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Additive manufacturing — Qualification principles — Framework for categorizing resources and process capabilities

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Foreword

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Introduction

The introduction of additive manufacturing (AM) in the production of parts to support temporary self-sufficient systems (e.g. oil rigs, ships, forward operating bases) has opened new possibilities. However, the limited resources (e.g. space, equipment, utilities, personnel and training) within these systems pose challenges for the implementation of AM. Due to these limitations, it is not realistic to have the AM equipment, and staff to respond to all possible needs at the same AM service site at every self-sufficient system. Rather, it is necessary to optimise the set-up of the AM service site in order to correspond to the most frequent and critical needs of each self-sufficient system. However, this optimisation will mean that there could be situations when the local AM service site cannot respond to the actual need at the time of need. Still, it would be possible for capabilities of different self-sufficient systems to complement each other, thus forming a framework enabling higher levels of combined self-sufficiency, operational readiness and resilience. To enable such a framework to work efficiently it is necessary to specify and categorize the available resources and process capabilities of each AM service site, thus providing a clear structure for coordination of capabilities. This document establishes a system for categorization of AM resources and processes capabilities thus providing clarity and consistency for planning and logistical support of self-sufficient systems.

In addition to the requirements for AM in self-sufficient systems, this standard also facilitates support between different frameworks. For example: ships equipped with Level 2 AM capabilities can support those with Level 1 AM, or ships with no AM capabilities, or even from different shipping companies, and from different nationalities.

By implementing this standardized framework, collaboration and assistance between different systems become easier, enabling the exchange of resources, expertise, and part production.

This normative approach addresses the allocation problem, where to put AM capabilities depending on the available resources on site, not by focusing on quality or cost minimization, but rather by prioritizing availability, speed, and the reduction of time back online and mean time to repair. The framework can be resilience-optimized to meet the unique needs of isolated operating systems and to support them remotely with optimized logistics. The AM integration process is dynamic, evolving through iterative phases of analysis, structuring, and implementation. This ensures that the AM framework becomes increasingly adaptable over time, supporting the broader adoption and effective utilization of AM technologies in challenging environments.

In addition to its primary function of enabling AM in self-sufficient systems, the standardized framework brings forth a multitude of advantages, prominently among them being the enhancement of supply chain resilience. These benefits extend to both civilian and military domains, underlining the framework's significance.

In summary, the standardized framework not only facilitates AM but also fosters a cohesive AM ecosystem. It does so by promoting interoperability, collaboration, and efficiency across diverse self-sufficient systems, thereby contributing significantly to overall supply chain resilience, particularly in times of uncertainty or crisis.

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Additive manufacturing — Qualification principles — Framework for categorizing resources and process capabilities

1 Scope

This document specifies a standardized level framework for the implementation of additive manufacturing to support temporary self-sufficient systems. It defines principles and criteria, from a resource perspective (personnel, training, infrastructure, materials, etc.) and provides guidance for categorizing additive manufacturing processes into different levels to support self-sufficient systems (ships, small islands, oil rigs, etc.). Support can be established through onboard and onshore operation. This covers the complete part cycle from design (if applicable), manufacturing, to a finished part that meets requirements.

It aims to provide clarity and consistency for non-AM experts dealing with logistical support of self-sufficient systems.

This document is applicable to industries, military institutions, research institutions, and regulatory bodies involved in additive manufacturing, facilitating interoperability and harmonization of practices across different stakeholders.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/ASTM 52900, *Additive manufacturing — General principles — Fundamentals and vocabulary*

ISO/ASTM 52901, *Additive manufacturing — General principles — Requirements for purchased AM parts*

ISO/ASTM 52904, *Additive manufacturing of metals — Process characteristics and performance — Metal powder bed fusion process to meet critical applications*

ISO/ASTM 52920, *Additive manufacturing — Qualification principles — Requirements for industrial additive manufacturing processes and production sites*

ISO/ASTM 52926 (all parts), *Additive manufacturing of metals — Qualification principles*

ISO/ASTM/TS 52930, *Additive manufacturing — Qualification principles — Installation, operation and performance (IQ/OQ/PQ) of PBF-LB equipment*

ISO/ASTM 52935, *Additive manufacturing of metals — Qualification principles — Qualification of coordination personnel*

ISO/ASTM 52942, *Additive manufacturing — Qualification principles — Qualifying machine operators of laser metal powder bed fusion machines and equipment used in aerospace applications*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/ASTM 52900, as well as the following apply.

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ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
temporarily self-sufficient system
system capable of independent operation for defined periods, meeting its own needs and tasks without external support

Note 1 to entry: Additive machines and supporting equipment implemented in this type of system are expected to be capable of performing a build cycle in the working environment of the system, such as while in motion on a ship, while in orbit on a space station, and therefore must be secured to resist environmental influence such as swell, movements and others as required in Table 1.

Note 2 to entry: Examples are a ship, an oil rig, small island, international space station, a mobile spare parts manufacturing unit, etc.

3.2
additive manufacturing level framework
additive manufacturing level framework
structured approach and set of principles that guide the implementation and operation of additive manufacturing within an organization

4 Principle

The AM level framework for the implementation for systems and personnel operating in temporarily self-sufficient systems categorizes AM capabilities into four progressive levels.

Level *n*+1 shall be able to replicate or encompass the capabilities and processes available at level *n*.

— **Level 1 additive manufacturing - Basic prototyping:** AM equipment is suitable for basic operations, prototyping and non-critical parts. Operators shall have sufficient training for the available AM equipment. Minimal auxiliary equipment is sufficient for fulfilling the needs for small-scale AM machines.

— **Level 2 additive manufacturing – Intermediate production:** Industrial-grade AM systems are suitable for creating functional prototypes and moderately complex parts. Operators shall receive training, corresponding to the requirements for executing the processes and handling the equipment.

NOTE This can include post-processing operations and part finalization.

Requirements for level 2 shall include the requirements for level 1.

— **Level 3 additive manufacturing – Advanced AM capabilities:** AM facilities with a high specialization, capable of producing complex and functional parts that meet higher durability and precision standards. The facility shall fulfil the requirements for industrial additive manufacturing processes and sites as specified in ISO/ASTM 52920. Operators shall have training for the available equipment, corresponding to, or equivalent to qualification requirements in ISO/ASTM 52926 standard series. Corresponding qualifications are required for all available post processing and auxiliary equipment.

Requirements for level 3 shall include the requirements for level 2.

— **Level 4 additive manufacturing – Certified manufacturing:** Certified manufacturing facilities with a focus on producing parts that meet stringent standards for critical and regulated applications. The facility shall be certified to fulfil the requirements for industrial additive manufacturing processes and sites as specified in ISO/ASTM 52920. The site shall have quality assurance capabilities for the available processes. Operators shall be certified for the available equipment, corresponding to, or equivalent to qualification requirements in ISO/ASTM 52926 standard series. Corresponding qualification and certification is required for available post processing, quality assurance and auxiliary equipment.

Requirements for level 4 shall include the requirements for level 3.

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