Gun Launch Dynamics

Benchmarking the State of the Art

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Background

"Why should I believe anything coming out of Sim?" – Paraphrase of many comments from Prominent Customers

Gun Launch Dynamics is Critical to Design of Projectile Systems

- Only way to get significant insight into what is happening inside gun

But…

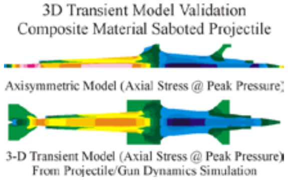
The Enemy is the Imperfect Physics

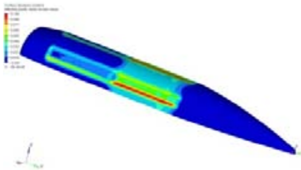
- Uncertainty of material behavior & dynamic loading
- Ability of modeling tools

Not All Models Are Created Equal

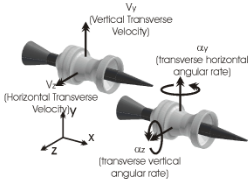
Enablers

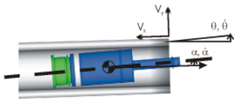
Modern Computing Capabilities

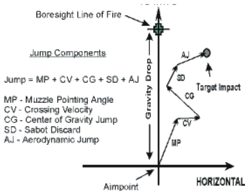




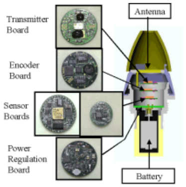
Deep Understanding into the Physics



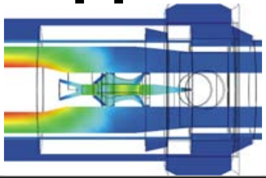


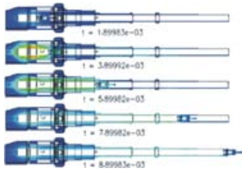


Advances in High Fidelity Experiments



Need Insight to What is Happening Inside a Gun



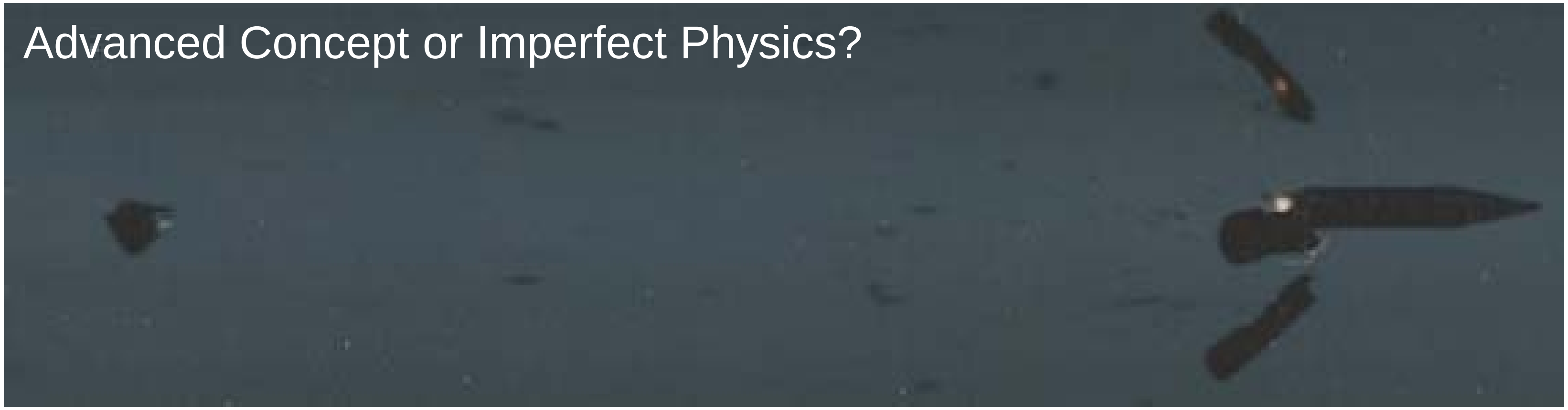


Significant Advances in Journey to Complete Understanding

Imperfect Physics

Example – XM1002 Tail Cone Separation

- Detailed Analysis Prior to Launch
- Assumption: Used idealistic propellant loading
- Imperfect Understanding: Double Chamber Phenomena Existed



Incomplete Understanding

What do I need to know about projectile Launch?

1. Does the projectile survive?
2. Are the mechanical and electrical systems operational?
3. What are the projectile states at exit (performance)?
4. What are the gross motion and stress state of the gun?

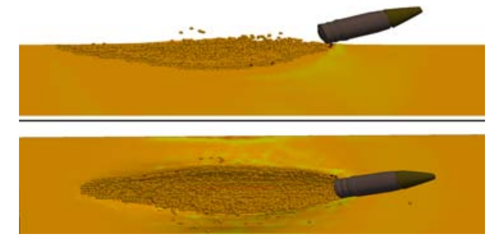

Where do you go for Complete Understanding?

The Boss?

Complete Understanding Results in Reduced Development Time and Reduced Risk

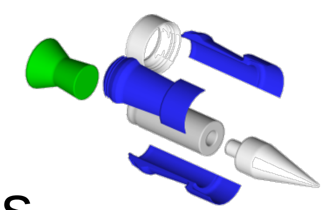
How are Simulations Done?

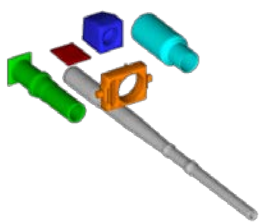
Tools:



- Lagrangian Hydrocodes
  - Same technology used in car crash simulation
- Short Duration Explicit Codes
- Commercial & Gov’t Codes Available
  - (ANSYS, ABAQUS, Presto, Pronto, …)

Process:





- Models are built very similar to real systems
- Simulation & Experimentation treated similarly (plan & execute)

Projectile Gun Launch Dynamics is in Developmental Mainstream

Limitations

Model Descriptions:

- Material Properties – Constituative Relationships
- Model Simplifications

Understanding of Environment:

- Environmental Effects – Temperature, Moisture, …
- Loading Conditions – Set-back, Balloting, Spin, Set-Forwad
- Boundary Conditions/Initial Conditions
- Data Obtained in Incorrect/Incomplete Conditions

Assumptions Driven by Incomplete Understanding

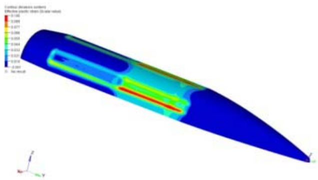
Validation

Direct Measurement:

- Instrumented Projectile
- Post Test Evaluation – Damage vs. Prediction
- Laboratory Testing – (i.e., Air Gun, SCaT Gun)

Inferred Data:

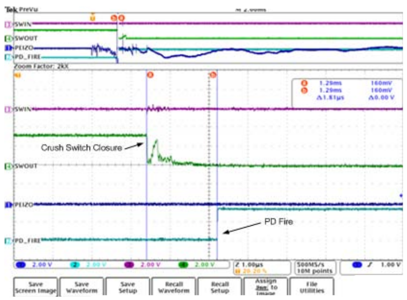
- Qualitative Cause & Effect Comparison
- Multiple Models with Same Prediction



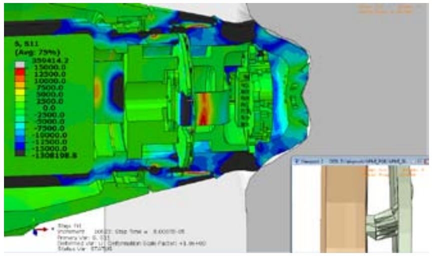
Confidence Only Comes from Validation

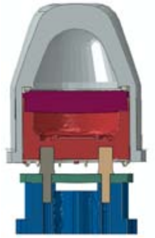
Analysis Framework – PGK Example

Define the Problem:
- Nose Crush Timing – Integral to Performance

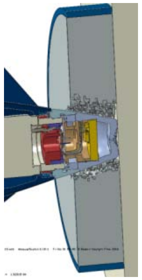


Utilize Multiple Independent Analyses:
- ARDEC & ATK Analysis





Validate the Model:
- Air Gun Tests Conducted to Validate Model



Subject Matter Expert Review:
- PGK SME Peer Review
  - ARDEC, PM-CAS, ATK, ARL

Disciplined Process Ensured Design Margin

Measure of Good

Timeliness of Answer

- Cost & Schedule Limitations Drive Answers

Multiple Independent Sources

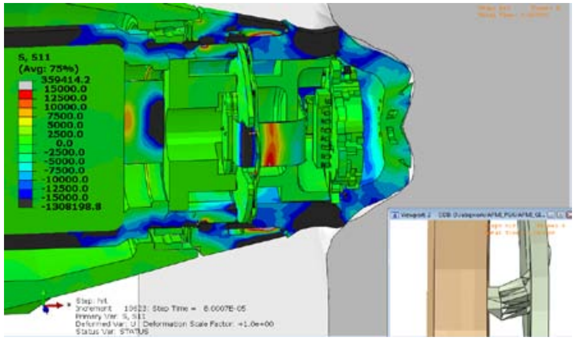
- Uncertainty Reduced through Redundant Models

Model Validation

- No Confidence without Validation

Review of Subject Matter Experts

- Experience is a Key Success prediction



Not for the Faint of Heart, but it can be done right!

Projectile Design Requires a Host of Simulation Capabilities

- Projectile Gun Launch Dynamics Modeling is the Cornerstone
- “The days of Half-A– guessing are gone”

But …


Good


Bad


Ugly

Must follow Disciplined Engineering Process as with any other aspect of development

It Isn’t Hard to Tell the Difference Between Good and Bad

Acknowledgments

Modeling & Simulation Community

Too many to mention but all distinguished

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