THE SSA NEO SEGMENT AND GAIA: PRESENT OPPORTUNITIES AND FUTURE DEVELOPMENTS

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THE SSA NEO SEGMENT AND GAIA: PRESENT OPPORTUNITIES AND FUTURE DEVELOPMENTS

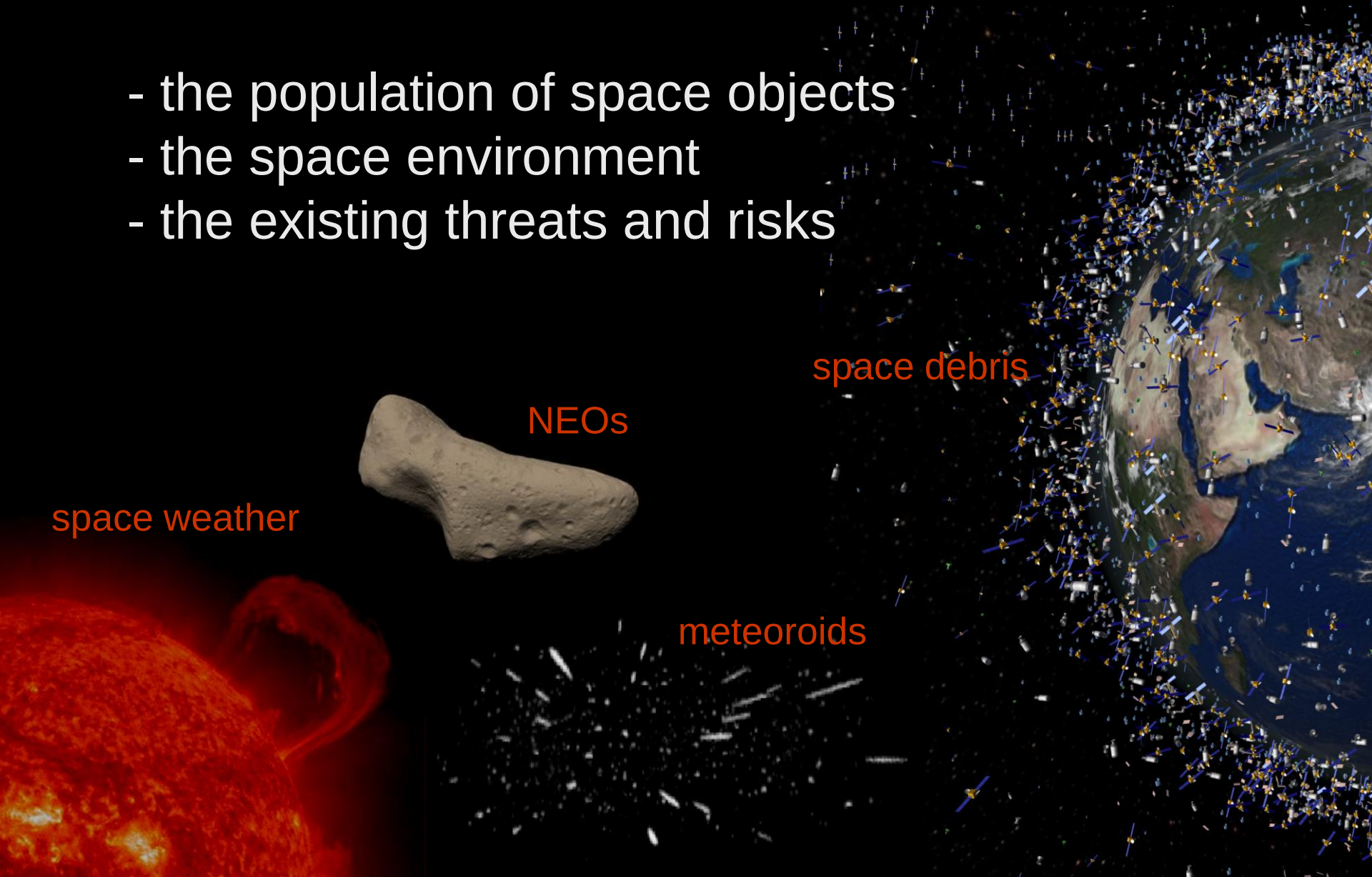
- ESA Space Situational Awareness
- NEO Segment Design
- NEO Precursor Services
- NEO Segment observations
- Space Based Assets
- Gaia Simulations
- Risk Assesment and Mitigation
- Gaia ⇔ NEO Segment interaction

SSA: the ESA Space Situational Awareness Programme

The aim of the Space Situational Awareness Programme is to support the European independent utilisation of and access to space for research or services, through providing timely and quality data, information, services and knowledge regarding the environment, the threats and the sustainable exploitation of the outer space surrounding our planet

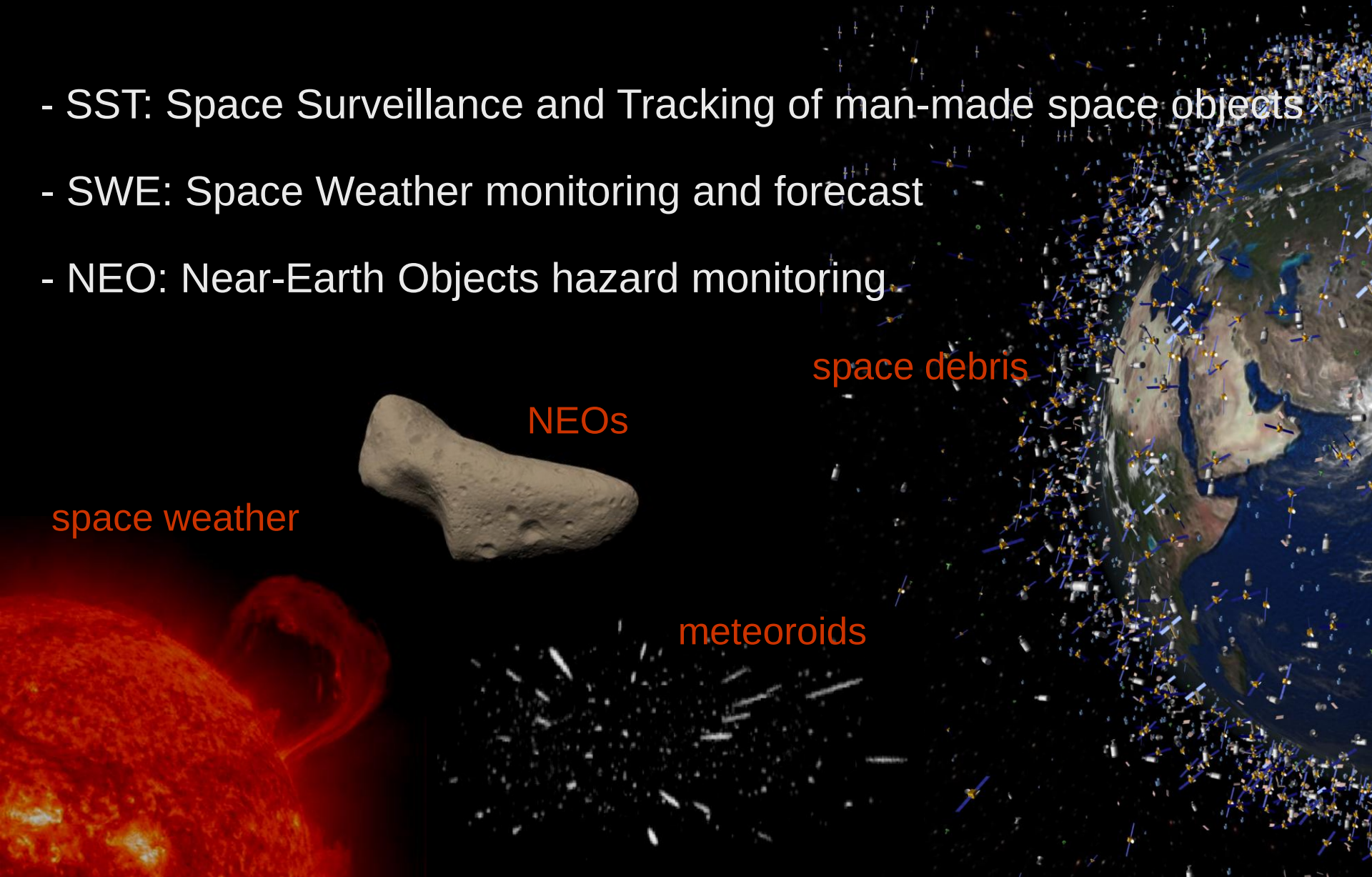
SSA: awareness on

- the population of space objects
- the space environment
- the existing threats and risks



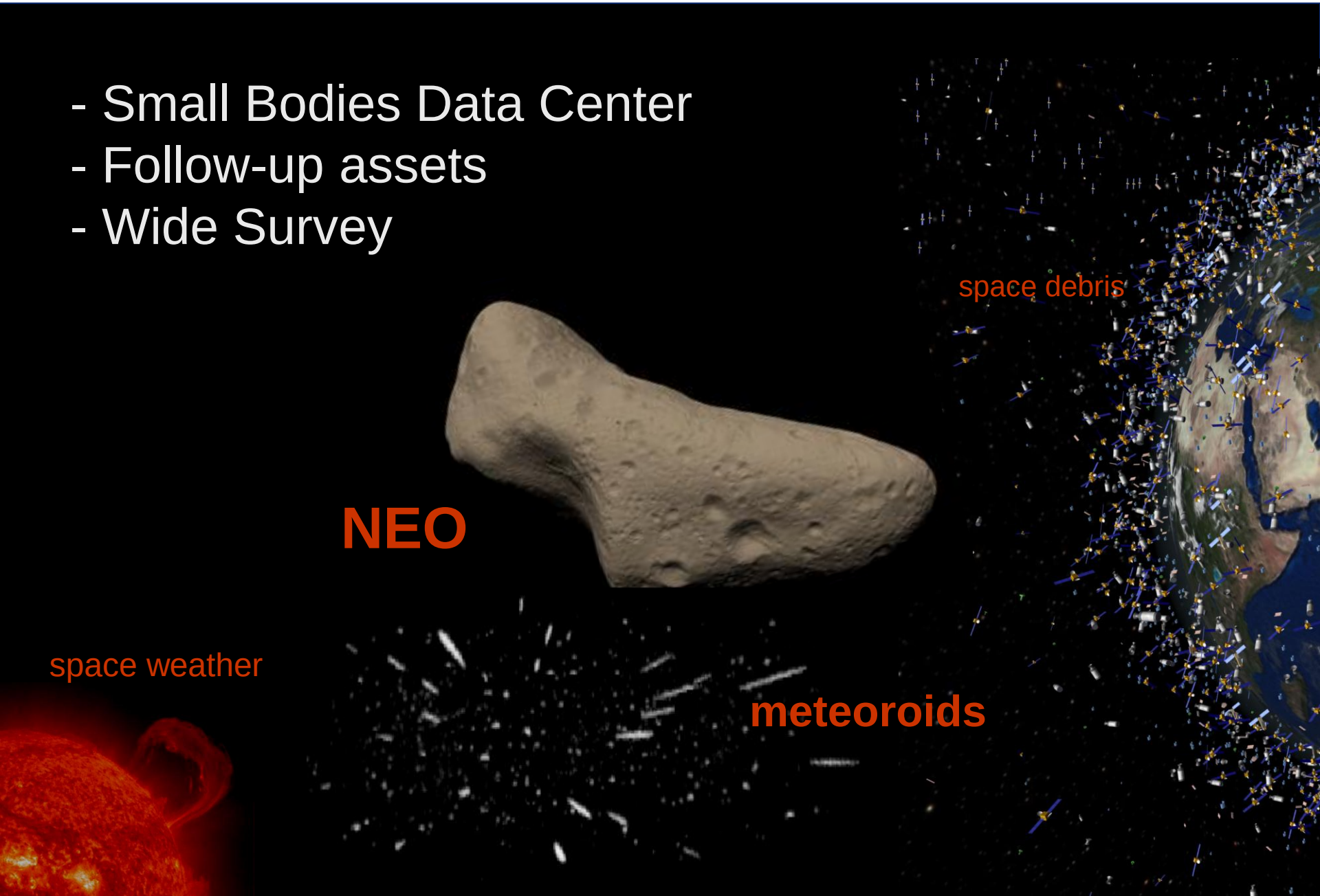
SSA: Programme Segments

- SST: Space Surveillance and Tracking of man-made space objects
- SWE: Space Weather monitoring and forecast
- NEO: Near-Earth Objects hazard monitoring



SSA: the NEO Segment

- Small Bodies Data Center
- Follow-up assets
- Wide Survey



The NEO Risk Problem

Detection

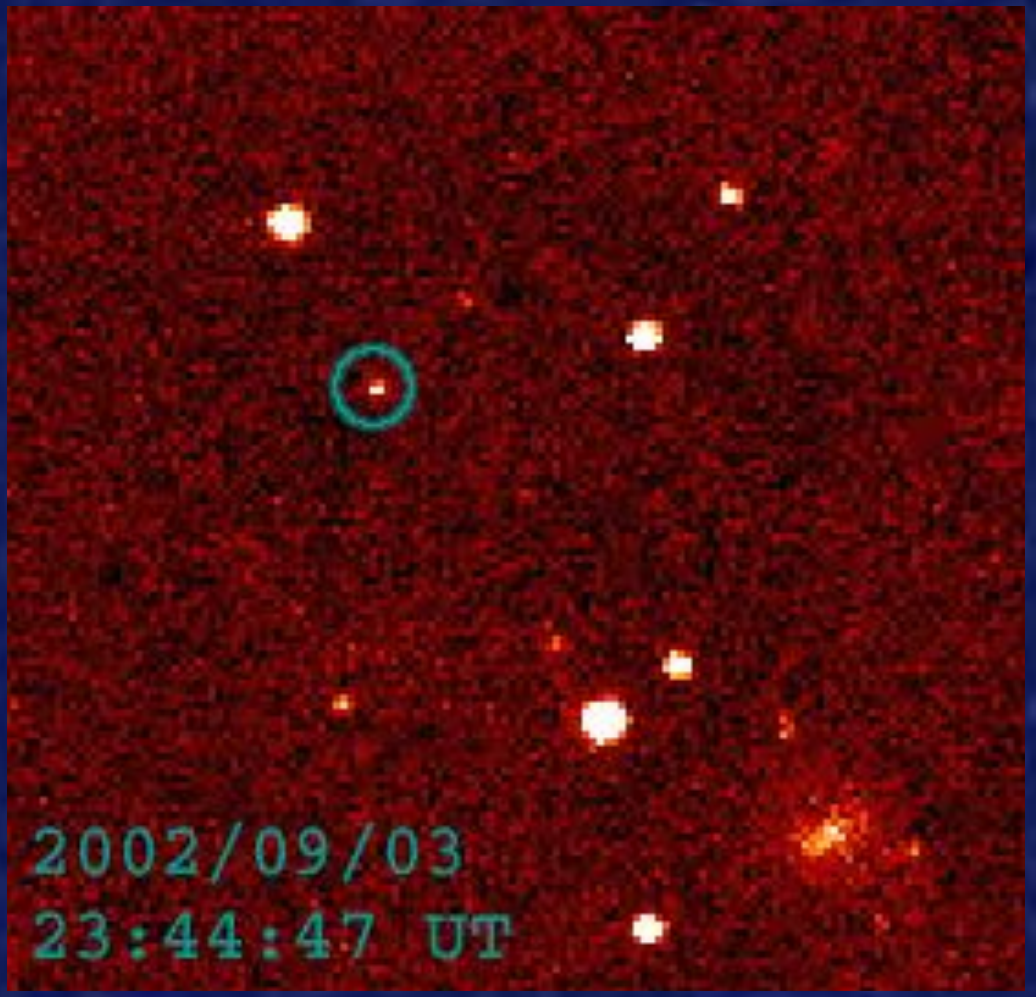
Orbit determination

Impact monitoring

Orbit improvement;

Risk assessment

Mitigation



The NEO Risk Problem: DETECTION

Detection

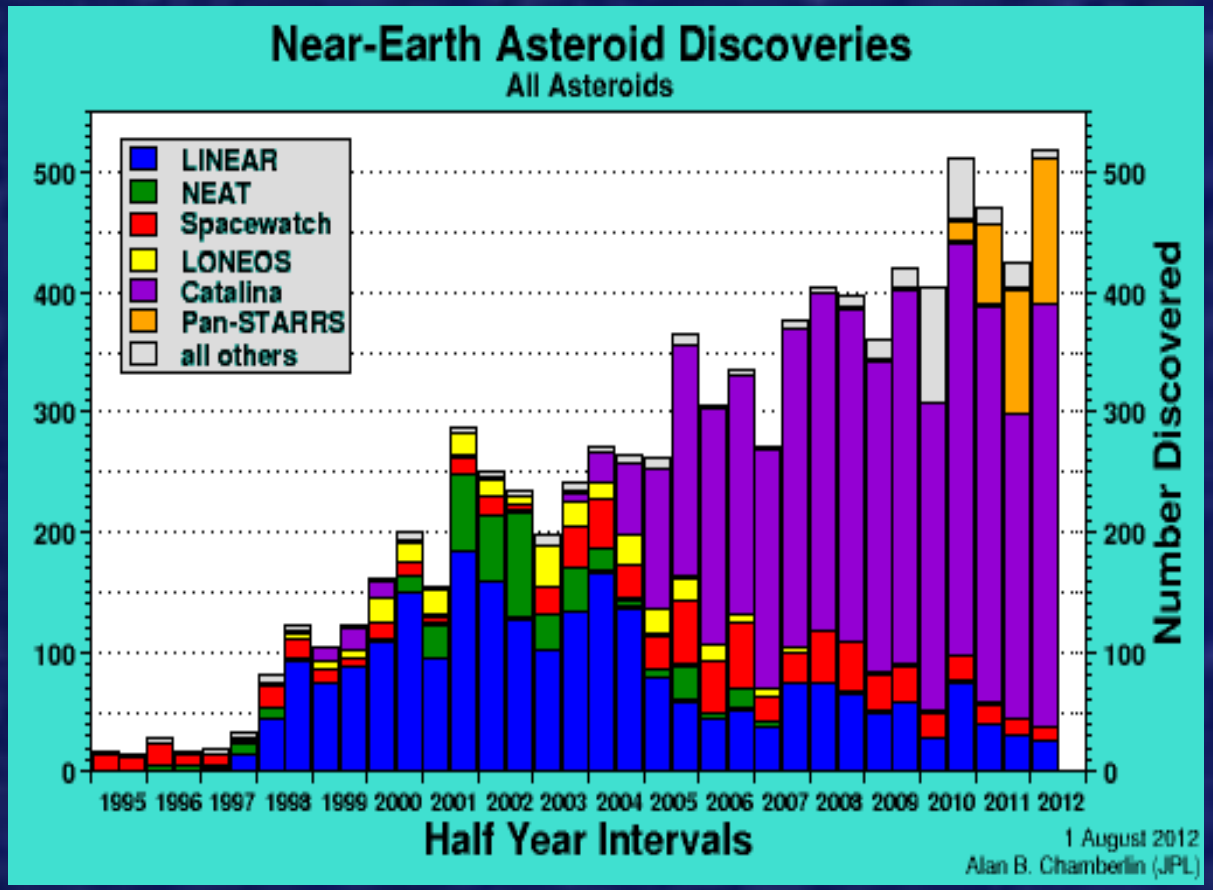
Orbit determination

Impact monitoring

Orbit improvement

Risk assessment

Mitigation



US ground based sky surveys are ruling NEO discoveries

The NEO Risk Problem: OD & IMPACT MONITORING

Detection

Orbit determination

Impact monitoring

Orbit improvement;

Risk assessment

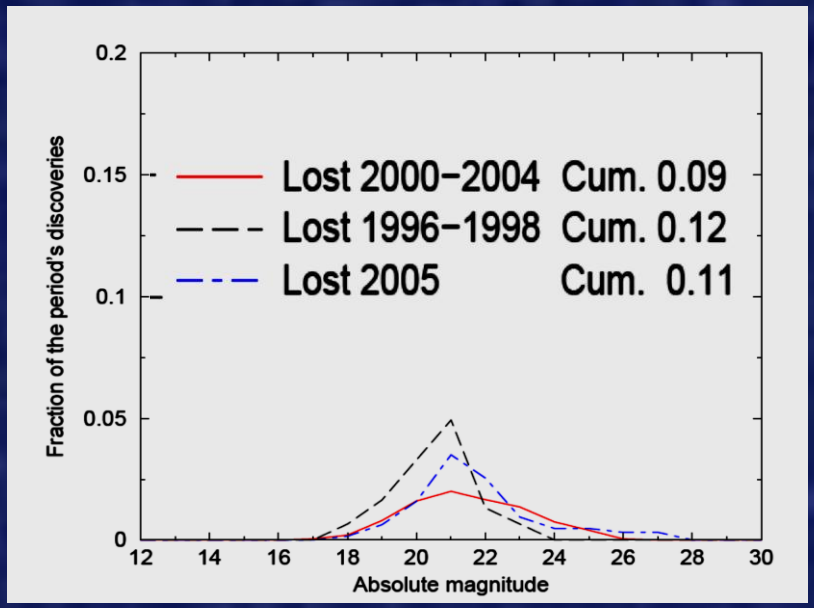
Mitigation

NEODyS @ University of Pisa, operated by SpaceDys under ESA funding

MPC on behalf of IAU & Sentry @ JPL under NASA funding

The NEO Risk Problem: ORBIT IMPROVEMENT

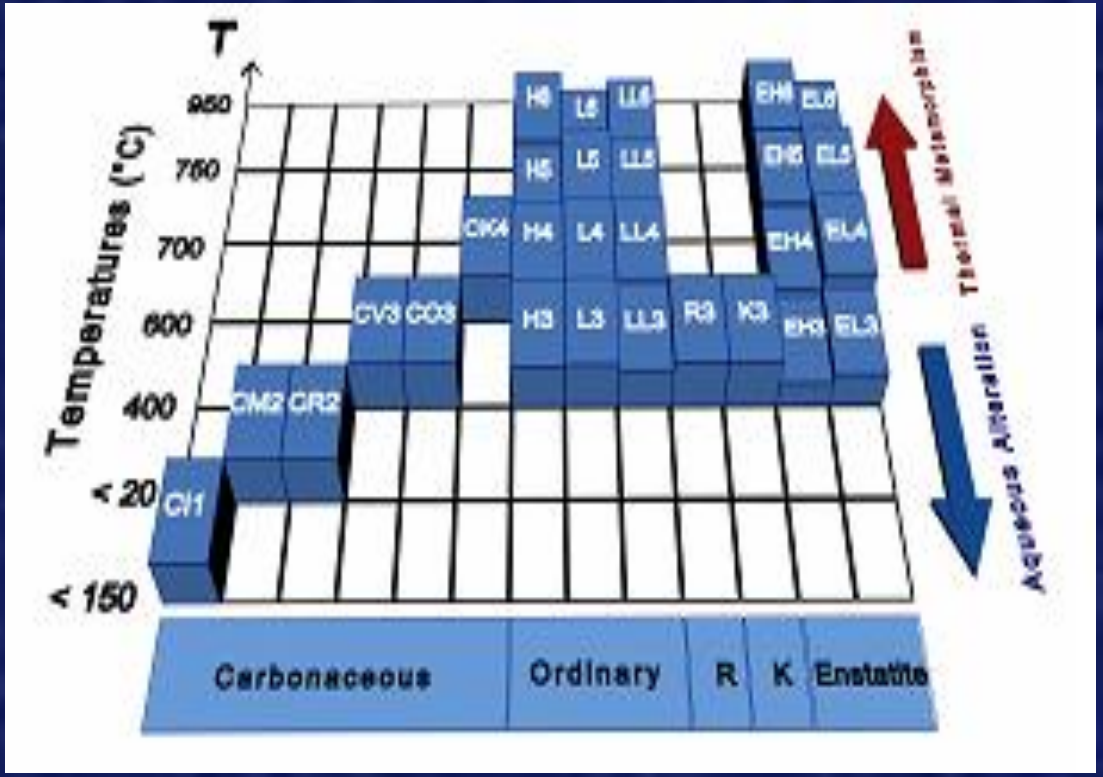
- Detection
- Orbit determination
- Impact monitoring
- **Orbit improvement**
- Risk assessment
- Mitigation



The Spaceguard Central Node priority list addresses follow-up observations performed by professional and amateur astronomers

The NEO Risk Problem: RISK ASSESSMENT

- Detection
- Orbit determination
- Impact monitoring
- Orbit improvement
- **Risk assessment**
- Mitigation



Physical properties follow-up observations (spectroscopy, polarimetry, radar imaging, in situ exploration etc.) performed worldwide

EARN (European Asteroid Research Node) database maintained at DLR

The NEO Risk Problem: MITIGATION

- Detection
- Orbit determination
- Impact monitoring
- Orbit improvement
- Risk assessment
- **Mitigation**

Small NEOs entering the atmosphere are likely to become the most frequent event that future NEO alert systems will detect, filling the gap between NEOs and meteoroids/fireballs

The NEO Risk Problem: Enabilng Technologies

- *10 years operation of NEO alert systems has gained Europe worldwide excellence (NEODyS)*
- *European expertise and facilities for NEO physical characterization are competitive although coordination is necessary (EARN)*
- *A significant European contribution to NEO discoveries is still possible if focused on high magnitude low MOID (minimum Orbit Intersect Distance) objects : Wide Survey concept.*
- *The same applies for the possibility of performing quick astrometric follow-up of challenging objects (ESO)*
- *The WISE success has highlighted the contribution of space-based assets (GAIA)*

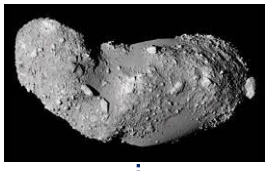
(Enabling Technologies for SSA NEO Segment; ESA study, 2010)

NEO Segment: Design

The proposed NEO segment of the final SSA system foresees the deployment of the following elements:

- **Wide Survey** - network of optical telescopes performing an all-sky survey focused on the discovery of small size, potentially hazardous (low MOID) objects
- **Small Bodies Data Centre** – data processing (astrometric data collection, orbit determination, risk assessment, follow-up coordination) and services (raw image archives, fireball database, precovery etc.)
- **Collaborating Observatories** - dedicated astrometric and physical follow-up (e.g. under SLAs) even under short notice; unsollicited and serendipitous observations (e.g. amateurs, space telescopes, etc.)

NEO Segment: pre-operational services



NEOs

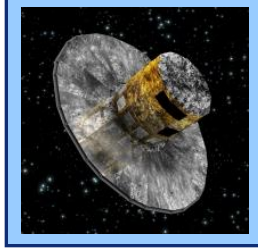
Minor Planet Center (US)

SSA tasking centre

National Cooperating telescopes

SSA sensors

Space missions



SSA-NEO Data Centre

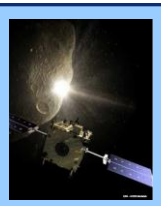
- Risk assessment
- Obs. Planning
- Phys. Properties
- Databases
- Light curves
- Shape models

Political entities

General users

National research expertise

Space mission studies



NEO image credit: JAXA

NEO Segment: Precursor Services

The NEO Data Center at ESRIN (presently under testing phase within the ESA SSA-SNIII contract) **is intended to deliver SSA NEO services and act as a focal point for the European and international NEO community**

- NEODyS system interface
- SCN Priority List generation
- Enhanced EARN node for physical data
- Orbit Visualization Tool
- Raw image database
- Fireball Database
- Education and public outreach
- Know how and team building (preparing for the future)

NEO Segment: Web Portal

NEO Segment: Federating Assets

Survey	Telescopes	CCD (pixel)	FoV (arcmin)	Sampling (arcsec/pixel)	Limiting Magnitude (V)
Campo Imperatore	Schmidt 0.6 m f/3 (optical)	2048x2048	51'x51'	1.5	20.5 (with exposure of 60s) 21.5 (with exsposure of 300s)
	Ritchey-Cretien 1.1 m (infrared)	256x256	4.4x4.4	1.04	17.7 (J), 16.9 (H), 16.2 (K)
La Sagra	Reflector 0.45 m f/2.8 (optical)	4008x2672	1°63'x1°63'	1.47 l	20 (with exposure of 40s) 21 (with exsposure of 240s)
Teide	The Carlos Sanchez (TCS) Dall-Kirkham 1.52 m f/13.8 (infrared)	256x256	1.7'x1.7'	1	17
	IAC80 Cassegrain 0.82 m f/11.3 (optical)	2048x2048	10.6'x10.6'	0.34	21 - 22
	Optical Ground Station (OGS) Ritchey-Cretin 1 m f/4.5 (optical)	4096x4096	0.7°x0.7°	0.6	20 - 21
Klenot	1.06 m f/3 (optical)	1024x1024	33'x33'	1.9	21.5 (with exsposure of 120s)
Toppo di Castelgrande	Ritchey-Cretien 1.54 m f/8.9 (optical)	2048x2048	12'.32x12'.32	0.361	

NEO Segment: OGS and La Sagra

OGS - ESA Optical Ground Station (Teide observatory,Tenerife). 1-m Zeiss telescope; Coude' and Ritchey-Cretien reduced focus configurations. NEO follow-up observations, photometric observations, survey mode.

Overview			
Number of scheduled nights(*):	**31**	Clear nights:	20
		Bad weather:	11
Follow-up observations			
Number of objects from NEOCP and SCN list:	~200		
Number of MPEC entries for J04:	**29**		
Survey			
Hours spent on survey:	~100	Movers which were automatically confirmed and designated:	6902
Number of discovery candidates:	**266**	No. of automatically reported positions:	22296
Secured multi-opposition objects:	38	No. of asteroids to which the automatically reported positions correspond:	5599
Numbered objects:	10	No. of amateurs helping in validating the detections not associated to a known object:	18
Named:	2	No. of false detections as visually identified:	29482
Lost to other discoverers:	24		

(Koschny et al 2011)

LSSS – La Sagra Sky Survey (Andalusia, Spain).

Three 0.45-m f/2.8 telescopes, FoV 2x1, 1x0.5 (sq. deg.), limiting magnitude ~ 21 V. Follow-up done with a dedicated tracking telescope. Discovery rate of ~10 NEAs/year (e.g. peculiar object 2012 DA14)

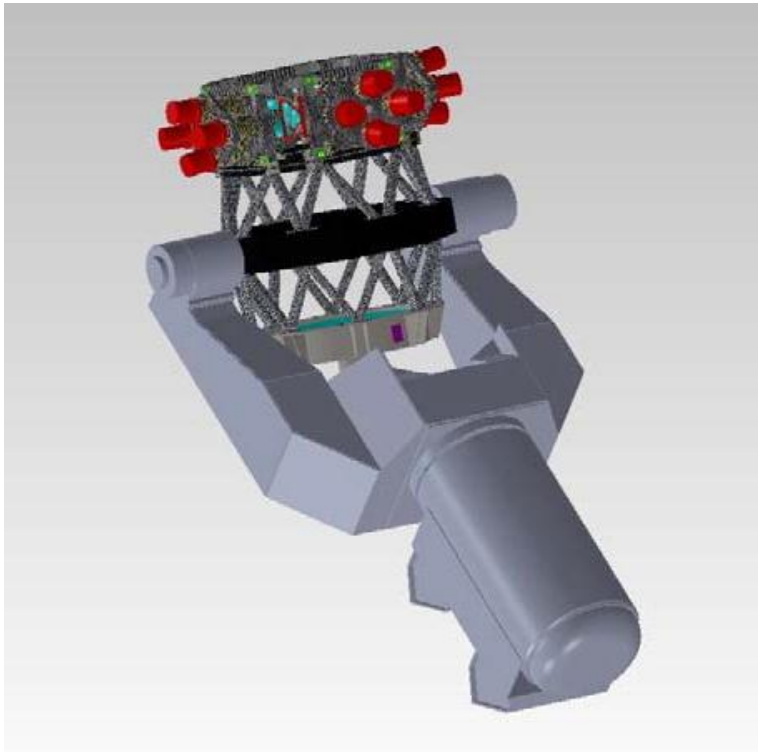
NEO Segment: Deep Follow-up

- Access to ESO could follow policies similar to the existing ones for transient phenomena (e.g. Director's Discretionary Time, automatic trigger of observations after a GRB etc.).
- e.g. ESO-NTT (La Silla): Diameter 3.6 m. past experience (Boattini et al. 2004): a total of 56 NEOs has been followed-up in 3 nights with limiting magnitude up to 24 V. 2 new NEAs were also discovered.
- Estimated average time for follow-up : 30 min.
- Assuming 4 to 5 hours per month of observing time results in ~50 hours per year of observing time at ESO telescopes.

NEO Segment: Fly-Eye telescope

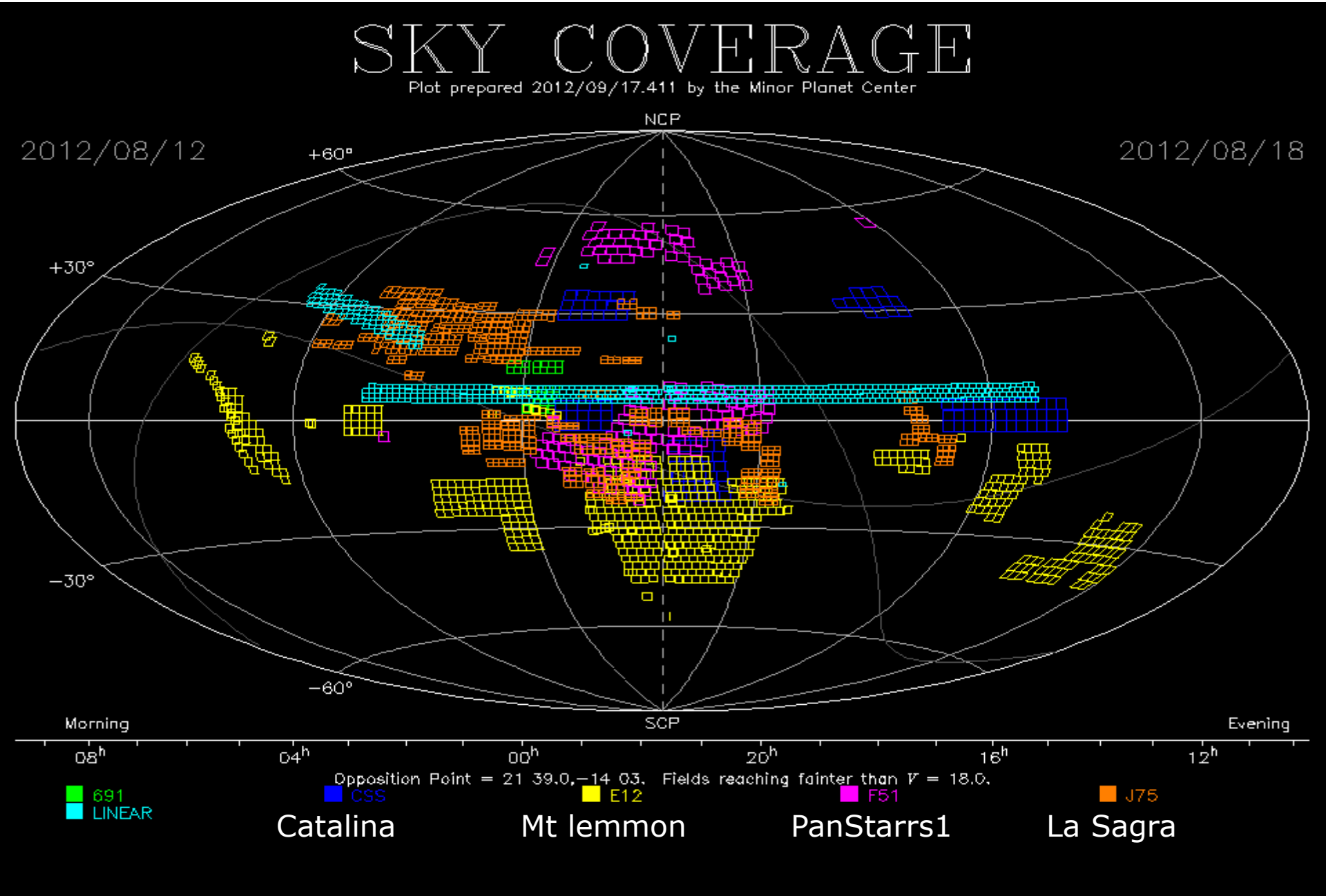
NASA mandate: discover 90% NEOs with d> 140m: (Catalina, PANSTARRS, LSST etc)

ESA plan: discover small size (10m-class) potentially hazardous objects with significant warning time.



- Innovative Fly-Eye technology by INAF/CGS (Compagnia Generale dello Spazio)
- 45 square degrees (6.7 x 6.7) FOV allow an all sky-survey covering at least once per night the whole sky
- cost effeciveness: originally proposed for Space Debris detection (SSA-SST Segment) on high LEO (1200 km)

NEO Segment: Wide Survey



Space Based Assets

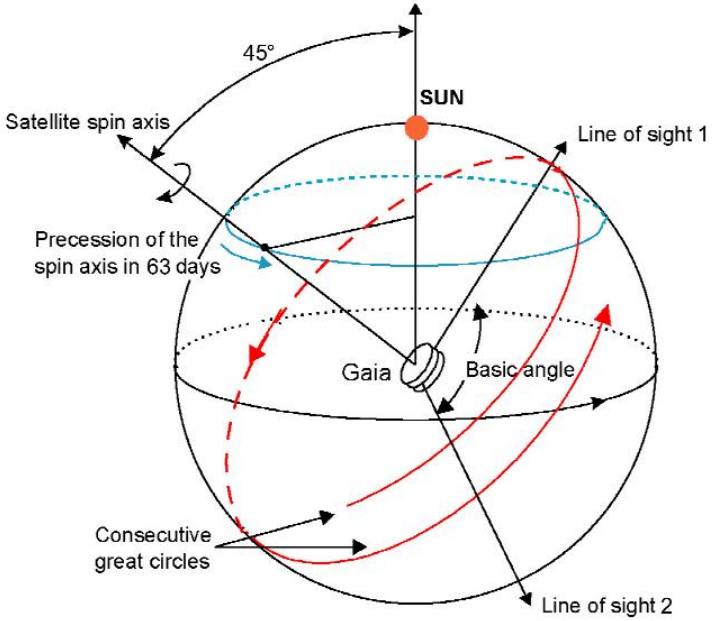
	Herschel	Bepicolombo	Asteroidfinder	NEOSSat	Venus Express	Rosetta	Gaia
Primary mission	Infrared observatory	Mercury exploration	NEOs	NEOs	Venus exploration	Comet exploration	Star catalogue
Operator	ESA	ESA	DLR	CSA	ESA	ESA	ESA
Nominal operation dates	2012-2017	2014-2020 cruise 2020-2021 Mercury	~~2013-2014~~	2012-2013	2011-2012	2014-2015	2012-2017
Instrument type	IR telescope	3x star trackers	Optical telescope	Optical telescope	2x star trackers	Optical/IR telescopes	Dual optical telescope
Limiting Magnitude	- ?	5.2	18.5	20	5.5	12 (WAC) 16 (NAC)	20
Observable region	All sky Sun-LoS angles down to 60.3º	All sky from Mercury	All sky Sun-LoS: 30º-60º	All sky Sun-LoS: 45º-55º	All sky from Venus	Depending on allowable manoeuvres	Celestial Sphere Sun-LoS: down to 45º
Field of view	0.25º	20º (cone)	2x2º	0.85º	16.4º	2ºx2º (NAC) 12.1ºx12.7º (WAC)	0.7ºx0.7º
Observation strategy	Fine pointing / scan law modes	Close-range passive detection	Sky survey from sun-synchronous orbit	Sky survey from sun-synchronous orbit	Close-range passive detection	Pointing on demand	Optimized for uniform sky coverage
Type of observations	Follow-up Physical observations	Follow-up	Discovery	Discovery Follow-up	Follow-up	Follow-up	Discovery Physical observations
Expected return	Low	Very Low	Very high	Very high	Very low	Low	High

Ref. "Gaia and Space Based Assets Contribution", TN10, ESA Contract SNIII – NEO precursor Services

Space Based Assets: Gaia simulations

Although in the long run many objects in small, highly eccentric orbits will be discovered as they reach favorable observing geometries, in the short term they represents a potential threat because direct impactors coming from inside the solar system will not be seen until immediately before impact.

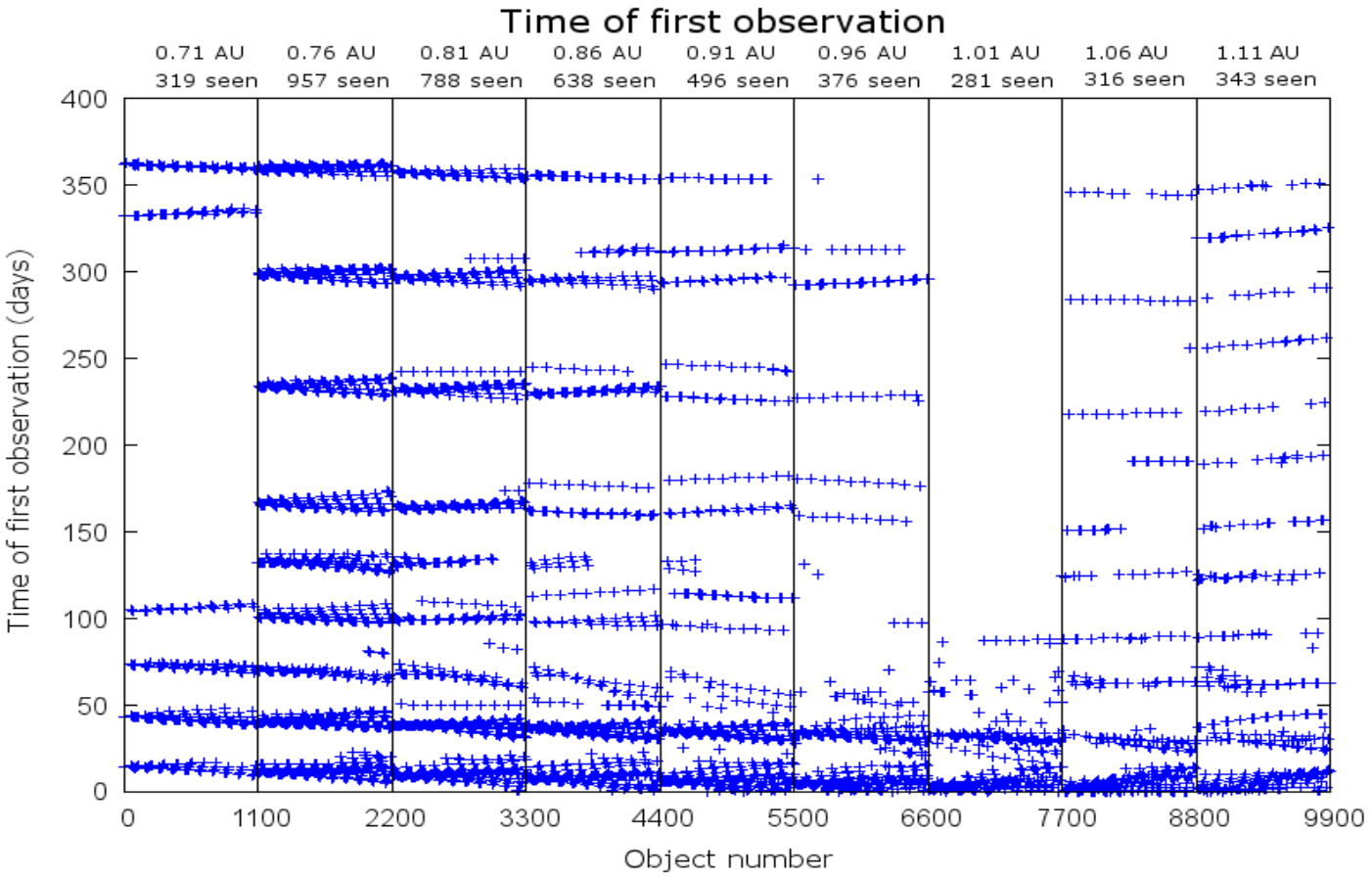
Although the GAIA scanning law is not optimized for NEO detections, the possibility of observing down to 45 deg from the Sun and the peculiar rotation of the S/C provides a good opportunity for contributing to NEO observations and to the discovery of new IEOs.



Simulations

- synthetic population of objects in low inclination circular orbits of semimajor axis between 0.71 and 1.1 AU
- H = 18.12 (e.g C-Type 1 km diameter)
- not representative of the NEO population but of Gaia peering through the inner solar system

Space Based Assets: Gaia simulations



- The time of detection of new objects occurs at 31.5d interval (half the Gaia precession): lowest semimajor axis objects detection frequency.

- . The gap for high synodic period objects (P=1.1y means T=11 i.e. 35.7º/year) implies a blind zone about 30 deg wide,

Space Based Assets: conclusions

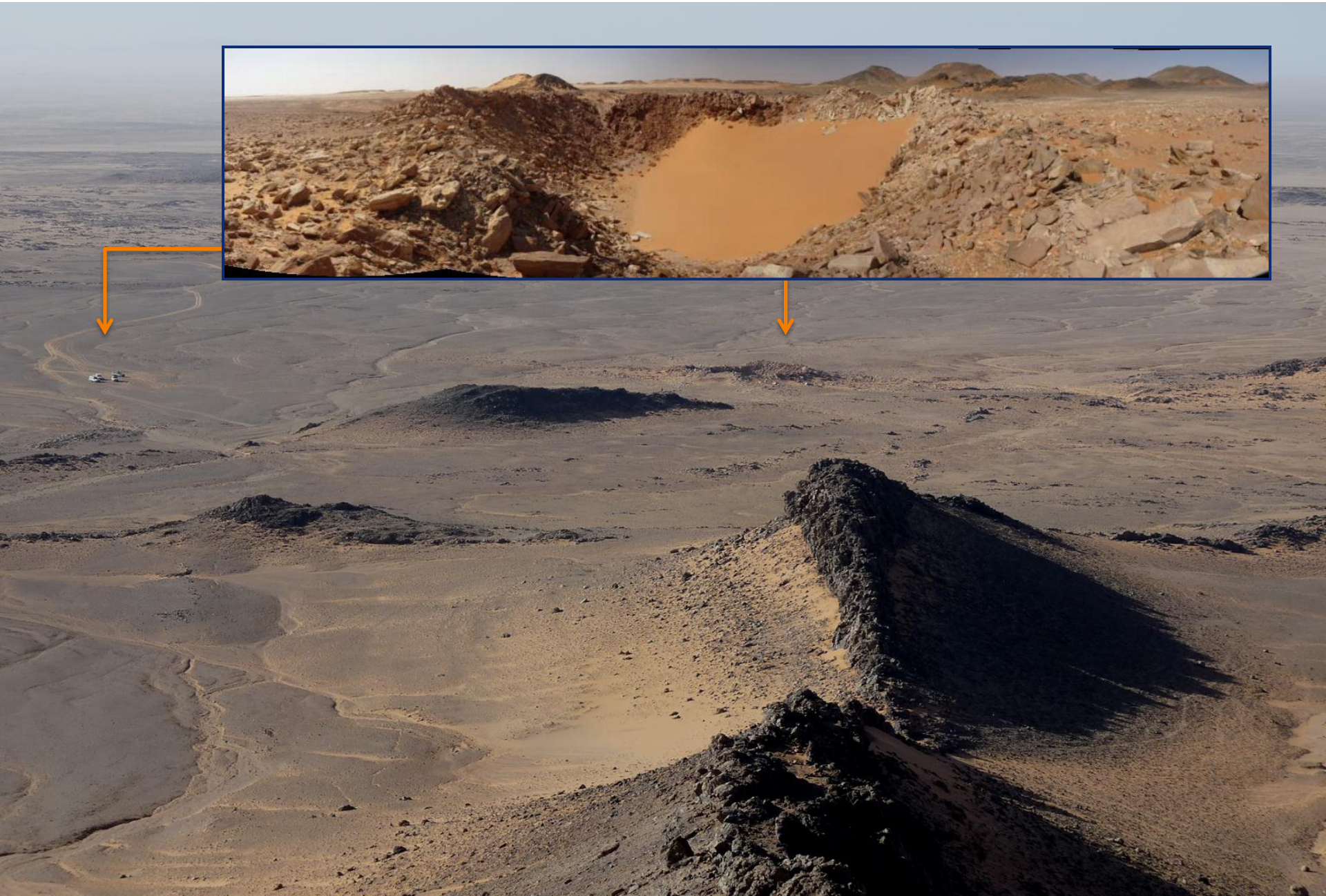
- Among space-based missions not devoted to NEO observations, only Gaia could provide a significant return to the NEO Segment
  => *Gaia is an European space asset providing NEO physical and orbital data*

- The Gaia FUN-SSO bears strong similarities with the planned federation of existing assets for performing NEO Segment follow-up
  => *establish two-way collaboration between Gaia-FUN-SSO and the NEO Segment.*

- Direct impactors coming from approximately the direction of the Sun cannot be detected with sufficient warning time from present/near future space based assets.
  => *study a space-based mission to address this problem*

NEO Segment: Mitigation

Risk assessment: the Kamil Crater Expedition



Gaia ⇔ NEO Segment interaction

Gaia => NEO Segment

- *NEO discovery (detection)*
- *High-quality astrometry (orbit determination / improvement)*
- *Photometry (for risk assessment and mitigation)*
- *Follow-up ground network (orbit improvement)*

NEO Segment => Gaia

- *NEO data centre (alerts dissemination, priority list, precovery services etc.)*
- *Follow-up ground network (alerts confirmation contribution)*
- *Real-time Wide Survey transients detection / confirmation*
- *Hazard warning & mitigation (UN Action Team 14)*