



Deliverable D5.6

Feasibility studies on prototypes

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Summary: This deliverable describes the activities pursued and the major achievements realized during Phase II of the development of robotics technology for the public sector (PDTI – Public end-user Driven Technology Development) in ECHORD ++. Special attention is given to the mechanisms and tools put in place to facilitate an effective, successful and enjoyable co-creation process between different stakeholders. To contribute to future projects which involve co-creation, the deliverable provides lessons learned for the future.

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Executive Summary

The deliverable D5.6, as introduced with Amendment V to the Grant Agreement of ECHORD++, describes the activities performed and the results achieved during Phase II of the technology development of PDTI in the areas of urban robotics (challenge provided by the public sector: sewer inspection) and healthcare robotics (challenge provided by the public sector: Comprehensive Geriatric Assessment). The R&D work in these two areas is described as well as the methods used by the E++ core consortium to assess the performance of the competing R&D teams. In both challenges different approaches were implemented in terms of the technology development. The deliverable outlines those differences, the facts motivating them and the impact this had on the two challenges. Special attention is given to the interaction between different stakeholders during the entire PDTI process.

Further information is provided in the following:

- Section 1 provides information on the starting points of the two challenges when entering Phase II, the differences in the approaches and the impact these had on the process
- Section 2 and 3 provides a description of major activities and achievements in the urban robotics and healthcare PDTI respectively.
- Section 4 summarizes the lessons learned during Phase II

Primary conclusions/results include the following:

- In order to develop technology which meets the expectations of the public sector, the end-users have to be tightly integrated into the development process and need to put quite a lot of effort into the collaboration to trigger an effective (an enjoyable) co-creation process
- PDTI requires the precise definition and tight collaboration between all the stakeholders relevant to the final product; adjusting communication to the reception abilities of the different target groups is key to achieve understanding
- The access to test environments has proven a crucial success factor
- The “quality” of the public stakeholders (also in terms of their willingness to purchase and actively contribute to the technology development) needs to be assessed prior to the collaboration or accepting a challenge.
- Procurement agency and end-user can be separated institutions with very different assessment criteria to motivate innovative procurement.

In the document, the terms external experts, external evaluators or external reviewers are used as synonyms.

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1. Introduction

The current deliverable is connected to Phase II of the Public-End-User Driven Technological Innovation (PDTI) focusing on the two application areas Healthcare (Comprehensive Geriatric Assessment) and Urban Robotics (Sewer Inspection). In the previous deliverables D5.4 and D5.5, the definition of challenges for the Open Call in close collaboration with the public sector (so-called phase 0) and the first six months of the actual technology development (Phase I, Design Phase) have been described respectively (see <http://echord.eu/pdti/>).

Differences between the two PDTI challenges in terms of timeline and stakeholder groups involved in the design of the product (in case of healthcare two end-users – the hospital and the patients – call for patient-centred care) triggered differences in the approach of the two challenges. Even though this imposed a huge organizational change on the management team of E++, it also provided the opportunity to implement two different technology development philosophies: sequential development via agile approach in loops.

Sequential development models have an emphasis on planning, in which development is seen as flowing steadily downwards through several pre-planned phases. This model relies on intensive periods such as drafting requirements for a product before design and development activities take place. It has also an emphasis on time schedules, target dates and documentation. Products developed using this model are intended to be complete according to set-out requirements when released to customers.

In contrast to this, the agile approach prioritizes the iterative way of working, encouraging regular feedback from stakeholders, where requirements and solutions evolve via collaboration between self-organizing cross-functional teams. This model has an emphasis on testing stakeholder's responses throughout the process and adjusting to that feedback; refining ideas and development activities with the intention of delivering products which better reflect what the stakeholders need.

The below table compares the work on the challenges in terms of timeline, definition of KPIs, involvement of stakeholders during the monitoring, the major challenges and the expected technology readiness at the end of Phase III.

Table 1 Comparison Healthcare and Urban Challenge at the end of Phase II

	Healthcare	Urban
Timeline	<p>End Phase I: 09/2016 Start Phase II: 06/2017 Reason: Redress by ARNICA On-site review: 28.02.2018 Start Phase III: 06/2018 Reason for the delayed start: Reduction of the scope for the technology development (which was overambitious at the beginning) needed to be approved by the EC and the public stakeholders needed to confirm that the technology was still relevant (despite the reduced scope).</p> <p>Development time Phases II and III: 17 months Phase II: 10 months (06/17-03/18) Phase III: 7 months (06/18-01/19)</p>	<p>End Phase I: 06 / 2016 Start Phase II: 09/2016 (decoupled from healthcare) End Phase II: 09/2017 One-site review: 16.-17.10.2017 Start Phase III: 11/2017</p> <p>Runtime: 24 months (equally divided between Phase II and Phase III) Phase II: 09/2015 – 09/2016 Phase III: 12/2017 – 12/2018</p>
Monitoring	<p>Combination of remote monitoring based on KPIs and on-site review at the end of Phase II; in-between physical testing in hospitals to involve end-users.</p> <p>The monitoring was based on KPIs discussed between the E++ core consortium and both RTD teams between June 2017 and September 2017. The active monitoring implemented since early September with monthly calls.</p>	<p>4 monitoring periods with documentation and tests required from both consortia to describe and illustrate the progress (for further description of the phases see section 3).</p> <p>Evaluation criteria for Phase II discussed between public body and E++ core; presented to the two RTD teams in a kick-off meeting and summarized in a dedicated document; recommendation after Phase I: improve the prototype and the technological solutions.</p>
Benefits of the respective approach on monitoring	<p>Allowed for an open dialogue with all stakeholders (RTD teams, public body, E++ core consortium, and the independent experts) to assess the performance in the on-site review after Phase II.</p>	<p>The more top-down approach on the definition of the evaluation criteria allows for a swift process as fewer interactions and verification loops are necessary. Sewer started with full-fledged set of evaluation criteria from the beginning. Thus, the targets were very transparent</p>

	<p>Democratic approach on negotiating KPIs with all stakeholders (based on a suggestion by TUM / BOR) led to identification of “bottlenecks” which otherwise might have caused problems later on (i.e. voice recognition).</p> <p>Stakeholder engagement led to inclusion of test and metrics which facilitated a shift from qualitative towards quantitative (more objective) KPIs for performance assessment and comparability between the teams.</p>	<p>for both teams from the very beginning of Phase II.</p> <p>Physical demonstrations are essential to assess performance if the refinement of prototypes is key.</p> <p>The constant access to the physical testing environment strengthened the links between the end-user and the RTD teams. The end-user – unexposed to robotics at the beginning, now clearly sees the benefits.</p>
Budget	Equally divided between Phase II and Phase III (230.000 €)	2/3 for Phase II and 1/3 for Phase III
Number of prototypes expected:	<p>After Phase II: One per team</p> <p>After Phase III: 3 per team</p>	<p>After Phase II: One improved prototype for each team</p> <p>After Phase III: Two prototypes per team</p>
TRL Levels	<p>After Phase II: 6</p> <p>After Phase III: 7 (originally foreseen 8)</p>	<p>After Phase II: 6</p> <p>After Phase III: 7-8</p>
Special features:	<p>Delay by redress of ARNICA;</p> <p>No time for exploitation after Phase III;</p> <p>High comparability between the teams due to identical set of KPIs despite differences in approach of the two teams;</p> <p>Business training (proof of approach for DIHs);</p> <p>Independent experts to assess performance in on-site review are part of the monitoring and give guidance to the two teams.</p>	<p>More a top-down approach at definition of evaluation criteria and procedures (defined between E++ core and public body);</p> <p>Physical demonstrations in combination with permanent access to testing in the sewer properly reflects the requirement to improve the prototype;</p> <p>Both consortia were asked to submit business plans. Both solutions are economically viable. The challenge for both RTD teams lies in overcoming the constraints of their technologies.</p>

2. PDTI Urban: Major activities and achievements in Phase II

2.1. Overview of the Process

The final evaluation of the Phase I led to suggestions to the consortia selected for Phase II, to improve the first prototype developed and the technological solutions proposed. The document “Evaluation results and recommendations of Phase I” was sent to the consortia to inform them about the outcome of Phase I and at the same time provided valuable input from the two independent experts involved in the on-site evaluation and the subsequent panel meeting for the two remaining teams to steer their development activities.

2.2. PDTI Urban Robotics: Development of Deliverables and Evaluation Criteria for Phase II

The document “Utility infrastructures and condition monitoring for sewer network. Robots for the inspection and the clearance of the sewer network in cities. Evaluation Criteria Phase II” was elaborated by the public stakeholder BCASA (representing the city of Barcelona) and UPC. Phase II was divided into four monitoring periods. At the end of each one of these periods, the consortia were required to provide documentation and tests to describe and illustrate progress. Discussions between the public entity (BCASA), the monitoring team (UPC), and both consortia have focused on aspects related to prototypes’ development and optimization of the operational procedure. The four periods can be summarized as follows,

1st Monitoring Period: 15/09/2016- 15/12/2016

At the kick off meeting (November 15th 2016, Barcelona, Spain), BCASA, UPC, and TUM gave an explanation of the monitoring process, the evaluation criteria, the dissemination activities and the required deliverables for Phase II. A closing monitoring telco was conducted on December 15th, 2016. At the conclusion of the period, the consortia submitted the following deliverables:

- D26-3: Mobility, autonomy and communications, ARSI
- D28-3: Mobility, autonomy and communications, SIAR

2nd Monitoring Period: 15/12/2016-30/03/2017

On March 15th 2017, the monitoring team visited the ARSI consortium for a demonstration of the developed prototype (autonomy test) on premises of EURECAT, in Cerdanyola del Valles,

Barcelona. A similar event was organized for SIAR on March 30th 2017, in Pablo Olavide University, Sevilla.

3rd Monitoring Period: 30/03/2017-15/06/2017

The third monitoring period was concluded with a monitoring telco on June 15th 2017, and the following deliverables were submitted by the two teams:

- D26.4: Technological devices for the inspection and clearance of the sewer network in cities, ARSI
- D26.5: Operational procedure and sewer inspection service, ARSI
- D28.4: Technological devices for the inspection and clearance of the sewer network in cities, SIAR
- D28.5: Operational procedure and sewer inspection service, SIAR

4th Monitoring Period: 15/06/2017-30/09/2017

The consortia provided the final deliverables for Phase II at the conclusion of the fourth monitoring period, in September 2017:

- D26.6: Prototype, ARSI
- D26.7: MAV platform verification for sewer inspections requirements, ARSI
- D26.8: Autonomous navigation and data recording, SIAR
- D28.6: Robotic Solution Description, ARSI
- D28.7: Multimedia Report, ARSI
- D28.8: Impact and Exploitation, ARSI

Final evaluation of Phase II for the Urban Challenge, including demonstrations and expert panel evaluation, was performed shortly after this period, on October 16th-17th 2017.

The evaluation of consortia performance at the end of the Phase II was based on marks given in the three areas of: 1) Scientific and/or technological excellence, 2) Quality and efficiency of the implementation and the management of the project, and 3) Potential Impact through the development, dissemination and use of the project (in short: Excellence, implementation, impact).

In order to assess the performance of the two competing teams in these areas, the evaluators had access to the following material:

1. Documentation of / reports on the tasks performed required during the period
2. Physical prototypes
3. Open trials to test the prototypes during the entire duration of Phase II
4. On-site testing and demonstration during the on-site review after Phase II
5. Description of the economic viability of developed products

The following section provides some background information on the activities behind those five aspects:

Positive evaluation of the tasks and documentation required during the period: The consortia sent by email the required documents and deliverables on the dates programmed. These documents were reviewed by the public entity, the UPC team and the external experts. The criteria to assess the progress was based in the results offered in the deliverables and demonstrated in the tests performed along phase II. The monitoring periods structure the dialogue between all the stakeholders involved.

Prototypes: Both consortia developed new prototypes during Phase II. Deliverables D26/28-3 describe the “Changes and Improvements in mobility, autonomy and communications functionalities and technological devices for the inspection and clearance of the sewer network in cities” proposed by the consortia after the evaluation and comments received at the end of Phase I. These improvements were implemented in the first prototype used in Phase I and in a second prototype used at the end of Phase II. The deliverables D26/5-6-7-8 and D28/-5-6 describe the prototypes’ improvements.



Figure 1 Prototypes developed, ARSI (left) and SIAR (right)

Operational procedures: BCASA offered during all the period (12 months) open trials for testing the prototypes within the operational environment, the Barcelona sewer network. As it happened in Phase I, both consortia tested their prototypes on site on several occasions, with the human support of the BCASA’s brigades required for the sewer operational procedure. At the beginning of Phase II, the public entity explained the importance of developing a robot that matches the functions required for a complete inspection and

maintenance of the sewer network. Moreover, operation of the robotic prototype had necessarily to comply with established operational procedure followed by the brigade. Deliverables D26-4 and D28-4 describe the prototypes' operational procedure, including logistics required and operational issues. The deliverables were presented and discussed at the end of the 3rd monitoring period on June 15th, 2017.

On-site testing and demonstration: Tests were organized to allow both consortia to assess efficacy of robotic solutions developed. For the purpose of the final Phase II evaluation, time allowed to inspect the sewer area under consideration (with a length of about 640m), including setup and disassembly, was limited to 6h. Location of this final test was the surroundings of the Cultural Centre of Mercat del Born that includes Comercial Street, Passeig Picasso, Ribera Street, Passatge Mercantil, and Fusina Street. Geographic Information System (GIS) data of the considered sewer sections was made available to the consortia, including sewer section types, and location of permanent obstacles (singularities). The following table shows the updated functionalities detailed in the Challenge Brief and the relative importance they are afforded (weight).

Table 2 Sewer Inspection functionalities detailed in the challenge brief

FUNCTIONS			WEIGHT
Sewer serviceability inspection	Sewer performance 1000 lineal meter/labour day)		Crucial
	Images (Video)		Crucial
	Geometric analysis (scanning)		Crucial
	Monitoring	Air	Interesting
		Water	Interesting
Structural defect inspection			Interesting
Sampling			Interesting

The consortia prototypes arrived at the Barcelona sewer location the week before the date of the final demonstration. Six different sewer section types were present in the area used. Irregular obstacles were present, including sedimentary accumulations in lower areas, and tubes/conduits from the ceiling.



Figure 2 The ARSI team on the day of the final evaluation (left), prototype in operation (right)

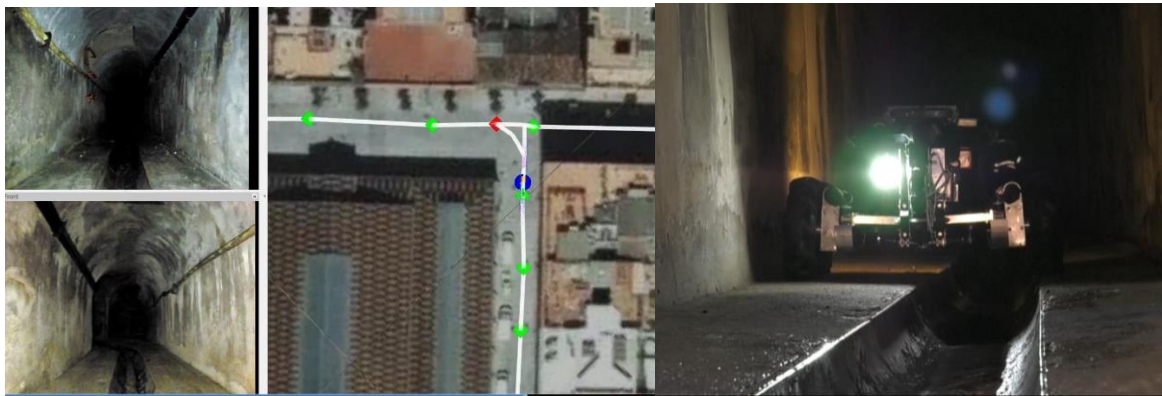


Figure 3 Data capture from the SIAR team on evaluation day (left), prototype in operation (right)

Economic viability of developed products: As discussed in the document “Evaluation criteria Phase II,” the aim of PDTI is to improve the functionalities and /or to reduce the costs of a public service, financing research and development of a pre-commercial product. The work performed should develop the economic viability for the future companies and institutions involved, including SME intending on bringing the robotic product on the market, the logistic service company, and the public entity. To illustrate this, the RTD consortia were asked to provide the expected operational cost per meter of sewer serviceability inspection (over 1.000.000 meters); the cost per meter of structural defect inspection (over 1.000.000 meters), and the cost per sampling (50 samples/year). Both consortia discussed the economic viability of their product in their deliverables. In particular, ARSI presented the economic feasibility and their business plan in deliverable D26.2 at the end of Phase I. The deliverable includes a business plan for each partner involved. SIAR provided deliverable D28.8 (Impact and

Exploitation) at the end of Phase II, which includes detailed information on economic viability, scalability, and transferability to other domains.

2.3. PDTI Urban Robotics: Progress Phase II

A. ARSI

The ARSI consortium has achieved an important milestone during Phase II by demonstrating a stable and semi-autonomous flight in the sewer during the on-site testing. This is of crucial importance to produce a viable solution. A manually controlled flight is almost impossible in the narrow sewers. The on-site testing revealed that the following goals were fully met by the consortium:

- Safe and stable take & landings
- Simple trajectories low level commands
- Improved height estimation
- Satisfactory following of the wall lining

The localization of the MAV in the YZ plane is satisfactory and allows a relatively stable flight. The flight control and the straight navigation are also satisfactory. The control interface is simple and adequate for the purpose, which is commendable. Major challenges still to meet are: the MAV platform should be improved because of the payload restrictions; the communication bandwidth is a critical issue and should be investigated to be adequate to the operational procedure; the visual data and reconstruction for inspection tasks should be improved with better equipment. The consortium will need to analyze in more detail the operational requirements. As the expert evaluation exposes, there is very high potential for the ARSI type solutions, if the crucial issues are solved. The ARSI team has a close working relationship with FCC, which should exploit to the benefit of practical solutions, which provides satisfactory inspection results.

B. SIAR

The consortium has made remarkable progress during Phase II. The design of the robot has been significantly improved. Adding the spring-loaded suspension with variable width has increased the reliability of operation and the versatility of the system. The following milestones have been achieved:

- Safe and stable start, motion and stop
- Simple trajectories

- Wall following and following a trajectory in straight line
- Ground obstacle observation
- Autonomy (duration of continuous operation): 4 hours which is satisfactory.

Communication with the robot is satisfactory, as is the repeater system. Visual data is acceptable to the end users and the 3D reconstruction is adequate. The payload of the vehicle is satisfactory. Lighting: Is adequate. The control interface is simple and adequate for the purpose. The SIAR prototype developed in phase II shows a robotic arm to do sampling tasks. The mission execution and working procedures are efficient and adequate. The major challenges for the remaining runtime of PDTI will be: Execution of complex trajectories is not robust and needs improvements to avoid unrecoverable situations in turns and intersections; water protection needs further improvements specifically for the motors looking for a robust commercial solution. In order to avoid more complexity to the technology and looking that sampling and monitoring of gases and liquid is considered a low priority task in the inspection performance, the expert panel recommends SIAR Team to remove the robotic arm in the next prototype to test in phase III.

2.4. PDTI Urban Robotics: Panel Meeting and Outcome

At the Expert Panel held on October 17th 2017, the two external experts, Tjibbe Bouma and Ivan Olivella, evaluated the progress of the robotic solutions. Both consortia achieved the technological requirements of autonomy, mobility and communication, making possible the operational procedure for the robotic inspection of the serviceability of the sewer network. The results and marks from the experts were included in the document "PDTI Sewer Phase II. Final Report." Respective strengths and weaknesses of both prototypes reflected to a large extent the nature of the two very different technological strategies pursued. ARSI has made the choice of using Unmanned Aerial Vehicles (specifically, quadrotors) to address the problem. This solution is proving very agile, having no problem in safely, autonomously navigating sewer sections. However, power autonomy is a limiting factor. In particular, limited flight times (of the order of 10min) require frequent recovery and redeployment of the system, which significantly complicates operational procedures. In addition, weight constraints also limit the range of sensors that can be carried on-board, negatively affecting quality of monitoring data collected. Conversely, SIAR relies on a wheeled solution (six-wheel

Unmanned Ground Vehicle). The result is a system with excellent power autonomy (about four hours), able to carry a complete suite of sensors, better able to capture data relevant to the monitoring task. The solution faces challenges in terms of agility. The propulsion solution developed includes a mechanism allowing to adjust axle-width (wheel-to-wheel distance, across the vehicle's longitudinal axis of symmetry) at run-time. This function allows adjustment of the vehicle to different types of sewer sections. It also finds use in situations in which the vehicle must traverse uneven ground (e.g. negotiating a fork in the sewer system). Traversal efficacy of the vehicle has made strides since Phase I. It however remains a limiting factor, and the system had to be manually recovered on several occasions during final evaluation demonstrations. Both experts pointed out the progress made by both consortia since Phase I, which they qualified as remarkable. In addition, the consensus was that both consortia were successful in achieving objectives set for Phase II, and thus qualified for Phase III, as discussed in the Panel Evaluation report.

3. PDTI Healthcare: Major activities and achievements in Phase II

3.1. Overview of the Process

The redress submitted by the ARNICA consortium, following the conclusion of Phase I and corresponding selection process, has had a significant impact on the schedule of the Healthcare Challenge, delaying the start of Phase II till beginning of June 2017 and led to decoupling PDTI Healthcare from PDTI Urban robotics. With the start-date leaving 20 months till project's end (January 2019) for both Phase II and Phase III, the decision was made to divide the remaining time evenly between Phases II and III. Accordingly, Phase II will span the 10 months from June 2017 to March 2018, while Phase III will start in June 2018 and end in January 2019. Final evaluation of Phase II is scheduled to occur on February 28th 2018; that is, about a month prior to the end of the phase. The decision for an anticipated evaluation was motivated by the necessity for a timely start of Phase III, and in particular to leave sufficient time to process the Amendment required to include Phase III within the project, in the eventuality of a positive Phase II evaluation. Throughout the decision process that has led to the above schedule, Core Partners have pro-actively engaged dialogue with RTD consortia, and a consensus agreeable to by all parties was reached in terms of phases' duration, start dates, and Phase II evaluation date.

3.2. PDTI Healthcare: Progress Phase II

A. CLARC:

CLARC proved to be very active early on before the official start date of Phase II, following up and addressing feedback received from Phase I evaluation's review report. Phase II officially started June 1st 2017. CLARC organized a kick-off meeting in January 2017, prepared an initial set of KPIs and a PR plan in February 2017, and continued with their first user tests in March 2017. Throughout Phase II, CLARC has been proactively trying to address shortcomings highlighted in the Phase I evaluation (inadequate Human-Machine-Interface) by involving the end-user through Troyes University of Technology (UTT). As a result, the interface has made tremendous strides. This outcome illustrates the merit of the approach to PCP enacted in ECHORD++ and underlines the quality of actionable feedback provided by the evaluation process. Involvement of reviewers with different, complementary expertise has led to a holistic product development perspective, effectively supporting and guiding the RTD team in areas where they may not have had the expertise. The final evaluation highlighted clear obstacles to success for CLARC. In Phase II, before even the official start, the monitoring team offered support in terms of expanding on insights provided by the evaluation report and offered connections to the right partners to decisively address the identified shortcoming.

Concretely, CLARC took the initiative in late 2016 to invite an additional partner to their consortium with expertise in translating user needs and user studies with the prototypes. To that end, CLARC created an overview of potential partners based on desktop research and suggestions from reviewers, TUM, and BOR. Evaluation criteria were discussed in a telco with TUM and BOR, in which three final potential partners were identified. Among these, CLARC selected their final partner on their own, the [ActivAgeing Living Lab](#), from UTT. Based on first recommendations from UTT, CLARC redesigned the interface mock-up, which was then used in the first user studies and focus groups. These were conducted to investigate preliminary usability and acceptance feedback from geriatric patients and took place from March 28th-30th 2017 at a retirement home in Seville. On the first day, the clinicians received a demonstration of the robot. The actual tests (Get up and go and Barthel tests) were conducted on the second day with elderly patients at the retirement home. For this first testing trial, test subjects were not geriatric patients, but instead well-functioning subjects. On the last day, CLARC organized a focus group to discuss the design of the robot with engineers, a physiotherapist,

geriatricians, a nurse, a psychologist, an elderly patient accompanied with caretaker, and a retiree.

Information gathered was exploited to re-design the interface (Figure 4 left) and design a new chassis for the robot (Figure 4 right). The interface has been re-designed to fit the specific needs of elderly people, e.g. integrating large and specialized buttons. The chassis was developed based on focus-group feedback and three co-design sessions led by MetraLabs and UTT. Development decisions including form, colour, and shape were discussed in light of the testing/focus group results (Figure 5).



Figure 4 Interface re-designed (left), robot Chassis re-designed (right)

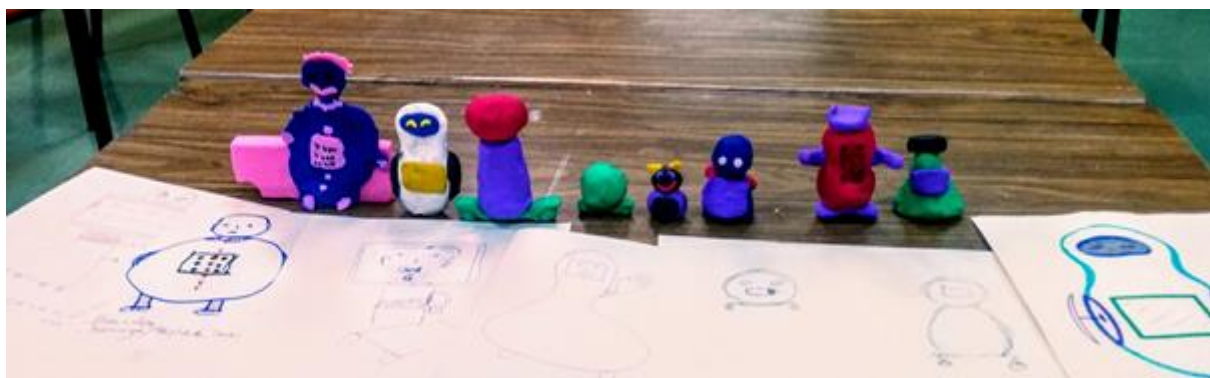


Figure 5 Workshop outcome to re-design robot chassis

A first call with CLARC and BOR took place in May to have a first discussion on CLARC's point of view concerning common KPIs for Phase II. Discussions continued with TUM and BOR when Phase II officially began. A first official monitoring call was organized in late summer to receive an update on CLARC's progress, which was evaluated positively. The new robot prototype was ready for testing on November 1st, 2017. The outcomes of the testing reported by CLARC in a second monitoring call, joined by external reviewer Andreas Müller, revolved around the ability of patients to interact with new technology. CLARC added a pre-test phase, to adjust testing procedures to the variability between test-subjects in terms of technology acceptance and willingness to engage. In later stages of Phase II, CLARC will focus on testing and tuning

this pre-test, to allow the robot to continuously evaluate and adjust on the fly to the patient's needs, by e.g. adjust tone of voice, repeating information, enlarging text. Additional testing will be conducted to assess merit of the developed HMI, gather feedback on the chassis, and evaluate efficacy of the pre-test procedure.

It is clear to the monitoring team that the CLARC team is highly motivated, and their progress in Phase II has been significant. In end of Phase I, their HMI was flagged as clearly inadequate by reviewers. They have embraced this feedback and risen to the challenge. The team's work has clearly benefitted from the PDTI structure, especially the monitoring input from multidisciplinary experts and the definition of clear KPIs. Structured progress discussions during monitoring calls has assisted them in structuring the way they approach their work, organize their workflow, and manage priorities. It is the monitoring team's belief that the PDTI experience will prove beneficial to CLARC, in particular in fostering a product- and innovation-technology-development mind-set, invaluable to them in pursuing placement of their products/technology on the market, and in approaching customers or investors.

B. ASSESSTRONIC:

ASSESSTRONIC has demonstrated a more organized approach to their work, with a clear focus on product development. They followed an end-user driven approach in Phase I and developed a concept based on this. Their plan for Phase II was to implement and test this solution. ASSESSTRONIC needs, in terms of assistance from the monitoring team, are very different from those of CLARC. One of their greater challenges in Phase II was the shift in timing, which compressed development time. A first call with TUM and BOR took place in summer to discuss KPIs for Phase II. One monitoring call followed in autumn and two in December (one of which included both external reviewers).

In terms of work performed in Phase II, ASSESSTRONIC needed to develop the actual interface, based on the mock-up developed in Phase I (very well received by the external reviewers). In addition to this, they needed to integrate and test their mobile robotic platform. The approach pursued was different from CLARC's, placing a greater emphasis on modularity, as opposed to the more monolithic platform of CLARC. Based on test results in Phase II, they adjusted their mobility solution, while retaining modularity. The current platform includes,

1. Perception box: Sensors and processing for get-up-and-go-test (Kinect camera and PC).

2. Interface/tablet: For an app-based interface. The end-user is able to parallelize testing through the use of different tablets for different patients.
3. Mobility solution: Off-the-shelf mobile robotic platform (transporting the perception box). At concept stage in Phase I, the perception box was integrated within a custom-designed, mobility device. This change of orientation is presented as cost-neutral for a mobile system. The user is however free to rely only on the perception box and interface app (placing the box by hand).

The change of orientation in the manner in which the team handles mobility is such that, in some configurations (specifically, tablet plus perception box, exclusively), the developed system cannot be characterized as robotic. Whether or not the work performed remained within the scope of ECHORD++ (a Technology Transfer project in *robotics*), was openly discussed with the monitoring team and external experts. The conclusion was that the product developed builds upon technology from several areas relevant to robotics (perception, HMI, ICT), and that, generally, it would prove counterproductive to artificially enforce strict robotic qualities to the system (e.g. making locomotion mandatory). The constraint could lead to a worse (less cost-effective, less attractive) product. In the opinion of the monitoring team, the work conducted very much remains within the scope of the project, and the RTD team was reassured in their design choices.

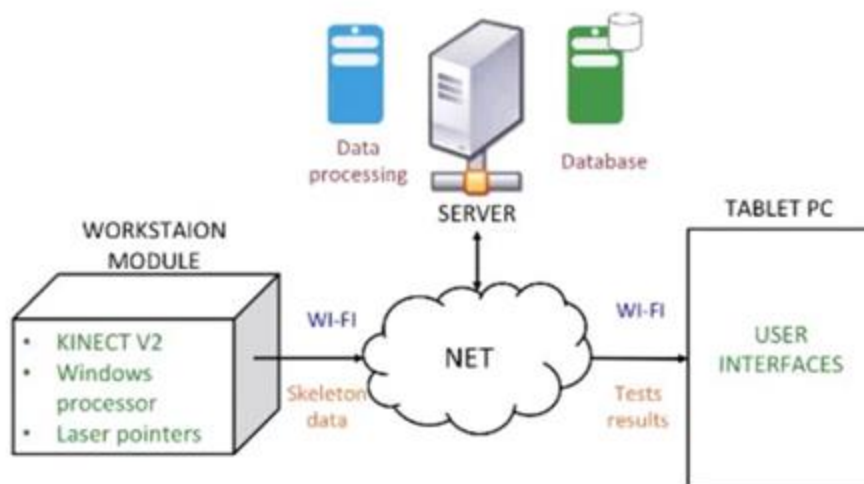


Figure 6 IT Infrastructure ASSESSTRONIC

The next steps for ASSESSTRONIC are to test the different components in a lab environment, integrate them, and test the integrated system, in particular with patients, towards the end of Phase II. ASSESSTRONIC demonstrated a carefully thought out development approach in

both Phase I and II. Monitoring calls in Phase II have served more as a reminder to discuss their plans and to motivate them to actively challenge themselves to set out ambitious goals.

3.3. PDTI Healthcare: Development of Deliverables and Evaluation

Criteria for Phase II

Assessment of consortia's progress and achievements is performed through two complementary modalities; continuous remote monitoring throughout the Phase, and a final, on-site evaluation at the end of the Phase. The intent behind the monitoring procedures enacted (built upon the foundations laid in ECHORD and in the ECHORD++ Experiments' Instrument) consists in promoting an open dialogue between monitoring team, RTD consortia, external experts, and stakeholders. The approach provides transparency in terms of the consortia's progress towards objectives well ahead of the final evaluation. This facilitates work of evaluators, who are kept apprised of achievements at regular intervals. It is also to the benefit of the RTD consortia, as they are able to clearly appreciate to what extent they are meeting expectations. Supporting this monitoring process, providing a clear roadmap for the consortia to follow and goalposts to strive for, is a set of Key Performance Indicators (KPIs). The definition process of this set of KPIs was collegial, initially proposed by the monitoring team, then refined through discussion with the consortia, the evaluators, and mainly with the stakeholder. Feedback from all parties was consolidated into the final version of the KPIs. Direct inclusion of the consortia within this definition process was intended to further promote transparency and underline inclusiveness and consideration for their input. On a practical note, it has allowed to detect and adjust as appropriate (following verification with experts and stakeholder) KPIs that could have proven problematic (e.g. voice recognition of geriatric patient, which lacks the robustness to prove reliably useful, as later verified with the stakeholder). This definition process and corresponding discussions and negotiations occurred over the summer of 2017, with conversations on- and off-line (Skype and emails) with consortia from June to early September, in some instances with both consortia in the call, in other cases with each consortium separately. Concertation with the end-user proved particularly beneficial as, beyond ensuring selected KPIs provided a fair reflection of the user's need, a number of tests and metrics were included and allowed to make KPIs more quantitative (and thereby more objective) in places where they could have been exceedingly qualitative and subjective. In particular, on aspects related to assessing quality of data

gathered by the testing procedure (fundamental to the ability of the system to be of use to the end-user). Monitoring procedures include Skype discussion between the monitoring team, the RTD consortia, external evaluators, and stakeholder. Active technical monitoring began in September, following definition of the aforementioned set of KPIs (shown in Figure 7, full version can be find in Appendix), and was pursued up to time of writing of this document, with a monthly frequency to official monitoring calls, complemented by additional calls with a subset of the above groups (e.g. RTD consortia with stakeholder only).

KPI	Explanation	Measurement	Importance (1-4)
1. Reliability of machine-to-patient communication:	Patients able to understand statements formulated by the robot through whichever modality is used, written text, visual diagrams, synthesized speech, or any relevant combination thereof.	# of times a message/statement/query from the robot to a patient needs to be clarified by the HP, over all relevant tests performed	4
2. Reliability of patient-to-machine communication:	Robot's ability to capture, understand or interpret test-relevant communication from patients.	# of times patient test-responses captured by the system do not reflect what was expressed by the patient	4
3. Data management:	Ability of the system to make data collected during tests available to the health-care professional in a convenient manner, including file format, remote network access, relevant viewers, and relevant data sovereignty aspects.	Ease of viewing test data collected, locally on the system, and remotely Ease of importing test data collected Capacities for processing collected data	4 4 1
4. Power autonomy, system mobility:	Length of time the system is able to operate (in nominal, test delivery conditions), and ability to move	Time measured during typical test support operation Safe movement speed (m/s), turning radius (m)	1 1
5. Technology Readiness Level (TRL):	Using EC scale, expected TRL by the end of pil is 6.	Initial estimation performed by e++ monitoring team, on the faith of monitoring information. Final evaluation performed by external experts on the occasion of the end-of-phase II on-site review and corresponding demonstrations	4

KPI	Explanation	Measurement	Importance (1-4)
1. Reliable test-delivery speed:	Speed at which the system is able to reliably perform CGA tests.	Duration of each test Duration of a complete sequence* of tests # of tests/hour (each one test to be applied to different people) # of complete sequences of tests/2 hours including preparation time between patients # of patients who may be evaluated in a regular day (4h)	3 3 3 3 4
2. Test-support efficacy:	System efficacy in reliably performing automatable aspects of the test, in support of the health-care professional, allowing her/him to focus her/his attention on the patient.	% of test application's time the HP has to be present with robot and/or patient per test # of times HP has to intervene during test's application % of test application's time the HP has to be present with robot and/or patient for whole sequence # of times HP has to intervene during a complete sequence of test Time saved for the HP, allowing her/him to focus on patients' care plans (3rd phase of CGA process)**	4 4 4 4 4
3. Quality of clinical information:	For relevant tests, ability of system to perform tests resulting in correct clinical information.	Validity evaluation of test score results in comparison to a "gold standard" method*** Reliability evaluation (test/retest) of test through standardized method like kappa coefficient or equivalent Specific for motion analysis: # of clinical parameters which may be reliably evaluated by the device (gait speed, length of step, balance evaluation, etc.) Specific for motion analysis, for quantitative items: precision of data collected or estimated (confidence intervals 95%, standard deviation)	4 4 2 2
4. Data presentation:	Efficacy of the system in presenting the data gathered in the test(s) in a manner that facilitates the assessment work to be performed by the health-care professional. To be evaluated by health-care professional.	# of different test evaluations applied during session on same screen # of episodes of each test on same screen in order to see evolution during certain timeframe # of different tests with score evolution on same screen	1 1 2
5. Patient acceptability:	Willingness of CGA patients to interact with the system for the purpose of the tests.	Score of usability standardized test for each test and for global system (based on significant sample)	3
6. Ease of operation and flexibility:	Ease of operation of the system, ease of addition of new CGA tests, ease of addition of languages. To be evaluated by health-care professional (for ease of operation), and stakeholder's IT personnel (for addition of tests and languages).	Duration of time configuration to schedule plan for tests Time interval between test finalisation and result output on screen Duration per test for HP to setup new test # of new item/measures which can be added for new tests, # of type of items which may be considered for new tests- likert, quantitative items, text Applied to HPs: score of usability standardized test for global system	2 1 2 1 3
7. Quality of business plan:	Including considerations of cost, possible evidence of industrial interest, IP aspects, and argumentation of system relevance to address additional technological needs beyond the presently considered CGA challenge; to be supported by a detailed analysis.	Evaluated by E++ monitoring team in light of the opinion of, and in concertation with, potential interested customers.	4

HP: Healthcare Professional, Importance from 4: Crucial, to 1: Interesting

* Complete sequence: Barthel, MMSE and Get up and Go test (GuG) applied to a patient, in that order

** You can consider 60 min as current usual time for a whole CGA process for one patient

*** Gold standard for Barthel, MMSE, and GuG tests are the test's scores completely gathered by a qualified HP

Figure 7. KPIs PDTI Healthcare Phase II

3.4. PDTI Healthcare: On-Site Testing and Evaluation

The on-site testing took place on February 28th, 2018 at the public end-user Hospital Sant Antoni Abbat, in Vilanova i la Geltru. The testing started with a prototype demonstration by both consortia, where they gave a short introductory presentation to their prototypes developed/re-designed in Phase II. After this, they demonstrated the prototypes in the hospital room with CGA patients (Figure 8 and Figure 9) during three tests: a physical test (Get up and Go) and two cognitive tests (MMSE and BARTHEL). After the demonstrations, the evaluators had time to ask questions. In the afternoon, both consortia presented their achievements concerning. The presentation agenda was as follows:

- Presentation of the approach
- KPI achievements
- Perspective towards Phase III and beyond



Figure 8 Testing set-up Assesstronic: Get Up and Go Test (left) MMSE and BARTHEL test (right)



Figure 9 Testing set-up CLARC: Get Up and Go Test (left) MMSE and BARTHEL test (right)

3.5. PDTI Healthcare: Panel Meeting and Outcome

The expert panel meeting took place on March 1st, 2018 at the Hospital Sant Antoni Abbat, in Vilanova i la Geltru. The meeting started with an explanation of the agenda, procedures and planned outcome of the day. The evaluators presented their assessment results of the KPIs for both consortia. An external expert with a strong business focus acted as the panel moderator to steer the discussing so that all three could agree on consolidated results. A panel report was drafted by the evaluators after the meeting.

The main outcome of the panel meeting and a strong recommendation from the external evaluators was to reduce the scope of the technology development during Phase III in order to bring the technology with this restricted scope to a higher TRL level. Thus, the ECHORD++ consortium was requested to get clear feedback from the public stakeholders involved that the technology – even with the restricted scope - was still of interest to them. All public stakeholders directly involved in PDTI for healthcare sent their statement of interest to us. Even with the reduced scope, the technology is still promising and there is a market for it. However, there is still a lot of work ahead for both consortia and challenges to tackle within a relatively short period of time. The process of reducing the scope and to obtain letters of support by the public body, took longer than anticipated. Thus, Phase III could not begin on April 1st, 2018 as planned, but started June 1st, 2018. Phase III will end January 2019. These 8 months will have a very strong focus on commercialization and customer involvement. Engagement with the market will be part of the KPIs for Phase III.

4. PDTI: Lessons Learned

By involving all relevant stakeholder groups – the public bodies (challenge providers) with their corresponding testing environments, academia and industry (as RTD consortia) combined with additional external expertise (depending on the challenge), as well as members of the E++ core consortium (as coordinators and facilitators of the process), PDTI can be taken as a prototypical example of user-centred design and technology development. In the case of the CLARC consortium, PDTI has demonstrated that the close interaction between end-users and technology development teams (with moderators acting as transmission belts in-between) can initiate a mind-shift in the design approach and enable technology transfer that may not have happened otherwise. In both Challenges – Healthcare and Urban Robotics – the continuous monitoring and easy access to test environments has proven a crucial success factor. In addition to this, PDTI has shown to provide the necessary flexibility to adjust to different objectives (here: urban and healthcare) while keeping the main principle – the involvement of all stakeholder groups in the entire technology development process – intact. The PDTI activities during Phase I and Phase II have again demonstrated that inspiring the user-centred approach in development teams is a tremendous effort, particularly if the teams have not been exposed to such an approach before. The coordination during all the process by a multidisciplinary team, not only technological one (robotic in our case) is

crucial to prevent the development of research-driven technology which fails to meet market needs.

The active involvement of the public sector is key to the success of the technology development. Both, public procurers as well as practitioners contribute know-how and experiences which are unique. Often the procurement agency is organizationally separated from the end-user of the technology. This separation can be tricky if the weight of the end-user in the purchase decision is not entirely clear. It makes sense to put an emphasis on clarifying the roles prior before setting up joint projects. It also makes sense to implement a methodology on how to assess a public stakeholder in terms of purchase power, organizational structure, engagement, contribution to commercialization etc.

Appendix

- Evaluation report PDTI Urban
- KPIs PDTI Healthcare
- Evaluation report PDTI Healthcare