Hypervelocity Nuclear Interceptor System for Optimal Fragmentation and Dispersion of Near-Earth Objects

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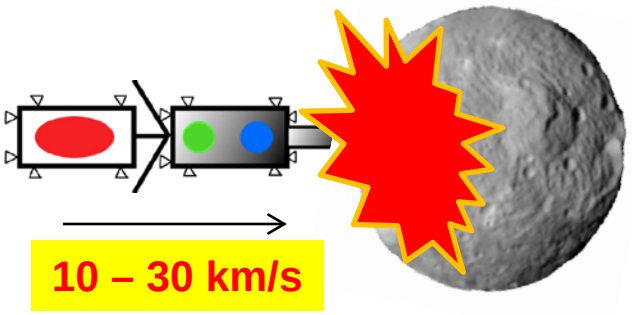
Asteroid Deflection Research Center

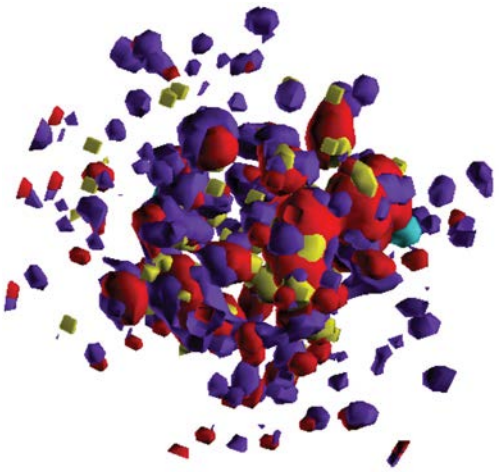
Dept. of Aerospace Engineering

Iowa State University, Ames, IA



David Dearborn (Co-I)

Lawrence Livermore National Laboratory



NIAC Phase 1 Spring Symposium

March 27-29, 2012

Introduction

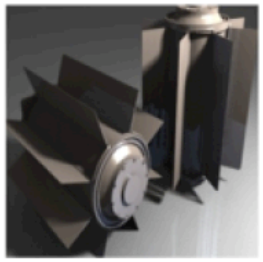
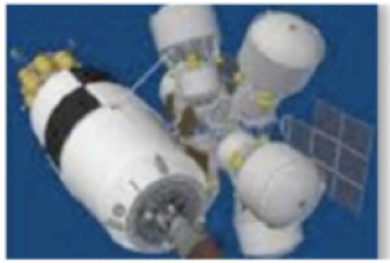
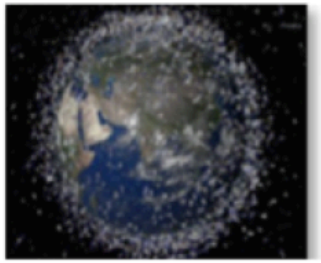
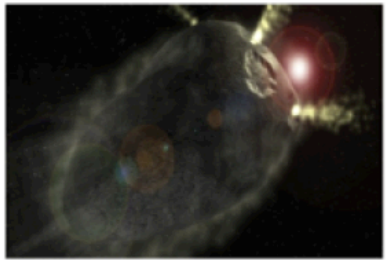
- **The most probable impact threat of near-Earth Objects (100 m – 1 km) with a short warning time (e.g., < 10 years)**

- **Warning (or mission lead) time:**
  detection → launch → NEO intercept → Earth flyby

- **Nuclear explosion options:**
  - ✓ **standoff (near-surface) blast**
  - ✓ **surface contact burst**
  - ✓ **buried or penetrated subsurface explosion**

- **Key references for NEO impact threat mitigation:**
  - ✓ **2007 NASA NEO Report**
  - ✓ **2010 NRC NEO Report**
  - ✓ **2004, 2007, 2009, 2011 Planetary Defense Conferences**

NASA Space Technology Grand Challenges (2011)

Space Technology Grand Challenges			
Manage In-Space Resources			
			
Affordable Abundant Power	**Space Way Station**	**Space Debris Hazard Mitigation**	**Near-Earth Object Detection and Mitigation**
Provide abundant, reliable and affordable energy generation, storage and distribution for space exploration and scientific discovery.	Develop pre-stationed and in-situ resource capabilities, along with in-space manufacturing, storage and repair to replenish the resources for sustaining life and mobility in space.	Significantly reduce the threat to spacecraft from natural and human-made space debris.	Develop capabilities to detect and mitigate the risk of space objects that pose a catastrophic threat to Earth.

NASA Space Technology Grand Challenges (2011)

Space Technology Grand Challenges			
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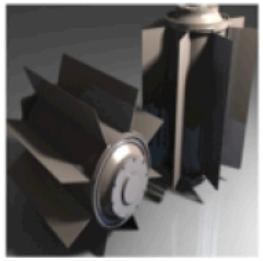	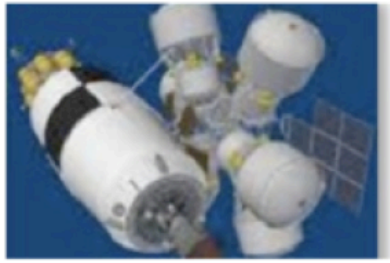	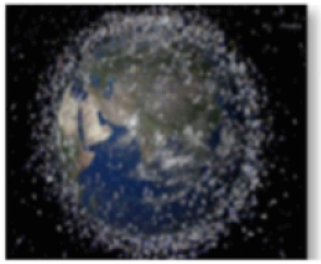	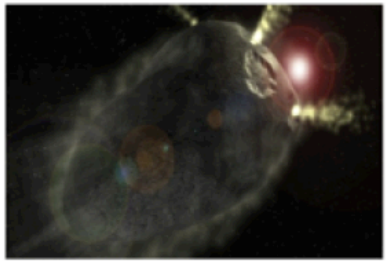
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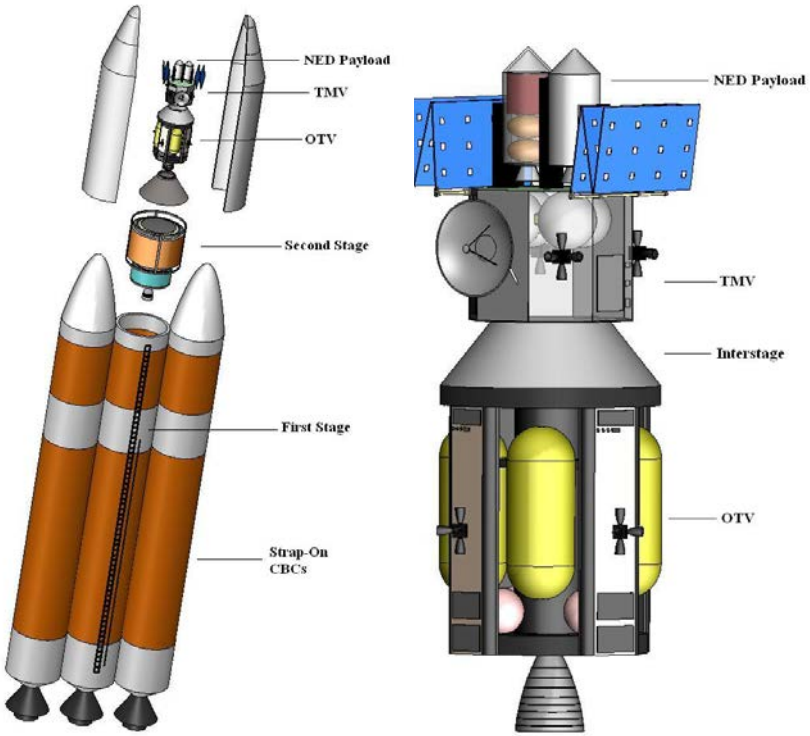
But, no funding yet for NEO mitigation technology study !

Interplanetary Ballistic Missile (IPBM) System Architecture Concept for NEO Deflection

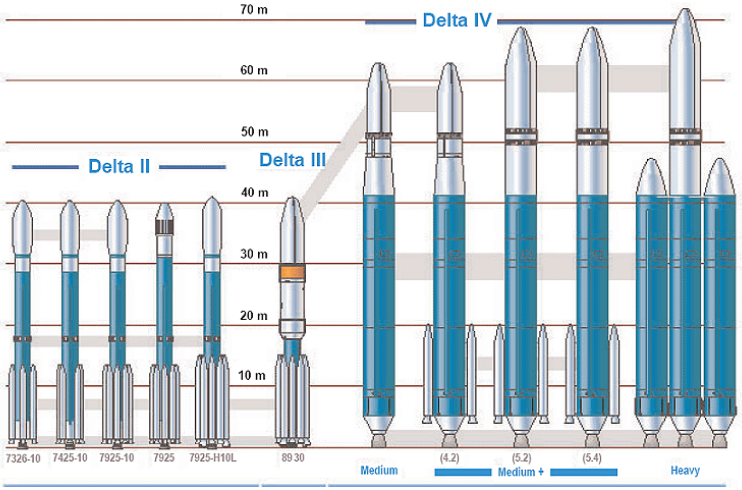
Wagner, Pitz, Zimmerman, and Wie
(IAC-09.D1.1.1, 60th IAC, 2009)

- **Delta IV Heavy**
  - **1500 kg Nuclear Payload**
    (≈2 Mt yield) for 1 km NEO
- **Delta IV M+**
  - **1000 kg Nuclear Payload**
    (≈1 Mt yield) for 500 m NEO
- **Delta II or Taurus II**
  - **300 kg Nuclear Payload**
    (≈300 kt yield) for 200 m NEO



Launch Vehicle Options

- **Launch vehicles**
  - **Delta II class: $60M-100M**
  - **Delta IV class: $170M-324M**
  - **Atlas V class: $177M-246M**
- **Available launch vehicles**
  - **Delta II 732X, 742X, 792X, 792XH**
  - **Delta IV M, M+(4,2), M+(5,4)**
  - **Delta IV Heavy**
  - **Atlas V 401, 431, 551**



Nuclear Options & Issues

- **Rendezvous vs. intercept**

✓ **Standoff (flyby) near-surface blast**
✓ **Surface contact burst**
✓ **Penetrated subsurface explosion**

- **Late intercept missions (with a short warning time) will result in hypervelocity impact velocity of 10 – 30 km/s.**

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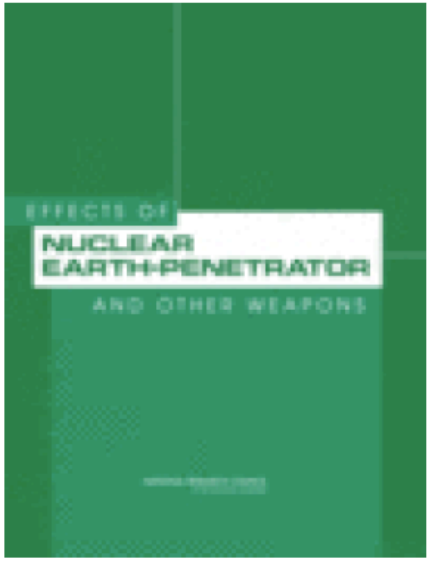
- **Impact velocity of Nuclear Earth-Penetrator Weapons (NEPWs) < 300 m/s (or < 1.5 km/s)**

2005 NRC Report on NEPW



Effects of Nuclear Earth-Penetrator and Other Weapons

Committee on the Effects of Nuclear Earth-Penetrator and Other Weapons, National Research Council

ISBN: 0-309-55106-4, 150 pages, 8 1/2 x 11, (2005)

This free PDF was downloaded from:

http://www.nap.edu/catalog/11282.html

EARTH-PENETRATOR WEAPONS 27

300-kt EPW at 3-m DOB is equivalent to a 6-Mt surface contact burst

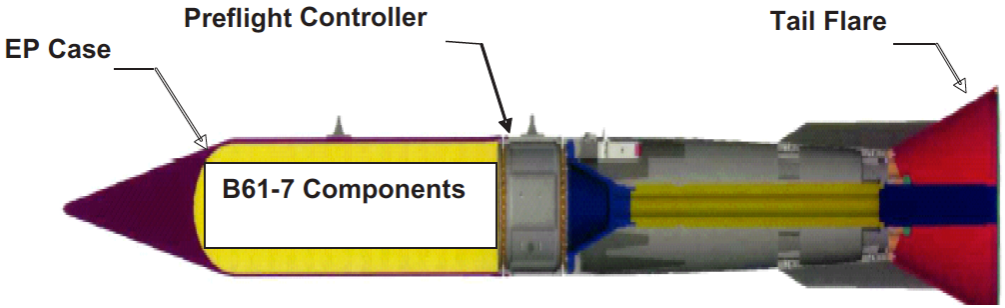
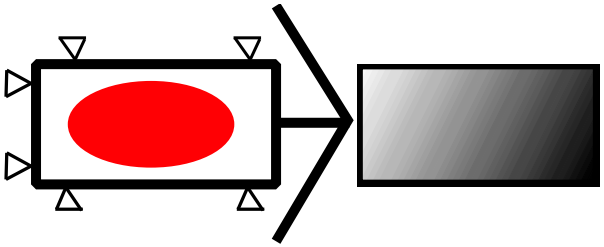


FIGURE 3.5 Final design of the nuclear, earth-penetrator (EP) B61-11. SOURCE: Sandia National Laboratories. 2003. *B61-11 Final Weapon Development Report (U),* SAND 2003-2344, Albuquerque, N.Mex. (Classified).

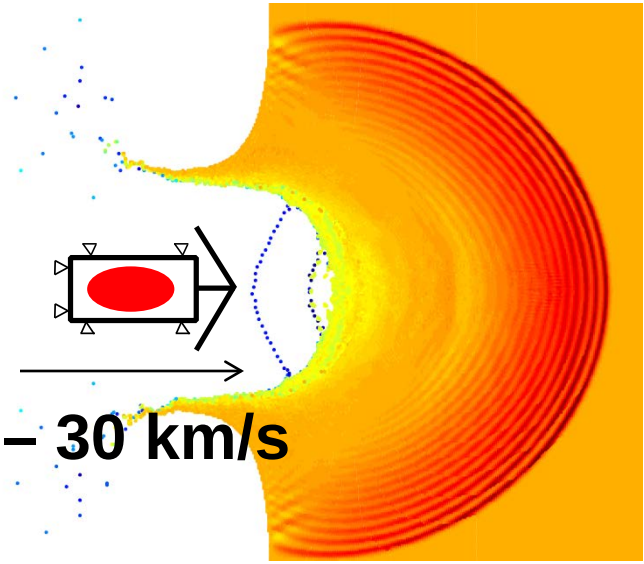
Hypervelocity Nuclear Interceptor Concept for Penetrated Subsurface Explosion @ 10 - 30 km/s

Presented at 2011 Planetary Defense Conference, Bucharest, Romania, May 2011



Follower Spacecraft
with Nuclear Explosives

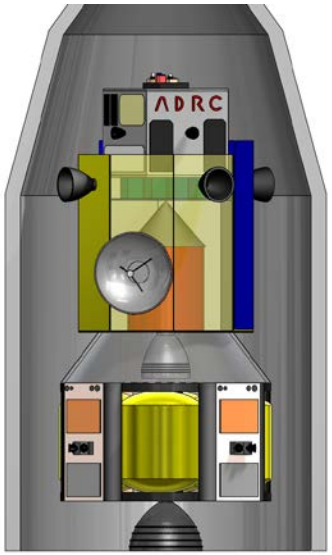
Leader Spacecraft
(Kinetic-Energy Impactor)

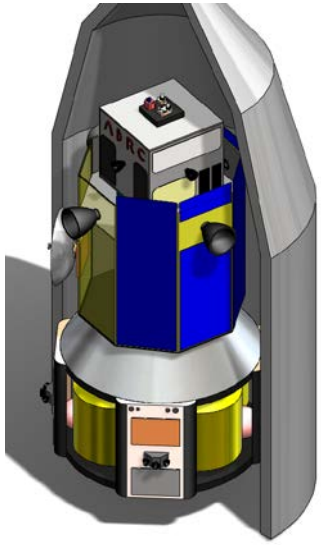


Phase 1: Conceptual Design

Presented at AAS Space Flight Mechanics Meeting, January 2012
AAS 2012-225 by Pitz, Kaplinger, Wie, and Dearborn

- **Mission cost:**
  - **$500M mission with 300-kg NED**
  - **$1B mission with 1000-kg NED**
  - **$1.5B mission with 1500-kg NED**
- **Two-body configuration:**
  leader (impactor) and follower S/C





Mission Class	Total Mass of HNIS (kg)
300-kg NED (300-kt yield)	1843
1000-kg NED (1-Mt yield)	4251
1500-kg NED (2 Mt yield)	5720

Phase 1: Conceptual Design

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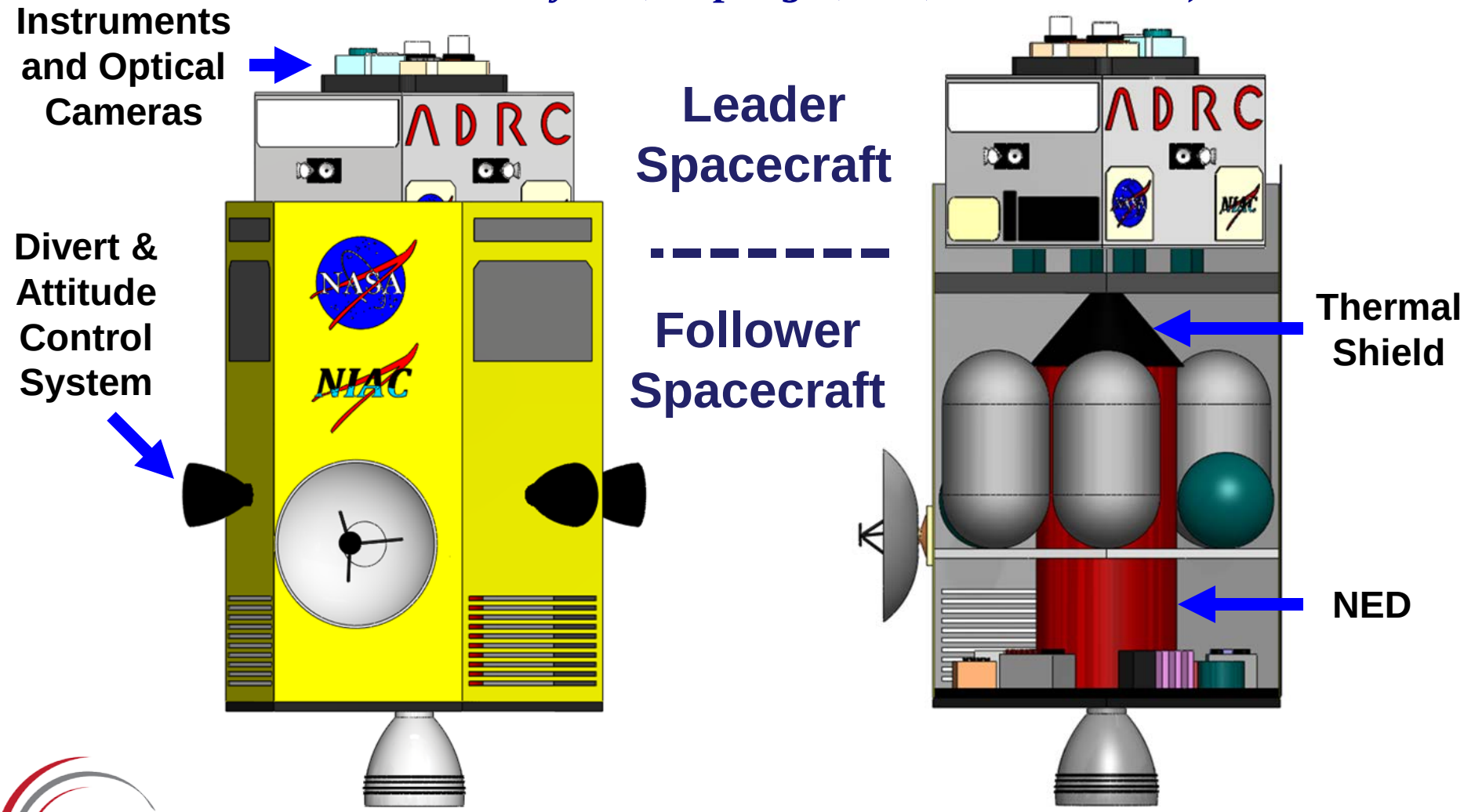
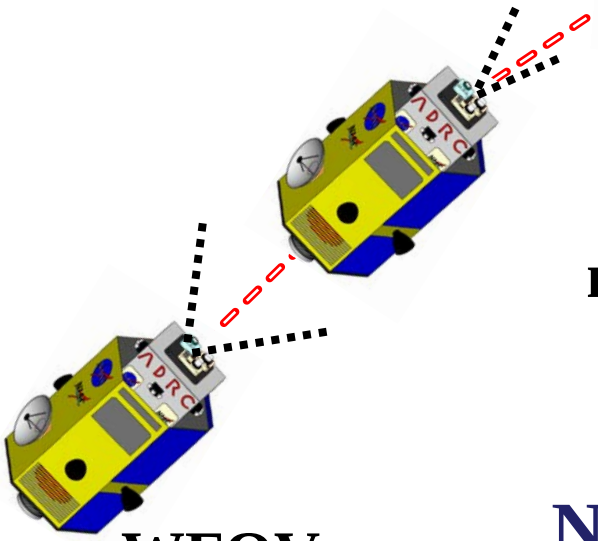
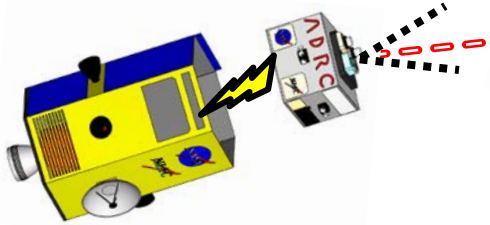


Hypervelocity Nuclear Interceptor System Terminal Phase Operations

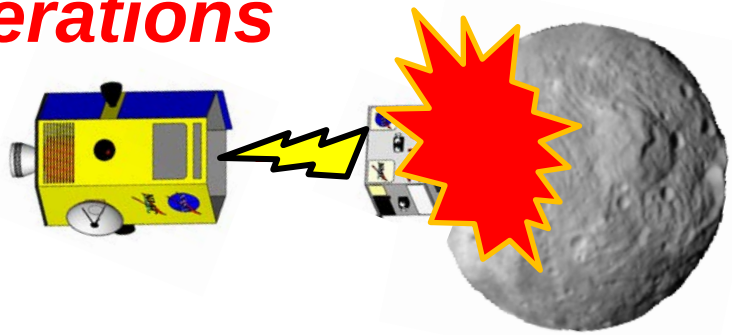
WFOV ’ NFOV and attitude maneuvers



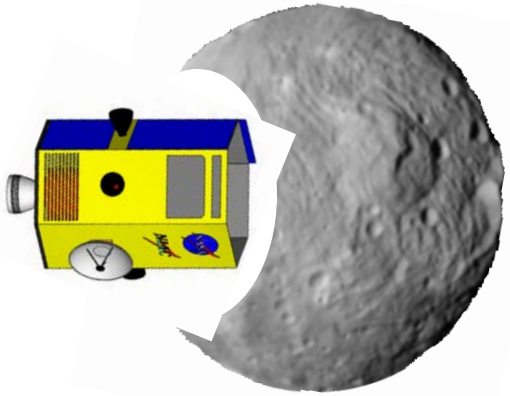
WFOV identifies target NEO



Leader separates and NED fuzing mechanisms begin



Leader S/C impacts and creates a shallow crater



Follower S/C with NED enters crater and detonates

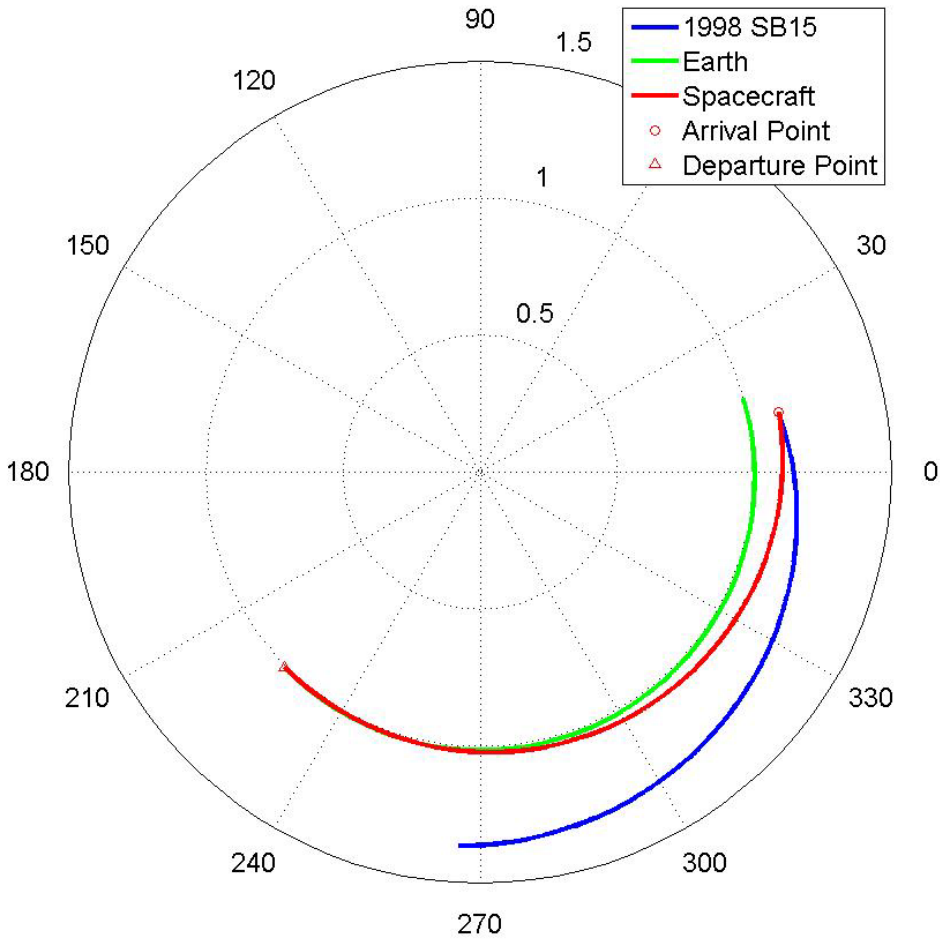
NED Payloads

- 300-kg NED (H300 kt)
- 1,000-kg NED (H1 Mt)
- 1,500-kg NED (H2 Mt)

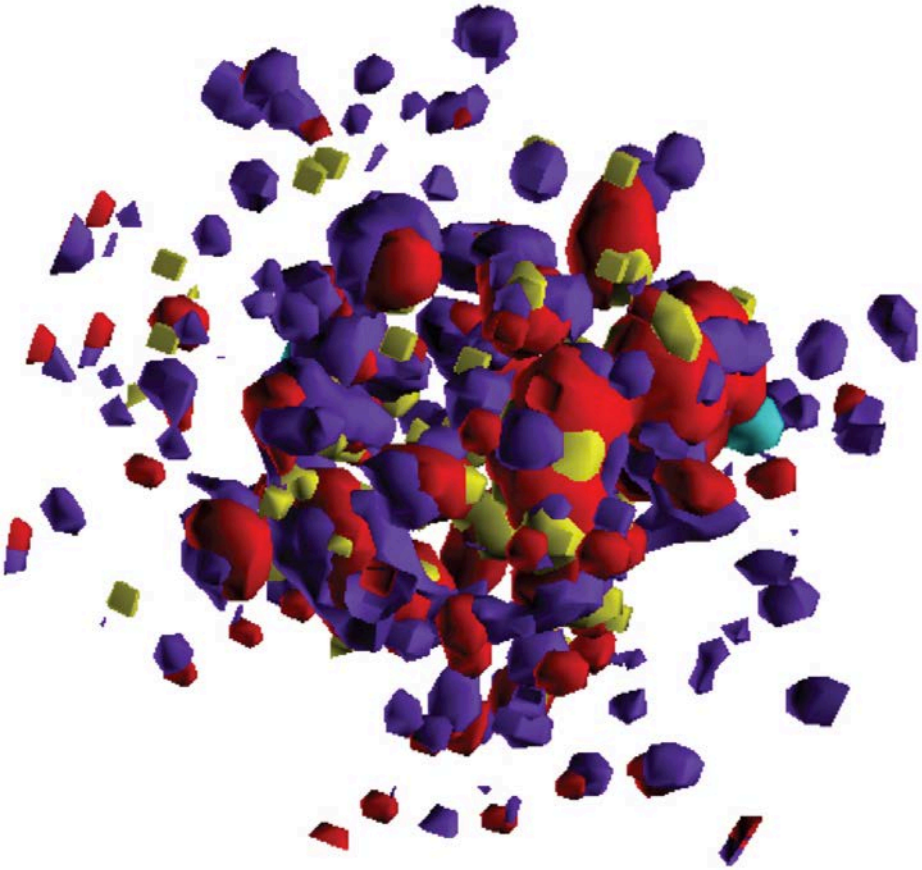
$500M Demo Mission to 1998 SB15

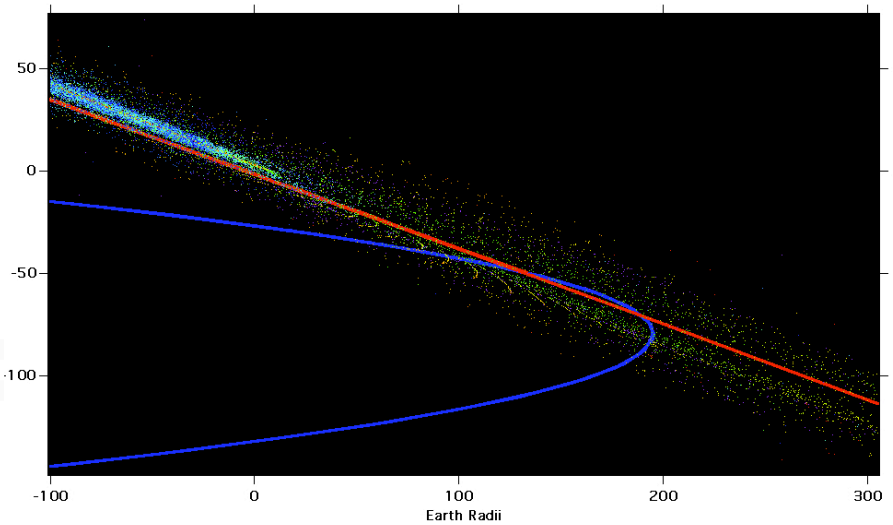
Presented at AAS Space Flight Mechanics Meeting, January 2012
AAS/AIAA Paper 2012-128 by Vardaxis, Pitz, and Wie

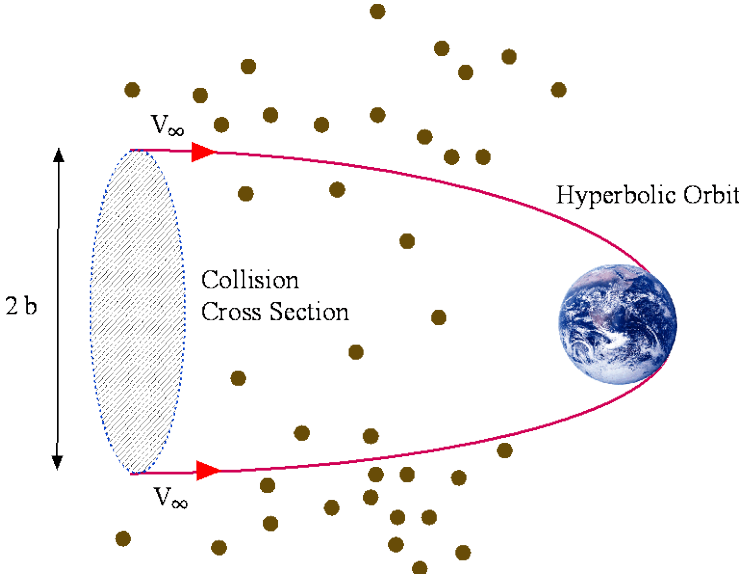
Launch Vehicle	**Delta II 7920H**
S/C Mass	1843 kg
Payload	300 kg
Total Launch Mass	**5800 kg**
Departure ” V	3.35 km/s
C3	2.37 (km^2/s^2)
Target Diameter	330 m
Departure Date	05/05/2017
Transfer Time	159 days
Arrival Date	10/11/2017



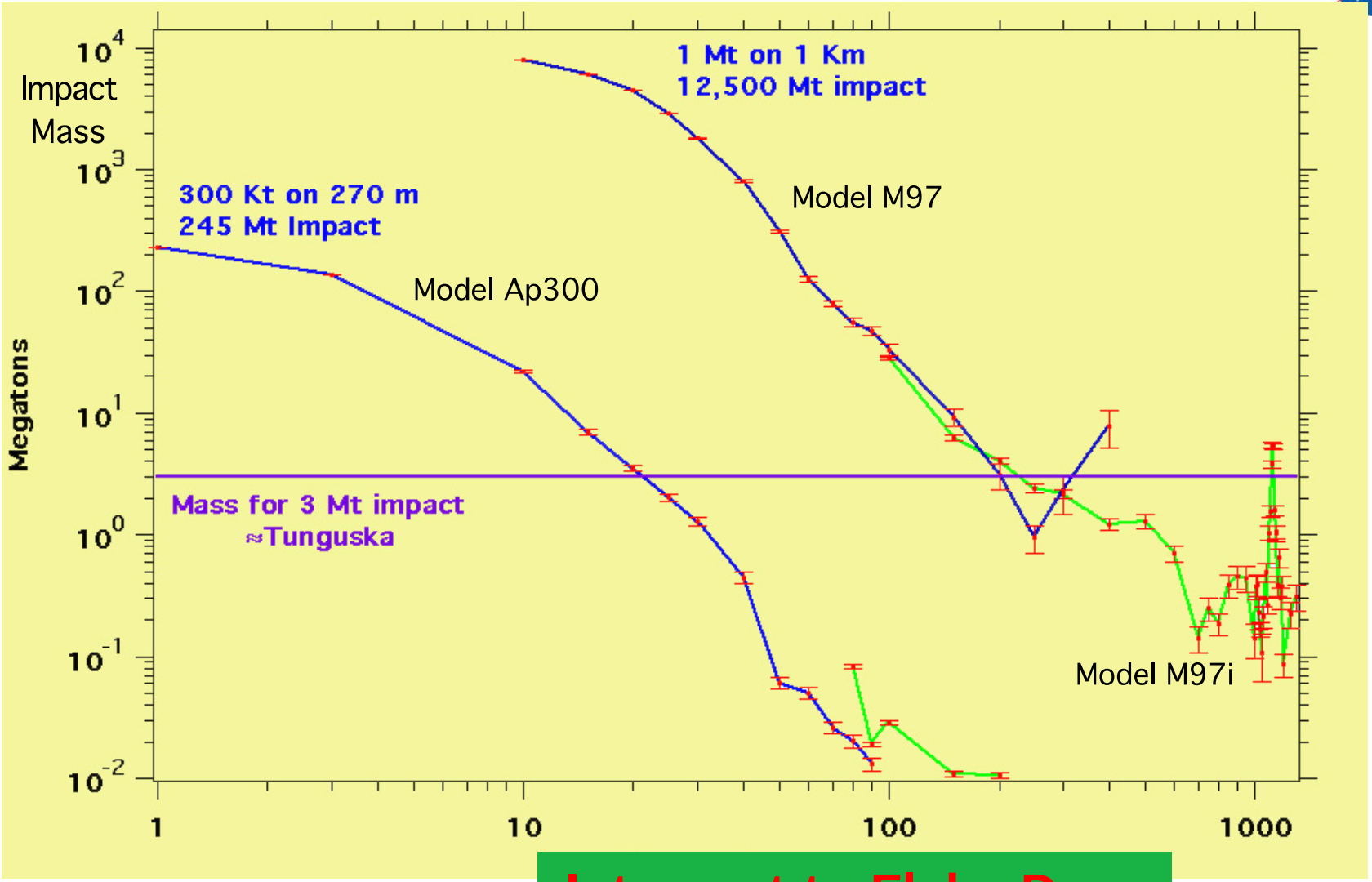
Nuclear Subsurface Explosions (1/2)





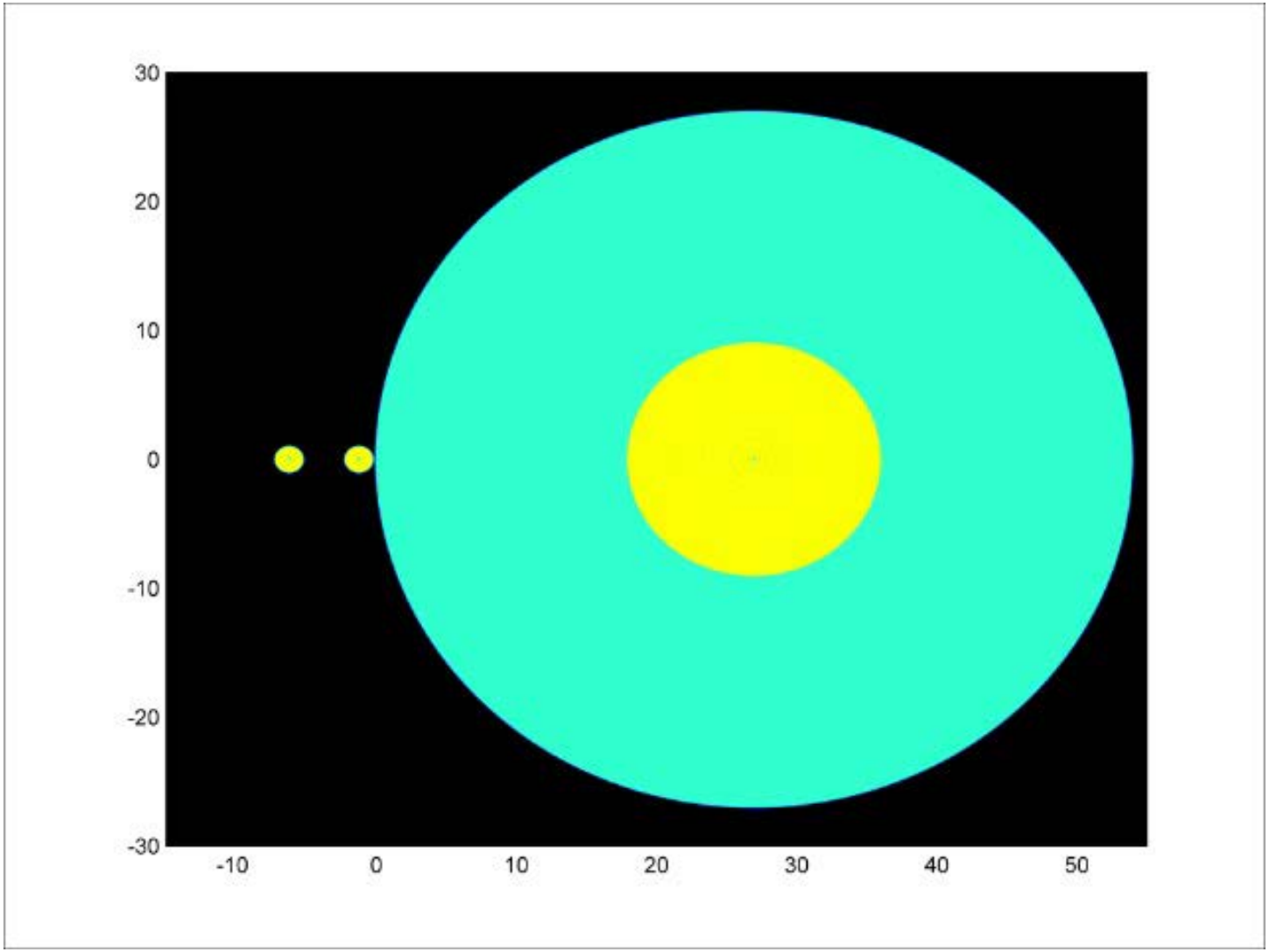


Nuclear Subsurface Explosions (2/2)

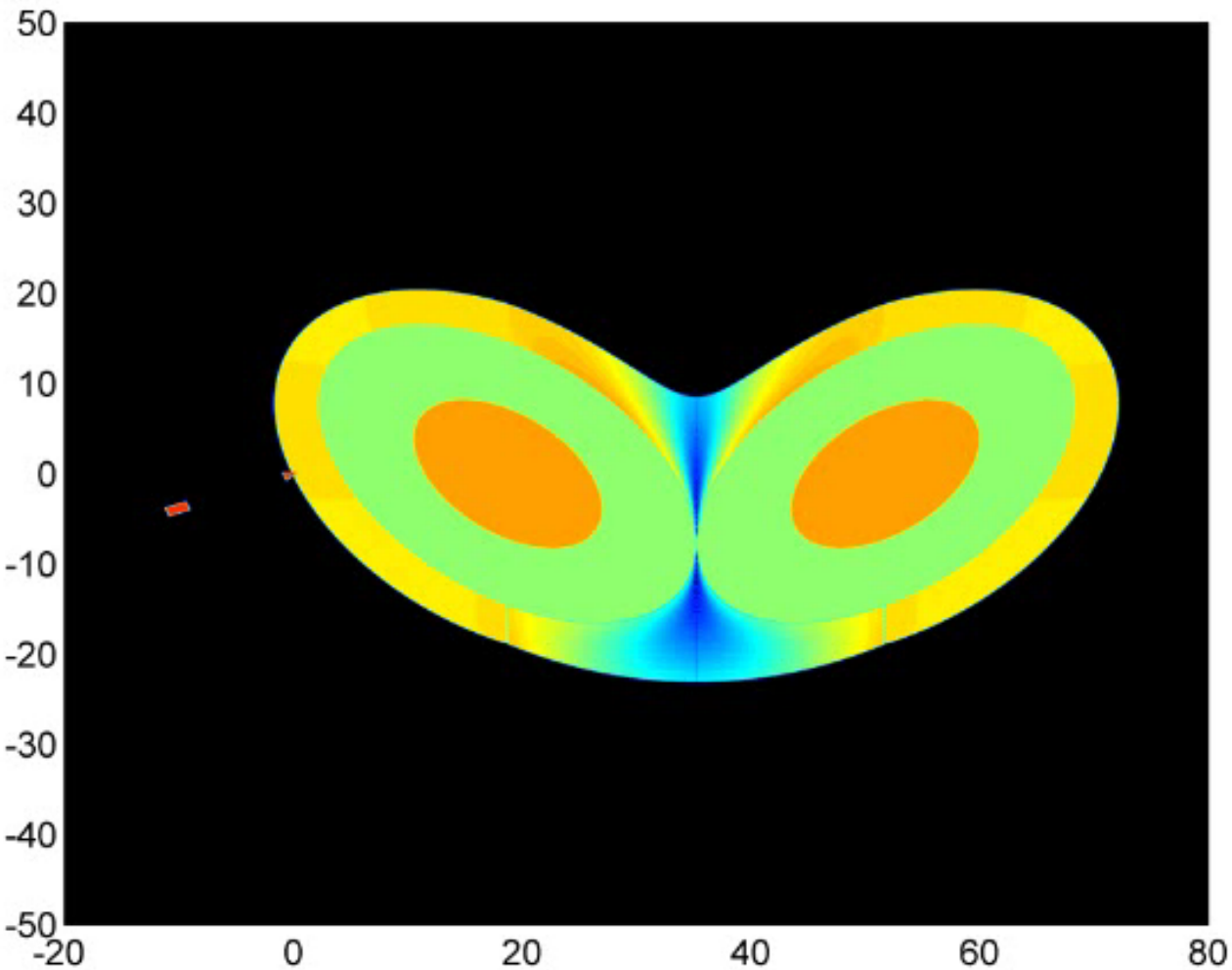


Intercept-to-Flyby Days

Hypervelocity Impact and Nuclear Explosion



Hypervelocity Impact and Nuclear Explosion



NIAC Phase 1 Outcomes

- **An innovative, but yet practical & cost effective, solution to NASA's NEO Threat Mitigation Grand Challenge**
- **Baseline spacecraft system/mission architecture concept design (Task 1)**
- **Physical modeling and high-performance computational simulation tools (Task 2)**
- **Planetary Defense Technology (PDT) flight demonstration mission concept**

ESA's Don Quijote mission (cancelled)

→ ***Lewis & Clark (?) mission***

Phase 1 Publications

- Pitz, A., Kaplinger, B., Wie, B., and Dearborn, D., "Conceptual Design of a Hypervelocity Nuclear Interceptor System," AAS/AIAA Space Flight Mechanics Meeting, January 2012.

- Kaplinger, B., Wie, B., and Dearborn, D., "Earth-Impact Modeling and Analysis of a Near-Earth Object Fragmented and Dispersed by Nuclear Subsurface Explosions," to appear *in Journal of Astronautical Science*.

- Wie, B., "Hypervelocity Nuclear Interceptor System Concept," to appear in *Acta Astronautica.*

- Kaplinger, B., Wie, B., Dearborn, D., "Nuclear Fragmentation/Dispersion Modeling and Simulation of Hazardous Near-Earth Objects," to appear *in Acta Astronautica.*

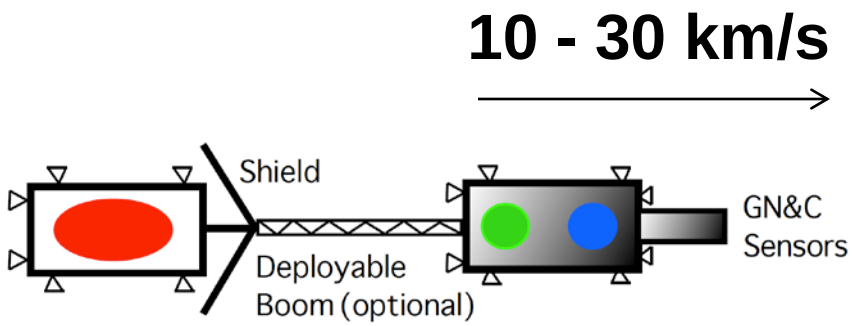
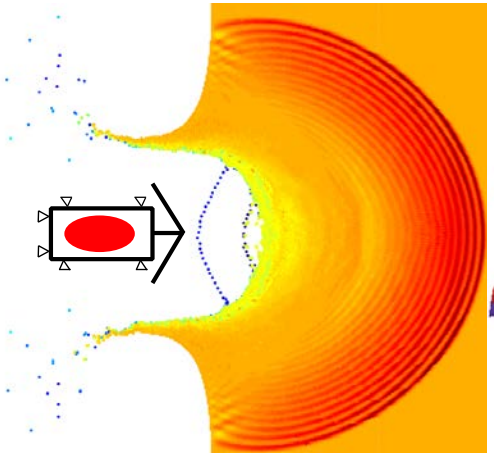
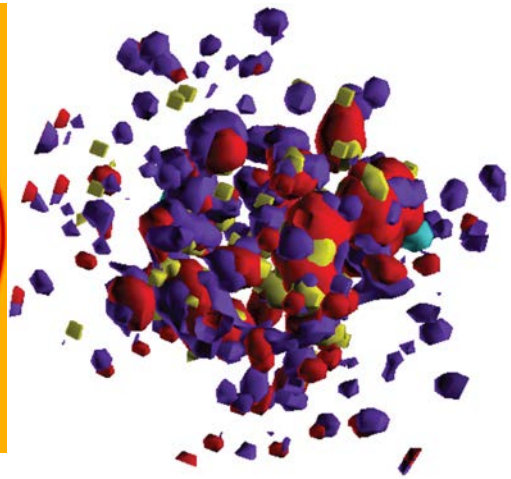
PDT R&D Milestones

- NIAC Phase 2 ($500K) ?
- NASA Iowa EPSCoR ($750K) ?
- Game-Changing Technology Program of the NASA OCT ($3M) ??
- Development of Planetary Defense Technology (PDT) R&D Program ($10M - $100M) ????

⋮

- Lewis & Clark PDT Flight Demo Mission (> $500M) ??????

Concluding Remarks

- **For the most probable impact threat with a short warning time, nuclear fragmentation & dispersion is the only practically viable, but yet cost effective, solution.**

- **However, the hypervelocity nuclear interceptor technology needs to be flight validated in space (but, without nuclear payload !).**