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

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Ready to Launch  

Build and Launch

2006 NEO Report by NASA
2010 NEO Report by NRC

Nuclear

Sufficient Warning Time for Deflection

Civil Defense

Warning Time (Years)
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?
• 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)?

The 1 km wide Barringer Meteor Crater caused by a 20 to 50 m nickel-iron meteorite impact
• A practical innovative 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.

• The capability of the ATLAS last alert system needs to be further exploited for active planetary defense.
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 2015-2016.

- 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"
• If our proposed flight 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 ALL other “non-nuclear deflection” options will require much earlier warning of at least 10 to 20 years.
Our proposed flight 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, an innovative yet practical solution to NASA’s Asteroid Grand Challenge has been found;
• 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, an innovative yet practical solution to NASA’s Asteroid Grand Challenge has been found; however, further studies as well as a flight validation mission is needed.
NIAC 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.
- \( \Delta V = 10 \text{ km/s} \) requires a 96% propellant mass (300-s Isp)
- \( \Delta V = 30 \text{ km/s} \) 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)
Precision Terminal Intercept Guidance

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

Cameras identify target NEO

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

NED Payloads

- Delta IV Heavy
  - 1500 kg NED
  - (∼2 Mt yield)

- Delta IV M+
  - 1000 kg NED
  - (∼1 Mt yield)

- Delta II Clasaurus II
  - 300 kg NED
  - (∼300 kt yield)
Fragmentation 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
Terminal Intercept Guidance Using Visual and Infrared Seekers
\( \vec{R}_S \)

\( \vec{P}_1 \)

\( \vec{P}_3 \)

\( \vec{R}_3 \)

\( \vec{R}_1 \)

Sun

Target Asteroid Body-Fixed Reference Frame \( A \)

Asteroid Surface Element
HAIV Design by NASA GSFC for a Flight Validation Mission

Atlas V

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

Spacecraft Bus with NED Payload

10-m AstroMast Deployable Boom

Kinetic Impactor

GNC Sensors

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HAIV Flight Validation Mission Trajectory

2005 Deep Impact Mission Trajectory
Suborbital Nuclear Intercept and Fragmentation Mission Scenario

Minuteman III
6.6 km/s

20 minutes
2,500 km max

Asteroid

SM-3 IIA

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

Early Warning (> 10 yrs)

> 2 yrs

“Build and Launch”
(Deflection vs. Disruption)

< 1 yr

“Ready to Launch” (Disruption)

ATLAS Last Alert

3-week (> 140 m)

“Ready to Launch”
(Interplanetary)

1-week (> 45 m)

1 day – 1 wk

“Ready to Launch”
(inside/outside lunar orbit)
Asteroid Deflection Research Center

Ready to Launch

Build and Launch

2006 NEO Report by NASA
2010 NEO Report by NRC
(2005 NEPW Report by NRC)

Nuclear

Sub Orbital HAIV Mission

Interplanetary HAIV Mission (Disruption)

Civil Defense

Nuclear Standoff Kinetic Impactors Gravity Tractors (Deflection)

Warning Time (Years)

10000 (meters)

2014 RC
Chelyabinsk Meteorite

2012 DA14