556 Test & Evaluation Squadron

53 TMG, Detachment 4

Testing - Tactics - Training

Characterization & Modeling of Target Coordinate/Elevation Generation Systems

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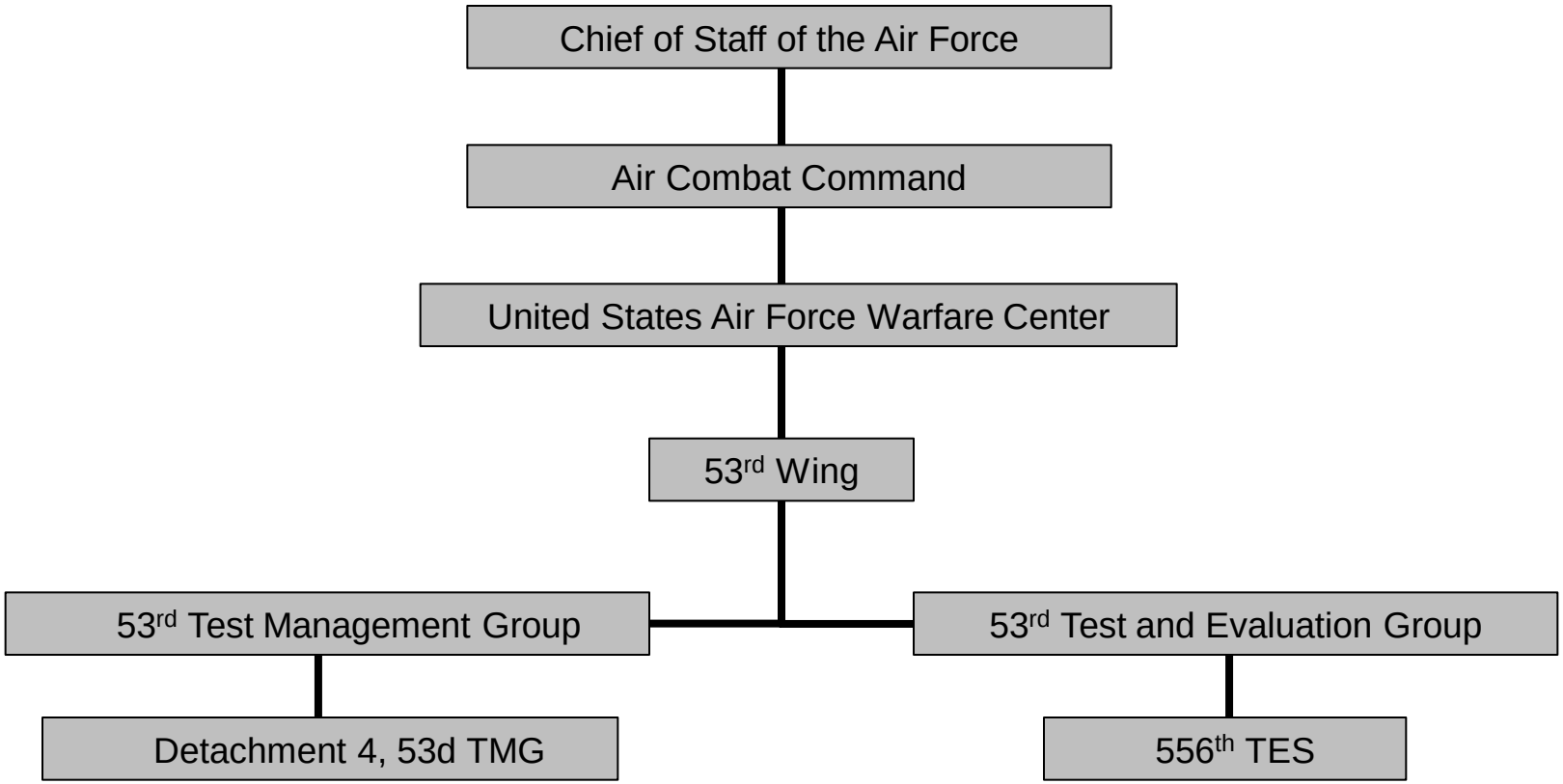
Test Organization



Overview

- Traditional (Black Box) Approach
- Error-Propagation Modeling Approach
- Importance of Vector Components for both approaches
- Comparison of Black Box to Error-Propagation Model
- Conclusions / Recommendations

Target Location Error (TLE) Testing Goals

- Characterization of targeting accuracy for MQ-1 Predator & MQ-9 Reaper
- Provide a baseline for future upgrades
- Determine which factors have primary influence on targeting accuracy for reporting & tactics development
- Efficient use of resources

Two Test Approaches

- Traditional (Black Box) Approach:
  - Ignore inner workings of targeting system

  - Plan, Execute, Analyze & Report
- Error-Propagation Modeling Approach
  - Consider system design:
    - Perform instrument tests directly if possible
    - Estimate error of each sub-system
    - Feed the model
  - Plan, Execute, Analyze & Report

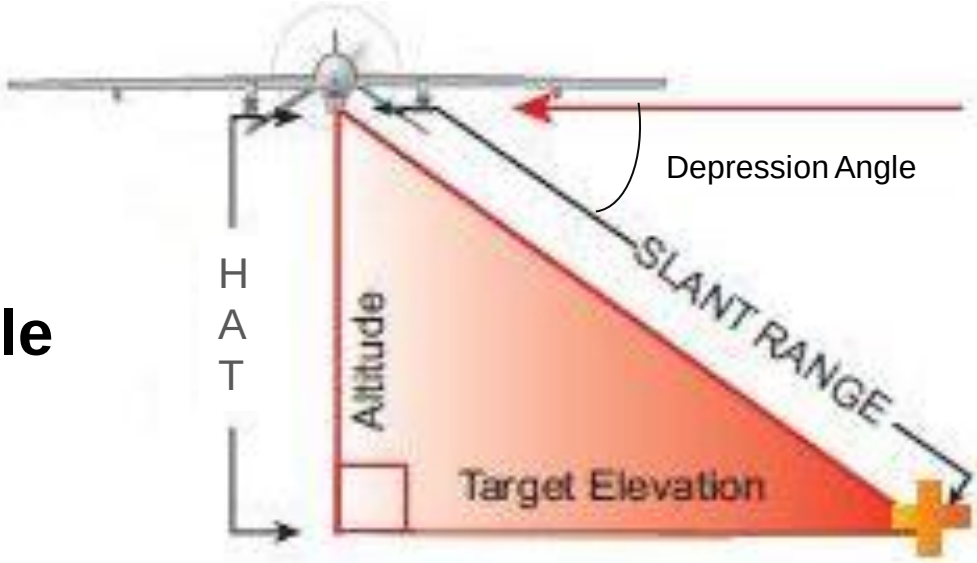
Traditional Approach Planning & Execution

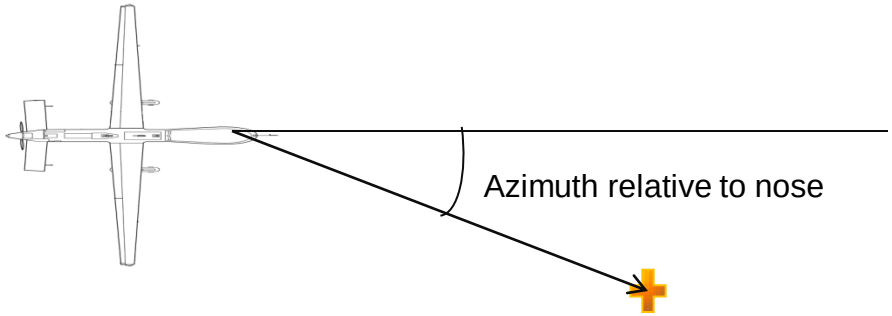
- Design of Experiments (DOE) to plan test
  - Minimize test time, assets & data required
  - Optimize factor investigation
- Test execution
  - Difficult to randomize
  - Control of factors
  - Safety of flight considerations
  - Range restrictions

Executed in the traditional manner of flying operationally representative patterns & collecting data continually.

Traditional Approach Planning & Execution

- **Main Factors**
  - **Altitude**
  - **Slant Range**
  - **Depression Angle**
  - **Airspeed**
  - **Camera type**
  - **Azimuth**
  - **Terrain**

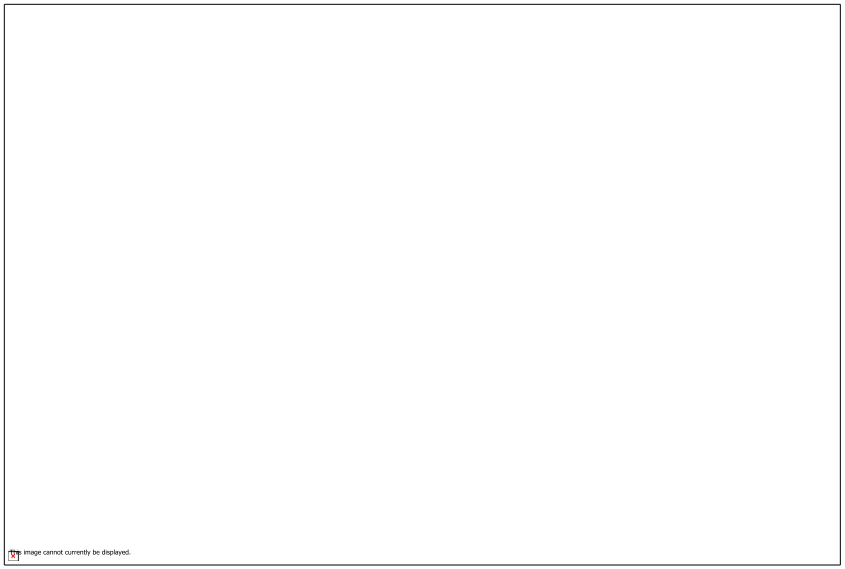


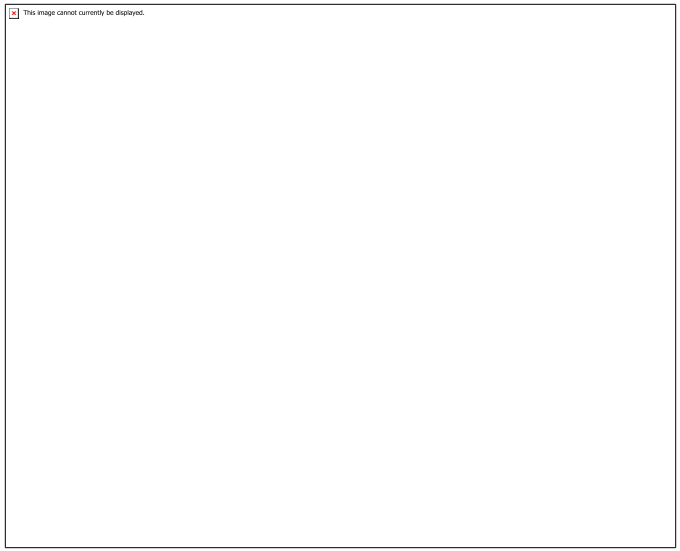


Initial Matrix had
576 Data Points

Analysis Challenges

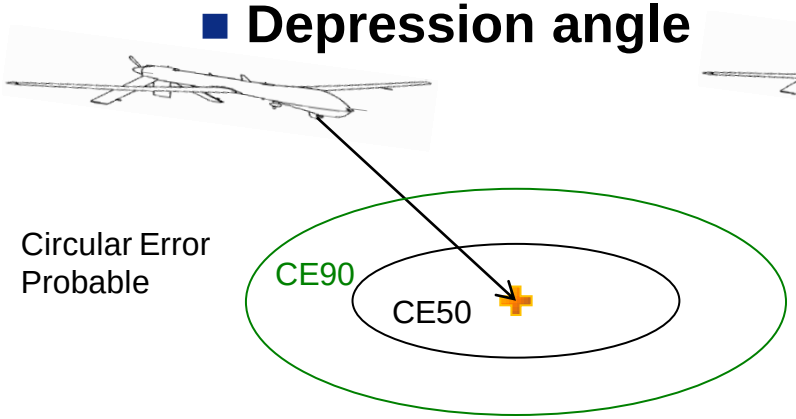
- **Effects Analysis**
  - **Non-normal distribution**
  - **Transforms**
    - **Causes error residuals to look normal**
  - **Analysis of Variance (ANOVA)**

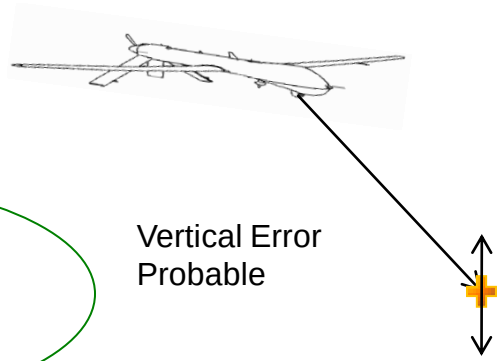


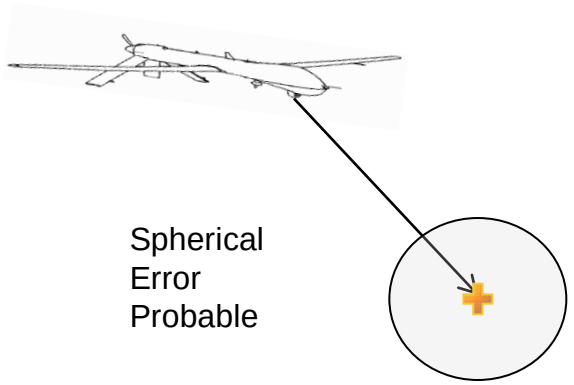


Traditional Approach Reporting & Limitations

- **Typically Report**
  - CE50 / 90, Max CE
  - VE50 / 90, Max VE
  - SE50 / 90, Max SE
  - Conditions
    - Slant range
    - Height above target
    - Depression angle
- **Limitations**
  - CE, VE, SE Non-normality:
    - Increases Experimental Error
    - May prevent useful conclusions
  - Error often not circular or spherical



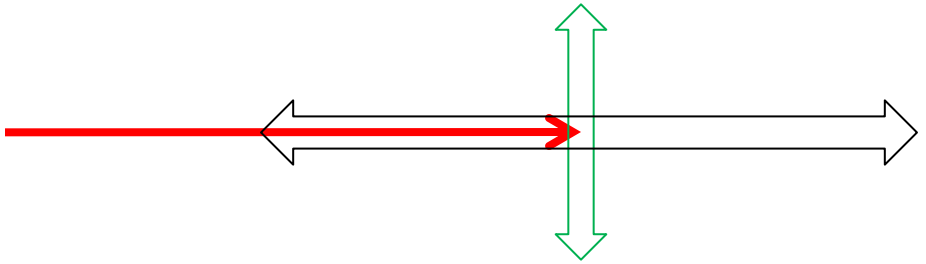




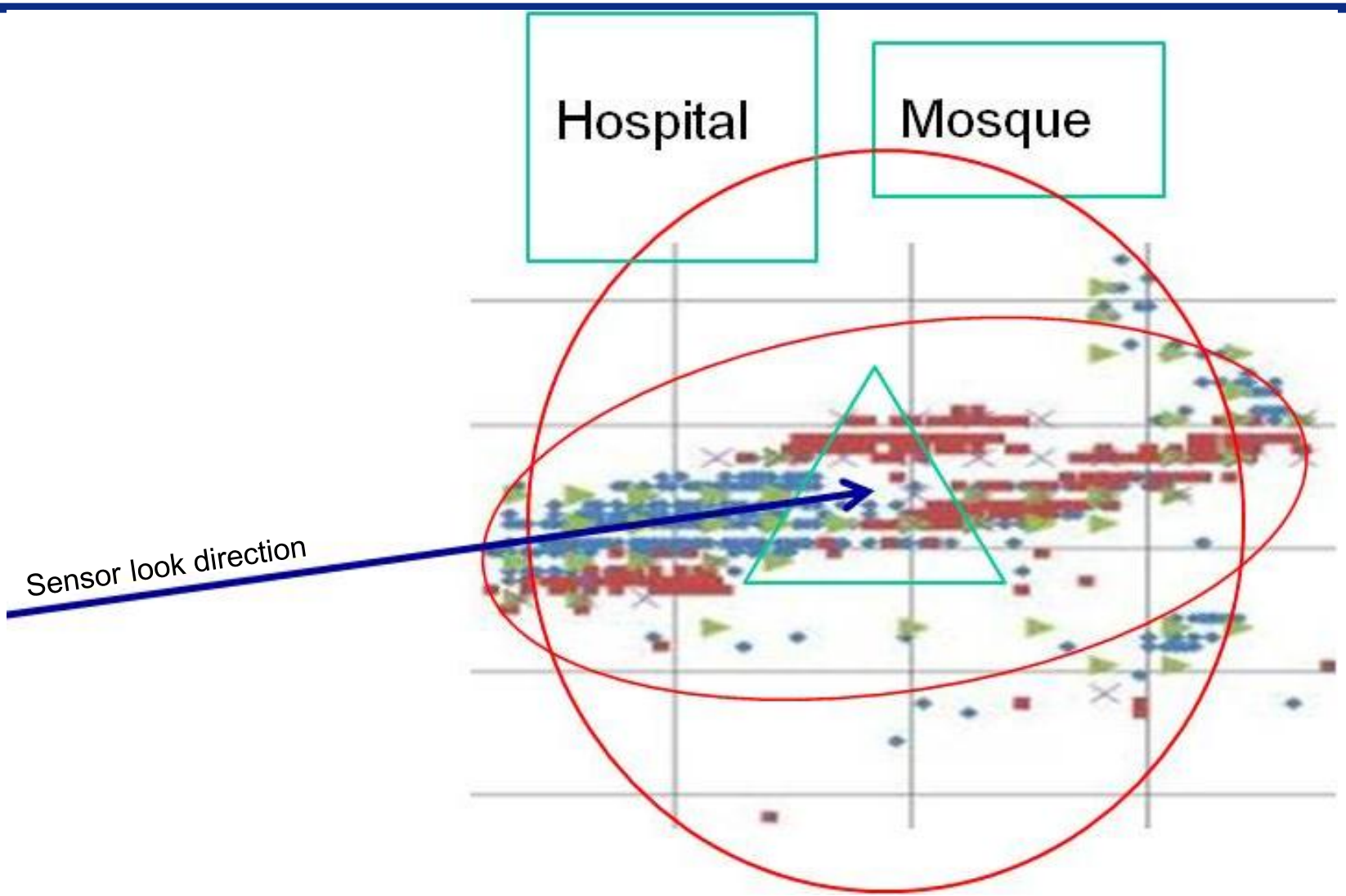
Vector Components

- Resolve short-long and left-right errors relative to:
  - Pointing direction of targeting pod
  - Direction of motion
  - True North
- Resolved components are distributed more normal
- Facilitates effective modeling of system behavior

Directional Vector
Short-Long
Left – Right

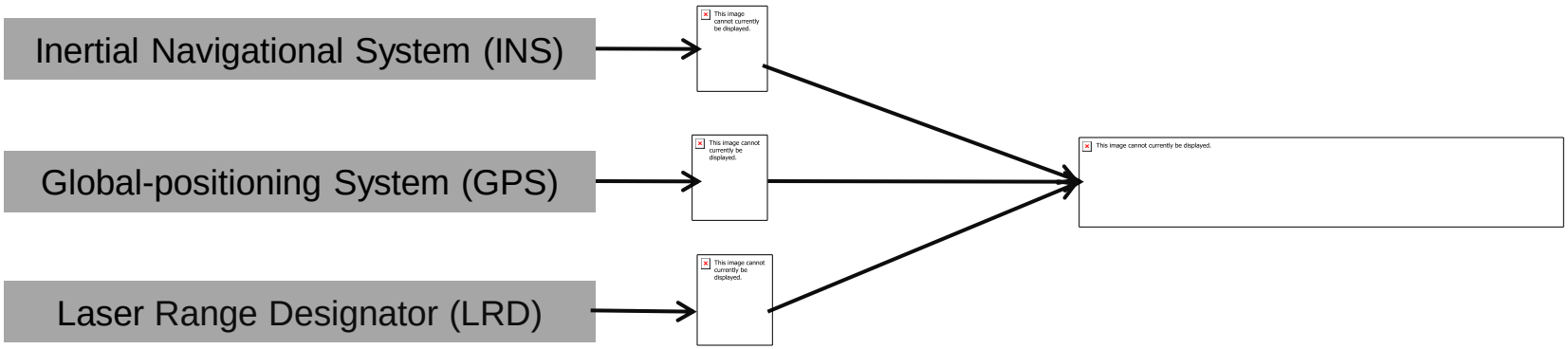


Reporting Challenge



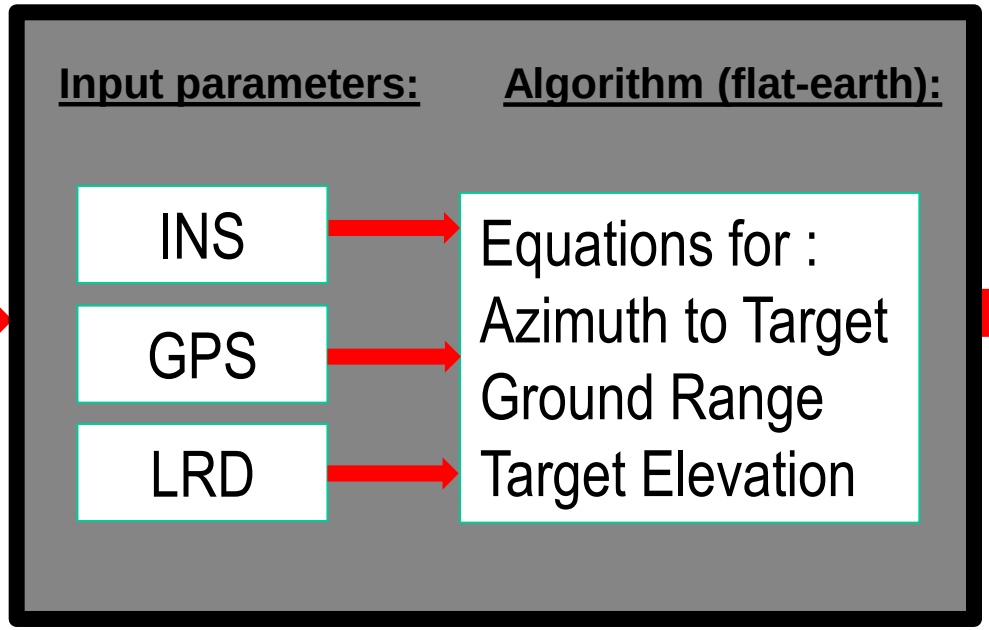
Sub-system Error Propagation

- The portion of the total error due to a specific sub-system may be known up front
  - Example: Rangefinder affects component in short-long direction of the vector, ± x feet
- Facilitates appropriate modeling
- Improves anomaly investigation



Error-Propagation Modeling

Factors:
Maneuvering
GR/SR/AZ/DA
Environment
Sensor settings
Latency
Target Attributes



Target:
Latitude,
Longitude,
Elevation

Error-Propagation Modeling

- Input parameters have error distributions σ_{SR}, σ_{DA}, etc.
- Resulting error distributions will propagate to resulting error distributions in the following manner:

*Bevington, 1969

- This approach can yield models for each output:
  - Vector components (Short-Long, Left-Right)
  - CE, VE, SE

Models achieve better planning, execution, analysis & results

Benefits of Error-Propagation

- **Interpolation of system performance**
- **Provide support for proposed system modifications**
- **Planning for future testing facilitated**
- **Better tactics, techniques, & procedures (TTPs)**

Ultimate goal is real-time, predictive & accurate 3D display for the warfighter; only achievable with error propagation modeling approach

Conclusions

Traditional Approach:

- **Pros:**
  - No dependence upon prime contractor for design details
  - Can be tried in every case
- **Cons:**
  - Ignores system design (treats as black box)
  - No insight into biases / sources
  - Transforms likely have no connection to reality
  - Lower sensitivity to effects
  - Less efficient

Error-Propagation Model Approach:

- **Pros:**
  - Components more normal
  - Biases visible
  - Better sensitivity to effects
  - Transforms based upon reality
  - Optimal for:
    - Interpolation
    - Design change gains
    - Anomaly insight (sources)
    - TTPs
    - Real-time display
- **Cons:**
  - Misinformation hazard
  - Knowledge of system design & algorithm required

Recommendations

- If system design is defined or bounded:
  - Use error-propagation model
- For both methods
  - Analyze vector components
  - Attempt elliptical characterization in addition to circular / spherical

Questions?

References

Bevington , Philip R., Data Reduction and Error Analysis for the Physical Sciences, McGraw Hill Book Company, 1969.

Montgomery , Douglas C., Design and Analysis of Experiments, Sixth Edition, John Wiley & Sons, Inc. , 2005.

Triola, Mario F., Elementary Statistics, Tenth Edition, Pearson Addison Wesley, 2006.