APPLICATION OF ORBIS METHOD FOR STATIC SOURCE ERROR TESTING

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Outline

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  - Traditional Navy test techniques
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- Orbis Method
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Static Source Error

- Why do we care?
  - Reduced Vertical Separation Minimum airspace (flight levels 290 to 410)
    - Altimetry system error has to be less than 80 ft
    - Mean error +3σ must be less than 200 ft
- Each aircraft group has a certain amount of static source error
- Testing is required to certify/verify an aircraft for RVSM airspace

Traditional Navy Static Source Error Test Techniques

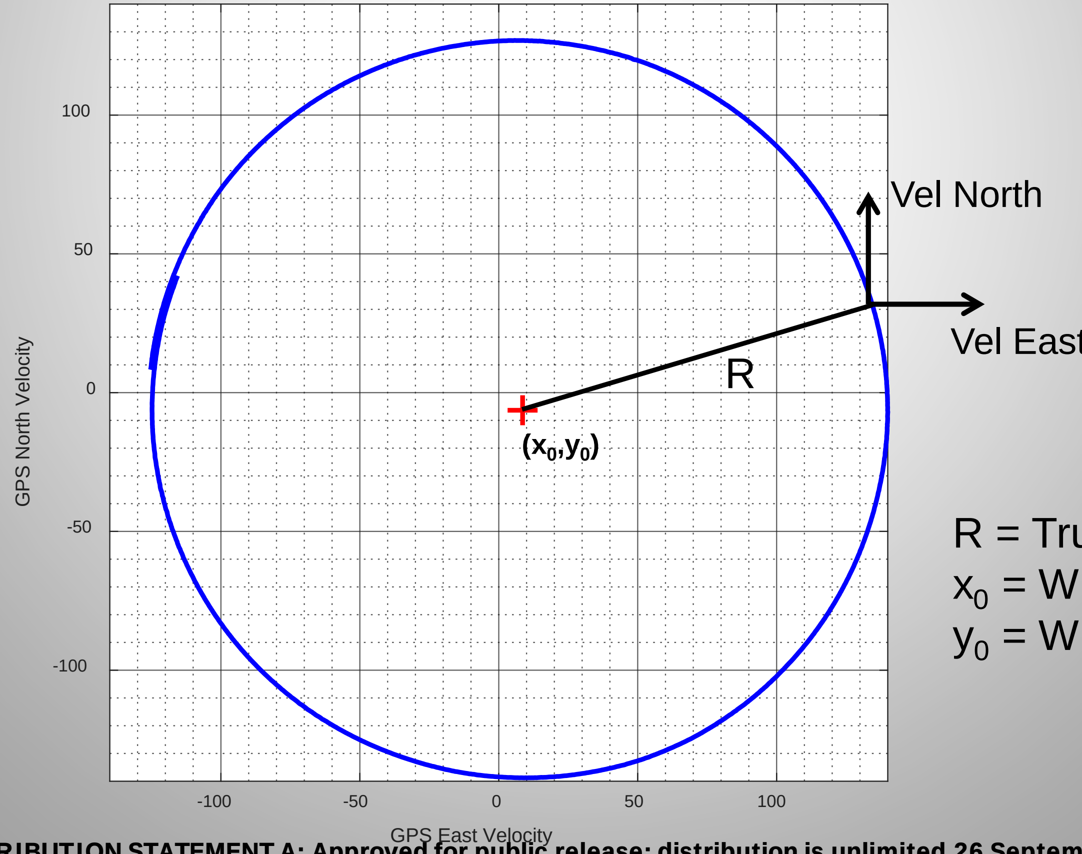
- Pacer Aircraft
  - Cannot always match the performance of the test aircraft
  - Easy, if pacer aircraft is available and maintained
- Trailing Cone
  - Potentially expensive and unreliable
  - Accurate
- Tower Fly-by
  - Provides data within a limited portion of the RVSM envelope
  - Easily repeatable
- Noseboom
  - Expensive, aircraft incompatibility
  - Reliable

Introduction to the Orbis Method

- Orbis Method test technique:
  - Level turn
  - Constant airspeed, bank angle, winds
- Advantages:
  - Inexpensive (no additional instrumentation)
  - May not need dedicated flights
- Disadvantages:
  - Aircraft may not be able to achieve steady state conditions
  - Estimates P_S using V_T, P_T, and TAT

Orbis Method

- Using only **GPS velocities**, true airspeed and winds can be calculated



R = True Velocity
x_0 = Wind Velocity East
y_0 = Wind Velocity North

Computing Static Pressure from True Airspeed

First compute Mach from the following equations:

$$sound = \sqrt{\gamma * R_{air} * T_s} \quad , T_s = T_t - \frac{.2 \cdot V_t}{\gamma R_{air}}$$

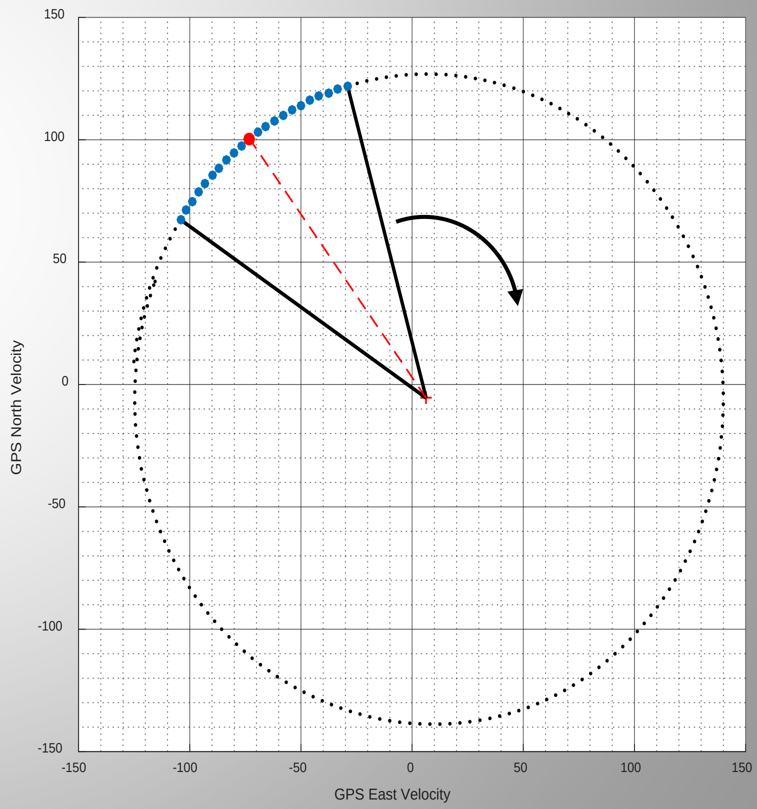
$$Mach = \frac{V_t}{sound}$$

Then static pressure can be calculated:

$$P_s = \frac{P_t}{\frac{M^2}{5}^{\left(\frac{\gamma}{\gamma - 1}\right)} * \frac{\gamma - 1}{2}}$$

General Approach

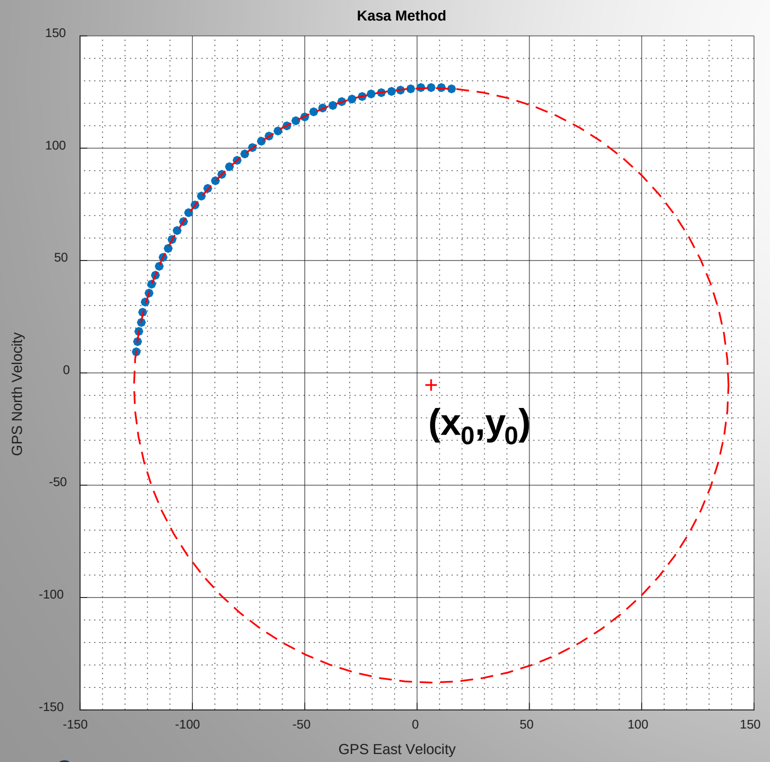
- Analyze a small subset of the data
- Increment around the circle
- Choose heading change/number of points that minimizes the standard deviation in estimated airspeed



Orbis Method Analysis

Kasa Method

- Geometric circle fitting technique that minimizes a modified least square error

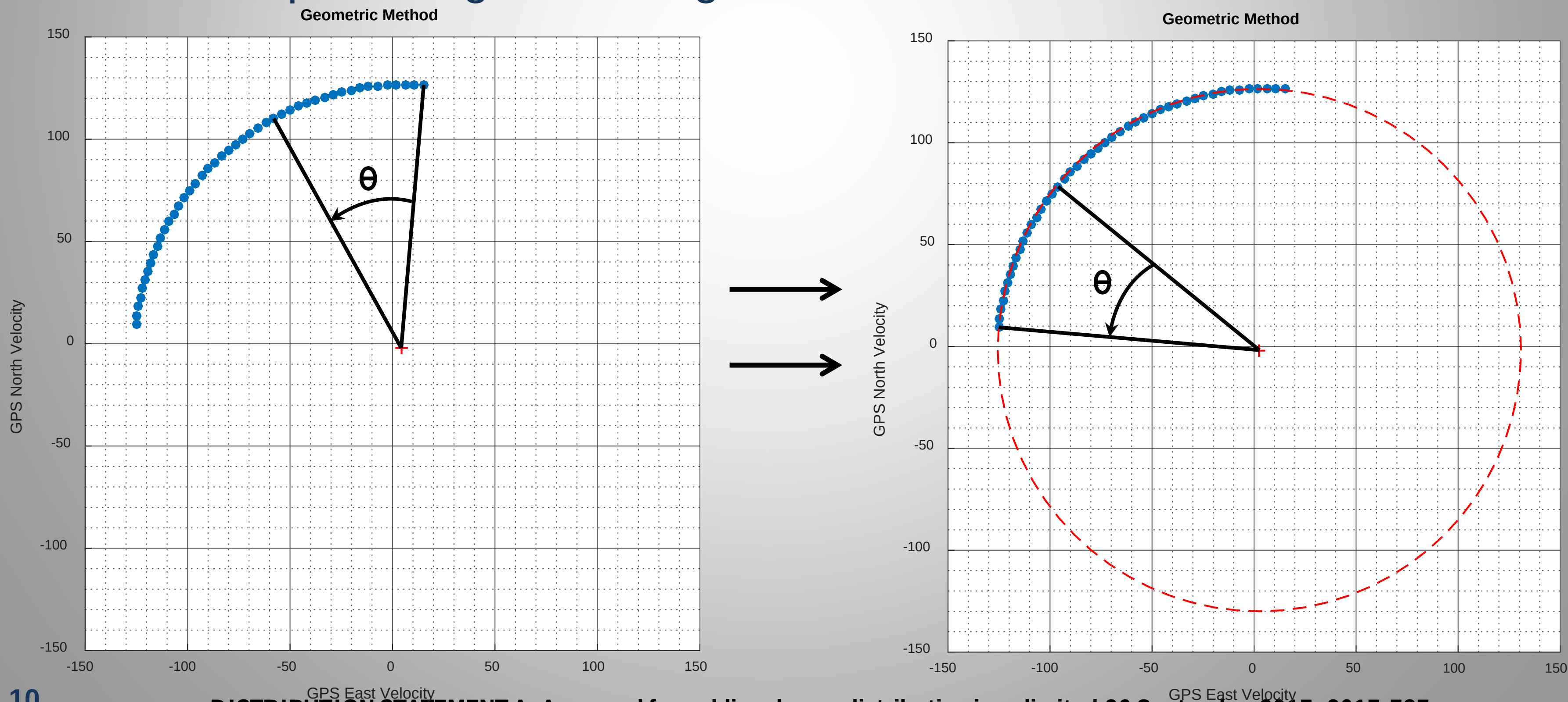


$$\sum_{i=1}^{N} \left(R_i^{\,2} - R^2\right)^2 = min$$

$$R_i = \sqrt{(x_i - x_0)^2 + (y_i - y_0)^2}$$

Orbis Method Analysis
Geometric Method

- Estimates the circle's radius based on the heading change between two points
  - Sweep this segment along the arc



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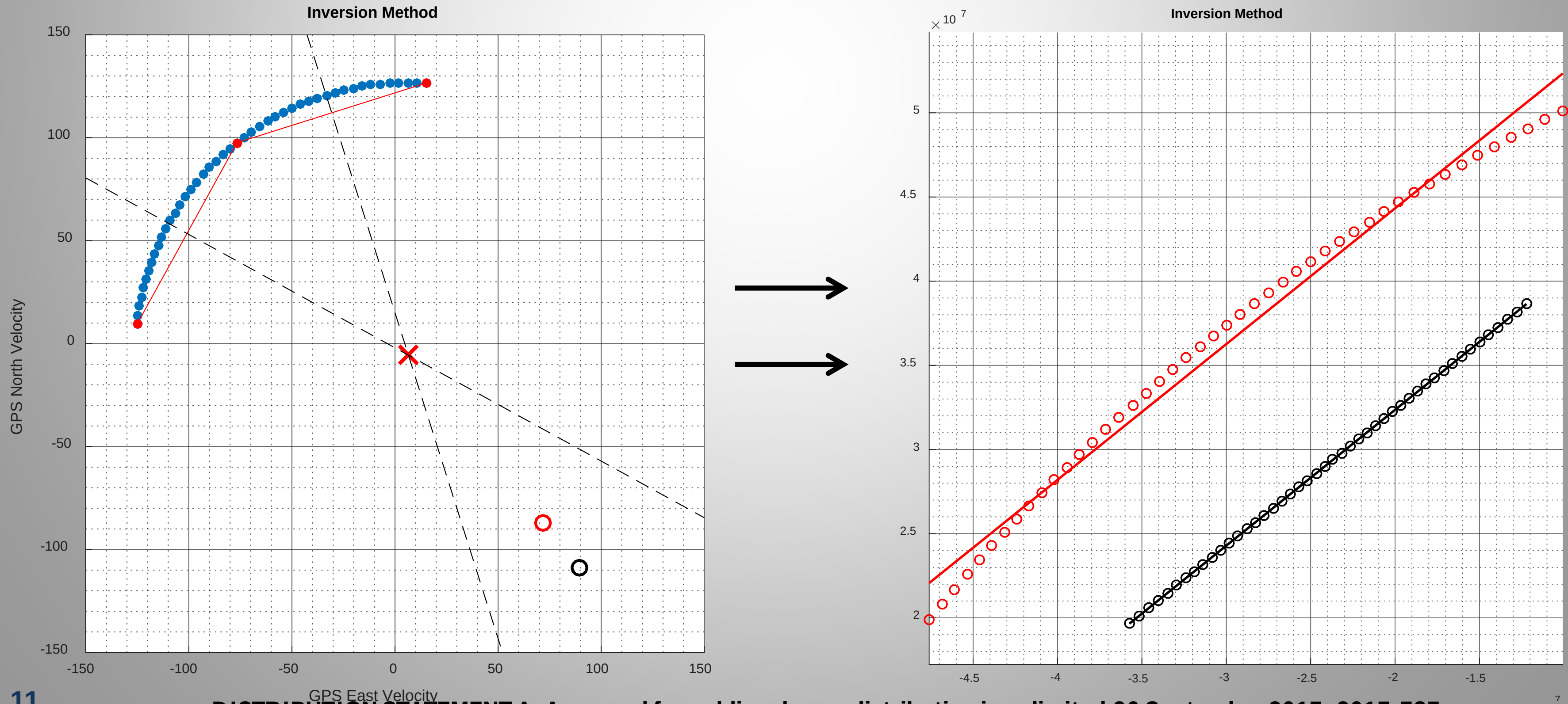
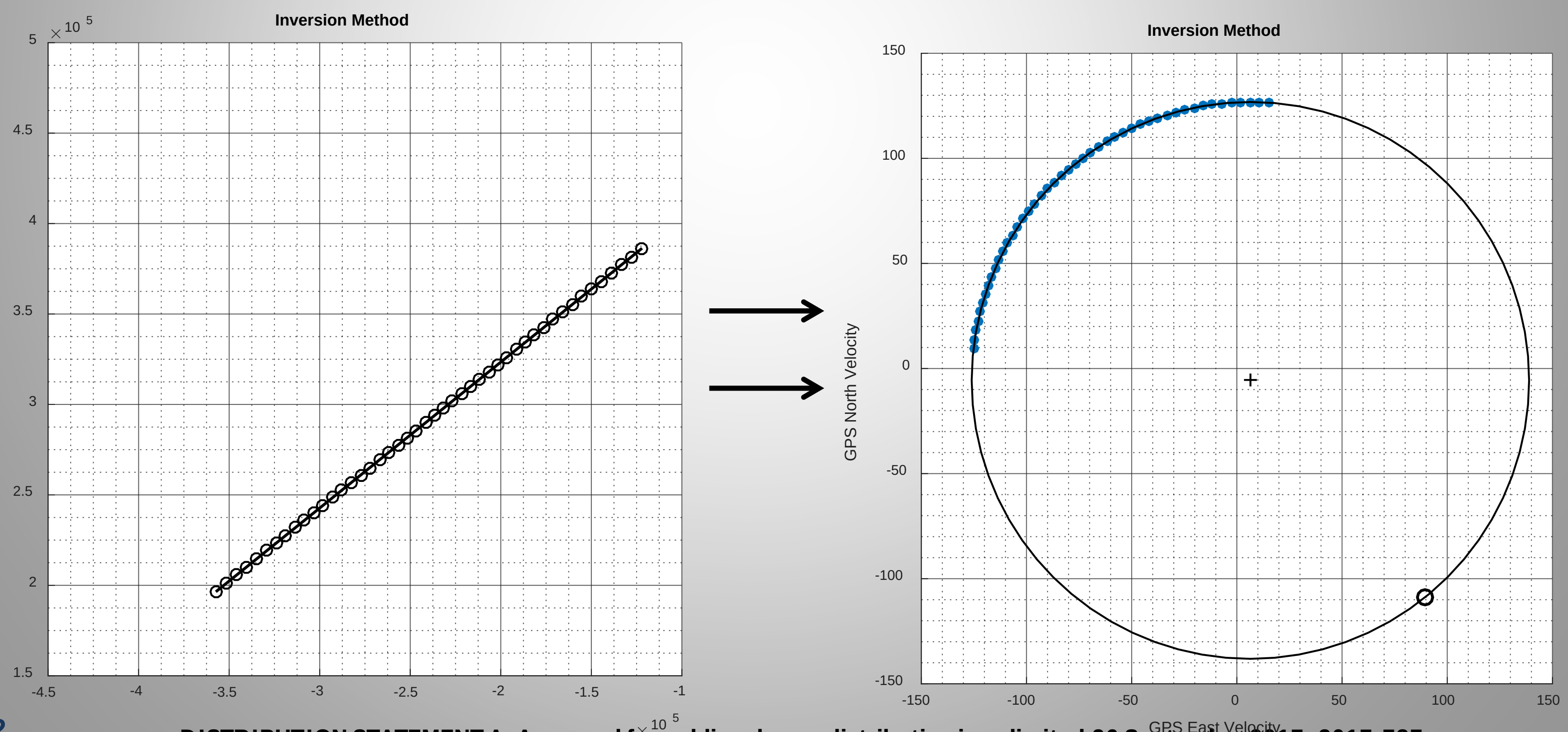
Orbis Method Analysis
Inversion Method

- Uses inversion transformation to map an arc to a straight line
  - Pole of inversion must be on the fitted circle for best fit

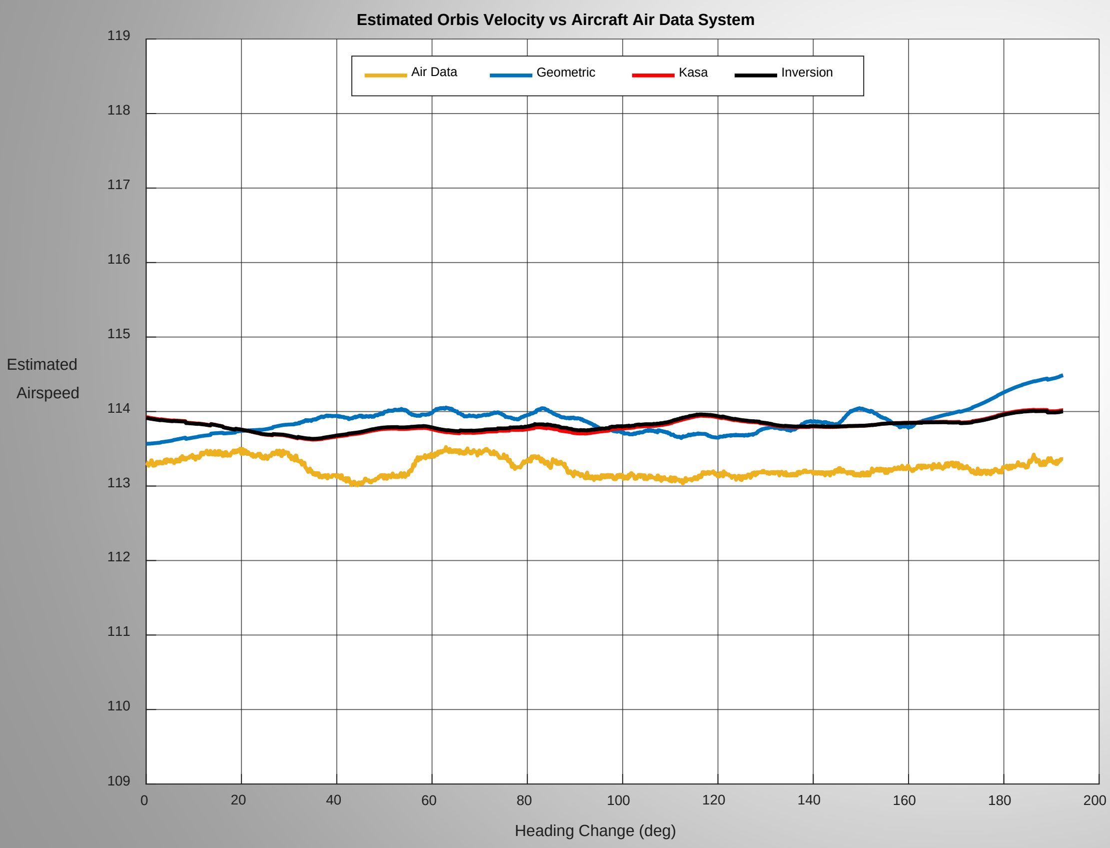


Orbis Method Analysis
Inversion Method

- After transformation to a straight line, find the best linear fit then map back to a circle



Presentation of Results



$$Mean\ Error = \frac{\sum_{i=1}^{N} |R_i - V_t|}{N}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{N} (R_i - \bar{R}_i)^2}{N}}$$

Results

Standard Deviation of Estimated Airspeed

	Geometric	Kasa	Inversion	Air Data System
	Standard Dev. (kts)	Standard Dev. (kts)	Standard Dev. (kts)	Standard Dev. (kts)
Platform A	1.75	0.86	0.85	0.41
Platform B	0.59	0.15	0.15	0.23
Platform C	0.92	0.63	0.63	0.99

Standard Deviation of Estimated Altitude

	Geometric	Kasa	Inversion	Air Data System
	Standard Dev. (ft)	Standard Dev. (ft)	Standard Dev. (ft)	Standard Dev. (ft)
Platform A	63.5	29.4	28.3	4.29
Platform B	11.2	4.2	4.2	1.92
Platform C	23.4	15.8	16.8	3.13

Sources of Error

- Multiple systems and instruments contribute to position error
  - Total Pressure - P_T
    - Ambient Pressure - P_S
    - Impact Pressure - q_C
  - Estimated Airspeed - V_T
  - Total Temp - T_{tot}
    - Instrument Error
    - Recovery Factor
    - Self Heating
    - De-icing Heater

$$\sigma_{P_s}{}^2 = \left|\frac{\partial P_s}{\partial P_T}\right|^2 \left(\sigma_{q_c}{}^2 + \sigma_{P_S}{}^2\right) + 2\left|\frac{\partial P_s}{\partial V_T}\right|^2 \sigma_{V_T}{}^2 + \left|\frac{\partial P_s}{\partial T_s}\right|^2 \left(\sigma_{T_{tot}}{}^2 + \left|\frac{\partial T_{tot}}{\partial C_{RF}}\right|^2 \sigma_{C_{RF}}{}^2 + \left|\frac{\partial T_{tot}}{\partial C_{SH}}\right|^2 \sigma_{C_{SH}}{}^2 + \sigma_{C_{Deice}}{}^2\right)$$

Uncertainty Analysis

Component of Uncertainty (ft)						
Method	Total Altitude Uncertainty (ft)	Impact Pressure	Static Pressure	True Airspeed	TAT Recovery Factor	TAT Self Heating
Platform A						
Geometric	22.94	9.20	5.75	17.94	9.20	1.38
Kasa	14.01	8.68	4.90	5.74	7.98	0.56
Inversion	13.59	8.45	5.07	4.68	8.06	0.91
Platform B						
Geometric	17.08	6.17	2.91	14.34	6.26	0.58
Kasa	10.02	6.17	2.91	3.80	6.26	0.58
Inversion	9.99	6.17	2.91	3.71	6.26	0.58
Platform C						
Geometric	28.96	10.84	6.02	23.49	11.44	1.51
Kasa	18.59	11.70	5.76	7.43	10.96	0.56
Inversion	18.11	11.16	6.84	6.84	10.44	0.90

Conclusions

- This method is not precise enough to develop source error corrections, only to verify the aircraft is compliant.
- The Orbis Method is a viable option to certify Navy aircraft for RVSM airspace.
- The instrumentation uncertainties can be mitigated by calibration.