The European Robotic Arm, ERA, is a robotic servicing device for use in space. Originally intended for use on HERMES, but it will now be used for servicing of the Russian segment of the International Space Station (ISS).

ERA is supposed to support a variety of tasks around the ISS including:
- Integration of the International Space Station
- Manipulation of larger building blocks
- Exchange of small and larger replaceable units
- Inspection of the surfaces of the ISS
- Extra-Vehicular Activities of the cosmonauts

ERA offers multiple modes of operation including:
- Automated pre-programmed maneuvers
- Interactive control of ERA operations
- Control from cosmonauts outside the ISS
- Control from cosmonauts inside the ISS
- Control from ground based facilities

ERA Control System Software

Terma was responsible for analysis, design, development and validation of the on-board control software for ERA. This software is the first real safety critical software ever made by ESA and subject to extremely high reliability and safety requirements.

The ERA software monitors and controls the automated or manual execution of tasks - ranging from replacement of payloads to inspection and repair of the space station’s external surface. Objectives are to execute arm control with respect to position, orientation, input from cameras, torque and force, and to avoid collision between the arm and other objects. Also, the software will support non-nominal behavior, including failure detection, isolation and recovery.

The software will execute on an autonomous computer located at the arm. The computer communicates with sensors and actuators located in the joints, as well as the basic end effects and cameras of the robotic arm. Within
the ERA on-board software, a layer of bridging software facilitates communication with the station’s mission computer.

Hence the control software functionality includes:
- Control of ERA’s movements
- Internal communication via ERA bus
- External communication via ISS bus
- Security checks
- Event management
- ERA health monitoring

**Safety Considerations**
Because of the use of ERA in an environment where cosmonauts may be present, the software has been rated Safety Critical.

More specifically, the safety requirements state that ERA shall remain operational in the event of a single point failure. In the event of two simultaneous failures, the robotic arm should remain in a safe condition.

In order to ensure a safe and reliable performance of ERA, a number of safety measures have been used during the design phase. They comprise:
- Hazard and Operability Analysis (HAZOP)
- Software Fault Tree Analysis (SW FTA)
- Software Failure Modes Effects and Criticality Analysis (SW FMECA)
- Time Line Analysis

The HAZOP defines those dangers that may occur during manual and automated operations and leads into a Fault Tree Analysis. In return, this identifies how barriers may be used to guard against catastrophic and serious faults.

Subsequently, FMECA techniques were utilized to determine the consequences of errors in the software components on the overall arm operation, again with the aim of building in safety barriers.

The use of these techniques for software engineering has been a major new development during the ERA project.

Time lining analysis was done in connection with the ERA simulator to ensure proper reaction times, in particular for the safety mechanisms.

**Implementation**
Design of the robotics control software was done, using the Hard Real-Time HOOD method. With its emphasis on different object types: passive, active, periodic, sporadic and protected, the design methodology caters for high reliability, for instance, by formally allowing verification of all tasks meeting their deadlines. The decision between one thread and multiple threads is augmented through the object type.

The ERA on-board software was developed in Ada. This implementation language is well matched to the design approach with HOOD (Hierarchical Object Oriented Design) and provides an extensive range of mechanisms suitable for high performance software.

**Status**
The software was developed with support from TechnoSpazio (Italy) that have implemented the application layer of the system.

ERA is developed for ESA by a number of European space companies, with Airbus Defence and Space Netherlands (formerly Dutch Space) as prime contractor. The robotic arm will be launched by a Proton rocket, along with the Multipurpose Laboratory Module (MLM), in 2018 to be put to work in space by the ISS crew. The MLM will also serve as home base for ERA.