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DESIGN AND QUALIFICATION METHODS FOR ADDITIVE MANUFACTURING IN SPACE APPLICATIONS

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GLOBAL LAUNCH COMPETITION

Awarded Global Commercial Launch by Market Share

Diagram from Tim Hughes, July 2017 (Space Exploration Technologies Corp.)
NEXT GENERATION ROCKET ENGINE

VULCAIN 2.1: LH2-LOX

PROMETHEUS: LOX-METHANE

Picture from CNES (French Space Agency)
ADDITIVE MANUFACTURING

3D CAD model → Slicing → Layer-wise assembly → Complete part

Powder Bed Fusion

Pictures from ESA, Trumpf, EOS
AM IN SPACE APPLICATIONS

Reduced lead time for product development

Reduced lead time for production

Suitable for low volume manufacturing

WHY?

Reduced cost:
• Fewer parts
• Fewer manufacturing processes
• Faster manufacturing

Increased design freedom and optimisation for:
• Weight
• Performance
• Producibility

"AM is a perfect fit"
WHERE IS AM TODAY?

Secondary structures: in flight

Primary structures: in test

Pictures from Thales Alenia Space and NASA
PROJECT SCOPE

- **Purpose**
  - Focus on design and qualification methods for AM in space applications

- **Objectives**
  - Develop the product development process to facilitate the use of AM capabilities
  - Define qualification strategies for AM in space applications
  - Identify prerequisites and limitations with AM technologies
  - Reach Licentiate
RESEARCH APPROACH

Study I

- Literature
- Study tour
- 11 study visits

Study II

- Company A
- 8 semi structured interviews
- Company documents

Study III

- Company A
- Company B
- Company C
- 3 workshops

Study IV

- Company A
- 15 semi structured interviews
- Company documents
QUALIFICATION CHALLENGES

- Inspection methods
- Testing
- Post-process treatment
- Mechanical properties
- Manufacturing process
- Standards
- Material supply
- Process modelling
- DfAM
- ?

Qualification of Additive Manufacturing
Lack of understanding for AM processes today
- Simulation of AM process is still rudimentary
- Difficult to know how to analyse AM materials
- Non-Destructive Testing (NDT) methods are not standardised

→ Testing is necessary
→ Test artefacts have to be part-representative

Pictures from Neikter et al. (2017), Seifi et al. (2016), Lockheed Martin, EOS/RUAG
**DESIGN FOR AM**

- AM is an ‘end-to-end manufacturing process’
  - Material supply, early design, manufacturing, post-processing, qualification are linked

- DfAM in the ‘strict sense’ – How to design a part utilising AM potentials (e.g. guidelines)

- DfAM in the ’broad sense’ – Considerations for manufacturability, process suitability etc.

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*Kumke et al. (2016). A new methodological framework for design for additive manufacturing. Virtual and Physical Prototyping, 11(1).*
PROCESS MODEL FOR DFAM
PROCESS MODEL FOR DFAM

- Build AM process experience
- Explore the design freedom
- Understand part criticality

Enabler for innovation!
CONCLUSIONS

- Given the maturity of AM processes, learning by doing is inevitable and companies have to invest in process development and process understanding to fully utilise AM.

- The "rapid manufacturing" is an enabler to build this understanding through concurrent process and part development.

- Design for AM is an integral part of using AM in product development, also for qualification. Challenges are:
  - Finding the right part design for the chosen AM process
  - Define the right level of requirements for the part

- System knowledge should be utilised in the development of space parts for AM, and in setting the right requirements for parts and their qualification.

Picture from 3D Systems
OBJECTIVES REVISITED

- Develop the product development process to facilitate the use of AM capabilities
  - The proposed DfAM process model builds on findings from studying product development and qualification in the space industry. The model is currently being further developed in collaboration with industry in the RIQAM project (also NRFP3).

- Define qualification strategies for AM in space applications
  - Qualification strategies for AM are presented and discussed in the academic publications. In general, a deeper understanding of the process-part relationship and other qualification drivers are needed in order to qualify critical space components.

- Identify prerequisites and limitations with AM technologies
  - A literature review of AM Powder Bed Fusion processes is presented and discussed in the academic publications. Specifically, challenges for AM in space applications are emphasised.
  - Master thesis at GKN: A Cost Breakdown and Production Uncertainty Analysis of Additive Manufacturing


Thank you for listening!

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