THE POWER CONTROL USER INTERFACE STANDARD

CONSULTANT REPORT

Prepared For:
California Energy Commission
Public Interest Energy Research Program

Prepared By:
Lawrence Berkeley National Laboratory

DECEMBER 2002
P500-03-012F

Prepared By:
Lawrence Berkeley National Laboratory
Alan K. Meier, Ph.D
Bruce Nordman
Berkeley, CA
Contract No. 500-98-032

Prepared For:
California Energy Commission

Don Aumann,
Contract Manager

Nancy Jenkins,
PIER Buildings Program Manager

Terry Surles,
PIER Program Director

Robert L. Therkelsen,
Executive Director

Legal Notice

Prepared for the U.S. Department of Energy under Contract No. DE-AC03-76SF00098.

Acknowledgements

LBNL greatly appreciates and wishes to acknowledge the invaluable assistance of the many people who made the project both possible and successful. For all those we have inadvertently failed to name here, our apologies and gratitude.

Nancy Jenkins, California Energy Commission
Don Aumann, California Energy Commission
Eric Stubee, California Energy Commission
Judith Efhan, California Energy Commission
Gary Klein, California Energy Commission
Joseph Wang, California Energy Commission
Alan Hedge, Cornell University
Jonathan Puleio, Cornell University
Jenna Melissa Shanis, Cornell University
Goran Bryntse, Dalarna University
Jacob Lindborg, Dalarna University
Malin Kindblom, Dalarna University
Emil Westerberg, Dalarna University
Melanie Bohac, Dell
Bill Kuhlmann, Dell
Andrew Fanara, Environmental Protection Agency
Craig Hershberg, Environmental Protection Agency
Fred Lathrop, HP
Marty Marzinelli, HP
Mary Ann Christie, IBM
Candace Soderston, IBM
Edward Rashba, IEEE
Doug Gabel, Intel
Alec Gefrides, Intel
Christoph Scheurich, Intel
Scott Lofgren, Intel
Paul Sorenson, Intel
Ken Salaets, ITI
Tommy Bangthamai, Lawrence Berkeley National Laboratory
Marcy Beck, Lawrence Berkeley National Laboratory
Robert Clear, Lawrence Berkeley National Laboratory
Jeff Harris, Lawrence Berkeley National Laboratory
Ronnen Levinson, Lawrence Berkeley National Laboratory
Chris Payne, Lawrence Berkeley National Laboratory
Mary Ann Piette, Lawrence Berkeley National Laboratory
Mary Ann Shiffman, Lawrence Berkeley National Laboratory
Rich Wilson, Lawrence Berkeley National Laboratory
Robert Howard, Lunar Design
Kent Sullivan, Microsoft
Chad Magendanz, Microsoft
Tony Pierce, Microsoft
John Calhoon, Microsoft
Curtis Chong, National Federation of the Blind
Bob Davis, Network Appliance
Hans-Paul Siderius, NOVEM
Peter Mennen, Oce'
C. (Kees) Kessels, Oce'
Kaoru Kawamoto, Osaka Gas Company
Kousuke Ito, Ricoh
Ian Miller, Samsung
Dave Traver, Sony
Sudershan Goyal, Sun
Craig Hartley, Sun
Peter Boyce, RPI
John Bullough, RPI
Azeen Chamarbagwala, U.C Berkeley
Phoebe Kuan-Ting Liu, U.C Berkeley
Craig Rixford, U.C Berkeley
Rashmi Sinha, U.C. Berkeley
Mary Trombley, U.C Berkeley
Bin Xin, U.C Berkeley
David Ensign, U.S. Department of Energy
Alan. Godlas, University of Georgia
Tom Burke, Underwriters Laboratories
Bill Laplant, U.S. Census Bureau
Bill Lempesis, VESA
Bryan Bashin
Debbie Driscoll
John Walters
And many many more

Table of Contents

Appendices

List of Figures

List of Tables

Table **Page**

Preface

The Public Interest Energy Research (PIER) Program supports public interest energy research and development that will help improve the quality of life in California by bringing environmentally safe, affordable, and reliable energy services and products to the marketplace.

The PIER Program, managed by the California Energy Commission (Commission), annually awards up to $62 million to conduct the most promising public interest energy research by partnering with Research, Development, and Demonstration (RD&D) organizations, including individuals, businesses, utilities, and public or private research institutions.

PIER funding efforts are focused on the following six RD&D program areas:

- Buildings End-Use Energy Efficiency
- Industrial/Agricultural/Water End-Use Energy Efficiency
- Renewable Energy
- Environmentally-Preferred Advanced Generation
- Energy-Related Environmental Research
- Energy Systems Integration

What follows is the final report for the Next-generation Power Management User Interface for Office Equipment Project, #500-98-032 conducted by Lawrence Berkeley National Laboratory. The report is entitled The Power Control User Interface Standard – Final Report. This project contributes to the PIER Buildings End-Use Energy Efficiency program.

For more information on the PIER Program, please visit the Commission's Web site at: http://www.energy.ca.gov/pier/index.html or contact the Commission's Publications Unit at 916-654-5200.

Executive Summary

The large quantity of energy used to operate equipment and consumer electronics could be significantly reduced if more users could correctly implement energy-efficient power management interface standards when using individual devices. While power management interface controls (labels, terms, symbols, colors, etc.) are present already in hardware and software, often they are used incorrectly or not at all because the user finds them to be confusing, inconsistent, or overly complex. One solution to this problem would be to create a common vocabulary for these controls so that future devices will be easier for people to understand and use, thereby leading to energy cost savings through increased and widespread use of the controls.

Therefore, it was critical that the Power Management Controls Project work with the office equipment and consumer electronics industries to create a new, standard user interface for office equipment power management. The new standard then would have a greater chance of being acceptable to and voluntarily adopted by those industries, standards organizations, and the U.S. EPA's ENERGY STAR program.

This project was conceived to be a combination of research and marketing. The research portion involved reviewing products, standards, literature, and other topics to identify the scope of the interface standard and its specific content. Engaging industry was essential, both to gain valuable feedback, and to give the project more credibility and support. Finally, publicizing the project and its results has been important in order to spread the word.

Objectives

The key objectives of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new Interface standard
- Develop and test elements of the proposed Interface standards

Outcomes

Based on its objectives, the project had the following primary outcomes:

- Conducted an "Institutional Review," which clearly revealed that no universal standards or conventions currently exist for power management through the use of user interface controls.
- Developed and tested a draft Standard Interface based on broad industry input provided by the Professional Advisory Council (PAC).
- Conducted or instigated four separate tests of portions of the draft Standard Interface.
- Integrated test results and comments from the PAC and others into a final Standard Interface that includes the key elements listed below.

  Static Interface

  - Use only three power states when possible: *On*, *Off*, and *Sleep*.
  - Use the word "Power" for terminology about power.

- Redefine the ⏻ symbol to mean "power" as for power buttons and power indicators; use the ⏼ symbol (on / off) only when necessary.
- Use the "sleep" metaphor for entering, being in, and coming out of low-power states; use the moon symbol — ☾ — for *sleep*.
- Adopt "green / amber / off" color indications for power state indicators.
- Present PC "hibernate" modes as a form of *off*.

Dynamic Behavior

- Use "power up" to mean turn on or wake up, and "power down" for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green / amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.

- Introduced and promoted the Project and the new Standard Interface through presentations, conferences, web sites, and personal contacts.
- Examined relevant international standards and identified obstacles to incorporating the proposed standards.
- Created an IEEE (Institute for Electrical and Electronic Engineers) Working Group to transform the project results into an IEEE standard.

Conclusions

A Power Control User Interface Standard has been successfully developed showing that a core foundation for power controls can be established and demonstrating the value of working with all interface elements across diverse device types to form a coherent interface. It is clear that no previous attempts had been made in this area and that industry was not sufficiently motivated by the topic to address it. However, we are cautiously optimistic that the standard has, and will continue to, gain adherents and proponents. A solid foundation has been designed; it now needs to be implemented in further work through integration into an IEEE standard.

We showed how human interface considerations can determine the success of a technology, in this case power management, and that improved interfaces — if reasonable and low-cost — will be adopted by industry. This has implications for other aspects of energy use that are increasingly influenced by user interfaces. These include space conditioning, lighting (as it becomes more electronic and networked), and real time pricing.

The Power Control User Interface Standard will be a tool that makes it easier to save energy once it is incorporated into future products. Some PAC members and others have said that they have begun using parts of the Standard already, though specifics were not available because products have not been released yet. Use of the Standard and energy savings will grow as it is ratified by standards organizations and incorporated into labeling programs.

Recommendations

Recommended actions for the Commission to take in the future include:

- Support finalizing and implementing the Standard via outreach and IEEE.
- Explore other areas for user interface improvement and standardization related to energy consumption such as lighting, space conditioning, and real-time pricing.
- Consider human interface elements in future mandatory efficiency standards.

Benefits to California

Past Commission work with standards has been mandatory and focused on building construction (Title 24) or equipment sales (e.g. appliances, Title 20) in California. This project demonstrates that for *some* end uses, voluntary standards, and a national or even international focus may be the best way to gain results in California.

Office equipment is largely an international market, meaning that manufacturers market the same models across the globe. Thus, it is necessary to aim for success in changing product designs globally to most effectively influence the devices sold and used in California. Consumer electronics have been traditionally marketed nationally, but manufacturers are increasingly selling the same models internationally, much like office equipment.

Earlier work by LBNL found that the “power management gap” for office equipment in the U.S. in 2000 resulted in costs of about $1.3 billion per year — costs that could be saved through reduced energy consumption if power management was enabled on all devices capable of performing it. In addition, there were indications that in the absence of efforts to the contrary, the gap was likely to rise in the future (due to an increased number of devices and device types with multiple power modes, greater differences between active and sleep levels, and increased availability of devices offering more hours per year). California’s portion of this gap is likely to be greater than our 12% population share of the country. How fast the standard will be incorporated into new products and how much of the gap is closed by this or other reasons is difficult to assess, but savings of $100 million dollars per year just in California seem attainable.

Abstract

The goal for the Power Management Controls project was to create a standard for the user interface elements used in power controls with the expectation that incorporating these into future projects would increase the portion of devices that have power management enabled and saving energy. The key objectives of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new Interface standard
- Develop and test elements of the proposed Interface standards

The major accomplishments of the project were the successful development and testing of a power control user interface protocol, the packaging of this protocol into a draft IEEE (Institute for Electrical and Electronic Engineers) standard, and the creation of an IEEE working group. This set the stage for converting the project recommendations into an IEEE standard, possibly amending international standards, conducting further outreach, and incorporating the standard into the design of future products.

In the process of creating the standard, we assembled a Professional Advisory Committee (PAC) made up of representatives of major hardware and software manufacturers. The committee reviewed project plans and results. Our background research included a review of the relevant literature and national and international standards (and responsible committees). We introduced and marketed the project and standard through presentations, conferences, web sites, and many personal contacts. And finally, we conducted four separate tests of the standard.

Key elements of the Power Control User Interface Standard are to:

- Use only three power states when possible: *On*, *Off*, and *Sleep*.
- Use the word “Power” for terminology about power.
- Redefine the ⏻ symbol to mean “power” as for power buttons and power indicators; use the ⏼ symbol (on / off) only when necessary.
- Use the “sleep” metaphor for entering, being in, and coming out of low-power states; use the moon symbol —☾—for *sleep*.
- Adopt “green / amber / off” color indications for power state indicators.
- Present PC “hibernate” modes as a form of *off*.
- Use “power up” to mean turn on or wake up, and “power down” for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green / amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.

Other parts of the standard cover the "dynamic behavior" of devices (i.e., behavior of indicators in transition or error states, transition metaphors and audio indications, state changes caused by power button use). The report includes a draft of the IEEE standard, and appendices describing the rationales behind the standard, a literature review, accessibility to the disabled, color choices in indicators, the wider standards context, issues around the crescent moon symbol, and testing of the standard. The project web site (http://eetd.lbl.gov/Controls) includes all project documents, related background information, and post-project activities.

1.0 Introduction

The Power Management Controls project addressed user interface elements such as terms, symbols, and indicator lights. The core result of this project was a "User Interface Standard" for future electronic products that should increase the enabling of power management and hence save energy. Although the overall project objective was to achieve energy savings by improving power management, the content of the standard is independent of the amount of the savings so the quantitative energy discussion is kept to Section 2. In this section we present the background context of the project, the specific project objectives, and the organization of the report.

1.1 Background and Overview

The power control user interface is the combination of manual and automatic controls and indications of power status. It includes terms, symbols, colors, operating metaphors, and the behavior of the device in response to input and equipment operation over time.

User controls for power management of office equipment show little consistency in the terms and symbols used and in their overall structure. This is particularly true across device types (e.g. between a PC and a copier), but often holds true even within the same type of device. For example, the *standby* mode on some copiers refers to the state when they are fully on and immediately ready to act, but the *standby* mode on other computers and monitors refers to a low-power mode in which they have reduced capability and take time to recover. "Standby power" also is used to identify a device's minimum power state, which is often its *off* state. The confusion and ambiguity of so many power management controls often discourage people from using them, or even attempting to do so.

A second deterrent to optimal use of power management is that users often cannot ascertain the power status of office equipment easily, so they don't know when they should change settings (assuming they do know how to).

Controls that are highly configurable — adaptive to user behavior or informed by daily or weekly calendars — also raise the specter of over-complexity. Delaying the development of standard power management user interfaces will make it even more difficult to gain convergence in the future. We still have the opportunity to develop and standardize user-friendly interfaces.

While the focus of this project is primarily office equipment (and, secondarily, consumer electronics), the principles and standards apply to many other types of devices. Reducing the confusion caused by disparate user interface systems will improve consumer satisfaction. Improved comprehension will lead to additional energy savings as people operate their systems more effectively. In addition, the success of power management controls standardization could stimulate a follow-on effort for residential energy controls (e.g. home lighting and space conditioning systems) and for non-energy controls such as imaging (printing and copying), and water use. Power management in office equipment is a logical first effort in this larger domain.

The original name for this project was the "Next-generation Power Management User Interface for Office Equipment". This is rather unwieldy for general use, so we began to refer to it as the "Power Management Controls" project. The name of the proposed standard developed during the project is the "Power Control User Interface Standard," or the "User Interface Standard."

We use the term "information technology" and the abbreviation "IT" because IT better encompasses the equipment under consideration, and it includes a larger set of devices than office equipment. Office equipment (e.g. PCs) is the most important subset of IT equipment, although, increasingly, less of it is being used for office functions or in offices. For clarity, power "modes" (states) are italicized, e.g. *on*, *sleep*, and *off*.

1.2 Energy Context of Office Equipment and Power Controls

1.2.1 Energy Use of Office Equipment and Savings from Power Management

Office equipment today is responsible for about 2% of total U.S. electricity consumption (Kawamoto et al., 2001). Consumer electronics and other electronic devices only add to this figure. Office equipment also requires the output from about a dozen large (1,000 MW each) power plants. Californians consume less electricity per capita than the United States as a whole, but the office equipment component is probably more intensive than the United States average. Thus, the portion of California's electricity devoted to office equipment is likely considerably higher than the national average.

The problem of large amounts of energy being used by office equipment was first noted in the late 1980s, and by the mid-1990s a solid and comprehensive program for energy-efficiency was operating (ENERGY STAR). Electricity savings from power management of office equipment has been one of the premier success stories for the energy efficiency community. ENERGY STAR was largely responsible for creating aggressive low-power — or "*sleep*" — modes in nearly all forms of office equipment. The devices can automatically shift into the low-power *sleep* mode after a user-determined length of inactivity, and then quickly recover for use when needed. Engaging *sleep* modes offers large energy savings, as shown in Figure 1 .

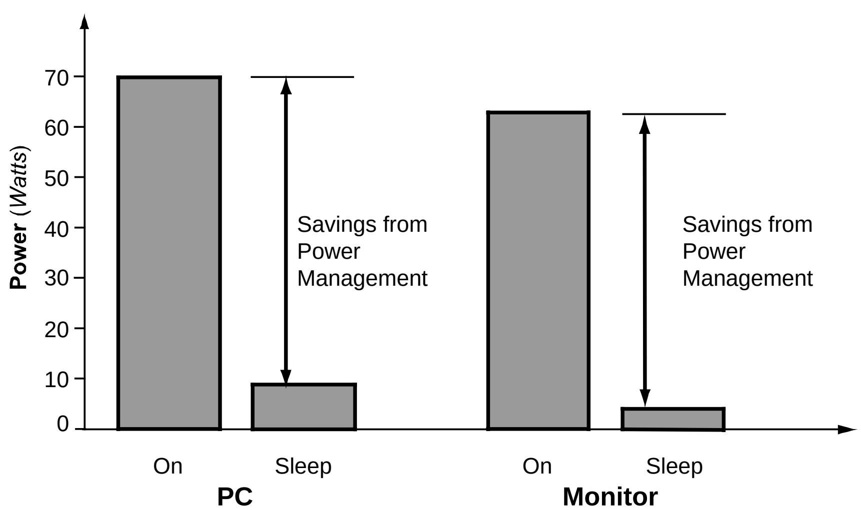


Figure 1. Example power management savings from a monitor and PC[1]

[1] The power levels shown here are from (Roberson, 2002) which reports power levels for recent PCs and monitors.

Despite this success, many devices that are capable of power management are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by hardware or software conflicts. The rates of power management enabling vary widely with the kind of equipment and situation. No truly representative national surveys of enabling rates have been undertaken. Limited surveys have been undertaken (see Table 1), and their findings indicate that the majority of PCs do not have power management enabling capabilities. For monitors, printers, and copiers the enabling rates are above 50%, but significant improvement is still possible.

Table 1. Observed rates of power management enabling in office equipment

Device	Enabling Rate
Personal Computers	25%
Monitors	55%
Copiers	70%
Printers	80%

Notes: The figures for Personal Computers, copiers, and printers are from (Nordman, 2000). The monitor figure is from (Webber, 2001).

Thus, if higher power management enabling rates can be achieved, considerable additional electricity can be saved. The goal of this project was to demonstrate a way to capture those savings by increasing the rate at which power management is enabled and operates successfully. The mechanism is a standard for power control user interfaces. Nearly all of the commercial electricity customers in California (and many residential and industrial customers as well) will benefit from these savings.

The most comprehensive and applicable study of office equipment energy use was conducted at LBNL and presents a snapshot as of the end of the year 1999. Table 2 shows the results for the U.S. as a whole, and our estimate for California, which assumes that the state has similar usage patterns and equipment densities per capita as the rest of the country. Those results are the total office equipment electricity use, and the potential *additional* savings if all IT equipment with power management capability was enabled to do so.

Table 2. Office Equipment Energy Consumption and Savings from Power Management

	United States	California
Total Office Equipment Electricity Use (GWh / year)	71,100	8,500
Potential Savings — 100% Power Management (GWh / year)	16,700	2,000
Likely Impact of the User Interface Standard (GWh / year)	5,800	700
Savings of each 1% of Potential (GWh/year)	**170**	**20**
Total Office Equipment Electricity Cost ($mil / year)	5,700	1,300
Potential Savings — 100% Power Management ($mil / year)	1,300	280
Likely Impact of the User Interface Standard ($mil / year)	470	100
Savings of each 1% of Potential ($mil/year)	**13**	**2.8**

Notes: National consumption and savings are from Kawamoto, 2001. The figures for California take it as 12% of the national figures. All figures annual for end of 1999. Electricity rates are 8 cents / kWh for the country as a whole and 14 cents / kWh for California. The "likely savings" figures are based on achieving 35% of the potential energy savings from increased use of power management. The existing savings from power management are 22.8 and 2.7 TWh / year for the U.S. and California respectively, with a dollar value at the above electricity rates of $1,800 and $380 million / year. These existing savings are with respect to *no* use of power management, and the "potential savings" reflect 100% enabling of power management — both with no change in manual turnoff rates.

It is difficult to assess just how much of the potential national or California savings can be captured by implementation of the User Interface Standard. Because the savings figures vary with the assumption of the percentage of savings gained, a simple way to understand the potential is with the effect of *each* 1% of the potential savings. One can easily multiply this by any percentage.

To provide an indication of the likely impact of the standard, we take 10% to 60% of the potential as the range of plausible estimates, and the midpoint of this range is 35% savings. Table 2 shows the "Likely Impact of the User Interface Standard" based on this 35% figure. To put the 35% figure in perspective, it could be accomplished by increasing copier enabling from 70% to 80% and PC enabling from 25% to 50% (that is, bringing PCs to a place well below what has been achieved already in other devices). Note that the potential does not include any existing use of power management — only possible increases in its use. For all of these savings it is important to recognize that they recur each year and require no extra manufacturing cost if changes are implemented during the normal product design cycle.

1.2.2 Future Trends In Power Management Savings

The figures in Table 2 reflect the stock and usage patterns of equipment as of the end of 1999. Savings from the User Interface Standard will occur in future years, after products meeting the standard are designed and sold, and after users gain enough experience with products and operating instructions based on the User Interface Standard to get the benefit of their consistency and clarity. There are forces driving the potential savings both up and down. Trends tending to increase potential savings from power management are:

- *More Types Of Devices With Multiple Power Modes*
  Power management will appear in more and more types of products. Devices not

traditionally "electronic," such as appliances, lighting, and space conditioning, are increasingly getting electronic capabilities. The trends towards greater portability (so that power management is required for extending battery life), and more communication and networking, both increase the range of devices with power management features.

- *More Of Each Device Type*
  The sheer number of devices with power management is on the rise, such as more PCs and displays. Wireless networking eases the deployment of many devices in a home or office that all access the same services (processing, storage, and communications).
- *More Hours Per Year Wanted To Be Available*
  Operating times are on the rise — devices are wanted to be available an increasing fraction of the time, as people rely on them more and for more functions. Devices need to be available to communicate with other devices in addition to being used by people. As devices become networked, interdependent, and smarter, the number of factors affecting power management will only increase, so that controls will likely become more complex and unwieldy.
- *More Power Difference Between* On A*nd* Sleep
  The difference in power levels between *on* and low-power modes is increasing, particularly for computers.

Trends that will reduce potential savings are:

- Transfer of efficient technologies from battery-powered to mains-powered devices
- Lower recovery times, removing that as a barrier to enabling power management

And finally, two trends that could increase *or* decrease potential savings are:

- Changes in the active power levels of devices
- More capability to finely control device behavior

We expect that the overall direction of potential power management savings — the combination of all of these factors — will be up, increasing the importance of the User Interface Standard.

In summary, the potential savings of the Standard are substantial and accrue across California, the nation, and the globe. What savings actually are achieved are difficult to assess either in advance or after the fact; they could be substantially more than the figures shown here, as the pool of potential savings is likely to grow, and the percent achieved could be higher than assumed.

1.2.3 Cost Effectiveness

Implementing the User Interface Standard will not raise the cost of manufacture of IT equipment if introduced during the normal product design cycle.

Since implementation of the User Interface Standard costs so little relative to the savings, the cost-effectiveness of the project is high regardless of the savings ultimately achieved (even without including non-energy benefits and possible energy savings from reduced heat loads in air-conditioned buildings). In most energy efficiency endeavors, there is some increased first-cost to manufacture a better appliance or build a better building. While these can pay off quickly, the program or standard design content necessarily depends and is based on the anticipated extra cost and savings. For the User Interface Standard, however, there are no extra manufacturing costs if introduced during the normal product design cycle. Because of this, the content of the standard depends only on what is clear to people and adaptable to many product environments. The User Interface Standard content is completely independent of the amount of savings projected or attained.

1.3 Project Objectives

The stated objectives at the outset of the project were to:

- Create the Interface Standard Development Plan
- Conduct research to guide a new standard interface
- Develop and test proposed interface standards:
    1. Development process
    2. Testing
    3. Standards adoption

The project was designed to support the PIER program objective of improving the energy cost/value of California's electricity. This goal was to be accomplished by setting the stage for power controls for future electronic products that are easier to understand and, more importantly, consistent from device to device. The improved user interface should make it easier for people to take advantage of the hardware capabilities built into the products they purchase and use.

1.4 Report Organization

The remainder of this report describes the Project Approach, the Project Outcomes, and the Conclusions and Recommendations resulting from the project. A Glossary and References section provide further detail.

Attachment I is a first draft of the proposed standard: "Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments," which we refer to as the Power Control User Interface Standard.

Appendix I provides background and rationale for the specific decisions underlying the standard content. Appendix II is a review of literature relevant to power control user interfaces. Appendix III discusses how these interfaces can be made more accessible to people with disabilities. Appendix IV addresses issues with color choices, particularly for LED power indicators, to make them more accessible to the color-deficient. Appendix V lists relevant existing standards and standards committees (and describes why they are relevant). Appendix VI provides background about how the crescent moon symbol is used within Islam and how it should be best constructed as an international symbol for *sleep*. Appendix VII reviews the several testing exercises conducted in the course of this project. Appendix VIII delves into the "hibernate" mode used on many computers and how it can and should be treated in power controls.

2.0 Project Approach

The Power Management Controls project was divided into two main phases, each of which served a content and institutional purpose. The first phase accomplished the "Create the Interface Standard Development Plan" objective (a process of refining the project plan, not the yet-to-be-written standard). This process took the first six months of the project and culminated in a daylong, in-person PAC meeting in early November of 2000 at the LBNL offices. The intent was to prepare background material explaining the problem, the context, and pointing the way towards a solution, including deepening the project plan. Assembling the PAC facilitated making contacts at companies, and the background material set the stage for the rest of the project.

The second phase addressed the other two objectives: conducting the research to guide a new standard interface, and developing and testing proposed interface standards. These were conducted in parallel, as the structure and details of the proposed interface became apparent in the course of conducting the research. Also, industry reaction to the initial proposals guided the continuing research in a feedback process. Similarly, the testing was conducted in parallel, occurring in three phases that provided feedback to the standard and to the later testing.

Early on it became apparent that the standard could be divided into two distinct portions: the *hard* or *static* interface elements (terms, symbols, and indicator colors), and the *dynamic behavior* of devices (how the device and interface elements respond to changes and transitions). The latter depends on the former, so the six principles that form the hard interface were put out for industry comment first. Dividing it into these two parts helped make each easier to digest at one time for those providing comment.

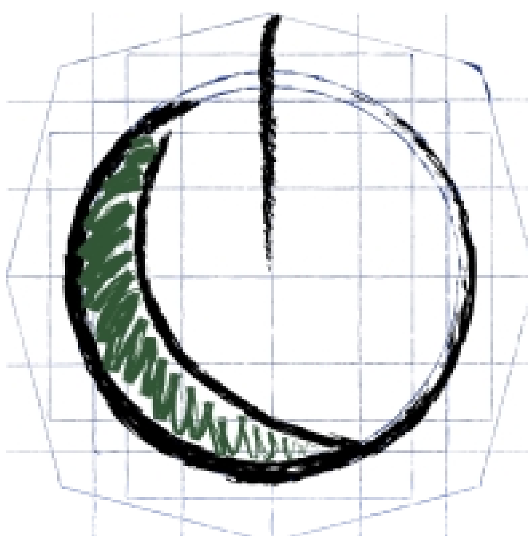


Figure 2. The Final Project Logo

In addition to developing the project content, we also engaged in a variety of outreach activities and methods to publicize the effort and results, get feedback, and collect contacts for marketing the results. These activities included showing posters, submitting papers to conferences, making individual phone calls, distributing brochures, and contacting media. As part of this, we created two project logos, the second of which is shown in Figure 2[2].

Because the project is essentially non-quantitative and involves what people see on products, the use of graphics and images was important. We collected several hundred images and dozens of product manuals (or at least those portions that mentioned the power controls). These are some of the raw data of the project — empirical evidence of existing control implementations. The images also evoke ideas and show how the same interface elements can be deployed in widely different ways on products.

A final activity was to determine where to deposit the Standard at the project's conclusion to assure its long-term maintenance and enhance its credibility — in other words, to find a "home" for the standard. Standards organizations are obvious places to consider for this, both national and international. We therefore contacted many standards organizations to determine the best location for the standard.

Much progress in energy efficiency has been accomplished through the use of mandatory standards, as in buildings and appliances. In contrast, experience with the office equipment part of the EPA ENERGY STAR program showed that the electronics industry was willing to work as a whole with outside actors to promote energy efficiency in a voluntary atmosphere. Neither approach is inherently better — it is only an empirical question as to which approach works best for a particular industry or end use at a given time.

Drawing on the lessons of ENERGY STAR, an important method for gaining the interest and support of industry in the process was to emphasize that the results were intended to be strictly voluntary. Avoiding a regulatory framework also suited the nature of the problem; while simple test instruments can objectively measure power levels, user interfaces can be difficult to test for strict compliance with a standard and inevitably get bogged down in minutiae. Finally, as electronic devices and applications evolve, there will be a need to experiment with better interfaces so that worthwhile and intentional innovation should not be stifled.

3.0 Project Outcomes

The major outcomes of the Power Management Controls project are described below, organized according to the project objectives to which they pertain. The details of the content of the standard are found in the appendices; this report focuses on the process.

3.1 Objective 1: Create the Interface Standard Development Plan

The purpose of the first phase of the project was to set the stage for the main research and development of the second phase — to build a solid foundation upon which to work. The foundation was both *content* — plans and anecdotal research — and *institutional* — assembling the PAC.

A first step was to conduct an "Institutional Review" (or "Who is involved in Power Management Controls" as we called it — [Nordman, 2000b]). This was a review of the context

[2] The final project logo--a combination of the standard grid for designing international graphic symbols, the power ("standby") symbol, our proposed new moon symbol, and the green color to indicate "on". All are done in a "sketchy" style to show that we are specifying a framework, not a precise implementation.

of the project and a summary of existing standards and standards committees (international and U.S.), trade associations, labeling programs, manufacturers, and multi-company technology initiatives and protocols. At this early stage it became apparent that graphical symbols were a key topic, and several key standards and committees were identified. Our research confirmed that no existing standard covered the entire power user interface and that our proposal is truly "new"; existing standards take only one aspect (e.g. symbols or indicators) and make no strong or detailed correlation to other standards. There are no U.S. standards that address power controls, with the exception of brief reiterations of international safety standards in U.S. safety standards. In Europe, there is considerable transnational trade within the region so that standards to ensure that this is possible and that national standards are not used as trade barriers. As such, the U.S. is less standards-oriented than is Europe. Since standards activities are more centered in Europe, and the U.S. has only a single vote on standards committees, compared to Europe standards are more often seen in the U.S. as a potential source of problems and less often as a venue for positive change.

Figure 3. The ENERGY STAR Logo

The premier worldwide energy-labeling program is ENERGY STAR (see the program logo in Figure 3). The Power Control User Interface Standard developed in this PIER project is already in the ENERGY STAR monitor specification for 2003 (as a voluntary component), and in the future it will be incorporated into specifications for other products seeking the ENERGY STAR label.

The ACPI (Advanced Configuration and Power Interface) PC interface specification and the VESA (Video Electronics Standards Association) display interface specifications provide critical plumbing for power management. These standards do not directly specify user interface elements, but the terminology of internal protocols is sometimes incorporated into user interfaces.

In summary, the Institutional Review laid out the context within which power controls exist and showed that there was no existing standard or convention occupying the space we intended to fill.

Before the first PAC (Professional Advisory Committee) meeting we investigated the question of intellectual property (IP). If any user interface elements or design principles that we considered as part of the standard were claimed as being owned by a company anywhere in the world, that would be a reason for companies to avoid using them and pose problems for establishing them in standards. Just a claim of IP can be a serious problem, even if it is not valid in the long run, so the research team steered clear of potential IP claims. We concluded that we were unlikely to run into existing claims of intellectual property (e.g. patents or trademarks) in our work due to the nature of the interface elements in question being so common and widespread.

The next aspect of this phase was assembling the PAC and conducting general outreach to industry. For outreach we drew heavily on LBNL's existing contacts with the IT and consumer electronics industries. We sought out contacts at companies that had a large market share, were seen as innovators, or both. In some cases, we found people who were not willing to serve on the PAC, or who did not fit the profile of people we were seeking for the PAC, but who were still interested in following the course of the project. We have built up an email list of such people over the course of the project.

In addition to manufacturers, we sought out representatives from two other organizations: ITIC and the EPA ENERGY STAR program. ITIC is the Information Technology Industry Council, a trade association[3]; including a representative from ITIC was intended to assure the organization (and by extension member companies) that the project is not a problem for industry, and could actually be a benefit. There were several reasons to include ENERGY STAR as part of the PAC and project generally. For one, the project should help the increase power management enabling rates and thereby increase ENERGY STAR savings. Secondly, the program could be of assistance in outreach and implementation. Finally, the terminology in the standard and in ENERGY STAR specifications can be harmonized, and ultimately the standard can be referenced in ENERGY STAR specifications.

A next step was to update the "Project Plan" (Nordman, 2000c) and then revise it based on the input of the PAC at the first meeting. The plan itself was modified only slightly, with an intended timeline added up front. The more important change was the development of the "Project Scope and Research Topics" (Nordman, 2000d). This document clarified the specific user interface (UI) elements of interest, their location, and the types of devices to address — primarily IT equipment but with some attention to consumer electronics. We also noted areas *not* to address, such as safety, internal mechanisms, and anything subject to intellectual property claims. Then we identified 22 separate topic areas that could be explored. It was clear that we would not necessarily cover all of them, but they mapped out the terrain that we might address. At the meeting, the PAC modified a few of the topics, then ranked them for both their relative priority and the level of effort they deserved. The final list of topics is shown in Table 3.

---

[3] While in principle supportive, trade associations have not expressed much interest in this project. Ironically, disinterest can be seen as a positive sign. Such associations are most likely to get involved when there is something that the industry wants to collectively oppose, so not attracting that type of attention is good. They also get involved when there are developments that may save the industry money or increase market share, and this project does not convincingly do either (though it probably will save support costs from reduced phone calls).

Table 3. Research Topic Names

Priority 1 Topics	Priority 2 Topics
Basic symbols and switches & buttons [L]	Disability [M]
Basic indicators [L]	Culture [S]
Changing power states [L]	Temporary changes [S]
Transition indicators [L]	System status after power failure [S]
Underlying archetype of power management behavior, including basic terms [L]	Terminology [S]
Controlled and controlling devices [L]	Miscellaneous [S]
Remote indicators and controls [L]	
Composite devices and diversity of low-power modes [L]	**Priority 3 Topics**
Power management 'schemes' [L]	Language [S]
Behavior based on wake event type [M]	Batteries [S]
Linked behavior [L]	Role of the term "ENERGY STAR" [S]
Interactions with non-power modes [S]	Self-monitoring [S]

Notes: [L], [M], and [S] denote large, medium, and small levels of effort. Priority 1 is most important.

The initial PAC meeting took place at LBNL on November 2, 2000. The companies on the PAC at that time were: Compaq, HP, IBM, Intel, Microsoft, Ricoh, Samsung, Sony, and Sun, in addition to ITIC and EPA[4].

The PAC reviewed the background material and project plans and then made some amendments to these. Background content prepared for that meeting included a poster describing the problem and the path ahead towards a solution, along with initial examples of existing interfaces. The PAC also carefully reviewed the Institutional Review at the meeting.

Having so many people fly to the November 2000 PAC meeting demonstrated strong industry support, and comments during the meeting confirmed this.

3.2 Objective 2: Conduct Research To Guide A New Standard Interface

One part of this objective was a review of the relevant literature. The project plan anticipated that the amount of existing literature that *directly* addressed the topic was small at best, and in fact, we found no studies that had the power control user interface as a primary topic. There are two types of literature that we did find and report on. A few studies address power controls in passing in some other context; we report on these in discussions where they are specifically relevant. For example, a study on copier symbol recognition included only one power symbol among several dozen copier-related symbols.

The other type of literature that we surveyed was that on user interface design generally. The resulting "Insights from User Interface Literature" (Nordman, 2001, and updated as Appendix

[4] Nearly all representatives were able to attend. In 2002, Dell joined the PAC.

II) was organized into sections that addressed: Bolstering the Rationale for This Project, Relation to Past Designs, Approach, Design Principles, Metaphor, Modes, Interaction / Transitions, Indicator Lights, Icons, and A Cautionary Tale (about Don Norman's experience with trying to standardize power controls within one company for one type of device — Apple Macintosh computers). The results confirmed assumptions underlying the project, clarified and deepened others, and pointed to issues that we had not previously considered. There is an increasing cadre of IT professionals who see their primary job as "usability" — optimizing products for the user — of which this project is a clear example.

The majority of literature and effort on the topic of usability and good design is intended for people who are designing *all* aspects of a *single* device. However, we are trying to design a *few aspects* of a *wide range* of devices. This makes the basic problem(s) to be solved, and hence data and approaches, quite different — though general principles of good design apply equally as well. Also by contrast, the literature is oriented to more complex interactions (e.g. web site navigation) rather than the more simple and dispersed interaction that people have with power controls.

Explaining this project to others in just a few words has been a challenge from the beginning. We drew upon familiar user interface examples in which standardization has played an important role. An effective example is the touch telephone keypad. We interviewed one of the people on the committee that created the "*" and "#" keys, shortly after the basic arrangement of the 10 digits was established. While the other parts of telephone keypads are not particularly standardized (and neither is the actual meaning of "*" and "#"), the 12 core keys are essentially universal[5]. Traffic signal lights are another good example. There is a vocabulary of meanings that can be adapted to a wide variety of situations (varying color, position, shape, and flashing). While signal lights are not all identical, figuring out what each set does mean is generally easy to do. A final example is automobile gear shifts, in which the basic labeling and structure of the shifting is consistent from vehicle to vehicle even though the number of gears, location of reverse, and physical design details can vary.

The history of the generation of each of these standard interfaces differs; however, once a critical mass was reached, there was great incentive for companies to adhere to that standard. Attaining that critical mass is the goal of the effort of which this research project is a first step.

For field research, we relied on a variety of methods. The single most critical of these was *reviewing owner's manuals* of a wide variety of products for the power control features present and the way they are labeled and explained. An increasing portion of companies makes operation manuals available on the Internet for new products. The PAC specified that the great majority of our effort should be for new products, so the typical lack of on-line information about older models was not a problem. Owner's manuals usually itemize the hardware features present, their behavior, special conditions, and specify the name given to a feature such

[5] When the "*" and "#" keys were created in the mid-1960s, AT&T was a regulated monopoly and prohibited from being involved in the *content* of telephone calls; it could only provide dialing and connection services. So any usage intended for these keys by AT&T had to be restricted to dialing issues. The people who created the "*" and "#" keys understood that their greatest use would be during calls, not during dialing and making connections, and history has shown them to be correct. To this day, there are no consistent meanings for the two keys, so voicemail and other systems are routinely inconsistent in their usage of them.

as a "power button" (as opposed to an "on / off switch"). Some of the information in the manual could be difficult to discover by inspection, such as that it is necessary to hold down a button for a specific time period for the function to occur and the effect of error conditions. There are limitations, such as that some manuals don't specify the color of indicator lights or noise or other feedback that occurs during operation. The way that features are explained can be significant, such as PC manuals that say "Your computer has a *sleep* mode and it is called '**standby,**'" (emphasis added) which makes clear that the writer thinks that *sleep* is a clearer concept than is *standby*. Owner's manuals also usually show screenshots of key software control panels.

The other major approach was *direct inspection of devices*, finding devices in homes and offices, at tradeshows, and in stores. The latter two methods were helpful for reducing the number of "old" devices seen and getting a general sense of the relative market share of different interface elements. Direct inspection also allowed photographing selected elements, which is helpful in note taking and for later use in posters, brochures, etc. In most circumstances, however, it is difficult or impossible to identify the full range of interface elements and behavior that an owner's manual shows, though there are occasional behaviors or other relevant attributes (e.g. that the yellow and green colors used on a particular device's power indicator are not especially distinct, even to someone with full color vision) that aren't described in the manual.

An important result of direct inspection (and, to a lesser degree, our inspection of owner's manuals) is the collection of a *photo library* of elements of interfaces and interface elements. We collected literally hundreds of digital photos that we organized and cropped. These were invaluable in reviewing interface element usage and in preparing presentation slides, posters, brochures, and written discussions.

Some types of data gathering were less successful. We attempted to gain access to those portions of *corporate design guidelines* that address power controls. Several people (PAC members and others) said that such documents exist, but none were able to produce them for our viewing (and apparently in some cases they are not in English). Some power control design decisions are driven by safety guidelines from Underwriter's Laboratories (UL) and international standards, but these are not company-specific.

Sometimes PAC members and others would refer to internally conducted *usability studies* that helped determine design choices. None of these studies were provided to us, though when pressed it was often revealed that they consisted of showing several design options to a dozen or so co-workers. These types of small, local usability studies can be valuable, but industry seems to try to create the impression that more testing and more comprehensive testing is done than usually seems to be the case.

One of the original intents of the project was to conduct *structured interviews* with product designers about the various design choices made. We ultimately conducted *un*structured interviews, engaging the interviewees in conversation to elicit the issues and details that they saw as important. We did not use a common structure for discussions with product designers for several reasons:

- We rarely were able to get in contact with the people who made the specific design decisions of interest to us (manufacturers were reluctant to provide names);

- Many design decisions are made in other countries, and it is particularly difficult to pose questions to company personnel in Asia;
- Design decisions about the power user interface seem to be diffuse (no point at which the various elements were considered together);
- Mundane factors such as inertia from previous products or simply using symbols observed on other products in designers' offices were the most common explanations we were given for why specific interface elements were used.

In retrospect, social science theory suggests that unstructured interviews are actually more appropriate in this case. Any structure we used would impose a pattern on people's thinking and an organizational structure that simply does not exist, so our results would be heavily tainted by the particular questions and structure chosen and miss details that didn't fit the pattern.

Our research showed that the interface elements often vary among products from the same company, even within the same type of product (e.g. among PCs, or among printers). For example, power symbols often change from model to model. A major printer manufacturer has placed the power controls in different "menus" on different models. A non-power example is the assignment of functions to "F" or "Fn" keys at the top of computer keyboards, such as those for switching among video output destinations, varies widely even among products from the same manufacturer. The obvious lack of attention to consistency in power controls may have caused manufacturers to be reluctant or unable to talk about the underlying decision-making (or lack of it).

A development in recent years that has been helpful to this project is the rise of "usability" professionals — people whose primary job responsibility is to assess what it is about current or future products that are difficult for people to use and how to change the designs to make them easier. In the case of web pages, the goal is to keep people at a web site and make sure they are not impeded from making a purchase (or whatever the company's goal is). Particularly for hardware suppliers, a concern is to reduce consumer calls to customer support lines. These can easily mount to more than the per-unit margin that a company makes on the sale, so companies are particularly sensitive to them. Products with better user experiences also can improve a company's image and aid future sales. We have found usability experts to be good contacts at organizations as they readily grasp the importance of standardizing the power interface, and are not burdened by too much knowledge of internal implementations that impedes clear thinking about how users actually perceive products.

Anecdotes from manufacturers and ordinary people were a notably helpful type of data to obtain and generally occurred during free-form conversation about power controls. For example, a PC manufacturer representative noted that feedback had been received about consumer confusion over computers with multiple sleep states that had different wake events depending on the sleep state (e.g., in light sleep keyboard or mouse activity would wake it but in deep sleep only the power button would). This would cause people who successfully used the lighter sleep to then assume the machine was broken when confronted with the deeper sleep state that didn't wake from the action that worked earlier. This helped to cement the importance of the principle that within a power state, capabilities and behavior should be consistent. Similarly, we often introduced people to the topic by pointing to or describing the ⏻ symbol at which point a response of “oh, the power symbol” was most common.

We conducted *detailed research* on several topic areas that seemed important. The specifics are described in the Appendices, but examples of these are: The “hibernate” mode, the crescent moon and Islam, selected internal power control mechanisms (principally ACPI), industry specifications (e.g. PC Design Guides), color deficiency, and accessibility in general. Smaller inquiries were made into portable electronic device (PEDs) on airplanes and popular (non-power) usage of symbols.

Delving into *standards* was a major research activity. Most standards are offered for sale rather than being available free on the web, and the University of California library system has very few international standards in its holdings. It is difficult to know which standards might have relevant discussion in them, and there is a labyrinthine network of committees, subcommittees, working groups, national standards organizations, industry standards organizations, and draft and final standards. Also, it is key to know which are commonly observed and which are routinely ignored. Much of this can only be navigated by personal contact, usually by phone or email. Appendix V is a summary of relevant standards and committees.

Much of this project’s research consisted of bringing together information from widely disparate sources into a common framework to reveal or clarify some issue. In several cases we produced new data. One example is the discussion of the “hibernate” state as implemented in a variety of computer systems, including Windows® PCs. It seems clear that the industry has not thought through the issues involved in the detailed and comprehensive way that we did.

Some pursuits came up largely empty. With a few exceptions, accessibility was an example of this. Many people and policies assert the importance of designing products to be accessible to the widest range of users possible. We contacted many people whose primary job function is accessibility and, when pressed for suggestions on how this could be accomplished for power controls, we got a quite limited response. What we did come up with is parts of the dynamic behavior portion of the standard.

3.3 Objective 3: Develop And Test Proposed Interface Standards

Key principles in the standards development process were to identify interface elements that were *common*, and those that were *clear* (and clarity often requires simplicity). This was tempered by the content of existing standards to form our initial proposals. These were then released for comment by the PAC and other industry contacts and revised. The key parts of the standard were subject to several rounds of testing and ultimately formalized in the IEEE standard format.

3.3.1 Developing The Interface Standard

The standard was released for comment in two phases: the first covered the *hard* or *static* parts of the interface, and the second, the *dynamic behavior* of devices. The static part included five initial principles and the groundwork for a sixth (on hibernate). The dynamic behavior portion started with nine principles, one of which was dropped based on PAC input. The critical aspect of the standard as developed is that it all works together as a whole — in stark contrast to existing standards, which treat each interface element (e.g. symbols or indicators) in isolation.

The insights gained from our review of the user interface literature generally were an important factor in shaping the standard development. Another factor was the consideration of a wide variety of devices and applications, a key difference from conventional product design. One example is how to code power states on indicators: with colors or flashing (for *sleep*). Flashing can only be used with displays or lights but cannot serve as a coding in a static way, such as the background color on a shutdown dialog box on a PC or on a mechanical switch. Also, while it might be acceptable for a single device (e.g. a PC) to flash in *sleep*, if all devices did this a future household might have dozens of devices in it, each blinking in its own way and causing great distraction. Another example is the distinction between the ⏻ and ⏼ symbols for whether the device consumes zero or non-zero power in *off*. While this can be determined reliably on many devices, it can vary for those that can utilize batteries (which may or may not be present at any given time), and it can be problematic for use in operating systems (in which the software may be unable to know if *off* is zero power or not and therefore be unable to show the proper symbol). A third example is extensibility: the use of the sleep metaphor allows for gradations (e.g. *light sleep* or *deep sleep*) for those products that may have more than one low-power mode, and for convenient phraseology, e.g. "wake up." This is in contrast to other terms used such as "standby" or "energy-save" that lack both of these attributes. Internationalization is a fourth case, though one more commonly dealt with by existing manufacturers, particularly of IT equipment.

We were also cognizant of areas in which it was not feasible to extend the standard. One example was the specific capabilities that one can expect in the *sleep* and *off* modes. There was significant diversity among products in these modes, and neither mandating capabilities nor disallowing them is a reasonable option. Some devices can be turned on over a network connection and others can't. Some can wake on keyboard input, and others require pressing the power button to wake up. We also were careful to avoid tying the user power states to particular power levels, even for *off*[6]. There is too much variety in devices, their requirements, and the trajectories of future technologies to burden long-lasting user interface conventions with specific quantities. Also, there are already good methods for doing this, such as purchasing mandates (e.g. for standby power), mandatory standards, and voluntary labeling (e.g. ENERGY STAR).

While we tried to stay away from internal mechanisms for controlling power status, in the case of ACPI it was necessary to address some of its detail, since it impacted the discussion of hibernate. It is best if internal systems are not encumbered by the user interface and vice-versa, though consistency in terminology and principles can help avoid conflicts.

It is well known that symbols, colors, and other aspects of user interfaces can be significant in specific cultures. We were attentive to this in the entire process, but it became a major concern only in the case of the crescent moon and Islam. We studied the issue in depth and ultimately concluded that it did not present a problem if a few guidelines were observed in order not to make crescent moons look too Islamic.

---

[6] It may seem desirable for the user interface to communicate the difference between zero-power and non-zero-power off-states, but doing so consistently makes the interface that much more complicated and generally would not affect how people operate a device. It also would not indicate how much different from zero any non-zero *off* power state is, so people would not have a rational basis by which to decide if it was significant or not.

The topics that raised the most disagreement among PAC members were indicator colors and how to treat the “hibernate” state. For indicators, there was concern about using color as the only coding mechanism for power state and so instead use flashing for sleep states. We had conducted research showing that color ambiguity can be mitigated and flashing calls attention to itself so the PAC consensus supported the use of colored, non-flashing lights. For hibernate, there remain some individuals within the industry who have difficulty adopting the specification that hibernate is a form of *off*, but the great majority of people do accept this.

3.3.2 Testing The Interface Standard

There were four separate testing exercises conducted for this project — two at UC Berkeley, one at Cornell University, and one at LBNL itself. All focused primarily on the static part of the standard, though questions about power button behavior and flashing indicators helped inform some of the dynamic behavior specifications. The goal was to determine if the proposed standard was as compelling to ordinary people as the rationale behind suggested it ought to be. The *content* of the test results is reviewed in Appendix VII; here, we consider only the *process.*

All of the tests included both explorations — looking for associations and inclinations — and validation — checking to see that the draft standard was consistent with user expectations, or at least not in conflict with them. Table 4 summarizes key information about the tests. In each of the tests, subjects were asked about the meaning of symbols and indicators, and the first three asked about what actions the user would take to cause a specific action to occur.

Table 4. Testing Summary

	UCB1	UCB2	Cornell	LBNL
Respondents	37	12	105	36
Questions	27	43	33	11
Power Symbols	X	X	X	X
Indicators	X	—	X	X
Sleep Associations	X	—	X	—
Use of Sleep Modes	X	—	X	—
Changing States	X	X	X	—
Assessing State	X	—	—	—

The UCB testing provided some practice in what questions to ask and in user reaction that provided useful results and insight as to how subsequent testing should be conducted. The Cornell tests were similar, though they were conducted based on the UCB study plan rather than on direct work with LBNL. The LBNL testing followed the procedure outlined in the project plan, beginning with a plan to be presented to the PAC, a revised plan based on PAC input, the actual test, and a report summarizing the process and results. The earlier studies were beneficial in helping to improve and focus the LBNL test. Readers are encouraged to view the UCB reports directly[7].

3.3.3 Adopting the Interface Standard

There are two basic aspects to standards development for this project: the *content* to be embodied as a standard and the *process* and *ultimate destination* for the content.

The content was developed in two parts, but they have been combined into one final document in Attachment I. Standards are traditionally crisp presentations of content with little background or rationale for the choices made in developing them. Part of the reason for omitting the rationale is to facilitate compromises and papering-over of differences among countries, but it seems an unwise way to do business when standards are voluntary or need to be revised or extended. We believe that recording the rationale is vital, at least for this standard, and we present that in Appendix I.

For process and destination, it has to be borne in mind that the standards universe and the real world of products and manufacturers evolve in parallel, only intersecting periodically. Standards proceed slowly, particularly in cases like this that do not make or break products (unlike for example communications protocols such as IEEE 802.11). We do not want any manufacturer to wait until standards processes have finished before implementing the user interface standard, and in fact the use of the standard in products is likely to accelerate the standards process. On the other hand, establishment as an official standard does provide credibility and a mechanism for distributing and updating the content, and the fact of working towards a standard should accomplish some of this. So, it is essential to work along both tracks in parallel.

A logical ultimate home for the user interface standard is the IEC (International Electrotechnical Commission) as this is where the most relevant existing standards reside. However, there is no committee within the IEC that clearly has a mandate to pursue our scope. Thus, immediate progress through the IEC is not plausible. We have been attempting to engage the relevant committees for symbols, but this has been stymied because the U.S. is not a member of the most critical committee (IEC SC 3C). We have yet to identify a committee with U.S. membership that has the ability, mandate, and interest to forward our proposal. Late in the process we concluded that it might be best to separate the two proposals (creating a moon symbol — ☾ — for "sleep" (see Figure 4) and changing the definition of the "standby" symbol — ⏻ — to mean "power"). The sleep symbol is self-contained, and does not directly undermine the historic symbols and their definitions, and so should not be controversial. The change to the ⏻ symbol is likely to bring to the surface lingering disagreements about how it should be defined and used, and it could be interpreted as a criticism of the existing symbols. Thus, it could be controversial and, at a minimum, take longer to gain consensus for.

The near-term opportunity is through IEEE (the Institute for Electrical and Electronic Engineers). IEEE provides a mechanism that is tractable in access (we already have a working

---

[7] http://www.sims.berkeley.edu/courses/is271/f01/projects/PowerControls/

group created for this standard), geography (no international meetings required), and process (we only need to seek out a domestic balloting community to succeed rather than convince disinterested members of other countries' international standards committees). While the user interface standard is intended to be global, we can expect to have greater initial success with U.S.-based companies for whom IEEE is a more respected standards organization and the IEC is seen as more marginal. Non-U.S. companies typically pay more attention to IEC standards. Furthermore, just recently (November, 2002), the IEEE and IEC came to an agreement about putting a dual logo on key IEEE standards, so that transition of content from IEEE to IEC should be easier in future.

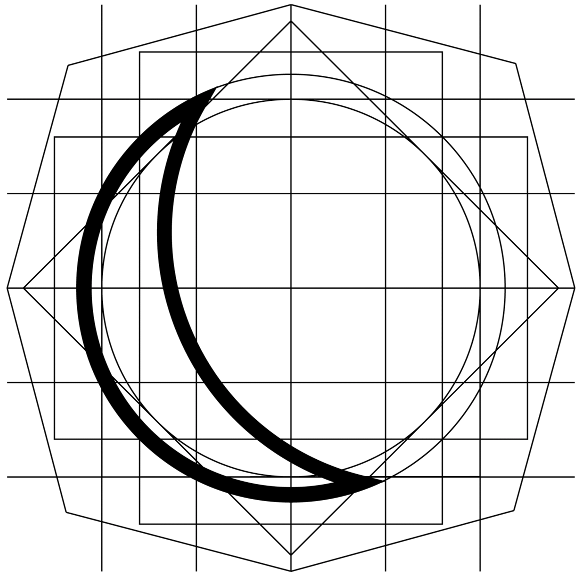


Figure 4. The proposed "Sleep" symbol

Part of developing a new standard is to be comprehensive in identifying relevant existing standards, to refer to, use definitions from, build on, and (as necessary) propose changes. In this process we have found existing standards and ones currently in development that address user interface elements specifically, interface design generally, or topics such as energy test procedures whose terminology could be harmonized with our standard.

Another aspect of standardization is multi-company industry plans and protocols (or actions of a single company, such as Microsoft), is that it can affect the products of many other companies through the operating system. We have attempted to influence these to be compatible with and support the user interface standard. The standard is already included as a voluntary component of the ENERGY STAR monitor specification for 2003, and is to be incorporated into other ENERGY STAR product specifications as they are revised. This is included as "strongly recommended" — not required — consistent with the project premise that a voluntary standard will attract more industry cooperation than a mandatory one. The plan is for EPA to include this in all future electronics specifications as they come up for revision. The Swedish labeling organization (TCO) intends to harmonize many of their specifications with ENERGY STAR and so should incorporate the standard into their specifications. Several companies have indicated that they are using the indicator standard for future products but are reluctant to be explicit until the products are released.

In the course of the project we came across a standard in development for "service indicators" for IT equipment (VITA, 2002). At first glance it appeared that the scope and usage of this standard would conflict with our standard. However, we determined that because of the intended application (data centers and telecommunications facilities) and specific indications and symbols there was no actual conflict. We were able to assist the developers of that standard and ensure that it was not amended to conflict with ours.

The ACPI specification is already consistent with the standard except in how it presents the Hibernate state. Future VESA (Video Electronics Standards Association) standards may be able to incorporate elements of the standard; we are monitoring this. Intel sponsors a web site called

Formfactors.org, which provides standard chassis specifications for the reference of manufacturers. Future specifications could reference the user interface standard. Microsoft included a paper by Bruce Nordman (Nordman, 2002b) in its 2002 WinHEC (Windows Hardware Engineering Conference) and could include the user interface standard (or parts of it) in future white papers by Microsoft employees.

3.4 The User Interface Standard Content

Key elements of the User Interface Standard — the static interface — are to:

Use only three power states when possible: On, Off, and Sleep.

Use the word "Power" for terminology about power.

- Redefine the ⏻ symbol to mean "power" as for power buttons and power indicators; use the ⏼ symbol (on / off) only when necessary.
- Use the "sleep" metaphor for entering, being in, and coming out of low-power states; use the moon symbol — ☾ —for *sleep*.
- Adopt "green / amber[8] / off" color indications for power state indicators.
- Present computer "hibernate" modes as a form of *off*.

For the "dynamic behavior" of devices, the standard specifies:

- Use "power up" to mean turn on or wake up, and "power down" for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green / amber can be used to mean error if red is not available.
- Power buttons should toggle between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.

Usually, when a device is *asleep* the input causing a wake event should be discarded. Attachment I presents the content of the standard in more detail and Appendix I reviews details of the background and rationale for the choices made in developing the Standard.

3.5 Technology Transfer

While much of this project was traditional research and development, a key part of it was introducing and "marketing" the concept and results to the target industries. This involved creating the marketing materials and bringing them to individuals, groups, and organizations. It was important to do this early so that organizations knew they were consulted and had the opportunity to comment — even if they ultimately didn't end up having substantive feedback.

[8] For purposes of power controls, the terms "amber," "yellow" and "orange" are taken as synonymous.

The industry plans and protocols discussed throughout the report are examples of institutions we have been working on influencing. Other avenues are described in the following paragraphs.

We presented the project to the PC Ease of Use Roundtable[9] three times in the course of the project (April, 2000; August 2001; and June 2002). This is an opportunity to reach many PC manufacturers at once, and the very goal of that group is the means we seek to achieve our energy savings objective. In fact, prior to our project they were beginning to work on power management, but deferred their own efforts to this project.

We took the poster to the IBM Make IT Easy conference twice (June, 2001; June, 2002), and to the 2000 ACEEE Summer Study on Energy Efficiency in Buildings (August, 2000).

Presentations were made at LBNL (December, 2001), the VESA annual conference (April, 2002), an ENERGY STAR meeting on revising the monitor specifications (April, 2002), to an innovative product design company (Lunar of San Francisco in April, 2002), at the Commission's workshop on standby power (August, 2002), to a U.S. standards committee (IEC TC 108 TAG in October, 2002), and at the 2002 ACEEE Summer Study on Energy Efficiency in Buildings (August, 2002). Brochures were sent to several conferences. Finally, the most important mechanism for outreach has been the telephone, supplemented by email; hundreds of calls have been made to spread the word.

Articles on the project have appeared in MIT's TechnologyReview.com (June, 2002) and in the Ease of Use Roundtable Newsletter (October, 2002).

Outreach materials we produced in the course of the project include two posters (and sub posters to accompany them), two brochures, and a series of Powerpoint® presentations, all of which are on the project web site. The web site itself is an important part of outreach, and it has received the compliments of many in its visual design. The web site will be similarly important in the steps ahead.

While the main effort of this project was making the case for the merit of and need for the standard, and details required for the development process, manufacturers have been asking for more simple and concise summaries of how to implement the standard in future products.

Finally, the standards development process is a core part of dissemination.

[9] The Ease of Use Roundtable meets about six times a year to work on issues that impede user purchasing of PCs and causes support and other costs to manufacturers that may be alleviated by making PCs easier to use. http://www.eouroundtable.com/.

4.0 Conclusions and Recommendations

The major conclusions and recommendations of the Power Management Controls project are presented below.

4.1 Major Conclusions

This project made significant progress towards a future with consistent and clear power user interfaces for electronic devices, one with much greater savings from power management. Our development of the Power Control User Interface Standard shows that a core foundation for power controls can be established and that it is necessary to work with all interface elements together across diverse device types to form a coherent interface.

The division of the standard into static and dynamic portions was helpful in organizing the research and presentation.

It is clear that no previous attempts had been made in this area, and therefore it was important for that vacuum to be filled. It is also clear that the relevant industries were not sufficiently motivated by the topic to address it on their own. However, we are optimistic that the standard has and will continue to gain adherents and proponents. A solid foundation has been designed; it now needs to be implemented in further work and, later, extended and deepened.

This project also demonstrates the importance of user interfaces that affect energy use and that improving them is a viable energy-saving strategy. This has implications of other aspects of energy use that are or will increasingly be influenced by user interfaces. These include space conditioning, lighting (as it becomes more electronic and networked), appliances, and real time pricing.

Past Commission work with standards has been mandatory and focused on buildings constructed (Title 24) or equipment to be sold (e.g. appliances) in California. This project demonstrates that for *some* end uses, voluntary standards and a national and even international focus are appropriate. California is significantly affected by international trends (such as standards) and in turn the state can have an impact on international products and energy use.

4.2 Commercialization Potential

In the context of this project, "commercialization" means incorporation of the standard into products sold to consumers. Many products already comply with the standard in part, and some do entirely (particularly some simple ones). There is no technical barrier to commercializing the standard; the barriers are inertia and lack of attention to the topic. The potential is nearly 100% of the market in the long run. In between, product model lines need to be turned over (manufacturers will not change this aspect of the user interface of an existing model), and some internal technical implementation issues need to be solved (specifically, transition indicators for PCs). The Power Management Controls project has been a success in setting the stage for commercialization.

4.3 Benefits To California

The energy quantification of the potential savings from more use of power management was conducted prior to the project initiation, but for a variety of reasons future potential savings will be even larger. Based on the results to date, the technology developed under the Power

Management Controls project appears very likely to generate substantial economic and environmental benefits to California ratepayers in the years to come.

If all U.S. office equipment in 2000 that had power management capability had been optimally utilized, an estimated $1.3 billion per year of direct electricity could have been saved (Kawamoto et al, 2000). Improved controls will not save all of this because there are other reasons why power management is not always utilized. However, with modest assumptions about savings the project may attain, California's share of savings from the standard could easily be $100 million / year. For a variety of reasons cited in the background section, the power management opportunity — and so savings from the User Interface Standard — can be expected to grow.

4.4 Recommendations

Recommendations for future action are organized below.

- Recommended LBNL Actions:
  - Continue to host the Power Management Controls web site.
  - Pursue other research projects that bring user interface issues to energy consumption and savings.
- Recommended Commission Actions
  - Support finalizing and implementing the Standard via outreach and IEEE.
  - Explore other areas for user interface improvement and standardization related to energy consumption such as lighting, space conditioning, and real-time pricing.
  - Consider human interface elements in future mandatory efficiency standards.
- Recommended Actions by Others
  - ENERGY STAR should continue to incorporate the standard into future specifications.
  - Manufacturers of IT equipment, consumer electronics, and other electronic devices should design their products in accordance with the standard.

5.0 Glossary

ACPI	Advanced Configuration and Power Interface — A specification of the interface among a PC operating system, BIOS (Basic Input – Output System), hardware, and other system devices. http://www.acpi.info
CEC	California Energy Commission — A state of California agency.
Enabling rate	The portion of devices that have their power management features turned on.
ENERGY STAR	A product-labeling program run by the U.S. Environmental Protection Agency and U.S. Department of Energy.
IEC	International Electrotechnical Commission — An international standards organization oriented to electrical and electronic products and applications. http://www.iec.ch
IEEE	Institute for Electrical and Electronic Engineers — A membership organization of professionals in the electrical and electronic fields, one of whose functions is the development of standards. http:/ieee.org
IP	Intellectual Property — such as patents, trademarks, etc.
ISO	International Organization for Standardization — An international standards organization with a broad mandate. http://www.iso.ch
IT	Information Technology — Office equipment such as computers, printers, etc.
ITIC	Information Technology Industry Council — A trade association of leading companies in the IT field. http://www.itic.org
LBNL	Lawrence Berkeley National Laboratory — A U.S. Department of Energy National Laboratory in Berkeley, CA. http://www.lbl.gov
PAC	Professional Advisory Committee — A group of people, mostly from IT and CE companies, who review project results and periodically meet to discuss and approve them.
PED	Portable Electronic Device — A consumer device on an airplane that could theoretically produce radio frequency emissions that might interfere with airplane navigation.

PIER	Public Interest Energy Research — A research program of the CEC.
Power Control User Interface	The combination of manual and automatic controls and indications of power status. It includes terms, symbols, colors, operating metaphors, and the behavior of the device in response to input and over time.
TCO	A Swedish trade union organization that runs a labeling program similar to ENERGY STAR, but with added ergonomic and environmental requirements.
UL	Underwriters Laboratories — "an independent, not-for-profit product safety testing and certification organization" (from the ul.com web site)
User Interface	The mechanisms by which an electronic device communicates with a user to provide status information and control capability. It can include both hardware and software.
WinHEC	Windows Hardware Engineering Conference — An annual meeting sponsored by Microsoft to explain company initiatives related to the Windows platform and get feedback from manufacturers.

6.0 References

References below are listed in two categories:

1. Materials published in the general literature
2. Materials published on the project web site (*http://eetd.LBL.gov/Controls*).

Materials Published In The General Literature

Compaq, Intel, Microsoft, Phoenix Tech., and Toshiba. 2000. Advanced Configuration and Power Interface Specification: Revision 2.0. [http://www.acpi.info]. 2000.

IEC 1998. Graphical symbols for use on equipment. IEC 60417. First Edition, Geneva, Switzerland: International Electrotechnical Commission. Part 1: Overview and application; Part 2: Symbol originals. 1998.

ISO/IEC 2000. Collective Standard: Graphical symbols for office equipment. ISO/IEC 13251. First Edition, Geneva, Switzerland: International Organization for Standardization and International Electrotechnical Commission. 2000.

ISO 1989. Graphical symbols for use on equipment: Index and synopsis. ISO 7000. Second Edition, Geneva, Switzerland: International Organization for Standardization. 1989.

Kawamoto, Kaoru, Jonathan Koomey, Bruce Nordman, Richard E. Brown, Maryann Piette, and Alan Meier. 2000. Electricity Used by Office Equipment and Network Equipment in the U.S. Published in the Proceedings of the 2000 ACEEE Summer Study on Energy Efficiency in Buildings. Washington, D.C.: American Council for an Energy-Efficient Economy. 2000.

Kawamoto, Kaoru, Jonathan G. Koomey, Michael Ting, Bruce Nordman, Richard E. Brown, Mary Ann Piette, and Alan Meier. 2001. Electricity used by office equipment and network equipment in the U.S.: Detailed report and appendices. LBNL-45917. Berkeley, CA: Lawrence Berkeley National Laboratory. 2001

Kawamoto, Kaoru and Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier. 2002. Electricity used by office equipment and network equipment in the US. *Energy—the International Journal*. vol. 27, no. 3, pp. 255-269. March, 2002.

Nordman, Bruce, Alan Meier, and Mary Ann Piette. 2000. "PC and Monitor Night Status: Power Management Enabling and Manual Turn-off." In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy, 2000a.

Nordman, Bruce, Alan Meier and Don Aumann, "Fixing the Power Management Controls Problem", 2002 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C.: American Council for an Energy-Efficient Economy, 2002a

Roberson, Judy A., Gregory K. Homan, Akshay Mahajan, Bruce Nordman, Carrie A. Webber, Richard E. Brown, Marla McWhinney, and Jonathan G. Koomey, "Energy Use and Power

Levels in New Monitors and Personal Computers", LBNL-48581, Berkeley, CA: Lawrence Berkeley National Laboratory, 2002.

Rosen, Karen, Alan Meier, and Stefan Zanelin. 2000. "National Energy Use of Consumer Electronics in 1999" *In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings*, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy.

VITA, 2002, 40-2002: Service Indicators, VITA Standards Organization, Fountain Hills, AZ.

Webber, Carrie A., Judy A. Roberson, Richard E. Brown, Christopher T. Payne, Bruce Nordman, and Jonathan G. Koomey. 2001. *Field Surveys of Office Equipment Operating Pattern*s. LBNL-46930. Berkeley, Calif.: Lawrence Berkeley National Laboratory. 2001.

Materials Published on the Project Web Site

(Intermediate documents produced during the course of this project; all by Bruce Nordman unless otherwise noted, and all available at: [http://eetd.LBL.gov/Controls]).

The Standard

"Dynamic Behavior", August, 2002.

"Toward a Standard User Interface for Power Controls", April, 2002 included in the conference papers for the Microsoft Windows Hardware Engineering Conference (WinHEC) and available at the WinHEC Conference web site. [http://www.microsoft.com/winhec/], 2002b.

"Tentative Recommendations", July, 2001.

"Designing the new Moon Symbol" and a precise drawing, June, 2002

Other Results

"The Power Control User Interface Standard: Fall 2002 Testing Results and Conclusions", October, 2002; also the slide sets used in the testing process (September, 2002).

"Power Switch Labeling - for Medical and Other Devices", November, 2002.

"Insights from User Interface Literature", July, 2001. 2001a.

"Who is involved in Power Management Controls?", December, 2000, the "Institutional Review", 2000b.

"Sleep, the Crescent Moon, and Islam", May, 2002.

Testing

"User Perceptions of Power Controls, Icons and Power States" by Jonathan Puleio and Jenna Shanis, Cornell University, 2002.

"Testing the User Interface Standard: UCB Survey Results", May, 2002.

"On, Off, or Asleep?: User Perceptions of Power Controls on Common Office Equipment" by Azeen Chamarbagwala, Phoebe Kuan-Ting Liu, Craig Rixford, Mary Trombley, and Bin Xin, SIMS, University of California, Berkeley, October, 2002.

"Power Controls -- Form and Function: Mapping the User's Mental Model", Craig Rixford and Azeen Chamarbagwala, SIMS, University of California, Berkeley, December, 2002.

"Instructions for Powering your PC", June, 2001.

"Hibernate", September, 2002.

"Industry (PAC) Comments on UI Standards Recommendations", May, 2002.

"Project Questions", January, 2002.

"Field Testing the User Interface Standard", May, 2002.

Project Plans

"Project Scope and Research Topics", December, 2001, 2000d.

"Project Timeline", December, 2001.

"Updated Project Plan", December, 2001, 2000c.

Agendas and meeting summaries for each Professional Advisory Committee (PAC) Meetings.

7.0 Attachment I: Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments

IEEE P1621

December 15, 2002

Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments

Sponsored by the
Microprocessor Standards Committee
of the
IEEE Computer Society

Introduction

(This introduction is not part of IEEE P1621, Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments.)

The electronics industry has been proactive in including product features that reduce power levels when possible to save energy, and extend battery life. Much of this has been accomplished through industry work with the U.S. EPA ENERGY STAR program, and globally, billions of dollars of electricity are saved each year through the use of power management[1]. Despite this success, many devices that are capable of power management are not saving energy because the power management features are disabled, incorrectly configured, or thwarted by a hardware or software conflicts[2]. For PCs, the great majority are not power-managing. For monitors, printers, and copiers, the rates are above 50%, but significant improvement is still possible. Thus, there is the potential for considerable additional savings through higher enabling rates in power management. In addition, there are a variety of reasons to expect that the opportunity for energy savings from power management will only increase in coming years, such as more devices and device types that can power manage, greater number of hours these devices are wanted to be available, and greater difference between on and sleep states.

The goal of this standard[3] is to capture energy savings by increasing the rate at which power management features are enabled and operate successfully. This standard should lead to other benefits such as improved ease of use and reduced burden of customer support on manufacturers.

At present, power management controls in office equipment and other electronic devices show little consistency in the terms, symbols, and indicators used and in their overall structure. This is particularly true across device types (e.g. between a PC and a copier), but often holds even within the same type of device. For example, the standby mode on some copiers refers to the state when they are fully on and immediately ready to act, but the standby mode on some computers and monitors refers to a low-power mode in which they have reduced capability and take time to recover. “Standby power” also is used for a device’s minimum power state, which is often when it is off. The combination of controls and indications of power status is the user interface.

The confusion and ambiguity of so many power controls precludes many people from being able to understand power controls and power status. The problematic interfaces further deter these people and others from attempting to change power management settings or successfully doing so.

This standard is intended to accomplish a broad similarity of experience of power controls of any electronic device that is used in a normal work or home environment. It is intended to do this through voluntary means. It is not intended to stifle innovation in user interfaces, nor preclude deviations from the standard where clearly warranted.

The first draft of this standard is based on research conducted at Lawrence Berkeley National Laboratory, and funded by the Public Interest Energy Research (PIER) program of the California Energy Commission.

---

1 Kawamoto, Kaoru and Jonathan G. Koomey, Bruce Nordman, Richard E. Brown, Mary Ann Piette, Michael Ting, and Alan K. Meier. 2002. Electricity used by office equipment and network equipment in the US. *Energy—the International Journal.* vol. 27, no. 3, pp. 255-269. March, 2002.

2 Nordman, Bruce, Alan Meier, and Mary Ann Piette. 2000. “PC and Monitor Night Status: Power Management Enabling and Manual Turn-off.” In Proceedings of the ACEEE 2000 Summer Study on Energy Efficiency in Buildings, 7:89-99. Washington, D.C.: American Council for an Energy-Efficient Economy. Also, Webber, Carrie A., Judy A. Roberson, Richard E. Brown, Christopher T. Payne, Bruce Nordman, and Jonathan G. Koomey. 2001. Field Surveys of Office Equipment Operating Patterns. LBNL-46930. Berkeley, Calif.: Lawrence Berkeley National Laboratory.

3 This Draft Standard was initially published as Attachment 1 to California Energy Commission report #P500-03-012F, available at www.energy.ca.gov/pier/buildings/reports.html

The report of that research (The Power Control User Interface Standard[4]) is available at the project web site: http://eetd.LBL.gov/Controls and on the Energy Commission website (#P500-03-012F at www.energy.ca.gov/pier/buildings/reports.html).

At the time this standard was completed, the working group had the following membership:

Bruce Nordman, *Chair*

The following members of the balloting committee voted on this standard. Balloters may have voted for approval, disapproval, or abstention. (To be provided by IEEE editor at time of publication.)

---

[4] Nordman, Bruce, "The Power Control User Interface Standard — Final Report". Lawrence Berkeley National Laboratory. P500-98-032. Contract No. 500-98-032. LBNL-52526. December, 2002.

Contents

Draft Standard for User Interface Elements in Power Control of Electronic Devices Employed in Office/Consumer Environments

1. Overview

1.1 Scope

This standard covers the user interface for the power status control of electronic devices that ordinary people commonly interact with in their work and home lives, including, but not limited to, office equipment and consumer electronics. Key elements are terms, symbols, and indicators.

This standard does not: specify maximum power levels; address safety issues; or cover internal mechanisms or interfaces for industrial devices.

1.2 Purpose

To accomplish a similarity of experience of power controls across all electronic devices so that users will find them easier to use and be more likely to utilize power management features that save energy.

2. References

This standard shall be used in conjunction with the following publications. When the following standards are superseded by an approved revision, the revision shall apply. See Annex A for informative references. Uniform Resource Locators (URLs) provided in this standard are current as of the date submitted for publication.

CIE Technical Report CIE 107-1994, Review of the official recommendations of the CIE for the colours of signal lights, International Commission on Illumination.

IEC 447:1993, Man-machine interface (MMI) — Actuating principles.

IEC 60073:2002, Basic and safety principles for man-machine interface, marking and identification—Coding principles for indication devices and actuators.

IEC 60417-1:1998, Graphical symbols for use on equipment—Part 1: Overview and application.

IEC 60417-2:1998, Graphical symbols for use on equipment—Part 2: Symbol originals.

IEC 59/267/CD:62301:2002, Measurement of standby power. Draft.

IEC 80416-1:2001, Basic principals for graphical symbols for use on equipment—Part 1: Creation of symbol originals.

IEC 80416-3:2002. Basic principals for graphical symbols for use on equipment—Part 3: Guidelines for the application of graphical symbols.

ISO 7000:1989, Graphical symbols for use on equipment: Index and synopsis.

ISO 9186:2001, Graphical symbols—Test methods for judged comprehensibility and for comprehension.

ISO 9241-10:2001, Ergonomic requirements for office work with visual display terminals (VDTs)—Part 10: Dialogue principles.

ISO 9241-1:1996, Ergonomic requirements for office work with visual display terminals (VDTs)—Part 1: General introduction.

ISO/IEC 13251:2000, Collective Standard—Graphical symbols for office equipment.

VITA 40-2002, Service Indicators.

3. Definitions, terminology, and acronyms

In this standard, to increase clarity, power states are *italicized*.

3.1 General Definitions

3.1.1 device: An electronic machine, usually a commercial product, that is commonly used and interacted with by ordinary people in their work or home life. This includes devices traditionally electronic, such as office equipment and consumer electronics, as well as appliances, telecommunications devices, space conditioning equipment, and any other device that has non-trivial power controls. In this context, devices are usually separately powered from the mains, separately controlled by the user for their power status, and have a separate power indicator.

3.1.2 manual power control: An action taken by a user, or external device (including network activity), to change the power state of the device.

3.1.3 power control: The combination of manual power control and automatic power management.

3.1.4 power control panel: A set of software controls for viewing and/or changing parameters relevant to the power controls such as delay timers, switch behavior, summaries of usage patterns, and device behavior after unexpected power loss.

3.1.5 power indicator: A color, word, or other display that communicates the power state of a device to a user. Common examples are simple lights (e.g. a light emitting diode), text display (e.g. with a liquid crystal display), or an element of a larger visual display. Power indicators may also have audio or tactile indications.

3.1.6 power management (automatic): The active modulation of the energy consumption of a device for purposes other than the intended function of a product. Examples of other purposes are mains electricity conservation, battery life extension, overheating avoidance, and noise reduction from less fan noise.

3.1.7 power state: A condition or mode of a device that broadly characterizes its capabilities, power consumption, power indicator coding, and responsiveness to input. Basic power states are *on*, *sleep*, and *off*. Devices may have multiple instances of one or more of the basic states (e.g. *light sleep*, *deep sleep*), and need not have any *sleep* states. All devices have at least one *on* state, and at least one *off* state (*unplugged*). The term "power mode" may be substituted and has identical meaning.

3.1.8 power switch: A user mechanism for causing a power state transition. May also be called a "power button".

3.1.9 tactile nib: A small raised surface, usually on a key, that does not interfere with normal usage but allows identification of the key through tactile means only. May be also found on buttons or switches. Common examples are "F", "J", and "5" keys.

3.1.10 wake event: A manual or automatic action that causes a system to initiate a transition from a *sleep* power state to an *on* power state.

3.2 Power State Definitions

3.2.1 hard-off: An *off* power state in which the device uses no power from the mains or a normal operating battery.

3.2.2 on: A power state in which the device has greater (or similar) power consumption, capability, and responsiveness than it does in the *sleep* or *off* state.

3.2.3 off: A power state in which the device has less (or similar) power consumption, capability, and responsiveness than it does in the *sleep* or *on* state.

3.2.4 sleep: A power state in which the device has greater (or similar) power consumption, capability, and responsiveness than it does in the *off* state, and has less (or similar) power consumption, capability, and responsiveness than it does in the *on* state.

3.2.5 soft-off: An *off* power state in which the device may use some power from the mains or a normal operating battery. When it is unknown whether the *off* power is zero, the *off* state shall be considered to be *soft-off*.

3.2.6 unplugged: A form of the *off* power state in which all normal operating power supplies have been disconnected. For devices that can operate from battery power, this requires that the battery be removed or otherwise disconnected from the ability to supply the system. A device that is unplugged cannot be turned on until at least one source of the power supplies is connected. Incidental battery power such as that which supplies clock circuits but is not capable of powering the device in an *on* state does not qualify as normal operating power. A battery which provides only short-term operating power (e.g. for less than 1 minute) also does not qualify.

4. The Standard

4.0 General Principles

This standard shall not be used to impede innovation in power controls, nor shall it be used to prohibit deviations from the standard in cases where the difference is clearly merited. The standard shall be interpreted in ways that maximize consistency across devices and simplicity and clarity for users.

4.1 Power States

Power states for this standard are *user* power states, and are not required to correspond directly to internal power states. Devices shall be limited to the three basic power states — *on*, *sleep*, and *off*. Any additional power states shall be variants of one of the basic states rather than a fourth state.

This standard does not address absolute power levels, nor does it make specifications about peak power consumption so that no restriction is placed on short-term fluctuations in power levels.

Power levels for purposes of this standard are only relevant as they affect long-term energy consumption. Thus, power should be measured over an extended time period; IEC 62301 provides procedures for measuring average power over such periods.

The only power consumption requirements of this standard for power states are that:

$$\text{Power}_{\text{ON}} \geq \text{Power}_{\text{SLEEP}} \quad \text{and} \quad \text{Power}_{\text{SLEEP}} \geq \text{Power}_{\text{OFF}}.$$

Common forms of *sleep* are *light sleep* and *deep sleep*. As with basic power states, $\text{Power}_{\text{LIGHT SLEEP}} \geq \text{Power}_{\text{DEEP SLEEP}}$.

Common forms of *off* are *soft-off* and *hard-off*. *Soft-off* implies that some power may be consumed by the device even though the power state is *off*. *Hard-off* requires that no power is consumed, either from mains power or a normal operating battery.

4.1.1 User Experience of Power States

The *off* power state does not require information about the device functional state to be lost. For example, a television may remember the channel and volume settings when *off*, and a computer may remember its functional state in *off* through the use of a “hibernate” feature, saving the system state to non-volatile memory (e.g. a hard disk).

When feasible, devices shall have consistent behavior, responsiveness to input, and capability to act in all substates within a basic state. For example, wake events shall be consistent across all sleep states when feasible.

Users shall not be required to understand the differences among substates to properly use a product, but devices are not prohibited from communicating which substate the device is in.

When feasible, user interfaces shall not differ between *soft-off* and *hard-off* except when the *hard-off* symbols need to be used. Users should generally experience only *off*.

4.1.2 Relation between Power States and Operating System State

The state of a device operating system and the power state of the device shall be differentiated, but may have common controls. For example, a command to power on a device may also start the operating system, and a command to power down may also shut down the operating system. However, a device can be in a special mode and be *on* but without the primary operating system operative, and a device can be *off* but have the operating system state saved for immediate use after power on (this is commonly called “hibernate”).

A command to “restart” a device operating system is generally not a power state transition, since the device usually begins and ends in the *on* state. However, it is appropriate to present a restart operation as a pair of power state transitions (power down immediately followed by power up).

4.2 Power Symbols

Power symbols shall be those used in IEC 60417 as well as the sleep symbol. The are listed in Table 1. IEC 60417 defines ⏻ as for use with a power switch that does not do a total mains disconnect, and hence the device consumes “standby” power. ⏻ is generally used and understood to mean “power”, as on power buttons, indicators, and elsewhere. ⏻ therefore means “power” with a non-zero power level in the *off* state. Electronic devices shall use ⏻ to be a synonym for “power” on power controls. Even if used on a power button that does go to a *hard-off* state, that should not introduce any safety issue.

Table 1. Power Symbols

Symbol	Name	Usages in addition to use within power control panels
I	On	On a switch, best used in conjunction with the Off symbol, as on a rocker switch.
○	Off	On a switch, best used in conjunction with the On symbol, as on a rocker switch.
⏼	On/Off	For use on a power switch that always switches to *hard-off* in the *off* state. For use with a power indicator if the off indication is always *hard-off* and the distinction from *soft-off* is important.
⏻	Power	For use on a power switch or button if the *off* state is *soft-off*, is variable, is not known, or the distinction from *hard-off* is not important. Also for use with a power indicator, or as the icon for the power control panel.
⏾	Sleep	For use on a sleep button, or with a sleep indicator.

In accordance with IEC 80416-3, symbols can be filled, rotated, have their lines thickened, or used on digital displays, so long as the meaning remains clear.

4.3 Power Metaphors, Affordances, and Terminology

Metaphors and affordances can be used in the construction of terminology, documentation, and product design. For power controls, they should be used as described below, but used precisely and sparingly.

Power states shall be understood to have physical relationships to each other. Specifically, *on* is taken to be above *sleep,* and *sleep* above *off*. Consequently, "power up" refers to a transition from *off* to *on*, *off* to *sleep*, or *sleep* to *on*. "Power down" refers to a transition from *on* to *off*, *on* to *sleep*, or *sleep* to *off*. "Power on" refers to transition to an *on* state. "Power off" refers to a transition to an *off* state.

For low-power modes, the "sleep" metaphor shall be used, for the name of the power state, for transitions ("going to sleep", "waking up", and a "wake event"), and for the sleep symbol—⏾.

User terminology used for controls for power states shall be organized around the term "power". Common examples include a "power switch", "power button", "power indicator", "power control panel", and "power management". User terminology is often used on the outside of devices; in documentation, and on displays.

For power indicators, the colors and color names "yellow", "amber", and "orange" shall be considered to be equivalent, though orange is the least preferred. This standard uses the name "yellow" to be consistent with IEC 60073. The specific colors to use are specified in Section 4.4. Care should be taken when translating the color names to other languages that the term used for yellow is clearly not that used for any form of "red".

Common terms used to refer to *on* states are *on*, *full-on*, *ready* and *active*, but no difference in meaning is implied by this standard to these different terms.

Standard translations of key terms shall be used in documentation, and on products (when present). Key terms include: power, *sleep*, *on*, and *off*.

4.4 Power Indicators

4.4.1 General Principles

Power indicators shall communicate stable device power states or transitions between power states. Power indicators may also communicate non-power-state information provided that ambiguity is not introduced.

4.4.2 Static Power States

For power indicators, color coding for power states shall be green for *on*, yellow for *sleep*, and off for *off*. Black or gray may be substituted for off (as on a graphic display or with a mechanical indicator). These color assignments are consistent with IEC 60073.

For *sleep* indicators, color coding for power states shall be off for *on*, yellow for *sleep*, and off for *off*.

Power indicator colors shall be used in accordance with CIE 1994, which specifies color limits for traffic signal lights. For fully saturated colors, green shall be between 498 *nm* and 508 *nm*; yellow between 585 *nm* and 593 *nm*; and red between 615 *nm* and 705 *nm*.

For text or graphic displays, *on* can be specified by the lack of power-state information (and presence of other information), the term “on” (or a clear synonym), or the on symbol—⏽; *sleep* states can be communicated by the term “sleep” or the sleep symbol—⏾; the *off* state can be communicated by the display being off, use of the term “off”, or the off symbol—⭘. Table 2 presents a summary of power state indications.

Table 2. Summary of power state indications

State/ Term	Indicators		Symbol	Text / Displays
	Power	Sleep		
On	green	off	⏽	The lack of power-state information (and presence of other information). “On” may be substituted by a clear synonym,
Sleep	yellow	yellow	⏾	The term “sleep”.
Off	off	off	⭘	The display being *off*, or use of the term “off”.

Power indicators may be on remote devices. For example, a computer may display the power state of other devices it can connect to. This allows indications of an *off* state other than an indicator light or entire display being off.

Some mechanical switches can reliably show the power state so long as the device is powered.

For devices for which a constantly illuminated power indicator would use excessive energy or be particularly intrusive, a brief flash of the power indicator in the appropriate color is allowed (e.g. one tenth of a second on followed by 1.9 seconds off).

Non-power information can be combined with power indications in the following ways. An error indication can be shown with a red color in the place of a power indication; when this is done, no power state information is communicated. When red is unavailable, alternating green and yellow at the normal flashing rate can be used to indicate an error, but shall not be used to indicate that a safety hazard is present. Alternating red and green or red and yellow shall be used to simultaneously indicate an error condition and power status. Other non-power-state information, such as communication occurring, can be indicated by the slow flashing rate. Per IEC 60073, normal flashing rates are 1.4 Hz to 2.8 Hz, and slow flashing rates are between 0.4 Hz to 0.8 Hz.

4.4.3 Power State Transitions

From the user perspective, some devices change from one power state to another instantly. For devices with user-perceptible transition times *between* states (e.g. more than one second), the power indicator shall communicate the fact of the transition state and its direction. Even for instant transitions, a "blink" of the indicator is recommended as it helps the user to see that the transition has occurred.

Color power indicators shall flash or otherwise modulate during transitions, green for a "power up" transition, and yellow for a "power down" transition. Text or graphic indications shall flash or provide some other indication that there is a transition state. Flashing shall be consistent with IEC 60073 normal flashing rates (1.4 Hz to 2.8 Hz).

Devices with audio capability shall have optional audio indications of power state transitions. The audio indications shall be of one of the types shown in Table 3.

Table 3. Audio indications of power state transitions

Type	**Details**
Click	A power-up transition shall be indicated by a single click or beep. A power down transition shall be indicated by a double click or beep.
Tone	Powering up shall be indicated by a rising tone or two tones with the second having a higher pitch than the first. Powering down shall be indicated by the reverse (a falling tone or two tones with the second having a lower pitch than the first). *Sleep* shall be accommodated in these indications by using a tone with a pitch intermediate between the two tones used for *on* and *off*.
Other	Other sound indications (e.g. musical notes or speech) shall clearly indicate the direction or endpoint of the transition.

Devices with extended transitions and the capability to display a progress indicator shall display one. A progress indicator shall show (via graphics or text) the estimated elapsed portion of the total transition time or the time remaining in the transition.

4.5 Power Switch Labeling and Behavior

When feasible, pressing a power button shall toggle the device between the two most commonly used power states. When a device is asleep, and can wake itself up, pressing a power button shall wake up the device.

Power switches shall be one of two types: *hard-off* and *soft-off*. When safety is involved, the user interface shall be unambiguous as to whether an *off* state is *soft-off* or *hard-off*. When safety is not involved, preference shall be given to the ⏻ symbol.

The present set of international standard symbols for power control lacks a workable designation for *soft–off* —equipment that are functionally *off* but continue to draw some power (the ○ symbol is reserved for zero power). Thus, designs should be avoided that would require such a symbol.

It is recommended that rocker switches be used for power controls <u>only</u> when *off* is a zero power state. It is also recommended that push-button switches be used for power controls when *off* is non-zero power. These usages avoid the need for a symbol that clearly means the *off* power state, but means *soft-off*.

When a device has two power controls, or otherwise has a *hard-off* and *soft-off* mode (with the *hard-off* obtainable other then by unplugging from the mains or normal battery), both will have the power indicator off. Only inspection or manipulation of the power switches will clarify which mode it is in. When two power controls are present, the secondary control should be labeled with ⏻.

For devices which need an emergency override, it shall be accomplished by holding down a power button for at least four seconds. An emergency override will usually force the device into an *off* state and is necessary when ordinary means to do this are not possible.

In product design, consideration shall be given to the specifications of IEC 60073 for actuators for *on* and *off*. However, this standard makes no requirements for actuator colors. Among the specifications of IEC 60073arethat for a control that goes to *off*, red may be used and green shall not be used; for controls to go to *on*, green maybe used and red shall not be used; and for controls that switch among power states, neutral color such as white, grey, and black are preferred, yellow and green are not to be used, and red is to be used only in special circumstances.

4.6 Wake Events

Devices with *sleep* states shall have one more wake events. When feasible, wake events shall be consistent across all *sleep* states. When feasible, pressing a power button shall cause a wake event.

For general purpose controls such as keyboards, and where the meaning of a key press depends on mode information not apparent in the *sleep* state, the wake event itself shall be discarded from the normal input stream.

4.7 Tactile Interfaces

When a tactile marking is used on a power control, it shall be a single nib or set of three nibs in a horizontal line on the power button or on the "on" side of a power switch.

Tactile indications of states and transitions shall be broadly consistent with those of the other modalities of this standard.

Appendix I — Rationales for the Standard[1]

1.0 Introduction

This appendix presents facts and considerations behind the specifications in the Power Control User Interface Standard. Other appendices address specific issues in detail, but this one covers the broad scope of the issue and standard.

The standard emerged from a combination of a review of user interface literature, examination of the operation and design of current products, and consideration of how principles could be applied across a wide range of products and contexts to have both simplicity and flexibility.

It is good interface design practice to not change designs unless there is a compelling reason to do so. Current product design has been informed by some design insights and market-driven evolution, so that some deference must be paid to the status quo. Thus, when there is not a problem with it, standardizing that practice which is most common is the default choice. Other key priorities are simplicity and internal consistency.

It is helpful to divide the standard into two parts. The first can be called the *hard* or *static* interface[2] — switches, indicators, and the terms and symbols around them. The second is *dynamic*, covering the *behavior* of devices over time.

There are several reasons for this organization: The hard parts of the interface are what we first encounter with a product (and are sometimes all of the interface); they have more limitations than other parts of the interface; they are more universal (they apply to nearly all products whereas other aspects apply only to subsets); and it is easier to adapt the other parts of the controls to the hard portions than vice-versa.

It is helpful to keep in mind that the standard was developed with electronic devices (office equipment and consumer electronics) as the primary focus, as these have the most complex power control user interfaces. However, the standard is intended to be applied to any device[3] that has some electronic character, which is an increasingly larger number including many appliances and even automobiles.

---

[1] [1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

[2] Per Appendix II, the "hard control panel" is "control panels with conventional controls and displays", in contrast to display-based controls that may mimic hard controls or software interfaces.

[3] Several text conventions are used throughout this report. The terms "amber", "yellow" and "orange" are taken as synonymous (amber is used here). Basic power states are italicized, such as *on*, *sleep*, and *off*. "Device" means a distinct electronic product that can operate on its own (some electronic discussions reserve device to mean an entity within a computer such as memory, an add-in card, and such). There is no distinction made between the idea of a "power state" or "power mode".

1.1 Structure

Table 1 presents key concepts related to the User Interface Standard. The Standard is built around these, derived from current implementations of them, and to be implemented in future ones.

Table 1. Key Concepts in Power Control User Interfaces

States	Devices have basic power **states** that are shown by *indicators* and changed by controls. They have names (terms) and graphic representations (symbols), and standard indicator colors or behavior. There are basic states, substates (e.g. levels of sleep), and times of transition between states.
Controls	Controls can be manual controls (e.g. switches) or automatic controls (e.g. timers). The behavior of controls may be fixed, or adjustable by software control panels.
Manual Controls	Manual controls include switches, buttons, lid switches, and signals from objects that function as part of a device (e.g. a keyboard or mouse). The controls can be labeled with terms and symbols and may have integral indicators.
Automatic Controls	Automatic controls can be based on time (e.g. time of no activity or real-time-clock alarms) or external input (e.g. network activity or another connected device as a PC controls a monitor).
Indicators	Most commonly colored LED lights, but also (portions of) displays generally, and audio and tactile indications. Light indicators can be labeled with a term, symbol, or be associated with a manual control.
Software Control Panels	These can change the behavior of manual or automatic controls. There is a name (and possibly a symbol) for the panel as a whole, and it may use terms, indicators, and symbols within it.
Terms	There are names of states, user interface elements (e.g. "power button"), manual controls, automatic control options, and indicators. Terms need to be translated into each language.
Symbols	Symbols represent power states and / or controls to change state. There is usually a term associated with each symbol. Some symbols are nation-specific, but most are intended to be global. They can appear on the outside of devices and on displays.
Documentation	Instructions for how a product works and is to be used can appear on the product, on printed manuals, on-line, or on the product's display. All user interface elements may be described in the documentation.

The combination of controls, indicators, and states that a particular device has can vary tremendously. In addition, the physical arrangement and location of interface elements also varies widely. This is a combination of the diverse needs of the devices, reasonable aesthetic and design choices, and variation without any apparent purpose or value. Even within the category of office equipment, there are devices without switches, without indicators, without labels, and one without any of these[4].

2.0 Overview

It would be easiest to explain and organize this presentation by treating each part separately; however, this cannot be done. There are close linkages among them and there is not a simple ordering in their derivation. Thus, there is first a review of what the standard specifies, and then a discussion of each portion of it. The discussion of each part presumes as given the other parts of the standard. A few parts of the rationale are discussed elsewhere, such as the crescent **moon** symbol for sleep (Appendix VI) and how to treat the **hibernate** mode (Appendix VIII), but these also follow the pattern of taking as given the other parts.

The Hard Interface:

- Use only three basic power states: *On*, *Off*, and *Sleep*.
- Use the word "Power" for terminology about power.
- Use the ⏀ and ⏻ symbols to mean "power". ⏀ guarantees that *off* always means zero power but should only be used when that is important. (This requires changing the ISO / IEC standard).
- Adopt the "green / amber / off" color indications for power indicators. Red should be reserved for warnings, alarms, or errors.
- Use the "*sleep*" metaphor for entering, being in, and coming out of low-power states; use the moon symbol for *sleep* — ⏾.
- Present "hibernate" modes to the user as forms of Off.

Dynamic Behavior[5]:

- Use "power up" to mean turn on or wake up, and "power down" for turn off or go to sleep.
- Use flashing green on the power indicator for powering up and flashing amber for powering down.
- Provide optional audio indications for power state transitions.
- Alternating green / amber can be used to mean error if red is not available.
- The power button toggles between the two most common power states.
- When a device is *asleep*, pressing the power button will (usually) wake it up.
- Holding down a power button for an extended time will trigger an emergency action.
- Usually, when a device is *asleep*, the input causing a wake event should be discarded.

---

[4] In 2000, we found a low-cost inkjet printer with no labels, indicators, or switches. It was always on when plugged in, and all indications were accomplished on a software control panel on the PC it is connected to. With no indicators or switches, there is no need for any power-related labeling.

[5] An additional recommendation to "Provide icons to show what types of input may be active" was dropped as not being sufficiently developed for inclusion in the standard.

Again, each principle presumes the others.

2.1 States

The User Interface Standard is concerned with **power states**. Devices also have other states, often "functional states" such as being connected to a network (or not), imaging (or not), and displaying media content (or not). While functional states are often correlated to power states (e.g. a device can perform some functions only while *on*), only changes in power states should determine the power user interface. Device power states are a combination of their electrical and functional characteristics. All devices have an "unplugged" state (or battery removed if they can be run from a battery) which is one type of *off* state, and all have at least one *on* state.

Most devices currently have either two *basic* power states (**on** and **off**) or three (on, off, and a **low-power** mode). The standard specifies that devices be limited to these three basic states. Indicator colors, capability, switch operation, and overall behavior should be consistent within each basic state. Any additional states should be variants of one of the basic states rather than a fourth basic state. For example, rather than be a separate mode, "hibernate" should be a form of *off* (see Appendix VIII for an explanation of why this is best). Also, multiple low-power modes can be all be types of a basic *sleep* mode.

The possible alternatives to there being three basic states is to have two or four. Two basic states is not enough; we currently have a user interface vocabulary built on two states and it has caused a great deal of confusion around power control. Low-power states are sufficiently different from *on* or *off* states that they cannot be successfully mapped into them on most devices. Four states adds significant complexity over three, and there is not evidence that suggests that this burden on users is needed. Devices need not have all three states; many lack a *sleep* state, and some have unplugged as their only *off* state. So, the *possibility* of three states does not burden devices with states that they don't need.

The idea of mapping internal states to fewer external ones is not new. For example, the ACPI specification defines a few "Global System States" that are apparent to the user and many more System States. ACPI provides for multiple sleep states (that may be identical in outside appearance), and device and processor states (which are not made apparent to the user).

The "hibernate problem" is addressed in Appendix VIII. That discussion identifies criteria by which to categorize power states, six possible solutions to the "hibernate problem", and issues and problems with each solution. The conclusion based on all of this is that the solution of mapping hibernate to be a form of the *off* state has the least problems.

2.2 The Term "Power"

It is helpful to have one idea and term to organize power controls around. For terminology about power controls, the standard specifies that the term "power" should be used, such as "power button" (or power switch), "power indicator", "power control panel", etc.

Power is the most common generic term in this area. Next (but far less common) is "energy" as in "energy saver" and "ENERGY STAR". However, the terms "Energy button", "energy indicator", "energy management", and "energy control panel" sound odd to the ear or suggest concepts different from those intended. From usage on current devices there are no other candidate terms, there is no reason to consider a new term, and no need to question the existing dominant usage of "power".

The word need not be used on the hard interface itself. A standard translation needs to be identified for each language[6].

In addition to the term, standard affordances of power should be utilized such that *on* is up, to the right, clockwise, etc. (see Appendix V).

2.3 Power Symbols

With a common organizing principle for power controls — "power" — it makes sense to have a graphic symbol that is a synonym for this basic term for simplicity and for language independence. The symbol can then be used for different purposes, such as a power button, power indicator, or power control panel. The standard provides that the ⏻ symbol should be used to mean "power". This is consistent with common design practice on electronic products, but not directly with existing international standards for graphical symbols (shown in Table 2)[7].

The current symbols and definitions cannot be applied to modern devices in a way that is consistent and readily coherent to ordinary people. Modifying and supplementing them is essential. For those who find a problem with the content of the User Interface Standard, the only useful response is to propose an alternative system which is better and has fewer or less severe problems.

The most common and prominent power control is an on / off switch with a power indicator nearby. The most common labeling of this on current products is the ⏻ symbol. It seems (though we did not quantify the effect) that there is a shift away from the ⏼ symbol. We speculate that designers find ⏻ more visually appealing. Also, more devices consume power while off and so cannot use the ⏼ symbol.

⏻: A Summary

For graphic symbols, there is a the original need which propels their creation, the context in which they are used, their incarnation in standards, popular understanding of them, and the best ways to apply them to future products. It is instructive to review these for the ⏻ symbol.

- Need: The ⭘ and ⏼ symbols quite specifically require that the "off" position be a mains disconnect and indicate guaranteed zero power consumption and consequently no possibility of electrical hazard in that *off* mode. Controls that didn't meet this strict criterion required a different symbol — hence the introduction of ⏻.

---

[6] It is possible that "power" will become an international standard word in the way that "STOP" has become, transcending English. This should not be forced nor relied on, but accepted if it occurs.

[7] The international standards also have an on-off symbol for "momentary on" buttons (a circle with a T in it). We have not observed this in use on office equipment or consumer electronics and recommend against its use on them. However, it may have good uses in other areas (e.g. heavy machinery) and so an appropriate part of the international standards. There are also variants of the key symbols for "remote station" or "part of equipment" which also are used infrequently, and with dubious comprehension by users.

Table 2. IEC/ISO Graphical Symbols related to power status

Symbol	Name/Number	Definition
⏽	"ON" (power) IEC 5007, JTC1 001	To indicate connection to the mains, at least for mains switches or their positions, and all those cases where safety is involved.
○	"OFF" (power) IEC 5008, JTC1 002	To indicate disconnection from the mains, at least for mains switches or their positions, and all those cases where safety is involved.
⏻	Stand-by IEC 5009, JTC1 010	To identify the switch or switch position by means of which part the equipment is switched on in order to bring it into the standby condition.
⏼	"ON" / "OFF" (push-push) IEC 5010, JTC1 003	To indicate connection to or disconnection from the mains, at least for main switches or their positions, and all those cases where safety is involved. "OFF" is a stable position, whilst the "ON" position only remains during the time the button is depressed.
	Electric energy ISO 0232, JTC1 008	To signify any source of electric energy, for example on devices starting or stopping the production or use of electric energy.
	Pause; interruption IEC 5111, JTC1 011	To identify the control device by means of which the run (e.g. of a tape) is interrupted by means of a break mechanism and mechanical disconnection from the driving mechanism which continues to run.
	Ready ISO 1140, JTC1 009	To indicate the machine is ready for operation.

Notes: In IEC 13251, the definition of 5010 ON / OFF ends with "Each position, "ON" or "OFF" is a stable position.
IEC numbers are from IEC 60417. ISO numbers are from ISO 7000. JTC1 numbers are from ISO / IEC 13251.

- Context: The power symbols were originally used in hard interfaces only, but now also arise on displays. Similarly, they were introduced before electronics became so widespread and before the rise of automatic controls. A problem with ⏻ is that it was not clarified in the beginning how it was intended to be used, to be simple, clear, and consistent.
- Standards: The definition of ⏻ (as cryptic as it is), indicates that it is to be used to identify a *state* (like *on* or *off*) as well as a *control* (like a power button); this is in contrast to the other symbols which specify only a state (⏽ and ○) or a control (⏼).
- Popular understanding: The popular understanding of ⏻ has come to mean "power" or "power on" (see below). The distinction from ⏼ is technical (safety) and one that doesn't affect the great majority of people who use the devices it is placed on.

- Application: The best ways to apply ⏻ (and the other symbols) to future products are described in section 4.

⏻ *Means "Power"*

There is diverse evidence that the average person associates ⏻ and the term "power". Much of this is based on experience in the U.S., but it is likely that it holds true elsewhere in the world as well.

- In the late 1990s, a magazine named "Time Digital" was renamed "ON" magazine and used ⏻ as its logo, clearly indicating that it was to mean "On". The magazine fell victim to the dot-com bust and was discontinued in late 2000.
- The U.S.-based Exelon Corporation was created out of an energy utility merger in 2000. The company chose ⏻ (in green) for the new corporate logo. A representative of their public relations department and a corporate web page (http://www.exeloncorp.com/) both said that the symbol was chosen because it means "Power On".
- In late 2002, the Gateway computer company changed its corporate logo to a sideways version of ⏻, to bring to mind both the "G" of Gateway, and to symbolize power on. In all three of these cases, the companies clearly wanted to communicate the idea of power, activity, and capability, and not passivity and inactivity, which the term "standby" suggests.
- Several office equipment product designers told us that ⏻ was chosen for the power symbol on their products because that is what was on the existing office equipment in their office at the time that design decision was made. Very few product designers have copies of the international standards, or material which reviews their content for power controls.
- Our testing showed that very few people know that the symbol means "standby", and that most think it means "power", "on", or "power on". While the testing was all conducted in the U.S., the results were so dramatic that it seems likely that the same trend holds true elsewhere, even if the difference was not quite so dramatic.
- Most user manuals for office equipment and consumer electronics sold in the U.S. refer to a "power button" and "power indicator" and provide little or no elaboration on this; people know what to expect from these controls. For office equipment, these are most commonly labeled with ⏻. For consumer electronics, the word "power" is common along with ⏻.

As ⏼ means an "on/off" switch, it can also be seen as meaning "power", just as ⏻ is. The confusion between ⏻ and ⏼ is compounded by two further facts. The symbols are often used interchangeably with respect to their meaning (this is particularly confusing on battery-powered devices for which the original reason for the distinction — disconnection from the mains — does not apply). Secondly, the way they are printed often blurs the distinction, with the vertical bar on ⏻ sometimes lowered, the one on ⏼ lengthened, and the circle on ⏻ nearly closed. It is not surprising then that few people distinguish between the symbols in practice.

What to do?

Having two such similar symbols with different meanings seems contrary to good design practice. The standard does not recommend any change to the "on" | and "off" ◯ symbols, but these are best used as a pair on rocker (and similar) switches (rather than in isolation or in combination with other symbols). See Section 4 for a discussion of how to apply the symbols on products.

2.4 Power Indicators

A power indicator communicates the power state of the device. The standard provides that the indicator needs to communicate up to three states — *on*, *sleep*, and *off*. For off, almost all consumer devices use an indicator light being off[8]. For *on*, green is clearly the best choice (more on this below). The only major question around power indicators is how to indicate *sleep*. Consideration of design issues and results of the user testing we conducted both suggest steady amber for *sleep*.

For *on*, the power indicator is most commonly green or red (the latter more so on consumer electronics), though the occasional blue or white power indicator can be found. When LEDs first began to be used for power indicators, red was the cheapest and most available color (and most power-efficient, a key consideration for battery-powered devices). Red and orange are also associated with energy and fire, so have some basis as the color for a power indicator. On the other hand, from traffic signal lights and stop signs we associate red with "stop" (see Appendix IV) and indicator standards specify that red is to mean error or warning (see Appendices II and V). Our user testing (see Appendix VII) also found green as a better choice for power than red. From all this, and the already widespread use of green to mean *on* (particularly on office equipment), it is the clear choice.

For *sleep*, while amber is the most common indication, blinking green makes a respectable showing. Legitimate concern about how using green and amber accommodates people who are colorblind is addressed in Appendix IV.

A considerable minority of devices use blinking green for sleep states, or use blinking for other meanings, so the use of this interface device needs serious consideration[9]. Some current devices use blinking for a transition state, e.g. "warming up" (or "waking up") or "cooling down" (as on a projector), but these are of limited time. Some devices use blinking of the power indicator for non-power meaning, such as an error mode, message waiting, network activity, etc.

---

[8] A few special devices not for consumer use have an indicator light on to show that the power is being supplied to the device and it is ready to be turned on.

[9] An example of how power states are mapped onto indicator lights comes from the Eizo company (which manufactures monitors under the Nanao brand name) which calls its power management capability "PowerManager". DPMS "Stand-by" (which reduces power only 20% nominally on this brand) results in the indicator remaining green. When the monitor goes onto DPMS Suspend mode (called "PowerManager Mode 1") the indicator blinks green. When it goes into DPMS Off mode (called "PowerManager Mode 2") the indicator turns amber. When the device is actually *off*, the indicator is off.

The key benefit of a blinking green indicator is that it can be implemented with a single (or single color) LED.

The benefits of using steady amber for *sleep* are many. It is consistent with traffic light color usage. It is consistent with indicator light standards (e.g. IEC 73). It is consistent with the colors used in traffic lights, with amber indicating caution or slowness. It allows other uses of blinking. The power state can be assessed instantly rather than require a steady gaze for a few seconds. It is not annoying or calling attention to itself as blinking is to many people in many contexts. It is not dynamic, allowing the color coding for other uses in user interfaces beyond just the indicator light.

An exception to the blinking standard is made for battery-powered products. Some of these presently conserve power by illuminating the power LED only during brief blinks while on and others during sleep modes. If this is used, the standard color assignments (green and amber) should be retained. The brief blinks also distinguish this from the flashing during transitions in which the on and off periods are approximately the same. Blinking indicators for transitions are covered in Section 2.7.

The standard also provides that alternating green and amber can be used to indicate an error when the red color is not available. Some devices use high speed flashing to indicate an error. The alternating colors is a simpler, more distinct way to express the error condition.

Other Indication Mechanisms

Beyond normal LED indicators, some devices use a display (usually LCD) to include the power status by turning the display off when off and displaying "SLEEP" or some other word when in a sleep mode, and/or turning the backlight off. Backlight behavior should be at the discretion of product designers (or even users). The key for displays is to use some combination of the sleep symbol, the word "sleep", or color associations to communicate that the device is in a *sleep* state.

In principle, a mechanical indicator could be used for the power state. This has some advantages, but is not used at present except as manifested by the mechanical state of some switch positions. Mechanical indicators could be used to indicate the operating system state when the device is off (to be able to distinguish hibernate from other forms of *off*).

2.5 Sleep Metaphor and Symbol

For naming power states, there is no reason to question "on" and "off", and for low-power modes, "sleep" is the clear choice.

For some devices, it is helpful to distinguish among *on* states by the functional state of the device, through terms such as "ready" or "active". Variations of *off* can also be helpful, such as soft-off, hard-off, and shutdown ("hibernate" should be a form of *off*, but the term "hibernate" should not be used as it implies a form of *sleep*).

The only real question is how to label the low-power mode. Words used on current and recent devices include: sleep, standby, suspend, energy-saver, low-power, idle, doze, PowerManager Mode, deep sleep, power-saver, ENERGY STAR mode, and conservation mode — but there are others.

For devices in a reduced-capability, low-power state, the ”sleep” metaphor is the most common and clear metaphor used, and is often referred to in manuals even in cases in which other terms (e.g. standby or suspend) are used in the user interface. “Sleep” is the clear choice in terms of the clarity of the metaphor, names for transitions, ease of creating sub-state terms, graphic representation, and ease of translation.

For the competitors to sleep, the idea of “suspending” activity may conjure up a clear idea, but is problematic as some devices (e.g. a printer or copier) have a mode of activity or inactivity that is separate from whether the device is globally awake or asleep. There is also no obvious visual analog to “suspend”, nor is the verbal extensions appealing (“going into suspend”) or obvious (e.g. “resuming” from suspend).

The term “standby” does not seem to reside within a single obvious metaphor, and is problematic due to its many diverse meanings (see Section 3 for more on this).

Another archetype, perhaps less well defined than sleep, is “Ready”. Some copiers and printers have a “ready” indicator to show when they are available to perform their primary function, namely imaging. Some discussions of PC use use the phrases “ready-to-use” or “ready-for-use” (Ease of Use Roundtable, Computer Power Management Questionnaire, 2000). Thus, “not ready” could be used to mean sleep, though this really addresses a functional state rather than a power state.

None of these alternatives remotely challenges the merits of “sleep” as the organizing principle for low-power modes.

The sleep metaphor could be carried too far, such as to imply that a device that is off is “dead”. This does not seem to be a problem with current devices that use the sleep metaphor.

The metaphor manifests itself as: the term “sleep” which can be used on graphic displays to show a low-power mode, and in control panels; the “moon” symbol for buttons that manually put the device into or out of the sleep mode (or, rarely, for a sleep indicator separate from the power indicator); and the phrases and ideas of “waking up” and “going to sleep”.

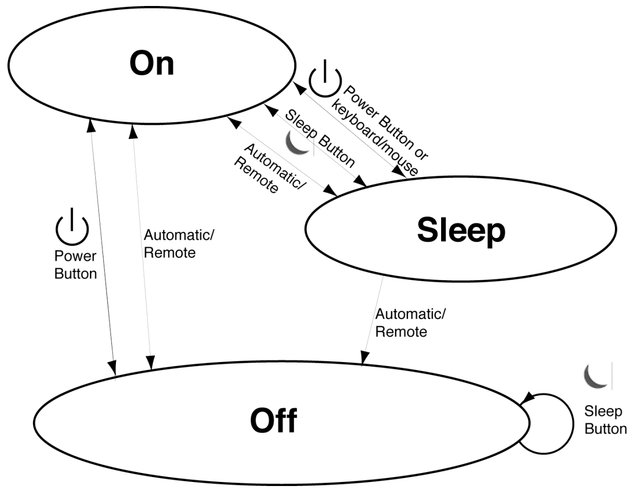
The moon symbol — ☾ — is the most common graphic representation of sleep (though multiple “Zs” (ZZZZZ) are sometimes used). There is no similar symbol on products that it could easily be confused with, and meets the criteria of simplicity for symbol design. Details on this and how the moon is used in the context of Islamic are presented in Appendix VI.

2.6 Transitions

Most of the User Interface Standard covers static power states, but it is also necessary to address how state transitions are initiated, and what behavior is exhibited during them. This topic is also addressed in Section 4.

Figure 1 shows a sample state diagram for a PC. On some PCs, the behavior of power controls such as the power button, sleep button, and lid switch are all programmable, so that not all possible transitions are always available. An example of an automatic transition is one based on a delay timer, a real time clock (e.g. turn on the PC at 8:30 a.m.), or an alarm (e.g. too high of an internal temperature). An example of a remote transition is one initiated by a device elsewhere on the network.

Figure 1. A sample PC state diagram.



Four elements of the dynamic behavior part of the standard have to do with hardware aspects of transitions.

The power button toggles between the two most common power states.

This is to provide for the most common power state changes to be able to be made by the same control, in the way that conventional light switches use the same element for turning on and off. This aids people to use devices without having to think about other controls in most circumstances.

When a device is asleep, pressing the power button will (usually) wake it up.

This is also to provide the power control as a central mechanism to change states. It also can alleviate devices from having to monitor other inputs which may be unavailable in sleep modes or power-intensive to monitor. Exceptions are when an external device is controlling the power status, as a PC does for a monitor.

Holding down a power button for an extended time will trigger an emergency action.

Many devices require some mechanism to reset hardware when the system gets into a problematic state. As the power button is usually the most protected (to avoid accidental pressing), this makes accidental reset unlikely. Also, should there be an emergency such that powering off the device without delay is required, pressing the power button is the most obvious control to do this.

Usually, when a device is asleep, the input causing a wake event should be discarded.

In many cases, the information context of a device is not apparent when the device is *asleep* as the display which shows the context is *off* or *asleep*. Because of this, using the content of the wake event could cause bad consequences, and often the input is simply intended just to cause the wake and nothing else. Some wake events can be executed without problem, such as if a media eject button is the event.

The power indicator is to flash during state transitions. The reasons for this are several: it is usually more important to signal a change of state to the user than it is to signal a long-term stable state; the flashing helps reassure the user that something is happening (it is a simple “progress indicator”); and device behavior may be different during the transition than it is during any of the stable states.

For transitions, the standard also provides for optional audio indications. Devices with motors that spin up and down with their power state provide a model. These range from jet planes to the hard disk drives on PCs. These suggest using a rising tone for a turn-on or wake-up event, and a falling tone for a turn-off or going-to-sleep event. The interval the tone covers could be much larger for the on / off transitions than for the sleep transitions to indicate the magnitude of the change. Everything else about the audio signal could be left to the discretion of the designer, such as time duration, tone intervals, tambre, pitch, etc. Current systems which have a constant tone on boot-up are perhaps connoting an orchestra tuning up indicating a “ready” state, but this doesn’t seem to have good analogues for sleep transitions or turn-off.

Sometimes it is advantageous to suppress state transitions. For example, the DPMS Standard [VESA, 1993 recommends that there be a five second delay when a transition from “On” seems apparent – this to avoid inadvertent transitions when changing display resolution and / or timing. In practice this seems to be implemented by having the screen trace all black content and maintain the power indicator green for the five second duration. The DVI specification (DDWG, 1999) similarly states that a display should power down if the data stream ceases for more than five seconds.

3.0 The “Standby” Problem

The most problematic term in the area of power control is “Standby”. It is a reliable source of confusion to individuals, and confusion over the meaning of the term between professionals at an industry meeting was the original instigation for the project that created the User Interface Standard.

Terms for power modes stretch back to the dawn of computing, to at least 1951. The first commercially available computer, the UNIVAC, includes a switch on its control panel with one setting both “**OFF**” and “**STAND-BY POWER**” (see Figure 2). What the switch does, and why “stand-by” was used we do not know. A likely possibility is that this was not a main power switch to cut power to the whole system to zero, but rather was a functionally-off state with auxiliary systems (e.g. the vacuum tube heaters) remaining on.

At the present time, “standby” has a variety of different meanings with respect to electronic devices.

- On a *copier*, “standby” is the mode when the machine is fully powered up and ready to copy (but not actually doing so). This exists on products and in the ASTM measurement standard for energy consumption of copiers.
- On *some computers*, “standby” refers to a low-power mode. Depending on the hardware and software, this can be a relatively small or quite large percentage reduction from the full-on state. Important references for this usage are the DPMS and APM standards, and most versions of the Windows operating system.

Figure 2. A corner of the UNIVAC control panel

Source: Smithsonian Institution, National Museum of American History

- In other contexts, “Standby Power” is the energy used while a device is at its lowest power level or even nominally “off”. Important sources for this usage are the Executive Order on Standby Power, the Department of Energy / Federal Energy Management Program efforts in this area, and research on the topic[10].
- The older use of the term “standby” for equipment and people was a statement about its capability to be put into use on short- or no-notice. This is really a statement about functionality which does not map directly onto power states in a clear way.

In each of these cases, the term was first used in technical discussions or documents, and only later migrated to more general usage and into the user interface.

A minor issue is that “standby” is sometimes hyphenated and products and sometimes not, as in international documents. Products and documents of U.S. origin generally do not include hyphenation; those from elsewhere sometimes do.

4.0 Power Switch Labeling

Clearly and unambiguously labeling power switches and buttons for modern electronic devices is becoming increasingly challenging. The international symbols for power control (see Table 1) were established in 1973 with some dating back at least sixty years. At that time, most devices had just two power modes (*on* and *off*), a single mechanical power switch, and zero power consumption in *off*. Today, electronic devices commonly have multiple power modes and

[10] More about these can be found at: http://www.whitehouse.gov/news/releases/2001/07/20010731-10.html — http://www.eere.energy.gov/femp/resources/standby_power.html and http://standby.lbl.gov

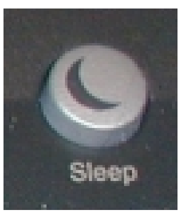
multiple power switches[11]. In addition, many consume "standby" power — non-zero power consumption in the minimum power mode, usually an *off* mode — so that the only way to achieve zero power draw is to pull the plug.

An increasing portion of electronic devices have automatic controls — they can change their power state without user action, in some cases even to turn themselves *on* from an *off* state. Automatic controls and external power supplies are some of the reasons for the increasing use of "soft" switches and buttons that send a signal rather than change power status directly.

The existing vocabulary of symbols is not adequate to clearly and unambiguously capture all the common power control implementations we find on contemporary devices. The two major complicating factors are low-power "*sleep*" modes and non-zero-power *off* modes (consuming "standby power"). Solutions are needed that are as compatible as possible with current product usage, and minimize the disruption to the symbol standards. Consistency and clarity should be the paramount goals, to minimize confusion and errors.

4.1 User Interface Elements

Power Modes/States



Sleep modes are usually entered by means other than a power switch (such as a delay timer), and so are not generally identified by a switch position. When *sleep* does need to be labeled, a crescent moon symbol — ⏾ — should be used (though not yet an IEC symbol). For power switches, the modes indicated by the switch position are generally are *on*, *soft-off* (non-zero power consumption) and *hard-off* (zero power consumption). Indicator lights generally differentiate among *on*, *sleep*, and *off*.

Switches

Switch types commonly found on consumer devices include:

- Rocker switch - 2 state. Switches between *on* and *soft-off* or *on* and *hard-off*. May be movable to *off* by automatic means.
- Rocker switch - 3 state, with *on* a momentary state. The intermediate state of the switch is *on* or automatic *off*.
- Push-button - 2 state, with a mechanically observable difference between the two states. Can be a notebook lid switch; an example of a non-traditional switch format.
- Momentary contact switch — a button or slider. Only one stable state. Moving the switch may cause a transition to the opposite state, or always to *on*.

Symbols

The IEC power control symbols are: I for *on*, ○ for *off*, ⏼ for an *on/off* switch, and ⏻ for "standby". For both ○ and ⏼, safety standards specify that the *off* state is to be a zero-power *off* — *hard off*. This leaves just ⏻ for a multitude of

[11] "Switch" here refers to anything performing the switch function, including buttons, lid switches, etc.

other uses and meanings. There are many examples of devices which use non-IEC symbols for power controls. Needless to say, these create even more different labeling possibilities and opportunities for user confusion.

Indicators

"Power indicators" are usually called just that. They show the power state — *on*, *sleep*, or *off* — and for mechanical switches, *sleep* occurs in the *on* position. They only rarely distinguish between *hard-off* and *soft-off*. Indicators are often simply adjacent to the power switch and not separately labeled; when they are, they are usually labeled with ⏻ or "power".

The ⏻ problem

With clear and precise definitions for |, ⭘, and ⏼, a multitude of uses have been assigned to the ⏻ symbol on recent products, guaranteeing that some will be in conflict. There is a large body of evidence that the symbol is best understood by people in the U.S. (and probably elsewhere) as meaning "power" (or (or "power-on", or the "on button"). There is no existing symbol that means "power", so the usage of ⏻ as meaning "power" arose out of a clear need. The previous meaning of "standby" may have made sense at the time it was established (decades ago) but is now obsolete. The ⏻ symbol should be used as a substitute for "power" throughout the power control context as for a power button, power indicator, or power control panel.

4.2 Applications of Interface Elements

Good Applications

Some common applications are clear with the present symbols. Examples are devices with:

- A rocker switch in which *off* is zero power; it will be labeled with | and ⭘.
- A push-button 2 state switch in which *off* is zero power; it will be labeled with ⏼
- A push-button or momentary contact switch with non-zero power in *off*; it will be labeled with ⏻.

4.2.1 Applications with problems

Other applications raise ambiguities, inconsistencies, and confusion. These can lead to annoyance, energy waste, and in the medical context, perhaps safety concerns.

Soft-off. Some devices have a rocker switch that toggles between *on* and *soft-off*. When this occurs on office equipment, it usually has | for *on* and ⏻ for *off*. The problem with this is that it identifies ⏻ as meaning *off*, whereas when it is used on a power button, people interpret it as meaning *power* or *on*.

Multiple power switches. Other devices have two power switches: one which controls the functional power state (for which the *off* power level is not important) and the other which is used to switch the device to zero power. User manuals often call the latter a "main power" switch. The question arises as to whether the icon labeling of the two switches should make clear their relationship, or whether cues such as location are always sufficient (e.g. the main power switch being on the back of the device near where the power cord enters). Regardless, if the main power switch goes to zero power on *off*, it should have the | and ○ symbols.

Unknown *off* power. In some contexts, the power consumption while *off* may not be known or may change. This occurs in operating systems that may not know the power status of the hardware they run on and so may not know which symbol(s) to use. This also can occur with devices that can be operated on battery or mains power; their status while *off* may vary depending on whether the device is mains-connected, and also whether the battery is present[12].

Automatic state changes. Automatic controls can change the power state, which is particularly a concern for transitions to and from *off*. This requires either avoiding switches (like most rockers) that mechanically show the power state, or utilize ones that can be physically moved by the device (some copiers use these).

4.3 Recommendations and Conclusions

The purpose of the standard is to provide a simple set of interface elements that are applied universally on products in a clear and consistent way. In concert with the User Interface Standard, the following recommendations get us closer to that goal.

Create a new symbol for non-zero-power off.

The present set of international standard symbols for power control lacks a workable designation for equipment that are functionally off but continue to draw some power (the ○ symbol is reserved for zero power). This would solve the problem of a rocker switch with a non-zero off. Unfortunately, at present there are no obvious candidates.

Specify that ⏻ means "power", and use it for power buttons and indicators.

This should be used to mean "power" on power controls — even if a power button goes to a *hard-off*, that should not introduce any safety issue. The symbol standard should be changed, but manufacturers need not wait for that to be finalized before using ⏻ for "power".

Only use rocker switches for power controls when off *is zero power,* and
Use push-button switches for power controls when off *is non-zero power.*

These recommendations get around the lack of a good symbol for soft-off.

Use caution with indicators when multiple power switches are used.

When a device has two power controls, or otherwise has a *hard-off* and *soft-off* mode, both will have the power indicator off. Only inspection or manipulation of the power switches will clarify which mode it is in. To avoid ambiguity, some devices have more than one power

[12] UPS (uninterruptible power supply) systems might also introduce similar ambiguity.

indicator to get around this, and some use a different color (e.g. red) to indicate *soft-off*, but both of these solutions are potentially confusing.

Use hard-off switches when possible.

Hard-off switches — labeled with ○ or ⦶ — have the advantage of eliminating “standby power”.

Appendix II — Insights from User Interface Literature[1]

1.1 Introduction

The following is a summary of ideas and concepts relevant to the Power Control Standard from recent literature on user interface design, supplemented by data from a few older ergonomic references[2]. The project workplan called for reviewing the literature for general principles that can be applied to power controls, and for specific references to power controls in the user interface literature. Since we found almost none of the latter, this discussion focuses on general principles and explores how they should be applied to power controls. Words that are underlined are significant concepts from one or more of the references. While the literature is oriented mostly to software design, many of the principles apply to hardware design as well. Paragraphs with the "➥" symbol are key conclusions for the standard.

The primary books reviewed are: *The Humane Interface* (Jef Raskin, 2000), *About Face* (Alan Cooper, 1995), *The Design of Everyday Things* (Don Norman), *The Art of Human-Computer Interface Design* (edited by Brenda Laurel, 1990), and *Bringing Design to Software* (Terry Winograd, 1996). In addition, more limited data were gleaned from: *Human Factors in Product Design* (Cushman and Rosenberg, 1991), and *Industrial Design in Engineering* (Flurscheim, 1983), and *Ergonomic Design for People at Work* (Eastman Kodak, 1983).

1.2 Bolstering the Rationale for The Standard

In the user interface literature, it is often noted that consistency (as via standards) is a good thing. This is primarily asserted within the context of a single hardware or software product, but also applies across products. Standards and consistency help develop habits. They allow for some tasks to be done unconsciously, to not interrupt the flow of thought; ideally, the interface disappears. There exist population stereotypes, which is the type of behavior that groups of people expect in objects; an example is the idea of "up" on a switch meaning on. A recent example of shaping such stereotypes is how cables are connected to PCs. People will be more successful in setting up peripheral products if the connectors and cables are labeled with standard icons, colors, and labels (Ease of Use Roundtable, 1999).

While each design problem could be solved in a different way, that would introduce much too much complexity. What is needed is a few solutions that effectively solve many problems (and doing this is hard).

When inconsistency exists, problems result. Examples include the danger of reversing car brake and accelerator pedals, or the controls on remotely-piloted model airplanes. Inconsistencies force a task to become conscious that needs to remain unconscious to be timely and avoid crashes. When indicators are lacking, people will make errors by acting in accord with the

[1] [1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

[2] Since this appendix was written, an interesting and valuable book was published: "User Interface Design for Electronic Appliances", edited by Konrad Baumann and Bruce Thomas, Taylor & Francis, 2001.

wrong mode (though the same problem can occur if people are not focused on the indicator even if it is present).

The idea of devices going to sleep was applauded by several authors, as was the functionality that "hibernate" provides.

In these ways and others, the design principles espoused in the literature confirm the motivations and goals that underpin the standard.

1.3 Relation to Past Designs

There is some merit to sticking with past designs, for consistency, but as the task becomes more common, the reasons to consider change increase. Cooper is more emphatic, stating that only minimal heed need be paid to past products; design should be all about the future; bad designs should not be maintained.

➥ For power controls, we should continue to use the most popular interface elements on current devices except in those cases in which it clearly causes confusion. The bar for changing design is higher for interface elements that are universal (as power controls are) than it is for software controls specific to a particular application.

1.4 Approach

For Raskin, an interface is "the way that you accomplish tasks with a product — what you do and how it responds", and it is "humane" if it is "responsive to human needs and considerate of human frailties". For the customer, the interface *is* the product.

For Cooper, one should start with the users goals, before considering specific tasks that implement these (though others say that task analysis is determining what people want to do which edges back to goals). As "few users are consciously aware of their goals", ferreting this out can be challenging, but is necessary.

It is critical to take the user's perspective during key parts of the design process; ideally this means asking or watching real users, but can also include exercises to place oneself in the user's stead and assessing a situation or design. **Designers are not typical users**. There may also be considerable variations among users, so that one needs to find what is common. Most authors believe in iterative design processes which include user testing as part of the review / redesign. For example, one listing of design stages is Product Definition, Research, Brainstorm, Generate Design Solutions, Analyze, Prototype, Test, Redesign, Implement. It is important to bring people from all disciplines into the design process. User Centered Design is the current preferred term for this overall approach.

➥ Writing the documentation in advance of creating the product is a key way to get better designs. To implement this, early on in the standards development process we created "Instructions for Powering your PC". In addition, a document should be prepared that outlines the goals and tasks that users bring to power controls, and a set of scenarios developed for different types of products, users, and use contexts.

A "population stereotype" refers to the fact that "people expect things to behave in certain ways when they are operating controls or when they are in certain environments". As an example of how these can vary, in many parts of the world such as the U.S., people expect a toggle switch for a light to turn *on* when pushed up; in the UK, a toggle switch is usually pushed down for *on* by convention.

1.5 Design Principles

As for general design principles, many authors applaud simplicity. Unnecessary complications tend to make interfaces more difficult to use. Another principle is to take advantage of affordances — this powerful idea recognizes the fact that some entities have natural actions one can take with them that are inherent and intuitive, as that a knob can be rotated, a toggle switch flipped, etc. When designing interfaces it is important to notice how often an action is taken, not just the fact that it is sometimes taken, so that rarely-used actions don't clutter up menus, or and don't rank before commonly used ones.

➥ The basic interface should be the simplest one which meets the needs of the majority of devices and users. There will be exceptions which require exceptions or complexity, but these will be relatively few.

It is critical to distinguish among several different concepts that can explain a product's operation (Cooper):

- The "Implementation Model" is the specific internal details of an application or product. For example, a hard disk drive is organized by pointers, sectors, and cylinders which the user need not have any awareness of.
- The "Conceptual Model" or "Mental Model", is what the user imagines is going on. In the disk example, it includes files being "inside" of folders or directories, which is not literally true.
- Possibly different from the user's model is the "Manifest Model" which is what the software or device actually shows to the user. This difference is possible because users may ignore or misunderstand (possibly for good reason) the manifest model. Another source refers to the "product's functional capability" for its actual operation.

There is no need to burden the user with internal details, and in fact in good design practice the user interface will be designed before the internals exist.

➥ A goal of the standard should be to make the manifest and mental models as consistent as possible, masking the various underlying implementation models. Hiding internal terminology is the most apparent aspect of this.

"An agent is accessible if a user can predict what it is likely to do in a given situation on the basis of its character" (Laurel, p363).

➥ While this refers to software agents, it does raise the question of whether devices which have or lack particular capabilities should indicate that in hardware or software (e.g. whether a device can go into a sleep mode). This also applies to wake events.

One author argues that the next leap in interface technology after the Graphical User Interface is cyberspace — a three-dimensional animated interface. This will be multi-sensory, and provide for and require additional types of interface elements.

➥ This suggests that power indicators for the cyberspace context will need to be developed. For example, as entities in cyberspace may have exteriors with more in common with human faces than they have with current control panels, then standard elements, behaviors (in sight, sound, etc.) that model power states will be needed.

1.6 Metaphor, etc.

The idea of metaphor is one of the more controversial in the user interface world. Cooper and some others believe they are bad; whatever initial benefit exists isn't worth the limitations and "dead weight" they impose. Others believe that using metaphors does not mean adhering to them slavishly; to some degree they are always present and it is just a matter of choosing them well and using them to the right degree. They can be "cognitive aids to users and … aids to creativity in designers" (Laurel). Metaphors can provide some structure, to hang ideas on, and lend themselves to representation, through sight or sound.

As metaphor is extended to entities which take action independently on behalf of users (e.g. software agents), anthropomorphism may be used. This is reasonable, as as with metaphor, it can be used selectively. Two aspects are present: "responsiveness" to wants, and "capacity to perform actions".

Raskin rejects the idea of an intuitive interface; rather, he believes they are all just familiar or habitual and thus feel intuitive.

Related to the idea of metaphor is the paradigm used to create the interface (Cooper). These include:

- Technology — which presents the "raw" internal implementation to the user;
- Metaphor — which uses an external reference to guide product design;
- Idioms — which are small, clever concepts; and
- Global — which imposes a single metaphor as much as possible (Cooper sees global metaphors as a form of insanity).

Another proposed alternative to metaphor is the "well thought out unifying idea".

➥ The ideas of "on" and "off" as well as the existing power symbols are entirely idiomatic. The metaphor of sleep and the moon symbol are used narrowly (extending the metaphor could suggest that a device that is on is "alive" or that one that is off is "dead", neither of which we are trying to do).

1.7 Modes

Another controversial idea is modes, in which a product responds very differently depending on which mode it is in (examples include early text editors with "insert" and "command" modes, and paint programs with modes such as draw, select, and zoom. Personalizing software (or hardware) can be seen as a form of a mode — usually not a visible or standard one — and so is not recommended. Some authors dislike modes intensely; others see them as reasonable when used appropriately.

One aspect of modes that is not popular is distinct "beginner" and "expert" modes which lead to different behavior. Most people will be intermediate users — neither beginners nor experts — and the design should be optimized for them. While programs should learn from user behavior, the interface should not be changing significantly based on this, but adapt subtlely. Programs and devices should be able to remember things and learn when appropriate.

One way to avoid mode problems is to not reuse commands between modes. One author asserts that when a physical action is required, mode problems disappear.

If mode indications are not familiar, they may be distracting.

➥ While some authors decry modes, they are inherent in power status — limiting the available capabilities of a product in *sleep* or *off* modes is required for the power reductions to occur. While utilizing modes for power status is unavoidable, limiting their number makes them less confusing.

1.8 Interaction/Transitions

Devices should go from *off* to fully functional in as little time as possible (to be appliance-like). Returning to the same state (hibernate) is also desirable. Confirmations that are routine become automatic and so lose their effectiveness. Confirming that a file save is OK to do when the previous version of the file is being replaced is an example of this. Similarly, explicit reporting that all is well is useless to do.

People take about 10 seconds to switch contexts, but when the perceive delays, any sort of sense stimulus can assuage annoyance, with sound a key example. When interruptions occur, people should be returned to the previous state.

Routine actions should be streamlined (e.g. don't report dramatically that nothing is wrong). Feedback can be key, particularly if there is any delay involved. "Progress indicators" should report how much longer a lengthy task (e.g. downloading a file) will take, and provide a way to cancel it. A "splash screen" (something with marginal content displayed when a device or application is started) must be displayed immediately after initiation.

➥ Turning a device on or off, or putting it to sleep or waking it up may all be lengthy and so require some sort of progress indicator — visual and / or auditory.

With windowing systems there is a question as to whether a mouse click that changes the focus to a new window (and possibly a new application) should be used *only* for that context switching, or also used as a regular click in the window. While there is merit to each argument, discarding them is the safer route. The same issue applies to input device events that wake a system up from a sleep mode.

Graying out menu items that aren't available is a useful tool.

➥ For common power management functions, this should be done so that the overall structure remains more consistent.

An "accelerator" is "an additional, optional way to invoke a function from the keyboard… usually with a function key". These should only be used for common actions, should be shown on menus as reminders, and should follow standards (e.g. control-C for copy, control-V for paste, etc.). Better standards for these are needed. Regardless, for common functions, multiple ways to do them should be implemented.

➥ An accelerator for *on/off* seems unnecessary, but a standard one for *sleep* may be appropriate for ease of use, and for devices which lack a dedicated sleep button. Some notebook computers use function keys for this, though the number of the function key varies from implementation to implementation. It might be worth having *sleep* or *off* functionality available by clicking on an icon on the screen, and / or on a pop-up menu easily available (e.g. by a right mouse click on Windows PCs).

1.9 Indicator Lights

When there is a known delay that the user will notice (such as from disk access, computation, etc.), it is essential to provide user feedback that the process is underway, and an indication of how far it is in the process or how much time remains. On current computers, this is accomplished by changing the cursor or providing a dialog box.

➥ The mechanism for providing such feedback is not appropriate for standardization, but the implementation of particular mechanisms may be. Text feedback can use the terminology identified in the standard. For graphic feedback (e.g. a changed cursor), there four relevant cases: turning on; turning off; waking up; and going to sleep.

Table 1 shows the defined associations for several colors from a few standards references[3]. IEC 73 specifies associations for “safety of persons or environment”, “condition of process”, and “state of equipment”; we combined the last two. While up to 10 colors can be readily distinguished, it is recommended to limit the number used to three. Color-blindness is said to affect 8% of males and 0.5% of females.

➥ The green / yellow / off color set seems to have no serious competition, as does the addition of red for errors / warnings. In addition, it seems prudent to reserve flashing for transitory states (transitions between basic power states) and / or for non-power-status information (e.g. receiving information, etc.). If flashing is used for transitions, then it is probably most important to show the state being entered which suggests flashing green for turning on or waking up, flashing yellow for going-to-sleep or turning off. Since red for an error doesn’t show the power state, then an alternating red with green or yellow could do both.

One source stated that flashing is said to be the best mechanism for implementing “warning lights”; another that "displays that blink … imply urgency and excitement". Good flash rates for warning lights are said to be 3 to 10 times per second, with a minimum on-time of 0.05 second.

➥ Flashing with the goal of getting attention as for errors should probably be faster than flashing for indicating state transitions.

---

[3] An interesting note about color standardization is the report that until 1927, traffic light colors were not standardized in the U.S. In addition to red, yellow, and green, they were purple, orange, and blue presumably with varying meaning as well. “In some states green meant *go*; in others *stop*”. NBSIR:87-3576: "The ABC's of Standards-related Activities In The United States"

Table 1. Ideas associated with selected colors

Color	IEC 73	British Standard 4099[a]	Widely held associations[a]	Population Stereotype[b]
Red	Emergency; faulty	Danger – alarm; action needed	Alarm, critical, disabled, emergency, failure, stop	Stop or danger
Yellow	Abnormal	Caution – impending change	Marginal condition (caution), standby	Caution
Green	Normal	Safety – proceed, equipment safe	Active, enable, normal, on, on-line, run	Go or on
Black	No specific meaning		Off	

Note. One source said that most commonly, audio / video recorders use red lights for recording, green for play, and yellow for pause. [a]From Flurscheim (1983). [b]From Eastman Kodak (1983).

1.10 Icons

A good icon is "visually distinct … [and does] a good job of representing the appropriate concept" (Raskin). Icons may not translate well across cultures. A "Graphic symbol" is usually "an abstract or arbitrary symbol without obvious meaning" as opposed to a "pictographic symbol" or "pictogram" which depict familiar objects. Research has shown that icons developed with the participation of typical users have better effectiveness than those developed by product designers alone. Solid shapes are preferred to those with outlines.

Icons can be derivative of a metaphor (to a greater or lesser extent), or idiomatic.

- ➥ The moon symbol should be made up of just two basic arcs, and solid rather than an outline. Angling the moon might help distinguish it from the left parenthesis "(".

One source (Flurscheim) states that "The preferred position for symbolic labels is *above* the associated mechanical / electrical elements", but this probably refers to control panels with many elements and so may not be relevant to power control elements that are more isolated.

1.11 A Cautionary Tale

A particularly relevant user interface discussion is one by Don Norman (in "Bringing Design to Software") about his effort to improve and standardize the treatment (placement and function) of the power switch on Apple Macintosh products. Practical concerns of design and especially organizational difficulties thwarted the effort.

While many aspects of the Macintosh software and hardware interfaces are consistent,

> "the lack of standardization of the power switch seems bizarre. Some machines have it in the front, others in the back. Some have toggle switches, others have pushbuttons. Some machines do not appear to have any power switch at all. Users continually have trouble finding the switches."

A particular problem was models which placed the switch away from the power indicator, in a place that a disk eject button might be expected to be found (Macs don't need such a button so don't have one). This caused many people to press the power button by accident, often losing their recent data.

Norman determined that no one in the organization was really responsible for the issue. Design generally was distributed among four divisions. The consumer division placed a priority on price; the notebook division on power conservation; and the server division on protecting the switch from accidental use. Other corporate goals came into play, such as localization for international markets, safety issues and regulations, and accessibility for the disabled.

A single solution was elusive, even though many recognized the value of one. The switch issue was further complicated as user's were supposed to normally turn the machine on with a keyboard switch (which wasn't also for turning off). The keyboard switch is itself instructive:

> "In our current models, the keyboard power-on keys are labeled with a left-facing triangle. Why? Because the symbol does not mean anything! The symbol used earlier (a vertical line inside a circle) was not permitted because the European standards authorities insisted that it was reserved for hard power switches. The triangle has no meaning, so it does not violate any standards. Few people — European or American — are confident about the meaning of the vertical bar and circle (on and off respectively), let alone a bar inside of a circle (a toggled on-off), or a vertical bar inside a broken circle (toggled soft power), but the European standards committee is strict."

He continues, "The final proposal had a soft power key on the keyboard, labeled "on / off" (translated … [as] appropriate)". Also, "A policy of indicator lights was established, so that a user could tell whether the machine was on, off, or in energy-saving mode." Also, holding the power key for five seconds would cause an emergency power down.

One of the many barriers in the organization to addressing this was that user interface design was perceived as a solely software domain, with hardware being limited to industrial design issues.

➥ One solution not available when the controversy was brewing is for the power switch to engage hibernation on the assumption that this is commonly used. A shutdown to the non-hibernate off mode could still be accomplished from a menu selection.

➥ The ISO and IEC are international organizations, but Norman's view of them as at least highly oriented to Europe is widespread in the U.S.

1.12 References

Raskin, Jef, The Humane Interface: New Directions for Designing Interactive Systems, Reading, MA: Addison-Wesley, 2000.

Cooper, Alan, About Face: The Essentials of User Interface Design, Foster City, CA: IDG Books, 1995.

Norman, Donald, The Design of Everyday Things, New York: Doubleday, 1990.

Laurel, Brenda (ed.), The Art of Human-Computer Interface Design, Cupertino, CA: Apple Computer, 1990.

Winograd, Terry (ed.), Bringing Design to Software, New York: ACM Press, 1996.

Cushman, William H., and Daniel J. Rosenberg, Human Factors in Product Design, New York: Elsevier, 1991.

Flurscheim, Charles H., Industrial Design in Engineering, London: The Design Council; New York: Springer Verlag, 1983.

Eastman Kodak, Ergonomic Design for People at Work, Rochester NY: Eastman Kodak, 1983.

IEC 1996. Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators. IEC 73. Draft, Geneva, Switzerland: International Electrotechnical Commission. 1996.

Appendix III — Accessibility of Power Controls[1]

Careful attention to accessibility was part of our original project plan, and also something that the Professional Advisory Committee repeatedly made clear that it was also a priority for them (the general topic, not just for power controls specifically). Too often in design processes, accessibility is considered long after the main design has occurred. We wanted to consider it concurrently, to provide feedback to the rest of the standard.

The premise of accessibility is that it is possible and desirable to facilitate the widest range of people to be able to readily engage in a given activity — to remove barriers to access that may arise from any number of disabilities. From the perspective of the Power Control User Interface Standard, greater accessibility of power controls facilitates more energy savings and greater consistency in user interfaces, and so is only a benefit. As the user interface standard is not mandatory, inclusion of accessibility provisions in the standard does not burden any product or manufacturer. So, as long as there are sound provisions available to make power controls more accessible in a standard way, they should be included.

Many discussions of accessibility note that measures taken for the purpose of accessibility often also have benefits for the majority population. One example is audio feedback during a state transition; this can be essential for the blind or those with limited sight, but can be useful for anyone when the device in question is out of view, or not being looked at directly. With the increasing portion of the population that is elderly, diminished faculties are an ever-growing reality.

Accessibility of power controls runs into challenging problems. For example, how should a device that is *off* indicate that state to someone who is blind, when audio feedback is the usual way to make devices more accessible to the blind?

1.0 Background

The most commonly addressed disabilities are inability or difficulty in: seeing, hearing, speaking, touching, manipulating, understanding, or combinations thereof. Similarly, Microsoft divides accessibility responses into the following areas: Hearing, Vision, Mobility, Language and Learning, Seizure Disorder, and "All"[2]. The greatest problem of accessibility of power controls is for the blind.

The U.S. federal government's efforts around accessibility were most recently (1998) spawned by Section 508 of the Rehabilitation Act. Section 508 standards are coordinated by "The Access Board" (officially the "Architectural And Transportation Barriers Compliance Board") which has an "Electronic and Information Technology Access Advisory Committee" (EITAAC). That committee made recommendations in May, 1999 which specified general areas of IT equipment operation that need to be accessible. The committee recommendations were the basis of a "notice of proposed rulemaking" of March 31, 2000 on "Electronic and Information Technology Accessibility Standards". The final rule was published in the Federal Register on December 21,

---

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

[2] http://www.microsoft.com/enable/products/chartwindows.htm.

2000 (36 CFR Part 1194, [Docket No. 2000-01], RIN 3014-AA25). No changes were made which particularly affected power controls, other than that "Products located in spaces frequented only by service personnel for maintenance, repair, or occasional monitoring of equipment" were exempted (1194.3 (f)). Specific requirements of this rule are addressed below.

Many organizations (standards and other) have policies on accessibility, but the vast majority of these make no specific mention of power controls. There are many general principles for accessible design; the Access Board specifications cover most of these as they affect power controls.

A standard is presently being developed on protocols for assistive devices by committee V2 on Information Technology Access Interfaces of INCITS (the InterNational Committee for Information Technology Standards (operating under the auspices of ITIC).

2.0 Approach

This project has not attempted to invent novel ways to design user interfaces generally, and accessibility is no exception. There are two types of results we sought:

- Insights from the accessibility literature generally that can be applied to power controls in a specific way (we are not attempting to simply repeat general advice), and
- Recommendations beyond that directly suggested by the literature.

We looked to two sources for inspiration: the accessibility community — which we accessed through is literature and members (government, academic, advocacy, and corporate) — and features included on current products.

We contacted *many* individuals that work in the area of accessibility to ask about what the user interface standard should include. Few had ever considered the question and specific recommendations were even scarcer. The one area where we were able to dig deeply into an accessibility issue is making power indicator lights accessible to the "color-deficient"; that is covered in Appendix IV.

3.0 Access Board Provisions

The Section 508 rules defines "Operable Controls" as specifically including on / off switches and buttons. No requirements are made of power controls specifically, but the following general specifications have some relevance to them.

"Color coding shall not be used as the only means of identifying a visual element". An example given is to avoid a web page that says something like "click the red square for more information", and simply adding text to the square makes it accessible. How this can be reconciled with power indicator lights is not clear, but the attention to color specifications should address much of the concern.

Flashing elements are not to have a frequency greater than 2 Hz to avoid triggering epileptic seizures in people sensitive to such phenomena. The flashing rates specified by IEC 73 include "normal flashing" as being permitted to be between 1.4 and 2.8 Hz. The Trace Center, in comments on the proposed Access Board rule, recommended 3 Hz as a better cutoff than 2 Hz.

When actions must be done within a certain time, that time be adjustable to five times the default. This is not intended to apply to long time periods such as typical delay times for devices to go to sleep, but rather to times on the order of a few seconds or less. The only part of power controls that operates in that timeframe for user action is the holding down of the power button for four or five seconds to cause a system reset (reboot).

Controls such as keys are to be distinguishable through touch, such as the marks on some keyboard keys and the layout of number pads. Power controls are generally separated from other ones to avoid accidental use, and in some cases (like rocker switches) are of unique form. However, tactile markings could reduce the ambiguity in locating power controls.

"Toggle controls" on a device are to indicate their status by both "visual means and by touch or sound". This suggests that standards should exist for what a depressed power button means, and for each possible transition (sleep buttons are always non-mechanical). By convention, a power switch is *on* when depressed, which unfortunately conflicts with the comonpopulation stereotype of down meaning *off*. A switch which remains depressed to indicate its state is problematic if the mode can be changed by means other than pressing the switch, such as automatic controls. One way around this is for the switch state to change automatically (some copiers move their on/off switch position when an auto-off transition occurs; others require that the switch be moved to off then back to on to turn it back on again).

"The use of an image will be consistent throughout an application". This probably refers to icons, but generally supports the assertion that a consistent user interface is better for any user.

System startup and restart need not be accessible. This derives from the statement that "The advisory committee also recommended that system startup and restart be accessible, however, the Board has not included that provision in the proposed rule since no measurable standards were recommended." The likely focus of this is the "boot-up" process of a PC; for practical and technical reasons, making these generally accessible (e.g. through audio) would be difficult.

Use ascending and descending tones to show that a switch is turned on or off. This provision was not described with power controls in mind, but could be readily extended to them. With power controls, there is also a *sleep* mode between *on* and *off* on many devices that should be included. In addressing the accessibility of power indicators to the blind, a guide from the Access Board notes that when a PC is *on* the fan is running, and when a disk is accessed it can be heard spinning.

4.0 Other Data Sources

Curtis Chong, Director of Technology for the National Federation of the Blind, provided several insights on the phone and in a paper (Chong, 1996). Some points of his aare already described under the Section 508 discussion and are not repeated in this section.

Many blind people use noise and vibration of PCs and other electronic devices to assess their power state. Manufacturers are trying to reduce or eliminate these signals so that they may be unavailable to the blind in future. Replacements for these (unintended but useful) indications are needed. A helpful facility for the blind is a "test button" which when pressed would indicate the current power state without changing it.

It is desirable to clearly identify power state transitions. One pattern to adopt could be a high tone for a transition to *on*, and a low tone for a transition to *off*. A variant of this is the convention adopted by elevators, which beep once for going up and twice for going down.

An important resource for accessibility generally is the Trace Research and Development Center at the University of Wisconsin. Among their publications we found several useful items. Raised lettering as on keys should be at least 1/32" in height (0.8 mm). Release times (e.g for pressing a key) that are less than 1.5 seconds can be problematic (thus, the 4-5 seconds typical for holding a power button to cause a system reset seems OK). A table of movement stereotypes shows for *On*: up, right, forward, clockwise, pull; and for *Off*: down, left, rearward, counterclockwise, push. *Raise* is up and back; *lower* is down and forward (there is thus an inconsistency on forward/back between *on* and *up*). The flicker cutoff that they recommend is no faster than 5 Hz.

5.0 Conclusions and Recommendations

Based on all this, we don't see a problem for accessibility with the user interface standard as it stands. It would be desirable if there were more ways for the standard to address accessibility, but we simply did not find them on products, or receive them as suggestions from qualified people. Specific conclusions are:

- Use the color specifications in Appendix IV to reduce green/yellow (and yellow/red) confusion among the color-deficient.
- Power controls should be identified with a raised "nib" as found on many "F", "J" and "5" keys. We did not find a mechanical specification of how these should be constructed other than one that they should be at least 1/32" (about 0.8 mm) high. Several existing products (at least one TV and a TV remote from a different manufacturer) use three nibs in a row on their power buttons, but in the absence of more compelling evidence, we recommend a single nib on a power button, or on the "on" side of a power rocker switch.
- Use movement stereotypes for *on* and *off*, particularly up and down respectively. This applies to the physical layout of rocker and toggle switches, and to terminology.
- Provide for <u>optional</u> audio transitions of power states, either with a rising or high tone for on, or a falling or low tone for off. If only simple tones are available, use one for going to *on*, two for going to *off*, or three for going to *sleep* (the first two from practice with elevators).

6.0 References

Chong, Curtis, "Commercial Technology for the Blind", The Braille Monitor, Publication Of The National Federation Of The Blind, June, 1996.

IEC 1996. Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators. IEC 73. Draft, Geneva, Switzerland: International Electrotechnical Commission. 1996.

Appendix IV — Power Indicator Colors and Accessibility[1]

1.1 Introduction

The Power Control User Interface Standard specifies color assignments for power states for indicator lights; the "power indicator" should be green for *on*, amber for *sleep*, and off for *off*. About 8%of the U.S. male and 0.5% of the female population has some form of color deficiency (what is colloquially called "color blindness"). It is important to understand the implications of the user interface standard on this population and consider alternatives. The Professional Advisory Committee specifically asked that we investigate power indicator colors and their impact on accessibility.

Among the reasons to choose the green / amber / off color assignment is consistency with traffic signal light colors, and with the international standard for indicators (IEC 73). While not a power state, when an error is to be indicated red should be used, so we included red in our review of color issues.

Many color-deficient people find green and yellow colors difficult to differentiate[2]. We have anecdotal evidence that some existing office equipment have green and yellow indicator lights not readily distinguishable by many color-deficient people (and specifications of some current bi-color LEDs confirm this). Choosing the right colors can largely eliminate the problem. Even people without color deficiency may benefit by being less likely to misinterpret indicators that are designed to be accessible to the color-deficient. This discussion provides background information to help product designers specify colors for accessibility.

While the term "amber" is often used in the context of power indicators, the traffic signal light literature uses "yellow", so we use that in the remainder of this discussion, except for when product literature uses amber specifically.

1.2 Color Metrics and Perception

Color science is an extremely complex field. It is possible to describe colors in many different ways, some of which depend on how the color is created (e.g. from a light source directly), reflected (as from a printed page), or shown on a computer display. Some descriptions are objective measures of the light itself (e.g. the peak wavelength), but others are keyed to knowledge about how a typical human eye perceives colors.

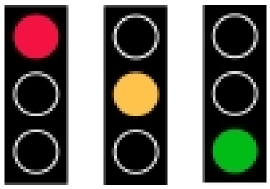
In this discussion, we review three primary measures of color: dominant wavelength (a single frequency — λ_d), CIE *xy* color coordinates (a pair of numbers), and RGB color components for computer monitors (a triad). Printing of colors as with CMYK systems is not addressed. The dominant wavelength is the pure color that will be perceived as closest to the LED color by a typical human eye. LED colors are usually specified by their dominant wavelength, and this is

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http: / / eetd.LBL.gov / Controls

[2] The most common form of color deficiency is "deuteranomalia", which is a partial loss of function of green receptors.

usually close to the peak wavelength. Color *xy* coordinates do not address the luminance (intensity) of the light — that would require a third coordinate. Two-dimensional color representations are essentially projections of a three-dimensional space onto two dimensions for convenience and ease of viewing. That such a large area of the CIExy chart (see Figure 1) is green is a combination of the peculiarities of this specific color projection, and how the human eye perceives color.

1.3 Traffic Signal Lights



User confusion with traffic signal lights presents safety issues with potentially deadly consequences. As a result, there has been considerable attention to how traffic lights are perceived by the color-deficient. In recent years, the lamps in many traffic signal lights have been converted to light emitting diodes (LEDs) due to their energy efficiency and lifetime advantages. With traffic lights and power indicators on electronics sharing the same underlying technology and the same key colors, we should look to traffic signals for guidance on how to address color specification for power indicators.

There are two recent studies on traffic lights and color deficiency, one from Europe (CIE, 1994) and one from the U.S. (Freedman, 2001). Both the CIE (International Commission on Illumination) and U.S.-based ITE (Institute of Transportation Engineers) had earlier specified limits for the allowed colors of traffic signal lights; the new studies updated these limits. The recommendations from the two recent studies are not significantly different from the power indicator perspective.

Traffic signal lights are viewed in a significantly different context than office equipment and consumer electronics. They may be viewed from a distance or (relatively) close; there might be bright sun from any direction, or no sun (night); and there can be fog or other impediments to clear viewing. Power indicators, by contrast, are mostly viewed indoors, and mostly under artificial light. Thus, the best limits for power indicator colors may differ modestly from those appropriate for traffic signals, but in the absence of other testing (and none is likely anytime soon), the traffic light recommendations are the best substitute.

1.4 Traffic Light and LED Colors

Figure 1 shows two CIE color charts. On the left chart are placed the color limits specified by the CIE traffic signal light study. Note that the yellow and red regions are at the periphery of the chart (highly saturated). Since LEDs are also highly saturated, we reduced our analysis to the points of these regions along the edge. These points can be described by their *xy* coordinates, their frequency of light (for fully saturated colors), or a RGB combination for rendition on a computer monitor.

The ENERGY STAR specifications for LED traffic lights are based on the 1985 ITE standard. This is fairly close to the CIE standard (as evaluated by (Freedman, 2001)).

Most power indicators are LEDs, so it is worth knowing what LED manufacturers produce and how they characterize the colors. The following is drawn from a sample of current product specification sheets. As expected, LED traffic signal light products use colors within the CIE ranges, but LEDs for non-traffic signal applications use much wider ranges, particularly for green.

In (HP, 1977) it is noted that "a *yellow* LED [585 *nm*] is *yellowish-orange* and a *green* LED [572 *nm*] is actually *greenish-yellow*". This was written in 1977 when color choices for LEDs were more limited, but many LEDs sold today match this pattern.

Green

The limit in the CIE recommendations is 498 to 508 *nm*. Green LEDs sold by Agilent range widely, at least from 505 to 572 *nm* — the latter in a bi-color LED with yellow only as far away as 586. LEDs for traffic signal lights are usually 505 *nm* (e.g. Dialight). Luxeon / Lumileds calls a 505 *nm* LED "cyan", and sells a 530 *nm* LED called "green".

Manufacturers should clearly pay attention to specifying greens in the CIE color range (at the blue end of the green range).

Yellow

The CIE specification for yellow traffic lights is from 585 to 593 *nm*. The 1931 CIE color chart defines *yellow* as about 575 to 580 *nm*; the traffic light colors span the middle of *yellowish-orange* to the early part of the *orange* space; thus, a yellow traffic light is more orange than yellow. Agilent sells yellow at 586 *nm*; Dialight at 590 *nm*. Luxeon / Lumileds calls a 590 *nm* LED "Amber".

Regarding traffic signals, the "pedestrian orange" color (CIE) is 595 to 610 *nm*. For yellow, there are variants on the upper end of the yellow range, for particularly high or low illuminance. In the absence of better information, we used the normal illuminance value.

Red

Red in the traffic signal specification ranges from 615 to 705 *nm*.

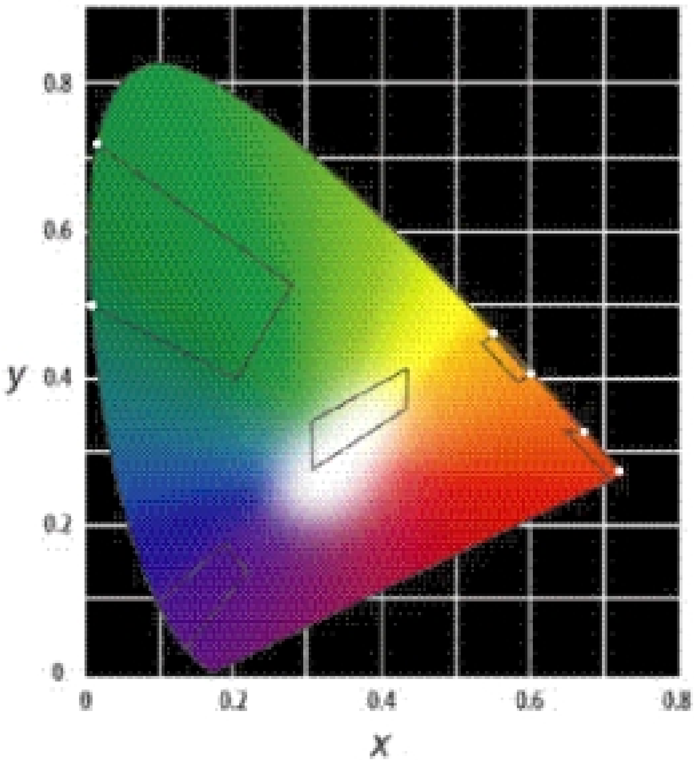
1.5 RGB Colors

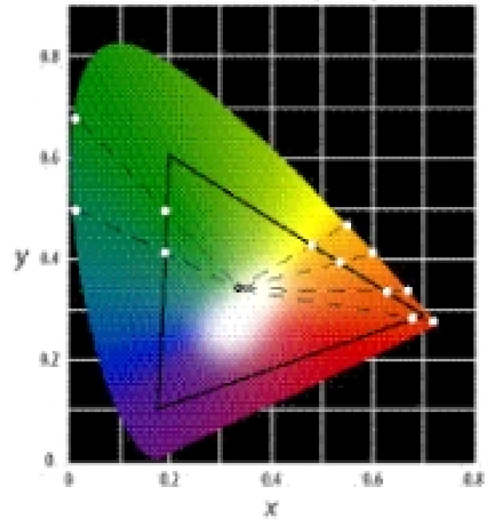
Red-Green-Blue (RGB) colors will be used on power indicators shown on computer displays. An example is a list of printer icons, that might include the power indicator color to communicate each printer's power state. Power control panels for setting delay times and shutdown dialog boxes may also benefit from use the power state color assignments.

Computer monitors can only show a portion of the full color space, so RGB values for them are for the closest approximation that a particular display can show. The RGB values presented here are for a typical CRT. Figure 1 shows how pure colors are projected on to a CRT gamut (the triangle on the right side).

That the green colors appear slightly bluish is to be expected; this helps maintain maximum differentiability from the yellow for those who have trouble distinguishing them. This color chart is adapted from one available on the Adobe, Inc. web site. As shown here it may not be quantitatively precise, but is sufficiently good for illustrative purposes.

Figure 1. CIEXYZ color chart annotated with CIE traffic signal light limits.





	G min	G max	Y min	Y max	R min	R max
x	0.012	0.009	0.545	0.592	0.680	0.735
y	0.494	0.720	0.454	0.407	0.320	0.265
nm	498	508	585	593	615	705

1.6 Web colors

Another set of colors are the 216 standard "web colors" often used on web browsers. These are derived by combining each of six different intensities each of red, green, and blue in every possible combination. In HTML, colors can be expressed as `RRGGBB` hexadecimal numbers (each digit in the range 0..9 or A..F) to represent a range of 0 to 255 for each color (in some cases we list two web colors when the range limit falls between two color). The green range spans from `00FF99` to `00FF33` (a 3-color range); yellow from `FF9900`/`FFCC00` to `FF6600`/`FF9900` (only one color clearly within the range); and red from `FF3300` to `FF0000` (two colors).

1.7 Recommendations

In summary, we found no technical obstacles to making power indicators more accessible to the color-deficient, and found sound technical basis for specific color limits to utilize. We recommend that designers of future electronic products (and by extension to those who manufacture and market LEDs used for power indicators) use the color limits specified in Figure 1. For LEDs, these are 498 to 508 *nm* for green, 585 to 593 *nm* for yellow, and 615 to 705 *nm* for red.

1.8 References

Clear, Robert, personal communications, July 2002 through November, 2002.

IEC 1996. Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators. IEC 73. Draft, Geneva, Switzerland: International Electrotechnical Commission. 1996.

CIE (International Commission on Illumination), "Review of the official recommendations of the CIE for the colours of signal lights", Technical Report CIE 107-1994, Vienna, Austria, 1994.

Freedman, Mark, "Visibility Performance Requirements for Vehicular Traffic Signals: Revised Final Report", prepared for the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, by Westat, Inc., Rockville, MD, 2001.

Hewlett-Packard Company, Optoelectronics Applications Manual, New York:McGraw Hill, 1977.

Appendix V — Standards[1]

1.0 Introduction

This appendix reviews the standards and standards committees that are relevant to the Power Control User Interface Standard. As the documents and committees continuously evolve, this is necessarily a snapshot, as of the end of 2002. This topic was first addressed early in the development process for the User Interface Standard (Nordman, 2000a).

The existing relevant standards and committees fall into several categories: graphical symbols, energy consumption and safety, indicators, ergonomics and usability, accessibility, and terminology. The majority of the relevant standards and committees are international. The national committees cited here are all based in the United States. An increasing number of standards are defined by industry consortia rather than through traditional standards organizations.

The topics covered by the user interface standard do not fall cleanly into the existing work areas of any single existing standards committee. This is because existing committees and standards cover only a single interface element in isolation, or provide only vague, general principles for user interface design. In contrast, the Power Control User Interface Standard presents a specific and coherent system of all of the elements with clear correspondences among them.

The user interface standard as proposed requires creating a new standard graphical symbol for "sleep" — ☾ —and changing the definition of the "standby" symbol — ⏻ — to mean primarily "power" while retaining its meaning that the *off* condition is not a zero-power *off*.

1.1 International Standards Bodies

The two international standards organizations most relevant to the user interface standard are the International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC). The ISO and IEC also have a joint body — Joint Technical Committee 1 (JTC1) on Information Technology. Each of these entities has an extensive tree of technical committees, subcommittees, and working groups. In some cases, there are joint working groups created to coordinate topics that span more than one committee, along with extensive networks of individual liaisons between committees.

1.2 U.S. National Standards Bodies

ANSI, the American National Standards Institute, coordinates most U.S. standards efforts, and often serves as a conduit for relations with international committees. For example, for JTC1, the U.S. JTC 1 TAG reports to JTC 1 through ANSI. The U.S. National Committee of the IEC operates under the auspices of ANSI. A national committee that corresponds to an international committee is called a "TAG" (Technical Advisory Group).

---

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

2.0 Standards and Standards Committees

2.1 Graphical Symbols

The most important symbol standard for power control is IEC 60417: Graphical Symbols For Use On Equipment (IEC, 1998). IEC 60417 was originally published in 1973 and updated frequently since, including in 1997. More recently (the latter part of 2002), it has been converted to an electronic database format so that it can be updated continuously.

IEC 60417 defines over 600 symbols, the great majority of which have nothing to do with energy use or power control. A modest number have something to do with office equipment and consumer electronics, such as those for audio or video controls. The key power control symbols, I, ◯, ⏼, and ⏻, all reside in IEC 60417, as do their variants for "part of equipment" and "remote station". The core power symbols were all present in the first edition of IEC 417 (as it was previously called), in 1973.

IEC 60417 is the responsibility of TC 3/SC 3C — Graphical Symbols For Use On Equipment, which is a subcommittee of TC 3: Documentation and Graphical Symbols. The United States is not a member of TC 3 or SC 3C[2]. In fact, no country in the western hemisphere is a member of SC 3C.

A second collection of graphical symbols is ISO 7000: Graphical Symbols For Use On Equipment (ISO, 1989). ISO 7000 covers a similarly wide range of symbols as IEC 60417, though the IEC symbols are more oriented towards electrical, electronic, and medical equipment, and the ISO symbols include many designed for industrial equipment (e.g. handling cloth). The fact that symbols reside in one standard or the other is not always obvious, such as that most of those related to copiers are in the ISO standard[3]. The two symbols from ISO 7000 that are commonly found on power controls are Ready — ◡ — and Electric Energy — ⊕. Symbols for "manual control", "remote control", and "battery charging" are in ISO 7000, but are generally not found on office equipment or consumer electronics.

Responsibility for ISO 7000 lies with TC 145: Graphical Symbols, and specifically TC 145/SC 3 Graphical Symbols For Use On Equipment. The U.S. is a member of SC 3, and in fact holds the chair. However TC 145/SC 3 serves a registration and coordination function and generally does not originate symbols itself.

The symbols relevant to office equipment from IEC 60417 and ISO 7000 are collected into a third document, ISO/IEC 13251: Information Technology — Collective Standard — Graphical Symbols For Office Equipment (ISO / IEC 2000). As this is a joint document, it was prepared by a JTC1 committee, SC 35: User Interfaces (WG 3: Graphical symbols).

IEC 80416-1: Basic Principles For Graphical Symbols For Use On Equipment — Part 1 Creation of graphical symbols (IEC, 2000) provides guidance on creating graphical symbols. IEC 80416-1 contains a pattern (a set of grid lines) upon which symbol originals are to be designed, and specific instructions for how to do this (another document of this type is ISO 3461: General Principles For The Creation Of Graphical Symbols). A second part of this standard, IEC 80416-3 Basic principles for graphical symbols for use on equipment — Part 3: Guidelines for the application of graphical symbols (IEC 2002), specifies how symbol originals can be adapted for use on products.

[2] The U.S. is a member of SC 3D on Data Sets For Libraries, but that is not relevant to the User Interface Standard.

[3] One possible explanation is that as copiers were originally more mechanical than electrical.

Examples of application guidance for symbols are that line thickness can be changed, that outlined spaces can be filled in, and that color should be avoided unless where necessary.

The crescent moon symbol proposed in the User Interface Standard was designed in accordance with IEC 80416-1.

With several different committees working in essentially the same territory, coordination is vital, and so there is a Joint Working Group (JWG 11) combining members of IEC SC 3C and ISO TC 145.

SC 3C operates under Annex J of IEC Supplement to ISO/IEC Directives (Ed. 4: 2001). Annex J specifies the method to specify a new graphical symbol. A proposal can come from SC 3C itself (in the process of maintaining IEC 60417), from a technical committee, or from a "national committee … with technical committee liaison". A new symbol is part of 60417, not a new standard, so does not require "new work item" paperwork.

Normally, proposals for a committee originate in a member country's TAG, but as the U.S. is not part of SC 3C, that is not possible. There are related committees such as for medical products (TC 62), appliances (TC 59), and audio / video / multimedia equipment (TC 100).

2.1.1 Other Symbol Standards/Committees

IEC 11581 Icon Symbols and Functions is for those symbols used on displays. None of the existing symbols are specific to power status or management. Some general symbols such as a clock symbol are likely to be needed for future power control panels.

ISO 9186, Graphical Symbols — Test methods for judged comprehensibility and for comprehension (ISO 2001a) specifies procedures to be used in advance of establishing international standard symbols. Some of the principles can be extended to the other interface elements. This standard is further addressed in Appendix VII on Testing.

IEC 61592: Household Electrical Appliances – Guidelines for consumer panel testing does not mention power controls specifically, but supports the idea of improved user interfaces. The panels of people to test devices are to be diverse on many criteria, and topics to address include "aspects that can be evaluated" as "legibility, visibility and comprehensibility of indications" and "simplicity of use of control panel and programming". IEC 61592 references other publications: ISO/IEC 37 (1995) and ISO/IEC Guide 37, both entitled Instructions for use of products of consumer interest and ISO/IEC Guide 71, Guidelines for standards developers to address the needs of older persons and persons with disabilities.

For the U.S., ANSI Z535 specifies safety signs, symbols, and colors but contains no power symbols. Several Underwriters Laboratories (UL) standards replicate the brief symbol specifications of the IEC safety standards. We believe that there is no U.S. national standard that addresses power controls[4], and this was confirmed by an authoritative source (Peckham, 2002).

[4] The exception is the safety standards that refer in passing to the basic power control symbols.

2.2 Energy Consumption and Safety

IEC TC 108 on Safety Of Electronic Equipment Within The Field Of Audio/Video, Information Technology And Communication Technology is primarily concerned with safety issues. It is presently addressing energy consumption through a draft standard IEC 62018 on Power Consumption of Information Technology Equipment: Measurement Methods. TC 108 was created out of the merger of two previous committees: TC 74 on IT Equipment and TC 92 on Audio / Video Equipment.

The energy work of TC 108 has not addressed user interface issues, though power modes are specified for technical measurement purposes: two “energy saving modes” and a “full-on mode”. TC 108 is responsible for IEC 60950, Information technology equipment — Safety: Part 1: General requirements which in passing notes that ⏼ is for a mains disconnect and ⏻ is for controls that do not accomplish a mains disconnect. TC 108 is not concerned with the user interface beyond this narrow issue.

IEC TC 59 on Performance of household electrical appliances is creating a standard IEC 62301 on “Measurement of Standby Power” (IEC, 2002a). While IEC 62301 was designed initially for appliances, it was crafted so as to applicable to a much wider range of devices. The “standby mode” is the long-term stable mode in which the device consumes the minimum power of all such modes while still being connected to mains power. As such, this could be an *on*, *sleep*, or *off* mode, depending on the device and its design. For example, a telephone answering machine might have its normal *on* mode as the standby mode; a television may be effectively in a *sleep* mode in its minimum power mode (still being able to be turned on by a remote control); and computer monitors are in their *off* mode while in “standby”. As such, “standby” is a power level and not a specific operating or power mode.

Safety issues inevitably cross paths with power controls. In general, the concern for safety and power is how to label switches to communicate the way to completely disconnect power in an emergency. As such, ○ and ⏼ are safety symbols since they imply a mains disconnect, but the ⏻ symbol is not. Safety during servicing of devices is of lower concern, since one can simply unplug a device before opening the chassis.

UL 6500, Audio/Video and Musical Instrument Apparatus for Household, Commercial, and Similar General Use is the UL version of IEC 60065, Audio, video and similar electronic apparatus — Safety requirements. UL 6500 states that “graphical symbols shall be in accordance with IEC 60417 and ISO 7000 as appropriate”.

UL 60950, Safety of Information Technology Equipment is the U.S. version of IEC 60950, Information technology equipment — Safety: Part 1: General requirements. IEC 60950 states that “symbols shall conform with ISO 7000 and IEC 60417-1 where appropriate symbols exist”. The use of colors is to be in accordance with IEC 60073 when safety is involved. When safety is **not** involved, any color can be used (including red) for “functional controls or indicators”. The I, ○, ⏼, and ⏻ symbols are specifically mentioned, with the latter only clarified to its meaning as “A ‘stand-by’ condition”. IEC 60950 also mentions indicators, stating that “where safety is involved, … indicators shall comply with IEC 60073” but that otherwise they need not. This is indirect evidence that manufacturers of consumer electronics do not see power indicators for those devices as having safety implications since so many are red.

2.3 Indicators

The key indicator standard is IEC 60073: Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators (IEC 1996). It includes specifications for color assignments, audio indications, and flashing rates.

The User Interface Standard is consistent with IEC 60073, but it would be helpful for IEC 60073 to refer specifically to power indicators.

2.4 Ergonomics/Usability

IEC 447: Man-machine interface (MMI) — Actuating principles (IEC, 1993) provides many basic principles for user interface design. It notes that devices have both "normal" and "error" conditions that need to be considered. A power switch or button is an "actuator". A "stop" action is to have priority over "start". While this makes sense for mechanical devices for which being able to stop is a safety issue, for IT equipment, the more likely risk is data loss from accidental use of stop, so that the priority action should probably be the reverse. Effects of actuators are of three types: increasing, decreasing, and other. It seems clear that for power controls, the application of this is for "higher" power states to be caused by an increasing actuator, and lower states by decreasing actuators. Increasing is to be to the right, up, clockwise, and "away from the operator" (with one exception). The standard specifies basic principles for visual, audible, and tactile indications, but none of these have obvious implications for power controls.

ISO 9241-1, Ergonomic requirements for office work with visual display terminals (VDTs) — Part 1: General introduction and ISO 9241-10, Ergonomic requirements for office work with visual display terminals (VDTs) — Part 10: Dialogue principles provide general guidance on principles for designing interaction scenarios with software systems, though many of the principles can also apply to hardware. These do not mention power controls specifically, and the content that does apply is consistent with and reiterates the design principles discussed in Appendix II, the Literature Review.

A U.S. military standard (MIL-STD-1472F) on Human Engineering makes reference to indicator lights, LEDs, and controls, but makes only minor references to power indicators and controls specifically. A display that is *off* can signal that fact by being entirely off and not generally require an active indicator. Volume and power controls are not to be combined generally. Color associations are standard, such as that red is for an error, yellow for a "marginal condition" or "caution" or "unexpected delay"; and green is for "ready". Flashing is only to be used with red for an emergency condition. Some of these specifications are derived from aviation standards.

2.5 Accessibility

There are many committees, national and international, that address issues of accessibility for the disabled in one respect or another. Most of these don't have power controls within their purview or scope of interest. One exception is INCITS V2 on "Information Technology Access Interfaces". This committee is creating a protocol for communicating between electronic devices and "access devices" that are brought to the electronic device by people with disabilities. These access devices can deliver a user interface in the form best suited to the individual, be it graphic, auditory, or tactile. The protocol describes the interface abstractly and does not need to know the details of the access device. The protocol is in development, but using power controls as an example is presently under consideration. INCITS (www.incits.org) is sponsored by ITI.

2.6 Terminology

The area of terminology is generally used in standards circles to include only terms used for technical purposes, not those terms used by ordinary people. As such, the topic is only marginally related to the User Interface Standard, though it is advantageous for internal and user terminology to be consistent. The committees responsible for terminology are ISO TC 37: Terminology (principles and coordination), and IEC TC 1: Terminology. The latter includes in its charter to "determine the equivalence of the terms used in the different languages", and the translation of technical terms to other languages may be helpful to the translation of terms for general use.

The IEEE Dictionary (1996) defines terms peripherally related to power controls. In the dictionary, a "state" is a "condition" and a "mode" is "an operating condition … of the system". Power terms included are all internal terminology that would not rise to the level of the user interface. Terms such as "on", "off", "sleep", "low-power" and the key colors are not defined.

3.0 References

ISO / IEC 2000. Collective Standard: Graphical symbols for office equipment. ISO / IEC 13251. First Edition, Geneva, Switzerland: International Organization for Standardization and International Electrotechnical Commission. 2000.

IEC 1998. Graphical symbols for use on equipment. IEC 60417. First Edition, Geneva, Switzerland: International Electrotechnical Commission. Part 1: Overview and application; Part 2: Symbol originals. 1998.

ISO 1989. Graphical symbols for use on equipment: Index and synopsis. ISO 7000. Second Edition, Geneva, Switzerland: International Organization for Standardization. 1989.

ISO 2001a. Graphical symbols — Test methods for judged comprehensibility and for comprehension. ISO 9186. Second Edition, Geneva, Switzerland: International Organization for Standardization. 2001.

IEC 2002a. Power consumption of information technology equipment — measurement methods. IEC 62018. Draft, Geneva, Switzerland: International Electrotechnical Commission. 2002.

IEC 2002b. Household electrical appliances — Measurement of Standby Power. IEC 62301. Draft, Geneva, Switzerland: International Electrotechnical Commission. 2002.

IEC 2001. Basic principals for graphical symbols for use on equipment — Part 1: Creation of symbol original. IEC 80416-1. Draft, Geneva, Switzerland: International Electrotechnical Commission. 2001.

IEC 2002c. Basic principals for graphical symbols for use on equipment — Part 3: Guidelines for the application of graphical symbols. IEC 80416-3. Geneva, Switzerland: International Electrotechnical Commission. 2002.

ISO 2001b. Ergonomic requirements for office work with visual display terminals (VDTs) — Part 10: Dialogue principles. ISO 9241-10. Second Edition, Geneva, Switzerland: International Organization for Standardization. 2001.

ISO 1996. Ergonomic requirements for office work with visual display terminals (VDTs) — Part 1: General introduction. ISO 9241-1. First Edition, Geneva, Switzerland: International Organization for Standardization. 2001.

IEC 1996. Basic and safety principles for man-machine interface, marking and identification — Coding principles for indication devices and actuators. IEC 73. Draft, Geneva, Switzerland: International Electrotechnical Commission. 1996.

IEC 1993. Man-machine interface (MMI) — Actuating principles. IEC 447, Second Edition. Geneva, Switzerland: International Electrotechnical Commission. 1993.

Compaq, Intel, Microsoft, Phoenix Tech., and Toshiba. 2000. Advanced Configuration and Power Interface Specification: Revision 2.0. [http://www.acpi.info]. 2000.

Nordman 2002a. Who is involved in Power Management Controls? The "Institutional Review" for the Power Management Controls Project. http://eetd.LBL.gov/Controls/publications/reviewdec00.pdf

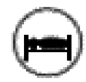
U.S. Department of Defense, 1999. "Department of Defense Design Criteria Standard: Human Engineering". MIL-STD-1472F. August, 1999.

Peckham, Geoffrey. 2002. Personal Communication. Hazard Communications Systems, Inc. November 11, 2002.

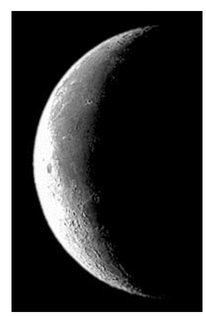
Appendix VI — Sleep Symbols, the Crescent Moon, and Islam[1]

A key element of the interface standard is to use the metaphor of devices being *asleep* when in low-power modes. Terminology related to sleep needs to be translated into the language(s) used for each product market. The standard further specifies that the graphic symbol for sleep should be a crescent moon (e.g. on a sleep button or software control panel). One reason to choose the moon is that it is already the most common symbol used for sleep on office equipment, but there are other advantages as well. This discussion reviews some of the reasons for choosing the crescent moon, the relationship of the crescent moon to Islam, and implementation details for the moon symbol, including a proposed standard design. This document is intended primarily for members of standards committees and product designers.

1.0 The Moon as a Sleep Symbol



Common graphic associations[2] with the idea of "sleep" in the U.S. include a bed, multiple letter "Z"s, and the moon (for its more prominent appearance at night). The bed has the disadvantage of being associated with a person going to sleep, which seems inappropriate for use on electronics. "Zzzz" incorporates the roman alphabet, and letters and numbers are to be avoided in graphic symbols — though it is used most commonly on some PCs made for sale in Japan and on a few models sold in the U.S. Of these three symbols, the moon is the most abstract, simplest to draw, and something that any sighted person can experience. All of these reasons and others presumably led so many product designers to "reach for the moon" when choosing a sleep icon. That sleep is such a good metaphor and has such a solid graphic representation is one of the reasons to choose it to represent low-power modes.



Once the moon is chosen, the question becomes "which moon?". Usage on existing office equipment is most commonly the crescent moon as it is the most obviously "moonlike"[3]. Another consideration is whether a proposed moon symbol closely resembles an existing graphical symbol. There are two international standards which specify graphic symbols to be used on office equipment — (IEC, 1998) and (ISO, 1989). A *full moon* looks like any circle (and much like the IEC "Off" symbol — ○). The *new moon* is blank. A *quarter moon* is already used in international standard symbols: ◖ is "light", ◗ is "dark" and ◑ is "contrast" (Symbol numbers ISO 7000-2165, ISO 7000-2166 and IEC 60417-5057 respectively). There is a potential similarity of the crescent moon to the telephone symbol — ✆ (IEC 60417-5090) if the moon is tilted 45 degrees (though as fewer phone handsets are the

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

[2] See the user testing done for this project (Appendix VII), specifically, the first UCB study for an assessment of associations with "sleep".

[3] The moon has other minor associations, many of them culturally dependent. For example, in the U.S. at least there is the idea of the "Man in the moon", and a crescent moon was used on many outhouse doors. Also, the moon has an association with mental illness ("lunatic") and for years some people proclaimed that the old Proctor and Gamble "moon" corporate symbol had associations with the devil.

traditional shape, perhaps that symbol will ultimately be changed). For precisely drawing international graphic symbols, IEC 80416 (Part 1) specifies details such as a how to construct symbol originals precisely. Designs are to be “simple”, “readily distinguishable”, “easily associated with its intended meaning”, and easily adapted to “usual manufacturing and reproduction methods”.

There are a variety of graphic options in depicting a crescent moon.

- **Fill**: Few if any moon symbols on equipment depict craters on the moon — most use an outline or solid fill. In any case, good symbol design avoids detailed articulation as craters would require. IEC 80416 specifies that differences in meaning depending on fill status are to be avoided when possible, and due to the way symbols are printed or embossed on devices, this is a wise criterion. Both filled and unfilled moons should be seen as equally correct.

- **Points**: The angular distance between the points of the crescent, going around the moon, is in principle, always 180 degrees for the real moon. Some graphic representations use somewhat less, and some (particularly in Islam; see Figure 1) use much more, as much as a full 360 degrees.

- **Direction**: Facing the equator in the northern hemisphere, the crescent moon opens to the left as it waxes, and to the right as it wanes. In the southern hemisphere, the directions are reversed. Astronomical symbology uses the left-facing moon —◗. Most Islamic flags use the right-facing version (more on this below).

- **Tilt**: Some crescent moon symbols have the points in a vertical line; others are at an angle, usually with the crescent opening slightly up. A slight tilt seems pleasing to the eye, and helps to differentiate it from the ☾ symbol (but not tilted so much as to confuse it with ✆).

- **Exposure**: A quarter moon shows half of the moon surface exposed. A crescent moon is defined as anything greater than a new moon and less than a quarter moon. An obvious extension of the quarter moon showing one half the surface is to have the crescent moon show one fourth of the surface.

- **Stars**: Depictions of the moon can have one or more stars adjacent to it, either all around or at one side. Islamic flags often depict a star in front of the moon.

In evaluating the suitability of a symbol, ISO 9186 specifies ways to test graphic symbols for “comprehensibility and comprehension”. In testing comprehensibility, subjects are provided with the symbol and its intended meaning and asked what portion of the population they think will correctly understand it. For comprehension, people are presented with the symbol and asked what they think it means. The standard also defines the “referent” as the “idea or object” to be represented. Testing is to be done in two or three countries.

2.0 The Crescent Moon — the "Hilãl"[4]

One question which arises in considering a moon as the symbol for sleep is whether it has any associations which would call its suitability into question. The principal one we have considered is the association with Islam — whether people of Islamic faith would be offended. In the United States generally (and presumably the rest of the industrialized west), the association does not cause any significant concern, which is demonstrated by the use of the moon on many computer products, in hardware and software. The primary question then is how it is seen from countries where Islam is dominant.

The "hilãl" is the "crescent moon" or new moon symbol, often shown with one or more stars. It is important as many events in the Islamic calendar are determined by the first sighting of the crescent moon as it waxes (begins to increase in size). When a hilãl is shown with a single star, that "star" is the planet Venus, the "morning star". The hilãl's association with Islam is not original, but has grown over the last few centuries.

The "Encyclopædia of Islam" (Lewis et al., 1971) reviews historical use of the hilãl in art / décor, flags, and buildings, all in considerable detail. The first reported use of the crescent moon is on coins in the year 695 A.D. (year 75 in the Islamic calendar), in combination with a star. From the beginning, it was often quite stylized with the two points of the moon nearly or actually touching each other. In addition to coins and artwork, the hilãl has been sometimes used on top of mosques, in the way that a Christian cross is used on churches. However, the use of hilãl on mosques is not as universal as the cross's use on churches and cathedrals, and the hilãl has also been put atop non-religious buildings as well.

The hilãl is reported to be used on military flags beginning in the 15th century. Modern nations began using it on national flags beginning in the early 1800s with the Ottoman Empire / Turkey, Tunisia, and Egypt. In the 1900s, other countries adopted it as part of their flags, such as Pakistan in 1947.

2.1 Modern Flags Incorporating The Hilãl

Quite a few countries use a crescent moon on their national flag, as shown in Figure 1. Most Islamic flags use the right-facing crescent, even though it is to symbolize the first sighting of the waxing crescent, which would be left-facing as facing the equator in the northern hemisphere. One possibility for this seeming anomaly is that the goal of having the moon face away from the flag hoist (flag depictions by convention have the hoist on the left) was a higher priority than astronomical correctness and northern hemisphere bias.

Most of the flags in Figure 1 have some moving of the points past 180 degrees, with Turkey's (the oldest) the most stylized. All but one have one or more stars, and all but two have five-pointed stars (this last point is significant in Islam). Most have the points aligned vertically, and only two resemble the crescent moon for power controls — Pakistan's, though it has a prominent star on top of the moon, and Maldives, which has the points in a vertical line.

---

[4] The word "hilal" is supposed to have a long bar "-" on top of the "a", not the tilde as shown here.

Figure 1. Crescent moons on National Flags as of 2002

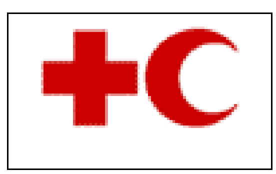
Source: The CIA "World Factbook 2001" http://www.cia.gov/cia/publications/factbook/ Accessed April 2002
Note: For those with monochrome copies of this discussion, green is the most common color of the flag fields, with red the second. Most of the moons are white with two yellow and two red.

2.2 The Red Crescent

The "Red Crescent" is used in place of the Red Cross as the basic medical relief symbol in dominantly Islamic countries. It has its origin in the Ottoman Empire, shortly after the Red Cross began to be used by European wartime medical relief services. While many in the Red Cross movement insist that the Red Cross is not a Christian cross, the perception that it is remains strong despite many attempts to unify the movement around the Red Cross (or some other symbol). Thus, the dual emblems remain[5], and are shown in Figure 2.

While the documentation of the origins of the Red Cross symbol is scant, it is not intended to be a religious symbol, and officially the Red Crescent is neither, though clearly many people perceive otherwise. Regardless, the Red Crescent does not seem to pose a problem for our moon.

Figure 2. The Red Cross and Red Crescent



Source: The International Committee of the Red Cross, http://www.icrc.org, April, 2002.

2.3 Some Expert Opinion

It is always helpful to consult those who are experts in a field, so we contacted one — Dr. Alan Godlas, Associate Professor (Islamic Studies and Arabic), Department of Religion, University of Georgia, USA. We put the questions of using the moon as a sleep symbol on electronic devices to him and he kindly queried colleagues and students on the matter. He responded via email:

---

[5] Israel uses a red Star of David, though this is not recognized as an official international symbol by the movement. Iran used a Red Lion and Sun until 1980.

> “As far as I can see, it would NOT be offensive. Nevertheless, I am in the process of polling both a number of colleagues who are professors of Islamic Studies as well as local Muslims from a variety of countries. Thus far all agree with me.” *(November 6, 2001)*

> “Nine professors of Islamic Studies from all over the US, most of whom are also Muslims, responded to my query. Eight of them said it would NOT be offensive, one said it might be. Also, nine members of the local Muslim student association responded (and they are all from various Muslim countries and ethnic origins) and they unanimously said it would NOT be offensive.” *(November 10, 2001)*

3.0 Recommendations

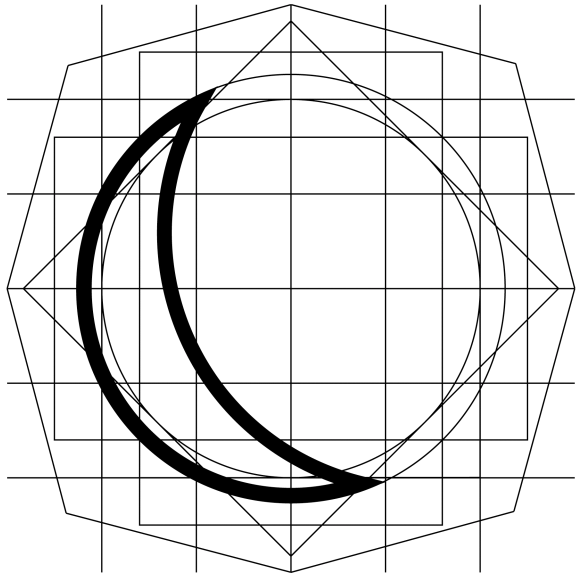
The crescent moon used on some existing PCs and proposed for use as a standard symbol lacks the specific stylization of Islamic use, particularly the points moved much closer to each other and the presence of one or more stars. For this and other reasons, the use of the moon as a symbol for sleep does not seem problematic culturally.

For the graphic options in depicting a crescent moon, we recommend:

- **Fill**: Use just a solid fill, or a blank outline (no craters). After all, we are referring to the moon’s *associations* (with sleep in this case), not the moon itself. Do not use a red crescent, to avoid causing confusion with the International Committee of the Red Cross logo.
- **Points**: The angular distance between the points of the crescent, going around the moon, should be about 180 degrees. Anything more will be unnecessarily imitative of the hilãl.
- **Direction**: As astronomical symbology uses the left-facing moon, using the right-facing one for sleep provides a modicum of differentiation.
- **Tilt**: We propose to “tilt” the moon by the earth’s angle of inclination (23.45 degrees). There is no rational basis for this specific choice — just some subtle fun. However, this also works well with the tilts that we want to avoid — zero (which could look like a left parenthesis) and 45 degrees (which could look like the phone symbol).
- **Exposure**: The crescent moon should show one half of what the quarter moon shows — as a quarter moon exposes half of the moon surface, the crescent should show one fourth.
- **Stars**: It is best to avoid stars entirely. If stars are used, place them scattered all around the moon, never on it, or concentrated near its open end, so as to not imitate the hilãl.

IEC 80416 specifies how to construct symbol originals precisely. Office equipment and consumer electronics often stylize existing standard symbols, and we expect the moon to be treated the same. These specifics are for the standard version, and should be reviewed by those who stylize the symbols as background. A precise drawing of the proposed new symbol is shown in Figure 3. An explanatory graphic is presented in Figure 5.

Figure 3. A precise drawing of the proposed new moon symbol.



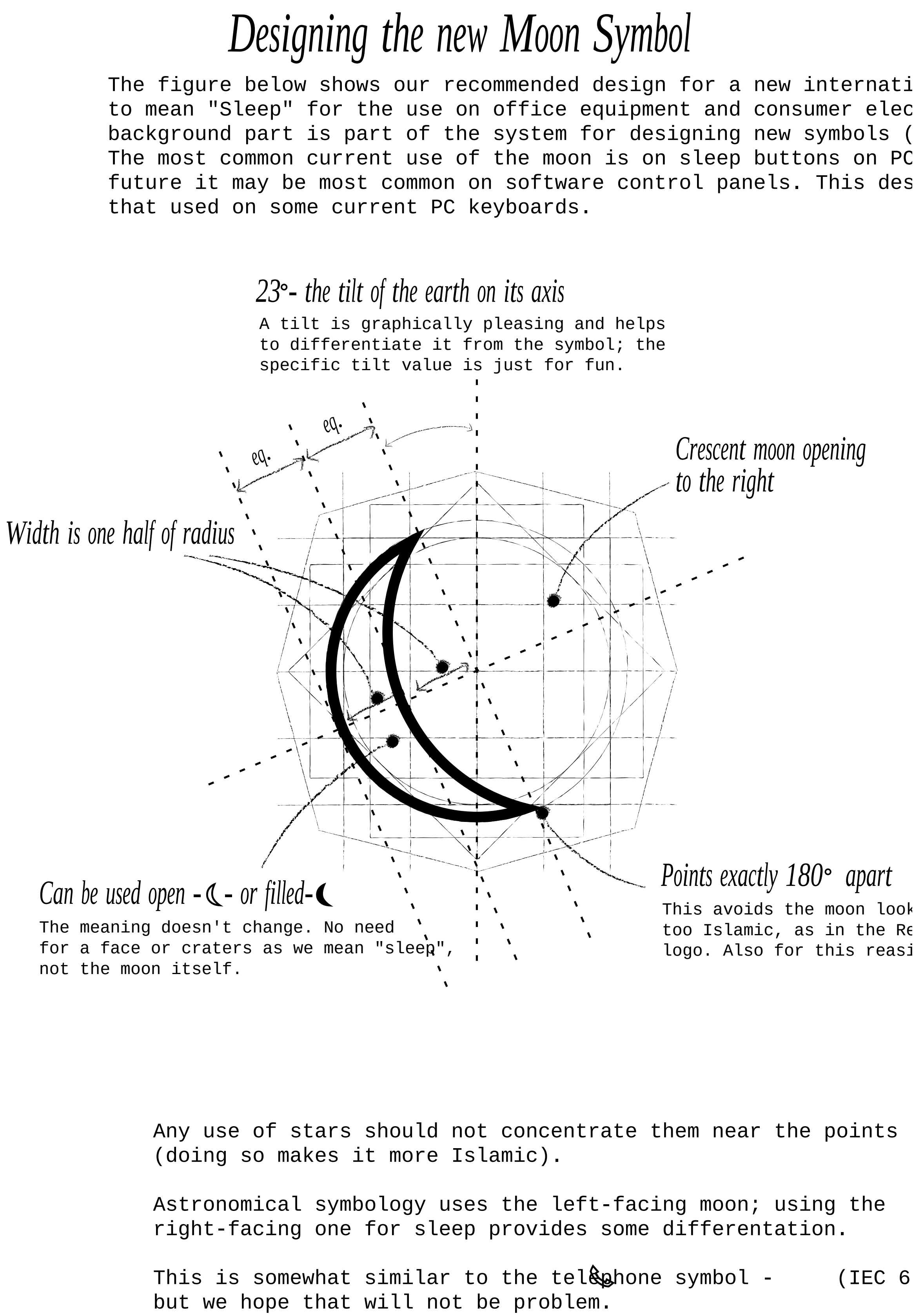
Note: The background grid is that specified by IEC 80416; the line width is 2 mm.

4.0 Some Current Moons

Figure 4 shows selected moons found on contemporary office equipment. Note that many of the variants discussed here occur, but our recommendations are in each case consistent with the most common usage. The variants cover articulation, direction, fill, exposure, and stars.

Figure 4. Moons found on recent office equipment

Figure 5. "Designing the new Moon Symbol" explanatory graphic



Designing the new Moon Symbol

The figure below shows our recommended design for a new internati
to mean "Sleep" for the use on office equipment and consumer elec
background part is part of the system for designing new symbols (
The most common current use of the moon is on sleep buttons on PC
future it may be most common on software control panels. This des
that used on some current PC keyboards.

Any use of stars should not concentrate them near the points
(doing so makes it more Islamic).

Astronomical symbology uses the left-facing moon; using the
right-facing one for sleep provides some differentation.

This is somewhat similar to the telephone symbol - (IEC 6
but we hope that will not be problem.

5.0 References

ISO / IEC 2000. Collective Standard: Graphical symbols for office equipment. ISO / IEC 13251. First Edition, Geneva, Switzerland: International Organization for Standardization and International Electrotechnical Commission. 2000.

IEC 1998. Graphical symbols for use on equipment. IEC 60417. First Edition, Geneva, Switzerland: International Electrotechnical Commission. Part 1: Overview and application; Part 2: Symbol originals. 1998.

ISO 1989. Graphical symbols for use on equipment: Index and synopsis. ISO 7000. Second Edition, Geneva, Switzerland: International Organization for Standardization. 1989.

ISO 2001a. Graphical symbols — Test methods for judged comprehensibility and for comprehension. ISO 9186. Second Edition, Geneva, Switzerland: International Organization for Standardization. 2001.

IEC 2000. Basic principals for graphical symbols for use on equipment — Part 1: Creation of symbol original. IEC 80416-1. Draft, Geneva, Switzerland: International Electrotechnical Commission. 2000.

Lewis, R, and V.L. Menage, Ch. Pellat, and J. Schacht., *Encyclopædia of Islam*, New Edition, Volume III, 1971.

Appendix VII — Testing[1]

1.1 Introduction and Background

Any design process that touches on human interaction should include testing of candidate designs on "ordinary" people. For *products*, these can be elaborate and drawn out — particularly for complex interfaces such as software or web sites. For *standards*, the process is necessarily more granular and limited, as just specific elements of the interface are being tested (if a test becomes complex, then the results will say more about the testbed than the elements themselves).

This appendix reviews the testing exercises conducted in the development of the Power Control User Interface Standard. Four separate tests were done at three locations, covering a variety of aspects of the power control standard.

Four separate testing exercises were conducted: two at the University of California, Berkeley (UCB1 and UCB2); one at Cornell University (Cornell); and one at Lawrence Berkeley National Laboratory (LBNL). Most of the testing addressed the meaning and usage of the power symbols and indicator lights. The UCB2 test probed selected issues from UCB1 in more detail. The Cornell test built on both UCB tests, and explored many of the same issues but in slightly different ways. The LBNL test addressed the two issues that were most important at that stage of the standard development. Table 1 summarizes key information about each test. A total of 190 people were surveyed.

Table 1. Testing Summary

Topic	**UCB1**	**UCB2**	**Cornell**	**LBNL**
# Respondents	37	12	105	36
# Questions	27	43	33	11
Power Symbols	X	X	X	X
Indicators	X	—	X	X
Sleep Associations	X	—	X	—
Use of Sleep Modes	X	—	X	—
Changing States	X	X	X	—
Assessing State	X	—	—	—

The results of all four tests supported the User Interface Standard as proposed, and provided additional insights. All four tests were conducted with the aid of a computer, with all but the Cornell test guided by an experimenter.

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

1.2 Test methods for ISO/IEC standards

ISO 9186, “Graphical Symbols — Test methods for judged comprehensibility and for comprehension” (ISO 2001a) specifies procedures to be used in advance of establishing international standard symbols. Some of the principles can be extended to the other interface elements. It was not our intention to conduct tests according to this standard, but it is a useful reference.

Per ISO 9186, tests can be of two types: “comprehension judgment”, what percent of others will understand a symbol; and “comprehension”, whether the subject herself / himself understands it correctly (our tests included both types). The “referent” of a symbol is the “idea or object that the graphical symbol is intended to represent”.

Depending on the test, testing in two or three countries is required, with the goal that they be of substantially different cultures. The standard provides for computer display based testing. Symbols are to be presented in random orders. At least 50 “respondents” are required for each country a test is done in. Respondents are to be:

- Representative of the user population.
- Presented with both test types about the same symbol or referent.
- Told the context in which the symbol will usually be used in, then asked what they think it means, and (if applicable) what action they should take.
- Asked for their age (by a broad range), gender, education, cultural background, and where relevant, physical ability.

2.0 UCB Results

The two UCB tests (UCB1 and UCB2) were conducted in the fall of 2001, by groups of graduate students at UC Berkeley. They worked from the initial recommendations about the static interface (Nordman, 2001a), and some ideas about device behavior. While the data from this collaboration were useful, the process of creating the survey instruments themselves was also instructive. The sample sizes were small, so the results may not be decisive, but they are indicative and provide good anecdotal evidence. The detailed reports on both tests are published online (Chamarbagwala et al. 2001c)[2]. In both tests, many questions were multi-part.

The full reports contain much quantitative information about the survey results. This presentation mostly avoids specific percentage values for ease of reading, because of the small sample sizes, and to cope with sometimes ambiguous or obtuse results. A complicating factor is that two different meanings for ⏻ were being tested — this can lead to confusion both for survey subjects and those interpreting the results. Some issues were addressed by more than one set of questions, particularly when both surveys are considered together. The results were not always self-consistent or reconcilable with a clear mental model. The reporting of the first

[2] This was in the context of SIMS 271, a course in the School of Information Management and Systems about Quantitative Research Methods for Information Management. The instructor was Rashmi Sinha, a lecturer in the department. As of April 5, 2002, the reports and the original survey instruments were still available online (Chamarbagwala et al., 2001c).

study was not always clear, but the second was quite well done. Both tests were web-based, allowing good use of graphics, color, and blinking.

2.1 UCB Test 1

This test (Chamarbagwala et al. 2001) addressed the existing IEC standard symbols and our replacements, their usage, the color indications, and the sleep metaphor and moon symbol. The sample of subjects was 37 UC Berkeley students, none of which reported being color-deficient.

Over a third of subjects reported actively disabling power management, and others reported never using it (this suspicious as ENERGY STAR labeled equipment is supposed to always be shipped enabled). The most common reason reported for disabling was not failure to properly awaken after sleep, but that power management occurred too soon. This problem should have led them to extend the delay time rather than entirely disabling power management, so something that an improved user interface should help. Almost half of disabling was due to excess delay time or people unsure how to use the controls.

Some of the testing referred to a notebook or a copier to see if expectations for how to change device state differed by device type. No significant difference was observed. Pairs of buttons were shown — ⏼ / ⏻ and ⏻ / ⏾. Subjects were asked to change a device from *sleep* to *on*, *on* to *sleep*, and *sleep* to *off*[3]. Interestingly, ⏻ was preferred by most subjects for all cases. The proposed symbol set was always implemented more reliably than the current pairing, both for consistency and correctness of responses. However, the number of people who reported not being sure was large (25-32% in four of the six cases). It appears that: people are confident pressing ⏻ to control power states; they differentiate ⏾ much more than ⏼ from ⏻; and there is considerable confusion in general.

For some questions, rather than use verbal descriptions, subjects were shown images of a notebook in a variety of states (two options for sleep — amber and blinking green). Subjects were asked to change to a new state. While most subjects acted in accord with current typical PC operation, the number that didn't was suspiciously high.

Several tests were done to gauge the pairing of power and sleep buttons. Interestingly, in some of the tests there was a clear preference to use ⏻ to turn devices on, with little interest in ⏼, but a large desire to use ⏼ to turn devices off. This is in accord with anecdotal U.S. perception of ⏻ meaning "power on" — connoting both "power" and "on". The moon symbol elicited little interpretation contrary to sleep. There was considerable more clarity between functions for ⏻ / ⏾ as compared to ⏼ / ⏻.

Some further questions addressed how people assess device states. For notebooks, about half would "prod" or "poke" the machine to see what it did (with the mouse or keyboard), and half would look at it or listen. Only a sixth relied on indicator lights. For a copier, only 9% would take an action (perhaps because it might cause a copy or delay), with most either looking at the control panel screen or indicator lights. That indicators do not rate higher in general might be due to their current inconsistency.

[3] This is not quite a fair question, as for notebook PCs, people are instructed to turn them off via software not via the power button. This will likely change in future, but is not part of many people's present experience.

Another set of questions addressed the correspondence between device state and indicator color. Questions were asked both ways — what color corresponds to a particular state, and what state corresponds to each color. Green was overwhelmingly the choice for *on*, and "no light" was the dominant choice for *off*. For the latter, red made a respectable showing, which may have been due to subjects reading the question as addressing the color of an on / off button (like a STOP sign) rather than an indicator light. For *sleep* there was the least clarity, with blue rating higher than yellow (possibly this is due to yellow not standing out on the white background of the survey). This is odd as we have never seen blue as a sleep indicator on any device.

The reverse associations (what state each color implies) were asked with green, orange, yellow, and red, and blinking versions of each. Why the students chose to ask about both orange and yellow isn't clear; the fact that both were present may have led some subjects to think that yellow should mean something different from orange. Green was overwhelmingly identified with *on*. Interestingly, red was never identified with Attention / Input or Error, but rated the highest on Don't Know. Non-blinking was rarely identified with Attention / Input, Error, or Transitions, which is good evidence for blinking for these indications. Aside from red, blinking rated well for *sleep*, but not as high as constant orange or yellow.

Another set of questions asked subjects to rate their association of the idea of sleep with various symbols including the word "sleep", beds, moons, stars, "Zzzz"s, and some combinations of these. Interestingly, the crescent moon rated in the middle of the full set of choices, with the word "Sleep" the highest, followed by some beds. Icons with multiple elements rated higher than those with just one.

2.2 UCB Test 2

The second UC Berkeley test (Chamarbagwala and Rixford, 2001) focused primarily on user expectations of device behavior. It covered some of the same ground as the first phase as well as some new topics and approaches. Subjects were presented with images and questions on-line (guided by an experimenter) and asked questions about the meaning of interface elements and what they would do to accomplish certain actions. Because PCs are the most problematic device, three types (notebook, desktop, and tablet) were the models used to illustrate the elements.

One of the findings was that the type of computer did not significantly affect people's actions and expectations — good news for standardization. For taking a device from *sleep* to *on*, most subjects chose some action other than pressing a button — consistent with most current machines for which mouse or keyboard input will wake it up. People were most likely to press the ⏻ button regardless of whether it was in a "Standby" or "Power" context, suggesting that prior associations with the symbol overrode other information about the situation.

Another part of the test involved moving from *sleep* to *off*, which is something that people generally don't do to a PC — they wake up the device, then turn it *off*. However, as hibernate is used more widely as a form of *off*, this will become more viable[4]. In this case, pushing a button

[4] The fact that an ACPI PC will always go through the full on state internally when going from sleep to off is not important to the user interface.

was the preferred way to perform the action. When both the ⏼ and ⏻ were options there was confusion as to which to use, but when ⏻ and ⏾ were presented, there was near certainty about which to use. When the question (how to move from *sleep* to *off*) was asked in a different way, there was less certainty that button-pressing was the appropriate action (but again this is a sort of trick question as it not how people presently use PCs).

When asked about the meanings of the various buttons, the subjects' responses varied with the actions they were trying to accomplish. This internal inconsistency shows that people don't have a clear underlying model of how the device behaves. People were confident that the ⏻ button would do something, though there was less consensus on what it does. The fact that they tended towards ⏻ meaning to turn it *off* may have been influenced by the earlier questions of how to move from *sleep* to *off* in which they chose the ⏻ button when in fact no action would accomplish that. For the ⏾ button, subjects were split on whether it would move a device from *sleep* to *on* or do nothing, but almost no one associated it with *off*.

People were grouped into four types depending on their expectations for the ⏻ and ⏾ buttons as shown in Table 2. Almost 20% were found in each type showing a lack of consensus about their expectations and the underlying model. More people were found in the types for which only one of the two buttons brings it out of the sleep mode, suggesting that people might be discounting the idea of redundant controls.

Table 2. General User Expectations for Power Controls

ACTION		**Pressing Proposed Sleep Button** ⏾	
	Expected Behavior of Device	Only puts device into *sleep* mode	Puts device into *sleep* mode & brings it out of *sleep*
Pressing Proposed Power Symbol ⏻	Only turns device *on* and *off*	18 %	36 %
	Turns device *on* and *off* & brings it out of *sleep*	27 %	18 %

Source: Chamarbagwala and Rixford, 2001.

2.3 Summary of UCB Test Results

While the sample sizes in these experiments were not large enough to be definitive, some clear results emerge.

- User expectations and preferences largely ratify the standard.
- No fundamental problems with the standard were raised.
- The subjects expectations were similar across device types.
- Subjects are comfortable pressing the ⏻ button — it rated highly as the solution for any power state change task.
- The moon rated only in the middle of eleven sleep symbols tested for its association with the idea of *sleep*, but nevertheless, its meaning is clear.

- People readily understood that the sleep button puts the device into *sleep*, but relied on the power button for wake up.
- No clear common mental model was apparent across the subjects, so it seems safe to impose one that makes sense to product designers so long as it is not inconsistent with widespread perceptions in a way that may cause problems (e.g. turning a machine off unexpectedly).
- The subject's responses mostly makes sense in light of what people see on current products.
- To check power status, people "poked" notebooks but observed copiers. (If future PC keyboards don't wake them up from *sleep*, some re-education will be necessary).

3.0 Cornell Test

The Cornell test (Puleio and Shanis, 2002) was conducted subsequent to the two UCB tests. It was focused specifically on computers (desktop and notebook) rather than on office equipment generally.

The reported rate of use of "sleep" features was 20% less than at UCB. Possible reasons for this include the more narrow focus on computers and the use of a specific term ("sleep") rather than the generic "energy saving" as used at UCB. More than half of respondents entered *sleep* by "allow[ing] time to pass" with use of the "start menu" capturing most of the rest of laptop users, and pressing a sleep button most of the rest of desktop users. To wake up the computer, moving an input device (e.g. the mouse) was preferred by over two-thirds of subjects. For reasons that might cause them to "increase use of sleep mode", the top two reasons were to "know how" and "easier to use".

The Cornell study asked similar questions (as the UCB studies) about indicators and produced similar results for how to indicate *off* and *on*, and for associations with green. For *sleep*, yellow and orange were both offered as options, and together over 70% of people cited it as best (the confounding blue option from UCB1 was not offered). For the meaning of blinking green, over 65% cited it as meaning a transition state or "needs attention" — less than 15% cited *sleep*. For orange (yellow was not asked about), blinking was most associated with a problem / error or "needs attention" with one fourth "don't know". For solid orange, a third associated it with *sleep*, but half didn't know what meaning to assign.

For the degree of association of various symbols with *sleep*, the ordering of the symbols was quite similar to that found at UCB (the ranking method was different so the results are not comparable other than by order). For what symbol should be used on a button to go to *sleep*, ⏾ was preferred, but for all other purposes, ⏻ (and "power") was chosen. When asked which to use for going to *sleep* between ⏻ and ⏼ (with the moon not an option), only 10% chose ⏻ (with 40% undecided). For transitioning from *on* to *off*, two-thirds chose software as the mechanism and one third a button. For *off* to *on*, a button was the overwhelming choice, with twelve times as many people choosing ⏻ over ⏼.

4.0 LBNL Test

The LBNL testing was conducted in September, 2002. An earlier presentation (Nordman, 2002b) shows the results in more detail, and the actual survey instrument is available on-line which allows the animated slides to be viewed[5].

The intended procedure for this testing process was outlined in (Nordman, 2002a), based on the results of the previous tests, and needs identified by the Professional Advisory Committee (PAC). Two topics were identified for testing: power symbols (drop the ⏼ symbol from use and redefine ⏻ to mean "power") and indicator light colors and behavior[6]. The other four core principles of the standard were taken as assumed.

A set of presentation slides (with Powerpoint v.X [7]) was created and copied to a Macintosh iBook notebook computer[8]. Three versions of the slides were used — one on each of the three days that data were collected. After the first day, some questions were dropped and one modified. Also, the order of slides was slightly changed between each version to try to eliminate some of the effect of presentation order[9].

The slide deck was pretested on several people to eliminate obvious errors and ambiguities. The responses of those individuals were not included in the collected data.

4.1 Results and Discussion

Thirty-six people took the survey over the course of three days, and all who started the survey also finished. There were slight differences in the instrument between the three days, mostly slide or image ordering, with a few text changes. This discussion makes no claims about statistical validity. Images from the instrument and the full results are presented in (Nordman, 2002b).

4.2 Symbol Recognition

The first slides asked whether the respondents recognized the current power symbols — ⏼ ("on / off") and ⏻ ("standby") — and whether they knew their meaning.

For both symbols, recognition of them as power-button-related (mostly *on-off* or *power*) was 44%. Only 31% of respondents recognized both reasonably correctly. A few people mentioned

---

[5] See [http://eetd.LBL.gov/Controls/publications/test6b.ppt].

[6] The characteristics of this test make it exempt from approval by the LBNL Human Subjects Committee and so the appropriate exemption forms were filed prior to beginning the testing.

[7] Some of the slides required animated GIF files which need newer versions of Powerpoint (2000 or later) to function.

[8] The power button on the iBook was taped over since it uses one of the symbols in question and is just below the screen.

[9] A card table and two folding chairs were set up with signs asking people to participate in a survey about "office equipment". The power connection was not mentioned until the fourth slide. All three testing days took about three hours each of data collection time to recruit and interview a dozen people, and all occurred between 11am to 3pm. Answers were recorded with pen and paper; some responses were "yes / no / don't know" and for others the key word, phrase, or set of phrases in the response were written down. The typical time required for the survey was about five minutes. After the survey, the project purpose and standard content was offered to people to the extent they were interested.

electrical terms not power-button related). For those who didn't know the symbols' meanings, some remembered seeing the symbols in the past and some said they had never seen them before.

Discussion

With the wide use of the power symbols on office equipment and consumer electronics, it is nearly certain that all respondees had successfully used power buttons with these symbols. It seems likely that people use design clues such as location, size, and relation to the power indicator to identify the power button rather than closely examining at the symbol itself. This casts doubt on using symbol variations to communicate user information in cases where it doesn't affect how one uses the product (and where safety is not at issue).

The symbols presented in the text were large (about 4 inches across) and out of any context. This may have reduced the ability of people to connect them to power buttons and indicators, though people were told that the survey was about office equipment (so that the universe of possible symbols was limited).

4.3 Differentiating ⏼ and ⏻

The next slide presented ⏼ and ⏻, explained that one is for zero power when off and the other for some power when off, and asked several questions: *Do you know which is which? Is the difference important to you? (For buying? For using?)* and *Which do you prefer to see?*

No one correctly *knew* that ⏼ is for zero power when *off*, but of the 33 who guessed, 79% were correct. Half of respondees said that having the two different symbols was important when buying a product[10] with nearly the same importance assigned for when using a product . For preference between the symbols for a power button, 42% chose ⏼ and 50% ⏻, with the rest having none.

We were interested to see if there was a correlation between the recognition of each symbol to the importance cited for having two symbols. These two responses were compared for each respondent, and we found that for those who thought it was not important to have two symbols, just over half of subjects recognized the symbols, but for those who thought it was important, just over two thirds did not recognize the symbols. This is curious and ironic.

Discussion

More people thought that *having* two different symbols (for zero and non-zero power when off) was important than *recognized* the current symbols as even related to the power button — let alone understand the details of their meaning. It seems likely that at least some people thought that they *should* favor retaining the two symbols lest they be seen as indifferent to energy waste (quite a few seemed familiar with the idea of standby power).

The difference in recognition between those who thought it important or not to have two separate symbols suggests several possible interpretations. One is that the interest in maintaining multiple symbols is associated with people who don't understand as well how the systems work and so want more cues to their operation. Another is that the population that

[10] For the first third of respondees, the buying vs. using differentiation was not made.

doesn't want multiple symbols are more likely to be heavy users of technology who would have had more opportunity to notice the symbols.

We didn't ask people about how they might alter their behavior based on the difference in the symbols. The difference could be used in purchasing or in unplugging or using power strips to cut power to zero. However, since the size of the off-power consumption isn't known (the symbols don't distinguish between 10 W and 0.1 W for the *off* mode) people don't have a rational way to decide when it is worth unplugging devices when *off* or not. Concern about standby power is real and worth harnessing, but it isn't clear that multiple power symbols is an effective way to do this.

That almost 80% of respondees guessed that ⏼ (rather than ⏻) is the symbol to go to zero power is compelling evidence for reserving this symbol for situations in which knowing that power is zero is actually important for functional or safety reasons (⏼ would <u>guarantee</u> zero-power for off when it matters; ⏻ would be used for all other cases). When the distinction isn't relevant to people's behavior, the distinction gets lost. Few people use equipment for which the distinction is important; those that do (e.g. medical professionals) could be trained to recognize the difference.

The respondees from the university campus (the first two sites of the LBNL test) recognized the symbols more frequently than those from the shopping area (the third site). This might have been due to greater use of office equipment for that sample.

4.4 Indicator Light Color Recognition

The next 5 (or 6) slides showed a ⏻ symbol and a power indicator of various colors (including some blinking) and asked what people associated with it. They were told verbally and by text on the screen that it was specifically a power indicator.

The color green for a power indicator light was associated with *go* or *on* by 92% of people, and the indicator light off was recognized by 89% as *off*. We intentionally put green first to steer people to assuming that that is to mean *on*. When red was presented before light off, half of the people associated it with *off*, but when presented after light off, nobody associated it clearly with *off*. Stoplights were mentioned by several people, which is probably the source of the association between red and *off*. 42% said red meant something bad, and for those who saw it after the light off slide, the portion was over half.

For the first round, flashing yellow was presented as the last slide (after flashing green) and most people said that it had the same meaning as flashing green. People seemed to not specifically recognize flashing yellow so it was dropped from the test for the second and third rounds.

Table 2 summarizes the associations people provided for yellow and flashing green indicator lights. The classification is necessarily judgmental (for example, that "caution" implies a minor problem).

For transition indicators, a power-up transition is more associated with flashing green and for power-down, yellow is. Over four times as many people associated yellow with low-power than did so for flashing green. Several results support the idea that flashing green calls attention to itself: a slightly greater association with major problems, more associations with an error, and many more that the device wants the user to do something. Several people said that the flashing was annoying, and several more cited this issue while answering the next (final) question. Combining these, for flashing, 47% were annoyed, believed that attention was wanted, or thought an error was indicated.

Table 2. Associations with Yellow and Flashing Green.

Yellow	Fl. Green	Association
4	6	Transition Up
2	0	Transition Down
2	4	On / Active
13	3	Low-power
6	4	Minor Problem
2	4	Major Problem
1	9	Input – waiting for / wanting
7	7	Don't Know (and other)

Discussion

With red commonly indicating on on consumer electronics, the "priming" of people with green was quite effective at discouraging the "red = *on*" association. The association of red with error conditions is notable, but in general red is confusing for power indicators — in part this may be due to the fact that on office equipment its use on a power indicator is rare.

The results support the current incarnation of the user interface standard in that the population seems to lean towards it, though clearly not in an overwhelming way.

4.5 Choice for Indication of Sleep

The final slide showed three options for sets of indicators for *on*, *sleep*, and *off*. In all three cases, *on* was signified by green, and *off* by the light off. The options were steady yellow, flashing green, and "breathing" green. The presentation order was rotated each time to eliminate that as a factor.

Two-thirds of the subjects preferred yellow to indicate *sleep* status; 19% chose flashing green, and 14% liked breathing green. For why people chose the solutions they did, most of those were naturally from yellow partisans. Many said that using the same color for both *on* and *sleep* would be confusing. Some noted that a quick glance at a flashing or breathing indicator would always provide the wrong answer — they require maintaining one's attention on the power indicator for several seconds to be sure of the correct state. Flashing was sometimes associated with a transition or activity in progress — neither a stable state. Several specifically said that flashing was annoying. Those who favored one of the green indications were few and no clear patterns among their reasons is apparent.

4.6 Conclusions

The sample size for this survey was large enough to produce the results needed for this project, showing a combination of clear preferences and confusion. Clear results include:

- Most people use power buttons without recognizing the symbols on them — ⏼ and ⏻.
- A majority of people want to maintain two different power symbols, though how they would use this in practice is not clear. The interest seems to be motivated in part by concern over standby power.
- Some associations are widespread, such as ⏼ meaning a switch for zero power (when explained), green for indicating *on*, and the light off for *off*.
- Red, flashing green, and yellow have diverse associations, but there seems to be fertile ground for the associations in the user interface standard.
- Yellow is the dominant choice for a *sleep* indicator, and a significant number of people find flashing annoying and / or calling attention to itself.

These results are consistent with the rationale and design elements in the interface standard with the exception of whether it is desirable to maintain two different symbols for power buttons.

There are two approaches to the use of testing in any design process including this one: generating the designs from user preferences, or picking a design and then checking to see that user preferences are not at odds with it. This project uses the latter approach.

In some cases, user beliefs seem clear and so that result determines the content of the standard. The steady green and off indications are examples of this.

The results from two other indications illustrate an alternative approach — to confirm that people do not have clear prior associations. In the case of yellow and flashing green, it is clear that at present people do not have a consistent interpretation of their meaning. Thus, the role of standardization in this case is impose an understanding on people that does not conflict with their current associations. The associations revealed by this testing do suggest that use of the meanings in accordance with the interface standard would tap into existing leanings, and so easier to make successful. Specifically, up transitions are more associated with flashing green, and down with yellow. Low-power is significantly more associated with yellow than flashing green.

5.0 Key Conclusions

The four tests all pointed to several key points:

- The power user interface is in many respects confusing to people.
- Many parts of the standard are confirmed by user expectations.
- When user expectations don't match the standard, they are diverse, rather than concentrated on a preferred alternate design.
- ⏻ is a preferred symbol for people to use for most power purposes.
- The meanings of color and blinking in the standard match user expectations.

A possible next step is to replicate selected portions of these tests in other countries, to see if the same results hold elsewhere.

6.0 References

Chamarbagwala, Azeen, and Phoebe Kuan-Ting Liu, Craig Rixford, Mary Trombley, and Bin Xin. 2001. "On, Off, or Asleep?: User Perceptions of Power Controls on Common Office Equipment". School of Information Management and Systems, University of California, Berkeley. October, 2001.

Chamarbagwala, Azeen, and Craig Rixford. 2001b. "Power Controls — Form and Function: Mapping the User's Mental Model". School of Information Management and Systems, University of California, Berkeley. December 2001.

Chamarbagwala, Azeen, and Craig Rixford. 2001c. "Quant. Methods Projects: Power Controls". School of Information Management and Systems, University of California, Berkeley. [http://www.sims.berkeley.edu/courses/is271/f01/projects/PowerControls/] December 2001.

Nordman, Bruce. 2002a. "Field Testing the User Interface Standard", May 19, 2002. [http://eetd.LBL.gov/Controls/publications/testing0519.pdf].

Nordman, Bruce. 2002b. "The Power Control User Interface Standard: Fall 2002 Testing Results and Conclusions", [http://eetd.LBL.gov/Controls/publications/testingoct9.pdf].

Nordman, Bruce. 2001a. "Tentative Recommendations". [http://eetd.LBL.gov/Controls/publications/July01/TentRec.7.01.pdf]. 2001.

Puleio, Jonathan, and Jenna Shanis. 2002. "User Perceptions of Power Controls, Icons and Power States". Cornell University. 2002.

ISO 2001a. Graphical symbols — Test methods for judged comprehensibility and for comprehension. ISO 9186. Second Edition, Geneva, Switzerland: International Organization for Standardization. 2001.

Appendix VIII — Hibernate[1]

An increasing portion of personal computers (PCs) sold today include a "hibernate" feature which saves the system memory state to non-volatile memory (usually the hard disk) and then turns off the system. When the system comes out of this state, the memory image must be read off the disk and basic device reconfiguration done. This is considerably more complex and time-consuming to accomplish than entering or leaving typical sleep states. However, as operating systems become more reliable, it becomes an increasingly attractive state to use to maximize energy savings and battery life. Unfortunately, the concept is ill-understood by most people, and likely to be confusing. User manuals and operating systems present hibernate in a variety of inconsistent ways. Rather than wait till the problem emerges as a large one for the industry, it makes sense to solve it now and we undertook to try to do just that. The goal is to arrive at a common, simple, and consistent presentation of the hibernate state to ordinary PC users. One solution stands out as the simplest and cleanest — that hibernate is a form of *off*.

1.0 Introduction

One of the parts of the Power Control User Interface Standard that elicited the most concern among manufacturers is the specification that "*hibernate*" be clearly identified as a form of *off*. Among those people who were presented with the question, almost all fell into three categories:

- Hardware professionals — people who work with the electrical details of PC hardware. They mostly saw *hibernate* as a form of *sleep*.
- Usability professionals — people who deal with making PCs easier to use. They uniformly agreed that *hibernate* is *off*.
- Everyone else. When the issue was explained, they generally agreed that *hibernate* is *off*, though few of these people would have considered the issue previously, and would not be likely to have a firm opinion.

Faced with this lack of consensus (particularly for the hardware people whose views on safety issues are taken most seriously), we prepared a discussion of the advantages and disadvantages of each design solution. The intent was to fairly represent all views, with the hope to gain a consensus around one solution.

The process began with a first draft from LBNL that was then circulated to the PAC and key other individuals. The last table of the draft included a ranking system to rate the problems that each solution exhibits to show the degree to which each are problematic. The intent was to obtain close review of the discussion and incorporate comments into the text and the rating table. Several people provided verbal comment, which has been incorporated, but no one provided the ratings. Most of the "hardware" people didn't change their minds (some did), though how much attention they gave to the discussion is not known.

For clarity, operating modes (as the user perceives them) are italicized, e.g. the *off* mode versus an LED being off.

---

[1] This appendix provides detailed background information about the development of the Power Control User Interface Standard. For the full report and more about the Standard, see http://eetd.LBL.gov/Controls

2.0 Dissecting The Issue

This appendix presents our analysis of the hibernate problem. It includes the goals of classifying internal system states to externally perceived ones, six possible solutions to the hibernate problem, and how each solution fares with respect to eleven potential problems. None of the solutions is perfect, but they vary considerably in the number and severity of their problems.

2.1 Context

This discussion presumes as accepted (except where otherwise noted) the other five core pieces of the user interface standard:

- Use three power states (*on*, *off*, and *sleep*);
- Use the term "Power" (for buttons and indicators);
- Use Green / Amber / Off for power indicators;
- Change the international "standby" symbol — ⏻ — to mean "Power"; and
- Use the sleep metaphor and moon icon — ☾.

At present, the issue is only of major concern for personal computers (PCs), because they are the only devices that have a complex system state *and* commonly restart the operating system. Many devices remember some context between *on* states (e.g. a TV remembering the channel being viewed), but the state information is simple and easily saved in non-volatile memory. Devices such as PDAs are only rebooted when a serious error occurs, not in conjunction with normal on / off cycles. Thus, PDAs lack a normal *off* state other than hibernate. This discussion is organized around PCs (desktop and mobile) running on ACPI and the Windows operating system (version XP or earlier) but the principles should apply to any computer operating system, and ultimately any device.

This "hibernate problem" reduces to assigning ACPI states to user-perceived power states. Possible machine states (in this case for PCs or any device) are shown in Table 1.

Table 1. Possible device states

State	ACPI State(s)	Comments
Active / Full-on	S0	Processing
On	S0	Waiting for input
Resting	S1 or S2	Screen dim
Light Sleep		Faster recovery than *Sleep*
Sleep	S3	
Deep Sleep		Slower recovery than *Sleep*
Hibernate	S4 or Mech. Off	
(Soft) Off	S5	
(*Hard) Off*	Mech. Off	Unplugged, any battery dead or removed

As one moves down the scale, capability, responsiveness, and power consumption all drop. It is unlikely that any machine would have all of these states. It is possible that the assignment of internal states to user-perceived states will eventually vary from system to system, but the goal would be to hide this fact from the user.

Criteria that should be considered in allocating internal system power states to user-perceived states include:

- Indicator light status
- Behavior:
  Wake events: (responsiveness to buttons, switches, keyboard / mouse input, network activity, etc.)
  Noise made by the machine (e.g. fans, disks)
  Recovery time to a full-on state
- Power consumption *(W)*
- Ability to unplug without bad consequences
- Ability to modify internal hardware (e.g. PCI cards, memory, disks)
- Ability to modify external hardware (e.g. USB devices, PC cards, docking station)

The ACPI specification addresses this issue in Table 2-1 (ACPI 2.0 specification, 2000), and is reproduced here as Table 2. The ACPI specification is ambiguous about hibernate, sometimes calling it a sleep state, other times making clear that it is off, and at other times suggesting that it occupies a system state in addition to those shown here[2]. By this table, hibernate differs from sleep in latency and power consumption. Tellingly, hibernate can occur in G2 / S5 or G3, that is, with or without the system energized with power while off. It differs from each of these states *only* by the "OS restart required" criterion.

Table 2. Summary of Global Power States (from ACPI 2.0 Specification)

Global system state	Software runs	Latency	Power consumption	OS restart required	Safe to disassemble computer	Exit state electronically
G0 Working	Yes	0	Large	No	No	Yes
G1 Sleeping	No	>0, varies with sleep state	Smaller	No	No	Yes
G2 / S5 Soft Off	No	Long	Very near 0	Yes	No	Yes
G3 Mechanical Off	No	Long	RTC battery	Yes	Yes	No

In addition, it should be kept in mind that at present machines are usually turned *on* with a

[2] The ACPI specification itself uses neither the term "hibernate" nor "standby".

power button, and *off* with operating system interaction. However, with greater use of *hibernate*, the power button may be increasingly used to go to the *hibernate* form of *off*.

If a user has moments before put a system into hibernate or off, most of the time they will remember which was used (though not always, particularly if it is not their usual computer). The cases that are the most likely to raise issues are when the machine is encountered much later (perhaps days or weeks), or by a different person.

The goal is to identify a set of principles that result in machines that are as simple as possible for people to understand and use while not compromising capabilities.

2.2 Possible solutions

The six solutions shown in Table 3 span the range of reasonable solutions to the "hibernate problem". We believe that no other such solutions exist, so that one of these must be chosen (the *status quo* is effectively solution E).

Table 3. Possible solutions to the "hibernate problem"

Solution	Description
A	*Hibernate* is *off*.
B1	*Hibernate* is a fourth mode — the power indicator light indicates *hibernate*
B2	*Hibernate* is a fourth mode — the power indicator is off
C	*Hibernate* is a form of *sleep* (the power indicator is amber in *hibernate*)
D	*Hibernate* and *sleep* and are both forms of *off*.
E	*Hibernate* state assignment and indicator light usage varies by machine, even among those running the same operating system. For example, the power light might be on during *hibernate* for a desktop PC but off for laptops, or only on for laptops when the lid is open.

As solution E fails the basic criteria of general consistency from device to device, it is not evaluated. Since E potentially includes all of the other solutions, it is a problem for all of the issues below. Solution E resumes that consistency is not possible.

The "hibernate" term should be replaced, though by what hinges on hibernate's state assignment. For solutions A and D, it should be "off" (versus "shutdown off"). For C it should be "deep sleep".

2.3 Bad consequences with user mis-understanding of power user interface (UI)

- <u>Failure to resume</u> — From changing internal hardware while in *hibernate* (or *sleep*).
- <u>Energy waste</u> — From not using *sleep* and / or *hibernate* due to user confusion.
- <u>Lost data</u> — From losing system state due to unplugging or battery loss while in *sleep*.
- <u>User confusion</u> — From inconsistent or confusing interfaces. Users may not get the benefit of the power modes and behavior which best matches their needs.

- Manufacturer costs — From customer calls to Technical Support lines and / or bad associations with the product and brand.

2.4 Simple arguments for each solution

A: Major problems with other solutions; only problem with this one is changing internal hardware in hibernate (already a problem).

B1: *Hibernate* is sufficiently different from *sleep* to warrant a separate mode.

B2: *Hibernate* is sufficiently different from *sleep* to warrant a separate mode, but indicator burns energy so turn it off.

C: State is saved in both *hibernate* and *sleep* so same to user.

D: We can simplify to just *On* and *Off*

2.5 Issues

The following issues are ones that might be of concern in deciding what to do about hibernate.

Simplicity and Consistency of Power UI

The "at most three states" principle is violated

B1 and B2 both require that user's understand that there is a fourth basic system state. Adding a fourth state adds complexity to people's mental models and indicator implementation.

The principle that there is a 1:1 correspondence between states and the power indicator is violated

In B2, both *hibernate* and *off* are both indicated by off.

The default "Off" state (from power button) will vary across machines

This may be correlated to whether it is a desktop or laptop, and is already user-selectable. This is true for any of the solutions.

The principle that responsiveness to input is consistent within a state is violated

In C and D, a PC will have different wake events and different recovery times depending on whether it was internally in *sleep* or *hibernate* (or *off*). (A solution to part of this is to remove sleep buttons and disable any wake event from *sleep* other than pressing the power button, but the recovery time difference remains).

The power indicator will be more complicated

B1 requires an additional indication method to show a fourth basic state.

What can the user do without turning a machine on

In one sense these issues are not problems in that the *power state* (*on*, *off*, or *sleep*) and *system state* (booted up or shut down) are different concepts. It is not the function of the power indicator to show the *system state*; the power indicator shows the *power state*, not how the machine got there. Users are accustomed to correlating the two, but if that can be broken (as with a PDA), this is not a problem.

One can't tell from the power indicator if the system's state is saved

This is a problem with A, B2, and D. The system must be woken / resumed / turned-on to determine what the state was. This is only a problem if users rely on the power indicator *alone* to decide if the machine can be opened up and internal components changed.

One can't tell from the power indicator if the machine can be unplugged

This is a problem with C and D — in both cases *sleep* and *hibernate* look the same, and with D, *off* also looks the same.

One can't tell from the power indicator if it is OK to change internal hardware

This is a problem with A, B2, and D. It is also a problem with B1 and C if the battery runs out, is replaced, etc.

For B1 and C, if there is a power outage or the machine is unplugged, then plugged back in, the indicator should come on. This might require extra hardware to implement.

Safety instructions specify that the system should be shut down, unplugged, and any battery removed. So, this is not a safety problem, so long as people follow instructions.

One can't tell from the power indicator if it is OK to change external hardware

Examples are USB devices, PC cards, and notebook docking stations. Whether this is an issue is likely to vary across devices and over time.

<u>Other</u>

The hibernate indicator will run down the battery

This is a problem for B1 and C. It could be mitigated by an intermittent flash, but would still be a problem.

The power consumption can't be inferred from the indicator light

This is a problem with C and D if sleep power is much different than hibernate power. It is assumed that hibernate power = off power.

Machine behavior differs when the power control is a rocker (to zero power) switch, <u>not</u> a button

B1, C, and D can't be implemented.

Machine behavior differs when there is a rocker switch (to zero power) <u>in addition to</u> a power button

B1 and C won't indicate *hibernate* when main power is off. With C and D, you can't tell if it is OK to turn the rocker switch to off. Because of these problems, *hibernate* is not likely to be implemented with these solutions and both a rocker switch and power button on the device.

3.0 Emerging Issues

The context of evaluating *hibernate* is always evolving. The recovery times from *sleep, shutdown,* and *hibernate* are all changing with memory sizes, disk and processor speeds, operating systems, configurations, and the availability of non-volatile main memory. In addition, some of the issues discussed above could be mitigated if a *mechanical* indicator of the *hibernate* state was included so that power would not be required to maintain it.

4.0 Results and Conclusions

Table 4 summarizes the issues reviewed in Section 2.5, provides severity levels for each issue, and the total degree of problem presented by each of the five solutions, weighted by the severity, and a simple count. Four of the solutions are failry close in the degree of problem they present, particularly when seen from the weighted perspective. Only one solution stands out as least problematic — Solution A.

Hibernate should be seen as a form of *off*. This solution (A) has the fewest problems for users, manufacturers, and energy consumption.

5.0 References

Compaq, Intel, Microsoft, Phoenix Tech., and Toshiba. 2000. Advanced Configuration and Power Interface Specification: Revision 2.0. [http://www.acpi.info]. 2000.

Table 4. Summary of Solutions/Issues and Severity Ratings

Issue	**A**	**B1**	**B2**	**C**	**D**	Severity
Simplicity and Consistence of Power UI						
The "at most three states" principle is violated		X	X			3
No 1:1 correspondence between states and power indicator			X			3
The default "Off" state (from power button) will vary	X	X	X	X	X	1
Responsiveness to input is not consistent within a state				X	X	3
The Power indicator will be more complicated		X				2
What can the user do without turning a machine on						
Can't tell from the power indicator if the system's state is saved	X		X		X	2
Can't tell from the power indicator if machine can be unplugged				X	X	2
Can't tell from the power indicator if OK to change internal hardware	X	*	X	*	X	1
Can't tell from the power indicator if OK to change external hardware	?	?	?	?	?	0
Other						
The hibernate indicator will run down the battery		X		X		3
The power consumption can't be inferred from the indicator light				X	X	1
Behavior differences when the power control is a rocker (to zero power)		X		X	X	1
Behavior differences when there is a rocker switch *in addition* to a button		X		X	X	1
Total (as if problems were of equal severity)	3	6+	5	7+	8	
Totals by severity rankings	4	11+	10	12+	12	

Severity: 1 = minor concern; 3 = major concern; * = possibly a problem after power failure; ? = not sure if a problem