Horizon 2020

Call: H2020-MSCA-ITN-2016
(Marie Skłodowska-Curie Innovative Training Networks)

Topic: MSCA-ITN-2016

Type of action: MSCA-ITN-EID
(European Industrial Doctorates)

Proposal number: 721462

Proposal acronym: PUMA

Deadline Id: H2020-MSCA-ITN-2016

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How to fill in the forms?

The administrative forms must be filled in for each proposal using the templates available in the submission system. Some data fields in the administrative forms are pre-filled based on the previous steps in the submission wizard.

1 - General information

Topic	MSCA-ITN-2016
Call Identifier	H2020-MSCA-ITN-2016
Type of Action	MSCA-ITN-EID
Deadline Id	H2020-MSCA-ITN-2016

Acronym	PUMA
Proposal title	Pattern matching Units for Multiple Applications

Note that for technical reasons, the following characters are not accepted in the Proposal Title and will be removed: < > " &

Duration in months	*48*
Panel	PHY

Please select up to 5 descriptors (and at least 1) that best characterise the subject of your proposal, in descending order of relevance. Note that descriptors will be used to support REA services in identifying the best qualified evaluators for your proposal.

Descriptor 1	*Particle physics*	Add	
Descriptor 2	*Medical engineering, biomedical engineering and technol*	Add	Remove
Descriptor 3	*Algorithms, distributed, parallel and network algorithms, a*	Add	Remove
Descriptor 4	*Scientific computing and data processing*	Add	Remove
Descriptor 5	*Sensor networks, embedded systems, hardware platform*	Add	Remove

Free keywords	*Pattern matching, Trigger circuits, Imaging, Parallel processing, FPGA, ASIC, GPUs, Multi core computing, High Performance Computing, Quantitative MRI, 7T, MR fingerprinting, Space debris trails*

Proposal ID **721462** *Acronym* **PUMA**

Abstract

Pattern matching (PM) algorithms look for sequences of tokens (data) that constitute predefined patterns. They are used for data processing that require identification of specific sequences inside real-life applications (such as smart phones, security services, data servers) and demanding scientific applications (e.g. high energy physics, medical imaging, DNA identification). Such applications demand strong data reduction with minimal loss of information. Employing existing experience on real-time processing, the PUMA project will develop novel hardware platforms based on programmable accelerators that can be customized based on the application requirements. The novel platforms will increase the performance, reduce the energy consumption as well as satisfying the required QoS (quality-of-service) constraints. PUMA proposes to extend our real time image processing experience, to target new problems:

(1) Real time and offline charged track reconstruction at the Large Hadron Collider experiments at CERN.
(2) Detection of faint trails of space debris orbiting the Earth, that could harm space assets, in order to catalogue the space debris population and, in case, perform the necessary collision avoidance early enough.
(3) Clinically-feasible magnetic resonance (MR) fingerprinting, a new medical imaging technique quantitatively measuring tissue properties using standard MR hardware, currently limited by PM execution time.

Application dependent hardware platforms (for data intensive pre-processing) consisting of parallel processing elements (FPGA, CPU, GPU and high density ASIC called Associative Memory for flexible high level management of the pre-processed information), will be studied aiming at identifying the effective implementations, under several design criteria. Also, software and hardware optimizations will deliver excellent research results with large impact on critical scientific disciplines and society.

Remaining characters 54

Has this proposal (or a very similar one) been submitted in the past 2 years in response to a call for proposals under the 7th Framework Programme, Horizon 2020 or any other EU programme(s)? ○ Yes ◉ No

Declarations

1) The coordinator declares to have the explicit consent of all applicants on their participation and on the content of this proposal.	☒
2) The information contained in this proposal is correct and complete.	☒
3) This proposal complies with ethical principles (including the highest standards of research integrity — as set out, for instance, in the European Code of Conduct for Research Integrity — and including, in particular, avoiding fabrication, falsification, plagiarism or other research misconduct).	☒

4) The coordinator confirms:

- to have carried out the self-check of the financial capacity of the organisation on http://ec.europa.eu/research/participants/portal/desktop/en/organisations/lfv.html or to be covered by a financial viability check in an EU project for the last closed financial year. Where the result was "weak" or "insufficient", the coordinator confirms being aware of the measures that may be imposed in accordance with the H2020 Grants Manual (Chapter on Financial capacity check); or	○
- is exempt from the financial capacity check being a public body including international organisations, higher or secondary education establishment or a legal entity, whose viability is guaranteed by a Member State or associated country, as defined in the H2020 Grants Manual (Chapter on Financial capacity check); or	◉
- as sole participant in the proposal is exempt from the financial capacity check.	○

5) The coordinator hereby declares that each applicant has confirmed:

- they are fully eligible in accordance with the criteria set out in the specific call for proposals; and	☒
- they have the financial and operational capacity to carry out the proposed action.	☒

The coordinator is only responsible for the correctness of the information relating to his/her own organisation. Each applicant remains responsible for the correctness of the information related to him/her and declared above. Where the proposal to be retained for EU funding, the coordinator and each beneficiary applicant will be required to present a formal declaration in this respect.

According to Article 131 of the Financial Regulation of 25 October 2012 on the financial rules applicable to the general budget of the Union (Official Journal L 298 of 26.10.2012, p. 1) and Article 145 of its Rules of Application (Official Journal L 362, 31.12.2012, p.1) applicants found guilty of misrepresentation may be subject to administrative and financial penalties under certain conditions.

Personal data protection

Your reply to the grant application will involve the recording and processing of personal data (such as your name, address and CV), which will be processed pursuant to Regulation (EC) No 45/2001 on the protection of individuals with regard to the processing of personal data by the Community institutions and bodies and on the free movement of such data. Unless indicated otherwise, your replies to the questions in this form and any personal data requested are required to assess your grant application in accordance with the specifications of the call for proposals and will be processed solely for that purpose. Details concerning the processing of your personal data are available on the privacy statement. Applicants may lodge a complaint about the processing of their personal data with the European Data Protection Supervisor at any time.

Your personal data may be registered in the Early Warning System (EWS) only or both in the EWS and Central Exclusion Database (CED) by the Accounting Officer of the Commission, should you be in one of the situations mentioned in:
-the Commission Decision 2008/969 of 16.12.2008 on the Early Warning System (for more information see the Privacy Statement), or
-the Commission Regulation 2008/1302 of 17.12.2008 on the Central Exclusion Database (for more information see the Privacy Statement) .

List of participants

#	Participant Legal Name	Country
1	UNIVERSITA DI PISA	Italy
2	GENERAL ELECTRIC DEUTSCHLAND HOLDING GMBH	Germany
3	Space Dynamics Services s.r.l.	Italy
4	INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS	Greece
5	MAXELER TECHNOLOGIES LIMITED	United Kingdom

Information on partner organisations

Partner Organisation number	PIC Search PIC	Organisation legal name	Country	Academic Sector	Role of associated Provide training	Host secondmends	
1	949800333	IMAGO 7 FONDAZIONE DI RICERCA	Italy	No	Yes	Yes	
2	997363604	KAYSER ITALIA SRL	Italy	No	Yes	Yes	

2 - Administrative data of participating organisations

Coordinator

PIC	***Legal name***
999862712	*UNIVERSITA DI PISA*

Short name: UNIPI

Address of the organisation

Street LUNGARNO PACINOTTI 43/44

Town PISA

Postcode 56126

Country Italy

Webpage www.unipi.it

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes
Non-profit ....yes
International organisation ....no
International organisation of European interest ......no
Secondary or Higher education establishment ....yes
Research organisation ....yes

Legal person ....yes
Academic Sector ....yes

Enterprise Data

SME self-declared status.................................2012 - no
SME self-assessment .... unknown
SME validation sme....................................... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Nace code 853 -

Department(s) carrying out the proposed work

Department 1

Department name: Physics Department

☐ not applicable

☐ Same as organisation address

Street: Largo Bruno Pontecorvo , 3

Town: Pisa

Postcode: 56127

Country: Italy

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721462** *Acronym* **PUMA** *Short name* **UNIPI**

Person in charge of the proposal

Title: Prof.

Sex: (•) Male ( ) Female

First name **Mauro** Last name **DELL'ORSO**

E-Mail **mauro.dellorso@pi.infn.it**

Position in org.: full professor

Department: Physics Department

☐ Same as organisation

☐ Same as organisation address

Street: Largo Bruno Pontecorvo , 3

Town: Pisa Post code: 56127

Country: Italy

Website: https://www.df.unipi.it/

Phone: +39-050-2214-416 Phone 2: +39-339-2892069 Fax: +39-050-2214-317

Participant

PIC	***Legal name***
990434021	*GENERAL ELECTRIC DEUTSCHLAND HOLDING GMBH*

Short name: GENERAL ELECTRIC DEUTSCHLAND HOLDING GMBH

Address of the organisation

Street BLEICHSTRASSE 64-66

Town FRANKFURT AM MAIN

Postcode 60313

Country Germany

Webpage

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....no

Non-profit ....no

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....no

Legal person ....yes

Academic Sector ....no

Enterprise Data

SME self-declared status.................................2013 - no

SME self-assessment .... unknown

SME validation sme....................................... unknown

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Nace code 93 - Other service activities

Department(s) carrying out the proposed work

Department 1

Department name: Diagnostics, Imaging & Biomedical Technologies – Europe

☐ not applicable

☐ Same as organisation address

Street: Freisinger Landstrasse 50

Town: Garching bei München

Postcode: 85748

Country: Germany

Dependencies with other proposal participants

Character of dependence	***Participant***	

Person in charge of the proposal

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Dirk**

Last name: **Bequé**

E-Mail: **dirk.beque@research.ge.com**

Position in org.: Lead Scientist

Department: Diagnostics, Imaging & Biomedical Technologies – Europe (DIBT-E)

☐ Same as organisation

☐ Same as organisation address

Street: Freisinger Landstrasse 50

Town: Garching bei München

Post code: 85748

Country: Germany

Website: http://www.geglobalresearch.com/locations/munich-germany

Phone: 0049 089 5528 3718

Phone 2: +xxx xxxxxxxxx

Fax: 0049 089 5528 3180

Participant

PIC	***Legal name***
927818969	*Space Dynamics Services s.r.l.*

Short name: SpaceDyS

Address of the organisation

Street Via Mario Giuntini 63

Town Navacchio di Cascina (PI)

Postcode 56023

Country Italy

Webpage www.spacedys.com

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....no

Non-profit ....no

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....no

Legal person ....yes

Academic Sector ....no

Enterprise Data

SME self-declared status.................................2014 - yes

SME self-assessment ....2014 - yes

SME validation sme....................................... unknown

Based on the above details of the Beneficiary Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

Nace code 7210 -

Department(s) carrying out the proposed work

No departement involved

Department name ☒ not applicable

☐ Same as organisation address

Street *Please enter street name and number.*

Town

Postcode

Country

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721462** *Acronym* **PUMA** *Short name* **SpaceDyS**

Person in charge of the proposal

Title: Dr.

Sex: (•) Male ( ) Female

First name: **Fabrizio** Last name: **Bernardi**

E-Mail: **bernardi@spacedys.com**

Position in org.: Chief Executive Officer

Department: Space Dynamics Services s.r.l. ☒ Same as organisation

☒ Same as organisation address

Street: Via Mario Giuntini 63

Town: Navacchio di Cascina (PI) Post code: 56023

Country: Italy

Website: www.spacedys.com

Phone: +390507519607 Phone 2: +393455040077 Fax: +39050806038

Participant

PIC	***Legal name***
999654356	*INSTITUTE OF COMMUNICATION AND COMPUTER SYSTEMS*

Short name: ICCS

Address of the organisation

Street Patission Str. 42

Town ATHINA

Postcode 10682

Country Greece

Webpage www.iccs.gr

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....yes

Non-profit ....yes

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....yes

Legal person ....yes

Academic Sector ....yes

Enterprise Data

SME self-declared status..................................2007 - no

SME self-assessment .... unknown

SME validation sme..2007 - no

Based on the above details of the Beneficiary Registry the organisation is not an SME (small- and medium-sized enterprise) for the call.

Nace code 721 -

Department(s) carrying out the proposed work

Department 1

Department name: Microlab, ECE, ICCS

☐ not applicable

☐ Same as organisation address

Street: 9 Heroon Polytechneiou, Zographou Campus

Town: Athens

Postcode: 15780

Country: Greece

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721462** *Acronym* **PUMA** *Short name* **ICCS**

Person in charge of the proposal

Title: Prof.
Sex: (●) Male ( ) Female

First name: **Dimitrios** Last name: **Soudris**

E-Mail: **dsoudris@microlab.ntua.gr**

Position in org.: Associate Professor

Department: Microlab, ECE, ICCS
☐ Same as organisation

☐ Same as organisation address

Street: 9 Heroon Polytechneiou, Zographou Campus

Town: Athens Post code: 15780

Country: Greece

Website: http://www.microlab.ntua.gr/~dsoudris

Phone: +302107724270 Phone 2: +3021077223548 Fax: +302107724305

Participant

PIC	***Legal name***
968922816	*MAXELER TECHNOLOGIES LIMITED*

Short name: Maxeler Technologies Limited

Address of the organisation

Street Down Place 1

Town London

Postcode W6 9JH

Country United Kingdom

Webpage www.maxeler.com

Legal Status of your organisation

Research and Innovation legal statuses

Public body ....no

Non-profit ....no

International organisation ....no

International organisation of European interest ......no

Secondary or Higher education establishment ....no

Research organisation ....no

Legal person ....yes

Academic Sector ....no

Enterprise Data

SME self-declared status.................................2009 - yes

SME self-assessment .... unknown

SME validation sme.......................................2009 - yes

Based on the above details of the Beneficiary Registry the organisation is an SME (small- and medium-sized enterprise) for the call.

Nace code 72 - Computer & related activities

Department(s) carrying out the proposed work

Department 1

Department name	Dataflow Software Engineering	☐ not applicable
	☒ Same as organisation address	
Street	Down Place 1	
Town	London	
Postcode	W6 9JH	
Country	United Kingdom	

Dependencies with other proposal participants

Character of dependence	***Participant***	

Proposal ID **721462** *Acronym* **PUMA** *Short name* **Maxeler Technologies Limited**

Person in charge of the proposal

Title: Prof.

Sex: (•) Male ( ) Female

First name: **Georgi** Last name: **Gaydadjiev**

E-Mail: **georgi@maxeler.com**

Position in org.: VP of Dataflow Software Engineering

Department: Dataflow Software Engineering

☐ Same as organisation

☒ Same as organisation address

Street: Down Place 1

Town: London Post code: W6 9JH

Country: United Kingdom

Website: https://www.maxeler.com/

Phone: +44(0)2037716528 Phone 2: +xxx xxxxxxxxx Fax: +xxx xxxxxxxxx

Proposal ID **721462** *Acronym* **PUMA**

3 - Budget

Researcher Number	Recruiting Participant (short name)	Planned start month	Duration (months)
1	ICCS	9	36
2	Maxeler Technologies Limited	9	36
3	ICCS	9	18
4	SpaceDyS	27	18
5	GENERAL ELECTRIC DEUTSCHLAND HOLDING GMBH	7	36
6	UNIPI	7	36
7	UNIPI	7	14
8	Maxeler Technologies Limited	14	22
Total			216

Participant Number	Organisation Short Name	Country	IOEI	No of researchers	Number of person.months	Researcher Unit Cost			Institutional Unit Cost		TOTAL
						Living allowance	Mobility Allowance	Family Allowance	Research, training and networking costs	Management and overheads	
1	UNIPI	IT	no	2	50	165918,50	30000,00	12500,00	90000,00	60000,00	358418,50

Proposal ID **721462** *Acronym* **PUMA**

Participant Number	Organisation Short Name	Country	IOEI	No of researchers	Number of person.months	Researcher Unit Cost			Institutional Unit Cost		TOTAL
						Living allowance	Mobility Allowance	Family Allowance	Research, training and networking costs	Management and overheads	
2	GENERAL ELECTRIC DEU	DE	no	1	36	110616,48	21600,00	9000,00	64800,00	43200,00	249216,48
3	SpaceDyS	IT	no	1	18	59730,66	10800,00	4500,00	32400,00	21600,00	129030,66
4	ICCS	EL	no	2	54	155680,38	32400,00	13500,00	97200,00	64800,00	363580,38
5	Maxeler Technologies Limit	UK	no	2	58	216997,14	34800,00	14500,00	104400,00	69600,00	440297,14
Total				8	216	708943,16	129600,00	54000,00	388800,00	259200,00	1540543,16

4 - Ethics issues table

1. HUMAN EMBRYOS/FOETUSES		Page
Does your research involve Human Embryonic Stem Cells (hESCs)?	◯ Yes ◉ No	
Does your research involve the use of human embryos?	◯ Yes ◉ No	
Does your research involve the use of human foetal tissues / cells?	◯ Yes ◉ No	
2. HUMANS		**Page**
Does your research involve human participants?	◉ Yes ◯ No	23
Are they volunteers for social or human sciences research?	◯ Yes ◉ No	
Are they persons unable to give informed consent?	◯ Yes ◉ No	
Are they vulnerable individuals or groups?	◯ Yes ◉ No	
Are they children/minors?	◯ Yes ◉ No	
Are they patients?	◯ Yes ◉ No	
Are they healthy volunteers for medical studies?	◉ Yes ◯ No	23
Does your research involve physical interventions on the study participants?	◯ Yes ◉ No	
3. HUMAN CELLS / TISSUES		**Page**
Does your research involve human cells or tissues (other than from Human Embryos/ Foetuses, i.e. section 1)?	◯ Yes ◉ No	
4. PERSONAL DATA		**Page**
Does your research involve personal data collection and/or processing?	◯ Yes ◉ No	
Does your research involve further processing of previously collected personal data (secondary use)?	◯ Yes ◉ No	
5. ANIMALS		**Page**
Does your research involve animals?	◯ Yes ◉ No	
6. THIRD COUNTRIES		**Page**
In case non-EU countries are involved, do the research related activities undertaken in these countries raise potential ethics issues?	◯ Yes ◉ No	

Do you plan to use local resources (e.g. animal and/or human tissue samples, genetic material, live animals, human remains, materials of historical value, endangered fauna or flora samples, etc.)?	◯ Yes ◉ No	
Do you plan to import any material - including personal data - from non-EU countries into the EU? *For data imports, please fill in also section 4.* *For imports concerning human cells or tissues, fill in also section 3.*	◯ Yes ◉ No	
Do you plan to export any material - including personal data - from the EU to non-EU countries? *For data exports, please fill in also section 4.* *For exports concerning human cells or tissues, fill in also section 3.*	◯ Yes ◉ No	
If your research involves low and/or lower middle income countries, are benefits-sharing actions planned?	◯ Yes ◉ No	
Could the situation in the country put the individuals taking part in the research at risk?	◯ Yes ◉ No	
7. ENVIRONMENT & HEALTH and SAFETY		Page
Does your research involve the use of elements that may cause harm to the environment, to animals or plants? *For research involving animal experiments, please fill in also section 5.*	◯ Yes ◉ No	
Does your research deal with endangered fauna and/or flora and/or protected areas?	◯ Yes ◉ No	
Does your research involve the use of elements that may cause harm to humans, including research staff? *For research involving human participants, please fill in also section 2.*	◯ Yes ◉ No	
8. DUAL USE		Page
Does your research have the potential for military applications?	◯ Yes ◉ No	
9. MISUSE		Page
Does your research have the potential for malevolent/criminal/terrorist abuse?	◯ Yes ◉ No	
10. OTHER ETHICS ISSUES		Page
Are there any other ethics issues that should be taken into consideration? Please specify	◯ Yes ◉ No	

I confirm that I have taken into account all ethics issues described above and that, if any ethics issues apply, I will complete the ethics self-assessment and attach the required documents. ☒

How to Complete your Ethics Self-Assessment

5 - Call Specific Questions

Open Research Data Pilot in Horizon 2020

If selected, all applicants have the possibility to participate in the Pilot on Open Research Data in Horizon 2020[1], which aims to improve and maximise access to and re-use of research data generated by actions. Participating in the Pilot does not necessarily mean opening up all research data. Actions participating in the Pilot will be invited to formulate a Data Management Plan in which they will determine and explain which of the research data they generate will be made open.

We wish to participate in the Pilot on Open Research Data in Horizon 2020 on a voluntary basis	(•) Yes	( ) No

Participation in this Pilot does not constitute part of the evaluation process. Proposals will not be evaluated favourably because they are part of the Pilot and will not be penalised for not participating.

[1] According to article 43.2 of Regulation (EU) No 1290/2013 of the European Parliament and of the Council, of 11 December 2013, laying down the rules for participation and dissemination in "Horizon 2020 - the Framework Programme for Research and Innovation (2014-2020)" and repealing Regulation (EC) No 1906/2006.

Data management activities

The use of a Data Management Plan (DMP) is required for projects participating in the Open Research Data Pilot in Horizon 2020, in the form of a deliverable in the first 6 months of the project.

All other projects may deliver a DMP on a voluntary basis, if relevant for their research.

Are data management activities relevant for your proposed project?	(•) Yes	( ) No

A Data Management Plan will be delivered (Please note: Projects participating in the Open Research Data Pilot **must** include a Data Management Plan as a deliverable in the first 6 months of the project).	☒
Data Management is part of a Work Package.	☒
Data Management will be integrated in another way.	☐

START PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Innovative Training Networks (ITN)
Call: H2020-MSCA-ITN-2016

PART B

"PUMA"

This proposal is to be evaluated as:

EID

LIST OF PARTICIPANTS (*max. 2 pages*)

Consortium Member	Legal Entity Short Name	Academic (tick)	Non-academic (tick)	Awards Doctoral Degrees (tick)	Country	Dept./ Division / Laboratory	Scientist-in-Charge	Role of Partner Organisation[1]
Beneficiaries								
University of Pisa	UNIPI	√		√	Italy	Physics	Mauro Dell'Orso	
GE Global Research Europe[2]	GEGR-E		√		Germany	Diagnostics, Imaging and Biomedical Technologies Europe	Dirk Bequé	
SpaceDyS	SDS		√		Italy	N/A	Francesca Guerra	
Institute of Communications and Computer Systems	ICCS	√		√	Greece	Microlab, ECE, ICCS	Dimitrios Soudris	
Maxeler Technologies Limited	MAX		√		UK	Dataflow Software Engineering	Georgi Gaydadjiev	
Partner Organisations								
IMAGO7	IMAGO7		√		Italy	Medical Physics and Magnetic Resonance Laboratory	M. Tosetti	MRF research training Host secondments
Kayser Italia Srl	KI		√		Italy	Electronics hardware department	A.Bardi	Hardware development and test trainings - Host secondments

Data for non-academic beneficiaries:

Name	Location of research premises (city / country)	Type of R&D activities	No. of full-time employees	No. of employees in R&D	Web site	Annual turnover (in Euro)	Enterprise status (Yes/No)	SME status (Yes/No)
SpaceDyS	Cascina / Italy	SW development for space applications	11	8	www.spacedys.com	674000	Yes	Yes
GE – Deutschland Holding GmbH	Garching b. München, Germany	Diagnostics, Imaging and Biomedical Technologies; Aero-Thermal and Mechanical Systems; Composite Manufacturing; Electrical Systems	194	167	www.geglobalresearch.com/locations/munich-germany	43 Million Euro (2014)	No	No
Maxeler	London, United Kingdom	Hardware and software platforms for High Performance Computing applications using	60	50	www.maxeler.com	N/A, (privately- owned company)	YES	YES

[1] For example, delivering specialised training courses, hosting secondments, etc.
[2] Zweigniederlassing der GE Deutschland Holding GmbH

		reconfigurable dataflow supercomputing technology							

- The information in the above table **must be based on current data, not projections**
- The capacity of institutions participating in successful proposals will be subject to verification during the grant preparation phase
-

Declarations

Name (institution / individual)	**Nature of inter-relationship**
SpaceDyS	Spinoff of the University of Pisa
IMAGO7	UniPi is a founding member of IMAGO7

- Please use the table above to **declare any inter-relationship between different participating institutions or individuals** (e.g. family ties, shared premises or facilities, joint ownership, financial interest, overlapping staff or directors, etc.)

1. Excellence

1.1 *Quality, innovative aspects and credibility of the research programme*

- Introduction, objectives and overview of the research programme.

In many different problems involving pattern recognition, the quality of the results is strongly correlated to the efficiency and power of the used computing devices. This project aims at setting new standards for speed of computation for pattern recognition, enabling technological advancements useful to research and society. We aim to test novel extremely compact, fast, efficient, low consumption computing technologies. These technologies are based on hardware-dedicated processing units whose development is already in an advanced status:

1) **MAX Dataflow Engine**. This platform is an array of field programmable gate arrays (FPGAs) with multiple digital signal processors (DSPs) and high bandawith interconnections that can perform scalar products with a high degree of parallelism.

2) **Baseline Processing Unit (PU).** This technology is based on the combination of FPGAs and a full custom associative memory (AM) chip. The PU has been developed for high energy physics (HEP), but delivers flexible features for potential application in a wide range of fields. In the AM chip, pattern matching (PM) is executed with the maximum parallelism, and the results are then refined using FPGAs.

There are a large number of potential applications for the technologies in study, from triggering at hadron colliders, astrophysical and meteorological calculations, to robotic automation, and security applications. The same approaches could be relevant for simulating human brain functions in experimental psychology (cognitive image processing), accelerating and automating data processing for medical diagnosis, as well as for machine learning applications.

Different problems would however require a different degree of adaptation of current technologies and algorithms. In this project, we have selected three applications with a high computational demand. We aim to test our devices in these fields and probe opportunities for commercialisation. The applications here are three cases of "Big data processing" where real time, high quality processing would have a huge impact. They will be the benchmark to test and compare different architectures for the successful implementation and commercialisation of the next generation of devices. The three targeted scientific applications are the following:

(1) High Energy Physics: The main background leading to the development of the baseline PU has been real time track reconstruction at hadron collider experiments, a crucial task for the success of such experiments. There, the most interesting processes are very rare and hidden in an extremely large level of background information. Selecting interesting events form the background in real time is therefore essential to fully exploit the physics potential of experiments where only a very limited fraction of the produced data can be recorded. Only ~1 over 10^7 produced images, called "events", can be written to tape to perform physics analysis. Therefore, the trigger[3] must be extremely accurate and fast in order to store and post-process potentially interesting events. Tracking devices, and in particular silicon detectors that are becoming the predominant tracking technology, play an essential role in the identification of interesting events. In fact, they provide very detailed information for charged particles and they can separate most of the different particle trajectories in the overlapping collisions recorded in the same event. However, these detectors contain hundreds of millions of channels, so they make the problem of complete tracking a formidable challenge even for large computing farms. Figure 1 gives an adequate idea of the task complexity. The events contain many soft, not interesting collisions (called pile-up) superimposed to the interesting one, the hard scattering. This level of confusion is due to the collider extremely high luminosity necessary to produce rare particles, as the Higgs[4] boson recently discovered at CERN, at an appreciable rate. These conditions are going to worsen in the future experiments. The very high luminosity of

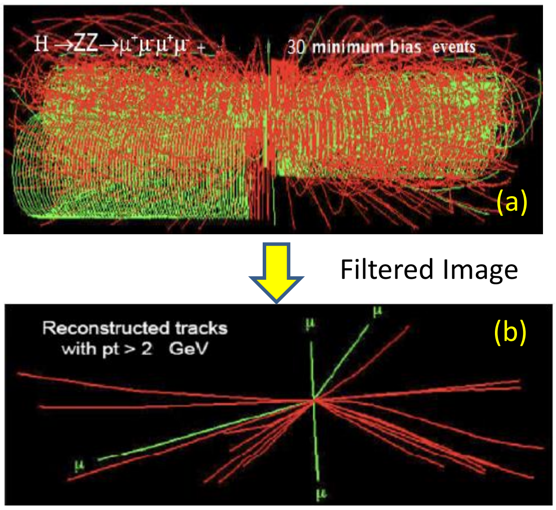

Figure 1 (a) 30 pile-up collisions superimposed to the hard scattering that has produced a Higgs decaying into 4 muons. (b)Only energetic tracks filtered out: the four muons (green lines) are clearly visible.

[3] W. Smith, "Triggering at LHC Experiments", Nucl. Instr. and Meth. A, vol. 478, pp. 62–67, 2002.

[4] ATLAS Collaboration, Phys. Lett. B716, 1 (2012); CMS Collaboration, Phys. Lett. B716, 30 (2012).

the Large Hadron Collider (LHC) at CERN will produce ~80 pile-up events before 2020 and this number will grow up to hundreds of collisions for the following machine upgrade.

On the other hand, the state-of-the-art electronics are advanced enough to overcome the problem. We provided real-time tracking using a massively-parallel high-performance system. Our solution provides the required performance for a relatively low cost, lower energy consumption, and saving space (by using a more compact system). We implemented an innovative strategy, based on the optimal mapping of a complex algorithm on different technologies. Our target is to get the best results by combining the high performance of rigid dedicated hardware with the distinctive flexibility of general-purpose, but lower-performance, CPUs. The architecture's key role is played by new generation FPGA, while the majority of computing power is provided by cooperating full-custom ASICs named Associative Memories[5] (AM). The AM chip is suitable for massive parallelism in data correlation searches and it is the most ingenious piece of the entire system. It is able to execute 50×10^6 M comparison instructions per second. The memory access bandwidth and number of comparisons per second has, to the best of our knowledge, no equal in commercial resources. It takes full advantage of the intrinsic parallel nature of the combinatorial problem by comparing at once the image under analysis to a set of pre-calculated "expectations", or patterns. This approach reduces to linear the exponential complexity of CPU-based algorithms and the problem is solved by the time data are loaded into the chip.

Figure 1 shows the filtering action performed by the AM on a very simple Higgs event made by only four muons, but hidden by 30 superimposed, not interesting interactions. By filtering only energetic particles the Higgs event is clearly observable in figure 1b, where the four green muons are clearly visible. This task has to be performed inside a fixed latency of few tens of microseconds.

The use of such parallelized architectures for real time event selection opens a new huge computing problem in these experiments, related to the analysis of the acquired samples. For each kind of trigger selection implemented in the experiment, millions of events have to be simulated to determine with a small statistical error the efficiency and the bias of that trigger selection on the particular collected physics sample. The AM, like any other device performing online algorithms, has to be simulated in detail to study its effects on the efficiency and background of the acquired samples. In addition real time tracking is very important at trigger level, so it will be involved in almost all sample selections, for more than 20 years, a “Big Data” problem that requires an extremely efficient solution. The AM chip emulation is a complicate task. Functional reproduction of such parallelized hardware on conventional CPUs, where the same parallelism cannot be implemented, is an extremely slow task. The AM chip simulation is resource-demanding: requires extremely large memory and CPU for the execution of entire events. The emulation of a single event requires almost 6 minutes (10 μs on the real time hardware) at the highest pileup level foreseen for LHC before 2020. The 6 minutes of AM simulation of a single event has to be compared to the hundreds of events that are written on tape each second. Simulated samples should have not smaller statistics than acquired samples. It is evident that the attempt to mimic the AM workflow, extremely natural and fast in this special chip, is very inadequate, slow and convoluted in software. While the trigger problem is strongly mitigated by the AM, the offline computing task becomes extremely complex. PUMA proposes to use a hardware co-processor made with the actual AM chips in place of their simulation. In this way simulating the behaviour of the AM chip is rendered useless, since the chip itself is used to provide the results**.** This is a typical Hardware-in-the-Loop (HiL) implementation, which is a state-of-the-art technique used in the development and test of complex embedded systems[6]

(2) Space Debris: The second area of PUMA interest is the detection of space debris trails in astronomical images. It is a key element for the Space Situational Awareness programmes (such as the ongoing project at the European Space Agency) aiming to build up a catalogue of debris that could be potentially hazardous to space assets. The main problem is to process the images, i.e. to detect all possible space debris trails, in a very short time, down to few seconds. This is necessary, because images are taken in intervals of 3-4 seconds and they need to be processed immediately in order to provide the list of tracklets (set of measurements of a space debris trail) to the correlation data centre as soon as possible. Timing is crucial for the purpose of building up a catalogue of orbits, in particular of Low Earth Orbits space debris (LEOs, because in one single day a LEO space debris may orbit several times (15 or more) around the Earth. The correlation of tracklets obtained from several orbits later is a difficult task

[5] M. Dell'Orso and L. Ristori, NIM A, vol. 278, pp. 436-440, 1989; A. Annovi, et al., IEEE TNS, vol. 53, no. 4, pp. 2428-2433, August 2006

[6] D. Diamantopoulos, E. Sotiriou-Xanthopoulos, K. Siozios, G. Economakos and D. Soudris, “Plug&Chip: A Framework for Supporting Rapid Prototyping of 3-D Hybrid Virtual SoCs”, ACM Transactions on Embedded Computing Systems, Vol. 13, No. 5s, Article 168, pp. 1-25, Nov. 2015.

and the classical correlation approach is usually failing. The investment in R&D both in hardware and in software is important to reach a technological leadership in this sector that is a key factor for any Space Situational Awareness programme. One of the key assets that is going to be developed in Europe is the so-called Fly-Eye telescope, a new optical design telescope with a Field of View of 45 sq. degrees that will be able to cover a huge sky area in one single night. The enormous quantity of data that this telescope will produce needs also a very efficient image processing pipeline. The capability to detect very small space debris with an innovative telescope sensor, such as the Fly-Eye telescope, and to process the data in a very short time, will allow reducing dramatically the costs of development and operations, at the same time enormously increasing the system performance. As an example, with the present available technology, to detect and dynamically characterize a 5 cm space debris orbiting at about 1400 km of altitude, one needs either an enormous and potentially dangerous radar sensor, whose cost is more than a billion euros, or an incredibly big number of classical telescopes, with a very high degree of system complexity. The research and development expected for this study is a key element of the SSA system architecture and is innovative and valuable in terms of technological transfer.

(3) Magnetic Resonance Fingerprinting: The third area is a new medical diagnostic technique based on magnetic resonance imaging (MRI), called MR fingerprinting[7] (MRF). Magnetic resonance fingerprinting is a novel, quantitative medical imaging technique. This technique has the potential to replace multiple different qualitative MRI exams with a single, reproducible measurement for increased sensitivity, specificity and efficiency. Historically, quantitative MRI scans have been infeasible due to the lengthy scan times to obtain parameters sequentially. Recently, MR fingerprinting has been proposed which has the potential to address this problem by a novel data acquisition and reconstruction strategy. In MRF, a fast acquisition is followed by a pattern recognition task, where signal responses are matched to entries from a dictionary of simulated, physically-feasible responses, yielding multiple tissue parameters simultaneously. However, to date, only two dimensional datasets using a single tissue excitation and signal acquisition method (steady state free precession) have been explored, and measured parameters have been limited to longitudinal (T1) and transverse (T2) relaxation times.

The inclusion of further parameters into MRF may permit to tackle different aspects of disease without increasing scan time. First, metrics based on diffusion of water are invaluable markers in stroke, cancer, neurodegeneration and a host of other pathologies. Secondly, new high field scanners have unmasked the effects of magnetic susceptibility changes relevant in neurological diseases such as Parkinson's and Alzheimer's disease and amyotrophic lateral sclerosis (ALS). Features that are highlighted by this mechanism include pathological metallic ion deposits and vascular changes, particularly venous differences, which may be an early warning of pathology at disease onset. In addition, chemical shift imaging can be used to discriminate different contributions to the MR signal, enhancing changes generated by disease and reducing typical image artifacts confounding the exams (such as fat-water chemical shift artifacts). All of these advances can theoretically be included in MRF and this method can be extended to three-dimensional acquisitions. However, it is recognised that one of the main current limitations of the technique is represented by the pattern matching processing time, which scales exponentially with the number of variables in the dictionary[8].

Application of MRF reconstruction to a typical 3D dataset with 4-5 finely sampled relevant parameters would take a time of the order of days per reconstruction of each performed scan on a high-end workstation[9]. In the clinic, it is often important to perform a visual inspection of the results of imaging within a reasonable time from their acquisition. Short reconstruction times are therefore an important requirement to translate new MRI protocols from the research to the clinical environment. It is possible to address this problem by using clusters of CPUs, and this is being investigated at present. However, a low-consumption and cheaper device to substitute or complement the use of clusters might be more suited to the current deployment model of MRI scanners in clinical environments. In this project we investigate the use of hardware accelerators, focussing on the identification of the best technology for a potential distribution of MRF as a commercial product for clinical use. As MRF needs pattern matching for each pixel in the image or volume, requiring massive parallelism, its algorithm is remarkably similar to the tracking executed in HEP. Therefore, the existing hardware accelerators in study here may in their current form act as an enabling technology for the successful implementation of fast, quantitative multi-parametric MRI and thereby considerably increase the diagnostic capability of MR imaging.

PUMA objectives are: (1) the integration of its baseline hardware processor with the most powerful commercial computing devices to optimize speed, resources, cost and power; (2) the investigation of new modern architectures

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[7] D.Ma et al Nature 495,187–192 (2013) doi:10.1038/nature11971
[8] Cauley SF et al MRM 2015 doi: 10.1002/mrm.25439;
[9] Buonincontri G et al MRM 2015 doi: 10.1002/mrm.26009;

and frameworks to be compared with the baseline; (3) the implementation of the specific algorithms of the three scientific areas in the available architectures; (4) the measurements of the technology performances for each of the three research areas, including the evaluation of the relative costs; (5) the development educational material (lectures and labs) to teach PhD students and young engineers about state-of-the-art hardware/software co-simulation and co-design methodologies.
This is a multidisciplinary plan where academic institutes and companies with interests in these three different scientific areas and technology will join their efforts to find a common efficient platform that will allow them to advance strongly in their field, with a large impact on the society. Training young researchers in the development of intelligent algorithms efficiently implemented in the best available technologies is a strategic investment. It will disseminate important expertise in the next generation of researchers.
Finally, PUMA aims to rich a good gender balance in the network. The consortium is committed to make every effort to attract female students by exploiting networks and contacts.

PUMA baseline: from HEP hardware to a system for every day applications - The PUMA algorithms have been used in the past, but only in hadron collider experiment triggers. They have been adopted for the first time at the CDF[10] experiment at Fermilab (USA) and recently proposed at LHC for both the ATLAS (Fast Tracker[11], FTK, project) and CMS experiment. FTK is the main component of the research program of the FP7-PEOPLE-2012-IAPP FTK[12] project. Data processing speed is achieved with pipelining, and parallel processing. Track reconstruction is executed into a 2-level pipelined architecture. The AM implements the first stage by recognizing track candidates (roads) at low resolution. The second stage, the Track Fitter (TF), is implemented into FPGAs. The TF receives track candidates and high resolution hits to refine pattern recognition at the associative memory output rate. "Hit" refers to a particle's energy deposition cluster centroid. Track fitting is done rapidly by replacing a helical fit with a simplified calculation that is linear in the local hit position in each silicon layer. The calculation is a set of scalar products of the hit coordinates and pre-calculated constants that take into account the detector geometry and alignment. Tracks passing a relatively loose $\chi^2/ndof < 6$ cut are kept. While FTK is under construction, CMS is developing its R&D for online tracking. The CMS R&D exploits a similar approach for real time track reconstruction at much higher rates in the CMS upgraded experiment that should take data after 2020. A second EU funded project, FP7-PEOPLE-2012-ITN INFIERI[13] includes part of the CMS R&D activities.
Both projects are built of many equal engines working in parallel: FTK has a computing core made of 128 Processing Units (PU) which are large 9U VME boards, while the CMS R&D foresees a system of 48 ATCA crates filled by 11 boards, each one assembled with 4 PUs, for a total of 2112 PUs. In both cases one FPGA executes full resolution track fitting inside roads found by a set of 16 AMchips. PUMA exploits the experience of the FTK and INFIERI projects, adopting this architecture for its baseline hardware, but with the main goal of a transformation in new modern standards. PUMA aims to make the system suitable for an open range of applications in which massive and parallel data processing makes the difference. It plans to increase the FPGA parallelism by associating more FPGAs to the AM chips and integrating them with multicore CPUs or GPUs. The preferred configuration is one FPGA for each AM. The FPGA configures and handles the AM and provides a flexible computing power to process the its selected shapes. PUMA has a strong relation also with the IMPART[14] project whose goal is the miniaturization of the PU putting the two chips in a single package (AMSIP). While PUMA will develop the FPGA logic and the software to demonstrate the PU impact on its three applications, IMPART will develop the technology of the AMSIP. A further exploitation could be a SOC where the AM regular architecture would be directly connected on silicon to the FPGA, but such advancement can be only justified by a large range of applications with a wide social impact. PUMA results will provide at least part of the justification.

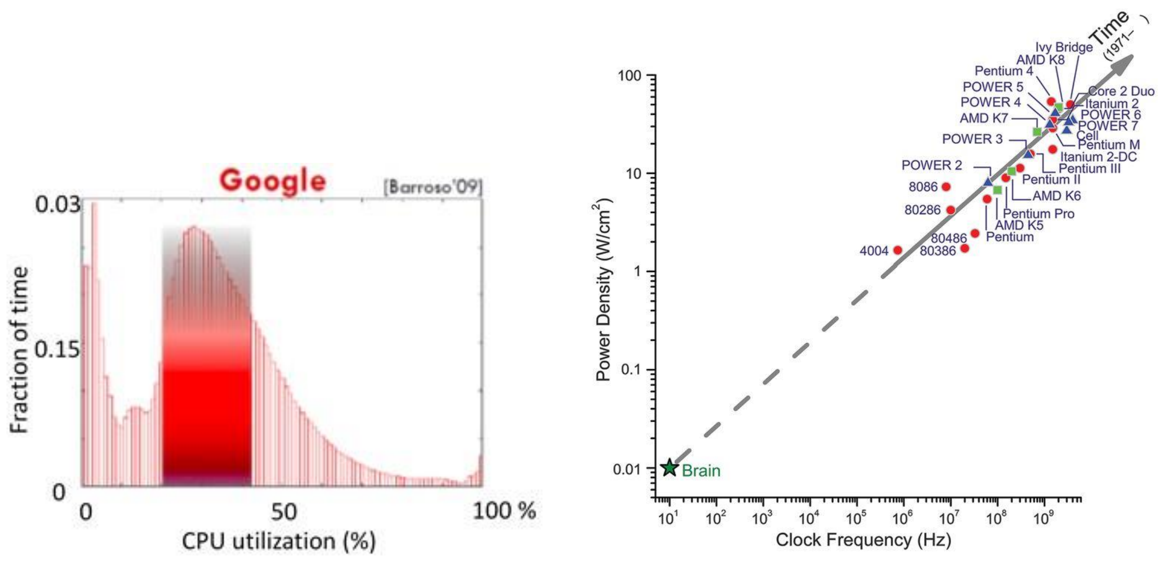
PUMA new platforms – The PUMA network has acquired very critical new partners, with respect the FTK FP7 IAPP project, namely the Microprocessors and Digital Systems Laboratory (MicroLab) of ICCS and the Maxeler Technologies company (MAX). In particular, Maxeler hardware platforms incorporate traditional CPU based sub-systems with high performance Dataflow Engines (DFEs), which include high-end FPGA chips. ICCS/MicroLab has a long track record in developing design- and run-time techniques for the optimization of embedded systems based

[10] W. Ashmanskas et al., "The CDF online Silicon Vertex Tracker", Nucl. Instr. and Meth. A, vol. 485, pp. 178-182, 2002.
[11] ATLAS Collaboration., "The Fast Tracker (FTK) Technical Design Report" CERN-LHCC-2013-007 ; ATLAS-TDR-021; available online: https://cds.cern.ch/record/1552953
[12] http://cordis.europa.eu/project/rcn/106069_en.html
[13] http://infieri-network.eu/
[14] IMPART: project for young researcher funded by INFN, sector applied research; PI: Alberto Stabile.

on digital systems design of multicore/many-core and reconfigurable systems (FPGAs) with implementation in Biomedical/Bioinformatics field and Space domain. The new technologies will open new opportunities regarding with the implementations of PUMA applications. Commercially novel FPGA based platforms (e.g., Zynq, Intel+Altera) will affect the conventional programming models as well as the acceleration of PUMA applications. The comparison of different implementations will judge if the AM ASIC has really a fundamental role also outside high energy physics domain.

- Originality and innovative aspects of the research programme

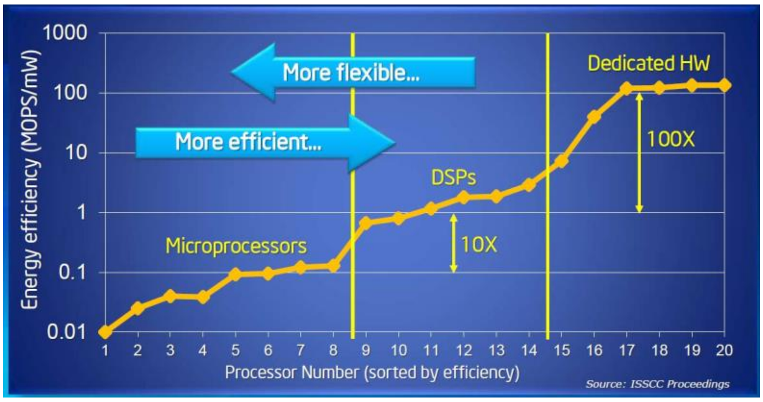
Originality and innovative aspects -The idea of using dedicated mixed-technology Supercomputers is innovative in a world where dedicated hardware is relatively underused. Usually commercial CPUs are preferred since handling complex electronics components requires availability of FPGA hardware and knowledge of computer-aided-design (CAD) tools, skills that are not widely disseminated. Our developments in this area can conversely show the big potential of these dedicated but flexible devices and spread the skills needed to use them in the numerous fields where top performance, extreme low latency and efficiency are crucial. Specifically, in various domains the proposed technologies enable computations otherwise infeasible with traditional approaches within the application constraints (e.g. extreme low-latency pattern matching). Furthermore, our cross-application-domain approach can substantially reduce the entry barrier to the exploitation of this technology as the basic computations, which require specific skills to be tuned, will be made available to the application-level programmers through a simple and general interface. There are examples showing that the use of a tuned combination of CPUs and FPGAs can expand not only in physics experiments, but also in other academic and even non-academic fields, for example in financial applications. The “Workshop on High Performance Computational Finance” is an instance of the many occasions for discussing techniques for using FPGA hardware accelerators in the financial domain.
The MAX platforms and their results show the importance of these efforts to accelerate computing with hardware devices. PUMA will export the HEP experience to show the impact of this strategy in the area of telescope image processing and MRF medical imaging. PUMA provides new “Big Data cases”, new applications, this is the best way to disseminate and reinforce MAX-like technologies.
State of the art – The amount of produced data has increased dramatically over the last years, outperforming even Moore’s law. The gap between the data growth compared to transistor scaling has started becoming obvious over the last 5 years. Cloud Computing promises flexibility, high capabilities, cost effectiveness, however we experience low resource utilization <20%, (**Error! Reference source not found.**a). In addition, further scaling of transistor leads to steadily increasing power consumption (Dennard scaling law), high power density and high clock frequencies, heading away from the operating points of a biological brain (**Error! Reference source not found.**b).



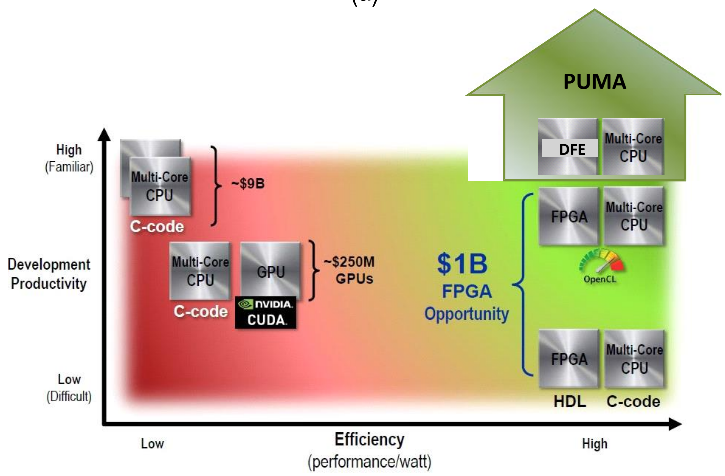
(a) (b)

Figure 2 a) CPU utilization in the Google cloud (from Barroso 2009), b) Power density as a function of clock frequency for von-Neumann computational architecture compared to brain capability (from Merolla et al. Science 2014).

Comparisons between different hardware solutions show that dedicated hardware has extremely high efficiency (Figure 3a), at the expense of increased programmability cost. However, this complexity could be reduced if the expertise to handle the dedicated hardware would be largely disseminated. According to several studies, hardware accelerators can achieve up to 25x better performance per watt and 50-75x latency improvements compared to CPU/GPU implementations[15]. Compared to CPU and GPUs, FPGAs can provide much higher energy efficiency in several applications like sliding-windows applications and in some cases orders of magnitude better than CPUs and GPUs[16]. The fine-grain programmable logic elements of FPGAs can provide high flexibility (Figure 3b) but they occupy a large amount of area for the switching elements that connect the configurable blocks. The utilization of more efficient programmable elements targeting specifically dataflow-based application can further reduce the power consumption by 4x-8x compared to FPGAs.



(a)



(b)

Figure 3. (a) Flexibility vs. Efficiency. PUMA will increase the flexibility of dataflow engines in heterogeneous systems while offering the same efficiency of dedicated HW (b) Productivity versus Efficiency for different versions of computing systems [Source Altera]: PUMA will further increase the productivity and the efficiency of the accelerator-based platforms.

New computing approaches - New brain-like architectures and cognitive computing systems are proposed to face Big data generated in mobile devices, instruments and embedded sensors that need to be processed with low power and low latency. This is an ongoing revolution and our project is in line with these revolutionary ideas. Our baseline processing unit emulates the brain for image processing (contour identification process). This technology developed for the trigger of experiments at hadron colliders is an example of solution for a specific case of the “Big Data” problem. This solution is based on the organization of the trigger in different levels of selections, exploiting at low level parallelized, dedicated hardware for an extremely efficient pre-processing step. This organization is similar to models[17] of the vision processing task performed by the brain. The most convincing models that try to validate brain functioning hypotheses are extremely similar to the real-time architectures developed for HEP. A

[15] “The Xilinx SDAccel Development Environment: Bringing the best performance/watt to the Data Center”, Xilinx 2014

[16] . Fowers et al., A Performance and Energy Comparison of FPGAs, GPUs, and Multicores for Sliding-Window Applications”, FPGA 2012

[17] M. Del Viva, G. Punzi, and D. Benedetti. Information and perception of meaningful patterns. PloS one 8.7 (2013): e69154

multilevel model seems appropriate to describe the brain organization for image processing: “the brain works by dramatically reducing input information by selecting for higher-level processing and long-term storage only those input data that match a particular set of memorized patterns. The double constraint of finite computing power and finite output bandwidth determines to a large extent what type of information is found to be meaningful or relevant and becomes part of higher level processing and longer-term memory”. The AM pattern matching has demonstrated to play a key role in high rate filtering/reduction tasks. We implemented the algorithm inside FPGAs and replicated the results of static 2-D images with short latencies[18]. We are implementing the algorithm on our technology to extend its application to 3-D images and movies.

New applications – Two new applications outside HEP provide an innovative benchmark of the proposed architectures. For the first time hardware accelerating techniques will be used in these fields.

The emulation of the brain for image processing will be used for the first time in the telescope images processing for space debris detection, producing a relevant transfer of knowledge.

The second innovative application will be MRF. MRF is a natural candidate for highly-parallel computing hardware and is a reconstruction problem extremely similar to the HEP tracking problem. Clusters of CPUs and GPUs are already widely used in medical imaging, exploiting the obvious advantage of performing operations simultaneously on each pixel of an image. However, the effective use of FPGAs and custom chips, while having been recognised as highly promising, has not yet been widely explored for these applications. Here, we will contribute to train the next generation of researchers who will be able to further advance medical imaging taking advantage of the acceleration provided by new tools for parallel computation.

Research methodology and approach PUMA research program is organized into seven work packages (see Figure). WP1, Specifications for Applications and HW requirements, will propose a common strategy between the different applications, different platforms and different partners, to create a "community", more than being just a consortium. WP2, WP3, WP4 will be devoted to the three research areas and WP5 will complete the ESR education with a valid network-wide training program. To ensure the wide applicability and usage of derived results as well as the robust running of this ambitious initiative, two WPs will be devoted on the dissemination (WP6) and project management (WP7) activities.

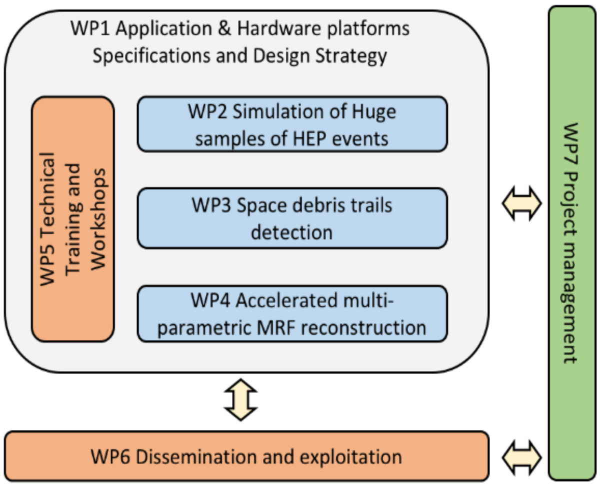


Figure 4 Proposed interaction between work packages

WP-1 Application & Hardware platforms Specifications and Design Strategy. The main target of WP1 is twofold. Firstly, the definition of the definition of the specifications of the three key applications and the requirements/features of hardware architectures, where these applications will be mapped/realized. Secondly, the systematic design strategy for implementing the complex applications as well as the associated CAD tools, used throughout the project will be developed. The outcome of WP1 will drive the research and technical activities to be done in WP2, WP3 and WP4.

WP-2 Simulation of Huge samples of HEP events. The experiments that will use the AM system to select their physics samples at trigger level have a huge offline computing problem to produce the millions of Monte Carlo events needed to study in detail the trigger efficiency. Both the VME solution used by FTK and the ATCA one from INFIERI are very powerful and offer a lot of computational power but they are large (not portable) and require a specific interface (VME or ATCA standards). It is not easy to use for every day applications in a computer center. For these reasons the FTK community is studying more modern, compact solutions for its offline applications. The new PUMA baseline embedded system needs the following characteristics: 1) powerful FPGAs (Field Programmable Gate Arrays) with large on-board memory, 2) Ethernet & PCI Express I/O, 3) handling (distribution and collection) of all AM chip serial links, 4) configuration and control of the AM pattern bank, 5) provision of extra functionality to complete the AM functions in real-time.

[18] http://ftk-iapp.physics.auth.gr/

While the AM chip needs challenging developments, one of the advantages of the FPGA task is that boards already available on the market are powerful enough to cover the above listed specifications. New generation commercial FPGAs are already available (e.g. Xilinx Ultrascale FPGAs) and will allow us to develop the high performance embedded system in times scales consistent with PHD theses. Figure 5 shows the new processing unit (PU) currently used for AM chip tests in FTK and INFIERI, based on a Xilinx Ultrascale evaluation board. Two mezzanines, one with single, the second with multiple AM chips, are connected to the large connectors on the top of the board. The mezzanine organization offers flexibility: it allows using the system in different configurations and with different AM chip versions. Now AM05[19] is available with all the functionalities implemented, but a small die and pattern bank (only 2000 patterns/chip). Next version produced by FTK, AM06, will contain 128 k patterns (available early 2016), while AM07, under design, should provide a further factor 4 on pattern density. When available, the AMSIP could be used on this PU. This system is scalable, since the needed number of PUs can work in parallel to reach the required size of the pattern bank and the required timing performance.

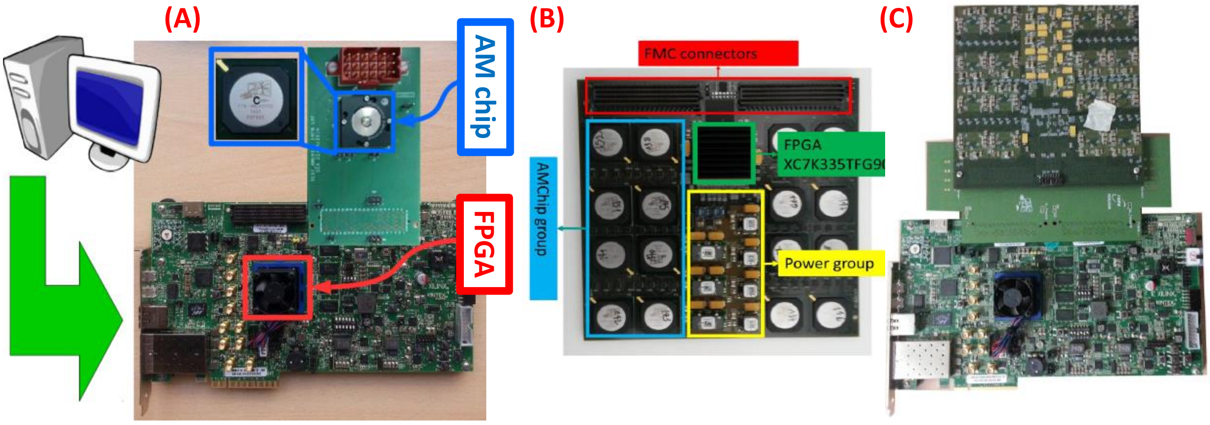


Figure 5: the EK-U1-KCU105-G Kintex Ultrascale Development board equipped with a single (A) and 16 AM chips (B and C).

The participation of the Maxeler company will open a new horizon for large scale tracking in hadron collider experiments. The array of high-end FPGA chips can easily implement the pattern matching and the track fitting as scalar products, a computing task that the FPGAs can easily parallelize on large scale, thanks to their powerful sets of Digital Signal Processors and large distributed memories embedded in the chips.

Two students will be recruited in this WP. The first one will implement the Monte Carlo event production simulating the pattern matching and track fitting on the baseline PU integrated with multicore CPUs or GPUS. The second one will do the same using Maxeler Technology solutions. Both students will have to face software and hardware issues to optimize the existing FTK simulation on the new platforms, produce events and measure the best timing performance of each system. Four institutions will be involved: (a) UNIPI, with its large experience in hadron collider triggers, FTK and R&D developments for LHC running after 2020, will provide the ATLAS (FTK) and CMS (INFIERI) simulations and all the needed high energy physics background to both students; (b) ICCS, with its consolidated experience in developing, design- run-time techniques for the optimization of embedded systems based on digital systems, design of multicore/many-core and reconfigurable systems (FPGAs), will supervise both students for integration and optimization of different technologies in a single efficient platform; (c) KI will offer its organization for hardware and firmware production and tests, hosting the student that will work on the baseline PU for his fraction of time at the industrial partner; (c) MAX will supervise the student working on its platform hosting him for his fraction of time at the industrial partner.

WP-3 Space debris trails detection – The goal is the reconstruction of curved trails, of space debris, in presence of typical background noise. This WP involves a single student, so a single platform will be used, the MAX array of FPGAs. SDS, ICCS and MAX will supervise the student. Algorithms will be executed in pipeline to filter out of the large image the signal, suppressing the background, and to identify the curvature (pattern matching algorithm will be compared with more standard algorithms): (a) we will use the algorithm that emulates the brain for image processing to suppress the background and extract the candidate trajectories. The results can be compared to well-known different algorithms, like Canny algorithm used for edge detection and Gaussian Smoothing for better background suppression; (b) the filtered image will be processed by a clustering algorithm that finds groups of

[19] AM05

contiguous pixels, as implemented in a simplified form[20] in FTK. This algorithm will select groups of pixels whose consistency with an arc will be checked by a following step.
Part of the mentioned algorithms have been already implemented into FPGAs. They will be completed, integrated and optimized in the new MAX platform, to reach the best efficiency and speed.
WP-4 Accelerated multi-parametric MR Fingerprinting (MRF) reconstruction - The goal of WP4 of this proposal is to speed up MRF reconstruction to clinically-acceptable times, even with more diagnostically relevant parameters than currently feasible. In order to complete the pattern matching in MRF, time evolutions for each pixel in the image are compared to all the entries in the dictionary. Currently, each comparison is performed using a scalar product of measured signals with dictionary elements, and the match is observed if the vectors are aligned (maximum value for the scalar product). The scalar products are executed sequentially inside CPUs.
In this work package, we will implement and compare MRF reconstruction performed by three different hardware accelerators to speed up this task. The first technology used here is represented by top-range commercial GPUs, while the second and third technologies are represented by the two novel accelerators (MAX platform and baseline PU). In our comparisons we will focus on accuracy and speed, but also on cost and scalability. While GPUs and the MAX platform will be used to perform the scalar products in parallel, the baseline PU uses a more sophisticated, scalable approach. Before the matching task, the dictionary is compressed (low resolution) and downloaded in the AM bank. Pattern matching is then executed in two steps. First, a low-resolution matching is executed with the maximum parallelism in the AM chips. There, each measured vector is presented to the bank, and all dictionary elements that match are presented to the AM output into few cycles. Then the second step is performed in the FPGA, where the PU is able to refine the match at the full resolution.
To achieve the goals of this research, the combined efforts of three ESRs are required. The three research projects are tightly connected and there are many opportunities for interaction. While two ESRs will work specifically on the development and implementation of algorithms optimised for each one of the two new accelerators, a third ESR will focus mainly on new data acquisition techniques using MRF. This ESR will develop an expertise in MR acquisition and will work to guarantee the quality of the measurements through optimization of the dictionary and data collection. In MRF, matching accuracy depends not only on the quality of the data, but also on the impact of particular aliasing and noise patterns. For this reason, each reconstruction method will have to be evaluated taking a realistic amount of aliasing and noise into account. In addition, it will be possible to use acquired data to develop data-driven dictionary compression strategies to be included in the reconstruction. It is therefore important that new acquisition designs take into account the specific algorithm used during reconstruction and vice-versa. This makes the creation of new MRF protocols an interactive task, which requires constant communication between the researchers working on the acquisition and the reconstruction part.
WP-5 Technical Training and Workshops – Courses and workshops, which cover both technical, administrative and management topics, will take place throughout the project aiming at: (i) improvement of technical awareness of participants, including the young scientists and (ii) growth of administrative and organizational skills.
WP-6 Dissemination and Exploitation – These activities represent the key factors to broaden internally and externally to the Consortium the use of the developed knowledge, techniques and tools, not only spreading scientific and technological achievements at the end of the PUMA project lifetime but also while it is in progress.
WP7- Project Management -The detailed description of the Project Management structure and related activities are in Section 3.2. UNIPI is the WP Leader. Each partner will contribute to a smooth management of the activities and review meetings. Internally to each WP, appropriate measures will be taken by the WP Leader to ensure the proper development of the research activities. Although all the partners in the project will actively participate in the management activities and are represented at the appropriate level, we've tried to allocate to them a minimum manpower effort. The Project Coordinator (PC) is the unique interface between the PUMA project and the European Commission. The PC will manage all the communications to/from the EU Commission, the periodic reporting and organization of the review meetings with the Project Officer. The PC will submit the four Project Periodic Reports to be sent to the EU Commission at the end of each year. The Project Periodic Reports will describe the progress of research, demonstration, dissemination and exploitation, management activities carried out during each reporting period, including the ones crossing the period and not associated to deliverables.

Table 1.1: Work Package (WP) List

[20] C.-L. Sotiropoulou, et al. "A Multi-Core FPGA-based 2D-Clustering Implementation for Real-Time Image Processing", in IEEE Trans. On Nuclear Science, vol. 61, no. 6, pp. 3599 - 3606, December 2014.

WP No	WP Title	Lead Beneficiary num.	Start Month	End month	Activity Type	Lead Beneficiary Short Name	ESR involvement[21]
1	**Application & Hardware platforms Specifications and Design Strategy**	4	1	18	Research	ICCS	1-6
2	**Simulation of Huge samples of HEP events**	1	1	48	Research	UNIPI	1, 2
3	**Space debris trails detection**	3	1	48	Research	SDS	3
4	**Accelerated multi-parametric MRF reconstruction**	2	1	48	Research	GEGR-E	4,5,6
5	**Technical Training and Workshops**	3	6	48	Dissemination	SDS	1-6
6	**Dissemination and Exploitation**	4	1	48	Dissemination	ICCS	1-6
7	**Project Management**	1	1	48	Management	UNIPI	n/a

1.2 *Quality and innovative aspects of the training programme*

The Training Network is primarily designed for young physicists and engineers who have completed a university Masters or Diploma level qualification. The training will certainly provide essential skills in the three distinct scientific areas (high energy physics, medical imaging, astrophysics) and the PUMA network and activities will ensure inter/multi-disciplinary interaction and synergy. The training will have a common focus on "learning the importance of computing technology" as an essential mean to advance science and technology, to surpass the computational limits that are a common challenge in the three research areas. High performance computing techniques required by these different Big Data problems will be the research training that will attract the students working in different areas, in a unique community. "Setting new standards for speed of computation" will be the common effort. The network is also rich of high-quality industries (more non-academic than academic institutions), so the inter-sectoral aspect of the training is guarantee. Gender aspects: each time a selection procedure for participation from outside the network to PUMA trainings or schools will be necessary for limited space or fund availability, the PUMA gender officer (see section 3.2) will participate to the selection to guarantee equal opportunities. Specific actions will promote the dissemination of the PUMA research arguments to categories of young students that are a minority in the PUMA fields. A particular goal will be the dissemination of electronics and computing science to young female students. When establishing mentoring relations, particular attention will be given on promoting gender balance, e.g. by enabling female students to develop leadership skills and provide them knowledge required to increase their participation in decision making processes.

Overview and content structure of the training (ETN) or doctoral programme (EID/EJD), including network-wide training events, complementarity with offered locally (tab 1.2a & 1..2b)

All the early stage researchers will be employed on doctoral programs in the universities of the Network, via the physics or engineering departments present in the nodes. The two academic nodes, UNIPI and ICCS, are extremely qualified and complementary: UNIPI is the leader since many years of the dedicated technology specifically developed for real time tracking at hadron colliders while ICCS has a leading experience in the HPC modern platforms currently available. Table 1.2.a list the ESRs in the network and their recruitment details.

Table 1.2 a Recruitment Deliverables per Beneficiary

Researcher No.	Recruiting Participant (short name)	Planned Start Month 0-45	Duration (months) 3-36
1. WP2	**ICCS (seconded to KI)**	**9**	**36**
2. WP2	**MAX (seconded to UNIPI)**	**9**	**36**
3. WP3	**ICCS**	**9**	**18**
3. WP3	**SDS**	**27**	**18**
4. WP4	**GEGR (seconded to UNIPI)**	**7**	**36**
5. WP4	**UNIPI (seconded to GEGR)**	**7**	**36**
6. WP4	**UNIPI**	**7**	**14**
6. WP4	**MAX**	**14**	**22**

[21] Indicate which ESR(s) will participate in the Work Package in question

Total			216

In order to ensure the students acquire the abilities of an independent scientist or engineer with international visibility and leadership potential, the training offered in the doctoral schools and relevant industries described in WP 2,3 and 4, will be complemented by the following activities (see Table 1.2b): (a) attend specialized events (workshops and schools) organized by members of the network. The high technology events will focus on the topics developed within the proposed project according to its technological objectives, including lectures to the fields of “space debris”, “MRF” and “LHC experiments”. They will be opened to other young researchers and engineers in the fields and will be an opportunity for them to get all together for a strong interaction between the three fields. (b) Present the results achieved by the Network at international conferences and workshops. (c) Hands-on training sessions on the most advanced technological and scientific aspects of the research field, in both sector nodes of the Network. (d) Complementary skills related to new aspects of researcher and engineer careers.

Role of non-academic sector in the training programme

MAX is the hardware and software resources provider for accelerating highly-data intensive and streaming applications. Also, cloud computing infrastructure for big data applications will be available. Its proprietary dataflow engine (DFE) is a proven shift paradigm in High Performance Computing (HPC) field and therefore, PUMA applications will benefit significantly by their implementation on MAX engines. Apart from the hardware infrastructure, the new programming model will affect significantly the implementation of future complex applications by training the new generation of scientists with new knowledge. Three computing problems get in contact with powerful existing solutions to search together an evolution. This is a fertile background for high level research and technological trainings.

GE Global Research is the central research organization of General Electric (GE). GE is a major manufacturer of healthcare products, as well as products serving many other needs of industry and society. GEGR-E will contribute to training the researchers in the latest MRI acquisition and reconstruction techniques in the context of existing technology and current commercial needs. This approach aims at a meaningful translation of the technology developed here to the field of clinically-feasible MR fingerprinting. In addition, GEGR-E will also provide transferable skills training relevant to industrial development projects.

IMAGO7 is a highly interdisciplinary environment, where scientists and clinicians work together to exploit the capabilities of a new 7T MR system. Here, during their secondments, ESRs will be exposed to a clinical research environment while developing new technologies.

SpaceDyS provides know-how in software development for applications in the space business. SpaceDyS has already experience in image processing of astronomical images, in particular for detecting space debris trails. SpaceDyS is the right environment where to apply the technological transfer, because the goal of the proposal research will have several industrial applications. SpaceDyS has in house senior scientists and developers that will tutor the researcher, also in collaboration with S. Bartolini from the “Department of Information Engineering and Mathematical Sciences” (DIISM) of the University of Siena (see section 5). SpaceDyS will lead the WP5 and will provide the necessary support (e.g., logistics, publicity …) for the organization of workshops and trainings

KI as aerospace company has extraordinary skills in electronics, aeronautics, mechanics, thermodynamics, physics, computer science, optics, molecular biology and a large experience producing custom hardware for space missions. In addition of this Bardi has a strong knowledge of the hadron collider trigger thematic and in particular of the associative memory system. For this reasons KI is the perfect environment to train the HEP ESR developing the new AM-based accelerator and to collaborate to the high technology events organized by PUMA.

KI, **IMAGO7** and **SpaceDys** provide also specific trainings in their field of expertise.

Table 1.2 b Main Network-Wide Training Events, Conferences and Contribution of Beneficiaries

	Main Training Events & Conferences	ECTS (*if any*)	Lead Institution	Project Month (*estimated*)
Technical Training				
1	VHDL design/implementation in FPGAs (1 week)		UNIPI	9
2	Effective parallel programming in modern C++ (2 days)		SDS	10
3	HLS (High Level Synthesis, 3 days)		ICCS	11
4	Designing in FPGA SoCs e.g. Zynq (1 week)		ICCS	11
5	Course on MRF (3 days)		IMAGO7	36

6	Technology in space applications, with reference to ASI and ESA research activities (2 days)		KI	46
Schools				
1	GPU programming school (2 days)		SDS	22
2	School at Fermilab (2 students/year, 2 months)		UNIPI	18,30,42
3	CMS detector upgrade school (1 week)		UNIPI	33
4	MAX Design flow and OpenSPL programming (3 days)		MAX	24, 34
Administrative and Management Trainings, transferable skills				
1	Italian language courses (2-months lessons)		UNIPI	When in Pisa
2	SixSigma Quality Management		GEGR-E	27
3	PHD+, technology transfer		UNIPI	36-38
4	TRIZ Problem Solving Tool		GEGR-E	39
Scientific Contribution in Conferences/Workshops				
1	PUMA Workshops		All	11,19,26,37,48
2	Contributions to Hipeac CSW		SDS	19,31,43
3	1 IMAGO7 event		IMAGO7	14
4	FTK workshops @CERN		UNIPI	17, 29, 41
5	Special Session Organization at Conferences/Workshops		ICCS	1/year

1.3 *Quality of the supervision*

- Qualifications and supervision experience of supervisors

Each of the 6 ESR students is supervised by two researchers, one from the academic institution providing the doctorate, the other from the industrial institution where he will spend at least 50% of his time. These are the supervisors for each student:

ESR1 (HEP) Supervisors: D. Soudris from ICSS and L. Serafini from KI
ESR2 (HEP) Supervisors: F. Palla and A. Rizzi from UNIPI and Georgi Gaydadjiev from MAX
ESR3 (Space debris) Supervisors: D. Soudris from ICSS and F. Guerra from SDS
ESR4 (MRF) Supervisors: Michela Tosetti from UNIPI and Dirk Bequé from GEGR-E
ESR5 (MRF) Supervisors: Alberto Annovi from UNIPI and Dirk Bequé from GEGR-E
ESR6 (MRF) Supervisors: Michela Tosetti from UNIPI and Tobias Becker (MAX)

All the supervisors (see also "Participating Organisations" tables of section 5) have large experience in supervising research (many PHD and undergraduate thesis supervised in the past) and specific high-level knowledge of the related scientific fields. They have participated to other national and European research programs, have the time needed to offer the research trainee appropriate support (10% minimum FTE per ESR), to monitor the research progress and to provide the feedback action if necessary. Additional, high experience personnel is available from many Institutions in particular UNIPI, as described in Section 5.

- Quality of the joint supervision arrangements

The ESRs supervisors will discuss and establish a career development plan (CDP), which will be followed up, discussed and updated regularly (WP7). Given the healthy participation at each institute in the network of experienced staff, the good supervision of the young researchers is guaranteed. The progress of ESRs will be followed closely and the supervisors, in the spirit of maximizing their career prospects, will make suggestions/corrections. They will be strongly advised to take an active role in training activities. A 6 month planning of their work is foreseen and a yearly report to the institute on their progress will be given. As described in the previous sections, distinct tasks and responsibilities will be attributed to each of the ESRs of the network. On the limit of the finality of the recruitment, the tasks will be assigned to the ESR's taking into account their personal preference. The supervisor, in consultation with the Executive Board and on the basis of the importance of their scientific results, will advise on the ESRs participation in workshops and conferences and on the presentation of the scientific results. High priority will be given to ESRs to present the results achieved within the network in collaboration meetings and international conferences. The aim is to give the researchers the necessary visibility that will help them in their future career.

Work conditions - Organization and continuous scientific discussions are the bases of the high research productivity of the relatively small, but excellent research groups participating to this network. Each member has

individual responsibilities and is required to discuss its work weekly with the rest of the correlated group. Seminars in front of the whole scientific community of each institute are periodically required. This style is a strong stimulus to acquire clarity, independence, management capability, and presentation skills.
We care to provide a continuous stimulus to improve "leadership capability". Independence and management capabilities are strongly encouraged and rewarded. The ESRs will have the opportunity to supervise undergraduate students working in the same area. The fellow work will have the opportunity to be presented to a large and international scientific community. Presentations at conferences are strongly encouraged, even the dissemination of new ideas and results not currently popular in the research community (dedicated hardware for example, suffer of the large farms competition).
All the participating institutions are intellectually very active and offer seminars and possible interactions on a wide range of topics in particular in HEP, MRF, and space missions, technological areas related to high performance computing, and also in totally different fields.

1.4 *Quality of the proposed interaction between the participating organisations*

The network has three components specialized in the corresponding application areas, providing all the expertise related to the area: (1) HEP is represented by UNIPI that holds the leadership of the real time custom tracking technology at hadron colliders; (2) GEGR-E with the partner IMAGO7 is a strong component working today in the MRF field; (3) SDS represents the activity of sky observation for debris identification.
The other members instead provide the expertise for developing new high performance computing platforms: MAX, already providing platforms to many research fields, will enlarge its application area; KI, a strong aerospace company producing high-quality custom boards and devices, will have the opportunity to enter new scientific areas providing custom products under new requests. ICCS with its extraordinary experience on embedded systems, FPGA programming and software for multicore CPUs, its network capability in the HPC community, will be the guide, a sort of glue for the network. This is demonstrated by the fact that ICCS participates substantially to all work packages.

- Contribution of all participants to the research and training programme

ICCS - ICCS is leader of WP1 for the global research strategy definition and leader of the WP6 for dissemination, exploitation of results. It identifies three general directions for the use and promotion of the research results obtained within the projects. These are: a) the enhancement of its knowledge and competence in the field of hardware accelerators, programming frameworks and heterogeneous parallel computing systems with the goal to improve industrial collaborations and attract more research funding, b) the spreading of this knowledge through educational and industry oriented courses and preparation of specialized teaching material and c) improve its know-how and IPR portfolio with the long term target to attract capital investments and even create new start-up companies. Therefore, ICCS's participation in innovative research projects with increased potentials for exploitation is of great importance, in order to guarantee continuity in advanced research fields, educate the next generation of skilled engineers and also foster a long-term, sustainable technological lead and excellence both in a local level and within the European Union.
With respect to PUMA project, ICCS is investing significant effort in the research work of HEP, MRF and Space debris domains. Through these activities, ICCS is targeting a significant improvement of its prior work on hardware accelerators for heterogeneous computing systems. ICCS has identified this topic as one of the strong research outcomes of ICCS Microlab group with significant potentials for exploitation, and will support actively any future development with business plans and promotion activities.
ICCS participated/participates as Dissemination Leader/Manager in several EU-funded projects (AMDREL, 2PARMA, HARPA etc). Therefore, ICCS people will emphasize on disseminations activities with different stakeholders. In particular, ICCS will organize at least one Workshop annually, as an embedded event in Conference with large visibility, for example HiPEAC, DATE, ARC, and FPL. The structure of each workshop will include contributions from consortium partners as well as an invited speaker. Depending on the workshop topic, technical and marketing experts from industry might be invited. Their contribution will be useful for closing the gap between the delivered research results from the Ph.D. students and the commercialization of them in real products.
UNIPI is the connection of the network with the high energy physics community, in particular with the experiments at LHC. The UNIPI proponents of this project are active essential participants of these experiments and have a leading role in the real time tracking at hadron colliders since 1985. The AM idea was born in Pisa in 1989. The SVT project at CDF and the FTK project at ATLAS were proposed and largely built by the Pisa group. The group developed the physics case for the SVT and FTK proposals and a realistic simulation of the two systems to be able

to predict the processors capabilities to produce B-physics and Higgs results, respectively at CDF and ATLAS. Pisa had a large impact on this 15 year long story and will continue, soon with the FTK installation and its upgrade for the future research at LHC. In this sector UNIPI will offer the opportunity of knowing the CERN environment, additionally an important HEP experience (summer school) at Fermilab, and a CMS school on detector technologies for the HL-LHC. The SVT-FTK experience has developed a strong electronic expertise in the Pisa group. This expertise will be valuable for the interaction with KI and MAX, especially developing FPGA firmware for the two available platforms and to provide one training, "VHDL design & validation", with laboratory sessions. Additional Contributions are for management skills and language lessons.
UNIPI will contribute significantly also to the MRF sector, since M. Tosetti teaches at the University of Pisa and will be the supervisor of two ESRs. Also A. Retico participates through the well-established collaboration UNIPI-INFN (see section 5).
GE Global Research has a leading role for trainings in the MRF sector, providing the necessary background knowledge in the field, definition of new procedures, acquisition of new data, reviewing the analysis results. GEGR-E will work in close collaboration with IMAGO7 that has a unique infrastructure featuring a 7T MRI scanner and an excellent interdisciplinary research team. IMAGO7 is already active in developing and applying new MRF acquisitions in collaboration with GEGR-E. Recently, investigations performed in collaboration between the two centres highlighted the need for a pattern matching acceleration technique in order to extend the MRF technique. GEGR-E will provide also a considerable part of the transferable skills offered by the network: two training actions and events that equip the doctoral candidates with the skills necessary for future industry employment, which will comprise of the key areas:
• Workshop 1: SixSigma Quality Management Workshop: An introduction to this data-driven methodology to achieve sustained process improvement and standardization; and to design Six Sigma products and processes.
• Workshop 2: TRIZ Workshop: Focus on the use of main problem identification tools and TRIZ-based tools for problem solving. It provides participants with basic skills that can be applied to improve functionality and/or reduce costs for products and devices. GEGR will closely interact with UNIPI, MAX, IMAGO7 and ICCS, in order to identify the best platform for hardware acceleration of MRF reconstruction.
IMAGO7 has an important role in the MRF sector, as described above. There, researchers will receive training on MRF, focussing on the exploitation of the acceleration achieved to develop new acquisitions using a new 7T system.
SDS - SpaceDyS has in house a very specialized team of researcher in space dynamics and space software development. The contribution of SpaceDyS for the research training is provided through the supervision of senior scientists and through the involvement with industrial R&D projects. SpaceDyS, exploiting the collaboration with the University of Siena where S. Bartolini teaches and researches on multi-/many-core computer architectures and programmability, will organize training events on parallel and GPU programming. For instance a two-day training on effective parallel programming in modern C++ (in the second year of the project) and a similar course on effective GPU programming in one of the subsequent years, possibly to be included in the PhD course program and with a distinguished lecturer.
MAX is the computing platform provider with HPC features and their role will be related about the efficient implementation of HEP and MRF applications. Furthermore, MAX will host two ESRs sharing with them not only MAX design flow, but also access to additional scientific benchmarks. Apart from the technical activities, MAX will be responsible for making the exploitation plan and running the corresponding activities of PUMA (WP6). Regarding with the training activities, MAX will organize training activities about the programming environment and the MAX design flow.
KI will offer to the students the opportunity of understanding the main challenges represented by the space environment by organizing specific workshop/events addressed to the development of hardware for space environment. The supervised student, in particular, will benefit from the high-level training provided by the highly specialized staff at Kayser, with expertise in a wide range of different fields (e.g., electronics, mechanics, physics) gaining fundamental experience in the design and development of equipment for challenging applications.

- <u>Synergies between participants</u>

The common interest (the increase of the algorithm speed) and the use of common platforms favour the sharing of advancements: each step ahead in one specific area has a good probability to produce a correlated advancement also in the other areas. Certainly there will be a constructive interaction between the students and the staff researchers. The interest of all the parts in a real success reaching the common goal, guarantee a continuous, efficient interaction between the parts.

Important synergies will be naturally available to enlarge the dissemination of results, since the inter-disciplinary nature of the network enlarges its visibility inside four different communities.

- Exposure of recruited researchers to different (research) environments, and the complementarity thereof

Also for the ESRs will be optimal the possibility to know four different high technology communities with their challenging goals and tasks: HEP, MRI, space research and high performance computing. They will share common technical problems, but will know also the different complexities. The high level academic environment will offer a clear picture of both the fundamental and applicate research while the modern high technology industries will provide a clear idea of the work and the organization in the private sector.
Industry will have a key role in research training since ESRs will gain a better insight into their preference with regard to their potential career paths.

2. Impact

2.1 *Enhancing the career perspectives and employability of researchers and contribution to their skills development*

The PUMA training will prepare the ESRs for careers in research and academia, health, electronics, and computing science research and related industries. The multidisciplinary nature of PUMA provides many opportunities for the ESRs.

High performance computing- The mobilization of resources of PUMA (most of which will be invested in R&D activities) coupled with the expertise of the partners involved, guarantees that innovative technologies in the area of platforms will be created during the execution of the project. The participants of this proposal are part of a very wide community of academic institutes and high technology companies, working on improvements and advancements solving the "Big Data" problem. Certainly acquiring skills in this sector, even more obtaining good results for the PHD thesis, will be an important advantage to develop a successful career.
Additionally the students will have specific opportunities in the 3 specific application areas:

LHC experiments – this also is a huge community involving many academic institutes inside and outside of Europe, with important involvement of many companies. The FTK project popularity is quickly increasing and its influence on future projects for the HL-LHC plan is strong, both for physics and for technological developments. The FTK scientific impact on HEP experiments will be extremely important. FTK will play a key role in efficient selections of the very rare Higgs events, thus substantially improving the capability to discover new physics. Having expertise in the FTK technology and its simulation will give priority in the large number of institutions that will participate to these developments. Additionally the industries connected to CERN experiments are extremely interesting and perform high-level technological research, so they are an optimal environment for good careers.

MRF - The extension of MRF proposed in WP4 is suitable for translation to the clinical routine. The involvement of GEGR-E, closely linked to GE Healthcare, in this project helps creating new technologies that can be integrated into commercial products, stimulating investment and strengthening academic collaboration with internationally excellent industrial partners. In addition, the collaboration between the FTK researchers and GE may permit the commercialisation of new hardware solutions for novel applications beyond the ones described here, acting as an incubator for the successful commercialisation of a top class technological device originally designed for HEP research. Further, the first results using PUMA will open new important R&D questions, which will help the fellows securing a career in academia or industry.

Space debris studies - The problem of space debris that may hit space assets has enormously increased the interest and the funding for the R&D activities related to the mitigation of the risk. EU, ESA and European national programs are already investing several millions of euros in this sector. The possibility to develop new technologies and in particular new know-how with this proposal project will be very valuable for the next decades activities of the SSA programs in Europe. The specific problem of space debris detection is very challenging, in particular concerning the need to detect a space debris and process the data in a very short time. The training of young and skilled people is a key factor for the space debris population characterization. This project is a great opportunity for a research career in this challenging sector.

2.2 *Contribution to structuring doctoral/early-stage research training at the European level and to strengthening European innovation capacity*

High performance computing - The PUMA results will allow implementation of data-intensive applications into the modern and future High performance computing/embedded platforms/reconfigurable platforms to enter in the

'More than Moore' epoch by addressing applications features as well as industrial partner requirements. The silicon technology scaling reduces the circuit/system reliability and increases the SoC parallelism, key design aspects with tremendous impact on application mapping. We aim at demonstrating the efficiency of new techniques and methodologies (e.g., design space exploration techniques and scenarios) in data intensive applications with industrial relevance and therefore, favour even closer cooperation between academia and industry.

HEP - In high-energy physics, the LHC upgrade, currently called the High-Luminosity LHC (HL-LHC), will widen the capability to search new phenomena that are beyond the scope of our current theory of matter and energy, the Standard Model (SM). In the next few years an impressive harvest of data will be collected and at the same time R&D at the technological frontier will be pursued for HL-LHC. These experiments will have a fundamental impact on physics and technology for the next 20 years. This is an important opportunity for the fellows and companies in our network, since LHC experiments require an enormous technologic effort, determinant for advancing our understanding of the matter and the universe. In addition, solving the problem of the simulation of FTK itself, or even producing an important speed up of the generic offline tracking will open new frontier of research, increasing the capability to observe what today is not visible.

MRF - The MRF technique is a relatively new, highly-promising medical imaging method. Most of the research published on this topic so far has been conducted in the US, mainly focussing on the acquisition side of the technique. Despite this, it has been recognised that the potential for widespread clinical application, as well as the continued development and improvement of the data acquisition, are considerably limited by the low efficiency of reconstruction[22]. By developing new algorithms to address this challenge, the fellows will increase the MRF capabilities to a clinically-satisfactory level and develop a thorough understanding of this new medical imaging technique. This has the potential of stimulating future European R&D on this topic, through a cutting-edge research program applying new technological solutions to an open challenge in medical imaging. In addition, this research may ultimately have a significant impact on the EU healthcare system and economics. Currently, multiple MR sequences are acquired during an exam, typically each one investigating a single parameter. The research described in WP4 will enable new, multi-parametric MRF techniques grouping these measurements together, for a reduced scan time and a better resolution and spatial registration of the distinct parameters. This, at the same time, reduces the required scan time per patient and increases the diagnostic quality of the information obtained. At total estimated annual cost of over 3 billion for the European healthcare systems[23], every percent in reduced MRI scan time or avoided scans (by eliminating unnecessary repetitions) amounts to over €30 million yearly saving.

Space debris studies – The space debris studies and impact mitigation are still in early stage in Europe and worldwide. Nevertheless, there is an enormous interest both at national and European level for this specific research. SpaceDyS is already involved in several studies at EU, ESA and national level concerning the SSA activities, in particular for the dynamics characterization and image processing. The capacity to develop new HW and SW tools which will allow to process images in a very short time is a key factor for having a winning technology in the SST (Space surveillance and tracking) activities. The investment in training young researchers for this specific task is essential for a successful technology that can compete with the rest of the world.

2.3 *Quality of the proposed measures to exploit and disseminate the project results*

- <u>Dissemination of the research results</u>

PUMA project will distinguish between *internal* and *external* dissemination plan, based on different channels to spread out the knowledge created in the project.

Internal Dissemination Plan aims at ensuring a good diffusion of information and documentation among the project partners with the aim of sharing the developed know-how. Access will be restricted to partners of the consortium (and partially to EC officers and reviewers) and protected by user authentication. The Internal Dissemination will mainly be achieved through the following channels/measures:

- *Internal project website:* the internal website will be used to ensure the proper information availability for all partners and the correct activities' progression. It will be used as database and knowledge management tool, gathering knowledge base on PUMA-related scientific topics, reports, state-of-the-art and outputs of the project, and information on specific resources that will be available to all the different partners.

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[22] Buonincontri G et al MRM 2015 doi: 10.1002/mrm.26009;

[23]Estimated 24 million MRI scans performed in EU p.a. (OECD Health Statistics 2014, Eurostat Statistics Database 2014, http://dx.doi.org/10.1787/health-data-en.). Average cost of MRI scan in European states €180 based on insurance estimates (International federation of health plans, 2013 price report).

- *Internal web-based project document repository*: this will be used for providing access to designs, algorithms, software tools and documents to all the partners.
- *Internal workshops and meetings:* internal project workshops and meetings will be organized to share information and to strength the cooperation among the partners in the consortium.

External Dissemination Plan aims at ensuring the visibility and awareness of the results outside the consortium border, i.e. in the scientific community, in academic institutions, in organizations, or in companies. More precisely, external visibility and public awareness and knowledge of the PUMA project will be ensured through the following channels/measures:

- *Public project website:* the PUMA public website will provide access point for interested scientific and business parties into the PUMA project by presenting general project information, scientific publications done during the project, news about the project, events organized and public deliverables. The long-term objective of this public website is to create a community of interested parties around the project, to accelerate their involvement and to create awareness of the research results.
- *Organization of Conference/Workshop/Special Session/Panel*: A number of related events will take place during workshops and conferences, with participants and invited experts from academia and industry.
- *Educational dissemination*: Curricula of appropriate graduate courses will be enriched by the appropriate results from the developed design methodologies and tools by the academic partners.
- *Publication of research results:* project results and innovations will be submitted for publication in scientific journals (e.g., ACM TRETS, TODAES, TECS, IEEE TCAD, TVLSI, Computers, Design & Test and Computer,: IEEE TNS for HEP, MRM, JMRI, MRI and Neuroimage for MRF, TOC and TPDS for space research), conferences (e.g., DATE, DAC, ISCA, FPGA, FCCM, HPCA, FPL, PACT, and FDL, MRI conferences like ISMRM, ESMRMB, OHBM, IEEE NSS for HEP), and workshops relevant to the topic of the research activity carried out during the project. The submission of papers jointly written by project partners will be encouraged.
- *General press* releases to newspapers, including popular science and other public interest publications, will be prepared and distributed by partners.
- *Social networks*: We plan to use a number of widely accepted social networks (like Facebook, Google+, Twitter, LinkedIn, etc). Social networking sites allow users to share ideas, activities, events, and interests within their individual networks.
- *Book publication* from a well-known international publishing house describing the state of the art technology developed by PUMA proposal is planned by the end of project.

Through the above mentioned channels/measures, the specific groups that the project is targeting will be reached.

- Exploitation of results and intellectual property

Specific exploitation strategies differ for the various industrial partners in the consortium, since different value chains are addressed: technology hardware and software vendors, medical equipment manufacturers and large scale organizations. The academic and industrial partners will incorporate PUMA research results in internal development projects to produce innovations that might be transferred to their business entities as part of products and business solutions. Further, the testing and exploitation of results in concrete scenarios will enable the industrial partners to increase the market opportunities and their competences enabling advanced technological developments in the future heterogeneous parallel computing systems. The industrial partners will also take the lead role in feeding relevant standardization bodies and global industry initiatives, apart from contributing to the regulatory landscape in Europe. The industry players will also promote an active patent policy to get royalties on these patents when the technological concepts within PUMA will be more mature and implemented as part of an operational system.

Knowledge Management and Protection Strategy - The competitiveness of organizations is more and more depending on the ability of all stakeholders to work in networks in order to collaborate in synergy for a common knowledge base. To such purpose, it is necessary to implement a strong IPR management strategy for an efficient trade and transfer of IPR assets and technology.

Aspects of innovation and management of knowledge and intellectual property is a significant part of the planned work in the respective work packages and will maximize the return from the research and protect the investments made. Intellectual property management will be two-fold: On one hand, IPR applications for new systems and solutions will be prepared and filed by the partners. On the other hand, information will be disseminated to external bodies such as publications and presentations of scientific results and open source software, and to regulatory and standard bodies, but only after the necessary steps for ensuring the protection of IPRs have been made. This ensures that intellectual property will be secured in the interest of the project partners. The project's participants are committed to engage in the "Open Access to Research Data" initiative. They further anticipate to develop a considerable part of the PUMA programming framework under the Open Source / Free Software model, a proven means to continue useful software beyond project lifetimes. Most of the developed software will be accessible via a series of APIs, the primary goal of which will be to enable code reuse in research and development. A detailed description of the research data and PUMA software for public dissemination will be laid down in the consortium agreement.

For the success of the PUMA project it is essential that all project partners agree on explicit rules concerning IP ownership, access rights to any Background and Foreground IP for the execution of the project and the protection of intellectual property rights (IPRs) and confidential information before the project starts. The main tool for this will be the Consortium Agreement between all project partners where such issues will be addressed in detail. The main purpose of the Consortium Agreement is to establish a legal framework for the project in order to minimize any internal issues within the PUMA consortium related to the work, IP-Ownership, Access Rights to Background and Foreground IP for the duration of the project and any other matters of the consortium's interest. As starting point in the negotiations regarding the consortium agreement we preferably will use the IPCA agreement template model (provided by Digital Europe).

2.4 *Quality of the proposed measures to communicate the project activities to different target audiences*

- Communication and public engagement strategy of the project

PUMA proposes a set of events to disseminate its applied research to the public. We will focus on the importance of computational technology for the advancement of scientific investigation and its impact on society and economics. We plan one annual occasion for each of the listed corresponding deliveries:

PUMA Open Days (~2 days in February/March): UNIPI and SDS will participate each year to the Open Universities occasions organized in Tuscany, opening their labs to the public. SDS will do it in the University of Siena, specifically into the Computer Architecture laboratory of the Departiment of Information Engineering and Mathematical Sciences, within the "Open University" (Università Aperta) initiatives towards the wide audience of citizens in general as well as potential students and companies, thanks to the collaboration with S. Bartolini. SDS will disseminate a) the trail detection problem and its relevance for social security and for related fields, b) the scientific and practical achievements reached in the various stages of the project development, c) the obtained and perspective synergies with the other application fields of the PUMA project. UNIPI will open the FTK labs at the Physics Department to show the racks, crates, boards and chips developed by the collaboration. Teachers (the fellows in particular) in front of posters in the lab will describe the importance of the real time analysis performed on FPGAs (PUMA type of computing) to make sophisticated decisions in few microseconds, for HEP experiment triggers as well as for other applications outside HEP. Simple CAD stations (Xilinx and Altera systems) will be provided to visitors to investigate how these tools work.

PUMA at the Night of researchers: same activities as described for the Open Days.

PUMA Workshop day - Communication of project challenges and achievements to wide different audiences. In some case the audience will be the university or high school students (from February/March to May/June). - Project challenges, relevance and achievements will be illustrated to perspective engineering students at the university of Siena and Pisa during the yearly visits from high-school institutions. These events can be short visits to the labs as well as weekly thematic stages. Seminars and lectures will be provided to let them know the PUMA activities, with its 3 different research areas. This will be also the occasion to announce the Summer school week plan when available, like the opportunity to spend a period during summer in Fermilab.

A different scientific audience will be the one attending the EU HiPEAC NoE ("Network of Excellence on High Performance and Embedded Architecture and Compilation") "Computing System Weeks - CSW" initiatives (http://old.hipeac.net/csw) where specific sessions on active projects are organized and allow an effective cross-fertilization within EU and extra-EU academic and industrial groups dealing with high-performance/ embedded computing and programming themes. Particularly interesting is to focus on one of the two yearly meetings that hosts the HIPP (HiPEAC Industry Partner Program) event (e.g. http://old.hipeac.net/add/res/116/523) in order to create exploitation opportunities in possible future projects and industrial impact. Typically this can be done presenting results and project status in one of the two yearly CSW-initiatives, within a thematic session on related topics (e.g. parallel processing). CSWs are organized in Spring and Autumn.

Other PUMA Workshops will be organized at CERN for HEP and medical research communities.

For **MRF** a particular strategy will be followed in order to favour patient and public involvement (PPI), which a large body of evidence has shown to be advantageous to medical research. In addition to standard academic vehicles,

we will work through patient groups and funding bodies such as Telethon Italy and AIRC (Italian association for cancer research) to publicise our findings to a wider audience. We will actively seek press coverage and organise open events for the public in order to favour PPI in our research. During this project, one open events is already scheduled and will be held at the IMAGO7 institute.
Visiting scientists will be present at the IMAGO7 event and one FTK workshop.

3. Quality and Efficiency of the Implementation

3.1 Coherence and effectiveness of the work plan

Table 3.1 a Description of Work Packages

WP Number	**1**	**Start M1 – End M18**
WP Title	Application & Hardware platforms Specifications and Design Strategy	
Lead Beneficiary	**ICCS**	

Objectives
O1.1 Analysis of the three real-life use cases and corresponding requirements
O1.2 Specification of the design strategy, methodologies and techniques as well as software tools requirements
O1.3 Definition of the specifications of the system architecture components
O1.4 Definition of the specifications of the hardware platforms

Description of Work and Role of Specific Beneficiaries / Partner Organisations
T1.1 Analysis, specifications and requirements of the application areas [Task Leader: UNIPI, Participants: All, M1-M6]
A rich set of scientific application domains (HEP, Space debris and MRF), which also has strong industrial relevance, will be analyzed through state-of-art profiling tools. Functional and non-functional parameters, for example, computation complexity, size of dataset, input programming language, target performance, memory size, throughput and power consumption will be analysed and/or quantified. Additionally, emphasis will be given on the bigdata of the applications and the real-time (or time-constrained) signal processing.
T1.2 Definition of specifications of system architectures and hardware platforms [Task Leader: MAX, Participants: All, M1-M6]
In this task we will derive the specifications of the hardware architectures and the programming models for the selected applications in WP2, WP3 and WP4 for the assessment and validation of the design techniques and tools developed in the project. State of art programming techniques and architectures will be analyzed to i) expose the performance, scalability, ease of programming and power limitations and quality of service (QoS) and ii) to show the optimization capabilities delivered by the adoption of heterogeneous computing engines. More specifically, PUMA will explore heterogeneity considering the following architectures, which span across the most promising computation models: (i) General-purpose multi/manycores, e.g., Intel Phi Xeon (ii) Customizable Multiscale Dataflow Acceleration architecture provided by MAX, (iii) GPU architecture and (iv) FPGA Reconfigurable architectures, e.g., commercial platforms Xilinx Ultrascale, Altera Stratix.
T1.3 Definition of the structure of the design strategy and optimization techniques, and the design flow [Task Leader: ICCS, Participants: All, M6-M18]
The main goal is to elaborate a development plan of the design techniques and tools that will drive the research activities to be carried out in WP2, WP3 and WP4. Particularly, the task activities will be i) the development of profiling and source-to source optimisation techniques, ii) the definition and development of design approach and software tools and iii) the exploration and selection of design techniques for each application domain.

Description of Deliverables
D1.1 Definition of specifications of applications [ICCS, M06]
D1.2 Definition of specifications of hardware architectures [MAX, M06]
D1.3 Preliminary definition of design methodology and flow for implementing the three applications [ICCS, M12]
D1.4 Final definition of design methodology and flow for implementing the three applications [ICCS, M18]

WP Number	**2**	**Start M1 – End M48**
WP Title	Simulation of Huge samples of HEP events	
Lead Beneficiary	**UNIPI**	

Objectives
O2.1. Learn about baseline PU, especially the AM chip, to be connected to multicore CPUs/GPUs.
O2.2. Development of firmware for both used platforms finalized to simulate MC events.
O2.3. Production of Software to operate both platforms (baseline PU and MAX solution).
O2.4. Validation of the systems for a short MC production on both platforms.
O2.5 Final evaluation of best solutions for FTK, in particular AM, simulation and evaluation of next steps for future exploitation of results.
O2.6 Final evaluation of the best solution for tracking at hadron colliders, and evaluation of next steps for future exploitation of results.
O2.7 ToK between research institutions about the two compared technologies.

Description of Work and Role of Specific Beneficiaries / Partner Organisations
T2.1 Installation of baseline PU version at UNIPI & KI for FW development & ToK [Task Leader: *UNIPI, Participants: ICCS collaboration, ToK with SDS,* M?-M?]
T2.2 Software development to handle the baseline PU [Task Leader: *UNIPI, Participants: ICCS collaboration, ToK with SDS*]
T2.3 Firmware development for the baseline PU FPGA [Task Leader: *KI*, Participants: *ICCS, UNIPI*]
T2.4 Integration of the baseline PU with commercial CPUs/GPUs [Task Leader: *UNIPI*, Participants: *ICCS, KI and TOK with SDS*]

T2.5 Firmware development for MAX technology [Task Leader: *MAX*, Participants: *ICCS, UNIPI,* M?-M?] T2.6 Implementation of FTK simulation, tracking into MAX technology [Task Leader: *MAX*, Participants: *ICCS, UNIPI,* M?-M?] T2.7 Comparison of performances: SW-only solutions with mixed HW/SW solutions [Task Leader: *UNIPI*, Participants: *KI, ICCS, MAX*,] T2.8 Small production of Monte Carlo events [Task Leader: *UNIPI*, Participants: *KI, ICCS, MAX*] T2.9 Evaluation of future evolution for exploitation [Task Leader: *UNIPI*, Participants: All]	
Description of Deliverables D2.1 (a) PU ready at UNIPI & KI (b) Strategy for FTK simulation & tracking implementation on MAX technology ready [UNIPI, M12] D2.2 (a) PU software ready for integration with GPUs/multicore CPUs (b) Software ready to use MAX technology [UNIPI, M24] D2.3 (a) PU firmware ready to start integration with GPUs/multicore CPUs (b) Firmware ready for MAX technology [UNIPI, M26] D2.4 Successful Test of (a) PU integrated system; (b) simulation/tracking with Maxeler technology [UNIPI, M37] D2.5 Monte Carlo events produced with (a) PU integrated system; (b) MAX technology; performance comparisons [UNIPI,M46]	

WP Number		**Start M1 – End M48**
WP Title	Space debris trails detection in telescope images	
Lead Beneficiary	**SDS**	
Objectives O3.1 Analysis of requirements and features of advanced algorithms for trail detection in big astronomical images (curved trails). O3.2 Production and profiling of modular, layered, scalable, parallel and heterogeneous CPU/GPU compliant, software implementation of selected algorithm candidates. O3.3 Development of specific firmware and/or tuning for supporting low-level trail detection processing through the MAX FPGAs. O3.4 Development and evaluation of optimized trail detection software for the full-exploitation of MAX platform in conjunction with parallel, heterogeneous CPUs/GPUs O3.5 Cross-validation against SW implementation and profiling of overall the final HW/SW platform for fine-tuning across all layers O3.6 ToK between research institutions about available technology and firmware development (in) and about trail detection issues and possible application-specific solutions (out)		
Description of Work and Role of Specific Beneficiaries / Partner Organisations T3.1 Analysis of state-of-the-art trail detection strategies and software implementation of selected algorithms [Task Leader: SDS, Participants: ICCS] T3.2 Investigation on MAX platform suitable for data elaborations from trail detection algorithm [Task Leader: ICCS, Participants: ToK with SDS, MAX] T3.3 Development and evaluation of specific pattern matching strategies for trail detection and definition of synthetic image reference train/test sets [Task Leader: SDS, Participants: ICCS, MAX] T3.4 Implementation of a parallel software architecture and CPU/GPU-like/MAX integrated execution [Task Leader: ICCS, Participants: SDS, MAX,] T3.5 Development of specific FPGA firmware for low-level trail detection. Validation and profiling of the heterogeneous software version for identifying, (architectural simulation), suitable parallelization and MAX offloading opportunities [Task Leader: ICCS, Participants: SDS and MAX] T3.6 Integration of the advanced software version with offloading low-level processing to MAX accelerator platform (HW/SW solution). Functional Cross-validation of HW/SW solution and extensive performance assessment over different conditions for images and trail features [Task Leader: MAX, Participants: ICCS and SDS,] T3.7 Global optimization of parameters, regression testing (e.g software and data structure organization, task assignment to heterogeneous executors, parallelization strategies) [Task Leader: SDS,]		
Description of Deliverables D3.1 Candidate trail detection algorithm definition [SpaceDys, M12] D3.2 MAX platform strategies for trail-detection definition and firmware ready [MAX, M26] D3.3 Parallel software implementation and MAX-accelerated software integration [MAX, M30 D3.4 Hybrid MAX-advanced software integrated platform tests [MAX, M48]		

WP Number	**4**	**Start M1 – End M48**
WP Title	Accelerated multi-parametric MR Fingerprinting reconstruction	
Lead Beneficiary	**GEGR-E**	
Objectives O4.1 Development of optimised PM code for MRF on standard CPU and GPU O4.2. Development of new algorithms for MRF pattern matching with baseline PU accelerator O4.3 Development of new algorithms for MRF pattern matching with FPGA arrays O4.4 Application of the two new PM methods to standard 2D MRF O4.5 Development and acquisition of novel multi-parametric 3D MRF sequences O4.6 Application of the new PM methods to novel 3D MRF sequences		
Description of Work and Role of Specific Beneficiaries / Partner Organisations T4.1 MRF pattern matching coding using C++ and CUDA; Led by ICCS; IMAGO7 provides current MRF code and collaborates with SDS-ICCS for code optimization: ToK MAX-SDS-ICCS-IMAGO7 T4.2 Test of GPU based (standard) MRF reconstruction code with data taken at IMAGO7 and GEGR-E; Led by GEGR-E; IMAGO7 provides MRF data		

T4.3 Development and evaluation of algorithms for baseline PU MRF, by using hardware simulation – Led by UniPi, IMAGO7 and GEGR-E provide MRF data T4.4 Comparison of matching accuracy: algorithm for baseline PU with standard algorithm Led by GEGR-E; IMAGO7 collaborates T4.5 Implementation of MRF code optimized for FPGA arrays [Task Leader: ICCS, Participants: UniPI, MAX] T4.6 Implementation of MRF code optimized for baseline PU [Task Leader: UNIPI, Participants: KI, ICCS] T4.7 Comparison of computing time between baseline PU, FPGA only and standard hardware - Led by GEGR-E; SDS, ICCS, KI and MAX collaborate for optimised code evaluation and HW control] T4.8 Implementation and validation of dictionary compression strategies [Task Leader: GEGR-E, Participants: IMAGO7, UniPI] T4.9 Evaluation of impact of dictionary compression on computing time and accuracy [Task Leade*r: GEGR-E,* Participant: ToK IMAGO7] T4.10 Quantification of the effect of diffusion-sensitising field gradients and variable echo time in MRF sequences - *Led by GEGR-E, IMAGO7 collaborates to perform experiments at 7T* T4.11 Creation of a MRF dictionary including new parameters [Task Leader: UNIPI, Participant: *IMAGO7*] T4.12 Evaluation of the new PM algorithms on the new MRF sequences *Led by ISCC; MAX, UniPI collaborates. GEGR-E to provide data*
Description of Deliverables D4.1 Optimised MRF reconstruction using GPUs [ICCS, M18] D4.2 Implementation of code simulation to use with baseline PU [UniPI, M24] D4.3 MRF reconstruction using FPGA arrays – delivery date [ICCS, M32 D4.4 MRF reconstruction using the baseline PU [UniPI, M42] D4.5 MRF with compressed dictionary and multiple parameters [GEGR-E, M42] D4.6 Comparison of new MRF methods featuring new reconstruction hardware with standard MRF [ICCS, M48]

WP Number	**5**	**Start M1 – End M48**
WP Title	**Technical Training and Workshops**	
Lead Beneficiary	**SDS**	
Objectives O5.1 Offer a suitable environment for trainings, to facilitate the sharing of knowledge and culture between the participants O5.2 Organize a number of technical workshops related to the application and hardware platforms specifications and requirements O5.3 Organize training courses for applications design and implementation O5.4 Enhance the administrative and managerial capacity of PUMA participants		
Description of work T5.1 Organization of technical training courses [Task Leader: SDS - Task Participants: ALL, M1-M48] Several training courses will be organized throughout the project execution aiming at covering key design and development skills not only the young scientists, but also engineers and professionals from different disciplines. The list of training courses with corresponding organizers is provided as follows: (1) VHDL Design and Verification Techniques for FPGA [UNIPI], (2) Effective parallel programming in modern C++ [SDS], (3) HLS (High Level Synthesis) [ICCS], (4), Designing in FPGA SoCs e.g. Zynq [ICCS], (5) MRF design and algorithms [IMAGO7], (6)Technology in space applications, with reference to ASI and ESA research activities [KI]. Depending on the specific topic, the duration of training courses may vary from a few days to a whole week. Also, lab sessions will be provided for certain topics. Evaluation of ToK between participants and evaluation of results of PUMA Workshops will be also considered. Depending the project execution and advance, some additional intensive training courses might be organized to cover very specialized topics. **T5.2 Provision of courses in transferable skills** [Task Leader: GEGR-E - Task Participants: ALL, M1-M48] Specific training courses to educate for the young scientists with non-technical skills, which will be in their professional life. Typical workshops will be: (i) SixSigma Quality Management, [GEGR-E], (ii) TRIZ Problem Solving Tool, [GEGR-E], and (iii) Italian Language and PhD+ (http://www.unipi.it/phdplus) courses for students at UNIPI.		
Deliverables D5.1. PUMA Technical Training/Workshop Reports (List of attendees, work programme, workshop results summary, audiovisual material and slides) [Responsible Training/Workshop organizer, delivery dates M9, M10, M11, M36, M46] D5.2. PUMA Reports for non-technical training (List of attendees, work programme, workshop results summary, audiovisual material and slides) [Responsible Training/Workshop organizer, delivery dates M27, M36-38, M396]		

WP Number	**6**	**M1 – M48**
WP Title	Dissemination and Exploitation	
Lead Beneficiary	**ICCS**	
Objectives **O6.1.** To raise awareness about the project results and activities **O6.2.** To carry out professional marketing actions – digital and offline/traditional **O6.3.** To set up project website and maintain social media activities (Twitter, LinkedIn, Facebook and relevant blogs) **O6.4.** To prepare press releases and selected other materials for dissemination to the media and other stakeholders in all EU Member States and non-European countries. **O6.5.**To develop an organizational structure for exploitation and sustainability of the project **O6.6.** To manage the derived knowledge, generating Intellectual and Industrial Protection actions and publications		
Description of Work and Role of Specific Beneficiaries / Partner Organisations In this WP, the consortium will undertake a range of measures designed to increase visibility of project results and support their impact, by promoting dissemination of the innovative content developed and by adopting a joint open-source and proprietary model to exploit the results		

obtained. In particular, every partner will contribute to the overall goal of the WP undertaking activities tailored to the specific role (industry, tool vendor, academic, research center) assumed in the project, in order to assure the wider range of exploitation of the project results. Industrial partners will adopt the technology developed in the applications. Academic research partners will make available developed modules to external industrial partners or as open-source modules to the scientific community worldwide. More details about Dissemination and Exploitation plans and activities are reported in **Section 2.3**

The WP structure consists of the following complementary tasks:

T6.1: Dissemination Plan & Activities, **[**Task Leader: ICCS - Task Participants: ALL, M1-M48]

This task mainly concerns the definition of the dissemination strategy and its execution during the project. All through the project execution, public dissemination of scientific and industrial results will be encouraged. Various dissemination channels will be used such as publications, articles, participation in conferences, workshops, exhibitions and social media (more details in Section 2.3). Public participation and awareness will be reached using newspaper, local media information network, public exhibitions and social media. The PUMAweb site will be deployed including presentation of the project objectives and applied methodology, highlighting the impact of conceptual, scientific and technological innovation. Progress, public deliverables and workshops contribution will be regularly updated. Dissemination events will be organized to disseminate internally and externally the technologies and the methodologies provided and developed by the different partners. Moreover, project results will be presented in events, conferences, workshops, Ph.D. Forums and submitted to be published in relevant scientific and professional journals, with the goal to disseminate them to a wider research community. It is expected that at least fifteen (15) conferences and six journals to be published. Also, a book is planned to available by the end of project. Prototype and new services will be exposed as they become available during the lifetime of the project.

T6.2: Exploitation Strategy & Activities **[**Task Leader: MAX Task Participants: ALL, M12-M48]

This task defines the strategy to exploit the project results mainly following two complementary approaches: (i) Open-source Exploitation: The academic partners participating to this task will contribute to define the strategy adopted to make available some of the techniques and tools developed during the projects to the opens-source community and (ii) Industrial Exploitation: Proprietary models, algorithms and tools will be exploited through their inclusion in commercial tools or through their utilization in further cooperation with industrial partners, both internal and external to the consortium. Industrial partners devoted to technology transfer will exploit the developed tools, both open-source and proprietary, in their respective fields of application. The exploitation plan will describe how the results of the project will be transferred to real-life commercial applications.

T6.3 Knowledge Management [Task Leader: ICCS - Task Participants: ALL, M12-M48]

During this task, all the knowledge generated by the Consortium will be continuously tracked and qualified, by managing: (i) Confidentiality issues: the Consortium may decide that information should be kept confidential within the partnership, whenever their interests should be preserved and (ii) Intellectual Property Issues: appropriate legal protection means will be investigated every time results can be protected. Owners of the results should be the participant(s) that generated the knowledge. Confidentiality, IPR, dissemination and exploitation issues are addressed by the Consortium Agreement that will be signed before the signature of the Grant agreement with the EC.

T6.4 Public Engagement [Task Leader: IMAGO7 – Task Participants: ALL, M1-M48]

Researchers will ensure that their research activities are made known to society at large in these organized events: open days, workshop days and schools. Schools: (a) Summer School at Fermilab [UNIPI, M18, M30, M42for a couple of students], (b) (v) GPU programming [SDS, M22], (c) CMS upgrade school [UNIPI, M33], (d) MAX Design flow (3 days) [ICCS, M24, M34].

Description of Deliverables
D6.1 PUMA Web Site D6.1.0: (ON-GOING from M3 to M36): Set up the Website with public and private areas [ICCS, P] [ICCS, M1]
D6.2 PUMA Brochure and Press Release [ICCS, M6, M18, M36, M48]
D6.3 Dissemination Plan and Report [ICCS, M12, M24, M36, M48]
D6.4 Exploitation Strategy Plan & Activities [MAX, M12, M24, M36, M48]
D6.5 Knowledge Management Plan [ICCS, M24, M36]
D6.6 Data Management Plan [ICCS, M12, M48]
D6.7 Open days [event organizer, M13, M19, M31, M38
D6.8 Workshop days [event organizer, M13, M26, M29, M38]
D6.9 Schools [School organizer, M18, M22, M24, M30, M33, M34, M42]

WP Number	**7**	**Start M1 – End M48**
WP Title	**Project Management**	
Lead Beneficiary	**UNIPI**	

Objectives

O7.1 To monitor the project, in administrative, technical and financial terms and to ensure its strategic and everyday management.
O7.2 To guarantee the adherence of the work to the overall project plans, available resources and timing.
O7.3 To offer the necessary interface to the EU services and external actors.
O7.4 To assure the high quality of the project outcomes and to provide the guarantee that the project development will be in line with existing and emerging standards and application guidelines.
O7.5 To identify project risks by performing an effective risk management

Description of work
T7.1 Project Management [Task Leader: UNIPI - Task Participants: ALL, M1-M48]
The project management activities are responsible for: (a) the day-by-day management of the research, demonstration, dissemination and exploitation activities to guarantee the proper progress of the project and the coordination of all the partner activities to meet the project

objectives; (b) the administrative coordination of the project; (c) monitoring of the progress done with respect with the proposed workplan and handling corrective actions (if any); (d) monitoring of the progress of each ESR including deliverables and milestones respecting the given deadlines; (e) organization of regular meetings of the General Assembly and Executive Board by the Project Coordinator (PC). **T7.2** Quality Assurance & Risk Management [Task Leader: UNIPI - Task Participants: ALL, M1-M48] This task aims to ensure the proper implementation of the project plan and the satisfaction of its objectives and will contain Quality procedures and Risk Management. The Quality procedures will be coordinated by the PC and will be assisted by major partners' representatives in order to formalize the Quality Assurance Strategy for the project, and produce the relevant Quality Management Plan, to assure the conformity and the quality of all project deliverables with their requirements and to perform internal assessment of the project. The Risk Management will cover the risks that will be constantly assessed and evaluated within the whole project duration. It will perform a continuous monitoring of risks, both to prevent risks from occurring and, should any risk actually materialise, to assess corrective actions and plans to counter the problem and mitigate its impact on project outcomes. A full description of the activities is provided in Section 3.2 and Table 3.2a. **T7.3** PUMA plenary technical meetings [Task Leader: MAX - Task Participants: ALL, M1-M48] This task aims to promote communication between the project participants, to strengthen the planning and the synchronization of the technical activities, as well to the project, discussion of results and research planning for advancement. A set of internal workshops will be organized: (1) PUMA Kick-off Meeting at UNIPI, (2) PUMA Meeting at Athens at start of PHD studies, particularly focused on WP1. (2) PUMA Meeting at SDS (beginning 2nd year), particularly focused space debris detection WP3, review of WP2 and WP4 status. (3) PUMA Meeting at IMAGO7 (during 3rd year), particularly focused on MRF results and perspectives (WP4), review of WP2 and WP3. (4) PUMA Meeting at MAX (during 4th year), particularly focused on HPC platforms based on FPGA, review of WP2, WP3 and WP4. (5) PUMA final Meeting at UNIPI near the end of 4th year, to discuss all the project results and the exploitation plan.
Deliverables D7.1 Project Reports (including meeting reports) [UNIPI, M12, M24, M36, M48] D7.2 Advertising Vacancies [recruiting institution, M3] D7.3 Recruitment report [UNIPI, M7 for WP4, M9 for WP2, WP3]: a report with all information on the recruited ESRs. D7.4 Declaration of Conformity for each ESR [recruiting institution, M8 for WP4, M10 for WP2, WP3] D7.5 Career Development Plan (CDP) for each recruited candidate [ESR supervisors, M10 for MRF, M12 for HEP and Space debris]

Table 3.1 b Deliverables List

Scientific Deliverables						
Deliverable Number	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Dissemination Level**	**Due Date**
D6.1	Web site set-up & development	6	ICCS	PDE	PU	M1,M3-M36
D1.1	Definition of specifications of applications	1	ICCS	R	CO	M06
D1.2	Definition of specifications of hardware architectures	1	MAX	R	CO	M06
D1.3	Preliminary definition of design methodology and flow for implementing the three applications	1	ICCS	R	CO	M12
D2.1	(a) PU ready at UNIPI & KI (b) Strategy for FTK simulation & tracking implementation on MAX technology ready	2	UniPi	R	CO	M12
D3.1	Candidate trail detection algorithm definition	3	SpaceDys	R	CO	M12
D7.1	Project Reports (including meeting reports)	7	UniPi	ADM	CO	M12, M24, M36, M48
D1.4	Design methodology final definition & flow for implementing the three applications	1	ICCS	R	CO	M18
D4.1	Optimised MRF using GPUs	4	ICCS	R	PU	M18
D2.2	(a) PU software ready for integration with GPus/multicore CPUs (b) Software ready to use MAX technology	2	UniPi	R	CO	M24
D3.2	MAX platform strategies for trail-detection definition	3	MAX	R	CO	M24
D4.2	Simulation to evaluate implementation feasibility in the baseline PU	4	UniPI	R	CO	M24
D2.3	(a) PU fw ready for integration with GPus/multicore CPUs (b) fw ready for MAX technology	2	UniPi	R	CO	M26
D4.3	MRF reconstruction using FPGA arrays	4	ICCS	R	PU	M32
D3.3	Parallel software implementation and MAX-accelerated software integration	3	MAX	R	CO	M36
D2.4	Successful Test of (a) PU integrated system; (b) simulation/tracking on Maxeler technology	2	UniPi	R	PU	M37
D4.4	MRF reconstruction using baseline PU	4	UniPI	R	PU	M42
D4.5	MRF with compressed dictionary and multiple parameters	4	GEGR-E	R	PU	M42
D2.5	Monte Carlo events produced with (a) PU integrated system; (b) MAX technology; performance comparisons	2	UniPi	R	PU	M46
D3.4	Hybrid MAX-advanced software integrated platform tests	3	MAX	R	PU	M48
D4.6	Comparison of new MRF methods featuring new reconstruction hardware with standard MRF	4	ICCS	R	PU	M48

Management, Training, Recruitment and Dissemination Deliverables						
Deliverable Number	**Deliverable Title**	**WP No.**	**Lead Beneficiary Short Name**	**Type**	**Dissemi nation Level**	**Due Date**
D.6.1	Web site set-up & development	6	ICCS	ADM	PU	M1,M3-M36
D.7.2	Advertising Vacancies	7	Recruiting Institution	ADM	PU	M03
D.7.3	Recruitment report: a report with all information on the recruited ESRs.	7	UniPi	ADM	CO	M09
D.7.4	Declaration of Conformities	7	UniPi	ADM	CO	M8, M10
D.7.5	Career Development Plans	7	UniPi	ADM	CO	M10, M12
D.5.1	PUMA Technical Training/Workshop Reports	5	Training/Workshop Organizer	R	CO	M6, M18, M28, M36
D.5.2	PUMA Reports for non-technical training	5	Training/Workshop Organizer	R	CO	M6, M18, M28, M36
D.6.2	PUMA Brochure and Press Release	6	ICCS	R	PU	M6, M18, M36, M48
D.6.7	Open Days	6	IMAGO7	R	CO	M13, M19,M31, M38M38
D.6.8	Workshop Days	6	IMAGO7	R	CO	M13, M26, M29, M38
D.6.3	Dissemination Plan and Report	6	ICCS	R	CO	M12, M24, M36, M48
D.6.4	Exploitation Strategy Plan & Activities	6	MAX	R	CO	M12, M24, M36, M48
D.6.6	Data Management Plan	6	ICCS	R	CO	M12, M48
D.6.5	Knowledge Management Plan	6	ICCS	R	CO	M24, M36
D.6.9	Schools	6	UniPi	R	CO	M19, M22, M24, M31, M34, M43

Table 3.1 c Milestones List

Number	Title	WP No.	Lead Beneficiary	Due Date	Means of Verification
M6.1	PUMA Web Site	6	ICCS	M1	D6.1
M1.1	Analysis and specifications of applications	1	ICCS	M06	D1.1
M1.2	Analysis and specifications of hardware platforms	1	ICCS	M06	D1.2
M5.1	Technical Training Reports available	5	SDS	M9, M10, M11, M36,M46	D5.1
M5.2	Non-Technical Training Reports available	5	SDS	M27, M36, , M39	D5.2
M3.1	Definition of reference candidate trail detection algorithms and reference synthetic image set ready	3	SDS	M12	D3.1
M6.2	PUMA Brochure & Press release (v1), Dissemination Plan and Report (v1)	6	ICCS	M12	D6.2
M7.1	Annual Technical Report	7	UniPi	M12, M24, M36, M48	D7.1
M1.3	Definition of design approach and optimizations	1	ICCS	M18	D1.4
M4.1	MRF reconstruction in C++ and CUDA	4	ICCS	M18	D4.1
M3.3	Firmware for trail detection algorithm ready	3	ICCS	M26	D3.2
M4.2	functioning PM algorithm for MRF using PUMA simulation	4	UniPI	M24	D4.2
M6.3	PUMA Brochure & Press release (v2), Dissemination Plan and Report (v2). Exploitation Strategy Plan(v1), Knowledge Management Plan(v1)	6	ICCS	M24	D6.3

M2.1	Software/firmware ready for (a) PU working with a simple PC (b) MAX technology	2	UniPi	M26	D2.2
M3.4	Parallel CPU/GPU software platform ready	3	SDS	M30	D3.3
M4.3	Functioning PM using FPGA arrays	4	ICCS	M36	D4.3
M4.5	Working compression algorithms for MRF	4	GEGR-E	M36	D4.5
M6.4	PUMA Brochure & Press release, Dissemination Plan and Report (v3) Exploitation Strategy Plan (v2), Knowledge Management Plan (v2)	6	ICCS	M36	D6.2, D6.3, D6.4, D6.5
M2.2	Comparison of performances of integrated systems with state of the art done	2	UniPi	M37	D2.5
M3.5	Accelerator integrated with parallel software ready	3	MAX	M46	D3.4
M4.4	Functioning PM using PUMA	4	UniPI	M40	D4.4
M2.3	Evaluation of possible exploitation of results	2	MAX	M48	D2.5
M6.5	Press release (final), Dissemination Plan and Report (final), Exploitation Strategy Plan (final)	6	ICCS	M48	D6.3, D6.4
M6.6	Data Management Plan	6	ICCS	M48	D6.6

Table 3.1 d Individual Research Projects

Fellow *ESR1*	**Host (recruiting) institution ICCS**	**PhD enrolment Y**	**Start date M9**	**Duration 36 months**	**Deliverables D2.1a, D2.2a, D2.3a, D2.4a; D.2.5a**
Project Title and Work Package(s) to which it is related: AM based accelerator for FTK simulation.					
Objectives: all objectives of table describing WP2, focusing on baseline PU hardware; production of an AM-based accelerated computing architecture to simulate FTK in detail for huge Monte Carlo events production.					
Expected Results: D.2.1a: PU ready at UNIPI and KI; D.2.2a and D.2.3a: PU software and firmware ready for integration with GPUs or multicore CPUs; D.2.4a: Successful PU integration tests; D.2.5a: Monte Carlo events produced with PU.					
Planned secondment(s): ESR1 will be recruited by ICSS where he will spend 18 months under the supervision of Dimitrios Soudris for software and integration purposes. For 18 months he will be seconded to KI (industrial sector) under the supervision of Luca Serafini for firmware development. Both Hosting institutions will participate to develop the analysis of results and plan their exploitation.					

Fellow *ESR2*	**Host (recruiting) institution MAX**	**PhD enrolment Y**	**Start date M9**	**Duration 36 months**	**Deliverables D2.1b, D2.2b, D2.3b, D2.4b; D2.5b**
Project Title and Work Package(s) to which it is related: MAX platform application to FTK simulation and tracking at LHC.					
Objectives: all objectives of table describing WP2, focusing on MAX hardware; use of the MAX platform to simulate FTK in detail for huge Monte Carlo events production and generic tracking at LHC.					
Expected Results: D.2.1b: Strategy to implement FTK simulation and tracking on MAX technology ready; D.2.2b and D.2.3b: software and firmware ready to use the MAX platform; D.2.4b Successful Test of simulation/tracking on MAX technology; D.2.5b: Monte Carlo events produced with PU.					
Planned secondment(s): ESR2 will be recruited by MAX (industrial sector) where he will spend 18 months under the supervision of Georgi Gaydadjiev. For 18 months he will be seconded to UNIPI under the supervision of xxx. UNIPI will provide all the needed background about the Monte Carlo simulation task and tracking of LHC events, while MAX will provide the needed competences to use efficiently its platform. Both institutions will participate to develop the analysis of results and plan their exploitation.					

Fellow *ESR3*	**Host institution SDS**	**PhD enrolment Y**	**Start date M9**	**Duration 36 months**	**Deliverables D.3.1, D3.2, D3.3, D3.4;**
Project Title and Work Package(s) to which it is related: Space debris trails detection in telescope images					
Objectives: all objectives of table describing WP3: use of the MAX platform to process large telescope images in real time, using brain-like algorithms.					

Expected Results: D.3.1: candidate trail detection algorithm defined; D.3.2 MAX platform strategies for trail-detection defined; D.3.3: parallel software implementation and MAX-accelerated software integration; D.3.4: hybrid MAX-advanced software integrated platform tests;
Planned sharing time between academic and not-academic institute(s): ESR3 will be recruited by SDS (industrial sector) under the supervision of Francesca Guerra and by ICCS for other 18 months under the supervision of Dimitrios Soudris. SDS will provide all the needed background about the space debris detection task using its experience on the field, while ICCS will provide the needed competences to use efficiently the MAX platform. Both Hosting institutions will participate to develop the analysis of results and plan their exploitation.

Fellow ***ESR4***	**Host institution** **GEGR**	**PhD enrolment** **Y**	**Start date** **Month 6**	**Duration** **36 months**	**Deliverables** **D4.1; D4.5; D4.6**
Project Title and Work Package(s) to which it is related: Advanced multi-parametric 3D MRF, WP4					
Objectives: O.4.5 Development and acquisition of novel multi-parametric 3D MRF sequences; O4.4 Application of the two new PM methods to standard 2D MRF; O.4.6 Application of the new PM methods to novel 3D MRF sequences					
Expected Results: D4.1 Optimised MRF using GPUs;D4.5 MRF with compressed dictionary and multiple parameters; D4.6 Comparison of new MRF methods featuring new reconstruction hardware with standard MRF					
Planned secondment(s): ESR4 will be recruited by GEGR-E (industrial sector) where he/she will spend 18 months under the supervision of Dirk Bequé. GEGR-E will provide the needed competences for training on MRI and MRF acquisition. ESR4 will spend 18 months in Pisa, of which 9 months at IMAGO7 to work on new acquisitions for 7T. The supervisor for both UniPI and IMAGO7 will be Michela Tosetti. All institutions will participate to develop the analysis of results and plan their exploitation.					

Fellow **ESR5**	**Host institution** **UNIPI**	**PhD enrolment** **Y**	**Start date** **Month 6**	**Duration** **36 months**	**Deliverables** **D4.2; D4.4; D4.5; D4.6**
Project Title and Work Package(s) to which it is related: Accelerated MRF reconstruction using the PUMA hardware, WP4					
Objectives: O.4.2 Development of new algorithms for MRF pattern matching with PUMA accelerator; O4.4 Application of the two new PM methods to standard 2D MRF; O.4.6 Application of the new PM methods to novel 3D MRF sequences					
Expected Results: D4.2 functioning PM algorithm for MRF using PUMA simulation; D4.4 MRF reconstruction using PUMA; D4.5 MRF with compressed dictionary; D4.6 Comparison of new MRF methods featuring new reconstruction hardware with standard MRF					
Planned secondment(s): ESR5 will be recruited by UniPI (academic sector) where he will spend 18 months under the supervision of Alberto Annovi UNIPI will provide all the needed background about the baseline PU. GEGR-E will provide the needed competences for training on MRI and MRF reconstruction, including dictionary compression specific to AM chip. At GEGR-E ESR5 will be supervised by Dirk Bequé. Both institutions will participate to develop the analysis of results and plan their exploitation.					

Fellow ***ESR6***	**Host institution** **UNIPI-Maxeler**	**PhD enrolment** **Y**	**Start date** **Month 6**	**Duration** **36 months**	**Deliverables** **D4.1; D4.3 D4.6**
Project Title and Work Package(s) to which it is related: Accelerated MRF reconstruction using FPGAs, WP4					
Objectives: O.4.1 Development of optimised PM code for MRF on standard CPU and GPU; O.4.3 Development of new algorithms for MRF pattern matching with FPGA arrays; O4.4 Application of the two new PM methods to standard 2D MRF; O.4.6 Application of the new PM methods to novel 3D MRF sequences					
Expected Results: D4.1 Optimised MRF using GPUs; D4.3 MRF reconstruction using FPGA arrays; D4.6 Comparison of new MRF methods featuring new reconstruction hardware with standard MRF					
Planned secondment(s): ESR6 will be recruited by MAX where he/she will spend 22 months under the supervision of Tobias Becker and for 14 months he/she will be recruited to UNIPI, including a secondment at IMAGO7 for six months. Michela Tosetti will be the supervisor for UNIPI and IMAGO7, and will provide the needed background about the MRF reconstruction, while MAX will provide the needed competences to use efficiently its platform. All institutions will participate to develop the analysis of results and plan their exploitation.					

3.2 Appropriateness of the management structures and procedures

- <u>Network organisation and management structure</u>,

The Network will sign a Consortium Agreement before the start of the project.

Financial Management The PC has the overall project financial management (WP7), receiving the funds, distributing them to the beneficiaries, and the partners as expected by their involvement on the trainings of the ESRs and as described in the Consortium Agreement. Partners hosting and training students will receive the "Research, Training and Network Costs" for all the months the student is hosted. The financial follow-up will be realized in collaboration with the individual beneficiary institution coordinators. Expenditures are monitored and recorded at the level of each individual institution in compliance with EU rules.

Supervisory boards The project is managed by an Executive Board (EB), and a General Assembly (GenA). The EB is responsible for implementation of the Network program and the GenA oversees and coordinates the actions of the Network. The Network coordinator chairs the EB, which includes an academic and a non-academic representative of each WP as well as one gender officer, which will also be involved in the recruitment. The EB is responsible for the recruitment and the monitoring of the progress. The EB will also organize the Network-wide events, such as the workshops and schools. The same body will coordinate the presentation of the Network activities to workshops and conferences and the publication of the results. The GenA instead is composed by one representative member per participant (either full or associated) and meets twice per year. The GenA monitors the actions taken by the EB ensuring that the Network goals are met.

Joint governing structure The scientific and administrative coordination of the individual ESR research projects are carried out by the participating institutes (both academic and non-academic institutions). The academic supervisor will be the project contact person, but either the academic or non-academic supervisor can inform the EB (balanced between academic and non-academic sector) of any problems that might arise. The EB can propose changes to the research and/or training program that need to be also approved by the GenA. In the case the changes result in possible deviations from the contractual obligations of the ITN, the EU Commission Officer in charge of the ITN will be promptly involved.

Recruitment strategy The Network strategy for recruitment will comply with the European Charter of Researchers and the Code of Conduct for the Recruitment of Researchers, adopted by the European Commission. In order to recruit the best candidates, the Network ensures that the positions will be widely advertised through the main job posting services, which includes the following steps:

(i)Job description: each Network participant, in accordance with the GenA and the EB, will define the job research work and the profile of the candidate.

(ii) Job posting: All positions will be advertised in "CORDIS" mobility portal of the EU, local institution Web servers, in the communities of the involved research area.

(iii) Selection of candidates. The host institution is in charge of clearly stating the scientific job description together with the required key skills and selection criteria. An eligible applicant should submit his/her application to the recruitment office of the local network participant, together his/her CV and at least two recommendation letters in due time. Positions for the ESR are requested to be hired in compliance with the individual institution's rules for PhD recruitment, which vary from one EU member to another. In the case where exams are requested, the selection criteria should be clearly stated. Assessment will be based on discerning the best candidate through individual colloquia, CV and the letters of presentation, evaluating the academic qualification, experience, achievements, pro-activeness, English language knowledge, capacity to work in teams and mobility. The board of selectors will include one local Network participant representative, the two future student supervisors and the gender officer.

Progress monitoring and evaluation of individual projects WP Leaders will report at regular intervals of three months to the PC. The completion milestones will be discussed in the PUMA technical meetings (T7.3). If information affecting the achievement of a specific milestone becomes available before the due date, the WP Leader will be notified immediately and appropriate action will be taken. The detailed evaluation procedure of the individual projects includes two fundamental phases: (i) *The Deliverable Assessment Procedure*: The deliverable assessment procedure consists of two stages: (a) each deliverable will be reviewed by the corresponding WPL and submitted to some reviewers selected from the other members of the Consortium and (b) each deliverable will be approved by the PC and issued to European Commission. (ii) *The Milestone Assessment Procedure*: The milestone assessment procedure is based on a document to be provided by the WPL composed of two parts: (a) a *Generic Part*, common for all the milestones (reported in Appendix A) and (2) a *Specific Part*, customised for each milestone, which will be specifically defined during the first meeting of the associated WP. Intermediate checks about the assessment of each milestone will be done periodically during the PTC meetings. The assessment of each milestone will be performed during the first technical meeting after the due date. In case of non-approval, corrective actions will be defined and the milestone will be re-submitted in the next technical meeting. A report on the approval of milestones will be provided at the end of each reporting period in the PPR.

Risk management The Consortium will implement a risk management plan, based on a rigorous and continuous risk analysis methodology involving all the partners. Thus, throughout the project, the PC will be in charge of the early identification of prospective major risks and the analysis of their possible consequences on project results. The PC will promptly inform all the partners and concerned bodies and provide them with one or more of: (1) an *Avoidance Plan* giving the right solutions to prevent risk occurring and (2) an appropriate *Mitigation Plan* to review the foreseen RTD objectives and to reduce the chance of risk occurring; and (3) a Contingency Plan to minimise the risk impact once it has occurred. A global contingency plan has been already identified in the Risk Table, and will be checked and updated at the end of each Reporting Period. The revised Risk Table will be inserted in each PPR, including a column for the assessment of each risk as well as the set of newly identified risks (if any).
Intellectual Property Rights (IPR) The general rules for access, dissemination and use of intellectual property will be applicable to the ITN project. The GenA will ensure that scientific results from the project will be disseminated as effectively as possible, compatible with the protection of intellectual property of the non-academic Partners involved. Non-disclosure agreements might be required by industrial partners (or technology Institutes) before granting access to detailed information about their proprietary technologies. The Consortium Agreement and the deliverable reports of T6.3 will established during the early execution of project the IP rights and policies, which be followed by all partners. Particularly, IPR will be an important section of the Consortium Agreement, defining the ownership of a derived result (e.g., methodology, software, design technique etc).
Gender aspects (both at the level of recruitment and that of decision-making within the project). The Network will pursue an Equal Opportunity policy, addressing not only gender balance, but also broader issues, such as disabled researchers, life-work balance, culture diversity and family obligations. Diversity will be monitored. In order to minimize gender bias, each selection board should have adequate balance of women and men. Special attention is paid in choosing gender balance among the speakers for training lectures and seminars, as well as relevant roles in committees. One member of the EB will be appointed as gender officer to care about all gender aspects.
Strategy for dealing with scientific misconduct PUMA decided to adopt the principles of the "Scientific Misconduct Strategy of ERC (European Research Council)", which is the European (and worldwide) leader in pioneering research. Additionally, ERC follows the "A comprehensive strategy on how to minimize research misconduct and the potential misuse of research in EU funded research." In context of PUMA, all concerns about potential scientific misconduct or suspected breaches of research integrity concerning a member of network, will be addressed by the PC and GenA. In addition, the PC will inform immediately the EC Project Officer, who is responsible for PUMA technical and management activities. The Table 3.2a describes the mitigation plans of PUMA personnel.
Data Management Plan (DMP) The PUMA consortium participates to the Pilot on Open Research Data in Horizon 2020. The consortium policy on data management will be reported in the DMP report at M6 of WP6. The DMP will be continuously updated and a final report will be available by M48. PUMA data will be "easily discoverable, accessible, assessable, intelligible, usable, and wherever possible interoperable to specific quality standards", following the guidelines from the "Open Access to Scientific Publications and Research Data in Horizon 2020". Emphasis will be given on how each partner or group of partners will deploy, implement and materialize the key goals of the PUMA DMP. Additionally, the DMP activity will instruct the young scientists about the European Initiatives and policies on Open Data strategy. The Dissemination WP Leader will act as "Data Manager", following the Horizon 2020 guidelines to provide accurate and complete documentation for data preservation. Finally, appropriate clauses for data management will be included in the Consortium Agreement. It's worth mentioning that PUMA consortium decided to participate in Open Research Data European Initiative because the young scientists (ESRs) should be aware about the EU policies and how them will affect their career and eventually, they should understand in depth, the opportunities in the future research and business EU landscape.

Table 3.2a Implementation Risks

Risk No.	Description of Risk	WP Number	Proposed mitigation measures
Management Risks			
1	Consortium has no harmony	WP7	The Project Coordinator will continuously be in contact with all partners. This guarantees that any team problems will be identified and solved before they escalate.
2	Partner leaves Consortium	WP7	Consortium is of sufficient strength and diversity so that partners can be replaced if required. Also, the coordinator will ensure appropriate control and management of the work in progress so that the remaining partners can complete the work, until a new partner is found.

3	Key staff illness/leave during critical project phase	WP7	All partners have experienced staff that may replace and take over the work assigned to the leaving member, either temporarily or permanently.
4	Poor quality of deliverables and delay in meeting the deadlines	WP1- WP7	Proper internal peer review procedures and criteria will be in place in order to ensure the quality of the deliverables and their preparation in a timely manner.
5	Personnel: an ESR supervisor leaves the consortium	WP2,WP4, WP3, WP4	Each academic and industrial partner will replace ESR supervisor, with another professor from the same institute and a senior expert from the company.
6	Managerial risks such as not meeting timelines	WP7	Continuous monitoring of effort by the GA and comparison between achieved and set goals during the whole project. If needed we will adjust the manpower distribution across the WPs and activities to find the best project-wide trade-off between quality and available effort/resources
Technical Risks			
1	Application monitoring provides inaccurate feedback	WP2, WP3, WP4	To mitigate this risk we'll use corroborating sources of evidence in order to detect human or machinery related incidents with important inaccuracies.
2	Integration with existing heterogeneous systems fails	WP2, WP3, WP4	The design and implementation of components should be strictly decoupled from all tool- specific details. Interfaces should be compatible with the existing standards.
3	HW Platforms are not available on time or underperforming	WP1, WP2, WP3, WP4	The validation will be carried out on other existing HW platforms or by simulation. Possibly alternative technology suppliers will be considered. A run-time reallocation of the manpower could be considered.
4	Difficulties in adoption, deployment and integration of the new technologies	WP2, WP3, WP4	Early assembly and validation of components is foreseen within each WP. Interfaces between WPs and research groups are clearly defined. The breakdown in WPs and activities is designed to minimise the risk upfront. Extra tuning will be done as needed.
Exploitation Risks			
1	Disputes over ownership of IPR amongst consortium partners	WP6, WP7	Standard IPR and access rights clauses will be included in the Consortium Agreement, which will be signed before work starts to avoid future disputes. Moreover, the consortium has already discussed internally these aspects.
2	Breach of IPR conditions within consortium agreements	WP6, WP7	It will be ensured that any IPR clauses are properly understood before signing the Consortium Agreement. Any clauses which present difficulties will have to be negotiated beforehand among partners.
3	Lack of interest on the PUMA project by external stakeholders	WP6, WP7	The Task partners on this part of the project will manage a continuous operation on communication channels in order to keep in touch with multiple stakeholders. Also, various dissemination activities will be carried out to raise the awareness and increase the interest

3.3 *Appropriateness of the infrastructure of the participating organisations*

UNIPI - the FTK/INFIERI laboratories are the perfect environment, since all instrumentation and personnel needed for real time developments will be equally necessary for the baseline PU assembly, test and use.

GEGR-E provides the needed expertise and networking to achieve engineering and implementation goals relevant to medical imaging products. There, the supervision and resources for the fellows are close to ideal. The centre connects clinical and research needs with development solutions. Within GEGR-E, fellows have access to the latest technology in computing and medical imaging. Indeed, the center is one of the main R&D sites of a major scanner manufacturer (GE Healthcare). Collaborating with an imaging system vendor significantly improves the chance of success, as well as opening possibilities for wider applications and collaborations within the network of GE scanner users.

IMAGO7 is a leading centre for the study and application of new medical imaging technologies. The centre has a 7T MRI scanner with access to patients with neurodegenerative disease, cancer as well as psychiatric individuals. Further, the centre is located inside a paediatric hospital, and the group has a long and successful history of paediatric research using MRI. This environment will permit the timely application of the techniques developed here to groups of patients with different diseases, with the potential for new discoveries in neurology and radiology.

Kayser Italia, inside its 5000 sq. meters of property, has a highly qualified Electronics hardware department, laboratories, clean room, manufacturing, inspection and integration area. The electronics laboratories include oscilloscopes, multimeters, logic analyzers, spectrum analyzers, data acquisition systems, signal conditioners, power supplies, sensors, calibrators and development tools for various microprocessors and FPGA. The student will have the possibility to gain fundamental expertise from the continuous interaction with the highly skilled staff members.

SpaceDyS infrastructures for research include one open space SW development area, one meeting room with teleconference facilities, a server room equipped with a server Supermicro 2042G-TRF –CPU AMD Opteron Sixteen Core 6278, with 64 cores plus other smaller service servers. The open space area has up to 12 workstations available for the employees.

ICCS: The Microlab includes suitable computing infrastructure including several manycore Intel Phi, SCC as well as state-of-the art FPGAs boards. Also, software tools for supporting the design mapping on computing platforms. Both hardware and software will materialise the adopted design strategy.

Maxeler's lab facilities in London include a mix of heterogeneous HPC infrastructures including multi-core servers as well as Maxeler MPC-C and MPC-X Series dataflow nodes, high performance networking and storage, which will be available for use in the project. As well as general-purpose resources, Maxeler will construct a configurable multi-DFE system to be hosted in London and made available for remote access by the other project participants.

3.4 *Competences, experience and complementarity of the participating organisations and their commitment to the programme*

- Consortium composition and exploitation of partners' complementarities:

This project brings together leading centres for an innovative training program aimed at successfully implementing and applying new technology. ICCS, MAX are leaders in high-performance computing and KI is leader for specific hardware production for specific problems. Here, their expertise will be merged with the complementary capabilities of the other institutions, which are expert in potential applications of novel hardware accelerators, specifically: UniPI for HEP, SpaceDys for debris trails and GEGR-E and IMAGO7 for medical imaging. With this project, a new community will be created, where the needs of potential "users" of new and performant technologies will be linked to top researchers and engineers capable of fulfilling such needs. Through such an arrangement, based on mutual respect and trust between experts in different fields, we envision a successful implementation of meaningful technological advancements, immediately relevant to multiple applications. This will create a next generation of experts which will be able to fill the gap between technology development and application, and will be able to communicate both to developers and to users. Further, using such a practical and interactive approach, we aim at a fast and effective commercialisation of technological products arising from this research, with a potential extension to even more complementary fields.

- Commitment of beneficiaries and partner organisations to the programme

Each beneficiary and partner organisation have contributed to drafting the proposal and have revised and agreed with the latest version. Each institution will take full responsibilities for an effective implementation of the work they have committed to as described in this proposal. Administrative staff and heads of department have been informed and have been supportive of the current proposal. Commitment letters for partner institutions are enclosed within this application.

i) Funding of non-associated third countries (not applicable):

ii) Partner organisations:

PUMA includes two partner organizations, IMAGO7 and KI.

Within the **IMAGO7** research centre, data is acquired and analysed in a variety of patient populations, including neurodegeneration as well as pediatric patients, and the group has leading expertise in new quantitative methods for data acquisition and image analysis. The centre will offer secondments on MRF acquisition and analysis and will host a three-day EU course on MR Fingerprinting. Currently, to our best knowledge, there has never been a course on this technique and this may represent one of the first to be held worldwide. In addition, during the secondments at IMAGO 7, the fellows will acquire knowledge on the emerging topic of ultra-high field MRI, including the main engineering problems of ultra-high field scanners, as well as application within research programs in volunteers and patient groups.

KI has hardware development expertise very important for the Network. KI will offer the possibility to accommodate one Early Stage Researcher (ESR) from the ITN for a period of 18 months to implement and test the baseline PU. The ESR will receive training in FPGA development. KI will participate to part of the activities related to WP1 as described in section 3.1 of the PUMA proposal, to the WP5 offering the Network-Wide Training Event "Technology in space applications, with reference to ASI and ESA research activities". Senior staffs from KI will be invited to some of the ITN workshops and annual schools.

DOCUMENT 2 (*no overall page limit applied*)

4. Gantt Chart

Reflecting ESR recruitments, secondments, training events, management and dissemination / public engagement activities

	Months	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	
	Colour Legenda						UNIPI					ICCS					SDS					MAX				GEGR-E					IMAGO7						KI												
Researcher Recruitment	ESR 1 WP1 & WP2									S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S	S																						
	ESR 2- WP1 & WP2									S	S	S	S	S	S	S	S	S	S	S	S	S																			S	S	S	S	S				
	ESR 3 WP1 & WP3																																																
	ESR 4 WP1 & WP4											S	S	S	S	S	S	S	S	S	S	S	S	S								S	S	S	S	S													
	ESR 5 WP1 & WP4													S	S	S	S	S	S	S	S	S	S	S	S	S	S							S	S	S	S												
	ESR 6 WP1 & WP4								S	S	S	S	S	S																																			
Training (WP5)	Conference																																																
	Trainings																																																
	Visiting Scientist														V			V																															
	Other																																																
Mana-gement (WP7)																																																	
	Meetings		K									1								2							3											4											E
	Workshop																																																
Dissemi-nation. Public engage-ment WP6	HiPEAC CSW																																																
	FTK workshop																																																
	Imago7 Eve																																																
	Dissemination																																																
	Exploitation																																																
	Web site																																																
	Open Days																																																
	Workshop Days																																																
	Schools																																																

S = Secondment[1]
K = Kick-off meeting
E = End of project

[1] **30% secondment rule**: Under ETN, each recruited researcher can be seconded to other beneficiaries and /or to partner organisations for a duration of up to 30% of his/her recruitment period (this limitation does not apply to EID and EJD, insofar as time spent at other participating organisations occurs in line with the proposal).

5. Participating Organisations

Beneficiary Legal Name: University of Pisa (UNIPI)	
General description	The Enrico Fermi department of Physics in Pisa is classified (2015 QS ranking) number 30 in the world. It has ~90 faculty members. The Physics department collaborates strongly and finds a common infrastructure in the Pisa division of Istituto Nazionale di Fisica Nucleare (INFN), for both particle physics and its applications in the medical sector. Pisa had a leading participation into many particle physics experiments: CDF (Fermilab), Aleph (LEP), CMS and Atlas (LHC) for collider physics. The Tracker Inner Barrel (TIB) was designed/produced in Italy and integrated in the large Pisa infrastructures. The Atlas group is small but had an important role in the tile calorimeter construction and has now a leading role in the FTK project. The Heavy Flavour experiments have been strongly represented both in the K (Epsi) and B (Babar) sectors; the neutrino sector by the Chooz and Nomad collaborations, the rare decay experiments by the MEG and the N64 experiments, the gravitational wave physics by the VIRGO laboratory. A large activity is present for astroparticle physics (Glast, AMS, Cream, Magic, Antares and Nemo) and physics applied to medical aspects: NMR (IMAGO7), PET and multimodality (TRIMAGE) and computer aided medical diagnosis, CAD, (MAMMOGRID, MAGIC5) are strongly represented.
Staff Expertise	Physicists with large experience in Hadron Collider Physics (CDF, Atlas), in particular trigger and online/offline tracking (SVT at CDF and FTK at Atlas): **(1) UNIPI Full Professor** M. Dell'Orso (management-dissemination-outreach, FTE=40%) one of the two researchers that proposed the AM technology in 1989 [NIM A 278, 436 (1989): VLSI Structures for Track Finding]; international coordinator of the European project FP7-PEOPLE-2012-IAPP FTK (GA N. 324318); **(2) UNIPI Assistant Professor** A. Rizzi (15%) expertise on both hardware design/test and software development; **(3) UNIPI researchers:** M. Tosetti (20%) teaches the undergraduate course in MRI. She has extensive experience in the field of novel MR techniques applied to neurosciences, neurological and neuropsychiatric disorders of the developmental age. Recently she works on Ultra-High Field Magnetic Resonance (UHF-MR) as Project Manager of the first Italian 7T MR system installed at the IMAGO7 Foundation in Pisa. S. Donati (30%) responsible of the CDF trigger in 2009-2011, expertise on software development and management; (6) C-L Sotiropoulou; (30%) leader of the real time imaging R&D, expertise on firmware development and tests, dissemination and management activities; **(4) UNIPI technological staff:** Engineer M. Piendibene (30%) responsible of the AM boards development in FTK , large experience in hardware development and test. **(5) INFN directors of research**: P. Giannetti (30%) proposer and PI of the R&D, part of the management of FTK project, expertise on management, dissemination, hardware development and tests; F. Palla (15%) responsible of integration and commissioning of the CMS tracker detector and co-leader of the CMS Level 1 Tracker for Phase II, expertise on management, dissemination, software development and tests; **(6) INFN researcher**s A. Annovi (20%,) project leader of FTK , expertise on management, dissemination, software/hardware development and tests; A. Retico (10%) large experience in the medical sector, NMR and CAD diagnosis, management, dissemination skills.
Key facilities and infrastructure	HEP and applied physics (medical sector) activity is strongly supported by (a) a strong theoretical team, (b) large laboratory space for all different activities (c) high-level infrastructures for electronics service (designing and production/test of ASICs, FPGAs, boards), mechanics service (designing, developing, integrating detectors and large structures), high-technology (clean-rooms for silicon detectors with all necessary machines), computing (GRID facilities).
Previous involvement in Research Programmes	EU funds: 254410 FP7-PEOPLE-2009-IOF (Scientist in Charge A. Annovi), 39099 FP6-PEOPLE-2006-IOF (Scientist in Charge P. Giannetti); 00326 FP5-PEOPLE-2002-HPRN-CT (Scientist in Charge for INFN-Pisa F. Palla) National funds: (1) FTK - INFN National Scientific Committee (NSC) V,I funds : 1999-now; (2) CDF trigger Upgrades, in particular Silicon Vertex Tracker (SVT) – INFN NSC I funds 2003-2007 (3) CMS TRACKER construction – INFN NSC I funds 2000-2006 (4) "Medical Applications on a Grid Infrastructure Connection", MAGIC5 (2004-2010), SEVEN (2011-2012), TESLA (2013-2014) - INFN NSC V funds (5) TEMA (Monitoring Techniques in Hadrontherapy), Scientist in charge for INFN A. Retico – funds INFN-RT (POR FSE 2007-2013)
Current Involvement in Research Programmes	EU projects: FP7-PEOPLE-2012-IAPP FTK (GA N. 324318, international coordinator M.Dell'Orso); FP7-PEOPLE-2012-ITN INFIERI (GA N. 317446, Scientist in Charge for INFN F, Palla); H2020-MSCA-RISE-2015 MUSE (GA 690835 S, Scientist in Charge for UNIPI S. Donati) National & regional projects: (1) PRIN 2013 HTEAM (MIUR - coordinator G.Tonelli); (2) PRA 2015 (coordinator S. Donati); (3) R&D for Level-1 Track Trigger for HL-LHC (A. Annovi & F. Palla INFN coordinators)– INFN NSC I funds 2015 (4) RD53 65 nm rad-hard readout chip for the silicon pixel detectors for HL-LHC (F. Palla Pisa coordinator). nextMR (INFN NSC 5, coordinator A.Retico) RF coil development and SW application for UHF MRI (2015-2017.) Project GR2317873 (Ministero della Salute e RegioneToscana, Scientist in Charge for INFN A. Retico) and ARIANNA (Regione Toscana, Bando FAS Salute 2014, Scientist in Charge for INFN A. Retico)
Publications	(1)"Observation of B0s - anti-B0s Oscillations". CDF Collaboration, Phys. Rev. Lett. 97, 242003, 2006; (2) A. Annovi et al., "A VLSI Processor for Fast Track Finding Based on Content Addressable Memories". IEEE Transaction on Nuclear Science, vol. 53; p. 2428, 2006 (3) C-L Sotiropoulou et al, "A Multi-Core FPGA-based 2D-Clustering Implementation for Real-Time Image Processing", IEEE Transactions on Nuclear Science, vol. 61, no. 6, pp 3599-3606, December 2014; (4) Andreani et al, "The Fast Tracker Real-Time Processor and its Impact on Muon Isolation, Tau and b-Jet Online Selections at ATLAS ", IEEE Trans, Nucl. Sci. 59, pp 348-357, 2012 (5) A. Annovi et al, "Associative Memory for L1 Track Triggering at LHC ", Vol. 60, I. 5, Part 2, pp. 3627-3632, 2013

Beneficiary Legal Name: GE Deutschland Holding GmbH – GECR-E	
General Description	GE Global Research (GEGR) is the Industrial Research Organisation of General Electric (GE). It is a multi-disciplinary organization with ~180 scientists in Germany and ~3000 scientists worldwide (US, India, China, Brazil). GE Global Research - Europe (GEGR-E), the European Research Center of GE and part of GE Deutschland GmbH, conducts research in the fields of Diagnostics, Imaging and Biomedical Technologies; Aero- Thermal and Mechanical Systems; Composite Manufacturing and Electrical Systems.
Role and Commitment of key persons (including supervisors)	Dr. ir. Dirk Bequé, Lead Scientist in GEGR-E, has expertise in image reconstruct-tion, system modelling and calibration of/for CT, PET, SPECT, XPCi, and MRI. He will act as key contact for GEGR-E, act as industrial mentor for 2 Early Stage Researchers and coordinate the educational program offered at GEGR-E, representing an FTE of 20%.
Key Research Facilities, Infrastructure and Equipment	GEGR-E is located on the Research Campus Garching (‘Forschungscampus Garching’) near Munich, Germany. The campus is the major site of the Technische Universität München (TUM) and houses 3 Max-Planck-Institutes (MPI) as well as various other renowned research institutes. DIBT – Europe, the medical imaging laboratory of GEGR-E, is equipped with an experimental 3T MR-system in-house and a jointly operated clinically certified 3T MR-system located on the premises of IMETUM, part of TUM. GEGR-E also has a high-performance computing cluster in-house.
Independent Research premises	GEGR-E has its own research premises on the Forschungscampus Garching with its own 3T MRI system and high-performance computing cluster. GEGR-E further jointly operates a 3T MRI scanner with IMETUM, part of TUM. The latter MRI system is located on the premises of IMETUM.
Previous Involvement in Research and Training Programmes	1) BMBF Mobitum (FKZ 01EZ0826 – June 2008 – November 2011), supervision of 1 PhD project. 2) Two joint PhD projects together with TUM GSISH. 3) German BMBF-funded grant (Innovation competition medical technology 2010 (3-y collaborative research on 13C metabolic MR imaging, FKZ 01EZ1114A, together with TUM and Rapid Biomedical), supervision of 7 PhD projects. **4)** Bavarian research program on phase-contrast X-ray imaging („Leitprojekte Medizintechnik“ (BayMed)), supervision of 2 PhD projects.
Current Involvement in Research and Training Programmes	1) GEGR-E is currently actively involved as associate partner in ITN ‘Biomedical Imaging & Informatics – European Research and Training Initiative (BERTI)’. 2) GEGR-E is currently actively involved as associate partner in ITN EUROPOL on ‘Developing New Applications for Hyperpolarisation NMR’.
Relevant Publications and/or Research / Innovation Product	[1] Sperl J.I., **Bequé D.**, Kudielka G.P., Mahdi K., Edic P.M., Cozzini C., “A Fourier-domain algorithm for total-variation regularized phase retrieval in differential X-ray phase contrast imaging, “ *Optics Express*, 22(1), pp. 450-462, 2014. [2] Seeber D., **Bequé D.**, Koch K., “Phantom Results with a Matrix Shim Coil,” *ISMRM*, Milan, Italy, 2014. [3] Sperl J.I., **Bequé D.**, Claus B., De Man B., Senzig B., and Brokate M., „Computer Assisted Scan Protocol And Reconstruction (CASPAR) – Reduction of Image Noise and Patient Dose,“ *IEEE Trans. Med. Imag.*, Vol 29(3), pp. 724-732, 2010. [4] **Bequé D.**, Nuyts J., Suetens P., and Bormans G., “Optimization of Geometrical Calibration in Pinhole SPECT,” *IEEE Trans. Med. Imag.*, Vol 24(2), pp. 180-190, 2005. [5] **Bequé D.**, Nuyts J., Suetens P., Bormans G., “Characterization of Pinhole SPECT Acquisition Geometry,” *IEEE Trans. Med. Imag.*, 22(5), pp. 599-612, 2003.

Beneficiary Legal Name: SpaceDyS (SDS)	
General description	SpaceDyS (SDS) is a company founded in 2011 as a spin-off of the Celestial Mechanics Group of the University of Pisa, located in Cascina (Pisa, Italy) at "Polo Scientifico e Tecnologico di Navacchio". SDS is made up by a team of experienced researchers in the space sector with high-level background in Mathematics, Physics, Astronomy and advanced skills in Flight Dynamics, Mission Design and Computer Science. At present, SpaceDyS has a group of eleven associates, the senior ones having a strong experience in the space business, with many years of work on programmes with space agencies such as ESA, NASA. and ASI. SDS collaborates strictly with the "Department of Information Engineering and Mathematical Sciences" (DIISM) of the University of Siena, consisting of 76 scientists, about 50 PhD students and post-doctoral fellows in Information Engineering topics. S. Bartolini from DIISM will support SDS for research, training, dissemination, outreach.
Role and Commitment of key persons (including supervisors)	**Francesca Guerra** has a Laurea degree in Mathematics and has worked for the ATIP project (Advanced Tracklet Image Processing), funded by the European Space Agency. Project allocation: 25% **Fabrizio Bernardi** has a PhD degree in Astronomy and several years of experience in observational astronomy with high-class telescopes. In particular he has developed several programs for image processing of moving objects (asteroids or space debris). Project allocation: 10% **Sandro Bartolini**,got a PHD in "Computer Science and Engineering" in 2003 (UNIPI). He is Assistant Professor (Researcher) at DIISM. His main interests comprise: computer architecture, heterogeneous programming of parallel architectures, feedback-driven compiler optimizations for cache memory hierarchy and low power, chip-multiprocessors enabled by integrated photonics, special-purpose accelerators for embedded and high-performance systems. DIISM will be a perfect environment for trainings, dissemination and outreach. Project allocation: 10%
Key Research Facilities, Infrastructure and Equipment	SpaceDyS is located inside the "Polo Tecnologico" of Navacchio, where several services and facilities are available: meeting room, fast internet connection, PR office … SpaceDyS has also its own meeting room equipped with a teleconference system. SpaceDyS has a server room with a rack where a 64 cores server is placed together with other smaller servers for support services (project management, website, …) SpaceDyS is also equipped with several work stations (13). DIISM lab is equipped with several high-performance computing nodes (up to 64-cores, up to 1 TB RAM, various NVidia GPU cards and Xeon Phi accelerator) and dedicated software (e.g. Intel Parallel Studio). It is available for SDS research and trainings, open to students for the Open days, Night of Researchers events, very useful for SDS contacts with Engineering students.
Previous and Current Involvement in Research and Training Programmes	FP7- SPARC:Space Awarenes for Critical Infrastructures. Contract n. HOME/2011/CIPS/AG/4000002119 FP7 – Stardust (ITN). Contract n. PA/STARDUST/115939 PRO-CReO: CEOD Computational Engine for Orbit Determination ESA studies: ATIP,SN-III, SN-V,CO-II, P2-NEO-I, P2-NEO-II, SLA1,SLA2,SLA3, NEOSTEL, P2-SST-IV, EOLDC, GOCE Re-entry. ASI studies: BepiColombo mission MORE experiment, JUNO mission.
Relevant Publications and/or Research / Innovation Product	• ATIP – Advance Tracklet Image Processing. Funded by ESA for a triangulation initiative. • Wide Eye Debris telescope allows to catalogue objects in any orbital zone, Cibin, L.; Chiarini, M.; Milani Comparetti, A.; Bernardi, F.; Ragazzoni, R.; Pinna, G. M.; Zayer, I.; Besso, P. M.; Rossi, A.; Villa, F., Memorie della Societa Astronmica Italiana Supplement, v.20, p.50 (2012) • Discovery of Very Small Asteroids by Automated Trail Detection, Milani, A.; Villani, A.; Stiavelli, M., Earth, Moon and Planets, Volume 72, Issue 1-3, pp. 257-262 • Grani P., Bartolini S., Furdiani E., Ramini L., Bertozzi, D., "Integrated cross-layer solutions for enabling silicon photonics into future chip multiprocessors," in Mixed-Signals, Sensors and Systems Test Workshop (IMS3TW), 2014, pp.1-8; • Grani P., Bartolini S. "Design Options for Optical Ring Interconnect in Future Client Devices", ACM Journal on Emerging Technologies in Comput. Sys., 2014,25 pp;

Beneficiary Legal Name: – Institute of Communications and Computer Systems (ICCS)	
General description	The Institute of Communications and Computer Systems (ICCS) is a non-profit Academic Research Body established in 1989 by the Ministry of Education in order to carry research and development activities in the fields of all diverse aspects of telecommunications and computer systems. ICCS is associated with the School of Electrical and Computer Engineering of the National Technical University of Athens (NTUA). The personnel of ICCS consists of a number of Research scientists and more than 500 Associate scientists (including PhD students). The Microprocessors and Digital Systems Laboratory (MicroLab) of ICCS, which participates in the current proposal, is actively involved in the implementation of digital systems, from system level up to chip level, using the most advanced and modern technologies and methodologies, ranging from microprocessors and microcontrollers, embedded systems development boards, signal processors, special purpose ICs and FPGAs. The MicroLab has been granted many European and National Research Programmes (> 55 projects). The main results of all projects have been published in relevant international conferences and journals, and, received best paper awards and the EU-sponsored HiPEAC awards. Additionally, ICCS has long experience on the coordination and execution of plethora dissemination activities in several EU-funded projects.
Staff Expertise	ICCS/MicroLab has a long track record in developing design- and run-time techniques for the optimization of embedded systems based on digital systems design of multicore/many-core and reconfigurable systems (FPGAs) with implementation in Biomedical/Bioinformatics field and Space domain: **(1)** Assoc. Professor: D. Soudris (FTE=20%) which during the past two decades had technical and managerial roles (WP Leader, Dissemination and Exploitation Leader) in 14 EU-funded projects (ESPRIT IV, FP5, FP6 and FP7) and in Horizon 2020 (Technical Coordinator of AEGLE and Project Coordinator of VINEYARD). Additionally, he was/is technical coordinator in 3 ESA-funded projects about the implementation of highly-complex applications in FPGAs for ExoMars mission. Additionally, he is/was dissemination leader in several FP7 EU funded projects. He has also a proved a particular attitude to drive the cooperation between industry and academy, gained cooperating for several years with the Corallia Cluster technology transfer center of Ministry of Development, Athens, in the role of Scientific Mentor and Head of the Embedded System and Space Unit. He is active member of the HiPEAC NoE, e.g., Co-General Chair of HiPEAC Computing Systems Week, October 2014 and his interests and background are well centered between the reconfigurable architectures, embedded systems and HPC; **(2)** Senior Investigator G. Lentaris (5%) expertise on hardware design in FPGAs for space applications; **(3)** Senior Investigator S. Xydis (5%) expertise on software and hardware design in manycore platforms FPGAs.
Key facilities and infrastructure	Digital Signal Processing (DSP) of implementing image/video algorithms activities is supported by (a) a strong theoretical team and (b) computing infrastructure for manycore platforms (Intel) and FPGAs and software tools for design space exploration. This expertise will be used in HEP field and Space debris
Previous involvement in Research Programmes	EU funds: 1. "MNEMEE: Memory management technology for adaptive and efficient design of embedded systems," FP-216224 (Coordinator, Dr. Peter Leemans, IMEC, Belgium) 2. "MOSART: Mapping Optimisation for Scalable multi-core ARchiTecture," FP-215244 (Coordinator, Bernard Candaele, Thales, France) 3. 2PARMA: PARallel PAradigms and Run-time MAnagement techniques for Many-core Architectures, FP7-248716 [EU considered 2PARMA as "Success Story"] (Coordinator, Cristina Silvano, Polimi, Italy) 5. TOISE: Trusted Computing for European Embedded devices, ENIAC-270001-2, (Coordinator, Bernard Candaele, Thales, France) ESA funding: «SPARTAN: SParing Robotics Techonologies for Autonomous Navigation» (Coordinator, GMV, Spain)
Current Involvement in Research Programmes	EU projects: 1. VINEYARD: Versatile Integrated Accelerator-based Heterogeneous Data Centres, H2020-687628 (Project Coordinator Dimitrios Soudris) 2. "AEGLE – An analytics framework for integrated and personalized healthcare services in Europe, H2020-644906 (Project Technical Coordinator Dimitrios Soudris) 3. SWAN-iCARE: Smart wearable and autonomous negative pressure device for wound monitoring and therapy," 4. FP7-317894 (Coordinator, EXUS, Greece) 4. HARPA: Harnessing Performance Variability» FP7-612069 (Coordinator, W. Fornaciari, Polimi, Italy) ESA funding: "COMPASS: Code Optimisation and Modification for Partitioning of Algorithms developed in SPARTAN/SEXTANT," (Coordinator, GMV, Spain)
Publications	(1) C. Kachris, G. Sirakoulis, D. Soudris, A Configurable MapReduce Accelerator for Multi-core FPGAs, 22nd ACM/SIGDA International Symposium on Field-Programmable Gate Arrays (FPGA'14), Monterey, CA, Feb. 2014 (2) C. Kachris, G. Sirakoulis, D. Soudris, Performance Evaluation of Embedded Processor in MapReduce Cloud Computing Applications, International Conference on Cloud Computing (CloudComp'12), Wien, Austria, Sept. 2012 (3) Iraklis Anagnostopoulos, et al "Distributed run-time resource management for malleable applications on many-core platforms," in Design Automation Conference (DAC), Austin, TX, June 2-6, 2013, pp. 1-6. (4) Andreas Raptopoulos, et al "Reconfigurable Computing for Analytics Acceleration of Big Bio-Data: The AEGLE Approach," ARC 2015, 13 - 17 April 2015, Bochum, Germany, pp. 531-5418. (5) Elias Kouskoumvekakis, et al "Many-core CPUs can deliver scalable performance to stochastic simulations of large-scale biochemical reaction networks," in IEEE HPCS, 20-24 July 2015.

Beneficiary Legal Name: – Maxeler (MAX)	
General description	Maxeler Technologies provides complete hardware and software platforms for High Performance Computing applications using reconfigurable dataflow supercomputing technology. Maxeler hardware systems incorporate traditional CPU based sub-systems with high performance Dataflow Engines (DFEs) using high-end FPGA chips. Maxeler dataflow computers have been used to deliver 20--30x improvements in performance/W and performance/space with respect to conventional systems across a range of application areas including oil and gas exploration, financial risk analysis, data analytics and low- latency network processing. Maxeler's MaxCompiler is a complete high level development environment for Maxeler systems based around the principles of the Open Spatial Programming Language (OpenSPL); while Maxeler's MaxelerOS is a combined hardware/software runtime management environment that orchestrates the data flows during the system runtime. The main role of Maxeler in the project is the research and development of next- generation, programmable dataflow processors for HEP and MRF domain.
Staff Expertise	Maxeler's R&D team consists of hardware engineers, software engineers and application experts, based primarily at company's main headquarters in London, UK. Oskar Mencer (5%), CEO & CTO. Prior to founding Maxeler, Oskar was Member of Technical Staff at the Computing Sciences Center at Bell Labs in Murray Hill, leading the effort in "Stream Computing". Besides driving Maximum Performance Computing at Maxeler, Oskar was Consulting Professor in Geophysics at Stanford Univ. and he is also affiliated with the Computing Department at Imperial College London, having received two Best Paper Awards, an Imperial College Research Excellence Award in 2007 and a Special Award from Comsult in 2012 for "revolutionising the world of computers". Oskar's main role in the project will be dissemination and exploitation of project results to potential customers and planning exploitation of project results both within Maxeler and in association with partners. Georgi Gaydadjiev, VP of Dataflow Software Eng. Georgi (10%) has a long lasting experience in designing various computer systems in both Industry and Academia for more than 25 years. Georgi has three Best Paper Awards (ICS-10, USENIX/SAGE-06), one of his projects won CES Design & Engineering Showcase Award in 1999 and his academic research for the last 12 years was funded by the EC, National Agencies in the Netherlands and Sweden and Google Inc., USA. Georgi will oversee Maxeler's participation in the project and manage the technical work. Tobias Becker (5%) is the Head of MaxAcademy at Maxeler Technologies where he coordinates various research activities and Maxeler's university engagement. Before joining Maxeler he was a research associate in the Department of Computing at Imperial College London. Tobias received his Ph.D. from Imperial College London in 2011. His research interests include reconfigurable computing, custom accelerators, adaptive computing, low-power optimisations, and financial applications
Key facilities and infrastructure	Maxeler's lab facilities in London include a mix of heterogeneous HPC infrastructures including multi-core servers as well as Maxeler MPC-C and MPC-X Series dataflow nodes, high performance networking and storage, which will be available for use in the project. As well as general-purpose resources, Maxeler will construct a configurable multi-DFE system to be hosted in London and made available for remote access by the other project participants. Maxeler is pioneering a multi-disciplinary approach to accelerate scientific computing applications, including bioinformatics, oil&gas, weather forecast and quantum chemistry providing improvements speed and energy management. Through its university program, the company also has research relationships with well over 100 universities around the world.
Previous involvement in Research Programmes	EU funds: 1. "SAVE – Towards Efficient Resource Management in Heterogeneous System Architectures, FP7-610996 (Coordinator, Cristiana Bolchini, Polimi, Italy) 2. "FASTER: Facilitating Analysis and Synthesis Technologies for Effective Reconfiguration," FP7- 287804 (Coordinator, Dionisios Pnevmatikatos, FORTH-ICS, Greece) 3.FP7- Marie Curie Initial Training Network, HPCFinance: Training in Modern Quantitative Methods and High-Performance Computing for Finance (Coordinator, Tampere University of Technology)
Current Involvement in Research Programmes	EU projects: 1. 2020-IA AEGLE (An analytics framework for integrated and personalized healthcare services in Europe; ICT-15-2014 No. 644906) 2015-2019 (Coordinator, Andreas Raptopoulos, EXUS, Greece) 2. H2020- 643946, CloudLightning: Self-Organising, Self-Managing Heterogeneous Cloud, (Coordinator, Univ. Cork, Ireland) 3. FP7-318521 HARNESS: Hardware- and Network-Enhanced Software Systems for Cloud Computing, 2012-2015 (Coordinator, Alex Wolf, Imperial College London) 4. POLCA: Programming Large Scale Heterogeneous Infrastructures, FP7-610686 (Coordinator, Stefan Wesner, Univ. ULM, Germany) 5. FP7- 619525, QualiMaster: A configurable real-time data processing infrastructure mastering autonomous quality adaptation, (Coordinator, Claudia Niederée, Univ. Hannover)
Publications	(1) Shengjia Shao, Liucheng Guo, Ce Guo, Thomas C.P. Chau, David B. Thomas, Wayne Luk, Stephen Weston, "Recursive Pipelined Genetic Propagation for Bilevel Optimisation," 2015 FPL, London, UK (2) Frederik Grüll, Udo Kebschull, "Biomedical Image Processing and Reconstruction with Dataflow Computing on FPGAs," in FPL, 2-4 Sept, 2014, Munich (3) C. Tomas et al "Acceleration of the anisotropic PSPI imaging algorithm with dataflow engines" 82nd Society of Exploration Geophysicists (SEG) Meeting, Las Vegas, September 2012. (4) T. C. P. Chau et al "SMCGen: Generating Reconfigurable Design for Sequential Monte Carlo Applications," 2014 FPL Conf. Munich, (5) M. Flynn et al "Moving from Petaflops to Petadata" Communications of the ACM, Vol. 56 No. 5 May 2013.

Partner Organisation Legal Name: IMAGO7	
General description	IMAGO7 is a charitable foundation active in research. It features a young multidisciplinary team composed of physicists, engineers and physicians. Its research interests are focused on application of cutting-edge MRI techniques to the detection of neurodegenerative and developmental diseases, as well as studying the healthy brain.
Key Persons and Expertise	*Michela Tosetti*, Research Group leader, Director of Medical Physics and Magnetic Resonance Laboratory of IRCCS Fondazione Stella Maris and IMAGO7 Research Foundation, shares competence in a multidisciplinary manner, coordinates the complementary actions of people with different professional skills. *Guido Buonincontri* is a young researcher who was recently awarded a Marie-Curie Individual Fellowship at IMAGO7 and an INFN grant for excellent young researchers. He has experience in MR fingerprinting in the preclinical environment and is now applying this new technique to patients. He will coordinate a European course on MR fingerprinting. His participation to the ITN will be activated after the end of the MC fellowship.
Key Research Facilities, Infrastructure, Equipment	The lab features a 1.5T and a 7T GE MRI scanner, which was the first to be acquired in Europe. The group is also actively involved in the construction of dedicated hardware using a fully-operational radiofrequency laboratory.
Previous and Current Involvement in Research and Training Programmes	The key person has been already involved in many research programme both at European and at national level, and in training as Phd supervisor. IMAGO7, together with the Department of Physics of the University of Pisa (local Supervisor M. Tosetti and A. Del Guerra), is partner of the High field Magnetic Resonance (HiMR) Innovative Training Network (ITN) in the framework of the FP7 Marie Curie ITN. Other projects involve the supervisor in the cutting edge, multidisciplinary research program of the UHF MR centre, both at EU level (DESIRE; TRIMAGE; NextGenVis) and in National Researches (Ministry of Health, Ministry of Research)
Relevant Publications and/or Research / Innovation Product	**1) G Buonincontri** SJ Sawiak (2015) MR fingerprinting with simultaneous B1 estimation, Magn Reson Med. doi: 10.1002/mrm.26009 2) M Cosottini, D Frosini, L Biagi, I Pesaresi, M Costagli, G Tiberi, M Symms, **M Tosetti** (2014) Short-term side-effects of brain MR examination at 7 T: a single-centre experience EUROPEAN RADIOLOGY Volume: 24 Issue: 8 Pages: 1923-1928 3) M Cosottini, D Frosini, I Pesaresi, M Costagli, L Biagi, R Ceravolo, U Bonuccelli, **M Tosetti** (2014) MR Imaging of the Substantia Nigra at 7 T Enables Diagnosis of Parkinson Disease, Radiology, 271: 3 831-838

Beneficiary Legal Name: – Kayser Italia Srl (KI)	
General description	KI is a private independent aerospace company in Livorno (Italy). 50 specialized engineers are organized in the many departments (Design, Development, Manufacturing, Quality Assurance etc.) with expertise in electronics, aeronautics, mechanics, thermodynamics, physics, computer science, optics and molecular biology. KI participated to more than 50 space missions with over 80 payloads completed with full success, especially in the area of life science (biology and human physiology). They have been flown on the Russian capsules Bion, Foton, Progress, Soyuz, the Shuttle Transportation System, the Japanese HTV module, the chinese Shenzhou-8, the European ATV module, and the International Space Station. KI is certified ISO 9001, personnel is qualified for electronic circuits and harness manufacturing, inspection, in accordance with ESA standards.
Staff Expertise	Bardi Antonio (Electronic Engineer degree, UNIPI,1996) was at INFN since 1997, developing systems based on the AM chip for experiments at the Tevatron collider (Fermilab, USA) and Large Hadron Collider (Cern, Switzerland). Bardi contributed to research presented at conferences (IEEE NSS et al.), published articles on scientific papers (IEEE TNS, NIM et al.), teaching activities at UNIPI (Engineering and Physics departments). Since 2006 Bardi joined KI. He was involved in many projects as Project/System engineer for aerospace equipment and systems. Serafini Luca (Electronic Engineering degree and Ph.D in Information Engineering, both at UNIPI. MAIN SKILLS: (a) Embedded systems study, design and development for space applications; (b) Digital design of acquisition, control and data-processing systems based on FPGA and Microcontrollers; (c) Knowledge of Hardware Description Languages and tools for FPGA design and development; (d) Software design, development for microcontrollers
Key facilities, infrastructure	5000 m^2 organised into modern offices, meeting rooms, conference room, laboratories, clean room, manufacturing, inspection area and integration area. Laboratories are for: electronic, mechanics, biology, environmental tests.
Previous involvement in Research Programmes	MYOAGE – FP7 project to understand and combat age-related muscle weakness DATAFORM, specific targeted research project (FP6-STREP, in Aeronautics and Space Activity) to study, develop and apply digitally-adjustable multi-point tooling to the manufacture of 3D aircraft panels. DANGER, a ASI macro-project (Italian Space Agency) for the application and of the pre-operative services based on satellite navigation for the planning, forecast and management of dangerous goods transportation.
Current Involvement in Research Programmes	FACT, Future Atomic Clock Technology, ITN FP7.To prepare leaders in fundamental science, technology, industry. SOC2-Toward Neutral atom Space Optical Clock – FP7. The project will demonstrate transportable optical atomic clocks with performance significantly beyond microwave clocks. V-FIDES: co-funded by Tuscany Region: technologies required for new autonomous underwater vehicles
Publications	1.W.Ashmanskas et al. The CDF Silicon Vertex Tracker, NIM A477:451-455, 2002 2.A. Bardi et al, The CDFII online Silicon Vertex Tracker. ICALEPCS-2001-THBT003.Invited talk, San Jose (USA) 3.A.Bardi et al. A Prototype of programmable Associative Memory for track finding, IEEE TNS 46, 940-946 (1999)

6. Ethics Issues

Research on Humans

The work described in the proposal will include reconstruction of image series obtained from MRI scans in humans to test new MRF sequences. All data will be anonymised prior to use in this research.

The sites performing MRI scans on humans (GEGR-E and IMAGO7) have all studies approved by a local ethics committee formulated according to the Declaration of Helsinki. All relevant procedures for all organisations conform to Good Clinical Practice procedures. All subjects taking part as volunteers in these studies are provided with written information explaining the purpose of the research, describing the examination itself and possible side effects, and indicating that participation is completely voluntary. The informed consent form meets the requirements as laid out in the guidelines for “informed consent” as required by the EC. Subjects will only be included after being informed and signing the consent form. The form is countersigned by the project member responsible for explaining the study. All subjects are covered by liability and travel accident insurance provided by the participant organizations. All studies involving human subjects involve sufficient numbers of subjects to ensure adequate statistical power to obtain a meaningful result.

All staff and students involved in obtaining informed consent from subjects are trained in Good Clinical Practice (GCP) principles. Our students will be required to explore the ethical issues and societal impact of their research, and to engage with each other and the public in discussion surrounding these issues through the course of their studies

The procedure and protocols adopted during the experiments, in particular procedures for MR safety include the use of a standard Magnetic Resonance Procedure Screening Form and the use of ear plugs or headphones to prevent damage to hearing due to noise during the scanning procedures. For the UHF MR studies performed at IMAGO7, since no 7 Tesla is currently certified as a Medical Device, no medical diagnosis can be made based on images derived with the UHF systems. Nevertheless, subjects are informed that in the case of suspicious findings in the 7 Tesla images, they will be contacted by an appropriately qualified medic who will provide a recommendation for further clarification with routine diagnostic procedures. Subjects not willing to be informed about suspicious findings will be excluded from the study.

APPENDIX A

Milestone Assessment Template (Generic Part)

Topic	Possible Answers	Assessment*	Comments
Final Milestone Approval			
Have the MILESTONE objectives been achieved?	Yes/Partially/No		
Have the MILESTONE results been presented to the project Consortium?	Yes/Partially/No		
Can be the presented results considered satisfactory for the project Consortium?	Yes/Partially/No		
Are the documents and deliverables related to the MILESTONE available?	Yes/Partially/No		
Intermediate Milestone Check			
Are the plans for the future work satisfactorily?	Yes/Partially/No		
Did you see some critical issues for the next period?	Yes/Partially/No		
Do you recommend any change in objectives and plans for the next period?	Yes/Partially/No		
What is the percentage of the final MILESTONE that has been reached?	0 to 100%		

***Note**: Please select the appropriate possible answers.

APPENDIX B

Table of short terms

ALS	Amyotrophic Lateral Sclerosis
AM	Associative Memory
AMSIP	Associative Memory System In Package
ASI	Agenzia Spaziale Italiana
ASIC	Application Specific Integrated Circuit
ATCA	Advanced Telecommunications Computing Architecture
ATLAS	A Toroidal LHC ApparatuS
EB	Executive Board
ESA	European Space Agency
CA	Consortium Agreement
CAD	Computer-Aided-Design
CDF	Collider Detector at Fermilab
CDP	Career Development Plan
CMS	Compact Muon Solenoid
CPU	Central Processing Unit
DFE	Dataflow Engine
DIISM	Department of Information Engineering and Mathematical Sciences
DSP	Digital Signal Processor
ERC	European Research Council
ESR	Early Stage Researcher
FPGA	Field Programmable Gate Array
FTK	Fast TracKer
GE	General Electric
GenA	General Assembly
GPU	Graphics Processing Unit
HEP	High Energy Physics
IPR	Intellectual Property Rights
LEO	Low Earth Orbits
LHC	Large Hadron Collider
MRF	Magnetic Resonance Fingerprinting
MRI	Magnetic Resonance Imaging
PC	Project Coordinator
PM	Pattern Matching
PU	Processing Unit
R&D	Research and Development
ToK	Transfer of Knowledge
VHDL	VHSIC Hardware Description Language
VME	Versa Module Europa bus
WP	Workpackage
WPL	Workpackage leader

7. Letters of Commitment
Letters of Commitment from partner organizations

1. Letter from Kaiser Italia
2. Letter from IMAGO7

KAYSER ITALIA

I hereby certify that Kayser Italia Srl (KI) intends to participate to the Innovative Training Networks (ITN) PUMA coordinated by the University of Pisa, should the network be selected for funding by the European Commission, as **Associated Partner**, in the following ways:

- A senior staff member of KI will have a seat in the General Assembly
- KI will offer the possibility to accommodate one early Stage Researcher (ESR) from the ITN for a period of 18 months. The ESR will receive training in FPGA development
- KI will participate to part of the activities related to WP1 as described in section 3.1 of the PUMA proposal
- KI will participate to the WP5 offering the Network-Wide Training Event "Technology in space applications, with reference to ASI and ESA research activities"
- Senior staffs from KI will be invited to some of the ITN workshops and annual schools
- The participation of KI in the research is described in the PUMA proposal

Sincerely,

Valfredo Zolesi

Kayser Italia President and Contract Officer

Letter of intent

Ref: Participation in the Horizon 2020 Marie-Sklodowska Curie InnovativeTraining Network PUMA

I hereby certify that the IMAGO7 foundation intends to participate in the Horizon 2020 ITN PUMA, coordinated by the University of Pisa, should the network be selected for funding by the European Commission, as associated partner, in the following ways:

- IMAGO7 will be able to accommodate two early stage researchers (ESR) from the ITN for a research placement for up to 18 months. The ESRs will receive practical training on novel MR acquisition and reconstruction techniques, focussing mainly on quantitative methods based on MR fingerprinting and ultra-high field MRI.
- A senior member of the Foundation will sit in the supervisory board and the training panel.
- IMAGO7 will offer access to a research 7T MRI scanner on its premises and to high-end facilities for computation.
- IMAGO7 will contribute to the overall ITN program with a three-day course on MR Fingerprinting.
- IMAGO7 will offer two open events to disseminate its results and research funded by the EU to a wider audience, for effective patient and public involvement in research.
- The participation of IMAGO7 in the research and training program is described in detail in the section B of the proposal.

Signed:

Dott. Roberto Cutajar

FONDAZIONE
IMAGO 7
IL PRESIDENTE
Dott. Roberto Cutajar

END PAGE

MARIE SKŁODOWSKA-CURIE ACTIONS

Innovative Training Networks (ITN)
Call: H2020-MSCA-ITN-2016

PART B

“PUMA”

This proposal is to be evaluated as:

EID

European Commission

PARTICIPANT PORTAL E-RECEIPT

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