FLARM Ecosystem

- Technology designed for GA+UAS
  - Situational Awareness
  - Collision Avoidance
  - Remote Identification
  - Real-time tracking
- Cooperative, low-latency, real-time, infrastructure-independent
- Privacy levels and security
- Available from many suppliers
- Accepted by regulators
- Crowd-funded in 2004
- Used in 35k+ manned aircraft today
- Half of Europe’s fleet equipped
Mining Vehicle Safety

- FLARM spin-off with 30k+ units in use, acquired 2014 by Leica/Hexagon
- Initially only cooperative CAS, then
  - Fleet management
  - (Semi-)autonomous driving, vehicle intervention
  - Pedestrian protection
  - V2X services
  - Fatigue monitoring
- Technologies open-sky + indoor
  - GNSS, TOF ranging, UWB localization
  - V2V, V2X communications
  - Computer vision, (event-based cams)
  - Radar
  - FLIR
Flight Tests

https://youtu.be/mRbw7sg5lUM

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Flight Tests

https://youtu.be/H8jgoJHVX7U
OPV Flight Tests

Diamond DA42 Centaur OPA R-711 by Aurora Flight Science

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TBS Crossfire

Hongkong-based TBS
- Supplier-agnostic real-time video-link/C2 electronics
- Leading video, latency and long-range tech
- US primary market, 20k+ units in use

TBS FLARM = first-in-the-industry solution
- Safety, situational awareness, fun and RID
- SW-only retrofit on existing diversity HW + GPS
- OSD/FPV video telemetry for traffic display

3 products levels
- **Pulse**: RID+tx only, the new default setting
- **Buddy**: Pulse + rx TBS traffic + OSD traffic
- **Aviation**: full solution = dedicated FLARM

https://youtu.be/W65ooyvrktg

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FLARM in lower airspace vs 1090ES

Below 4km MSL (about FL130)

Above 4km MSL (about FL130)

Vertical profile

1090ES equipment rates
2013-06 to 2016-04
Lessons Learned + Assumptions

- Limitations of See & Avoid
- Technology vs. rules + hope
- Safety does not sell (alone)
- Installation + configuration
- Airliners vs GA vs UAS
- Non-certified equipment vs safety benefit (EFB, NORSEE, ...)
- ADS-B
  - Does not scale for UAS
  - No security, privacy
  - Lacking content for CAS+UTM
  - USA goes solo (parallel UAT)

FLARM Conspicuity
- Simple + affordable
- Combines safety, security, fun
- Ecosystem of products
- Adaptive from toys to CS-2x, from balloons to parachutes
- Forward trajectory-based
- Software upgradeability
- Sufficient regulatory acceptance
- 1st RID mandate in major EU country
Lessons Learned + Assumptions

- While amateur UAS usage explodes, rules and technology become more complex
- Accountability now, UTM+ later
- Drone risk overestimated
- Professional drones will live longer
- Drone experts gain aviation knowhow
- Investor’s hype to calm:
  - Showcases now, broad adoption later with unexpected use cases
  - Volumes <> smartphones
  - Only few are profitable yet
  - Size of future market unknown
Lessons Learned + Assumptions

- Performance of complex sensors will be reached by commodity sensors
- IoT is not uniform, partially proprietary, long range, low data, long life smart sensing
- Drone technology will change aviation, but slowly
  - Inertia of manned aviation
  - Cost (e.g. OPV certification)
  - Concept of airspace
  - Communication, security, trust
  - UTM/ATM
- Dynamic market > dynamic technology
- “RPAS will have to be as safe as, or safer than, present manned operations” (ICAO)
  - Most UAV cannot be seen > most UAV to avoid manned aircraft?
  - Pilots are expensive and a risk
  - Humans excel in new and complex tasks, not as supervisor of autopilot
  - Autonomous-flying is simpler than autonomous-driving
  - Mixed traffic is challenging
Computer Vision-based DAA

- Early, fast and reliable detection
- Video stabilisation
- ST-cube
- Motion compensation

Open-source annotated image sequence library

Copyright © Prof Pascal Fua, EPFL CV Lab
## Comparison of Solutions

<table>
<thead>
<tr>
<th></th>
<th>PCAS</th>
<th>TAS (TCAS I)</th>
<th>TCAS (TCAS II)</th>
<th>ADS-B IN (1090ES)</th>
<th>FLARM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Target Aircraft Identification</strong></td>
<td>Partially</td>
<td>Partially</td>
<td>Partially</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Works without SSR Coverage</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td><strong>Accuracy</strong></td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
<td>High</td>
<td>Very High</td>
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<tr>
<td><strong>Compatible with</strong></td>
<td>XPDR A/C XPDR S</td>
<td>XPDR A/C XPDR S</td>
<td>XPDR A/C XPDR S</td>
<td>ADS-B OUT</td>
<td>FLARM</td>
</tr>
<tr>
<td><strong>Target Display</strong></td>
<td>Range, altitude</td>
<td>Bearing, distance, altitude, TA</td>
<td>Bearing, distance, altitude, TA, RA</td>
<td>Bearing, distance, altitude</td>
<td>Bearing, distance, heading, altitude, TA</td>
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<tr>
<td><strong>Base Price before install</strong></td>
<td>1k$</td>
<td>10k$</td>
<td>50k$</td>
<td>1k$</td>
<td>&lt;1k$</td>
</tr>
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</table>
Comparison of Technologies

<table>
<thead>
<tr>
<th>Feature</th>
<th>XPDR A/C</th>
<th>XPDR S</th>
<th>ADS-B OUT 1090ES</th>
<th>FLARM</th>
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</thead>
<tbody>
<tr>
<td>Remote acft identification</td>
<td>No</td>
<td>Yes 24bit</td>
<td>Yes 24bit</td>
<td>Yes Open</td>
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<tr>
<td>Position</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
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<tr>
<td>Altitude</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Speed, Heading</td>
<td>No</td>
<td>No (ELS)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Future trajectory forecast</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Interrogation independent</td>
<td>No</td>
<td>No</td>
<td>Yes (cooperative)</td>
<td>Yes (cooperative)</td>
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<tr>
<td>Display error typ.</td>
<td>230m/50NM</td>
<td>230m/50NM</td>
<td>&lt;150m</td>
<td>&lt;10m</td>
</tr>
<tr>
<td>Designed for</td>
<td>ATC/ACAS position rep.</td>
<td>ATC/ACAS position reporting</td>
<td>ATC position reporting</td>
<td>Collision Avoidance</td>
</tr>
<tr>
<td>Transmit / Receive</td>
<td>Transmit on interrogation</td>
<td>Transmit on interrogation</td>
<td>Transmit only</td>
<td>Transmit + receive</td>
</tr>
</tbody>
</table>
Thank you!