ESA Cross Cutting Technologies

ESA Thematic Information Day

Belspo, June 2012

General: Technology development, objectives and challenges

The (inter-related) objectives of technology development in ESA are:

- **Enabling** the future science and service driven missions, launchers and infrastructures
- Strengthening the **competitiveness** of European industry and of space
- Promoting **innovation** and technical excellence
- Assuring **non-dependence** on critical space technologies

This in a context of:

- Increasingly demanding requirements and tighter budgets
- Stronger competition, export and environmental restrictions
- Fast moving technology base and changing industrial landscape
- Evolving European context

General, cross cutting initiatives

- Technology development programmes take into account needs of user programmes and industry and the potential of technology and research

- In addition 4 cross cutting initiatives are addressed
    - **Future instrument technologies** for science: user driven, joining efforts to develop technologies of interest for several scientific domains so as to afford more than separately and progress farther and faster in science
    - **Technologies for Exploration**, providing the complete view across all programmes so as together address the three destinations, LEO, Moon and Mars, robotic and human
    - **Space and Energy**, making Space benefit of joint efforts with a much stronger sector
    - **CleanSpace**, turning an issue into an opportunity, a competitive advantage

- Objectives, context and cross cutting initiatives are reflected in corporate technology programmes TRP, GSTP, ECI-TnD and TTP

Cross-cutting initiative: Future instrument technologies

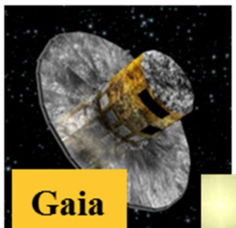
Enabling the missions: Cross cutting initiative, instrument technologies

2015

2020

Accelerometer
Bench, caging mech
Propulsion
Metrology

Largest focal plane
Data processing
Optics



High temp techno
Propulsion
Solar arrays

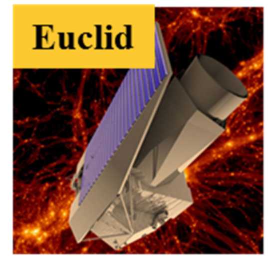
Instrument
Optical bench

High temp techno
Solar arrays
Autonomy

Sun

Dark Energy

Detectors, Optics
Comms
Mechanisms



Dark energy

M3

1st wind lidar

Backscatter lidar
High frequency radar

EEx 7 EEx 8 Eex-X Earth Explorers >8

Long and short wavelength radar
Large apertures
Detectors
Spectrometers

Enabling the missions: Cross cutting initiative, instrument technologies

- This cross-cutting initiative “Instrument Technologies”will be based on the recommendation of the Future Technology Advisory Panel (FTAP)
- FTAP is an advisory body within the framework of ESA Science Advisory Structure
- It advices D/TEC on future technologies relevant to the science community
- It meets on a regular base, at least 2 times per year
- Membership:
  a. Three members of the panel are recognized experts in technology, space and non space, appointed by D/TEC ad personam.
  b. There is one ex-officio member from each Working Group of the Science Advisory Structure assuring user drive
  c. The Chair of the HISPAC is invited to attend the meetings.

FTAP is looking for advanced technologies & synergies between the technologies required for advancing science

FTAP recommendations endorsed by HISPAC will be addressed in work plans of technology programmes

Enabling the missions: Cross cutting initiative, instrument technologies, Example: Optical Clocks

Subject / function description:

- ❑ Optical Cavity Clock
- ❑ Optical Atomic Clock

TRL 2 / 3

Timescale
Long

Life Science
Physical Science
Solar System
Astronomy
Earth Science
Navigation

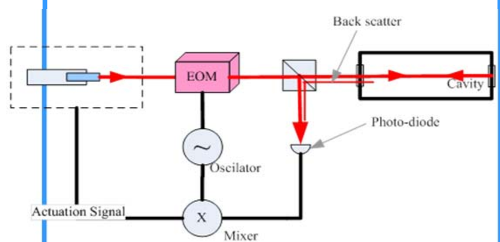
Specification:

- Goal: Provide frequency standards ad timing at the ~10^{-18} level, working in the THz domain (optical)
- Two types of optical clock can be considered:
  - Optical Cavity Resonator – laser locked to a low CTE cavity
  - Optical Atomic Clock – laser locked to an atomic reference transition
- Sub-systems: High finesse cavity, Laser, Magneto Optical Trap, frequency comb, control electronics

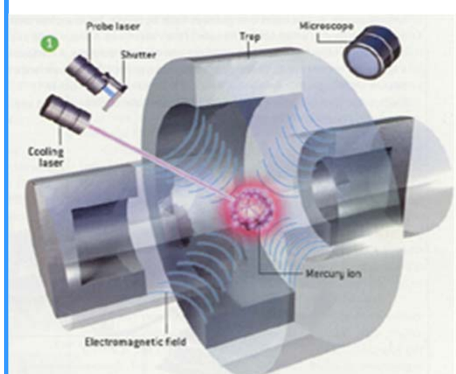
Application:

1. Gravitational Red-shift Measurements
   - High accuracy, Long term stability ~10^{-18},
2. Tests of special relativity
   - Isotropy of light, Special relativity parametric
3. Time and frequency reference
   - Worldwide distributed at a frequency resolution better than 10^{-18}
   - Measuring fundamental constants over time
   - Next generation satellite navigation
   - Global atomic time

Cavity Clock



Optical Atomic Clock
(Credit: L. Hollberg)



Missions:

- ❑ Earth's Gravitational Field
- ❑ Pioneer Anomaly and Heliospheric Gravity
- ❑ Gravitational Red-shift measurements
- ❑ Frame Dragging Measurements
- ❑ Optical Atomic Clocks in Space (Time & Frequency standards)
- ❑ Universality of free fall

Enabling the missions: Cross cutting initiative, instrument technologies, Example: Deployable Structures

esa

Subject / function description:

❑ Ultrastable Deployable Mast and Mechanisms

TRL 2

Timescale Medium

Life Science
Physical Science
Solar System
Astronomy
Earth Science

Specification:

- Goal: Deploy large structures or instruments at large distances from spacecraft
- Materials can be thin walled CFRP for structural elements
- Motorised hinge mechanisms working in synchronisation
- Large antennas, mirrors and large focal lengths not normally compatible with launcher fairings could be possible
- Alternative to formation flying for science missions

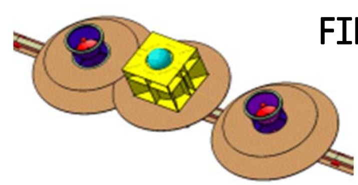
Application:

1. Large Baseline Interferometry
   - Resolution can be increased by having large baselines formed by deploying detectors on long booms
   - Positioning of telescope arms to within 0.01^0 on deployment.
2. Extended Focal Planes (X-Ray Astronomy)
   - X-Ray optics require very large focal lengths (> 20m)

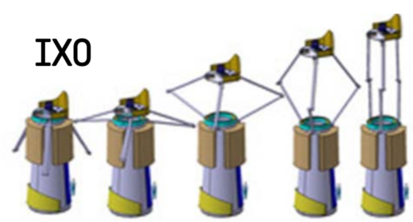
Motorised Hinges

Deployable Booms

FIRI



IXO



Missions:

- ❑ Far-IR Observatory
- ❑ Advanced X-Ray Telescope
- ❑ Earth Magneto Sphere Mapping
- ❑ Telecomm Satellites
- ❑ SAR
- ❑ Deep Space Radio Astronomy

Enabling the missions: Cross cutting initiative, instrument technologies, Example: Cold Atom Physics

Subject / function description:

- ❑ Space Magneto Optical Trap (MoT)

TRL 2 / 3

Timescale
Long

Life Science
Physical Science
Solar System
Astronomy
Earth Science

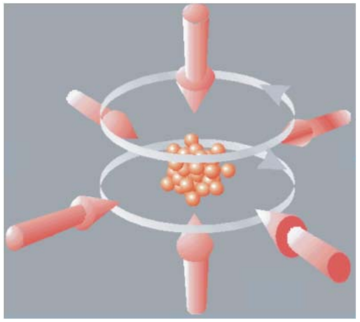
Specification:

- Goal: Cool and release into free fall a sample of an atomic species.
- On the order the of de Broglie wavelength allows increased accuracy
- Typical Temperature < 20 mK over 20 seconds
- Ambient Pressure < 10^{-9} Pascal (Vacuum of space 10^{-7})

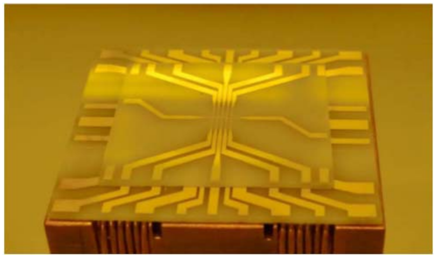
Application:

1. Atomic Interferometric Accelerometer (TRL 3)
   - Differential measurement between two atomic species at ~10^{-15} accuracy using ^{87}Rb & ^{85}Rb
2. Atomic Interferometric Gyroscope (TRL 2)
   - Measuring rotation in the order of sensitivity 10^{-12} rad/s at 1 s integration time
3. Cold Atom Optical Atomic Clock (TRL 2)
   - Atomic reference transition for clockwork stability
4. Bose Einstein Condensate Micro Laboratory (TRL 2)
   - Long free fall times to cool atoms, to characterise macroscopic behaviour of quantum gases

Magneto Optical Trap (MoT)



Atom Chip

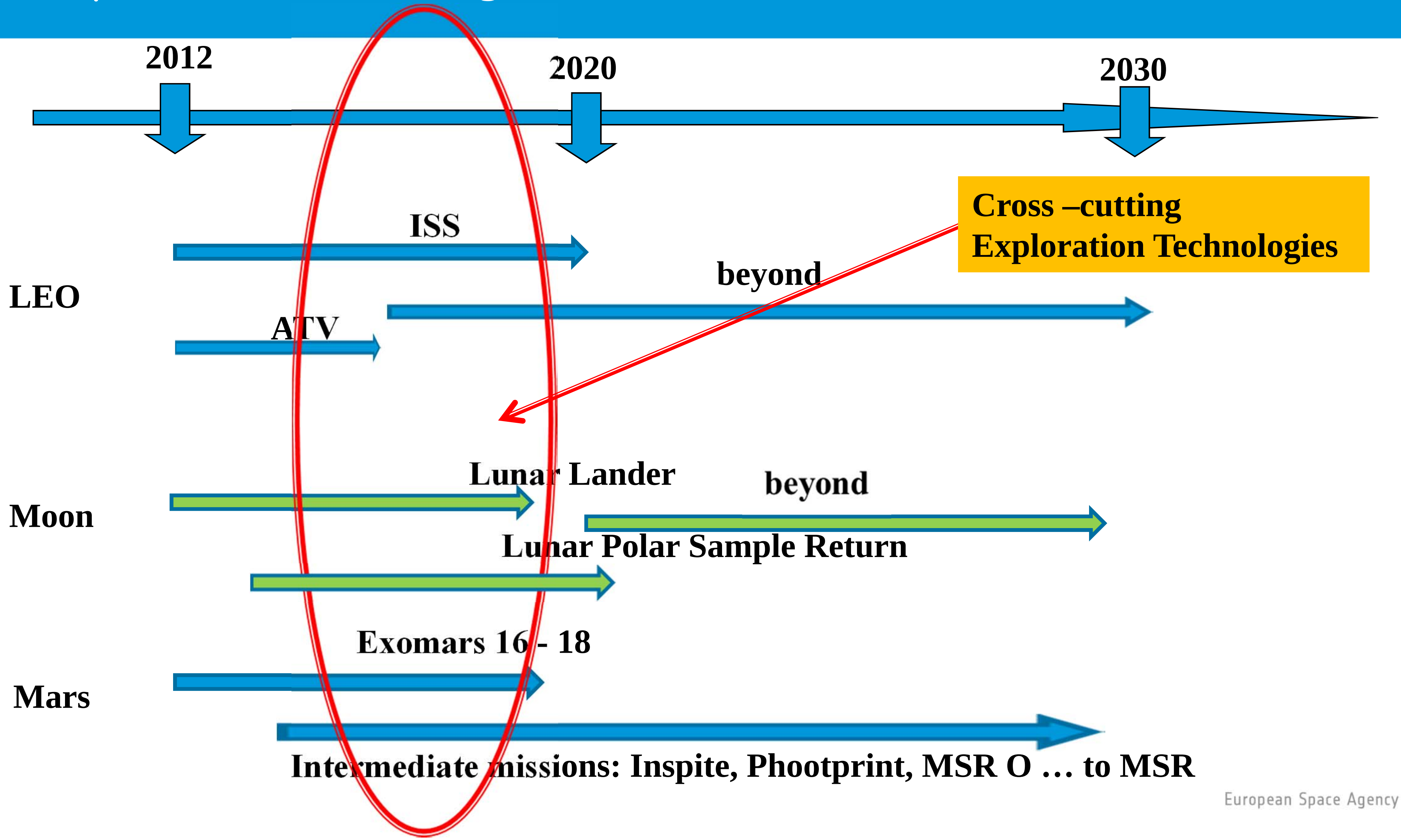


Missions:

- ❑ Earth's Gravitational Field
- ❑ Pioneer Anomaly and Heliospheric Gravity
- ❑ Gravitational Red-shift measurements
- ❑ Frame Dragging Measurements
- ❑ Optical Atomic Clocks in Space
- ❑ Universality of free fall
- ❑ Microgravity Cold Atom Physics Laboratory

Cross-cutting initiative: Exploration Technologies

Enabling the missions: Cross cutting initiative, Exploration Technologies

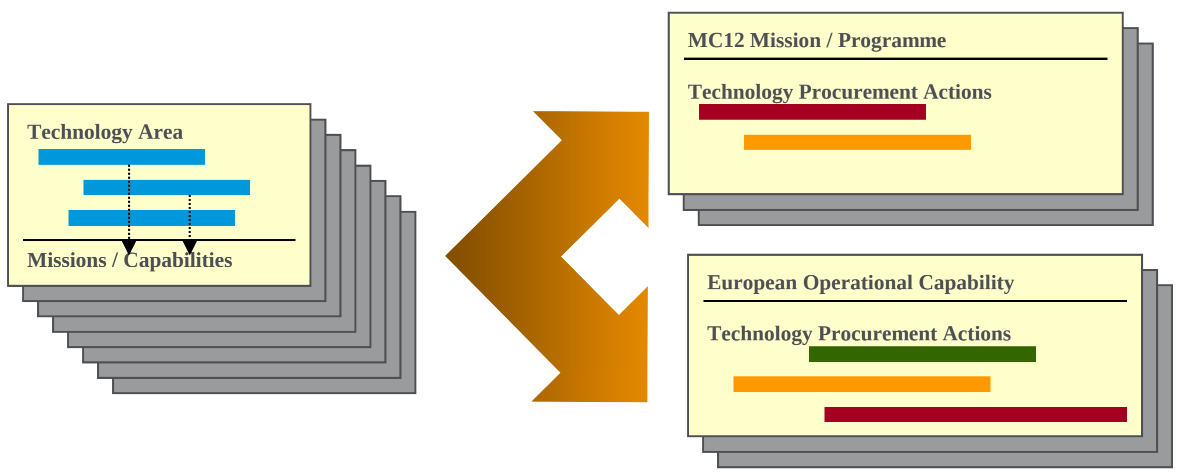


Enabling the missions: Cross cutting initiative, Exploration Technologies

Considers

- the Exploration destinations, LEO – Moon – Mars; robotic and human
- the required enabling capabilities, RVD, cargo transfer, etc.
- the technology domains involved

Establishes technology roadmaps



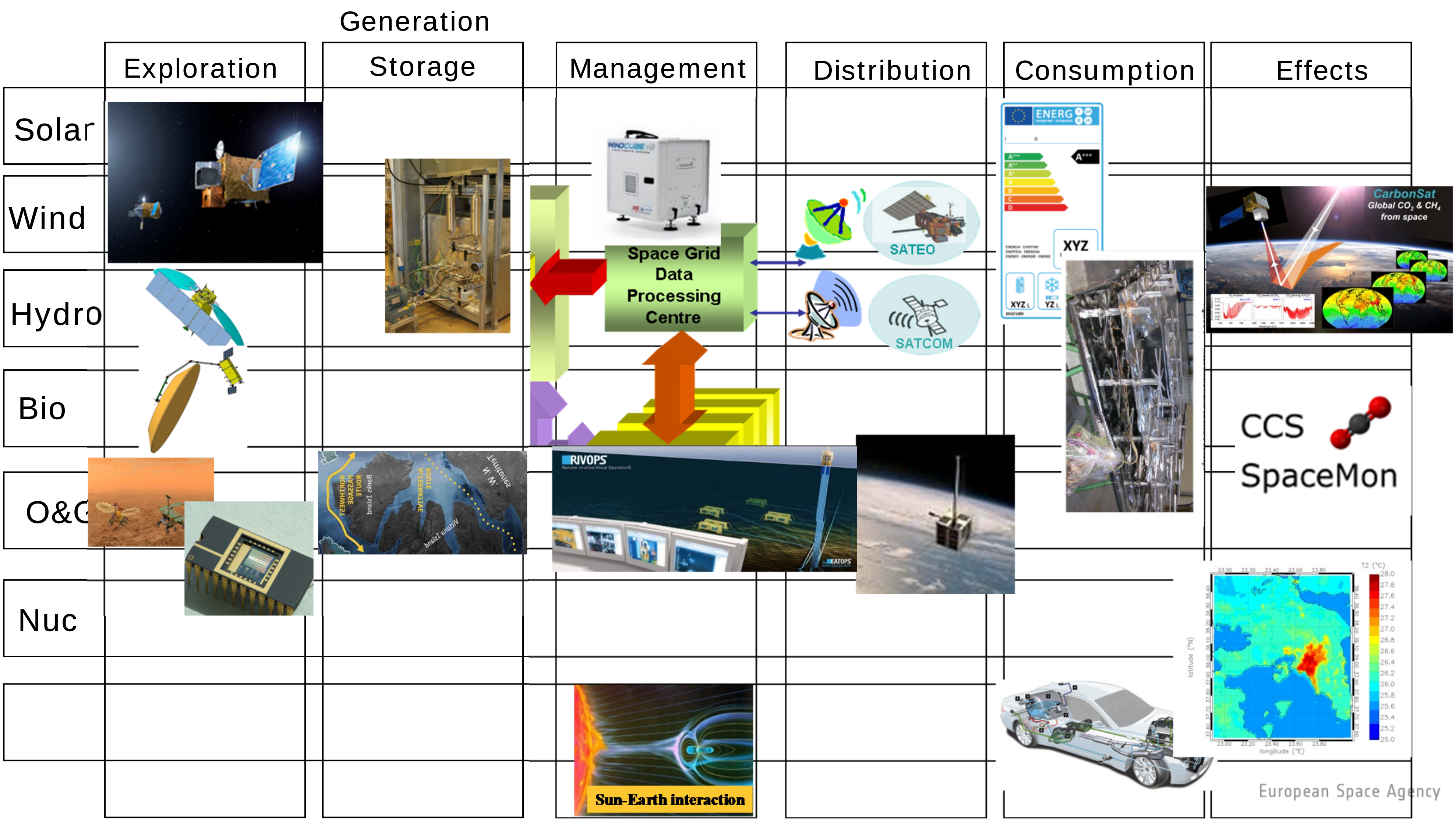
Enabling the missions: Cross cutting initiative, Exploration Technologies

List of Major **Operational Capabilities** *(to be updated)*

1. RdV and Docking with (non) collaborative target
2. High Capacity Cargo Transfer
3. High Efficiency Orbit Insertion
4. Orbital re-fuelling
5. Fast and Sustainable Human Cruise
6. Nuclear energy utilisation
   a. Non-electrical heating for landers, rovers, deep-space
   b. Power capability for small lander
   c. Power capability for deep space and surface missions (robotic, human)
7. High Speed Entry, Deceleration and Descent
8. Precision Soft Landing (with Hazard Avoidance)
9. Robotic / Tele-robotic Surface Operations
10. Human Surface Habitability and Operations
11. In-Situ Resource Utilisation
12. Surface Take-off and Return (Robotic / Human)

Cross-cutting initiative: Space and Energy

Innovation and competitiveness, cross cutting initiative: Space and Energy



Innovation and competitiveness, cross cutting initiative: Space and Energy, Technologies (1)

- There are numerous examples of technologies initially developed for space, which have been successfully used for energy applications (for example the silicon photovoltaic cells, the lithium ion batteries, the heat pipes or thermo-syphons, etc.)

- The synergies between space and energy technologies, materials and competences shall be further enhanced by a dedicated development work-plan, focused on the parallel challenges of the Space and Energy sectors.

- While providing space technology solutions to the energy question, the space industry will be strengthened by new business opportunities.

Innovation and competitiveness, cross cutting initiative: Space and Energy, Technologies (2)

- Examples of technological areas for high potential synergetic developments:
  - photovoltaic generation,
  - power management and distribution,
  - energy storage,
  - hydrogen storage,
  - thermal control,
  - space weather effects,
  - remote sensing,
  - life support / recycling technology
- The space experience in terms of modeling, testing ad reliability prediction would be very beneficial to the energy sector, where these issues are becoming more and more important (e.g. in terrestrial photovoltaics)

Cross-cutting initiative: Clean Space

Overview of Clean Space

Clean Technologies for space is defined by ESA as those which contribute to the reduction of the environmental impact of space programmes, taking into consideration the overall life-cycle and the management of residual waste and pollution resulting from space activities, both in the Earth eco-sphere and in space.

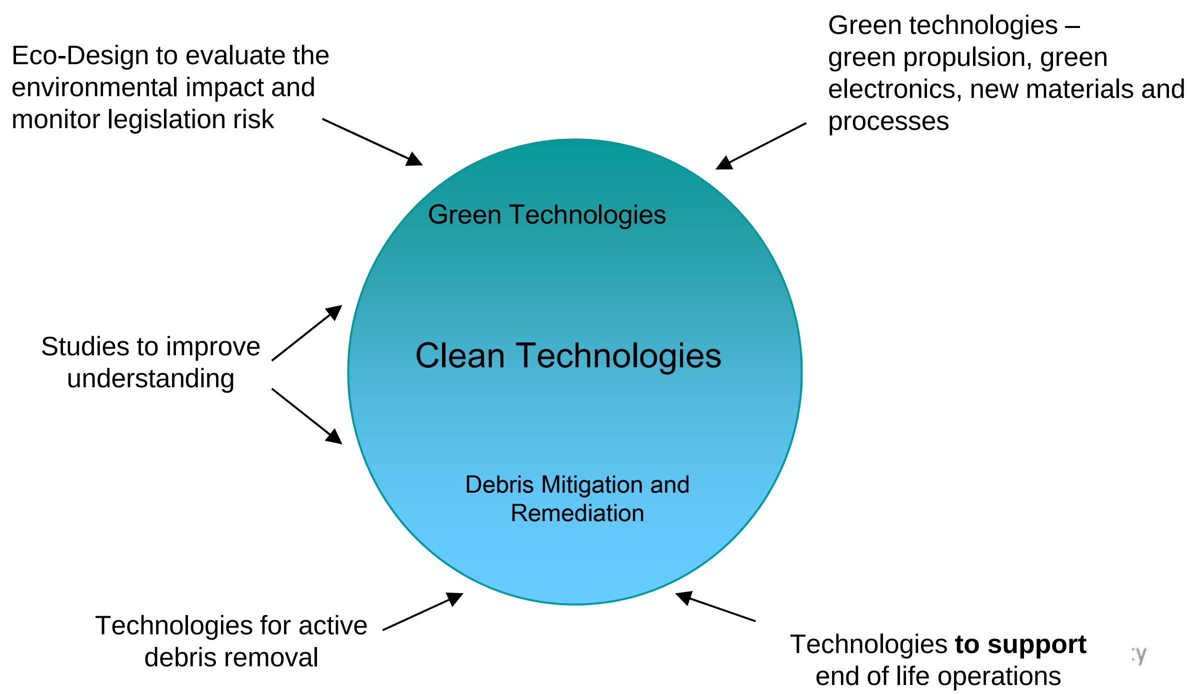
Four Branches:

1 – Eco-Design

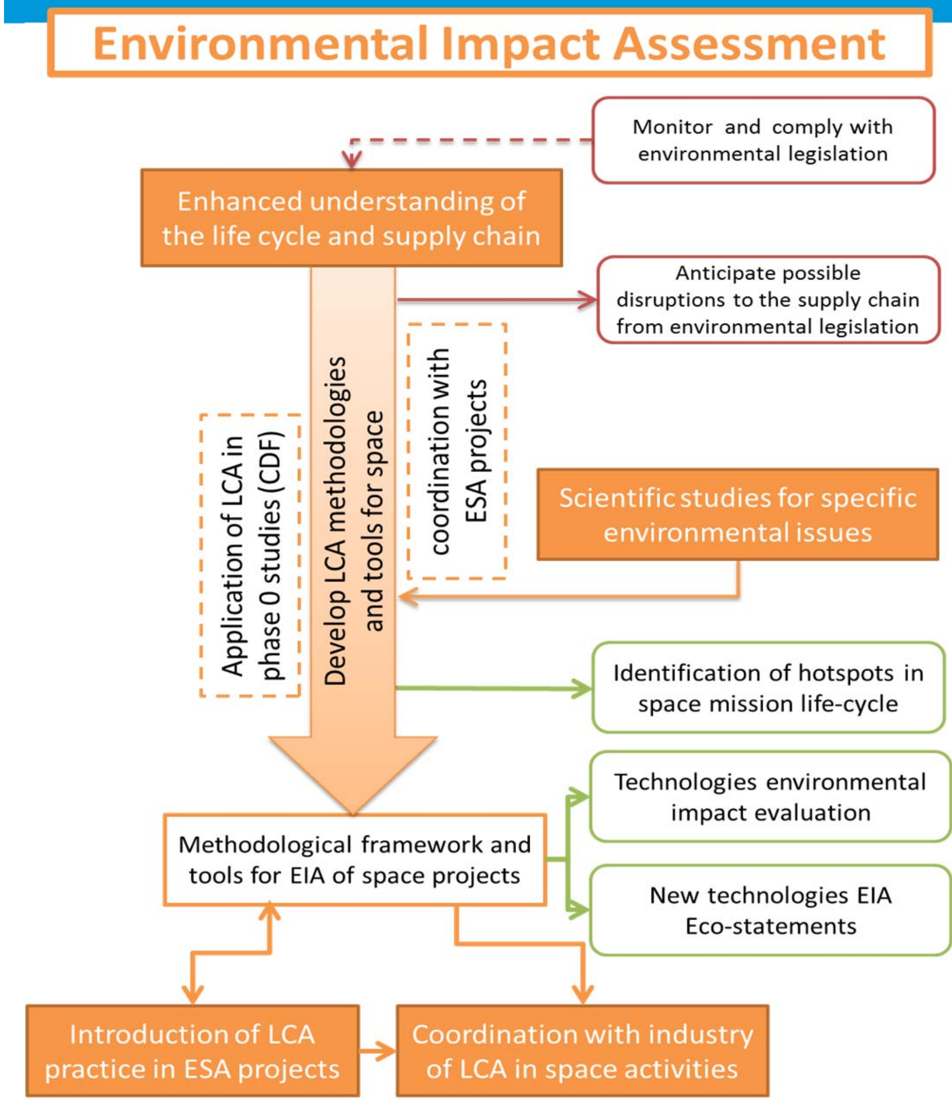
2 - Green Technologies

3 – Space Debris Mitigation

4 – Space Debris Remediation

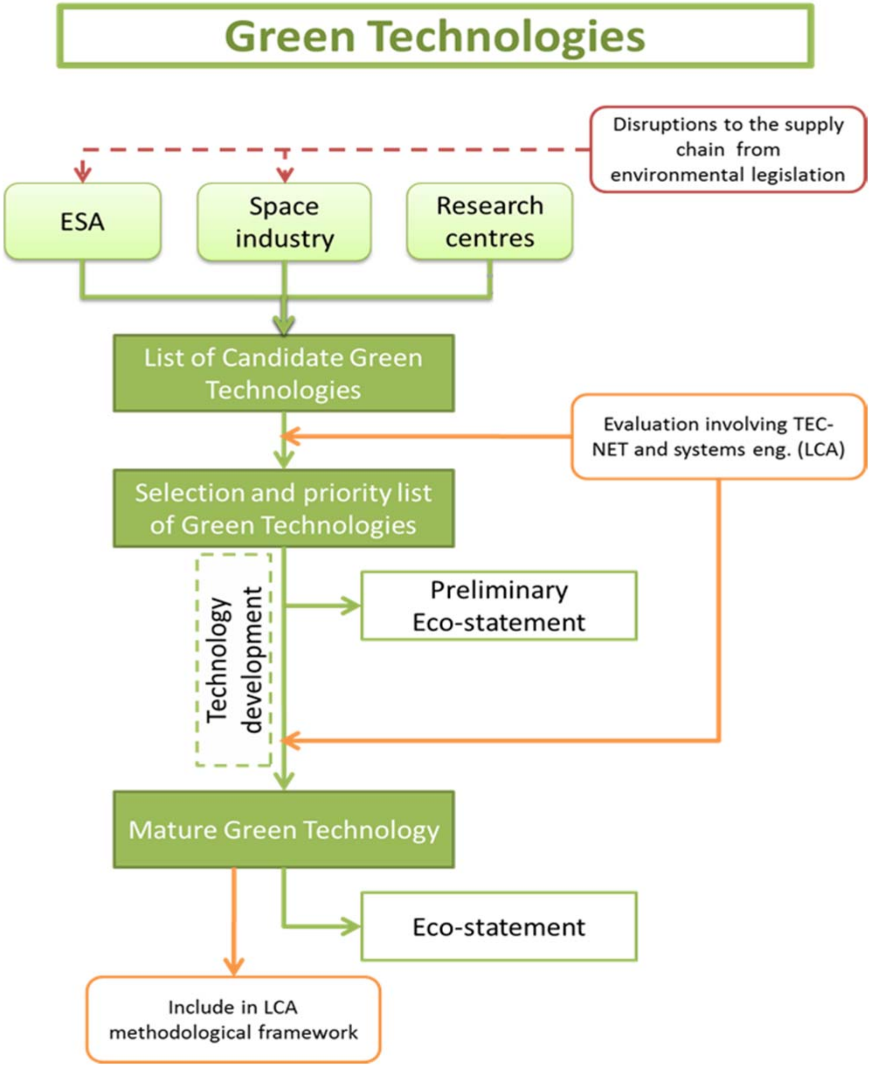


Branch 1 – Eco-Design



- **Clean Space will actively monitor and comply with environmental regulations in Europe, e.g. REACH, which could have disruptive effects on the industrial supply chain**
- **Enhance Life Cycle Assessment (LCA) methodology and tools for space activities, in order to develop the framework to assess their environmental impact in a consistent way.**
- **Specific studies may be needed in some areas, e.g. Combustion and Plumes**
- **These activities are the corner-stone for the implementation of eco-design for S/C and launchers.**
- **Indispensable to define the priority of green technology developments consistently, avoiding shifting the burden.**

Branch 2 Green Technologies



Green propulsion

- **Primary focus of green propulsion so-far has been on reduction of propellant toxicity**
  - **Mono-propellant – Hydrazine replacement (e.g. ADN based, hydrogen peroxide) up to qualification of thrusters (e.g 1N, 10N, 300N)**
  - **Bi-propellants – Alternatives to MON/MMH (e.g. Kerosene/H2O2, Ethanol/H2O2, DMAZ)**
  - **Solids – Alternatives to ammonium perchlorate (e.g. ADN based)**
  - **Hybrids and high performance propellant options (e.g. HTPB/H2O2, HTPB/GOX, NOFBX)**

*** Proposed work-plan in line with harmonisation roadmap.**

New materials and processes

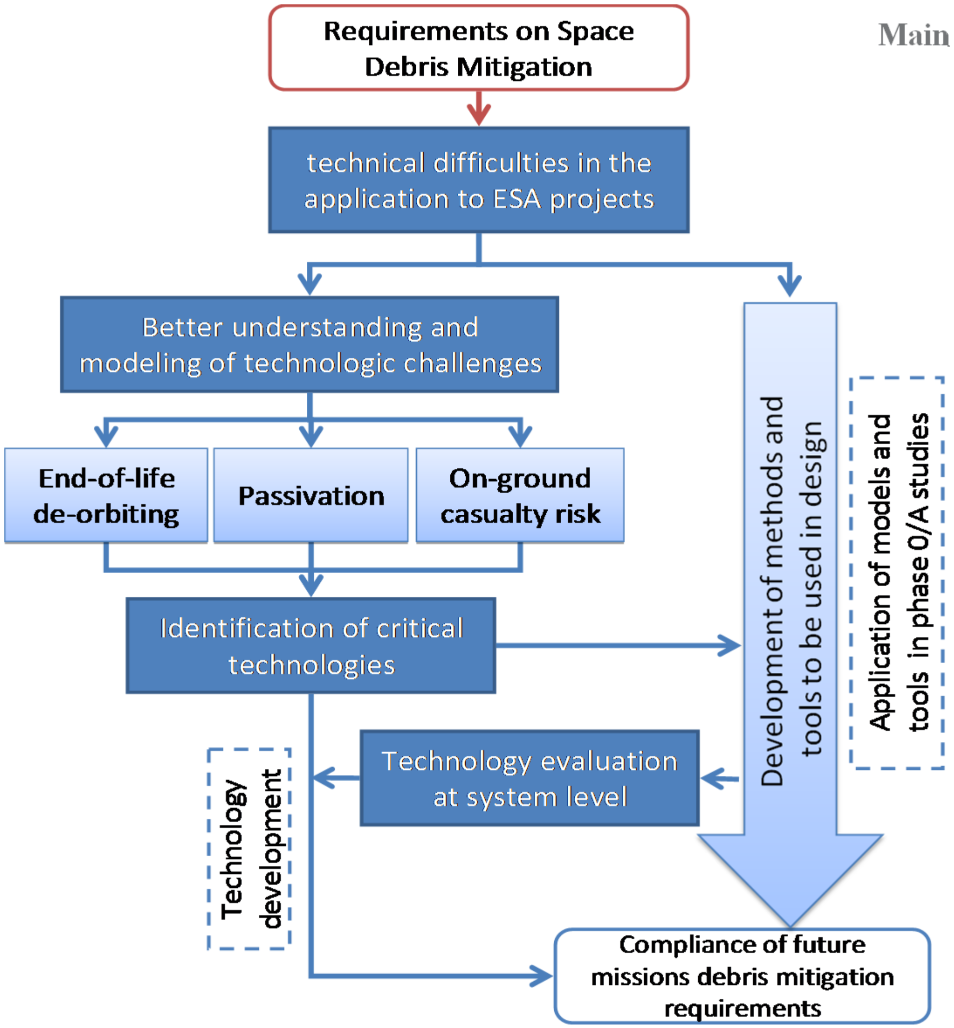
- **Alternatives reduce weight, decrease energy consumption during manufacturing, decrease the production steps and the use of hazardous chemicals**
  - **Additive Manufacturing (ALM, DD)**
  - **Advanced joining technologies**
  - **New coatings (e.g. TSA)**

Green electronics

- **Existing and future environmental legislation implies large design changes in the electronics industry**
  - **Gallium arsenide**
  - **Use of lead in soldering alloy**

Branch 3 - Space Debris Mitigation

The technologies for space debris mitigation shall cover a large range of application in order to develop the necessary set-up for the systematic compliance of ESA missions and launchers with the debris mitigation requirements.

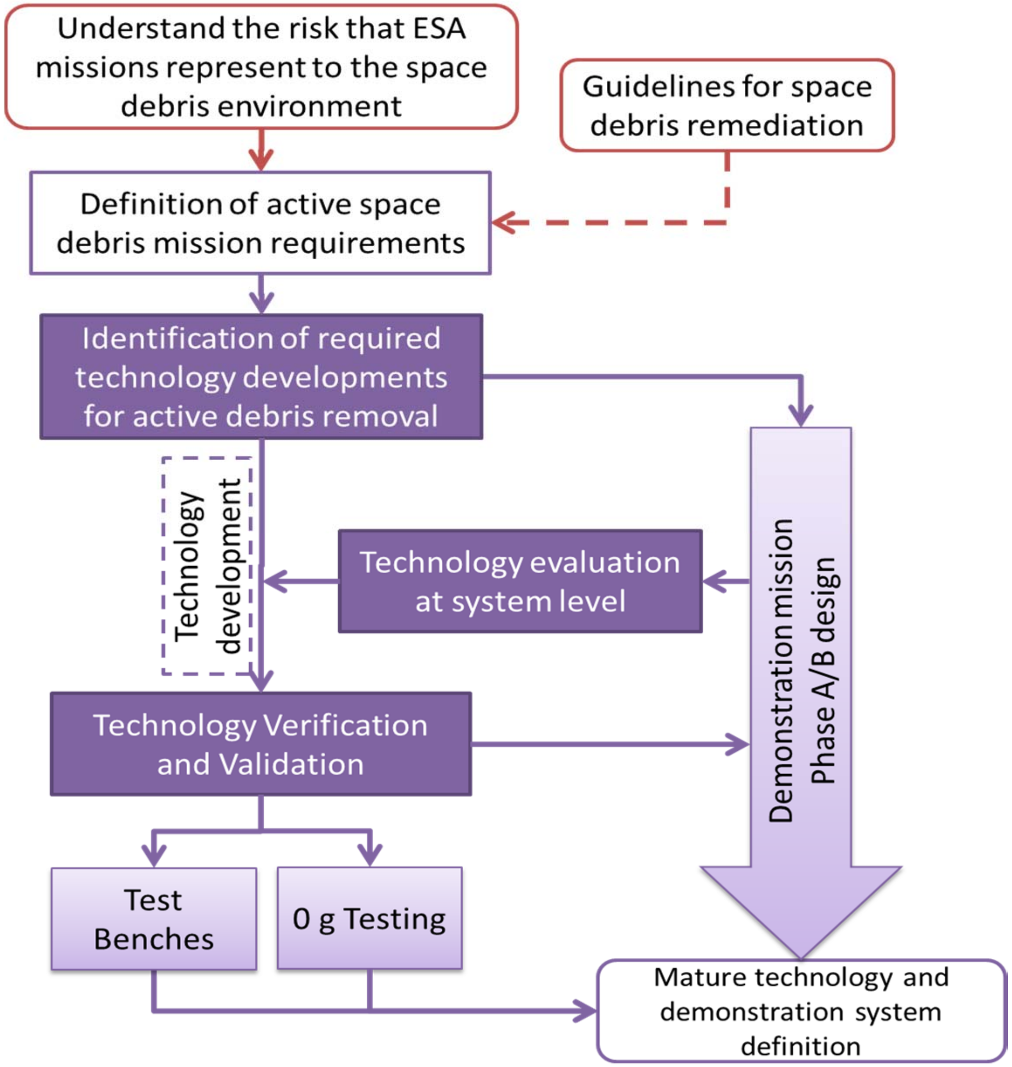


Main technical challenges:

- <u>Re-entry within 25 years of S/C in LEO protected region</u>
  - Very problematic for small S/C, especially the ones without propulsion system.
  - Passive de-orbiting devises can lower in-orbit lifetime, need to be further studied and developed.
  - Controlled re-entry / removal to graveyard orbit of large S/C due to on-ground casualty risk has an enormous impact on the design.
  - Active de-orbit devises can promote the immediate re-entry or graveyard of satellites after the end of operations with limited impact on the design.
- <u>Keep on-ground casualty risk bellow 10^{-4}</u>
  - Very problematic for medium and large satellite missions in LEO.
  - Design for Demise materials and technologies to enhance the demise of the S/C parts during the atmospheric re-entry.
- <u>Passivation of power and propulsion systems</u>
  - Main source of debris in the past. Advanced passivation methods for current and future missions shall be identified and implemented.

Branch 4 - Space Debris Remediation (Active Debris Removal)

Objectives: development of the required technologies for future missions for space debris rendez-vous, capture and re-entry. Technology developments will be streamlined by system activities for a mission to de-orbit Envisat ensuring its controlled atmospheric re-entry.



Main technologic capabilities:

- **Sensors for rendezvous with un-cooperative target**
- **Capture mechanism for space debris**
- **Control of stack after capture**
- **Stabilisation of tumbling targets**
- **Non invasive de-orbiting options**
- **V&V framework**