Meeting at BELSPO

3rd July 2012

SSA Programme (ESA)

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PURPOSE OF THE SSA PROGRAMME

"The objective of the Space Situational Awareness (SSA) programme is to support the **European independent utilisation** of, and **access to, space** for research or services, through the **provision of timely and quality data**, information, services and knowledge regarding the **space environment**, the **threats** and the sustainable exploitation of the outer space **surrounding our planet Earth."**

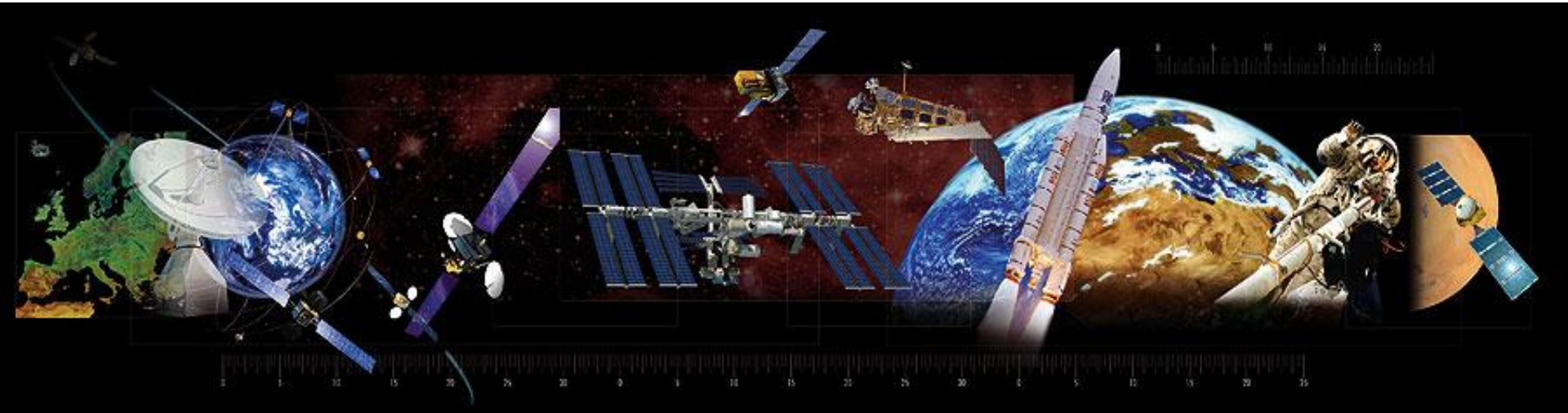
- **ESA Ministerial Council November 2008**

AIMS OF THE SSA PROGRAMME

- Independent utilisation of Space
  - **Space assets are critical assets and require protection (collision avoidance, space weather effects) through services provided by a SSA System**
- Guarantee access to Space
  - Diplomatic,
  - Political
  - Regulatory
  - Technical
- Serve EU "Lisbon Objectives"
  - New Applications
  - New Jobs
  - New Markets

CUSTOMERS FOR SSA SERVICES
Protection of space and ground-based infrastructures

- European Governments
  - EU, EC
  - National
  - Regional
- European Space Agencies
  - ESA
  - National
- Spacecraft Operators
  - Commercial
  - Academic
  - Governmental
- Space Insurance
- Space Industry
- Energy
  - Surveying
  - Electrical Grid
  - Power Supply
- Network Operations
- Telecommunications
- Air Traffic Control
- Search and Rescue Entities
- United Nations
- Defence
- Civil Protection



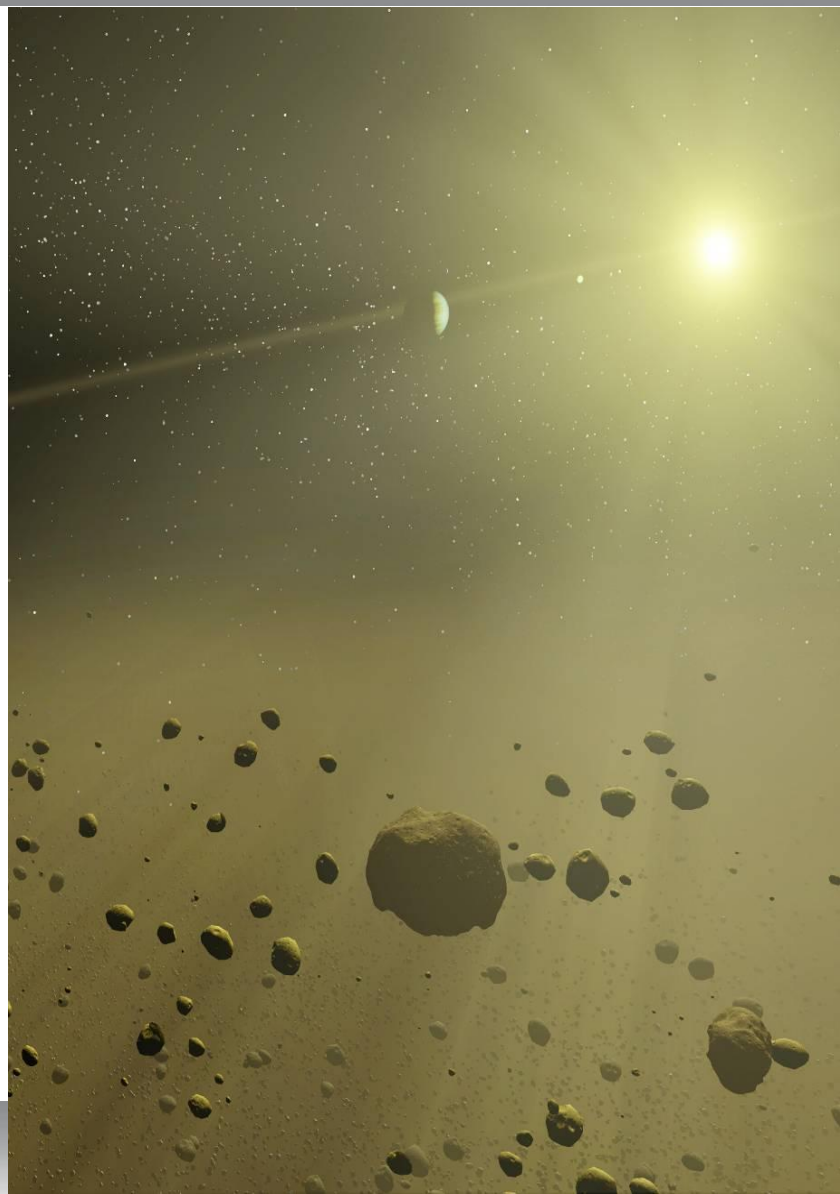
SSA Programme – an implementation in periods

2009 – 2012 (Period 1)

- **SSA Preparatory Programme**
  - Governance Definition
  - Data Policy
  - Mission, customer and system requirements
  - Architecture
  - Federation of existing assets
  - Precursor Services
  - Radar Breadboards
  - Pilot Data Centres

2013 – 2016 (Period 2)

- **SSA Development, Test & Validation**
  - Development of essential components corresponding to the required architecture
  - Networking of assets
  - Testing & Validation of SST, SWE and NEO Segments



SSA Preparatory Programme Structure

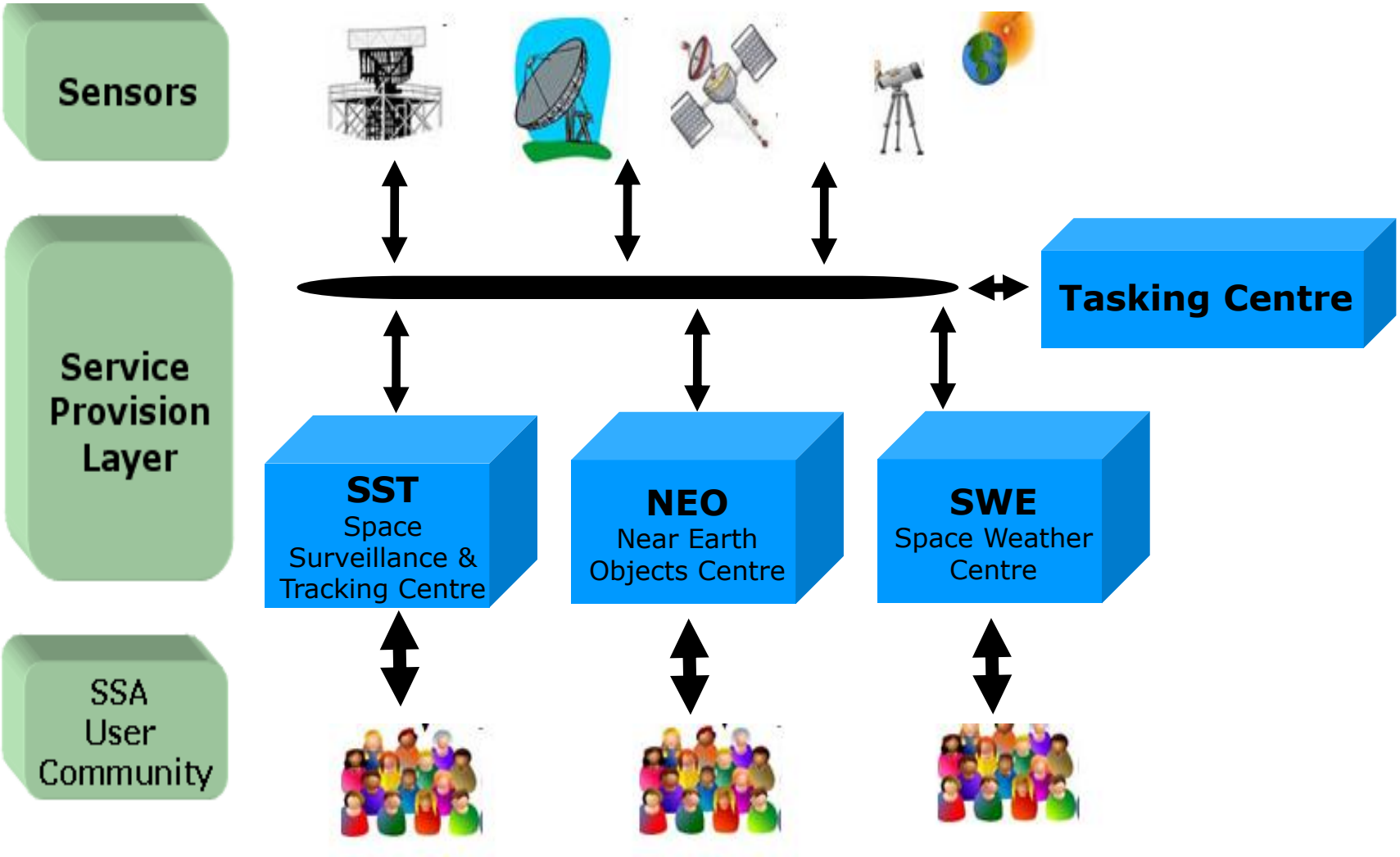
1. Core Element
   - Mission Requirements
   - SSA Customer Requirements
   - SSA System Requirements
   - SSA Architecture
   - Governance
   - Data Policy
   - Security
   - Space Surveillance and Tracking Segment
2. Space Weather Element
   - (including NEO activities)
3. Radar Element
   - Prototype Development of demonstrators
4. Pilot Data Element
   - Transversal support for all segments

SSA Participating States

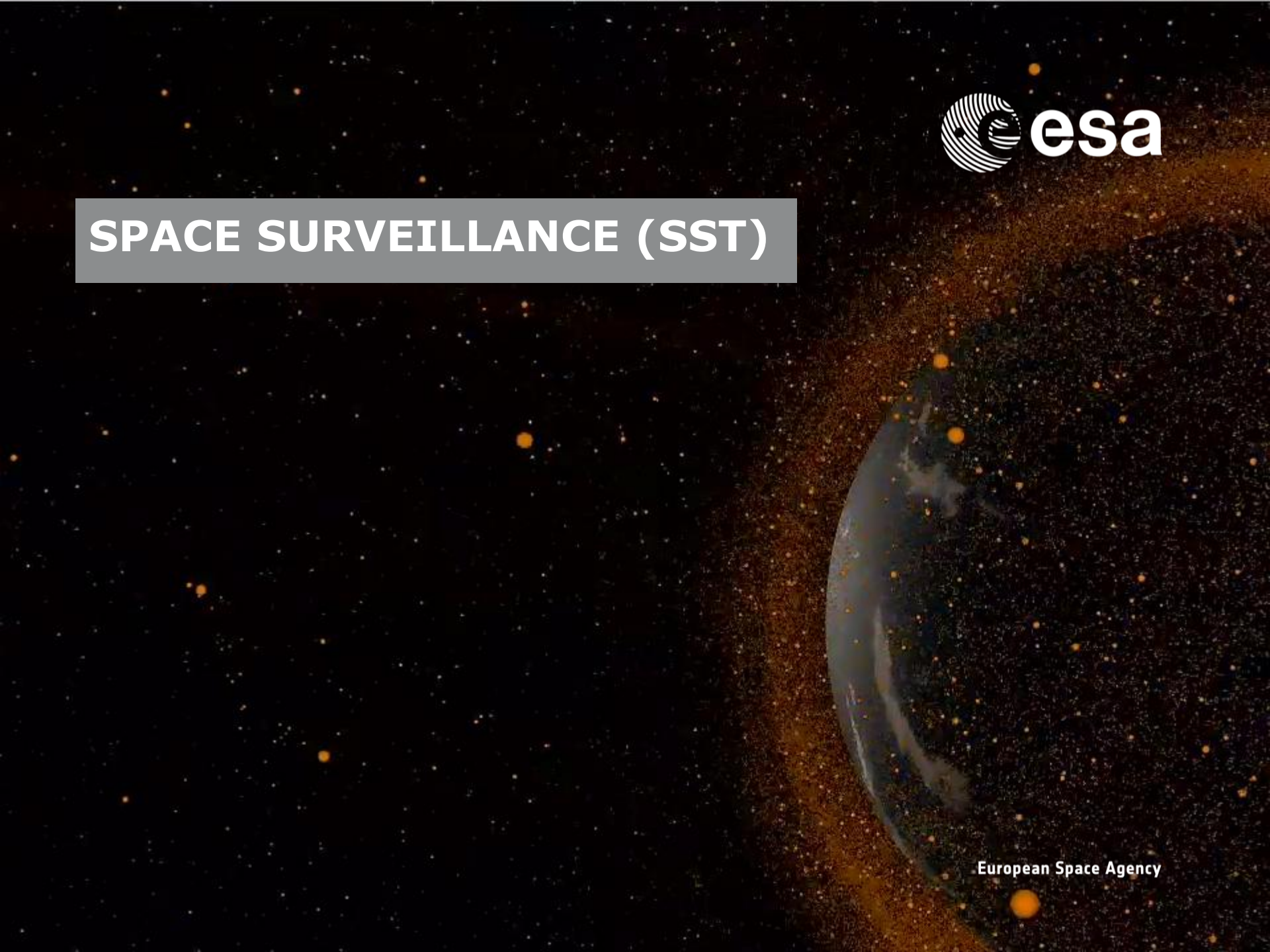
- **Austria**
- **Belgium**
- **Finland**
- **France**
- **Germany**
- **Greece**
- **Italy**
- **Luxembourg**
- **Norway**
- **Portugal**
- **Spain**
- **Switzerland**
- **United Kingdom**
- **New Participating States are expected to join the SSA Programme for its Period 2 (2013 – 2016)**

European SSA System

SSA Programme Structure

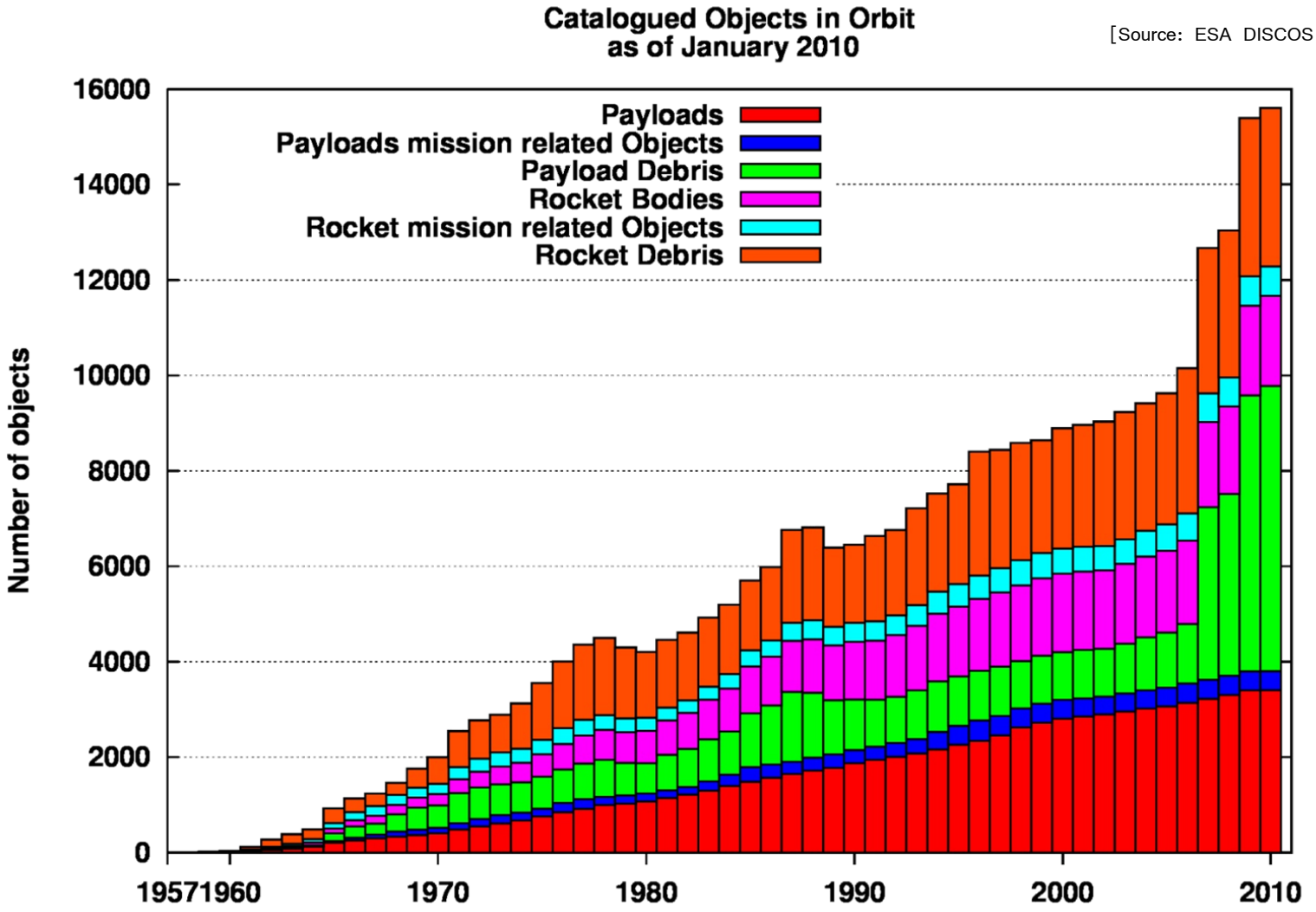


SPACE SURVEILLANCE (SST)



European Space Agency

SPACE SURVEILLANCE
The Environment

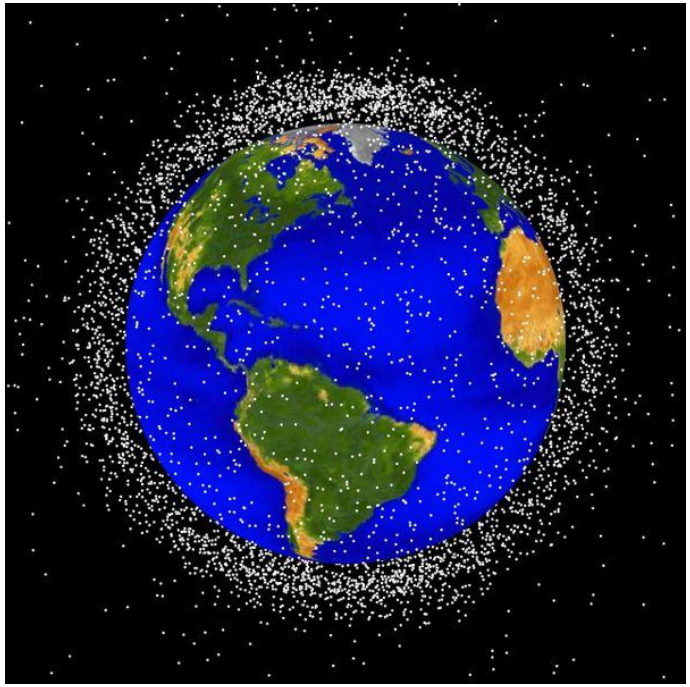


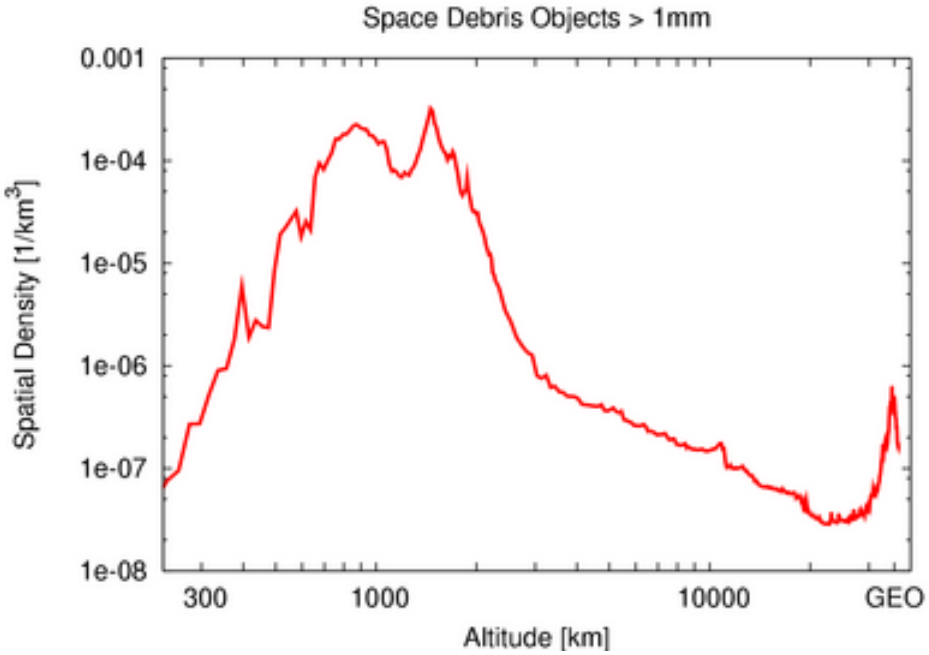
Estimated number of objects in orbit

space objects larger than d [cm]		LEO		MEO-L	MEO-H	MEO-H & GEO	GEO
d [cm]	count	res.[%]	trans.[%]	res.[%]	res.[%]	trans.[%]	res.[%]
100	4,658	50.0	17.5	0.9	4.5	7.1	20.0
50	6,549	52.3	18.1	2.7	3.7	7.0	16.2
30	9,091	56.6	16.5	2.2	3.3	7.2	14.1
10	20,505	54.2	13.6	1.0	3.9	10.7	16.4
5	44,092	48.6	13.5	0.5	4.5	14.3	18.4
3	90,541	44.8	15.1	0.2	4.8	15.9	19.0
1	606,474	32.1	23.3	0.2	5.6	24.8	13.8
altitudes [km] ⇨		120 to 2,000 km			15,000 to 38,000 km		
observability ⇨		radar		difficult	optical		

Distribution and observability of space objects (MASTER 2005)

Distribution of objects in Earth orbit





SPACE SURVEILLANCE
The Services

1. Launch and Early Operation (LEOP)

   Provide orbit data where necessary and confirm event success (such as separation)

2. Contingency Situations

   Assist in cases where location of satellite is unknown or state is uncertain.

3. Mission Support

   Survey and tracking of passive objects or components

4. Collision Avoidance

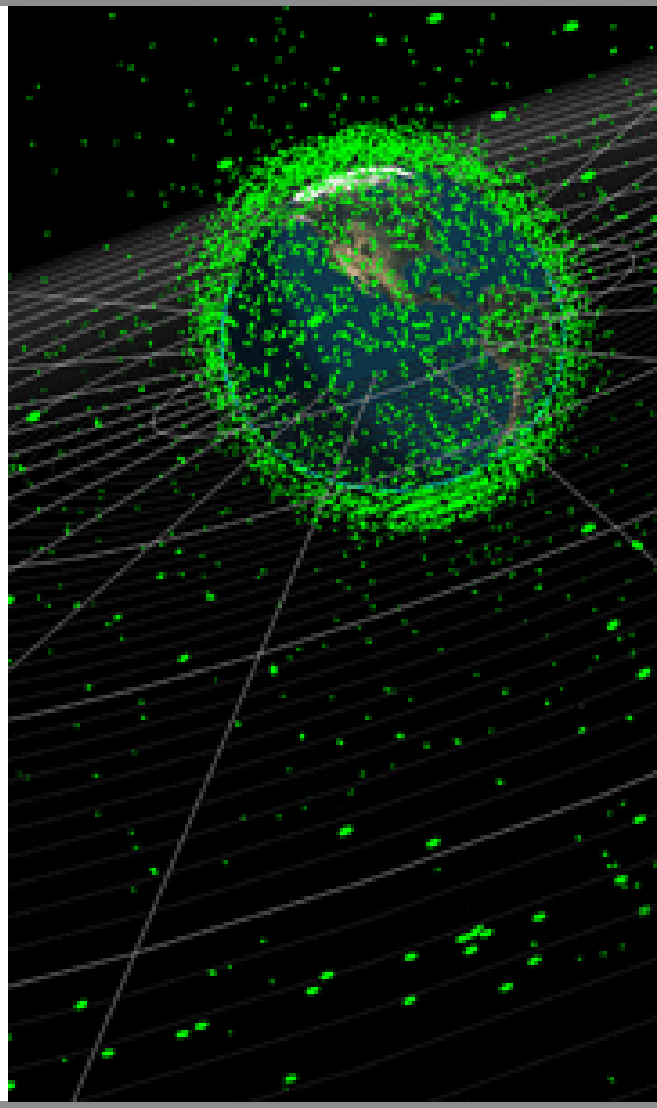
   Monitor and predict the trajectories of all critical Earth orbiting bodies. Calculate potential intersections and assist in the implementation of corrective actions where possible.

5. Re-entry prediction

   Track decay trajectories and calculate the potential impact area(s).

6. Space Traffic Awareness

   Detection of insertion orbits, fragmentation and overall situation in near Earth orbit.

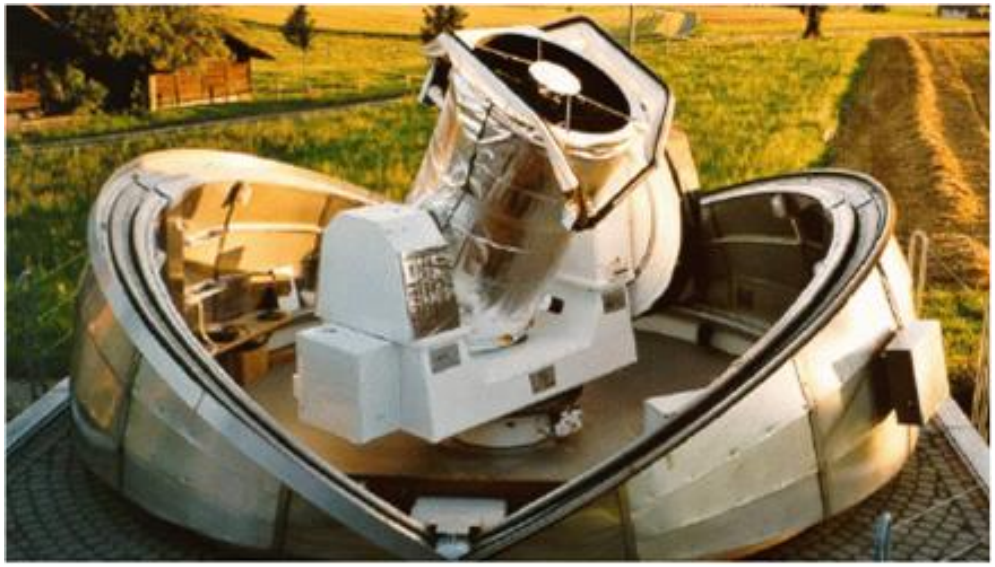


Sensors for surveillance and tracking

Graves (France) – Bi-static surveillance radar

Sensors for surveillance and tracking

FGAN (Germany) – tracking radar



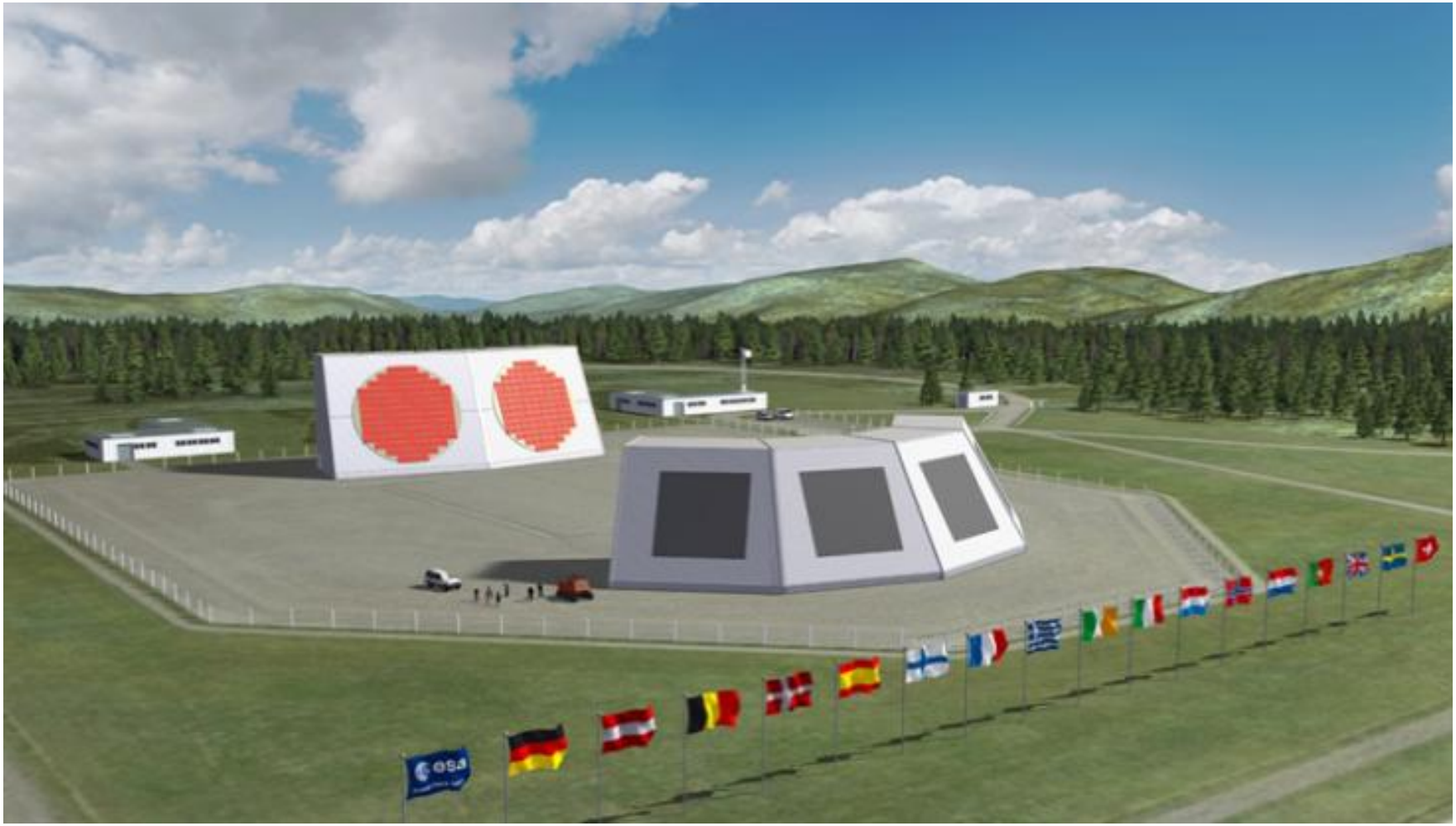
Zimmerwald (Switzerland) - tracking telescope

Sensors for surveillance and tracking

EISCAT antennas at Svalbard

SPACE SURVEILLANCE

Artist view of a close monostatic surveillance radar

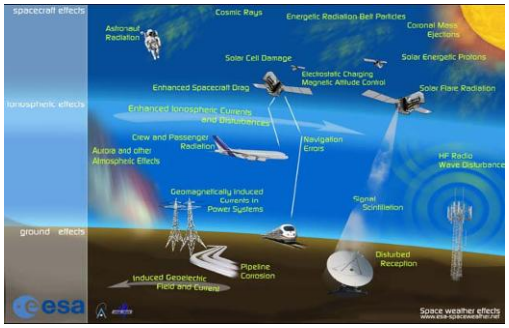


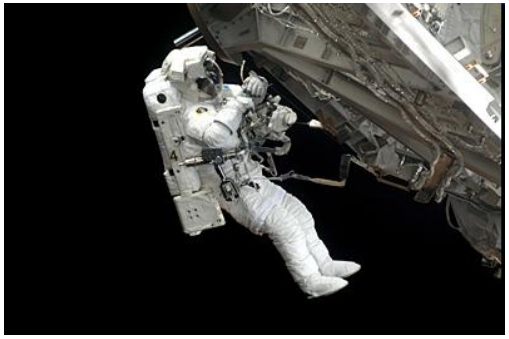
SPACE WEATHER (SWE)

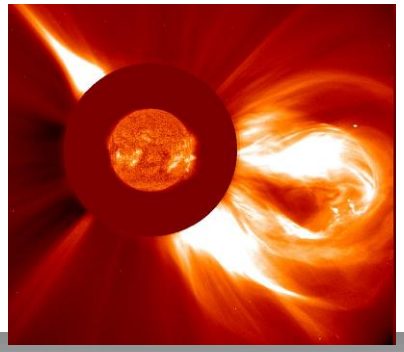
Space Weather Objectives

Detection and forecasting of the Space Weather events and the effects it has on European space assets and ground based infrastructure:

- Comprehensive knowledge, understanding and maintained awareness of the natural space environment
- Detection and forecasting of SWE and its effects
- Detection and understanding of interferences due to SWE
- prediction and/or detection of permanent or temporary disruption of mission and/or service capabilities
- provision of predicted local spacecraft and launcher radiation, plasma and electromagnetic environment data







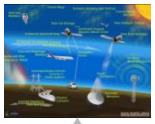
Images: (ESA & NASA)

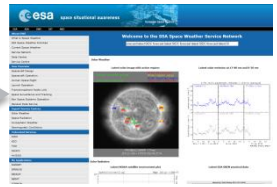
SSA-SWE Service Concept

- Development of the SSA-SWE services is based on utilisation of European space weather assets and expertise
  - ⇒ ESA is coordinating the system development and establishing a framework to network European assets
  - ⇒ Services will be provided by European centres forming Expert Service Centres (ESCs)
  - ⇒ Federated SSA-SWE Services
- ESA will establish agreements with
  - ESCs for service provision
  - Asset owners (ground based and space borne assets) for access to the SWE data
- ESA will continue the development of the SSA-SWE space segment to ensure availability of the space weather data

SSA Space Weather Segment
Precursor Service System in June 2012

SSA-SWE Users





SWE Service Portal

SWE Data Centre
Redu, Belgium

SWE Service Coordination Centre, BIRA, Belgium

SWE Expert Service Centre
Solar Weather

Coordinator:
ROB, Belgium
Austria: Kanzelhöhe

SWE Expert Service Centre
Ionospheric Weather

Coordinator:
DLR, Germany

SWE Expert Service Centre
Space Radiation

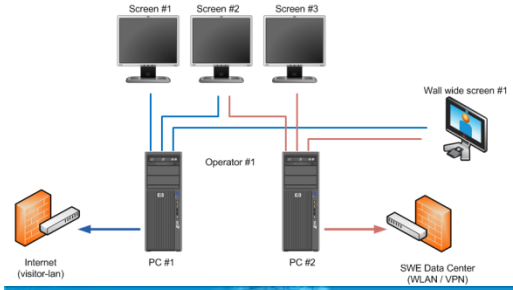
Coordinator:
BIRA, Belgium
Austria: AIT

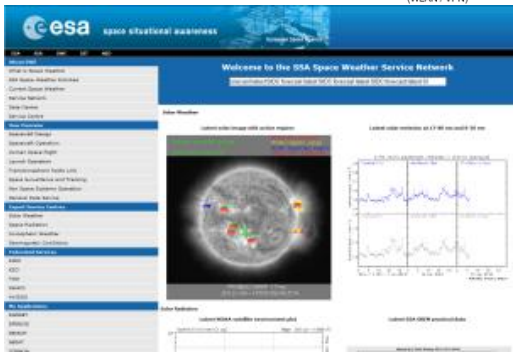
SWE Expert Service Centre
Geomagnetic Conditions

Coordinator:
TGO, Norway

SSA Space Weather Segment
SWE Service Coordination Centre (SSCC)

- SSCC is the first point of contact for SSA-SWE services
  - operates and maintains the applications and databases in the SSA-SWE Data Centre
  - monitors the availability of the SSA-SWE services including the federated services
  - monitors the accessibility SSA-SWE Service Portal
  - appoints the second level user support by appropriate ESCs
- SSCC for the SSA PP has been established in Royal Observatory of Belgium
- The operators are
  - Belgium Institute of Space Aeronomie
  - Royal Observatory of Belgium
  - Space Application Services
  - Spacebel S.A.



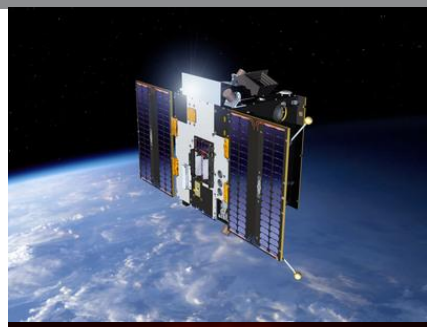


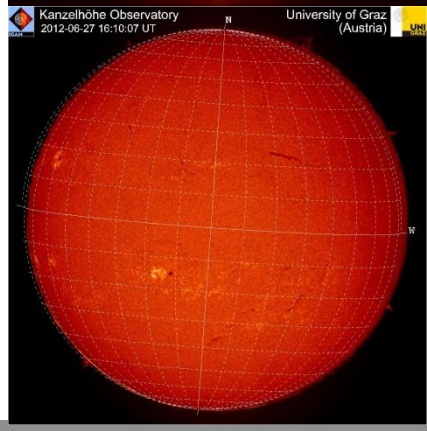
SSA Space Weather Segment
SSA-SWE Data Centre

- SSA-SWE Data Centre has been established in the ESA Redu Station
- The Data Centre hosts
  - the servers needed to run some of the applications supporting the SSA-SWE services to the end users and the SWE Service Portal
  - hard disks containing space weather databases established in the frameworks of ESA contracts with ESA ownership
  - all necessary infrastructure to ensure 24/7 availability of the databases and applications hosted by the Data Centre
- SSA-SWE Data Centre is operated by the SSCC and the ICT is maintained by ESA
- It is foreseen that the SSA-SWE Data Centre will be networked with federated data centres in the next periods of the SSA Programme
- The objective is to make the SSA-SWE Data Centre one of the central nodes in the European space weather database system

SSA Space Weather Segment
ESC: Solar Weather

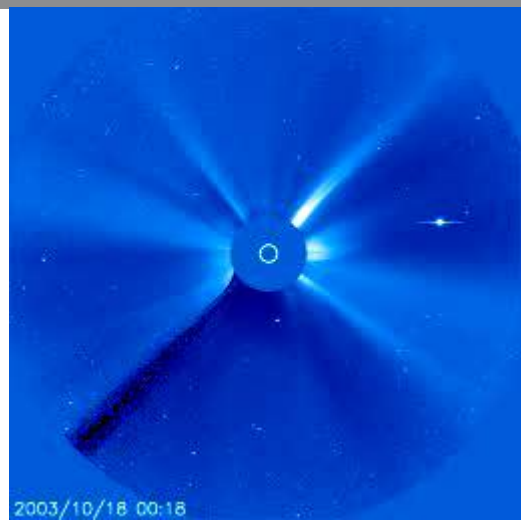
- Solar Weather ESC centralises the expertise on solar drivers of the space weather
- The expertise offered by the ESC includes
  - Long term solar cycle prediction
  - Solar flare monitoring and statistical prediction
  - Coronal Mass Ejection (CME) monitoring and geo-impact prediction
  - Coronal hole monitoring and geo-impact prediction
- Provides a large number of federated SSA-SWE services:
  - solar event alerts (automatic and forecaster triggered)
  - Solar weather predictions and forecasts
  - Latest and archived solar data
  - solar indexes
- Coordinator: **Royal Observatory of Belgium, Belgium**
- Participants: **University of Graz, Austria**

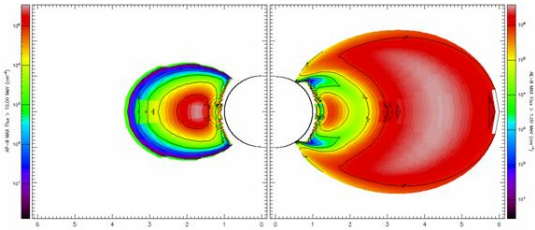




SSA Space Weather Segment
ESC: Space Radiation Environment

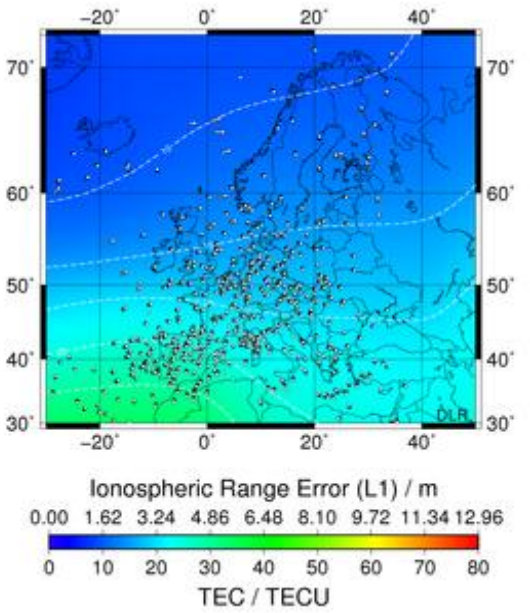
- Centralises the expertise on radiation environment in space and in aircraft flight altitudes
- End user support includes
  - Solar Energetic Particle (SEP) events: potentially harmful for manned spaceflight and airline crews/passengers on polar flight
  - Trapped radiation particles: harmful for spacecraft electronics, electrical systems and solar cells
  - Cosmic rays: harmful for spacecraft electronics and cause for background radiation dose for aircraft crew/passengers
- Applications made available to end users:
  - SPENVIS (SPace ENVironment Information System)
  - AVIDOS (AVIation DOSimetry)
- Coordinator: **Belgian Institute of Space Aeronomie, Belgium**
- Participants: **Austrian Institute of Technology, Austria**





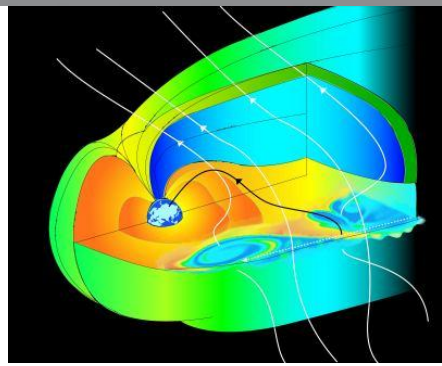
ESC: Ionospheric Weather

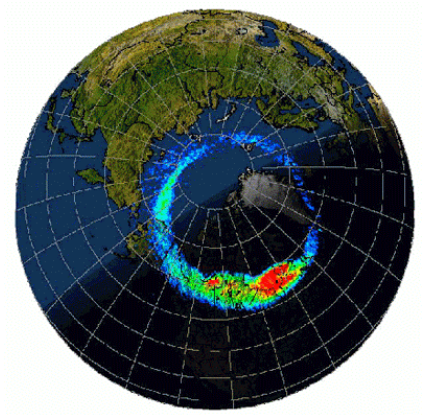
- Ionospheric Weather ESC centralises the expertise on the ionized upper layers of the atmosphere
- Disturbances in the ionosphere impact satellite telecommunication, navigation and VHF/UHF radio communication
- Federated services offered by the Ionospheric Weather ESC include:
  - Regional and global maps and forecasts of Total Electron Content (TEC)
  - Ionospheric disturbance information and alerts
  - Ionospheric scintillation information
  - 2D electron density in the plasmasphere
- Coordinator: **Deutschen Zentrums für Luft- und Raumfahrt, Germany**

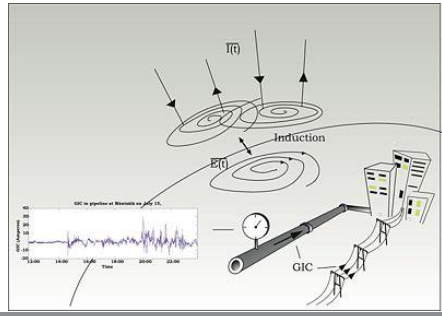


ESC: Geomagnetic Conditions

- Geomagnetic conditions ESC centralises expertise on variations in the Earth's magnetic field
- Geomagnetic storms can cause problems in traditional navigation systems, Geomagnetically Induced Currents (GIC) in power systems and pipelines and are related to ionospheric disturbances
- The end users of the Geomagnetic Conditions ESC services include:
  - Power grid and pipeline operators
  - Resource exploration and exploitation industry
  - Geomagnetic surveying companies
  - Auroral tourism sector
  - Other ESCs requiring geomagnetic data
- Coordinator: **Tromsø Geophysical Observatory, Norway**

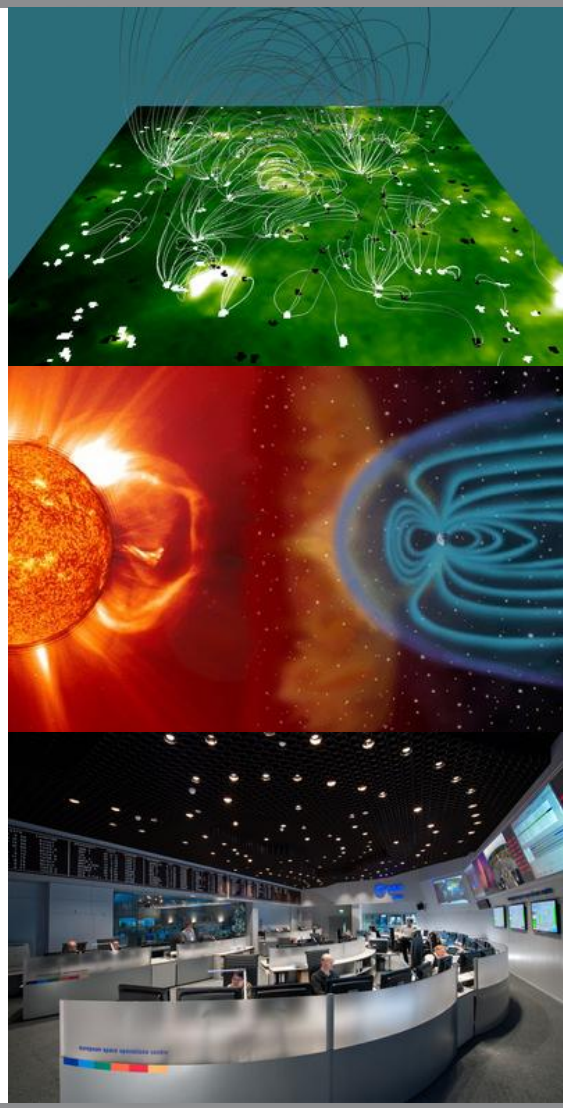






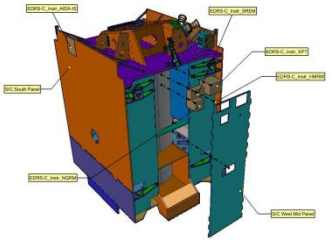
ESC Concept Evolution

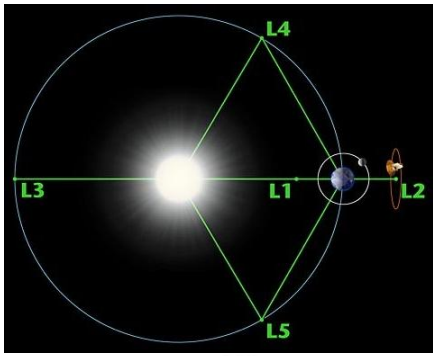
- Existing ESCs have been established focusing on physical domains of space weather
- New participants to the existing ESCs are expected already during SSA PP to establish more services to the users
- Additional ESCs will be considered during SSA Period 2
- **Interplanetary environment** modelling is one potential new ESC topic
- Development of the ESC concept and the federation of the SSA-SWE services will be continued throughout the SSA Programme
- ESCs and the participating entities are the core of the SSA-SWE service provision system



SSA Space Weather Segment
SSA-SWE Space Segment Development

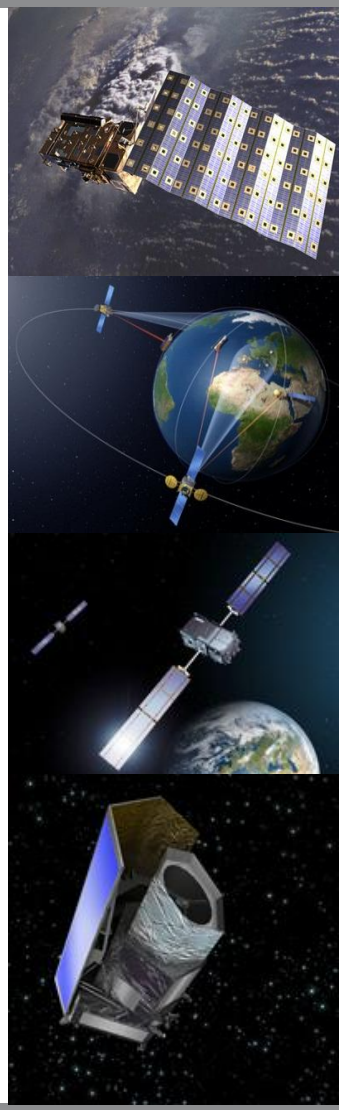
- SSA-SWE services depend critically on space borne observations
- SSA Period 2 proposal includes activities for
  - SWE instruments as Hosted Payload for GEO, MEO and LEO missions
    - Radiation environment, s/c charging, solar x-ray, micro-particles, magnetic field and plasma measurements
    - Phase C/D development for selected instruments either as part of the SSA Programme or in national activities
  - System studies for enhanced SWE monitoring from L4/L5 points with a heliospheric imager mission
  - Exploitation of data from existing and already planned SWE missions including e.g. Proba-2, GIOVE A and B, Galileo FOC, MTG,…
  - Phase A/B/C/D development of a miniaturized wide angle coronagraph
  - Phase A/B studies on new space based SWE instruments





SSA Space Weather Segment
Candidate Missions for SWE Hosted Payload

- Hosted payload missions are an affordable approach for selected elements of the SSA-SWE space segment
- Candidate missions for hosting SSA-SWE instruments include
  - GEO: EDRS-C (potentially EDRS-A), Commercial telecom missions, EuroStar
  - MEO: Galileo-FOC
  - LEO: Jason-CS, CSG-1 & 2, Metop-C
  - L2: Euclid
- Most HP missions can host only individual instruments, big missions like Metop-C or some GEO missions can host multiple instruments
- Non-European missions are considered, but with lower priority
- Hosted payload flight opportunities are constrained by the requirements of the primary satellite mission



European instruments for HP Missions

- 45 European SWE instruments currently under development in ESA or national programmes
- Most suitable instruments for HP missions have been identified including
  - Plasma monitors and plasma density instruments
  - Radiation monitors
  - Dust monitors
  - Satellite surface and internal charging detectors
  - GNSS receiver for ionospheric sounding
  - UV and X-ray flux monitors
  - X-ray and particle spectrometers
  - Accelerometers
- No suitable host mission for all instruments have been identified yet
- Hosted payload flights are always second priority for the main mission

=> Last minute cancellations or limited instrument operations are a risk

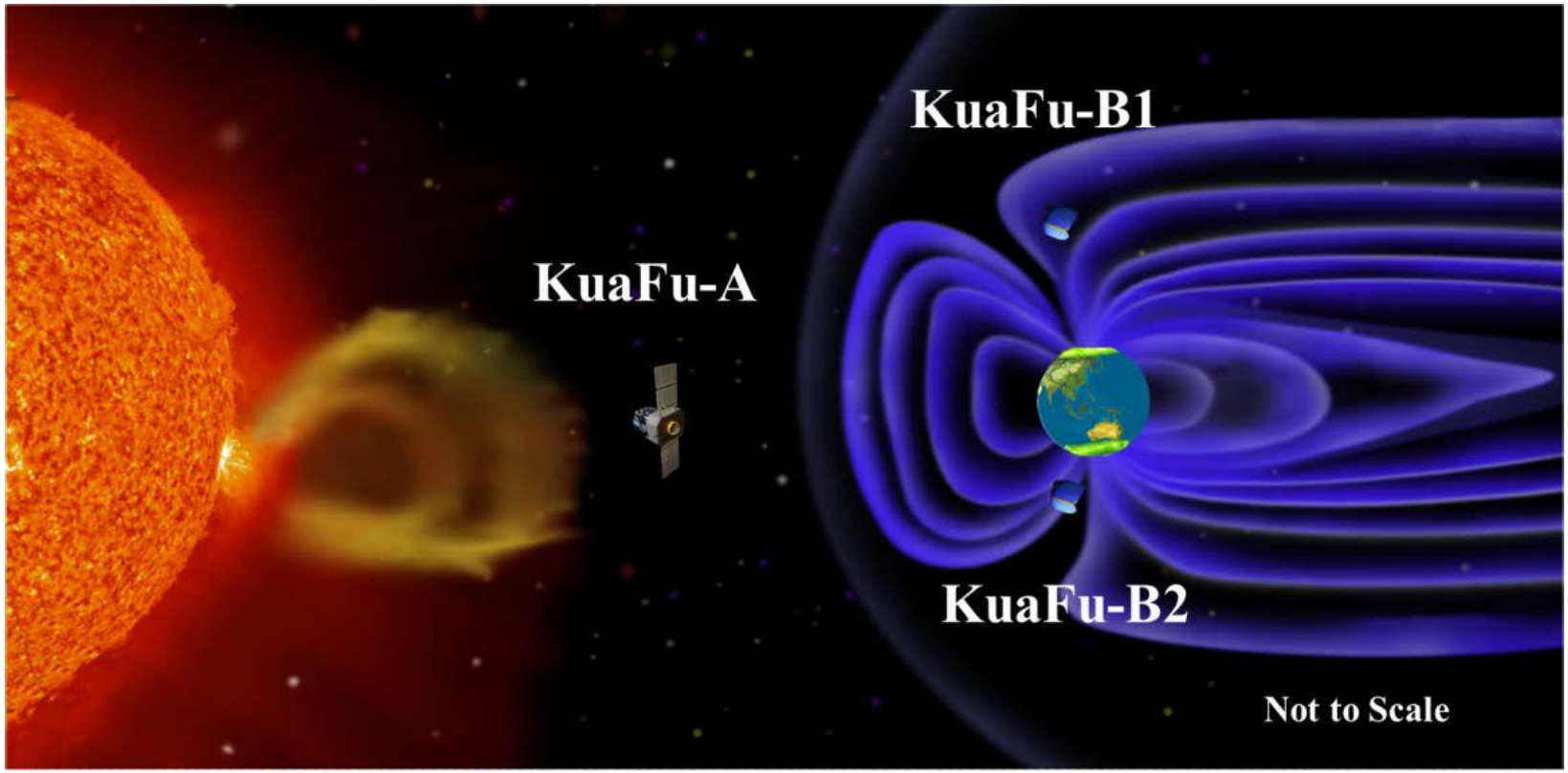
SSA Space Weather Segment
Dedicated SSA-SWE Missions

- Some SWE observations are very challenging to implement with HP missions
  - Solar wind measurement ahead of Earth on Sun-Earth line
  - Solar radio observations below ionospheric cut-off
  - Auroral activity via auroral imaging
  - Terrestrial radio observations below ionospheric cut-off
  - Nearly continuous solar corona imaging, solar x-ray imaging, solar EUV imaging
  - Comprehensive near Earth radiation belts and plasma monitoring
- Solar corona and solar wind observations are critical for SSA-SWE service and existing observation systems (ACE, SOHO) are aging

  => Planning for ensured continuity of these observations is carried out during SSA Period 2
- International collaboration will be explored for implementation of these missions

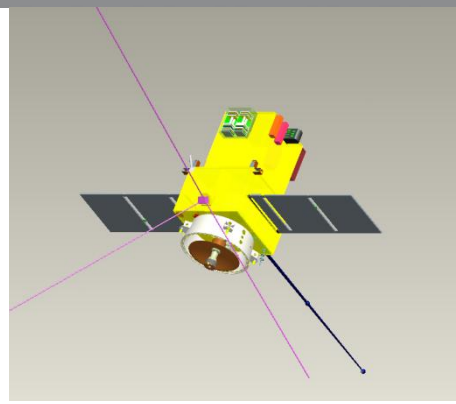
SSA Participation to KuaFu Mission

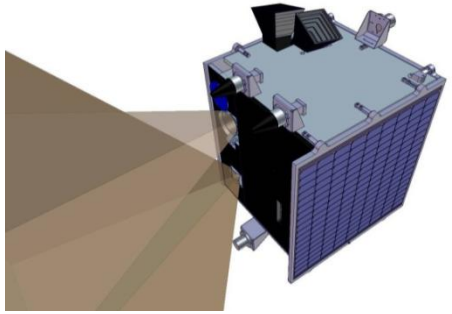
- Joint participation to the Chinese KuaFu mission together with ESA Science programme is considered
- KuaFu mission concept includes a spacecraf (KuaFu-A) in halo orbit around L1 and two spacecraft (KuaFu-B1 and KuaFu-B2) in Molnyia-type orbit around the Earth

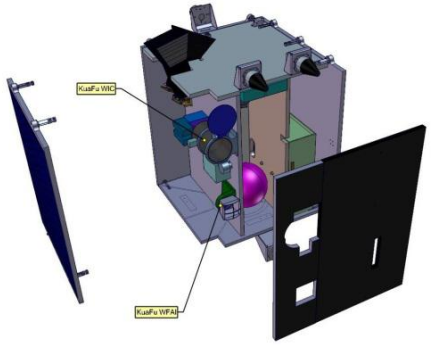


KuaFu Payload

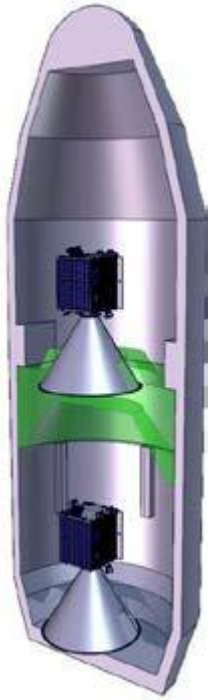
- KuaFu-A
  - Lyman alpha imager
  - Coronagraph
  - Fluxgate Magnetometer
  - Plasma Instrument
  - Hard X-ray/Gamma-ray spectrometer
  - Solar High-Energy Proton Detector
  - Solar High-Energy Electron Detector
  - Solar High-Energy Ion Detector
  - Solar electron-proton telescope
  - Digital Absolute Radiometer
- KuaFu-B
  - Wide Field Auroral Imager
  - Wideband Imaging Camera
  - Magnetometer (TBC)
  - Possibly other SWE instruments (TBC)







KuaFu Implementation Scheme



- China is proposing to implement Kuafu as Sino-European partnership
- Proposed cooperation scheme:
  - China to implement L1 S/C – ready for launch in 2017
  - Europe to implement Molnya-orbit S/C – China offering launch
  - Possible shared P/L provision
  - Possible shared operations concept
  - Full access to all data for both partners
- KuaFu is initially proposed as a science mission

  => SSA Programme participation will require mission upgrade to dowload solar wind and coronagraph data with a short timeliness

· ESA participation to KuaFu is considered as a shared activity between SSA Programme and the Science Programme to implement KuaFu-B mission

· ESA participation to KuaFu-A mission with selected instruments (e.g. wide angle coronagraph) and ground segment is also considered

SSA Benefits from KuaFu Mission

- KuaFu-A mission offers an unique opportunity to implement critical element of the SSA-SWE system to monitor solar corona, solar wind and interplanetary magnetic field at a shared cost
- KuaFu-B mission complements the data from KuaFu-A supporting SSA-SWE system customer requirements for
  - Post event analysis of spacecraft, aircraft, telecommunications or satellite navigation anomalies
  - Auroral forecasting for tourism and other commercial applications
  - Verification of geomagnetic disturbance nowcasting and forecasting including prediction of GIC impacts on power grids
  - Verification of telecommunication outage warnings in the polar region
  - Verification of space weather forecasting and improvement of the forecasting skills to avoid false alarms
  - Support SSA-SWE objectives for public outreach and education services
  - SSA-SWE support for third-party service providers

NEAR EARTH OBJECTS (NEO)

Status of knowledge on NEO environment (most data from NEODyS, 15-Dec-2010)

More than 400,000 known meteoroids, asteroids and comets

- Near Earth Objects (NEOs) are solar system objects with a perihelion of less than 1.3 AU.
- As of May 2012: 8971 NEOs have been discovered
- 294 in risk list (NEOs with non-zero chance of impact with Earth during next 100-200 years)

It is estimated that we know:

- 90% of NEOs larger 1 km in diameter (total ≈ 1050)
- 5% of NEOs larger than 140 m (total ≈ 100,000)
- 0.5% of NEOs larger than 40 m (total ≈ 1,000,000)

Largest Near Earth Asteroid (NEA): 1036 Ganymed (≈ 38 km)

Largest Asteroid: Ceres (≈ 950 km)

System overview

NEOs

Minor Planet Center (US)

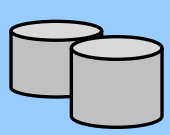
National Cooperating telescopes

SSA tasking centre

Political entities

SSA sensors

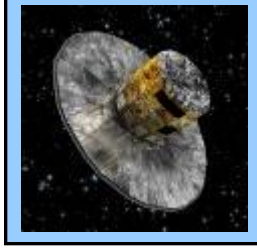
SSA-NEO Data Centre



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

General users

Space missions



National research expertise

Space mission studies

NEO image credit: JAXA

Services as of System Requirements Document – updates in Development Phase

- (S1) Issue NEO impact warnings and news releases.
  - Push information to decision makers
- (S2) Provide direct access to data in the NEO database
  - Add fireball database, all asteroids
- (S3) Provide access to data in the NEO database available only via registration.
  - Add proper access
- (S4) Perform additional observations.
  - Set up survey, tasking of existing and new telescopes
- (S5) Provide high priority information.
  - Add e.g. impact ground tracks, impact effects
- (S6) Provide educational and PR material.
  - Add educational material
- (S7) Provide user tools.
  - Add user tools (only simple observation planning tool available)

Extensions of capabilities and services

- Main service providers (see the following pages) already federated in the precursor services – but need to be expanded and detailed :
  - NEODyS/ASTDyS from the University of Pisa
  - Physical properties database from the European Asteroid Research Node at DLR Berlin
  - Priority list of the Spaceguard Central Node, INAF/Rome
- Foreseen extensions:
  - Calculation of ground corridor of potential impact locations
  - Inclusion of additional perturbing forces for orbit and impact predictions
  - Inclusion of comets in impact risk assessments
  - Establish distribution lists for NEO information notes and impact warnings.
  - Establishment of redundancy and upgrade capabilities for NEO services
  - To be added: fireball database, light curve database, shape models

Federated assets

- NEODyS = NEO Dynamic Site
  - http://newton.dm.unipi.it/neodys/
  - Operated by Univ. Pisa (I) and company SpaceDys
  - Daily computation of the impact risk of newly discovered NEOs
  - Provides risk list including errors
- European Asteroid Research Node (EARN)
  - http://earn.dlr.de/
  - Database containing the physical properties of NEOs
  - Maintained DLR Berlin

European Asteroid Research Node

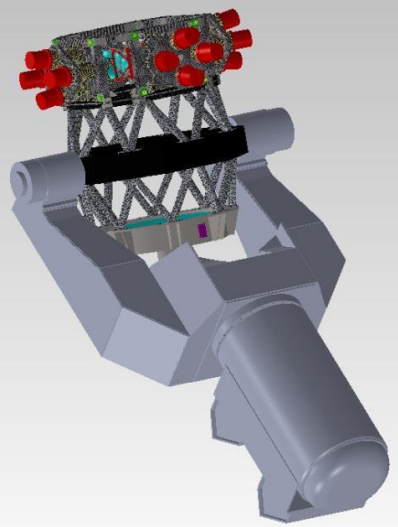
- Spaceguard Central Node priority list
  - http://spaceguard.iasf-roma.inaf.it/SSystem/SSystem.html
  - Maintained by INAF/Rome
  - Lists NEOs in urgent need of observations, even when not any more on NEO Confirmation Page

Observational efforts

- Continue to use the Optical Ground Station (OGS), ESA's 1-m telescope on Tenerife for follow-up observations
- Continue to support the La Sagra Sky Survey (LSSS), in Southern Spain
- Demonstrate scheduling capabilities
- Add a first wide-field survey telescope
- Set up tasking centre
- Build up interface to large telescopes (>2 m) for deep follow-up and physical properties observations

Optical Ground Station' of ESA (image: ESA)

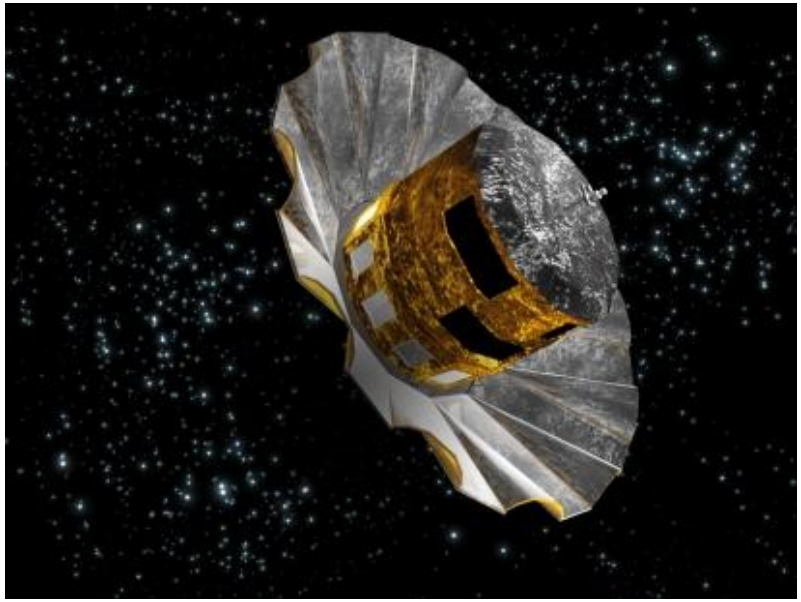
La Sagra Sky Survey (Image: LSSS)



Fly-eye telescope (CGS)

Interface to space missions

- Prepare for mitigation mission
- Close link to Gaia mission
  - Use high-precision astrometry to increase accuracy of NEO orbits
  - Support Gaia by optical observations of the spacecraft
- Other opportunities
  - Use Star Trackers for asteroid research
  - Space-based search telescopes

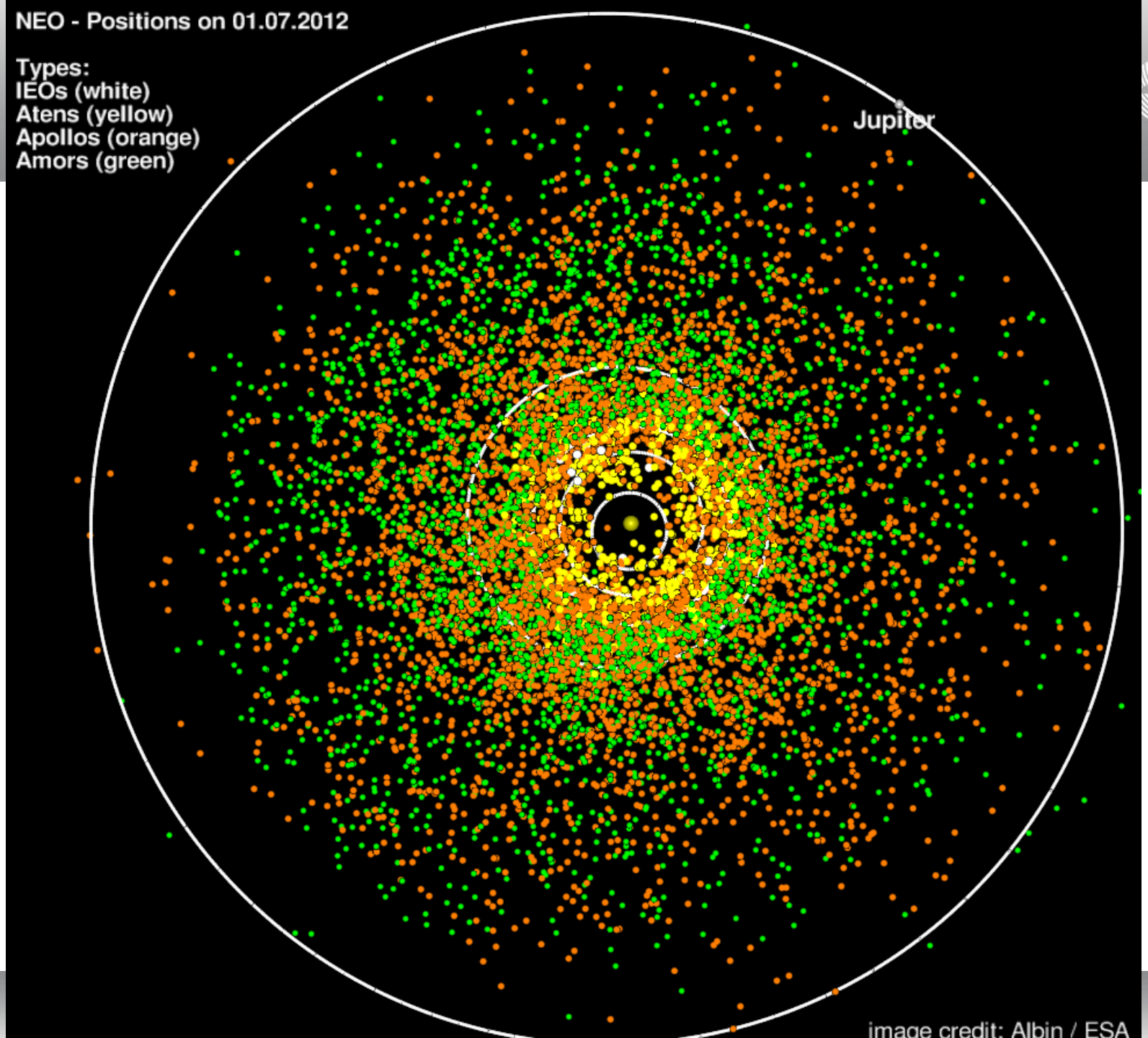


Gaia sun shield deployment

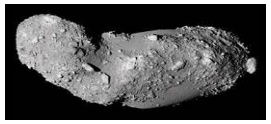
Image: ESA

Additional work and studies

- Finalize political decision process
  - Set up information chains in Europe
  - interaction with disaster management community
- Develop models and tools to assess impact effects
- Build up excellent knowledge related to impact mitigation missions, prepare for a demonstrator mission


NEO - Positions on 01.07.2012
Types:
IEOs (white)
Atens (yellow)
Apollos (orange)
Amors (green)
Jupiter
image credit: Albin / ESA

NEO Data Centres and Capabilities



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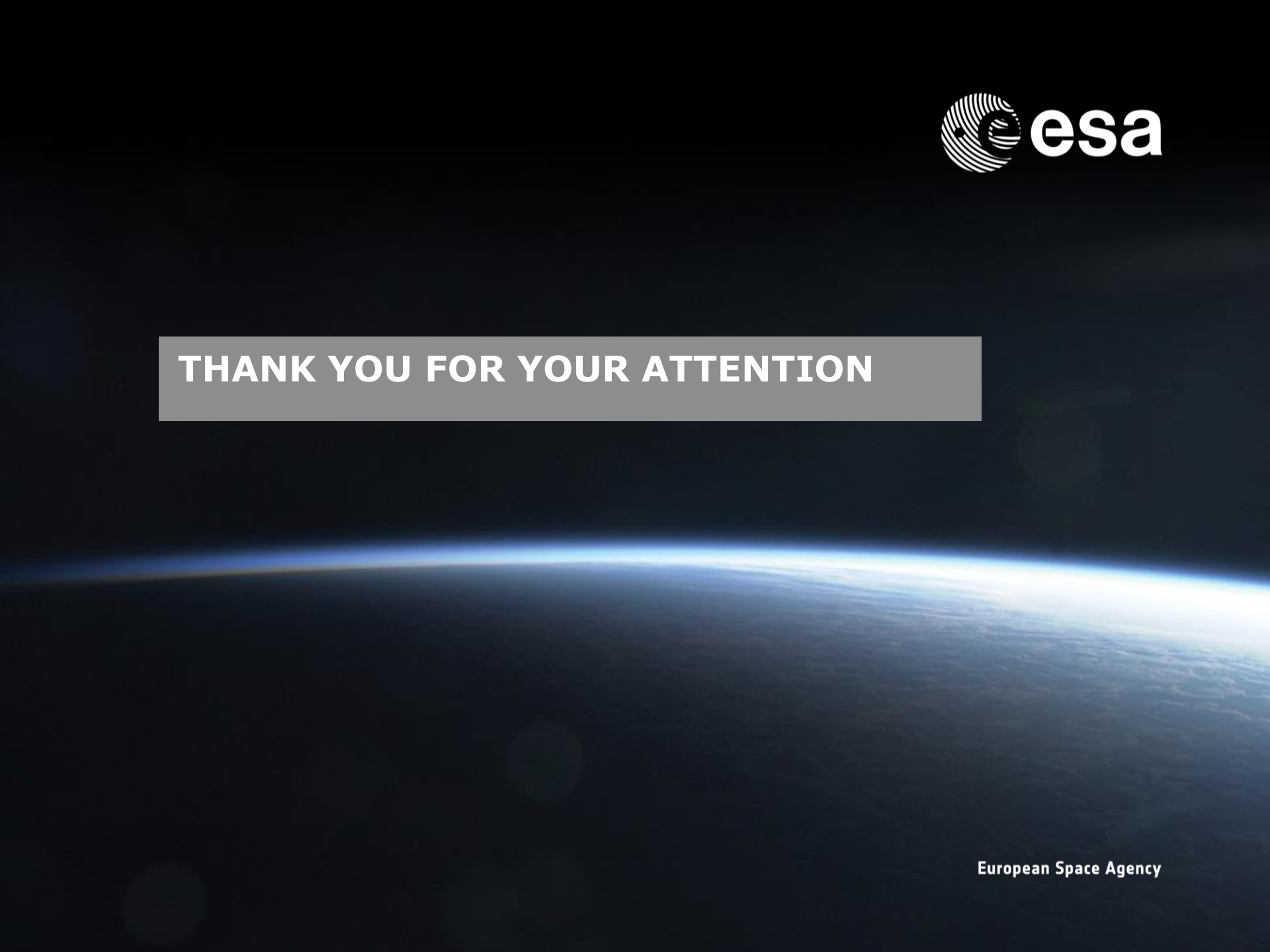
NEO image credit: JAXA


esa
THANK YOU FOR YOUR ATTENTION
European Space Agency