EUROPEAN NANOELECTRONICS INFRASTRUCTURE FOR INNOVATION

G.Casanova
CAPA 23/10/13

Content

- Objective/activities
- ENI2 members
- Methodology
- Status/Future deliverables
- ENI2 versus collaborative instruments
- Support from the PAs

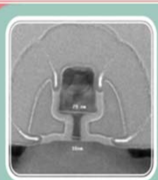
European Nanoelectronics Infrastructure for Innovation

Objectives/Activities

- The objective of **The European Nanoelectronics Infrastructure for Innovation (ENI2**) is designed to create mid- and long- term technology roadmaps for cooperative (3-6-9 years) R&D&I projects in nanoelectronics and to establish strategic groupings of research communities with common interests.
- To set-up « large federative projects » of European interest for technology prototyping and demonstrations.

eni^2 ’s ambition: being a 2 way bridge between academic knowledge and marketable products by industry

In nanoelectronics, a successful innovative infrastructure will rely to a three R&D levels organization

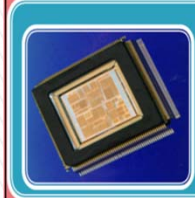


ACADEMIC LABORATORIES

- Basic understanding, test and validation of innovative architectures, materials and processes in order to identify the most promising topics for future ICT

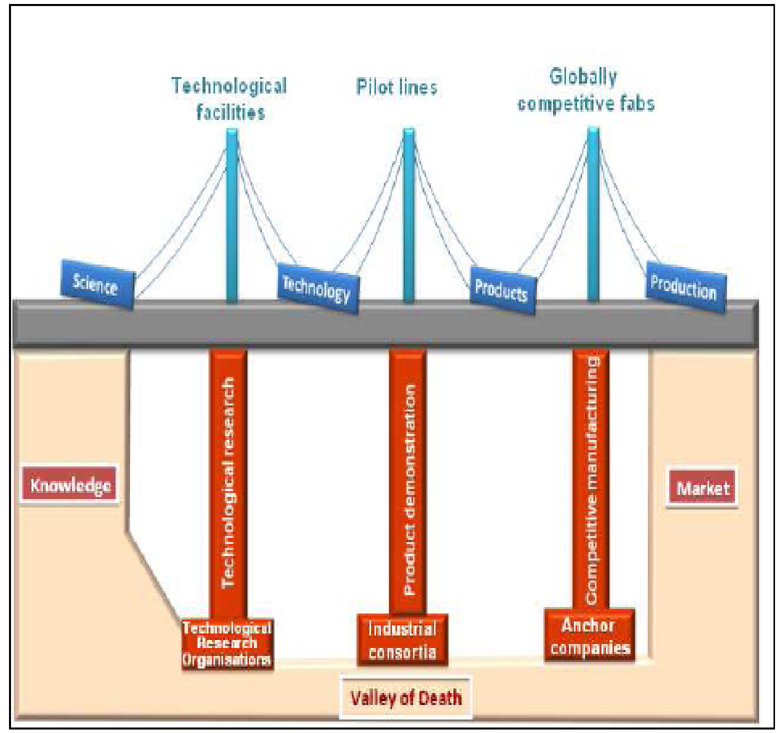
INSTITUTES (Integration Centers)

- Technology implementation and performance assessment on R&D equipments ; development of high performance Logic, Memories, Derivative, Power devices



INDUSTRIALISTS

- Technology exploitation as functional product, process optimization, yield, product reliability, device and interconnect architecture and design



Innovation crosses the bridge from left to right but it’s a 2 way bridge meaning there is a feedback loop to academics

ENI2 MEMBERS

INSTITUT POLYTECHNIQUE DE GRENOBLE	FRANCE
CONSORZIO NAZIONALE INTERUNIVERSITARIO PER LA NANOELETTRONICA	ITALY
COMMISSARIAT A L ENERGIE ATOMIQUE ET AUX ENERGIES ALTERNATIVES	FRANCE
ASM INTERNATIONAL N.V.	THE NETHERLANDS
CIRCUITS MULTI-PROJETS	FRANCE
FRAUNHOFER-GESELLSCHAFT ZUR FOERDERUNG DER ANGEWANDTEN FORSCHUNG E.V	GERMANY
INTERUNIVERSITAIR MICRO-ELECTRONICA CENTRUM VZW	BELGIUM
AIT AUSTRIAN INSTITUTE OF TECHNOLOGY GMBH	AUSTRIA
AGENCIA ESTATAL CONSEJO SUPERIOR DE INVESTIGACIONES CIENTIFICAS	SPAIN
ECOLE POLYTECHNIQUE FEDERALE DE LAUSANNE	SWITZERLAND
EDACENTRUM GMBH	GERMANY
FORSCHUNGSZENTRUM JUELICH GMBH	GERMANY
ION BEAM SERVICES	FRANCE
CATALAN INSTITUTE OF NANOTECHNOLOGY	SPAIN
INFINEON TECHNOLOGIES AG	GERMANY
INSTYTUT TECHNOLOGII ELEKTRONOWEJ	POLAND
KUNGLIGA TEKNISKA HOEGSKOLAN	SWEEDEN
MICRON SEMICONDUCTOR ITALIA SRL	ITALY
NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS"	GREECE
THALES SA	FRANCE

NXP SEMICONDUCTORS BELGIUM NV	BELGIUM
OPEN ENGINEERING	BELGIUM
INSTITUT SINANO ASSOCIATION	FRANCE
STIFTELSEN SINTEF	NORWAY
STMICROELECTRONICS S.A.	FRANCE
THYIA TEHNOLOGIJE D.O.O	SLOVENIA
TECHNISCHE UNIVERSITEIT DELFT	THE NETHERLANDS
NEDERLANDSE ORGANISATIE VOOR TOEGEPAST NATUURWETENSCHAPPELIJK ONDERZOEK - TNO	THE NETHERLANDS
UNIVERSITY COLLEGE CORK, NATIONAL UNIVERSITY OF IRELAND, CORK	IRELAND
UNIVERSITE CATHOLIQUE DE LOUVAIN	BELGIUM
UPPSALA UNIVERSITET	SWEDEN
TEKNOLOGIAN TUTKIMUSKESKUS VTT	FINLAND
TECHNISCHE UNIVERSITEIT EINDHOVEN	THE NETHERLANDS
TUBITAK	TURKEY
INSTITUTO DE TELECOMUNICACOES	PORTUGAL
UNIVERSITY OF BRADFORD	UNITED KINGDOM
COMMONWEALTH ITU Group	UNITED KINGDOM
IMT BUCHAREST	ROMANIA
INSTITUTE OF TECHNICAL PHYSICS AND MATERIALS SCIENCE	HUNGRIA
SLOVAK UNIVERSITY OF TECHNOLOGY	SLOVAKIA
WROCLAY UNIVERSITY OF TECHNOLOGY	POLAND

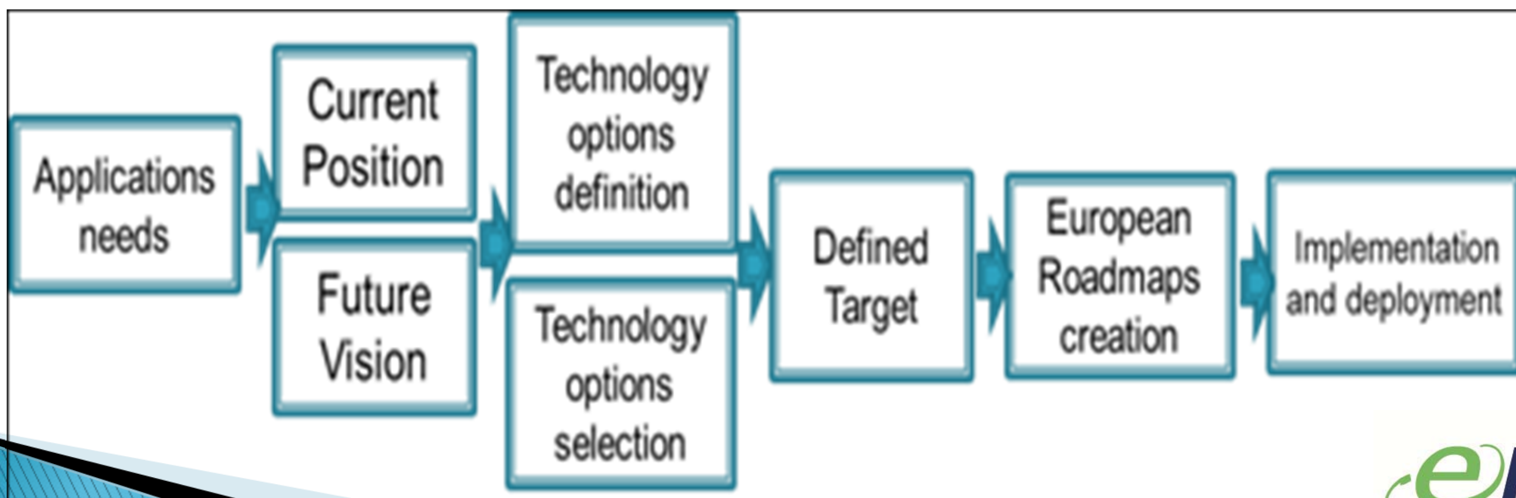
METHODOLOGY

- Applications needs
- Research Domains
- Template
- Road-mapping activities
- Who is doing what
- Long-term Program/concrete case

TECHNOLOGY ROADMAPPING

For the technological domains (nanoscale FET, Smart energy and Smart sensors), we have agreed on the following road mapping process:

(1) **Identify the "Applications**" that will be the focus of the roadmap. (2)Explain the **state of the art and the vision.** (3) Define the **technology options** and select **the areas of cooperation** to be addressed at European level (4) **Create the roadmaps** by specifying the major technology areas (devices, interconnect, materials…..) and associated **targets** (6) Generate and implement a plan to develop and deploy **Long term Programmes**.



Applications needs

- Nanoscale FET (Set Top Box, Smartphones, HPC, mini-servers);
- Smart Energy (smart grid, electrical cars).
- Smart sensors (Internet of things, e-health).
- Heterogeneous integration to offer greater functionality at lower cost.

-For improving performance of interconnect: Computing (mini-server, APs, HPC)

- For improving the form factor (smaller volume) : Interfaces (Haptic, Sensors, Hearing aids)

- For demonstrating heterogeneous integration and modularity: Smart energy

Selection of five short to long-term research programs

HETEROGENEOUS INTEGRATION & SYSTEM DESIGN

NANOSCALE FET

life.augmented

SMART ENERGY

SMART SENSORS

EQUIPMENTS & MANUFACTURING SCIENCE

Driving the execution

Role	Company	Name
Project Manager	ST	G.Casanova
Steering Committee	Sinano-IUNET-CEA/Leti-ASM-FHG-NXP-IFX-ST- IMEC	F.Balestra- E.Sangiorgi -J.Pelka - B.Van Nooten - W.Dettmann-P.Pype -G.Casanova-A.Van den Bosch
Project Team	Core Group	Annexe
Team Leads	TUDelft-STE-Thales-TUE-ST-NXP-IFX-Sinano-FHG-KTH-CMP-Tyndall-IMEC - STE	M.Graef-P.Blouet- J.P.N Haagh - G.Thomas-M.Ostling -A.Bouffioux F.Balestra - J.Pelka- B.Courtois-A.Mathewson - A.Van den Bosch C.Reita
Executive Sponsors	Aeneas-Catrene offices	

ENI2 Expression of Interest form

Nanoscale FET **Areas of collaboration**	**Potential contribution Yes/no**	**Priority level (*)**
Properties of materials and devices built at the nanoscale		
Modeling of properties of materials and devices		
Multi-physics and multi-scale modeling methodologies		
Novel materials and new functionalities		
New device architectures		
Novel interconnects architectures		
Development of ultimate processing technologies		
Nano devices for adding new functionalities to CMOS		
Physical and electrical nano characterization		
Integration of very high densities of nano devices		

Other suggested collaboration areas

NANOSCALE FET

2014 2017 2020 2023

Targets

ULTIMATE CMOS Logic & Memories			
BEYOND CMOS			
NANOCMOS for CMOS DERIVATIVES			
NOVEL INTERCONNECT ARCHITECTURE			
ULTIMATE PROCESSING			
3D SEQUENTIAL INTEGRATION			

TEXT

Smart Energy

The “Smart energy” wording has been defined as referring to a peculiar technology which combines the integration of high-V / high-I devices with “smart” features capabilities and new materials, in order to provide high efficient all-in-one “power”, in System-on-Chip (SoC) or System-in-Package (SiP) forms.

ResearchTopics	< 3 years	3-6 years	>6 years
1.COMPOUND MATERIALS			
2. INTEGRATION OF SMART AND POWER			
3. SMART SYSTEM/MODULE INTEGRATION			
4. POWER TECHNOLOGIES			
5. DESIGN METHODOLOGIES			

Smart Sensors

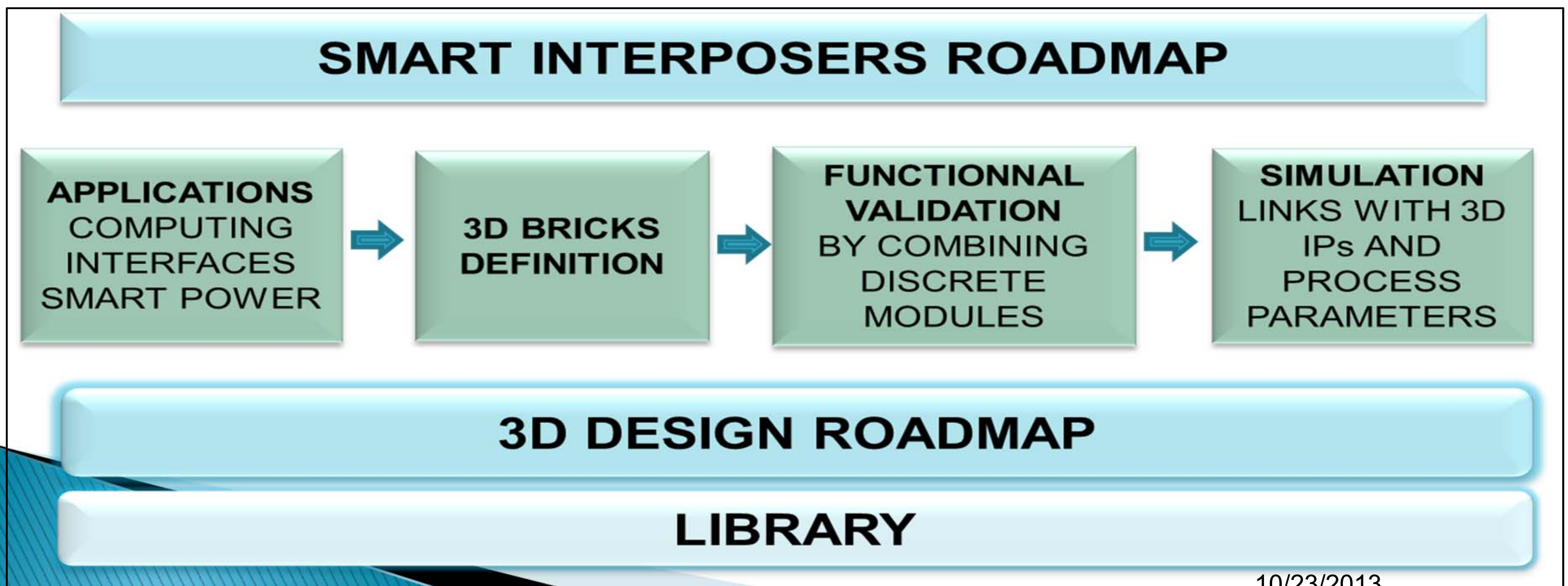
Smart sensor will rely on various heterogeneous technologies like analogue, digital and RF (Radio Frequency) electronics, MEMS (Micro Electro Mechanical System) coupled with photonics for energy scavenging and integrated chemical batteries. It may also rely on fluidics, pneumatics, optics, chemical, biochemical or mechanics for the transport of the sample to analyze and for its characterization.

ResearchTopics	< 3 years	3-6 years	>6 years
1. NEW GENERATION OF SENSORS (gas, biosensors…)			
2. ULTRA LOW POWER NETWORK			
3.SMART SENSORS INTEGRATION			
4. MATERIALS AND PROCESSES			
5. OTHER			

HETEROGENEOUS INTEGRATION

2014 2017 2020 2023

SMART INTERPOSERS			
DESIGN	TEXT		
3D INTEGRATION TSV & Interconnect			



STRUCTURE OF THE NANOSCALE FET ENI2 ECOSYSTEM COMBINING BY COMPETENCES THE DIFFERENT RESEARCH HORIZON

	ULTIMATE CMOS	BEYOND CMOS	NOVEL INTERCONNECTS ARCHITECTURES	ULTIMATE PROCESSES TECHNOLOGIES	3D SEQUENTIAL INTEGRATION
ACADEMICS	Tyndall	Tyndall	TU Delft	VTT	
	FZ Julich	Univ. Stuttggart	Tyndall	Tyndall	
	IuNET	IuNET	Grenoble INP	Grenoble INP	
	Univ.Granada	Univ.Granada	FZ Julich	FZ Julich	
	IMEL	IMEL	Uppsala Univ.	Uppsala Univ.	
	Uppsala Univ.	Uppsala Univ.		KTH	
	Newcastle Univ.	Newcastle Univ.		CNM	
	Univ. Twente	Univ Twente		IMEL	
	URV	URV		TUBITAK	
	Grenoble INP	Grenoble INP			
	UCL	UCL			
	Warwick Univ	KTH			
	Univ. Glasgow	Univ. Glasgow			
	CNM	CNM			
	IEMN	TU Delft			To be consolidated in Q4
	IES	VTT			
	Chalmers	ICN			
	VTT	TUBITAK			
	TU Delft				
	ICN				
	TUBITAK				
	KTH				
INSTITUTES	FHG	FHG	IMEC	IMEC	Leti
	ITE	ITE			
	Leti	Leti	Leti	Leti	
	IMEC	IMEC		FHG	
INDUSTRIALIST	ST	ST	ST	ST	ST
	Thales	Thales	Thales	ASM	
	Micron	Micron		IBS	
		NXP			

Example of inputs collection in Smart Energy

Materials & Processes / Power Production Technologies

Smart energy Areas of collaboration	#	IFX	ST	CEA	TND	CNM	TUD	ITE	SIN	UCL	THA	UCC	F-IISB	UPU	IU	VTT	LQAT	ICB
Materials and Processes																		
New materials for high Power semiconductors (SiC, GaN, Saphir, Diamond…) and associated manufacturing processes (Homo-hetero-localized epitaxy, characterization and test…)	15	1	1	1	2	1	1	2	1	N	1	1	1	1	1	2	N	1
On SOI medium power technologies	8	1	1	3		N	3	N	1	N	N		N	2	**2**	1		
Low power Mixed analog technologies	8	2	2	N (*)		N	2	1	1	1	N		N	N	1	N	1	
Low power RF technologies	11	2	1	N (*)		N	2	1	2	1	N		N	2	1	1	1	1
New materials and associated processes for Smart derivatives compatible with power	8	1	2	N	3	1		N	1	N	2		N	N	**1**	3	N	
New materials for large passive capacitors and inductors (high power, high frequency…) used together with semiconductors in power conversion	10	N	2	3	1	N		N	1	N	1	1	1	2	**2**	2	N	
Logic with HV applications and embedded flash: shrink path & HV properties (40….100V)	7	1	1	N		1		N	2	N	3		2	N	**2**		N	

Smart energy Areas of collaboration		IFX	ST	CEA	TND	CNM	TUD	ITE	SIN	UCL	THA	UCC	F-IISB	UPU	IU	VTT	LQAT	ICB
Power production technologies	**0**																	
300mm power production (process, metrology, materials, infrastructure)	7	1	1	2		N		N	2	N	N		2	N	**2**	N	N	**1**

Architectures & System Module../ Methodology & Tools

Smart energy Areas of collaboration		IFX	ST	CEA	TND	CNM	TUD	ITE	SIN	UCL	THA	UCC	F-IISB	UPU	IU	VTT	LQAT	ICB
Architectures & system/module – integration for power	**0**																	
High power, high voltage, high current, silicon chips	8	1	1	3		1	1	N	1	N	2		N	N	**1**	N	N	
New 3D power semiconductors architectures	8	2	1	1		2	2	N	1	N	2		N	N	**1**	N	N	
System-on-Chip complex integration of Power devices, CMOS, and smart derivatives	10	1	1	1	2	3	1	2	N	3	1		N	N	N	3	N	
Power devices with true galvanic isolation	5	1	1	N	3	N		N	N	2	2		N	N	N	N	N	
Optimized blocks for Generic product structures: harvesting energy + energy management + energy storage + function + sensor/actuator + RF transmission	13	1	1	1	1	2	2	2	1	1	2		N	N	**1**	1	2	
Embedded software and algorithms for energy applications	5	N	3	N		N	3	N	N		2		N	N	N	3	2	
Module integration for power modules	8	1	1	N	Y	1	3	3	N		1		N	N	N	2	N	

Smart energy Areas of collaboration		IFX	ST	CEA	TND	CNM	TUD	ITE	SIN	UCL	THA	UCC	F-IISB	UPU	IU	VTT	LQAT	ICB
Methodology & tools	**0**																	
Mixed simulation tools covering electrical, mechanical, thermal, magnetic and optical strengths fields.	14	1	1	2	1	1	2	1	1	1	2		N	3	**1**	2	1	
Reliability aspects	11	1	1	N		1	2	2	1	1	1		N	2	1	3	N	
Verification tools	2	N	N	N		N	2	N	N	N	2		N	N	N	N	N	

Equipment & Special Interest

Smart energy Areas of collaboration		IFX	ST	CEA	TND	CNM	TUD	ITE	SIN	UCL	THA	UCC	F-IISB	UPU	IU	VTT	LQAT	ICB
Equipment (to be consolidated in a later stage with equipment makers)	**0**																	
Equipment for new materials (homo-hetero-localized Epitaxy, implantation, doping…)	6	1	1	1		N		N	1	N	N		1	N	N	2	N	
Disruptive equipment technologies for thin and large wafers manufacturing, deep trenches, 3D power architectures	7	1	1	2	3	N		N	1	N	N		1	N	N	1	N	
Equipments for power 3D Wafer Level Packaging,	7	3	2	2	2	N		N	3	N	N		1	N	N	2	N	
Equipment for multi chip power Systems-in-Package: chip mounting, stacking… characterization and complex testing (power + smart derivatives + RF…)	7	3	2	N	1	3		N	N	N	2		3	N	N	1	N	

By F-IISB

Other suggested collaboration areas
Beyond equipment:
Energy and resource efficient manufacturing methods using smart idle mode and smart process flow planning and scheduling

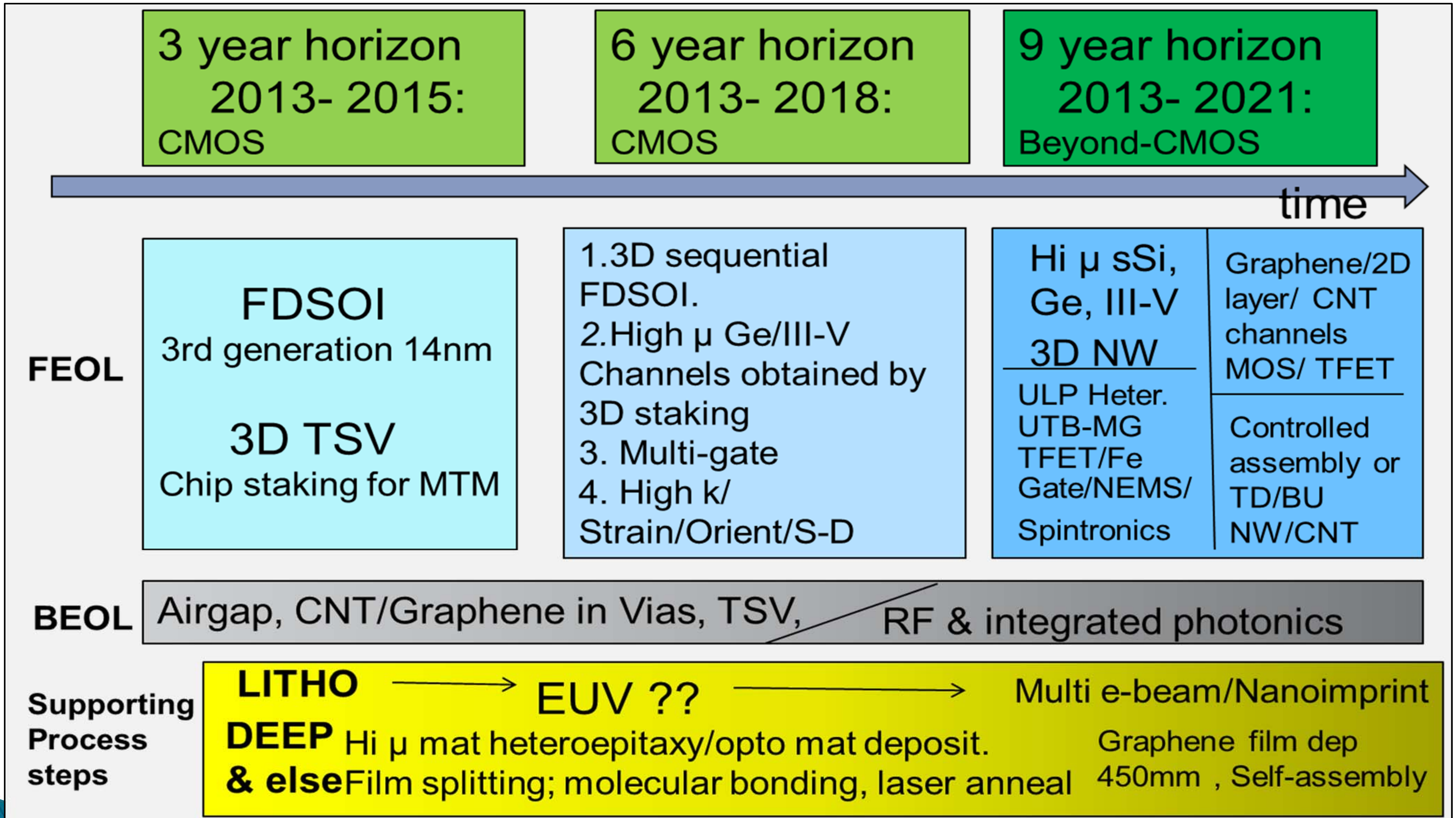
By LQAT

Other suggested collaboration areas
Smart energy, Sensors
Power efficient communication devices (gateways, smart clients). Methods and test for interoperation between different technologies (e.g. PLC to WLAN, DSL)

Long term strategic Programmes must be built-up based on:

- Joint technical roadmap addressing short, medium and long term horizon research
- Corresponding ecosystems (who is doing what)
- Excellence Centers
- Mechanisms of collaboration
- Routes of access

Concrete cases-ie:nanoscale FET



NANOSCALE FET MULTI-YEARS PROGRAM

Integration Centric	Process centric
• Ultimate CMOS ST	• Novel Interconnect architecture IMEC
• 3D Sequential integration CEA-Leti	• Ultimate processing ASM
• Memories Micron	
• Beyond CMOS Sinano	

Horizontal activities

- Equipment assessment
- Mechanisms of collaboration
- Routes of access

Ecosystems

Key targets ie : novel interconnects

2014-2017

- New materials to meet conductivity requirements and reduce the dielectric permittivity
- Electrical, thermal, and mechanical reliability
- Three-dimensional control of interconnect features with it's associated metrology
- Modeling and characterization

2017-2020

- Low-κ dual damascene metal structures / air gap-Optical and RF interconnects, CNT/Graphene interconnects/via
- Identify solutions which address 3D structures and other packaging issues
- Modeling/characterization for new interconnects

2020-2023

- Ultra low-κ materials with κ<2.0 and to introduce air-gaps, the hybrid of low-κ materials and air-gaps could be the best solution.
- The TSV and 3D stacking technologies will also become of key importance.
- In order to replace Cu, other metals (Ag, silicides, …), Nanowires, CNT, Graphene Nanoribbons,Topological insulators, Superconductors, and novel non-charge-based interconnects (Optical -interchip/intrachip, or Wireless

EUROPEAN NANOSCALE-FET INFRASTRUCTURE

Technical Roadmaps

Targets	2014	2017	2020	2023
ULTIMATE CMOS Logic & Memories				
BEYOND CMOS				
NANOCMOS for CMOS DERIVATIVES				
NOVEL INTERCONNECT ARCHITECTURE				
ULTIMATE PROCESSING				
3D SEQUENTIAL INTEGRATION				

TEXT

European Programmes of Common interest

3 year horizon 2013- 2015: CMOS	6 year horizon 2013- 2018: CMOS	9 year horizon 2013- 2021: Beyond-CMOS

time →

FEOL

- FDSOI 3rd generation 14nm; 3D TSV Chip staking for MTM
- 1.3D sequential FDSOI. 2.High μ Ge/III-V Channels obtained by 3D staking 3. Multi-gate 4. High k/ Strain/Orient/S-D
- Hi μ sSi, Ge, III-V; 3D NW; ULP Heter. UTB-MG TFET/Fe Gate/NEMS/ Spintronics
- Graphene/2D layer/ CNT channels MOS/ TFET; Controlled assembly or TD/BU NW/CNT

BEOL Airgap, CNT/Graphene in Vias, TSV, RF & integrated photonics

Supporting Process steps

- **LITHO** → EUV ?? → Multi e-beam/Nanoimprint
- **DEEP** Hi μ mat heteroepitaxy/opto mat deposit. Graphene film dep
- **& else** Film splitting; molecular bonding, laser anneal 450mm , Self-assembly

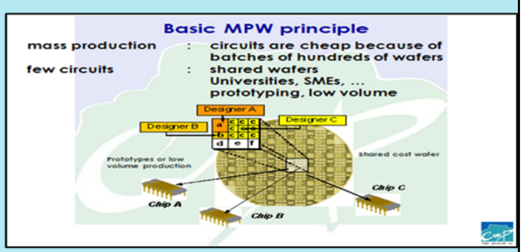
COMPETENCES CENTERS R&D TOPICS

MATERIALS	DEVICES ARCHITEC TURES	MODELING & SIMULATION	CHARACTE RIZATION & TEST	RELIABILITY	INTERCONN ECT & PACKAGING	EQUIPMENT ASSESMENT

ECOSYTEMS

	P1 ULTIMATE CMOS (Logic & Memories)	P2 BEYOND CMOS	P3 NANO DEVICES FOR CMOS DERIVATIVE	P4 NOVEL INTERCONNECTS ARCHITECTURES	P5 ULTIMATE PROCESSING TECHNOLOGIES
ACADEMICS	Tyndall	Grenoble INP	FZ Julich	TU Delft	Uppsala Univ.
	FZ Julich	IUNET	Grenoble INP	Tyndall	Tyndall
	IUNET	ICN	IMEL	Grenoble INP	FZ Julich
	Univ. Granada	IMEL	ITE	FZ Julich	Grenoble INP
	IMEL	Univ. Granada	IUNET	Uppsala Univ.	IMEL
	Uppsala Univ.	Uppsala Univ.	Tyndall		KTH
	Newcastle Univ.	Univ. Twente	Uppsala Univ.		CNM
	Univ. Twente	ITE	Univ. Granada		VTT
	URV	Newcastle Univ.	ICN		
	ICN	Tyndall	Newcastle Univ.		
	KTH	UCL	Univ. Twente		
	Grenoble INP	URV	URV		
	UCL	KTH	KTH		
	ITE	CNM	UCL		
	Warwick Univ.	TU Delft	CNM		
	Univ. Glasgow	Univ. Glasgow	TU Delft		
	CNM	VTT	Liverpool Univ.		
	TU Delft	Univ. Stuttgart	VTT		
	IEMN				
	IES				
	Chalmers				
	VTT				
INSTITUTES	IMEC	IMEC	IMEC	IMEC	IMEC
	LETI	LETI	LETI	LETI	LETI
	FhG	FhG	FhG		FhG
INDUSTRIALIST	ST	ST	ST	ST	ST
	Thales	Thales	Infineon	Thales	ASM
	Micron	Micron	Thales		
	Intel		Micron		

MECHANISMS OF COLLOBORATIONS & ROUTES OF ACCESS



eni2 European Nanoelectronics Infrastructure for Innovation

Status and future deliverables (1/2)

Intermediate report has been issued in May

available at http://www.aeneas-office.eu/web/nanoelectronics/Eni2.php

- **NanoscaleFET**

Achieved: Detailed roadmaps/ecosystems

long-term programme(LTP) structuration ongoing

meeting oct. 1st

- **Smart Energy**

Achieved: Detailed content for roadmaps; 1st ecosystem identified

Smart sensors

Methodologie has been agreed. Consolidation ENI2/ Guardian Angels Nov. 20

.

Status and future deliverables (2/2)

- **Heterogeneous Integration**

Achieved: Detailed roadmaps/ecosystems

- **System Integration**

Technology roadmap (tentative) Sept. WS LTP Nov

- **Equipment and manufacturing**

First draft proposing road mapping activities: July

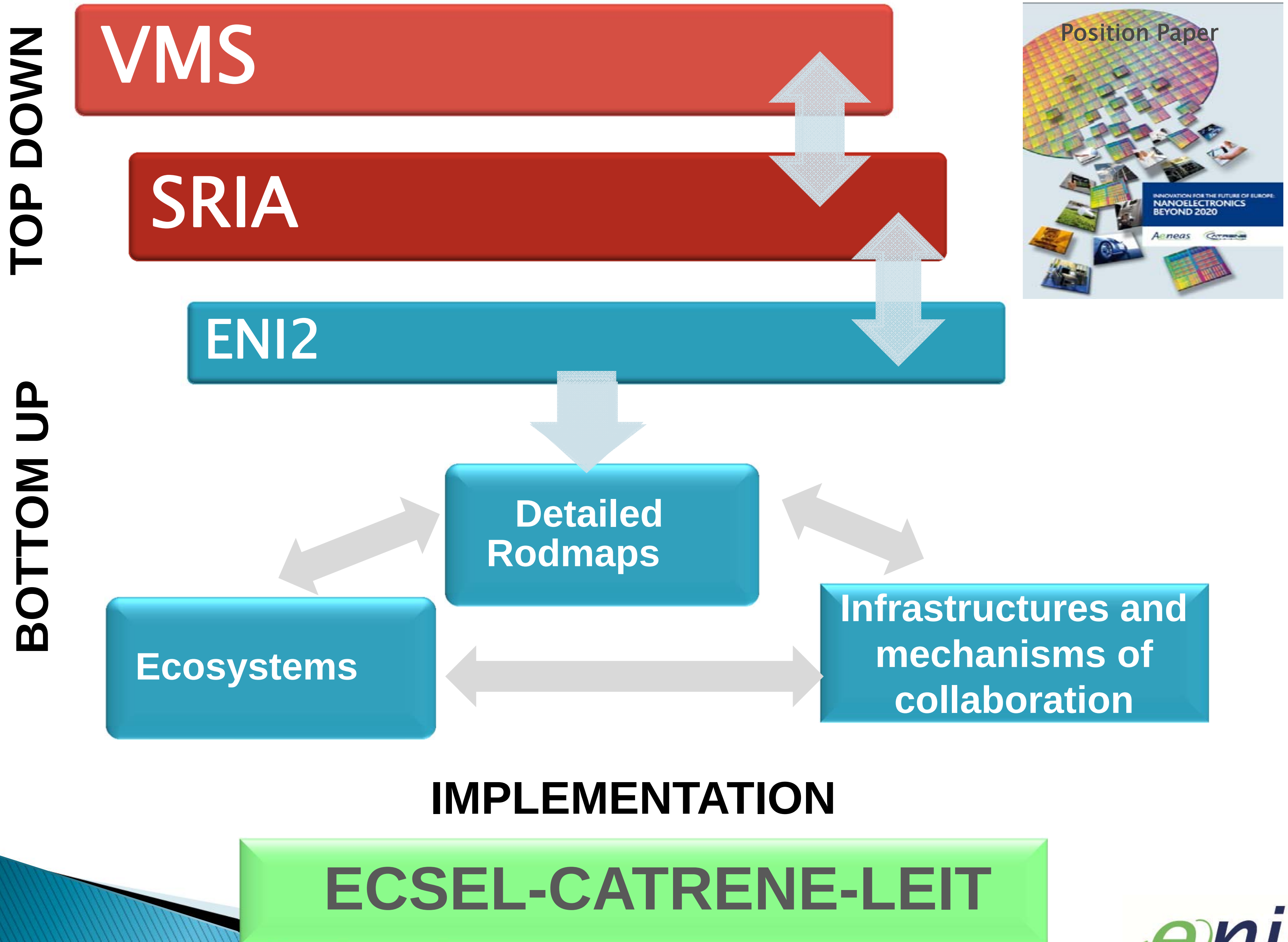
Other deliverables (Q4):

- Mechanisms of collaboration & Routes of access
- LTP governance
- Excellence centers

Final Report Dec. 2013

ENI2 versus collaborative instruments

- ENI2 is a Framework of coordinated long-term activities serving as a basis for proposals in response to the calls to be launched by funding instruments (Horizon 2020, Catrene, ECSEL…)
- ENI2 could Contribute to the future Catrene White book (beyond 2015) and to the ECSEL MASP…..
- ENI2 collected and aligned inputs used in the update of the AENEAS/CATRENE VMS

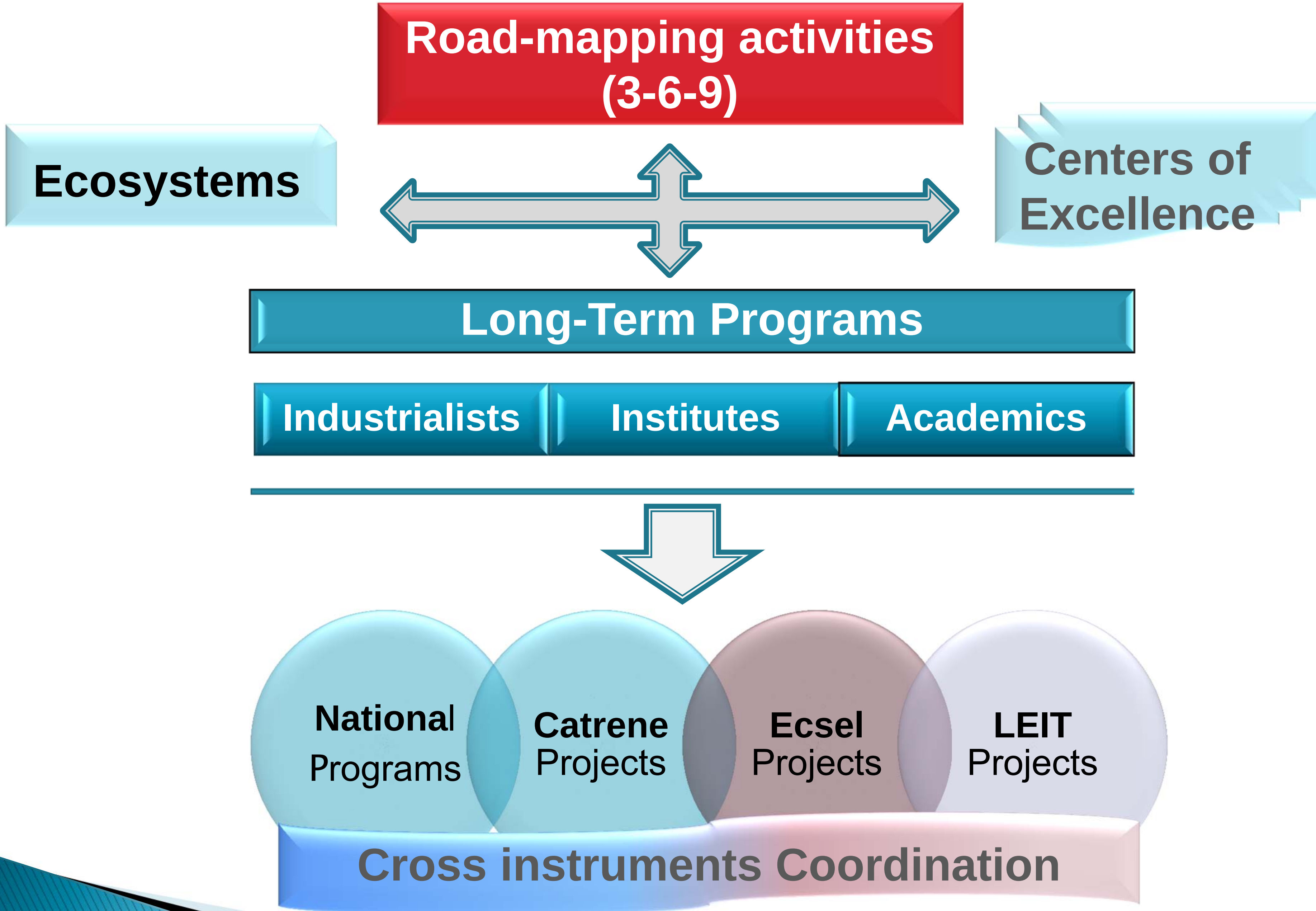

TOP DOWN
VMS
SRIA
ENI2
Position Paper
INNOVATION FOR THE FUTURE OF EUROPE:
NANOELECTRONICS
BEYOND 2020
Aeneas
BOTTOM UP
Detailed Rodmaps
Ecosystems
Infrastructures and mechanisms of collaboration
IMPLEMENTATION
ECSEL-CATRENE-LEIT

ENI2 versus collaborative instruments

- The ENI2 partners have seen that it is required to work on ecosystems and roadmaps in a **general not on funding oriented way**.
- LEIT-CATRENE-ECSEL….They all have road mapping activities, but dedicated to their targets , interests.

Support from PAs

- ENI2 is offering to the PAs a **detailed** shared vision of the technical priorities and associated targets to be pursued.
- The Strategic long term Programs will be submitted to the PAs for approval.
- Each Program will rely on a well identified ecosystem (who is doing what) reflecting the involvement of each Member State.
- ENI2 is delivering aligned content enabling long term funding support.


Road-mapping activities (3-6-9)
Ecosystems
Centers of Excellence
Long-Term Programs
Industrialists
Institutes
Academics
National Programs
Catrene Projects
Ecsel Projects
LEIT Projects
Cross instruments Coordination