Remote operation kit with modular conception and open architecture : the SUMMER concept

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Abstract

The article presents an original command and control architecture, realized for French MoD (DGA), aiming at operating any robot through a low level controller acting as an abstraction layer between actuators and high level orders, whilst ensuring liability of the remotely operated system as well as allowing high level mechanisms to help the operator in assisted mode or to plan semi or fully autonomous mobility actions while the operator concentrates on its inspection or observation mission, with the ability to keep the control of the machine in any case.

The Man Machine Interface has also been a big achievement for this project since profile settings allow all controls to be fully configurable and being instantly modified, adjusted, new functions added.

Lastly, a brief description of the company is provided to know more about ECA.

A. Reasons for modularity : the Summer concept aim

Cybernetix company has been developing since years several prototypes aiming at inspecting and observing the suburb region as well as operating remotely in case of harsh or hostile environments.

One of our current realizations concerns a global solution for French MoD (DGA/ETAS) able to remote operate different types of vehicles with the same command & control architecture and the readiness and mechanisms to implement autonomy functions as well as testing new MMI configurations. The following pictures show the variety of vehicles to be adapted.

All photos courtesy of DGA

Picture 1 : Summer vehicles

The problem therefore is of different kind :

- o size : because the range of vehicles goes from a truck pillar to a quad, solution has to be compact,
- o ruggedness : because it must operate in all-terrain,

- liability : because this is for use in fine by military force for strategic operations eliminating the possibility for any error,
- modular : because the kit must be adapted and fitted for different platforms and components must be replaced or added easily
- open : because the final objective is to find the right architecture and set of sensors so many tests must be done, the task of implementation must be eased as much as possible,
- adaptive : because as a prototype, several configurations and improvements or modifications must be done in a short time to make it usable.

To find the right compromise between all of these constraints has been the objective of the study phase, as well in terms of forecasting what will be needed in the next future as in terms of ease of use for pilots, not specialists in using computers and a powerful but complicated MMI.

The results are shown in the next paragraphs.

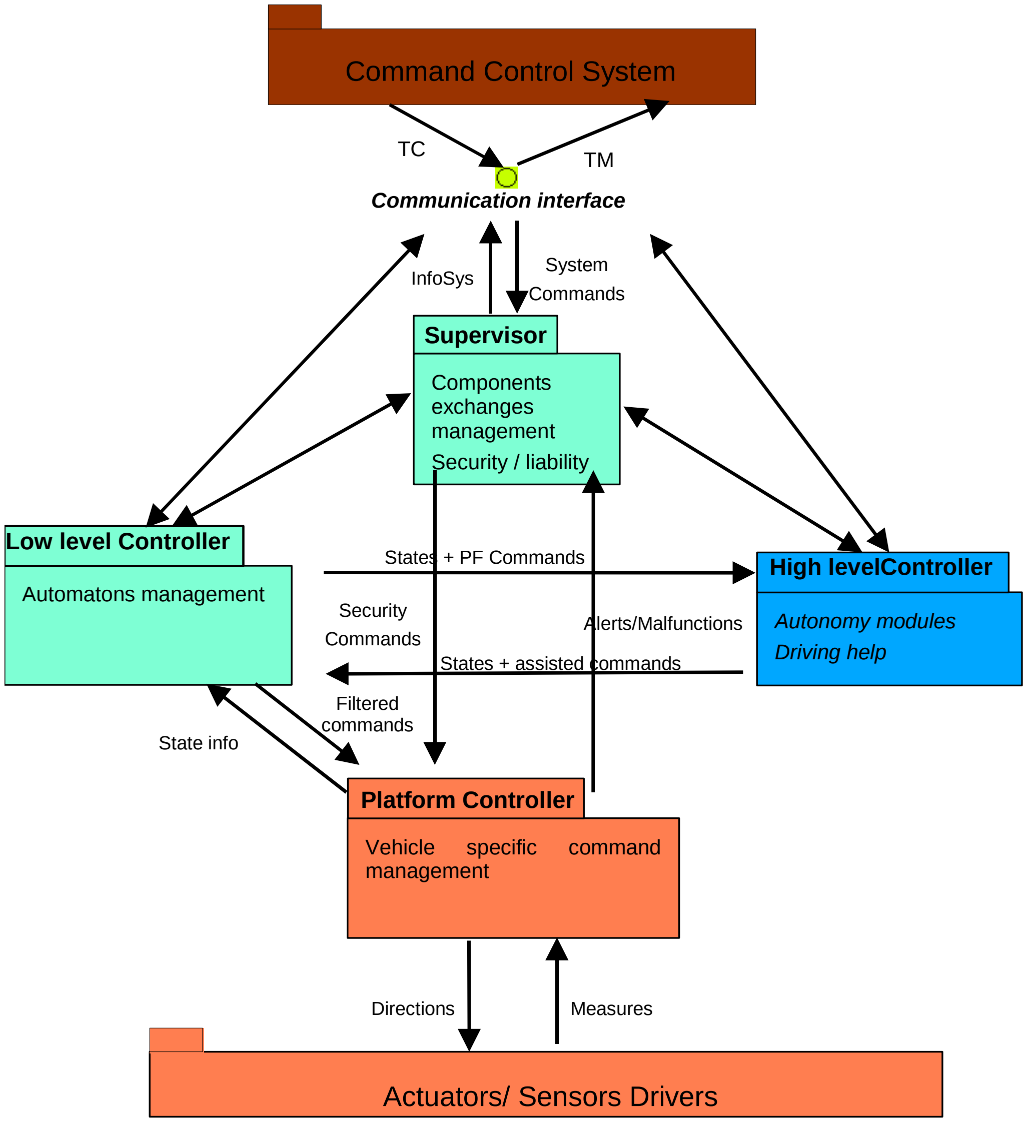
B. Command & Control architecture

Components

The command & control architecture is composed of several subsystems :

- the Command & Control system (C²S) i.e. the place from which the operator is giving the orders or supervising what's happening. This subsystem is then subdivided into mobility & mission dedicated work stations. Further details on this will come in the next chapter.
- the on-board layers : a cPCI computer architecture is used to provide all services needed from the interpreter to the physical command of the actuators, it is divided into the following components :
  - a communication interface that deals with transmission protocol between C²S and low level on-board calculator. Thus, a change in the protocol from cyclic to acyclic transmission, or change in the delivery rate of cyclic packets will result only in a change in this layer (and the same in C²S of course),
  - a supervisor (SUP), in charge of all security aspects managements and arbitration of possible conflicts between the components.
  - a low level controller (LLC), whose role is the management of all automatons for remote operation, meaning placing the commands in correct….
  - a platform controller (PFC), that acts as an abstraction layer between the platform and low level orders. This layer has the responsibility to provide the link from orders to physical command of the actuators through the various installed boards (analog and digital I/O, counters, serial links, …). This is the only specific part of the architecture, platform dependent, that need to be adapted for each different type of vehicle (apart from specific transmission).
  - a high level controller (HLC) who can communicate with the LLC to get information from the platform to run value-added algorithms and give back orders to the LLC for driving the robot or simply give feedback to the user via the MMI through the SUP to help in the driving or alert if an automatic obstacle detection is activated for example. To prevent any malfunction caused by a high level function and also maximizing the calculation power needed for the algorithms, a physical calculator is provided for high level functions to ensure in case of hang up of a function or a module, or in case of severe software failure, the low level will so be still alive and allow the user to keep control of the platform.

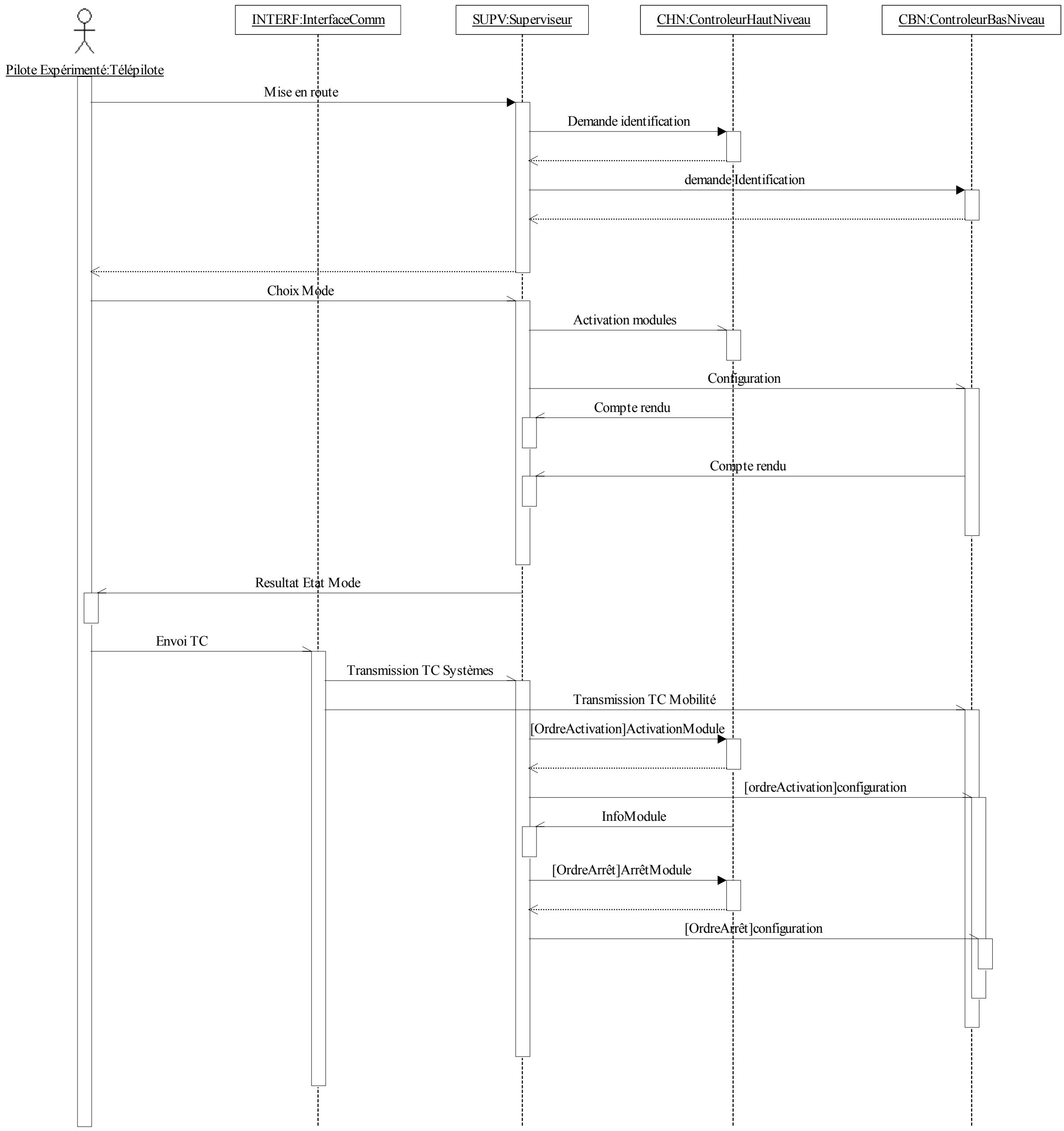
The following scheme sums up the interaction between all components of the system.



Picture 2 : the Command & Control architecture

Automatons

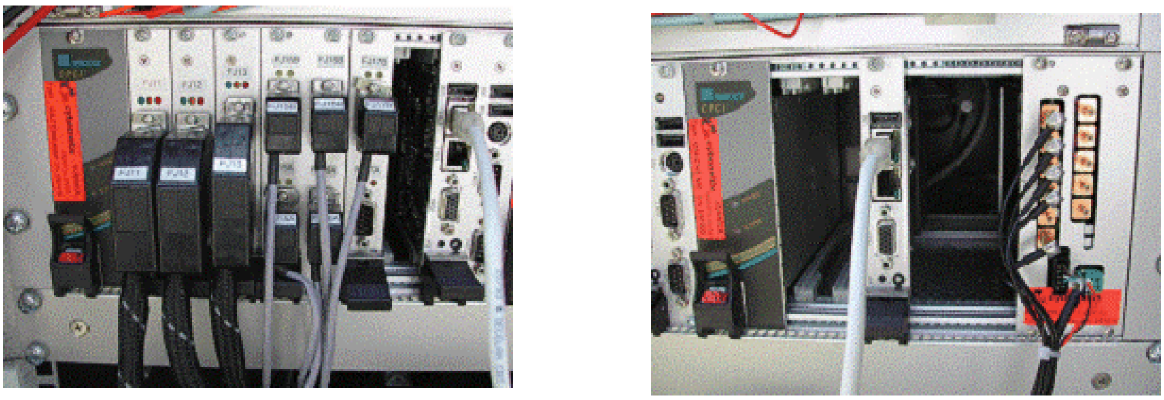
After identification, the functions have been analyzed to elaborate the state machines. Below is an example of such an automaton, showing the interactions and data exchange between components.



Picture 3 - Automaton example, high level module activation

C. Implementation

Hereafter are shown the low and high level computers, cPCI architecture based with all acquisition or communication cards (analog and digital I/O, counters, RS232, 485, 422).



Picture 4 : Low level (left) and High (right) level computers

In terms of on-board sensors, we can detail on the vehicle :

- 4 driving cameras (1 in the front, 1 back, 2 laterals)
- Observation camera (zoom control)
- Pan & tilt unit with shock absorbers
- 6 DOF Inertial sensor giving speed and acceleration in XYZ directions
- Differential GPS
- Inclinometers in axial and transverse directions
- Odometry (ultrasound radar)

In the central unit, some space is left to provide additional sensors, and a dedicated connector is available, providing needed digital and analog I/O as well as various types of power supply (+12V, +5V, …), ensuring a quick connection and the test of any sensor within a short time.

Concerning transmissions, the protocol used for TeleCommands (TC) and TeleMeasures (TM) is RS422 @19.2Kbds. At this rate, the maximum transmission lag is 100ms, sufficient for driving a vehicle at 50km/h (max). The installed system is analog and the range of reception is about 500m. To avoid any lose of control of the platform, in case of transmission loss after a threshold period (to prevent from micro-cuts), an immediate stop is activated. The security chain comprises also an independent emergency stop besides normal ES, watchdog, immediate stops, … It uses the UHF band within the range [400..450] MHz.

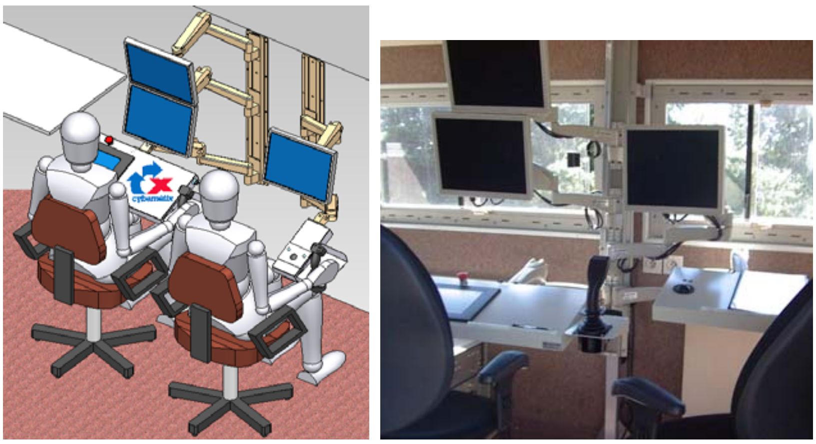
The modular conception allows also the use of a digital transmission system with a range of 5kms with a relay system instead of the analog one. The only procedure to conduct is to connect a single plug containing all cables on the vehicle, to connect also the cables in the control station and to change the transmission profile in the interface, easily done through the tactile screen.

Concerning the videos, 2 communication links are provided to send PAL format videos at full rate:

- 1 for mobility purpose consisting of a proprietary card connected to 1 to 4 cameras, allowing any configuration of the pictures, thus making possible to drive having the front video whilst keeping in the corners the lateral views to be alerted in case of danger. When activating the reverse gear, the main picture switches from front to back camera.
- 1 for the observation camera intended to be used by the navigator.

The range [2.2..2.4] GHz is used for videos.

D. Adaptive and modular MMI implementation



Picture 5 : from mock-up to realization

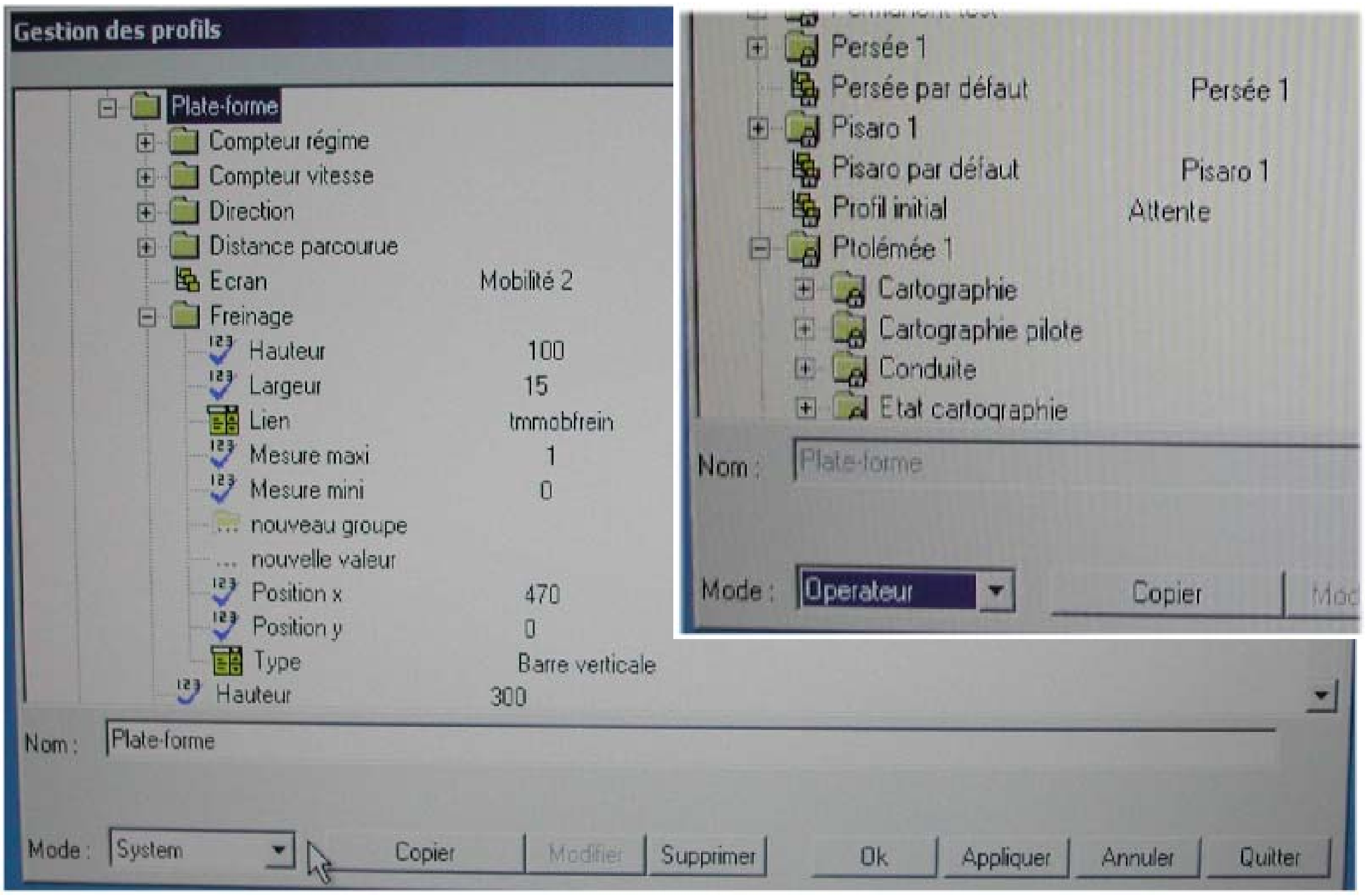
The building of a Man Machine Interface for such a complex system is obviously an iterative process that has been conducted together with the final client to find the best compromise between ergonomics presentation, making the interface user-friendly whilst guarantying an access to security organs at any time through dedicated areas of the tactile screen and mechanisms (dead-lever on joystick, watchdog, emergency stop on loss of transmission, …).

The picture 4 illustrates the matching between the various mock-up versions presented as well in terms of architecture as for the graphic aspect of the buttons and its disposition and pasting through the different screens.
The composition below presents the various functions of the MMI.

Picture 6 : MMI operated

E. Profile management

The aim of the profile management tool is to allow the user to configure his environment. The adopted philosophy is a Windows™ one. It uses the registry principles, with a list view containing the different categories, and all controls beneath.
The following pictures illustrate the realization.
Depending on the mode the MMI is used, different privileges are granted, thus preventing hazardous modifications from inexperienced users. The visibility of the parameters is so following the mode, a lock indicates a category that cannot be modified.
All elements can be customized, from video size to position of the bitmaps, or alarm thresholds, aso…

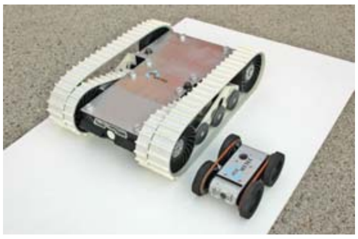


Picture 7 : profile customization

F. Company profile

ECA (http://www.eca.fr) is a high tech company located in Toulon, south of France, specialized in defence and civil robotics, industrial automation, systems and information. Established in 1936, ECA has six offices in France and four subsidiaries. Two of them are located in France (HYTEC specialized in Remote control systems for inspection and intervention in hostile environments, and ECA AERO- which is focused on automated systems for aeronautics), one in England (ECA CSIP oriented in automated systems for harsh environments (Remote technology, Defence, Environmental Systems)), and one in Turkey (OD ECA Support and equipment for defence).

ECA employs currently around 300 people. The main customers are military clients with more than 20 national marines, and companies oriented in aeronautic, automobile, offshore oil and gas, nuclear power activities. ECA is the market leader for sub sea robotics for mine warfare.

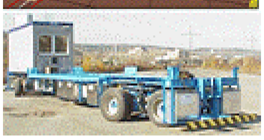


ECA also builds ground robots for French Army and intends to re-use the technology in civil applications: beach-cleaning activity has been identified as a major application. To define the prototype, ECA provides the knowledge for all the electronic parts (sensors and the artificial intelligence), the engine and the frame. As soon as the studies are completed and the prototypes developed, ECA uses the acquired expertise to develop and manufacture small series of repetitive products.

ECA has significant means in terms of Research & Development, including mechanical, hydraulic, electronic and information engineering and design as well as specialised workshops (optics, magnetism...) permitting the company to conceive and fabricate demonstrators or prototypes.

ECA collaborates with a number of research organisms and universities in France and abroad to maintain very high level of innovation in its systems.

The Parisian premises of ECA, formerly known as Cybernétix – **Homeland & Security** branch, will be in charge of the project, has the following activities :



- *W*ith a unique know-how in remote-operated systems and mobile robots for interventions in hostile environments. ECA offers standard systems and equipment as well as turnkey solutions. The strategy of ECA as a robotics and automation specialist, is based on the complementarity between technological research & production of robotized equipment and systems in market "niches" with strong potential.

  ECA develops and manufactures autonomous and remote-controlled mobile robots for the French Defence and Civil Security Services, operations in difficult environments and industrial applications. ECA offers innovative solutions for extending human actions at inaccessible depth (acoustic guided AUV-Autonomous Underwater Vehicle- for sub sea applications: bringing significant savings in installation and maintenance operations) or in hostile environments (remote controlled mobile robots especially dedicated to handling and neutralizing explosives as well as operations in nuclear, bacteriological or chemical fields). Designed to carry remote controlled inspection and intervention operations in complete safety for the operator, these robots can easily be transported in a car or by helicopter or ships. They are equipped with different type of manipulators and monitoring systems (measurements systems, camera and vision systems, location systems, etc.) depending on the application. ECA has also an important background on big transport systems for containers manipulation, through several European RTD projects.