PATH TECHNOLOGY ROADMAPPING

INFORMATION TECHNOLOGY TO ACCELERATE AND STREAMLINE HOME BUILDING

BACKGROUND PAPER

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November 2000

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INTRODUCTION

This paper has been prepared for participants in the "Information Technology to Accelerate and Streamline Home Building" Roadmapping Team (IT Roadmapping Team) organized by the NAHB Research Center in conjunction with the "Partnership for Advancing Technology in Housing" (PATH). PATH is a public-private partnership that was created to stimulate use of new and improved technologies to improve the affordability, energy efficiency, environmental performance, durability, disaster resistance and worker safety of American homes between now and the year 2010.

PATH Program Goals

- ★ *reduce the monthly cost of new housing by 20 percent or more*
- ★ *cut the environmental impact and energy use of new housing by 50 percent or more and reduce energy use in at least 15 million existing homes by 30 percent or more*
- ★ *improve durability and reduce maintenance costs by 50 percent, and*
- ★ *reduce by at least 10 percent the risk of loss of life, injury, and property destruction from natural hazards and decrease by at least 20 percent residential construction work illnesses and injuries.*

The objective of PATH technology roadmapping is to identify potential technologies that can, in combination, allow the building industry to achieve the PATH goals by 2010 and to define specific, time-phased research and development activities required to implement these technologies. The PATH Roadmaps are intended to help coordinate and leverage private sector and public sector R&D for maximum benefits. The completed roadmaps will

- ✓ Provide a common, shared vision among the public and private sectors of how the technology, if effectively implemented, will benefit the industry.
- ✓ Serve as a guide for public sector investment in R&D.
- ✓ Provide direction to academia and the private sector on needed research.
- ✓ Facilitate or encourage joint private/public sector activities that will reduce or eliminate barriers to achieving the vision -- e.g. development of software and communication standards.

Roadmapping work began in March 2000 with a two-day "brainstorming" session where a cross-section of industry experts identified and evaluated 40 "Technology Options" as candidates for roadmap development. Five specific options that involved expanded use of information technology were consolidated into an Information Technology "Portfolio" that was recently designated as the highest priority area for roadmap development. This high priority reflected a strong belief in what the Internet, enterprise resources planning, wireless communications, location/GPS technologies and other rapidly evolving tools can do to make homes more affordable, energy efficient and durable. Thus, the Information Technology Roadmapping activity to be initiated on November 1 is focused upon expanding the application of these technologies to the home building process.

More information about PATH, including its technology outreach and technology roadmapping activities, appears in Appendix A. The balance of this paper presents a vision of what can be achieved with information technology, along with more details about the various Technology Options that make up the IT portfolio.

EXPANDING THE USE OF INFORMATION TECHNOLOGIES

The Opportunity - "Builders are recognizing limitations of the existing home building production system and the inefficiencies embedded in the way homes are built" reports *New Horizons in Quality Management, A Building Industry Technology Roundtable*, April 23, 1999 (NAHB Research Center, PATH and *Professional Builder* Magazine). One production builder said "We're aggressively working on automation of customization -- I think that's going to have a profound impact on the industry." The report goes on to explain that "Use of integrated computers is the key. Once a change is made in the CAD system, related drawings are automatically updated."

At an August, 2000 meeting of the steering committee for the HUD-sponsored "Industrialization of the Residential Construction Site" project, being performed by Virginia Polytechnic Institute (Virginia Tech), a builder said "The use of IT in construction should be much broader than is currently done. IT should be utilized in all phases of homebuilding from land searches through service (after the sale)".

The potential to reduce cycle time and labor content is large. The ability to reduce mistakes and rework, optimize schedules (including subcontractors), and deliver a more cost-effective, durable product is equally important.

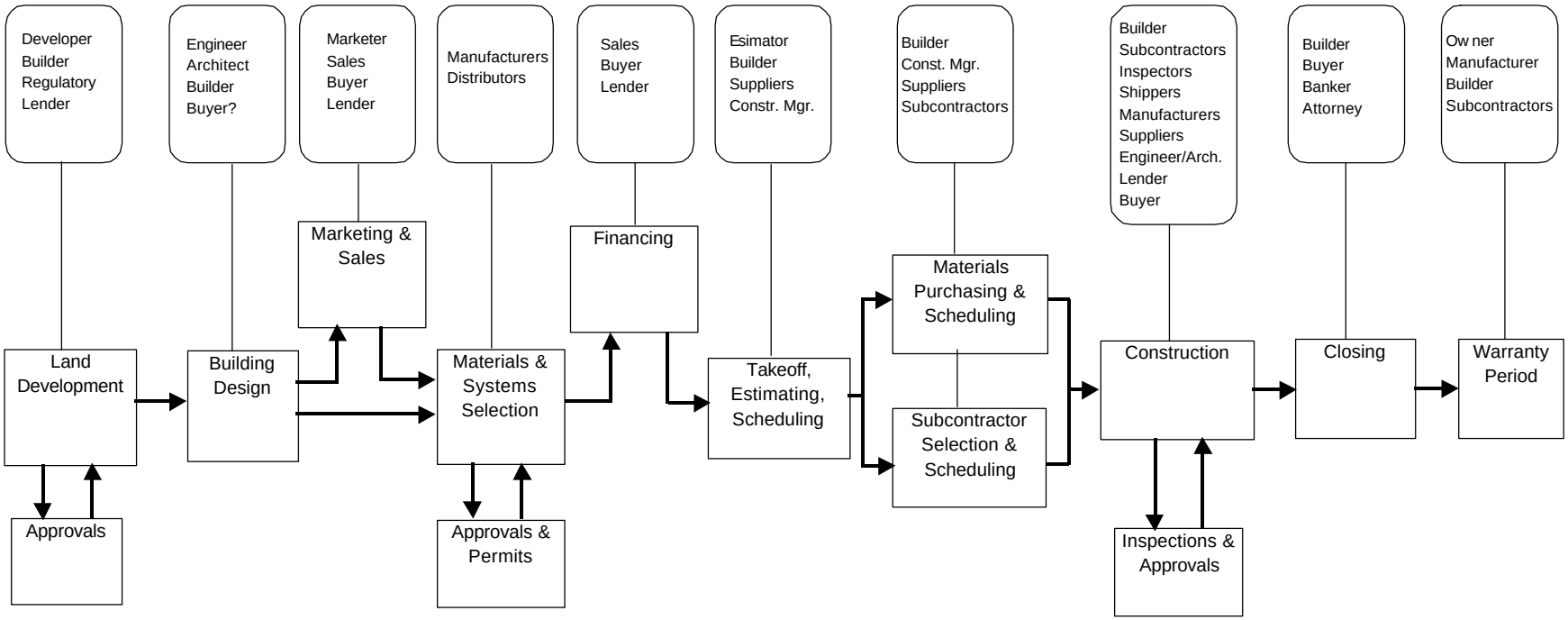
The Vision - ***Information and assistance are available when and where needed by each participant in the home building process to perform his or her function accurately, efficiently, and on time.***

This vision has many implications, such as the following:

- **designers and specifiers have rapid access to comparative data on product costs, features, limitations and availability in formats that can easily be compared and used to merge selections into CAD plans**
- **permit applications and plan submittals are carried out electronically without any need to travel to the permit office or wait in line, and approvals are returned in electronic form**
- **accurate, up-to-date design details, manufacturers instructions, safety data, fastener specifications and similar information are available to workers and field superintendents in real time**
- **change orders, customer option choices, plan revisions and unforeseen delays are entered once, then accommodated seamlessly in revisions to working documents and process schedule with updated information propagating to all affected parties**
- **required inspections for regulatory approvals or to meet lending criteria are performed on-demand, without any need to suspend work or schedule the inspector**

Achieving this vision requires understanding the interactions, information flows and key parties involved in the home building process. A simplified chart showing these relationships is in Figure 1.

Figure 1



Note:
This flow diagram is derived from a diagram in *Industrializing the Residential Construction Site* July 2000
Center for Housing Research, Virginia Polytechnic Insititute and State University
Michael O'Brien, Ron Wakefield, Yvan Beliveau
Prepared for: U.S. Department of Housing and Urban Development
Office of Policy Development and Research

Some other opportunities and constraints to keep in mind when considering how to achieve the vision are:

- The technical approaches should be usable by small builders as well as production builders, factory producers and land developers.
- Implementation must be able to begin with pieces of the overall process, then expand to the entire process.
- The latest plans, schedules, take-offs and related information must be accessible to and shared across multiple parties including supervisors, subcontractors and consumers in order to support coordination, scheduling and execution
- Workers on the site can be provided with plans, design details (such as plumbing, electrical and HVAC layout), and similar information using convenient display technologies, whether high-resolution video or "heads up" displays on safety glasses.
- Digital photography, wireless data transmission and GPS/location technology can be used for virtual inspections or for remote monitoring of work in progress and jobsite conditions; jobsite monitoring should support implementation of a low cost, open air security system to prevent theft and vandalism in homes under construction
- The mortgage loan process should be integrated, including electronic submittal of loan applications and remote, on-line closings.
- Homebuyers should be provided with comprehensive information including basic house plans, product operating instructions, product warranties and contact information for suppliers and subcontractors.

The field of information technology offers exciting opportunities for building better homes at lower costs. The key is to apply information technology to the home building process while at the same time adjusting the process to take advantage of the technology. The focus is on making accurate, complete information available when and where it is needed in the process. The entire residential construction process can benefit from information technology, starting with land development and house design, through the entitlement, construction and inspection processes and to completion of the home.

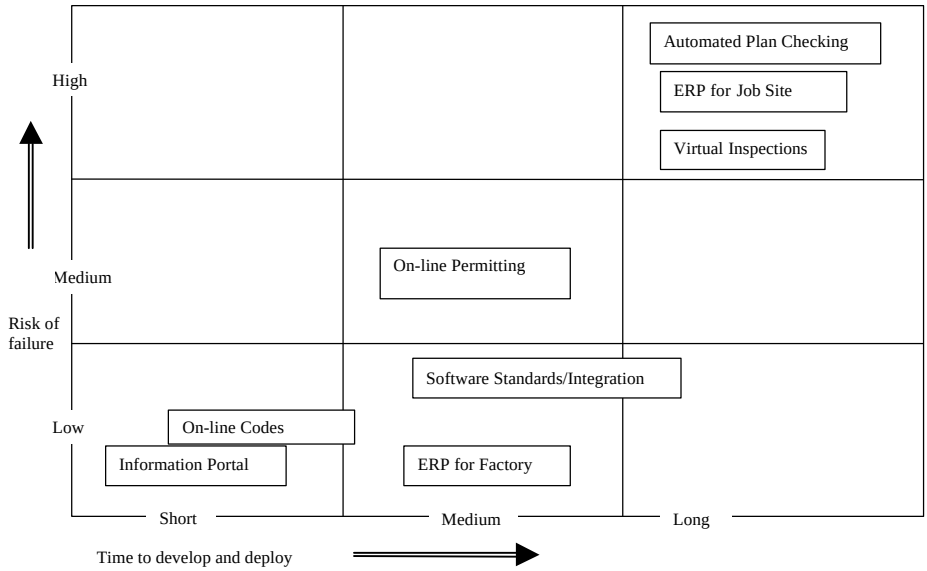
Process change that takes advantage of the benefits of current and emerging information technologies is critical to this concept. For example, if e-permitting involves just electronic delivery of plans, only a short time is saved out of what could be a months-long process. But, if the application is checked *in parallel* by the various code departments, and required changes are immediately transmitted to the contractor for initiating corrective actions, more time can easily be removed from the process.

INFORMATION TECHNOLOGY PORTFOLIO OVERVIEW

The Information Technology portfolio includes at least the set of technologies shown in Figure 1. In the regulatory arena they range from the technically and procedurally simple concept of *making codes available on line*, to the technically challenging concept of *automated computer plan checks*.

The *information portal for the building industry* can be implemented with today's technology and at relatively low cost. However, development of *software standards and/or implementation of integrated software* that is capable of going from site and home design through construction and completion will take longer. *Enterprise resource planning* should be relatively easily transferred from other industries to factories, but implementation out on the job site has technical risks and may require significant process changes. The risks and time required to implement each of these technologies is graphically depicted below in Figure 2, based on evaluations by the Technology Roadmapping Working Group. This is followed by a short description of each component.

Figure 2
INFORMATION TECHNOLOGY AREAS FOR ROADMAPPING



On-line Permitting -- This technology involves using the Internet for submitting, checking, marking-up and revising plans. Successful implementation will require changes in the permitting process as well as application of some already available technologies. Several communities in California are already testing e-permitting for simple permits and Fairfax County, Virginia is in the early stages of implementing on-line permitting.

On-line Access to Codes -- The concept is to make local codes available to designers, developers and builders on line. If properly implemented, this would assure that these users are always using the correct version of the code, and that they can access the codes from the field (using wireless Internet access). On-line codes are already happening to a limited extent (e.g., see *www.codecheck.com*).

Current technology can easily support this concept, but implementation across the multitude of local jurisdictions may be lengthy and costly. Local code bodies across the country typically modify the national model codes to suit local needs or desires. The technology would need to accommodate very easy ways for local agencies to publish their codes (although conversion of Word documents to on-line compatible pdf files is already very simple). Another area to explore is the use of information technology to assist in interpreting and understanding codes. A current software

package named "Code Buddy" offered by Carl Mileff & Associates, Inc. is an example of this type of package. The website *www.cmapc.com* is a step in this direction.

Automated Plan Checking -- The use of computers to check electronic building plans for conformance to codes has the potential to greatly reduce the time and labor required for review and mark-up. The knowledge-based systems technology to do this type of checking is fairly well developed, but applying it to plan checking would require significant time and investment. Also, deployment could be a lengthy process.

On the positive side, the benefits could be great, given that plan checking is labor intensive and typically requires skilled personnel. In addition, imagine that the contractor had access to the same automated plan checker as used by the code department. This means that the applicant could identify and resolve all of the routine issues *in advance*, so that when the plans were submitted the planning and code departments would need to deal only with intentional deviations or exceptions.

Virtual Inspections -- The concept is to implement process and technology improvements that will take most of the delays out of the inspection process. This could allow regulatory agencies to accomplish their goal of assuring compliance with codes without causing cycle-time delays and without adding manpower to their offices. Processes that allow self-inspections supplemented by electronic validation need to be developed. Concepts to be explored include certification of contractors to perform inspections (e.g. the site supervisor), use of cameras to record critical information, possible use of GPS to validate locations, digital cameras in combination with wireless communications, etc.

Information Portal -- Builders and trade contractors need information that helps them make better decisions about whether and how to use new products and technologies. They need product descriptions, warranty information, performance data, cost information, distribution information and installation instructions - all at little or no cost to them. Manufacturers need feedback from builders and contractors -- information on problems/issues with products in the field so that they can provide timely product improvements. Builders, contractors and manufacturers need to be able to search building industry related sites, topics, idea exchanges and foreign developments/technologies. The basic platform to accomplish this knowledge management seems to be the Internet, specifically a web-based information portal that is easy to use (e.g. YAHOO) and provides quick access to every useful website related to building products, services and processes. For maximum credibility, comprehensiveness and ease of use the portal needs to be non-commercial, i.e., not supported by advertising.

The technologies for implementing such a portal already exist. However, the portal needs to be designed and a significant development and deployment effort is needed not only to develop the portal but also to identify and coordinate with the multitude of information sources that would be linked with the portal. The NAHB Research Center is currently designing and will implement a non-commercial portal as part of the PATH Program.

Enterprise Resource Planning (ERP) -- The concept is to apply information technology to fabrication of major housing subsystems (especially wall, roof and/or floor panels) in the form of "Enterprise Resource Planning" (ERP). ERP converts data to understandable information for each

participant in the manufacturing process and communicates actions taken to the other participants. ERP is a fully integrated suite of manufacturing and enterprise management applications, which brings the benefits of information technology (IT) to the production process. It is an "open system" architecture, which enables other applications to "plug-in" while ensuring the system continues to evolve consistent with technological changes. IT enables production efficiencies and controls to be applied to the processes on the factory floor. ERP becomes the engine that drives the process using numerous, related technologies such as CNC, bar codes, laser scanners, digital data, pneumatic logic, etc. ERP also includes information for inspectors.

ERP is already used in many industries, and to some extent in the manufactured housing sector. However, it can be much more widely deployed into truss and component manufacturing.

ERP for the Job Site -- Although ERP for the factory floor seems to be relatively low-risk and should be achievable in the short term, moving this technology to the job site presents more of a challenge. However, the potential benefits of implementing ERP at the job site, accompanied by significant process changes (JIT, flow control, etc.) could provide significant reductions in labor, cycle time and wasted materials and large improvements in quality/durability.

Software Standards/Integration -- There are currently many useful independent software packages for design, list of materials, construction management and other phases of construction, but they are typically difficult to tie together because of incompatibilities in the way information is defined and presented. Other manufacturing industries (e.g. automotive) have made significant progress in tying together the entire process, from design through production and testing. Similar techniques need to be applied to residential construction.

Standardized communication protocols and/or integration of software is needed for all phases of construction, design, engineering, evaluation, modeling, bill of materials, estimating, and ordering. This is to include design (CAD) programs for architectural framing layout, structural design, plumbing, mechanical, HVAC, etc. All computer based design programs need to be in standardized, layered systems. Standards would also be highly desirable for development of information portals, where a set of content and format standards at the application level would make finding technical and product information much easier.

Potential Benefits of the IT Portfolio

Making more and better information easily available to all participants in home building provides benefits broadly across all of the PATH goals and for new and existing housing. According to the ratings provided by our TRWG members, they believe that these technologies will provide much more affordable and energy efficient homes that are significantly more durable, disaster resistant, and much safer for workers. The numerical results of the TRWG member ratings of these technologies for new homes predicted the following improvements (these numbers are scaled to account for potential market penetration):

Affordability - over 8%
Energy - over 9%
Environment - about 4%
Durability - over 8%
Disaster Resistance - about 5%

Worker Safety - over 5%

The TRWG member ratings for existing housing also predicted significant durability improvement and substantial reduction in energy use associated with this portfolio.

Potential Risks of the IT Portfolio

The technical risks estimated for developing a portal, providing codes and implementing entitlement and permitting on line were very low -- about 10%. The other risks associated with these technologies have to do with acceptance by users - local code departments, builders and designers - were predicted at about 20%. The other technologies - virtual inspections, enterprise resources planning and virtual inspections - were estimated to have technical and other risks about twice as high, i.e. about 20% and 40% respectively.

INFORMATION TECHNOLOGY PORTFOLIO WRITE-UPS

The information technology portfolio developed by the PATH Technology Roadmapping Working Group in the spring of 2000 includes the following five Technology Options.

- Non-commercial Information Portal
- Information Technology for the Approval Process
- Virtual Inspections
- Enterprise Resource Planning (ERP) for Home Construction
- Software Integration and Standards

These technology options seem to be, as a minimum, a subset of those that will be required to achieve make significant progress toward PATH goals. However, there may well be additional areas that need to be addressed and for which roadmapping is required. These will be identified during the November 1 and 2 meetings of the IT Roadmapping Team. Write-ups documenting each of these technology options are below.

Non-commercial Information Portal

Technology Description: Builders and trade contractors need information that helps them make better decisions on whether and how to use products. They need product descriptions, warranty information, performance data, cost information, distribution information and installation instructions - all at little or no cost to them. Manufacturers need feedback from builders and contractors -- information on problems/issues with products in the field so that they can provide timely product improvements. Builders, contractors and manufacturers need to be able to search building industry related sites, topics, idea exchanges, and even learn about foreign developments/technologies.

The basic platform to accomplish this knowledge management should be the Internet, and the specific technology is a web-based information portal that is easy to use (e.g. YAHOO). It should provide quick access to every website related to building products, services, ideas and process. The portal needs to be non-commercial, which means not supported by advertising. Ideally, the portal would provide a way to compare product types and products. For example, it should provide information that allows a builder to compare windows with different types of frames - wood, plastic, vinyl sheathed wood, composite wood-plastic. The builder should be able to find information about durability, sizes, climatic considerations and other factors and should then be able to compare the products of different vendors side-by-side to select products. At some point the builder needs to be able to transfer to an e-commerce, B2B site to get pricing data and purchase the materials or products selected.

Current Status: The Internet already offers many web portals, including a large number for the home building industry. They vary in design and function, but the property most have in common is that they are commercial sites. Typically manufacturers or vendors of materials or products pay a fee to put advertisements for their materials and products or for their companies on the site and/or the users pay a subscription fee to use the site. There are some sites that offer catalogs of building products -- for example Sweet's publishes a catalog of information for specifiers -- but this typically consists of manufacturers' advertising literature and does not provide quick, easy access to the information required to compare and select products or materials. Other "commercial" services compile product information from manufacturers, but desired information is often difficult to locate through a profusion of advertising. A less commercial approach is favored by builders but has little support from product manufacturers.

Builders currently are not using the Internet nearly as much as commonly imagined. Several surveys conducted by the NAHB and the NAHB Research Center during the summer of 2000 show that almost 70% of builders use email once or less daily (almost 40% don't use it at all). Slightly more than 10% of builders use the Internet to locate products or manufacturers but only a few percent actually use the Internet for buying material and products. Focus groups of builders during the summer of 2000 revealed builders' feelings that: email has severe security/spamming problems, search engines gemerally give the user an overload of worthless information, and using the web is too time-consuming, especially downloads (most builders are on dial-up modems).

The NAHB Research Center has developed and maintains a website that is part of a joint, public/private sector outreach program named "ToolBase." HUD and PATH are the public sector sponsors. The purpose of ToolBase is to provide a two-way communication path for technical information between home builders and manufacturers and others in the home building industry. The ToolBase website is being redesigned and will be implemented as a portal, providing a builder-friendly, easy to navigate source. It will include a builder-oriented taxonomy to permit users to find information by browsing and a targeted search capability that includes selected URLs and predefined queries.

Non-commercial Information Portal (continued)

Benefits

Easy access to more information helps builders more easily find out how, when and where to use products which can accelerate adoption of new technologies and improve the selection and application of existing products. Manufacturers could make appropriate, targeted information available to their customer base and it would be information that gets used. With appropriate web-based feedback methods, manufacturers and builders can quickly learn about emerging problems with products and materials in the field and react appropriately. Researchers would also be able to access information that allows them to target research on emerging issues. In addition the portal would promote better integration of manufacturers and facilitate joint ventures.

Affordability	Moderate to high effect on affordability because builders can find the most cost-effective product for their application.
Energy and Environment	Moderate to high effect because builders can find information on existing and emerging products, compare and evaluate, and receive necessary application information.
Durability	High - information on correct application and installation, as well as improved feedback on problems in the field should significantly improve durability.
Safety	Low to moderate as more safety information should improve job-site safety.

Technology Development Risks and Barriers

- The technology for information portals exists, and is rapidly being improved. "Off-the-shelf" software tools are available to build portals. The challenges are; a) to structure the information in a manner most useful to users and b) to convince manufacturers to "buy in" to the process. The potential of the portal will be achieved only if the majority of the industry participates to expand the available body of public domain and private material available in electronic format.
- Currently residential construction lacks a common language that permits products to be described and specified on the Internet in a manner that allows them to easily be located, compared and selected for a specific application. The development of a detailed set of attributes for an aecXML schema that the industry agrees upon is the type of standard that may be able to solve this issue.

Other Risks and Barriers

- The cost of development and maintenance of the portal will be high, and it is not clear where funding for a non-commercial portal will come from.
- Many competitors may continue to do bits and pieces of the portal and a one-stop, integrated portal will not be achieved.

Information Technology for the Approval Process

Technology Description: Many builders and land developers believe that the approval or entitlement process is the most costly segment in their development and construction process. According to *Streamlining the Nation's Building Regulatory Process - 2000 Business Plan* (NCS/BCS, April 3, 2000). "Streamlining the nation's building regulatory processes at all levels of government can save as much as 60% of the current cost to regulate construction".

Changes in the approval process accompanied by implementation of information technology (IT) can connect people and accelerate many time-intensive steps in this process. Specific functions which can be implemented using currently available IT include:

- electronic submission, distribution and review of plans
- on-line application for and granting of permits
- on-line access to codes by designers, builders and inspectors
- automated plan checking for use by designers, builders and regulatory agencies

These technologies are currently being implemented, but in relatively few localities, mostly larger jurisdictions where building is booming and regulatory agencies face pressure to maintain or improve standards of customer service.

Current Status: Many code offices across the country are working at streamlining their processes. The NCS/BCS website -- www.ncsbcs.org -- provides a wealth of information about streamlining activities going on across the U.S. For example, San Diego, California has implemented "Process 2000", a single-stop permit office with customer service as the primary goal. The project includes a major restructuring of the code office and the way they do business and also replacement of 12 separate automation systems with a single, integrated system that includes GIS imaging and a windows-based client-server project tracking system. The project has been used as a model and successfully implemented in Savannah, Georgia and Portland, Oregon.

Fairfax County, Virginia has been working at automating and integrating its systems for several years, and is currently developing an online system for e-permitting. The office already has many capabilities online, including the GIS imaging. It already allows for on line tracking of the status of land development applications, and has applied information technology to inspections as well as home-office functions. Currently the work on e-permitting is proceeding under the guidance of an e-Permitting Steering Committee comprised of representatives of builders, the federal government (HUD and NIST), architect/engineers, NCS/BCS and others. The Fairfax County system will serve as a model for implementation of an on-line, customer-oriented permitting and entitlement system.

NCS/BCS has been leading the *Streamlining the Nation's Building Regulatory Process* project for almost 4 years, and has documented 54 model programs; a few of them summarized above. To date the focus has been on the process, but NCS/BCS just this year announced a new activity oriented towards information technology -- the "National Forum for Improving Regulatory and Building Construction Processes through Uses of Computer Technology." The forum, to be held in early 2001, will result in an action agenda. Coordination and communication of the PATH Information Technology Roadmapping activity with this forum will assure useful, effective strategies for this very important element of the home building process.

Benefits

Affordability: Streamlining the process will significantly reduce cycle time and cost. The NCS/BCS report mentioned above reported that San Diego's Process 2000 system reduced permit processing time from 25 to 12 days, saved the government more than $10 million and customers over $3.5 million. Kansas City stated their streamlined system removed 30 to 60 days from the process, and Irvine, California estimates a 30% reduction in the time for approval. On-line

	availability of code information will also allow designers and builders to implement cost effective designs. If automated plan checking is developed the economies will be further improved.
Energy and Environment:	Knowing what the code is and easily identifying where it is or is not satisfied can result in improved energy efficient with lower environmental impact.
Durability:	Better designs give better durability.
Safety:	Better designs that conform to code can improve resistance to structural damage and thereby reduce injury or death of occupants due to natural disasters.

Technology Development Risks and Barriers

- Most of the technology exists in pieces but needs to be linked and integrated to give the desired capabilities. Success of implementation hinges on the availability of interoperable software (ideally software standards) and clearly defined approval procedures.
- Automated checking of plans is doable using expert system or similar technologies, but will require lengthy and costly development, then may need a multitude of local variations to accommodate administrative procedures in different localities.
- The system must provide information and knowledge, not raw data.
- Electronic "wet stamps" may be required. The National Council of Examiners for Engineers and Surveyors has established a task force to investigate the issue of using digital technology for signing and sealing documents.

Other Risks and Barriers

- Designers, trade contractors, builders and inspectors may be reluctant to accept electronic approval processes.
- Low cost broadband access is needed by all users to realize the full potential of this approach. This is rapidly becoming available to users in larger metropolitan areas as DSL and/or cable data modems at low cost (about $50/month).

Estimated Time to Develop and Deploy

Will likely be developed and deployed in steps, starting with simple permitting which is already underway. But widespread use of electronic submittal and approval is at least several years off.

Virtual Inspections

Technology Description: Inspections slow the construction process, even with the best efforts of builders and regulatory officials. Scheduling inspections to assure that the inspector shows up at exactly the right moment, much less the right day, is almost impossible in most localities. Although some localities are working to improve their responsiveness by training contract inspectors to handle overloads, that probably is not the most cost-effective solution. Information technology could significantly improve this part of the home building process. For example, local code agencies could implement a system that uses information uploads from builders. Self-certifications or photographs could be used for proof of compliance. GPS location equipment also might be used, for example to prove that a photograph has been taken at a specific location. Current or emerging technologies that seem especially applicable to this application include small digital cameras, portable PCs, wired and wireless data communications (and Wireless Application Protocol - WAP) and GPS location equipment.

Current Status: Electronic technologies are currently available to perform most of the required functions. These include inexpensive laptop and palmtop computers, wireless voice and data communications, and low-cost digital cameras. In fact, Fairfax County already uses laptops for accomplishing inspections and uses the Internet to upload inspection results to the office. The office also downloads to the laptops the sites to be inspected and the schedule for inspection. Also, construction websites that can keep all parties, including inspectors, aware of the schedule, are currently available. These, in combination can provide capability to get inspection information from the job site to the inspector's office and allow the inspector to interact with the building team at the jobsite in real time.

Benefits

Affordability:	Large reductions in cycle time would greatly reduce cost. Builders could take control of their schedule. The streamlined "virtual" inspection process would reduce or eliminate the down time that occurs when inspections aren't timely and construction cannot continue.
Energy and Environment:	Could potentially improve the quality of inspections, therefore the assurance that energy codes are implemented.
Durability:	The process could significantly contribute to higher quality levels in the construction process as builders and their trade contractors learn to "self certify" and inspectors get the information they need to make accurate JIT inspections.
Safety:	Improved quality of inspections could improve resistance of houses to natural disasters.

Technology Development Risks and Barriers

- Can the system and software be sufficiently user friendly so that the average builder, trade contractor and inspector can easily use it?
- Not a hardware problem as much as an integration problem for code offices' and builders' operations.
- Software vendors and systems integrators and web developers and communication providers should see this as a huge opportunity.

Other Risks and Barriers

- Developing the system would be expensive, but the training and effective implementation could be much more expensive.
- Although large, volume builders should be able to acquire and use this type of system easily, it's not clear that the many small builders and contractors will be able and/or willing to.
- Smaller code offices may have great difficulty in adopting this system.
- It is not clear what levels of documentation, verification, audit and record keeping are needed.

ERP for Home Construction

Technology Description: Enterprise Resource Planning (ERP) systems typically have the capability to plan, schedule and control production, purchasing, inventory, sales, and logistics. They are sometimes considered the information backbone of an operation and have been installed in many large production facilities. In 1999 the ERP market was estimated at over $20 billion and expected to grow at an annual rate of over 30% for the next five years ("Small Manufacturers Seek Best ERP Fit", *Manufacturing Engineering*, October 1999).

ERP converts data to understandable information for each participant in the manufacturing process. It communicates actions taken to the other participants. ERP is a fully integrated suite of manufacturing and enterprise management applications that brings the benefits of information technology (IT) to the production process. In its ideal form, it is an "open system" architecture, which enables other applications to "plug-in" while ensuring the system can continue to evolve consistent with technological changes. IT enables production efficiencies and controls to be applied to the processes on the factory floor. ERP becomes the engine that drives the process using numerous, related technologies for manufacturing such as computer controlled machines, robots and data collection devices such as bar code readers and laser scanners. Although "classic" ERP has been an internal management tool, the providers of ERP are increasingly providing ERP extensions for customer-relations management, supply-chain management, and distribution chain management. These extensions relate closely to the recent emergence of Internet applications for business-to-business (B2B) and business-to-consumer (B2C) commerce.

In the near term, the concept is to apply ERP technology to fabrication of major housing subsystems such as wall, roof and/or floor panels in factories where these assemblies are constructed. Then, in the longer term, ERP needs to be extended on out to the jobsite. ERP can provide a structured process such that permits builders and subcontractors to fabricate components on site or near site using factory processes. This process will allow for automatic flow of data (information) from design to component assembly. If the process involves integrated wall, floor, roof systems, then the quality control of subsystems (thermal inertia, R-factor, electrical, sewer, water, cooling, heating, etc) can be brought to one location under an overreaching site coordination. On-site ERP, although much more of a challenge to implement than factory ERP, has the potential of reducing or eliminating the transportation problems associated with factory-built components or modules, and will not require large changes to the site-built paradigm currently followed by the majority of home builders.

Current Status: ERP is now routinely used in many manufacturing environments. For example, Whirlpool, a supplier to home builders, recently implemented an ERP system. It has traditionally been implemented in large manufacturing environments, but many medium size manufacturers are also beginning to use it. Some of the important changes occurring in ERP are:

- It is becoming more modular so that it can be implemented in stages
- It is being offered by applications service providers (ASPs) so that the smaller manufacturer (builder) can get the features or functions without buying the software and hardware and without developing an internal IT capability.
- It is expanding in scope to include customer management and supply and distribution-side management

ERP is beginning to be a factor in the home building industry. It is at various stages of implementation in factories that produce components such as windows, trusses, panels and also facilities/companies that produce modular and factory built homes. Production builders are seriously looking at ERP (and some may be implementing it). Some builders are moving in small steps. One production builder is looking to implement gradually, starting with the sales office information technology, then to project management using the web, and only then to ERP or data warehousing. Use of ERP and web-based information technology for purchasing and procurement is not a high priority for this builder.

ERP for Home Construction (continued)

Benefits

Affordability	Affordability can be significantly improved through improved labor control, improved production efficiencies, potential for mass customization, virtual elimination of jobsite waste, reduction in cycle time.
Energy and Environment	High, based on opportunities to improve design and workmanship..
Durability	Excellent depending on material chosen. The controlled quality environment offered by ERP will virtually assure that the components are installed correctly, every time. This means that various "systems" problems (incorrect flashing, improperly installed house wrap, etc.) should be virtually eliminated.
Safety	High improvement should be achieved in worker safety as the controlled, factory or factory-like environment is implemented.

The application of ERP that can evolve with product and material technologies will open the door for more internal R&D -- a better environment for product and process innovation.

Technology Development Risks and Barriers

- The underlying software and hardware technologies are well developed for ERP in factories, although there may be additional requirements unique to construction of components for houses. Also, the integration of software (described separately under "Software Integration and Standards) is critical to success of ERP. ERP on or near the job site may require significant development of information technology hardware and software.
- A high level of technical expertise needed will be needed on the part of builders who will also be required to think like a manufacturer, not a builder.
- Realizing the full potential of ERP is greatly complicated in firms that subcontract extensively because relevant information is more dispersed.

Other Risks and Barriers

- Implementation requires a cultural mindset change in the industry. Also, there is little tangible proof of profit and it has proven hard to predict cost of implementation -- software has been said to reflect only 20% of the total cost.
- Recent ERP implementations in some large companies has been problematic (Whirlpool and Hersheys are two that have reported problems).
- Implementing ERP in the multitude of small and very small companies that characterize the home building industry will be extremely difficult.

Software Integration and Standards

Technology Description: Standardized communication protocols and/or integration of software for all phases of construction, design, engineering, evaluation, modeling, bill of materials, estimating, and ordering. This is to include design (CAD) programs for architectural framing layout, structural design, plumbing, mechanical, HVAC, etc. All computer-based design programs need to be in standardized, layered systems.

The description of building components and materials needs to be standardized to permit designers, specifiers and sales people (typically using automated design and configuration software) to find and insert in the specification a description that adequate to assure that the house will be built as designed. The description would also be sufficiently complete to support purchasing.

Current Status: Currently, many useful independent packages exist, but the packages are typically difficult to tie together because of proprietary formats, undocumented interfaces and incompatibilities in the way information is defined and presented. Other manufacturing industries (e.g. automotive) have made significant progress in tying together the entire process, from the design through production and testing. Similar techniques need to be applied to residential construction.

The aecXML (extensible markup language) is an information exchange protocol that shows promise of allowing the disparate software packages to pass information. To date there has significant activity in defining XML schemas for the commercial construction sector, but not much for the residential sector. And, even in the commercial sector there has been a tendency to do use "attribute" definitions, which means that the way details of a component or material are described can change from manufacturer to manufacturer. The industry needs to reach agreement on these detail descriptions.

The National Institute of Building Sciences, working with the American Institute of Architects (AIA), the Construction Specifications Institute (CSI) and the U.S. CADD/GIS Technology Center, has developed a "U.S. National CAD Standard." The standard includes CAD Layer Guidelines, Plotting Guidelines and a Uniform Drawing System.

Benefits

Standardization or integration improves communication between design professionals, eliminates potential errors and re-work, speeds the design process, facilitates structural optimization and whole house design and eliminates problems on the job site. Both new construction and remodeling will benefit.

Affordability	This technology would significantly affect affordability because it would reduce cycle time and labor overhead in many ways.
Energy and Environment	The effect on energy and the environment would be low. Some gains could be afforded by the improved/increased application of CAD to HVAC designs and specifications and to energy analysis software tools.
Durability	The durability should be improved at least moderately because of improvements in quality afforded by the integrated software.
Safety	No improvement in worker safety is expected.

Technology Development Risks and Barriers

- Major, significant software development would be required to provide the integration, even after standards are developed, and there is no assurance this will take place.
- Desire of software companies to retain proprietary information and protocols may impede progress. Software provider cooperation is critical. Open source software may help change this mindset.

Other Risks and Barriers

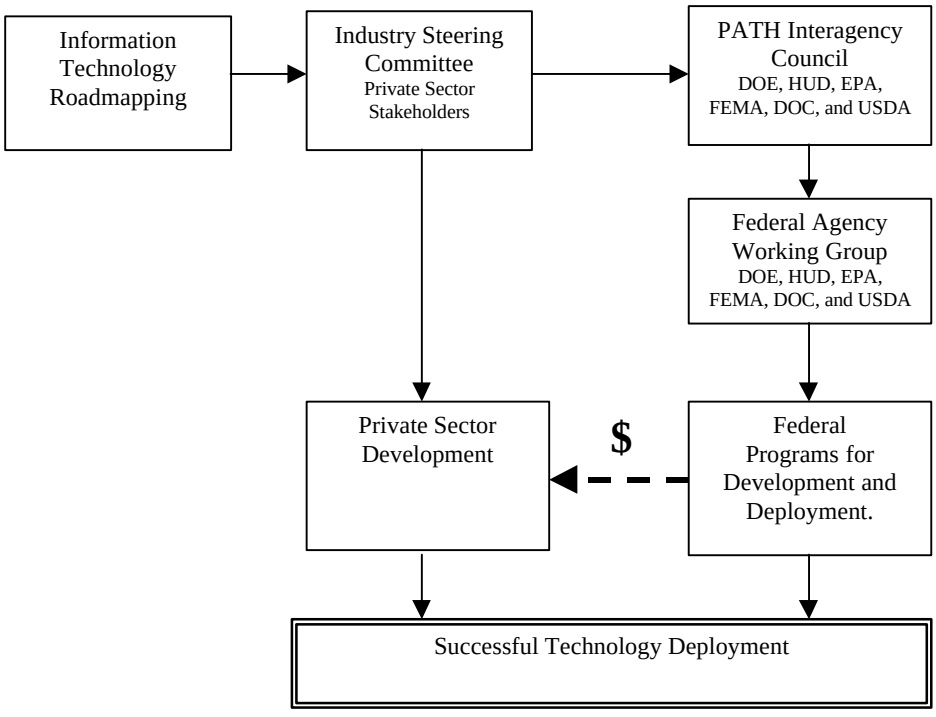
- It is not clear who would take the lead for developing the standards (although NIST has done so on the BACNET standard for commercial building control).
- Participation in standards development is costly, and developing consensus can take several years.

APPENDIX A

PATH Organization, Technology Outreach and Technology Roadmapping

Work is underway on several fronts in pursuit of the PATH goals. Extensive technology outreach activities are ongoing, both over the Internet and in field evaluations or demonstrations around the U.S. At the same time, PATH has a Technology Roadmapping Working Group, which has been laying groundwork for the development and introduction of beneficial new products over the life of the program. The diagram below shows how the technology roadmap information flows. The roadmapping information - time-phased strategies and projects - is approved by the Industry Steering Committee which is comprised of private sector members.

The approved roadmaps are then provided to the public sector via the PATH Interagency Council, which consists of the Assistant Secretaries of participating agencies. High priority items may eventually result in R&D or other types of programs that would accelerate the technologies. The roadmaps are also made available to the private sector, where companies might decide to separately or cooperatively develop products related to or derived from the technology. The end result will drive R&D funding by both the private and public sector.



In addition, four other PATH Working Groups have been organized to focus on the various institutional forces that affect technology adoption and utilization, including (1) finance, (2) labor and quality issues, (3) barriers and insurance, and (4) consumer education. Activities of these PATH Working Groups are also under the general oversight of the Industry Steering Committee are summarized below:

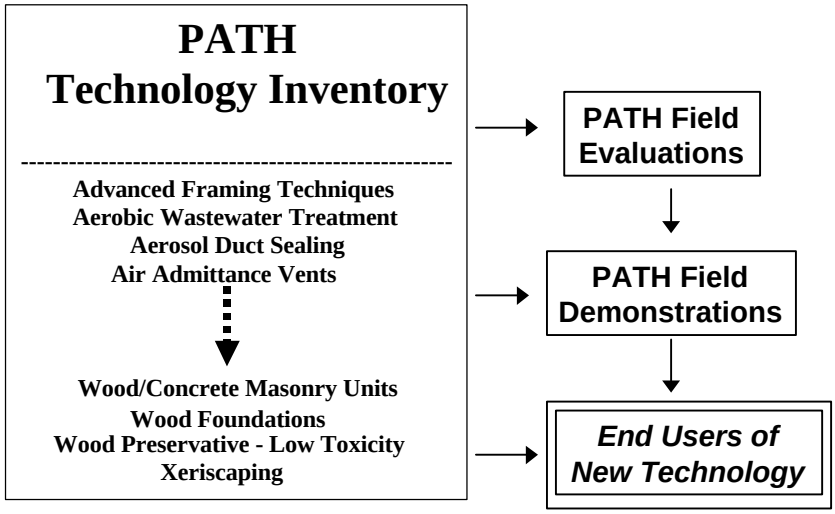
Barriers and Insurance Working Group. This group is investigating ways to help control exposure to liability and translate improved building performance into lower insurance premiums as a consumer incentive.

Consumer Education Working Group. This group is looking at ways to stimulate consumer demand and create market "pull" for PATH technologies.

Labor and Quality Working Group. This group is working to promote quality improvement methods and provide training that will address persistent labor shortages in the construction market. It could potentially play a role by identifying strategies for training construction labor to use information technology and maximizing the quality improvement potential of ERP.

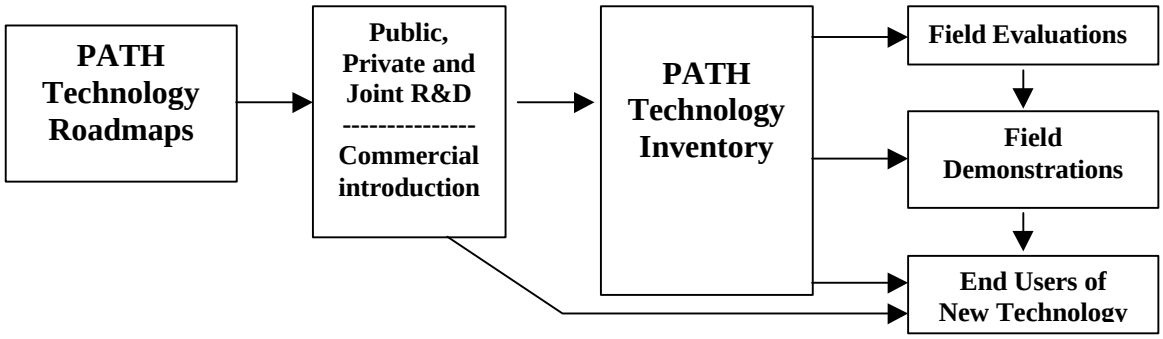
Finance Working Group. This group is working to enhance "energy efficient mortgages" and define similar products offering expanded access to financing or reducing the cost of originating mortgages and other loans.

PATH Technology Outreach. An extensive Technology Inventory with information about new, emerging or underutilized housing technologies was developed early in the program and placed on the Internet at "http://www.nahbrc.org/toolbase/xtech.html". Visitors will find searchable information about the nature and status of more than 150 technologies for housing. Several of these technologies are being more closely studied and reported on as part of PATH Field Evaluations. Others are being used and documented on a larger scale in PATH Demonstration Projects.



Notably lacking from the PATH Technology Inventory are information technologies. The fact that information technologies do not appear in the list is no doubt partly because the technical evaluation team was not looking for such technologies, but may also be symptomatic of the small amount of emphasis the industry has to date placed upon information technologies.

PATH Technology Roadmapping. PATH initiated a process of Technology Roadmapping to complement the technology outreach and help accelerate the development and introduction of new technologies that can achieve progress towards the PATH goals. Roadmapping can be viewed as intended to ensure a future supply of new items for inclusion in the Technology Inventory, and for PATH Field Evaluations and Demonstrations, as shown below. Specific areas for roadmapping will be selected by the Industry Steering Committee, which will review and approve the results.



The roadmapping process began with a two-day brainstorming session in March 2000, where a diverse group of 35 experts reviewed all the PATH goals, then identified and documented a total of 40 "technology options" as candidates for further study. The titles of these options give some idea of their scope and content.

TECHNOLOGY OPTIONS IDENTIFIED DURING MARCH, 2000 PATH BRAINSTORMING

Advanced Roof Coverings	Helical (screw) Footings	Precast Insulated Wall Panels
Augmented Reality	Homogeneous Wall Panels	Precast Panelized Roof Components
Automated Tools	Improving Safety in Roof Construction	Prefabricated Ducts
Connected Home	Indoor Air Quality	Radiant Heating
Cooling with Night Air	*Information Technology for the Approval Process	Roof Sandwich Panels with Utilities
Distributed Generation - Fuel Cells	Insulating Concrete Forms	Self-Fitting Membrane Interiors
Distributed Generation - PV Solar Cells	Integrated Wall, Floor and Roof Systems	*Software Integration/Standards
Electronic Control Technology for HVAC	Interlocking Roof Sections	Sound Isolation
Enclosed Attic Space	Less-Finished Interiors	Targeted Heating and Cooling
*Enterprise Resource Planning for Home Construction	Mechanical System Disentangling	*Virtual Inspections
Flexible, Adaptable Space	Microtechnology	Water Recycling and Reuse
Foundation Stave System	Modular/Whole House Systems	Whole House Process Redesign
Frost-Protected Shallow Foundations	*Non-Commercial Information Portal	Wireless Communications
		Zero Negative Emissions

*The technology options marked with an asterisk are assigned to the Information Technology roadmapping team.

One-page write-ups of all 40 options in the list can be viewed on-line through the Public Access area at "http://roadmap.nahbrc.org". The brainstorming was followed by an evaluation process in which benefits, risks, market potential and other factors were assessed for each technology option. Based on the results of the participant evaluations, the following three "portfolios" were selected for initial roadmap development:

1. *Information Technology to Accelerate and Streamline Home Building*
2. *Advanced, Panelized-Type Systems*
3. *Whole-House and Building Process Redesign*

Each of these portfolios includes one or more Technology Options that received very high ratings along with other closely related items. Roadmapping task groups being organized under each of these areas will operate concurrently this fall and into the year 2001.