A Vision for International Standardization in Software and Systems Engineering

François Coallier
École de technologie supérieure
francois.coallier@etsmtl.ca

Abstract

The importance of standards in enabling the development of industry and commerce through the standardization of components, interfaces and specifications is well known and understood. As our societies move toward a post-industrial era, services' share of national economies and global commerce has increased. This article gives an introduction to international standardization in Information Technology. It also provides a status and describes current activities in international software and systems engineering standardization, and concludes with a vision of future activities in this area.

1. Introduction

Standards are important in enabling the development of industry and commerce. They do this by creating markets through the standardization of components, interfaces and specifications. Activities in this area have been going on since the first international standardization organization, the International Communication Union (ITU), was founded in 1865.

As our societies move toward a post-industrial era, services' share of national economies and global commerce has increased as corporations and supply chains become more global. This creates the need for internationally recognized standards that facilitate interoperability between people and organizations.

This is because interoperability between people and organizations means sharing a common vocabulary, having compatible work processes, and being able to benchmark individuals and organizations. Thus a growing need for standards in areas such as processes, methods and good practices, bodies of knowledge and formalisms.

2. Fundamentals of Standardization

Using the ISO definition as a baseline, standards are '*guideline documentation that reflects agreements on products, practices, or operations by nationally or internationally recognized industrial, professional, trade associations or governmental bodies'*.

Standards are referred to as guidelines documents since they are not compulsory unless mandated so by an individual or an organization. They are agreements because they often reflect a certain level of consensus. Standards can be classified as follows [1] [2]:

- Organizational Standards, such as internal company standards
- Market Standards (de facto), such as the CMMI
- Professional Standards, developed by professional organizations (such as the IEEE or INCOSE)
- Industry Standards, developed by industrial consortia (such as OASIS, WS-I,...)
- National Standards, developed or adopted by national standards organizations (such as ANSI or BSI)
- International Standards (de jure), developed or adopted by formal international standards organizations (such as ISO)

A given standard may be developed in one environment (market, professional, industry, national), and migrate into a formal international standard. Market, professional and industry standards may also represent an international consensus or *de facto* state which differs from the formal International Standards in the degree of the breath and formality of this consensus.

The notion of consensus is important to all standards that are not market imposed. ISO defines consensus as the following:

"General agreement, characterized by the absence of sustained opposition to substantial issues by any important part of the concerned interests and by a

process that involves seeking to take into account the views of all parties concerned and to reconcile any conflicting arguments".

Which essentially means the following [2]:

- That all parties involved were able to voice their views.
- That the best effort was made to take into account all of the above views and resolve all issues (meaning all comments tabled during a ballot).
- That nearly all or (ideally) all parties involved can live with the final result.

In the ISO system, we have the one country/one vote system. In professional organizations, each individual has a vote and represents himself. In industrial fora or consortium, votes are usually associated with corporate members.

3. ICT standardization

3.1 ICT standardization scope

A large number of ICT standards are required to enable our modern post-industrial society to function properly. These standards cover a wide breath of areas that can be illustrated as in figure 1.

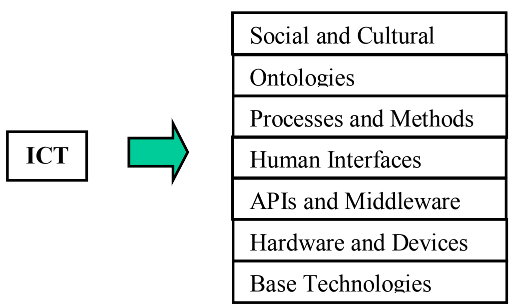

Figure 1: The breath of ICT standardization

For instance, base technologies standards cover the basic building blocks of IC areas such as:

- Machine level representation of data
- Encoding
- Compression
- Encryption
- Telecommunication Protocols
- File systems
- Processor Instruction Sets
- Programming Languages
- Data Description Languages
- Graphic Description Languages
- Document Description Languages
- Data and Document Query Languages
- Transaction Description Languages
- Event Description Languages
- Architecture Description Languages
- Meta Languages
- Modeling formalisms

Hardware and devices standards cover physical devices standards such as:

- Bar Codes Labels
- Wireless Tags
- Buses
- Storage Medias
- Storage Devices
- Identification Devices
- Biometric Devices
- Human Input Devices
- Machine Input Devices
- GPS Interfaces
- Connectors and Cables
- Cabinet and racks
- Wireless and Optical Systems
- Neural Networks

API and Middleware standards cover the logical interfaces between IT components and systems such as:

- Operating System APIs
- Storage System Services
- Data Exchange Protocols
- Transaction Protocols
- Document Exchange Protocols
- General Middleware
- Directory services
- Geographic/Location Services
- Authentification services
- Biometric Data Management Services
- Security Services
- Network Services
- Transaction Processing Services
- Rights Management Services
- Document Management Services
- Messaging Services and EDI
- Voice Messaging Services
- Mobile Services
- Collaboration Services

Human interface standards cover the logical and system interfaces between IT systems and humans such as:

- Fonts
- Colours
- Documents
- Hypermedia Documents
- Graphical User Interface Elements
- Graphical User Interfaces
- Accessibility
- Ergonomics
- Web Agents
- Voice Interfaces

- Video Interfaces
- Virtual Reality Systems
- Direct human-to-machine interface

Process and methods standards cover the processes, methods and supporting tools for the management, engineering and operation of IT products and systems such as:

- Generic Data Dictionary
- Software Engineering
- System Engineering
- Enterprise Architecture Management
- Bodies of knowledge
- Methods
- Methodologies
- Tools Environment
- Asset Management
- Security Management
- ICT Risks Management
- Data and Storage Management
- Document Management
- Knowledge Management
- Network Management
- Distributed System Management
- Mobility Management
- QoS Management
- Design and Architecture Patterns

Ontology standards regroup all domain specific dictionaries, document definitions, processes and codes necessary for the comprehensive implementation of machine to machine transactions such as:

- Vocabulary
- Domain Specific Data Dictionary
- Domain Specific Document Template
- Codes

Finally, human social and cultural standards covers IT support for human culture and society, human cultural exchanges and social activities such as:

- Consumer Requirements
- Learning Support
- Privacy Management
- Cultural Adaptability
- Natural Language Support
- Automated Translation
- Legal Issues
- IT in education

3.2 Key players

Elaborating such a wide variety of standards requires an important amount of technical resources. ICT standards are thus elaborated by a large number of organizations, most of which are industrial consortia or fora.

The European Telecommunications Standards Institute (ETSI) maintained in the past an inventory of fora developing standards in ICT. The last time this page was visited by the author (in 2003), before it was no more accessible, about 350 organizations were listed, ranging from very large industrial fora to smaller, more specialized organizations.

A number of fora, de jure and professional organizations can be active in the same technical area, as illustrated in Table 1 for a few selected standardization areas.

Table 1: ICT Standardization Scope.

Standardization area	Main organizations
Web Services	OASIS, W3C, WS-I, JTC 1, ISO, UN/CEFACT
Ontology	OASIS, Commercial associations
Security	JTC 1/SC27, W3C, OASIS
Grid Computing	GGF, Globus Alliance / Globus Consortium, EGA
Privacy Management	IETF, Liberty Alliance, W3C
Mobile Computing	OMA, W3C, MPP, MIPI, Open GIS, SALT
Wireless	IEEE
IT Systems Engineering	JTC 1/SC7, IEEE-CS, OMG, The Open Group, INCOSE
Multimedia	JTC 1, W3C

Some of these consortia and fora can be quite large. For instance, the Organization for the Advancement of Structured Information Standards (OASIS) has, according to its Web site, more than 5000 participants in its standardization activities. They represent more than 500 organizations. OASIS accepts individuals and organizations as members. More than 65 committees are active at OASIS.

3.3 De jure ICT standardization

As mentioned previously, in the ICT world country based organizations which carry out standardization activities are commonly referred to as *De Jure* organizations. These are principally:

- International Telecommunication Union (ITU)
  <u>Founded:</u> 1865
  <u>Scope:</u> international organization within the United Nations System where governments and the private sector coordinate global telecom networks and services.
- International Electromechanical Commission (IEC)
  <u>Founded:</u> 1906
  <u>Scope:</u> the leading global organization that prepares and publishes international standards

for all electrical, electronic and related technologies.

- International Organization for Standardization (ISO)
  Founded: 1947
  Scope: the mission of ISO is to promote the development of standardization and related activities in the world with a view to facilitating the international exchange of goods and services, and to developing cooperation in the spheres of intellectual, scientific, technological and economic activity.

To which we should add the *United Nations Centre for Trade Facilitation and Electronic Business* (UN/CEFACT) which is known for its Electronic Data Interchange (EDI) and ebXML (co-developed with OASIS) standards.

In 1987, ISO and IEC joined forces and created a Joint Technical Committee – Joint Technical Committee 1 (JTC 1) with the following mandate:

Standardization in the field of Information Technology.

Information Technology includes the specification, design and development of systems and tools dealing with the capture, representation, processing, security, transfer, interchange, presentation, management, organization, storage and retrieval of information

JTC 1 is still, nowadays the only joint committee of ISO and the IEC, and presently consists of the Sub-Committees (SC) listed in Table 2. The higher the number of a Sub-Committee or (SC), the more recent was its creation. The last SC to be created was SC37, whose scope is in biometric. It was created in 2002.
In the remaining parts of this paper, we will concentrate on the Software and Systems Engineering area, which is under the responsibility of SC7.

Table 2: JTC 1 Sub-Committees

Technical Areas	JTC1 Subcommittees and Working Groups
Application Technologies	SC 36 - Learning Technology
Cultural and Linguistic Adaptability and User Interfaces	SC 02 - Coded Character Sets SC 22/WG 20 – Internationalization SC 35 - User Interfaces
Data Capture and Identification Systems	SC 17 - Cards and Personal Identification SC 31 - Automatic Identification and Data Capture Techniques
Data Management Services	SC 32 - Data Management and Interchange
Document Description Languages	SC 34 - Document Description and Processing Languages
Information Interchange Media	SC 11 - Flexible Magnetic Media for Digital Data Interchange SC 23 - Optical Disk Cartridges for Information Interchange
Multimedia and Representation	SC 24 - Computer Graphics and Image Processing SC 29 - Coding of Audio, Picture, and Multimedia and Hypermedia Information
Networking and Interconnects	SC 06 - Telecommunications and Information Exchange Between Systems SC 25 - Interconnection of Information Technology Equipment
Office Equipment	SC 28 - Office Equipment
Programming Languages and Software Interfaces	SC 22 - Programming Languages, their Environments and Systems Software Interfaces
Security	SC 27 - IT Security Techniques SC 37 - Biometrics
Software and Systems Engineering	SC 07 - Software and Systems Engineering

4. Subcommittee 7

4.1 History

The origin of Subcommittee 7 (SC7) goes back to ISO/TC97 (TC = Technical Committee), which was created in 1960 for international standardization in the field of *information processing*. When JTC 1 was established in 1987, ISO/TC97 was combined with IEC/TC83 to form JTC 1/SC7, with *Software Engineering* as its initial title and area of work [2]. When SC7 was created, it had five standards under its responsibility.

SC7 was hardly a pioneer in the development of software engineering standards. The first software engineering standard was published in 1976 by the US National Bureau of Standard [3] [4]. In 1976, the IEEE created the Software Engineering Standards Subcommittee of the Technical Committee on Software Engineering (TCSE). This committee published it first standard in 1980: IEEE Std 730™, IEEE Standard for Software Quality Assurance Plans.

The IEEE collection had already 27 published standards in 1994. By 1997, this collection was 44 documents strong while the SC7 collection had 18.

4.2 Standards and Software Engineering

Software Engineering is, as an engineering discipline, very young. While areas such as civil engineering date from before the pyramids, and mechanical engineering can trace its roots to classical Greece, the term 'Software Engineering' was coined in 1968 [5].

The objective of science is to understand nature, and engineering's is to build useful things using science. Another, probably too simple, way to put it would be that scientists do reverse engineering while engineers do forward engineering. Engineers have not only to build things, but also to do it within budget, schedule, resources, regulatory and operational constraints. Many of the systems built by engineers can be safety or, in the case of financials and electronic commerce systems, financially critical. In many cases, the best way to minimize risks when developing such systems is through re-use or incrementally improving proven solutions. This means that engineering is by nature a profession where re-use, be it of development methods or architectural patterns, is a way of life.

While the foundations of Software Engineering include fields such as Computer Sciences, Systems Engineering and Project Management, standards have played a significant role in the development and codification of this discipline[4]. This culminated in the publication of the Software Engineering Body of Knowledge (SWEBOK) in 2004 by the IEEE [6]. The SWEBOK was subsequently adopted by ISO and IEC as a technical report, TR 19759 [7].

As mentioned in the introduction of this paper, standards are very useful in our global service economy. Understanding their limitations is also important. Standards being the product of a consensus building process are by nature 'imperfect'. Excellent as they can be as a baseline reference, they do not necessarily encompass in many cases the state of the art of a given area.

4.4 Application Domain Perspective

As mentioned, software systems are pervasive in our society. While the application domains were these systems are found are numerous, they can be divided into three broad categories:

- Embedded Systems: where software is part of a physical device, product or system;
- Information Systems: the classical information systems using general purpose computers;
- Interactive Media Systems: this includes games and virtual environments.

Software Systems can also be segregated between safety critical, where failure can have an impact on the safety of humans; financially critical, where failure can have severe adverse financial impact; and others. Safety critical systems have a tendency to be usually embedded systems while financially critical systems are usually information systems.

The challenge for standards developer is to develop general purpose standards that can, with proper tailoring, be applied to all these classes of software systems. Specific standards may then be required to address safety and financial critical systems, either by adding additional requirements and/or by constraining the applications of the generic standards.

In some cases, domain specific standards must be elaborated. Such standards may incorporate requirements tied up to the application domain and/or other requirements associated to the regulatory environment. This was done, for instance, in the area of train signaling (IEC 62279) and medical instrumentation software (IEC 62304).

4.5 SC7 Evolution

SC7's original mandate was to elaborate standards in software engineering. From five published standards in 1987, its collection grew slowly to eleven standards in 1995 (see figure 2).

In the early 90's, SC7 was active in the following areas:

- Software life-cycle
- Software process assessment, which resulted in the 15504 standards, commonly know as the SPICE (Software Process Improvement and Capability dEtermination) standards.
- Software product quality evaluation, which gave rise to the ISO/IEC 9126 standards
- User documentation
- Software engineering environment
- Functional size measurement.

It became apparent to the subcommittee that software was always part of something larger – what we call a *system* in engineering terms. To accommodate this reality, systems engineering processes were integrated into the Software life cycle processes standard that was first published in 1995 (ISO/IEC 12207) and work was initiated on a Systems Engineering life cycle standard (ISO/IEC 15288) that was published in 2002. Work to further harmonize the software and systems life cycle standards was immediately started after the publication of 15288.

Consequently, in 1997, SC7's mandate was formally extended to include systems engineering and a formal liaison was established with the International

Council of Systems Engineer (INCOSE). INCOSE became very soon an active partner of SC7 in the development of systems engineering standards.

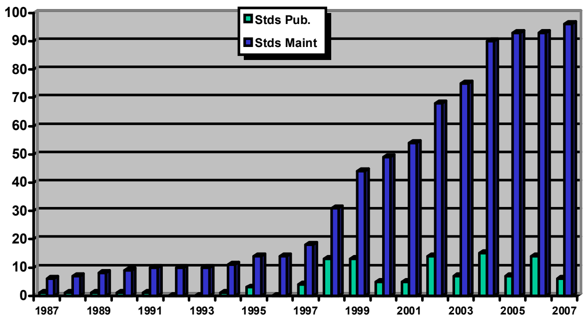

Figure 2: Growth of the SC7 Standards Collection

At the same time, an important partnership was established with the IEEE Computer Society. The business case for this partnership was very straightforward given the importance of the IEEE collection of software engineering standards and the customer base (about 100 000 members) it represented. The objective of this partnership, which was enabled through a liaison and a formal agreement, was to merge as much a possible the IEEE and the ISO/IEC standard collection. Another objective was to initiate joint projects to develop new standards or update existing ones.

This partnership has been very successful. Since 1996 [8]:

- IEEE has adopted five SC7 standards
- SC7 has adopted five IEEE standards
- One shared standard has been revised
- Two standards from respectively SC7 and IEEE have been merged.

Many projects are currently underway, noteworthy:

- The elaboration of a consolidated vocabulary (project 24765). This vocabulary is already available online at: http://www.computer.org/sevocab.
- The revision of ISO/IEC 15026: Systems and Software Assurance
- The elaboration of a four part standard on software testing using contributions from IEEE and the British Standards Institute (BSI)

Once the entire sets of current projects are completed, a substantial level of integration will be reached between both collections.

Initially SC7 work program focused mainly on the development of software systems. As its work progressed, the operational and governance components became more apparent. This happened not only with the software and systems engineering life cycle standards, were a governance process was incorporated in 15288, but also through projects in software maintenance (ISO/IEC 14764) and software asset management (ISO/IEC 19770) to name a few.

This topic was discussed at the SC7 Brisbane (Australia) plenary in May 2004 concurrently with the possibility of adopting and integrating the British standard BS 15000 on IT Service Management, a standard related to the IT Service Library (ITIL) which is a recognized international benchmark in this area.

SC7 invited BSI to submit BS 15000 through an accelerated process (*fast track*), and in 2005 the international version of the standard, ISO/IEC 20 000, was published. At the same time, work was initiated to revise and harmonize this standard with the SC7 collection and a liaison was established with the IT Service Management Forum (itSMF). With chapters in more than 40 countries, itSMF was a natural partner of SC7 in the service management area.

As this work was done, it became apparent that one other piece was missing to have a complete coverage of the needs of the Information System, or Enterprise IT area. As we can see in Figure 3, enterprise IT can be divided in three broad practice domains [9]:

- Governance, whose goal is *to support the organization's strategic directions, to define the IT vision, strategies, tactics and implementation plans, to manage the implementation of these plans and to ensure the delivery of required services.*
- Delivery, whose goal is *to deliver to the organization in a predictable, efficient and timely manner the business processes, applications and IT infrastructure that are planned for, as well as any modifications to these elements.*
- Operations, whose goal *is to introduce new and/or modified systems and processes into the organization and the IT environment in an efficient manner.*

These three components are required to ensure that IT services meet their required service levels.

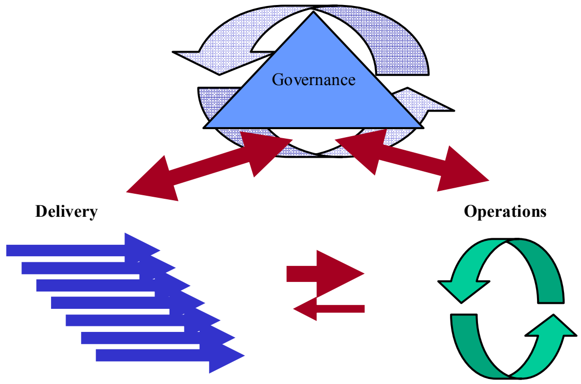

Figure 3: Enterprise IT Processes

To address the governance area, SC7 created a study group at its 2006 Bangkok Plenary and invited Australia to submit their IT Governance standard as a *Fast Track*. At the time this article was written, the study group was still active and the Fast Track was still open. Furthermore, a liaison with the Information Systems Audit and Control Association (ISACA) and the IT Governance Institute is currently under consideration.

4.6 Current Status

As of early 2007, ninety-five published standards are under the responsibility of SC7. At this point in time, there were also twenty-four ongoing standards development projects. The work is done in fifteen actives Working Groups (WG) as illustrated in Figure 4. Two Specials Working Groups (SWG) have been created to assist in the management of the SC: SWG1 for the strategic planning and SWG5 for the management of the architecture of the standard collection.

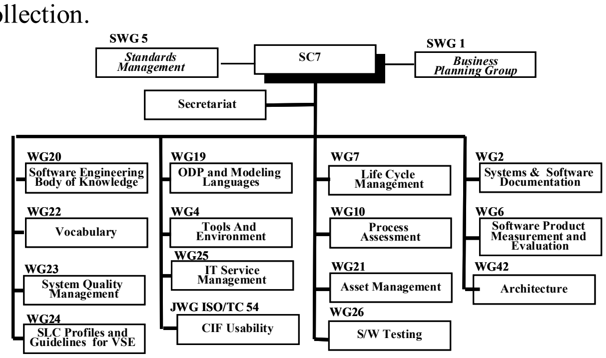

Figure 4: SC7 Structure

SC7 has currently 34 countries participating in its work. Each of these countries has a national organization that is contributing technical experts for the technical work and votes on the proposal. The process followed in the technical work is documented in directives and strictly enforced. 19 other countries have an observing status. SC7`s work program presently covers the following areas:

- Software and systems engineering processes:

  In partnership with the International Council of Systems Engineers (INCOSE), the Institute of Electrical and Electronics Engineers Computer Society (IEEE-CS) and other parties, SC7 is developing and improving on standards which describe good software and systems engineering practices, as well as standards to consistently assess organizational software and system engineering practices against a given benchmark. A project on Requirements Engineering has been initiated recently.

  Work has also been initiated in this area to provide guidelines on the usage of SC7 standards for very small enterprise.

- Software system products:

  Developing and improving on standards which allow acquirers and buyers to size and document software products as well as to express measure and evaluate the quality of the software that is produced and its contribution to the final product or application system. These standards are principally found in the ISO/IEC 25000 series, commonly known as SQuaRE (Software product Quality Requirements and Evaluation).

  A working group is also dedicated to the area of information systems documentation (ISO/IEC 6592 and 15289).

  Work is also being done, in cooperation with the IEEE-CS and INCOSE, in software and systems architecture, with an IEEE standard having been recently adopted (ISO/IEC 42010). A new project on Software Testing has been initiated in May of 2007.

- Techniques for Specifying IT Systems:

  In partnership with the Object Management Group (OMG), SC7 is developing and improving on Open Distributed Processing (ODP) standards to integrate IT and business system definition and provide the software and system engineering tools to implement enterprise information systems. Noteworthy in this areas have been the UML standards that came through the OMG (ISO/IEC 19501) and the new standard on Metamodel for Development Methodologies (ISO/IEC 24744).

- <u>Software engineering environment:</u>
  Developing and improving on standards which make it easier to use software engineering environments and to re-use and re-deploy the data contained in them. The main standards in this area are ISO/IEC 14102 and 15940).
- <u>Software engineering body of knowledge:</u>
  Working with the Institute of Electrical and Electronics Engineers Computer Society (IEEE-CS) on their guide to the Software Engineering Body of Knowledge (SWEBOK), SC7 published it as an ISO/IEC Technical Report (ISO/IEC TR 19759). A project on the certification of software engineers is currently active. In addition SC7 is considering as a possible ISO/IEC Technical Report the INCOSE Systems Engineering Handbook, version 3.
- <u>IT Service Mangement:</u>
  In partnership with the IT Service Management Forum (itSMF) and other parties, SC7 is developing and improving on standards which describe good IT service management practices, including areas such as the management of software assets.

Finally, it should be noted that a project has been initiated in the area of software product lines, specifically on Tools and Methods of Requirement Engineering and Management for Product Lines.

5. A vision for the future

To have a proper understanding of the future evolution of IT, it is necessary to have an understanding of its past history. Figure 5, adapted from [10], provide an interesting view.

The figure illustrates both the technological evolution, viewing it as a series of 'waves' or phases, and the social impacts by showing an estimate of the number of users of IT on the Y axis.

The first phase was when the industry was dominated with large mainframe and minicomputers based systems located in centralized data centers and operated by elite groups of people. This was the time of proprietary hardware dominated systems.

The second phase came with the microprocessor and the personal computer. Suddenly, computing moved from the small data center elite to end-users. It also started to become mass-market phenomena. A de-facto market set of standards quickly dominated this market: the so-called Wintel (Windows operating systems and Intel processor) standard. At the same time, the mass introduction of micro-controllers made computing devices more pervasive.

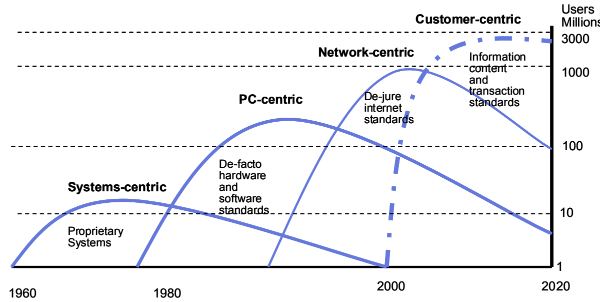

Figure 5: Stages of IT industry expansion

The third phase became visible when, in 1993, a group of students from the University of Illinois developed the first Internet browser, Mosaic. Quite suddenly, the Internet moved from a network for small elite of researchers to a mass market phenomenon. At about the same time, Microsoft introduced direct support for networking in its operating systems. PCs, as well as the data centres computers, started to evolve from islands of automations to nodes of a network. This evidently had a significant impact on the design of computer applications.

Predicting the future is always speculative, but the following elements are visible for this fourth phase:

- An open transactional environment dominated by machine to machine (M2M) communications and supported by open middleware and other open standards.
- The practical emergence of intelligent systems
- An increase pervasiveness through mobile applications
- A continuous increase in the amount digital information created worldwide, increasingly multimedia in nature and increasingly available on the Web

Developing software systems has also evolved significantly since the early 90's. Sophisticated development frameworks are now available. Development patterns have been codified for processes and methods as well at the architectural, design and implementation level.

On the other hand, some classes of information systems, such as large electronic commerce systems, now require engineering skills traditionally found in the embedded systems world. This is due not only to the distributed nature of these systems, but also to the importance of quality attributes, also knows as 'non-functional requirements', such as availability, security and scalability.

Finally, a global market for software and systems engineering, as well as IT, services has been created.

This is illustrated by Table 3, taken from a Gartner report by [11].

Table 3: The global IT services market.

LEADER	India
CHALLENGERS	Canada, China, Czech Republic, Hungary, Ireland, Israel, Mexico, Northern Ireland, Philippines, Poland, Russia, South Africa
UP-AND-COMERS	Belarus, Brazil, Caribbean, Egypt, Estonia, Latvia, Lithuania, New Zealand, Singapore, Ukraine, Venezuela
BEGINNERS	Bangladesh, Cuba, Ghana, Korea, Malaysia, Mauritius, Nepal, Senegal, Sri Lanka, Taiwan, Thailand, Vietnam

In summary, SC7 work must continue to be responsive to the evolution of the global IT market and of IT technologies. This includes:

- Increase globalization of IT Services
- Growing importance of IT operations services
- Growing importance of Systems Integration
- Continual increase in IT ubiquity
- Continual increase in the importance of the global IT infrastructure to the global economy

This can be achieved by, among other things:

- Increased integration and harmonization of SC7 standards
- Increased coverage of Systems Engineering, IT Service Management and IT Governance.
- Increased harmonization of Software Engineering, Systems Engineering and IT Service Management Standards
- Integration of SC7 standards with IEEE's
- Continue to work closely with strategic partners sucha as the IEEE-CS, INCOSE, the OMG, the ITU-T, and itSMF.

6. Conclusion

Standards will continue to play a role in both the codification and the globalization of the software, and systems engineering market. Even with a large collection of published standards, SC7 has many challenges to overcome in the next few years to adequately respond to the needs of the global market and technological changes.

To meet these challenges, SC7 will need to work closely with international professional societies and industrial fora. It will also need to continue proactively assess the needs of the global IT market.

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