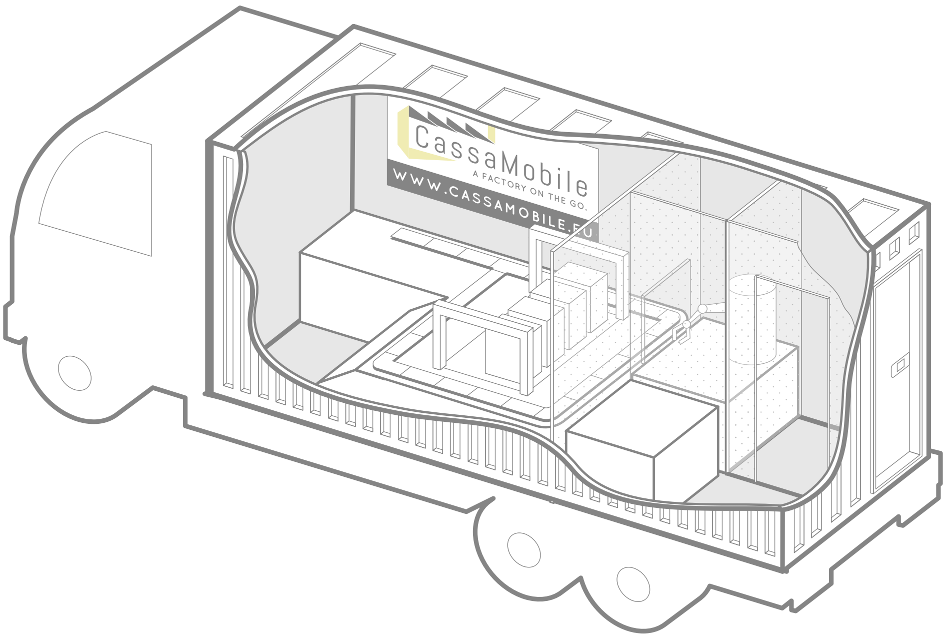
CassaMobile
A FACTORY ON THE GO.

Flexible mini-factory for local and customized production in a container

Second Periodic Report Publishable Summary

1 March 2015 - 31 August 2016



Co-funded by the European Union

The main goal of the CassaMobile project was to develop a new kind of local, flexible and environmentally friendly production system for highly customised parts based on a combination of different manufacturing processes like 3D printing, CNC-milling and assembly technologies in a cleanroom environment inside a transportable container. Major milestones were achieved within the first period of the project including the 'Integration Methodology Workshop' and establishing the 'Industrial requirements' leading to process module specifications and the first system concept and architecture. These developments resulted in specifications for each process module as well as the complete container. The processes were developed to meet the needs of the use cases as well as the necessary boundary conditions to achieve the complete system integration of all processes into an all-in-one flexible manufacturing system.

In parallel, a generic 'Product Demonstrator' was developed for testing all the processes. The 'Product Demonstrator' had all the necessary features needed from the technical requirements and enabled testing of each module with a repeatable standard part. By month 18 (M18), all the process modules were available with basic functions and system integration began.

Similarly, the first version of the software, which included the Human Machine Interface (HMI), main control and a workflow manager, were available by M18.

Since then the project has moved into the realisation and integration stages. Now at the end of the project, all process modules have been built and delivered to the coordinator site. The container has also been produced and delivered to the site. The software has been developed and tested in a virtual environment. The individual modules have all been installed in the container and mechanical and electrical integration achieved. The full functionality of all modules in the container has been proven and a live demonstration has been given at the final CassaMobile workshop.

Results have been published in different academic and trade journals and presented at conferences to address the wider community. A comprehensive summary of all project outcomes is available on the project website.

CassaMobile consortium

The CassaMobile consortium gathers 11 partners – research institutes, SMEs, companies, universities and is composed of the following organisations:

1. **Fraunhofer Institute for Manufacturing Engineering and Automation**
2. **AFT Automation & Feinwerktechnik GmbH**
3. **University of Stuttgart**
4. **Critical Manufacturing**
5. **Materialise**
6. **TNO**
7. **Loughborough University**
8. **SCHUNK GmbH & Co. KG**
9. **COLANDIS GmbH**
10. **Peacocks Medical Group Ltd.**
11. **SCIPROM**

Contact details

Dipl.-Ing. (FH) Christian Seifarth
Fraunhofer Institute for Manufacturing Engineering and Automation
Nobelstraße 12 - 70569 Stuttgart, Germany

+49 711 970-1790
Christian.Seifarth@ipa.fraunhofer.de
http://www.cassamobile.eu

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Modular System Architecture (WP1)

Work package 1 'Modular System Architecture' started in September 2013 (M1) and consisted of four distinct tasks that form the framework for the whole project. As a basis for the project the industrial requirements from the use cases 1 – 3 were collected and summarised in a report. Based on those requirements necessary production processes for the use cases were analysed, the modular design of the complete CassaMobile processes chain were specified, and the 'System concept' developed. The comprehensive overall system concept is implemented in all R&D work packages 2 – 5. The project is scientifically coordinated and supervised out of work package 1 to ensure successful cooperation of all participants. Relevant standardisation, regulation and pre-normative research aspects were considered throughout the industrial requirements and the system concept.

User Machine Interface and CAM software –UMICAM (WP2)

Work Package 2 (WP2) commenced in February 2014 (M6), and is composed of three primary tasks: establishing a Human Machine Interface (HMI), a CAD/CAM system, and a Quality module – the latter starting in March 2015 (M19). Activities performed up to February 2014 (M18) were focused on defining the UMICAM concept, software architecture design and specification, concepts for integrating these systems, as well as the specification required for implementation of the various identified components and software systems.

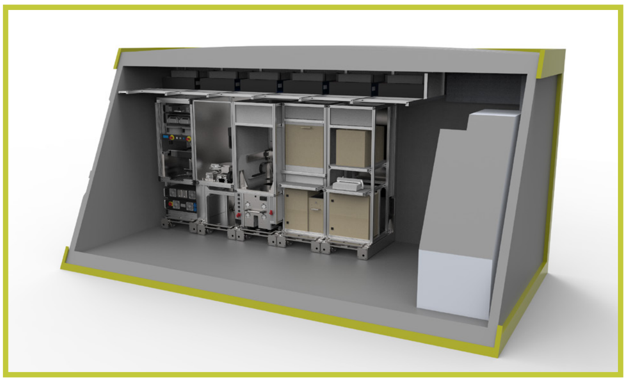
The HMI is a single page application that evolved between M19 and M36. Project partner Materialise (MAT) have extended their software components to support the manufacturing, with specific focus on establishing a Build Processor (BP) framework which has been broadened to also generate specific files for the CassaMobile modules (e.g. milling). Work has been performed on a CAD/CAM converter tool, therefore providing the HMI and Main Control with specific CAM data – depending on which modules are required to provide the specified part. Integration of the HMI, CAD/CAM, and Main Control system within the CassaMobile container has been completed and successfully validated.

Self-Adaptive Control System (WP3)

State-of-the-art control systems have been designed and therefore require appropriate configuration by a suitably trained expert with prior knowledge of the implemented system. Within WP3, a self-adaptive control system for the CassaMobile container has been developed, and is capable of handling the demands associated with a modular CassaMobile concept featuring interchangeable process modules.

The Main Control of the CassaMobile container facilitates communication between the HMI/CAD-CAM conversion systems, and the individual process modules. More specifically, it comprises of the Configuration Manager, Workflow Database, and the Workflow Manager – thus enabling easy configuration of the overall CassaMobile production system. Central to the

Rendering of the modules placement within the container



Main Control is the Workflow Manager. This central software system orchestrates the individual process modules via the ModuleViewer (MV) (located within each module control). The MV is a general purpose software solution used to visualise, control, and automate server applications, while the Workflow-Manager co-ordinates the process modules to perform appropriate job related processes.

The CassaMobile Central Control System (CCS) enables operation of the various process modules without the need for their own control system. A Configuration and Information Memory (CIMory) system has been developed to enable each process module the ability to provide information to the Configuration Manager – subsequently using the CCS module to implement a real-time software-based control system.

Process Module Development (WP4)

Work Package 4 (WP4) commenced in December 2013 (M4) and consists of five distinct tasks. Activities performed up to February 2015 (M18) were focused on the development, set-up, and preliminary testing of the four core process modules; Additive Manufacturing, CNC-milling, Assembly, and Cleaning.

Through the identification of key use case and operational requirements, the specification of each process module was established. Individual module developers were also able to identify and benchmark appropriate hardware and software components. A generic demonstrator component was also established to test the performance of a range of activities executed across the various process modules during development. Initial testing of key activities performed within each process module demonstrated successful results, with scope for further development and process optimisation beyond M18.

To facilitate the 'plug and produce' integration of modules within the CassaMobile container architecture, a generic module carcass concept was also established to house the hardware and software elements associated within each process module. Further optimisation and realisation of the each process module was performed between March 2015 (M19) and February 2016 (M30). Integration and validation of the various hardware and software elements relating to each process module has been performed up to August 2016 (M36), after which full functionality of all container modules has been proven.

System Integration (WP5)

Work Package 5 (WP5) started in December 2013 (M5). Activities performed up to February 2015 (M18) were focused on the development, design, manufacturing, and assembly of the module platform racks and the design of the overall CassaMobile container system.

Members of the CassaMobile project are preparing a module for its integration in the container.

The integration process continues.

A container system design integrating the modular machine and providing supply and filtered air conditioning has been realised. A modular machine design was proposed – with each rack facilitating the easy exchange of the various process modules. The modular racking proposal was developed and has been used as a basis for the incorporation of hardware components within the various process modules.

The integration of the various process modules has been performed between March 2015 (M19) and August 2015 (M24). Electrical hardware PLC, software, and safety components were identified and appropriately set up.

The module work flow within the container environment has been optimised, with appropriate modifications to the supporting hardware where necessary.

Use case 1 (WP6)

As stated within the CassaMobile Description of Work (DoW), the primary goal of Work Package 6 (WP6) is to demonstrate the working principle and the potential of the CassaMobile mini-factory for the localised production of bone drill guides.

The work package commenced in September 2013 (M1) and ended in August 2016 (M36). During the early phase of the CassaMobile project, a number of workshops and meetings were held to discuss and identify the industrial requirements relating to the specified use case. Requirements relating to material properties, software, and equipment were established and formalised.

Within Task 6.2, first exercises were performed relating to the design of the CassaMobile container for the specific and localised production of guides. During Consortium Meeting 4 (CM4) in M21, a proposal to change the specific use case within (WP6) was put forward and agreed by the consortium. Although the specific outcome had been changed from bone drill guides, the agreed technical demands and specifications relating to the manufacturing and technical aspects of the use case remain unchanged. The agreed new platform for the WP6 case-study focussed on an 'Idea's Worth Making' system in which the complete CassaMobile container will be used for the localised manufacturing of components for maker-base communities and educational institutions.

The quality of the printed work pieces has been evaluated and the performance of the container has been validated with regard to the targeted use.

Use case 2 (WP7)

Work Package 7 (WP7) ran for the duration of the CassaMobile project and required Peacocks (PEA) to utilise the CassaMobile mini-factory for the production of orthotic devices. Following commencement of this WP, a comprehensive product and materials investigation was performed to establish the requirements for the orthotic products and appropriately disseminated to the CassaMobile module developers.

To achieve 'A preliminary description or the modular orthotic concept', PEA considered a number of Additive Manufacturing (AM) processes. Based on this investigation, and in close collaboration with project partners University of Loughborough (UoL) and Fraunhofer (FhG-IPA), an appropriate AM machine was purchased – with minor modifications made to align its manufacturing capabilities with the established use case requirements. Milling choices were also considered with the purchase of an appropriate milling machines to commence testing. Preliminary design concepts were developed for both FO and modular AFO devices, with initial prototypes built for validation with both the AM printer and Milling apparatus. In order to validate the performance and fatigue properties of the manufactured components, a number of test methods and rigs were designed and established in-line with the performance requirements of the FO & AFO's.

Following CM4 (M21), it was agreed by the consortium that due to manufacturing limitations, the WP7 case study will solely focus on the design and manufacture of the FO components – all manufacturing requirements remained unchanged. The CassaMobile concept has been validated by manufacturing appropriate FO prototypes. The fatigue performance of FO's and digital data acquisition methods have been evaluated.

Use case 3 (WP8)

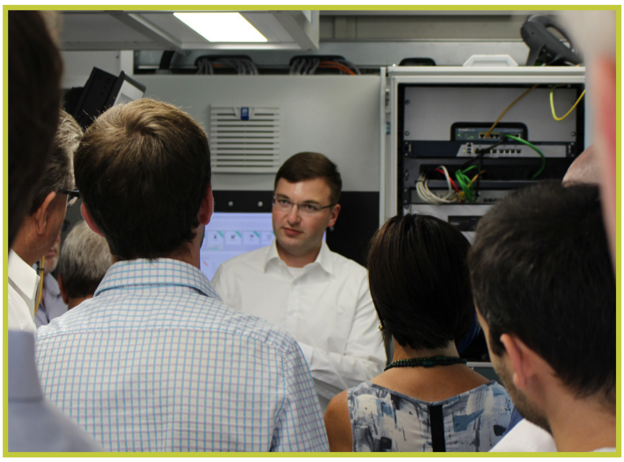
Work Package 8 (WP8) commenced in September 2013 (M1) and consisted of three distinct tasks. Activities performed up to February 2015 (M18) were focused on the requirements and specifications for individual grippers and the development of concepts for generic customizable grippers. Through the identification of key use case requirements, the specification for customisable grippers was established. By doing such, the members of WP8 were able to define the range of expected grippers and the definition of a process leading to an automated virtual adaption of the tools depending to the handling object.

Up to August 2015 (M24) SCHUNK performed further development on the planned use-case featuring three different concepts for individual grippers. The CassaMobile generic demonstrator component was also manufactured to perform handling tests to assess the various processing and handling steps required for the production the gripper concepts. In co-operation with MAT and UoL, between September 2016 (M25) and August 2016 (M36) additional activities were performed to further optimise the identified gripper concepts for realisation within the CassaMobile process flow.

Potential Impact

The aim of the project was to create significant impact by enabling manufacturers to respond to rapidly changing market dynamics with high value-added products whilst reducing time-to-market, cost, environmental footprint and set-up time. This is to improve European machinery and equipment manufacturing sectors and specifically SMEs' and competitiveness against USA and Asia.

Visitors ready for the live demonstration.



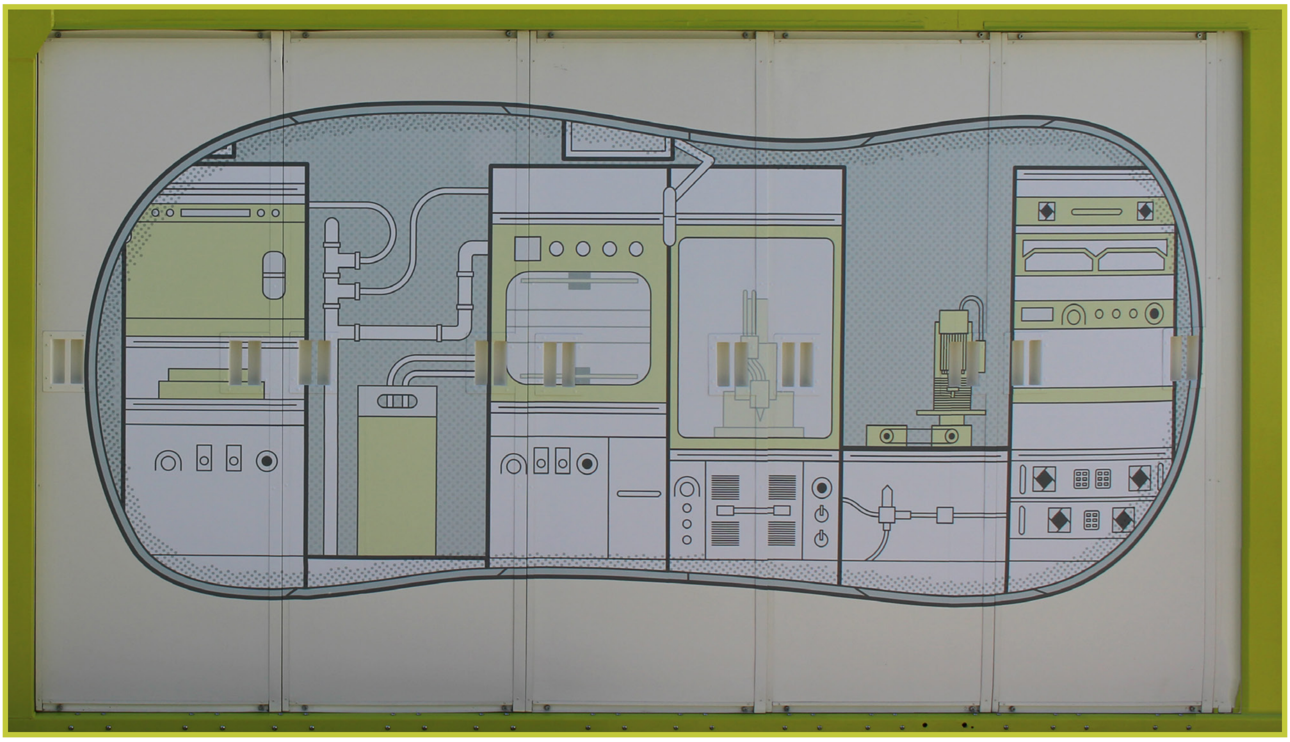
CassaMobile has managed to achieve all its objectives resulting in a truly modular and adaptable manufacturing system. The plug and produce capability demonstrated in CassaMobile allows manufacturers to be as flexible as the market and to carry out production at the location of need and 'just in time'. It can significantly reduce the lead-time by reducing required infrastructure as well as reducing the transport time, cost and environmental effects related to transport. This can significantly increase the manufacturers' competitiveness within the market as well as increasing manufacturing efficiency.

Industrial impact of the CassaMobile system was illustrated by the aid of three use cases during the project. Highly demanding products, bone drill guides and orthoses from medical sector and industrial grippers from the automation industry were chosen. The system's ability to meet these demanding product requirements was demonstrated. During the project, the exploitation outcome, impact and unique selling point (USP) of CassaMobile within the selected industries as well as others were identified.

Regarding the specific use cases, the CassaMobile system helps industrial partners to significantly improve their advantage compared to their competitors. The ability to take the container to the customer is hugely beneficial. It could be used to demonstrate the system's capability. In another scenario, the reason behind customer visit could be to educate the customer on technology possibilities, which results in design and manufacturing efficacy as well as resulting in happier customers.

The same approach can be taken to educate students, the future manufacturers and customers. It can help to give them a realistic and practical view on the possibilities of each individual technology. The long-term effect of such educational use of CassaMobile system can be expected to influence the future of European market. This would enable students to access and utilise the full experiences and benefits of a factory in a safe and convenient manner that would be impossible or impractical for each School to invest in individually.

On the external wall of the container an illustration indicates the position of each module.



In the Orthotic use case, the digital CAD/CAM environment provided by the CassaMobile concept, with optical scanning of patient anatomy, will allow manufacturers to engineer the orthotic products utilising Finite Element and musculoskeletal models. This will increase the uptake of more advanced designs based on solid scientific and engineering principles and accelerate the development of new approaches, in particular dynamic devices tailored to the patient's gait cycle. The result will be a more effective orthotic, which hugely benefits the patient. Better outcomes can reduce secondary care costs and increase mobility allowing greater independent living and, in many cases, contributing to enablement for return to active work or other contributions to society.

The small footprint of the CassaMobile container along with its mobility, permit local and on-site manufacturing in hospitals and clinics. Combined with digital data capturing, digital designing and local manufacturing, this will result in significant reduction in lead-time. This reduced lead-time directly impacts the patient. With an aging population, the number of people requiring and depending on orthoses is increasing, therefore the societal impact of a better healthcare service will be more significant.

Additionally, the CassaMobile system can reduce the manufacturing cost of orthoses by at least 30%. The cost reduction is due to using suggested low cost material in the Additive Manufacturing module as well as reduced manufacturing time and transport costs. The overall cost reduction effects both healthcare providers and patients and results in a better public service.

In the case of industrial grippers, the use of additive manufacturing, novel material and design of gripper jaws to make it possible to 3D print in using material extrusion, reduces production costs. This enables manufacturers to bring the technology to industrial applications like automation components with the focus on handling tools. This can lead to individualized (customer-specific) parts with reduced costs, lightweight-constructions and shorter delivery times. Combined, they can result in meeting customers need in time with a lower cost to differentiate the manufacturer from competitors.

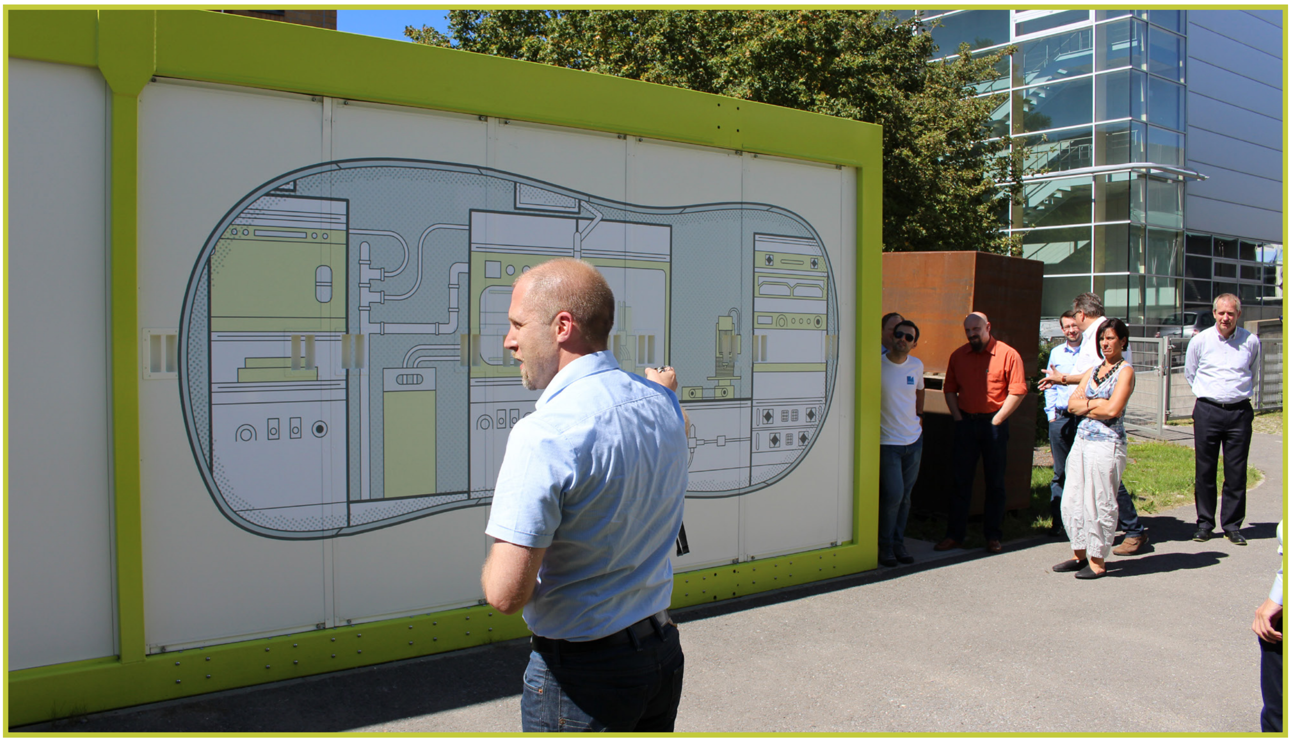
Additionally the additive manufacturing capability of the system allows production of highly customised grippers matching any product shape and size. This increases production efficiency by eliminating the need to reconfigure automated production lines to match the products. The possibility of having such huge flexibility increases the number of potential customers and commercial impacts.

In summary, the CassaMobile system allows manufacturers to follow rapid market dynamics by using a configurable, modular and mobile production facility. The presence of modules such as additive manufacturing, CNC milling and assembly can significantly increase the manufacturing ability for highly customised products. While the local, on-site manufacturing reduces the lead-time and cost of final products, as well as reducing the environmental impact of shipping and transport. The presence of in-process inspection results in higher accuracy, reduced post-process inspection and less waste.

Digital design combined with additive manufacturing can result in eliminating the need for process stages such as tool making for customised parts while reducing waste compared to some traditional processes hence having lower environmental impacts.

Dissemination activities and the exploitation of results

Dissemination activities were multifaceted including a website, a video, scientific papers, articles in industry periodicals, presentations



Visitors outside the container, after the live demonstration.

at scientific conferences and industry exhibitions, various promotional materials and public demonstrations. Also the CassaMobile container itself has been branded in line with the project's visual identity.

To date 9 scientific papers have been published with more in preparation or under peer review. There were 9 presentations and 5 posters presented at scientific conferences. 4 articles were published in industry periodicals and there were 3 presentations at industry seminars or exhibitions. Stands were taken at two industry exhibitions. Promotional materials were made and distributed, including a flyer, a foldable container model, a CassaMobile branded folder with project documents and a final project video. A public website was created (M1) and regularly updated, featuring a dedicated 'Container Blog' to follow the assembly of the container. Two public workshops were held, the second including a live demonstration of the fully functional container. The consortium is continuing to pursue dissemination and demonstration activities beyond the completion of the project.

In total 20 potential exploitation results were identified and documented during the project. Use cases were evaluated closely and a road map until 2020 was created guiding the next activities to maximise the commercialisation impact.