Institution: Plymouth University
Unit of Assessment: B11

a. Context

UoA11 research, located in the Centre for Robotics and Neural Systems (CRNS), focuses on the investigation of the neural and cognitive bases of behaviour in natural and artificial (e.g. robot) systems, and the requirements to translate fundamental scientific results into new applications and services with economic and societal impact. As such, Unit staff are actively engaged in direct collaborations with industry and potential non-academic beneficiaries. In particular, three primary types of users have been engaged in knowledge transfer activities with the Unit: (i) industry users - as direct beneficiaries of the design and application of robotic and machine learning systems in service and education robotics and in the defence industry; (ii) health and community users, especially children in hospital and the elderly/infirm requiring physical, health and social support, provided through robot companion applications; (iii) non-governmental organisation policy making in oceanography and environmental protection.

Engagement with such a broad spectrum of users has led to a variety of economic and societal impacts. There has been direct economic impact on the UK defence industry and the UK Ministry of Defence (MOD) through implementation of machine learning systems, which have resulted in efficiency savings in the deployment of new combat aircraft (impact case 1). CRNS robotics research has led to direct impact on the economy, society, education and health. Economic benefit has resulted from commercialisation of the Miabot mobile robot platforms developed by Bugmann for the robot-football competition and education activities in national and international schools and universities. In addition, impact on health and social care has resulted from the design and use of robot companions with outpatient children at the San Raffaele Hospital in Milan and disabled children in educational activities (impact case 2) and with the elderly at the Municipalities' Social Care Units in Peccioli (Italy) and Orebro (Sweden). The implementation of algorithm and software developed by Culverhouse for automatic plankton recognition has resulted in enhanced environmental and oceanographic protection. On-going impact activities with NVIDIA Inc. are focussing on the use of GPUs and neuromorphic systems in robotics applications.

b. Approach to impact

In 2009 Plymouth University established 'Enterprise' as one of its primary missions alongside teaching and research. This new drive to link academic and research activities to enterprise and knowledge transfer was supported by new institutional initiatives and support, including a Research and Innovation Strategy, resulting in Plymouth being nominated twice as Enterprise University of the Year (Times Higher Education awards). The CRNS has directly exploited three of the University's enterprise support initiatives:
- A Proof of Concept fund to pump-prime knowledge exploitation;
- A strategic commercialisation partnership with Frontier IP Ltd, for exploitation of intellectual property;
- The expertise of the University's commercial arm - University of Plymouth Enterprise Limited (UoPEL) in supporting external consultancy and industry collaboration.

Two CRNS staff have been awarded *Proof of Concept grants*: Marocco for the production of a working prototype for industry demos on soft robotics materials, and to Harris for extending his European and Japanese patent in noise modeling in motor control optimisation, for application to robotic arm movement control. *Frontier IP* is also currently supporting financially the testing in advance of commercialization of a pilot Hardware-In-the Loop system to control stability boundaries in electronic circuits, involving a £10K investment for Rodrigues. UoPEL has a well established support structure for consultancy and was crucial in Cangelosi's involvement in the SciSys/MOD impact case.

The CRNS has also initiated a structured programme to embed an impact culture in the Centre itself. A CRNS Impact Away Day in 2009 defined the Unit's strategic impact plan (see section 3). It also put in place a set of initiatives to identify, support and monitor actions to deliver the impact potential of research.

We have a close engagement with the UK and international robotics industry. Cangelosi and

Bugmann are amongst the founding and board members of BARA-AFR,the Academic Forum for Robotics within the UK British Automation and Robot Association, representing all the UK robotics industry. BARA played a key role in the EPSRC's "Shaping Capability" exercise on robotics, by providing an overview of current UK academia's fields of expertise and of the matching robotics industry opportunities. We have built strong links to Japan through Belpaeme's invited visit to Japanese robotics companies during the Technology Strategy Board's UK-Japan Robotics Mission. The CRNS subsequently hosted the CEO of the Japanese service robotics company TMSUK, who then became industry advisor in the EPSRC BABEL project. We have also appointed as visiting professors Murukiah Arumugam, the founder and CEO of Broadline Inc, a large Indian company specialising in software solutions for e-government, health and education, and Dr Ian Phillips, from ARM Ltd to advice on electronic engineering activities. US links have been established through on-going collaboration with NVIDIA, one of the two major international manufacturers of GPU technology. This is aimed at the adaptation of GPU technology to robotics research and has included a graduate placement visit at the company's R&D Headquarters in Santa Clara, and the setup of an NVIDIA centre at Plymouth.

Staff and students are trained in R&D and entrepreneurship skills. Industry engagement has also been core in the training of MSc and PhD students and postdocs and early-career staff in R&D and entrepreneurship skills, following the University's commitment to research-informed teaching. The RobotDoc Marie Curie ITN, coordinated by Plymouth, has amongst its partners an SME (Telerobot, Italy), the automation industry association (BARA for the UK) and the European R&D institute of a multinational company (Honda, Offenbach Germany). They have provided entrepreneurship knowledge training expertise and secondment opportunities to the ITN fellows, including the three staff in Plymouth. For the MSc Robotics in Plymouth, there is a specific "Future Robotics Industry Seminars" module, which has seen the presence of speakers from SME and large companies such as ST Microelectronics and SciSys Ltd, and fostered industry-based MSc projects. Visiting Professor Murukiah Arumugam, CEO of Broadline Inc, has been involved in training sessions with the CRNS group, and further one-to-one support sessions with individual staff.

We have built direct collaboration with clinicians and social care experts, supporting societal and health impact opportunities through the development of robot companions (e.g. Nao robot) for hospitalised children and for older persons' care (through engagement with San Raffaele Hospital described in the Impact Case 2). Aldebaran Robotics, the Nao robot manufacturer, which recently directed part of a €100 Million venture capital investment specifically to health-companion R&D, has now become involved in the CRNS hospital collaboration. A similar approach is being used in the FP7 ROBOT-ERA project, which is testing robot companions for the elderly in two social care sites, one in Peccioli (Italy) and one in Orebro (Sweden). Clinical staff expertise is provided by our project partner, The Hospital for Old People in Ancona, Italy. The ROBOT-ERA project's industrial partners include companies in robot manufacturing and in service robotics (e.g. MetraLab), with the common aim of providing a tested solution for robot companions by 2015.

Impact activities on environment and oceanography have been strengthened through development of the relationship with the Scientific Committee on Oceanic Research (SCOR).Culverhouse's long-standing research track record on automatic plankton recognition has led to world-wide societal impact on environment and oceanography. Culverhouse was invited to co-chair the Scientific Committee on Oceanic Research (SCOR) Working Group on Automatic Plankton Visual Identification. The SCOR unit provided standards and support for the take-up of open-source software for plankton classification (as for the Zoo/PhytoImage software applications), and paradigm change in the use of automatic recognition systems for oceanography and environmental protection.

To monitor and support the various impact cases and plans, academics at the CRNS are supported by dedicated staff at the Research and Innovation Division. This has involved strategic meetings with the commercialisation partner Frontier IP Ltd, for advice on the prioritisation of exploitation efforts and the targeted award of the Proof of Concept funding.

c. Strategy and plans
The strategy and plans to support impact at the CRNS build on the above approach and involve a commitment to five key objectives:

1.   To exploit the commercialisation partnership with Frontier IP for the follow-through of ongoing Proof of Concept cases and pump-priming funding of future knowledge transfer opportunities. This involves following-up the 3 current Proof of Concept investments with applications for further pump-priming support for existing RCUK and FP7 projects (BABEL, ROBOT-ERA, POETICON++ and ALIZ-E).

2.   To nurture engagement with UK and international industry, in particular with companies active in service robotics and autonomous systems. This is important in the light of the government's identification of robotics and autonomous systems as one of the 8 Great Technologies for technological innovation. It is pursued by continuation of board membership in the BARA-AFR association, and CRNS membership of the PPP (Public Private Partnership) euRobotics aisbl.

3.   To engage with clinicians and social carer experts, in association with the Plymouth University School of Medicine and Dentistry, for the testing and exploitation of robot companion technologies and deep-brain stimulation technologies. This is pursued by focusing on the clinical testing of the Nao robot companion at the San Raffaele Hospital Milan, now with industrial partner Aldebaran Robotics; completing our collaboration with the Charing Cross Hospital and Imperial College Healthcare Trust through the pilot testing of the use of their computational model of deep brain stimulation during the surgical treatment of Parkinson's disease patients.

4.   To strengthen collaboration with companies specialised in parallel and neuromorphic computing for the integration of computational neuroscience and robotics methodologies. This involves links with NVIDIA for GPU programming in the design of custom-made GPU systems for the iCub humanoid robot and with ARM for the SpiNNaker chip and applications to robotics in general. We will exploit the impact pathway in the current BABEL project industry advisory panel for the integration of the SpiNNaker neuromorphic system with the iCub robot for action and language-learning systems in the field of service robotics (with TMSUK Japan) and the car industry (with Honda Offenbach) and in the field of small humanoid platforms for the home market and robot football competition.

5.   To secure UK and EU funding for industry-academia partnership and continuous professional development of staff and students in knowledge transfer and entrepreneurship skills. This is to be achieved through the submission of a joint CRNS–Aldebaran Robotics application to the next round of the Marie Curie Industry-Academia Strategic Partnership Scheme.

d. Relationship to case studies

The two case studies submitted for REF2014 (SciSys/MOD and Robotics Applications) exemplify the effectiveness of the Unit's approach to knowledge exploitation and impact.

   The SciSys/MOD example is the explicit outcome of the University's emphasis on enterprise and the CRNS's strategy of nurturing contacts with industrial beneficiaries - in this case through visits and seminars. Specifically, contact with SciSys was initially made at a seminar being given by a SciSys R&D engineer for the MSc module "Future Robotics Seminars". Subsequently, Plymouth University Enterprise Ltd. provided support to Cangelosi to initiate the formal collaboration and the work on the exploitation of the machine learning systems for defence.

   The Robotics Applications case shows the effectiveness of the support of CRNS students' spin-off companies (Merlyn Robotics and Syntheligence). Moreover, the extension of the impact of robot companions to health follows the strategic focus on engagement with clinicians and social carer through the large FP7 projects (ALIZ-E and ROBOT-ERA). This reflects the critical and continuous relationship between research and exploitation – to which CRNS and the University are committed.

   The experience on these two cases has helped the Unit to extend the approach to other ongoing impact activities. The success of the initiation of the collaboration with SciSys is being strategically applied to other areas and partners, for example with recent visits to CRNS from Augusta Westland UK and TMSUK Japan. Targeted investment is also being directed at the application of robot companion research to healthcare. This has been sustained by the organisation of workshops with the local Derriford Hospital and Medical School staff, and the joint work on a joint NIHR i4i (Invention for Innovation) bid for translation to clinical practice.