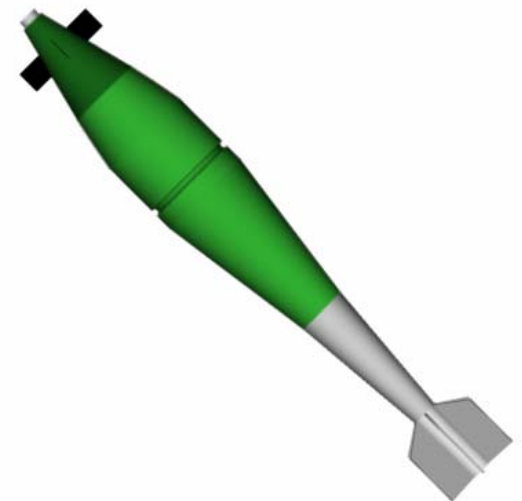


# Lean (and Agile) System Simulation of Guided Projectiles in the Early Development Stage

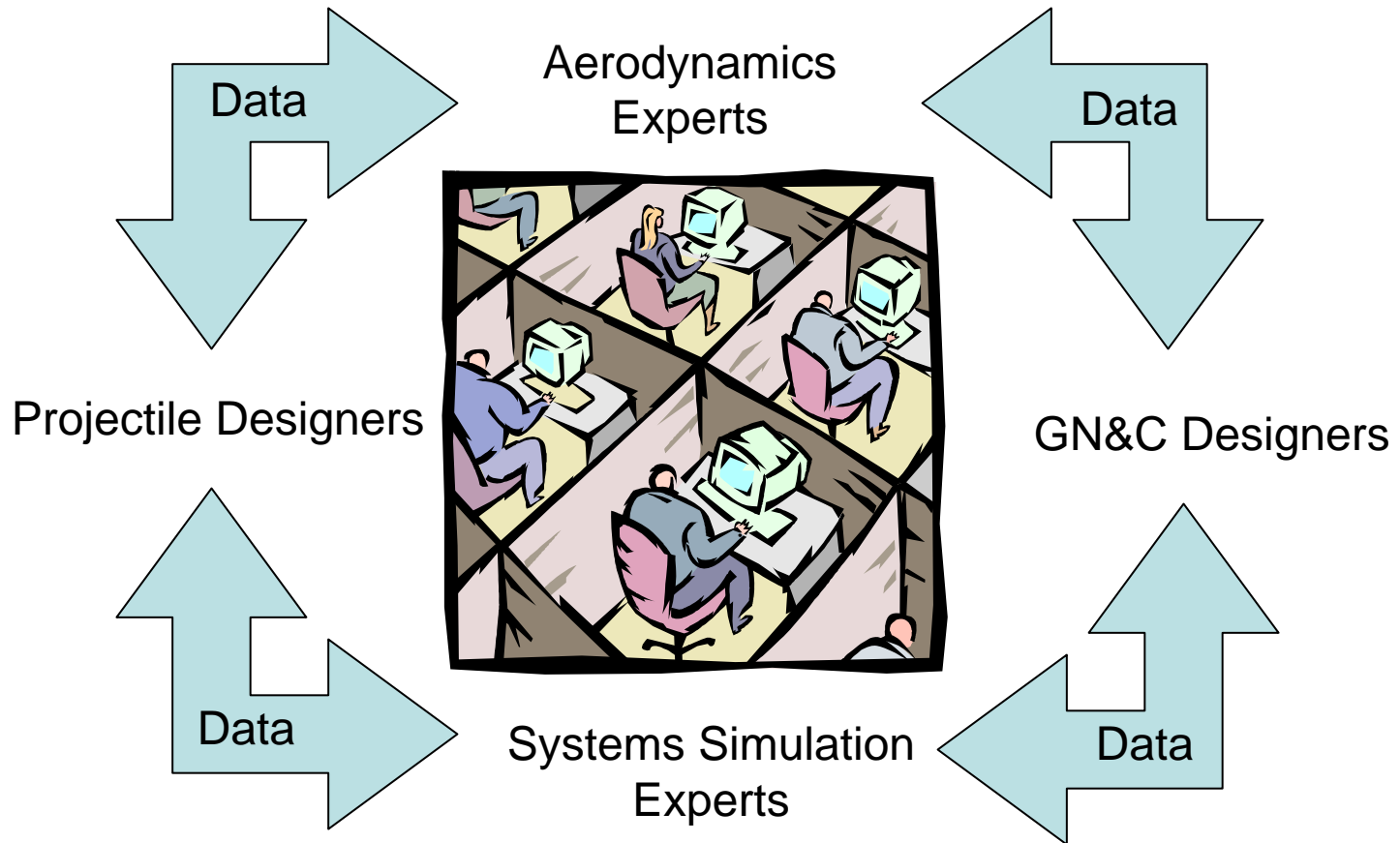


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# Typical Guided Projectile Development Team



# Lean (and Agile) Concept

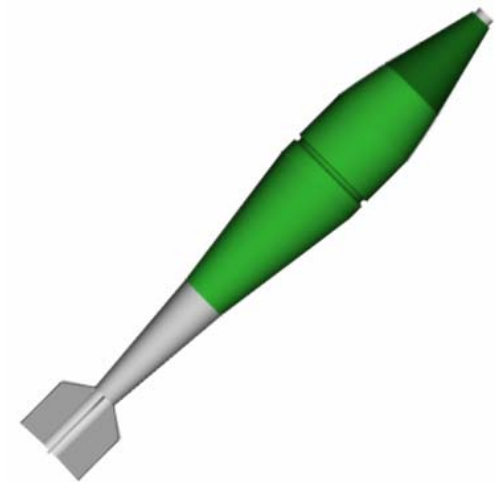
- ❑ Standardize on a validated toolset
- ❑ Eliminate waste and add value
- ❑ Streamline the process

# Characteristics of the Toolset

- ❑ Easy to use with common interface
- ❑ Seamless data flow between applications
- ❑ Industry standard algorithms to provide confidence in the results
- ❑ Easy to extract results for proposal support

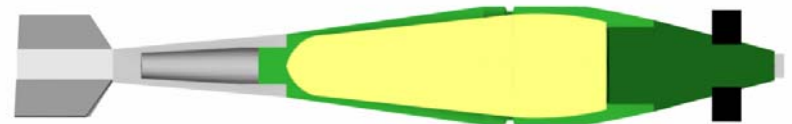
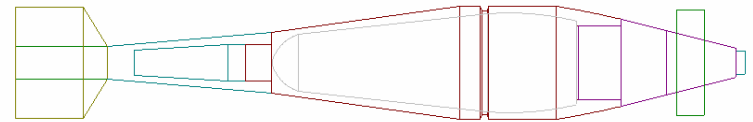
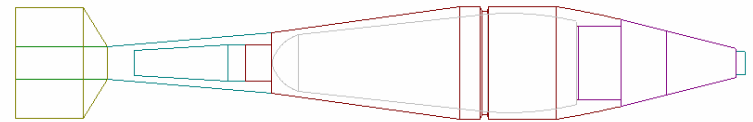
# Example Walk Through

- ❑ Design a retrofit fuze to guide 81mm Mortar
  - Trade off control mechanisms
  - Trade off sensor options
  
- ❑ Evaluation
  - Range extension
  - CEP



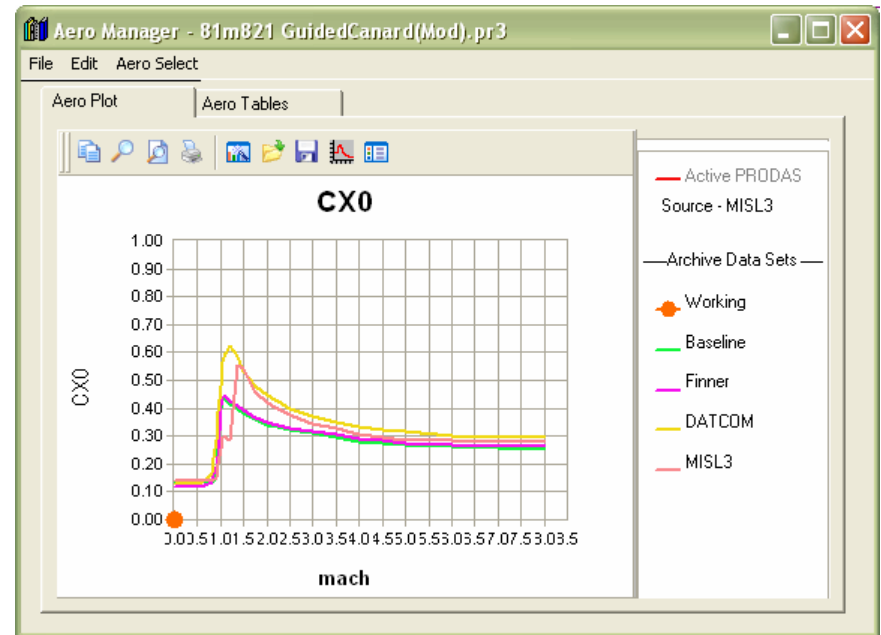
# Build the Model

- ❑ Multiple options
  - Build from scratch (1hr)
  - Modify existing (5 min)
  - Projectile Tracing Tool (15 min)
  - Import via DXF or IGES (30 min)



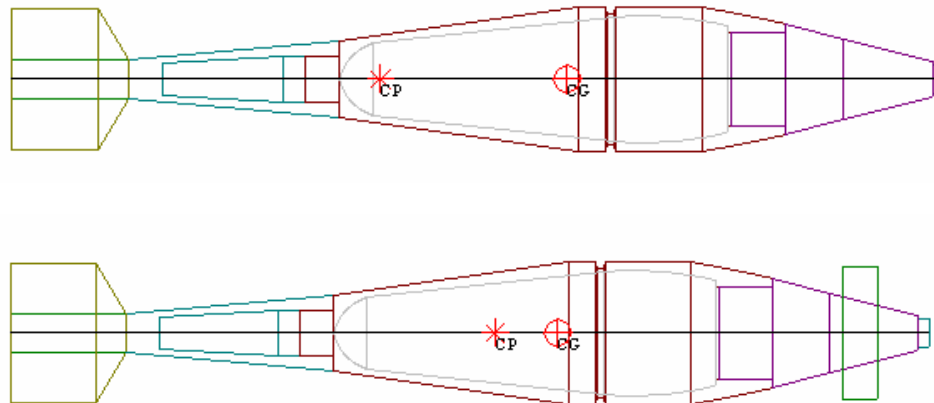
# Estimate Aerodynamics

- ❑ Multiple Estimators
  - Spinner by Arrow Tech
  - Finner based on DeJonge
  - Missile DATCOM
  - MISL3 by Near
  - AP98 by NSWC



# Evaluate Aero Stability

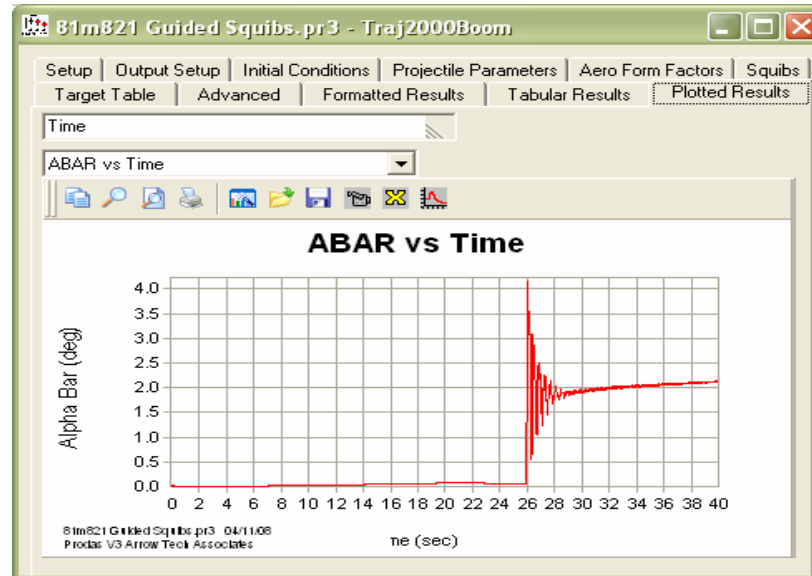
- Stability Evaluation
  - Baseline Static Margin 1.3 calibers
  - With canards 0.45 calibers





# Evaluate Control Authority

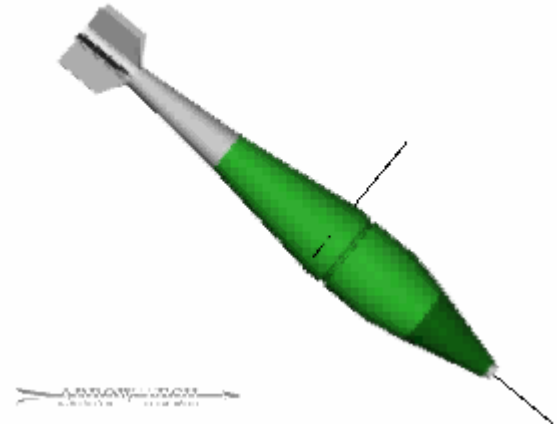
- ❑ Use CONTRAJ Module (Controlled Trajectory)
- ❑ Trade off Squibs versus Canards



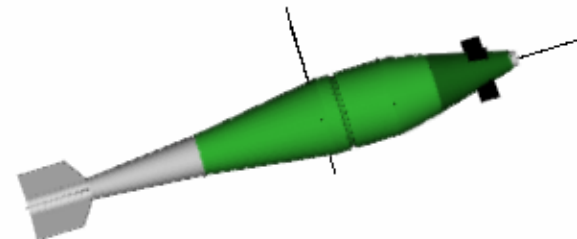
# Control Authority Results for this Example

- ❑ Squibs at this location
  - Lots of Motion
  - Small lateral movement
  
- ❑ Canards
  - 50% more range
  - Tremendous control authority

3D PRODAS2000 3D - 81m821 Guided Squibs.pr3



3D PRODAS2000 3D - 81m821 Guided Canard GPS.p



If you Can't Get a Bigger Target...

# Recap

- ❑ Made two models based on an existing model
- ❑ Predicted the aerodynamics with three prediction codes
- ❑ Assessed aero stability of the modified shapes
- ❑ Evaluated control authority of squibs and canards
- ❑ Down selected the canard design

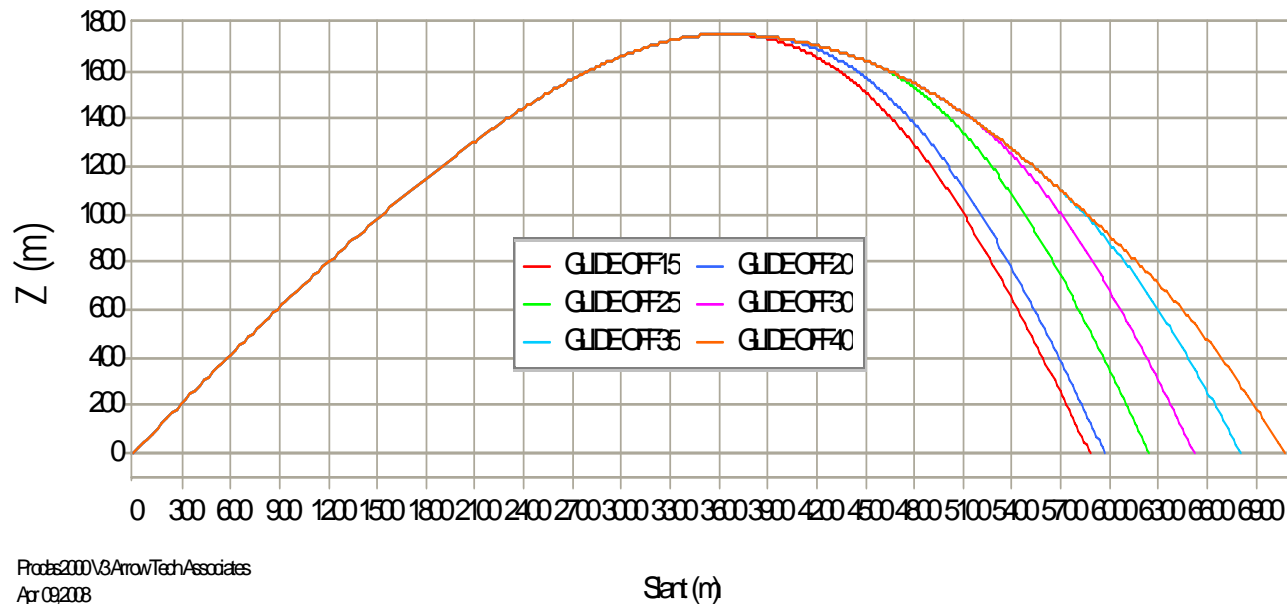
***Total time invested up to this point ~ 2 hours***



If you Can't Get a Bigger Target...

# Next Step - Simulation

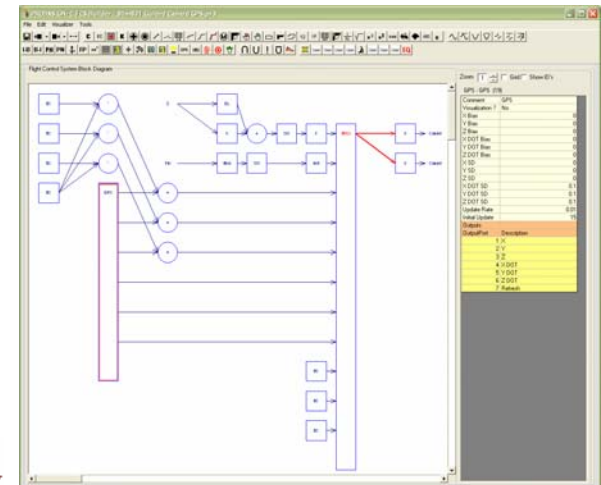
- ❑ Trajectory Codes
- ❑ System Effectiveness Simulation



If you Can't Get a Bigger Target...

# The GN&C Prototype Module

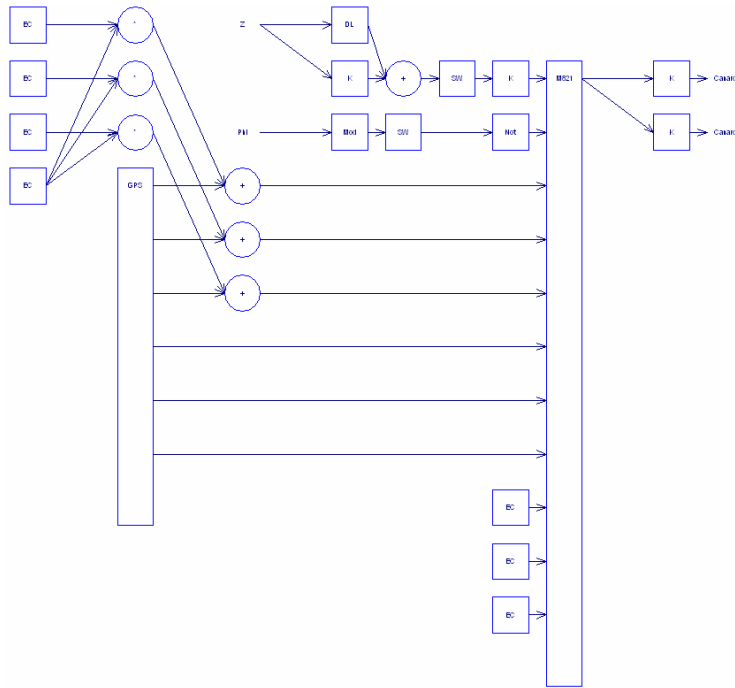
- ❑ Fully integrated 6DOF/GN&C Simulation
- ❑ Control with canards, squibs or generic forces
- ❑ Short learning curve w/ drag/drop FCS editor
- ❑ Control system can be coded in C or FORTRAN and linked at run time



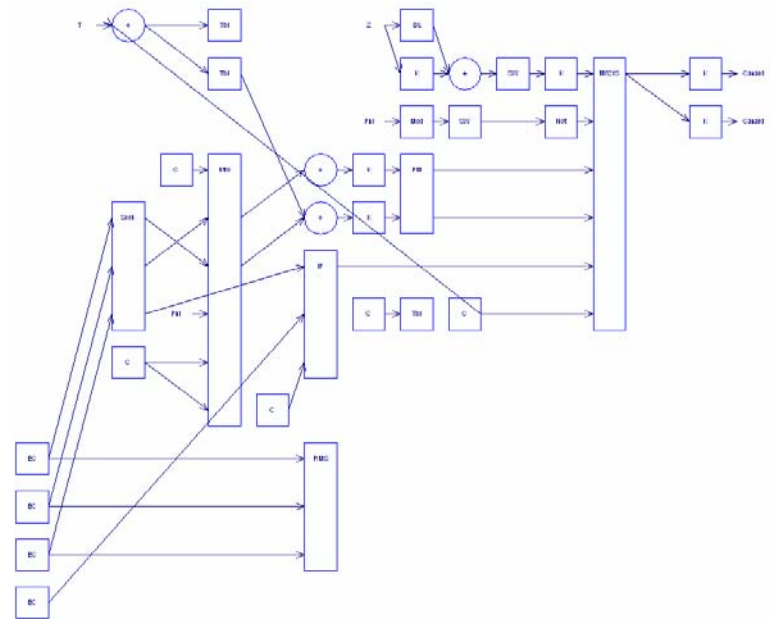
# Why use the GN&C Prototype Tool

- ❑ Validated 6DOF that runs in real time or faster
- ❑ Intimately linked to the other tools
- ❑ Pre-built library of common projectile sensors and control surfaces
- ❑ Visualization modules can quickly produce reasonable marketing or training visuals

# Example Systems



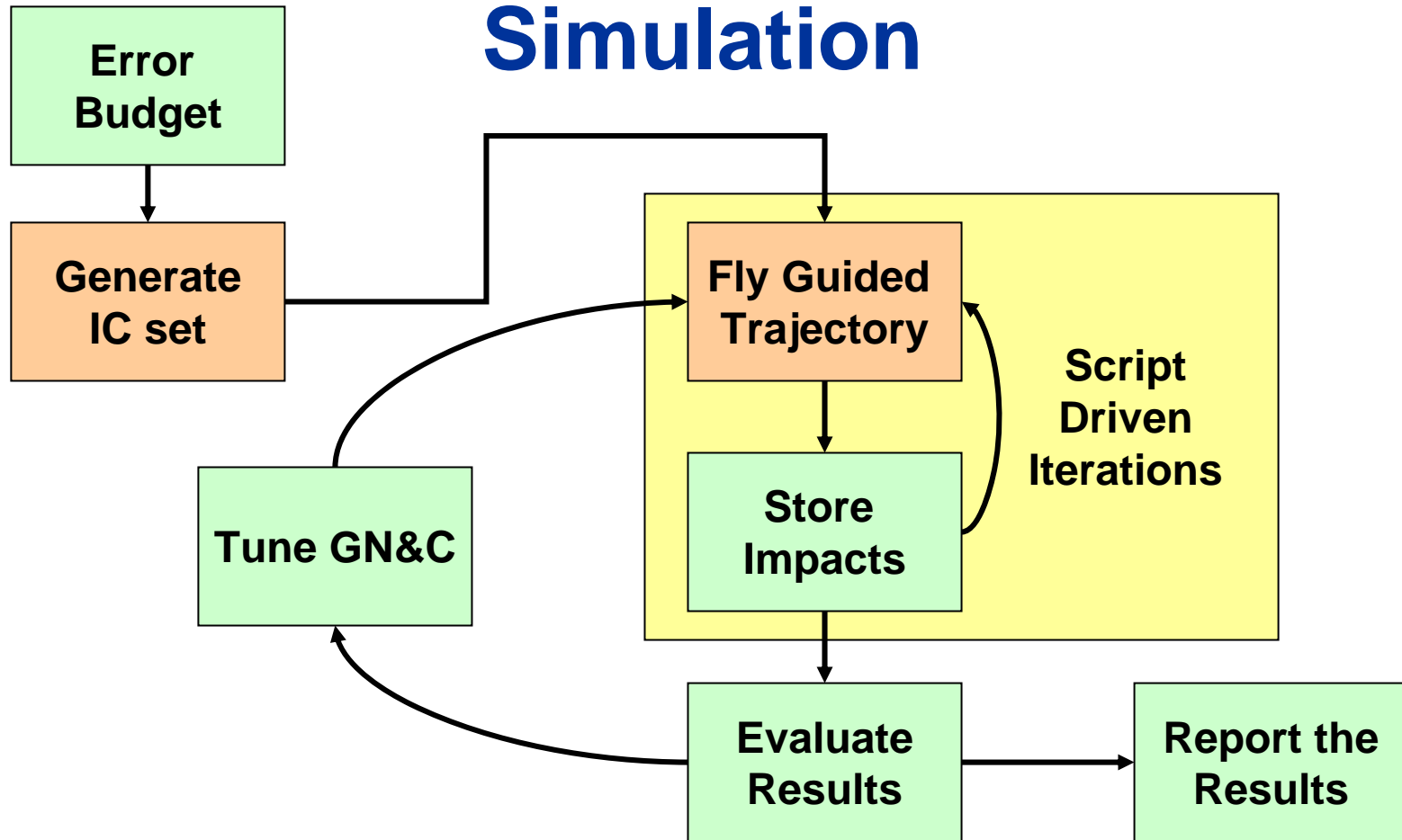
GPS guided



Seeker guided



# Guided System Effectiveness Simulation

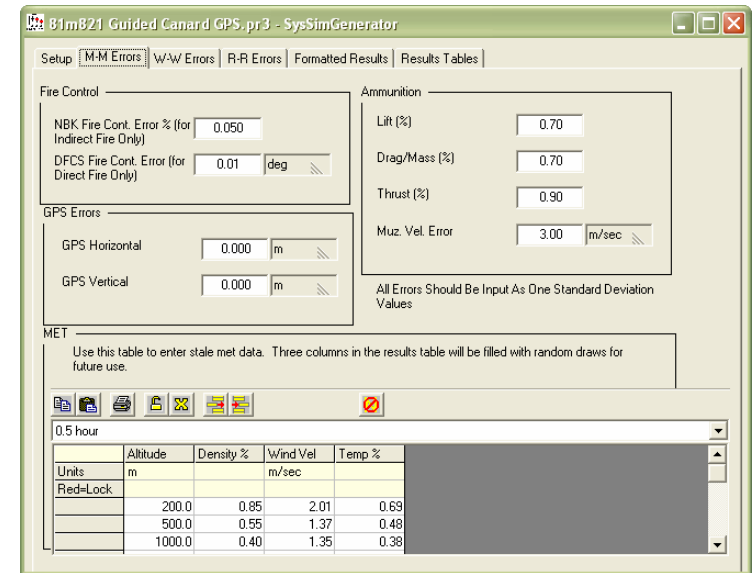


If you Can't Get a Bigger Target...



# Initial Conditions Generator Module

- ❑ Generate error deltas from the error budget
- ❑ Delta plus nominal provide IC's for all of the subsequent runs
- ❑ Reality checked with ballistic projectile



# Build an Automation Script

- ❑ Macro script language
  - Based on Visual Basic (EXCEL)
  - Projectile extensions added
- ❑ Build Options
  - Hand Code
  - Use Analysis Bot module
- ❑ Output text results file or cross plots



# Recap

- ❑ Built Models & Estimated Aeros 2 hours
- ❑ Designed GN&C
  - GPS (modified existing) 2 hours
  - Seeker (new) 8 hours
- ❑ Developed Error budget and IC set 2 hours
- ❑ Modified existing scripts 1 hour
- ❑ Ran Systems simulations 1 hour

***Total time invested up to this point ~ 16 hours***

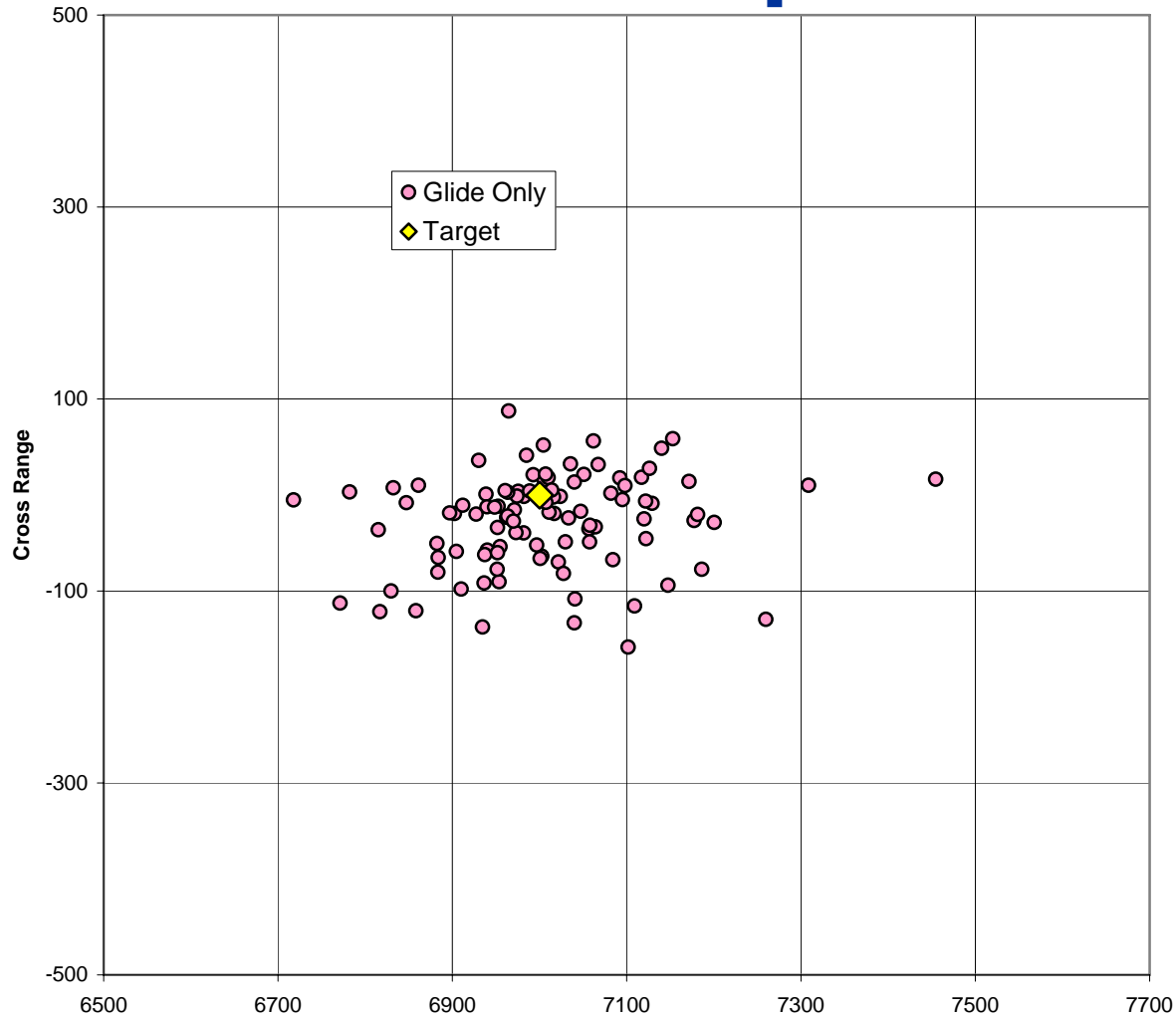


# Conclusions

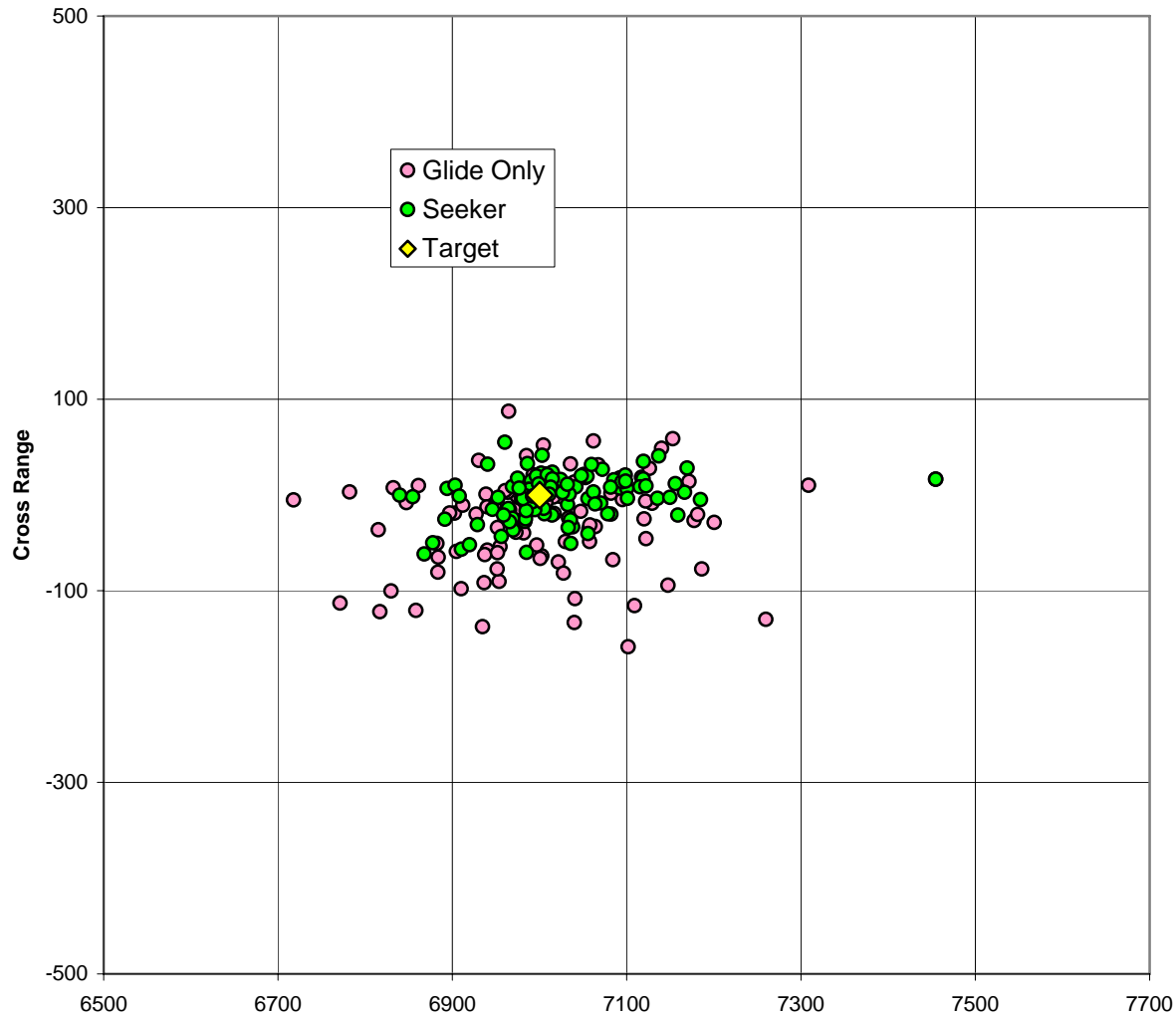
- ❑ It is possible to streamline the early stage development of a guided projectile
- ❑ Tools need to be integrated and inclusive
- ❑ System effectiveness comparisons of configuration changes as well as guided projectile performance can be evaluated in a timely manner, using readily available tools.
- ❑ Design the projectiles – NOT THE TOOLS



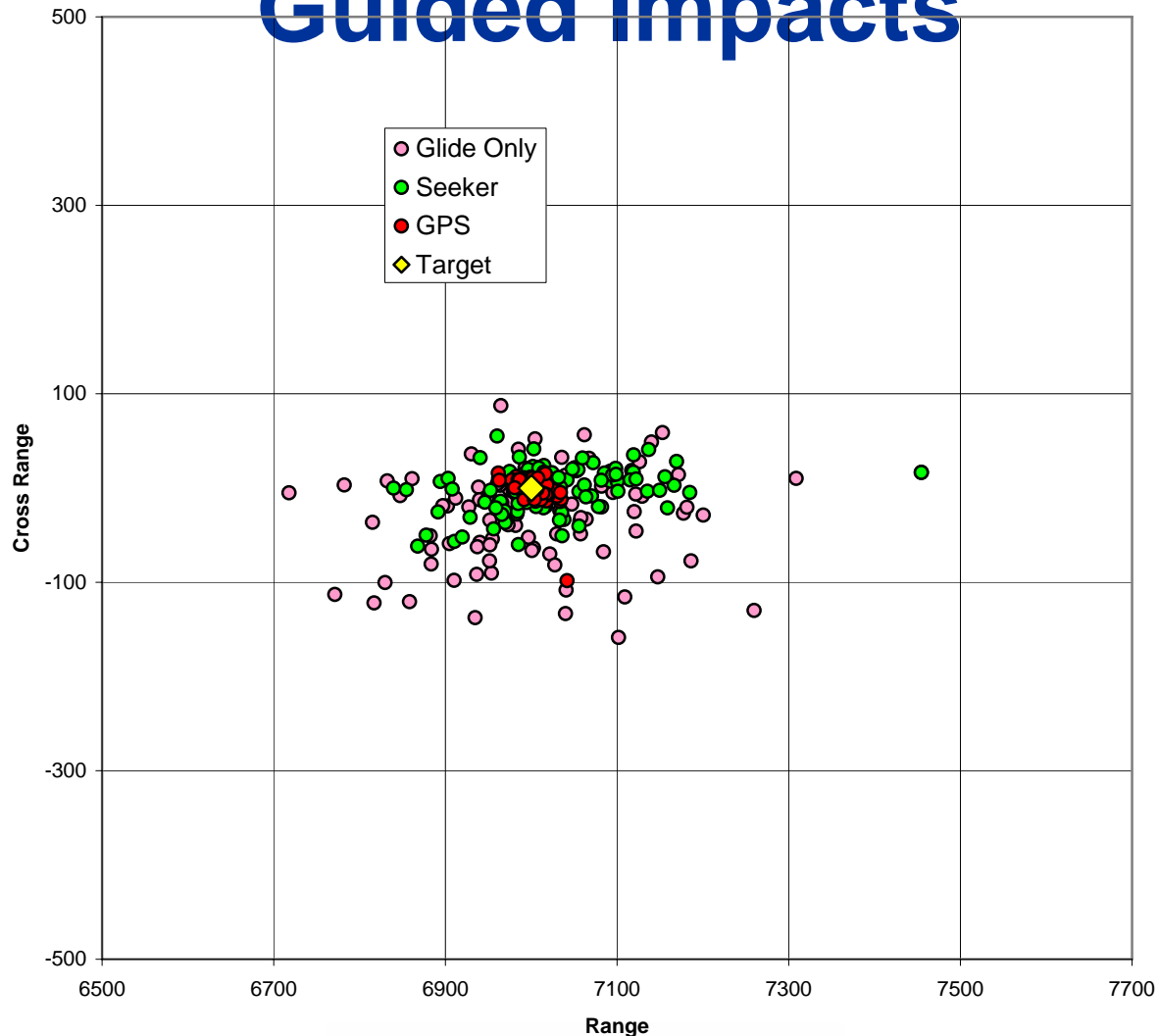
# Ballistic Impacts



# Ballistic and Seeker Guided Impacts

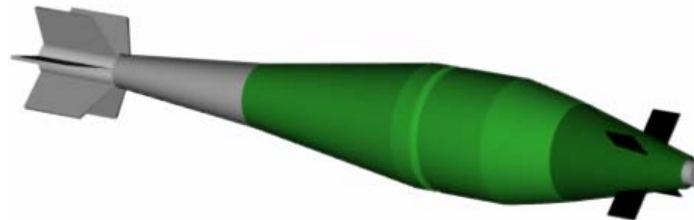


# Ballistic, Seeker and GPS Guided Impacts



# Results from our Example

	Range km	CEP m
Ballistic	5.1	96
Ballistic with Glide	7	106
Seeker Guided	7	68
GPS Guided	7	16



**ARROW TECH** →



# Questions ?

