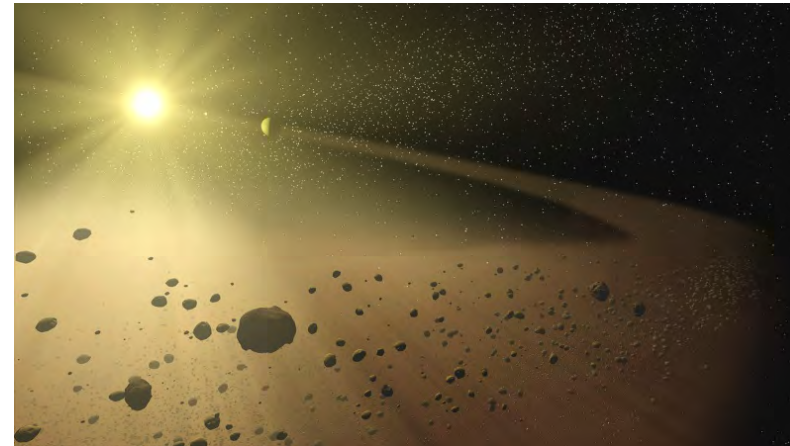
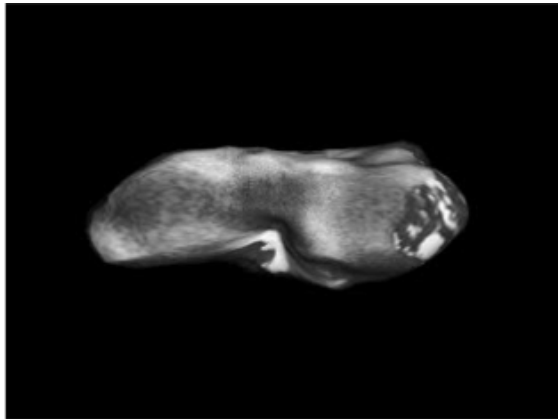


The Status of NEO-related Activities in Germany

Alan Harris

DLR Institute of Planetary Research, Berlin

(Including material provided by Jürgen Oberst and Tra-Mi Ho)



Knowledge for Tomorrow

NEOShield (1 & 2)

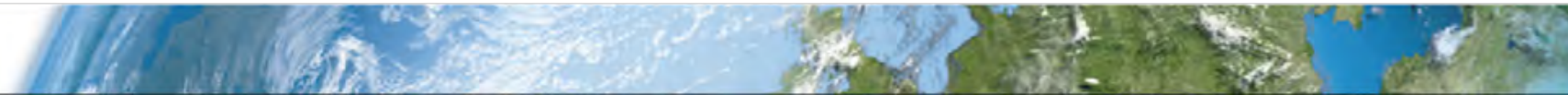


NEOShield-1, FP7:

- **November 2010:** Submitted in response to the European Commission's FP7-Space-2011 call for research proposals. Category:
- **“Prevention of impacts from near-Earth objects (NEOs) on our planet”**
- **January 2012 – June 2015.**
- Total NEOShield funding = 5.8 million euro (13 partner organisations from 6 nations).
- Coordinator: DLR Institute of Planetary Research (A. Harris)

NEOShield-2, Horizon 2020:

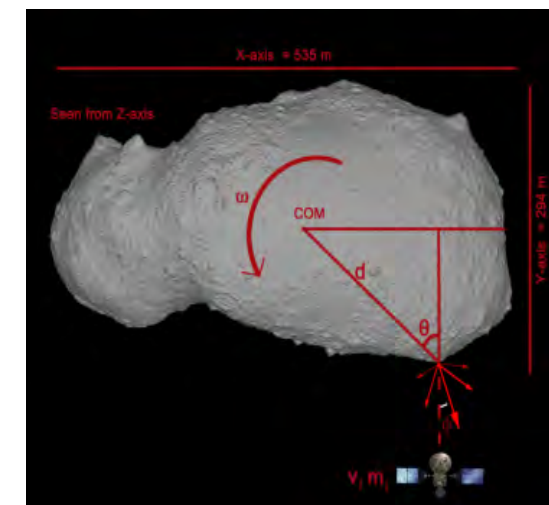
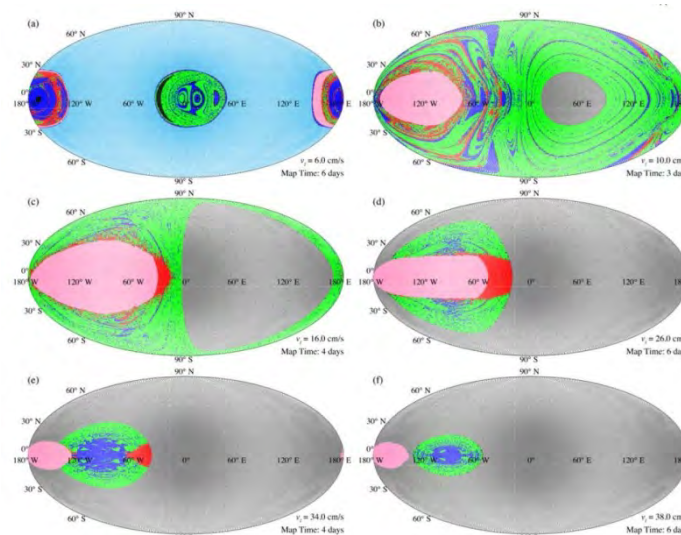
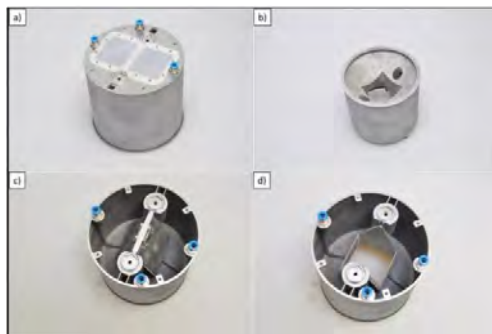
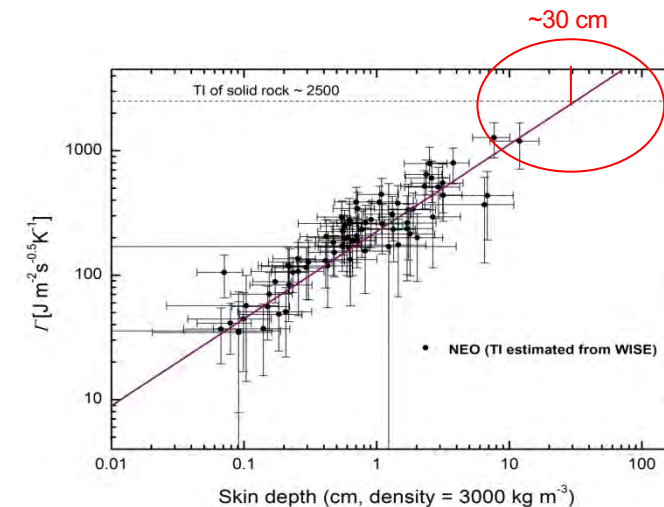
- **“Access technologies and characterization for near-Earth objects”**
- **March 2015 - September 2017.**
- Total NEOShield-2 funding ~ 6 million euro (11 partner organisations from 5 nations).
- Coordinator: Airbus D&S, Germany (A. Falke)



Results from the NEOShield and NEOShield-2 Projects

<http://www.neoshield.eu/>

- Modelling and trade-off studies of NEO deflection methods.
- Detailed studies of feasible space missions to test NEO deflection methods.
- Analyses of observational data on deflection-relevant physical characteristics of NEOs and associated modelling.
- Modelling of impacts on asteroids (kinetic impactor).
- Technical developments in support of in-situ investigations of NEOs.

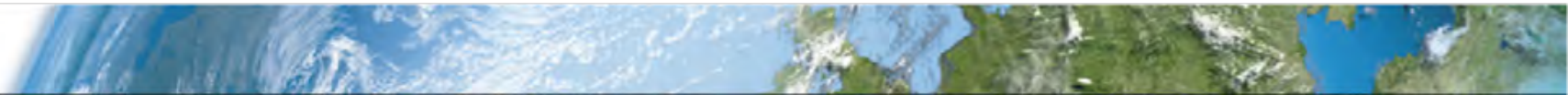


NEOShield-2: Physical properties of Asteroids

Analysis of observational data

Results obtained	No. NEOs observed	NEOShield-2 partner
Taxonomy via colours	430+	INAF, Italy; IMCCE, Paris, France
Taxonomy via phase functions	11+	INAF, Italy
Taxonomy via spectroscopy	137+	Obs. Paris, France
Spin periods	56	IMCCE, Paris, France

Results obtained	No. asteroids for which data retrieved from archives	NEOShield-2 partner
Astrometry from precovery detections in archival Pan-STARRS images	30	Queen's Univ., Belfast, UK
Sizes, albedos, thermal properties	2000	CNRS, France
Estimated thermal inertia, surface structure	6000	DLR, Germany





NEOShield-2 Project Executive Summary

Home / Mission / NEOShield-2 Project Executive Summary

Find here an [executive summary](#) of the **first** NEOShield-2 periodic report provided to and accepted by the European Commission.



Contents at a Glance [\[hide\]](#)

- 1 Executive Summary
 - 1.1 Context & overall objectives
 - 1.2 Work performed & main achievements
 - 1.3 Progress beyond the state of the art & expected potential impact
- 2 More detailed Executive Summary (incl. illustrations)
 - 2.1 Summary of the context and overall objectives of the project
 - 2.2 Work performed from the beginning of the project to the end of the period covered by the report and main results achieved so far
 - 2.3 Progress beyond the state of the art and expected potential impact (including the socio-economic impact and the wider societal implications of the project so far)

www.neoshield.eu

Executive Summary

Context & overall objectives

As a result of modern observing techniques thousands of near-Earth objects (NEOs) have been discovered over the past 20 years and the reality of the impact hazard has been laid bare. Even relatively small impactors can cause considerable damage: the asteroid that exploded over the Russian city of Chelyabinsk in February 2013 had a diameter of only 18 m yet produced a blast wave that damaged buildings and caused injuries to some 1500 people [Fig. 1]. The potentially devastating effects of an impact of a large asteroid or comet are now well recognized. Can we protect our civilisation from the next major impact?

In contrast to other natural disasters, such as earthquakes and tsunamis, the impact of an asteroid discovered early enough can be predicted and prevented. Following on from the original NEOShield project (FP7), the objectives of NEOShield-2 included improvement of the targeting accuracy and relative velocity of a kinetic impactor spacecraft to deflect a small asteroid, and development of autonomous spacecraft control systems to facilitate navigation close to a low-gravity, irregularly shaped asteroid. Scientific objectives included astronomical observations of NEOs and the analysis of archival data (radar, infrared, spectroscopy, etc.), complemented by modelling and computer simulations, to improve our understanding of their physical properties and how a NEO would respond to a deflection attempt (for a more detailed [Executive Summary including the illustrations see below](#)).

Work performed & main achievements

We have carried out detailed investigations of key technologies vital to the exploration and deflection of NEOs [Fig. 2], including autonomous guidance, navigation, and control systems for a spacecraft in the final approach and proximity phases to an asteroid for the purposes of in-situ science such as surface observations and setting down a lander module, and for a kinetic impactor spacecraft to maximize the targeting accuracy. A harmonized verification approach [Fig. 4] for those technology developments was established leading to an independent validation of all three scenarios to TRL 5-6 by extensive test campaigns. Furthermore, an innovative low-cost kinetic-impactor deflection demonstration concept called NEOTwiST [Fig. 3] has been developed. We have also demonstrated techniques for precise and rapid NEO orbit determination [Fig. 5] and developed mechanisms for the collection of material samples from the surface of a NEO [Fig. 6].



NEOSShield – there's no shortage of scientific and technical research results...

<http://www.neoshield.eu/>



Near-Earth Objects

Chapter 27

Advances in Space Research
Volume 52, Part 2, pp. 247-253
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Table with 2 columns: Author, Title, Journal, Year

Author	Title	Journal	Year
Alan W. Harris and Line Druhe	Handbook of Cosmic Hazards and Planetary Defense	Springer International Publishing	2014
L. Drube, A. W. Harris, T. Hoerth, P. Michel, D. Ferna and F. Schäfer	NeosShield – A Global Approach to Near-Earth Object Impact Threat Mitigation	Advances in Space Research	2013
S. Egel, A. Ivantsov, D. Hestrofer, D. Pernia	Precision Astrometry in Asteroid Perspective	Planetary and Space Science	2013
Alan W. Harris, Patrick Michel, Martin Jutzi, Patrick Michel	Hypervelocity Impacts on Asteroids and Momentum Transfer	Icarus	2013
Alan W. Harris, S. A. Mescheryakov, Yu. M. Lipnitskiy	Estimated Efficiency of the Deflection of a Dangerous Space Object Using an Explosion or Impact	Acta Astronautica	2013
Alan W. Harris, Mark Boslough, Clark R. Chapman, Line Druhe, Patrick Michel, Alan W. Harris	Asteroid Impacts and Modern Civilization: Can We Prevent a Catastrophe?	Acta Astronautica	2013
Alan W. Harris, Mark Boslough, Clark R. Chapman, Line Druhe, Patrick Michel, Alan W. Harris	How to Find Metal-Rich Asteroids	Acta Astronautica	2013
Alan W. Harris, Mark Boslough, Clark R. Chapman, Line Druhe, Patrick Michel, Alan W. Harris	The 13th Hypervelocity Impact Symposium	Acta Astronautica	2013

Post mitigation impact risk analysis for asteroid deflection demonstration missions

Sigfried Egel^{a,*}, Daniel Hestrofer^a, William Thuillot^a, David Bascidin^b, Juan L. Cano^c, Philipp Chubock^c

^aCEOS (European Space Agency), DLR, L. 17000, Cologne, Germany

^bCEOS (European Space Agency), DLR, L. 17000, Cologne, Germany

^cCEOS (European Space Agency), DLR, L. 17000, Cologne, Germany

MISSION ARCHITECTURES AND TECHNOLOGIES TO ENABLE NEAR-EARTH OBJECT IMPACT THREAT MITIGATION

- Mr. Noah Saks
Astrium GmbH, Friedrichshafen, Germany
- Dr. Alan Harris
Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR)
- Dr. Craig Brown
Astrium Ltd, Stevenage, United Kingdom, Craig
- Mr. Marc Chapuy
Astrium SAS, Toulouse, France, Marc Chapuy
- Ms. Noelia Despre
Astrium SAS, Toulouse, France, Noelia Despre
- Mr. Juan L. Cano
Deimos Space S.L.U., Tres Cantos (Madrid), Spain, Juan
- Mr. Gabriele Bellei
Deimos Space S.L.U., Tres Cantos (Madrid), Spain, Gabriele

GASES AND LIQUIDS

Estimated Efficiency of the Deflection of a Dangerous Space Object Using an Explosion or Impact

S. A. Mescheryakov^a and Yu. M. Lipnitskiy^{a*}

^aCentral Research Institute of Machine Building, Pionerskaya ul. 4, Korolev, Moscow oblast, 141070, Russia

*e-mail: lipniju42@mail.ru

Abstract—The efficiency of various methods for deflection of dangerous space objects (e.g. asteroids) is studied. The main physical processes related to a distant nuclear explosion are analyzed, and the momentum is calculated. Mechanical momenta resulting from explosions of buried nuclear charges are quantitatively estimated. Approximate expressions for estimating of the mechanical momenta of explosions of highly-velocity impact are derived. The topicality of the protection of dangerous space objects and the corresponding particular problems are discussed.

INTRODUCTION

Possible collisions of the earth and small objects of the solar system (NEOs) are a serious threat to mankind. We assume that the moon to evaporation of the surface of the earth.

PRECISION ASTROMETRY IN ASTEROID PERSPECTIVE

S. Egel¹, A. Ivantsov¹, D. Hestrofer¹, D. Pernia², I. Ivantsov¹

Abstract. Among the currently known Near Earth Objects (NEOs), a significant fraction are hazardous asteroids. The recent Chelyabinsk event has shown that the threat to mankind is not negligible. The potential impact risk is high. The European Commission to investigate aspects of NEO mitigation mission success. After a brief introduction for deflection demonstration projects, we present a comprehensive overview of the current astrometric performance, requirements and possible issues with NEO mitigation demonstration missions.

Keywords: asteroid deflection, NEOSShield, astrometry, Near Earth Object

Asteroid Impacts and Modern Civilization: Can We Prevent a Catastrophe?

- Alan W. Harris
German Aerospace Center (DLR) Institute of Planetary Research
- Mark Boslough
Sandia National Laboratories
- Clark R. Chapman
Southwest Research Institute
- Line Druhe
German Aerospace Center (DLR) Institute of Planetary Research
- Patrick Michel
Lagrange Laboratory, Université Côte d'Azur, Observatoire de la Côte d'Azur, CNRS
- Alan W. Harris
MormData, Inc.

Abstract—We are now approaching the level of technical expertise necessary to deflect a near-Earth asteroid (NEA) capable of destroying a large urban area, if not a small country. The current level of activity in the field, including survey programs, physical characterization, and international initiatives to assess mitigation strategies, is unprecedented. However, we have only just started to explore the relevant properties of the small end of the NEA population (diameter < 300 m), and a serious danger to life and property. Political awareness and international response efforts are still at a very primitive stage. For a global guarantee of protection, advances in scientific and technical competence must be matched by improvements in international coordination, as well as preparedness at the political level.

The 13th Hypervelocity Impact Symposium

for in Hypervelocity Impact Experiments on Rock Targets

Schäfer¹, Jan Hapfel², Oliver Millon³ and Matthias Wicken⁴

¹ESA, ESTEC, Noordwijk, The Netherlands

²ESA, ESTEC, Noordwijk, The Netherlands

³ESA, ESTEC, Noordwijk, The Netherlands

⁴ESA, ESTEC, Noordwijk, The Netherlands

NeosShield – A Global Approach to Near-Earth Object Impact Threat Mitigation

L. Drube^a, A. W. Harris^a, T. Hoerth^b, P. Michel^c, D. Ferna^d and F. Schäfer^e

^aGerman Aerospace Center (DLR) Institute of Planetary Research, Berlin, Germany

^bFraunhofer Institute for High-Speed Dynamics, Ernst Mach Institute, EML, Freiburg, Germany

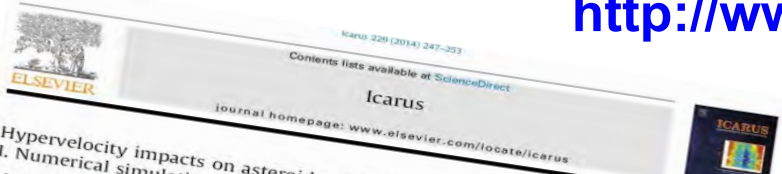
^cLagrange Laboratory, University of Nice Sophia Antipolis, CNRS, Côte d'Azur Observatory, Nice, France

^dLESIA, Observatoire de Paris, CNRS, UPMC, Univ. Paris 06, Univ. Paris-Diderot, Meudon, France

^eLESIA, Observatoire de Paris, CNRS, UPMC, Univ. Paris 06, Univ. Paris-Diderot, Meudon, France

Abstract

NEOSShield, a project funded by the European Commission, brings together an international team of 13 partner organizations to address the global issue of near-Earth objects (NEO) impact prevention. The project's goals are to investigate the feasibility of techniques to prevent a potentially catastrophic impact on Earth by an asteroid or a comet and to develop detailed designs of appropriate missions to test deflection techniques.



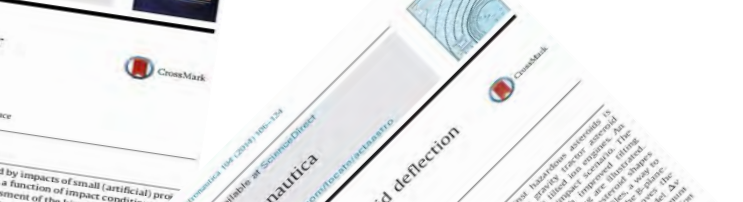
Hypervelocity impacts on asteroids and momentum transfer

Martin Jutzi^{a,*}, Patrick Michel^b

^aUniversity of Bern, Center for Space and Habitability, Physics Institute, Sidlerstrasse 5, 3012 Bern, Switzerland

^bLagrange Laboratory, University of Nice Sophia Antipolis, CNRS, Observatoire de la Côte d'Azur, B.P. 4229, 06204 Nice Cedex 4, France

Abstract—In this paper, we investigate numerically the momentum transferred by impacts of small (artificial) projectiles on asteroids. The study of the momentum transfer efficiency as a function of impact conditions and the internal structure of an asteroid is crucial for performance assessment of the inertial impactor or deflection of an asteroid from its trajectory. The momentum transfer is characterized by a so-called multiplication factor β , which has been introduced to define the momentum of the impactor, which porosity takes the form of macro porosity and/or micro porosity. Here we present results of code calculations which indicate that the momentum transfer efficiency is significantly affected by the porosity of the impactor. The results of laboratory experiments (Hollberg et al., 2013; Proceedings of the 13th Hypervelocity Impact Symposium, 2013) show that the momentum transfer efficiency is significantly affected by the porosity of the impactor.

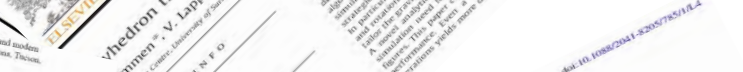


Neutron tracking and gravity tractor asteroid deflection

Ummen V. Lippas

Acta Astronautica 103 (2015) 197–204

Abstract—The objective of this paper is to investigate the possibility of using neutrons for asteroid deflection. The neutron tracking method is compared with the gravity tractor method. The neutron tracking method is shown to be more efficient than the gravity tractor method in terms of deflection efficiency and cost.

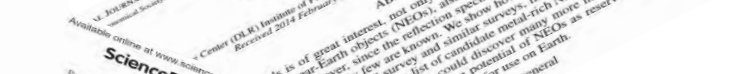


HOW TO FIND METAL-RICH ASTEROIDS

Alan W. Harris and Line Druhe

Acta Astronautica 103 (2015) 197–204

Abstract—The objective of this paper is to investigate the possibility of finding metal-rich asteroids. The paper discusses the importance of finding metal-rich asteroids for asteroid deflection and the challenges associated with finding them.



Procedia Engineering

The 13th Hypervelocity Impact Symposium

Schäfer¹, Jan Hapfel², Oliver Millon³ and Matthias Wicken⁴

Abstract—The objective of this paper is to investigate the possibility of finding metal-rich asteroids. The paper discusses the importance of finding metal-rich asteroids for asteroid deflection and the challenges associated with finding them.



NEOShield – there's no shortage of media interest...



NEWS
Home Video World UK Business Tech Science Magazine Entertainment & Arts
Science & Environment
NEOShield to assess Earth defence
Jonathan Amos
Science correspondent
© 20 January 2012 | Science & Environment

FAZ.NET LEBENSWEGE SCHULE
HERAUSGEGEBEN VON WERNER D'INKE, JÜRGEN KAUBE, BERTHOLD KOI
Frankfurter Allgemeine Wissen
Freitag, 05. Juni 2015
POLITIK WIRTSCHAFT FINANZEN FEUILLETON SPORT GESELLSCHAFT STIL TECHNIK & NOTIZEN
Home > Wissen > Weltraum > Asteroid 2012 DA14: Rendezvous mit einem kosmischen Besucher
Asteroid 2012 DA14
Rendezvous mit einem kosmischen Besucher
Wenn der Asteroid 2012 DA14 an diesem Freitag Abend dicht an der Erde vorbeizieht, dann ist das nicht nur ein spektakuläres Ereignis. Es zeigt auch, wie bedroht die Erde von einem größeren Einschlag ist.
15.02.2013, von MANFRED LINDNER

Comment détourner un astéroïde qui menace la Terre?

NASA: Asteroid flyby next week closest ever of its size

Defenders of the Earth
The cosmic near-miss in February has boosted research on space rocks
Jun 20th 2013 | From the print edition
Stopping asteroid strikes



Scientists race to build asteroid shield

DLR Institute of Planetary Research in Bonn had its kick-off meeting this week
Expertise from across Europe, Russia

Stopping asteroid strikes
The cosmic near-miss in February has boosted research on space rocks
Jun 20th 2013 | From the print edition

German.CHINA.ORG.CN
Aktuelles
Home
30.01.2012
"NEOShield": Deutsche Raumfahrtagentur will Asteroiden abwehren

ASTEROIDEN-ABWEHR
Forscher planen Schutz vor kosmischen Bomben

Der Asteroid „Apophis“ rast Richtung Erde. Der Einschlag droht in 17 Jahren. Nach Berechnungen wird er 36 000-mal verheerender als eine Atombombe. Forscher wollen jetzt einen Schutz gegen die kosmische Bombe entwickeln!
Die internationale Organisation NEOShield (NearEarthObjects) = Objekte nahe der Erde) prüft verschiedene Möglichkeiten, solchen Objekten aus dem All wehrgevooll entgegenzutreten. Professor Alan Harris, Asteroidenforscher beim Deutschen Zentrum für Luft- und Raumfahrt, leitet das Forschungs-Team. Über die kosmischen Bomben sagt er: „Um ihre Umlaufbahn zu ändern und eine Kollision mit der Erde zu verhindern, muss man ihnen bereits auf ein hundertstel...

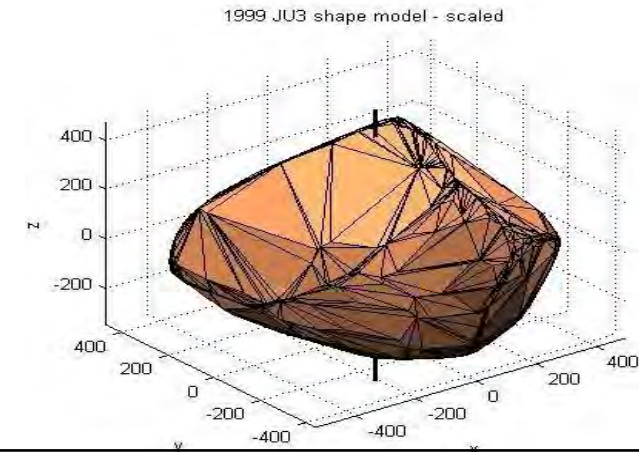
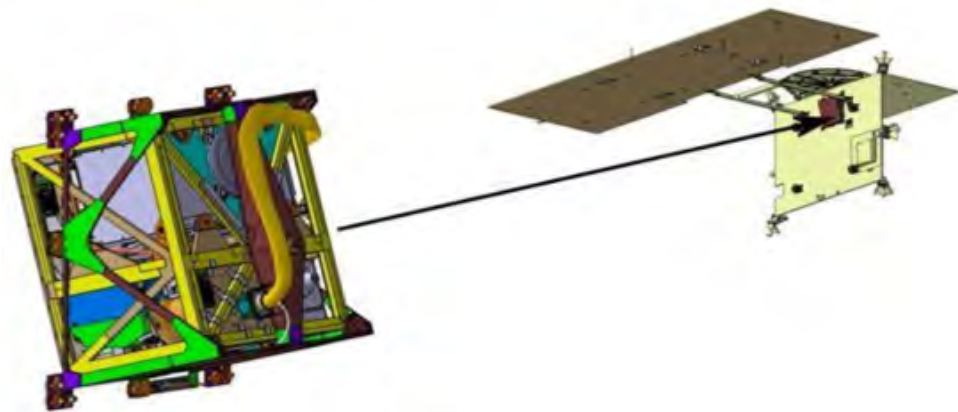
German.CHINA.ORG.CN
Aktuelles
Home
30.01.2012
"NEOShield": Deutsche Raumfahrtagentur will Asteroiden abwehren
Am Freitag hat ein Asteroid von der Größe eines Basars die Erde nur knapp verfehlt. Statistiken der NASA zufolge befinden sich rund 1000 bekannte Asteroiden in Umlaufbahn. Es scheint, dass die deutsche Raumfahrtagentur (DLR) im Auftrag der Bundesregierung mit dem NEOShield-Übersicht...

Europe is developing an asteroid shield... but it won't be in time for the 19-mile wide monster hurtling past Earth next week
Schemes are being tried to find a way to protect Earth from the giant rocks which loom around the solar system.
The NEOShield project, which will look for a way to protect earth from the "space rocks", is expected to take three years to complete.
Some of the ideas being tested around at the moment include repelling asteroids with propellers or explosives or using gravity to change its course.



MASCOT onboard Hayabusa 2 (HY2)

- Hayabusa Immediate follow-on Asteroid Sample Return Mission (JAXA/ISAS).
- Target Object: NEA (162173) Ryugu (C-Typ).
- Launch: Dec 2014.
- Arrival + Ops: July 2018 + 18 months.
- Return to Earth: 2020.
- PL: Four orbiter experiments, impactor, sampler, 3 Minerva rovers + MASCOT (DLR/CNES).

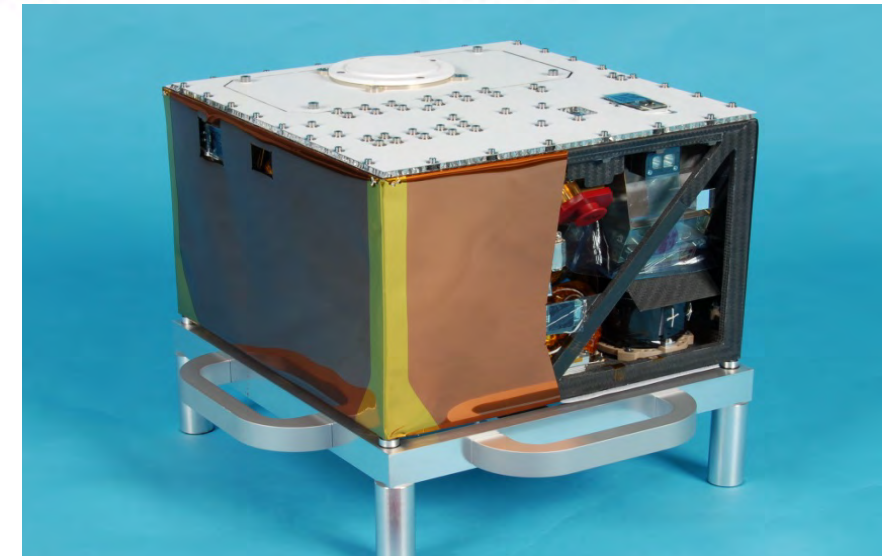
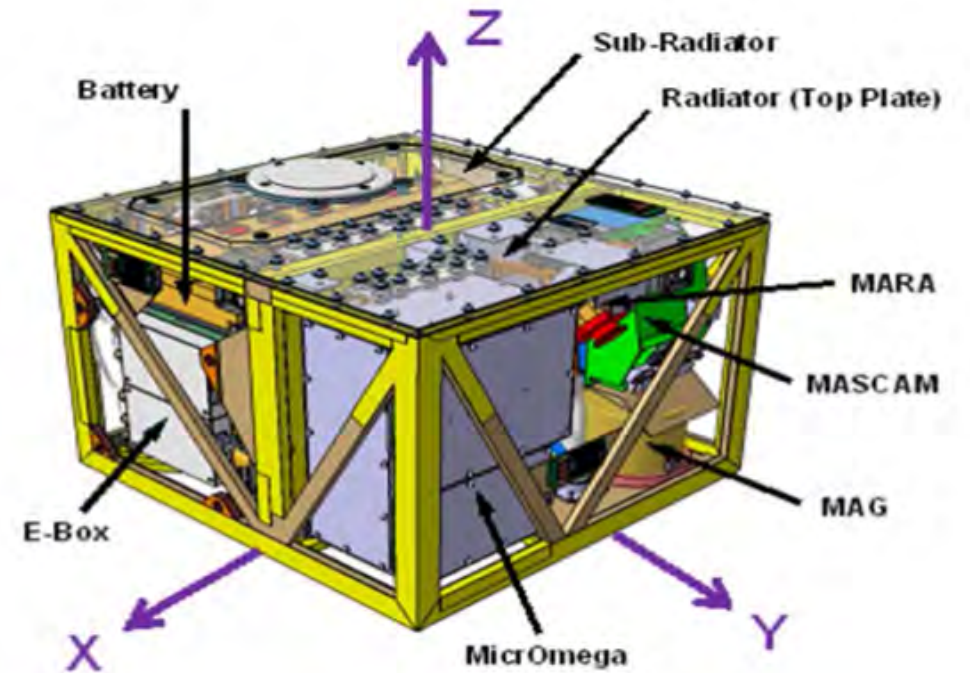


Parameters	
Mean volume-equivalent diameter (km)	0.87±0.03
Bulk density (kg/m ³)	1300
Spin period (hrs)	7.63±0.01
Spin axis (J2000), positive pole	λ _{ecl} = 73.1° β _{ecl} = -62.3° retrograde rotation Obliquity = 151.6°
V _{esc} (m/s)	0.37±0.03
Thermal inertia (global average) (Jm ⁻² s ^{-0.5} K ⁻¹)	Notional: 400
Emissivity	0.9 (assumed)
g (m/s ²)	1.5 × 10 ⁻⁴
Surface fraction covered with craters	0.4 – 0.9



MASCOT

- A small and agile surface science platform carrying a suite of 4 scientific instruments.
- Total mass is ~ 10 kg.
- Total volume is ~ 0.3 x 0.3 x 0.2m³.
- Separation & descent onto the asteroid via free-fall.
- Self righting and relocation ability.
- Current landing window: Oct 2018 (backup window: Feb/May 2019).



Deutsches Zentrum
für Luft- und Raumfahrt
German Aerospace Center



MASCOT Science Payload

Camera (MasCam)/DLR PF

- *Ground truth* for orbital measurements of the HY2 instruments and the in-situ MSC sensor suite.
- Geological context of the samples.

Radiometer (MARA)/DLR PF

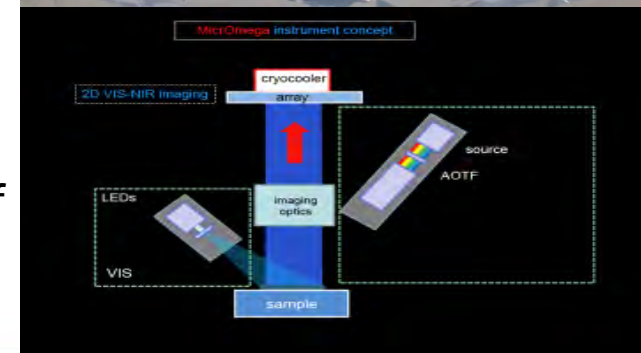
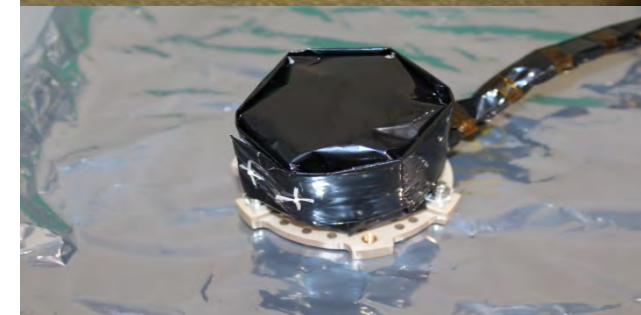
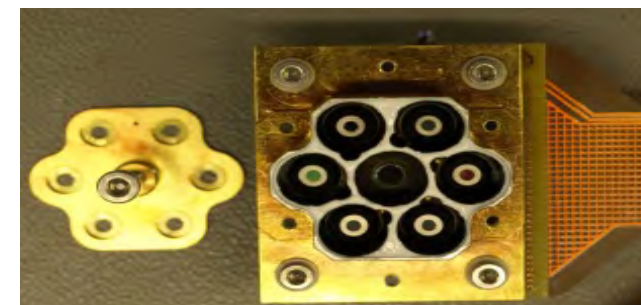
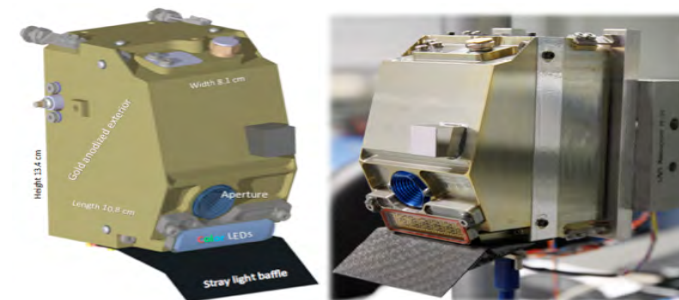
- Surface brightness temperature for a full asteroid rotation.
- Surface thermal inertia and spectral slope in the IR.

Magnetometer (MasMag)/TU Braunschweig

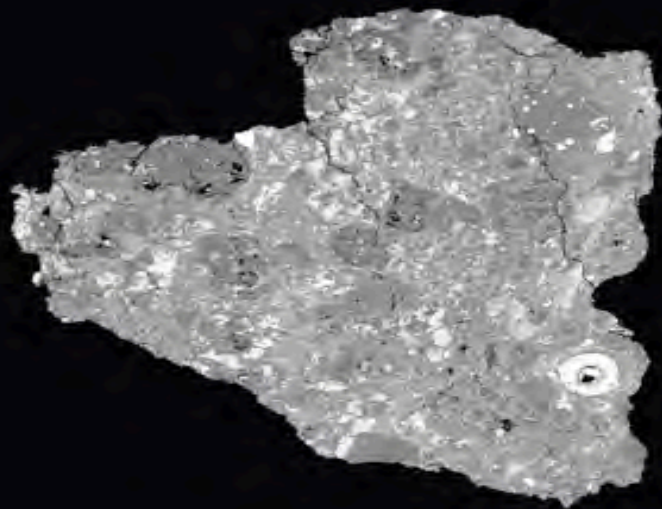
- Observe the magnetic field profile during descent and hopping.
- Identification of global and local magnetization of asteroid and reconstruct the coordinate system of the magnetic field vector.

IR Hyper-Spectral Imager (MicrOmega)/IAS Paris

- Composition of the asteroid's surface, at grain scale in terms of minerals (pristine, altered), ices/frosts, organics.
- Microscopic structure of the soil, and the relation between the various phases of distinct compositions.



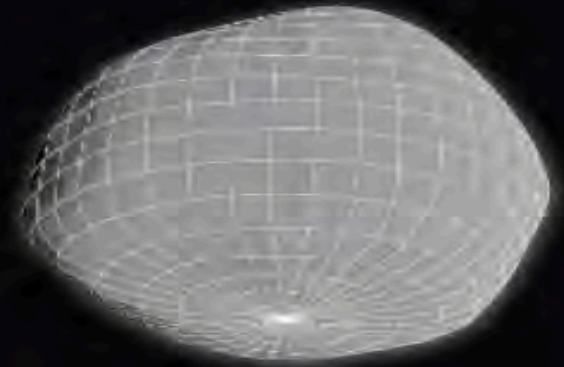
MASCOT will serve as ground truth tie point between sample science (10^{-3} - 10^{-6} m) & remote sensing sciences (10^3 - 10^3 m)



nm-mm



m



km



Return sample analyses

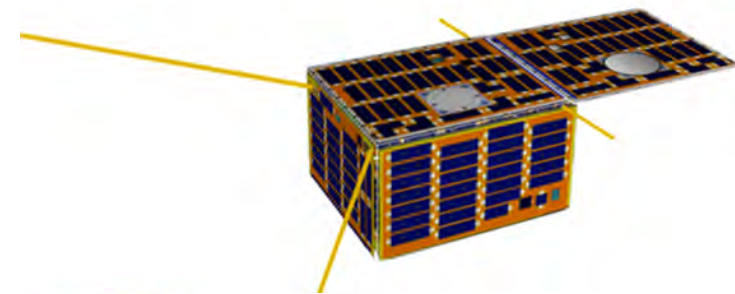
Remote sensing

MASCOT

$\log_{10} L$ [m]

MASCOT: Conclusions/Outlook

- The MASCOT concept is agile, lightweight and flexible. \Rightarrow It is applicable for various future exploration missions of low gravity bodies.
- The MASCOT lander is part of future missions studies such as
 - AIM (ESA): Asteroid Impact Deflection Mission
 - MMX (JAXA): Mars Moons Explorer Mission.



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Feuerkugelnetz = Fireball Network

Background

- Earth is bombarded by several 10,000 t of meteoroids every year.
- Spatial/temporal distribution of meteoroids is complex; small meteoroids travel in swarms and streams.
- Public very interested in meteor events!

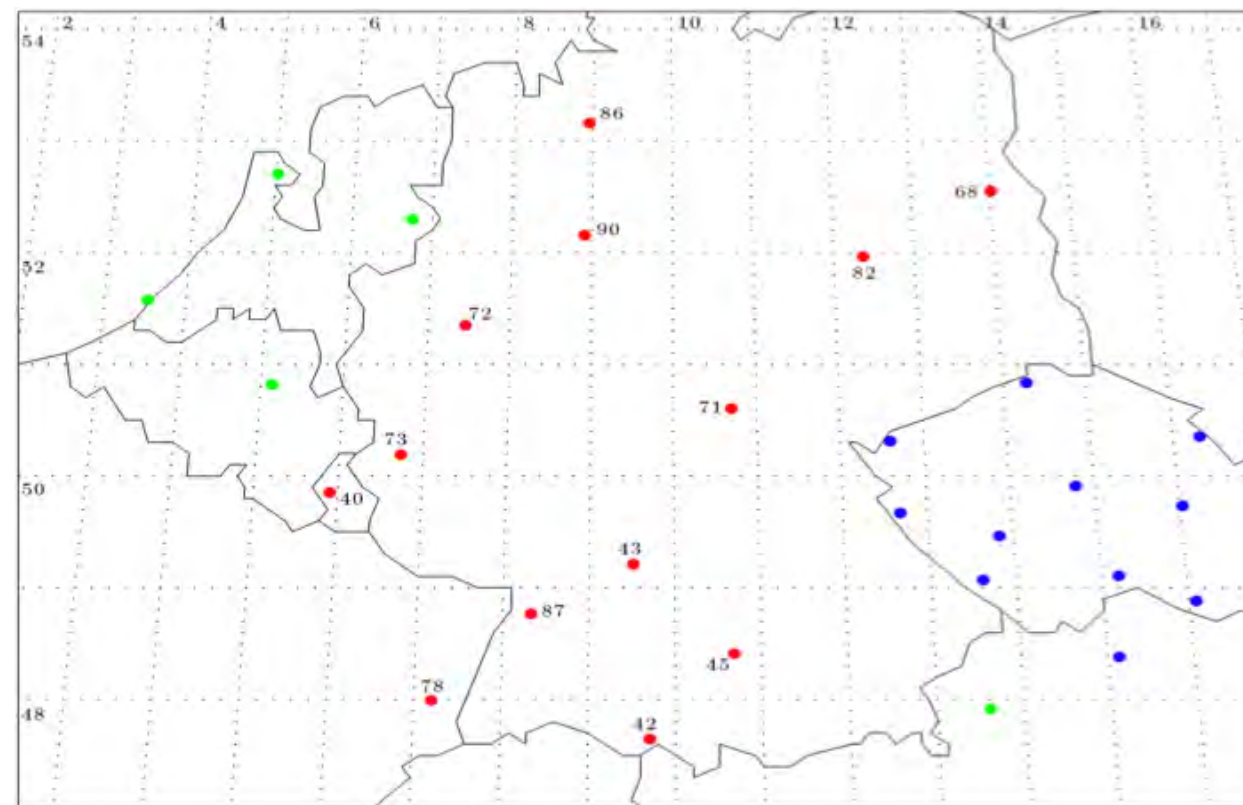
Science Goals

- Study spatial/temporal mass/frequency distribution of the meteoroid flux.
- Track large fireballs and enable meteorite recoveries.
- Contribute to public awareness of space environment.



Fireball Observations

- Early network established in the 60s, Max Planck-Institute für Kernphysik, Heidelberg
- Today there are 25 cameras stationed in Germany, Czech Republic, Belgium, Luxembourg and Austria.
- One long exposure per night. The camera looks into a convex mirror, or is fitted with a fisheye lens, to provide a view of the entire sky.
- A propellor shutter rotates at 12.5 Hz in front of the camera to aid the analysis of meteor tracks.
- Some 50 meteors per year with V brighter than -6 are detected.



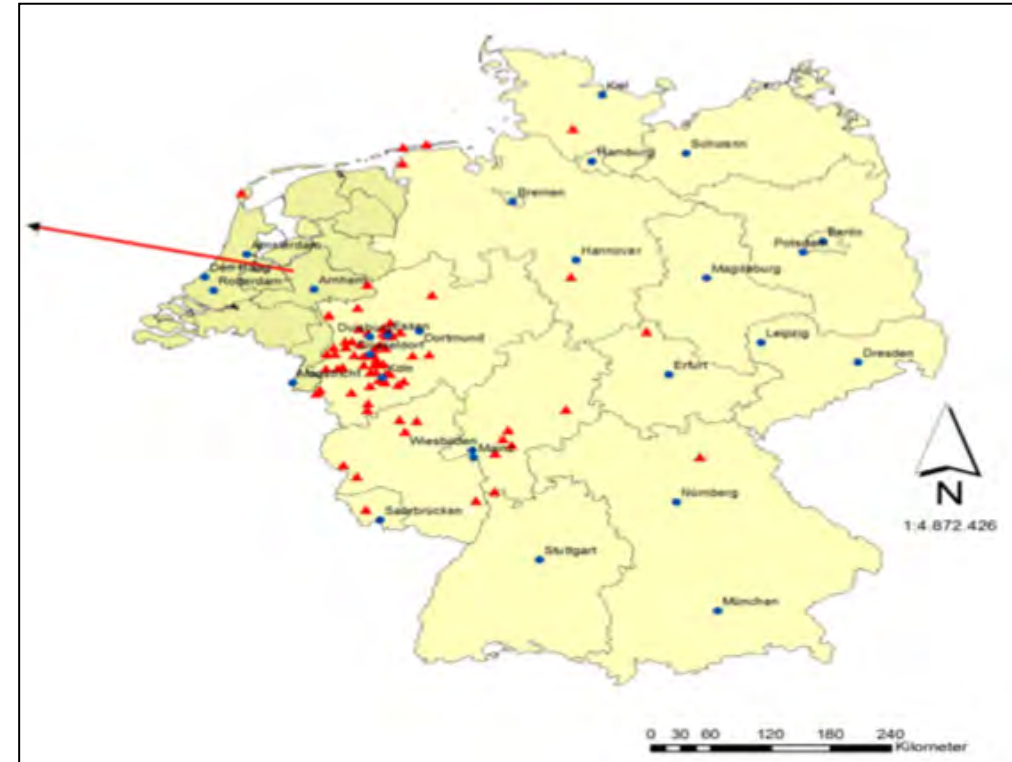
Activities in Berlin

- Development of digital meteor camera prototypes.
- Software development for event detection, trajectory reconstruction, orbit determination, photometric solution.
- Joint activity with TU Berlin.
- Test campaigns of the prototypes.
- Provision of an E-mail address for event reporting (feuerkugel@dlr.de).



Activities in Berlin

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Eyewitness reports received on feuerkugel@dlr.de for a large meteor event on 21. September 2017



Future perspectives DLR, Berlin

- The impact hazard is mentioned in the DLR's latest strategy document:
DLR-Strategie 2030: "Investigations of planets, asteroids and comets in our Solar System, including improvements in our understanding of the potential danger from impacts of [NEOs] on the Earth."
- Nice words but no money!
- We're hoping for further financial support from the EU's Horizon 2020 research programme (earliest September 2018).

