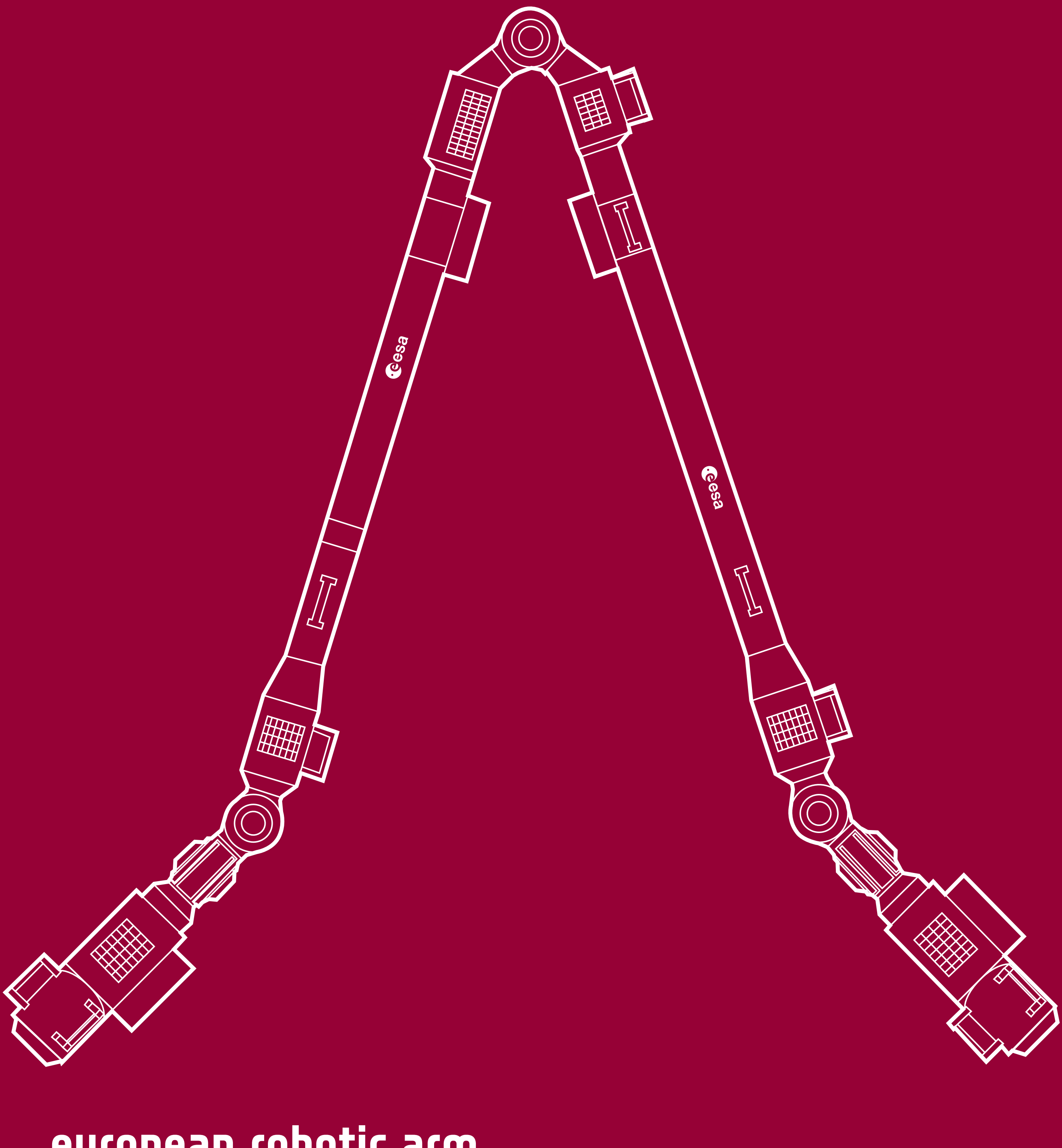

# european robotic arm

## THE INTERNATIONAL SPACE STATION'S LATEST UPGRADE

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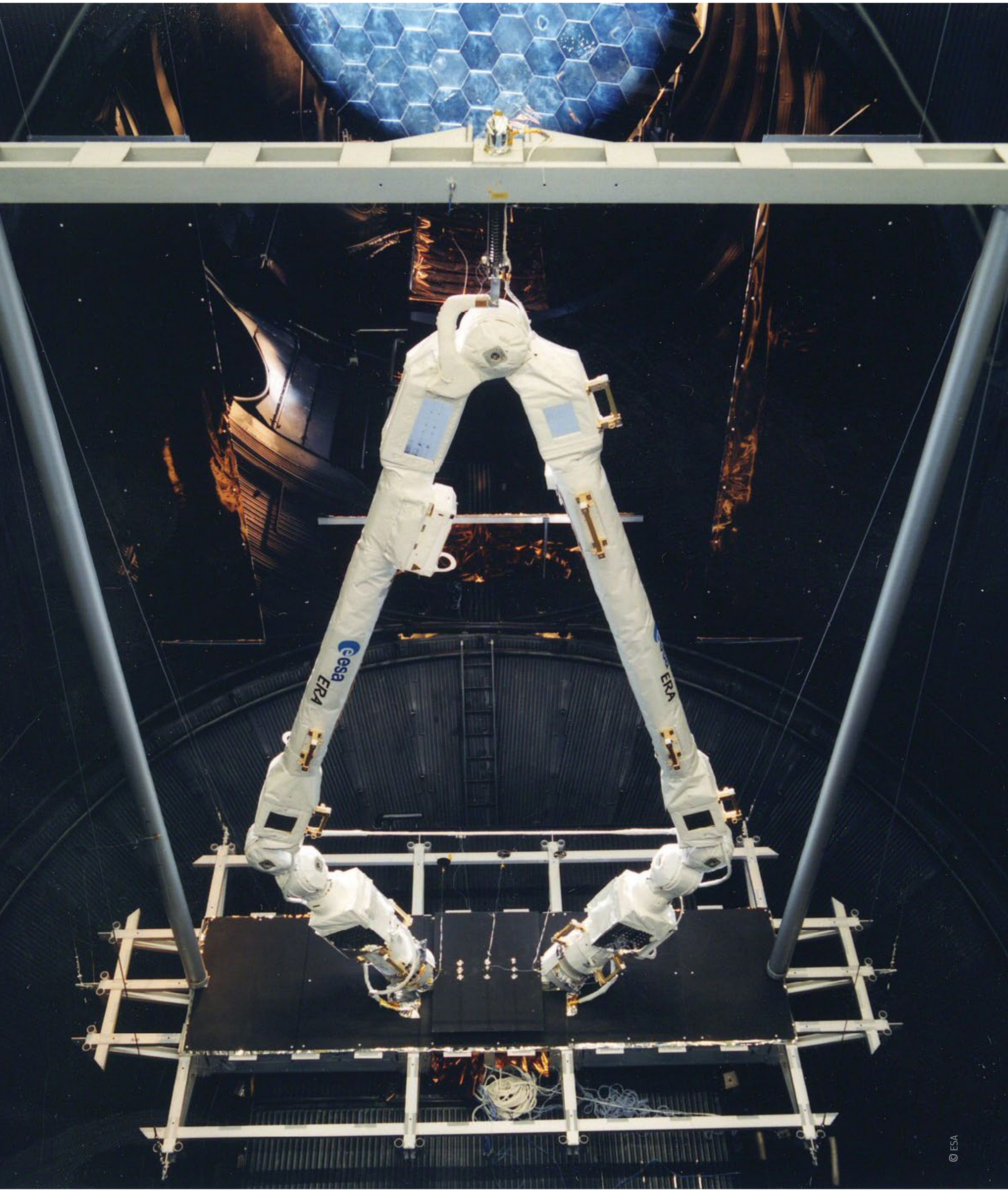
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# SMART SPACEWALKER

## A new robot to handle the Space Station

**It is much like a human arm. It has an elbow, shoulders and even wrists. The European Robotic Arm (ERA) is the first robot able to 'walk' around the Russian segment of the International Space Station.**

Light yet powerful, the orbital arm has the ability to anchor itself to the Station and move back and forward by itself, hand-over-hand between fixed base-points. This space robot looks like a pair of compasses and has a length of over 11 m. When stretched, it could pass a football from a penalty spot to the goalkeeper.

The robot will serve as main manipulator on the Russian part of the Space Station. Its seven joints can handle multi-tonne payloads with a large range of motion for assembly tasks.

The arm and its two control stations – one for inside and another for outside the orbital outpost – will be launched into space together with the Multipurpose Laboratory Module, called 'Nauka', from the Baikonur Cosmodrome, in Kazakhstan, on a Russian Proton rocket. The launch is set for the summer of 2021, after two decades of technical and programmatic challenges.

The robotic arm brings new ways of operating automated machines to the orbital complex. ERA has the ability to perform many tasks automatically or semi-automatically, can be directed either from inside or outside the Station, and it can be controlled in real time or preprogrammed.

Once it starts working from its home base at the Russian Multipurpose Laboratory Module the robot arm can help install, deploy and replace elements in outer space. ERA's first tasks in orbit, after deployment and checkouts, are to set up the airlock and install a radiator for the latest module of the Space Station.

Astronauts will use the robotic arm to save time and effort in Space Station maintenance. It will act as a tool to transfer small payloads directly from inside to outside the Space Station without the need for spacewalks, but will also help spacewalkers by transporting them around like a cherry-picker crane. Its four infrared cameras will support inspections and operations outside the Space Station.

## Why ERA?

The International Space Station already features two robotic arms: Canadarm2 and the Japanese Experiment Module Remote Manipulator System. Both play a crucial role in berthing visiting vehicles and grappling external payloads on the US and Japanese modules.

However, the Canadian and Japanese arms cannot reach the Russian segment of the Space Station. The different types of base points and payload mounting units do not allow to operate them in other parts of the Station.

ERA comes to the stage to service the Russian segment. Even though the Multipurpose Laboratory Module will be its home base, ERA's design and flexibility provide the freedom to move hand-over-hand around the Russian parts of the Station. It will supplement the two 'Strela' cargo cranes.

The mounting points on the Russian segment are optimised for the robotic arm. There is no need for ERA to manipulate spacecraft – Russian spacecraft dock automatically.

### Facts and figures


**ERA's 11 m structure can manoeuvre 8-tonne payloads.**

**It is a true autonomous robot, fully programmable.**

**It can be operated by the crew from both inside and outside the Space Station.**


**It teleoperates with an accuracy of 5 mm.**

**It is designed to cope with the hazards of outer space.**

**It is reversible – a hand can become a shoulder, and vice versa.**

**Arm length:** 11.3 m

**Reach:** 9.7 m

**Tip position accuracy:** 5 mm

**Maximum speed of operations:** 10 cm/s

**Degrees of freedom:** 7

**Launch mass:** 630 kg

**Handling capability:** 8000 kg

**Control:** Autonomous or by astronaut commands

**Main construction materials:** Carbon fibre and aluminium

**Home base:** Multipurpose Laboratory Module (Nauka)

**Range of motion:** Hand-over-hand on the Russian Space Station segment

## Tasks

ERA arrives at the International Space Station with a varied to-do list in cooperation with the crew. This includes:

- installing, removing or replacing experiment payloads and large Station elements.
- transferring small payloads in and out of the Station through the Russian airlock.
- transporting crew members from one external working site to another.
- freeing cosmonauts to do other work during spacewalks.
- using its cameras to inspect the outside of the Space Station.

# SEVEN DEGREES OF FREEDOM

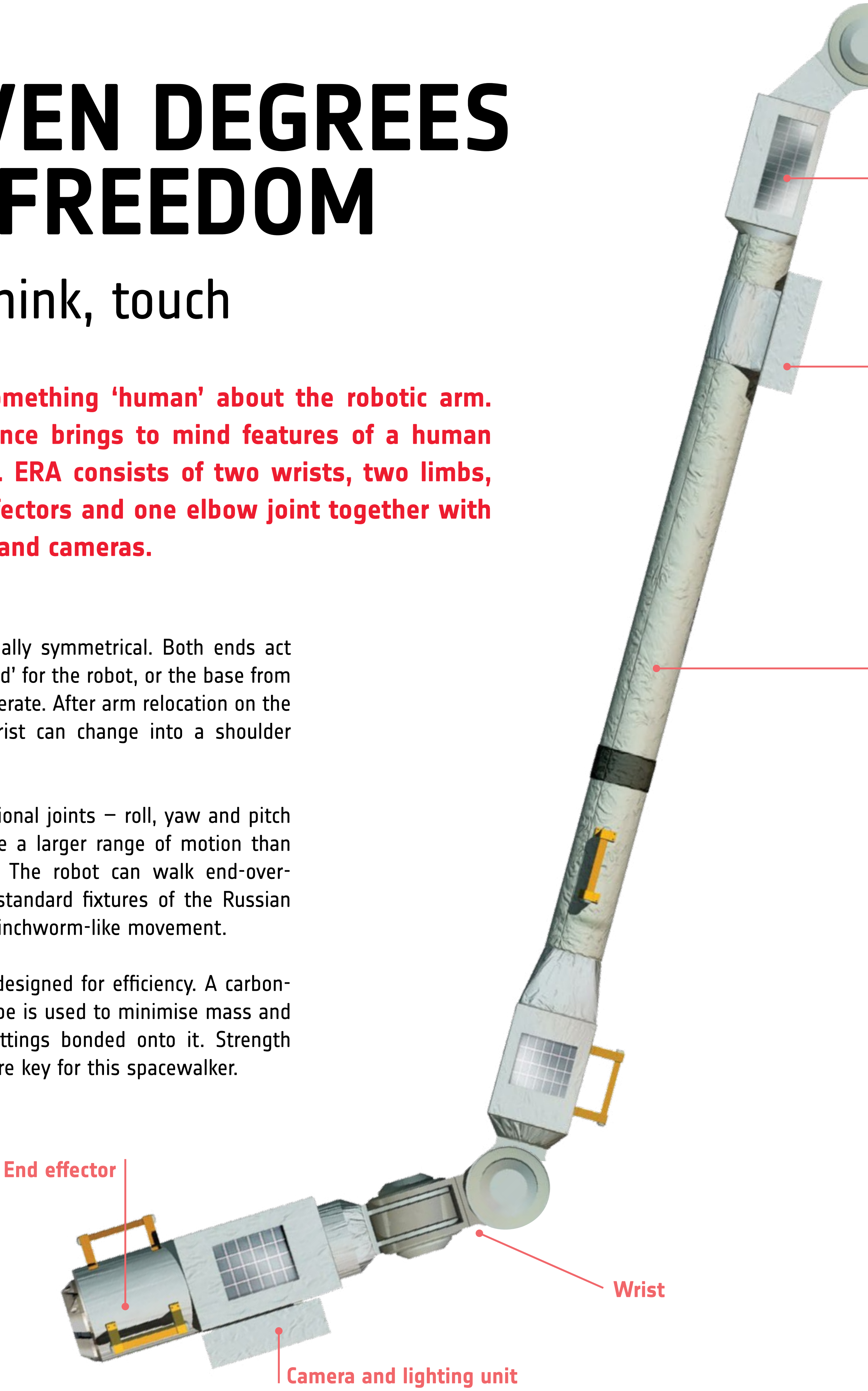
## See, think, touch

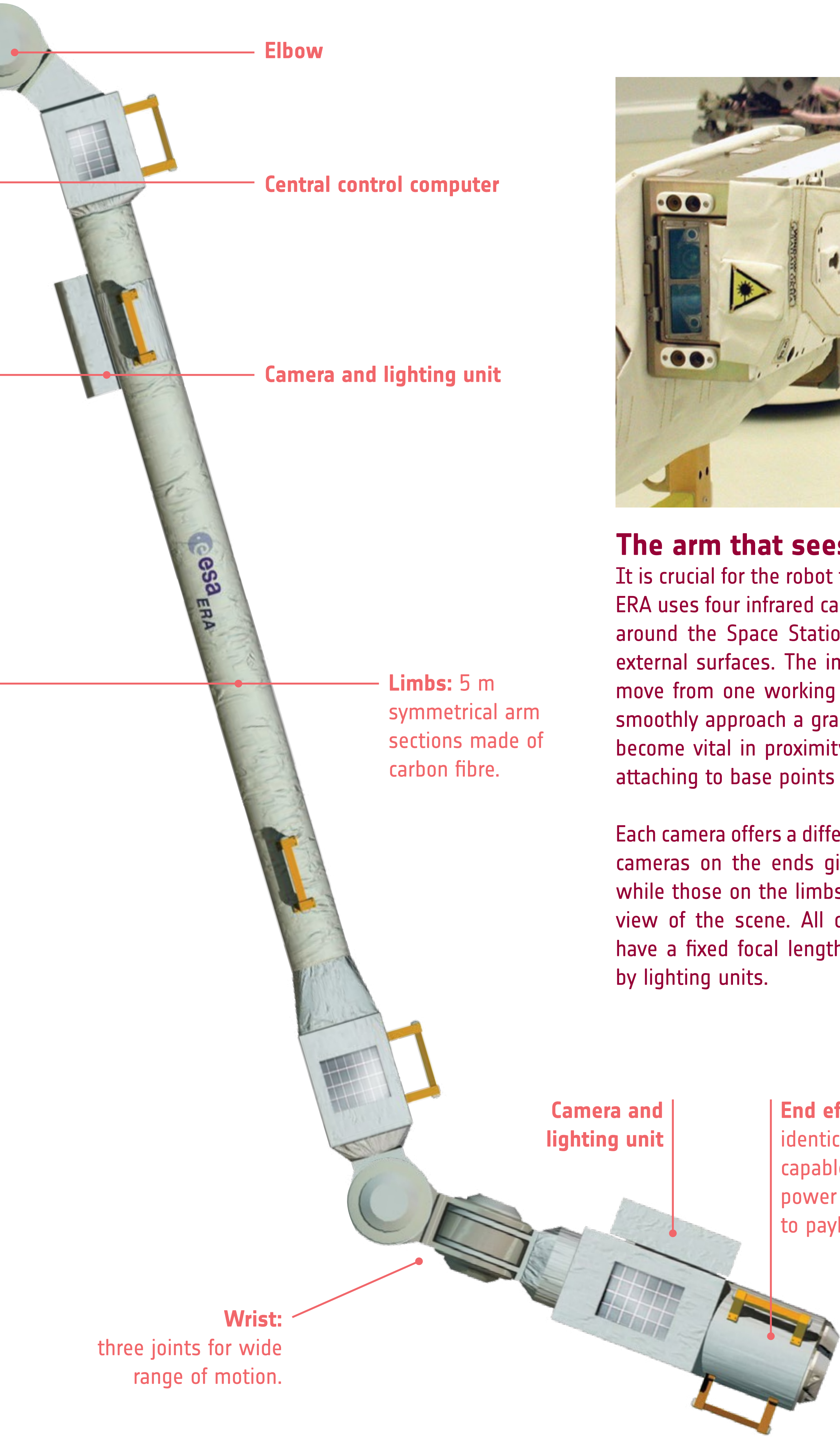
**There is something 'human' about the robotic arm. A quick glance brings to mind features of a human upper body. ERA consists of two wrists, two limbs, two end effectors and one elbow joint together with electronics and cameras.**

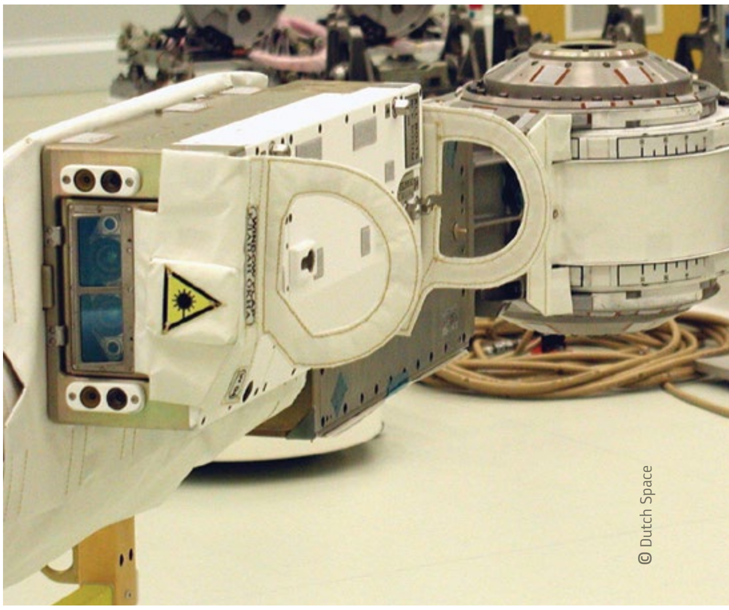
ERA is functionally symmetrical. Both ends act as either a 'hand' for the robot, or the base from which it can operate. After arm relocation on the Station, the wrist can change into a shoulder and vice versa.

Its seven rotational joints – roll, yaw and pitch joints – provide a larger range of motion than a human arm. The robot can walk end-over-end grappling standard fixtures of the Russian segment in an inchworm-like movement.

The limbs are designed for efficiency. A carbon-fibre-wound tube is used to minimise mass and has titanium fittings bonded onto it. Strength and flexibility are key for this spacewalker.





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## The arm that sees

It is crucial for the robot to know where to go. ERA uses four infrared cameras to find its way around the Space Station and to inspect its external surfaces. The images enable ERA to move from one working area to another and smoothly approach a grapple fixture. Cameras become vital in proximity operations such as attaching to base points or fetching payloads.

Each camera offers a different field of view: the cameras on the ends give close-up footage, while those on the limbs provide a bird's eye view of the scene. All of the camera optics have a fixed focal length, and are supported by lighting units.

## The brain

The central control computer is embedded next to the elbow and interfaces with other parts of the arm. This 'brain' runs automated sequences under the supervision of a human operator. These commands allow astronauts to closely supervise ERA's tasks and actions.

ERA is able to rethink its movements. During arm motion, several control loops add layers of safety. Proximity sensors and real-time collision avoidance algorithms compensate for misalignments as the arm approaches the target. Torque and force sensors also provide a sense of touch that prevents errors during payload pick-up and insertion.

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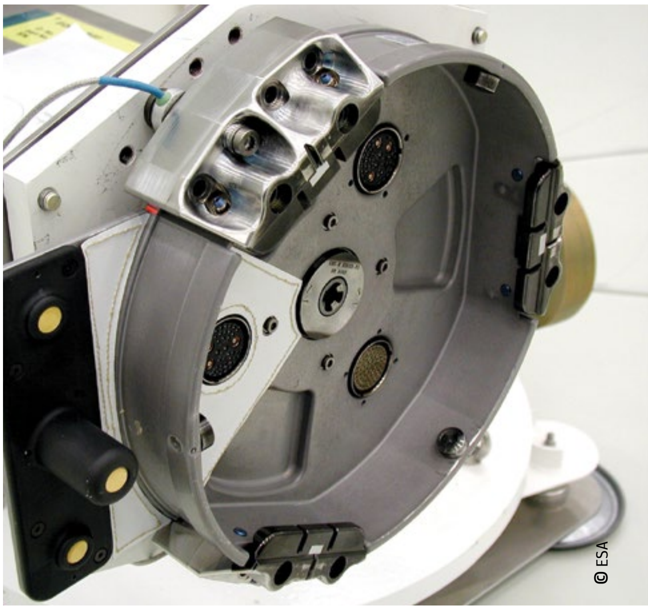

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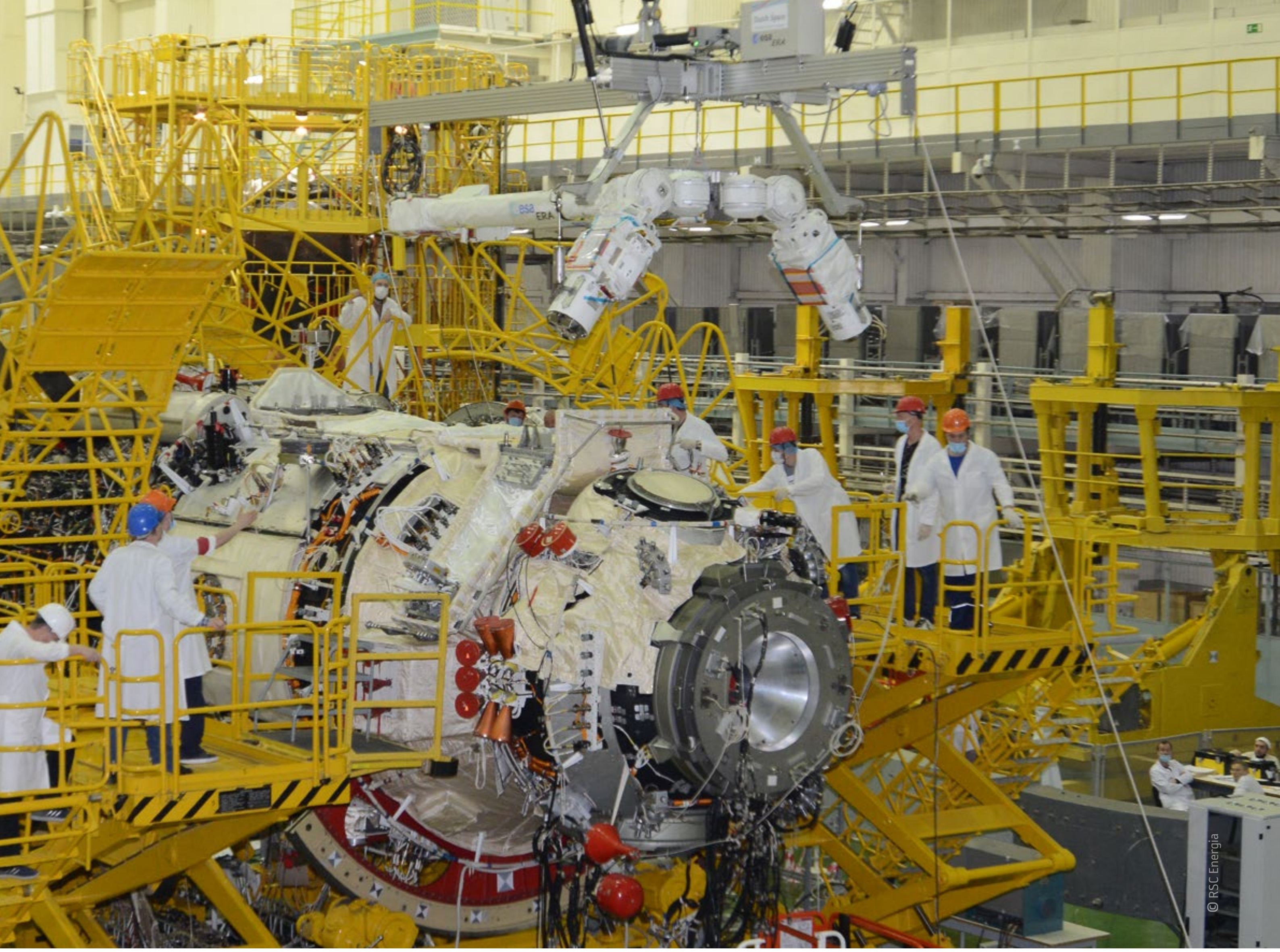
## Hands-on robot

The ends of the robot are at the centre of the action. These mechanisms are used for either grappling payloads and moving them to different locations, or for attaching ERA to one of the multiple base points on the external surface of the Station.

ERA offers mechanical actuation to a payload using a built-in motorised screwdriver with programmable torsion and rotational speed. The arm is capable of carrying out hands-on operations with maximum safety. All functions have a mechanical override, which is available to crew members if necessary.




# INTO MOTION

## Space embrace

**The European Robotic Arm will reach low Earth orbit together with what will be its home base in space, the Multipurpose Laboratory Module, also known as Nauka ('science' in Russian).**

All 11 m of the arm will travel mounted in the 'Charlie Chaplin' launch configuration, a nickname given by ERA engineers due to the resemblance of the arm's layout to the classic comedy actor's stance.

ERA will be coupled in this fashion to Russia's primary research module on the Space Station. Both elements are integrated and launched on the powerful Proton-M rocket, with a Breeze-M upper stage.

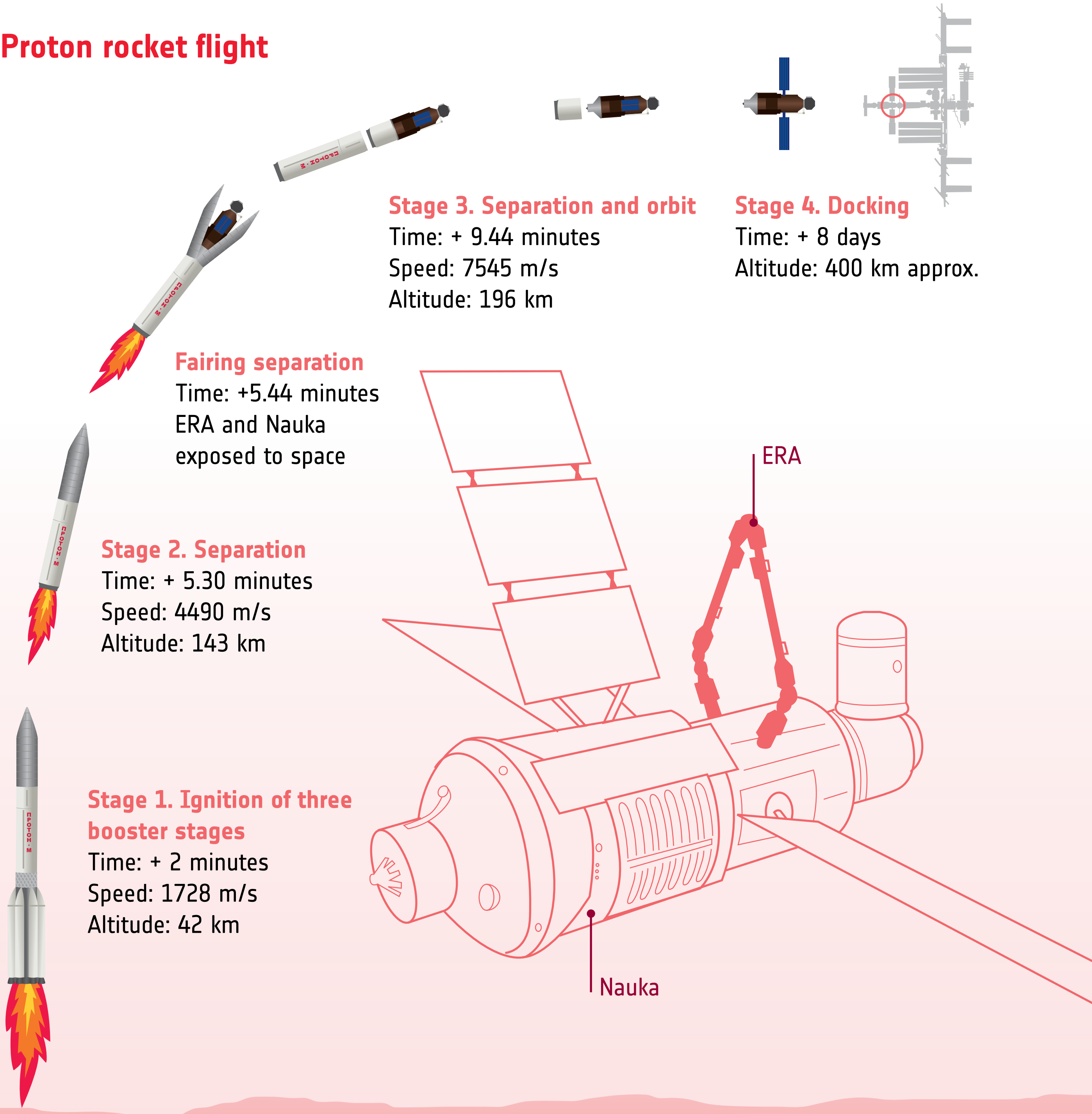
## LAUNCH

| | |
|---|---|
| Launcher | Proton-M |
| Launch site | Baikonur Cosmodrome, Kazakhstan |
| Launch date | 15 July 2021, 19:18 CEST |
| Docking | 23 July 2021 |

Proton is Russia's **largest operational vehicle** and a crucial asset in deploying the Space Station, it served as a heavy-lift launcher to build the Russian Mir space station and to send spacecraft to the Red Planet with the **ExoMars programme**.

This three-stage and **57 m booster** is capable of launching about 22 tonnes to low Earth orbit.

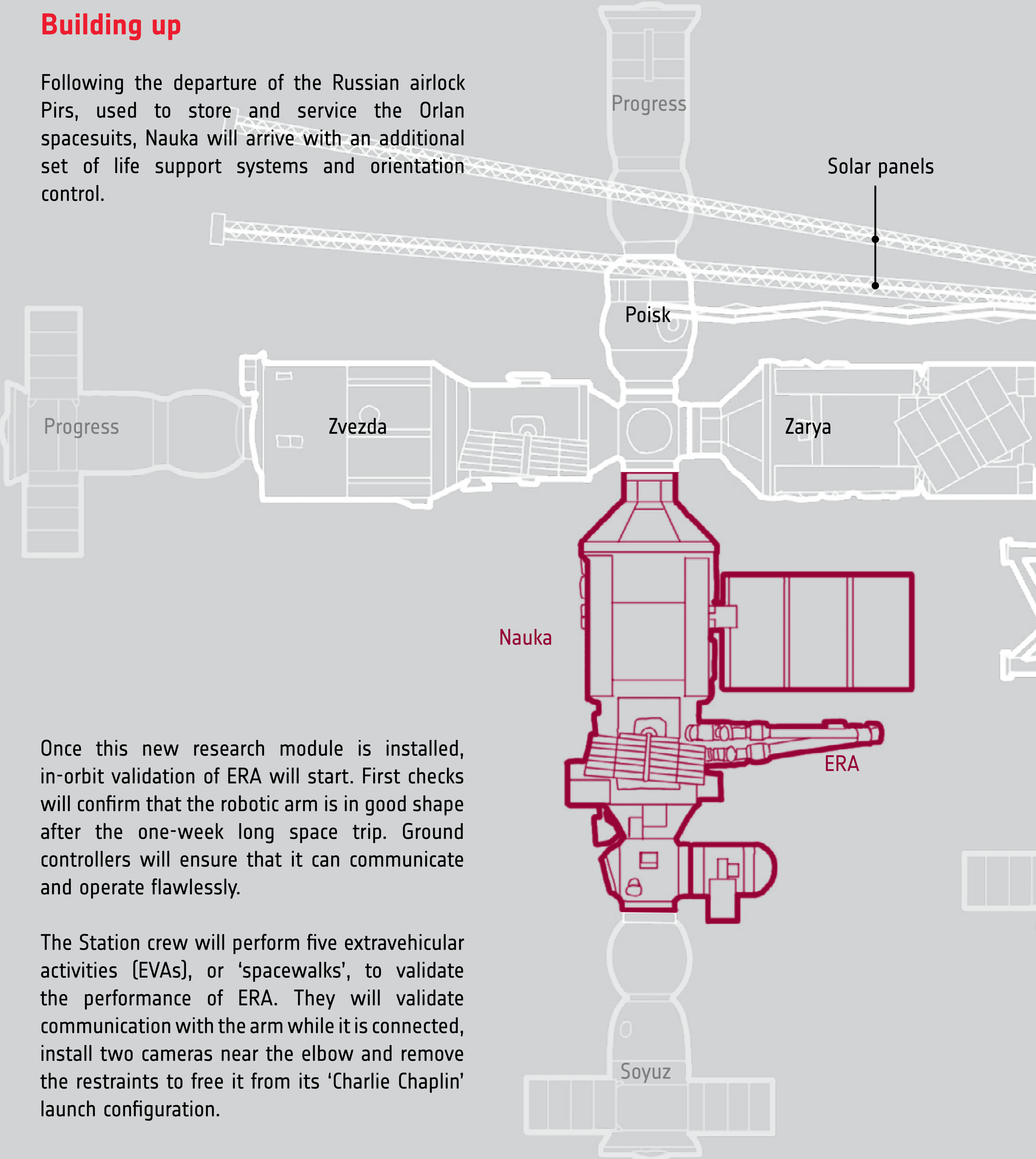
## Proton rocket flight




Following launch, it will take Nauka about a week to slowly raise its orbit and catch up to the Space Station. On arrival, the Russian module will dock automatically with its own engines to Zvezda. Nauka, Zarya and Zvezda are the only three modules on the Station that can provide manoeuvring capability.

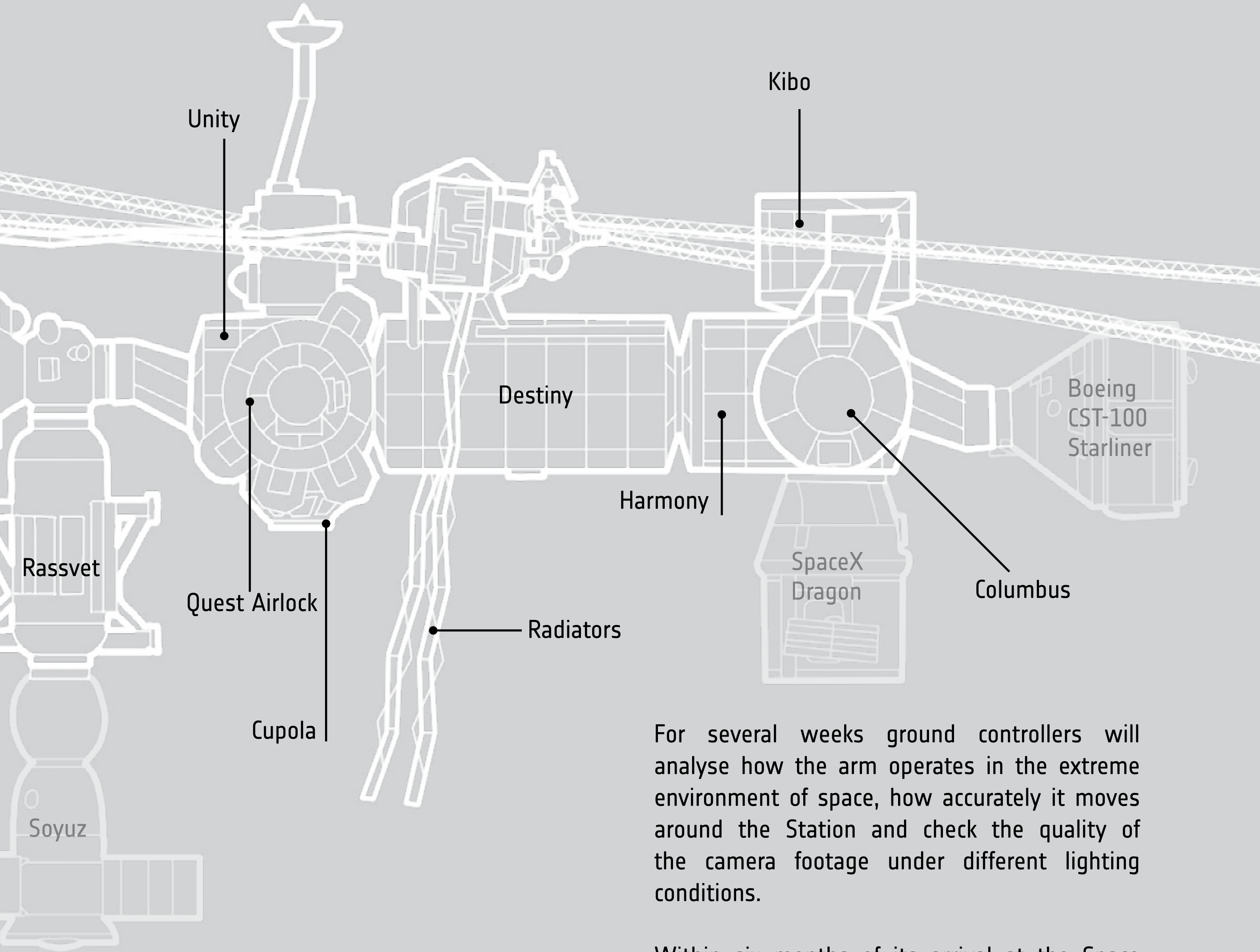
## Building up

Following the departure of the Russian airlock Pirs, used to store and service the Orlan spacesuits, Nauka will arrive with an additional set of life support systems and orientation control.




Once this new research module is installed, in-orbit validation of ERA will start. First checks will confirm that the robotic arm is in good shape after the one-week long space trip. Ground controllers will ensure that it can communicate and operate flawlessly.

The Station crew will perform five extravehicular activities (EVAs), or 'spacewalks', to validate the performance of ERA. They will validate communication with the arm while it is connected, install two cameras near the elbow and remove the restraints to free it from its 'Charlie Chaplin' launch configuration.




For several weeks ground controllers will analyse how the arm operates in the extreme environment of space, how accurately it moves around the Station and check the quality of the camera footage under different lighting conditions.

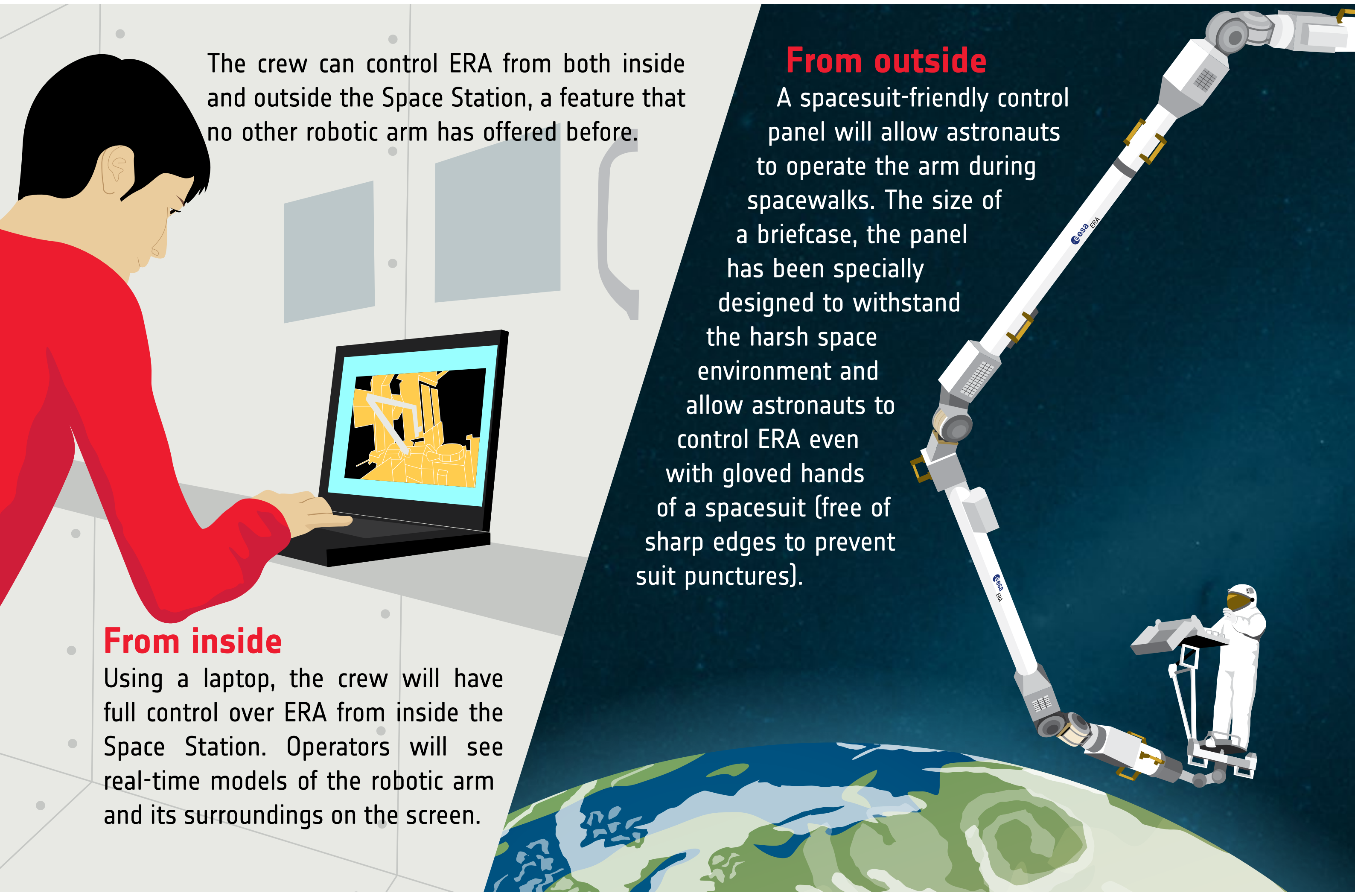
Within six months of its arrival at the Space Station, ERA will be ready to perform its first tasks. These include installing a radiator on the Multipurpose Laboratory Module, setting up the airlock and exchanging replaceable units, as well as inspecting external surfaces and transporting a cosmonaut on the tip of the arm.

# A TRUE ROBOT

## When humans and machines team up

**Human and robot will work shoulder-to-shoulder in space. Astronauts will find in ERA a most valuable ally – it will save crew members precious time and free them to do other work in space.**

Human–machine interfaces are the essential connections that allow the crew to control the robotic arm in orbit. Designed and tested by space experts, including astronauts, these interfaces reduce the preparation time for a spacewalk and will allow ERA to work alongside astronauts.



The crew can control ERA from both inside and outside the Space Station, a feature that no other robotic arm has offered before.

### From outside

A spacesuit-friendly control panel will allow astronauts to operate the arm during spacewalks. The size of a briefcase, the panel has been specially designed to withstand the harsh space environment and allow astronauts to control ERA even with gloved hands of a spacesuit (free of sharp edges to prevent suit punctures).

### From inside

Using a laptop, the crew will have full control over ERA from inside the Space Station. Operators will see real-time models of the robotic arm and its surroundings on the screen.

## Made in Europe

ERA is 100% made-in-Europe. A consortium of European companies led by Airbus Defence and Space Netherlands designed and assembled it for ESA. Up to seven European countries have participated in the industrial undertaking: the Netherlands, Italy, Belgium, Germany, Switzerland, Denmark and Sweden. The consortium also involved RSC Energia, from Russia, in ERA's development and production.

Every piece of ERA's hardware has undergone rigorous analysis to confirm that it is fit for space after its prolonged shelf life on Earth, and that can withstand the extreme conditions of launch and its time in orbit.

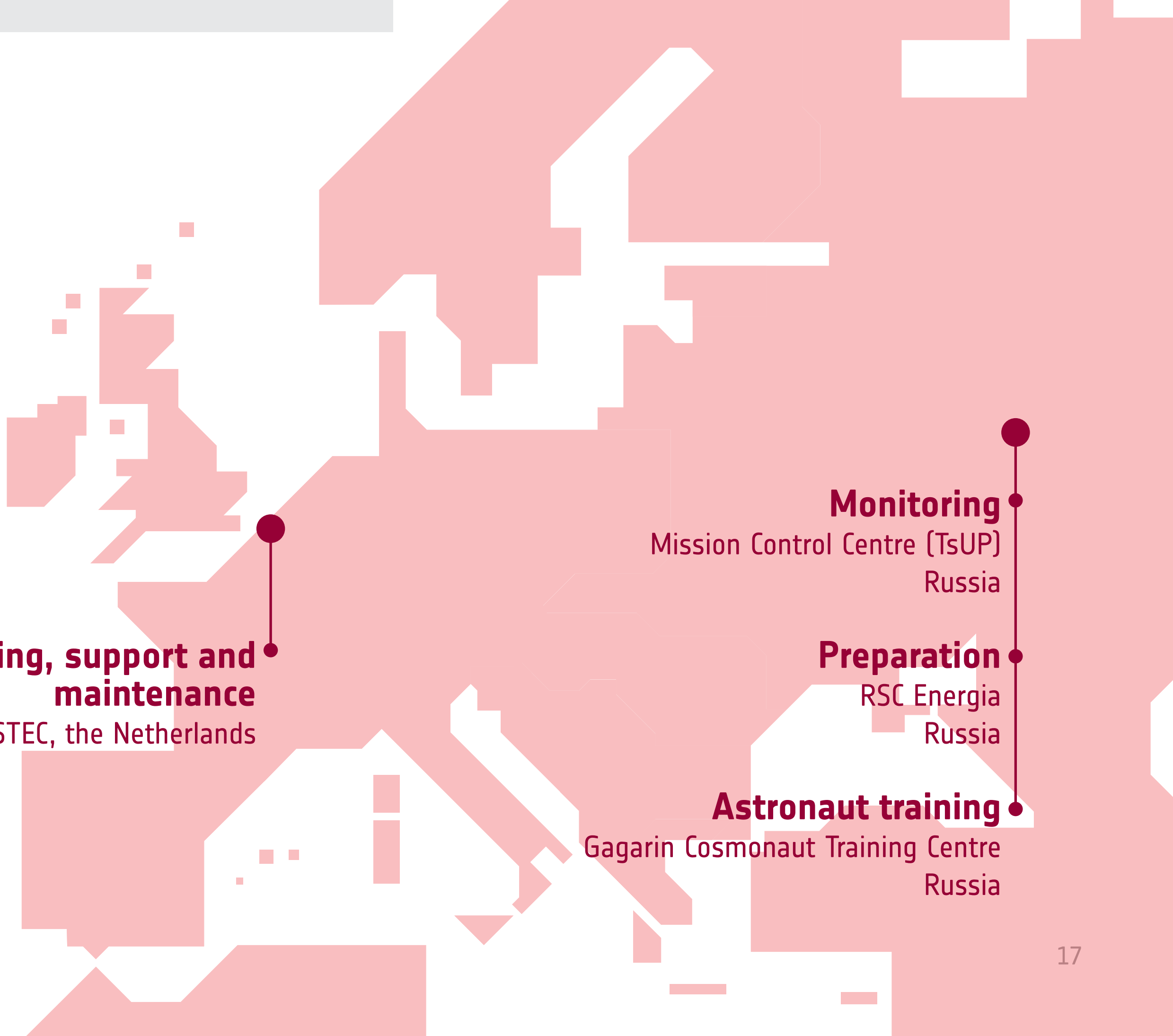
Tests proved that the arm can function in a vacuum and in extreme temperatures ranging from −150°C to +120°C, as well as withstanding exposure to radiation.

## How do you handle it?

ERA is ready to serve the Station for years to come. During this time, the Russian Mission Control Centre will monitor its operations, supported by ESA engineers at the ERA Support Centre at ESA ESTEC, in the Netherlands.

Astronauts from different missions will have to work hands-on with the robot. Separate sets of training equipment have been set up in three different locations for operators in space and on ground.

To complement astronaut training, a software application called the 'Refresher Trainer' provides astronauts with the capabilities to rehearse the missions. This simulator can prepare, store and replay mission sessions.



# ANOTHER EUROPEAN IN SPACE

## A story of perseverance

**Flexibility, resistance, functionality: the characteristics of the robot arm also apply to the European team that made ERA a reality after two decades of programmatic challenges. Now the project reaches a further milestone, this time in orbit.**

All is in place for the arrival of the arm in the summer of 2021. The spare units of the elbow and booms were launched back in 2010 on board Space Shuttle *Atlantis*, while mission preparation and training equipment for ERA has been refurbished to overcome obsolescence.

The story of ERA is one of perseverance – it has survived four changes of scenario, dealt with different space agencies and kept an international team motivated towards its final goal in space.

In the 1980s, plans were made for the European space shuttle Hermes. A robotic arm called HERA was designed as a cargo crane and for the maintenance of the space vehicle. The capability of the robot arm to relocate itself comes from the earlier need to step over from the Hermes spaceplane onto another spacecraft.

While the Hermes programme was discontinued, studies for a robotic arm to fly on the Mir-2 space station project began. These studies highlighted the value of a robotic manipulator in saving time during spacewalks.

Russia became a full partner of the International Space Station programme in 1993, so Mir-2 plans were abandoned and ERA elements were adapted to the Russian segment of the Station.

ESA and the Russian space agency Roscosmos signed a cooperation agreement for ERA in 1996. Since then, the systems of the robotic arm have been successfully qualified for space.

Delays have also been part of ERA's development. Budget shortfalls and changing plans modified its launch configuration, design and its home base on the Station. Its initial 'residence' on the planned Russian Science and Power Platform was replaced with the current Multipurpose Laboratory Module.

The long-awaited premiere of ERA in space is finally happening.

| Hermes | MIR-2 | ISS: Russian Science Power Platform | ISS: Multipurpose Laboratory Module |
|---|---|---|---|
| 80s | Mid 90s | 1996 - 2005 | 2005 - present |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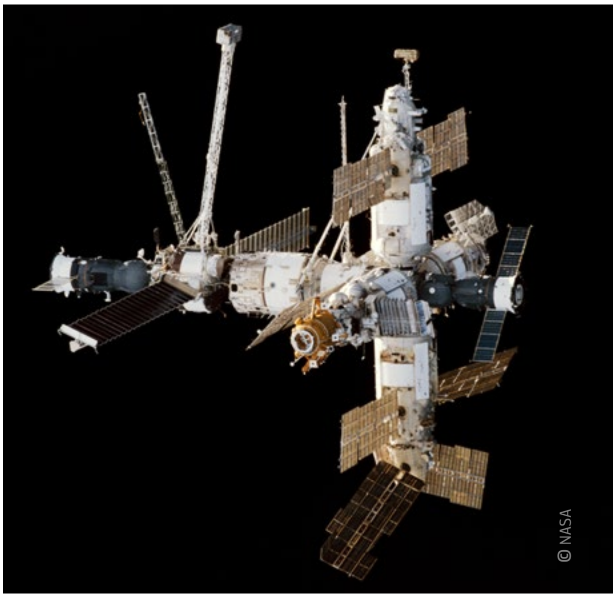
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## A European-Russian handshake

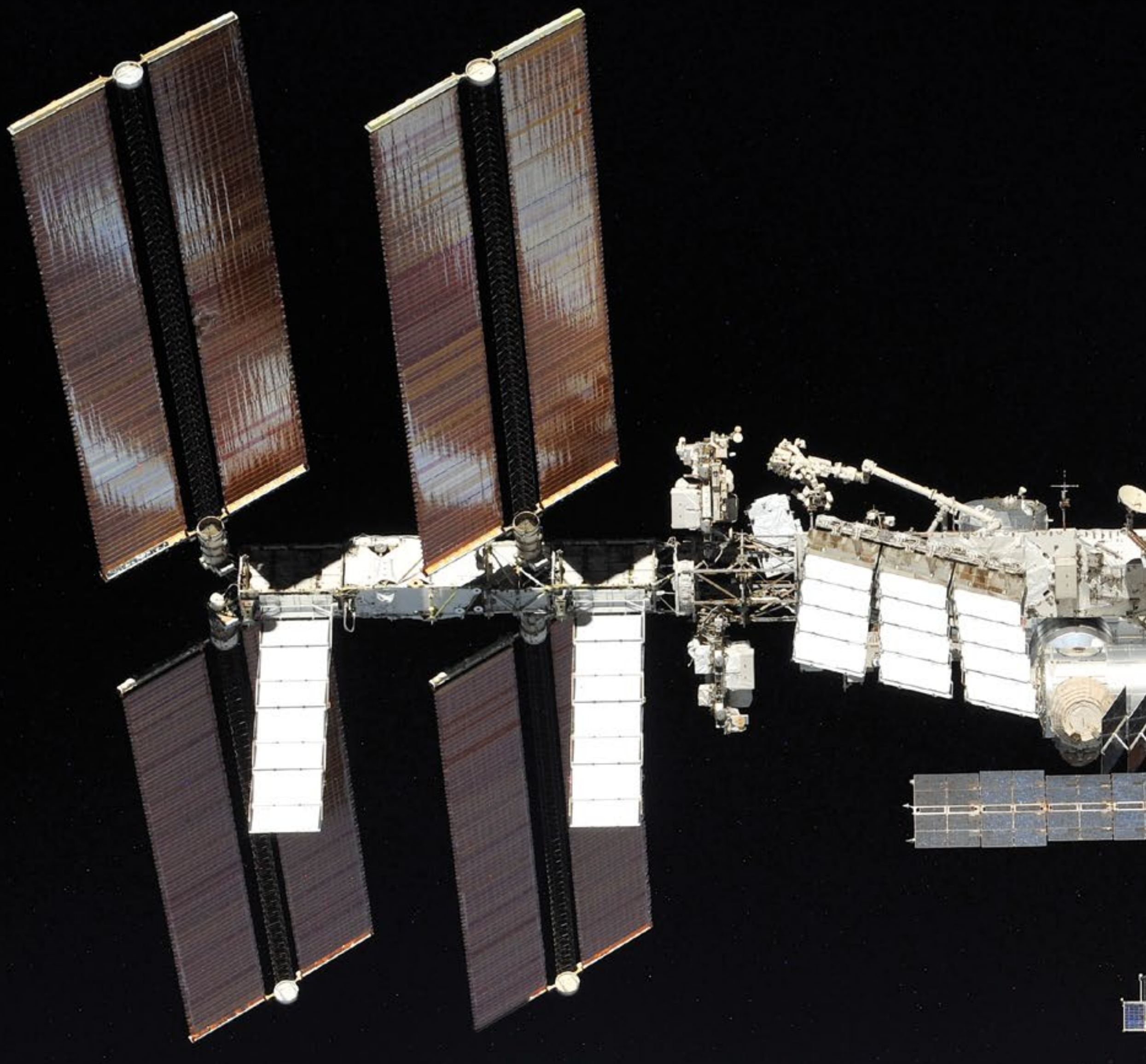
Europe and Russia have a long-standing cooperation in space. ERA is a cooperative venture between ESA and the Russian space agency Roscosmos.

It is not only the first robot arm developed for space by Europe, but also the result of two different cultures working together. ERA is in fact a bilingual robot: its interfaces are in both Russian and English.

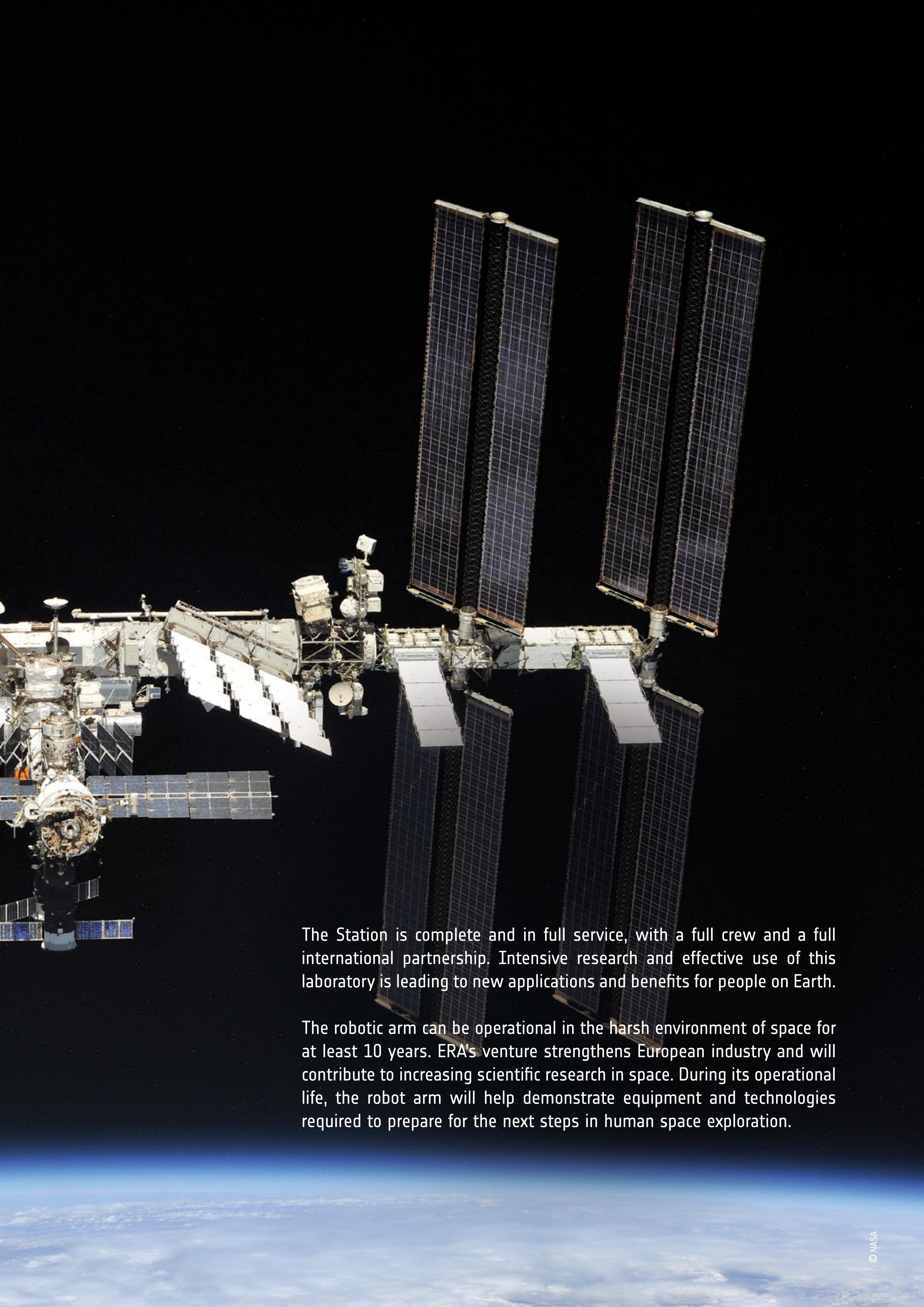
Once it reaches the Space Station, ERA will become an essential tool for the Russian segment. Trained cosmonauts will use it for installation and maintenance operations.

# UPGRADING THE STATION

## Next-level science

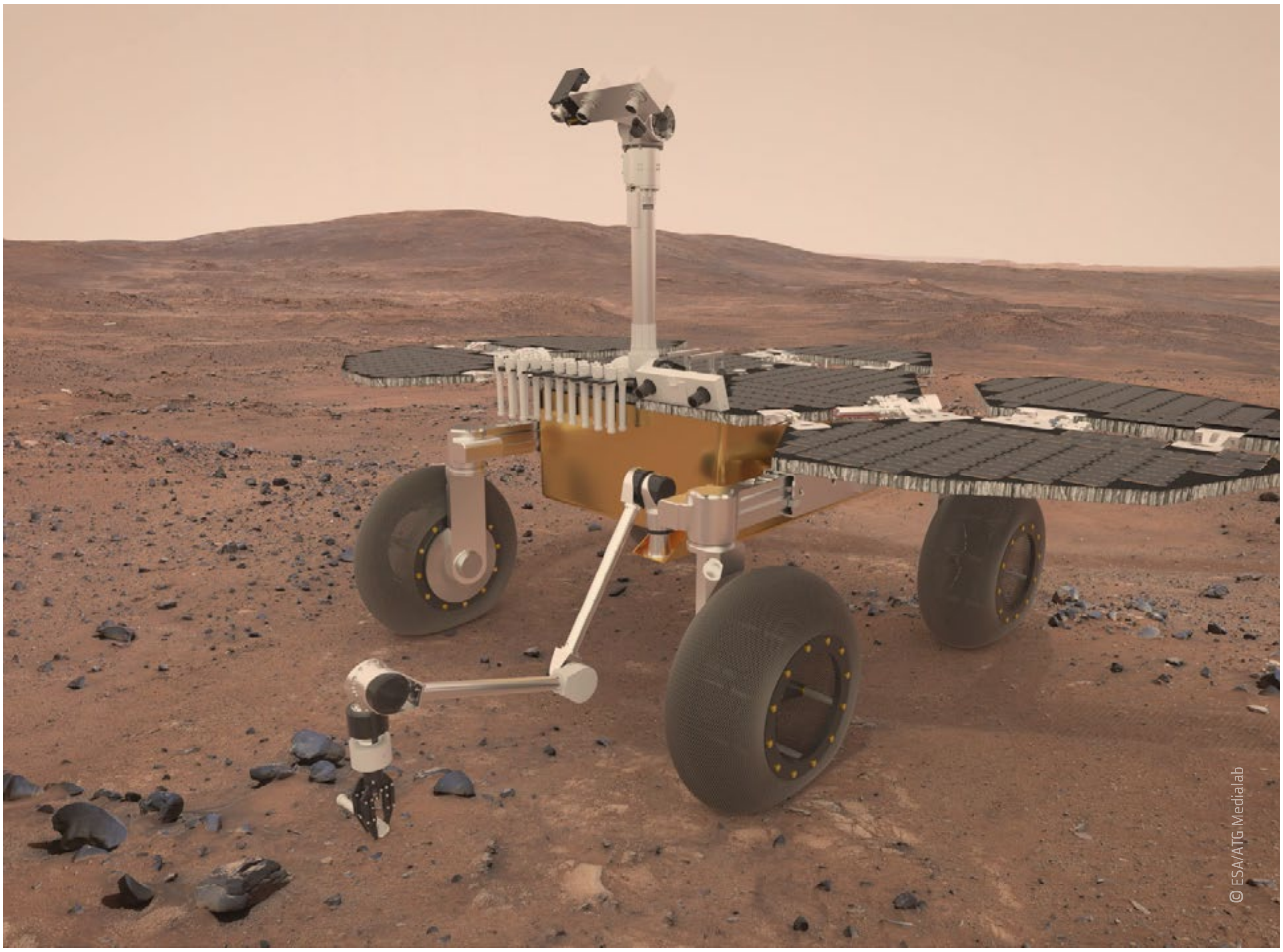


**The International Space Station is one of the largest partnerships in the history of science. This human outpost in Earth orbit, where people have lived and worked since 1998, is a stepping stone for further space exploration. ERA is ready to serve the Station and boost science on board for a few more years.**



The Station is complete and in full service, with a full crew and a full international partnership. Intensive research and effective use of this laboratory is leading to new applications and benefits for people on Earth.

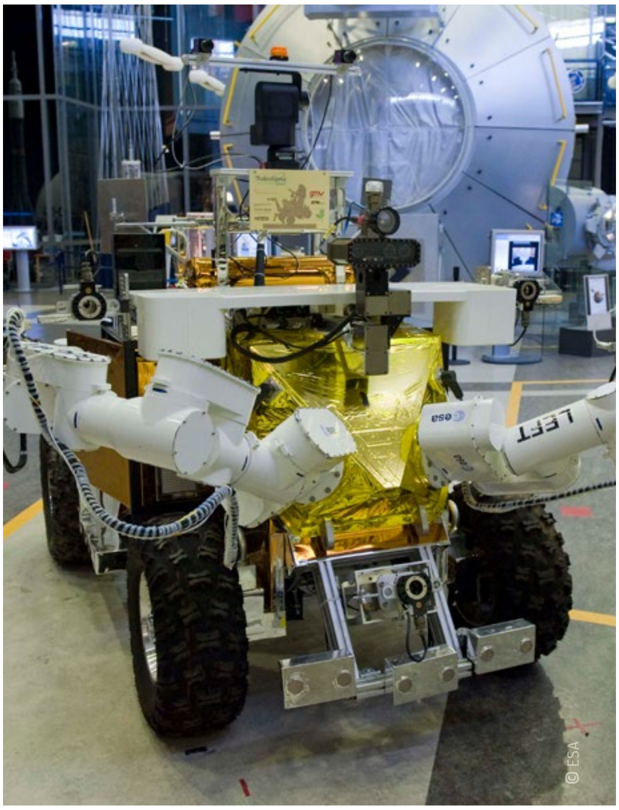
The robotic arm can be operational in the harsh environment of space for at least 10 years. ERA's venture strengthens European industry and will contribute to increasing scientific research in space. During its operational life, the robot arm will help demonstrate equipment and technologies required to prepare for the next steps in human space exploration.




ESA is already developing more challenging technology for orbital robotics. The METERON project aims at controlling robots on Moon or Mars from ground or from a space station orbiting the Moon or Mars. Robots on Earth have already been controlled from the Space Station to test several scenarios and validate the related technologies.

These autonomous and real-time telerobotic operations from space to ground will provide answers for the design of future exploration mission scenarios on the Moon, Mars or an asteroid.

ERA's operational experience in robotics will remain key to future space adventures, such as the transfer of samples from Mars back to Earth with the Mars Sample Return mission.



# MORE INFORMATION

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