Independent LifeStyle Assistant (I.L.S.A.)

Technical Proposal

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NIST

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Approved for Public Release

March 7, 2000

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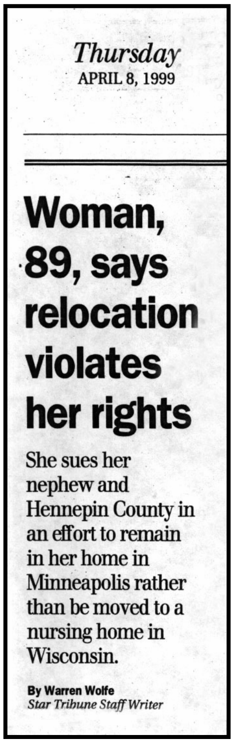


Thursday
APRIL 8, 1999

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

1. Executive Summary

1a. Scientific and Technical Merit

This Minneapolis Star Tribune headline exemplifies the strong feelings elicited by elder care issues. When it becomes apparent that a loved one can no longer safely take care of themselves, a nursing home is often the only option, in spite of the financial and emotional strain placed on the family.

Historically, 43% of people over the age of 65 will enter a nursing home for at least one year. With this demographic growing rapidly—the Administration on Aging estimates that it will double to 69.4 million, 22% of the population, by 2030—the economic strain assumed by the nation will increase dramatically.

We propose a better alternative. Emerging home sensing and automation technologies represent an exciting opportunity to develop an *Independent Life Style Assistant* (ILSA). ILSA offers the potential to incorporate the partial equivalent of a full-time caregiver into an existing home. By providing intelligent, affordable, usable, and expandable integration of home automation devices, ILSA will support daily activities, facilitate remote interaction with family and caregivers, provide safety and security, and otherwise assist the elderly or disabled, thereby deferring nursing home care for years.

1a.1 Innovation in Technology

Researchers and manufacturers are developing a host of home devices that will soon be available. However, no one is working on an *integration* of these individual functions and information sources into an *intelligent*, *coherent, useful environment* that helps people enjoy and independent life. ILSA will provide this integration through a unique, knowledge-based approach to situation assessment and interaction generation. That is, ILSA will coordinate device inputs to understand the situation holistically and coordinate device outputs to provide aid to its clients. ILSA must:

- Provide accurate situation assessment for unconstrained, unstructured environments, using a network of low cost sensors.
- Provide intelligent, accurate, safe, and acceptable user interaction generation for potentially technophobic users with varying capabilities and constraints
- Provide easy-to-use, low cost installation and configuration aids, and on-going intelligent adaptation to support situation assessment and response.

1a.2 High Technical Risk and Feasibility

The technical challenges of ILSA pose significant but addressable risks in three strategic areas: 1) situation assessment accuracy, 2) system usability and user acceptance, and 3) machine learning and configuration assistance. Much of this risk arises from the application of cutting edge technology to a the highly varied legacy home domain. However, success in this domain will provide solutions to the same problems in other domains, including aviation, manufacturing, refinery, military, and space. The breadth and complexity of the problem affords many alternative approaches and fallback positions; even partial success will still lead to strong technological, scientific, economic, and social payoffs.

1a.3 Quality of R&D Plan

We have developed a 30-month, three-phase plan with intermediate deliverables in the form of significant technology demonstrations and incremental releases of functionality. Each phase corresponds to one of the three risks described above. Each phase follows an iterative development cycle of knowledge acquisition, system requirements analysis, design, implementation, and extensive human-in-the-loop evaluations. Each phase has demonstrable project goals, well-defined success criteria with associated mitigation strategies, severable benefits, and quarterly re-evaluation of cost, schedule and technology goals.

1b. Potential for Broad-Based Economic Benefits

1b.1 Economic Benefits

We estimate that a successful ILSA system would lead to over $30B in savings annually in the USA alone, in addition to significant quality of life improvements and market expansions. Specific 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 nursing homes and assisted living facilities,
- Improvements in quality of life for both care recipients and caregivers, and
- Expansion of both healthcare and home automation industries.

We believe that ILSA's infrastructure will coalesce existing and future technologies to reduce future expenditures and associated drain on funding programs. In addition, ILSA's open architecture will encourage the introduction of new devices from any company.

1b.2 Need for ATP Funding

The risk associated with ILSA's underlying technologies, the ambitious deviation from Honeywell Home and Building Controls (H&BC) traditional HVAC focus, as well as the increase in scope and price over current H&BC consumer products make securing internal funding nearly impossible. Other companies are concentrating only on specific point solutions for elder care, yet as these individual solutions increase, no one is working on the *integration* that will allow solutions to actually work together and move home healthcare to the next level. U.S. industries should not delay in addressing this problem, and ATP funding can facilitate the solution.

1b.3 Pathway to Commercialization

Since a need for ILSA exists now, we will begin commercialization as soon as research findings and prototype tests confirm product feasibility. Our strategy is to add ILSA functionality to the Home Controller that is now being developed for Honeywell's Home Vision product line. Sets of functionality will be handed-off to the Home Controller product team for parallel product development and commercialization. With this strategy, Honeywell can introduce new functionality to base product every 3 to 6 months. In addition to Honeywell commercialization efforts, ILSA's open architecture will enable third-party medical, home, and healthcare providers to integrate their specific solutions into ILSA. To accelerate industry-wide acceptance, we will actively disseminate details of the architecture and other promising results, present papers at conferences, and host periodic workshops and demonstrations, and actively work with third party product providers.

2. Project Narrative

2a. Scientific and Technological Merit

Data from the Administration on Aging shows that the number of people in the US over the age of 65 will double to 69.4 million by 2030—22% of the population [3]. Historically, 43% of people over the age of 65 enter a nursing home for at least one year, yet a Health Care Financing Administration (HCFA) survey found that 30% of the elderly would "rather die" than do so [10]. The financial and emotional trauma of such moves affects thousands of families yearly.

We propose a better option. Emerging home sensing and control technologies offer a unique opportunity to develop an *Independent Life Style Assistant* (ILSA). ILSA offers the potential to transform a legacy home into something of a full-time caregiver by giving individual sensing and automation components an integrating 'mind' with enough intelligence to coordinate and direct their behaviors for the good of the client. By providing intelligent, affordable, usable, and expandable integration of home automation devices, ILSA will support daily activities, provide safety and security, monitor chronic medical conditions, and otherwise help professional and informal caregivers to help the elderly or disabled, deferring nursing home care for several years.

In Section 4B, we show that both the elderly and their caregivers are very interested in such a solution. Here, we show that ILSA, though highly innovative and risky is feasible in the near term.

2a.1 Technology Background

The arrival of the 'smart home' of the future is upon us. Companies are selling microwaves that connect to the Internet and refrigerators with computer displays. Builders have thus far concentrated on the devices themselves and the network protocols necessary for them to communicate. Experience in other domains (avionics, refineries, surgical theaters) shows that such innovations will merely produce a collection of distributed devices with localized intelligence which are *not integrated*, and which may actually *conflict* with each other in their installation and operation. Again, our experience shows that to consistently exhibit intelligent behavior, these networked devices will need a coordinated, situation aware, controlling intelligence.

The techniques required to provide this intelligence are emerging from computer science and human-centered systems design (HCSD)—and Honeywell is a world leader in their application. Of various terms used by researchers [14; 19], we choose to call the underlying technology an *Interaction Design System* (IDS). IDSs process sensor data to understand the 'situation' and user needs, then rely on knowledge of HCSD and action automation to develop *interaction plans*—that is, a series of control actions designed to assist a client through information presentation or adaptive automation behaviors. Our goal is to combine home control devices with the *knowledge-based awareness and intelligence* to provide aid and a safety net to aging clients and their caregivers.

2a.2 Innovation in Technology

2a.2.1 Problem Challenges

The unique challenges involved in developing our vision of ILSA include:

- *Interpreting and handling the needs of a population with varying capabilities and constraints, acting in unconstrained, unstructured environments*. Clients will differ widely in cognitive, sensory, and mobility capabilities; moreover their capabilities can change, sometimes slowly over time, sometimes abruptly.

- *Designing interfaces and interactions that will be usable and accepted by a potentially technophobic generation with divergent capabilities*. Even though being able to live at home is a strong motivator, we cannot depend on our users to learn about and adapt to ILSA.
- *Designing an affordable system*. Previous IDS developments have relied on industry or military funding. ILSA may have to rely on individual homeowners or caregivers. To realize its full social and economic benefits, ILSA must leverage existing structures and appliances of older, possibly antiquated homes. This challenge requires developing unique reasoning components that can analyze situations based on the inputs of a variety of low cost, off-the-shelf sensors—not expensive, specialized hardware. Furthermore, the developed system must enable an inexpensive, easy, and quick installation of hardware, software and knowledge-based components, and also must include methods for ongoing adaptation of those components to the changing needs and situations of the client.

Successfully overcoming these challenges will not only achieve over $30B annually in economic savings in the USA alone, it will also advance the state of the art in human computer interfaces, computer science, automation design, and greatly enhance the market potential for advanced home automation, sensors, and home medical devices. Above all, ILSA will make growing older easier for the elderly, their children and caretakers, and for society as a whole.

2a.2.2 Program Goals

Our overall *program goal* is to construct a home-based independent living assistant that helps the elderly and disabled live longer, safer, and more independent lives at lower social, emotional and economic cost. Our *research goal* is to design and develop a system that intelligently integrates home devices with high-level reasoning about home activities to produce automatically generated interactions that enables independent living.

Consider the vision of a working ILSA system in Table 1. To achieve our vision—of which this scenario is only one example—we must accomplish the following specific technical goals:

- Design, develop and validate *accurate situation assessment* from a network of low cost sensors. Without understanding the situation, ILSA's aiding will be guesswork. ILSA's HOme Monitoring Environment (HOME) will integrate multiple sensors' outputs to arrive at meaningful, high-level concepts to enable high-quality situation assessment.
- Design, develop and validate *intelligent*, *accurate, safe and reliable situation response through interaction generation*. Without the ability to take actions to aid the client, accurate situation assessment would be wasted. ILSA's Client Adaptive Response Environment (CARE) will use available effectors (devices that can control other devices in the environment—such as a light flasher or stove control switch) and displays to aid the client in recognized situations.
- Design, develop and validate *easy, low cost installation, configuration and on-going intelligent adaptation*. The hardware, software and knowledge-base complexity ILSA requires could easily drive the system beyond affordability. Our research will push the state of the art to create Machine Learning (ML) and Configuration Aiding (CA) modules to make fielding and maintaining ILSA's other modules feasible and cost effective.

ILSA, and its component innovations, will greatly advance the state of the art and current industry practice. Researchers and manufacturers are developing a host of individual sensors and effectors that will soon be available in the home. However, without ILSA, what will be lacking is the *integration* of all these separate functions, information sources, and devices into a *coherent,*

Table 1. An ILSA Scenario.

Lois Anderson is 83, and has lived alone since her husband, Albert, died a few years ago. Lately, she has been relying more and more on her walker, and doesn't get out much. Last week, she forgot to turn off the oven, and with her hearing so bad, she didn't even hear her smoke alarm when it went off. She was lucky she happened back into the kitchen before things got out of hand. Marge, Lois's daughter, lives nearby, but has three children and a full-time job. Marge worries about her mother, and lately there's been talk of a nursing home, just to be sure that Lois is safe—though no one likes that idea, least of all Lois. Thanks to Lois's health insurer, Marge discovers there are affordable systems that could transform Lois's house into something of a full-time caretaker—or at least, could provide some support to the overworked caregivers she already has. They're easily customizable for just the support Lois needs. Two weeks later, after a consultation session over the web, an installer comes out and puts Lois' ILSA system in one afternoon. Lois and Marge both feel safer and are glad that Lois can continue living at home. One night, Lois is on her way to turn off the teakettle when she's distracted by the phone's double ring which tells her that Marge is calling. The TV, which was loudly broadcasting the news, automatically mutes itself so that Lois can better hear the conversation. After Lois hangs up, she forgets all about her tea and goes back to watch Jeopardy. Later, the water in the teakettle has boiled away, and ILSA senses the beginnings of a particulate buildup through the kitchen's air quality sensor. Since Lois still has the same stove she bought in 1952, ILSA itself is unable to turn off the burner, so it must communicate with Lois directly. First it must find her though, because the insurance company didn't cover the full motion sensor suite. Because Lois recently used the remote control in the living room, and the television is still on, ILSA suspects she might still be there. It presents a message on the TV screen: "Lois, turn off the stove," along with an image of a stove and smoking pan. A spoken message would have been required if Lois had been blind, or if ILSA had thought she was asleep, but neither is true. Given that Lois has responded more frequently to visual text and image combinations in the past, ILSA chooses this interaction method. Unfortunately, Lois is no longer watching TV. She has gone to the bedroom for her knitting during a commercial. Because she hasn't responded to the alert, and this is an emergency, ILSA flicks selected lights on and off several times throughout the house to get her attention. In her bedroom, Lois checks the bedside ILSA display and hurries to the kitchen to turn off the stove. She arrives just in time, too—any longer, and ILSA would have called the next-door neighbor or other help if necessary. That night, while preparing for bed, ILSA's bedroom speaker reminds Lois to use the glucose monitor that her doctor recommended. When the device was installed, it came pre-programmed with data from the physician who ordered it and the prescribed care regimen. ILSA integrates that knowledge automatically without needing to ask Lois or Marge additional questions. Since the device is still a bit new, ILSA provides instructions on how to use it. ILSA reads the data gathered by the monitor and stores it, since it knows it's supposed average glucose levels over week-long periods.

useful environment that helps people live their lives. ILSA will provide that integration for the client, and do it affordably, reliably and acceptably.

2a.2.3 Rationale for Goals & Barriers to ILSA development

We have consciously selected the highest risk/highest payoff goals to drive our proposed ATP-funded research. While the IDS technology, ILSA's foundation, is far from commonplace, it is not unprecedented. Cutting edge IDS technology is also the basis for the recently flight tested Rotorcraft Pilot's Associate (RPA), the fielded (and largely unaccepted) Microsoft™ Office Assistant (the animated paperclip named Clippit™), and elements from Honeywell's ATP-funded Abnormal Situation Management (ASM) project. Thus, we are not claiming the development of an IDS as an innovation per se—though it will certainly be one within the home control domain. Rather, our goals focus on overcoming the most significant barriers to IDS acceptance. The problems of accurate situation awareness, usability, ease of setup and ongoing adaptation have plagued each of the IDSs listed above and are largely responsible for the failure of others (including, most notably, Clippit™). We will address these challenges in one of the most difficult domains possible—the home of an elderly client.

The successes of ILSA will not only generate significant economic and social benefits, but will also provide scientific advances that will make IDS and other advanced automation technologies feasible. The methods ILSA will employ to reason about widely varied users (effective SA using low cost sensors coupled with ML) will contribute to more adaptive, usable and intelligent automation across domains. The interfaces ILSA will require to interact with and be accepted by an aging population will provide a better understanding of computer usability in general, and for the elderly in particular. The techniques ILSA uses to flexibly accommodate a wide variety of off-the-shelf sensors and appliances will result in affordable home control systems, which in turn will result in a wider proliferation of such systems and auxiliary business.

Our decision to work in the home domain will provide intermediate, severable benefits at multiple points short of full ILSA success. Among these are: a rich model of home activities and situations suitable for future home control design efforts, improvements in speech recognition through situation awareness, sensor integration techniques to improve performance in the home, and machine learning techniques to improve information presentation and situation assessment. These and other benefits are presented in detail in Section 4b.1.

Other technologies will be critical to the success of ILSA. These include network communications, hi-speed internet access, video monitoring and processing, communications security, RF communications, information assurance, home sensors, actuators and in-home medical sensing devices, speech recognition and generation, and system health management. After extensive review, we believe that each of these technologies is either on-track to provide acceptable capabilities within ILSA's time frame, or is currently being researched to a degree that we could provide no added benefit. We will continue to track developments in these fields during ILSA research, but will devote our efforts primarily to developing the IDS components and to integrating these technologies and driving them to solve the legacy home problem identified above.

2a.2.4 Strategic Technical Approach

ILSA's architecture will contain several technology components, arranged as shown in Figure 1:

- *HOME situation assessor*, to provide rapid, accurate situation assessment,
- *CARE client response module*, to design and generate interactions,
- *Configuration Aid,* to provide easy installation and initial setup,
- *Machine Learning*, to provide ongoing adaptation and improvement, and
- *Infrastructure*, to provide data communications within the home and to outside caregivers.

Below, we discuss these components, and the innovations each contributes to the ILSA system.

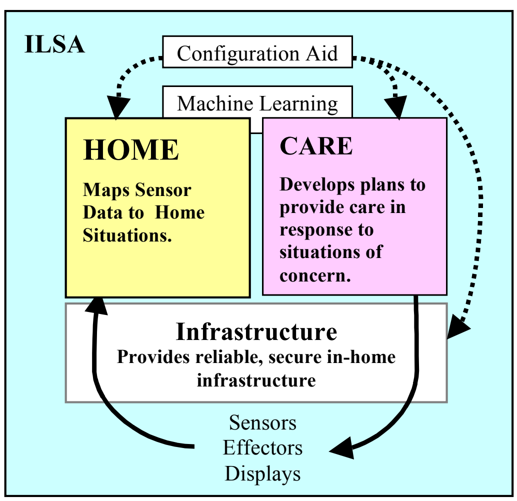


Figure 1. ILSA High-Level Architecture.

2a.2.4.1 Infrastructure

What it is. The infrastructure will provide the necessary support to enable inter-device communication, external communication to caregivers, and interfacing with ILSA.

Core Technical Approach. ILSA's infrastructure will be built on Honeywell's Home Controller (HHC), Universal Plug and Play (UPnP) devices, and the Global Home Server (GHS). HHC is an embedded hardware/software system that allows devices to communicate and acts as a control center for sensors and effectors. It can host applications through which users manipulate their household devices. The GHS enables users to issue instructions to HHC from outside the home.

The HHC core software runs on a WindowsCE platform, and has been built to run unattended for long periods of time. The software includes an HTTP web server, which ILSA will use to interact with out-of-home caregivers. The architecture is based on Honeywell's HomeAPI standard, a basis for the UPnP protocol (http://www.upnp.org). Future versions of HHC will use the UPnP protocol, allowing the automatic integration of new devices into its open architecture.

Innovation. HHC with UPnP represents the state of the art in home control integration. While there are other similar technologies such as the Open Systems Gateway Initiative (OSGI), none is further along, and most are behind our chosen combination. Use of UPnP allows straightforward growth paths, and the GHS provides a Web-based platform for near-universal connectivity and security. Our innovation will be to use this infrastructure to host ILSA and thereby enable a powerful new level of coordinated, situation-aware, intelligent service for home automation.

2a.2.4.2 HOME

What it is. Without understanding the current overall situation, ILSA's decisions would be guesswork at best. The Home Observer and Monitoring Environment (HOME) provides the situation assessment and knowledge sharing capability for ILSA. HOME's feature detectors process raw data coming from the sensors, and the Situation Assessor (SA) then aggregates the evidence from multiple features into a model of the current situation (Figure 2). This innovative approach processes data into much more abstract concepts than traditional sensors produce, enabling other ILSA components to reason explicitly about meaningful independent living concepts, without worrying about low-level, sensor-dependent data.

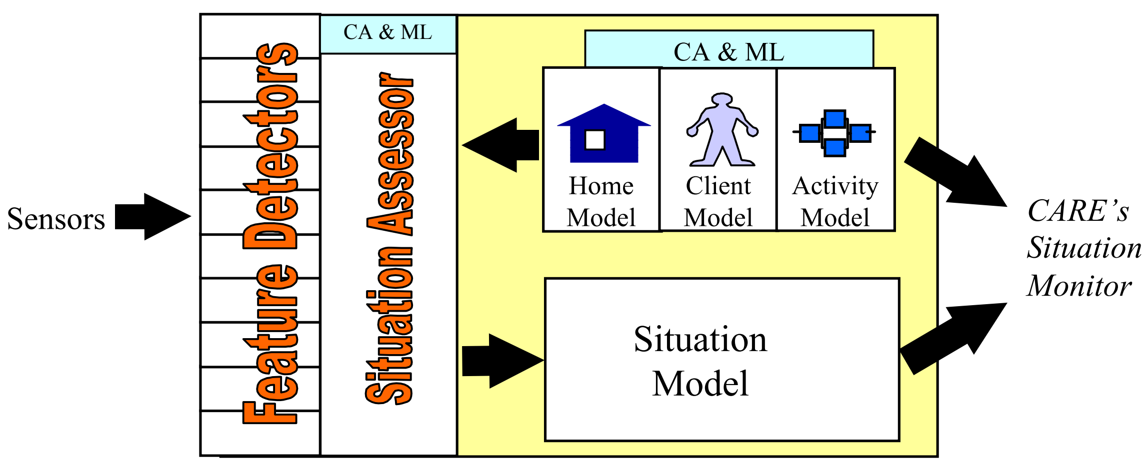


Figure 2. Architecture and Dataflow of ILSA's HOME Module.

Core Technical Approach. The technical challenge in developing an accurate SA module is determining how to handle the wide array of (possibly low-quality) sensor information. Even very accurate sensors will generate many false-positives. To avoid this problem and develop reliable SA, we need to combine data from multiple sensors. For example, a 'fall sensor' might report sound patterns consistent with a fall, while the camera reports the client lying down, and the motion sensors report no motion. These three pieces of evidence need to be aggregated into a single, confident decision about the client's status. HOME's models represent this relationship by capturing information at different levels of abstraction, with associated probability propagation.

Our approach to situation assessment is *Qualitative Bayes Nets* (QBN) [30]. QBNs are a graphical representation of independence relationships between features of the problem domain. They enable probabilistic reasoning using qualitative probabilities, based on a measure that captures order-of-magnitude differences in the likelihood of different events. For example, it is far more likely that the client is watching TV than that there is gunfire in the family room. On the other hand, real evidence (especially from multiple sources) can easily swamp QBN's prior probabilities—thus if a window shatters and a sensor reports gunfire, SA will accurately conclude an emergency situation—even if the TV is on. QBNs are an extension of normal Bayesian reasoning for qualitative probabilities, and can be used to estimate the most likely event for the sensor data. QBNs allow us to aggregate data from multiple sensors without requiring precise estimates of their joint probability distribution, a factor that will ease integrating disparate sensors. They allow multiple hypotheses for likely events, and their selections are provably correct (within the accuracy of the system).

While the chief challenges for HOME lie in SA, HOME will need models of possible situations to do SA against. We will use object-oriented knowledge representations to build four models in HOME: models of the home, the client, the client's activities and of the situations themselves.

Innovation. No other approach to situation assessment provides this kind of accurate flexible evidence aggregation. Other methods of evidence combination like voting schemes or Dempster-Schafer Theory [7] have been shown to incorrectly value evidence in some cases, producing incorrect situation assessments. We pioneered applications of QBNs in our ATP-funded ASM work. ILSA will advance the state of the art for SA still further by applying QBNs to data from many disparate and potentially poor quality sensors.

The object-oriented knowledge representations used for HOME's models are not, in themselves, innovative, but we will have to discover the important concepts and the appropriate level of abstraction for this new domain. Further, we expect to develop an innovative extension to the traditional representation by augmenting it with functional and spatial relationships between domain objects.

2a.2.4.3 CARE

What it is. Without the ability to take actions to aid the client, accurate situation assessment would be wasted. The Client Adaptive Response Environment (CARE) is responsible for generating coordinated, client-centered interactions in response to the situations identified by HOME. CARE receives assessed situations as input, determines interaction needs, and generates an interaction response plan. Not only will CARE generate appropriate client interactions, it will also generate plans to interact with outside caregivers. CARE will effectively utilize all available devices (displays, sensors, effectors) to meet the client's needs in an acceptable and usable fashion.

Core Technical Approach. The technical challenge for CARE is to design and create an intelligent, user-oriented interaction in response to widely diverse situations. To overcome this barrier, CARE's interaction design process depends on three independent modules with unique processing responsibilities (Figure 3) and related knowledge representations.

CARE's *Situation Monitor* subscribes to the situations in HOME's situation model and decides whether to invoke an interaction request by posting a set of *Interaction Needs*. These needs describe a set of high-level goals, relevant constraints, and desired characteristics (e.g. "increase the confidence of a fall", with an urgency and a location.) The Situation Monitor determines which needs to post based on a pattern match between the current situation and a set of 'interaction elements'. The *Interaction Designer* uses conditional planning to decompose super-ordinate interaction needs into a plan outline of sub-goals and generic actions (with relevant conditional branches) that satisfy those goals; for example the actions "ask" and "look" both satisfy the sub-goal of increasing confidence of a fall. The *Adaptive Interaction Manager* receives this abstract conditional plan, and decides how to execute each action based on constraint reasoning over existing component capabilities, desired action characteristics, good HCSD principles, and user preferences. It will design the specific verbal, display interactions, and sensor interactions, utilizing pre-existing templates for common interactions, and special-case generators for novel needs. The interaction manager can also post requests to HOME's situation assessor to monitor for specific user activities that it expects—for example, telling vision routines to look for hands at the client's throat to verify whether s/he is choking.

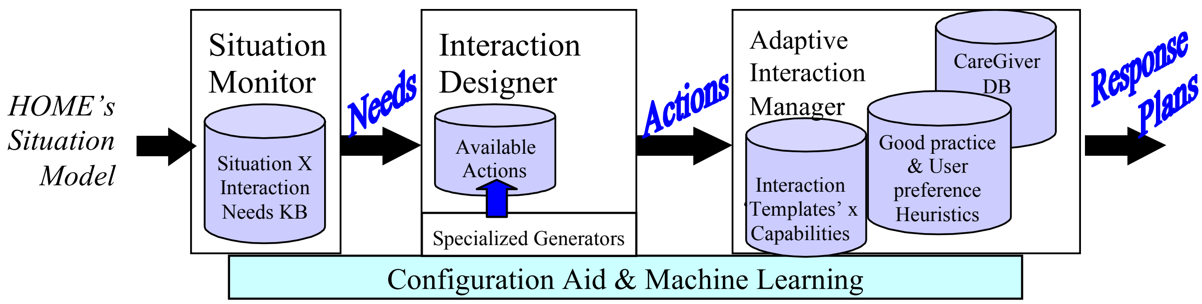


Figure 3. CARE Architecture and Dataflow.

The special case generators include a *Monitor Activity Generator,* a *Discourse Generator*, and a *Visual Information Exchange Generator,* for sensor, verbal and visual interactions respectively. The discourse generator, for example, formulates a dialog script to accomplish the interaction. It uses a stored database of parameterized dialog scripts, which contain the actions necessary to carry out a dialog with a user to accomplish a goal. The scripts also contain lists of expected words or sub-vocabularies for listening to user responses at different points in the dialog.

Let's say HOME assesses the situation 'unattended stove' with certainty 30%. HOME's databases record that the stove has been on for one hour, that the client has been in the living room with the TV on for that time, that he is nearly deaf, and that the TV can be instructed to present visual, textual and spoken output. CARE's Situation Monitor determines that it is necessary to interact with the client to determine whether the stove should be on. The Interaction Designer breaks down that goal into sub-goals and matches each to available actions. The Adaptive Interaction Manager takes recommended actions and generates the response plan below:

Sub-Goals	Recommended Action	Response Plan
Get client's attention; importance 6	Issue Alert	Display Graphical alert on TV
Query client: "should stove be on?"	Display Textually	Display text on TV
Monitor user for response	Monitor for response	Monitor remote control for response
React to response if necessary		Turn off stove if it shouldn't be on

Initial, general knowledge in each of CARE's three modules will be created by ILSA researchers through the expertise of In Home Health and Dr. Krichbaum, and an analysis of client needs in the domain. Additional client-specific knowledge will be captured at setup by ILSA's CA. Machine learning components will then continuously tune and refine this knowledge. Each of the modules in CARE will therefore make effective situation-dependent decisions.

Innovation. There are no known applications of adaptive interaction design for the home domain. Our vision for CARE is comparable to the state-of-the-art (but beyond state-of-practice) in industrial processing (ASM), aviation (RPA), and building management (DIGBE). CARE's innovation over these domains will be developing IDS technology for an untrained user and a highly unconstrained action set. CARE's interaction design reasoning will be more nearly a 'first principles' approach to generating interactions than the more compiled situation-response rules that have been previously used. This innovation will make IDSs more flexible in accommodating new situations, devices and client needs. Finally, the integration of an ML component to grow and tune CARE's knowledge bases is a powerful innovation that will be discussed below.

2a.2.4.4 Configuration Aid

What it is. The Configuration Aid (CA) is a suite of decision aids, help routines, semi-automated integration routines and knowledge elicitation interactions designed to improve the speed and ease with which ILSA can be installed and set up for service by non-technical customers.

Core Technical Approach. There will be three aspects to the CA, each involving somewhat different technical approaches. First, the CA will provide *decision support* to aid the installer and maintainer of the system (a cognitively capable relative, caregiver, or client) in selecting appropriate components for the specific situation facing the client. This module, offered via the internet, will offer advice and tradeoff information about equipment options. Secondly, the CA will supply specific *installation guidance* to the ILSA system installer—perhaps a trained specialist or a non-technical person requiring very specific directions. The CA may incorporate graphics and even video clips to guide the installer through the process. The third novel aspect of the CA will provide *semi-automated knowledge acquisition capabilities* to enable ILSA to interact with the installer and/or the client to obtain relevant initial knowledge for populating ILSA's knowledge bases. Technologies for this function include HCSD techniques, advanced adaptive form-generation techniques [22], and perhaps even computer-generated personifications to interest the client sufficiently that he willingly spends time 'training' ILSA [4]. The CA will also be designed to allow the user to revisit it should he desire extensions or modifications to the system. The presence of a well-structured knowledge representation of the domain and the information required will facilitate in-home CA functions.

Innovation. Honeywell's Do-It-Yourself Home Security System incorporates a state of the art configuration aid. There are no other products in the market providing comparable ease of use to non-technical consumers. ILSA's CA will be more comprehensive, in a domain with more varied devices, and more requirements for initial knowledge acquisition. The incorporation of automated knowledge elicitation to customize an IDS represents a significant innovation.

2a.2.4.5 Machine Learning

What it is. Machine Learning techniques enable ILSA to adapt to its environment over time. Success in this domain requires that ILSA capture the complex interactions of its resources, as well as be responsive to constant changes. Using Machine Learning (ML) techniques, the fielded system will 1) tune itself to its actual operating environment, greatly reducing the amount of tuning and knowledge acquisition required at setup, 2) respond to changes in the users and the domain, directly reducing maintenance costs, and 3) capture the user's preferences, enhancing system usability. Machine Learning will permeate ILSA in almost every one of its functions.

Core Technical Approach. Making intelligent, situation-dependent domain inferences requires correlating detailed contextual information with available data, thereby recognizing patterns in the data. Our *situation-dependent learning* approach correlates detailed features of the environment with the collected data [12]. It recognizes and predicts that data has different values under different conditions. Our early work modeling situation-dependent action costs provides the conceptual foundation for building situation-dependent behavioral signatures and action utilities.

Situation-dependent Behavioral Signatures will answer the question "*what is normal?*" for the house, client, care-givers, and other relevant objects in the domain. For example, the "aural signature" of the house will be very different during the day (while the client is active) than at night (while s/he is sleeping). A typical relationship might be: **f (time, day, room) → aural signature**. CARE's Situation Monitor can use these signatures to determine whether a given input is abnormal, and if so, invoke an interaction request. Our goal is to predict the raw data streams of the sensors, and also high-level inferred behaviors of the users. Essentially, using inferred behavior patterns to infer other behavior patterns allows direct inter-behavior correlation, which HOME's Situation Assessor can use to build new evidence aggregators.

Situation-dependent action utilities will enable ILSA to make decisions based on the learned details of its environment. By attaching a situation-dependent utility value to each action, the CARE module can decide which action to take and how to instantiate the variables of an action based on the current conditions. For example, a general rule might be "Call for help if the resident is non-responsive." A situation-dependent utility function might capture the learned utility of calling each of the different "help" phone numbers depending on the likelihood of (a) the seriousness of the situation, (b) reaching a person at that number, and (c) actually getting assistance from that person, rather than, say, being redirected.***Innovation.*** Only recently has ML been incorporated into real world physical domains, where learning results are used for decision making. The most advanced of these research efforts are robot soccer [25], web-usage profiling [5], and Honeywell's oil refinery modeling [24]. ILSA will capture a greater variety of knowledge, in a much more varied and complex domain than these.

ML has been discussed as a means to enhance the accuracy and coverage of IDSs since 1987 [13] with no serious effort to evaluate its capabilities, in part because of an assumption that the domains had strong structure and little variance (piloting fighter jets, airline ticket sales, logistics form generation, etc.). Not only are those assumptions radically untrue in ILSA's domain, they've also proved somewhat false in the other domains as well. ILSA, by utilizing learning in each decision-making component of the system, for many types of sensor data, and over an extended lifetime, will be a significant step forward.

2a.2.4.6 Human-Centered Systems Development (HCSD)

What it is. HCSD is a design philosophy that defines human users as integral components of any human-machine system. The goal of HCSD is to develop systems that behave in ways that match users' expectations and is sensitive to their physical, psychological, and cognitive abilities.

The application of advanced technology to the home does not inherently provide ease-of-use. It does provide increased design flexibility, which in turn creates an opportunity for optimal system performance. To achieve this, the ILSA development team will focus on *interaction* design in addition to *interface* design. Interaction design subsumes interface design but moves it a step deeper. Interfaces are designed artifacts that exist more or less fixedly across situations. Interaction design, especially in an adaptive IDS, is done dynamically in response to changing situations. Thus, for an IDS, HCSD techniques must be *used to design the process of design* and, inevitably, some HCSD knowledge must be incorporated into the IDS itself.

Core Technical Approach. User input begins in the knowledge acquisition phase and continues throughout development, ensuring user preferences, needs, and abilities are reflected in the system requirements. Technology development is thus driven by the needs of the user rather than the capabilities of technology. In addition, user testing is woven into the technology development process through iterative cycles to ensure design efforts remain aligned with the users.

In a domain as diverse as ILSA's, it will be necessary for us to first establish the range of users and situations of interest. We will do this initially through review of documentation (e.g., AARP studies) and with our consultant experts. Then we will choose diverse and representative points within the domain and apply traditional knowledge acquisition to them. This process will employ observation, interviews and 'ride alongs' with caregivers and technical installers. Similarly, when investigating human interaction with ILSA, we will select representative scenarios to inspect the range of possible situations, users, devices, etc. Once selected, user interactions with ILSA will be done in naturalistic and lab settings (including the Honeywell House home laboratory). This increasingly detailed map of the 'terrain' of the home domain will be critical for creating HOME's models, for understanding the situations that SA must accurately recognize, for creating response capabilities for CARE and for planning evaluation studies.

Innovation. The traditional techniques used for HCSD will require innovative adaptation for IDS design. Previous IDS systems have been more focused on achieving intelligent behaviors rather than usable ones. We will not make that mistake—HCSD will be a part of our process from the beginning. It is difficult to test a highly advanced system before it is built. It is also essentially impossible to test all of the behaviors ILSA could provide. We will explore a range of part-task evaluations and Wizard of Oz (human emulation of system behavior) techniques to achieve HCSD inputs early and often. One innovative result will be better understanding of how to best test and design an IDS in a human-centered fashion. Another mistake we will not make is assuming that initial human reactions will remain homogenous—especially unlikely with a learning system. We will include long term, in-home evaluations of ILSA at the end of the program and will evaluate user acceptance changes over time.

2a.2.4.7 Supporting Technologies

ILSA will require several additional technologies. It is not within our scope to research these areas; instead we will maintain awareness of them, and leverage the best available technology for ILSA. The following technology areas are important enough to merit special note:

Speech Input and Output—Speech is an ideal interface for users with impaired vision, mobility, dexterity, or users uncomfortable with traditional computer interfaces, and our surveys show it is a highly desired ILSA capability (see Section 4b). Information in ILSA's client and activity models will be used to drive situation-dependent speech interaction. ILSA will use speech interaction in two ways: client-initiated speech requests and ILSA-initiated dialogs. ILSA will use speech recognition to continuously monitor client-initiated requests. Information from ILSA's client and activity models will be used to predict and constrain the recognizer's vocabulary, improving recognition accuracy. Results of the speech monitoring will be one of the features used by the HOME's SA. CARE will use speech interaction to guide ILSA-initiated dialogs. CARE will tailor these dialogs according to available client and activity information, producing more natural, acceptable interactions. Speaker-independent continuous speech systems have recently become a reality. Though accuracy and vocabulary sizes are improving, there is still much room for improvement, especially for recognition in noisy environments and for conversational speech.

Equipment Status Monitoring**—**Equipment Status Monitoring identifies and reports internal device errors, and will be more important for ILSA than for the basic HHC because of the critical role ILSA will play in clients' safety, and because clients may not be fully capable of understanding and handling error conditions. The HHC infrastructure currently handles subsystem errors by reporting them to users via any of the user control points (e.g. SUI, Web). We will therefore enhance the base capability to transmit error conditions to a caregiver or repair technician as appropriate (using email and/or telephone).

Communication, Security & Power**—**The proposed ILSA communication network is open, heterogeneous, scalable, and possibly very large. It operates within and outside the home among a variety of locations and users. It includes several communications media and many protocols. Many of the sensors and actuators will be installed and integrated using wireless communications. There are numerous industry developments underway that support this need, including Bluetooth, Home RF "Lite" link, Honeywell's IC chip, and Honeywell very low-power radios that will enable many devices to be conveniently installed without wires and to operate on the same battery for many years. ILSA communications will have several different types of security requirements including the privacy of patients' medical information, and the prevention of unauthorized access. A variety of communication encryption mechanisms can address most of these requirements, providing authentication, integrity, and privacy for all ILSA functions. With a key in place, the Secure Sockets Layer (SSL) built into most Web browsers provides sufficient communication security. Non-real-time encryption can be addressed with a number of approaches, including NIST's Advanced Encryption Standard (AES).

2a.2.4.8 Summary of Innovation

ILSA will make both technological innovations by extending and adapting IDS techniques to a new and challenging domain, and scientific innovations by extending the sciences of situation assessment, adaptive interface generation, human-centered systems design, and machine learning. Table 2 contains a summary of ILSA's innovations.

Table 2. ILSA's Innovative Technology.

- ❑ Technology innovation in application of IDS to home environment:
- ❑ Intelligent, coordinated (not just networked and data sharing) integration of multiple sensors, effectors and displays
  - ➢ Effective, compelling use of networked home control devices
  - ➢ Ease of integration of new devices into the situation-aware infrastructure
  - ➢ Effective automation for the elderly and disabled
  - ➢
- ❑ Scientific and technological innovation in Situation Assessment:
  - ➢ SA from low cost, fault-vulnerable sensors of disparate types
  - ➢ Integration of machine learning to improve SA
  - ➢ Extensions to QBNs
  - ➢ Application of SA to much less structured domain
  - ➢ SA of slowly developing behavioral trends (e.g., failing hearing)
- ❑ Scientific and technological innovations in Adaptive Interaction Design:
  - ➢ Deepen first principles knowledge of interaction planning
  - ➢ Adapt interaction design to incorporate emerging knowledge about elderly needs
  - ➢ Incorporate many more divergent multimodal devices than previously
  - ➢ Operate in more varied, less predictable home situations and for a more demanding, potentially less capable audience
  - ➢ Integration of machine learning to improve interaction designs

- Scientific and technological innovations in Machine Learning:
  - Application to a difficult, real world domain
  - Application to improving operation of IDSs
  - Extensions to encompass huge data sets, faulty data, and multi-source data
- Scientific and technological innovations in Human-Centered System Design:
  - Development and validation of techniques for IDS design and evaluation
  - Improvements in understanding of elderly interactions with computers and automation

2a.2.4.9 Technical Leverage and Impact on U.S. Technology Base

While our focus will be on developing technologies for the home and the aging population, the technical benefits listed above extend far beyond these domains. IDS technology has already been developed for domains as diverse as military aviation, oil refining, and home computer use—the barriers to broader acceptance of IDSs in these and other domains are precisely the ones we are targeting in ILSA—accurate SA, usability, ease of installation and ongoing adaptation. Success on ILSA will open the doors to IDS technology in other applications. As we will demonstrate with home devices (including even Lois's legacy stove), wrapping an IDS around existing devices gives them intelligence and integration undreamed of previously. The benefits in terms of comfort, ease of use, productivity and connectedness are enormous.

We can also leverage immediate benefits by providing integrated intelligent, in-home support for other segments of the population, including the disabled, children, and other people who could benefit from automated assistance. The technologies will have broader impact on such diverse domains as home confinement (in lieu of minimum-security prisons), child care guidance and supervision. Installations in larger domestic environments such as nursing homes and hospitals could lead to improved care with reduced staff there as well.

Finally, our approach offers severable benefits that will also be of widespread use, including detailed models of home situations, improved knowledge of interface design for the elderly, improved techniques for SA from low cost sensors, machine learning techniques from rich, real world data, and others described in section 4a.4.

2a.3 High Technical Risk and Feasibility

The technical challenges of ILSA pose significant but addressable risks. These risks occur in three strategic areas that we are targeting for special investigation during the project: 1) situation assessment accuracy, 2) overall system usability customized to individual users and situations and 3) machine learning and configuration assistance. In Section 4a.4, we describe specific risks associated with each of the tasks in the ILSA R&D plan, our approach to managing those risks, specific success criteria, evaluation points, alternatives and severable benefits. Here we highlight the technical risks from an overall program perspective. A theme that permeates these "global" risks is the challenge of introducing highly innovative IDS technology into the home environment of an elderly client.

Accuracy in situation assessment – Traditional automation (especially home automation) operates using very simple situation-response patterns. If the temperature in the house is above a setpoint, the thermostat turns off the furnace. This simplicity proves effective because it is reliable, and it makes use of human oversight to ensure that what the automation does is appropriate in context—e.g., to determine whether the setpoint is correct, and the furnace is functioning.

The ILSA approach vastly compounds this situation. ILSA provides benefit to the elderly by taking on (or sharing) much of the responsibility for reasoning about what is appropriate in context.

This responsibility means that (1) ILSA must have vastly more, and more complicated, situation-response patterns than traditional automation, (2) those patterns must take much more into account, and (3) responses need to be coordinated over many possible devices.

A critical risk for ILSA is that it will be inaccurate or imprecise in detecting situations of interest, because of faulty or insufficient sensor data, bad links between sensor data and situations, and/or an incomplete or erroneous set of defined situations. The problem of accurate situation assessment has plagued prior IDSs. For example, most users of Microsoft Word™ 95 or 97 have had the experience of the Office Assistant offering help with drafting a letter when all they wanted to do was move a figure.

The risk of inaccurate situation assessment is exacerbated by several factors: first, a 'situation of interest' will differ from client to client and household to household. Second, available sensors will also likely differ in each home. Third, the number of options available to a person moving about his/her home is likely far greater (and thus, predictability will be far lower) than a pilot following his mission plan. If, due to any of these barriers, ILSA's HOME cannot deliver accurate and reliable assessment of a sufficient number of critical situations, then all of CARE's ability to customize interaction responses will be in vain.

Our recent success in Diagnostics Evidence Aggregation from ASM shows that situation assessment from multiple sensors is feasible. Expertise gained on that project will be used on ILSA. Other mitigation strategies give us additional confidence that this risk is manageable, including:

- Our extensive knowledge acquisition strategies will help to identify the bounding set of situations, with associated priorities, for different classes of clients.
- Our architectural decision to separate situation representations from home and client status gives us the ability to create or learn many different paths from sensed data to a situation. This modularity reduces the risk of reliance on any one sensor or set of sensors, and turns diversity of home configurations into a virtue.
- ILSA's Configuration Aid will assist in seeding ILSA's knowledge bases for the individual client by helping make set-up decisions (e.g., what sensors to deploy for types of situations to be detected) and capturing critical situations and lifestyle knowledge.
- ILSA's use of machine learning technologies will help to improve situation assessment accuracy and customize it to the lifestyle patterns of an individual client.
- Finally, some degree of uncertainty can be managed via ILSA's interaction design capabilities, either by developing interactions which will eliminate uncertainty, or by providing interaction responses which are appropriate to a set of possible current situations. We are world leaders in developing this kind of interaction in real world systems [18].

Overall System Usability—While IDS systems like ILSA are currently reaching reality, system usability remains a paramount issue. The Microsoft™ Paperclip has failed because it did not use the IDS capabilities it possessed in a user acceptable fashion. User acceptance levels of the RPA were newsworthy not because they were extraordinarily high [17, 18], but precisely because they were beginning to indicate feasibility in a real world setting.

The usability challenges facing ILSA are particularly daunting. Not only is the 'science' of determining or predicting usability for IDS systems in its infancy [16], but the science of providing usable human-computer interactions for elderly or special-needs clients is also far from developed. To meet these challenges, we will be forced to make progress on both fronts simultaneously—and our successes will provide leverage for both communities.

Previous experience in other domains has shown user discomfort with feeling ‘out of control’ or ‘watched and supervised.’ We have also noted the extreme visibility of a single error compared to 100 ‘correct’ actions. We expect users’ acceptance issues with ILSA to stem from concerns about their 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 that is perceived to be too computer-like.

We will mitigate these risks by employing a user-centered development process that devotes substantial program effort to both initial knowledge acquisition and subsequent usability testing. Honeywell has one of the top usability assessment groups in the country with special capabilities in the domain of home automation. Furthermore, we are among the very few developers of interaction configuration systems who have been explicitly wrestling with issues of human usability [16, 17, 18, 21]. We have learned from past experience and have solution approaches to all of the problems cited above. Finally, we have specifically staged knowledge acquisition and usability testing to maximize the potential to try out various interaction approaches. Our final field tests will be staggered to allow at least three opportunities for trying out interaction philosophies and tuning ILSA behaviors both to learn more about what works, and to arrive at a specific, viable solution in the ILSA domain. We also anticipate that as users become familiar with ILSA, its perceived benefits will outweigh many of the technology-based concerns users may have.

Machine Learning and Configuration Aid**—**Both Machine Learning (ML) and the Configuration Aid (CA) are intended as mitigation strategies for one of ILSA’s largest overall risks—that it will be too difficult to set up, configure, customize, maintain and modify to make it feasible for the home environment.

While IDSs are becoming feasible in some domains, they have proceeded by taking one of two strategies: either they rely on a dedicated, trained staff of set up specialists in a labor- and cost-intensive process (e.g., RPA, ASM); or they rely on a comparatively static, homogenous domain so that such costs are minimized (e.g., DIGBE, Microsoft™ Office Assistants). Neither approach is feasible for ILSA.

The CA will aid users in developing an ILSA configuration that meets the needs of the client. While the technologies for CA are not themselves overly risky or innovative, there is risk in relying too heavily on them. The challenge is to find an optimal mix of human-aided setup and knowledge acquisition (KA), followed by automatic ongoing adaptation. Our domain analysis and customer interaction activities will help us to identify this mix, and previous experience building configuration aids will help us to develop the CA that best meets ILSA’s needs.

While ML will empower ILSA with the ability to improve and adapt its behavior over time, machine learning in this domain has several important risks to consider. The ML approaches for use in ILSA are only beginning to prove themselves outside the laboratory. The home domain is one of the largest and most variable in which ML will have been tried. “Raw data” like acoustic signatures in this domain are extremely data intensive. When the number of discriminating features in the data grows, the search space grows exponentially. Moreover, the more noise in the domain, the harder the concept is to learn. Most home data should be amenable to statistical generalization techniques; for example, clustering techniques and principal component analysis will identify similarities in data, and the speech recognition community has developed signal-processing techniques that can parameterize waveforms [23]. If these generalization steps are not sufficient, we will explore the use of Honeywell's *Visual Query Language* (patent application in process), a technique that compares the similarity of waveforms.

Payoff vs. Risk**—**Much of ILSA's risk arises from our proposed intersection of cutting edge technology with a deep and varied social problem. However, this breadth and complexity also offers a wide array of alternative approaches and fallback positions, as will be illustrated next. The risks imply that not all of our components will succeed exactly as proposed. But partial success can still lead to a successful program with strong technological, scientific, economic and social payoffs. Those technologies that do succeed can be integrated into a valuable product, and even those that fail will provide valuable lessons for future efforts in related domains.

2a.4 R & D Plan

We have developed a 30-month program plan with iterative deliverables and incremental releases of functionality. The project time line and deliverables are summarized below.

	Phase I	Phase II	Phase III		
Project Tasks	**'00 '01**	**'02**	**'03**	**Total**	**Major Milestones**
1. Knowledge Acquisition				176K	Requirements documents
2. Infrastructure Development				90K	Fully implemented HW/SW/ Communications infrastructure
3. Technology Assessments				103K	Inputs to ILSA development Phases and Eval scenarios
4. HOME Development				652K	SA capability demonstrations
5. CARE Development				911K	Interaction capability demonstrations
6. ML Development				550K	Learning capability assessments
7. CA Development				191K	CA usability evaluation
8. Evaluation Environment				348K	Environment demonstration and checkout
9. Evaluation Studies				201K	Study results documents and recommendations
10. Dissemination				188K	Industry workshops, demos
11. Prgm Mgmt				671K	Program reviews
Funding Totals	1,791K	1,819K	471K	4,081K	(Total for program labor only)

Each phase will follow an iterative, incremental development cycle, with demonstrable project goals and quarterly evaluation of cost, schedule and technology goals. Conceptually, the program is divided into three phases as illustrated at the top of the chart. Phase I has the demonstration of the core HOME and CARE systems as its major goal. Phase II will demonstrate the ML and CA components. Phase III will emphasize final usability testing and tuning. Even though these elements will be the foci of their phases, work will go on throughout the program under each element, as illustrated.

Significant system demonstrations and HCSD evaluations will be held near the end of each phase. These are our major deliverables, marked on the timeline by black diamonds.

Table 3 provides a summary of the projected accomplishments of each phase, the emphasized technologies and their success criteria, anticipated functionality and severable benefits, along with a scenario representative of what these capabilities could provide for ILSA's clients. Note that each phase emphasizes a central element of the risks described above, accurate SA in Phase I, ML & CA improvements to installation and ongoing adaptation in Phase II, and overall usability in Phase III. Thus our program plan is intimately tied to overcoming our risks—and our evaluation studies provide the data to assess success. More detailed technology development goals, success criteria, decision points and alternatives are provided by major program task in the following paragraphs, followed by a list of activities to achieve the expected outcome. To mitigate task performance risk, we use Honeywell's Six Sigma Plus Program Management Process which provides SEI level III compliance, tailored for high risk research. This process requires documentation and tracking of program plans, desired activity outcomes, deliverables, cost information, personnel, material and supporting infrastructure. Our process plans and progress will be reviewed by an SEI auditor on a quarterly basis. If there is a need for project re-planning, this process will identify it to minimize schedule, financial and technical risk.

Table 3. Summary of Anticipated Projected Accomplishments

	Phase One	Phase Two	Phase Three
Project Goals & success criteria	Develop HOME & CARE representations and reasoning capabilities. Demonstrate fundamental HOME-CARE capabilities across a few disparate situations. Demonstrate speech output. Extensive KA to support knowledge base design. Usability evaluations in home laboratory setting. Sponsor 3 industry advisory groups. At least 6 publications or presentations.	Expand number of devices, and situations cover-ed. Demonstrate ease of setup, change and ongoing adaptation. Show learning of clients actions. Handle a change in client capabilities. Demo situation-dependent speech recognition with go/no-go decision. Improve situation assessment accuracy. More extensive usability evaluation including set up and configuration. Continue advisory groups and publications. Demo ILSA at NIST workshop.	Expand to enhance coverage & flexibility. Show interaction design for diverse devices. Show improvements in situation assessment with ML. Show improved overall system performance for unexpected situations. Evaluate configuration aid. Long term, in-home field tests of usability and acceptability. Continue advisory groups and step up publicity. Demo ILSA at a trade show.
Sample Evaluation Scenario	ILSA detects smoke in the kitchen and uses motion sensors and reasoning to locate and alert the client. ILSA determines whether to notify the fire department, nearby caregiver and/or distant relative. In another scenario, ILSA assists the client in finding help on a medical condition.	ILSA determines the stove has been on and is not used. ILSA produces interactions to turning it off and determines if and how the caregivers should be notified. In another scenario ILSA determines that client has not been taking their medication, first issues reminders, then notifies the appropriate caregiver.	ILSA detects that the client has fallen and uses medical and motion sensors to assess severity. ILSA uses voice dialog to talk the client through the situation and to get more information on the client's state. ILSA selects among multiple media such as the phone, internet, or pager, to notify caregiver of the situation.
Functions and Severable Benefits	- Extensive knowledge base of potential client activities - Integrated monitoring of comfort, security and client actions - Multi-modal communication with client using visual displays, speech output or flashing room lights - Remote access to monitored data by authorized individuals via phone or secure web page	- Recognition and detection of in home client activities as well as medical status information - Learning repeated behavior patterns & detection of deviance - Situation dependent speech recognition. - Device independent response generation for abnormal situations, including remote alerting	- Situation assessment for complex situations involving multiple types of sensors - Adaptive situation assessment - Automatic generation of interactions across diverse media - Situation-dependent interactive dialogs (naturalistic speech I/O) - Intelligent configuration aid tool - Definition of conditions for user acceptance

Task 1. User Studies

Intent	Provide understanding of domain and user requirements.
Outcome	Documented findings for ILSA design requirements from both client and caregiver perspectives.
Risk	Users may not know what they need, may have difficulty envisioning advanced technology.
Mitigation	Good HCSD techniques, multiple knowledge acquisition sessions, multiple potential users, part- and whole-task simulations. Consultants on Geriatrics, Home Care Nursing and Retirement Home facilities.
Value	Ensures human-centered, usable system; Basis for HOME & CARE. knowledge representation.

- *Year 1:* Develop UI and system requirements based on reviewing prior studies (e.g., AARP) interviews, observations and ride alongs with a variety of potential caregiver and client types. Define parameters for client, home, activity, and situation models
- *Year 2:* Similar activities. Enhance and refine system models. Define usability parameters for installation and setup. Define usability criteria for Phase III.

Success Criteria	Emerging consensus perspective(s) providing a suitable basis for ILSA design.
Decision Points	2/3 through KA task in each program phase: determine ability to construct requirements.
Alternatives	Extend KA or focus on a subset of potential users.

Task 2. Infrastructure Development

Intent	Enable communication between sensors, effectors, display devices inside home, communication with external care providers, and interaction with HOME and CARE. Blackboards.
Outcome	A reliable, secure infrastructure that supports HOME & CARE, based on the Honeywell Home Controller and Universal Plug and Play protocol.
Risk	Alternative communication protocol succeeds in the marketplace.
Mitigation	Monitor marketplace. Ensure modular design so changes affect only lower levels. Adopt new protocol. Rely on HHC and HAPI expertise to develop infrastructure.
Value	Provides foundation for ILSA's reasoning and interactions.

- *Year 1:* Fully implement infrastructure that supports HOME, CARE, external communications access and multiple sensors, effectors and display devices.
- *Year 2 & 3:* Modifications as needed.

Success Criteria	An infrastructure that supports demonstration systems using dominant market protocol.
Decision Points	Alternate protocol becomes dominant in marketplace.
Alternatives	Adapt ILSA/infrastructure interface to use dominant protocol.

Task 3. Technology Assessments

Intent	Maintain awareness of technologies important to ILSA's; influence developments.
Outcome	Inputs to ongoing ILSA design and to the Eval study situations and devices we support.
Risk	None for assessment; technologies themselves may not offer desired capabilities for ILSA
Mitigation	Awareness of tech state enables alternate ILSA configurations making best use of available tech. Honeywell expertise provides accurate assessments. On-going, non-ILSA work creates or influences tech improvements.
Value	Developments in these fields will affect the types of ILSA's, and their associated behavioral capabilities, that can be provided. We need to keep abreast to do good ILSA development.

- *Years 1-3:* Honeywell Technology Center experts in relevant fields (communications security, RF communications, information assurance, home sensors, actuators and in-home medical sensing devices, speech recognition and generation, and system health management) will perform a thorough technology survey in Phase I, followed by ongoing tracking activities, and will consult with ILSA designers on their findings.

Success is defined by the availability of technology reports and advice when needed; there are no significant decision points or alternatives within program scope (though influence on external technology development is possible through the Dissemination task below).

Task 4. HOME Development

Intent	To provide situation assessment and knowledge sharing for the home environment.
Outcome	Provides current situation model from which CARE can develop interaction response plans.
Risk	Home environment may have inadequate sensor coverage: poor coverage, low variety, low quality data and non-intersecting weaknesses. Inaccuracy due to use of qualitative probabilities.
Mitigation	Develop HOME relying only on low cost sensors; add higher-quality sensors if needed to enhance reliability and accuracy. Accommodate widest possible range of current and future sensors. Rely on our experience (ASM and IA) to define situation vocabulary whose probabilities are typically not close.
Value	Provides high-level situational awareness which is the basis of CARE's value-added.

- *Year 1*: Define knowledge representations for models and implement for 2+ each: homes, clients, sensor types, effector types, display types; and 10+ each: typical client activities and ILSA situations. Acquire speech recognizer and build vocabulary for 5+ activities/situations. Demonstrate situation assessment using blackboard with confidence and importance values.

- *Year 2*: At least double the capabilities of each model. Include caregiver models, unusual activities, emergency situations, medical devices; Incorporate ML for sensor reliability and feature correlation to improve assessment accuracy and track changes in client capabilities.
- *Year 3*: At least double model capabilities again. Discriminate pets and visitors from clients; Demonstrate ease of use for integrating new devices and revising client reference model. Reassess speech recognizer and acquire and integrate new technology if needed. Enhance vocabulary to improve usability and user acceptance.

Success Criteria	Y1: ILSA performs real-time situation assessment for 3+ critical situations with 80% accuracy. Y2: Expanded situation numbers and types, chronic situations, 95% accuracy on 5+ situations. Y3: Expanded situation numbers, types and complexity. Slowly evolving client incapacities tracked.
Decision Points	Demonstrations scheduled at end of each phase: compare capabilities to goals.
Alternatives	Add more and better sensors. Use ML to create/modify situation assessment probabilities and relationships. Design ILSA to ask client to help disambiguate situation assessment. Explore use of domain knowledge to enhance QBN. Greater restrictions on sensor package requirements.

Task 5. CARE Development

Intent	To generate coordinated, situation-appropriate client-centered interactions
Outcome	A component that can plan and execute interactions in response to situations identified by HOME.
Risk	Recommended action knowledge not rich enough. Insufficient or inappropriate devices. Intrusive, annoying, trivial, uninteresting or incomprehensible interactions destroy user acceptance.
Mitigation	Expand knowledge bases and develop default interactions for unpredicted needs. Ensure comprehensive knowledge-base by running challenging simulation and fielded site experiments. Apply especially extensive and rigorous HCSD standards within an iterative design process. Rely on extensive past experience and KA for acceptable interaction design approaches.
Value	Provides the ability to take action and negotiate with clients and caregivers to meet needs.

- *Year 1*: Define knowledge representations for interactions and devices. Develop simple situation monitor with pre-defined interaction needs based on groupings of situational features. Implement for 5+ situations. Define multiple interaction templates for 2 types each of sensors, effectors, and displays—at least half to involve more than one device—and demonstrate capability to execute coordinated behaviors. Implement Discourse Generator to build dialogs for at least 5 situations.
- *Year 2*: Incorporate ML into Situation Monitor to adaptively re-balance response triggers and response accuracy. Implement Interaction Needs to handle at least double situations. Add adaptation methods to Interaction Needs to handle learned situations. Define interaction templates for all devices used by HOME. Expand Discourse Generator; implement prototype Visual Interaction and Monitoring Interaction Generators.
- *Year 3*: Ensure Situation Monitor easily handles expansions in HOME and CARE. Expand Interaction Needs and templates as needed. Incorporate ML feedback into Good Practices and Preferences knowledge base.

Success Criteria	Y1: ILSA designs interactions for situations tracked by HOME. Users report moderate acceptance. Y2: Expanded interactions & devices. Speech interactions deemed acceptable. Auto-registration of interactions for at least 2 novel devices. User acceptance moderate to high. Y3: Expanded interactions & devices. Improved interactions over time with ML. User acceptance high.
Decision Points	Demonstrations scheduled for end of each phase: compare capabilities to goals.
Alternatives	Improve interaction knowledge and limit flexibility in interaction generation. Use ML to tune interaction decisions. Improve manual configuration options. Improve situation assessment coming from HOME. Increased use of manual/visual interactions to replace speech.

Task 6. Machine Learning Development

Intent	Enable ILSA to adapt its behaviors over time to its environment.
Outcome	Automatic adaptation over time to the actual operating environment and the user and his/her preferences (and changes in either).
Risk	Search space grows exponentially large. Too much noise in data to successfully learn concepts. ILSA learns to ignore real alarms.
Mitigation	Use statistical generalization. Use Honeywell's Visual Query Language. Use domain models to restrict changes to certain categories of alarms. Restrict learning to a 'configuration phase'. Request authorization for learned modifications.
Value	Cost effective installation and configuration, reduced maintenance costs, enhanced usability.

- *Year 1*: Design ML access points in ILSA components. Identify ML need in each processing unit and database. Design best mechanism for ML/data interaction. Influence data representations to facilitate ML. Implement baseline ML for one mature ILSA component.
- *Year 2*: Design & implement a baseline ML for rest of the components. Collect and use data from in-home sensors for learning tests. Demo high accuracy, efficiency, and robustness. Extend ML based on actual data.
- *Year 3*: Scale up ML for new sensors and homes. Evaluate ML performance over time in field tests. Develop compression approaches to handle data size problems, if necessary. Evaluate accuracy, efficiency, robustness, and amount of representation captured. Evaluate metrics based on increased sensing capability.

Success Criteria	Accurate, efficient, robust ML component that handles specific evaluation scenarios. General improvements in ILSA capabilities or ease of implementation traceable to ML outputs
Decision Points	Demonstrations scheduled for end of each phase: compare capabilities to goals.
Alternatives	Apply statistical generation techniques. Implement knowledge-based constraints. Institute configuration phase. Limit ML scope—place more responsibility on Config Aid and direct user input.

Task 7. Configuration Aid Development

Intent	To enhance the speed and ease of ILSA installation and configuration.
Outcome	A suite of decision aids, help routines, and semi-automated knowledge acquisition tools.
Risk	Set up time can increase if relied on too much. Clients and caregivers don't necessarily have perfect knowledge about their own behaviors, or their desired ILSA behaviors.
Mitigation	Combine with machine learning to adapt configuration to actual behaviors.
Value	A trained system technician will be able to install and configure a new ILSA system in under 8 hours. Users & clients will be able to directly assist in populating ILSA's initial knowledge base.

- *Year 1*: Compile requirements and design concepts from emerging HW/SW designs.
- *Year 2*: Collect usability data on most important and time-saving aids for setup. Design, implement, and demo prototype. Collect usability data on prototype.
- *Year 3*: Modifications as necessary.

Success Criteria	System technician is able to install and configure a system in no more than 8 hours. Users happy with ease of configuration.
Decision Points	End of 2nd phase: evaluating results from prototype demonstration.
Alternatives	Extend usability studies & development resources; rethink installation method (more installer training).

Tasks 8&9. Evaluation Environment Implementation and HCSD Evaluation

Intent	To demonstrate ILSA capabilities to target audiences and study usability of ILSA in each phase.
Outcome	A quantitative and qualitative assessment of ILSA's functionality and usability.
Risk	Effective, comprehensive ILSA evaluation with limited time and resources; ability to field a credible evaluation platform for studies; retention of study participants.

Mitigation	Use range of study techniques across a carefully selected range of situations, environments and participants (including caregivers, clients, installers, medical experts, & geriatric specialists). Do long term field testing for most difficult data to collect otherwise. Do extensive evaluation scenario and environment design—use Wizard of Oz study to evaluate other potential behaviors. Use subject screening and offer remuneration. Use Honeywell House for controlled testing in a home-like environment.
Value	Ensures that ILSA systems meet goals, and are easy to use, reliable, and accepted by clients.

- *Year 1*: Evaluate appropriateness and effectiveness of presentation modalities and formats. Measure users' awareness and understanding of overall system concept. Identify areas for improvement. Run part-task usability study with 6 participants in Honeywell House.
- *Year 2*: As above, but include evaluation of situation assessor and speech interface. Identify users' preferences and areas for improvement. Run Wizard-of-Oz (emulated system behaviors) study with 6 participants in a Honeywell House laboratory setting. Evaluate ML in home settings. Evaluate prototype CA with installers and offer suggestions for improvement
- *Year 3*: Evaluate usability, user acceptance, patterns of use, and system performance. Measure users' awareness and understanding (mental model) of the system and its behavior in the context of daily us— in 6 homes, with 12 participants (6 clients and 6 caregivers). Stagger in-home field tests ranging from 1-3 months each with system improvements made throughout Evaluate ease of set up and configuration and identify areas for improvement.

Success Criteria	System usability improves in each year. Over 75% of participants in all classes rate usability and acceptance High in year 3.
Decision Points	End of Environment Design phase to proceed with study, then end of each study phase.
Alternatives	Identify areas for improvement and redesign to address problems.

Task 10. Dissemination

Intent	Support the wide dissemination of ILSA plans and results to improve national technology development and increase the chances of ILSA's impact on the marketplace.
Outcome	Delivered papers, articles and talks, technology demonstrations and workshops. Publish web page.
Risk	Limited attention and acceptance and, ultimately, industry ignoring of the ILSA approach
Mitigation	Increasingly active engagement with industry and academic partners. Lead roll on standards committee.
Value	This task will generate interest in ILSA (devices, users, scientists).

- *Years 1-3:* Conference and trade show presentations, publications in scholarly and popular press; triannual workshops for information exchange with potential manufacturers; ongoing work with developers to ensure product compatibility open demonstrations in the Minneapolis Honeywell House. Publish ILSA web page, continue roll on UpnP standards committee.

Success Criteria	10+ publications or presentations per year, SRO attendance at workshops, 30+ requests for information per year, ILSA-compliant products under development by program end
Decision Points	Inability to attract 'significant' players to any workshop; industry commitments to moves incompatible with ILSA (e.g., abandonment of home network standards efforts).
Alternatives	Incentivized developer relationships, Honeywell development or acquisition of specific, hi-profile ILSA devices or packages.

Task 11: Program Management

This task has no technical risk and will not be discussed here.

2b. Potential for Broad-Based Economic Benefits

The population distribution of the United States is shifting to a higher proportion of aged people. The number of people in the U.S. over the age of 65 will double from 34.7 million now, to 69.4 million in 2030, over 22% of the U.S. population [3]. 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 [27]. The problem is compounded by a trend towards smaller (and more geographically remote) families who will find it harder to support 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 [9].

Consequently, nursing home admissions will increase. But, a Health Care Financing Administration (HCFA) survey has shown that 30% of elderly people would rather remain in their homes until death than move [10]. Thus, our program goal: ILSA will bring evolving technologies to bear on the problems of the elderly, to allow them to stay in their "legacy home," to defer the time they must move to assisted living or nursing facilities, and to improve the quality of life for both them and their caregivers.

2b.1 Economic Benefits

The dramatic increase in the number of elderly over the next 30 years and the associated challenges for the decreasing number of caregivers is well documented [3, 27, 28]. Our project addresses these problems by creating the Independent LifeStyle Assistant, a system that supports older persons in their Activities of Daily Living (ADLs), leveraging the time and attention of family and other caregivers, creating the opportunity for seniors to reach out to their community or caregivers for support services, delaying or preventing the need to move into an assisted living center.

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 their 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, medical sensors).

2b.1.1 Reduction in Costs Associated with Formal Home Caregiving

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 [10]. We anticipate that ILSA will provide the technology to reduce 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 infrastructure providing the support for monitoring, alerting, and telemedicine type services will provide more than 20 "virtual visits" per day.

The costs quoted above 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) [11]. 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, the annual impact would grow to over $8B per year.

2b.1.2 Reduction in Costs Associated with Informal Home Caregiving

The U.S. General Accounting Office reports that 85% of all home healthcare is provided by family and friends. Only 14% of home care is rendered by paid providers [28]. The magnitude of the statistics is immense:

- 23% of U.S. households are involved in caregiving to persons 50 or older [1],
- An estimated 14.4 million full- and part-time workers are balancing caregiving and job responsibilities [15],
- 33% of full time and 37% of part-time employees have lost time due to care giving responsibilities [1],
- 15% of previously employed caregivers chose early retirement [20],
- 7 million Americans are long distance caregivers for older relatives; the average travel time to reach their relatives is four hours [29],
- The average duration of care giving is 4.5 years [26], and
- The average time consumed for personal and household assistance is 12 hours per week [15].

Informal family home healthcare 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 [15]. 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 [6].

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

2b.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. 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.

2b.1.4 Improvements in Quality of Life

It is 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 [2]. Furthermore, mental and emotional problems are increasingly being reported with family caregivers. Studies show that an estimated 46%, primarily spouses, are clinically depressed [8]. 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 a system that monitors health conditions, provides status updates remotely, and responds appropriately to critical situations will greatly reduce the stress of both caregivers and clients.

2b.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, our extensions to the reliability, usability, and installation ease of IDSs will be applicable to a very broad range of sensing, monitoring, understanding, alerting/alarming, and control problems beyond independent living. Indeed, if we can successfully achieve the innovations described in Section 4a, they will even have benefits in the military aviation domain where much of this work originated.

2b.1.6 Benefits Summary

The costs associated with care for the elderly, already measured in the $10s of billions per year, are projected to be in the $100s of billions with the aging of America. We believe that the infrastructure ILSA provides will coalesce technology to reduce future expenditures and the associated drain on funding programs. Savings will be realized by formal caregivers and nursing-home facilities as their labor resources are more efficiently distributed across clients. U.S. employers will benefit through decreases in lost work time and increased productivity. ILSA has a potential annual economic benefit of $26B for these sectors of the U.S. economy. Since ILSA's open architecture will provide a basis for the introduction of newly developed devices from any company, the benefits for device manufacturers will be widespread. Most importantly, ILSA can be expected to improve the quality of life for both the elderly and their families. Care recipients will experience a stronger sense of autonomy and independence, easing the emotional strain on their informal caregivers.

2b.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. There are already 35 million individuals in the U.S. over the age of 65, 43% of whom can be expected to eventually enter a nursing home. Assuming we are successful in demonstrating an infrastructure and system that will allow people to live independently longer, even a conservative 1% market penetration represents a projected 140,000 installations per year. This is not just a market for Honeywell. Our open system architecture means this area will be a significant peripheral market for other companies.

An important factor in success is acceptance of the system by the elderly, their family members, and the medical and healthcare professions. Other factors include cost of installation and configuration, and the probability of technology advances not directly addressed in this program. To determine potential market interest in our envisioned ILSA product, Honeywell conducted two surveys over the past three months. The first was distributed to 500 people and listed 31 potentially feasible functions for ILSA. Respondents were asked to rank each function from "no use at all" to "very useful" on a scale of 1 – 5. Over 210 people responded (indicative of the interest in an ILSA product). Based on the results of this survey, we defined a basic product description and a set of optional features and conducted a second survey to determine what the market considered to be an acceptable price. The following features were identified:

Basic Product Features	Optional Product Features
Path lighting when it's dark inside the home	Chronic health problem management
A simple visual display for messages that could also be shown on the television screen	Two-way audio and video between the client and whomever is calling
Assistance with some hearing and vision challenges (e.g., larger letters on the visual display for a person with poor eyesight)	Location tracking when the client is outside the home, with location information available on demand via the secure Web page
Two-way speech interaction between the client and ILSA from anywhere in the house	Analysis of noises in the home and an information display about what they are
Home security and an "everything's okay" message on the display when appropriate	Detection of signs of depression and notification of a caregiver
Fall detection and caregiver notification if the client is not responsive	The ability to see on a display or television who's at the door before opening it
Passive collection of information about the client, with data security and confidentiality, being available to only authorized persons	A medication supervisor to remind the client when to take what, with notification to a caregiver if the client fails to take his/her medication at the right time
Family member notification if the temperature in the home exceeded a preset criteria	Automatic shutoff of the stove/oven under criteria set by the client and a caregiver, with automatic shutoffs logged on the secure Web page
Power company notification in the event of an electricity or gas outage	A mobile robot to bring the functionality of ILSA to the client's location
Calendar and to-do list with verbal & visual reminders	

The pricing survey was sent to 500 adult children, ages 30 to 61, with an equal number in each age range. Half those surveyed in each age range were men and half were women. There was no way to identify a respondent from the survey. The surveys were sent to the adult children in the belief that they would be the ones most likely to purchase the product.

The survey first described the basic model and asked if the respondent would buy it if s/he could for a reasonable price. If they answered "Yes," they were asked to indicate how much they would pay; bracketed price options ranged from $1,000 to $4,000 or more. Those who indicated they would buy the basic model were then asked to consider each option individually and to indicate how much they would pay for each. Price options varied depending upon the feature. The least expensive options were the unusual noise analyzer and the automatic stove/oven shutoff, each ranging from $100 to $500 or more. The most expensive option was the mobile robot, with prices ranging from $2,000 to $5,000 or more.

The response to this survey was very encouraging, with 79% of the respondents indicating they would buy the basic model at a weighted average price of just over $2000. In addition, over half would buy some of the options presented. The weighted average price respondents would pay for a bundled product was just under $4000.

Effective cost considerations demand an architecture that can be implemented with minimal initial installation. Since we anticipate that installations will have to be commissioned and configured to specific circumstances, the practicalities of commercialization become a major driver for the innovative technology being proposed, and a major business risk if such technologies are not available, driving our primary phase II focus on ML and CA.

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 pursue advances in mobile robotics on this program, but substantial added benefits could be provided if breakthrough technology produces affordable robots. Similarly, a number of sensors that could complement ILSA are being studied in the MIT consortium entitled Home Automation and Healthcare and will likely be commercialized by one or more of their member companies.

The ultimate market will also depend upon a definition of whom ILSA's purchasers might be. In addition to seniors themselves, their immediate family or adult children provide a customer base. The federal government pays well over half of current home healthcare and nursing home expenses through Medicare and Medicaid. Long-term care insurance currently represents a small but growing contributor. A price range for ILSA of $2,000 to $4,000, depending upon configuration, would represent less than 2 months of the average cost for one individual in a nursing home. As ILSA's benefits are documented, its savings to the government and insurance industries could result in ILSA becoming an allowable expense, vastly enhancing both its market impact and the associated cost savings.

2b.3 Need for ATP Funding

The need for ATP funding on this program comes from several circumstances. 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. Historically, product development at Honeywell Home and Building Controls (H&BC) has been HVAC related and R&D efforts have been focused on that market. Although the proposed ILSA concept builds on our home and building products, it is outside the traditional focus and represents a new market and a risky technology. It involves intelligent software development and establishment of a complex IDS 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. ILSA represents a radical departure.

Multi-year, multimillion-dollar developments are unlikely to gain internal approval. In fact, late in 1999 ILSA was proposed internally for a Honeywell funded "Home Run." Home Runs are typically well-funded 1-2 year internal programs intended to transfer near technologies from research to product. The Home Controller and Global Home Server both won. ILSA lost. The message was clear. With so much technical (and business) risk, we need significant government funding to undertake this high-payoff technology development.

When we proposed ILSA to NIST last year, we foresaw a number of companies developing point solutions for specific elderly care issues, but no one was bringing these solutions together as an integrated system. Devices such as glucose and heart monitors, fall detectors, etc. are appearing even faster than we anticipated. One can envision a conglomeration of miscellaneous devices, all acting without coordination, in the home of the future. Yet no one has stepped up to the challenge we are proposing for ILSA.

The above situation also speaks to the need to accelerate the program. Thus, we are proposing a two and one-half year program rather than the four-plus years as we proposed previously. We are also proposing a coordinated technical and commercialization plan that provides incremental releases of technology for transfer to H&BC in support of their separate productization activities.

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. Even today's situation is less than ideal—caregivers, both formal and informal, are overworked, stressed, and less effective than they could be. Our solution is not expected to eliminate the problem, but to mitigate it. It will improve the quality of life for hundreds of thousands of elderly, the disabled, and their caregivers. It will lower health-care costs, thereby lowering Medicare, Medicaid, and insurance rates. It will boost 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 solutions to complex technical problems and allow U.S. industry to be first-to-market in this very critical area.

2b.4 Pathway to Economic Benefit

2b.4.1 Commercialization

Because a need exists for ILSA functionality now, we will begin commercialization as soon as research results and prototype tests indicate product feasibility. This section describes our commercialization plan, which will be pursued in Honeywell-funded activities that parallel NIST-funded research and development.

Our commercialization strategy is to add ILSA functionality to the base Home Controller now in development for Honeywell's home control product line. Modules of functionality will be handed-off to the Home Controller product team for parallel product development and commercialization. This development strategy between HTC and Honeywell's Strategic Business Units enables us to add functionality at 3-6-month intervals.

Our commercialization work will follow standard Honeywell Product Development Process (PDP). This process calls for a series of documents that progress from market requirement to detailed product specifications. Marketing will be supported strongly by our teammates. The PDP results in a detailed business plan for guiding the work of product engineering groups and marketing personnel. Following the PDP will also facilitate conformance of the eventual products to ISO 9001.

An important aspect of our commercialization plan is the development of an open architecture that follows established communication standards, such as UPnP and CEBus, to create opportunities for others to develop ILSA modules. To accelerate industry-wide adoption of the ILSA open architecture, we will disseminate information on the architecture and other promising work as we progress through publications and presentations in research, trade, and popular venues. Honeywell will also host workshops three times per year to foster mutual information exchange between our team and interested manufacturers. We will present our objectives, protocols, and progress, and in turn obtain guidance about what is needed to ensure product compatibility.

A major strength of Honeywell being 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 are a leader in e-business, providing our home and building customers with a Web resource, YourHome, to receive advice from home experts and access home product information (http://www.honeywell.com/yourhome/home2000.htm). We have built a team with significant experience and expertise in healthcare and medical equipment to assure that we understand the market and the potential for commercialization. We foresee an initial commercialization effort through both existing healthcare channels and existing home product sales (to informal caregivers, i.e., the adult children of the elderly).

2b.4.1.1 Commercialization Environment: Understanding of the Market

Four major positive pressures characterize the current commercialization environment:

- *Need:* The need for alternatives to labor-intensive caregiving is large, and growing. This need has provided a fertile market for an integrated solution like ILSA.
- *Home networking* is 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, which will become a key enabler for ILSA, and 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, Universal PnP, Home PNA.) Honeywell is a participant with most of these evolving communications standards.
- *The Internet and the WWW* is expanding rapidly and becoming commonplace. 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 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 is a world-class sensor developer that specializes in analog and other home sensors. These developments are commercialized and produced by Honeywell's strategic business units.

Many companies and organizations could be considered competition for the ILSA concept, but many can also be considered potential vendors of systems and devices used by ILSA. These companies are participants in the areas of home control, communications, healthcare, telemedicine, software development, etc. They include American Telecare, Ameritech, Compaq, HELP Innovations, IBM, Johnson & Johnson, Medtronic, Microsoft, Pfizer, Siemens, Sony, System Monitoring Services, 3M, TI, and many small regional companies as well as several large foreign companies. Honeywell's leadership in applied IDS technology makes it unlikely that any 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.

The alternative, traditional solution to the problems of a higher proportion of aged people is labor-intensive, costly, socially undesirable, and 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 the ability to deal with aging demographics. There are no other technologies that compete with the breadth and depth of ILSA concept.

2b.4.1.2 Market Risks

The three primary market risks are *timing*, *acceptance* and *cost*. The aforementioned technology evolutions, combined with growing need, make the timing for ILSA critical. Now is the time to conduct this research and start making a difference in the lives of caregivers and clients, mitigating the high cost of caring for the elderly. Research 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 major U.S. university research programs (e.g., MIT) in healthcare. The aging demographics in Japan represent a worse caregiver-to-client ratio than in the U.S. ILSA will utilize many components that foreign competitors can manufacture and sell. Several European firms are also developing healthcare products, primarily Siemens. Our approach to managing risk from overseas competition is reflected in this proposal. By obtaining NIST support to accelerate the development of the ILSA concept and address the underlying research issues as soon as possible, we can offer a product in the shortest possible timeframe.

Acceptance and cost risks include the reluctance of the elderly to invest in a technology product, potential lack of acceptance by portions of the healthcare industry, traditional home product 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 team's expertise and visibility in the potential customer arena. The cost risk will be managed by our expertise in producing low cost home control products.

2b.4.1.3 Commercialization Alternatives

The ILSA concept provides abundant commercialization alternatives. The most interesting involves licensing the broadly applicable ILSA technology to a variety of markets. Honeywell Intellectual Property, Inc. (HIPI), a wholly owned subsidiary of Honeywell International, Inc., owns all Honeywell intellectual property and employs a staff of IP marketing professionals and attorneys who can quickly make agreements with companies interested in our technology.

Honeywell has already demonstrated that licensing works. A change in business climate and strategy recently caused Honeywell to look for indirect ways to sell technology developed on the ATP sponsored APCFI. HIPI worked with HTC on a licensing agreement with Object Space. Object Space, a very capable small company, is now aggressively deploying the technology in the semiconductor industry.

2b.4.2 Spillovers and Broader Diffusion

The ILSA concept offers a unique combination of extremely strong social and economic benefits to the nation. Certainly there is profit to be made by private companies once the concept is developed. But to achieve the vision we propose, ILSA will require a complex combination of technologies and domain knowledge, jump-started with public research funding. Once realized, this concept will not only dramatically impact the elderly who wish to remain in their legacy homes. Obvious spillovers include offering ILSA 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 we develop will be directly applicable to these other situations.

Less obvious spillovers exist outside the healthcare industry. HTC's previous IDS work has been developed for commercial building and refinery management, pilot aiding, and driver aiding but is being applied here to support independent living. Similarly, we believe our extensions to IDS technology will find application in many other areas. For example, we believe the core technologies we develop are applicable to other Honeywell operations including buildings, industrial control, aviation, and space. Furthermore, we expect the low cost communications, sensors and effectors, intelligent software modules, and interaction design logic we develop to spill over into other applications.

One 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. It's important that we avoid both the possibility of others offering a proprietary closed system, and the possibility that the first system to market is foreign.

The breadth of the ILSA team will facilitate diffusion of the technology into related industries. Honeywell researchers, joined by university researchers and healthcare experts, will present papers at conferences to expand ILSA's visibility and share our findings both to the specific home control and medical industries and to the academic communities in which we will be making advances (primarily computer science and human factors). We will conduct several demonstrations and technology evaluations to bring our work to the attention of others. User groups will be involved in these tests and their experiences will further diffuse our work beyond the ILSA team. We will consider licensing technology on a case-by-case basis. We intend to look at several distribution models as a part of company-funded commercialization activities.

2b.4.3 Program Administration

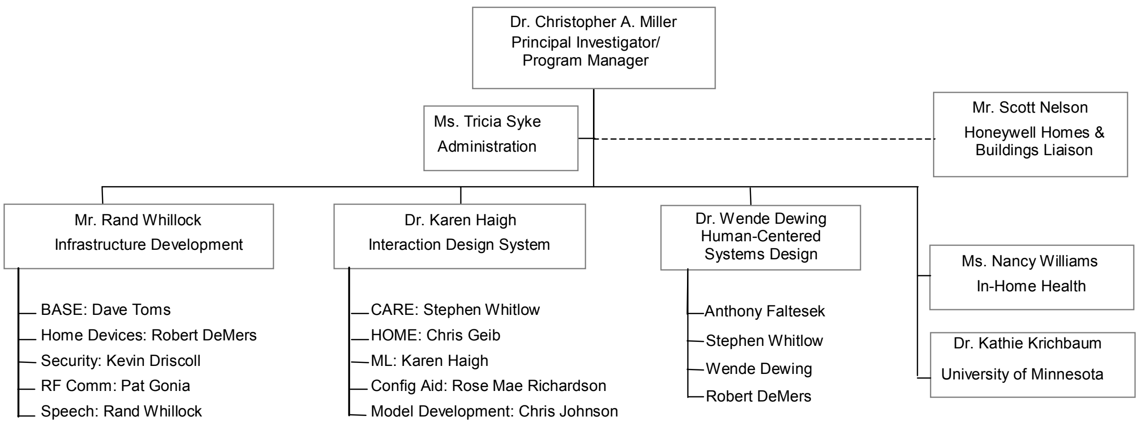
The Honeywell ILSA team has both breadth and depth, and is committed to working together to develop superior results. We intend to achieve breakthrough solutions to this problem, and we have organized our program to take advantage of early successes and ensure that the results of the program are commercialized.

2b.4.3.1 Commitment

Our team has developed the ILSA concept to help people remain independent by allowing them to live in their homes longer, postponing the expensive and upsetting move to a nursing home. For HTC, this will be an extremely large investment in a paradigm shifting R&D. We strongly believe in the social and business drivers for such a development, and are committing a significant amount of our resources to this high priority effort. For Honeywell's H&BC business, this program represents a significant commitment of resources to a new area of research. During ILSA's evolution, H&BC will not only provide significant financial assistance, but will also undertake parallel efforts to assess market potential and initiate productization efforts. Their continued guidance will ensure that while we are developing key technological innovations, we also address the outcomes and directions that will allow commercialization of a viable Independent LifeStyle Assistant product.

2b.4.3.2 Project Management

2b.4.3.2.1 HTC Plan



The functional organization of the program is shown above. Dr. Christopher Miller, the program manager, will be responsible for the overall program, including cost, schedule, and technical product. Three technical leads will coordinate three major aspects of ILSA: infrastructure development, the interaction design system, and HCSD design. Two external consultants will provide domain expertise. Finally, Ms. Tricia Syke will provide administrative support, and Mr. Scott Nelson will serve as liason to H&BC.

2b.4.3.2.2 Sub-Contractor Teaming Arrangements

In Home Health and Dr. Kathie Krichbaum will serve as consultants to provide domain expertise in home caregiving and geriatrics. In Home Health was founded in 1984 as a provider of comprehensive home healthcare 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 have been an essential member of the proposal team, providing real world domain knowledge. 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.

Dr. Krichbaum will serve as a consultant and co-investigator to provide domain knowledge and expertise in the areas of gerontology, geriatrics, and chronic health management. She will also advise on the state of the art of medical monitoring sensors, helping us to identify non-intrusive monitoring technologies and develop requirements for their integration into ILSA. In addition, Dr. Krichbaum's expertise will be essential to the design of our HCSD evaluations. She will serve as our liaison with the IRB for the Academic Health Center at the University of Minnesota, for our evaluations involving human participants.

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

Dr. Kathie Krichbaum**—**Associate Professor, University of Minnesota (Ph.D., University of Minnesota) and Fellow, Minnesota Area Geriatric Education Center. Her research focuses on assessing care options for elderly clients, evaluating nursing home care, and measuring the cognitive and emotional impact of admittance to a nursing home

2b.4.3.2.3 Resumes of Key Personnel

Name, Responsibility, Percent Allocation	**Education and Relevant Qualifications**
Dr. Christopher Miller Program Manager Principal Investigator	Ph.D., Cognition and Communication Psychology, University of Chicago. Dr. Miller has over 10 years experience in creating knowledge representations and computational approaches to adaptive user interfaces, automation and decision aids. He recently managed Honeywell's Information Policy Management program for DARPA's Agile Information Control Environment. He was the PM/PI for Honeywell's role in the U.S. Army's Rotorcraft Pilot's Associate (RPA) program implementing an information management system to coordinate information presentation and task flow between two pilots and advanced automation systems. Dr. Miller recently won Honeywell's highest technical achievement award for his design of the intermodule and human communications aspects of the Abnormal Event Guidance and Information System (AEGIS).
Dr. Karen Zita Haigh IDS Lead Machine Learning Lead	Ph.D., Computer Science, Carnegie Mellon University. Dr. Haigh's research foci lie in Machine Learning and Planning. She pioneered the situation-dependent learning approach in two robotics' planning domains. She has been developing learning techniques to recognize patterns in natural language, to recognize anomalous signals in large alarm systems, and to model behaviors for monitoring systems.
Mr. Rand Whillock Infrastructure Lead Speech Lead	M.S., Computer Science, University of Minnesota. Mr. Whillock has specialized 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, and user-centered systems design.
Dr. Wende Dewing HCSD Lead	Ph.D., Human Factors, Virginia Polytechnic Institute and State University. Dr. Dewing specializes in the application of HCSD principles to the specification, design, and evaluation of systems. She was the lead user interface designer and usability evaluator for the Honeywell Home Controller. Dr. Dewing also is leading user interface design and evaluation efforts for Honeywell's Cockpit Control Language (CCL) program and the Navy sponsored Reduced Ships-crew by Virtual Presence (RSVP) program.
Mr. Stephen Whitlow, CARE Lead	M.S., Cognitive Psychology, University of Illinois Urbana-Champaign. Mr. Whitlow specializes in user interface design, human-automation interaction, HCSD process, and semantic modeling. He has conducted KA efforts in the petroleum processing industry, airline operations, pulp and paper industry, and building management.
Dr. Chris Geib HOME Lead	Ph.D., Computer Science, University of Pennsylvania. Dr. Geib's research interests include Artificial Intelligence intent recognition and situation assessment, planning methods, reasoning under uncertainty, and constraint based reasoning. Dr. Geib has worked projects involving action under uncertainty, and helped designed the Diagnostic Evidence Aggregator for ASM.
Ms. Rose Mae Richardson Configuration Aid Lead	M.A. Child Psychology, University of Minnesota. Ms. Richardson's expertise is in requirements analysis and user interface design. She has designed configuration interfaces for several large building- and plant-management systems, including ATRIUM.
Dr. Christopher Johnson Knowledge Models	Ph.D., Computer Science, Northwestern University. Dr. Johnson's' specialties include incorporating task models and other forms of explicit, semantic knowledge into intelligent interfaces, knowledge management systems, and performance support and training systems.

Mr. David Toms HHC Expert	B.S., Computer Science, East Stroudsburg University, East Stroudsburg, PA. Mr. Toms leads development for web-based interaction on HHC, acted as a lead designer for the Honeywell Do-It-Yourself security system, and represented Honeywell technically on the HomeAPI consortium for two years.
Mr. Bob DeMers Home Devices	B.S., Mechanical Engineering, University of Minnesota. Mr. DeMers has 10 years experience at Honeywell. He specializes in rapid prototyping and test equipment development for experimentation.
Mr. Kevin Driscoll Security Expert	B.A., 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. Prior to joining Honeywell, Mr. Driscoll was a cryptography specialist for the U.S. Army's Communication Command and later the Army Security Agency.
Mr. Pat Gonia Communications Expert	M.S., Electrical Engineering, University of Minnesota. Mr. Gonia has 20 years experience in data communications and distributed object oriented software architectures for control applications. He is also leading an industry consortium developing a very low cost wireless home network (Home RF Lite).
Mr. Anthony Faltesek, Housing Domain Expert	M.S., Kennedy School of Government, Harvard University. Mr. Faltesek specializes in housing issues for elderly and differently-abled individuals, and has extensive facilities research experience.

2b.4.3.2.4 Related Experience

The ILSA team has significant experience in the technologies and applications associated with ILSA, as well as in the management of successful research and development programs. Previous NIST ATP awards to Honeywell include:

Abnormal Situation Management (ASM)—In this $1.6M NIST ATP program, 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 that work with operations personnel during an abnormal plant event to minimize loss of production, contamination of the environment, and injury. These software products, collectively called AEGIS, 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. Consortium members continued development efforts after the end of the ATP program, resulting in huge savings to users and spawning new products for Honeywell and participating vendors.

Advanced Process Control Framework Initiative (APCFI)—Honeywell and Advanced Micro Devices (AMD) collaborated in the development of an advanced process control 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 APCFI capabilities has been the cost and risk associated with integrating with existing manufacturing systems. Project results included 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 M per quarter.

Relevant federal contract awards over the past five years are listed below.

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, and communication bandwidth) as demands change. Team members include Georgia Tech and Texas A&M.			
Shared Human- Computer Interaction Environment	Decision support	1995/$3.1 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 recent HTC research investigations that are relevant to the proposed ILSA effort include:

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 H&BC 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.

Detection of Events for Threat Evaluation and Recognition (DETER). The objective of HTC's DETER project is to develop a high-end automated security system based on machine learning from heterogeneous sensor data. The vision for DETER is an automated cooperating agent computing network capable of inferring and reporting threats, a function currently performed by humans. The system will perform object tracking and use Machine Learning to identify suspicious behavior.

Dynamic Interaction Generation for Building Environments (DIGBE)—Currently under development at HTC, DIG is intended as the basis for 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, and presentation elements. It also has specialized knowledge that is the basis for automatic composition of interactions based on situational constraints, including knowledge about the proper selection and layout of user interface components. DIG eliminates 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 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. DIGBE is an implementation of DIG for building management.

Genetic Optimization of Neural Networks for Power Industry Applications—An EPRI-supported machine learning program, in which HTC investigated the application of genetic algorithms for optimizing neural network designs. The genetic algorithm searches simultaneously for network topology, input variables, and learning algorithm parameters. The genetically optimized models have been favorably compared with manually designed networks and some of the best known nonlinear regression techniques in the statistical community. In addition to providing high levels of accuracy, the neuro-genetic optimization approach is also considerably easier to use than conventional methods, a feature due largely to the fact that it makes few constraining assumptions about the problem.

Honeywell Home Controller (HHC)—The HHC combines Honeywell software, wireless sensors and controls, and a friendly user interface to enable home owners to establish security, lighting, appliance, and climate control schedules that fit their lifestyle. In addition, remote access and control of all HHC functions are provided through the Global Home Server. The system logs events that occur in the home. Additional features will include temperature zone control, energy management, a family calendar, and rule engine capabilities.

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 airborne gases, mold, bacteria, and other harmful substances.

Human Factors Design Guidelines for People with Disabilities and the Elderly—Starting in 1987, a group of Honeywell engineers compiled a set of human factors design recommendations for special populations. This research program supported design guidelines for individuals who are challenged by limited vision or by arthritis, spinal cord injury, and multiple sclerosis that decreased hand flexibility and strength. These research data and guidelines were applied to the development of Honeywell thermostats for special populations. Thousands of these adapted thermostats continue to be manufactured by Honeywell each year.

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.

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 is a state of the art inferencing system.

Rotorcraft Pilot's Associate (RPA)—RPA is a six year, $80M Applied Technology Demonstration funded by the U.S. Army and led by Boeing Helicopters in Mesa, AZ. The goals of the program are to develop, demonstrate and flight test a cognitive decision aiding system to integrate cockpit avionics systems into an intelligent and situation aware 'associate' system. Honeywell, with Dr. Chris Miller as PI, had the lead role on the design of the Cockpit Information Manager, whose job was to track pilots' goals and intentions and then dynamically configure cockpit displays and controls and to adaptively allocate automation behaviors to aid pilots in ensuring situation awareness and managing workload. RPA has now completed a series of full fidelity simulations and a full flight test series. Among other successes, statistically significant workload reductions were obtained and pilot acceptance levels of the CIM were high.

Simulator for Electric Power Industry Agents (SEPIA). In this recently concluded contract from the Electric Power Research Institute (EPRI), HTC and its subcontractor the University of Minnesota developed and delivered a prototype agent-based modeling and optimization tool for the deregulated electric power industry. Through a full-feature GUI, users can define, configure, and interconnect agents that represent both physical (power plants) and business (generating companies) entities. The agents are endowed with advanced machine learning algorithms for performance optimization.

Speech Applications-Honeywell's human factors group has approximately 20 years of experience in the selection of speech technology for aviation, military, industry, and consumer products applications. Recent projects included the design of speech recognition and playback capability for a prototype home thermostat, a voice output capability for a home security system, a speech recognition system for tuning radios on a business aviation flightdeck, and a system for mobile infantry soldiers that combines speech recognition with 3-dimensional speech output.

User Initiated Notification (UIN)—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.

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 dynamic control domains. In this IR&D program, AI techniques were applied to the problems of recognizing users' goals and supporting task-specific actions to achieve those goals.

2b.4.3.3 Facilities and Equipment

Honeywell, Intl. is a $24-billion diversified technology and manufacturing leader of aerospace products and services; control technologies for buildings, homes and industry; automotive products; power generation systems; specialty chemicals; fibers; plastics and advanced materials. The company provides quality products, integrated system solutions and services to customers around the world. Honeywell products touch the lives of most people everyday, whether they're flying on a plane, driving a car, heating or cooling a home, furnishing an apartment, taking medication for an illness or playing a sport. The company employs approximately 120,000 people in 95 countries and operates hundreds of facilities throughout the world.

Honeywell 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 we demonstrate 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.

The Honeywell Technology Center (HTC) is the company's centralized research and development organization, delivering advanced technology, processes, and product and service concepts to satisfy Honeywell's aerospace, industrial, and commercial customers worldwide. HTC recruits the best and brightest scientists and engineers in a variety of disciplines: chemistry and material sciences; sensors; infrastructure, systems and software technologies; controls and control systems architecture; and information and decision technologies. A dynamic portfolio of internally funded and contract-funded programs ensures an intimate understanding of the state and direction of technology advancement, the high technology marketplace, and Honeywell's advanced research needs.

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.

HTC maintains and coordinates 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.

The Honeywell House (Figure 4) is a unique research and demonstration facility. It is a fully functional, contemporary, 2,080 ft^2 home used to test home and building automation, system integration, and environmental control systems in real-life conditions. The House is equipped with several state-of-the-art or prototype features including network-equipped wireless home security and HVAC and house-wide CEBus (Twisted pair and powerline carrier). The House is tethered to HTC's main building with a 10 Mbit Ethernet connection and is on the HTC LAN.

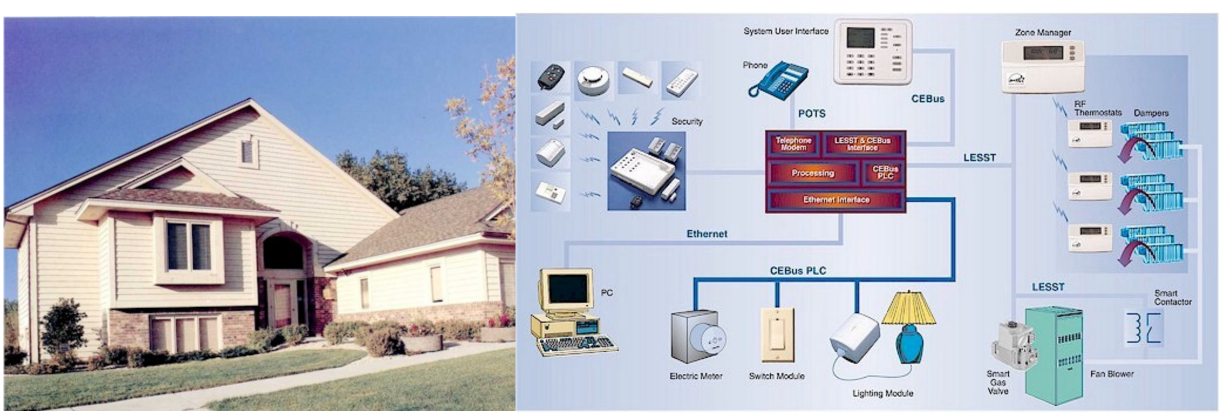


Figure 4. The Honeywell House (left) and its automation network (right).

2b.4.3.4 Past History and Organizational Performance

Year	Revenue ($M)	Cost of Sales	R&D Expenditures	Income Before Taxes	Income After Taxes	Total Assets	Total Liabilities	Net Worth
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
1999	23,735	18,495	909	2,248	1,541	23,527	14,928	8,599

Year	Total FT Employees	Total FT R&D Personnel
1997	57,500	9,500
1998	57,000	10,000
1999	120,000	20,000

2b.4.3.4.1 Responsibility for Financial Reporting

The Financial Officer for HTC, Ms. Paula Buchner, will have financial and accounting authority for the ILSA program.

5. Abbreviations

ADL.	Activities of Daily Life.
ASM.	Abnormal Situation Modeling.
CA.	Configuration Aid.
CARE.	Client Adaptive Response Environment.
DIGBE.	Dynamic Interaction Generation for Building Environments.
GHS.	Global Homes Server.
H&BC.	Home and Building Control.
HCFA.	Health Care Financing Administration
HCSD.	Human-Centered Systems Development
HHC.	Honeywell Home Controller.
HOME.	Home Observer and Monitored Environment.
HVAC.	Heating, Ventilation, Airconditioning Control
HTC.	Honeywell Technology Center.
IDS.	Interaction Design System.
ILSA.	Independent Life Style Assistant.
KA.	Knowledge Acquisition.
ML.	Machine Learning.
QBN.	Qualitative Bayes Nets.
RPA.	Rotorcraft Pilot's Associate.
SA.	Situation Assessor/Assessment.
UPnP.	Universal Plug & Play.

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