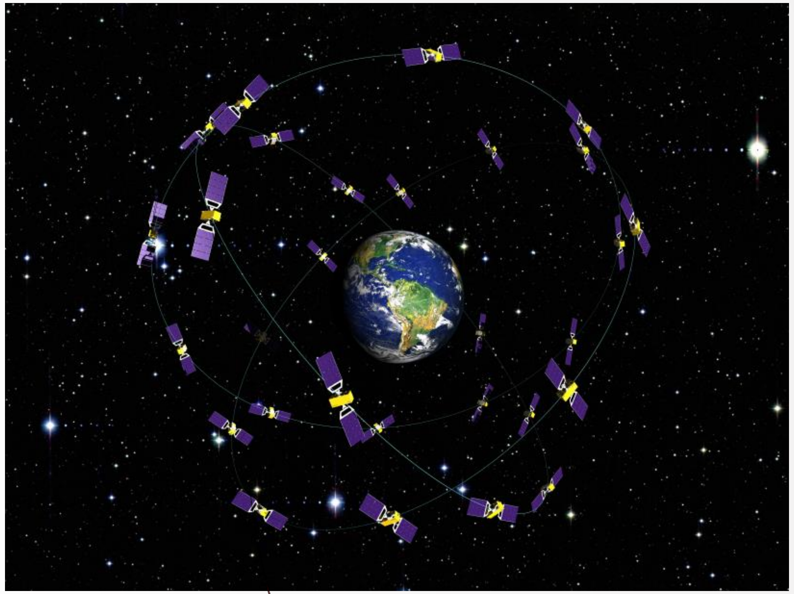
Topic: The Global Position System

Where am I in the environment?



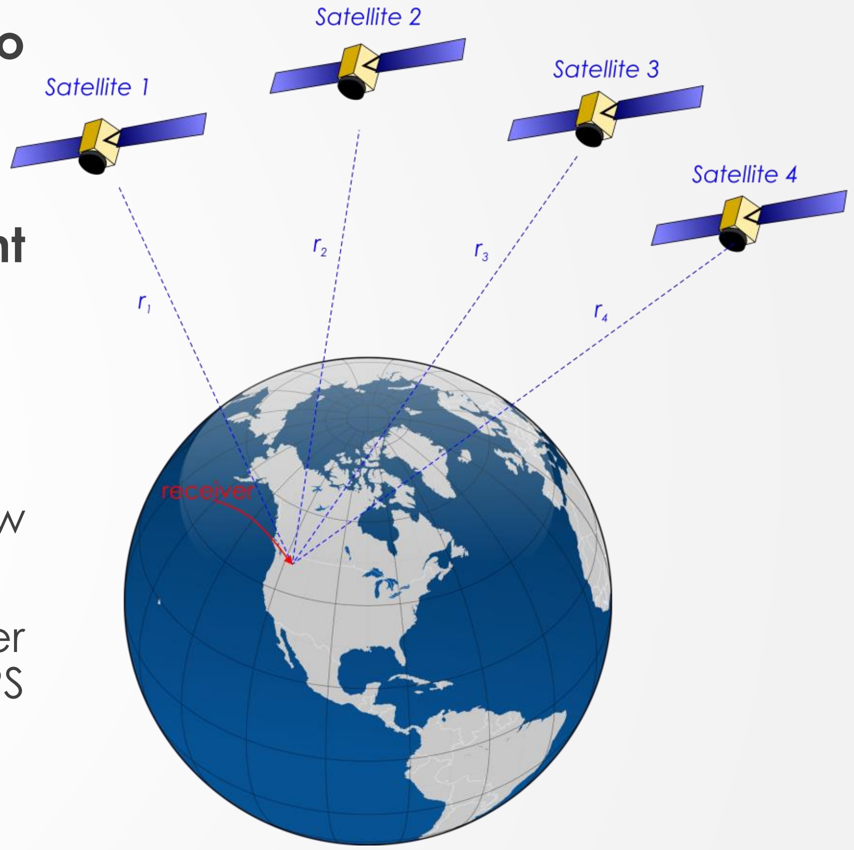
Global Positioning System

- 24 Satellites orbiting the Earth (*and some back-ups*).
- Altitude set at 20,180km
- Any point on Earth's surface can be seen by at least 4 satellites at all times.
- Time-of-Flight of radio signal from 4 satellites to receiver in 3 dimensions.
- 4 range measurements needed to account for clock offset error.
- 4 nonlinear equations in 4 unknown results:
  - Latitutde
  - Longitutde
  - Altitude
  - Receiver clock time offset

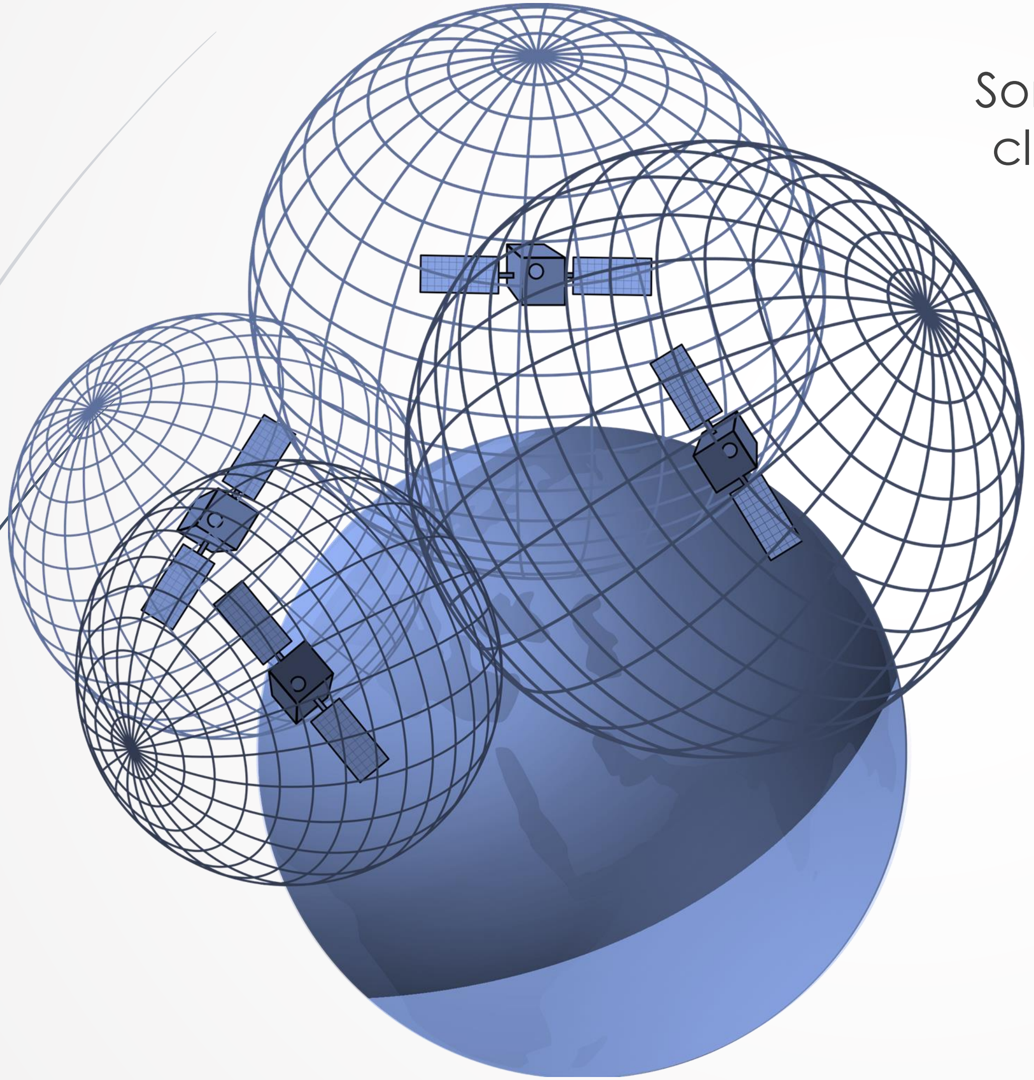


Global Positioning System

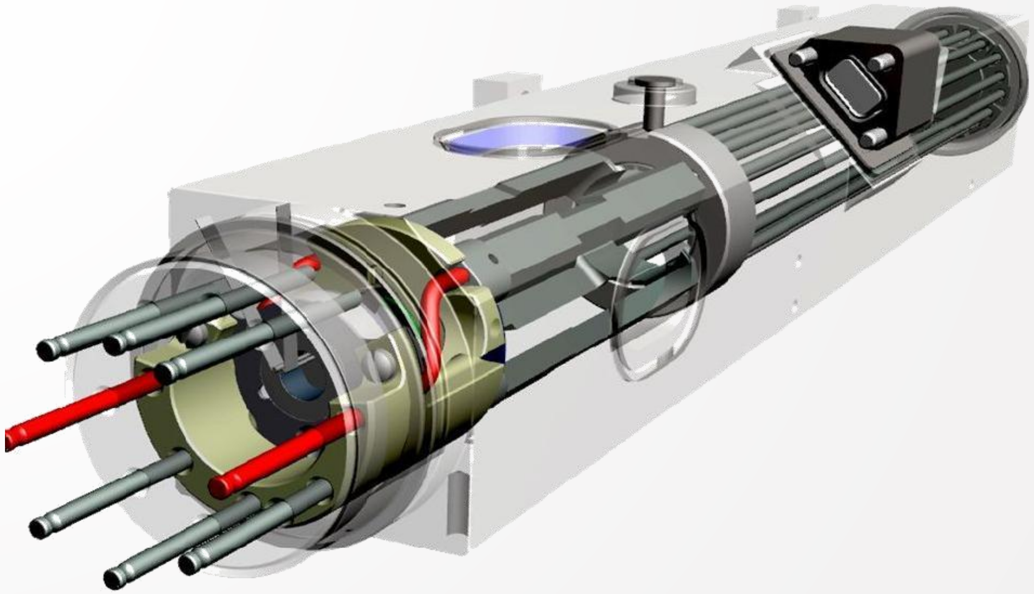
- **Time-of-Flight of the radio signal from satellite to receiver used to calculate pseudorange.**
  - Called pseudorage to distinguish it from true range.
- **Numerous sources of error in time-of-flight measurement:**
  - Ephemeris Data – errors in satellite location
  - Satellite clock – due to clock drift.
  - Ionosphere – upper atmosphere, free electrons slow transmission of the GPS signal.
  - Troposphere – lower atmosphere, weather (temperature and density) affect speed of light, GPS signal transmission.
  - Multipath Reception – signals not following direct path
  - Receiver measurement – limitations in accuracy of the receiver timing.
- **Small timing errors can result in large position deviations:**
  - 10ns timing error leads to 3m pseudorange error.



GPS Trilateration

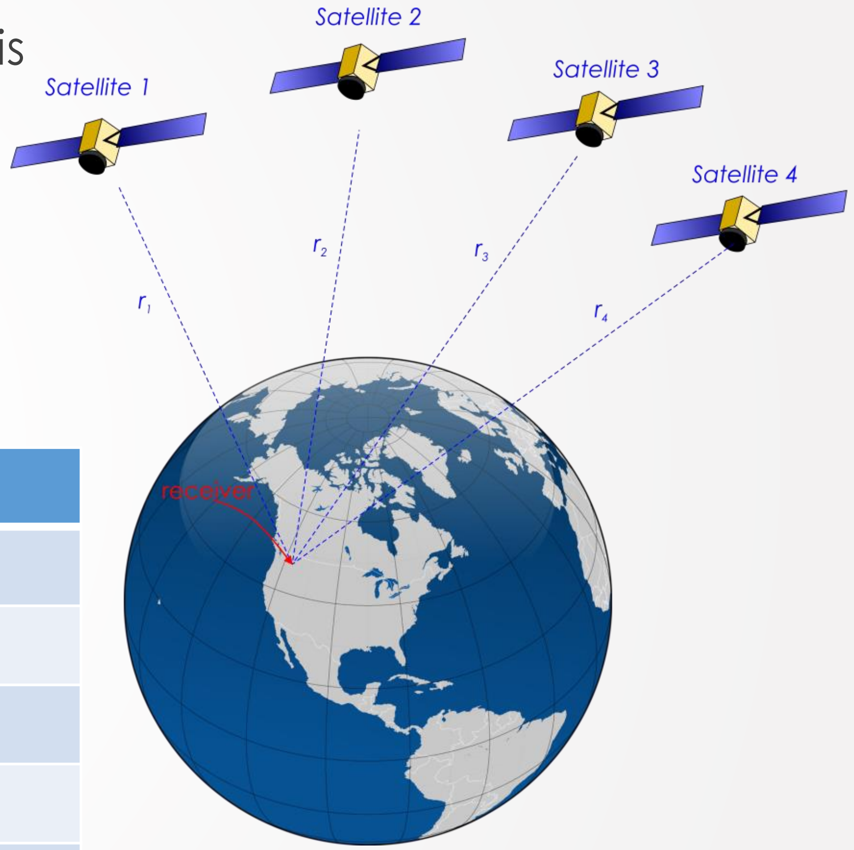


Some math and an atomic clock-based "stopwatch"



GPS Error Characterization

- Cumulative effect of GPS pseudorange errors is described by the **User-Equivalent Range Error (UERE)**.
- **UERE has two components:**
  - Bias
  - Random

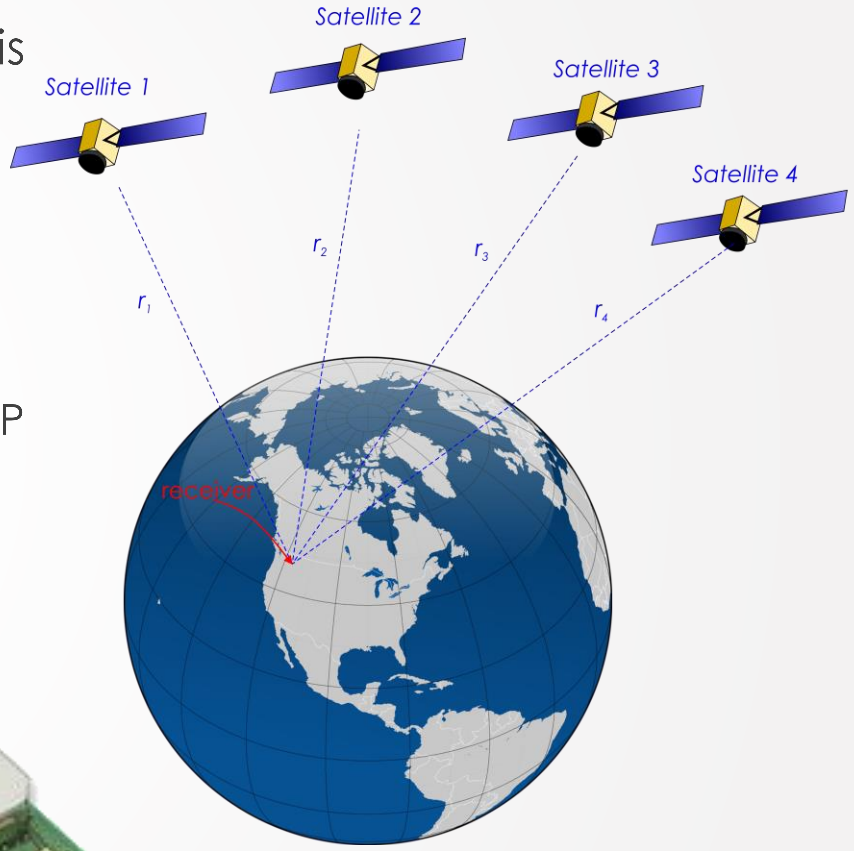


1σ, in m

Error source	Bias	Random	Total
Ephemeris data	2.1	0.0	2.1
Satellite clock	2.0	0.7	2.1
Ionosphere	4.0	0.5	4.0
Troposphere monitoring	0.5	0.5	0.7
Multipath	1.0	1.0	1.4
Receiver measurement	0.5	0.2	0.5
UERE, rms	5.1	1.4	5.3
Filtered UERE, rms	5,1	0.4	5.1

GPS Error Characterization

- Effect of satellite geometry on position calculation is expressed by dilution of precision (DOP).
  - Satellites close together leads to high DOP.
  - Satellites far apart leads to low **DOP**.
  - DOP varies with time.
  - Horizontal DOP (**HDOP**) is smaller than Vertical DOP (**VDOP**):
    - Nominal HDOP = 1.3
    - Nominal VDOP = 1.8



Total GPS Error

- **Standard deviation of RMS error in the north-east plane:**

$$E_{n-e,rms} = \text{HDOP} \times \text{UERE}_{rms} \Rightarrow$$
$$E_{n-e,rms} = (1.3)(5.1) = 6.6\text{m}$$

- **Standard deviation of RMS altitude error:**

$$E_{h,rms} = \text{VDOP} \times \text{UERE}_{rms} \Rightarrow$$
$$E_{h,rms} = (1.8)(5.1) = 9.2\text{m}$$

- As expected: an **ellipsoidal error model**.

Further categorization

- Let’s categorize the sensors we overviewed.

Absolute	Rate
GPS Barometer Accelerometer Magnetometer	Airspeed sensor Gyroscope

Position	Orientation
GPS Airspeed Barometer	Accelerometer Gyroscope Magnetometer

Sensor	Measures	Predicts
Accelerometer	Extracts orientation and measures acceleration	Velocity

SenseSoar

Flight Tests:
Dynamics and Onboard Avionics Evaluation
May, 24th 2013

REA

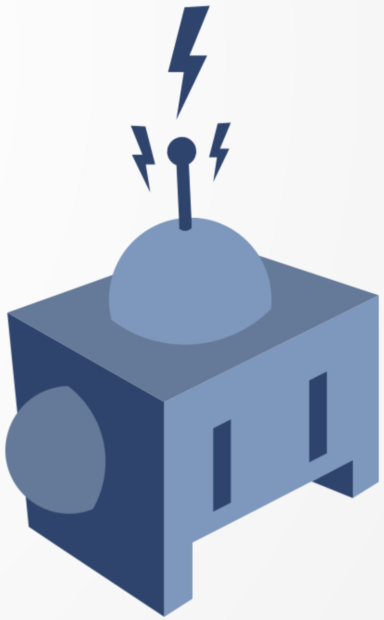
ICARUS

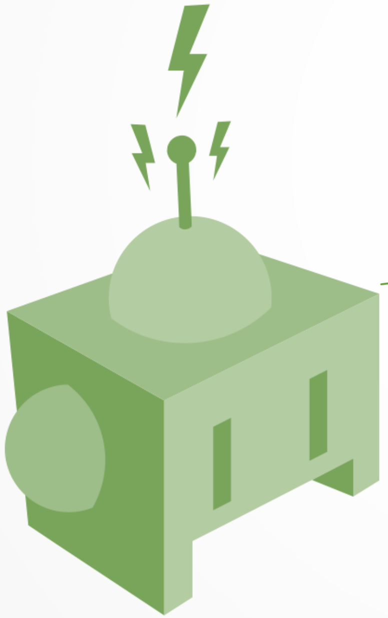
Integrated Components for Assisted Rescue and Unmanned Search operations

ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

Autonomous Systems Lab

How do I fuse all the sensors to get attitude?





Refer to the State Estimation lecture

Find out more

- http://www.autonomousrobotslab.com/literature-and-links.html

Thank you!

Please ask your question!