U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

High-efficiency Low Global-Warming Potential (GWP) Packaged Rooftop System

United Technologies Research Center

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Project Summary

Timeline:

Start date: 1/1/2018

Planned end date: 2/28/2020

Key Milestones

- ✓ Design Review (Go/No-Go) 9/25/2018
- First prototype system tested at key SEER conditions (5/1/2019)
- Second prototype system meets value proposition (1/1/2020)

Budget:

Total Project to Date: $665k (as of 3/15/19)

- DOE: $466k
- Cost Share: $200k

Total Project : $1,885k

- DOE: $1,320k
- Cost Share: $565k

Key Partners:

Carrier Central Engineering
Carrier Commercial HVAC (North America)
Carrier Advanced Systems

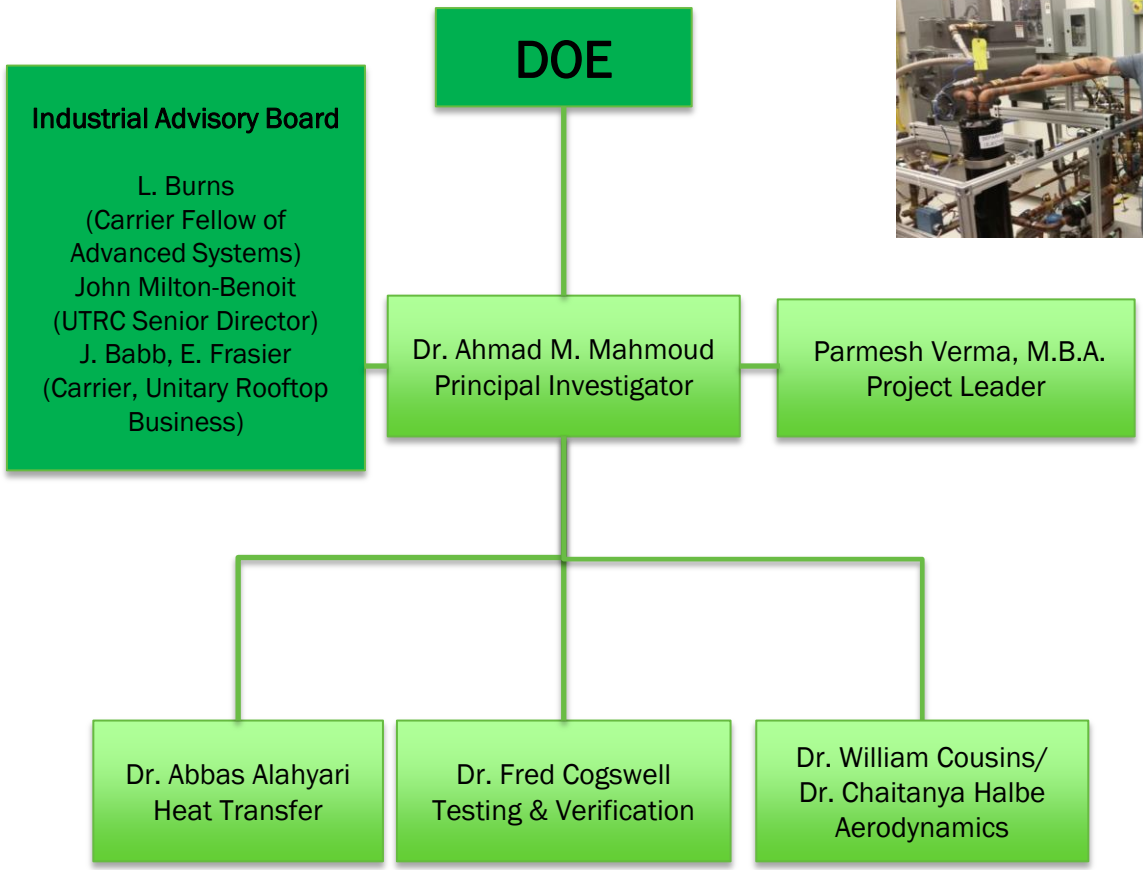
Project Outcome:

United Technologies Research Center (UTRC) proposes to demonstrate (TRL6) a high-efficiency 5TR packaged cooling Rooftop Unit (RTU) that:

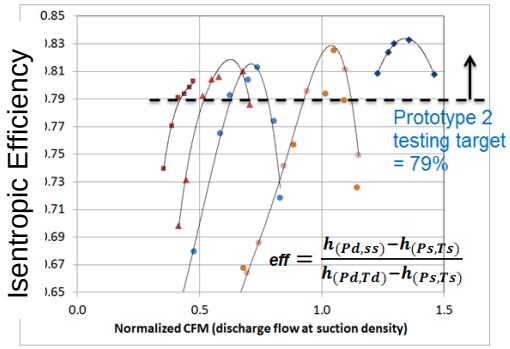
- Uses a non-flammable, low GWP and high efficiency refrigerant as a disruptive, high efficiency sustainable and safe space cooling solution.
- Has the potential to provide >30% annual energy savings with a primary seasonal COP > 2.1 (DOE goal 2.0)

High-efficiency Low GWP Packaged RTU System

Team



Compressor Development



Efficiency Curves

System Test Facilities

Unique Qualifications

- Completed compressor development project
- Market analysis & cost (Carrier BU)
- High-fidelity modeling & experimental facilities

High-efficiency Low GWP Packaged RTU System

Problem Definition:

- Current small commercial building HVAC systems use R410A with GWP=2088*.
- Potential regulations and market drivers are pushing the HVAC&R industry to lower direct GWP and higher efficiency systems (indirect GWP).
- New low-GWP refrigerants require new approaches for compressor and system design in order to achieve high efficiency and safe/reliable operation.

Solution must be cost-effective and have favorable value proposition (e.g. <2 year payback in new and retrofit construction)

Target Market and Audience:

Packaged Systems:

- Primary: Commercial rooftop cooling systems
- Secondary: Residential cooling systems

High-efficiency Low GWP Packaged RTU System

The Solution

State-of-the-Art

- Radical departure in compressor, heat exchanger and system balance of plant and integration requires significant R&D
- Current technology solutions pose challenges with future GWP or flammability mandates

Develop and demonstrate (TRL6) a high-efficiency 5TR packaged roof-top system:

- Cost-effective
- Sustainable, non-flammable, non-toxic and high-efficiency refrigerant
- High cycle efficiency (>+10% vs. R410A).
- Technology shall be matured from Technology Readiness Level (TRL) 4 to 6* in 26 months (a fully functional prototype tested at relevant conditions in a relevant environment)

Metric	State of the Art	Proposed
Use of Low GWP A1 refrigerants	R410A; Not possible to meet capacity and efficiency targets	Integrated system with low GWP refrigerant: • High-efficiency compressor • Highly effective and low pressure drop evaporator • High-effectiveness compact condenser
Primary COP	15.6 SEER Rooftop systems (5– 20 Ton)	>20SEER (i.e. >2.1 primary seasonal COP) leading to 30% primary energy reduction
Payback	<5 years	< 2 years (new construction & retrofits)

*https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

High-efficiency Low GWP Packaged RTU System

Approach

Phase 1: Component and system design and optimization and supplier engagement.

Phase 2: Two prototypes will be built, and commissioned and tested at UTRC Psychrometric Facility to demonstrate:

1) targeted system performance i.e. Seasonal Energy Efficiency Ratio (SEER)
2) system operability over a wide range of conditions dictated by market needs
3) validate value proposition.

Advantage, Differentiation, and Impact

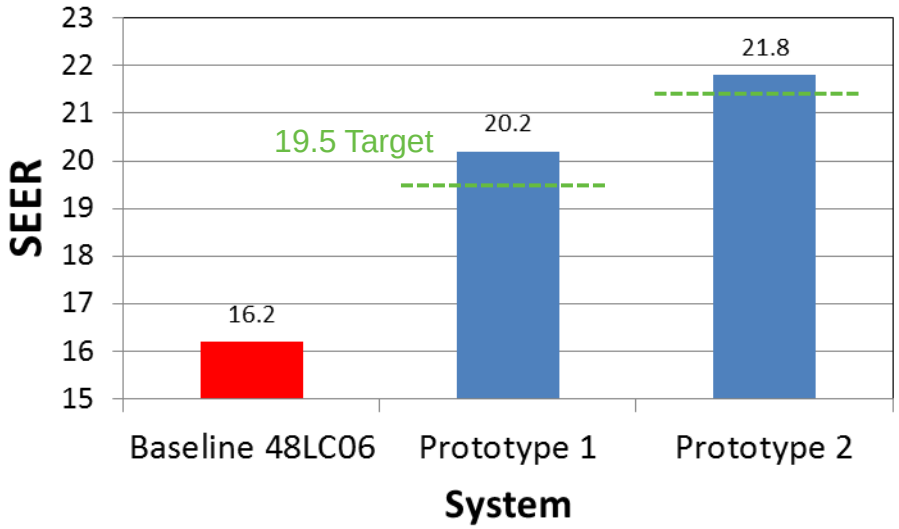
UTRC's detailed system analysis shows that the proposed high-efficiency low GWP system has the potential to provide **primary seasonal COP > 2.1 (vs. 2.0 BTO goal)** at a cost premium that meets market needs.

Other "desirable characteristics" include:

- Demonstration of long-term safe low-GWP refrigerant solution
- High part-load performance
- Significant energy consumption potential upon full (new and retrofit) commercialization

Packaged RTU System Analysis

SEER ANALYSIS: Target > 21.5 SEER for Prototype 2



Prototype 1 = Baseline + proposed MCHX coils, Novel compressor, High-efficiency indoor and outdoor fans

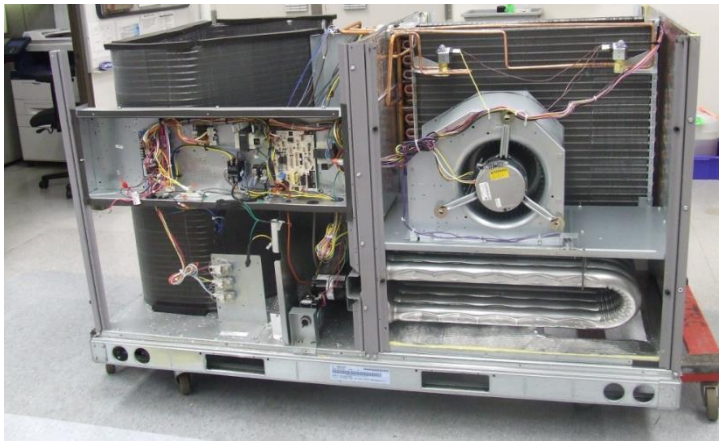
Prototype 2 = Prototype 1 + Re-optimized Compressor

Design Assumptions:

- Motor efficiency (including bearings and windage) = 90%
- Inverter efficiency = 97%.
- SEER cycle degradation factor = 0.1
- OD fan speed optimized at each point.
- ID fan CFM varied to maintain SHR < 0.78.
- Net capacity is reduced by ID fan heat, heat gain from ambient (constant in A, B and C), and motor cooling.

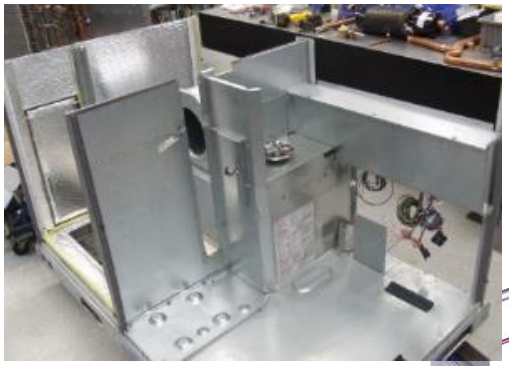
System Fabrication

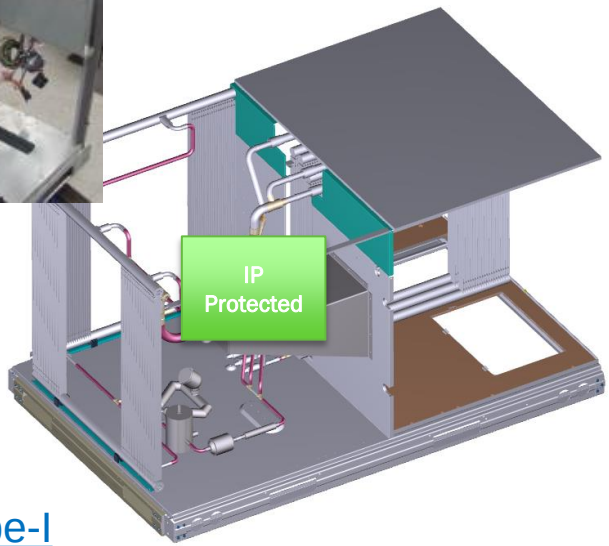
3D system design completed; Fabrication complete



Baseline Unit (5TR 48LC06) RTU

- Single scroll
- 2 row ID RTPF coil w/ dehumidification coils
- Wrap-around RTPF condenser
- Gas Heat
- Standard ID blower





Prototype-I

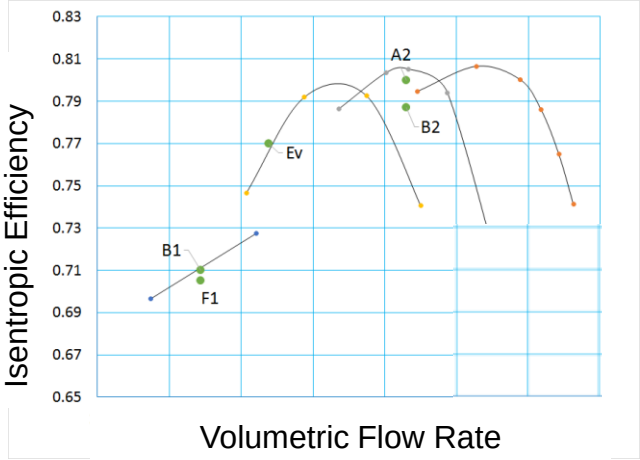
- Novel compressor
- Parallel micro-channel ID coil
- Parallel micro-channel OD coil
- Gas heat retained
- ID Centrifugal Fans

Compressor Design Optimization

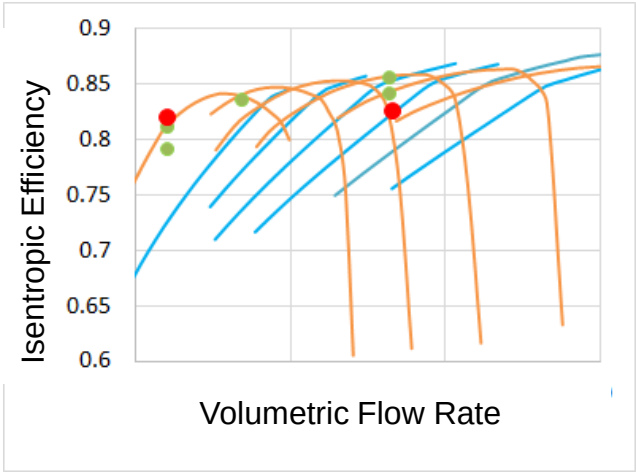
SEER ANALYSIS: Target > 21 SEER

Compression Efficiency for SEER targets

Prototype 1



Prototype 2 redesign,
Efficiency peaks moved to left.

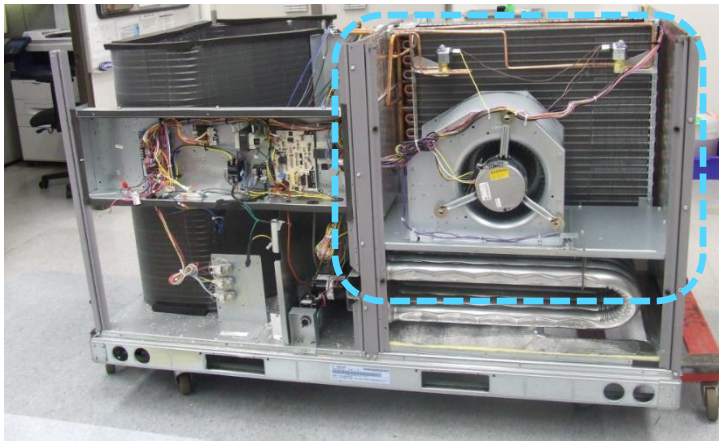


Ev, B1 and F1 have low efficiency.

SEER Condition	A2	B1
Pressure Ratio	1.74	1.49
Efficiency	0.81	0.82

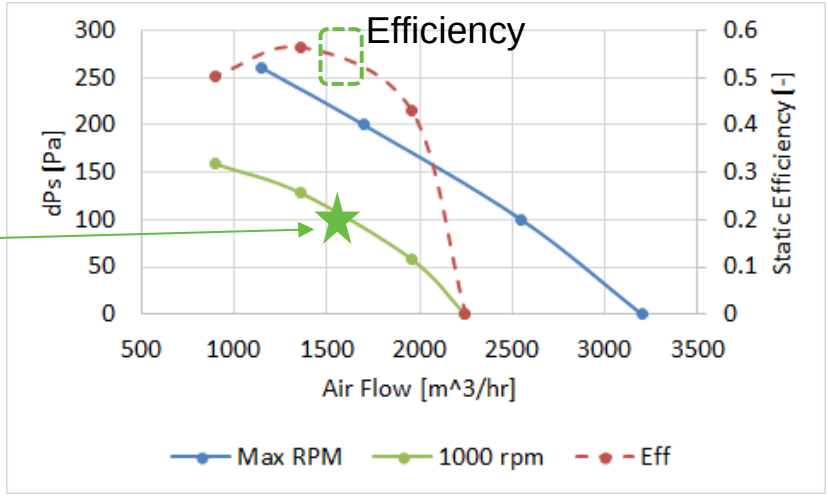
Indoor Blower Optimization

Indoor blower selected to deliver flow at required efficiency



Centrifugal Fan

A2 Design Requirement:
1800CFM @ 0.4 in-H2O
= 3060 m^3/hr @ 100 Pa
Using Two Fans (1530m^3/hr);
Speed ~1000rpm
Efficiency > 50%.

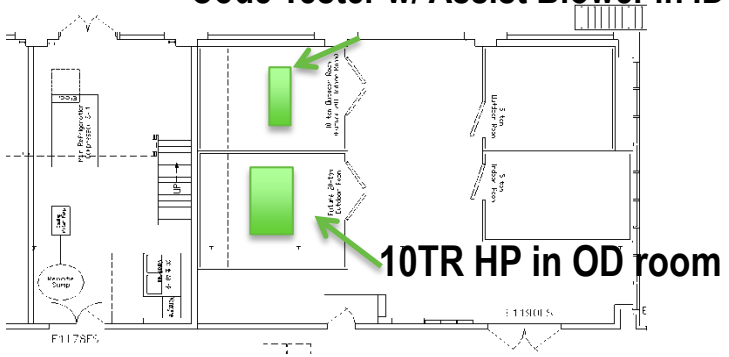


Lab Capabilities

This UTRC facility provides the ability to test air-to-refrigerant and hydronic systems under a wide range of operating conditions within world-class energy balances

- ***Capability***
  - Matching 5TR indoor and outdoor rooms
  - >10TR indoor and outdoor rooms
- ***Operating Ranges***
  - Air-side (indoor room): 45 to 145 ^{o}F, 30 to 95%RH, and 4,000 SCFM
  - Air-side (outdoor rooms): -15 to 145 ^{o}F, 20 to 95%RH, and 6,500 SCFM and 8,500 SCFM
  - Hydronic-side: 40 to 200 ^{o}F (5TR and 10TR)

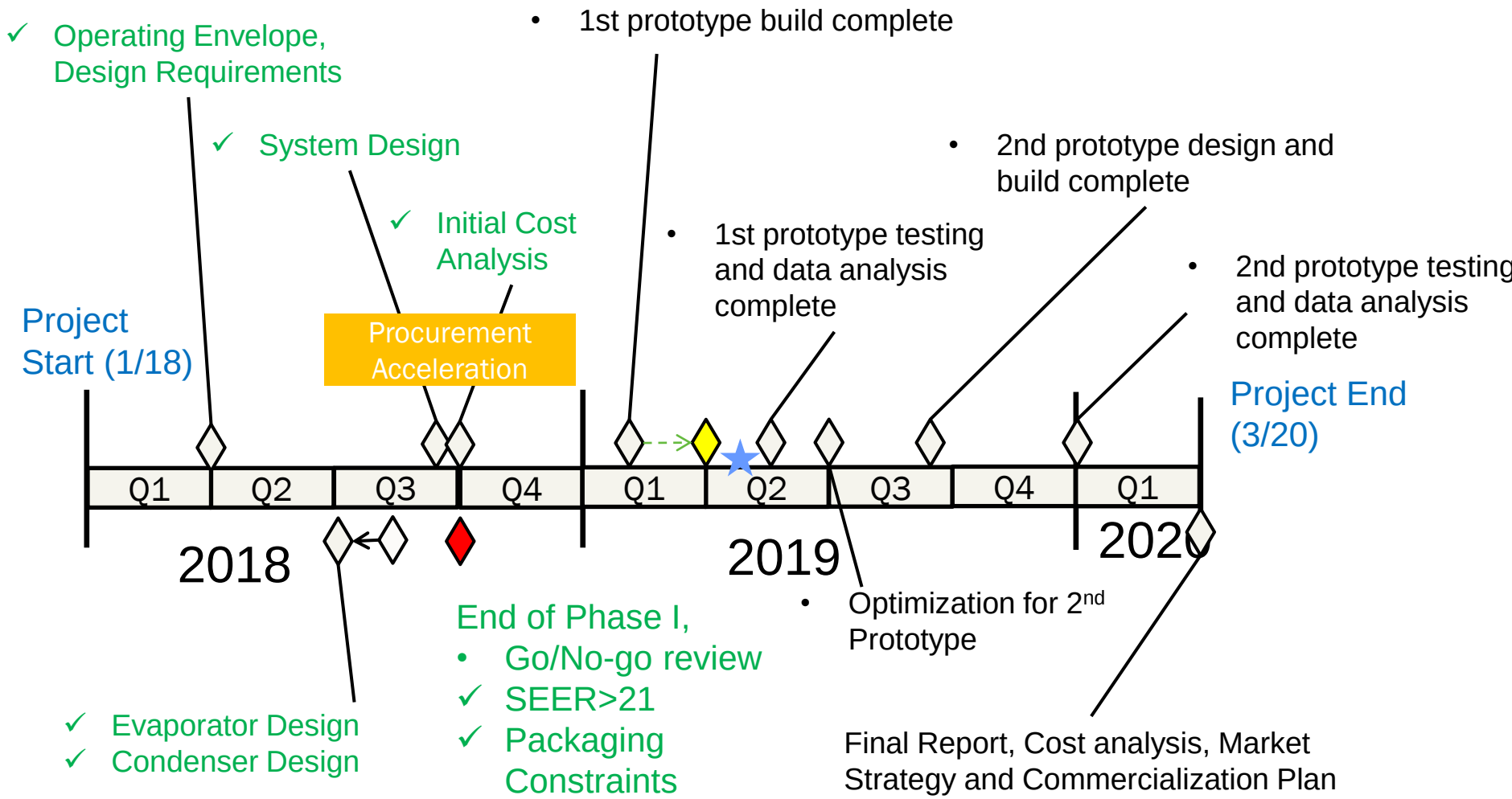
Code Tester w/ Assist Blower in ID room



Test Energy Balance

Ambient	1-Q_{air}/Q_{refrig}	Typical
47F	4%	~4%
17F	8%	~11%
-13F	<16%	unknown

Project Plan and Future Work (from SOPO and Milestone table)



Project Integration and Collaboration

Project Integration:

- **Carrier Corporation is the commercialization path for HVAC technologies and concepts developed at UTRC.**
- **Carrier is the world's largest manufacturer and distributor of HVAC&R equipment and has a long history of developing successfully commercialized products.**
- **UTRC project team is closely engaged with product and engineering teams to ensure metrics are met during conceptualization and testing phases**
- **Carrier directly providing cost share for this project and significant in-kind contribution**

Partners, Subcontractors, and Collaborators: UTRC is only performing organization under this contract

Communications: Underway

Thank You

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REFERENCE SLIDES

Project Budget

Project Budget: Project started January 1, 2018. Ends March, 2020.
Variances: None. No Changes.
Cost to Date: 35%
Additional Funding: None

- Milestones tracking well
- Go/ No-Go Sept 25, 2018 successfully completed
- BP2 started: Hardware Procurement Acceleration

Budget History

FY 2018 (January start) (Past)		FY 2019 (planned)		FY 2020 – 2/28/ (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$355k	$152k	$750k	$321k	$214k	$92k

Total Project : $1,885k

- DOE: $1,320k
- Cost Share: $565k