PROJECT FINAL REPORT

JU Grant Agreement number: Artemis-621439
Project acronym: ALMARVI
Project title: Algorithms, Design Methods, and Many-Core Execution Platform for Low-Power Massive Data-Rate Video and Image Processing
Funding Scheme: Collaborative project
Date of latest version of Annex I against which the assessment will be made: 03-11-2016

Period covered: from 1 April 2014 to 30 June 2017

Name, title and organisation of the scientific representative of the project's coordinator[1]:
Frank van der Linden
Philips Healthcare
Tel: +31 40 2796896
Email: Frank.van.der.linden@philips.com

Project website[2] address: **www.almarvi.eu**

[1] Usually the contact person of the coordinator as specified in Art. 8.1. of the JU grant agreement .
[2] The home page of the website should contain the generic European flag and the FP7 logo which are available in electronic format at the Europa website (logo of the European flag: http://europa.eu/abc/symbols/emblem/index_en.htm logo of the 7th FP: http://ec.europa.eu/research/fp7/index_en.cfm?pg=logos). The area of activity of the project should also be mentioned.

Table of Contents

1 Final publishable summary report

1.1 Executive summary

In order to address new societal challenges in the various fields (especially "Healthcare and wellbeing" and "Green, safe and supportive transportation"), platform solutions for high-end image/video processing need to be brought to the next level. The ALMARVI project aims at proactively addressing these issues at various system layers.

ALMARVI aims at providing cross-domain many-core platform solution, system software stack, tool chain, and adaptive algorithms that will enable massive data-rate image/video processing with high energy-efficiency. ALMARVI will provide mechanisms and support for high degree of adaptability at various system layers that will abstract the variations in the underlying platforms (e.g., due to imperfections in the fabrication process), communication channels (e.g., available bandwidth), application behaviour (dynamic workloads, changing requirements) from the application developer. This is crucial for providing consistent performance efficiency in an interoperable manner when considering heterogeneous platform options and dynamic operating conditions. The key is to leverage image/video content-specific properties, application-specific features, and inherent resilience properties of image/video processing applications.

The goal of ALMARVI is to develop:

- Adaptive, scalable, and parallelised algorithms for image and video processing
- Cross-domain system software stack with adaptive run-time system for efficient resource/power management and improved interoperability
- Concepts for continuous hardware and software adaptations
- Cross-domain many-core execution platform scalable with off-the-shelf heterogeneous acceleration fabrics like FPGAs, embedded GPUs, DSPs, etc.
- Design tools and methods for execution platform
- Industrial-grade demonstrators for multiple application use cases to validate the project results.

ALMARVI's scientific and technological developments will be validated and demonstrated in diverse use cases from three key industrial domains i.e., healthcare, security/surveillance/monitoring, and mobile. Therefore, in addition to providing scalable and cross-domain computing platforms for embedded systems, ALMARVI aims at providing "*the core of solutions for the big societal challenges like affordable healthcare and wellbeing, green and safe transportation, reduced consumption of power ... [Artemis JU Annual Work Programme (AWP) 2013, Section 1]*".

ALMARVI's technological developments will help in combating the complexity of advanced image/video processing applications from key industrial domains of European market, thus providing improved productivity and increased competitiveness of European market in different sectors. ALMARVI's platform solution will enable development of low-cost solutions for a wide-range of market in different industrial domains and create new market opportunities, in particular supporting SMEs.

The ALMARVI project exhibits a consortium with complementary skills, market/industrial/business experience, and technical/organizational competence. This is crucial to accomplish the challenging goals of ALMARVI. ALMARVI partners are highly active at EU and international levels/markets. They possess a vast experience in contributing, successfully executing, and managing EU R&D projects.

1.2 Summary description of project context and objectives

Embedded systems are proliferated in almost all of application domains from low-end to high-end processing solutions. Image and video processing are among the most fundamental applications in major industrial domains like automotive, smart phones, healthcare, security/surveillance, entertainment, mobile consumer, etc. One common requirement of these applications is an insatiable demand for more performance at low cost in almost all the major market segments. Advanced image/ video processing applications for high-quality services (in terms of better healthcare, safety/comfort in automotive, etc.) exhibit a voracious appetite for computational power, while at the same time constrained with the low-power consumption requirement which is an inevitable design constraint when considering green computing and better environment. Examples of some prominent use cases in healthcare, security/surveillance/monitoring, and mobile domains that require massive data rate image/video processing at low-power budget are:

- **in Healthcare (medical imaging, eHealth):** minimal invasive treatment for cardiovascular diseases, minimal invasive low-power X-Rays, CT, MRI, ultra sound, in-vivo continuous monitoring, medical imaging assisted diagnostic and therapeutic process, tele-operation theatres, image fusion, pre-/post-processing (reconstruction, correction, segmentation, visualization) of medical images for X-Ray detectors, etc.
- **in Security (Surveillance, Monitoring, Protection, etc.):** distributed monitoring with mobile and fixed video sensor nodes, object detection/recognition, multi-frame video resolution enhancement (super-resolution), object tracking, motion tracking, video event detection/analysis, asset protector, event synchronization, defect detection.
- **in Mobile domain:** multimedia, software defined radio, etc. on ultra-energy-efficient heterogeneous multicore embedded platform.

Need for Adaptive Many-Core Computing Platform Solution: The advanced image/video processing embedded systems are to satisfy stringent requirements for low weight, low power consumption, low heat dissipation, variability, or any combination of thereof, yet providing massive data rate processing to support high-end applications in various domains.

Need for Heterogeneity, Flexibility, and Programmability: The stringent performance and power consumption requirements – often hard to meet in software – are often fulfilled by embedding the imaging/video functionality as hardware accelerators implemented in FPGAs or as ASICs. This has advantage such as computation speed, high energy and area efficiency, etc. However, this is associated with high engineering and manufacturing cost. In recent years software-based approaches on commodity hardware, notably on embedded graphics processors (GPUs) and multi-core CPUs, have increasingly gained attention. These *alone* cannot fulfil the stringent performance, power, and area constraints. Therefore, it is highly desirable to combine multiple heterogeneous acceleration fabrics (i.e. FPGAs, GPUs, DSPs, etc.) in one embedded many-core system, *seamlessly integrated* with COTS (commercial off-the-shelf) multi-core CPUs to provide scalability and heterogeneity required to achieve massive data rate processing of image and video data.

Need for Cross-Domain Support, Interoperability, and Tool Chain: Another important factor is the *cross-domain applicability, interoperability, and flexible mapping of algorithm on heterogeneous platform* without completely re-designing/implementing the algorithms, tools and system software stack. Moreover, new applications require massive data rates under low-power constraints. Therefore, there is a need for a cross-domain and scalable many-core embedded computing platform solution with modular and extensible hardware accelerations fabrics, such that the underlying computing platform

can be *scaled with minimal effort without completely redesigning the hardware and supporting tool chains*.

ALMARVI's Novel Concepts

The ALMARVI project addresses the low-power processing of massive image/video data (under diverse application scenarios from different industrial domains) through

(i) Cross-domain adaptive many-core computing platform solution with extensible hardware accelerators,
(ii) Adaptive image/video processing algorithms,
(iii) Cross-domain system software stack and design tools,

The key is to *leverage the properties of image/video content* while *jointly adapting algorithms and hardware* in order to achieve a much higher potential for power savings and to enable massive data rate processing.

To maintain the cross-domain functionality with consistent efficiency, there is a need to research and develop novel methods for:

1) Automatically extracting image/video content properties, deriving resource/power requirements of image/video processing algorithms, and forwarding them to the hardware layer for enhanced resource and power management;
2) Negotiating between algorithms and hardware, such that in case underlying hardware does not provide the required performance/power efficiency (for instance, due to workload, resource, bandwidth, and/or process variations), algorithms adapt themselves to curtail their computational requirements while trading off the quality requirements;
3) Identifying and exposing the knobs at algorithmic level in order to control the algorithmic computational complexity.

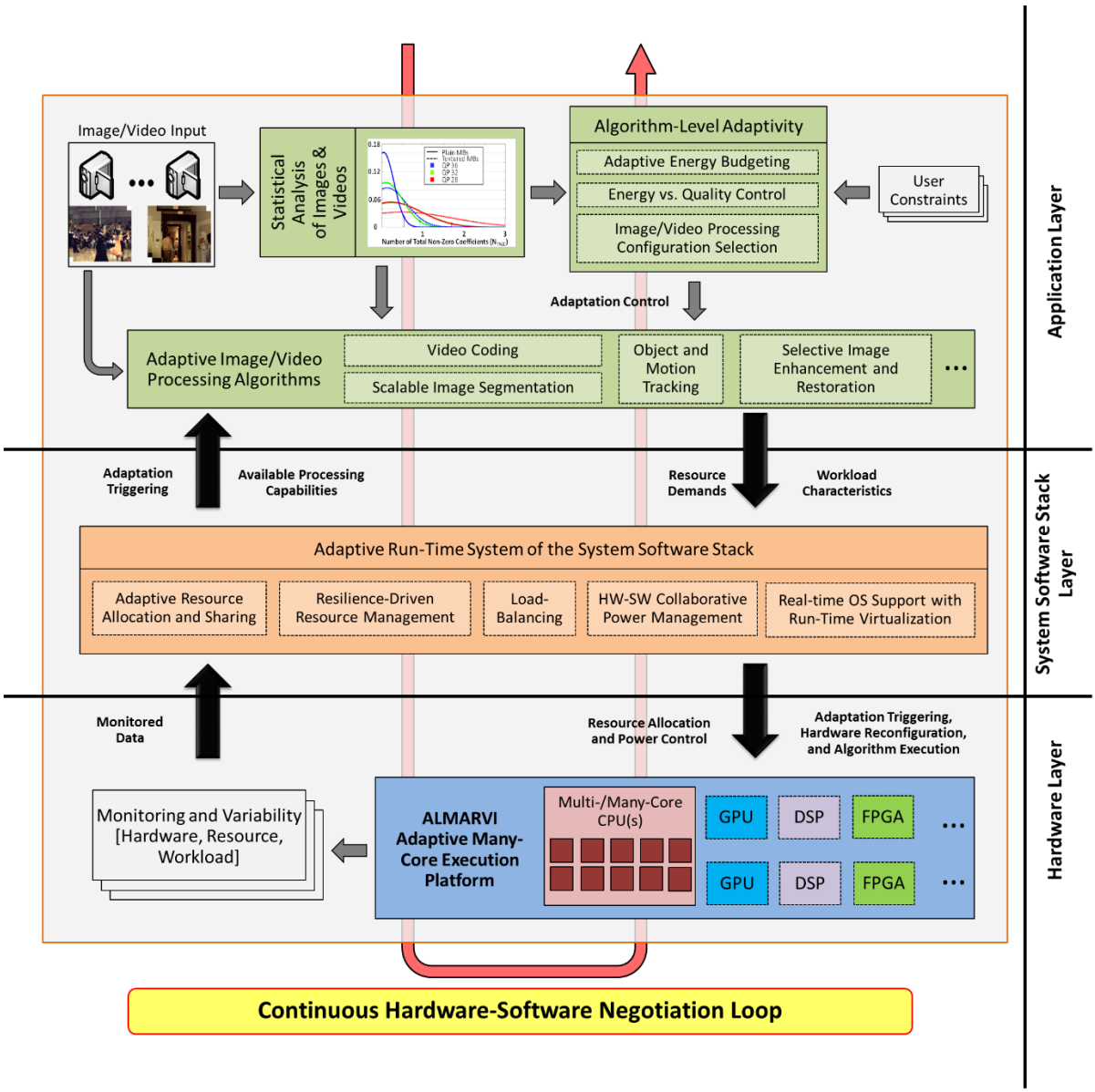


Fig. 1: ALMARVI's Approach for Continuous Hardware-Software Negotiation

Fig. 1 shows the ALMARVI's approach of continuous hardware-software negotiation highlighting the collaborative adaptations for obtaining massive data rate image/video processing with high power/energy-efficiency. The key to achieving this is to adapt the different system layers to the highly varying workload conditions caused by the diverse characteristics of image/video content and run-time changing user constraints (required performance, throughput, energy efficiency, etc.) and system conditions (like available energy budgets, resources, bandwidth, etc.).

In the following, ALMARVI's novel concepts to enable enhanced adaptability at three system layers, i.e. (1) application layer; (2) system software stack layer; (3) hardware layer. The monitored information from the hardware layer is fed back to system software stack that forwards it to the application layer in order to trigger the algorithm-level adaptation. In this way, ALMARVI realises *continuous hardware-software negotiations* where *collaborative adaptations* provide the foundation to obtain massive data rate processing with high energy-efficiency.

The overall objective of ALMARVI project is to provide foundation and platform solution to enable massive date rate image/video processing at low power budgets under variability conditions. The key is to leverage joint hardware-software adaptations and properties of image/video content and algorithms. Various applications scenarios from healthcare, security/surveillance/monitoring, and mobile industrial domains will be considered. Specific objectives of the ALMARVI project are:

Objective-1 – Enabling Massive Data Rate Processing:

ALMARVI enables massive data rate_image/video processing on embedded devices executing advanced high-efficiency image/video processing algorithms. The goal is to develop:

(i) adaptive many-core execution platforms that are scalable with heterogeneous acceleration fabrics (like FPGAs, DSPs, GPUs, etc.);
(ii) application-specific image/video processing cores and coprocessors;
(iii) design tools to expedite the development flow and to enable the IP reusability;
(iv) application-specific parallelisation; and
(v) methods for joint hardware-software adaptations based on algorithm resilience properties.

The precise requirements from different application domains are used to derive the following target performance requirements for massive data rate image/video processing:

- Image processing (analysis, filtering, fusion, etc.) of single channel 4Kx4K 16-bits/pixel images at 100Hz with an end-to-end latency of <100ms and a jitter of <10ms.
- Video processing (filtering, compression, etc.) of 4-6 channels of HD1080p 8-bits/pixel at 30-60 frames per second.

Objective-2 – Achieving Low Power Consumption

ALMARVI aims at enabling cross-domain power-efficient techniques and methods for efficient and lightweight resource and power management at various system layers, while jointly accounting for the architectural features, algorithmic properties, and image/video content characteristics. The goal is to develop:

(i) low-power architectures of image/video processing cores;
(ii) low-power adaptive algorithms with run-time quality vs. energy trade-off;
(iii) novel hardware-software-collaborative power-management techniques; and
(iv) methods to exploit algorithmic resilience for increased power-efficiency.

The inputs from various industrial partners from different application domains are used to derive the following target power requirements for the ALMARVI project:

- Video processing (filtering, compression, etc.) of HD1080p data with 30% reduced energy consumption and/or keeping the power consumption below 2Watts (preferably close to the ideal 1Watt goal).
- Image/Video processing (analysis, tracking, super-resolution, etc.) of HD1080p data with a power budget of less than 10Watts.
- Radio signal processing: 3GPP LTE r11 600Mbit/s downlink reception and 200Mbit/s uplink transmission with a power budget of less than 1Watt

Objective-3 – Composability, Flexibility, and Cross-Domain Applicability

To enable independent development of various system components and smooth integration for demonstrators from different domains. One of the key objectives of ALMARVI is to provide a cross-domain scalable platform solution with efficient design tool chain, IP reuse, composability, and system software stack for seamless interoperability, and scalability on commercially available heterogeneous acceleration fabrics. The success of this objective will be evaluated through

- Instantiations of cross-domain design concepts for multiple demonstrators from diverse application domains;
- Deployment of the cross-domain tool chain, system software stack, and architectural components (like adaptive cores, memory hierarchies, interconnects, etc.); and
- Integration and extensibility.

Objective-4 – Robustness to Variability

ALMARVI targets consistent and predictable system performance and power consumption over different product categories and application domains that are subjected to variability in underlying processing hardware, communication channels, application workload behaviour, system state (available resources and energy budgets), environmental factors, etc. To achieve this, the goal is to devise power-aware scalability and adaptabilty at the algorithm and system levels while exploiting inherent resilience properties of image and video processing applications for adaptive resource and power management. The success of this objective will be measured as the reduction in throughput variations, power/energy consumption variations, and quality of service variations of the overall system when deployed for different demonstrators (i.e. distinct product types and categories).

1.3 Description of the main S&T results/foreground

Table 1 Main innovations and results (at least 1 per WP)

Type	Innovation	Result
Related to WP1	3-layer system architecture	APIs and libraries for portable application software, across a range of modern high performance and energy efficient heterogeneous computing architectures.
Related to WP1	Cross-layer models for estimating system properties/parameters	Cross-Layer hierarchical performance, power and error resiliency models. Three layer models: component-layer, application-layer and multiple-applications layer.
Related to WP2	Image & video algorithms	Parallelised algorithms for image/video segmentation, clustering, parallel object recognition and tracking, motion analysis algorithms, image enhancement and image restoration
Related to WP3	Execution platform	The heterogeneous hardware platforms include CPU, GPU/FPGA, TTA, and ρVEX. Systems deployment on recent OpenCL-2.0 extensions: shared-memory architectures, pipelining, and abstract accelerators, and utilization in embedded computer architectures.
Related to WP4	Adaptive run-time system	The Almarvi software stack is based on OpenCL, using the new developments of the pocl open-source implementation. This choice is a good match with the application domains that Almarvi targets, on high-performance imaging and video analysis and mobile multi-media.

		Application concurrency is deployed through OpenMP version 4.0 that also target heterogeneous architectures. To support hardware integration, a common ALMARVI IP block interface called AlmaIF was developed.
Related to WP5	Demonstrators	Several demonstrators in each application domain, each building on results from the other Work Packages and addressing the respective ALMARVI objectives
Technical	In the work packages	
Materials development	none	
Other main fields	none	

1.4 Potential impact

1.4.1 Social-economic impact

The ALMARVI platform solution with scalable cross-domain platform, efficient design tools, system software stack, and adaptive image/video processing algorithms, embedded system developers will be able to:

1) develop more complex image/video processing system in a shorter time than before;
2) handle an increased complexity due to increasing data rates;
3) reduce design/development cycles;
4) bridge the gap between design realization and compute capabilities.

Cross-domain applicability of ALMARVI's technology (i.e. cross-domain platform solutions, IP-cores, design tools, system software stack, etc.) will reduce fragmentation, thus significantly increasing the market share of European supplier industry. Similarly, integrated and well-tested cross-domain technology of ALMARVI will facilitate OEMs from decreased system cost, development costs, time-to-market, etc., thus significantly lowering the market barriers, increased end-use uptake, and improve EU standards of living. This will lead to new ventures of application developments by the established EU-industry and potentially new players. Furthermore, synergies of diverse expertise of industrial partners in ALMARVI will result in new innovation ventures, applications, services, business areas with added values, etc.

1.4.2 Wider societal implications

ALMARVI's integrated multi-vendor platform solution, technological developments, and industrial-grade demonstrators for massive data rate image/video processing will aid in addressing the large-scale societal challenges in the fields of "Healthcare and wellbeing" and "Green, safe and supportive transportation". The use of image/video processing has been proliferated in application domains like surveillance, healthcare, security, consumer electronics, avionics, which are among the key industries

of Europe. For instance, the use of camera-based processing has been increasing in automotive in order to facilitate drivers (especially old-age people) and to reduce risk of accidents. Better healthcare and diagnostics based on medical imaging lead to reduced health risks and improved affordable health services. Similar examples can be found in other domains like smart security environments using many camera nodes provide a better environment for living, advanced situation awareness in avionics, increasing use of UAVs in civil applications like fire-fighting, surveillance of large-scale industrial deployments like pipelines, livestock monitoring, cargo, rescue operations, catastrophe management, etc. ALMARVI will contribute towards an unprecedented increased in the welfare of European citizens by improving the healthcare, transportation, and security standards, while improving the economic factors.

1.4.3 Main dissemination activities

Main dissemination activities performed under the ALMARVI project over the last three years (i.e., M01-M36) are described in the deliverable D7.7. The dissemination activities have been performed along three directions:

- Website (Target: the general public, the scientific community, and the industrial community): The ALMARVI website contains and maintains the overview of the project, latest news, publications etc.
- Open software (Target: the scientific community and the industrial community): A large number of open software were developed, extended and integrated under the ALMARVI project. The open software are described in the website and the corresponding links to access the software are given.
- Scientific publications (Target: the scientific community and the industrial community): A special emphasis is given on project scientific publications in premier conferences and journals with a special focus on embedded systems. The academic partners are more active in national and international scientific publications while the industrial partners are more focused on outreach activities and demonstrations at the national level.
- Seminars, workshops and tutorials (Target: the industrial community and the scientific community): Along this line, there are two categories of activities. First, as a part of ALMARVI dissemination activities, various partners participated in a number of public events. Section 5 describes the participations in various public events supported by the ALMARVI project in the reporting period. Second, various partners organized a number of public events to further disseminate the ALMARVI results.

1.4.4 Exploitation of results

The industrial grade demonstrators for the healthcare, security/surveillance/ monitoring, and mobile use cases will directly lead to marketable applications and products in their relevant domains. The integrated and well-tested releases of the image/video processing algorithm libraries, reference design tools and platforms, and system software stack solutions will be made available along with their evaluation for the demonstrated use cases. Favourable licensing conditions will support these feature-limited releases. For commercial exploitation and a relatively long-term market adoption, full-fledge versions will be provided with proper support and maintenance. Moreover, for a more long-term market adoption, ALMARVI's platform solution, design tools, and algorithms will be promoted at a large scale.

Individual exploitation results represent the outcome of the activities of the ALMARVI partners. They highlight the most relevant potential project results.
Moreover, the entire ALMARVI consortium is still collaborating to ensure visibility of the project results at both European and international levels covering all aspect, i.e. exhibitions, trade shows, industrial demonstrations, end-suppliers contacts, research and technological forums like conferences, magazines, journals, workshops, special sessions, poster sessions, etc. This ensure that the results are given maximal chance of being exploited internally and outside the project.
With these exploitation results described in this report, the consortium generated valuable industrial-grade results and technological developments aligned to the market demands, such that they can be deployed in real-world applications/products, while disseminating the knowledge to the entire embedded systems and applications community.
ALMARVI's platform solution will enable development of low-cost solutions for a wide-range of market in different industrial domains and create new market opportunities, in particular supporting SMEs.
The exploitation of the results developed in the ALMARVI project targets the actual implementation of project outcome within the industry that will lead to technologically competitive products allowing European companies to achieve a leading position in image/video processing solutions at the international level.
The companies in the project serve large markets for professional users, and consumers. They enable applying massive image processing at low cost and low latency to their clients. These clients get better information at the same or lower cost. The equipment cost reduction is originating from reduction of development, material, hardware and maintenance costs. These costs are addressed by the project aims to provide flexibility towards the used hardware platform and the reduction of the number of processing units to serve a system. The costs of ownership are reduced and the ease of use is improved by low power consumption.
The user advantages are important for the position of the companies in their markets. Certain partners provided multi-core tooling that enables the industrial partners to obtain the above mentioned benefits.
University partners are using the results achieved in this project to enrich the curricula provided to students with industrially relevant topics, and to focus their research agendas to match industrial needs. It has led to improved consultation, training, theses and dissertations. Certain project results are finding their way in the open source arena.

1.5 Public website

The ALMARVI website (www.almarvi.eu) contains overview of the projects, objectives, work packages, details of the consortium, contacts along the latest news and details of the publications. It is maintained and regularly updated with news, publications and public deliverables.

Home Consortium News Open Software Publications Public Deliverables ALMARVI SVN Contact

Algorithms, Design Methods, and Many-core Execution Platform for Low-Power Massive Data-Rate Video and Image Processing
Artemis 2013 GA 621439

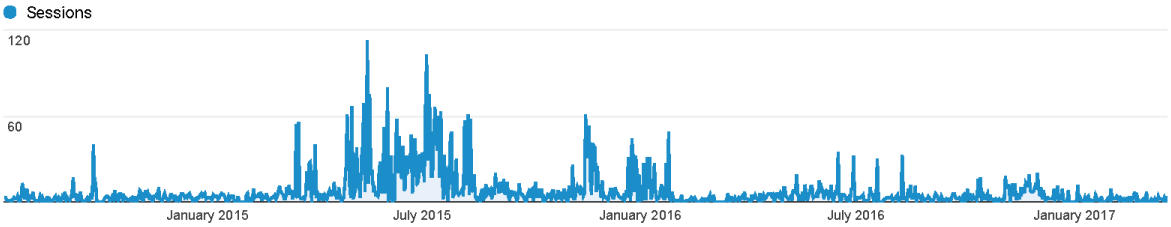
Project Description | **Societal Impact** | **Objectives**

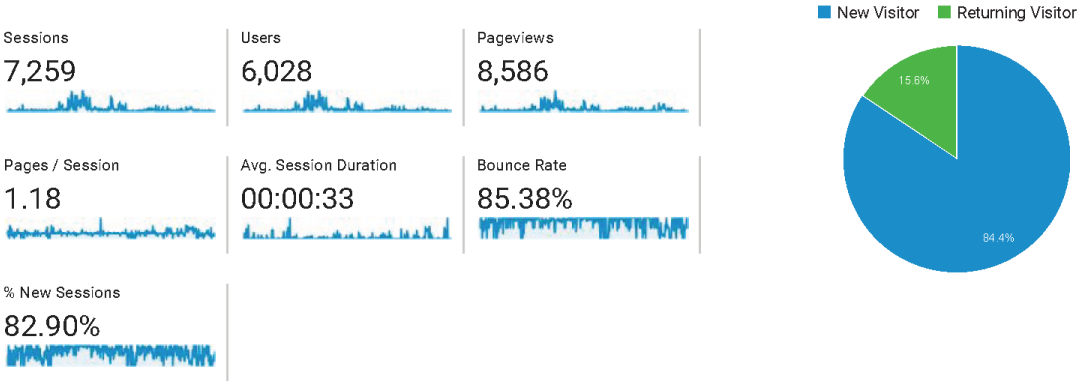
Technical Innovation

Advanced image and video processing systems are becoming a crucial and resource consuming part of embedded applications in many sectors. ALMARVI aims to facilitate the transition from a vertically structured market to a horizontally structured market. In particular, it focuses on reducing overall system design cost and time-to-market and enabling low cost solutions for high volume markets in different industrial domains and creating new market opportunities, and supporting SMEs.

The demonstrators developed under this project for the healthcare, security/surveillance/monitoring, and mobile use cases will directly lead to marketable applications and products in their relevant domains. Integrated releases of the image/video processing algorithm libraries, reference design tools and platforms, and system software stack solutions will be made available along with their evaluation for the demonstrated use cases. Cross-domain applicability will reduce fragmentation, thus increasing the market share of European supplier industry.

Visibility (using Google Analytics): Google analytic is used as the ALMARVI web analytic service in order to track and report the website traffic. This deliverable reports the number of views of the website from the time that it has been launched. The statistics are included. The page visits are relatively distributed while countries like the Netherlands has a higher rate of visits. The USA has opened highest number of sessions which indicates a good visibility outside the participating counties. Sessions are also opened from countries like UK, Germany and Brazil. Overall, around 7000 sessions are used by over 6000 users.





	Country	Sessions	% Sessions
1.	United States	1,652	22.76%
2.	(not set)	1,022	14.08%
3.	Netherlands	804	11.08%
4.	Russia	392	5.40%
5.	Finland	366	5.04%
6.	United Kingdom	329	4.53%
7.	Brazil	273	3.76%
8.	Turkey	233	3.21%
9.	China	229	3.15%
10.	Germany	216	2.98%

1.6 ALMARVI Beneficiaries and contact persons

Partner	Name	(Cell) Phone	E-mail
Philips Healthcare	Frank van der Linden	+31-622522460	frank.van.der.linden@philips.com
Technische Universiteit Delft	Zaid Al-Ars	+31-152789097	z.al-ars@tudelft.nl
Technische Universiteit Eindhoven	Dip Goswami	+31-40-2478242	d.goswami@tue.nl
Hurja Solutions Oy	Antti Väänänen	+358-442851525	antti.vaananen@hurja.fi
Visidon Oy	Matti Niskanen	+358-405934331	matti.niskanen@visidon.fi
University of Eastern Finland	Pekka Toivanen	+358-405439021	pekka.toivanen@uef.fi
VTT Technical Research Center of Finland	Janne Keranen	+358-403566470	janne.s.keranen@vtt.fi
Tampere University of Technology	Pekka Jääskeläinen	+358-408490772	pekka.jaaskelainen@tut.fi
University of Turku	Lauri Koskinen		Lauri.koskinen@utu.fi
Ustav teorie informace a automatizace AV CR, v.v.i.	Jiri Kadlec	+420-266052216	kadlec@utia.cas.cz
Brno University of Technology	Pavel Zemcik	+420-603487824	zemcik@fit.vutbr.cz
CAMEA, spol. s r.o. (ltd.)	Lukas Marsik	+420-732853334	l.marsik@camea.cz
ASELSAN	Toygar Akgun	+90-312-847-5300/5224	takgun@aselsan.com.tr
Ozyegin University	Fatih Ugurdag	+90-5356926314	fatih.ugurdag@ozyegin.edu.tr
Nokia Technologies Oy	Heikki Berg	+358-504868655	Heikki.Berg@nokia.com
	Antti Väänänen	+358-442851525	antti.vaananen@hurja.fi

2 Use and dissemination of foreground

2.1 Section A (public)

ALMARVI partners have shown their visibility in various national and international forums reaching all three categories of targets – the general public, the scientific community and the industrial community.

- Nearly 50 high quality scientific articles are published in well-known conferences and journals.
- The ALMARVI partners organized 8 workshops and conference special sessions in renowned conferences. There are 2 journal special issues (i.e., TODAES and Springer JSP) either published or planned to be published on ALMARVI related activities. Further, Springer JSP is going to publish ALMARVI results of all the work packages.
- Around 10 keynote speeches, tutorials and invited talks are given by different ALMARVI partners.
- ALMARVI supported development of 8 open software and all of them linked to ALMARVI website.

The ongoing activities on demonstrators will be further disseminated in the form of various publications. Moreover, the university partners (e.g., TUE, TUD, TUT, BUT, OZYEGIN) are going to produce a number of doctoral theses from the works by the PhD candidates under ALMARVI. It is expected to publish around 5 doctoral theses. For example, two PhD candidates supported by ALMARVI at TUE are expected to graduate in 2018.

2.1.1 Outreach activities, keynote and presentations

- **ASELSAN**: ASELSAN intends to present one or two posters/papers in the national conferences and universities in Turkey. Moreover, ASELSAN is planning to participate in a workshop on parallel processing where specific scientific ALMARVI concepts will be presented.
    - **Lead**: Toygar Akgün
    - NVDIA GP-GPU meet up in Turkey
- **Hurja Solutions** aims attend to international fairs when new applications developed in ALMARVI are ready for demonstration. Towards this, it had attended **Slush 2015** which is detailed in Section 4.
    - **Lead:** Antti Väänänen
- **Nokia** aims to participate in a number of international and national fairs and workshops. Along this line, NOK gave a presentation on their results under ALMARVI in a **workshop at WEEE** organized by UTURKU (detailed in Section 5)**.**
    - **Lead:** Heikki Berg
- **CAMEA** aims exhibit with its own booth in a number of national and international trade fairs. Current results of the ALMARVI project such as hardware demos (e.g. object detection in ZYNQ, all-in-one camera solution and so on) were shown in **Expotraffic Moscow 2015**, **Intertraffic Istanbul 2015**, **ITS World Congress Bordeaux 2015**, **Intertraffic Amsterdam 2016** – detailed in Section 4**.**
    - **Lead**: Lukas Marsik
- **Presentation** by **Lauri Koskinen** (**UTURKU**) at **TUE** in May, 2015 on "Adaptive ultra-low power (ULP) processing". As a part of collaboration under ALMARVI, Lauri Koskinen gave a public presentation and as a followup, possible collaborations are being discussed being these parties.

- **Keynote at IS&T/SPIE** Electronic Imaging 2015, San Francisco, California, United States, February 8 – 12, 2015
    - **Speaker:** Filip Sroubek UTIA (Czech Republic)
    - **Title:** Advances in image restoration: from theory to practice
- **Keynote at IDEA Workshop 2016** on Integrating Dataflow, Embedded Computing, and Architecture
    - **Speaker**: Zaid Al-Ars, TUDelft (Netherlands)
    - **Title**: High Performance Embedded Computing Using Heterogeneous Computational Fabrics - The ALMARVI Vision and Beyond
- Invited talk by Fatih Ugurdag (OZyegin) at IEEE EAST-WEST DESIGN & TEST SYMPOSIUM in September, 2015.

2.1.2 Participation in public events, tutorials and workshops

In the following, we summarize the participation in public events, tutorials and workshops by the ALMARVI partners in the reporting period.

- Participation and presentation Artemis/ECSEL Brokerage 2015 Event by UEF, Amsterdam, Netherlands by Pekka Toivanen and Keijo Haataja.
- **Participation in Slush 2015 event in Helsinki:** Hurja Solutions attended to look for new business opportunities for services and applications which are developed in ALMARVI project.
- **Participation in ICTexpo 2016 event in Helsinki:** Hurja Solutions attended to look new business opportunities for services and applications which are developed in ALMARVI project.
- **Participation in Expotraffic 2015 in Moscow:** Tomas Bia (collaborator of CAMEA) attended a number of talks and had fruitful discussions regarding technology addressed in ALMARVI project. The audience was various industrial bodies and customers.
- **Participation in Artemis - ITEA II Co-summit** in March, 2015 by UTIA and UEF at Berlin Congress Center, Germany, ALMARVI booth
    - Lead: Jiri Kadlec, Pekka Toivanen, Keijo Haataja, Lauri Väätäinen, and Maarit Tamminen
- **Participation in Intertraffic in Istanbul 2015 by CAMEA:** Poster presenting intermediate results of ALMARVI project by Lukas Marsik and Tomas Bia. The audience was various industrial bodies and customers.
- **Participation in Intelligent Traffic Systems (ITS) 2016 World Congress Bordeaux by CAMEA:** Poster presenting intermediate results of ALMARVI project by Lukas Marsik and Lucie Brnkova. The imtermediate protype of the Zynq-based detector has been shown as well. The audience was various industrial bodies and customers.
- **Participation in Intertraffic Amsterdam 2016 by CAMEA:** Poster presenting pre-final results of ALMARVI project by Lukas Marsik and Lucie Brnkova. The pre-final protype of the Zynq-based all-in-one camera with object detector has been shown as well. The audience was various industrial bodies and customers.
- **Participation in TNO-ESI Symposium**, **Eindhoven, April 2016 by TU Delft** (Joost Hoozemans and Zaid Al-Ars): Demo on real-time schedulability
- Participation in Artemis/ECSEL Brokerage 2016 Event in Strasbourg, France by UEF, by Keijo Haataja.
- Participation in HiPEAC, Stockholm, January 2017 by TU Delft (Joost Hoozemans):

- Presentation at Workshop Reconfigurable Computing: "Improved dynamic cache sharing for communicating threads on a runtime-adaptable processor" (no formal proceedings)
- Poster: „Liquid Architectures - The ρ-VEX Polymorphic VLIW Processor"

- Participation in Digital Innovation Forum (DIF) 2017 in Amsterdam by ARTEMIS-IA and ITEA: Presentation of Almarvi results at booth with demos from several partners
  - PHILIPS, UTIA, TUD
- Participation in Artemis/ECSEL Brokerage 2017 Event in Brussels, Belgium by UEF, by Keijo Haataja.
- **Participation and presentation in 2nd Tensilica Day, 2017, Hanover, Germany** by Pekka Jääskeläinen (TUT). Presented the TCE toolset further developed in the ALMARVI project.
- Participation and presentation in Workshop on System-Level Design for Signal and Information Processing", Oct. 24, 2016 in College Park, MD, US by Jarmo Takala / TUT. Presented the TCE toolset further developed in the ALMARVI project.
- Participation in ICT.OPEN 2017 in Amersfoort, NL by TU Delft (Joost Hoozemans, Jeroen van Straten)
  - Presentation (full length oral presentation and poster) at PROGRESS track: 'VLIW-based FPGA Computation Fabric with Streaming Memory Hierarchy for Medical Imaging Applications'
  - Demo of both the 64-core streaming platform and the dynamic core, awarded with the **best Demo award** (Meet the Demo Award 2017)

2.1.3 Organization of public events, tutorials and workshops

In the following, we report the dissemination by organizing in public events, tutorials and workshops in the ALMARVI partners.

- Special session in SAMOS 2015 on ALMARVI

Session Organizers: Zaid Al-Ars (TUDelft, Netherlands), Jarmo Takala (TUT, Finland)
Description: The expected participants include international technology experts, healthcare and security industry representatives, image processing device manufacturers, end users, industry and research representatives as well as the project partners. All partners will be invited to submit their contributions. The special session will have about 6 papers, preferably about collaborative work between different partners.

- ALMARVI Workshop at Ozyegin University in 2015 in Istanbul, Turkey

Organizer: OZYEGIN (Fatih Ugurdag) and Aselsan (Toygar Akgün)
Description: Application of ALMARVI results in parallel processing, and effective GPU programming and its application to video processing with target audience university researchers, doctoral candidates and graduate/undergraduate students

- **Organizing Workshop at WEEE by UTURKU**: 3rd Workshop on Energy Efficient Electronics and Applications in 10-12 September 2015, Helsinki, Finland.

Organizer: Lauri Koskinen (UTURKU)
Description: The objective of the workshop is to bring together experts, from both industry and academia, to discuss the challenges and the latest trends in the development of low-power and ultra-low-power embedded systems. In addition to the workshop, an optional student day will be organized in September 10th. The day includes two separate courses on high-level processor design: Designing

TTA processors with TCE (tce.cs.tut.fi) and Constructing Hardware in a Scala Embedded Language (https://chisel.eecs.berkeley.edu/).

- 10th September (student day): Course on TTA architectures
- 11th September (Workshop day 1: 2 ALMARVI related presentation (Nokia, TUT)
- 12th September (Workshop day 2): ALMARVI related presentation (Phillips Healthcare)

- **Tutorial in ESWEEK in October, 2015 in the Netherlands** by TUE and TUDelft (and TNO). The tutorial and the presented work is supported by ARTEMIS projects **621429 EMC2** and **621439 ALMARVI**

Organizer: Dip Goswami (TUE)
Speakers: Teun Hendriks (TNO), Zaid Al-Ars (TUDelft) and Dip Goswami (TUE)
Title: "Design Challenges in Compute-intensive Mixed-criticality Systems: System, Platform and Application Perspectives"
Description: This tutorial is composed of three parts: System perspective (Part 1), Platform perspective (Part 2) and Application perspective (Part 3). At the system-level, architectural design and deployment challenges will be illustrated based on an industrial use-case stemming from the collaboration between TNO (www.TNO.nl) and NXP (www.nxp.com), and extended with results of TNO's research in the European Artemis project EMC2 (artemis-emc2.eu, grant no. 621429). Next, at the platform-level, the tutorial will draw its motivation from the healthcare domain, iXR in particular, and illustrate results from the ongoing European Artemis project ALMARVI (almarvi.eu, grant no. 621439). Finally, at the application-level, the tutorial will discuss various performance and trade-offs analysis methods for embedded control systems while considering shared implementation platforms. Results will be shown from the ongoing activities under both the EMC2 and ALMARVI projects.
Details: http://www.es.ele.tue.nl/~dgoswami/ESWeek2015Tutorial.pdf

- **Seminar Series at** OZYEGIN University, Istanbul, Turkey, August, 2016
  - **Speaker:** Aydın E. Guzel
  - **Title:** MAFURES
- **Presentation at** International Symposium on Computer and Information Sciences (ISCIS), Krakow, Poland, October 2016
  - **Speaker:** V. Emre Levent
  - **Title:** Output Domain Downscaler
- **Presentation at** IEEE East-West Design & Test Symposium (EWDTS), Yerevan, Armenia, October 2016
  - **Speaker:** Aydın E. Guzel
  - **Title:** Using High-Level Synthesis for Rapid Design of Video Processing Pipes
- **Tutorial at ICPR_**23rd International Conference on Pattern Recognition, Cancun, Mexico, December, 2016
  - **Speaker:** Filip Sroubek, Barbara Zitova, Jan Flusser
  - **Title:** Handling Blur
- IDEA Workshop 2016 on Integrating Dataflow, Embedded Computing, and Architecture organized by Twan Basten (TUE), Waheed Ahmad, and Alok Lele. Proceedings are available as: Waheed Ahmad, Twan Basten, Robert de Groote, Alok Lele, and Orlando Moreira (eds.), IDEA 2016: Integrating Dataflow, Embedded Computing, and Architecture, Proceedings. Report ESR-2017-01, Eindhoven University of Technology, Department of Electrical Engineering, Eindhoven, the Netherlands, January 2017.
  - **Keynote by Zaid Al-Ars (TUDelft):** High Performance Embedded Computing Using Heterogeneous Computational Fabrics - The ALMARVI Vision and Beyond

- The workshop accepted 11 extended abstracts and full papers for interactive and full presentations, including the following from TUE: "Analysis and Visualization of Execution Traces of DataFlow Applications" by Hadi Alizadeh Ara, Amir Behrouzian, Marc Geilen, Martijn Hendriks, Dip Goswami and Twan Basten
- Extended abstracts of all presented submissions have been published in the above mentioned proceedings. Selected full papers from the workshop have been published in a special section of ACM Transactions on Design Automation of Electronic Systems (TODAES) after an open call for papers and four review rounds – publication details are given below

- **Special Section: Integrating Dataflow, Embedded Computing and Architecture** by **Twan Basten (TUE)**, Orlando Moreira, Robert de Groote. Editorial, ACM Transactions on Design Automation of Electronic Systems (TODAES), 22(2), Article No. 35, February 2017, http://doi.org/10.1145/3023455
- **Tutorial in ARC by TU Delft** (13th International Symposium on Applied Reconfigurable Computing), Delft, The Netherlands, April 3 - 7, 2017

Organizer: Joost Hoozemans, Jeroen van Straten, Stephan Wong (TU Delft)
Description: On the last day of ARC, a tutorial is organized to familiarize the participants with the ρ-VEX platform that is developed at Delft University of Technology. The tutorial will highlight 2 use cases of the platform; 1) The FPGA prototype of the dynamic core, 2) An FPGA overlay fabric consisting of 64 cores running on 200MHz targeting streaming image processing workloads. There will also be room for participants to port their application of interest to one (or both) the platforms to experiment with either the reconfigurable properties or the streaming fabric under guidance of the ρ-VEX developers.
Details: http://www.arc2017.tudelft.nl/program/#workshopfriday

2.1.4 Scientific publications

In the following, we report the scientific publications supported by the ALMARVI project. A number of technical articles are already published and several dissemination activities are already confirmed (or accepted) at various venues over the last eighteen months. Publications supported by ALMARVI contain the following ALMARVI acknowledgement: "This research is supported by the ARTEMIS joint undertaking under grant agreement no 621439 (ALMARVI)."

1. I. Pöllänen, B. Braithwaite, T. Ikonen, H. Niska, K. Haataja, P. Toivanen, and T. Tolonen, "Computer-Aided Breast Cancer Histopathological Diagnosis – Comparative Analysis of three DTOCS-based Features: SWDTOCS, SW-WDTOCS, and SW-3-4-DTOCS", 4th International Conference on Image Processing Theory, Tools, and Applications (IPTA'2014), Paris, France, October 14–17, 2014.
2. D. Goswami, D. Müller-Gritschneder, T. Basten, U. Schlichtmann, S. Chakraborty "Fault-tolerant Embedded Control Systems for Unreliable Hardware," International Symposium on Integrated Circuits (ISIC), Singapore, 2014 (December).
3. T. Ikonen, H. Niska, B. Braithwaite, I. Pöllänen, K. Haataja, P. Toivanen, J. Isola, and T. Tolonen, "Computer-Assisted Image Analysis of Histopathological Breast Cancer Images Using Step-DTOCS", 14th International Conference on Hybrid Intelligent Systems (HIS 2014), Kuwait, December 14-16, 2014.
4. H. Kultala, T. Viitanen, P. Jääskeläinen, J. Helkala, and J. Takala, "Compiler Optimizations for Code Density of Variable Length Instructions," in Proc. IEEE International Workshop Signal Process. System, Belfast, UK, Oct. 20-22 2014, pp. 127 – 132.

5. T. Viitanen, H. Kultala, P. Jääskeläinen, and J. Takala, “Heuristics for Greedy Transport Triggered Architecture Interconnect Exploration,” in Proc. International Conference Compilers Architecture Synthesis Embedded System, New Delhi, India, Oct. 12-17 2014.
6. K. van Gend, Vector Fabrics, “Cut Power Consumption by 5x Without Losing Performance”, LinuxCon 2014, Düsseldorf, Germany, Oct. 13-15 2014.
7. Zliobaite, I.; Hollmén, J.; Teittinen, J.; Koskinen L.; “Towards hardware-driven design of low-energy algorithms for data analysis” ACM SIGMOD Record archive, Volume 43 Issue 4, December 2014, Pages 15-20.
8. B. Braithwaite, H. Niska, I. Pöllänen, T. Ikonen, K. Haataja, P. Toivanen, and T. Tolonen, “Optimized Curve Design for Image Analysis Using Localized Geodesic Distance Transformations”, IS&T SPIE Electronic Imaging, San Francisco, California, USA, February 8–12, 2015.
9. I.Szentandrási, M. Zachariáš, J. Tinka, M. Dubská, J. Sochor, A. Herout, “INCAST”, International Symposium on Mixed and Augmented Reality ISMAR 2015, Fukuoka, Japan, October 2015
10. Article in the ARTEMIS-IA news, March 17, 2015: artemis-ia.eu/news/almarvi.html.
11. Turnquist, M.J.; Hiienkari, M. ; Makipaa, J. ; Koskinen, L. ; “A Fully Integrated Self-Oscillating Switched-Capacitor DC-DC Converter for Near-Threshold Loads” IEEE A-SSCC, 2015 (Asian Solid-State Circuits Conference).
12. M. Hradiš, J. Kotera, P. Zemčík and F. Šroubek, “Convolutional Neural Networks for Direct Text Deblurring”, Proceedings of The British Machine Vision Association and Society for Pattern Recognition BMVC 2015, Swansea, UK, 2015, pp. 1-13.
13. J. Kotera, B. Zitová and F. Šroubek, "PSF accuracy measure for evaluation of blur estimation algorithms," 2015 IEEE International Conference on Image Processing (ICIP), Quebec City, QC, 2015, pp. 2080-2084.
14. A. Brandon, J. Hoozemans, J. Van Straten, A. Lorenzon, A. Sartor, A. Beck, S. Wong, "A sparse VLIW instruction encoding scheme compatible with generic binaries," 2015 International Conference on ReConFigurable Computing and FPGAs (ReConFig), Mexico City, 2015, pp. 1-7.
15. J. Hoozemans, J. Johansen, J. V. Straten, A. Brandon and S. Wong, "Multiple contexts in a multi-ported VLIW register file implementation," 2015 International Conference on ReConFigurable Computing and FPGAs (ReConFig), Mexico City, 2015, pp. 1-6.
16. Ikonen T., Pöllänen I., Braithwaite B., Haataja K., Toivanen P., Tolonen T., and Isola J.: Morphological Extraction of Cancerous Nucleus in the Diagnostics of Breast Cancer. Intelligent Systems Design and Applications (ISDA'2015), Marrakesh, Morocco, December 14-16, 2015.
17. P. Jääskeläinen, C.S. de La Lama, E. Schnetter, K. Raiskila, J. Takala and H. Berg: “pocl: A Performance-Portable OpenCL Implementation,” Int. J. Parallel Programming, Vol. 43, Issue 5, pp. 752 – 785, 2015.
18. H. Yviquel, A. Sanchez, P. Jääskeläinen, J. Takala, and M. Raulet, “Embedded Multi-Core Systems Dedicated to Dynamic Dataflow Programs,” J. Signal Processing Systems, Vol. 80, Issue 1, pp. 121 – 136, 2015.
19. T. Äijö, P. Jääskeläinen, T. Elomaa, H. Kultala, and J. Takala, “Integer Linear Programming Based Scheduling for Transport Triggered Architecture,” ACM Trans. Architecture and Code Optimization, Vol. 12, Issue 4, pp. 59:1-59:22, 2015.
20. M. Koskela, T. Viitanen, P. Jääskeläinen, J. Takala, and K. Cameron, “Using Half Floating-Point Numbers for Storing Bounding Volume Hierarchies,” in Computer Graphics International Conference, Strasbourg, France, 2015.

21. V. Korhonen, P. Jääskeläinen, M. Koskela, T. Viitanen, and J. Takala, “Rapid Customization of Image Processors Using Halide,” in Proc. IEEE Global Conf. Signal Inf. Process., Orlando, FL, USA, 2015.
22. P. Jääskeläinen, H. Kultala, T. Viitanen, and J. Takala, “Code Density and Energy Efficiency of Exposed Datapath Architectures,” J. Signal Processing Systems, Vol. 80, Issue 1, pp. 49-64, 2015.
23. J. Glossner, P. Blinzer, and J. Takala, “HSA-Enabled DSPs and Accelerators,” in Proc. IEEE Global Conf. Signal Inf. Process., Orlando, FL, USA, 2015.
24. Adyanthaya, S., Alizadeh Ara, H., Bastos, J.P., Baghbanbehrouzian, A., Medina Sanchez, R.A., Pinxten, van, J.H.H., Sanden, van der, L.J., Waqas, U., Basten, A.A., Corporaal, H., Frijns, R.M.W., Geilen, M.C.W., Goswami, D., Stuijk, S., Reniers, M.A. & Voeten, J.P.M. (2015). “xCPS : a tool to eXplore cyber physical systems” Proceedings of WESE'15 : Workshop on Embedded and Cyber-Physical Systems Education, October 2015, Amsterdam, The Netherlands.
25. T. Viitanen, M. Koskela, P. Jääskeläinen, H. Kultala, and J. Takala, “MergeTree: A HLBVH Constructor for Mobile Systems,” in ACM SIGGRAPH Asia, Kobe, Japan, 2015.
26. H. Kultala, J. Multanen, P. Jääskeläinen, and J. Takala, “Impact of Operand Sharing to the Processor Energy Efficiency,” in Proc. CSI Int. Symp. Comput. Arch. & Digital Syst., Tehran, Iran, 2015.
27. F. Sroubek, J. Kamenicky, and Y. M. Lu, “Decomposition space-variant blur in image deconvolution,” IEEE Signal Processing Letters, vol. 23, no. 3, pp. 346-350, 2016.
28. M. Buyukmihci, V.E. Levent, A.E. Guzel, O. Ates, M. Tosun, T. Akgun, C. Erbas, S. Gören, H.F. Ugurdag, "Output Domain Downscaler", in Proc. Intl. Symp. on Computer and Information Sciences (ISCIS), pp. 262-269, Krakow, Poland, Oct 27-28, 2016.
29. A.E. Guzel, V.E. Levent, M. Tosun, M.A. Ozkan, T. Akgun, D. Buyukaydin, C. Erbas, H.F. Ugurdag, “Using High-Level Synthesis for Rapid Design of Video Processing Pipes”, in Proc. of East-West Design & Test Symposium (EWDTS), Yerevan, Armenia, Oct 14-17, 2016. DOI: 10.1109/EWDTS.2016.7807644.
30. Hadi Alizadeh Ara, Marc Geilen, Twan Basten, Amir Behrouzian, Martijn Hendriks and Dip Goswami, “Tight Temporal bounds for dataflow applications mapped onto shared resources”, Accepted for publication and presentation at the proceeding of the 11th IEEE International Symposium on Industrial Embedded Systems 23-25 May 2016.
31. Amir Behrouzian, Dip Goswami, Marc Geilen, Martijn Hendriks, Hadi Alizadeh Ara, Eelco Horssen, Maurice Heemels and Twan Basten, “Sample-Drop Firmness Analysis of TDMA-Scheduled Control Applications”, Accepted for publication and presentation at the proceeding of the 11th IEEE International Symposium on Industrial Embedded Systems 23-25 May 2016.
32. E.P. van Horssen, A.R.B. Behrouzian, D. Goswami, D. Antunes, T. Basten and M. Heemels, “Performance analysis and controller improvement for linear systems with (m,k)-firm data losses”, in Proc. European Control Conference, ECC, Aalborg, Denmark, 2016.
33. M. Hendriks, J. Verriet, T. Basten, B. Theelen, M. Brassé, and L. Somers, “Analyzing execution traces — critical-path analysis and distance analysis”, Accepted for publication in Springer International Journal on Software Tools for Technology Transfer, 2016.
34. P. Svoboda, M. Hradiš, D. Bařina, and P. Zemčík. Compression Artifacts Removal Using Convolutional Neural Networks. Journal of WSCG. Plzeň: 2016, roč. 24, č. 2, s. 63-72. ISSN 1213-6972.

35. P. Svoboda, M. Hradiš, L. Maršík, and P. Zemčík. CNN for license plate motion deblurring. In: IEEE International Conference on Image Processing (ICIP). Phoenix: IEEE Signal Processing Society, 2016, s. 1-4. ISBN 978-1-4673-9961-6.
36. J. Podivýnský, O. Čekan, J. Lojda, and Z. Kotásek. Functional Verification as a Tool for Monitoring Impact of Faults in SRAM-based FPGAs. In: Proceedings of the 2016 International Conference on Field Programmable Technology. Xi'an: IEEE Computer Society, 2016, pp. 289-290. ISBN 978-1-5090-5602-6.
37. J. Lojda, J. Podivýnský, M. Krčma, and Z. Kotásek. HLS-based Fault Tolerance Approach for SRAM-based FPGAs. In: Proceedings of the 2016 International Conference on Field Programmable Technology. Xi'an: IEEE Computer Society, 2016, s. 297-298. ISBN 978-1-5090-5602-6.
38. Kritchallo V., Braithwaite B., Vermij E., Bertels K., and Al-Ars Z.: Balancing High-Performance Parallelization and Accuracy in Canny Edge Detector. 29th International Conference on Architecture of Computing Systems (ARCS'2016), Nuremberg, Germany, April 4-7, 2016.
39. M. Koskela, T. Viitanen, P. Jääskeläinen, and J. Takala, “Half-Precision Floating-Point Ray Traversal,” in Proc. Joint Conf. Comput. Vision Imaging Comput. Graphics Theory Appl., Rome, Italy, 2016.
40. Ikonen Tiia, Haataja Keijo, Toivanen Pekka, Tolonen Teemu, and Isola Jorma: Nuclei Malignancy Analysis Based on an Adaptive Bottom-Hat Filter. Proceedings of the IEEE 16th International Conference on Intelligent Systems Design and Applications (ISDA'2016), Porto, Portugal, December 14-16, 2016.
41. O. Čekan, J. Podivýnský, and Z. Kotásek. Random Stimuli Generation Based on a Stochastic Context-Free Grammar. In: Proceedings of the 2016 International Conference on Field Programmable Technology. Xi'an: IEEE Computer Society, 2016, pp. 291-292. ISBN 978-1-5090-5602-6.
42. Heikki Kultala, Timo Viitanen, Pekka Jääskeläinen, Jarmo Takala: “Aggressively Bypassing List Scheduler for Transport Triggered architectures.” SAMOS XVI: Embedded Computer Systems: Architectures, MOdeling, and Simulation, Samos, Greece, July 2016.
43. Joonas Multanen, Timo Viitanen, Pekka Jääskeläinen, Jarmo Takala: “Xor-Masking: a Low-Overhead Method for Instruction Fetch Energy Reduction with Emerging SRAM Technologies.” SiPS 2016: IEEE Workshop on Signal Processing Systems. Dallas, Texas, October 2016.
44. Joonas Multanen, Heikki Kultala, Matias Koskela, Timo Viitanen, Pekka Jääskeläinen, Jarmo Takala, Karen Egiazarian, Aram Danielyan, Cristóvão Cruz: “OpenCL Programmable Exposed Datapath High Performance Low-Power Computational Imaging Accelerator.” IEEE Nordic Circuits and Systems Conference. Copenhagen, Denmark, November 2016.
45. N.Behmann, C. Seifert, G. Paya-Vaya, H. Blume, P. Jääskeläinen, J.Multanen, H. Kultala, J. Takala, J. Thiemann, S. van de Par: “Customized High Performance Low Power Processor for Binaural Speaker Localization.” IEEE Int'l Conference on Electronics, Circuits, & Systems. Monte Carlo, Monaco, December 2016.
46. M. Hendriks, M. Geilen, A.R.B. Behrouzian, T. Basten, H. Alizadeh, and D. Goswami. “Checking metric temporal logic with TRACE,” in 16th International Conference on Application of Concurrency to System Design (ACSD 2016), Torun, Poland, 2016.
47. Pekka Jääskeläinen, Timo Viitanen, Jarmo Takala, Heiki Berg: “HW/SW Co-design Toolset for Customization of Exposed Datapath Processors”. A book chapter in Computing Platforms for Software-Defined Radio. Springer. December, 2016.

48. Hadi Alizadeh Ara, Amir Behrouzian, Marc Geilen, Martijn Hendriks, Dip Goswami and Twan Basten, "Analysis and Visualization of Execution Traces of DataFlow Applications", IDEA Workshop on Integrating Dataflow, Embedded Computing, and Architecture, 2016.
49. Adyanthaya, S., Alizadeh Ara, H., Nogueira Bastos, J.P., Baghbanbehrouzian, A., Medina Sanchez, R.A., van Pinxten, J.H.H., van der Sanden, L.J., Waqas, U., Basten, A.A., Corporaal, H., Frijns, R.M.W., Geilen, M.C.W., Goswami, D., Hendriks, M., Stuijk, Sander, Reniers, M.A. & Voeten, J.P.M. (2016). "xCPS: a tool to explore cyber physical systems". ACM SIGBED, 14(1), 81-95.
50. A. Brandon, J. Hoozemans, J. Van Straten, S. Wong, "Exploring ILP and TLP on a Polymorphic VLIW Processor", to appear in the proceedings of the 30th International Conference on Architecture of Computing Systems, Vienna, Austria, 2017.
51. J. Hoozemans, R. Heij, J. Van Straten, S. Wong, "VLIW-based FPGA computational fabric with streaming memory hierarchy for medical imaging applications", to appear in the proceedings of the 13th International Symposium on Applied Reconfigurable Computing, Delft, the Netherlands, 2017.

- SAMOS XV, 2015 Special session on "Mid-Term Results of the ALMARVI ARTEMIS project" organized by J. Takala and Z. Al-Ars includes the following publications:
  - "Multi-Constraint Multi-Processor Resource Allocation" by A. R. B. Behrouzian, D. Goswami, T. Basten, M. Geilen, H. Alizadeh Ara (**TUE**)
  - "GPU Implementation of an Anisotropic Huber-L1 Dense Optical Flow Algorithm Using OpenCL" by D. Buyukaydin and T. Akgun **(ASEL**)
  - "Using VLIW Softcore Processors for Image Processing Applications" by J. Hoozemans, S. Wong and Z. Al-Ars (**TUD**)
  - "Power Optimizations for Transport Triggered SIMD Processors" by J. Multanen, T. Viitanen, H. Linjamäki, H. Kultala, P. Jääskeläinen, J. Takala, L. Koskinen, J. Simonsson, H. Berg, K. Raiskila and T. Zetterman (**Multi-partner collaboration: TUT, UTU, NOK**)
  - "Current Analysis Approaches and Performance Needs for Whole Slide Image Processing in Breast Cancer Diagnostics" by I. Pöllänen, B. Braithwaite, K. Haataja, T. Ikonen and P. Toivanen (**UEF**)
  - "Performance evaluation of image noise reduction computing on a mobile platform" by J. Hannuksela, M. Niskanen and M. Turtinen (**VIS**)
  - "Video Chain Demonstrator on Xilinx Kintex7 FPGA with EdkDSP Floating Point Accelerators" by J. Kadlec **(UTIA**)

- Springer, 2017 Special Issue on ALMARVI results on Springer Journal of Signal Processing Systems organized by Zaid Al-Ars (TUDelft) and Jarmo Takala (TUT)

The ALMARVI project partners made agreements with the Springer Journal of Signal Processing Systems (JSPS) to publish a special journal issue describing the objectives and achievements of the ALMARVI project. JSPS is an established journal with a field of interest that well covers the objectives of ALMARVI, publishing research on the areas of system design and implementation, algorithms, architectures, and applications. The special issue features 12 scientific papers that provide an overview of the project and highlight how the different partners collaborated to address the various challenges in an integrated way. The special issue will be indexed by many widely used search engines in the field, and will be made publicly accessible. This will keep a permanent record of the achievement of

ALMARVI, thereby maximizing the impact of the project and ensuring the visibility of the results to a wider audience**.**
The structure of the journal special session is as follows:

- Introduction paper discussing the general vision of ALMARVI and the work packages in the project.
- 4 work package papers about the content of the goals and achievements of each work package, e.g.,
- 2 technical papers by a number of collaborating partners from each work package

The submission and publication schedule of the journal is as follows.

- Call for papers released: Feb 1, 17
- Submission deadline: Apr 1, 17
- Feedback and improvements: Jun 1, 17
- Final version: Jul 1, 17
- Publication: Aug 1, 17

Some of the under preparation submissions for the above special issue are as follows:

- "Modeling and Analysis Techniques On FPGA Accelerator Node Networks for Real-time Streaming Video Processing Applications in the Healthcare Domain" by S.C. van der Vlugt, R. J. de Jong, M. Hendriks, H.A. Ara, R. Guerra Marin, M. Geilen, D. Goswami (**PHILIPS, TUE**)
- "ALMARVI demonstrators" by S.C. van der Vlugt and Z. Al-Ars (**All WP5 partners**)
- "Frame-based programming, stream-based processing" by J. Hoozemans, R. J. de Jong, S.C. van der Vlugt, J. van Straten, Z. Al-Ars (**TUD, PHILIPS**)
- "Applying Monotonic Optimization to Dataflow Buffer Sizing", M. Hendriks, H.A. Ara, M. Geilen, T. Basten, R. Guerra Marin, R. J. de Jong, S. C. van der Vlugt (**TUE**)
- "Board support packages with runtime reconfigurable floating point accelerators for design of video processing algorithms in Xilinx SDSoC environment" by J. Kadlec, Z. Pohl (**UTIA**)
- "ALMARVI video processing SoC platform on Zynq" by J.J.Hoozemans, T. Viitanen, A. Tervo, J. Kadlec (**UTIA, TUdelft, TUT**)
- "Image restoration methods: HW platform-related analyzes and optimizations" by J. Kamenicky, F. Sroubek, B Zitova, M. Turtinen, M. Niskanen (**UTIA, VISIDON**)

template A: list of scientific (peer reviewed) publications, starting with the most important ones										
NO.	Title	Main author	Title of the periodical or the series	Number, date or frequency	Publisher	Place of publication	Year of publication	Relevant pages	Permanent identifiers[3] (if available)	Is/Will open access[4] provided to this publication?
1	pocl: A Performance-Portable OpenCL Implementation	P. Jääskeläinen C.S. de La Lama, E. Schnetter, K. Raiskila, J. Takala, H. Berg	Int. J. Parallel Programming	Vol. 43, Issue 5	???	???	2015	pp. 752 – 785	???	???
2	Embedded Multi-Core Systems Dedicated to Dynamic Dataflow Programs	H. Yviquel, A. Sanchez, P. Jääskeläinen, J. Takala, M. Raulet	J. Signal Processing Systems	Vol. 80, Issue 1	???	???	2015	pp. 121 – 136	???	???
3	Integer Linear Programming Based Scheduling	T. Äijö, P. Jääskeläinen, T. Elomaa, H. Kultala, J. Takala	ACM Trans. Architectu	Vol. 12, Issue 4	???	???	2015	pp. 59:1-59:22	???	???

[3] A permanent identifier should be a persistent link to the published version full text if open access or abstract if article is pay per view) or to the final manuscript accepted for publication (link to article in repository).
[4] Open Access is defined as free of charge access for anyone via Internet. Please answer "yes" if the open access to the publication is already established and also if the embargo period for open access is not yet over but you intend to establish open access afterwards.

	for Transport Triggered Architecture		re and Code Optimization							
4	Code Density and Energy Efficiency of Exposed Datapath Architectures	P. Jääskeläinen, H. Kultala, T. Viitanen, J. Takala	J. Signal Processing Systems	Vol. 80, Issue 1	???	???	2015	pp. 49-64	???	???
5	Decomposition space-variant blur in image deconvolution	F. Sroubek, J. Kamenicky, Y. M. Lu	IEEE Signal Processing Letters	vol. 23, no. 3	???	???	2016	pp. 346-350	???	???
6	xCPS: a tool to explore cyber physical systems	Adyanthaya, S., Alizadeh Ara, H., Nogueira Bastos, J.P., Baghbanbehrouzian, A., Medina Sanchez, R.A., van Pinxten, J.H.H., van der Sanden, L.J., Waqas, U., Basten, A.A., Corporaal, H., Frijns, R.M.W., Geilen, M.C.W., Goswami, D., Hendriks, M., Stuijk, Sander, Reniers, M.A. Voeten, J.P.M.	ACM SIGBED	14(1)	???	???	???	pp. 81-95	???	???

2.2 Section B (Confidential[5] or public: confidential information to be marked clearly)

2.2.1 Part B1

Template B1: List of applications for patents, trademarks, registered designs, etc.			
Type of IP Rights[6]: Patents, Trademarks, Registered designs, Utility models, etc:	Application reference(s) (e.g. EP123456)	Subject or title of application	Applicant (s) (as on the application)

[5] Note to be confused with the "EU CONFIDENTIAL" classification for some security research projects.

[6] A drop down list allows choosing the type of IP rights: Patents, Trademarks, Registered designs, Utility models, Others.

2.2.2 Part B2

Please complete the table hereafter:

TEMPLATE B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable foreground (description)	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
Parallel image processing algorithms	Interventional X-Ray systems, Thermal and infrared imaging systems, Mobile standalone systems, Person identification, Mobile camera	Medical, Surveillance, Security, Mobile	2018		Philips, ASEL, OZYEGIN, HURJA, VISI, VTT, UTIA, UEF
TTA processor architecture	Radio modem & audio signal processing	IoT	2018		TUT (Owner), Nokia
ALMARVI execution platform with OpenCL and ρ-VEX on FPGAs	Interventional X-Ray systems, Thermal and infrared imaging systems, mobile standalone systems,	Medical, Surveillance, Mobil	2018		TUD (Owner), Philips, ASEL, VISI, CAMEA, BUT, UEF

[7] A drop down list allows choosing the type sector (NACE nomenclature) : http://ec.europa.eu/competition/mergers/cases/index/nace_all.html

TEMPLATE B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable foreground (description)	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	Mobile camera, Traffic surveillance				
Apply alternative off-the-shelf heterogeneous processors such as GPUs for image processing	Interventional X-Ray systems, Thermal and infrared imaging systems, mobile standalone systems, Mobile camera	Medical, Surveillance, Mobile	2019		UTIA (Owner), Philips, ASEL, OZYEGIN, VISI
ASIP	Radio modem & audio signal processing	IoT	2018		UTU (Owner), Nokia
Almarvi platform stack	Thermal and infrared imaging systems & mobile standalone systems, Mobile camera	Surveillance, Mobile	2018		ASEL, VISI
HLS tools in the design process	Interventional X-Ray systems	Medical	2018		Philips, TUE
TCE tool chain	Radio modem & audio signal processing	IoT	2018		TUT (Owner), Nokia
Automated synthesis tool chain	Thermal and infrared imaging systems &	Surveillance	2018		ASEL, OZYEGIN

TEMPLATE B2: OVERVIEW TABLE WITH EXPLOITABLE FOREGROUND					
Exploitable foreground (description)	Exploitable product(s) or measure(s)	Sector(s) of application[7]	Timetable, commercial or any other use	Patents or other IPR exploitation (licences)	Owner & Other Beneficiary(s) involved
	mobile standalone systems				

The ALMARVI consortium is still collaborating to ensure visibility of the project results at both European and international levels covering all aspects, i.e. exhibitions, trade shows, industrial demonstrations, end-suppliers contacts, research and technological forums like conferences, magazines, journals, workshops, special sessions, poster sessions, etc. This ensures that the results are given maximal chance of being exploited internally and outside the project. The consortium generated valuable industrial-grade results and technological developments aligned to the market demands, such that they can be deployed in real-world applications/products, while disseminating the knowledge to the entire embedded systems and applications community. ALMARVI's platform solution will enable development of low-cost solutions for a wide-range of market in different industrial domains and create new market opportunities, in particular supporting SMEs.
The exploitation of the results developed in the ALMARVI project targets the actual implementation of project outcome within the industry that will lead to technologically competitive products allowing European companies to achieve a leading position in image/video processing solutions at the international level.
The companies in the project serve large markets for professional users, and consumers. They enable applying massive image processing at low cost and low latency to their clients. These clients get better information at the same or lower cost. The equipment cost reduction is originating from reduction of development, material, hardware and maintenance costs. These costs are addressed by the project aims to provide flexibility towards the used hardware platform and the reduction of the number of processing units to serve a system. The costs of ownership are reduced and the ease of use is improved by low power consumption.
The user advantages are important for the position of the companies in their markets. Certain partners provided multi-core tooling that enables the industrial partners to obtain the above mentioned benefits.

University partners are using the results achieved in this project to enrich the curricula provided to students with industrially relevant topics, and to focus their research agendas to match industrial needs. It has lead to improved consultation, training, theses and dissertations. Certain project results are finding their way in the open source arena.

3 Report on societal implications

A General Information (completed automatically when Grant Agreement number is entered.	
JU Grant Agreement Number:	ARTEMIS- 621439
Title of Project:	Algorithms, Design Methods, and Many-Core Execution Platform for Low-Power Massive Data-Rate Video and Image Processing
Name and Title of Coordinator:	Frank van der Linden

B Ethics	
Did you have ethicists or others with specific experience of ethical issues involved in the project?	No
2. Please indicate whether your project involved any of the following issues (tick box) :	YES
Informed consent	
• Did the project involve children?	
• Did the project involve persons not able to give consent?	
• Did the project involve adult healthy volunteers?	
• Did the project involve Human genetic material?	
• Did the project involve Human biological samples?	
• Did the project involve Human data collection?	
Research on Human embryo/foetus	
• Did the project involve Human Embryos?	
• Did the project involve Human Foetal Tissue / Cells?	
• Did the project involve Human Embryonic Stem Cells (hESCs)?	
Privacy	
• Did the project involve processing of genetic information or personal data (eg. health, sexual lifestyle, ethnicity, political opinion, religious or philosophical conviction)?	
• Did the project involve tracking the location or observation of people?	
Research on Animals	
• Did the project involve research on animals?	
• Were those animals transgenic small laboratory animals?	
• Were those animals transgenic farm animals?	
• Were those animals cloned farm animals?	
• Were those animals non-human primates?	
Research Involving Developing Countries	
• Use of local resources (genetic, animal, plant etc)	
• Benefit to local community (capacity building i.e. access to healthcare, education etc)	
Dual Use	
• Research having potential military / terrorist application	

C Workforce Statistics

3. Workforce statistics for the project: Please indicate in the table below the number of people who worked on the project (on a headcount basis).

Type of Position	Number of Women	Number of Men
Scientific Coordinator	0	1
Work package leaders	0	7
Experienced researchers (i.e. PhD holders)	6	42
PhD Students	3	13
Other	5	36

4. How many additional researchers (in companies and universities) were recruited specifically for this project?	
Of which, indicate the number of men:	6
Of which, indicate the number of women:	1

D Gender Aspects

5. Did you carry out specific Gender Equality Actions under the project? ○ Yes ● No

6. Which of the following actions did you carry out and how effective were they?

	Not at all effective				Very effective
❑ Design and implement an equal opportunity policy	○	○	○	●	○
❑ Set targets to achieve a gender balance in the workforce	○	○	●	○	○
❑ Organise conferences and workshops on gender	●	○	○	○	○
❑ Actions to improve work-life balance	○	○	●	○	○

○ Other:

7. Was there a gender dimension associated with the research content – i.e. wherever people were the focus of the research as, for example, consumers, users, patients or in trials, was the issue of gender considered and addressed?

○ Yes- please specify

● No

E Synergies with Science Education

8. Did your project involve working with students and/or school pupils (e.g. open days, participation in science festivals and events, prizes/competitions or joint projects)?

○ Yes- please specify

● No

9. Did the project generate any science education material (e.g. kits, websites, explanatory booklets, DVDs)?

○ Yes- please specify

● No	
F Interdisciplinarity	
10. Which disciplines (see list below) are involved in your project? ● Main discipline[8]: Engineering & technology ○ Associated discipline[8]: ○ Associated discipline[8]:	
G Engaging with Civil society and policy makers	
11a Did your project engage with societal actors beyond the research community? *(if 'No', go to Question 14)*	○ Yes ● No
11b If yes, did you engage with citizens (citizens' panels / juries) or organised civil society (NGOs, patients' groups etc.)? ● No ○ Yes- in determining what research should be performed ○ Yes - in implementing the research ○ Yes, in communicating /disseminating / using the results of the project	
11c In doing so, did your project involve actors whose role is mainly to organise the dialogue with citizens and organised civil society (e.g. professional mediator; communication company, science museums)?	○ Yes ○ No
12. Did you engage with government / public bodies or policy makers (including international organisations) ● No ○ Yes- in framing the research agenda ○ Yes - in implementing the research agenda ○ Yes, in communicating /disseminating / using the results of the project	
13a Will the project generate outputs (expertise or scientific advice) which could be used by policy makers? ○ Yes – as a **primary** objective (please indicate areas below- multiple answers possible) ○ Yes – as a **secondary** objective (please indicate areas below - multiple answer possible) ● No	

13b If Yes, in which fields?

Agriculture Audiovisual and Media Budget Competition Consumers Culture Customs Development Economic and Monetary Affairs Education, Training, Youth Employment and Social Affairs		Energy Enlargement Enterprise Environment External Relations External Trade Fisheries and Maritime Affairs Food Safety Foreign and Security Policy Fraud Humanitarian aid		Human rights Information Society Institutional affairs Internal Market Justice, freedom and security Public Health Regional Policy Research and Innovation Space Taxation Transport	

[8] Insert number from list below (Frascati Manual).

13c If Yes, at which level? ○ Local / regional levels ○ National level ○ European level ○ International level	
H Use and dissemination	
14. How many Articles were published/accepted for publication in peer-reviewed journals?	
To how many of these is open access[9] provided?	
How many of these are published in open access journals?	
How many of these are published in open repositories?	
To how many of these is open access not provided?	
Please check all applicable reasons for not providing open access:	
❑ publisher's licensing agreement would not permit publishing in a repository ❑ no suitable repository available ❑ no suitable open access journal available ❑ no funds available to publish in an open access journal ❑ lack of time and resources ❑ lack of information on open access ❑ other[10]: ……	
15. How many new patent applications ('priority filings') have been made? ("Technologically unique": multiple applications for the same invention in different jurisdictions should be counted as just one application of grant).	0
16. Indicate how many of the following Intellectual Property Rights were applied for (give number in each box). — Trademark	
Registered design	
Other	
17. How many spin-off companies were created / are planned as a direct result of the project?	
Indicate the approximate number of additional jobs in these companies:	

18. Please indicate whether your project has a potential impact on employment, in comparison with the situation before your project:		
❑ Increase in employment, or	■	In small & medium-sized enterprises
■ Safeguard employment, or	■	In large companies
❑ Decrease in employment,	❑	None of the above / not relevant to the project
❑ Difficult to estimate / not possible to quantify		

19. For your project partnership please estimate the employment effect resulting directly from your participation in Full Time Equivalent (*FTE = one person working fulltime for a year*) jobs:	Indicate figure:

[9] Open Access is defined as free of charge access for anyone via Internet.
[10] For instance: classification for security project.

Difficult to estimate / not possible to quantify	■

I	Media and Communication to the general public

20. As part of the project, were any of the beneficiaries professionals in communication or media relations?

○ Yes ● No

21. As part of the project, have any beneficiaries received professional media / communication training / advice to improve communication with the general public?

○ Yes ● No

22 Which of the following have been used to communicate information about your project to the general public, or have resulted from your project?

❑	Press Release	■	Coverage in specialist press
❑	Media briefing	❑	Coverage in general (non-specialist) press
❑	TV coverage / report	❑	Coverage in national press
❑	Radio coverage / report	❑	Coverage in international press
❑	Brochures /posters / flyers	❑	Website for the general public / internet
❑	DVD /Film /Multimedia	❑	Event targeting general public (festival, conference, exhibition, science café)

23 In which languages are the information products for the general public produced?

❑	Language of the coordinator	■	English
❑	Other language(s)		

Question F-10: Classification of Scientific Disciplines according to the Frascati Manual 2002 (Proposed Standard Practice for Surveys on Research and Experimental Development, OECD 2002): 2.2

Fields of science and technology

1. Natural Sciences

1.1 Mathematics and computer sciences [mathematics and other allied fields: computer sciences and other allied subjects (software development only; hardware development should be classified in the engineering fields)]

1.2 Physical sciences (astronomy and space sciences, physics and other allied subjects)

1.3 Chemical sciences (chemistry, other allied subjects)

1.4 Earth and related environmental sciences (geology, geophysics, mineralogy, physical geography and other geosciences, meteorology and other atmospheric sciences including climatic research, oceanography, vulcanology, palaeoecology, other allied sciences)

1.5 Biological sciences (biology, botany, bacteriology, microbiology, zoology, entomology, genetics, biochemistry, biophysics, other allied sciences, excluding clinical and veterinary sciences)

2 Engineering and technology

2.1 Civil engineering (architecture engineering, building science and engineering, construction engineering, municipal and structural engineering and other allied subjects)
2.2 Electrical engineering, electronics [electrical engineering, electronics, communication engineering and systems, computer engineering (hardware only) and other allied subjects]
2.3. Other engineering sciences (such as chemical, aeronautical and space, mechanical, metallurgical and materials engineering, and their specialised subdivisions; forest products; applied sciences such as geodesy, industrial chemistry, etc.; the science and technology of food production; specialised technologies of interdisciplinary fields, e.g. systems analysis, metallurgy, mining, textile technology and other applied subjects)

3. Medical Sciences
3.1 Basic medicine (anatomy, cytology, physiology, genetics, pharmacy, pharmacology, toxicology, immunology and immunohaematology, clinical chemistry, clinical microbiology, pathology)
3.2 Clinical medicine (anaesthesiology, paediatrics, obstetrics and gynaecology, internal medicine, surgery, dentistry, neurology, psychiatry, radiology, therapeutics, otorhinolaryngology, ophthalmology)
3.3 Health sciences (public health services, social medicine, hygiene, nursing, epidemiology)

4. Agricultural sciences
4.1 Agriculture, forestry, fisheries and allied sciences (agronomy, animal husbandry, fisheries, forestry, horticulture, other allied subjects)
4.2 Veterinary medicine

5. Social sciences
5.1 Psychology
5.2 Economics
5.3 Educational sciences (education and training and other allied subjects)
5.4 Other social sciences [anthropology (social and cultural) and ethnology, demography, geography (human, economic and social), town and country planning, management, law, linguistics, political sciences, sociology, organisation and methods, miscellaneous social sciences and interdisciplinary , methodological and historical S1T activities relating to subjects in this group. Physical anthropology, physical geography and psychophysiology should normally be classified with the natural sciences].

6. Humanities
6.1 History (history, prehistory and history, together with auxiliary historical disciplines such as archaeology, numismatics, palaeography, genealogy, etc.)
6.2 Languages and literature (ancient and modern)
6.3 Other humanities [philosophy (including the history of science and technology) arts, history of art, art criticism, painting, sculpture, musicology, dramatic art excluding artistic "research" of any kind, religion, theology, other fields and subjects pertaining to the humanities, methodological, historical and other S1T activities relating to the subjects in this group]