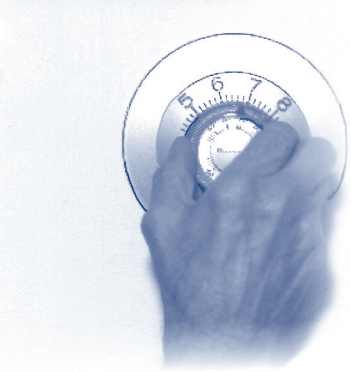
T² RERC

REHABILITATION ENGINEERING RESEARCH CENTER ON TECHNOLOGY TRANSFER

Accessible Thermostat



In Cooperation With:

Center for Assistive Technology
University at Buffalo

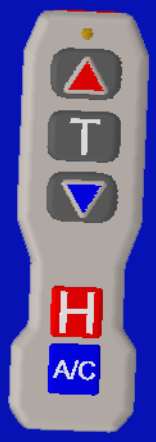
AZtech

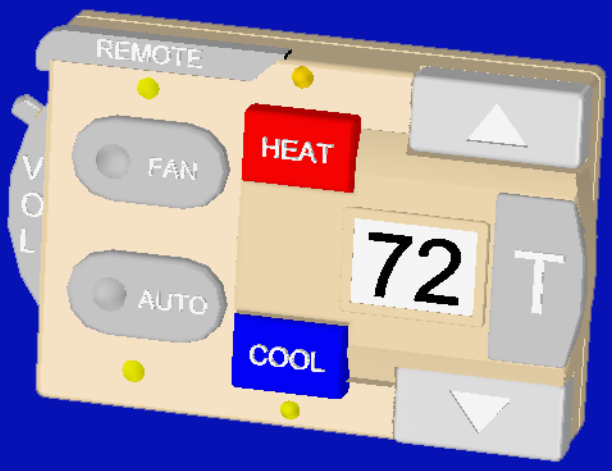
Independent Living Project of
Western New York, Inc.

RERC on Technology Transfer
State University of New York at Buffalo
515 Kimball Tower • 3435 Main Street • Buffalo, New York 14214-3079
Phone: (716) 829-3141 • Fax: (716) 829-3217 • Voice/TDD: (800) 628-2281
http://cosmos.buffalo.edu/t2rerc/

National Institute on Disability and Rehabilitation Research

ACKNOWLEDGEMENT
This is a publication of the Rehabilitation Engineering Research Center on Technology Transfer, which is funded by the National Institute on Disability and Rehabilitation Research of the Department of Education under grant number H133E980024. The opinions contained in this publication are those of the grantee and do not necessarily reflect those of the Department of Education.





Accessible Thermostat with Remote

Table of Contents

SECTION A: Executive Summary

SECTION B: Overview
- Current Situation

SECTION C: Accessible Thermostat Features
- Control Interface
- Digital Readout
- Auditory Feedback
- Remote Control
- Programmability

SECTION D: Marketing Potential
- Target Market
- Market Projections
- Competing Products and Manufacturers
- Opportunity for Accessible Thermostat
- Sales Projection

SECTION E: Consumer Focus Groups

SECTION F: Appendices
- Appendix A: US Patent # 5,690,277
- Appendix B: CAD Drawings
- Appendix C: Market Size for Persons with Disabilities
- Appendix D: Design Requirements
- Appendix E: Competitive Product Matrix
- Appendix F: T^2 Project Overview

T^2RERC

Section A

Executive Summary

T²RERC

EXECUTIVE SUMMARY

Product Description

The Accessible Thermostat is an electronic residential thermostat intended for installation in new construction, or as a part of an upgrade to existing heating systems. This unique design has distinct advantages over existing thermostats in the marketplace due to its user friendly operation, voice output, and remote control. The thermostat provides auditory, tactile and visual feedback to its user. The Accessible Thermostat interface has controls whose size, shape, color and position optimize accessibility, visibility, intuitive use and require low force to operate. The thermostat's remote control provides an alternative user interface.

Key Features

- Large high contrast buttons, icons, and symbols to provide visual, cognitive and tactile cues
- Auditory feedback for both temperature and control status
- Remote control
- Backlighting for most control buttons to ensure controls are easily visible at night

Target Markets

The Accessible Thermostat was designed to benefit the entire population, while targeting certain key segments; the elderly, people with mobility and vision impairments, and people with poor neuromuscular ability. There are 33.9 million Americans over the age of 65 and the 13.2 million adults between the ages of 18 and 69 with mobility and vision impairments and poor neuromuscular abilities.

Market Projections

Based on current trends, there appears to be great opportunity for the device. According to the U.S. Bureau of Census, there are an estimated 117 million housing units in America, with an average of 1.3 million (1,351,000) new private housing units completed each year, and $100 billion dollars spent on maintenance, repairs and improvements: often made to the more than 38% of these homes built prior to 1960. Of the 117 million housing units, 20.8% (24 million) are owned by the elderly population, of which 53% (12 million) were built before 1960. The senior housing industry is growing rapidly, particularly assistive living communities, with nearly 51,000 units being constructed in the past year. Potential annual sales for the Accessible Thermostat are projected to be $5,066,250. Additional sales for use in home renovations would increase this sales estimate significantly.

Purchase Intent - Price Point

Our consumer focus groups and surveys showed that 82% of the surveyed population stated that they definitely or probably would purchase the heating/cooling version of the Accessible Thermostat with its unique features at a price of approximately $99.

Intellectual Property Status

Auditory Thermostat U.S. Patent Number 5,690,277 issued November 25, 1997 (Appendix A).

Section B

Overview

- **Current Situation**

T²RERC

OVERVIEW

Accessible product design for broad markets incorporates features addressing customer needs, environmental limitation and functional limitation. Accessible design anticipates the breadth of needs and limitations, resulting in products with broader market and deeper penetration.

The Accessible Thermostat can be used by almost all persons, in almost all environments, more easily than a typical thermostat. The Accessible Thermostat can be used by many persons, unable to utilize a typical thermostat. Features incorporated into the Accessible Thermostat are consistent with the Electronic Industry Association Electronic Industry Foundation "Design Guidelines for Accessible Electronic Products" and the Center for Universal Design's "Seven Principles of Universal Design." Where possible, feature details such as button colors, icons, shapes, and position reflect customer preferences based upon focus group and survey results.

While **all persons** benefit from the features of the Accessible Thermostat, four major customer populations, characterized by their functional limitations, are especially benefited. These customer populations are:

- Persons with reduced mobility or stability
- Persons with visual impairments
- Blind persons
- Persons with reduced upper extremity strength or fine motor control

For all persons, their ability to access and control the thermostat is reduced by environmental limitations. These environmental limitations include:

- Darkness or poor light
- Obstacles located near the thermostat
- Distance between user and thermostat

Current Situation

Temperature control units can be found in virtually every home in the United States. The majority of these thermostats are rectangular shaped units with a lever adjustment for the temperature setting or round adjusting dial units with on/off heating, fan and air conditioning switches on the outside of the dials. Thermostat functions range from simple heat and fan controlling units to programmable HVAC system controllers.

While thermostats are found in virtually every home, the accessibility of these thermostats varies greatly across individuals. Users with impairments involving vision, mobility, and dexterity often have great difficulty in operating their thermostats, which amounts to approximately 13.2 million Americans. In addition, there are approximately 33.9 million Americans over 65, bringing with them an increased rate of disabilities due to aging.

Our consumer research with persons with disabilities, homeowners and service repair professionals, reveals that many people are not satisfied with thermostats currently on the market. Most participants interviewed expressed difficulties in operating their own thermostats. They stated problems with reading temperature settings and the control markings. Others were unable to easily set the controls because of arthritis, loss of sensation or other impairment in fine motor skills.

Some of the solutions these consumers found for overcoming their obstacles for reading the thermostat included: standing very close to the unit to read and adjust the settings; using a magnifying glass or flashlight to read the temperature or adjust the settings; listening for the heat or air to kick on. To overcome physical inaccessibility they often had someone else to adjust (and read) the thermostat, or compensated for themselves by opening a window when warm or grabbing a blanket or sweater when chilly. The perceived level of success from using these make-do adaptations ranged from just adequate to entirely unsatisfactory. One participant captured this sentiment by stating that no alternative method of using a thermostat is truly satisfactory if it relies on someone else making the adjustment for you.

If consumers have no better options, then thermostat manufacturers may accept this high level of dissatisfaction with such a ubiquitous product. However, the manufacturer who recognizes this significant market opportunity may capture a large portion of sales for new thermostats and a strong market in heating upgrades.

Section C

Accessible Thermostat Features

- Control Interface
- Digital Readout
- Auditory Feedback
- Remote Control
- Programmability

T²RERC

Control Interface

The Accessible Thermostat has a very "friendly" control interface and temperature readout. The following table lists major features and the impact of these features on thermostat function.

Table 1 **Thermostat features with potential impact for consumers who use it.**

FEATURE	IMPACT
Large button size	Large buttons reduce the requirements for precise motor control. This is especially important for persons with diminished fine motor control.
Buttons have unique shapes, colors, icons and labels	Shapes, colors, icons and labels distinguish buttons from each other and suggest their function. In addition, the combination of shape, size, color and icons provides information redundancy. High contrast colors improve button visibility.
Button placement	Buttons with similar functions are grouped close together. Buttons with dissimilar functions are separated. Buttons most frequently used are located along the right edge so as to be most easily accessed by the majority of people. Buttons less frequently used are in less accessible locations. Buttons projecting beyond the edge of the thermostat can be easily accessed using a closed fist. Buttons are located such that they provide intuitive use.
Contour and Texture	Buttons can be located and identified by touch in low light or no light environments or by persons with visual impairments or blindness.
Button Back-Lighting	Backlighting makes most buttons visible in the dark and semi-dark.
LEDs	Most controls have an LED that lights up when the button is activated and is off otherwise. LEDs are located near the button that it provides feedback for.
Large, High Contrast Digital Temperature Display	Display has large, high contrast numbers easily visible under any light condition. Digital readout is strongly preferred by customers over analog displays.
Volume Control Dial	The volume control dial has a small paddle which makes this dial easier to manipulate and also provides information as to volume level.

The most accessible products with the broadest market appeal should utilize design guidelines and incorporate user preferences. For example, the symbol and color for the "Furnace ON/OFF button" preferred by customers was "H" and RED. Specific detail of this sort can only come directly from customers. Buttons should be activated or deactivated when pushed with between 10 and 20 ounces of force. Most persons can operate buttons at this level of force.

The following table describes the Accessible Thermostat controls. Design details are based upon the EIA-EIF Design Guidelines and customer feedback obtained through focus groups and surveys. All buttons are assumed to be backlit to allow user access in darkness or semi-darkness.

Table 2 **Description Of The Control Interface**

CONTROL	DESCRIPTION
Raise or Lower the Temperature Setpoint	Most frequently used controls. Located on right, top and bottom corners near digital temperature readout. Minimum dimension ¾″ to 1″. Opaque, gray background with translucent symbol in foreground. Shape is square. Buttons extend beyond edge of housing. Raised UP and DOWN triangle provide symbolic and tactile feedback.
Temperature Status	Commonly used control. Located on right hand side near temperature readout. Minimum dimension ¾″ to 1″. Opaque, gray background with translucent symbol in foreground. Button shape is semi-rectangular. Raised icon provides symbolic and tactile feedback. Buttons extend beyond edge of housing.
Furnace ON/OFF	Commonly used control. Located on upper center of thermostat housing. Housing is curved to provide raised edge (similar effect to extending button beyond edge of housing). Minimum dimension ¾″ to 1″. Opaque, red background with translucent white symbol in foreground. Button shape is semi-rectangular. Raised 'HEAT' provides symbolic and tactile feedback.
Air Conditioner ON/OFF	Commonly used control. Located on lower center of thermostat housing. Housing is curved to provide raised edge (similar effect to extending button beyond edge of housing). Minimum dimension ¾″ to 1″. Opaque, blue background with translucent white symbol in foreground. Button shape is semi-rectangular. Raised 'COOL' provides symbolic and tactile feedback.
Remote locator	Moderately used control. Located on left upper surface of thermostat housing. Like an alarm clock "snooze" button.

Fan Run In "Continuous Mode"	Rarely used control. Located on middle left of thermostat housing. Minimum dimension ½″ to ¾″. Opaque grey background with translucent white symbols in foreground. Raised "FAN" provides symbolic and tactile feedback.
Fan Run In "Auto Mode"	Rarely used control. Located on the lower left of thermostat housing below "fan continuous" control. Minimum dimension ½″ to ¾″. Opaque grey background with translucent white symbol in foreground. Raised "AUTO" provides symbolic and tactile feedback.
Volume control	Rarely used control. The control is in the form of a dial. Located on the left side of the thermostat. The dial has a small paddle which provides visual and tactile feedback for the volume level.

Digital Readout

There are clear drawbacks having both an analog and digital display. These include added cost and added size. In addition, temperature status can be readily accessed through auditory feedback. The clear recommendation therefore is to utilize a digital temperature readout supplemented by auditory feedback.

Feature	**Advantage**
◆ Large, high contrast digital temperature readouts.	◆ Easier for users to see and interpret in both well lit and poorly lit environments.
Preference ◆ Between digital and analog temperature readouts. ◆ Between having a digital readout or both an analogue and digital readout.	**Consumer Feedback** ◆ 100% of the consumers surveyed preferred the digital readout. ◆ 66% of the consumers surveyed preferred having only a digital readout.

Auditory Feedback

Auditory feedback is a revolutionary feature of the Accessible Thermostat making the device usable for persons with visual impairments or blindness or persons utilizing the thermostat in darkness or semi-darkness. Auditory feedback also provides temperature and control status for persons accessing the thermostat with a remote control.

There are of course many possible variants on the auditory feedback which might be provided. In general however, a thermostat providing auditory feedback should generally provide such feedback as mentioned above in the table for all thermostat functions.

Table 3 **Accessible Thermostat auditory feedback.**

Control Accessed	Auditory Feedback
Raise or Lower the	"Current Temperature is 75 Degrees"
Temperature Setpoint	"Temperature Setpoint is 73 Degrees"
Temperature Status	"Current Temperature is 71 Degrees"
Furnace ON/OFF	"Furnace is now ON" or "Furnace is now OFF"
Air Conditioner ON/OFF	"Air Conditioner is now ON" or "Air Conditioner is now OFF"
Fan in "Continuous Mode"	"Fan is now in continuous mode"
Fan in "Auto Mode"	"Fan is now in auto mode"
Remote Locator	"Beep" sound from the remote

There are many inexpensive voice recording technologies that are suitable to provide auditory feedback. Information Storage Devices (ISD) is a leading manufacturer of this technology.

Remote Control

Remote control is another revolutionary feature of the Accessible Thermostat. It makes the Accessible Thermostat very easy to use by persons with mobility and stability impairments. Persons with visual impairments and blind persons also preferred the remote control as their means of accessing the thermostat. In addition, thermostat control from remote locations, in dark environments and increased convenience are likely to appeal to all customers.

Control buttons on the thermostat and remote control should be similar in terms of their shape, symbol, color, tactile features and icons. For example, if on the thermostat, the "Furnace ON/OFF" button is 'H' shaped and RED in color, then the "Furnace ON/OFF" button on the remote should also be 'H' shaped and RED in color. Designing the remote in this way will make its function intuitively consistent with the thermostat.

Infra-red (IR) remote controls require a line of sight between the transmitter and receiver. This restriction significantly diminishes the value of the remote control to the user. With radio frequency (RF) based remote controls, the thermostat can be operated from "anywhere" provided that the transmitter and receiver lie within some radius.

Low frequency RF remote controls should cost about the same as an IR based remote. Low frequency RF remotes could interfere with other low frequency RF operated devices such as cellular phones, TVs, garage door openers, etc. However, this interference problem can be overcome by coding the remote RF signal. Remote controls utilizing high frequency RF transmitters and receivers are not recommended because they are probably more costly than low frequency RF remotes. Overall, a low frequency, RF remote control with coded signal seems to be the best alternative.

As with any remote control, batteries are consumable and must be periodically replaced. Clearly, a remote control designed to have a long typical battery life will be preferred by the customer.

Programmability

Programmability is a popular thermostat option for consumers. Manufacturers are very familiar with the programmable options on current thermostats. Little effort on our part was addressed toward modifications or improvements to these options.

Section D

Marketing Potential

- Target Market
- Market Projections
- Competing Products & Manufacturers
- Opportunity for Accessible Thermostat
- Sales Projection

T²RERC

Target Market

The Accessible Thermostat was designed with the goal of creating a universally accessible device that could be operated by individuals of any ability level. The device is therefore targeted at all homeowners as a universally accessible thermostat that can be used by anyone. The prevalence of homes with individuals of varying abilities is increasing. As mentioned earlier, many individuals, due to various impairments, are unable to operate their thermostats. This would be an ideal thermostat that could be operated by any user in the home.

More specifically, the Accessible Thermostat's unique features make it an ideal device for particular segments of the population, including the elderly with growing physical impairments due to the natural aging process, and people with disabilities involving poor neuromuscular ability, mobility impairments, and vision impairments.

Market Projections

Projections in the general population, as well as in our specific target segments show an increasing need for a thermostat with universal features.

General Population

According to the U.S. Bureau of Census, there are an estimated 117 million housing units in America, with an average of 1.3 million new private housing units completed each year[1], and $100 billion dollars spent on maintenance, repairs and improvements[2]: often made to the more than 38% of these homes built prior to 1960[3]. These figures indicate a growing market within the general population for thermostats in general.

Elderly

When focusing on our target markets, the need for the Accessible Thermostat intensifies. Of the 117 million housing units, 20.8% are owned by the elderly population, of which 53% were built before 1960. This number will continue to escalate as the population continues to age, particularly the baby boomers. In fact, the elderly population is currently 13% of the U.S. population at 33.9 million. This number is expected to increase to 39.4 million by 2010, and 53.2 million by 2020[4]. As this number increases so too will the number of elderly owned households.

[1] US Census Bureau. "New Privately Owned Housing Units Completed: 1968 to 1998." *World Wide Web document:* http://www.census.gov/ftp/pub/const/www/c22index.html
[2] The Builder Business News. "Expenditures For Improvements & Repairs For Residential Properties: Report & Tables." *World Wide Web document:* wysiwyg://www.nwbuildnet.com/nwbn/repairs.html
[3] Program Resources Department, AARP, Administration on Aging, US Dep. Of Health and Human Services (1998). "Profile of Older Americans." *World Wide Web document*: http://researchaarp.org/general/profile97.html
[4] Citro, J & Consumer Team, PPI (1998). "Housing Characteristics of Older Households: 1995." *World Wide Web document:* httpl/research.aarp.orglil/dd37housing.htmI

Seniors today and in the future are less likely to spend the later part of their lives in senior living communities or nursing homes. With the increased cost of healthcare and the reduction in financial support for elder care programs, more people are choosing to age in place within the familiar surroundings of home and neighborhood. A 1992 survey published in the Journal of Housing for the Elderly studied 280 people over the age of 75, ninety percent were satisfied living in their homes.

Of the elderly polled in 1992, over half (53.9%) or 18.3 million elderly people reported at least one disability which limits their ability to carry out Independent Activities of Daily Living, which includes activities such as preparing meals, using the telephone, doing housework, and operating thermostats[5].

The senior housing industry is growing rapidly as well, particularly assistive living communities, with nearly 51,000 units being constructed in the past year. The 51,000 units account for 75% of new senior housing construction in 1998, while congregate senior housing accounted for 15%, senior apartments for 6% and continuing care retirement communities for 4%. These types of housing units, along with private homes will be the residences of the 33.9 million Americans over the age of 65. Devices such as the Accessible Thermostat will allow this growing segment the increased independence they desire.

People with Disabilities

There are approximately 13.2 million Americans between the ages of 18 and 69 with mobility and visual impairments and poor neuromuscular ability who would benefit from this device[7]. This age group would be the primary age of nonelderly Americans who would operate thermostats in housing units they own, rent, or live in. Mobility impairments including paraplegia, Cerebral Palsy, and Multiple Sclerosis, visual impairments such as blindness and low vision, and poor neuromuscular ability due to Parkinson disease, rheumatoid arthritis, carpal tunnel syndrome and upper extremity impairments severely limits an individual's ability to operate standard thermostats. The inability to control their environment is a serious impediment in their quest for achieving independent living.

[5] Program Resources Department AARP, Administration on Aging, U.S. Dep. Of Health and Human Services (1998). "Profile of Older Americans." *World Wide Web document:* http://research.aarp.org/general/profile97.htnd
[6] American Association of Homes and Services for the Aging. "Assisted Living." *World Wide Web document:* http://www.aahsa.org/public/assisbkg.htin
[7] LaPlante, M.P. and D. Carlson (1996). "Disability in the United States: Prevalence and Causes, 1992." Disability Statistics BQort (7). Washington, DC, U.S. Department of Education, National Institute on Disability and Rehabilitation Research.

As the population in the United States continues to age, the difference between disability and aging markets will blend together. People with disabilities are living longer and people who live longer are often challenged with increased disabilities. The trend in today's seniors' market is for aging in place due to the reduction in healthcare dollars and funds previously available for long term living facilities.

As with every other market segment, the cohort group that includes the Baby Boomers is the market segment worthy of tracking. They are the ones with the highest disposable income. They are most likely to make home modifications due to lifestyle changes relating to changes in family structure or due to personal health. In fact, people over the age of 50 spend 55% more on home modifications than their younger counterparts.

Today's Baby Boomers are the caregiver to aging parents. By the year 2000 80% of people over the age of 50 will have at least one living parent. Boomers are also the mature markets for tomorrow that have learned from the experiences of their parents and will adapt their lifestyle prior to it becoming a need. Within the next twenty years, people over the age of 65 will become 25% of the market share.

Competing Products and Manufacturers

A competitive product search has revealed that no thermostats are currently on the market designed for universal accessibility. The thermostats found to be a direct competitor to the Accessible Thermostat varied in the number of features offered and level of accessibility, according to price.

The highest priced competing product found was the LHS25 Talking Heat/Cool Thermostat, manufactured by LS&S Group Inc. This audio thermostat was specifically designed for individuals who are blind or have low vision. It provides voice feedback when adjusting the temperature setting, and contains no visual feedback such as analog or digital temperature readout. It is currently available in assistive technology catalogs and retails for approximately $160.

Honeywell offers a line of thermostats designed for individuals with low vision, blindness or limited hand control (www.honeywell.com). The Honeywell EasyToSee heat pump thermostat includes high contrast, large, raised temperature scale numbers and marking for system HeatOffCool and fan AutoOn settings. It also has a "click" felt for every two degrees of dial movement and at every system and fan control switch position. In addition, it has a large temperature setting lever and switches for system and fan control, which are easy to locate and move. The EasyToSee thermostat is priced at $39.95.

The EasyToUse accessory ring fits Honeywell's round EasyToSee thermostat and provides a gripable area of the temperature adjustment dial. With this adaptation, the dial can be brushed or rolled to the desired setting. It is priced at $11.95.

Also available for the round Honeywell thermostat and similar round thermostats are thermostat magnifiers. These are plastic magnifiers that when attached onto the thermostat face, enlarge the standard size of the print on the face of the thermostat. Cost for the Magnistat is $10.

While these particular thermostats and accessories were designed specifically for people with disabilities, the other competing thermostats are designed for the general population, and can be found in mainstream retail outlets and catalogs. These models ranged in price and features from the Chronotherm Programmable thermostat from Honeywell retailing at $119.00 to the Economy Stat Heat from Lux retailing at $9.97.

Opportunity for Accessible Thermostat

Based on our research and contact with consumers through focus groups and surveys with a representative sample of our target markets, a competitive product matrix has been constructed evaluating the Accessible Thermostat and its competing products against the features desired by consumers. This matrix, located in Appendix E of this report, indicates the superiority of the Accessible Thermostat in meeting the needs of consumers. The wide range of features offered by the Accessible Thermostat, including voice feedback and a remote control option, make it a device which is truly universal and accessible and attractive to the entire population.

Consumers reinforced this conclusion. Based on focus group and survey results conducted by the T^2RERC, approximately 82% stated they definitely or probably would purchase the Accessible Thermostat at a competitive price between $51 and $99.

Based on its unique features and universal accessibility, the significant growth trends in the general population and the target markets, and the positive response from consumers, it is evident that the Accessible Thermostat has a great opportunity to make significant inroads in the home thermostat market.

Sales Projection

If, in a given year, five percent or 67,550 of the 1,351,000 new housing starts purchased the heating/cooling Accessible Thermostat, the potential annual sales based on a selling price of $75 would be $5,066,250. A manufacturer may sell this product for 1/4 the price. Potential annual sales for the manufacturer of the Accessible Thermostat are projected to be $1,266,563. Additional sales for use in home renovations would increase this sales estimate significantly.

Section E

Consumer Focus Groups

T²RERC

The T²RERC held five consumer focus groups, consisting of a total of 44 participants. Each group averaged 9 people per session, with a demographic profile of 12 elderly, 10 wheelchair users, 6 mobility impaired nonwheelchair users (canes, crutches or walkers), 8 blind/visually impaired, 6 contractors, and 2 people who were nondisabled. Participants were asked to participate in an open forum discussion led by a focus group moderator. The two primary topic areas included (1) the current status of each participant and their satisfaction level of thermostats used in their homes, and (2) description of the ideal product.

(1) Current Status and Satisfaction Level

To determine the current status and consumer satisfaction levels, the participants in the five focus groups were asked to provide information on a variety of related topics. Their raw responses were as follows: (Full focus group details can be provided upon request.)

- In order to adjust their present thermostat, (with the exception of one or two with portable space heaters), all were required to go to wall-mounted units, which were found in every conceivable area of the home, even the basement.

- Some participants expressed a strong desire to control their own thermostat as: it was an important aspect of their independence, permitted them to minimize expenditures for heat, or was a safety concern for them.

- A few had programmable units which automatically varied the temperature; other group members indicated they adjust their thermostats from zero to five times per day, with most making 2 or 3 adjustments, and some only if changes in the weather required it.

- Taken as an aggregate, our participants' existing thermostats had a number of features: on/off switch; temperature adjustment; switching between heating and air conditioning; manual fan on; inside and exterior temperature readouts; programming capability, often using the date and time; and a few had Braille markings, raised letters or other tactile indicators.

- With regard to the cognitive processes required to use the device, they acknowledged that the consumer must be able to read and understand the readings and tell if they have changed, and to realize how to work with the controls, possibly including the programming of the automatic units.

- The difficulties our participants experienced with their own thermostats were numerous, with many involving problems reading the temperature levels and control markings with limited sight, sometimes requiring the addition of raised markings. Others cited problems with: understanding or using the controls or programming automatic functions (particularly with arthritis in the hands, a loss of tactile sense or other impairment in fine motor skills); temperatures that fluctuate, are difficult to change, or do not match what is set; confusing output displays; control levers that are too small; poor location of the unit; and inability to adjust it if one is confined to bed or has other mobility concerns. Some existing products are

sufficiently complicated that it is a challenge to set the date or time - an ability needed at least twice a year for Daylight Savings Time changes.

- Some of the solutions the disabled consumers found for overcoming these obstacles were: standing very close and using a magnifying glass or a flashlight to see the control labels and readouts; as suggested earlier, putting Braille dots or raised markings on the dial to indicate desired settings or temperature ranges; or listening for clicks as one moves the dial; also, making small adjustments depending solely on how warm one feels, without trying to read the numbers. Some less direct methods were: getting somebody else to read and set the thermostat; opening windows to reduce the temperature; or intentionally leaving the setting lower than the normal level and adding or removing blankets to adjust one's personal comfort.

- The perceived level of success from using these make-do adaptations ranged from just adequate to entirely unsatisfactory, with the majority indicating they were not very good. While a few of the participants allowed that some of these methods did "get the job done", resetting the temperature with reasonable accuracy, most were negative, noting problems with depleted flashlight batteries or, if needed, not always having someone available to make the adjustments. One focus group member captured this sentiment by stating that no alternative method of using a thermostat is truly satisfactory if it relies on someone else making the adjustment for you.

(2) Description of the Ideal Product

For the purpose of brevity the following is a synopsis of the features required by the consumers to be present in the ideal thermostat product. Full focus group details can be provided upon request. The thermostat must have:

- A "User-friendly" interface
- A remote control
- Programmability
- Digital only readout
- Voice output

The "User-friendly" interface of the thermostat provides auditory, tactile and visual feedback to its user. The Accessible Thermostat interface has controls whose size, shape, color and position optimizes accessibility, visibility, intuitive use and requires a low force to operate.

The remote control makes the Accessible Thermostat very easy to use by persons with mobility and stability impairments. Programmability allows the user to control daily operation of the thermostat through pre-arranged settings with no consumer involvement other than the initial programming of the settings.

The large, high contrast digital temperature readout appears to be easier for users to see and interpret in both well-lit and poorly lit environments. When asked to choose between digital and analog temperature readouts, 100% of the customers surveyed preferred the digital readout. When asked to choose between having a digital readout or both an analog and digital readout, 66% of the customers surveyed preferred having only a digital readout.

Voice output allowed those with visual impairments the ability to easily recognize what adjustments they had made to their thermostat and environment. With the growing elderly population, this seemed to be a feature that should definitely be incorporated into the thermostats of the future.

Importance Summary

When considering the relative importance of each feature, it shows that consumers place highest importance on a user-friendly interface. A remote control and programmability are the next most important features followed by a digital temperature readout and then voice output, though both are considerably less important than the other two features. Price of the thermostat is the least important feature, which suggests that if a thermostat is available with desirable features, consumers will be willing to pay a higher price.

A follow-up survey to the groups identified critical features as rated by the participants to include:

- a userfriendly interface (93% of respondents)
- programmability (77% of respondents)
- warning signals if temperatures varied outside a “safe” range (75%)
- color contrast buttons (70% of participants)

The cost for all of the above was estimated between $51.00 and $100.00 (63%). The remainder of the participants who were willing to pay more than $100 for a thermostat wanted to have voice activation and a remote control feature included into the basic design. People who need these features are willing to pay the premium prices for the convenience and independence that such as device would provide them.

In summation, it appears currently there is a significant market opportunity for an Accessible Thermostat comprised of the key features we have listed. Consumer dissatisfaction with current thermostat models seems to be opening the door for a manufacturer to introduce a new 21st Century type thermostat. The manufacturer that introduces such a new design will be able to maintain or in some cases make significant gains in their marketshare.

Section F

APPENDICES

- Appendix A: U.S. Patent # 5,690,277
- Appendix B: CAD Drawings
- Appendix C: Market Size for Persons with Disabilities
- Appendix D: Design Requirements
- Appendix E: Competitive Product Matrix
- Appendix F: T^2 Project Overview

Appendix A

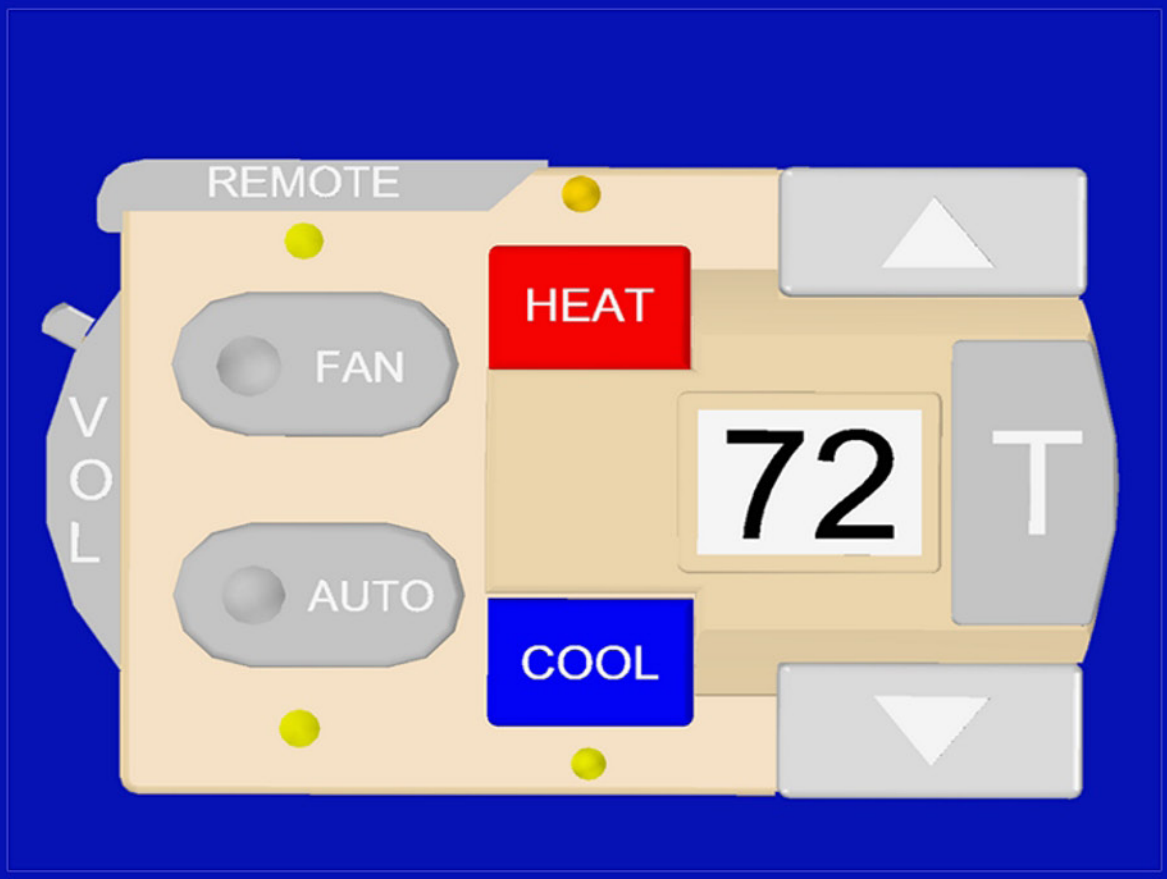
U.S. Patent # 5,690,277

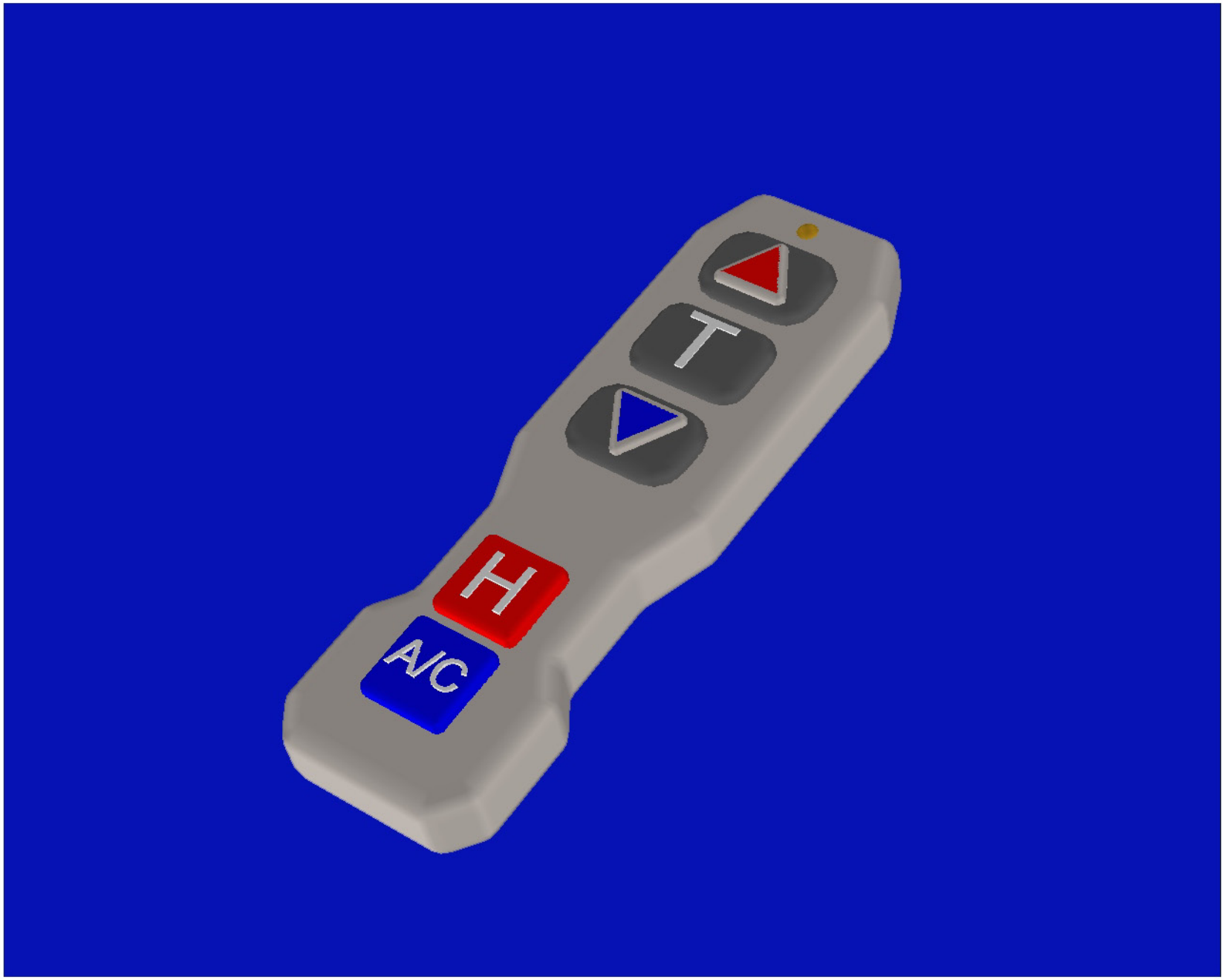
T²RERC

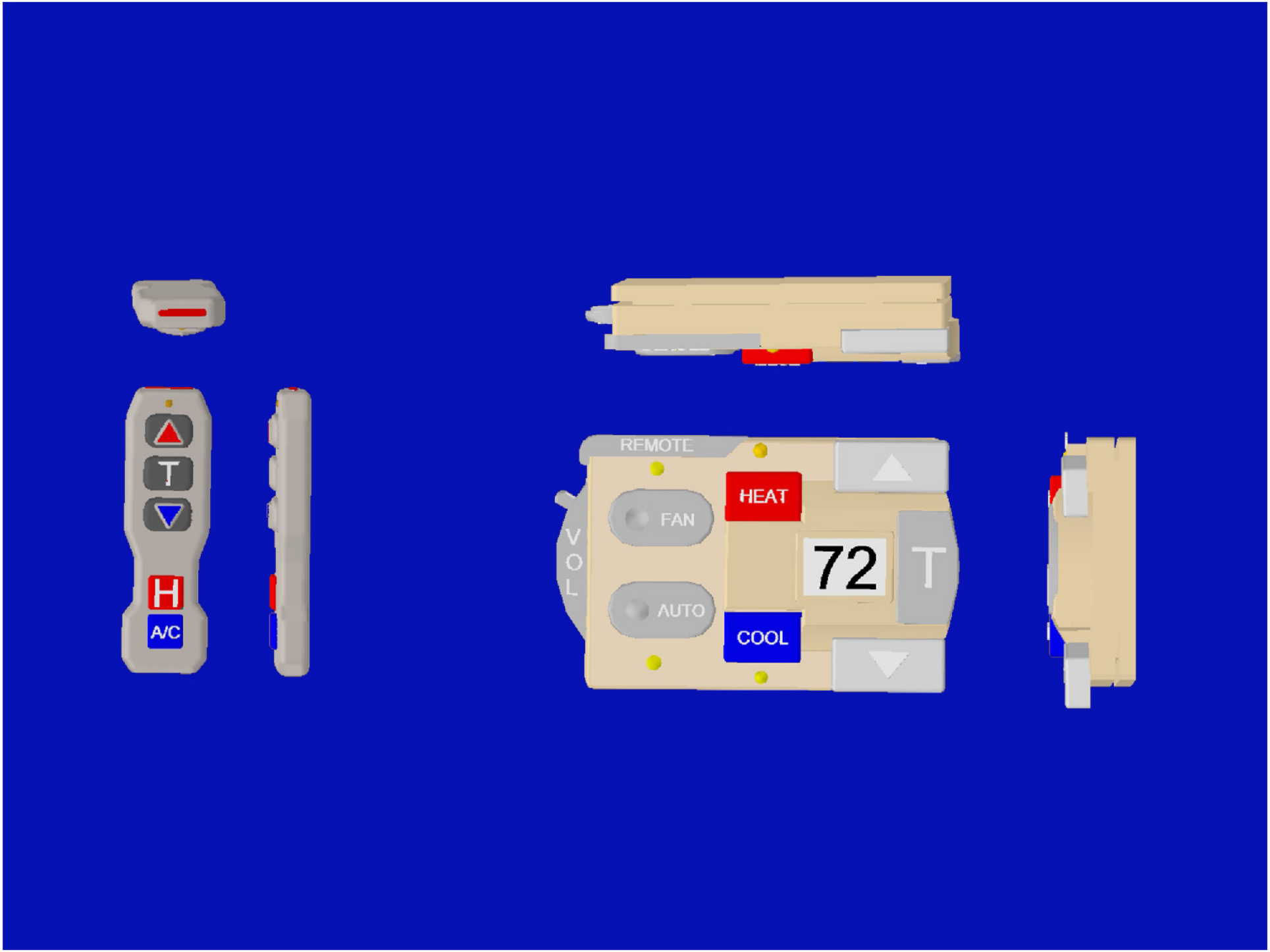
Appendix B

CAD Drawings

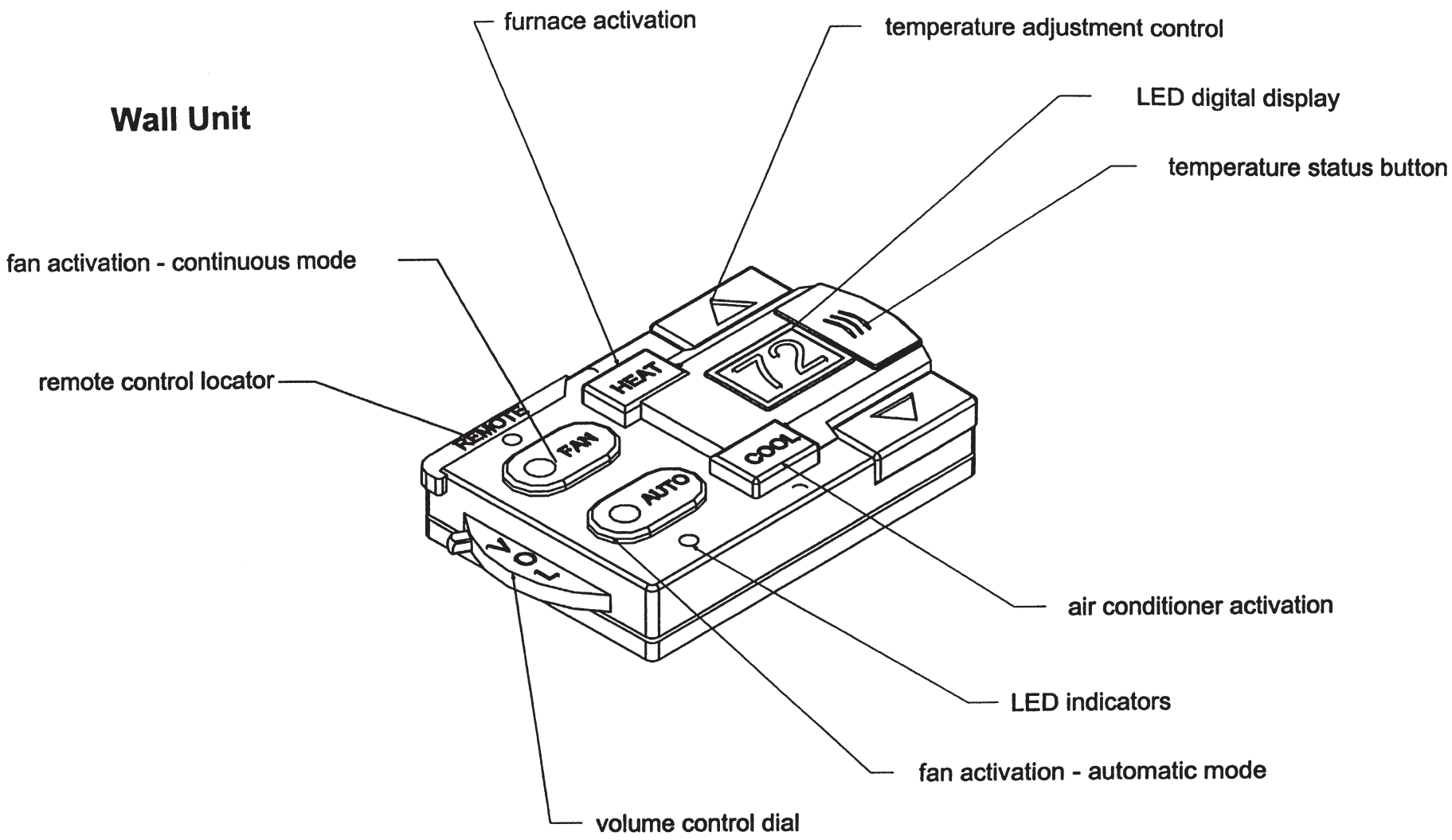
T²RERC


REMOTE
VOL
FAN
AUTO
HEAT
COOL
72
T


T
H
A/C

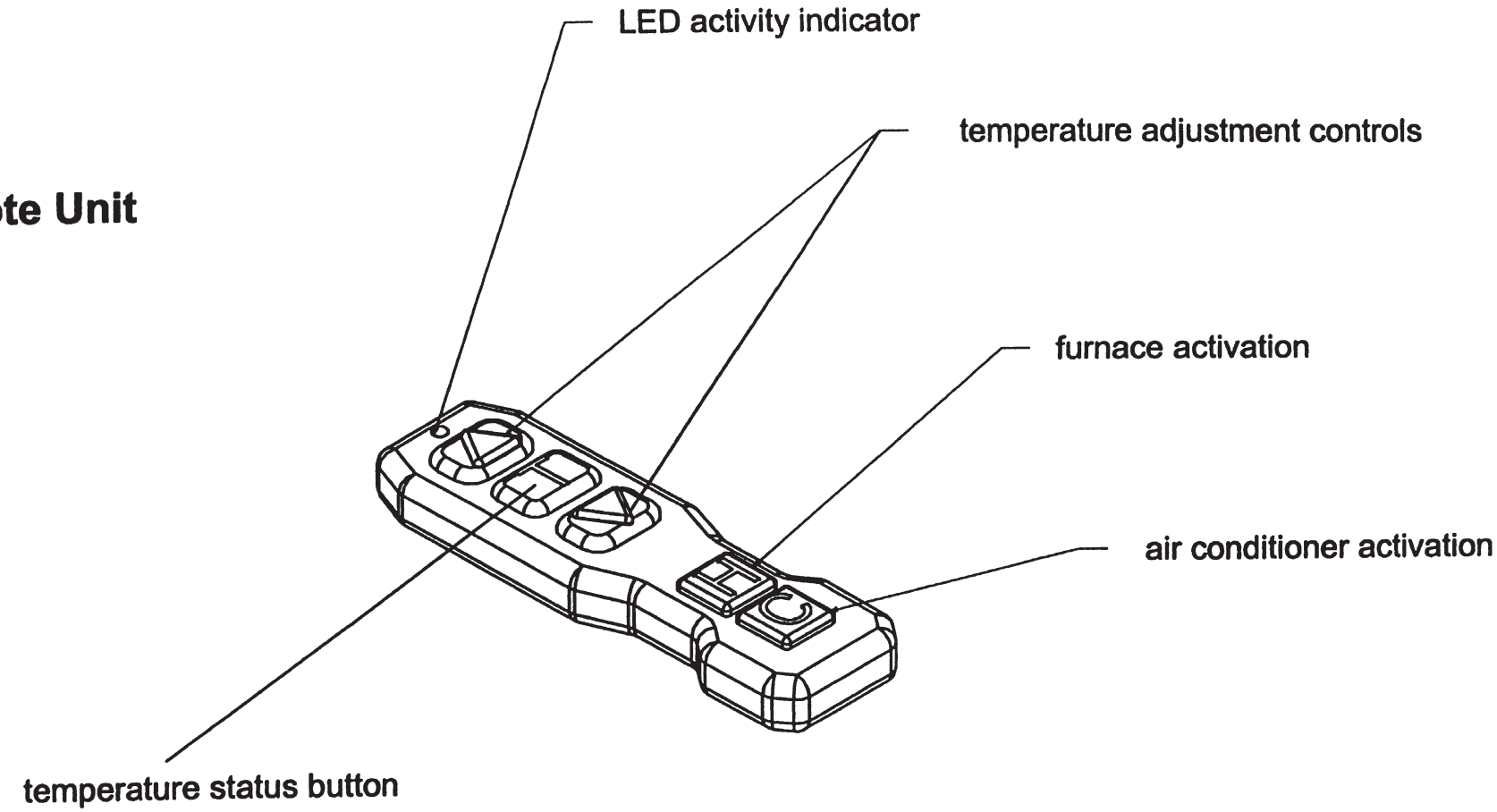

T
H
A/C
REMOTE
HEAT
FAN
VOL
72
T
AUTO
COOL

Wall Unit



Accessible Thermostat The Center for Universal Design

Remote Unit


LED activity indicator
temperature adjustment controls
furnace activation
air conditioner activation
temperature status button

Appendix C

Market Size for Persons with Disabilities

T²RERC

APPENDIX C

Market Size for Persons with disabilities (numbers in thousands). Number of people (age range of 45 to 80+) with disabilities in the U.S.A.

Mobility Impairment	In thousands	
Absence or loss, lower extremity	198	
Quadriplegia	41	
Hemiplegia	52	
Paraplegia	47	
Hemiparesis	122	
Paralysis of upper extremities	30	
Cerebral Palsy	107	
Partial paralysis of upper extremity	46	
Paraparesis	30	
Other partial paralysis of lower extremity	38	
Paralysis of other sites, complete or partial	100	
Curvature of spine or back	334	
Spina bifida	42	
Congenital dislocation/deformity of hip and/or pelvis	30	
Deformity of the lower extremity	176	
Deformity neck or trunk bones or of shoulder or upper extremity	89	
Orthopedic impairment of back or neck	3469	
Orthopedic impairment of hip and/or pelvis	317	
Orthopedic impairment of lower extremity	2217	
Multiple Sclerosis	214	
Amyotrophic lateral sclerosis	86	
Mononeuritis of lower limb	142	
Spondylosis and allied disorder	568	
Intervertebral disc disorders	2232	
Sub-Total		**10727**

Table continued on following page...

Continued...

Visual Impairment		
Blindness in both eyes	161	
Visual impairment in both eyes	255	
Blindness in one, Visual impairment in other	35	
Blindness or visual impairment in one eye: Other eye good vision or not known	249	
Sub-Total		**700**
Poor Neuromuscular ability		
Poor Neuromuscular ability	55	
Parkinson disease	269	
Carpal tunnel syndrome	1067	
Orthopedic impairment of shoulder and/or upper extremity	461	
Rheumatoid arthritis		
Sub-Total		**1852**
Overall Total		**13279**

The Accessible Thermostat will increase the user population by the groups listed above and will expand market opportunities to the manufacturer and distributor.

Appendix D

Design Requirements

T²RERC

APPENDIX D

Design Requirements vs. Consumer Functional Ability and Markets

Table below gives an estimate of the number of people, in thousands, to whom a design feature is particularly useful.

design feature likely to strongly address functional limitations.

design feature likely to moderately address functional limitations.

	Design Features								
	Large, distinct shaped buttons on thermostat	Raised buttons on thermostat as well as on remote	Large bright digital display	Intuitive placement of control buttons [1]	Separation of control buttons [2]	Control Status LEDs	Voice feedback	Remote control	Backlight
Functional Limitation									
Mobility Impairment			7598				7598	7598	
Low Vision	664	664	664	664	664	664	664	664	664
No Vision	222	222		222	222		222	222	
Poor Neuromuscular Ability	1474	1474			1474			1474	
Total	**2360**	**2360**	**8262**	**886**	**2360**	**664**	**8484**	**9958**	**2138**

The purpose of the above table is to illustrate which features of the "Auditory Thermostat" address critical needs of distinct user population. It is important to emphasize that **ALL USER** - the general population and hearing impaired individuals for instance - would clearly benefit from the above desiqn features.

[1] Example: Button to raise the temperature is placed above temperature setting LED while the button to lower the temperature is placed below the LED.

[2] Similar controls are placed together while dissimilar controls are separated from one another. Example - "Temperature control" buttons are grouped together and placed toward the right side of the thermostat while "Fan control" buttons are grouped together and placed towards the left side of the thermostat.

Table 1 (B)
Table 1 (A) Design Requirements Versus Environmental Limitations

	Design Features								
	Large distinct shaped buttons on thermostat	Raised buttons on thermostat as well as on remote	Intuitive placement of control buttons [11	Separation of control buttons [2]	Status control LEDs	Control Backlighting	Large bright digital display	Voice feedback	Remote control
Environmental Limitation									
Darkness [3]	Y	Y	Y	Y	Y	Y	Y	Y	Y
Small Distance [4]	N	N	N	N	Y	N	Y	Y	Y
Large Distance [5]	N	N	N	N	N	N	N	N	Y
Local Obstacles [6]	N	N	N	N	Y	N	Y	Y	Y

Key: Y = Design feature is likely to help address environmental limitation
N = Design feature is not likely to help address environmental limitation

[1] Example - Button to raise the temperature is placed above temperature setting LED while the button to lower the temperature is placed below the LED.

[2] Similar controls are placed together while dissimilar controls are separated from one another. Example - “Temperature control” buttons are grouped together and placed towards the right side of the thermostat while “Fan control” buttons are grouped together and placed towards the left side of the thermostat.

[3] Example - Thermostat located in a dimly lit hallway.

[4] Example - User in armchair, watching TV, thermostat 15´ away on hallway wall.

[5] Example - User upstairs in bed, thermostat downstairs in den.

[6] Example - A desk located under the thermostat makes the user bend forward “in a long reach” to the thermostat. (Head about 3.5˝ away).

Appendix E

Competitive Product Matrix

T²RERC

Appendix E: Product Evaluation Against Design Requirements

	Features Desired by Consumers									
	Control Interface									
Thermostat/Model Number and Manufacturer	Large, distinct shaped buttons on thermostat	Raised buttons on thermostat as well as on remote	Intuitive placement of control buttons	Separation of Control Buttons	Control Backlighting	Status Control LEDs	Large, Bright Digital Display	Voice Feedback	Remote Control	Cost
Heat										
The Round/CT87A- Honeywell										$22.87
Tl0-1141- Lux										$9.97
CM80- Robert Shaw										$17.94
BB200- Robert Shaw										
Heating- 2 and 3 Zone/ CT1800A 1004- Honeywell										$76.00
Heat/Cool										
LHS-25 Talking Heat/Cool Thermostat- LS&S Group, Inc.			✓					✓		$160.00
CT 87B 4008- Honeywell										$38.86
DMH 100- Lux		✓					✓			$18.97
TL 650- Lux			✓		✓					$19.97
T 101143- Lux										$16.97
Heat/Cool/Programmable										
Accessible Thermostat	✓	✓	✓	✓	✓	✓	✓	✓	✓	$51-$99
Magic Stat 32 Program/ CT3200A 1001- Honeywell				✓	✓		✓			$59.00
Programmable Round/ CT2700A 1019- Honeywell		✓		✓						$49.00
7 Day Programmable/CT3600A 1002- Honeywell				✓	✓		✓			$89.00
Chronotherm Programmable/ CT8602C 1001- Honeywell				✓			✓			$119.00
TX 500- Lux		✓		✓			✓			$29.97
TX 1500- Lux		✓		✓			✓			$39.00
TX 9000- Lux				✓			✓			$54.87

Appendix F

T^2 Project Overview

T^2RERC

Rehabilitation Engineering Research Center on Technology Transfer
Overview

"The Tech Transfer RERC advances the methods, technologies and products of technology transfer, through collaboration with all stakeholders, to improve assistive technology devices and services. The goal is to improve the quality of life for people with disabilities."

To fulfill this Mission Statement, the Tech Transfer RERC:

- advances the methods of technology transfer through research;
- transforms technologies into products through development; and
- facilitates the commercialization of new and improved assistive devices.

Research will develop, validate and disseminate a comprehensive model of technology transfer. Development will identify and transfer up to three breakthrough technologies to industry annually through a demand pull model, and will identify and transfer three to five useful new inventions to the marketplace annually through a supply push model. Facilitation through training, dissemination and technical assistance, will benefit the various stakeholders in the field. Dissemination includes state-of-the-practice conference in 2001, and training includes an instructional program available for presentation at other conferences.

The Tech Transfer RERC is designed to function as an intermediary and a catalyst, improving the process while expanding the network of stakeholders participating in the field of assistive technology. Accomplishing the mission requires close collaboration with academic, industrial, clinical, consumer and government stakeholders.

The Tech Transfer RERC is a partnership of technical, marketing and consumer agencies experienced in assistive technology evaluation, transfer and commercialization. The partnership, led by the Center for Assistive Technology, University at Buffalo, includes the Western New York Independent Living Center, AZtech Inc., and the Research Triangle Institute. The Tech Transfer RERC is funded by the National Institute on Disability and Rehabilitation Research of the Department of Education under grant number H133E980024.

For additional information on the mission of the T^2 RERC and the services the agencies of this partnership provide, contact James A. Leahy, Project Administrator, T^2 RERC at jimleahy@acsu.buffalo.edu or by telephone at 716-829-3141.

T^2RERC