An Innovative Solution to NASA's NEO Impact Threat Mitigation Grand Challenge and Flight Validation Mission Architecture Development

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Study Justification (1/2)

An Airburst of 17-m Chelyabinsk Meteor on Feb. 15, 2013

17 m (diameter)
10,000 tons
18.6 km/s impact
440 kt of TNT
(30 Hiroshima bombs)
Airburst @23.3 km

1,500 people were injured; 7,200 buildings damaged

What if it were a 17 m *nickel-iron meteorite*?

Study Justification (2/2)

- **Asteroid 2012 DA14 (367943 Duende), discovered on Feb. 23, 2012, had a close encounter with Earth (27,700-km near-miss) on Feb. 15, 2013.**

- **What if the 30-m DA14 were predicted to collide with Earth with its impact damage of 150 Hiroshima nuclear bombs (or 2.3 Mt of TNT)?**

Study Justification (2/2)

- **Asteroid 2012 DA14 (367943 Duende), discovered on Feb. 23, 2012, had a close encounter with Earth (27,700-km near-miss) on Feb. 15, 2013.**

- **What if the 30-m DA14 were predicted to collide with Earth with its impact damage of 150 Hiroshima nuclear bombs (or 2.3 Mt of TNT)?**

Study Outcome (1/3)

- **A complete and versatile solution to NASA's NEO Impact Threat Mitigation Grand Challenge has been found through a NIAC study.**

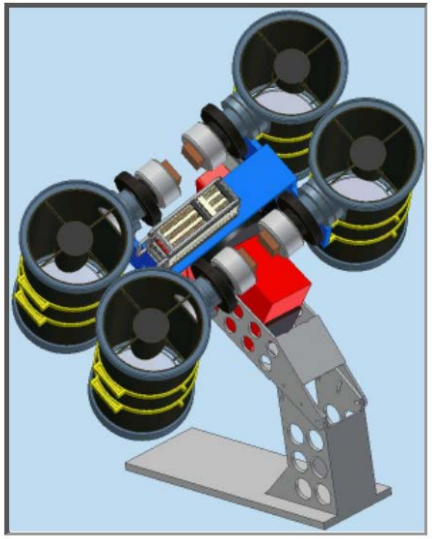
- **The NIAC study for short (< 1 year) warning time scenario has been justified by the Chelyabinsk event and the near-miss of 2012 DA14.**

- **An asteroid last alert system, such as the ATLAS, is now part of the complete solution.**

ATLAS Last Alert System

(Asteroid Terrestrial-Impact Last Alert System)

- A $5M project started in 2013 (due to the Chelyabinsk event)
- The ATLAS is currently scanning the sky with a prototype camera and telescope, and will be fully operational in 2015.
- So far, only for civil defense (evacuation)
- One-day alert for a 8-m, 30-kt "town killer"
- One-week alert for a 45-m, 5-Mt "city killer"
- Three-week alert for a 140-m "county killer"



An early ATLAS design concept.

Study Outcome (2/3)

- **If our proposed system becomes ready to launch at anytime in the future,**

- ✓ **Given one-week warning from the ATLAS, an asteroid (> 45 m) can be intercepted/fragmented far outside the orbit of moon.**
- ✓ **Given three-week warning from the ATLAS, an asteroid (> 140 m) can be intercepted/fragmented far outside Earth's gravitational field.**

- **Note that any other "non-nuclear deflection" mission will require much earlier warning of at least 10 years.**

Study Outcome (3/3)

- **Our proposed system can also be used for a "deflection" mission, provided that much earlier warning of 5 to 10 years is available.**

- **Also, it can be used for the worst-case scenario with a very short warning time (< 1 week).**

- **In summary, <u>the</u> complete, yet practical and versatile, solution to NASA's Asteroid Grand Challenge has been found;**

Study Outcome (3/3)

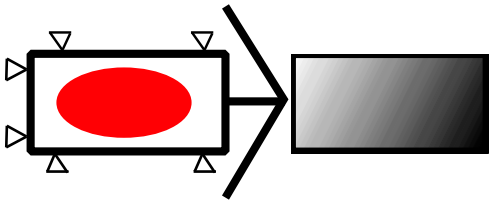
- **Our proposed system can also be used for a "deflection" mission, provided that much earlier warning of 5 to 10 years is available.**

- **Also, it can be used for the worst-case scenario with a very short warning time (< 1 week).**

- **In summary, <u>the</u> complete, yet practical and versatile, solution to NASA's Asteroid Grand Challenge has been found; however, this conceptual solution needs to be further studied and flight validated.**

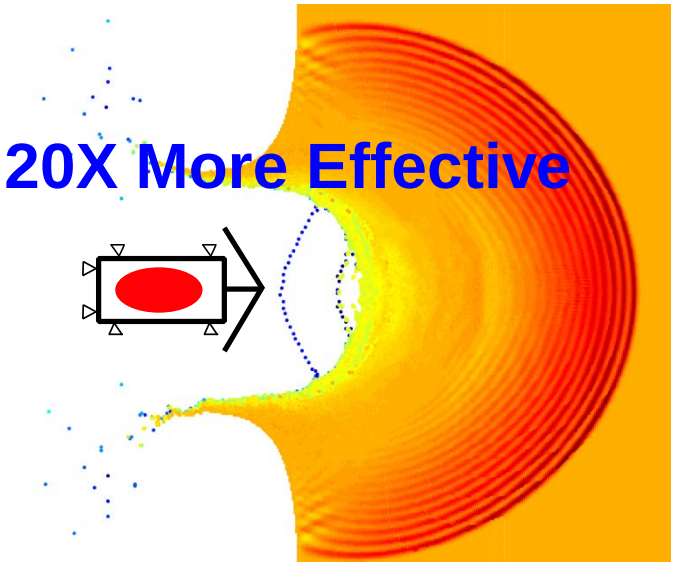
Phase 1 Proposal (2011)

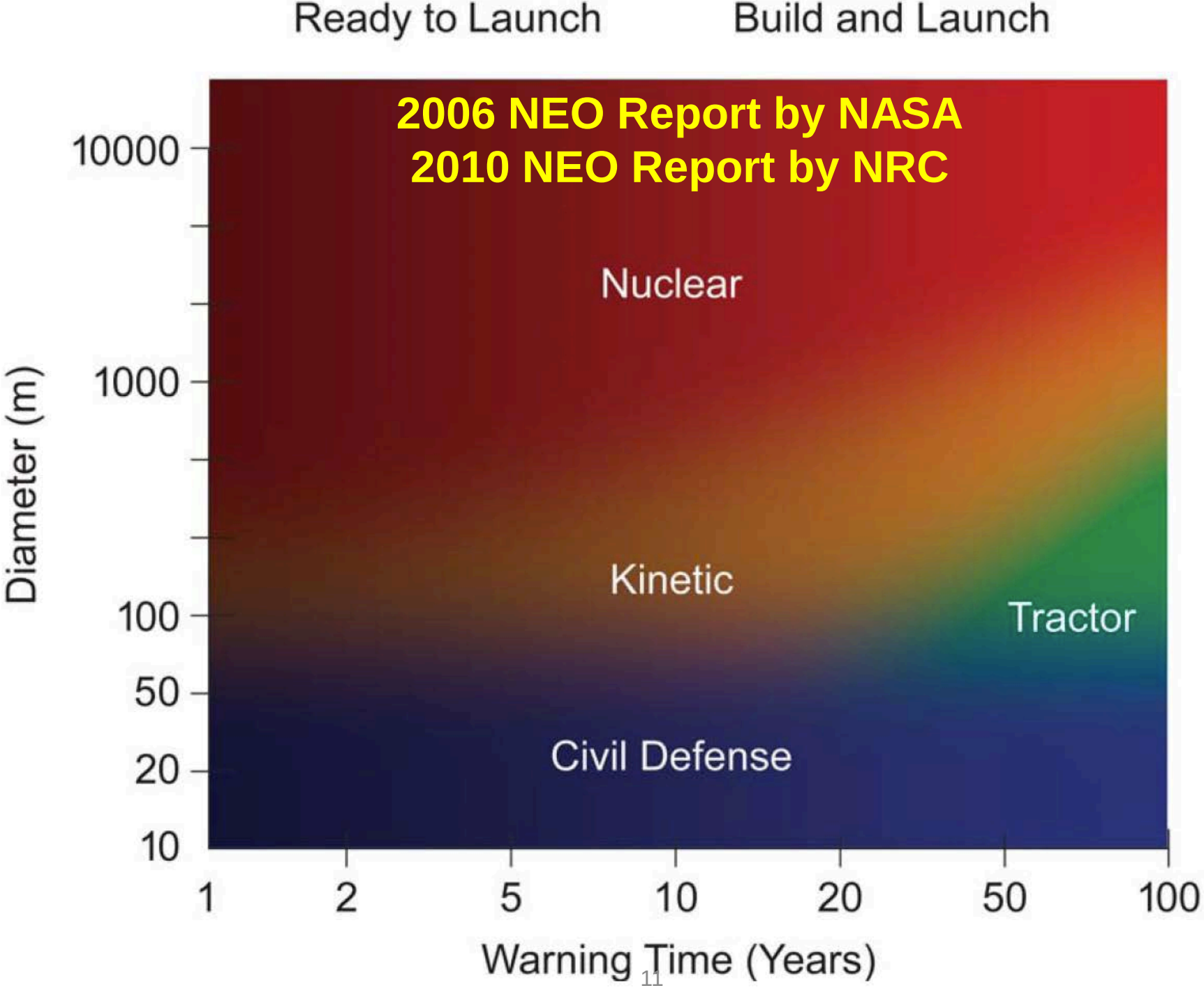
- **Late intercept missions, with short warning times < 1 yr, will result in a hypervelocity arrival closing (relative) velocity of 5 to 30 km/s.**
- **ΔV = 10 km/s requires a 96% propellant mass (300-s Isp)**
- **ΔV = 30 km/s requires a 99.99% propellant mass ratio**
- **Impact velocity of nuclear explosive devices (NEDs) is limited as 300 m/s max (or 1.5 km/s ?)**

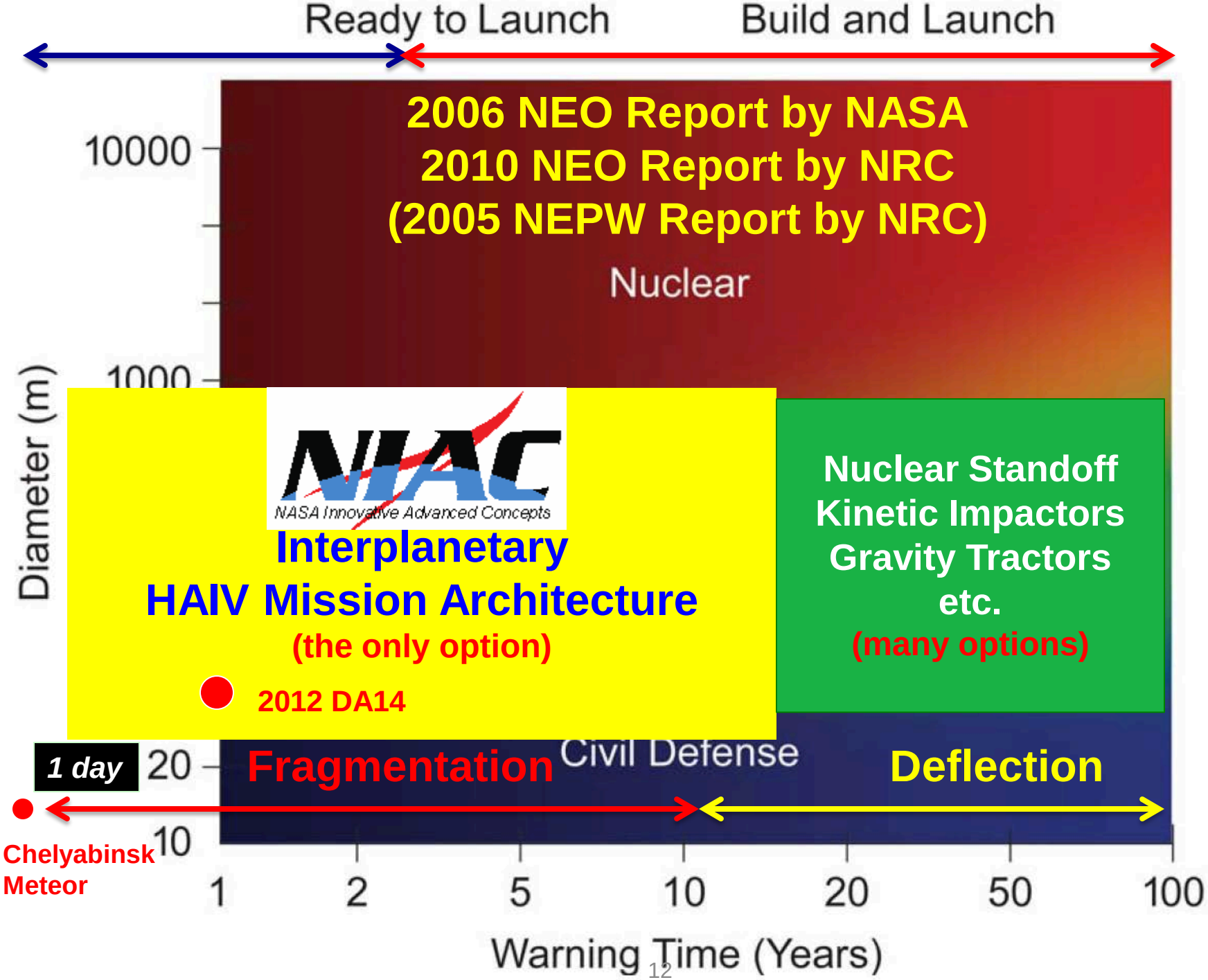


Follower Spacecraft with Nuclear Explosives

Leader Spacecraft (Kinetic-Energy Impactor)

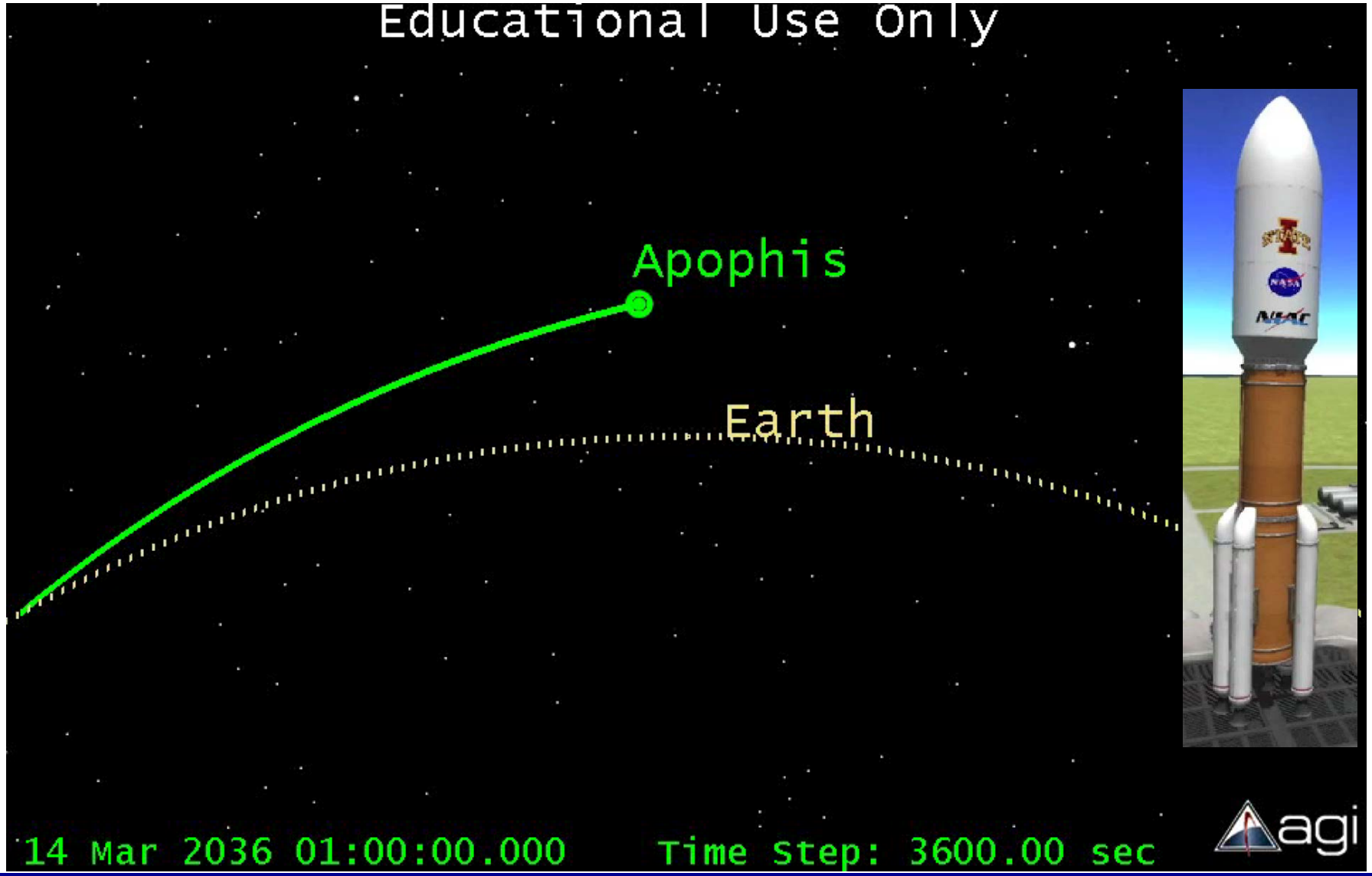



Ready to Launch
Build and Launch
2006 NEO Report by NASA
2010 NEO Report by NRC
Nuclear
Kinetic
Tractor
Civil Defense
Diameter (m)
10000
1000
100
50
20
10
1
2
5
10
20
50
100
Warning Time (Years)

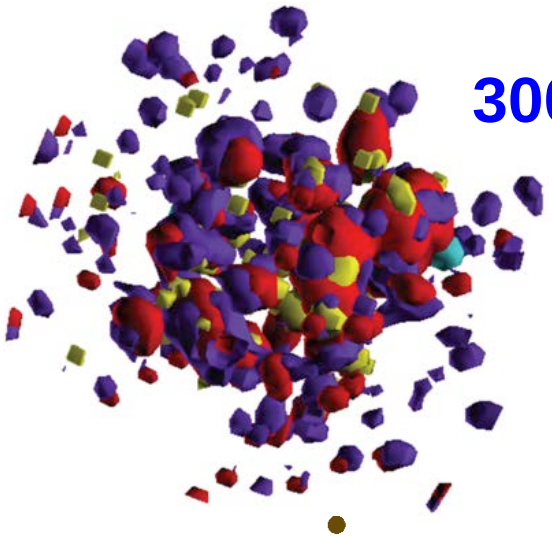

Ready to Launch
Build and Launch
2006 NEO Report by NASA
2010 NEO Report by NRC
(2005 NEPW Report by NRC)
Nuclear
10000
1000
Diameter (m)
NIAC
NASA Innovative Advanced Concepts
Interplanetary
HAIV Mission Architecture
(the only option)
2012 DA14
Nuclear Standoff
Kinetic Impactors
Gravity Tractors
etc.
(many options)
1 day
20
Fragmentation
Civil Defense
Deflection
10
Chelyabinsk
Meteor
1
2
5
10
20
50
100
Warning Time (Years)

HAIV (Hypervelocity Asteroid Intercept Vehicle) Interplanetary Ballistic Missile (IPBM) Concept

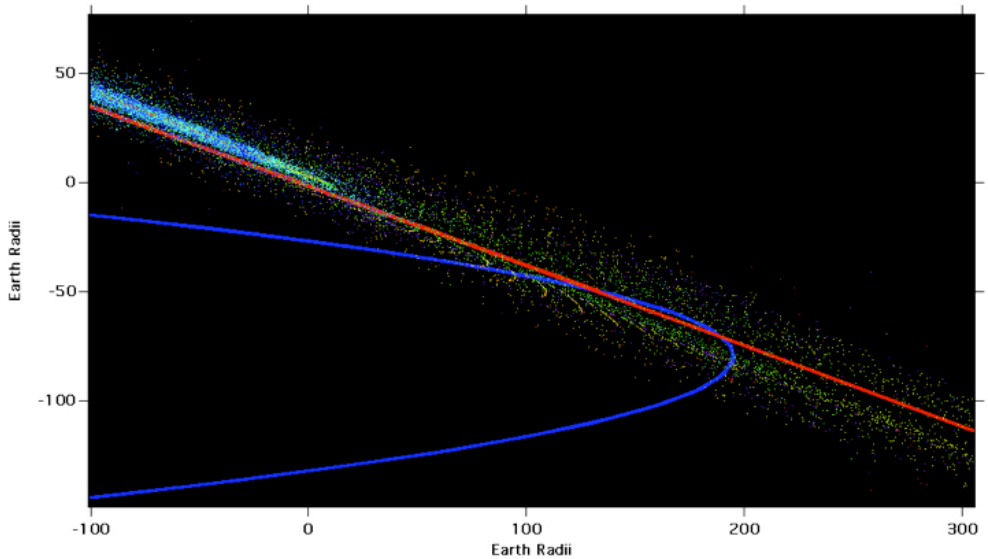
Fragmentation and Dispersion of a 300-m Asteroid with a 30-day Warning Time

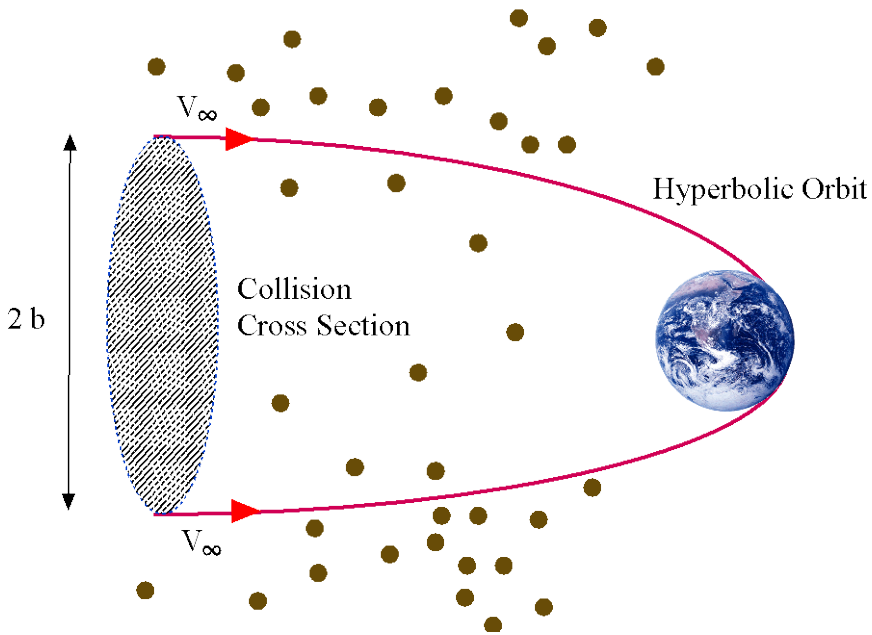


Disruption, Fragmentation, and Dispersion



300 m

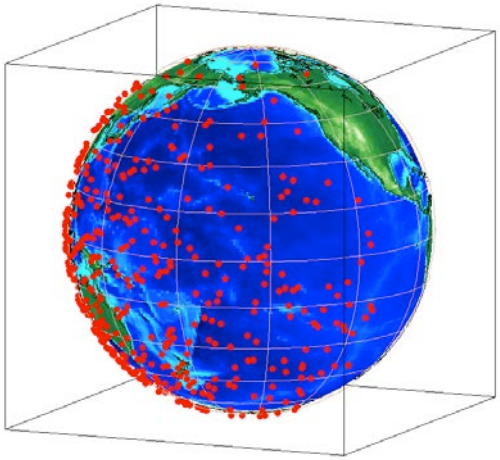




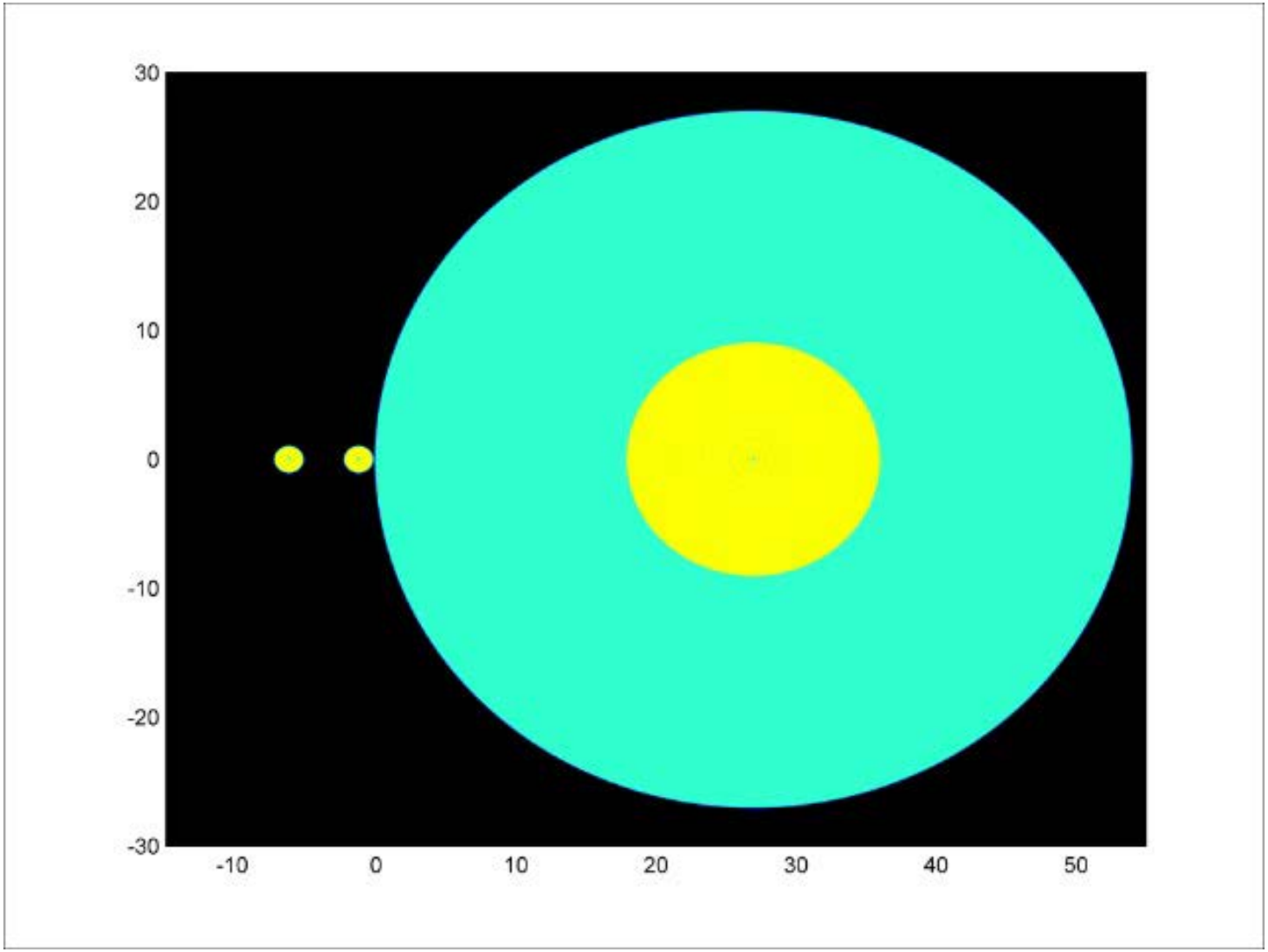
Heavy meteor shower
or many Chelyabinsk meteor events

or

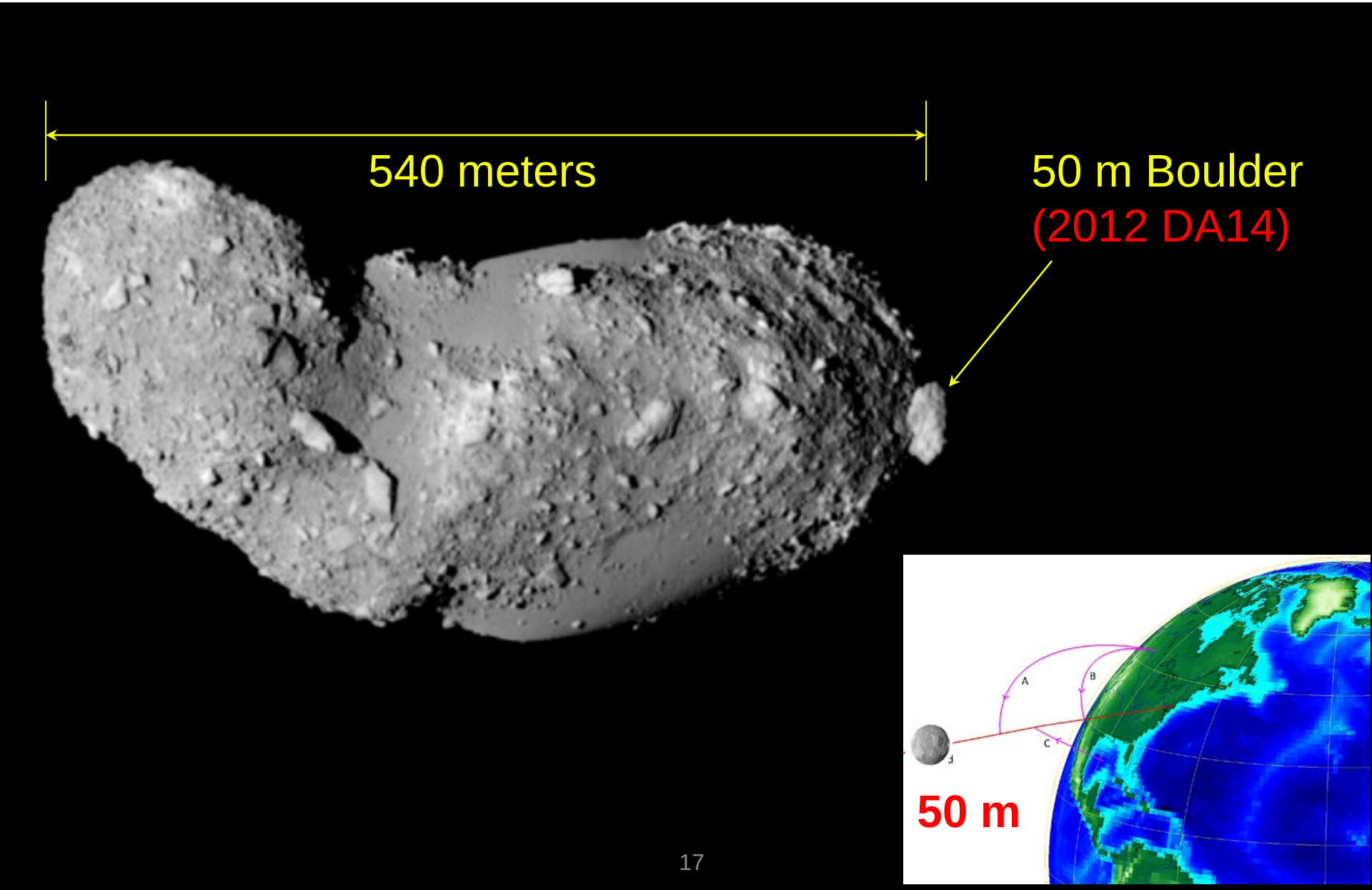
150 x 1000
Hiroshima
Nuclear Bombs



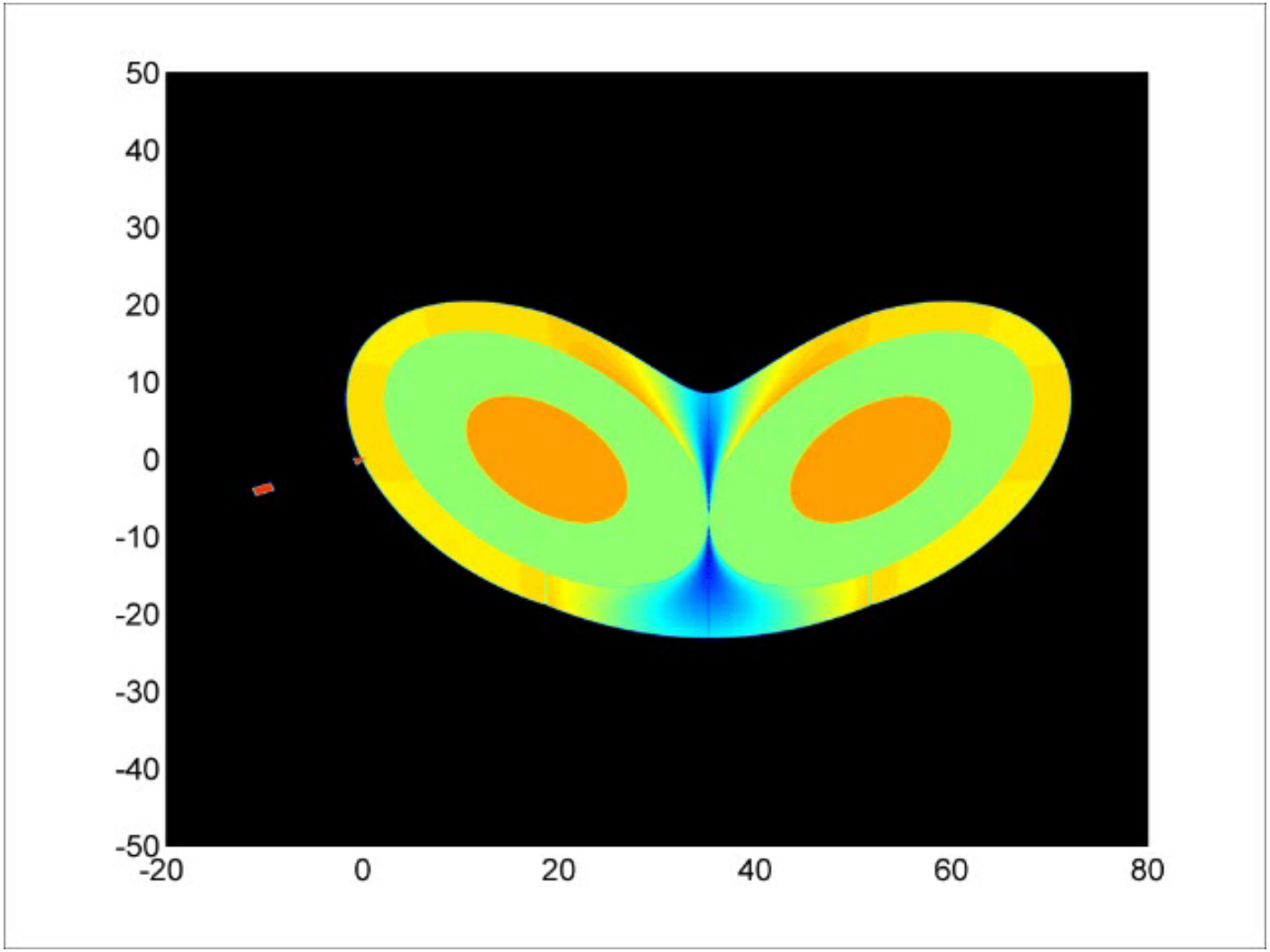
Blended Kinetic Impact and Subsurface Nuclear Explosion; In-House SPH Hydrocode Simulation



Asteroid 25143 Itokawa



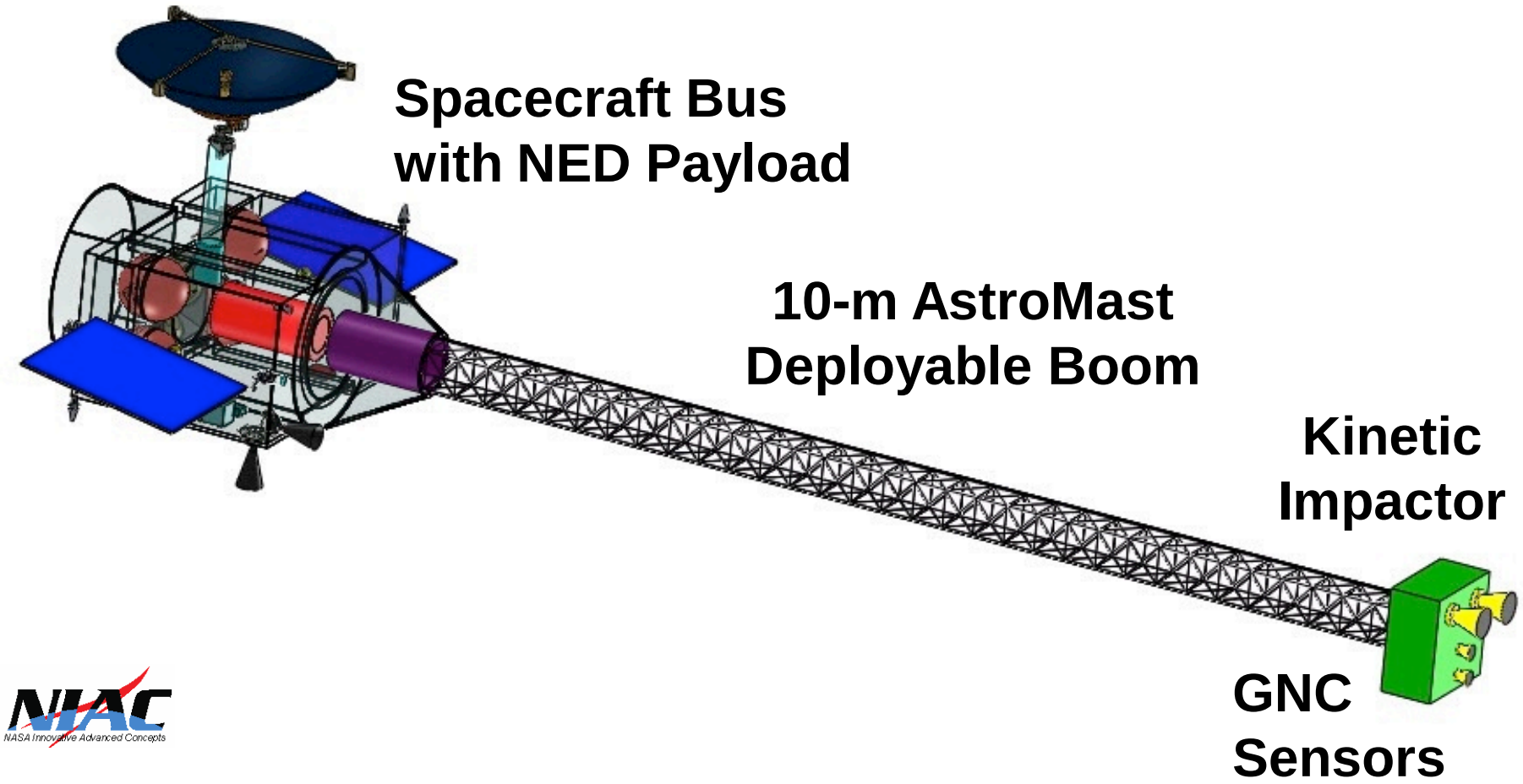
Fragmentation Simulation of an Asymmetric Asteroid Using In-House GPU-based SPH Hydrocode



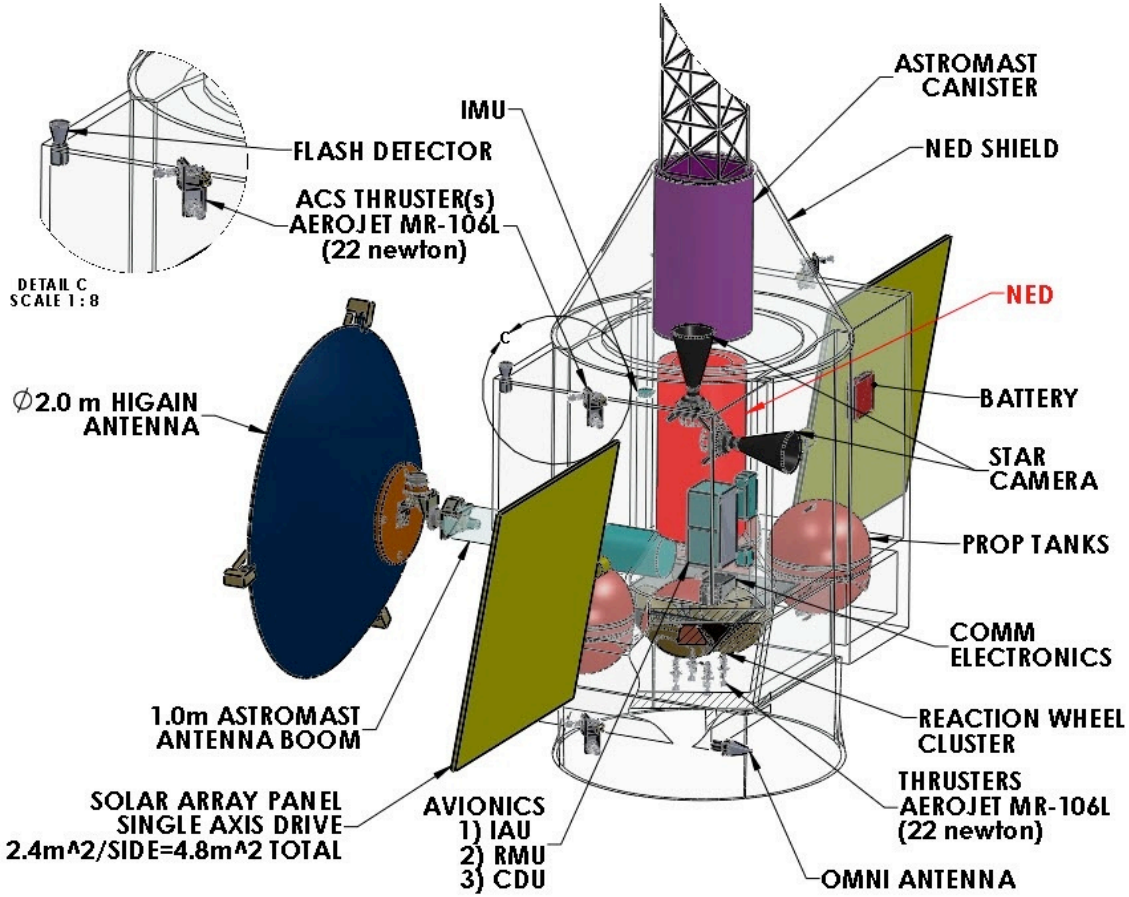
Phase 2 Accomplishments

- **Task #1: Hypervelocity kinetic impact and nuclear subsurface explosion modeling/simulation was further investigated using an in-house GPU-based SPH hydrocode and a commercial AUTODYN software. The HAIV concept was computationally validated.**
- **Task #2: Detailed terminal guidance system design using an optical sensing system model was performed.**
- **Task #3: Asteroid mission design optimization tool was developed for optimal target selection for a HAIV flight validation mission as well as planetary defense missions.**

HAIV Design by the Mission Design Lab (MDL) of NASA Goddard Space Flight Center (Task #4)



HAIV Design by NASA GSFC for a Flight Validation Mission



Atlas V

NIAC Publications (2011 – 2013)

40 Technical Papers Presented at AIAA GNC, AAS/AIAA Astrodynamics, AAS Space Flight Mechanics Meeting, IAA 2011 & 2013 Planetary Defense Conferences

7 Journal Articles

ADRC website:
http://www.adrc.iastate.edu

Numerous invited talks, internet media articles, and videos

Graduate Research Assistants for NIAC Phase 1 and 2 Studies

Alan Pitz (MS, May 2012), currently at Lockheed Martin

Tim Winkler (MS, May 2013), currently at The Aerospace Corporation

Matt Hawkins (PhD, May 2013), currently at NASA MSFC

Brian Kaplinger (PhD, May 2013), currently an Assistant Professor, Florida Institute Technology

Sam Wagner (PhD), George Vardaxis (PhD), Joshua Lyzhoft (PhD), Ben Zimmerman (PhD), Pavithra Premaratne (MS)

Undergraduate Research Assistants:
Jake Harry, Christian Setzer, Dalton Groath, Justin Van Sambeek, Ted Harding, Elmer Tse, Ryan Hupp, Spencer Dewild

Summary

Early Warning (> 10 yrs)

"Build and Launch" (Deflection)

IPBM/HAIV

Summary

Early Warning (> 10 yrs) → **"Build and Launch" (Deflection)**

> 2 yrs → **"Build and Launch" (Deflection or Disruption?)**

IPBM/HAIV

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> 2 yrs → **"Build and Launch" (Deflection or Disruption?)**

< 1 yr → **"Ready to Launch" (Disruption)**

IPBM/HAIV

Summary

Early Warning (> 10 yrs) → **"Build and Launch" (Deflection)**

> 2 yrs → **"Build and Launch" (Deflection or Disruption?)**

< 1 yr → **"Ready to Launch" (Disruption)**

ATLAS Last Alert

3-week (> 140 m) →

1-week (> 45 m) → **"Ready to Launch" (Interplanetary)**

→

1 day – 1 wk → **"Ready to Launch" (inside/outside lunar orbit)**

IPBM/HAIV

Thank You !