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
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

=> 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 5th of May, 2015:

- 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
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 already 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

European Space Agency
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
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!