International Standardization in Software and Systems Engineering

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The last decade saw an increase in the phenomenon of globalization and concurrently the pervasiveness of computing in our society. This article provides an introduction to international standardization in information technology, gives a status and describes current activities in international software and systems engineering standardization, and explains why all of these are important for professionals and organizations in this area.

The last decade saw an increase in the phenomenon of globalization and concurrently the pervasiveness of computing in our society. Products based on the information and communication technologies (ICTs) and software intensive systems are now ubiquitous in industrialized societies, whether for commercial, industrial, defense, or domestic applications. The global information technology (IT) procurement industry, which includes telecommunication equipment, computer systems hardware, software licenses, semiconductors, and IT services, should now be around $1.4 trillion, according to Gartner Dataquest [1].

As a direct result of the use of computerized devices, the world is now very dependent on software systems. ICT-based products are software-intensive systems and the software in them is essential to their functioning.

The ability to design and implement ICT systems and products has greatly improved in the last 10 years. A recognized core body of knowledge in software engineering now exists – a sign that software engineering is maturing into a recognized profession. Challenges still abound because of the pressure to build even more complex applications and products in an ever-shorter time frame (a *Web year* is three months) [2].

In response to these market needs, there has been significant development in international standards in software and systems engineering in the last decade. This article will give an overview of these developments as well as the context in which they are happening.

The International Standardization Context

Standards are essentially either a *de jure* (formal) or a *de facto* (current state of things) mandatory set of conventions and/or technical requirements or practices [3]. Standards can be classified into the following categories:

- Organizational standards such as internal company standards.
- Market standards (de facto) such as the VHS format.
- Professional standards developed by professional organizations such as the Institute of Electrical and Electronics Engineers (IEEE).
- Industry standards developed by industrial consortia such as the World Wide Web Consortium, and the Organization for the Advancement of Structures Information Standards.
- National standards developed or adopted by national standards organizations such as the American National Standards Institute.
- International standards developed or adopted by formal international standards organizations such as ISO.

A given standard may be developed in one environment (market, professional, industry, or national) and migrate into a formal international standard. Market, professional, and industry standards may also represent an international consensus or de facto state. The difference with the formal international standards is in the degree of the breadth and formality of this consensus. This will become clearer later in the article.

Formal international standards in the ICT are developed by the following organizations:

- International Telecommunication Union, founded May 17, 1865. This is the international organization within the United Nations System where governments and private sectors coordinate global telecom networks and services.
- ISO (International Organization for Standardization), founded in 1947. 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 develop cooperation in the spheres of intellectual, scientific, technological, and economic activity.
- International Electromechanical Commission (IEC), founded June 1906. This is the leading global organization that prepares and publishes international standards for all electrical, electronic, and related technologies.

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

Table 1: *Current JTC 1 Subcommittees* (**Note:** 10 Jan. 2002, taken from <www.jtc1.org>)

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 – Information Technology Security Techniques
Software Engineering	SC 07 – Software and Systems Engineering

"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" [4].

JTC 1 presently consists of of the subcommittees lists in Table 1.

International standards can come into being through different processes:
- As a proposal that is developed in working groups through the *standard* six-stage process described in Table 2 (three to five years from initiation to publication).
- As a proposal with a base document that can be internally *fast-tracked*, e.g., processed through a compressed schedule (about two years).
- As a proposal with a complete document that can be fast-tracked by JTC 1 (one four-month ballot, less than one year).
- As a proposal with a complete document that can be proposed by external (but recognized) organizations and fast-tracked as a four-month ballot known as the Publicly Available Standard process (one to two years).

It is a misperception that the development of formal international standards always takes an exceeding amount of time. When this is the case, it is usually due to one (or a combination) of the following reasons:
- The topic is new thus it takes time to develop a unified international view.
- International consensus on the topic is weak due to positions that are difficult to bring together.
- Management of the development process is suboptimal.

This brings us to another key concept in standardization work: the notion of *consensus*. Standards represent a consensus, and the essence of the ISO standard process is the achievement of a proper level of consensus. 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" [5].

This essentially means the following:
- That all the parties involved were able to voice their views.

Stage No.	Stage Name	Stage Description
0	Preliminary	A study period is under way.
1	Proposal	A new project is under consideration.
2	Preparatory	A working draft is under consideration.
3	Committee	A committee draft /final committee draft is under consideration.
4	Approval	A final draft international standard is under consideration.
5	Publication	An international standard is being prepared for publication.

Table 2: *Standard Six-Stage Process for the Development of International Standards*

- 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 the parties involved can live with the final result.

As ISO notes in its guidelines, consensus does not mean unanimity. The minimal numerical for international standards adoption in ISO is a two-thirds majority of the participating members (e.g., countries) voting. For technical reports (e.g., guides), it is a simple majority.

So what added value do international standards bring in addition to a well-known brand? They bring the following:
- They represent an international consensus attained through a very rigorous and uniform process.
- They usually represent a set of conventions and/or technical requirements or practices that are relatively stable.

In addition, the international standardization process makes it relatively difficult and costly for special interest groups to take over a given standardization project, especially if the topic is controversial. This would mean controlling many country delegations, as well as liaison organizations. For a project to be accepted in ISO, at least five countries must be willing to contribute experts. In Subcommittee 7 (SC7) of JTC 1, there are currently 27 participating countries.

Evidently, nothing is perfect. Industry and de facto standardization dominate in some fast-evolving ICT areas. The international standardization process is not built to accommodate the requirements in these areas, especially when the technology and the market are unstable. On the other hand, once things stabilize, industry standards developed by an industrial consortia (for example, the object management group or OMG) should be able to migrate to the formal international scene using one of the compressed processes presented earlier in this article. This has been happening in the ICT since JTC 1 was created.

International Software and Systems Engineering Standardization

The SC7 has the mandate within JTC 1 for, as described in its terms of reference, standardization of processes, supporting tools, and supporting technologies for the engineering of software products and systems.

The origins of SC7 go back to ISO/Technical Committee (TC) 97, initiated 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. This was extended to software and systems engineering in 2000.

There are currently 69 published international standards under the responsibility of SC7. By early 2004, this will rise to 81 if the work proceeds as planned. As illustrated in Figure 1 (see page 20), the availability of so many international standards in software and systems engineering is a recent occurrence.

In 1990, only eight standards were under the responsibility of SC7. One of the eight standards was on software documentation (ISO/IEC 6592, last revised in 2000), the balance being diagramming and charts standards, six of them still existing as *legacy* standards. At the same time, the IEEE already had a substantial collection of 14 software and systems engineering standards, a collection that grew to 27 in 1994 and presently stands at about 50 standards. To get the complete picture, it is good to keep in mind that the first software engineering standard was a U.S. military standard in 1974, and the first IEEE software engineering standard was published in 1979 (software quality assurance plans) [6].

The increase in the number of published international standards in software and systems engineering in the last 10 years is due to the following:
- The increased dependencies of our global society and economy on the ICT and software intensive systems.
- The maturing of the software and systems engineering profession in the 1990s due to the work of professional organizations such as the IEEE, the European Strategic Program for Research in Information Technology (ESPRIT) projects, and Japanese IT research initiatives to name a few.
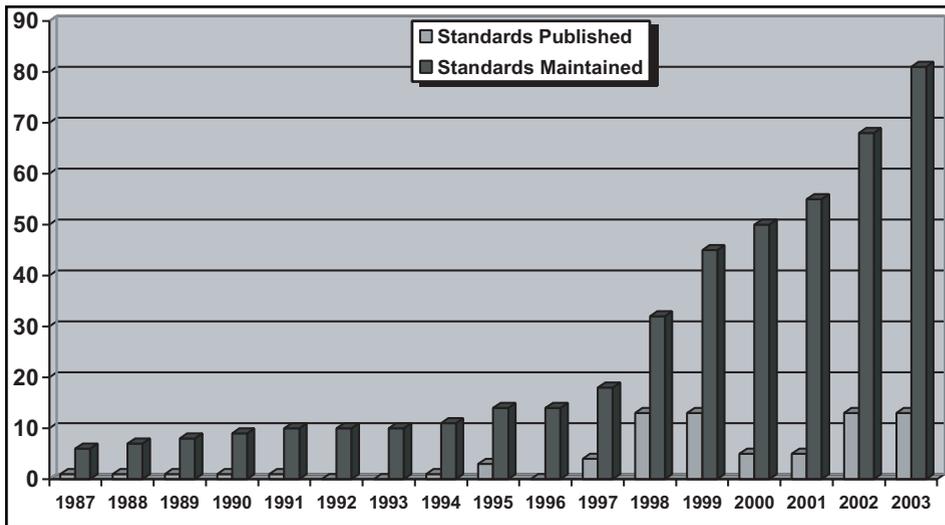- The dedication of all the technical

Figure 1: *Evolution of Published International Standards in Software and Systems Engineering*

experts and professionals who work on these standards.

In background to all this – as mentioned at the beginning of this article – is the very significant expansion of the ICT market during the 1990s, driven by Moore's Law[1] and the Internet.

Another evolution took place in the standardization area. The Computer Society of the IEEE (IEEE-CS) saw its membership become more international, with more than half now coming from outside the United States. The IEEE-CS has adopted key international standards from SC7 such as ISO/IEC 12207 (available in an IEEE edition). Also, as we will see in some examples that follow, IEEE standards are being considered by SC7. This means that the two sets of standards should become more integrated with time. SC7 and IEEE-CS are presently working together to become more systematic in their relationship.

The SC7 standardization portfolio can be presently divided into the following areas of work:

• **Legacy Standards.** These are essentially legacy information processing standards that SC7 still has in its portfolio (six standards).
• **Software and Systems Engineering Processes.** These are standards that describe good software and systems engineering practices, as well as standards to consistently assess organizational software and systems engineering practices against a given benchmark (19 standards, eight active projects).
• **Software Systems Products.** These are standards that allow developers, purchasers, 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 systems (25 standards, six active projects).

• **Enterprise Architecture.** These are standards to integrate IT and business systems definitions and to provide the software and systems engineering tools to implement enterprise information systems (12 standards, nine active projects).
• **Software Engineering Environment.** These are standards that make it easier to use software-engineering environments and to reuse and re-deploy the data contained in them (two standards, one active project).
• **Software and Systems Engineering Formalisms.** These are standards for formal representations and modeling of software and systems (five standards, two active projects).
• **Software Engineering Body of Knowledge.** These are guidelines that establish the appropriate set(s) of criteria and norms for the professional practice of software engineering upon which industrial decisions, professional certification, and educational curricula can be based (one active project).
• **Management of Software Assets.** These are standards that will describe the basic requirements of a software asset management environment (one active project).

Let us look in greater detail into the last seven areas, focusing on key standards and projects.

Software and Systems Engineering Processes

Four standards are the cornerstones of this area:

• The ISO/IEC 12207 Software Life-

Cycle Processes was published in 1995 and amended in 2002.

• The ISO/IEC 15288 Systems Life-Cycle Processes was published in 2002. It was developed with a strong participation of the International Council on Systems Engineering (INCOSE).
• The ISO/IEC TR 15504 Software Process Assessment series was published in 1998 and 1999 as technical reports. They are currently being revised, with their scope widened to cover any type of processes and upgraded to international standards. The Capability Maturity Model® Integration℠ (available through the Software Engineering Institute) is compatible with the current version of ISO/IEC 15504 [7].
• The ISO/IEC 9000-3 Guidelines for the Application of ISO 9001 to Computer Software was transferred to SC7 from another ISO committee (ISO/TC176) and is currently undergoing a revision to be aligned to the 2000 version of ISO 9001.

The relationship between these four standards is illustrated in Figure 2.

These key standards, including the recently published ISO/IEC 15288, are well known in the software and systems engineering community. Since these standards were developed on different timelines, it is normal that differences crop up among them. This is why a harmonization project between 15288 and 12207 is under serious consideration in SC7.

The following complements this top-level set of standards:

• ISO/IEC TR 15271 – Guide to ISO/IEC 12207.
• ISO/IEC 14764 – Software Maintenance.
• ISO/IEC TR 15846 – Configuration Management.
• ISO/IEC 15910 – Software User Documentation Process.
• ISO/IEC 15939 – Software Measurement Process.
• ISO/IEC TR 16326 – Guide for the Application of ISO/IEC 12207 to Project Management.

The following two standards should join this set by the third quarter of 2003:

• ISO/IEC TR19760 – Guide for ISO/IEC 15288.
• ISO/IEC 16085 – Risk Management.

It is interesting to note that the ISO/IEC 16085 is a fast-track of IEEE 1540:2001.

Software Systems Products

There are five main sets of standards in this area:

• The 9126 series on *software quality char-*

acteristics. The initial standard was published in 1992. This standard is currently being revised and expanded into a three-part document.

- The 14598 series on *software product assessment.* Initially published between 1998 and 2001, this six-part standard got significant inputs from the Software Certification Program in Europe, ESPRIT project of the early 1990s.
- The 14143 series on *functional size measurement.* This five-part standard publication will span from 1998 through early 2003.
- A group of four *functional size counting methods* standards (19761, 20926, 20968, 24570). These are in the final approval stage, three of which are fast-tracked through the PAS process.
- A block of *software and systems reliability* standards. These include the standard on Systems and Software Integrity Levels (15026) and the recently transferred project from IEC/TC 56 Guide to Techniques and Tools for Achieving Confidence in Software (IEC 16213).

The 9126 and 14598 standards are currently being integrated and reworked into the new 25000 series titled "Software Product Quality Requirements and Evaluation" (SQuaRE). The architecture of the SQuaRE standards is given in Figure 3.

Enterprise Architecture
The enterprise architecture standards of SC7 currently consist of a series of documents on open distributed architecture (principally 10746 and 13235 series, 14750, 14752, and 14753). This work is being carried cooperatively with the OMG, which is fast-tracking many of the documents. More details on the applications of these standards can be found in [10].

Software Engineering Environment
Published standards in this area cover the evaluation (14102) and the adoption of CASE tools (14471).

Software and Systems Engineering Formalisms
A key standard in this area is the Unified Modeling Language (19501) that is currently being fast-tracked from the OMG.

Software Engineering Body of Knowledge
This is a cooperative project with the IEEE-CS to publish their Software Engineering Body of Knowledge as an ISO technical report – ISO/IEC TR 19759 [11]. This project is near completion.
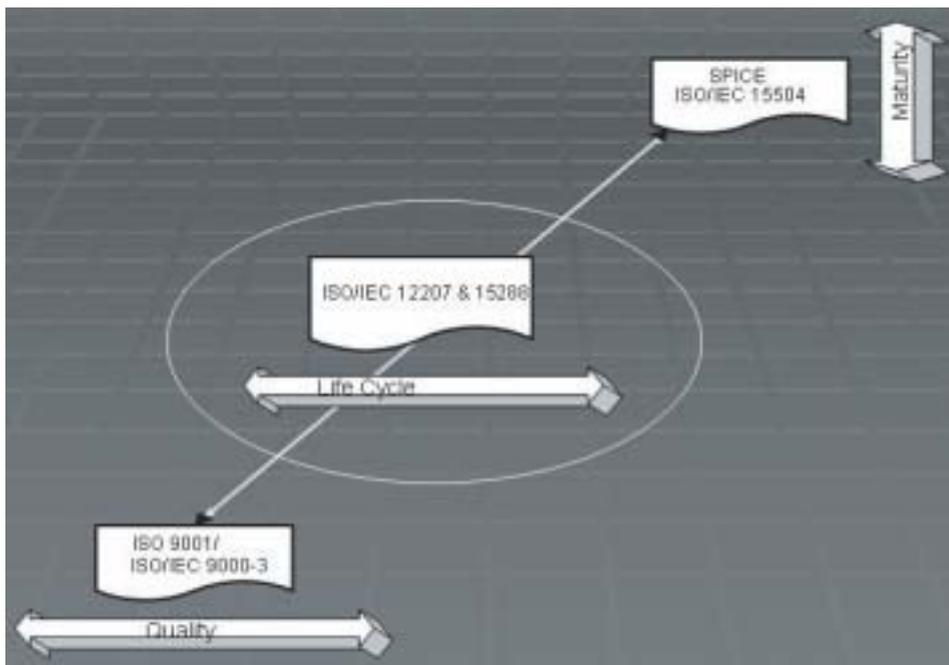

Figure 2: *Relationship Among Key SC7 Software and Systems Engineering Process Standards* [8]

Management of Software Assets
This is a new project (19770) initiated in 2001 that aims to develop a standard on a software asset management process. A first working draft of this standard has been published on the SC7 Web site.

Conclusions
The increase in international software and systems engineering standardization is a consequence of both the continuing growing importance of the ICT and the ICT-based systems, products, and services in the global economy as well as the growing maturity of the software and systems engineering disciplines.

The SC7 will strive to fulfill its mandate and deliver to the international software and systems engineering community the tools it requires in the global information society. This will be done in cooperation with other standards-developing organizations, not only the national standards organizations but also, increasingly, professional and industrial ones.

Additional Information
The SC7 Web site <www.jtc1-sc7.org> provides more information. All JTC 1/SC7 standards can be purchased directly from ISO or from the American National Standards Institute at <http://webstore. ansi.org/ansidocstore /default.asp>.

It is necessary to be accredited with a national body to participate in the development of SC7 standards. In the United States, the contact for the U.S. Technical Advisory Group on software and systems

Figure 3: *SQuaRE Architecture* [modified from 9]

Quality Requirements Division 2503n	Quality Model Division 2501n	Quality Evaluation Division 2504n
	Quality Management Division 2500n	
	Quality Metrics Division 2502n	

engineering is Mike Gayle at s.m.gayle@jpl.nasa.gov.

Acknowledgements

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Note

1. Moore's Law <www.webopedia.com/TERM/M/Moores_Law.html>.

Further Information

1. IEEE-CS Software Standards: <http://standards.computer.org/sesc>.
2. IEC: <www.iec.ch>.
3. INCOSE: <www.incose.org>.
4. OMG: <www.omg.org>.
5. ISO: <www.iso.ch>.
6. JTC 1: <www.jtc1.org>.
7. SC7: <www.jtc1-sc7.org>. Provides information on current SC7 activities, published standards, and more. Many documents are available for download.

About the Author

François Coallier is professor of software and information technology (IT) engineering at the École de technologie supérieure. He has nearly 22 years of industrial experience in one of Canada's largest companies, where he held various engineering and managerial positions in engineering, quality engineering, IT procurement, IT infrastructure deployment and operation, and IT enterprise architecture management. Coallier is currently the international chairman of the Joint ISO and International Electromechanical Commission (IEC) subcommittee responsible for the elaboration of Software and Systems Engineering Standards ISO/IEC JTC1/SC7, and also a fellow of the American Association for the Advancement of Science. He has a bachelor's of science degree in biology from McGill University, a bachelor's degree in engineering physics, and a master's of science degree in electrical engineering from Montreal's École Polytechnique.

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