Additive Manufacturing – Decision Support System (AM-DSS)

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Duration: June 2014 – June 2017

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Aim of the Meeting

- To Introduce the PhD
- To present the AM-DSS
- To gather feedback on the AM-DSS
- To perform case studies to verify and validate the AM-DSS

Phalanx CWIS 2016-2021.
Service category No 1: Maintenance and repair services

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Introducing the PhD

**PhD Title:** “Modelling Applications of Additive Manufacturing in Defence Support Services”

**PhD Aim:** “To develop a Framework to assess the Cost and Benefits of Additive Manufacturing applications in Defence Support Services”

**Research Theme:** Systems Engineering

**Research Type:** Exploratory applied research

**Research Stakeholders:**

**PhD’s Contribution to Knowledge:** AM Mathematical Models, DS2 System of Interest, Conceptual Framework

**PhD’s Output:** Additive Manufacturing – Decision Support System (AM-DSS) Software tool

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Wire+Arc Additive Manufacturing (WAAM)

- WAAM hardware currently uses standard, off the shelf welding equipment: welding power source, torches and wire feeding systems
- Combination of an electric arc as heat source and wire as feedstock
- MIG, TIG, Plasma

<table>
<thead>
<tr>
<th>Key Performance Indicators (KPIs)</th>
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<tbody>
<tr>
<td>Metals</td>
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<tr>
<td>Wire Based</td>
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<tr>
<td>Deposition Rate</td>
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<td>Maximum size</td>
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<tr>
<td>Accuracy</td>
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<tr>
<td>Equipment Cost</td>
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<td>Material Cost</td>
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Wire+Arc Additive Manufacturing

Adapted from: Colegrove (2013)

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Applications of AM in Defence Support Service

AM may be applied in various location of the DS2, moreover different AM technologies have different cost structure.

\[
A_o = \frac{O_t + S_t}{O_t + S_t + PM_t + CM_t + AD_t + PD_t + LD_t}
\]

\[
A_o = \frac{O_t + S_t}{O_t + S_t + PM_t + CM_t + CT_t}
\]

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The logic behind the Assessment

1. Develop a Conceptual Framework for AM applications in DS2
2. Define a standard structure of a DS2: System of Interest and System Configurations
3. Identify the Key Performance Indicators of a DS2: Availability, Service Cost, Travel Times, Up Time, Down Time
4. Identify where AM can be applied in a DS2
5. Develop Mathematical Models to estimate Time, Cost and Benefits
Introducing the AM-DSS (1)

- It’s a **Software Tool** engineered for Research & Development (R&D) departments
- Tailored to early stages “technology/capability acquisition” programs
- Performs **simulations** and **estimations** on **TIME** and **COST**
- **Static** and **Deterministic**

The AM-DSS has been developed to evaluate the acquisition of:

“the capability to **additively manufacture** critical-to-availability **components next/close to the point of use**, only when they are required, to **maximise Operational Availability** of Complex Engineering Systems and reduce the time and cost of the support service”

AM-Decision Support System
Introducing the AM-DSS (2)

1. Mathematical representations of Additive Manufacturing technologies. These are able to estimate the TIME and COST.


3. An Analytical Tool which defines the logical sequence to perform an exhaustive assessment of AM applications in DS2.

Contribution to Knowledge

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AM Mathematical Models

\[ R_m = \frac{\text{InvCost}}{T_u + R_u} / (1 - O_v) \]  

(1)

\[ R_s = \frac{\text{InvCost}}{T_u + R_u} \]  

(2)

\[ R_{sa} = \frac{G_s + C}{A_{hr}} \times O_v \]  

(3)

\[ Bid_c = R_{sa} \times Bid_{time} + Est_{time} \times (R_{sa} + R_s) \]  

(4)

\[ Geo_c = Des_{time} \times (R_{sa} + R_s) \]  

(5)

\[ Dep_c = Cal_c + En_c + Non_c + Mac_c \]  

(6.1)

\[ Cal_c = (time_v \times R_m) + (time_v \times R_{sa}) + (time_v \times KW_{abs} \times KW_{rate}) + Mat_{dep} \]  

(6.1.1)

\[ En_c = Dep_{time} \times KW_{abs} \times KW_{rate} \]  

(6.1.2)

\[ Non_c = Dep_{time} \times (1 - FDM_{Eff}) \times R_m \]  

(6.1.3)

Three Mathematical Models have been developed to estimate the time and cost of “Wire+Arc Additive Manufacturing” (WAAM), “Selective Laser Melting” (SLM) and “Fused Deposition Modelling” (FDM).

The models have been developed through a study of the IDEF0 of the systems and process mapping of the end-to-end deposition process.
The SoI defines what a DS2 is, what are the System Elements, the sequences, the Logistic Platforms, the System Configurations and where AM can be applied.

It has been developed through primary research and published in the IJSAM in 2017.
It consists of five phases through which the user must go through to perform an exhaustive assessment of AM applications in DS2:

- **Phase 1** consists in providing the data input of the logistic platforms employed in delivering the spares.
- **Phase 2** allows to define the distances between the stages of a support service system.
- **Phase 3** consists in retrieving the AM product data.
- **Phase 4** allows to define the System Configuration of the support service.
- **Phase 5** allows to simulate the scenario and estimate key performance indicators such as availability, logistic delay and service cost.
AM-DSS Module-1

1. Sol as Visual Aid for the User
2. Text Box to INPUT distances between Systems Elements
3. Rates of Logistic Platforms
4. Text Box to INPUT financial data on Logistic Platforms

Logistic Platforms

- Helicopter
- Truck
- Airplane
- Cargo Ship
- Royal Auxiliary Fleet

Logistic Module

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AM-DSS Module-2

Product Inputs

Inputs: Setup Time and Design Time

Outputs: Cost Breakdown Structure (CBS)

Outputs: Key Performance Indicators

Machining

Deposition

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1. System Configuration (Current)

\[ A_o = \frac{MTBF}{MTBF + AD_t + PD_t + LD_t} \]

2. Availability INPUTS

\[ A_o = \frac{MTBF}{MTBF + AD_t + PD_t + LD_t} \]

3. System Configuration (Next Gen)

4. Availability INPUTS

\[ A_o = \frac{MTBF}{MTBF + AD_t + PD_t + LD_t} \]

5. Outputs Current

6. Outputs Next Gen

Availability, Up Time, Down Time, Travel Times and Logistic Costs
AM-DSS Architecture

Module – 1 “Logistic Platforms”

Module – 2 “Additive Manufacturing”

Module – 3 “Simulation”

Product Cost Estimation

User Input
Default Input
Option Input
Meta Output
Output

Current Practices OUTPUTS

NextGen Practices OUTPUTS

- Shows how the Modules are integrated
- Outlines INPUTS/OUTPUTS of each Module
- Outlines Type of INPUTS/OUTPUTS
FDM Cost Model

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