Honeywell

Independent LifeStyle Assistant (ILSA)

Thursday
APRIL 8, 1999

Woman, 89, says relocation violates her rights

She sues her nephew and Hennepin County in an effort to remain in her home in Minneapolis rather than be moved to a nursing home in Wisconsin.

By Warren Wolfe
Star Tribune Staff Writer

Approved for Public Release

A Proposal to NIST Advanced Technology Program General Competition 99-01

Submitted by the ILSA team:

Honeywell

HELP Innovations

In Home Health

MN Department of Human Services

Fletcher Allen Health Care

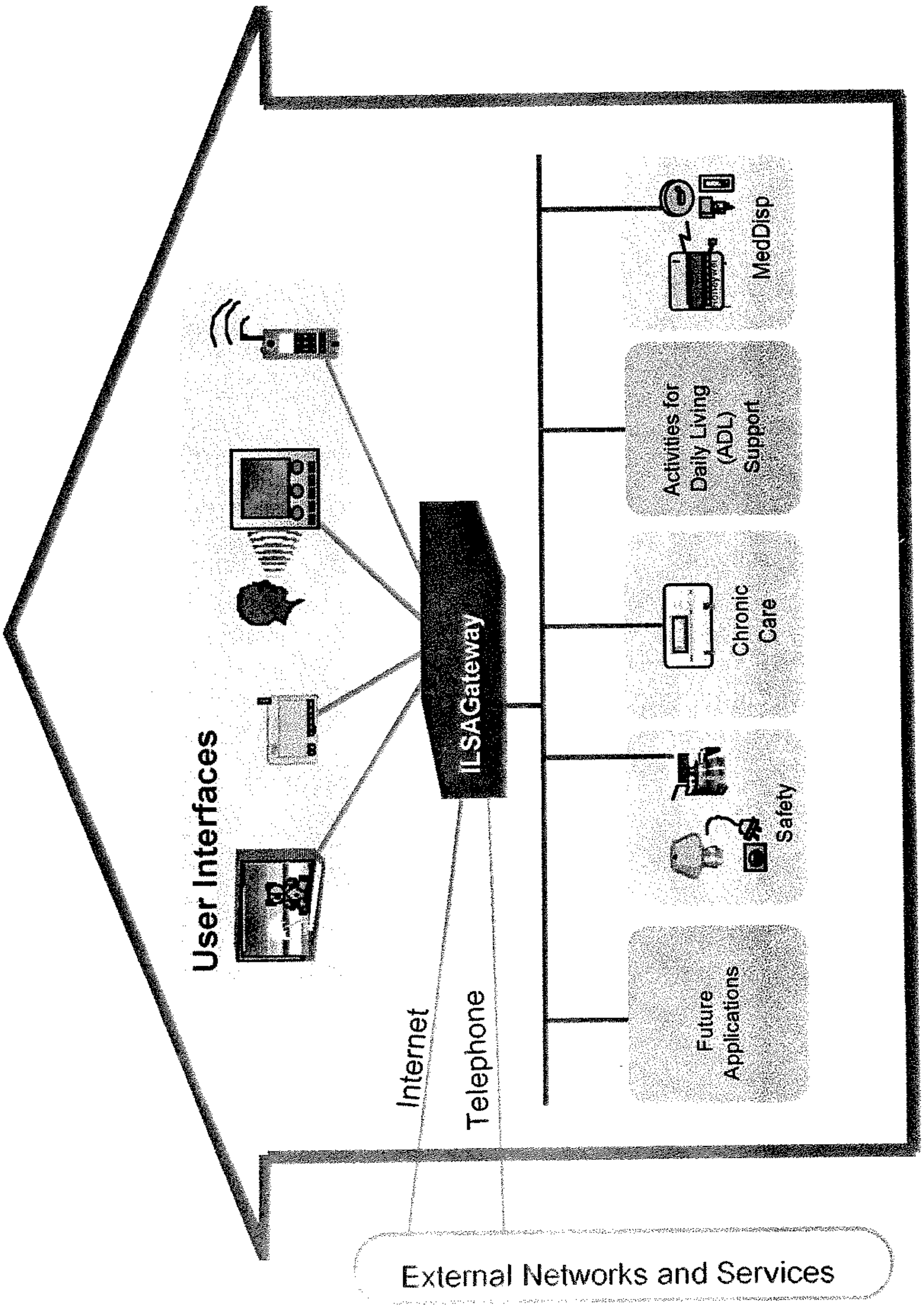
April 14, 1999

Contact Person:

Dr. Lee Levitan, Honeywell Technology Center
3660 Technology Drive, Minneapolis, MN 55418
Phone: (612) 951-7393, Fax: (612) 951-7438
Internet: levitan_lee@htc.honeywell.com

Honeywell Technology Center
3660 Technology Drive
Minneapolis, Minnesota 55418

Inside the ILSA Home



Part 3
Executive Summary

The population of the United States is aging rapidly: The number of people over the age of 65 will double between now and 2030, and those over 85 will quadruple. Historically, 43% of people over 65 eventually move to a nursing home, in many cases despite their desires. Our team will develop the technologies required for a unique and innovative healthcare system called the Independent LifeStyle Assistant (ILSA). The program goal is to bring evolving technologies to bear on the problems of the elderly to allow them to stay in their "legacy homes," defer moving to assisted living or nursing facilities, and improve the quality of life for them and their caregivers. Billions of dollars of savings in reduced healthcare costs are anticipated annually.

Our R&D goal is an ILSA system that provides intelligent integration, high-level reasoning, and automatically generated interactions for care recipient health monitoring and management. To accomplish this we have established a team of technology and domain experts to address the issues of healthcare, activities of daily living (ADLs), secure communication, decision support, and user interface development. The project includes three phases of technology development and test and evaluation to develop and integrate the technologies needed to make ILSA useful and acceptable to the various user communities.

We have also defined a clear pathway for commercialization, not only for ILSA but also for device manufacturers who will provide peripherals as they become available in the future. The basis for this will be an open architecture with published protocols that will accommodate plug-and-play adaptation of newly developed capabilities.

Technology Innovation and Research Plan

Our proposal describes in detail the underlying technologies needed to develop ILSA and the associated risks.

We will develop and extend the Home API (application programming interface) specification developed by Honeywell, Intel, Microsoft, Philips, and Compaq as the basis for the advanced, ubiquitous home automation. This will include ensuring compatibility with competing home networking protocols and adding new services and applications.

ILSA must accommodate a wide range of user capabilities. Thus, it will automatically configure the user interface and communicate about situations that cannot be predicted in advance. We intend to develop and validate an emerging automated reasoning technology called Dynamic Interaction Generation (DIG) to dynamically generate user interfaces and interaction support.

The sensitive nature of some of the information associated with ILSA, and the fact that the system can be queried externally, means that communication security is of critical importance. Our program includes developing means for privacy, authentication, and integrity.

We intend to develop a decision support system incorporating intelligent behaviors, models, and/or knowledge to analyze, process, and infer knowledge from current and historical data. Application of multiagent research including matchmakers, brokers, and mediators will be developed and implemented.

These essential technologies have either not been developed or have not been shown to be adaptable to large numbers of installations, sufficiently robust, and/or economically viable for application to ILSA. Our proposal details the considerable risks involved in each one, as well as our mitigation plan based on three incremental test and evaluation cycles.

Benefits to the Nation

ILSA will provide major economic benefits and additional (though less easily quantified) improvements in the quality of life and peace of mind of seniors and family caregivers. These benefits include reduction in costs associated with home healthcare from both formal (paid) and informal caregivers (usually family members), reduction in costs associated with assisted living facilities and nursing homes, improvements in quality of life, and expansion of healthcare industries (e.g., medical and ADL devices and sensors).

Projections are that by 2005 nursing home and formal home healthcare costs will be nearly $187 billion. Currently, 57% of these costs are government funded through programs such as Medicare and Medicaid. In addition, 85% of home care is provided informally by family members, but at the price of personal stress and reductions in workplace productivity. Seven million Americans now provide caregiving services long distance. Data indicate that even at a very conservative market acceptance, ILSA could produce annual savings of over $8 billion annually. We also believe that the ability to query a care recipient's status and the knowledge that alerts will trigger appropriate actions will help the more than 80% of employed family caregivers who report emotional strain.

Our commercialization strategy is to add ILSA functionality to the Home Controller that is now being developed for Honeywell's Home Vision product line. Honeywell's Home and Building Control division has considerable experience in the productization and subsequent marketing and distribution of home products. The plan is strengthened by the breadth of the project team, particularly in the medical domain. And, the commercialization plan extends beyond the team. By building an open architecture we are enabling third party medical and other healthcare product providers to integrate their specific solutions into ILSA. We will foster this integration through an ILSA industry working group.

A program this large and diverse needs ATP funding. There is substantial risk in the underlying technologies of the integrated system. Single companies already in the healthcare business do not have expertise in the nonmedical components of the system. Similarly, companies involved in the technologies such as automated reasoning and user centered interface development are generally not experienced in healthcare. Because the proposed program represents a technical leap for both types of organizations, there is a reluctance to invest in what is uncharted territory.

This program is what an ATP should be: the development of technologies with high technical risk focused on a potential product that will provide substantial benefits to the nation's economy. It addresses a real problem that is of high concern now and is getting worse. And the payoffs make it worth public funding to complement the financial investments committed to by the Consortium members on the program.

Part 4
A. Technical Approach

The Administration on Aging (AOA) data show that the number of people in the US over the age of 65 will double from 34.7 million in 2000 to 69.4 million in 2030. Currently, 13% of the US population is over the age of 65. By 2030, that percentage will increase to over 22% (AOA, 1998). Historically, 43% of people over the age of 65 enter a nursing home for at least one year. A Health Care Financing Administration (HCFA) survey has found that 30% of the elderly surveyed said they would rather die in place than move (HCFA, 1998). Our program goal is to bring evolving technologies to bear on the problems of the elderly to allow them to stay in their "legacy home," defer moving to assisted living or nursing facilities, and improve the quality of their lives and of their caregivers' lives.

Our R&D goal is a system we call the Independent LifeStyle Assistant, or ILSA. ILSA will integrate advanced technologies with expert knowledge about the lives of the elderly and the best ways to care for them into a system that provides constant status monitoring and safety for the care recipient and the appropriate information for the various caregivers who are responsible for the care recipient. To set the stage for the technology development we are proposing for the program, we first present our vision of what ILSA will do. We then describe in detail the underlying technologies that will be the focus of this program.

1.0 Independent LifeStyle Assistant Vision

ILSA will monitor care recipient activities and biological parameters, store these data for analysis and evaluation, determine the current status of the care recipient along several important dimensions (e.g., safety, chronic disease status), and communicate with care givers. In addition, ILSA will have an intelligent decision support system, which will allow important decisions about the medical and other status of the care recipient to be made and appropriate notification made to caregivers. ILSA's decisions will not determine the type of care to be given, which is the prerogative of the care giver. Such a system offers the significant advantage of offloading caregivers' time by acting as a first-level data analyzer. Our team members provide significant expertise in care of the elderly, and we will integrate their knowledge into ILSA to ensure that the decision support system contains a reasonable decision protocol.

ILSA will include a two-way audio and video link between the care recipient and caregivers. We will provide a secure communication link to protect the privacy of the information being sent and to prevent unauthorized access to ILSA's functions.

When ILSA is put into a home, the care recipient's capabilities will be determined and entered into the system. Using our Dynamic Interaction Generation (DIG) technology, ILSA will then automatically configure the user interface to match those capabilities; Honeywell has begun early development of DIG, but further development and refinement are necessary.

For this program, we will develop modules for ILSA that will significantly improve the lives of the elderly living independently and their caregivers. What follows is a brief description of some of the features of two modules we will develop as part of this program; ILSA's open architecture will provide access for others to plug-and-play new modules as they are developed.

1.1 The Safety Module

In the course of everyday activity, individuals may find themselves in situations that stress their capability to move or to safely use equipment in the home, and emergencies can occur. To provide a safe environment, ILSA will track the care recipient's location in the home and monitor key environmental events. When needed or requested, ILSA will provide assistance and alert caregivers. This module will have several components:

- Appliance and water temperature monitoring. ILSA will monitor the use of all potentially dangerous electrical and gas appliances; after some preprogrammed time period, they will be automatically turned off. While the appliance is on, ILSA will place a message on the user interface devices in the house (e.g., the television set) as a precautionary measure to indicate to the occupants that a hot appliance is in use. ILSA will log use of these appliances and any automatic shutoffs for later review by a caregiver. ILSA will also monitor the inlet temperature of faucets. If the temperature of the water entering (say) the bathtub is unsafe, ILSA will reduce it to a safe level; the level will be programmable by a family member or other care giver. For safety, there will be an upper limit to the allowable temperature that cannot be overridden. As with appliance monitoring, ILSA will log the time and duration of hot water use, plus any automatic temperature modifications.
- Path lighting control. ILSA will provide appropriate lighting during periods of darkness or dim light that would make navigation through the house a problem. ILSA will track the care recipient's movement through the house and turn on lights in the room ahead. The care recipient will be able to override the ILSA-set lighting level using either voice control or a portable remote control device. During the nighttime hours, low-level path lighting between rooms will be automatically provided whenever the care recipient gets out of bed.
- Accident recognition and alerting. ILSA will use a combination of acoustic, video, and location sensors to determine when a person has fallen. If the person is conscious and can request help, he/she can use ILSA's speech interface to make a verbal request for help. Alternatively, ILSA can ask the care recipient whether he/she needs help, and send an to the caregivers if the person says "yes" or if there is no response at all. If the initial alarm goes unanswered, ILSA will continue to send one at periodic intervals until there is an acknowledgment.
- Location monitoring and navigation assistance. When the care recipient is outside the home, a Global Positioning System (GPS) receiver will track his/her location, which will be transmitted to ILSA via RF. ILSA will send alerts based on criteria preset by the caregiver and the care recipient (e.g., as soon as the care recipient leaves the house, when he/she leaves the property). If the individual wanders to a place that no longer has GPS coverage, the tracked locations in the log will allow the caregiver or other assisting individuals to more easily find the care recipient.

1.2 The Chronic Care Module

It has become clear that certain chronic medical conditions can benefit from careful observation and early intervention in the home setting. These conditions include chronic airway disease or emphysema, chronic congestive heart failure, childhood asthma, and Type I diabetes; each of these conditions requires close monitoring and fine tuning of medications to avoid deterioration and hospitalization. The Chronic Care Module will monitor key parameters of a care recipient's chronic disease state, store the data for analysis and evaluation, and send alerts when necessary to the care recipient and caregivers. For each disease, ILSA will provide a list of important medical parameters that can be selected for monitoring and analysis; the care recipient and caregiver can choose which parameters are appropriate for the care recipient. ILSA will collect data about the selected parameters and store them in a database. The raw data will be available to authorized caregivers. In addition, ILSA's intelligent decision support system will determine if an out-of-bounds condition exists based on a sophisticated mapping of an individual's personal profile, e.g., history data, current and recent activity level, and current medications, against ILSA's medical knowledge of acceptable values for the parameters. When a true out-of-bounds condition is detected, ILSA will send an alert to the designated individuals.

2.0 ILSA Technology

The objective of the proposed program is to build a system with the capabilities of our vision of ILSA. We have developed an initial architecture for ILSA highlights a number of technical advances that are necessary for its realization. We discuss each of these advances in detail after briefly describing the preliminary architecture.

2.1 ILSA Components

ILSA requires the development of an open, extensible, and modular component-based framework that can host current and future applications and devices from many manufacturers. A functional block diagram of the initial ILSA multi-agent system that we will develop under this program is shown in Figure 4-1. In the center of the diagram is the Home API component, which provides uniform access to the wide variety of hardware devices and sensors in the home. In addition to this solid substrate for ILSA, a set of basic services is shown at the top right of the diagram. These five Core Component Services provide common capabilities for the system. Finally, a set of application specific components (top left of the figure) provide monitoring and other assistance to the care recipient and caregivers. Each of these major component sets and the multi-agent architecture within which they function is described in detail below.

2.2 Home API/Honeywell Home Controller

The deployment of home networks and smart controllable home devices will enable the development of compelling new home applications that move us closer to the vision of the "intelligent home" that enhances consumers' ability to live independently. One problem in developing such applications is that there are numerous competing home networking protocols and no standard application programming interfaces (APIs) for accessing home devices. The Home API addresses this by working with any protocol and consolidating communications gaps. It uses an advanced processing platform capable of integrating a number of diverse home network protocols and home control functions. Currently used for such things as home security, lighting control, and environmental comfort control, the Home Controller portion of ILSA will support the addition of independent living technologies. The system has an open architecture to allow other vendors to plug-and-play new products.

In addition to the existing Home API services, ILSA will require new technology in the form of infrastructure services (Core Services) to manage the interactions of the system, and decision support components (User Applications) to provide automated reasoning and information collection capabilities.

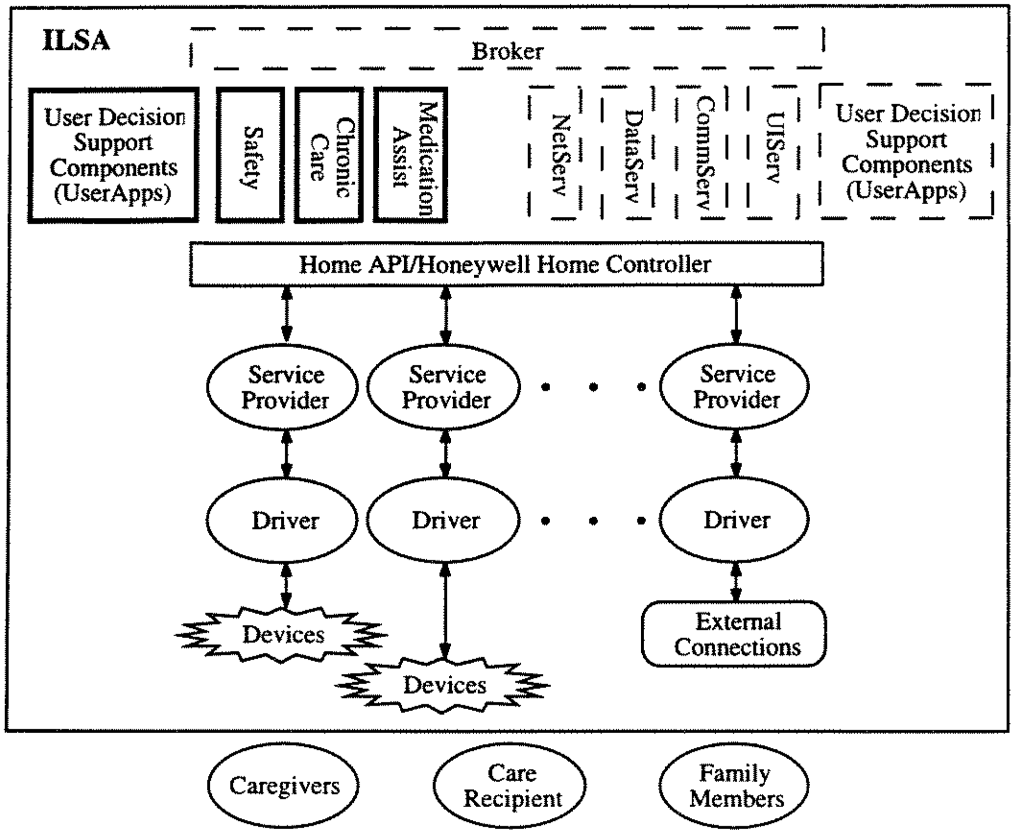


Figure 4-1. Top-Level ILSA Framework Architecture

2.3 Core Services

Core Services manage the communication between ILSA and the external world and allow the integration of specialized UserApps. Five core services are shown in Figure 1; each will support a well-defined, public interface that will enable other Core Services and the UserApps to use the functions that a given Core Service provides. The Core Services will include Data and Event Warehousing (DataServ), Communication and Alert (CommServ), Device and Network Application Support (NetServ), User Interface Module (UIServ), and a Request and Conflict Resolution Broker (Broker). Each of these is described below.

Data and Event Warehousing Service—DataServ will maintain a history of events and alerts generated by the ILSA components and provide persistent data warehousing for ILSA. It will use a combination of storage media to accomplish this task. DataServ's actions will adapt to specific details of the site and caregiver procedures, e.g., when local data storage fills up, DataServ will archive older data at an off-site data warehouse. If archived data are later required, DataServ will retrieve them. By wrapping access to these devices within the Home API, DataServ will know the interface for writing/retrieving data to/from long-term storage, but will not need to know the specific device(s) in use.

Communication and Alert Service—CommServ will handle the details of communication outside the home. As ILSA components generate alerts or notifications, the CommServ will prioritize them, process them according to a preset protocol, and monitor their acknowledgment. CommServ will also be responsible for reacting when an alert is not acknowledged, by increasing its priority or changing the notification mechanism. CommServ could also send the alert to a secondary recipient with higher availability (e.g., an after-hours service center).

Device and Network Application Support—NetServ will be based on the underlying protocol-independent architecture of the Home API. Since home networks are likely to remain heterogeneous, with multiple incompatible protocols used to discover and control different types of devices, application writers are faced with the prospect of using multiple protocol-specific networks with no common underlying programming model. This diversity of devices and networking requirements has frustrated efforts to establish a set of common protocols for seamless interoperability. For example, home network bandwidths range from a few bits per second for X-10 to 400 Mbps and higher for IEEE 1394. Simple devices with low bandwidth requirements cannot afford the expense of connecting to a high-speed network such as 1394. Furthermore, many protocols suitable for use on high-speed networks are entirely inappropriate for low-speed networks. NetServ will manage secure communications over these diverse networks and manage the various protocols required by other components inside and outside of ILSA.

User Interface Service—UIServ will provide the interaction layer between the ILSA components and the Home API, and provide user interface and context management services for any component or device. UIServ will analyze information from multiple ILSA and Home API modules, maintain a persistent dynamic model of the interaction situation, and communicate user interface designs or interaction specifications generically (via XML or Java). With these capabilities, it will be able to serve multiple ILSA functions, from brokering communications between application-specific components and Home API functions to formatting and presenting a simple and useful interface on the human user's remote control or through speech output. This component is necessary to provide ease of commissioning and installation and to provide transparent user access to any ILSA function.

Request and Conflict Resolution Broker— Broker will enable anonymous communication between ILSA components and resolve conflicts that occur at runtime. For example, one module might want a light turned off (e.g., to make sure the care recipient gets his/her sleep) while another wants it turned on (e.g., to make sure the care recipient does not stumble over an object). Broker will be capable of resolving such conflicts using predetermined priorities and knowledge of the current context. It will also create and maintain a representation of the ongoing situation, for use by ILSA's automated decision and reasoning systems.

2.4 User Applications: Lifestyle Support Components

The power of ILSA will be realized with the addition of lifestyle support components (UserApps) that provide decision support and other services tailored to the user's specific needs. Each UserApp will interact with the users and the other ILSA components through the services provided by the core components. For example, each UserApp will rely on UIServ for home-based interactions, and UIServ and CommServ for external interactions. Each UserApp will also be able to issue alerts when certain user-defined conditions are seen; the alert triggers can be defined and modified at runtime. These alerts, like all alerts and external communication needs, will be provided by the core service CommServ.

Two of the user applications we will develop for this program were detailed above: the Safety Module and the Chronic Care Module.

2.5 Technical Development Requirements

To develop and integrate ILSA's individual components, we have identified a number of challenging technical hurdles that must be overcome. First, an advanced, ubiquitous home automation system must provide the substrate for ILSA. Second, we must solve the problems of providing automatically designed and dynamically presented interfaces between the system and all users in response to the demands of changing situations. Third, we need to accelerate the development of a ubiquitous speech interface, to provide true ease of use and remote communications capabilities. Fourth, we need to overcome pressing communications and security issues to assure that the data and information dealt with by ILSA are private and secure. Fifth, we need to develop robust and predictable decision support systems. Finally, we must integrate all of the components, provide sensor fusion and information capabilities, and provide a modular, extensible substrate for additional functions and technologies.

2.6 Advanced, Ubiquitous Home Automation Systems

The Home API, developed by Honeywell, Intel, Microsoft, Philips, and Compaq, is a set of software services and programming interfaces that enable applications to discover and control home devices such as security systems, lights, and climate control systems. This device set is easily extensible through the construction of "service providers" for any future controllable device. The primary goal of Home API is to simplify and reduce the cost of developing software applications through the intelligent use of home devices. Home API interfaces are communications protocol-independent so that applications using Home API are shielded from differences in the underlying networks and protocols used to communicate with home devices. This new software interface specification has drawn over 40 companies as participants within months of going public, and is gaining wide support. Products based on the Home API will soon be rolled-out by multiple manufacturers.

Honeywell's near-term product, the Honeywell Home Controller (HHC), is expected to be the first WinCE based implementation of the Home API architecture. This initial Honeywell product, expected in the 3rd quarter of 1999, will support multiple control networks and host applications for comfort, convenience, and peace of mind. To provide uniform access to the devices envisioned for ILSA, the proposed research program will develop services and applications not previously envisioned for this product. In particular, all interactions with people, systems, and devices will be accomplished through the Home API layer and will enable the population of devices and end users (or systems) to change dynamically without interfering with the internal ILSA structure.

With the proliferation of home automation, medical, and other devices under development today, using the Home API enables the system to be maintainable and expandable over time. Our approach accommodates other home networking initiatives (e.g., HAVi, CEBus, Home RF-LITE, Home Plug-and-Play). The ILSA NetServ module layered on the Home API architecture does not define a protocol; rather, it defines a protocol-neutral programming and extensible service provider architecture that enables device and network vendors to make their hardware accessible to ILSA applications. With this approach, ILSA applications can query and control devices that use incompatible protocols without dealing with any protocol-specific issues.

2.7 Dynamic and Automated User-System Interface Research and Design

ILSA must accommodate users with a wide range of capabilities if it is to accomplish its ultimate objectives. For example, care recipients will differ in visual and auditory capabilities. To be truly useful, ILSA must automatically configure the user interface to match those capabilities and evolve as those capabilities change. In addition, ILSA must communicate with the user simply and elegantly about situations that cannot be predicted in advance. UIServ will provide the adaptive user interfaces that such situations require. For example, consider the situation where a device to determine the user's insulin requirements is added to the system when the device is activated, UIServ will interrogate the device (through the HomeAPI layer) to determine its user interface requirements. Since this is a relatively unsophisticated device, all UIServ might be able to determine is that it is a sensor, and that it provides required insulin amounts parts per million. Using established, accepted models of user interface design, UIServ will determine that the caregiver and patient require visibility to these values as part of a patient data overview and detail task. Furthermore, as other modules become aware of the new information, via the same method as UIServ, they inform UIServ of their changing UI tasks. New user interaction requirements might include a trend report of the insulin requirements, a summary of the treatment's effectiveness, and so on. In addition, if one of the agents requires additional information that is not provided by the new device, it may request that UIServ supply it—by requesting UIServ to initiate a dialog with the user (e.g., care recipient, physician) to provide the required information.

As the UI requirements change, UIServ will modify the existing user interface design using in-depth knowledge of the task and the interface requirements for ILSA operations, coded as a set of generative constraint-based models and procedures for interface design and presentation. Based on these models, UIServ will automatically design interactions based on the constraints of the situation, resulting in a dynamic model of the interactions required at any particular time. When an unmet interaction requirement exists, UIServ will combine knowledge of the domain demands, the type of interaction, the user, and the hardware situation to generate the appropriate user interface elements. As it interacts with the user, UIServ will keep the interaction model up to date, modify the internal representation of the situation, communicate with the Broker to change situational representations, and notify any components that are interested in the domain elements involved in the interaction. UIServ will dynamically update and modify the user interface presentation as the interaction progresses. The resulting design will be a device-independent representation of the required user interface. It will then use the most convenient device on which to display the interaction.

UIServ will communicate with other ILSA components in several ways. It will generate XML, for example, to present a user interface in a browser, or formulate a Java user interface to present a graph on a handheld device. It will contribute to the shared model of the semantics of the domain, which can be used by any ILSA component through registration with the Broker that the component is interested in various elements of the model. It will also be able to communicate directly with other software components, both within and outside of ILSA, as appropriate.

A system that does automated design and dynamic presentation benefits everyone:

- Designers are provided with a means to easily test and refine frameworks and heuristics. They are also provided with a testbed for the incorporation and evaluation of potential advances in interaction psychology, task and user modeling, and hardware and software technologies. Rapid prototyping, reuse, and graceful evolution are implicitly provided through the dynamic design process.
- Developers are assured of good design and a consistent look and feel to applications and products. They can rapidly and easily modify and create user interfaces to their systems through modification of the interaction models. Developers receive the greatest benefit from inherent reuse and automatic documentation capabilities, which result in reduced development costs and effort. In addition, inter-

faces can be used as integrators of diverse legacy systems to gracefully accommodate incremental advances in computing capabilities, languages, and infrastructures.
- Users are not required to perform laborious interface definition and configuration, but are automatically provided with well designed state of the art user interfaces. This can contribute to greater feelings of control and connectedness to tasks. It will also simplify software upgrade processes, reduce the need for training and support, and provides dynamic responsiveness to context, task, situation, and user intentions.

To provide the capabilities of UIServ, we will extend an emerging technology called Dynamic Interaction Generation (DIG; Penner, 1998), which promises a modular, evolvable, intelligent method of providing consistent user interfaces and interaction support for multiple situations, applications, services, devices, and users. Honeywell has begun early development of this technology, but further development and refinement is necessary. DIG distinguishes itself from other current work in the area of automatic interfaces by generating not only the user interface descriptions, but also an underlying model of the interaction itself, which is dynamically updated as the situation changes.

UIServ will also help manage the semantics of the various components that make up the complex process, contributing to the development of Broker. UIServ will help to manage the internal model of the components of a particular system and, using DIG technology, will create and format interactions with the user that make it easy to define new systems, change existing ones, operate components, and interact with the day to day ILSA functions. UIServ will fully and automatically specialize each ILSA system for optimal service to each user and to accommodate devices and interactions that cannot be predicted in advance, and to fine tune interfaces for the individual and the situation.

2.8 Ubiquitous Speech Interfaces

Speech is a natural interface with many advantages. It combines speech input and output with remote speakers and microphones into a natural interface that make ILSA easier and more flexible to use. Its use will make ILSA more acceptable to many care recipients that would not tolerate other interfaces.

A speech interface is extremely flexible, allowing communications with ILSA without manipulating controls or even looking at the system. It is ideal for users with impaired vision, mobility, and/or manual dexterity. By tuning the vocabulary, it can be customized for each user. Since the dialogue interface will use speech prompts to guide the care recipient through interactions, it will require little or no training of the care recipient to use. The care recipient will be able to control most ILSA functions and be able to communicate with people outside the home using a remote telephone connection.

The speech recognition system will be speaker independent so it will not have to be trained for a specific user. The vocabulary will, however, be customizable, allowing the addition of site-specific words. A broad vocabulary and recognition of continuous speech will allow the care recipient to easily talk with the system using natural speech. The system will also include a phonetic based speech synthesizer, which has an unlimited vocabulary, allowing maximum flexibility in output messages.

The speech system will be contained within ILSA's base unit; it will use remote microphones and speakers so it will be usable around the house. The system will also include a voice remote unit to communicate voice messages to and from the base unit. This remote can be a small, handheld unit or one worn by the care recipient. Although we will apply commercially available speech hardware components, the integration and specialization of these components for the ILSA environment present significant challenges. Additional, special challenges are posed by the need for integration with UIServ to allow the system to formulate and conduct natural language spoken interactions with users.

A major design concern with the speech system is how to activate the interface to give it a command. Since continuous monitoring of all speech in the house would result in an unacceptable numbers of false activations (e.g., an innocuous "Would you like some help with that?" might be heard by an always-on system as an emergency call for help), other triggers must be used to "wake" the interface. Under this program we will work with domain experts and potential end users to develop the requirements for the speech dialogue interface and implement a speech interface component to support research and testing. We will then integrate the interface to control a subset of ILSA's functions. Our research will include conducting user studies and evaluations to address specific design issues and to assure that the interface is usable by and acceptable to the widest range of potential care recipients.

2.9 Communications Security

Communications to and from an ILSA-equipped residence will have several different types of security requirements. Most of these requirements will be the same as for other communications domains, including e-commerce and telemedicine. Thus, development efforts in this program will also be extensible to other applications, and security advancement by others will be taken advantage of for ILSA.

A common security requirement in telemedicine is maintaining the privacy of patients' medical information. Growing awareness and concern for patients' privacy are producing an increasing amount of regulation requiring more safeguards be taken to protect patient information. Another general requirement for telemedicine is the prevention of unauthorized communication that could actuate some procedure or corrupt medical records, either of which would cause care recipient harm.

In addition to requirements in common with telemedicine, ILSA will have other requirements (e.g., without secure communication, the home security part of ILSA could be compromised, either passively or actively). It is obvious that communication using dial-up phone lines or radio transmission can be intercepted and/or manipulated. Even the use of "dedicated" phone lines does not solve communication security problems, because this "line" is still multiplexed with other "lines" as it passes through one or more telephone switches and these switches have been broken into remotely.

Significant advances in communication security are required for ILSA. There is a wide selection of existing communication encryption mechanisms that can be applied against some of the ILSA and telemedicine security requirements. However, using encryption creates an additional computational burden on the systems that use it. Creating efficient cryptographic algorithms is still in its infancy; most in use today (or those being contemplated for wide use such as the Advanced Encryption Standard [AES]) are designed for e-mail transmission, file storage, and smart-card transactions. These applications do not have hard real-time requirements, while ILSA may include functions that require real-time control and real-time requires fast, efficient algorithms with low worst-case latency.

Honeywell has been concerned that existing encryption algorithms are not well suited for hard real-time control. The main characteristic of communications for hard real-time control is that there are deadlines for the completion of communication actions; missed deadlines cause failures. Average performance is not important, only worst case counts. Although speed is important for real-time control, latency (the time from when a action is initiated until the action completes) is more important. The low worst-case latency is the most difficult requirement to meet by cryptographic algorithms.

These shortcomings with respect to real time requirements have led Honeywell to initiate development of its own symmetric-key cryptographic algorithm specifically for real-time systems. The algorithm we are researching is intended to have the following benefits compared to the state-of-the-art:

- 2x to 60x faster for large messages,
- 10x to 6,000x faster for the small messages typical of control systems,
- much smaller working data size (10s of bytes versus 1,000s),
- 1:1 byte replacement (no block padding).

This algorithm will provide integrity (messages cannot be modified without detection), authentication (messages cannot be forged), and privacy (contents cannot be revealed without authorization). Generally, a symmetric-key algorithm provides only privacy, enhancements are needed to provide integrity and authentication. Authentication and integrity (with privacy) can be maintained once initial authentication has been performed and session keys exchanged. This is a hybrid protocol in which a public key algorithm is used to exchange session keys for subsequent use in the symmetric key encryption. This algorithm includes a highly diffusive autokey feedback (as one part of the algorithm) that makes it difficult to defeat what ordinarily would be a simplistic integrity mechanism.

The Honeywell algorithm being developed is specifically designed to minimize the time needed to do a key change. The key setup or key scheduling used by existing algorithms creates a worst-case latency that is far from the mean, which is a problem for real-time systems. Key change performance is also a problem for communication hubs or when a terminus must communicate using several different keys (e.g., an ILSA installation responding to multiple caregivers and family members).

2.10 Testbed

The ILSA testbed will allow hardware and software developers to continually test their technologies during the development cycle. This lab-based testbed will provide a realistic set of sensors and interface hardware. Our goal is to provide an environment that will exercise the developing technologies as fully as possible while maintaining the ability to easily make changes. The testbed will support quick configuration changes and will allow developers to work with individual components rather than the full system. The testbed will be modified as needed in each phase of the project in order to support the subsequent technology development. The design will be driven by the high level requirements generated for that phase.

During each phase, ten field test systems (technology demonstration units) will be built. They will be easily transportable to the test site and installable in a day or less. Any components accessible by the test participants will be safe to operate and robust enough to survive small accidents. Since acceptability is a major concern, the design, especially of the interface, will reflect this.

2.11 Field Test

A field test will be undertaken at the close of each technology research phase. The objective of these field tests is to obtain feedback on the ILSA system in the context of daily use for both groups of ILSA users—care recipients and caregivers. This feedback will provide information about ILSA usability, user acceptance, system effectiveness, and system performance and will help guide refinements to ILSA.

Ten care recipients will be recruited for participation in each field testing phase; they will be identified through the Consortium caregiving organizations and will be located within their local caregiving networks. Family and professional caregivers will comprise a second group of participants. Ten individuals will be recruited by the Consortium caregiving organizations. All caregiver participants will have direct personal contact with care recipients and will be responsible to some degree for monitoring their health and assisting with ADLs or IADLs. All participants will have to give their signed consent, and all will be compensated for their participation.

2.12 Advanced Decision Support

A significant benefit of ILSA is the ability to assist caregivers, family members, patients, and other stakeholders with making complex decisions. Decision support (DS) systems are software systems that incorporate intelligent behaviors, models, or knowledge to analyze, process, and infer knowledge from current and historical information and data to facilitate human decision-making. They can be a collection of intelligent agents, but that is not a requirement. Not only will the ILSA team construct decision support systems, but third-party vendors will also develop decision support systems for use in geriatric health care, quality of life decisions, and other complicated reasoning processes. The necessary variety of these systems, due to different reasoning processes, data requirements, and tasks, requires ILSA to be extraordinarily flexible in integrating with and providing support to those systems.

DS systems in ILSA can be categorized into two general types. The first type are those that are "external" to ILSA. ILSA will treat them as external users of the systems, and as such they will be fairly easy to integrate. They will access ILSA through the external communication protocols and devices used by other external users and modules. For example, a DS system may create a network connection to ILSA and have ILSA push data as required, while another might periodically dial in over a phone line to pull data. Because they will use the external protocols already planned, this type of DS system poses few developmental requirements for ILSA.

The second type of ILSA DS system, however, introduces a significant technology risk to ILSA's success. These are DS systems that operate within ILSA, conform to its internal protocols, and utilize its CoreServices: these are the UserApps. They provide on-site monitoring, assistance, and information to and about the care recipient. Each UserApp must incorporate specific knowledge necessary to accomplish its tasks (e.g., blood pressure trend detection). The UserApps will incorporate trend analysis, internal models, heuristics, and other reasoning mechanisms to make important decisions and recommendations about the medical and other status of the care recipient. It is important to note that any recommendation to change a care regimen or other medical decision will be reviewed and approved, modified, or rejected by an authorized caregiver before taking effect. ILSA will advise caregivers, not replace them.

2.13 Modular, Extensible ILSA Architecture

The UserApps as well as all components of ILSA must function within a modular, extensible architecture that minimizes the development costs and simplifies installation, configuration, and modification. In particular, the ILSA architecture must allow each component to:

- Implement a UI that can function on a variable set of user interaction devices that is unknown at design time. That is, each ILSA installation might have a different set of hardware devices for user interaction with ILSA. For example, variability in patient sensory capabilities will require different approaches to presenting information. Requiring each component to allow for this variability would take an inordinate amount of implementation work, dramatically raising the price and lowering the maintainability of each component.

- Operate with little or no *a priori* knowledge of the specific software and hardware components of the system. A component will need to know the functions or services it requires for its operation, but should not be required to know the specific set of components that provides those services.
- Inform the existing ILSA components of its resource requirements and information needs as well as the tasks and services it can provide. When a new component is installed, it must make its presence known and determine what services are available. If, for example, key services are unavailable, the UserApp might deactivate portions of itself until the services come on-line.
- Augment the ILSA schema with the specific information it provides. A component might provide a class of information that was unknown to ILSA before it was installed. For example, suppose a new UserApp is provided with a device that monitors changes to the diameter of a patient's arterial walls and that the ILSA schema does not have representations for arteries, let alone their thickness. The schema must be automatically updated to reflect this new information.

A significant level of research, investigation, and testing will be required for the development of the automated reasoning capabilities of this architecture. The considerable activity in multi-agent research has produced techniques that help address some of the requirements defined above. In particular, ILSA will leverage work done in matchmakers, brokers, and mediators (e.g., Cohen et al., 1994; Foner, 1997; Kuokka and Harda, 1995; and Decker & Lesser, 1995) to implement the Broker CoreService that enables anonymous communication, brokers requests, manages conflicts, and facilitates integration of the shifting ILSA components. This program will also leverage knowledge representation and communication work to provide a flexible, yet straightforward, mechanism for interagent coordination (e.g., Bradshaw, et al. 1997; Cohen & Levesque, 1995; and Finin et al., 1994).

Each ILSA component will be modeled on Honeywell's ISociety architecture (Penner, 1996; Nelson, Penner, & Soken, 1998). Each module will have an area of expertise, possessing knowledge that allows it to automatically reason about the things for which it is responsible. Each will also have an area of interest, allowing it to register interest in things and events that will impact its decisions and actions. Based on locally shared blackboards and joint maintenance of shared context, the individual components will be able to provide specialized services to other components while providing integrated and collaborative assistance.

3.0 Risks

There is very high technical risk in the program we propose. Robust decision support is extremely complex and requires sophisticated information integration and reasoning structures. The automation of user interface design and presentation is still in its infancy. Secure communications are currently very costly and significant innovation will be required to develop a cost-effective solution for ILSA. In addition to the risks inherent in developing the individual technologies that ILSA requires, there are more subtle risks associated with productizing such a system. These risks include cost, ease of use, and acceptance by the target user groups. Each of those risks, and the approaches we are taking to mitigate them, is discussed below.

3.1 Technical Risks

3.1.1 Decision Support and Its Complexity—Each UserApp incorporates specific knowledge necessary to accomplish its tasks (e.g., blood pressure trend detection) and, each must ensure that the knowledge is accurate and robust. For the UserApps built as part of this program, this risk will be addressed through a team consisting of medical and geriatric experts as well as experts in automated reasoning and knowledge based systems. For example, a Honeywell-developed technique for real-time feature detection, already used to monitor medical data, will be applied for trend monitoring (Nelson & Hadden, 1994). The protocols and interfaces resulting from this program will enable third-party vendors to provide additional UserApps. The various vendors will be responsible for ensuring the accuracy and completeness of their modules. To facilitate this, testing and quality assurance measures developed during the development of UserApps on this program will be included with the published protocols and interfaces.

Not only must the UserApp reasoning and knowledge be accurate and complete, the variability of these components places additional risk to implementing an architecture within which the UserApps can operate with the other ILSA components. UserApps must be capable of functioning in a system where not only will the hardware devices be different, but the software components they rely on may also vary. It is unreasonable to require each UserApp vendor to support a seemingly infinite variety of ILSA configurations. Instead, ILSA must provide an adaptive architecture into which each UserApp can be easily inserted.

To address these risks, we will leverage and extend research in multi-agent software systems. This active area of research combines automated reasoning, knowledge based systems, distributed processing and networking, knowledge representation, and human computer interaction research to develop software modules that:

- Receive sensory input from their environment and react flexibly to that input;
- Act without direct intervention by humans or other agents;
- Directly control their own actions and internal state;
- Take goal-directed initiative, when appropriate, to change their state or its environment;
- Interact in a peer-to-peer manner with other agents or humans (Sycara, 1998).

Although the technical risk is mitigated because of these concepts, many agent-oriented concepts have not been reduced to practice or implemented to meet the reliability and robustness constraints imposed by a real-world application such as ILSA. We will address this risk by leveraging our experience in transferring technology from research to industrial-strength software as well as our own experience in multi-agent research. In particular, ILSA will leverage our work on the SARA program (Nelson, Penner, & Soken, 1998) that has provided a partial implementation of a collaborative multi-agent architecture for mixed-initiative decision support.

We categorize agents into four broad categories: interaction agents that interact with and help the user (physically and mentally) collaborate with other users, domain agents that track and perform the tasks necessary for decision support, information agents that access and interpret external information sources, and dispatcher agents that facilitate both the management of individual and group needs as well as the management of the communication between agents.

This categorization is similar to Decker's (Decker et al, 1997), which consists of interface agents, task agents, and information agents. In addition, we add dispatcher agents which facilitate interagent communication by routing requests, translating between ontologies, and allowing agents to cooperate without *a priori* knowledge of each other. Many researchers are developing dispatcher agent technologies (e.g., Cohen et al., 1994; Decker & Lesser, 1995; Foner, 1997), but very few address the issue of ontological synchronization. Ontological synchronization is the process by which the ontology (or schema) shared by the agents in a system can be dynamically modified to incorporate previously unknown types of information (e.g., new classes or properties) provided by a new agent. Honeywell as begun research into an approach to combine automated reconciliation (e.g., automatically adding a new subclass or property to a known class) with directed human-involvement (e.g., unresolvable conflicts are identified and a mechanism provided for an engineer to resolve them). This nascent capability will be further designed and implemented as part of this program to provide a robust and adaptive schema to facilitate interagent communication and simplify integration.

3.1.2 Automating User Interface Design and Presentation—Good user interface (UI) design is difficult. Not only must specialists design them, but they are time-consuming to create and validate and they are deceptively easy to get totally wrong. The demand for good user interfaces keeps increasing, the functions that must be provided through them are becoming more complex, and the amount of accessible information is at an all-time high. At the same time, processes that produce good user interfaces are available and mature, and new devices and visualizations are being developed to support new interactions and improve existing interfaces. Although the practice and the practitioners of user interface design are more available to software and hardware development teams than they once were, they are still relatively rare. The need for adaptive user interfaces that are easy to use and useful adds a major risk to this program.

A key technical differentiator that we bring to our ILSA development approach is the use of the human-centered systems development (HCSD) process. The HCSD process is a user-centered, user-driven research and design methodology that defines the system as the connection between the human user and the application software and hardware. It focuses evaluation on whether the system delivers the right information in the appropriate way for the target users. This is a tried-and-true methodology for determining the system requirements from the user's perspective, designing an interface to the system based on those requirements, testing the design on the user population, and making refinements as needed based on the test results. The critical difference between the HCSD process and the traditional software development process is the former's iterative focus on the users and their interaction with the system. The HCSD process has the product's ultimate users involved from the outset and continues to involve them throughout the research and development process

While we are making great strides in overcoming the problems of providing consistent, easy to use, transparent user interfaces, there is an additional impending complication: task requirements and information availability are becoming more and more unpredictable as computing becomes more distributed, ubiquitous, and powerful. Even when performed optimally, static interaction design is no longer sufficient to meet the complex task and information needs of networked information systems. Situations that would benefit from ILSA systems have even more complexity because of the variability of users, situations, and devices.

Given the nondeterministic nature of a ubiquitous computing environment with multiple collaborating computational and human agents, static design will no longer be sufficient to provide useful and usable interfaces between people and machines. Areas of maximum unpredictability include decisions about which interactions will be required, what information will be available, what hardware and software capabilities will exist in local and distributed forms, and what experiences the human will bring to the system. This unpredictability will also vary extensively over time and location.

Researchers and practitioners have attempted to address this problem in a number of ways. When graphical user interfaces became practical in the 1980s, emphasis on user interface management systems resulted in attempts to automate graphical user interface generation. Industrial and university researchers generally concluded (Szekely, 1996) that user interface generation is too difficult because it depends on human knowledge of task structures and domain requirements. Many of these researchers continue to concentrate on approaches in which automated, model-based systems provide critique of static designs developed (mainly) by human designers (Byrne et al., 1994).

Recently, university researchers have begun reporting success in task modeling, but modeling of the process of designing user interfaces is unique to Honeywell. Our approach to ILSA's user interface is required to help manage the emerging changes in computing and the diversity of ILSA situations. We hypothesize that the unpredictability of tasks and information available within emerging systems like ILSA will only become more important, overshadowing the difficulty of defining and applying dynamic design knowledge. We have been investigating the types of knowledge processes and models that are required to support dynamic design, using a multiagent architecture as the basis for the organization of and operations on this knowledge. To facilitate this, we have been developing an assistant for dynamic interaction design, which we call DIG (Dynamic Interaction Generation), and applying it within the domain of collaborative systems management. This research has resulted in the implementation of an automated reasoner that designs and creates simple user interfaces to large building systems. The Dynamic Interaction Generator for Building Environments (DIGBE) responds to the current user, the requirements of the task, and the semantics of the data, by automatically designing an appropriate task interaction from generic components, dynamically specializing this interface based on the current user/task situation, and interactively presenting the user interface for the interactions that are required.

To provide these capabilities for ILSA, we will create a UIServ component based on DIG. While intended to reduce the usability and configurability risks of the complex and dynamic ILSA system, the application of DIG technology carries its own inherent risks. DIG is in its infancy, and it is unknown whether it will prove robust enough for ILSA. It has been applied only to a small subset of the interactions in a building management system and it is currently limited to system configuration, monitoring, and control of the comfort and lighting elements of the rooms in a small building. Although we are confident that the system is robust and scalable, we have not extended this application to larger systems or those with additional functional subsystems, leading to a considerable risk for the proposed development.

The proposed expansion of these concepts into a more complex and variable environment involves barriers that will also have to be overcome in the development process. We have not integrated DIG with systems such as the HomeAPI. Further, we have yet to demonstrate an agent that is concerned with overall human health. We intend to reduce these risks through emphasis on modularity, proper design and iteration practices, and a phased introduction of capabilities.

A further risk is the chance that the knowledge possessed by UIServ will not result in well designed and usable interfaces. In order to assure that UIServ is capable of generating good interactions, we will use a bottoms-up human-centered systems development user interface design approach in which user needs drive the development of the user interface design and presentation knowledge possessed by UIServ. Initially, we will obtain user requirements from experts in home healthcare and focus groups of elderly people. Once our testbed is available, data regarding user needs will be acquired through a series of field tests spanning the project. These field tests will employ multiple techniques for the collection of user feedback, including in-home usability testing of ILSA user interfaces, post-field-test user interviews, and observation of care recipient-caregiver exchanges. These findings will be iteratively integrated into the reasoning structures of UIServ to provide evolutionary improvement in UIServ's capabilities.

3.1.3 Communication Security—The ILSA communication network we propose will be open, heterogeneous, scalable, and complex. It will operate in the home and outside the home to a variety of locations. It will include several communications media and many protocols. And it must be secure. It is this balancing of two somewhat contradictory requirements—making data available remotely to a variety of trusted sites that have a variety of platforms versus keeping the data secure from view and secure from modification—that most challenges the development of this facet of ILSA. A particular difficulty is communications that require real time response while maintaining authentication, integrity, and/or privacy. These problems are similar to many other remote real-time control concepts. Our research in this area will involve significant collaboration with others working in the communications security area, since a solution to these problems for other applications will also be a solution for ILSA.

The cost constraints of eventual ILSA products preclude the use of dedicated cryptographic hardware for communications security; security must be provided by software that can run on the ILSA hardware. The inclusion of cryptographic hardware would also classify an ILSA product as a munition, with the attendant export/import control problems. With software, the cryptographic functionality can be removed from export to those countries where cryptography control precludes this usage.

The heavily multitasked nature of the Home API component creates additional constraints for any cryptographic software. It must not consume much of the throughput and data space of the Home API's microprocessor and must maintain adequate performance even while suffering continuous interrupts in its processing. This performance applies to a wide range of communications, from the high bandwidth audio and video to the very small messages and low latency of real time control, to the much less taxing transfer of patient records.

Honeywell has created a symmetric-key cryptographic algorithm concept that is much better suited to these requirements than any of the existing or proposed algorithms. A risk is that the algorithm may not be as secure as is assumed. While this algorithm is based on sound cryptographic principles, it still must be tested and analyzed by independent experts to minimize the possibility of any weakness. In addition, the problems of key management must be solved. Given the intended users of ILSA, it is unreasonable to expect them to key and re-key the cryptography mechanism. (The key is secret data much like a password that is used to encrypt and decrypt data.) Periodic re-keying is needed to prevent a cryptanalyst from accumulating sufficient ciphertext on which to mount a successful attack and to minimize the amount of data that is compromised in case a key is lost or stolen. There also must be separate keys for different levels or types of access to ILSA, e.g., family members and doctors may have different keys. Public key cryptography can be used to solve part of these problems and a good key management protocol can solve the rest. However, public key cryptography is computationally very expensive and needs to be avoided to the extent possible in systems with real time requirements. With an algorithm that is fast to re-key, such as the proposed Honeywell algorithm, a hierarchy of keys can be established in which master keys are used to encrypt and exchange new keys without user intervention and without the use of public-key cryptography. This could minimize the expensive public-key cryptography to a one-time usage upon the first contact.

The Honeywell algorithm has been under development for a year. As with any new cryptographic algorithm, it needs to be externally tested for strength. Outside the proposed program, Honeywell is hiring Certicom to do an initial independent analysis. To further the maturity, we would like to have an additional independent analysis. We have been talking to Bruce Schneier of Counterpane Systems about doing this, but we do not have the funding required for both Certicom and Counterpane. ILSA funding will be used to allow Counterpane Systems and us to fully analyze this algorithm to determine if it has sufficient security for the real time communications required by ILSA. Of course, such an algorithm cannot be proven to be secure against all possible future threats, but we can minimize the possibility of a successful threat through careful analysis/testing.

3.2 Productization Risks

3.2.1 Ease of Commissioning, Configuring, and Use—A key technical challenge is the diversity of issues represented in this population. As we get older, our capabilities diminish. We may not be able to see, hear, walk, or otherwise function as effectively as at an earlier age. In defining and designing ILSA, we will address both physical issues (e.g., reduced vision and hearing) and cognitive issues (e.g., memory loss). Further, we recognize that at least the current generation of elderly will most likely be technology-naive and possible technology-averse.

As described in detail in the economic benefits discussions in the next part of the proposal, we expect the market for ILSA products to be substantial. ILSA must be tailorable to the health conditions of the specific person it serves, however. When installed, only the subset of the functionality (decision support, medical devices, etc.) required for the specific care recipient needs to be purchased and activated. For example, a diabetes module need not be activated for a congestive heart failure patient without diabetes. Over time, additional components may be required (e.g., if the patient develops diabetes). This feature will allow the caregiver to minimize cost by purchasing only the necessary components. But a major risk is introduced by this approach. Not only does the variability of equipment and users at a site complicate the task of commissioning and configuring each new unit, it also imposes the task of reconfiguring the unit over time. Honeywell experience with home comfort devices has shown that even today's very simple home automation and security systems are difficult for specialists to install, tune, and configure. While this will be alleviated to a great degree by the Home API efforts, we are still far from being able to provide the ease of installation and configuration required by a system as complex and specialized as ILSA. Furthermore, with the large size of the expected ILSA market, sending a team of specialists to each site that requires commissioning and configuration modifications is completely unreasonable for both cost and logistic reasons.

Thus, ease of commissioning and reconfiguration represent major risks. It has been demonstrated many times that any software or hardware system that is difficult to install, difficult to operate, and difficult to modify is simply difficult to use. And systems that are difficult to use. Our target population adds a critical stressor to this factor, since they will be using technology that is generally 30 years in advance of their formative experiences. It is imperative that ILSA be extremely simple to install, configure, specialize, adjust, modify, and use in daily life. To be truly usable and reduce the risk associated with difficult or expensive configuration and modification, the system must have the following capabilities:

- It must recognize and make use of all information available from devices and software components;
- It must maintain a dynamic model of an ILSA installation and the components, users, task requirements, and data in the system;
- It must automatically perform configuration, reconfiguration, specialization, and integration tasks to a great extent without user intervention;
- Where user intervention is required, it must present dialogs and information exchanges in simple, easy to use, and intuitive ways;
- It must have knowledge of the requirements of configuration and specialization and use this knowledge to automatically respond to changes and dynamically interact with users and components to manage the changes;

- It must have knowledge of the environmental constraints of the user, the hardware, and the software, and react dynamically to these constraints as they change to make the most optimal use of the capabilities of each constrained entity.

The integrated ILSA system will provide these capabilities through a combination of core services from the Broker and UIServ. To be successful, ILSA must overcome the technology risks associated with the automated reasoning and data fusion capabilities required for decision support and dynamic management of user interfaces. In addition, it must provide an organized, extendable substrate to intelligently manage a diverse and changing set of users, systems, and devices, providing the support and guidance necessary for the users of this system.

3.2.2 Acceptance—Product acceptance is a significant market risk and poses important technology requirements on the ILSA concept. Anecdotal evidence implies that the elderly will not favor high-technology solutions, computers, or monitoring of their activity. Our healthcare advisors say that the elderly will welcome help—more regular monitoring by professionals or family and the opportunity for more information and contact. This uncertainty and risk will be dealt with through extreme attention to user interfaces and focus groups for user input and testing, both in the user interface lab and in field test sites, in order to provide the services that are truly desired and helpful in a nonobtrusive way.

Some users' acceptance issues will stem from concerns about reliance on technology to perform functions previously carried out by a person, a product look-and-feel that is incompatible with the users' home environment, and a human-system interaction style that is perceived to be too computer-like. Some care recipient resistance to technology may wane as the upcoming technology-comfortable generation ages. However, ILSA's first deployment will be tailored to the needs of individuals who did not grow up using computers and who may be expected to distrust computer-based systems.

We believe the strongly human-centered approaches we are taking to development of the UIServ component will enable us to develop a system that users will welcome in their homes and deem friendly and easy to use. We also anticipate that as users become familiar with ILSA, its perceived benefits will outweigh many of the technology-based concerns some users may initially have.

3.2.3 Cost—Because of the complexity of its underlying functionality, ILSA will be more expensive than most home control products; therein lies a significant risk. The initial capital costs for ILSA will probably create a psychological barrier that must be overcome. We will actively pursue approaches to lower this risk, such as leasing the capital equipment rather than selling it, or offering the service without selling/leasing the equipment. Alternatively, we could reduce the amount of hardware required for installations by "serving" reasoning and communications services from remote locations. Honeywell, through its Home & Building Control (H&BC) business unit, will be particularly sensitive to the component cost and product cost issues. Unlike medical equipment manufactures, the H&BC customer set is already in the home, where products are generally low cost.

3.3 Payoff versus Risk

The large payoff expected from the ILSA research and development effort is detailed in Part 4B of the proposal. Much of the risk arises out of the breadth and complexity of the program. However, this breadth and complexity also offers alternative approaches and fallback positions. The risks imply that not all of our components may succeed exactly as we propose them. But in the ILSA concept, partial success can still lead to a successful program and to technologies that can be integrated into a valuable product. Although several of our concept components are risky, there are others of less risk and others not yet conceived. Therefore, we are confident that the program we propose is a worthwhile investment of public funding and our private investment.

4.0 Technical Plan

This program has been collaboratively planned and incorporates a number of strategies to enhance our opportunities for success. The Consortium will take full advantage of its previous work to further define the key issues and establish the requirements. We will fully leverage Honeywell's current development of a home control gateway, the diverse expertise of our telemonitoring and telemedicine provider members, and the creative talents of our healthcare provider members. Our technology development will be conducted by a multidisciplinary team working together over a 44-month period. Our development will follow a spiral evolutionary design process that consists of a six-month testbed and infrastructure development phase, and three 13-month research and development iterations. Each iteration will include tasks addressing requirements, architecture extensions, design, technology development, testing, and evaluation.

The development testbed and technology demonstrations will build on Honeywell's Home Vision products as a foundation. A scalable architecture and the baseline ILSA concept suite will be designed and prototyped using appropriate software design tools, and will be demonstratable in the testbed 10 months after the start of the program. Each of the 13-month R&D iterations will conclude with an expanded product-concept set and the associated enhanced ILSA component suite. Each iteration will result in a technology demonstration. In concert with, but not a part of the NIST program, these product-concept prototypes will be assessed for market potential as part of Honeywell's Home & Building Control commercialization process.

Each of our three technology research/testing cycles includes tasks to verify the issues to be addressed, define the scope of the technology demonstration, identify and develop any required testbed infrastructure, specify the functional requirements of the next technology demonstration, conduct research, build and evaluate the technology demonstration, and assess the lessons learned. Our statement of work for doing this is described next in the proposed Work Breakdown Structure (WBS). The WBS is the basis for all task descriptions, scheduling, and costing. Progress will be monitored, controlled, and reported according to this WBS. For each task, the objectives, major activities, team member roles, and deliverables are identified. Where appropriate, dependencies on inputs from outside the program are indicated. In addition, a program schedule is presented showing the timing and estimated completion of each major task. In developing this proposal, additional levels of detail have been defined, costed, and scheduled. The first program year is planned in much more detail than the following years. Additional detail is available for NIST review but is not included in the proposal because of the page limitation.

4.1 Statement of Work and Work Breakdown Structure

In this section we describe the various tasks we will perform under this program.

Task 1.0 Testbed Development
Early in the program we will establish an ILSA testbed, which will allow hardware and software developers to test their products during the development cycles. Activities during this task include requirements definition, design, Home Controller installation, hardware purchase and build, software acquisition and development, and integration and test. Following each field test iteration, the testbed will be

extended and enhanced as a result of the lessons learned in the field tests, to support the research to be conducted in the next phase.

Task 2.0 Phase I Technology Research

An iterative development cycle is planned for the program. A separate task is described below for each development task. The iteration over each task will result in a three-step research and development process in which each step is based on the research and lessons learned in the previous step. ILSA concepts are expanded in breadth and capability during each iteration.

Task 2.1 High-level requirements definition —The requirements defined in the proposal effort will be tuned and expanded. This will be done iteratively in conjunction with the following three activities: initial documentation, requirements discussions (at the internal kick-off and review meeting and the NIST kick-off meeting), and requirements documentation.

Task 2.2 Framework design —We will rank the requirements based on criteria including, but not limited to, criticality to ILSA objectives and commonality across Core Service modules and User Decision Support Applications (UserApps). Currently, there are expected to be five Core Services and three UserApps; the scope may change as a result of this task. Although the overall design and all of the Core Services and UserApps will be addressed, two Core Services and one UserApp will be selected for design and implementation. Lessons learned and reusable code from this implementation will simplify subsequent developments. We will design a solution that satisfies as many requirements as possible with an emphasis on those that are common to all Core Services and maximize the reusability of software on subsequent tasks. We will locate and evaluate sensors, actuators and algorithms required to realize the design. We will document the ranking, selection, and design solution, including the ILSA architecture specification. To ensure an open architecture and industry acceptance of the ILSA architecture specification, we will form and lead an ILSA Working Group. The initial core group will include the ILSA team members, but will be expanded to include other community members as the specification matures.

Task 2.3 Honeywell Home Controller (HHC) development —In parallel with Core Services and User Applications research, further research and development on the next versions of the basic HHC will proceed. This research and development is necessary to extend the base system's capability to meet the evolving ILSA increasing functionality demands.

This Version 2.0 of the HHC is planned to address requirements for high speed Internet access via cable and digital subscriber line technologies. Research and development topics will include the use of these full time access techniques to enable the development of significant external services. Initial versions of these external services will be developed and issues dealing with ease of installation will be investigated.

Task 2.4 Framework development —Following the design of the ILSA framework, a prototype will be implemented as the basis for testing, evaluation, and other research activities. This development will implement the selected Core Services and UserApps. To test the implementation, tests and metrics will be defined to verify that the selected requirements were met. Tests will be executed and the results recorded. Results will be analyzed to derive lessons learned and provide input to the subsequent development phase. The implementation language and tools will be selected to minimize development time and maximize progress. This development provides input to the testbed development task, and usability testing, and also depends on the outcome of those tasks.

Task 2.5 Communications security development —We will verify the required security and timing performance of our communications security software and implement this software for field testing. We will apply previous research at Honeywell and the work of others to the ILSA requirements. Security verification will include investigating this software's cryptographic properties using the latest cryptanalysis techniques.

Task 2.6 Speech interface development —Research into the speech interface for ILSA will include requirements definition, design, build, and test. A speech interface will be developed using a commercially available speech development kit. Throughout the program we will conduct user studies and evaluations to address specific design issues and to assure that the interface is usable and acceptable to the widest range of potential care recipients.

Task 2.7 User interface development —User interfaces for both the caregivers and the care recipient will be researched, designed, and tested. Other activities during this task include user requirements definition, designs, implementation of designs, usability testing and evaluation, and reporting.

Task 2.8 Build and integration —This activity will consist of the assembly and integration of the components needed for installing test systems at ten field sites. Sufficient spares will also be procured to maintain the test units in case of component failures. The build of the field test units will incorporate the designs of the technology demonstration. Additional design work will be carried out to address packaging, transportability and installation requirements. Hardware specific to the field tests will be manufactured and incorporated. Tool kits will be assembled to support two field installation teams. The test units will be tested, and packed for shipping to the two test sites.

Task 3.0 First Technology Demonstration Field Testing
Following the first research cycle, a field test will be conducted to put our first technology demonstration in the homes of potential users. Participants will be selected by our healthcare and medical team members. Activities will include selecting test sites; preparation of field test tools; installation of test units; user training; data collection, analysis, and interpretation; and report generation.

Task 4.0 Phase II Technology Research
The activities in Phase II repeat the structure of Phase I as an iteration on the ILSA design. That is, each task described above in Phase I are conducted again using the previous research and lessons learned to expand the breadth of the technology and increase ILSA's capability. As in Phase I, we will address several Core Services and User Applications and select at least two of the former and one of the latter for implementation and addition to the ILSA suite. The details of this work have been estimated to scope the program but are not included here for brevity. Further, we expect that the work in Phase I may lead us in new ways for several of the ILSA components.

Task 5.0 Second Technology Demonstration Field Testing
A field test, as described in Task 3.0, will be conducted in this second technology demonstration.

Task 6.0 Phase III Technology Research
The activities in Phase III again repeat the structure of Phase I as a second iteration of ILSA's design. That is, each task described above in Phase I is conducted again using the previous research and lessons learned to expand the breadth of the technology and increase ILSA's capability. As in Phase I, we will address several Core Services and User Applications. The details of this work have been estimated to scope the program but are not included here for brevity. As before, we expect that the work in Phases I and II may lead us in new ways for several of the ILSA components.

Task 7.0 Third Technology Demonstration Field Testing
A field test, as described in Task 3.0, will be conducted of this third technology demonstration.

Task 8.0 Program Management
This task includes the kick-off meeting at NIST, the program's first team meeting and review, and the preparations for those meetings. It includes first quarter training for those technologists that have not had formal training or experience in healthcare of the elderly. It includes all periodic reviews and meetings, both internal and at NIST, and attendance at yearly NIST workshops. It includes documentation in the form of quarterly reports to NIST, presentation materials, and the final report. This task also includes the work of the Program Manager, the Technical Coordination team, and the Business Administrator. The Project Management structure for the program is described more fully in Part 4C, Section 3.0.

Task 9.0 Team Member Activities

Task 9.1 HELP Innovations—HELP Innovations will conduct four tasks in support of the research and development of the ILSA concept. These tasks are as follows:

Task 9.1.1 Requirements definition— HELP Innovations will apply telemedicine experience to review design ideas and concepts with respect to the requirements. They will provide background information about the emerging telemonitoring and telemedicine industry, and they will support requirements definition by participation in team meetings and sharing needs identified in HELP's work with hundreds of remote patients.

Task 9.1.2 Clinical record and database development—HELP Innovations will conduct research and development to implement and demonstrate an electronic clinical record and database that receives digital data from remote locations. This module will reside on the base component of ILSA to provide a single source for nurse interaction with the patient's clinical information and documentation. This module will allowing storage of video, audio, text, and digital data from multiple sources.

Task 9.1.3 Establish protocol library—HELP will establish a research-based clinical protocol library that is embedded in the electronic record for use in tracking the care of and interventions with the patient.

Task 9.1.4 Establish field testing—This activity includes the identification of sites, support of the implementation by field personnel, support of data collection, and support of the evaluation of the test data.

Task 9.2 In Home Health—In Home Health will provide expertise in creating safe environments for the elderly and those with chronic disease management issues in their legacy home. Support will include informal training of technologists by including them in caregivers' daily rounds to in-home clients, requirements definition, and evaluation of concepts and test results. This work will emphasize the ADL and IADL issues in the home environment.

Task 9.3 Minnesota Department of Human Services Aging Initiative—The Aging Initiative staff will provide technical information and expertise related to the specific needs of the frail elderly trying to remain independent in their homes or apartments. This will include support of requirements definition, review of design ideas and concepts developed through the program, and participation in team meetings.

Task 9.4 University of Vermont/Fletcher Allen Health Care—Dr. Michael Ricci and members of the FAHC staff will support requirements definition and concept evaluation in the areas of medical expertise, site selection, decision support, and other potential applications.

4.2 Accomplishments by Year

This subsection briefly describes the program plan and progress by project year, that is, at each 13-month interval after the start date. Figure 4-2 is a high level Gantt chart showing the timing of the major activities defined in the WBS, the budget by task, and the major milestones. A medium-level schedule is included in Part 2 of this proposal, Budget Narrative. The ILSA team will be working to a much more detailed schedule that identifies each of the ILSA modules, the design and build schedule for each module, and the research studies associated with each module.

	Program Year					
Major Project Tasks	Year 1	Year 2	Year 3	Year 4	Total Funds, $K	Major Project Milestones
1.0 Testbed development					275	Complete the testbed for each technology development cycle
2.0, 4.0, 6.0 Phases I, II, and III technology research					6,954	Complete an integrated technology demonstration field test unit in each of the three development cycles
3.0, 5.0, 7.0 First, second, and third technology demonstration field testing					949	Complete report on results of field testing in each of the three test cycles
8.0 Program Management	---(1)---	-----(1)---- (2)	-----(1)---- (2)	---(1)--- (2) (3)	3,159	(1) Quarterly progress reports (2) Annual reviews (3) Final review Task includes all Honeywell travel for indicated trips + internal quarterly review trips
9.0 Team member activities					3,272	Provide consulting on delivery of medical care, health status monitoring, ADLs/IADLs, electronic clinical record and database
Funding Totals	4,922	4,170	3,841	1,676	14,609	

Figure 4-2. Project Plan, Milestones, and Budget.

4.2.1 First Year Accomplishments—At the conclusion of the first year the ILSA team will have completed our initial requirements definition; completed development of the initial testbed; conducted our first phase technology development; and begun the design, build, and field tests of the first ILSA concepts. The team will have shared significant technical knowledge bringing medical personnel, caregivers, and ILSA's underlying technologies into a common understanding of the problems, issues, technology barriers, research topics, and technology solutions. This integration of our respective expertise will be accomplished by the significant level of interaction that we have planned and the operation of our testbed. Outside the NIST program, Honeywell's H&BC product development team will have subjected our research results to their commercialization process, and we expect portions of the first concept to be on the commercialization path. Market studies and commercialization results will also be considered when determining the ILSA design for the next development cycle.

4.2.2 Second Year Accomplishments—Early in the second year we will complete the first set of field tests. At the conclusion of the second year we will have completed the research on the second ILSA concept and begun its test and evaluation in the field.

4.2.3 Third Year Accomplishments—At the conclusion of our third year of research, we will have completed the second field test and much of the third iteration of technology development, test, and evaluation. Outside the program, H&BC will have submitted these enhanced concepts to their commercialization process and development of products with greater functionality will have begun.

4.2.4 Fourth Year Accomplishments—Eight months into the fourth year we will complete the program. At this time we will have completed three iterations of ILSA concept research and field test and evaluation. An ILSA concept with extensive functionality of demonstrated utility to our target user populations will have been developed and received wide visibility. We expect the first (baseline) version of the product (the result of the first technology demonstration) to be on the market at this time.

It should be noted that the ILSA team does not expect to develop all of the potential ILSA modules in this three-year research project. We fully expect that our efforts and early successes will facilitate increased industry funding in these areas, from the ILSA teammates and from other companies that will make sensors, devices, and software modules that can be incorporated into the ILSA architecture.

4.3 Task Rationale

We have organized our work into seven major technical tasks as illustrated in the work breakdown structure in Figure 4-2. We begin our work by finalizing our initial requirements and building a testbed. Thereafter, we will conduct three iterations of research and development that include technology research and field tests to support that research. The rationale for this structure is to first lay a firm foundation for the research activities that includes significant team exchange of ideas, concepts, and needs during establishment of the top-level requirements. The testbed will be developed using available, state-of-the-art hardware and software to provide the researchers with a robust, functional platform on which they can do their research and development. Following the establishment of this foundation, we will use a spiral evolutionary approach (three steps) to facilitate collecting early results and incorporating them into the next round of development. This approach has proven to be much more effective in this type of program than the traditional "waterfall" approach where all activity is planned in advance and the technologist have only one pass to get everything right. The rationale for each of these major tasks is described below.

Rationale for Task 1.0—This activity establishes the hardware and software foundation for the research and development in the tasks to follow. This is a relatively low-risk activity that will establish a testbed that researchers can depend on as the basis for risky developments. This testbed will use the Honeywell Home Controller as its basis and will be made up of the latest technology components; designing and building the testbed will not be a research activity per se.

Rationale for Task 2.0—The Phase I Technology Research consists of eight subtasks, each addressing specific technology development. We have subdivided the work this way to provide visibility for each of these efforts, most of which will be conducted by specialist teams. This decomposition of the research by technology area clarifies the WBS/SOW and the schedule and cost management. This task begins with the high-level requirements definition in which all of the technology teams and domain experts will work together to finalize the initial concept requirements. Thereafter, each technology team will conduct the research activities that apply to these requirements. The degree of risk in each case is dependent on the technology area, the requirements, and the approach. In most cases the technologists will use rapid-prototyping within their research tasks to facilitate early learning from partial functionality implementation. The primary development philosophy we will follow is this iterative, evolutionary process in which concepts are tested and functionality is added piece by piece. This will enable us to quickly test risky ideas and get early results in many areas that will guide the research that follows.

Rationale for Task 3.0—The First Technology Demonstration Field Testing takes our Phase I research developments into the field for test and evaluation. Since our concepts are technology-rich and intended for use by the technology-wary, it is essential that we obtain this type of test exposure early in the program. Our rationale is to expose elderly people and both informal and formal caregivers to our early concept to gain usage information and other feedback. These field test units will not be product-grade or have full functionality, and the users will be in no way depending upon them for their safety or disease management. The field test participants will be selected by our healthcare teammates to assure full understanding of the tests. The results of the field tests will be an essential portion of the reassessment and expansion of our requirements and the plans for the second phase of research and development.

Rationale for Task 4.0—The rationale for the Phase II Technology Research is an extension of the rationale for Task 2.0. This will be the middle step in the evolutionary process of doing research and building technology demonstrations based on the results of that research. We expect this step to benefit greatly from the first field tests. The research will be pointed more toward specific requirements not met previously, and the final version of the Phase II technology demonstration will have significantly more functionality than the earlier version.

Rationale for Task 5.0—The rationale for the second field testing is an extension of the rationale for the first (Task 3.0). The testing is expected to be more comprehensive using a concept with more functionality.

Rationale for Task 6.0—The rationale for the Phase III Technology Research is a further extension of the rationale for first phase research (Task 2.0). This will be the final step in the evolutionary process of doing research and building technology demonstrations based on the results of that research. We expect this step to benefit greatly from the second field tests. The research will be pointed more toward problems not yet solved and new features that have been identified. This final concept will have significantly more functionality than the previous versions.

Rationale for Task 7.0—The rationale for the third field testing is an extension of the rationale for earlier field tests. The testing is expected to be more comprehensive using a concept with more functionality.

Rationale for Task 8.0—On a large, multidisciplinary program such as this, close attention to cost and schedule, close coordination among team members and the customer, and careful direction and integration of the various expertise is a substantial task. Thus, we have defined a specific Project Management task rather than incorporate these activities in the technical tasks. Our SOW and cost estimates include program meetings, reports, training, management travel, financial administration, and program management in this task.

Rationale for Task 9.0—We have described our team members' activities in a separate task to provide them with more visibility and to more clearly identify the special domain expertise they bring to the program. Their work will be critical in supporting the activities described in the previous tasks. Monitoring and administrating this work will be facilitated by this structure.

4.4 Team Approach

No single organization has the ability to research, develop, integrate, and achieve market success for a system such as ILSA. The diversity of domain knowledge needed alone is sufficient to require a collaborative effort. In addition, the technologies available to address the issues of independent living will expand and evolve over a long period of time. Because of the universal nature of some of our developments, and the intention to be open to other vendors, we will establish an ILSA industry working group. This will be patterned after industry groups such as Home PnP, Home API and Home RF in which Honeywell is a key participant. The objective of this working group will be to develop an open specification for the ILSA architecture. This will permit multiple companies to develop ILSA systems and components based on the open architecture. The initial core group will be comprised of the ILSA team. As the initial specification matures, the group will be opened to other interested parties. To accelerate industry-wide adoption of the ILSA open architecture we will disseminate information on the architecture and other promising work as we progress. This will be accomplished by the ILSA team members presenting papers at pertinent conferences and by conducting demonstrations and field tests.

The ILSA team is made up of researchers, computer scientists, and healthcare professionals. This team's commitment and cooperation during the proposal activity was an excellent indicator of the activity level and style we expect in conducting the program. We will continue to communicate regularly, both through our formal review meetings and through informal methods such as e-mail, videoconference, and phone Because of the breadth of the issues and technologies, and because the Honeywell technologists are not healthcare experts, we have planned significant travel to avail ourselves of the work and knowledge that resides at our team members' sites and at other universities, medical centers, and companies we have contacted in the last year. The technologists will have frequent discussions and will work together directly without the need for an additional, intermediate contact.

B. Economic Benefits, Commercialization Plan, and Need for ATP Funding

1.0 Economic Benefits

The population of the United States is aging rapidly. The Administration on Aging (AOA) data show that the number of people in the U.S. over the age of 65 will double from 34.7 million in year 2000 to 69.4 million in 2030. Currently, 13% of the U.S. population is over the age of 65. By 2030, that percentage will increase to over 22% (AOA, 1998). In other words, "The Baby-Boomers are coming!" And they're going to live longer. The average life expectancy for persons reaching age 65 is an additional 17.6 years, an increase of 3.3 years just since 1960) (U.S. Bureau of Census, 1999). The problem is compounded by a trend towards smaller (and more geographically remote) families who could provide support to their parents. For example, the State of Minnesota Project 2030 reports that the number of children (per woman) has dropped from 3.2 (20 years ago) to 1.8 today (Gomez, 1998).

Historically, 43% of people over the age of 65 will enter a nursing home for at least one year. A Health Care Financing Administration (HCFA) survey has shown that many elderly people do not want to move to assisted living facilities—30% said they would rather die in place than move (HCFA, 1998). Thus the program goal of ILSA: To bring evolving technologies to bear on the problems of the elderly—to allow them to stay in their "legacy home," defer moving to assisted living or nursing facilities, and improve the quality of life of the elderly and their caregivers.

1.1 Benefits

The dramatic increase in the number of elderly over the next 30 years and the associated impact on the nearly constant or decreasing number of caregivers is well documented (Aging Initiative, 1997; AOA, 1998; Gomez & Moria, 1998; U.S. Bureau of Census, 1999; U.S. GAO, 1994). Our project addresses that problem by creating a system that supports older persons in tasks of daily living, leverages the time and attention of family and other caregivers, creates the opportunity for seniors to reach out to their communities for support services, delays or prevents the need to move into an assisted living center, is expandable as new devices become available, and is responsive to users' needs by being both dynamically designed and personally customizable.

We anticipate that ILSA will provide major economic benefits and additional (although less easily quantified) improvements in the quality of life and peace of mind of the elderly and family caregivers. These benefits include: reduction in costs associated with home healthcare from formal (paid) caregivers, reduction in costs associated with informal (usually family) caregivers; reduction in costs associated with assisted living facilities (and nursing homes); improvements in the quality of life, and expansion of healthcare industries (e.g., medical and ADL devices, telemedicine sensors)

1.1.1 Reduction in costs associated with formal home healthcare—In 1996, 1.6 million people received home healthcare from formal caregivers. The cost associated with these services was $30.2B. HCFA has projected the number of recipients to increase to 2.0 million by 2005 with associated cost projections of $56.7B per year (HCFA, 1998). We anticipate that ILSA will provide the technology to reduce or eliminate the necessity for some of the services provided by traditional home healthcare professionals, thereby eliminating both travel time wasted and travel costs. Nationally, traditional home nurses provide five visits per day; we anticipate that an ILSA providing monitoring, alerting, and telemedicine type services will increase the number of "virtual visits" to more than 20 per day.

The costs quoted above were incurred due to direct care by formal caregivers in the home, and do not include visits to emergency rooms, hospitals, or extended care facilities. HELP Innovations conducted a case study during the first half of 1998 in which they compared the utilization of services and costs before and after installation of a telemedicine system. They identified a 66% decrease in total cost per patient day ($179 vs. $61) and a 52% decrease in total number of encounters per 1000 patient days (242 vs. 115) (HELP Innovations, 1998). If a fully functional ILSA were to be available in 2005, and market penetration were a conservative 10%, a reduction in home healthcare costs could be expected to be greater than $3B annually. By 2010, with increases in the elderly population and a 20% market penetration, the annual impact would grow to over $8B per year.

1.1.2 Reduction in costs associated with informal home healthcare—The U.S. General Accounting Office reports that 85% of all home healthcare is provided by family and friends. Only 14% of home care as described above is rendered by paid providers (U.S. GAO, 1994). The magnitude of the statistics is immense:

- 23% of U.S. households are involved in caregiving to persons 50 or older (AARP, 1997);
- An estimated 14.4 million full- and part-time workers are balancing caregiving and job responsibilities (MetLife, 1997);
- 33% of full time and 37% of part-time employees have lost time due to care giving responsibilities (AARP, 1997);
- 15% of previously employed caregivers chose early retirement (Otten, 1991);
- 7 million Americans are long distance caregivers for older relatives; the average travel time to reach their relatives is four hours (Wagner, 1997);
- The average duration of care giving is 4.5 years (Stone & Kemper, 1989)'
- The average time consumed for personal and household assistance is 12 hours per week.

Informal family home healthcare is not free, and in fact it is a major cost for U.S. employers. A 1997 study by the Metropolitan Life Insurance Company showed that the annual costs due to family caregiving was $11.2B (MetLife, 1997). These costs were incurred as a result of employee absence, workday interruptions, eldercare crisis, supervisor's time, and replacement costs for employees that quit in any year. The MetLife study did not address the magnitude of unpaid labor by family members. Research findings suggest that unpaid caregiver support saves the U.S. taxpayer $33.3B just in caring for persons with Alzheimer's disease (Ernst, 1994).

We anticipate that ILSA can provide a significant contribution to the reduction in these costs as market penetration is achieved. In fact, we believe this group of caregivers represents a customer base for ILSA installations in their parents' homes. We project a $1B savings in 2005 that would continue to increase because of population demographics and market acceptance.

1.1.3 Reduction in costs associated with nursing homes—In 1996 approximately 1.6 million people received care in over 16,000 nursing homes at a cost of $78.5B. HCFA projections are that nursing home costs will be $130.9B by 2005. Currently, the federal government pays 57% of that cost through Medicare and Medicaid, programs whose financial viability has become a national issue. The average cost of living in a nursing home is $47K per person per year. Although we are confident that ILSA will allow older people to live independently at home for a longer period, we may not be able to prevent the eventual necessity of a nursing home until some significant advances occur beyond the scope of this program. To evaluate the economic benefits of ILSA relative to nursing home costs, we have to consider the status of the current population. HCFA studies indicate that 48% of nursing home residents have dementia, and 83% need help with three or more ADLs. If the remaining 17% could defer moving to a nursing home for even one year, that would represent a $22B economic impact in 2005.

1.1.4 Improvements in quality of life—It's difficult to quantify quality of life in dollars, but we believe that this is one of the major benefits of ILSA. In a recently released AARP survey, 67% of older parents did not think they needed additional services to live independently, but 51% of their adult children felt they did. At the same time, 58% of parents who had experienced health problems within the past five years were very concerned about living independently (AARP, 1999). We expect that a system that monitors health conditions, assists in ADLs, and provides status and/or alerts will have a positive impact on all involved.

Currently, mental and emotional problems are being reported with family caregivers. Studies show that an estimated 46%, primarily spouses, are clinically depressed (Gallager et al., 1989). Caregivers also use prescription drugs for depression, anxiety, and insomnia at a rate of two to three times that of the average population. Approximately 80% of workers who also have responsibilities at home for caregiving report emotional strain. We expect that the ability to query status and the knowledge that alerts will trigger appropriate actions by appropriate people or organizations should reduce the overall stress on the family caregiver.

1.1.5 Expansion of healthcare and ADL device markets—There is a substantial potential for leveraging the core technologies developed in this program. To maintain a reasonable scope, we have chosen to focus our technology development on a specific portion of a significant global problem—the shrinking ratio of caregivers to those needing care. However, the technologies we will be developing are applicable to a wide variety of similar applications. For example, products and systems we develop for the legacy home will be directly applicable to new homes, retirement communities, condominiums, apartments, assisted living facilities, nursing homes, and hospitals. Further, the technologies we develop for the advanced agent architecture will be applicable to a very broad range of sensing, monitoring, understanding, alerting/alarming, and control problems outside those listed above and beyond healthcare.

1.1.6 Summary—The costs associated with care for the elderly are already measured in the 10s of billions of dollars per year, and with the aging of America are projected to be in the 100s of billions. We believe that the infrastructure ILSA provides will coalesce existing and future technologies to reduce future expenditures and the associated drain on funding programs. In addition, the open architecture of the system will provide a basis for the introduction of newly developed devices from any company,. Perhaps most importantly, ILSA can be expected to improve the quality of life for both the elderly and their families.

1.2 Market

The magnitude of the market is not only defined by the demographics discussed above, but also by the degree of success of our technology development, acceptance of the system by the elderly, their family members, and the medical and healthcare professions, the cost of installation and configuration, and the probability of technology solutions to problems not directly addressed on this program. There are already 35 million individuals in the U.S. over the age of 65 (20 million households), and an additional 4-5 million will turn 65 each year in the near future. Assuming our technology developments are successful in demonstrating an infrastructure and system that will allow people to live independently longer, even a conservative 10% market penetration represents an estimated 300,000 installations per year. This is not just a market for Honeywell and our teammates. The fact that we are defining an open systems architecture that will accept technologies and devices that are developed in the future by other companies represents a significant peripheral market.

Two issues that must be addressed are acceptance and cost. Acceptance is a potential problem with both the elderly and the medical profession. A Forrester Research study (Forrester, 1998) confirms a perception that today's seniors are still a technologically reluctant group. While communications-oriented applications are a favorite of this group, of seniors without a PC, 59% will not buy one at any price. Thus the user-centered design of the system to provide an appropriate, comfortable interface for seniors is an important part of the research: as much of the technology as possible must be transparent to the user.

Our telemedicine partners have experienced issues associated with keeping the doctor in the loop. Some of these issues can be addressed through the decision support system by providing the right data at the right time. Other issues, such as billing and crossing state lines, will need to be addressed as part of the downstream commercialization plan.

Cost is always a market driver. An architecture must be developed that can be implemented downstream in a manner that minimizes an initial installation cost. Further, we anticipate that installations will have to be commissioned and configured to specific circumstances at a reasonable cost. We intend to mitigate these costs through the development and incorporation of the Dynamic Interaction Generation technology.

Finally, we anticipate that the market will be enhanced by developments that are not actually part of the proposed program. For example, we are not intending to actively address the problems associated with Alzheimer's disease, but there is considerable research being conducted in this area. Similarly, a number of sensors that could complement the system are being studied in the MIT consortium entitled Home Automation and Healthcare and presumably will be commercialized by one or more of their member companies.

The ultimate market will also depend upon a definition of who the payors might be. In addition to seniors themselves, their immediate family or adult children may provide a larger customer base. According to Forrester, 58% of seniors have a household income of less than $35,000 per year and their adult children may be financially more capable of purchasing the system. As indicated above, well over half of current home healthcare and nursing home expenses are paid by the federal government through Medicare and Medicaid. Long-term care insurance currently represents a small, but growing percentage contributor. If the price range of ILSA is $5,000 to $10,000 depending upon configuration, this would represent less than 3 months of the average cost for one individual in a nursing home. As the system becomes commercialized and the benefits are documented, we would envision the possibility of ILSA becoming an allowable medical expense.

2.0 Need for ATP Funding

The need for ATP funding on this program comes from the following set of circumstances. First, there is substantial risk in developing the variety of underlying technologies we are proposing and integrating them into the type of product that we envision. Single companies that are already involved in the healthcare business (e.g., using telemedicine, developing/producing medical devices) often (if not typically) do not have the expertise in most of the nonmedical components of our proposed program (e.g., agent technology) because their products are not dependent on such knowledge. They are likely to shy away from attempting to develop a product such as ILSA without some significant incentive to do so. On the other side of the equation are companies that have expertise in such areas as agent technology, but that have limited or no healthcare and/or medical expertise. For such companies, the type of program we are proposing is a largely new business area—one that they are likely to shy away from for the same reason as the healthcare companies. And, because the program we are proposing represents a large technological leap for both types of companies, they will be reluctant to invest substantial financial resources to enter what is basically uncharted territory. However, each type of company is willing to invest its own resources in continuing to develop the technologies in which they are already experts, and of course they do. But the best chance, perhaps the only way, to get a program such as ILSA going is for two things to happen: the right mix of expertise must be brought together in a team that offers a realistic likelihood of success and there must be an incentive for both types of companies to take the risk and branch out into very new areas. The team we have brought together for this program meets the first need of—we have a team of experts that combines the best state-of-the-art expertise in the required technologies and domain knowledge. To meet the second need it is critical that Federal funding be made available as the incentive the various companies need to invest *their* financial and other resources into developing their technologies and developing the unique concept we envision.

Historically, product development at Honeywell Home and Building Controls has been HVAC related and R&D efforts have been focused on that market. Although the proposed ILSA concept builds on our Home Vision products, it is outside the traditional focus and represents a new market and a risky technology. It involves agent software development and establishment of a complex agent architecture, concepts that cannot be successfully addressed within the typical product enhancement cycle and funding limits. Furthermore, H&BC products for homes have typically been targeted at the $30 to $200 price range. These low-cost products must be very competitively priced and have very low margins. Several-year-long multimillion-dollar developments are unlikely to gain approval. Thus, we a need a broad capability alliance and significant government funding to undertake this high-payoff technology development.

The research interests of our teammates have focused on very specific medical problems. These endeavors, while representing millions of R&D dollars, represent only elements, or at most subsystems, of the ILSA concept. Organizations like our teammates would not pursue a concept like ILSA without a large successful systems integrator as lead with financial support for the research.

This project deserves public support; it addresses a national problem that is getting worse. The demographic projections for the next 50 years clearly show that the ratio of caregivers to those needing care will decrease significantly. Today's ratio offers no margin to brag about—caregivers, both professional and informal, are overworked, stressed, and less effective than they could be. Our solution is not expected to eliminate the problem, but it will surely mitigate it. It will improve the quality of life for hundreds of thousands of elderly and hundreds of thousands of caregivers. It will be of use to people with disabilities. It will alter the balance of economic spending by lowering healthcare costs, thereby impacting Medicare, Medicaid, and insurance rates. It will boost the development of technologically advanced home healthcare devices. It will enable U.S. industry to sell these products abroad before foreign companies develop the products and sell them to us. NIST ATP funding can make this happen; it can support this broad alliance solving complex technical problems and allow U.S. industry to be first-to-market in this very critical area.

3.0 Pathway to Economic Benefit

3.1 Commercialization

ILSA research is being conducted to establish the basis for designing, producing, and marketing products that will benefit the U.S. socially and economically. Since there is a need for ILSA functionality now, commercialization activity will be started as soon as research results and prototype tests indicate product feasibility. This subsection describes our commercialization plan, a plan that will be carried out by Honeywell and other members of the ILSA team in company-funded activities that parallel the NIST-funded research and development.

Our commercialization strategy is to add independent living functionality to the base Home Controller that is now in development for Honeywell's Home Vision product line. Our ILSA plan expects sets of functionality to be handed-off from the ILSA team to the Home Controller product team for parallel product development and commercialization. This is a normal development strategy between the Honeywell Technology Center and Honeywell's Strategic Business Units. With this strategy, a baseline product is able to add functionality at 3-6-month intervals.

Our commercialization work will follow HBC's Policy & Procedure called CPDM (Common Product Development Methodology) (Honeywell, 1998). CPDM applies to all research and development projects within Honeywell Home and Building Control businesses worldwide. Following the CPDM will also facilitate conformance of the eventual products to ISO 9001. This policy calls for the development of a series of marketing and engineering documents that progress from market requirement to detailed product specifications. The marketing efforts will be supported strongly by our teammates. Honeywell's understanding of the healthcare market is limited, but we will rapidly expand that knowledge with the assistance of our teammates and other healthcare market experts. In total, these efforts will result in a detailed business plan for guiding the work of the product engineering groups and the marketing personnel.

Our commercialization plan is further facilitated by the breadth of the proposing team. Honeywell researchers are joined by university researchers, medical professionals, and other healthcare experts. Each of our commercial partners will be given the opportunity to integrate commercial software, services, and devices into the commercialized advanced Home Controller and become part of the commercial ILSA.

HELP Innovations sees two distinct commercialization tracks for this product and/or different levels of components of the ILSA product: the private/consumer and healthcare providers. Clearly, in both circumstances, FDA approval will be required for any automated triggering initiated by the decision support software. Dependence on this automatic functionality is not anticipated in the proposed program, but it will be required at the time of commercialization and effort will be made during testing to collect the appropriate information to support this process.

Throughout the program, in parallel activities, HELP Innovations will test and validate a set of commercialization assumptions to ensure a successful commercialization roll-out for the products and resulting services. These assumptions include demographics (both age and co-morbid statistics), basic and advanced services, distribution channels, care trends, medical payment legislation, and cost of alternatives.

ILSA will be based on an open communications architecture. Honeywell and its teammates will create opportunities for others by following the established communication standards such as HomeAPI, CEBus, X-10, Ethernet and LESST in the development of the equipment and software modules. This will facilitate the adoption and inclusion of modules and devices from other vendors that follow the accepted standards.

Our commercialization plan extends beyond just a Honeywell-and-its-partners plan. By building on an open architecture, similar to the IBM PC, we are enabling other medical product providers to offer integrated solutions that select from a large array of modules and devices that we expect to be built to the ILSA open architecture. We will also establish an ILSA industry working group to develop an open specification for the ILSA architecture. This group will be patterned after industry groups such as Home PnP, Home API and Home RF in which Honeywell is a key participant. This will permit multiple companies to develop ILSA systems and components based on the open architecture. The initial core group will be made-up of Honeywell and its teammates in the ILSA research effort. As the initial specification matures, the group will be opened to other interested parties.

The breadth of the proposing team will facilitate diffusion of the technology into the healthcare industry. To accelerate industry-wide adoption of the ILSA open architecture we will disseminate information on the architecture and other promising work as we progress. This will be accomplished by the ILSA research team members presenting papers at pertinent conferences and by conducting demonstrations and field tests. Further, we intend to diffuse the core technologies we develop into other Honeywell operations including buildings, industrial control, aviation, and space. We expect many of the software modules we develop to be easily adaptable to a wide variety of applications beyond this program.

A major strength of Honeywell as the prime contractor is H&BC's dominant position in the home control market. We have the technical and business knowledge to perform successfully in this market. We have built a significant team with experience and expertise in healthcare and medical equipment to assure us that we understand the market and the potential for commercialization. We foresee an initial commercialization effort through both existing healthcare channels (as offered by our partner HELP Innovations) and existing home product sales (to informal caregivers, i.e., the adult children of the elderly).

3.2 Commercialization Environment: Understanding of the Market

Four major positive pressures characterize the current commercialization environment—the need, a rapidly developing home networking market, Internet and Worldwide Web (WWW) availability, and both low cost and smart sensors. Each of these four pressures is described below.

- As described earlier, the need for alternatives to labor-intensive caregiving is large and growing as the population changes. This need has provided a fertile market for an integrated solution like ILSA.
- Home networking in now positioned to be the next major application in the home electronics market. The frenzy of activity in this arena today will produce robust low cost communications solutions for connecting systems and devices both inside and outside the home. This environment will become a key enabler for ILSA. The communications environment mentioned above is broad and complex. It includes the dramatic expansion of personal communications alternatives (POTS, ISDN, DSL, cable, Home RF SWAP-CA, Home RF LITE, Bluetooth, CEBus, 10baseT, Home PnP, Home PNA.) Honeywell is a participant with most of these evolving communications standards.
- The use of the Internet and the WWW is expanding rapidly. This technology is becoming commonplace in many walks of life. Many new products, applications, and activities are arising to use the Internet and its existence is a critical part of the commercialization environment.

- Sensor technology (and associated applications) is advancing rapidly, resulting in a large number of new sensing devices. These developments are offering a vast array of sensor capabilities—old sensors made smart with computation and communication capabilities; old sensors made small, light and cheap; and new sensors not previously available. This technology development has created a commercialization environment that can provide some high-technology, low-labor alternatives to today's in-home care, assisted living, and nursing support through the ILSA concept. HTC has a world-class sensor development technology area that has specialties that include home sensors, automotive sensors, industrial sensors, and space and aviation sensors. These developments are commercialized and produced by Honeywell's strategic business units.

In addition to these four positive pressures, a negative factor (both informal and formal) in the commercialization environment is acceptance—by the elderly, the healthcare providers, and the healthcare funding organizations. These issues are addressed in Part 4 A, Section 3.2.2 where we discuss risks.

There is a wide range of companies and organizations that can be considered competition. However, many can also be considered potential vendors of systems and devices that follow the ILSA architecture. These companies are participants in the areas of home automation, communications, healthcare, telemedicine, software development, etc. They include American Telecare, Ameritech, DEC, HELP Innovations, HOST, IBM, Johnson & Johnson, Medtronic, Microsoft, Pfizer, Siemens, Sony, System Monitoring Services, 3M, TI, many small regional companies, and probably several additional large foreign companies. In all likelihood, none will have an ILSA-like concept, but each is aware of the problem we are addressing and each is pursuing some appropriate product to try to meet some part of the needs. Several of these companies are either on the ILSA team or are involved in other Honeywell alliances.

The current competition for the ILSA concept is labor-intensive. That solution is destined to become less and less successful. The Minnesota Department of Human Services Aging Initiative has concluded that only technology or a change in the nation's immigration policy can offer the workforce what will be needed to deal with the aging demographics. There are no other technologies that compete with the breadth and depth of the ILSA concept.

3.3 Commercial Applications

The ILSA concept consists of a framework that will contain several modules and applications. In the broadest sense, the applications we will research and eventually productize are a set of modules/elements that facilitate the life of the elderly and their caregivers as they age-in-place. We expect the initial target elements of this application to be an integration of telemonitoring with extensive in-home sensing; monitoring; data collection and analysis; and reminding, prompting, alerting, and alarming in a simple, user-friendly interface. These elements will require the least amount of research and are based on many existing technologies. Full functionality for ILSA, on the other hand, will require significant research into broader areas and deeper complexity as we offer a chronic disease support framework and more complex safety, medication, nutrition, exercise, and telemedicine capabilities and network security. Other applications will include offering the ILSA functionality to people with disabilities, retirement communities, senior buildings, assisted living facilities, and nursing homes. We foresee the day when ILSA functionality will be used by everyone as a part of a "healthy home" that helps avoid or manage sickness and supports graceful aging.

3.4 Alliances

In building the ILSA team we have had discussions with and formed alliances with for-profit corporations, nonprofit organizations, universities, healthcare providers, and governmental agencies. Through these alliances we will establish user groups to support the development process. Users will consist of elderly persons that desire independent living, volunteer caregivers (relatives, friends, etc.), professional caregivers (nurses, doctors) and other experts in the field of geriatrics. User groups will be used for domain knowledge, requirements definition, testing, and evaluation. Honeywell will publish research progress and results, and we expect other members of our team will do likewise. Similarly, members of the alliance will patent hardware and software and offer licensing of the technologies developed. It is in the interest of the team members to provide an open and accessible system that many vendors can supplement and many customers can use, thus, we are seeking the widest possible visibility, breadth, and availability to expansion. This philosophy is also in the best interests of the healthcare industry, the caregivers, the cared for and the nation.

Further sets of marketing alliances will be pursued as research results point toward the first product offering. Honeywell has many marketing alliances now (e.g., AmeriNet in the healthcare area) and will continue to establish appropriate partners in the healthcare area.

3.5 Market Risks

The three primary market risks are timing, acceptance and cost. The aforementioned technology evolutions, combined with the growing need, make the timing for this endeavor critical. Now is the time to conduct this research and start the process of making a difference in the lives of caregivers and care recipients and to begin to mitigate the high cost of caring for the elderly. Research focused on the stated healthcare problems must be started now to offer a timely product to the growing market and to assure the nation that this market will not be satisfied by products from other nations. The most pressing market risk is in meeting the market need before foreign competition does. We see the names of many Japanese companies associated with university research in the healthcare area. The aging demographics in Japan represent a worse caregiver-to-cared-for ratio than in the U.S. The ILSA concept will utilize many components that foreign competitors can manufacture and sell. There are also several European firms developing healthcare products, primary among them Siemens.

Our approach to managing the risk from overseas competition is reflected in this proposal to obtain NIST support to accelerate the development of the ILSA concept and conduct the underlying research issues as soon as possible, thereby offering a product in the shortest possible timeframe.

The other market risks, acceptance and cost, have been addressed earlier in the proposal. They include the reluctance of the elderly to invest in a technology product, potential lack of acceptance by portions of the healthcare industry, home product traditional cost thresholds, and the risk that insurance companies and the government will not recognize ILSA as a medical expenditure. The acceptance risk will be managed through our partnership members' expertise and visibility in the potential customer arena. The cost risk will be managed by our expertise in producing low-cost home control products and by support from our healthcare partners.

3.6 Commercialization Alternatives

The ILSA concept provides abundant commercialization alternatives. Our technologists and our preproposal focus groups have come up with more potential solution elements than we can address here. We will assess a variety of elements to identify the ones with the greatest payoff per dollar and per risk, and we will pursue them to the point that they can be handed off to product developers and the commercialization process. We will not complete this Independent LifeStyle Assistant work in three years. But we will be far enough along to prove the viability of the technologies and the market, so that the path will be started and the technology will be enabled to continue the research, development, and commercialization on private funding.

4.0 Spillovers and Broader Diffusion

The ILSA concept offers a unique combination of extremely high public social benefits and significant economic benefits to the nation. To be sure, there is profit here to be made by private companies once the concept is developed. But, as discussed above, this will require a complex combination of technologies and domain knowledge, jump started with public research funding, to achieve the vision our ILSA team is proposing. Once realized, this concept will have not only dramatic impact on the subset of healthcare that we are addressing (the elderly that wish to remain in their legacy home) but numerous related healthcare areas and potentially areas—outside the healthcare field. Obvious spillovers include offering ILSA and/or portions of the ILSA concept to retirement communities, senior condominiums and high-rises, assisted living facilities, nursing homes, and hospitals. We have chosen to limit our scope in this program to the legacy home because it represents a greater challenge than wiring a senior high-rise, and it offers a greater potential good for the nation. But most of the technologies that we develop will be directly applicable to these other situations.

Less obvious spillovers exist outside the healthcare industry. Just as DIG is being developed for commercial building management and is here being applied to healthcare management, we believe the extensions to DIG will find application in many other areas. Furthermore, we expect low-cost communications, sensors and actuators, agent modules, and decision support logic we develop to spill over into other applications. This technology-rich and risky program has a unique breadth that will result in new concepts and new solutions that can support further advances in other areas.

4.1 Benefits to Users

The benefits to those who use our technology to produce other products are described below in the subsection on competition (4.2). We consider three primary groups in considering the benefits to users: the elderly, the informal caregivers (e.g., family, neighbors, friends, and volunteers) and the formal caregivers (professionals such as nurses and doctors). Each will receive significant benefits as discussed below.

The elderly will realize an improvement in quality-of-life and, in many cases, longer life. For the day-to-day routine benefits, there will be an improved psychological state knowing that they are safe, monitored and helped by ILSA. They will be in their legacy home with confidence that they will be able to live where they wish. Thus they will have the positive expectation that they can avoid a disruptive and costly move to a location that will drain their finances and take away their independence. They can expect to be less of a burden on their children. Further, they will have a convenient means to communicate with their family, friends, and other caregivers. They will have an easy means to find new friends (over the Internet) and to easily access information and education.

Those with significant medical conditions will have regular medical care. They will be supported in their regime of medication, exercise, nutrition, or other elements of their lives to enable them to be in the best health they can be. They will be able to avoid episodes of crisis, fear, pain, and trips to the emergency room. For those with dementia (especially those in early stages where the person knows that sometimes things are going wrong and wonders when it will happen again—and how fast it will get worse), ILSA will offer confidence that they are being monitored, they are safe, and if they have an episode, someone will know, and someone will help.

Informal caregivers will also realize an improvement in their quality-of-life. Children who live distant from an elderly parent but worry about her or his condition will have a log of activity and other data to review as they wish, and they will have the videophone capability to contact their parent from home, work, or elsewhere. Those adult children who live nearby and play a regular role in visiting and care-giving will have this same assurance that things are going well in their absences (and they will be notified if things do go wrong). This will allow them to spend less time in travel, less time checking up, and more time in positive socializing (over the videophone). ILSA will also be conducting tasks and activities that had once been the caregiver's sole responsibility thereby further reducing the care load. And the caregiver will have the psychological relief that the situation is under control, there will be fewer crises and emergency room visits, and the threat of the expense of supporting institutionalized living is lessened. Thus, the informal caregiver realizes a powerful financial benefit in addition to the peace-of-mind and reduced workload.

Formal caregivers will also benefit in several ways. Our teammates frequently comment about the time it takes to visit in-home patients. Formal caregiver visits can increase 10-fold by conducting the visits by two-way audio/video links. And the stress, frustration, and real cost of driving will be minimized. Therefore, professional caregivers will be able to give more and better care, and they will spend their days doing what they're trained to do and enjoy, rather than driving. Further, formal caregivers will have a vast new array of data to help in their care of the elderly. ILSA will be constantly monitoring the home-owner and sensors will record many activities and parameters that could only be vaguely implied through post-activity questioning previously. These data will be instrumental in both the care of the elderly, and in the further research that will help understand the lifestyle of the elderly for future care protocols and applications.

Although not a user per se, we expect government, insurance companies, and companies to also benefit from ILSA through the cost saving it will provide. Section 1.0 described these benefits in detail so they will not be covered further here.

4.2 Impact on Competition

There is a wide range of companies and organizations that can be considered competition. However, many can also be considered potential vendors to the system we develop. These companies are participants in the areas of home automation, communications, healthcare, telemedicine, software development, etc. Some of these companies are listed above in Section 3.2. The primary impact we seek is to exclude or minimize foreign competition for the baseline foundation of the system. Strategically, we will be researching and developing a system that is flexible, open, and scalable, one that invites other vendors of hardware and software to develop sensors, actuators, devices and applications to broaden and/or improve the concept and thereby provide a better product suite, one that offers even greater value to the elderly, the informal caregivers, and the professional healthcare industry. Tactically, we want to be first to the market, to avoid the possibility of others offering a proprietary closed system and the possibility that the first to market is a foreign system. When successful in our strategic and tactical approach, competition will benefit from the opening of a new market and the nation will benefit from the availability of this new system that improves the quality of life for millions and saves healthcare costs.

4.3 Diffusion of Technology to Others

Diffusion of the technology into the healthcare industry will be facilitated by the breadth of the proposing team. Honeywell researchers will be joined by university researchers and healthcare experts in presenting papers at conferences that will expand the visibility of the effort and share our findings. We will conduct several demonstrations and field tests to bring our work to the attention of others. User groups will be involved in these tests and those experiences will further diffuse our work beyond the ILSA team. We also intend to diffuse the core technologies we develop into other Honeywell operations including buildings, industrial control, aviation, and space. We expect many of the software modules we develop to be easily adaptable to a wide variety of applications beyond this program. Similarly, both our for-profit partners and our university partner will be diffusing the knowledge gained into broader areas of product development and research. The for-profit members of the team will be patenting hardware and software ideas. We will consider licensing technology on a case-by-case basis. We will be forming alliances that will bridge the home comfort product/healthcare industry/medical industry markets. We intend to look at several distribution models as a part of company-funded commercialization activities.

C. Program Administration

1.0 Commitment

The ILSA team is composed of Honeywell, the University of Vermont's Fletcher Allen Health Care Center (a member of the Telemedicine Hall of Fame), HELP Innovations (voted as one of the Top Ten telemedicine companies in 1998), In Home Health (experts in ADLs and IADLs for the elderly), and the Aging Initiative (experts on the aging population). Our team has both breadth and depth, and is committed to working together to develop superior results. We intend to achieve breakthrough solutions to this problem, and we have organized our program to take advantage of early successes as well as to ensure that the results of the program are commercialized.

The members of our team have developed the ILSA concept and submit this proposal in an effort to accelerate progress toward a comprehensive solution to helping people remain independent in their homes for longer, thereby eliminating or postponing an expensive and upsetting alternative: moving to an assisted living facility or a nursing home. In addition to the financial investment commitment of the Consortium, critical personnel have been assigned by each team member, significant legal and organizational issues have been overcome and large portions of the research agendas of the participants have been impacted to take advantage of this opportunity. Some examples of the commitment the members of this team have made include:

- For the Honeywell Technology Center (HTC), this will be both the largest investment in and the largest overall R&D project ever undertaken in the healthcare area. We are committing a significant amount of our resources to this effort and we are giving the project highest priority.
- For Honeywell's Home and Building Control (H&BC) business, this program represents a significant commitment of resources to this new area of research. During the evolution of the ILSA concept, H&BC will assess the market potential and initiate their standard commercialization process. Their continued guidance and help will ensure that while we are developing technological innovations in the key areas for this program, we are also addressing the outcomes and directions that will allow us to commercialize a viable Independent LifeStyle Assistant product.
- HELP Innovations, a for-profit, woman-owned, small business, will be applying a substantial portion of their research during the program period to ILSA applications. This will include engineering development of an electronic clinical record and database and clinical development of the protocol library embedded in the electronic record.
- In Home Health, a for-profit business, will provide expert consulting on providing and maintaining a safe home environment for the elderly and persons with chronic diseases.
- The Aging Initiative, a Minnesota State program, will provide expertise on the specific needs of the frail elderly as they age in place and on demographic and economic trends related to this population.

A letter of commitment from each of consortium members is included in Part 1 of this proposal following the Form NIST-1263 Page 4. These letters verify the availability of cost-sharing funds that will support this program. Most of these partners also represent potential customers of the ILSA product. Each team member has the draft Consortium Agreement and we will be negotiating a mutually satisfactory agreement. Also included with the consortium letters of commitment are letters from the highest level of management at the Honeywell Technology Center and at our Home and Building Controls business unit.

2.0 Organizational Structure

Our team is structured to obtain the widest possible view of the problem being solved, the best expertise available in the development of home healthcare technologies, the participation of innovative applications developers, and multiple clear paths to commercialization for the technologies being developed. Initially, in seeking new markets for home-based products for the next decade, Honeywell researchers became aware of the changes in the nation's demographics and the expected tremendous reduction in the ratio of caregivers to those who need care, specifically the elderly. While discussing technologies to support caregivers it became apparent that addressing this problem and its potential solutions successfully would require several organizations that would complement Honeywell's technology expertise in this healthcare research. At Honeywell's invitation, these companies came together to jointly develop solutions for the current home healthcare problems. When it became clear that developing a comprehensive solution would require a significant investment—beyond any single company's resources given their traditional markets and the current economic climate—the team identified NIST as a potential vehicle to share the cost and facilitate the development.

The team is committed to the success of this program because of its implications for our future competitiveness. The Honeywell Technology Center will act as the Program Administrator and will lead the technical aspects of this effort. HTC is the corporation's primary advanced technology development research facility and has expertise in operations aiding, cognitive science, user interfaces, artificial intelligence, advance multimedia communications, and systems and software technologies, and has a successful track record of participation in advanced technology programs.

All consortium members will report to the Consortium Management Committee, which will be chaired by the Honeywell Program Manager, according to the procedures agreed to in the Consortium Agreement. Top-level program direction decisions will be made by the Consortium Management Committee and HTC will be responsible for carrying out and delegating their decisions. More detail on Project Management is shown below in Section 3.0.

Some Consortium members will involve manufacturing/product development/commercialization staff in the program activities to assess the progress, evaluate the product potential, and coordinate commercialization activities. These activities will be funded independently of this program, not by NIST.

We believe that this is the right organization to attack these healthcare problems, conduct the research and prove the concept. However, the Consortium is open to adding members if it will facilitate a successful program.

2.1 Consortium Members

The ILSA Consortium will have four members:

Honeywell Inc.—The Honeywell Technology Center (HTC) is Honeywell's centralized research and development organization, delivering advanced technology, processes, and product and service concepts to satisfy Honeywell's home and building control, industrial, and aerospace customers worldwide. HTC recruits the best and brightest scientists and engineers in several disciplines: sensors, processors and processing, software, communication, architectures, user-centered design, and displays. A dynamic portfolio of both internally- and contract-funded programs provides the fertile information flow that ensures an intimate understanding of the state and direction of control system technologies and application markets. HTC has built an impressive success record in technology development and transfer into commercial product. An acknowledged world leader in control technologies, HTC developments currently account for billions of dollars in Honeywell revenues each year.

Home and Building Control (H&BC) is a global leader in providing comfortable, healthy, safe, and energy-efficient indoor environments. Customer loyalty to our brand is based on more than 3,500 products, a broad range of systems and services, a large installed base, and an unmatched distribution network that supports our customer solutions worldwide. Sales in 1998 were $3.441 billion, with an operating profit of $349 million. As part of the U.S. government's policy to reduce energy use 30 percent by 2005, Honeywell was selected to participate in contracts worth up to $1 billion to upgrade federal facilities in the 11-state central region and U.S. Air Force bases in nine western states. In 1998, growth initiatives in building security continued with key contract wins around the globe. H&BC will be the primary organization for commercializing ILSA when research from this NIST ATP demonstrates technical feasibility. H&BC is providing the Honeywell Home Controller foundation of our testbed and technology demonstrations, and a significant portion of the program cost share.

HELP Innovations—HELP Innovations, Inc. was founded in 1993 with the goal of contributing to a larger health care solution by promoting care in the appropriate setting and by enhancing the capabilities of health care professionals to provide quality and cost effective solutions to high-risk populations. The company is dedicated to the development and leveraging of new technologies that facilitate the caring/healing process in a home setting. HELP Innovations endeavors to increase patient satisfaction, capture outcome data that will provide the basis for cost-benefit analysis, forecast health resource utilization, and define best practice patterns.

HELP Innovations will support the ILSA project in collecting data from the test sites in a computerized, standardized format and by assisting with the development of a decision support system and software. They have 14 telehome care monitoring sites which are located throughout the country in both rural and urban settings. Each site has between 15 and 50 patient units in the field supporting patient monitoring and interactions. A site is defined as a central nursing staff call center that is the connection point for multiple patient units in remote locations within a defined service area. Using these and upcoming site installations, HELP Innovations will provide sites at which to deploy and test the ILSA system and support the data collection and analysis. At the scheduled implementation of the first test site, they will have an installed base of over 1,000 patients in both rural and urban locations. Based on this install base and HELP's R&D efforts over the past three years, HELP Innovations will be able to enhance the definition of the ILSA requirements from both the customers' and the users' perspectives. HELP Innovations will also play a significant role in commercialization. They represent both a customer for ILSA and a commercializer of several ILSA modules.

In Home Health—In Home Health was founded in 1984 as a provider of comprehensive home health care services. It is a for-profit corporation with 44 agencies in 28 states. In Home Health is committed to providing and maintaining safe home environments for the elderly and individuals with chronic disease management issues. They are also committed to providing testing and teaching field experience.

In Home Health provides healthcare services for clients in their homes. They have been an essential member of the proposal team providing real-world domain knowledge to the HTC technologists. Their expertise will continue to support the program through requirements definition and concept development. Further, they can provide local participants for evaluating functionality and user interfaces. Domain expertise from persons working directly with the elderly and their caregivers is essential to the program.

Aging Initiative—The Aging Initiative is an activity within the Minnesota State Department of Human Services. Their charge is to ensure quality care and services for seniors who need help living independently. An overriding goal is to support elderly people in their homes. Supports provided through the Aging Initiative include chore services, home delivered meals, home healthcare, adult day care, and other community-based services. Four major issues addressed by the Aging Initiative are increased personal responsibility to save and pay for retirement and long-term care costs; expanded emphasis on health promotion to reduce disability rates; increased age-sensitive physical, health, and social infrastructures, including land use, housing, health systems, and social ties; and continued strong economic vitality, including creative use of the aging labor force and growth in contributory roles of older persons. The Aging Initiative works in partnership with communities, volunteer organizations, counties, and area agencies on aging to build networks to meet seniors' needs and maintain their independence. This focus promotes self-sufficiency and reduces reliance on publicly subsidized long-term care.

The Minnesota Department of Human Services' Aging Initiative will provide the project with demographic data and projections, trends in disability, information regarding specific problems associated with decreased functional ability, and the incidence and prevalence of activities of daily living (ADL) limitations. They have gathered current information on these issues, made projections for future needs of the growing elderly population, and highlighted the important role that technology can play in addressing the needs of the frail elderly. Policy directions promoted by the Aging Initiative within the area of technology and aging include increasing the productivity in human service delivery through creative use of high level technology that can replace staff and interact with people, and improving our quality of life as we age through new inventions and discoveries.

2.2 Small Business Participation

The ILSA Consortium includes a for-profit small-business member. HELP Innovations is a woman-owned small-business that provides telemedicine service to in home patients. Their home-care recipients include persons of all ages recently discharged from hospitals to elderly persons with a variety of health conditions. They provide care in both rural and urban settings. We intend to use Kansas City, Pittsburgh, and Gainesville sites to do urban field tests.

The team also includes two nonprofit members: the Minnesota State Aging Initiative and the University of Vermont/Fletcher Allen Health Care (who will act as consultants to the Consortium on medical decision making and chronic disease management).

2.3 Subcontractors and Vendors

The ILSA Consortium is fortunate to have the expertise of Fletcher Allen Health Care (FAHC) in support of our program goals. Founded in 1995, FAHC is one of only 125 national premier academic medical centers. Associated with the University of Vermont, Fletcher Allen provides services to one million patients. Telemedicine links Fletcher Allen's tertiary care expertise to nine rural hospitals in Vermont and northeastern New York. Virtually every medical specialty is represented in their telemedicine program. Remote teleconsults are available with Cardiology, Gastroenterology, Nephrology, Emergency Medicine, Trauma, Vascular Surgery, endocrinology and many others. In addition to their medical knowledge, FAHC will provide rural sites for our concept field tests.

3.0 Project Management

There will be two functional organizations for the program; they are shown together in Figure 4-3.

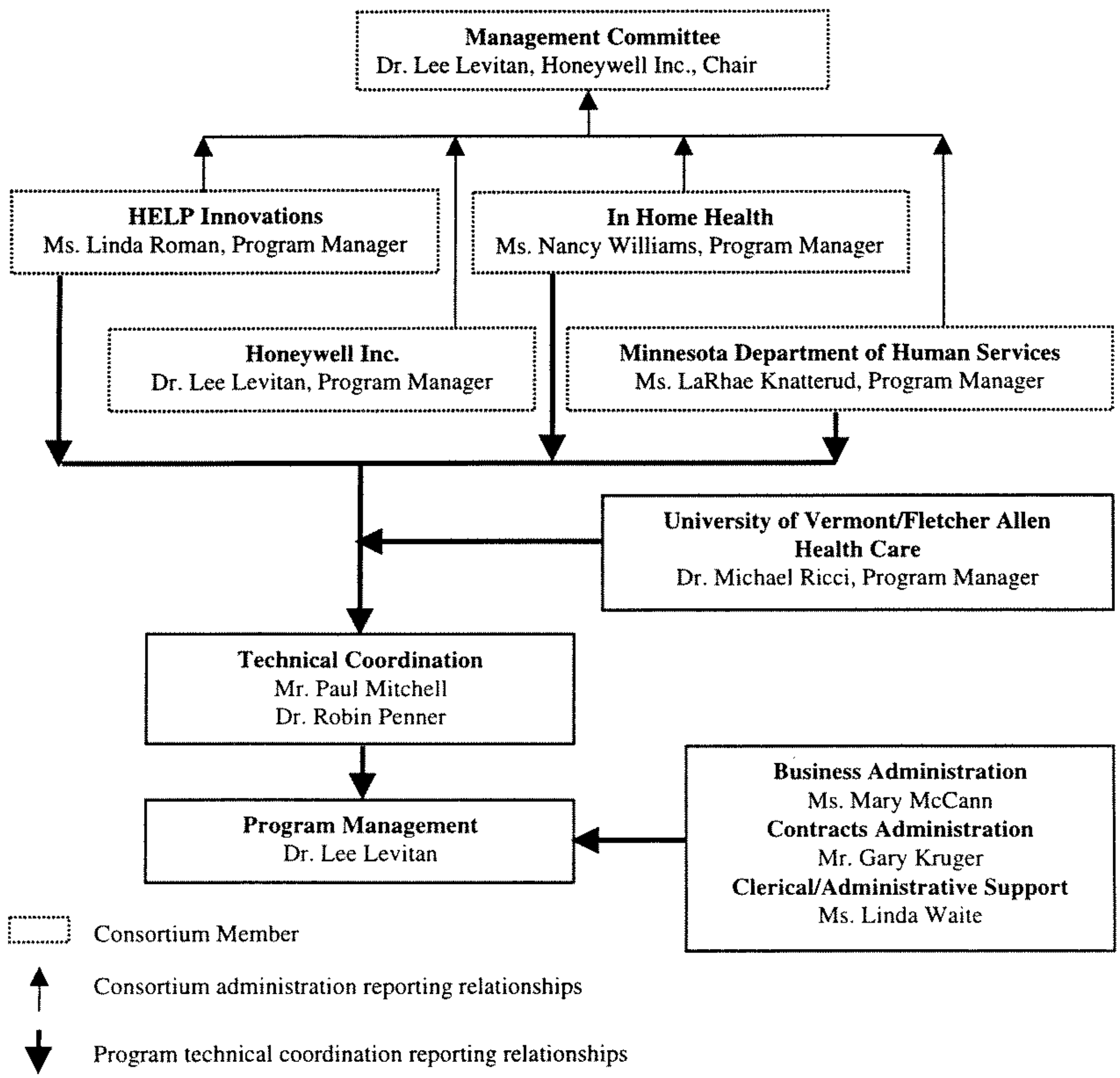


Figure 4-3. Organization Chart for the ILSA Program.

The strategic direction and administrative aspects of the program will be determined by a Management Committee comprised of a single representative from each Consortium Member organization, as defined in the enclosed Consortium Agreement. The Honeywell Program Manager, Dr. Lee Levitan, will chair the Committee and will act as the liaison between the Consortium and NIST for all pertinent matters. As shown in Figure 4-3 with the upward-pointing arrows, Consortium Members will report to the Committee through their respective Program Managers. Dr. Levitan will act as the interface among the various Partners and our Consortium Consultant (the University of Vermont/Fletcher Allen Health Care), and will work to remove any organizational obstacles to program success. Recommended changes in direction for the program will be discussed fully with NIST before implementation; Dr. Levitan will have final authority for executing the program determined jointly by the Management Committee and NIST.

The technical organization is shown in Figure 4-3 with the downward-pointing arrows. The Honeywell Program Manager will have overall responsibility for the program, including cost, schedule, and technical product. Because of the multidisciplinary nature of the program, its overall size, and the complexity of the work to be done, we will have a two-person Technical Coordination team with day-to-day responsibility for the technical aspects of the program. They will be responsible for overseeing and coordinating the two major activities on the program: technology development and technology demonstration integration/testing. Both activities will involve working closely with the technology experts within Honeywell and the domain experts at our Partners and at our Consortium Consultant to ensure that this substantial landscape of expertise is blended into a coherent vision. In addition, the Technical Coordinators will work with our commercialization liaison so that we continue to not only aim toward a viable product, but take maximum advantage of early spin-off possibilities. We understand that NIST will not pay for commercialization activities, and this will be a coordination effort only. In addition to the Technical Coordinators, the Program Manager will have an excellent administrative support staff: Ms. Mary McCann (Business Administration), Mr. Gary Kruger (Contract Administration), and Ms. Linda Waite (Clerical/Administrative).

The Consortium will hold two-day meetings quarterly to review progress, have a formal technical interchange (in addition to the expected e-mail, phone, and other communication that will go on daily), and conduct its administrative business. Each team member organization will be represented at the meetings, which will rotate among our various locations to maximize participation.

The Program Manager, on behalf of the Consortium Administrator, will submit quarterly financial, technical, and business reports to NIST and to all the team members In addition, he will coordinate our formal meetings with NIST (the kickoff meeting, annual reviews, the final review, and workshops).

The Work Breakdown Structure (WBS), Statement of Work (SOW), schedule, and budget provide the basis for managing the program. The task descriptions, schedule, and task budget are all tied together by the common WBS. Monitoring, control, and reporting will be by WBS line item. The Program Manager, Technical Coordinators, and Business Administrator will meet regularly to assess progress and cost.

4.0 Experience and Qualifications

4.1 Personnel

The roles of principal personnel are shown in Table 4-1 along with their level of commitment to the program. The project is structured so that many different contributors can make intensive contributions over brief periods of time. Brief biographies are included for principal personnel.

Table 4-1. Roles of Principal Personnel

Principal Personnel	Project Role	Affiliation	Commitment
Lee Levitan	Program Manager	Honeywell	75%
Paul Mitchell	Technical Coordination	Honeywell	50%
Robin Penner	Technical Coordination/DIG	Honeywell	50%
Bob DeMers	Testbed Development	Honeywell	45%
Kevin Driscoll	Communications Security	Honeywell	5%
LaRhae Knatterud	Elderly Healthcare	Minnesota Aging Initiative	10%
Steve Metz	User Interface/Field Testing	Honeywell	50%
Kyle Nelson	Decision Support	Honeywell	50%
Michael Ricci	Medical Knowledge	Fletcher Allen Health Care	10%
Linda Roman	Clinical Record & Database	HELP Innovations	25%
Larry Stickler	Framework Development	Honeywell	25%
Rand Whillock	Speech Interface	Honeywell	35%
Nancy Williams	Elderly Healthcare	In Home Health	10%
Bob Bonnema	Commercialization Liaison	Honeywell	5%

Dr. Lee Levitan—Senior Principal Research Scientist, Honeywell Technology Center (PhD, Experimental Psychology, University of Minnesota). Dr. Levitan has over 21 years experience at Honeywell and specializes in program management. Most recently he managed a $2,000,000+ program to investigate the human factors aspects of automated highway systems and a $600,000 program to develop a unique, six degree of freedom hand controller (which resulted in two patents). Dr. Levitan is the Associate Technology Group Leader for the User-Centered Design group at HTC. In this capacity he does staff career planning and guidance, performance appraisals, and mentoring.

Mr. Paul Mitchell—Senior Program Manager, Honeywell Technology Center (BS, Physics, Purdue University). Mr. Mitchell has been a supervisor and a staff scientist in several R&D technical areas. His expertise includes program management, team process, and facilitation. In this capacity he has coordinated and managed inter-disciplinary teams to achieve systems engineering success. He is currently leading an internal Independent Living activity and the associated concept pursuit, and he is serving on the Software Process Engineering Group, a task force responsible for raising the SEI Level of HTC's software processes. Previously, Mr. Mitchell was the Program Manager on projects for EPRI, PG&E, NASA, DARPA, Canada Post, and the Federal Reserve Bank.

Dr. Robin Penner—Cognitive Scientist, Honeywell Technology Center (PhD, Cognitive Science, University of South Florida). Dr. Penner has over 15 years of Honeywell experience in advanced home automation research, intelligent collaborative agent technology, and user interface design. She specializes in applying cognitive science principles to improve processes and products within Honeywell and for external government and industry contracts. Dr. Penner is currently lead developer for her innovative approach to automated user interface design and presentation (DIG) and the application of this technology to home automation, building management, and maintenance of smart spaces.

Mr. Bob DeMers—Senior Research Scientist, Honeywell Technology Center (BS, Mechanical Engineering, University of Minnesota). Mr. DeMers has 10 years experience at Honeywell, primarily in the space and aviation domain. He specializes in rapid prototyping and test equipment development for human factors experiments. Mr. DeMers is currently working on advanced flight deck development and is leading pursuits in perception management and carrier flightdeck safety. He also has served as lead hardware design engineer for the Honeywell Technology Center flight simulator and for Honeywell studies conducted at the National Driving Simulator at the University of Iowa.

Mr. Kevin Driscoll—Staff Scientist, Honeywell Technology Center (BA, Computer Science, University of Minnesota). Mr. Driscoll has 22 years experience at Honeywell as an architect for real-time systems that have stringent safety and security requirements. He is currently designing systems required to have less than 10^{-9} probability of failure. Mr. Driscoll is a member of the International Civil Aviation Organization (ICAO) panel that is setting the security standards for the next generation of aviation communications. Prior to joining Honeywell, Mr. Driscoll was a cryptography specialist for the U.S. Army's Communication Command and later the Army Security Agency. His work included teaching at the cryptography school in Fort Monmouth, New Jersey; heading the secure voice station in Seoul, Korea; and activating a new secure communication network.

Ms. LaRhae Knatterud—Planning Director, Minnesota State Aging Initiative (MA, Public Administration, Humphrey Institute of Public Affairs, University of Minnesota). She is responsible for managing a team that is identifying the impacts of the aging of Minnesota's population and preparing the State's response to these demographic changes. Her major concentrations at the Humphrey Institute were gerontology and health care policy.

Mr. Steve Metz—Senior Principal Research Scientist, Honeywell Technology Center (BA, Psychology, St. Olaf College). Mr. Metz has 17 years of experience integrating R&D technologies into commercial Honeywell products. His expertise is in graphical user interface design, design for cross-cultural and special populations, and usability testing. He has applied universal design principles to the design of home security and environmental controls for people with disabilities, resulting in the first "Easy-to-See" thermostat for people with low vision and the "Easy-to-Use" thermostat for people with limited hand dexterity and strength. These products have been produced and distributed through Honeywell for over 10 years. Mr. Metz also has completed and published several human factors research studies that helped characterize the abilities of individuals with arthritis to manipulate basic controls.

Mr. Kyle Nelson—Senior Research Scientist, Honeywell Technology Center (MS, Computer Science, University of Minnesota). Mr. Nelson, with Honeywell since 1988, recently served as Principal Investigator and Program Manager for the DARPA-sponsored Shared Human-Computer Interaction Environment program. He also has served as the blackboard design-and-implementation lead for the NIST-sponsored Abnormal Situation Management program. Additionally, Mr. Nelson served as PM/PI for a NASA-funded Integrated Vehicle Health Maintenance project to develop a modular and extensible architecture for on-board failure prediction and detection on the Space Shuttle.

Dr. Michael Ricci—Associate Professor of Surgery and the Clinical Director of Telemedicine at Fletcher Allen Health Care and the University of Vermont (MD, SUNY Upstate Medical Center). Dr. Ricci has been instrumental in the implementation of the Telemedicine Program that has twice been named one of the Top Ten in the nation while maintaining a full time practice in clinical vascular surgery. He maintains a basic science lab in vascular surgery and has also done research on the utilization and efficacy of Fletcher Allen's telemedicine system. Dr. Ricci is the author of 86 peer-reviewed publications and four book chapters on topics in telemedicine and vascular surgery.

Ms. Linda Roman—President and CEO, HELP Innovations, Inc. (BS, Health Care Administration, Wichita State University). Ms. Roman founded HELP Innovations, Inc. in 1984 and is actively involved in all business functions. She conceptualized and developed HELPlink™ in 1994, organized the management team, alpha and beta tested the system, negotiated Medicaid reimbursement in the State of Kansas, and has presented the product at national and international telemedicine conferences. Ms. Roman previously has served as President and CEO of Innovative Health of Kansas, Inc. where she was actively involved in state and federal health care political agendas.

Mr. Larry Stickler— Senior Principal Engineer, Honeywell Technology Center (MS, Electrical Engineering, University of Illinois). Mr. Stickler has over 10 years of experience in developing systems and industry standards for home control. He was the principal leader of the Home Plug-and-Play working group and is now a key leader in the development of the Home API specification. He represents Honeywell on the Board of Directors of the CEbus Industry Council. He has been a principal architect in five multicompany home control projects, work on which included an emphasis on ease of commissioning.

Mr. Rand Whillock—Principal Research Scientist, Honeywell Technology Center (MS, Computer Science, University of Minnesota). Mr. Whillock has 18 years of Honeywell experience, specializing in hardware and software systems design and implementation for applications ranging from small mobile robots to aircraft flight decks. He has most recently been designing and implementing speech interfaces for military and commercial systems. Mr. Whillock also has experience in signal and image processing, artificial intelligence, and user-centered systems design.

Ms. Nancy Williams—Market Director/Director of Operations, In Home Health (MS, Public Health Nursing, University of Minnesota). Ms Williams is an experienced health care professional with a history of using entrepreneurial instincts in guiding successful health care organizations. She has 20 years experience in the home care industry and specializes in the nuances of issues related to ADL's/IADL's in the home environment. She has previously served as a product/program development consultant for the ConvaTec Division of the Bristol-Myers Squibb Company.

Mr. Bob Bonnema—Program Manager, Home Control Systems, Honeywell Technology Center. Mr. Bonnema has more than 20 years experience at Honeywell, specializing in project management, production management, and product development for Home and Building Control products. He is currently Program Manager for the Home Controller Gateway project, Honeywell's first retail wireless home control product. Mr. Bonnema also has managed projects in the areas of home automation, energy management, laser reference systems, and vision sensors.

Ms. Mary McCann—Senior Business Administrator, Honeywell Technology Center (BS, Business Administration, Southwest State University). Ms. McCann has 18 years experience at Honeywell, including business administration of numerous multimillion dollar, multiyear contracts for various government agencies and commercial customers. Ms. McCann has previous experience with NIST contract administration.

Mr. Gary Kruger— Contract Representative, Honeywell Technology Center (MBA, University of St. Thomas). Mr. Kruger has been with Honeywell since 1995. He started at our Solid State Electronics Center where he had responsibility for the negotiation and administration of contracts and management of projects supplying smart sensors for the avionics and automotive industries. He currently has contract management responsibility for the *Advanced Air Transportation Concepts and Technologies* program with NASA; the current value of this Task Order contract is $3.9M, with HTC acting as lead for this nine-member team. Mr. Kruger also has contract management responsibility for a variety of other R&D programs for the Department of Defense and other U.S. Government agencies and for educational institutions.

Ms. Linda Waite—Technology Group Assistant, Honeywell Technology Center. Ms. Waite has been with Honeywell for 20 years, providing clerical and administrative support for the Technology Group Section Head and a group of 25 engineer/scientists. Major contracts she has supported include the Federal Highway Administration's $5,000,000 *Human Factors Design for Automated Highway Systems* project and NASA's *High Speed Research* and *Advanced Air Transportation Technologies* projects.

4.2 Related Experience

The ILSA team has significant experience in the technologies and applications associated with the proposed project, as well as in the management and successful performance of research and development programs.

4.2.1 Previous ATP Awards—Previous NIST ATP awards to Honeywell include:

Advanced Process Control (APC) Framework Initiative—Honeywell and Advanced Micro Devices (AMD) collaborated in the development of an advanced process control framework. This program developed a basic framework for an integrated factory-level production control environment for the semiconductor industry. While many semiconductor fabricators have implemented limited point solutions, the major barrier to adoption of APC capabilities has been the cost and risk associated with integrating APC solutions with existing manufacturing systems. The system controls production lots across the factory and enables real-time, automated, feedforward and feedback refinement of the individual process steps. The results of the project include a software architecture, an integrated suite of software components, and a set of standard specifications for deploying APC solutions in semiconductor factories. This framework enabled AMD to establish an integrated factory-level production control environment at their Fab25 facility, which has already increased revenue by over $10 million per quarter.

Abnormal Situation Management (ASM)—Honeywell and a consortium of petrochemical companies collaborated in the development of decision support technologies for improving the performance of industrial plant operations personnel under abnormal plant situations. The inability of the automated control system and plant operations personnel to control abnormal situations has an economic impact of at least $20 billion annually in the petrochemical industry alone. Several decision support software systems were designed under this program that work with operations personnel during an abnormal plant event to minimize loss of production, contamination of the environment, and injury. These software products provide innovative new tools for oil and gas refinery operators, enabling them to define process conditions to monitor; to use portable, wearable computers to access process data and procedures while walking around the refinery; and to better understand advanced control algorithms using graphical user interfaces that help users visualize complex mathematical equations. These prototype concepts will be brought to market as three separate products by the Honeywell Industrial Automation and Control division within the next two years.

4.2.2 Recent Federal Contract Awards—Relevant federal contract awards to ILSA Consortium members over the past five years are listed in Table 4-2 below.

Table 4-2. Recent Federal Contract Performance (1994 to present)

Title	ILSA Relevance	Date/Amount	Sponsor Agency
Adaptation with Real-Time Performance Guarantees (QUORUM)	Communications	1997/$1.8 million	NRAD/DARPA
Program objective: To develop a "service layer" for distributed operating systems (i.e., a software layer between applications and operating systems). The intent was to provide distributed applications with predictable, reliable service, with the ability to dynamically adapt computing resources (e.g., processors, memory, communication bandwidth) as demands change. Team members include Georgia Tech and Texas A&M.			
Shared Human- Computer Interaction Environment	Decision support	1995/$1.1 million	DARPA
Program objective: To employ agents that possess decision support expertise to complement humans in the search and rescue domain. The resulting system, called the Search and Rescue Assistant (SARA), will aid the U.S. Military Joint Services Search and Rescue operations through dynamic, context-dependent information management, activity tracking, and information display.			
Intuitive Policy Specification for Optimized Flow of Asynchronous C3I Transmissions in Operations (IPSO FACTO)	Distributed information control	1999/$3.7 million	DARPA
Program objective: To develop software that enables "information policies" to be derived from a commander's plan for conducting the battle. This policy will then be passed to other Agile Information Control Environment (AICE) layers to be used in controlling the flow of battlefield information and the use of communication resources. Our approach ensures that the policies will be in keeping with the commander's overall battlefield goals and allows policies to be stipulated with a minimum of effort over that required to develop the battle plan in the first place			

Other ILSA Consortium Research and Development—ILSA Consortium members have extensive experience in technology development, product design, and commercialization with the ILSA core technology areas of sensors, communication, decision support, user interface design, and home automation. Recent ILSA Consortium research and development in these areas include:

The Victoria PC-based Home Control—This is a do-it-yourself home automation system currently distributed through Sears. It combines Honeywell software, wireless sensors and controls, and a friendly user interface to enable home owners to establish security, lighting and climate control schedules that fit their lifestyle. The product also includes a line of sensors that detect intrusion, smoke, carbon-monoxide, temperature fluctuations, water levels, and energy usage. The software allows the owner to specify the security actions to be taken should any of the sensors trigger. Security actions consist of sounding an alarm and/or initiating a telephone dial-out. Finally, the system logs events that occur in the home, and maintains the log for later retrieval.

Home Controller Gateway—The Gateway product is an enhancement of the Victoria PC-based Home Control product. Gateway will offer world wide web access to all Home Controller features via the home PC, a web TV, or a portable, wireless user interface. Additional features include temperature zone control, energy management, a family calendar, and messaging capabilities.

Interaction Society™ (ISociety)—ISociety is a multiagent architecture designed to provide collaborative assistance in information-intensive situations. ISociety leverages the architectural concept of a collaborative agent society. Individual agents are organized into groups around the metaphor of a "society" that is formed to provide task assistance in a specific domain. Each member of the society contributes a specialized skill to the group and, in return, relies on other society members for help with accomplishing their tasks. Like other researchers who adopt the society metaphor, we use a number of agents with differing reasoning processes that are integrated via rules, object representation networks, scripts, and a blackboard system. We treat each agent and set of agents as a knowledge source; the assistance function is provided by a number of agents, all working together. The specific organization that has evolved is called the Interaction Society ™ since the main purpose of the supporting society structure is to provide a framework for interaction between the various agents who are collaborating in an endeavor.

Dynamic Interaction Generation (DIG)—An HTC-developed technology that provides automatically designed and dynamically presented user interfaces based on the situation, the user, the task, and the information. Using software modules that act as intelligent agents, DIG possesses semantic knowledge of the entities, data, tasks, task elements, and presentation elements that can participate in user interactions. It also has specialized knowledge that is the basis for automatic composition of interactions based on situational constraints and affordances, as well as knowledge about the proper selection and layout of user interface components for the available hardware devices. DIG makes it possible to eliminate much of the hard coding required to provide user interfaces to advanced functionality. It provides a consistent, easy to use, branded interface across a number of applications. In addition, it provides situated user interfaces that dynamically tune themselves to the situation and the information. Finally, it provides hardware independence, automatically adapting to multiple hardware and software platforms.

User Initiated Notification—The UIN application is designed to support operators in answering general types of questions about the operational status of a system that will improve their situation awareness and reduce the overhead of the monitoring task. UIN allows users to define personal, context-sensitive monitors of computer-based information. A monitor may either notify users when a specified condition has occurred or it may spawn other processes depending on the users' goal. The research underlying UIN was conducted as part of the NIST Abnormal Situation Management program.

Real-Time TDC Expert—Honeywell developed a unique, object-oriented knowledge base language tailored to the task of continuous system monitoring and advising in real-time domains. The resulting product of this IR&D program, TDC 3000 Expert, is now in widespread use; the inferencing system still represents the state of the art.

Advanced User Interface Demonstration (AUI)—Honeywell has developed a conceptual prototype of the next generation user interface of the industrial process control that incorporates live video, video conferencing, speech input and output, advanced graphics, embedded expert assistance, and user intent recognition. This IR&D demonstration portrays a collaborative response to an alarm management scenario in a petrochemical plant.

Atrium—Atrium, a Honeywell Home and Building Control product, is an Internet-based service designed to allow remote monitoring of building data. Atrium is an information management and distributed control service that collects real time building data via the Internet and transforms the data into value-added business data. The software user interface was designed to allow easy configuration of data as well as ease of remote monitoring of the building data being stored.

HELPlink™—The HELPlink™ system to date focuses on providing a two-way interactive audio/video and data connection over standard telephone lines. The base stations are designed to operate as either a separate business unit or as a joint venture between HELP Innovations and a regional health system. Each base station has a Windows-based PC running the HELPpath™ software, the proprietary electronic patient management software developed by HELP Innovations.

Human Factors Design Guidelines for People with Disabilities and the Elderly—First organized as a volunteer effort in 1987, a group of Honeywell human factors and other engineers developed a document that compiled human factors design recommendations for special populations.

resourceLINK™—This is a multimedia telemedicine communications system composed of a base station, the patient unit, and peripheral devices. The base station is maintained at the health care provider's facility. The patient unit installs unobtrusively into the patient's home and works in conjunction with the base unit to establish a video link between the patient and the caregiver. Many additional items can be added to the basic units in order to provide specific types of care. This includes medical peripherals that measure blood pressure, blood glucose, temperature, pulse, and heart monitoring.

User Intent Recognition (UIR)—Honeywell has developed a functional prototype demonstrating user intent recognition for context-sensitive task support for operators of complex systems in control domains. In this IR&D program, AI techniques were applied to the problem of recognizing users' goals and supporting task specific actions to achieve those goals in dynamic environments.

Honeywell Sensor Research—Honeywell has extensive experience developing and commercializing sensors using a variety of technologies, including infrared, optoacoustic, and laser. Optoacoustic sensors have been used in our home automation product lines to detect human presence in a room and adjust airflow to maintain air quality as room population changes. Infrared sensors have been used to detect motion and discriminate between animal and human motion in a room. Other sensor technologies allow the detection of various air borne gases, mold, bacteria, and other harmful substances.

Personal Information Processing Systems (PIPS)—PIPS provides software interface products for remote system interaction for roving operating teams. It utilizes client-server based wireless communications to provide interactive procedural information to field personnel. The software user interface for PIPS is designed to be used with portable body-worn or handheld hardware conducive to remote operations.

VtMedNetPlus—VtMedNetPlus is an open, multipurpose communications and research tool under development through Fletcher Allen Health Care. The system is designed to provide video consultation to facilitate remote interactive diagnostic or treatment consultation and continuing medical education. The system is supplemented with enhanced electronic mail that features intelligent text, forms, and image and video messaging incorporating user-defined rules (e.g., "page me if a lab result matches a specific criterion"). Caregivers and care recipients are also provided with Internet access to global medical information via Telnet, the Web, and services such as Medline. In addition, the system provides a healthcare knowledge base to aid caregivers in assessing patients' health status or diagnosing and managing patient problems.

4.3 Consortium Partners

Honeywell has formed the ILSA Consortium for the express purpose of proposing and implementing the ILSA program. A statement of work for each organization is included in Part 4A, Section 4.1. The three consortium members, HELP Innovations, Minnesota State Aging Initiative, and In Home Health, are described in Part 4C, Section 2.1.

4.4 Consultants and Subcontractors

The ILSA consortium will employ the services of Fletcher Allen Health Care as a subcontractor. Other consultants or subcontractors may be added to the team as needed.

4.5 Facilities

HTC is housed in a facility supporting a diverse, collaborative research and development organization of over 300 scientists and engineers. HTC supports systems research with an extensive suite of labs and systems development facilities, including a user-centered design and usability testing laboratory and a high performance communications laboratory. Our user-centered design and usability testing laboratory will be used to evaluate ILSA user interface prototypes. It is comprised of video recording/editing equipment, separate test and observation cells, and dedicated PC and distributed control system platforms. Our high-performance communications laboratory will be used to develop and demonstrate underlying ILSA communication technologies.

HTC is tasked with providing Honeywell's worldwide divisions with state-of-the-art services; therefore, we are continually tracking, acquiring, and evaluating emerging approaches, products, and lines of inquiry. We conduct programs specifically aimed at discovering and adapting emerging technologies in a wide variety of commercial and military domains. We receive corporate and divisional funding, in addition to outside contracts from DoD, NASA, NIST, EPRI, and other agencies. We maintain and coordinate an eclectic computing environment including Sun, Macintosh, PC, Silicon Graphics, Hewlett-Packard, Hypercube, Touchstone, and other platforms. We have proficiency in all the required design and development tools for this project, including C, C++, Lisp, Ada, HTML, Java, Visual Basic, etc. We maintain and make use of high-speed digital networks for communication, collaboration, and distributed, parallel development. We currently support, for example, internal and external web-based information exchange services, internal newsgroup discussions, and real-time video conferencing capabilities at the group and individual level.

The on-site HTC library provides information services for all of Honeywell. We maintain over 12,000 books, 500 current journal subscriptions, and 70,000 documents. Our on-line library search capabilities include access to hundreds of trade, science, military, and government databases, including DTIC/Defense RDT&E On-Line Systems, NASA/RECON, DRI/Defense and Aerospace Information Service, and NEWSNET (access to the specialized newsletters of several industries).

4.6 Organizational Structure

Honeywell is the world's leading controls company, offering people ways to increase productivity, save energy, enhance comfort, improve safety and security, and protect the environment. As the company's primary research center (see Figure 4-4), HTC has benefited from substantial research and development investment in next-generation technologies. The role of HTC is to develop and track technological advances that have strategic importance to Honeywell products and services and to work with Honeywell's world-wide businesses to mature technologies to a point where they can be introduced into the product development lifecycle. The Systems and Software Technology Area of HTC is committed to the development and transfer of advanced systems and software technologies to help Honeywell divisions support their customers. We effectively combine technologies from automated reasoning, user-

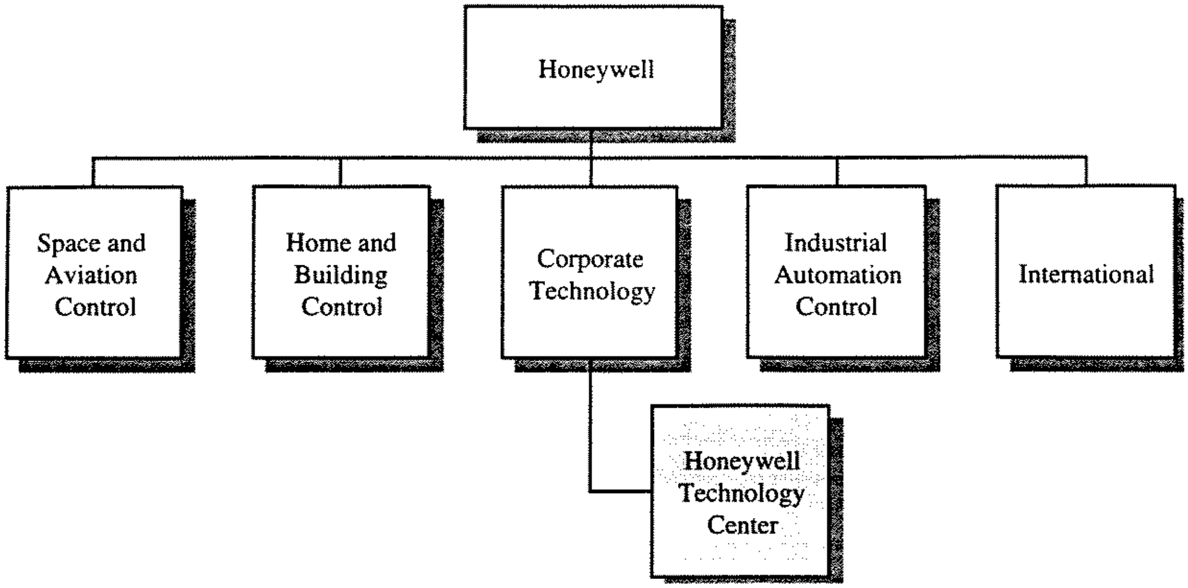


Figure 4-4. Honeywell Corporate Organization.

centered design, software engineering, applied research technology, embedded systems and communication, and distributed architecture and computing to create opportunities to enhance the value of Honeywell products and services.

4.7 Past Financial Performance

The past financial performance of the Consortium members is summarized in Table 4-3; employment information is presented in Table 4-4.

Table 4-3. Past Financial Performance of ILSA Consortium Companies ($M)

Company	Year	Revenue	Cost of Sales	R&D Expen-ditures	Income Before Taxes	Income After Taxes	Total Assets	Total Liabili-ties	Net Worth
Honeywell	1996	7,311	4,975	353	610	403	5,493	3,288	2,205
	1997	8,028	5,425	447	703	471	6,411	4,022	2,389
	1998	8,427	5,677	482	829	572	7,170	4,385	2,786
HELP Innova-tions	1996	.3		.8	(.6)	(.6)	.9	1	(.1)
	1997	.3		1.5	(1.8)	(1.8)	1.2	1.1	.1
	1998	.6		.5	(1.9)	(1.9)	.6	1.8	(1.1)
In Home Health	1996	125,086	67,108	0	(1165)	(982)	82,683	55,925	26,758
	1997	110,139	70,570	0	(21,937)	(20,157)	50,224	46,636	3,588
	1998	97,008	53,885	0	3,450	3,450	48,360	37,231	11,129
Aging Initiative*	1996	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.5*
	1997	N/A	N/A	N/A	N/A	N/A	N/A	N/A	7.6*
	1998	N/A	N/A	N/A	N/A	N/A	N/A	N/A	8.4*

*The Aging Initiative budget is listed in the net worth column. In addition, the Aging Initiative also sets policy for and/or administers an additional $1.6875 billion in federal Medicaid, Older Americans Act funds, and related State grant funds.

Table 4-4. 1998 Employment Information for ILSA Consortium Companies

Company	Year	Total FT Employees	Total PT Employees	Total FT R&D Personnel	Total PT R&D Personnel
Honeywell	1996	53,000	*	7,000	*
	1997	57,500	*	9,500	*
	1998	57,000	*	10,000	*
Honeywell Technology Center	1996	555	*	296	*
	1997	584	*	303	*
	1998	606	*	313	*
HELP Innovations	1996	7	0	2	0
	1997	18	0	5	0
	1998	24	0	6	0
In Home Health	1996	1,212	1,944	0	0
	1997	1,064	1,793	0	0
	1998	729	1,274	0	0
Aging Initiative	1996	65	1.75	0	0
	1997	75	1.75	0	0
	1998	85	1.75	0	0

References

AARP (American Association of Retired Persons), Family Caregiving in the U.S.: Findings From a National Survey, June 1997.

AARP (American Association of Retired Persons), A National Study of Caregivers: Final Report, Washington DC, 1998.

AARP (American Association of Retired Persons), Independent Living: Do Older Parents and Adult Children See It the Same Way, AARP Research Group, 1999.

Aging Initiative: Project 2030, Minnesota Department of Human Services, 1997.

AOA (Administration on Aging), Profile of Older Americans: 1998, http://www.aoa.gov.

Bradshaw, Dutfield, S., Benoit, P., and Woolley, J., 1997, "KAoS: Toward an Industrial-Strength Open Agent Architecture", in *Software Agents*, J.M. Bradshaw, editor, AAAI Press, Menlo Park, CA.

Cohen, P. and Levesque, H., 1995, "Communicative Actions for Artificial Agents", in Proc. First International Conference on Multi-Agent Systems (ICMAS).

Cohen, P., Cheyer, A., Wang, M., and Baeg, S., 1994, "An Open Agent Architecture", AAAI Spring Symposium.

Decker, K. and Lesser, V., 1995, "Designing a Family of Coordination Algorithms", in Proc. First International Conference on Multi-Agent Systems (ICMAS).

Ernst, R.L. and Hay, J.W., The U.S. Economic and Social Costs of Alzheimer's Disease Revisited, American Journal of Public Health, 84(8):1261-1264, 1994.

Finin, T., Fritzson, R., McKay, D., and McEntire, R., 1994, "KQML as an Agent Communication Language", The Proceedings of the Third International Conference on Information and Knowledge Management (CIKM'94), ACM Press, November.

Foner, L., 1997, "Yenta: A Multi-Agent, Referral-Based Matchmaking System", in Proc. First International Conference on Autonomous Agents, February.

Gallagher, D., et al., 1989, Prevalence of Depression in Family Caregivers, The Gerontologist, 29(4):449-456.

Gomez, Maria, 1998, Technology and Aging: Project 2030, Human Service Technologies: Shaping our Future, 9 September.

HCFA (Health Care Financing Administration), http://www.hcfa.gov/stats/nhe-proj/, 4 September, 1998.

HELP Innovations, Case Studies Company Document, November 1998.

Honeywell Inc., 1998, Home and Building Control, Common Product Development Methodology (CPDM), Policy & Procedure, Version 2.4. Honeywell internal document.

Kuokka, D. and L. Harada, 1995, "Communication infrastructure for concurrent engineering", Artificial Intelligence for Engineering Design, Analysis, and Manufacturing, vol. 9, pp. 283-297, Cambridge University Press.

MetLife, (Metropolitan Life Insurance Company), The MetLife Study of Employer Costs for Working Caregivers, Westport, CT, June 1997.

Nelson, K., Penner, R., & Soken, N., 1998, ISociety: A multi-agent architecture for collaborative command and control. Proceedings of the 31st Hawaii International Conference on System Sciences, Hawaii, January.

Nelson, K., Penner, R., and Soken, N., 1998, "SARA: A Multi-Agent System for Collaborative Command and Control", Proc. 31st Hawaii International Conference on System Sciences, January.

Otten, A, Wall Street Journal, 22 April, 1991.

Penner, R., 1998, Automating user interface design. 1998 Proceeding of Systems, Man, and Cybernetics, San Diego, California, October.

Penner, R., 1996, ISociety Architecture for Collaboration. Proceedings of the Human Factors Engineering *Society*.

Ricci, M.A, Callas, P.W., and Montgomery, W.L., 1997, The Vermont telemedicine project: Initial implementation phases. *Telemedicine Journal, 3,* 197–205.

Stone, R.I. & Kemper, P., 1989, Spouses of Disabled Elders: How Large a Constituency for Long-Term Care Reform?, The Milbank Quarterly, 67:485-506.

Sycara, K., 1998, "The Many Faces of Agents", AI Magazine, Vol 19, No. 2, pp. 11-12.

U.S. Bureau of Census, Population, 1999, http://www.census.gov/population/.

U.S. GAO (U.S. General Accounting Office), Long-Term Care: Diverse, Growing Population Includes Millions of American of all Ages, GAO/HEHS-95-26. 7 November, 1994.

Wagner, D.L., Long-Distance Caregiving for Older Adults: Healthcare and Aging, National Council of the Aging, Spring 1997.