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Deliverable D7.1 CENTAURO Integration Concept

Dissemination Level: Public

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Grant agreement no.:	644839
Lead beneficiary:	progenoX GmbH, Bischofswiesen
Authors:	Frank Woodcock and Sandeep Pradeep, Nils Goerke
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0.1	2015-08-06	Sandeep Pradeep	Initial version
0.2	2015-09-07	Nils Goerke	Extended
0.3	2015-09-18	Nils Goerke	Incorporated partner feedback
1.0	2015-09-30	Nils Goerke	Submitted version

Executive Summary

The deliverable D7.1 reports how the integration of the different functional, hardware and software building blocks (modules) is structured and how the respective interfaces (hardware and software) will be established. The planned six-step concept for integration is described, followed by the realization plan for this concept. After an identification (Step 1) of the relevant modules and interfaces, the properties and parameters for these modules and interfaces will be specified (Step 2). In Step 3 the modules will be implemented by the partners. A "Real Life Check" will be performed to evaluate the implemented interfaces (Step 4) to be followed by an amendment and stricter specification of parameters and limitations (Step 5). To monitor the improvements and developments a continuous supervision (Step 6) is planned, including several assessment and amendment cycles. A document (Interface Identification Sheet (IIS)) is provided, as tool for securing and fixing the relevant parameters for the interfaces. An Integration Work and Equipment Breakdown Structure (EWBS) is set up to assist all CENTAURO project members in planning their integration programs and to provide a control mechanism for the project management. In addition, a detailed suggestion for the communication link between the robot and the tele-presence suit is presented.

Contents

1 Introduction

This deliverable describes the concept to perform continuous integration of CENTAURO building blocks into the complete CENTAURO disaster response system. This deliverable has been produced by partner UBO – Rheinische Friedrich-Wilhelms-Universität Bonn – and partner PGX – progenoX GmbH (PGX) – leading WP7. Integration is paramount to the CENTAURO project. The many novel contributions of all partners need to be integrated into a functional system to be evaluated in several disaster-response scenarios in WP8. Please see the CENTAURO Grant Agreement [2].

The integration concept covers the systems architecture and infrastructure for integration (Task T7.1) followed by the integration of the core components into a stable system (Task T7.2), and finally the integration of the complete system to produce the fully functional CENTAURO disaster-response system (Task T7.3) (see Fig 1).

Work package WP7 (Integration) performs system architecture design and continuous integration of the CENTAURO disaster response system. PGX is the leader for this WP, but all beneficiaries are involved in this activity. The objectives of the work package have been defined to be:

- To define the overall technical and software system architecture of the project.
- To implement and characterize the communication link between robot and control station.
- To integrate core components on robot, simulation, and control station for evaluation.
- To integrate the CENTAURO disaster-response system for system evaluation.

Software integration is an important part of the overall system integration. For successful software integration, a good software architecture design is mandatory. The Robot Operating System (ROS) [1] provides a rich set of middleware tools for distributed development, such as inter-process-communication and package management. A common GIT repository will be established, in which the individual partners will integrate their developments into ROS modules. Continuous integration frameworks such as Hudson/Jenkins will be used to compile code in the repository and to run unit tests and integration tests periodically. While partners continuously integrate core components onto robot, simulation, and telepresence interfaces, all partners will be involved in joint integration efforts to enable evaluation of the CENTAURO system for milestones MS3 and MS4. In this way, problems will be avoided that typically arise during late software integration. For software project managing, a tool such as Redmine will be used.

An Equipment and Work Breakdown Structure (EWBS) is provided to assist all CENTAURO project members in planning their integration programmes and provides one possible control mechanism for the project management.

The integration is organized in six steps:

- Step 1: **Identification** of relevant modules and interfaces.
- Step 2: **Specification** of properties and parameters for modules and interfaces.
- Step 3: **Implementation** of the modules and their related interfaces.
- Step 4: **Assessment** – to perform a “Real Life Check” and evaluate the interfaces.
- Step 5: **Amendment** and stricter specification of parameters and limitations.
- Step 6: **Continuous Supervision** including several Assessment and Amendment cycles.

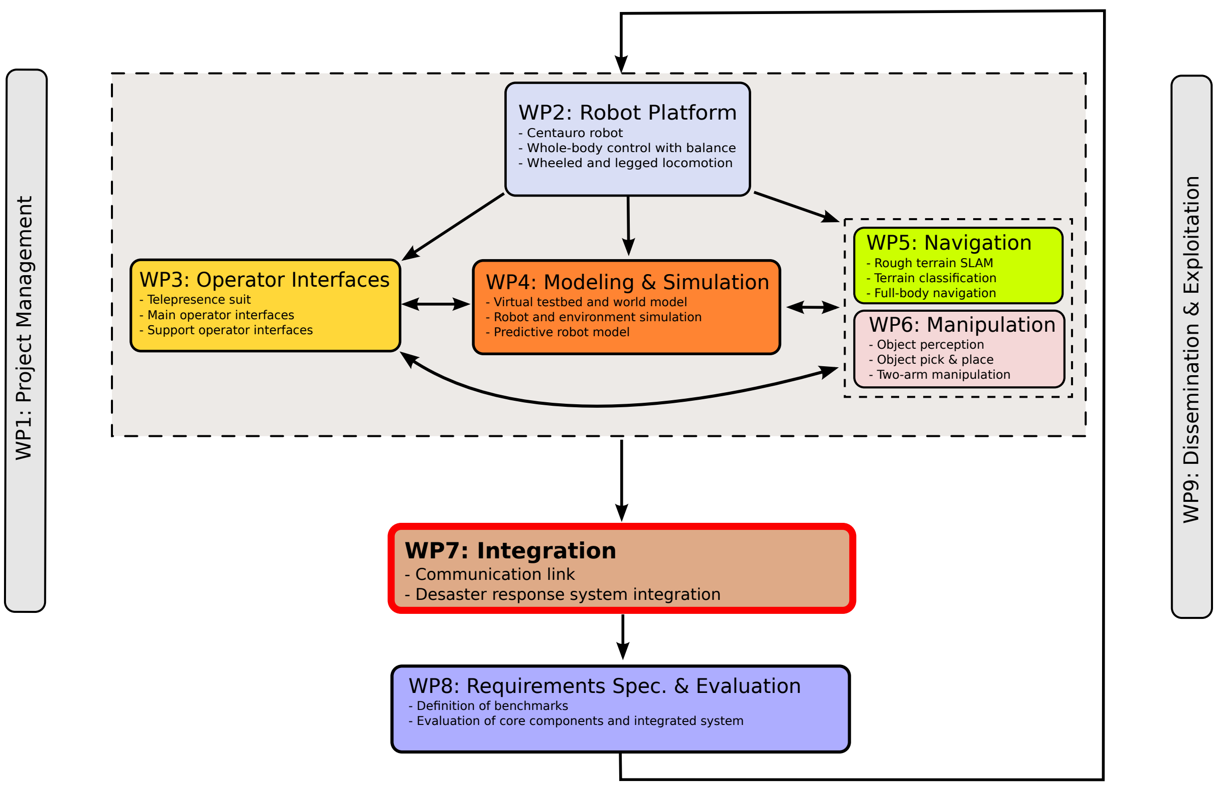

Figure 1: The integration work package WP7 integrates the technical developments from WP2-WP6 into a fully functional disaster-response system, which is evaluated in WP8.

2 Integration Concept

The concept to integrate the developments within CENTAURO is considered to be subject to refinements and changes due to the research nature of the project. It is expected that the novel developments from within CENTAURO and possible improvements in the state-of-the-art from outside the project might require a change of interface-layout, and thus an alteration of the integration procedures. At the beginning of new development cycles (M1, M7, M15, M25), all partners will join efforts to define requirements on their components from a systems perspective. Therefore, the initial integration concept is trying to deal with this uncertainty by explicitly including repetitive assessment and amendment steps into the concept.

The task T7.1 (Integration infrastructure and system architecture) defines the overall technical and software system architecture of the project. This also includes the implementation of the communication link between robot and control station. PGX is the leader for this task, however, all beneficiaries are involved in this activity.

In task T7.2 (Integration of core components) the research conducted in WP2-6 will be continuously integrated in ROS modules and unit tests will be implemented early on to discover potential shortcomings. While some partners may not have access to the real robot and control station hardware, they develop their modules using simulation and placeholder components (CENTAURO Grant Agreement [2]).

The concept for the integration is organized in six steps:

- Step 1: **Identification**
  The first task is to identify and name all the modules and building blocks in the CENTAURO project, following the work breakdown by tasks (see Fig. 2 and Table 1) that depend directly on the integration with other modules. Relevant modules are those that have interfaces with modules from other WPs and other tasks. The interfaces between two modules will be identified and named. Within this step, each of the identified modules, is assigned to a project partner who will be in charge of specifying and maintaining the respective module with close coordination with the other directly involved partners and tasks. The responsibility for interfaces is shared by the partners who are responsible for the connected modules.

- Step 2: **Specification**
  The second step is to specify the properties and parameters for all of the identified modules and interfaces. The partner in charge for a module will collect the requirements and constraints for this module from the involved partners and combine them to a first specification listing. *Interface Identification Sheets* will be used to outline the specification (see Sec. 4) of interfaces. It does not seem necessary to establish a formal specification sheet for all modules covering the complete functionality within CENTAURO at the moment. As soon as the developed software might be relevant for a real application, this will have to be revised.

- Step 3: **Implementation**
  The partners will implement the modules following the specification determined in Step 2. Especially when implementing the interfaces, the involved partners, being responsible for the modules on both sides of the interfaces, will have to collaborate closely. At

this stage, a documentation of the internal module structure and the specifications implemented has to be created and synchronized among the partners.

- Step 4: **Assessment**
  This step will perform a "Real Life Check", to see and evaluate if the implemented interfaces are functional or not with respect to the real robot - to a sufficient simulation - or even to a functional emulation of modules. The plan is to combine and couple some of the core modules from different WPs and tasks to assess whether the chosen integration procedure is functional under real conditions.
  In the first development phase of the project (M7-M18), the research conducted in WP2-6 will be continuously integrated in ROS modules and unit tests will be implemented early on to discover potential shortcomings. While some partners may not have access to the real robot and control station hardware, they develop their modules using simulation and placeholder components or functional emulations.

- Step 5: **Amendment**
  The results from the assessment in Step 4 might require a re-thinking of the integration procedures, including a re-definition of the modules and will probably demand a re-design, and a stricter specification of the parameters and limitations set up in initial Step 1 and Step 2. This is the normal process of re-design and improvement during the developmental phase. Later in the project, the amount of re-design should be smaller due to the progress in integration. In case this stabilizing is not happening automatically, some precautions (Step 6) to ensure this will have to be necessary to obtain a stable interface definition for all the modules involved.

- Step 6: **Continuous Supervision**
  The progress reached in CENTAURO will demand a continuous monitoring w.r.t. the interfaces and modules. Step 4 (Assessment) and Step 5 (Amendment) will be repeated several times during the developmental phases of the CENTAURO project (see Milestone 2, M18, and MS3, M30).
  Continuous integration frameworks such as Hudson/Jenkins will be used to compile code in the repository and to run unit tests and integration tests periodically. In this way, problems will be minimized that typically arise during a late software integration, and an early warning can be obtained before anything runs out of focus.
  It is expected, that the effort for the continuous supervision will be moderate during the development phase, but will increase versus the end of the project.

To ensure integration of all developed components to a functional disaster-response system, WP7 (Integration) will organize **integration weeks** towards the end of years two and three. Here, the researchers who developed the components will bring them together, establish the planned interfaces, and resolve arising difficulties. The first year integration week will have a different purpose: It will be used for learning about the methods of the other groups and will contribute so to the integration of the CENTAURO consortium. This integration week will be the event to realize Step 1 of the six-step integration concept.

The integration concept relies heavily on the use of the middleware ROS (Robot Operating System) [1], all the involved software modules, and the interfaces (hardware and software) between the tasks. The underlying software architecture design is to be aligned with the ROS tools available for a distributed development.

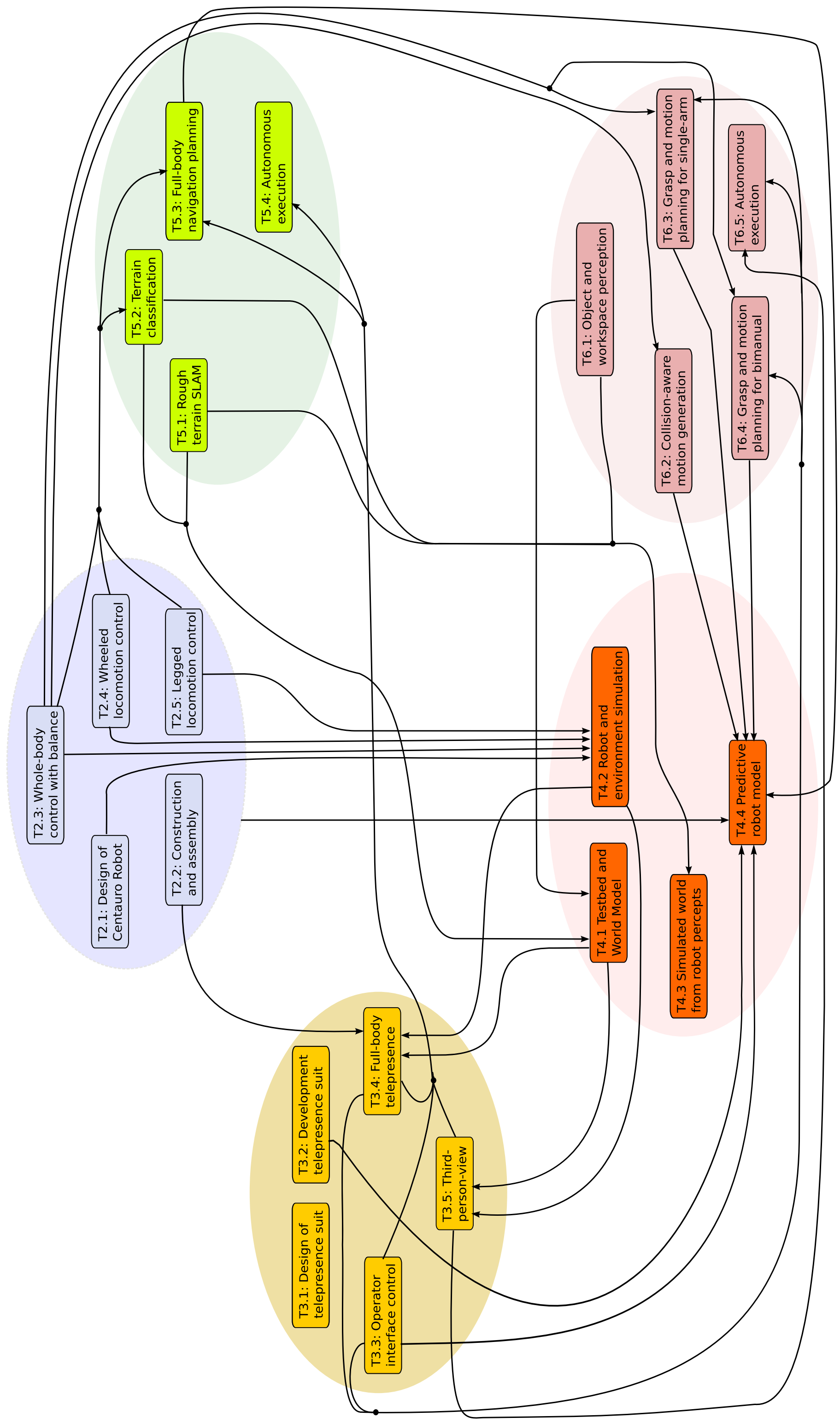

Figure 2: Graphical visualization of the interdependencies of the CENTAURO tasks, Table: 1 shows an alternative representation of the same dependency structure.

	Task depends on task in left most column																							
	T2.X					T3.X					T4.X				T5.X				T6.X					
Task	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	
T2.1												+												
T2.2									+					+										
T2.3												+				+	+			+	+	+		
T2.4												+				+	+							
T2.5												+				+	+							
T3.1																								
T3.2														+										
T3.3														+			+	+			+	+	+	
T3.4																	+	+			+	+	+	
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T4.1									+	+														
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T5.1											+		+											
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T5.4																								
T6.1											+		+											
T6.2														+										
T6.3														+										
T6.4														+										
T6.5																								

Table 1: Table of the interdependencies of the CENTAURO tasks, a visualisation of this is depicted in Fig. 2.

3 Realization Plan

The realization of the integration concept is aligned with the six steps.

3.1 Identification

The first task is to identify all the modules, building blocks and interfaces that are primarily involved or directly depending on the integration with other modules. As a starting point, all partners generate a list (or lists) of the modules and interfaces that are integration-dependent. These lists should allow a classification into core components, necessary components, and auxiliary ones. WP7 leader (PGX) collects these WP-specific lists and integrates them into a full list that is maintained in a CENTAURO repository.
Then, a joint meeting with all partners becomes necessary to secure the results with a mind map technique. As suggested during the kick off meeting, the use of mind mapping will be a suitable tool to secure the results of the identification lists. The mind map has the advantage of being dynamic and giving rich support to categorize and organize the ideas/subsystems that are brainstormed. It facilitates identifying their relationships among each other. In this step, we identify all the involved hardware and software requirements and plot it using a mind map (e.g. Xmind). This will be only done with help of all the partners who have to give input upon the subsystems they plan to use. By this way, we can identify what are the interfaces that will be there for each component. In the same meeting an assignment of partner responsibility to modules and interfaces is envisaged.
An initial version of the identified modules and their interfaces, which has been derived from the Grand Agreement, dependencies identified at the Kickoff Meeting, and the M6 deliverables is attached as appendix.

3.2 Specification

The second step is to specify the properties and parameters for all of the identified modules and interfaces. For this, the proposed assignment of partners to modules will have to be fixed. The partner in charge for a module will collect the requirements and constraints for this module from the involved partners and combines them to a first specification listing. All partners should name the specification needs for each of their modules and each interface involved. Per module and per interface a wish-list shall be collected and harmonized if possible. We have identified the Interface Identification Sheet (IIS) as a good basis to secure the interface descriptions as a standard format within CENTAURO. A similar form for the module description is not considered necessary at the moment. The Interface Identification Sheet (IIS) gives an overview about the items relevant in the interfacing of modules in order to specify the properties and limitations (e.g. capacity of batteries, layout of connectors, load capacity robot etc.).

3.3 Implementation

The partners will implement (Step 3) the modules following the specification determined in Step 2. Especially when implementing the interfaces, the involved partners, being responsible for the modules on both sides of the interfaces, will have to closely collaborate. To ensure this, the synchronization among the partners can be supported by exchanging code fragments (while preserving the individual IPRs), to test the functionality of the modules on both sides of the interfaces. The documentation of the internal module structure and the specifications and limitations encountered during the implementation phase will provide easier access to the software for the involved partners to identify possible problems. The implementation of the modules will be conducted continuously during the project. Especially in the Amendment (Step 5), it is likely that parts of the modules will have to be re-implemented, or at least some of the specifications might need a change.

3.4 Assessment

Step 4 will perform a "Real Life Check", to see and evaluate if the implemented interfaces are functional or not w.r.t. the real robot - or a sufficient simulation – placeholder components – or even a functional emulation of modules or interfaces. Since modules need to be integrated with the actual hardware and software (robot, control station, Virtual Testbed, etc.), we will conduct joint integration weeks at one of the evaluation or partner sites. As described in the management procedures of the Grant Agreement [2] an *integration week* will be organized (a possible date could be around month M10). All beneficiaries participate in the joint integration weeks that are organized as meetings at one of the evaluation or partner sites. The integration weeks will not only be used to integrate the individual components but will also be used to carry out preliminary evaluation, tests runs, and contingency planning.

At the beginning of the week, the partners will inspect the status of the individual partner's components and set up a work plan for an on-site system integration. While this work plan is implemented during the workshop, partners meet on a daily basis to discuss progress, adapt the work plan and develop solutions in case of contingencies.

The philosophy is to start to integrate all pairs of directly interfacing components, and then extend the integration on a `n+1` basis, adding more modules one-by-one to reach the complete system. We start with the two partners that are directly providing and/or the main users of the data going over the channel for the interface.

At the end of the week, a list of integrated modules and interfaces shall be generated stating if the integration was fully successful, or failed, or is still in progress, or was partially successful during the workshop. The experiences made during the integration week have to be monitored and secured into a report.

3.5 Amendment

The results from the integration week assessment in Step 4 can require a re-thinking of the integration procedures, including a re-definition of the modules and will probably demand a re-design, and a stricter specification of the parameters and limitations set up in initial Step 1 and Step 2. Part of the amendment will be done at the last day of the integration week with all CENTAURO partners present. The tool to secure the found results can be again a mind map technique.

The larger part of the amendment will be done again at the partner locations, refining the module and interface description, and further specifying the parameters. The amendment will require a closer interaction between the two (or three) partners that are directly depending on an interface or a module. This closer cooperation and the tests might be operated in part on a distributed basis (e-conference, E-Mail,...) but will require on-site consultations (lab-rotation, ...). Follow up integration weeks, (Step 4 and 5) will be organized and executed as stated in the Grant Agreement.

3.6 Continuous Supervision

The progress reached in CENTAURO will demand a continuous monitoring w.r.t. the interfaces and modules. This is done in Step 6.

Continuous integration frameworks such as Hudson/Jenkins will be used to compile code in the repository and to run unit tests and integration tests periodically. The partners will conduct monthly consultations (mails, telephone and sometimes conference calls) to discuss the current progress on development and integration, to resolve integration issues and conflicts, and to identify new requirements or contingencies. To ensure integration of all developed components to a functional disaster-response system, WP7 (Integration) will organize integration weeks as physical consortium meetings. The Steps 4 (Assessment) and 5 (Amendment) will be repeated several times during the developmental phases of the CENTAURO project (see Milestone 2, month M18 and later Milestone MS3, month M30).
As described in the management procedures an *integration week* will be organized (around month M10) at the beginning of the system integration phase and last for a couple of days. The follow up workshops shall take place a couple of months before system evaluation (M21, M33) at the beginning of the system integration phase and will as well last for a couple of days.

3.7 Interface Identification Sheet (IIS)

The Interface Identification Sheet (IIS) (Appendix to this report) is considered to be a helpful tool for securing and fixing the relevant parameters for the interfaces. It is a basic requirement for the preparation of interfaces used by different subsystems.
As progenoX is responsible for integration of the subsystems, a first overview about the planned subsystems is necessary (see Step 1). For the communication interface those are first line interface hardware, in order to know about the estimated power consumption and weight household of the complete system. The IIS is foreseen to be negotiated at the events as e.g. a Preliminary Design Review (PDR) but will be dynamic over the project life. The IIS will be filled and distributed by progenoX for the communication link (proposed so far) and with that as a reference for the rest of the partners to complete.

A sample IIS for the communication link, a blank IIS, and an initial version of the identified modules and their interfaces are in the appendix of this document.

3.8 Equipment and Work Breakdown Structure (EWBS)

The Equipment and Work Breakdown Structure (EWBS) is to assist all CENTAURO project members in planning their integration programmes and provides the control mechanism for the project management. A first version of an EWBS, to be further developed, is in the Appendix to this report. It can also serve as an elementary document for the partners involved and responsible for a successful integration of all components into the CENTAURO project.

The purpose of the EWBS is to break down the integration work into separate manageable tasks and sub-tasks that are used to allocate funds and resources towards effective project management leading to efficient program accomplishment. On major system projects, dividing a program down to the lowest manageable task requires a large amount of planning and resource allocation. The EWBS identifies the first three levels of the CENTAURO System WBS with the related activities for the integration (see Appendix). In addition, the EWBS serves also to identify all involved hardware and software modules and interfaces that require technical resources within the CENTAURO project as a complete HW and SW system. Only with a complete overview, a proper dimensioning of capacities (mechanical, power supply, computing and processing, etc.) can be achieved.

4 Communication Link Concept

From the Requirements Specification Workshop, 1st-2nd July 2015, Karlsruhe, KTH, it was decided the communication link should meet the following three criteria:

- A low latency and low bandwidth system, which is needed for force feedback implementation.
- A high bandwidth and a considerable latency for data (video) communication.
- A highly reliable and low bandwidth communication, just to have an access to the system.

The distance of communication should be several hundred meters.

4.1 Low Latency (Force Feedback)

The typical parameters for this system are:

- Latency = $1ms$
- Bandwidth = low bandwidth

The commercially available E-band/V-band technology seems interesting as it promises an ultra-low latency. There are number of commercially available products in market.

1) Siklu from Scalcom.
We have two frequency ranges, which could be interesting: $60Ghz$ and $80GHz$. The main arguments for 60 and $80GHz$ point-to-point connections are interference-free and high bandwidths. The manufacturer is Siklu (www.siklu.com) from Israel.

Point-to-point backhaul: $\underline{80GHz}$ E-Band

- The E-band spectrum is $10GHz$ - paired so of $71 - 76GHz$ and $81 - 86GHz$.
- Maximum recommendable Distance: about $3km$
- Maximum distance with a 99.999% = $1400m$
- Minimum bandwidth: $100Mbit/s$ full duplex
- Maximum bandwidth: $2Gigabit/s$ full duplex
- Latency = 250μs
- AES 256bit encryption

$\underline{60GHz}$ = V-band

- The V-band spectrum is $7GHz$ wide and lies in the frequency range $57 - 64GHz$
- Maximum recommendable Distance: $700m$
- Maximum distance with a 99.999% = $380m$
- Minimal Bandwidth: $50Mbit/s$ full duplex
- Maximum bandwidth: $500Mbit/s$ full duplex
- Latency = 350μs

- AES 256bit encryption

Installation videos for 60 and $80GHz$ systems [1]

2) Ad-Hoc solution - point-to-multipoint Mobility:
Airmux-5000 Mobility of RAD Data Communications

- Ideal for mobile applications in the $5GHz$ band
- consists of a base station sector antenna and + Subscriber module
- Bandwidth up to 250 Mbit / s in the sector (eg, 360^o, 180^o degrees or less)
- AES 128bit encryption

Video for Mobility Solution [2]
With the Airmux-5000 Mobility solution they have lit the first 9 km of the S-Bahn network of RBS Bern. This solution brings a much higher and more stable bandwidth than UMTS in the train and it can be used for applications such as Wi-Fi, Digital Sygnage, process data transmission, video surveillance (real time) to be implemented.

3) Nano DDL from Microhard Systems

- Frequency: $300MHz$ - $6GHz$, Varies by model
- Link Rate: Up to $12Mbps$ (Adaptive)
- TX Power: $20dBm$ - $30dBm$ (Selectable)
- Channel Bandwidth: 4 / 8 MHz (Selectable)
- Error Detection: 32 bits of CRC, ARQ
- Data Encryption: 128 bit AES (Subject to Export Restrictions)
- Sensitivity: $-90dBm$ @ $12Mbps$
- $-95dBm$ @ $6Mbps$
- Serial Interface: RS232, RS485, RS422
- Serial Baud Rate: 300 bps to 921 kbps
- Latency: Depending on the packet size and other factors a latency of $1ms$. Suggested setting (One way latency of $1ms$, Packet size $<$ 1500Bytes , wireless distance $< 50km$, signal strength at receiver end constantly $> -70dBm$.)

4.2 High Bandwidth (For Data/Video Communication)

The typical values for the system are :

- Latency = $50ms$ (Considerable value)
- Bandwidth = $>$ 100Megabaud

[1] https://www.youtube.com/watch?v=8dLy7fnE7k0
[2] https://www.youtube.com/watch?v=rFuxSdpoCQw

1) Netgear R7000 (11ac product)
In the DARPA Robotics Challenge, the following 802.11ac product was used with good results: http://www.netgear.com/home/products/networking/wifi-routers/R7000.aspx

- Bandwidth = 600 to $1300Mbps$
- Distance = 30 - $100m$

Details about latency are not available (since these are commercial routers) There are other 11ac router options with more less similar values of Bandwidth and distance.
This link gives the router comparison. http://www.smallnetbuilder.com/tools/charts/router/view
And it clearly states that Netgear R7000 is better in terms of throughput.
But the distance of communication for this product will be around $30m$ to $100m$. If distance of communication is a not a problem, It can be used well with the data communication. Another option would be to make use of extenders or repeaters with this product.

2) MIMO5800 from Microhard systems

- Latency = $5 - 6ms$ can be achieved using right configurations.
- Bandwidth = Upto $300Mbps$

This product is robust and the distance of communication is also larger enough for our need. But this product is limited by its datarate which can be reached till $300Mbps$.
Link to the datasheet: http://www.microhardcorp.com/brochures/MIMO5800.Brochure.Rev.1.4.pdf

3) Siklu from Scalcom is also an option.

4.3 Highly reliable system (For access of the system)

Any option from Microhard Systems will be do good as they have a very good range and with a lower data rate.

VIP2400 :http://www.microhardcorp.com/brochures/VIP2400.Brochure.Rev.3.2.pdf
VIP 4900 : http://www.microhardcorp.com/brochures/VIP4900.Brochure.Rev.2.1.pdf

These products have being used for unmanned aerial as well as ground vehicles. They have a good range (up to $16km$) with a tolerable bandwidth. The products are robust and well suited for our application.

5 Conclusions

Deliverable D7.1 reports an initial plan for the integration in CENTAURO.
Work package 7 (Integration) performs system architecture design and continuous integration of the CENTAURO disaster response system. PGX is the leader for this WP, however, all beneficiaries are involved in this activity.

The envisaged six step concept for integration is described, followed by the realization plan for this concept.

- Step 1: Identification
- Step 2: Specification
- Step 3: Implementation
- Step 4: Assessment
- Step 5: Amendment
- Step 6: Continuous Supervision.

A document (Interface Identification Sheet (IIS)) is provided, that is considered to be a helpful tool for securing and fixing the relevant parameters for the interfaces. An Equipment and Work Breakdown Structure (EWBS) is set up to assist all CENTAURO project members in planning their integration programmes and to provide a control mechanism for the project management. In addition, a detailed suggestion for the communication link between the robot and the telepresence station is presented.

References

[1] Morgan Quigley, Ken Conley, Brian P. Gerkey, Josh Faust, Tully Foote, Jeremy Leibs, Rob Wheeler, and Andrew Y. Ng. Ros: an open-source robot operating system. In *ICRA Workshop on Open Source Software*, 2009.

[2] European Commission Directorate General for Communications Networks, Content and Technology Components and Systems: Robotics. Grant Agreement 644839: CENTAURO—Robust Mobility and Dexterous Manipulation in Disaster Response by Full-body Telepresence in a Centaur-like Robot, 2014.

Appendix

Additional Material:

Example for an Interface Identification Sheet
File: `IIS.xlsm`
Issued by PGX.

Example for an Interface Identification Sheet
High Bandwidth Communication, Microhard MIMO5800
File: `Microhard+MIMO5800_IIS.xlsm`
Issued by PGX.

INTEGRATION WORK & EQUIPMENT BREAKDOWN STRUCTURE
File: `CS_07_11_11_03_03_150612-1344.pdf`
Issued by Sandeep Pradeep, PGX, on 24. August

The EU Framework Programme for Research and Innovation H2020
Research and Innovation Action

INTEGRATION

WORK & EQUIPMENT

BREAKDOWN STRUCTURE

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on

24. August 2015

DOCUMENT CONFIGURATION CONTROL

This document is managed by Sandeep Pradeep. This document shall be amended by issue of complete main section, annex or appendix. Amendment status shall be recorded in the footer information of affected pages.

A new issue of the document will be produced upon completion of each project phase.

Version No	Date	Affected Pages	Description of Change	Amendment Incorporated by
(a)	(b)	(c)	(d)	(e)
1.0	24.08.15	N.A.	Initial Document	N.A.

CONTENTS

WORK BREAKDOWN STRUCTURE

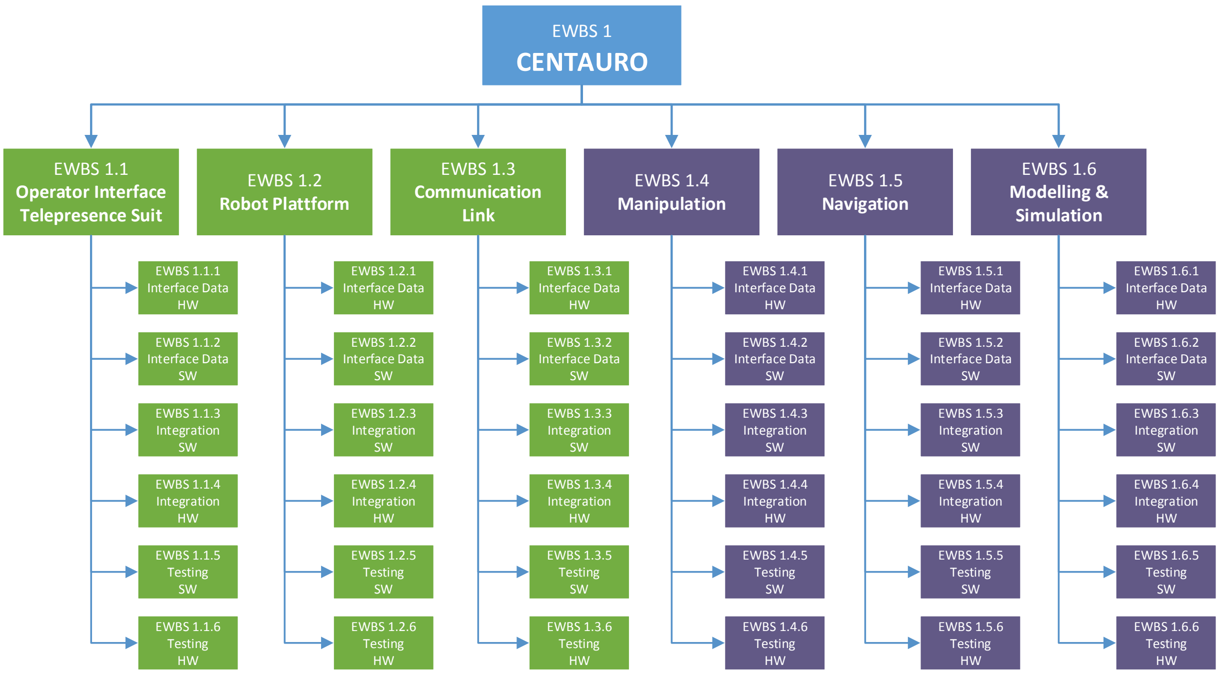
AIM

The Integration Work and Equipment Breakdown Structure (EWBS) is to assist all CENTAURO Project members in planning their Integration programmes and provides the control mechanism for the Project Management and the Donator of the CENTAURO project.

It also serves as elementary document for the partner involved and responsible for a successful integration of all components into the CENTAURO project.

EQUIPMENT AND WORK BREAKDOWN STRUCTURE (EWBS)[1]

The purpose of this EWBS is to break down the Integration work into separate manageable tasks and sub-tasks that are used to allocate funds and resources towards effective Project Management leading to efficient programme accomplishment. On major system projects, dividing a programme down to the lowest manageable task requires a large amount of planning and resource allocation. Figure 1 identifies the first three levels of the CENTAURO System WBS with the related activities for the integration.
In addition, the EWBS serves also to identify all involved Hardware and Software and Interfaces that require technical resources within the project "CENTAURO" as a complete HW and SW system. Only with a complete overview a proper dimension of capacities (mechanical, power supply, computing and processing, etc., can be achieved)



[1] EWBS or EBS is in MIL usage the abbreviation for "Extended ...." in the case of this document the abbreviation means "Equipment and Work Breakdown Structure"

Figure 1.1 CENTAURO Integration WBS

INTEGRATION WORK BREAKDOWN STRUCTURE

The Integration WBS is to be further broken down into a number of different areas as shown in figure 2. The sub-divisions of the Integration WBS Level 3 i.e. "Camera" under WBS 1.2.1.

1. CENTAURO

1.1. OPERATOR INTERFACE TELEPRESENCE SUIT (SSSA – WP3)

1.1.1. Interface Data HW

1.1.2. Interface Data SW

1.1.3. Integration SW

1.1.4. Integration HW

1.1.5. Testing SW

1.1.6. Testing HW

1.2. ROBOT PLATTFORM (IIT – WP2)

This chapter describes the entire robot including the body, locomotion (wheels and legs), manipulator, and the sensors needed to interact with the other EWBS structure elements as operator interface and telepresence suit.

1.2.1. Interface Data HW

1.2.2. Interface Data SW

1.2.3. Integration SW

1.2.4. Integration HW

1.2.5. Testing SW

1.2.6. Testing HW

1.3. COMMUNICATION LINK (PGX)

The wireless communication link transmits sensory measurements and percepts from the robot to the operators and motion commands or action goals from the operators to the robot. The CENTAURO robot and control station is equipped with an advanced wireless transmitter. The CENTAURO system constantly monitors the quality of the communication link. In case of bandwidth limitations, latencies, or outages, the sent information is reduced to only the essential amount that is necessary to continue robot control. If an outage persists, the robot will stop slowly to ensure safety. For operation in shielded environments, wired transmission will also be supported.

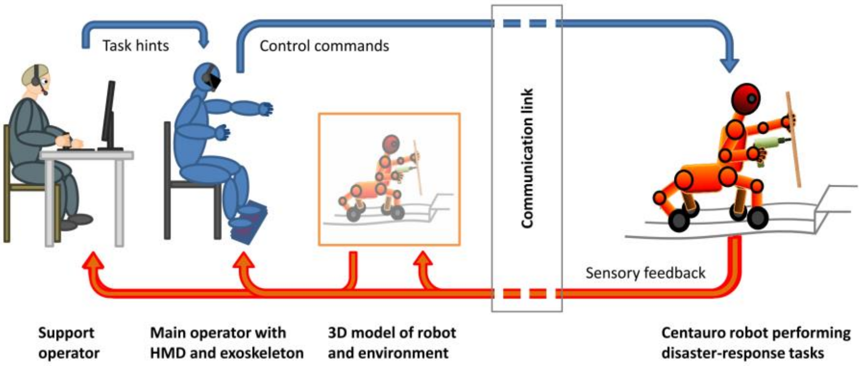


Figure 1 Bidirectional communication link control center ⇔ robot.

1.3.1. Interface Data HW

The datalink is subdivided into three basic channels.

- A low latency and low bandwidth system, which is needed for force feedback implementation.
- A high bandwidth and a considerable latency for data (video) communication.
- A highly reliable and low bandwidth communication, just to have an access to the system.

The distance of communication should be several hundred metres.

The entire Hardware of the communication link will consist of three links, including each a transceiver unit at the operator’s center and at the robot unit.

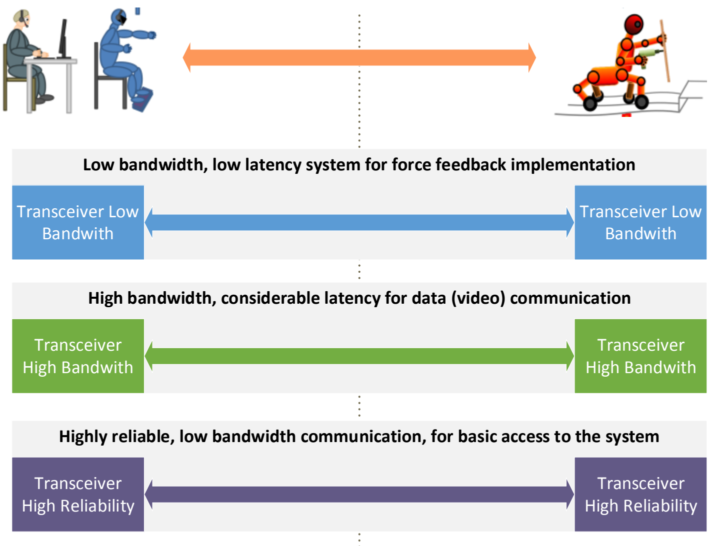


Figure 2 Communication link and involved HW

The components will be located at control canter and the robot.

1.3.1.1. LOW BANDWIDTH, LOW LATENCY CHANNEL

Nano DDL from Microhard Systems
Frequency: 300 MHz - 6 GHz, Varies by model
Link Rate: Up to 12 Mbps (Adaptive)
Channel Bandwidth: 4 / 8 MHz (Selectable)
Data Encryption: 128 bit AES (Subject to Export Restrictions)
Sensitivity: -90dBm @ 12 Mbps - 95dBm @ 6 Mbps

Connectors

Antenna	RP-SMA Female x2 (Outdoor: N-Female x2)
Serial Data	RS232 DB-9F Locking terminal connector
Ethernet	RJ-45 (x2)
Console	RS-232 DB-9F

Dimension: 145 mm x 95 mm x 30 mm

Weight: 395 Gramm

Power Voltage: 9-30VDC

Power consumption: 50 Watt

1.3.1.2. HIGH BANDWITH, CONSIDERABLE LATENCY CHANNEL

MIMO5800 from Microhard systems
Frequency: 5.725 - 5.875 GHz
Link Rate: Up to 300Mbps
Channel Bandwidth: 20MHz or 40 MHz
Data Encryption: WEP,WPA, WPA2 MAC Authentication, RADIUS Server, MAC Blocking
Sensitivity: 802.11a: -96dBm@6Mbps -79dBm@54Mbp

Connectors

Antenna	RP-SMA Female x2 (Outdoor: N-Female x2)
Serial Data	RS232 DB-9F Locking terminal connector
Ethernet	RJ-45 (x2)
Console	RS-232 DB-9F

Dimension: 145 mm x 95 mm x 30 mm

Weight: 395 Gramm

Power Voltage: 9-30VDC

Power consumption: 50 Watt

1.3.1.3. High Reliability channel

VIP 2400 from Microhard systems
Frequency: 5 2.4000 - 2.4835 GHz
Link Rate: Up to 54Mbps
Channel Bandwidth: 5MHz, 10MHz, 20MHz, 40MHz (Selectable)
Data Encryption: WEP,WPA, WPA2
Sensitivity: -97dBm @ 6Mbps -74dBm @ 54Mbps

Connectors

Antenna	RP-SMA Female Bulkhead (Outdoor: N-Female)
Serial Data	RS232 DB-9F Locking terminal connector
Ethernet	RJ-45 (x2)
Console	RS-232 DB-9F

Dimension: 145 mm x 95 mm x 30 mm

Weight: 395 Gramm

Power Voltage: 9-30VDC

Power consumption: 50 Watt

1.3.2. Interface Data SW

1.3.2.1. Low bandwith, low latency channel

Serial Data	RS232: RxD, TxD, RTS, CTS, DCD, DSR, DTR RS422: Tx+, Tx-, Rx+, Rx- RS485: 4-wire/2-wire 300bps to 921kbps
Serial Console	RS232: RxD, TxD
LAN/WAN Ethernet	10/100BaseT IEEE802.3

1.3.2.2. High bandwith, Considerable latency channel

Serial Data	RS232: RxD, TxD, RTS, CTS, DCD, DSR, DTR RS422: Tx+, Tx-, Rx+, Rx- RS485: 4-wire/2-wire 300bps to 921kbps
Serial Console	RS232: RxD, TxD
LAN/WAN Ethernet	10/100BaseT IEEE802.3

1.3.2.3. High Reliability channel

Serial Data	RS232: RxD, TxD, RTS, CTS, DCD, DSR, DTR RS422: Tx+, Tx-, Rx+, Rx- RS485: 4-wire/2-wire 300bps to 921kbps
Serial Console	RS232: RxD, TxD
LAN/WAN Ethernet	10/100BaseT IEEE802.3

1.1.1. Integration SW

1.1.2. Integration HW

IP Classification?
Shock and Vibration?
Temprature?

1.1.3. Testing SW

1.1.4. Testing HW

1.1. MANIPULATION (UBO – WP6)

1.1.1. Interface Data HW

1.1.2. Interface Data SW

1.1.3. Integration SW

1.1.4. Integration HW

1.1.5. Testing SW

1.1.6. Testing HW

1.2. NAVIGATION (KTH – WP5)

1.2.1. Interface Data HW

1.2.2. Interface Data SW

1.2.3. Integration SW

1.2.4. Integration HW

1.2.5. Testing SW

1.2.6. Testing HW

1.3. MODELLING & SIMULATION (RWTH – WP6)

1.3.1. Interface Data HW

1.3.2. Interface Data SW

1.3.3. Integration SW

1.3.4. Integration HW

1.3.5. Testing SW

1.3.6. Testing HW

Interface Identification Sheet

Customer:	progenoX GmbH	**Project description:**	CENTAURO

Interface name:	High Bandwidth Communication
Identification:	Microhard MIMO5800
Interface responsable:	
Partners involved:	

Hardware

The MIMO5800 is a Rugged High Power, 300Mbps Broadband Ethernet Bridge & RS232/485/422 Serial Gateway. Simultaneously supporting high bandwidth backhaul, dual Ethernet ports, and integrated serial port capabilities, the MIMO5800 brings forth a complete solution at a whole new performance level. Built using a robust & rugged design for harsh environments, the MIMO5800 can excel in any application!

Dimensions:	Outdoor: 8.5” x 7.0” x 2.0”
Weight:	Approx. 1245g
Connectors:	**Antenna :** RP-SMA Female x2 (Outdoor: N-Female x2) **Serial Data :** RS232 DB-9F **Ethernet:** RJ-45 (x2) **Console** : RS-232 DB-9F
Interface:	
Powerconsumption:	9-30VDC

Interface Identification Sheet

Customer:		**Project description:**	
Interface name:			
Identification:			
Interface responsable:			
Partners involved:			
Hardware			
Dimensions:			
Weight:			
Connectors:			
Interface:			
Powerconsumption:			