The Other Computing

Is Canada Ready for the Internet of Things?

Perspectives for Embedded System in Canada
Industry Profile and Market: - 2011-2013
Data, Trends and Issues for Consideration

CATAlliance

ISBN 978-2-9812174-3-1

The Other Computing – Canada 2012

Library and Archives Canada, 2012

Contents

Abbreviations

ASIC	Application Specific Integrated Circuit
BGA	Ball Grid Array
CMOS	Complementary Metal–Oxide–Semiconductor
DSP	Digital Signal Processor (or Processing)
EDA	Electronic Design Automation
EMS	Electronics Manufacturing Service
ESDM	Electronics System Design and Manufacturing
ESL	Electronic System Level
FPGA	Field-Programmable Gate Array
IDM	Integrated Device Manufacturer
IP	Intellectual Property
JDM	Joint Design Manufacturing
MCU	Micro Controller Unit
MEMS	Micro-Electro-Mechanical System
ODM	Original Design Manufacturer
OEM	Original Equipment Manufacturer
PCB	Printed Circuit Board
PCI	Peripheral Component Interconnect
PDU	Power Distribution Unit
SEU	Single-Event Upset
SMT	Surface Mount Technology
SOC	System-On-a-Chip

List of Figures

Foreword: The Virtualization of Embedded Computing[1]

Marc Perron

President, Alizem inc.
and
Secretary of the 'Electronic Systems on Chip' Technical Committee
of the IEEE Industrial Electronics Society

* * *

Embedded systems are a horizontal technology, but their applications scopes are vertical. Many people are studying the embedded system itself, but the real challenge is to apply this knowledge to vertical applications. That is why I introduce myself as a software engineer who migrated to energy applications. I speak both "electric motor" and "embedded software". Too often, electric motors specialists are not knowledgeable about embedded software and vice versa. Alizem's expertise is to translate the needs of electric motor-based system designers into embedded software solutions.

Embedded systems: a horizontal technology but vertical applications.

It is not sufficient to be an expert in C programming to be able to design an application that will fully satisfy a particular need. Too often, developers think they are able to create all purpose applications. That's why the cost of embedded systems software development is skyrocketing. For my part I tend to consider that software programming is an engineering core skill. It's like reading and writing: it is not because someone can write that he is equally capable of writing novels, political speeches and pamphlets for department stores.

It is not sufficient to be a programming expert to be able to design an application.

For an engineer, the challenge is to design solutions that encapsulate application knowledge (complex, rare and expensive to develop), within a short time to market, but without compromising product quality and performance. The technology of embedded systems is known and accessible to all. The challenge is to quickly and efficiently integrate modules that work first time around.

How to design and integrate quickly and efficiently modules that work first time around.

The Challenge of the Growing Chip Computing Power

Moore's Law noted that the density of chips doubled every 18 or 24 months, but the problem is that the productivity of people who program and design these chips, does not increase as fast – by far. This generates a long-term productivity gap that creates problems for the industry of microelectronics.

The density of chips doubled every 2 years, but human productivity does not increase that fast.

Worse: Moore's Law has a dark side which is less discussed. Every time the number of transistors on a chip would double, the complexity and costs of

[1] Excerpt from a face to face interview, - September 28, 2011.

R & D and manufacturing production would grow accordingly. To develop a new chip, you have to invest large sums that must be amortized very quickly, because the life cycles of consumer goods are shortening all the time. But under the shock of global competition, the chips' selling prices also decrease dramatically. The result is a limited number of giant manufacturers producing less varied chips in larger and larger volumes.

On the other side, given the ever increasing chips and peripherals complexity, the software costs to develop chip-based applications are exploding. That is why the big chip manufacturers began to surround themselves with a whole ecology of software component suppliers that will assist application developers.

Birth of an ecosystem of specialized applications developers as third parties.

This is exactly the same phenomenon that occurred in the field of mobile phones. Before the mobile phone was a non-configurable electronic product. Now, with iPhone, Android, Blackberry and others, the mobile phone has become an electronic platform which remains the same for everyone, but configurable by each individual to suit his needs. The manufacturer delegated the task to set the phone to the user.

The same concept is now being adopted throughout the embedded systems industry.

EDA

Cadence is a major player in the development of software specifically geared towards computer chips design. Called Electronics Design Automation (EDA), this sub-sector was born in the 80s and, in addition to Cadence, its key players are Synopsys, Mentor Graphics, Magma Design Automation, and Zuken.

The main signal of change was given in April 2010 when the California-based Cadence Design Systems has released a manifesto of 30 pages entitled "EDA360: The Way Forward for Electronic Design." The authors state that while the microprocessor has become a commodity, the ultimate market differentiator in microelectronics is the number, variety and quality of software applications.

The EDA-360 manifesto states that software, not microprocessor, is the great differentiator in microelectronics.

The EDA360 manifest does not stop there and argues that this shift in value is reversing the process of designing embedded systems. From now on, when you start a project, specifications must first address the user application and its underlying software. Only then comes the question of which hardware can best support the selected software.

An embedded system project must tackle software first and only then determine which hardware to use.

It is possible to compare the embedded system to a home. For centuries, it is the people who were makers of brick and cement that built the houses. The design, modeling and decoration of the house came as an afterthought. This process has changed beyond recognition when we started asking architects to make plans for our houses – or to program them virtually, if we are to continue our analogy. Even decorators – more often referred to as interior designers – are consulted from the start of the house project. It is they who define the plans of the house – the contractor comes later, to handle the actual construction.

In home building, the architect comes before the bricklayer. It is the same in embedded systems: software engineers are the project architects.

Everything happens exactly the same way in the embedded world. The engineer in microelectronics is the contractor with the bricks and mortar. If a microelectronics firm persists in programming an embedded system application from 'a' to 'z', it behaves like the ancient contractor who made himself the bricks with which he built a house, then would seek the aggregate of the mortar on the side of the river and so on.

Such behavior was probably justified for the early embedded systems when devices had limited computing power and range of applications. Developers who all belonged to the world of electrical engineering approached their various projects from a hardware perspective: they had to practically invent their work tools as well as the final product. The rudimentary software used, a few hundred lines of code, was a detail they did not care about too much. But times have changed and electronics has become a commodity: the bulk of the value is migrating towards the software side.

An embedded system developer must use existing software tools, not reinvent the wheel for each project.

Today, embedded systems are software-driven. It is up to the software engineer to be both the architect and the decorator – he is the natural project manager. This role reversal is hard to accept by traditional electronic engineers. The result is a culture shock.

The rise of software engineers results in a culture shock.

The engineers who maintain a traditional approach in their embedded projects complain about productivity problems in general, and about the rising costs of software development in particular, as they design the mechanical and electronic components first, pushing the question of the software to the end of the project. In doing so, they address the problem from the wrong end. Given the impact and the high costs of software development in a project, it is in everyone's interest to start the application development by designing the software architecture.

With the EDA360 vision the industry says loud and clear that the future of microelectronics no longer lies in integrated circuits, but in software. It is repositioning itself in the value chain to provide the common platform upon which application developers will integrate third-party components.

Actually, this means that each EDA or chip company intends to create a sort of embedded software App Store where it will offer its customers – the embedded system designer – a set of application software ready for their newest microprocessors generation[2]. In the highly competitive semiconductors market, the range of features created by third-parties will be their main differentiating factor, as are the Apple App Store or the Google Android Marketplace in the mobile phone market.

Software tools are not developed project by project but acquired in embedded software "App Stores".

The Chip Disintegration

At the same time, microprocessors themselves are changing in nature. When we talk about electronic chip, we usually think in terms of application specific integrated circuit (ASIC). The chip is built as a monolith and nothing can be modified by the buyer. There is another type of chip called field-programmable gate integrated circuit (FPGA) that can be programmed at will – and we are not referring to software programming, but *hardware*

Duel ASIC vs. FPGA.

[2] See Avnet October 26, 2011 news release: Avnet Electronics Marketing and ARM Launch Embedded Software Store. http://www.avnet.com/

programming. This is a blank chip with an architecture that can be configured in a software manner to fit the most advanced needs of the industrial user.

Once the developer of the embedded system has configured the hardware of the FPGA chip, it behaves just like an ASIC. It is then possible to program different applications as it was previously done on an ASIC platform – except that this work takes place on a custom configured hardware. Moreover, FPGA technology is made configurable hardware: it has the timeliness of the hardware and the adaptability of the software.

Here comes the age of vacuum chips which can be programmed and reprogrammed at will.

Birth of the Intellectual Property (IP) Trade

In the unique world of semiconductors, intellectual property (IP) has nothing to do with the ownership of a patent or copyright, it is a generic and reusable block of lines of code that sells as such.

The basic tool of embedded system is intellectual property (IP) i.e. a generic and reusable block of lines of code that sells as such.

One example is the UK-based ARM produces virtual microprocessors which are seriously challenging the Intel dominance in the semiconductor industry. Yet ARM does not manufacture anything physical: the company sells IP blocks for configuring a microprocessor that runs on bare hardware.

These IP blocks have the advantage of being industrial quality products, which is to say compliant with quality and environmental standards, and tested. By decoupling chip function and chip implementation, all physical defects that may affect the design, manufacture or operation of the IP components are now in the hands of the chip manufacturer.

IP blocks are tested, which reduces errors and project' cost overruns.

At the heart of the embedded system, the chip itself has become a diversified system that includes not only a central processing unit (CPU), but also a whole range of peripheral devices. We speak now of system-on-a-chip (SoC). What was previously based on a PCB is now integrated within the chip which can in principle be ASIC or FPGA. But once we entered the path of virtualization, there is reason to believe that the solution of the FPGA empty chip will prevail as and when the last constraints are gone. This new perspective positions the FPGA, not as a chip, but as an integration platform for virtual components or some kind of "software PCB".

In this model, it is not the semiconductor manufacturer that configures the system, but the industrial user: he chooses in a library of reusable components – the equivalent to the semiconductor App Store pr Android Marketplace – the microprocessor and peripherals that suit his specific needs. Where we often had several ASIC chips from different manufacturers, each with a fixed set of features, we now have a single FPGA chip with the exact components required for the needed applications.

It is not the semiconductor manufacturer that sets the system, but the user who obtains this way a system fully adapted to his specific needs.

Impacts on Embedded Developers and Industrial Customers

When software programmers intervene, they will focus on the development of application programs where true product differentiation and the value they bring to the market reside. The great benefit is that they can work on a system – microprocessor and peripherals – preconfigured according to end applications instead of programming everything on their own, wasting

The Cost Constraint

The cost per unit of FPGA chips is still higher than ASIC's ones, but the gap tends to decrease, especially if we take into account their low programming costs. FPGA chip worth $50 a decade ago is now worth $5 – compared with an average of $2 for an ASIC chip. Moreover FPGA technology provides a completely new value proposition, which explains why it does not need to be sold at the same nominal price to be attractive.

valuable time and increasing the opportunities for errors. There will be a great homogeneity between the base material and the final applications. Their work will be much easier. The embedded systems industry will cease to have large software cost overruns and projects consistently delivered late.

The developers' work will be made easier and embedded system projects will be on schedule.

The other advantage is the immediacy of the business process. In the typical ASIC chip approach, the whole chip needs to be perfectly designed and tested at first time since "respin" is going to cost a huge amount of time and money. In the new FPGA approach, the system designer can modify the configuration of its embedded system or correct any bug by simply reprogramming the FPGA chip. This is something particularly important for products having long lifetime such as those designed for the industrial market.

Pretested components are available on the spot.

This change means that microelectronics is becoming a matter of programming – hardware programming as much as software programming. Material production of microprocessors is carried out by a small group of giant corporations at ever decreasing unitary prices (and geographically located near large manufacturing centers in Asia). The value has migrated to the architecture design and applications that are themselves made up of IP blocks. This industrial dynamics has the effect of reversing the hierarchy of values within the production chain to put the software engineer at the controls and relegate the engineer in microelectronics in the background.

Embedded system value migrated from hardware to software having the effect of putting software engineers in the driver's seat.

* * *

1. Introduction: Study Objectives, Methodology and Acknowledgements

The battle to maintain an industrial base in Canada is being waged over the “intelligence of things”; that is to say over the introduction of advanced embedded systems in all manufactured products. The embedded system industry is difficult to define as it is an offshoot of microelectronics and as such the various parts of the supply chain are in an ongoing process of being disaggregated and reassembled in a new way.

The survey was conducted through a questionnaire sent to 716 companies throughout Canada over a four month period (May-August 2011). The response rate was 26 percent which is relatively good in an industrial environment.

Two-thirds of respondents are companies which design and develop embedded systems (EmS), the remainder being prime manufacturers users.

The survey was supplemented by 18 personalized interviews with companies, universities and non-profit organizations.

This survey was funded by the Canadian Advanced Technology Alliance (CATA). A first survey limited to the Quebec-embedded industry was funded by the Ministry of Economic Development, Innovation and Export Trade (MDEIE). The Quebec data were combined with the broader all-Canadian results in order to produce this report.

1.1 Why This Study?

Everyone agrees on the need to maintain an industrial base in Canada. Two models are open to us: that of Germany, where manufacturing accounts for about 30 percent of the value added produced by the country and that of France or Britain, where it represents about 16 percent of the value added .

However, today's industry main driver is the intelligence that is injected into the production. In practical terms, this intelligence is contained in embedded systems.

We distinguish two levels of intervention of intelligence in the industry:

1. manufactured goods production: all manufacturing processes that can be automated are expected to be using programmable systems;

2. manufactured objects themselves are enriched with computer applications that allow them to save energy, adapt to our personal needs, to communicate among themselves and with us (Internet of Things), to start and stop, without our having to think about them.

All industries are engaged in a race to incorporate intelligence in both their manufacturing processes and in their traditional products. Who will manufacture the embedded systems which are the bedrock of this intelligence?

The Canadian electronics is capable of manufacturing embedded systems as well as most of their components. Yet, it is necessary to know who are the manufacturers of embedded systems and make them known to users.

The battle to maintain a significant industrial base in Canada – or even to recover some of the production tools that have been relocated abroad – takes place today not only in the traditional manufacturing sector, but as well in mining and oil , agriculture, construction, utilities, health, and the public sector (police, ambulance, fire department, public transport, etc.). The main weapon to win this battle is the rapid adoption of intelligence, that is to say embedded in production processes and objects of consumption.

The companies that survive and thrive tomorrow in Canada are those who are capable of making by intelligent means intelligent objects. The others will disappear.

1.2 EmS Industry Structure

The embedded systems industry is heterogeneous; it is straddling microelectronics (becoming nanoelectronics) and software publishing. Unlike traditional computing, both hardware and software worlds cannot be separated. A draft board system must be planned simultaneously on both counts.

In this mix, we can also add the fragmentation of the industry. As we have seen, embedded systems were born in silos (first defence and aerospace, then later on, industrial automation, telecommunications, health, public transport, automotive, consumer electronics ...).

The first teams of designers/developers were part of large manufacturers or their direct suppliers. Thus, when Bombardier Transportation wanted to introduce embedded systems in the first rail cars in the late 1980s, it developed in-house expertise, while using a specialized SME called Pocatec (now Axion Technologies).

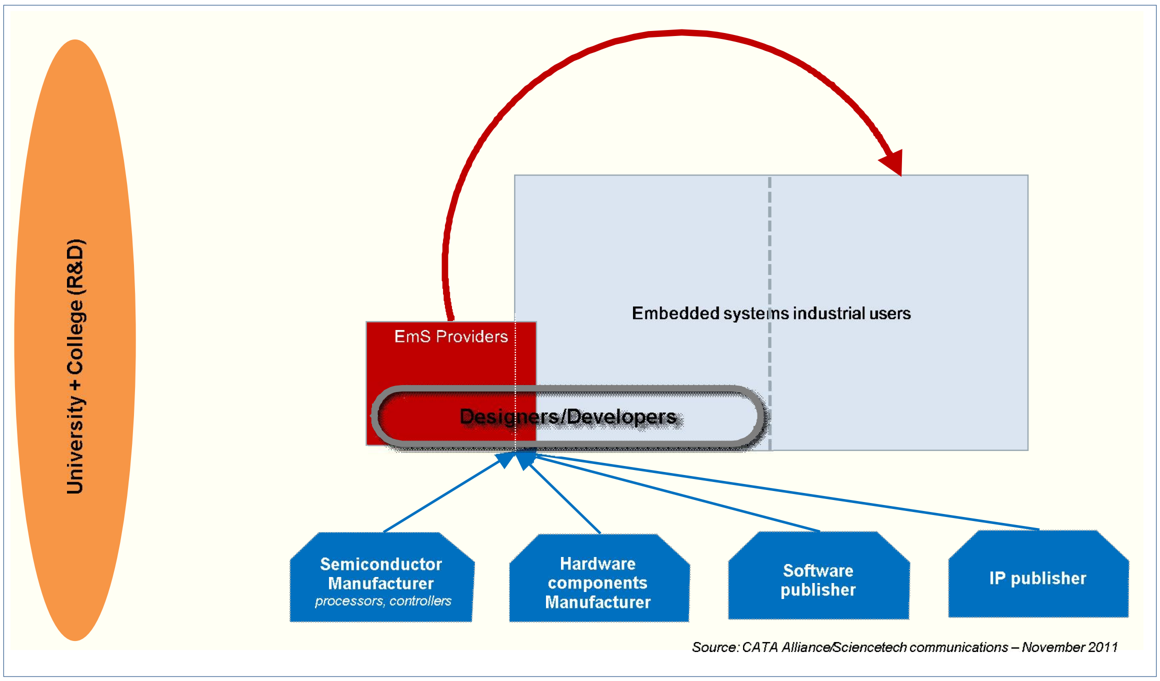
In addition, embedded systems follow the general trend in the electronics industry that favours specialization in layers. After an extensive process of disaggregation, what first was a highly integrated industry broke out into a series of specialized units. The most striking example is how the large semiconductor companies handed over the production of microprocessors or microcontrollers to specialized foundries. These semiconductor "manufacturers" are known as fabless or fablight companies.

Similarly, a new kind of software publishing was born that specialized in programs aimed at the design and development of microprocessors: the Electronics Design Automation (EDA). EDA vendors now tend to diversify and to supply intellectual property (IP) associated with very specific features. This IP is directly aimed at embedded system designers to help them configure applications.

Embedded systems are used in environments so varied that they must use all kinds of highly specialized hardware components such as sensors (camera, laser and photodiode, thermometer or thermistor, strain gauge, microphone or transducer, GPS...),[3] various actuators and interfaces of all kinds. These components are produced by many sub-sectors.

In the figure below, we made a distinction between software and IP publishers although in some cases it may be the same firms, as their features are different. IP vendors come from the semiconductor industry where the configuration of chips hardware had become overly complex and expensive due to extreme miniaturization.

FIG. 1 – EMBEDDED SYSTEM INDUSTRY ECOSYSTEM



IP commercialization is regarded by analysts as a way to industrialize the area of embedded systems where traditional culture still prevails; each development team develops its system from scratch with an approximate idea of the actual time and cost it will take. Let us say immediately that

[3] "Smart Sensor Networks: Technologies and Applications for Green Growth", OECD, December 2009, 48 pages.

some obstacles are hindering the widespread adoption of IP: some clients require the use of open systems, legal difficulties due to the infringement of existing intellectual property rights, etc.[4]

Embedded designers/developers come from the user industry and until now it is where the majority is still working. Initially, the user sector was dominated by prime manufacturers. This is no longer the case as EmS vendors are quickly becoming a self-sustaining industry: creation of an offer of standardized computer-on-modules (COM), commercial use of blocks of intellectual property (IP), etc.

Finally, the university plays a key role throughout the embedded sector value chain. This is where engineers are trained both in hardware and in software programming. Moreover, it is closely linked to the semiconductor industry which is heavily dependent on basic research.

One must never forget that the basic layers of embedded system are closely related to pure physics. On this infrastructure are added several layers of operating system, middleware, application program interfaces (API) which often require the use of new concepts, not yet tested in accordance with industry standards. This is why the evolution of embedded systems goes hand in hand with building bridges between enterprises and universities.

1.3 Methodology

The embedded systems study is based on three sources: a review of existing literature, an industry survey and a series of personal interviews with industry, university and government stakeholders.

1.3.1 References

An exhaustive list of documents consulted would be both long and tedious; however, there are a few key documents which influenced all of our research. Here are these selected sources:

Title	Organism	Origin	Date	Pages
Revitalizing Ontario' Microelectronics Industry	Information Technology Association of Canada (ITAC)	Canada	December 2007	26
Report on the evolution of the micro and nanoelectronics sector	Parliamentary office for the evaluation of scientific and technological choices	France	June 2008	64
Strategic Research Agenda of the European Technology Platform on Smart Systems Integration	European Technology Platform on Smart Systems Integration (EPoSS)	Europe	March 2009	75
The Future of Semiconductor Intellectual Property Architectural Blocks in Europe	Report for the European Commission,	Europe	March 2009	140
Microsystems: Creating Economic Value for Canada (A National Design Network Proposal)	CMC Microsystems	Canada	April 2009	80
2011 Embedded Market Study	EE Times (a subsidiary of UBM Electronics)	United States	March 2011	83

[4] Ilkka Tuomi, "The Future of Semiconductor Intellectual Property Architectural Blocks in Europe", Report for the European Commission, March 2009, 140 pages. Cf. the beginning of chapter 5 – The Intellectual Property Business, pp. 43-52.

Title	Organism	Origin	Date	Pages
Study on semiconductor design, embedded software and services industry	Ministry of Communications & Information Technology	India	April 2011	167
Making Embedded Systems: Design Patterns for Great Software	Author: Elicia White O'Reilly Media	United States	November 2011	328

The following magazines were systematically consulted:

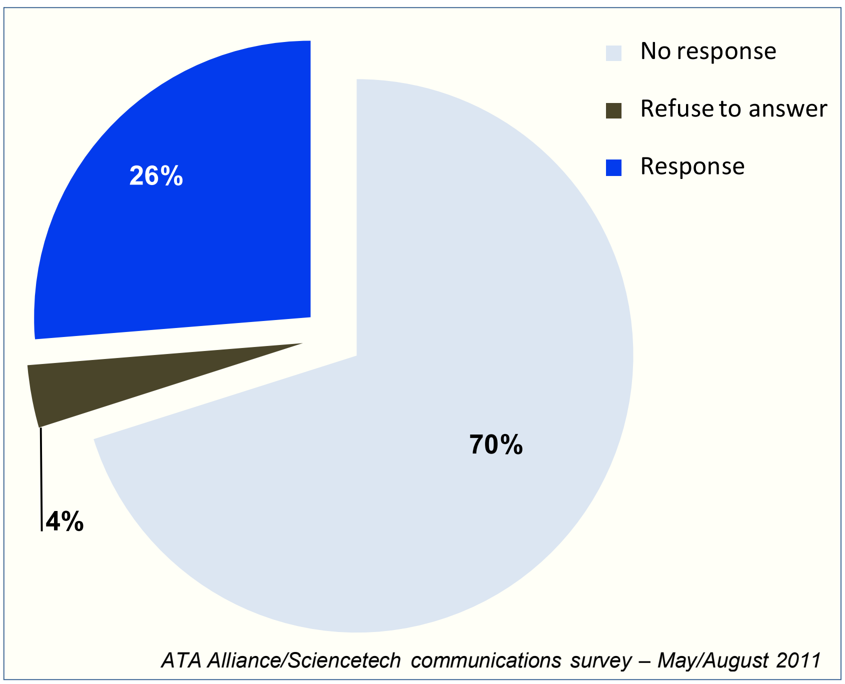
- *Canadian Electronics* (monthly magazine)
- *Electronic Products and Technology* (monthly magazine)
- *EE Times* (monthly magazine + daily newsletter)

Other secondary sources we have consulted and used occasionally are mentioned in footnotes.

1.3.2 Survey

The quantitative survey was conducted through a questionnaire (see Appendix II) sent by e-mail with telephone follow-up to 716 firms. Out of this population, 214 firms were contacted, 26 declined to answer and 188 responded, which gives a response rate of 26.3 percent. This is a relatively good rate in an industrial sector.

FIG. 2 – THE SURVEY RESPONSE RATE



A 26 percent response rate is more than enough to provide an acceptable accuracy in the survey results. It allows us to obtain a relatively precise snapshot of the industry's characteristics, practices and needs, at the national level. This is all the more obvious in the case of the embedded system industry where the respondents' responses tend to be tightly clustered according to a few parameters: mainly the size of the enterprise and the vertical markets it serves.

Size being equal, an Ontario company behaves as a Quebec or an Alberta company in a given field of activity – which would not be the case if we consider an industry heavily influenced by provincial legislations such as energy or health.

This allows us to define the status of the embedded industry in Canada relatively precisely, but not to make interprovincial benchmarking.

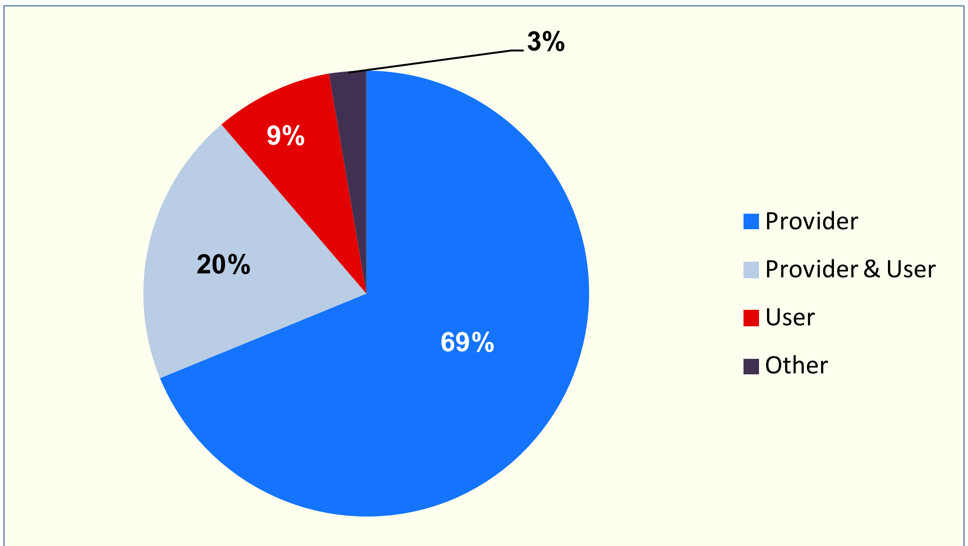
1.3.3 General Characteristics of Respondents

More than two-thirds of companies surveyed are developing embedded systems, to which we should add 20 percent of providers and users, since they are generally microelectronics companies that develop embedded systems among other electronic devices (sensors, accelerometers, sonar, gyroscopes, etc.). Companies like Smart and Exfo are part of this group of providers and users. Altogether, 89 percent of the respondents are typical embedded system designers and developers.

But why do only 9 percent of our respondents belong to the user sector? Indeed, all manufacturing companies are intended for use in embedded systems. To identify all business users would have required undertaking a survey of all industrial enterprises of Canada – a task that far exceeded our means.

On the other hand, it was impossible to ignore the user sector since it is, as we noted earlier, the source of the embedded system technology. Even today, it plays a key role as the subcontracting party. This is why we have included business sector representative user, such as Bombardier and Nova Bus, as well as SMEs which play the role of aggregators.

FIG. 3 – EMBEDDED SYSTEM PROVIDER OR USER?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

The result is a portrait as accurate as possible about the provider sector and only a sketch of the user sector. The overall conclusions that we will draw from this incomplete analysis, in terms of statistics, will therefore be estimations. In the present state of knowledge, it would be presumptuous to present our findings as definitive data (see Appendix III - Where classify firms embedded systems?).

In practice, we see that almost all companies that develop embedded systems come from the microelectronics industry – not from the software industry (the few non-microelectronics companies rather come from the user sector). The field of embedded systems appears as an upward extension of microelectronics.

Why is there no movement in the opposite direction? Why software vendors do not take up design and development of embedded systems? The issue is especially relevant because the world of embedded systems is now being rapidly virtualized.

However, it has not always been so. Initially, embedded software was rudimentary: a few lines of code added on the top of semiconductor hardware. Here again, it is clear that the embedded system world is strongly dependent upon its origin and even though it evolves more and more towards programming, it still appears as a sub-sector of microelectronics.

This difference has long been reinforced by the university that divided engineering into two entirely distinct branches: electrical or microelectronic engineering and software engineering. Today, the two branches still exist, but they increasingly tend to overlap. Microelectronics curriculum includes advanced training in software programming. In this regard, we can say that the university is playing a pioneering role which should help to bridge the gap that still separates the two worlds.

1.3.4 Interviews and Roundtable

The qualitative aspect of the study is based on a customized series of interviews and a roundtable. Many of these interviews led to a case study (see Appendix I), all served to clarify and enrich the statistics provided by the survey.

A °) One-to-one Interviews

Eighteen interviews were conducted (14 companies, two universities, two non-profit organizations and a private training school). The interviews were conducted face to face or by telephone, and while most respondents are in Quebec, three interviewees are based in Ontario and one in Boulder (Colorado).

18 One-to-One Interviews

- Alizem	Marc Perron	- President and founder
- Apera Technologies (Intel distribution)	Mario Duquet	- President
- Bautech	André Baune	- Director
- Bombardier Transportation	Paul Larouche	- Director Product Manager
- Celestica	John Sandhu	- Director Senior – Product Development
- MiQro Innovation Collaborative Centre (C2MI)	Normand Bourbonnais Christian Veilleux Pr Vincent Aimez	- President and CEO - Project Director - Director Scientific Partnerships Development
- CIMEQ	François Verdy-Goyette	- General Director
- CMC Micosystems	Ian McWalter Dan Gale	- President and CEO - Vice-President and Technology Director
- Ecole Polytechnique - Space Codesign Systems	Guy Bois	- Professor (University) - Founder (Corporation)
- Econo-Fan	Mathieu Durand	- President

- Ericsson	Pierre Boucher Laurent Marchand	- Director, Research & Innovation - Technical Director
- Gentec	Yannick Chartrand	- Design Engineer
- IBM (Bromont)	David Danovitch	- Senior Engineer
- Integral Technology	Richard Geoffroy	- President
- Kontron	Robert Courteau	- General Director (Canada and United States)
- Nova Bus (Volvo)	Marc Rondeau Bruno Lagendyk	- Manager, Electrical Engineering - Section head - Programming and Analysis
- UQAM	Guy Bégin	- Professor, founder of the first Advanced -Graduate Diploma in EmS in Canada

B °) The Roundtable

The gross results of the survey were presented to an evening roundtable on September 20, 2011 in Quebec City before the members of the Association of Electronics Manufacturers in Quebec (AMEQ). The presentation was followed by an hour and a half lively debate that was duly compiled and included in this study.

1.4 Production Team, Funding for the Study and Acknowledgements

1.4.1 The team

The 2011 study on the embedded systems industry in Quebec was led by Jean-Guy Rens, Vice President of the Canadian Advanced Technology *Alliance* (CATA) and Senior Partner of ScienceTech Communications Inc., in collaboration with Huguette Guilhaumon, also Senior Partner of ScienceTech Communications. The analysis team consisted of Pierre Bess, E & B Tech Logic, as well as Ali El Azzouzi of DataProtection (Casablanca, Morocco).

John Reid, President of the CATA*Alliance* oversaw the financing and administration of the study in collaboration with Cathi Malette, Executive Manager.

1.4.2 Financing

The constitution of the database and the completion of the overall study were funded by the CATA Alliance and by sales of the study.

A first survey limited to the Quebec-embedded industry was funded by the Ministry of Economic Development, Innovation and Export Trade (MDEIE). The Quebec data were combined with the broader all-Canadian results in order to produce this report.

1.4.3 Acknowledgements

Together CATA and ScienceTech Communications would like to especially thank Marc Perron, President of Alizem, for his intellectual contribution to the study, which took the form of a preface. It

is also a manifesto for the construction of an industry in direct contact with the latest trends of a market difficult to identify – that of the intellectual property of semiconductors.

Finally, we express gratitude for all the following people who have guided and supported throughout our work:

Pat Botsford	Marketing Analyst, CMC Microsystems
Vasudave Daggupaty	Senior Advisor, Ministry of Economic Development & Trade, Government of Ontario
Claude Gagné	Senior Advisor, Information and Communications Technologies Branch, Industry Canada
Martin Joncas	Industrial Development Advisor, Ministry of Economic Development, Innovation and Export Trade, Government of Quebec

We are also indebted to those working in the non-profit sector. The microelectronics industry is represented by several associations that did not hesitate to give us access to their members to distribute the survey questionnaire and to promote the study. Since the preparation of the questionnaire to the analysis of responses, their contribution was invaluable.

Disclaimer:
The CATA Alliance and the ScienceTech team assume responsibility for any error and omission in this study on the advanced security industry in Canada. Neither the many people who generously contributed to this project nor the partners nor the clients that put their trust in us can be held responsible for the content of this study.

2. Technological & International Environment

An embedded system (EmS) is composed of a microprocessor or a microcontroller designed to perform one or a few dedicated functions and installed in a product other than a computer. Over 95 percent of the microprocessors produced worldwide are aimed at EmS and not computers. Because they are invisible, we tend to neglect them – that's why we talk about *the other computing*.

Born with the moon programme and intercontinental ballistic missiles of the Cold War, the EmS surged and hit all industries with the advent of unlicensed wireless (primarily Wi-Fi). Today, the embedded industry is worth about $100 billion worldwide. The three major markets are the United States, Asia (mainly Japan) and Europe (mainly Germany).

Tomorrow, the EmS will face the major discontinuity that is about to hit the semiconductor. The extreme miniaturization of microelectronics leads to the production of microprocessors which become with each new generation less reliable. As a result, hardware failures must be corrected with the increased use of software patches. A new microelectronics comes up where the software determines hardware and not vice versa (see Foreword).

The embedded industry is extremely dependent on R&D, which is why all countries that lead the EmS race have to resort to the systematic action of the state. Canada has no real strategy, but it shows a mixture of vision (using university research by CMC Microsystems) and opportunistic attitude (creating M2CI to take advantage of the New York Tech Valley).

In addition to Canada, this chapter summarizes the EmS strategies of the United States, European Union, Germany, Taiwan and India.

2.1 What is an Embedded System?

Shortest Definition

Embedded systems are where the software meets the physical world.

Elecia White, author of "Making Embedded Systems", O'Reilly, 328 pages, 2011.

An embedded system (also called intelligent or smart system) is a microelectronic system programmed to perform one or a few dedicated functions, often in real time, which is "embedded" inside a product other than a computer to improve the product's performance and enhance its features. It is invisible, so we have referred to as "other computing".

Any embedded system includes at least one microprocessor or microcontroller and several other electronics peripherals needed to process information and, increasingly, networking features (ZigBee, Bluetooth, Wi-Fi, RFID, GPS, etc ...). The key component of an embedded system is its sensor which is its interface with the environment. According to its aim, it may also contain sensors and actuators, photonic components, system controls, and test systems...

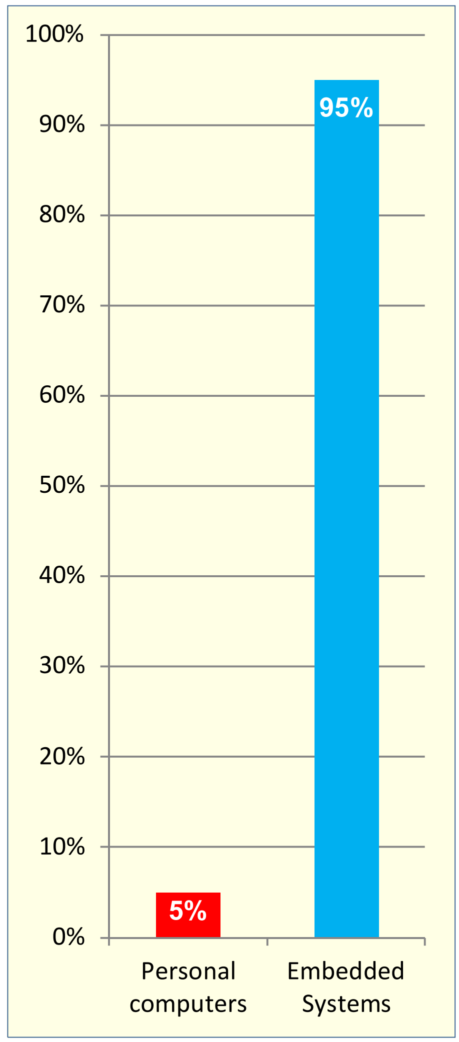
Embedded systems are always subject to a number of constraints, the most common are:

- Real-time operation (the operating system must also be real-time);
- Low power consumption (the systems are often inserted into equipment not connected to the grid);
- Off-road protection (impact resistance and weather resistance is critical in embedded systems in mobile objects – think of the antilock braking system in a car);
- Requirements for security, reliability and fault tolerance are often critical (critical applications in a vehicle, airplane, satellite);
- Limited resources (space, memory).

These are the specific constraints of embedded systems technology in comparison to the general purpose personal computer (although laptops also face some of these constraints). That is why the design of embedded systems is governed by separate processes in which test/verification occupies a crucial role. Untested embedded systems are worthless: they are not marketable.

IMPORTANT! Today it is estimated that over 95 percent of world manufactured processors are intended to be used in embedded systems. Intel dominates the market for personal computers, but is not the dominant player in that of embedded systems. It is the British manufacturer ARM which is the clear leader in this market, with Intel only in sixth place. The technological platform of the embedded systems industry is infinitely more varied than that of personal computers.

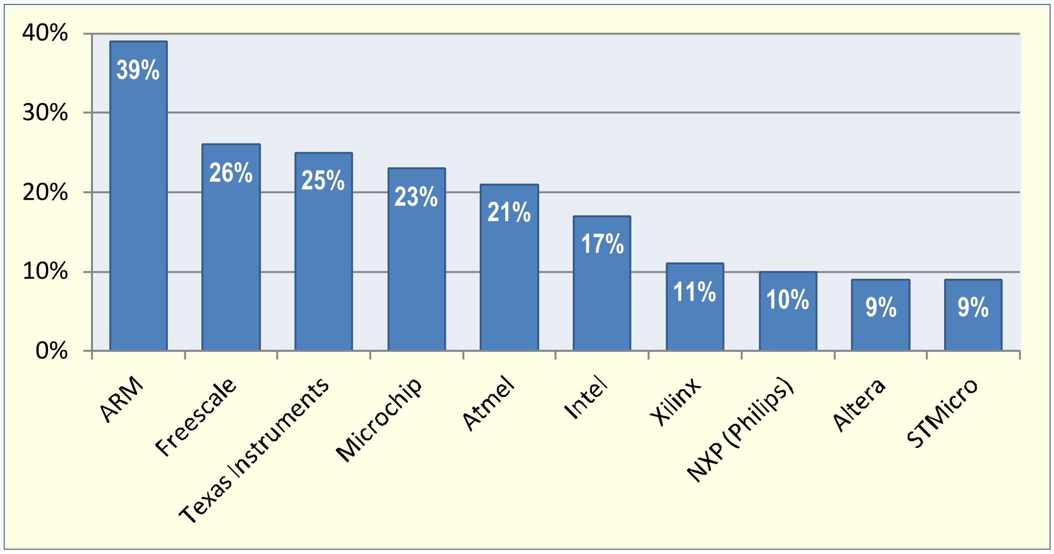
FIG. 4 – 95 PERCENT PROCESSORS AIMED AT EMBEDDED SYSTEMS



Common Technical Baseline:
http://esp.saxel.eu.com/CTB/History,-8.html

On the other hand, the 5 percent of microprocessors aimed at personal computers generate 30 percent of revenues in this market.[5]

FIG. 5 – WHAT PROCESSOR VENDORS ARE YOU CURRENTLY USING?



Source: 2011 Embedded Market Study, EE Times, March 2011

2.2 Growing Momentum of Embedded Systems

The embedded computing goes back to the moon programme and intercontinental ballistic missiles of the Cold War. However, the logic functions were still divided among several electronic components. This spatial and military origin characterized all the early embedded technology into the 1990s.

The first true embedded systems came out in 1975 with the arrival on the market of microcontrollers combining an increasing number of transistors on a single chip - or microchip. One refers primarily to the microcontrollers developed by Intel, Motorola, Texas Instruments or the famous PIC (Peripheral Interface Controller) launched by the microelectronics division of General Instrument (subsequently span off under the name Microchip Technology).

It is possible to distinguish two types of embedded systems:

- Custom embedded systems designed and developed for an industry or a company;
- Generic systems which are designed and developed to the level of the prototype by a supplier that then develops the specific applications to its customers.

Difference Between Microprocessor and Microcontroller

Microprocessor and microcontroller are integrated circuits that contain a central processing unit (CPU) able to process information according to a program. A microprocessor is connected to an external memory; on the other hand a microcontroller comes with an internal memory and can be used as a stand-alone. In principle, the microprocessors are more versatile and better suited to computers, while microcontrollers are limited to a few repetitive functions. However, this difference tends to disappear with the advent of System-on-chip (SoC) and virtual chips.

[5] Antoine Fraboulet, Fabrice Jumel, Lionel Morel, Tanguy Risset, "Introduction aux systèmes embarqués", Lab CITI, INSA Lyon, 2007.

Initially, the development of embedded systems was held in silos: for safety reasons, there was no way for the defence manufacturers to share their manufacturing processes from one country to another or even one sector to another. When the major aircraft and automotive manufacturers started to automate their products, they continued to do so for competitive reasons. There were also industrial robots custom-built for a company. They have played and continue to play a key role in factory automation, but their number remains limited by definition.

What is new is the sudden emergence from the year 2000 of an open market for embedded systems – which were previously all developed and produced in-house. It is estimated that open products account for 25 percent of the total demand. It's still a small segment but the dynamic are very much in favor of open embedded systems, where the market grows by 10 percent per year.[6]

Mass-produced embedded systems allowed the proliferation of intelligence in objects of everyday life: they open the doors of the subway, stabilize a camera lens, activate airbags in cars, count the bank-notes in ATMs, control the flush toilet, regulate your stationary bicycle and other cardio exercise equipment, allow non-invasive surgery, transform your cell phone into a smartphone, etc.

The cause of this sudden popularity is of course lower unit costs of integrated circuits – or chips – combined with their rising power (increasing number of transistors on a single integrated circuit). Often referred to as "Moore's Law", this double movement made possible the gradual popularity of embedded systems, but it was insufficient to cause the rapid surge of the 2000s.

The trigger has undoubtedly been the wireless and specifically the open wireless (see box). Now it became possible to connect devices outside of the frequencies controlled by the telecommunications companies. We began to talk about the Internet of Things.

In order to aggregate a growing number of electronic components into a network, it was still necessary to design embedded system "boilerplates."

Discontinuity in Wireless

The nature of wireless technology has changed not because of a technological breakthrough, but because of two regulatory decisions:

- 1985 decision of the Federal Communications Commission (FCC) not to regulate radio bands ISM (Industrial, scientific and medical);
- Setting in 1996 by the Institute of Electrical & Electronics Engineers (IEEE) of the standard 802.11 which became known as Wi-Fi. Other standards followed as Bluetooth, Zigbee, and Ultra-Wideband, even the ancient RFID has since found a sudden resurgence of interest.

The change came with the arrival of the concept of Computer-On-Module (COM) or System-On Module (SOM). A COM module is a mini-board with a microprocessor or microcontroller, a connection interface and basic components. Mass produced, these modules are to be mounted on a PCB.

Thanks to the COM modules, embedded systems developers benefit from the design and configuration of generic features and can focus on the programming of customized applications required by their projects. Furthermore, embedded systems sold or installed for a long time can easily be upgraded: just by changing the COM module on the motherboard. This way, customers can take advantage from the gains of the last generation of CPUs without changing its entire embedded system.

The mushrooming of embedded systems poses a new set of problems: let us think about the security of smart devices, interoperability and standardization issues.

[6] "The EU market for embedded systems", *CBI Market Information*, March 2010.

Already, embedded systems modules obey numerous standards developed by powerful standards bodies, such as PICMG and VITA that define the board architecture specifications.

A Few EmS Standards

- Since its founding in 1994, the PCI Industrial Computer Manufacturers Group (PICMG) has developed a range of specifications in line with the conventional PCI computer bus. In this capacity it defined a series of open specifications for high performance telecommunications and industrial computing applications. PICMG plays an active role in the normalization of COM modules.

- VITA Standards Organization (VSO) or by its full name VMEbus International Trade Association, was founded in 1984 to coordinate the evolution of the VERSAbus developed by Motorola in the late 1970s. All VITA-defined formats are meant to promote open system architecture for embedded computing.

- The PC/104 Consortium was created in 1992 to adapt the desktop computing technology to embedded systems. Since then, the PC/104 format has evolved to meet the demand for an ever-increasing speed and new specifications. But all the extensions proposed by the Consortium extend the basic format without abolishing it, in order to preserve the continuity of the equipment.

- Fearing the existing specifications like COM Express have exhausted their potential when it comes to developing the lowest-power-consuming and mobile applications, several companies collaborated to develop a new open standard to allow smaller sized and lower-power applications on COM modules. An ad-hoc consortium has created the standard Qseven specifically intended to ultra-mobile applications.

2.3 Emerging Discontinuities

2.3.1 Beyond Moore's Law

The first chip was created in 1959 with two transistors. The chips produced today have hundreds of millions of them. We are accustomed to assume that the densification of the chips is infinite – according to Moore's Law. But Moore's Law is not a physical law; it is a simple observation of a technological phenomenon.

Today, the size of transistors stacked in a chip is measured in nanometres. The components of the most advanced chips are close to the atomic scale. Is atom the fundamental barrier of chip scaling?

The chips are defined in terms of the size of the elements that make up their structures. If the physical gate width in the transistors is 90 nanometres, the chip is called a 90-nanometre technology node or a 90-nanometre process node. As nanotechnology deals with structures 100 nanometres or smaller, we can say that microelectronics converted to nanoelectronics around 2003 with the introduction of the 90-nanometre node.

Now the 32-nanometre generation is just out and the prime manufacturers are already preparing 22 and even 12 nanometres generations. All obstacles provided since the beginning of microelectronics have been taken. But at what cost?

As we will examine below, the construction of a new silicon foundry amounts per $4 billion to $5 billion (see Section 2.5.1 - USA). No company is able to finance on its own the construction of a newest generation foundry – even Intel, who claims to do so, actually needs help from the state R&D subsidies; most other companies have allied with each other and still seek assistance from the state.

Already, the gigantic investment necessary to build a new plant hinders competition.

But there is also a technological "cost". With each passing generation, chips become less and less reliable. We often hear about the heat generation inside the complex integrated circuits. But this is only one of the many obstacles faced by the physics of semiconductors.

Thus, connecting hundreds of thousands of components requires increasing length of metal lines: a chip can hold up to ten kilometres of interconnects![7] The stacking of all these lines creates parasites, their extreme miniaturization creates resistivity that slows the electrical signal, the manufacturing sensitivity increases – in short, shrinking the chip degraded its performance.

To correct the situation, it is necessary to call on software solutions. Microprocessor manufacturers must invest massively in programming in order to mitigate (partially) the effects of the extreme complexity of ongoing scaling.

Of course there are alternatives to current CMOS semiconductors – research is being done on quantum and photonics technologies or even molecular electronics – but no substitute is ready for industrial production, either now or in the foreseeable future. The solution is to be searched on solutions related to software engineering.[8]

This double economic and physical discontinuity in Moore's Law promises a crisis for some firms and regions, and opportunities for others – those that will be able to convert largely its manpower skill in advanced programming.

2.3.2 Embedded Systems' Virtualization

Already, it is estimated that on average 70 percent of embedded systems' project costs are due to software development – as opposed to hardware. But hardware itself is changing its nature. We now have virtual chips where it is up to the designer-developer to configure the functions that previously came integrated in a monolithic chip – whether FPGA or ARM (see preface by Marc Perron, "The virtualization of computing").

Embedded systems' virtualization is complex programming to the point that it becomes practically impossible for a small business, let alone a microbusiness, to design an embedded system from scratch. In the same way as he purchases electronic components (optical sensors, resistors, capacitors, etc.) on the market, the project manager is now able to

IP Private Detectives

Incidentally, the fragility of the information economy is giving rise to a new type of detective agencies conducting investigations by using reverse engineering, ripping out applications, middleware and microprocessors in search of pirated IP blocks. Canada occupies a special place in reverse engineering IP with the presence in Ottawa of three world-class companies: Chipworks, UBM TechInsights and Global Intellectual Strategies. This new industry employs hundreds of people in the Ottawa area tearing down any semiconductor devices from mobile phones to game consoles in search of stolen intellectual property.

Barrie McKenna, "An industry built on tearing things apart", *Globe and Mail*, December 6, 2010

[7] Bill Arnold, "Shrinking Possibilities", *IEEE Spectrum*, April 2009.
[8] Ilkka Tuomi and Marc Bogdanowicz, "The Future of Semiconductor Intellectual Property Architectural Blocks in Europe", Institute for Prospective technological Studies (IPTS), European Commission, 2009, 140 pages. Cf. pp. 10-13.

obtain ready-made software components – reusable code lines that are marketed as intellectual property blocks (IP blocks).

A new player entered the value chain of embedded systems that we call the publisher of IP blocks. This type of business has the same characteristics as a software vendor, but its activities harness both hardware configuration (ARM chip or FPGA) and pure software programming (customized applications). Far from loading the embedded development process with added complexity, this new player is going to dramatically simplify it, and even to impose a new mode of production: the industrial mode.

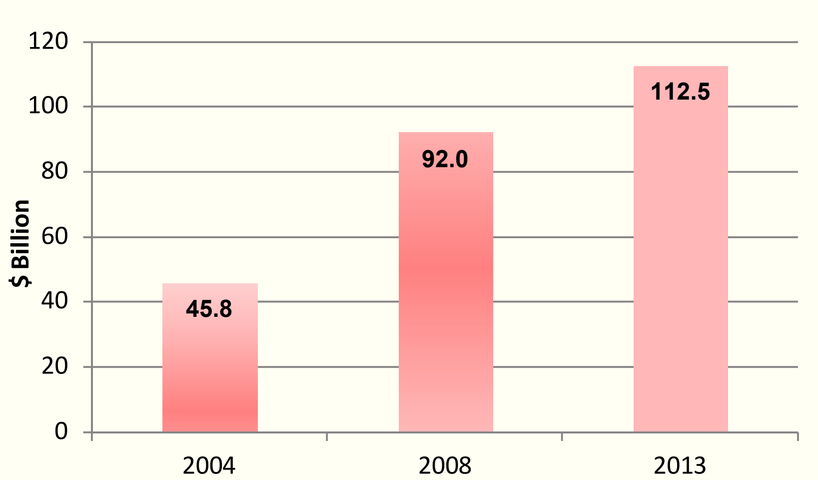
IP blocks can be licensed according to usage (proportional to the number of uses in different designs), to time (multiple uses, but limited in time), or on royalty payments (number of products sold with the IP block), or a combination of these. They can be offered directly by the publisher or through an embedded software online store, or by a semiconductor manufacturer who wishes to extend its hardware offering by creating a rich and diversified ecosystem.

IP blocks publishers are usually very small firms (fewer than five employees) who have close links with the universities and major semiconductor manufacturers. These firms require a minimum investment and face no barrier to entry. This is the information economy in its purest form with all the uncertainty it implies: poorly defined business model, very little legal protection, hard to counter fraud, etc.[9]

2.4 State of the Market: Global Trends

Embedded systems are divided between the open market that includes generic products marketed by pure-players and the market owner that covers products developed in-house. The open market is estimated at 25 percent of the world embedded market, as we already saw, while the proprietary market divided between vertical silos still represents a substantial 75 percent.

FIG. 6 – EMS WORLD MARKET GROWTH (2004-2013)



Source : BCC Research, Embedded Systems: Technologies and Markets, April 2009.

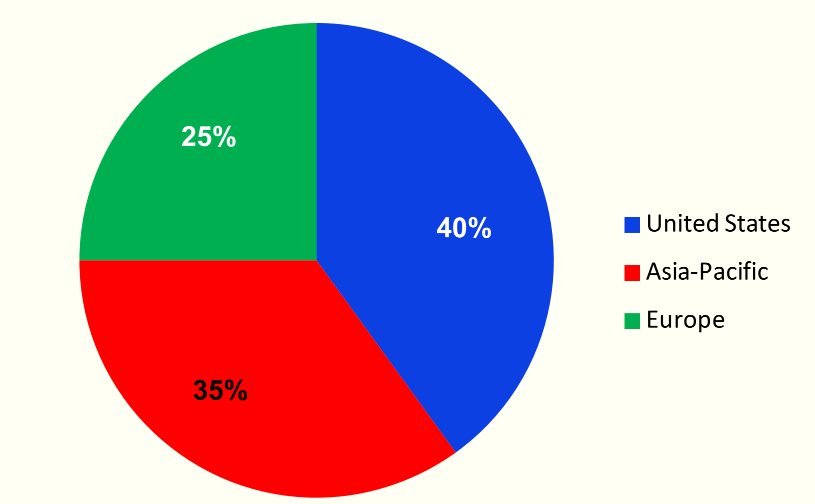
Though, the proprietary market is not completely locked, since much of the prime manufacturers outsource a variable portion of their production, the fact remains that a core group of big enterprises designs, develops and manufactures in-house embedded systems, and they will continue to do so for confidentiality reasons – in particular, in defence-related businesses.[10]

This market structure explains why it is difficult to

[9] Ilkka Tuomi, The Future of Semiconductor Intellectual Property Architectural Blocks in Europe, Institute for Prospective Technological Studies (IPTS), European Commission, 2009, 142 pages. Cf. pp. 12 and 47-50.
[10] "The EU market for embedded systems", *CBI Market Information*, March 2010.

get accurate figures on the actual size of the market for embedded systems. The consulting firm BCC Research estimated the global market for embedded systems in 2008 to $92 billion. Its average annual growth rate for the period 2008-2013 was 4.1 percent. During the previous period, before the financial crisis, the average was around 10-12 percent.

FIG. 7 – WORLD MARKET DISTRIBUTION



Source: CBI Market Information, The EU market for embedded systems, March 2010.

The largest market for embedded systems remains the United States with 40 percent of purchases, followed by Japan and Germany. Germany, which occupies most of the European market, is particularly interesting because in 2009 it adopted an embedded system strategy for the deliberate purpose to keep its manufacturing industry, especially automotive and machinery tool. In doing so, Germany is also to position itself in the health and medical equipment growing market. Embedded systems enterprises grow "naturally" around the user sector major clients and semiconductor manufacturers.

This development can take the form of a cluster or an ecosystem – we consider a cluster as geographically determined while an ecosystem is more flexible, it can thrive on a global scale around a common technological innovation, or alternatively it can take advantage of local relationships.

Typically, large manufacturers subcontract embedded systems to specialized microelectronics firms, or even help create them from scratch. This process first took place the "historic" segments – defence and aerospace – and thereafter in industrial automation (machine tools and robotics), automotive, security, energy, agribusiness, mining, transportation, medical equipment, microelectronics and telecommunications, particularly mobility.

The wide variety of products means that most embedded systems' projects require R&D. There no two identical projects. Each time, a new architecture must be designed, different components must be integrated, tight constraints must be met; in short, technology must be stretched to the utmost.

The other type of clusters develops by several firms spin-off from a parent company or set of parents and successful new start-up firms linked to a great semiconductor centre. The Silicon Valley served as role model for Japan and Taiwan which are now the two leaders in the area after the United States. In each case, the role of government was critical in building a semiconductor cluster. The continuous race for miniaturization and the microprocessor densification advancements is being held against a backdrop of pure physics and basic research. Even in the United States, where government intervention in the economy is unpopular, the injection of public funds is required.

2.5 Role of the State

2.5.1 United States

A - Federal Government Intervention

The U.S. federal government has a reputation for not intervening in the economy – with the exception of military contracts – leaving that responsibility to the states, regions and cities. This reputation is a priori more of an a priori political stance than a reality. During her brief stay as White House's Special Advisor for Science, Technology and Innovation at the, Susan Crawford estimated the number of federal programs involved in regional economic development at about 200.[11]

At the national level, the main policy instrument is the Technology Innovation Program (TIP) was established in 2007 by the National Institute of Standards and Technology (NIST). The program provides aid to start-ups innovating in areas of critical national need: the funding varies from three million dollars over three years for an individual SME, to nine million over five years for a joint venture (one of the partners must be an SME while the other can be a large company or university). During its first two years of existence, the TIP program has invested $280 million in very high risk projects.[12]

B - States Intervention: the Example of New York

The fact remains that it is up to the states to finance most economic development projects in order to attract business in their respective territories.

One of the world's leading semiconductor centers is being formed in and around Albany. The initial trigger was a two-step initiative of the State of New York to revive the long failing upstate economy: in 1993, it designated the University at Albany - State University of New York (SUNY) as a Center for Advanced Thin Film Technologies, and in 1997 it opened the NanoFab 200 Building.[13] Several years later, in 2001, IBM created its own Center for Excellence in Nanoelectronics and Nanotechnology also in Albany, and made the strategic decision to open it to international partners.

The company has become the "champion" who turned the trial into governmental international success, attracting prestigious semiconductor manufacturers: Intel, Samsung and two silicon foundries, Taiwan Semiconductor Manufacturing Co (TSMC) and GlobalFoundries (a "spin-off" of AMD). Encouraged by these initial successes, the State of New York in 2004 funded the creation of a College of Nanotechnology at the University of Albany to provide the highly educated working force needed by all these newcomers.[14]

This strategy led to the construction of a computer chip factory in 2008 by GlobalFoundries in Saratoga at a cost of $ 4.2 billion – that included a $665 million cash grant from the State of New York, the largest ever given in U.S. history.[15] This is as well the largest North American construction

[11] "Growing Innovation Clusters for American Prosperity", Summary of a Symposium, Charles W. Wessner, *Rapporteur*, National Academy of Sciences, 2011, 186 pages. Cf. p. 36. Susan Crawford stepped down in December of 2009 when her Net Neutrality project was blocked by White House economic adviser Larry Summers.
[12] NIST website: Funding Innovation for Critical National Needs, Technology Innovation Program - http://www.nist.gov/tip/factsheets/upload/tip_at_a_glance_2011.pdf
[13] "Growing Innovation Clusters for American Prosperity", idem, cf. pp. 61-64. The Center for Advanced Technologies was launched by Democrat Governor Mario Matthew Cuomo (1983-1994). The NanoFab facility was added by Republican Governor George E. Pataki (1995-2006).These are the two pillars of the New York state success in nanotechnology.
[14] Prior to 1993, the University at Albany (a branch of the State University of New York) not even had an engineering department.
[15] The calculation was made by Kenneth Thomas, a University of Missouri-St. Louis professor who has spent years tracking government subsidies, ranked the largest U.S. economic development deals dating back to 1999 in his 2010 book

site, and construction is still ongoing today as the project was expanded several times. It was then estimated that the new cluster would include more than 800 companies, accounting for 364,000 jobs with an average annual salary of $75,000.

FIG. 8 – NEW YORK TECH VALLEY

Such was the situation when, in October 2011, the consortium IBM has doubled its investment by an additional $4.4 billion over the next five years to produce the next generation of microprocessors: smaller circuits (22 and 14 nanometres) on larger wafers (300 to 450 millimetres). The state responded by announcing an additional $400 million subsidy in the he College of Nanoscale Science and Engineering (CNSE) of the University of Albany - (SUNY).[16]

In the end, the New York state has invested $1.2 billion, mainly in the University of Albany, and encouraging the private sector to invest $ 15 billion in what has become the "Tech Valley". With $10 billion, by far IBM is the largest investor. Nothing would have happened without IBM. But without the money from the state, IBM would likely not have come to Albany.

Let us note that IBM massive investment in the Tech Valley was probably facilitated by the location of its headquarters in Amonk, in the second ring suburb north of the city of New York. We cannot ignore the crucial importance of a proximity factor in the success of the Tech Valley. However, this cluster was able to reverse the trend of offshoring and attract businesses from Taiwan and Korea in North America.

2.5.2 Canada

The emergence of a similar university-enterprise center has already borne its first fruit in Canada with the construction of the Centre for Innovation Collaboration MiQro (C2MI) out of an original partnership between the University of Sherbrooke, Teledyne Dalsa and IBM Bromont. Launched in September 2009, the project valued at $ 218.5 million aims at creating a center of excellence for assembling chips and microelectromechanical systems (MEMS).

Construction of the new center was completed in 2011 and is expected to begin operating in early 2012.

"Investment Incentives and the Global Competition for Capital." Larry Rulison, “GlobalFoundries cash grant largest ever awarded in U.S.”, *Times Union*, Albany, October 9, 2011.

[16] Damon Poeter, “IBM, Intel, Others to Invest $4.4 Billion in NY Hub for Silicon R&D”, *PC Magazine*, September 27, 2011.

The C2MI strategy builds on the IBM cluster in the Tech Valley of New York. The governments of Canada and Quebec rely expressly on the proximity factor, despite the existence of the border with the United States. Indeed, the IBM plant in Bromont is supplied with silicon wafers by the factory in East Fishkill (New York) that are delivered by truck.

C2MI Funding ($M)	
Industry Canada	*82.95*
Government of Québec	*94.90*
IBM + Dalsa	*40.60*
Initial amount 2009	*218.45*
Consortium 2010	*23.20*
Total	**241.65**

As activities were bubbling south of the border, the response of the two levels of governments was flawless. The creation of C2MI consolidates high technology operations in IBM and Dalsa and among their subcontractors in Technoparc Bromont (3,500 jobs). However, it did not guarantee the creation of a microelectronics cluster in Canada.

This issue was first addressed in December 2010 when the federal government, the Quebec government and the founding private partners agreed to add $23 million in the C2MI funding for the marketing of additional services especially aimed at SMEs.

This means that the C2MI will offer custom services to third-parties based on the use of its infrastructure. Companies that have the necessary skills can directly use the infrastructure; others may hire the center experts who will carry out projects for them. It will be possible to develop a microsystem from A to Z. [17]

The C2MI is part of the Network of Centers of Excellence for Commercialization and Research (CECR) supported by the federal government. The purpose of these centers is to mobilize the best people in academia and high tech firms to innovate and to attract venture capital in five priority areas:

- environment;
- natural resources and energy;
- manufacturing/engineering;
- health and life sciences;
- information technology and communications.

This favourable environment does not constitute a strategy for developing embedded systems, far from it. Designating ICT as a priority does not mean much, as the scope of activities is far too extensive.

In this context, the creation of C2MI is all the more remarkable since Canada is usually reluctant to invest directly in research and development. The preferred mode of intervention of the federal government (and the provinces) is the indirect support through tax credits or university funding. In both cases, Canada is very generous. Indeed, the tax credits amount to 35 percent of R&D, up to three million – 20 percent thereafter. Quebec adds its own tax credit amounting to 17.5 percent of salaries of scientists - 37.5 percent for SMEs. The Ontario Research and Development Tax Credit (ORDTC) provides a 4.5 percent tax credit based on eligible R&D expenses. [18]

This type of tax credit is not targeted. It results a risk of R&D duplication as well as the inconvenience of subsidizing innovation efforts that would have been undertaken even without public support.

[17] Interview conducted at Sherbrooke on June 10, 2011 with Vincent Aimez, C2MI Director of Scientific Partnerships Development (professor at Sherbrooke University), Normand Bourbonnais, C2MI President and CEO, and Christian Veilleux, C2MI Project Manager.

[18] OECD (2011), Business Innovation Policies: Selected Country Comparisons, OECD Publishing, 155 pages. Cf. p. 42-43.

Entirely different is the universities funding program Embedded Systems Canada (emSYSCAN). Embedded Systems Canada is a project established by the federal government with the support of provincial governments. It is what comes closest to a national strategy of embedded systems. Valued at $54 million over five years (2010-2015), emSYSCAN provides hardware and software to Canadian universities to bring the teaching tools at the same level as those used by leading edge private enterprises (see Chapter 7 – R&D and education).

2.5.3 European Union

With 25 percent of the world of embedded systems, Europe is the third largest market behind the U.S. and Asia-Pacific (see Figure 7 – World Market Distribution). Germany is the main European market and, above all, by far the leading European producer of embedded systems.

The relative weakness of Europe on the world market has prompted the European Union to increase efforts in this area. As the EU does not have taxing authority (domain of Member States), it selected the launch of major structural projects and policy harmonization.

At the heart of the European embedded system strategy is the program ARTEMIS (Advanced Research & Technology for EMbedded Intelligence and Systems), a tripartite Public Private Partnerships comprising industry, Member States, and the European Commission, announced in June 2004 and established in December 2007.

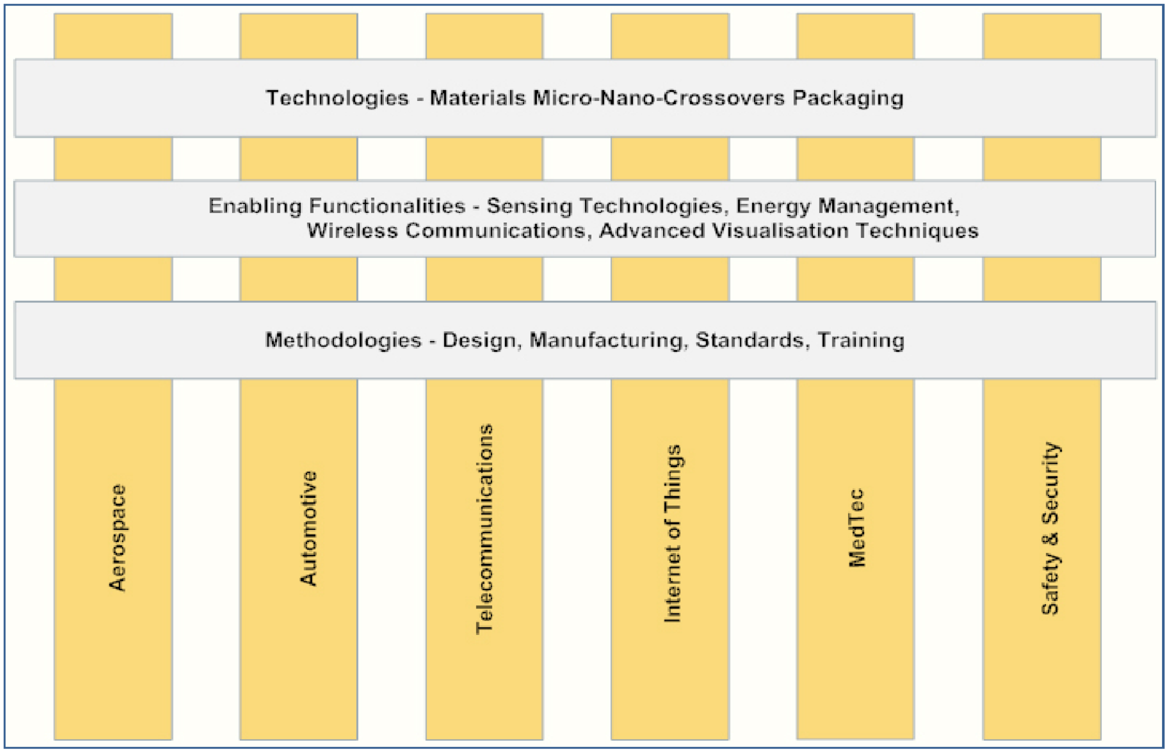
Its purpose was to introduce consistency in the fragmented market of embedded systems in Europe and to ensure stable funding through a Strategic Research Agenda (SRA). In fact, after more than three years of planning (June 2004-December 2007), only 25 projects were selected and its budget remains underfunded (€405 million on €2.6 billion planned). A final call will be issued in 2013.[19]

Although it seems unable to meet its strategic objectives, the program ARTEMIS nevertheless made significant achievements. Note the creation of EICOSE (European Institute for Complex Safety Critical Systems Engineering) has been designated by ARTEMIS as a center of innovation in the transport sector (automotive, aeronautics, space and rail). EICOSE includes an aerospace cluster in Toulouse (Aerospace Valley), an automotive cluster in Oldenburg (SafeTRANS) and a cluster of complex systems in the Paris region (System@tic Paris-Region).

This effort is complemented by the working group EPoSS (European Technology Platform on Smart Systems Integration) which was launched in July 2006 by a group of large companies seeking to align their R&D work. It acts as a coordinating body, not only between companies but also between the various European Commission programs (including ARTEMIS) and national programs. A true trend spotter of the European strategy for embedded systems, EPoSS makes an ongoing conceptualization work on the future of this technology in connection with related fields, especially nanotechnology.[20]

[19] ARTEMIS website : http://www.artemis-ju.eu/. "First Interim Evaluation of the ARTEMIS and ENIA Joint Technology Initiatives", European Commission, July 30, 2010, 47 pages.
[20] "Strategic Research Agenda of the European Technology Platform on Smart Systems Integration", EPoSS Office, version 2, March 10, 2009.

FIG. 9 – SMART SYSTEM INTEGRATION ACCORDING TO EPOSS



Source : EPoSS, March 2009.

2.5.4 Germany

Germany is the only European country to have a real strategy for embedded systems. This was expressed in a National Roadmap Embedded Systems document released in December 2009. This roadmap was jointly developed by a steering board including industry (Siemens, IBM, Daimler, Volkswagen, Bosch, etc.) and university (Technical University of Munich, Fraunhofer Institute for Experimental Software Engineering, etc.) with the support of the powerful ICT association BITKOM.

This ten-year plan (2010-2020) provides €150 billion in six R&D areas, not sectoral, but operational:

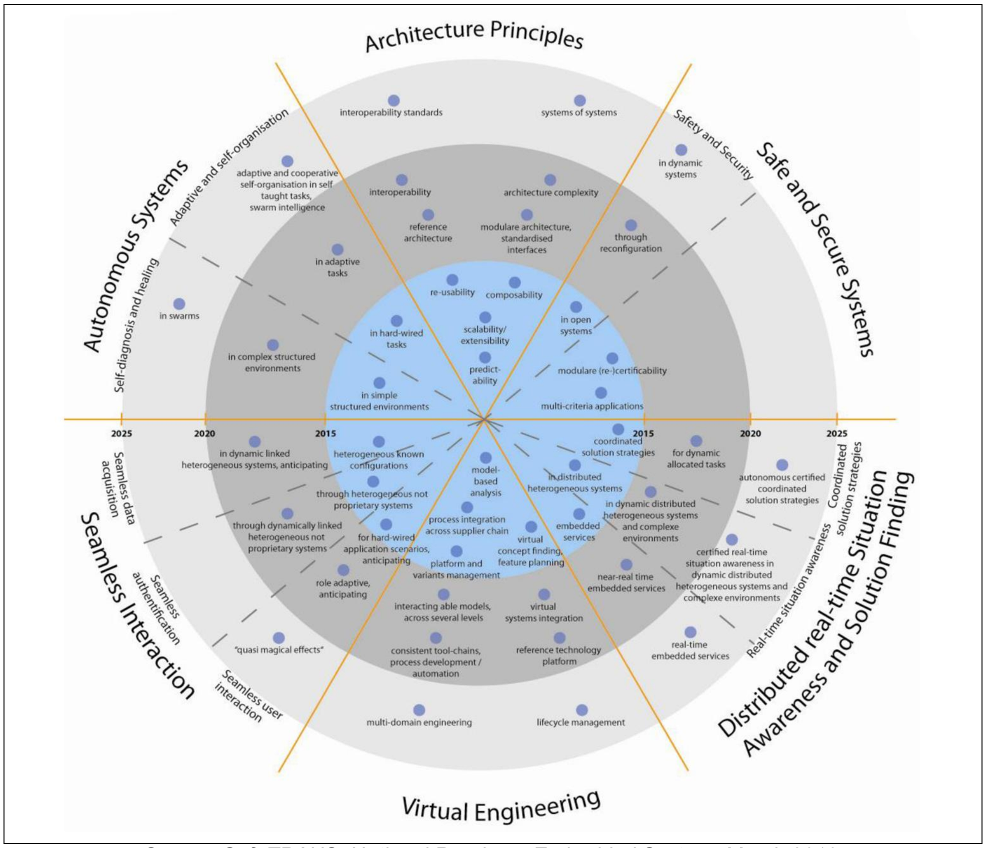
- autonomous systems;
- architecture principles;
- safe and secure systems;
- distributed real-time situation awareness and solution finding;
- virtual engineering;
- seamless interaction.

This segmentation underlines the willingness of Germany to eliminate the divisions between vertical sectors in order to create a horizontal cross-sectional technology driver.

Out the €150 billion budget, the governments' subsidy comes to €2.5 billion to be released by the German program Software Platform Embedded Systems 2020 (SPES 2020) and by the European program ARTEMIS.[21]

[21] Dominique Potier, "Briques Génériques du Logiciel Embarqué", idem, cf. pp. 61-3.

FIG. 10 – GERMAN ROADMAP RESEARCH AREAS



Source: SofeTRANS, National Roadmap Embedded System, March 2010.

Let us emphasize the specificity of the roadmap is to have been drafted by the private sector in association with the university – not by the government. It cannot guarantee public funding, it simply indicates preferences. This way of working gives a non-distorted picture of the actual needs of the industry.

Another feature of the German approach to innovation, not unique to embedded systems: the federal government subsidizes R&D directly and not indirectly, as in the majority of OECD countries. The tax credits are unknown in Germany. Year after year, the OECD criticizes the federal government for its R&D policy:

> *"The high uncertainty about the outcomes of R&D activities and the substantial spillover effects related to the inability of firms to appropriate all the rents from successful innovation expenditures are generally used to justify state intervention in this area to avoid potential underinvestment."*[22]

The German government has so far not deviated from its original line that allows it to concentrate R&D funding in medium-high technology manufacturing sectors – in return, the other sectors, particularly services, receive a below-average share of the total funds spent on R&D activities. [23]

In the same spirit, the German federal government has created a public procurement policy to foster innovation, by which six ministries (interior, economy, defence, transportation, environment and

[22] OECD Economic Surveys: Germany 2010, Volume 2010/9, March 2010, 150 pages. Cf. p. 122.
[23] OECD 2010, idem, cf. p. 117.

research) are committed to publish their long-term demand forecasts. To that end, the federal ministries practice a continuous market monitoring to identify potential new solutions and maintain an ongoing dialogue and exchange of experiences with suppliers and the various “Länder” procurement agencies.[24]

In the same spirit, the German government developed the method of "best available technology" as a criterion for public procurement in the environmental sector, instead of the criterion of the lowest bidder.[25] However, we have no indication that this approach is being practiced by the German government in the field of embedded systems.

The result of this unorthodox strategy is that "of the larger OECD countries, only Germany, Japan and Korea have maintained a strong and persistent presence in high and medium high-technology manufacturing."[26] What is interesting for our study is to note these sectors are precisely those where embedded systems are the most intensively used.

Today, the German market for embedded systems is €19 billion and grew by 8.5 percent per year despite the 2008 financial crisis. Approximately 40,000 people work in embedded systems firms and 250,000 in the embedded systems departments of corporate users. The result is that Germany faces a shortage of qualified staff with extensive knowledge in the field of embedded systems.[27]

2.5.5 Taiwan

The government of Taiwan has developed a strategy for developing semiconductors which is an example of public support to high-tech business. In 1980, it launched the Hsin-chu Science-based Industrial Park (HSIP) on the model of Silicon Valley to create an environment conducive to the high-tech industry, including semiconductors. Two of Taiwan’s oldest universities, being located nearby, and the HSIP can take advantage of skilled labour and ongoing technology transfers. During the first 20 years of operation, the Taiwanese government invested $18 billion in direct aid.[28]

SEMICONDUCTOR WORLD MARKET

Region	2010	
Japan	9.20	$Billion
Taiwan	9.11	
South Korea	6.20	
North America	4.47	
China	4.15	
Europe	3.11	
Rest of the world	7.32	
Total	*43.55*	

Source : SEMI March 2011

As the domestic market in Taiwan is too small (23 million) to allow companies to write off the cost significant investments in R&D, the government created several research centers. The best known is the Industrial Technology Research Institute (ITRI), which works closely with the private sector and ensures technology transfers from the foreign nations to the laboratory and from the laboratory to the private firms. Exchanges of researchers between ITRI and private firms are also encouraged.

This series of initiatives is extended by a dynamic fiscal policy: a tax holiday of five years for any new high-tech company (after which the corporate income tax is 17percent), exemption from customs duties on imported electronic components, various programs including tax credit for personnel

[24] OECD 2011, idem, cf. p. 89.
[25] OECD 2011, idem, cf. p. 90.
[26] OECD 2010, idem, cf. p. 115.
[27] “The Information and Communications Technology Industry in Germany”, Germany Trade & Invest, Issue 2011, Berlin, 10 pages. Cf. p. 4. MDEIE, Market cards, “Le marché des technologies de l'information et de la communication en Allemagne (logiciel, télécommunications et microélectronique)” – Webpage - http://www.mdeie.gouv.qc.ca/
[28] Kuen-Hung Tsai and Jiann-Chyuan Wang, “An Examination of Taiwan’s Innovation Policies and R&D Performance”, September 2002, 21 pages. Cf. p. 5.

training, low-interest loans for industrial R&D, accelerated depreciation rate... (see Appendix IV - Preferences to Encourage Foreign Investment in Taiwan).

The result of this policy is impressive. Taiwan is now the world second largest producer of semiconductors, just behind Japan. The top two semiconductors manufacturers are Taiwanese (TSMC and UMC). The Taiwanese industry is now working to move up the value chain and turns "naturally" to software architecture, system design and testing of embedded systems. The Government supports this movement by training system design engineers (National Si-Soft Project). The long term objective and vision is to promote the creation of intellectual property (IP).

2.5.6 India

India's relatively recent semiconductor industry has generated revenues amounting to $7.5 billion in 2010 and is growing at the rate of 17 percent per year. It is still at the embryonic stage (demand was 45 billion, also in 2009) but its growth is explosive. An estimated 80 percent of this production consists of embedded systems.[29]

The Indian government has decided to support the industry by launching in 2007 a National Semiconductor Policy to transform this country into a major chip provider. To this end, India offers many incentives and tax breaks for the semiconductor industry and related sectors, the main ones being:

- a weighted deduction of 150 percent on any expenditure on R & D in electronics manufacturing;
- a 10-year tax deduction on profits from the export of certain products by companies located in special economic zone (SEZ), a free trade zone, or a technology park.

This policy has often been considered a failure because it failed to attract silicon foundries. However, the country has strengthened its leading position in microprocessor design. In fact, this industry now employs 20,000 engineers who design 2,000 chips per year, the vast majority being, as we have seen, intended for embedded systems.[30]

A draft National Policy on Electronics (NPE) was introduced in October 2011 by the Minister of Communications and Information technology, which enhances the current tax benefits available throughout the value chain of electronic products, from design to manufacturing. To give an order of magnitude of India's ambition, let us indicate it intends to set up of over 200 electronic manufacturing clusters with world class logistics and infrastructure (see Annex IV).

As India is a federation, some states provide their own incentives for the development of the semiconductor industry. The most advanced is the Government of Karnataka. It introduced a policy of semiconductors in February 2010 which aims to provide financial assistance to start-up specializing in the design of embedded systems through a specialized fund. It provides, in particular, financial support to companies for filing intellectual property (IP).[31]

[29] "Does India's Semiconductor Policy Need an Extension?", A Frost & Sullivan White Paper, 2010, 15 pages. Cf. p. 3.
[30] Anand Kumar, "Semi-conductor sector: a fresh bid to attract foreign investors", Dawn.Com, Karachi, July 25, 2011.
[31] "Study on semiconductor design, embedded software and services industry", India Semiconductor Association, April 2011, 167 pages. Cf. p. 119.

3. Industry Profile

The embedded industry is composed of a minority of pure players (30 percent) and a majority of hybrid companies (70 percent) whose mission covers a range of activities in ICT – mainly in microelectronics. In summary, we can say that the embedded industry is the result of microelectronics' rise in the value chain – from hardware to software.

The typical advanced systems Canadian company of is an SME with 30 employees (average) born after 1980. It has overcome the financial crisis of 2008-2009. It often practices outsourcing of certain operational activities (manufacture, assembly, wiring ...) but mostly to other locally-based companies.

The main reason for outsourcing is looking for know-how or equipment which does not exist in-house –before cost reduction. Embedded system development is a local industry.

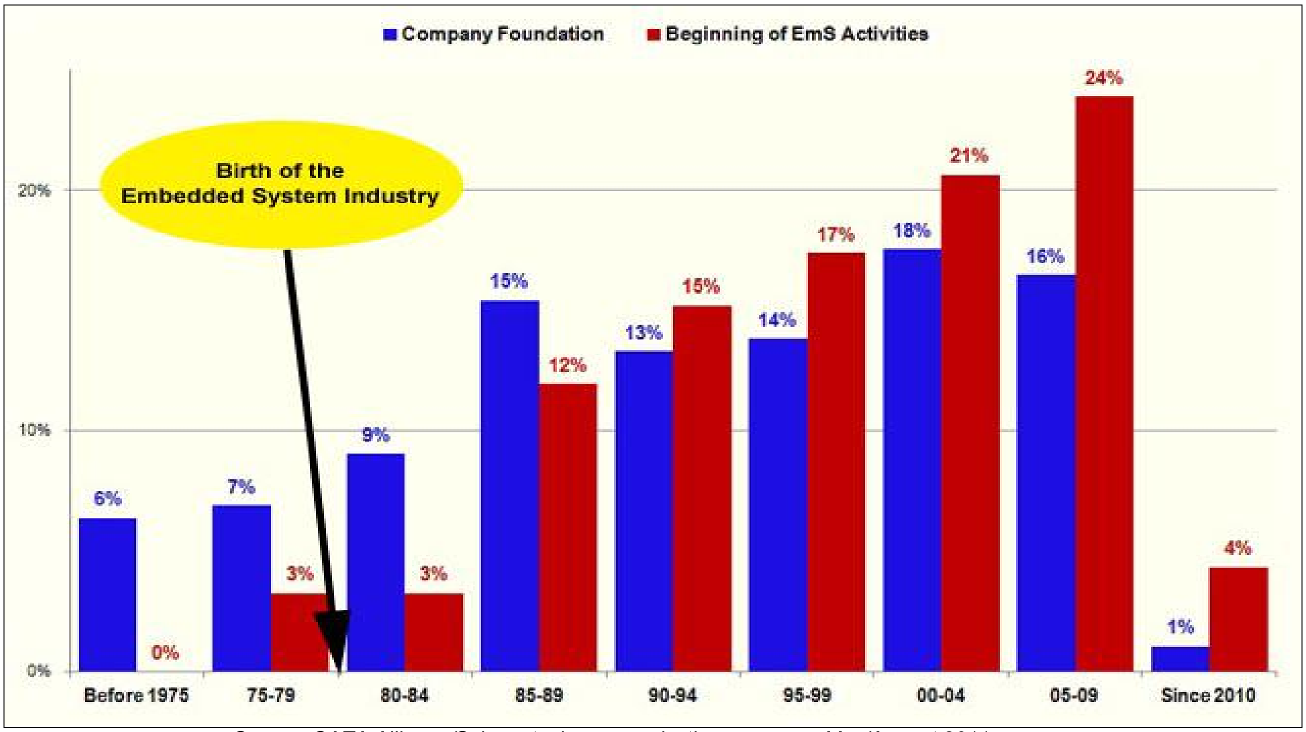
The CATA*Alliance* estimates that about 72,000 people work in the field of embedded systems in Canada (29,000 in the design and development companies, 43,000 in the user sector).

3.1 Age of the Corporations

The Canadian embedded systems industry is relatively young: 87 percent of companies were created after 1980 and what is more important 97 percent began developing embedded systems after 1980. It is not as tidal as was the creation of Internet companies in the 90's, but it is a steady and prolonged growth.

Note that embedded systems technology born in the late 1970s and began to spread in the 1980s. The oldest companies in our sample are those that were involved in different activities before 1980. They belong whether to the user sector or to various areas of the ICT sector, as IBM or CMC Electronics (formerly Marconi Canada).

FIG. 11 – REGULAR GROWTH



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

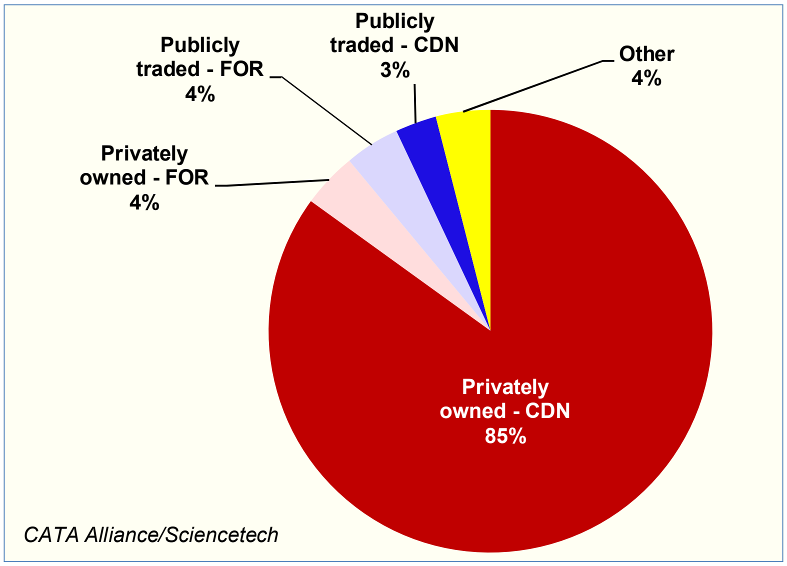
3.1 Nature and Size of the Companies

3.1.1 Ownership Structure

The majority of embedded systems firms are privately owned by Canadians (85 percent). There are only 7 percent of publicly traded firms (4 percent are subsidiaries of foreign corporations and 3 percent are based in Canada).

The vast majority of publicly traded companies are users of embedded systems (Bombardier and Nova Bus) or subsidiaries of foreign companies, U.S. and Europe (Alstom and ABB).

FIG. 12 – AN OVERWHELMING MAJORITY OF PRIVATELY OWNED COMPANIES



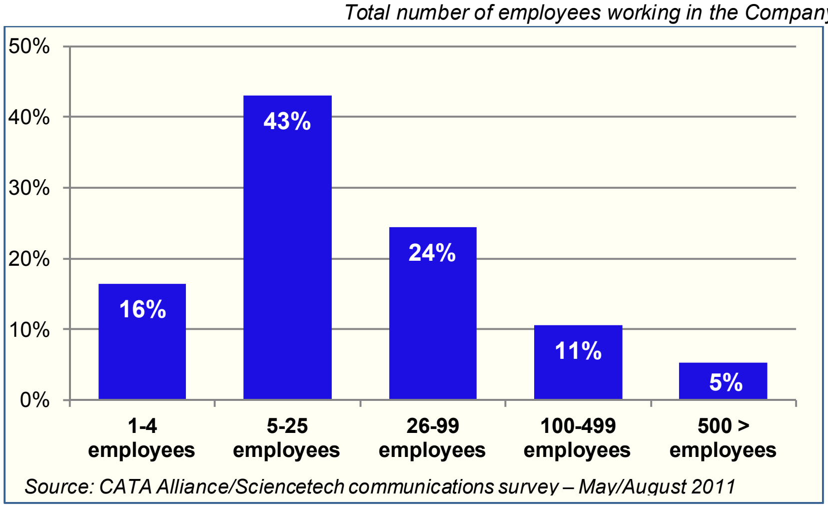
Obviously Canadian companies rarely use the stock market to finance their growth. The most common is to be bought by a foreign company whether privately owned or publicly traded. In most cases, not only the legal ownership is given away, but also the local roots of the management: these companies stop conducting on site R&D – if some activities are maintained, they are restricted to a limited field – they lose control of intellectual property, and they have no community involvement (there are notable exceptions such as IBM but they are uncommon).

3.1.2 Size of the Companies

We must make a difference between the size of the companies and the size of the teams (specialists and support employees) allocated to embedded systems. Some very large companies may have small teams allocated to embedded systems (Smart Technologies or Nova Bus). However, a team of 20 employees at Nova Bus belongs to a worldwide giant (Volvo) and has little in common with a 20 employees pure player such as Microtronix Datacom or Elliptic technologies.

FIG. 13 – SIZE OF THE COMPANIES

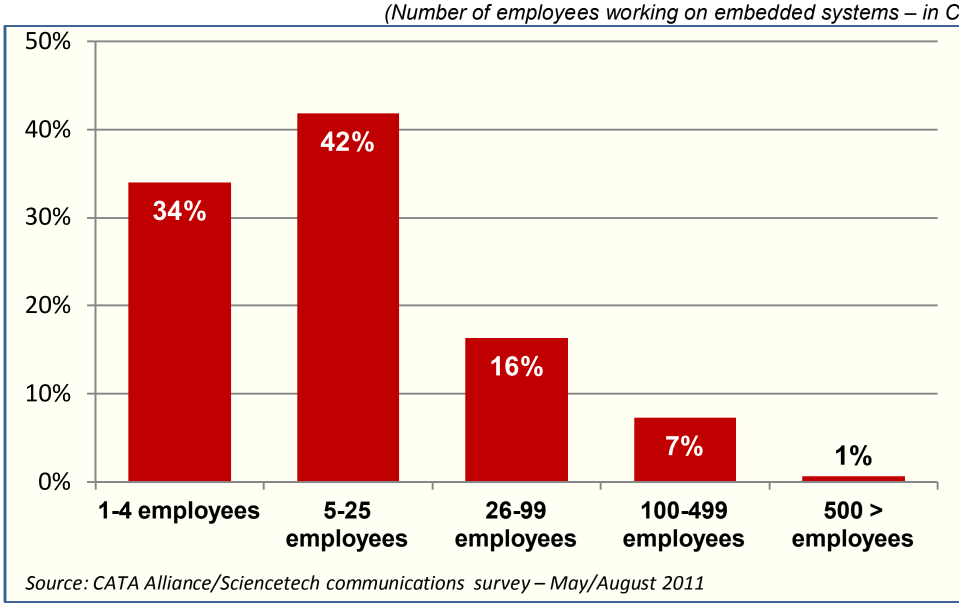
Total number of employees working in the Company – in Canada only



Few big teams in the development of embedded systems: only 8 percent of the Canadian teams have over 100 employees allocated to embedded systems – only one team has over 500 employees. Large companies are mainly located in Toronto and Ottawa: note the exceptional position of QNX which has gained a worldwide reputation for designing reliable, effective real-time operating system software (Neutrino, development tools and services for a variety of mission-critical purposes. The average size of teams is 32 employees (median 9).

FIG. 14 – SIZE OF THE TEAMS

(Number of employees working on embedded systems – in Canada only)



Analysis

Among survey respondents, if we consider only design and development firms, excluding corporate users, there are 5,109 people working in 165 embedded systems firms (includes support personnel).

The only province where we know the exact number of embedded systems firms is Quebec (218 firms employing 6,750 people). If we consider this province represents about 23 percent of IT jobs in Canada, we can assess the national level of employment in the embedded system sub-sector to about 29,000 people.[32]

As the user sector was only marginally covered in our population survey, it is impossible to proceed in the same way. However, we know that in other industrialized countries, the majority of embedded systems activities take place in the user sector. If we take the ratio of 65 percent as an average for Canada, we would get for the user sector an employment level of around 43,000 people.[33] These very rough estimates are only given here as an order of magnitude of the embedded system sector.

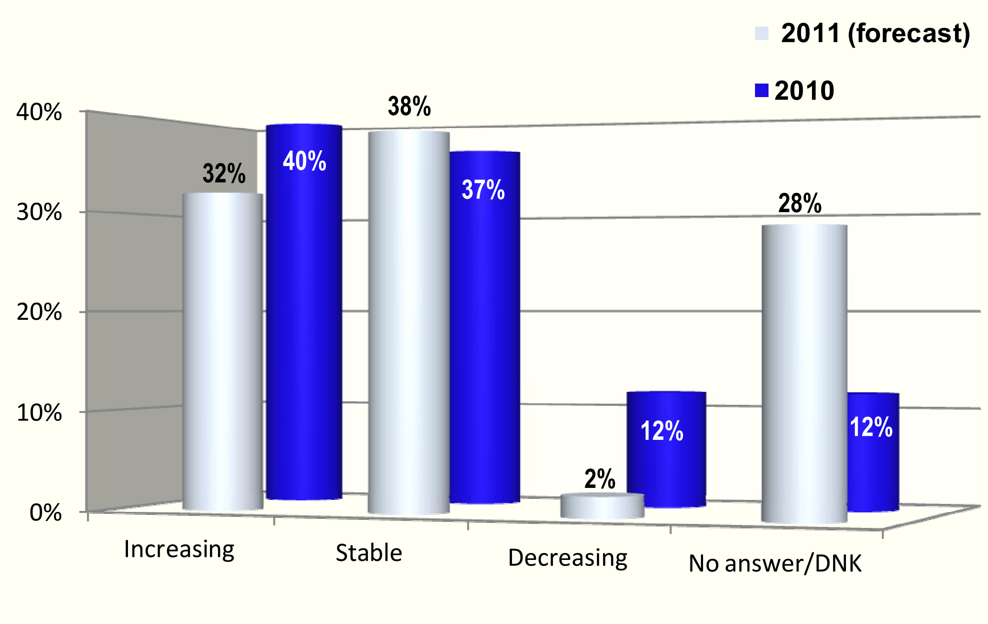
[32] See our study on Quebec: "L'autre informatique", November 2011, cf. p. 39. For the percentage of IT jobs in various Canadian provinces: *Analysis of Labour Force Survey Data for the Information Technology Occupations*, Information and Communications Technology Council (ICTC), March 2011, Table 6, p. 16.

[33] "The bulk of activities (65 percent) are to be found among industrial users and integrators of embedded technologies, software and services." *Briques Génériques du Logiciel Embarqué*, idem, cf. p. 27 (our translation).

3.1.4 Employment Trends

The effects of the financial crisis of 2008-2009 appear to have been overcome in the area of embedded systems. Only 12 percent of Canadian businesses report having experienced a decrease in the number of employees in 2010 while 40 percent registered an increase. This shows that the 2008 financial crisis is passed and a strong recovery occurred.

FIG. 15 – VARIATIONS IN THE NUMBER OF EMPLOYEES (2010-2011)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

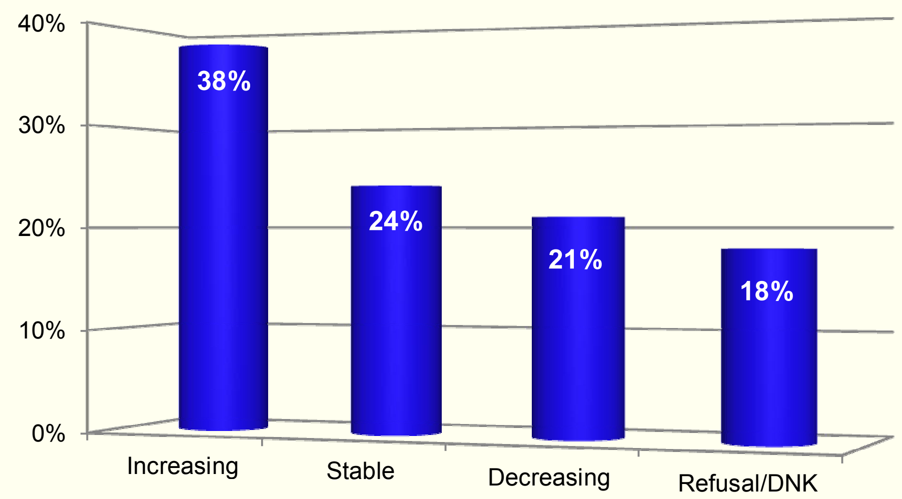
However, in 2011 stability seems to prevail: 38 percent of companies expect steady employment, and only 32 percent higher. The high rate of uncertainty in 2011 (28 percent did not know or refused to answer) may partially be due to the estimated nature of the data (the survey was administrated at mid-year). But this reluctance also reflects the lack of recovery in the U.S. and Europe.

Here we must note that the 2008 financial crisis was particularly severe in Ontario with 19 percent of companies saying that the number of employees decreased in 2010 and 25 percent forecasting another decrease in 2011. These results are aggravated by a much higher rate of uncertainty (42 percent for Ontario instead of 28 percent for the Canadian average).

3.1.5 Sales Trends

Similarly, 38 percent of Canadian firms have increased their turnover in 2010 confirming the financial crisis was over. However, the proportion of firms having lost revenues in 2010 (21 percent) is much higher than the number of firms having licensed employees (12 percent) the same year.

FIG. 16 – VARIATIONS IN SALES (2010)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

Analysis

The companies having registered increased sales in 2010 have the same size profile as the Canadian average. [34]

Size of the Teams	Sales Growth	Average Canada
100 > employees	8 percent	8 percent
25-99 employees	18 percent	16 percent
5-24 employees	40 percent	42 percent
1-4 employees	34 percent	34 percent

Similarly, if we consider the main clients of the embedded industry, growth companies markets are similar to average companies markets (see chapter 5.3 - Who are the clients of the embedded system companies?). However, differences appear in two markets:

- energy/mining (17 percent)
- transportation (14 percent).

Growth companies draw a bigger volume of their revenues from these two markets than the average embedded systems companies do.

Sectors	Sales Growth	Average
Manufacturing	13 percent	16 percent
Energy/Mines	**17 percent**	**13 percent**
Defence/Aerospace	7 percent	10 percent
Transportation	**14 percent**	**8 percent**
IT + Telecom	6 percent	8 percent
Microelectronics	6 percent	7 percent

[34] See fig. 14 – Size of the teams.

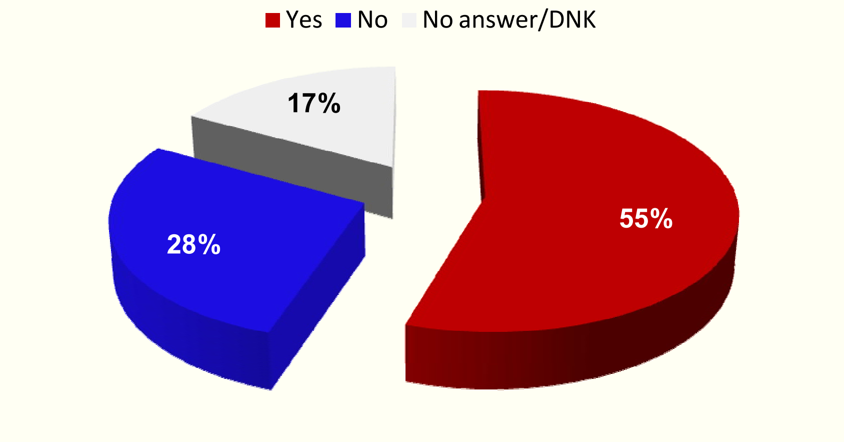
Automotive	4 percent	7 percent
Health	8 percent	7 percent
Security	6 percent	6 percent
Public Sector	3 percent	4 percent
Agri-food	6 percent	4 percent
Retail	3 percent	4 percent
Laboratory	2 percent	2 percent
Home automation	3 percent	2 percent
Other	2 percent	3 percent

3.2 Outsourcing and Offshoring

3.2.1 A Majority of Companies Are Outsourcing

More than half the embedded systems companies are outsourcing. This high rate should not surprise us. Indeed, since its inception, the microelectronics industry has systematized worldwide outsourcing at all stages of the value chain.

FIG. 17 – DO YOU OUTSOURCE PART OF YOUR ACTIVITIES?



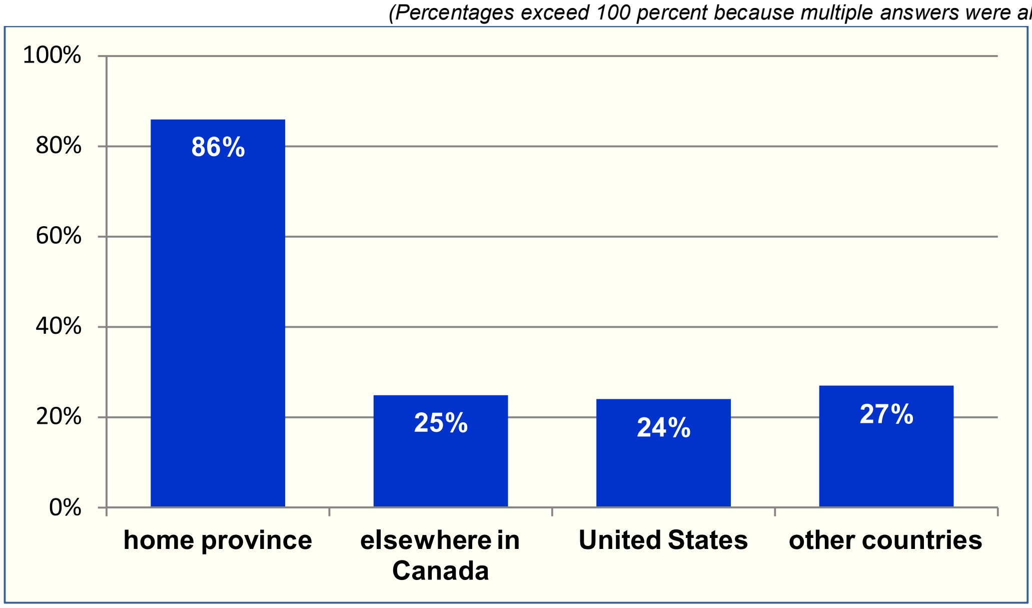
Source: CATA Alliance/Sciencetech communications survey – May/August 2011

3.2.2 Few Outsourcing in Asia

The vast majority of outsourcing companies are doing business with local subcontractors. More than 85 percent of embedded systems companies use local subcontractors and 25 percent use sub-contractors from other provinces (note that companies can outsource both in their home province and elsewhere). However, few companies do business with overseas companies (mainly Asia and to a lesser extent Europe).

FIG. 18 - WHERE ARE YOUR SUBCONTRACTORS LOCATED?

(Percentages exceed 100 percent because multiple answers were allowed.)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

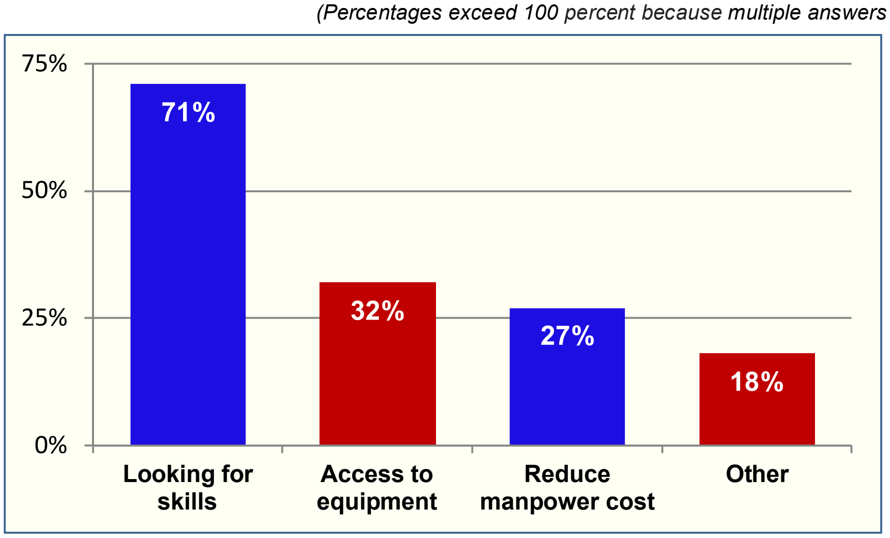
3.2.3 Reasons for Outsourcing

The main reason for outsourcing is the need for specialized skills and abilities (71 percent of respondents). Far behind, the embedded system firms cite the need to access to equipment and facilities they lack in-house (32 percent). Only 27 percent of respondents cite the cost of labour.

It is interesting to note that among the latter group only 43 percent call in Asian subcontractors. Even to reduce labour costs, many Canadian companies prefer to rely upon local subcontractors (and to a smaller extent subcontractors based in other Canadian provinces or in the U.S.)

FIG. 19 – WHY DO YOU OUTSOURCE?

(Percentages exceed 100 percent because multiple answers were allowed.)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

Among the other reasons for outsourcing, respondents mentioned:

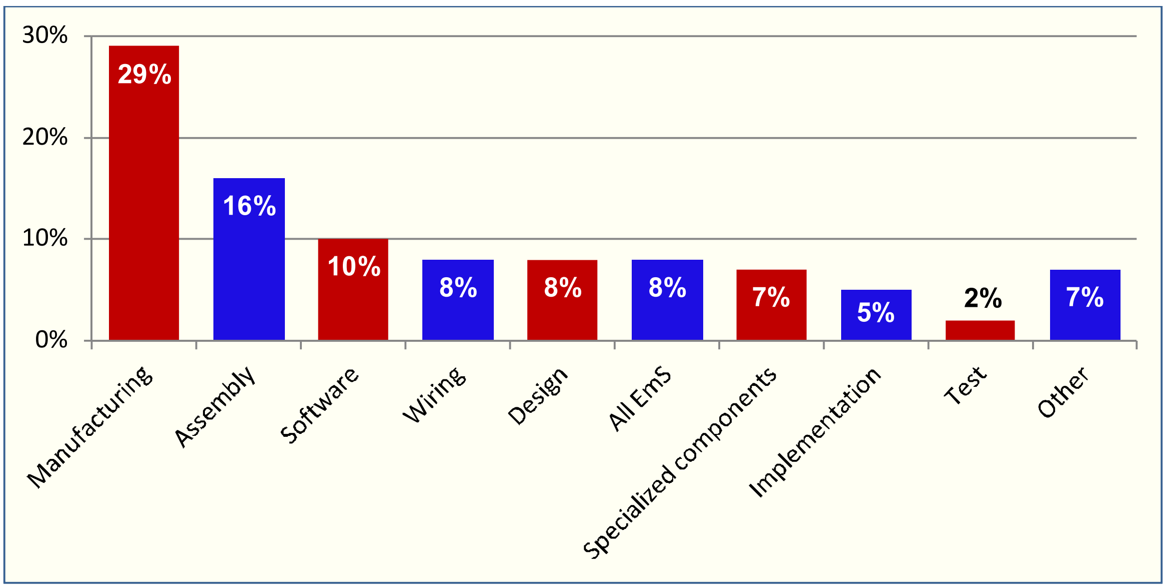
- time constraints (delivery times are too short): 6 companies
- volume too small to justify the manufacture in-house: 3 companies
- lack of internal capacity: 2 companies
- various reasons: local purchasing policy, lack of in-house facilities for toxic products, coop program with a university, and so on.

3.2.4 Nature of Outsourcing

What is most commonly outsourced is manufacturing (29 percent of respondents), which is consistent with global trends in the microelectronic industry. Second and far behind comes packaging and assembly services (16 percent) followed by a wide range of activities (10 percent and below). The variety of responses shows that everything can be outsourced.

To get a true picture of the embedded systems industry, however, we will ignore the 8 percent of respondents who outsource the entire embedded system because they belong to the user sector.

FIG. 20 – WHAT DO YOU OUTSOURCE?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

<u>Analysis</u>

In embedded systems, outsourcing is deeply rooted in the local industry: this technology is dependent upon the presence of a wide range of complementary industries, as confirmed by a recent IDC survey (see box).[35] Companies prefer doing business with local suppliers, which makes sense because we know that the area of embedded systems is dominated by custom projects. Even generic computer-on-modules (COM) must be adapted to the different applications and constraints needed by each client.

Asia's competitive edge becomes irresistible when embedded systems are produced in large series. As long as the amounts are in the order of a few hundred or a few thousand units, companies prefer

[35] Conseil des technologies de l'information et des communications, « Perspective sur les ressources humaines dans le marché du travail des TIC 2011–2016 », chapitre 2 - Tendances du marché du travail dans les TIC, 2011.

to produce in-house or from local suppliers. Indeed, the interaction between the designer/developer and the client are so intense at all stages of production, from prototyping to the final tests, that proximity is an important asset.

Above 70 percent of off-shoring companies are micro or small businesses (5-25 employees), the rest being composed of small and large firms (more than 50 employees). The main reason for off-shoring is not lower costs of labour, but the search for non existing in-house expertise. This reason explains that not only China and India are cited as outsourcing destinations, but as well the U.S., Great Britain, Germany, France, Netherlands, Switzerland and Finland – all countries that are not known for their cheap labour.

Off-shoring Limitations

IDC Canada estimates suggest that off-shore centres account for approximately 9-10 percent of the Canadian outsourcing market, but around 15 percent of outsourcing jobs. This difference between foreign suppliers' share of value of and their share of jobs is due to the relatively low quality of the bulk of subcontracting work.

***ICTC,** Trends in the ICT Labour*

Finally, we must mention the strategy of scaling up in the value chain demonstrated by some outsourcers. For instance, Celestica, the main Canadian outsourcer, is representative of the electronics manufacturing services (EMS) industry, which is currently adding everything from design and development of system architecture until prototyping and testing, to their current core business (manufacturing).

Celestica is about to in-shore certain activities now located in Asia. In-shoring does not mean that Celestica and the other EMS companies (Flextronix, Foxconn, Sanmina-SCI, etc.) are going to "repatriate" jobs that had previously been off-shored, but they are going to create upscale jobs in North America. Already some upscale jobs were created in the Toronto and Ottawa areas because of the Ontario government photovoltaic dynamic policy.

Typically, the EMS providers that are transforming themselves into original design manufacturers (ODM) tend to relocate high-end jobs in North America.

4. Working Environment

The embedded systems industry operates by successive projects. At first, there was no continuity from one project to another, but today project managers increasingly tend to reuse the old systems in order to update and improve them. However, in Canada almost two-thirds of current projects still are about new products – which indicate the industry and market are still young.

The platform most frequently used in Canada is the ARM processor just ahead of Intel – while ARM clearly dominates the world embedded market. The main criterion for choosing a processor is performance, well ahead of costs. Curiously, the factor "availability of development tools" comes only in third position, while it comes first at the global level.

Similarly, Canadian companies mainly use commercial operating systems, while Open Source systems predominate on the world market.

4.1 Reuse in Embedded Systems

Embedded systems companies operate by projects. There is no ongoing assembly line; rather, an embedded systems company sets up a team around the request of a given client. Initially, all projects started from scratch and developers had to program new code that responded to client needs.

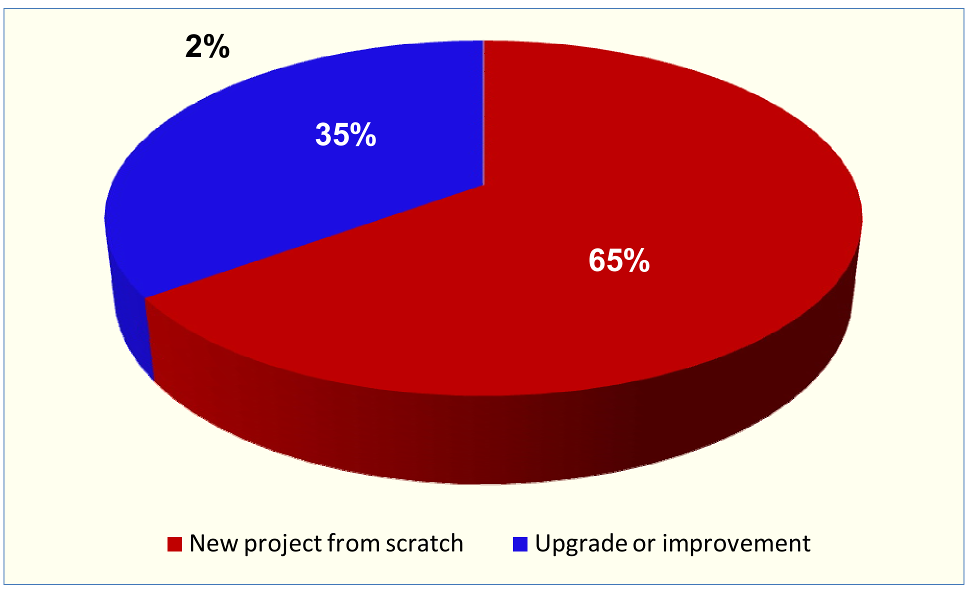
Today, no company would proceed this way. As far as possible, it prefers to upgrade the existing embedded system. In some cases, it is about taking advantage of the extra power offered by the emergence of a new generation of microprocessors. In this case, the use of COM modules where the new microprocessor comes with the basic configuration, offers significant gains in time and costs.

But there are other reasons to perform an update: it may be the introduction of new environmental standards, or the introduction of new features in the user line of products... In many cases, it is possible to keep the existing hardware and to reprogram the application.

Canadian embedded systems firms show a reuse rate of 35 percent. Though, the reuse levels vary a lot: 18 companies declared that 75 percent or more of their current projects are reusing existing embedded systems (10 companies are reusing 100 percent of their projects).

FIG. 21 – NATURE OF EMBEDDED PROJECTS

Volume of current projects



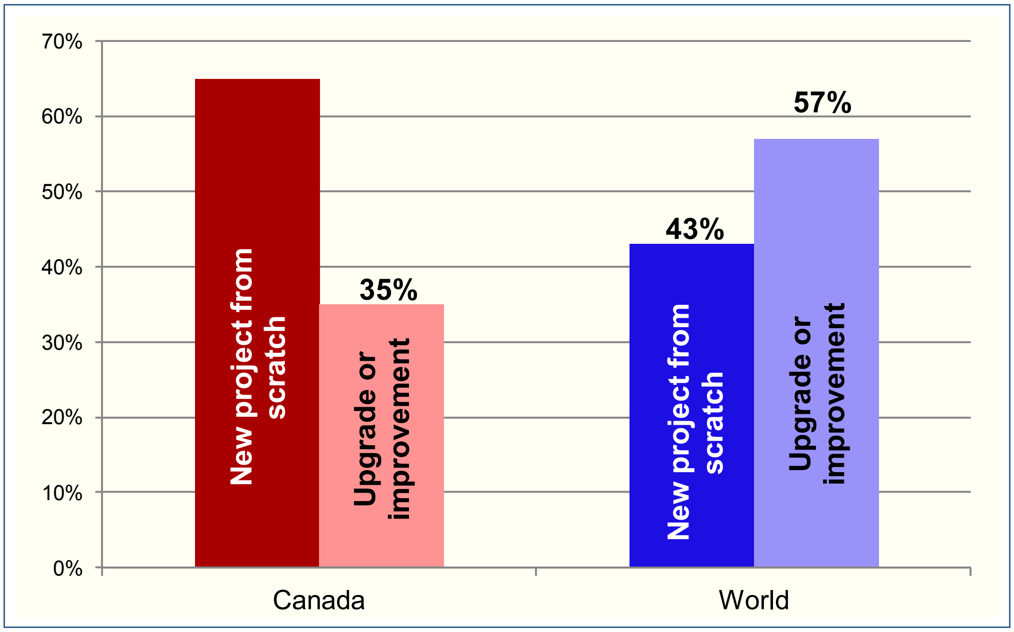
Source: CATA Alliance/Sciencetech communications survey – May/August 2011

However, a reuse rate of 35 percent is below the world average of 57 percent, according to the study of California magazine *EE Times*.

This difference can be partially explained by the youth of the user sector in Canada. A client that injects intelligence into its products for the first time obviously needs an original embedded system. The other explanation is that reuse is not yet passed on the habits of designers, developers and their customers.

FIG. 22 –CANADIAN REUSE RATE IS BELOW WORLD AVERAGE

How would you describe your current embedded projects?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011 and EE Times, Embedded Market Study – February 2011.

In any case, whether it is an entirely new project or the upgrade of an existing embedded system, nobody is going to generates new code, from scratch, for every project. Programmers are going to use code components or IP blocks available in a series of software libraries – internal or external.

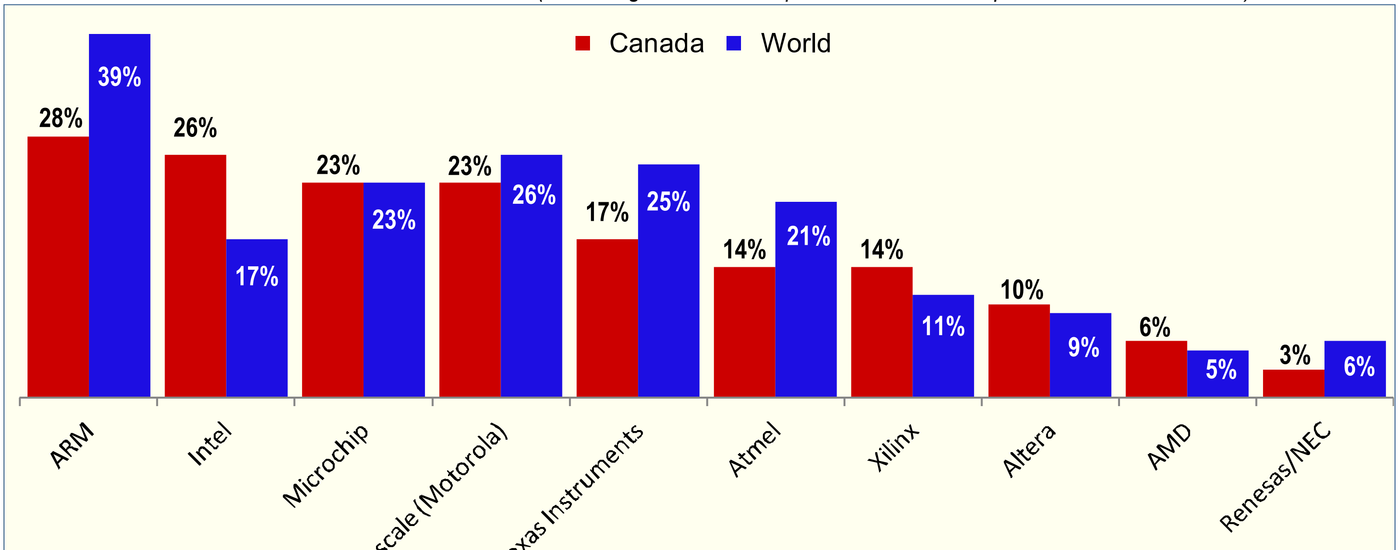
4.2 Preferred Processors

The Canadian market is marked not so by the first rank of ARM (28 percent of respondents), but by the second rank of Intel (26 percent). Indeed, the difference is so small it can be considered a tie. This is proof that Intel's launching in April 2008 of the low-power-consumption Atom series, is beginning to bear fruit, at least regarding Canada.

Most embedded systems designers and developers are working on several platforms depending on project characteristics such as: project size and complexity, environment constraints, etc. The data collected in CATA's survey only represents current projects.

However, Intel's strong showing in Canada is all the more surprising since ARM processors have become the new global standard for embedded computing (it is used in 39 percent of the world projects). Soft-core processors are the symbol of the continuing microelectronics evolution toward dematerialization. This new technological and business concept allows developers to purchase a license for a virtual CPU or CMU on which they can add additional circuits: flash memory, standard Wi-Fi, audio codec, etc.

FIG. 23 - WHAT MICROPROCESSOR DO YOU CURRENTLY USE IN YOUR EMS PROJECTS?
(Percentages exceed 100 percent because multiple answers were allowed.)

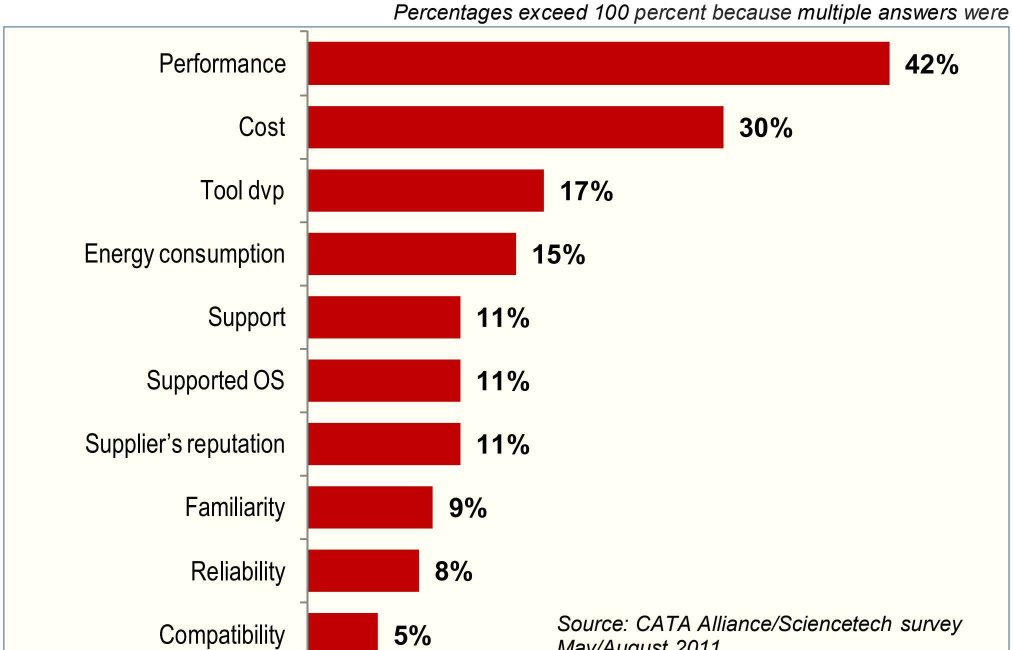


Source: CATA Alliance/Sciencetech communications survey May/August 2011, and EE Times, Embedded Market Study – February 2011.

The determining criterion in the choice of a microprocessor is performance, even before cost. Curiously, the factor "availability of software development tools" comes in third position with 17 percent of responses; while at the global level, it comes from far away in first place with 71 percent of responses.

Here again, the large discrepancy between the national and international results may be attributable to the immaturity of the embedded systems industry in Canada.

FIG. 24 – WHAT IS MOST IMPORTANT WHEN CHOOSING A MICROPROCESSOR?
Percentages exceed 100 percent because multiple answers were allowed.



Source: CATA Alliance/Sciencetech survey May/August 2011

4.3 About Operating Systems (OS)

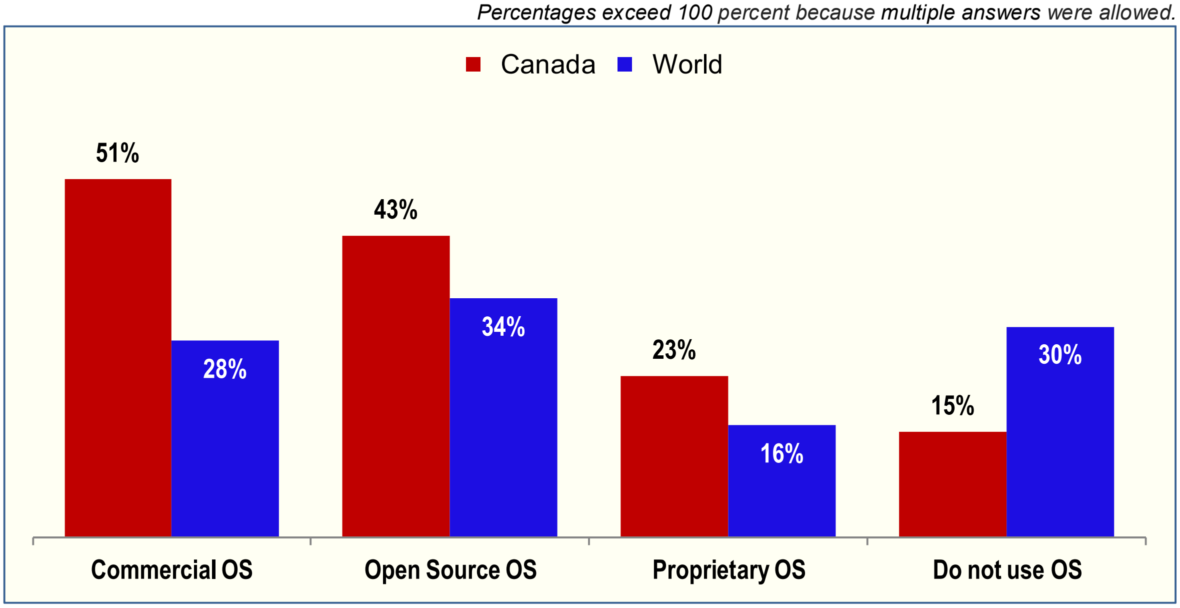
Canadian embedded systems firms rely heavily on commercial systems. In this regard, they stand out clearly from the global trend towards open source systems.

It is clear that Linux is not the universal solution for all applications of embedded systems. The great benefit about Linux is its free kernel. In terms of cons, support costs are borne by the developer, they are higher than in a commercial OS and, more importantly, they are difficult to predict.

The fact remains that the difference between Canada and the rest of the world is too pronounced to be ignored.

FIG. 25 - WHAT OPERATING SYSTEM DO YOU CURRENTLY USE IN YOUR EMS PROJECTS?

Percentages exceed 100 percent because multiple answers were allowed.



Source: CATA Alliance/Sciencetech communications survey – May/August 2011, and EE Times, Embedded Market Study – February 2011.

5. Customer Profile

The embedded market is dominated by large and medium businesses, which is normal since the technology was born in the large manufacturing sector (aerospace and defence). This origin also explains that close to half of Canadian companies are concentrated in one segment (manufacturing, followed by energy/mining and transportation).

Near half the sales volume of Canadian businesses is intended for the local market - even more telling is the fact that out of 173 respondents, 33 say they do 100 percent of sales in their home province. This confirms the importance of the proximity factor in the market for embedded systems.

The industry exported about 40 percent of its sales volume - 22 percent in the United States and 17 percent overseas.

5.1 Customer Segments by Number of Employees

The embedded system market is dominated by large and medium businesses, which is normal since the technology was born in the large manufacturing sector (aerospace and defence).

What is interesting is the emergence of a relatively large segment of small companies (44 percent). This is a sign that embedded systems are beginning to be adopted by the mainstream users.

When it comes to micro-businesses, they are often subcontractors for large industrial users.

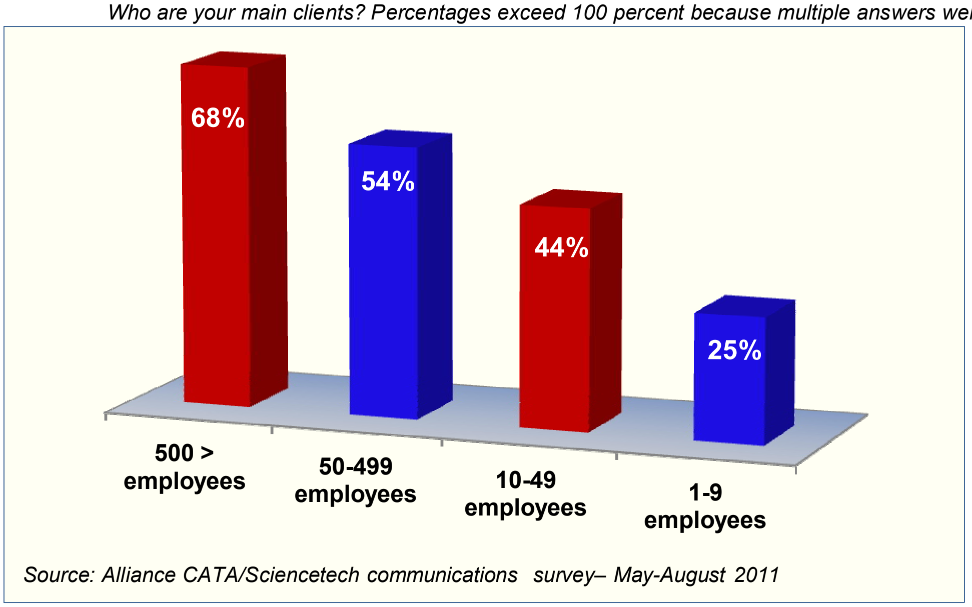
SME Definition

In this report, embedded systems companies are categorized under the following employment size ranges:

- Large 500 + employees
- Medium 50-499 employees
- Small 10-49 employees
- Micro 1-9 employees

FIG. 26 - THE MARKET IS STILL DOMINATED BY LARGE CORPORATIONS

Who are your main clients? Percentages exceed 100 percent because multiple answers were allowed.



5.2 Customer Segments by Economic Sectors

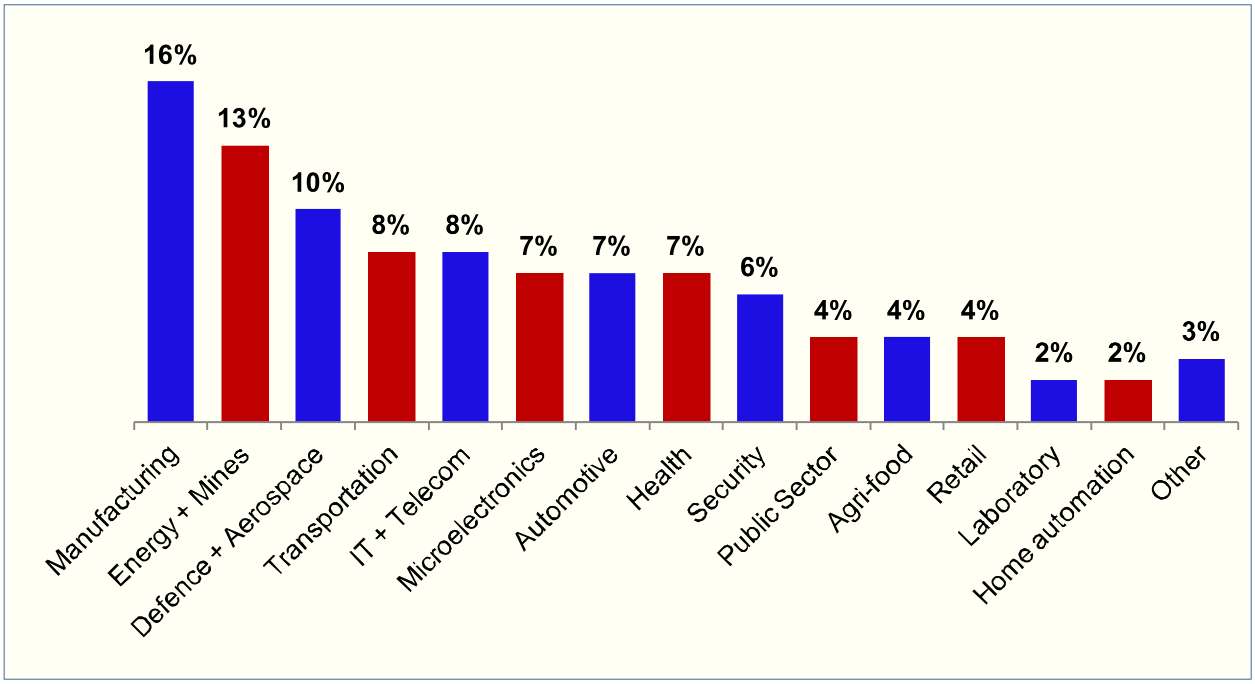
Embedded systems activities are concentrated in manufacturing. Not only respondents say that 16 percent of the volume of sales are directed to the manufacturing sector, but if we include transportation, defence/aerospace, microelectronics and automotive that also belong to manufacturing, this makes it close to half the volume of sales (precisely 48percent).

However, we have to make a distinction between embedded systems aimed at the manufacturing processes (plant automation) and those aimed to public infrastructures (transportation, utilities networks...) or consumer products (smartphones, TV sets...). However, in both cases, embedded systems users belong to the industrial sector.

While the impact of plant automation has long been felt, infrastructure and consumer products are just emerging. This is where the main growth is to be expected.

FIG. 27 - MAIN CLIENTS OF THE EMBEDDED SYSTEMS INDUSTRY

What percentage of your clients works in...



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

5.3 Vertical vs. Horizontal Markets

About 40 percent of Canadian embedded systems firms are serving only one market: they are specialized companies that operate vertically.

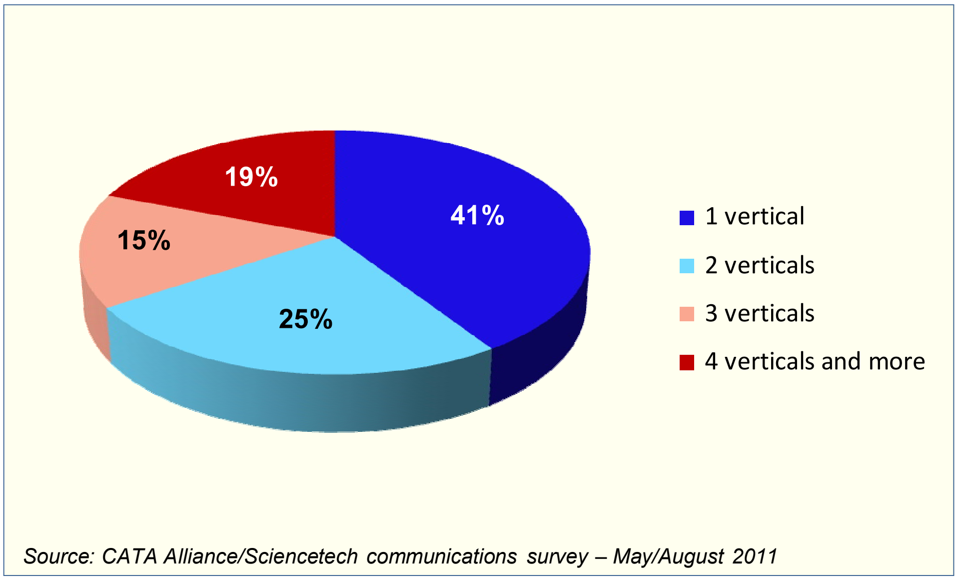
This approach is typical of the early embedded systems industry. It is a result of the vertical structure of the defence and aerospace environment where embedded technology first appeared. These sectors have very strict requirements for safety and reliability.

This fragmentation undermines the exchange of knowledge and best practices as well as collaborative development, technology transfers and standardization. As the technology is spreading in everyday embedded applications, we are witnessing the birth of versatile companies who are able to serve many sectors.

On the other hand, one third of respondents (11 percent + 21 percent) can be considered as multi-sector: when a firm serves 3 sectors, we can say it operates in a multi-sector environment. Some respondents even refused to identify precisely what sector they serve and answered: all sectors.

This is not a lack of focus. These firms actually provide products adaptable to a wide range of products.

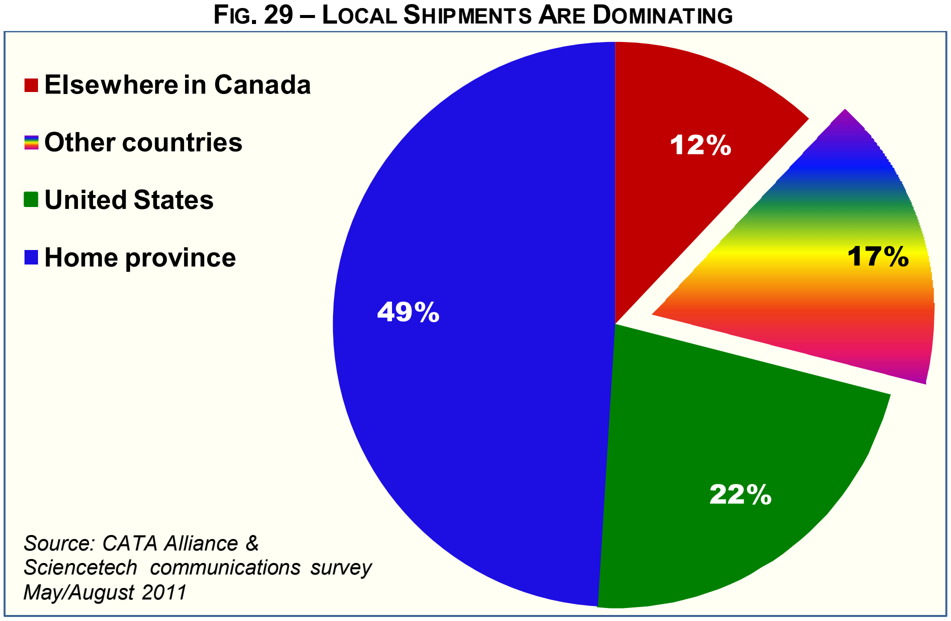
FIG. 28 – VERTICAL MARKETS ARE DOMINATING



5.4 Customer Segments by Geographic Shipments

About half of the sales volume of embedded companies is intended for the local market. Most telling is the fact that out of 173 respondents, 33 do 100 percent of their sales in their home province. This result underlines the local roots of the embedded systems industry.

FIG. 29 – LOCAL SHIPMENTS ARE DOMINATING

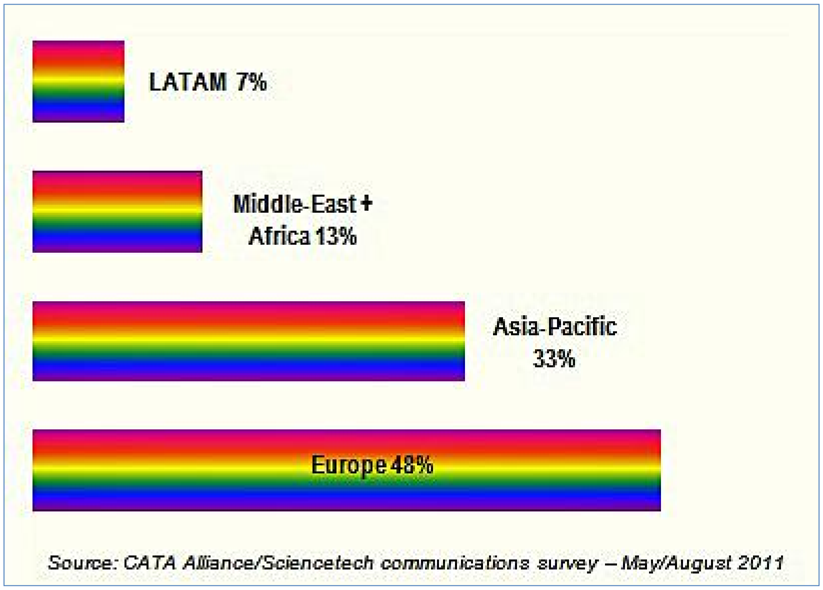


There are 71 firms which conduct business overseas, that is to say a little more that 40 percent of the respondents, however, they only ship 17 percent of their production overseas. Among overseas exporters, 11 respondents perform 100 percent of their sales outside Canada.

If we consider the destinations of embedded systems exports, Asia-Pacific is relatively low compared to Europe. Considering the huge construction effort taking place in Asia, this performance can be regarded a san anomaly. So is the very low volume of exports towards Latin America (7 percent).

In general, international export firms have exactly the same profile as the overall industry. However, the bulk of the overseas exports are made by companies that have more than 100 employees: they all carry between 75 and 99 percent of their sales outside Canada (overseas and the U.S.).

FIG. 30 – OVERSEAS SALES



6. Market Forecasts

About 40 percent of Canadian embedded systems companies do not intend of diversifying their market to other industry sectors - only 37 percent intend to do so.

Conversely, 58 percent intend to expand towards new geographic markets - primarily in the United States and other Canadian provinces.

Only a minority targets overseas markets (28 percent). Asia-Pacific comes on equal terms with Europe.

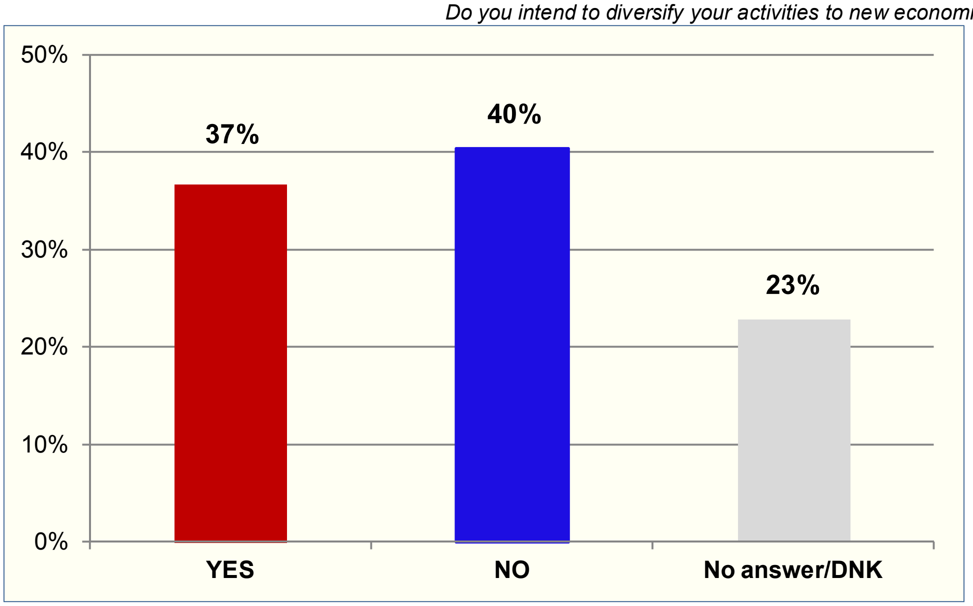
6.1 Industry Diversification

A minority of 37 percent of embedded systems companies intend to diversify their sales to new sectors. This is not due to lack of entrepreneurship, but to the industry structure. As we have seen (section 5.3 - Vertical vs. Horizontal Markets), Canadian companies are often attached to one or a few prime manufacturers and are only beginning to get out of their vertical markets.

Moreover, no dominant trend can be identified out of the stated intentions of companies looking to diversify; 23 percent do not know; some of those which answer YES still hesitate between two or three sectors.

FIG. 31 – SECTOR DIVERSIFICATION INTENTIONS (2011-2013)

Do you intend to diversify your activities to new economic sectors?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

Analysis

The development of embedded system companies still follows historical domains: first of all, aerospace and defence; but as well mining and energy. This organization is optimal to ensure quality service to the user sector, but it is restrictive in terms of the embedded systems industry growth.

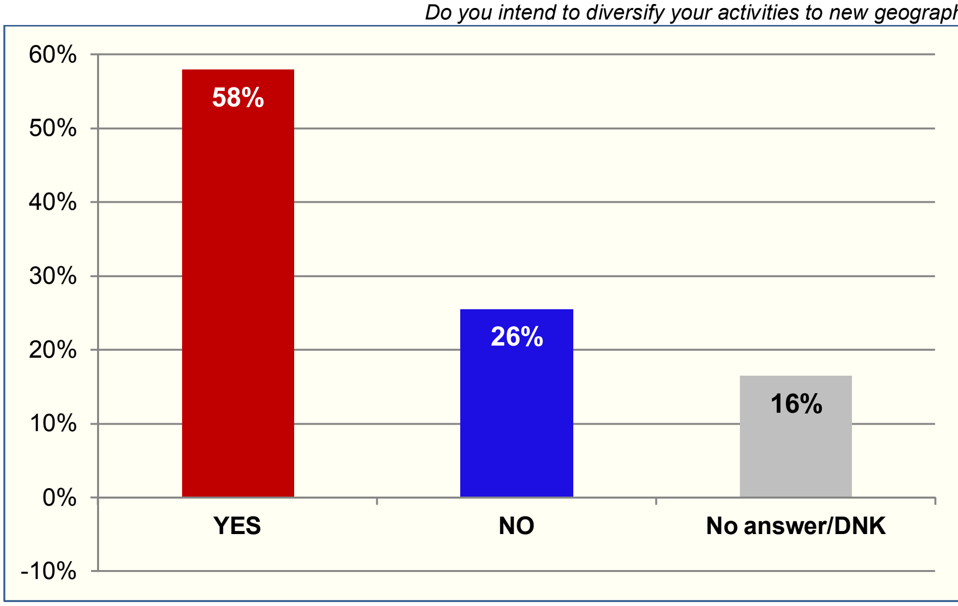
Embedded systems companies must go beyond the traditional vertical approach and vigorously pursue a move towards multi-domain activities. The increased importance of reusable hardware modules and IP blocks in the embedded systems technology should support this move.

6.2 Geographic Diversification

When we consider geographic diversification: everything changes. Canadian companies are on the lookout for business opportunities outside their home provinces - 58 percent say they have plans overseas.

FIG. 32 – GEOGRAPHIC DIVERSIFICATION INTENTIONS (2011-2013)

Do you intend to diversify your activities to new geographic markets?

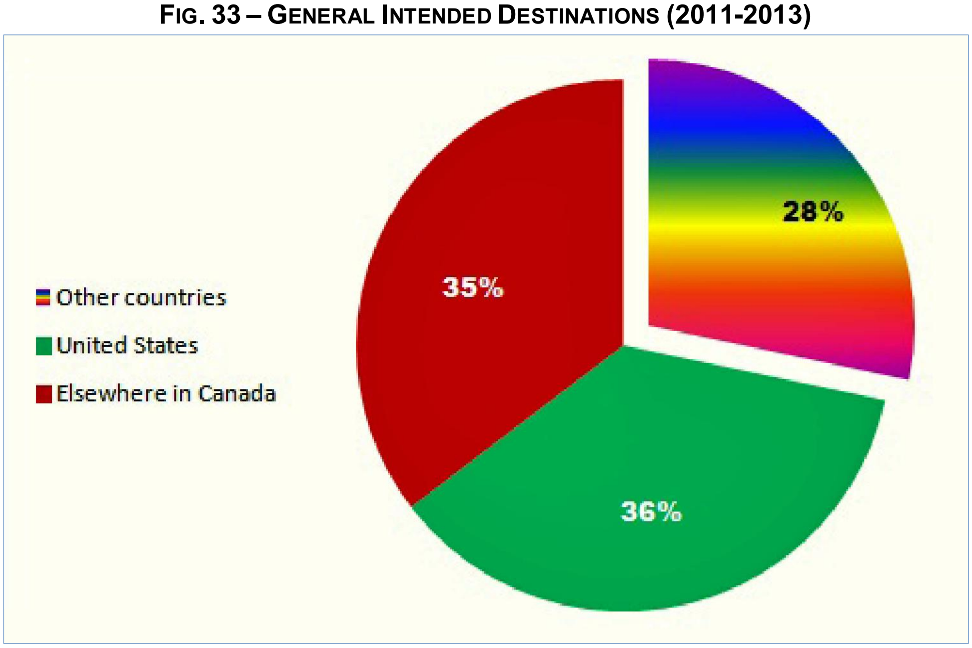


Source: CATA Alliance/Sciencetech communications survey – May/August 2011

6.3 Intended Destinations (2011-2013)

In addition, the stated intentions are clear. Embedded systems companies target the U.S. and Canadian markets outside their home markets almost on a par (36 and 35 percent).

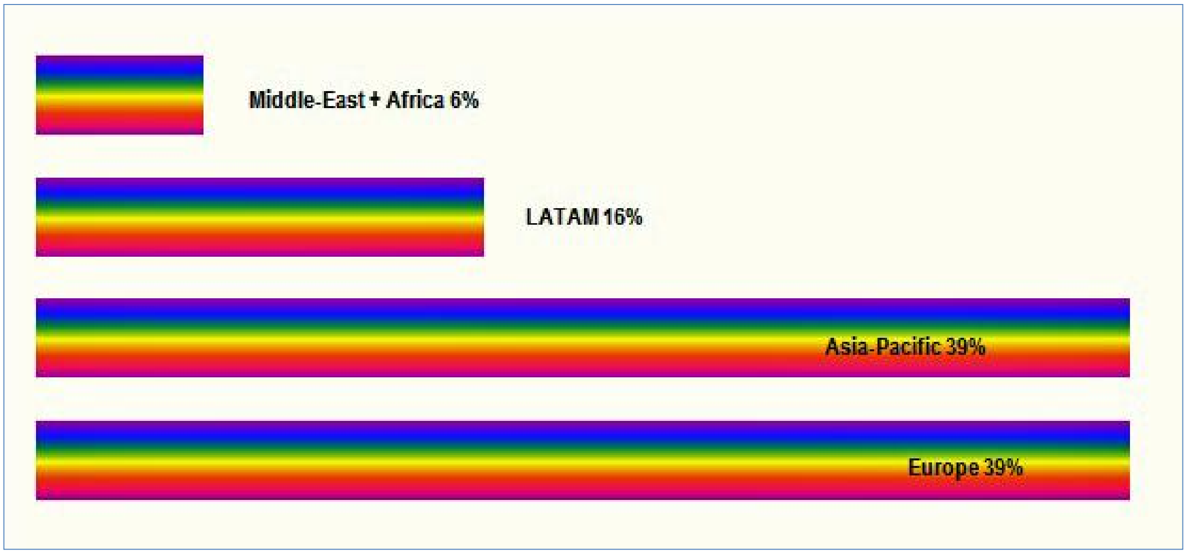
FIG. 33 – GENERAL INTENDED DESTINATIONS (2011-2013)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

Overseas export projects (28 percent of respondents) are by definition diverse. Intended exports towards Asia-Pacific and Europe are equal. This may signal a rebalancing of the current export trend that strongly favoured Europe (see Fig. 30 - Overseas Sales).

FIG. 34 – OVERSEAS INTENDED DIVERSIFICATION (2011-2013)



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

7. Research & Development and Education

Between eight and nine in 10 companies say they are conducting R&D, in other words: everyone or almost! There is a strong link between the embedded systems industry and research.

Paradoxically, this finding underscores the traditional character of the development process of an industry that too often prefers to start a project from scratch – which implies repetitive R&D – instead of reusing existing hardware and software.

University plays a pioneering role in embedded systems by systematically bridging microelectronics and software engineering. The near future is assured thanks to CMC Microsystems' emSYSCAN project (2010-2015) which involves 37 universities all over Canada. This project provides university research with funding to purchase tools necessary to design and develop new generations of embedded systems.

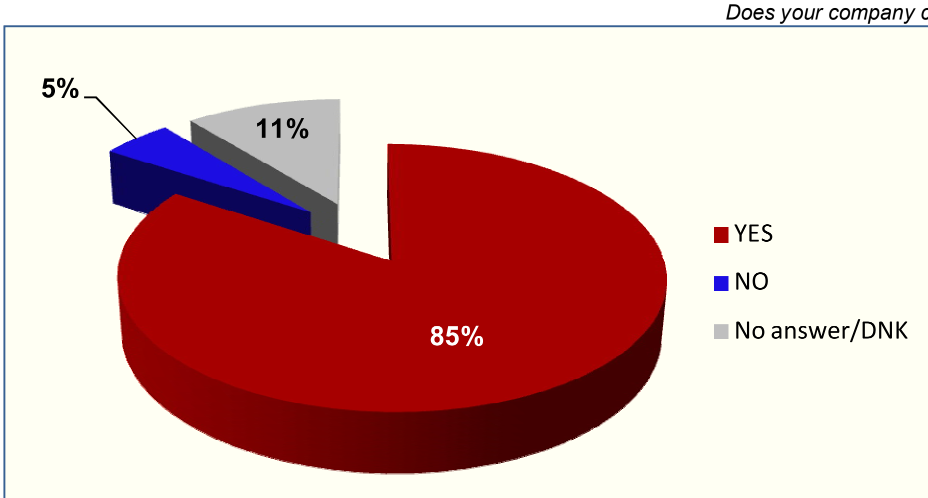
Education is considered excellent by the embedded systems industry, but the numbers of graduates is not sufficient. Since the bursting of the dot.com bubble in 2001, science subjects' enrolment has dried up dramatically.

7.1 The Essential R&D

Between eight and nine in 10 companies say they are conducting R&D, in other words: everyone or almost. The trend is so pervasive that it is possible to conclude that the embedded systems industry cannot be dissociated from research – or else that research is an integral part of embedded system technology.

FIG. 35 – THE EMS INDUSTRY IS BOUND TO R&D

Does your company conduct R&D?

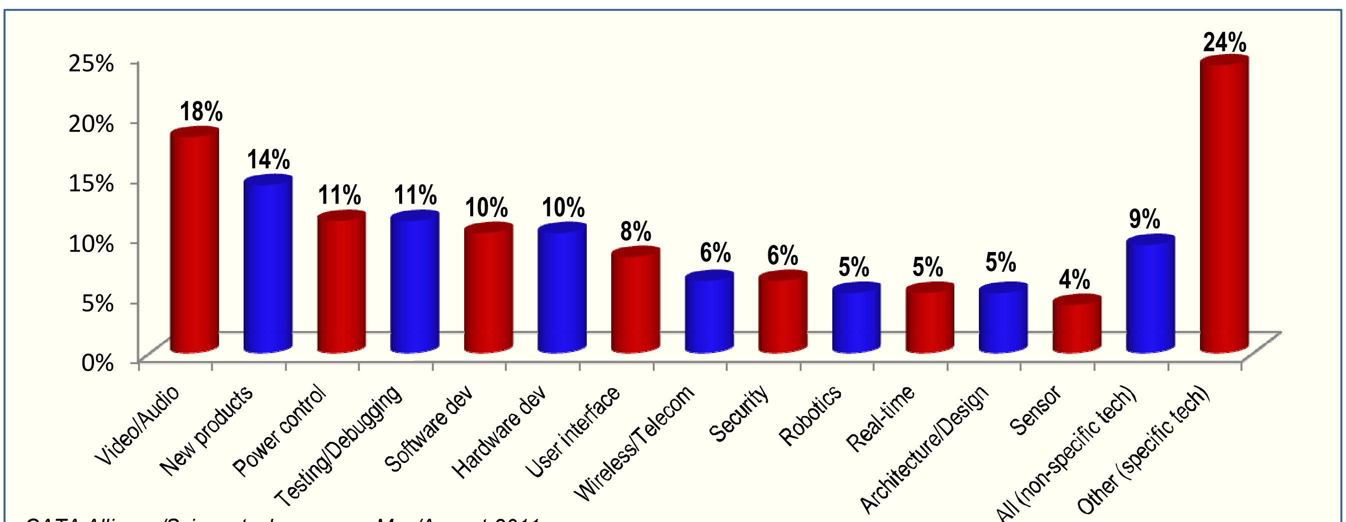


Source: CATA Alliance/Sciencetech communications survey – May/August 2011

The following question on corporate R&D has produced vague responses, as many respondents refused to respond (108 refusals) or were reluctant to acknowledge the nature of their R&D programs (hence the 15 percent "new products" answers, or the 9 percent "all technologies" answers).

Still, we can observe that the main broad themes mentioned are related to Video/Optics/Audio (18 percent), Power Consumption Reduction (11 percent) and Testing/Debugging (11 percent).

FIG. 36 – RESEARCH FIELDS



CATA Alliance/Sciencetech survey – May/August 2011

Analysis

Why the embedded system industry is so tightly linked to R&D? First, it should be remembered that the embedded system industry proceeds by distinctive projects and not as a steady flow as do most industrial companies. The process of design, development and manufacturing is triggered by the client's order.

Even the most innovative companies in off-the-shelf core modules, such as Kontron, do not store standardized COM modules. Typically, these companies design and develop a semi-custom embedded system solution down to a prototype. This tested module delivers the core functionality of the embedded system while all of the application-specific features are designed according to the industrial user specifications.

In order to be designed and developed, an embedded system needs the specific data of the final product. There are as many embedded systems as there are industrial products – and each product changes with each technology generation. The result is a lack of continuity from one project to another which requires a production process similar to traditional craft. Each embedded system must be completely "reinvented" from the design of the overall architecture to the most meticulous testing and final implementation into the client's product.

Under these conditions, it is not surprising that the embedded system industry would be R&D intensive. Insomuch as a large proportion of embedded systems provide real time safety critical functions: think of flight and engine control in an aircraft, robotic surgery technologies, or the Antilock Brake Module (ABM) in a vehicle... it is imperative that these embedded systems be perfect, i.e. faultless, but R&D takes time and is costly.

The great transformation underway in embedded systems is precisely the need to industrialize the production method. Wherever possible, the various parties are trying to create "ready-made" components that would save designers from "reinventing" an entirely new embedded system for each project. On the hardware side, as we have mentioned, it is the role of computer-on-modules. On the software side, industrialization is based on the marketing of reusable semiconductor IP blocks, also known as IP cores.

Much work remains to be done on the road to the industrialization of embedded systems production development. It is probably an ongoing process designed to track a moving target, owing to the increasing complexity of microelectronics and the ever-widening variety of applications included in industrial products.

The production of embedded systems will continue to work on the project mode and will continue to involve an element of R&D, especially at the development level. However, in order to prosper, the embedded system industry will need to include a growing share of industrially produced hardware and software.

Companies that are the fastest to systematize the use of industrial processes in embedded systems development are acquiring a major competitive advantage, in terms of lower R&D, design and testing costs, as well as reducing time-to-market and meeting project deadlines constraints.

Industrialization of the Production

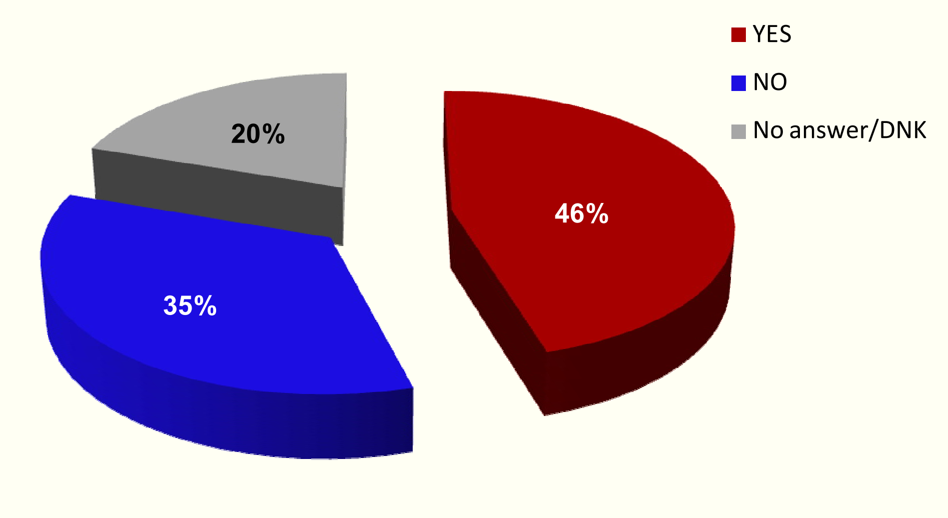
This sector is also characterized by lack of industrial processes, as most players still hold their development projects in a 'vertical', which prevents good practices exchanges and knowledge capitalization.

"Industriels des systèmes embarqués et ingénierie offshore", Pierre Audoin, Paris, 2010
(Our translation)

7.2 Cooperation with University/College

As expected in an R&D intensive industry, a relatively large proportion of companies have developed links with universities and colleges. Companies that collaborate with universities are generally proud to mention it. Business-university cooperation is seen as a proof of seriousness.

FIG. 37 – DOES YOUR COMPANY COLLABORATE WITH A UNIVERSITY OR COLLEGE?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

The two main types of links between embedded systems companies and universities or colleges are co-op or internship programs (46 percent) and R&D contracts (43 percent). Another 11 percent mentioned a special partnership or alliance with a university.

The institutions mentioned by one or more respondents were:

- University of Calgary
- École Polytechnique
- École de Technologie Supérieure (ÉTS)
- Université Laval
- McGill University
- University of Ottawa
- Queen's University
- Université de Sherbrooke
- University of Toronto
- Université du Québec à Montréal (UQAM)
- University of Waterloo

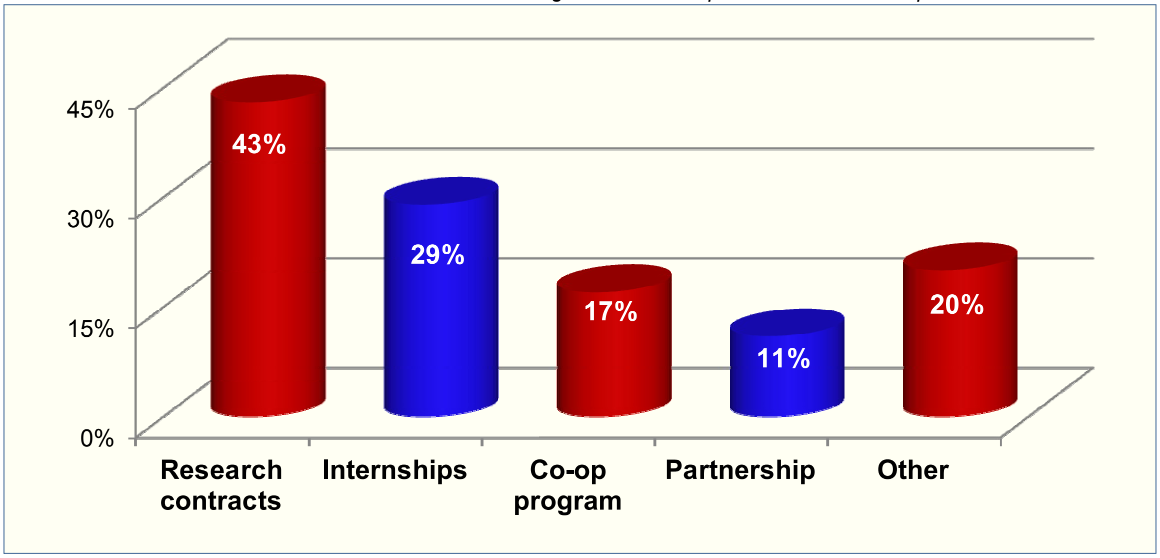
Only one college was mentioned (Ste Thérèse). The Natural Sciences and Engineering Research Council of Canada (NSERC) was also quoted by some respondents, which is predictable since this agency supports university-based research and business-university cooperation.

Two foreign institutions were mentioned:

- Clay Mathematics Institute (Boston);
- National Science Foundation (Washington).

FIG. 38 NATURE OF THE RELATIONSHIP

Percentages exceed 100 percent because multiple answers were allowed.



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

7.3 Education

Most embedded systems professionals come from the departments of microelectronics (or electrical engineering) and computer science (or software engineering). For a long time, this dual origin has been a problem for the industry.

The survey data (see below fig. 41 - Main obstacles facing the Canadian embedded system industry), our one-on-one interviews and a roundtable organized with the help of a Quebec-based microelectronics association[36] , reveal that education is considered excellent, but the numbers of graduates is not sufficient. In other words, the quality is there, but not the quantity.

7.3.1 The Excellence of Training

Since the early 2000s, the education system seems to be poised to succeed in ending the gap between the microelectronics and computer science. Recent microelectronics graduates told us they had to take programming classes and get fully immersed in computer culture. The trend in software engineering is comparable: current programs include training in design, development, testing, and installation of computer hardware.[37]

The establishment in the fall of 2011 of a post-graduate diploma in embedded systems by the University of Quebec in Montreal (UQAM) is particularly meaningful. It is the first Canadian university to offer such a qualification in embedded systems. This post-graduate certificate program is highly practice-oriented; all courses include laboratory work. According to the head of the new program, the challenge is to attract an increasing number of software engineering graduates, not just microelectronics engineering graduates.[38]

[36] AMEQ roundtable – September 20, 2011.
[37] AMEQ roundtable – idem.
[38] Interview with Pr Guy Bégin, Program Director, Computer Science Dpt., UQAM, June 22, 2011.

A - CMC Microsystems

Bridging hardware and software is well underway in Canadian universities. One of the key players of this success is the non-profit corporation CMC Microsystems, founded in 1984 in Kingston and funded by the Natural Sciences and Engineering Research Council of Canada (NSERC), the Canada Foundation for Innovation (CFI) and private sector contributions in software, equipment and technology transfers. CMC Microsystems also handles one-time grants related to special projects.

The mission of CMC Microsystems is to provide Canadian universities with the microelectronic equipment and software tools necessary to be at the forefront of world technology and in line with the most advanced needs of the private sector. Its instigator was Nortel (then Northern Telecom), which offered to design, manufacture and test microsystems concepts for free. In the 1980s, the telecommunications giant was expanding fast and had a continuous need for graduates in microelectronics and software engineering.

To that purpose, CMC Microsystems created Canada's National Design Network (NDN) which invested approximately $500 million in equipment since its inception, so that students, teachers and researchers always have at their disposal tools equal to, or better than, the best the industry. The principle is to never let the university behind the private sector technologically and help the academic research community to avoid dead-end solutions paths.

In total, the network of CMC Microsystems serves more than 760 teachers and 2,000 students and graduates in 45 post-secondary institutes across Canada. The coordination with the private sector is provided by an ongoing dialogue with above 300 companies interested in contributing to business-university research, which is its community of reference.

B – The emSYSCAN Program

The Embedded Systems Canada (emSYSCAN) program is what is closest to a Canadian strategy for embedded systems. Worth $ 54 million over five years (2010-2015) provided by the CFI and the provincial governments, the program will involve 200 researchers in 37 university institutions (see Appendix VI). The emSYSCAN infrastructure consists of national research labs connected by secure links to a management hub, with operations based at Queen's University.

Several generations of infrastructure systems will be delivered to the university research community, which will serve as tools to explore embedded systems including nano-scale devices. The emSYSCAN infrastructure will shorten the embedded systems development cycle leading to rapid commercialization, publication, and training of highly qualified personnel.

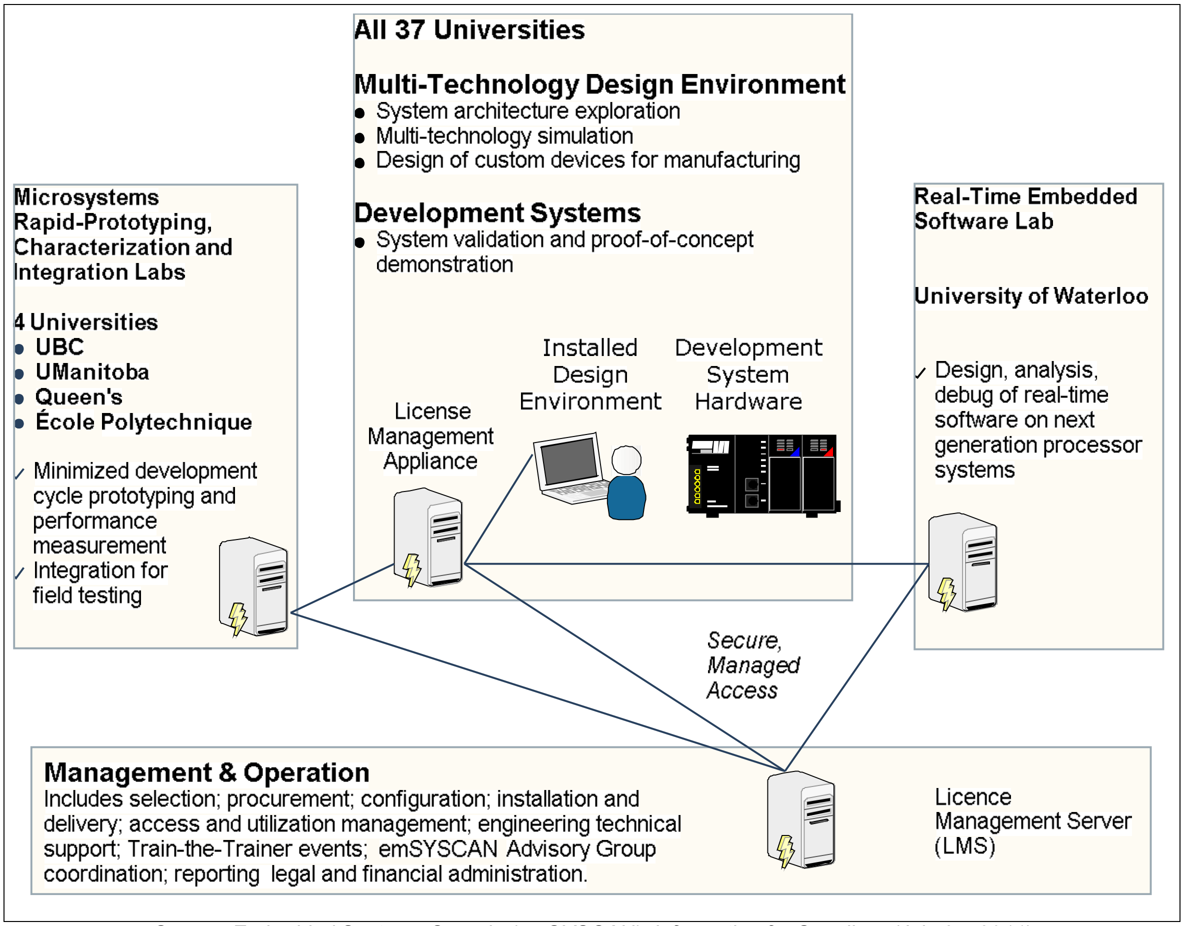
Entirely designed and managed by CMC Microsystems, the emSYSCAN program represents a major step in this organization traditionally focused on microelectronics, towards the leading edge of software engineering

There are four groups of equipment:

- Computer-Aided Design (CAD) tools and Intellectual Property (IP) - Multi-Technology Design Environment;
- "Desktop" Development Systems;
- Rapid Prototyping (Characterization, Integration and Assembly);
- and a real-time Embedded Software Lab located at the University of Waterloo.

Most platform infrastructure will be broadly distributed to participating researchers as "desktop" design stations, while design tools will be accessible by all participants through a central license server managed from Queen's University. All infrastructures will have provisions for shared access.[39]

FIG. 39 - EMSYSCAN NATIONAL INFRASTRUCTURE



Source: Embedded Systems Canada (emSYSCAN): Information for Suppliers (July 25, 2011)

We conclude that Canada has an up-to-date university research infrastructure thanks to the efforts of CMC Microsystems to equip universities since the mid-1980s, in close cooperation with the private sector. CMC recent emphasis on embedded systems bodes well for the future of this industry.

7.3.2 ICT Student Shortage

The skill shortage in the embedded system industry is due to the low enrollment in university scientific classes. According to the Information and Communications Technology Council (ICTC), "full-time undergraduate and college enrolments in mathematics and computer science peaked

[39] emSYSCAN, Research Proposal, Kingston, ON, October 2, 2008, 73 pages. Cf. Project Summary, p. 3.4/17.

in the first half of the previous decade and declined thereafter, following the bursting of the dot.com bubble."[40]

More precisely, the demise of Nortel business destroyed the very symbol of Canadian excellence in the high tech industry. For decades, this company had supported university education in order to fulfill a long-term demand for qualified skills. This was creating a notable incentive for students to enroll in science subjects.

Due to a lack of statistical data, we are reduced to conjecture on the exact extent of this shortage within the embedded systems sub-sector. All we can say is that all the professional occupations of the embedded systems industry are in short supply.[41]

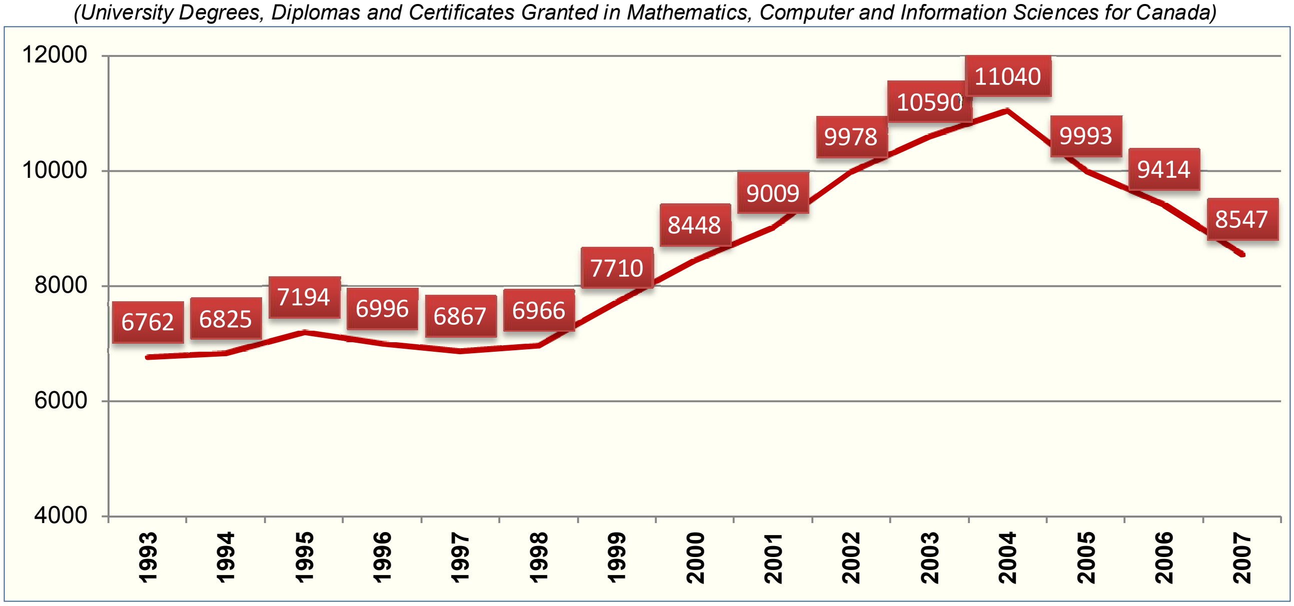
EmS Visibility Issue

We must also address the issue of embedded systems lack of visibility. When a university or college student chooses computer science, he almost always thinks about video games and multimedia applications, not embedded systems. This lack of visibility is further reinforced in the fact that much of the work is not done in Canada, but in Asia.

Round table of AMEQ
Quebec City, September 20, 2011.

FIG. 40 – ENROLLMENT DECLINE IN IT PROGRAMS

(University Degrees, Diplomas and Certificates Granted in Mathematics, Computer and Information Sciences for Canada)



Source: 2010 ICT Labour Market Trend report – Q2.

7.3.3 The Special Case of Technicians

The technicians' labour market is different from the professionals' labour market: outsourcing affected them in particular. Entire low-value ICT departments or plants moved off-shore at the end of the 1990s and during the 2000s, which led to an excess supply in the number of Canadian technicians. However, the full impact of the off-shoring trend seems to have been absorbed and no

[40] "Outlook for Human Resources in the ICT Labour Market, 2011–2016", ICTC, March 29, 2011. Cf. chapter 2 – Trends in the ICT Labour Market.
[41] "Outlook", idem.

further reduction is foreseen; a small employment growth will take place, but the surplus of workers will continue.[42]

This is not to say the industry is satisfied with the current situation. Indeed, it is estimated that 30 percent of manufacturing defects stem from bonding techniques. There is a need for improving the skill of a trade that does not require a degree, but almost entirely relies on on-the-job training.

Completion of secondary school is usually required for electronics assemblers, fabricators, inspectors and testers. A few technical colleges provide specialized programs, but they are not available everywhere and this explains why the skills and knowledge of Canadian electronics technicians lack consistency.

Some provinces decided to remedy to the problem: a two-year apprenticeship and voluntary trade certification is available for electronics assemblers in Ontario and Saskatchewan.[43] In 2011 Quebec launched a professional standard and an apprenticeship program in the workplace for assemblers in electronics, based on the principle of companionship.[44]

[42] Working in Canada Report, Occupation: Electronics Assemblers, Fabricators, Inspectors and Testers, NOC 9483-C.
[43] Unit Group: 9483 - Electronics Assemblers, Fabricators, Inspectors and Testers. Human Resources and Skills Development Canada. (http://www5.hrsdc.gc.ca/noc/english/noc/2006/Profile.aspx?val=9&val1=9483)
[44] Interview André Baune, bonding instructor, October 3, 2011. The official name of the program is “Programme d'apprentissage en milieu de travail”.

8. Obstacles to Development

The No. 1 problem of the embedded systems industry in Canada is the shortage of skilled human resources and financing difficulties come second. The preferred source of financing is venture capital, just before public funds (NRC-IRAP, BDC and various provincial agencies). The stock exchange is almost absent.

The lack of government support is rarely mentioned by the respondents and the few who do, deplore the complexity of administrative procedures (particularly in applying for tax credits).

The list of hurdles faced by the embedded systems industry should not make us forget that 15 percent of companies surveyed said they did not face any particular obstacle in their development.

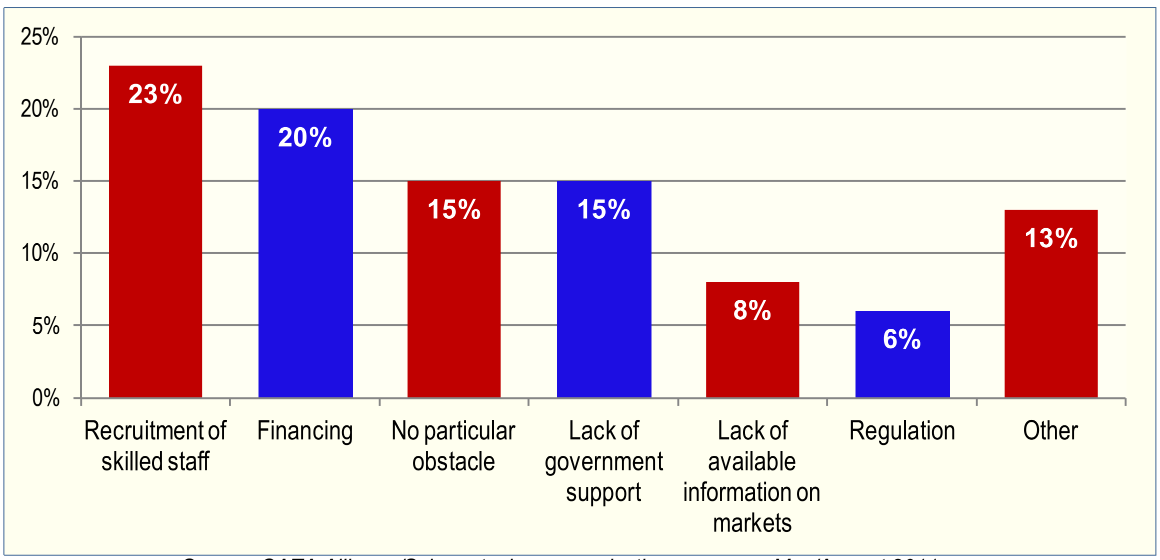
8.1 Skilled Labour Shortage

The No. 1 problem of the embedded systems industry in Canada is the shortage of qualified human resources; financing difficulties only come second (more details on financing in 8.2 - The Financing Issue).

Among the companies that responded "Other", foreign competition (from Asia and from the U.S.) is most often mentioned, followed by customers' difficulty in understanding the software side of project valuation (customers understand hardware pricing, but argue about software development costs). As the software component of a project accounts for roughly 70 percent of the total development cost, this misunderstanding may delay project approvals. Embedded systems developers believe that the real value of the work on embedded systems is unrecognized, neglected and all this together makes it a difficult market.

Some respondents shed a further light on the lack of skilled labour: not only engineers are scarce, but also marketing and sales professionals who understand both embedded systems and the business processes to which embedded systems are applied. Marketing professionals often consider embedded systems as an arcane sector reserved to techno geeks – not to mention some microelectronics executives who do not regard the business management professionals at fair value and are reluctant to hire them.

FIG. 41 – MAIN OBSTACLES FACING THE CANADIAN EMBEDDED SYSTEM INDUSTRY



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

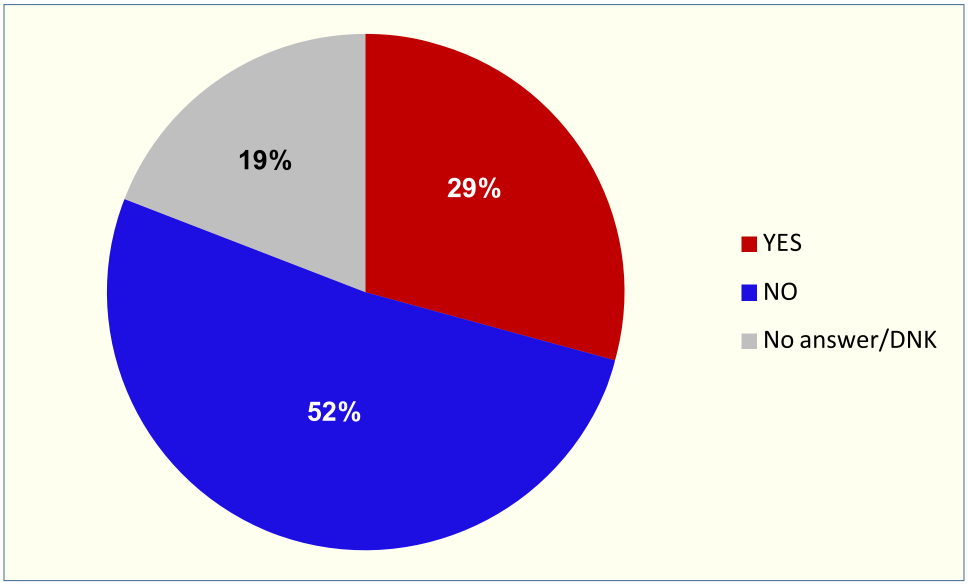
Finally, let us note the presence of a category of respondents who lead us to put into perspective the obstacles of the embedded systems industry: no less than 15 percent of Canadian businesses consider not having any particular problem. The embedded systems industry is not in a bad situation, even though it still lags far behind the world leaders (the U.S., Japan and Germany).

8.2 The Financing Issue

Over half of Canadian companies are not looking for new funding. Among the minority seeking financing, 47 percent are looking for venture capital, 35 percent public funding (National Research

Council-Industrial Research Assistance Program, Business Development Bank of Canada and various provincial agencies), and 12 percent bank credit. Only one company mentioned the stock exchange (initial public offering). A company also mentioned the possibility of licensing patent rights.

FIG. 42 – ARE YOU LOOKING FOR FINANCING?



Source: CATA Alliance/Sciencetech communications survey – May/August 2011

Once again, a caveat is in order. The subgroup which indicated the financing source they anticipated using does not include all the companies that answered "YES". Only a fraction of them has agreed to provide information about it (17 companies out of 55).

9. Conclusion, Prevailing Trends and Issues for Consideration

Reminder of the main themes of the study :

- Embedded systems come from microelectronics, not from software
- A R&D-based industry
- Skilled labour shortage
- Changing technology: the rush to virtualization
- Good news: China is missing ... but not for long!
- A locally-based industry

Prevailing trend are an “invasion” of all areas of production by the computer sector, like what happened in telecommunications during the 1980s and 1990s; and the rehabilitation of the manufacturing sector by the Internet of things.

This chapter concludes with some issues for consideration:

- Creation of a Canadian roadmap modelled on the German "National Roadmap".
- Creation of a Prime Manufacturers’ Club.
- Creation of an Embedded Systems Institute.
- Policy of "better purchase" of the federal and provincial governments.
- Support for targeted innovation.

9.1 Conclusion

9.1.1 Embedded Systems Come from Microelectronics, Not from Software

The embedded sector comes from the microelectronics industry and large prime manufacturers (defence, aerospace, telecommunications, transportation and automotive...).

Few or no software vendors are active among embedded systems firms. Most of them are microelectronics firms moving up the value chain by incorporating an ever-increasing proportion of software engineering in their work, not the other way around.

This trend is accelerating with the hardware virtualization of the foundation of microelectronics: the processor is fast becoming a programmable architecture that can be configured at will depending on the applications that we intend to develop. Today, the majority of software programming jobs are on the side of embedded systems, rather than on computers or game consoles.

9.1.2 An Industry Based on R&D

The embedded sector is linked to R & D since, as previously noted, embedded systems firms operate by projects' cycles, not by a continuous flow production process (see 4.1 – Re-use of embedded systems and 7.1 – R&D: a "must"). This craft process has generated many problems of late delivery and cost overruns, particularly in R&D duplication or repetitive R&D from one project to another.

The tendency to reuse hardware (Computer-on-Module) and software (IP blocks) does not remove the need for innovation, but it provides standard platforms, from which the designer can focus on the application domain specific to his client.

This is not to say that the embedded systems industry must give up R&D. Embedded systems are bound up to R&D, but it must prioritize R&D focussed on IP reusable algorithms and complex systems. In order to be effective and efficient, R&D must come before system development, even before system design.

9.1.3 Skilled Labour Shortage

The field of embedded systems is not popular with students in software engineering. Who would undertake a computer science program in order to work in the embedded sector? Few people. The "Other computing" does not have the somewhat "glamorous" aura of mainstream computers and especially video games. The embedded area remains in the shadows and it is a serious problem.

In addition, many software professionals are reluctant to go to work in a manufacturing company where IT is a marginal activity. How can one have a career in a company where the IT department is small, without strategic responsibility and away from decision-making? A prolonged stay in such workplace may even give a negative image to a software engineer when it comes time to change jobs.[45]

It is recognized that the entire ICT sector suffers from a lack of human resources in Canada. However, the situation is worse in the field of embedded systems for the reasons just mentioned.

[45] Douglas Lippoldt and Piotr Strysczowski, "Innovation in the Software Sector", OECD, 185 pages. Cf. p. 185 (footnote 2).

This situation is not unique to Canada. The United States and Germany are obliged to call largely upon foreign professionals to address the shortage of skilled labour in embedded systems. When we know the efforts of emerging countries like India to bring back its skilled labour force based abroad, it is reasonable to foresee that relying on immigration is not a long term solution.[46]

This situation threatens to encourage Canadian companies (developers and industrial users) to outsource their operations overseas.

There is also a shortage of jobs in certain activities related to embedded systems: specialized salespersons and marketing professionals.

Labour Shortages in Canada's Tech Sector

As a result, the ICT labour market is characterized by recurring and systemic skills shortages. These shortages constrain the competitiveness of the ICT industry and hamper the efficiency of ICT operations in User Industries. The problem cannot be addressed in a piece-meal way. It requires looking holistically at how ICT programs are designed: what mix of skills students acquire in those programs, how they obtain practical experience alongside theoretical training, how the skill profile of graduates aligns with employers' needs, and how recent graduates are then transitioned into entry-level jobs.

Outlook for Human Resources in the ICT Labour Market, 2011–2016 (chapter 2 - Trends in the ICT Labour Market)

9.1.4 Changing Technology: the Rush to Virtualization

The embedded domain goes virtual. Already, we evaluate to 70 percent the portion attributable to software in the production cost of an average embedded system project –– and this share is increasing.

Until now, we only programmed the applications of embedded systems. Now we also program the hardware platform as it is being transformed into a logical architecture. ARM processors are currently sold through the Internet and can be installed on existing commodity hardware. It is then possible to add more functionality by incorporating reusable IP blocks also downloaded through the Internet.

A plane, a car, and tomorrow all our electrical goods are turning into a whole range of software platforms that will evolve at the frantic speed of IT. This is particularly crucial in the mobile industry where manufacturers want to upgrade their clients' phones with the latest technologies and features each time a competitor launches a new model. But what is currently taking place in the mobile industry is going to spread to all manufactured articles that will require remote upgrading for a variety of reasons (environmental regulation, energy management, additional functions...).

The Internet of things being built before our eyes will not be hardware-centric but entirely software controlled. The added value of our manufacturing base resides within these blocks of intellectual property that will be programmed in Canada – or imported from abroad.

And as, in a few years, all manufactured goods being sold will have to "intelligent" – or they will not be sold at all –, Canada must adopt an "all-software" strategy if it is to keep an industrial base.

---

[46] In Canada, internationally educated professionals account for approximately 14 percent of the ICT labour force, based on 2006 Census estimates. Immigration of ICT professionals peaked in 2005 with 9,670 persons immigrating to Canada and identifying an ICT occupation as their intended field of work". Information and Communications Technology Council, *Outlook for Human Resources in the ICT Labour Market, 2011–2016*, Chapter 2, Trends in the ICT Labour Market, Ottawa 2011.

9.1.5 Good News: China Is Missing... But Not for Long!

Internationally, the big three of the embedded industry are the United States, Japan and Germany, three countries with an industrial structure similar to Canada, with a salary structure also comparable. China is not in the picture: not yet...

China seeks to establish itself in this industry too. As evidence, trade shows, conferences and exhibitions devoted to embedded systems are increasing in China. Shanghai started off the trend in 2008 with "Embedded China", which takes place every year. The event is no longer isolated, far from it: the conference "Real-Time and Embedded Computing" also takes place annually, but in different months in Beijing, Chengdu, Shenzhen and Xi'an.[47]

Canada has a few years left, but not much, judging by the speed of implementation of industrial strategies in China. It needs to train engineers and technicians and it needs to adopt an "all-software" policy for its manufacturing sector – not to forget mining, energy, and agri-food which too are major consumers of embedded systems.[48].

9.1.6 A Locally-Based Industry

The geography of the embedded industry is marked by the proximity factor due to intense interactions that characterize the relationship between users and suppliers. From design to prototyping, the comings and goings are constant between the client and the system developer. This is a constant trend:

> *To be fair, in electronics manufacturing, high-mix, low-volume production has largely remained on our shores. Medical, defense, aerospace, and security equipment are among the leading electronic products still built in the US and Canada.*[49]

So should we be surprised if 54 percent of the sales of Canadian embedded systems firms are made locally? If we added interprovincial trade, the volume would go up to 66%.

However, the proximity factor is not absolute. It especially prevails early in the production process (design and development) or in the manufacture of small series (a few hundreds or thousands of units). When we reach mass production, competition from Asian electronics manufacturing services (EMS) steps in and the difference in labour cost fully comes into play.

However, the example of IBM and Dalsa Microsystem plants in Bromont, Quebec, shows that it is possible to meet the challenge of international competition in some high-end products. The increasing complexity of semiconductor generation (32 nm and beyond) requires increasing software design – virtualization process – and therefore highly qualified skill where Canada still retains a competitive advantage

[47] Please see Real Time Systems & Embedded Systems Trade Shows in China (Asia - Pacific) - http://www.eventseye.com/fairs/cst1_trade-shows_china_real-time-systems-embedded-systems.html
[48] Please see figure 27 - Main Clients of the Embedded Systems Industry.
[49] Barbara Jorgensen, Execs Cite Reasons for Onshoring, EBN Community Editor, December 16, 2011.

9.2 Prevailing Trends

9.2.1 The Great Invasion

CATA highlights a major trend in the survey: embedded systems are the tip of a larger phenomenon that is the entrance of IT in all industry sectors.

Today we are witnessing a phenomenon similar to what was happening in the telecommunications sector during the 1980s and 1990s when digitization spread over all parts of the network: terminals, transmission and switching. We called this process of convergence between computing and telecommunications. The polite word "convergence" referred to a merger of equals between the two sectors.

We saw what happened. Far from an orderly convergence between comparable sectors, we witnessed the all-out invasion of telecommunications by computing. Telecommunications was based on extreme equipment reliability and durability (a Nortel phone was guaranteed for 40 years), vertical integration, hierarchical organization and universal service.

This quasi-perfect scheme has given way to the hectic pace of IT teams made of passionate techies who can work day and night, but also tear at each other in ruthless competition. The pyramidal organization has given way to permanent disintegration of the value chain in search of an immediate return with repeated innovations and technological breakthroughs in the bargain.

In short, Nortel did not start manufacturing computers. Nortel disappeared, and Apple, a computer manufacturer, produces phones better and more versatile than anything had ever dreamed by the boldest telecommunications people.

All industries will have to go through the same transformations as the old telecommunications – that is to say, suffer the same shock.

Sector after sector, the whole Canadian economy will be affected by the computing flood of which embedded systems are the concrete manifestation. That is why CATA can maintain that harnessing embedded systems is crucial for the future of the Canadian industry.

Facts speak for themselves: half of our companies are producing embedded systems for manufacturing – including aerospace, automotive and transport, as well as microelectronics. If we add energy and health, we understand the dimension of the phenomenon. All sectors are concerned.

The digitization of the economy is under way. How will we cope with it?

9.2.2 The Internet of Things

As embedded systems spread to all industries, a new reality appears: the 'Internet of Things'. Although the concept is rather vague, everyone agrees on the ubiquity of a phenomenon that is rapidly transforming both business and our personal lives.[50]

The Internet of Things rekindles the manufacturing sector. The service economy which has been promoted over the last 50 years is nearing completion. Today, humankind is linked to a global

[50] "The Internet of Things", Rob van Kranenburg, Erin Anzelmo, Alessandro Bassi, Dan Caprio, Sean Dodson and Matt Ratto, Paper prepared for the 1st Berlin Symposium on Internet and Society, October 25-27, 2011, 57 pages. Cf. p. 3. "The Internet of Things", ITU Internet Reports 2005, Executive Summary, November 2005, 17 pages. Cf. p. 2.

telecommunications infrastructure, at steadily increasing access speed, and at ever declining prices. Yet, something is missing... Our relationship to the outer environment remains opaque. The material world is silent.

The role of embedded systems is to inject intelligence into manufactured objects and into the whole human-made environment (buildings, roads, bridges, canals, dams...). This process is not neutral. It forces us to reassess the role of the manufacturing sector which was neglected to the point of being excluded from our society.

The very symbol of this long disregard is the massive outsourcing of the manufacturing sector to a distant developing world. Experts and scientists then talked of a post-industrial society and a fabless economy as the future of the developed world. Production was polluting and costly, North America would focus on the “noble” task of innovation.

Now, as intelligent objects start responding, we rediscover manufacturing with a surprise. The material world becomes interesting again and our attitude is beginning to evolve. The recent financial crisis has obviously contributed to make people's mentality change. But social, economical, technological, and military reasons are not sufficient to explain the rise of the new industrial paradigm.

Objective factors are seldom the cause for paradigm change, there needs to be culturally specific factors such as values, behaviours, and opinions. In the case of manufacturing, the triggering factor of the new human/machine relationship is the smartphone considered as the main interface between people and the Internet of things. The researcher Carlo Irio (Université Libre de Bruxelles) wrote a brilliant analysis on this phenomenon:

> *… it is very important to find simple and intuitive methods in order to facilitate the interactions between the people and the smart objects of the real world. This is possible because: on the one hand there is the Internet of “things” and in the other hand there are the physical mobile interactions. The idea is to combine these different domains in a unique domain where the smart phone is the mediator between them. This is possible thanks to the fact that physical objects are associated with digital information (Internet of Things) and to usage of the physical mobile interaction techniques as: Touching, Pointing, Scanning, User-Method object selection and Indirect-Remote control.*[51]

The pleasure of using smartphones such as Apple’s iPhone creates a new ecosystem that allows individuals to enter into a dialogue with matter, in the form of intelligent objects and environment. The smartphone is the magic device that induces the discovery of the enchanted world of speaking matter. This is only the first step. The smartphone as universal mediator will soon extend its reach to more advanced technologies based on organic or even anthropomorphic interfaces.

Embedded systems are the underlying components of the Internet of Things (including its smartphone interface). As such they constitute one of the key drivers of the transition to a world where “everything will be a part of the web… So you begin to think of a shoe as a chip with heels and a car as a chip with wheels.”[52]

[51] Carlo Iorio: "Smart phone interactivity and pervasive connectivity", in Seminar on Pervasive Networks and Connectivity, Bilhanan Silverajan (Editor), Tampere University of Technology, Department of Communications Engineering, seminar series on special topics in networking, Spring 2008, 177 pages. Cf. p. 81.

[52] Transcription of Kevin Kelly's talk about the next 5000 days of the web, December 2007. http://wiki.littera.deusto.es/en/index.php/Ist0809/KevinKelly5000days

9.3 Issues for Consideration

Many countries already have or plan to have strategies for the deployment of embedded systems. The importance of these strategies is confirmed by the spectacular success of several Asian economies and Germany.

Canadian decision makers must act quickly and comprehensively or be prepared to be left behind.

9.3.1 Private Sector

It is up to the private sector to take the initiative to formulate a comprehensive strategy, in partnership with the academic sector.

A – Canadian Roadmap)

Although, not directly specialized on embedded systems, the MiQro Innovation Collaborative Centre (C2MI) can play a facilitating role for the industry. The C2MI intends to play "an essential role in the microelectronics ecosystem of the North-East Continent".[53] All components to fulfill this mission exist, but success is never granted.

The C2MI was created jointly by IBM Canada, Teledyne-DALSA and the University of Sherbrooke. It is a Centre of Excellence for Commercialization and Research (CECR) and as such must "help to foster environments where researchers are able to commercialize their findings to the benefit of Canadians."[54] To fulfill its role within the embedded systems domain, it has to work with SMEs and even microbusiness. Indeed, a vast majority of embedded systems providers are small, and this is especially the case in the IP business.

It may therefore be useful to create a Canadian roadmap on the German model (*"National Roadmap"*). Developed by the C2MI and the various microelectronics associations, in partnership with interested universities and colleges (CMC Microsystems could help aggregate them), this plan would reflect industry needs and foster the involvement of a large spectrum of individual corporate executives.

The focus could be placed on the development of intellectual property trade among the embedded systems vendor, even among the microbusiness, and among the user sector. Indeed, the issues of software engineering are so foreign to the core business of some prime manufacturers they even forget to capitalize software development done in-house! There is value in systematizing the re-use of IP blocks, even within the company.

The Canadian Embedded System Roadmap could, for example, help identify and assess (provisional list):

- Emerging embedded system technologies for Canada's technology clusters;
- Reference architectures for embedded systems;
- Certification of IP blocks;
- Safety and security standards of embedded systems;
- Promising innovations in interactive interfaces;
- Best practices in corporate-business and business-university cooperation;
- Promotion of the embedded system college and university studies, and professions;

[53] Please see C2MI home page: http://www.c2mi.ca/en/home/
[54] News release: "C2MI is now a recognized Centre of Excellence for Commercialization and Research (CECR) of the Networks of Centres of Excellence (NCE)", Ottawa, December 6, 2010.

- What structures are to be set up to promote cooperative orders, especially in the manufacturing phase of product development?

Cooperative Purchasing Is a Necessity

One way to remain competitive is to encourage cooperative purchasing from the design stage to manufacturing. When comes the time to manufacture, the Chinese themselves group together to proceed by joint purchasing of microelectronic components. To combat this tidal wave, you have to act like the Chinese, starting even earlier: from the design stage. Only then a truly comprehensive cost sharing will be possible and will allow various companies at work on different projects to order the production of large series of embedded units at a competitive cost.

François Verdy-Goyette, CIMEQ, August 16, 2011

B – Creation of a Prime Manufacturers' Forum

The industrial user sector is not involved in the work of microelectronics trade associations which do not reflect its needs.

When users meet in their respective business associations, embedded systems are only one concern among many. In addition, the variety of user business associations does not promote inter-industry interactions.

The rallying of prime manufacturers into a forum could be organized in order to facilitate technology and market information exchanges with Canada-based embedded developers. The Prime Manufacturers' Forum should be geographically very decentralized and be made up of provincial clubs where day-to-day issues should be addressed. Its primary purpose would be to share best practices among several strategic industry clusters (aerospace, automotive, communications equipment, mining and energy, iron and steel, primary nonferrous materials, etc.).

One of the initial terms of this outsourcers' Forum could be the identification of reusable software tools from one company to another and from one sector to another, allowing them to optimize their investment or make it profitable, and enable suppliers to strengthen.[55]

9.3.2 Education

The launching of the emSYSCAN national program by CMC Microsystems is about to create a favourable environment for embedded systems in academia. Already, the creation of an Advanced - Graduate Diploma in embedded systems by Montreal-based UQAM is a step in the right direction.

Moreover, the creation of a C2MI in Bromont, Quebec sends us a strong signal. Canada is going to need highly trained graduates.

It is time to go further and engage the university. Here are three ways to explore, that are by no means exclusive of each other:

1. Creation of an Institute of Embedded Systems on the model of what already exists in leading countries: Germany and the United States.
   - Germany developed by far the largest team of excellent researchers in the field of reconfigurable computing world-wide through the DFG funding program.[56] Among

[55] Such a Forum already exists in France. *Briques Génériques du Logiciel Embarqué*, idem, cf. p. 21.

the better known are the Institute for Communication Technology and Embedded Systems (ICE) of Aachen, or the Institute of Embedded Systems / Real-Time Systems of the Ulm University.

- The German model already propagated to its immediate neighbors: Netherlands and Switzerland. Netherlands created its Embedded Systems Institute (ESI) in Eindhoven, of course, the city of Philips. Switzerland established the Institute of Embedded Systems in Winterthur (affiliated with the Zurich University of Applied Sciences).
- Another interesting model is the United States where a whole range of embedded systems institutes flourished. Just to mention a few famous ones: the Center for Embedded Systems jointly managed by the National Science Foundation (NSF), universities (Arizona State University and Southern Illinois University) and the private sector (Intel, Qualcomm, Caterpillar, Toyota ...), the Center for Robotics and Embedded Systems (CRES) at the University of Southern California Viterbi-Los Angeles, or the Center for Hybrid and Embedded Software Systems (CHESS) at Berkeley.

2. Creation of a department of embedded system engineering as the Institut für Technische Informatik, University of Stuttgart.

3. Or, else a chair in embedded systems like the one created by the Karlsruhe Institute of Technology.

Such a policy is not a German or American specialty. There are university institutes of embedded systems in India, Singapore, and Hong Kong, only to mention a few know ones.

It is the only way to put an end to the “amateurish” culture that too often prevails in the microelectronics industry when the time comes of dealing with software development, to emphasize the seriousness of embedded software and to create a solid Canadian expertise. It would also have the indirect effect to send a clear message to the current and future students: embedded systems are the future of the industry.[57]

A Cowboy Mentality

Writing software for these things is more difficult than computer software because the systems have so few resources. Instead of building better software, the trend has been to allow a cowboy mentality of just getting it done. We can do better than that. We must do better than that.

Elecia White, author of “Making Embedded Systems”, O’Reilly, 328 pages, 2011.

9.3.3 Public Sector

We observed (section 7.1 – *The essential R&D*) that the sector is structurally linked to embedded R&D and, consequently, universities and some specialized colleges. Special attention should be paid to the R&D assistance (tax credits), university-enterprise cooperation and training. Yet this attention alone is not sufficient. It should include as a top priority a sustained government action.

* Interview of Elecia White by Gretchen Giles, Why embedded systems are "terrifyingly important", O’Reilly Radar, November 16, 2011.

[56] The Deutsche Forschungsgemeinschaft (DFG) or German Research Foundation is the self-governing organisation for science and research in Germany.

[57] See the interview of Elecia White by Gretchen Giles, “Why embedded systems are *terrifyingly important*”, *O’Reilly Radar*, November 16, 2011.

A – Innovative Procurement Policy

The Government of Canada has everything to gain by establishing a procurement policy based on innovation, with two components:

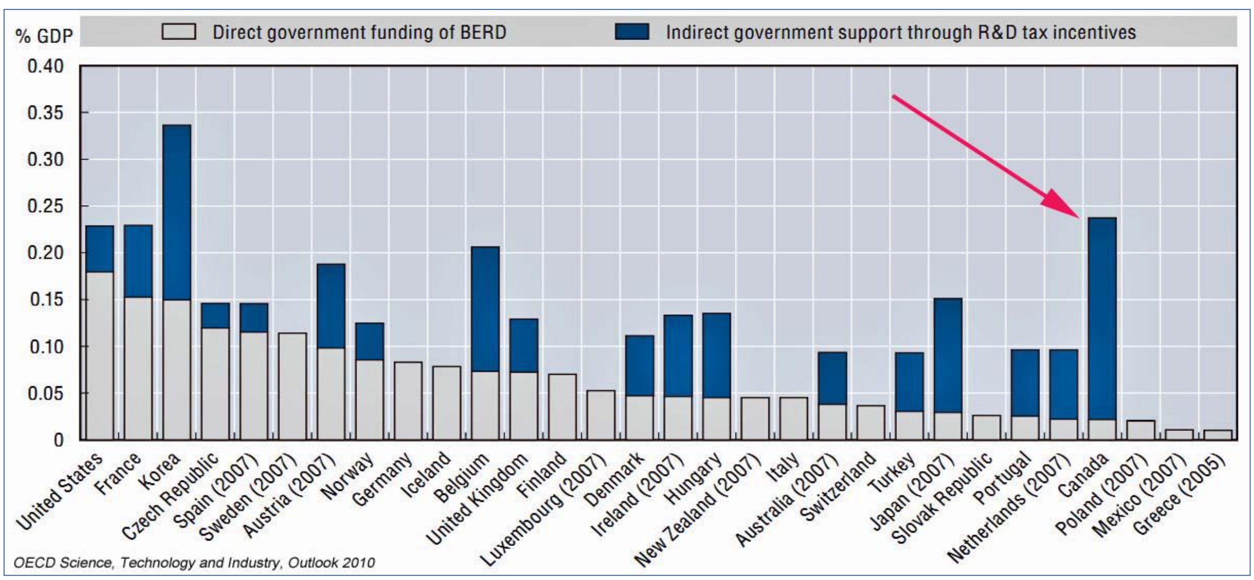
- 1°) Innovative procurement – Key departments are required to publish their long-term demand forecasts. To this end, these departments are asked to engage in continuous market analysis to identify new technology trends and to establish mechanisms for consultation with embedded systems suppliers, including microbusiness. This ongoing dialogue should be conducted on both a sectoral and cross-sectoral base and should include all interested provincial governments.[58]

- 2) Calls for tenders and proposals concerning embedded systems must include the method of "best available technology" long used by the German government in the environmental sector, instead of the automatic criterion of the lowest bidder now being used. This method requires much more preparation for the government, but the issues at stake are high. Let us only mention that the "best available technology" method has enabled Germany to become the world leader in the photovoltaic sector.[59]

B - Support for Targeted Innovation

The approach to innovation support through tax credits on R&D is currently being reviewed by the federal government. Without deciding on the merits of tax credits for R&D and possible alternatives, we want to bring forward the issue of targeted assistance. Canada invests more than the OECD average in R&D and the result is a low degree of innovation, as confirmed by the low number of patent applications filed by Canadians (see figures 43 and 44).

FIG. 43 – GOVERNMENT SUPPORT TO R&D (2008)



There exists a clear discrepancy between Canada's investment in R&D and the level of innovation. The number of patents filed by country residents is not the only way to assess the intensity of R&D but this finding comes in line with the results of a recent research performed by the Centre for

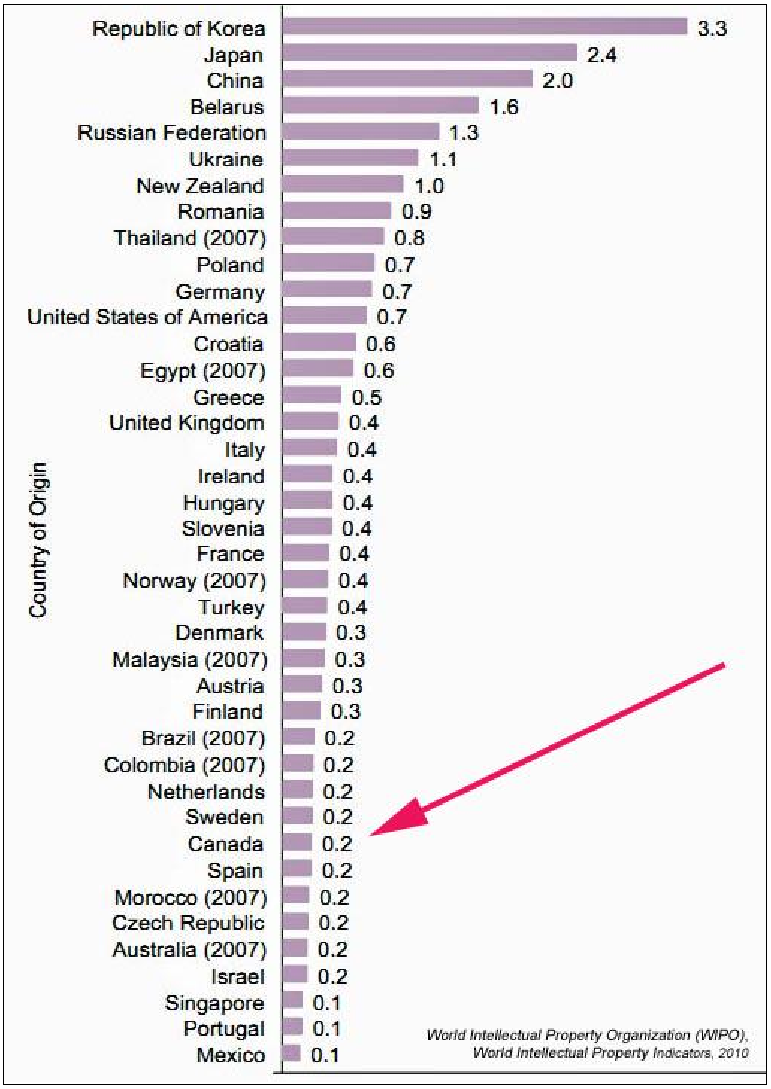
[58] Germany selected six departments: interior, economics, defence, transport, environment and research. OECD (2011), Business Innovation Policies: Selected Country Comparisons, OECD Publishing, 155 pages. Cf. p. 89.
[59] OECD (2011), idem, cf. p. 90.

Productivity and Prosperity of HEC Montreal.[60] Our position is to encourage Canada and its provinces to target their R&D support policies on embedded systems.

Far from advocating a policy of picking winning technologies, our goal is to encourage governments to focus on the small number of priorities that can "make a difference." What we call "embedded systems" or the "other computing" could be one of these priorities. It is not a technology, but a cross-section of multiple technologies and processes; it is a major innovation driver in most industry sectors and has strategic importance for the economy.

FIG. 44 – INNOVATION DENSITY

(Resident patent applications per $million R&D expenditure)



[60] Robert Gagné & Pierre-Olivier Lachance, "La performance québécoise en innovation", HEC Montreal, April 2011, 35 pages. HEC Montreal is an international business school. "The federal government earmarks the equivalent of 0.24 percent of GDP for R&D, placing Canada second among the OECD countries, after South Korea. And yet, the number of patent applications stemming from these investments simply does not measure up: in 2008, Canada registered only 75 patents per million residents, ranking 18 out of 22 among OECD members." (Available in French only)

Appendix I - Case Studies

Companies profiled in this section were chosen to illustrate the different segments of the industry so as to give as complete a picture as possible of the variety of embedded systems industry activities. This is in no way a list of the best companies selected based on any comparative standard (technological innovation or marketing, sales, best practices, etc.).

Alizem inc. *

1173 Charest Blvd. W.
Suite 300-5,
Québec, QC, G1N 2C9
marc.perron@alizem.com
www.alizem.com

Interview	Marc Perron, President
Contact	Idem
Data	▶ *Founded* ▶ 2006 ▶ *Headquarters* ▶ Québec ▶ *No. of employees* ▶ 1-4 ▶ *Employees in embedded systems* ▶ 1-4 ▶ *Products* ▶ System level blocks of software specialised in electronic power applications. ▶ *Clients* ▶ Industrial et medical
Mission	Alizem is a system-level IP Core provider specialized in FPGA-based power electronics applications.
Strategy	Supplier of third-party reusable design components aimed at programming electronic chips in embedded systems.
Means	Partnerships with high growth semi-conductor manufacturers.
Markets	Alizem’s clients are based in the United-States, except for one in Ontario.
Issues and opportunities	Alizem’s solutions take advantage of the flexibility of the technical capabilities of FPGAs and offer features that go beyond those offered by conventional motor control integrated circuits. These customizable solutions enable users to increase industrial energy savings and reliability of their products while reducing costs and time to market.

Company History

The company was launched in 2006 by Marc Perron, a 33 year old engineer who belongs to the generation of those born with a computer: "At 12, with a cousin, I launched my first company to debug computers." Marc Perron completed all his studies – bachelor, masters, and PhD – in partnership with industry. He chose to specialize in the software control of electric motors.

His doctoral thesis was on how to improve the controller architecture in order to optimize the energy efficiency of electric motors. When asked why he chose higher education, this born entrepreneur said "I got a PhD to start my own business. My doctoral thesis was the opportunity to acquire an intellectual capital in a specific area. In the knowledge economy, the real capital is knowledge."

Technology

Alizem is a vendor-independent 3rd-party system-level IP Core provider for power electronics applications in industrial, automotive and home appliance markets.

Semiconductors manufacturers now enlist groups of component suppliers that will allow developers to configure microprocessors according to the solutions required by the industrial user. Typically, developers do not want to program a microprocessor from scratch, they prefer using software applications developed by third parties. Alizem provides these applications.

Business Strategy

Alizem sells semiconductor intellectual property (IP) blocks that allow configuring of advanced integrated circuits (ICs). Its target market consists of companies who used to connect ASIC chips to printed circuit boards (PCBs) and are now adopting FPGA chips. In order to configure FPGA processors, developers need reusable, off-the-shelf, virtual components (or IP blocks).

As the cost of FPGA chips is still higher than ASIC chips, Alizem's target market is precision electric motors, rather than appliances (although the sub-sector of the high-end appliances is opening up).

Alizem partners with the manufacturers of computer chips (Altera, Microsemi) or virtual chips (ARM) in order to take advantage of these manufacturers' powerful sales forces. Each time a developer buys industrial products from these major manufacturers, Alizem's potential market grows.

Conversely, whenever Alizem creates new IP blocks, it enriches the large manufacturers' ecosystems; it allows them to differentiate themselves. They have a vested interest in promoting Alizem products and services to their customers.

Issues

The benefit of virtualization is the immediacy of the business process. Alizem configures and tests in advance each IP block. When an order is placed, the customer instantly receives the required IP block, instead of waiting months for the delivery of a physical chip, or to carry out its internal development.

The acceleration of the product life cycle imposes shorter and shorter deadlines for the delivery of embedded systems. Alizem preconfigures, pretests and preprograms IP blocks that addresses today market needs.

Bombardier Transportation *

1101 Parent Street
Saint-Bruno-de-Montarville, QC
J3V 6E6
Tel. (450) 441-3025
http://www.bombardier.com/en/transportation

Interview	Paul Larouche, Director Product Management	
Contact	Idem	
Data	▶ *Founded*	▶ Bombardier (Group): 1942 Bombardier Transportation: 1973
	▶ *Headquarters*	▶ Bombardier (Group): Saint-Bruno (QC) Bombardier Transportation: Berlin (Germany)
	▶ *Number of employees*	▶ Bombardier (Group): 65 400 Bombardier Transportation: 34 900 Bombardier Transportation (Canada): 2 200[61]
	▶ *Employees in embedded systems*	▶ Bombardier Transportation : ± 130
	▶ *Products*	▶ Wireless systems, sensors
	▶ *Clients*	▶ Railroad and public transport companies
Mission	Optimize safety, efficiency and environmental performance of rail vehicles	
Strategy	Integration of heterogeneous subsystems in a product that is more effective, efficient, safe and environmentally friendly.	
Means	Automation controls and real-time measurement capabilities of the vehicle (temperature, lighting, doors close ...)	
Markets	Rail and mass transit operators	
Issues and opportunities	Increased reliability and reduced maintenance costs.	

Company History

- Bombardier entered public transports in 1973 with the production of cars for the Montreal subway system that was being expanded in view of the 1976 Olympic Games.
- At the time, Bombardier was a snowmobile manufacturer. Its main plant was located in La Pocatière in the region of Lower St. Lawrence and was underutilized because the snowmobile market had collapsed; moreover, the production of Moto-Skis had been transferred to Valcourt, in the Eastern Townships.
- The La Pocatière plant specialized in the manufacturing of small recreational products in large quantities, while transit transport requires much more complex products, but in relatively small quantities. The then president of Bombardier, Laurent Beaudoin, opted to engage the company in public transit.
- The birth of embedded computing dates back to 1987 when Bombardier was awarded a contract for the provision of 72 cars for the Walt Disney World Monorail System in Florida. The challenge was to create a brand new train without increasing the initial train's weight, because the infrastructure would remain the same. The solution was to reduce the internal complex wiring with the development of an avant-garde multiplex communication system.
- Bombardier's start in the embedded systems technology was made possible by a dual approach: hiring computer specialists internally and partnering with external suppliers,

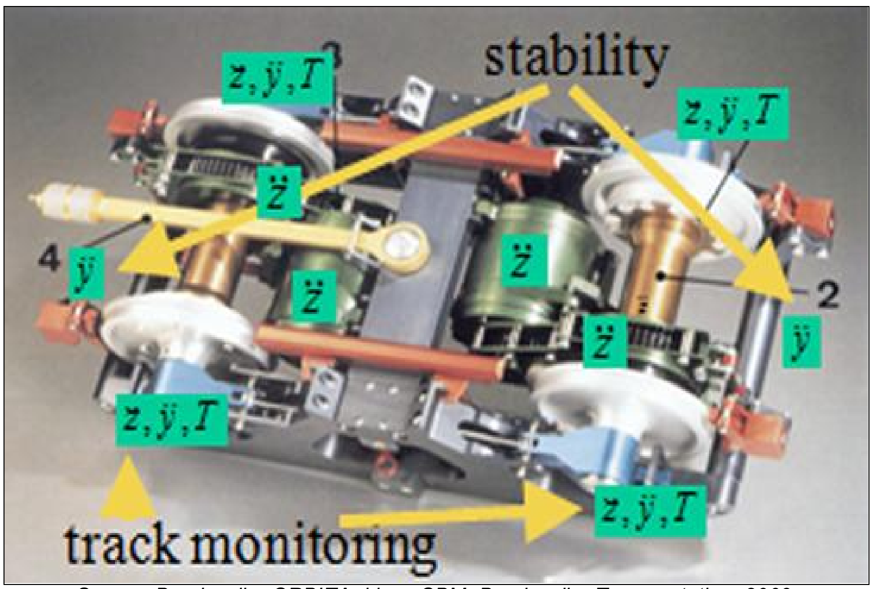
[61] Michael Renner and Gary Gardner, Global Competitiveness in the Dail and Transit Industry, Worldwatch Institute/Northeastern University, September 2010, 34 pages. Cf. p. 15.

especially the firm Axion Technologies (then Pocatec) based in L'Assomption, region of Lanaudière.

Technology Platform

The central embedded system has continually been evolving since the initial multiplex system. Today, the intelligence of Bombardier's rail vehicles is contained largely in the Train Control and Management System (TCMS). This is a high capacity infrastructure based on an open standard IP technology, with multiple interfaces to different systems that are distributed in the train, such as doors, pantograph, HVAC (Heating Ventilation and Air Conditioning) among others. TCMS allows a homogeneous control and monitor of all train internal communications and control mechanisms.

FIG. 45 – CONTROL OF A BOGIE ON A BOMBARDIER VEHICLE



Source: Bombardier ORBITA drives CBM, Bombardier Transportation, 2009.

Organization Chart

Bombardier Transportation's expertise in embedded systems projects varies according to projects and the expansion of the company. However, we can distinguish two main groups:

1. The Software Development Group (SDG) is located at the St. Bruno headquarters. About thirty people are specialized in designing, developing and maintaining embedded software for trains and subways, mainly monitoring systems used for the collection of all data types needed for control, security and passenger information e.g. data from surveillance cameras, passenger announcements, data to control the operation of the train and coaches (doors, propulsion, lighting....).[62]

2. The Competence Center for High Power Propulsion and Control, which is responsible for the development of the permanent magnet motor (MITRAC) that serves not only to power trains, but also offers smart features (remote diagnostic systems, propulsion control, etc.). The MITRAC solution includes TCMS in order to provide a powerful processing capability

[62] Nabil Berrhouma, Claude Y. Laporte, Mikel Doucet et Alain April, "Mesure du coût de la qualité logicielle d'un projet d'envergure de la société Bombardier Transportation", *Revue Génie logiciel*, Paris, N°88, mars 2009.

and a very high bandwidth for the real time exchange of data, both throughout the train and with the outside world, via up to date mobile communications. The Competence Centre is based in Zurich (Switzerland) and includes hundreds of experts spread across a dozen centers around the world.

Business Strategy

- Bombardier Transportation acts as a systems integrator. To successfully integrate the final product which is a train, the company must have a thorough knowledge of all the subsystems – in this case: embedded systems. This is the only real protection against supplier default. If a supplier for one reason or another is unable to deliver the required embedded system, Bombardier takes over and produces the embedded system internally.
- The MITRAC/TCMS Technology is used both on Bombardier new trains generation, and sold to other transport manufacturers.

Issues

Two major issues can be distinguished:

1. The intelligent platform MITRAC/TCMS enables train-to-wayside communications (access to remote data), and application engineering for commissioning and maintenance of rolling stock. Thus, an increasing portion of embedded systems in rail vehicles is passive (sensors only). Intelligence tends to be concentrated in remote servers that are located at the railway or transit operator facilities or at a Bombardier centre.

2. The equipment designed by Bombardier has a life expectancy of 40 years. Bombardier's customers want guarantees that the operating system of the all the embedded systems can be updated and run for that time period. In this perspective, they want a guaranteed access to source code MITRAC/TCMS. On the contrary, Bombardier wants to prevent its customers or third parties to perform changes to the embedded systems that may incur its corporate liability in case of an accident. All Bombardier contracts include the appointment of a well established Escrow agent who is committed to keep all the source codes and their user manuals for the life time of the concerned equipment. The Escrow agreement provides for release of the source code to the customer only in specific limited circumstances such as the supplier's bankruptcy.

Celestica

844 Don Mills Road
Toronto, ON M3C1V7
mandrade@celetica.com
www.celestica.com/globalsolutions

Contact	Mike Andrade, Senior Vice President and General Manager	
Interview	John Sandhu, Sr. Director, Product Development Services, Boulder, CO, USA	
Data	▶ *Headquarters (Canada)* ▶ *Activity* ▶ *Technologies* ▶ *Employees* ▶ *Revenues* ▶ *Markets*	▶ Toronto, ON ▶ Electronics Manufacturing Service (EMS) ▶ Design, manufacturing and updating embedded systems ▶ Worldwide: 35 000; Canada: 4 600 ▶ Embedded in Canada: 100 + ▶ $6.5 G ▶ Global
Mission	Celestica product development services mission is to help customers develop their products.	
Strategy	Celestica moves from pure electronics manufacturing to provide the entire development process (vertical diversification).	
Means	1) The company goes back to previous stages of its *production cycle (design and architecture) and to* subsequent stages of the same cycle (after market and back-end). 2) Acquisition: In 2010, Celestica acquired Invec Solutions (UK) to enhance its after-market services offering, and Allied Panels (Austria) to enhance its healthcare offering; in 2011, it acquired Brooks Automation (US) to strengthen its industrial market offering, (complex mechanical and systems integration services).	
Benefits/ Issues	Celestica's services help OEMs reduce (1) their operating costs and invested capital, and (2) their time-to-market, resulting in lower product lifecycle costs, better financial returns and improved competitive advantage in their respective business environments.	

<u>History</u>

Celestica's Toronto headquarters were originally the location of IBM's Canadian head office, which also supported a small a manufacturing unit. In January 1994, as IBM transitioned from a hardware company to a software and service company, it formed Celestica as a wholly owned subsidiary. In October 1996 IBM Canada sold the business to Onex. This triggered rapid expansion at Celestica.

In July 1998 Onex took Celestica public, raising $414 million, which was the largest IPO in the EMS field. This infusion of capital sparked another round of growth that lasted until the dot-com and telecoms crash in 2001. The company had to lay off thousands of employees. Operations stabilized, along with the rest of the market, through 2008.

Today, Celestica's global manufacturing network comprises more than 40 locations in the Americas, Europe and Asia. The company's global services include design and engineering, manufacturing and systems assembly, fulfillment and after-market services. Celestica also holds a contract for Xbox 360 console repairs for defective units produced in Canada.

Services

Celestica is an Electronics Manufacturing Service (EMS) company. However, more and more its services encompass all phases of the product life cycle:

1. Design: Celestica's involvement in a project starts at the very beginning with technology consulting. Its services will range from providing design services (do the design according to the customer specifications) and design analysis (predicted performance of the product) to more typical industrialization services (design for manufacturability, design for testability, design for supply chain...).

2. Production: Celestica builds prototypes and does the testing, and when it gets closer to manufacturing, it makes specials tools and develops test systems to be used in the factory (in-circuit test, functional test, environmental test...). Celestica develops these systems and deploys them in its factories and then the new product enters the manufacturing phase.

3. After market: Celestica also provides sustaining engineering services to the customer as its final product with the embedded system goes through its life. It can help the customer deal with obsolescence problems when, for example, a new generation of microprocessors hits the market. It can also help the customer deal with issues related to environment regulation such as RoHS (Restriction of Hazardous Substances Directive) and WEEE (Waste Electrical and Electronic Equipment Directive). A company may have a product in production and when an environmental standard comes into play, the entire design has to be modified.

4. Back-end: Celestica provides repair services. It has repair depots around the world.

Technology

Celestica offers a wide range of advanced manufacturing technologies, test capabilities and processes to support customers' needs. As it deals with the customer across a broad segment of industries, it can provide tools and processes that have already been used in many circumstances.

To assure a safe provisioning of its customers, Celestica has developed strong ties with several partners. For example, Intel is a very strong partner for the enterprise business segment, particularly in the computing space: servers and storage controllers. Similarly, Celestica often works with Freescale in the communications segment.

Market

Celestica depends upon a relatively small number of customers for a significant percentage of its revenue: its top 10 customers represented 72 percent of its total revenue. To reduce this reliance, it is currently targeting new customers and new services in its traditional markets, as well as expanding in new markets such as industrial, aerospace and defence, healthcare and green technology.

Embedded systems activities are divided into five verticals:
1. Aerospace: avionics and entertainment.
2. Defence: network warfare, missiles control, military aircraft and many small sub-segments.
3. Health tech: Celestica has a focus on diagnostic and imaging (ultrasounds, computed radiography, digital radiography, film printing...) and personal monitoring.
4. Green tech: renewable energy (solar and wind), smart grid, and new sources of energy.
5. Industrial: very broad segment that goes from ATM to factory automation.

Competition

Celestica competitors include Benchmark Electronics, Flextronics International, Hon Hai Precision Industry, Ltd., Jabil Circuit, Plexus, and Sanmina-SCI, as well as smaller EMS companies that often have a regional, product, service or industry-specific focus. In addition, original design manufacturers (ODMs), companies that provide internally designed products to OEMs, continue to increase their share of outsourced manufacturing services across several markets and product groups, including personal computer motherboards, servers, notebook and desktop computers, and smartphones and cell phones.

Internal Organization

There are three design entities in Celestica:

- Global Design Services that handles the enterprise communication and storage products that are done on a roadmap JDM model (Joint Design Manufacturing). This team of about 240 people is mainly in Taiwan and Singapore, but none in Canada.
- Product Development Services » has more than 150 people scattered around the world which are dedicated to customized embedded systems. This group is growing rapidly and should reach 350 in the next four years.
- On top of that, there are services of industrialization of design. They are in the Test Development Services, and Assembly Technology Services. It is the biggest group. In Toronto only there are more than 100 people in industrialization of design.

At least 50% of its work is R&D.

In the embedded system area, Celestica has customers in the aerospace industry in Toronto, several customers in Ottawa.

Issues

Celestica is maximizing corporate value creation by adding architecture design and product development to regular manufacturing. One of the means is company acquisitions; the other is hiring highly qualified manpower.

CertiChip Inc

585 Leighland Drive
Waterloo, ON
N2T 2K2
Manoj.sachdev@certichip.com
www.certichip.com

Contact	Manoj Sachdev, President	
Interview	Idem	
Data	▶ *Headquarters* ▶ *Activity* ▶ *Technologies* ▶ *Employees* ▶ *Revenues* ▶ *Markets*	▶ Waterloo, ON ▶ Digital circuit design, mixed-signal circuit design, test and manufacturing issues of integrated circuits. ▶ Development of circuit designs which significantly improve the soft-error robustness in CMOS circuits. ▶ 1 ▶ n. a. ▶ Microelectronics industry
Mission	CertiChip is a semiconductor intellectual property (IP) company specializing in circuit techniques and architectures to improve the robustness of integrated circuits (ICs) manufactured in advanced CMOS processes at or below 90 nanometers.	
Strategy	CertiChip develops and patents logic and memory IP that is either resistant to or immune from single-event upsets (SEUs). It holds more than 4 granted pending US patents in the broad area of VLSI circuits.	
Means	Licensing the rights to semiconductor companies.	
Benefits/ Issues	Allow semiconductor companies to produce smaller VLSI circuits that are at the same time more robust.	

History

University of Waterloo professor Manoj Sachdev has performed research on low power and high performance digital circuit design and has filed several patents on robust circuits for nanometric CMOS circuits. In 2008, he created CertiChip with the help of two colleagues in order to commercialize the concept. The new company received seed money from the OCE Commercialization program which is aimed to address the "innovation gap" between valuable research results and the new, marketable products and services that drive economic growth.

Technology

The basic concept is simple: increased miniaturization makes integrated circuits fragile not because of design errors, but because of environmental radiation (also called soft errors) caused by high-energy particles. CertiChip technologies can mitigate the impact of radiation in the integrated circuit through innovative circuit design.

Market

All semiconductor companies are potential clients. In particular, companies designing integrated circuits for high reliability applications are the target. These include aerospace, bio-medical, and telecomm domains.

Issues

After some initial success, CertiChip needs an influx of cash flow to expand its operations. It is now looking for a second round of financing through white angels.

Another way to address the financing issue is through licensing the patents to logic libraries providers, but CertiChip lacks a marketing force.

CIMEQ

150 Duquet Street
Ste. Thérèse, QC
J7E 5B3
450-971-7820
www.cimeq.qc.ca

Contact	François Verdy Goyette, MBA	
Interview	François Verdy Goyette, MBA	
Data	▶ *Headquarters:* ▶ *Activities* ▶ *Employees* ▶ *Market*	▶ Ste. Thérèse ▶ Design of hardware and software up to pre-production prototype ▶ 20 ▶ Quebec, exports early stages
Mission	- Applied research to promote technology transfer to corporations. - Internally, allowing teachers to reflect the industry reality and students to do internships.	
Strategy	SME management	
Issue	Identify the most efficient technologies and practice of technology transfer by minimizing the risk to clients.	

Context

The Quebec Microelectronics Innovation Centre (CIMEQ)[63] is a non-profit organization (NPO) established in 1983 on the Lionel-Groulx College campus. The CIMEQ belongs to network of college centres for the transfer of technology (CCTTs) which specialize in microelectronics. More than 75 percent of its activities are related to embedded systems.

There are 46 CCTTs in Quebec regrouped in the Trans-Tech Network. The CCTT are organizations recognized by the Ministry of Education, Recreation and Sports (MELS) and the Ministry of Economic Development, Innovation, Export and Trade (MDEIE).

CCTTs must finance their activities by offering services in R&D, development, technical, expertise and training to the private sector. Close to 80 percent of CIMEQ activities are already self-financed. Contrary to universities, the ownership rights of R&D do not belong to CCTTs, all intellectual property rights including patents are transferred to the client corporations.

Each CCTT has a provincial mandate. Although attached to the Lionel-Groulx College, CIMEQ enjoys a wide autonomy over operational management: it can define its mission and its development strategy in the areas of applied research in microelectronics. It is managed as a small business.

CIMEQ does not compete with other CCTTs. On the contrary, joint projects are common. Mr. Verdy Goyette, director of CIMEQ explains:

> *"We plan to create virtual clusters with the Center for Physics Technology in Pocatière and the C2T3 in Trois-Rivières. Also we are tightening our links with universities to increase the scope of our applied research. In addition, we are very close to organizations such as the CRIQ, NRC and NSERC whose activities are complementary to ours in many areas."*

[63] Centre d'innovation en microélectronique du Québec.

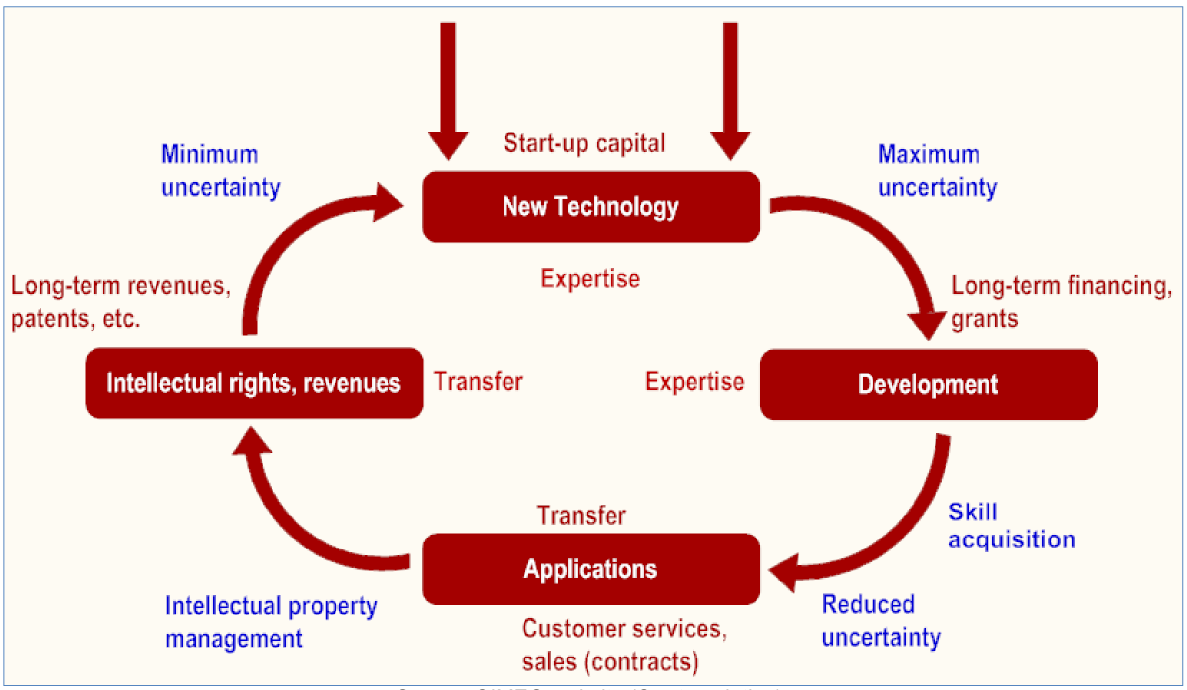
CIMEQ currently generates an average of 30 projects per year and gross revenues of about $1.3 million, and growing. According to Mr. Verdy-François Goyette, CIMEQ's performance is due to its neutral approach:

> *"When we deal with a SME, we first look for all government programs that could apply. We limit our intervention to the only domains where nothing is available. Similarly, at the end of the contract, the SME remains sole owner of the source code and all other information necessary to its project. This is not always the case in the private sector where consultants withhold proprietary information."*

<u>Mission</u>

CIMEQ's mission is to contribute to the competitiveness of Quebec companies by optimizing the business cycle "Acquisition / Technology Transfer." To remain competitive, SMEs need to take full advantage of the latest technological innovations, but in doing so they often incur considerable risk. This is where CIMEQ comes in: with funding from the government (mainly from provincial ministries), a technology watch is put in place, a highly qualified team is deployed and technology transfer to the private sector is conducted at acceptable risk.

FIG. 46 TECHNOLOGY TRANSFER CYCLE



Source: CIMEQ website (Our translation)

More and more companies from traditional industries want to incorporate microelectronics into their products but they do not know where to start. CIMEQ acts as an initiator to the SMEs from the initial project planning stage.

The range of potential projects is virtually unlimited: building automation system (BAS), intelligent transport (railways, automotive, motorcycle, bicycle ...), defence, health, eco-design, intelligent environment, not to mention smart grid solutions for public utilities.

CIMEQ coaches its commercial and industrial customers all along the process for skill acquisition in embedded systems. A typical example of this approach is that of Micro-Thermo Technologies when it was a three employee microbusiness working on freezers for supermarkets. The CIMEQ suggested the establishment of a network with distributed intelligence that can serve not only the freezers sensors, but all electrical equipment of any kind. Today, Micro Thermo's staff has grown to 60 employees including 20 in R&D. The intelligent platform designed with the help of CIMEQ is now being used in 3,000 retail outlets.

Market

CCTT's natural market is Quebec. However, the CIMEQ has some foreign contracts (smart card for Volvo in Sweden). For Mr. Verdy-François Goyette, regional expansion comes first:

> *"We participate in the Ottawa EPTECH Show each year. We intend to use the microelectronics corridor that spans from Albany to Upper New York. The creation of M2CI in Bromont with the University of Sherbrooke, IBM and Teledyne Dalsa extends this corridor on this side of the border. It is a model similar to that of the auto industry 50 years ago in Ontario."*

Companies that work with CIMEQ get a competitive advantage. In addition to tax credits from the federal and provincial governments, they can apply for a technology intensification grant of up to $50,000 per project administered by the Ministry of Economic Development, Innovation, Export and Trade (MDEIE). They also have access to an R-D scholarship program managed by the Ministry of Education. There also benefit from five free hours of engineering services offered by the NRC. In addition, what is new, NSERC offers level 3 grants ranging from $75,000 to $150,000.

Issues

Two main issues:

1. The first issue is the lack of young technicians to ensure the replacement of the current generation. There is no enrolment in technical programs: "Sensitizing students to technology is an emergency."

2. The Asian competition relies on low cost labour, but it has disadvantages (distance, delays, confidentiality, intellectual property issues...). For the same price, companies prefer to deal with Canada-based suppliers. CIMEQ encourages its customers to cooperate on non-competitive projects and to lodge joint purchase orders in order to spread costs and obtain better discounts on electronic components.

Écono-Fan

389 Principale Street
Upton, QC
J0H 2E0
(450) 549 4587
info@econofan.com
http://www.econofan.com/

Contact	Mathieu Durand	
Interview	Mathieu Durand	
Data	▶ *Activities* ▶ *Employees* ▶ *Markets*	▶ Management of animal farming environment (ventilation) ▶ 4 ▶ Canada and France
Mission	Develop low fan power consumption	
Strategy	Market development and R-D	
Issues	In the short term, convince Hydro-Québec that Econo-Fan products are reliable and should be eligible for grants.	

Company History

Based in Upton (100 km east of Montreal), Econo-Fan was founded in 2008 out of the R&D department of a company specialized in ventilation systems for livestock operators (poultry farming, pig farming and egg production). The mother company was in business since 1985 to produce and install traditional fans for livestock. Later on, the company diversified into heating, ventilation and air conditioning (HVAC) for greenhouses.

Technology

Econo-Fan entirely designs, develops and builds embedded systems through the prototype phase in its own facilities – manufacturing per se is outsourced to a local foundry. The new Econo-Fan products control the ventilation according to outside temperature, the quantity of fresh air required, and the cost of the electrical power. In a way, the embedded unit acts as a smart thermometer.

This technology is ideal for northern countries (southern countries can benefit from natural ventilation throughout the year). Econo-Fan employs a full time R&D technician on improving the environmental management software.

Strategic Positioning

Econo-Fan defines itself as a livestock products manufacturer. Its clients range from the independent family farm to large corporations owning more than 100 pig farms that employ hundreds of people.

Econo-Fan has diversified its sales to France with a new product line: stale air exhaust extractor fans equipped with an energy saving motor. A sales office was opened in Rennes, Brittany.

Econo-Fan products are so successful in France that a local economic development agency is contemplating the idea of imposing an Econo-Fan quality standard in the tender specifications for new farm building construction.

Issues

Hydro-Quebec has so far refused to take into account energy savings achieved by the users of Econo-Fan products. The public utility is not yet convinced of the benefits of the product. This means Econo-Fan customers do not get the rebate available for using energy efficient products. However, in the coming months, Hydro has said it will consider testing the Econo-Fan innovation in the agricultural sector.

Gentec

2625 Dalton Street
Quebec, QC
G1P 3S9
Tel. (418) 651-8000
www.gentec.ca/

Interview	Yannick Chartrand, design engineer	
Contact	Idem	
Data	▶ *Creation* ▶ *Headquarters* ▶ *Number of employees* ▶ *Employees in embedded systems* ▶ *Products* ▶ *Clients*	▶ 1959 ▶ Quebec City ▶ 135 ▶ 135 ▶ Energy management systems + Engineering services & manufacturing ▶ Industrial corporations and public utilities
Mission	Optimize energy efficiency of its clients' products.	
Strategy	Develop exports through partnerships with multinationals.	
Means	Web site, agents and partnerships.	
Markets	Public utilities, industrial firms.	
Issues/Opportunities	Gentec solutions bring energy savings to its clients and add new features to their products and services. Gentec solutions pay for themselves (win-win proposition).	

Company History

Gentec was founded in 1959 by Theodore Wildi, a professor at the Department of Electrical Engineering and Computing at Laval University. An outstanding personality, this pioneer of microelectronics in Quebec also established the company Lab-Volt and founded the School of Industrial Electricity; a serial innovator, he held over 20 patents to his name and was the author of several books in the field of electronics.

The company first worked on mechanical and electrical systems, as well as welding tools for printed circuit boards intended for the education sector. Subsequently, the company evolved into the development of industrial battery chargers and laser manufacturing and measurement. In 2000, the thermal laser power/energy measurement division became an independent company under the name of Gentec Electro-Optics (Gentec-EO).

Today, Gentec inc. specializes in the design and manufacture of electronic solutions for energy management, data acquisition and signal processing. Since its inception, the company has established and expanded its strategic supplier relationship with Hydro-Quebec. It now exports to the United States, Chile, Vietnam, Iceland, Island of Guam and Cameroon. The current Gentec president, François Giroux, also holds a stake in Gentec-EO.

Products and services

Gentec is both an original equipment manufacturer (OEM) and a provider of electronic manufacturing services (EMS).

1) As an OEM, Gentec designs and manufactures five lines of standard products:

- Data acquisition systems for electrical distribution stations. Gentec's solutions measure, monitor or control events in a given industrial environment.
- Industrial power systems: Battery chargers and inverters used with switchgear, motor starters and process control systems in industrial and public utilities substations.
- Capacitors: From pre-packaged, pre-designed capacitors to custom-engineered harmonic filter capacitor banks, Gentec has a range of power factor correction equipments that meet all the needs of power correction and power quality.
- Energy management: Called Ambiance, the Gentec's integrated energy management system will help control energy costs while preserving the environmental comfort of commercial buildings (shopping centers, hotels and restaurants, hospitals and nursing homes, or any other type of buildings).
- Lighting control: The Kameleon line offers a wide range of solutions to suit any lighting control requirement (from SMEs to large corporations).

Each of these solutions is built around an embedded system and developed through full prototyping phase. Whenever possible, Gentec avoids storing large inventories of equipment. Since Gentec provides highly technical and specialized solutions that cater to unique business needs, the final product must include a balance of custom development (typically software) and off-the-shelf-components.

2) Gentec offers its engineering services to companies which do not want to maintain a full research department but still need to develop and use embedded systems. It can also work on special projects where companies look for expertise not included in their R&D facilities. Examples of this situation are provided by the current Hydro-Quebec CATVAR project which involves setting up a system for voltage regulation and reactive power control in order to reduce energy losses; or the AddÉnergie Technologies charging stations (see below).

Technological Platform

Gentec is now migrating to standard platforms for embedded systems. Previously, every time a product was developed, all the features of the embedded system were programmed from scratch. As a result, each PCB had its own code, but now, there are companies that specialize in creating standard platforms for embedded systems. Gentec is about to adopt the QNX Software Systems platform, that is to say, the QNX Neutrino microkernel. The microkernel allows developers to activate only the required features – if they want to add extra features, they just turn on the inactivated features or download them from a shared library, without having to change the OS itself. The minimal complexity of the microkernel makes it an ideal solution for embedded systems.

The transaction between Gentec and QNX is purely immaterial. Gentec purchases an access license to the Neutrino microkernel that can run on most microprocessors on the market (AMCC, Atmel, Freescale, IBM, Intel, Kontron, Texas Instruments ...). This OS, which remains the same from project to project, has been tested and ensures that developers start their projects on an error-free basis. Applications can then be programmed for any specific embedded system without having to start from scratch. Furthermore, it creates a consistent basis from project to project.

The new platform is expected to run on a Freescale microprocessor that provides enough power for sophisticated applications. In addition, Freescale systems are tailored to suit embedded systems increased communications needs.

Embedded systems are manufactured in-house. Gentec prefers to use its own production line rather than to outsource, because its solutions are highly specialized and targeted at a niche clientele (production limited to a few thousand units).

Business Strategy

Gentec is a major strategic supplier for Hydro-Quebec. It is present in all major projects of the public utility. Recently, Hydro-Québec launched the CATVAR project whose objective is to reduce consumption and energy losses in the distribution network by maintaining a stable end-of-line voltage close to the lower threshold of 110V. This must be done without compromising the quality of service - the expected energy savings will be about two terawatts / hour. Approximately 2000 units of remote controlled cabinets for capacitor banks will need to be installed on the network by 2015.[64] Gentec received the order to supply both products for Hydro-Quebec's distribution system.

The bulk of Gentec's production such as the data acquisition and industrial power systems are sold in Quebec, but certain products, such as the Ambiance line (energy management) has a large customer base in the rest of Canada and the United States.

Gentec's geographic expansion uses two channels:

- an e-commerce website with secure extranet capabilities available to customers,
- an international sales team with a local presence.

Gentec remains a North-American player, despite some breakthroughs overseas (Chile, Vietnam, Iceland, the island of Guam and Cameroon).

President François Giroux recently announced plans to expand sales to the world through a strategy of partnerships with multinational corporations[65]. Negotiations currently taking place encompass all avenues, including the sale of Gentec products under its multinational partners. Such a move would reinforce the EMS component of Gentec activities.

This expansion has been prepared for a long time as evidenced by the implementation in 1995 of the ISO 9001 quality management standard, a commitment that was reiterated in 2001 by the upgrade to ISO 9001: 2000 version. The implementation of an international standard assures customers of Gentec's commitment to quality management and guarantees that its products will consistently meet their design specifications.

New business venture

Gentec has entered into a partnership agreement with AddÉnergie Technologies to produce a charging station for electric vehicle and plug-in hybrid adapted to the robustness of the northern climate. The two Quebec companies pooled their expertise for a stake in this promising industry. Gentec took charge of all the charging station electronics and software design. The first charging stations of the SmartTwo family of products were commissioned in August 2011 by Communauto, the oldest carsharing service in North America. A first group of 200 beta-testers were able recharge the new Nissan Leaf (100 percent electric technology) on a network of 10 parking stations (interior and exterior) in Montreal and Quebec City where the charging infrastructure was implemented with the help of Hydro-Quebec.

SmartTwo is an intelligent terminal that allows Communauto users to fill electricity by inserting their membership card into the ID player. Once the card is processed, the member has access to the gun that plugs into the car and the filling is exactly the same way as in a gas station. This terminal is designed for northern climates where temperatures range from - 40 º C to + 65 º C. After five months of experimentation backed by the beta-testers strong enthusiasm, Communauto opened its self-serve electric vehicle fleet in January 2012 to all Montreal/Québec City 25,000 current members.

[64] "CATVAR: Distribution System Voltage Regulation and Reactive Power Control" Hydro-Quebec, March 2010 - http://www.hydroquebec.com/innovation/en/pdf/2010G080-28A_CATVAR.pdf
[65] Aude Marie Marcoux, "Gentec mise sur des partenariats avec des multinationales", *Les affaires*, 21 April 2011.

FIG. 47 – THE ADDÉNERGIE/GENTEC ELECTRICAL VEHICLE CHARGING DOCK

SmartTwo charging station equipped with a Gentec embedded system

As this is an emerging technology, the challenge was to develop a product in the absence of software and microelectronic standards and, on the contrary, in the presence of a profusion of competing models none of which are compatible with the other. The situation is made more complex because the major brands of cars - including Nissan - also produce their own charging stations. For entrepreneurs, the result is a very fluid situation, where time is of the essence, and quality is an absolute requirement.

Starting now, the two partners, AddÉnergie and Gentec target the international market with special emphasis on the Nordic countries – the rest of Canada, the northern United States, Scandinavia, Japan and northern China. But temperate or hot countries are not excluded. Initially, the terminal will be deployed in public and private parking lots (hotels, commercial buildings, industrial sites, etc.) to ensure the simultaneous recharging of several electric vehicles.

<u>Issues</u>

Gentec has a recognized expertise in a wide range of microelectronics solutions adapted to energy supply. As the world economy is entering a phase of depletion of fossil energy resources whose prices are doomed to increase, the need for general energy efficiency and for fossil energy replacement should explode in the coming years.

In both circumstances, business opportunities will multiply for Gentec, in Canada and the United States, as in the rest of the world. Gentec's challenge is to create a distribution network capable of exploiting the potential of its highly specialized and promising niche it occupies.

IBM Canada (Bromont)

23 De l'Aéroport Blvd.
Bromont, QC
J2L 1A3
Tel. (450) 534-7073
TUTUwww.ibm.com/ca/en/

Contact	Dave Danovitch, senior engineer	
Interview	Idem	
Data	▶ *Creation* ▶ *Headquarters* ▶ *Activity* ▶ *Technology* ▶ *Employees* ▶ *Revenue* ▶ *Market*	▶ 1917 (Canada); 1911 (United-States) ▶ Markham, Ontario ▶ Chip encapsulation ▶ New generation of flip-chip testing and assembly facility. ▶ 2,800 (Bromont); 16,000 (Canada); 427,000 (world) ▶ $700 million (Bromont); $100 milliard (world) ▶ IBM internal market + electronic manufacturers
Mission	The Bromont plant's mission is to transform the world's most advanced semiconductor chips into microelectronic technologies solutions. This achievement is made possible through teamwork spread over several technology sectors – including interconnection, lab, micro-cabling, flip chips, logic testing, etc.	
Strategy	IBM has chosen to focus on manufacturing of high value-added components, such as microprocessors for computers and video game consoles (PlayStation 3, Xbox and Wii) or specific applications for markets such as networks, cell towers, etc.	
Means	Specializing in the conditioning and testing of highly complex products, such as Cell technology used in the most recent Sony PlayStation 3 gaming console or IBM's new, cutting-edge Power 7 processor. The Bromont plant can also perform large-scale product personalization. .	
Issues - opportunities	Develop the technological processes on which to build the next generation of semiconductors, in order to be able to produce in large quantities at competitive prices.	

Company History

Inaugurated in 1972, the Bromont plant is the largest IBM semiconductor assembly and testing facility in the world and the sole IBM plant in Canada. It assembles 200 types of products using 800 processes. In this state-of-the-art facility, a new production batch enters the assembly line every three minutes and a new part number is assigned every two hours. Around $700 million worth of products is exported annually

Nature of the offer

The Bromont plant uses semiconductor wafers manufactured at the East Fishkill, NY plant. Typically, IBM wafers are silicon discs with a diameter of 300 mm that are chopped into individual dies that must be tested to separate the good dies from the bad. The good dies are then flipchipped on build-up organic substrates, encapsulated and tested again so as to become qualified chips ready for use, together with other electronic components.

The Bromont plant assembles and encapsulates these die-chips on support plates called substratum. The challenge for interconnect technology is how get all the processing power out of these new super chips and turn them into something that can be used by in a real world environment.

As current chip interconnections are so small, they cannot be directly connected to a board. For example, a chip can have up to 12,000 small solder pads. When the Bromont experts want to attach the solder pads to the substratum in order to create interconnections, they must first encapsulate them as a protection against the stress, the corrosion and the heat produced by these powerful chips. Only then will the new "modules" be connected to the PCB, but this operation will be outsourced to IBM other plants or to outside suppliers. The Bromont plant specializes in first-level packaging.

Technology

The modules are increasingly manufactured with substrates made of organic materials that are more efficient than ceramic or silicon substrates. On the other hand, the thermal expansion coefficient of organic substrates is greater than that of ceramics or silicon chips, which places considerable strain on the solder joints used to attach the chip to the module.

Furthermore, each new generation of chips is more powerful than the previous one and gives off more heat. But, as temperature rises, performance degrades and reliability decreases.

Finally, regulations in the major industrial countries tend to restrict the use of lead solder in microelectronic circuits. The replacement of widely used tin-lead alloys with different lead-free alloys raises many difficulties. If new alloys remain tin-based, they must be combined with other elements such as silver and copper that are less dangerous, but also less ductile and more brittle.

To transform the world's most advanced semiconductor chips into advanced microelectronic solutions, IBM Bromont faces a triple technological challenge: reduce mechanical stress, improve heat dissipation and develop robust lead-free alloys.

R & D investments made at the Bromont plant vary between $20 and $25 million dollars a year.

Organization Chart

The Bromont plant is part of the IBM Systems and Technology Group, and works closely with US plants in East Fishkill, NY, and Burlington, VT, which make IBM’s silicon wafers. These plants operate 24/7 and transport their productions by truck. This example shows the importance of geographical proximity as an economic catalyst.

Markets

Part of the substrates or modules assembled in the Bromont plant is used in the IBM mainframes System-P (for SMEs) and System-Z (for large companies). They also play an important role in the Internet of Things. Some others constitute the basis of supercomputers like Blue Gene widely used in universities and private R&D laboratories.

Currently, a significant portion of the production is shipped to the three video game leaders for their consoles: Sony, Microsoft and Nintendo. This application where microprocessors are mounted on modules, sometimes with memories, is typical of embedded systems assembly.

Finally, IBM Bromont also manufactures application-specific integrated circuits (ASIC), which are used in unique applications that require high speed execution and can do without programmable microprocessors. Typically, these applications are used for systems such as routers and switches. IBM sells high end ASICs to telecommunications manufacturers: Cisco Systems, Juniper Networks and Huawei Technologies. Speaking of the latter Bromont engineers say jokingly: “unlike products made in China, ours are made for China”.

In total, IBM Bromont produces about 50 million microsystems per year, which means between 100,000 and 120,000 units per day. Each computer or server manufactured by IBM in the world contains at least one component from Bromont. In addition, a growing number of non-IBM products integrate components manufactured in Bromont.[66]

Partnership Strategy

The development of new generations of microprocessors has become so expensive that major silicon foundries (except Intel) tend to pool their resources. IBM has teamed up with Samsung in 2006 to create the Common Platform alliance. GlobalFoundries, AMD's former manufacturing arm, joined later. This alliance gave birth to an ecosystem of 150 companies working in sync on the development of integrated circuits with low power consumption.

The heart of the Common Platform alliance is the Albany Nanotech Laboratory where IBM invested heavily; and Samsung is about to do the same. In addition, GlobalFoundries started building a giant silicon foundry in Malta, NY that will be operational in 2012. IBM’s partnership strategy has led to the creation of an extensive semiconductors complex along the Tech Valley corridor; and Bromont, QC is located at its northern peak.

FIG. 48 – TECH VALLEY

*Tech Valley is regarded as the East Cost equivalent of the Silicon Valley. It is the home to more than 1,000 technology companies employing 50,000 people. Some estimate the economic impact to several billions of dollars. A new semiconductor plant is being built by GlobalFoundries in Saratoga County at a cost of $ 5 billion.**

[66] Jeremy Torobin, In Quebec, IBM finds a better way to get things done, Globe and Mail, Jul. 26, 2010.

* Tech Valley is the east coast version of Silicon Valley. Today, Tech Valley is home to more than 1,000 technology companies with 50,000 jobs contributing an annual economic impact in the billions of dollars. A new $5 billion semiconductor plant is being built by GlobalFoundries, in Saratoga County.

Similarly, in Bromont, IBM has partnered with Teledyne Dalsa and the University of Sherbrooke to create the MiQro Innovation Collaborative Centre (C2MI), with support from the governments of Canada and of Quebec. This major investment aims at selecting innovative technologies for cutting out the microchips, linking those to innovative packages (like 3D packs), managing heat dissipation, testing them and preparing them for shipment. The Centre will also work on designing packages for future generations of microelectromechanical systems (MEMS).

Issues

- To produce competitive products in North America (and consequently in Quebec) for the international market, IBM focuses on highly advanced systems that meet a specific need. If both of these conditions are met, North American companies can gain a global technological advantage and even reverse the offshoring phenomenon in their favor and manufacture products for Japanese companies (Sony) or Chinese (Huawei).

- The tremendous development of a new generation of highly miniaturized, powerful and energy efficient semiconductors – a perfect fit for embedded systems -- is a business opportunity for all Canadian manufacturer which use embedded systems in its products. Access to cutting-edge techniques developed in the same country facilitates the intense interactivity required all along the development of custom systems.

- SMEs not large enough to do business with industry leaders, have the opportunity to partner to place orders for off-the-shelf modules which will then be programmed to meet specific customer applications.

Space Codesign Systems

Space Codesign Systems
450 St. Pierre Street, Suite 1010
Montréal, QC
H2Y 2M9
www.spacecodesign.com/

Interview	Guy Bois, professor, École Polytechnique and founder of Space Codesign	
Contact	Idem	
Data	► *Established* ► *Headquarters* ► *No. of employees* ► *Products* ► *Clients*	► 2008 ► Montreal ► 4 ► Development tool ► Large multimedia and aerospace companies
Mission	Simplify the conception and programming of advanced embedded systems	
Strategy	University-private sector technology transfers	
Means	Conduct pilot testing with potential customers	
Markets	Multimedia and aerospace	
Issues - Opportunities	Cut development costs by half and accelerate the cycle of production	

Company History

Space Codesign is an R-D spin-off from R&D efforts originating in the Realtime and Embedded Systems Group at École Polytechnique de Montréal, where the Space Codesign technology had matured progressively to become a powerful and unique toolbox of its own. In 2008, the technology platform was transferred to a start-up and brought to the commercial level, with the support of venture capital and Polyvalor (Polytechnique's commercialization subsidiary).

Context

Space Codesign addresses the Electronics Design Automation (EDA) market. The annual EDA turnover is $4 billion worldwide and includes the design houses which develop software tools for semiconductors manufacturers (see box on page 2).

Within EDA, Space Codesign focuses on the electronic system-level design (ESL) niche which provides solutions for the design of highly miniaturized microprocessors.ESL includes both hardware and software design, it is the area where design starts to incorporate more than simply hardware. ESL represents a market of $400 million worldwide.

Currently, much of the capacity of new chips (several hundred million transistors) is simply not used for lack of appropriate tools. Space Codesign goal is to automate programming so as to allow developers to use all available capacity for a reasonable price, within a reasonable timeframe, and eliminating the many errors of manual programming.

Technological Approach

Traditionally, system hardware and embedded software were developed sequentially and the process could take up to two years. The Space Codesign ESL tool makes it possible to quickly set up a virtual platform before creating any hardware. This allows software engineers to design embedded electronic applications and system architecture specifications. Meanwhile, microelectronics engineers can continue to work in parallel on the physical platform. Production time of is cut by half.

Nortel's disappearance has left Canada with very large few foundries[67]. Furthermore, few companies use ASIC chips. Today, almost everything is done with FPGA chips that are reprogrammable circuits. This approach is appropriate for the embedded industry which mainly does custom work. Working on an FPGA chip is very different from programming software. It is like working on hardware but following an overall "pattern" which allows developers to work more quickly.

When the embedded companies work in verticals as is often the case in Canada, production series rarely run beyond 3 or 4,000 units. FPGA is integrated in the system. The chip will operate as a dedicated ASIC circuit. This results in a kind of software-hardware design that eliminates the high foundry costs of non-recurring productions.

The ESL Space Codesign tool can be applied to all platforms: the output can be either ASIC or FPGA.

Go to Market Strategy

So far Space Codesign products have been adopted as pilot projects. As its solutions are only used in large companies, the sales cycle is extremely long.

Target markets are multimedia, tablets, mobile phones, aerospace (GPS, altimeter ...), and medical equipment (pacemakers, surgical tools ...).

The companies that will use ESL tools are those who need to develop high-performance embedded systems to cope with a maximum of constraints (especially low energy consumption). This kind of embedded system is not intended for washing machines or air conditioner manufacturers.

According to Space Codesign's internal market research, 80 percent of the company's potential customers are located outside Canada (U.S., Europe and Asia). Market strategy is built on web presence and participation in vertical international conferences (European aerospace, California multimedia...).

[67] Teledyne-DALSA, which employs near 400 people, provides high-volume specialized wafer foundry services with capabilities in MEMS, CCD (image sensors), and CMOS. It is the world's 6th MEMS foundry. With about 150 employees, Edmonton-based Micralyne also manufactures MEMS for various markets (telecommunications, energy, life sciences, automotive, aerospace, and defence). It comes in 10th position in the world MEMS foundry business. Peter Clarke, "Top 20 MEMS foundries ranked", *EE Times*, April 27, 2011.

Appendix II - Questionnaire

Respondent Information

Q.01	**Last name** ……………..….. ____________ **Name of company** ……..... ____________ **First name** ………………… ____________ **Website** …………………… ____________ **Email** ……………..…….......... ____________ **Street/Place/Blvd/Ave** ….. ____________ **Phone** ………….............….. ____________ **City** ……………………… ____________ **Function**…………………... ____________ **Province** __ **Postal code** ____________
Q. 02	**Is your company …** *[Choose all that apply.]* **… developing embedded systems?** ☐ **… using embedded systems in its products?** ☐ ☐ **Other** *[Please specify]* ________________________________ *[For those who answered "Other", please go to Q.04.]*

Company Description

Q.03	**What is your company's core business?** *[Only within the embedded system domain.]* *[Please use your own words from dealing with clients. For example, it could be:* Software Design & Development, Hardware/Software Integration, Designing Hardware for Embedded Systems, Firmware/Software Design, SOC (system-on-chip) Design, Board/Layout Design...] 1 - …………………………________________________________ 2 - …………………………________________________________ 3 - …………………………________________________________ **Other activities, if any:** ________________________________
Q.04	**In what year was your company established?** *[For international corporations: Please indicate the incorporation date in Canada.]* ________
Q.05	**In what year did your company begin to work in embedded systems?** ________

Q.06	**How many full-time employees currently work for your company?** **In your home province ……………………………..** ___ **Elsewhere in Canada ……………** ___ **In foreign countries …………………………** ___ **For those who have employees elsewhere in Canada, please specify which province(s):** __________________________________ **For those who have employees in foreign countries, please specify which country(ies):** __________________________________
Q.07	*[Only embedded system employees – specialists and support – based in Canada]* **In your company, are the number of employees:** **Last year** *(2010)* / **In 2011** *(forecast)* Increasing …………………………………………………… ☐………………… ☐ . Decreasing …………………………………………………… ☐………………… ☐ Stable ………………………………………………………… ☐………………… ☐ Don't know/Not sure ………………………………………… ☐………………… ☐

Q.08	**In your company, what proportion of your workforce (specialists and support) is allocated to:** *[The sum of the numbers entered must equal ±100.]* **Embedded systems** ……………………………………………___% **Other domains** ………………………………………….___ percent

Company Activities

Q.09	**Do you outsource part of your activities :** **YES ☐ NO ☐ Don't know yet / Not sure ☐** **If you answered "YES", please specify what domains:** __________________________________ *[For those who do not outsource, skip the two following questions. Please go to Q.12]*
Q.10	*[For those who outsource part of their activities.]* **Where are your subcontractors located?** **In your home province** …………………… ☐ **In Europe** ……………………………… ☐ **Elsewhere in Canada** …………………… ☐ **Other countries** ………………………… ☐ **In the United States** …………………… ☐ **Don't know** ……………………………… ☐ **For those who answered "Elsewhere in Canada", please specify what provinces:** __________________________________ **For those who answered "Other countries", please specify what countries:** __________________________________

Q.11	**Why do you outsource?** *[Choose all that apply.]* ***Reduce manpower cost ....*** ☐ ***Looking for specialized skills and abilities ....*** ☐ ***Access to equipment and facilities ....*** ☐ ***Other ....*** ☐ **If you answered "Other", please specify:** ______________________________
Q.12	**How would you describe your current embedded projects?** *[As a percentage of your embedded system activities.]* **New to the world (a new project from scratch)** ....__ **%** **Upgrade or improvement from existing products** ....__ **%** **Other** ....__ **%**
Q.13	**What microprocessor do you currently use in your embedded system projects?** *[For example,: ARM, Freescale, Texas Instruments, Intel, Atmel, Microchip, Xilinx, AMD, Altera...]* ______________________________ **What is most important when choosing a microprocessor?** *[For example: the chip's performance, its cost, the operating systems it supports, software development tools available, power consumption, supplier's reputation, the processor's debug support, familiarity with architecture...]* ______________________________
Q.14	**What Operating System do you currently use in your embedded system projects?** ☐ **… commercial OS** (Windows, Wind River, Texas Instrument DSP/BIOS...) ☐ **… open source OS** (Free RTOS, Linux Debian, Red Hat…) ☐**… internally developed OS** ☐**… does not need an OS** **If you use a commercial OS or an open source OS, please specify:** ______________________________
Q.15	**What programming languages do you most often use in your embedded system projects?** *[For example, C, C++, Assembly Language, Java, BASIC, XML …]* ______________________________

Market Information

Q.16	**Who are your main clients?** *[Choose all that apply.]* **Companies of more than 500 employees** ☐ **Companies of 50 to 499 employees** ☐ **Companies of 10 to 49 employees** ☐ **Companies of 1 to 9 employees** ☐

Q.17	**What percentage of your clients work in...** *[For example:* Aerospace, Automotive, Defence, Gaming, Education, Computers & Peripherals, Energy, Health, Mobile Telecommunications...*]* **1 - ______________________ .... %** **2 - ______________________ .... %** **3 - ______________________ .... %** **Other sectors if any:** ______________________
Q.18	**What percentage of your sales do you ship to…** **…your home province ……… __ percent** **…elsewhere in Canada …….. __ percent** **… the United States ………… __ percent** **… other countries …………… __ percent** **For those who answered "Other countries", please specify what countries:** ______________________
Q.19	**How would you qualify your sales in 2010?** *[Embedded systems only.]* **☐ Increasing ☐ Stable ☐ Decreasing ☐ Don't know**
Q.20	**Do you intend to diversify your activities to new economic sectors?** *[For instance, aerospace, automotive, telecommunications…]* ☐ **YES,** this coming year **(2011)** ☐ **YES,** within two years **(2013)** ☐ **NO** ☐ **Don't know yet / Not sure**
Q.21	**If you answered "YES", please indicate what sectors:** ______________________
Q.22	**Do you intend to diversify your activities to new geographic markets?** *[For instance, elsewhere in Canada, in the United States, other countries …]* ☐ **YES,** this coming year **(2011)** ☐ **YES,** within two years **(2013)** ☐ **NO** ☐ **Don't know yet / Not sure**
Q.23	**If you answered "YES", please indicate what markets:** **Elsewhere in Canada ……………………. ☐** **In the United States …………………… ☐** **Other countries …………………………. ☐** **Don't know ………………………………. ☐** **For those who answered "Other countries", please specify what countries:** ______________________

Corporate Strategy

Q.24	**Does your company conduct R&D?** **YES ☐ NO ☐ Don't know ☐** **If YES, how many employees are allocated to R&D?** *[Researcher-year equivalent.]* _______ *[If NO, please go to Q.26]*
Q.25	**Please indicate in broad terms the research fields pursued by your company:** *[E.g. user interface, power consumption, improving the debugging process, time to market, etc.]* ____ ____
Q.26	***Does your company collaborate with a university*** or college? **YES ☐ NO ☐ Don't know ☐** **If YES, please describe the nature of the relationship:** *[For example, research contracts, internship recruitment, co-op program...]* ____

Q.27	Are you looking for financing? YES ☐ NO ☐ Don't know ☐ **If YES, what financing source do you anticipate using?** *[Venture capital, angel investors, bank financing, or public sector financing such as Business Development Bank of Canada* programs, etc.] ....
Q.28	**What are the main obstacles facing the Canadian embedded system industry today?** ☐ Regulation ☐ Recruitment of skilled staff ☐ Financing ☐ Lack of government support ☐ Lack of available information on markets ☐ No particular obstacle ☐ Other
Q.29	**For those who answered "Other", please specify:** ____ ____

Q.30	**Have you already attended conferences related to embedded systems?** *[Embedded Systems Conference (Silicon Valley), ARM Tech Con, Freescale Tech Forum, Real Time Computer Show (RTECC), Embedded Systems Conference (Boston), Intel Developer Forum, DesignCon, CeBIT...]* YES ☐ NO ☐ Don't know ☐ **If YES, please specify:** ____ **If NO, please give your reasons:** ____

DO NOT FORGET TO RETURN YOUR QUESTIONNAIRE

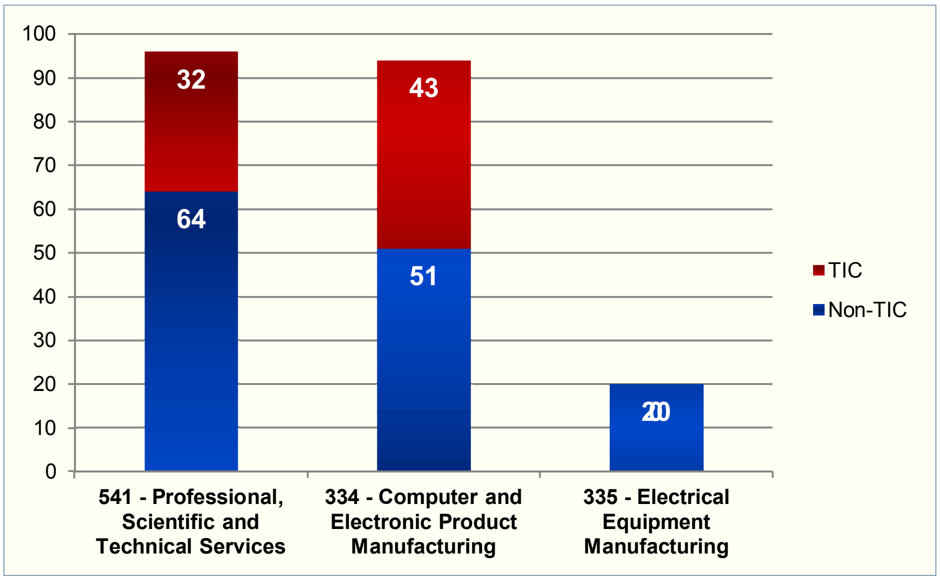
SERVICE@CATA.CA

THANK YOU !

Appendix III Where to classify embedded systems firms?

The hybrid nature of many of the companies that design and develop embedded systems explains the difficulty of classification.. When we look at the classification of the embedded systems domain by Industry Canada, the vast majority of the 188 respondents are classified in categories unrelated to information technology and communications (ICT). The categories 541 and 334 are hybrid and non-ICT ICT. But the category 335 is a non ICT one. Yet 20 companies reported activities under the Electrical Equipment, Appliance and Component Manufacturing.[68]

FIG. 49 – CLASSIFICATION BY NAICS CODES



Source: Industry Canada (compiled by CATA Alliance/Sciencetech communications)
Absolute numbers – Some companies have more than one activity.

This confirms microelectronics' nature of embedded developers. Only three respondents had activities in the category 511210 – software publishers. This same observation shows an electrical equipment manufacturing category, which is natural since a significant portion of embedded computing was born in the power motor systems (uninterruptible power supply or rectifier, charger, amplifiers, voltage calibrator, etc..).

This classification of several activities at the heart of embedded computing in non-ICT categories has a direct impact on how we measure the information economy: ICT is by definition under-represented to such an extent that it appears marginal to the economy. This why Industry Canada can list in its page on the ICT sector:

> In 2009 ICT sector GDP was $59.4 billion. This represents (...) the source of 5.0 percent of Canadian GDP.[69]

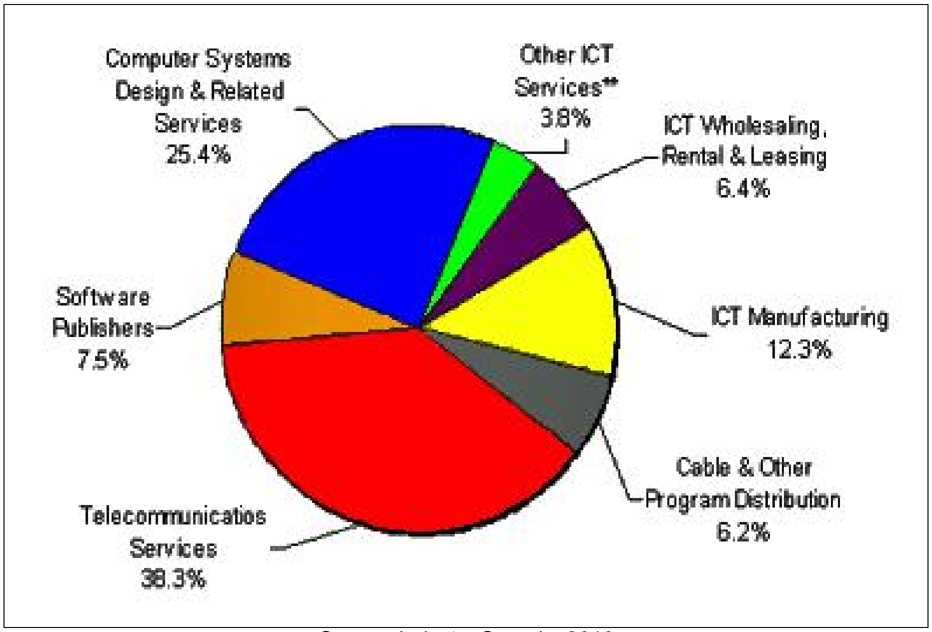
This definition does not include ICT embedded in manufacturing. Already, an estimated 35 to 40 percent of the production cost of a luxury car is due to embedded systems – microelectronics

[68] Statistics Canada, "North American Industry Classification System (NAICS) 2007", http://www.statcan.gc.ca/subjects-sujets/standard-norme/naics-scian/2007/index-indexe-eng.htm
[69] ICT Sector Gross Domestic Product (GDP), 2009 (Last Update: November 2010) - http://www.ic.gc.ca/eic/site/ict-tic.nsf/eng/h_it05864.html

and software included. The car is no exception: it is estimated that in Europe embedded systems account for one third of R&D costs of the products of heavy industry (automotive, aerospace, telecommunications, security, energy, logistics...).[70] The situation is probably similar in Canada.

The chart below shows the distribution of the ICT sector in Canada (59.4 billion). Embedded systems are partly in the "Computer Systems Design and Related Services" and the "ICT Manufacturing," and confused with pure computing. The ICT concept is both vague and restrictive because it ignores the fact that a plane, a bus or a subway train is more a software platform where the equipment is a more and more decisive part.

FIG. 50 – DISTRIBUTION OF GDP BY ICT INDUSTRY



Source: Industry Canada, 2010

The systematic underestimation of the real value of ICT in economic life is caused by the distinction ICT/non-ICT. It is impossible to assess the economy and productivity, nor the need for labour, with such an inappropriate tool. Not only the added value leaves the traditional production processes of the industry, but even within embedded systems, it moves from hardware to software.

The European economist Geomina Turle proposed a new approach to economic evaluation instruments based on the value of what she calls Embedded Digital Technology (EDT).[71] Geomina Turle proposes to classify the areas not in terms of finished goods but according to the measurement of EDT intensity. She proposes to single out EDTs from overall productive inputs (intermediate consumption, capital and labour force) along the value chain of different goods and services.

The share of the cumulative value of these inputs throughout the value chain compared to the total value of products and services would provide an adequate measure of the EDT intensity. In the process, the European economist proposes to isolate the ICT-related R&D from the overall R&D

[70] Robert N. Charrette, "This Car Runs on Code", *IEEE Spectrum*, February 2009. / Dominique Potier, "Briques Génériques du Logiciel Embarqué, ministère de l'Industrie, Secrétariat d''État à la Prospective et au Développement de l'Économie Numérique, October 2007, 83 pages. Cf. p. 11. (In French only)

[71] Geomina Turlea, "Tracking the Economic Value of Embedded Digital Technology: A Supply-side Methodology", European Commission, Joint Research Centre, Institute for Prospective Technological Studies, 2011, 69 pages. Cf. p. 8.

expenditures. Applied in Canada, such an approach would increase the share of ICT in the economy much above the current 5 percent, but we would then speak of the entire spectrum of digital technologies – not just the ICT restrictive concept.

To give an idea of the magnitude of this underestimation, we note that the OECD has calculated that spending on ICT R&D carried out in other sectors than ICT is an additional 30 percent.[72]

Conversely, it should be noted that the NAICS sector “Professional, Scientific and Technical Services” covers Electronic Manufacturing Service (EMS) companies such as Celestica. According to the traditional approach, EMS should be treated as part of the manufacturing sector. But the NAICS code puts it in the service sector.

The traditional classification framework available to us does not explain any more the economic evolution due in large part to the proliferation of embedded systems in our industrial environment. This statistical mismatch is not a mere marginal malfunction of an otherwise functional system. It is a sign of the economic discontinuity created by the surge of embedded computing.

[72] “The 2011 Report on R&D in ICT in the European Union”, European Commission, Joint Research Centre, Institute for Prospective Technological Studies, Luxembourg, 122 pages. Cf. p. 22.

Appendix IV - Preferences to Encourage Foreign Investment in Taiwan

Item	*Preference*	*Contact*
Tax	▶ Emerging important strategic industry (investment tax credit for shareholders or 5 year tax free) ▶ Personnel training expenditure (business income tax credit based on 35 percent of the training expenditure of the same year) ▶ R&D expenditure (business income tax credit based on 35 percent of the R&D expenditure of the same year) ▶ Accelerated depreciation of facilities (maximum depreciation period: 2 years) ▶ Tax credit for the purchase of facilities and technology investment ▶ Tax free for import facilities ▶ Income tax free for technology transfer or technology cooperation ▶ Tax preference for the establishment of operation headquarter	Ministry of Economic Affairs
R & D Subsidy	▶ Industrial Technology Development Program (ITDP) ▶ Small Business Innovation Research Program (SBIR) ▶ Industrial Technology Development Alliance Program (ITDA) ▶ Strategic Service-Oriented Industry R&D Program (SRD) ▶ Information Technology Applications Program (ITAP) ▶ Industrial Technology Innovation Center Program for Local Enterprises （MNCD) ▶ Industrial Technology Innovation Center Program for Foreign Enterprises （MNCF)	Department of Industrial Technology, MOEA
	▶ Leading Innovative Product Development Program ▶ Enterprise R&D Alliance Program ▶ Enterprise Operation Headquarters Service solution@moeasmea.gov.tw	Industrial Development Bureau, MOEA
Low-Interest Loans	▶ Industrial R& D Loan	Ministry of Economic Affairs
	▶ Low-Interest Loans for Mid- and Long-Term Capital	Council for Economic Planning and Development, Executive Yuan
	▶ Project Loans for Small and Medium Enterprise	Small and Medium Enterprise Administration, MOEA
	▶ Bank Draft and Loan Preferences for Development Fund, Executive Yuan	National Development Fund, Executive Yuan
	▶ Low-Interest Loans for Science Park	Science Park Administration
Personnel Training	▶ International Experts Recruitment	HiRecruit Services
	▶ Military Training Service Application	Military Training Project Office
	▶ R&D Substitute Service	R & D Substitute Service Program Office, Ministry of the Interior

Source: Semiconductor Industry: Analysis & Investment Opportunities, Department of Investment Services, Ministry of Economic Affairs, Taiwan, 2008/01.

Appendix V – A Draft National Policy on Electronics for India

With the Union Government announcing draft National Policy on Electronics, Indian electronics and semiconductor industry can still see there is a hope for India to become a manufacturing center for electronics. The draft policy sets out to achieve a turnover of about USD 400 Billion by 2020 involving investment of about USD 100 Billion. It also aims at ensuring employment to around 28 million in the sector by 2020, stated in the release.

Major strategies proposed in the draft policy include:

1. Providing attractive fiscal incentives across the value chain of the Electronics system design and manufacturing (ESDM) sector through Modified Special Incentive Package Scheme (M-SIPS).
2. Setting up of Semiconductor Wafer Fab facilities and its eco-system for design and fabrication of chips and chip components.
3. Providing Preferential Market Access for domestically manufactured electronic products including mobile devices, SIM cards with enhanced features, etc. with special emphasis on Indian products for which IPR reside in India to address strategic and security concerns of the Government consistent with international obligations in procurement.
4. Providing incentives for setting up of over 200 Electronic Manufacturing Clusters with world class logistics and infrastructure.
5. Creating an "Electronic Development Fund" for promoting innovation, R&D and commercialization in ESDM, nano-electronics and IT sectors including providing support for seed capital, venture capital and growth stages of manufacturing.
6. To use innovation and R&D capabilities to develop electronic products catering to domestic needs and conditions at affordable price points.
7. Setting up Very Large Scale Integration (VLSI) specific Incubation Centres across country.
8. Developing an India microprocessor for diverse applications/ strategic needs.
9. Creating a 10 year stable tax regime for the ESDM sector.
10. Setting up a specialized Institute for semiconductor chip design.
11. Encouraging greater participation of private sector in human resource development for the sector. Also encouraging setting up of skill-oriented courses for electronic designs along with hands-on laboratories enabling graduates from other disciplines to migrate to ESDM.
12. Developing and mandating standards for electronic products specific to Indian conditions of power, climate, handling etc.
13. Creating linkages for long term partnership between domestic ESDM industry and strategic sectors like Defence, Atomic Energy and Space.
14. Setting up of Centres of Excellence in the area of automotive electronics, Avionics, and Industrial electronics.

15. Adopting best practices in e-waste management

16. Setting up of a National Electronics Mission with industry participation to advance the implementation of various programmes in this policy.

17. The Department of Information Technology to be renamed as Department of Electronics and Information Technology (DeitY) to reflect the desired focus on electronics.

18. The draft Policy is available on the website of Department of Information Technology (www.mit.gov.in).

EE Herald, Bangalore, October 10, 2011
Full text available at: http://india.gov.in/allimpfrms/alldocs/16392.pdf

Appendix VI – The emSYSCAN Institutions, Users, Research Themes & Infrastructure

Users' Applicant Institution	Expected Users							Research Themes				Infrastructure				
	Principal and Others	Users who are CRC and NSERC Chairs	Known Potential Others	Potential Others, CRC or NSERC Chairs	User-Related Graduate Students in 2007	Company Collaborations with Users in 2007	Value (000) of Industry Collaborations in 2007	1. Rapid Syst. Modeling, Design and Prototyping	2. Wireless Networks	3. Embedded Systems, Architect., Programming	4. Microfluidic, Sensing and Analysis Systems	Multi-technology Design Environment	Development Systems	Rapid-Prototyping, Characterization	Real-time Embedded Software	Eligible Cost (000,000)
Carleton	1		29		129	10	$1,109		•	•		•	•			$0.99
Concordia	12		14		126	4	$463		•	•	•	•	•			$0.81
Concordia	12		14		126	4	$463		•	•	•	•	•			$0,81
Dalhousie	4		9		58	2	$280		•	•		•	•			$0.40
École Polytechnique	13	5	9	5	124	11	$1,327	•		•	•	•	•	•		$4,21
ÉTS	2		6		47	1	$175	•	•	•		•	•			$0,86
Guelph	4		5		42	1	$125			•		•	•			$0.77
INRS	1	1	5	2	28	4	$326		•	•		•	•			$0,26
Laval	4		4		29	3	$186		•	•	•		•			$0,60
Lethbridge	3				5	1	$105			•		•	•			$0.37
Manitoba	9	2	12	4	64	6	$331	•	•	•	•	•	•	•		$1.51
McGill	3		22	3	137	8	$731	•	•	•	•	•	•			$1,43
McMaster	6	1	25	3	116	4	$535		•	•		•	•			$1.22
Memorial	3		10		39	2	$130	•	•	•		•	•			$0.69
Montréal	2		1		11		$39	•		•	•		•			$0,87
NewBrunswick	8				23	1	$69	•	•	•	•	•	•			$0.45
Operations/Queen's																$8.19
Ottawa	7	2	12	2	84	14	$932	•	•	•		•	•			$0.71
Queen's	5		22	1	106	5	$391	•	•	•	•	•	•	•		$2.54
Operations/Queen's																$8.19
RMC	6		9		40		$140		•	•		•	•			$0.47
Ryerson	6		10		61	4	$403		•	•		•	•			$0.97
Saskatchewan	5		7	1	38	3	$61	•	•	•		•	•			$0.71
Sherbrooke	1		14	1	47	5	$306			•	•	•	•			$0,58
Simon Fraser	4	1	16		72	2	$260	•	•	•	•	•	•			$0.78
Toronto	11		50	7	273	21	$2,249			•	•	•	•			$2.39
UQAC	1		4		10		$46			•	•		•			$0,23
UQAM	7				15	6	$277	•	•	•	•	•	•			$0,76

UQAR	1		3		10		$49		•	•		•	•			$0,42
UQO	2	1	4		17		$95			•	•		•			$0,59
UQTR	3		4		47		$336		•	•		•	•			$0,78
Victoria	11		11	1	70		$186			•		•	•			$0.90
Waterloo	6	1	33	3	156	10	$958	•	•	•	•	•	•		•	$1.90
Western	3		15		70	1	$341	•	•	•	•	•	•			$1.42
Windsor	7		3		33	3	$114	•		•		•	•			$0.83
York	1		3		12	1	$79			•		•	•			$0.25
Total	**202**	**16**	**420**	**36**	**2511**	**155**	**$14,957**	--	--	--	--	--	--	--	--	**$48.26**

Source: CMS Microsystems, Research proposal presented to the Canada Foundation for Innovation (CFI), October 2008.

The other computing

Is Canada ready for the Internet of Things?

Embedded systems are the tip of a larger phenomenon that is the entrance of information technology in all industries. More and more everyday objects are being embedded with processors and sensors, connected to distant servers, creating tomorrow's Internet of things.

Today we are witnessing a phenomenon similar to what happened in the telecommunications sector during the 1980s and 1990s when the network was digitized. We called this process "convergence between computing and telecommunications" as if the two domains were equals.

We saw what happened. Nortel did not start manufacturing computers. Nortel disappeared, and Apple is now manufacturing phones better and more versatile than anything ever dreamed by the boldest telecommunications people.

All industries will have to go through the same transformations as the old telecommunications – that is to say, suffer the same shock.

Sector after sector, the whole economy will be affected by a computing flood of which embedded systems are the concrete manifestation. That is why CATA Alliance can assert that the control of embedded systems is crucial for the future of Canada's manufacturing industry.

This survey was made possible by the contribution of the Canadian Advanced Technology Alliance (CATA).

Produced by

Sciencetech communications

Price: $110 + taxes

Library and Archives
Canada, 2012
ISBN 978-2-9812174-3-1