Automated Projectile Design Software

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Projectile Design

- Ballistic Projectile Design
  - Performance Specs
  - System Interface
  - Candidate Design
    - Mass Properties
    - Aerodynamics
    - Ballistic Effectiveness
    - Payload Effectiveness

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- Guided Projectiles
  - Same as ballistic plus
  - Control mechanisms
  - Sensors
  - Autopilot
  - Guidance strategy

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  - Remove system errors
  - Trajectory shaping
    - Glide for extended range
    - Dive to clear obstacles or for lethality

Bottom Line

- You now have to:
  - Design the projectile
  - Decide on a control mechanism
  - Design the auto pilot
  - Implement a Guidance strategy

Commercial/Military Projectile Design Tools

- Custom/Proprietary Software
  - Developer uses different analysis modules handing off data from one to the other
  - Stand alone modelers
    - Model building (PRO-E or Solid Works)
    - Aerodynamic estimation (CFD, Missile DATCOM, MILS3 or AP)
  - Simulation codes
    - Hand coded custom solutions
    - Typically Project A evolves into Project B evolves into Project C
- PRODAS
  - Legacy codes embedded into an integrated software system
  - Validated simulations
  - Macro language
- MATLAB/Simulink
  - Like Legacy Simulation codes except within an environment
  - Pre-built simulation blocks and integration engines

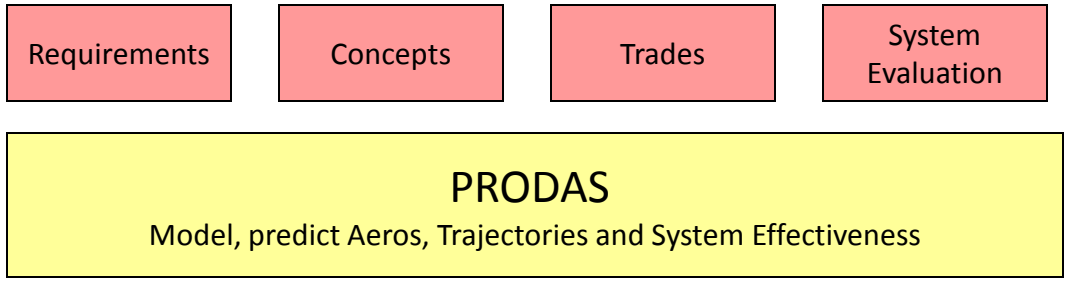
Software Metrics

Smart Weapon Development Levels

- First Level - Conceptual Design Studies (Proposal)
  - For a Given Projectile, What Improvements in Performance Can be Obtained IF a Control Force and/or Moment is Available?
  - Simple to model and assess the Benefit of a Flight Control System
- Second Level - Detailed Design Studies (Design)
  - Perform Parametric Trade Studies to design the details of the Control Mechanism
  - Assess the Performance of a Smart Weapon
- Third Level - Final Detailed Design (Test)
  - At this Stage, Detailed Models of the Sensor Suite and Control Law are Included in Analysis
  - Models will include real time loop rates
  - Model should generate C code for embedded processors

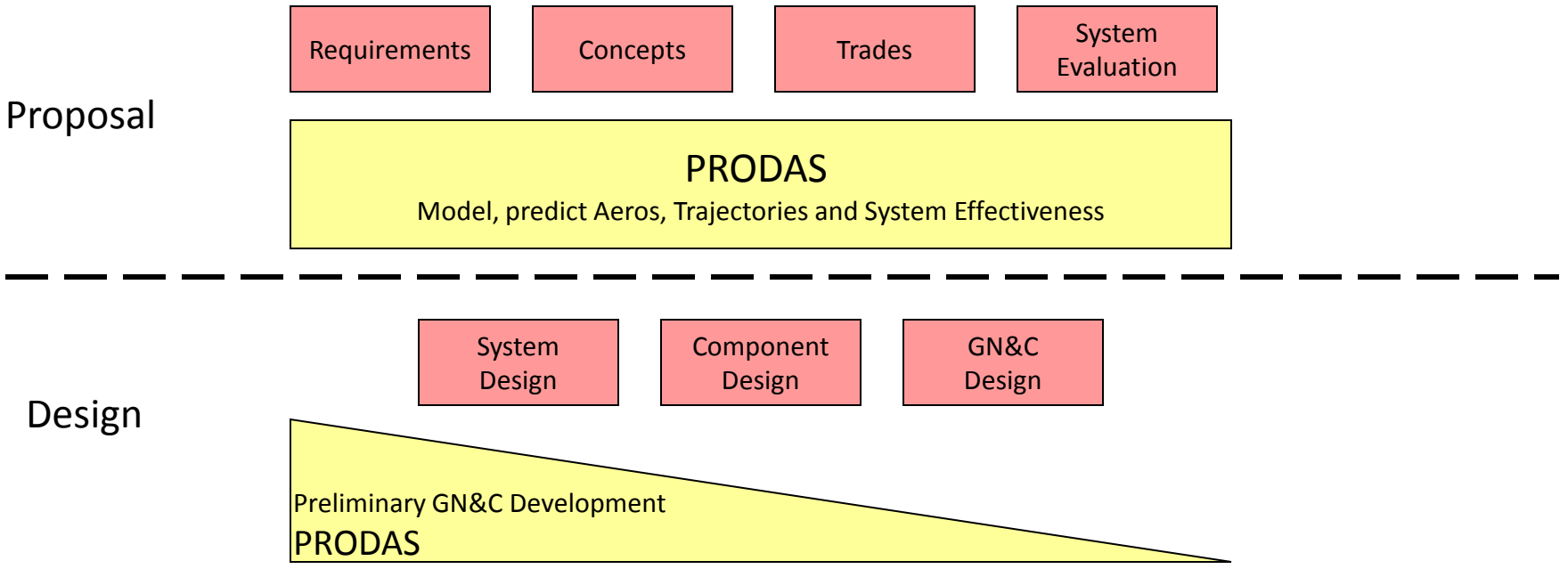
Guided Projectile Development Cycle

Proposal



ARROW TECH

Guided Projectile Development Cycle



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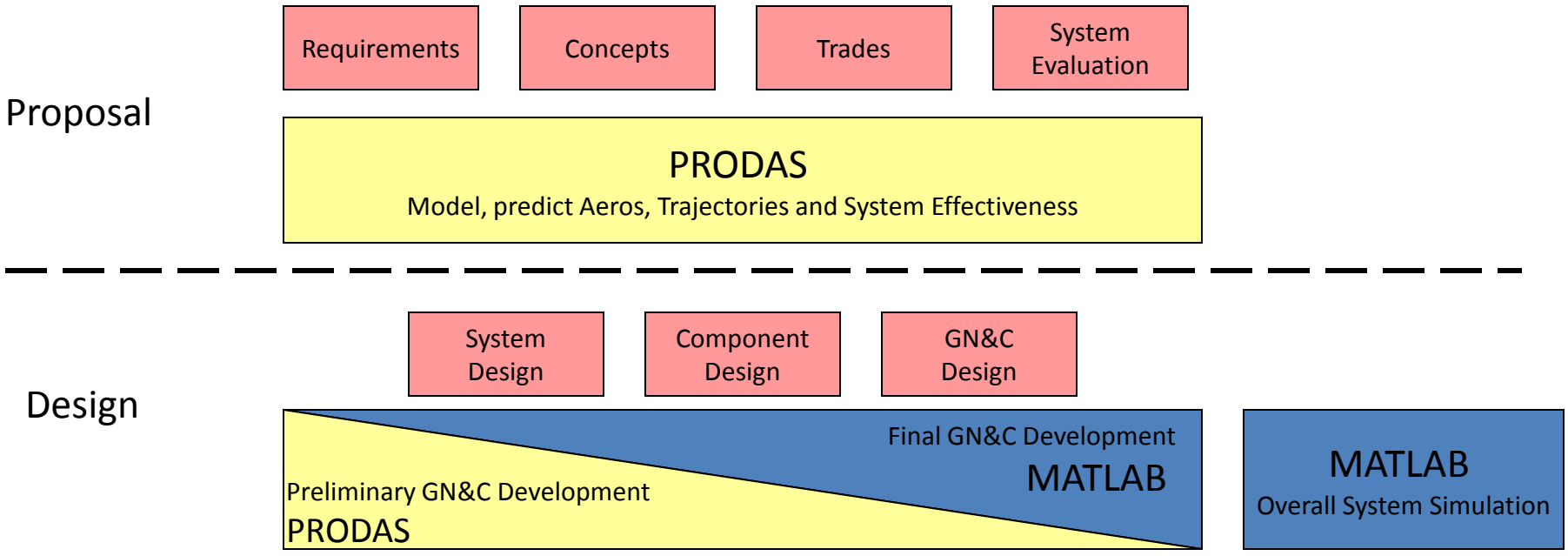
Guided Projectile Development Cycle



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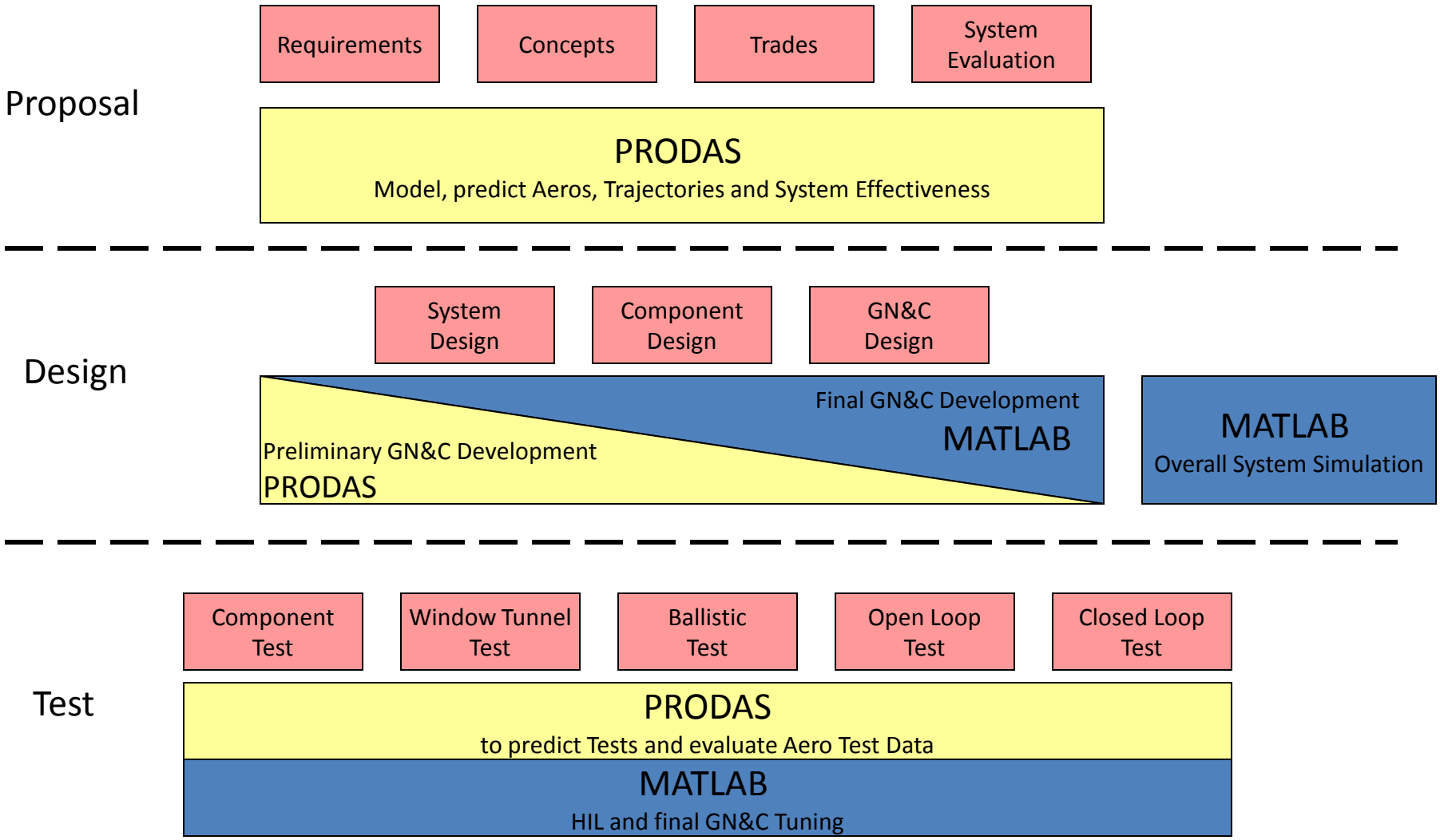
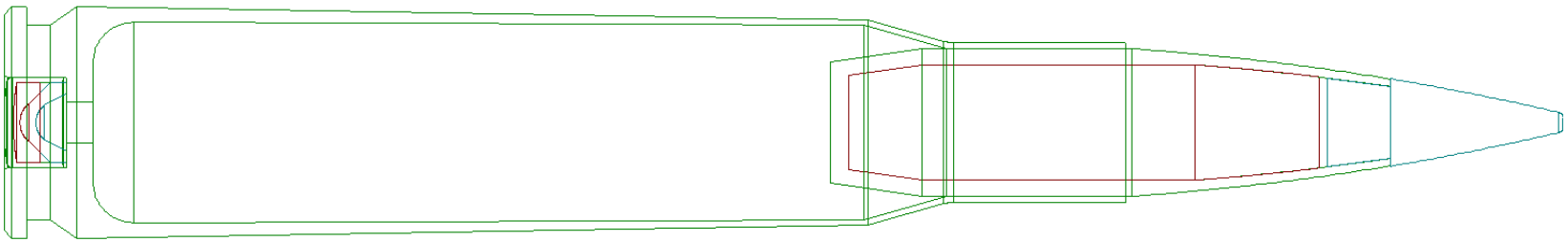
Guided Projectile Development Cycle



Example #1 Ballistic Projectile

- Design a 50 caliber projectile that will minimize wind sensitivity at 1000m
  - Start with basic shape
  - Vary boat tail length and Ogive length and shape



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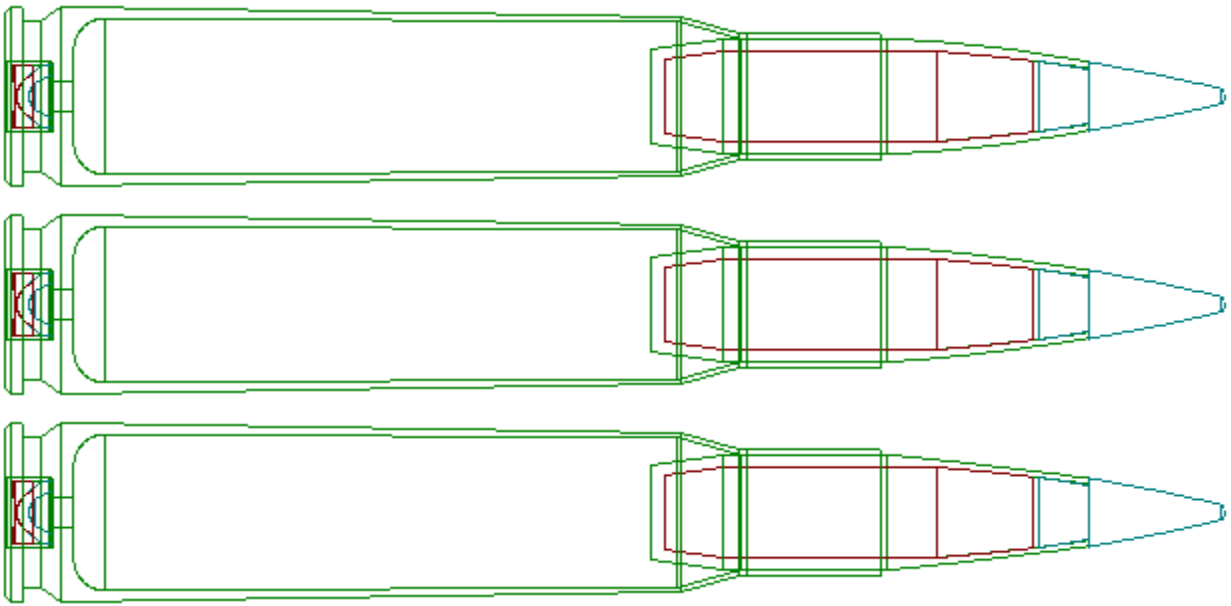
Subtle Changes to Ogive Shape



154mm radius

254mm radius

664cm radius

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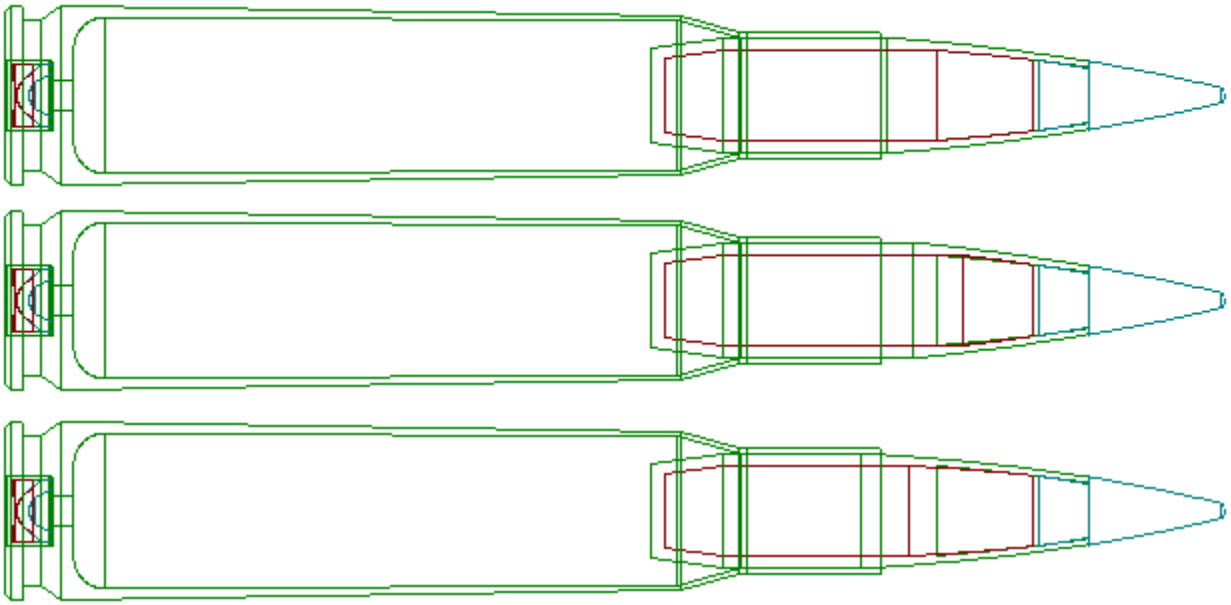
Not So Subtle Changes to Ogive Length



Standard

-3mm

+3mm

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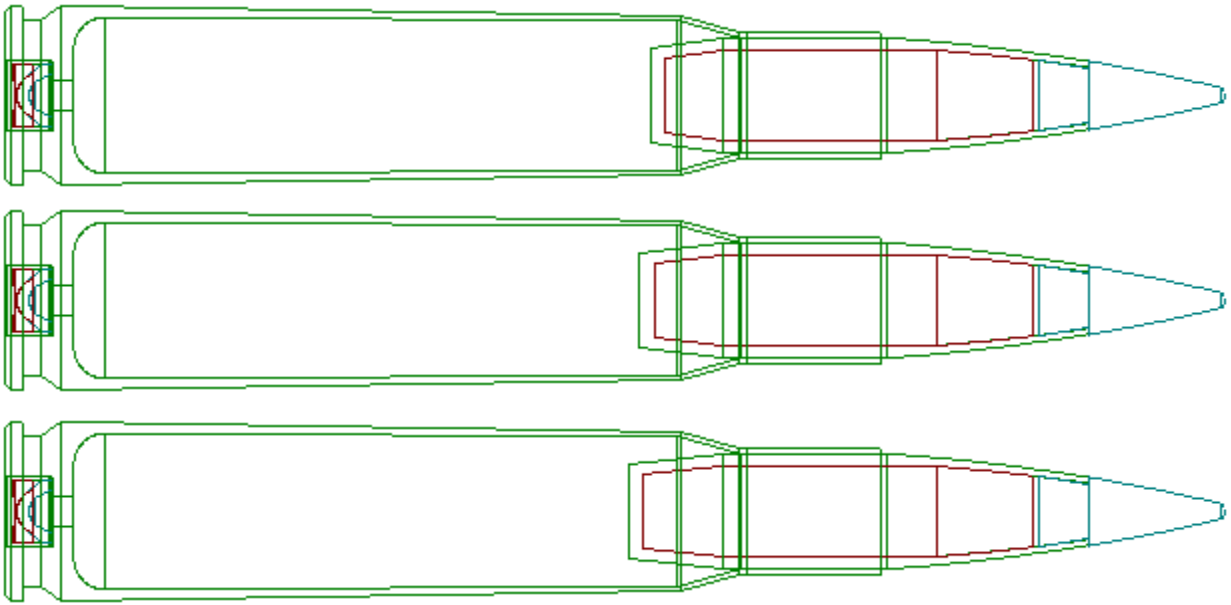
Not So Subtle Changes to Boat Tail



Standard

+15%

+30%

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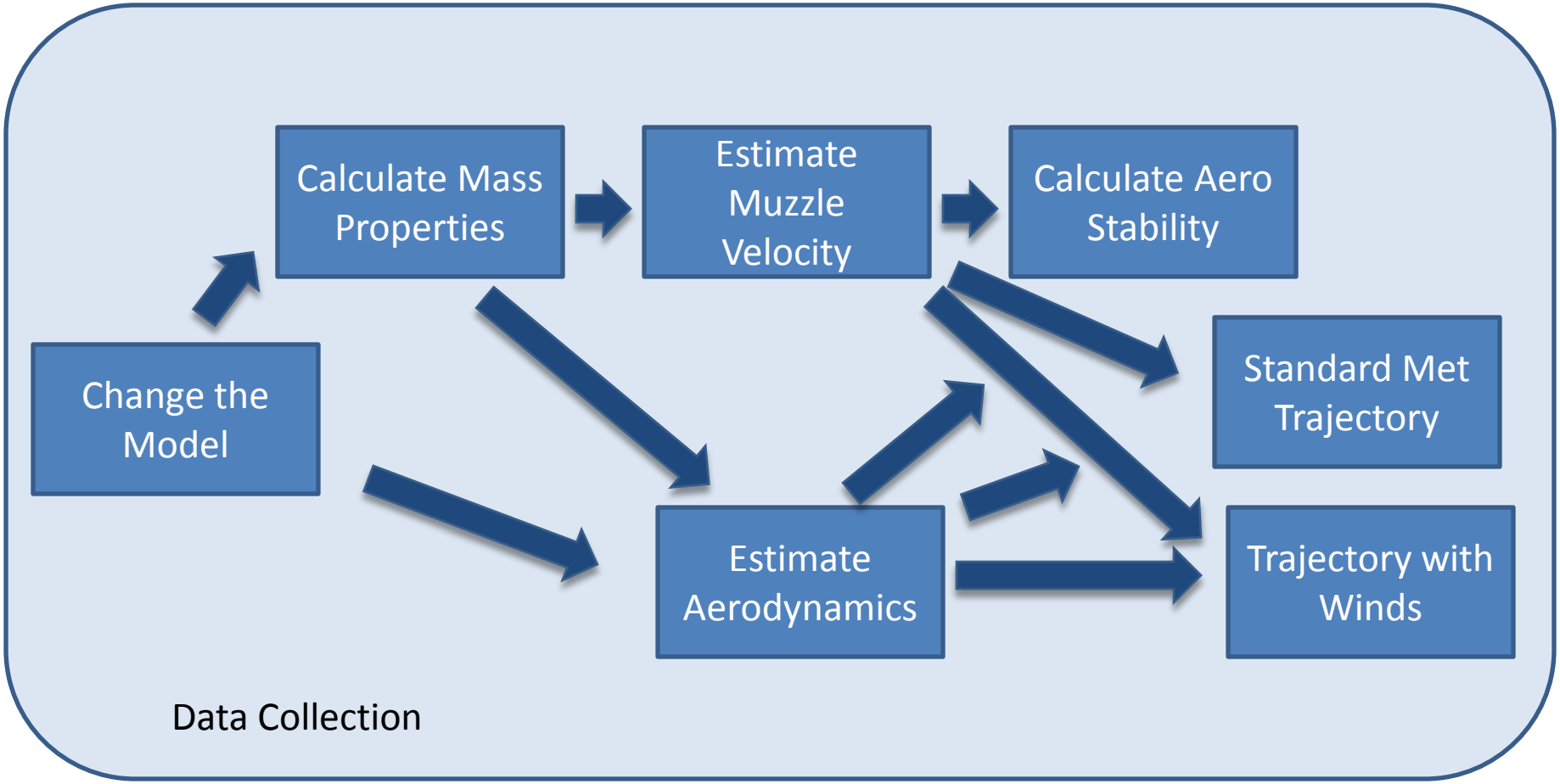
Analysis Map



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Example #1 Metrics

- 27 designs evaluated
- 7 analysis modules executed
- 50 seconds run time
- 200 lines of PRODAS macro code
- 4 hours to develop
- 1 Excel file of results

- Results:
  - Decreased wind sensitivity by 7.6%
  - Some configurations increased by as much as 10%

Example #1 Extended Metrics

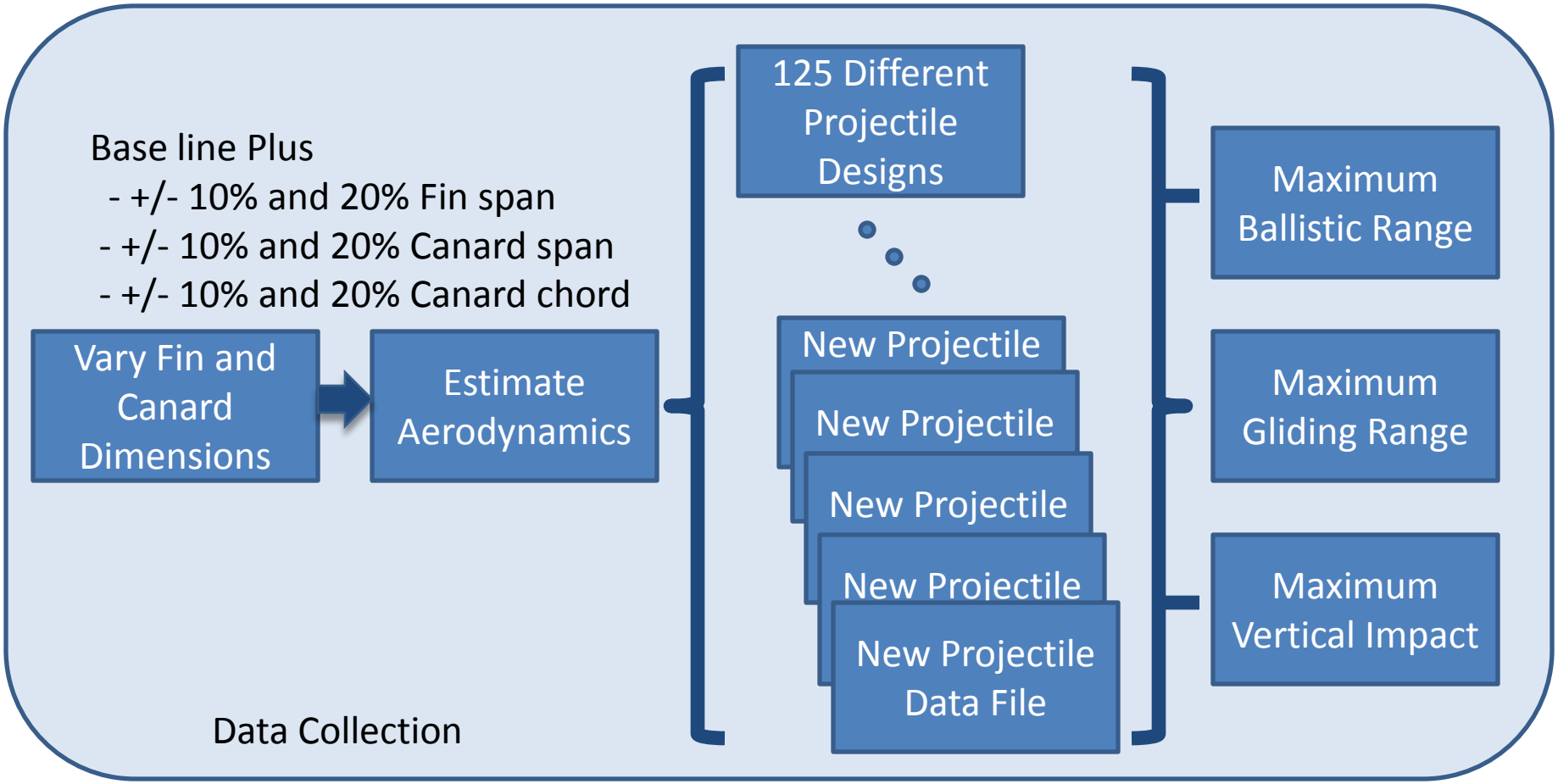
- Started with previous macro
- 125 designs evaluated
- 7 analysis modules executed
- 4 minutes run time
- 212 lines of PRODAS macro code
- 2 minutes to modify
- 1 Excel file of results

- Results:
  - Decreased wind sensitivity by 7.8%
  - Some configurations increased by as much as 25%

Example #2 Guided Projectile

- Basic design of mortar body is fixed, evaluate different fin/canard designs to meet multiple requirements.
  - Find maximum ballistic range
  - Find maximum gliding range using open loop control
  - Find maximum target range with vertical impact using open loop control

Analysis Map



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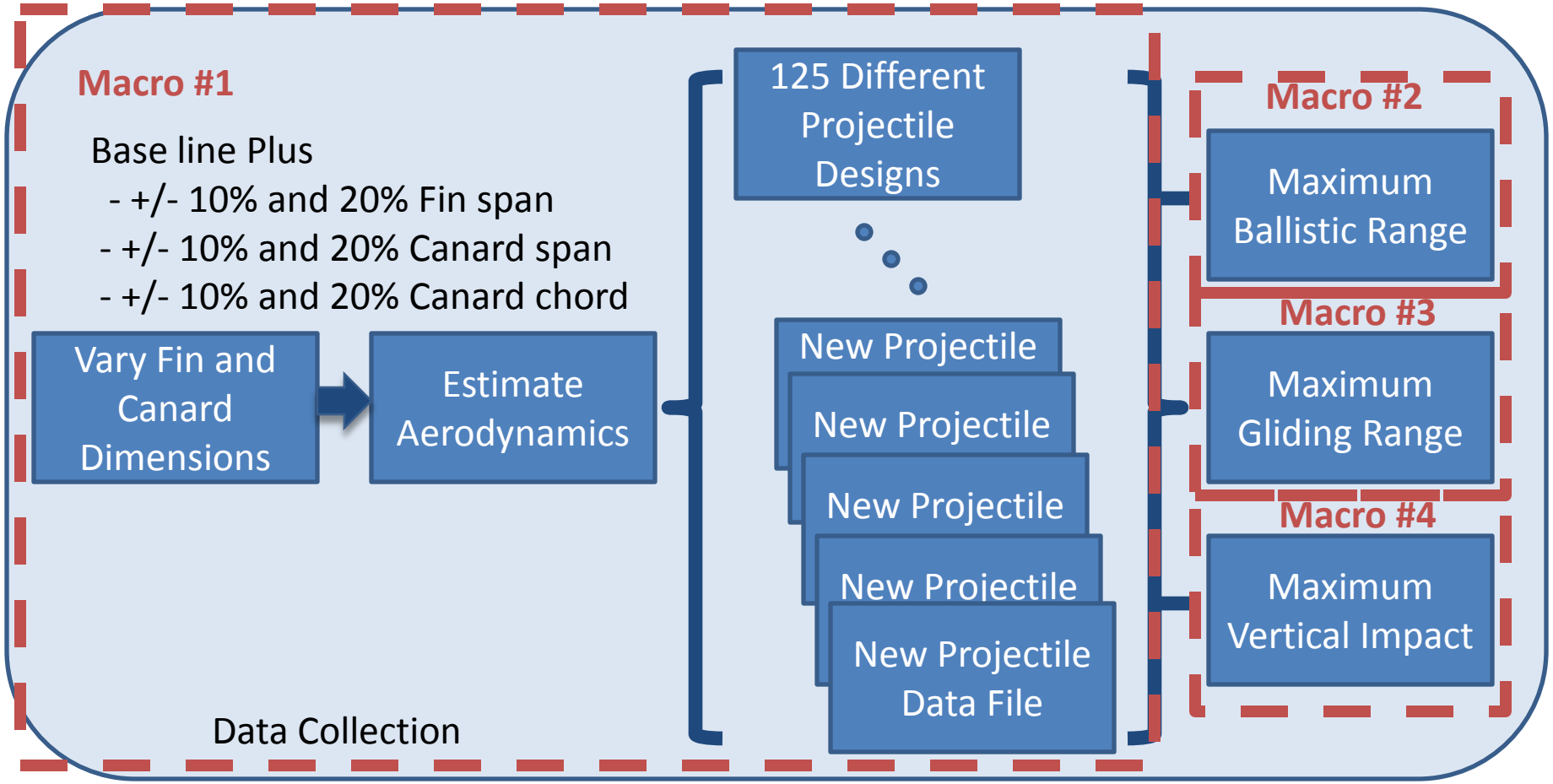
Macro Map



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Guided Flight Macros

- Simple open loop canard controller embedded in the GN&C Prototype tool
- Maximum Gliding Range Macro
  - Macro to iterate these design variables:
    - Quadrant elevation
    - Time Glide on
    - Canard application level to limit total AOA
- Maximum Range with Vertical Impact
  - Macro to iterate these design variables:
    - Quadrant elevation
    - Time Glide on
    - Time Dive on
    - Canard application level to limit total AOA

Example #2 Results

- About half of the configurations unstable
- 40% met the ballistic requirement
- 15% met the extended range
- 8% met all the requirements

- Iterated this analysis with three different air frames

Conclusions

- Thorough ballistic development is tough
  - Automation lessens the burden
  - Guided projectiles are even worse
- Match the tool to the job
  - Where are you in the development cycle?
  - Fast or Detailed?
  - Do you have to validate the sims?

- Tools are readily available

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