Advanced Machinery & Productivity Initiative
Work Packages 2.1 and 2.2 – scope of work and expectations

This document provides an overview of the outcomes and deliverables of the two work packages.

SiPF submission:

Below is the detail of each University of Salford work package, which was included within the UKRI SIPF bid, submitted November 2020. For details of all of the work packages (which were an appendix of the submitted bid), please visit this link. The submitted SiPF proposal itself (the Case for Support) can be accessed here.

WP 2.1	**Dynamic resilient machines and fabrication technologies**											**Lead:** UoS
Start month	3	**Duration (months)**	53	**WP Linkages**	1.3, 1.4, 2.3, 2.4, 2.5, 2.6, 2.7, 2.8					**Cost**	COMPLETE	
Partners		AMP	CRS	FLL	NPL	PTG	RDA	UoH	UoL	UoM	UoS	WAL
Aim: To design highly physically modular, reconfigurable, low cost, Intelligent and self-adapting machine technologies beyond state-of-the art. We will investigate the combination of soft, lightweight materials, muscular actuation, sensing skins, fabrication technologies. *Obj* (i) Development of a lightweight modular low cost robotic manipulator, using a combination of actuation units, that is rapidly reconfigurable based on the task request; (ii) Reconfigurable dexterous end effectors for unknown object and tasks (iii) Design and control of high speed lightweight machines (iv) Smart robotic machines for additive manufacturing												
Gates	**G2.1.1** Results from D2.1.1 (M18); **G2.1.2** Results from D2.1.3 (M36)											
Deliverables	**D2.1.1** Smart machine 3D manufacturing platform created, commissioned & demonstrated (M18). **D2.1.2** A demonstration of mobile smart machine platform operating in dynamic environments forces (e.g during re-machining) (M36). **D2.1.3** Universal adaptable end effector demonstrated and delivered (M36). **D2.1.4** Demonstration of reconfigurable lightweight manipulator using the combination of the multi-drive systems units (M50)											
WP 2.2	**Human-machine interaction systems**											**Lead:** UoS
Start month	3	**Duration (months)**	53	**WP Linkages**	1.5, 2.1, 2.3, 2.6, 2.7					**Cost**	£1,000,404	
Partners		AMP	CRS	FLL	NPL	PTG	RDA	UoH	UoL	UoM	UoS	WAL
Aim: To develop control architecture for HRI that implements the coordination of actions as a dynamic and flexible process that integrates teaching by demonstration, compliant architecture and advanced motor behaviours. The architecture will consist of three main layers (i) learning of elementary tasks; (ii) hierarchical combinations of tasks; (iii) decentralized motor control structure responsible for torque/ position trajectory tracking (iv) integration to the compliant manipulator (D2.1.4) for testing of the skill through kinesthetic teaching.												
Gates	**G2.2.1** Results from D2.2.1 (M36)											
Deliverables	**D2.2.1** Development of a user-friendly Multimodal HM robotics Pal interface (M36); **D2.2.2** Control architecture completed and tested (M50). **D2.2.3** Demonstration directly in the compliant manipulator's workspace (M60).											

More details about the deliverables:

These were provided by Salford post-submission…

Work Package 2.1 Dynamic Soft-Rigid hybrid machines

To design highly physically modular, reconfigurable, low cost, Intelligent and self-adapting machine technologies beyond state-of-the art. We will investigate the combination of soft, lightweight materials, muscular actuation, sensing skins, fabrication technologies.

Activity No.	Activity Description	Deliverable(s)
1	State of the art on reconfigurable systems for cross sector application	Report
2	Design of lightweight soft sensors	Electro/Mechanical design soft/lightweight sensor
3	Building the soft sensors	Soft/lightweight sensor built and tested
4	Design of lightweight soft-rigid hybrid actuators	Mechanical design of soft-rigid hybrid actuator
5	Building of lightweight soft actuators	Soft-rigid actuators built and tested
6	Design of lightweight soft-rigid hybrid robot arm	Electromechanical design of soft-rigid hybrid robot arm
7	Building lightweight soft-rigid hybrid robot arm	Robotic arm designed and tested

Work Package 2.2 Control and Human-machine interaction architecture for soft-rigid hybrid systems

To develop control architecture for HRI that implements the coordination of actions as a dynamic and flexible process that integrates teaching by demonstration, compliant architecture and advanced motor behaviours.

Activity No.	Activity Description	Deliverable(s)
1	State of the art on autonomy and Control architecture for Human Robot Interaction and collaboration of soft robots	Report
2	Autonomous and intelligent control architecture framework for HRI	Report
3	Development of learning of elementary tasks and behaviours for soft-rigid hybrid robot	Algorithms developed and tested
4	Development of intelligent decision systems for soft-rigid robot	Decision systems developed and tested
5	Development of perception and situation awareness algorithms for soft-rigid hybrid robotics	Perception and situation awareness algorithms developed and tested
6	Development of a user-friendly Multimodal HM robotics interface	Multimodal HM robotics interface
7	Implementation of the autonomous control, decision and the perception algorithms on the soft robotics arm for plaster board fixing and other application demonstrations	Semi-autonomous soft-rigid hybrid robotic arm for plaster board installation demonstrated

Exploitation Plan

Each partner within the AMPI SIPF programme is required to develop an Exploitation Plan outlining the impacts and expectations of their work. The following is the information received from Salford to date.

Summarise the innovative aspects of the project, are they still innovative?
The main innovative aspects of the projects will be the development of robotic manipulators that have enhanced performance behaviours and characteristics when compared to traditional industrial robots. This will result in the development of robot manipulators with greater dexterity than traditional robot arms. Traditional robots are not suited to close operation around human, and even the recent trend towards cobots is less than ideal as often the performance of the robot is reduced to ensure safety. This project will develop a new generation of robots with enhanced safe physical Human Robot interaction abilities whilst maintaining robot performance. This will result in the increased application of inherently safe robots used in collaborative tasks with human operatives and this will be achieved through the development of novel soft-rigid robots.

Market Opportunity

Summary of Expected Deliverables From Project
The University of Salford is involved in two work packages, WP2.1 - Dynamic Soft-Rigid hybrid machines and WP2.2 - Control and Human-machine interaction architecture for soft-rigid hybrid systems. Within WP2.1 the main deliverable is the design, construction and application of a Soft-rigid hybrid robotic arm, there are a number of sub deliverables as follows: D2.1.1 - Report on the state of the art on reconfigurable systems for cross sector application D2.1.2 – Electro/Mechanical design soft/lightweight sensor D2.1.3 - Soft/lightweight sensor built and tested D2.1.4 – Mechanical design of soft-rigid hybrid actuator D2.1.5 – Soft-rigid actuators built and tested D2.1.6 – Electromechanical design of soft-rigid hybrid robot arm D2.1.7 – Soft-rigid hybrid robotic arm designed and tested

Within WP2.2 the main deliverable is the implementation of an autonomous control, decision and the perception system for the hybrid robot created in WP2.1. The sub deliverables are as follows:

- D2.2.1 - Report om state of the art on autonomy and Control architecture for Human Robot Interaction and collaboration of soft robots
- D2.2.2 – Report on autonomous and intelligent control architecture framework for HRI
- D2.2.3 - Algorithms for learning of elementary tasks and behaviours for soft-rigid hybrid robot
- D2.2.4 - Decision systems for soft-rigid hybrid robot
- D2.2.5 - Perception and situation awareness algorithms
- D2.2.6 - A user-friendly Multimodal HM robotics interface Multimodal HM robotics interface
- D2.2.7 - Semi autonomous soft-rigid hybrid robotic arm for plaster board installation and other example applications.

Commercial Opportunity

For each product, process or service envisaged, identify:

1. The Market Niche for each Outcome

Where industry requires human operators to work closely with robots it is poorly served by existing technology. Cobots are attempting to address this but have limitations in terms of reduced performance. The project will develop robots that can safely operate alongside people but retain many, and even enhance, the abilities of existing industrial robots.

2. The predicted value and growth in the selected market niche

No information provided.

3. The existing or emerging competitive offerings

The existing competition comes from the relatively new breed of robots known as the cobot. However, these typically achieve safety at the sacrifice of performance e.g. speed and payload.

4. The means by which IPR will be protected

New hardware developed, including the soft rigid hybrid design, soft actuators and soft sensors will be protected through patents where there is a demonstratable inventive step over existing systems. Software and control systems will be not be made freely available and may include the use of encryption where necessary.

Potential Impact

Summary of wider benefits from the Project for those outside the consortium

The project will contribute to the GM strategy to achieve the goal of net zero, this will be achieved through the reduction in the energy costs associated with running robotics equipment. This will be achieved in a large part through lightweighting but also through the selection and use of appropriate materials.

The system developed will allow companies reduce waste and increase productivity through the use of robots. The soft rigid hybrid robot has the specific benefit of allowing close cooperation and collaboration between humans and robots. This is of particular benefit in processes that contain tasks that are impossible or prohibitively expensive to automate as it means a combination of manual and automated tasks can be combined safely. There are many potential areas where this new technology could be applied outside the consortium, the NHS and food manufacturing are just two examples. The novel robot will have many potential cross sector applications which will be explored during the project.

Potential Impact

Summary of wider benefits from the Project for those outside the consortium
The project will contribute to the GM strategy to achieve the goal of net zero, this will be achieved through the reduction in the energy costs associated with running robotics equipment. This will be achieved in a large part through lightweighting but also through the selection and use of appropriate materials. The system developed will allow companies reduce waste and increase productivity through the use of robots. The soft rigid hybrid robot has the specific benefit of allowing close cooperation and collaboration between humans and robots. This is of particular benefit in processes that contain tasks that are impossible or prohibitively expensive to automate as it means a combination of manual and automated tasks can be combined safely. There are many potential areas where this new technology could be applied outside the consortium, the NHS and food manufacturing are just two examples. The novel robot will have many potential cross sector applications which will be explored during the project.