# Pitch-In Mini-Project Application Form v5 130718

**Please keep this form to no more than 4 sides of A4 (Arial 11).**

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| **Title of Mini-Project** | Business case for IoT instrumentation of existing machines: A Laser Based Additive Manufacturing (LBAM) use case | | |
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| **Project Short Title** | IoT instrumentation of existing machines | | |
| **Key Words** | IoT; Internet of Things; Manufacturing Digitalisation; Additive Manufacturing | | |
| **Select Pitch-In Theme(s)** | Manufacturing | | |
| **Date submitted** | 14 Nov 2018 | **Internal HEI Project Reference Number** |  |
| **Anticipated start date** | 01 January 2019 | **Anticipated end date** | 30 June 2020 |

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| 1. **What do you want to do?** |
| A research based on a survey with 235 German industrial companies revealed that high investment and unclear economic benefits are the main barriers to implementing IoT [1]. The challenge lies in putting forward a business case on what is often a technically challenging and costly instrumentation project where the novelty and element of adventure can act as a barrier to implementation as the risk on return on initial investment can be high. Implementation of IoT within companies is also hindered by an educational barrier of unfamiliarity with IoT. This project will develop a business case for IoT implementation by developing, cataloguing and demonstrating how to integrate IoT sensors and control systems to existing manufacturing processes. The project uses Laser Based Additive Manufacturing (LBAM) process as a use case for the business case. The developed business case will be useful as a knowledge base/template for other businesses looking to augment current legacy machines for real-time process monitoring. Overall, it will provide evidence to the benefits of quality and cost saving that integrating IoT solutions can bring.  The choice of LBAM as a use case is driven by its potential as a future manufacturing technology and the impact that IoT could have on the LBAM process. LBAM provides a unique capability for creating customised/complex shapes utilising powder material. The LBAM process is subject to systematic fluctuations and random external disturbances that effect overall quality, productivity and sustainability of the manufacturing process. The recent advancement in sensors and industrial IoT provides an opportunity to mitigate these problems through in-process monitoring and control. However, traditional LBAM machines do not house such capabilities [2], and for many SMEs it is simply not possible to upgrade to newer machines.  The proposed use case focuses on exploiting IoT for monitoring and control of two key LBAM parameters: **Monitoring powder flow rate:** Variations in powder ﬂow resulting from disturbance in chamber backpressure, powder clogs or other instabilities affect the laser beam interactions with the feedstock and can lead to process instability. **Monitoring the thermal history of full part and not just the melt:** In the absence of any mechanical processing, the microstructural evolution of the part is determined solely by the thermal history during the process.  Our vision is to address the key barrier of business case development in the implementation of IoT; this is demonstrated by the exploitation of IoT for in situ sensing of parameters for LBAM process. In addition, we will also develop training material for companies that will enable them to digitalise the existing legacy machines.  **Aim:** The aim is to develop and document a business and education case for an IoT solution on an existing manufacturing process using LBAM as a use case.  **Objectives:** The aim will be achieved through the following objectives:   1. Develop a monitoring system for powder flow rate using available loss-in-weight feeders and multi-modal sensors. 2. Develop imaging setup using infra-red and temperature sensors for historical capture of thermal history beyond just the melt pool. 3. Develop a business case template that could be used for implementation of IoT on existing industrial processes. 4. Develop educational material to inform businesses on the costs, benefits and return on investments of IoT implementation.  Outline project plan and deliverables: The project plan is outlined below and depicted in Figure 1. Use Case: The LBAM process is carried out using an existing BeAM machine, a directed energy deposition machine provided by the EPSRC MAPP Hub. **WP 1: Monitoring mass flow rate**  In LBAM, it is critical to feed powders consistently and accurately into subsequent unit operations of the process line, as feeding is typically the first unit operation and the composition and quality of the final product is heavily influenced by mass flow rate [3]. The early detection of mass flow rate deviations enables a more efficient and dynamic process management, enhancing efficiency and final product quality. However, monitoring mass flow rate is not an easy task when dealing with bulk materials such as fine powders. This work package will focus upon integrating IoT technologies (such as electrostatic charge [4] and acoustic emissions [5]) for accurate measurement of mass flow rate.  **Task 1.1:** *Sensor identification:* This task involves a thorough review of the available sensing and measurement technologies for identifying mass flow rate before validation and integration into BeAM machine. Deliverable: **D1.1:** Set-up for mass flow rate monitoring.  **Task 1.2:** *Set-up and experimentation:* This task will prepare an experimental set-up using BeAM machine and compare mass flow rate measurements from the loss-in-weight technique and other sensing methods. Deliverable: **D1.2:** Test set-up.  **WP 2: Thermal characterisation of melt pool and material structure**  We propose a new IoT-based data-driven modelling scheme to characterise the temperature distribution of the melt pool, and identify the relationship between powder flow rate, melt pool characteristics and defects.  **Task 2.1:** *Setup and data capture pipeline:* This task is focused upon identification and validation of suitable imaging sensors and supporting IoT hardware and infrastructure, integrating into the BeAM working environment and developing a data pipeline for capture and pre-processing. This will look at standard approaches such as thermographic sensors, thermal and hyperspectral imaging. Deliverables: **D2.1:** Technology demonstrator.  **Task 2.2:** *Online melt pool characterisation:* This task will use the streamed data captured from the BeAM machine to characterise through multi-modal sensor data the melt pool and its impact on the surrounding region. The use of machine learning methods will be investigated to build automated detection of process characteristics linked to defect generation. Deliverables: **D2.2:** Setup foronline thermal characterisation.  **WP 3: Development of business case and training material**  This work package will focus on developing a business case template and supporting educational material to address the key business and educational barriers to implementation of IoT.  **Task 3.1:** Develop a business case for IoT instrumentation of the BeAM machine. This will include an analysis of the costs, benefits and return on investment for IoT implementation on the BeAM machine. This particular use case will be generalised to produce a business case template that could be used by companies to support decisions around IoT implementation on their existing processes. Deliverable: **D3.1**: A business case template for IoT implementation.  **Task 3.2:** Develop short course training material that will enable companies to make confident decisions regarding IoT adoption for their existing machines and processes. Deliverables: **D3.2:** Short course training material. **D3.3:** Project report on identified KPIs/objectives.    Figure 1: Gantt Chart of the proposed project  **References: [1]** V. Koch et al. (2014) “ Industry 4.0: Opportunities and challenges of the industrial internet” Strategy & PwC**. [2]** E.W. Reutzel *et al*., (2015) "A survey of sensing and control systems for machine and process monitoring of directed-energy, metal-based additive manufacturing", Rapid Prototyping Journal, 21, pp.159-167. **[3]** M. Grasso, B.M. Colosimo, (2017) “Process defects and in-situ monitoring methods in metal powder bed fusion: a review”, Measurement Science Technology. **[4]** L. Peng, *et.al*. “Characterization of electrostatic sensors for flow measurement of particulate solids in square-shaped pneumatic conveying pipelines”, Sensors Actuators A Phys. 141 (1) (2008) 59–67. **[5]** Y. Zheng, Y. Li, Q. Liu, (2007) “Measurement of mass flow rate of particulate solids in gravity chute conveyor based on laser sensing array”, Opt. Laser Technol. 39, pp 298–305. |
| 1. **Which IoT related KE barrier(s) and KPIs are being addressed?** |
| KPI(s): KPI 1.1; KPI 1.3; KPI 1.5; KPI 1.7. |
| Pitch-In Barrier (No and text): No 6: Business Case; No 3: Educational; No 7: Data Issues |
| *Narrative:* This proposal looks to address a range of barriers associated with the implementation of IoT, sensor and digitalisation technologies on existing processes.  **Business Case:** We will look to address challenges 6 (a) and 6 (c) through the deployment of IoT on a manufacturing process and development of an IoT business case template.  **Educational:** We will look to address challenges 3 (a) and 3 (b) by increasing familiarity of companies with IoT through demonstration on a use case and development of a short course training material.  **Data Issues:** We will look to address challenge 7 (b) by providing knowledge of analytical tools through demonstration on a use case and development of short course training material. |
| 1. **What is the evidence of the need for this work?** |
| There is evidence that high investment and unclear economic benefits are the main barriers to implementing IoT [1]. The challenge lies in putting forward a business case as the perceived risk on return on initial investment can be high. The project demonstrates this through a use case based on LBAM. Our discussions with our partners in MAPP have concluded that the application domain of LBAM is in need of IoT technologies which can enable a more real-time system to enhance production quality and reduce scrap. This is reflected in [6], which says “controlling the process chain and the anomalies produced during the AM process [can] help to establish process control, enabling repeatable and predictable part quality”. This is further supported in an ATI report [7] which indicates the need for “high dynamic range devices for automated rapid detection, precise location, measurement and classification of AM defects”.  [6] P. Caracciolo, “Improving metal 3D printing processes for aircraft parts” (2018) The Engineer  [7] “Product Verification: Growing UK Productivity and Competitiveness” INSIGHT\_05, Dec 2017 |
| 1. **What will success look like and how will this be evidenced?** |
| The success of this project will be evidenced by:   1. A business case template covering the costs, benefits and return on investment for IoT implementation on existing manufacturing processes (KPI 1.7). 2. A short course training material using the BeAM machine use case (KPI 1.3). 3. Successful demonstration of an IoT based real-time process monitoring system for the BeAM machine to aid in the reduction of defects and improve repeatability (KPI 1.1). 4. A full report on the development, implementation and results of the experimentation and system integration of the IoT solutions for the BeAM machine use case (KPI 1.1). 5. Findings of the project work will be presented to MAPP and Rolls-Royce and published in journal/conferences (KPI 1.3). 6. In addition, the outcome of this project provides for two clear avenues for future funding. The first is to expand the scope of project to include more sensors and in-process monitoring with non-conventional sensors and IoT devices through a low TRL EPSRC project. The second is to work with our partners MAPP and Rolls Royce through a joint ATI or Innovate UK call (KPI 1.5). |
| 1. **List internal and external partners (including HEIs) and detail their roles** |
| |  |  |  | | --- | --- | --- | | **Collaborative? Yes** | **Number of HEIs: 1** | **Number of non-HEIs: 1** |   Names and roles: **University of Sheffield (ACSE)** – Providing expertise in Digital Manufacturing, Industrial IoT and Data Analytics.  **University of Sheffield (MAPP)** – Providing expertise in Additive Manufacturing. This proposal is match funded in collaboration with the **EPSRC** **MAPP Hub** that will provide access to the BeAM machine. The MAPP Hub has agreed to match fund £30k of the project costs through in-kind support. This includes providing access to the BeAM machine for experimentation (@ £1500/Day) and support staff (@ £500/Day).  **Rolls-Royce** – Use case engagement, technical advice and future proposal. |
| 1. **What is the full economic cost of this activity?** |
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| 1. **What contribution to these costs have you already secured?** |
| **Description:** In-kind match funding from EPSRC MAPP Hub (£30,000). |
| 1. **How much are you requesting from Pitch-In?** |
| We are requesting that Pitch-In provide £49,967 to cover the costs for this proposal in particular that of the research time for the research staff. |
| 1. **State Aid: Is a state aid declaration needed?** State Yes or No or TBA |
| **No** |
| 1. **Does this project need ethical approval?** State Yes or No or TBA |
| **No** |

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