6TH ROUND TABLE ON MICRO/NANO TECHNOLOGIES FOR SPACE, ESTEC, 8-12, 2007

Introduction of RF-MEMs in Space Hardware : A Long Road Needing a Good Map

Augustin Coello-Vera, Thales Alenia Space, Toulouse
Jeremie Bouchaud, WTC- Wicht Technologie Consulting
Bernardo Knoblich, WTC- Wicht Technologie Consulting

Your Experts in Microtechnology & Electronics.

Outline

- Introduction
- Position of Europe in the global supply chain
- Public funding of RF MEMS worldwide
- Strengths and weaknesses of Europe
- Outlook for satellites
- Recommendations to Agencies

Introduction

A good deal of this presentation has been based on the results of

ARRRO

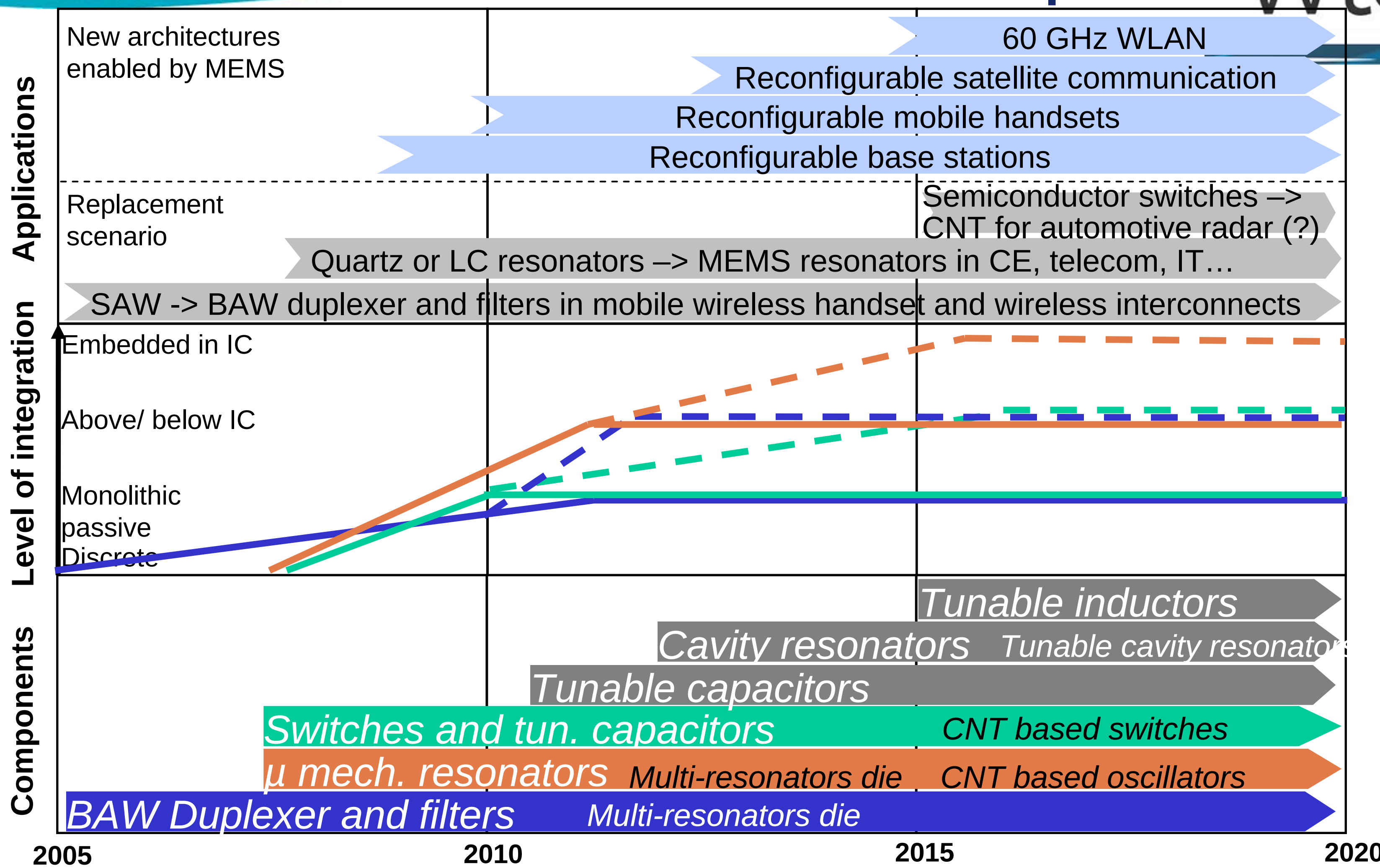
RF MEMS ROADMAP

Applied Research Roadmap for RF micro/nano systems

Project type: Specific Support Action – FP6, call 4

Duration: February 2006 – April 2007

Overall RF MEMS roadmap



Introduction of RF-MEMs in Space Hardware : A long Road needing a Good Map

RF MEMS supply chain in overview

Legend

North American players

European players

Asian players

National and International Bodies

DARPA, NSF (USA), 5th and 6th European FP, ESA, National Asian programs in J, ROK, Sing.

Academic R&D

Michigan Uni (USA)
Purdue (USA)
GiorgiaTec (USA)
San Diego Uni (USA)
…

VTT (FIN)
IMEC (B)
CEA LETI (F)
CNRS-LAAS (F)
…

Tokyo Uni. (J)
KAIST (ROK)
GPSC (Sgp.)
ITRI (TW)...

RF MEMS manufacturers

RF-MEMS Startups

Radant (USA)
Xcom (USA)
Teravicta (USA)
Discera (USA)
Wispry (USA)
Siverta (USA)
SiTime (USA)
SiliconClocks (USA)...

BaoLab (E)

MEMS Startups

MicroAssembly (USA)
MEMSCAP (F/USA)
Protron (D)...
MEMS Solution (ROK)

Large IC manufacturers which also do MEMS

Intel (USA)
IBM (USA)
Motorola Labs (USA)
FreeScale (USA)
ADI (USA)

Infineon (D)
STMicroelectronics (F)
Philips (NL)

Samsung (ROK)
NEC (J)
LG (ROK), Toshiba (J)...

Integrators with own MEMS development

Defense & aerospace
Raytheon, Rockwell, Northrop Grum. (USA)

Thales (F), BAE (UK), Raphael (Il), EADS (D)...

RF devices manuf.

Avago, Triquint, Skyworks, Maxim… (USA)

Epcos (D)

Fujitsu (J), Matsuchita (J)
Murata (J)

Integrators & users

Wireless telecom terminals and Infrastructure

Semiconductor and RF test

Automotive

Aeronautics space and Defence

Services

MEMS CAD & IP	MEMS test & characterisation	RF CAD & EDA	MEMS Foundries	RF + semicon. foundries	MEMS Packaging
Coventor (USA), IntelliSenseSoft (USA) SoftMEMS (F)	Epsilon (F) NovaMEMS (F) MEMS TC (NL)	Modelithicss (USA) Sonnet (USA) Agilent (USA) APLAC (FIN)...	**DALSA (CND)** IMT (USA) Tronic's (F), APM (Tw)	Jazz (USA) Peregrine (USA) TSMC (Tw)	Shellcase (IL) Hymite (DK)

Introduction of RF-MEMs in Space Hardware : A long Road needing a Good Map

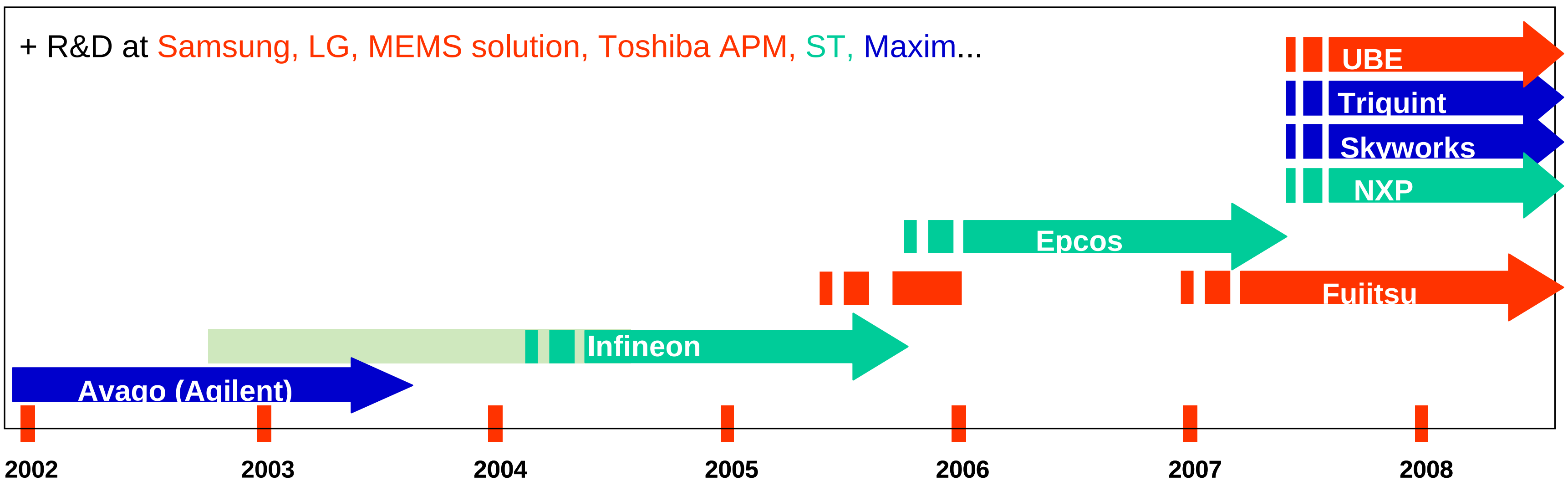
Outline

- Introduction
- **Position of Europe in the global supply chain**
- Public funding of RF MEMS worldwide
- Strengths and weaknesses of Europe
- Outlook for satellites
- Recommendations to Agencies

RF MEMS supply: EU good for high volume markets (1)

- **E.g. FBARs duplexers and filters for cell phones**

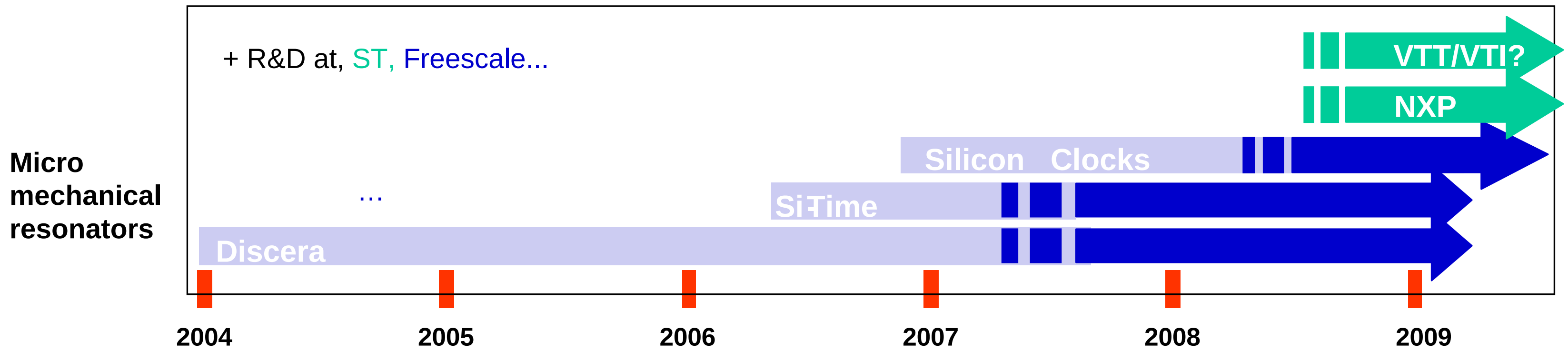
Status of commercialisation of FBAR



RF MEMS supply: EU good for high volume markets (2)

- **E.g. Micro-mechanical resonators for consumer electronics and cell phones.**
  - Europe well positioned for key market TCXO for cell phones

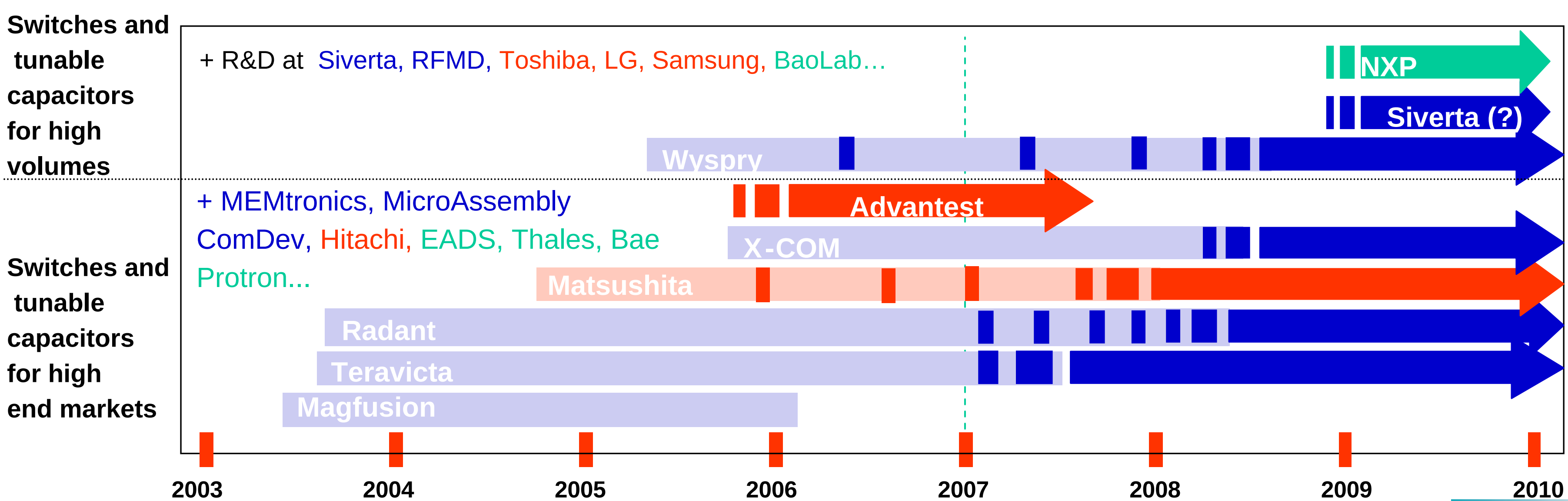
Status of commercialisation of micro mechanical resonators



RF MEMS supply: EU weak for high end applications

- **RF MEMS switches and tunable capacitors for demanding applications in aerospace, automotive and defence**

Status of commercialisation of RF MEMS switches and tunable capacitors

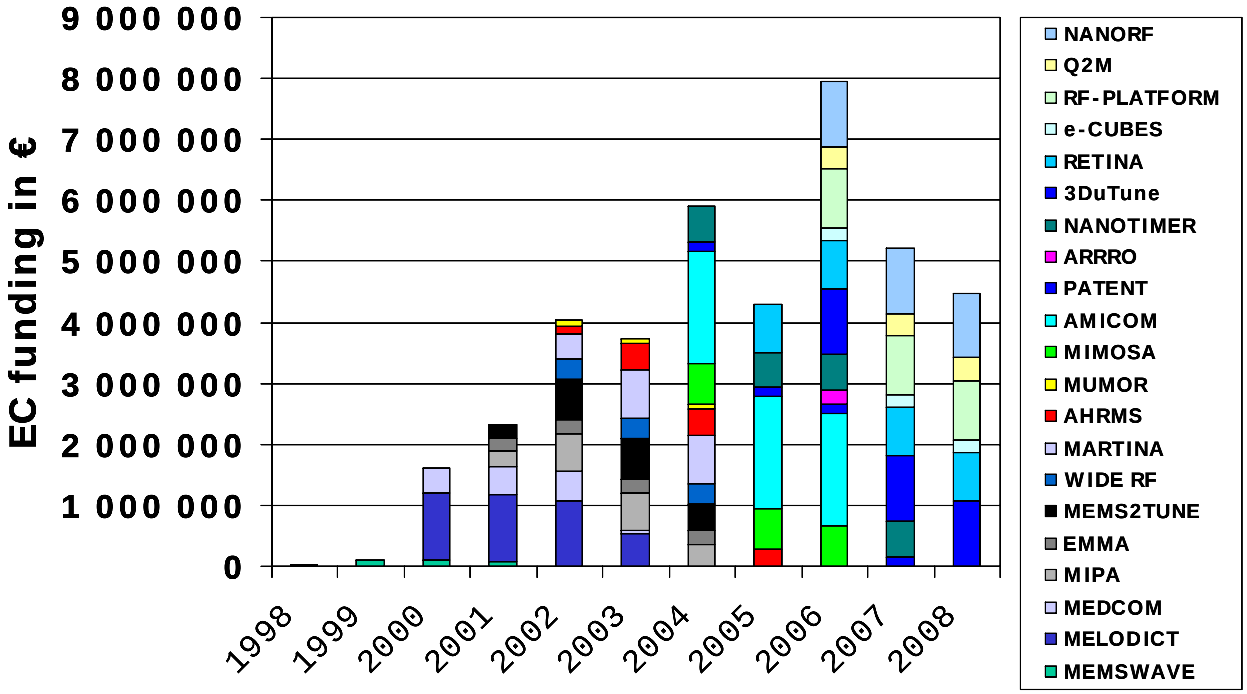


Introduction of RF-MEMs in Space Hardware : A long Road needing a Good Map

Outline

- Introduction
- Position of Europe in the global supply chain
- **Public funding of RF MEMS worldwide**
- Strengths and weaknesses of Europe
- Outlook for satellites
- Recommendations to Agencies

Public funding of RF MEMS in Europe



EC is the major contributor in Europe

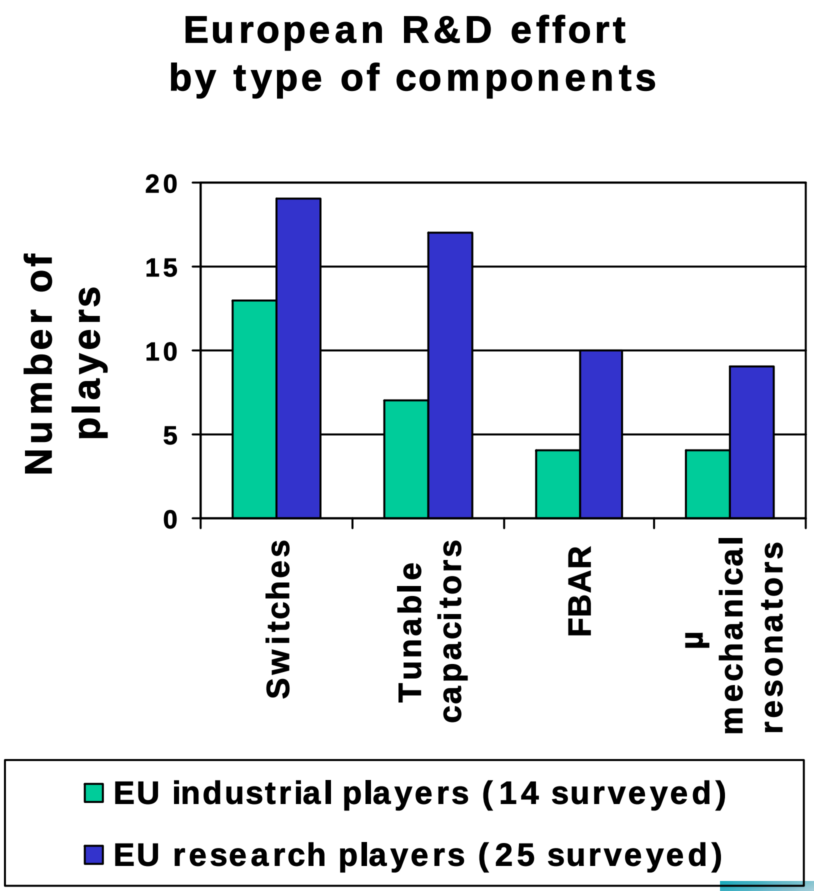
- 22 RF MEMS related projects referenced since 1998
- €30 M in total between 1998 and end 2006

➢**ESA: RF MEMS is MEMS subject number 1:**€11.5 M since 2000

➢**National projects: limited effort, scattered among number of countries:** € 1,5M to 2,5 M p.a. Cumulated estimated €13-14M

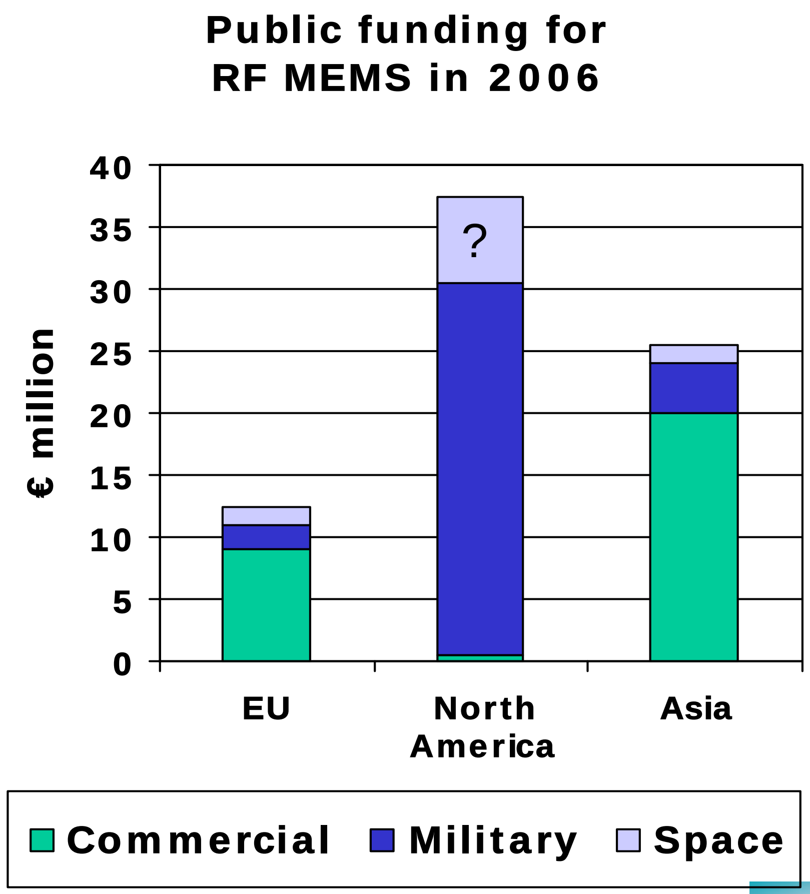
European research: Main conclusions

- **Started 5-10 years after the US**
- **Caught-up when R&D highly focused and concentrated in the hand of a limited number of players**
  - E.g. FBAR
  - E.g. µ mechanical resonators
- **Lack of critical mass on key issues such as reliability. Effort scattered among too many EC and national project.**

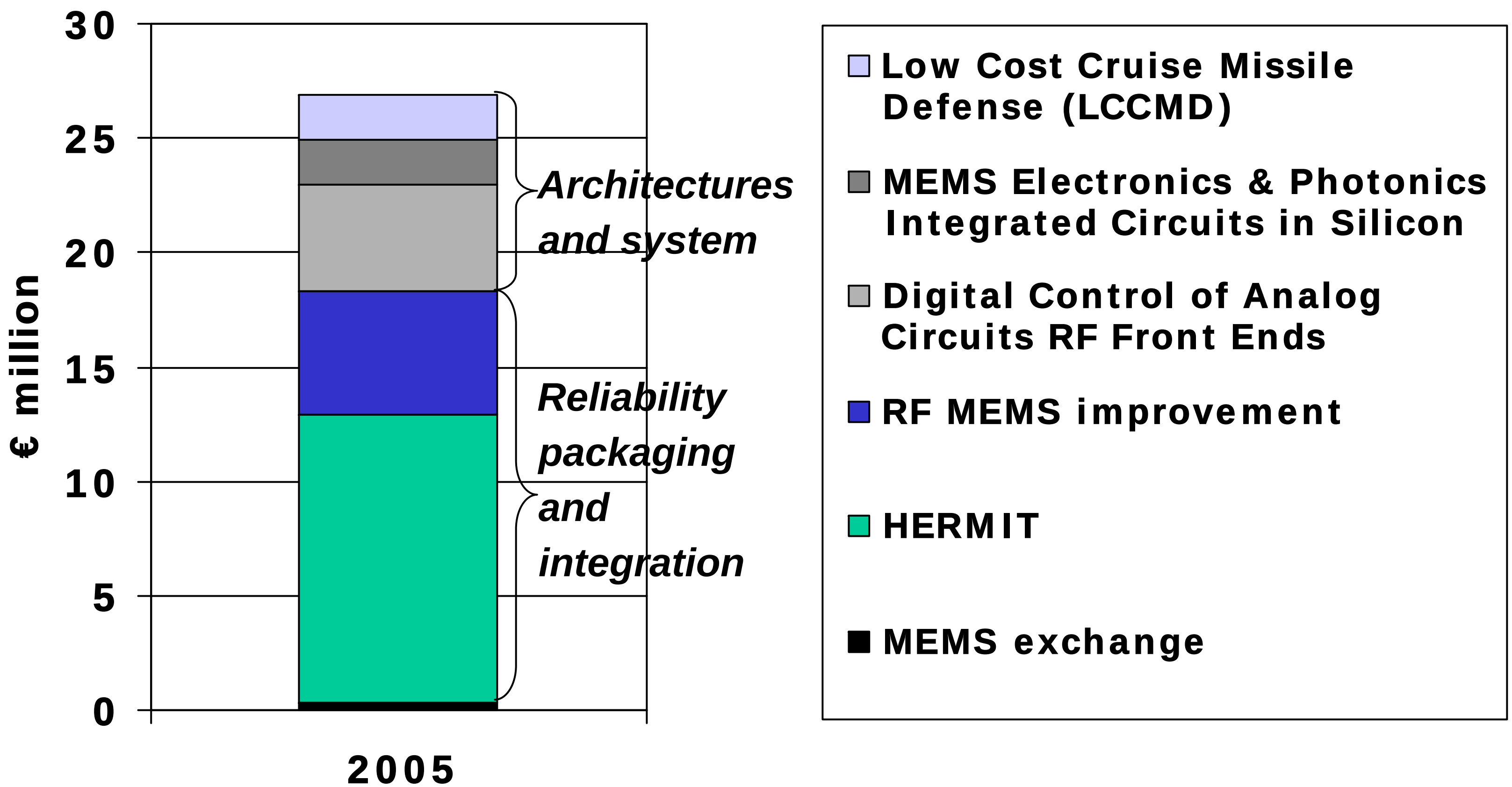


Funding of RF MEMS R&D worldwide

- **Public funding of RF MEMS is much higher in North America**
  - Driven by military applications
  - Private Venture Capital finances R&D for commercial applications
- **Public funding is also more efficient in the US**
  - Fewer project with high critical mass focusing on key issues
  - E.g. “RF MEMS improvement” project: $ 21 M in 2003- 2005 for reliability, packaging and performance of RF MEMS switches



RF MEMS funding at DARPA in 2005



Currency exchange used: 1 € = 1.29 US$ (January 16th 2007)

Outline

- Introduction
- Position of Europe in the global supply chain
- Public funding of RF MEMS worldwide
- **Strengths and weaknesses of Europe**
- Outlook for satellites
- Recommendations to Agencies

☺ Strengths of Europe

- Good for present and future supply of volume RF MEMS in cell phones
- Strong user-based industry
- Very good Research Institutions and teams

☹ Weaknesses of Europe

- Dilution of effort in large (many partners) trans-national projects in Europe vs. fewer project with high critical mass focusing on key issues in the USA
- Many funding bodies (EU, ESA, National Governments) with different priorities and schedules (leading to considerable duplication) in Europe vs. basically one funding body (DARPA), with clear, well defined priorities in the US
- Often not critical mass for key research issues
- No strong VC/start-ups system. Lack of entrepreneurial spirit.
- Incomplete manufacturer base in Europe. Non-existent for high value niche applications

Outline

- Introduction
- Position of Europe in the global supply chain
- Public funding of RF MEMS worldwide
- Strengths and weaknesses of Europe
- **Outlook for satellites**
- Recommendations to Agencies

RF MEMS = Commercial/ military end users

TELECOMMUNICATION SATELLITES

- **Standard transparent telecom repeater**
- **RF routing in commercial payloads**
- **Reconfiguration Matrix on Regenerative Payloads**
- **Reconfigurable / Flexible equipments**
- **Redundancy switch in reflector antennas**
- **Reconfigurable reflect array**

OBSERVATION SATELLITES

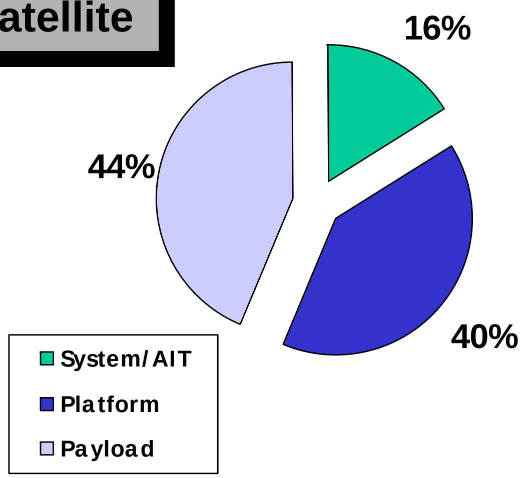
- **Phased-Array Antennas**
- **Reconfigurable front-end for radar applications**

It is very important to differentiate the replacement scenarios from new architectures enabled by MEMS: **The Roadmap is not necessarily the same**.

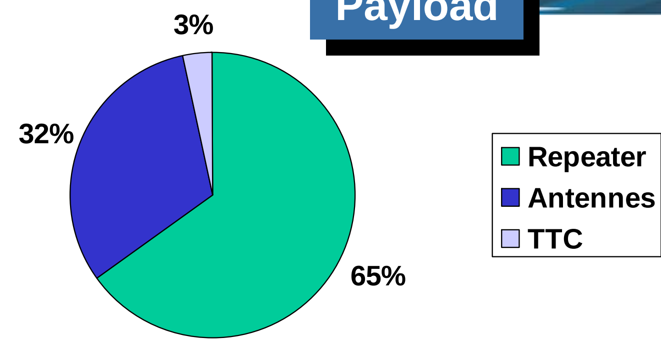
Telecom Satellites

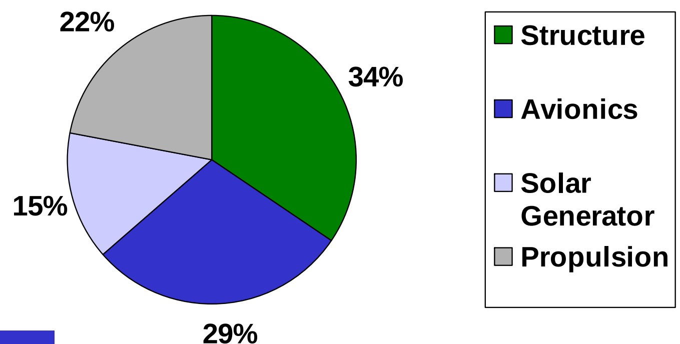
RF MEMs for Replacement

Satellite

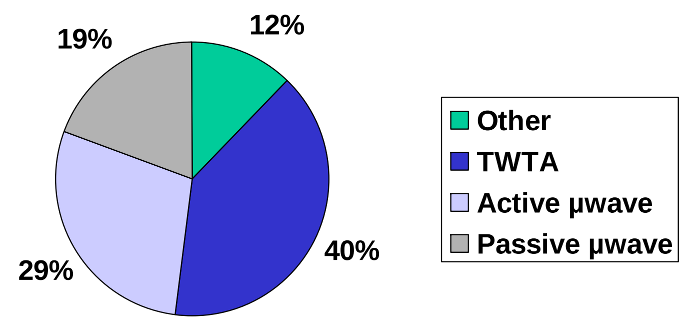


Payload





Platform



Repeater

Introduction of RF-MEMs in Space Hardware : A long Road needing a Good Map

RF MEMs for Replacement

- ➔ **If a ‘miracle’ technology brings 10% cost reduction to <u>all</u> active µwave equipment in the payload ➔ The satellite cost is reduced by 0.8% (800 K€ for a satellite costing 100 M€)**
- ➔ **Typical insurance costs for our customer, the operator, is 15% for launch and first year in orbit + 2-3% for each additional year.**
- ➔ **If the ‘miracle’ technology is new and without flight heritage, it may result in increased insurance rates that will wipe out any price reduction proposed by the satellite manufacturer.**

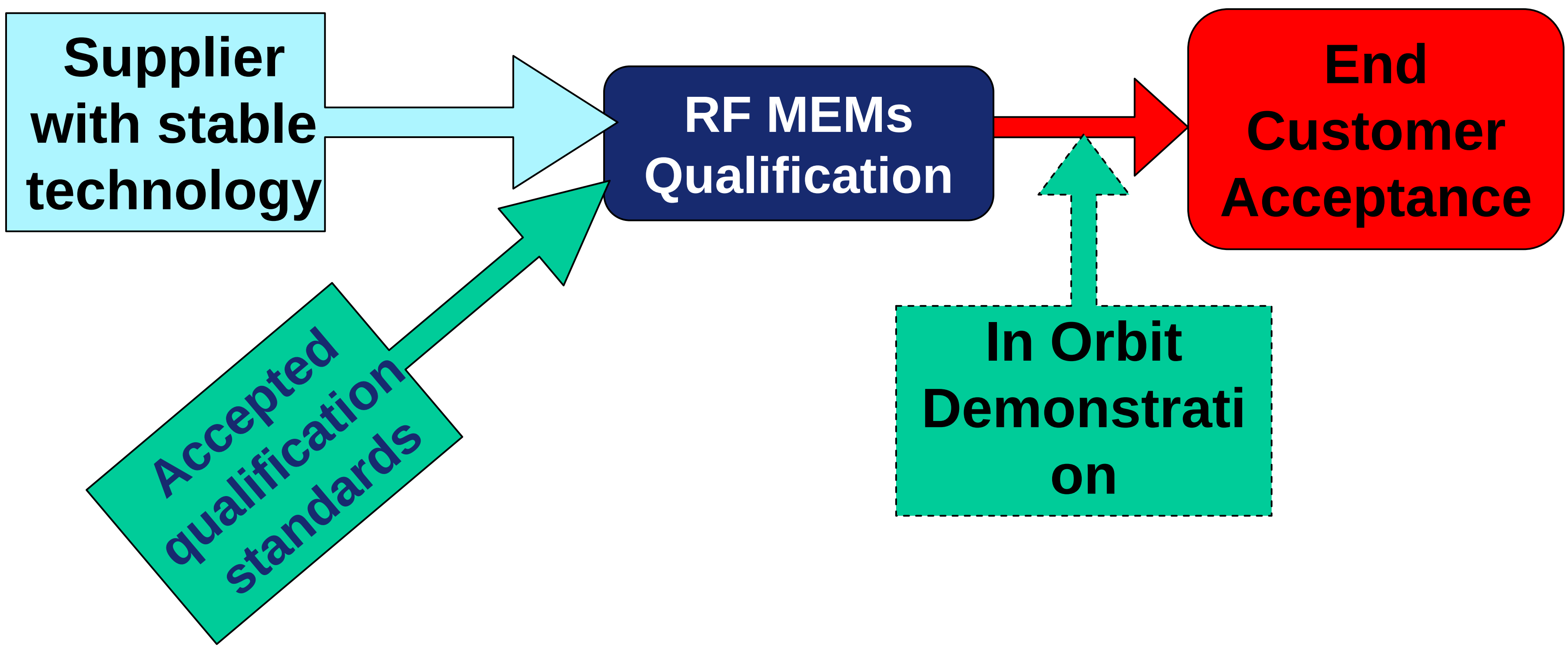
➔ The customer will, most of the times, not take the risk if the technology is not mandatory for the mission ➔ RF MEMs will be more easily introduced when enablers of new architectures.

Excerpts from CTB Dossier

Some well known truths worth recalling

- ➔ New technologies with little or no space heritage pose unacceptable risk to costly spacecraft and tend not to be flown. This is still the case for most devices coming from micro/nano-technologies.
- ➔ For the use of MEMS components in space equipments it is fundamental to have detailed test and qualification procedures.
- ➔ Because of the complexity of MEMS components it is not easy to write them. Studies have to be pursued to enable this work.
- ➔ New activities should address quality standards for design, selection, procurement, and qualification of MEMS devices for future use in new generation satellites.
- ➔ It is also recommended that requirements relating to product manufacturing, evaluation, qualification, performance, QML approach, and capability approval are developed under the ESCC System

The Road as we see it



Where is the map?

CTB MNT WG Map

RF MEMS Roadmap

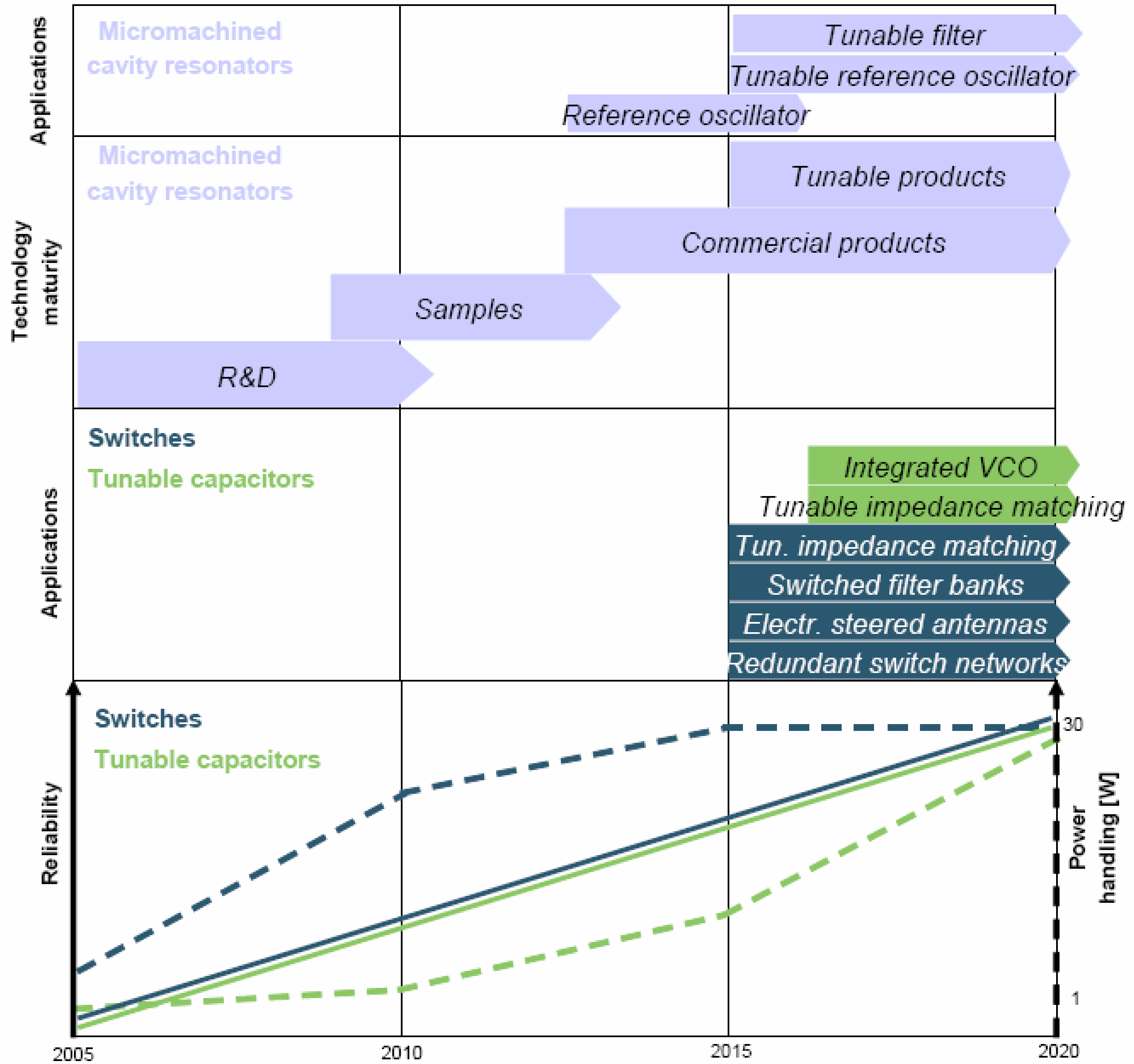
Action Line		Technology & related action items	Dossier Ref.	2007	2008	2009	2010	2011	2012	2013
RF 1		RF MEMS switch for reconfigurable microwave application	§ 5.6.3 § 5.6.4	TRL3	TRL4	TRL4	TRL6	TRL6	TRL6	TRL8
1	I	High reliability MEMS redundancy switch								
2	I	Very large order switch matrices using MEMS technology								
3	P1	Transfer / Industrialisation of small signal RF MEMS technology								
4	P2	Redundancy, low signal, RF MEMS switch: space qualification								
5	P2	Redundancy, low signal, RF MEMS switch: commercial flight								
RF 2		RF MEMS switch for antenna application	§ 5.7	TRL3	TRL3	TRL3	TRL4	TRL4	TRL6	TRL6
1	P1	RF MEMS switch for antennas application: design, validation								
2	P2	RF MEMS switch for antennas application: Technology qualification								

Transversal activities Roadmap

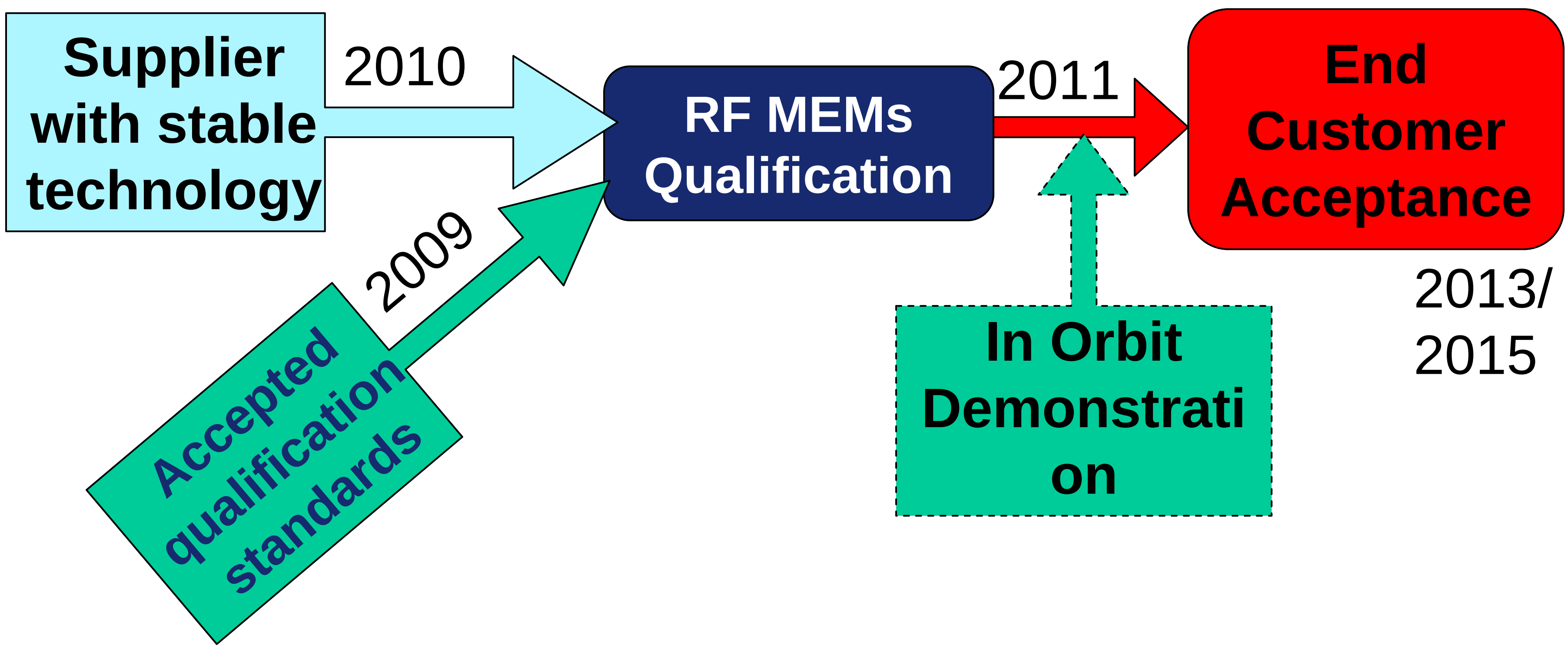
Action Line		Technology & related action items	Dossier Reference	2007	2008	2009	2010	2011	2012
QUAL 1		Reliability assessment, qualification methodology and standardisation of MEMS	§ 12.2 § 12.4	TRL not applicable					
1	P2	MEMS physics of failure in Space applications							
2	P1	Methodology for the reliability assessment of MEMS devices							
3	P3	Standardisation of MEMS							
4	P3	Elaboration of a properties database for the materials used in MNT							

Introduction of RF-MEMs in Space Hardware : A long Road needing a Good Map

ARRO's Map


Applications
Micromachined cavity resonators
Tunable filter
Tunable reference oscillator
Reference oscillator
Technology maturity
Micromachined cavity resonators
Tunable products
Commercial products
Samples
R&D
Applications
Switches
Tunable capacitors
Integrated VCO
Tunable impedance matching
Tun. impedance matching
Switched filter banks
Electr. steered antennas
Redundant switch networks
Reliability
Switches
Tunable capacitors
Power handling [W]
30
1
2005
2010
2015
2020

The Road and the Map



Supplier with stable technology

2010

European Industrial Players

F=Foundry, P=Packaging

	RF MEMS Switches	Tunable capacitor	BAW	Micro-mechanical resonator	μ-machined cavity resonator	Micro-machined inductor	Tunable inductor
Atmel	X						
BAE SYSTEMS Advanced Technology Centre	X						
Baolab Microsystems	X						
EADS Deutschland GmbH	X			X			
Epcos AG			X			X	
FBK **(F)**	X						
Hymite A/S **(P)**	X	X	X	X	X	X	X
ImegoAB	X	X				X	X
Infineon Technologies AG			X				
Intel Electronics, Ltd.	X	X	X	X			
MEMSCAP	X					X	
microFAB Bremen GmbH **(F)**							
Microsaic Systems, Ltd	X					X	
Nokia Research Center							
NXP (Next eXPerience) Semiconductors	X	X	X	X	X		
Protron Mikrotechnik GmbH	X						
QinetiQ	X			X		X	
Reinhardt Microtech					X		
Selex Si	X						
ShellCase, Inc. **(P)**							
Silex Microsystems AB **(F)**							
SoftMEMS **(SW)**							
STMicroelectronics			X	X			
Thales Alenia Space	X						
TRONIC'S Microsystems SA	X	X				X	X

European Industrial Players

F=Foundry, P=Packaging

	Mobile handsets, Consumer electronics	Base stations	Road transport	Satellites	Aeronautics & Defence	Test equipment
Atmel	X					
BAE SYSTEMS Advanced Technology Centre			X		X	
Baolab Microsystems	X					X
EADS Deutschland GmbH				X	X	
Epcos AG	X	X				
FBK **(F)**				X	X	
Hymite A/S **(P)**						
ImegoAB						
Infineon Technologies AG	X					
Intel Electronics, Ltd.	X					
MEMSCAP	X				X	
microFAB Bremen GmbH **(F)**						
Microsaic Systems, Ltd						
Nokia Research Center	X					
NXP (Next eXPerience) Semiconductors	X					
Protron Mikrotechnik GmbH		X		X	X	
QinetiQ				X	X	
Reinhardt Microtech					X	
Selex Si			X	X	X	
ShellCase, Inc. **(P)**						
Silex Microsystems AB **(F)**						
SoftMEMS **(SW)**						
STMicroelectronics	X					
Thales Alenia Space				X	X	
TRONIC'S Microsystems SA		X	X		X	


2009
Accepted
qualification
standards

Transversal activities Roadmap

Action Line		Technology & related action items	Dossier Reference	2007	2008	2009	2010	2011	2012
QUAL 1		Reliability assessment, qualification methodology and standardisation of MEMS	§ 12.2 § 12.4	TRL not applicable					
1	P2	MEMS physics of failure in Space applications							
2	P1	Methodology for the reliability assessment of MEMS devices							
3	P3	Standardisation of MEMS							
4	P3	Elaboration of a properties database for the materials used in MNT							

Where are the actions and budgets?

Outline

- Introduction
- Position of Europe in the global supply chain
- Public funding of RF MEMS worldwide
- Strengths and weaknesses of Europe
- Outlook for satellites
- **Recommendations to Agencies**

Recommendations to Agencies

1. **Secure the commercialisation supply chain for RF MEMS for Space**
   - Identify as soon as possible a small set of MEMs suppliers and foundries with experience and expertise in RF MEMS and motivated to supply to the Space Industry
   - Prescribe the inclusion of one of those within all of funded R&D projects
2. **Enhanced focus of R&D for RF MEMS in Europe**
   - Dedicated major R&D projects for the key challenges: reliability, qualification tests and packaging.
   - Reduce the effort being placed on demonstrators.
   - Narrowing down the number of applications and components
   - R&D resource and funding effort should also be focused on a limited number of industrial and academic partners

Thank you for your attention and….

Have a nice
and safe trip