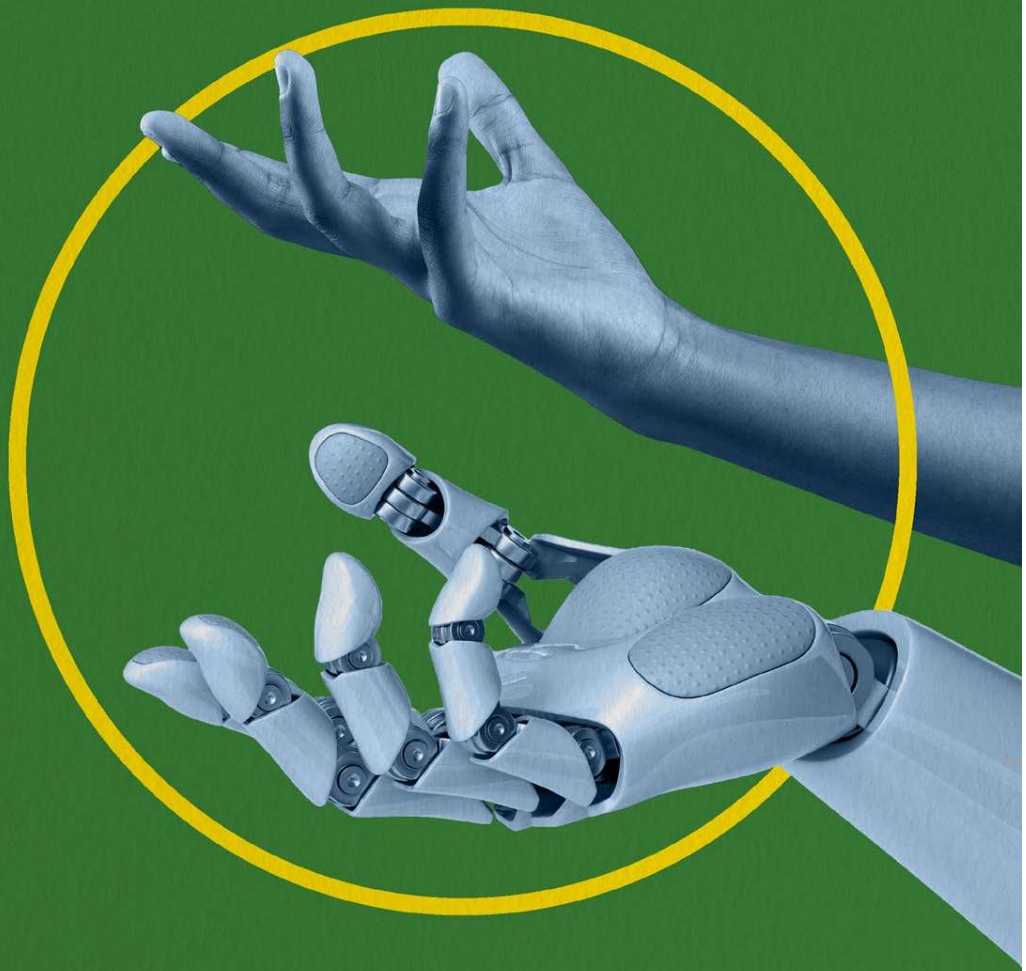
03 | Innovation

Engaging in **open innovation** to provide nuclear power for **space exploration**.



At NNL, we have built a distinct identity as the UK's technical authority on nuclear fission but no single area of expertise resides in just one organisation.

Engaging in open innovation is fundamental to our work in science and technology. By partnering with the brightest minds across academia, government and industry, we are able to find solutions to some of the world's most pressing scientific challenges, keep our scientists and researchers at the cutting-edge and ensure we're delivering impact.

Across the nuclear sector, we are developing new and pioneering solutions to minimise the contact dose to operators when handling radioactive materials. As part of this, over the past year, we have been working with Cumbrian small and medium-sized enterprise *(SME)*, Resolve Robotics, to build a pair of mechanical hands. Created to support the European Space Agency's *(ESA)* forthcoming lunar mission in the first instance, the mechanical hands will in future be deployed in applications beyond space.

A model of the Mars Perseverance rover; powered by Am-241 power cells

Quality

Science and technology to fuel the European Large Logistic Lander on the moon

"Previously, the European space programme lacked an independent capability in nuclear power sources. Such systems are vital enabling technologies for many exciting missions to the outer solar system or to the moon and Mars surface. NNL has developed and proven a process to create radioisotope fuel in a sustainably affordable way, and has provided the foundation from which a European space nuclear power programme can be launched. It's essential for ESA that such activities are conducted with the highest standards of safety and technical rigour. NNL is a valuable partner in this regard."

Keith Stephenson
European Space Agency

Nuclear fuel, through Radioisotope Power Sources *(RPSs)*, is critical for deep-space exploration. It remains the only way to fuel long-term, long-distance missions which are key to furthering global understanding of the solar system and Earth's creation.

In the late 2020s, ESA will launch the maiden flight of its European Large Logistic Lander *(EL3)*. EL3 aims to deliver payloads ranging from 1,500 to 1,700 kg anywhere on the lunar surface. It will conduct both science and logistic cargo missions and will provide survival and operation through the two-week long lunar night.

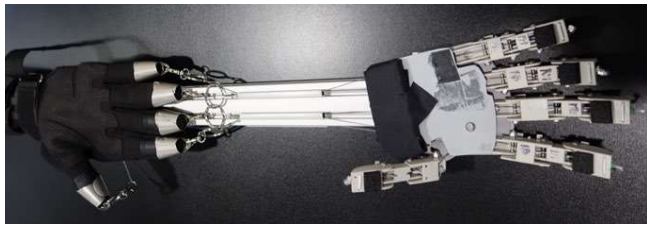
This capability is contingent on securing a volume of americium-241 *(Am-241)* and NNL is uniquely placed to provide it.

Typically, RPSs are fuelled by plutonium-238 *(Pu-238)*; however, supplies of this isotope are limited, costly and entirely dependent on the United States of America and Russia as producers. In partnership with ESA and the University of Leicester, our experts at NNL have identified a new and more affordable alternative – Am-241.

With a half-life of around 430 years, compared to around 90 years for Pu-238, Am-241 can be separated from aged plutonium dioxide, of which the UK has a civil stockpile on the Sellafield Ltd site. As well as producing an indigenous supply of Am-241, boosting our national reputation as a sovereign space-faring nation, we are helping to recycle used nuclear materials.

"Americium-241 based radioisotope power systems will be transformational in providing a power source, complementary to Pu-238 and other larger reactor-based systems, for planetary surface and deep space exploration missions. The UK has the expertise, know-how and facilities to be at the forefront of space nuclear power enabled science and exploration missions."

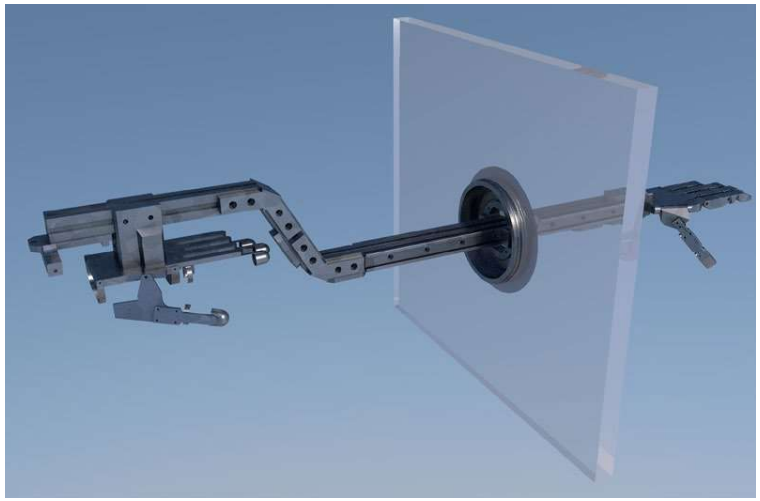
Prof. Richard Ambrosi
Space Park Leicester
Executive Director



Top left
Early prototype unit of the mechanical hand developed with Resolve Robotics

Bottom left
The mechanical hand prototype being demonstrated to glovebox operators at our Workington Laboratory

Right
3D CAD drawing of the deployable units



To perform the separation of Am-241, operators typically place their hands in a pair of gloves attached to the glove box and directly handle part of the radioisotope. In doing so, the operator receives a safe and small contact dose, regulated by our robust dose-management procedures.

However, to extract the volume needed for the mission, around 500g per year, continuous hands-on operations are required. Our primary challenge was to find a way to maintain this, whilst guaranteeing the operator's contact dose remains at a safe level. We also wanted to ensure the solution would be cost effective, low carbon, durable and quick to design and deploy. needed for the mission, around 500g per year, continuous hands-on operations are required. Our primary challenge was to find a way to maintain this, whilst guaranteeing the operator's contact dose remains at a safe level. We also wanted to ensure the solution would be cost effective, low carbon, durable and quick to design and deploy.

Partnerships

Our solution: driving innovation through collaboration

In 2020 we launched an Open Innovation campaign to promote our challenge to over 50,000 cross-sector innovators, internationally.

Following a 12-week feasibility study, the technology put forward by Resolve Robotics was selected as the winning solution. Crucially, as well as addressing the challenge, this solution met our criteria for cost, carbon, durability and deployability.

Leveraging Resolve Robotics' experience in puppetry and animatronics and our capabilities in handling radioactive materials, together, we have developed two mechanical hands – a left and a right – that allow the operator to carry out the separation of Am-241 whilst reducing their contact dose.

With smooth edges and quick-release functionality, the mechanical hands act as an extension of the operator's own hands. Importantly, this solution also enables the operator to retain their line of sight so they can directly see what they are doing. Throughout the development phase, we were able to use a mock-up glovebox at our Workington Laboratory to demonstrate prototypes of the mechanical hand.

"Collaborating with Resolve Robotics has been incredibly fruitful, with working prototypes developed and tested in a matter of months. The innovation of applying puppetry more typically seen in film industry applications, to allow safer handling of active material, cannot be understated. Working with an external company has enabled me to develop ideas with engineers from an entirely different industry and look to solve a real nuclear handling related issue."
James Rigby, Mechanical Engineer, NNL

The mechanical hands are set to be deployed in an active glovebox in 2022.

"Working with NNL has been transformative not just for our business but also for our ability to create innovative solutions for the nuclear sector. Our background is in robotics but aligning this with NNL's expertise in handling radioactive materials means that we've been able to deliver a new product that is fit for purpose and will directly contribute to future space exploration."

Andrew Ludar-Smith
Technical Director of Resolve Robotics

Impact

What we have achieved:

Embraced open innovation to create an entirely new and cost-effective solution that both meets the contact dose management challenge at hand and, as a sign of its quality, supports the delivery of a multi-million pound programme for ESA;

Stimulated the supply chain by partnering with a Cumbrian SME, helping to promote regional growth and ensure the North West of England can continue to offer high-quality and high-skill employment;

Built a positive and collaborative working relationship with a partner organisation who bring expertise beyond just the nuclear sector. As part of this, we worked with the team at Resolve Robotics to ensure a fit-for-purpose solution was delivered in less than a year, providing them with access to our facilities at Workington where they were able to test, trial and demonstrate the solution;

Employed technology and expertise from the film and TV special effects industry to solve a unique, nuclear challenge. Through this cross-sector collaboration, we have been able to produce a technology which has the potential to be deployed more widely across other glovebox scenarios, including in the handling and repackaging of cans of plutonium for longer-term storage.