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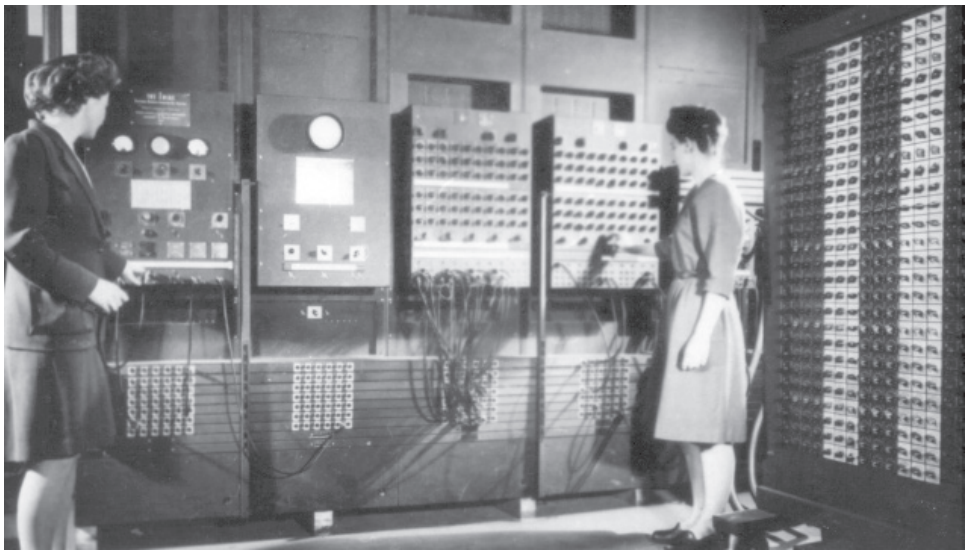
Standards, the Glue for Innovation

Sandy Ressler

This paper was the second place winner in the 2018 World Standards Day Paper Competition



ENIAC, The first electronic computer

Introduction

The most interesting and impactful innovations occur at the intersections of technological domains. Standards can provide the glue to define these intersections and make them realizable. Experts from different domains often talk in their own very specialized languages (jargon). While useful for discussions within a domain, differences in language across domains are an impediment to fruitful collaboration. Standards can provide a common language to strengthen collaboration between specialists from different domains. This essay addresses how standards contribute to an "Innovation Nation." Specifically, it examines how the development of standards contributes to the success of many industries.

What is a Standard, Anyway?

A standard is a "document, established by consensus and approved by a recognized body, that provides for common and repeated use, rules, guidelines, or characteristics for activities or their results, aimed at the achievement of the optimum degree of order in a given context."[1]

For information technologies (IT), a standard can be both a technical set of requirements and a description of interfaces between functional domains that can be implemented in a product, process, or system. Interface standards connect two different domains, such as operating systems and applications, to make meaningful communications possible both literally and semantically.[2] The development of consensus standards is done by stakeholders from industry, government, academia, etc. The number and diversity of the participants can lead to a more rigorous and technically sound standard. Of course, there are instances where too many divergent views can lead to gridlock on reaching consensus. Capable leadership is a major factor in achieving consensus.

Standards don't simply pop into existence. The most successful ones are created to solve real world problems. Standards development can be anticipatory, foreseeing new technologies and markets. Standards development can be reactionary, responding to products, processes, and services already in the marketplace. Often, IT standards development is somewhere in the middle of anticipatory and reactionary. There may be competitive standards projects that compete for the same markets. Given all this, not all standards efforts are successful. Sometimes the standards are too early. Sometimes the standards are too late to have meaningful impact. Poor leadership can doom a standards project. Even if unsuccessful, the standards frequently have important influence on future

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SES Vision

To be the premier organization developing standards professionals through education, certification, and recognition.

SES Mission

To provide opportunities for professional development through programs and services, and to promote awareness, use, and value of standards and conformity assessment.

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From the Editor

The March/April issue leads off with Standards, the *Glue for Innovation* by Sandy Ressler—the second place paper in the 2018 WSD paper competition. Sandy discusses the impact of significant technology standard. Our other main article is *Gender Inclusion* in Standards, where Steve Oksala reviews activities related to both the recognition of gender in standards and the challenge of gender inclusion in the development of standards. This is an area that has received attention in Europe, but as far as I can tell, there has not been much interest in the US standards community. We also have our usual news about members, the law, and standards in general, as well as our occasional look at standards that struck the editor's fancy *in Standards, Standards, Everywhere*. And, of course, words from our president and executive director.

You will note elsewhere in this issue a "help wanted" ad for the SES editor. While I have enjoyed my time in this seat, particularly the interaction with many standards professionals, there comes a time when moving on becomes more attractive. For me, celebrating my seventy-fifth birthday in January was the driver; it is time to let a different voice proceed and keep the journal as an important part of educating and informing standards professionals. I expect that new blood will take us in somewhat different directions, and that's good—it is an opportunity for everybody in the Society to stop and think about what is important going forward.

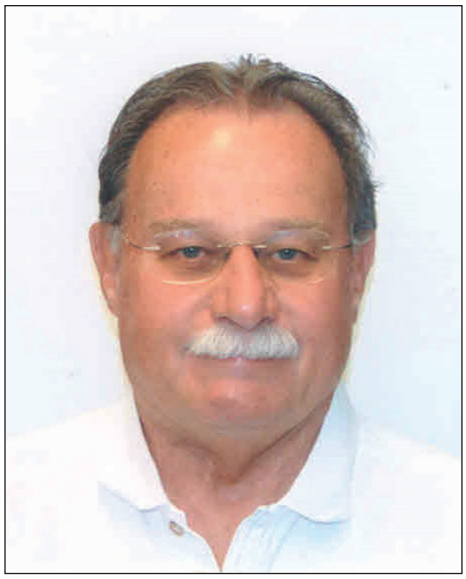
I am not, however, leaving right away—I will be keeping the flame lit until a new editor is in place. I also intend, after that, to contribute articles for publication in the journal, particularly in the area of the history of standards.

So don't forget—I am still looking for articles that help our members with useful tips, new technology, or anything else that can make their working lives more productive. And if you can, consider taking that next step to editorship.

Steve Oksala

In This Issue

From the Executive Director



I hope by now the polar vortex has lost its grip on those of us in the snow belt. It has been a long cold winter, but things are looking warm and bright for the upcoming year here at SES!

We are gearing up for a great conference this August in Montreal. Keep checking our website for details and check out the page in this journal about the conference sessions and educational opportunities.

It is with great regret that we have accepted Steve Oksala's request to step down as our editor of this journal. He has done a terrific job in this position during the last six years. He brought a wealth of experience to this job that will be hard to replace. We wish him the very best in his continuing retirement.

Here's snapshot of what is happening in some of our committees:

The **Marketing Committee** is just completing a project to revamp the SES advertising branding and has begun using the new look in our online social media. The committee is also working on ways to provide the membership with SES branded merchandise, allowing members to show their SES pride at work and during events. Finally, the committee is working closely with the other committees in preparation for the 2019 SES Conference to ensure a successful event including designing flyers, advertising, and assisting in upkeep of the conference webpage.

The **Membership Committee** is developing a survey that will be sent to members about various topics that we need your input on: education, leadership and development, and conference logistics. They are also actively working on member retention and recruitment activities. The committee has also established a scholarship program to support students involved in the use of standards in their academic curriculum. We know that each new generation of graduating students holds the potential for helping us achieve our mission of increasing awareness and use of standards. See our website for all the details at https://www.ses-standards.org/page/Scholarship. There are two scholarships this year, sponsored by Underwriters Laboratories and CSA Group.

The **Standards Committee** is currently working on an effort to reinvent SES 2 to improve its relevancy and ease of use. It is anticipated that the new SES 2 will differentiate between requirements and best practices, and address not only voluntary consensus documents, but also consortia and corporate operating procedures. We hope to receive feedback from the SES Annual Survey regarding the needs of our stakeholders with respect to SES 2.

Under the **Publications Committee**, the World Standards Day paper competition has begun for 2019. You will find all the information on our website https://www.ses-standards.org/page/WSD2019 and in this journal. The deadline to have your paper submitted this year is midnight, **September 13, 2019.**

Our mission is to help you in your development as a standard professional by offering education and the only certification in the US and Canada specific to standards professionals. I encourage you to consider it. I would be happy to discuss it with you; call me any time.

I am here to support you in any way I can. Please feel free to contact me on my cell 309-716-6504. My email is admin@ses-standards.org.

Mike Morrell

As always, Mike

Help Wanted

The SES Executive Director, in conjunction with the Board of Directors, has convened a Search Committee for the position of Editor of *Standards Engineering*, the official, bi-monthly Journal of SES – The Society for Standards Professionals.

The Editor of *Standards Engineering* is primarily responsible for soliciting articles for each issue of the Journal, writing some articles, including an editorial for each issue, editing all Journal content, working with vendors on layout and production, and actively participating in the Publications Committee which is responsible for overseeing the Journal.

Applications for the Editor position should be sent by June 3, 2019 to admin@ses-standards.org. To view the full job description and for further information, go to www.ses-standards.org.

(Continued from page 1)

standards so the efforts are rarely a complete failure. Consensus among the individuals of a standards committee is often difficult but when led fairly and with knowledgeable direction, the resulting standard is often greater and more valuable than simply the sum of its parts.[3]

Standards can also be inspired by visionary individuals who predict not-yet-realized systems or early prototypes that instantiate particular visions. Two innovative examples are Vannevar Bush's *As We May Think*[4] originally published in 1945 and Doug Englebart's *Mother of All of Demos*[5] created in 1968. Bush's essay predicted the use of hypertext and the World Wide Web, far ahead of its time. Englebart's demo for an effort funded by the US Defence Advanced Research Project Agency (DARPA)[6] included the use of a mouse (which he invented) and audio/video communications all working seamlessly together. Innovation isn't just a historical activity. Current innovation is often led by eloquent visionaries such as the recent work of Bret Victor[7] and his collection of video demonstrations of new systems for computer programming, interfaces to documents, and haptic environments for tangible programming. These may lead to future standards while at the same time taking advantage of existing standards.

Innovation in an interdisciplinary domain, at one of these domain boundaries, is inherently more difficult than within a single domain. Academic and institutional organizations naturally segment along domains. An organizational structure that is often created to deal with multiple disciplines is some type of "center of excellence" or a type of "joint institute." The US National Science Foundation provides this definition of interdisciplinary research:[8]

"Interdisciplinary research is a mode of research by teams or individuals that integrates information, data, techniques, tools, perspectives, concepts, and/or theories from two or more disciplines or bodies of specialized knowledge to advance fundamental understanding or to solve problems whose solutions are beyond the scope of a single discipline or area of research practice."

The role of Application Programming Interfaces (APIs)

One of the interesting consequences of the desire to separate functionality into different layers is the rise of the API. APIs have become so pervasive that they are a domain of study themselves. But what is an API really? It is a language and methods to communicate between a client and a server.

In the US government, there is an organization called 18F[9] that seeks to use best practices to improve IT projects. 18F, "partners with Federal agencies to improve the user experience of government," clearly a non-trivial task. Their developer program page on the benefits of APIs lists the following: efficiency, wider reach, leverage government assets, automation, apps, partnerships, integration, personalization, and mashups. APIs are a key technical approach to meet their mission and are critically important when it comes to the implementation of standards.

Let's examine a few examples of information technologies and how standards development across domains helped create or improve their development, and then explore their impacts.

Development of the World Wide Web

Domains: networking, graphics, security

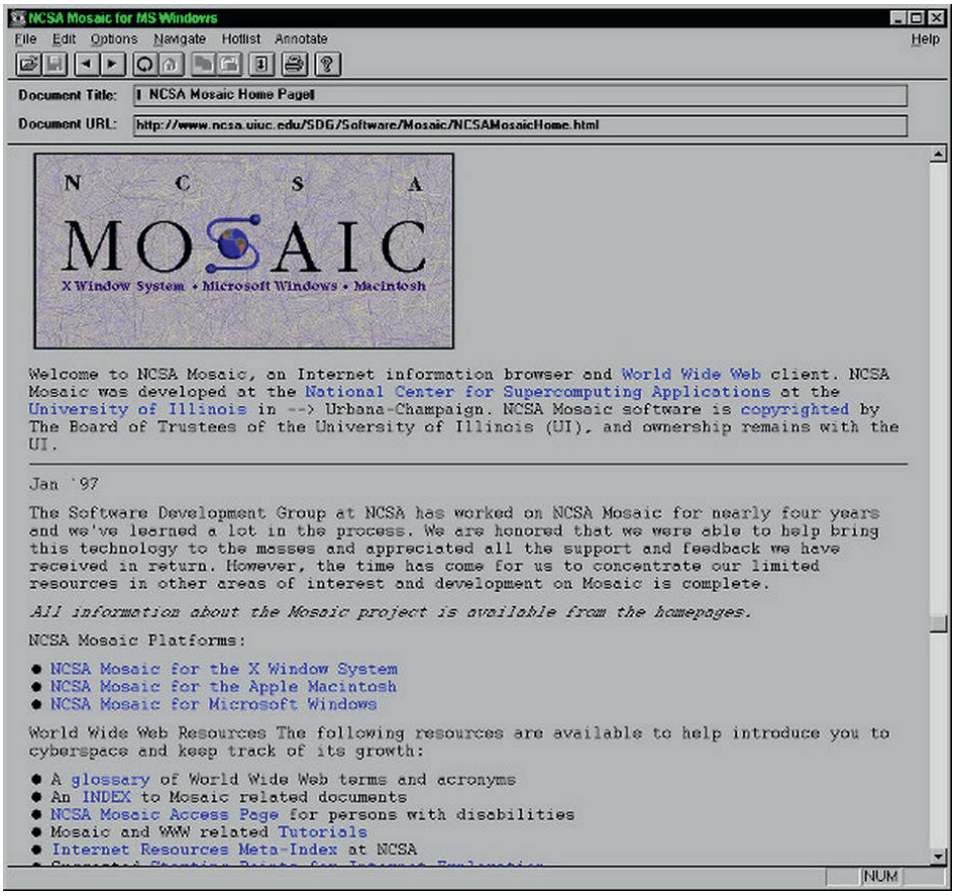


Figure 1: The first large scale web browser (Mosaic)

Key Standards: GIF[10], HTML, JPEG[11], TCP/IP, URI, HTTP, SSL[12]

One of the most revolutionary technologies in the past twenty years was the development of the World Wide Web.[13] The Web created by Tim Berners-Lee wasn't all that complicated, which is perhaps a sign of its importance. Created in 1993, but exploding in use in 1994, the Web was really a small set of protocols built on top of Internet networking protocols. The Internet (based on the US military's ARPANET) was also a series of protocols, each doing a specific task and ignorant of the functionality of protocol levels farther away. To create a web site using the HTML standard, you didn't need to know the details of TCP/IP networking.[14]

The web really took off with the introduction of graphical web browsers.[15] Pictures and text with hyperlinks could be seamlessly browsed, creating a web of information users could explore with ease. The web browser interpreted the HTML document standard and communicated via the HTTP[16] protocol to the web server. Tim Berners-Lee's genius was to define a set of protocols: HTML, the

HyperText Modeling Language, defines the document format specification; the URI Uniform Resource Identifier (commonly called a URL, or Uniform Resource Locator, for an HTML document), identifies a document or other resource over the network.); and HTTP, the Hypertext Transfer Protocol, defines methods to retrieve linked resources. Berners-Lee also wrote the software for the first web server and web browser.

This required interfacing between disciplines of user interface design, network programming, computer science, and hypertext. Berners-Lee's decision to make all the specifications open and free enabled the World Wide Web to scale. An interesting counterexample is Project Xanadu, Ted Nelsen's project, which never really took off even though he was the inventor of hypertext and the whole conceptual basis for a web of information back in 1965.[17] The impact of the World Wide Web has been profound.

Smart Phone

Domains: mobile networking, Internet, graphics, security

Key Standards: GSM, CDMA[18], WiFi, HTML, TCP/IP, URI, HTTP, SSL

Computing has moved from the mainframe to desktop and now to the smartphone.[19] Mobile computing platforms are the leading way people interact with computing services of all types.[20] The technology embedded in a smart phone, including the myriad of sensors, networking capabilities, and high resolution displays, is truly astounding. This highly integrated functionality would not be possible without the use of a huge number of standards. First, the set of standards for telephony. Next, the standards for access to the Internet and its suite of WiFi networking. Web services and displays all adhere to the suite of W3C standards for web pages used by all mobile web browsers.[21] The apps themselves, while often proprietary, adhere to vendor mandated APIs which let them securely interact with the outside world of standards and their interfaces.

In a recent video interview,[22] Vint Cerf (co-creator of the Internet) pointed out that the development of smartphones, the combination of mobile phones and the Internet, was due to the use of APIs. The combination of these two technologies was a mutually reinforcing event because of the use of APIs which allows Internet applications to be ignorant of the details of the mobile phone. In 2007, when Steve Jobs introduced the iPhone, the magic of smartphones truly accelerated. The mobile API and Internet APIs are happily ignorant of each other, making application development far less complex.

WebXR: Virtual Reality on the Web

Domains: position tracking, networking, real-time graphics,

Key Standards:, 802.11,[23] HTML, TCP/IP, URI, HTTP, WebVR, WebXR

Virtual and Augmented Reality (VR & AR) is an interdisciplinary domain involving user interfaces, computing hardware, real time computer graphics, and spatial audio, all in an effort to transport the user to new simulated environments.[24] VR and AR have been around for over twenty-five years, but have never really taken off in the wider mainstream. Part of this is just the usual time delay for any revolutionary technology to diffuse into society.

Many technologies must work seamlessly to give the illusion of presence, hopefully resulting in an "immersive" experience. (Note that WebXR[25] is a new term encompassing WebAR, WebVR, and WebMR.[26]) WebXR is particularly interesting because it is an attempt at merging the ubiquitous use of web browsers with VR. A WebXR capable browser is aware of the hardware capabilities of head-mounted displays[27] and knows how to process the user's head position and orientation. The browser is able to read the data conforming to the WebXR standard.[28]

The resulting system enables VR producers to simply publish a web URL and all the software needed is built into the web browser. This marriage of web browsing and VR has the potential for enabling much wider penetration of VR technology to the mainstream. Yet again, this capability is only possible due to the use of a wide variety of standards.

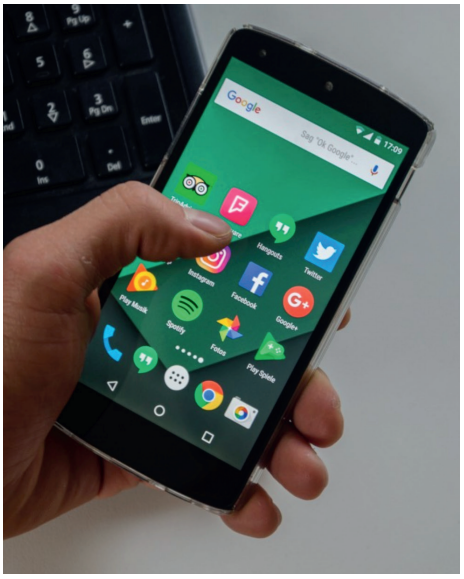


Figure 2: Smart phone

Figure 3: Virtual reality (head mounted display) in use

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3D Printing
Domains: chemistry, networking, graphics, electromechanical systems
Key Standards: STL, X3D,[29] HTML, TCP/IP

Recent advances in electro-mechanical systems, along with chemistry, and integrated with computing power has given us desktop 3D printing.[30] Standardized file formats, primarily stereolithography (STL),[31] make it simple to take the graphic description of a 3D object from a variety of 3D file formats, convert it to STL, and print the object. Many different materials are available from a host of 3D printing service providers,[32] ranging from simple, one color plastic to hard metals, ceramic, and full color objects.

Like most practical technologies, the history is much longer. 3D printing has been around for forty years, beginning with a process called stereolithography. A plastic compound is spread out layer by layer on a surface, slowly building up the object. "The key to stereolithography is a kind of acrylic-based material known as photopolymer. Hit a vat of liquid photopolymer with a UV laser beam, and the light-exposed portion will instantly turn into a solid piece of plastic, molded into the shape of your 3D-model design."[33] However, the integration of the chemistry of photopolymers with the representation of 3D file formats really made the technology takeoff. Now, there are lots of online 3D asset stores where you can buy preformed objects or make your own from your own data. Another accelerator has been the adaptation of the inkjet printing technology to print with other materials. The concept of controlled printing of substances is being used to make biological organs,[34] electronics that you print on skin,[35] and concrete,[36] among other things.

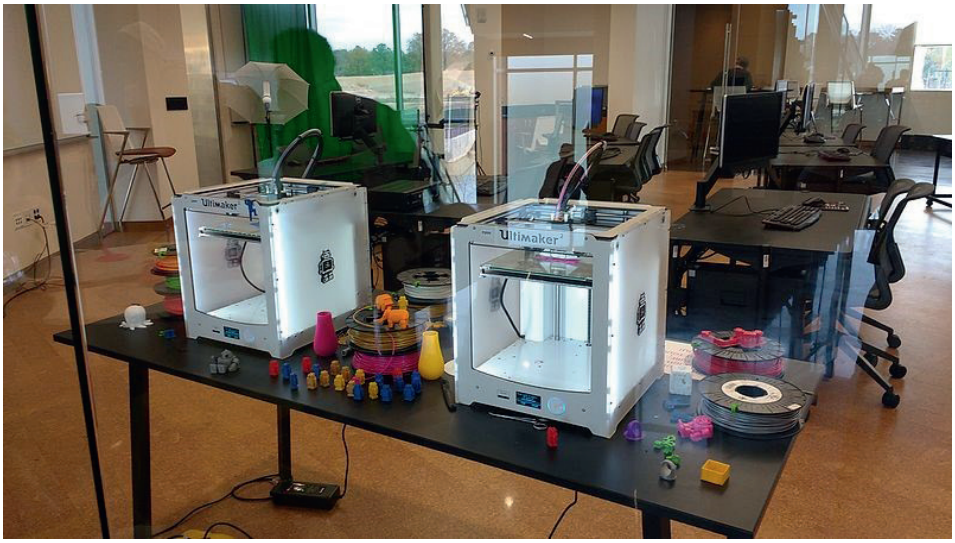

Figure 4: Two desktop 3D printing machines in a library

Self-Driving Cars
Domains: LIDAR, path planning, networking, graphics, embedded electronics, power management
Key Standards: GPS, NHTSA,[37] HTML, TCP/IP

Self-driving cars are a great example of a compelling application made possible by

Figure 5: Cruise automation Chevy Bolt under test

the integration of numerous technologies and standards.[38] In addition to purely technical standards, legal regulations also come into play, as adherence to standards and specifications is literally a matter of life and death. There is a huge amount of investment taking place to make self-driving cars a reality.[39]

The intersection of legally binding regulation and self-driving technical standards is a fascinating area of research. Self-driving car algorithms must determine what is the "least worst" action to take. For example, should the car hit a pedestrian in order to avoid running into a tree and hurting the driver?

What does it mean when you write software that must make ethical decisions?[40] Standards can help bridge the world of legal language and regulation and technical specifications. One early example is the development of "levels of autonomy" by the SAE (Society of Automotive Engineers) as shown in Table 1.[41] This standards development organization has created a six-level hierarchy of self-driving capabilities.

Reliable GPS[42], LIDAR[43] sensing to give a car data on the 3D environment, GPU processors to compute the real time data and react to obstacles and provide crash avoidance. The self-driving car is a high performance computer on wheels with a highly integrated system.[44]

The important aspect isn't that this definition of levels is complete or necessarily accurate. It's important because it gives us a language to which we can write technical and regulatory specifications. If we agree on the language, we can make significant progress.

Table 1: SAE Autonomy Levels

LEVEL	Name	Narrative definition		Execution of steering and acceleration / deceleration	Monitoring of driving environment	Fallback performance of dynamic driving task	System capability (driving modes)
Human driver monitors the driving environment							
0	No Automation	The full-time performance by the human driver of all aspects of the dynamic driving task, even when "enhanced by warning or intervention systems"		Human driver	Human driver	Human driver	n/a
1	Drive Assistance	The driving mode-specific execution by a driver assistance system of "either steering or acceleration/ deceleration"	using information about the driving environment and with the expectation that the human driver performs all remaining aspects of the dynamic driving task	Human driver and system		Some driving modes	
2	Partial Automation	The driving mode-specific execution by one or more driver assistance systems of *both steering and acceleration/ deceleration*		System			
Automated driving system monitors the driving environment							
3	Conditional Automation	The driving mode-specific performance by an automated driving system of all aspects of the dynamic driving task	with the expectation that the *human driver will respond appropriately to a request to intervene*	System	System	Human driver	Some driving modes
4	High Automation		*even if a human driver does not respond appropriately to a request to intervene*			System	Many driving modes
5	Full Automation		*under all roadway and environmental conditions* that can be managed by a human driver			System	All driving modes

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Cryptocurrency

Domains: economics, security regulation, law, public key cryptography, networking

Key Standards: PKI[45], TCP/IP, SEC[46] regulations, ERC

Digital currency has become a raging fad with the exploding value of Bitcoin, Ethereum, and a host of other cryptocurrencies.[47] While this technology was created first by the pseudonymous Satoshi Nakamoto[48] and then by a group of open source developers, the developers recognized the value of standards and quickly put into place a set of processes to expand the core technology with such things as BIPs (Bitcoin Improvement Proposals) analogous to the RFC (Request For Comment)[49] process used by the Internet Engineering Task Force[50] for the development of Internet standards.

Discussing standards in the context of cryptocurrency is somewhat ironic as much of the philosophy for the development of cryptocurrencies is based on a libertarian, even anarchistic, mentality. However, at its core, cryptocurrencies are defined by the code used to implement these systems. The code represents what truly exists and the code may or may not adhere to some specification. Almost all the real cryptocurrency projects are "open source" and anyone can modify the code if it is accepted by the people controlling the source code libraries. If you want to make a change that is not accepted you can "fork" the code causing a branch in the code and sometimes a duplication of the tokens of value. This has happened several times both for Bitcoin and Ether. There exists Bitcoin and Bitcoin Cash and Bitcoin Gold, each fork of the base code attempts to solve one or another problems. The same is true for Ethereum.

From a standards point of view, this is somewhat annoying. However it has been ameliorated by the development of some more rigorous standards. In the case of the Ether network and the Ethereum token there is a standard for "smart contracts." A smart contract is code that is executed on the Ether network itself. There is a standard called ERC20[51] which defines the interface to the network for basic functionality. (ERC stands for "Ethereum Request for Comment," and is like the previously described RFC process for developing Internet standards.) If you want to produce a new type of smart contract, you can simply ensure that it conforms to the ERC20 specification, and your smart contract is then fully functional on the Ethereum network. In general, ERCs let you define your own token, which is the reason there are so many tokens.

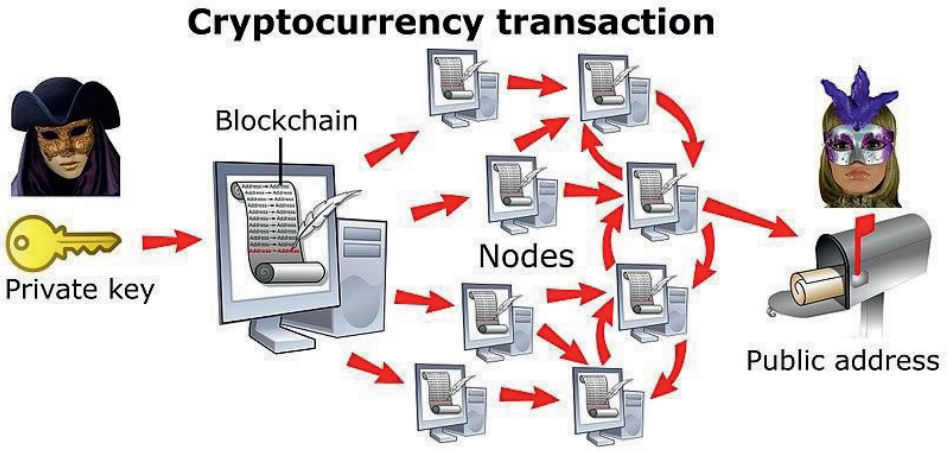


Figure 6: Communication in a block chain that can hold cryptocurrency

Digital Video[52]

Domains: cryptography, compression, video, audio

Key Standards: DVD, ISO 9660, MPEG, MP3, MP4

My favorite example of a hugely impactful standard is MPEG.[53] This suite of standards was responsible for the revolution of music on Compact Discs (CDs)[54] and then video on Digital Video Discs (DVDs). The technical specifications for music and videos were of sufficient quality to allow the digitization of formerly analog media. The move from analog to digital media exploded the distribution of music and video on all types of platforms, first with CDs and DVDs, and now with media streaming. These would simply not have been possible at such a scale, without the MPEG standards.

It also gave rise to highly problematic issues of intellectual property. Music and movies are very expensive to produce and the artists and studios want to be paid for that work. There is always a balance between copyright protection and usability. The technical committees came up with some highly controversial and, from a user point of view, annoying protections. The copy protection, limitations of region codes (DVD players are mandated to play the DVD only within a single predefined geographic region) and the extremely easy to hack Content Scrambling System (CSS) did not help DVD

Figure 7: Digital video content

popularity. CSS was quickly circumvented with DeCSS.[55] From the Wikipedia page on DeCSS: "DeCSS was developed without a license from the DVD Copy Control Association (DVD CCA), the organization responsible for DVD copy protection—namely, the CSS used by commercial DVD publishers. The release of DeCSS resulted in a Norway criminal trial and subsequent acquittal of one of the authors of DeCSS. The DVD CCA launched numerous lawsuits in the United States in an effort to stop the distribution of the software."[56] DeCSS was not developed with the intent to break copyright and let people steal DVDs. Rather, it was to get around the fact that DVDs could not be played on Linux machines because of the enforcement of DeCSS by DVD players. It was all really about usability.

The solution, at least for the music portion, was the creation of easy-to-use interfaces, first popularized by Apple's iTunes. Of course the even easier to use Napster, which offered peer-to-peer music copying,

was free; but it was ultimately found to be illegal, and was shut down. It did, however, spur industry to come up with user-friendly and legal methods to share music such as iTunes, Spotify, and others.

User convenience is key to the ability to charge and collect money for content. If the service is convenient and doesn't block the user from reasonable use, people are happy to pay. If not, content circumvention is likely to occur.

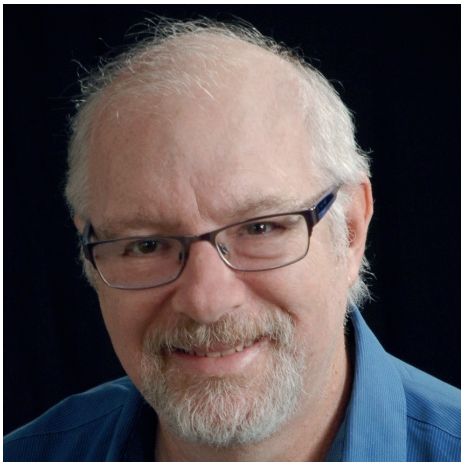
What's Next?

Standards development is as strong as ever. However, new publication methods such as online, open source, and the use of more non-traditional information sources are important. What remains constant is the standardization community, which is comprised largely of private sector standards developing organizations. The standards participants come from industry, academic institutions, professional societies, consumer groups, government, and nonprofits. They are motivated by market forces, public interest, and consumer protection. The resulting standards are both driven by innovation and drive innovation.

A wide range of future technologies such as artificial intelligence, quantum computing, drones, robotics, internet-of-things, brain-computer interfaces, and most anything imaginable will benefit eventually from the use and development of standards, especially if they hope for widespread dissemination. Standards development is, at the end of the day, a human activity fraught with complications and complexity but which can lead to amazing new technologies.

About the Author

Sandy Ressler has over forty years of experience with a wide variety of computer graphics and user interface technologies, the last thirty with NIST. He began his career at Bell Labs followed by a stint at a video game startup he is a pioneer and visionary in the development of 3D computer graphics for use on the Internet. He was on the Web3D Consortium's, board of directors for six years, two years as vice president. From 1997-2001, he created and ran the world's leading website for 3D on the web at About.com. Ressler ran several Web3D Showcase events (demonstration events) at SIGGRAPH (the premier conference for the computer graphics industry) which exposed tens of thousands of people to Web3D applications. Ressler has also been a leader in applying visualizations for 3D anthropometry (human measurement) data, resulting in safer children's products. He has published over 20 peer-reviewed articles and is widely regarded as one of the leading figures in the industry as illustrated by articles in the press including the NY Times, Federal Computer Week, and Popular Mechanics. Ressler has also authored three books, two on electronic publishing and coauthored the classic *Life with UNIX*. He holds an MFA in visual arts (computer graphics) from Rutgers University.



Disclaimer

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1 ISO/IEC Guide 2:2004 Standardization and related activities -- General vocabulary

2 Shiffrin, R. M., and K. Borner. "Mapping Knowledge Domains." *Proceedings of the National Academy of Sciences*, vol. 101, no. Supplement 1, 2004, pp. 5183–5185., doi:10.1073/pnas.0307852100

3 ISO, "Economic Benefits of Standards", https://www.iso.org/publication/PUB100403.html

4 Bush, Vannevar. "As We May Think." *Interactions*, vol. 3, no. 2, Jan. 1996, pp. 35–46., doi:10.1145/227181.227186

5 MarcelVEVO. "The Mother of All Demos, Presented by Douglas Engelbart (1968)." YouTube, 9 July 2012, www.youtube.com/watch?v=yJDv-zdhzMY

6 DARPA, the Defense Advanced Research Projects Agency, has been a notable funding resource for advanced technologies

7 "Bret Victor." *Bret Victor, Beast of Burden*, www.worrydream.com/

8 https://www.nsf.gov/od/oia/additional_resources/interdisciplinary_research/definition.jsp

9 18F is part of the US General Services Administration; see http://www.18f.gov

10 The Graphics Interchange Format (GIF) is a bitmap image format most commonly used for small animations was an early supported image format on the original web browsers

11 JPEG is a set of standards (ISO/IEC 10918) for the compression of digital images (still pictures) developed by the ISO/IEC/JTC1 Joint Photographic Experts Group

12 Secure Sockets Layer (SSL) is a cryptographic protocol that provides secure communications over a computer network

13 Mortillaro, Nicole. "The World Wide Web Turns 25: How It Changed Everything." *GlobalNews*,23Aug.2016,www.globalnews.ca/news/2897780/the-world-wide-web-turns-25-how-it-changed-everything/

14 TCP/IP is the Internet protocol suite—Transmission Control Protocol and Internet Protocol. They are the foundational networking protocols of the Internet

15 Figure 1 from https://www.zdnet.com/pictures/say-hello-to-the-early-days-of-web-browsers-gallery/4/. The National Center for Supercomputer Applications (NCSA) is home to the Mosaic web browser is responsible for the Mosaic browser

16 HyperText Transfer Protocol (HTTP) is the primary standard for communication between web clients and servers making the World Wide Web a reality

17 Project Xanadu, https://en.wikipedia.org/wiki/Project_Xanadu

18 GSM and CDMA are the two major radio systems for cell phones. GSM dominates Europe, while CDMA is used by some carriers in the US; other US carriers, and most of the rest of the world, uses GSM

19 Figure 2 photo from https://pxhere.com/en/photo/478359

20 "Internet Trends Report 2017" Mary Meeker, Kleiner Perkins, https://kpcb.com/InternetTrends

21 The World Wide Web Consortium (W3C) is a standards organization dedicated to developing standards for the web

22 "ConversatioNIST: The Internet and Cybersecurity" https://www.nist.gov/video-category/information-technology

23 IEEE 802.11 is a suite of specifications for wireless local area network computers

24 Virtual Reality is a type of computer graphic display that responds to a users position and

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orientation in space giving one the illusion of being "present" in that synthetic space. Augmented Reality is an interactive experience of a real-world environment whereby the objects that reside in the real-world are "augmented" by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory

25 "Bringing Mixed Reality to the Web" https://blog.mozilla.org/blog/2017/10/20/bringing-mixed-reality-web/

26 MR, or mixed reality, is the blending of the physical world and digital world

27 Figure 3 photo by Sandy Ressler

28 "Towards the Immersive Web," https://www.w3.org/blog/2018/01/towards-the-immersive-web/

29 X3D is a royalty free standard (ISO/IEC 19775-1) for declaratively representing 3D computer graphics

30 Figure 4 photo from https://commons.wikimedia.org/wiki/File:3D_printing_demonstration_at_Libbie_Mill_Library.jpg

31 A 3D file format widely for 3D printing used for creating models, prototypes, patterns, and production of parts in a layer by layer fashion using photopolymerization, a process by which light causes chains of molecules to link, forming polymers

32 Shapeways (https://www.shapeways.com/) has a particularly wide array of materials

33 "History of 3D Printing," https://www.autodesk.com/redshift/history-of-3d-printing/

34 "Three dimensional printing of biological matter" https://www.sciencedirect.com/science/article/pii/S2468217916300144

35 "Breathable, wearable electronics on skin" https://www.printedelectronicsworld.com/articles/11381/breathable-wearable-electronics-on-skin

36 "Concrete3DPrinter,"https://www.sculpteo.com/blog/2018/01/03/concrete-3d-printer-the-new-challenge-of-the-construction-business/

37 The National Highway Transportation and Safety Administration (NHTSA) is a US government agency responsible for regulations concerning self driving cars

38 Figure 5 from "Cruise Automation," https://en.wikipedia.org/wiki/Cruise_Automation

39 "Some of the companies working on driverless car technology", https://abcnews.go.com/US/companies-working-driverless-car-technology/story?id=53872985

40 https://www.sciencealert.com/self-driving-cars-may-soon-be-making-moral-decisions-like-humans

41 Seehttps://www.sae.org/standards/content/j3016_201806/

42 Global Positioning System (GPS) is a set of satellites that provide physical position on and around the earth operated by the US Air Force

43 LIDAR stands for LIght Detection And Ranging; it is a method of measuring the distance to a target with a pulsed laser

44 Inhttps://en.wikipedia.org/wiki/Autonomous_car

45 Public Key Infrastructure (PKI) is a set of rules, policies and procedures to create, manage, distribute, use, store and revoke digital certificates and manage public-key encryption

46 The US Securities and Exchange Commission (SEC) is responsible for enforcing the Federal securities laws, and intersects with a number of aspects of cryptocurrencies

47 Figure 6 from https://commons.wikimedia.org/wiki/File:Cryptocurrency_transaction.jpg

48 "Bitcoin: A Peer-to-Peer Electronic Cash System," Satoshi Nakamoto, https://bitcoin.org/en/bitcoin-paper

49 "Request for Comments." *Wikipedia*, Wikimedia Foundation, 29 Apr. 2018, en.wikipedia.org/wiki/Request_for_Comments

50 The Internet Engineering Task Force is the organization responsible for the specifications that enable the Internet to function

51 "ERC: Token standard #20," https://github.com/ethereum/eips/issues/20

52 Figure 7 from https://columnistofweek.com/6430065/global-digital-video-content-market-status-2018-amazon-com-comcast-directv-youtube-hulu-netflix-apple-att-blinkbox/

53 MPEG is a set of standards (ISO/IEC 11172) for audio and video compression and transmission developed by the ISO/IEC/JTC1 Moving Picture Experts Group. MP3 refers to: MPEG-1 Audio Layer 3 or MPEG-2 Audio Layer 3, an audio coding format for digital audio. MP4: (MPEG-4 Part 14) is a digital multimedia container format most commonly used to store video

54 Compact Disc is a digital optical disc data storage format co-developed by Phillips and Sony released in 1982

55 "Gallery of CSS Descramblers," http://www.cs.cmu.edu/~dst/DeCSS/Gallery/

56 DeCSS, https://en.wikipedia.org/wiki/DeCSS