# TULIPP

## H2020-ICT-O4-2015

## Grant Agreement n° 688403

# D[6.6]: [Reference Platform – Standardisation Recommendation]

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# Abstract

D6.6 is a public summary of the overall efforts inside the TULIPP Consortium in respect of creating a generic Reference Platform for image processing application, alias *"TULIPP Starter Kit"*, the use of industry standard interfaces to enable the *"TULIPP Use-Cases"* to create demonstration of the entire solution and recommendation for standardization and future work in the domain of any low-power system, based on our own experience and the feedback from the TULIPP Eco-System of more than 30 external individuals – see http://tulipp.eu/advisory-board-members/

This is document is deliberately kept short, as more details can be found in the following official deliverable on the TULIPP web-site:

1. http://tulipp.eu/public-deliverables/wp1-reference-platform-definition-v3/
   a. Full description of the hardware, software, use-cases
   b. Details about the almost 50 'Guidelines' written during the project
      i. https://github.com/tulipp-eu/tulipp-guidelines/wiki

2. http://tulipp.eu/public-deliverables/d2-2-optimized-instance-of-a-power-efficient-board/
   a. Full details about Sundance's hardware development

3. http://tulipp.eu/public-deliverables/d3-2-low-power-multicore-rtos-release-report/
   a. Full details about HIPPEROS's RTOS for ARMv7 and ARMv8 MultiCore CPUs

4. http://tulipp.eu/public-deliverables/d4-4-final-tool-chain/
   a. Full details about the NTNU developed Toolchain to accelerate IP-Cores
   b. Full details about TUD utilities for Image Processing development

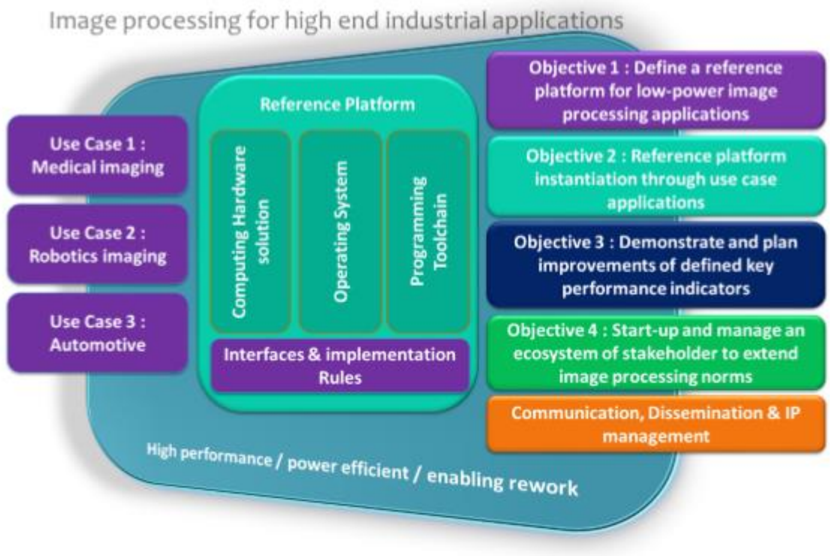


FIGURE 1 - THE TULIPP PROJECT OVERVIEW

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# 1. TULIPP Reference Platform

*What is the TULIPP Starter Kit?*

The goal of the Starter Kit is enabling an instant "Out-of-Box" experience in terms of running an example on the combined platform within a few hours. It also serves as a proof of concept for users' own developments and as a baseline that users can reuse as is or adapt and modify to fit their needs.

Thus reusability, flexibility, and adaptability are the main characteristics of this platform. In order to obtain those characteristics, the reference platform was designed to be as modular and "plug & play" as possible.

FIGURE 2 - TULIPP STARTER KIT WITH LYNSYN POWER MONITOR

## 2. A path towards standardisation – WP1 (Total Man-month = 72)

WP1 was where the “Cookbook” was defined and written. This is effectively D1.3 (http://tulipp.eu/public-deliverables/wp1-reference-platform-definition-v3/) in a book format

It is an essential guide to understand the selection process of the various standards for components that, put together, makes the TULIPP platform.

The “Cookbook” groups insights, guidelines and generally speaking recommendations to help designers build low power embedded vision systems as quickly and as efficiently as possible.

The “Cookbook” shows how to build such a platform, it reviews and explains a collection of standards. It also shows how to select the best suitable standards and how to combine them to build an energy efficient platform. These standards are then considered as *defacto* standards for building such a platform, which is then called the reference platform.


FIGURE 3 - TULIPP ‘COOKBOOK’

Since there is no “one-fits-all” standard for each component type, the most relevant standards are explained and compared in the cookbook. It explains the standards that are used and discuss their advantages and drawbacks in consideration to low-power platforms.

The Academic Partners of TULIPP has committed to get the “Cookbook” published towards end of year 2019 and a number of Eco-Systems members are committed to produce material, based on their experience with “*TULIPP Starter Kit*”.

# 3. Hardware Components – WP2 (Total Man-month = 34)

WP2 was the work package dealing with the design of the hardware platform. For the Tulipp hardware instantiation platform, we decided to opt for a COTS solution that contains a Xilinx Zynq SoC on a 40mm x 50mm “System-on-Module – see figure 4 – to enable upgrade during the project. D2.2 cover details.

FIGURE 4 - TULIPP ZYNQ SOC SOM

One of the requests from the Eco-System was to target the TULIPP platform towards robotics solutions, as the Zynq is very versatile in terms of handling I/O and Images processing without latency and below solution was shared amongst the more than 20x delegates that participated in the HiPEAC event in January 2019

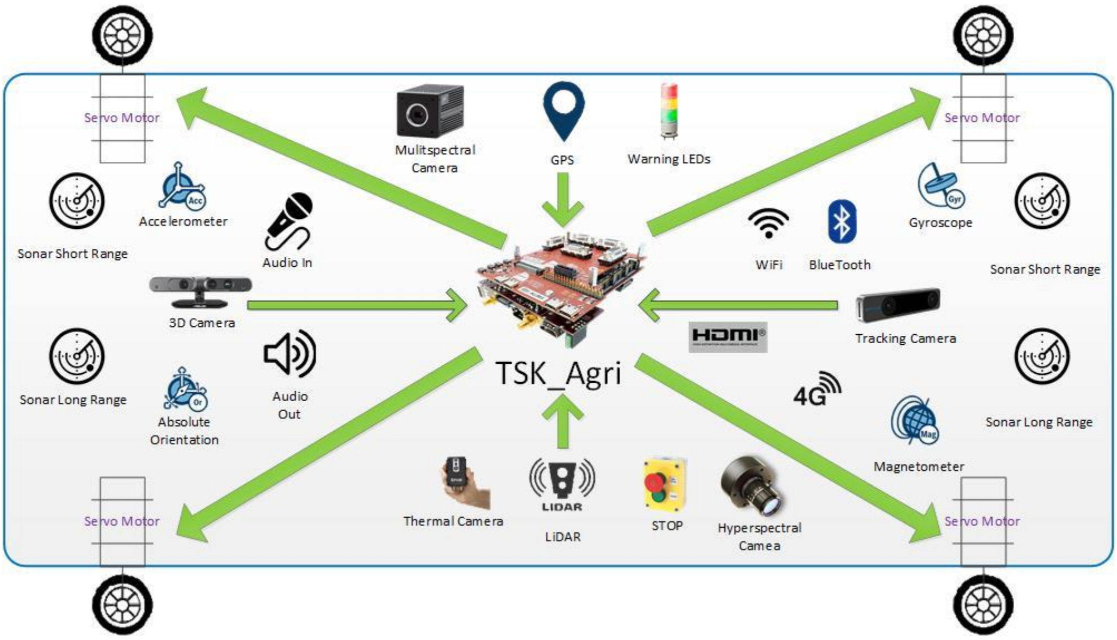


FIGURE 5 - TULIPP AGRI KIT

# 4. Software Components – WP3 (Total Man-month = 78)

In an embedded system, where you have highly demanding constraints and limited resources, it is the role of the operating system and the middleware to provide the right combination of Performance, Reliability, Efficiency, and Security (PRES) to make the development of quality systems affordable.

In the case of TULIPP, we developed an operating system that is "hard real-time", as missing deadlines impacts the quality of the vision system or makes it unsafe.

A natural question is: *"Why not use Linux? It's free, it's there!"*. The simple answer is that Linux does not support real-time, has a very large memory footprint and large latencies, giving it lower worst-case performance in any image processing application

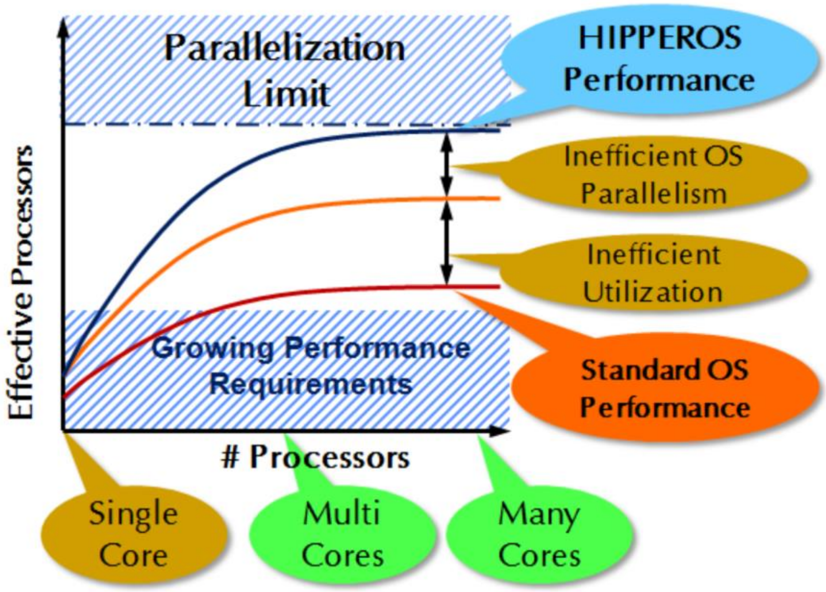


FIGURE 6 - MIGRATION FROM SINGLE CORE TO MANY-CORE

While the selection process of a RTOS is critical for success, then selection APIs to support the reference platform, is also important. We covers this in this deliverable [http://tulipp.eu/public-deliverables/d3-3-generic-rtos-apis-and-libraries-documentation/](http://tulipp.eu/public-deliverables/d3-3-generic-rtos-apis-and-libraries-documentation/)

# 5. Toolchain Components - WP4 (Total Man-month = 91)

The TULIPP toolchain (STHEM) was developed to combine any vendor specific software components with chosen hardware solution and integrate with the RTOS.

Although STHEM for TULIPP is targeted towards the Xilinx tools and has a route integrating high-level synthesis to convert "C-to-VHDL" to enable non-VHDL programmers to use the FPGA fabric of the Zynq SoC without a steep learning curve, then it could be ported to support any FPGA that support High-Level-Synthesises (HLS)

STHEM has to interface with the component vendor's tool chains, so it is difficult to define a sole standard that can be used for any tool chain. The integration of vendor tools is more empirical and requires, in most of the cases, to go deeply into the tools to understand how the configuration files are architecture. This same apply to support of image processing libraries and partial reconfiguration of a FPGA. This function are very vendor specific.

Hence it was decided that the entire STHEM was released as "Open Source" and can found on this GitHub - https://github.com/tulipp-eu/sthem - to allow the community to adopt, change and improve the TULIPP efforts

In the early stages of the project we were struggling to find suitable hardware that would allow us (and future Users) to actually measure the wattages of the total solution. Many SoCs, like the Zynq, has internal temperature sensors/monitors, but does not help much to calculate the overall power consumption, hence LynSyn was developed

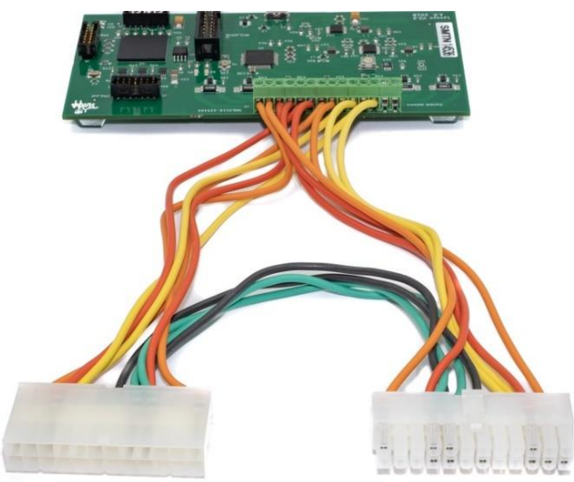

FIGURE 7 LYNSYN POWER MONITOR FOR TULIPP

More details inside D4.4 and the above GitHub location.

# 6. Use Case Application – WP5 (Total Man-month = 69)

The saying *"The proof of the baking is the eating of the cake"* has never been so true.

The Tulipp project aims was to bring powerful computing resources into any embedded systems with low-power and high-performance and we opted for three very varied application to show that TULIPP would leave a legacy.

### 6.1.1. Medical Application

The application is a solution to remove noise on C-arm images. A C-arm is used in operation theatre to see inside the body thanks to X-rays. The main drawback of X-rays is the radiation given to both the patients and medical staff.
The good news is, we can reduce this radiation dose, but, it adds noise to the images and requires therefore extreme performance for a short burst of time, during a scan of patients.
More details here - http://tulipp.eu/medical-x-ray-imaging/

### 6.1.2. UAV Application

Although the example is for Unmanned Aerial Vehicles, then the same kind of requirements holds for robots and autonomous ground vehicles. The focus is a dynamic reconfiguration of the processing. The current application is a binocular vision analysis to compute distances and to allow the UAV to find its way in the air.
More details here - http://tulipp.eu/surveillance-and-rescue-uavs/

### 6.1.3. ADAS Application

Advanced Driver Assistance Systems in the form of image processing is finding it's way into all areas of car technology as we progress towards autonomous (Driverless) transportation of goods and people. The focus on our application is pedestrian (humans or animals) safety and anti-collision. Our current application is a human pedestrian detection using Viola & Jones classifier.
More details here - http://tulipp.eu/advanced-driver-assistance/

# 7. Standardisation recommendations

During the project we have made contacts with a number of working groups and alliances that have been successful in standardisations, but the process is slow and expensive. One such is Khronos - https://www.khronos.org/about/ and another is EMVA – www.emva.org.

Successful standardisation takes decades to establish and although TULIPP Partners intend to continue working together after the completion of the project, we cannot be sure to establish any of our technology as new standards for Image Processing, but we will try to influence stakeholders of the domain as well as leave inspiring legacy that anyone will be able to use to propose new standards or modification to existing ones.

## 7.1. Paths towards influencing standards

This is possibly the obvious candidate to influence standards, as we 'only' have to write about our collective experiences and knowledge and share our man-years of experience and insights in a digestible and fluent way and as short and precise as possible.

We have already made contacts with Springer and we will get a version of the book ready before the end of 2019. A first step was made when we got a chapter in below Springer book **"Hardware Accelerator in Data Centres"**. https://www.springer.com/us/book/9783319927916

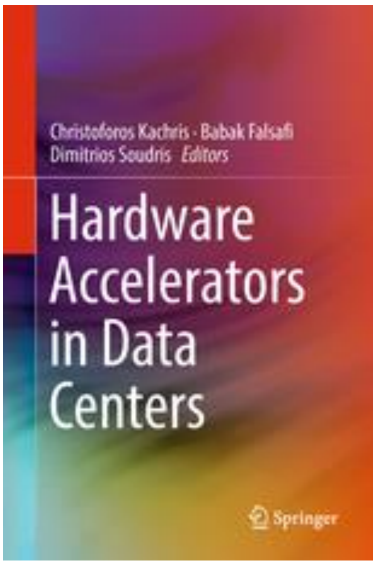


FIGURE 8 TULIPP CHAPTER, PAGES 181-199

The electronics that Sundance has designed follows several industry standards. One example is the PC/104 form-factors – www.pc104.org. The collection of standards is a way to define a standard for such a hardware platform. To share this work with others and allow anyone to reuse it, we have already moved the current hardware onto CERN's "Open Hardware Repository" – see http://www.ohwr.org/projects/emc2-dp/wiki.

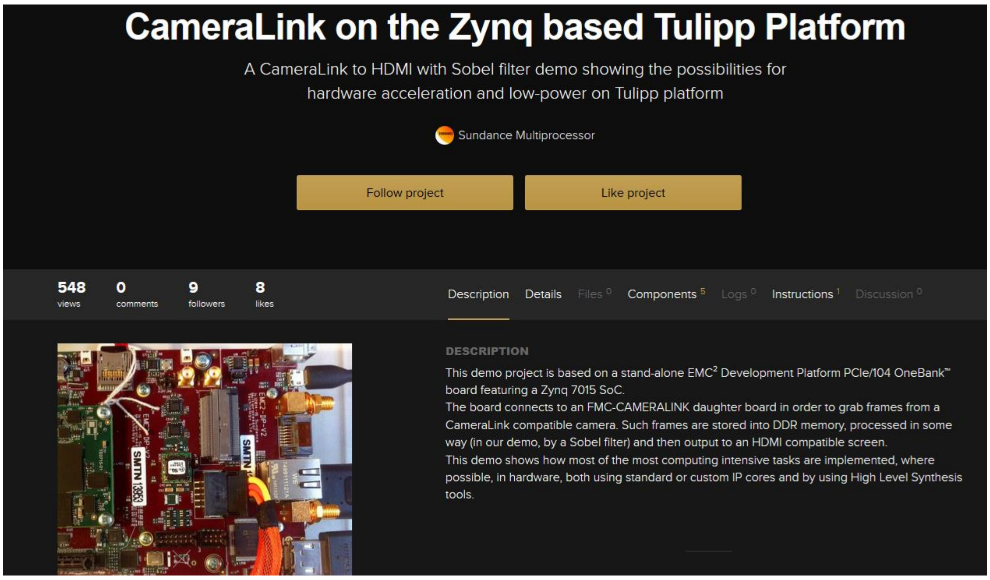


FIGURE 9: SHARING OF A CAMERALINK INTERFACE

We implemented some of proposed hardware standard interfaces, like CameraLink and HDMI interface to the current platform and these are shared on one of the main domains for "Maker" hardware - https://hackaday.io/search?term=Tulipp. We have developed interfaces for MIPI cameras and GigE cameras and these will commercialised by the industry Partners in the future.

## 7.2. Operating system and low-level library standards

What are the chances of HIPPEROS becoming the chosen Parallel RTOS for low-power image processing? Who knows?

The HIPPEROS implementation of the operating system is not free and is not opened. It is a commercial product that brings many advantages to the ones that will adopt it.
However, the API selection effort that is going on through the TULIPP project will be public, opened and shared through publications and the final book.

This impact will still be lasting, as we will share the demonstration that the API defined in Tulipp is a good combination to bring a good balance of energy efficiency and performance on embedded devices used for image processing.

## 7.3. Toolchain standards

As already explained earlier in this deliverable, the toolchain relies on vendor tools and has to adapt to them. The encouraging fact is that toolchain development is owned by our Academic Partners [RUB/TUD & NTNU) and they will be using the technology for teaching and for on-going R&D projects. Their students will then also be the ambassadors of the ideas developed in TULIPP and this will help spreading the ideas and will be a good way towards building new standards.

## 7.4. Use Case Components

The use cases are not meant to produce new standards but to use our solutions on real cases.

Even though, they all share an Open Source algorithm, it will commercially not make sense to release the final solutions into the open domain. Fraunhofer will continue own research into the UAV, Synective and Thales will be selling or using the ADAS and Medical results for many years.

This is not standardisation per se, but since it will use and rely on the standards used, developed and modified thanks to TULIPP, we might see this utilisation in the use cases as a first step towards using the developed standards.

# 8. Conclusions

The TULIPP consortium makes efforts in several directions to be able to produce an impact towards standardisation and an easy-to-use reference platform.

Information is spread through Publications, press releases, and books. As we have discussed standards and propose new tracks/ideas and it will allow inspiration for others to continue the work and promote it to standardisation.

The publication of the “TULIPP Cookbook” will be the most important contribution towards standardisation from the project and we have seen signs of interest in using the TULIPP Starter Kit for new project proposal from non-Partners and Sundance, HIPPEROS and NTNU has submitted a proposal to use the “TSK-Agri’ platform for “Precision Agriculture” in H2020 FTI proposal.

The use of open source is also an important step that helps spreading ideas and impose them as standards as they get adopted by an always larger number of people. The CERN’s OHR that we use to share our open hardware schematics will at least give access to the developed hardware components to the many people that will want to understand how we achieved the TULIPP results and that will also want to produce the same kind of solutions.

The low-level software will not be distributed for free but will be accessible as commercial products using the standard selection efforts produced in TULIPP. As the APIs will be described and discussed in the deliverables and the final book it will also be a path towards standardisation.

Two of our partners are part of the EMVA organisation and will be able to propose and continue the standardisation efforts even after the project.

The academia partners of the project will also use the work produced in TULIPP as teaching material that will in turn be a source of inspiration to students that will later be actors of modification of standards.

The prototypes developed in TULIPP for our three use cases will be the first real application to use the standards we will select and benefit from the advanced technology that is developed in TULIPP.