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If you can't get a bigger target...

***Beyond TSPI*: Using Data Fusion to Combine Multiple Sources of Live Fire Test Data to Determine Aerodynamics and Characterize Control Events**

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Problem:

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- TSPI: Time, Space, Position, Information
  - Will Always Be Important in Live Fire Testing
- However, We Need to Look Beyond TSPI -> Data Fusion
  - How To Make Best Use of all Available Live Fire Test Data?
  - Multiple Instrumentation Sources

    Ground-Based Instrumentation
    - Doppler Radar
    - Position Radar
    - KTM Optical Cameras
    - Etc.

    On-Board Instrumentation
    - GPS
    - Accelerometers
    - Sun Sensors
    - Etc.
  - Instrumentation May Only Cover Portion of the Flight
    - Instrumentation Signal "Drop-Out"

Solution: Data Fusion of All Sources Combined With Parameter Identification

Parameter Identification

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- **Assume:** System Model has unknown parameters influencing flight
  (Ballistic Flight or Guided Flight)
- **Objective:** Determine magnitude of unknown parameters to obtain simultaneous best fit all of the test data
  - Obtain flight simulation that matches observed flight path and dynamic motion with minimum errors
  - Compare predicted flight motion using standard equations of motion with measured motion, differentially adjust aerodynamics to minimize differences

Parameter Identification Provides Accurate Assessment from Largest Portions of Test Data

Parameter Identification

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1. Process starts with the standard equations of motion and estimated initial conditions & aerodynamics
2. Develops partial differential equations for each test measurement and coefficient for a set of parametric equations
3. Performs numerical integration to obtain partial derivatives for each test measurement and coefficient
4. Differential correction equation from Taylor Expansion
5. Solves for aerodynamics & examines residuals, updates equations of motion & iterates until change in residuals is "zero"
    - Using a sensitivity matrix, the most sensitive parameters "fit" first.

Parameter Identification Uses All Available Measurements

Analysis Procedure

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- Preliminary Analysis
  - Data Screening (e.g. does data have large noise?)
  - Estimates of Initial Velocity & Conditions (Gun QE & Azimuth of Fire)
  - Estimates of Burn-On & Burn-Off times (if needed)
  - Overlapping Sectional Fits of Complete Trajectory via Equations of Motion
  - Axial Force & Spin vs. Time & Mach and/or Thrust vs. Time
- Parameter Identification
  - Complete Parameter Identification
    - Four Degree of Freedom (for ballistic flights)
    - Six Degree of Freedom (w/Control Forces; w/ On-board sensors only)

Data Fusion Analysis Procedure of all Measurements

Examples

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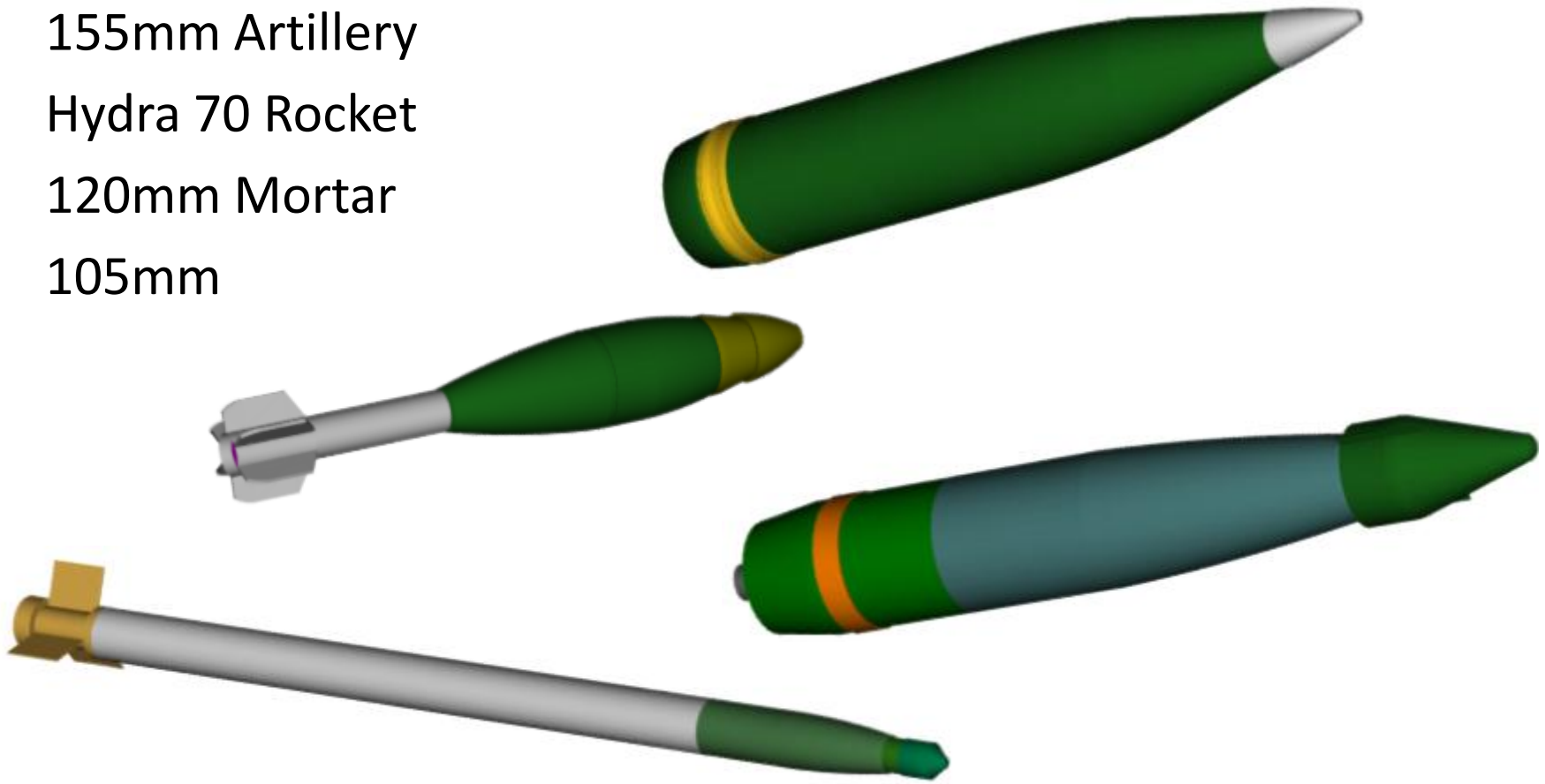
- 155mm Artillery
- Hydra 70 Rocket
- 120mm Mortar
- 105mm



Wide Range of Uses; Ballistic, Powered & Guided

Ground-Based: Radar

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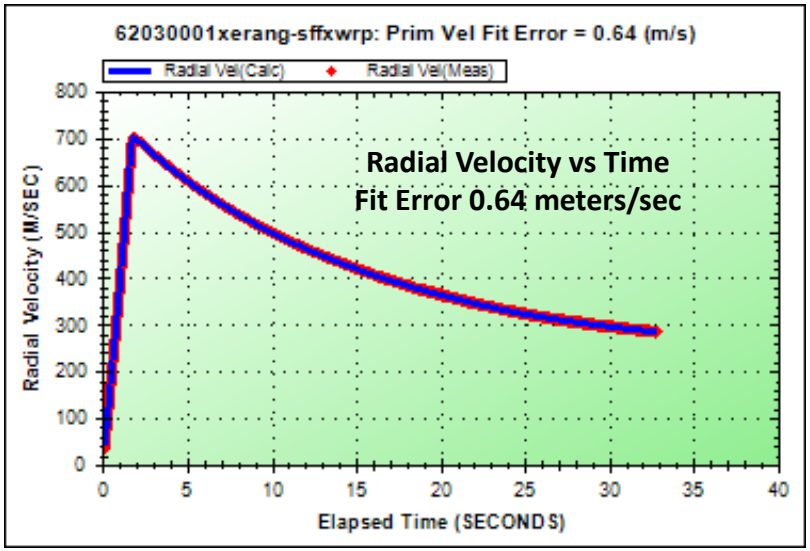
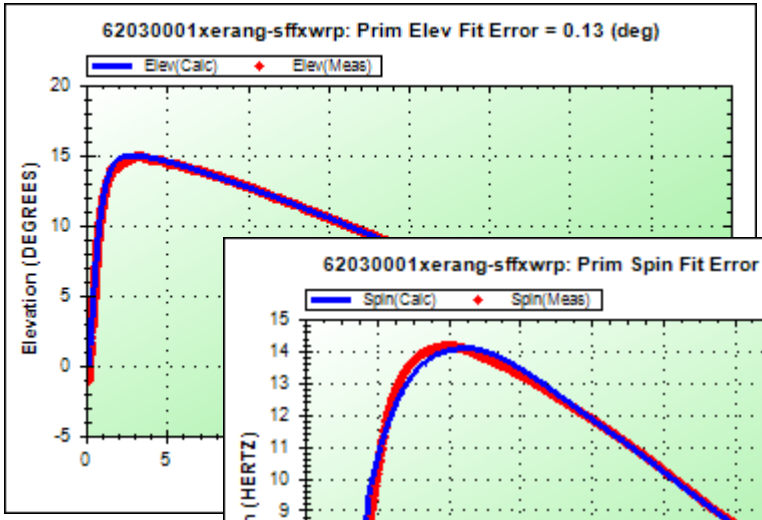
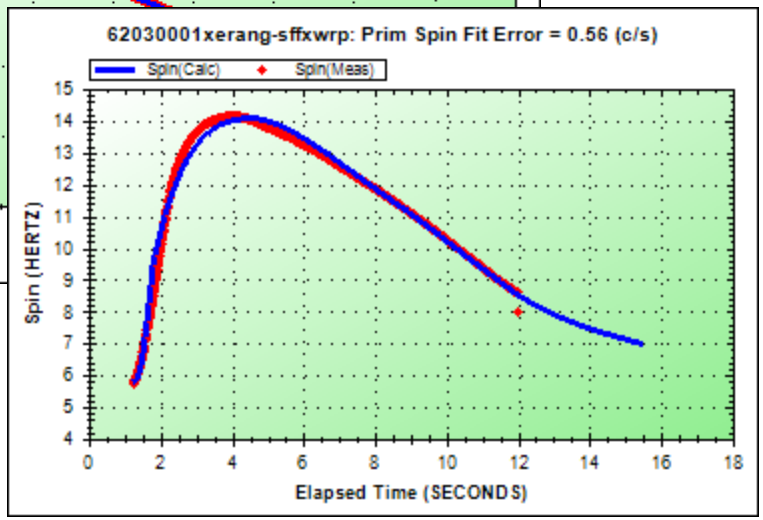
- Tracking Doppler Radars
  - Provides Radial Velocity, Azim. & Elev.
  - "Behind the Gun" & "Down Range" Doppler
- Position Radar
  - Provides Range, Azim. & Elev.







Velocity-Time Data is Basis for Drag/Thrust Solution

Ground-Based: Radar plus KTM

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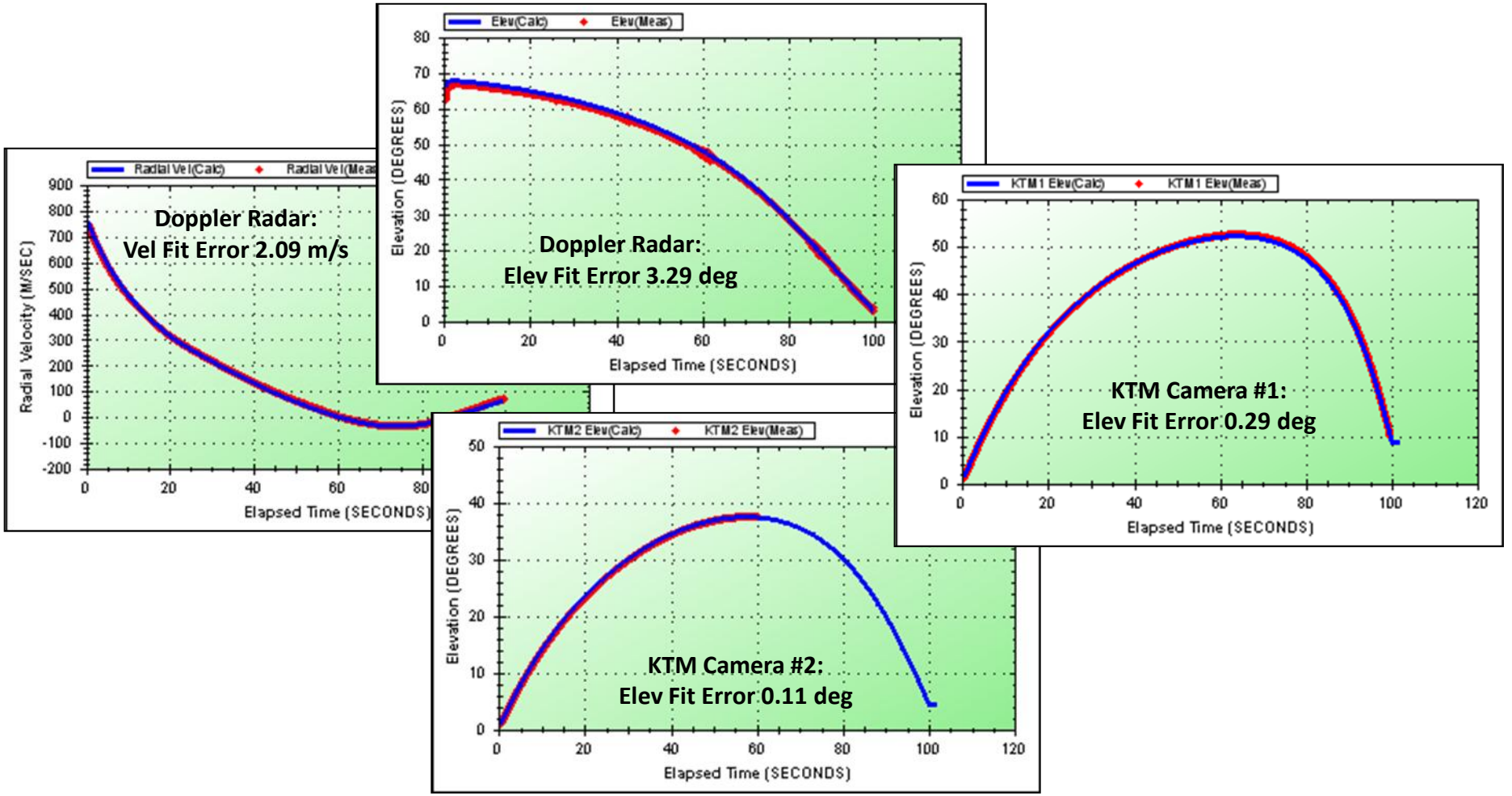

Simultaneous Reduction of Multiple Source of Data

On-Board: Magnetometers

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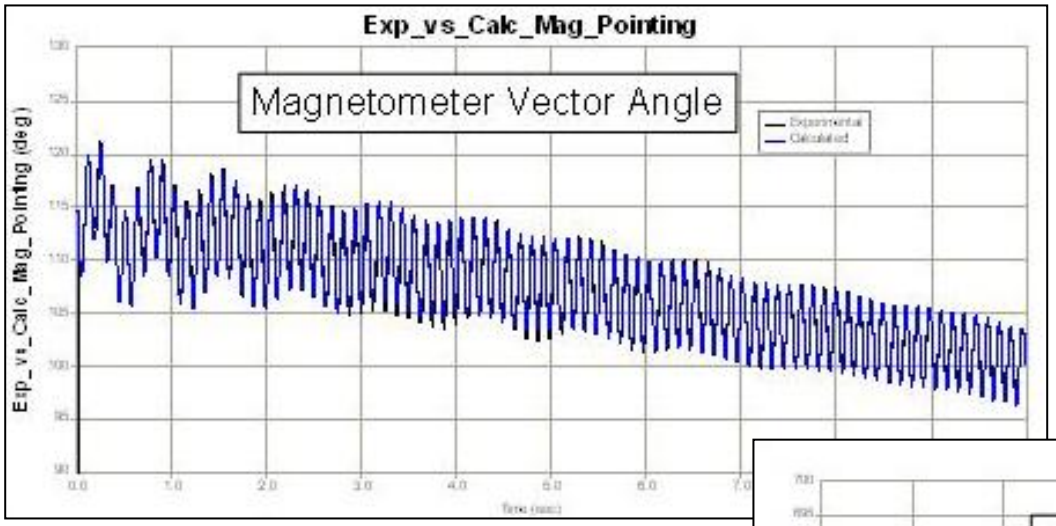

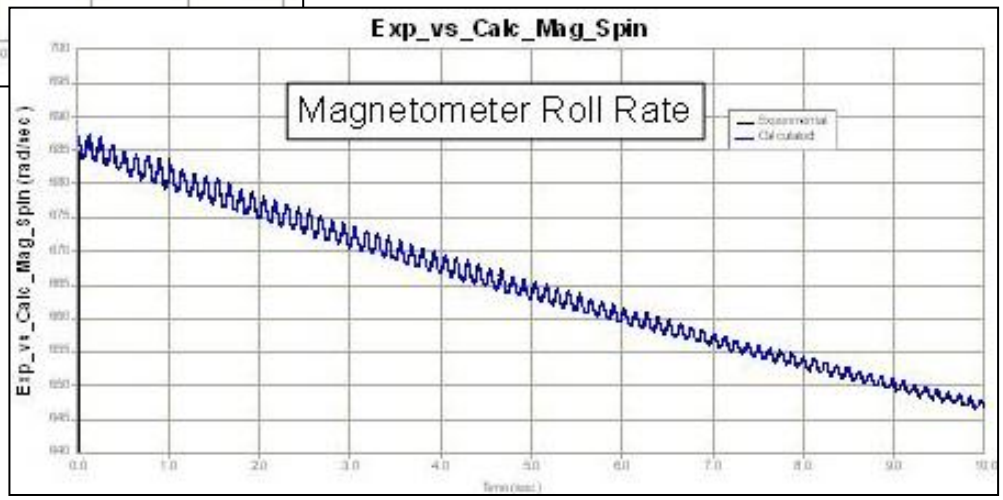

Magnetometer Provides Yaw & Roll Angle Data

On-Board: Accelerometers

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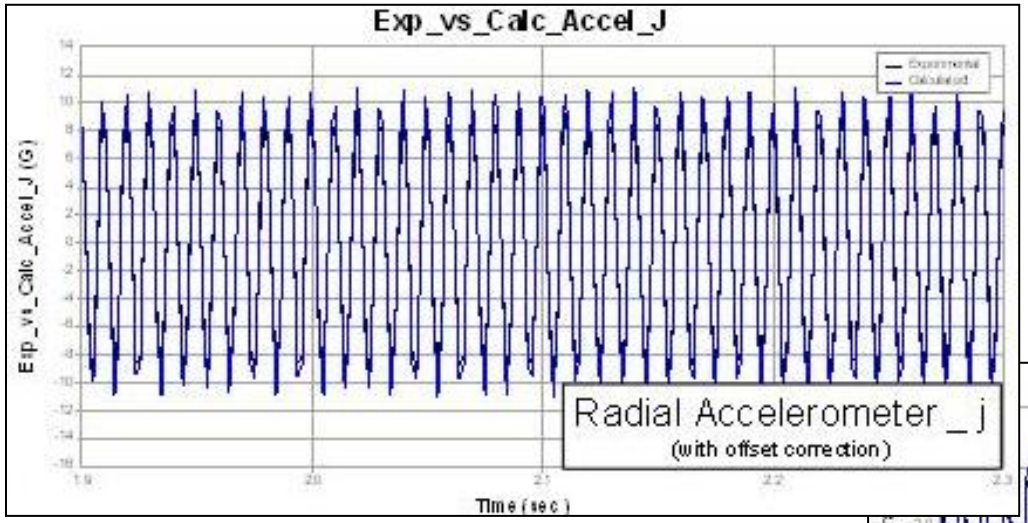

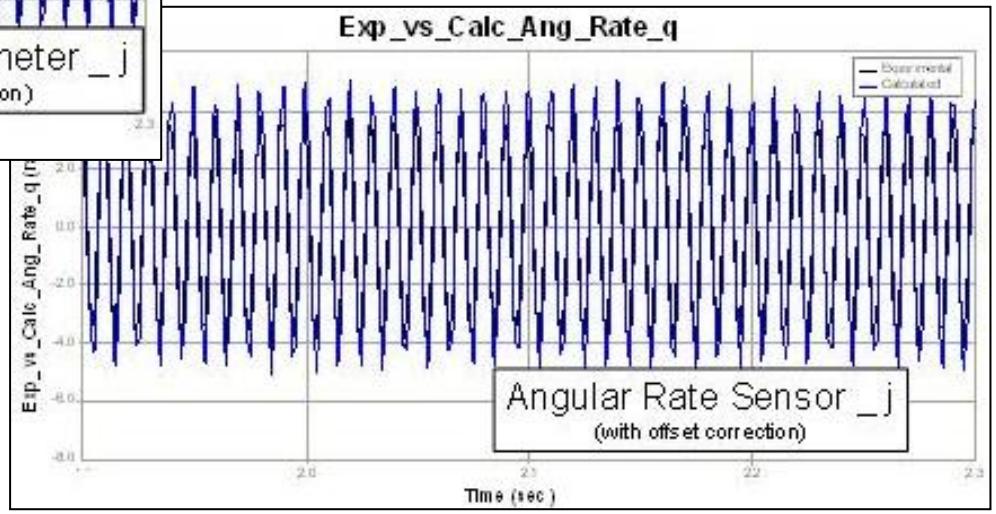

Accelerations & Angular Rates Provide Information about Normal Force Coefficient & Dynamic Stability

Ground-Based: Radar plus KTM

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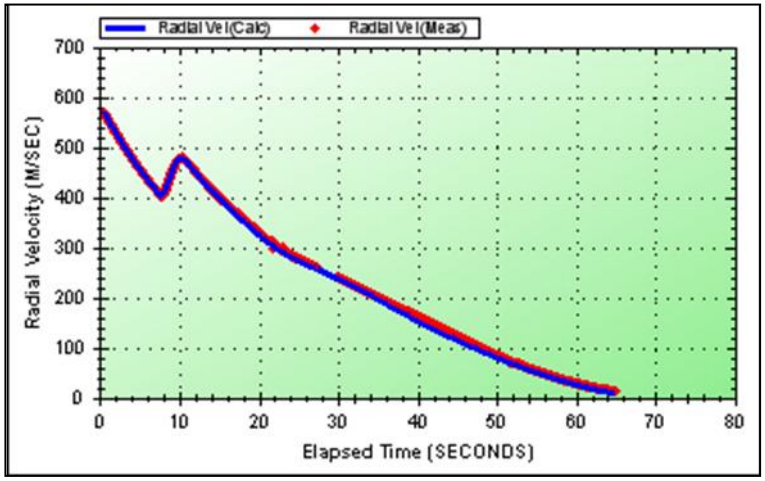

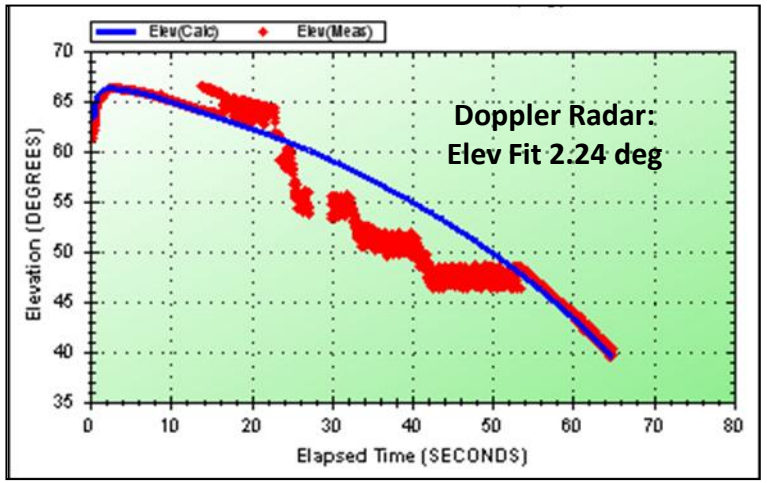

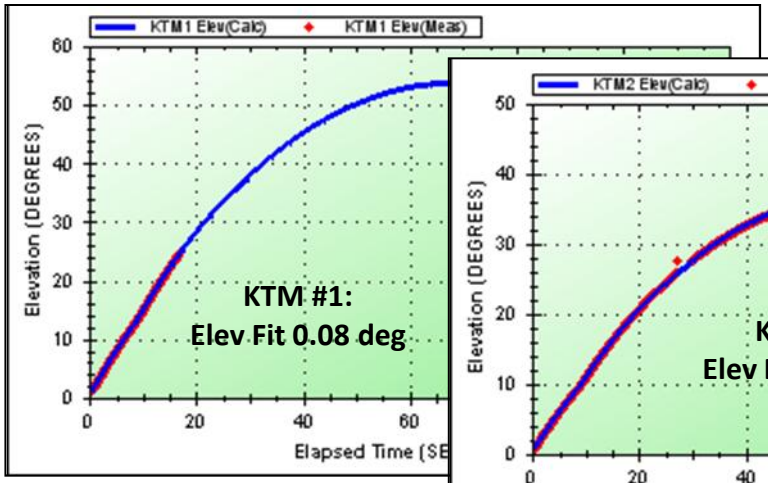

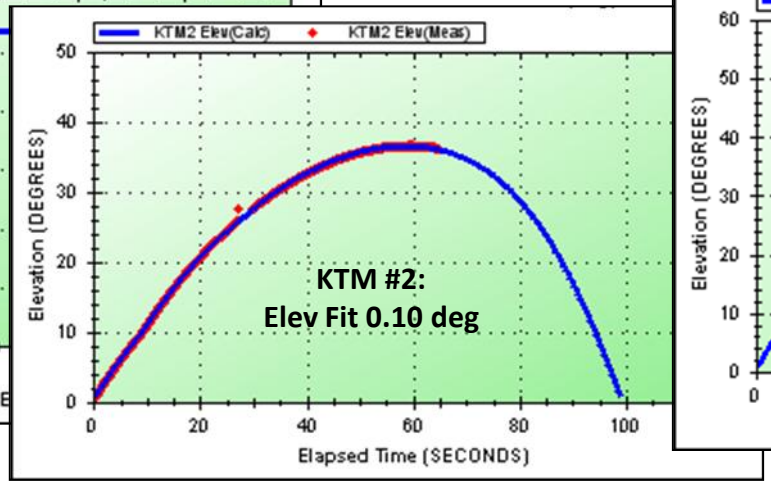

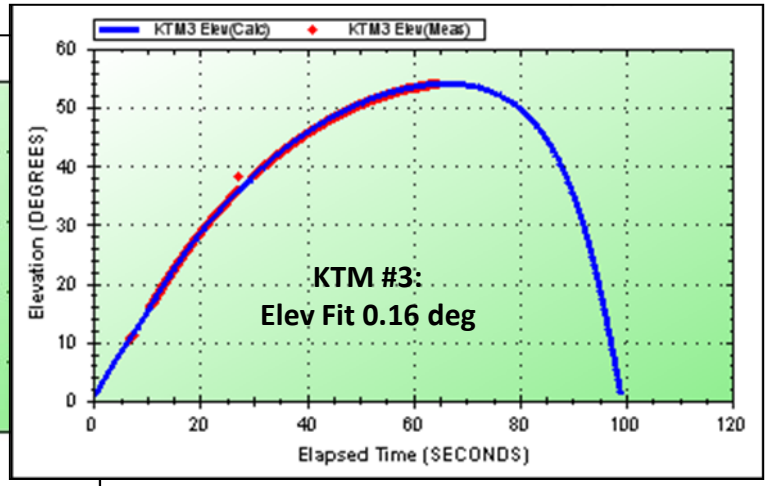

Data Fusion Can Help Overcome Poor Test Measurements

Summary & Conclusions

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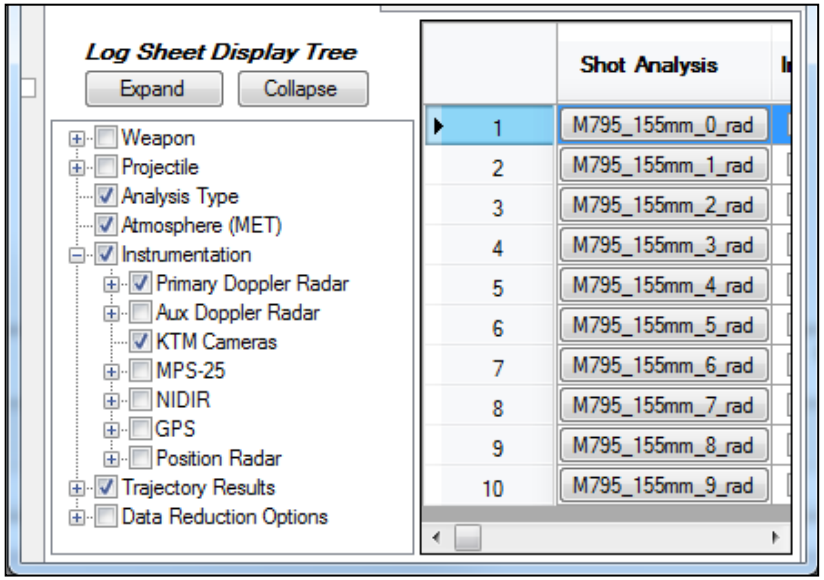
- **Improved Data Fusion**
  - Combining of sensor data from disparate sources
  - Improved Fit Accuracy
  - Use fewer KTM cameras to reduce test cost w/equivalent accuracy
- **Feedback Loops Direct from Test to Design Activity**
  - Aerodynamics
  - Stability
  - Control Systems, Guidance, and Sensors
- **Tools Must be Adaptable**
  - New data sources/instrumentation
  - New control systems



Data Fusion of Data from Different Sources Gathered from Live Fire Testing Can Improve Both TSPI and Aerodynamics

Contact Information

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