SEVENTH FRAMEWORK PROGRAMME

HORIZON 2020
THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION

Beyond NEOShield
A Roadmap for Near-Earth Object Impact Mitigation

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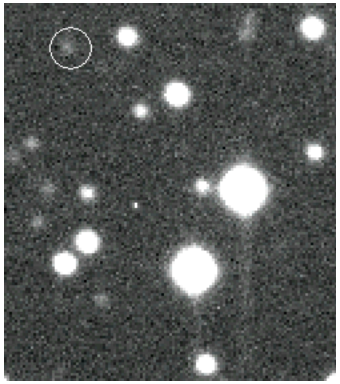
NEOShield Project Coordinator

NEOShield

DLR

The Impact Hazard - What Should We Do?

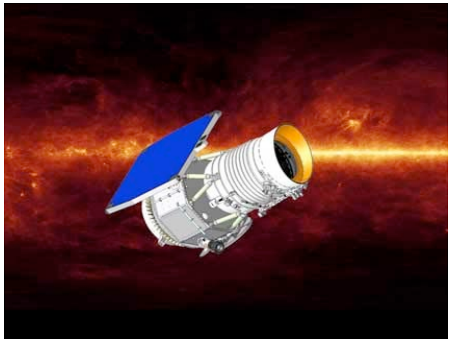
- **Search the night skies for (small) near-Earth objects.**
- **Understand their compositions and physical properties.**
- **Carry out NEO deflection test missions.**



Don Quijote, kinetic-impactor deflection concept (ESA).

Missions to asteroids and comets, e.g. Hayabusa (Japan), OSIRIS-REx (NASA), Rosetta (ESA)

Ground-based telescopes, e.g. Pan-STARRS.



Telescopes in space, e.g. Spitzer, WISE.

The NEOShield Project
Brief description (1/2)

PRIMARY AIM: investigate in detail the three most promising mitigation techniques: *kinetic impactor, gravity tractor, blast deflection*.

Main themes/tasks of the project:

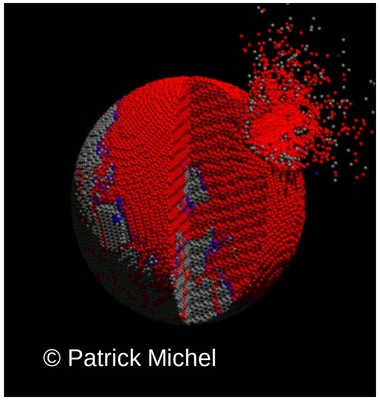
1. Science

- **Physical properties of NEOs:** **Analyze properties from the point of view of mitigation requirements; what are the most likely properties of the first object to trigger space-borne mitigation action?**

- **Mitigation precursor reconnaissance:** **Determine requirements, strategy, instrumentation, for ground-based facilities and space missions.**

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

- **Numerical simulations:** **Impact and momentum transfer modeling scaled to realistic NEO sizes.**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The NEOShield Project
Brief description (2/2)

Main themes/tasks of the project (continued):

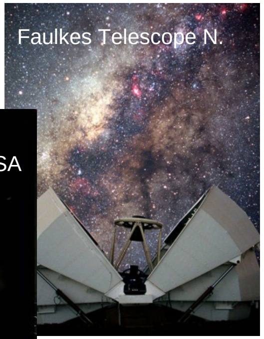
2. Mitigation demonstration missions

- **Suitable mission targets:** **Identify and characterize suitable target NEOs for mitigation demo missions.**

- **Space mission design:** **Provide detailed designs of technically and financially realistic missions to demonstrate the effectiveness of mitigation techniques. Investigate mission funding and implementation options.**

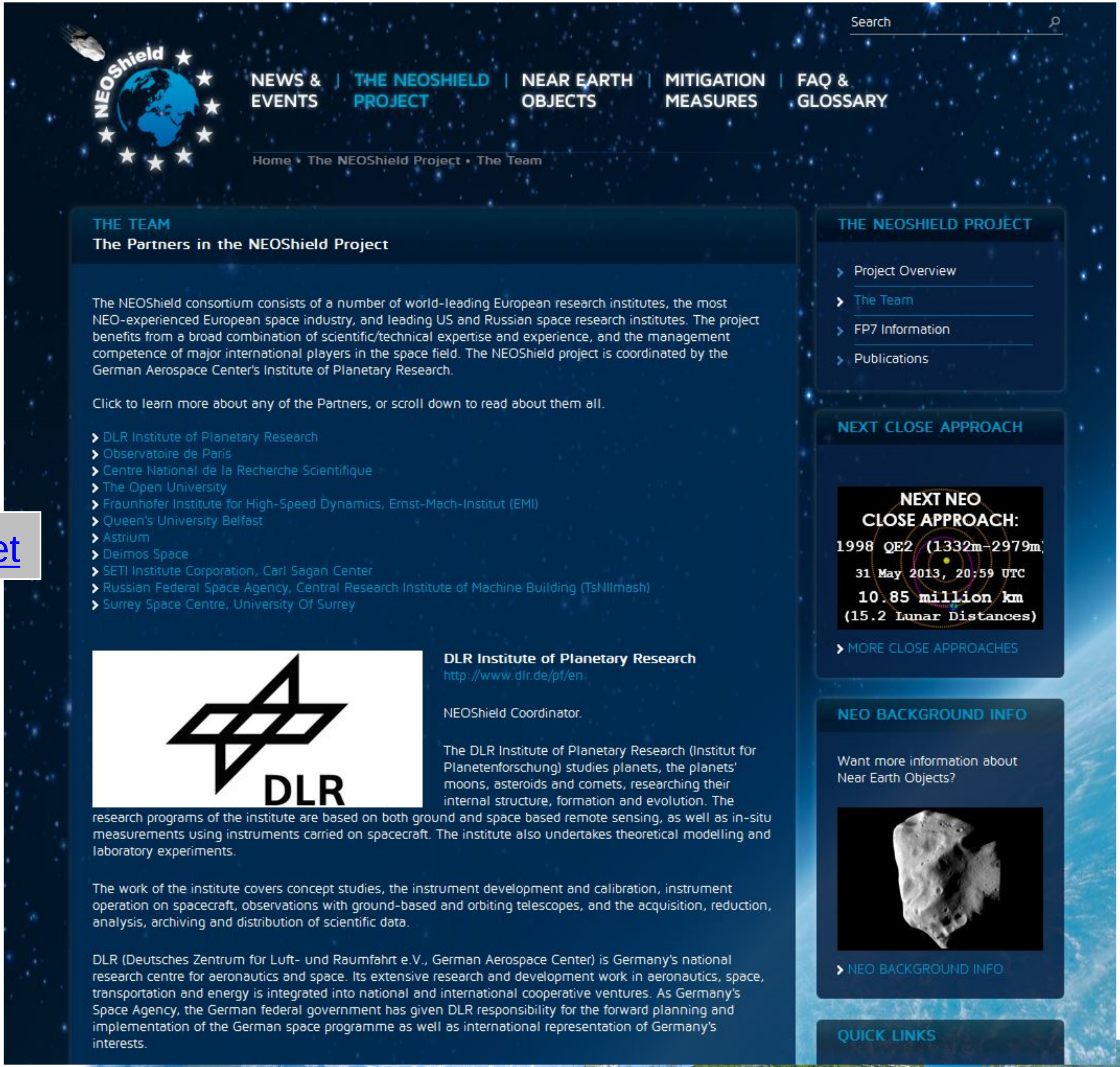
3. Global response campaign roadmap

- **Impact threat response strategy:** **Develop a decision-making tool to aid in response planning. Develop a global response roadmap in collaboration with partners such as the UN, space agencies, etc.**



The NEOShield Consortium

Participant organisation	Leading personnel	Country
German Aerospace Center (DLR), Berlin (*Coordinating partner*)	A. W. Harris, L. Drube	Germany
Observatoire de Paris	LESIA: M. A. Barucci, M. Fulchignoni IMCCE: D. Hestroffer, W. Thuillot	France
Centre National de la Recherche Scientifique (Observatoire de la Côte d'Azur, Nice)	P. Michel	France
Open University	S. F. Green	UK
Fraunhofer – Ernst-Mach-Institute, Freiburg	F. Schäfer, T. Hoerth	Germany
Queen's University Belfast	A. Fitzsimmons	UK
Astrium (Airbus D&S) (*supervisory interface for technical work packages*)	A. Falke, U. Johann M. Chapuy, E. Kervendal M. Trichas	Germany France UK
Elecnor Deimos, Madrid	J. L. Cano	Spain
Carl Sagan Center, SETI Institute	D. Morrison	USA
TsNIIMash, Roscosmos	Y. Lipnitsky, S. Meshcheryakov,	Russia
University of Surrey	V. Lappas, N. Ummen	UK



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THE TEAM

The Partners in the NEOShield Project

The NEOShield consortium consists of a number of world-leading European research institutes, the most NEO-experienced European space industry, and leading US and Russian space research institutes. The project benefits from a broad combination of scientific/technical expertise and experience, and the management competence of major international players in the space field. The NEOShield project is coordinated by the German Aerospace Center's Institute of Planetary Research.

Click to learn more about any of the Partners, or scroll down to read about them all.

- DLR Institute of Planetary Research
- Observatoire de Paris
- Centre National de la Recherche Scientifique
- The Open University
- Fraunhofer Institute for High-Speed Dynamics, Ernst-Mach-Institut (EMI)
- Queen's University Belfast
- Astrium
- Deimos Space
- SETI Institute Corporation, Carl Sagan Center
- Russian Federal Space Agency, Central Research Institute of Machine Building (TsNIImash)
- Surrey Space Centre, University Of Surrey

DLR

DLR Institute of Planetary Research
http://www.dlr.de/pf/en

NEOShield Coordinator.

The DLR Institute of Planetary Research (Institut für Planetenforschung) studies planets, the planets' moons, asteroids and comets, researching their internal structure, formation and evolution. The research programs of the institute are based on both ground and space based remote sensing, as well as in-situ measurements using instruments carried on spacecraft. The institute also undertakes theoretical modelling and laboratory experiments.

The work of the institute covers concept studies, the instrument development and calibration, instrument operation on spacecraft, observations with ground-based and orbiting telescopes, and the acquisition, reduction, analysis, archiving and distribution of scientific data.

DLR (Deutsches Zentrum für Luft- und Raumfahrt e.V., German Aerospace Center) is Germany's national research centre for aeronautics and space. Its extensive research and development work in aeronautics, space, transportation and energy is integrated into national and international cooperative ventures. As Germany's Space Agency, the German federal government has given DLR responsibility for the forward planning and implementation of the German space programme as well as international representation of Germany's interests.

THE NEOSHIELD PROJECT

- Project Overview
- The Team
- FP7 Information
- Publications

NEXT CLOSE APPROACH

NEXT NEO CLOSE APPROACH:
1998 QE2 (1332m-2979m)
31 May 2013, 20:59 UTC
10.85 million km
(15.2 Lunar Distances)

MORE CLOSE APPROACHES

NEO BACKGROUND INFO

Want more information about Near Earth Objects?

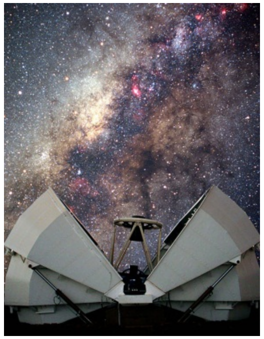
NEO BACKGROUND INFO

QUICK LINKS

www.neoshield.net

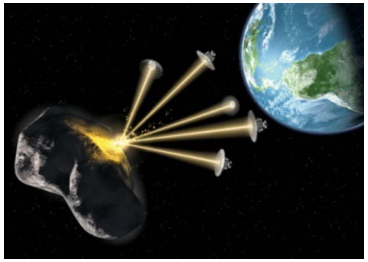
NEO Impact Mitigation:

the NEOShield perspective



- **NEO physical properties:** We have only started to understand the mitigation-relevant physical properties of NEOs of different sizes and compositions.

- **NEO targeting**: Accurate guidance, navigation, and control of a high-velocity (> 10 km s^{-1}) kinetic impactor spacecraft targeting a small NEO requires further development work.



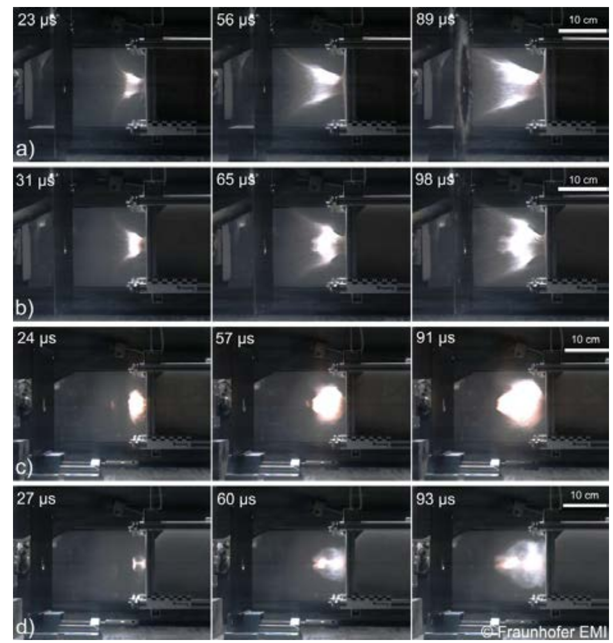
- **Novel techniques for NEO mitigation:** The first hazardous NEO to trigger a space-borne mitigation action will probably be in the size range 50 m – 200 m (could destroy a large city or national region). Alternative techniques to deal with very small asteroids should be investigated.

- **Space mission(s) to test mitigation techniques are essential**: Theoretical work, lab. experiments computer modelling, must be followed up with attempts to change the orbit of a real NEO.

Examples of Scientific Results from NEOShield

Lab. work with hypervelocity gas guns:

- **Provides detailed characterization of asteroid surface analogue materials required for modelling and numerical simulations of the impact process.**
- **Provides a vivid demonstration of the dependency of the momentum transfer on the target material.**
- **An important task for the future is to design more sophisticated experiments to test the effects of different projectile shapes on the momentum transfer.**



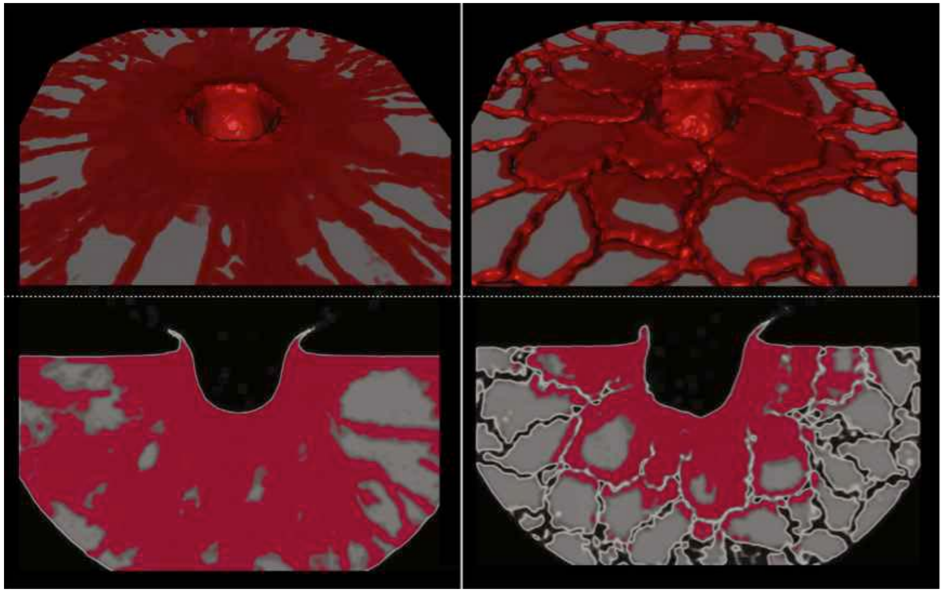
Ejection process for different target materials with different porosities ϕ. a) quartzite (ϕ ~ 3 %), b) sandstone (ϕ ~ 25 %), c) limestone (ϕ ~ 31 %) and d) aerated concrete (ϕ ~ 87 %). The experiments illustrate how the ejecta dynamics depend on the target material properties (from NEOShield Deliverable 4.3).

Fraunhofer Ernst-Mach-Institut, Freiburg

Examples of Scientific Results from NEOShield

Modelling and computer simulations:

- **Determine the magnitude of the additional momentum imparted to an asteroid by the ejecta produced in a high-velocity impact ("kinetic impactor").**
- **Results show the effects of ejecta are small for porous targets, even for very high impact velocities (V_{imp} ~ 15 kms^{-1}). Porosity, strength, impact velocity all play important roles.**



Snapshots of impact simulations on a micro-porous target (left) and a target with both micro- and macro-porosity (right). Regions damaged by the impact are shown in red. The top views are from above the surface, the bottom views show cross-sections, allowing the crater size, depth, and the damaged area inside the target to be seen

From NEOShield Deliverable 3.2
CNRS, Nice

Hypervelocity impacts on asteroids and momentum transfer I. Numerical simulations using porous targets
M. Jutzi, P. Michel: 2014, Icarus, 229, 247

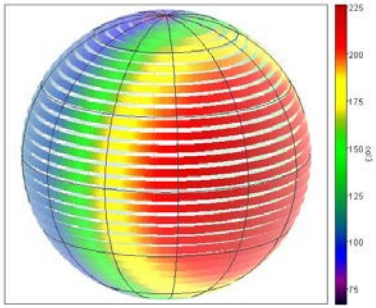
Examples of Scientific Results from NEOShield

Interpretation of thermal-infrared observations of asteroids

Near-Earth Asteroid Thermal Model (NEATM*):

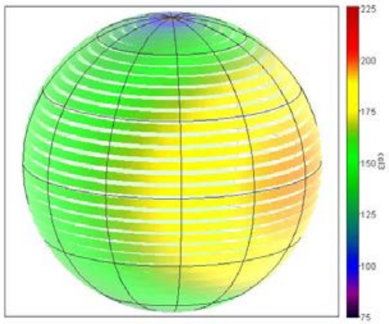
Observations of heat radiation emitted in infrared provide information on size, albedo, and thermal inertia.

Zero TI, η = 1



Low TI (e.g. sandy surface): rapid cooling at dusk.

High TI, η = 2.5

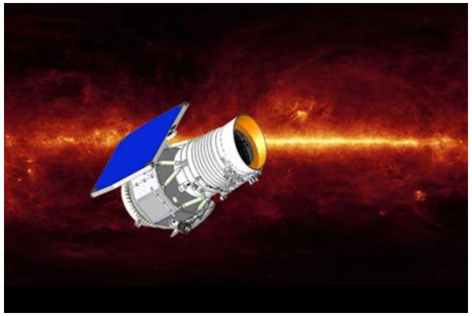


High TI (e.g. solid rock): heat radiation spread around asteroid – noon temperature lower.

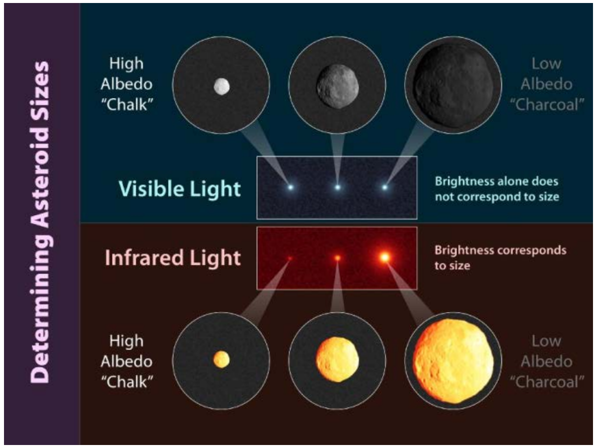
*Harris, A. W. 1998, Icarus, 131, 291

NASA WISE Mission: infrared survey:

Determined sizes and albedos of over 100,000 main-belt and near-Earth asteroids using NEATM.



NASA Wide-Field Infrared Survey Explorer



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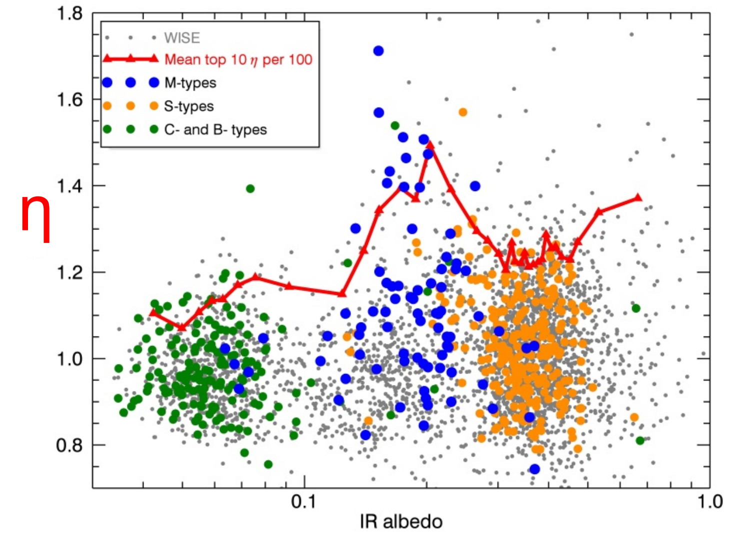

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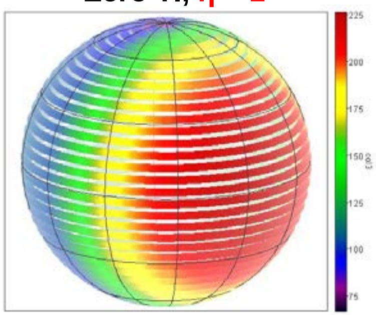

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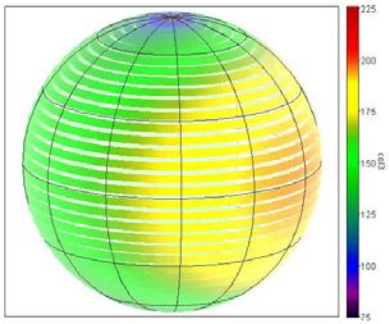

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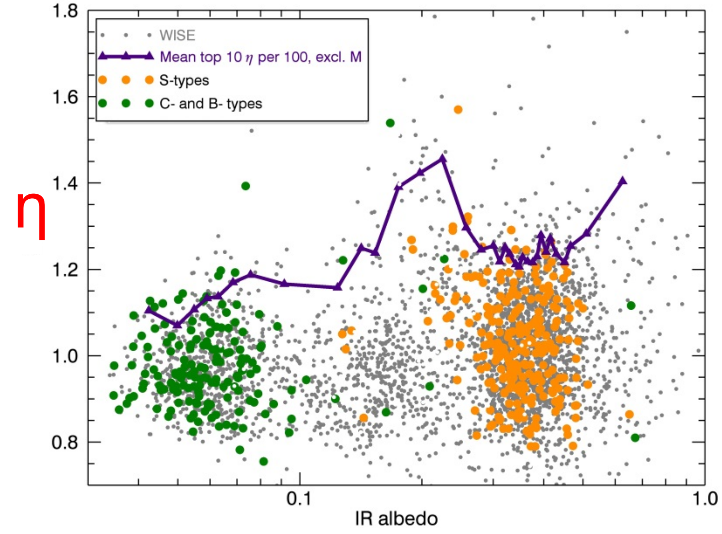

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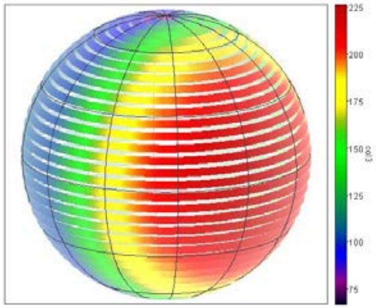

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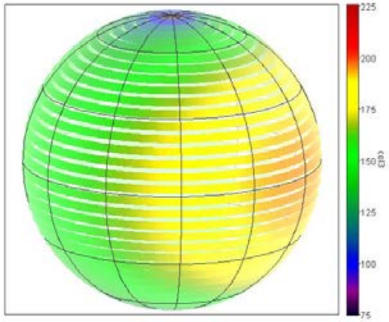

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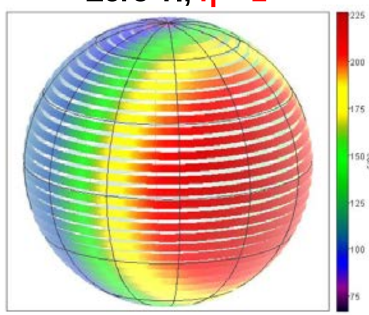

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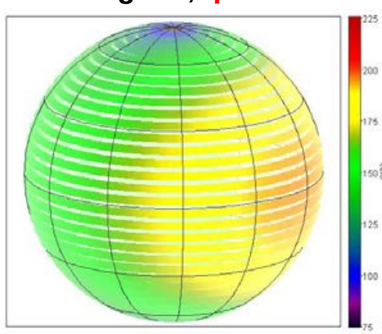

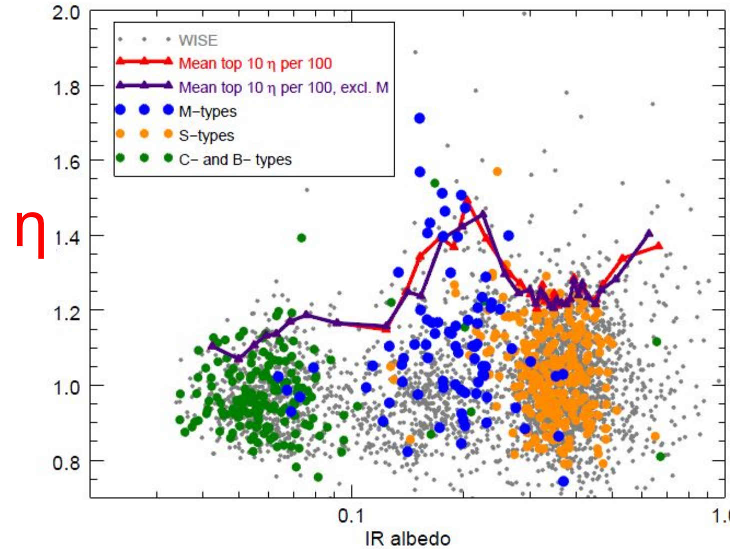

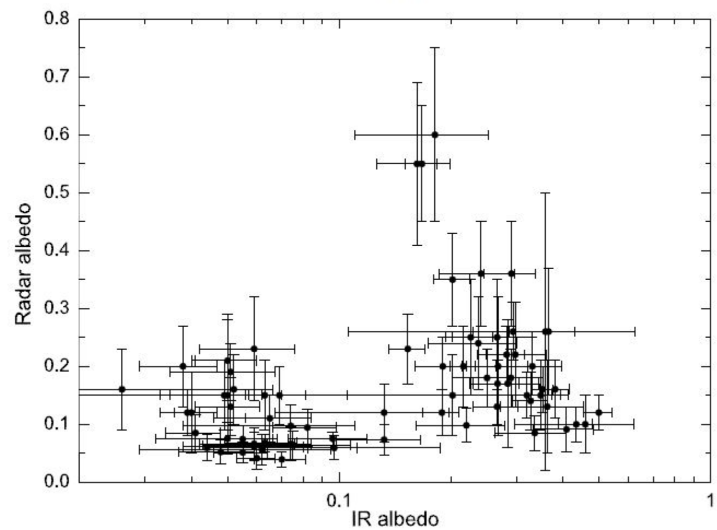

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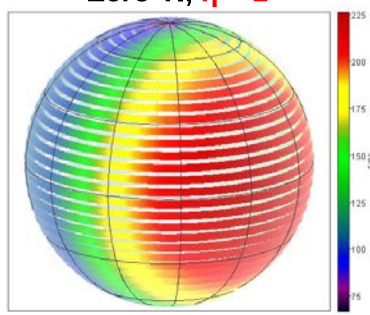

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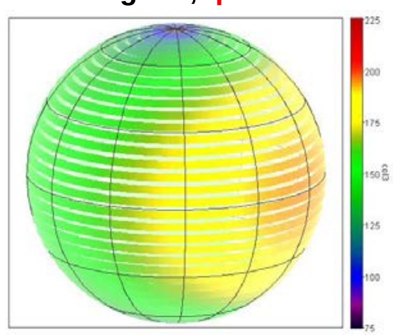

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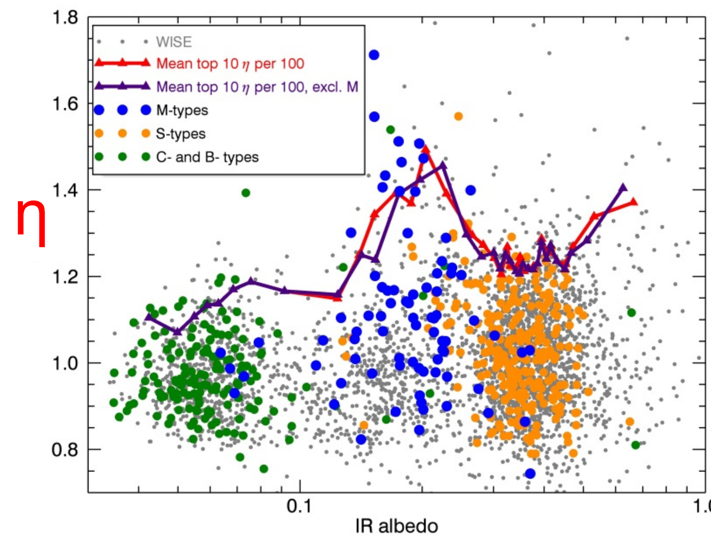

From NEOShield Deliverable 2.1
DLR, Berlin

How to Find Metal-Rich Asteroids
Harris, A. W., Drube, L., 2014,
Astrophysical J. Letters, 785, L4

DLR

Examples of Scientific Results from NEOShield

Why is it important to find metal-rich asteroids?

Examples of two impact events:

30m - 50m diameter stony impactor - exploded in atmosphere.

(Tunguska, Siberia)

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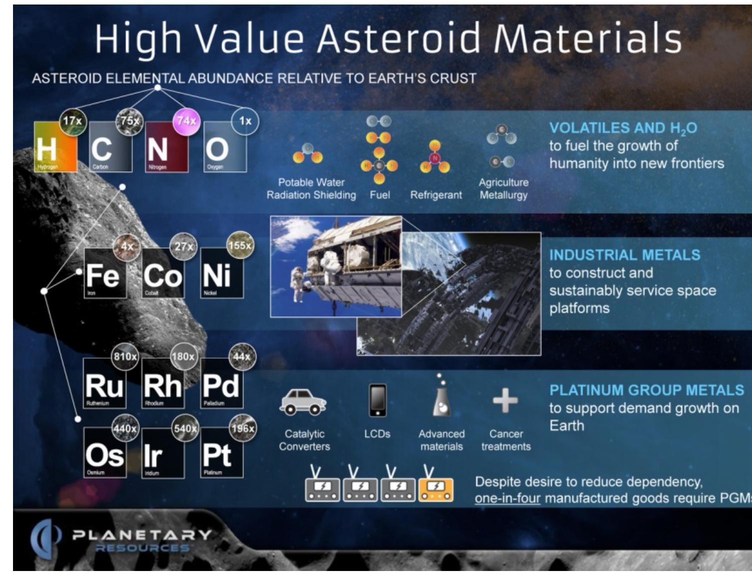
30m - 50m diameter metallic impactor – produced crater (potential for far worse damage).

(Barringer Crater, Arizona)

Planetary Resources:

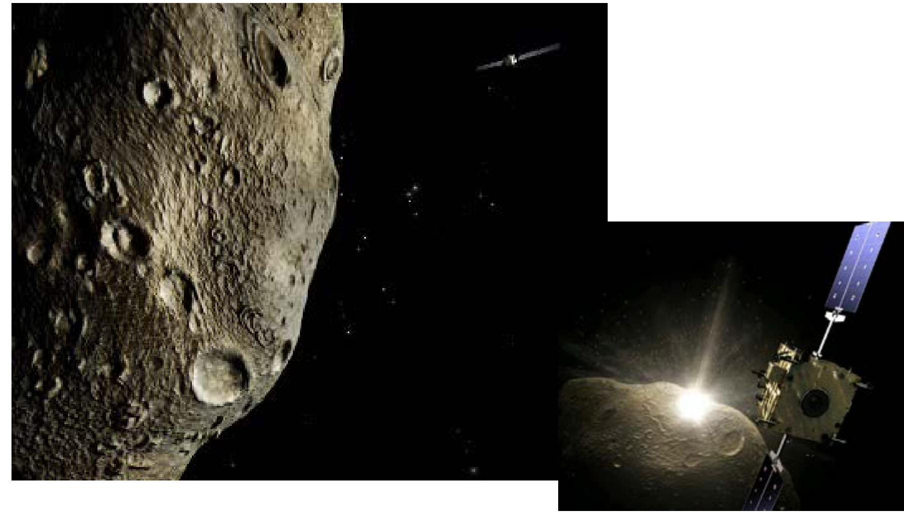


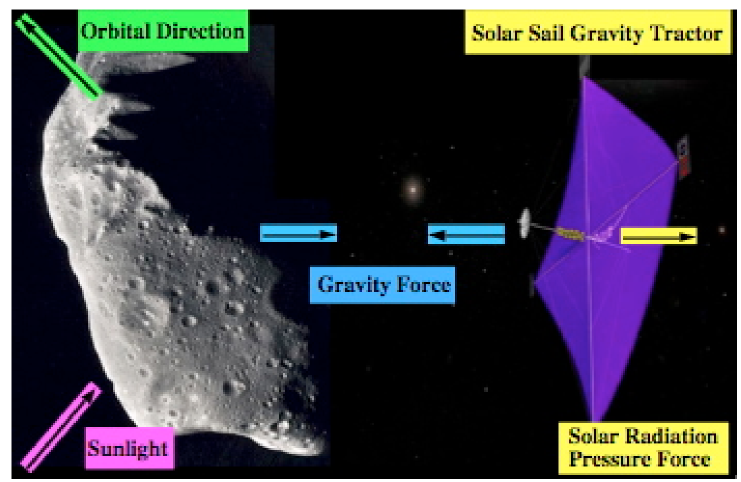
Mitigation Demonstration Missions

- **Back-of-the-envelope calculations can give us some confidence, but there's no substitute for proving we can move an asteroid by actually doing it.**

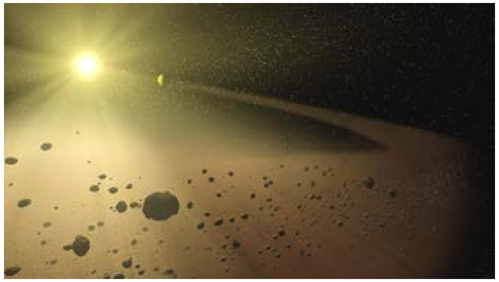
- **NEOShield funding does not stretch to launching a space mission but we aim to provide detailed designs of feasible mitigation demonstration missions, at least of the kinetic impactor and/or gravity tractor methods.**

- **We are working with colleagues at ESA (SSA programme), the UN (COPUOS, Action Team 14 on NEOs), NASA, etc. to lobby for the funding of a mitigation demonstration mission.**



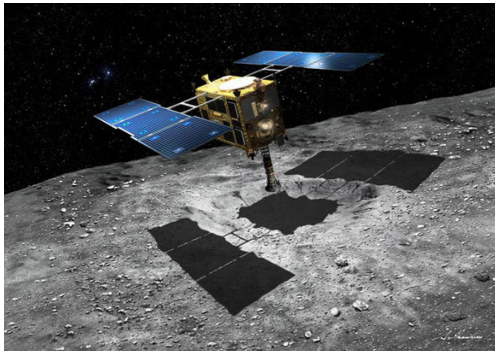


NEO Impact Mitigation:
priorities for future research



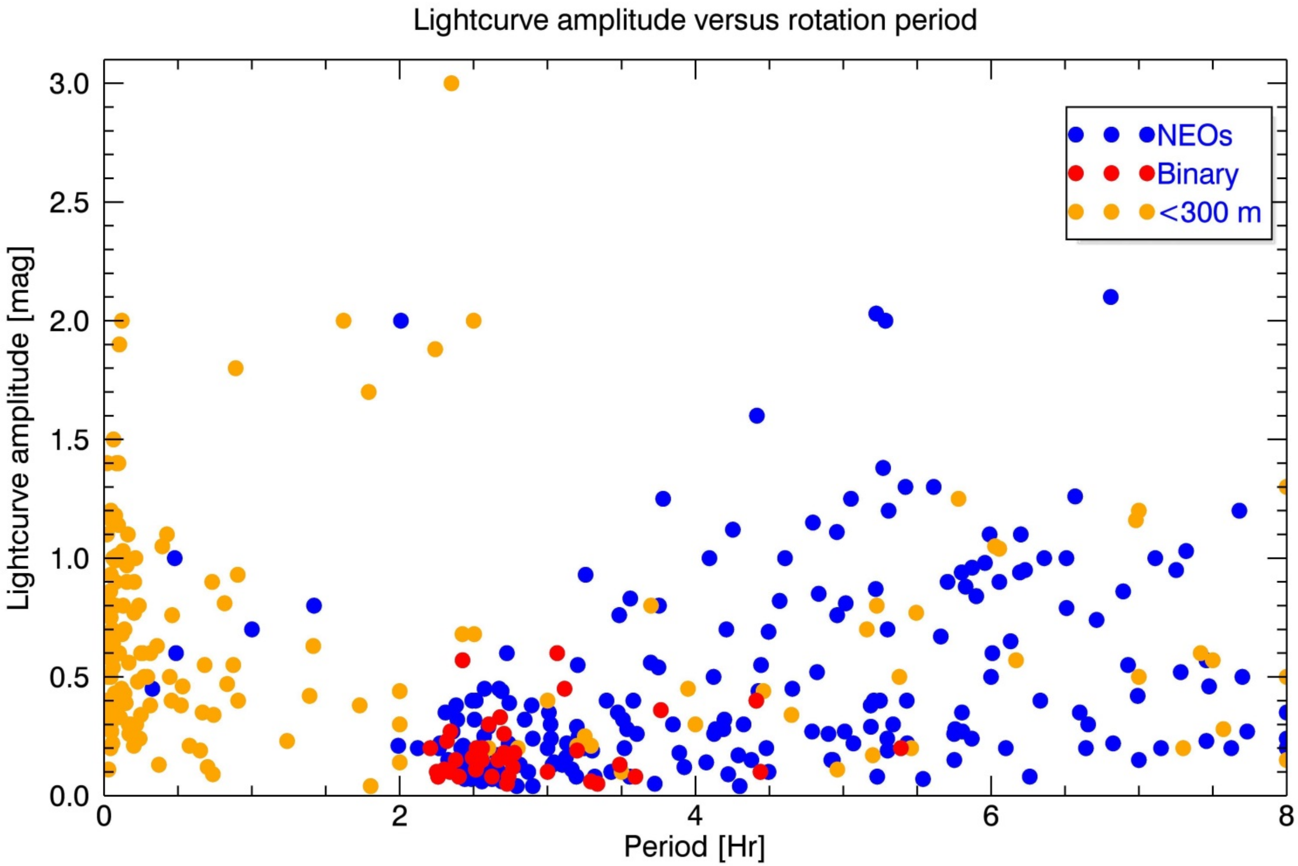
- **Exploration of NEOs:** Further characterization of the NEO population is required. The population of small NEOs (D = 50 – 300 m; about 200,000 objects) remains largely unexplored. We need to determine sizes, albedos, mineralogy, shapes, densities, structures, porosities, frequency of binaries, frequency of rubble piles, etc. Ground-based observations and complementary space missions are essential.

- **Orbiting, hovering, manoeuvring close to a small asteroid:** NEOs have very weak gravity fields. Appropriate space technology needs to be developed.



- **Development of techniques for robotic exploration:** Moving around the surface, surface material sampling and collection, in-situ analysis, sample return to Earth, etc.

NEO Impact Mitigation:
priorities for future research



From NEOShield Deliverable 2.1, DLR, Berlin

Bottom Line

- If we don’t act to protect ourselves a major catastrophic impact of a large near-Earth object is just a matter of time.
- The NEO impact threat is a truly global problem: any country in the world could be affected.
- Space-faring nations should take the lead in developing a mitigation strategy for the planet (under the auspices of the UN).
- Collaboration between space agencies and political decision-makers is essential.