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Mine Countermeasure Dart Dispense Modeling & Simulation

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Outline

- Description of Mine Countermeasure Darts
- Background of Dart Dispense Working Group
- Simulation Matrix
- Model Results
- Discussion

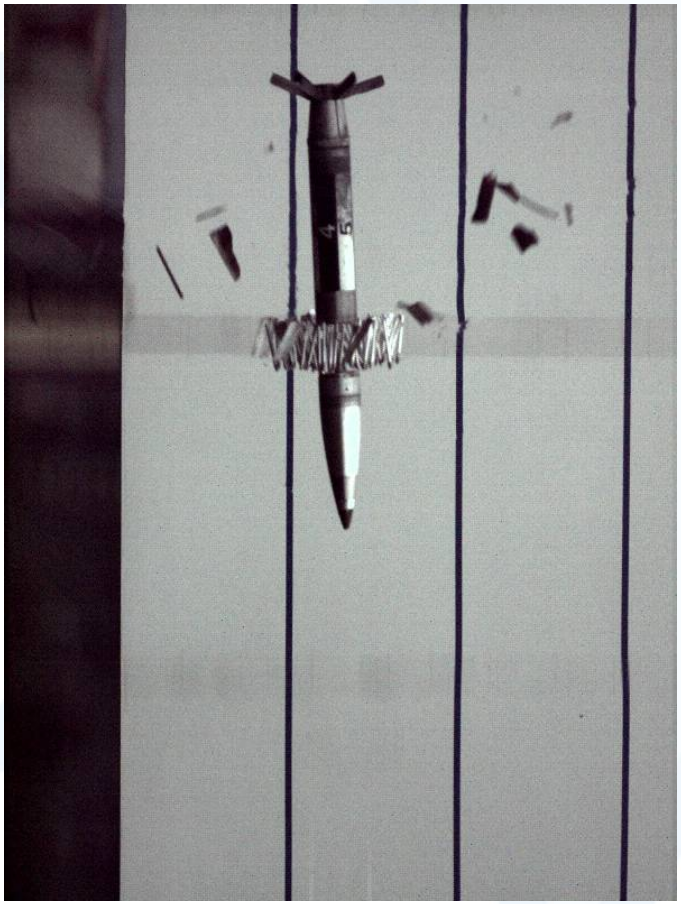
Navy Mine Countermeasure Programs

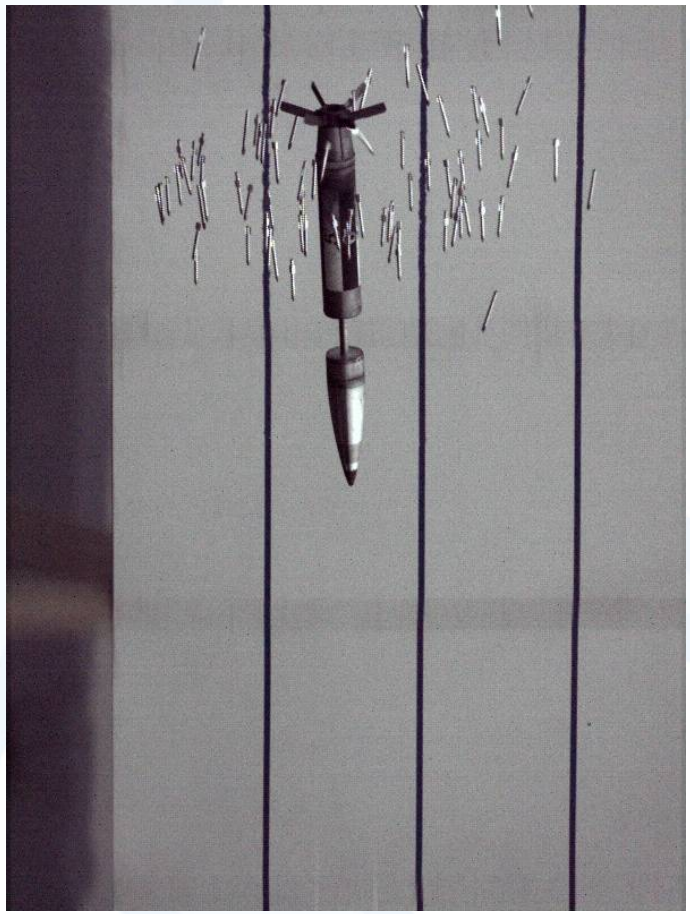
- Indian Head supports 3 Mine Countermeasure Programs w/ Dart Dispense:
  - **MODS**
  - **Hydra 7**
  - **Gun Launched CMCO Round**

Venom Penetrator Dart

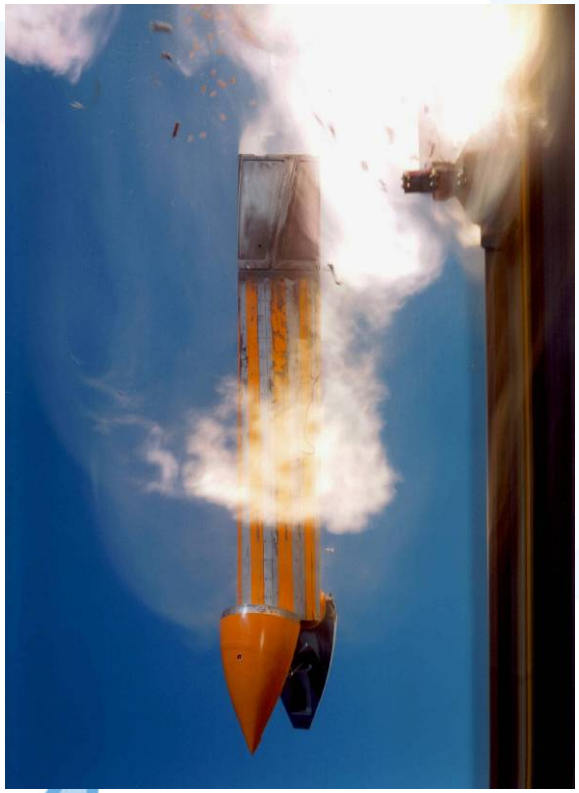
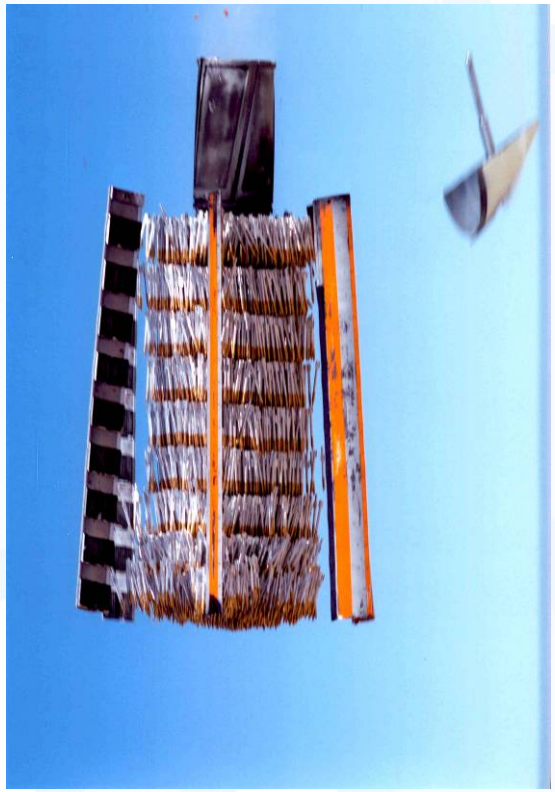
Revolutionary Research . . . Relevant Results

- Naval Gun Fire System CounterMine CounterObstacle Dispense





- MODS Dispense of 6000+ darts


Background

- History of Dart Dispense M&S Working Group
  - **Initial Dispensing Technology Workshop, coordinated by Mr. Brian Almquist, Office of Naval Research, held in February 2002**
  - **Working Group formed – kickoff meeting in June 2002**
  - **Team Members:**
    - ONR
    - NSWC/Indian Head
    - NSWC/Panama City
    - Army Aeroflightdynamics Directorate, Ames Research Center
    - NASA/Langley
    - NEAR, Inc.
    - Digital Fusion
  - **DoD High Performance Computer Project "Modeling of Mine Countermeasure Dart Dispense" initiated FY2003**
  - **Challenge Project Status awarded during 2007 & 2008 (1,000,000+ CPU hours per year)**

Objectives of Working Group

- Enhance state-of-the-art techniques for predicting dart aerodynamics during dispense
- Transition techniques to 6-DOF models to predict multiple dart trajectories and impact patterns
- Enhance 6-DOF tools used in Analysis of Alternatives

The Challenge !!

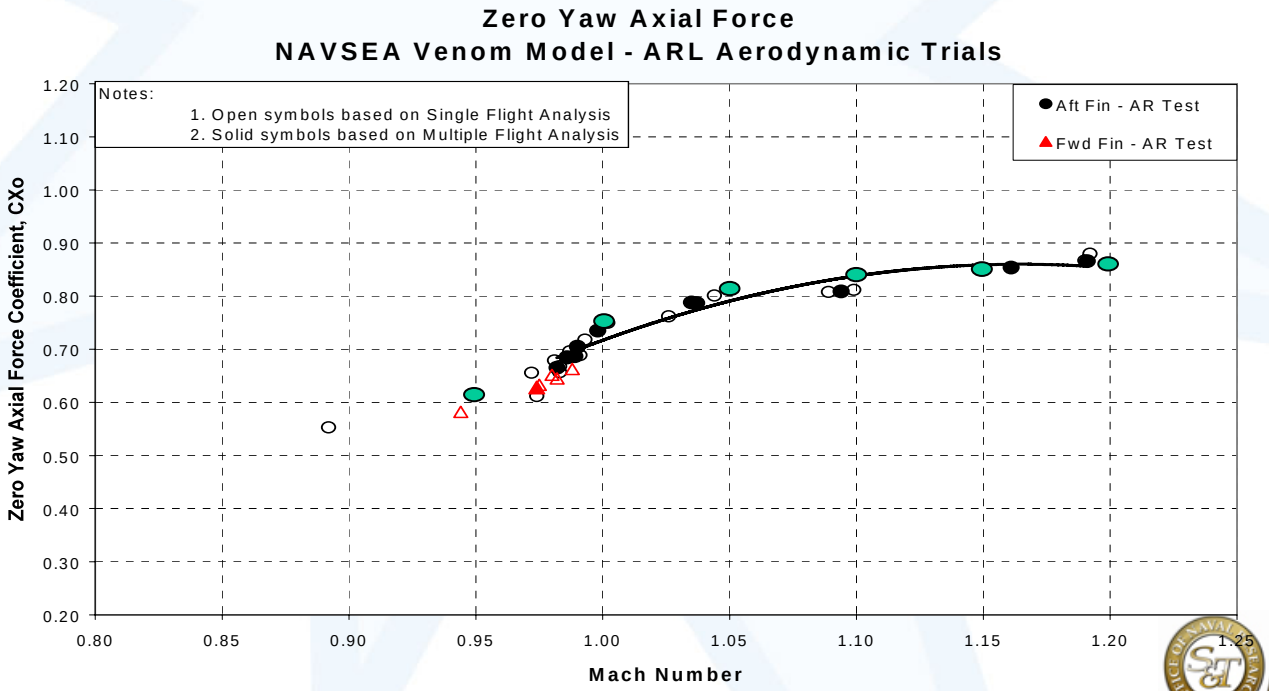
- Accurately model the dispense of multiple darts, approaching a full MODS payload: Multiple-Body Six Degrees-of Freedom (6-DOF) Computational Fluid Dynamics (CFD) with Collisions

- Determine how many darts need to be modeled to capture the overall dispense dynamics

- Given enough memory and computing power, can we model the dispense of all 4000+ darts?

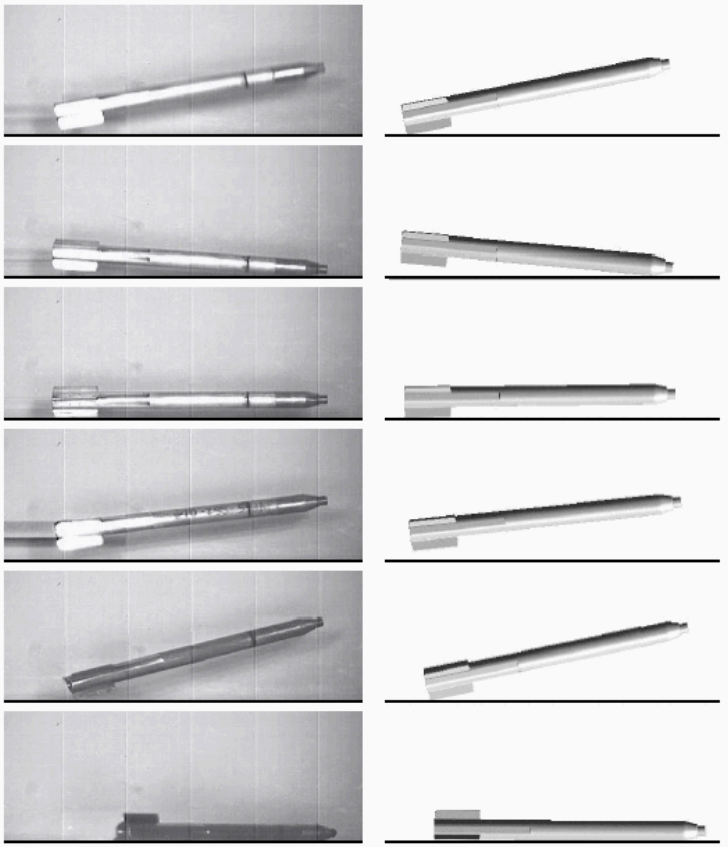
Preliminary CFD Simulations

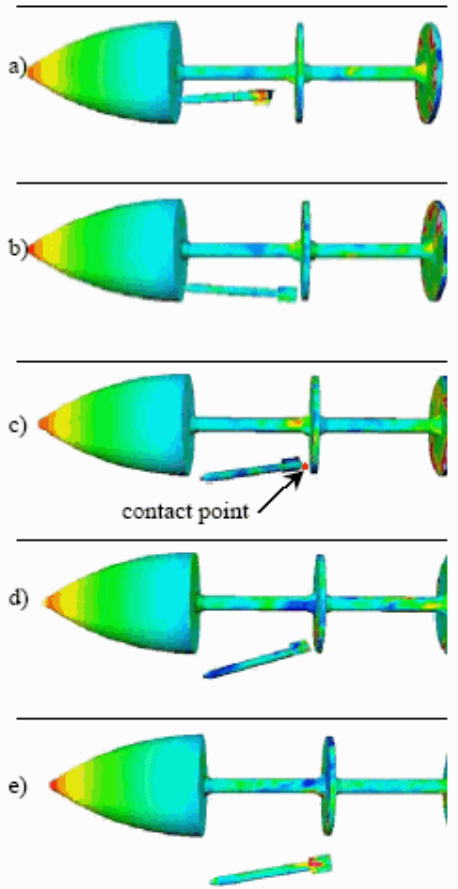
- Evaluated several CFD codes
- Compared results of single dart simulations to Aeroballistic Test Range data (from Aberdeen and Eglin AFB)
- OVERFLOW selected as primary CFD code



Code Modifications

- Collision Module added to OVERFLOW
  - **Provides for dart-to-dart and dart-to-dispenser collisions**
  - **Validated against single dart drop tests**





Simulation Matrix

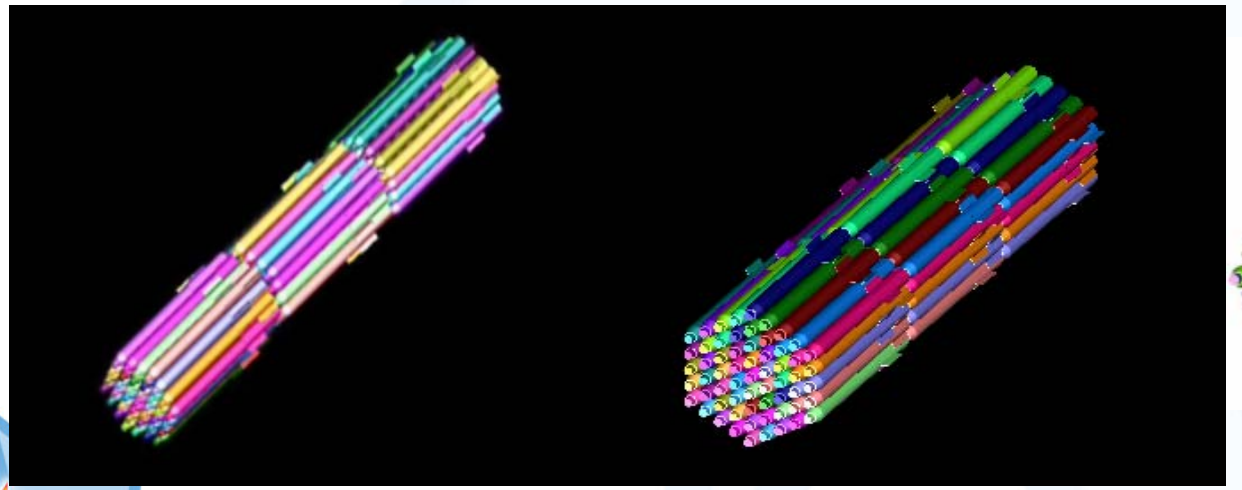
1. 273 darts (3 axial layers x 5 radial rows), 6 Hz spin rate, Mach 1.2
2. 273 darts (3 axial layers x 5 radial rows), 12 Hz spin rate, Mach 1.2
3. 273 darts (3 axial layers x 5 radial rows), 18 Hz spin rate, Mach 1.2

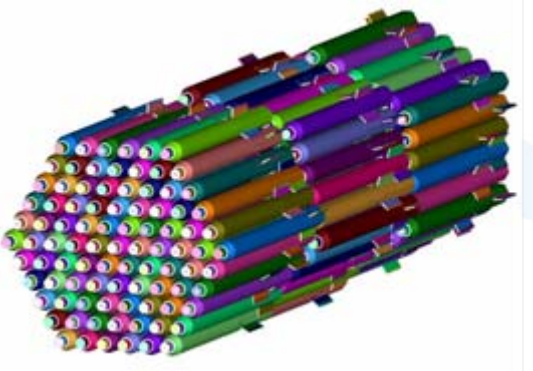
4. 111 darts (3 axial layers x 3 radial rows), 12 Hz spin rate, Mach 1.2
5. 183 darts (3 axial layers x 4 radial rows), 12 Hz spin rate, Mach 1.2
6. 381 darts (3 axial layers x 6 radial rows), 12 Hz spin rate, Mach 1.2

7. 273 darts (3 axial layers x 5 radial rows), 12 Hz spin rate, Mach 1.6
8. 273 darts (3 axial layers x 5 radial rows), 12 Hz spin rate, Mach 2.0

“Number of Darts” Study

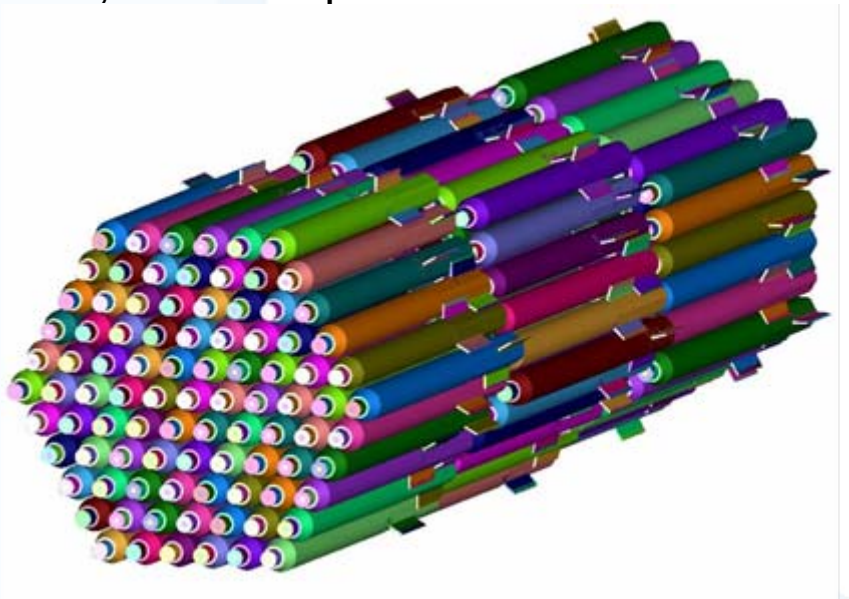
- Compare Matrix runs #2, #4, #5, & #6 to determine differences in dispense behavior resulting from 111, 183, 273, & 381 dart packs
- Matrix run #6 (381 darts) has not been completed
- All runs performed at same Mach number (1.2) and Spin Rate (12 Hz)





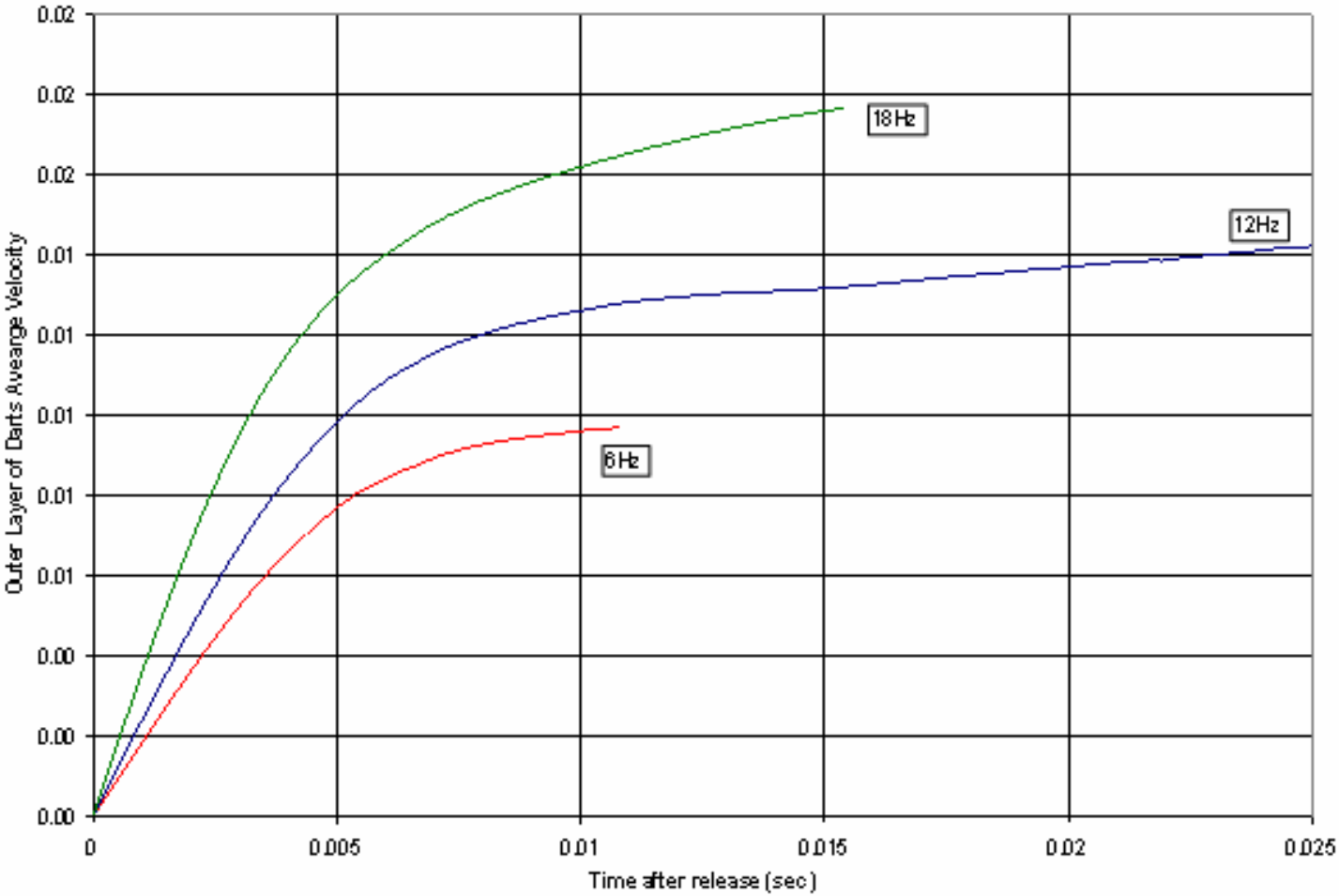
“Spin Rate Effects” Study

- 5 Radial Layers, 91 Darts Per Row, 3 Rows = 273 Darts
- Full 6-DOF Simulation with Collisions, Various spin rates
- ~400 Million Grid Points
- Viscous grid spacing
- Initial Spacing Factor = 1.2
- Physical Run time
    - 6 Hz = ~0.01 seconds
    - 12 Hz = ~0.025 seconds
    - 18 Hz = ~0.015 seconds

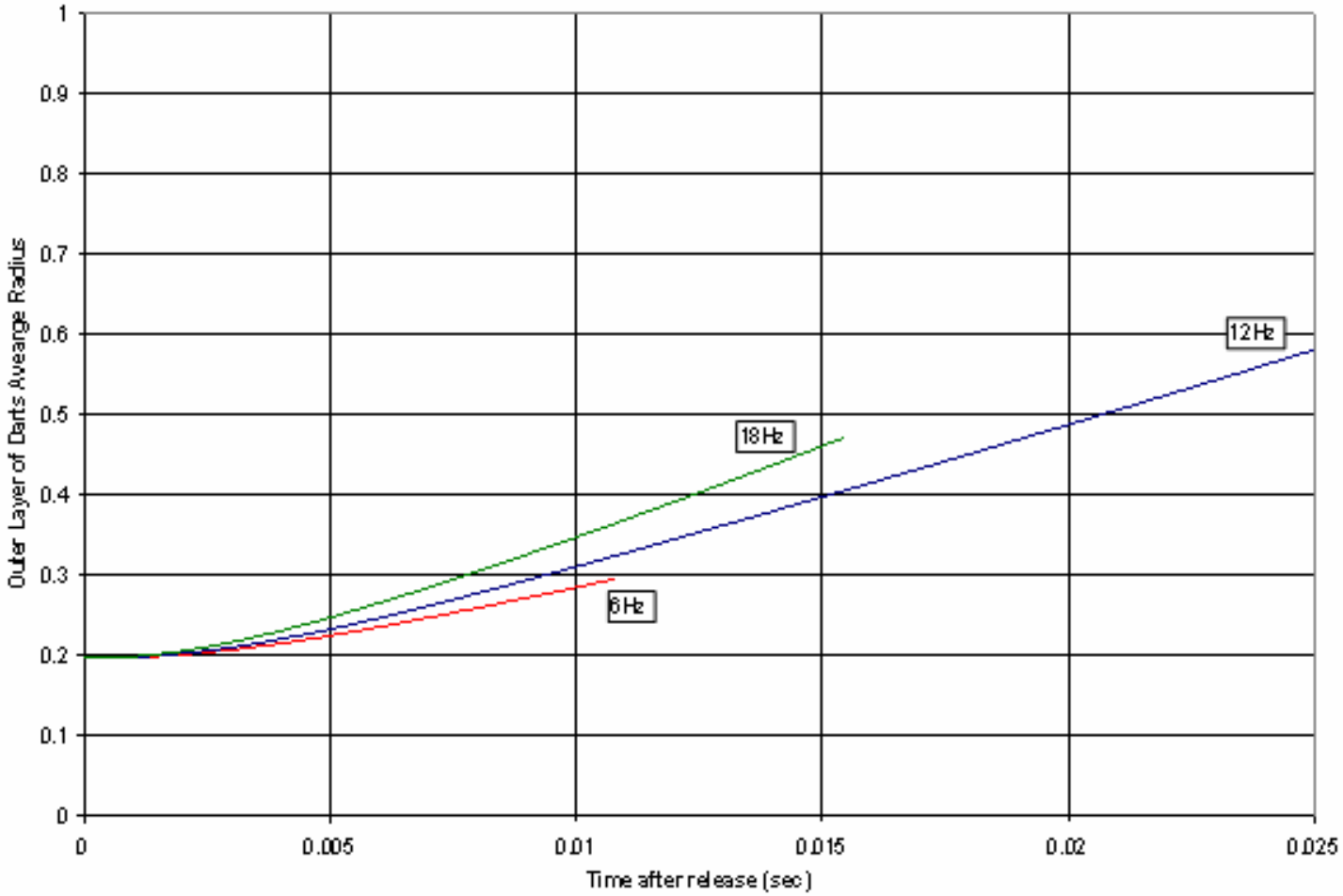


- Errors out due to bugs in OVERFLOW-2 grid adaptation feature (bugs fixed in later versions) and memory limitations

273 Darts – Average Normalized Velocity Comparison



273 Darts – Average Radius Comparison



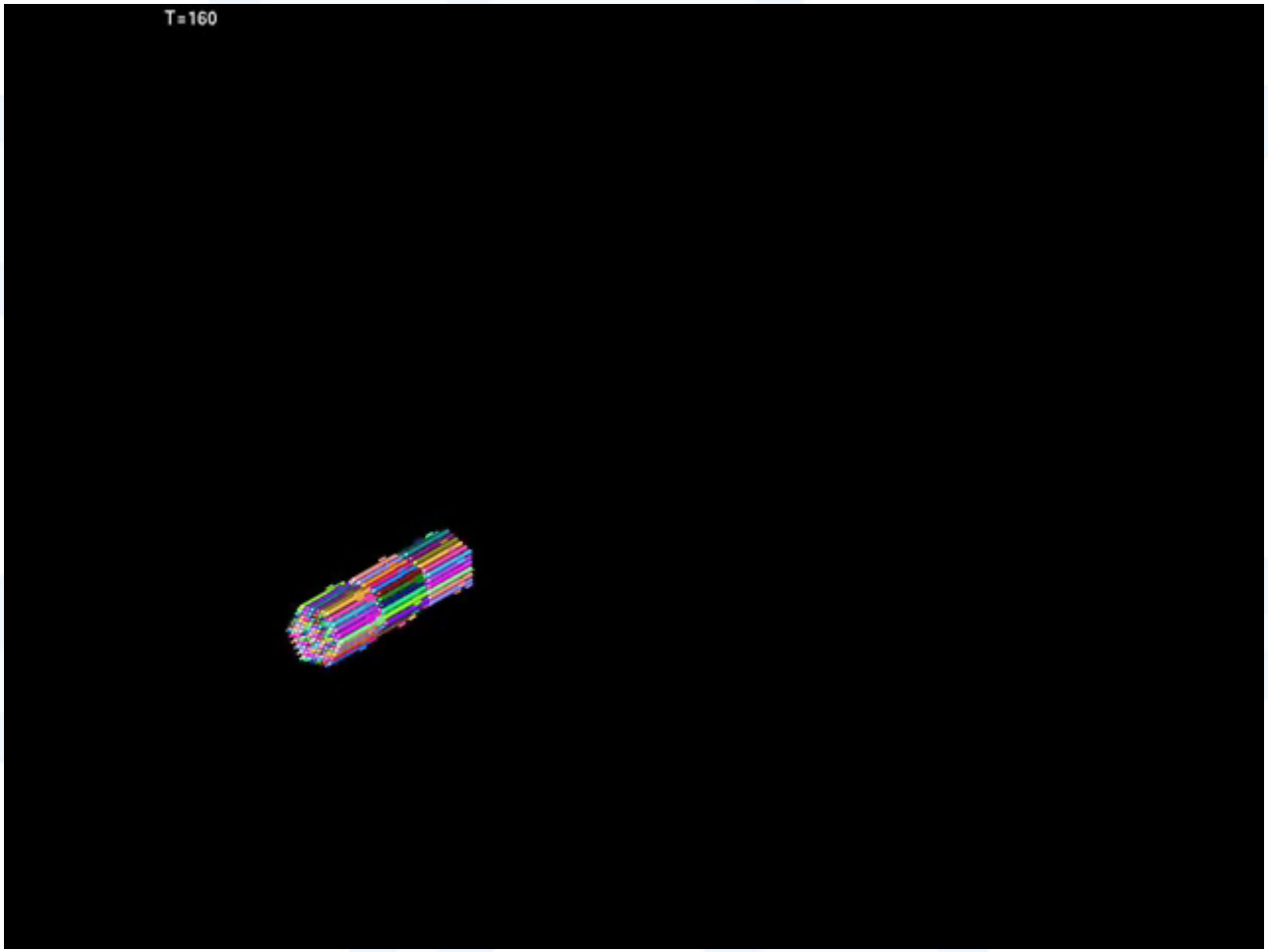
Revolutionary Research . . . Relevant Results

273 Darts (Longer Run Times)

- 5 Radial Layers, 91 Darts Per Row, 3 Rows = 273 Darts
- Full 6-DOF Simulation with Collisions, 12 Hz spin rate
- ~300 Million Grid Points
- Wall Function Grid, y+ = ~50
- Initial Spacing Factor = 1.1 (previous simulations at 1.2)
- Run time ~0.1 seconds after release
- 600-840 processors
- Errors out due to one dart hitting outer boundary

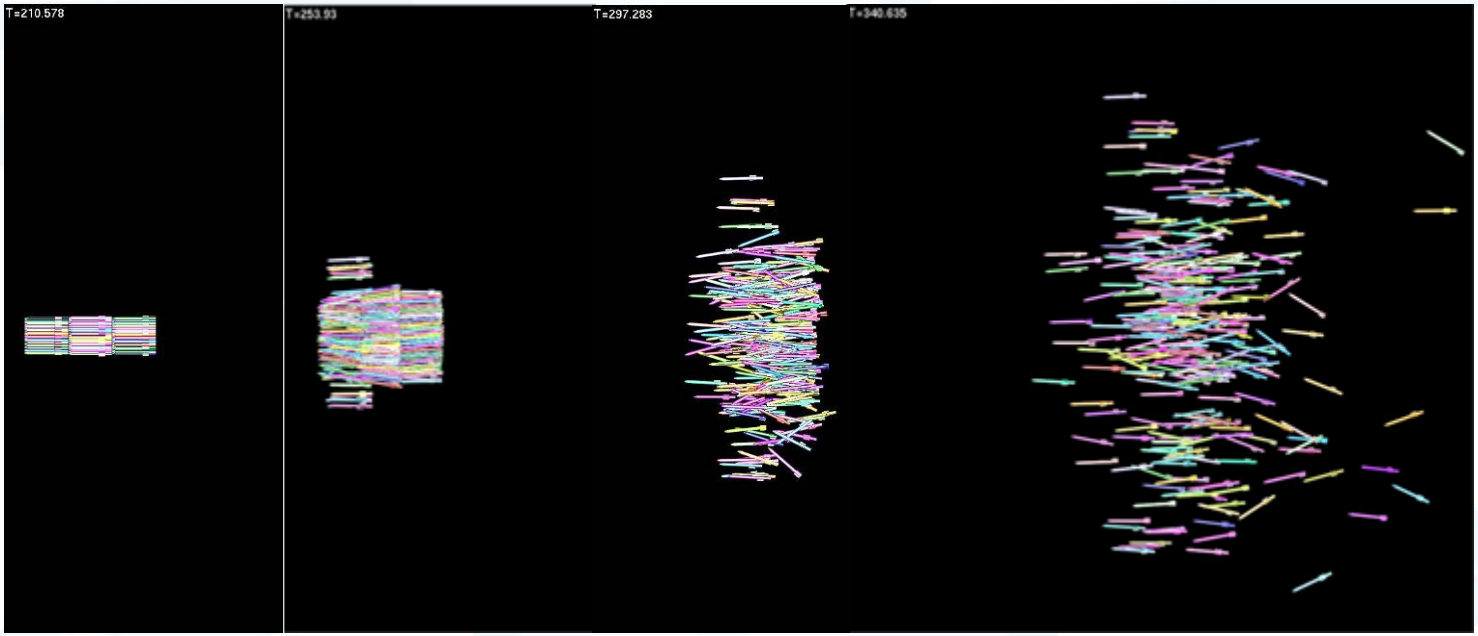
273 Darts (Longer Run Time)

Run to ~0.1 sec after release (MOVIE)
Iso View



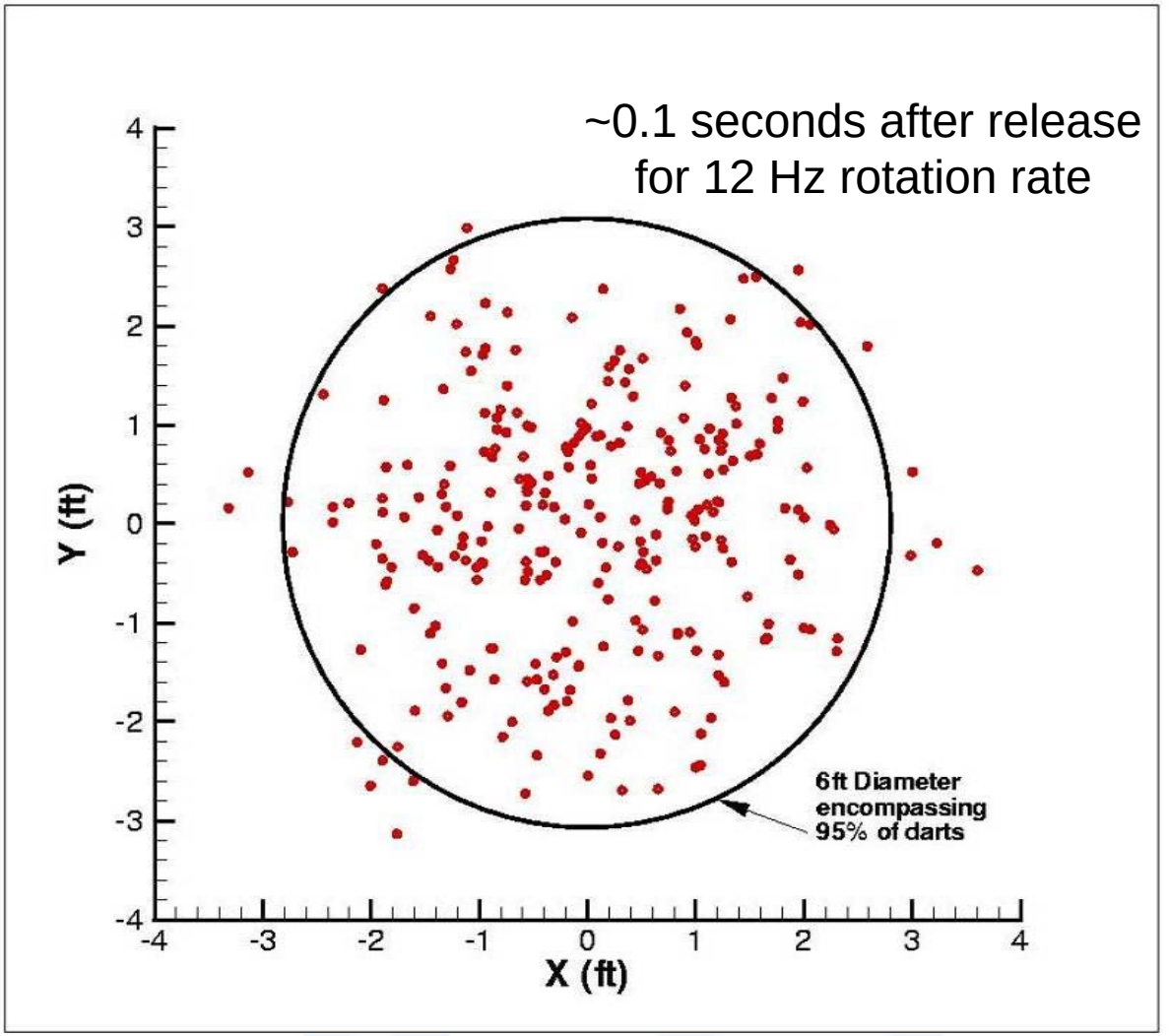
273 Darts (Longer Run Time)

Dispense sequence at Mach 1.2 with 12 Hz rotation rate



T=0s T~0.03s T~0.06s T~0.1s

273 Darts – Spread (12 Hz)



Modeling Lessons Learned

- Wall Functions reduce point count, ease memory requirements
- File size is still a significant problem – storage and transfer
- Memory is limitation, not CPU time
- Increase processor count to get required memory
- Most CPU time spent in initialization and spin
- Graphics/post-processing is a concern

Results/Conclusions

- "Number of Darts" Study
  - **Collisions may play big role in determining pattern size**
  - **Drafting effects are reduced after 3 axial layers**
  - **Additional axial rows of darts may fill in the "gaps" left by the first couple of rows**
  - **Darts are almost independent of each other after 0.1 sec for 273 dart case (small clusters)**
  - **Hexagonal pattern preserved, additional darts on the sides may produce more circular pattern**
- "Spin Rate Effects" Study
  - **Average Radial Dart velocities proportional to spin rates**
  - **Higher spin rates may produce "cleaner" patterns**

Future Plans

- Additional simulations of larger dart packs are progressing (2009 Challenge Project)
- Plan to run Mach 1.6 and Mach 2.0 for 273 darts (Mach number effects study)

NAVSEA
WARFARE CENTERS

HPC Modernization Program
SOLVING THE HARD PROBLEMS

QUESTIONS?

IHDIV
ENERGETIC SYSTEMS

ONR
Revolutionary Research . . . Relevant Results