



# Systems Design Innovation for a Smart Nation

Presentation for:  
CSD&M Asia 2016



**Our Vision: The world's premier scholarly hub for technology intensive design research and practice**



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# Our Journey...

## An Interactive E-Book Presentation

Beginnings

Chapter I

Chapter II

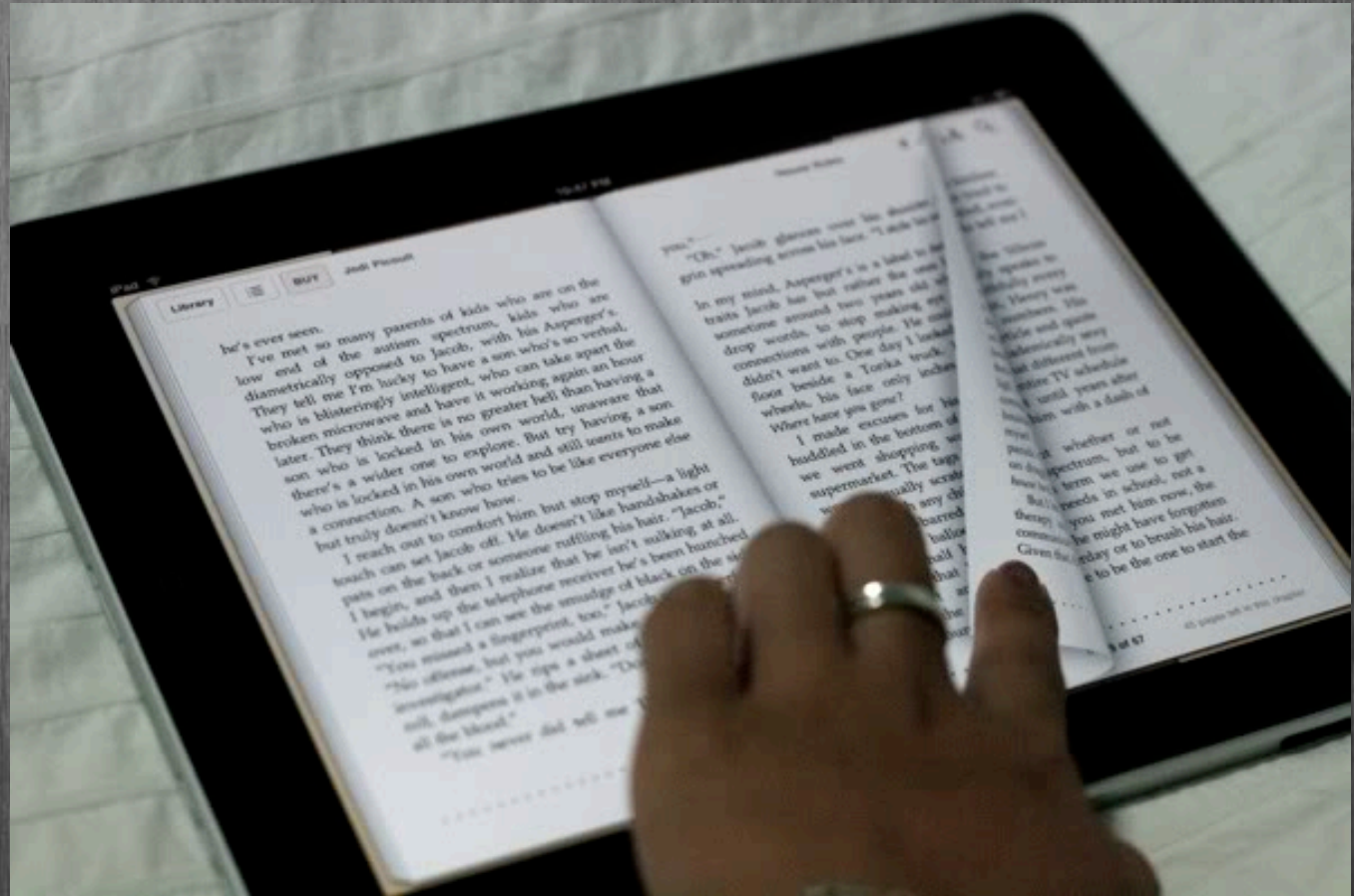
Chapter III

Chapter IV

Chapter V

...

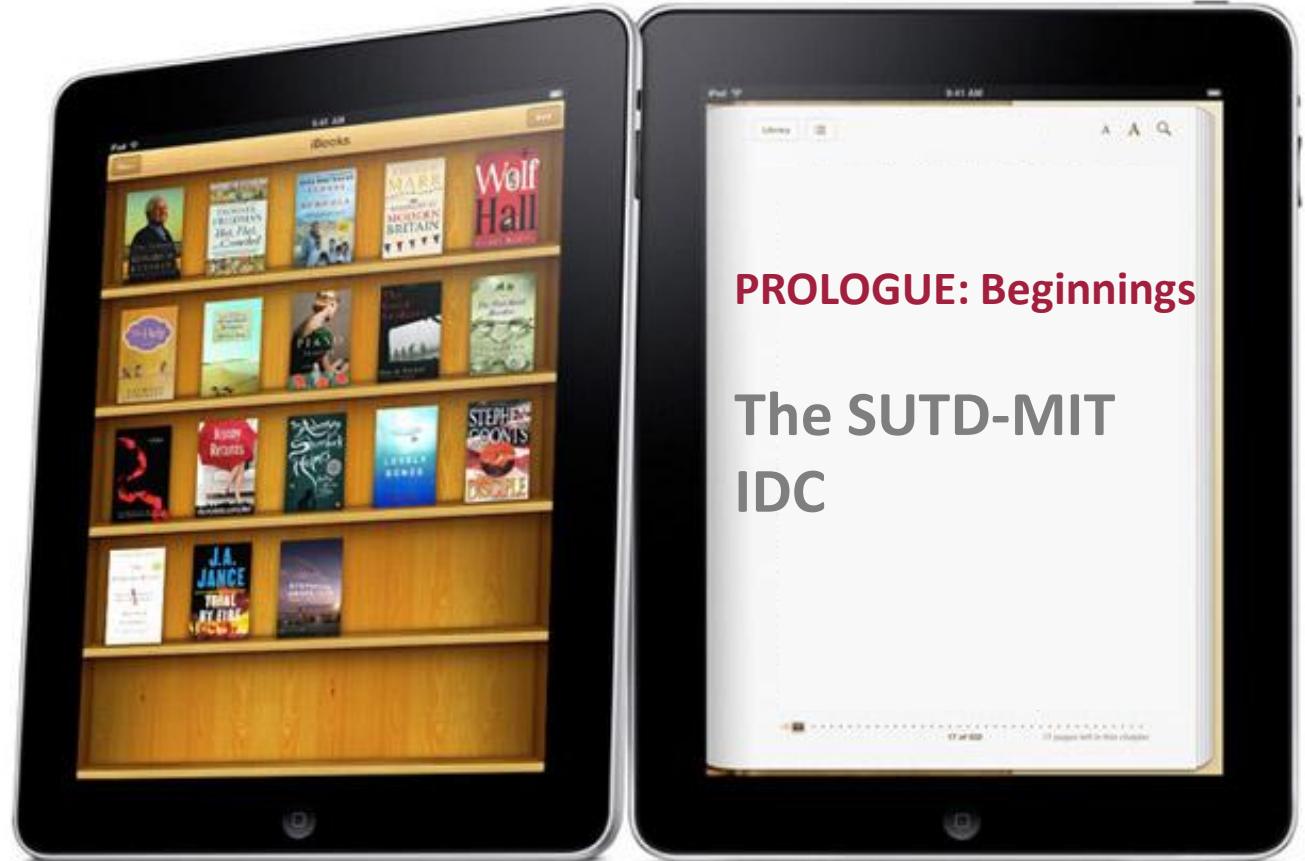
Epilogue

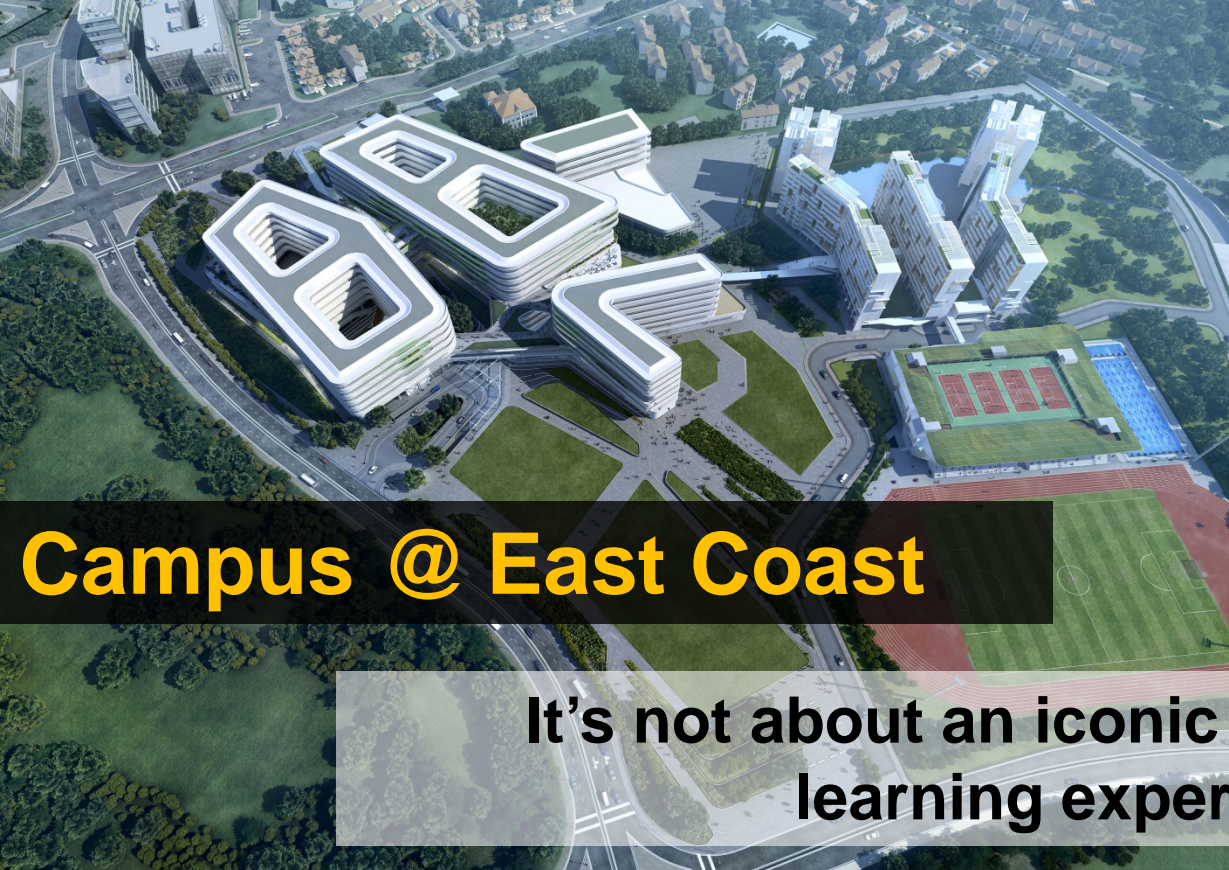


Pic reference: <http://secretsatsixth.livejournal.com/>

# Prologue-Beginnings

Prologue-  
Beginnings:

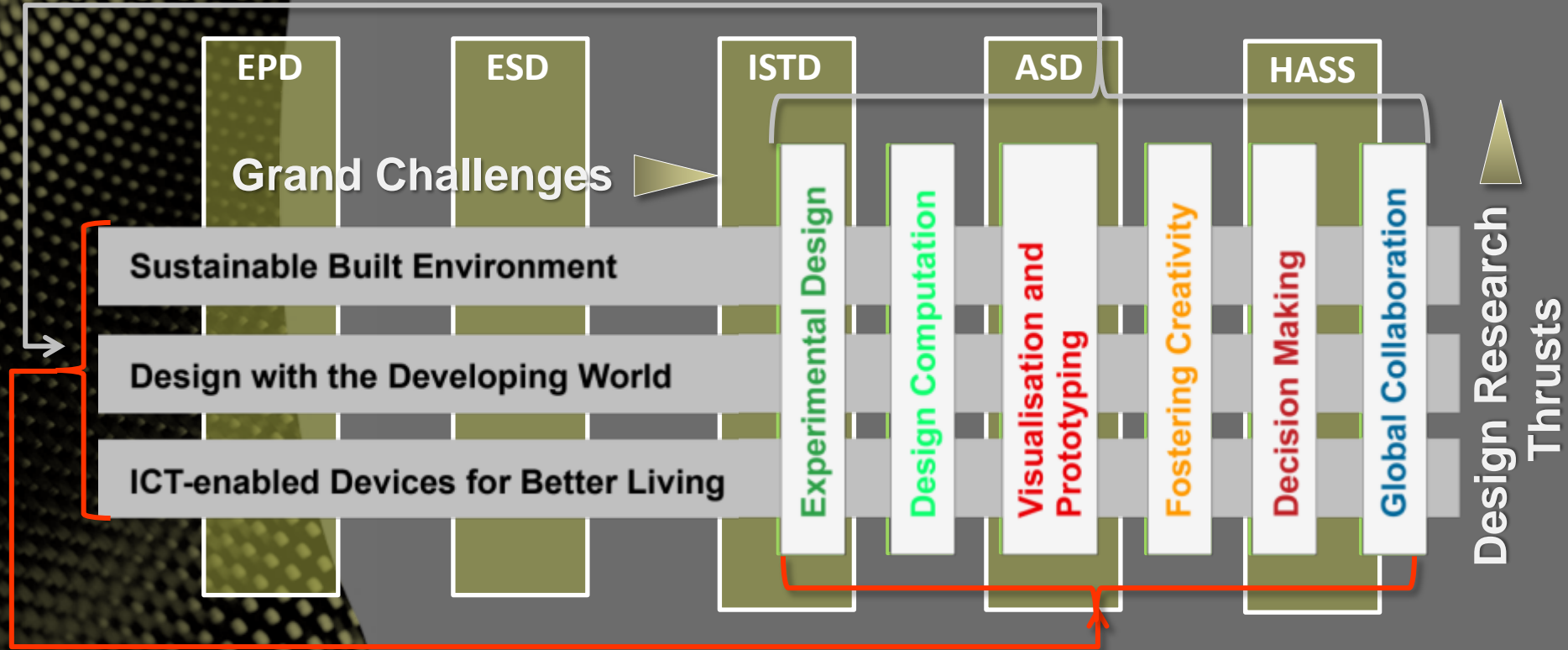




# Campus @ East Coast

It's not about an iconic building but an iconic learning experience for the students





- Directly feeding SUTD teaching, pedagogy and fifth row
- Breadth across Pillars
- Interfaces & Intersections of science, pillars, humanities, and social science

# The SUTD-MIT IDC: Voices of SUTD Interdisciplinary Faculty





**IDC Grand Opening: 11 August 2015**

# SUTD IDC space at the East Coast Campus – Level 1



Discussion Areas | Project Space | Place to Refresh!



# Chapter I: Interactive E-Book Presentation

Prologue-  
Beginnings:

CHAPTER I





SUTD-MIT  
INTERNATIONAL  
DESIGN  
CENTRE (IDC)

Undertake the impossible, Design the unexpected

# What is Design Thinking or Design Innovation?

## *The Basics...*



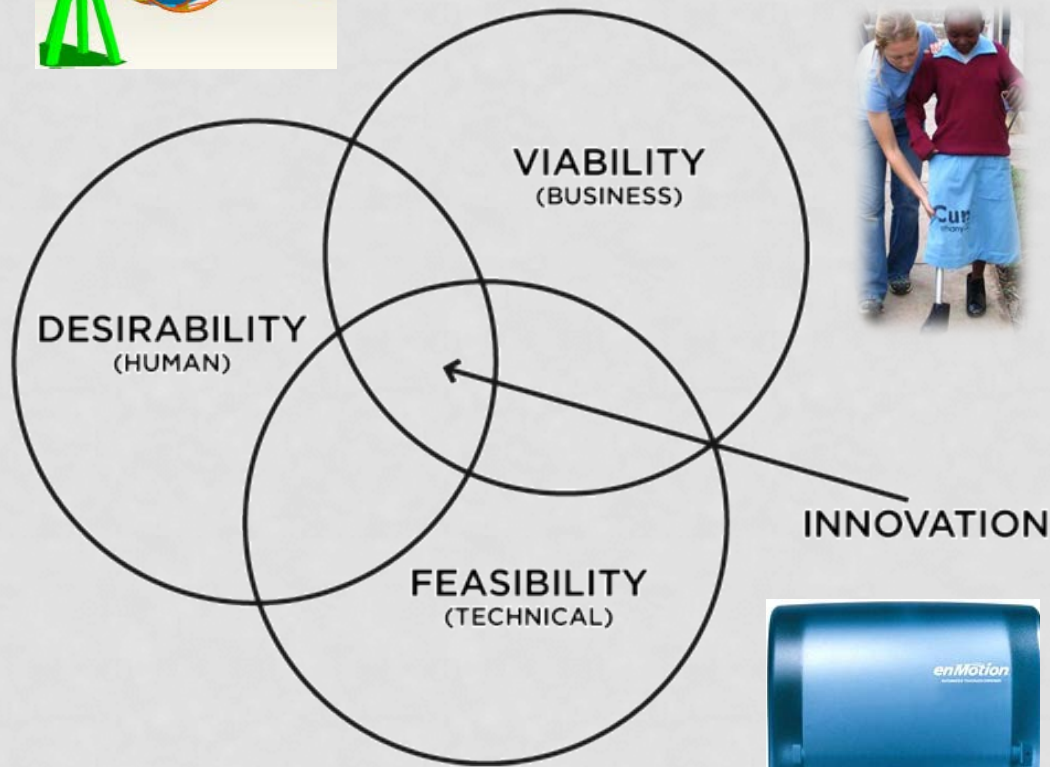
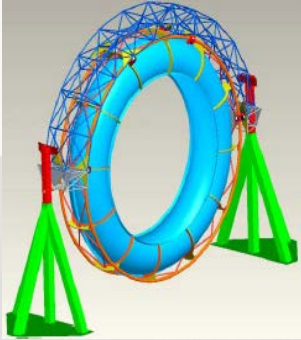
Massachusetts  
Institute of  
Technology



SINGAPORE UNIVERSITY OF  
TECHNOLOGY AND DESIGN

Established in collaboration with MIT

# WHAT IS INNOVATION?



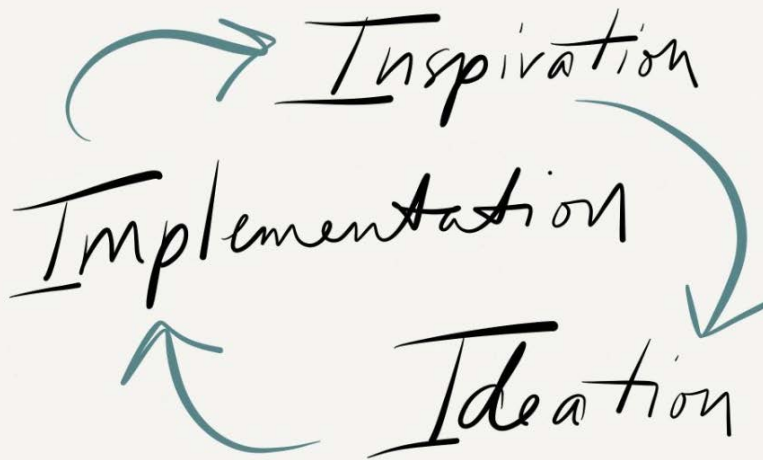
Uses designer's **sensibility** and **methods** to match **people's needs** with what is **technologically feasible** and what a viable **business strategy** can convert into **customer value** and **market opportunity**.



[www.ideo.com](http://www.ideo.com)



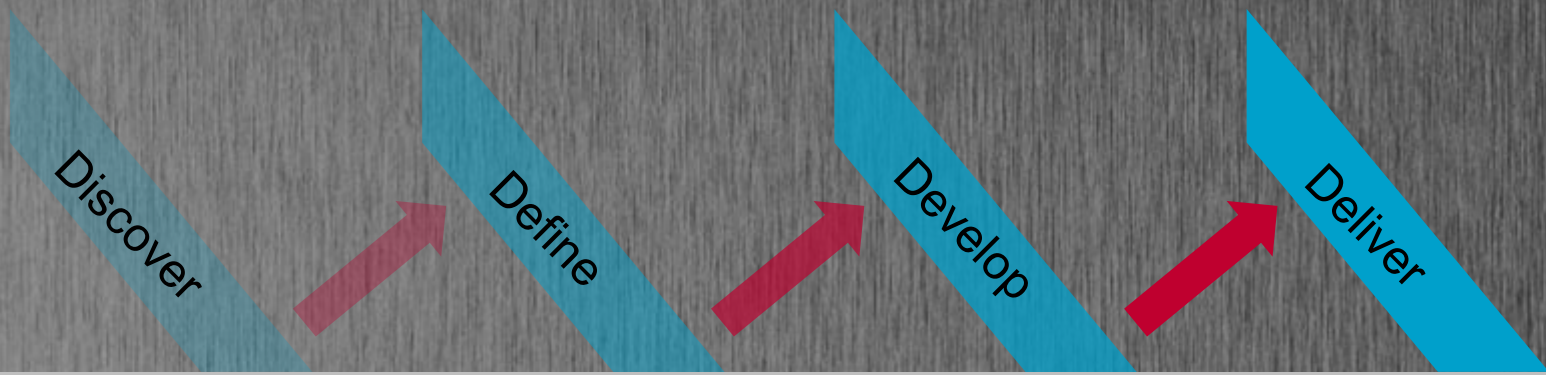
# IDEO DESIGN THINKING MODEL



Design thinking develops through three stages:

- **Inspiration:** identify an opportunity
- **Ideation:** conceive general solutions
- **Implementation:** define details

<http://www.google.com.sg/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&uact=8&docid=2qSczvDr71xY3M&tbnid=BY7UhiSEJhpyIM.&ved=0CAUQJRw&url=http%3A%2F%2Flibedge.blogspot.com%2F2013%2F01%2Fcarol-kuhlthau-meets-tim-brown-guided.html&ei=FviWU46dBJPfsASCm4BY&psig=AFQjCNGO13yF87ksWEa2v2O1VzI7nRnSxO&ust=1402489203386598>



**Tools**

CN Analysis  
Contextual Needs  
Journey Mapping

Mission Statement  
Black Box  
Activity Diagram  
Affinity Analysis

C-Sketch  
Design by Analogy  
Word Tree  
Mindmapping

Prototyping  
User-Validation  
Scaled Prototypes  
Iterative Prototypes

Likes/Dislikes  
Multisensory Analysis  
Articulated Use  
Surveys

Personas  
Functional Modeling  
Workflow  
Benchmarking

Bio-Inspired  
Brainstorming  
Co-Creation  
Morphological Matrix  
SCAMPER

Isolated Subsystem  
Mock-ups  
Parallel Testing  
Requirement Relaxation  
Design of Experiment  
Testing (Spiral Plan)

Site Analysis  
Lead User  
Scenarios  
Focus Group  
Empathic Lead User

Specifications Sheet  
Want/Needs  
Requirements Document  
Background Research

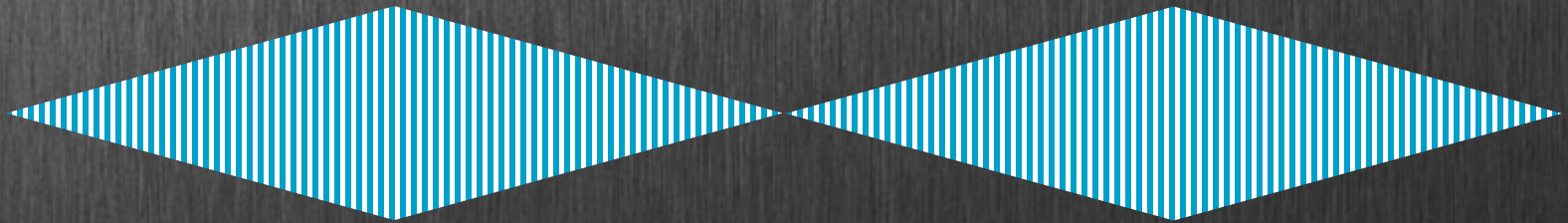
Pugh Chart  
TRIZ  
Storyboarding  
Deep-dives

Paper Prototyping

Required

Recommended

Extended



# Chapter II: Interactive E-Book Presentation

Prologue-  
Beginnings:

Chapter I

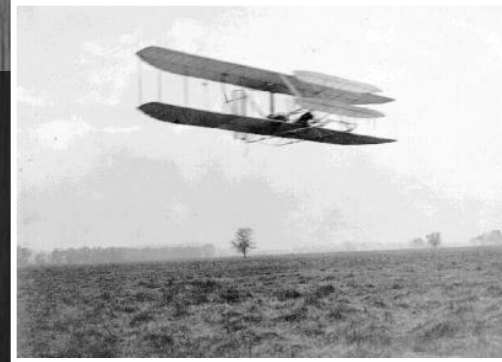
Chapter II



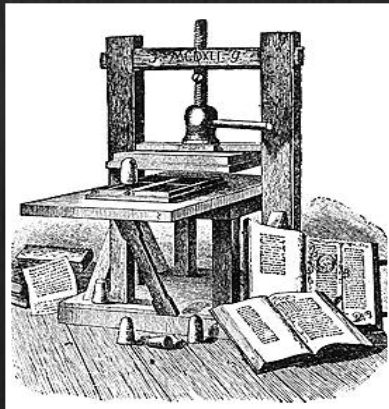
# Innovations: In History



Edison Telegraph



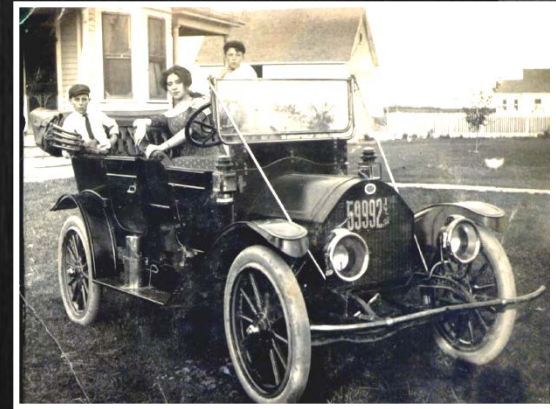
Wright Brothers Biplane



Gutenberg Printing Press



Kilby's Integrated Circuit



Ford Model T

# Recent Innovations



RevoPower Wheel



Transition Drivable  
Airplane



MEMS Devices



[www.nandahome.com](http://www.nandahome.com)



[www.popsci.com](http://www.popsci.com)



[www.makezine.com](http://www.makezine.com)



# Energy Innovation Research Programme Smart Grid Grant Call 2012

## “Demand Focused Smart Energy Management in End User Environment for Sustainable Cities”

<b>Lead PI</b>	<b>: Prof. Kristin Wood</b>
<b>Institution/Coy/Org</b>	<b>: Singapore University of Technology and Design</b>
<b>Co-PIs</b>	<b>: Prof. Chau Yuen, Dr. Wayes Tushar Prof. Selin Ahipasaoglu, Prof. Yunjian Xu Prof. Erik Wilhelm, Prof. Suranga Nanayakkara (SUTD)</b>
<b>Collaborators</b>	<b>: Mr. See Gim Kerk (Power Automation) Prof. Naveed Ul Hassan (LUMS)</b>
<b>Project Duration</b>	<b>: 36 months</b>



# APPROACH & METHODOLOGY

Overall *project scope* can be broken down as follows:

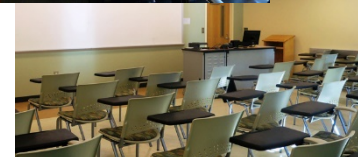
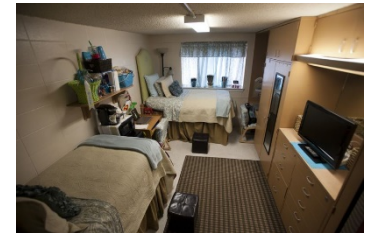
- **Project 1:** Focuses research in private spaces, with emphasis on managing distributed loads with minimal inconvenience to the users.
- **Project 2:** Focuses research in shared spaces, with emphasis on designing mechanisms that can fairly distribute cost and benefits.
- **Project 3:** Focuses on implementation and user behavior studies.
- Testbed development and user interaction studies.

## ***Project 1:***

- Scheduling and resource allocation.
- Optimization, queuing, and game theory.
- Load models: shiftable vs throttleable for all load, multi-state vs thermal-state for thermal load.
- Incentives: dynamic pricing, subscription plans.

## ***Project 2:***

- Incentive compatible mechanism design: Generalized AGV mechanism.
- Fairness criteria: equal allocation of social welfare, and Max-min fairness.
- Solve parameter optimization problems.
- Development of web-based user interface for preference reporting.
- Experimental study of group decision in shared spaces.



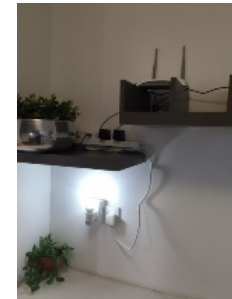
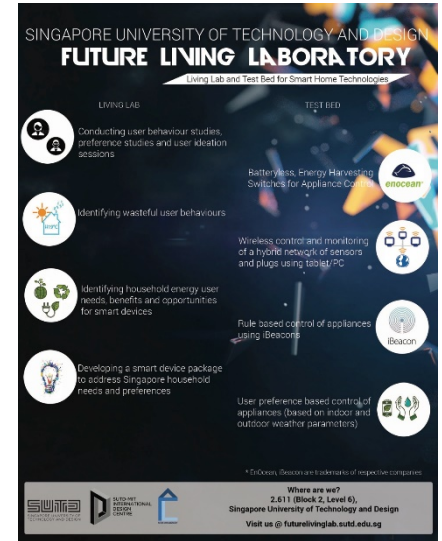
# APPROACH & METHODOLOGY

## Project 3:

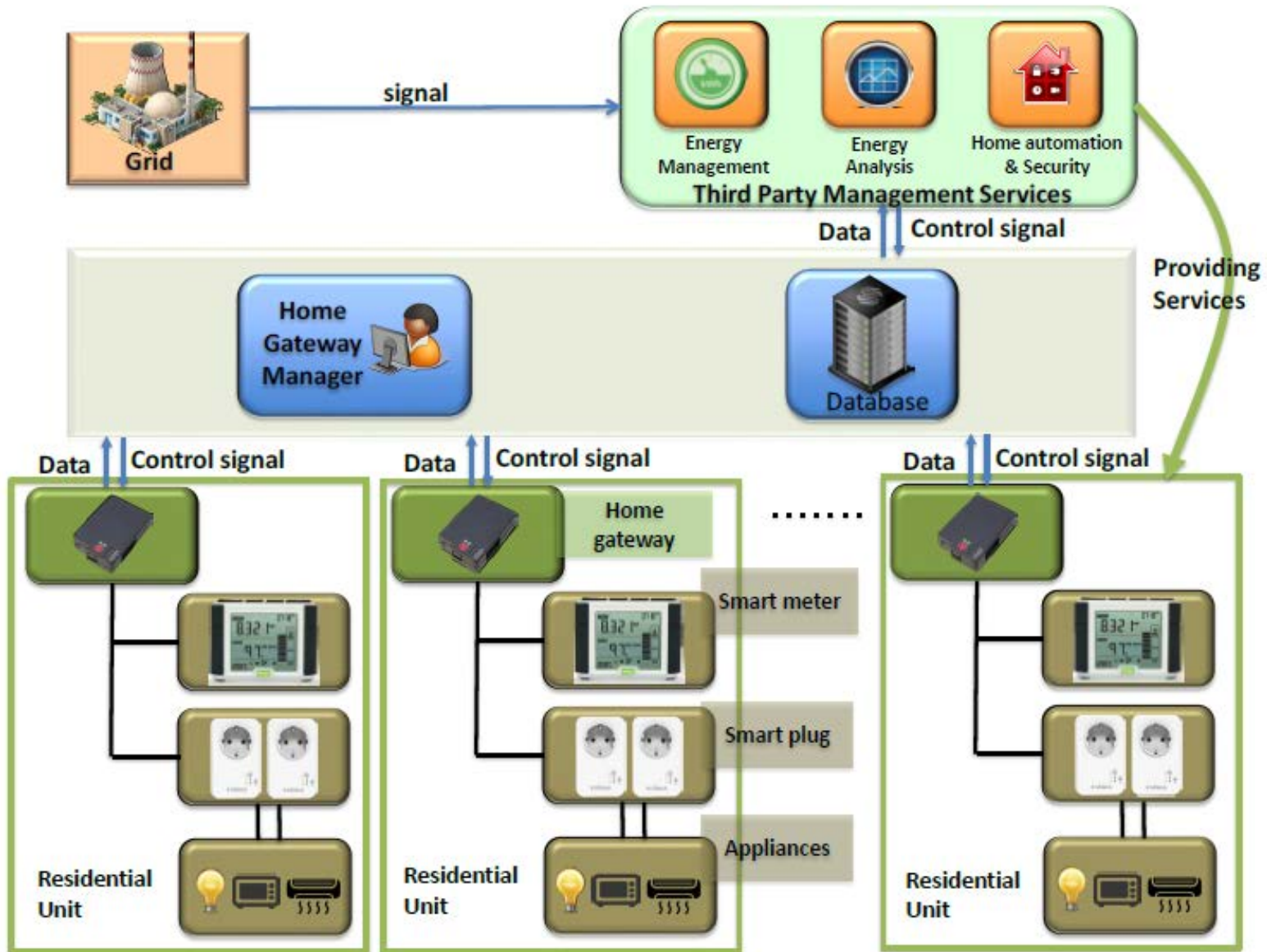
- User study in the FLL of simulated everyday behaviour
  - Day-to-day household wasting behaviour identification and categorization as design opportunities.
- Household energy user preference elicitation studies to develop smart device systems aiming at different household market segments
- User participatory design through focus group, structured interviews and surveys to generate new product/service concepts.

## Testbed and User Interaction Study:

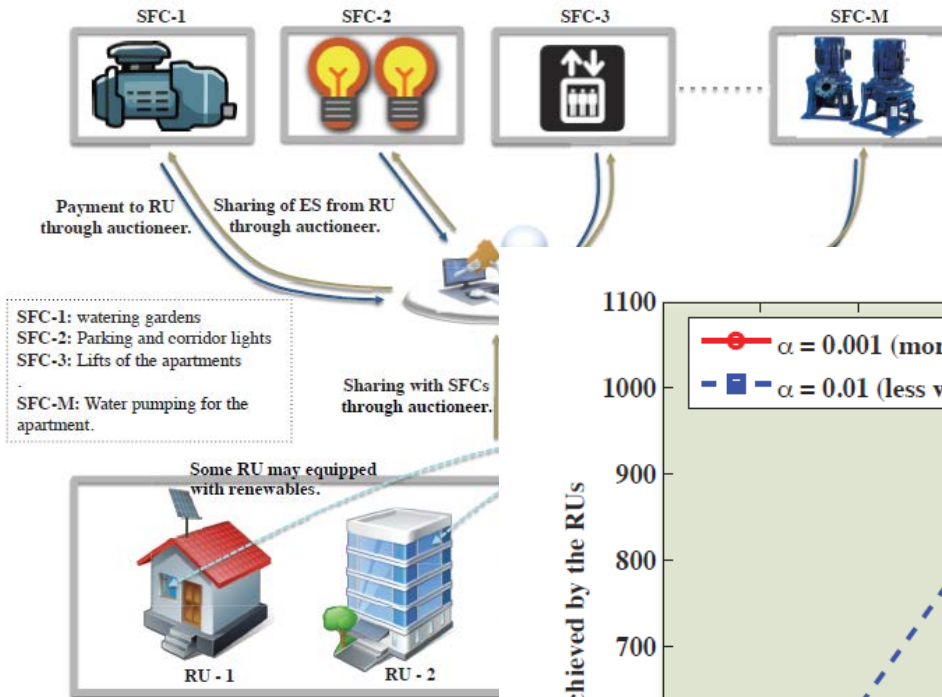
- Data and control of air conditioning systems at SUTD service apartments.
- Data and control of appliances at individual space (SUTD).
- Data and control of appliances at shared space (meeting rooms).
- Real-time energy wastage identification in SUTD office rooms.
- Real-time demonstration of PA's smart home gateway and plugs at HDB.
- Data and analysis of cohort classroom energy usage.
- Real-time energy usage feedback at FLL.



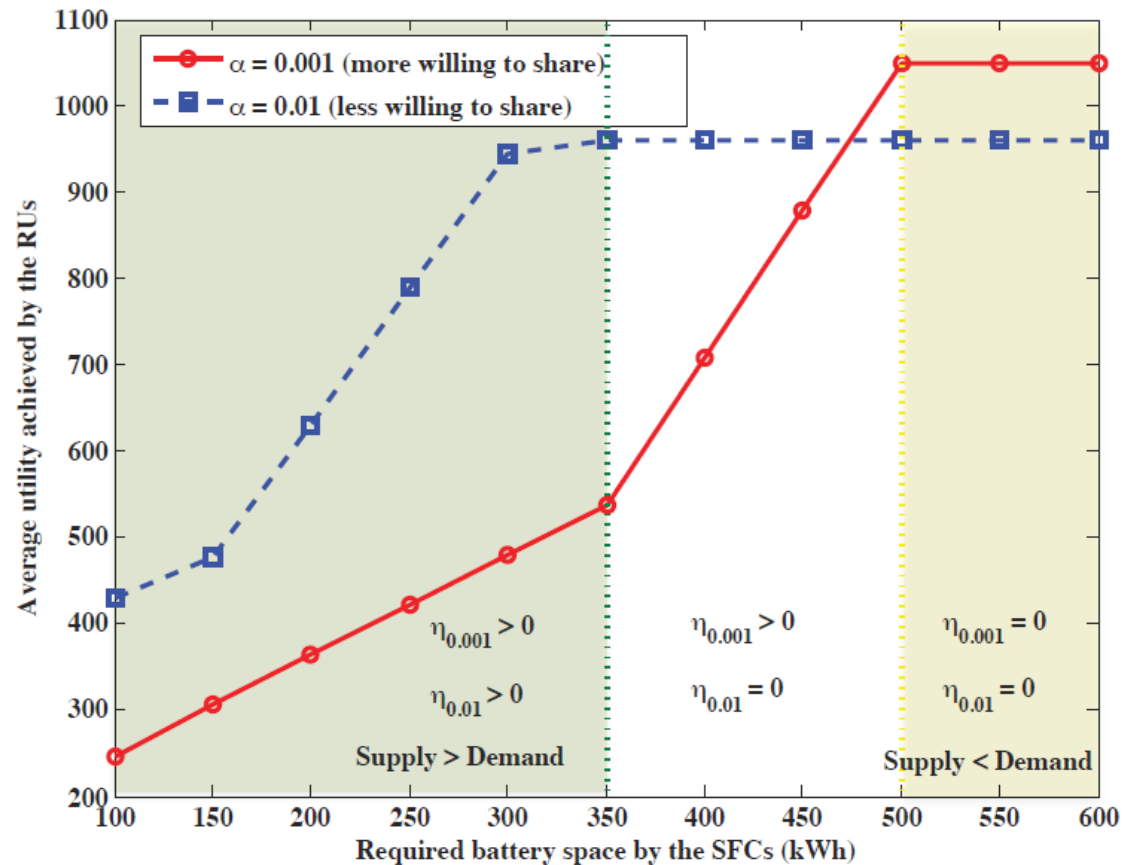
# RESULTS AND FINDINGS (PROJECT 1)



# EXEMPLAR RESULTS AND FINDINGS (PROJECT 1)

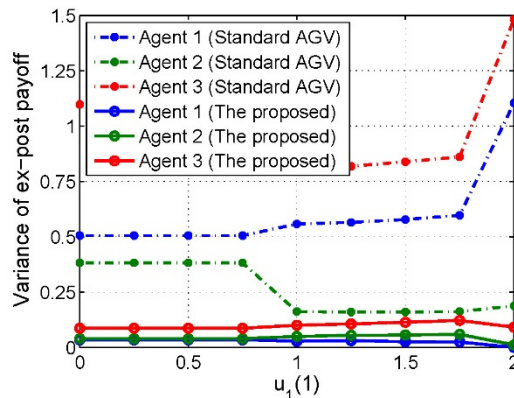
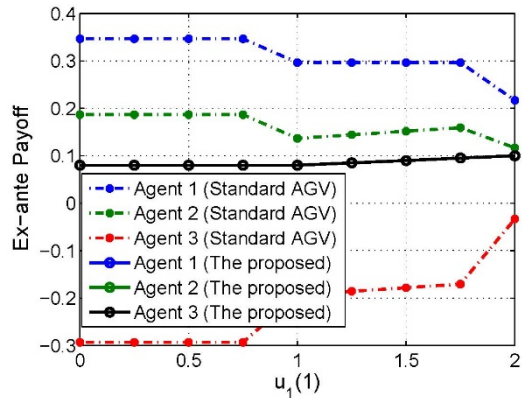


Energy Storage Sharing in Smart Grid: A Modified Auction Based Approach, IEEE Trans. Smart Grid, Dec 2015.



# RESULTS AND FINDINGS (PROJECT 2)

- Proposed a fair incentive mechanism for energy management in shared spaces : **Efficiency, Incentive Compatibility, Budget Balance** and **Equal Ex-ante Payoff**.



**Max-min Fairness of Generalized AGV mechanisms**, IEEE Conference on Decision and Control, Dec 2015

Agents' ex-ante payoffs and Variance of ex-post payoffs, under different  $u_1(1)$ .

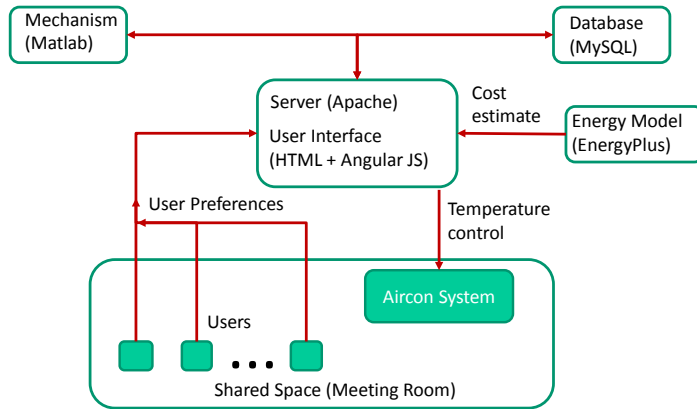
- Built a web interface for collecting users' temperature preferences and the payments.

The interface consists of two main parts: preference submission and outcome display. The preference submission screen shows the current temperature (24°C) and balance (\$5). It includes a table for the cost of changing temperature and a selection interface for preference types (Type 4, Type 5, Type 6). The outcome screen displays the selected preference (Type 5) and the resulting temperature change (0°C) and payment (\$0.08). A table at the bottom summarizes the results for the current round.

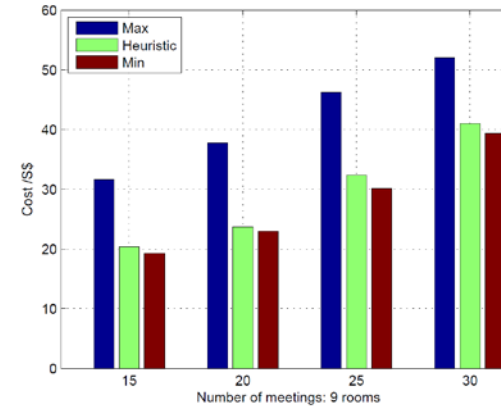
Rd	Ini. T	Pref.	S.	Pay.	ΔT.
1	24	Type-5	V	0.08	0

# RESULTS AND FINDINGS (PROJECT 2)

- An on-going experiment with human subjects on group decision making in a shared space.

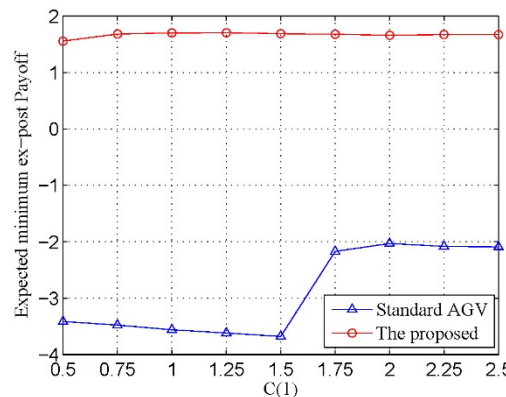
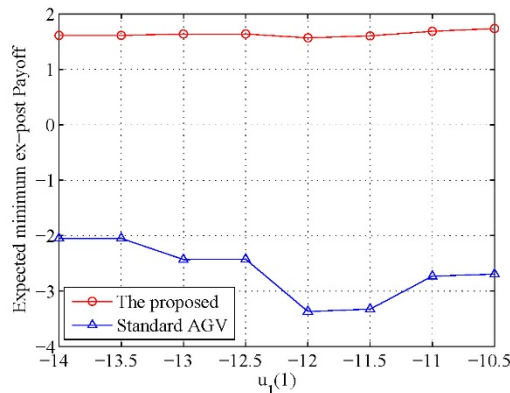


- A new approach that efficiently schedules meetings in commercial or institutional buildings with environmental considerations taken account.



Comparison of the average costs computed by three methods for 9 meeting rooms

- Proposed a mechanism keeps the good properties of **Ex-post Efficiency**, **Bayesian Incentive Compatibility**, **Ex-post budget balance**, and **“Max-min Fairness”**: expected value of minimum ex-post payoff among all agents is maximized.



Expected value of minimum ex-post payoff of all agents, under different  $u_1(1)$  and  $C(1)$ .

**Max-min Fairness of Generalized AGV mechanisms**, submitted to IEEE Trans. Automatic Control, Jan 2016



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Undertake the impossible, Design the unexpected

# It's about People and User Experience: Empathy



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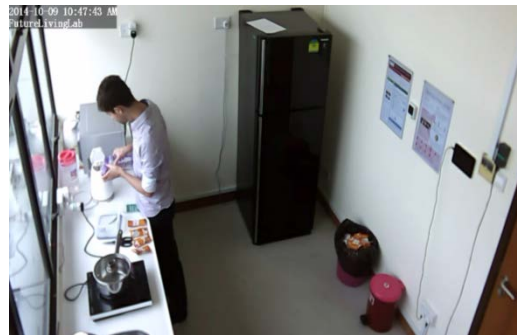
Established in collaboration with MIT

# RESULTS AND FINDINGS (PROJECT 3)

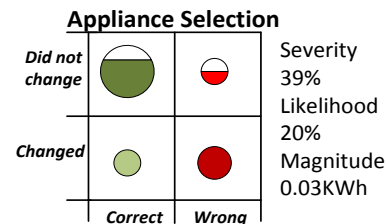
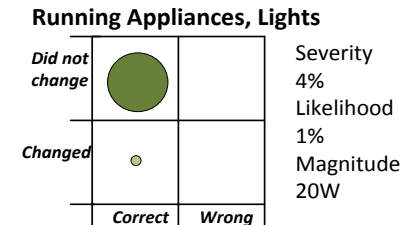
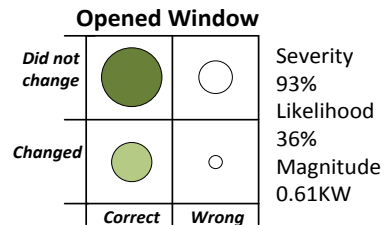
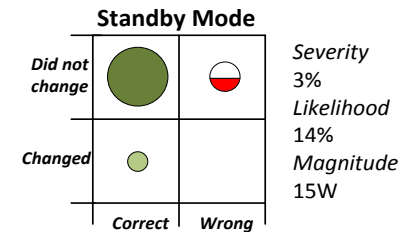
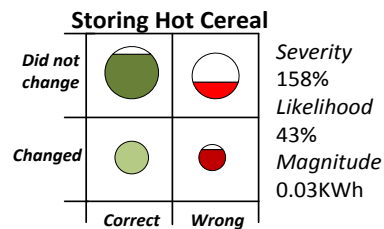
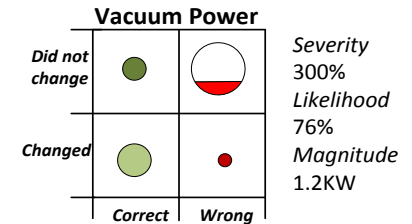
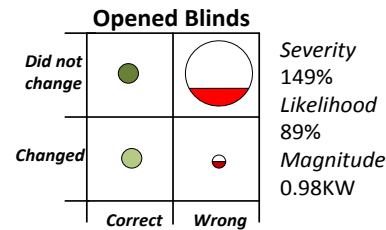
- *Low awareness on energy efficient methods to complete day-to-day tasks*

Identifying and categorizing opportunities for design for sustainable user behaviour.  
IDETC/CIE, Aug. 2014.

<i>Did not change</i>	Good, knows and does it	<b>Missed opportunities</b> 	<i>The behaviour was</i> <b>Unintentional</b> <b>Intentional</b> (from the interview responses)
	<i>Knows but does not do</i>	<b>Misconceptions or guesses</b>	
<i>Changed</i>	Correct	Wrong	



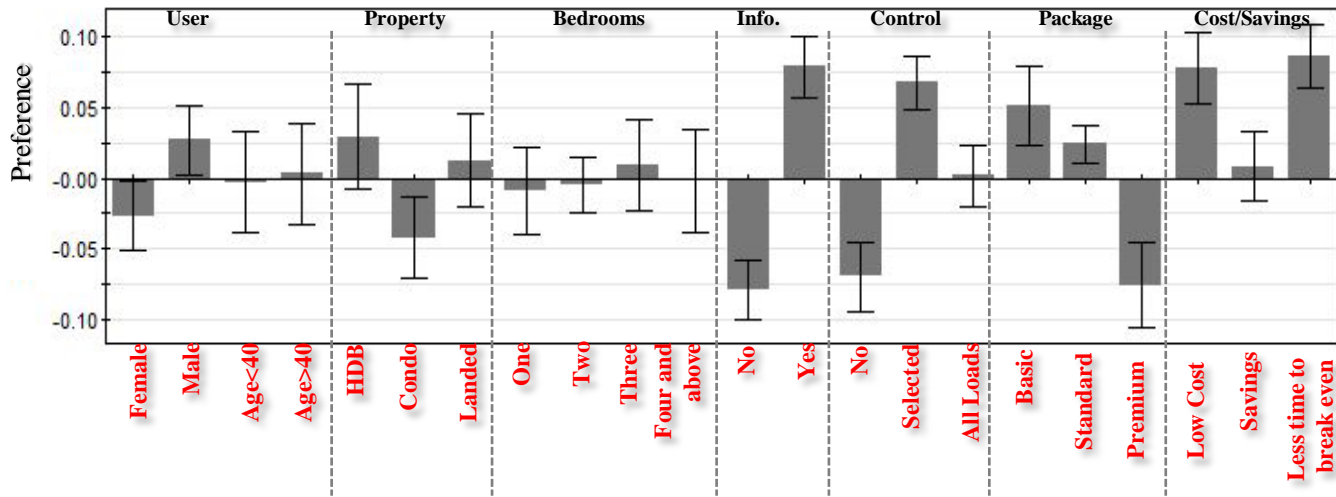
*Identify high waste activities to help users reduce consumption*



**Sustainable design opportunity classification based on user understanding.**  
Journal of Mechanical Design (under review).

# RESULTS AND FINDINGS (PROJECT 3)

- User study participants from HDB apartments are willing to accept the smart device packages with more benefits, and low break even times
- They are willing to share power consumption information, and participate in a peak shedding program with incentives and discounts
- User study participants from condominiums want to use smart device packages as home automation systems
- Participants are looking for alternative benefits such as child care, elderly care, and security
- Cost, privacy and security are the key user concerns



## User preference studies to compare various smart grid packages

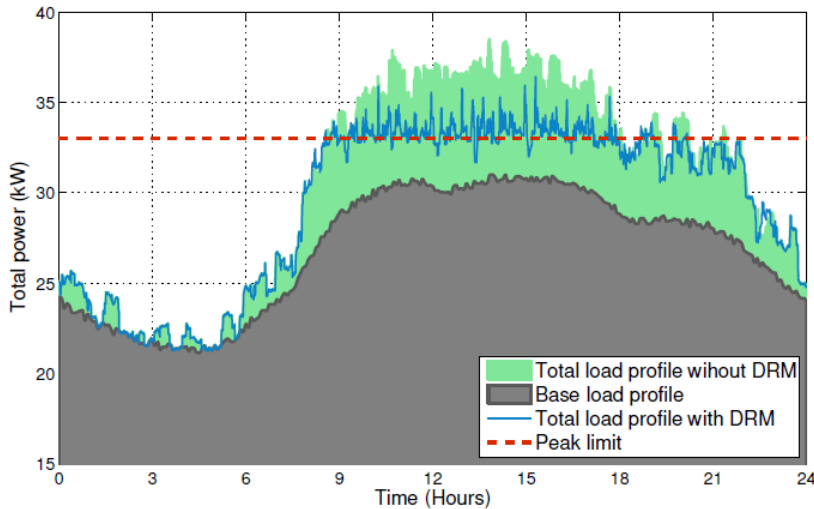
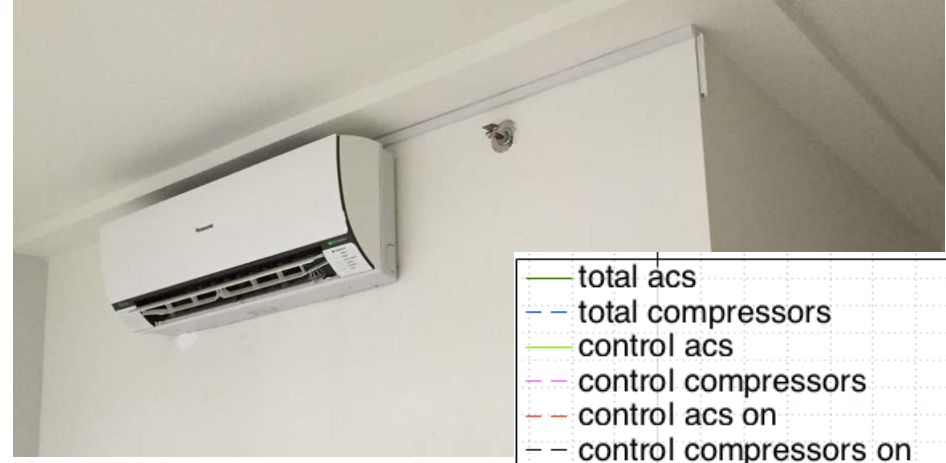
Household user needs, expectations and preferences on smart grid enabling devices: An explanatory study (working paper for IEEE Trans. Smart Grid).



# RESULTS AND FINDINGS (TESTBED)

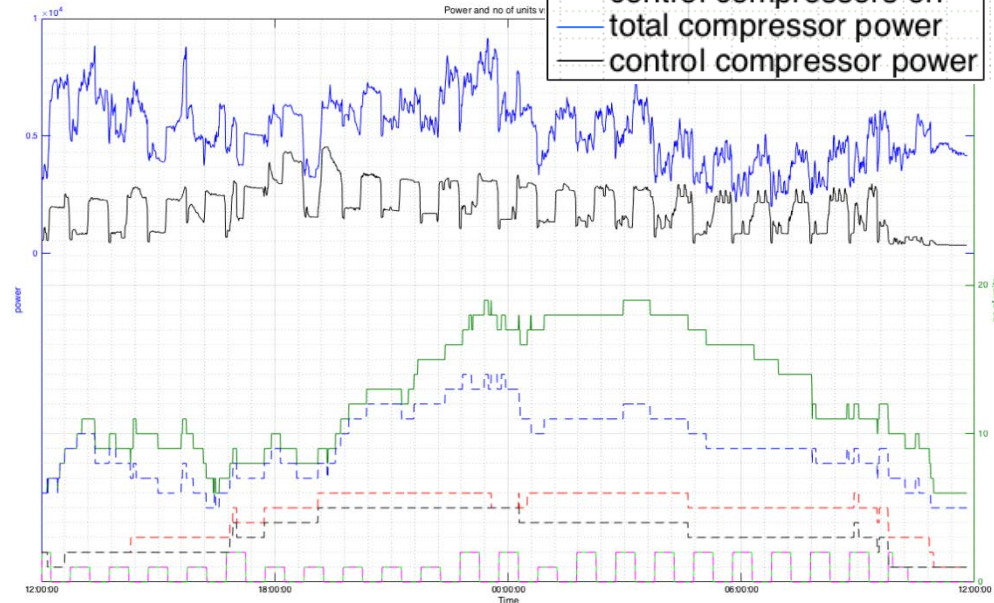
Home Gateway (PA Smart Plug)

Faculty Housing (Panasonic Aircon)



**Demand Response Management for Residential Smart Grid: From Theory to Practice**, IEEE Access, Oct 2015.

<NRF2012EWT-EIRP002-045> : <Demand Focused Smart Energy Management in End User Environment for Sustainable Cities, Kristin Wood>



**Related publication is in preparation.**

# ALIGNMENT WITH SMART NATION VISION



Connect  
Collect  
Comprehend

## Connect

Wider availability of connectivity to catalyse sensor deployment

## Collect and Comprehend

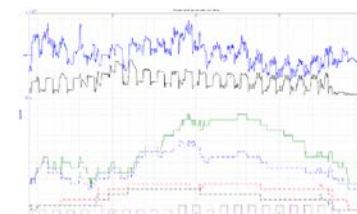
Better situational awareness through better real-time data



Real-time data monitor, collection & control devices



Real-time interaction and feedback



Intelligent control based on real-time data



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Undertake the impossible, Design the unexpected

It's about People and User  
Experience: Empathy,  
aspirations, and inspirations  
+  
Technical-Based Design  
Methods and Modeling



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Institute of  
Technology



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TECHNOLOGY AND DESIGN

Established in collaboration with MIT

# Chapter IV: Interactive E-Book Presentation

Prologue:  
Beginnings

Chapter I

Chapter II

Chapter III

Chapter IV





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Undertake the impossible, Design the unexpected

# EXEMPLAR SINGAPORE INNOVATIONS



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# MOM Experience



# Gardens by the Bay



# The South Beach Hotel



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Massachusetts  
Institute of  
Technology

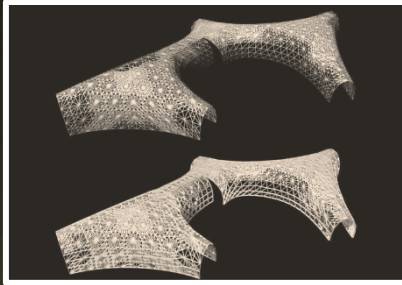
[idc.sutd.edu.sg](http://idc.sutd.edu.sg)



SUTD-MIT  
INTERNATIONAL  
DESIGN  
CENTRE (IDC)

# SG50 EXPO PAVILION

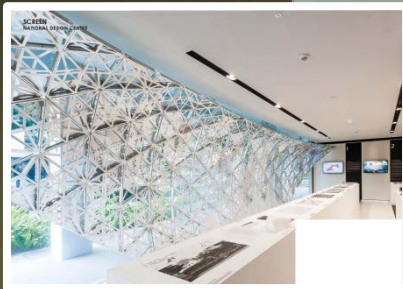
SG  
50



DHOBY GHAUT GREEN



SG 50 EXPO PAVILION @ MARINA BAY  
(opening 15-11-15)



SCREEN @ NATIONAL DESIGN CENTRE

Designed as a dynamic event space for the Singapore Futures Exhibition, the Expo Pavilion reinvents the experience of a public place in Singapore by providing a comfortable, unique, multi-sensorial and climatically appropriate environment to be enjoyed by everyone.

**Project Credit: Thomas Schroefer / SUTD Advanced Architecture Laboratory**

# Epilogue: Interactive E-Book Presentation

Prologue:  
Beginnings

Chapter I

Chapter II

Chapter III

Epilogue



# Engineering Grand Challenges of the 21<sup>st</sup> Century

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Make solar energy economical



Provide energy from fusion



Develop carbon sequestration methods



Manage the nitrogen cycle



Provide access to clean water



Restore and improve urban infrastructure



Advance health informatics



Engineer better medicines



Reverse-engineer the brain



Prevent nuclear terror



Secure cyberspace



Enhance virtual reality



Advance personalized learning



Engineer the tools of scientific discovery



Curiosity Required, Imagination Realized