SEVENTH FRAMEWORK PROGRAMME
THE PEOPLE PROGRAMME

*Annex I - "Description of Work"**

PART A:

Grant agreement for: **Initial Training Networks**
Call identifier: **FP7-PEOPLE-2013-ITN**

Implementation mode: **IDP**

Project acronym: PACMAN

Grant agreement no.: 606839

Project full title: A Study on Particle Accelerator Components' Metrology and Alignment to the Nanometre scale

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Project start date: 01/09/2013

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A.1 Project abstract

Keywords: instrumentation, microwaves, alignment, magnetic measurements, nano-positioning, high precision engineering, signal processing, actuators, electronics and numerical analysis, seismology

Abstract:

With new accelerators delivering beams always smaller and more energetic, requirements for very precise beam alignment become more and more challenging. After the Large Hadron Collider (LHC) and its planned upgrade, proposed lepton linear colliders require unprecedented tolerances of beam alignment at nanometre level. PACMAN, a study on Particle Accelerator Components Metrology and Alignment to the Nanometre scale, is an Innovative Doctoral Program, hosted by CERN. It offers training to 10 Early Stage Researchers in beam instrumentation, metrology, micrometric alignment, magnetic measurements, nano-positioning and high precision engineering. The training goal of PACMAN is to create a new generation of scientists equipped with a wide-ranging expertise in advanced engineering and a broad span of transferable skills. Special emphasis will be put on women scientists. The technical goal of the program is to develop very high accuracy metrology and alignment tools and integrate them in a single automatic test stand. The methods and tooling developed will be validated on components of the Compact Linear Collider (CLIC) currently being developed. This new multi-disciplinary approach will be applied on future facilities under development at CERN and elsewhere. Hardware and methods will be brought to the market by the network partners that will maintain technological leadership in these cutting-edge technologies. For each research field, the most innovative universities, laboratories and industries will work together. They have showed a genuine interest in the research goals. ESR will be supervised by internationally recognized experts, in an exceptional academic and industrial network. Precise alignment and metrology is already part of industrial standards in areas as diverse as high precision manufacturing, automotive, aerospace or telescope assembly. The result of this research will allow industry and research in Europe to stay one step ahead in precision manufacturing.

PART B:

B.1 List of participants

B.1.1. List of Participants (full beneficiaries)

Beneficiary Number	Beneficiary short name	Private Sector *(Y/N)*	SME *(Y/N)*	Country	Month enter project	Month exit project
CERN		N	N	CH	Month 1	Month 48

B.1.2. List of Associated Partners (including role and status)

N°	Associated Partner name	Short name	Country	Organisation type*	SME (Y/N)	Role in the project**
1	Cranfield University		UK	Public	N	TR, RES
2	Desarrollos Mecanicos de Precision	DMP	ES	Private	Y	SEC
3	Eltos		IT	Private	Y	SEC
4	Etalon AG	Etalon	DE	Private	Y	SEC
5	Swiss Federal Institute of Technology Zürich	ETHZ	CH	Public	N	TR, RES
6	Hexagon Metrology GmnH	Hexagon	DE	Private	N	TR, SEC
7	Instituto de fisica Corpuscular	IFIC	ES	Public	N	RES
8	Laboratoire d'Annecy-le-vieux de Physique des Particules	LAPP	FR	Public	N	RES, SEC
9	Metrolab		CH	Private	Y	SEC
10	National Instruments	NI	HU	Private	N	TR, SEC
11	Universita de gli studi del Sannio	University of Sannio	IT	Public	N	RES
12	SigmaPhi		FR	Private	Y	SEC
13	Laboratory for Materials and Mechatronics	SYMME	FR	Public	N	RES, SEC
14	Nederlandse	TNO	NL	Private	N	TR, SEC

	Organisatie voor toegepastnatuurwetens-chappelijkonderzoek					
15	Delft University of Technology	TUDELFT	NL	Public	N	RES

B.2 S&T Quality

B.2.1. Objectives of the research programme

CLIC (Compact Linear Collider) is a study for a future electron-positron collider that would allow physicists to explore a new energy region in the multi TeV range beyond the capabilities of today's particle accelerators. It would provide significant fundamental physics information complementary to the Large Hadron Collider (LHC) and a lower-energy linear e+/e- collider, as a result of its unique combination of high energy and experimental precision. It consists of two almost 50 km long accelerators that will accelerate electrons and positrons and collide them at a nominal centre-of-mass energy of 3TeV. The alignment of passive and active components along such an accelerator shall reach unprecedented small values at the nanometre and micrometre level. Indeed, this is a common requirement for the next generation of accelerators. Whether for producing a high number of collisions at the highest energy, or for producing the brightest light from light sources, the tolerance concerning the position of the beam inside an accelerator is becoming increasingly tight. In practise, the static alignment of three fundamental components must be included within a few micrometres with respect to a reference line over several hundreds of meters. These components are quadrupole magnets that keep the beam together, accelerating structures that boost the beam energy, and beam position monitors providing a non-invasive monitoring of the beam orbit. They are heavy objects sometimes weighting more than a hundred kilograms and measuring one meter long or more. Still, their reference axis must be aligned within a few micrometres.

The current alignment strategy consists of three steps: first to measure for each component the position of its reference axis w.r.t external targets named fiducials (fiducialisation process), then to align the components on a common support, and finally to align this support in the accelerator tunnel using alignment sensors. First tests concerning this strategy have shown that the precision and accuracy required for linear colliders and other future accelerators of 10 micrometres cannot be reached with this serial process. The scientific objective of the PACMAN network is to propose and develop an alternative solution integrating all the alignment steps and a large number of technologies at the same time and location, in order to gain the required precision and accuracy. This can only be achieved by mastering the in-depth knowledge of each element, in-line measurements of diverse nature and a real-time adaptive process control.

Accelerators are logically built out of modular elements built as mechanical supports on which the components are assembled. These modules constitute the backbone of sometimes several kilometres of accelerator and are industrially produced in large numbers, typically in the order of thousands of units. The requirement of tighter tolerances in the alignment inside these modules will thus be fulfilled at the manufacturing premises. The solution developed within the PACMAN network needs to be robust and also work reliably in an industrial environment.

A number of issues need to be tackled to reach this goal. They define the research goals and sub-objectives of the PACMAN network. In practise we have to:

- optimize the manufacturing of the mechanical components of magnets and monitors and their assembly by applying ultra-high precision engineering and accurate machining techniques,
- refine methods for magnetic measurements that will deliver the functional axis of magnets of very small aperture and with the required accuracy by using vibrating wire techniques and printed circuit boards rotating search coils,

- refine and propose new measurements for finding the electromagnetic centre of microwave cavities to nanometre resolution. Investigate laser and wire excitation and capacitive measurements,
- design new methods of absolute alignment between all the components inside the module and their associated fiducials using a stretched wire as reference,
- develop portable methods of absolute alignment based on new techniques like Micro Triangulation and Frequency Scanning Interferometry (FSI),
- improve the commercial apparatus and seismic detectors to work in harsh environment and in magnetic fields by reviewing their mechanical and electronic design as well as the integrated feedback,
- study ground motion and other environmental noise to be able to filter it accordingly using seismic sensors,
- position the quadrupole and the attached beam position monitor with actuators to the nanometre level,
- build a prototype alignment bench integrating all the metrology and electromagnetic measurements plus active nano-positioning and background monitoring,
- automatize this test bench.

To achieve these objectives which are beyond the present state-of-the-art, we need a motivated team that masters not only **the basic metrology principles but also: electromagnetism, mathematics, precision mechanics, microwave technologies, electronics, mechatronics, nano-positioning, controls engineering and computing.** PACMAN will realise this with a consortium of partners which are best-in-class in these fields. The partners share the same scientific interest and will work hand in hand with the researchers to achieve these goals. The consortium will be built such that the different expertise required to execute the project is available, thus forming a multidisciplinary team.
During the course of the program a prototype alignment bench will be built in which the final demonstration of the PACMAN system (methods, alignment sequence and algorithms) will be implemented.

Table 1. List of Work Packages

Work package No	WP Type	Work package title	Deliverables (D) / Milestones (M)	Lead benef.	Start month	End month
WP0	MGT	Management	D0-1, D0-2, D0-3/ M0-1, M0-2, M0-3, M0-4	CERN	M1	M48
WP1	RTD	Metrology and alignment	D1-1, D1-2, D1-3, D1-4, D1-5, D1-6, D1-7, D1-8/ M1-1, M1-2, M1-3, M1-4, M1-5, M1-6, M1-7, M1-8, M1-9	CERN	M4	M48
WP2	RTD	Magnetism	D2-1, D2-2, D2-3, D2-4, D2-5 / M2-1, M2-2, M2-3, M2-4, M2-5, M2-6	CERN	M6	M48
WP3	RTD	Precision mechanics and nano-positioning	D3-1, D3-2, D3-3, D3-4, D3-5, D3-6, D3-7 / M3-1, M3-2, M3-3, M3-4, M3-5, M3-6, M3-7	CERN	M6	M48
WP4	RTD	Microwave technology	D4-1, D4-2, D4-3, D4-4, D4-5 / M4-1, M4-2, M4-3, M4-4, M4-5	CERN	M6	M48
WP5	TR	Training	D5-1 / M5-1, M5-2, M5-3	CERN	M3	M42
WP6	DISS/OUT	Dissemination and outreach	D6-1, D6-2, D6-3, D6-4, D6-5, D6-6 / M6-1, M6-2	CERN	M1	M48

B.2.2. Research methodology and approach

Overall research methodology

The experimental and research plan consists of 4 phases:

- **a first phase of familiarization** with CERN, the project and the research topic,
- **a second phase of validation** in which the ESR will validate individual measurements,
- **a third phase of integration** on the prototype alignment bench followed by a measurement campaign,
- and **a fourth phase of analysis and extrapolation** to a fully exploitable method.

First phase of familiarization [M4 to M10]: The ESRs will start with a 6 months familiarization period of training on their subject in their respective groups. They will study state of the art through papers, conference, and discussion with experts. They will get the knowledge of the project and their discipline with a close supervision and mentoring of their supervisors from CERN, industries and universities.

Second phase of validation [M11 to M25]: The objective of this second phase is to have all the technical systems ready validated on individual test setups. Each researcher will design and build his/her own measurement set-up with the help of CERN qualified technicians and supervisors. The set-up will serve for validation of the method, acquisition systems and software.

Third phase of integration [M26-M32]: this phase will start by performing compatibility tests between the systems developed. Then, each technical system will be integrated and validated in the prototype alignment bench. A final alignment sequence will be found by optimization and characterized for reproducibility and robustness. This will be the object of extensive measurement campaigns.

Fourth phase of analysis and extrapolation [M33-M48]: During this fourth phase, the ESRs will analyse the data, draw conclusions and determine the accuracy and precision of their methods. Some ESRs will have to extrapolate the solution developed to make it suitable for portable utilization (ESR1.2, ESR1.3) or industrialization (ESR1.1, ESR2.1, ESR2.2, ESR3.1, ESR3.2). ESR4.2 will prepare the system for beam measurements.

Scientific risks and contingencies

As for any research project, scientific risk is an inherent part of the game. We have identified the most important risks for each work package and found mitigating solutions.

- The choice of the wire needs to be a compromise between all the different methods and systems using it. The performance of a particular method could be hindered by the choice of a non-perfect wire for that particular application. In order to alleviate these risks and to respect the independence between researchers, all the different technologies will work on smaller test benches first, using a customised wire. The performance on the final prototype alignment bench could be compared and weighted to the ideal conditions of a stand-alone measurement.
- From the scheduling point of view, delays in the development of sensors and components could have an impact on the other technical systems. Seismic sensors are for instance needed for characterisation of BPM background noise. A non-magnetic head is essential to perform metrological measurements at the same time as magnetic measurements take place. We have made sure that we have working sensors (seismic, optical) available in the market. Even if they do not fulfil the final accelerator requirements, they are perfectly appropriate for their use in simpler set-ups.

Commercially available seismic sensors can be used for the characterization of ground motion around the BPM when no sensible components are working. The current LEITZ CMM head can be used to validate the sensors in a separate bench before magnetic tests are integrated.

- The response of the BPM to external noise like ground motion or mechanical vibration may reduce the achievable accuracy. In this case, the individual BPM bench and the final prototype bench may have to be relocated in a tunnel-like environment for which we know ground motion is greatly reduced.

These risks could have an impact on the final multidisciplinary prototype alignment bench performances but in no circumstances on the individual ESR research. The final uncertainty of the research is mainly the level of tolerances that could be achieved for each sub-system and for the global integration of all systems in the prototype alignment bench. This will decide on the future choices of the CLIC project but will not in any case, hinder the individual research projects that will stay, in any case, at the edge of attainable technology.

Synergies/complementarities between teams and role of private sector participants

This project comprises **8 private companies** as Associated Partners that will provide training to the young researchers through secondments and tailored training. Two of them are large industries with worldwide representation and large R&D departments. **Five SMEs** are associated partners in the PACMAN network. During their practical secondment, ESRs will learn how to define requirements, prepare and perform review and approval of an engineering design in order to develop prototypes, embedded in the teams of large industries and SMEs. They will also have the opportunity to learn the working principles of a commercial venture from the product development to the expedition to the customer.

Synergies and common interests have been identified inside the network between industries and SMEs:

- FSI system developed by ETALON AG could be applied for the monitoring of position of CMM machines manufactured by Hexagon Metrology.
- DMP is equipped with a Leitz Infinity CMM from Hexagon Metrology, the same CMM that is the object of the project.
- Micro-triangulation, developed by university ETH Zürich, has been implemented on a tachometer TD5005, which is high precision surveying instrument manufactured by Hexagon Metrology. This firm could be interested in the solution of measurement proposed and the associated performances.
- DMP, Cranfield, TNO, the Technical University of Delft and CERN are all members of EUSPEN (European Society for Precision Engineering and Nanotechnologies). This society focuses on the development and exploitation of precision, micro and nano technologies, and provides a platform between the private sector and research institutes to develop contacts and knowledge.
- NI hardware will also be used for PhD subject of ESR3.3.
- There is a strong interest between the technical University of Delft and TNO to collaborate on the development of vibration sensors and nanometric positioning systems.

Partners have not only been selected on the basis of their experience and expertise in research and training, but also based on the complementary nature of their work. The interactions described above, underline the significant potential for synergies which be exploited during and after the completion of PACMAN.

B.3 Training

B.3.1. Quality of the training programme

Quality of the training programme

Training through research will be the main ingredient of the training program of the PACMAN ITN. The ESRs will be placed in different groups inside the Accelerator Sector of CERN where they will work together with renowned experts in their field on their research assignments**. Training through research will also take place during secondments on academic and industrial partners.** Scientific and technological training will be supplemented in the form of structured courses, network-wide training events and workshops, and secondments. Beyond their scientific capabilities, we expect the ESRs to act independently and take responsibility over the scientific content of their project and its execution**. The aim of the transferable skills program is to empower the young researchers** with skills and knowledge that will make a difference in their future career perspectives. An innovative combination of traditional courses, workshops and training received also in the course of their secondments will train the ESRs in communication and managerial skills, intellectual property and entrepreneurship.

We have structured the training program in seven distinct forms of training:
- Training through research at CERN and at the academic and research partners
- Exchange of knowledge through secondments in the industrial partners
- Learning from visiting scientists
- Scientific, academic and technological training courses
- Transferable skills training courses
- Training at workshops organized by the network
- Participation in external conferences and workshops

To this list of more or less conventional training, we would like to add learning from role models. Inside the PACMAN network, two out of three members of the management team are women, five out of the ten students will be supervised by women, and four out of fifteen partners are represented by women. This proportion of women is highly unusual in engineering projects and we would like to transform it into an advantage. As all members of the network, these women are brilliant scientists and excellent mentors. They will serve as role models for the ESRs men and women alike, and they will help young female researchers to become confident about their potential. The training program described in the following sections has been organized to fit the research work phases described in B4. The content of the courses as well as its timing is set to maximize the benefit for both the ESRs and the research program.

Supervision arrangements

Staff from the Beams, Technology and Engineering Departments at CERN will coordinate and supervise the young researcher’s daily work. Supervisors from CERN will come from different scientific areas and represent a large part of the accelerator technology. Within their doctoral program, each researcher will also have a university supervisor who will be more attentive to the academic content and quality of the PhD work. During their secondment in industry, they will also have a designated supervisor on-site. The industry supervisor, in most cases will follow the work of the ESR also while at CERN and advise on the feasibility and commercial impact of the research carried out by the ESR. Each ESR will then have three supervisors who will work together towards the achievement of the research work and the excellent training of the researcher.

Each ESR will have a personal career development plan which the supervisors, the ESR and the WP5 leader will put together at the beginning of the project. This plan concerns the training needs of the ESR and will have to adjust to the research assignment. Coherence among research plans and between research plans and personal career development plans will be assured by the Network Coordinator as the leader of WP0.

The members of the Supervisory Board will monitor the progress and accomplishments of the individual young researchers throughout the training program through periodic reports prepared by WP5 leader. They will also have regular contacts with the ESRs during the SB meetings to obtain feedback on the quality of the training.

B.3.2. Network-wide training events, schools, conferences, workshops

Network-wide training activities

The scientific training program to be followed by each ESR will be tailored to the particular needs of the research program he/she embark on. They will study state of the art through papers, conference, discussion with experts, and will get the knowledge of their research topics with close mentoring of their supervisors from CERN, industries and universities. A common core of knowledge for all the young researchers will be also necessary. Upon arrival to CERN, students will need general introductory courses to familiarise with CERN, the project and the accelerators, the CLIC project and metrology in particular. We have built a training core package specific to each ESR based on the specific characteristics of the PACMAN network. Some of the courses are regularly organized by the CERN training team as part of the CERN technical training. The PACMAN network has proposed a number of training initiatives to be delivered by renowned experts in metrology, precision engineering or intellectual property that will be organized during the program but which could also become part of CERN Technical Training catalogue in the future. We have indicated trainings and workshops that are organized by the PACMAN ITN in grey.

The network will organise three scientific PACMAN workshops with training and dissemination purposes. All three workshops will last about three days. The first workshop will take place at CERN while the location of the other two workshops has to be conveyed with the associated partners.

Table 2. Network-wide training activities

	Training events, workshops & conferences	Lead Organising Institution	Planned date
1	**AXEL :** introduction to particle accelerators (10h)	CERN	M7
2	**Basic principles of metrology and survey** Short course of 2 days, to be organized by members of the metrology and alignment team at CERN in two modules: fundamental notions of metrology; metrological laboratory at CERN	CERN	M8
3	**CLIC principles and technology challenges** Academic training to be organized by the network (4-6 hours). It covers subjects pertaining to CLIC technology like two-beam acceleration, positron sources, or high-frequency, high gradient RF cavities	CERN	M9
4	**Basic Labview training**	NI	M10

	To be organized together with NI (5 days). The course is an introduction to LabView and it includes modular programming, files I/O data acquisition, waverforms, instrument control, and RADE access examples.		
5	**Radiation effects on electronics** CERN technical training (4 days). It covers interactions, dose definition, single effects, examples in high radiation environment, components sensibility, mitigation techniques and experimental tests	CERN	M9
6	**Electromagnetic compatibility** CERN technical training (6.5 h). Introduction and advanced course covering parameters and terms, standards, EU directives, conformity systems, problems on laboratories, measurements, assessment and compliance.	CERN	M9
7	**MATLAB** CERN technical training (2 days). MATLAB fundamentals and programming: data analysis, visualization, modelling and programming.	CERN	M9
8	**CMM fundamentals basics and usage of operating software Quindos** Operation and performance of the Leitz CMM machine (1 day). Based on the metrology service CMM.	Hexagon	M10
9	**Advanced course in FSI** Sequential multilateration for machine calibration and the use of multichannel absolute interferometer for the design of precise networks (2 days).	Etalon	M9
10	**MAGNE**	CERN	M8
11	**ANSYS** CERN technical training (4 days). It includes an introduction to ANSYS modelisation, structural, thermal and couple-field analysis.	CERN	M10
12	**Workshop on Intellectual property and technology transfer** A seminar will be organized by the technology transfer group at CERN and will be open to all members of the network.	CERN, Hexagon, TNO	M23
13	**First, Second and Final PACMAN workshop (3 days each)**	CERN	M18, M36, M48
14	**Dimensional metrology** Principles of alignment for accelerator components (10 h). Academic training to be organized by the network and the academic lectures service at CERN with Robert Ruland, head of the Metrology Department at SLAC National Accelerator Laboratory in USA.	CERN	M18
15	**USPAS course on vibrational aspects for accelerators** This course to be delivered by the US particle accelerator school focuses on ground motion, cultural and technical noise and mitigation techniques (5 days)	CERN	M17
16	**Introduction to accelerator physics** Organized by the CERN accelerator school. In-depth residential course of the topics described in the first training (2 weeks)	CERN	M26
17	**CST Microwave Studio** 3D electromagnetic simulation suite. Introductory course with hands-on examples focused on modelling (2 days).	CERN	M11
18	**NI RF module** Specific module delivered by NI and including RF measurements fundamentals and RF application developments (5 days).	CERN	M11
19	**EMAG** CERN Technical Training (2 days). Foundations of Electromagnetism and Magnet Design held by CERN experts in the field of normal & superconducting magnets (5 days).	CERN	M10
20	**Conference in Optical metrology** organized by SPIE, organized each year	CERN	M21, M33
21	International Workshop on Accelerator Alignment (**IWAA),** held every two years.	CERN	M14, M37
22	Biennal **ISMA** conference on Noise and Vibration Engineering	CERN	M21,M33
23	Yearly international conference and industrial exhibition organized by the European Society for Precision Engineering and Nanotechnology (**EUSPEN**)	CERN	M26, M38
24	The International Magnetic Measurements Workshop (**IMMW**), organized every two years	CERN	M22, M34
25	International Conference in Magnet Technology (**MT**), organized every two years.	CERN	M11, M35
26	The International Workshop on Future Linear Colliders (**LCWS)** is a yearly	CERN	M14,M26,

	working event for world experts working on linear colliders		M38
27	The **LINAC** conference is devoted to linear accelerators all over the world.	CERN	M13, M25, M37
28	The International Particle Accelerator Conference (**IPAC**) reunites every year accelerator scientists and engineers. A special meeting of Women in Science is organized at this conference with presentations by women scientists in accelerators and engineering	CERN	M22, M34
29	**The European Gender Summit**, organized yearly by genSET.	CERN	M15, M27, M39

Local training activities

Training through research will be done mostly at CERN and at the premises of the research and academic partners. **However, industrial partners have shown an interest on placing the students at the centre of their R&D departments** and will thus participate to their research training. In table 3, we list the research program ESRs will join at each partner. For academic partners, that are underlined, we mention the doctoral program and master courses that he/she will enrol to.

Table 3. Local training activities

Partner	**Local training activities**	Type
CERN	Training in all the major research aspects of the network will be carried out in several groups of the Beams, Technology and Engineering departments at CERN. The groups involved will be materials & metrology and the engineering support sections of the mechanical & materials engineering group; the magnetic measurements and the magnet normal conducting sections of the magnets, superconductors and cryostats group; the tune and position section of the beam instrumentation group; and the klystrons and modulators section of the radiofrequency group. ESRs will have access at some of the best specialists in their field of research and the latest technological advancements. The diversity of projects handled by these teams will assure a very comprehensive practical training.	RES, TR
Cranfield Un.	Researchers will be enrolled in the PhD program of the School of Applied Science. It offers two MSc's in Ultra-precision nano-engineering and Ultra precision Technologies. Both masters include taught modules, group projects, and individual.	RES, TR
DMP	DMP will host ESR3.1 and ESR3.2 for hands-on training on high precision machining, quality control and alignment techniques. They will also collaborate with the management, manufacturing and logistics services.	SEC
Eltos	Eltos will train ESR 2.2 in PCB design and manufacturing. An important element of the training is the Gerber format used to describe the PCB which will be essential for the manufacturing of PCB rotating coils	SEC
Etalon	During their secondment in Etalon, ESR1.2 and 1.3 will participate on the development of new technologies for industrial high end dimensional metrology solutions.	TR, SEC
ETH-Zurich	The Geodesic and Geodynamics lab on ETH-Zurich will train ESR1.3 in industrial metrology and geodetic metrology fundamentals during his secondment. It will also provide academic supervision and a PhD degree to the students in metrology.	TR, RES
Hexagon	Hexagon will train ESR1.1 within their R&D departments. Essentially in new sensors validation and measurements head mechatronics.	TR, SEC
IFIC	Students in WP4 will arrange doctoral enrolment in the Universidad de Valencia and will follow an MSc in advanced physics. This is a multidisciplinary program with a combination of taught courses and an introduction to research.	RES, TR
LAPP	A member from LAPP will supervise ESR3.2 PhD as part of the "Universite de Savoie". The ESR will spend some time in the institution getting the basic training in seismic sensors, and mechatronics.	RES, SEC, TR
Metrolab	With an important re-investment of sales on R&D, Metrolab has a strong research program on high precision magnetic measurements that ESR2.1 will be able to join.	TR, SEC
NI	National Instruments will enrol researchers in their R&D internship program in which they will follow a project on creating and testing NI products.	TR, SEC

Sigmaphi	Sigmaphi will train researchers of WP2 in magnet manufacturing and the associated magnetic measurements.	SEC
Uni. Sannio	Researchers in WP2 will be enrolled in the "Dipartimento di Ingegneria" and follow the doctorate program of "IIngegneria dell'informazione". The researchers will integrate the GESIM group who develops new algorithms and architectures for signal processing.	RES, TR
SYMME	SYMME will provide supervision and enrolment in the University of Savoie of one ESR. It will train researchers in the fields of mechatronics and high precision mechanics.	TR, SEC
TNO	An internship of three months in TNO will provide ESR3.3 with training through research in the fields of nano-positioning and mechatronics in general.	TR, SEC
TUDelft	Enrolment in the PhD program of the Precision and Microsystem Engineering department and the MSc of mechanical engineering. This program also includes taught courses, a study and a graduation project as well as an internship.	RES, TR

Training activities on transferable skills

The course program focusing on transferable skills illustrated in the table below will be mandatory to all ESRs. Such skills are crucial to training a well-equipped future generation of scientists – not only in their academic expertise but also with respect to non-scientific skills that are especially valuable in the private sector.

Table 4. Training activities on transferable skills

Training		**Duration**	**Host / trainer**
Safety awareness Web-based course on safety hazards		1 hour	CERN
Communication towards the general public Part of the CERN guides training program, ESRs will attend a four-hour course on communication with the public. This training is regularly scheduled by the visits service that the young researchers will be required to join for a minimum of one year.		4 hours	CERN
Team building To be prepared by the network in collaboration with the technical training at CERN. This training will prepare the young researchers to collaborate together in their research project as well as to integrate smoothly during their passage through industry.		1 day	CERN
Communication program	Communicating effectively.	4 days	CERN
	Personal awareness and impact.	3 days	CERN
	Making presentations	3 days	CERN
	Negotiating efficiently.	2 days	CERN
Management program	Managing by project	2 days	CERN
	Project scheduling and costing	2 days	CERN
	Quality management.	2 days	CERN
	Risk management.	2 days	CERN
Entrepreneurship for researchers This training was organised in the past through the ACEOLE ITN with a large success. PACMAN will organise a new session for the benefit of ESRs in this and other young researchers at CERN		2 days	CERN
French/English. CERN official languages are French and English. Students will be enrolled in the corresponding language program depending on their mother tongue. CERN courses offer 9 levels of proficiency.		30 hours	CERN
Framework proposal writing Regularly organised by the CERN EU office.		1 day	CERN

B.4 Implementation

B.4.1. Workplan

Table 5. List of Fellows' individual projects

Fellow No.	Project title	Host institut.	Relevant WPs	Duration (months)	Indicative start date*
ESR1.1	*Non-Contact High Precision Sensor for Leitz Infinity Coordinate Measuring Machine*	*CERN*	*WP1*	*36*	*M5*
ESR1.2	*Development and Validation of an Absolute Frequency Scanning Interferometry (FSI) network*	*CERN*	*WP1*	*36*	*M5*
ESR1.3	*Micro-triangulation for High Accuracy Short Range Measurements of Dynamic Objects*	*CERN*	*WP1*	*36*	*M5*
ESR2.1	*Stretched wire systems for the Magnetic Measurements of Small-Aperture Magnets*	*CERN*	*WP2*	*36*	*M7*
ESR2.2	*Printed circuit board technology for small-diameter field probes*	*CERN*	*WP2*	*36*	*M7*
ESR3.1	*Ultra-Precise Quadrupole Magnets assembly and testing. Integration of an alignment test-bed towards an industrial production*	*CERN*	*WP3*	*36*	*M7*
ESR3.2	*Seismic sensor development and vibration characterization*	*CERN*	*WP3*	*36*	*M9*
ESR3.3	*Nano-Positioning of the main LINAC quadrupole as means of laboratory pre-alignment*	*CERN*	*WP3*	*36*	*M9*
ESR4.1	*Alignment and resolution of a Beam Position Monitor operating at Microwave Frequencies in the Nanometre Regime*	*CERN*	*WP4*	*36*	*M7*
ESR4.2	*Development of direct measurement techniques for the in-situ internal alignment of accelerating structures*	*CERN*	*WP4*	*36*	*M9*

The network as a whole undertakes to provide a minimum of 360 person-months of Early Stage Researchers whose appointment will be financed by the contract. Quantitative progress on this, with reference to the table contained in Part C and in conformance with relevant contractual provisions, will be regularly monitored at the consortium level.

Based on this work plan, milestones and deliverables are detailed in tables 6 and 7 below.

Table 6. List of Milestones

List of Milestones				
Work Package	**Milestone No.**	**Milestone**	**Lead Beneficiary**	**Month**
WP0	M0-1	Kick-off meeting	CERN	M3
WP0	M0-2	All ESRs recruited	CERN	M7
WP0	M0-3	Supervisory Board meetings	CERN	M12, M24, M36, M48

WP0	M0-4	Periodic appraisals (supervisor-fellows) performed	CERN	M18, M36
WP1	M1-1	Compatibility tests performed	CERN	M26
WP1	M1-2	CMM head upgrade proposed	CERN	M18
WP1	M1-3	CMM head for the Final Prototype Alignment Bench (FPAB)	CERN	M24
WP1	M1-4	CMM tests performed	CERN	M36
WP1	M1-5	Development of absolute FSI performed	CERN	M18
WP1	M1-6	FSI measurements performed	CERN	M36
WP1	M1-7	Micro-triangulation software + hardware specified	CERN	M15
WP1	M1-8	Micro-triangulation measurements carried out	CERN	M36
WP1	M1-9	Inter-comparison tests performed	CERN	M34
WP2	M2-1	Solution with stretched wire designed	CERN	M20
WP2	M2-2	Magnetic measurements ready for the FPAB	CERN	M24
WP2	M2-3	Measurements on FPAB performed	CERN	M26
WP2	M2-4	PCB solution ready	CERN	M31
WP2	M2-5	Algorithms of control and software specified	CERN	M20
WP2	M2-6	Inter-comparison tests performed	CERN	M36
WP3	M3-1	Quadrupole magnets assembly re-engineered	CERN	M18
WP3	M3-2	All technical solutions integrated in the FPAB	CERN	M29
WP3	M3-3	New version of sensor designed	CERN	M26
WP3	M3-4	Sensor validated under magnetic fields and radiations	CERN	M34
WP3	M3-5	Nano positioning prototype designed	CERN	M26
WP3	M3-6	Long range actuators studied	CERN	M26
WP3	M3-7	Nano-positioning displacements performed	CERN	M36
WP4	M4-1	Microwave test bench for BPM designed	CERN	M22
WP4	M4-2	Nanometer resolution of BPM demonstrated	CERN	M31
WP4	M4-3	Measurements on FPAB performed	CERN	M36
WP4	M4-4	Structure experimental programme proposed	CERN	M22
WP4	M4-5	Acquisition electronics and software designed	CERN	M31
WP5	M5-1	PACMAN workshops completed	CERN	M18, M36, M48
WP5	M5-2	All secondments completed	CERN	M33
WP5	M5-3	All doctoral credits completed	CERN	M23
WP6	M6-1	All outreach events completed	CERN	M41
WP6	M6-2	Exploitation plan accepted by all partners	CERN	M12

Table 7. Deliverables List

List of Deliverables						
Work Package No.	**Deliver. No.**	**Deliverable**	**Lead Participant** / **Other Participants**	**Nature**	**Dissemination**	**Month**
WP0	D0-1	Kick-off meeting minutes	CERN	R	CO	M4
WP0	D0-2	Website	CERN	O	PU	M6
WP0	D0-3	Minutes of Supervisory Board meetings	CERN	R	CO	M13, M25, M37, M48
WP0	D0-4	1st progress report, midterm report, 1st periodic report, 2nd progress report, final report, 2nd periodic report	CERN	R	CO	M13, M20, M25, M37, M49, M49
WP1	D1-1	Report of compatibility tests	CERN	R, P	PU	M27
WP1	D1-2	CMM head prototype	CERN, Hexagon	O, R	RE	M26
WP1	D1-3	Report of tests on FPAB	CERN	R, P	PU	M34
WP1	D1-4	FSI prototype	CERN, Etalon	O, R	RE	M25

WP1	D1-5	Report of FSI measurements	CERN	R, P	PU	M36
WP1	D1-6	Micro-Triangulation software + hardware	CERN, ETH	O, R	RE	M25
WP1	D1-7	Report of Micro-Triangulation tests	CERN	R, P	PU	M36
WP1	D1-8	Report of inter-comparison tests	CERN	R, P	PU	M37
WP2	D2-1	Solution with stretched wire	CERN	O, R	CO	M25
WP2	D2-2	Report on magnetic measurements	CERN	R, P	PU	M37
WP2	D2-3	Solution with PCB rotating coil	CERN	O, R	CO	M29
WP2	D2-4	Algorithms of control and software	CERN	O	PU	M33
WP2	D2-5	Report of inter-comparison	CERN	R, P	PU	M37
WP3	D3-1	Quadrupole magnets	CERN, DMP	O, R	RE	M23, M30
WP3	D3-2	Final Prototype Alignment Bench (FPAB)	CERN	O, R	PU	M25, M33
WP3	D3-3	Sensor prototypes	CERN, LAPP	O, R	RE	M32
WP3	D3-4	Report of sensor validation	CERN	R, P	PU	M35
WP3	D3-5	Nano positioning prototype	CERN	O, R	RE	M31
WP3	D3-6	Long range actuators	CERN, TNO	O, R	RE	M36
WP3	D3-7	Report on nano-positioning displacements	CERN	R, P	PU	M37
WP4	D4-1	Microwave bench	CERN	O, R	CO	M27
WP4	D4-2	Report of BPM nanometric resolution	CERN	R, P	PU	M32
WP4	D4-3	Report of BPM measurements on FPAB	CERN	R, P	PU	M37
WP4	D4-4	Report on structure experimental programme	CERN	R, P	CO	M36
WP4	D4-5	Acquisition electronics and software	CERN, NI	O, R	CO	M33
WP5	D5-1	Presentation of fellows at PACMAN workshop	CERN	P	PU	M18, M36, M48
WP6	D6-1	Outreach: school exhibition	CERN	E	PU	M34-M36
WP6	D6-2	University ambassadors	CERN	E, P	PU	M35-M43
WP6	D6-3	PACMAN open day (metrology day)	CERN	E	PU	M23
WP6	D6-4	Publications in journals	CERN	P, R	PU	M39-M44
WP6	D6-5	Publications in conferences	CERN	P, R	PU	M23-M40
WP6	D6-6	Participation in Researchers nights	CERN	E	PU	M15, M27, M39

B.4.2. Fellows individual research projects

Fellow	Host institution	Duration	Start date
ESR 1.1	**CERN**	**36 months**	**M5**

Project title : Non contact high precision sensor for Leitz Infinity Coordinate Measuring Machine (WP1)

Supervisor name: Dr Hélène Mainaud Durand

PhD enrolment: Yes: ETH Zürich / University of Savoie (SYMME)

Objectives:

- To develop an optical sensor to be plugged in the Leitz CMM measurement head for high precision positioning of objects such as ceramic balls and vibrating stretched wires. The sensor must provide absolute measurements in the local coordinate system of the CMM and provide the most accurate and repeatable measurements without relying on a similar external reference in order to establish a proportional relationship. Different sensor types (cWPS, oWPS, opto-coupler) must be studied including their mechanical, electronic and optical parts.
- To adapt the acquisition software and propose a calibration process.
- To upgrade the measurement head so that it can work in an environment with magnetic fields.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will work in the Leitz CMM available at the CERN metrology service. He/she will have to modify the electronics part of the sensor as well as the measuring and calibration algorithm. He/she will assess the perturbation of the measurements in the presence of magnetic field and will propose a solution with Hexagon. After a scientific review, he/she will implement the appropriate changes in the measuring head and proceed with the qualification of the new solution and final metrology of the CLIC components including magnets.
- 3rd phase of integration, the ESR will validate the methods of measurements.
- 4th phase of analysis and extrapolation for industrialization

Results:
- M1-1: compatibility tests performed / D1-1: report of compatibility tests
- M1-2: CMM head upgrade proposed / D1-2: CMM head prototype
- M1-3: CMM ready for the Final Prototype Alignment Bench (FPAB) / D1-3: Report of tests on FPAB
- M1-4: CMM tests performed.
- M1-9: inter-comparison tests performed / D1-8: report of inter-comparison tests

Dissemination:
- Conferences: conference organized by SPIE in Optical Metrology, Hexagon conference, IPAC, LCWS, PACMAN workshops
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondment: Hexagon will host ESR for implementation of the sensor and the measurement head into the CMM during 3 + 2 months [M13-M3]

Risk assessment: choice of the wire, to be tested on the Leitz CMM.

Fellow	Host institution	Duration	Start date
ESR 1.2	**CERN**	**36 months**	**M5**

Project title : Development and validation of an absolute Frequency Scanning Interferometry (FSI) Network (WP1)

Supervisor name: Dr Hélène Mainaud Durand

PhD enrolment: Yes: ETH Zürich

Objectives:
- To develop an absolute portable metrology method based on FSI
- To develop the fiducials allowing the centring of optical fibre in order to perform absolute measurements
- To study different configurations of FSI network through simulations in order to choose the best one for the measurements sequences.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will upgrade the current solutions of FSI in close collaboration with Etalon. The prototypes will be validated on a dedicated test set-up prepared with ESR 1.3. They will work separately and as a team to validate Micro-triangulation and FSI and to compare them for accuracy, reliability and robustness, before validating these solutions through cross-check measurements with the Leitz CMM
- 3rd phase of integration, ESR will validate the methods of measurements on the FPAB.
- 4th phase of analysis and extrapolation for portable utilization

Results:
- M1-1: compatibility tests performed / D1-1: report of compatibility tests
- M1-5: developments of absolute FSI performed / D1-4: FSI prototype
- D1-3: report of tests on FPAB
- M1-6: FSI measurements performed / D1-5: report of FSI measurements.
- M1-9: inter-comparison tests performed / D1-8: report of inter-comparison tests

Dissemination:
- Conferences: IWAA, IPAC, LCWS, PACMAN workshops
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondment: Etalon will train ESR in portable means of metrology and dimensional metrology solutions during 3 months [M13-M13]

Risk assessment: choice of the wire, to be tested on the dedicated test-setup prepared by ESR

Fellow	Host institution	Duration	Start date
ESR 1.3	CERN	36 months	M5

Project title : Micro-triangulation for high accuracy short range measurements of dynamic objects (WP1)

Supervisor name: Dr Hélène Mainaud Durand

PhD enrolment: Yes: ETH Zürich

Objectives:

- To adapt micro-triangulation for high accuracy short range measurements of dynamic objects.
- After training provided by ETHZ, to apply this technology to the project: increase the frequency of acquisition up to 50 Hz, synchronize the CCD camera and develop the detection algorithm for a vibrating stretched wire and targets.
- To perform simulations of the different configurations and verify on the experimental model.

Tasks and methodology:

- 1st phase of training and familiarization
- 2nd phase of validation: ESR will upgrade the current solutions of Micro-triangulation in close collaboration with ETHZ. The prototypes will be validated on a dedicated test set-up prepared with ESR1.2. They will work separately and as a team to validate Micro-triangulation and FSI and to compare them for accuracy, reliability and robustness, before validating these solutions through cross-check measurements with the Leitz CMM
- 3rd phase of integration, the ESR will validate the methods of measurements on the FPAB.
- 4th phase of analysis and extrapolation for portable utilization

Results:

- M1-1: compatibility tests performed / D1-1: report of compatibility tests
- M1-7: micro-triangulation software + hardware specified / D1-6: micro-triangulation software + hardware
- D1-3: report of tests on FPAB
- M1-8: micro-triangulation measurements carried out / D1-7: report of micro-triangulation tests
- M1-9: inter-comparison tests performed / D1-8: report of inter-comparison tests.

Dissemination:

- Conferences: IWAA, IPAC, LCWS, PACMAN workshops
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondment: Etalon will train ESR in portable means of metrology and dimensional metrology solutions during 3 months. ESR will also be trained by the Geodesic and Geodynamics Laboratory of ETHZ during 3 months in industrial metrology and geodetic metrology fundamentals [M13-M33]

Risk assessment: choice of the wire, to be tested on the dedicated test-setup prepared by ESR.

Fellow	Host institution	Duration	Start date
ESR 2.1	CERN	36 months	M7

Project title : Stretched wire systems for the magnetic measurement of small-aperture magnets (WP2)

Supervisor name: Prof. S. Russenschuck

PhD enrolment: Yes: University of Sannio.

Objectives:

- To develop a magnetic measurement system based on the oscillating wire field-measuring technique for small aperture magnets
- To integrate and combine metrological techniques: measurement of vibrations, tension, opto-couplers, data acquisition, digital integrators with methods of potential theory and the solution of the wave equation on vibrating strings.
- To work in close collaboration with the university of Sannio for the implementation of the method and for the theoretical aspects of the work.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will set-up his own experimental set-up including the stretched wire, mechanical support and motors, digital integrators, acquisition electronics and control program He/she will test the system against the calibrated magnets available at CERN. He/she will investigate the frequency spectrum of the oscillation and possible coupling to environmental perturbation. After optimization of the measurements, the same small aperture magnet will be measured by the methods developed by ESR2.1 and ESR 2.2, with the same mechanical support and fiducials.
- 3rd phase of integration, the ESR will setup a quad/BPM bench with ESR 4.1 to measure simultaneously the centre of the quadrupole with the BPM mounted in it. Then, the solution developed will be integrated into the FPAB and will be the object of extensive measurement campaigns.
- 4th phase of analysis and preparation of the system for industrialization

Results:
- M1-1: compatibility tests performed / D1-1: report of compatibility tests
- M2-1: solution with stretched wire designed / D2-1: solution with stretched wire
- M2-2: magnetic measurements ready for the FPAB / D2-2: report on magnetic measurements
- M2-3: measurements on FPAB performed / D1-3: report of tests on FPAB
- M2-6: inter-comparison tests performed / D2-5: report of inter-comparison

Dissemination:
- Conferences: IMMW, MT, IPAC, LCWS
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: ESR will be trained in magnet manufacturing and measurement techniques in SIGMAPHI (3 months) and METROLAB (3 months) [M13-M33]

Risk assessment: choice of the wire, to be tested first on a smaller test bench

Fellow	Host institution	Duration	Start date
ESR 2.2	CERN	36 months	M7

Project title : Printed circuit board technology for small-diameter field probes (WP2)

Supervisor name: Prof. S. Russenschuck

PhD enrolment: Yes: University of Sannio.

Objectives:
- To develop a magnetic measurement system based on rotating search coils with printed circuit board technology. This method will be used for direct comparison with the oscillating wire technique and for acceptance of the quadrupole magnets coming from industry
- To develop the control algorithms and software in order to create an industrial standard measurement device.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will design and build a magnetic measurement bench based on the printed circuit rotating coil including the mechanical support, rotating motor, fiducials, digital encoders, acquisition electronics and software. He/she will describe the magnetic field in very short magnets using theoretical foundations, in-situ calibration methods, and de-convolution of signals in the time domain. After optimization of the measurements, the same small aperture magnet will be measured by the methods developed by ESR2.1 and ESR 2.2, with the same mechanical support and fiducials.
- 3rd phase of integration, the ESR will setup a quad/BPM bench with ESR 4.1 to measure simultaneously the centre of the quadrupole with the BPM mounted in it..
- 4th phase of analysis and preparation of the system for industrialization

Results:
- M2-4: PCB solution ready / D2-3: solution with PCB rotating coil
- M2-5: algorithms of control and software specified / D2-4: algorithms of control and software
- M2-6: inter-comparison tests performed / D2-5: report of inter-comparison

Dissemination:
- Conferences: IMMW, MT, IPAC, LCWS
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: ESR will be trained by ELTOS (3 months) where he/she will learn the basics of the manufacturing of PCBs as well as their inherent limitations. He/she will also work closely with SIGMAPHI (2 months) and learn in their premises the basics of magnetic measurements from an industrial point of view. [M13-M33]

Risk assessment: The calibration efficiency for rotating search coils with an extreme ratio between coil radius and thickness

Fellow	Host institution	Duration	Start date
ESR 3.1	**CERN**	**36 months**	**M7**

Project title : Ultra-precise quadrupoles magnets assembly and testing. Integration of an alignment test-bed towards and industrial production (WP3)

Supervisor name: Ing. M. Modena

PhD enrolment: Yes: University of Cranfield / University of Savoie (SYMME)

Objectives:
- To re-engineer the quadrupole magnets assembly from the point of view of ultra-high precision engineering
- To re-engineer the yokes quadrant mating surfaces, Beam Position Monitor support and the assembly procedure to guarantee an initial co-alignment at the micrometre level.
- To perform the full mechanical integration of the prototype alignment bench. He/she shall pay special attention to the total error budget and perform statistical analysis from measurements and simulations.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will proceed first with the mechanical studies of the quadrupole and BPM support. He/she will optimize numerically the mating surfaces of the magnet yoke and collaborate with the mechanical workshop at CERN to produce a working prototype. He/she will then start to define and build the common prototype alignment bench for global alignment of all the components compatible with the CLIC existing module. This should include initially the mechanical support, the wire and optical targets associated to it as well as the motor parts. Ultimately, this prototype bench should take care of precise positioning of components and ancillary systems used during measurements, taking into account the thermal effects and stabilization, which should be simulated accordingly.
- 3rd phase of integration, the prototype alignment bench built by ESR will be equipped with the systems needed. A particular attention will be brought to the quadrupole/BPM assembly in this bench in order to minimize the original displacement of the BPM with respect to the magnetic field of the quadrupole.
- 4th phase of analysis and preparation of the system for industrialization

Results:
- M3-1: quadrupole magnets assembly re-engineered / D3-1: quadrupole magnets
- M3-2: all technical solutions integrated in the FPAB / D3-2: Final Prototype Alignment Bench (FPAB)

Dissemination:
- Conferences: EUSPEN, MT, IPAC, LCWS
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: DMP will host ESR 3.1 for hands-on training on high precision machining, quality control and alignment techniques (4 months). ESR will also collaborate with the management, manufacturing and logistics services [M13-M33]

Risk assessment: from the scheduling point of view, delays in the development of sensors and components could have an impact on the other technical systems and consequently on the final multidisciplinary prototype alignment bench, but in no circumstances on the individual ESR research, as the different technologies will be validated on smaller dedicated test setup first.

Fellow	Host institution	Duration	Start date
ESR 3.2	**CERN**	**36 months**	**M9**

Project title : Seismic sensor development and vibration characterization (WP3)

Supervisor name: Ing. O. Capatina

PhD enrolment: Yes: University of Savoie (LAPP)

Objectives:
- To determine the technological barriers that exist for resisting to radiation (could reach kGy) and to stray magnetic fields.
- To upgrade or develop sensors with a large bandwidth covering the whole frequency region of interest (0.1-100 Hz) and presenting sufficiently low noise to measure quiet ground motion. The sensors also need to be compact to fit in the crowded space of the prototype alignment bench and light-weight (typically less than a few kg) to avoid disturbing the measured structures. This will be performed in collaboration with LAPP, with regular visits to this laboratory.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will characterize in detail the frequency response of the current sensors used for stabilization by testing on vibration shakers. Within the field of mechatronics, he/she will study the spurious structural resonances of the mechanical structure in the frequency region of interest through numerical methods; optimize the electronics development for low noise acquisition; and large dynamic range, and study the eventual need for feedback. After this, he/she will propose an upgrade program including modifications and an experimental verification. After approval, the ESR will proceed with the modification and test the upgraded sensors on the prototype alignment bench. A full characterization of the vibration sources will be provided to be used by other ESRs.
- 3rd phase of integration, ESR will integrate the seismic sensors in the prototype alignment bench.
- 4th phase of analysis of measurements and preparation of the system for industrialization

Results:
- M3-2: all technical solutions integrated in the FPAB / D3-2: Final Prototype Alignment Bench (FPAB)
- M3-3: new version of sensor designed / D3-3: sensor prototypes
- M3-4: sensor validated under magnetic fields and radiations / D3-4: report of sensor validation

Dissemination:
- Conferences: EUSPEN, ISMA conference on Noise and Vibration engineering, IPAC, LCWS
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: DMP will host ESR 3.2 for hands-on training on high precision machining, quality control and alignment techniques (3 months). ESR will also collaborate with the management, manufacturing and logistics services. ESR will spend 3 months at LAPP getting the basic training in seismic sensors and mechatronics [M13-M33]

Risk assessment: from the scheduling point of view, delays in the development of sensors and components could have an impact on the other technical systems and consequently on the final multidisciplinary prototype alignment bench, but in no circumstances on the individual ESR research, as the different technologies will be validated on smaller dedicated test setup first.

Fellow	Host institution	Duration	Start date
ESR 3.3	**CERN**	**36 months**	**M9**

Project title : Nano-positioning of the main Linac quadrupole as means of laboratory pre-alignment (WP3)

Supervisor name: Ing. K. Artoos

PhD enrolment: Yes: TU Delft

Objectives:
- To upgrade the first prototype of nano-positioning to be used for the test setup.
- To study the possibility of using long range actuators in flexural guides for the combination of alignment and stabilization with sub-nanometre resolution in a millimetre range.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will set-up a nano-positioning system based on actuators and seismic sensors in the prototype alignment bench. He/she will design the system, validate it and check its compatibility with other systems, before performing nanometre resolution displacements required and analysing their consequences.
- 3rd phase of integration: ESR will integrate the nano-positioning system in the prototype alignment bench.
- 4th phase of analysis of measurements and preparation of the system for industrialization

Results:
- M3-2: all technical solutions integrated in the FPAB / D3-2: Final Prototype Alignment Bench (FPAB)
- M3-5: nano-positioning prototype designed / D3-5: nano-positioning prototype
- M3-6: long range actuators studied / D3-6: long range actuators
- M3-7: nano-positioning displacements performed / D3-7: report on nano-positioning displacements

Dissemination:
- Conferences: EUSPEN, ISMA conference on Noise and Vibration engineering, IWAA, IPAC, LCWS
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: ESR will join the internship program of TNO in a project applying precision technology, high accuracy mechanisms, metrology and vibration attenuation (3 months). [M13-M33]

Risk assessment: from the scheduling point of view, delays in the development of sensors and components could have an impact on the other technical systems and consequently on the final multidisciplinary prototype alignment bench, but in no circumstances on the individual ESR research, as the different technologies will be validated on smaller dedicated test setup first.

Fellow	Host institution	Duration	Start date
ESR 4.1	CERN	36 months	M7

Project title : Alignment and resolution of a Beam Position Monitor operating at Microwave frequencies in the nanometre regime (WP4)

Supervisor name: Ing. M. Wendt

PhD enrolment: Yes: University of Valencia

Objectives:
- To demonstrate the nanometre resolution of the Beam Position Monitor by using a RF excitation on the stretched wire. The measurement should prove sub-micrometre spatial resolution as well as calibration, absolute alignment and long term stability of a few micrometres or better, as well as high temporal resolution.
- To prepare the read-out and control system based on National Instruments hard and software, in close collaboration with NI.

Tasks and methodology:
- 1st phase of training and familiarization
- 2nd phase of validation: ESR will design and build a microwave test bench for the Beam Position Monitor including the mechanical support, the stretched wire as signal excitation, and the read-out electronics and acquisition software. For signal stimulus and read-out, he/she will explore the use of a vector network analyser as direct excitation and read-out of the signals, and alternatively a dedicated microwave down-converter front-end and digital I/Q demodulation. The ESR shall understand and optimize the setup with help of electromagnetic analysis methods, analytically and numerically. Impedance matching and electromagnetic launching of microwaves frequencies have to be studied, while considering mechanical properties of the wire.
- 3rd phase of integration: ESR will setup with ESR 2.1a quad/BPM bench to measure simultaneously the centre of the quadrupole with the BPM mounted on it, before integrating the whole assembly in the final prototype alignment bench.
- 4th phase of analysis of measurements and preparation of the system for beam measurements.

Results:
- M3-2: all technical solutions integrated in the FPAB / D3-2: Final Prototype Alignment Bench (FPAB)
- M4-1: microwave test bench for BPM designed / D4-1: microwave bench
- M4-2: nanometre resolution of BPM demonstrated / D4-2: report of BPM nanometric resolution
- M4-3: measurements on FPAB performed / D4-3: report of BPM measurements on FPAB

Dissemination:
- Conferences: IBIC, IPAC, LCWS, NI Days
- Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event

Planned secondments: NI will host ESR4.1 in its internship program in Debrecen, Hu (3 months). ESR will receive practical training on LabView software, PXI technology, high speed digitizers, timing and syncing modules [M13-M33].

Risk assessment: choice of the wire to be a compromise between all the different technologies, and the response of the BPM to external noise like ground motions or mechanical vibration (see § B2.2).

Fellow	Host institution	Duration	Start date
ESR 4.2	CERN	36 months	M9

Project title : development of direct measurement techniques for the in-situ internal alignment of accelerating structures (WP4) **Supervisor name:** Dr. N. Catalan Lasheras **PhD enrolment:** Yes: University of Valencia
Objectives: - To investigate an independent measure of the axis of RF accelerating cavities to cross-check against the mechanical alignment and provide laboratory non-destructive tests - To investigate the limits of the classical techniques and compare them to lasers excitation and stretched wire - To consider the use of the RF input ports and/or the damping waveguides as transmission lines. - To perform extensive simulation work, low power measurements using a vector network analyser or direct electronics as well as experimental validation on prototype CLIC accelerating structures.
Tasks and methodology: - 1st phase of training and familiarization - 2nd phase of validation: ESR will simulate the accelerating cavity to understand the transmission of waves generated by an off-axis excitation and compare it with an on-axis excitation. He/she will then propose an excitation mode based in a stretched wire, a laser, or direct transmission through the damping waveguides. After a scientific review, the researcher will design and build the acquisition electronics and software to either install it in the test set-up used by ESR4.1 and/or in a new set-up based on a laser source. - 3rd phase of integration: ESR will integrate (if compatible) the solution in the prototype alignment bench - 4th phase of analysis of measurements and preparation of the system for beam measurements.
Results: - M4-4: structure experimental programme proposed / Report on structure experimental programme - M4-5: acquisition electronics and software designed / Acquisition electronics and software
Dissemination: - Conferences: IBIC, IPAC, LCWS, LINAC, NI Days - Outreach activities: University ambassador, school exhibition, CERN visits, researchers nights, PACMAN open day, Women at CERN event
Planned secondments: NI will host ESR4.2 in its internship program in Debrecen, Hu (3 months). ESR will receive practical training on LabView software, PXI technology, high speed digitizers, timing and syncing modules [M13-M33].
Risk assessment: the excitation mode based in a stretched wire could be hardly detectable, and other solutions will be studied in parallel (laser or direct transmission)

B.4.3. Management structure, organisation and procedures

B.4.3.1. Network organization and management structure

Project management structure

The detailed work plan and schedule of the PACMAN project will be presented and validated during the kick-off meeting. It will include the tasks to be performed by each ESR, from the technical point of view as well as the plans for training, dissemination and outreach. The tasks with associated milestones and deliverables will be scheduled in the Microsoft Project software that will be used for the monitoring of the project. The need to update the schedule will be signalled by each WP leader, on the base of the information provided by PhD supervisors. WP leaders will inform the management team in case of deviation from the operational objectives as well as training or dissemination and outreach objectives.
The management of the ITN and the role and responsibilities of each body is described in the table below.

Table 6. Project management structure

	Membership and organization	Role
Supervisory Board (SB)	- The Network Coordinator (NC) - The Chair of the Selection Committee - The Head of the HR Recruitment, Programmes and Monitoring at CERN - One representative from each	• Approve and oversee implementation of the training programme for scientific, technical and complementary skills, as well as the network-wide training activities • Monitor and evaluate overall progress of the research

	Associated Partner. The chairperson of the board will be selected at the beginning of the project. The SB will meet at the kick-off meeting and in follow-up meetings every 1 year (5 meetings in total)	training programme • Ensure exchange of best training practice with the associated partners, in particular with the industrial partners • Approve the work plan, Personal Career Development plans, and the exploitation plan
Management Team	- The Network Coordinator - The Training WP leader - The Dissemination and outreach WP leader	• Communicate to/from the associated partners • Organize and prepare documentation for the SB meetings • Communicate and report to the European Commission • Coordinate the ITN research training programme • Organize network-wide training (courses, workshops) • Prepare the research plan and the exploitation plan • Review the Personal Career Development Plans
Work packages	Individual WP leaders. It will have regular meetings every 6 months, or more frequently if needed. Associated partners will be invited to attend.	• Manage the WP research programme • Manage and follow-up the progress of the individual research projects • Overview the integration of the ESR into the research teams • Prepare with supervisors and ESRs the Personal Career Development Plans • Disseminate best practices and projects results

Decision-making procedure

The executive decisions for the implementation of the research-training programme will be taken by the Management Team. Any changes in the research and/or training programme will have to be approved by the SB. **Where such changes may have impact on the contractual obligations of the ITN, the prior agreement of the EC Project Officer in charge of the IDP will be sought.** Should disputes arise, the person in charge of the specific project, with input from the researcher and the supervisor, will intervene to try and solve disputes amicably. In cases where such amicable settlements were to fail, disputes will be settled by the Management Team whenever possible. When such resolution is not possible the matter will be raised to the SB. The gender balance will be insured at the level of decision-making within the project.

Communication strategy

The publication rules will be considered an integral part of the **Consortium Agreement** and the NC will be the responsible for making all necessary arrangements for the review and/or amendment of it. The objective of the organisation and communication structure of the project is to obtain maximum transparency for all the associated partners concerning the technical and overall project status. All information (meeting minutes, progress reports, relevant publications, etc.) will be communicated to the NC, who assumes the responsibility for directing this information to the associated partners, where appropriate.
Communication between the ESRs and the associated partners in each Work Package will be coordinated by the WP leader. Frequent web-meetings will be encouraged.

Risk management

Risk management will be monitored throughout the project by each Work Package leader, according to a guideline prepared by the NC. This risk guideline will be approved by the Management Team before the start of the project and will be endorsed at the kick-off meeting by the SB. The mitigation of technical and scientific risks is based on proceeding with proven methodologies, the involvement of participants with the relevant expertise and the setting of well-defined goals and deliverables in a realistic timescale. There is a group of institutions behind each deliverable, thus in case of problems there is redundant expertise. It is unlikely that a failure or delay in one Work Package or task will have a "no-go" impact on the entire project and the training capacity of the ITN. The process or risk management will be as follows:

- The NC will be informed by the WP leaders of potential risks on scientific activities or training aspects
- The NC will initiate and counter measures in line with procedures defined in the risk guideline
- The NC will lead risk resolution attempts and will be responsible for consulting the SB and EU project officer if any significant changes to the project are likely
- The NC will pro-actively prepare and propose possible solutions.

According to the Special Clause 5 bis of Article 7 of the Grant Agreement, a mid-term review meeting must be organised, preferably during month 20-22 of the project. The venue and organisation of this meeting will be of the responsibility of the NC, and the timing and location of the meeting must be agreed with the REA project officer.

B.4.3.2. Financial management

The NC has the overall responsibility for the financial management of the training network. **A specialized unit in the Human Resources (HR) department at CERN**, led by M. Seamus Hegarty, coordinates all administrative and financial processes from project proposal to recruitment from production of annual reports, in close liaison with the Finance Department, the Internal Audit and EU office in order to observe strict compliance with EC reporting standards. The dedicated CERN-EU budget planning group will prepare a consolidated overview of the budgetary situation on the basis of the Partners' cost statements and the payments that have been made.

B.4.3.2. Recruitment strategy

Charter and code of researchers. The CERN recruitment policy, employment conditions and staff career development prospects are in good compliance with the guidelines of the European Charter for Researchers and the Code of conduct for the Recruitment of Researchers, and most of the recommendations contained therein are effectively implemented and part of internal practice. This concerns in particular the recommendations on non-discrimination, gender balance, research environment, funding and salaries, continuous training, evaluation and appraisal systems, complaints and appeals, working conditions and carrier development.

Advertisement of opening. All position will be advertised on the EURAXESS website, the CERN electronic recruitment tool e-RT (http://ert.cern.ch) as well as via networks inside the project and its partners. Specialised websites such as bright recruits, the CERN Courier magazine and website job position sections will be also used. At CERN, an extensively-used website contains information about possible Marie Curie Actions for which there are openings at CERN. In 2011, more than one thousand candidates applied for fellowship positions at CERN, highlighting the success of the advertisement approach. CERN participates in many career fairs where it presents specific information on Marie Curie programs. The material used to advertise the positions at CERN will be distributed to all the partners to increase the potential pool of candidates. The partners will use this material to advertise the PACMAN program via their websites, events and recruitment fairs. **We are conscious that the lack of women representatives in science is mainly driven by the shortage of female candidates.**

At this stage of the recruitment, the PACMAN management team and work package coordinators will make use of their personal networks in research institutes and universities to encourage bright women to apply for the PACMAN positions. We are confident that in this way, we can increase the number of female researchers in PACMAN. We will also focus our recruitment in the TOP WOMEN summit in Brussels where CERN participated in the past.

Selection process. All ESR applicants will submit their applications via CERN's electronic recruitment system e-RT and will undergo rigorous selection on grounds of quality and potential, as well as a matching of their scientific profile with the job specification. The Selection Committee will be constituted ad-hoc for each post and will include members of the Associated Partners, the PACMAN Management Team, a representative of HR, and of the Marie Curie Steering group at CERN. The appointment of selected candidate is under the responsibility of the Selection Committee which ensures correct application of the Marie Curie rules and criteria. Given that the ESRs will be engaged for 3-year appointments, all of them will be recruited within the first year of operation of the IDP network. Furthermore, considering the interdependencies between the individual ESR projects, fellowships will be advertised well in advance. The advertisement of posts and the timetable of the selection committee will be tailored to the intended recruitment schedule for the ESRs.

B.4.3.3. Gender aspects

As we pointed out previously, **a significant fraction of the network management and supervisory team is composed of female scientists. PACMAN intends to promote female prevalence also between the young researchers without applying positive discrimination**. After recruitment, special opportunities will be offered to them to improve their transferable skills, their confidence and potential. All efforts will be made to retain them in research after their PhD. This will be addressed through several lines of actions, such as:

- Encouraging applications from female individuals at all levels within the ITN
- Mentoring of the ESRs by the female senior members of the network
- Inviting female researchers to deliver talks at the workshops organized by the PACMAN ITN.

Since 1993, CERN has been actively applying its strong Equal Opportunities (EO) policy. With emphasis initially placed on recruitment and gender-related issues, activities have now broadened to include other EO issues such as dignity and respect, life-work balance, culture, age and gender diversity. With the aim of increasing the number of women coming into and retaining them in the field of particle physics, CERN and TNO have also been an active member of the FP6 initiative SET-Routes; CERN has introduced new courses in its internal Management & Communication curriculum which specifically address issues of women in management. To minimize gender bias and achieve a broader perspective in the approach to work, statutory working groups and selection boards at CERN are required to include women and this is also the case for the Marie Curie Selection Committee. In addition, potential supervisors will be asked to pay particular attention to female candidates when applications are circulated. To improve female participation in all job categories and at all levels, gender distribution is monitored and statistics are published annually (experience has shown the absence of any gender bias at the selection level). In training lectures and seminars, particular attention is paid to choosing, whenever possible, women scientists as speakers in order to provide positive role models to young female scientists.

B.4.3.4. Intellectual property

Intellectual Property (IP) management **will be described in detail in the Consortium Agreement**, which will be signed by all the Associated Partners of the network. The FP7 IPR rules are applicable therein and will be defined in the Consortium Agreement.
The IP management provisions shall secure the maximum protection of all rights of the parties. It will also address the confidentiality of any information made available by the disclosing party to the receiving part/parties. In the event that an Associated Partner wishes to include background to the proposed research project, for the implementation and effective accomplishment of the project objectives, any such pre-existing background, including knowhow, will remain the property of the right holder. Any such background will be listed in the Consortium Agreement. Any other background not included in the list shall be automatically excluded from project use, although an Associated Partner has an option to add background during the project, as it sees fit, for the attainment of the project objectives. Such inclusion of background shall be recorded in writing by the right holder. The standard IP rules under the Consortium Agreement are that the beneficiary who generates IP is the owner of that IP. In terms of a training network, what is generated by the researchers hired by CERN thus belongs to CERN. We can note that this particularly makes sense in situations like the current one where they actually spend most of their time at CERN and a limited amount of time at the other partners' (3 months on average). This being said, the Consortium Agreement also foresees that there might be cases where IP is jointly generated and jointly owned. In specific cases, network researchers, who are hosted by an industrial partner for a secondment, may be requested to sign a Partnership Agreement or a non-disclosure agreement with the company in order to protect designs, know-how and procedures owned by the company.

B.4.3.7. Consortium Agreement

A Consortium Agreement will be signed by the network and submitted to the REA within the first 2 months of the project.

B.4.4. Project monitoring and key performance indicators

Periodic and final reports are contractual deliverables, according to Article 4 and II.4 of the Grant Agreement. In addition, progress reports are due at the end of the first and third year in order for the REA to monitor the implementation of the project.
When preparing those documents, the NC should report according to the following key performance indicators and specify the means to monitor them.

B.4.4.1. Research Activities

- Research results obtained (including a short description of progress on the individual projects) and deviations, if any, to the original research work plan.
- Scientific highlights and achievements (scientific/technological breakthrough, patents, awards, prizes etc...).
- A full list of individual and joint publications, directly related to the work undertaken within the project (including citation index and impact factor), with appropriate acknowledgment of the funding source.
- Intersectoral and multidisciplinary collaboration.

B.4.4.2. Training Activities

- Implemented training events/activities and deviations, if any, to the original training plan (including Career Development Plans, coaching or mentoring activities in place at each host institution).
- Participation of the fellows in training events and meetings from the network (workshops, seminars, summer schools, etc), and at international conferences outside the network (names, places, dates).
- Transferable skills training (e.g. project management, presentation skills, language courses, ethics, intellectual property rights, communication, entrepreneurship, etc.).
- Implementation of visits/secondments undertaken within the network to both full participants and associated partners.

B.4.4.3. Management activities

- Status of ESR recruitments at each participant, and relevant issues related to the recruitment strategy/process and gender balance, with justification for any deviation from the original plan.
- Effectiveness of networking, communication and decision-making between stakeholders.
- Effectiveness of the "training events and conferences": external participation and integration in the training programme.
- Effectiveness of the financial management and compliance with Marie Curie salary rates.
- IPR management and commercial exploitation of research results.

B.4.4.4. Dissemination and outreach activities

- Implementation and analysis of the proposed outreach activities and deviations, if any, to the original work plan.
- Analysis of the dissemination activities.

B.5 Impact

B.5.1. Impact towards the policy objectives of the programme

Contribution to Policy Objectives

The PACMAN training network makes extensive use of the CERN’s science and industry community and of CLIC international collaboration in particular. As CLIC goes into prototyping and industrialization, new, promising industries and laboratories may join the project and build around it solid and durable relationships. PACMAN will allow some of the Associated Partners to discover the technological challenges of CLIC and join the international effort towards a new generation of colliders built as a gigantic watch piece. The industrial partners of the project acknowledge this **opportunity to work with one of the leading research institutes for emerging technology development** while getting in close contact **with young and resourceful researchers as a potential future work force** and source for new innovations.

Ultra-precision engineering and nanotechnology are already the primary motivation of the **EUSPEN society**. Although most of the network participants working on the field are already EUSPEN members, the contribution of the PACMAN network to these topics will definitely **generate the interest of new potential members** and at the same time, **reinforce the excellent reputation of the society**. We will also make use of this society and the conference they organize to broaden the horizons of the young researchers of the network.

Training on intellectual property and technology transfer is indeed new in science and research laboratories and of major importance for the network and its associated partners. The initial effort invested by the PACMAN network together with WIPO academy and the CERN Knowledge Transfer Group will become a standard for CERN training in the future. The interest of such initiative inside a research environment with a high industrial exposure is undeniable.
All **partners share the same interests in enhancing the participation and the role of women** in their organizations. PACMAN will provide them with a small pool of excellent female scientists and a catalog of training and outreach activities they can reuse in their future efforts in this direction. **Following the solid mutual interest among Partners, PACMAN has a strong potential to lead long-term inter-sectorial researcher training schemes and further R&D collaborations between the project Partners.**

Enhancing Public-Private Research Training Collaboration

Research collaboration between public and private sectors is mandatory for the development of accelerators. The large number of components necessary for the construction of LHC or CLIC relies on close collaboration between private industry and public institutions. The knowledge transfer flows in both directions as laboratory tests become prototypes and series production. The PACMAN research program aims to do research in industry on components such as the CMM sensors from which industry will again benefit not only for **commercialization of a new product** but also from the improved accuracy that the same sensors will **provide to industry outside the network.** Teaching and training researchers in magnetic measures will allow them to develop more precise techniques with which industry will manufacture more homogenous and accurate magnets.
With respect to training collaboration, the Hexagon conference is a relatively new initiative and it has been organised only during the last two years. As stated on their web page it consists of “four days of educational and networking opportunities”. All members of the network will profit from this newly found community to feed cross-disciplinary ideas from and into industry.
Communication and broadcasting, accelerators, and medicine communities make use of RF but do not work in general with each other while they share the same knowledge and technologies. Training on RF outside accelerators is very limited in Europe. Thanks to the NI training platform common to all these fields, researchers in the PACMAN network will have the potential to recognise and merge knowledge in different domains.

Contribution to key skills, career prospects, employability

The unique nature of this project, underpinned by the strong industrial links and the international environment of CERN itself, places the ESRs in a privileged position to realising their career ambitions. With a unique portfolio of technical and transferable skills, the researchers trained by the PACMAN network can expect to advance to senior positions in research, development, design, test, engineering, consultancy, and management in sectors such as automotive, space, aerospace, optics, medical engineering, and advanced metrology.

In the short term, the **young researchers in the PACMAN network will obtain a PhD** out of their research and will be exceptionally well prepared for integrating into the European workforce after that. As with any doctoral program, they will be prepared to apply the scientific method to their work enjoying the science and technological challenge it may bring. But unlike most other young scientists, they will have a plethora of tools in their possession thanks to the innovative and multidisciplinary nature of their training. They will also have the key advantage of having a **substantial network of colleagues and partners** in their own field of research coming from both the industry and the academic world. This will be particularly significant for the women scientists thanks to the special networking activities provided by the ITN like the European Gender Summit.

The topics in which the PACMAN network will train its collaborators, precision mechanics, metrology and nanotechnology, are of **increasing interests for European industry**. Their careers prospects are matchless and deemed to improve in the years to come.

Stimulating creativity and entrepreneurial mind-sets

The environment in which the ESRs will evolve is designed to promote curiosity and an entrepreneurial spirit. The ESRs will identify new ideas, **they will create something both new and appropriate for their research project and for the common interest of the network, and they will realize these opportunities in a productive way**. By emphasizing a general approach, individuals are encouraged to engage in creative acts, regardless of the technology they are using. Since they will take part in many project phases, they will gain valuable experience in many aspects of a large project, which they can apply in their own, later initiatives. Strong motivation, curiosity, a broad vision and an urge to solve relevant problems are some of the driving forces behind entrepreneurial mind-sets. The atmosphere and training in the network encourages these traits, and encourages free-thinking and innovative approaches to change.

The curriculum of transferable skills that PACMAN will procure its young researchers includes negotiation skills, entrepreneurship courses and proposal writing. This will have the added value of boosting their confidence and self-consciousness as potential managers and leaders. An entrepreneurial attitude is needed in both the public and private sectors – the ESRs interested in private sector careers and setting up their own company can profit from a recently-introduced course at CERN on “Setting up your own business”. In the same line of action, TNO offers counselling and help in creating and launching small technology companies. **When ESRs will witness their research being applied in industry and the market they will realise the value of their own creativity and personal qualifications as researchers and managers**.

The PACMAN network is composed of partners working in close relationship with CERN. The project will be an opportunity to strengthen these links and contribute to the establishment of long term collaborations. Moreover, industries and universities will be able to rely on the lasting structured training programmes.

B.5.2. Plans for exploitation of results and Dissemination strategy

PACMAN aims to develop new sensors, improve the already existent hardware and methodology for alignment measurements and metrology, and integrate them into an industrial environment. It is obvious that the first beneficiaries of the network results will be its members including researchers and network partners. The results of the PACMAN network will be **used in the private and public sector in agreement with the provisions** for exploitation and dissemination laid out in the Consortium Agreement. In due course, sensors and hardware developed by the individual work package will be commercialised by the associated industrial partner.

Aside from the industrial benefits of the individual research projects, the final achievement of nanometre scale accuracy on the alignment of the CLIC components will be determinant for the **capacity of Europe to build the next linear collider** and to fully exploit the physics discoveries of the LHC era. The alignment procedures will be used with minor modifications also for the high luminosity LHC upgrade. But the same approach will **also increase the brilliance and performance of light sources** and other large accelerator facilities around the world. Ultimately, the final alignment techniques and algorithms developed for the PACMAN project, will find a privileged user in European industry. **The capacity to align large, multicomponent sets to the nanometre scale in a short time and in an industrial environment can be exported in a near future to aerospace and automotive industry, research telescopes or satellites assembly to name only some examples.**

As part of WP6 the PACMAN network will submit the publications to open access repositories and journals, in line with the recommendations of the EC on open access to scientific information. Dissemination of research results will in most cases use journal publications as well as presentations/publications at conferences, seminars or workshops. **Most of the deliverables of the project will be the object of a report.** There will also be common publications of the ESRs, concerning the inter-comparison between FSI, CMM and Micro-triangulation, or concerning inter comparison between PC and oscillating wire techniques. Following the first results and analysis, the ESRs will present their achievements during the **spring and autumn conferences** of the fourth year. Any publication of results will take place according to the Intellectual Property Rights and publication policies agreed in the Consortium Agreement.
CERN’s Technology Transfer office is building a unique portfolio of technical competencies derived from more than 50 years of experience in building and running state of the art particle accelerators and detectors. This technical expertise is made available to external partners (companies, research, institutes,etc.). The results of the PACMAN network will be added to this portfolio as part of WP6.

As required by Annex II of the grant agreement, the NC should ensure that all publications and presentations by members of the project consortium - including all funded fellows - acknowledge the EU financial support received. This acknowledgement should specifically refer to the Marie Curie Initial Training Networks (ITN) action, as well as the project number and acronym.

B.5.3. Outreach activities

The number of **students enrolled in science is highly insufficient** for covering the necessities of a healthy expanding industry, while careers in science are often disregarded by young students. Despite the acknowledged fact that investment in R&D correlates positively with company performance, research vocation is considered by the public as an impractical way of earning a life and unbeneficial for society. As scientists, it is our duty to offer our enthusiasm to the general public and potential researchers in particular. The PACMAN network has designed an effective program of outreach activities targeting different layers of society. Participation in the following four activities will be mandatory for all ESRs.

Table 7. Outreach activities organized by the network

Outreach activity	Targeted audience	Topic	Impact
School exhibition	Children 8-11 years old	Metrology	Motivate children on following a scientific career
CERN guides	All public. Lots of high school and University students	CERN science	Motivate young adults on following a scientific career. Communicate on research benefits and justify tax expenses
High school women colloquia	High school female students	Women in science	Encourage young girls to follow a career in science.
University ambassadors	Last year university students	EU actions	Encourage science students to follow a research path.
Hands-on exhibition	Public	PACMAN research topics	All precedent three actions. Publicise EU initiatives. To be displayed at the • PACMAN open day • Researchers' night at CERN • Science: it's a girl thing! • Expanding your horizons
Women at CERN	Female PhD students	Science	Create networking opportunities among female researchers.

B.6 Ethical issues

The Beneficiaries accept to uphold the highest standards of scientific integrity and ethical conduct during the implementation of the grant agreement.

PART C:

Overall indicative project deliverables

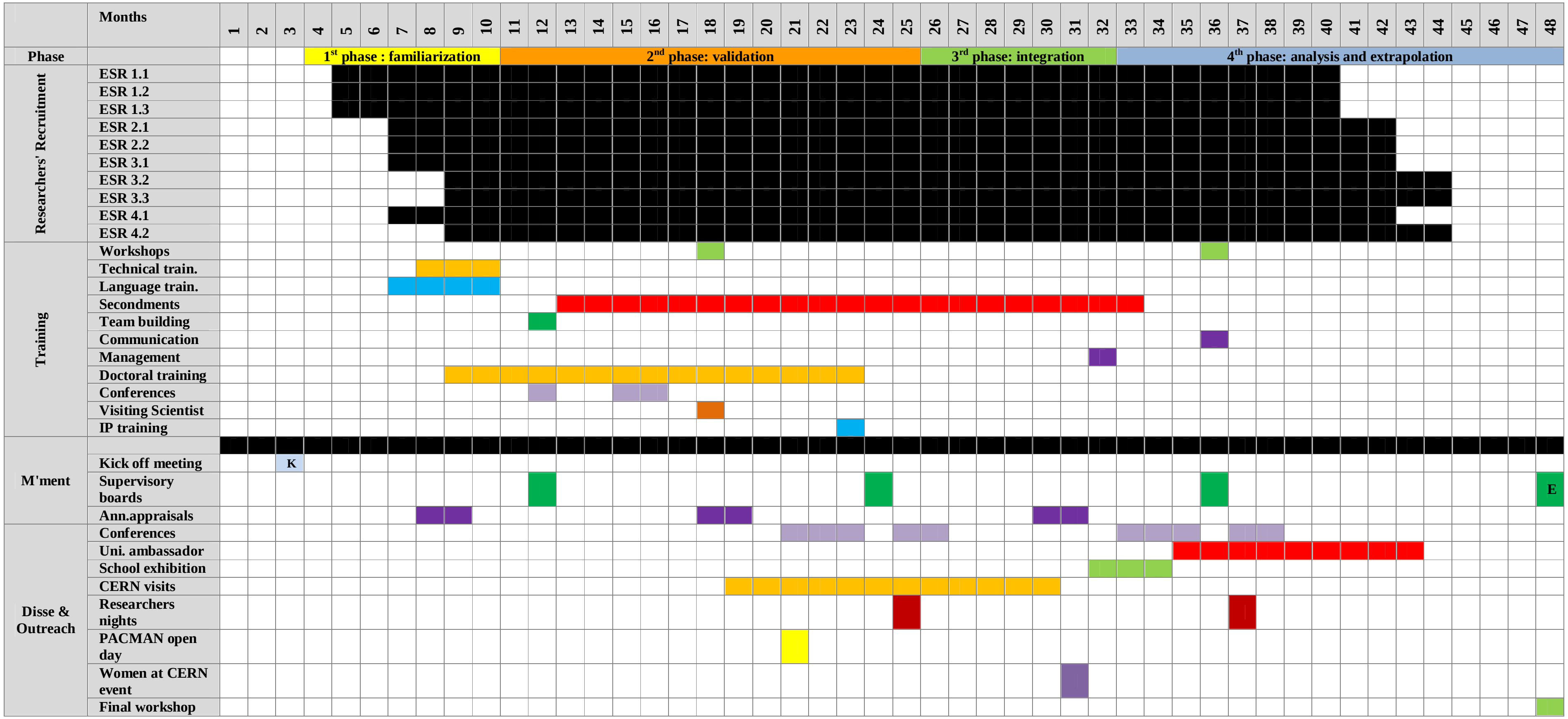
	Early-Stage researchers			Total
	Months	Researchers	% Fixed amount contract (B)	Months
CERN	360	10	0%	360
Overall Total	360	10	0%	360

PART D:

Overall maximum EU contribution

	Living allowance (1)	Mobility allowance (2)	Contribution to training expenses of eligible researchers and research/transfer of knowledge programme expenses(3)	Management activities (including audit certification) (4)	Contribution to overheads (5)	Total
Year 1	227,240.00	60,996.00	72,000.00	66,785.00	42,702.10	469,723.10
Year 2	454,480.00	121,992.00	144,000.00	66,785.00	78,725.70	865,982.70
Year 3	454,480.00	121,992.00	144,000.00	66,785.00	78,725.70	865,982.70
Year 4	227,240.00	60,996.00	72,000.00	66,786.00	42,702.20	469,724.20
Total	1,363,440.00	365,976.00	432,000.00	267,141.00	242,855.70	2,671,412.70

Appendix 1: Gantt chart



Appendix 2: Extract from the 2013 PEOPLE Work Programme

Structure of the cost categories applicable for ITN (adapted from Table 3.1 and 3.3 of the WP)

This information does not substitute the relevant information of the 2013 People Work Programme, which should be consulted for further details.

1 **Monthly living allowance**	**2** **Monthly mobility allowance**	**3** **Contribution to the training expenses of eligible researchers and research/transfer of knowledge programme expenses**	**4** **Management activities (including audit certification if applicable)**	**5** **Contribution to overheads**
Flat rate of : 38 000 Euro/year for ESRs and 58 500 Euro/year for ERs Rate for individual countries is obtained by applying the correction coefficients listed in Table 3.2 of the WP.	Flat rate allowance to cover expenses linked to the personal household, relocation and travel expenses of the researcher and her/his family in the host country: reference rate of EUR 700 for researchers without a family and EUR 1000 for researchers with a family. Rate for individual countries is obtained by applying the correction coefficients listed in Table 3.2 of the WP.	For multi-partner ITNs and IAPP: Flat rate of EUR 1800 per researcher-month managed by the host organisations to contribute for expenses related to the participation of researchers to training activities; expenses related to research costs; execution of the training/partnership project and contribution to the expenses related to the co-ordination between participants. For EID and IPD: Flat rate of EUR 1200 per researcher-month managed by the host organisation(s) to contribute for expenses related to the participation of eligible researchers to training activities and expenses related to research costs, as well as to contribute to the expenses related to the co-ordination between participants.	Maximum of 10% of the total EU contribution.	10% of direct costs except for subcontractors and the costs of the resources made available by third parties which are not used in the premises of the beneficiary.

EU27 and Associated Countries correction coefficients (adapted from Table 3.2 of the WP)

For other countries (such as ICPC and third countries), please consult the WP.

Austria	106.2
Belgium	100.0
Bulgaria	62.7
Cyprus	83.7
Czech Republic	84.2
Denmark	134.1
Estonia	75.6
Finland	119.4

France	116.1
Germany	94.8
Greece	94.8
Hungary	79.2
Ireland	109.1
Italy	106.6
Latvia	74.3
Lithuania	72.5

Luxembourg	100
Malta	82.2
Netherlands	104.1
Poland	77.1
Portugal	85.0
Romania	69.5
Slovak Rep.	80.0
Slovenia	89.6

Spain	97.7
Sweden	118.6
UK	134.4

Albania	63.1
Bosnia & Herz.	74.4
Croatia	83.0
FYROM	60.6
Iceland	95.0
Israel	96.4
Liechtenstein	109.9
Moldova	64.3

Montenegro	65.0
Norway	140.6
Serbia	74.0
Switzerland	119.6
The Faroes	134.1
Turkey	98.4