Air Force Test Center

412th Test Wing, Electronic Warfare Group

Integrity - Service - Excellence

U.S. AIR FORCE

Data Association Techniques for Open Air Range Testing

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Outline

- What is Data Association?
- Why Do I Care?
- Data Association Techniques
- Conclusion

Definitions

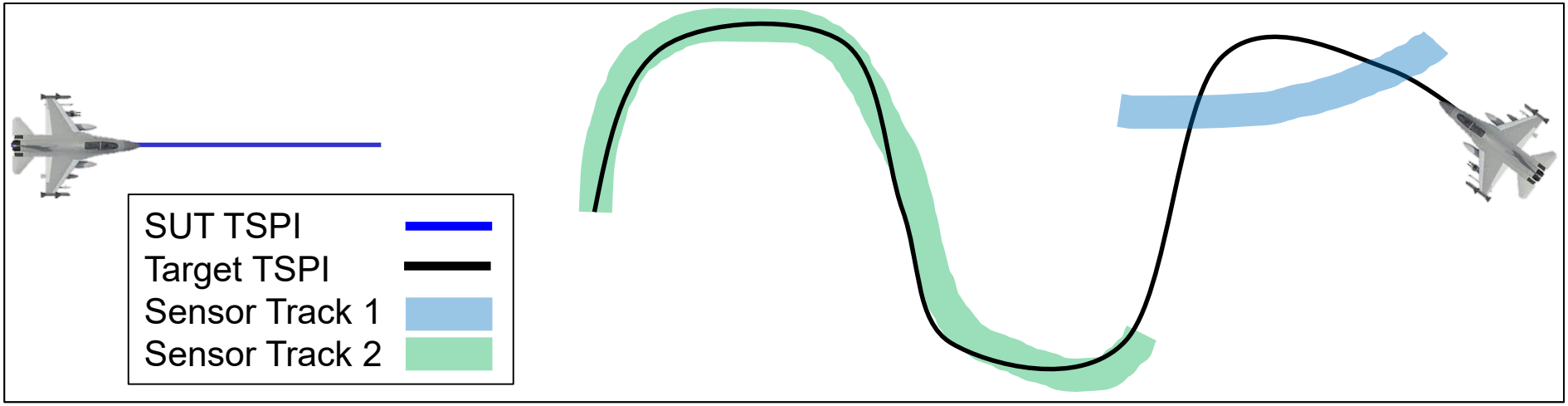
- **Plots**
  - **Individual independent measurements performed by a sensor**
- **Tracks**
  - **A collection of plots the system under test (SUT) has grouped and associated with a single target**
- **Sensor**
  - **Onboard system used to measure some physical property**
  - **Radar, Targeting Pod, Radar Warning Receiver, Transponder, Missile Warning System, Fusion**
- **TSPI (Time Space Position Information)**
  - **"Truth Data" generally recorded by an independent system**
  - **ARDS, GLITE, Ground Trackers, etc**
- **RF (radio frequency)**
  - **Electromagnetic energy in the MHz-GHz region**
  - **Transmitted by airborne and ground radars**
- **SUT - system under test**
- **MOP - measure of performance**

What is Data Association?

- Data Association
  - Multiple Target Tracking Problem
- In an Open Air Range / Flight Test context
  - Matching sensor data to truth data
- Ex: APG-81 radar tracking an F-16
  - Want to match radar sensor data with ARDS TSPI from the F-16
  - Disregard background aircraft in data analysis
    - Most of the collected radar data is on non-players

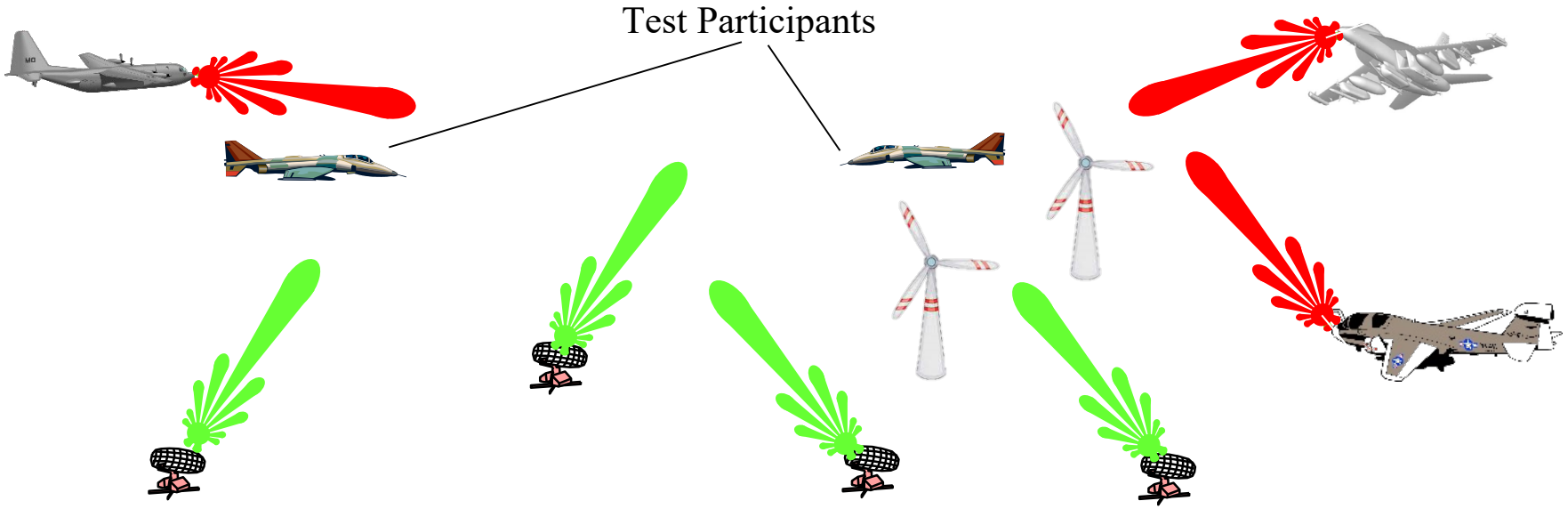
Why Do I Care?

- Required step for analysis of some Measures of Performance (MOPs)
- Data association accuracy affects MOP results
  - Poor matching can inadvertently and incorrectly penalize or improve apparent SUT performance
  - Max detection range example



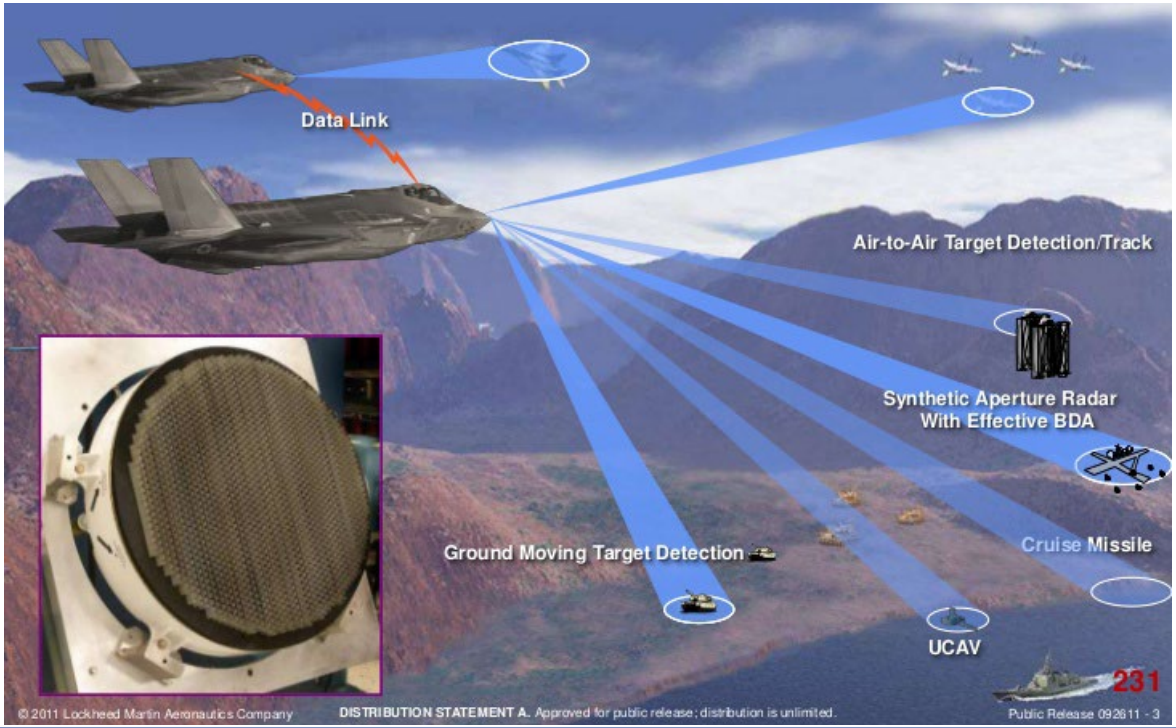
Why is This Hard?

- Lots of traffic in R-2508
- RF does not stop at range boundaries
- Other aircraft/emitters/clutter may interfere with your test and recorded data



Applications in 412TW

- DIADS
- Radar Testing
- EW Testing
- 5th Gen Fusion
- Any sensor tracking one or more targets

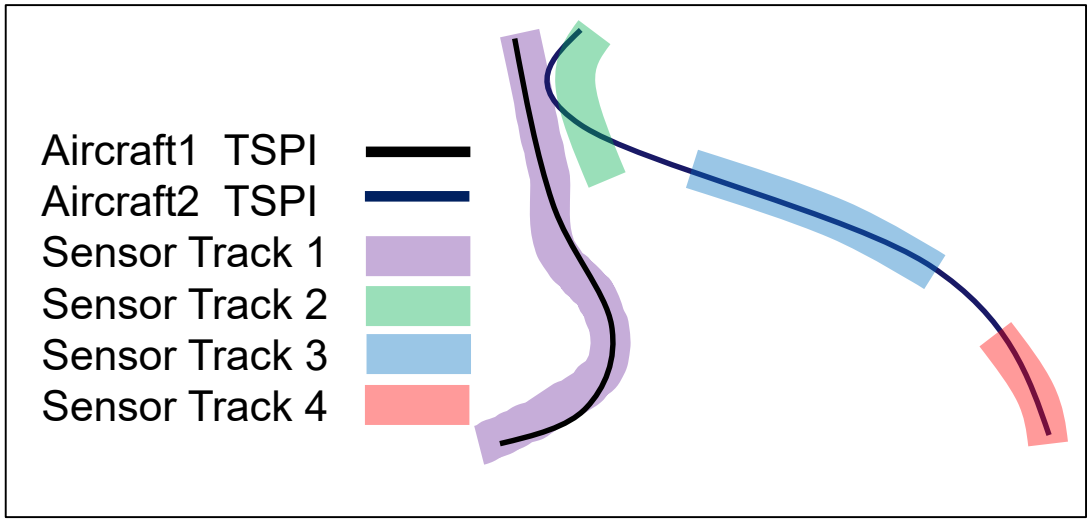


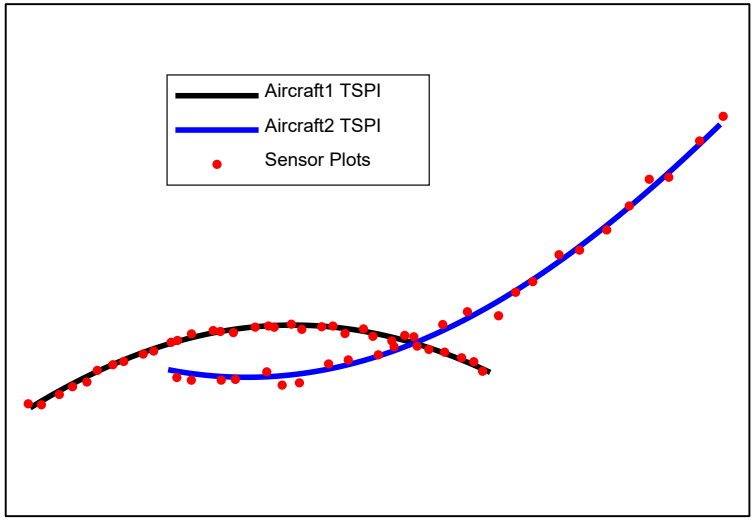
Techniques

- Depends on your application/sensor/target
- Lots of research on data association for tracking of multiple targets
- Real time vs post processing
  - Aircraft/IADS do it in real-time
    - Kalman Filters, Hypothesis Trackers, Probabilistic Data Association Filters, etc
    - Speed/Processing is big concern
  - Analysts do it post processing
    - Accuracy is paramount
    - Have additional information to assist (truth data)
    - Focus of this presentation

Techniques

- **Track Based Matching**
  - **Match SUT/sensor tracks to truth tracks**
- **Plot Based Matching**
  - **Match individual SUT/sensor measurements to Truth tracks**



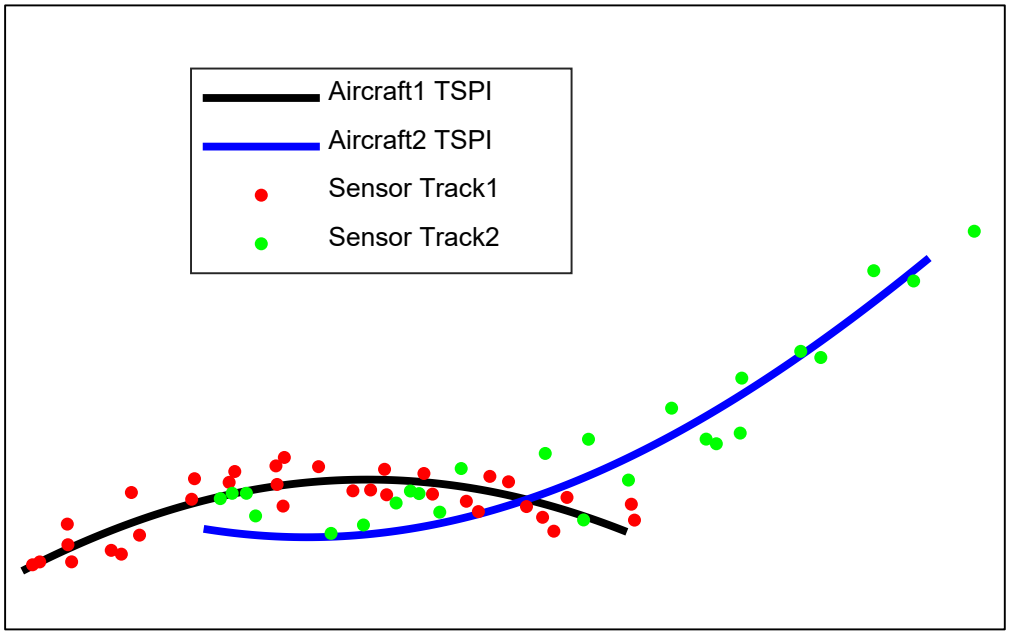


Mean Euclidian Distance

- **Average distance from every sensor track point to time coincident truth tracks points**
  - **Data sets for the lowest average distance are associated**

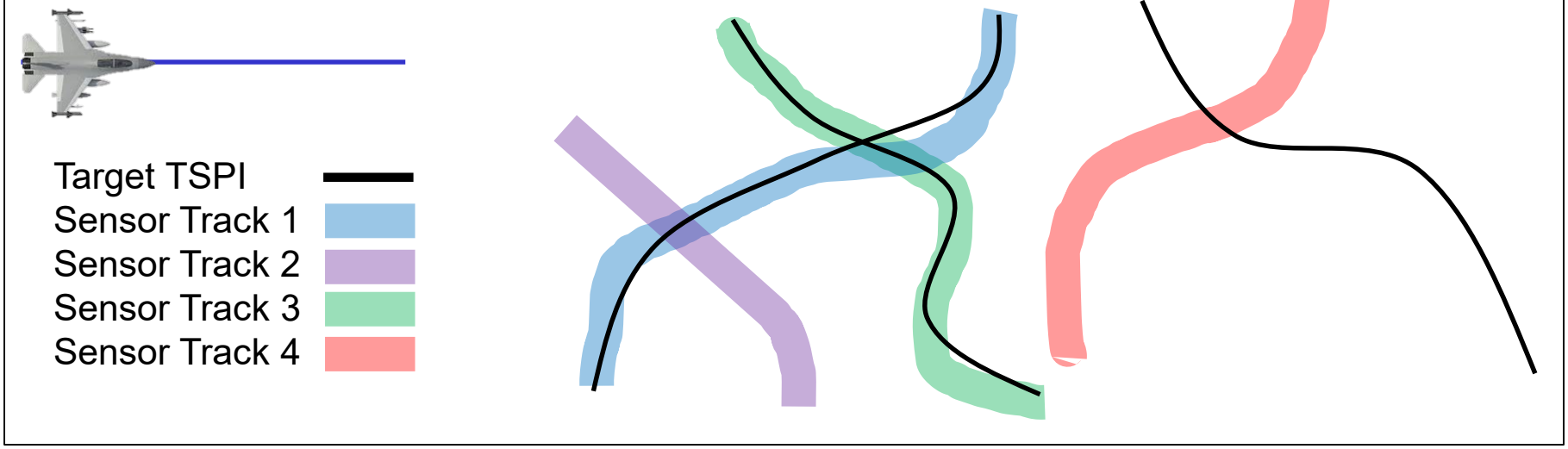
$$MED = \frac{\sum_{i=1}^{n} \sqrt{(s_{ix} - t_{ix})^2 + (s_{iy} - t_{iy})^2 + (s_{iz} - t_{iz})^2}}{n}$$

MED = Mean Euclidian Distance
n = number of sensor data points
s_i = the i^{th} sensor data point
t_i = the i^{th} truth data point
s_x = the x component of the sensor data point
t_x = the x component of the truth data point



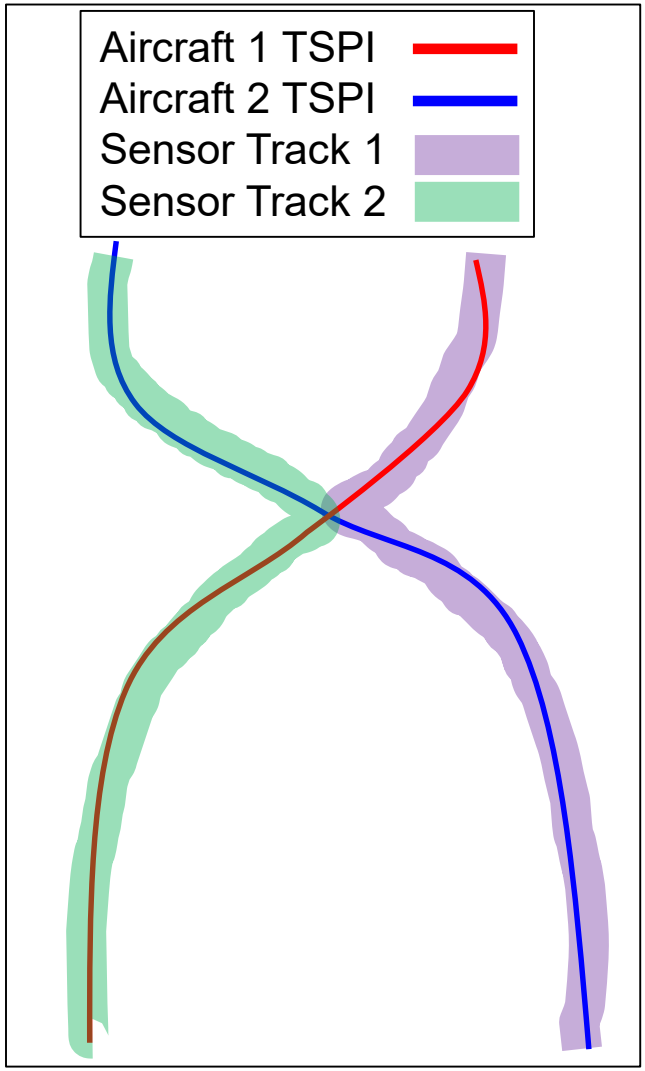
Sensor Data with no Truth

- **What do you do with sensor data that does not match to a truth track?**
  - **How can you tell if it was not part of the test?**
  - **Use additional truth data sources (TECCS)**
  - **Use a threshold**



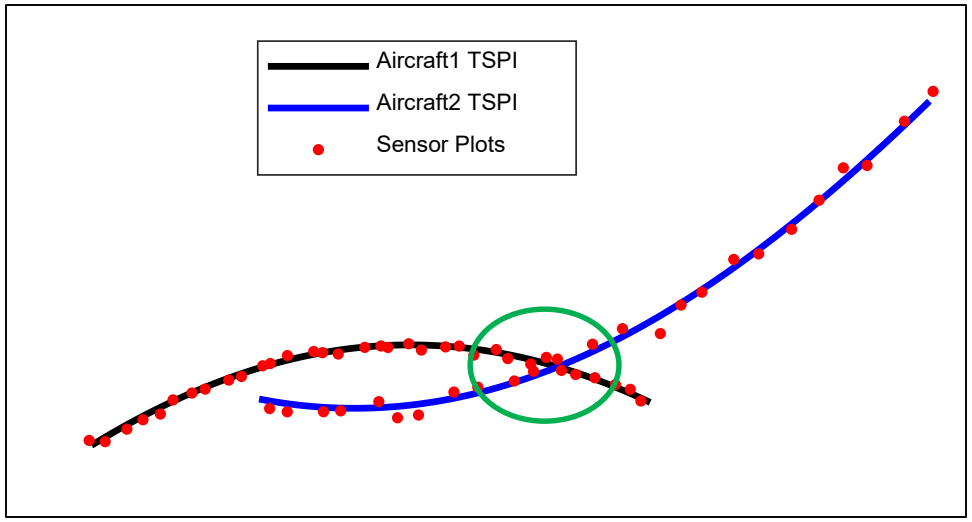
Track Based Matching

- **Advantages**
  - **Simpler**
  - **Let the SUT do the work for you**
  - **Lots of well defined metrics to evaluate**
- **Disadvantages**
  - **Can be less accurate**
  - **Does not deal well with track splitting and discontinuities**



Plot Based Matching

- Take all the raw sensor measurements and associate them individually with TSPI
- How to handle data in the circled region?
  - Need to use more information than track based matching
    - Velocity/Acceleration
    - ID, Covariance



Plot Based Matching

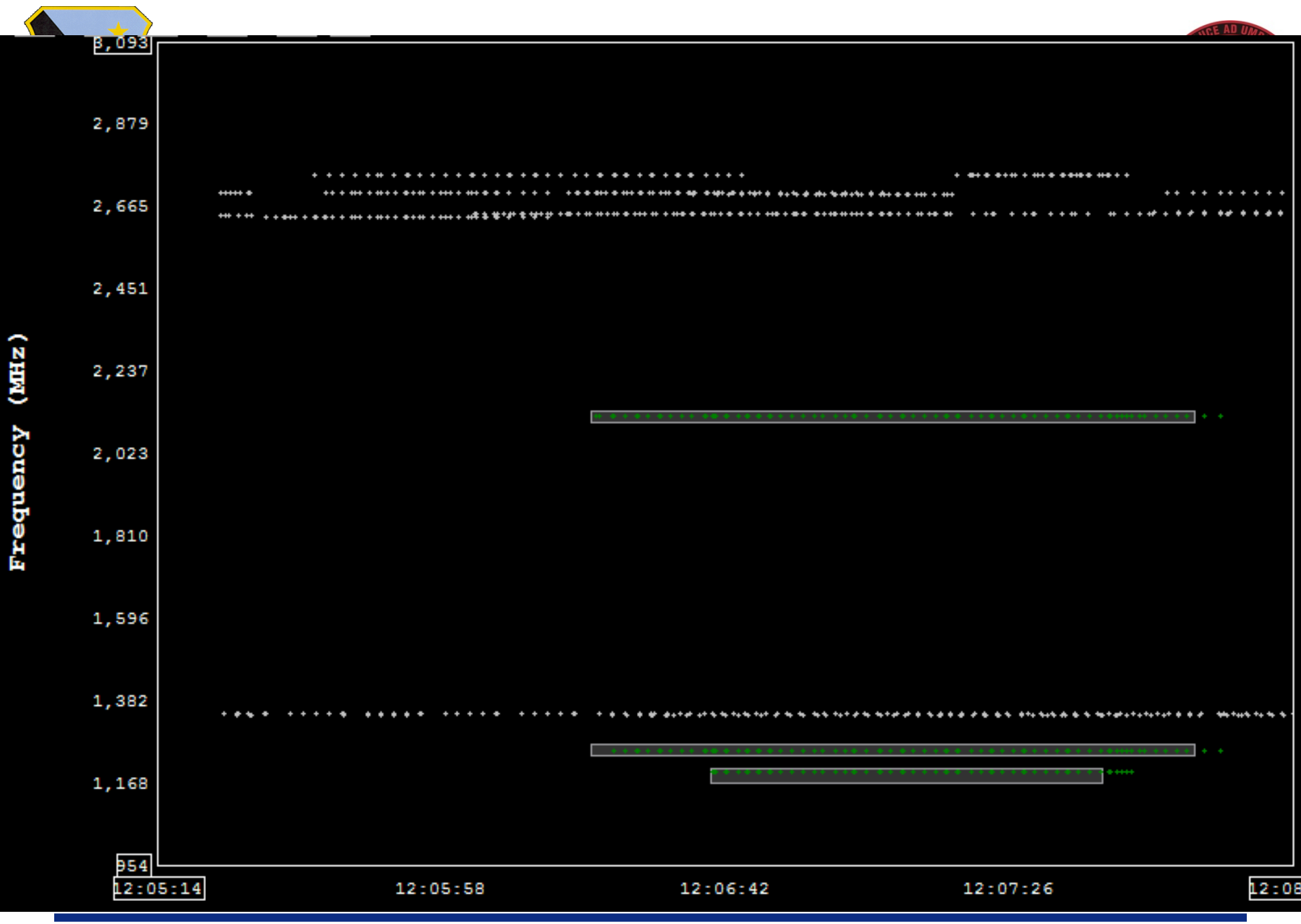
- **Tools for data association**
  - **Position**
  - **Velocity**
  - **Acceleration**
  - **Angles**
  - **Covariance Estimate**
  - **Frequency, PW, PRI**
  - **SUT Track Number**
  - **SUT Identification**
  - **IFF**
  - **Irradiance**
  - **Time**

Plot Based Matching

- **Advantages**
  - **More robust**
  - **Handles track discontinuities and splits**
- **Disadvantages**
  - **More difficult to implement**
  - **Harder to find a pre-canned solution**

Hybrid/Engineering Matching

- **Algorithm will often be insufficient**
- **Bring the Engineer into the equation**
  - **Manually match tracks/plots with truth**
  - **Verify matching done by algorithms**

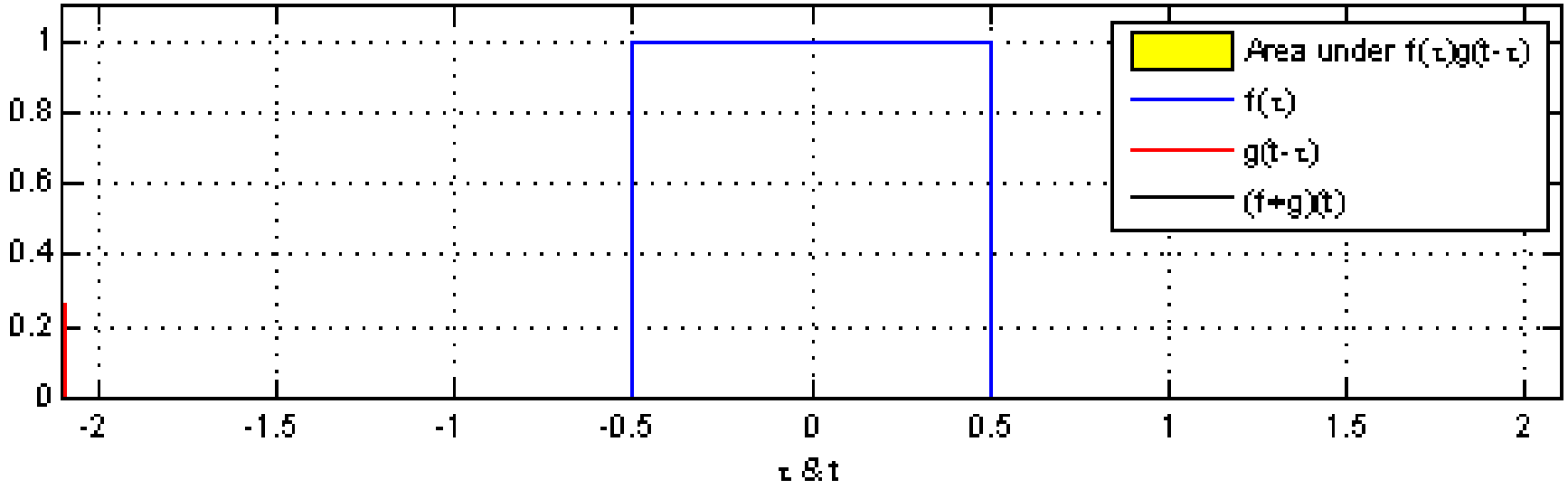

3,093
2,879
2,665
2,451
2,237
2,023
1,810
1,596
1,382
1,168
954
Frequency (MHz)
12:05:14
12:05:58
12:06:42
12:07:26

Additional Difficulties

- What if the time sources are not synchronized?
- Cross-Correlation/Convolution
  - Compute the lag

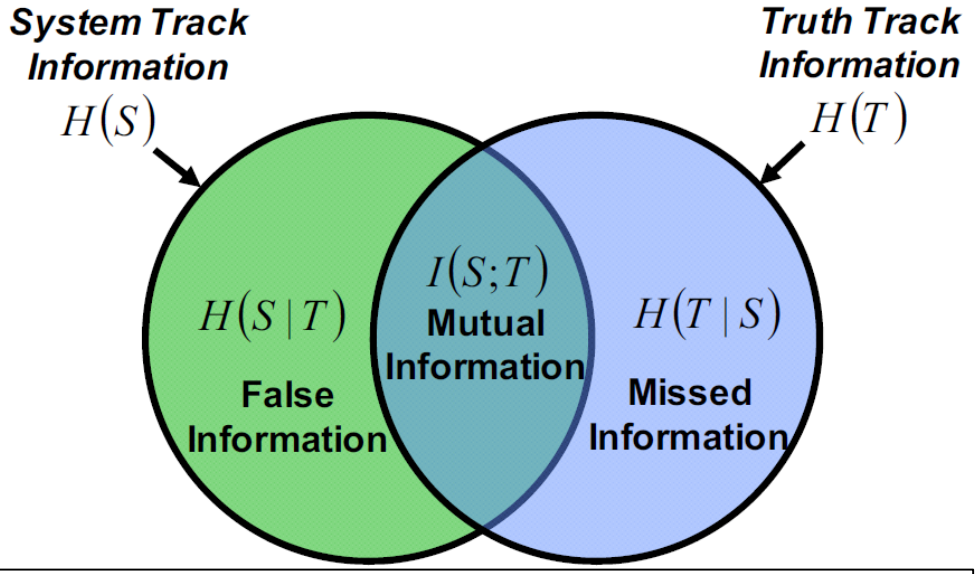
$$(f * g)[n] = \sum_{m=-\infty}^{\infty} f*[m]\, g[m+n]$$

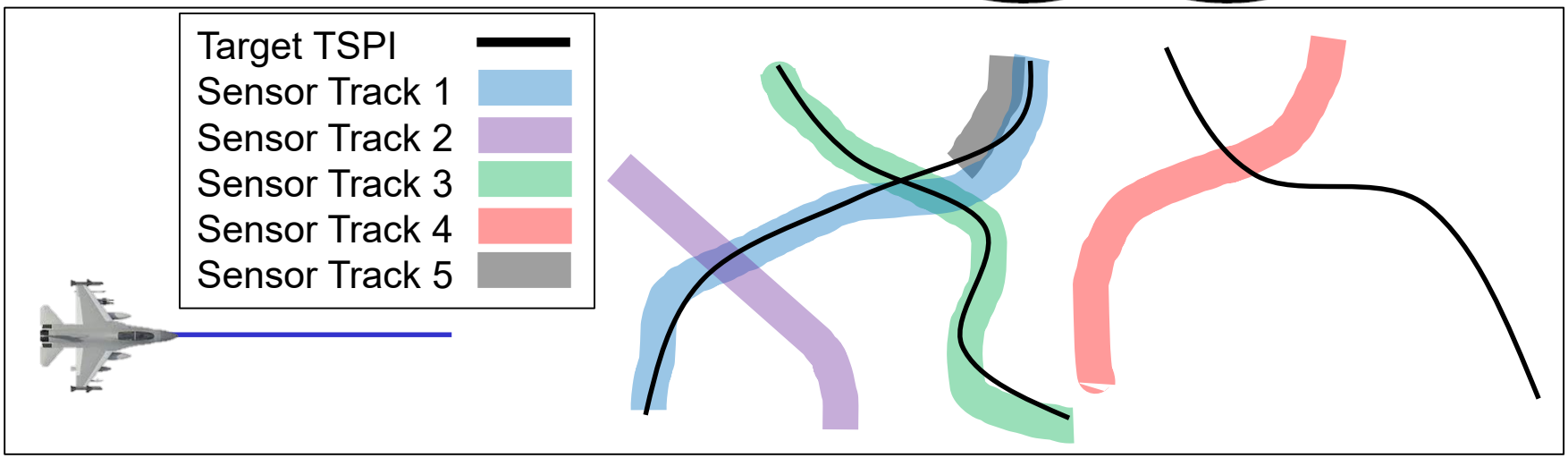
- Much harder in the context of an open air range
- Cannot see the delay on a Lat/Long plot



Measures

- **Information Entropy**
  - **False Information**
  - **Mutual Information**
  - **Missed Information**
  - **Clutter**





412 TW Data Association Examples

- DIADS
  - Automated methods. Good for simulation environment
  - Information Entropy Metrics
- 771st Test Squadron
  - DIVA
- 461st Flight Test Squadron
  - TECCS Data
  - Information Entropy Metrics
- 411th Flight Test Squadron
  - Large Force Exercise Events
- Emerging Technology Flight Test Squadron
  - Time syncing
- Orange Flag Exercise

Summary

- Data association is critical for MOP analysis
- Many variations and techniques
- Bring the engineer into the loop

References

- Kao, Daggert, Hurley, *An Information Theoretic Approach for Tracker Performance Evaluation*, IEEE ICCV, 2009.
- Miles and Moon, *Comparison of Plot and Track Fusion for Naval Sensor Integration*, UK MoD, 2002
- Blasch and Hong, *Data Association through Fusion of Target Track and Identification Sets*, Fusion 2000, July 2000
- McMillan and Lim, *Data Association Algorithms for Multiple Target Tracking*, Defense Research Establishment, Ottowa CA, 1990.
- Tharmarasa and Kirubarajan, *Performance Measures for Multiple Target Tracking Problems*, Conference on Information Fusion, 2011.
- Rhudy, *Time Alignment Techniques for Experimental Sensor Data*, IJCSES, 2014