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Quality and safety, a challenge for traditional and new space (1)

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HE NEED FOR PROCESS MONITORING IN IN-SPACE MANUFACTURING

Abstract

Proposed scenarios of manned missions to the Moon and Mars rely on automated processes that prepare the environment prior to the humans' arrival, either by harnessing and transforming local resources (e.g. producing fuel and oxygen) or by building habitats and infrastructures. Additional to the in-situ resource utilization, long-duration space missions require astronauts to have the ability to build structures and create tools and spacecraft components away from the surface of the Earth.

The status of in-space manufacturing has evolved from the first welding experiments upon Soyuz 6 in 1969, to the installation of the first 3D printer on the International Space Station (ISS) in 2014. Its descendant "Additive Manufacturing Facility" installed on ISS in 2016 has printed in-orbit more than 200 objects to date.

However, the flexibility to create critical components and spare parts on-demand raises another need. When aerospace components are manufactured on Earth, they undergo thorough examination and non-destructive testing to ensure their properties are within acceptable safety standards. These methods of quality assurance may not be an option when the components are printed in-orbit or on the surface of another celestial body, due to the lack of either human presence or specialized testing equipment. Therefore automatic process monitoring evaluation tools and analysis techniques are required, ensuring the manufacturing conditions and additional factors that contribute to the product's quality were maintained within acceptable limits throughout the production process.

In this paper the *status quo* of additive manufacturing process monitoring is assessed, highlighting the challenges that system developers have to face in order to achieve sufficient monitoring level and quality control on automated manufacturing processes in space. Various monitoring methods are presented in different manufacturing processes according to the materials used. Recent developments and applications of in-process metrology utilizing the Industrial Internet of Things (IIoT) in Industry 4.0 can pave the way to non-destructive evaluation in in-space manufacturing.