



FLARM Ecosystem

Lessons learned from 70k+ cooperative
Collision Avoidance Systems
in Aircraft and Mining Trucks

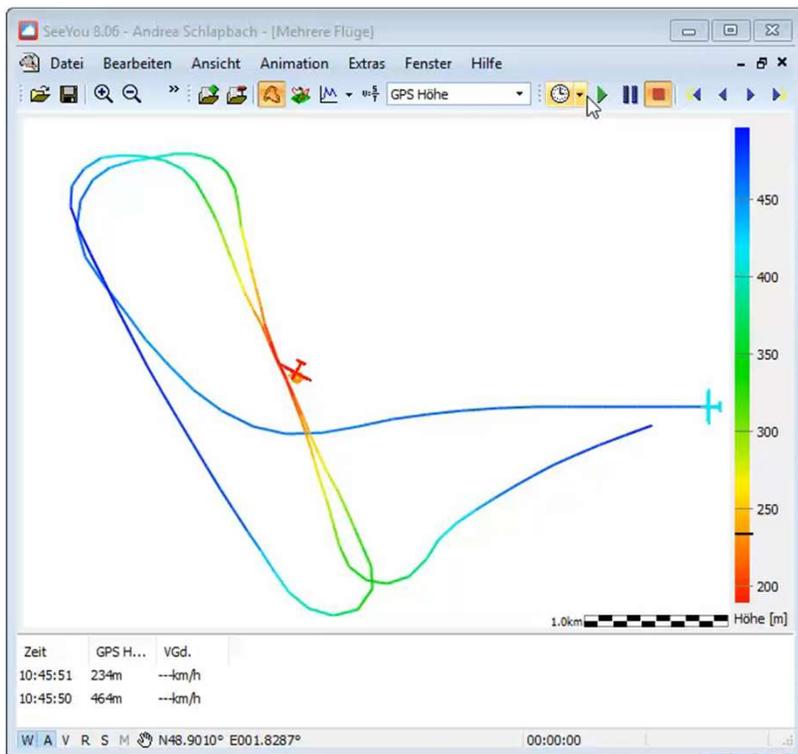
Mining Vehicle Safety



- 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



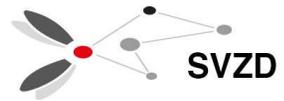
<https://youtu.be/mRbw7sg5IUM>



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Flight Tests



CN	Time	Gsp.	Trk
LIAV	08:29:08	34kts	8°
ACFT	08:29:08	105kts	305°



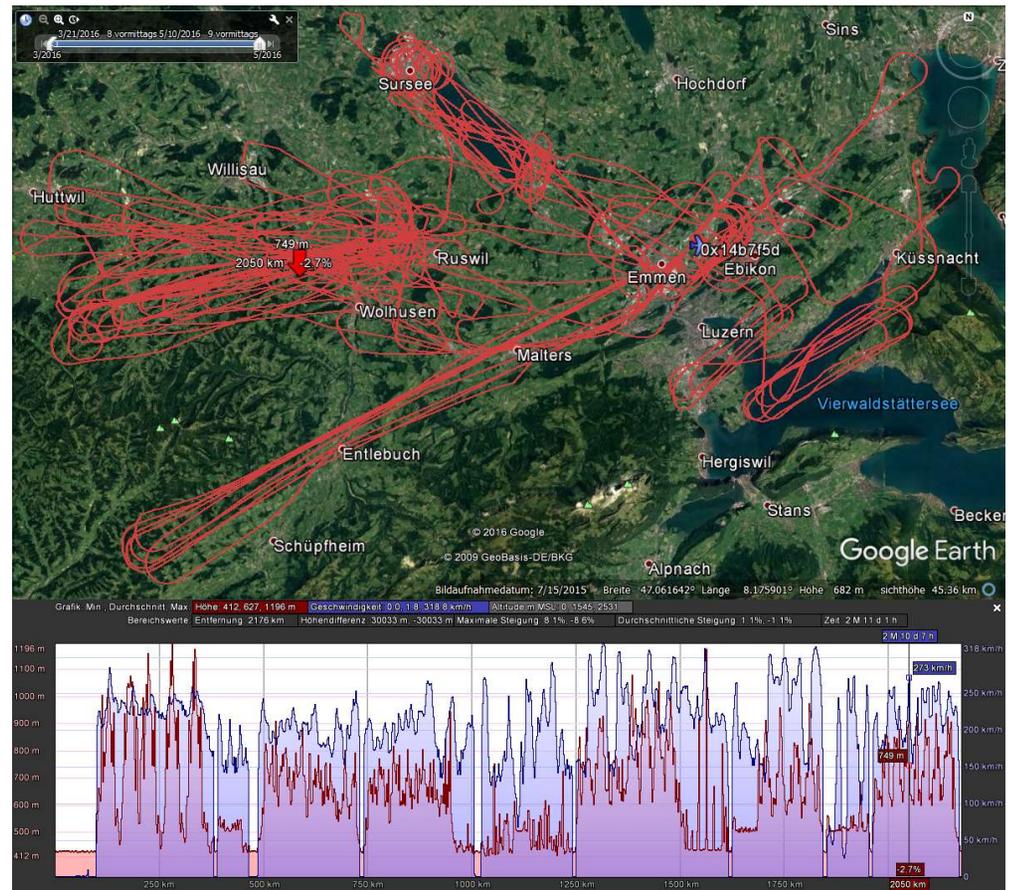
<https://youtu.be/H8jgoJHVX7U>

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OPV Flight Tests



Diamond DA42 Centaur OPA R-711 by Aurora Flight Science



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

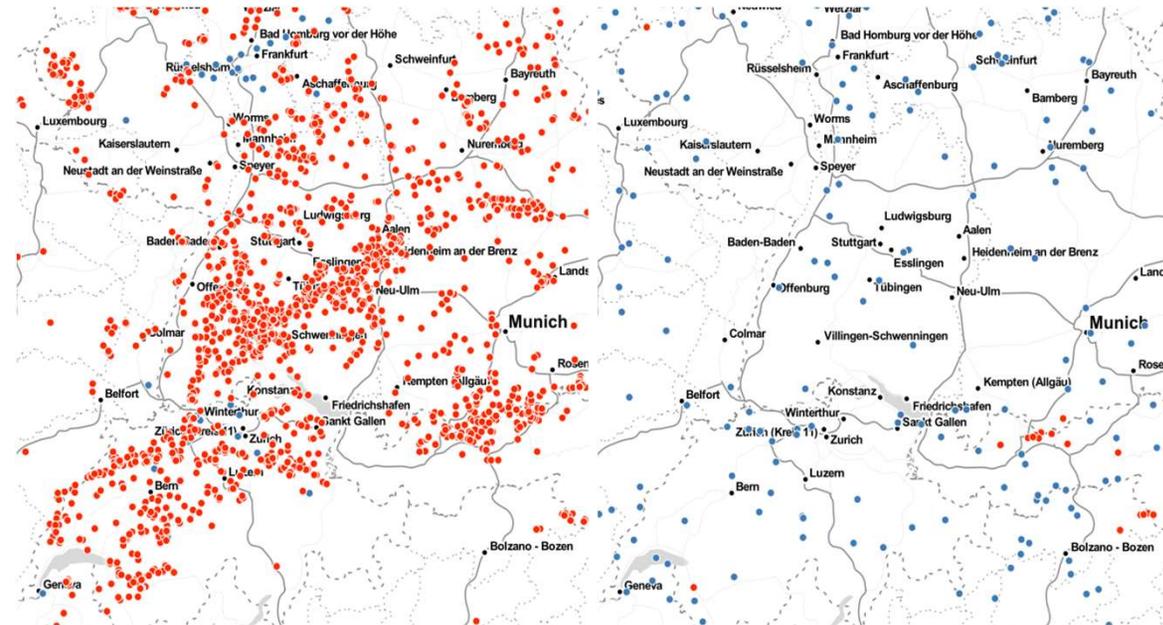
- **Pulse:** RID+tx only, the new default setting **FREE**
- **Buddy:** Pulse + rx TBS traffic + OSD traffic
- **Aviation:** full solution = dedicated FLARM



<https://youtu.be/W65ooyvrktg>

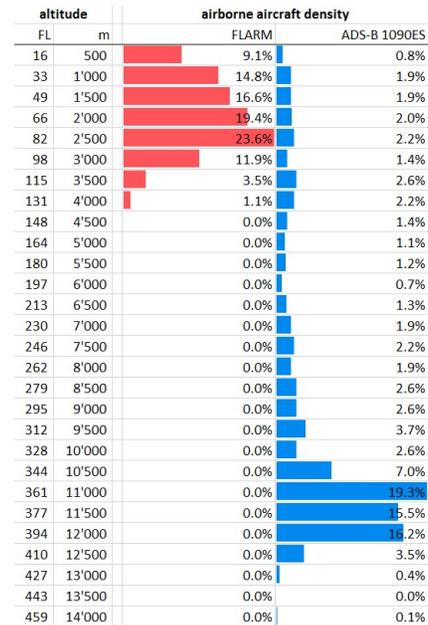
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FLARM in lower airspace vs 1090ES



Below 4km MSL
(about FL130)

Above 4km MSL
(about FL130)



Vertical profile

Manned Acft Type	Type%	1090ES%
Non-heavy <5.7t	85%	4.6%
Piston-Engine	38%	5.4%
Glider + TMG	28%	4.4%
Lighter than air	11%	2.2%
Rotary	9%	4.5%
Heavy	8%	86.2%
Mixed	7%	44.2%
3442 civil reg'd acft	100%	4.6%

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)

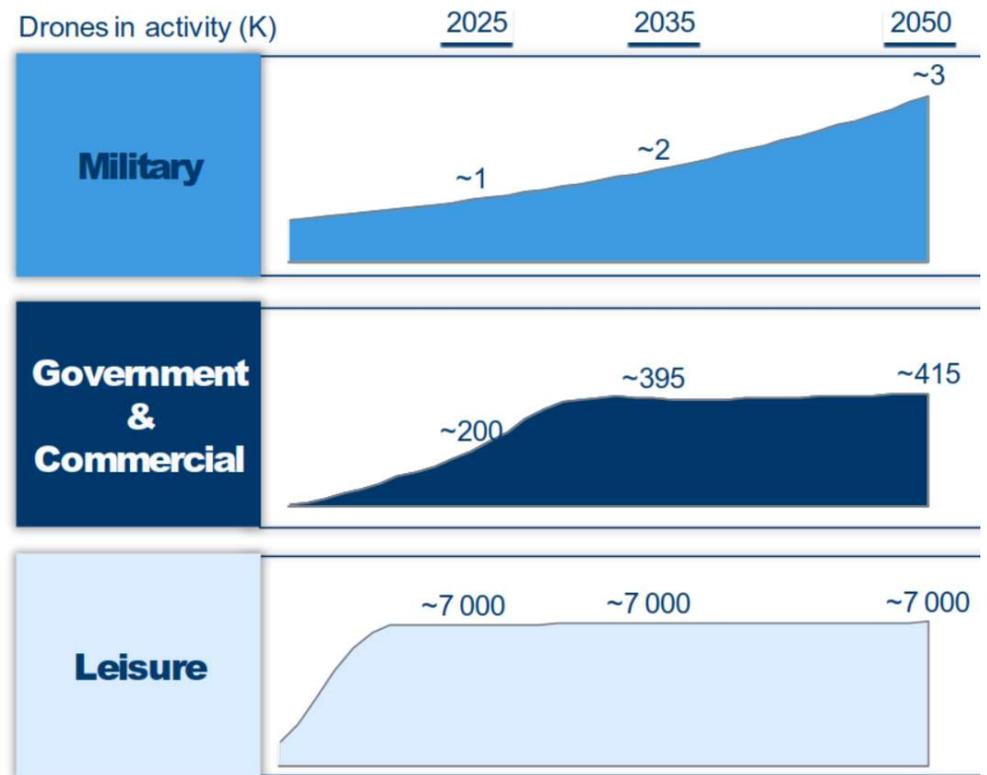
FLARM Conspicuity

- 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

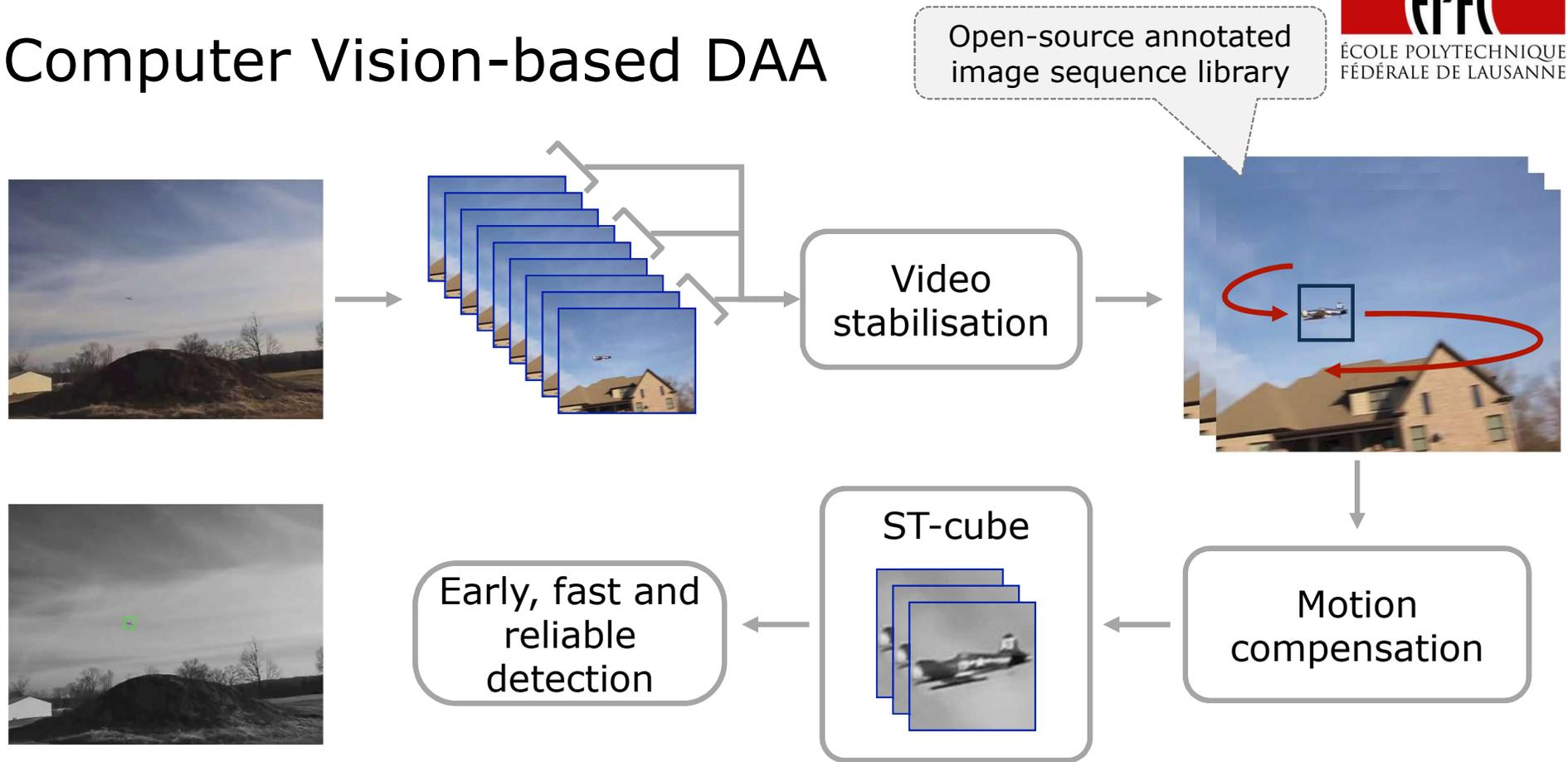
- While amateur UAS usage explodes, rules and technology become more complex
- Accountability now, UTM+ later
- Drone risk overestimated
- Professional drones will live longer
- Drone experts gain aviation knowhow
- Investor's hype to calm:
 - Showcases now, broad adoption later with unexpected use cases
 - 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



Open-source annotated image sequence library

Comparison of Solutions

	PCAS	TAS (TCAS I)	TCAS (TCAS II)	ADS-B IN (1090ES)	FLARM
Target Aircraft Identification	Partially	Partially	Partially	Yes	Yes
Works without SSR Coverage	No	Yes	Yes	Yes	Yes
Accuracy	Low	Medium	Medium	High	Very High
Compatible with	XPDR A/C XPDR S	XPDR A/C XPDR S	XPDR A/C XPDR S	ADS-B OUT	FLARM
Target Display	Range, altitude	Bearing, distance, altitude, TA	Bearing, distance, altitude, TA, RA	Bearing, distance, altitude	Bearing, distance, heading, altitude, TA
Base Price before install	1k\$	10k\$	50k\$	1k\$	<1k\$



Comparison of Technologies

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



Thank you!

