
TBAD
Transponder-Based Aircraft Detector
Tom Murphy
Aircraft Avoidance Systems
AAS

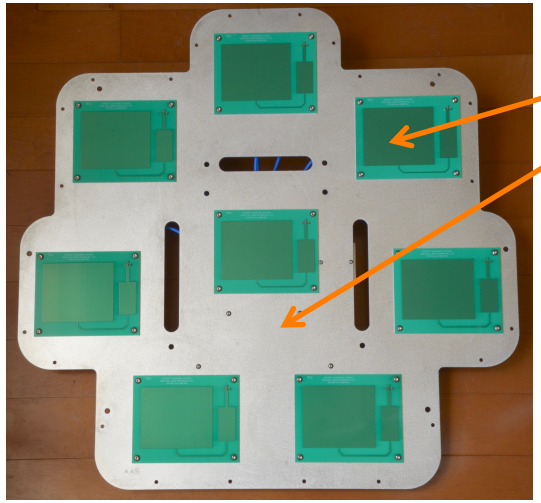
Introduction

- Astrophysics Background
- Instrumentalist
- Laser Propagator; Spotter woes
- Pilot
- TBAD Co-Inventor
- TBAD User (Apache Point)
- TBAD huckster (Aircraft Avoidance Systems)

TBAD Overview

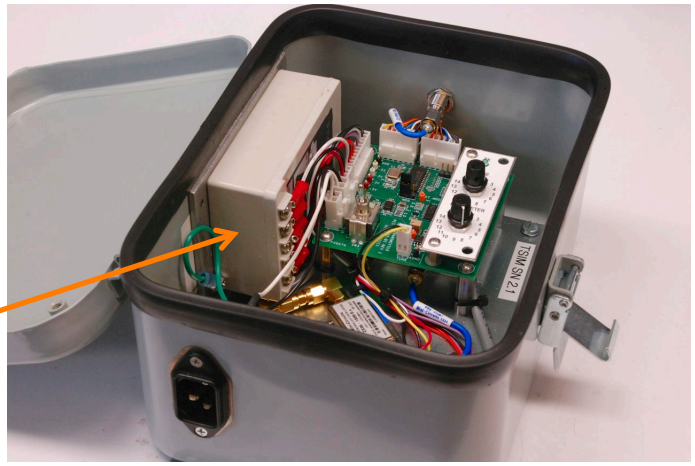
- Passively listens to transponder chatter
  - 1090 MHz Mode A/C/S, ADS-B and 978 MHz UAT/ADS-B
  - not fooled by meteors, moon, birds, bats, moths, clouds, satellites
- Robust directional sensitivity & shutter assertion
- A dozen units operating for LGSAO, laser ranging, optical communications
  - WMKO×2, Gemini×2, LBTO×2, Subaru, Apache Point, et al.
- Site-specific FAA-approvals for spotter-free operation
- Really Dumb
  - no operating system, no internet access, no computation or need to know telescope telemetry
  - safety based on low-level detection technology
- Highly-configurable hardware
  - tune to environment: sensitivity thresholds, beam size, requisite counts, logging behavior

TBAD Components



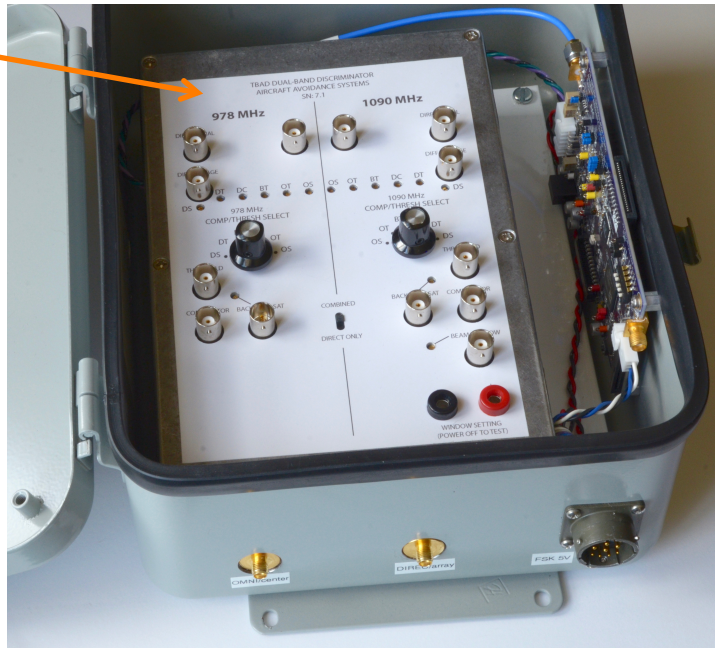
patch antenna

phased array (8 patches)



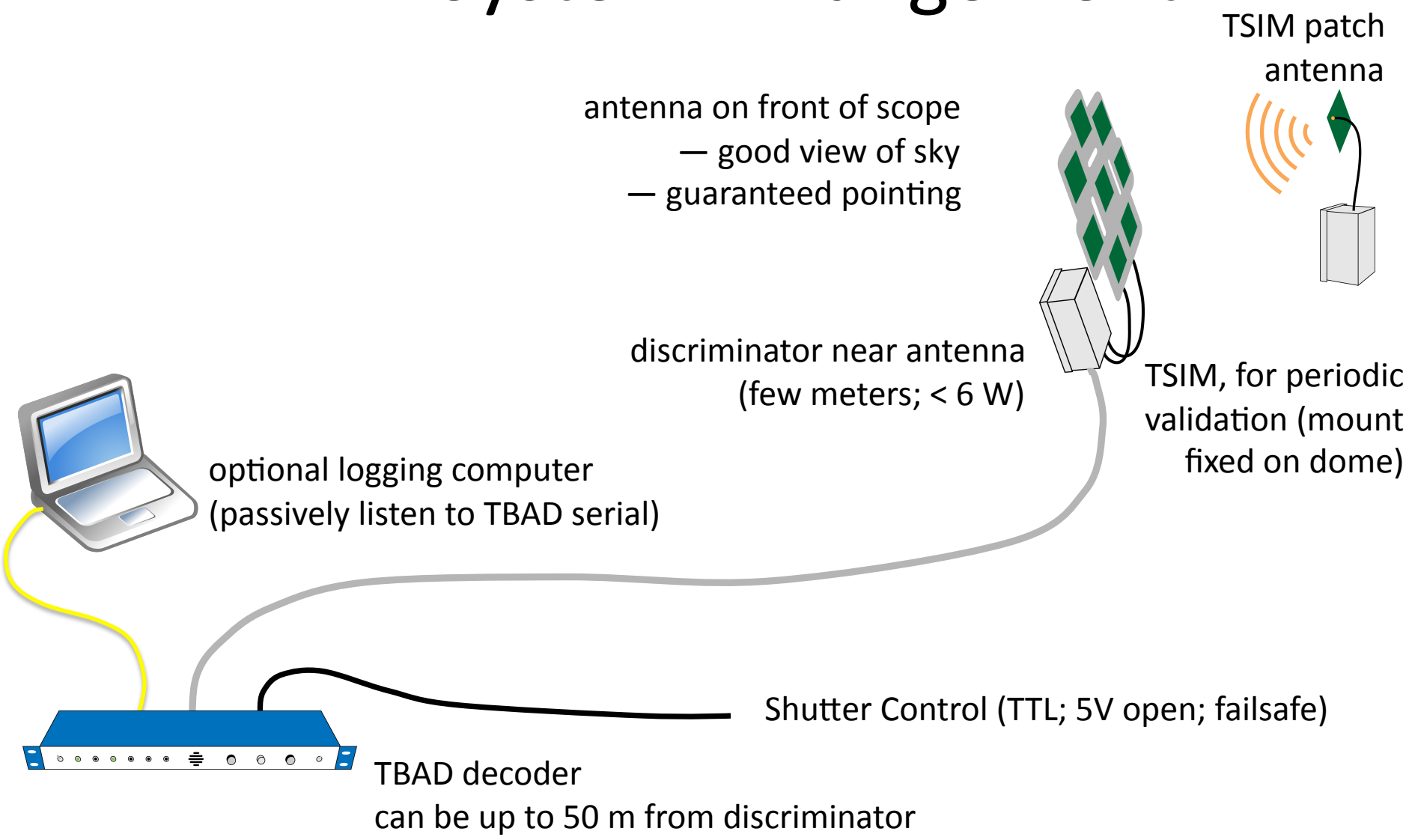
TSIM
validation!

discriminator



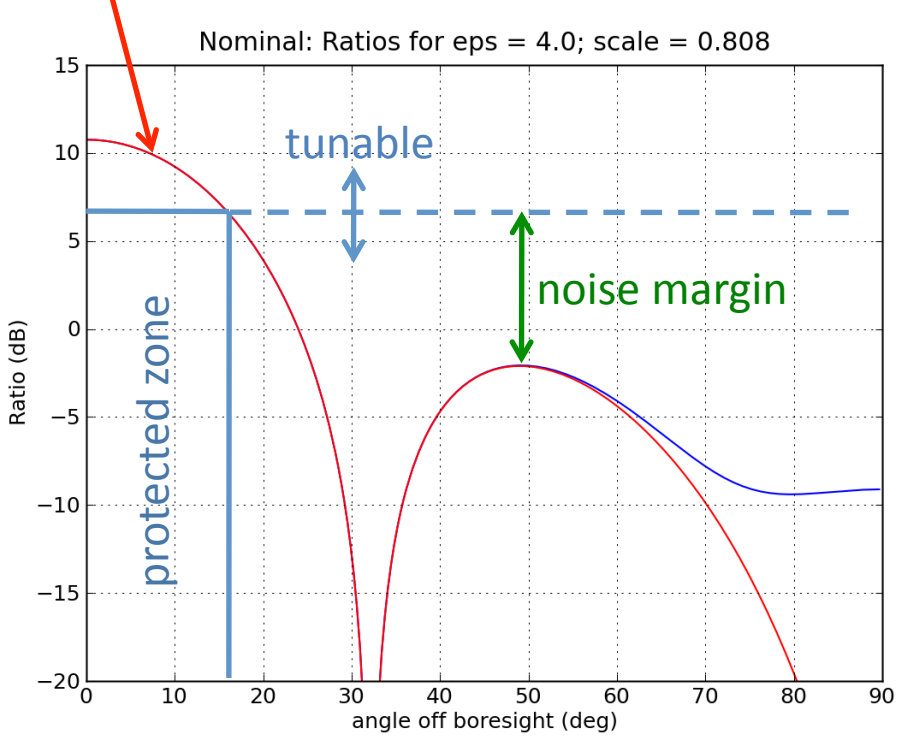
decoder

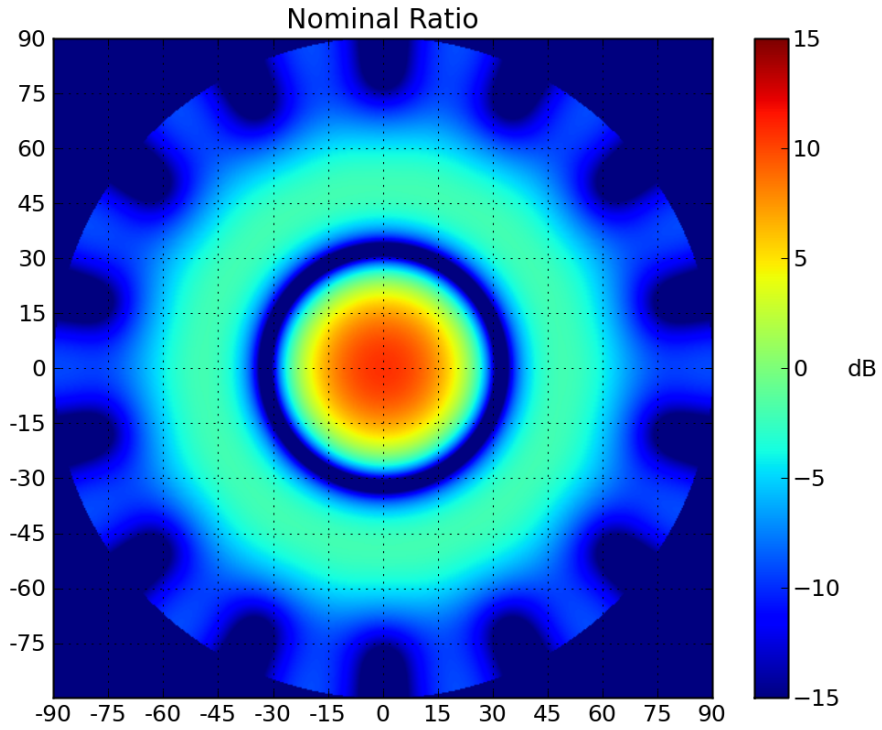
TBAD System Arrangement



Fundamental Idea

Ratio of full array to single patch is only above set threshold inside boresight zone





Differential measurement: insensitive to power, distance, polarization

Can set limits on distance/sensitivity and also trigger for nearby/strong signals

Transponder Requirements

- Transponders are required to *operate*:
  - above 10,000 ft (3048 m)
    - exception within 2,500 feet (762 m) of surface
  - in Class B and Class C airspace
  - within 30 nmi (56 km) of 37 major airports in U.S.
- Crop dusters, vintage craft, rural-only aircraft might not carry/operate transponders
  - FAA "speaks transponder"
  - sensible about "expected" traffic in area
- ADS-B required by 2020
  - spontaneous information-rich transmissions
  - either 1090 MHz (original) or 978 MHz if staying below 18,000 ft (5500 m)

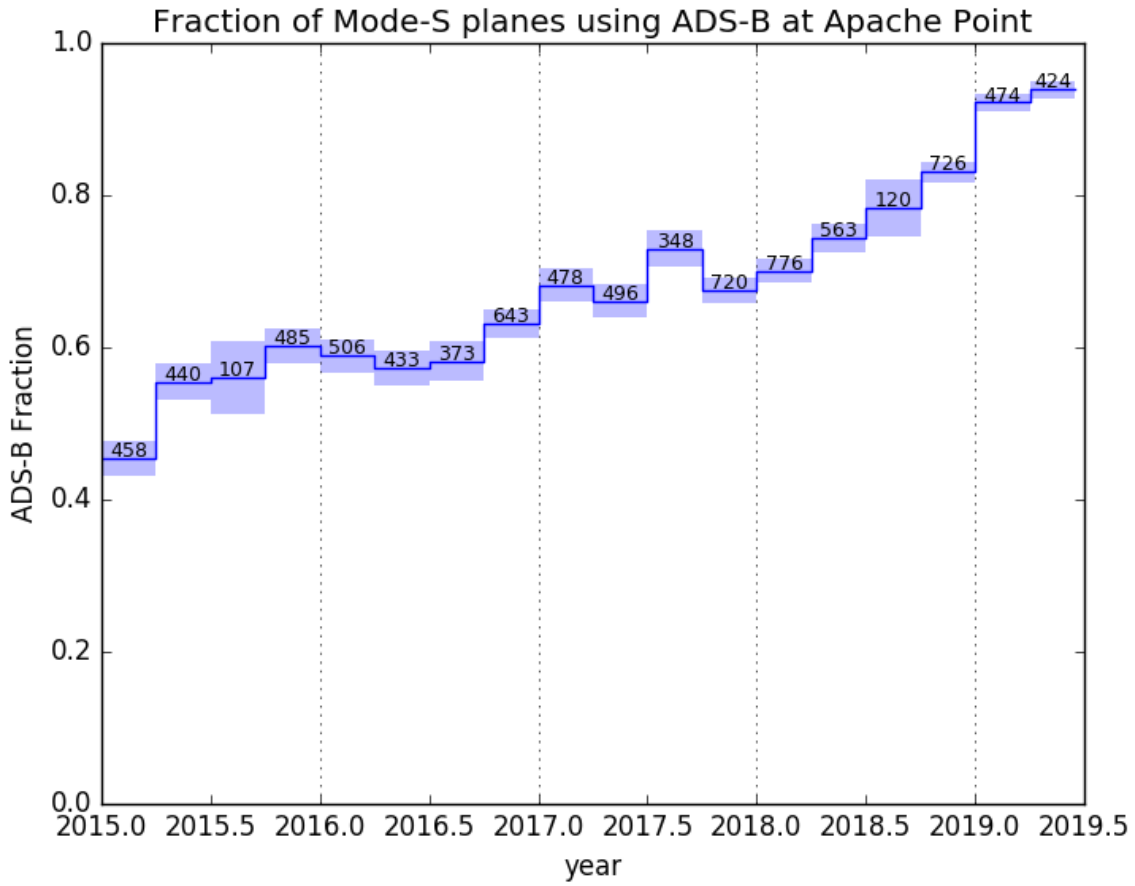
The Transponder Data Landscape

Feature	1090 M-A	1090 M-C	1090 M-S	1090 ADS-B	978 UAT
info. bits	12	12	32	88	144, 272
parity bits	0	0	24	24	96, 112
transmission	pulses	pulses	pulse pos.	pulse pos.	FSK FM
symb. per.	1.45 µs	1.45 µs	1.0 µs	1.0 µs	0.96 µs
Squawk ID	✔		DF-05	DF-21	select
Altitude		✔	DF-00, DF-04	DF-17a, DF-20	✔
Perm. ID			✔	✔	✔
Lat/Lon				DF-17a	✔
Velocity/Hdg				DF-17b	✔
Tail number				select	select
Flight #				select	?
Aircraft class					select

Mode A/C/S: interrogated

ADS-B: spontaneous

ADS-B Adoption: Approaching 100%



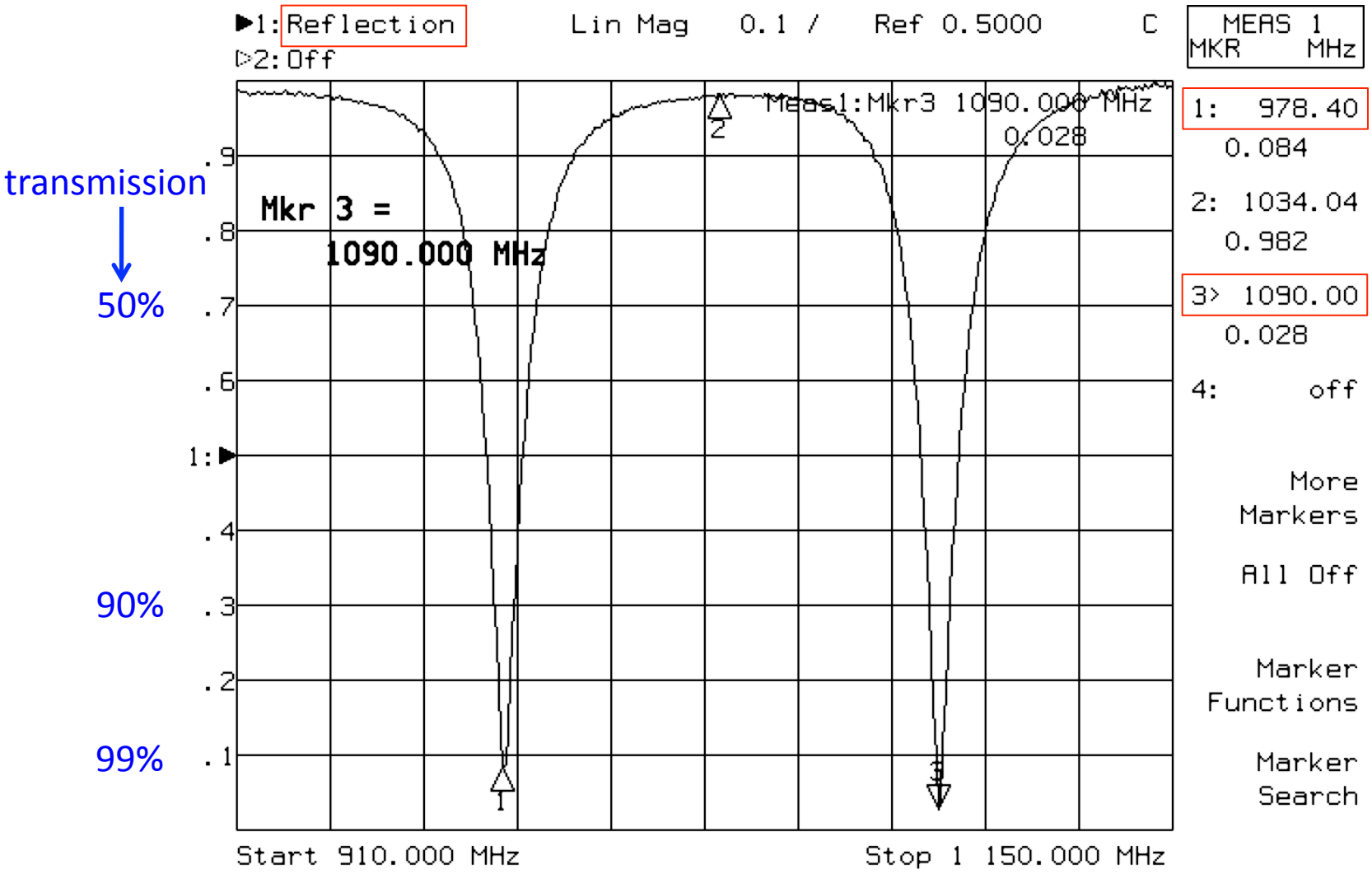
Continuous night-time (clear) monitoring from APO; count unique-ID planes using ADS-B

Binned quarterly; numbers are airplane counts; bars are statistical errors

Next-Generation ATC Capability

- Original TBAD (deployed) gets all 1090 MHz
  - including ADS-B
- Usage of 978 MHz increasing in G.A. aircraft
  - TBAD was deaf to this traffic: a hole in capability
- TBAD now supports both frequencies
  - separately tunable thresholds/behavior
  - utterly different demodulation schemes
- Upgrade path available, preserving footprints
  - shipped first upgrade May 2019

Dual Band Antenna: Perfect Tuning



reflection *amplitude* (linear); square for reflected *power*

Log Snippet: Reading the Matrix

```
2019-04-15 05:37:30.366 s00ab5c712eb351595a0607a910584260bf00O.BNFxa40 err 0/0
   UAT: AB5C71 air   32.8362 -117.1746   2025  134/ 99  -640
2019-04-15 05:37:30.375 s1200..BNF.FDC  ----- VFR
2019-04-15 05:37:30.396 s8DAB5C71590F91E40D73960A703B..BNFx491 DF-17
   DF-17: PPass, ID AB5C71, Alt 2025, Lat=32.83621, Lon=-117.17457
2019-04-15 05:37:30.466 s8DAB5C7199108482D82885DB5DF9..BNFx4AA DF-17
   DF-17: PPass, ID AB5C71, vel 133; hdg 99; vrate -576; dh=-100
2019-04-15 05:37:30.581 s020101B906DCDB..BNFx362 DF-00
   DF-00: Par. left AB5C71, Alt 2025
2019-04-15 05:37:30.609 s5DAB5C719A1D4E..BNFx394 DF-11
   DF-11: PPass, ID AB5C71
2019-04-15 05:37:30.612 s1200..BNF.FDC  ----- VFR
2019-04-15 05:37:30.636 s1200..BNF.FDC  ----- VFR
2019-04-15 05:37:30.694 s0520..BNF.FE0   2000
2019-04-15 05:37:30.730 s0520..BNF.FE0   2000
```

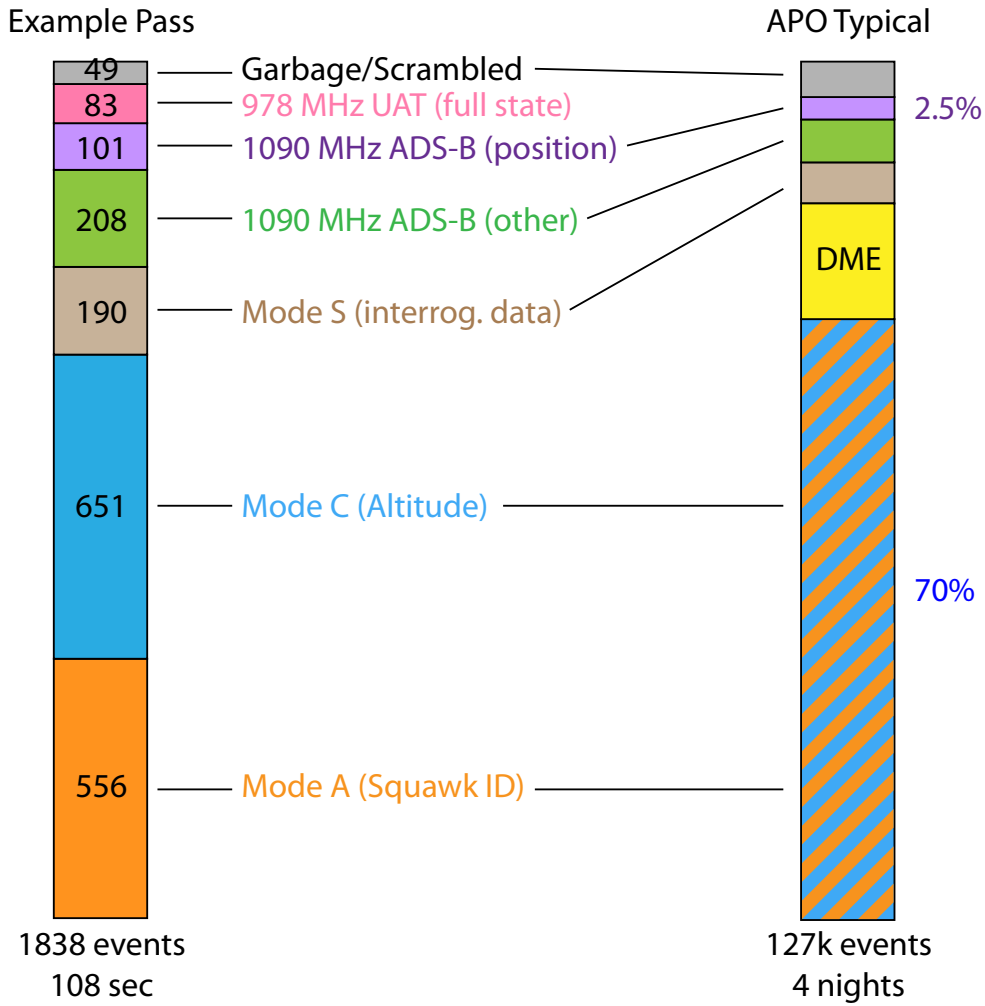
TBAD protection is independent of data

Δt = 0.364 s; Mode-A; Mode-C; Mode-S; 1090 ADS-B; 978 MHz UAT; interpretations; flags
Can't show full variety in one slide…

Code blocks are direct from TBAD; the rest is added by Python logging

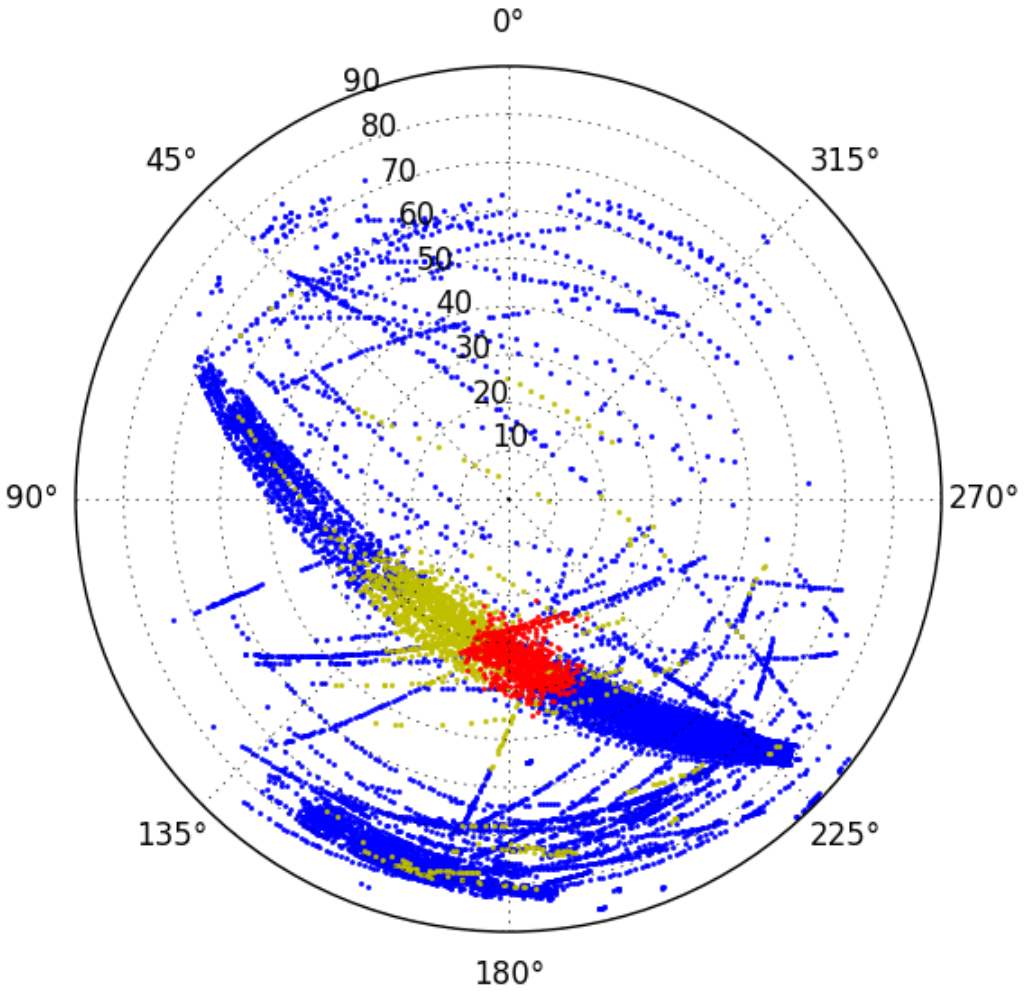
Aircraft AB5C71 flying VFR in SD at ~2000 ft at ~134 knots, 99° heading, descending ~600 fpm

Message Type Statistics



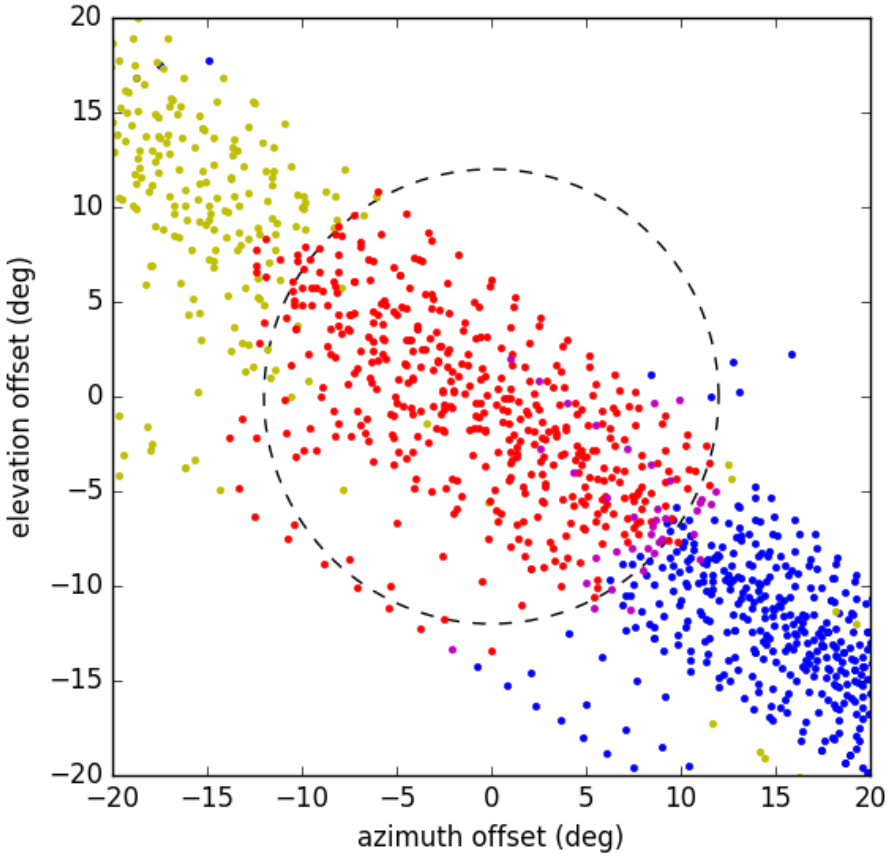
- At left: single pass from previous example
  - plane equipped with both 978 and 1090 MHz
  - 25 of 108 s “in-beam”
- At right is Apache Point composite over 4 nights
  - without 978 MHz UAT

All-Sky 1090 MHz ADS-B From TBAD



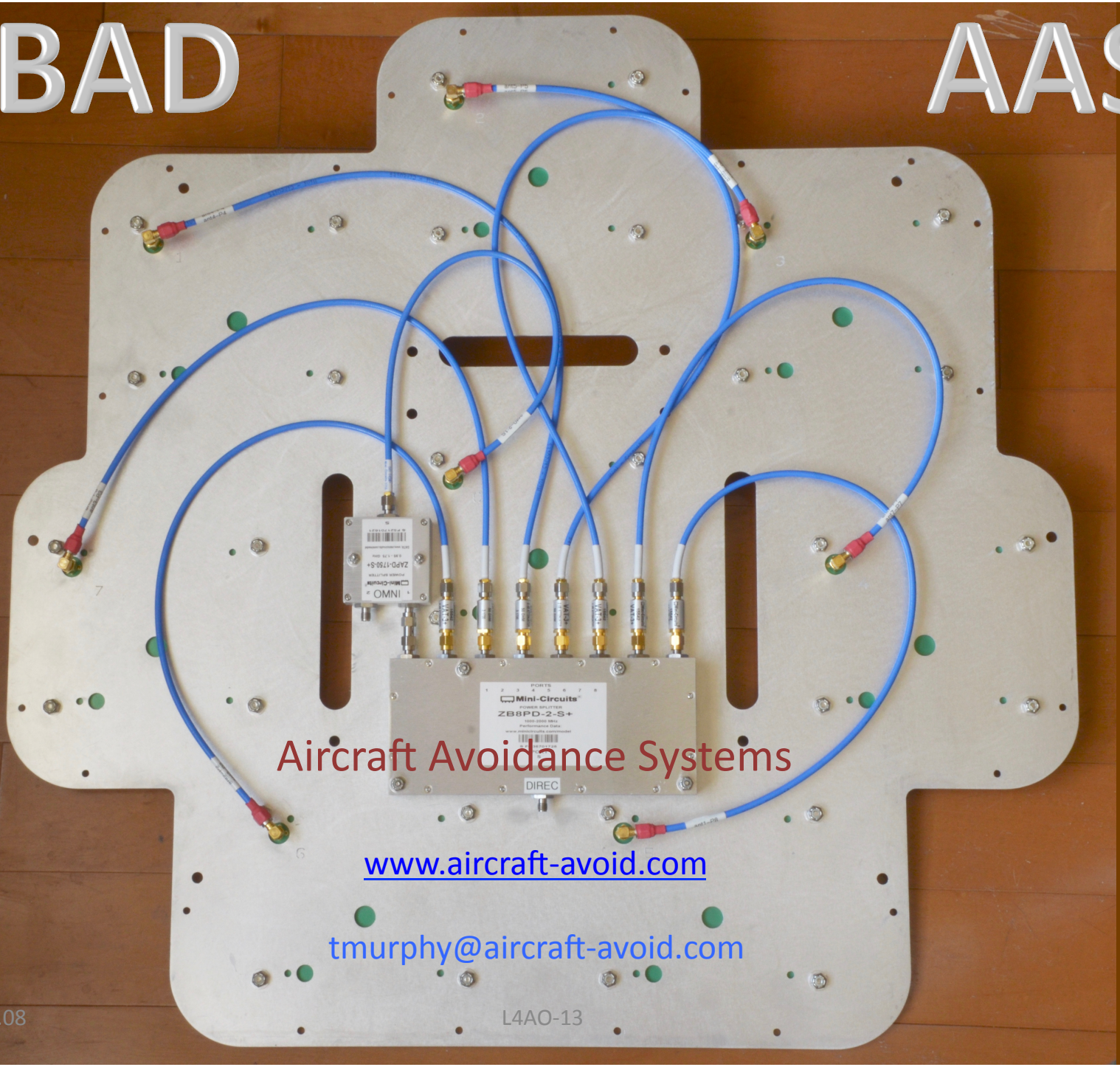
- 24 hours at location under prominent flight corridor
- TBAD antenna fixed
- Red: “in-beam”
- Blue: no threat
- Yellow: shutter closed
  - holds off 10 s for safety
  - some “collateral” yellow
- ADS-B is vast minority of signals
  - tracer bullets

Corridor close-up: protected zone



- Red means deemed in beam
- Blue deemed non-threatening
- Yellow means shutter (still) closed
- 12° radius circle is approximate protected zone
- Allows self-validation
- Predict impending shutter event

TBAD AAS



Aircraft Avoidance Systems

www.aircraft-avoid.com

tmurphy@aircraft-avoid.com