Advantage Note 16

Embedded Systems and attractive growth market

by

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Advantage Note Series

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Embedded Systems (@Note 16)

Consumer & Industrial Market Uses
Market structure & Supply Chain (H/W & S/W)
The Software Landscape
Embedded System Tools
Embedded Systems Software Stack
The Software Market Opportunity
Technology Drivers & Enablers

Background to Advantage Notes

Advantage is what creates value for you, your customers and your organisation. Focusing on advantage and sources of advantage through the life cycle of a business, whether it be commercial or not for profit, ensures entrepreneurs and leaders minimise risk and maximise value. In the book "Advantage" a framework is presented called "The Business Advantage Model (BAM™)" that supports leaders in the identification, creation, proving, securing, leveraging and changing of advantage. It is about doing the right things the right way at the right time across every aspect of starting, scaling and readjusting a business.

The book is a practical guide for entrepreneurs who wish to implement more agile and experimental approaches to business which are learning centric. It is aligned with latest theory and research that address the issues related to traditional sequential approaches that are focused on static business plans. It offers an approach based on learning, facts and data which inform the evolutionary stages of a business and provides more accuracy and reality to starting and scaling a business. It enables a living business plan and a dynamic start up. By adopting this agile information centric approach with a focus on Advantage we reduce risk and improve success rates in new and scaling businesses.

Leaders and team perform best when they have a framework/model and a focus and the BAM™ provides both.

Academic Reviewers have commended and recommended this new approach, as have IBM Innovation and Silicon Valley entrepreneurs.

Its goal is to help create more high performance organisations.

Advantage Notes

Advantage notes are a series of guides which expand in a pragmatic way how the BAM™ is applied and outline pointers for Entrepreneurs and Leaders on the opportunities and impacts when adopting more Agile, Experimental approaches to starting and scaling a business.

Advantage Note 16 "Embedded Systems an attractive growth market"

This Note, explains the market dynamics and opportunity that exist for embedded systems, it indicates the size and growth rates which make it an attractive market and, it outlines the hardware and software elements where opportunity exists. It explores the end user market drivers such as Automotive, Aerospace, Industrial and Communications, and it also reviews the technology drivers and enablers that are facilitating many of the major technology application advances underway today.

About the Author

Declan Kavanagh holds a DipEng in Telecommunications & Electronics from the Dublin Institute of Technology, a CDipAF from the ACCA, and an MBA from Dublin City University. He has over 34 years of experience, starting as a hardware test engineer in the IT industry up to founder and CEO in both multinational enterprises and entrepreneurial start-ups. Declan now advises entrepreneurs and business leaders on how to create momentum and acceleration in the Key Performance Indicators for their firms, as well as being actively involved as an added value investor with several technology start-ups. He has been a successful intrapreneur in large enterprises, where he led strategic business change and increased added value from subsidiary to parent. He has started, scaled and successfully sold an IT services business to the Capgemini Group. He has also been involved with struggling ventures, so he has had to lead in both good and challenging times. Declan developed the BAM™ and authored the book *Advantage* based on his research and experience. He identified that a road-map was needed for entrepreneurs, leaders and students that would complement the models already in use and help readers and users of the BAM™ in a practical and pragmatic manner pull their resources together and ensure they do the right things the right way at the right time.

Embedded Systems an attractive growth market

I have been working on a number of research assignments for clients in the embedded systems marketplace and its certainly an interesting and exciting marketplace. Recent analyst reports such as IDC, VDC, BCC and other all indicate there is a large , growing and attractive market ecosystem. A 2012 EU sponsored report from IDC estimated the total market in 2010 to be €852 bn and growing at a CAGR of 12% through to 2015 (€1.5 trillion). Most analysts predict continued growth at between 7% and 10% through to 2020. This sector represents a significant opportunity for Irish and EU technology organisations as its knowledge and innovation intensive and plays to our hardware and software technology base. What is interesting is that the opportunity for us is across the full value chain from R & D, Manufacturing, Certification, Operations and service, creating wealth and a broad array of employment.

An embedded system is a computer system with a dedicated function or set of functions within a larger mechanical or electrical system, often with real-time computing constraints. It is *embedded* as part of a complete device often including hardware and mechanical parts. The important thing to remember is it is about embedded intelligent devices , these can be simple single purpose such as smart sensors or complex multiprocessor controllers.

Technology innovation and advances are enabling growth in the market, along with application innovation to enhance the end user products which is driving demand. Let us consider some of the drivers and the structure of the market.

End user market and products examples

Industry *(IDC CAGR 2010-15, 2015 Revenue)*	**Consumer**	**Business**	**Observation**
Automotive €103bn, 12.2%	Engine control Unit, Other control units, Infotainment, Transport Telematics, Security, Navigation etc.	Fleet Management & Control, Route optimisation, Fuel consumption.	A typical car now has 65 Microprocessor control units covering most of its systems and infotainment. Embedded systems represent 25%+ of its cost. Electric vehicle systems,
Avionics & Aerospace €	Infotainment	Navigation, Instrumentation, Propulsion, Scientific, Security, satellite.	Commercial aircraft R & D as well as subsystem cost is now the significant cost for security, safety, reliability. The same can be said for satellite and space exploration. Flight control represents hundreds of millions of embedded lines of code on each craft.
Industrial Automation €207bn, 9.4%		Robotics, Process control, Environmental control	Automation of tasks impossible for humans, higher quality, consistency & productivity in Industrial environments. Safety, Security & Reliability.
Healthcare and Medical €75 bn, 11.4%	Tele-health, Integrated Health, Health monitoring devices	Diagnostic, Imaging, Therapeutic, Implanted devices	Technology has enabled significant advances in genetics, diagnosis and treatment. Intelligent medical devices are worn or implanted on patients and

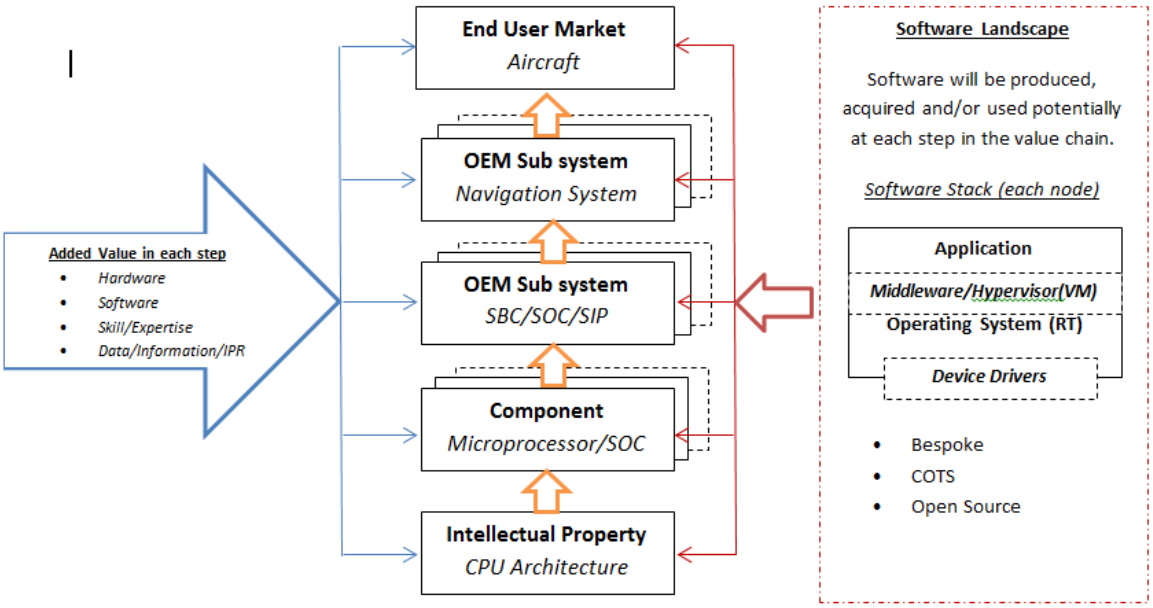
			are connected to management systems.
Energy €181 bn, 34%	Energy monitoring and management.	Smart Grid, Smart metering, Green energy devices and control	Optimising the supply of cost effective green energy requires many new intelligent devices on the networks talking to each other and automated control systems coupled with user systems to conserve and manage their energy usage. Smart meters and controllers. Vehicle to Grid for EV's
Communications €614 bn, 13.2%	Smart mobile devices. The internet of things (e.g. white goods connected to apps)	Infrastructure Fixed, Mobile, Satellite. Machine to machine communications and intelligence.	Machine to machine communications with every conceivable consumer and business device having connectivity to the internet. Giving us huge amounts of devices and data which require applications and systems that allow us access valuable information and control devices and systems.
Consumer Goods €333 bn, 6.3%	White goods, Consumer electronics	Food production, Food distribution, Agribusiness	Veterinary tele-health, crop planting and productivity, satellite data to guide food production. Connected consumer devices and infotainment creating autonomous or remote control. Systems for back office and consumer settlement relating to eTransactions e.g. charging an EV, Travel card etc.
Military & Defence	Security and warning systems	Communications, Intelligence, Guidance and Navigation , etc.	We ruggedize virtually every device/product for military application, while many technology innovations are born in military product R & D.

With the continued evolution of technology driven to improve society and life styles (or make money for entities) we can see the future demand growing, we experience embedded technology it in some way every day of our lives. Public transport smart cards are common place nowadays, every time you put them in proximity to a terminal multiple embedded devices process the transaction, move account balances, update databases and records.

Considering these end user device markets whether they be a satellite, Fridge, Central Heating or Pacemaker, the providers of these products and services are managing a full market and product life cycle, to grow their business and as such must have the skills , technologies and resources to leverage embedded system technology which is now a key enabler for them.

The Embedded system supply chain-market structure

We have considered the end user products and markets above but we know for many different reasons these end users will have many different suppliers and supplier types to enable them optimise their value proposition , their core competence and focus on their core customer, product and markets. They will use OEM's to supply certain strategic parts/sub systems. An original equipment manufacturer, or OEM, manufactures products or components that are purchased by another company and retailed under that purchasing company's brand name. OEM refers to the company that originally manufactured the product.



The Software Landscape relating to embedded systems

What we find is quite a fragmented market for software. There is a growing relevant importance in the software component of embedded systems, as we reach some of the physical limits of what can be achieved in hardware. For example, the software becomes a more differentiating feature in that often function, performance, security and reliability for a product, subsystem or component is determined by its software. We will consider that later when we look at technology drivers and enablers.

We need to consider the software tools landscape in addition to the software stack, and also each individual system will not necessarily have the same or consistent architecture when it comes to embedded systems. Remember we may have a very simple single function sensor that has some intelligence it passes directly or through a network to its manager, alternatively we may have a complex set of applications running on a single CPU or multiple platforms controlling a complex machine as an example. In some cases there may be a single piece of application code that has the application and OS functions tightly integrated to achieve its technical and/or business function.

There are many choices for a system or subsystem designer. The key question is how do we best achieve the target function, performance and standards we need to achieve, where do we get best outcomes by buying, renting or making the software component, while creating and controlling any unique IPR we may create. So what software can be considered in this market. Some of which are market segments with their own customer and supply base:-

Embedded software tools market

- ***Electronic Design Automation Tools (Suites & Point solutions)***
    - *Electronic design automation (EDA or ECAD) is a category of software tools for designing electronic systems such as printed circuit boards and integrated circuits. The tools work together in a design flow that chip , PCB and module designers use to design and analyse entire target functional system.*

- ***Integrated Development Environments (Suites & Point Solutions)***
    - *An integrated development environment (IDE) or interactive development environment is a software application suite that provides comprehensive facilities to computer programmers for software development. An IDE normally consists of a source code editor, build automation tools and a debugger. Most modern IDEs offer Intelligent code completion features. Some IDEs contain a compiler, interpreter, or both. The boundary between an integrated development environment and other parts of the broader software development environment is not well-defined. Sometimes a version control system and various tools are integrated to simplify the construction of a GUI. Many modern IDEs also have a class browser, an object browser, and a class hierarchy diagram, for use in object-oriented software development.*

- ***Product Life cycle management (Suites & Point Solutions)***
    - *Product lifecycle management (PLM) is the process of managing the entire lifecycle of a product from inception and requirements, through engineering design and manufacture, to service and disposal of manufactured products. PLM integrates people, data, processes and business systems and provides a product information backbone for companies and their extended enterprise, in the context of embedded systems it will cover hardware and software and their alignment.*

- ***Application Life cycle Management (Suites & Point Solutions)***
    - *Application Life cycle management is both a philosophy as wells as a methodology and set of processes that support managing the entire lifecycle for any software from innovation and requirements , through design, build, test, support, upgrade and retirement whether it be traditional waterfall or Agile in approach.*

The Software Stack

At the highest level of the end user application we may have the need for a core functional application that is managing the multiple functions and or functional contribution towards the end application. Technology is enabling multiple complex functions to be carried out and sometimes synchronised on one single embedded end user application. Here we will consider a single stack.

- ***The Application***
  - *This is the final set of functional code that allows the embedded system carry out its core function, ultimately it is the ones and zeroes that are the instructions and data for the chosen CPU architecture such as ARM, MIPS, PowerPC, X86, SPARC etc. Most commonly written in C, C++ and or Java but there are many options available. This is the code the embedded software engineering team is ultimately tasked to produce, though in the process they may develop many other different tools to help them develop, debug or test, or they may use a suite of procured tools or point solutions as listed above.*

- ***The Operating System***

  - *An operating system (OS) is a collection of software that manages computer hardware resources and provides common services for computer programs. The operating system is an essential component of the system software in a computer system. Application programs usually require an operating system to function. For hardware functions such as input and output and memory allocation, the operating system acts as an intermediary between programs and the computer hardware although the application code is usually executed directly by the hardware and will frequently make a system call to an OS function or be interrupted by it. Operating systems can be found on almost any device that contains a computer or microprocessor—from cellular phones and video game consoles to supercomputers and web servers. Most embedded systems have real time operating systems, which allow the CPU to immediately respond and address defined stimuli in the form of an interrupt such as a sensor detecting a target condition and/or changing state, because they need to respond in real time to events. The OS usually includes the device drivers, which are software components that enable software to interact with physical devices that may be attached such as storage, display, communications and proprietary devices*

- ***Middleware & Hypervisors***
  - *Middleware is a type of software that provides services to an application that may not be available from the OS, or it can be enhanced functional bridging to the OS. Middleware is used to help achieve productivity, quality and performance in how an application is put together and operates. A Hypervisor could be considered a type of*

middleware it allows virtual machines to be created on a single board CPU where multiple applications can be run on the same chip/board.

- ***Device Drivers***
  - *a device driver is a computer program that operates or controls a particular type of device that is attached to a computer. A driver typically communicates with the device through the computer bus or communications subsystem to which the hardware connects. When a calling program invokes a routine in the driver, the driver issues commands to the device. Once the device sends data back to the driver, the driver may invoke routines in the original calling program. Drivers are hardware-dependent and operating-system-specific. They usually provide the interrupt handling required for any necessary asynchronous time-dependent hardware interface.*

The embedded software Market

There is a relationship between what's happening in the embedded system market and the embedded software market so it's useful to understand some of the variables for example looking at the embedded system CPU/MCU market BCC Research (*Embedded Systems Technologies & Trends, Jan 2012)* indicates that 2010 total revenues for the segment $113bn (H/W $108bn, S/W $4.2bn), 2015 $158bn (H/W 152bn, S/W 6.1bn) (BCC Research), CAGR circa 7%, Growth drivers consumer devices , 3 & 4G, semiconductor advances, Indian and Chinese demand growth.

System designers must consider the right combination and of course the best performing combination of CPU architecture, OS, Development languages and tools and as hardware advances software must also advance to leverage hardware advantage and in a sense it's a circular process where hardware must also advance to enable new software functionality.

In a special EU study "Design of Future Embedded systems" SMART 2009/0063, published 2012 by IDC referred to above, the software development component of the study indicates €3.31bn in 2010 for packaged software, with a CAGR of 7.1% growing to €6.5 bn by 2015. (Note packaged software is in effect COTS and does not include bespoke development costs)

In Europe the 2010 embedded packaged software market is €986m (30% of total), growing at CAGR 6.3% there are over 430 software vendors with no more than 20 whose revenues are greater than €10m .

We also need to consider that vendors in one software category often have offerings in another category for example some RTOS providers also provide IDE's or other related point solutions. Some IP suppliers also provide tools, such as SPARC or ARM tools. Often an IP, a tool provider, a suite provider or a subsystem provider will provide tools and frequently they will provide these free of charge or heavily discounted as a means to make the selection of, development , integration and use of their core product easier for the software engineer. In addition we have open source initiatives such as Eclipse, SPARC etc. so what we have is a very fragmented marketplace, rapidly changing and growing. It is very attractive but comes with risks if you do not choose wisely.

So let us consider the highlights of the embedded system market

- $852bn Total embedded market 12% CAGR
- $113bn CPU embedded Market
- $3.31Bn packaged embedded software 7.1% CAGR ($6.5Bn in 2015)
- 10bn processors ship annually (98% embedded)
- 880k embedded software engineers globally 7% CAGR
- 40% of development projects behind schedule
- Shift to software as the critical and value creating element
- 50%+ of development costs relate to the software and its growing
- Professional growth is highest for development, test and QA engineers
- Total market for embedded s/w engineering $50bn (90% Labour $45bn, License & other $5Bn)

Technology drivers and enablers

Technology is converging though innovation on embedded systems, high performance and programmable devices such as Microprocessors and FPGA, combined with other circuitry and logic that allows connectivity with other devices and the internet are provided on small , low power footprints either circuit boards and/or system on chip packaging.

End user markets are seeking:-

- Higher performance
    - As technology has evolved, more and more end use product functions are electronically controlled , operated and integrated, more devices means more data and information to be managed, leading to greater functionality and performance required from the control units.
- Autonomous operation
    - Devices need to operate autonomously, with interoperability between devices, with no dependency on external interaction outside the end user device or system.
- Lower Power
    - As we increase functions and performance , we usually increase power consumption, however many devices are autonomous with limited power sources (such as batteries and/or solar as an example). Power means heat, cooling, size, cost and end user devices want to reduce all of these.
- Remote control and connection
    - Many different scenarios exist where there is a need for periodic or always on connectivity to the devices and their embedded subsystems, think of infotainment in a car where inbuilt is a smart device providing internet connectivity for either tracking, history, exceptions or user chosen applications , e.g. cars with internet connectivity and infotainment applications, or satellites that need to connect to

send back information or perhaps the need to change some parameter from the ground.

- Re-use and re purposing
    - For cost and ROI purposes as well as for practical reasons, moving away from embedded systems that are very proprietary and single purpose to systems which can be upgraded, changed, adapted while in service (or even out of service) reducing the need for re-engineering or a costly change process.
- Safety & Security
    - Safety and Security remain a priority in virtually every sector, though the standards get tougher as the risks increase in certain sectors
        - Commercial: the cost of the incident, impact on reputation, recovery/repair/Re engineering.
        - Consequential damage
        - Human factors such as injury or loss of life
        - Performance
    - The technology must enable the appropriate level of safety and security whether it be a washing machine, aircraft, car, satellite, assembly robot.
- Reliability
    - Reliability becomes more important in embedded devices
        - Operational environment must be considered what temperatures, humidity, vibration, electrical interference, cosmic interference, etc.
        - Accessibility, embedded systems are often buried in the end user device, how frequently does the labour cost in a garage exceed the parts cost when your car is in for maintenance. Or take a satellite you cannot just drop by and replace a part.
        - Maintainability, Have you designed in the ability to do diagnosis, test, make adjustment, replacement and/or repair.
    - Commercial Off the Shelf components (COTS) versus proprietary in-house developed or externally developed and supplied. There are advantages to using COTS components whether hardware and/or software as they tend to be lower cost and are future proofed, you may have to make trade-offs and perhaps lose some flexibility but these are typical design decisions. Semiconductor IP can be procured rather than designed.
    - Software is the key glue and enabler to releasing many if not most of the features above becoming one of the highest value components in the embedded system ecosystem.