



NIAC (NASA Innovative Advanced Concepts)

Phase 1 & 2 Studies (2011 – 2014)

An Optimal Mitigation Strategy Against the Asteroid Impact Threat with Short Warning Time

Bong Wie (PI)

Asteroid Deflection Research Center

Iowa State University

Brent Barbee (Co-I)

NASA Goddard Space Flight Center

**Graduate Students: Alan Pitz, Brian Kaplinger,
Matt Hawkins, Tim Winkler, Pavithra Premaratne,
George Vardaxis, Joshua Lyzhof, Ben Zimmerman**

NIAC Study Objective (2011 – 2014)

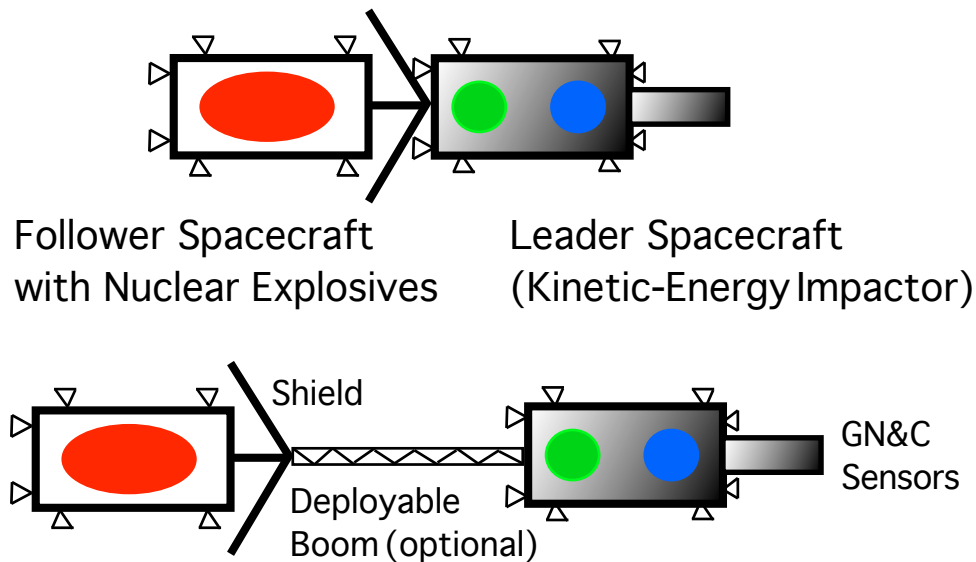
To develop an innovative yet practically implementable mitigation technique for the most probable impact threat of an asteroid or comet with short warning time (i.e., when we don't have sufficient warning times for a deflection mission)



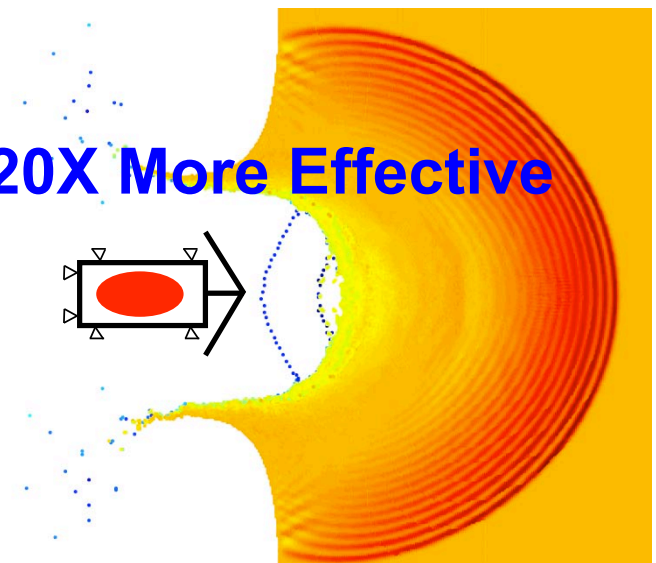
NIAC Phase 1 Proposal (2011)



- Late intercept missions, with short warning time < 1 yr, will result in a hypervelocity arrival closing (relative) velocity of 5 to 30 km/s.
- $\Delta V = 10$ km/s requires a 96% propellant mass (300-s Isp)
- $\Delta V = 30$ km/s requires a 99.99% propellant mass ratio
- Impact velocity of nuclear explosive devices (NEDs) is limited as 300 m/s max (2005 NRC Report on NEPWs)



20X More Effective



Precision Terminal Intercept Guidance

Terminal Guidance Begins
Impact - 2 hrs
for 50- to 150-m target

Cameras identify
target NEO

Target
Acquisition



Deployment of 10-m
boom with contact
fuzes and sensors



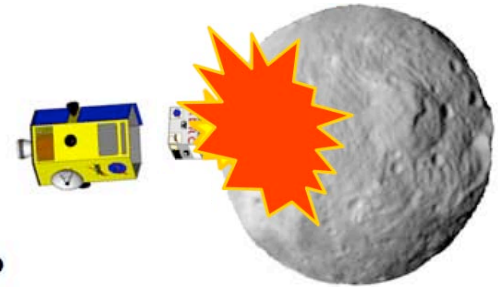
Leader S/C
separates from
Follower S/C



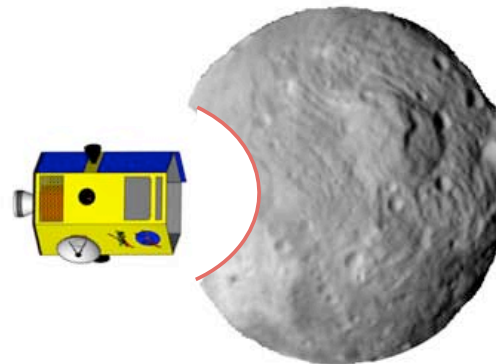
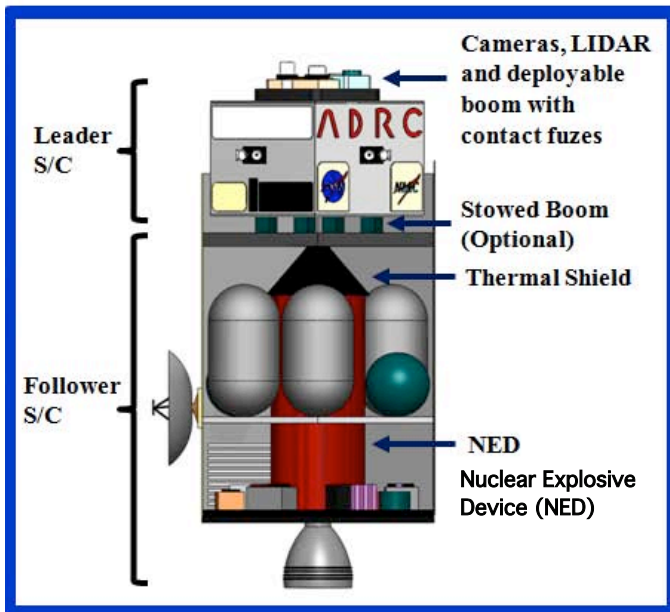
Sensors on boom detect NEO
surface and Leader S/C sends
a signal to initiate detonation
sequence of NED



Leader S/C impacts and
creates a shallow crater
allowing more surface
area to be exposed to NED



IPBM



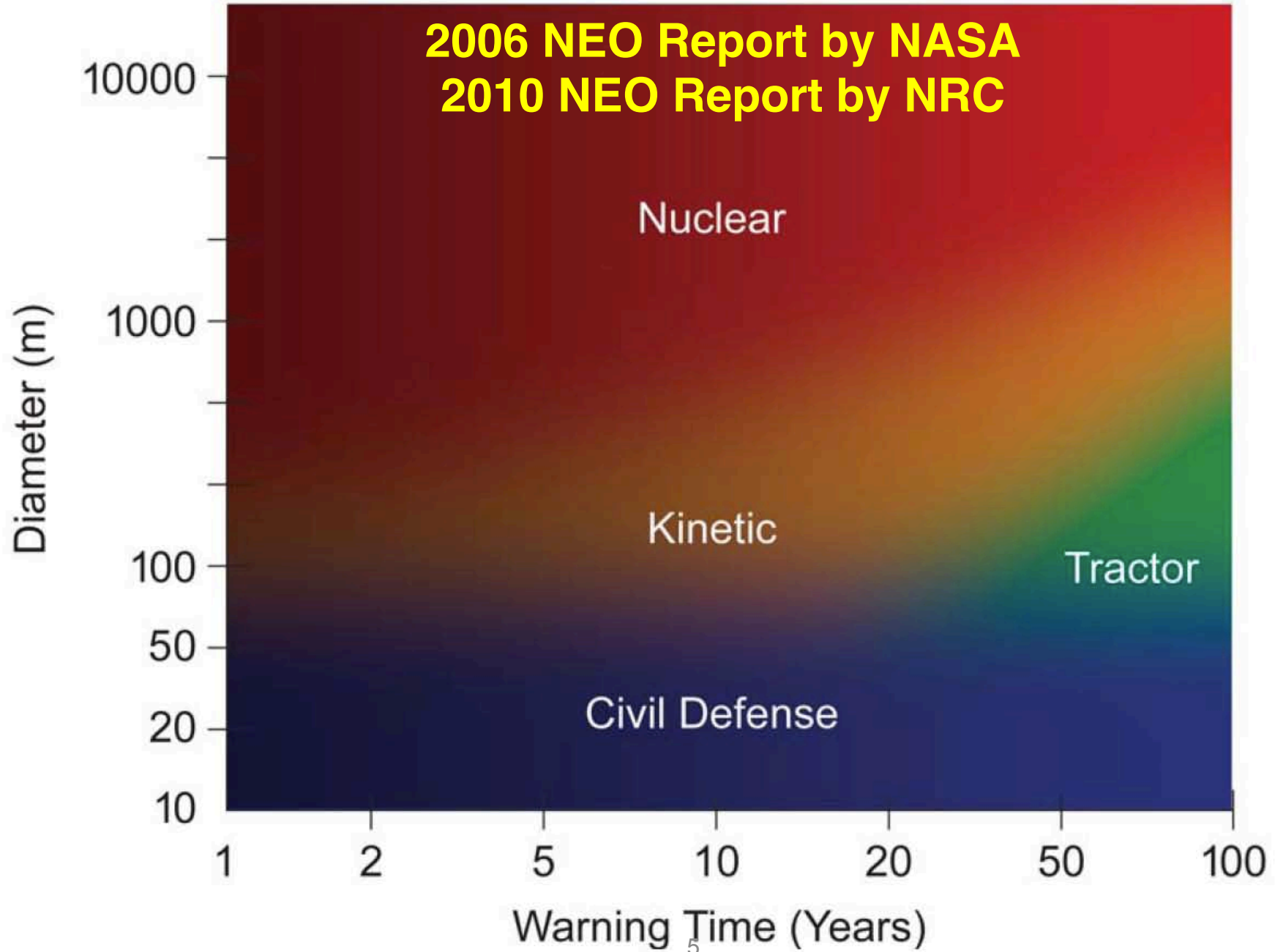
Follower S/C with NED enters
crater and detonates resulting in
optimal disruption of target NEO

Launch Vehicles

- Delta IV Heavy
1500 kg NED
(≈ 2 Mt yield)
- Delta IV M+
1000 kg NED
(≈ 1 Mt yield)
- Delta II Class
300 kg NED
(≈ 300 kt yield)

Ready to Launch

Build and Launch



Ready to Launch

Build and Launch

2006 NEO Report by NASA
2010 NEO Report by NRC

Nuclear

Warning Time (Years)

NIAC Phase 1 & 2 Studies

Disruption

Pulverization/Vaporization

Deflection

Civil Defense

20

10

1

2

5

10

20

50

100

Warning Time (Years)

NIAC Project Outcomes (1/2)

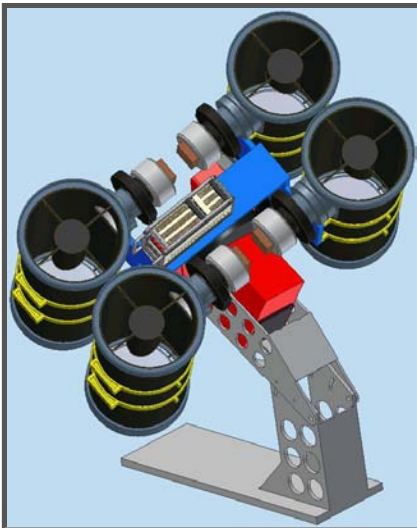
- The Hypervelocity Asteroid Intercept Vehicle (HAIV) mission concept of blending a kinetic impactor with nuclear subsurface explosion
- 7 journal articles + 30 plus technical papers
- 3 Ph.D. (graduated) + 3 MS (graduated) + 3 Ph.D. (current)
- The HAIV mission concept should further exploit the ATLAS last alert system **for active last-minute planetary defense (1 week – 3 weeks)**

ATLAS Last Alert System

(Asteroid Terrestrial-Impact Last Alert System)



ATLAS project head Dr. John Tonry with a conceptual drawing for an ATLAS telescope. The project would use two of these 20-inch telescopes. *Credit: UH/ifa*



An early ATLAS design concept.

- 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 2015-2016.
- **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”

NIAC Project Outcomes (2/2)

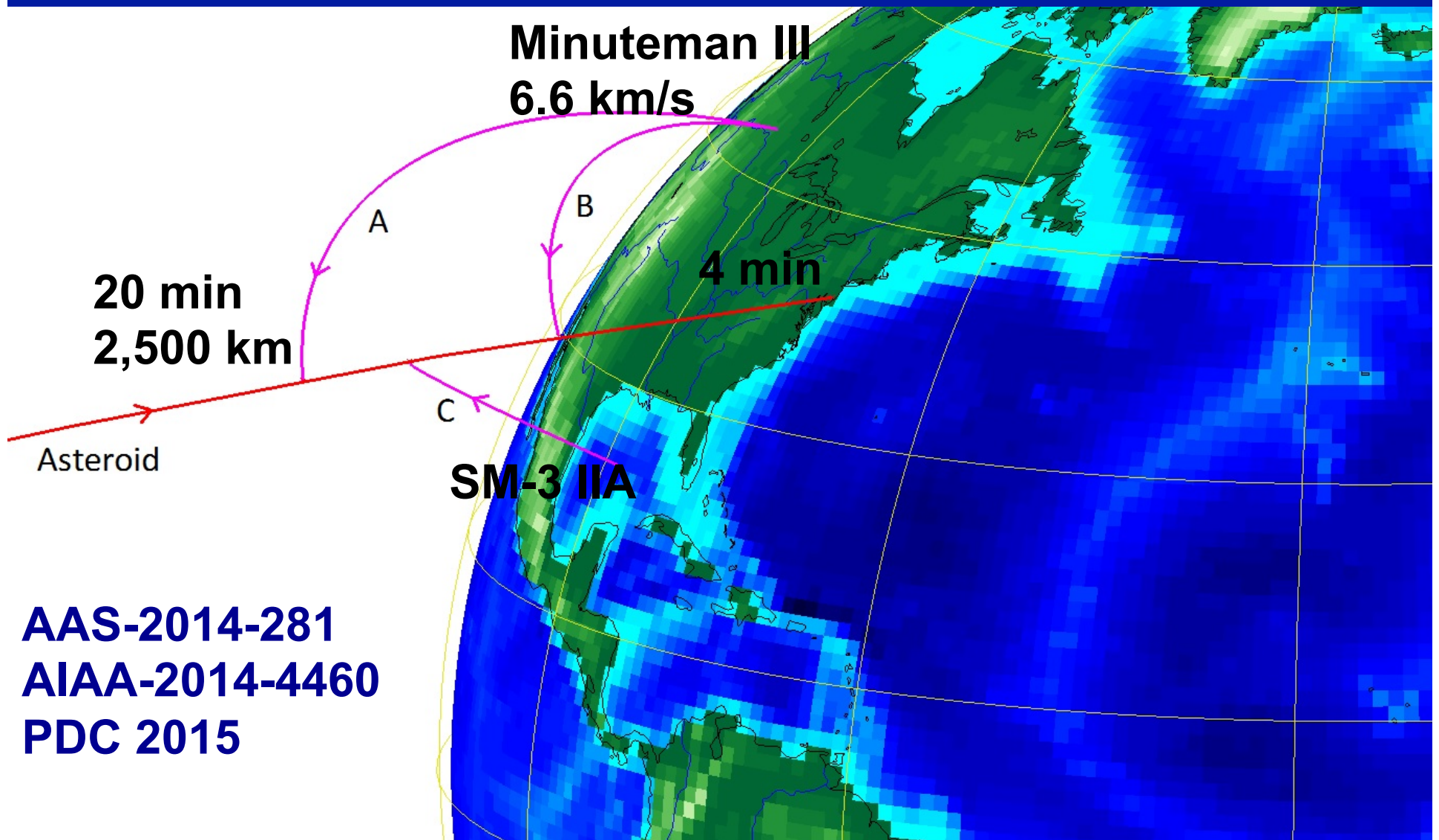
- If a HAIV/IPBM system (\approx \$200M- \$500M) becomes ready to launch at anytime in the future,



- ✓ 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 ALL other “non-nuclear deflection” options will require much earlier warning of at least 10 to 20 years.

Suborbital Nuclear Intercept/Pulverization Mission Scenario



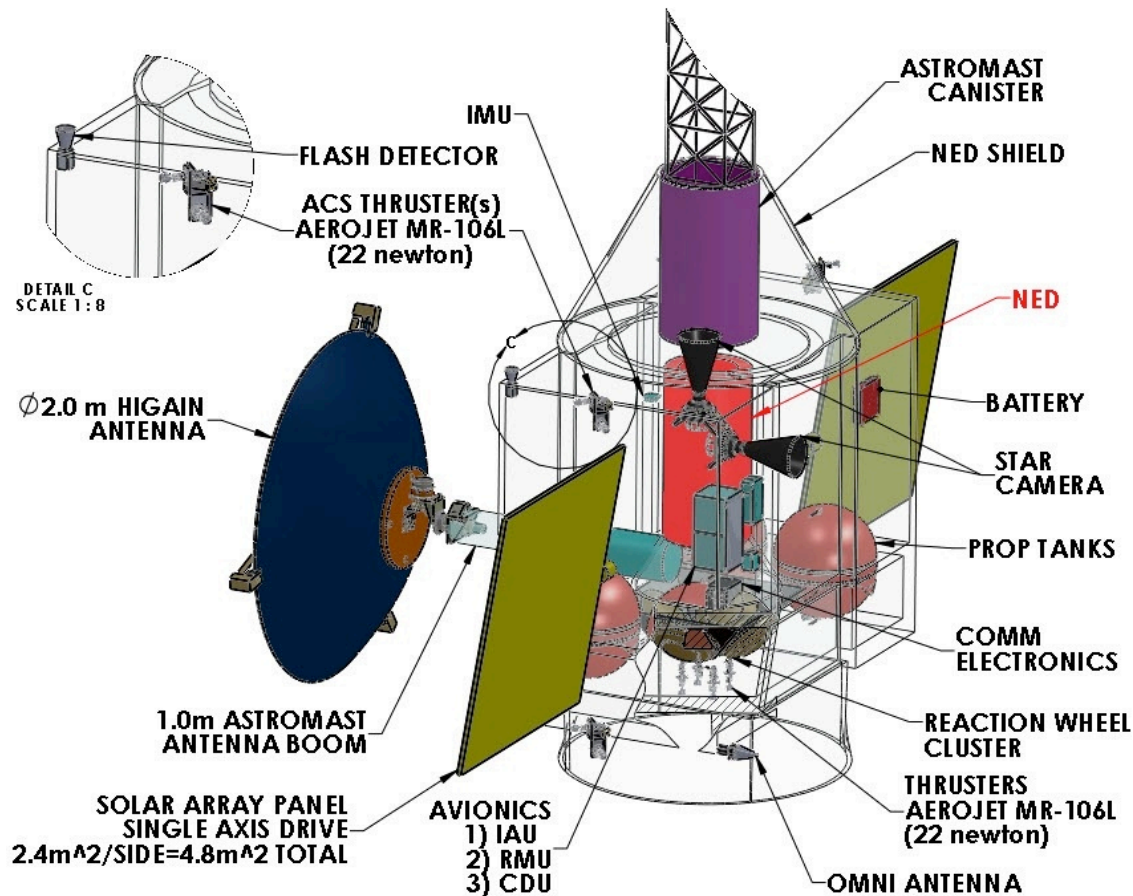
AAS-2014-281
AIAA-2014-4460
PDC 2015



HAIV Design by NASA GSFC



for a Flight Validation Mission (\$500M)



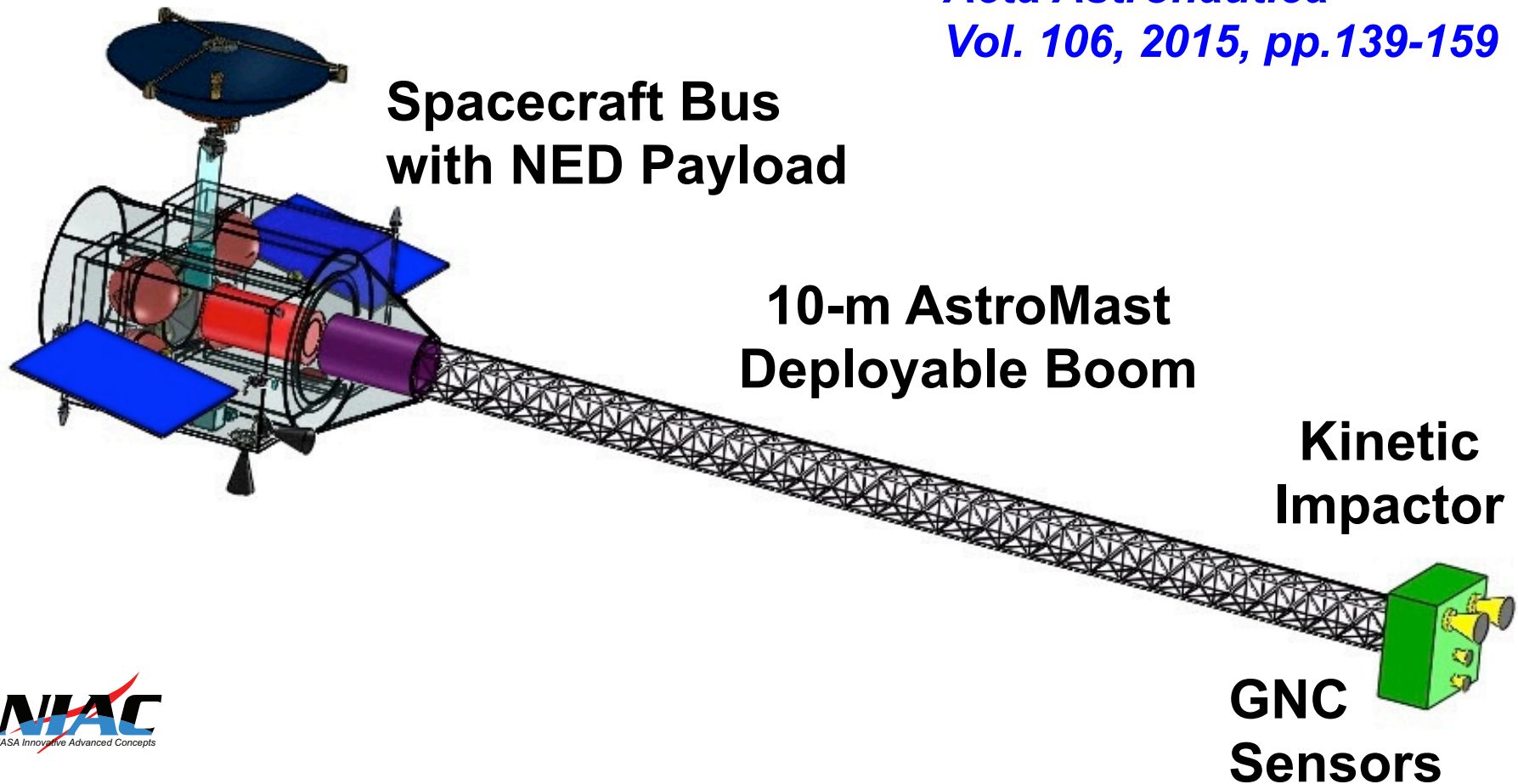
Atlas V



Acta Astronautica
Vol. 106, 2015, pp.139-159

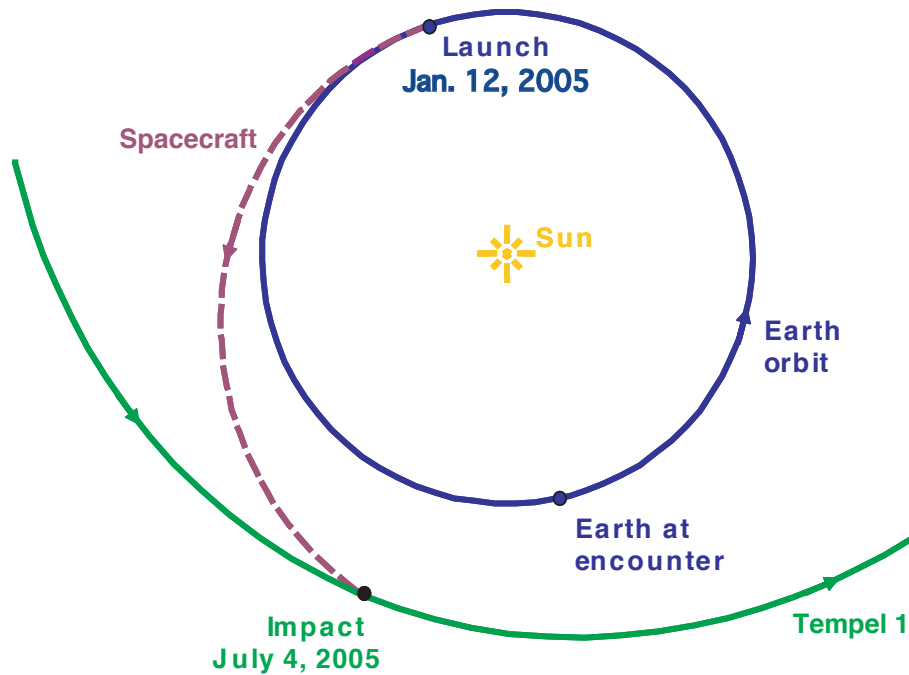
HAIV Design by the Mission Design Lab (MDL) of NASA Goddard Space Flight Center

Acta Astronautica
Vol. 106, 2015, pp.139-159

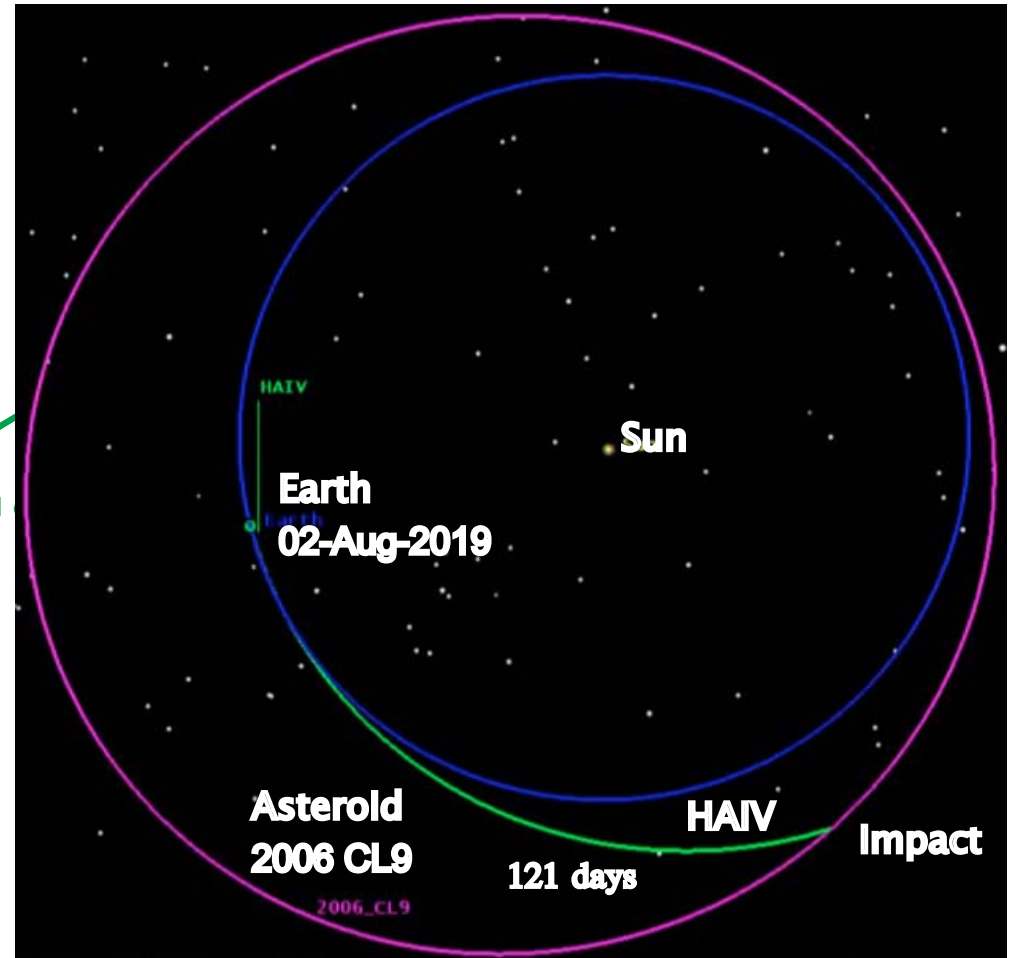




HAIV Flight Validation Mission Trajectory



2005 Deep Impact Mission Trajectory



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



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

Educational Use Only



14 Mar 2036 01:00:00.000

Time Step: 3600.00 sec



NIAC Study Summary

Early Warning (> 10 yrs)

“Build and Launch”
(Deflection)

> 2 yrs

“Build and Launch”
(Deflection vs. Disruption)

< 1 yr



“Ready to Launch” (Disruption)



ATLAS Last Alert



ATLAS project head Dr. John Tonry with a conceptual drawing for an ATLAS telescope. The project would use two of these 20-inch telescopes. Credit: UH/IfA

3-week (> 140 m)

“Ready to Launch”
(Interplanetary)

1-week (> 45 m)

1 day – 1 wk
“Ready to Launch”
(inside/outside lunar orbit)

IPBM/HAIV
\$200M - \$500M



Thank You !