Innovation at ESA

Advanced Concepts Team

Preparing for the future

Leopold Summerer
Advanced Concepts Team
Future Preparation and Strategic Studies Office
leopold.Summerer@esa.int

Objectives

- Inform about ESA, space R&D, opportunities
- Share information about advanced concepts and methods for disruptive innovation at ESA
- Obtain feedback and smart ideas for future of space

- Innovation in, by and for the government

Outline

- What is ESA
- Open Innovation at the ESA Advanced Concepts Team
- Other R&D Cooperation opportunities with ESA
- Advanced Manufacturing Initiative

What is ESA?

ESA FACTS AND FIGURES

- Over 50 years of experience
- 22 Member States
- Eight sites/facilities in Europe, about 2200 staff
- 4.4 billion Euro budget (2015)
- Over 80 satellites designed, tested and operated in flight
- Over 20 scientific satellites in operation
- Six types of launcher developed
- 200th launch of Ariane celebrated in February 2011

50 YEARS OF EUROPEAN COOPERATION IN SPACE

1964-2014

→ SERVING EUROPEAN COOPERATION AND INNOVATION

esa

- In 1964, Conventions of the precursors of ESA (ESRO & ELDO) entered into force.
- 2014 was dedicated to addressing the future in the light of these 50 years of unique achievements in space, which have put ESA among the leading space agencies of the world.
- 50 years of European cooperation in space was an anniversary for the whole space sector in Europe, which can be proud of its results and achievements.

PURPOSE OF ESA

"To provide for and promote, for exclusively peaceful purposes, cooperation among European states in **space research** and **technology** and their **space applications.**"

Article 2 of ESA Convention

European Space Agency

20 MEMBER STATES AND GROWING

ESA has 20 Member States: 18 states of the EU (AT, BE, CZ, DE, DK, ES, FI, FR, IT, GR, IE, LU, NL, PT, PL, RO, SE, UK) plus Norway and Switzerland. Estonia and Hungary will soon be part of ESA (2015)

Seven other EU states have Cooperation Agreements with ESA: Bulgaria, Cyprus, Latvia, Lithuania, Malta, Slovakia and Slovenia. Discussions are ongoing with Croatia.

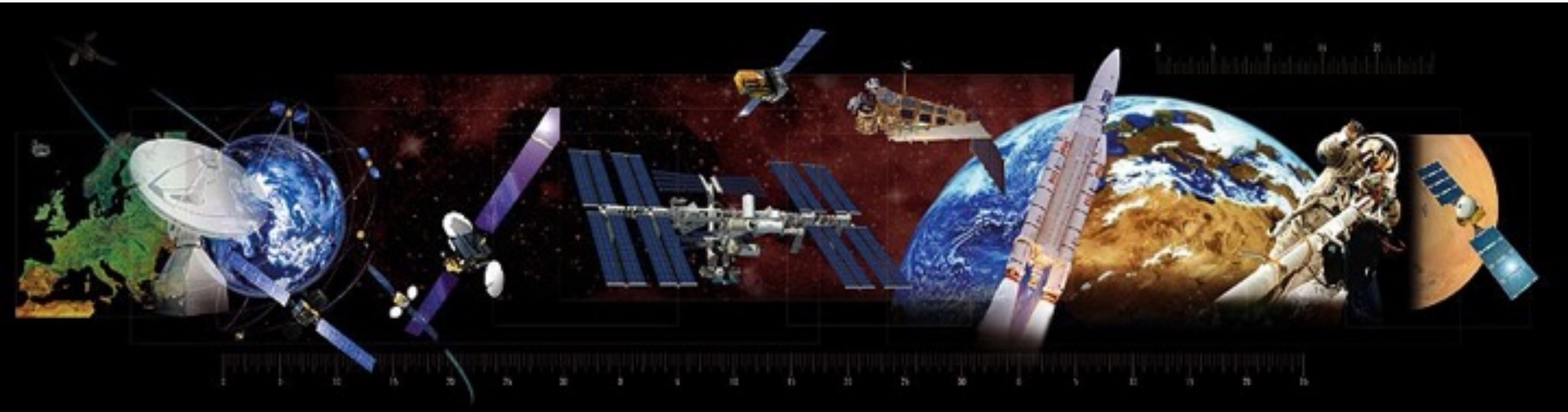
Canada takes part in some programmes under a long-standing Cooperation Agreement.

ACTIVITIES

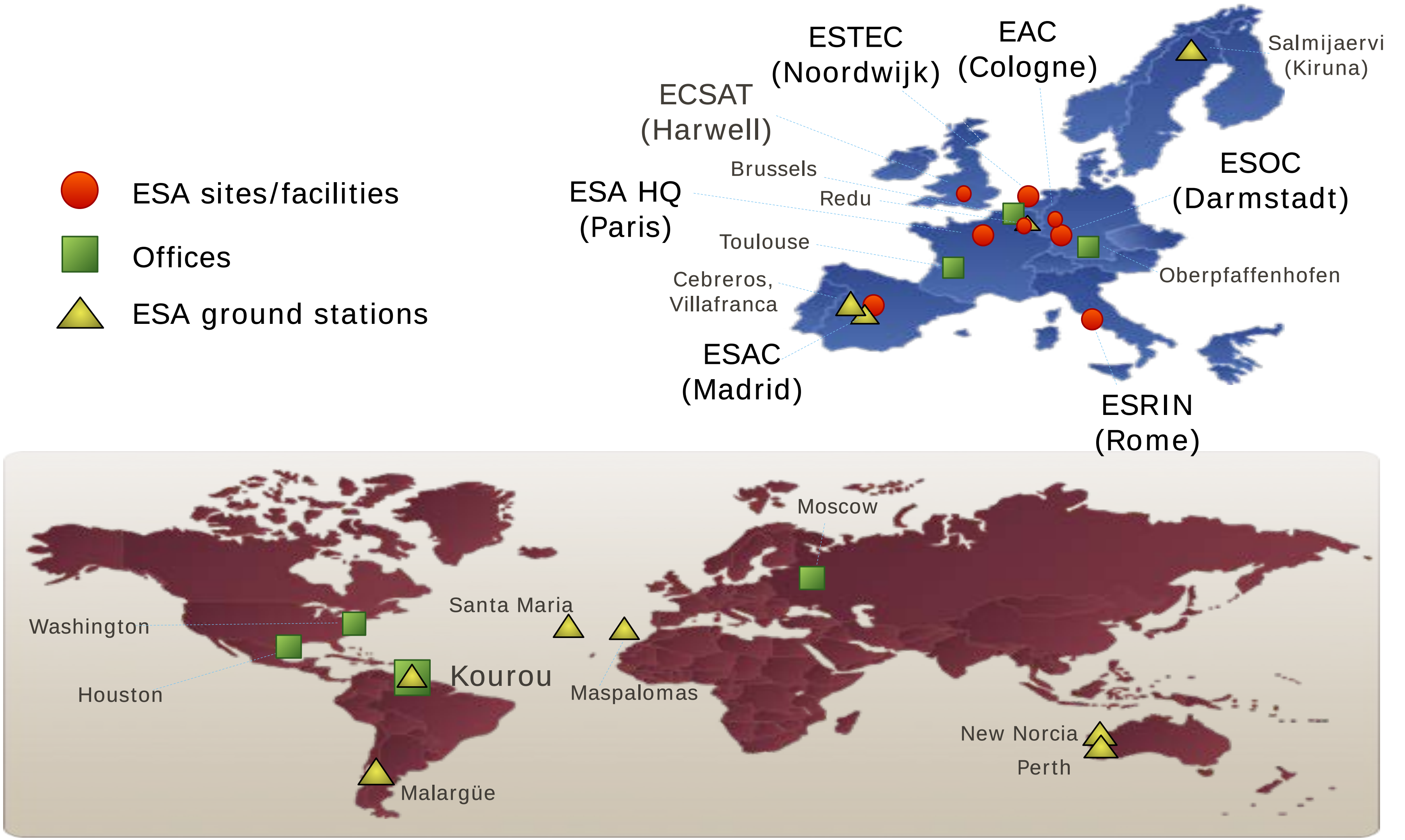
ESA is one of the few space agencies in the world to combine responsibility in nearly all areas of space activity.

- **Space science**
- **Human spaceflight**
- **Exploration**
- **Earth observation**
- **Launchers**
- **Navigation**
- **Telecommunications**
- **Technology**
- **Operations**

* Space science is a **Mandatory programme**, all Member States contribute to it according to GNP. All other programmes are **Optional,** funded ‘a la carte’ by Participating States.



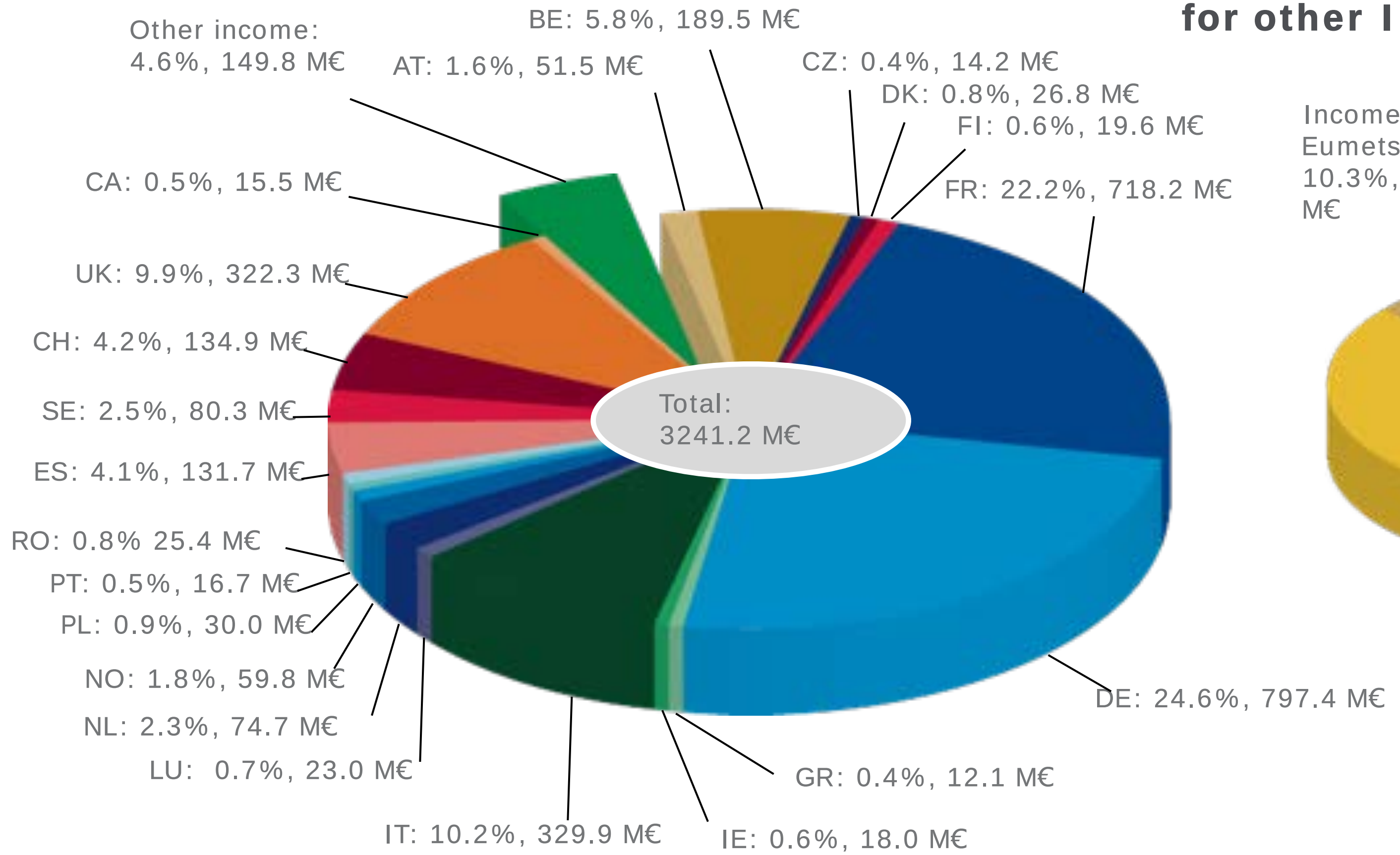
ESA'S LOCATIONS



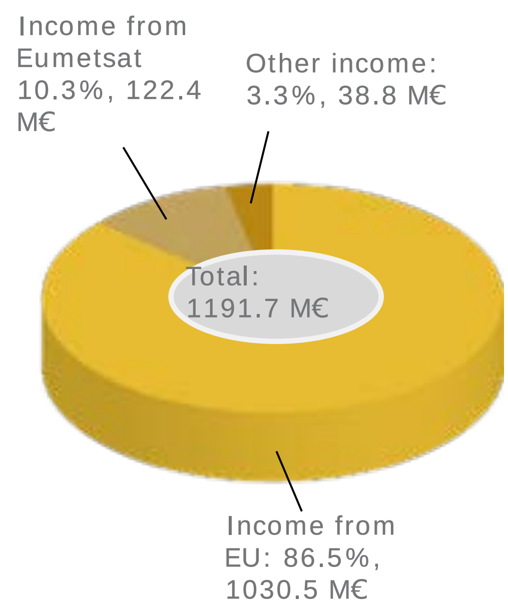
European Space Agency

ESA BUDGET FOR 2015

ESA Activities and Programmes



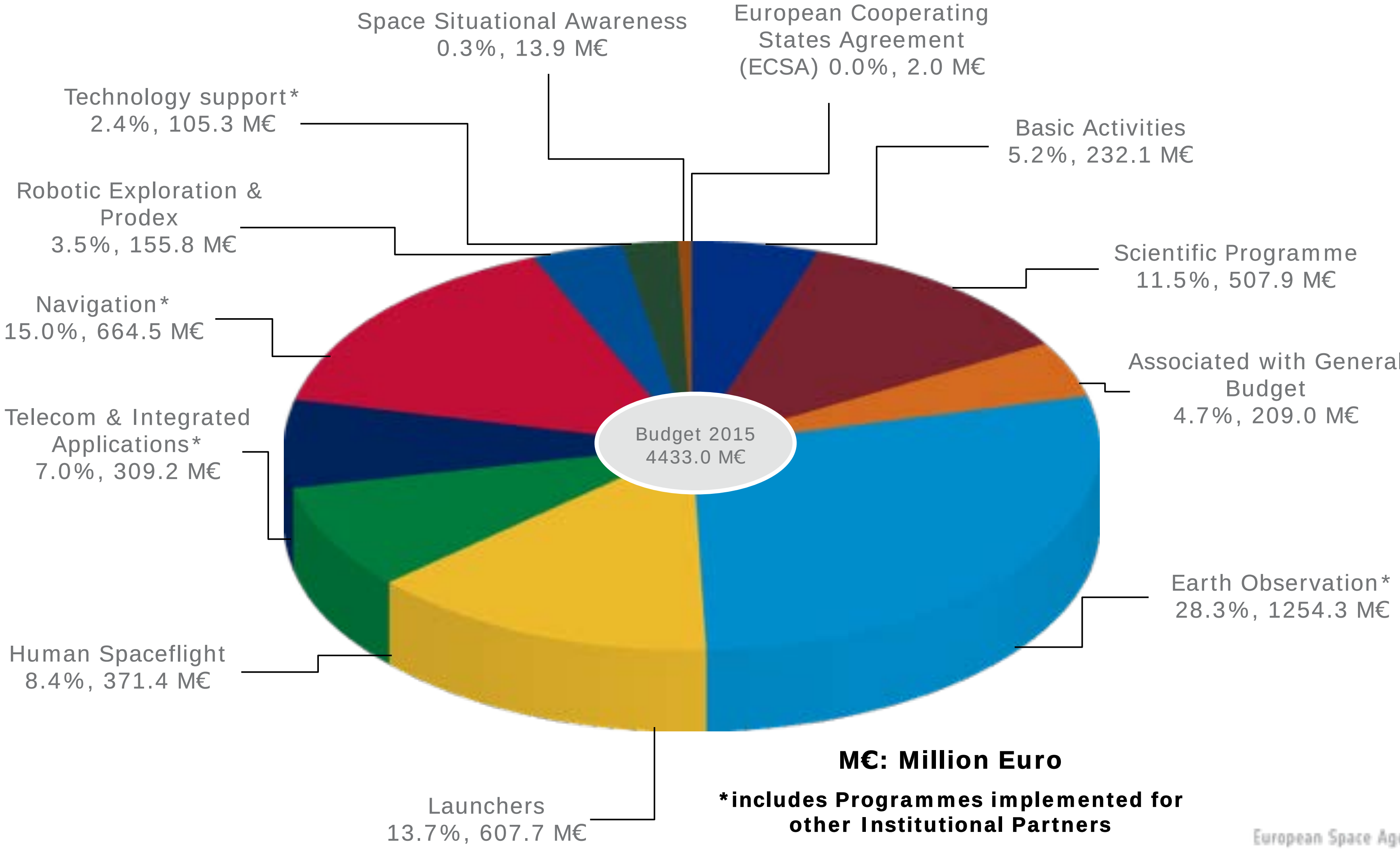
Programmes implemented for other Institutional Partners



TOTAL ESA BUDGET FOR 2015: 4433.0 M€

European Space Agency

ESA 2015 BUDGET BY DOMAIN



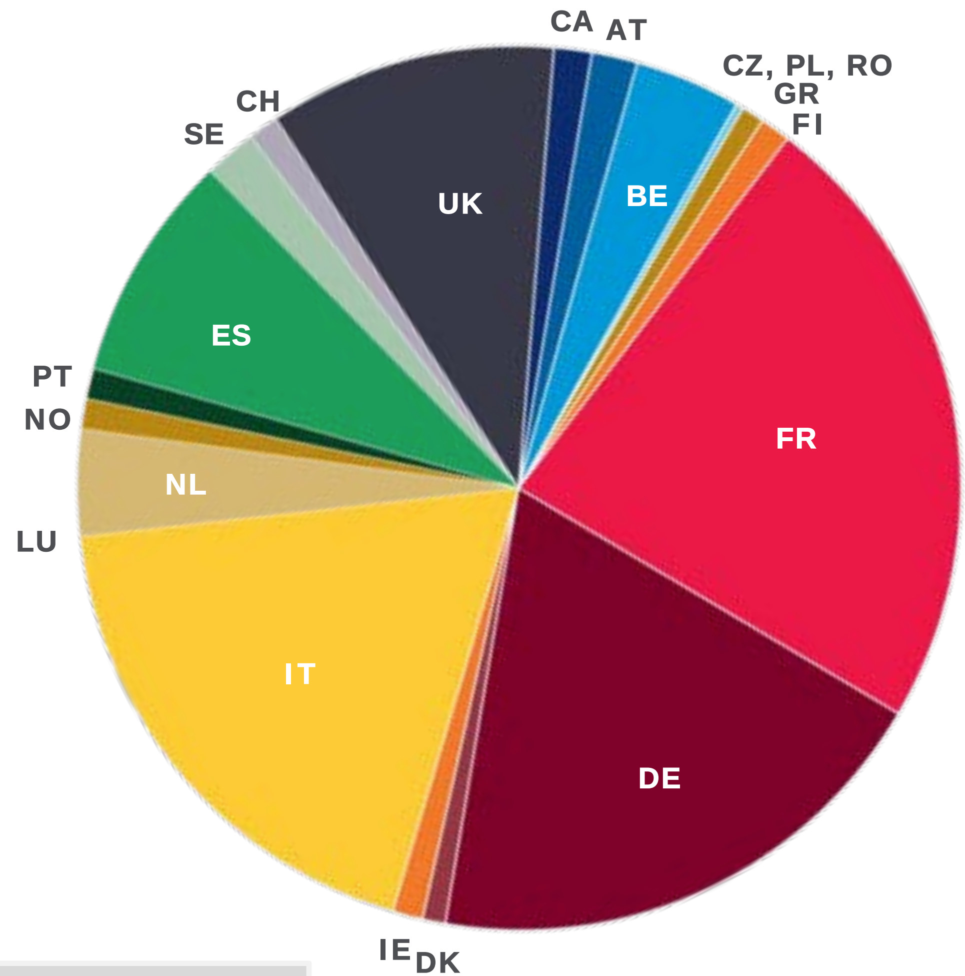
M€: Million Euro

***includes Programmes implemented for other Institutional Partners**

European Space Agency

STAFF BY NATIONALITY IN 2014

Austria	38
Belgium	90
Czech Republic	3
Denmark	17
Finland	19
France	510
Germany	425
Greece	20
Ireland	30
Italy	423
Luxembourg	2
Netherlands	80
Norway	22
Poland	4
Portugal	25
Romania	2
Spain	196
Sweden	41
Switzerland	28
UK	233
Canada	25



TOTAL INTERNATIONAL STAFF: 2233

European Space Agency

ESA DIRECTORS

Director General
Jean-Jacques Dordain

Director General (designate)
Jan Wörner

- Science & Robotic Exploration — **Alvaro Giménez Cañete**
- Launchers — **Gaele Winters**
- Human Spaceflight & Operations — **Thomas Reiter**
- Earth Observation — **Volker Liebig**
- Telecomms & Integrated Applications — **Magali Vaissière**
- Galileo & Navigation-related Activities — **Didier Faivre**
- Technical & Quality Management — **Franco Ongaro**
- Industry Procurement, & Legal Services — **Eric Morel De Westgaver**
- Human Resources, Facility Management & Communication — **Hans Georg Mockel**
- Finance, Controlling & Information Technology — **Giuseppe Morsillo**

ESA AND THE EUROPEAN SPACE SECTOR

ESA Member States finance 50% of the total public space spending in Europe. Because of the cooperation between ESA, EC and national space agencies:

- the European space industry sustains around 35,000 jobs
- Europe is successful in the commercial arena, with a market share of telecom and launch services higher than the fraction of Europe's public spending worldwide

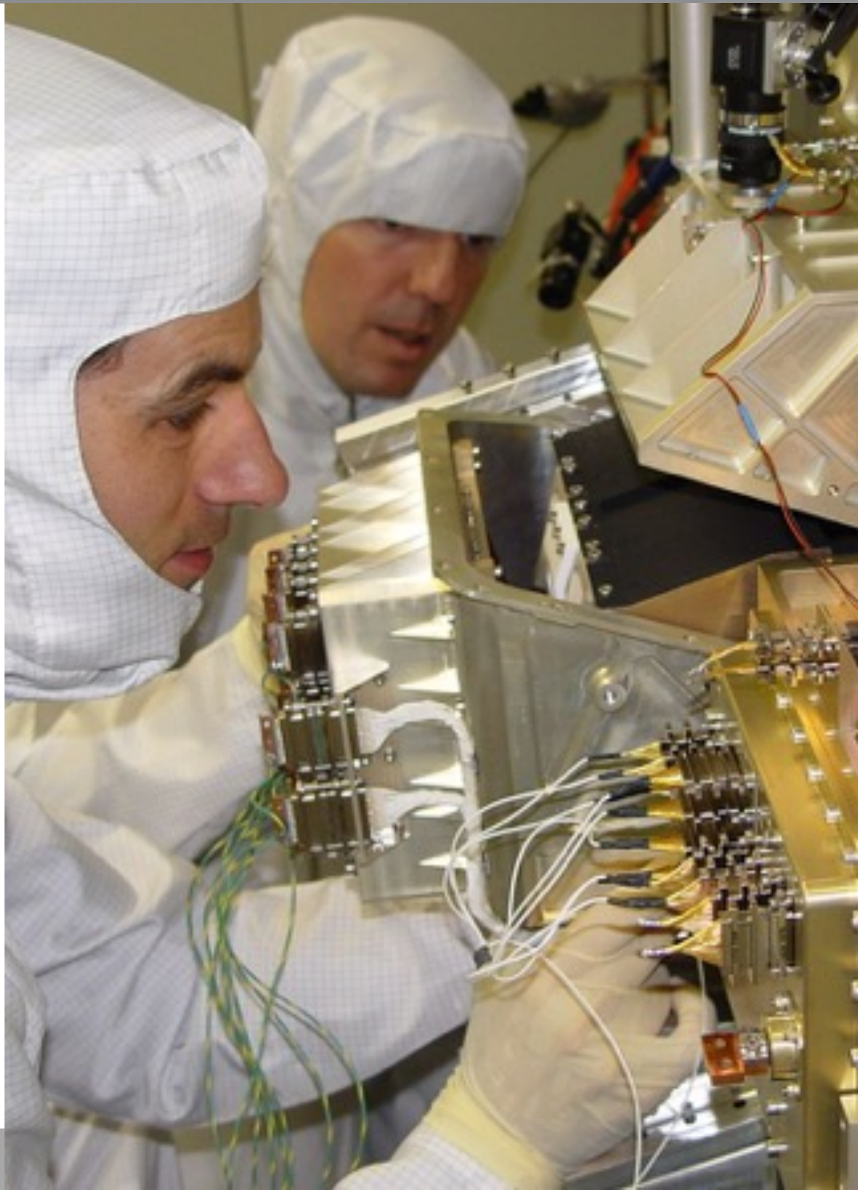
- European scientific communities are world-class and attract international cooperation;
- research and innovation centres are recognised worldwide;
- European space operators (Arianespace, Eumetsat, Eutelsat, SES Global, etc.) are the most successful in the world.

ESA'S INDUSTRIAL POLICY

About 85% of ESA's budget is spent on contracts with European industry.

ESA's industrial policy:

- ensures that Member States get a fair return on their investment;
- improves competitiveness of European industry;
- maintains and develops space technology;
- exploits the advantages of free competitive bidding, except where incompatible with objectives of the industrial policy.



BIRTH OF COMMERCIAL OPERATORS

ESA's 'catalyst' role

ESA is responsible for R&D of space projects. On completion of qualification, they are handed to outside entities for production and exploitation. Most of these entities emanated from ESA.

Meteorology: Eumetsat

Launch services: Arianespace

Telecomms: Eutelsat and Inmarsat

European Space Agency

Open Innovation at the ESA Advanced Concepts Team

Advanced Concepts Team – in short

Created in 2002 and based on temporary researchers

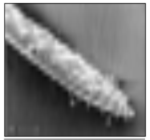
10-year ACT event

Origins and Goals

"to monitor, perform and foster research on advanced space systems, innovative concepts and working methods"

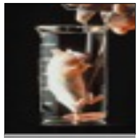
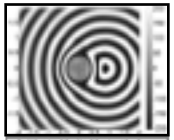
Think-tank *Research Fellows* *Ariadna framework*

Purpose

concepts, techniques & scientific domains with **no/ weak links to space**

biomimetic approaches to engineering, brain-machine interfaces, liquid breathing, curiosity cloning, peer-to-peer computing, crowd sourcing gaming, innovation diffusion and dynamics

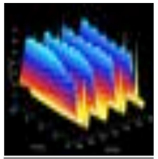
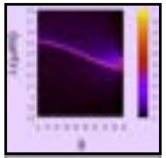
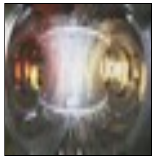
  

too **immature** for regular ESA programmes or projects

planetary protection research, space nuclear power sources, asteroid deflection, liquid ventilation, pulsar navigation, biomimetic drilling

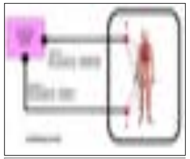
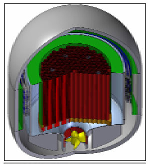
monitor, **perform** and **foster** research on advanced space systems, innovative concepts and working methods

emerging from cutting-edge **basic scientific research**

mathematical global optimisation techniques, cloud-based uncertainty modelling, helicon thrusters, pure general relativistic approach to GNSS constellation design, vibrating systems in general relativity, metamaterials in the optical frequency range, distributed/swarm intelligence, laser filamentation

topics on which ESA is **expected to have a position**

solar power from space, torpor/hibernation, asteroid deflection, active removal of space debris, novel working methods, terraforming, geoengineering

Learning from others…

Interdisciplinary
Most game-changing developments emerge around the fringes or intersections of disciplines

Scientific rigour and competence
Avoid drifting into the realm of science fiction

Encourage taking risks
Encourage and reward high risk / high gain activities

Regular renewal of personnel
Regular in-flow of new insights keeps team on the leading edge

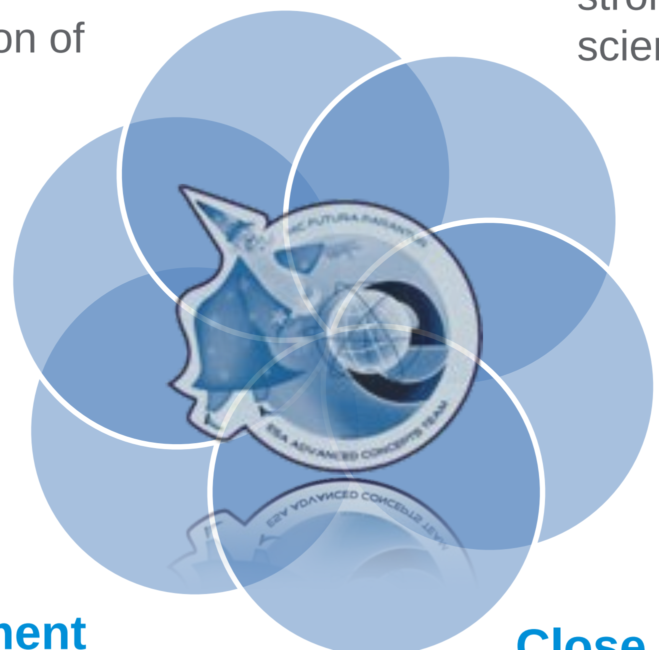
Support from top-management
Activities tend to be ridiculed, admired, not taken seriously or seen as threat to core of the establishment. Without clear support from top management, groups tend to struggle to survive, especially in successful organisations.

Close ties with academia
Most relevant ideas/concepts on a time horizon of 10+ years are generated within academia and research centres

… to derive own requirements

Interdisciplinary
- Researchers with different backgrounds (typically non directly to space)
- Targeting the intersection of disciplines
- Open-plan office

Scientific rigour and competence
- Reliance on post-doc's with a strong self-interest in their scientific reputation



Encourage taking risks
- Freedom to pursue novel research approaches
- Decisions unconstrained by ESA career considerations

Regular renewal of personnel
- Temporary researchers as core of the team (1-2 year) (RF, YGT, stagiaire)

Support from top-management
- Outside of core technical & scientific basis of ESA
- Direct support from upper management

Close ties with academia
- External relations almost exclusively with (European) universities
- Active research network, open science and academic attitude

Foster academic research - *Ariadna*

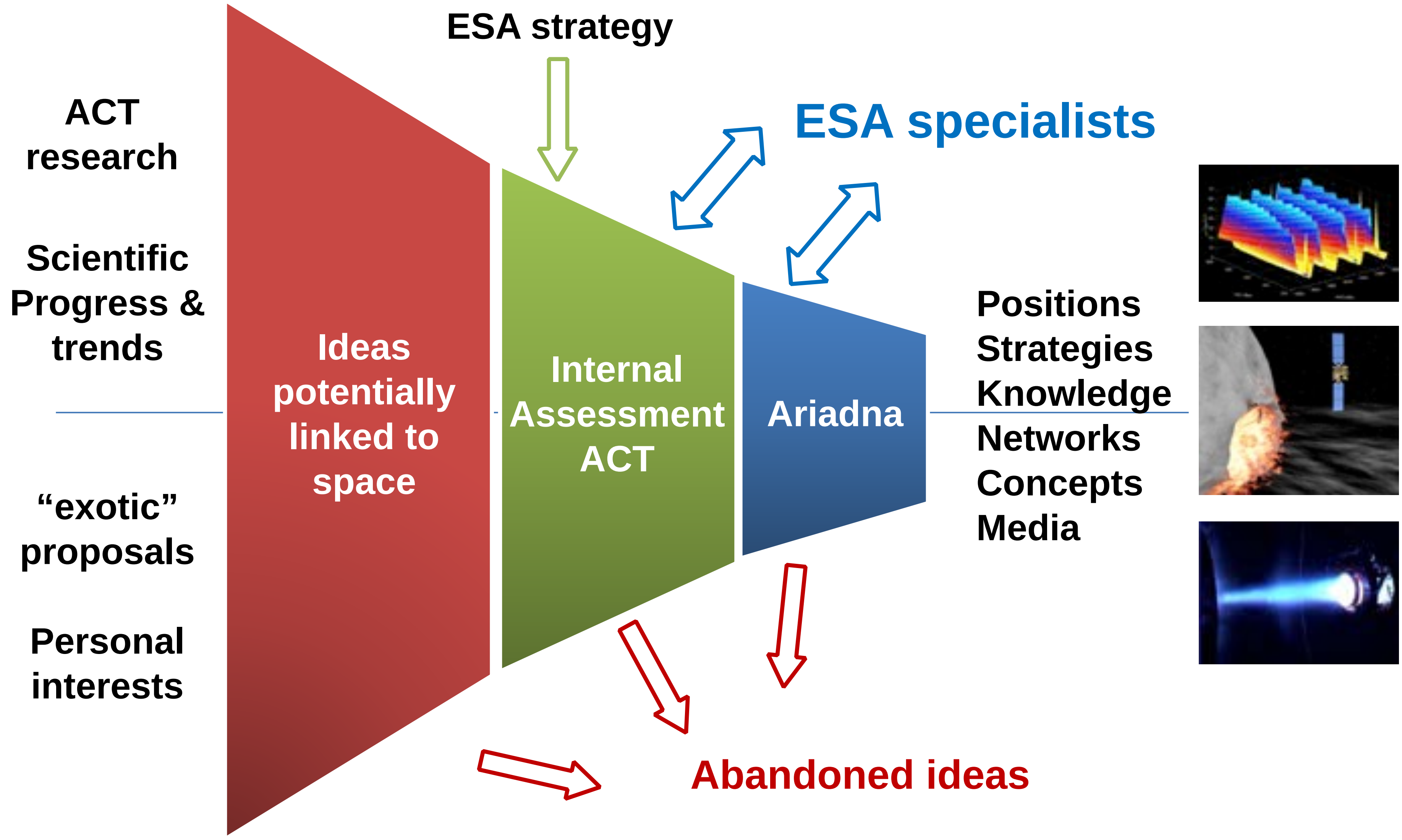
Special requirements for research with small university institutes

- Little administrative effort
- Fast and simple contractual procedures
- ACT as **peer** research group instead of funding source

Ariadna framework

- Predefined mechanism for European universities
  - Small/standard/extended (15/25/35k€)
- Flexible working links with research groups
- Participation of non-space research communities
  - Add space perspective to non-space topics
  - Foster novel space activities in Academia
- Improve the visibility between ESA and Academia

Think tank - idea funnel



ACT Research Areas - Objective

Fundamental Physics
Impact of new ideas in physics on the space sector

Biomimetics & Bioengineering
Benefitting from Darwinian evolution to solve engineering problems

Artificial Intelligence
Engineering of intelligent computer systems

Advanced Propulsion
Explore and review break-through propulsion concepts

Mission Analysis
Mathematical techniques for future-mission analysis

Energy Systems
Fundamental system of all future space systems

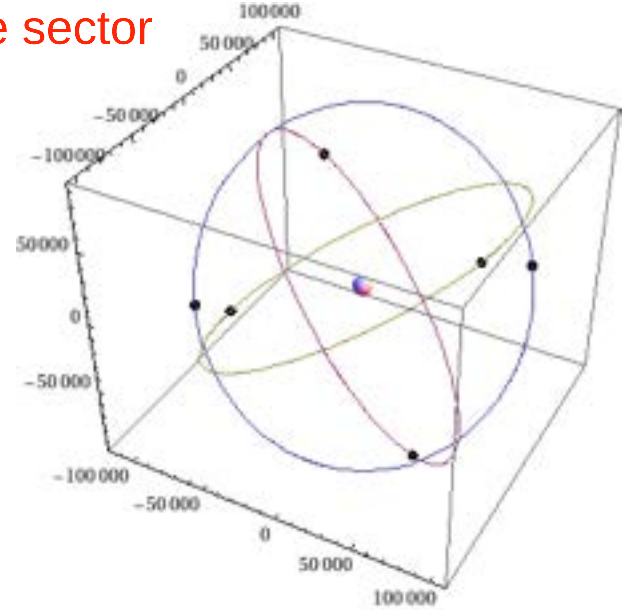
Computer Science & Applied Mathematics
Fast, efficient and parallel optimisation techniques

Planetary System Science
Options and opportunities from complex climate systems

Computational Management Science
Explore computational aspects of management

Fundamental Physics – Overview

Motivation: impact of new ideas in physics on the space sector

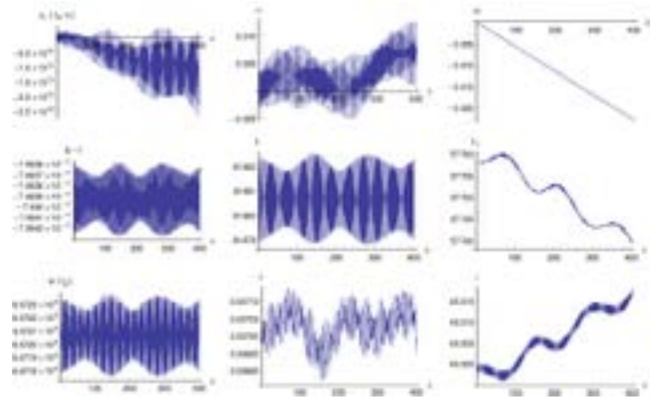


Past activities

- Metamaterials (optical, acoustic)
- Testing Einstein gravity
- Quantum entanglement
- Vacuum energy and Casimir effect

Ongoing: Relativistic Positioning Systems

- Construction of autonomous basis of coordinates (ABC)
- Involvement of TEC and NAV experts
- Ariadna with Univ. Ljubjiana, Univ. Prague and Observatoire de Paris
- Include gravitational perturbations in GR positioning and ABC
- Refine parameter values of gravitational perturbations using only ABC



Biomimetics – Overview

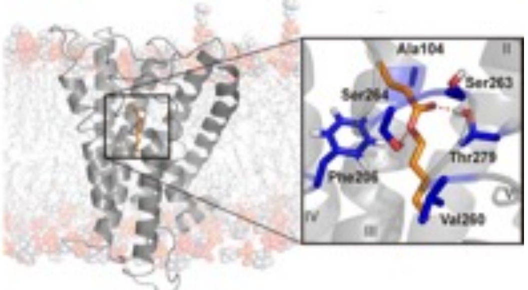
Motivation: Benefitting from Darwinian evolution

Past activities

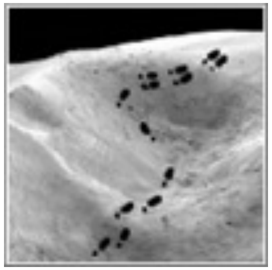
- Passive oscillation damping inspired by plant stems
- Ground anchoring based on plant roots
- Penetrators and parachute design
- Landing like a bee – optical flow & time-to-contact

Ongoing activities

- **Biosensors** – use structural change of proteins for multi-sensing based on spidersilk
- **Spider vision** – distance determination using (de)focused images
- **Brain-Train** - Cognitive repair functions stimulated by certain exercises



Motivation: to enable the engineering of systems possessing capabilities considered “intelligent” if performed by humans



Past activities

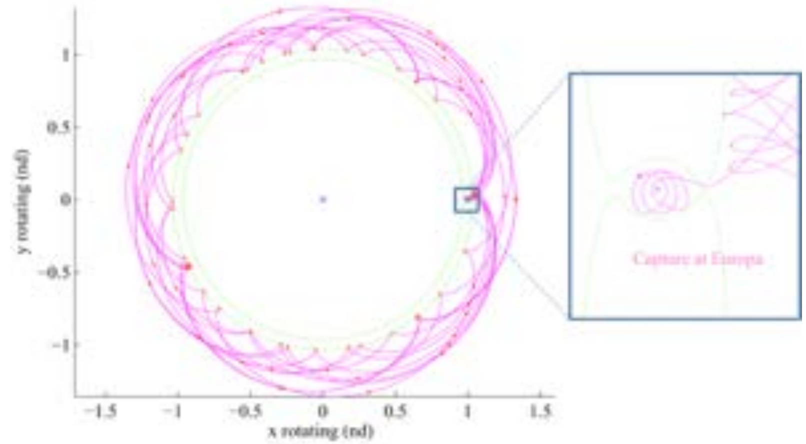
- Neural Network and machine learning
- Evolutionary computing (automatic design)
- Cognitive approaches (eg vision)
- Neuromorphic computing

Ongoing activities

- **Moon Hopper & Astrodrone** – scientific crowdsourcing games
- **Evolutionary Robotics for Satellite Swarms**

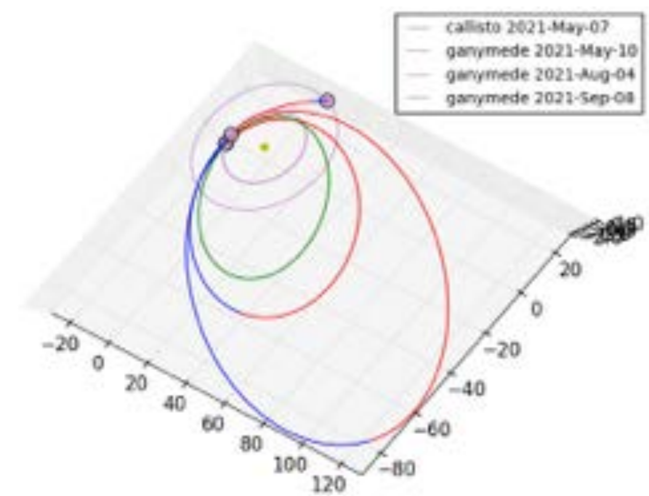
Mission Analysis- Overview

Motivation: Exploring how cutting-edge mathematical techniques could be used to perform mission analysis of future missions



Past activities

- Global optimisation methods for low-thrust trajectory design
- Formation flying and multi-body dynamics
- Advanced mission concepts (e.g. flower constellations, asteroid deflection, debris removal)
- Low-energy resonant transfer – Capture at Europe
- Multi gravity assist trajectories – Explore optimal sequence for lowest fuel use target orbit in the Jupiter system

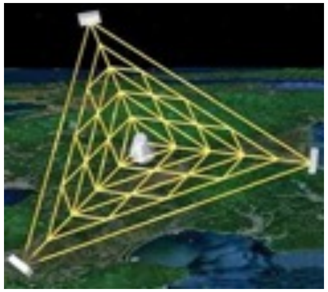


Ongoing activities

- **End of life strategies for Lagrange point missions** (StarDust – with space debris office)
- **GTOC** – annual global trajectory optimisation competition

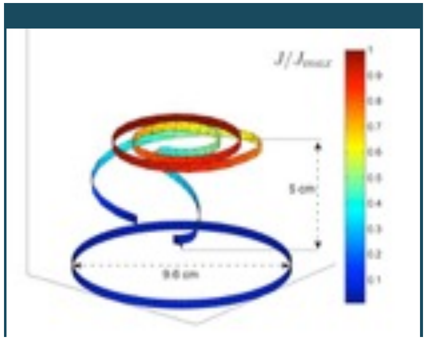
Energy Systems - Overview

Motivation: Energy systems are fundamental to all future space systems.



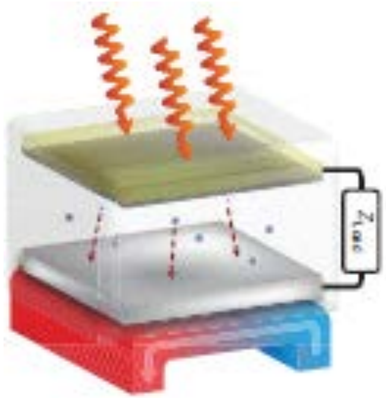
Past activities

- Wireless power transmission (short and long)
- Furoshiki & RobySpace, Suaineadh experiments
- Non-mechanical laser beam steering
- Biomass based fuel cells



Ongoing activities

- **Near-field wireless power transfer** – Antenna coil design using evolutionary algorithms
- **Photon-Enhanced Thermionic Emission** – Modelling charge behaviour at elevated temperatures in a combined photovoltaic thermionic cell



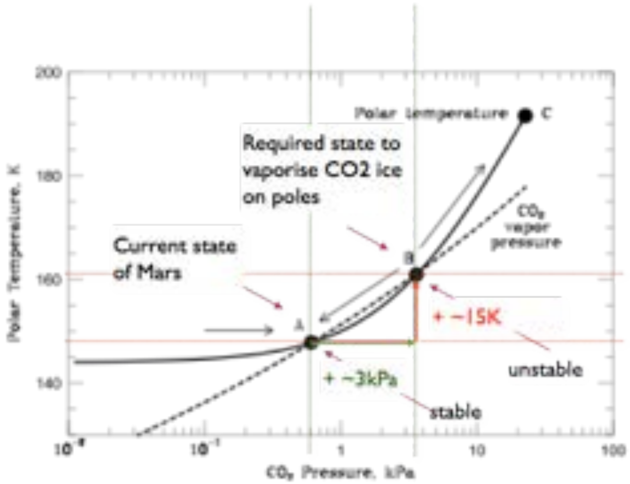
Motivation: Understanding options and opportunities offered by complex climate systems

Recent activities focus on

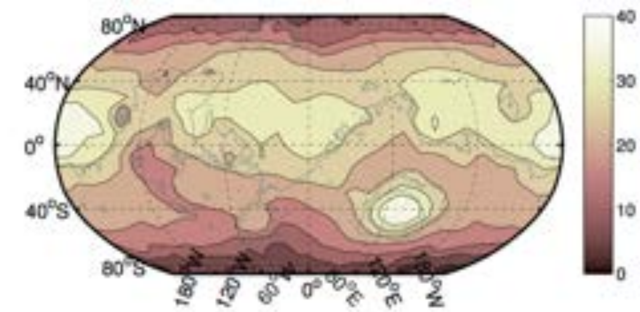
- Environmental impact of launchers
- Potential contributions from space towards geoengineering
- Martian climate engineering

Ongoing activities

- **Warming Mars with artificial GHG using Mars GCM** – LMD Paris and Kobe University (supercomputer)
- **Geo-engineering** – What-if? and space contributions (cooperation within FP7 consortium)
- **Tropical cyclone hazard** – Concept studies into microwave/laser beams from space to induce moisture changes
- **Laser Filamentation**

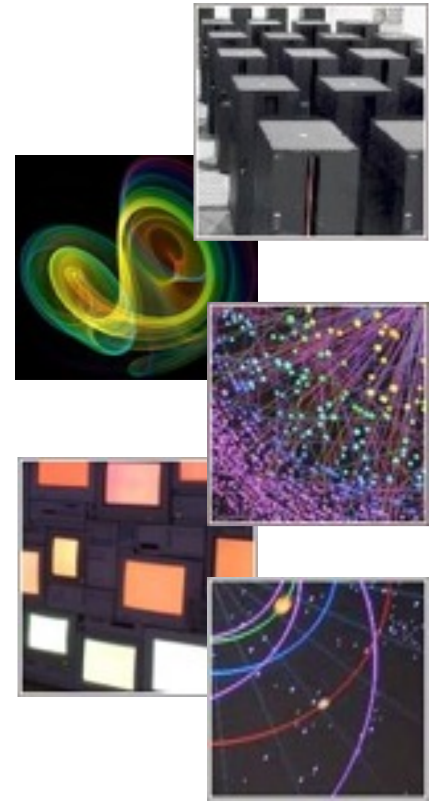


Annual surface temperature change (°C)



Computer Science - Overview

Motivation: One of the fastest moving research field with large potential impact on the space sector



Recent activities focus on

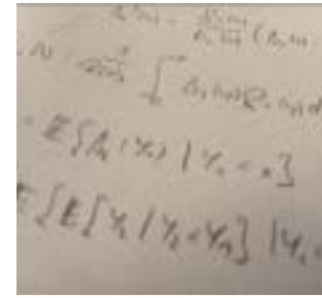
- Massive parallel computing (P2P computing)
- PyGMO and PyKEP
- Global optimisation and Evolutionary Computing

Ongoing activities

- **Optimisation as a Service** – Provide service for optimisation based on PyGMO/PaGMO
- **GSOC/SOCIS** – Enhancement of PyGMO functionalities
- **Machine learning / ordinal regression** – Ordinal regression by a generalised force model and extreme learning machines
- **Complex and non-linear systems** – Modelling non-linear phenomena in plasma's, multiplex networks, chaotic and self-organising dynamical systems

Computational Management Science - Overview

Motivation: Develop computational aspects of management science

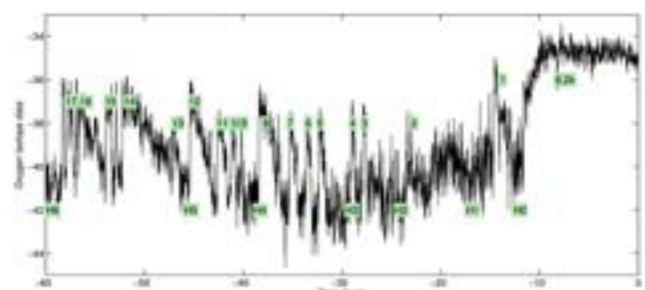


Recent activities focus on

- **Disruptive Innovation Theory -** Applying theory of disruptive innovation to space sector
- **Pricing and allocation of cubesat launches -** Combinatorial auctions provide flexible framework (Vickrey-Clarke-Groves mechanism)
- **Dynamic spectrum allocation -** Feasibility of short term band usage with dynamic bidding

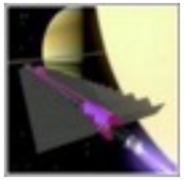
Ongoing activities

- **Ordinal Regression** – Ensemble learning
- **Time Series Analysis** – Neural Network Models applied to climate data, detection of tipping points indicators



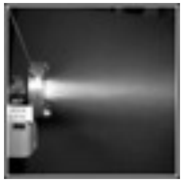
Plasma Physics and Advanced Propulsion – Overview

Motivation: Fundamental to all future space systems, we explore potential breakthroughs propulsion concepts



Novel High Isp concepts

- DS4G thruster
  - Advanced (gridded) ion thruster with Isp > 10.000s
- Electrodynamic tether study
  - Jupiter and its moons



Spin-in of technology into propulsion systems

- Ink-jet printing technology for propellant injectors in chemical rockets
  - Indication of improvement of propellant's injection behaviour

Radically different propulsion concepts and research

- Helicon thruster study
  - Advanced (grid-less) plasma thruster
  - Currently funded by EU FP7
- Inertial Electrostatic Confinement
- Kinetic modelling of Collisional De-exitation

Ariadna Follow-up studies

Space webs

4-grid ion thruster

Metal-hydride

Helicon thruster

Bio-inspired
dry adhesives

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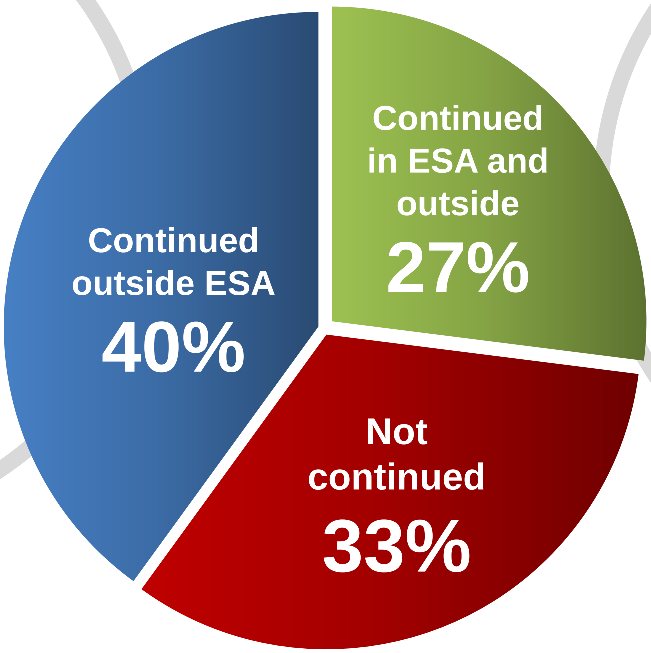
Academia
PhD positions
SME



opt. metamaterials

Trajectory design
under uncertainty

Active Debris Removal

Global optimisation

space NPS

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TRP
GSTP
Tools

Conclusion on aim, scope and method

With solid academic research, the ACT provides to ESA and the European space sector,

- In-house rigorous scientific knowledge on advanced topics that are currently outside the scope of the space sector
  - Rapidly available, academic standards, continuously adapting and exploring competence base
  - Research fellow at centre of approach – flexibility, risk taking, academic, efficient
- Provision of research related strategic analysis
  - Foundations and seeds for potentially disruptive innovation
  - Application of concepts/techniques outside their normal context
  - Interdisciplinary, independent and unconstrained
- Bridge to academia, in many cases outside the space sector
  - Research peers

More information

Further information about the ACT

Summerer, L., Thinking tomorrows' space - Research trends of the ESA advanced concepts team 2002-2012, *Acta Astronautica*, **95**(), pp.242-259, 2013. (link)

Summerer, L., Evaluating Research for Disruptive Innovation in the Space Sector, *Acta Astronautica*, 81(2), pp.484-498, 2012.(link)

Summerer, L., Izzo, D., Naja-Corbin, G., and I., Duvaux-Bechon, The seeds of disruptive innovation, *ESA Bulletin*, 144, pp.34-45,2010. (link)

www.esa.int/act

Other R&D Cooperation opportunities with ESA

Innovation Triangle Initiative

iti.esa.int

- A mechanism to support the introduction and fast validation of innovative concepts or technologies for space applications
- Continuously open Call for Ideas with a standing Evaluation Board
- Unsolicited proposals submitted through simple online template
- Short “time to contract”
- Aims specifically at technologies novel to space
- a rapid and successful introduction of disruptive innovations in Industry requires the collaboration of three different entities: an INVENTOR, a DEVELOPER and a CUSTOMER.
- Type A) Proof of Concept (for INVENTORS): fast validation of new ideas and demonstration of its advantages (<= 50 K €) – TRL3
- Type B) Demonstration of Feasibility and Use (for DEVELOPERS): component and/or breadboard development up to validation in laboratory or in a relevant environment (<= 150K€) – TRL4
- Type C) Technology Adoption (for CUSTOMERS): component and/or breadboard development, to be tested under key characteristics, technical and operational constraints imposed by the relevant environment and final targeted application (<= 2 M€ (50% Co-funded)) – TRL5 or above

Ariadna Research Collaboration

www.esa.int/ariadna

- collaborative research between ESA researchers and universities / research institutes
- “over the horizon” type topics exploring potential opportunities for space
- full focus on science, contractually fixed, non-negotiable, minimal overhead
- 15/25/35k€
- run by young post-docs in early career stages
- call for proposals: specific, targeted
- call for ideas: problem driven

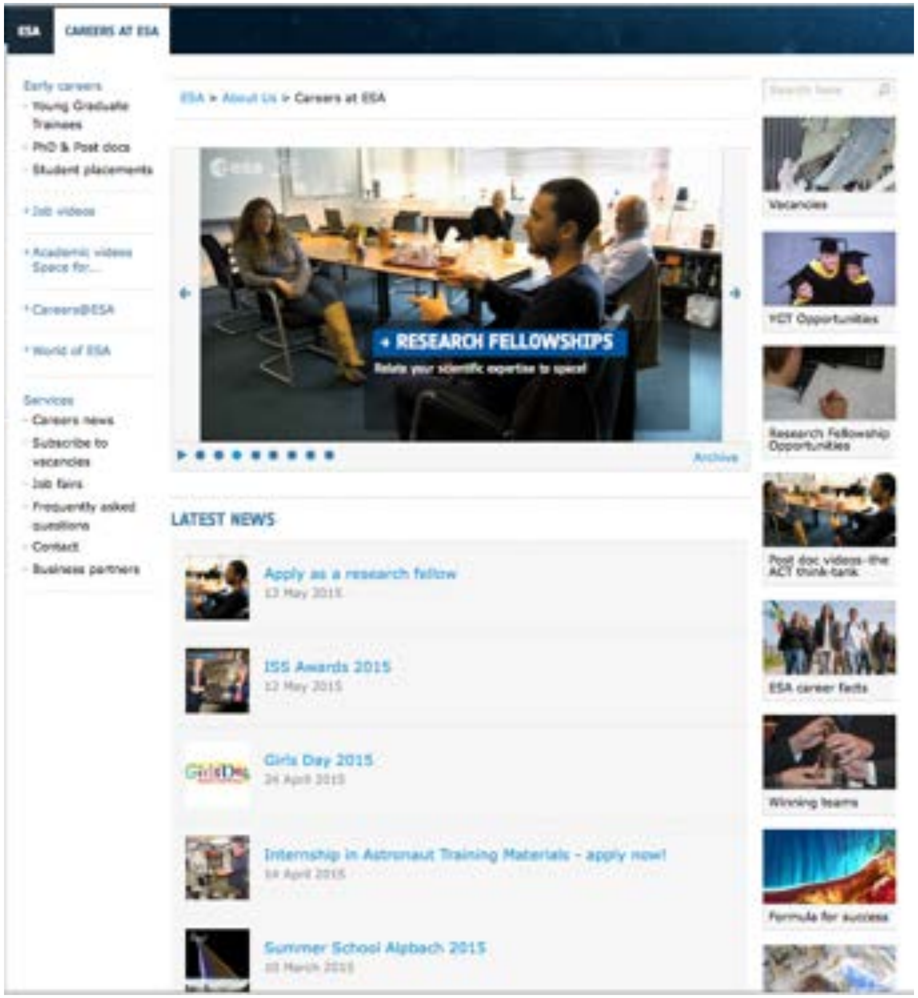
Networking/Partnering Initiative (NPI)

npi@esa.int

http://www.esa.int/Our_Activities/Space_Engineering_Technology/Networking_Partnering_Initiative

- supports work carried out by universities and research institutes on advanced technologies with potential space applications, with the aim of fostering increased interaction between ESA, European universities, research institutes and industry.
- Co-funding – up to 50% or €30,000 per year
- Access to ESTEC laboratories: use of ESTEC facilities for a minimum of six and a maximum of 12 months
- Technical support – access to ESA experts
- Facilitating search for industrial partners for further cooperation and build 'innovation networks' through ESA links
- contractual arrangement with the university or research institute concerned; researcher will remain a student or employee of the establishment.

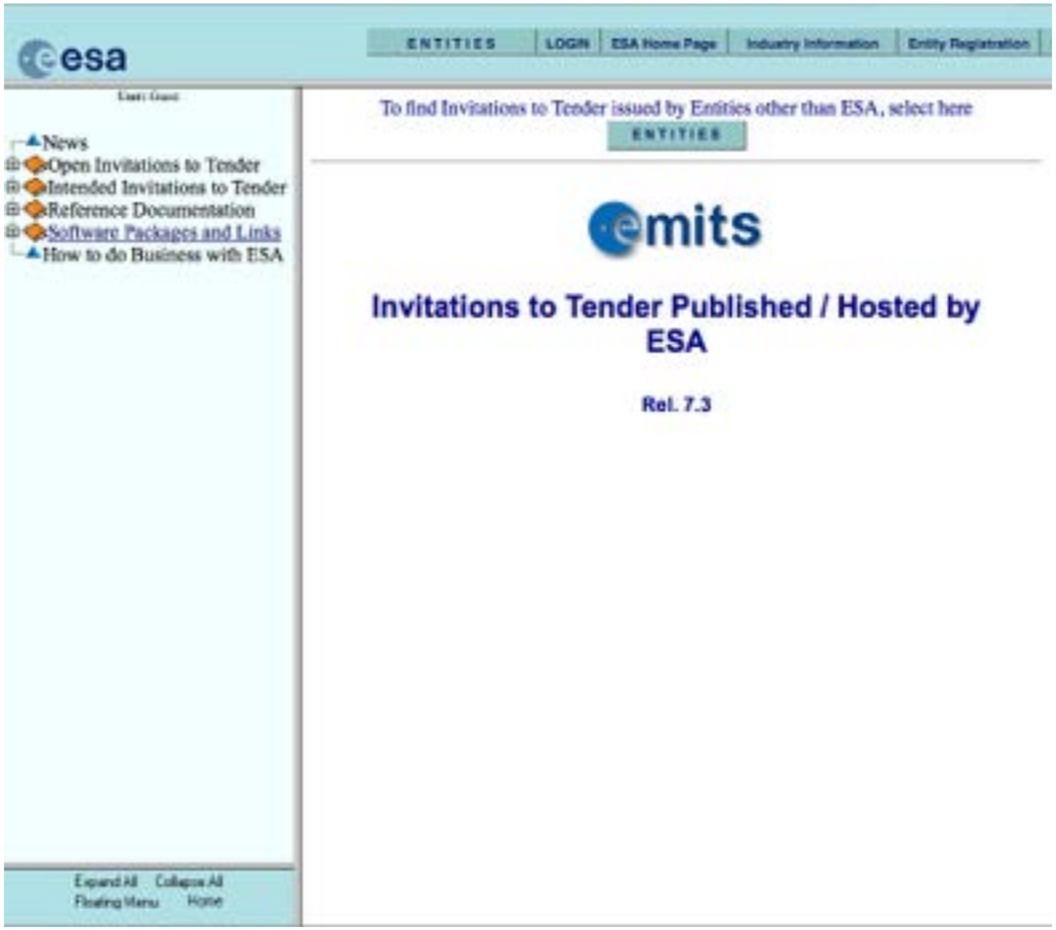
Young Researchers



http://www.esa.int/About_Us/Careers_at_ESA

- Young Graduate Trainees
  - training of young graduates at ESA
  - mainly technical and scientific topics
  - one year, potential for exceptional extensions
- Research Fellows
  - research opportunities for post-docs
  - scientific and technical topics
  - two years, potential for exceptional extension

emits - the portal for all ESA contract opportunities



- listing of all ESA contractual opportunities - open and intended ones
- title, price range, abstract
- full "statement of work" for registered entities
- need to register (free)

emits.sso.esa.int

Advanced Manufacturing Initiative

ESA contact point:
Tommaso.Ghidini@esa.int

Manufacturing Technology in Europe

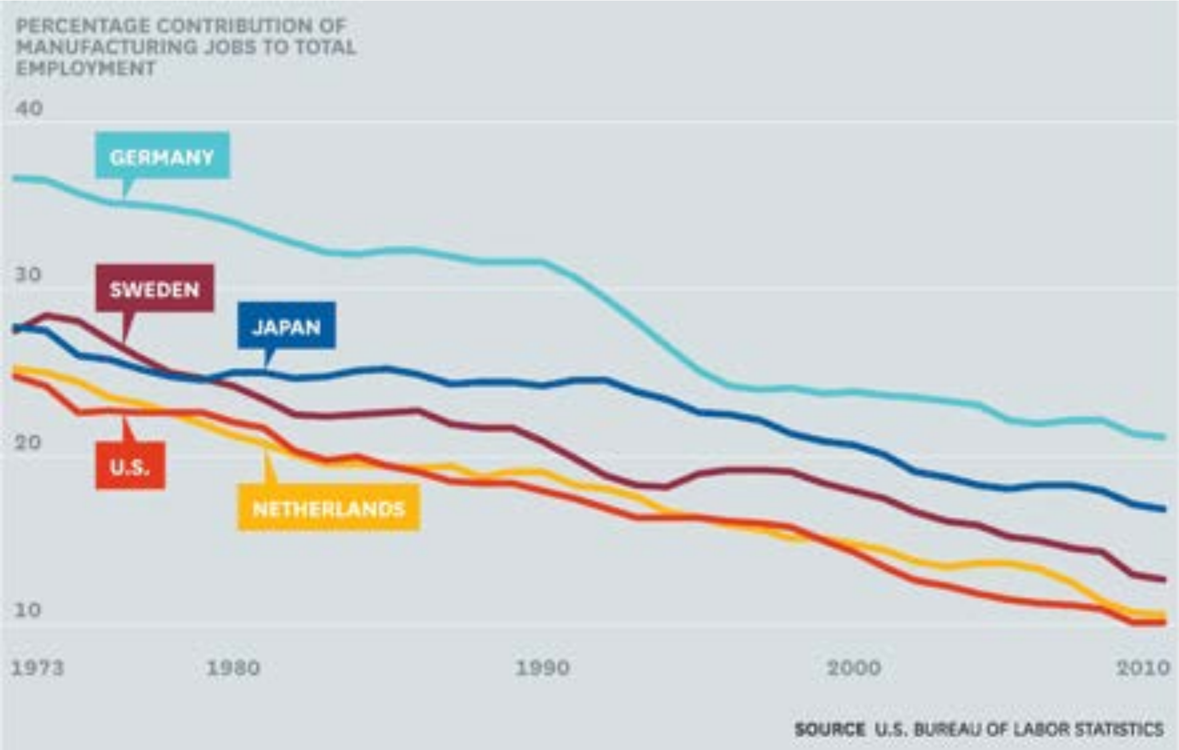
- Manufacturing within Europe has been in decline since the 1990's

➢ Outsourcing of manufacturing

➢ The need for cost reduction

➢ Technology is decentralised to overseas suppliers

- Certain competencies being 'lost' from Europe in general, not only Space



Manufacturing for Space Applications

European Space Industry has its own unique problems

- Only a few space primes in Europe and a relatively small number of Tier-1 suppliers.
- As the manufacturing processes are highly specialised, re-qualification of a new manufacturing entity, entails major non-recurrent costs

Consequence:

The rigid supply chain landscape of Europe offers limited opportunities for the designers to break the barriers of innovation

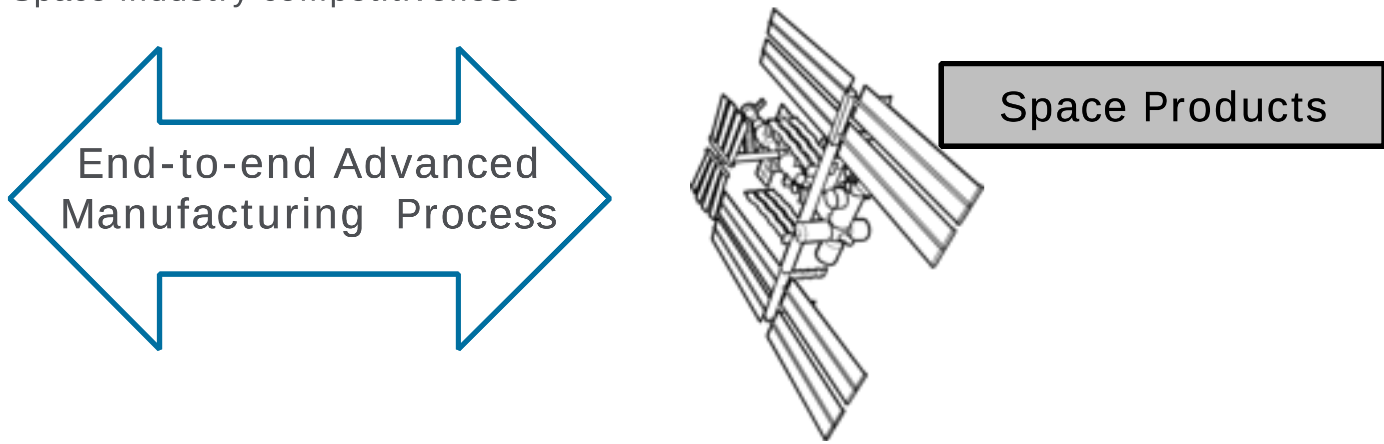
Advanced Manufacturing – Why?

Herschel Space Telescope Primary Mirror

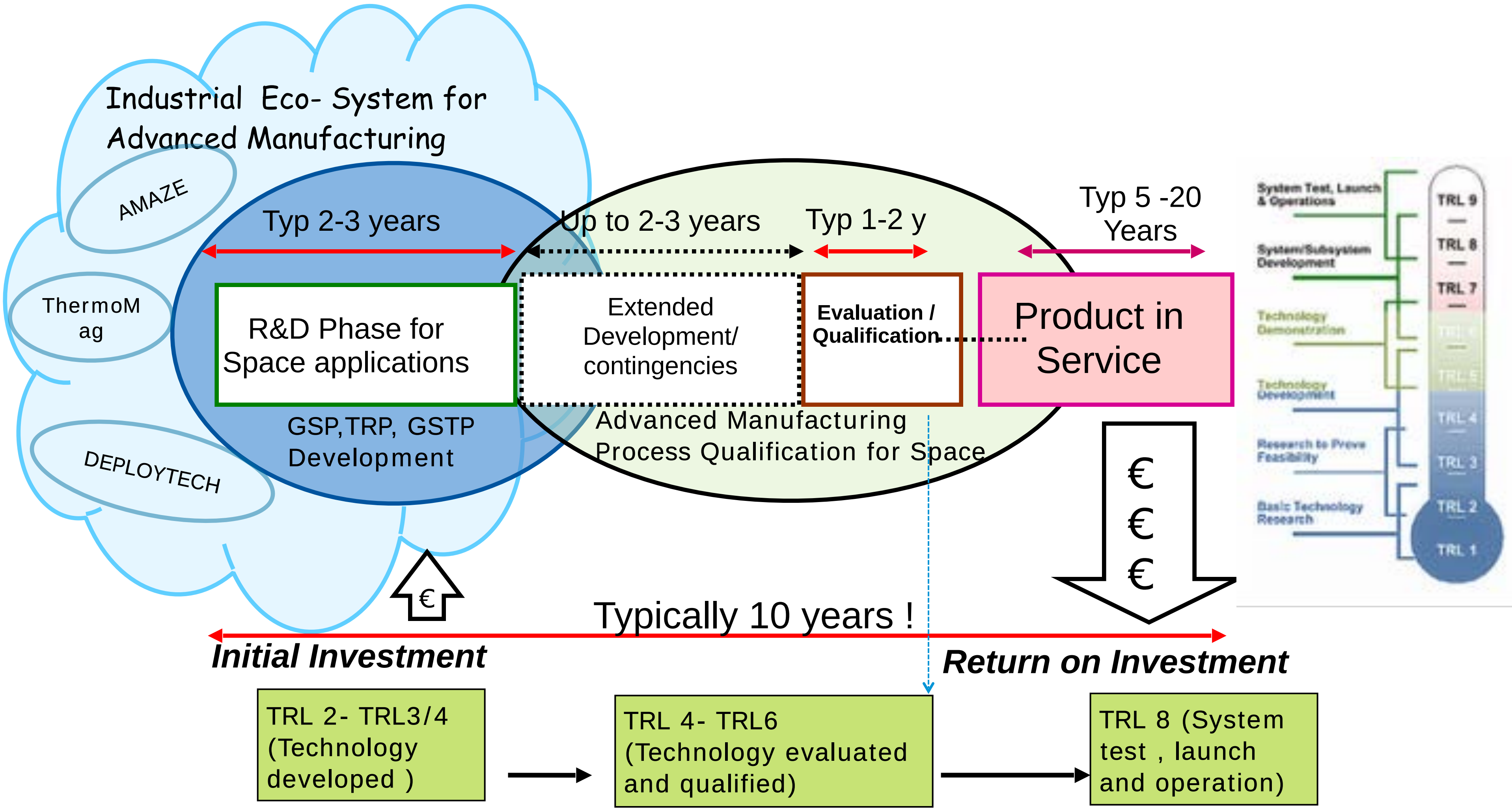
Only made possible by the development of advanced manufacturing of SiC structures

Advanced Manufacturing – Cross Cutting Initiative

- Many Advanced Manufacturing processes are today mature to be integrated in the portfolio of the manufacturing technologies for space hardware
- The ESA Advanced Manufacturing (AM) cross cutting initiative will:
  - Identify and implement new manufacturing technologies for space applications enabling design freedom, performances or costs and lead time (from concept to manufacturing) reduction
  - Enable the European Space Industry to create new high performance space products by reducing the limitations imposed by the traditional manufacturing processes/concepts
  - Foster multi-sectorial cross-fertilization, facilitating spinning-in/spinning-off opportunities across different high-end technology and industrial domains and infrastructure
  - Benefit of related Programmes supported by the EU (AMAZE, DEPLOYTEC, ThermoMag, etc.)
  - Promote creation and dissemination of design and verification/qualification/standardization methodologies maturing creating the market and its uptake
  - Maximize European Space industry competitiveness



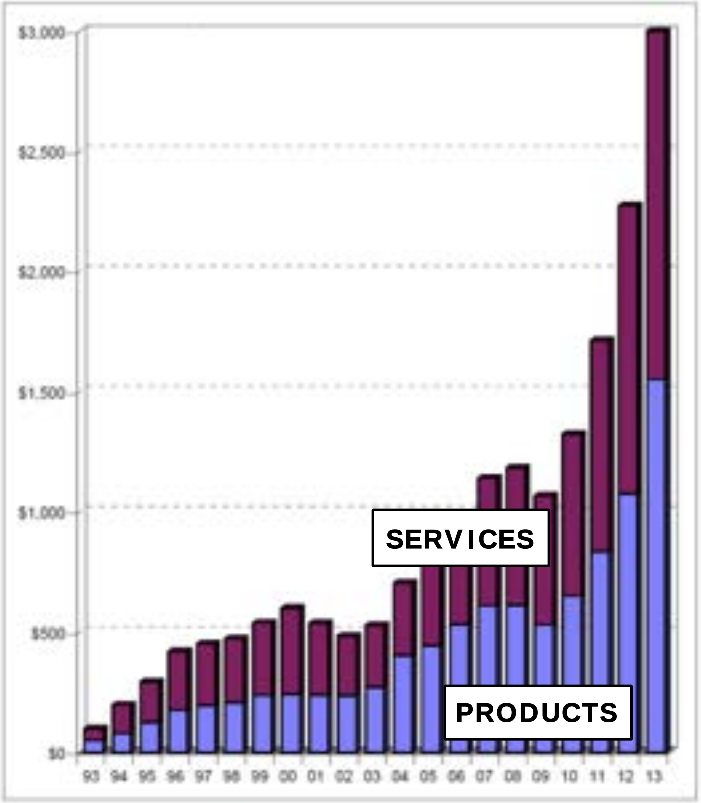
“It Takes Time and Sustainable Investment”



Additive Layer Manufacturing (ALM)

Market perspectives

- Compound annual **growth rate 2013: 44.5 %**
- ALM market will **quadruple** to **€ 6.8 bn** over the next **10 years**
- High potential **branches**: **Aerospace**, **turbine industry**, med-tech
- **Europe** is **in the lead** within metal ALM
  - But: significant financial means are allocated to ALM **outside Europe**:
  - **$ 1 bn** invested in the US for Additive Layer Manufacturing



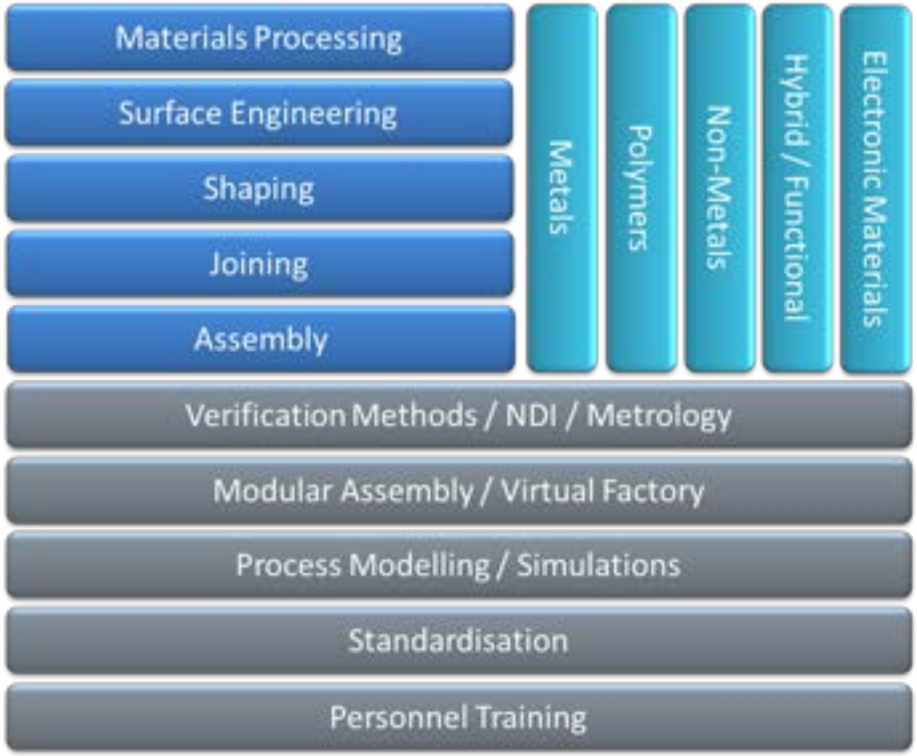
Source: Wohlers Associates, Inc.

- **=> important to act now, invest in ALM to further enhance European leadership in Space products !**

Programme Structure

The first step is to identify

- the manufacturing processes (Dark Blue)
- the material types/ categories (Light Blue)
- Cross cutting disciplines which apply (Grey)



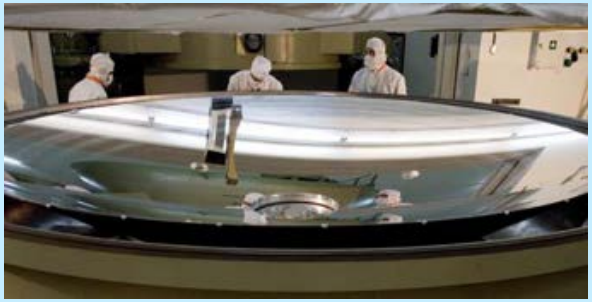
Select and prioritise the required advanced manufacturing technologies

Group similar activities and TRL levels

- Basic Research and prep activities (TRL 0-3)
    - Funded via GSP and TRP
- Main technology levels (TRL 3-7)
    - Funded via GSTP, Programme specific technology programmes, end user missions
- Qualification, verification and standards (TRL 4-8)

Examples of Key Technologies Already In Production in Europe

Herschel Space Telescope Primary Mirror



Only made possible by the development of advanced manufacturing of SiC structures

Additive Layer Manufacturing

Full size 3D printed Aluminium antenna support optimised for weight / structural performance.

Friction Stir Welding

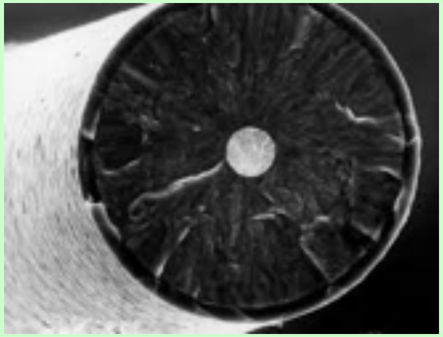
Full size welded demonstrator of a AA2195 tank manufactured and successfully tested in LH2 filled conditions (courtesy of TAS).

Examples of Technologies that could be adopted by ESA (GSTP / TRP)

Joining Technologies

- FSW of aerospace Al-Li alloys for
- Joining of Metal Matrix Composites
- Joining of structures such as TISIC
- Develop AlSiC/MgSiC
- Metallic Transition Joints
- Metallic/Ceramic Joints
- Metallic/Polymer Joints

Example of magnetic pulse welding / forming



TiSiC Fibre for high strength/stiffness applications

Examples of Possible Benefits

- ➢ Al-Li Demisable Tank + Relevant Transition Joints to Ti/SS pipes
- ➢ FSW Stringer/skin applications for launchers with reduced costs
- ➢ Simplified metal/ceramic joints for SiC space mirrors
- ➢ Joining of complex 3D structures such as TISIC/AlSiC/MgSiC

Examples of Technologies that could be adopted by ESA (GSTP / TRP)

Advanced Forming Technologies

- Spin Forming
- Superplastic Forming
- Superplastic Forming Diffusion Bonding
- Magnetic Pulse Forming
- Flow Forming
- Also applied after solid joining techniques

H-IIA tank domes SF + Ch. Mill

Examples of Possible Benefits

➢ Significant costs/lead time reduction

as well as

➢ Increasing performances if applied to launchers interstages, upper stages, wire rings, upper stages interconnections as well as large satellites and spacecraft tanks.)

Examples of Technologies that could be adopted by ESA (GSTP / TRP)

(Laser) Surface Treatments

- Local incremental forming
- Texturing of surfaces for tailored properties
- Laser shock peening (combined with in-situ ALM)
- Enhancement of bonding/coatings
- Controlled friction

Laser surface texturing (TWI)

Examples of Possible Benefits

- ➢ Controlled surface properties such as high/low friction
- ➢ Improved flow of liquids
- ➢ Improved bonding performances
- ➢ Improved corrosion performance and/or fatigue performance of key structural parts

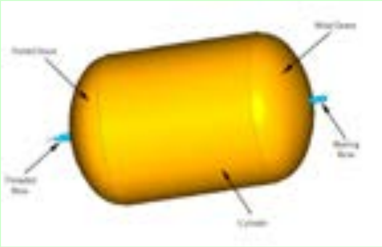
Examples of Technologies that could be adopted by ESA (GSTP / TRP)

Polymers and Composites

- Out of autoclave process
- Thermoplastic composites
- Advanced 3D weaving processes

Vega First stage Engine (Avio)

Examples of Technologies that could be adopted by ESA (GSTP / TRP)

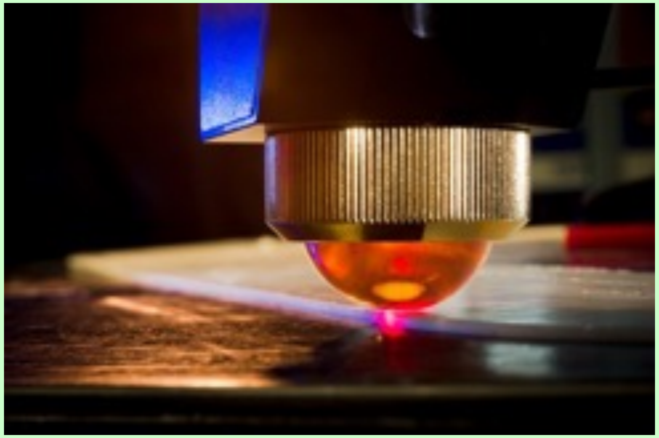


Advanced (Composite) Joining Technologies

- Induction Composite Welding
- Resistance Composite Welding
- Adhesive-less joining of ceramics and/or composites

Hybrid Materials

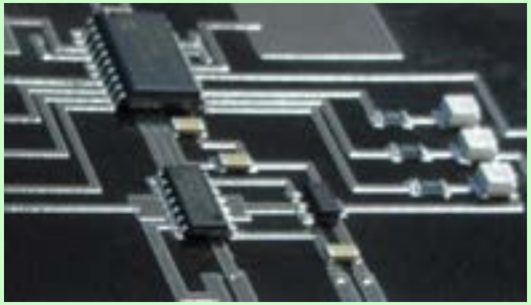
- Advanced sol-gel processing
- Self-healing materials
- Thin ply composite
- Embedded functional systems
- Advanced coating techniques



Examples of Technologies that could be adopted by ESA (GSTP / TRP)

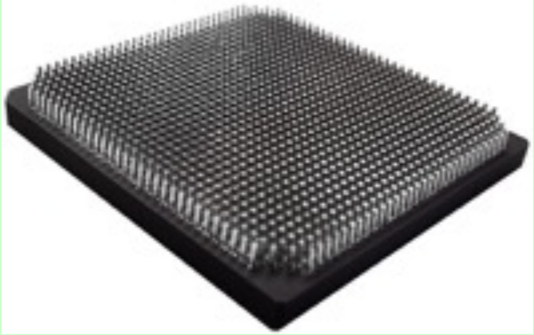
Electronic Processes and Materials

Example of a Printed PCB (Neotech)



- High reliability Printed electronics
- Sensors/actuators printing
- Next generation solders

High Density PCBs



- High reliability HDI PCBs
- Assembly of advanced area array devices

Summary and Next steps – Advanced Manufacturing

Conclusions

- **Terrestrial advancement** in the manufacturing technologies and investments in new materials research offer opportunities to **reshape the supply chain of the European Space Hardware** sector to meet the challenges of the 21st century
- New AM technologies offer opportunities (particularly for SMEs) to create **entirely new products** and streamline existing processes, and to **enter the space product supply chain**
- AM introduces **new materials and processes** as an integral part of future designs to provide a **faster and more cost efficient entry to the market with globally competitive space products**

Way Forward:

- Identify and implement the new AM technologies with highest potential for space applications in terms **design freedom**, **performances**, **costs and lead time** as well as **ROI**
- Bring together industrial and institutional partners to create, develop AM processes in Europe to serve both the European and global space industry
- First list of activities in March 2015
    - ➢ Additive Layer Manufacturing Roadmap (June 2015)
    - ➢ Composite Materials Roadmap (March 2015)

Additive Manufacturing for space

ESA contact point:
Tommaso.Ghidini@esa.int

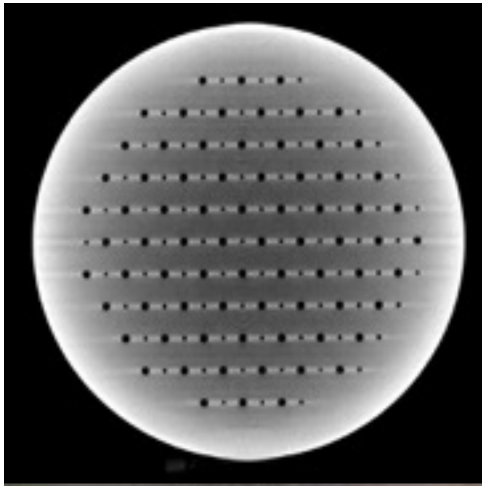
Additive Manufacturing (AM) at ESA

- **Challenges for Space Materials and Processes:**

- **Low Mass**
- **Small Production Series**
- Very High Reliability
- **Limited Manufacturing Processes**

5. **Small Geometries**
6. Very High Performances
7. **Challenging Material Procurement**

- **Why ALM?:**
  1. Well fitted to Space hardware => very small series.
  2. Applied to many materials => metals, polymers, composites, ceramics for space but also food (for astronauts), living cells and organs (for telemedicine).
  3. Dimensions from few micrometers to meters.
  4. Gains in performances with 2 digits => mass saving 40 to 90%, lead time reduced by weeks, suppress complex assemblies and controls.
  5. Environmentally friendly => excess material is re-used instead of being down-graded through re-cycling.
  6. Could be used for in-orbit or on other planets
- **Several developments are currently running under ESA funding including RF hardware, antennas components, propulsion, thermal management and structures**



ESA Learning Curve

- Started in 2006, powder bed and blown powder processes

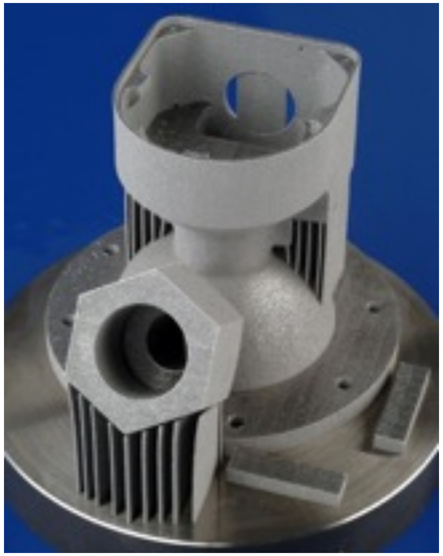
  ➔ **frustrating answers**

- reproducing a part designed for machining without weld

  ➔ substitute stainless steel by titanium

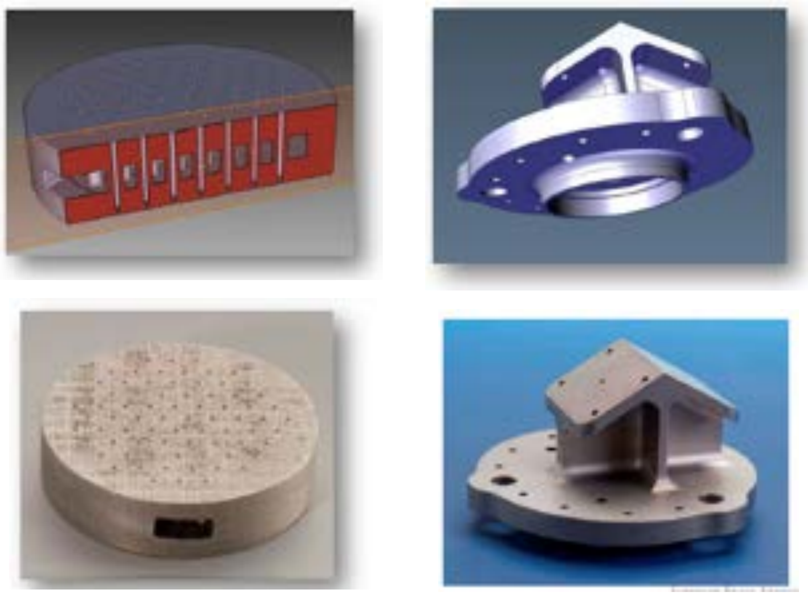
  ➔ cost and mass benefits

➔ **change in design thinking process, design for AM**

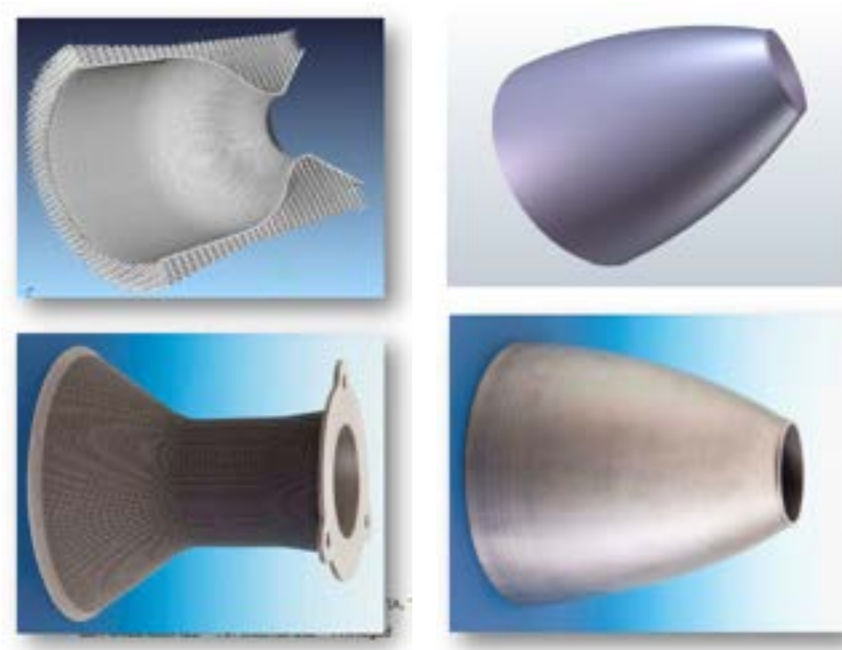


AM for Space Propulsion

Injectors



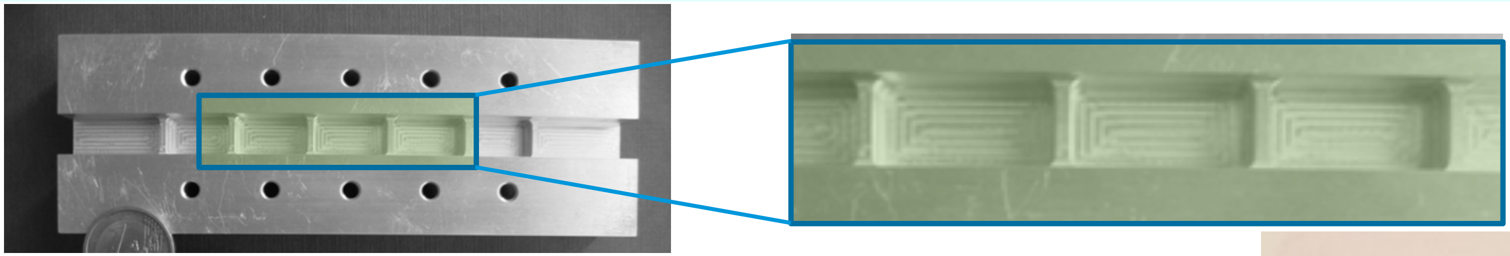
Chamber/Nozzles

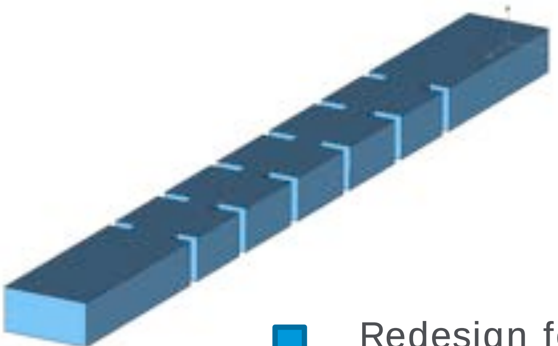


Monolithic Thrusters

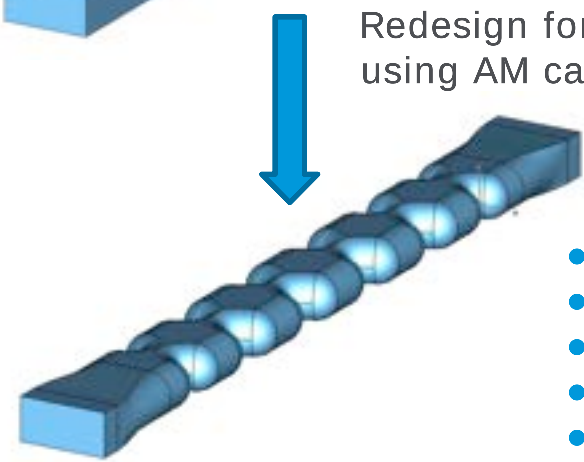
- Functionally graded materials with gradual transition in composition and structure for thruster performances improvement
- Reducing incompatibilities in material properties
- Enhanced monopropellant catalyst design
- Lattice structure for thermal/mass management

AM for Electrical Hardware

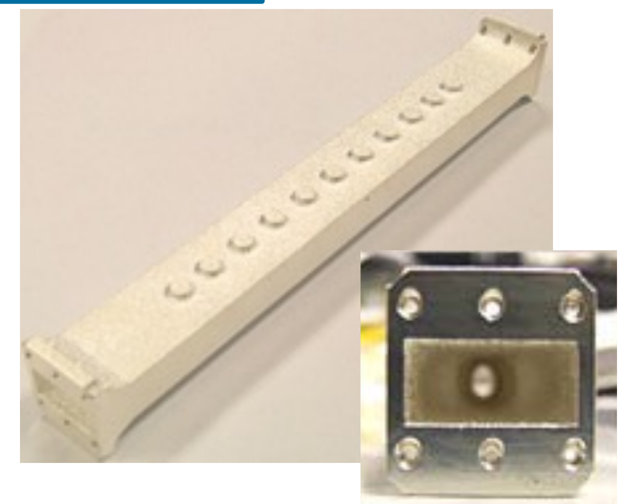




Conventional design for manufacturability, machining



Redesign for performances using AM capabilities



Collaboration ESA – TESAT(D) – ILT (D)

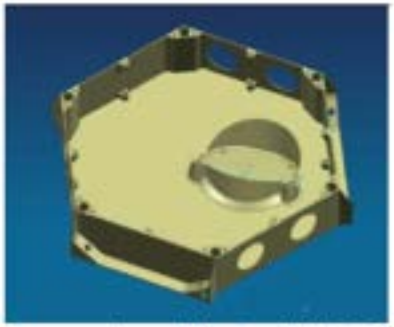
- Mass & room saving (50% mass, 30% projected area)
- Suppress assembly (cost saving, no failure risk)
- Easier to control (no tightening torque, no electrical leakage)
- Easier to silver coat (no sharp corner, easy electrode access)
- Lead time reduced by weeks (9 made in a machine run)

AM for Mechanical Hardware

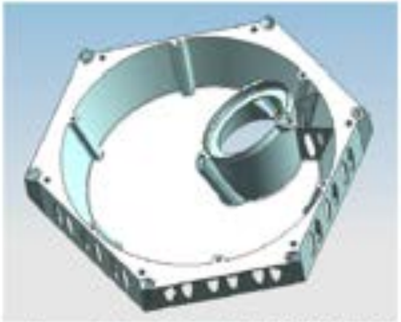
Conventional Design

Design optimized for AM

- 46 % mass saving
- Suppress interfaces
- Shock / Vibration Test passed
- Dimensional Control successful



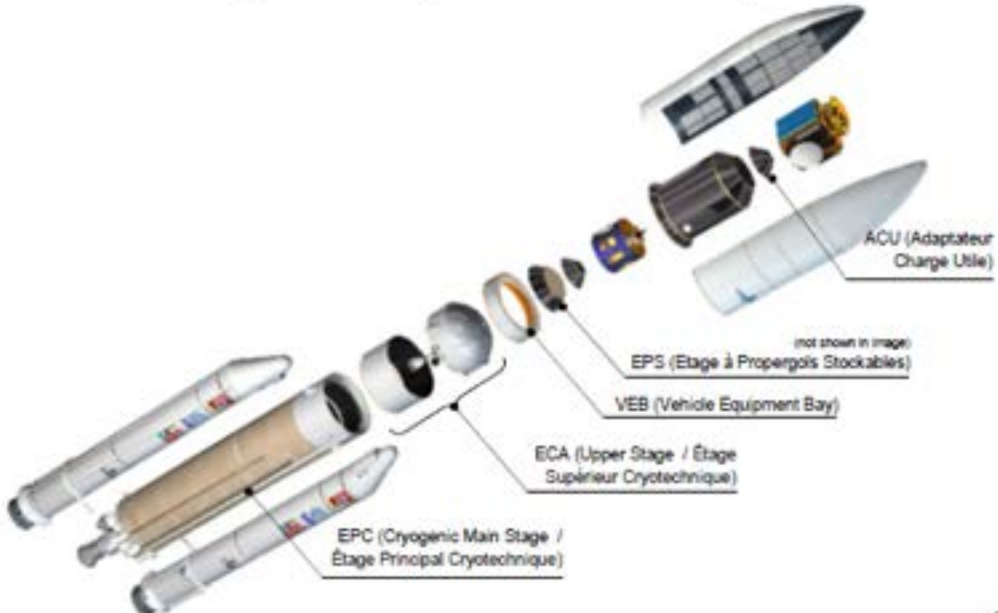
Conventional design (Al7075)

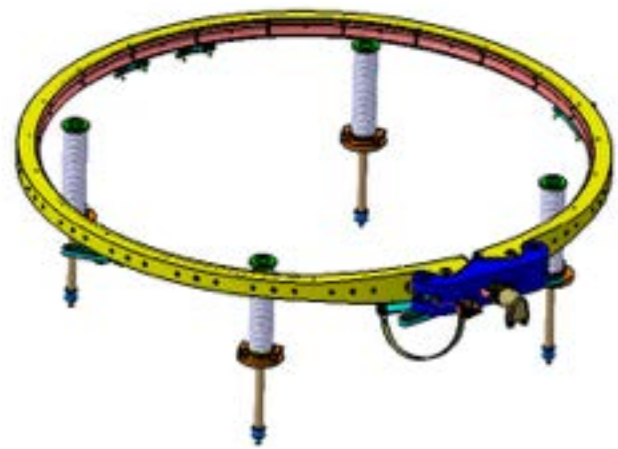


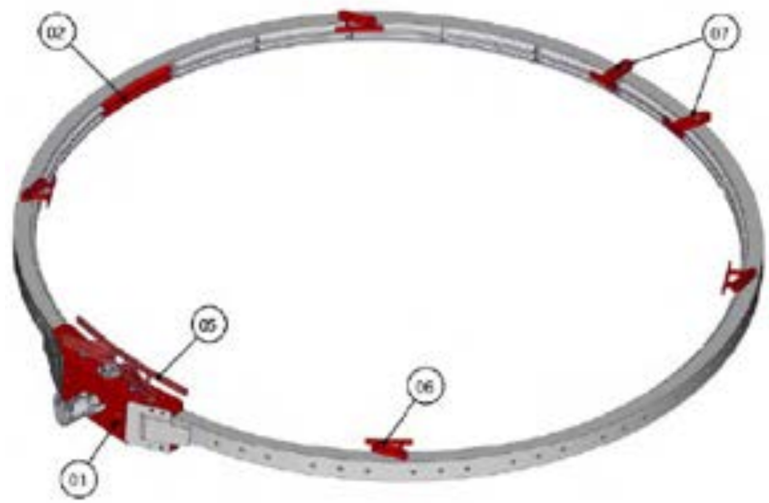
design suited for ALM (AlSi10Mg)

- Tensile Specimens in two orientations to characterize the anisotropy of the process
- Cubes to assess the density
- Two samples to characterize the feasibility of the design

AM for Launchers







AM for Launchers

Main goal: Evaluation of the potential benefits (and drawbacks) of a designed combination of **AM technology**, **materials** and **applications** for **future launchers** and next generation of space hardware

Phase 1 (status: finished)

Screening for target application

Phase 2 (status: finished)

Definition of development and verification plan

Mechanical characterization and advanced NDT
(static, fatigue, microstructure, tomography, UT, eddy currents, etc.)

Phase 3 (status: finished)

Execution of TVDP

Materials and Demonstrators

Phase 4 (finished)

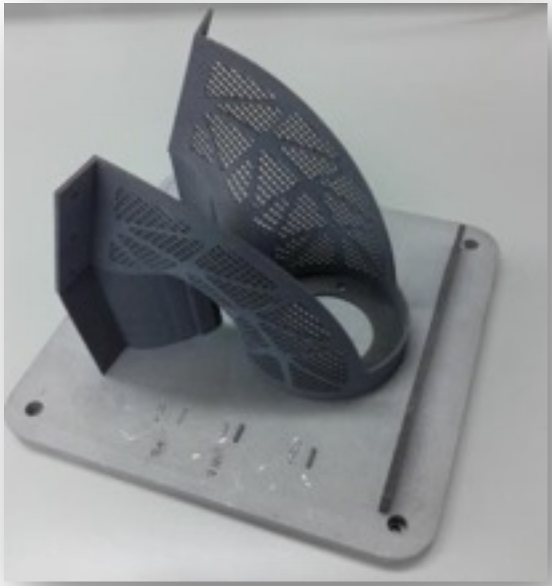
Preliminary Breadboard definition and topology optimization

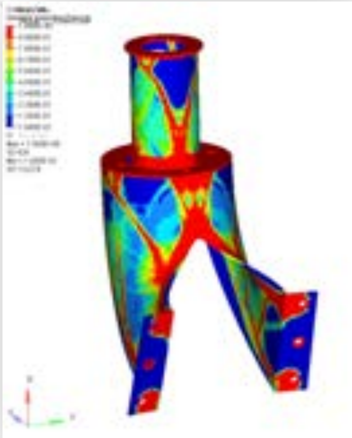
Phase 5 (Breadboard manufactured / Verification in progress)

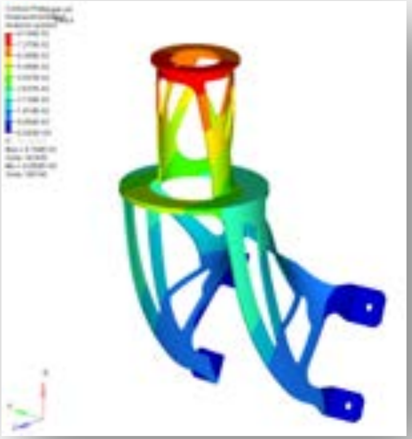
Manufacturing & Verification

Connector Support (AlSi12)

-62.9% @ -0.285 kg







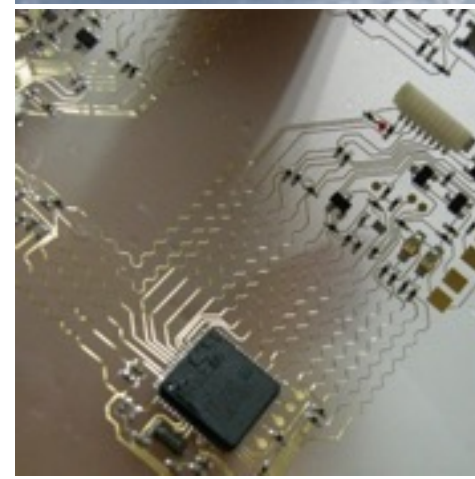
ISRU improved - Lunar base concept

On demand production of spare parts and tools remotely designed

Printed Electronics

What is printed electronics?

- Emerging additive manufacturing method
  - **Combining electronics and mechanical manufacturing into a single additive manufacturing process**
- Potential applications for ESA and the European space industry
  1. Sensors, antennas, batteries, solar cells
  2. Embedded component structures (PCBs) and flexible substrates/ cables
  3. Inkjet printed interconnections/conductors
  4. Possibility for astronauts to print electronics on demand
- <u>Not</u> a drop-in replacement for conventional electronics manufacturing
  - Complex structures, materials, tailored products
  - Combining traditional and printed manufacturing methods (Hybrid systems)
- Robust, flexible and economical method
- **Electrical performance and reliability not yet at the same level as for conventional electronics**



AM for Clean Space

- Smart development/selection of green technologies will lead to improved competitiveness of European Industry.

- ESA Roadmaps selected five themes to focus on M&P and EEE:

  1. **Additive (Metallic) Manufacturing**
  2. **(Metallic) Welding Technologies**
  3. **Green Surfaces and Processes**
  4. **New Materials & Processes**
  5. **Green Electronics**

Questions?