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IN-SPACE MANUFACTURING: FACTS AND MYTHS

Abstract

In-space manufacturing (ISM) requires rethinking established practices, blending known facts with myths to challenge the status quo.

The paper acknowledges the complex path to manufacturing excellence in space, comparing it to the gradual optimizations seen in terrestrial industries over decades. An immediate achievement of success in ISM is deemed unrealistic due to space's distinctive challenges. Thus, a meticulous and deliberate approach is essential, underpinned by a complex value chain that accommodates specialized roles and a commitment to recalibration and rigorous verification. It also advocates for a shift from vertical integration to a diversified and collaborative model, emphasizing specialization to challenge the myth of single-company dominance.

The misconception that miniaturizing earthbound manufacturing processes for microgravity use leads to automatic product enhancement is addressed. Real progress lies in redesigning these processes and products specifically for microgravity, signaling a departure from conventional models like SpaceX's. The key to ISM's success lies in the unique performance and innovation of the products created, not merely the engineering of the manufacturing units.

Standardization within ISM is emphasized as critical, ensuring products meet clear, consistent benchmarks. For example, recalibration and evaluation of ZBLAN fiber optics must follow standardized protocols to ensure accuracy and reliability. Biotech requires careful implementation of terrestrial standard like payloads and procedures.

A major obstacle in ISM is the prohibitive cost and logistical complexity of conducting iterative trials in space. The introduction of AI/ML-driven process control is proposed as a solution, facilitating process optimization before flight and reducing reliance on expensive, iterative experimentation. This enables the development of predictive models for scenario analysis and optimization in a virtual environment, significantly advancing the field. A profound understanding of microgravity science is portrayed as essential for driving innovation in space manufacturing. Entering ISM without this knowledge is cautioned against. The integration of AI/ML in process control heralds a future where ISM is not just feasible but also efficiently sustainable. The influx of investment into Low Earth Orbit (LEO) infrastructure and commercial space stations underscores the potential of ISM. However, the absence of adequate government funding and minimal investment in creating demand for unique, microgravity-derived products presents a challenge. Closing the business case for these ventures relies on generating revenue, with ISM emerging as the most viable option. Yet, the current financial backing for stimulating marketable space-manufactured goods remains insufficient, indicating a significant gap between potential profitability and the support needed for market-ready, space-made products.