Final Report

CARE

Coordinated Accelerator Research in Europe

Integrating Activity

implemented as

Integrated Infrastructure Initiative

Contract number: *RII3-CT-2003-506395*

Project coordinator: *Roy Aleksan – Commissariat Energie Atomique*

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Research Infrastructures Action

CARE Final Report

A. Activity Report

I. Introduction

The study of the sub-nuclear structure of matter, the study and the search of the elementary particles as well as understanding the origin of their mass and the fundamental forces governing their interactions require the most advanced particle accelerators. In many areas, the techniques involved for the development of these accelerators are innovative and necessitate significant progress beyond the state-of-the-art, which often leads to important breakthroughs in other fields of science.

The improvement of the existing infrastructures by upgrading their performances and/or by furthering their reliability and efficiency on the one hand and the realization of new accelerators on the other hand rely crucially on strong and steady RTD programs, the magnitude and diversity of which surpasses the intellectual, technical and financial resources of a single laboratory or institution, and thus necessitate a large international effort.

Finally, the size of these accelerators generally requires the industrialization of the developed techniques and hence ensuring an efficient technological transfer by promoting industrial partnerships is very important.

II. Fundamental CARE objectives

The main objective of the **CARE** project was to generate **a structured and integrated European area in the field of accelerator research and related R&D**.

A set of integrating activities involving the **largest European infrastructure** laboratories and their **user communities** "active in accelerator R&D", including **industrial partners** was established with the following general objectives:

1) To optimise the use of existing infrastructures for improving the European knowledge on accelerator physics
   - By promoting a coherent and coordinated utilization and development of infrastructures and to facilitate the access to accelerators and test facilities for carrying accelerator studies
   - By understanding accelerator operation and reliability issues
2) To tackle new or state-of-the-art technologies in a more co-ordinated and collaborative approach
   - By developing a coherent and coordinated accelerator R&D program in Europe and carrying out joint R&D projects allowing one to enhance the existing (or in construction) facilities provided by the research infrastructures. These facilities could also be used as test beds for future projects either
     - by developing and testing advanced accelerator components
     - by exploring and testing new ideas and concepts. More generally, by establishing a closer interaction between a large number of scientist
3) To enhance the collaboration amongst accelerator physicists on the one hand and to develop the synergy between particle physicists and accelerator physicists on the other hand.
   - By promoting inter-disciplinary collaboration including industry

- By developing further and reinforcing the European expertise for the conception, design, development, construction and operation of new particle accelerators for High Energy Physics.

The framework of CARE has successfully integrated the subjects, the infrastructures and the expertise.

- **The subjects**
  - On-going and new studies on several types of used and planned accelerator were integrated, in line with the recommendation and priorities set forward in the ECFA report on the "future of accelerator-based physics in Europe" (ECFA/01/213):
    - *Electron linear accelerator and collider*
    - *Neutrino (muon) beams*
    - *High-energy/high-intensity proton accelerators*
- **The infrastructures**
  - *CARE has included all the relevant infrastructures allowing one to develop an overall efficient R&D program for accelerators and establish the first step toward a pan-European distributed Technological Platform to carry research on accelerator. The proposed activities were articulated around:*
    - Large Scale Facilities, including the existing or in construction state-of-the-art accelerators (CERN accelerator complex including LHC, DESY accelerator complex as well as those from LNF, RAL, PSI, GSI),
    - Large-scale accelerator test facilities (CTF at CERN, FLASH at DESY)
    - Specialized large and medium size infrastructures allowing one to develop and test specific accelerator concepts and components (LNF, RAL, PSI, CEA/Saclay, CNRS-IN2P3/Orsay).

The following table shows the existing (or in construction) accelerator facilities located within the laboratories, which participated to the CARE project. The vast majority of these infrastructures is unique in Europe and a large number of them have been or will be improved using the outcome of the CARE research activities.

Laboratory	Accelerator	Description
STFC-RAL	**ISIS**	Accelerator complex for the neutron and muon facility
CERN	**Linac2, PS, SPS, LHC**	Proton accelerator complex
	CNGS	Neutrino Beam
	CTF3	Two beams electron linear accelerator test facility
DESY	**PETRA, HERA**	Electron and proton accelerator complex
	FLASH, X-FEL	Electron superconducting linear accelerator test facility and free electron laser
FZR	**ELBE**	Electron linear accelerator for free electron laser
GSI	**UNILAC. SIS, ESR**	Heavy ion accelerator complex
INFN-LNF	**DAPHNE**	Electron-Positron collider
	SPARC	Electron linear accelerator for free electron laser
PSI	**SINQ**	Accelerator complex for the neutron and muon facility

Similarly, the next table shows the existing (or in construction) specialized test facilities relevant for the CARE project

Laboratory	Facility	Description
STFC	**"Unnamed"**	Cryogenic facility for mechanical measurement
CEA	**IPHI**	3 MeV High Intensity Proton Injector
	RF stand	704 MHz RF test stand for pulsed SC cavity testing (1 MW)

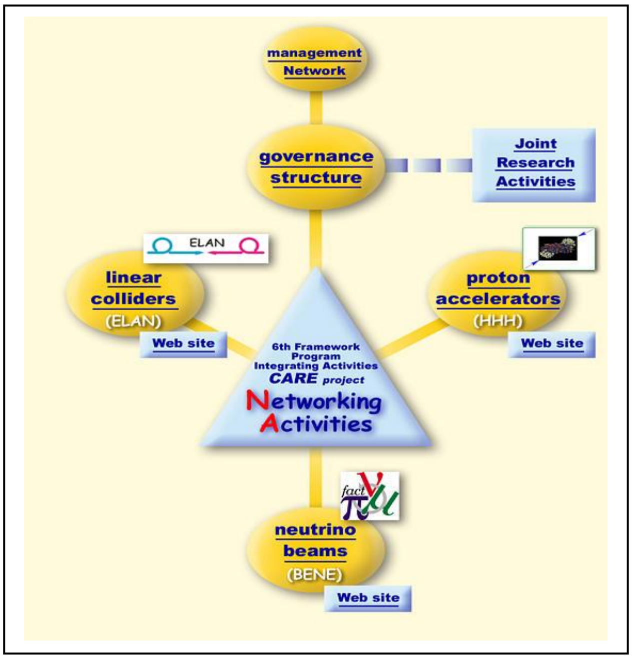
	Cryholab	Horizontal Cryogenic test stand
	W7X	Superconducting magnet test facility
	“Unnamed”	Cryogenic facilities for thermal, mechanical and electrical characterization
CERN	**Beqm chopping**	Test stand for beam chopping studies
	RF stand	352 MHz RF test stand for cavity testing (120 kW)
	FRESCA	Superconducting wire and cable test facility
CNRS-Orsay	**NEPAL** **“Unnamed”**	Test stand with photo-injector Coupler test laboratory
DESY	**CHECHIA**	Horizontal Cryogenic test stand
	“Unnamed”	Superconducting Magnet Test Facility
	PITZ	Photo-injector test facility
FZJ	**“Unnamed”**	Superconducting cavity test stand
GSI	**“Unnamed”**	Superconducting Magnet Test Facility
INFN-Ge	**“Unnamed”**	Superconducting wire test facility
INFN-Mi	**“Unnamed”**	High-Field Superconducting wire test facility

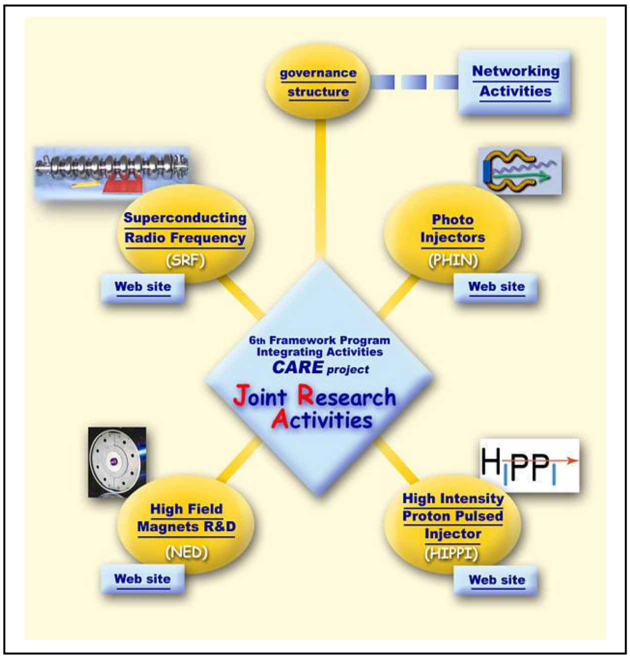
- **The expertise**
  - Most (if not all) European experts involved in the conception, design, development and construction of accelerator for particle physics (and to a large extend for nuclear physics and advanced light sources such as FEL) have participated to the CARE project.

Thus, the CARE project represented an innovative and unique opportunity in Europe as it involved almost all of the European expertise and know-how in accelerator physics and related technologies and has allowed one to address many of the issues relevant to particle accelerators. Futhermore, it has provided an integrated service to the entire European particle physics community and to some extends helped **other communities** (such as Nuclear Physics, FEL, Neutron Spallation) as well.

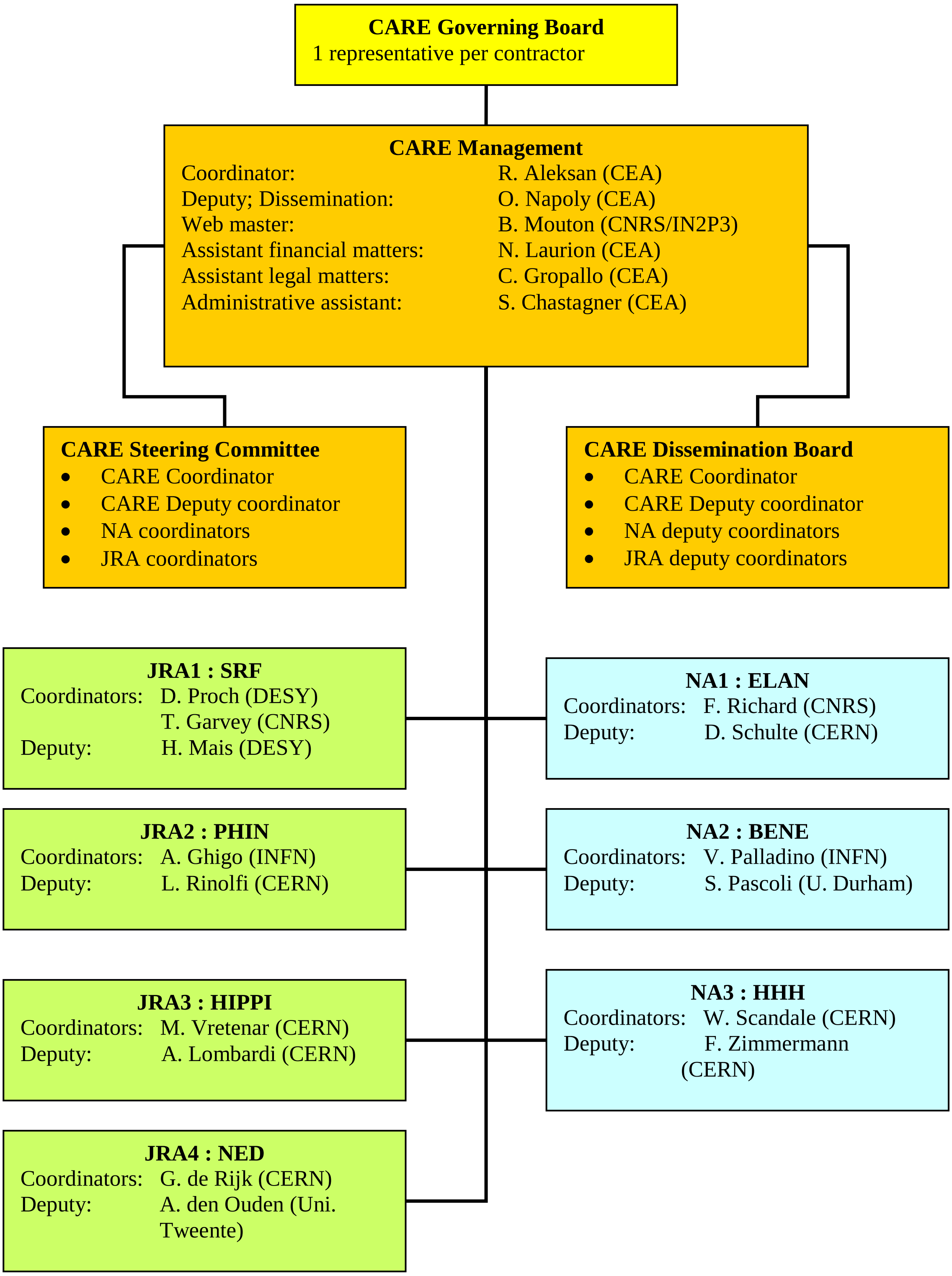
III. CARE Structure

CARE was articulated around **3 Networking Activities and 4 Joint Research Activities** including the most advanced scientific and technological developments relevant to accelerator research for Particle Physics, as can be seen from the figures below.





The overall management structure of CARE is displayed in the chart below



The aim of the Networking Activities was to foster and strengthen the European knowledge to evaluate and develop efficient and cost effective methods to produce intense and high-energy electron, proton, muon and neutrino beams as recommended by the European Committee for Future Accelerator (ECFA). They have established

- comparative studies on the various techniques, established collaborative
- prioritised R&D programs aimed at improving the exiting infrastructures
- technical roadmaps toward their longer-term evolution and the construction of new facilities of worldwide interest.

The participants have integrated their infrastructures, establishing a European technological platform for accelerator research allowing one to develop joint R&D projects and to foster strong and effective collaborations.

The following table shows the different type of particle beams, infrastructures and projects and their relevance for the 3 Networking Activities (N1, N2, N3).

<table>
<tr><th>Networking Activities</th><th>Existing or in construction large scale accelerators</th><th>Test facility or medium size facilities</th><th>Specialized test facilities</th><th>Accelerator Project</th></tr>
<tr><td>N1: Electron Linear accelerator Network</td><td></td><td>PHIL (LAL)
FLASH(DESY)
CTF(CERN)</td><td rowspan="3">Photo-Injector test facilities
(CNRS-Orsay,DESY)
“Cryolabs”
(CEA,CERN,DESY,FZJ)
“Super conducting magnet test stations”
(STFC,CEA,CERN,DESY,GSI,INFN-Ge,INFN-Mi)</td><td>ILC, CLIC</td></tr>
<tr><td>N2: Beams for European Neutrino Experiments (superBeam, βBeam, μ-beam)</td><td>CNGS(CERN)</td><td>ISIS(RAL)
SINQ(PSI)
IPHI(CEA)</td><td>Linac4,SPL, β-beams, ν-Fact</td></tr>
<tr><td>N3: High-Energy High-IntensityHadron Beams</td><td>LHC(CERN)
HERA(DESY)
SIS (GSI)</td><td>IPHI(CEA)</td><td>Linac4, SLHC, DLHC; FAIR</td></tr>
</table>

The ***four Joint Research Activities (JRA)*** aimed at developing critical or beyond the state-of-the-art components and systems allowing one to upgrade the infrastructures. They included

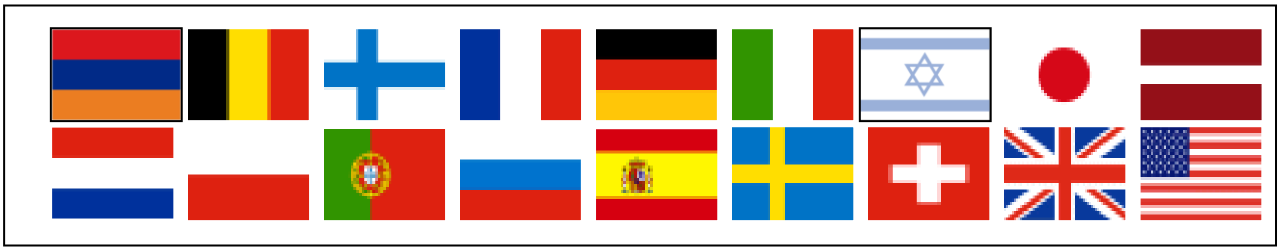
- **SRF**: The development of the superconducting cavity technology for the acceleration of electrons with gradient exceeding 35MV/m and the development of the subsequent necessary superconducting RF technology.
- **PHIN**: An R&D program for improving the technology of photo-injectors, in particular to match the severe requirements necessary for demonstrating the 2 beam acceleration concepts, new generation light sources and novel acceleration technique.
- **HIPPI**: The integrated developments of normal and superconducting structures for the acceleration of very high-intensity proton beams as well as challenging beam chopping magnets.
- **NED**: The development and mastering of the technology for reaching very high magnetic field (>15T) and high current densities (>1500A/mm^2).

The Joint Research Activities were closely connected and of extreme importance for the networking activities. The following table shows this relation and illustrates the overall integration of the CARE program.

NA / JRA	***N1**: Electron Linear Accelerator Network (**ELAN**)*		***N2:** Beams for European Neutrino Experiments (**BENE**)*			***N3:** HE/HI Hadron Beams (**HEHIHB**)*
Existing accel. Future projects	*FLASH,ELBE* ILC, XFEL	*CTF,SPARC* CLIC	*CNGS* Super Beams	β–beams	*ISIS, SINQ* μ–beams	*SIS, LHC* FAIR,SLHC/DLHC
SRF	X				X	
PHIN	X	X				
HIPPI			X	X	X	X
NED	X	X			X	X

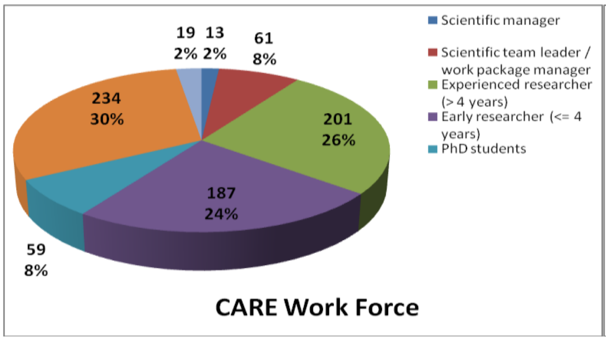
In fact the R&D projects were not only essential to the improvement of the existing infrastructures and the development of upgrade programs but have also established the foundation for new ones. Conversely the existing infrastructures were necessary to understand beam dynamics and properties, to validate ideas through dedicated machine developments and to test prototypes. The Research and Development carried in the JRAs have been presented and discussed in the networking activities. The achievements in the JRAs have influenced the studies in the Networking Activities, leading to new ideas, which in turn generated new research directions.

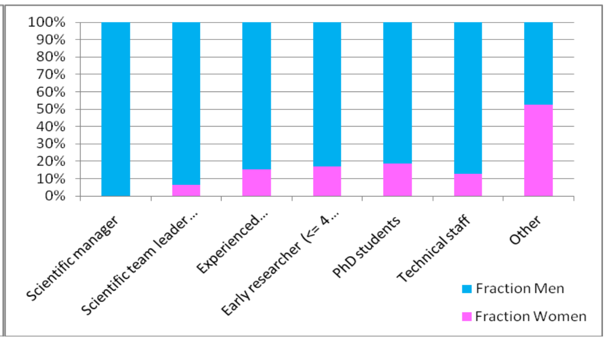
IV. CARE Collaboration



Twenty two contracting participants and a large number (62) of associated institutes (including 12 industrial partners and SMEs) participated in this unprecedented integrating effort, including accelerator physicists involved in Nuclear Physics accelerators, Free Electron Lasers and Neutron Spallation sources, see http://care.lal.in2p3.fr/Participants (the complete list is given in Annex 1).

In total, 774 persons have contributed to the CARE project. About 15% of the personnel were composed of women. The following diagrams show the distribution of the personnel according to various categories (scientific manager, scientific team leaders, experienced researchers, early researchers, PhD students and others) and their corresponding gender repartition.

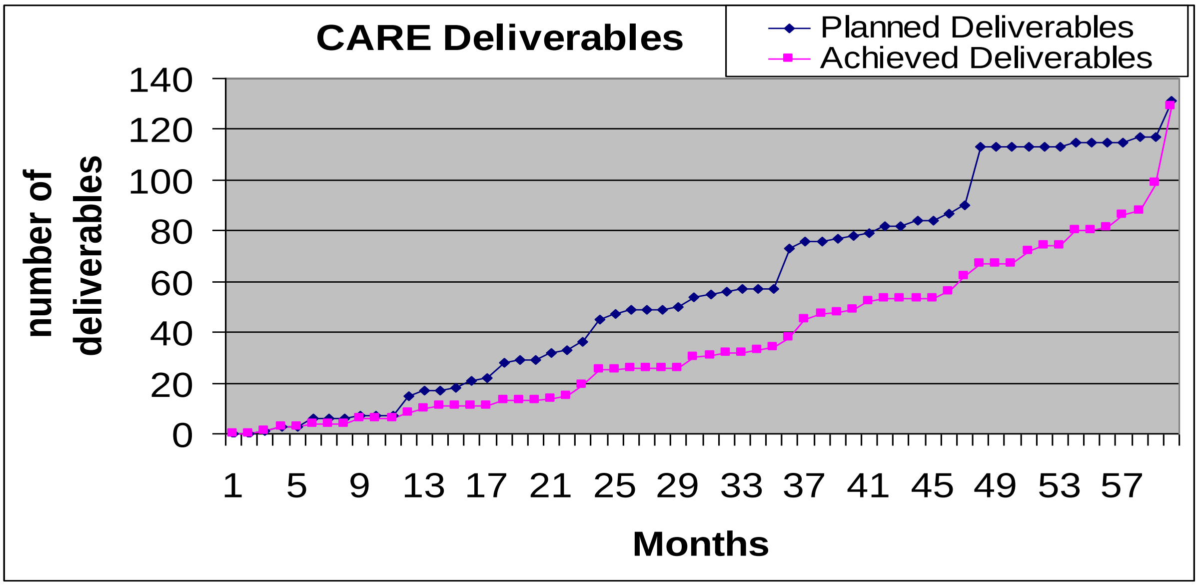




Finally, in order to implement a strong and efficient dissemination plan, a Web-based platform has been developed (http://care.lal.in2p3.fr), and was linked to the site of the European Steering Group for Accelerator R&D (http://esgard.lal.in2p3.fr).

V. Deliverables

CARE had an ambitious program including 131 deliverables as can be seen on the table below.



The complete list of the deliverables is shown in Annex 2. The JRAs had 99 deliverables, which have been all achieved within the duration of CARE, while the NAs had 32 deliverables, which have been all (but two) achieved. One of the missing deliverables was the submission of a proposal to the FP6 call on design study in 2004. This call has been cancelled by the EC. Fortunately, the planned activities have been integrated to a later proposal, which was approved by the EC. The second missing deliverable was the realization of a database for laser-plasma acceleration. However this activity has been integrated to a successful proposal initiated by the CARE NA-ELAN as a NEST project.

VI. Dissemination

The dissemination within CARE has been carried widely through several means: Web sites, CARE publications, presentations at conferences and organisations of workshops, conferences and general annual meetings. General meetings, common workshops and Dissemination Board activities have ensured an effective exchange of information while specialized joint workshops have been organized when several aspects of networking and joint research activities were common (ex. beams diagnostics and instrumentation, high field magnets needs for accelerators, etc...)

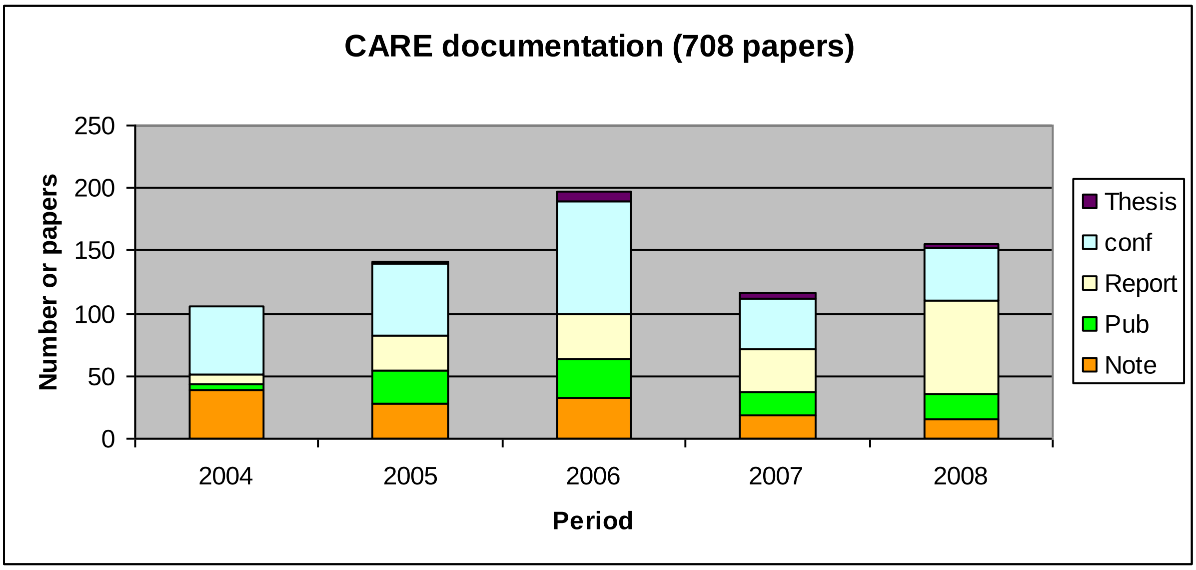
- The main Website of CARE

CARE has set up a main web site from which participants could access all relevant information as well as to secondary specialized web sites. The URL of the CARE site is: http://care.lal.in2p3.fr/

- CARE Documentations

A very large number (717) of documents (publications, reports, conferences contributions, notes and thesis) have been carries out by CARE. It is important to note that 18 theses were defended using the CARE work. The table and the figure below summarize this effort.

	All	2004	2005	2006	2007	2008
Note	133	39	28	32	19	15
Pub	102	4	26	32	19	21
Report	179	8	28	35	34	74
Conf. Contr.	285	54	58	91	40	42
Theses	18	0	2	7	5	4
Total	717	105	142	197	117	156



All these documents are accessible from the CARE publication database http://irfu.cea.fr/Documentation/Care/index.php.

- CARE Annual meetings and other events

Date	Location	Number of registered participants	Web site
Nov. 2–5, 2004	DESY (D)	191	http://care04.desy.de/
Nov. 23–25, 2005	CERN (CH)	164	http://indico.cern.ch/conferenceDisplay.py?confId=a059
Nov. 15–17, 2006	Frascati (I)	123	http://www.lnf.infn.it/conference/care06/index.htm
Oct. 29–31 2007	CERN (CH)	108	http://indico.cern.ch/conferenceDisplay.py?confId=15901
Dec. 2-5 2008	CERN (CH)	113	http://care08.web.cern.ch/care08/redir.do

In addition, each NA and JRA has participated to the organization of international conferences and have organized many internal meeting and workshops -see the NA/JRA sections for details.

VII. General CARE outcomes

The detailed outcomes of the CARE project are described in the NA/JRA sections. In general they have

- Considerably strengthened the European expertise and know-how in the field of accelerator R&D, far beyond the sole capacity of the largest research centres (such as CERN and DESY) to carry forefront accelerator R&D. **This can be considered as a major EU added value**.
- Helped many European Institutes and Universities for **developing their competences** on activities that are at (or beyond) the state-of-the-art technology in contact with the best experts in Europe. This collaborative effort can be viewed as a first step toward the long-term sustainability of accelerator R&D in Europe.
- Furthered the contact and the involvement of industry in R&D activities (12 companies have participated actively to the CARE activities).
- Established the basic development work allowing **the future strategic decisions** to be made on sound technological basis. CARE has provided several necessary technological inputs to ECFA and CERN Council.
- Identified the common issues relevant to other fields, contacted these communities and proposed common activities.

As already discussed, the CARE program has directly allowed one to raise the level of performance of the infrastructures, thanks to

- Networking Activities, that have compared and determined ways to upgrade the infrastructures both on the medium-term and on the long-term,
- Joint Research Activities, that have designed, constructed and tested prototypes for accelerator components, which are directly or indirectly used to improve the infrastructures.

In summary, the basic R&D for improving very significantly the performance of many European infrastructures for particle physics and for accelerator research in general has been successfully carried out, as acknowledged in the annex 3 by the letters of several laboratory directors. Some of these infrastructures have already benefited from the achievements of CARE and several others will benefit in the medium or long term. More details can be found below in the reports of each Networking and Joint Research Activity.

VIII. Long term sustainability and structuring effect

As shown above, one of the main objectives of the CARE project was to structure the European area on accelerator research. The prospects to achieve such an ambitious goal are rather brighter after CARE. This optimism is based on the fact that the entire particle physics community has adhered to and supported this initiative (even at the worldwide level with non-EU participation and ICFA support). Indeed,

1. All parties had a strong interest, motivation and commitment to CARE as it allowed them to both strengthen their individual and collective expertise on the long-term.
2. The structure set in place has permitted both extensive communication and wide dissemination of knowledge to take place, which will continue after the completion of the CARE program, as demonstrated for example by the FP7-IA EuCARD initiative.

3. A European Committee (ESGARD), which includes representatives from all major high-energy infrastructure laboratories, has been set up to oversee and monitor the European accelerator R&D activities relevant for particle physics. The foundation of this committee can be considered already as a first step toward ensuring the long-term sustainability of the collaborative effort put in place for CARE. It can be partly attributed to FP6. Discussions are underway to expand it to other fields such as Nuclear Physics, Free Electron Laser. This committee has already launched other initiatives such as Integrating Activities or Design Studies over the past years.
4. Most Joint Research Activities involves trans-field collaboration as well as industrial partnerships. They are the seed for extending or generating future collaborations.
5. CARE has offered an ideal framework for establishing specific collaborative arrangements. An unexpected example is a joint venture between industrial partners on the development of high performance superconductor cable. It is reasonable to expect that more such initiatives will be triggered, as people will collaborate more closely.
6. Several proposals for common European test platform have developed from the networking activities (for example: a Target Test Area or Superconducting Test facilities)
7. Most of the Joint Research Activities have contributed to lead to collaborative agreements to upgrade existing infrastructure (FLASH, CTF, CERN proton injector are good examples).They may even in some cases be the seed for the construction of new infrastructures.

Overall the CARE project has strongly contributed to establish a unique and durable interaction

- Amongst European accelerator physicist including connections with non-European partners
- Between accelerator and particle physicists
- Between different research field
- Between researchers and industrial partners

In conclusion, CARE has ensure the emergence of new ideas, new projects and new collaborations in a coordinated way and hence has provided all the ingredients for the long-term sustainability of the collaborative effort in the field of accelerator research, which it has initiated.