Additive Manufacturing (AM) for Space (and Earth) Applications

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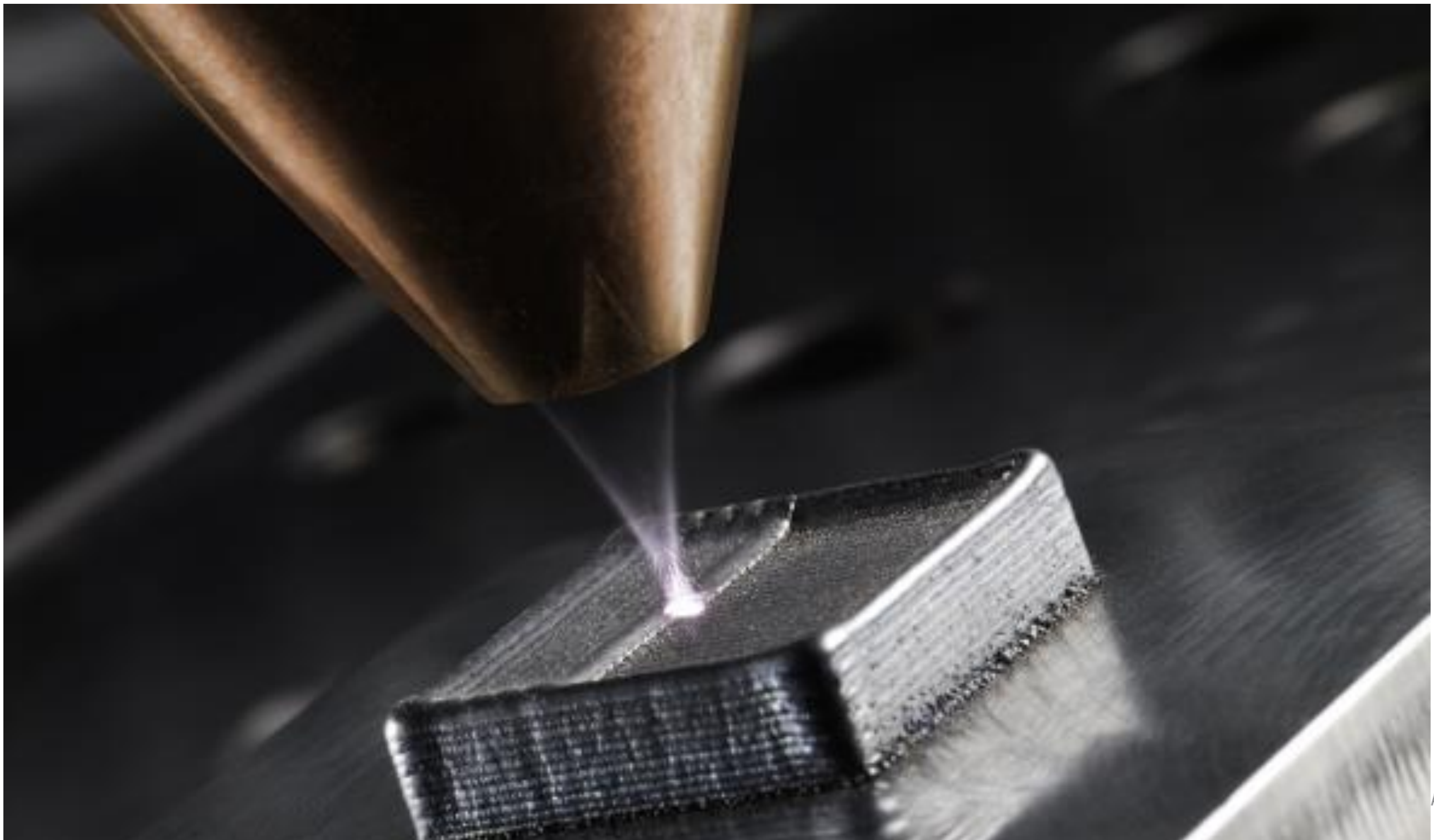
Additive Manufacturing (3D Printing): the Process

- **3D Printing: building 3D objects adding material layer by layer**

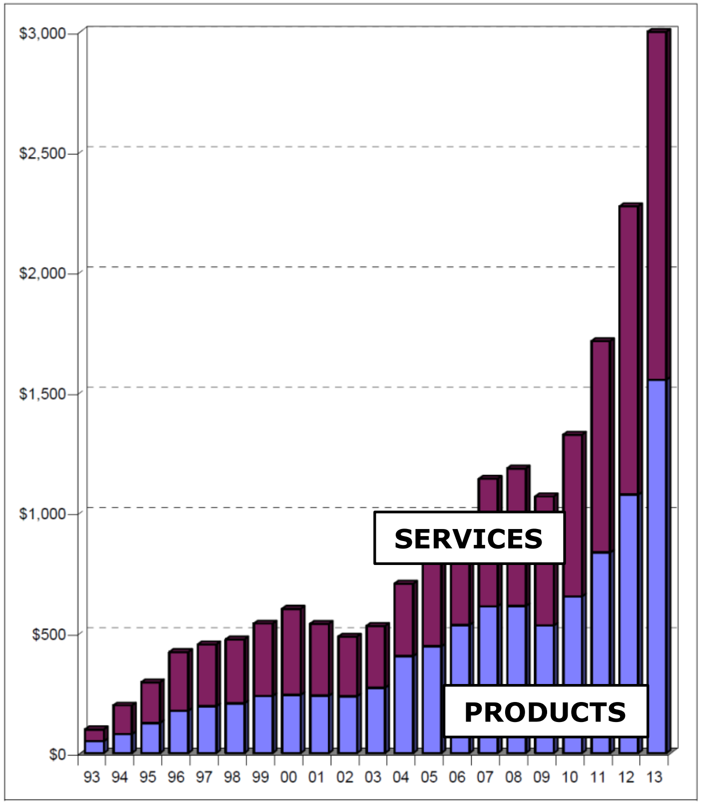


Agency

Additive Manufacturing (AM)

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 AM **outside Europe**:
    - **$ 1 bn** invested in the US for Additive Layer Manufacturing



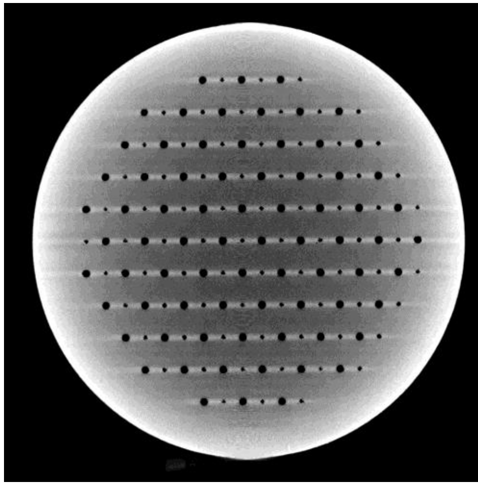
Source: Wohlers Associates, Inc.

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

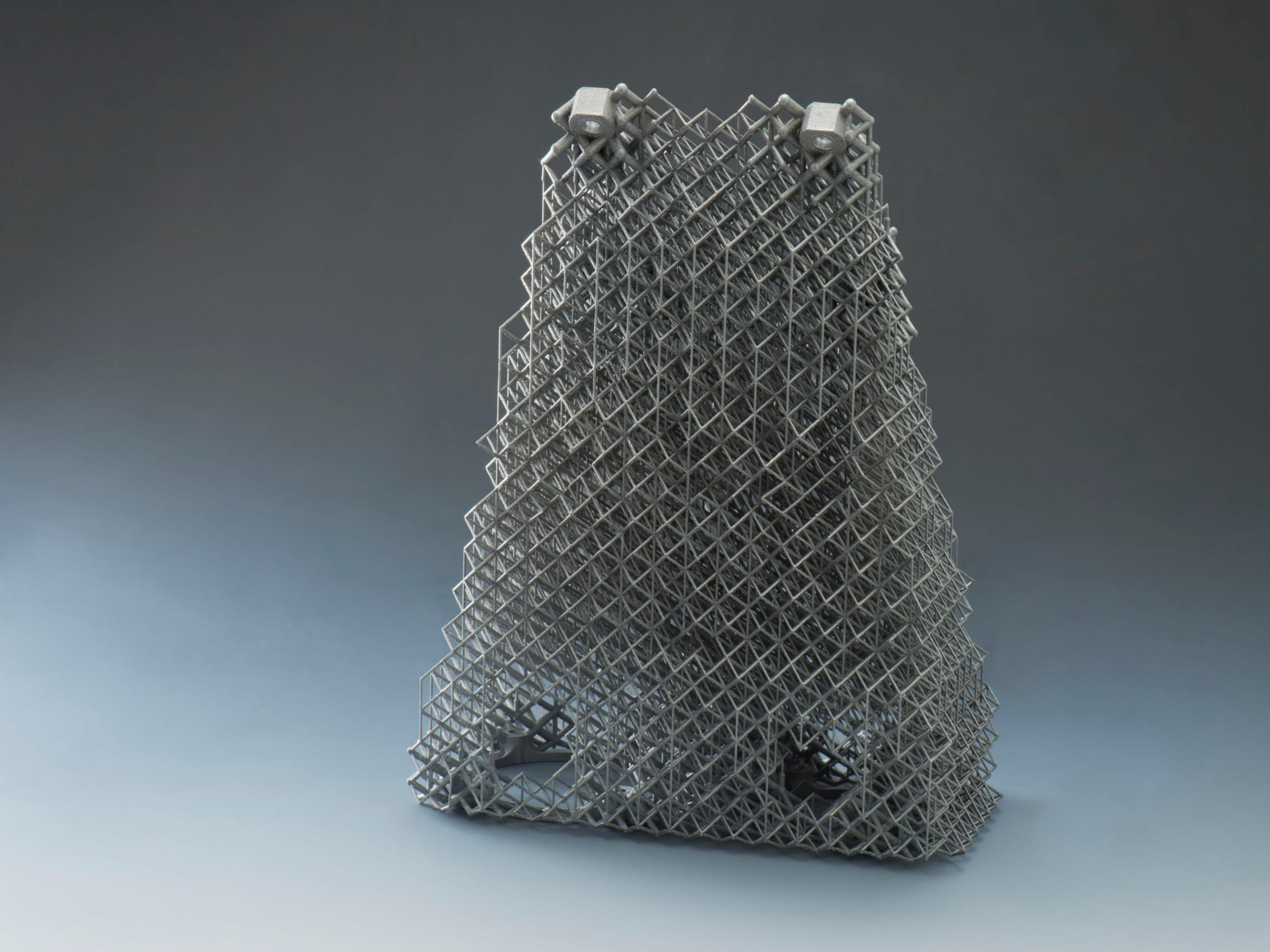
Additive Manufacturing (AM) at ESA

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

1. **Low Mass**
2. **Small Production Series**
3. Very High Reliability
4. **Limited Manufacturing Processes**
5. **Small Geometries**
6. Very High Performances
7. **Challenging Material Procurement**



- **Why ALM for Space?:**
    1. Very small series and highly complex geometry (not achievable today with other technologies)
    2. Large variety of materials possible: Metals, polymers, composites, ceramics for space but also food (for astronauts), living cells and organs (for telemedicine)
    3. Gains in performances with 2 digits => mass saving 40 to 90%, lead time reduced by weeks, suppress complex assemblies and controls
    4. Environmentally friendly => excess material is re-used instead of being down-graded through re-cycling
    5. Could be used for in-orbit or on other planets
    6. **Changing the access threshold for space**

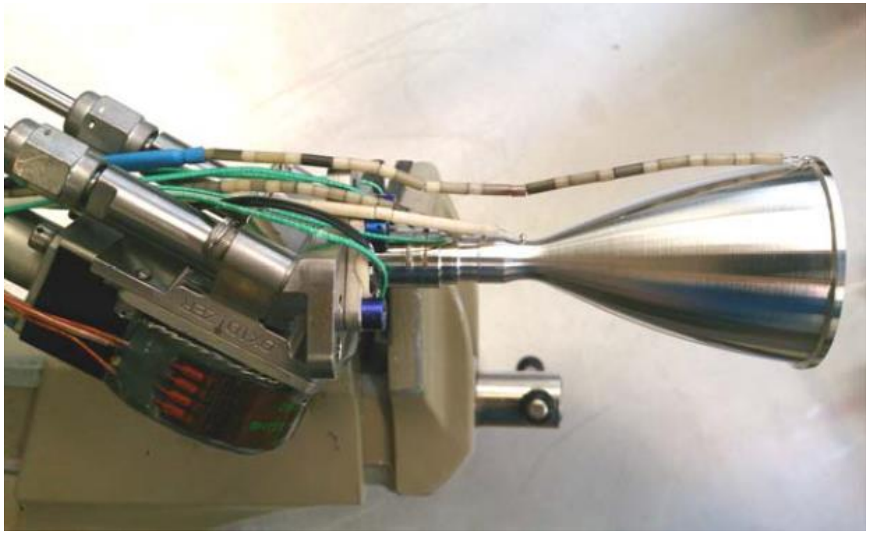


A Major Achievement

World´s first 3D printed platinum combustion chamber for space applications !!!

Successfully Hot Firing Campaign <u>5th of May, 2015</u>:

- **1,1 hrs firing time**
- **618 ignitions**
- **26 thermal cycles**
- **with a 32 min longest single burn**
- highest throat temperature of **1253°C** was reached



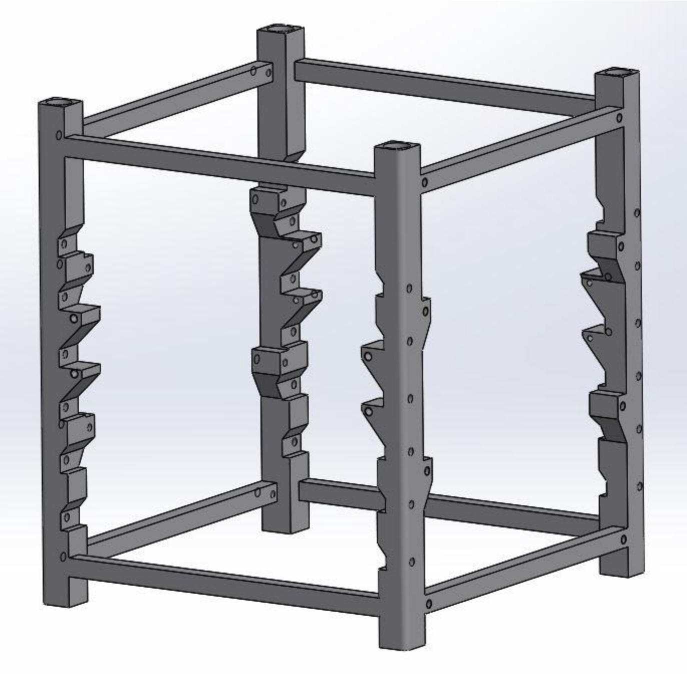
10N AM thruster maiden firing at nominal operation point

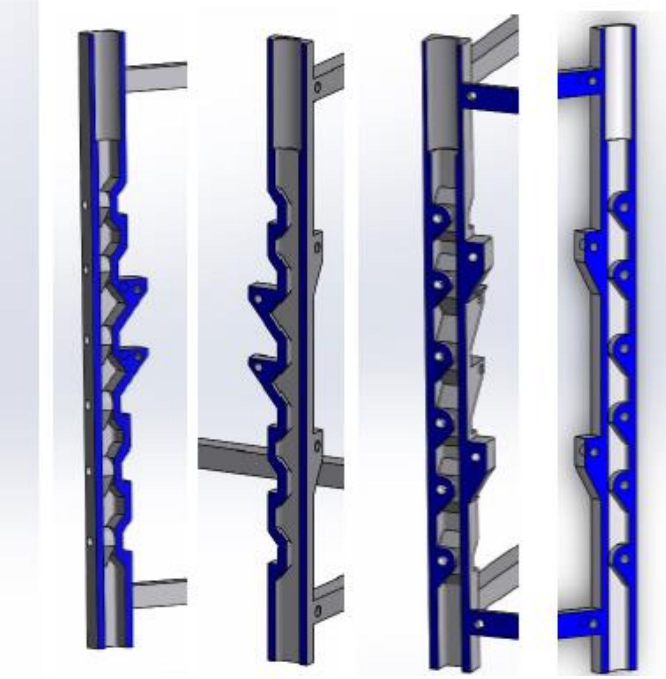
Priority Goal: AM for Launchers

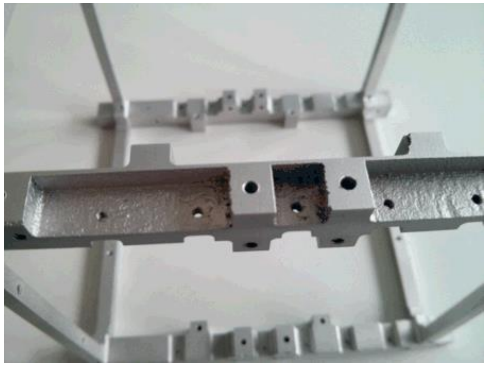
AM CUBESAT

Objectives:

- Re-design a Cubesat taking full advantage of Additive Manufacturing
- Use the Cubesat as a “low risk” platform for trying verification/qualification routes
- Assess the potential of AM for Cubesat and issue specific design guidelines







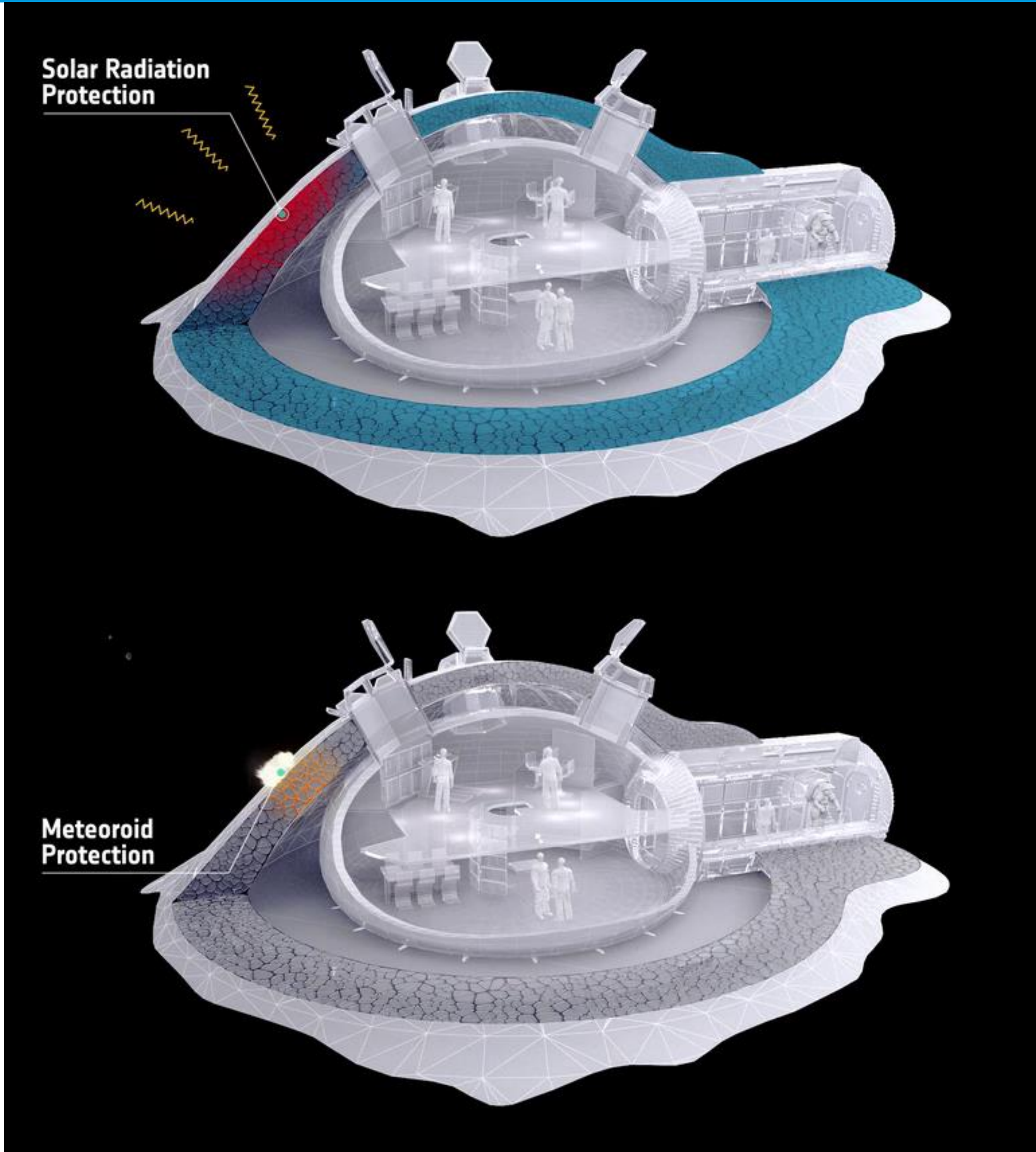
AM: Enabling Technology for Future Space Missions

Enabling Industry to maximise benefits of the technology requires:

1. **Reach confidence and quality required for space use**
2. **Change the way we think/work today**

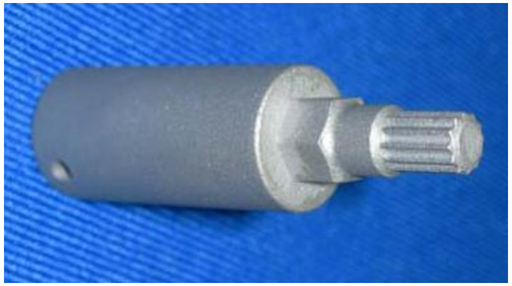
AM: Enabling Technology for Future Space Missions

- First Agency in the world having **<u>already</u>** printed a 1.5 tons Moon base demonstrator using Moon regolith
- Moon Base concept developed based on an inflatable structure and 3D printer shelter
- Current development solar oven
- Further steps definition of all tools/equipment/spare parts to be printed using in-situ resources



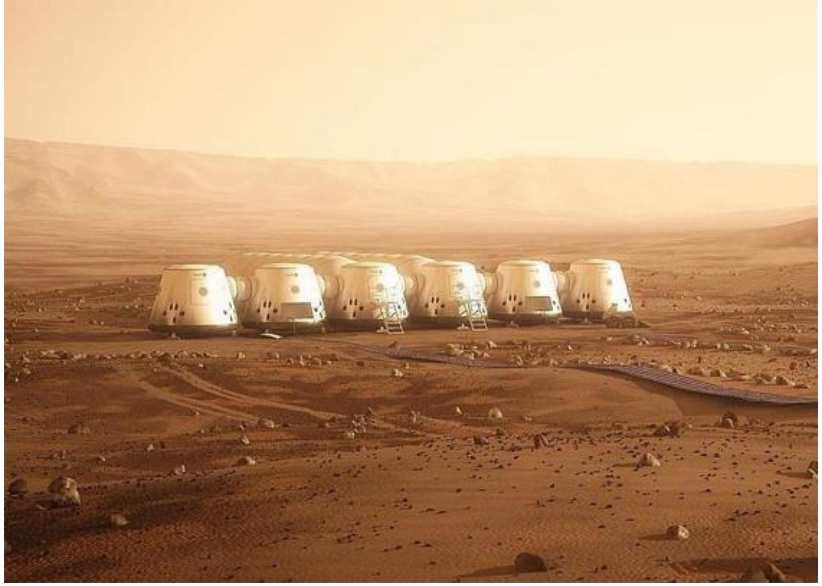
AM for New Exploration Mission Approach

ISRU improved - Lunar base concept



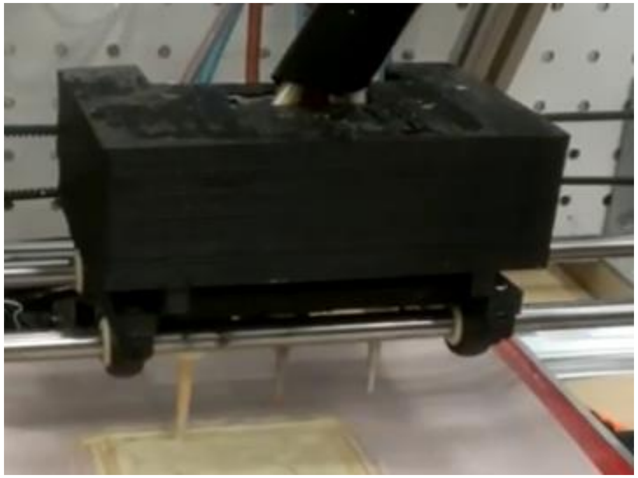
On demand production of spare parts and tools in limited resources environment, remotely designed

AM for New Exploration Mission Approach



Printing using in-situ resources and power optimization for Moon, Mars and beyond

Printing of Living Cells, Organs and blood

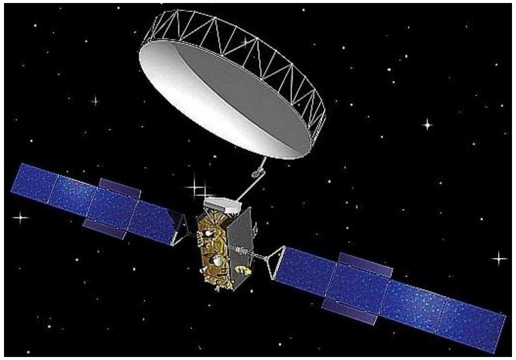


Printing of Food

European Strategic Effort on Additive Manufacturing for Space

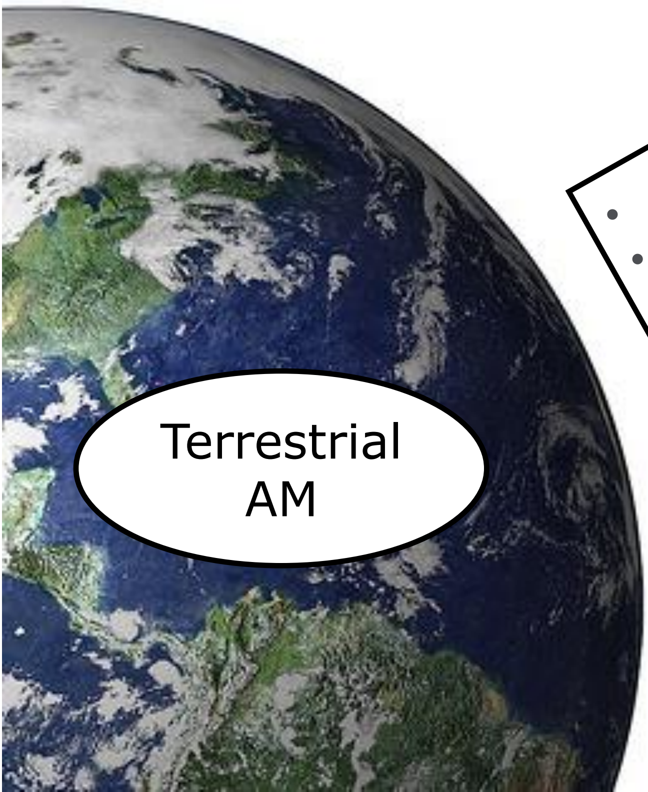
Challenges open:

- Massive effort coordinated by ESA
- Addressing all open challenges in a synthetic and coordinated manner without distracting resources
- **Final goal: safe and reliable use of 3D printing for space**



Aim A: Space Product

- Aim B: Design
- Aim C: Material supply
- Aim D: Processing
- Aim E: Post processing
- Aim F: Qualification
- Aim G: Standardisation



End-to-end AM process

Back to Earth

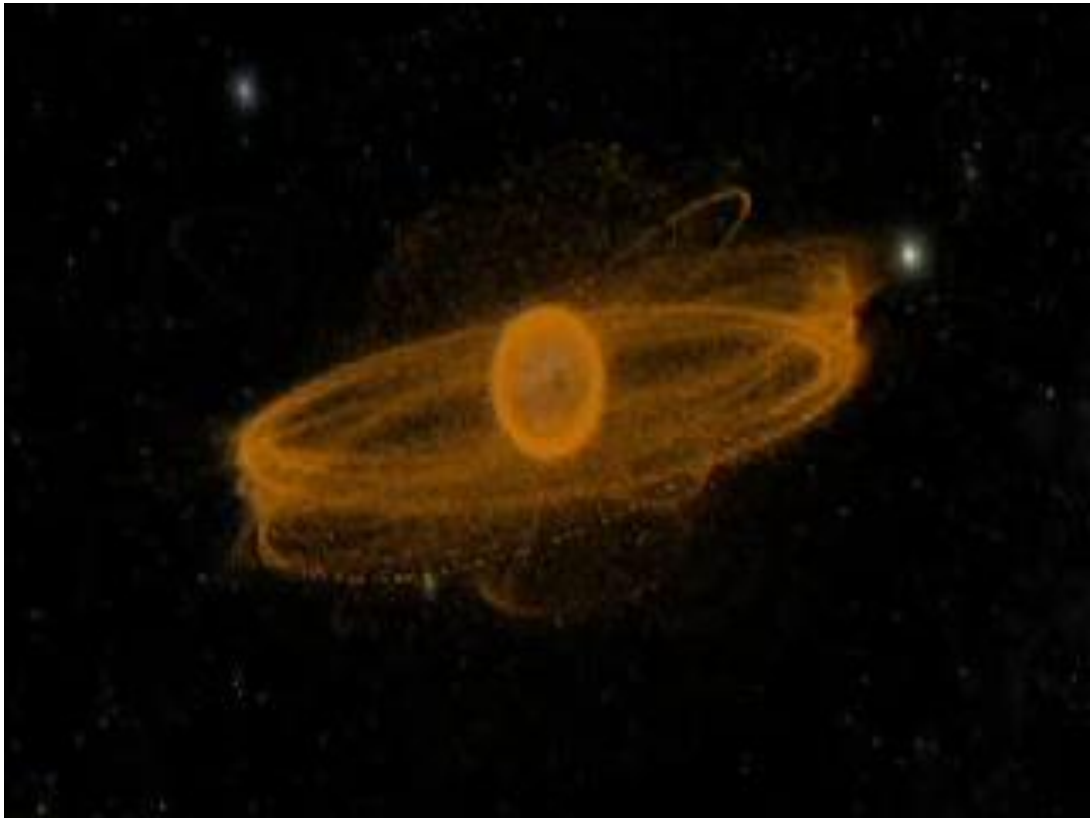
- Customized, affordable prosthesis, available also in remote areas
- 3D printing for the rapid construction of post-disaster emergency shelters (using local resources and even waste)
- Disrupting the supply chain, having broken parts scanned and printed on-demand and in-situ (also in remote and inaccessible areas with poor supply chain)
- 3D printing of high performances/highly compatible and integrating scaffolds and prosthesis
- 3D printing of on-demand surgical tools in remote areas

Summary and Next steps – Additive Manufacturing

- Additive Manufacturing is considered a potential **game changer** and **enabling technology for current and future space missions**
- **Additive Manufacturing lowers the threshold for space access** to Small/Medium Enterprises and opens access to high-end technology also to developing countries
- ESA has proposed a strategic roadmap in order to address and solve the presented challenges with a **harmonized approach**, **avoiding distracting European resources and efforts** and avoiding the **"mushrooming effect"**
- **On Earth (and for Earth based applications),** Additive Manufacturing can enable:
  - **Supply chain disruption** (multiple manufacturing plants/steps reduced to one)
  - Manufacturing **on-demand and in-situ on limited resources environment** (also for catastrophes recovery)
  - **Competences building in developing countries**
  - **Education**
  - **Optimization of the environmental footprint** (minimizing energy consumption and material waste/ maximizing recyclability)

Future Challenges: Space Debris

- Large number of Cubesats/Spacecraft is expected to be launched in the coming years
- It is unclear if the in-orbit traffic model leading to the 25 years rule for space sustainability is still valid
- ESA is preparing guidelines and practices handbook in order to increase safety and mission success rate




Thank you for your attention!