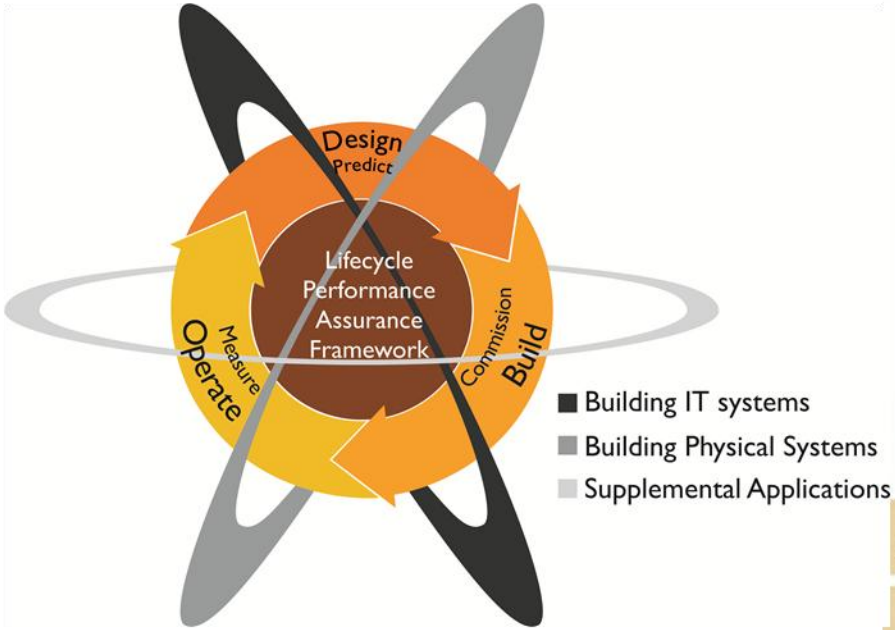
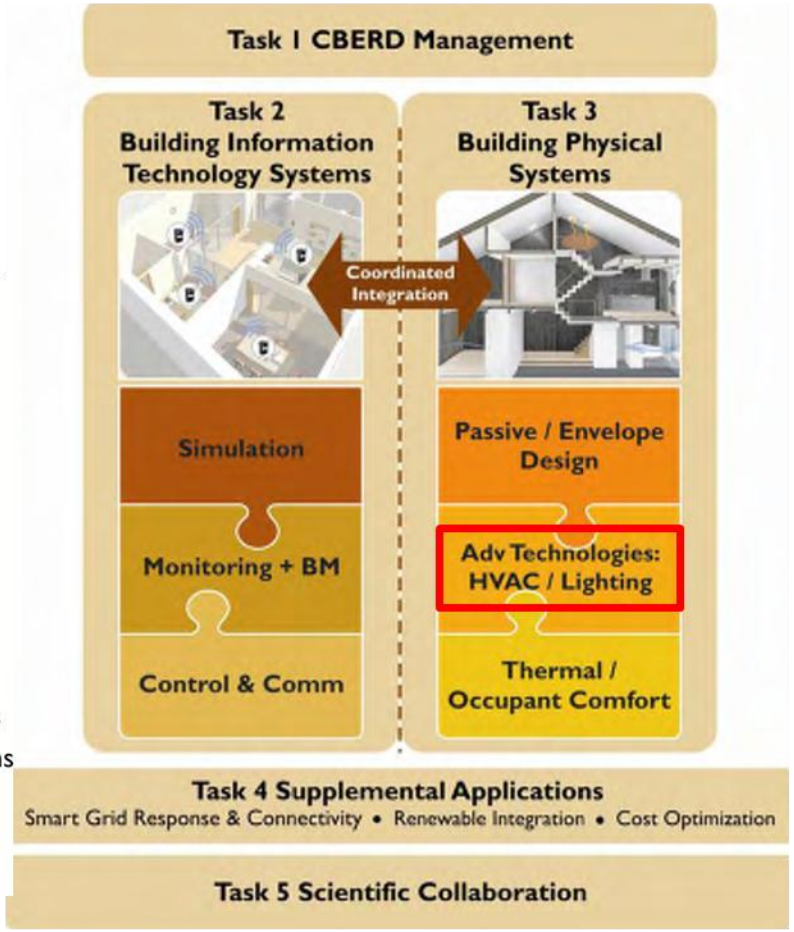
US India Joint Center for Building Energy Research and Development (CBERD):

Advanced HVAC Systems

2014 Building Technologies Office Peer Review

CBERD promotes innovation in energy efficiency through collaborative research, contributing to significant reduction in energy use in both nations.





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Project Summary

Timeline:

Start date: Oct 2012; Planned end date: Sep 2017

Key Milestones:

1. Framework for chilled water system analysis and test facility specification document (Sep 2013)
2. Design and testing of DOAS system (Dec 2013)
3. Integration of MCHX in 1.5 TR unitary system (Sep 2014)

Budget:

Total DOE $ to date: $200k (FY13 and FY14)

Total future DOE $: $300k (FY15-FY17)

Target Market/Audience: Commercial Buildings

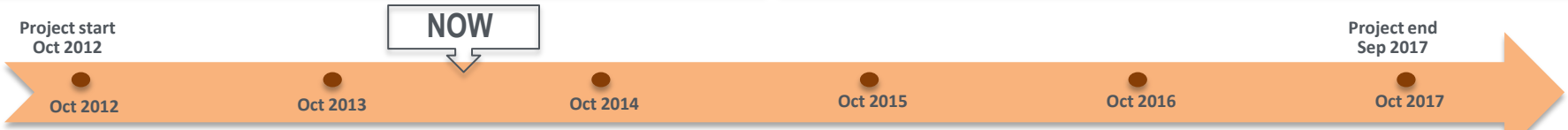
- Building owners and operators
- HVAC system and component manufacturers
- HVAC Design Community

Key Partners:

Institutional partners	Industry partners
Indian Institute of Technology Bombay (IITB) **Malviya National Institute of Technology Jaipur (MNITJ)**	1. Delphi, USA 2. Ingersoll Rand/Trane, USA* 3. Oorja, India

Project Goals:

- Re-optimize existing cooling and dehumidification system approaches for India's commercial/multi-family new construction market
- Target, develop, and test advancements to the state-of-the-art of physical system HVAC technology, whether compressor-based or non-compressor, which can significantly reduce cooling and dehumidification energy use in both the US and India



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Purpose and Objectives: Problem Statement

Increasing demand for HVAC in India

- More than 60% of all the buildings projected for 2030 yet to be built; economic development demands increasing level of thermal comfort
- Buildings consume 33% of nation's energy with 8% annual growth rate. (Climate Works, 2010)
- US experience: HVAC energy consumption is >30% in commercial buildings (Building Energy Data Book, 2007); India it is 40-50%

Need to improve energy efficiency of HVAC systems

- Optimize the operation of existing systems - Chiller operations, optimal charge and its monitoring
- Develop improved physical systems
  - To handle fresh air more efficiently to enable improved indoor air quality
    - » Simplified energy efficient dedicated outdoor air system (DOAS) –non-compressor based
  - Cost effective efficient design of small unitary systems (< 2TR)
    - » Micro Channel Heat Exchanger as evaporator: MCHX as condenser are already in use

Purpose and Objectives: Problem Statement

Target Market and Audience:

Market:

Contribute towards:

- US commercial (mostly retrofit) market: target 20% reduction in energy consumption by 2020; 30% by 2030
- Indian commercial (mostly new construction) market: target 60% reduction in energy consumption; 10% through retrofits

Audience:

- Building owners and operators for commercial buildings - reduced operating cost
- HVAC Industry: system and component manufactures - new and improved products for commercialization with opening up new market segment
- HVAC design community
- Society at Large: reduced emissions, improved IAQ and improved health and well being

Purpose and Objectives: Impact of Project

Near Term (during or up to 1 year after project)

- Change in design and operation practices for chilled water systems
- Better understanding of Indian chillers installations and issues related to performance - will benefit both US and Indian HVAC manufacturers and users
- Prospects of using non-compressor DOAS in both countries will increase - new avenues for HVAC industry
- Better collaboration opportunities with Indian industries and institutes

Intermediate Term (1-3 years after project)

- Integration of energy efficient non-compressor DOAS in HVAC systems
- Adaption of MCHX for evaporators in small capacity (<2TR) unitary systems

Long Term(3+ years after project)

- Growth in demand for improved energy efficient HVAC systems including DOAS and its integration for high performance buildings in US and India (new building stock and retrofits)
- DOAS systems developed could improve the performance of HVAC systems by up to 30% - contribute to energy efficiency goals of both countries

Approach

Approach:

- Through collaborative knowledge and partnership - investigate the energy savings potential opportunities in HVAC systems, deploy the novel strategies and technologies in developing energy efficient HVAC systems
- Capacity building and testing facilities in the area of HVAC systems
- Deployment path through the engagement of HVAC industry partners

Key Issues:

- Non availability of guidelines with respect to best practices for the operation of HVAC systems in Indian commercial building
- Need to develop standard testing procedures suitable for Indian operating conditions
- Lack of HVAC testing facilities in India and HVAC modelling capabilities
- Existing non-compressor based DOAS are complex, high pressured drops, high parasitic power requirement
- MCHXs as evaporators for small unitary systems have not yet penetrated the market due to issues related to refrigerant distribution, condensate drainage and form factor

Distinctive Characteristics:

- Direct involvement of HVAC Industry partners - manufacturers, users and consultants
- Use of novel extrusion profiles for air-to-air heat recovery and diabatic contacting device for liquid desiccant based DOAS systems

Approach

Distinctive Characteristics:

Task divided into four smaller subtasks:

- **Re-optimized chilled water system/operations in India**
  - establish realistic analytical framework, conduct analysis and document chilled water use and prevalent practices followed
  - evolve a detailed best practice manual
- **Refrigerant Charge Monitor**
  - development of a low cost charge monitor to facilitate control initial field charging in split units
  - document refrigerant use leakage during the product life cycle
- **Non-Compressor DOAS**
  - implement a patented profile in both Aluminium and Plastic air-to-air heat exchangers and explore use of Potassium Formate as liquid desiccant using diabatic contacting devices to overcome corrosion and carryover issues
  - Goal is to achieve cost effective solution to increase the effectiveness of up to 86% (existing system ~60%)
- **Micro Channel Heat Exchanger (MCHX)**
  - integrate MCHX for evaporator in a small unitary system (1.5 TR)
  - measure the performance of the system and study the different ways to improve the performance and shortcomings
  - goal is to come up with a new MCHX design for small unitary system

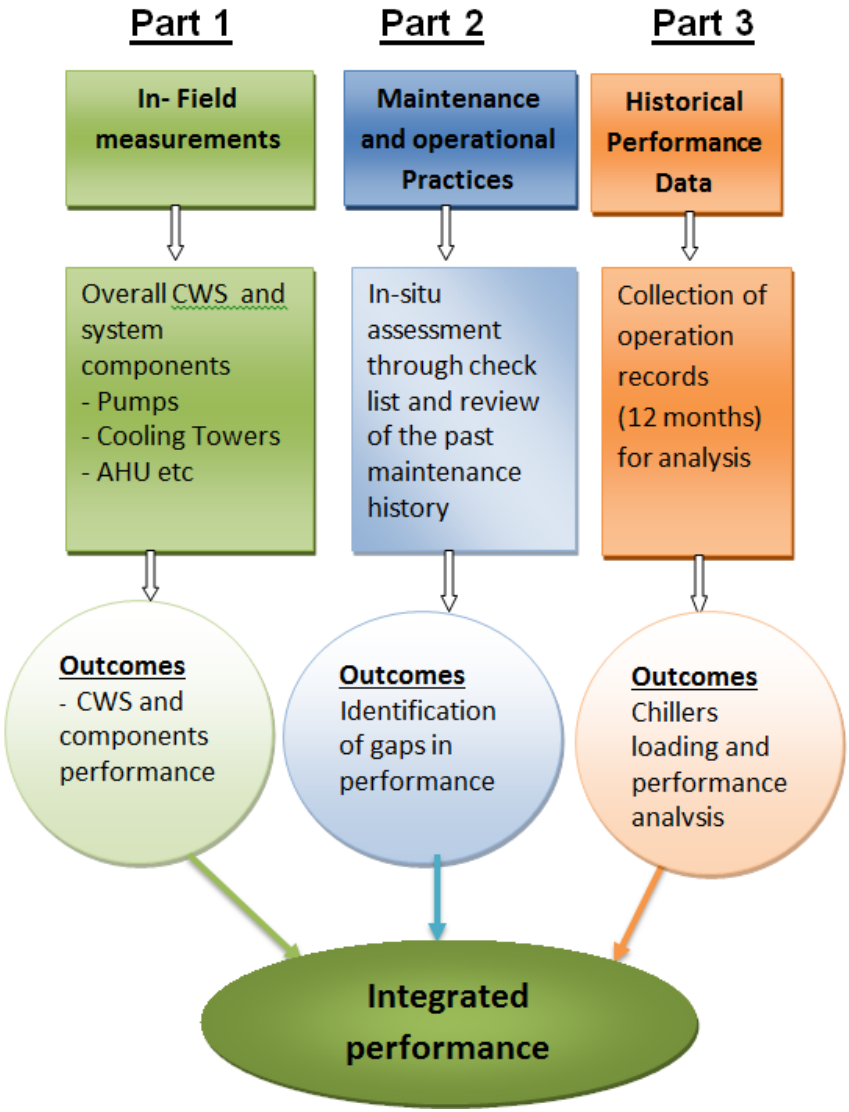
Progress and Accomplishments

Lessons Learned:

- Engage with industry partners early
- Participation Matrix for industry partners should also be explicitly defined
- Flexibility in project funding allocation

Accomplishments:

- Development of framework and methodology for assessment of chillers
- Pilot studies for CWS conducted at 6 locations



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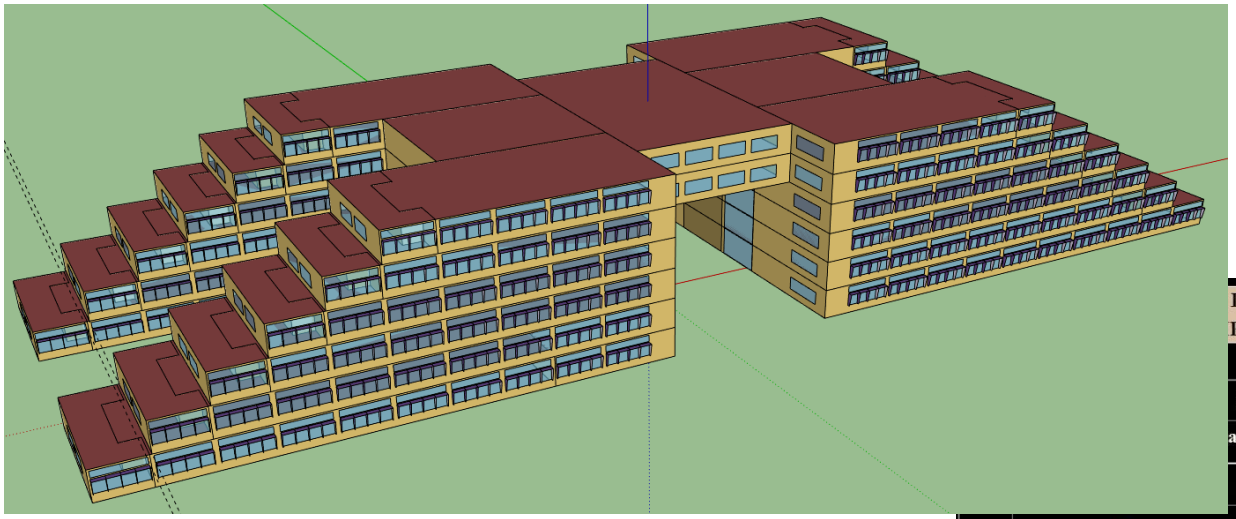
Progress and Accomplishments

Accomplishments:

Energy modeling capacity building in HVAC area

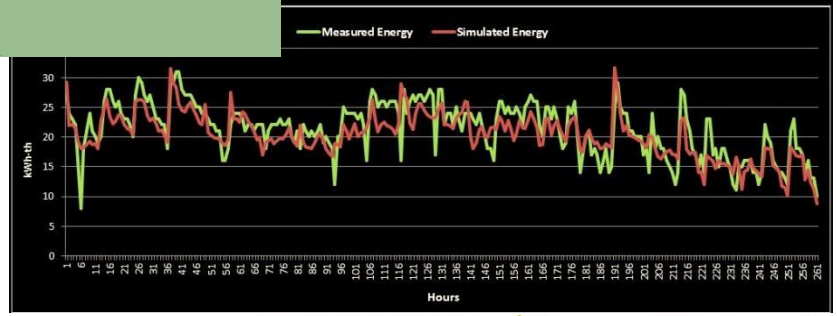
- Performance assessment of Tech Mahindra building for radiant cooling
- Modeling and calibration of two HVAC systems (Radiant and VAV) - Infosys building, Hyderabad (Composite climate), India



Limit (PMVP)	Limit (FEMP)
-	±10%
20%	30%

Index	Value
MBE	4.77%
CvRMSE	13.56%

Calibration Result



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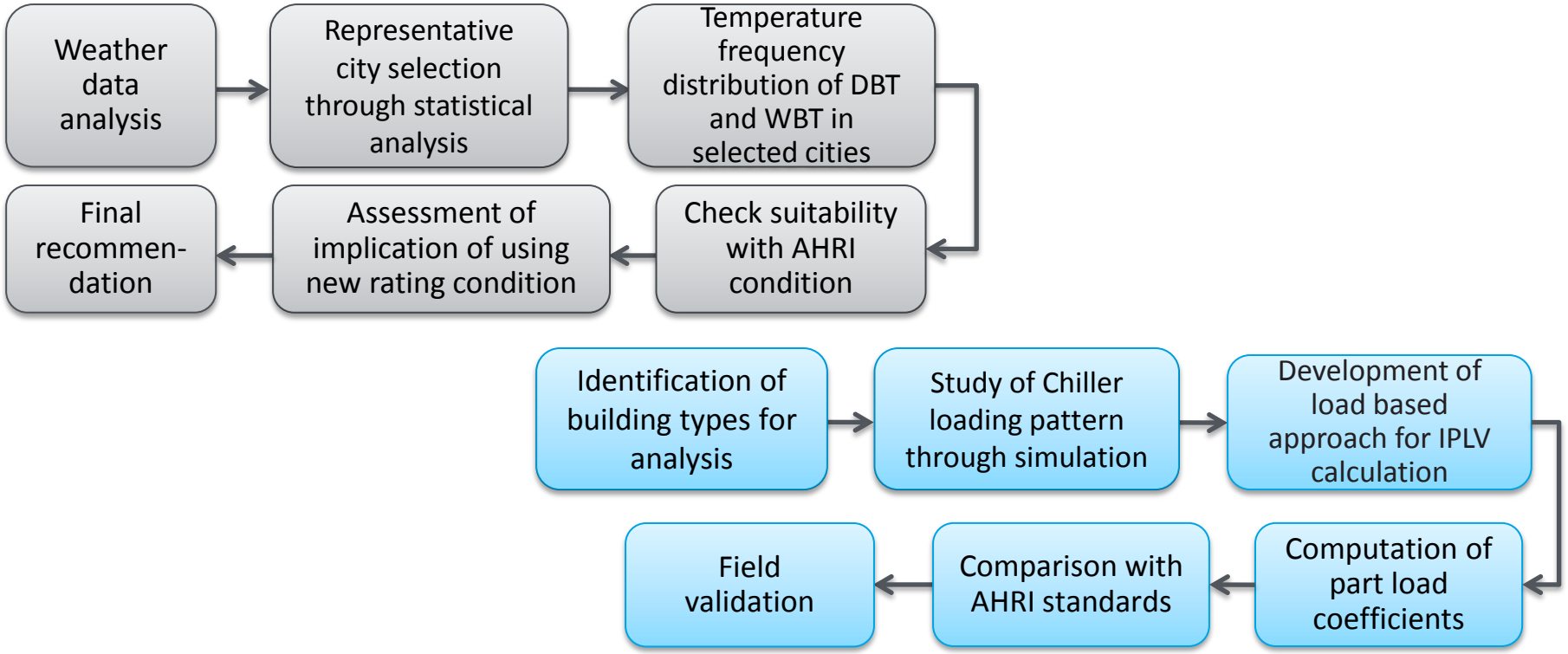
Progress and Accomplishments

Accomplishments:

- Analysis of weather conditions in different climatic zones to check the suitability of chillers rating standards



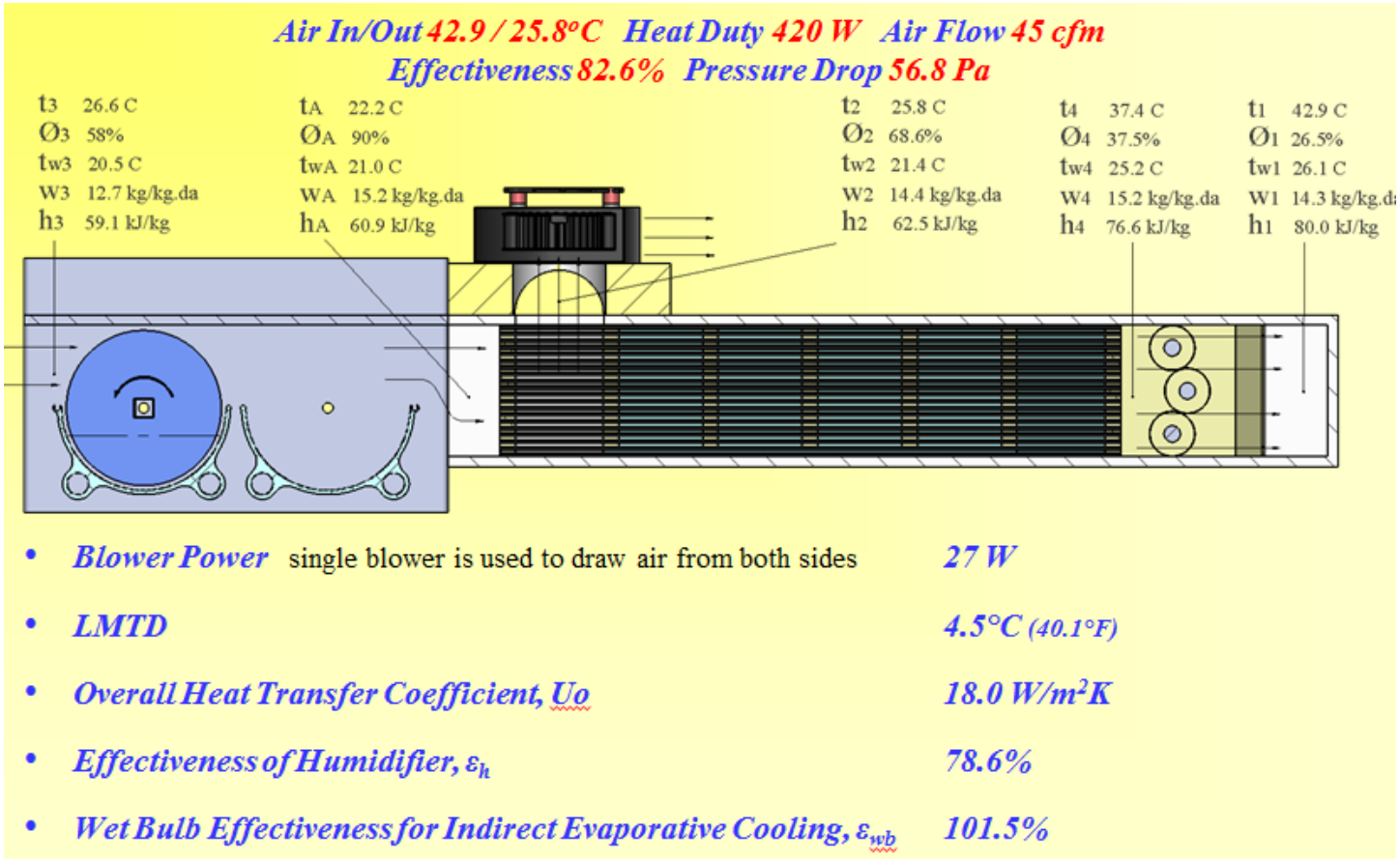
- **HVAC test chamber at MNITJ**

  Finalization of Technical specifications for HVAC test chamber at MNIT Jaipur

Progress and Accomplishments

Accomplishments:

- **DOAS – Evaporative precooling followed by air-to-air heat recovery**
  - A Novel DOAS has been designed, fabricated and performed initial tests
    - « Modular design, scalable *from 20 to 20,000 cfm*



Progress and Accomplishments

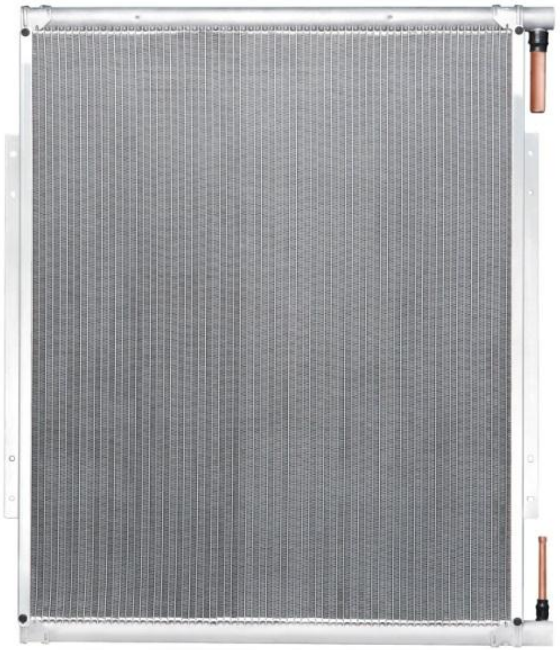
Accomplishments:

- **DOAS: Re-commissioned a 2 x 7.5 TR liquid desiccant based system**

Progress and Accomplishments

Accomplishments:

- **Micro Channel Heat Exchanger (MCHX)**
  - Literature review on MCHX evaporator designs to appreciate the issues related to deployment in small unitary systems
  - Integrated the MCHX evaporator , supplied by Delphi, in 1.5 TR unitary system



Project Integration and Collaboration

- **Project Integration**:
  - Short term and long term visits by Indian research partners to ORNL and other labs
  - Monthly phone calls or e-mail and GoToMeeting communications
  - US Industry partner, Delphi, designed and shipped the MCHX to IITB
  - Indian industry partner, Oorja, is extending support to MNITJ for radiant cooling applications

- **Partners, Subcontractors, and Collaborators**:
  - Research Partners and **main contributors**: **Indian Institute of Technology Bombay (IITB**) and **Malviya National Institute of Technology (MNITJ)**, India
  - Research Partners in support role: ORNL, USA
  - Industry Partners: Delphi, Ingersoll Rand/Trane, USA and Oorja, India
    - «Consulting partner: Infosys, India

Project Integration and Collaboration

Communications:

- **Joint Publication:** Jyotirmay Mathur, Vaibhav Rai Khare, Yasin Khan and Mahabir Bhandari, Radiant cooling system: a case study of assessment of energy savings in an office building, 3rd National Conference on Refrigeration and Air Conditioning (NCRAC-2013), IIT Madras, Chennai, India-December 12-14, 2013.
- Pramod Kumar, Manoj Singh, Anant Joshi and Jyotirmay Mathur, "Analysis of weather conditions of Indian cities with respect to rating conditions for HVAC equipment", 4th International Conference on "Advances in Energy Research," IIT Bombay, December 10-12, 2013.
- Milind Rane and Shreyas A Chavan, DOAS with Evaporative Precooling of Exhaust Air Using Rotating Contacting Device*
- Milind Rane, and Narendra Singh, Multi Utility Evaporative Cooler with Diabatic Contacting Device*
- Milind Rane and Shreyas A Chavan, Indirect Evaporative Precooling of Fresh Air Using Heat Exchangers with Enhanced Flow Passages, * First International Conference on Energy and Indoor Environment for Hot Climates, Organized by ASHRAE— February 24 - 26, 2014,Doha, Qatar
- **A Master's thesis jointly supervised by MNITJ faculty and ORNL researcher is planned for May 2014**
- **The DOAS prototype will likely to be included in the "IITB Team Shunya's solar Decathlon house" (first ever Indian team to be selected)**

Next Steps and Future Plans

Next Steps and Future Plans:

- Finalize the best practice report on chilled water systems
- Testing and understanding the performance of liquid desiccant based DOAS
- Test a lab prototype of 1.5 TR unitary HVAC system with MCHX
- Engage Industry partners to accelerate the deployment both in Indian and US market
  - First commercial building installation at Infosys site in India

Project Outcome Envisioned:

Re-optimized chilled water options (India)	Refrigerant Charge Monitor	Non-compressor DOAS	Micro-channel Evaporators for Unitary AC
Best practice guide for practitioners	Low cost charge monitor with improved design	Improved air-to-air heat recovery unit	1.5 TR Unitary HVAC Systems with MCHX as evaporator

REFERENCE SLIDES

Project Budget

Project Budget: $100k per year
Variances: None
Cost to Date: $100k
Additional Funding: None

Budget History

Oct 2012 – FY2013 (past)		FY2014 (current)		FY2015 – Sept 2017 (planned)	
DOE	Cost-share	DOE	Cost-share	DOE	Cost-share
$100		$100		$300	

Project Plan and Schedule