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Cloud Computing and Accessibility Considerations

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Reports on Computer Systems Technology

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Table of Contents

List of Figures:

List of Tables:

1. Introduction and Background

The NIST Cloud Computing Program (NCCP) released a draft two-volume US Government (USG) Cloud Computing Standards and Technology Roadmap[1] in November 2011 for public comments; it was published in final form in October 2014. The USG Cloud Computing Technology Roadmap lists ten requirements and several Priority Action Plans that should be followed to fulfill the requirements. Requirement #7 is to "***Define unique government regulatory requirements and solutions.***"

Section 508 of the Rehabilitation Act[2], among other laws, requires that federal employees and citizens have equal access to information and communication technologies (ICT) regardless of their disabilities. This qualifies as a "unique government regulatory requirement", and accessibility is considered to be fundamental to this solution.

Some comments to the Roadmap focused on accessibility with regard to the above requirement (see Appendix A). Although the Program's original goal was to stress three major challenge areas for USG adoption cloud computing in security, portability, and interoperability, it was evident that accessibility is as valid a challenge for the USG. Cloud computing solutions that address and highlight accessibility offer a path forward for an agency to fulfill its mission and requirements by providing a larger number of potential solutions that USG ICT managers can use to be creative in the development of new services and solve their unique accessibility requirements. As work progresses in cloud computing, it is important to promote, incorporate and discuss applicable standards in accessibility for cloud computing services as a discipline for investigation.

In response to the interest in cloud and accessibility, the NCCP formed a new Public Working Group (PWG) on "Cloud Computing and Accessibility" (CCA-PWG) in June 2013. This PWG will address the topics facing cloud computing with respect to accessibility, standards and usage. This document details the activity of that PWG, and is in part the key deliverable to date of the PWG. We hope that this document will be useful to its primary audience, ICT managers in federal agencies who are seeking to build accessibility into their cloud computing procurement and use.

[1] US Government Cloud Computing Technology Roadmap Volume I: High-Priority Requirements to Further USG Agency Cloud Computing Adoption; and Volume II: Useful Information for Cloud Adopters, NIST SP 500-293, http://dx.doi.org/10.6028/NIST.SP.500-293

[2] http://section508.gov/

2. User Experiences of Inaccessibility

2.1. Introduction to Use Cases

Accessibility, and thus inaccessibility, are almost entirely concerned with user experiences. Background processes are relevant only to the extent that they affect how users receive, perceive, and act upon the information and communication that is before them.

To fully explore the issues of accessibility to electronic information, we have developed a series of use cases that explore how a user interacts in different circumstances or cases. This is especially useful in considering accessibility in cloud computing, due to the strong interaction effects among device, browser, assistive technology (AT), app, etc. In many cases it is clear that there are policy and process barriers as well as purely technological ones.

The following personas do not always reflect specific personal experience, but were collected or drafted to express known difficulties encountered by ICT users with disabilities, including federal employees, some of whom contributed to this document.

Cora is a customer service in a specialized work group that covers income from foreign sources. She is blind from birth and uses a Braille display connected to her computer. Most of the information she handles shows up in specific blocks on the screen, and she has learned the keyboard commands to give those blocks focus on the Braille display as needed. Unexpected software updates to the internal cloud application sometimes change the layout and cause the Braille display to lose focus. This requires some assistance from the IT support center to get her back on track; in the meantime her productivity is compromised. The IT support people have come to expect her calls whenever there is a software update. They serve other blind users, who use a range of screen readers and Braille output devices. Cora and her blind peers have tried to escalate this problem but have had limited success.

Garrett is a wounded veteran with a moderate cognitive disability as a maintenance technician in a remote area. He drives between work sites and uses a mobile device that lets him navigate by GPS and retrieve his work orders through the company's app. Some work orders are confusing and he needs help. He must place a call to his supervisor, and slowly read aloud the text of the order. The supervisor then explains the work order and occasionally must text him a complete, simplified order, in a regular text messaging app. Keeping track of the company's app and the separate text messages can be confusing as well, and makes Garrett's recordkeeping less accurate, but it does let him get his maintenance work done. He and his supervisor talk about creating a simpler solution, but they do not have any resources to develop software or even explore what their organization may already have that they could use.

Deena is a program administrator at a federal contractor working on many projects with several agencies. She is an older worker and has been experiencing problems with her vision and memory. Her company and the multiple agencies she works with all use different management

applications, some in the cloud and some not. She has trouble keeping track of her logins and passwords; she keeps a 'cheat sheet' in her desk drawer, which is against policy. She also has trouble copying and pasting information from an agency application into her company's management tool – the highlight color is yellow on a white background, which doesn't work for her. So she copies the whole page, pastes it into a word processor with higher contrast, selects the text she wants to copy, and then pastes it into her company's tool. At the end of the day, she has many open word processor pages that need to be saved or discarded, and this is very time consuming. She says "in the old days" most of her work was done by phone, informally checking in with her colleagues in the federal agencies she was working with, but that nowadays there is a need to document everything, which means more typing and reading than she can easily do. She gets tired and has headaches many times during the week. She attended a workshop for low vision solutions such as larger or clearer monitors and high contrast settings a few years ago, but did not follow up with her supervisor.

Roberto works as a statistical analyst. He is deaf and uses video relay and video remote interpreting to communicate with his workmates. His supervisor encourages him to use direct text instead whenever possible, for budget reasons. Roberto finds sign language to be a more effective form of communication. Some of the training videos he needs to use have poor quality captions with errors, and the transcripts do not let him know what is being said at what part of the video. He and his deaf peers informally exchange information about good and bad captioning training videos; some admit that they choose what training they take based on the quality of the captions. A recent problem has been an increase in the use of telecollaboration for project meetings. Sign language is not available at all on these meeting calls. Real-time captioning (CART) is not always available and the quality is mixed. When it is slow or incorrect, he misses opportunities to ask questions or make comments. Moreover, when he is reading captions he occasionally misses some content of the graphs in the main part of the screen, and has to review the recording of the session to catch up. Lately, he has been using his tablet to attend these sessions. This is good for his flexible schedule, but he has to balance the size of the captioning and chat panes with the size of the text in the main content pane. Depending on the content, this can be problematic.

Virginia uses multiple applications plus email on a daily basis. Because of a spinal cord injury, she cannot use her hands for typing and has limited use of the mouse. She relies on Dragon Naturally Speaking, a speech recognition system that lets her speak words to type and say commands to control the computer. Virginia's component is working with a cloud service provider who plans to provide software as a service and to utilize a virtual desktop as a delivery mechanism. Because the virtual desktop, Citrix Receiver, does not work with Dragon Naturally Speaking, Virginia will not be able to work unless an exception is made to continue supporting her current configuration. Virginia knows this because she works in the accessibility group.

Allen uses multiple applications plus email on a daily basis. Allen has been blind from birth. He cannot use a mouse because he cannot see the screen to follow the cursor. He uses a screen

reader, assistive technology that speaks the screen information to him and lets him control the computer with the keyboard. Allen is in Virginia's component. His group is going to the virtual desktop next week. Allen doesn't know that his assistive technology will not work with the virtual desktop and is facing a work stoppage next week. His situation and user needs in general were not considered during the planning process. The virtual desktop vendors claim that assistive technology will work if installed on the remote desktop. Allen's agency has tested this and found that it works poorly or not at all. However, there is no requirement in place for the vendor to fix this compatibility problem in time for the transition; there is no timetable at all built into the service contract. The current plan is to have Allen use a separate system until the problem is resolved, but there is no clarity on how that will work or how long it will last.

In order to make compliance training more interesting and 'game-like' **Jason's** agency has begun to teach courses online so that units can track progress and compete for high scores and early completion of training. These courses often use graphics and interface elements that make it impossible for Jason, who is blind, to use a screen reader to independently complete the required training. The software developers did not follow best practices regarding accessibility, as it was not part of the contract. Jason often has difficulty completing courses, due to no fault of his own. One typical problem is that as the training application calculates his work to show progress graphically, his computer freezes and no record is retained. Jason's supervisor has to request system logs of Jason's training instead, which is time-consuming and cumbersome.

Nancy is an agency financial analyst with Attention Deficit Disorder. Her agency regularly requires her to teach using webinars. While the hosting software has the capacity to demonstrate calculations and can show the impact of proposed changes on the agency's finances in near real time, the screen cannot be modified by individuals. Nancy is often distracted by incoming questions when teaching and loses her train of thought. As a work around, Nancy tried to call into the seminar and ask a colleague to change screens for her and field questions but this has led to confusion when the slides were not in sync or when students were asking for demonstrations of calculations needed in their jobs and Nancy needed to comment on specific results.

The agency **Tuan** works at has approved apps on mobile devices to gather and support cloud-based data collection and analysis. Tuan, who has limited use of his hands, is knowledgeable about the assistive technology he needs, a switch selection system on his tablet. However, the apps his agency uses were not designed according to the accessibility recommendations for the operating system, which often change. Since the last update, Tuan is unable to perform specific key functions on the apps that let him import, compare, and aggregate data from multiple cloud sources, limiting his ability to explore the data creatively. This reduces both his value to the agency and the intrinsic reward he gets from his job.

3. From Use Cases to Barrier Categories

The next step in our analysis is to translate use cases like the ones listed above into a small set of barrier categories experienced specifically in cloud computing environments.

Although cloud computing has changed the landscape in ICT, the current consensus is that its unique accessibility implications are often minimal. That is, accessibility is more concerned with the user interface than the infrastructure on which that interface runs, the processes to which data is subjected, or the content the interface provides a port into. To an end user, whether the computing environment is cloud-based or not may often be invisible or secondary to the accessibility barriers encountered in the direct user experience. Taking that into account, the CCA-PWG identified a few issues that are unique to managing accessibility in the cloud:

3.1. Version control

Changes to cloud computing software (e.g., fixes and updates) are generally controlled by the provider, rather than an explicit part of customer enterprise operations management. This can result in unexpected accessibility jeopardies to users who may not be able to roll back the changes.

3.2. Reliance on browser

When cloud computing involves a browser rather than direct use of a cloud app, it inserts an additional link in the 'accessibility value chain', the sequence of technologies that must successfully interoperate for the appropriate accessibility features to reach the user. For example, conventional computing may link an operating system, a screen reader, and a spreadsheet program; a comparable cloud computing chain consists of an operating system, a screen reader, a browser, and a cloud-based spreadsheet. Note that browser interposition is not always a negative; browser settings such as enlargement and browser-based screen readers are sometimes easier to find and use than other options.

3.3. Platform quandary

Cloud computing is intended to simplify ICT operations in part by reducing the need for enterprises to provide dedicated support for too wide a range of platforms and operating systems. In general, this is good for accessibility in that savvy users can select and become expert in the platform that provides the best accessibility. However, it may unintentionally jeopardize non-expert users with disabilities who may have difficulty navigating the complicated decision space, while also not being able to rely on enterprise-supported ICT. For example, an employee who is permitted to use a personal device ('bring your own device' or BYOD) for work may have difficulty identifying which device (and version, and workplace applications, and utilities, and assistive technologies…) will best fit both the workplace requirements and his/her own accessibility needs.

3.4. Use of thin clients

The advent of cloud computing has brought the use of thin and very thin clients back into use. These are characterized by terminals that collect input (keyboard, mouse) and display output (screens), but leave all the computing to be performed at the other end. In fact, this is what many people think of what is essentially different about cloud computing – that the actual computing occurs in a network, not in a desktop or other user-facing device. If this includes having the screen rendered at the other end (and just the image sent back to the terminal) then many assistive technologies will not work. In particular screen readers (which would have to run on the remote server to access the screen information) suffer from control and audio delays that can significantly affect performance and use. Screen enlargers can be almost unusable if run on the remote server – and have no access to screen information for tracking if run on the local terminal. Other AT also may have to be installed and run on the remote servers – meaning that a person may have to have their AT installed on many servers instead of just on their personal terminal/computer.

3.5. Rich data visualizations

Dynamic data (e.g., weather) and large datasets are being used to create visualizations that make it easier for a sighted user to understand what's going on. Both the data and the processing are in the cloud, often due to client-side limitations. Since these are dynamic, the usual accessibility solutions such as static alt text, longdesc, or ARIA may not be possible, and no resources are widely available for creating on-the-fly alternatives. Sometimes the visualizations go beyond the complexity of the data. That is, if a screen reader user had access to the data he/she might be able to make sense of it, but the visualization is the only access provided.

4. Applications Categories and Accessibility Guidance

The next step of the analysis is to examine cloud computing applications to understand where and how they cause or prevent accessibility barriers. We begin by roughly categorizing them.

There are many kinds of cloud computing products, services, and features. To enumerate or catalog them is beyond the scope of this document. However, it is possible to categorize the most frequently used applications according to functionality as listed below. Note that, as is characteristic for cloud computing, many of these functions can be and are performed on a user's device, via a browser or app, or completely in the cloud. From a user perspective it is not necessarily important to understand the exact location of any computational function, since the user's experience is the result of the entire end-to-end interoperation. However, some of the following functions are more purely 'cloud' than others.

- Enterprise collaboration tools – email, calendaring, messaging, document co-editing, webinar platforms and related real-time collaboration tools
- Resource/budget planning/management and project management tools

- Customer relationship management (CRM), including customer support and documentation
- Web server/Content Management Systems (CMSs)
- Identity management
- Document retrieval/Library systems/Online storage

Many of the technology products and services associated with these functions are designed to be used in many situations, by many different types of users, for different purposes. That is, even a specific product like a project management tool is intended for flexible use, and has a wide range of capabilities, which are normally tailored down for a given environment of use. For many of these situations, the pathway to solution begins with identifying the specific goals in the environment of use.

To take one of the use cases we identified earlier, consider Garrett's situation. Part of his problem could be identified as pertaining to the mobile platform he uses. Selecting the right platform for his needs, that also meets agency platform compatibility and operational realities, is highly complex and rapidly evolving. One solution to part of his difficulty might be solved if he could view his current task at the same time as seeing the exchange of text messages with his supervisor, instead of having to shift back and forth between applications. An update to his current platform's operating system may permit such multi-tasking directly, or indirectly via a simple gesture swapping between applications.

We will discuss later how information resources play an essential role in solving specific accessibility problems. For now, we focus on the use case to develop the point that although accessibility must be considered globally during procurement and development, it must be managed locally during use. For Garrett, this means that identifying the specific function of "seeing the task and the message thread at the same time" is a requirement for successful use.

Appendix B provides some specific guidance on some of these application categories in addition to general guidance on cloud computing. We emphasize that for reasons of accuracy, comprehensiveness, and especially harmonization, those looking for technological guidance refer first to the Web Content Accessibility Guidelines (WCAG 2.0[3]); not only the Guidelines themselves, but the whole ecosystem of Success Criteria and other material provided there.

[3] http://www.w3.org/TR/WCAG20/

5. New Cloud-Based Accessibility Opportunities

So far, this document has focused on how cloud computing either replicates or exacerbates accessibility problems found in previous computing environment models. But cloud computing offers new and exciting accessibility opportunities, not just new problems. This section describes two of the most promising.

5.1. Global Public Inclusive Infrastructure (GPII)

The GPII[4] is a global multi-year program to build an accessibility infrastructure in the cloud. The GPII will allow people who have problems with standard interfaces and content – all of us, in some situation or other – to be able to use information and communication technology (ICT) products and services anywhere they encounter them. It will allow users to invoke the interface and content adaptations they want or need, automatically, on any device, anywhere, anytime. The purpose of the GPII is to ensure that everyone who faces ICT barriers due to disability or usability issues, literacy, digital literacy, or aging, regardless of economic resources, can access and use the Internet and all its information, communities, and services for education, employment, daily living, civic participation, health, and safety.

The GPII will encompass a family of tools and services:

- Tools for users to explore, select, store, and manage their preferences – the features they want or need for interfaces and content
- Ways to match those user needs and preferences with the capabilities of the devices users encounter: public computers, websites, online videos, transaction machines, etc.
- Ways to negotiate and implement those preferences on the user's current device, in real time – "automatic personalization"
- Development tools to let assistive technology and mainstream companies, commercial and non-commercial, build or adapt their accessibility software and services into the cloud, including ways for them to reach and serve more potential users
- Management tools so that all participating entities – consumers, software companies, AT funding agencies, ATM manufacturers, educators, employers, retailers, etc. – can be assured of highly reliable, effective, secure, private, efficient, and manageable accessibility solutions.

The GPII will not create new access technologies or services itself. It is the infrastructure for making their development, identification, delivery, and use easier, less expensive, and more

[4] http://gpii.net

effective. This is similar to building a road system; roads do not provide transportation but greatly enhance the ability of car companies and others to do so. They provide an infrastructure that car companies themselves cannot make. The Internet is the infrastructure for general information and commerce. The GPII enhancements to the Internet will enable the Internet to be truly inclusive for the first time.

We have an unprecedented opportunity to fundamentally change and advance accessibility – to create an infrastructure that supports both commercial and non-commercial efforts to make accessibility more affordable, to reach more of the people who need it than the estimated 3 - 15% we reach now, to make it all simpler, to serve disabilities and aging groups we don't now serve or serve well, and to build access that will work with the new technologies that are coming.

The implications for US federal cloud computing are powerful. The GPII will offer federal entities an integrated method to meet the needs of both employees and members of the public, as required by Section 508 and other laws, with greater confidence and lower cost. In order to redeem this promise, planning for federal cloud computing should factor in the development and implementation of the GPII as one of the solution paths agencies can travel. Policies and tools that NIST is building as part of its cloud computing roadmap responsibilities can help bring accessibility into the mainstream of federal ICT where its impact is greater and costs are lower; the GPII can be a significant part of that effort.

5.2. Accessibility Application Programming Interfaces (AAPIs)

An accessibility application programming interface (AAPI) is any capability built into an operating system or platform that provides developers with the necessary software interface for accessibility features such as screen reading and magnification. For example, the iOS platform provides global screen reading and magnification capabilities as a default for all apps developed on that platform. This vastly simplifies and standardizes accessibility solutions. AAPIs may not have originally been intended for promoting accessibility features, but have that effect, which is a natural outgrowth of ‘responsive design’ aimed at serving the wide range of mobile devices.

A persistent challenge for computer accessibility has been the limited adoption of accessibility APIs by developers. Many developers perceived limited benefits to incorporating accessibility APIs into their products. In the desktop era, software ran on a single device in a single context (i.e., a desktop computer in an office) and the vast majority of users could use software without the need for any adaptations. In the laptop era, software ran on two similar devices (desktops and laptop computers) in a larger number of contexts, but the need for adaptations by most people was still limited. The advent of cloud computing, in combination with mobile computing devices (e.g., tablets, smartphones), has created an environment where the same software can run on multiple devices with very different input and output capabilities and a wide variety of use contexts (e.g., while driving; while walking; one-handed; in a noisy environment; in direct sunlight). Developers adopt tools like HTML5 and CSS3 because they offer the promise of

the same software running across multiple devices. Developers should similarly adopt accessibility APIs because they allow software to run in multiple contexts. Developers who want their product to have a competitive advantage because users can access it in their office (on a computer), in their living room (on a tablet) and out and about (on their smartphone) regardless of where they are, what else they are doing and what is going on around them, but don't want to implement all these capabilities from scratch, should use cloud computing, cloud storage, non-native code and accessibility APIs. In this environment, accessibility should not be perceived as an obligation or additional requirement, but rather as a fundamental aspect of software development and a selling-point for a product.

Understanding the accessibility-related benefits of APIs allow system developers, system owners, and other stakeholders to modernize their systems in ways that benefit all stakeholders.

For example:

1. *Accessible Ports-of-Entry*: APIs can significantly leverage the ability to develop fully-accessible "ports-of-entry" to cloud-based resources.

2. *Efficiency*: API access allows content to be created one time in a manner that can enable developers to make it accessible and available through many channels.

3. *Wider Reach*: By allowing anyone to create new presentation layers, like a mobile/computer-based applications and websites, APIs can be used to create services and information that is fully-accessible to people with disabilities.

4. *Distribute Services and Information to New Audiences*: APIs can be used to distribute services and information to new audiences and in specific contexts that can be customized to meet the access needs of individual consumers.

5. *Leverage Government Assets*: Data and information produced by the federal government is a national asset, paid for by the American people. APIs can expose data that was only available to a few and make it more available to everyone, including people with disabilities.

6. *Automation*: APIs allow machines to handle workloads which might otherwise require the manual work of a human being. This can be as simple as having one content update propagate to multiple sections of an accessible website (or multiple accessible websites) at once.

7. *Application*: Providing API access to information or a service sets up the use of that information or service by accessibility experts developing mobile apps. This is especially

beneficial if an organization plans to build more than one app. APIs can serve as a shortcut to developing an accessible second, third, and fourth app.

8. *Partnerships*: The mission of every agency is supplemented by like-minded non-profits and businesses, who are interested in using agency information and services to provide services. They do this by consuming and repurposing agency material into new, useful products and putting agency content in front of their customers and clients. Enabling businesses to easily create accessible interfaces to government information can fuel innovation.

9. *Increasing Efficiency and Reducing Cost*: If developers plan to develop more than one resource, APIs can serve as a shortcut to developing additional ones.

10. *Integration*: APIs allow content to be more easily embedded or interwoven throughout websites and applications. It can help to ensure smooth, integrated, and accessible user experiences.

11. *Personalization*: Users of government websites can benefit from the ability to personalize and enhance the accessibility of sessions with the information and services that are most useful to them.

12. *Mashups*: Mashups allow the public to better understand government information in the context of other sources of information. An agency service or data stream can be a small, important part of another service... especially if it is easily mashed-up and made accessible.

13. *Future-Ready*: As needs change, APIs can help to support unanticipated future uses in manners that make it easier to render deliverables in an accessible manner.

6. The Role of Information Resources

At the beginning of 2014, the CCA-PWG turned to a separate but related issue in cloud computing accessibility. As can be seen in several of the use cases above, some accessibility problems are caused by a lack of information in the right hands at the right moment, rather than the total absence of a technological solution. In Garrett's case, we suggested that his agency keep an eye on the mobile environment to learn when that marketplace offers a mainstream solution to a key requirement, Garrett's need to see both his task and texts from his supervisor at the same time. Can his organization survey the mobile environment itself to discover this capability? If it cannot do this itself, can it learn from others, in the federal space or elsewhere, about emerging solutions?

Finding accurate, timely, situationally-relevant information about accessibility is not trivial. Although new features constantly pop up across the horizon of products and services, their accessibility implications are not usually highlighted or reported broadly or consistently. The speed and churn of modern mainstream ICT makes curating accessibility solutions challenging even to full-time accessibility professionals, let alone the many more part-timers, including people with disabilities themselves, who must identify and resolve specific problems with fewer resources at hand.

However, this is a known problem. Efforts have been and are being made to address the need for better information resources about accessible ICT.

6.1. Example: the FCC's Accessibility Clearinghouse

The FCC's Accessibility Clearinghouse[5] is a web repository of information about accessible communications products and services. It is mandated by the 21st Century Communications and Video Accessibility Act of 2010 (CVAA), which also requires the FCC to promote this resource to the public. The Accessibility Clearinghouse includes information on the following topics:

- Accessibility features of mobile phones
- Accessibility contacts at telecommunications and advanced communications services companies
- Free assistive apps for various computing platforms
- Organizations implementing the National Deaf-Blind Equipment Distribution Program (NDBEDP)[6].

To enable more flexible and targeted use of Clearinghouse information, the FCC has released a software development kit (SDK; blog post[7]; source code[8]; demo video[9]) that makes custom programming of inquiries to the database relatively easy with a free, popular language called Python. Python-based apps can query the Clearinghouse based on an application programming interface (API). Clearinghouse Information may be selectively filtered and combined with data from other sources as mashups. Views of information may be created that differ from the presentation on the Clearinghouse website, thereby tailoring value for particular constituencies or devices.

[5] http://www.fcc.gov/accessibilityclearinghouse
[6] https://www.fcc.gov/general/national-deaf-blind-equipment-distribution-program
[7] http://www.fcc.gov/blog/fcc-releases-software-development-kit-accessibility-clearinghouse
[8] http://www.github.com/FCC/clearinghouseSDK
[9] http://www.youtube.com/watch?v=_Pk0igOFmqY

7. Cloud Computing Accessibility Taxonomy

In order to create information resources that make sense to their users, it is essential to have consistent frameworks and terms. Using the API model of aggregation, it is possible for information resources to be shared such that a search of one reveals findings originally collected by another. This consistency and cross-communication promise greater efficiency on the input side, and greater usage on the output side.

The CCA-PWG decided to initiate research into accessibility taxonomies, in order to clarify what these opportunities might look like, and how they could be achieved.

7.1. Audiences and Goals

We begin the analysis with an attempt to understand who potential taxonomy users are and what their goals are.

Developers. Technology designers and developers need to have clear guidance and a suitable software framework for building accessibility into their products. In these cases taxonomies act as pointers to accessibility settings or libraries.

Content creators. Similarly, content creators (especially in the education field) need a standardized way to categorize their content to indicate the accessibility features it contains, such as captions, so that users can find what they need.

Users with disabilities. People with disabilities who are searching for ICT with the accessibility features they need would benefit from a taxonomical framework that supports intelligent search via common terminology. A key dimension would be functional limitation.

Practitioners. Similarly, special educators, therapists, and others would benefit from a framework that reflects their professional practice.

Technology managers. Enterprise staff such as accessibility program managers and ICT administrators would benefit from a taxonomy that could be used to inform the ICT procurement process. For example, a school district technology coordinator would be able to search the market for 7th grade science textbooks that have alternative formats; a CIO office could identify workplace ICT likely to have the features needed by a new job applicant.

Policy makers. An appropriate taxonomy could aid in evaluating gaps in the accessibility market and planning for their resolution, using market or regulatory tools. For example, Section 508 Voluntary Product Accessibility Templates (VPATs) are in a sense a regulatorily-driven taxonomy of accessibility features as applied to different technology families. Aggregated VPATs could be used to analyze the range of accessibility features and solutions found in the market, without having to perform a 'census' of technologies actually in use.

Clearly, the needs of these audiences are not identical, but there is substantial overlap. A clear taxonomy that arranges features by technology platform would benefit both developers and consumers in search of a new product. A taxonomy that is well documented would serve as an excellent introduction to the field of accessible technology for newcomers of all audiences.

One important distinction might be between audiences that can be characterized as **supply-side** (developers and authors) and **demand-side** (users with disabilities, AT/accessibility practitioners, technology managers, and policy makers). The former would use a taxonomy to identify and organize the accessibility work that needs to be done, find components that assist in developing accessible products, track the progress/features of the competitors, or report their progress within a product development process. The latter would use a taxonomy to identify products and features they may need (directly or indirectly), or to manage technologies organizationally (e.g., procurement oversight) or regulatorily. Most importantly, the needs of a developer-facing taxonomy in terms of technical complexity and code-friendliness (some entries should work like source code snippets) may require separate taxonomies or audience-targeted renderings of a unified taxonomy.

Another distinction is worthwhile. **'Pre-sale'** resources would help people in the market make their decisions; these resources would highlight the differences among comparable products in terms of features and functions. **'Post-sale'** resources would cover how a given ICT product or service, already in use, can be used most accessibly. Such a resource would include workarounds for AT compatibility issues, application notes, third-party utilities, and might even have a user group.

7.2. The Dimensions

Given those audiences and goals, here are the dimensions of categorization that may prove useful, with the potential benefits:

Disability category / human performance modality, such as "vision" and "hearing", either referring to the disability or to the performance modality. This will allow consumers with disabilities to search for products and features of interest to them, and specialized practitioners (e.g., speech therapists) to focus on their professional scope. There are often objections to this dimension, in that it can 'medicalize' accessibility instead of focusing on user needs and preferences, and also that it can limit the application of some features to a single disability category (e.g., 'text-to-speech' categorized under 'blindness').

Context of use, such as "education" and "employment". This will allow both supply- and demand-side users to focus in on specific use environments for context-dependent details on availability, features, application notes, etc.

Technology platform. This will allow both supply- and demand-side users to focus in on platforms (e.g., a specific operating system) already selected or out of their control.

Technology product, function and/or feature, both mainstream and AT. This is really the core of a useful taxonomy, for all audiences: the categorization of specific product features and functions, whether they are explicitly accessibility features or not. The comprehensiveness of the lists and their sound categorization are essential components. In many cases the product or product category will be a separate dimension.

Legal/regulatory coverage. All potential users would benefit from understanding where certain features or products are required by law, in which jurisdictions. Note that information in this dimension may relate to the environment of use. For example, a law may require captioning for resources used in elementary education.

Appearance in a standard. The benefit is largely for supply-side users, letting them align their work with specific technical standards.

AT vs. mainstream product. This would provide information about availability of funding in some circumstances.

Note that categorization within these dimensions should not be exclusive. For example, an accessibility solution should be appear in all contexts of use in which it provides benefit.

Appendix D is a collection of taxonomies the CCA-PWG analyzed.

7.3. Draft Taxonomy

The schema below is based on the following primary criteria, extracted from the above discussion of potential audiences and dimensions of interest:

- Intended for an audience of users and managers rather than developers. In general this means a focus on the result of a feature rather than how it is implemented, as well as substantially less complexity.
- Intended to aid in product selection. This is a key point. This taxonomy does not exhaustively identify differences in features between products. Rather it aims to place its user in the position of being able to identify a small enough set of candidate products so that he/she can then proceed to evaluate those products directly in order to make an informed selection.
- Capable of categorizing features as well as products. Some users will be in search of a product, while some will be seeking information on how to implement a feature within a product.
- Useful as a rough educational guide to the domain of accessible ICT. Naïve users should be able to get an idea of how the field of accessible ICT is structured.

Overall, the Raising the Floor/Consumer Electronics Foundation taxonomy fits these criteria best. The draft below differs from it significantly, however, partly just in order to explore an alternative structure, but largely to demonstrate a difference due to the second criterion identified above: focusing more on the product selection process than on exhaustive description.

7.4. Taxonomy Mind Map

The nominal Cloud Accessibility taxonomy is depicted in this list and attached MindMap figure which shows the 5 following major headings (nodes).

- **Audio & alternatives**
  - Assistive listening system
  - Audio enhancement
    - *Amplification*
    - *Noise reduction/clarification*
  - Captions & transcription
    - *Real-time*
    - *Stored*
  - Remote & relay services
    - *Sign language relay (video relay service or VRS)*
    - *Remote sign language interpreting (video remote interpreting or VRI)*
    - *Text relay*

- **Control, input & operation**
  - Alternative computer input device or system
    - *Alternative keyboard, including on-screen*
    - *Alternative mouse or pointer*
    - *Keyboard-only control*
    - *Morse code*
    - *Scanning*
  - Error prevention
    - *Auto-correction*
    - *FilterKeys etc.*
  - Gesture recognition
    - *Camera-based*
    - *Dynamic/multi-touch touchscreen or tablet*
  - Prediction, expansion & macros
    - *Abbreviations*
    - *Macros*
    - *Prediction*
  - Speech recognition
    - *For computer control*
    - *For text and other input*

- **Reading, understanding, learning & managing**
  - Coaching, assistance
    - *Help in context*
    - *Notification of and communication with others, including caregivers*
  - Learning & understanding
    - *Contextualization (breadcrumbs, etc.)*
    - *Dictionaries, glossaries, translations, etc.*
    - *Simplified versions*
    - *Summaries*
  - Reading
    - *Highlighting*
    - *Re-formatting for ease of reading*
    - *Text-to-speech*
  - Scheduling & reminding
    - *Calendars*
    - *Notifications*
    - *Prompting*

- **Speaking & communicating**
  - Communication aids (devices or software)
    - *Image/ icon-based*
    - *Text-based*
  - Speech-to-speech relay

- **Visual & alternatives**
  - Alternative text & video description
  - Braille & tactile
  - High contrast & readability
  - Magnification
  - Text-to-speech
    - *Screen reader*

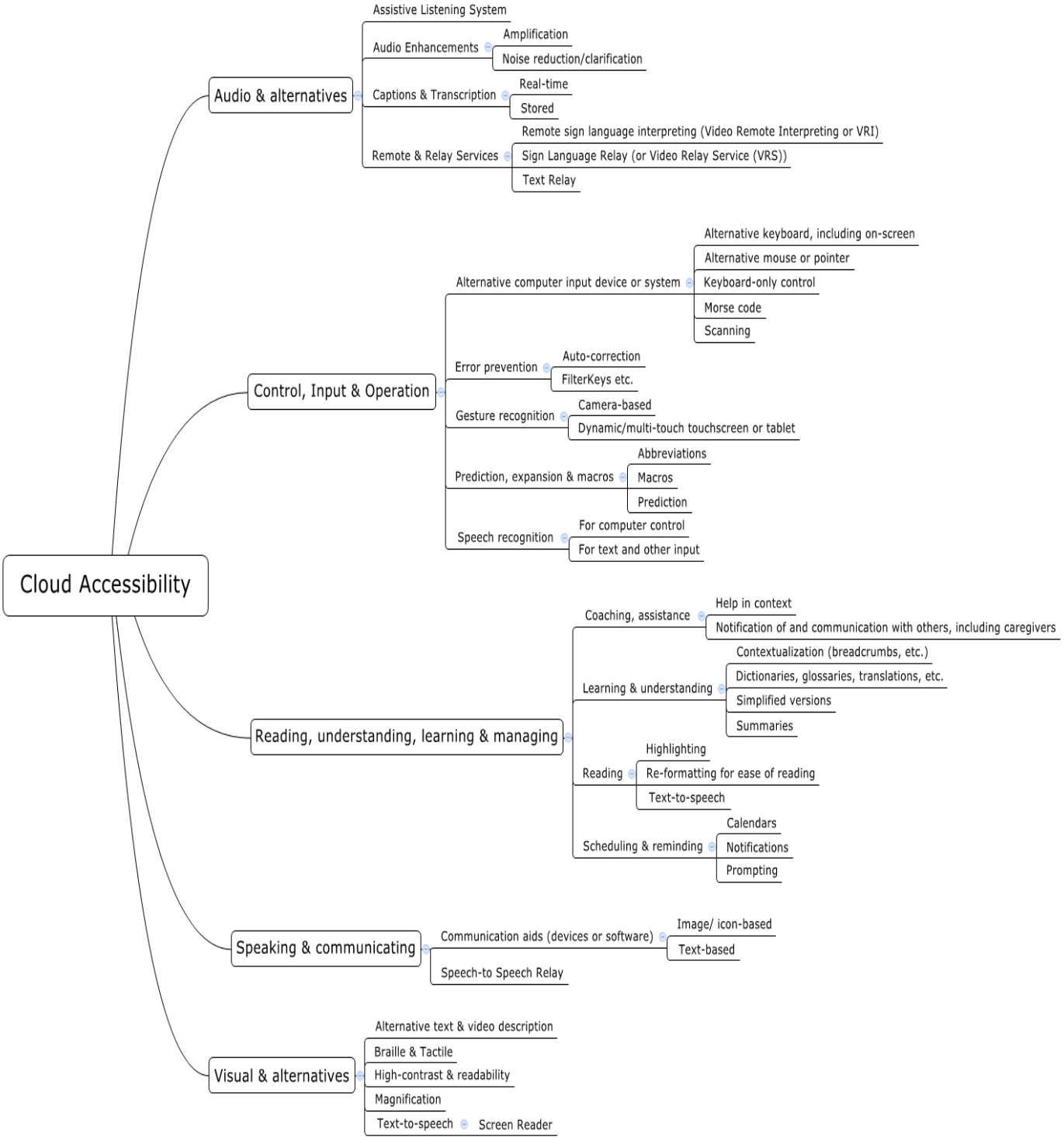

Figure 1 - Cloud Accessibility MindMap

8. Conclusions

The work of the CCA-PWG to this point has been to identify specific areas where cloud computing offers both opportunities and jeopardies to accessibility. In many ways, cloud computing is identical, from a user experience perspective, to conventional computing. However, we did identify several barrier categories that are unique to cloud computing, as it is being implemented, by collecting and analyzing a small set of use cases. These often point to the need for non-technological as well as technological solutions.

Regarding guidance, we emphasize the importance of relying on WCAG 2.0 as both a primary source and a rallying point for the accessibility communities of practice, but we do present some specific guidance for a few key categories of cloud computing products and services.

We also studied two cloud-based approaches to accessibility, the use of accessibility APIs, and the Global Public Inclusive Infrastructure.

The CCA-PWG recognized the need for better information resources about accessibility, and took upon itself some formative research about how current information resources organize the material – their taxonomies. After analyzing a large but not exhaustive set in terms of their audiences and domains of application, we created a draft taxonomy that could be used specifically on cloud computing.

Appendix A: Comments from Raising the Floor – International on "US Government Cloud Computing Technology Roadmap, Release 1.0 (Draft)"

3 December 2011

A1. Introduction

Raising the Floor – International[10] is grateful to the National Institute of Standards and Technology for this opportunity to comment on its Cloud Computing Roadmap (SP 500-293, Volumes I and II). Our comments will only cover the issue of **accessibility for people with disabilities**, from 2 perspectives:

- General accessibility of cloud computing resources
- The potential for the Global Public Inclusive Infrastructure (GPII) to address accessibility

We hope that our comments can be useful in refining the document, and in the follow-on work of developing policies for implementing cloud computing in the federal environment. We are available to provide explanation and/or detailed content for any of these recommendations.

A2. General Accessibility Comments

The Roadmap mentions accessibility at a few points, notably in Volume I as an example in Section 3.4, "Interdependency with Other National Priority Initiatives". However, we feel that accessibility should be emphasized more in the document. We note that the Roadmap consistently addresses 3 cross-cutting requirements: security, interoperability, and portability. If accessibility cannot be 'promoted' to this same level of salience, it should at least be dealt with in greater detail. Below we suggest some places where this may be appropriate.

[10] Raising the Floor (RtF – http://raisingthefloor.org) is an international non-profit organization whose mission is "to make the web and mobile technologies accessible to everyone with disability, literacy and aging-related barriers, regardless of their economic status." To this end, RtF participates in an international technology development program, the Global Public Inclusive Infrastructure (GPII – http://gpii.net). GPII is a cloud-based system for ICT personalization, so that the interface needs of any given person with a disability can be implemented automatically on any ICT device or service.

863 **Table 1:** Comments on NIST SP 500-293 Volume I with respect to Accessibility

Roadmap Section & Relevant Text for Volume I	Suggestion
2.1 Requirement 1: International Voluntary Consensus-Based Interoperability, Portability & Security Standards "Government, industry, and other stakeholders need to define requirements, develop international voluntary consensus-based interoperability, portability and security standards, and implement them in products, processes and services."	Add references to accessibility standards such as W3C's WCAG, UAAG, and ATAG. See Appendix C.
2.3 Requirement 3: Technical Specifications for High-Quality Service-Level Agreements Industry and USG need to develop and adopt consistent technical specifications, of high quality and completeness, to enable the creation and practical evaluation of Service-Level Agreements (SLAs) between customers and cloud providers.	This is the right place to include accessibility requirements & standards This requirement mentions using a standardized vocabulary (1st Priority Action Plan). It would be useful to clarify the meaning of "accessibility", distinguishing the disability-oriented usage from the technical usage where it refers to the availability of a facility (e.g., "The database is accessible via standard browsers.")
2.7 Requirement 7: Defined Unique Government Requirements and Solutions Why: In addition to policy related to cloud services adoption, USG agencies are subject to policy and regulatory requirements, which are unique to government agencies. Government agencies must ensure that cloud services and products meet these policy and compliance requirements as well as mission functionality. Although agencies use commercial services to complete key elements of their mission, USG agencies cannot delegate inherently governmental federal authorities and public trust responsibilities to the private sector. USG institutions cannot mitigate risk through commercial means (e.g., financial penalties, insurance, litigation) to the same degree as private sector organizations. Failure to recognize and address government constraints may slow the adoption of cloud services.	A reference to Section 508 and other accessibility laws and regulations that target the public sector should be included here. The purpose of the reference is to indicate that cloud computing is subject to Section 508, and that accessible cloud computing can be an efficient way to address Section 508.

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865 **Table 2**: Comments on NIST SP 500-293 Volume II with respect to Accessibility

Roadmap Section & Relevant Text for Volume II	Suggestion
2.2.2.3 Cloud Auditor A cloud auditor is a party that can perform an independent examination of cloud service controls with the intent to express an opinion thereon. Audits are performed to verify conformance to standards through a review of objective evidence. A cloud auditor can evaluate the services provided by a cloud provider such as security controls, privacy impact, and performance	Add a reference to audits undertaken to assess accessibility.
4.3 Accelerating the Development and the Use of Cloud Computing Standards	Each of the recommendations below has implications for accessibility in its detailed implementation.
Recommendation 1 – Contribute Agency Requirements Agencies should contribute clear and comprehensive user requirements for cloud computing standards projects.	Note: in addition to general Section 508 requirements, some agencies have their own additional requirements
Recommendation 2 – Participate in Standards Development Agencies should actively participate in cloud computing standards development projects that are of high priority to their agency missions.	One possibility would be to identify a lead agency for accessible standards development.
Recommendation 3 – Encourage Testing to Accelerate Technically Sound Standards-Based Deployments Agencies should support the concurrent development of conformity and interoperability assessment schemes to accelerate the development and use of technically sound cloud computing standards and standards-based products, processes, and services.	These assessment schemes should include deep evaluation of accessibility; identification of accessibility barriers should be reported back to the vendor and/or SDO.
Recommendation 4 – Specify Cloud Computing Standards Agencies should specify cloud computing standards as a factor in procuring cloud services and assess cases when multiple vendors offer standards-based implementations and there is evidence of successful interoperability testing. In such cases, agencies should ask vendors to show compliance to the specified standards.	Accessibility standards such as ISO 24751 should be included. This Recommendation could also refer to other aspects of the procurement process, and the forms and checklists used – this is another aspect of Section 508 oversight and management.

Roadmap Section & Relevant Text for Volume II	Suggestion
Recommendation 5 – USG-Wide Use of Cloud Computing Standards To support USG government requirements for interoperability, portability, and security in cloud computing, in coordination with and under the cognizance of the federal Enterprise Architecture program, the Federal Standards and Technology Working Group should recommend specific cloud computing standards for USG-wide use.	Accessibility standards such as ISO 24751 should be included.
Recommendation 6 – Dissemination of Information on Cloud Computing Standards A listing of standards relevant to cloud computing should be posted and maintained.	Accessibility standards such as ISO 24751 should be included.

866

867 ## A3. Global Public Inclusive Infrastructure

868 The Global Public Inclusive Infrastructure (GPII - http://gpii.net) is an international program to
869 develop cloud-based automatic personalization of user interfaces and user context adaptation
870 based on user preferences. From the GPII website: "Each ICT device will be able to instantly
871 change to fit users as they encounter the device, rather than requiring users to figure out how
872 to adapt, configure or install access features they need." GPII cloud elements will store user
873 preference profiles, accessibility solutions, and information about matching needs to device
874 capabilities in context.
875 Several federal agencies have indicated an interest in being early adoption sites for GPII, and the
876 program itself receives significant federal support.
877 We see a need to integrate GPII into federal plans for cloud computing implementation. We
878 believe that this integration will improve the accessibility of federal ICT resources for both
879 employees and members of the public, and the efficiency of doing so.
880
881 There are 2 specific sections in Volume I of the Roadmap where we feel a reference to GPII is
882 warranted:
883

884 **Table 3**: Comments on NIST SP 500-293 Volume I with respect to GPII

Roadmap Section	Suggestion
2.5 Requirement 5: Frameworks to Support Federated Community Clouds Industry and the USG need to develop frameworks to support seamless implementation of federated community cloud environments. (interoperability and portability guidance and technology)	In one scenario, GPII is implemented locally, as "cloudlets" within organizational firewalls. Add a reference to GPII as an example.

2.8 Requirement 8: Collaborative Parallel "future cloud" Development Initiatives Academia, industry, and USG need to initiate parallel —future cloud development initiatives. (interoperability, portability, and scalability technology)	Add a reference to GPII as one arena in which this collaborative development may occur.

As the Roadmap is implemented, and in other related federal cloud computing initiatives, we hope to offer GPII as an integrated solution.

A4. Other Recommendations

Volume I Section 1.2 and Volume II Section 1.3 recognize that the audience for the Roadmap includes agency CIOs and the US Federal CIO Council. The CIO Council has an Accessibility Committee; this Committee should be referenced in the document as a resource for implementing accessibility in cloud computing, along with points of contact for the Committee and its Subcommittees.

NIST itself has accessibility resources that should be brought to bear in elaborating and implementing the Roadmap, especially in standards development. NIST resources and their points of contact should be referenced in the Roadmap and explicitly supported for this role.

Appendix B: Guidance for Cloud Computing Accessibility

As stated in the body of this report, excellent accessibility guidance is available through WCAG 2.0 and the corresponding Section 508 regulations, currently (March 2015) under revision to bring it into close harmonization with WCAG 2.0.

This section will describe a set of general guidelines for accessibility for each of the application categories and discuss the utility of cloud computing which can alleviate the issues related to accessibility.

B1. General Guidelines

In general, cloud computing accessibility guidance will align very closely with other computing environments, since most accessibility implications concern the user interface rather than back-end processing. For reasons of clarity and harmonization, we suggest that both technology developers and managers refer to WCAG 2.0 for details.

However, there is the potential for cloud-specific guidance that can be attached to the cloud-specific barrier categories we described above.

1) Applications should not block the device's accessibility features.
    a) Many devices have built-in accessibility features. Users should be able to utilize these features within the application. Some of these features include:
        i) Zoom / Screen Magnification / Large Type
        ii) Voice Commands / Dictation
        iii) Voice Over / Speak Selection
        iv) Screen reading and Navigation, Braille displays?
        v) High Contrast/color customization for people who are color blind
        vi) Subtitles / Closed Captions
        vii) Hearing Aid Compatibility

2) Applications should provide multiple methods for users to create, read, update and delete information.
    a) User should be able to access software and devices to create, read, update and delete information. Some of these include:
        i) Screen Readers
        ii) Refreshable Braille Displays
        iii) Speech Recognition Software
        iv) Text-to-Speech (TTS) Synthesizers
        v) Screen Magnifiers/Zoom
        vi) Alternative Keyboards
        vii) Electronic Pointing Devices

    b) User should be able to utilize multiple methods to create, read, update and delete information. Some of these include:

i) Voice Commands
ii) Gestures
iii) Keyboards (on-screen and add-on)

c) Focus-based navigation should be enabled so that users can navigate using gestures, voice commands, screen readers and hardware devices.

3) Controls need descriptions
a) Image buttons, checkboxes and other interface components that do not have visible text should have text descriptions available. The exception for this is decorative images.

4) Controls need to be in a logical order
a) A user should be able to navigate the application using a hardware device such as a keyboard or spoken commands (next, previous) in a logical order.
b) Keyboard shortcuts should be available to help users navigate. The shortcuts should be identified by an underscore under the shortcut key (i.e. Save)

5) Feedback and Alerts should be provided in multiple formats.
a) The user should be able to receive alerts and feedback in multiple formats, set by user preference. Some of these include:
i) Audio alert (beep or ring)
ii) Visual alert (flashing light)
iii) Tactile alert (vibration)

B2. Enterprise collaboration Tools - email, calendaring, IM

1) Users should be able to access email content multiple ways (see General Guidelines 2)
a) Navigation in an email client should allow the user multiple ways to:
i) Move between messages
ii) Download new messages
iii) Delete one or more messages
iv) Scan message headers
v) Create a new message
vi) Reply to a message (one or all)
vii) Set up or delete an email configuration
viii) Sort messages (by sender, date, size, attachments, etc.)
ix) Search for specific content

b) Navigation in a calendaring tool should allow the user multiple ways to:
i) Create a new event including interact with online databases to invite attendees, identify available times for multiple attendees, set up reminders and repeated appointments
ii) Delete an event, current and future

iii) Scan events
iv) Receive alerts for events
v) Modify an event (date, time or details)
vi) Review attendees responses regarding availability or proposed new times
vii) Read items on calendar by date, week, month, and topic

c) Navigation in an Instant Messaging tool should allow the user multiple ways to:
i) Create a new conversation
ii) Respond to a conversations including emoticons
iii) Identify message senders
iv) Move between multiple conversations
v) Access and review archived conversations
vi) Delete an archived conversation
vii) Receive alerts for conversations
viii) Identify when individuals are on and off-line

d) Video messaging should provide a method for vision and hearing impaired users to participate. Some of these methods include:
i) Written transcripts or captions
ii) Instant Messaging
iii) Chats
iv) Confirm when camera is engaged and person in focus by non-visual means

e) Audio conferences should provide a method for hearing impaired users to participate. Some of these methods include:
i) Written transcripts or captions
ii) Instant Messaging
iii) Chats
iv) Supplemental video interpretation

d) Applications should work with the device's built-in tools and not require additional downloads or plug-ins

B3. Customer relationship management (CRM)

1) The application should be available to the user while the user is engaged with their customer

f) Fields should be easy to input and edit using multiple input methods. Some of these methods include:
i) Voice Commands
ii) Gestures
iii) Keyboards (on-screen and add-on)

B4. Web server / Content Management

1) The application should be accessible to content authors and end users

    g) Content authors should be able to easily navigate and:
        i) Create new content
        ii) Format content
        iii) Edit content and read edited content
        iv) Delete, retrieve or archive content
        v) Move content to a new section

    h) End users should have multiple ways to:
        i) Search content
        ii) Read content, including portions identified by user
        iii) Comment in forums or where user feedback is allowed
        iv) Identify comments by commenter, as displayed

B5. Identity Management

1) The user should have multiple methods to:

    a) Create a profile
    b) Sign in
    c) Recover a forgotten username
    d) Set up a password independently and recover a lost password
    e) Update a profile
    f) Delete a profile

2) The profile and identity should be separate from user preferences

3) CAPTCHAs are discouraged because they are not accessible

4) A single sign-on is encouraged. This can be via text (username and password), biometrics (fingerprint, voice recognition, or iris scan), or other method. If a biometric method is used, an alternate method should be available. SecureID devices will need an accessible alternative.

B6. Document Retrieval / Library Systems

1) Users should be able to access library content multiple ways (see General Guidelines 2)
    a) Navigation in a document retrieval/library system should allow the user multiple ways to:
        i) Search for documents
        ii) Refine search results
        iii) Retrieve documents
        iv) Read and navigate through content (Headings, tables of content, highlighted keywords, etc.) in documents

1054
1055 b) Content should be discoverable and search results should be easy to navigate.

1056 i) If search results span multiple pages, the focus should remain in the results section,
1057 not returning to the search pane.
1058 ii) Metadata is encouraged to aid in discoverability

Appendix C: The Role of Standards

Section 6.7 of NIST SP 500-291 (Version 2) of NCCP Standards Roadmap

Accessibility is relevant to cloud computing services at the application level where a human interacts with an application. This is where accessibility is measured. Therefore, many of the existing accessibility standards for ICT applications are relevant to cloud computing applications.

The U.S. Access Board is an independent federal agency devoted to accessibility for people with disabilities. The Access Board develops and maintains design criteria for the built environment, transit vehicles, telecommunications equipment, and for electronic and information technology. It also provides technical assistance and training on these requirements and on accessible design and enforces accessibility standards that cover federally funded facilities.

Section 508 of the Rehabilitation Act of 1973, as amended (29 U.S.C. 794d), requires that Federal employees with disabilities have access to and use of information and data that are comparable to the access and use by federal employees who are not individuals with disabilities. Section 508 also requires that individuals with disabilities, who are members of the public seeking information or services from a federal agency, have access to and use of information and data that are comparable to that provided to the public who are not individuals with disabilities. Both of these requirements must be met unless an undue burden would be imposed on the agency.

Section 508 standards that would be applicable for many cloud computing applications are:
Subpart B -- Technical Standards
1194.21 Software applications and operating systems;
1194.22 Web-based intranet and internet information and applications; and
1194.23 Telecommunications products.

The Access Board is in the process of revising the Section 508 standards. This is the first major revision since the standards were initially published in 2001. The initial product oriented approach to requirements is being replaced with a more functional approach. The Access Board plans to reference the W3C's Web Content Accessibility Guidelines (WCAG) 2.0[11] which is an international voluntary consensus guideline.

Additional voluntary consensus standards that may be applicable to cloud computing applications are:
ISO 9241-20:2008[12], Ergonomics of human-system interaction -- Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services

[11] http://www.w3.org/TR/WCAG20/
[12] http://www.iso.org/iso/iso_catalogue/catalogue_tc/catalogue_detail.htm?csnumber=40727

ISO 9241-171:2008[13], Ergonomics of human-system interaction -- Part 171: Guidance on software accessibility;
ANSI/HFES 200 [14]Human Factors Engineering of Software User Interfaces (Parts 1, 2, and 3); and ISO/IEC 24751-1:2008[15], Information technology -- Individualized adaptability and accessibility in e-learning, education and training – Part I: Framework and reference model.

Section 508 is more than a technical standard. It is a community of practice and a policy structure. For example, the Rehabilitation Act requires a biannual report to Congress on current agency compliance. The General Services Administration convenes a group of Section 508 Coordinators from the different agencies. This structure and community are under continuing development.

The White House released a Strategic Plan for Improving Management of Section 508[16] of the Rehabilitation Act, January 24, 2013. The strategic plan provides a comprehensive and structured approach to further improve agencies' management of the requirements of Section 508. The objective is to ensure that all electronic and information technology (EIT) that is developed, procured, maintained, or used by the federal government is accessible, as required by Section 508 of the Rehabilitation Act of 1973.

[13] http://www.iso.org/iso/home/store/catalogue_tc/catalogue_detail.htm?csnumber=39080
[14] http://www.hfes.org/Publications/ProductDetail.aspx?Id=76
[15] http://www.iso.org/iso/catalogue_detail?csnumber=41521
[16] https://www.whitehouse.gov/sites/default/files/omb/procurement/memo/strategic-plan-508-compliance.pdf

1116 **Table 4:** Excerpt from NIST SP 500-291

Categorization	Available Standards	SDO	Status
Accessibility	Section 508 standards (Technical Standards 1194.21 Software applications and operating systems; § 1194.22 Web-based intranet and internet information and applications; and 1194.23 Telecommunications products)	US Access Board	Approved Standard Market Acceptance Under Revision
	W3C Web Content Accessibility Guidelines (WCAG) 2.0	W3C	Approved Standard Market Acceptance
	ISO 9241-20:2008, Ergonomics of human-system interaction -- Part 20: Accessibility guidelines for information/communication technology (ICT) equipment and services	ISO/IEC	Approved Standard
	ISO 9241-171:2008, Ergonomics of human-system interaction -- Part 171: Guidance on software accessibility	ISO/IEC	Approved Standard
	ISO/IEC 24751-1:2008, Information technology -- Individualized adaptability and accessibility in e-learning, education and training -- Part 1: Framework and reference model	ISO/IEC	Approved Standard
	ANSI/HFES 200 Human Factors Engineering of Software User Interfaces (Parts 1, 2, and 3)	ANSI	Approved Standard

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Appendix D: Current Taxonomies

Below, in alphabetical order, is an annotated list of accessibility taxonomies currently in use, including those in active development. Some are implicit, in that they were not intended for use as taxonomies, but serve as informal categorization schemes. Note: some other taxonomies were collected, but not included in this document at this time; the list is shown in Appendix B.

D1. AbleData

http://abledata.com/

AbleData is a database of 20,000 assistive technology devices, oriented to clinicians and consumers with disabilities. Detailed product information is provided, including where it can be purchased. AbleData is supported by NIDILRR in the US Department of Health and Human Services.

It has 20 top-level categories, of which the ICT-relevant ones are:

- Blind and Low Vision
- Communication
- Computers
- Controls
- Deaf and Hard of Hearing
- Deaf Blind
- Education
- Environmental Adaptations
- Recreation
- Workplace

"Computers" is broken down further:

- Computer Accessories
  - Computer Accessories General
  - Cursor Control Accessories
  - Monitor Accessories
  - Tablet Computer Accessories
- Hardware
  - Cards
  - Central Processors
  - Disks and Tapes
  - Input
  - Modems
  - Output
- Software
  - Computer Access Interfaces
  - Computer Assisted Instruction
  - Computer Assisted Training

- Evaluation
- Functional Applications

"Computer Access Interfaces" is further broken down into "Motor Disability Access" (19 lowest-level categories, pointing to about 100 products) and "Sensory Disability Access" (40 categories, pointing to about 250 products).

D2. Access for All

http://imsglobal.org/accessibility/

The IMS Global Learning Consortium houses the Access for All (AfA) project on accessible learning materials and experiences. It is described as "promot[ing] an inclusive user experience by enabling the matching of the characteristics of resources to the needs and preferences of individual users." Those needs and preferences are to be captured in a user-defined statement, then used as the template for identifying resources that meet them. Although aimed at educational content, the AfA specification can be used more broadly, covering both content and interfaces in any use environment.

Currently, AfA Version 3 is in public review. Version 2 was published as ISO 24751.

The top level categories are "Display", "Language", "Control", "Content", and "Extension". The specification is structured as hierarchical classes with attributes. For example, the "Display" class contains a "Text Reading Highlight" attribute, which has its own class, which contains a "Pitch" attribute, etc.

Descriptor	Definition
Attribute name	voice recognition
Data type	Voice_Recognition
Value space	Container
Multiplicity	[0..1]
Description	Collection of needs and preferences for how to configure a *voice recognition system*.

Figure 2 - Screenshot of AfA Voice Recognition attribute within the Control class.

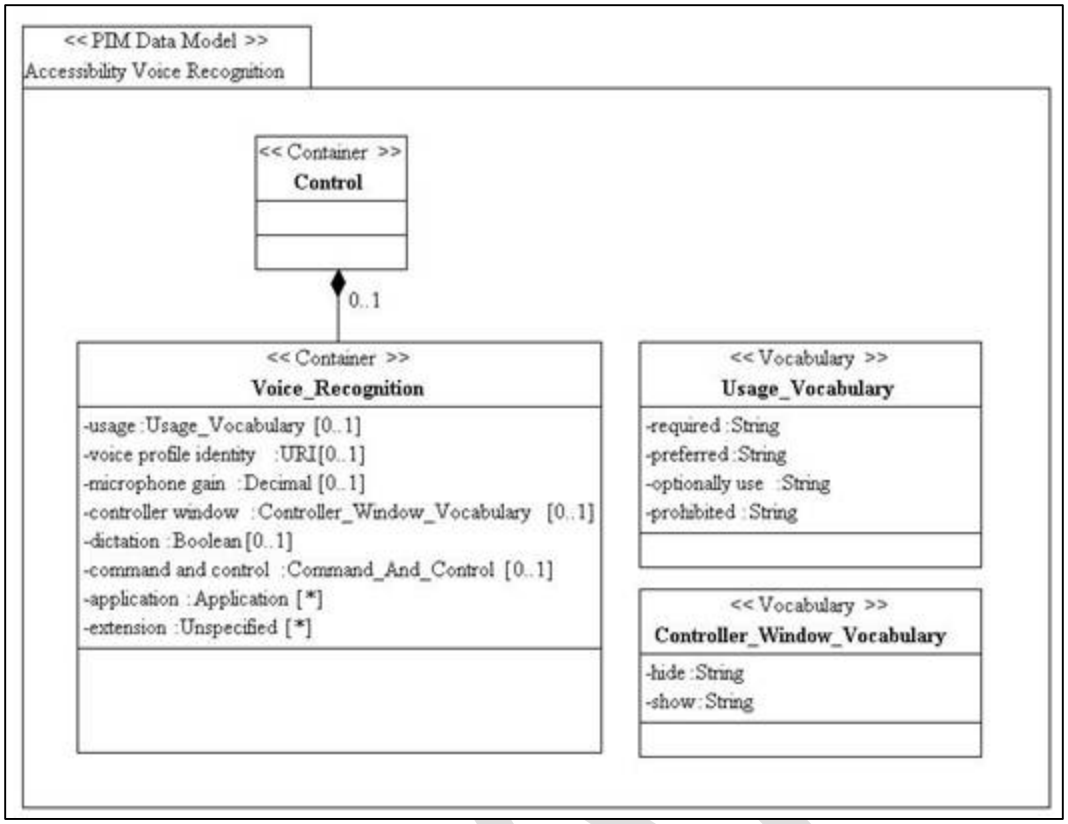

Figure 3 - Screenshot of AfA Voice Recognition data model, showing "voice profile identity" as one of several attributes.

Descriptor	Definition
Attribute name	voice profile identity
Data type	URI
Value space	See Table 6.1.
Multiplicity	[0..1]
Description	Data element identifying an external file containing a *voice recognition system voice profile*.

Figure 4 - Screenshot of AfA showing details of "voice profile identity".

The Accessibility Metadata Project (http://www.a11ymetadata.org/) has licensed an AfA subset to schema.org. Schema.org has modified and extended that subset and is actively disseminating it to the search industry, with the goal of letting content authors tag, and users find, accessible resources more easily.

D3. Cloud4All Semantic Framework for Content and Solutions (SEMA)

The Cloud4All project (one of the contributing projects to building the GPII) developed its Framework for developers who want to include their products and settings in GPII. They describe it as “an ontological layer containing instances and metadata about solutions, platforms, devices and their specific settings in a semantic hierarchical manner”. Thus it is structured with a registry of common terms, a repository of products and solutions, rules for matching solutions to needs, and a tool for managing the content of the framework, the Semantic Alignment Tool (SAT). This allows solution providers such as AT vendors to enter the characteristics of their products needed for GPII compatibility. The browser view of the SAT is too large to usefully show here. It has 2 navigation panes and a content pane.

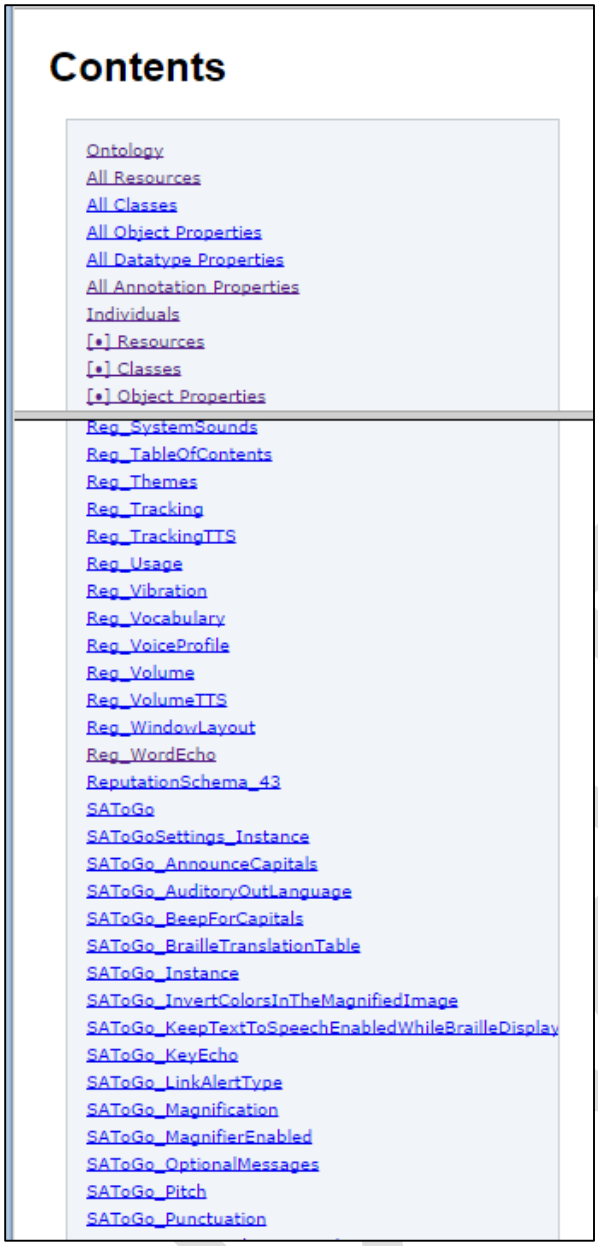

Figure 5 - Screenshot of SAT navigation panes.

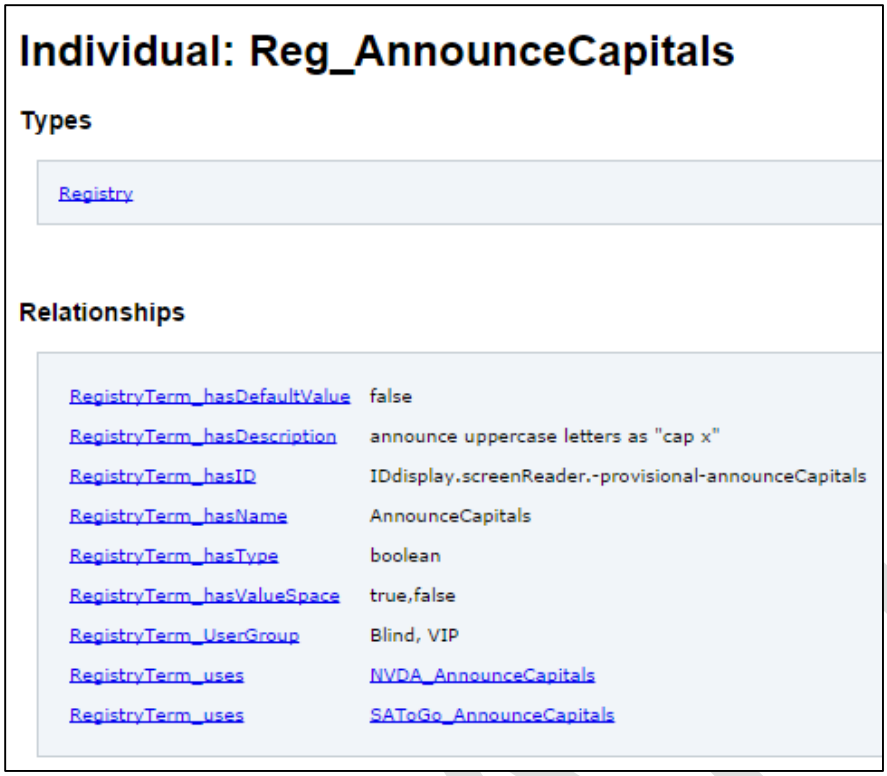

Figure 6 - Screenshot of SAT content pane.

The term "Reg_AnnounceCapitals" means that announcing capitals, a setting in a screen reader that aids recognizing proper nouns, is a common term in the Registry. Among its Relationships are its description ("announce uppercase letters as 'cap x'") and its possible setting value, true or false (on or off). Note that 2 vendors have entered the characteristics of their products, NVDA and SAToGo.

D4. EASTIN

http://www.eastin.eu/en/searches/products/index

EASTIN (European Assistive Technology Information Network) is an aggregation of European national information resources on AT. It uses the ISO 9999:2011 classification schema (see below) as its framework, so it includes non-ICT products and more or less medical devices. EASTIN has extended ISO 9999 with terms that pertain to ICT and/or characteristics of use, such as languages supported by the solution, or operating systems it can run on; and subdivided it for more detail, adding such terms as "touch screens" and "speech synthesizers". Not all of this new classification is exposed on the public EASTIN site.

The EASTIN taxonomy has 2 levels, Clusters and Features. For example, the Feature "tactile display" is found in the "Output device" Cluster.

Specific product information is available via several search pathways.

The full ICT-focused taxonomy can be found at
http://wiki.gpii.net/index.php/The_vocabulary_of_the_EASTIN_taxonomy

ISO Code	Code description	N. of products
	Classification	**75356**
22	**ASSISTIVE PRODUCTS FOR COMMUNICATION AND INFORMATION**	**11820**
22.03	**ASSISTIVE PRODUCTS FOR SEEING** Included are, e.g., magnifying devices.	1679
22.06	**ASSISTIVE PRODUCTS FOR HEARING** Devices for concentrating, amplifying and modulating sound for a person with hearing problems; Included are, e.g., hearing aids with built-in tinnitus masking and induction coil devices.; Sound stimulators, see >04 27 15; Induction loop devices, see >22 18 30	865
22.09	**ASSISTIVE PRODUCTS FOR VOICE PRODUCTION** Devices for assisting a person who has insufficient voice power to speak using his/her own voice; Microphones, see >22 18 33; Loudspeakers, see >22 18 36	63
22.12	**ASSISTIVE PRODUCTS FOR DRAWING AND WRITING** Devices assisting a person to convey information by producing figures, symbols or language; Weighted cuffs, see >04 48 18; Training materials for developing writing skills, 05 03 09; Assistive products for training in drawing and painting skills, see >05 24 06; Tactile maps, see >12 39 15	718
22.15	**ASSISTIVE PRODUCTS FOR CALCULATION** Computers and terminals, see >22 33	65

Figure 7 - Screenshot of EASTIN search results at the Cluster level, indicating the number of hits.

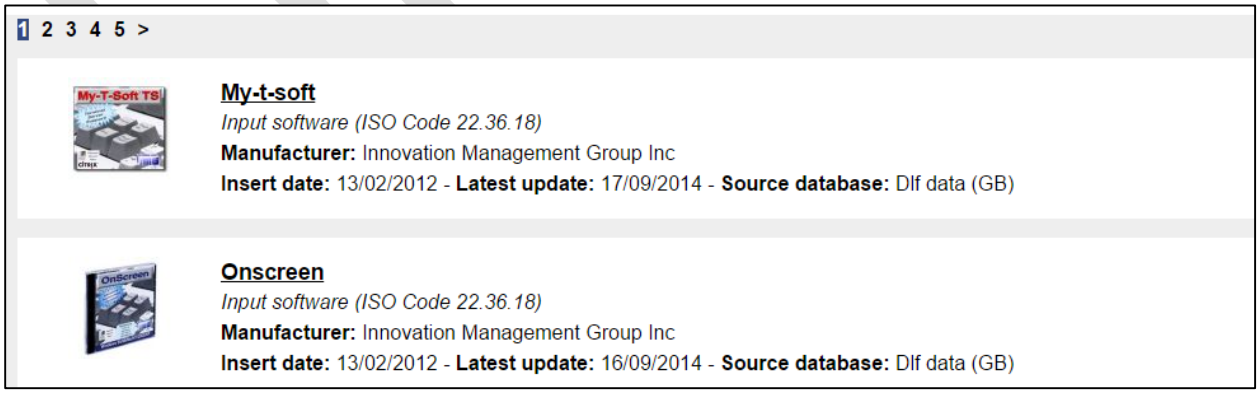

Figure 8 - EASTIN screenshot showing some of the results for "Assistive Products for Communication and Information … Input devices for computers … Input software".

D5. Global Accessibility Resource Initiative (GARI)

https://www.gari.info/

GARI is a database created and maintained by the mobile phone manufacturers (through their trade association, Mobile Manufacturers Forum) to help consumers with disabilities find phones they can use.

It is aggregated by the FCC for its Clearinghouse (mandated by CVAA).

GARI is broken down by disability category, and then by accessibility feature.

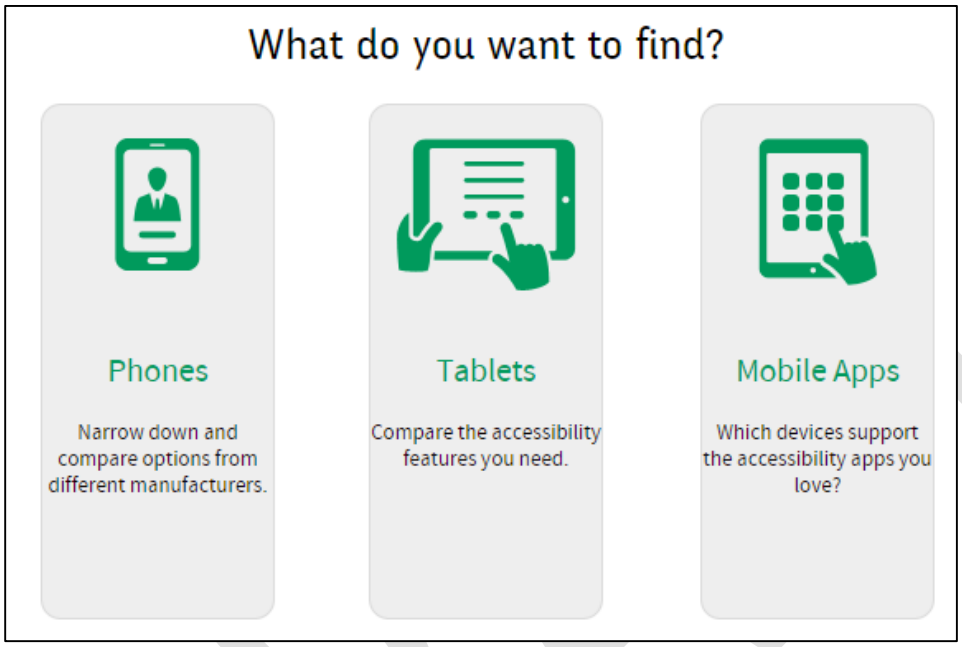

Figure 9 - Screenshot of GARI search portal front page.

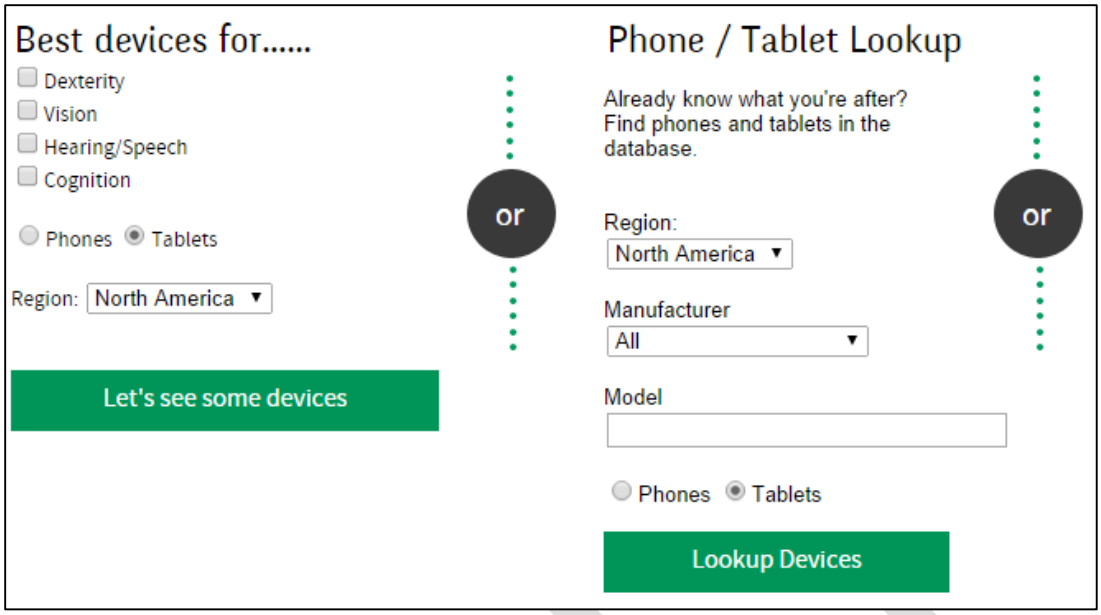

Figure 10 - Screenshot of GARI search option page.

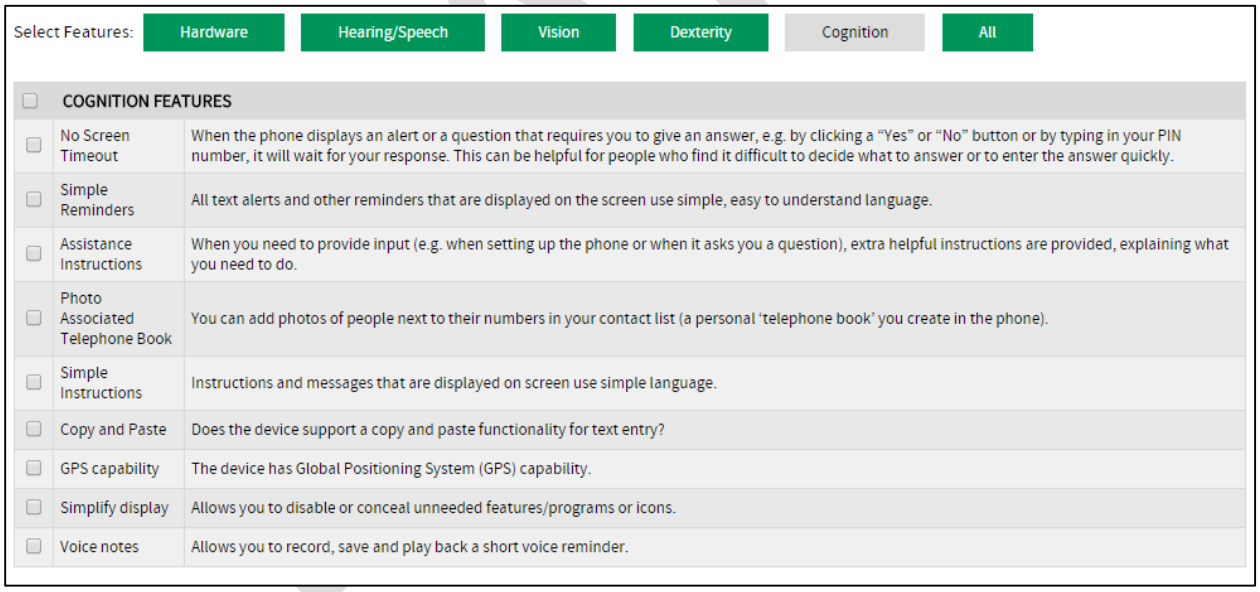

Figure 11 - Screenshot of GARI list of accessibility features associated with cognitive disabilities, with definitions.

D6. IndieUI User Context

The Independent User Interface (IndieUI) Task Force is a W3C/WAI project intended to develop unified interface guidelines to "… make it easier for web applications to work in a wide range of contexts — different devices, different assistive technologies (AT), different user needs" by

standardizing accessibility-relevant methods for software developers. There are 2 "sides" to IndieUI: Events and User Context; the latter is relevant here. The goal of the User Context work is "to provide authorized web applications access to information about a user's relevant settings and preferences…." Thus it refers to settings for text (font, color, background color), alternative formats (captions, description), high contrast, inversion, and screen reader. IndieUI is currently under development; the working draft of User Context is here: http://www.w3.org/TR/indie-ui-context/.

D7. ISO 9999:2011

This is a standard for categorizing assistive technology, and includes some medical devices. The ICT-relevant top-level categories are:

- Training in skills
- Communication and information
- Employment and vocational training
- Recreation

ISO 9999 uses a 3-part set of 2-digit codes. The first 2 digits refer to a domain of use (e.g., '22' is 'Communication and Information'). The second 2 digits either refine the domain of use (e.g., '22.21' is 'Face-to-Face Communication') or refer to a disability dimension (e.g., '22.06' is 'Hearing'). The third set is a specific AT product category (e.g. '22.36.03' is 'Keyboards').

The full set of subcategories for Communication and Information is:

- Seeing
- Hearing
- Voice production
- Drawing and writing
- Calculation
- Record, play, and display audio and visual information
- Face-to-face communication
- Telephoning and telematic messaging
- Alarming, indicating, reminding, and signaling
- Reading
- Computers and terminals
- Input devices for computers
- Output devices for computers

Note that ISO 9999 is used by EASTIN (above).

D8. Job Accommodation Network (JAN)

http://askjan.org/

The Job Accommodation Network is the US Department of Labor, Office on Disability Employment Policy's database of job-related accommodations, focused on commercial AT products. It is aimed at employers trying to find individual accommodations for employees (or applicants) with disabilities, and is also used by people with disabilities and AT practitioners.

JAN's main pathway to solutions begins with selecting from a list of disabilities, but one can also search directly by product or service:

Figure 12 - JAN's main pathway: Information by Product or Service

Beneath this level are specific AT product types; here's what's shown under "Product listing for Vision Impairments":

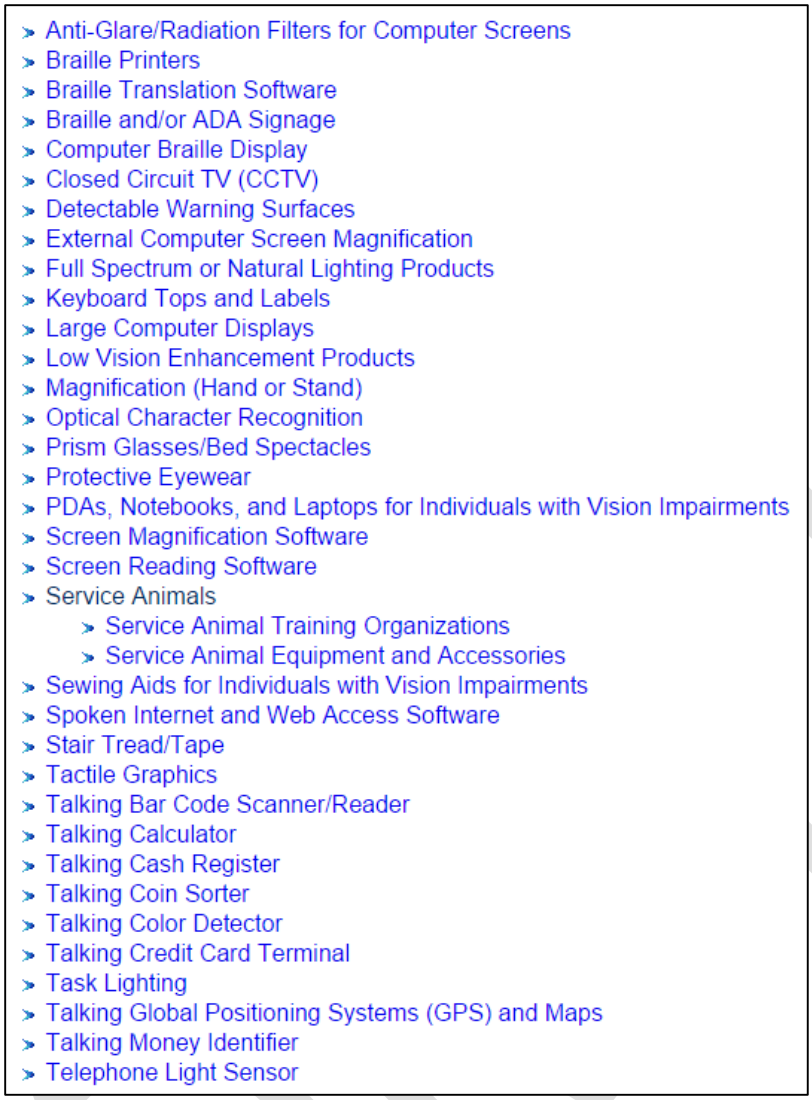

Figure 13 - Product listing for Vision Impairments

JAN target pages for these links give a list of manufacturers and their contact information.

D9. M376

Mandate 376 (M376) is a statement by the European Commission about the public procurement of accessible ICT, soon to be implemented in law. The Mandate led to a new European ICT accessibility standard, promulgated by 3 standards bodies: ETSI, CENELEC, and CEN. M376 is similar to Section 508, in that it is aimed at ICT in public procurement; the effort to build the European standard is aware of the parallel, referring to Section 508 in several places.

The main standards document is EN 301 549 (referred to as 'EN'). EN begins with functional performance statements covering vision, hearing, speech, dexterity/range, cognition, photosensitivity, and privacy.

The bulk of EN is structured in Clauses that cover requirements for different technologies, beginning with a Generic Clause for all technologies. This is followed by Clauses for 2-way voice, video, hardware, web, non-web documents, software, documentation, and relay and emergency services. Some Clauses are sub-divided (e.g., "Caption processing technologies" within "Video"). At the bottom level are specific requirements. The Web Clause parallels WCAG 2.0.

EN contains 2 Annexes, one of which explains the relationship between the functional performance statements and the requirements, in table form:

Table 5: Table B.2 shows the relationship between functional performance statements and specific requirements, indicating where the relationship is primary (supports the functional performance statement) or secondary (the feature is needed by some users, or in some situations).

Table B.2: Requirements in clauses 5 to 13 supporting the accessibility needs expressed in the functional performance statements

Requirements	4.2.1 WV	4.2.2 LV	4.2.3 WPC	4.2.4 WH	4.2.5 LH	4.2.6 WVC	4.2.7 LMS	4.2.8 LR	4.2.9 PST	4.2.10 LC	4.2.11 P
5.1.2.1 Closed functionality	-	-	-	-	-	-	-	-	-	-	-
5.1.2.2 Assistive technology	-	-	-	-	-	-	-	-	-	-	S
5.1.3.1 General (belongs to 5.1.3 Non-visual access)	P	S	-	-	-	-	-	-	-	S	-
5.1.3.2 Auditory output delivery including speech	P	S	-	-	-	-	-	-	-	S	-
5.1.3.3 Auditory output correlation	-	P	-	-	-	-	-	-	-	S	-
5.1.3.4 Speech output user control	P	S	-	-	-	-	-	-	-	S	-
5.1.3.5 Speech output automatic interruption	P	S	-	-	-	-	-	-	-	S	-
5.1.3.6 Speech output for non-text content	P	S	-	-	-	-	-	-	-	S	-

D10. Raising the Floor

http://research8.misericordia.edu/

Raising the Floor is developing an accessibility taxonomy on behalf of the Consumer Electronics Foundation, to categorize both accessibility features and consumer electronics products that might have them. In this it is similar to GARI, and it too may eventually be populated by manufacturers themselves, and used by consumers.

The Features section is divided into functional categories that map somewhat onto human performance ("easier to understand", "easier to physically operate", etc.), but moves away from a medical model, putting the focus on the design rather than the user. The Product Types section is driven by the intended domain, consumer electronics.

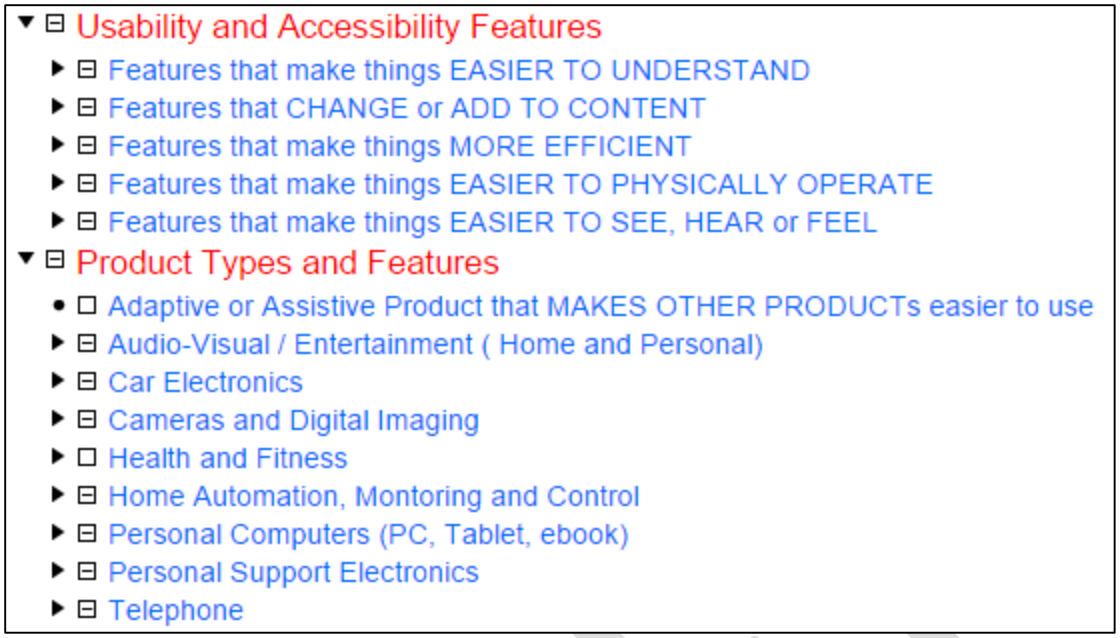

Figure 14 - Screenshot of RtF taxonomy, showing both the Feature and Product hierarchies and first sub-categories.

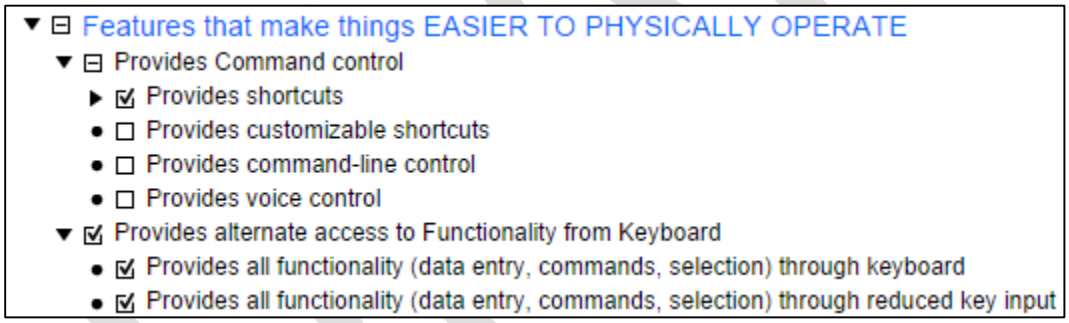

Figure 15 - Screenshot of RtF taxonomy showing bottom-level feature details

D11. Section 508

http://section508.gov

In brief, Section 508 of the Rehabilitation Act requires US federal agencies to purchase accessible ICT. Its use has spread to other parts of the public sector. It is currently under revision, which will change its product categorization schema. Currently, it is divided into:

- Software Applications and Operating Systems
- Web-based Internet information and applications
- Telecommunications Products
- Video and Multi-media Products

- Self-Contained, Closed Products (meaning products to which accessibility accessories cannot be attached, and onto which accessibility software cannot be installed, such as copy machines)
- Desktop and Portable Computers

(There are also functional performance criteria that use a typical disability categorization, and provisions for documentation and support not relevant here.)

Under each product category are provisions that cover specific accessibility issues. For example, in the Web category one provision states that "[A] method shall be provided that permits users to skip repetitive navigation links."

D12. Tables of Taxonomies

We have raised the point that information resources can be categorized along several dimensions, and in fact it is important to do so in order to understand how well those dimensions (especially audiences) are covered by the resources currently in use. As an experiment, below are some partial tables indicating how this categorization could be developed and visualized.

D12.1. By Audience

'P' indicates primary audience; 'S' indicates secondary audience.

	Developers	**Content creators**	**PWD**	**Practitioners**	**Technology managers**	**Policy makers**
AbleData			P	P	S	S
Access4All	S	P				
Cloud4All SEMA	P					
EASTIN			P	P	S	

D12.2. By Dimension

'X' indicates that the indicated taxonomy (row) is scoped to or includes information or categorization in the dimensions (columns).

	Disability / performance category	Context of use	Product category	Technology feature	Legal/regulatory	Standard
AbleData	X	-	X	X	-	-
Access4All	-	Education		X	-	ISO 24751
Cloud4All SEMA	-	-		X	-	ISO 9999
EASTIN	X	-		X	-	ISO 9999

D13. Taxonomies found within technical standards; not included at this time

Some taxonomies or sources of useful categorization were not included in this draft:

- HFES 200.2 is the accessibility portion of HFES 200, a usability standard for computer interaction.
- ISO 9241, a standard for the ergonomics of human-computer interaction.
- Voluntary Voting System Guidelines, a product of the Election Assistance Commission, which contains systematically specified requirements for usability and accessibility.
- Web Content Accessibility Guidelines (WCAG 2.0), especially the Techniques.

D13.1. ICF

http://apps.who.int/classifications/icfbrowser/

The UN's World Health Organization (WHO) puts forth a classification scheme for human functioning called the International Classification of Functioning, Disability and Health, or "ICF". The ICF is not explicitly technological; its relevant section categorizes human functions into Chapters in an attempt to move from a medical model of disability to a social model, wherein an individual's ability to fulfill social roles via active participation is seen as the interaction between personal characteristics (e.g., severe vision loss) and environmental factors (e.g., attitudes and social institutions). Technology is one of the environmental factors.

ICF is included here because it is a prominent taxonomy in disability studies and policy development, and several clinical tools have been built from it. It could be used, or cross-referenced, in a taxonomy for accessible technology.

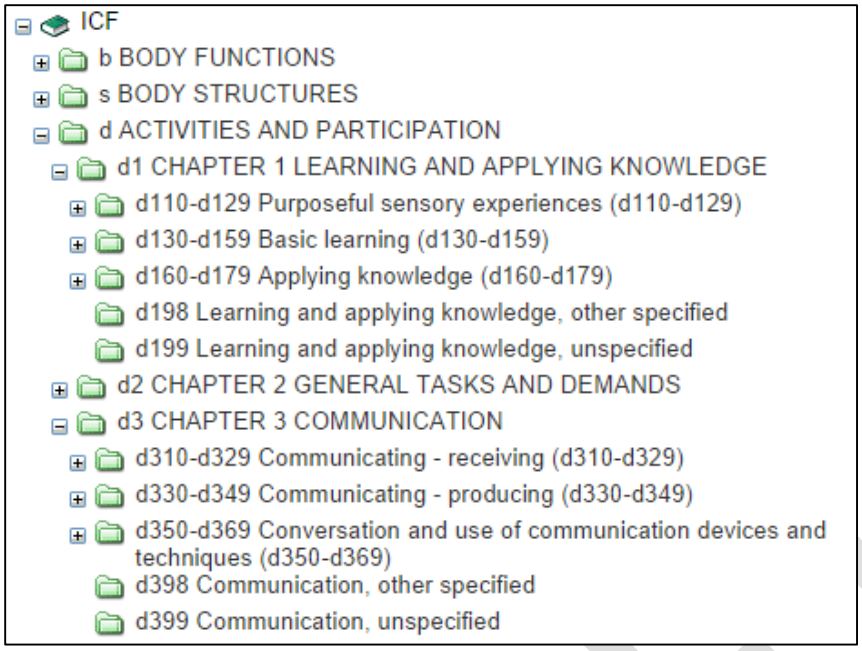

Figure 16 - Screenshot of ICF Browser showing Chapter structure within "Activities and Participation".

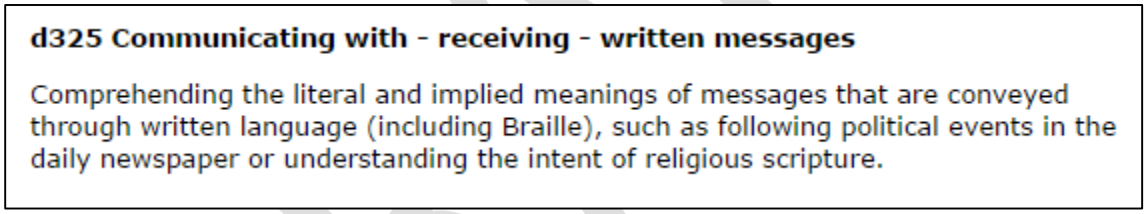

Figure 17 - Screenshot of ICF Browser showing functional detail.

As an example of how ICF could be integrated into an accessible technology taxonomy, an accessibility feature or product that addresses a functional limitation in receiving written content would be tagged under 'd325'.