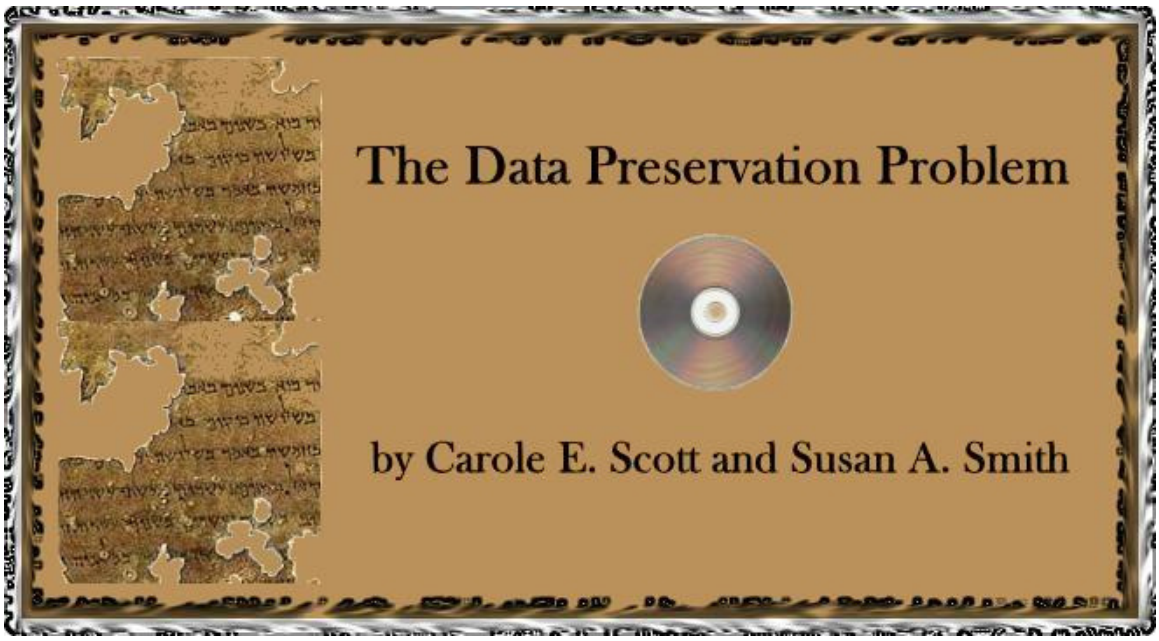

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Introduction

Today public and private archives and libraries are experiencing a preservation crisis as they seek to preserve and make readily available an enormous amount of data recorded in now obsolete, decaying formats, and they are drowning in a rapidly growing tsunami of new data that includes billions of records in digital form that has thrown them into a turbulent and uncharted preservation morass.

The earliest methods of recording text, such as stone and clay tablets, were more durable than a more recent method, vellum, which, in turn, was more durable than paper, which only in recent years became as durable as it was over a century ago after we returned to using acid-free paper. While it is very difficult to preserve paper for a few centuries, some clay tablets have lasted 5,000 years. Vastly older cave paintings created before there were any written languages still exist.

Up until the late nineteenth century when sound was first recorded, data and the arts were recorded in a physical form that could be read without the use of any equipment. In the twentieth century an increasing share of society's output of information and the arts was recorded in new forms--phonograph records, wire recorders, audio tapes, slides, movies, magnetic tapes, video tapes, computer diskettes, and printed material transferred to microfilm to save storage space--that required equipment in order for it to be accessed.

We are rapidly evolving into a world in which the principle method of creating, distributing, and storing text, images, and sound will be digital, resulting in an enormous amount of materials of every kind being easily accessible everywhere 24/7 by authorized users. The quality and cost of a format are the bottom line considerations in selecting the format to be utilized both in creating and preserving data.

A digital object is any type of information expressed in digital form that is recorded on either a magnetic or optical disk. Digital objects include both transcriptions of written documents such as books, magazines, correspondence, etc. and other methods of recording information that cannot exist in hard copy form such as interactive Web pages and virtual reality. Therefore, while printing the former is a method of preservation, there will be some possibly extreme loss in the case of the latter types of format.

"It took two centuries to fill the U.S. Library of Congress in Washington, D.C., with more than 29 million books and periodicals, 2.7 million recordings, 12 million photographs, 4.8 million maps, and 57 million manuscripts. Today it takes about 15 minutes for the world to churn out an equivalent amount of new digital information." (Smith, *Spectrum*)

Increasingly the electronic version of a publication is the "version of record". The version of record is the peer-reviewed, final, published version of an academic paper. (Increasingly, academicians are putting pre-publication drafts of their papers on the Web.) Some for-profit print publications do not provide a complete back run of their publications. Some fear that they cannot be counted on to provide a complete run of their electronic publications.

Through digitization the content of rare or fragile materials can be physically protected while making them available to everybody. Unfortunately, there is no guarantee that the new digital media will outlast printed documents. "…The ephemeral nature of both data formats and storage media threatens our very ability to maintain scientific, legal, and cultural continuity, not on the scale of centuries, but considering the unrelenting pace of technological change, from one decade to the next." (Smith, *Spectrum*)

"Physically, electronic media are less stable than their various predecessors (paper, parchment, clay tablets, microfilm, etc.) with

commensurately shorter life spans. Magnetic tape and computer disks can deteriorate to the point of being unreadable within 30 years. Optical media are slightly more durable, but neither comes close to matching the stability of acid-free paper or a clay tablet. (O'Brien)

Digitalization makes it possible to warehouse an enormous amount of data at a relatively low per unit storage cost, but, even if it could, should the Library of Congress keep everything—an everything that is increasing in size at an amazing rate and in the case of the Web in an ephemeral form—and do so forever? The same question applies to archives, libraries, and other organizations that have a narrower mandate than does the Library of Congress. If not, how should the pruning be done?

"People in charge of preserving our national heritage or public records must make decisions today that will have impacts well into the future. It is cheaper and safer to analyze and compare potential actions before actions are actually taken, and making a poor preservation decision today can lead to content loss or the need to engage in expensive salvaging efforts later. Yet, up till now there have been no objective means to identify which digital format is most apt to sustain the passage of time. There has been no way to compare two format specifications. There has been no scale to measure format specifications' preservation durability." (Stamescu)

Recognizing the importance of preserving information in digital form, in December 2000, the U.S. Congress asked the Library of Congress to lead a collaborative project called the National Digital Information Infrastructure and Preservation Program. (http://www.digitalpreservation.gov/)

It is, of course, not only newly created material that is being stored in digital form, as an ever larger share of existing material created over the centuries in printed form is being copied to digital media in order to preserve it and make it more widely and easily accessible. But while digital offers us enormous advantages in terms of storage space and use, it burdens us with many unique and complex problems.

Lack of Durability

Data stored on magnetic media are subject to bit rot—the degradation of these media due to physical factors. Nobody knows for sure how long a computer diskette will last even under ideal conditions. Although books can be destroyed by a too humid environment that causes micro-organisms to grow in them or a too dry environment that causes them to become so brittle that they flake apart in your hands, unlike books, machine readable formats like movie film and computer diskettes cannot be kept for decades in a place like your attic and still be readable as is sometimes the case with books. CDs, DVDs, and digital

tape media "…have little better life expectancy than the magnetic tape that they replace." (Cornwell, Enge, and Joerg)

One solution is to periodically copy data to new diskettes, but this is costly and time consuming, and how frequently this is necessary is undeterminable. Preservation microfilming is a way for prolonging the availability of information recorded on deteriorating media that is more permanent than digital imaging (TIFF, JPEG, etc.). (The Sarbanes-Oxley Act of 2002 requires that businesses save records, including electronic records and email, for at least five years. In the pharmaceutical industry records must be maintained for 30 years or more.)

The microfilm vault of UMI, which began as University Microfilms in 1938, constitutes the largest commercially available microfilm collection in the world. Consisting of 5.5 billion page images are drawn from thousands of literary, journalistic, and scholarly works. Today UMI is one of ProQuest Information and Learning's assets. http://proquest.com/promos/product/feature02_umi.shtml

According to a September 7, 2006 conversation with Jim Morrison, NACP Sales Representative, UMI will microfilm a library's archival collections and place it in the UMI vault; thereby preserving this material if digital copies are lost.

Lack of Standardization

Even if equipment for reading a given type of media exists, data may be unreadable due to lack of standardization. One of the authors in the early 1970s stayed in a new hotel in England where you could not move a lamp from one side of the room to the other because the outlets were designed for different sized plugs. The same situation exists today in the recording industry because, unlike our electrical industry, they have not standardized their products. A recent example of this type of problem is illustrated by the fact that while some computers can record and read only on DVD+RW and DVD+R, others only record and read DVD-R, DVD-RW or DVD-RAM. Therefore, to be able to read any DVD, you would have to have two computers. (The DVD medium was preceded by two kinds of floppy disks and the CD.)

A video produced in England cannot be played on a standard video player produced in the U.S. You can only play audiocassettes on a player designed to play the proper sized audiotape that has the correct number of tracks in the correct physical location. Who can play an 8-track tape today?

Obsolescent Equipment

"Digital longevity is a contradiction in terms….Professional and consumer archivists grapple with how to preserve documents, music and images produced by no-longer-relevant machines." (Baig)

Even if a machine readable only medium is preserved, the necessary equipment to access it may no longer be available. The reality is that introduction of new technology may cause machine readable mediums to become unreadable because eventually the equipment needed to read them is no longer produced because there is not a large enough market for it to justify their production, and it is not feasible to keep working versions of all now obsolete equipment.

In 1996, the BBC recorded on laserdiscs 900-year-old data about Britain. This data could only be read by a special system based on a BBC Micro home computer. Two years of painstaking work, completed in 2003, with a few still existent computers were required to transfer this material to a modern PC. (*Economist*) This data can today be viewed at http://www.domesday1986.com

That the introduction of new technology leads to the inability to access materials created with an earlier technology has long been obvious. Just the reduction of the size of the sprocket holes in 8 mm movie film in order to make the picture larger made it impossible to show the regular 8 mm films on a projector made to show Super 8, film. When the switch was made, Super 8 projectors that could be adapted to show Regular 8 were produced. To deal with advancing sound technology, some businesses are manufacturing equipment for transferring 45 RPM and LP records to CDs. Equipment for transferring cassette recordings to CDs is also available. Eventually the market for such equipment will be too small to justify its production.

While people who had computers that utilized the original, 5 ¼ inch floppy disks that were really floppy were out of luck when the much smaller, hard-plastic-contained floppy disks were introduced. For several years after CDs were introduced computers were produced that could read both. Today computers that can read CDs and DVDs are produced that cannot also read floppy disks.

As the fact that tires are still produced for antique automobiles illustrates, it is not certain that the use of old technology becomes impossible shortly after a successor technology is introduced, but clearly it has to be an exceptional situation.

Short of putting them under a microscope—a highly impractical project—microprint records resorted to by libraries in order to save space, can seldom be read today because it has been a long time since machines to read them have been produced. There is no feasible method of transferring this material to a new medium. However, microfilm copies of the data on microprint cards can and is digitalized, but doing this requires the use of microfilm readers that may someday be “gone with the wind.”

Archives and libraries often do the same thing people with 8 mm home movies have done in order to preserve their materials over the long run: transfer them to a new medium. This is called migration. “Migration strives to ensure

usable and trustworthy electronic records for as long as necessary without regard for platform. It converts electronic records to technology-neutral file formats and requires backward compatibility. Migration preserves the processibility of records but potentially risks losing the 'look and feel' of the original format and some original information." (Charles Dollar http://www.state.sc.us/scdah/dollarsumm0122.htm) This is said to be an expensive, error prone, and time-consuming task that is expanding in size as the amount of material in outdated formats increases. Due to technological progress, storage costs decline when data on an old platform becoming obsolete is transferred to a new platform.

Another proposed solution is called encapsulation. With this method files are wrapped with a physical layer that is human readable describing the encapsulated content and how to use it. A digital inner layer contains the specifications for the software, operating system, and hardware needed to read them.

Software No Longer Available

"The physical well-being of electronic records is of little importance if they fall victim to hardware or software obsolescence." (O'Brien)

The National Archives used to store engineering drawings of the Navy's ships on paper. If the right kind of paper and ink are used, paper documents will last for a very long time. Because the average service life of a Navy ship is 50 years, these drawings might need to be referred to for decades. Now this information is stored in digital form. For just one ship this accounts for hundreds of millions of computer files. Even if these files remain uncorrupted until a ship is decommissioned, it is not very likely that the necessary software to use these files will continue to be available. In New York land use and natural-resource inventories that were compiled in the late 1960s cannot be read because the customized software required to open the files no longer exists. NASA satellite data from the 1970s, too, is no longer readable. (Davenport)

The outmoding of the current standard used by digital cameras by a higher compression standard, warns Margaret Hedstrom, professor of information at the University of Michigan's School of Information, may make it very difficult in only a few years for people to view photos they are taking now. (Tristram, 38-39)

Because keeping operable some of every kind of computer ever used is not feasible, the most common way utilized to deal with the disappearance of the computers needed to read some material is to copy files from one generation of computers to the immediately following generation. A problem with this is that new software may introduce errors into the material. A way to deal with this is to employ what is called emulation. With this method software is used that

simulates the hardware of an obsolete computer on a modern computer. With emulation the original form of a file, such as interactivity, is maintained. An additional problem with this is that today's emulators will in the future need an emulator, and using them will probably introduce errors.

Security and Copyright Issues

In the case of huge amounts of data stored by government and business, the joint task of preserving while securing it from unauthorized access is a daunting task. This introduces such additional elements of data preservation as firewalls and the storage of media in unused salt mines.

In 2006, The Privacy Rights Clearinghouse reported that through the loss of backup tapes and laptops and inside jobs at such business giants as Bank of America, LexisNexis, DSW, MCI, Ameritrade, Time Warner, Boeing, Ford Motor Company, Verizon, MasterCard, Wells Fargo, the American Red Cross, and other business in addition to numerous universities and government agencies, the personal information of nearly 90 million people had been potentially exposed by data security breaches. (Mark)

As the search engine giant Google learned when it was sued after announcing that it planned to scan, digitize, and make searchable the collections of five of the world's largest libraries, using digitization and the web to make materials vastly more accessible raises yet unsettled copyright issues. (Google is being sued by both the Association of American Publishers and the Authors Guild.) Like Google, Yahoo also plans to digitize several large collections of books. Yahoo will provide access to a permanent archive of multilingual, digitized text and multimedia content organized by the Open Content Alliance (OCA), which is composed of a group of cultural, technology, nonprofit, and governmental organizations from around the world. In addition to Yahoo's site, it will appear at http://www.opencontentalliance.org/ .

Side Effects

Like the throwing of a stone in a pond, the impact of technological change ripples through society, bringing about changes that are often unexpected. Some are good; some are bad. For example, technological innovations both made it easy to drastically alter photographs and more difficult to detect alterations. On the other hand, the Web made it possible for anybody who detects an altered photograph to inform a very wide audience of this fakery because publishing on the widely-viewed Web is so cheap. As a result, even a major media outlet can be forced to withdraw the altered photograph.

The Web has made self publishing economically feasible for most people. It makes it possible for people with Web pages to widely disseminate false information because self-published material does not have to pass muster with

reviewers and editors. (Note, however, the findings at http://www.nature.com/nature/journal/v438/n7070/full/438900a.htm See also critique of the study reported on at this URL located at http://corporate.britannica.com/britannica_nature_response.pdf.) On the other hand, some might argue that an often biased filter has been removed; thereby providing views and information that formerly would never see the light of day.

Some fear that one "ripple" effect of the switch from paper to electronic records may make freedom of information laws obsolete. (Both the federal government and many states have freedom of information laws.) The threat arises out of the fact that in the case of electronic records redaction is vastly more difficult than using a black marker to conceal information in a printed document. The specific information a government is asked by an ordinary citizen or a reporter to provide may be buried within an enormous database containing both information that can and cannot be disclosed, and no software to retrieve only information that can be released to the public may exist. (Abrutyn)

As the still healthy market for paper and printers illustrates, the electronic revolution has not, as some assumed would happen, largely eliminated the use of paper documents. Technological advance has made it far easier to convert data stored in electronic form to paper and data stored on paper to electronic storage. Recently introduced is the multifunctional device that provides printing, copying, scanning, and faxing in a device that is network and Internet ready. Made possible by the multifunctional device is the saving of storage space by converting of material not in electronic form to this form and the convenience of being able transfer this information to paper for distribution to users who prefer having it in this form.

"The totally paperless office is still in the distant future. Today, organizations can become about 80 percent paperless. The requirement for original signatures and maintaining original documents and the mentality of individuals who simply must have paper prevents the completely paperless environment from existing." (Rivera, 26)

Some Innovations in Data Storage and Dissemination

In addition to the recent innovations previously mentioned, the Massachusetts Institute of Technology (MIT) is offering a new method for preserving and disseminating data called DSpace. It is an open-source system written in Java that runs on any computer platform that typically runs on top of Unix and Unix-based operating systems, such as Linux. Supported by DSpace is both bit migration and the attaching of tags about what has happened to the data over time necessary to prove legal provenance. A DSpace curator is responsible for migrating documents provided to it for preservation to new formats as older ones become obsolete. "…Preserving electronic publications has become a critical matter as the mass of e-publication increases and…communities have

begun to depend on electronic publications as they used to rely on paper." (Kenney) "The shift from print to electronic publication of scholarly journals is occurring at a particularly rapid pace. Researchers, teachers, students, and other readers demand electronic formats because it provides so many advantages over print, especially for search and retrieval. Recognizing the greater capability of the digital medium, editors are treating the electronic versions of journals as the definitive versions of record." (Digital Library Federation)

The Library at the University of Illinois provides an E-Journal Archiving Program called Portico that is a sort of insurance policy for maintaining access to electronic journals in case some unforeseen catastrophe should occur by providing a permanent archive of electronic scholarly journals. Initial support for Portico was provided by the Andrew W. Mellon Foundation, Ithaka, The Library of Congress, and JSTOR. Several publishers participate in Portico. As of September 1, 2006, over 3,700 titles were being preserved. Portico will preserve a library's electronic journals subscriptions even if the publisher goes out of business. Previously libraries had bound volumes after the publisher went out of business. With electronic access, there are no bound volumes and no microfilm for backup. http://www.library.uiuc.edu/blog/scholcomm/archives/2006/09/portico_ejourna.html Web journals and other material appearing on the Web are also today being preserved and made viewable on the web by the Internet Archive located at http://www.archive.org/web/web.php .

By typing a URL in its WaybackMachine, you can view pages at a web site as they appeared at a specified, earlier date. To date 55 billion pages have been archived. In collaboration with the Library of Congress and the Smithsonian Institution this organization--a 501(c)(3) non-profit--is building an 'Internet library' whose purpose is to provide "permanent access for researchers, historians, and scholars to historical collections that exist in digital format." (http://www.archive.org/about/about.php) Founded in 1996, it is physically located in the Presido of San Francisco. It preserves texts, audio, moving images, and software as well as archived web pages.

Today a substantial amount of scholarly material from all over the world, including not yet published papers, peer-reviewed articles, seminar papers, working papers, etc. are provided by open access repositories. (An example is the Australasian Digital Thesis Program at http://adt.caul.edu.au/) A problem with open access repositories of electronic documents is that redundancy is not addressed, and "…preservation efforts may vary depending on the expertise and resources of the institution running the repository…." (Honey)

"In the last quarter, over 780,000 records have been added to OAIster, suggesting that those open access archives are beginning to fill! There are 170 more titles in DOAJ, likely an understated increase due to a weeding project. 78 titles have been added to DOAJ in the past 30 days, a growth rate of more than 2

new titles per day. Disciplinary archives are showing remarkable growth. E-LIS has been increasing at the equivalent of 56% annually." (Morrison) OAIster is a project of the University of Michigan Digital Library Production Service http://oaister.umdl.umich.edu/o/oaister/ . DOAJ is the Directory of Open Access Journals http://www.doaj.org/ . (B>Quest is an open access journal.)

In conjunction with IBM Netherlands, the Koninklijke Bibliotheek (National Library of the Netherlands) has developed an emulation method called the Universal Virtual Computer (UVC) that makes it possible to view JPEG and GIF images without the original hardware and software. The UVC is a virtual representation of a simplified computer. Because of its simplicity, the UVC can in be made to work on any conceivable computer system. Basically, it involves the creation of an extra layer on top of ever changing hardware and software that provides a stable platform to UVC programs. "Detailed instructions will enable future developers to rebuild a UVC at any time." (Koninklijke Bibliotheek) UVCs must be rebuilt because there is no way to predict what kind of hardware will exist in the future.

Planned Obsolescence

Today consumers "…fret about the permanence of computers and electronics gear. They read about 'CD rot,' short-lived iPod batteries and pricey plasma TVs with traces of static images 'burned into' the display. And they pray that the most prized digital treasures—family photographs—will last from one generation to the next.

Sometimes, as with digital TV, the latest gear really is the next big thing. But often a new product merely reflects powerful market forces, like changing styles or planned obsolescence. Businesses require regular turnover to generate profit. Never mind that what exists might not need fixing." (Baig)

Makers of digital products appear to have increased their sales substantially by a combination of planned and technological obsolescence. While DVDs represent a vast technological improvement over the original five and one-quarter inch floppy disks in terms of storage space, it is often questionable as to whether version 2.5 of a piece of software represents any significant improvement over version 2.0. Furthermore, using it may require a considerable investment of time in learning a new way to do things the earlier version included but handled differently.

Planned obsolescence in software is called forced upgrade. If a software producer has a monopoly or near monopoly on a particular type of program, users are locked in. Intense pressure is placed on the user by such policies as ceasing to support the previous version of the software or provide security upgrades or new drivers needed in order for the program to be used with new hardware. (Security upgrades are essential in the case of Internet software due

to the constant introduction of new viruses and worms.) The following is an example of forcing people to upgrade.

"'We do not have plans to deliver Windows SP SP2 enhancements for Windows 2000 or other older versions of Windows,'" the company said in a statement. 'The most secure version of Windows today is Windows XP with SP2. We recommend that customers upgrade to XP and SP2 as quickly as possible.'" (Festa)

Conclusion

As private individuals we are--or should be--concerned about the possible loss of the digital photos we have taken of the babies in our family and emails we have received from family and friends. The digital photos replace the prints people used to paste in photo albums and the negatives they stored in a box with a lid that was kept on the shelf in the closet. Emails have replaced the treasured packets of letters our grandparents and their parents and grandparents tied together in bundles and kept in the bottom of a dresser drawer.

Traditionally, historians and novelists have used diaries and letters to recreate the past, and historians have depended on them in analyzing and interpreting the past. Historians worry about what documents from the 21st century will escape "bit rot" and so be available for the next generation of historians to use. Scientists and engineers figuratively "stand on the shoulders" of their predecessors. Those "shoulders" consist of information such as that appearing in scholarly journals that has in the past been recorded on paper. If scientific notes and journal articles are lost because we have failed to preserve their content, the loss to society would be unimaginably great.

How to best preserve data after the digital revolution provides us with vexatious technological problems faced, not only by librarians and archivists and those responsible for maintaining business and government records but by everybody. It is an enormously important problem for society as a whole. While this revolution provides us with extraordinary benefits probably not exceeded since writing developed, it also burdens us with vastly more complex problems than did any previous introduction of a new medium for preserving data.

In the past we have several times shifted from a longer-lived to a more convenient medium for preserving data. A clay tablet is far more durable than is a piece of paper. Some paper and inks provide a medium that deteriorates more slowly than does a piece of microfilm. The development of printing had an effect like the development of electronic media in that it made the production of documents far faster and cheaper; thereby making the information they contain available to far more people. But both the possible gains and losses the digital revolution presents are far greater than those previous revolutions presented society. The rate of technological change has speeded up. Shorthand lasted

longer than did the Dictaphone that first replaced it. Floppy disks were cutting edge longer than were CDs. Abacuses were cutting edge far longer than were mechanical adding machines, which were replaced by electronic ones.

Technological innovations have made it possible for the average amount of records kept per record keeper and the number of record keepers to increase at an astounding rate, and the rate of demand for and production of records, it seems, are going to grow at an ever increasing rate. In the future it will likely be essential that data collections be more severely pruned.

Individual organizations and associations of organizations have chosen a variety of different methods to preserve and distribute documents effectively and economically. Unfortunately, the method chosen often seems to become outdated even before all the existing documents are dealt with.

Perhaps some significant data preservers should unite and agree on a system analogous to the positive metal masters that were used to create the negative stampers that created phonograph records. If, for example, enough organizations decided to keep "master" copies of essential documents in the form of microfilm, this would provide a sufficient market to justify someone producing the equipment necessary to create microfilm documents and the equipment needed to digitalize it onto whatever digital medium is then available. (Eyeball readability is, of course, an important safety feature.)

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