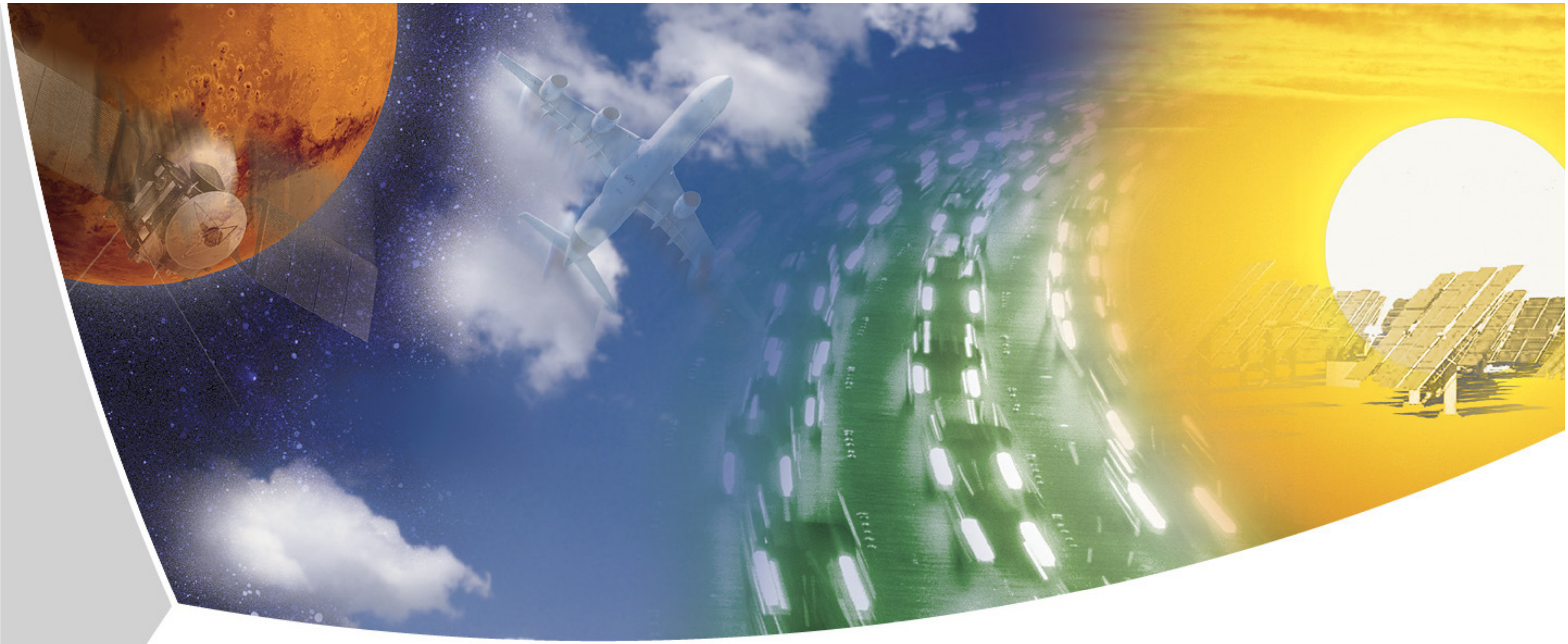

Mitigation of the NEO Impact Threat

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DLR Deutsches Zentrum
für Luft- und Raumfahrt e.V.
in der Helmholtz-Gemeinschaft

The NEOShield Consortium

Financed via European Commission's FP7 funding programme, 2011 Call:
"Prevention of impacts from near-Earth objects (NEOs) on our planet"
Total NEOShield funding = 5.8 million euro. Duration = 3.5 years. Start Jan 2012

NEOShield's primary aim: **investigate in detail the three most promising mitigation techniques: *Kinetic Impactor, Blast Deflection, Gravity Tractor*.**

Partner organisations:
German Aerospace Center (DLR), Berlin *Coordinating partner*
Observatoire de Paris (LESIA and IMCCE)
Centre National de la Recherche Scientifique (Observatoire de la Côte d'Azur)
Open University
Fraunhofer – Ernst-Mach-Institut
Queen's University Belfast
Astrium UK+ DE + FR (*supervisory interface for technical work packages*)
Deimos Space
Carl Sagan Center, SETI Institute
TsNIIMash (Roscosmos)
University of Surrey

The NEOShield Project:
Science

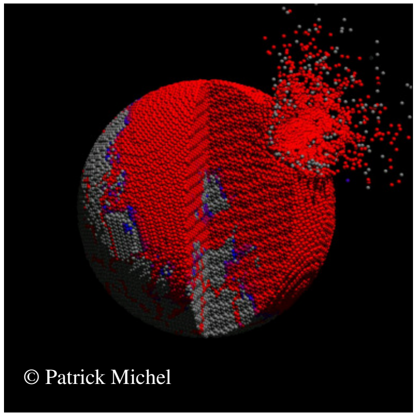
Main scientific themes/tasks of the project:

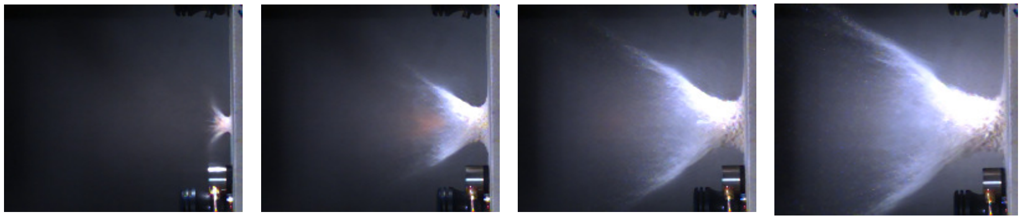
- **Physical properties of NEOs:** **Analyze properties from the point of view of mitigation requirements; estimate most likely properties of the next mitigation candidate; provide requirements for lab. impact experiments, modelling and demo-mission target selection.**

- **Lab. experiments on impacts -** **into asteroid surface analogue materials; validation of impact modelling at small scales.**

- **Numerical simulations:** **Impact and momentum transfer modelling scaled to realistic NEO sizes.**

- **Mitigation reconnaissance:** **Determine requirements, strategy, instrumentation, for ground-based facilities and space missions. Verify that the NEO deflection was achieved.**





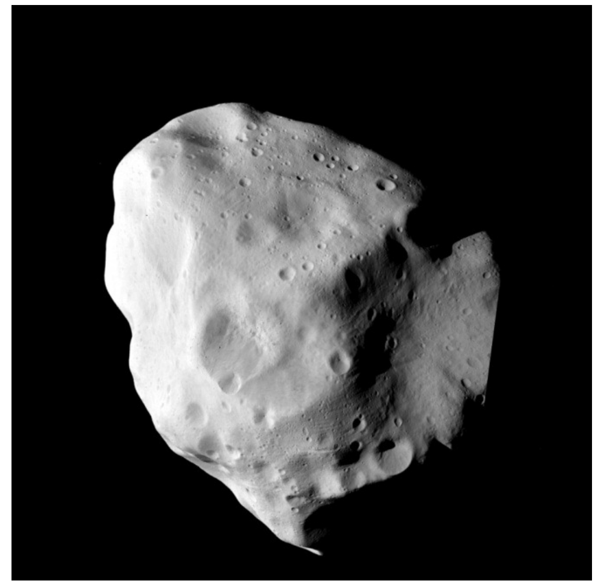
Fraunhofer EMI

Deutsches Zentrum für Luft- und Raumfahrt e.V. in der Helmholtz-Gemeinschaft

The NEOShield Project

Mitigation demonstration missions

Theoretical work, lab. experiments, computer modelling is essential, but must be followed up with attempts to change the orbit of a real NEO.



NEOShield tasks include:

- **Design demo missions: Provide detailed designs of technically and financially realistic missions to demonstrate the effectiveness of mitigation techniques. Investigate mission funding and implementation options.**
- **Choose suitable mission targets: Identify and characterize suitable target NEOs for mitigation demo missions.**
- **Decision-making tools: Develop software to aid decision-making for an effective response to the particular circumstances of an impact threat.**

www.NEOShield.net

Kinetic Impactor

A massive spacecraft impacts the asteroid at high relative velocity ($v > 10\ km\ s^{-1}$), **thereby transferring momentum and modifying its orbit**.

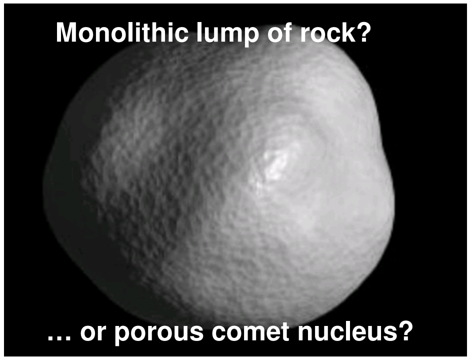
Advantage:

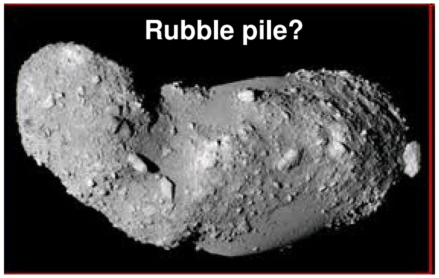
The technology is straightforward and (almost) ready.

Challenges:

- Automonous guidance, navigation and control performance for a high speed impactor.
- How does **impactor momentum transfer** depend on the bulk density, porosity, mineralogy, internal structure, etc. of the target NEO?
- How much impactor kinetic energy may be wasted in fragmentation and restructuring?

Momentum transfer in the case of a porous body is significantly less efficient. Rubble piles?



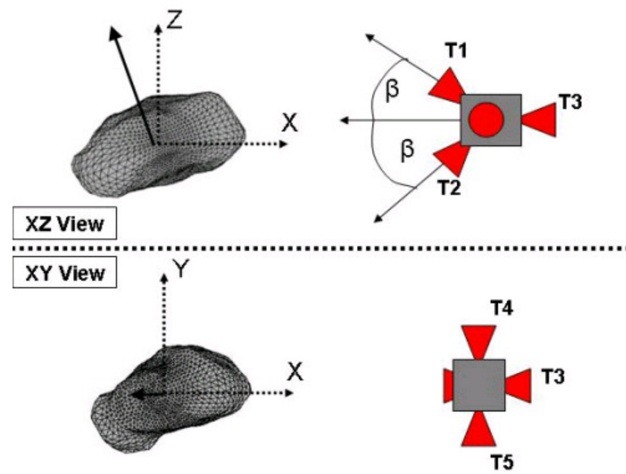


Gravity Tractor

A massive spacecraft positions itself close to the NEO and fires its thrusters so as to maintain a constant distance from the target. **The weak gravitational force between tractor and NEO acts as a tow-rope.**

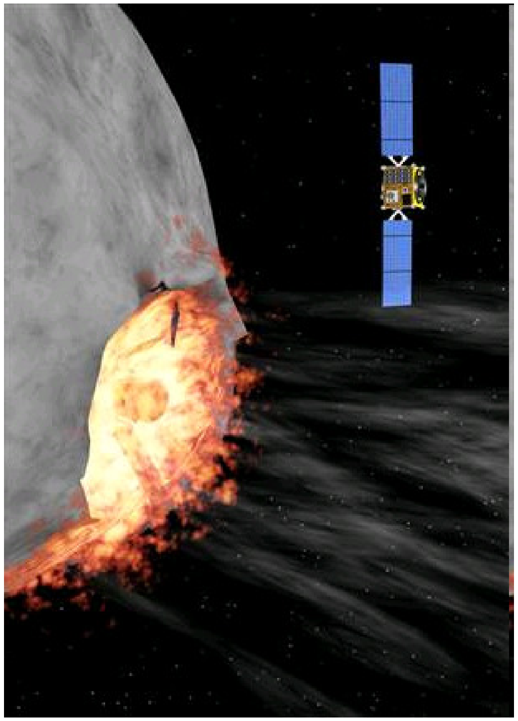
Advantage: no contact with the NEO; very little prior knowledge of physical properties required (only mass, shape, rotation vector).

Challenge: requirements for autonomous spacecraft control procedures to manage hovering station keeping and maintain stability of the traction system over a long period of time in the (very nearby) presence of an irregular rotating mass.



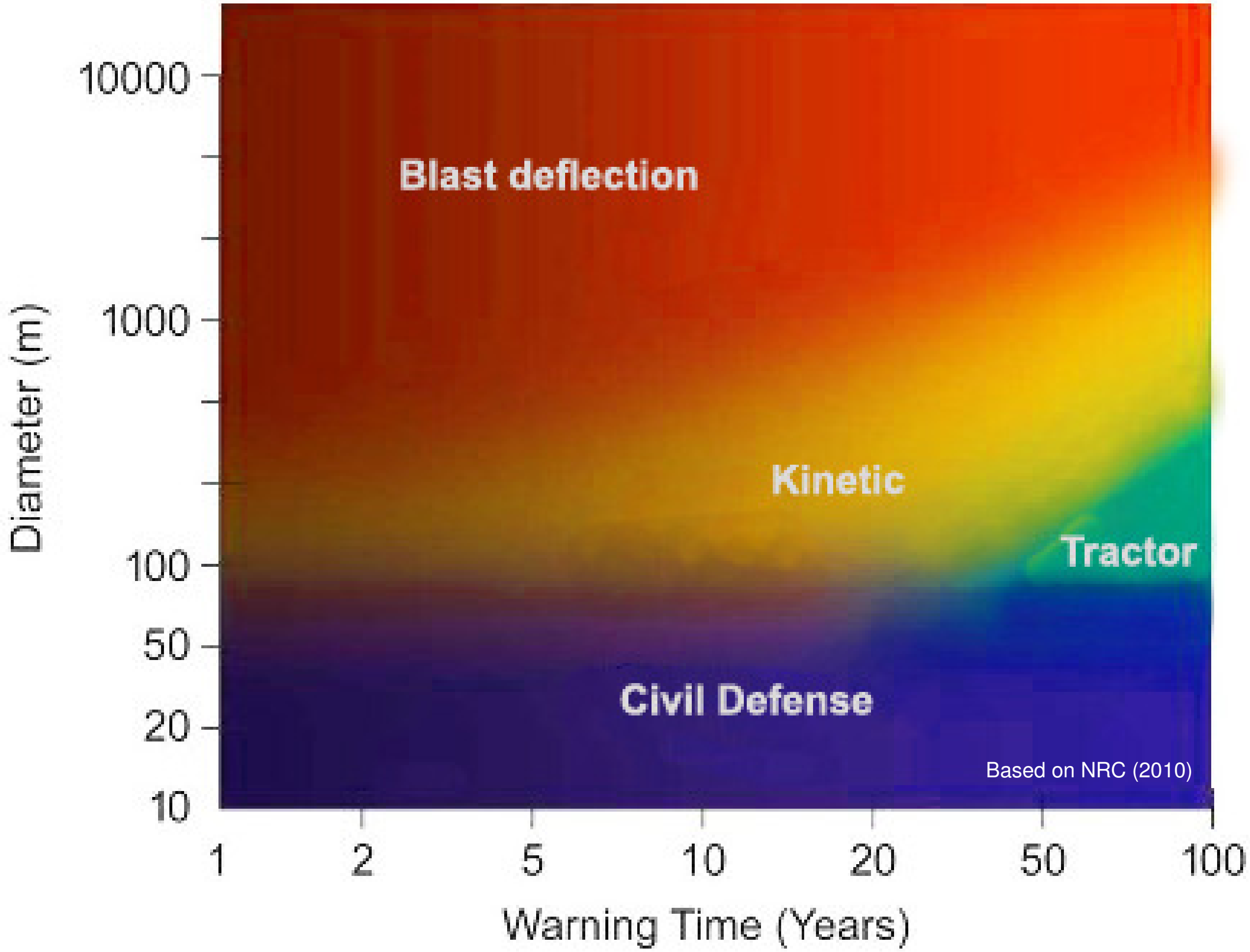
Blast Deflection

Exploding a nuclear device near, on, or below the surface of the asteroid would transfer an impulse to the asteroid by vaporizing and ejecting material from the surface. Small objects (D<100 m) could be destroyed: the fragments should present less danger than the original object. Considered a method of last resort, in the absence of other alternatives.



- **Advantage: Provides the "biggest bang per buck" of all methods.**
- **Challenges: Requires knowledge of the internal structure and surface material. Disruption of large objects may give rise to many hazardous impactors instead of just one. Danger during launch. Political issues.**

Mitigation methods



Mitigation demo-mission ideas

Example: ESA's Don Quijote Study 2005-2007

Two-spacecraft impactor mission:

***Sancho* (rendezvous)**

***Hidalgo* (impactor)**

Target size ~ 500 m

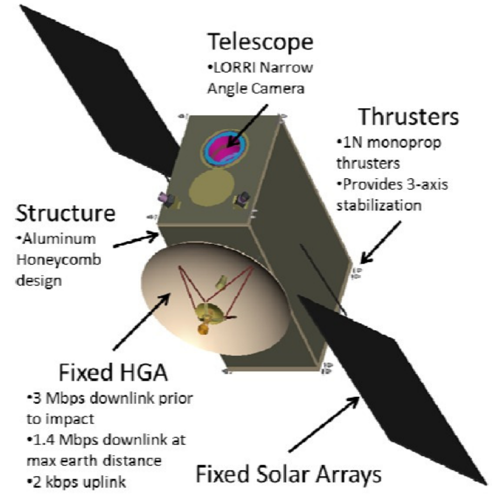
Objectives:

- **Pre-impact (Sancho 7 months at target): Measure size, shape, bulk density, mass distribution.**
- **Impact of Hidalgo: Info. on regolith properties, internal structure.**
- **Post-impact (Sancho 3-4 months at target): Measure Δv, observe impact effects.**

Mitigation demo-mission ideas

Example: AIDA / DART

- currently at the feasibility study phase



1 or 2 spacecraft impactor mission:

***DART* (300kg impactor) NASA**

***AIM* (rendezvous) ESA**

Target: 150 m moon of the binary NEO Didymos (mass of the moon ~9 million tonnes)

Impact time: 2022 during close Earth approach.

AIDA (= AIM + DART) would do a full characterization of the kinetic impact and of the asteroid and moon.

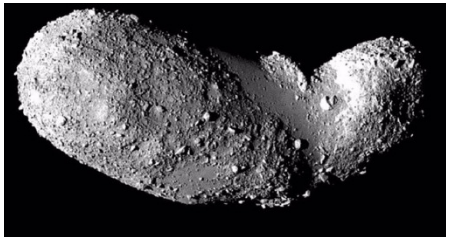
DART without AIM will use ground-based observatories to measure the 0.5-1% expected change in orbital period of the moon about the primary object. This will be a very basic demonstration of asteroid deflection for a low cost.

NEOShield & The Space Mission Planning Advisory Group

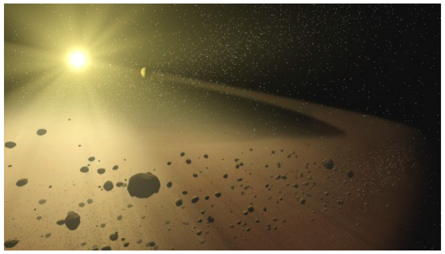
NEOShield tasks and those of the Space Mission Planning Advisory Group have much in common.

Future work in this area should include:

- **Exploration of NEOs:** **Further discovery and characterization of the NEO population is required. The population of small NEOs (D = 50 – 300 m; expected about 200,000 objects) remains largely unexplored. We need to determine sizes, albedos, spin, mineralogy, shapes, densities, structures, porosities, frequency of binaries, frequency of rubble piles, etc. Novel techniques specifically suited to very small asteroids should be investigated.**



- **Novel techniques for NEO mitigation:** **The first hazardous NEO to trigger a space-borne mitigation action will probably be in the size range 50 m – 200 m (could destroy a large city or national region). Alternative techniques to deal with very small asteroids should be investigated.**



In conclusion:

- The NEO impact threat is a truly global problem.
- Coordination of diverse competences and multiple technologies is vital.
- Collaboration among space agencies and international consortia is essential in providing a focused effort and an internationally agreed consensus of scientific and technical information in support of political decision-makers.
- We believe NEOShield is a good example of the type of scientific and technical collaboration that will be required to carry out the work of the Space Mission Planning Advisory Group.