A "Plug and Play" Air Delivery System for Low Load Homes

2017 Building Technologies Office Peer Review

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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Project Summary

Timeline:

Start date: 08/01/2015

Planned end date: 01/31/2017

Key Milestones

1. Complete Cost Analysis, 01/31/2017
2. Develop Design Methodology, 01/31/2017
3. Secure Builder and Manuf Interest, 01/31/2017

Budget:

Total Project $ to Date:

- DOE: $600,085.00
- Cost Share: $220,845

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- Cost Share: $220,845

Key Partners:

Housing Innovation Alliance

Project Outcome: The Project Goal is to develop a simplified residential air delivery system that is a solution to air distribution and comfort delivery issues in low-load production-built homes.

Outcomes include the following:

- A straightforward, intuitive design method and companion guidance documents
- Justification and suggested language for needed code and standard changes
- Commitment from a manufacturer partner to pursue product development and a builder partner to demonstrate the technology based on the project's findings

Purpose and Objectives

Problem Statement:

- The residential HVAC market is struggling to achieve effective HVAC system design, installation, and commissioning in lower-load homes
- Heating and cooling to each space is not optimally delivered from smaller-capacity equipment with traditional air distribution systems
- Traditional duct systems have a host of problems, including installation labor, leakage, constriction, and energy loss
- These issues can inhibit low-load homes from achieving broader industry performance goals, including energy efficiency and comfort

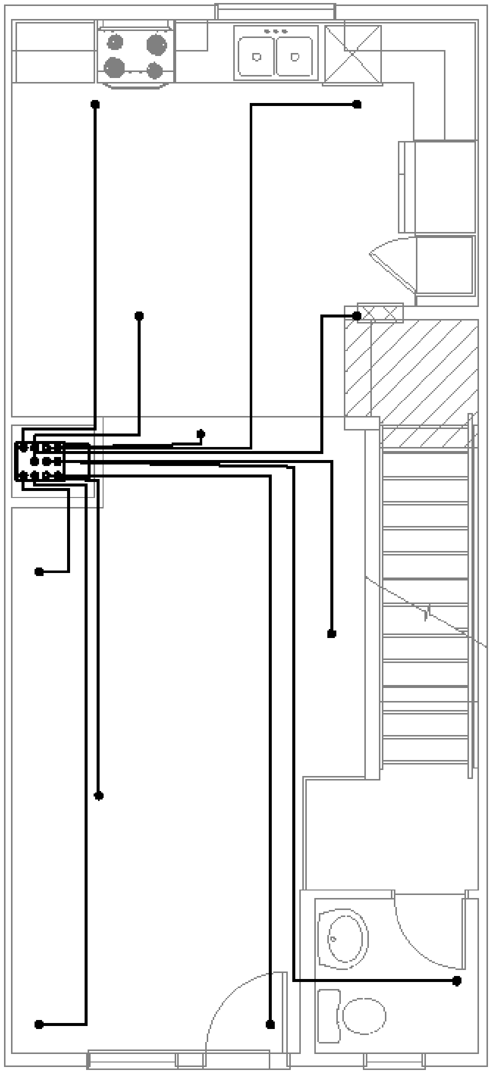
Target Market and Audience:

- <u>Market</u>: new construction low-load homes (0.01 quads/year)
  - 2012 IECC enclosure, 2,000-3,000 ft^2 "sweet spot"
- <u>Audience</u>: Home builders, HVAC contractors and system designers, HVAC equipment manufacturers and component suppliers, and material suppliers

Purpose and Objectives

Impact of Project: Project Outputs

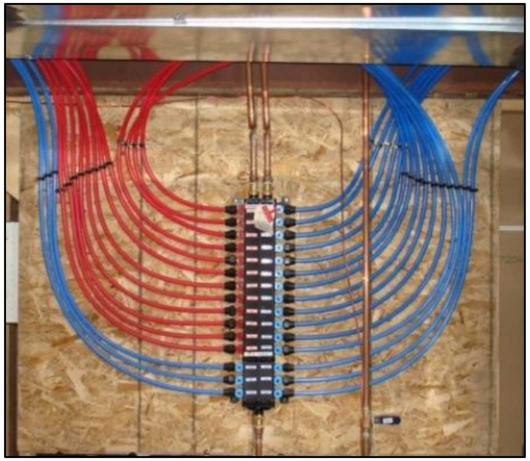
- Characterize the performance parameters for plastic small diameter rigid ducts and fittings and other, off-the-shelf duct products
- Characterize the installed "comfort" (temperature) impact of Plug and Play system
- Define the range of application for the system in terms of home size, load, load density, and climate
- Analyze the cost and installation impacts
- Compare the performance and cost to traditional air distribution system approaches
- Develop installation guidance
- Develop a documented design methodology
- Secure interest from a builder and manufacturer

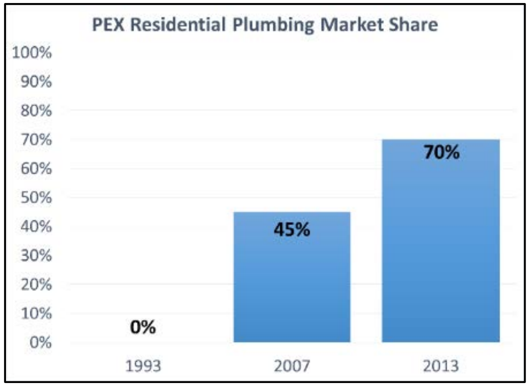


Purpose and Objectives

Impact of Project:

- Could revolutionize ducted air distribution like PEX piping impacted plumbing distribution
  - PEX costs 25% - 45% less, installed
  - Rapid claim to majority market share
- Potential for significant cost savings vs. conventional systems, with performance benefits
  - More discrete room-by-room zoning opportunities
  - Improved comfort - energy is effectively used
  - Simplified design and installation
  - Facilitates integration into conditioned space
- Alternative to all conventional and small diameter air distribution systems on the market
- Residential ductwork is a $1.2 Billion market annually
  - 10% new constr. market penetration in 5 years
  - 25% penetration in 10 years, plus retrofit market
- As costs decrease, market penetration increases





Purpose and Objectives

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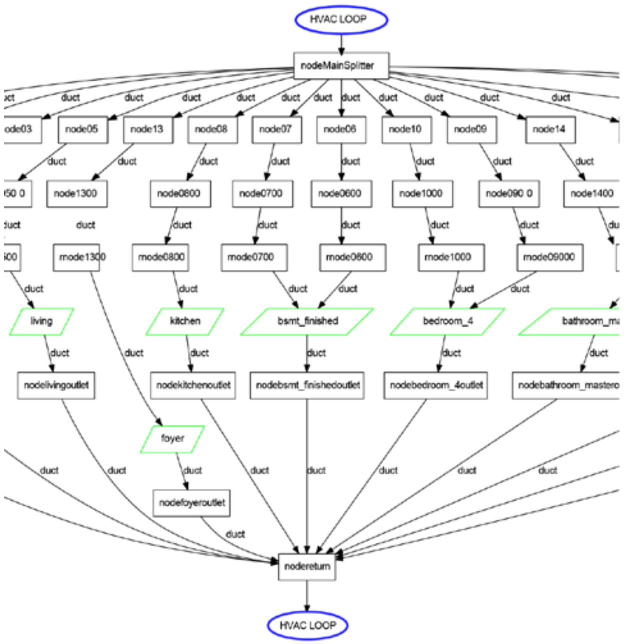
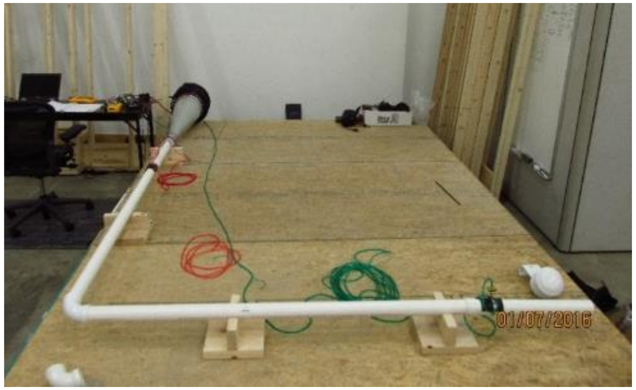
Approach

Approach:

- Use benchtop tests, mock ups, lab house tests, and performance simulation to do the following:
  - Develop a new “Plug and Play” design methodology (NO BALANCING DAMPERS)
  - Define its application parameters
  - Evaluate installation, constructability, and cost
  - Test this design against a conventional system
- Engage the market





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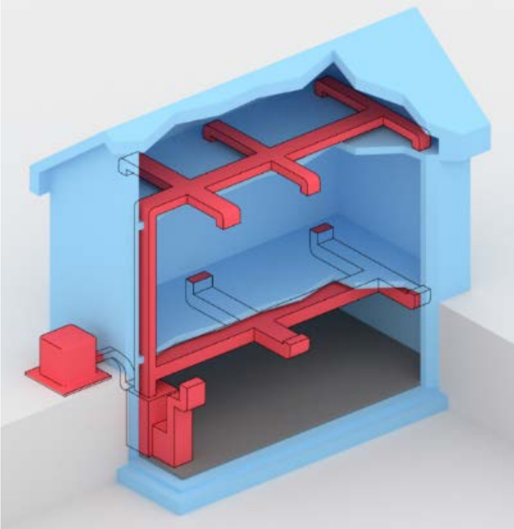
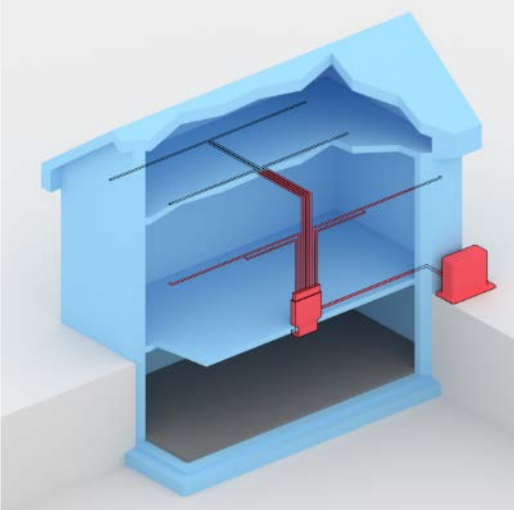
Approach

Key Issues: Conventional Duct Systems

- Difficult to access all duct runs for maintenance and dampering
- Current labor pool is unwilling, unskilled, or unavailable to practice good duct design and installation
- Traditional duct systems are often:
  - Oversized for low loads
  - Leaky, requiring secondary sealing
  - Routed though unconditioned space
  - Not well-integrated into home
  - Dirt collectors
- Comfort and performance suffers
- Too many SKUs





Approach

Distinctive Characteristics:

- A home-run manifold of small diameter (2-3 inch) ducts to work with small-capacity equipment to deliver predictable performance for low-load homes
- Intended to use off-the-shelf products as a kit-of-parts with fewer SKU's to install a simplified duct system with less error/waste than conventional systems
- Conventionally-skilled tradespersons and home designers will have a quick, efficient and credible method for designing an air delivery system that responds to the unique qualities of lower-load homes and emerging comfort systems, providing reliable design results.

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Progress and Accomplishments

Accomplishments:

- Completed a design methodology
  - Using ACCA Manual J loads and airflows
  - Based on plastic ducts but completed analysis of alternate duct materials
  - Evaluated range of applications for Plug and Play duct system
- Simulation
  - Created a detailed multi-zone model using Energy Plus Airflow Network
  - Calibrated model to unoccupied lab home data
  - Evaluated "comfort" performance of Plug and Play duct system compared to traditional systems
- Compared installation material & labor costs to traditional duct system
- Engaged Codes community around use of plastic ducts

Plug-and-Play Home Run Manifold Design Tool

v 0.1

Project

Nominal CFM	26	(based on 30' L, 60 Pa)
Available Pressure	0.35	in. wc. (from manual S) (minus 0.1" for manifold)
Heating factor	0.0231	Btuh / CFM
Cooling factor	0.0268	Btuh / CFM

#	Room	Htg Load (Btuh)	Clg Load (Btuh)	CFM	Len (ft.)	Elb	Ducts
1	Master Bedroom	2365	2316	55	29	5	2
2	Bath 2	642	220	15	12	3	1
3	Bedroom 2	2025	1500	47	15	4	2
4	Powder	798	620	18	22	3	1
5	1st Floor	6489	4486	150	16	3	5
6							
7							
8							
9							
10							
11							
12							
13							
14							
15							
16							
	Total:	12319	9142	285	94	18	11

Select Material

2" PVC

EL of 90	2
Pipe Diameter	2.0

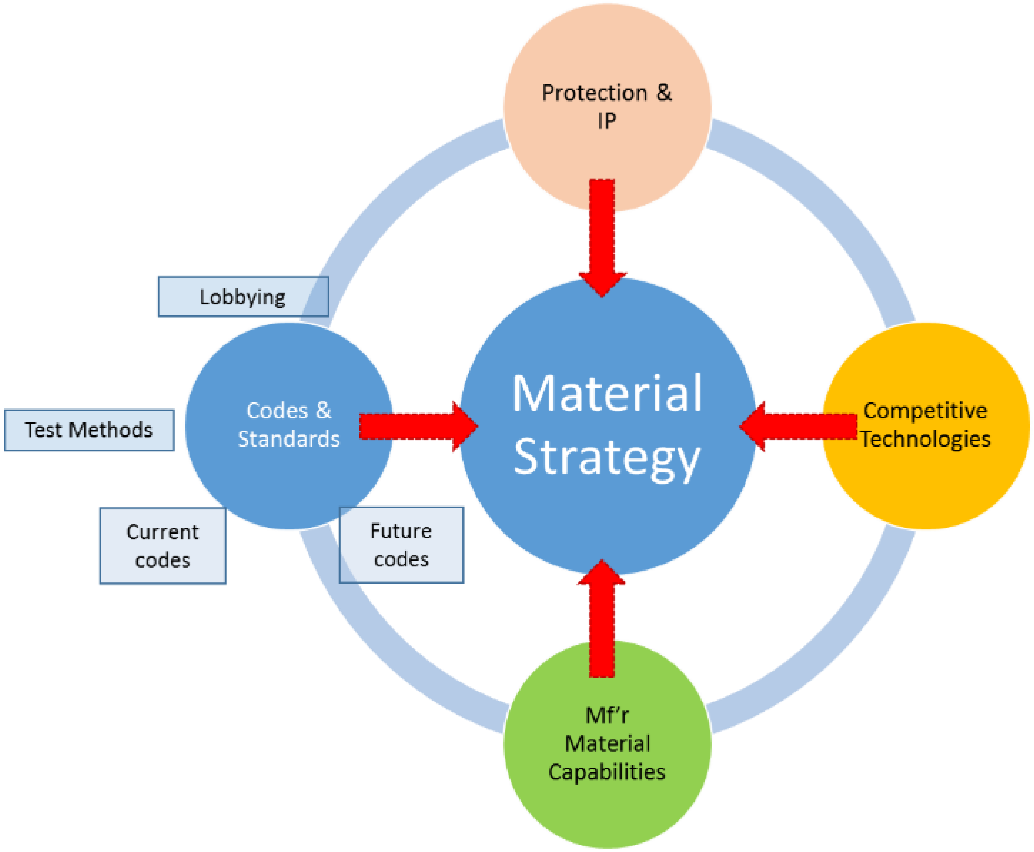
Coefficients – 2" PVC CFM = (Pa/C*L)^(1/n)

C	0.01146
n	1.70239

Progress and Accomplishments

Market Impact:

- Ongoing engagement with homebuilders – interest to demonstrate or pilot the technology when available
- Engaging potential commercialization partners
- Pursuing code approval of plastic ducts while exploring the use of existing, off-the-shelf duct materials
- Defining target house types and climate zones
- Developing cost comparisons and value story
- Engaging Standards organizations



Progress and Accomplishments

Awards/Recognition: None

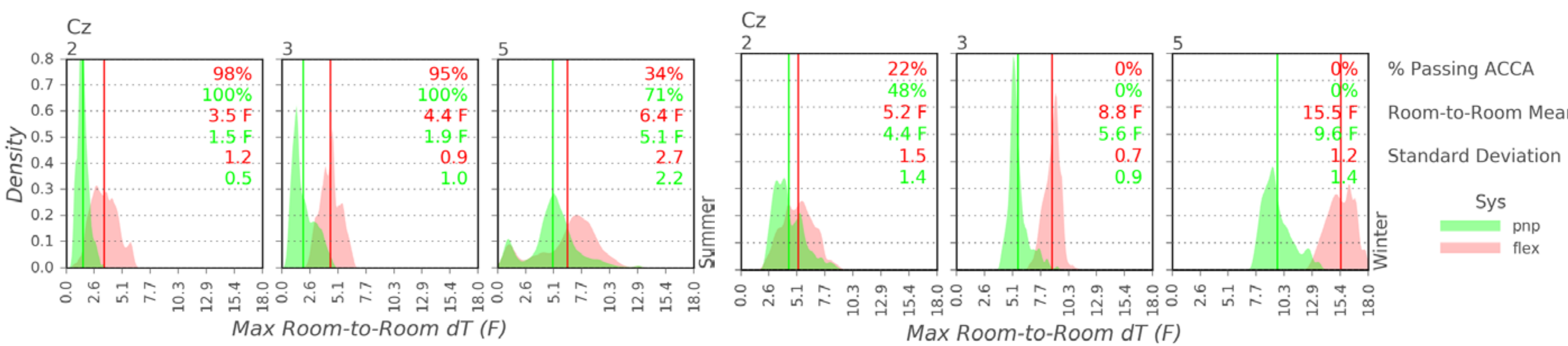
Lessons Learned:

- All homes could use 3.0” flexible ductwork.
- 2.5” smooth ductwork provides sufficient airflow for a 2200 sq. ft. home in climate zones 2-5.
- Smaller homes (<1200 sq. ft.) or very low load homes built (i.e. Passive House) can use 2.0” smooth ductwork.
- A simplified design method is possible with proper load calculations and uniform duct diameters & materials.

Progress and Accomplishments

Lessons Learned:

- Plug and Play achieves equal or better thermal uniformity in homes than a traditional duct system.
  - Exception when large disparity between heating and cooling loads and airflow needs in the house
- The EnergyPlus Airflow Network is a powerful tool to simulate the dynamic effects of air delivery systems



Progress and Accomplishments

Lessons Learned:

- The Plug and Play duct system is cost competitive to traditional duct systems, installed

Duct System	Hours	Labor Cost @ $33.35 hr.	Material Cost	SKU'S	Length of duct	Cost of ductwork system
Traditional	18 (including 6 hr bulkhead)	589	487	6	35' trunk + 50' flex	$ 1,076
2.5" PVC	10 (including 6 hr bulkhead)	330	686	6	210'	$ 1,017
2" PVC	6	195	440	6	250'	$ 635

Notes:

- PVC costs were off-the-shelf pricing
- Time and motion study was conducted in a 1,200 ft^2 2-story townhome
- 2.5" PVC is used only for furnace combustion pipes so off-the-shelf prices are escalated
- Schedule 40 pipe is not required for air distribution; schedule 10 to 15 would be more adequate which could reduce the material costs by half

Progress and Accomplishments

Lessons Learned:

- Code acceptance of plastic duct materials hinge on their function as a pathway between discrete zones (rooms) in a home
  - An automatic shutoff at the furnace could be a solution
  - Shutoff dampers between rooms is another option
  - Ultimately, a plastic meeting UL 181 Class 1 requirements for flame spread and smoke is ideal

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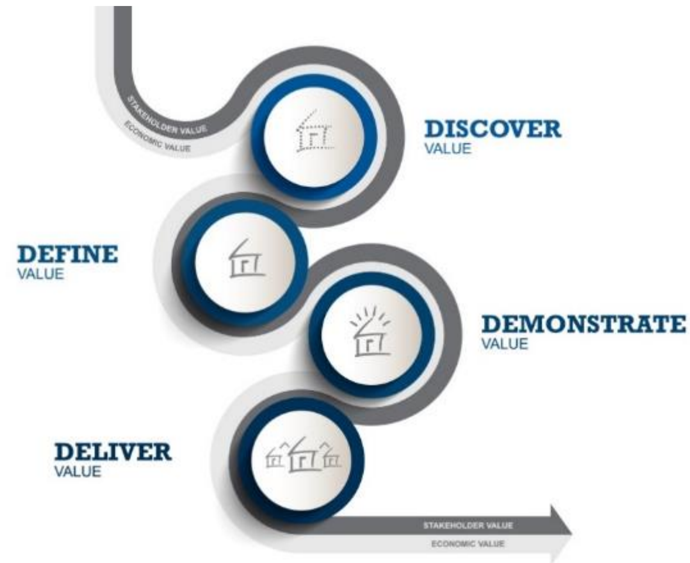
Project Integration and Collaboration

Project Integration:

- Innovation Pathway
  - Model for collaboration to discover, define, demonstrate and deliver innovative solutions with economic and stakeholder value
- Builder Engagement
  - Connect with builder clients and partners to socialize the technology concept and project outcomes
- Manufacturer Engagement
  - Explore commercialization partnerships
- National Lab Engagement
  - Critical collaboration on development of simulation aspects (i.e. EnergyPlus Airflow Network)
- Industry Codes & Standards Organizations
  - ASHRAE, ICC



ASHRAE®

INTERNATIONAL CODE COUNCIL®

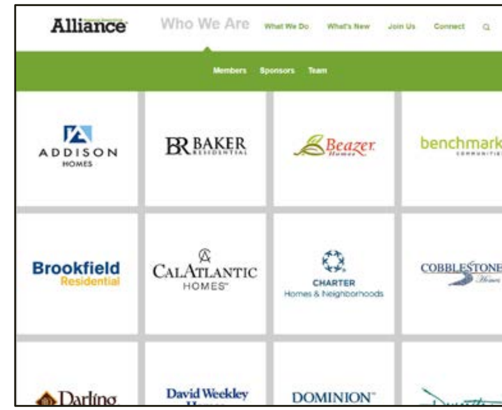
Project Integration and Collaboration

Partners, Subcontractors, and Collaborators:
Housing Innovation Alliance (a.k.a. "Alliance")

- 75+ homebuilder members
- Represent 200,000 housing units annually
- A dozen innovative building industry product suppliers and manufacturers
- Collaborative homebuilding solutions
- Multi-venue feedback loop
- http://www.housinginnovationalliance.com/

Alliance partnership provides ongoing venue for communication of project outputs, socialization among Top 100 homebuilders, manufacturer engagement, and opportunities for product demonstration and a path to market.

Housing Innovation Alliance™



Project Integration and Collaboration

Communications:
- Housing Innovation Alliance
- ASHRAE
- Pennsylvania Housing Research Center
- U.S. Department of Energy

Next Steps:
- Complete final project report and peer reviews
- Close out project documentation

Future Opportunities:
- Secure commercialization partner to develop technology and deliver to market
- Develop companion components: dampers, plenum/manifold, diffusers
- Develop design & commissioning standards
- Demonstrate product technology in field test homes and pilot projects
- Explore retrofit market integration

REFERENCE SLIDES

Project Budget

Project Budget: $820,930: $600,085 Federal + $220,845 Cost Share
Variances: A no-cost time extension was granted in June 2016 to extend the project timeline from July 31, 2016 to January 31, 2017.
Cost to Date: 100% of project budget expended through January 31, 2017.
Additional Funding: None

Budget History					
Aug. 1, 2015 – FY 2016 (past) THRU 9/30/16		FY 2017 (current)		FY 2018 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$529,866.77	$220,845.00	$600,085.00	$220,845.00	None	None

Project Plan and Schedule