Please provide a description of the potential impact (including the socio-economic impact and the wider societal implications of the project so far) and the main dissemination activities and the exploitation of results. The length of this part cannot exceed 10 pages.

The potential impact of this project can be maximized not just through the successful demonstration of a test bed with a self-sensing motor-drive-under-test integrated with a novel all-in-one optical fibre sensor system developed in this project but also through a series of dissemination and exploitation activities carefully planned and undertaken throughout the project period and beyond.

There are a number of **beneficiaries of the project** who have been recognized to be able to take up this innovation and play a key role in developing that impact and they are:

- **The EU aerospace industry**. The test bed includes the SMART motor drive under test, load motor and its control, together with the conventional sensors and their data logging systems. The sensor data generated from the all-in-one optical fibre sensor system have been successfully validated against the conventional sensors and the sensor data obtained are not just used for motor reliability monitoring, but also for motor control once such sensor data are integrated into the control software. Such innovative test bed is now at the Topic Manager's institution and made available to the EU aerospace industry for access to test various types of aerospace motor drives under the circumstances as the machine used in real world. Therefore there will be a significant *impact* on the design, integration, implementation and quality control in aerospace industry.
  - Design:
    - Hardware: The innovative sensor design and sensor mapping is made to be generic thus allows for the flexibility of the sensor system, either to be retrofitted into a variety of motor types and new electrical machines or integrated at the manufacturing setting, for aerospace applications.
    - Software: A generic software platform has been established, allowing for new functionalities or algorithms to be added when new types of motor drives with different control systems are tested.
    - The combination of the above will make their final product more reliable and more efficient. The detailed information is made available to all the Clean Sky partners.
  - Integration: A generic guideline in integration has been made available to the Topic Manager. It will be made available to the Clean Sky partners in order to standardize the procedure for sensor installation and integration into motor drives. This will also help with the production of SMART self-monitoring motor drives to increase their TRL level.
  - Implementation and quality control: The SMART self-monitoring motor drive and the test bed will enable the user to check new motor prototypes not only under standard conditions, but under conditions which meet the needs of the production and operation under extreme conditions. This will make the product more reliable and safe thus meeting the stringent regulations in aerospace applications.

In addition to the above impact on aerospace industry, there will also be a critical *impact* on the other beneficiaries, as indicated below:

- **The rail industry.** The research outcomes of this project have also been widely disseminated to the UK Rail industry through the workshop hosted at City University London. The specific focus has been on the **railway electrification system,** which supplies electrical energy to railway locomotives and multiple units so that they can operate without having an on-board prime mover. The main advantage of electric traction lies in the higher power-to-weight ratio than forms of traction such as diesel or steam that generate power on board. Electricity enables faster acceleration and higher tractive effort on steep gradients. Other advantages include the lack of exhaust fumes at point of use, less noise and lower maintenance requirements of the traction units. Given sufficient traffic density, electric trains produce fewer carbon emissions than diesel trains. Considering a similar challenge faced by the railway industry, the knowledge gained from this OFS-MOTOR project and the novel all-in-one sensor system developed can thus be further developed to meet the new demands arising from the rail industry. Thus a positive impact can be made by offering a better solution to monitoring the railway electrification systems, than

the conventional load cell, strain gauge and accelerators where a careful insulation is required, as they operate under ***extreme harsh conditions***: with high electromagnetic (EM) interference, to all weathers and to wide geographical spread when the train operates at speeds up to 250 mph and at 25,000 volts conditions.

- **The marine industry will also benefit from the outputs of this project.** The marine industry relies on fuel oils for most powering needs, but tighter emission regulations and the need to 'go green' are starting to convince operators to consider alternatives. Extensive discussions on hybrid marine propulsion system which involves *diesel and electric* are being on the agenda of the world marine industry: this has been reflected clearly in recent Electric & Hybrid Marine World Expo 2016, held in Amsterdam in June 2016 which was run in parallel with the Marine Maintenance World Expo and Conference 2016, to which Prof Sun was invited to disseminate the research outcomes arising from this project together with the others.
- The **whole community of electrical motor and generator designers and manufacturers** will benefit from the outcome of this project as the new technology will allow these machines to operate efficiently in challenging applications and severe environments where reliability and ease of maintenance is critical. Dr Matthias Fabian from City University, together with Dr James Bartolo from the University of Nottingham, gave a joint presentation in 2015 to such an audience in a seminar organized by the UK Magnetic Society under the specific theme of electromagnetic measurements: design, application and challenges.
- ***Early career staff, both in industry and in academia*.** The project will act as a platform for the technologically-focused training for both industry and academia and the skills development of early-career researchers, gaining significant industry-linked experience. Prof Sun was invited to give a public lecture to disseminate the outcome of this research and development at a Summer School organized by COST Action TD1001 with an audience of 66 PhD students carefully selected from the Universities across EU in 2014.
- ***The broad scientific community and wider public***. They will be better informed of the recent technological advancement in a field which is of their interest. In addition to international publications, Prof Sun and her team gave a number of public lectures to a broad community nationally and internationally with an aim to enhance the public awareness of this new monitoring approach now available for industry. In addition to the above, the work has been showcased at the exhibition of the Sengenia Limited, an SME spun out of the joint research between City University London and Queen's University of Belfast in the UK, at the European Workshop on Optical Fibre Sensors in 2016. The next exhibition has been lined up for the demonstration of the self-monitoring motor drive at the Research Forum organized by the Royal Academy of Engineering in the UK in September 2016.

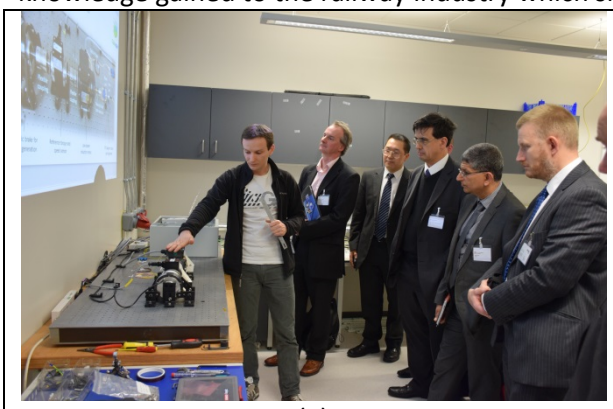
The ultimate goal of this OFS-MOTOR project is to enhance significantly the **competiveness of EU** in the field, through this successful joint adventure. This draws upon the complementary strengths from City University London in advanced optical fibre sensing and from the Topic Manager in the design and manufacture of novel electrical machines, thus to achieve seamless integration of the all-in-one sensor and motor technologies. The success of this pilot project will be able to ensure the leadership and competitiveness of EU in this area in the global context. Impact will be seen in the industry in EU being able to benefit from direct access to the published outcomes of the research carried out and the test bed made available to the Topic Manager and to the Clean Sky partners at the end of the project and beyond.

Following the clear identification of a number of beneficiaries highlighted above, a series of dissemination and exploitation activities has been carefully planned and undertaken, in parallel with the progression of the technical programme, in order to accelerate the delivery of impacts recognized.

1) Organization of an Industrial workshop on 30 April 2015 at City University London.

This industry workshop, as shown in Figure 1 (a), is hosted jointly by City University of London and Brecknell Willis, a world leader in the railway electrification/traction system based in the UK. In this workshop, both the 'smart' railway current-collecting pantograph and an optical fibre-based self-monitoring motor drive system are demonstrated. A strong presence of the key players in the railway industry, including RSSB (Rail Safety and Standards Board), Siemens, Rail Industry Association, Network Rail, Hitachi Rail, First Group,

Angel Trains and Serco, has been seen. Following this workshop, joint research funding applications have been submitted to the Innovate UK and to EPSRC (Engineering and Physical Sciences Research Council) in the UK, aiming to explore further the research outcomes obtained from this project by transferring the knowledge gained to the railway industry which shares a similar motor technology for electric traction.



(a)

(b)

Figure 1. (a) Industrial Workshop held at City University London on 30 April 2015; (b) FIGS Public Lecture given by Prof Sun at the Royal Academy of Engineering on 13 November 2014

2) The 2nd FIGS Events' Lecture in November 2014 in London: 'OPTICAL FIBRE SENSATIONAL'

Prof Sun was invited to deliver the 2nd FIGS Events' Lecture, 'Optical fibre sensors: a new monitoring approach for industry' before an invited audience from different fields of science and technology in London, on 13 November, 2014, at the Royal Academy of Engineering as shown in Figure 1 (b). Her presentation was chaired by John Newell MBE and she explained to the broad audience that optical fibres have been explored widely for their sensing capability to meet increasing industrial needs. This OFS-MOTOR project has been highlighted as one of the exemplars. This scientific lecture was well received and turned into what one attendee described as 'optical fibre sensational', clearly showing the impact made on the audience. A video of the presentation is now online at http://youtu.be/2NbOD1U9gCo and the full paper accompanying the lecture is available for free downloading from the FIGS Events' website www.figsevents.co.uk.

3) Lecture at the COST Action TD1001 Summer School, Chandolin, Swiss Alps, September 2014

COST TD1001 organized its second Summer School on 'Optical Fibre Sensors: from Research to Real World' in Chandolin in the Swiss Alps in September 2014. The purpose of the School was to give early stage researchers the opportunity to attend a series of key lectures by some of the top names in the field of optical fibre sensing. Prof Sun was one of the invited lecturers and she covered a number of case studies, which includes this OFS-MOTOR project, with each demonstrating how the scientific novelty can be translated to potential industrial innovation. 66 Early Stage Researchers from COST TD1001 participating institutes attended the Summer School. The venue for the School was an historical hotel high in the Swiss Alps, which was completely booked out by the School, creating an excellent networking platform between Early Stage Researchers and the teachers in a relaxed environment, as shown in Figure 2 (a).

(a)

(b)

Figure 2 (a) COST TD1001 Summer School in Swiss Alps in September 2014; (b) Workshop in December 2015 at CGCRI Kolkata, India, hosted jointly by City University London and CGCRI.

4) **Organization of a dissemination workshop on 16 December 2015 at CSIR-CGCRI, Kolkata, India**

This scientific workshop, as shown in Figure 2 (b), is hosted jointly by City University of London and the Central Glass and Ceramic Research Institute (CGCRI) in Kolkata, India, the largest Photonics Research Institute funded by the Indian government. In this workshop, Prof Sun gave a review presentation highlighting research achievements made in the development of a range of novel optical fibre sensors for wide industrial applications including the outcomes from this project to the international community. There has been a strong participation from the research institutes, industry and medical services both from India and from the other parts of the world, including Bhabha Atomic Research Centre in India, National Nuclear Laboratory in the UK and Northern Ireland Cancer Centre in the UK, and from academia internationally, including Macquarie University in Australia and University of Limerick in Ireland.

5) One-day seminar at QinetiQ, UK on 17 June 2015, organized by UK Magnetic Society

Dr Matthias Fabian from City University, together with Dr James Bartolo from the University of Nottingham, gave a joint presentation with a title of 'Towards optical fibre based, self-monitoring motor drives' at the one-day seminar organized by the UK Magnetic Society under the specific theme of electromagnetic measurements: design, application and challenges. The audience is primarily from the communities of high performance machines, measurement and sensors.

6) Exhibition at the European Workshop on Optical Fibre Sensors (EWOFS), 31 May – 3 June 2016, at the University of Limerick

The research outcome of this project has been showcased at the exhibition of Sengenia Limited, an SME spun out of the joint research between City University London and Queen's University of Belfast in the UK, at the EWOFS conference. There were around 300 attendees from all over the world, from academia and from industry. The format of the workshop was to stimulate a constructive interaction among the attendees, motivating PhD students for an effective participation. Additionally, it provided a forum for discussion of the trends and progresses in the optical fibre sensing field and their subsequent industrial take-up.

7) Exhibition at the Royal Academy of Engineering Research Forum 2016 on 8 September 2016

Arrangements have been made to exhibit the optical fibre-based self-monitoring motor drive at the incoming Royal Academy of Engineering Research Forum, which will be held at the Royal College of Surgeons in London on 8 September 2016. It has been a great honour for the team to be given the opportunity to showcase our self-monitoring motor drive system at this prestigious annual research forum organized by the Academy and demonstrate the system to the top engineers in the world.

8) International Publications

Due to the innovative nature of this project, the research outcomes of the project have been widely disseminated, after a careful consideration of longer term exploitation and Intellectual Property protection, through the publication of scientific and technical papers in workshops and international conferences as shown in the publication list. Two journal publications are currently being prepared for submission.