Northern Robotics Network: RAS Cluster:

Extreme-Environment RAS programme

Issue 4.0: 22/06/2016

The Northern Robotics Network

AISP
Autonomous Intelligent Systems Partnership

Authors: Paul Mort, Kevin Blacktop, Roger Ward, Prof S.Nefti-Meziani, Gordon Smith, Andrew Newsway

Table of Contents

Introduction

This is a Robotics and Autonomous Systems research & development programme to enhance capabilities and productivity of activities undertaken in extreme environments. The Extreme-Environment Robotic and Autonomous System (E_ERAS) has been developed by the Northern Robotics Network and is in line with the delivery of its strategy to get the following benefits to industry, regional development and the national economy :-.

- **Growth**: By having a coordinated RAS community it gives an opportunity to have UK economic growth.
- **Research**: Focus the research on industrial need, build on previous work and reduce duplication of effort.
- **Exploitation**: To give access to larger markets to strengthen the RAS community.
- **Networking**: Provide the opportunity link with the RAS supply chain community,
- **Solutions**: Build on solutions from other market sectors and give visibility to different solutions to maximise the use of available resource to get a tenfold increase in productivity.
- **Supply Chain**: Cross coordination of sector supply chains to create bigger markets to enable the supply chain to develop and grow.
- **Funding**: Gear the available funding

This is one of many planned clusters and this cluster focuses on requirements and scenarios addressing Extreme Environments.

This programme of work will follow the Northern robotics Business Delivery Model.

The Autonomous Intelligent Systems (AISP) and the Growing Autonomous Mission Management Applications (GAMMA) programmes are coming to an end and there is an opportunity to build on the lessons learnt technically and managerially to build the next nationally significant programme.

This report aims to identify the key scenarios clearly addressing challenges in the sectors to be addressed. This aligns to each of the industrial partners requirements and gives clear deliverables for the next programme (this could easily be expanded into be delivered through a catapult type model).

It is to be used as a communications document to attract more partners (including other AISP partners) and to demonstrate a clear direction to potential funding groups. The scenarios have been defined to enable the whole of the RAS supply chain and Higher Education Institutions to have an opportunity to be part of an overall RAS programme.

This document captures the requirements from a partnership group from the AISP are as follows.

- Sellafield Ltd and National Nuclear Laboratory
- Network Rail
- SciSys and UK Space Agency
- Schlumberger
- BAE Systems
- Defence Science and Technology Laboratory (DSTL)

Nuclear decommissioning sector

Restricted access cell decommissioning with a ten-fold improvement in productivity

The key challenges are as follows:

1. Entry into these cells is restricted by the hazards they pose, these principally being the following. High gamma radiation above the level a decommissioning operative can safely work in a restricted place where an operative cannot access.
2. A review of past experience indicates that remote type projects have taken three times as long and cost three times more than predicted.
3. The remote technology employed is restricted to control by an operative using simple direct control, and no advantage is taken from present advance in robotics and autonomous systems

The following project has been identified which delivers the benefit and satisfies the 3 challenges above.

- Fully autonomous remote decommissioning: Provide a remote system that is only controlled by strategic commands to decommission a cell. It will be capable of 24/7 operations with setup and recovery times of one month. By the use of modular robotics it will reduce the risks to the project time and budget; and by being capable of non-stop operations with no operator input, will increase productivity.

The following scenarios are variations on the main theme.

a) Fully remote dry cell decommissioning with integrated local waste management: The scenario takes the waste from the dismantling stage and locally size reduces, decontaminates, waste segregates and final waste packs fully autonomously. This will increase productivity and reduce costs by removing bottle necks and maximising waste management.

b) Fully remote dry cell decommissioning with Utilisation of a centralised waste management: Similar to scenario (a) but the items during the dismantling stage are removed as large as possible and transported to a centralised waste progressing facility. This scenario increases productivity and takes advantage of economies of scale by have a central waste management facility and again increasing productivity and safety.

c) Fully remote dry cell decommissioning using Agricultural type dismantling methods of process plant with local waste management: In the dismantling phase no consideration in take in planning the removal of the plant and equipment it is just ripped out of the cell.

This scenarios increases productivity and safety to the operative, but will pose challenges to the facility and the management waste processes.

Assisted manual operations with a ten-fold improvement in productivity

The key challenges are as follows:

1. An increase in incidents is predicted at the planned future number of manual cell entries.
2. The secondary generation of waste is high in proportion to primary waste removed, up to 12 times.
3. Productivity is directly dependent on the workface time of an operative on the task, this is typically limited to 2-3hrs.

The following projects has been identified, to which deliver the benefits required and satisfies the 3 challenges above.

a) Robot Assistants: Robotics will assist an operative by removing them from the hazardous part of the task and carrying out the tasks after the operative has left the workface. This will improve the operative's safety, efficiency and increase effective work facetime.

b) Robotic radiation and contamination monitoring: Provide robotics to carrying out basic surveys during non-productive time (eg evening, weekends) in preparation for the day's planned work and to support an operative during their decommissioning task.

Rail Sector

Autonomous Decision making for increasing productivity

The key challenges are as follows:

1. Significantly increasing amounts of data from remote condition monitoring and other systems will exceed our ability to turn this into useful information by conventional analysis.

2. We need to move from reactive to predictive asset management to improve reliability and capacity.

The following project has been identified which delivers the benefit and satisfies the challenge above.

a) Development of autonomous sensor system network for modelling, analytical and decision tools to support reduced cost and maximised network availability by non-disruptive inspection and targeted timely maintenance interventions

Autonomous Maintenance and Inspection

The key challenges are as follows:

1. Improve safety by reducing the need for personnel to be present during various maintenance and inspection activities.

2. Increasing productivity during maintenance possession times to offset reducing available possession times to increase track capacity and running time.

The following project has been identified which delivers the benefit and satisfies the challenge above.

a) Development of autonomous robotics systems for maintenance and inspection activities to reduce the requirement for site/trackside access to improve worker safety, reduce cost and maximise network availability by non-disruptive inspection and targeted timely maintenance interventions

Note:

- Autonomous & intelligent systems (AIS) and robotics technologies will require a mixture of early research, higher TRL development and the development of a supply chain to enable the implementation of this technology. Also some elements are already commercially available. Early work should include horizon scanning to determine the status of the various elements of the technology.

Space Sector

A Long Range Mars Rover

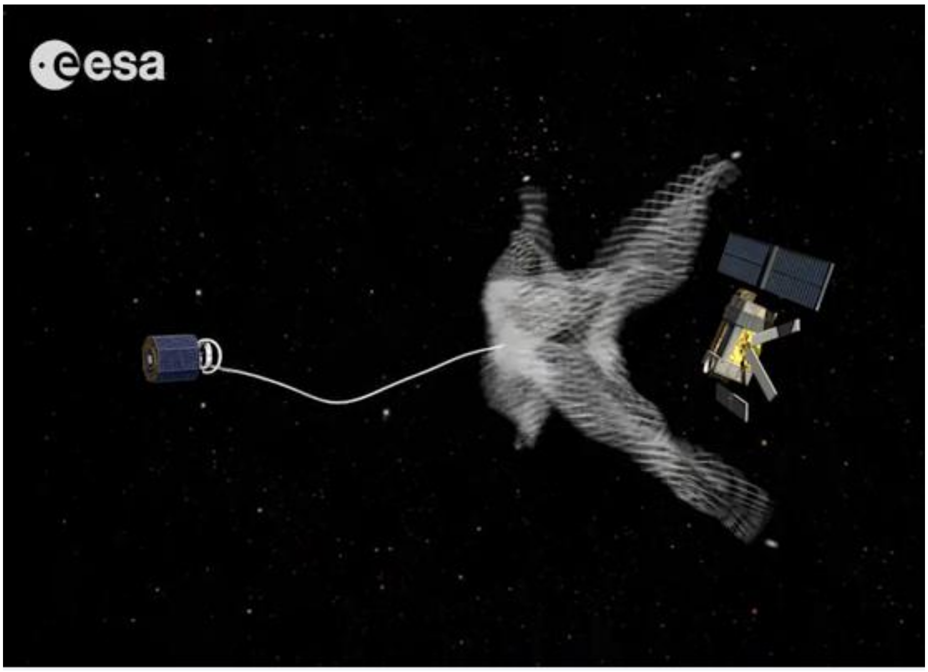
The focus of current Mars exploration activities in the US and Europe is to be able to get samples of scientifically interesting material from the surface of Mars and return it to earth.

The current approach is to divide the mission into two elements, The first is a scientific Rover to scour the surface of Mars for the most interesting samples, which will then be cached somewhere. The second phase is to send a second mission to fetch the cached samples and take them to an ascent vehicle which will return them to earth. The cached samples should be found and recovered rapidly.

The environment is very hostile and communications are limited to short periods typically 15 minutes every 12 hours. In addition the delays to radio signals mean that tele-operation is impossible. The missions must, therefore, be autonomous and robust yet be operated using systems that require minimal mass, power and processing resources. Getting the mission managers to accept that autonomy is dependable and useful is essential to getting it embarked on the vehicle.

The problem consists of navigating in a GPS free environment, avoiding hazards such as rocks, as well as less obvious ones like sand traps. The vehicle must ensure it does not simply drive past interesting science but must also repair its operations plan when circumstances change to ensure resources are not exhausted or communications sessions missed.

Satellite Servicing

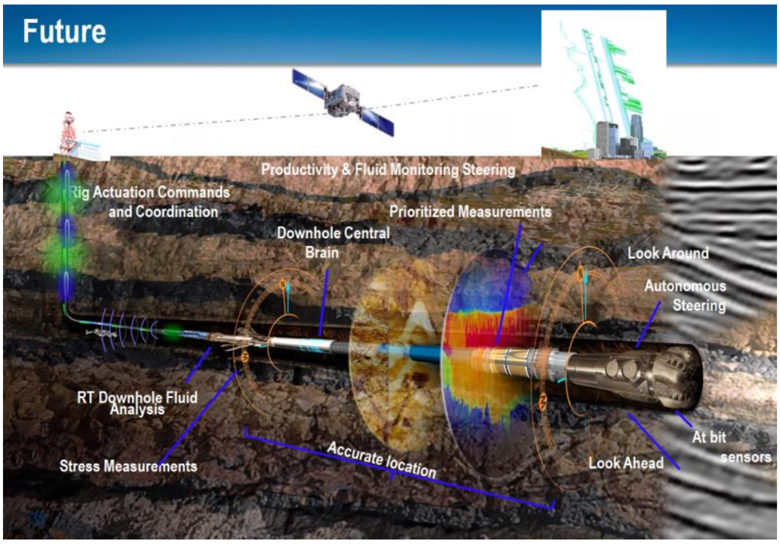


The possibility of on-orbit satellite servicing is becoming a growing reality. The vision is that free-flying service spacecraft would access, repair and refuel satellites either in geosynchronous Earth orbit or low Earth orbit adding precious years of functional life to spacecraft. This hinges on the spacecraft's ability to detect, accurately locate, approach, and ultimately match rates with the satellite to be repaired. Time delays in human communication, calculation, and commands, however, prevent ground controllers from directing the servicer quickly and precisely enough to execute the final capture phase of the rendezvous. The satellite to be captured would be un-cooperative and in the worst case be spinning in an unplanned way. Having reached the target the spacecraft needs to undertake an inspection flight around the satellite, and if assessed safe capture or dock.

The process of hardening chip technology to cope with the harsh environment means that computing performance will always be less than that available on Earth. A problem is that advanced stereovision & navigation systems have a high computational burden which conventional space avionics cannot support. Therefore this limited computing resource has to be used (and reused) as much as possible. Potentially there is a role for smart sensors with advanced data pre-processing capabilities able to pre-select relevant information and thus reduce the amount of redundant and irrelevant data. A further problem is that the system needs to cope with highly reflectively surfaces that may be spinning.

Once captured the spacecraft would undertake refueling/repair or potentially tow an unrepairable satellite into a safe orbit. The former would adaptable multiple function manipulator which will undertake high precision tasks (accuracy <10 mm). Thus there is a need for self-calibration of any robotic arm on a free floating platform.

Oil and Gas sector



Autonomous drilling systems as part of an oil well drilling team

There are numerous challenges in safely and economically finding and producing hydrocarbons to meet the world increasing energy demands, until renewables can fill the gap. The challenges can be broadly characterised as:

1) The surface, where we can put humans, however the remaining hydrocarbon reservoirs are often located in remote and difficult areas to access, under the sea, in deserts or jungles.

    1) Logistics of transporting humans, equipment and supplies, to maintain humans and machines are costly and complex.
    2) Social and lifestyle costs associated with keeping people at the well site for long periods of time. Work is organised around 12 hour shifts, however in some circumstances can be much longer. As a result it is difficult to recruit and retain the best people.
    3) Safety risks associated with the: rigs which are complex large machines moving large mass there is therefore always the risk of injury, the uncertainties in the subsurface pressure and inflammable hydrocarbons and poisonous gases, and the dangers associated with transport e.g. helicopters.

For these reasons we are moving to minimally manned rigs, possibly unmanned, which can be controlled by high level goals from a control centre. This requires the development the rig as an autonomous system capable of acting as part of the drilling team, making and communicating its own decision about the local environment and how to achieve the goal set for it by the command centre. In addition we would look to take advantage of the systems capability, such as being able to perform multiple parallel coordinated tasks at higher speeds than humans can, to improve performance, capability and consistency.

2) The subsurface, where we cannot put humans. As with the surface the remain hydrocarbons are difficult to reach from the surface, they are deeper further away, at higher temperatures, in more complex geological and fluid pressure regimes, in less productive rocks. The

objective is again to develop an autonomous drilling system that can navigate in the subsurface to the desired part of the reservoir, as with the rig acting as part of the drilling team, which includes the rig and the command centre. In many ways this looks like a SLAM (Simultaneous Localisation And Motion) problem the major challenge here is to deal with the environmental and technical constraints, which are:

1) Navigation, there is no GPS, navigation is generally done from the surface as the drill bit has no idea of the length of the hole, only inclination and azimuth.
2) Communication from downhole to surface is slow, 10 bits/sec, and high latency, form surface to downhole communication is slower.
3) Temperature limits processions and memory, currently we operate up to 175 degC
4) Tool size and packaging are small, tools are generally packaged in 5 cm diameter tubs
5) Power is limited, some downhole generation is possible, however generally Lithium batteries are use.
6) Shock and vibration can be extreme, electronics has to be capable of sustaining high shock levels 2-500 g at a range of frequencies for tens of hours.
7) There is uncertainty in the absolute location of the target in the reservoir.

Aerospace Sector

Scenario: Multiple co-operating systems of manned and unmanned assets that could be in air, ground, and/or sea environments.

Effective and reliable communications

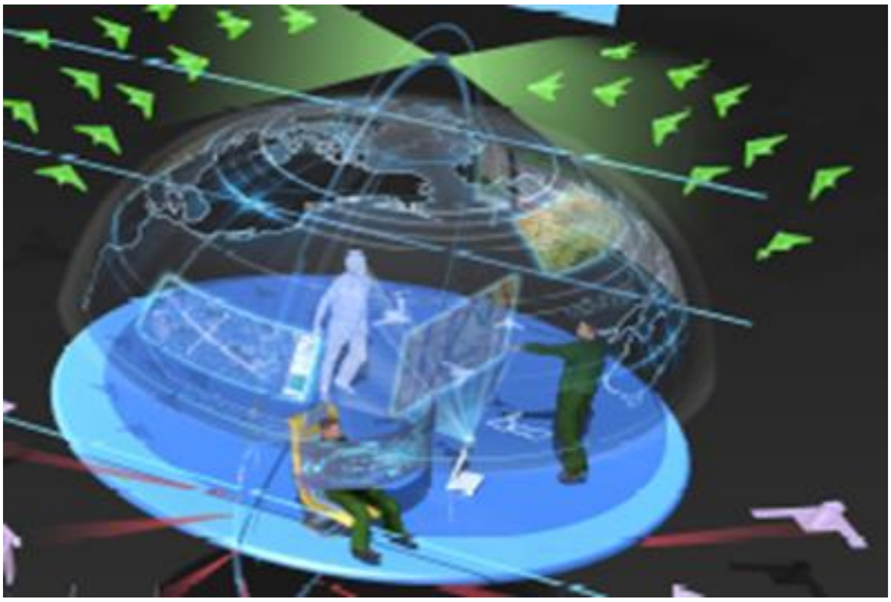
How is information collected and shared between systems so that every player has common understanding in an environment where communications may be congested with limited bandwidth available.

Development of a system that can autonomously determine what data needs to be shared, by whom and when, to increase the collective effectiveness of the 'team'.

Include features such as:

- knowledge extraction from data streams
- rapid data compression & de-compression
- secure communications and data link solutions
- data fusion
- encryption processes and delivery of relevant sensor data or meta-data

Human interface with the system at the right level - balance of awareness, trust, involvement for increased human/machine collective effectiveness



It is important from an operational perspective to understand how decisions emerge within complex systems. Autonomous systems will be expected to, and will be most effective, when working in partnership with humans, who will be responsible for the autonomous system, or collaborating with it. It is therefore vital for humans to be able to understand and have confidence in, i.e. trust, the autonomous system decision making rationale, particularly under conditions of limited or sporadic data link communications.

Autonomous decision making

Effective decision making across team of systems improves the performance of the task by reducing the workload of the human operator e.g.

- Optimal task allocation
- Sensor to task matching
- Reacting to changing circumstances as a team

Development of dynamic autonomous mission management technologies that will enable the planning and employment of reconfigurable autonomous systems that have the capability to automatically respond to changes in the operational situation.

Programme and Cost model

The E_ERAS programme is envisaged as a 7 year programme with the target of achieving a tenfold increase in performance in the specified areas of extreme environments, through the development and application of autonomous and robotics systems technologies.

The programme will comprise a core set of partners to develop and provide: industrial demand; technical direction; and programme infrastructure, integration & governance. They will contribute resources, expertise and funds in a coordinated way to achieve gearing synergies and economies of scale.

Wider stakeholders will be engaged to explore common interests and further areas of synergy in: research & technology themes; supply chain & SME development; regional economic growth.

It anticipates that some 30 development projects of between £50k-£500k ranging from feasibility studies to representative demonstrations will be undertaken. The programme is scaled at £15m according to participant involvement in terms of funding, expertise and infrastructure resources provided.

The programme will:

- Examine and express emerging end user requirements and appropriate technology development road maps for the applications;
- Examine and adopt appropriate systems architectures for Robotics and Autonomous Systems applications;
- Identify and contract Higher Educational Institutes (HEIs) and other innovators with relevant technologies and develop them through the E_ERAS infrastructure;
- Develop and provide a component testing, sub-system test, integration and demonstration infrastructure;
- Disseminate programme progress to raise awareness so as to leverage the value investment externally and to illicit the benefit of other related development
- Provide a Programme Management & Governance support structure.

In addition it is anticipated that the scope will provide:

- A framework to advance research themes;
- a mechanism for innovator development and growth by connecting them with Academia and potential end users;
- A route to exploitation for the technologies to develop supply chains and business growth.

Next steps

The following steps are required to turn this scope into a partnership programme.

- The E-ERAS programme will now share this framework with interested parties to illicit further requirements and resources.
- Using the scope described here develop a consistent road map across the programme of work. The idea is to engage with the EPSRC/innovateUK to jointly fund with industry to generate a road map for this work, using a consistent model, such as the DSTL model.
- The road map will be used to carry out a horizon scan to see what is already out there that can full fill element of the road map and define gaps requiring research and development.
- The map will then be split into the different Technology Readiness Levels (TRLs) to enable grant funding to cover low TRL: Academic, mid TRL: Academic/Small to Medium Enterprise (SME) and high TRL: SME/Major industry.

This is only a high level outline of the steps going forward as programme management and governance across the programme will be required. These elements are described in the NRN delivery strategy.