Document title:	**MEGAROB Final Publishable Report**
Project Title:	*Development of flexible, sustainable and automated platform for high accuracy manufacturing operations in medium and large complex components using spherical robot and laser tracker on overhead crane*
Project acronym:	MEGAROB
Instrument:	Collaborative Project
Thematic Priority:	FP7-2012-NMP-ICT-FoF
Grant Agreement:	314015
Period covered:	All project

Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the consortium (including the Commission Services)	

Approval		
Date	First name & Name	Visa
29/12/2015	Coordinator – José Antonio Dieste	OK

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1 EXECUTIVE SUMMARY

The main objective of the MEGAROB project is to develop a **flexible autonomous platform, based on robotics and mechatronics, to perform high accuracy manufacturing tasks on large components (>10 meters long) which can be found in different industrial sectors such as aeronautic, wind mills, civil engineering, railway and ships manufacturers**, achieving a long-range and high-accuracy robotic system adaptable to all types, sizes, quantity and complexity of parts, extensive to any other kind of sector or industry, as logistic, automotive or big machinery manufacturing.

The project, with a duration of 3 years has been developed successfully, achieving the most important objectives so far. Anyway, several important unexpected issues appeared as on any R&D project that were covered and solved with as much diligence as possible.

Technically, the project developed two different prototypes at different scales: a miniMEGAROB placed on Switzerland, where the core software and the correction algorithm was tested, and the full-sized final demonstrator (20m x 6m x 5m), that is placed on the facilities of AITIIP in Spain where the demonstration activities in a composite beam and a wind mill blade took place. The error compensation estimated as an objective was achieved on all zones of the part (accuracy of +-0.3mm on 10-12m parts). All of this integrated on a system: Software with CAM trajectories, Error compensation based on online Laser Tracker measuring (1000 times per second), Industrial Robot and Crane:

On the Management side, one partner leaving on the first months of the project, replaced successfully and another closing its activity and being assumed its activity by the coordinator are the only relevant points that it is necessary to mention.

Regarding Dissemination, a webpage that was (and will) updated constantly can be accessed on www.megarob.eu a **youtube channel** where all videos of MEGAROB operating can be seen and dozens of actions (Workshops,Scientific speeches, Press Notes, Articles in Press, etc) have been carried out during the project.

Finally, regarding the exploitation of the results, It was decided to exploit the main result (the demonstrator) through the coordinator with the support of the rest of members for two years after the project. All the income produced using this demonstrator on industrial services will be saved in order to create an spin-off based on MEGAROB in the future if it really profitable. Replication of the demonstrator is also another direct result of the project that can be exploited through the collaboration of the partners.

2 DESCRIPTION OF THE PROJECT CONTEXT AND THE MAIN OBJECTIVES

One of the main problems facing the industry today is the manufacturing and repairing tasks of large components (10 meters long and above). Indeed, manufacturing processes, such as **machining, milling, grinding, polishing, deburring, welding, riveting, screwing or painting**, on this type of components and structures, are still carried out manually mainly because of the problems related to the kinematics structure of the machines. That is the reason why there is no automated system that can achieve the tolerances required by the industry.

With the current State of Art it is very difficult to develop a robust system accurate enough for such operations, mainly because the positioning error grows exponentially when the size of the machine increases, the accuracy results from the accumulation of different errors, starting with the error in the manufacturing process of the machine itself.

There is an important gap between the accuracy that is currently achieved on small products and components and the precision achieved on large structures. As a result, it was increasingly necessary to develop a system capable of extrapolating the tolerances achieved in small components to large parts.

That is why the idea of developing MEGAROB as a research and development project appeared. Within the industrial sectors mentioned above, the MEGAROB project is more precisely dedicated to the manufacturing of large components such as airplanes and container-ships body parts or generator blades and masts for wind mills.

The main problems encountered when manufacturing large components are related to:

- The difficulty to maintain a high level of accuracy
- The need to move the parts from one site of the factory to the other in order to realise the different manufacturing operations
- The necessity to realise at least part of the manufacturing operations manually

Ultimately, these drawbacks have a negative impact on the competitiveness of the industry because of the increased processing time and the necessary investments in manufacturing equipments.

As a solution to this, MEGAROB system offer consists in a platform for the realization of such **operations automatically with a high accuracy rate in positioning of ±0.216mm+0.5µm/m. This supposes a tolerance of ±0.4mm in a 100 meters long part.** The targeted system is composed by a **spherical robot**, mounted on a conventional simple structure, such as a crane. This robot can cover a very large area, thanks to the capacity of the overhead crane.

The main problem to overcome for such a system is to work accurately enough to fulfil the requirements of the products to be manufactured.

Indeed, a robot by itself has a limited accuracy. If it is also mounted on a translation system, such errors theoretically should increase exponentially, by simply adding more axes of movement, and especially to dramatically increased kinematics size of the system.

The solution developed is to split the working area of the full crane, into three-dimensional sectors, with a particular shape. Each sector becomes a working sector where the robot is located to perform the manufacturing or repairing tasks in that area. Once located, the exact position of the robot is acquired using **laser tracker** systems.

Several targets are placed at the base of the robot, with a setting of 3 spheres, whose position allows unambiguous definition of a coordinates system.

The tracker points in real time the main target, and once set in position searches the other two targets. With the information of the spatial coordinates of the targets, the mathematic algorithm will be developed to create the changing matrix between the relative and the absolute origin.

Once the robot is located, the information about its position is sent to the High level control system that adapts the **CAM** paths to the actual position. This way positioning errors are corrected and MEGAROB adapt its behaviour and manufacturing plan for the new situation.

As a consequence, the proposed system has an industrial **robot working in vast areas without increasing its intrinsic positioning error**.

Positioning deviations errors are very important in the industrial manufacture of small parts. If the scale of these deviations is maintained for large parts, the parts processed with this system will easily pass the quality requirements. With this concept, the MEGAROB system will be able to manufacture and to repair parts or tools whose dimensions are above 10 meters long by performing milling, drilling, deburring, grinding, polishing, riveting, screwing, welding, painting, or quality dimensional control tasks, with applications in industrial sectors such as **aeronautics, marine, renewable energy, construction and civil engineering**, etc

<u>OBJECTIVES</u>

The final aim for MEGAROB was to develop an innovative multifunctional manufacturing system based on robot capable of achieving accuracy in positioning of ±0.216mm+0.5µm/m which implies a tolerance of .±0.4mm in a 100meters long part (position acquisition system located in the middle of the part) and to demonstrate its efficiency through.

In order to reach the above mentioned target, the MEGAROB consortium set, and achieved the following **scientific and technical objectives** which are twofold:

- **To develop a high level control system** whose components are:
  - **A specific accuracy correction algorithm**. This system combine **mechanics and optics** to analyse position. The use of laser tracker technology **compensate accuracy deviations**. The compensating algorithm was conceptually designed first and later on developed to monitor in real time movements of MEGAROB
  - **A dedicated Computer Aided Manufacturing**. Manufacturing tasks are controlled by computer. The CAM system for MEGAROB, is able to work in discrete zones, and **optimize** the movement sequence to **reduce processing time**.
  - **An alignment and centering algorithm**. Using the possibilities of **laser tracker technology**, an alignment and centering algorithm was programmed in order to exactly locate the position of the part to be processed. This takes place in the step preceding the manufacturing tasks. This system feeds CAM in order to set the references in the virtual CAD system. In parallel another algorithm was programmed based on the use of the **robot** to assure the aligning and centring processes.
  - **A virtual simulation environment**. A virtual simulator was used, included into MEGAROB hardware configuration, part to process, finished part, manufacturing plan, in order to assure safety of all the elements involved in the manufacturing process, including operators, if it is the case. With the virtual simulator MEGAROB behaviour and movements can be analyzed or even changed before they are executed.
- **To demonstrate the feasibility, the efficiency and the real performances of the MEGAROB concept by building a complete full scale prototype,** which was sucessfully tested on two different industrial applications: a wind mills blade and a composite beam.

Some pictures can be seen below, showing the manufacturing operations on the final demonstration parts:


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3 DESCRIPTION OF THE MAIN S & T RESULTS/FOREGROUNDS

During the 3 years of life of this project, several S&T results have been obtained and will be explained below:

WP1

For instance, **on the first months** of the project the consortium fixed the requirements for the different Hardware elements conforming MEGAROB:

In the case of the robot, the necessary parameters for its selection, performing a benchmarking of different industrial robots existing in the market. Also, starting requirements were established for the crane, and more precisely for the crane that will be developed and manufactured for the MEGAROB scale prototype, as well as the necessary characteristics for the laser tracker.

Moreover, an exhaustive study related to the manufacturing working blocks where the robot will work to cover the necessary working field was performed. It was defined the maximum size of those working blocks, and depending on different parameters that will be obtained during the development of the project, those working blocks will reduce its size, optimizing the manufacturing processes execution times. This optimization will be done keeping in mind the geometrical parameters analyzed in WP1 and calculation of the transition times between blocks that will be derived from the definition of crane in further steps. An initial definition of the 2 demonstrators that were implemented during the project, defining the requirements that will affect was carried out, both from the related manufacturing process point of view and from the geometries and precise applications that will be faced.

This allowed developing a first draft of the MEGAROB scale prototype hardware that will be used as a basis for its development, and will be the resource used for the real implementation of the demonstrators.

Regarding the software, it was defined first the high level MEGAROB concept that was developed and implemented accordingly in the next phases of the project, providing the details on the concept of the interface between the user and the system, the software modules and their implicit instructions set as well as the interfaces between MEGAROB components taking into consideration the architectural and implementation phases.

Finally, the last introductory development was the main LCA methodologies to be used in the project, as well as the representative impacts and indicators which were considered in the last period of the project, during the demonstrator assessment in WP6, where a complete Life Cycle Analysis was also carried out to test the performance on MEGAROB activities, under a real scenario.

General emissions, emissions to air, inorganic emissions to air (CO2) as well as several indicators measured by EI99 and CML 2001 have been defined as a reference, in order to be assessed during the life cycle analysis of MEGAROB demonstrators.

More detailed information about these indicators was extended during the last phase of the project, once the final scenario was totally defined.

WP2

Some research was done also on structural and process design optimisation.

In relation to high force requirements processes tests, the manufacturing forces were measured for milling processes on soft materials, performed by a spherical robot. With this base, a mathematical model was developed in order to predict maximum and average process in function of typical manufacturing parameters as tool rotational speed, tool translational speed, cut depth.

With this model new parameters can be programmed for new potential manufacturing tasks with a prediction of the forces that are going to be involved prior to the actual execution.

Forces obtained in the range of parameters used during the tests are always inferior to 300 N, so a 30kg pay load robot should be able to perform manufacturing tasks on the materials studied with the roughest parameters of the trials.

In case of the use of a different pay load range robot, the use of the mathematical models developed would be able to determine the maximum parameters to perform a potential manufacturing task. Although the robot is able to support these manufacturing efforts (with the parameters programmed), the tracking trials of the end effector of the robot shows a deviation from the theoretical programmed path.

Even without manufacturing forces, robot paths present an error that in the research developed is around 0.2mm. This is an intrinsic machine error that doesn't depend on the efforts supported.

When manufacturing, typical forces as the trials shows, produces a really large path deviation error that, with the parameters used, can reach 2.5mm. This is a large error that in a real actual manufacturing process would imply large geometrical deviation from the desired theoretical CAD shape.

With the results obtained, the conclusion is that the use of a spherical robot is not feasible with the materials in the research for industrial sectors that require high accuracy in the manufacturing process. **It is absolutely necessary to develop a system able to analyze in real time the actual position of the end effector of the robot and change the robot path to reach the theoretical position, during manufacturing task when robot kinematic is exposed to the manufacturing loads**, which in fact is one of the aims of the WP4.

In relation to low force requirements processes tests, studies conclude that grinding, deburring and polishing process, using the methodology developed, and the tool based on Aitiip background, are manufacturing process that are not very aggressive, even with hard materials, such as steel, resulting on forces lower than 80 N. Force is not close depending on parameters as rpm, feed rate, even abrasive size, and the only one that really affects is the cut depth. The reason why is that cut depth affects pressure that the tool makes against the workpiece. Material used to develop the tool has a pressure-deformation graph very flat, so the compression force is mainly constant when compression rate goes between 20% and 50%, this is a feasible process in MEGAROB environment, because for a 5 mm foam layer, it admits 1.5mm of positioning error, to maintain process results.

The values of the average and maximum loads obtained for polishing and grinding tasks, reveal that miniMEGAROB can perform finishing processes on all the materials tested during WP2, using the methodology developed. In the case of milling processes, results obtained show that miniMEGAROB is not the suitable hardware configuration to perform milling, cutting, drilling process on high performance material, such as aluminium or composites (Regarding the composite used for the tests, only milling tasks with less than 1mm cutting depth, and high rotational speed of the tool are admissible). In the case of aluminium is even less possible to be affordable in miniMEGAROB environment because load values obtained are even higher than with composites. Cutting thicknesses less than 1mm are also possible, but with small tool feed rate 1000mm/min and high tool rotational speed (12000rpm).

In addition to this, several processes and its adaptation to the robots and demonstrators were studied, and we can say that all the manufacturing process analysed are possible to be executed in MEGAROB environment. MEGAROB prototype and miniMEGAROB will be configured to perform milling, drilling, polishing and deburring activities mainly, but the rest of operations can be performed more or less easily, as there is no hardware barrier for the processes listed on D2.3. Both prototypes could be modified, once the industrial demonstration activities are finished, and integrating the tools, and consumables described, MEGAROB could increase the list of manufacturing task performed. From a further potential exploitation view, the most interesting of the processes described apart from the MEGAROB basics is MIG welding: with a low investment, and some efforts on software development, it could be applied to rapid manufacturing (additive manufacturing) of large components.

WP2/3

In parallel to the devlopments regarding the crane in WP3, in the WP2 also was studied through FEM simulations the feasibility of the crane design. On this regard, it was performed a very detailed FEM mechanical analysis to validate the full MEGAROB structure, with all subassemblies related (rail way structure, crab, trolley and vertical axis).

It was concluded that the structure is strong enough to bear the loads in the normal use of MEGAROB, and even during special situations, like emergency brake of the robot. Otherwise **reaction forces are very high** and it was recommended to implement **additional clamping systems** to fix subassemblies when the crane is stopped in a work block, to avoid reaction forces make guides go out of the rails (suggestion followed by GH on its developments on the crane)

Frequency analysis showed natural frequency modes very low, that are no going to occur during normal working of MEGAROB. Only in acceleration phase of the spindle system will go through these frequencies. The overpass will be only during a little time instant, and will be damped by the structure. No problems previewed for this issue. Structure has also been verified in some of these frequencies with FEM dynamic studies and damping performance is well acting. Also a simulation of real working path was done to have a range of the displacements that real time correction algorithm is going to face.

WP3

If we summarize the developments related to the crane, after analysing all the product range of cranes, it was concluded that the best option for MEGAROB project demonstrator from the point of view of the crane concept is to use an overhead bridge crane configuration instead of using any other crane configuration because of the following reasons:

- The overhead bridge crane configuration is considerably more common in the general industry than the rest of cranes configurations. Inside of the factories this is the more common configuration and the MEGAROB system is design to be installed inside, in a workshop.

- The stiffness and the resistance to the deflections is better in a bridge crane configuration than in the rest of configurations, because in this configuration there is not any legs so there are consequently less articulations which result in less mechanical clearances.

- The deflection in this configuration is considerably less than in a Console Crane type configuration because it has two supports.

From the other hand, related with the trolley concept it was decided to use a double girder crane configuration instead of a single girder one. The main reason is the installation of the third axle for the robot in the trolley. While in the double girder trolley option the third linear axle structure can be positioned just in the center of the 4 wheels, in the case of a single girder trolley the third linear axle structure has to be positioned in one side, not centered between the wheels, which involves worst stability and bigger dimensioning in order to reach the same solution than in a double girder crane. Summarizing, the characteristics for the MEGAROB prototype will be the following ones:

TECHNICAL FEATURES FOR THE BRIDGE CRANE
Crane Type: Bridge Crane
Number of girders: 2 girders
Span: 6 meters
Structure Capacity: 3,2 Tonnes
Camber of the Girder: 4,192 mm-s
Structure FEM Group: M6
Long Travel Length: 20 meters

And generally it can be set that the main characteristics for a crane to be possible the installation of the MEGAROB system, are the following ones:

TECHNICAL FEATURES FOR THE BRIDGE CRANE	
Number of girders	2 girders
Structure Capacity	More than 3,2 Tonnes
Structure FEM Group	A6
Long Travel Length	*
Span	*

*The span and the Long travel length are limited by the maximum length of the robot control cables

Nevertheless, It was also studied the adaptation of MEGAROB to other types of cranes or configurations: the steps or tasks for the adaptation of a standard existing overhead crane in a MEGAROB System are the following ones:

- To obtain the complete drawings package of the existing crane, including manufacturing drawings.
- To obtain the complete drawing package of the building where the existing crane is installed.
- In the case that some of the previous drawings packages are not available a complete measurement of the existing crane and building has to be taken.
- It has to be checked if the crane and the building are dimensionally suitable for installing MEGAROB system.
- The crane has to be modeled in 3D in order to perform a finite element analysis, statically and dynamically and check if the structure is suitable for installing MEGAROB system.
- Once, that it is confirmed that the crane is suitable for installing the MEGAROB system, a whole engineering project has to be done in order to design, manufacture and install the different components and solutions to transform the standard crane in a crane suitable for MEGAROB system.
- Install the laser tracker and all the required control hardware in the working area.
- The whole system including the building and all the obstacles in the working area have to be modeled in order to transfer them to the CAM of the system.
- The control software has to be updated to the geometry of the new installation.
- Installation of safety devices for the system depending on the whole configuration of the system.
- Commissioning and functional tests of the whole system.

Although the previous methodology to install MEGAROB in standard cranes is described, and as the conclusion the installation is possible with some developments and validation for the particular cases, there is **another possibility to build MEGAROB as a whole product with all the elements that are not standard in the cranes**. MEGAROB then will not change an existing crane, it will be assembled on. This MEGAROB concept should include:

- Double girder structure.
- Trolley with the described clamping system.
- Third linear axis with the brake systems.
- Industrial robot.

In this version all elements describe above would be delivered as a pack, and directly assembled in the new facilities, on the rails of the main crane, such a way that all the original functionalities of the destination crane would remain, and the functionality of MEGAROB will run in a separate girder system.

To avoid problems with the length of the cables, that as it was established, would be a problem, over 40 meters length. Robot controller would be installed on top of the girder. This way not further installation should be done in the original crane, and MEGAROB could be installed at a first time right approach.

In this case the only parameters to take into account is the width of the workshop (distance between rails), and the height of the ceiling.

To adapt MEGAROB to any crane a variable length double girder system should be previewed for the system, in order to be shortened or extended to fit with the new crane structure.

To overcome the problem with the ceiling height several options could be applied. For example a redesign of the trolley in order to lower the main attachment (sliding) point with the vertical axis, or even to make the design that could permit a flexible adaptation of the attachment point in function of the ceiling height.

WP4

The work package devoted to the software was the longest and also one of the most critical. Several developments on this regard were carried out, with some important achievements. On the one hand, the **real time position correction Algorithm:** There are two different concepts for correction of the tool path in Megarob. They are based in different principles and are independent one from the other. Both can work isolated as well as combined, accumulating their benefits. We can call these corrections parking correction and realtime correction.

Parking Correction: The parking correction aims to eliminate the error due to the positioning error of the crane. When the crane is moved to a new park position, there is an ideal theoretical value for this position. However, due to the several difficulties to accurately position the crane, there will intrinsically be an error in the achieved position (when compared with the theoretical). The magnitude of this error is not yet known, it might be several centimeters.

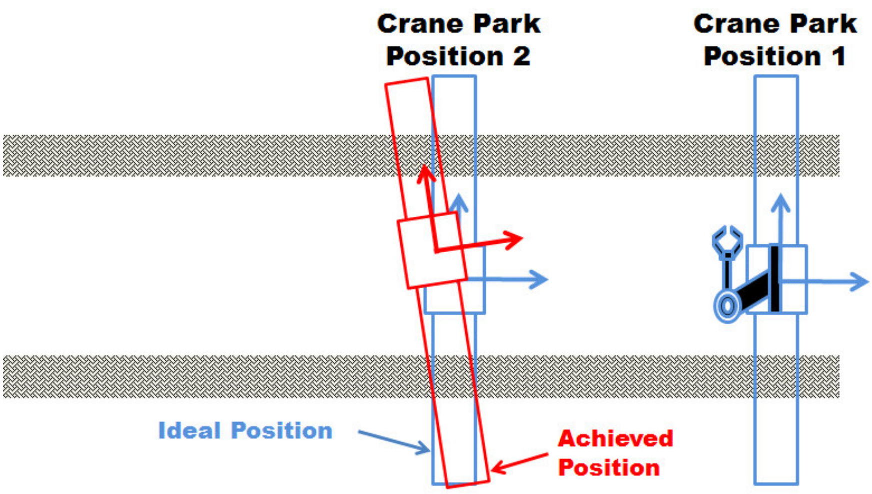


Illustration of the crane park position error

The parking correction is performed in the level of the robot trajectory planning. After the crane is parked in a position, the robot base in the object frame is accurately measured through a metrology procedure using the laser tracker. This is done by measuring the robot position in a number of reference points using the laser.

Then, a mathematical optimization algorithm finds the best transformation between robot base and laser. Since the position of the laser in the user (object) frame is known, the current position of robot base in the user (object) frame can be calculated. The result of this calculation is set in the robot controller as the position of the base of the robot in the user (object) frame. Then, since a robot program is defined by the position of the tool in the user frame, the robot will take into consideration the deviation of the positioning of the crane when planning the robot trajectory of a robot program. Therefore, the crane positioning error will be automatically eliminated in the trajectory that the robot will perform, resulting in a robot tool motion that matches the motion planned in CAM.

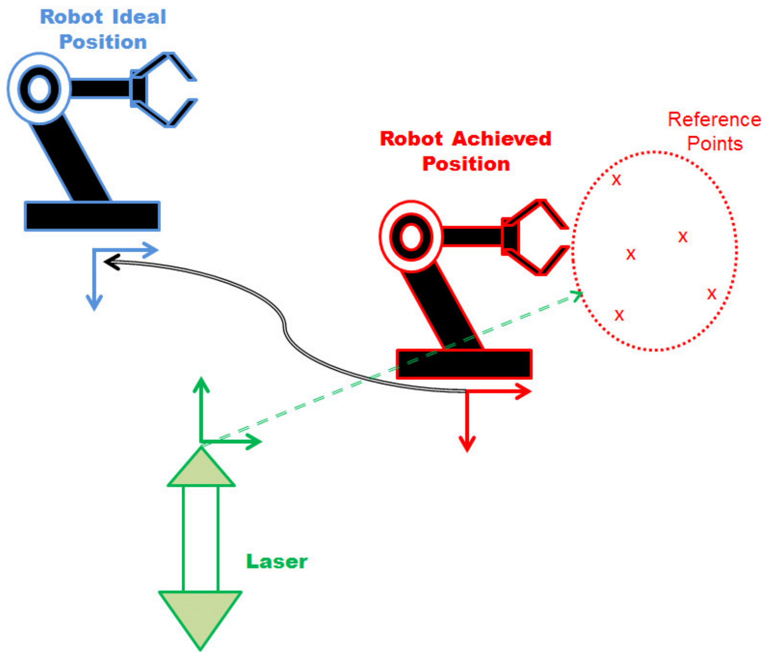
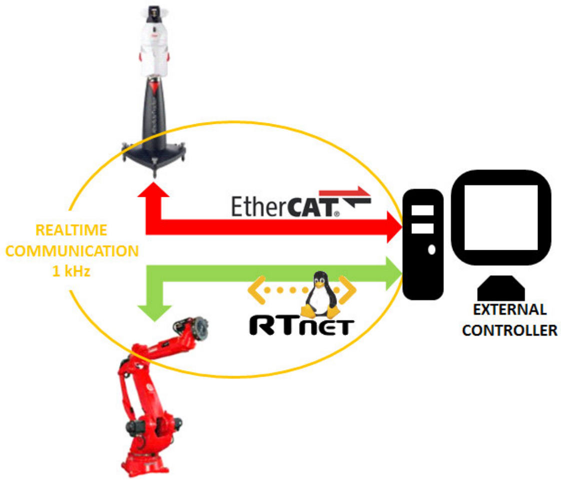


Illustration of the procedure to correct the park position error. A number of reference points of the robot is measured using the laser and this is used to identify the current robot base.

Realtime Correction : The realtime correction aims to eliminate both the intrinsic robot positioning error as well as dynamic errors of the system. Off-the-shelf industrial robots today present high repeatability, but low absolute accuracy. This means that the robot will have a variable positioning error in a fixed reference frame, which depends on the pose of the robot. Furthermore, robots have low stiffness, which results in an inability to reject disturbances in terms of processes forces. Machining processes require the robot to exert a process specific force, which, however, can vary during the process. As the robot present low stiffness, it will comply with the forces and deviate from the programmed path, intensifying the low accuracy of the robot (resulting in poor geometrical tolerance and quality surface in case of milling) as well as lead to damage of the machine, workpiece, reduced tool lifetime, among other effects. This will ultimately inhibit the robot to comply with the design tolerances of a part. In Megarob case, since the robot is mounted in a crane, this dynamic effect is intensified. In addition, other effects might appear, such as, dynamic deformation of the crane (due to, for example, thermical and mechanical effects) and unwanted dislocation of the position of the crane.

The realtime correction is performed in the level of robot motion control. Traditionally, an industrial robot controls its position by controlling the position of its joints. In such approach, all sources of positioning error in the system will have cumulative effect. Furthermore, such scheme does not allow the robot to take into account the structural flexibility of the kinematic chain nor the intrinsic positioning error of the robot structure. A form to overcome this problem is to control the position of the robot with an absolute position of the tool of the robot. This can be done using the absolute position measuring system (in case of Megarob, the laser tracker) to read the real position of the robot and on realtime correct the robot position to the planned position. The compensation is performed continuously in a closed loop at a frequency of 1ms and, although it is performed in the level of the robot motors, the controlled variable is the robot cartesian position.

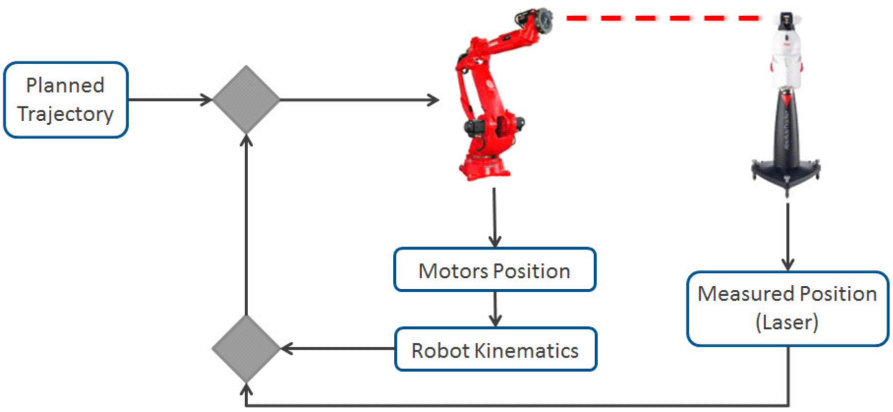
In order to implement such concept, it was used only commercial off-the-shelf hardware. Leica supplied a laser tracker system, which provides absolute 3D position and orientation of a tracked object, with accuracy better than 35µm. Using the Ethercat interface of the tracker, measurements can be read every millisecond. It was employed an industrial robot with an open interface to the motor control of the robot. Through this interface, it is possible to complement or completely replace the commands of the proprietary motor control of the robot using an external controller. This interface works over RTNet at a frequency of 1ms. As controller, it was utilized a regular desktop PC, installed with Linux and patched with RTAI extension, in order to ensure that the deadlines of hard realtime tasks are met..



Deployment of the realtime external controller of the robot position

The software developed to implement the external controller of the robot was developed by CSEM. It was developed a software framework for hard realtime applications under RTAI. It offers a number of abstractions to facilitate and increase reliability of software applications with realtime requirements.

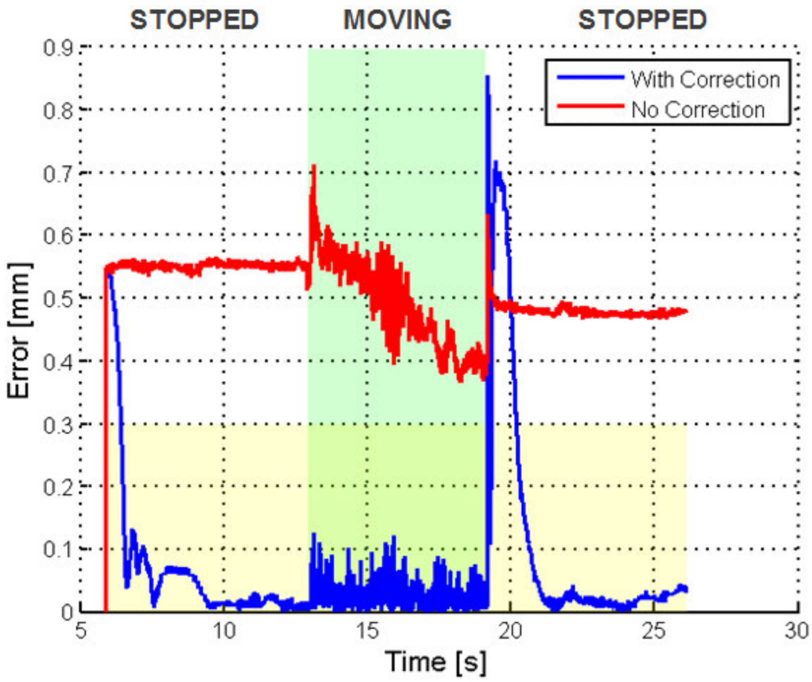
The external controller implements the robot correction. This controller continuously read the current robot position from the laser tracker and the desired position from the robot. It filters out outliers measurements as well as calculates a complementary command for the position control of the motors, controlling the robot cartesian position in closed loop.



Control loop schema that implements the realtime correction of the robot position

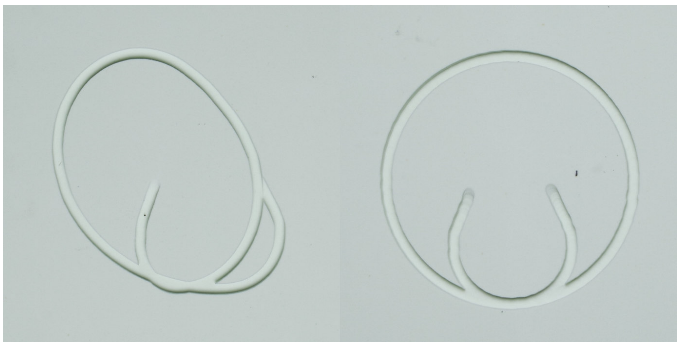
The realtime correction improves the accuracy of the robot. Anyhow, the accuracy of the robot, with or without realtime correction, will depend on a number of variables, such as trajectory, speed, acceleration, to name few.

Figure below shows the accuracy of the robot in static situation as well as when the robot is moving in a straight line. In static situations, the accuracy of the robot with realtime correction is better 0.05mm and in this dynamic situation, it is around 0.1mm.



Comparison of the robot accuracy with and without realtime correction in static situations as well as straight line motion in free space.

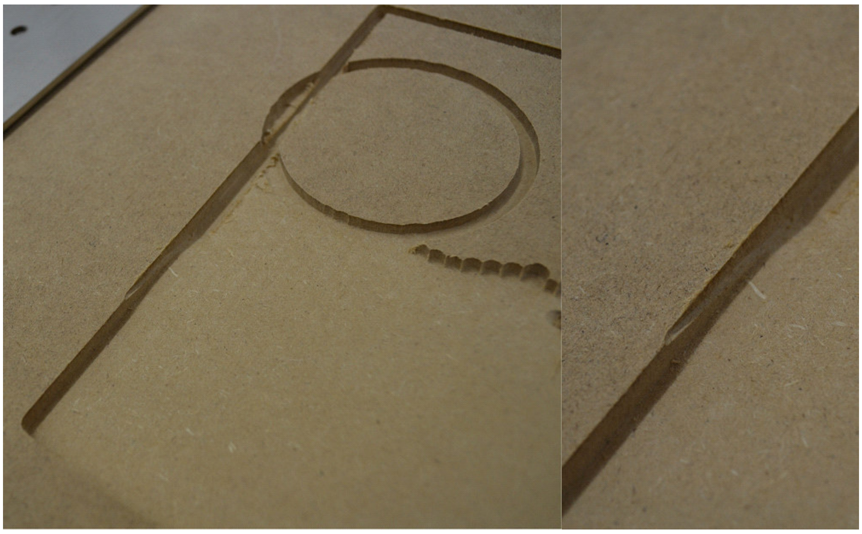
The external controller that implements the realtime correction extends the planned features of Megarob. This controller continuously estimates the current position of the robot and automatically adapts the trajectory of the robot. This concept results in a tool trajectory in a fixed user (object) frame that matches the planned one, even in situations when the robot base is moving. Initially, this features was implemented to auxiliate the rejection of disturbance in robot base. However, this worked well enough to allow the crane to move while the robot is working (for example, machining), while still ensuring an accuracy better than normally found in industrial robots. A comparison of the part produced by the system with and without correction when the robot base is submitted to an external disturbance in its base is seen in Figure 6. In this example, the robot base is moving back and forth on top of a linear rail.



Circle milled with the robot when its base is submitted to an external disturbance: with no realtime correction (left) and with realtime correction (right).

Combination Park Correction and Realtime Correction

As it was mentioned in the beginning of this section, park correction and realtime correction can work separately as well as combined. It was performed an experiment in the mini Megarob prototype installed at CSEM. In this experiment, it was milled the contour of a square in two parts. For each part of the contour, the robot was in a different position. Firstly, we did it without realtime correction, only with parking correction. It was noticeable an error of about 0.5mm in the region where the path of the parking position overlap. Then, the same experiment was repeated using realtime correction. It was not possible to neither see nor feel any deviation in the overlap.



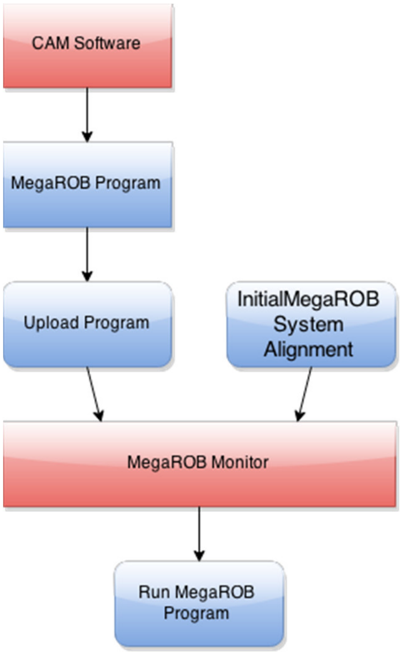
Milling the contour of the square in two robot positions using only parking correction: overview (left) and closed loop at the overlap point (right)

Milling the contour of the square in two robot positions using parking and realtime corrections: overview (left) and closed loop at the overlap point (right)

On the other hand we have the **virtual simulator and the graphic user interface**.

Regarding the virtual simulator, Megarob Project execution will pass through all the described steps to ensure that a part is machined with the highest precision as possible. First, the virtual simulator will position the robot and external axes in every point of the toolpath in such way that collisions and singularity positions are avoided. When a successful simulation is performed, the PDL2 files can be generated and imported into the robot. When a PDL2 program is ran, the Realtime Correction Algorithm ensures that the part is machined as close to the simulated toolpath as possible. During the test runs we did with the Virtual Simulator we were able to write PDL2 programs for a combined toolpath and then run both programs with the Realtime Correction Algorithm. The realtime correction algorithm showed clear improvements to the robot toolpath when the robot was repositioned.

The MegaRob System works on a CAM Software which integrates a Delcam PowerMILL[1] license. The MegaRob Plugin Teamnet developed is responsible for the creation of a MegaRob Program that will be uploaded in the MegaRob Monitor application which runs the program by commanding the included equipment while permanently monitoring each one. The CAM Software is also be responsible of dividing the part into working blocks with a default parking point and for the simulation of the Robot Movements in each block.

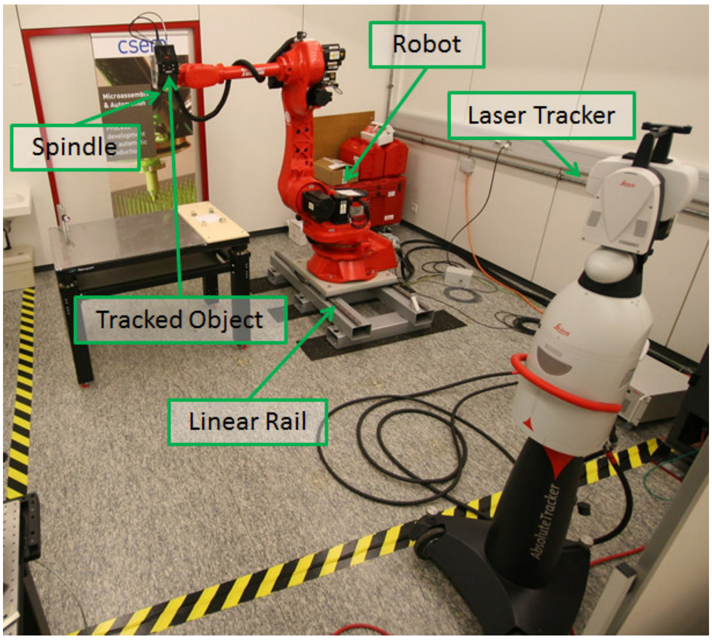


The monitoring application is also responsible of manual controlling the equipment. This includes the manual control of the Robot arm movements using the Robot Comau API and the manual movement of the Crane. Furthermore the initial System alignment can be manually done in the MegaRob Monitor interface by using the laser tracker API methods and the manual robot control.

The MegaRob program will be ran after all the equipment have been connected to the application and checked for any malfunctions. During the running of a MegaRob Program the EXU will be responsible of the Real-Time correction of the Robot Movements and the MegaRob Monitor will ensure the correct alignment after the Crane Movement between parking points.

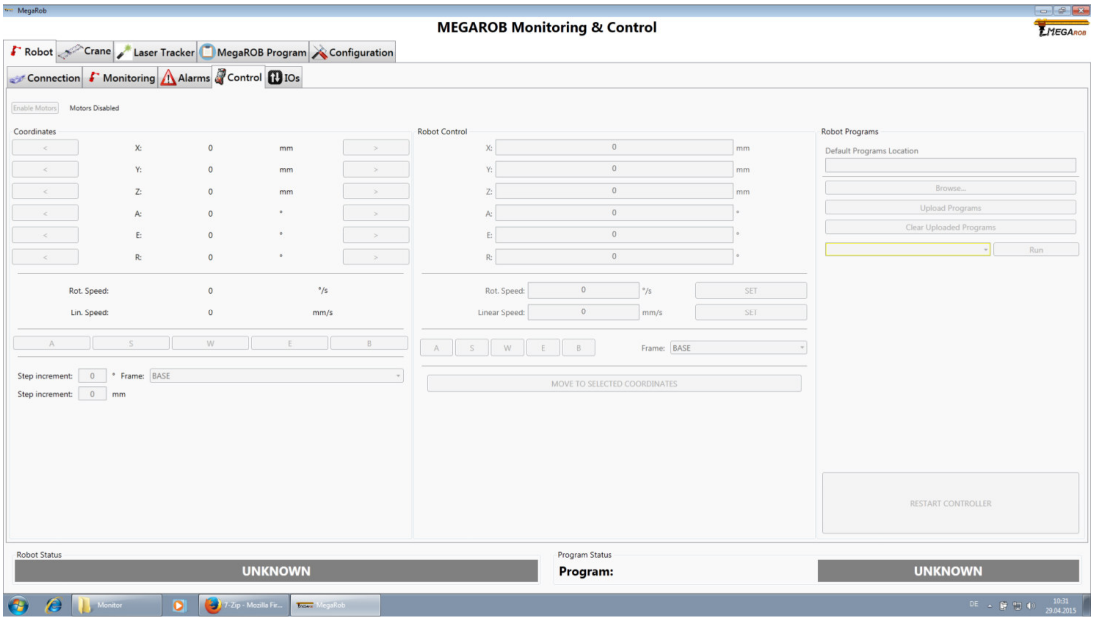
Furthermore, an alignment and centering methodology was developed by ESPACE and implemented in the software and, together with GH, a crane movement algorithm control.

Last but not least, during the development of WP4 the miniMEGAROB prototype was set up, and used to validate the operations shown previously regarding the control of the robot, alignment and centering and positioning correction algorithm.



miniMEGAROB prototype cell

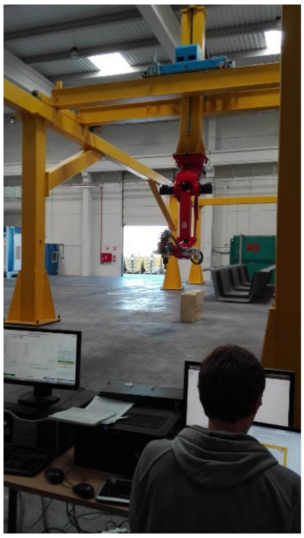
[1] http://www.powermill.com



Screenshot of the main software

WP5

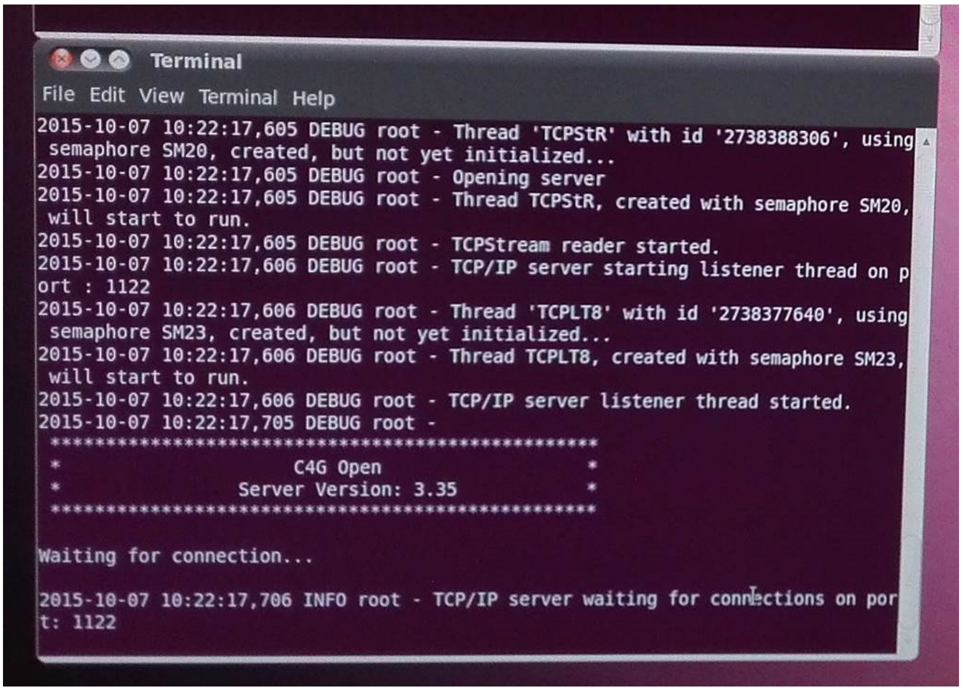
On the next steps of the project the integration of all the R&D developments so far were implemented into the final MEGAROB demonstrator. Despite the fact that several issues, mainly problems with delivery of third party elements for the system elements, that implied months of delay, the system set up was a real success, and the system works fine now. At the end of September the system could perform the operations expected on free space and during the last months, on the final demonstrators.



In addition to the hardware of the demonstrator, the Software developed for large scale MEGAROB prototype can be described briefly. Software in MEGAROB, is divided in two main systems, PSU (Planning and Supervising Unit), and EXU (Execution Unit)

EXECUTION UNIT

In execution Unit, the software running, and fully developed for MEGAROB project, is the real time Controller software. This software communicates with PSU, robot control, Laser tracker controller, and is in charge to monitor in real time the accuracy of MEGAROB and also execute the real time correction of the robot to achieve the high accuracy.



PLANNING AND SUPERVISION UNIT

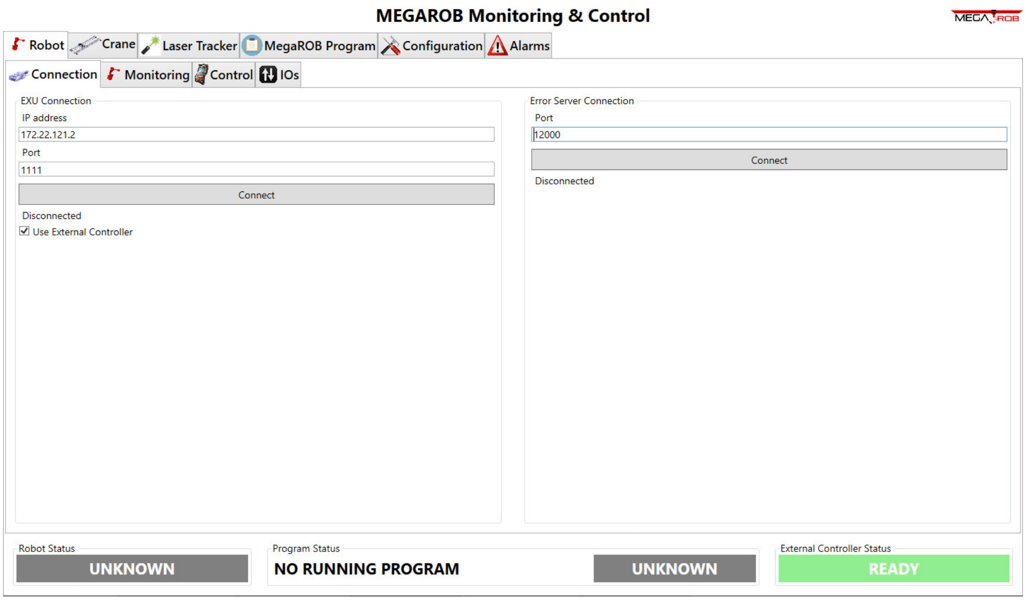
High level software in MEGAROB prototype are:

- MEGAROB Monitor
- MEGAROB CAM

Monitor

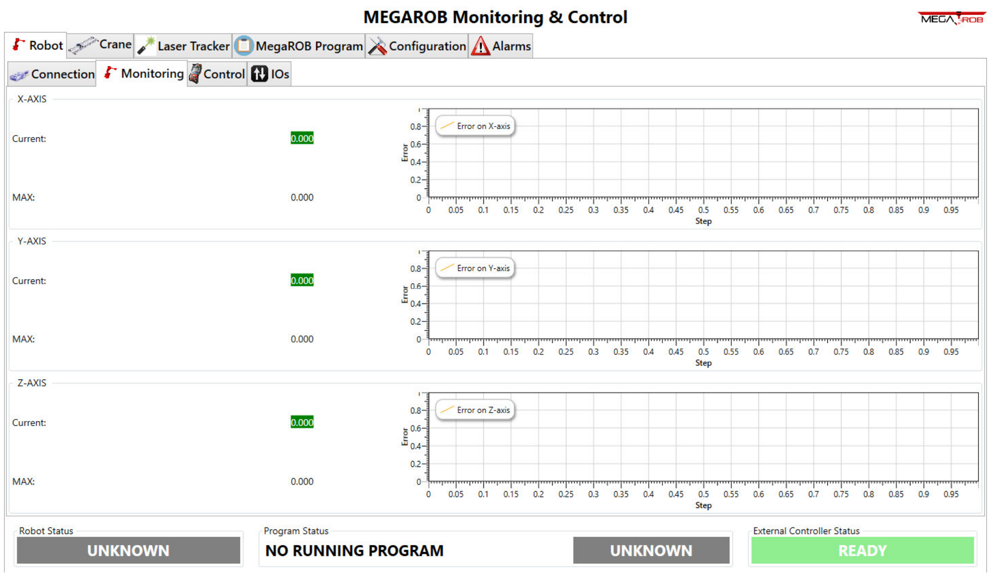
MEGAROB monitor software is making several functions. First is the interface for the User, but it is also the control panel for all MEGAROB task implementation and programming. It is divided in several parts, robot, crane, laser tracker, MEGAROB Program, Configuration and Alarms.

<u>Robot Interface</u>

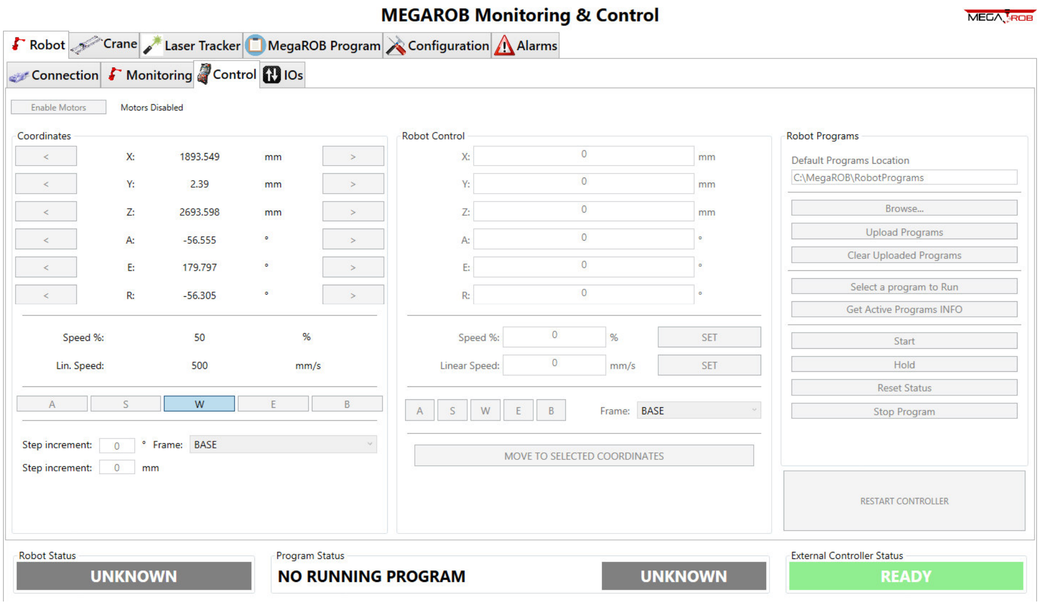


Connection screen

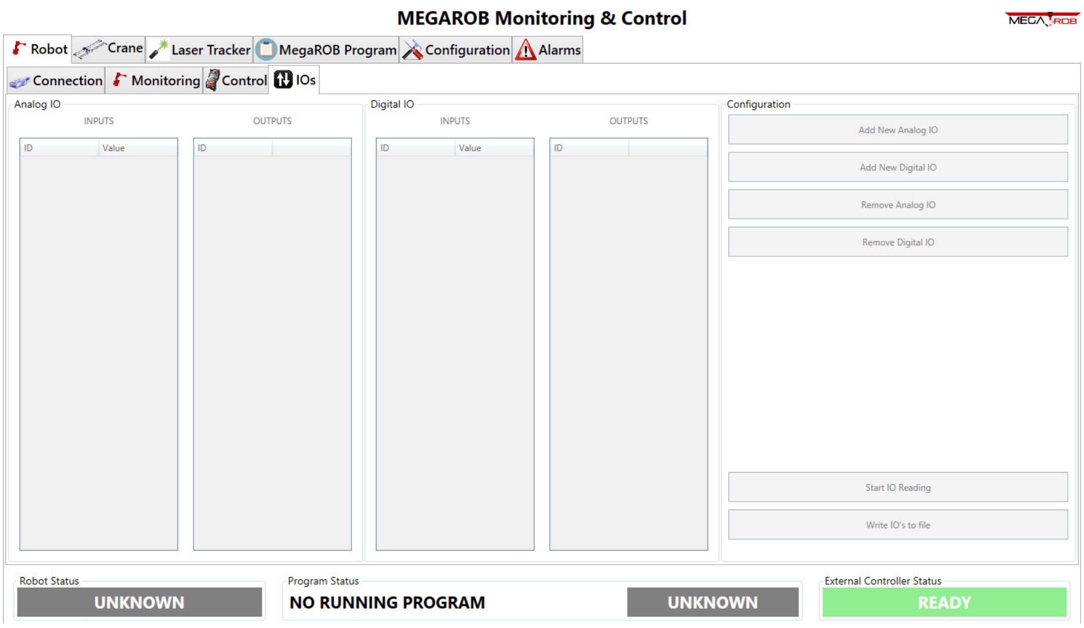
Robot interface is also divided in several screens. The function is to connect MEGAROB software with the Robot, by setting a IP address and port. Connection can be stablished directly with the robot control or with the external controller software when real time, or correction is going to be used. Through this window also connection with the error monitoring server is stablished.



Robot monitoring window shows the error graphs, when real time is used. This screen shows positioning errors in cartesian frame, and information is updated 10 times per second.



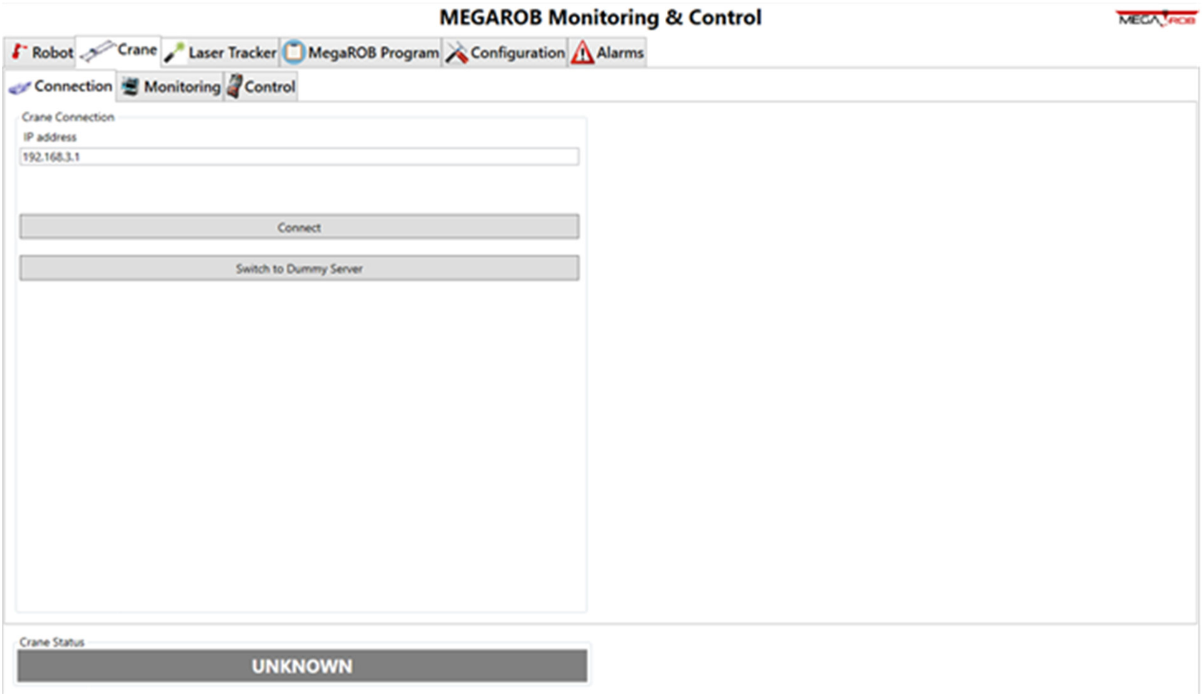
Robot Control window allow to work with the robot in manual or automatic mode. In manual mode it is possible to move the different axis of the robot with a defined angular step, or move in Cartesian coordinates in the different frames in the system. It is also possible to set coordinates or joint angles so send the robot to a defined pose. In the automatic mode this interface window permits to upload a new robot program, to run the program, and to hold, o stop the program running if any problem is detected. It shows also some of the parameters programmed in each moment as linear speed, flags, and robot motors enabling.



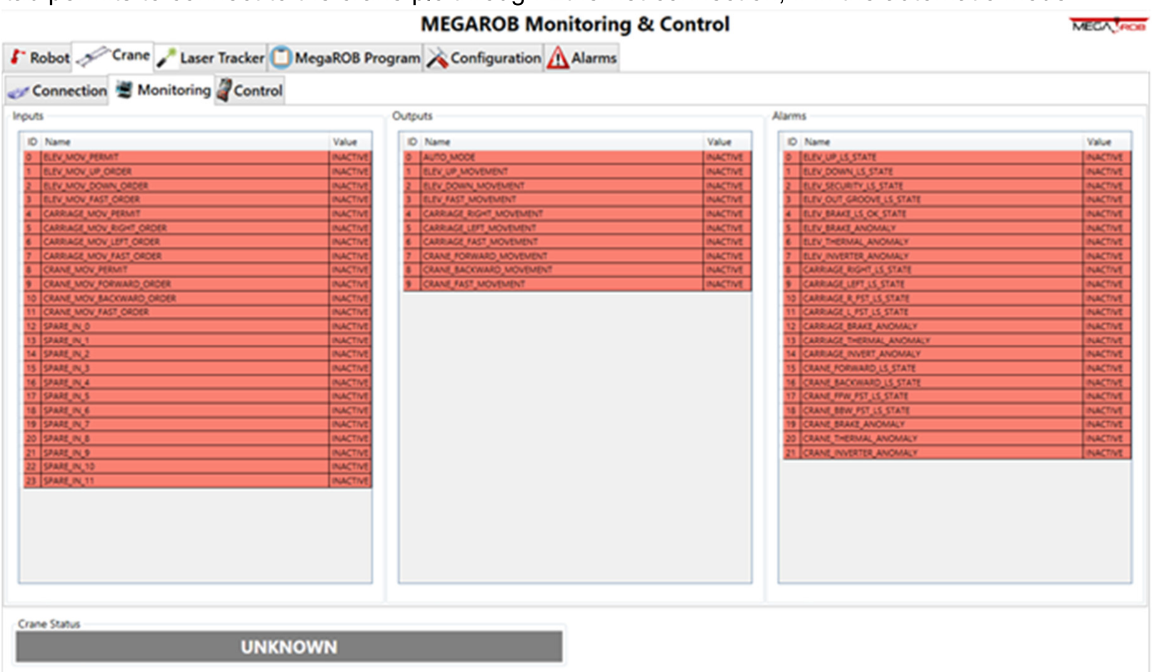
In the robot tab there is a last screen to control inputs and outputs through the robot controller. At the same time ios status can be monitored.

<u>Crane Interface</u>

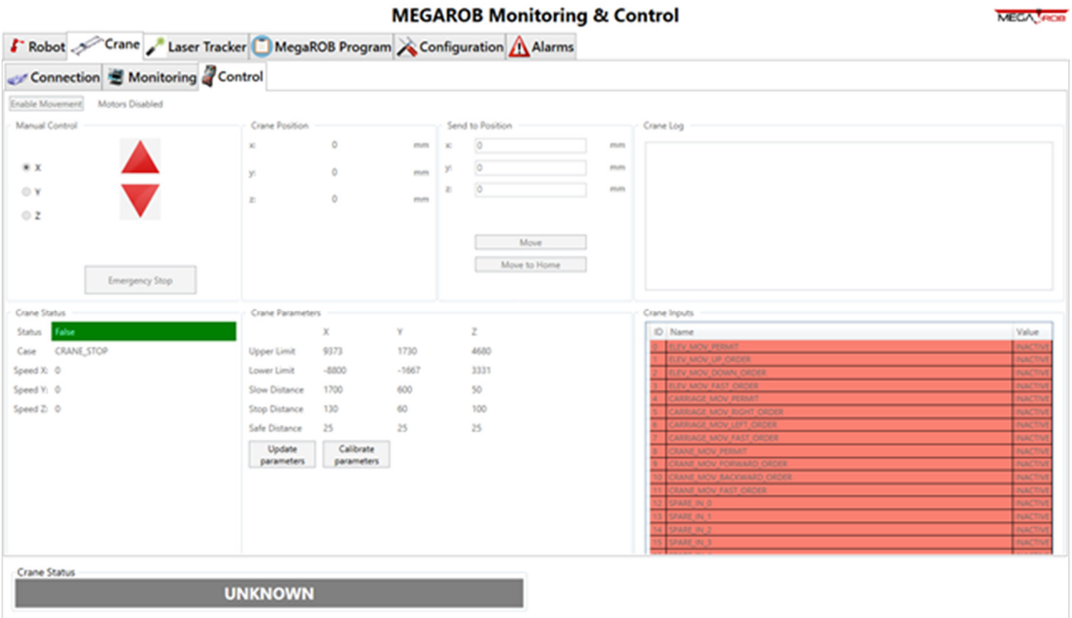
Crane interface is also divided in several tabs to control it.



First tab permits to connect to the crane plc through Ethernet connection, if in the automatic mode.



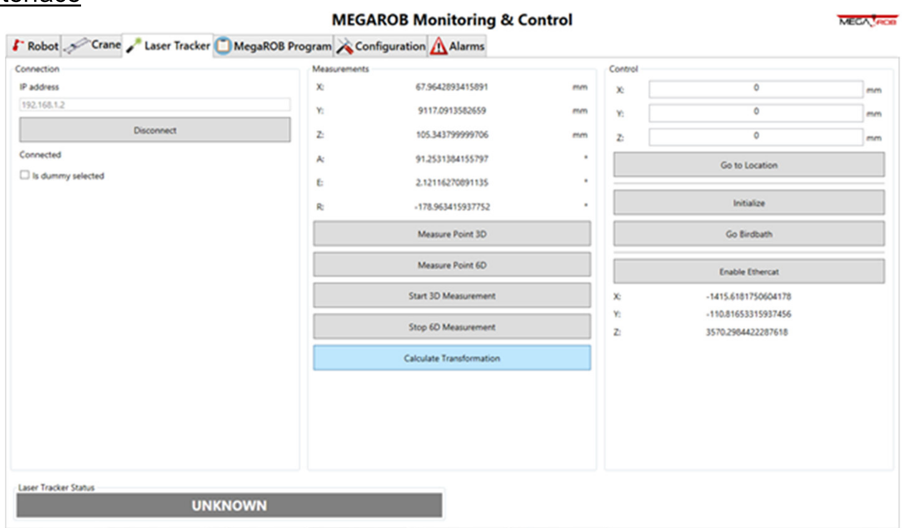
Second tab is labelled as Monitoring, and will show the status of the outputs and alarms coming from the crane plc. It allows also to activate and deactivate the inputs for the crane that manages the movements in all axis. So it is possible to move the crane directly from this tab.



Crane control tab is going to be the interface for a full automatic mode. To enable this screen the laser tracker must be measuring in 6DoF continuous mode. This screen will monitor the 3D position of the crane, and a defined position can be set, to make the crane travel an automatic way.

The travel to this programmed position will be monitored, and crane positioning algorithm will start the iteration in the 3 axis, in order to position the crane in the targeted placement, with the accuracy set. With this tab is also possible to move the crane in separate axis in cabin frame, by selecting x, y or z, while up or down buttons are selected.

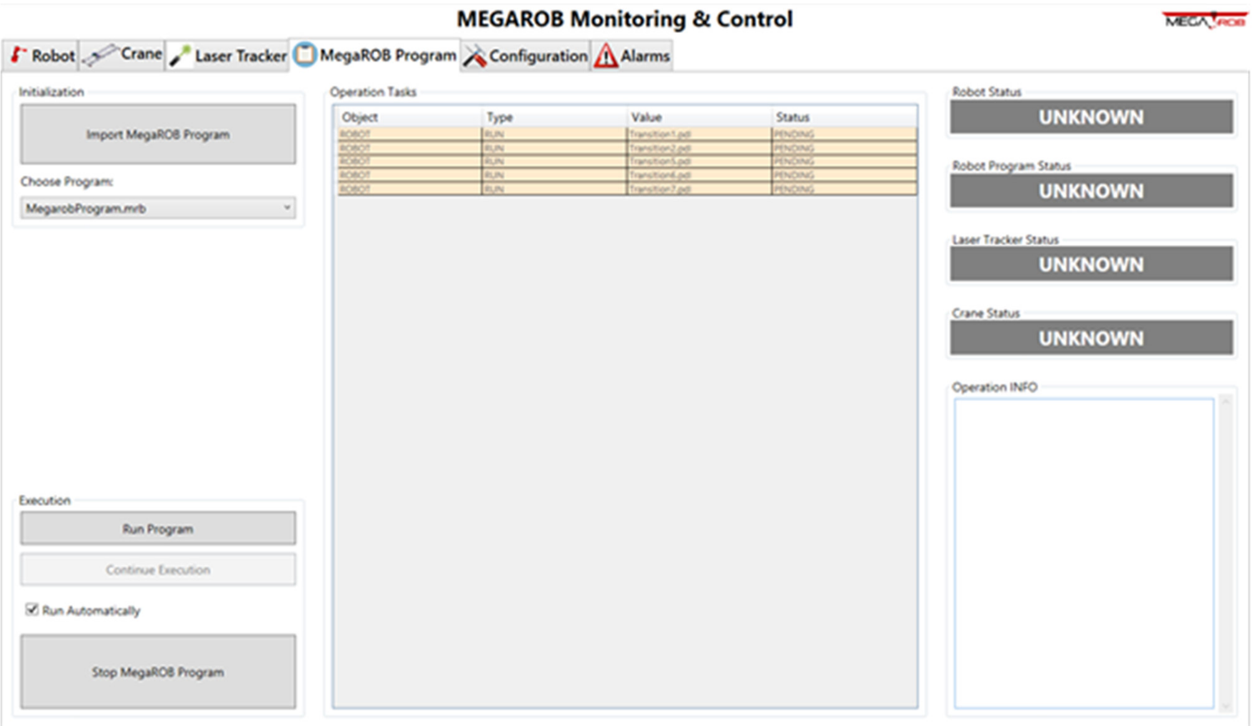
<u>Laser tracker interface</u>



This interface permits the ethercat connection to the laser tracker controller. Measurement 3D or 6D can be selected, and also a discrete or continuous measurement.

This screen shows also the measured values coming from the tracker. Set up buttons are also implemented to inizialize the laser controller, enable ethercat, and functions to send the laser beam to known positions as “go to location” or “go birdbath”

<u>MEGAROB Program tab</u>



This tab permits to execute direct CAM generated paths. Each path from the CAM is composed by several parking points for the crane, and several paths for each working block.

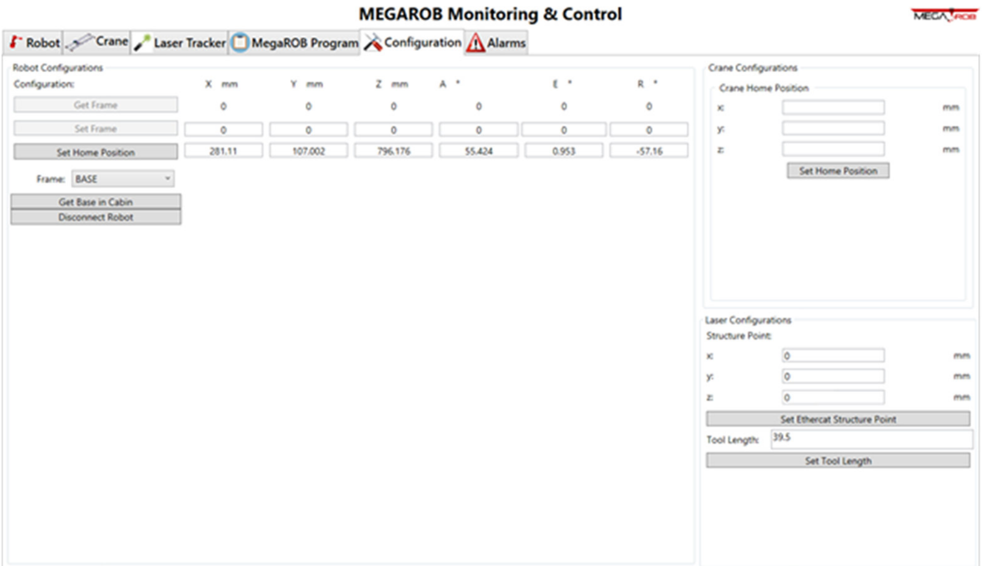
This MEGAROB program tab will manage this process, to control the crane when a new parking point, and then execute the correspondent robot trajectory.

This methodology is used also to perform the robot base identification procedure.

Configuration tab

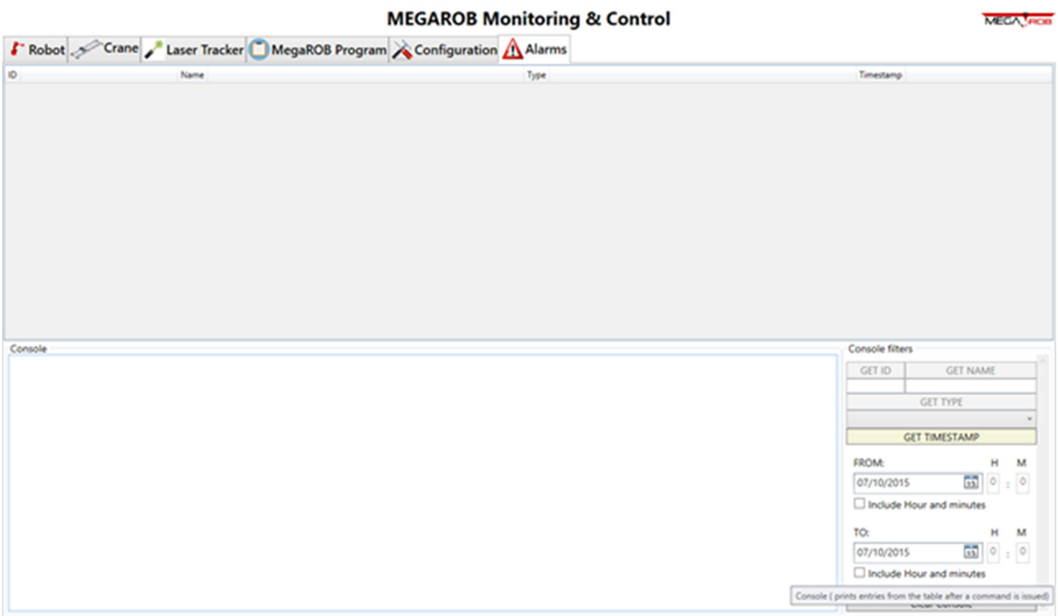
Permits to define or check all the frames needed for the work in MEGAROB:

- Cabin frame
- Laser frame
- User frames
- Tool frames
- T-Mac frame
- Robot base
- Robot tool frames.

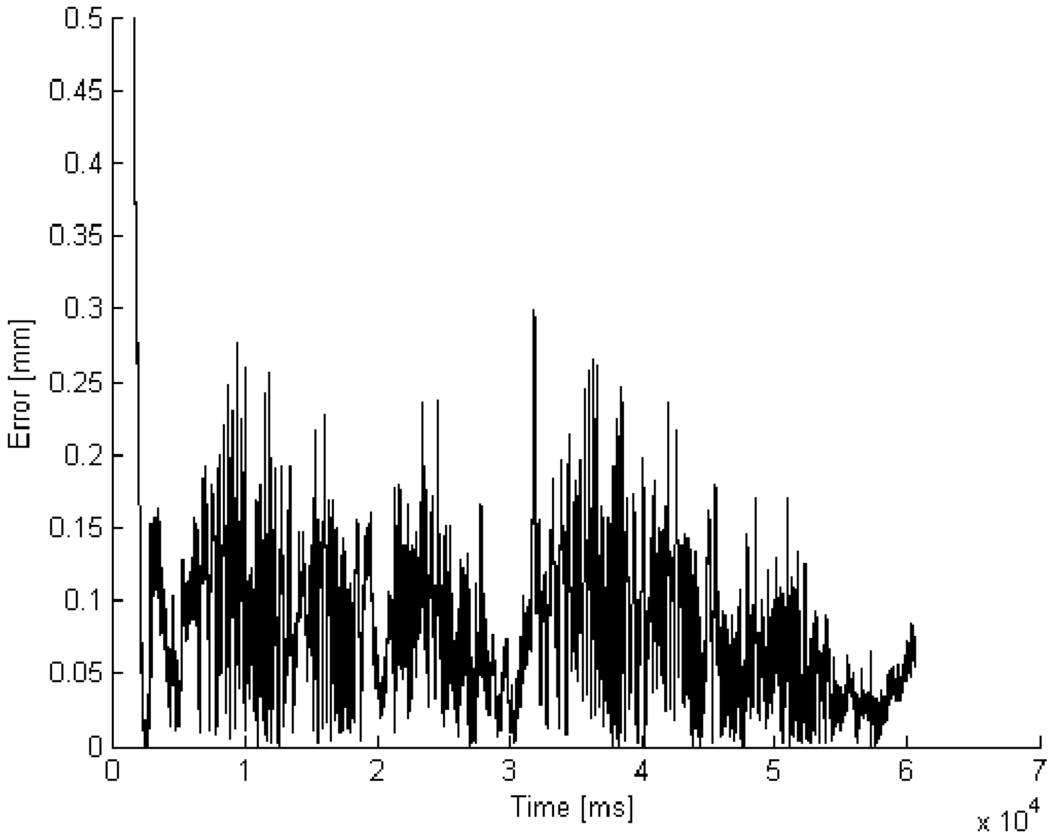


Alarms tab

Monitor and check all the possible alarms in MEGAROB, generating a database of the events in the working process.



Finally, regarding the behaviour of the control system and the real time position correction algorithm in the big demonstrator on real environment, it could not be better. The improvement on the control parameters shows values as the graph below:



Final error on MEGAROB

In the graph we can observe that even when MEGAROB is moving, and executing a trajectory, the position is corrected, and then the deviation of the point in the space between where robot tool should be, and where in fact it is, is reduced below 0.3mm.

One of the advantages of MEGAROB, is that this position correction, and then the error compensation, is used in the full workspace, so this high accuracies are **obtained in the full MEGAROB workspace.**

WP6

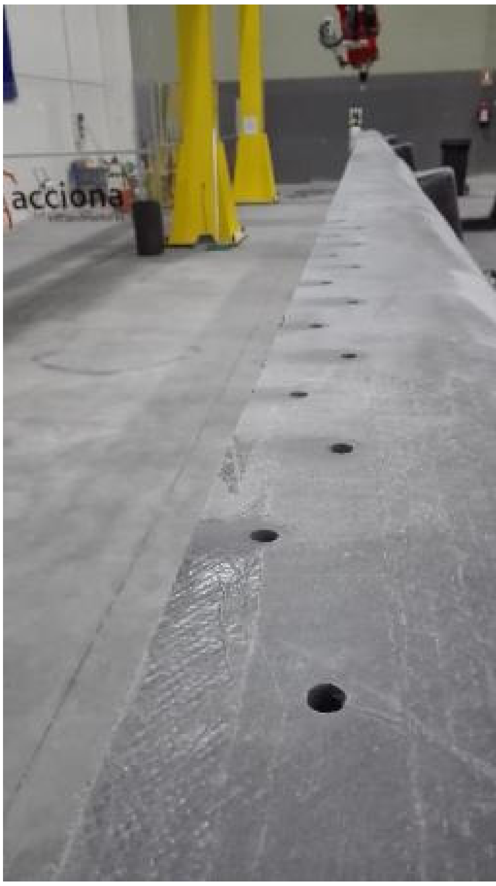
In order to finalise with the main S&T results achieved, the final tests and validations on the demonstrators were completely successful.

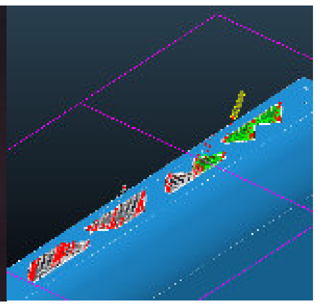
On the composite beam, the innovative solutions proposed in megarob have improved the quality of finishes and the speed with which the demonstrator's beam has been mechanized. The following table quantifies the improvement achieved with the prototype:

Operation	Time of operation		Accuracy over design	
	Traditional methods	**Innovative methods**	**Traditional methods**	**Innovative methods**
Drilling	180’	150’	80%	99%
Longitudinal cutting	120’	120’	85%	99%
Transversal cutting	60’	45’	90%	99%

Traditional method vs Megarob

Even new geometries that till the moment could not being done with the current manual process, now are available with Megarob technology.





The results obtained in the wind mill blade process were also successful. In this case tolerance of the contour definition was improved from the previous 4mm in the traditional process, to 0.3mm in Megarob, and although there is no data about the time involved in the traditional process, Megarob could do this task in only 18min.

A full polishing of the surface of the blade was done with a speed below 15min/m2.

Finally, Life Cycle Assessment of the two different manufacturing processes has been carried out by ACCIONA. The traditional (manual) and the innovative (automatized) final finishing have been compared using the LCA methodology. Main differences in emissions and environmental impacts have been associated to the difference in energy consumption during this final stage.

Thanks to the LCA methodology as well as its supporting tool, Gabi software, it can be concluded that in general terms, the **automatized process has a lower environmental impact than the manual process because of the required energy for the robotic arm is slightly lower than the radial arm.**

4 DESCRIPTION OF THE POTENTIAL IMPACT AND THE MAIN DISSEMINATION ACTIVITIES AND THE EXPLOITATION OF RESULTS

The Potential Impact of the Project results are very relevant. For instance:

Reduction of manufacturing and repairing times

- MEGAROB incorporates different manufacturing technologies, potentially milling, drilling, deburring, grinding, polishing, riveting, screwing, welding, coating, painting and even dimensional control.

Competitiveness improvement

- With MEGAROB developments, companies of a number of industrial sectors, such as aeronautics, rail, marine, renewable energies, can increase their competitiveness. This objective will be tested with the demonstration tasks for the industrial partners involved in the project.

Reduction of the investment in production machines:

- The multifunctionality of the system allows eliminating the investment in unitary machines that usually perform the production sequence step by step. In the same way, specific tools used to mount the part to produce in the traditional unitary production machine system will be suppressed
- The system will be designed with the possibility to be easily changed from one to another facility, using a new crane, without floor space consumption.
- By re-utilizing typical infrastructure in general production shops as its main hardware, such as an overhead crane

Finally, several application sectors will be influenced by the results coming from MEGAROB:

- Construction & Civil Engineering (Demo in the project)
- Wind Energy (Demo in the project)
- Aeronautic & Aerospace
- Other sectors (Ship building, railway, logistics, automotive or in general big parts manufacturers)

Regarding the dissemination actions, below a list of all of them with pictures where available.

Dissemination activities done by the partners:

- **Video**: several videos showing the results obtained from external controller in the mini Megarob prototype and also the complete prototype were recorded. This video was edited so that it can be shown also for non-technical audience. They are currently in the website of the project, **linked to the MEGAROB youtube channel.**

- The **brochure** has been updated with the current developments and pictures of the final demonstrators have been included.

Consortium

7 partners from 4 EU countries

2 Research Centres:

- **AITIIP Technology Centre (Coordinator)** - Research centre of engineering and technology transfer
- **CSEM (*Swiss Centre for Electronics and Microtechnology*)** - private research centre active in the field of micro- and nanotechnologies, microelectronics, systems engineering, microrobotics, photonics, information and communication technologies.

5 SME and Industrial Partners:

- **TeamNet International:** Company specialized in the development and implementation of the software applications based on the latest technologies.
- **ESPACE 2001** Metrology, laser tracker installation, calibration and use
- **GH Gruas** - Crane manufacturer company
- **Leica Geosystems** - Laser tracker and metrology system developer and manufacturer
- **Acciona Infraestructuras** - Developer and manager of infrastructure, renewable energy, water and services.

CONTACT INFORMATION

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50720, Zaragoza, (SPAIN)

Grant agreement no: 314015

MEGAROB

Development of flexible, sustainable and automated platform for high accuracy manufacturing operations in medium and large complex components using spherical robot and lasertracker on overhead crane

www.MEGAROB.eu

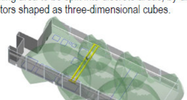
[FoF.NMP.2012-4] High-performance manufacturing technologies in terms of efficiency (volumes, speed, process capability etc), robustness and accuracy.

Objectives

To design a **flexible and sustainable platform** that automates high precision manufacturing operations in **mid and large sized parts** or structures (typically from 10 meters long and above) and to develop a full scale demonstrator.

MEGAROB system general view

The proposed system will consist in a **conventional spherical robot mounted on** a simple structure such as **an overhead travelling crane**, controlled by a friendly high-level control system with the suitable ICT support. This structure will be able to **cover a very large working area, releasing the 100% of shop-floor**, and will allow the robot or set of robots to have a huge workspace. It is planned for the working area to be split into discrete areas, by dividing it into sectors shaped as three-dimensional cubes.



100% Free floor area and covered by the system on final scaled-up solution

Using the latest technology in **laser tracker** a system will be developed to **continuously monitor the position of the robot**, and to adapt its behaviour to the on-going measurement, thus achieving the excellent accuracy expected (i.e. a tolerance of ±0.4mm in a 100 meters long part). As result **the new development will allow very precise manufacturing processes of mid and large sized complex parts and structures, with tolerances very similar to the high-accuracy achieved for smaller parts standards**, not yet reached for large parts in the current state of the art.

Solution Advantages for Industry

Reduction of manufacturing and repairing times: It incorporates different manufacturing technologies, potentially milling, drilling, deburring, grinding, polishing, riveting, screwing, welding, coating, painting and even dimensional control. A multifunctional system earn time, avoiding wasted time in movements of the part to process in the work shop, consequently reducing the manufacturing costs derived from large parts logistics in the working plant, and accelerating the delivering time of the products to process.

Reduction of the investment in production machines:

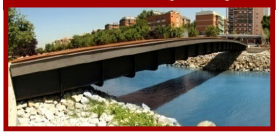
- The multifunctionality of the system allows eliminating the investment in unitary machines that usually perform the production sequence step by step. In the same way, specific tools used to mount the part to produce in the traditional unitary production machine system will be suppressed
- The system will be designed with the possibility to be easily changed from one to another facility, using a new crane, without floor space consumption.
- By re-utilizing typical infrastructure in general production shops as its main hardware, such as an overhead crane

Competitiveness improvement: With MEGAROB developments, companies of a number of industrial sectors, such as aeronautics, rail, marine, renewable energies, can increase their competitiveness. This objective will be tested with the demonstration tasks for the industrial partners involved in the project

MEGAROB main elements: Laser tracker, robot and structure

Markets / Applications

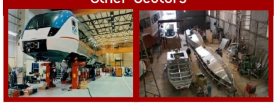
Construction - Civil Engineering



Wind Energy

Aeronautic - Aerospace

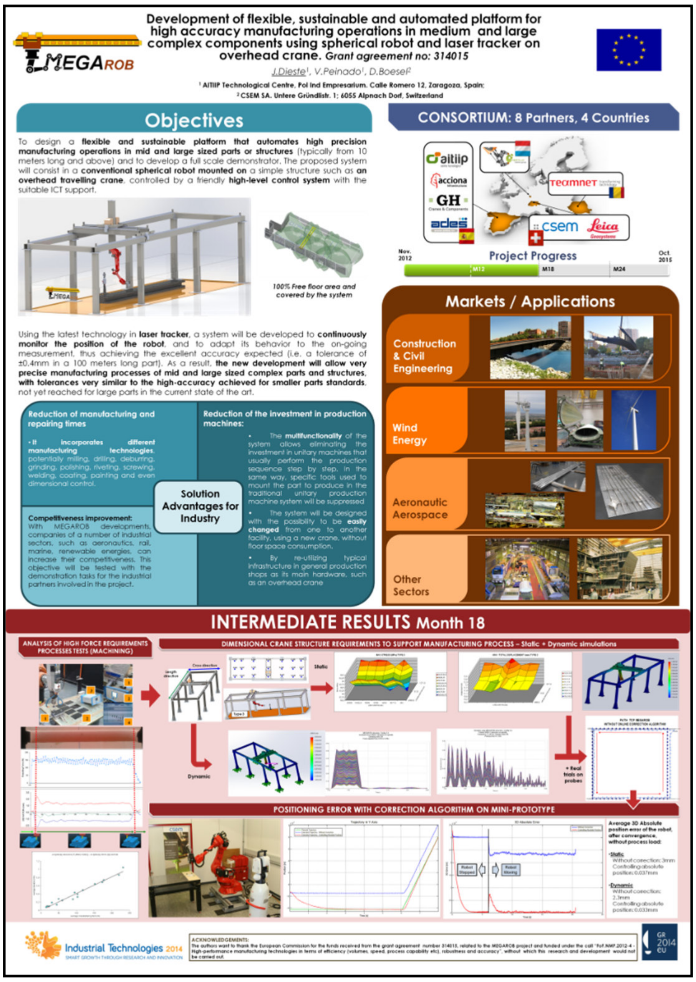
Other Sectors



MATIC (& MoldExpo) – Annual automation fair of Zaragoza, with scientific workshops where Megarob was invited:

ROBOCITY 13 – Leganés, Madrid (Universidad Carlos III) – *Workshop European Initiatives on Robotics*

INDUSTRIAL TECHNOLOGIES 2014 – 9-11 April 2014 Athens: Poster presentation



Other minor Events, where MEGAROB was mentioned and explained inside a more general dissemination activity or another project presentation similar to MEGAROB:

MESIC 5 (Manufacturing Engineering Society International Conference 2013), Zaragoza

Session 9. Non-traditional manuf. processes II

Chairs: **J. Vivancos, J.A. García-Manrique** Session Secretary: **S. Ontiveros**

Time	*Ref.*	*Authors*	*Title*
15:30	167	A. Alberdi, A. Suárez, T. Artaza, G.A. Escobar-Palafox, K. Ridgway	Composite cutting with Abrasive Water Jet
15:45	243	R. Hoto, J.P. Torres, J.A. García-Manrique	Manufacturing and mechanical characterization of Basalt Fibre Reinforced Bio-polymer composites
16:00	148	J.M. Arenas, C. Alia, R. Ocaña, J.J. Narbón	Degradation of adhesive joints for joining composite material with aluminum under adverse environmental conditions: immersion in water and motor oil
16:15	138	J. Minguella, D. Cuiñas, R. Uceda, J.V. Rodriguez, J. Vivancos	Advanced manufacturing of ceramics for biomedical applications: Subjection methods for biocompatible materials
16:30	151	I. Mendikoa, M. Sorli, A. Armijo, L. García, L. Erausquin, M. Insunza, J. Bilbao, H. Friden, A. Björk, L. Bergfors, R. Skema, R. Alzbutas, T. Iesmantas	Heat Treatment Process Energy Efficient Design and Optimisation
16:45	257	J.A. Dieste, A. Fernández, D. Roba , B. Gonzalvo, P. Lucas	Automatic grinding and polishing using Spherical Robot
17:00	143	L. Prades, J. Serrano, R. Sanchis	Design and implementation of a Monitoring and Control System for Setting and Balancing a Tile Grinding Line

CMH 19 – Tool-Machine Congress 19, San Sebastián

9.00 h. **Inauguración (auditorio)**

Grandes máquinas. Diseño y precisión (auditorio)

Presidente de mesa: D. José Luis Peña (Aotek)

09.30 h. Medida de la precisión de posicionamiento en máquinas-herramienta de grandes dimensiones.
Gómez-Acedo, E., Olarra, A., Zubieta, M., Kortaberria, G., (Fundación Tekniker), Olave, J (Zayer S.A.)

10.00 h. Desarrollo de una máquina virtual para el análisis dinámico de máquinas-herramienta de gran tamaño.
Sánchez, M., Armendia, M., Madariaga, J., Ruiz de Argandoña, I. (IK4-TEKNIKER)

10.30 h. Diseño y puesta a punto de una máquina de corte por láser tipo pórtico multi-cabezal de gran dinámica.
Etxeberria, M. (Lazpiur S.A.), Guruceta, E., Armendia, M., Madariaga, J., Ruiz de Argandoña, I. (IK4-TEKNIKER)

Conformado. Procesos (11-12)

Presidente de mesa: D. David Chico (Fagor Arrasate, S. Coop.)

09.30 h. Desarrollo de técnicas avanzadas de caracterización de material para la optimización del diseño de máquinas de aplanado de chapa vía simulación numérica.
Silvestre, E., Mendiguren, J., Saenz de Argandoña, E., Galdós, L. (Mondragon Unibertsitatea), García, D., Leizaola, M., Mas, A. (Fagor Arrasate, S. Coop.)

10.00 h. Desarrollo de una plataforma de fabricación de componentes lumínicos basados en tecnología Roll-To-Roll.
González, D.; Queipo, P.; Fernández-Vigil, A.; Sánchez, P.; Gourlay, J.; Bohlmann, H.; Götzen, R.; Wilmann, R.; Li Pira, N.; Reinhold, I.; Zapka, W.; Burgard, M.; Jolva, O.C.; Schloefli, N. (Prodintec)

10.30 h. Utilización del conformado incremental de chapa para fabricar piezas de electrodoméstico industrial.
Urrutia, B., Aranzabal, N. (Fagor Industrial); Rubio, A., Penalva, M.L. (Tecnalia)

11.00 h. Café Presentación foro del asociado

Aeronáutica. Nuevas tecnologías en procesos de mecanizado (auditorio)

11.30 h. AUTOPUL/SINIDE: Nuevas tecnologías aplicadas al proceso de acabado de moldes mediante el pulido automatizado asistido por nuevas estrategias de máquinas-herramienta. Sistema inteligente de acabado de piezas y utillajes mediante sistemas de pulido y desbarbado.
Dieste, J. A., Roba, D., Gonzalvo, B., Lucas, P. (F. AITIIP/UNIZAR); Fernández, A. (EINA)

12.00 h. Aplicación de la forja rotativa de Inconel 718 a una geometría del sector aeronáutico: análisis microestructural.
Mongas, A., Santos, M., Varela, S., San José, J. (Tecnalia)

Procesos de mecanizado (11-12)

Presidente de mesa: D. Javier Aramendi (IK4-TEKNIKER)

11.30 h. Taladrado de fundición Gris GG30 empleando un sistema de control adaptativo basado en la regulación del par de corte.
Arrazola, P. J., Hernández, M.; Iriarte, L. M. (Mondragon Unibertsitatea)

12.00 h. Predicción de la capa templada en el grind-hardening de piezas cilíndricas mediante un modelo FEM 3D.
Alonso, U., Ortega, N., Pombo, I., Sánchez, J.A., Plaza, S., Izquierdo, B. (Universidad del País Vasco UPV/EHU)

CSEM explained the project and/or showed mini Megarob prototype for the following institutions:

Organization	Place	Date
Jossi Systems	CSEM Alpnach	23.04.2014
Delcam	CSEM Alpnach	15.04.2014
Fraunhofer-Gesellschaft	CSEM Alpnach	27.03.2014
Güdel	CSEM Alpnach	19.02.2014
Comau	Comau Turin	06.09.2013
Synthes	CSEM Alpnach	2013

Dissemination Activities were done also by **ESPACE:**

ZeMA – "Montagetechnik und Montageorganisation" 2-3/04/2014

6. MONTAGE-TAGUNG / MONTAGETECHNIK UND MONTAGEORGANISATION

Programm, 2. April 2014

8:00	Öffnung Tagungsbüro sowie Eröffnung der Fachausstellung im Foyer und im Außenbereich	
9:00	Begrüßung: Annegret Kramp-Karrenbauer, Ministerpräsidentin des Saarlandes; Dr. Albrecht Köhler, Knorr Bremse AG, Geschäftsführer; Prof. Dr.-Ing. Rainer Müller, Zentrum für Mechatronik und Automatisierungstechnik gGmbH, wissenschaftlicher Geschäftsführer; Prof. Dr. Klaus Schmidt, Institut für Produktions- und Logistiksysteme Professor Schmidt GmbH, Geschäftsführer	
9:30	Bernhard Mattes, Ford-Werke GmbH, Vorsitzender der Geschäftsführung: **Apps statt PS – Neues Kundenverhalten treibt neue Produkte und Prozesse**	
10:10	Dr.-Ing. Carsten Intra, MAN Truck & Bus AG, Vorstand Produktion und Logistik: **Produkte, Prozesse, Menschen – Wege bei MAN zur Zukunftsgestaltung**	
10:50	Kaffeepause	
	KOMPLEXE AUFGABENSTELLUNGEN IN DER MODERNEN MONTAGE	
11:20	Prof. Dr.-Ing. Rainer Müller, Zentrum für Mechatronik und Automatisierungstechnik gGmbH, Wissenschaftlicher Geschäftsführer: **Planungsunterstützung bei komplexen Aufgabenstellungen in der Montage – ein Industrie 4.0 Projekt**	
12:00	Martin Stärz, ZF Friedrichshafen AG, Leiter Produktionsmanagement Methoden und Leiter Expert Team Assembly & Inspection: **Probleme und Herausforderungen bei der parallelen Produkt- und Prozessentwicklung**	
12:40	Mittagessen und Teilung der Konferenz	
	MENSCH-ROBOTER-KOOPERATION IN DER PRODUKTION	**WANDLUNGSFÄHIGE MONTAGESYSTEME**
14:00	Henning Borkeloh, Kuka Systems GmbH, Bereichsleiter: **Wandelbare Montagekonzepte mit sensitiver Leichtbaurobotik und Mensch-Roboter-Kooperation**	Lukas Hermanns, BMW AG, Planung Baukasten Montage und Baukasten Fertigmotormontage: **Ansätze einer flexiblen Motormontage**
14:40	Wolfgang Pomrehn, Robert Bosch GmbH, Senior Manager Robotic Systems and Image Processing Services: **APAS family – Ortsflexible Produktionsassistenten**	Peter Hentsch, XENON Automatisierungstechnik GmbH, Leiter Steuerungsentwicklung: **Rekonfigurationsmöglichkeiten für automatisierte wandlungsfähige Montagesysteme**
15:20	Kaffeepause	
	INNOVATIVE PRODUKTIONSTECHNOLOGIEN	**ASSISTENZ- UND MESSSYSTEME IN DER MONTAGE**
15:50	Dr.-Ing. Anne-Katrin Tomys-Brummerloh, Daimler AG, Technologiemanagement Truck Wörth: **Moderne Produktionstechnologien für die LKW Montage am Standort Wörth**	Dr. rer. nat. Björn Schwerdtfeger, EXTEND3D GmbH, Geschäftsführer: **Digitale Schablonen „Die Brücke zwischen CAD und dem Bauteil" am Beispiel der manuellen Montage im Flugzeug- und Automobilbau**
16:30	Alexander Schönberg, FFT EDAG GmbH & Co. KG Produktionssysteme, Entwicklung Informatik: **Automatisierte Handhabung und Montage von biegeschlaffen Bauteilen**	Dr.-Ing. Michael Kleinkes, Espace 2001 S.A., Geschäftsführer: **MegaRob – Hochgenaue Bearbeitung großvolumiger Objekte durch Online-Roboterbahnführung mit Laser-Trackern**
17:10	Ende der Vorträge	
18:00	Stadtführung	
19:00	Abendveranstaltung	

- Vision for Robotics: A BMVA Meeting" (London, 03.12.2014)
- "Austrian Robotics Workshop 2015" (Klagenfurt, from 02 to 03.05.2015).
- "CMH20" (San Sebastián, 10 to 12.06.2015) > together with a dedicated poster

In all conferences, the presentation received a very good feedback.

- **Fairs:** Megarob was presented also on:

- **Equiplast** (Sept.2014 – see picture) on the AITIIP stand,

on the Robotics fair **IROS Hamburg 2015,** ACCIONA present MEGAROB among other robotic projects

and also in the Aerospace fairs:

- **Feria Aeronáutica de Sevilla** June 2014 and
- **Feria Aeroadur**, at Pau (France) on Sept. 2014.

Furthermore, it is prepared the presence of MEGAROB on the event **ICT 2015 Innovate, Connect, Transform** on Lisbon, the 20-22 of October.

- **Workshops**:

Workshop “Automation Seminar”. Hexagon Metrology (group to which Leica Geosystems belongs to) organized a workshop for around 15 ateendees in the CSEM facilities on 15.04.2015. The atendees consisted of customers, commercial representants and integrators of the Leica Laser Tracker. Apart from presentations about the laser tracker and the Megarob concept, two demos were performed in the mini Megarob cell. They showed to the atendees the benefits of the Megarob solution over the state-of-the-art in machining with industrial robots.

Workshop “Efficient production– With laser trackers and robots to high precision”: with more than 30 attendees, it comprised two technical talks, a technology demonstration and a networking apéro. Organized by CSEM in its facilities in Alpnach Dorf (Switzerland) on September 15th, 2014, with support of Leica Geosystems / Hexagon Metrology.

- **Seminars:**
  - Automation/Integration seminar October 2015, presentation of megarob to several customers http://www.hexagonmetrology.ch/veranstaltungen_85.htm?id=10446#.VhKh0vmqpBc
  - Aerospace Seminar Sevilla http://www.hexagonmetrology.es/Eventos_85.htm?id=10783#.VhKiz_mqpBd
- **Media:**
  - **Interempresas** industrial magazine on 10/04/2015. *Desarrollo de una plataforma flexible y sostenible para fabricación de gran precisión en piezas complejas de medio y gran tamaño.*
  - **Internal note** on “el mensajero” de ACCIONA Infraestructuras, trimestral magazine for all ACCIONA workers.
  - **Press Notes** about MEGAROB installation starting on *El Periódico de Aragón, Metalmecánica and Mundoplast.*
  - **Press Notes** by HEXAGON: Metrology supports EU research Project, October 12 2015: http://www.hexagonmetrology.com/News_86.htm?id=6190#.Vh9K537hA-U
  - **Press Notes** about MEGAROB on Romanian language by TEAMNET (07/08/15):

    http://news.portal-start.com/post/teamnet-dezvolta-tehnologii-/
    https://www.roportal.ro/articole/despre/teamnet_dezvolta_tehnologii_in_domeniul_roboticii_indus

triale_pentru_proiectul_european_megarob/
http://index-stiri.ro/150807/teamnet-dezvolta-tehnologii-in-domeniul-roboticii-industriale-pentru-proiectul-european-megarob-2611697
http://www.diacaf.com/stiri/economic/proiectul-megarob/
https://www.agerpres.ro/sci-tech/2015/08/06/grupul-teamnet-integrator-roman-de-it-c-participa-la-proiectul-megarob-inventie-unica-prin-tehnologiile-folosite-15-17-02
http://www.ordineazilei.ro/it-telecomunicatii/p/proiectul-european-megarobromanii-de-la-teamnet-dezvolta-tehnologii-inovatoare-in-domeniul-roboticii-industriale
http://www.e-stireazilei.ro/stire.aspx?id=37334639&titlu=Grupul-Teamnet-integrator-roman-de-ITC-participa-la-proiectul-Megarob-inventie-unica-prin-tehnologiile-folosite
http://infoziare.ro/stire/3995184/Grupul+Teamnet+integrator+rom%C3%A2n+de+IT+C+particip%C4%83+la+proiectul+Megarob+inven%C8%9Bie+unic%C4%83+prin+tehnologiile+folosite
http://www.radiointact.ro/grupul-teamnet-integrator-romn-de-itc-particip-la-proiectul-megarob-invenie-unic-prin-tehnologiile-folosite_461499.phtml

- **Press Article** on HERALDO de Aragón (05/10/15)

Heraldo de Aragón | Lunes 5 de octubre de 2015

Megarob, un proyecto hacia la «fábrica del futuro» impulsado desde Zaragoza

● El centro tecnológico Aitiip capitanea en el polígono Empresarium esta iniciativa, que mejora la creación de grandes piezas para aeronáutica o construcción

ZARAGOZA. Tener que desechar una pieza de gran tamaño, como una viga o la pala de un aerogenerador, a causa de un defecto de fabricación es un problema que no solo supone una pérdida de tiempo, sino también un coste económico. Para evitarlo, el centro tecnológico aragonés Aitiip presentó a la Comisión Europea un proyecto llamado Megarob, destinado a diseñar un sistema extremadamente preciso de fabricación que ya es una realidad. Alrededor de medio centenar de personas de entidades de varios países han trabajado en su desarrollo tres años, y el resultado se encuentra en una nave de la sede de Aitiip en el zaragozano polígono Empresarium.

«José Lorenzo Vallés, jefe de la unidad de Nanomateriales y Procesos en la Comisión Europea, lo ha visitado y lo ha considerado un ejemplo de éxito de lo que se espera de la I+D conectada a las 'Factories of the future' (fábricas del futuro)», afirma orgullosa Berta Gonzalvo, directora de investigación de Aitiip.

Aspecto de la infraestructura de Megarob en la sede de Aitiip, en Zaragoza; en primer plano, el 'laser tracker' que ayuda a hacer más preciso el trabajo del robot montado sobre un puente grúa. ARÁNZAZU NAVARRO

Cuestión de micras

«Lo que queremos es resolver una necesidad industrial», dice José Antonio Dieste, coordinador de Megarob. Explica que actualmente la fabricación de grandes piezas en sectores como la aeronáutica, la construcción o la automoción pasa en ocasiones por el trabajo manual o por el uso de maquinaria que no es lo bastante precisa. «Es un problema de diseño: las máquinas te dicen que el robot de fabricación está en la posición correcta y no es así, por eso no lo detectas hasta que la pieza está acabada y se mide», señala. Si hay un defecto, a veces no se puede ya corregir y hay que tirar la pieza, como ocurre cuando el material es un composite, difícil además de reciclar. El composite es un «material avanzado de altas prestaciones mecánicas y muy bajo peso, formado por una matriz polimérica y un refuerzo que suele ser fibra de vidrio o de carbono», detalla Dieste. Como los que se usan «en los coches de fórmula», apunta Berta Gonzalvo.

Lo que han hecho en Megarob es desarrollar un sistema que combina el uso de láser con tecnología y programas informáticos adecuados para vigilar y corregir la posición del robot de fabricación 1.000 veces por segundo durante su funcionamiento, reduciendo de milímetros a micras (milésimas de milímetro) la posible desviación que haría inservible una pieza. «Es de una precisión extrema», subraya Dieste.

Megarob ha sido probado con una viga y con una pala de aerogenerador y está concebido para trabajar con piezas de más de diez metros de largo. Según Gonzalvo, puede suponer un ahorro de costes de «un 20 o un 25% en el proceso global» de fabricación. Además, el sistema tiene la ventaja de que «es escalable, porque queríamos que fuese lo más flexible posible para adaptarlo a distintos procesos de fabricación», agrega.

El prototipo instalado en Zaragoza consta de una grúa puente de 24 metros de largo en la que se ha montado un robot móvil controlado por un 'laser tracker' y dos ordenadores con programación específica. A partir de ahora, prestará servicio a la industria través de la gestión de Aitiip, lo que significa que, además del retorno de un millón de euros que ha supuesto su desarrollo para Aragón, nuestra comunidad es de algún modo depositaria del resultado los más de cuatro que formaban el presupuesto global de Megarob.

En el proyecto han participado también por parte española la pyme GH Grúas y la gran empresa Acciona. El resto de los socios han sido el Centro Suizo para Electrónica y Microtecnología (CSEM), la firma rumana Team Net International (especializada en software de alto nivel), la luxemburguesa Espace 2001 (software de control de 'laser tracker') y la alemana Leica Geosystems (fabricante de sistema de 'laser tracker' y metrología).

El sistema tiene aplicación en diversas áreas y ya se han interesado por él empresas españolas y extranjeras del «sector aeronáutico, tanto constructoras como proveedores de primer nivel, empresas de desarrollo de software para industria, integradores industriales y proveedores de automoción y ferrocarril», enumera Gonzalvo, quien aclara que Megarob «no viene a destruir empleo, sino a crear trabajo cualificado y de valor añadido, no solo para ingenieros sino también para gente de FP mecánica o automatismos, de los que en Aragón hay núcleos importantes». ?

R. CARTAGENA

- **TV Appearance** on **TVE News** (starting installation)

- **Social Media messages and information** through Partners' channels, mainly AITIIP, GH, and Hexagon/Leica

The **final event** on the 20th October had 93 attendees, the media was informed and the impact through the media and social network was impressive, as it can be section 5 of the Periodic Report, **in the ANNEX I. (not possible to be included here due to space limitations)**

Finally, regarding the **Exploitation Strategy,** the public information regarding this that the consortium wants to reveal is that the Industrial exploitable results directly coming out of the project are two:

MEGAROB as a service: providing this service using the cell installed in the AITIIP facilities, with the help of the other partners if necessary for maintenance. During the next two years, the benefits obtained using this service will be saved in order to at the end of these two years, evaluate if it is feasible to create the start up. If it is, the creation will be done with this savings, if not they will be divided by the partners.

MEGAROB as a product: it can be replicated on any place and sell as a product. It will be priced by the partners but not big developments should be done (easy to replicate)

MEGAROB new developments and especial adaptations could be done in the future if the benefits and the inquiries are enough to support them as a business apart.

5 PUBLIC WEBSITE ADDRESS AS WELL AS RELEVANT CONTACT DETAILS

Public website:

www.megarob.eu

Youtube channel

https://www.youtube.com/channel/UC2YIutshG8aNlv0sEBXZ9LQ

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