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 Structured 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 |
| Cultural and Linguistic Adaptability and User Interfaces | SC 22/WG 20 – Internationalization |
| Data Capture and Identification Systems | SC 17 – Cards and Personal Identification |
| Data Capture and Identification Systems | 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 |
| Information Interchange Media | SC 23 – Optical Disk Cartridges for Information Interchange |
| Multimedia and Representation | SC 24 – Computer Graphics and Image Processing |
| Multimedia and Representation | SC 29 – Coding of Audio, Picture, and Multimedia and Hypermedia Information |
| Networking and Interconnects | SC 06 – Telecommunications and Information Exchange Between Systems |
| Networking and Interconnects | 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 misconception 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.
- 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 only a few 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 experts involved.

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

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

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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 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 standards are 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 standards 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 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® IntegrationSM (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:


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


### Software Systems Products

There are five main sets of standards in this area:

- The 9126 series on software quality char-
characteristics. 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” (SOuRE). The architecture of the SOuRE 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.

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 engineering is at SC7/14 (technical committee on software and systems engineering).

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

Figure 3: SOuRE Architecture [modified from 9]
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References

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