

Supporting
European
Aviation



UAS Navigation Aspects and Interaction with other Airspace Users

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Andreas Lipp

GBAS and Approach Operations, CNS/INF/NMD

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Navigation and Autonomous Systems, a retrospective



- Georgia Institute of Technology
Research on Autonomous Systems
- In 1991 First Student Competition
<http://aerialroboticscompetition.org/>
- Mission:
Find disk, move to target across
tennis court by autonomous,
airborne robot
 - 6 participating teams,
 - Initially no autonomous flight
 - Very different ideas



Navigation and Autonomous Systems



**INTERNATIONAL
AERIAL ROBOTICS
COMPETITION**



- In 1992 – Autonomous take-off, flight, landing by GaTech team



- In 1995 – task fulfilled by Stanford team using DGPS for position, heading and attitude



Navigation and Autonomous Systems

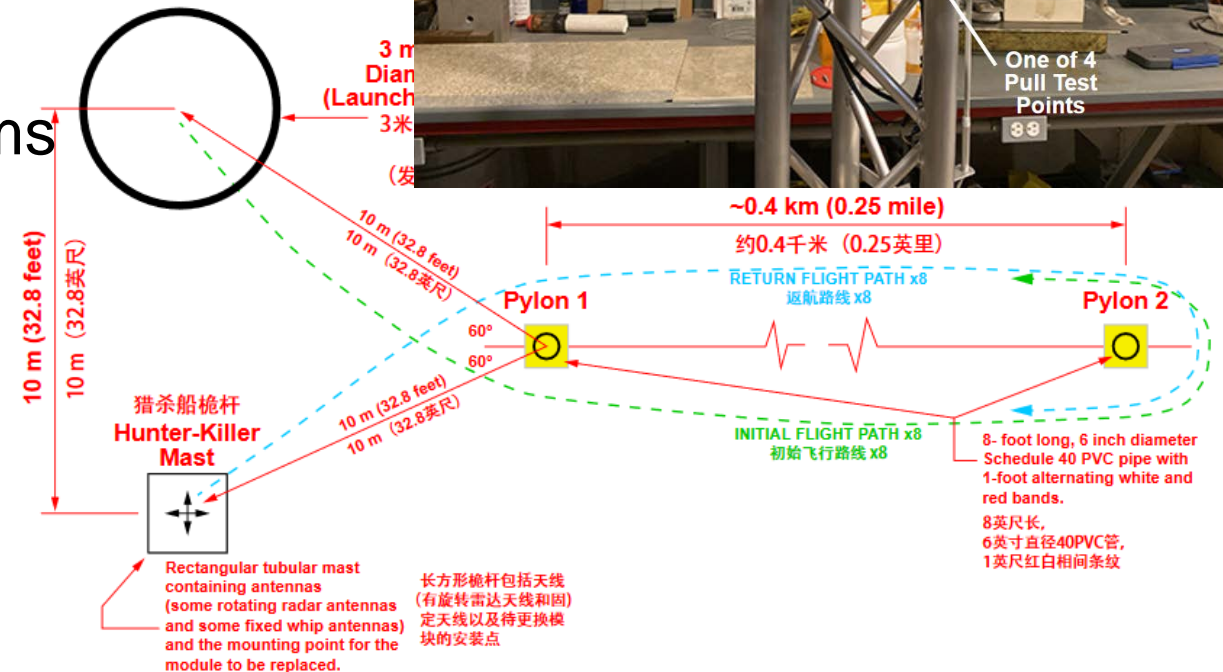
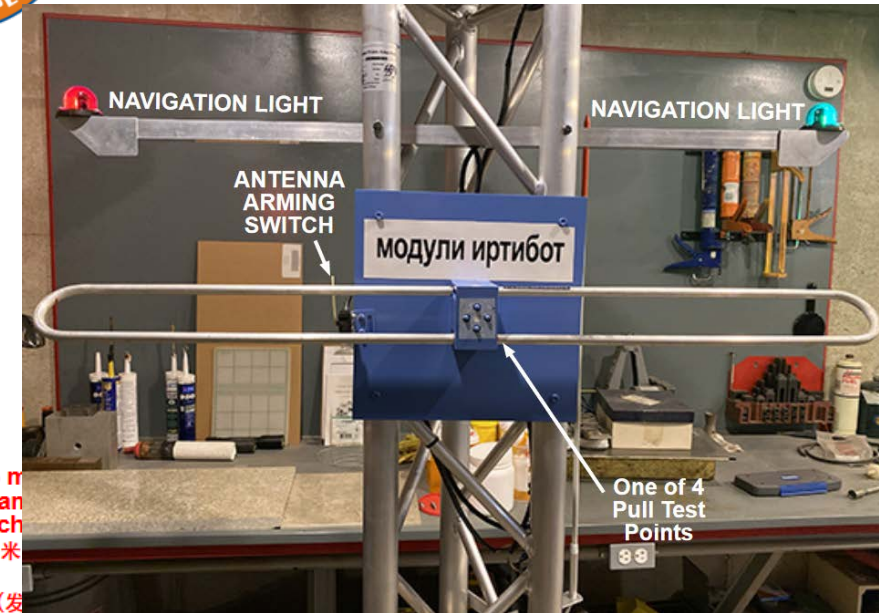


**INTERNATIONAL
AERIAL ROBOTICS
COMPETITION**



In 2020 Mission 9:

- Precision manipulation of large objects
- Fast outdoor operations over long distance (extension of MISSION 4)
- Interaction with moving frames of reference (extension of MISSION 7)
- Aerial robotic repair of mobile platforms
- Optical recognition (extension of MISSIONS 5, 6, 8)
- Using ONLY onboard computing



A more detailed look at Navigation aspects (1)

- Attitude proposed sensor suite:
 - 2-axis inclinometers Accustar/Spectrum (attitude)
 - 3-axis solid state rate sensors Watson/Accustar
 - 2-axis fluxgate (heading and attitude correction)

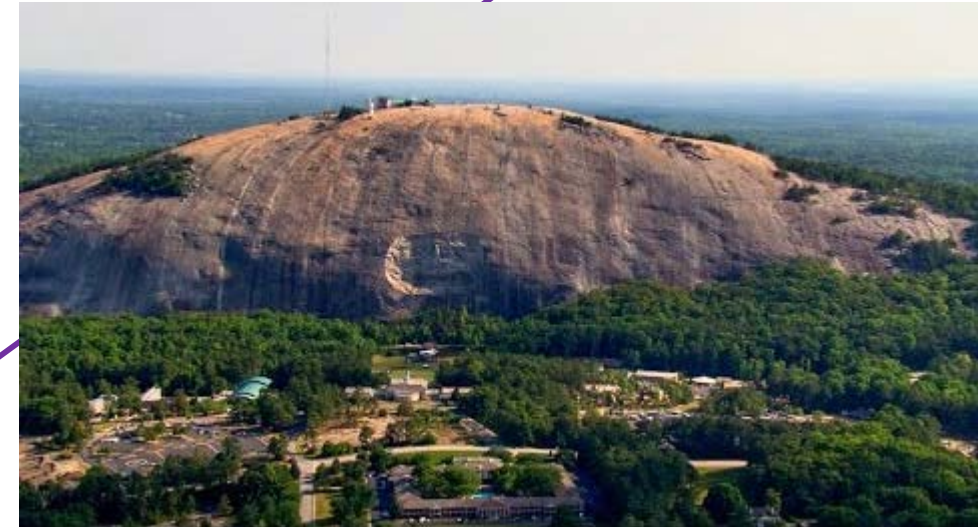


Experience with Attitude Sensors: Heading

- Atlanta is in a zone with magnetic anomalies:



Magnetic disturbances of as much as 10° exists at 4000' elevation in the vicinity of Stone Mountain



- True North would have been more reliable than Magnetic North

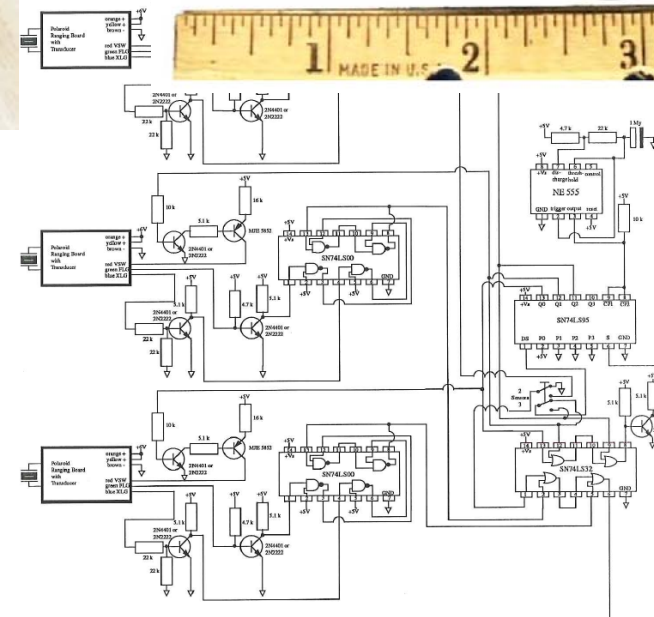
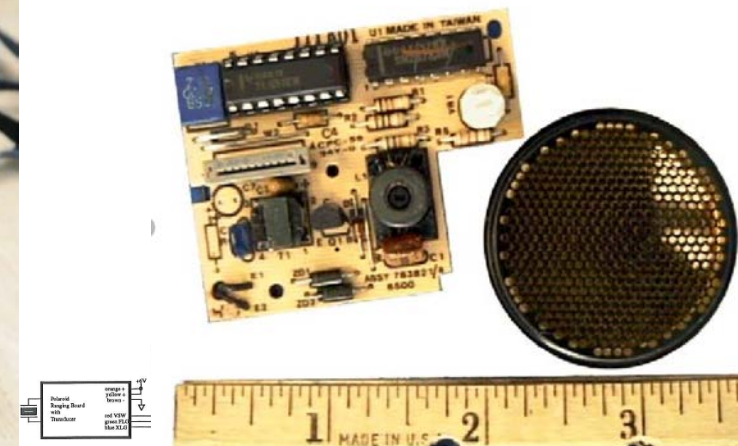
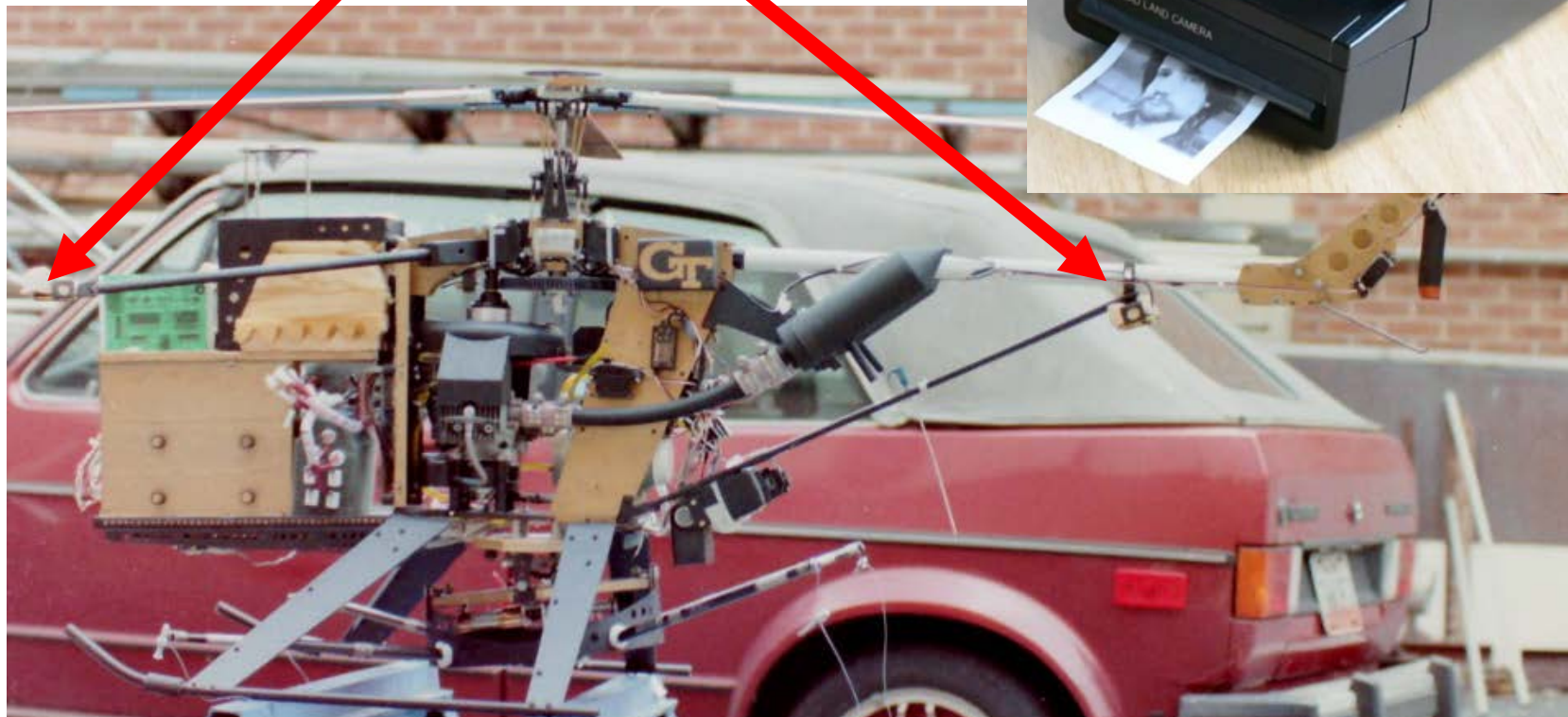
Lesson Learned for Today (1)

- Magnetic Anomalies and Movement of Magnetic Pole prompts manned aviation to use True North in some areas => to be expanded?
 - Metal aircraft construction has caused significant effort to maintain precise magnetic heading in manned aircraft
 - Electrical propulsion on UAS creates massive distortions in the magnetic field
- ⇒ Is magnetic North a suitable reference for joint UAS/aircraft operations?

Integrity, Interoperability (common reference frame)

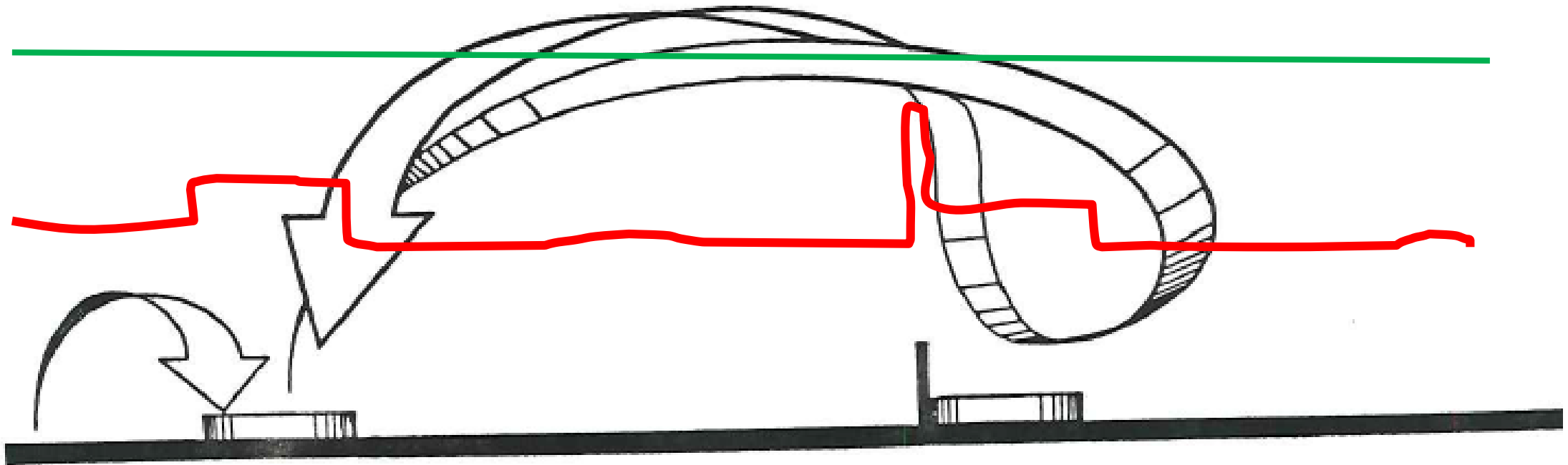
A more detailed look at Navigation aspects (2)

- Altitude: Triplicate Ultrasonic Sensors from Polaroid cameras



Experience with Altitude Sensors

- Relative Altitude only (Ultrasonic)
- Absolute Altitude (GPS)



Lesson Learned for Today (2)

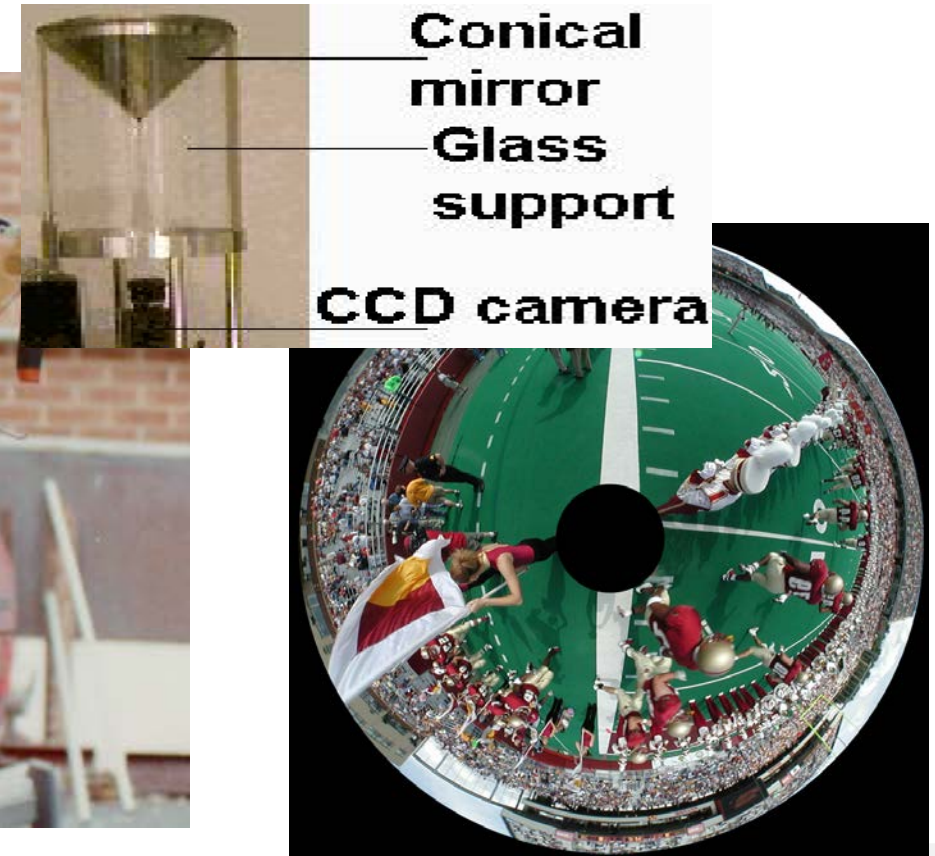
- Relative Altitude (ultrasound, baro) is useful – if it is the only measure used
 - Ground features however are best described in ellipsoid height
 - Baro measurement varies locally at low height (turbulence, venturi effect)
 - For manned aircraft height relative to ground used in precision application
 - For UAS baro altitude is affected by flight regime and turbulences
- ⇒ Is barometric altitude a suitable reference for joint UAS/aircraft operations?
- ⇒ Likely yes at high altitudes (engine settings, simplicity, all using same reference)
 - ⇒ Likely no at low altitudes

Accuracy, Integrity, Interoperability, Robustness

A more detailed look at Navigation aspects (3)

- Position: 360° camera based on lights target camera with flash

Control loop via offboard processing
⇒ data link in outer control loop



Experience with Position Sensors

- Lights outside arena for 360° camera – worked until TV crews installed their lights for the competition and until the sun was setting
- Datalink in public band worked fine during tests, but not with multiple competitors testing

Lessons Learnt for Today (3)

- Impossible to foresee all operating conditions
- Standardization is good, but requires discipline
- Availability and continuity may be determining success
- Security considerations against interference

⇒ Time is required for harmonisation and standardisation

Integrity, Continuity, Availability, Robustness, Security



Lessons Learned – the same as for Manned Aviation

- Datalink aspects: **Availability** and **Continuity** \Rightarrow **Robustness**
- Position Sensors (absolute and relative): **Accuracy**
- Agreed Common Reference Frames: **Integrity**
- Elements shared by multiple users: **Interoperability, Security**
- **But:**

**Similar Requirements
on all
Airspace Users**

separate functions

vs

integrated functions



- GPS in 1991



in 1995



Vision for UAS Integration from the ATM Master Plan

U-Space as framework

3.1 Achieving RPAS integration with manned aviation

- RPAS should be able to operate safely alongside manned aviation, respecting ICAO's key principles
 - In order to **integrate** seamlessly into the airspace, RPAS must, as far as possible, comply with the operational procedures that exist for manned aircraft. Flight operations must not present an undue hazard or burden to persons, property or other aircraft.
 - RPAS operations must not degrade the current level of aviation safety or impair manned aviation **safety or efficiency**. This applies equally to all operators and all drones.
 - RPAS should **conform to manned aircraft standards** to the greatest extent possible. When these principles are not achievable (due to unique RPAS designs or flight characteristics), and no alternative means of compliance are identified, the operation of such RPAS may be subject to safety risk mitigations, such as restricting operations to remain within segregated airspace.

Take-Away for Today

- **Aerial vehicles of all sizes and uses do need to consider similar requirement types**
- **If need to differ, maintain interoperability ⇒ safety**
- **Learn from past experience, but integrate where possible (C+N+S ⇒ iCNS)**
- **Standardization is slow, but necessary for interoperability**
- **In some areas, such as use of magnetic north and baro altitude at low level, further discussions within the entire aviation community are required**

Discussion

