Swedish Roadmap for Industrialization of Metal Additive Manufacturing

2016-03898 – Roadmap for research and innovation to industrialize additive manufacturing of metals in Sweden

Version 1.0

Med stöd från:
VINNOVA
Energimyndigheten
FORMAS
STRATEGISKA INNOVATIONS-PROGRAM

Background

Additive Manufacturing (AM) will be a game changer for Swedish industry. AM is a technology that is important to address due to its great potential to change the industrial transition to digital and smart industry [1,2]. It also contributes to find innovative solutions for the three horizontal societal challenges digitalization, life sciences and environmental and climate technology, identified by the National Innovation Council. AM is considered a "green technology" compared to most conventional manufacturing technologies, both because of waste reduction and energy consumption. Other important resource efficiency features of AM are enabling of remanufacturing and repair of parts. Furthermore, AM gives us a way to speed up the development of new, better materials and to manufacture materials which are currently difficult or impossible to manufacture. This will have a positive impact on the sustainability of products.

A roadmap for research and innovation to industrialize AM of metals in Sweden has been created and it was funded by Vinnova and SIP Metallic Materials [Project 2016-03898]. The project is performed in close collaboration with the "Swedish Arena for Additive Manufacturing of Metals" and two open workshops with around 60 participants have been arranged to get input from all stakeholders. The result is published in two open reports [3, 4].

Montfort Strata, has a textured stainless steel dial inspired by the Swiss alps made by binder jetting by Digital Metal. Picture courtesy of Montfort Watches (www.montfortwatches.com).

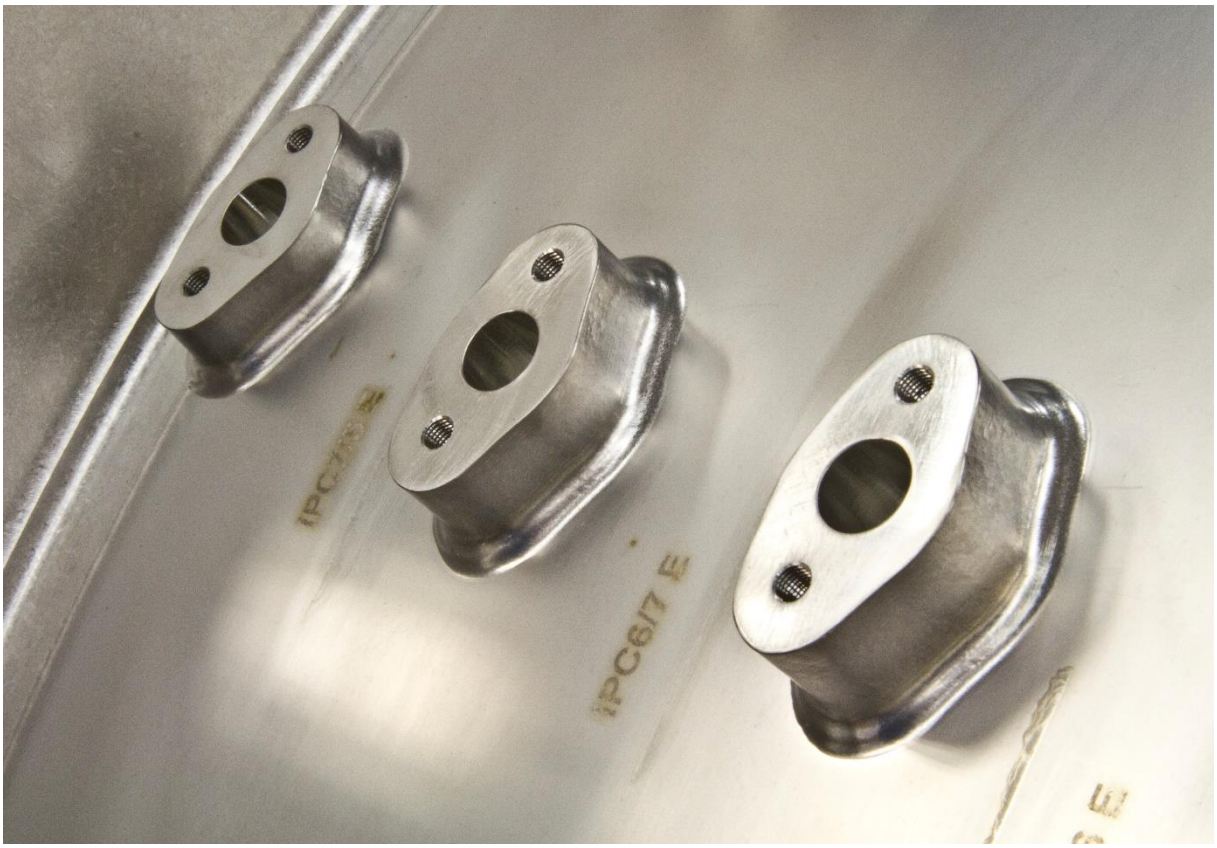
Areas of excellence

When speeding up the industrialization of metal AM in Sweden it is important to build on the existing strengths. Areas of excellence include:

- Materials and metal powder
- Manufacturing of high-end products
- Digitalization and automation
- Software and design
- EHS

Not less important are the mindset in Sweden in relation to:

- Early adopters of new technology
- Innovative thinking
- Strong cooperation industry-institute-university



Compressor borescope bosses in Titanium, deposited by Laser Metal Deposition with wire. Picture courtesy of GKN Aerospace Engine Systems.

State of the art

Today, metal AM production is running at Siemens Industrial Turbomachinery and GKN Aerospace. Sandvik Machining Solution has an AM-center for metals that is scaling up for production. Companies in the Wallenberg group are starting a joint AM-center in Karlskoga. Other industries have single machines or are outsourcing manufacturing of AM-parts. The Swedish metal component manufacturers are Lasertech, AIM Sweden and 3DMetPrint.

Within the first part of the value chain, the powder producers Höganäs, Carpenter Powder Products, Sandvik, Erasteel and Uddeholm act. Arcam and Digital Metals offer AM-equipment and Quintus Technologies offer hot isostatic presses (HIP) for post treatment.

On the software side, Thermo-calc Software offers AM solutions for alloy design.

Small companies within the Area are Exmet developing amorphous metals, VBN Components offering AM in special tool steel materials, Metasphere Technologies with a new powder process (owned by Höganäs) and Freemelt developing AM-equipment for research.

On the research side, many universities and institutes are building up research groups based on their existing competences. Printers have been installed at many universities in Sweden and at Swerea. Since summer 2017, Chalmers is hosting a competence center, CAM2, funded by Vinnova involving five research organizations and 27 companies. National research funding has increased considerably the last years and only Vinnova funds 130 MSEK in ongoing or just ended metal AM related projects.

Knee implant in Cobalt Chrome (F75) made by EBM. Picture courtesy of Arcam AB.

Koeningsegg Automotive AB, producer of exclusive supercars, uses tailored wind screen coil nozzles with the company´s logotype integrated in the design. The coil nozzle is made in stainless steel by binder jetting by Digital Metal. Picture courtesy of Digital Metal.

Vision – 5 and 20 years

For the next 5 years the overall vision is that a great number of small, medium and large sized companies have evaluated AM and thereby been able to set the direction for how to best utilize AM for strengthening their competitiveness, both nationally as well as internationally. To achieve the short term overall vision, a considerably wider industrialization of AM is needed. Sweden has long track record in a number of industries, such as material manufacturing, aerospace, automotive, energy, tooling, process and engineering, which all will benefit in different ways. Knowledge of AM and design processes for AM are important along the whole value chain in order to utilize the full potential of AM in product development.

For the next 20 years the vision is that Sweden, by a fast and resource effective industrialization, has taken a pole position in key competence as well as a prime provider in a number of areas and applications. This vision was developed for metal AM, but is most likely valid also for other material groups.

Challenges and needs

AM of metals is a new technology under rapid development and many challenges and needs still exist. Here follows a description of the main challenges and why they are important for Swedish industry and industrialization of metal AM.

Material

Limited number of materials is available on the market, not satisfying increasing needs of the growing end-user market. Taking into account strong position of the Swedish industry and academia in the powder field, material development is identified as one of the key research areas.

Part and system design

Challenges for AM of metal parts are to use the advantage of design freedom that is not possible for castings or machined parts. It is also important to take the anisotropy of the material into account and to design for AM already from the start by using proper design rules.

Process stability and product quality

For industrial AM, process stability and product quality are crucial and are today the major obstacles for industrialization. Better control of process robustness and reproducibility, as well as enhanced predictability of the process and the material will ensure first-time-right.

Production

Development of AM technologies has historically been in the context of prototyping, resulting in machine designs and processing methods suitable mainly for solo operations. This pose several constraints in production like limited size of builds, processing speeds, lack of continuous process and information flow, and automation in powder, part handling and post processing.

Environment, health and safety

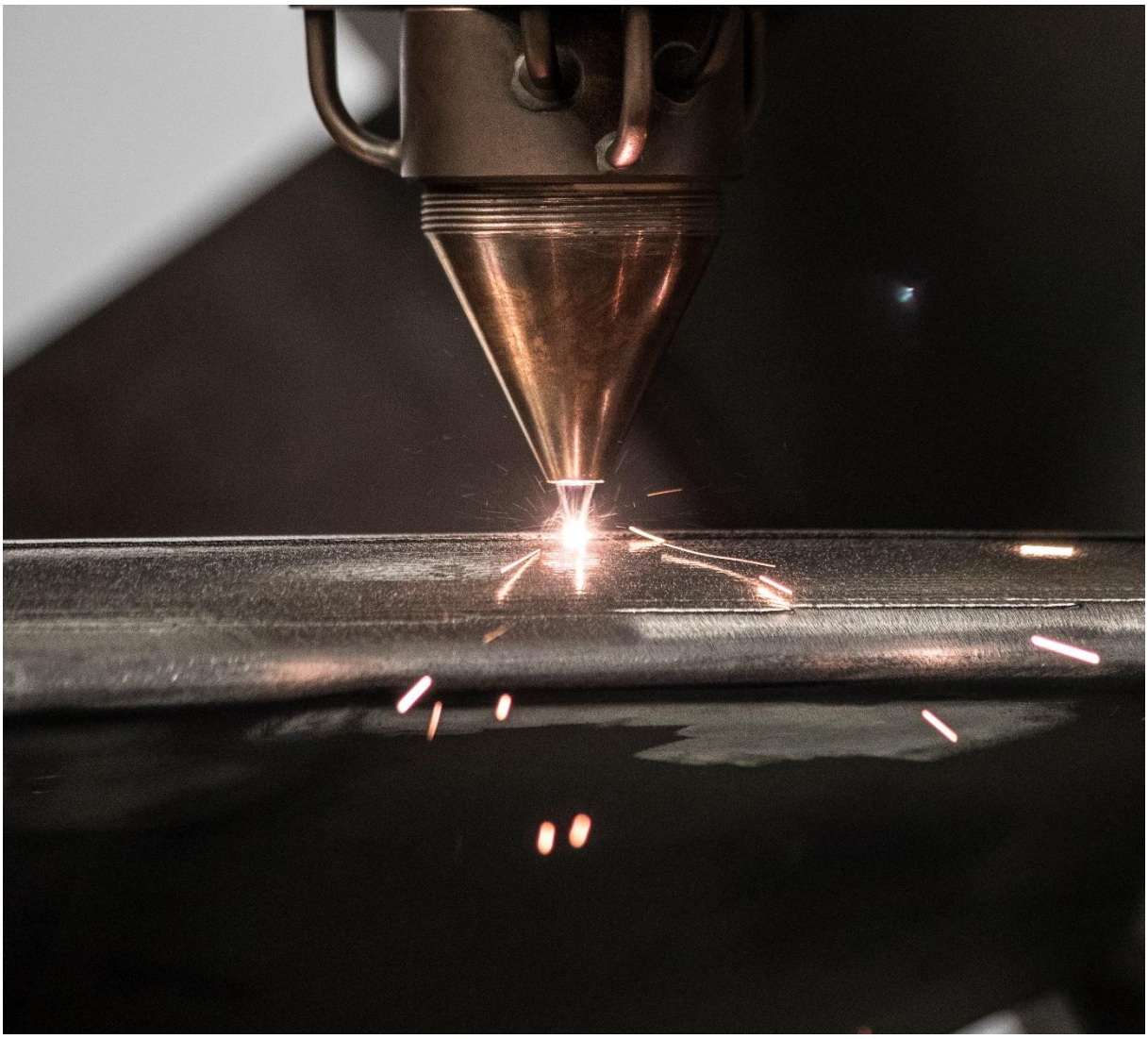
To address environmental, health and safety aspects along the complete value chain is important for sustainability. This could for example be to ensure a safe working environment and proper handling of metal powder, but also to minimize and recycle waste products.

Standards and certification

Standardisation and certification are necessary for the evolution and industrial usage of AM, but are in the early stages. The local Swedish group SIS/TK 563 is active within the international standardisation work and follows standardisation roadmaps for AM. It is important for Sweden to give input on industrial needs for standards and certificates to the existing groups. It could also be a task for Sweden to develop certain standards, within our areas of excellence.

Knowledge and education

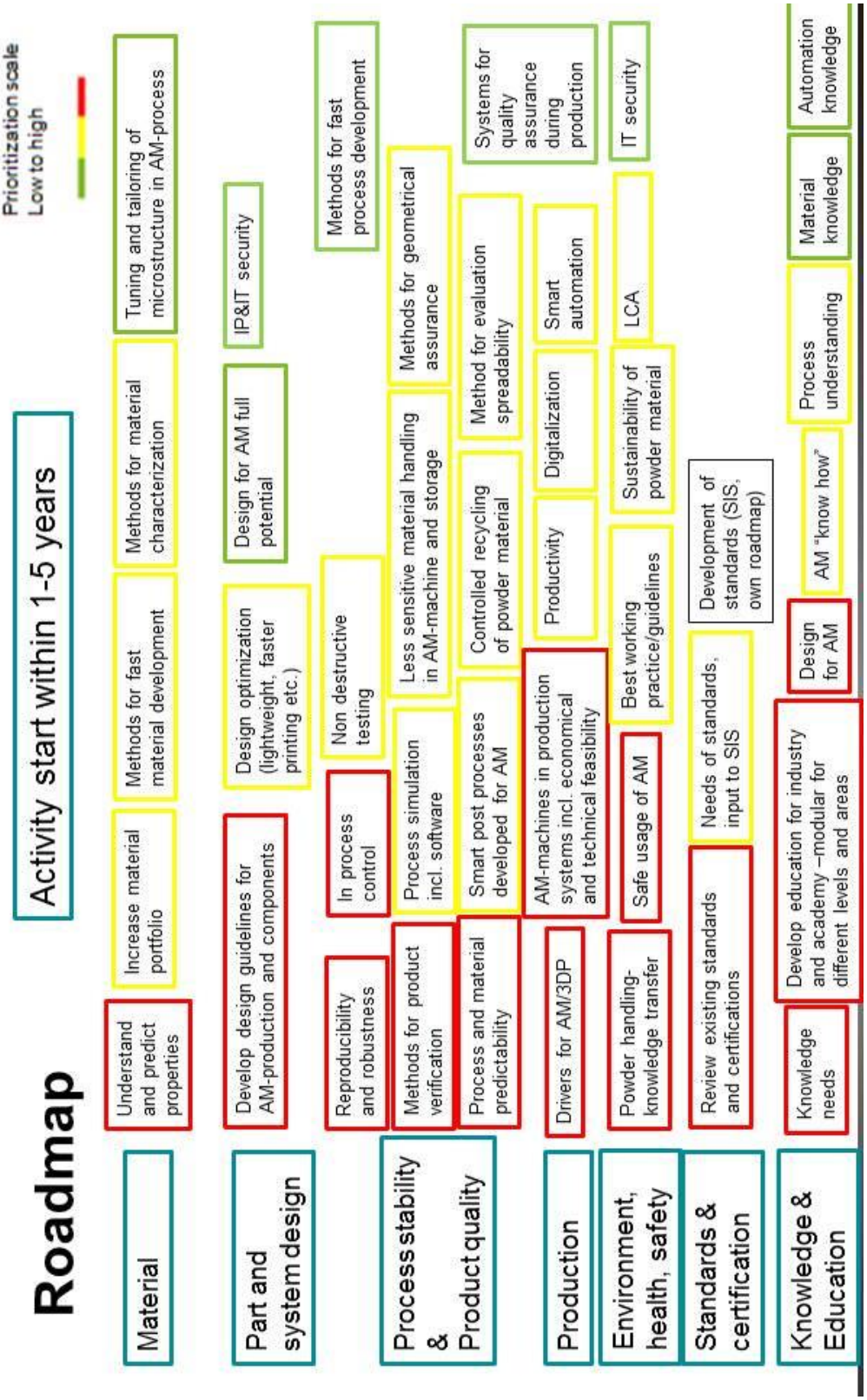
Knowledge and education will be needed on all levels in order to accelerate the industrial implementation of AM. The foremost priority is in fulfilling the multi-dimensional knowledge needs of the industrial stakeholders, but also to strengthen the research groups in Sweden to ensure sustained competence development.

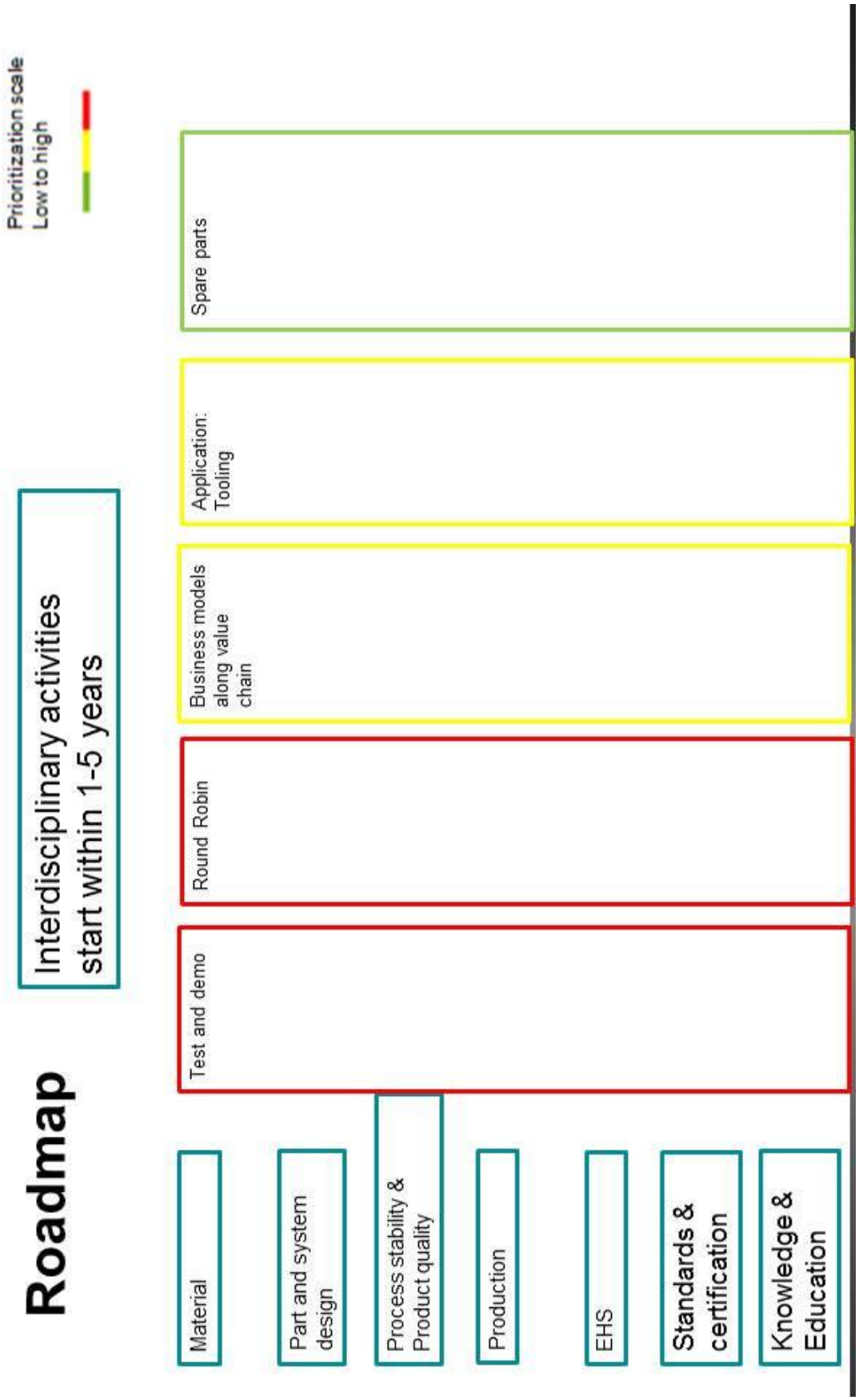


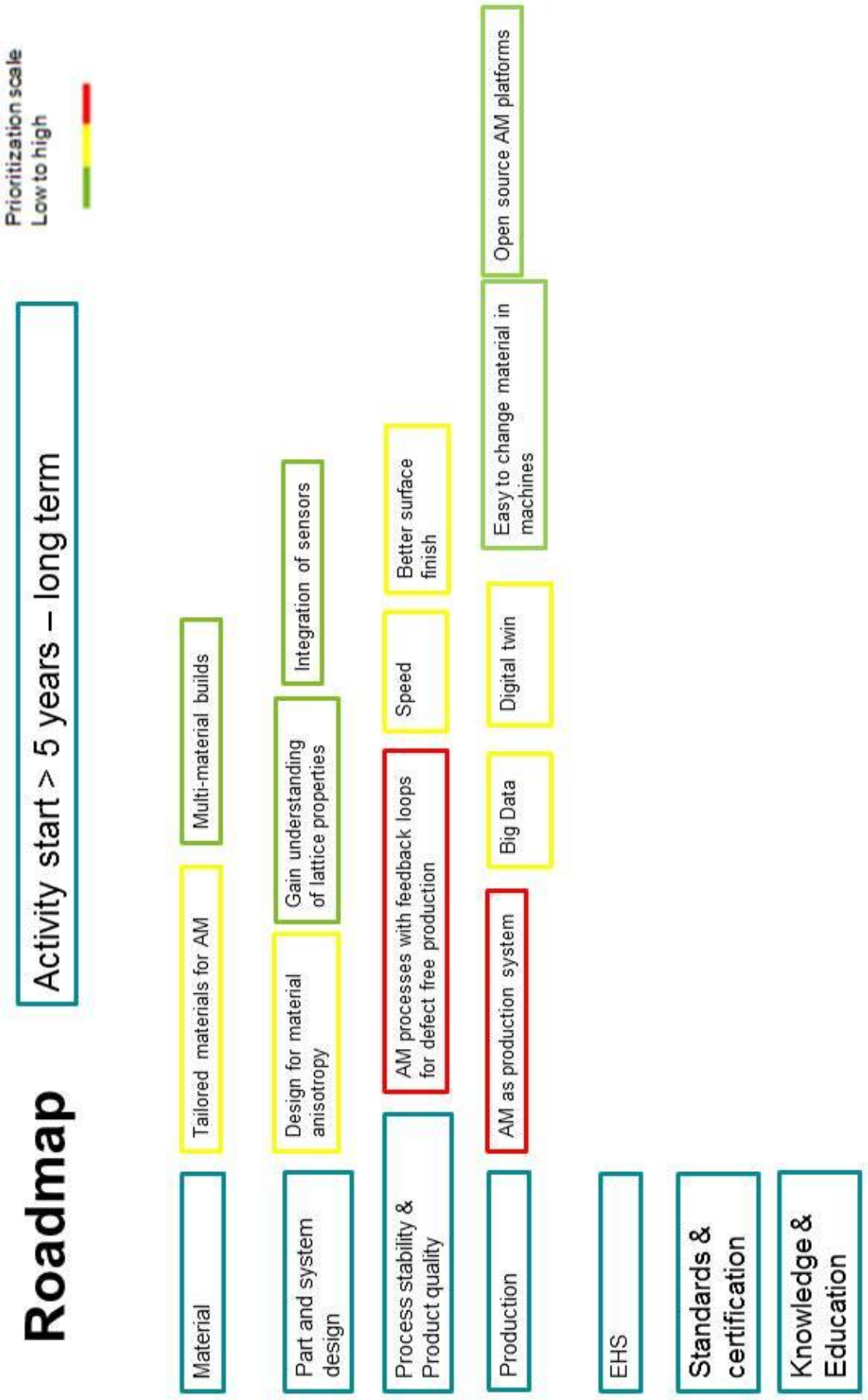
Laser Blown powder process in action. A superalloy deposited on a jet engine component. Picture courtesy of GKN Aerospace Engine Systems.

Roadmap – visual draft

Visual representation of the needs in a general time scale. The magnitude of priority is also indicated in the visual roadmap. The first two pictures on the following pages are for activities starting from 1-5 years and the third picture is for activities starting after 5 years or later.




Roadmap
Interdisciplinary activities start within 1-5 years
Prioritization scale
Low to high
Material
Part and system design
Process stability & Product quality
Production
EHS
Standards & certification
Knowledge & Education
Test and demo
Round Robin
Business models along value chain
Application: Tooling
Spare parts



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Most urgent research topics

From the input that has been provided by the industry, from activities ongoing in similar industry segments, as well as from the current state of the art from the AM industry, the following areas are proposed to be prioritized in the near future.

- Robustness in process and production including automation and in-process control
- Materials for AM
- Design for AM including research level education
- Future AM
- Economic feasibility of AM
- Productivity

A box in Titanium, deposited by Laser Metal Deposition with wire. Picture courtesy of GKN Aerospace Engine Systems

References

[1] *"The strategy for Smart industry - a strategy for new industrialization for Sweden",* The Swedish Ministry of Enterprise and Innovation, 2015, Report no: N2015.38.
[2] "*Digitalisering av svensk industri",* Vinnova, ISBN 978-91-983100-0-9
[3] RAMP-UP Report I, State-of-the-art for Additive Manufacturing of Metals, 22nd of June 2017
[4] RAMP-UP Report II, Research Needs and Challenges for Swedish Industrial Use of Additive Manufacturing, 6th of October 2017

The RAMP-UP reports can be downloaded from SIP Metallic Materials (www.metalliskamaterial.se) or the Swedish Arena for Additive Manufacturing of Metals (www.AM-Arena.se).

Acknowledgement

This project was funded by Vinnova and is a special project within SIP Metallic Materials. This is a collaborative work from all the project partners and the group is thankful for all help and support from other stakeholders around Sweden, the Swedish Arena for Additive Manufacturing of Metals and from our network around the globe. More than 50 persons participated actively in a workshop on the 12th of September 2017, when the roadmap was discussed. The project group consists of the following research organizations and companies:

Swerea KIMAB
Swerea IVF
Swerea SWECAST
Chalmers
Högskolan Väst
KTH

Arcam AB
Carpenter Powder Products AB
Construction Tools PV AB
GKN Aerospace AB
Höganäs AB
Quintus Technologies AB
Saab AB
AB Sandvik Machining Solutions
Scania CV AB
Siemens Industrial Turbomachinery AB
Uddeholm AB

METALLISKA MATERIAL

GJUTERI FÖRENINGEN
Swedish Foundry Association

Jernkontoret

Svenskt Aluminium

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