Standards: People, Process, Products and Productivity
Focus on Information Technology Standards

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Introduction

This proposal suggests a one year development effort for which a budget is provided. Following the year one proposal with the information requested, we have included an idea of what we would like to do in years two and three if NIST found the first year project productive. No budget or detailed description of year two and three activity is provided. The information is solely intended to allow NIST to see where we think such an effort could go.

The program of Information Science and Technology at the University of Pittsburgh, established in 1969, is generally credited as being the first department of information science in the United States. In 1986, it added a program in Telecommunications, which was also one of the earliest such programs in the US. In 1989, we developed and offered what we believe was the first graduate course dedicated to the introduction of information technology standards[1]. The course addressed not only the theory, process and structure of national and international standards, but it introduced students to a broad array of standards in four areas: networking, data interchange, operating system, human computer interaction, and applications. Over the last decade, the faculty has undertaken efforts to integrate standards and the standardization process into a number of courses in information science and telecommunications. Telecommunications courses deal with networking and protocols. Information science courses deal with data, OS, application and interface standards. As the importance of standards in IT became more persuasive, we increased the treatment of standards in a number of courses and combined the dedicated standards course with a course on web technologies where the importance of standards was easy to see. This proposal will build on these experiences to develop a new series of introductory and special focus modules that might be applied in undergraduate and graduate courses in information science, computer science, engineering and business.

The faculty involved in this proposal has significant experience in the standardization process and the application of standard. Spring has served on the Strategic Planning Committee of X3, was appointed by the National Research Council Panel for Information Technology of the Board of Assessment of the National Institute of Standards and Technology. He has served on the editorial boards of all of the journals on technology standardization. Martin

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[1] While the course at Pitt was the first graduate course on standards and standardization, we believe that Dorothy Cerni developed an earlier course for the telecommunication program at the University of Colorado at Boulder. As best we can determine that course was more narrowly focused on selected networking standards..

Weiss served on the ANSI standards committees X3V1 and X3S3 in the 1980s and conducted the first empirical research on standards that we are aware of; he also has served on journal editorial boards on standards. Both Weiss and Spring have published extensively on both the theory and practice of standardization. Tipper and Krishnamurthy work in the area of telecommunications and networking standards and have worked with NIST on standards related matters. Joshi works in the area of Role Based Access Controls (RBACs) and has made significant contributions to the related standards. Other faculty in the school have related expertise that could be brought to bear in succeeding years if NIST approves of our efforts. In addition, we will consult with colleagues who are or have made significant contributions in the field to validate our work. In particular, we have asked four of our colleagues for input: D. Linda Garcia, author of three significant OTA reports on standard and now a professor at Georgetown, Stephen Oksala, former Chair of the National Policy Committee and Conformity assessment Policy Committee and long-time board member of both X3 and ANSI, Carl Cargill, the author of the two best known books on Standards and Standardization and former standards manager at DEC, SUN, and now Adobe, and Martin Libicki, one of the most prolific authors on standards policy who works for the Rand Corporation.

Technical Project Approach

Our basic approach to standards education explores the importance of standards in everything we do backed by the fundamental rationale for standards. Standards result in economic and welfare benefits to users and or producers. These benefits are normally expressed in terms of lower product costs or lower operations costs or improved safety/health. Standards promote lower product costs because manufacturers have a larger market available than they would without standards or with multiple competing standards. Under a unified standard, manufacturers can take advantage of production economies of scale to reduce product costs. The reduction of operating costs normally arises due to variety reduction. Variety reduction implies that a firm must stock a lower variety of parts or supplies, and that these are used for a greater range of applications. Minimum attribute and regulatory standards frequently promote safety or health benefits

We will focus on technical standards in the information technology field developing modules that can be used in a variety of graduate and undergraduate courses. Each module will include four parts. A 45 minute video taking students through the main content, a corresponding set of PowerPoint slides with notes for use by the instructor, a set of student background materials with references to the relevant academic and professional literature, a web based laboratory exercise that can be used to demonstrate mastery of the content. We are prepared to work with NIST scientists and our colleagues mentioned above to refine and modify the modules to be produced but would begin with the following list of modules. The list contains two different kinds of modules. The first set (modules 1-3) provide an introduction, background on the standards organizations, and a basic picture of the standardization process. The second set (4-10) provide treatment of selected information technology standards we feel would be of interest to a broad audience. We are prepared to modify this set in consultation with NIST and our colleagues.

Base Modules

The base modules will be available for those instructors who wish to provide students with some context for the introduction to technical standards. They will be based on materials that have been refined over the last twenty years by the faculty in the School of Information Sciences.

Module 1: Introduction to Standards

This module will provide various legal and technical definitions of standards. The history of national laws pertaining to standards will be developed. The development of standards for communication and for money will be presented as examples of how standards make certain things possible. The scope of standardization will be described and the relationship between industry groups, and standards development groups will be explained. ITIC and NCITS will be used as examples. The relationship between national, regional and international standards will be explored. Current issues in standard such as intellectual property and the patent wars will be introduced.

Exercises: Students will be challenged to identify common standards they encounter in any day (Gasoline grades, road signs, book sizes, bridge heights, screw threads, weights and measures, stair and escalator slopes, meat grades, photo sizes, etc.) the standards that are manifest in a classroom (outlets, door sizes, occupancy limits, light switches, signage related to ADA, light bulbs, table heights, window sizes, etc.), and the standards that impact a standard session with a networked computer (keyboard layout, code sets, ports, networks, file types, operating system functionality, etc.).

Module 2: Standards Organizations

There are many players involved in standards. Students will be introduced to both national and international standards bodies; in addition, the role of industry consortia in standards setting will be addressed. A program of standards education must take into account the diverse set of organizations involved in setting standards. Standards are developed in several international, regional and national organizations. The relationship between the ITU[2] and ISO[3],

[2] The International Telecommunications Union (ITU is a specialized agency of the United Nations.

[3] International Standards Organization, a non-treaty organization.

and JTC1 will be explored. The ITU-T tends to focus on those standards that are of greater interest to the telecommunications portion of the information systems industry, whereas ISO tends to concentrate more on the computer and applications portions of the industry as well as how these organizations work together to avoid duplicating their efforts whenever possible through JTC1. The role of ANSI[4] and how the United States national standards organization compares with the sister organizations will be explored. The relation between the various industry groups will be explored. The relative roles of organizations such IETF,NCITS IEEE, NIST, W3C will be disambiguated.

Exercise: Students will be asked to pick one of the organizations discussed and to outline the scope of work for that organization describing how the working groups are organized and why. They will also be charged with determining how the group selected identifies and assigns new work items.

Module 3: The Standards Process

Information systems have some characteristics that are unique with respect to other standards. Cargill (1989) noted that standards frequently precede products in the information technology marketplace. Oksala, Rutkowski, Spring, and O'Donnell(1996) suggested the need for a more appropriate model to guide information standards development. More recently, Spring(2011) laid out a picture of the current theory in standards research. If we are to adequately educate individuals who will be responsible for the development of products and services in the information systems profession, then we will have to actively consider these unique aspects of the information systems standards. In particular RAND will be discussed as well as the various roles organizations play – including free ridership.

Exercise: Select an area of W3C standardization activity. In a five page paper, provide an assessment of the state of the standardization effort -- what is being standardized, what is the goal, who are the prime movers. In addition, address how it is being standardized, what are the related standards, how is the problem broken up, how are objections being dealt with. Finally, what is your view of the effort, its importance.

Selected Technical Standards

Information systems standards often include a high level of technical complexity that spans an enormous range of disciplines. For example, standards within the Internet environment or Open Systems Interconnection (OSI) Reference Model range from physical and electrical considerations to high level software constructs and structures. This requires a set of professionals with a wide variety of technical training. It is not unusual that these professionals do not always understand each other clearly, or that they are unaware of work going on

[4] The American National Standards Institute

elsewhere. Thus, some standards exist that overlap others in functionality and are incompatible with each other. Furthermore, a standard at an application level of detail may take advantage of some function specified at a lower level of detail; changes to the lower level must be propagated through the dependency chain. Our initial selection of Standards for review includes:

Module 4: Security Standards

The ANSI RBAC standard, and FIPS standard, and X.509 standards will be introduced and explained. For ANSI RBAC, we will discuss timeline for its development initiated by the NIST RBAC model. FIPS 186 Digital Signature Standard (DSS), and FIPS 197 Advanced Encryption Standard (AES) will be described and discussed. We will also overview the FIPS 140 standard to discuss the requirements for a cryptographic module implemented within the federal computer systems. The use and design of X.509 PKI certificates will also be discussed.

Exercises: Students will be assigned to create a policy using ANSI RBAC for a sample application. The students will be given an example of the details of a cryptographic module design and asked to apply the FIPS 140 based evaluation. For X.509 certificates, the students will be given assignment to create sample X.509 certificates for two entities and ask them to explain/write how confidential and/or integrity can be achieved/facilitate between the two parties.

Module 5a: Web Standards 1

The three central standards that control the web will be introduced and explained. Http, HTML, and URL standards will be described and discussed. The history and timelines for the development of the standards will be discussed. These standards will be related to other relevant standard e.g. how http is similar to smtp will be shown. The evolution of HTML from SGML and the relationship between SGML and ODA will be discussed. The advantages and disadvantages of URL over URI and URN will be discussed.

Exercises: Students will be given two exercises. First, they will shown how to use telnet/ssh to issue command line http request to obtain a full request header and body from a web server. They will be required to explain the meaning of the various headers that come back with the response.

Module 5b: Web Standards 2

The evolution of web standards such as xml, xsd, xslt, rss, rdf will be explained and situated. The lecture will explore the differences between html and xml and the importance of metadata as might be manifest through RDF will be explained. Simple demonstrations of document transformation and schema validation will be provided. Finally, web accessibility standards will be introduced

Exercises: Student will develop a web page or start from a given sample webpage written in html and be asked to transform the html to xhtml. They will be directed to the online xhtml validators and the WAI testing site to validate the transformation of their page to be standards compliant.

Module 6: Document Interchange Standards

Examples of interchange standards for documents will provide a history of competing standards and the impact of "run away" technology and how it impacts the perception of standards. This module will explore the evolution and relationship between ODA, SGML, HTML, and XML as document representation standards. The history and evolution will be explored. In addition, we will trace and examine the standards for Interpress, Postscript, HPGL, and PDF and how they evolved and relate

Module 7: Big Data and Data Mining

Although there are few real standards here, the business process has resulted in the creation of the Cross-Industry Standard Process for Data Mining or the CRISP-DM standard, which addresses the various aspects of data mining for businesses that need to be considered. This is a standard developed by industry for industry and will show a different approach for standardizing processes in comparison to other standardization models. To appreciate the details, some high-level topics in of big data and data mining will be covered in this module.

Module 8: Emerging Standards for Cognitive Radio (IEEE P.1900)

The next generation of radio systems are based on a set of technologies that together are called "cognitive radio" or "dynamic spectrum access systems". The IEEE P.1900 committee is developing standards for these emergent systems.

Module 9: Cellular Telephony and Wireless Networks

Standards for wireless networks can be separated into those developed for wide area coverage such as cellular networks and local coverage such as wireless LANs, Bluetooth, and sensor networks. The role of organizations such as the TIA and IEEE in these standards processes will be discussed. The evolution of cellular standards from GSM to UMTS to LTE along one path and from IS-95 to cdma2000 to LTE along a second path will be discussed. The relationship between 3GPP, 3GPP2, and ITU-T and how the standards develop and progress will be traced. In contrast, the IEEE 802 process (comprising the creation of working groups, project authorization requests or PARs, balloting, etc.) for standardizing wireless LANs, personal area networks, and WiMax will be considered in detail. Some high-level aspects of wireless networks will be discussed to provide the necessary background for the subject material.

Module 10: Networking Standards OSIRM and the Internet Stack (IP,TCP, DNS)

The basic reference model for open systems interconnection provides the conceptual framework within which particular standards for interconnection may be understood. While the internet protocols are now dominant, it is useful to compare and contrast the difference in approach to the development of standards represented by the ISO/ITU efforts of the 1980 and the IETF approach. Selected standards in the stack will be examined and compared. The evolution of internet mail will be contrasted with the ISO mail standard X.400.

Methodology and Project Management Plan

Materials related to several of the modules have been refined and tested over the last twenty years by the Co-PIs of this proposal. The basic methodology employed involves refinement of the material based on student success in carrying out the assignment. We will use each module developed in at least one offering of a course. We will in addition offer the modules to our colleagues in Computer Science, Business, and other departments at Pitt, CMU, Duquesne University, Robert Morris, and Allegheny County Community College and solicit their feedback and suggestions. The materials will be revised based on their feedback and submitted to NIST for review and final feedback. We will, in this process solicit specific input as to how they were used, in what courses, and where in the courses they were used. This information will be incorporated in a "module wrapper" that will be developed providing a description of where the module might be used, how it needs to be introduced to various cohorts, how much effort is expected and what kinds of results should be achieved.

Communication Plan

Our communication and dissemination plan will involve four channels:

1. We will mount a website and reference it from as many places as possible announcing the materials and making it available to as broad a community as possible. All of the materials will be made available along with information about any adopters – which we will solicit in the down load process.
2. We will work with NIST to make others aware of the availability of the materials through their organizational channels. We will undertake the same process with the various organizations that have a stake in standards education – ANSI, NCITS, IEEE, etc.
3. We will use our connections with various journals such as the International Journal of IT Standards and Standardization Research, Computer Standards & Interfaces, IEEE Xplore and Spectrum, to make their readership aware of the materials. We will also use the mailing lists used by the involved parties to establish awareness.
4. We will write up the results of the project in different forms for different conferences and present at those conferences. We believe appropriate papers could easily be developed for at least three conferences – The I-School Conference (http://iconference.ischools.org/iConference13/2013index/), the American Society

of Information Science and Technology(http://www.asis.org/conferences.html), and the ITU Kaliedescope conference. (http://www.itu.int/ITU-T/uni/kaleidoscope/2011/inex.html)

Staffing Description

The five faculty involved in this proposal have been teaching and working in this field and working with standards for a collective period of time that total almost 100 years. We provide brief descriptions here and have attached full CV as well as NSF biosketches with current and pending support for each individual.

1. **James Joshi** is an Associate Professor at the School of Information Sciences at the University of Pittsburgh. He received his MS in Computer Science and PhD in Electrical and Computer Engineering degrees from Purdue University. His research interests include security and privacy in distributed systems and networks. He has contributed extensively in the area of advanced access control models that extend the initial NIST RBAC model. His current research has focused on trust, security and privacy approaches for Cloud Computing, Social Networks and Collaborative systems, as well as trust based approaches to network security. He is an Associate Editor of **IEEE Transactions on Services Computing**, and is or has been in the Editorial board of Springer's **Journal of BigData**, **International Journal of Multimedia and Ubiquitous Engineering**, **International Journal of E-Business research** and **the International Journal of Network Security**. He has served as a Guest co-editor of six journal special issues, has published over 90 articles in book chapters, journals, and conferences/workshops. He is a co-author of the book **Information Assurance: Survivability and Security in Networked Systems**. He is a recipient of NSF CAREER award in 2006, is a co-founder and director of LERSAIS, and manages the NSF CyberCorp Scholarship for Service Program at Pitt.
2. **Prashant Krishnamurthy** is an Associate Professor of Telecommunications and Networking at the University of Pittsburgh. His research involves wireless networking and wireless security, with particular attention to localization, cryptography, and spectrum/network virtualization in wireless networks. He received his Ph.D. in Electrical Engineering from Worcester Polytechnic Institute, Worcester, MA. Dr. Krishnamurthy is the co-author of the book *Principles of Wireless Networks: A Unified Approach*, and has more than 100 articles and book chapters in the area of wireless networks, wireless security, and indoor localization. His current research is looking at virtualization of wireless networks, in particular, issues of research efficiency, isolation of services, and

customization.

3. **Michael B. Spring** is an Associate Professor of Information Science at the University of Pittsburgh. His research involves the application of technology to the workplace with particular attention distributed systems, structured document processing, collaborative systems, intelligent agents, and interface design. He has held appointments with Molde College in Norway as well as Mahidol and Siam Universities in Thailand and Jimma University in Ethiopia. He received his Bachelor's in Psychology from the College of the Holy Cross, Worcester, MA, and his Ph.D. from the School of Education, University of Pittsburgh. For more than a decade prior to joining the Department of Information Science, Dr. Spring served as Associate Director and then Director of the University External Studies Program at the University of Pittsburgh. Spring has authored three books and more than 100 articles and book chapters in the areas of text and document processing, collaborative authoring, information technology standardization, visualization, virtual reality, and educational technology. He has led research projects in the areas of on-demand publishing, intelligent text conversion, and document database publishing. His current research efforts involve the automated development of secure websites to support medical research, ontology mapping for semantic web applications, data mining of social web applications, and secure location based services.
4. **David Tipper** is an Associate Professor and Director of the Graduate Telecommunications and Networking Program at the University of Pittsburgh with a secondary appointment in the Electrical Engineering. He teaches courses on communication systems, wireless networks, network performance modeling and analysis, network design and infrastructure protection. Prior to joining Pitt in the Fall of 1994, he was a faculty member in the Electrical and Computer Engineering Department at Clemson University (Assistant Professor 1987-1993, tenured Associate Professor 1993 - 1994). His research interests include network design, virtual network design, methods for improving network survivability, the development of efficient algorithms for nonstationary/transient queuing analysis, and the design and analysis of network controls (e.g. routing, admission control, scheduling, etc.) His research has been supported by grants from various government and corporate sources such as the National Science Foundation, ARO, IBM, DARPA and MCI. He is a member of INFORMS, Sigma Xi, and a Senior member of IEEE. He is the co-author of the textbook **The Physical Layer of Communication Systems**, e is the co-editor and a contributor to **Information Assurance: Dependability and Security in Networked Systems**.
5. **Martin B. Weiss** is Associate Dean and an Associate Professor in the

telecommunications and undergraduate programs in the School of Information Sciences at the University of Pittsburgh and Associate Dean for Academic Affairs and Research for SIS. His research interests are broadly focused on the interaction between technology, public policy and industry as well as technical cooperation among competing firms. He focuses on specific issues in the telecommunications industry, such as spectrum policy, internet telephony, and broadband access. The research methodologies that my recent Ph.D. students have used include agent based computational economics, cost modeling, real options analysis, and game theory. For the past several years, the principal area of his work has been in dynamic spectrum access (DSA). He focuses on the technology and economics of market-based secondary use as well as on secondary spectrum markets (as opposed to auctions, which are the primary spectrum markets).

Use of Funds and Cost-effectiveness Description

This project leverages years of teaching in this area by the involved faculty. Indeed for Spring and Weiss, work in this area has been ongoing for more than 20 years. This project will fund only a small part of the total cost of producing these modules. Indeed, NIST will be paying for only that effort required to clean and generalize the materials so that they can more easily be adopted by faculty in a variety of course.

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Proposed Year 2 Work: Encouraging Research on Standards and Standardization

If additional funding is available in a second year, beyond the modules described above, we would like to develop a short course on research on standards and standardization. This would be more appropriate for a graduate course where there would be some expectation that some students would do major projects related to standards to contribute to the growing scholarly literature. To allow for research and educational activities in the area of information technology standardization:

1. a conceptual framework for theory development must be defined
2. a literature must be developed, collected, and organized
3. a methodology for inquiry compatible with the domain to be studied must be developed.

We would look to develop modules that would focus students on thinking about some of the issues conceptually. When we offered a dedicated course on standards in the late 1980, students were encouraged to engage in projects and research as well. Three notable outcomes of that effort were a well cited article on standards committees[5], a thesis on standards as change agents[6], and a proposal to ANSI/X3 to consider a reference model implementation on human computer interaction[7]. Our current thinking is to focus on three topics.

Types of Standards

Standards can emerge by three principle mechanisms. They can be the result of the free interplay of market forces (*de facto* standards), they can be established by force of law (*de jure* standards), or they can emerge from formal standards setting bodies (voluntary consensus standards). Much of the focus in information systems standards is on the development of voluntary consensus standards. It is important to note, however, that *de facto* and *de jure* standards exist as well. An example of a *de facto* standard is the IBM Personal Computer. An

[5] Spring, M.B., Grisham, C., O'Donnell, J., Skogseid, I., Snow, A., Tarr, G. and Wang, P., Improving the Standardization Process: From Courtship Dance to Lawyering: Working with Bulldogs and Turtles . Standards Development and Information Infrastructure, Technology Policy Working Group, Information Infrastructure Task Force, Rockville, MD, June 15-16, 1994.

[6] Bonino, M.J. and Spring, M.B., Standards as Change Agents in the Information Technology Market. Computer Standards and Interfaces. 1991, 12(2), pp 97-107.

[7] Spring, M.B., Jamison, W., Fithen, K.T., Thomas, P. and Pavol, R., Rationale, Policy Issues, and Architectural Considerations for a Human-Computer Interaction Reference Model (HIRM). SLIS Research Report LIS043/IS91011; October, 1991.

example of a *de jure* standard are the electromagnetic radiation standards that are mandated by the Federal Communications Commission (FCC).

Paul David (1987) has proposed a taxonomy of standards that is fairly comprehensive. David separates standards into reference, minimum attribute, and compatibility standards that can be applied to technical design as well as behavior. For example, technical reference standards are the weights and measures that are maintained by the National Institute for Standards and Technology (NIST). A technical minimum attribute standards is the minimum strength of material, such as steel. In contrast, the accreditation of a college or institution can be considered a behavioral reference standard, since it is compared to an absolute reference. In information systems, one of the key problems is the interoperability of systems, so the majority of standards are technical compatibility standards.

How do Standards Emerge

Traditionally, both *de facto* or voluntary consensus standards have been based on existing products. This model makes sense where prototypes based on existing products can be easily demonstrated. In the manufacturing industries, the leading candidates usually have a history of quality, and other manufacturers have already built devices compatible to these candidates. Thus, the standard would cause minimal change in the marketplace, except to provide additional credibility to the successful product. Initially, the information systems industry followed this model (Weiss, 1989b). In large part, this was acceptable because the marketplace wasn't as dynamic in the 1960's and 1970's as it is today.

However, the pace of technological change is increasing. This rapid technological change leads to some unique requirements. The information systems industry is currently in the process of developing an infrastructure of standards that will guide it for years to come. One can imagine that this industry is currently where the railroads were in the mid to late 19th century. At that time, railroad gauges varied widely, causing great inefficiencies. Railroad cars had to be unloaded and reloaded as they traversed the country. Furthermore, each city had its own time, based on the sun passing through the local meridian at noon (Stephens (1989)). As the industry evolved, standard times as well as standard railway gauges were established. This made the industry far more efficient.

The information systems industry is highly competitive. Firms are racing each other to bring out products based on new technologies to perform functions that were not possible previously; others are bringing out products that are more cost-effective implementations of leading edge products. Small firms are able to compete with large firms for the purchasing dollar of the users. Standards provide a number of features to the marketplace that have a significant impact on the competitive climate. Most manufacturers believe these impacts to be desirable, otherwise they would not participate in their development. The characteristics of the information systems industry combined with the features of the standards development process has lead to what Cargill (1989) has called "anticipatory standards". These standards, instead of lagging products by several years, as was described in the static model above, actually precede the products. That is, manufacturers develop the standard *before* they build products. Manufacturers no longer compete to have their product be adopted as a standard. Weiss (1989, 1989b) has concluded that they are, in effect, performing a significant portion of their product development in the public domain. This is a rather astounding development: some firms literally place technologies, in which they have invested significant sums of money, into the public domain so that they may be adopted into a voluntary consensus standard, at the risk of firms who benefit from the technology without making R&D investments (Toyofuku and Weiss, 1996).

This aspect of the information systems industry, the existence of anticipatory standards, gives it a unique character. It is this character that must be reflected in the educational programs in standards and in research on information system standardization.

The impact of standardization

If a manufacturer develops a technology and it is included, by their urging, in a standard, they must agree to license it uniformly and consistently to all who wish to use it. In order for it to be adopted, the firm must clearly and completely explain the nature of the technology to the members of the committee. This explanation must be in sufficient detail to convince the other committee members of its practicality and superiority.

If successful, standards assure large markets to manufacturers. This enables low cost manufacturers to make large investments in large scale production facilities and be assured of a reasonable return on their investment. It also reduces one aspect of product development risk a firm makes when developing a product. Firms that do not feel they can bring a product conforming to a standard containing an innovative or unique technology to market will not support that technology, so technologies that have not been proven are seldom adopted. Furthermore, firms may prevent any single firm participating in the standards process from gaining a competitive advantage through the adoption of their technology.

Standards create a more predictable marketplace. Since the standards process takes place in the public domain, firms are unlikely to be surprised by a competitor. Firms will continue to attempt to differentiate their products, but the basic functionality and compatibility will remain beyond competition. Thus, the scope of the competition is limited. This means that, in general, competing standards are avoided. Manufacturers can focus their competitive efforts at other aspects of the product.

Standards extend the life cycle of derived products. The existence of an established standard will encourage users to adopt the standard for their applications. Once adopted, users are generally reluctant to switch to a new standard (Farrell and Saloner, 1986). Thus, manufacturers will continue to supply products conforming to the old standard even though a new, perhaps superior standard exists. This allows manufacturers to extract additional profits from a market, particularly if it exhibits rapid technological change.

Methodology

Research on standards draws on methodologies developed in a variety of academic disciplines. Since the motivation for standards is rooted in cost reduction and market expansion, economics is a key discipline. Indeed, the great majority of research in standardization can be found in the economics literature. The focus of this has been on the relationship of standards to market dynamics and predation. In information systems, standards often have a great deal of technical content; effective standards participants must be competent engineers and scientists. Thus, the technologies on which information systems standards are based are critical, and the variety of disciplines that support them, such as electrical engineering and computer science, play a role. Finally, since many information systems standards are developed in committee, political theory is important. The standards research performed thus far has tended to neglect this important avenue of inquiry.

Proposed Year 3 Work: Simulation of the Standards Development Process

If work in years one and two meets NIST expectations, we would like to work with NIST on a hands on simulation of the standards process. This experience would tie together students in one or more institutions and schools providing an opportunity to develop a standard over the course of the semester in a simulated standards setting committee.

The purpose of this simulation is to provide students with experience in the standardization process. We believe this is the best solution to addressing the industry's need for trained and experienced personnel in standards development – short of having them actually participate in a standards meeting. Raiffa(1982) has had considerable success in using such a simulation to develop an understanding of negotiation. This course follows Raiffa's model, but extends it to a problem area where the solution domain is discrete.[8] The actual operation of standards committees is currently poorly understood in an objective, scientific sense. The formal structure of the process is well known, and many anecdotes about the process are available, but none of these comprise a complete understanding of the actual processes. Such an understanding may allow adjustments that could increase the efficiency and effectiveness of the developers. These adjustments can be tested in the simulated environment to measure improvements.

In this course, students will learn the nature of the standards process by developing a standard. To do this, however, it is necessary to duplicate as closely as possible the constraints and the motivations faced by the standards developers. This can be a fairly complex, since many constraints and motivations, sometimes conflicting, exist in the actual standards development process.

Course Design Issues

Several key issues exist for such a course to be successful. The resolution of these issues is critical to the development of a realistic simulation. While each of these will be discussed in some detail in subsequent sections, the overall background is outlined below.

We have characterized information systems standards as being part of the competitive product development process between firms. In order to have a realistic and effective simulation, essential aspects of this (external) environment must be reproduced. In a competitive marketplace, one can assume that each firm has a different portfolio of technical strengths, product history, corporate culture, and corporate strategy. Each of these factors can affect the posture and

[8] In standards, the participants must often choose between two alternatives; intermediate or compromise choices are not always available. Raiffa's domain of negotiation consisted of dollars, a continuous entity

behavior of a firm's representatives in a standards committee. Firms adopt positions through their representatives that they believe will give them the greatest advantage in the marketplace after the standard is complete. The objective of this game is market dominance.

Simulating the Motivation of Participants

Participants in the committee are individuals, motivated by the desire to meet personal objectives and achievements. The employer of the participants, *i.e.*, the firm they represent, influence those personal objectives to the extent that the representative becomes a spokesperson for the firm in the standards committee. In general, a victory for the firm also comprises a victory for the committee participant.

In the context of the course, this motivation must be simulated through group processes. The groups must be given an identity, and a sense of group loyalty must be developed. In the actual standards development process, this group loyalty is often supplemented by economic motivation. It will not be possible to simulate this in a practical (*i.e.*, cost effective) way in the course. Since the group loyalty is the principle binding mechanism, care must be taken so that the loyalty of an individual to the (simulated) standards committee does not exceed the loyalty to the original group. Limiting the frequency and duration of standards committee meetings is perhaps the most practical way of doing this.

Technical Background

In a given standards debate, several different technical contexts, or product development objectives, exist. For example, a firm that produces CAD systems would probably have a very different technical context for digital facsimile transmission than would a firm that has historically produced mass-market facsimile machines. The nature of the research and development activities at each of these firms would probably be quite different, as would be the design objectives. The CAD manufacturer would make a different cost-performance tradeoff, for example, than the mass-market fax manufacturer. In all probability, this phenomenon would be true even these firms would be targeting the same (new) market because their technical expertise and corporate tradition would be carried into the new market.

To simulate this divergence of technical background, students from different groups can be tutored on (different) specific technologies relating to the standard to be developed. Various recitation sections would gain expertise in a specific area and not in another. This technical training should not only cover the theoretical aspects of the applicable technologies, it should also focus on applications using these technologies. The student should develop sufficient expertise in their technology that they will be unwilling to accept the other(s) without considerable debate. When the simulated standards committee begins its deliberations, this divergent training should have an effect similar to the one that can be observed in actual standards committees.

Simulating the Standards Setting Process

The position of a firm is argued by the representative of that firm to the committee. This individual must have a background that is sufficiently technical to thoroughly understand the content of the contributions to the committee and the debate surrounding them. He or she must be able to adopt a position in the committee that best represents the interests of their firm. Secondarily, but equally importantly from an overall committee participation point-of-view, the representative must be able to "sell" the firm's internal product designers on the committee decisions, particularly if they are contrary to the firm's initial strategy. A participant who is unable to do this will not be viewed as an effective participant by the rest of the committee because any committee decisions involving that participant may be considered tentative in future.

Sufficient ambiguity exists between the overt and covert objectives of a firm and the position adopted by the committee that this relationship must be simulated. The Keeper of the Corporate Strategy is not always there to make key decisions in a committee, so the welfare of the firm lies in the hands of a representative with personal preferences in addition to a perhaps imperfect understanding of the firm's objectives.

This can be simulated in the course by having separate individuals responsible for committee participation and for the group's design decision-making. It will be up the chief designer to lay out a strategy that should be followed by the committee representative. If a sufficient group identity exists, then the committee representative will make his or her best effort to represent the strategy of the group's chief designer.

Committee Structure

The formal and, to a lesser extent, informal structure of standards committees has been fairly well documented (Cargill 1989). From the point of view of the simulation course, it is a small matter to reproduce this structure. Note that this is one variable that we can manipulate as researchers into the standards development process.

Economic Motivation

Firms incur the cost of participating in the standards process because they perceive an economic advantage to doing so. This economic advantage may take the form of competitive advantage in the specific product market covered by the standard, or it may take the form of developing good will to be used in other arenas. If the benefit is in the marketplace, then the firm has an incentive to develop a standard that is practical given their technological expertise. A standard that utilizes outdated technology or is difficult, costly, or impractical to implement is not worthwhile. Thus, the firm's representatives must ensure that the standard not only is consistent with the firm's strategy, he or she must also be sure that it can be implemented cost-effectively.

Given this practicality constraint, it is important that the standard that is developed by the students in the simulated committee be developed into a working product by other individuals from each group. The committee participant should act only as an advisor in this capacity. In order to simulate the economic benefit to being the first firm to market a compatible product that works, the first group to develop a product could earn a trophy or a pizza dinner sponsored by the remaining members of the class. Bragging rights and public acknowledgement can also be a powerful motivation.

Computer-based simulations

Simulation can be taken further as well. The development of agent-based modeling (using tools such as REPAST and NetLogo) may provide a reasonable basis to model the committee-based decision making process to explore how changes in rules and procedures might (or might not) affect outcomes. If sufficient funding is available, we will develop some software to enable students to learn through simulation about how rules affect outcomes.