Preliminary Validation of Scenario-based Amorphous Design (SAD)

INCOSE 2010

July 13, 2010

"I keep six honest serving-men:
(They taught me all I knew)
Their names are What and Where and When
And How and Why and Who."

From "The Elephant's Child" by Rudyard Kipling

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Agenda

- Design Methodologies are difficult to validate
- Other's works in Design Method Validation
- Preliminary Validation of SAD
  - Qualitative
    - Interviews, Votes, Roadmap (Aha, Oops, Eureka)
  - Quantitative
    - Statistical

Research Question

How can we methodically design systems-oriented products that are under-defined ?

Research Motivation

Kelley, Moggridge, Kim,
Mauborgne, Pruitt, Adlin, Cooper,
Christensen, Koen, Stevens,

Needs
(Market Potential)

Needsfinding
Fuzzy Front End

INSIGHT ? → **Existing Methods**

Technology
(Core Competency)

Functional Design

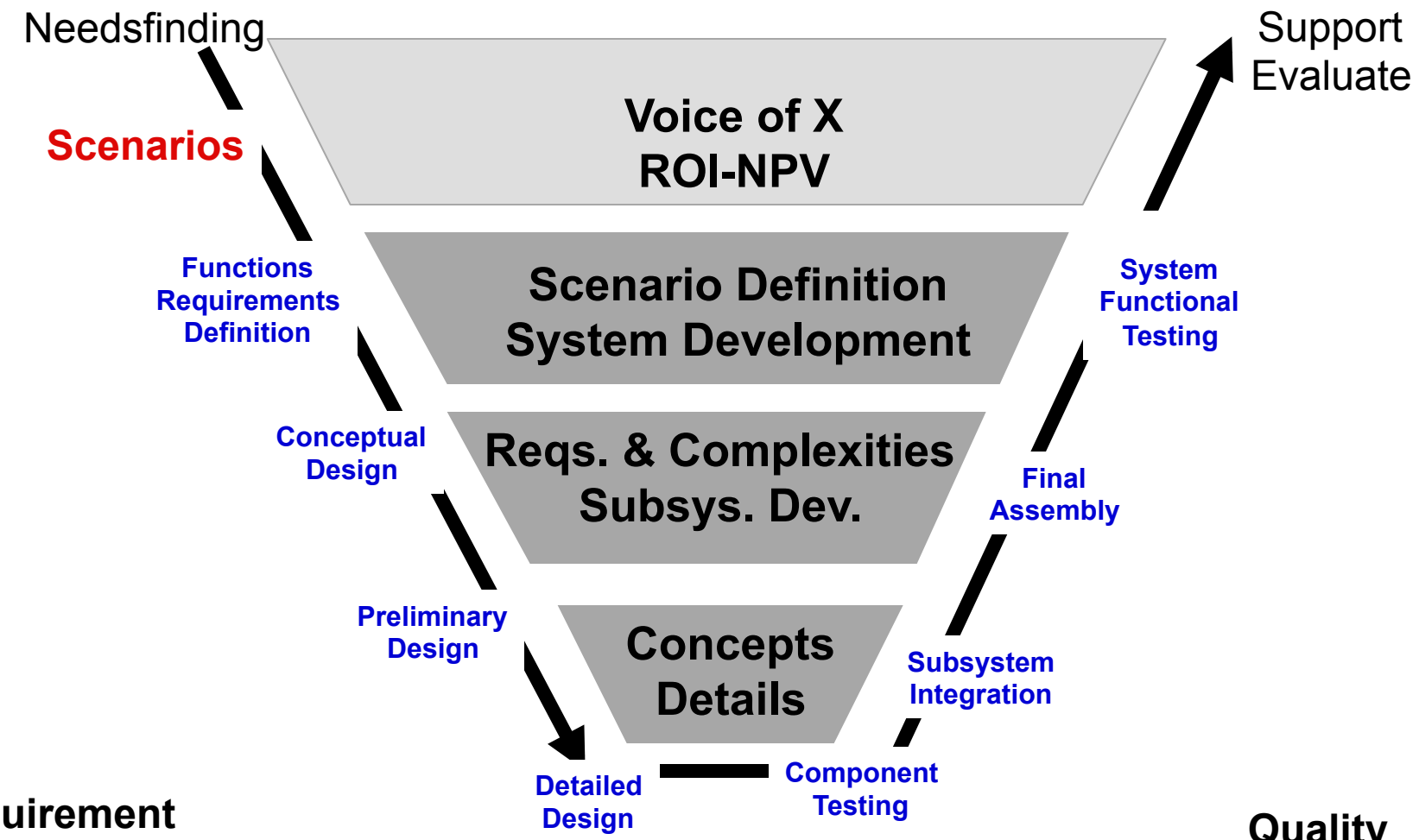
Suh, Altshuller, Pahl, Beitz,
Boothroyd, Dewherst, Cross, OMG,
INCOSE, Cagan, Vogel, Clausing

Attempts to design under-defined systems

	Contributions	Shortcomings
Preliminary Design of Amorphous Products (Beiter et al., 2006)	Applying dfX on "solution elements" rather than "parts", Used use-case	**Incomplete definitions, No exploration methods**
The Art of Innovation (Kelley et al., 2007)	Borrowed ethnography techniques from Anthropology	**Generic principles and techniques, culture Difficult to train**
Scenario-based Design (Carroll et al., 1993)	Collection of use-cases in the software engineering	**No systematic methods, No exploration methods**
SysML (OMG, 2008)	A formal language in describing systems	**Steep learning curve, Only analytical**

How SAD tools fit the ITERATIVE "V" Model

ME317, MML, Stanford (Boeing, NASA, MIT, Keio SDM, et al.)



Source: ALPS,, Keio University

Project descriptions give different levels of information – 6 W's

- Who
  - are the customers or the stakeholders involved with the product and the project?
- What
  - activities are happening?
- Where
  - or in which location is the product placed in?
- When
  - or under what circumstance are the customers in?
- Why
  - do the customers need this? What kind of value or goal does this product achieve?
- How
  - can the customer achieve this goal or value?

Amorphous: 3 W's or more are Under-defined

■Well-defined projects

☛**4 W's or more are well-defined.**

2004 Mfg. Process for Graphite Plies	
Who	operators
What	lay-up, apply pressure
Where	factory
When	require repetitive motion
Why	Increase productivity, reduce injury
How	layup automation, tools, arrangements

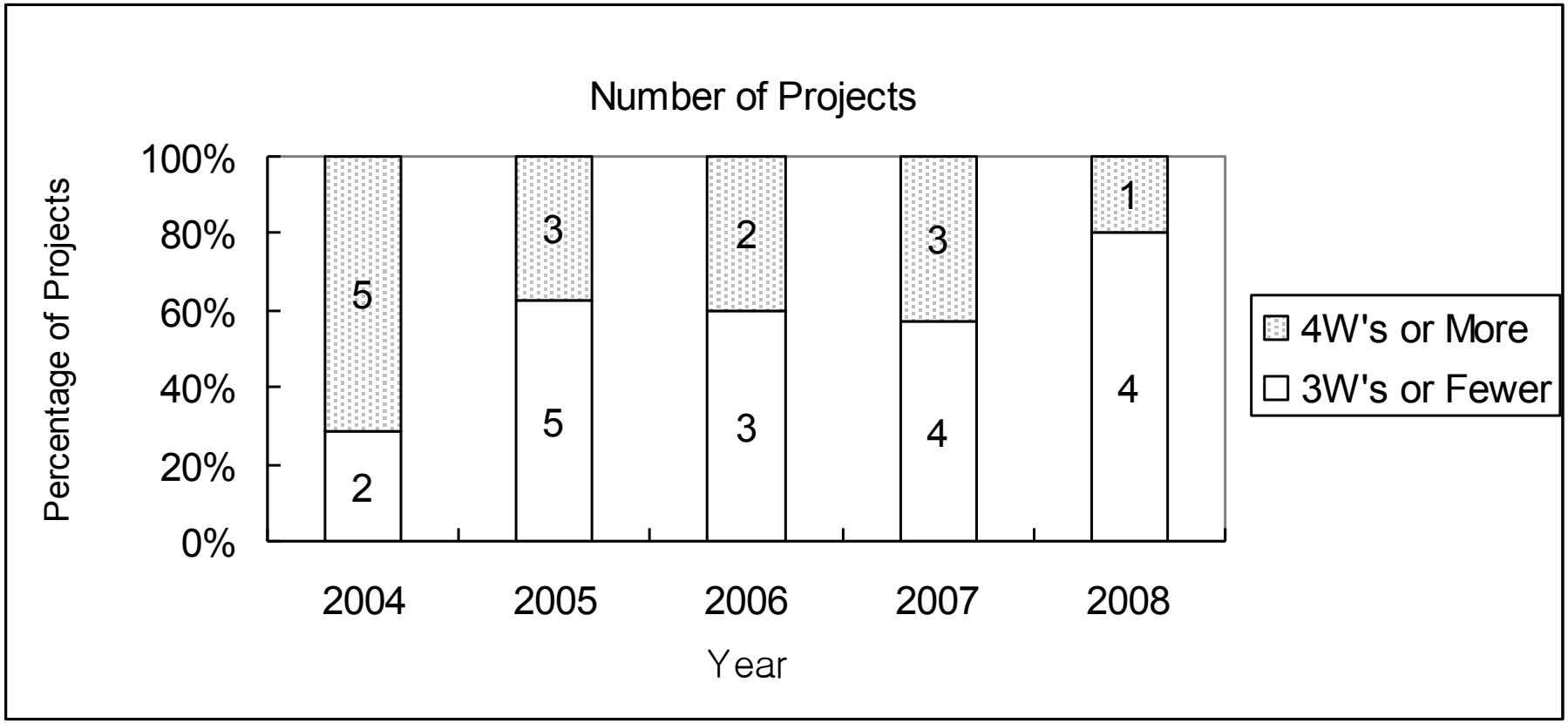
■ Amorphous projects

☛**3 W's or more are under-defined.**

2006 Car Communication	
Who ?	drivers, passengers, service provider, business owners, infrastructure, automotive companies, electronics companies, FCC, automotive/highway regulators, etc.
What ?	drive, talk, work, rest, entertain, eat, sleep, internet surfing etc.
Where	USA market, in cars, on/off road,
When ?	in traffic jam, at night, in accidents, lost, tranquil, hungry, in disaster, etc.
Why ?	increase revenue, benefit society, save environment, provide information, save lives, provide safety, provide convenience, create new world, etc.
How	using communication technology

Under-defined projects are increasing

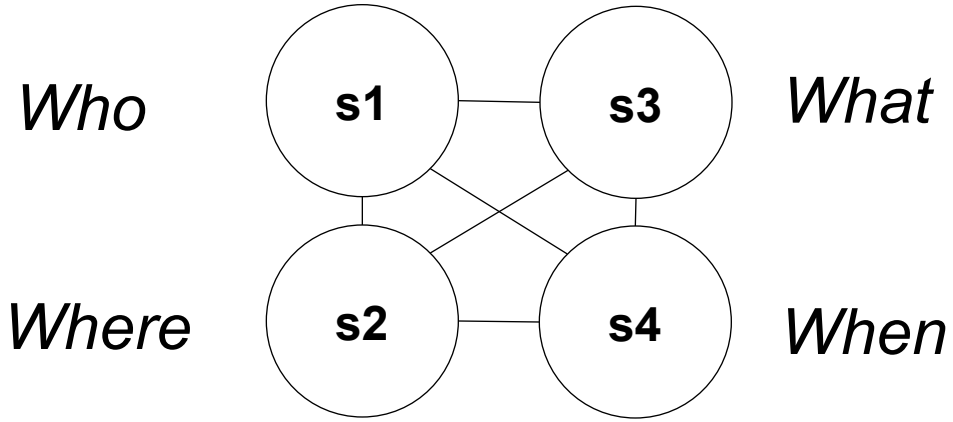
Most under-defined projects are systems-oriented



Source: Kim, 2009, Demystifying Ambiguity in The Design of Amorphous Systems, INCOSE 2009

A Scenario is a Set of *Who , What, Where & When*

- **A Common language for multidisciplinary teams, management, and customers**
  - ***Who:*** Stakeholders
  - ***Where:*** Location
  - ***What:*** Activities
  - ***When:*** Circumstance



Si= {s1, s2, s3, s4},
s1=Who, s2=Where, s3=What, s4=When
Ri = {{s1,s2},{s1,s3},{s1,s4},{s2,s3},{s2,s4},{s3,s4}}

Source: Kim, 2007, Scenario Graph: Discovering New Business Opportunities and Failure Modes , ASME IDETC 2007

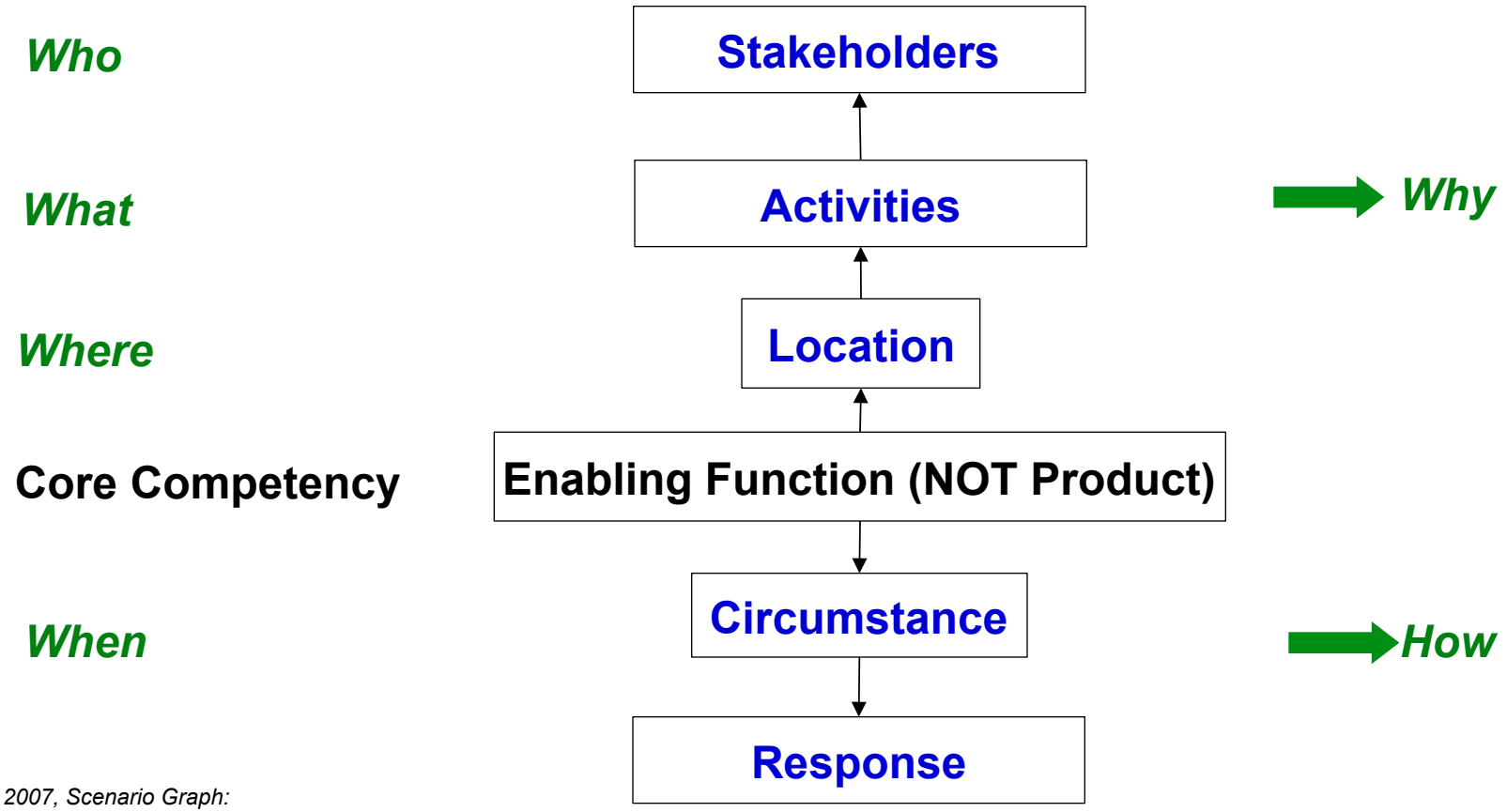
Scenario (context) is important!

- From Ambiguous Needs to Functions and Requirements
  - Simple methods to explore ambiguous needs
  - Send d.team OUT to capture user interactions
  - Provides a picture or a clear, common goal
  - Provides common language for multidisciplinary teams

- Based on Cognitive Science and Psychology
  - Situated Cognition (Greeno, Lave, Wenger, Brown, Gibson)
  - Mindmap (Buzan)
  - Diagrams (Tversky)
  - Semantic, Neural Network (Richens, Collins, Greeno)

Scenario Graph: 6 W's

- **Usage:**
  - Visualize, organize, and communicate scenarios
  - Identifying Failure Modes
- **What (Activities):** Active Verb + Noun Format



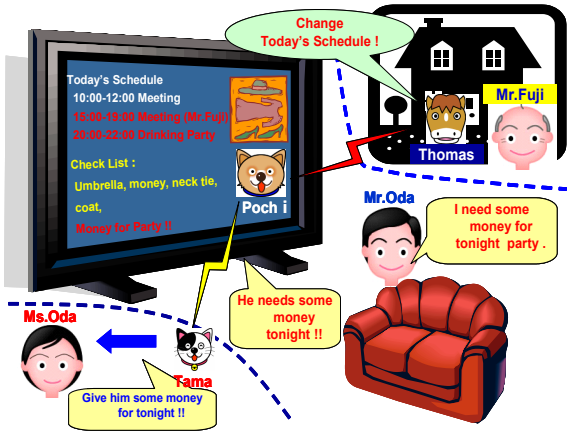
Source: Kim, 2007, Scenario Graph: Discovering New Business Opportunities and Failure Modes , ASME IDETC 2007

Case Study : From E-book Device to "Virtual Butler"

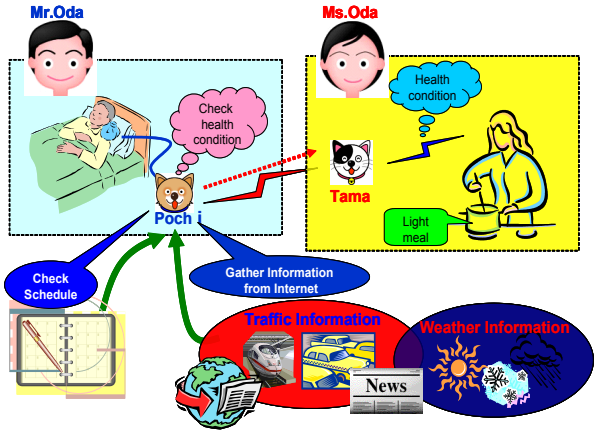
Before

After

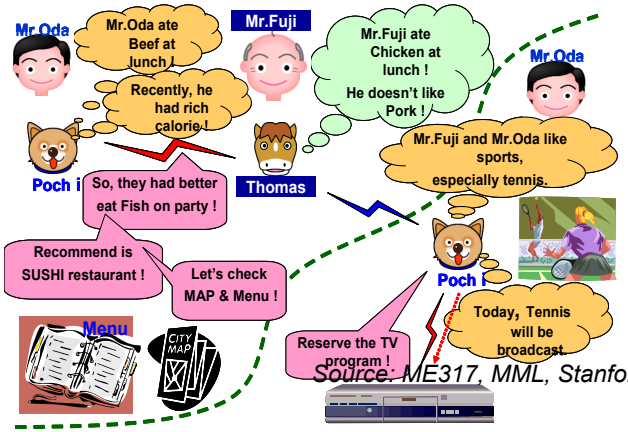
Butler System *- In the morning at home Living -*



Butler System *- In the morning at home -*

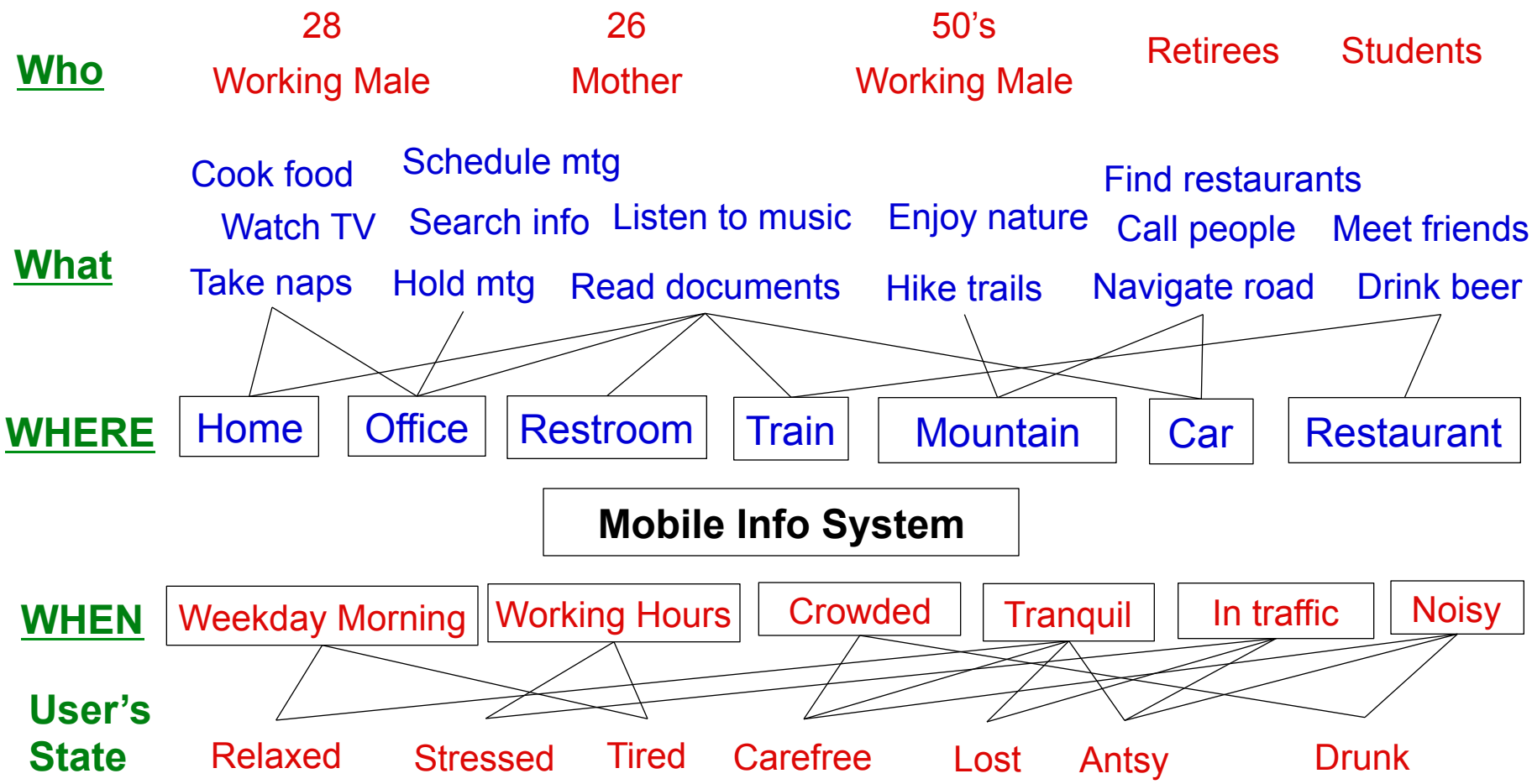


Butler System *- Personal profile -*



Source: ME317, MML, Stanford

Scenario Graph for Mobile Info System

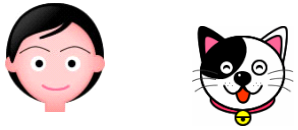


iDFACE IT Project: "Butler System"

By S.Sekimoto, Toshiba Sigma Consut.
Stanford NPI Roundtable, July 16, 2008

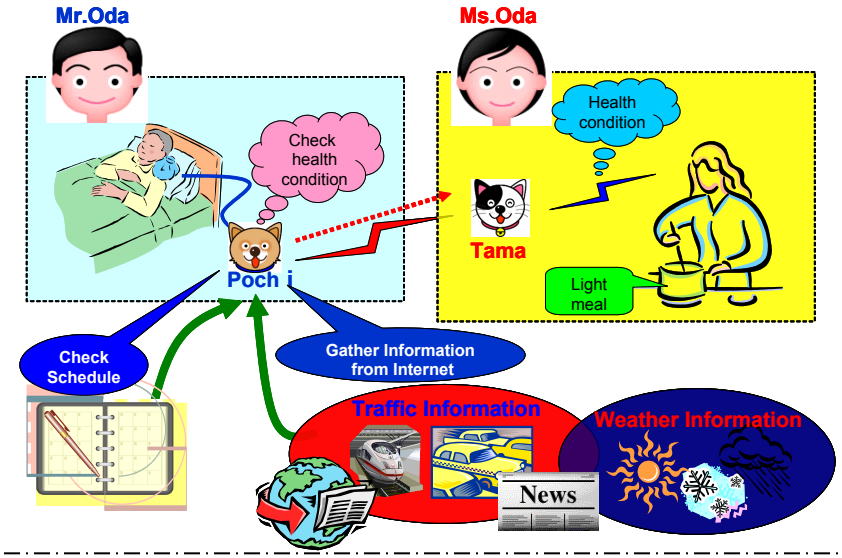
- **Characters**
  - **Mr.Oda**: 28 years old working TOSHIBA and has his butler named **Pochi**.

  - **Ms.Oda**: 26 years old and has her butler named **Tama**.

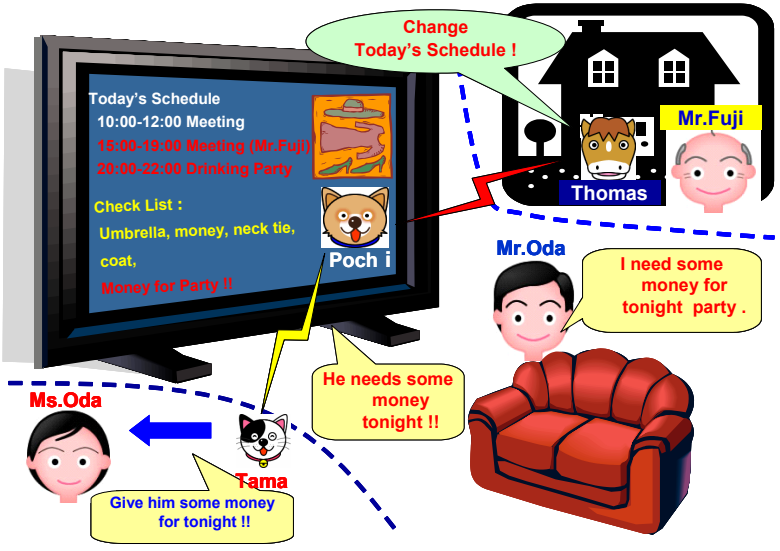


  - **Mr.Fuji**: 44 years old and Mr.Oda's boss and has his butler named **Thomas**

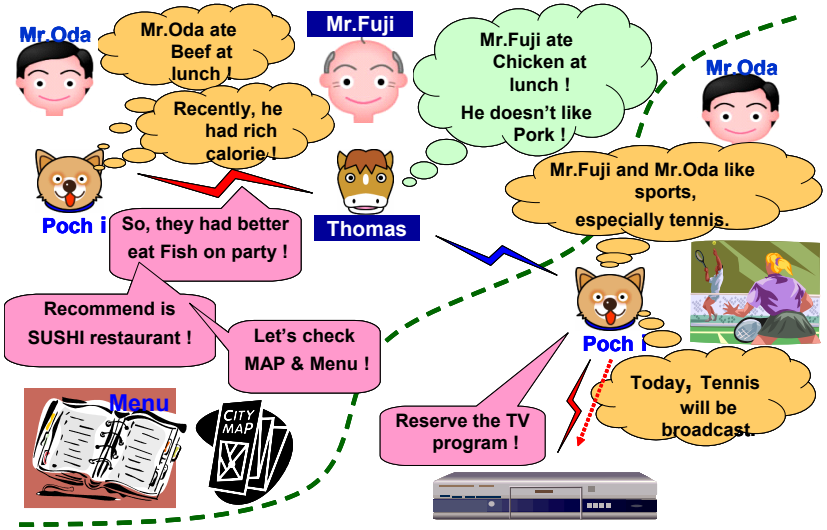
Butler System - *In the morning at home* -



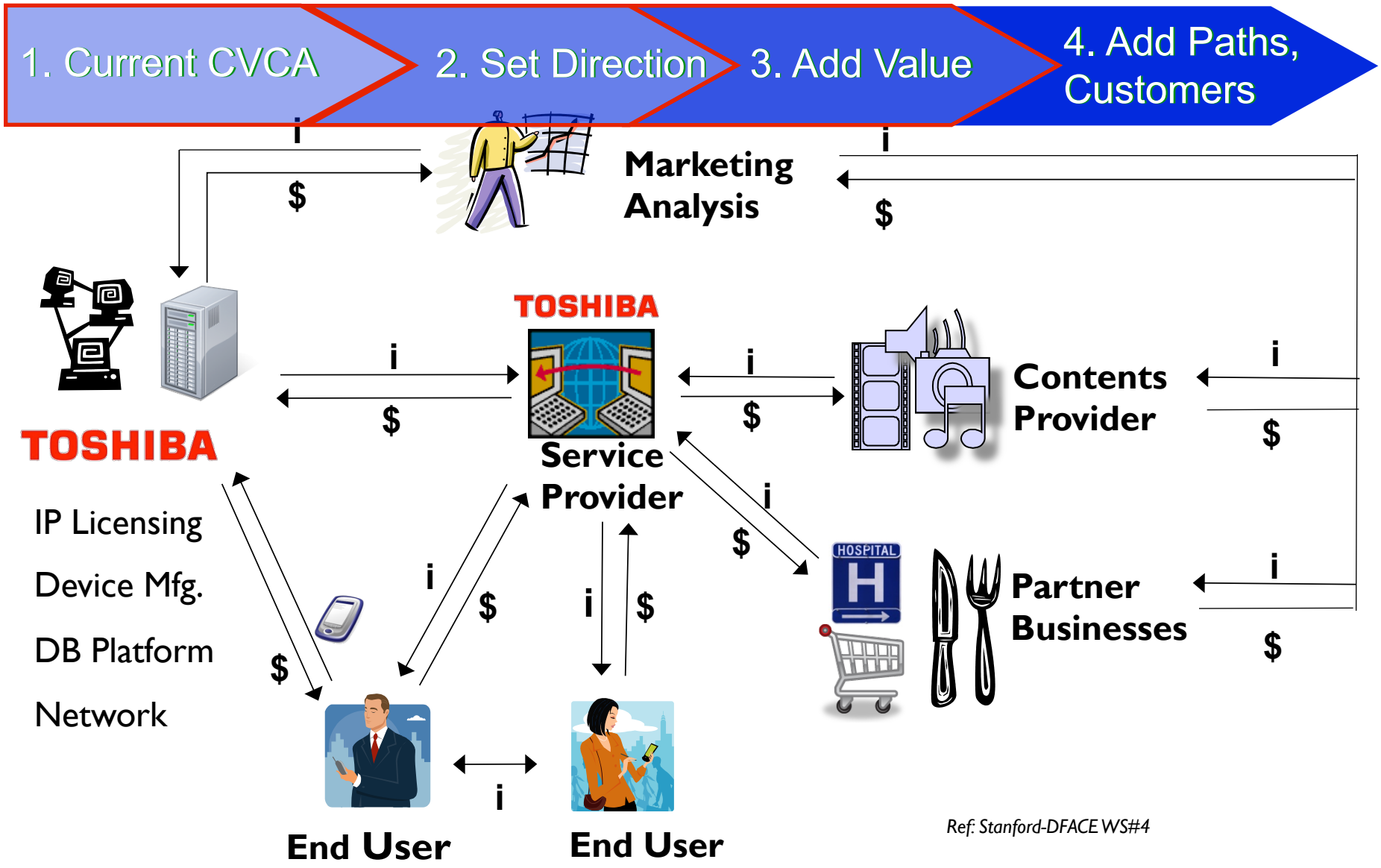
Butler System - *In the morning at home Living* -



Butler System - *Personal profile* -



Dynamic CVCA: "Butler" Case



Ref: Stanford-DFACE WS#4

Quantitative Validation

- **Method**
  - ☛ Survey before and after
- **Statistical Methods**
  - ☛ T-test, Wilcoxon-Mann-Whitney, Hierarchical Modeling
- **Sample Group**
  - ☛ CONTROL: ME317 teams from 2004 to 2008
  - ☛ TEST: Keio ALPS teams from 2008

Project Definition Checklist
simplified from the Edith Wilson checklist (4.6 on p. 60)

Scenario: team agrees on target VOS and scenarios?

- **Scenario-based Design, Scenario Morph**

Stakeholders: team captured and agrees on customer / stakeholder chain?

- **CVCA, Scenario Graph**

Customer Value: team understands CRs & EMs, innovation opportunity?

- **Value Graph, QFD, Project Priority Matrix**

Complexities: team understands the complexities (cost, time, etc.)?

- **Process analysis (e.g., assembly), Process FMEA, Cost Worth**

Concept Architecture: team selected and proposed (described) system?

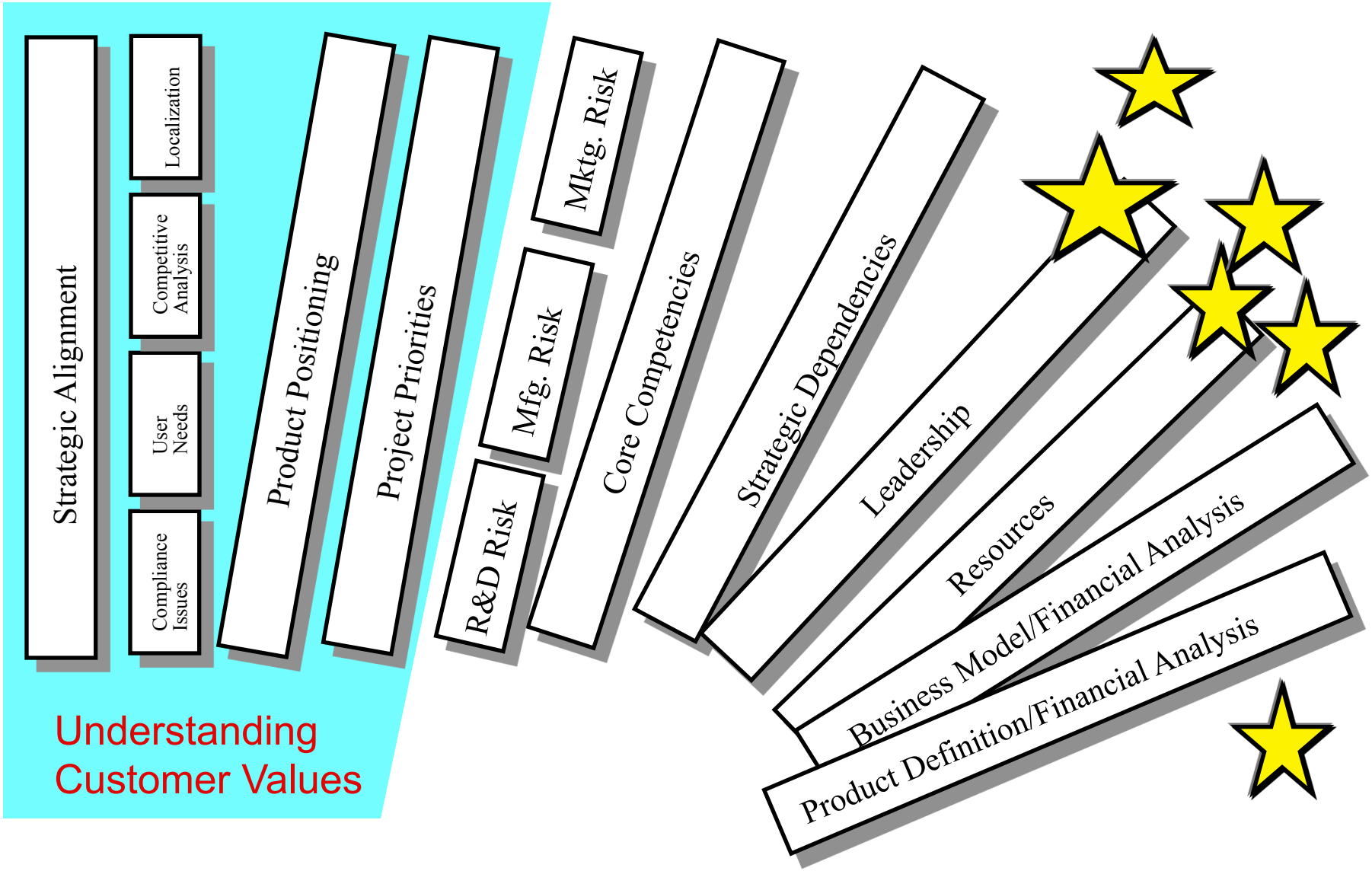
- **Morph & Pugh, Scenario-Function-Solution Elements Map, OPM**

Business Model and Risks: team has evaluated cash flows & uncertainties?

- **Dynamic CVCA, FMEA, Decision Analytical Scorecarding**

Product Definition: Domino Effect

section 4.3 (p.52) of "Value Creation (Ishii)"



Metric: Level of Understanding

1, 2, 3, 4, &10 addresses the 4 W's

- **When**
  - **1. Strategic Alignment:** Does the team understand the strategic objectives, the boundary conditions within which they need to operate, and the target market for the product?
- **Who, What, Why**
  - **2. Understanding User and Customer Needs:** Has the project team verified the target market segment, its attractiveness in terms of size and growth rates, and identified the fundamental needs of the market, e.g. productivity, cost effectiveness, ease of use, ...?
- **Where, When**
  - **3. Localization:** Are the variations in user needs and compliances understood by geography?
- **When**
  - **4. Compliances:** Has the team identified all relevant compliance standards?
- **What**
  - **10. Core Competencies:** Are all the core competencies, required for successful deployment of your project, identified and accessible?

Survey addresses 5 W's

	1. Strategic alignment	2. Understanding users and customers	3. Localization	4. Compliances	10. Core competency
Who		O			
What	O	O			O
Where			O		
When	O		O	O	
Why		O			

Validation Hypothesis

Research Hypothesis

- **The difference between the levels of understanding exhibited by teams in responding to the first and second administration of Product Definition Checklist questions was different for the team that used the SAD than for the team that did not use SAD.**

$$H_1 : \Delta\overline{X}_{Ai} \neq \Delta\overline{X}_{Bi}$$

A: Did not use SAD

B: Used SAD

Where

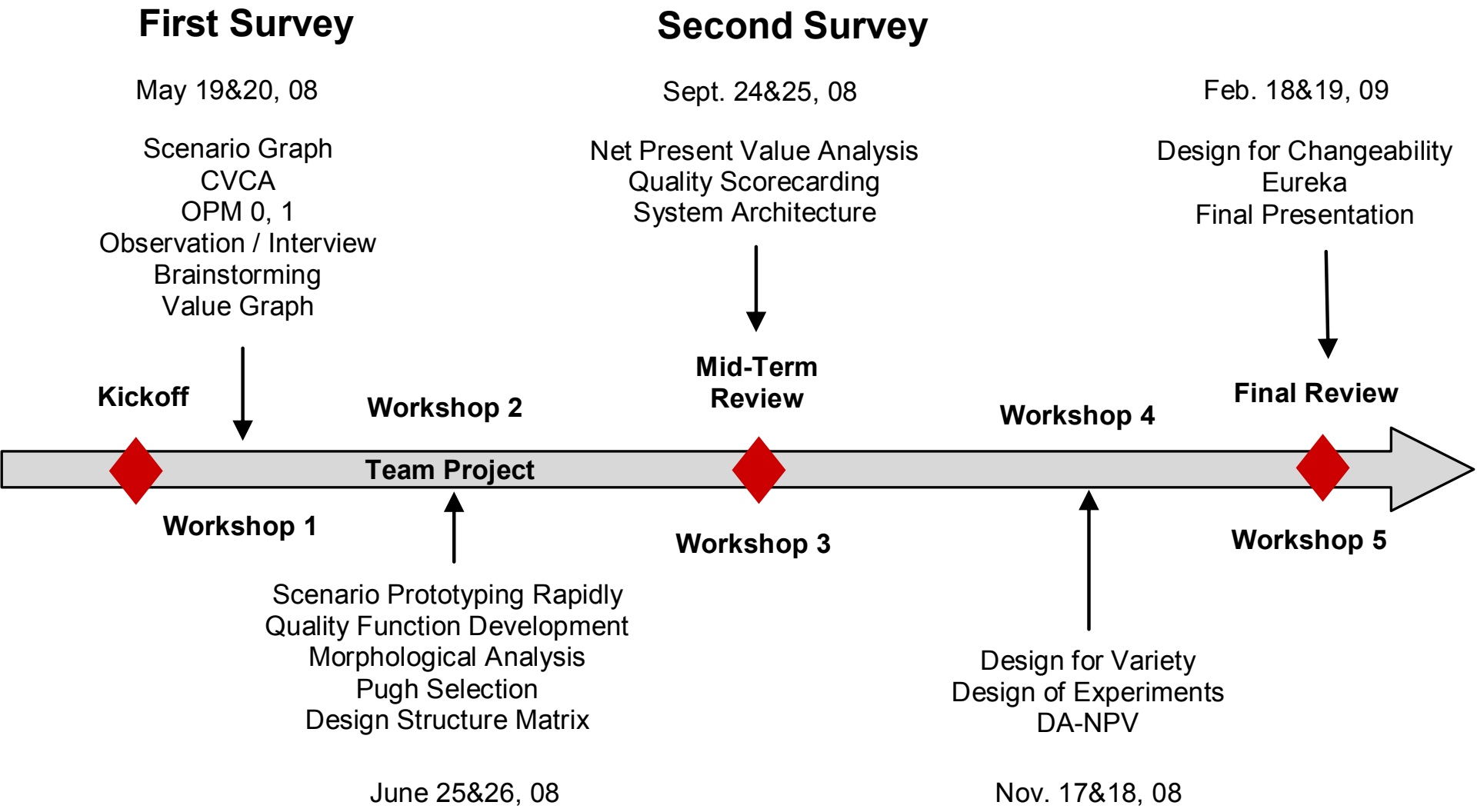
$\Delta\overline{X}$: Difference of understanding between 1st and 2nd survey

For i=1,2,3, 10

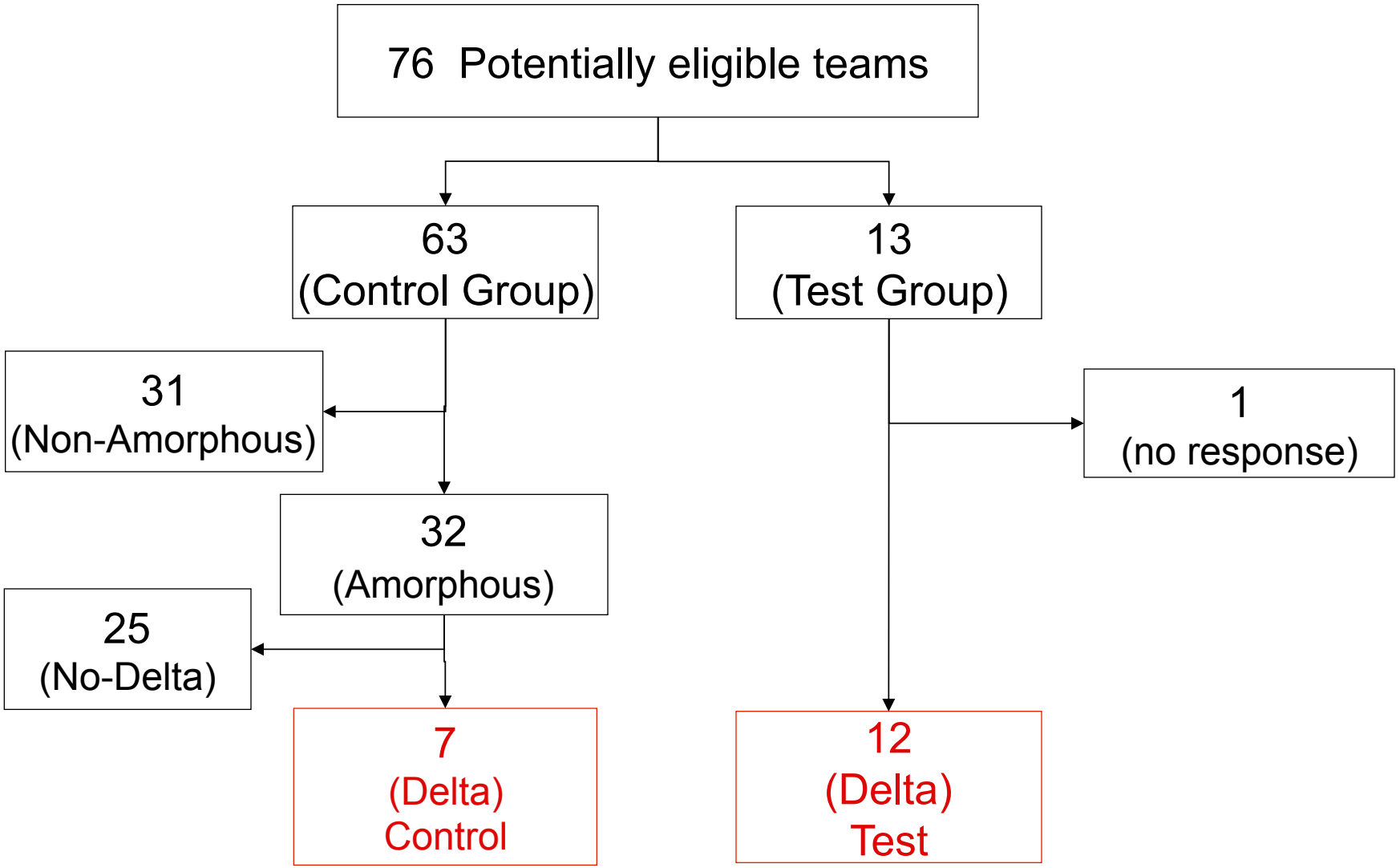
Null Hypothesis

$$H_0 : \Delta\overline{X}_{Ai} = \Delta\overline{X}_{Bi}$$

Timeline of Survey

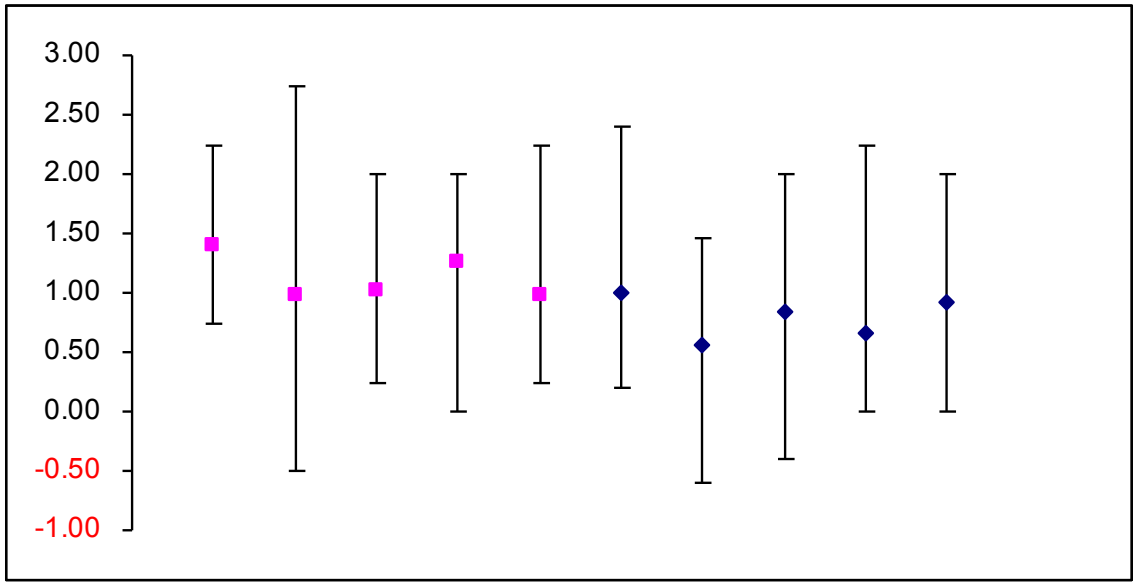


Flow of Participants



Results

Questions	1	2	3	4	10
P	0.118	0.174	0.295	0.053	0.424
t	1.231	0.967	0.550	1.709	0.194
Degree of Freedom	17	17	17	17	17
Mean Test	1.010	0.562	0.844	0.662	0.912
Mean Control	1.398	0.988	1.014	1.255	0.979
SD Test	0.730	0.617	0.770	0.564	0.680
SD Control	0.613	1.031	0.571	0.767	0.738



Quantitative validation requires further work

- **Biased group selection**
  - Cultural background, confidence level
  - Language barrier
  - Different projects
  - Educational background
- **Requires relevant survey, metrics**
- **Requires larger sample size**

Statistical Power	Required Sample Size
34.20%	32
26.50%	44
13.70%	172
55.50%	14
7.40%	1214

Qualitative validation is positive

"I am bewildered for practice (scenario work)."
"I could clarify the method of the system and engineering."
"I was very interested in "scenario"."
"I'm sure it will help me a lot. In the next lecture, I like to hear the real stories concerning creativity more."
-2008_05_20_Keio SDM ALPS student opinions

"I notice the importance of high level goal and concept…
To create sky-high idea, we try to use various methods…
The next time, I promise you to show the creative [prototyping rapidly]"
"Prototype rapidly was really fun…"
"I think that tools you show us Is important in our business. As a review, I want to use the tools on my business…"
-2008_06_26_Keio SDM ALPS student opinions

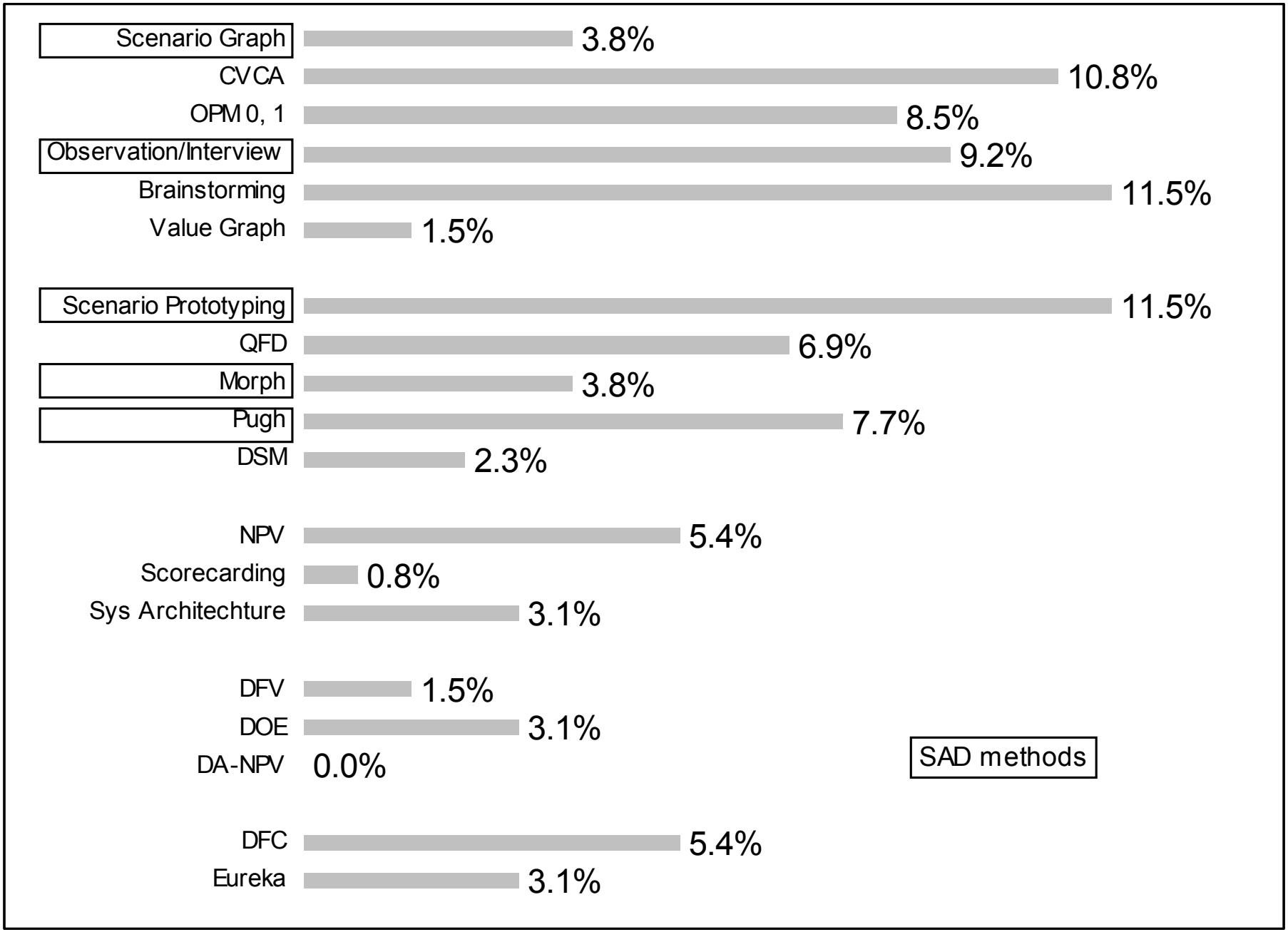
"Trial using the brainstorming and WAIGAYA …was the best"
"Method of scenario selection …was clear."
"I feel my brain become flexible…is best"
"Action Flow around VOS, Scenario…is clear"
"Divide and conquer…is useful."
"Vox framework…is useful."
-2007_Toshiba WS1
"Scenario Graph can generate many scenarios" (Toyota 2009)

Qualitative validation is positive

- **Keywords:**
  - Clarify, Create, Interested, Helped, Stories, Creative, fun, Sky-high Idea

- **Key quotes from design teams**
  - "importance of high level goal and concept"
  - "…I want to use the tools on my business…"
  - "Trial using the brainstorming and WAIGAYA …was the best"
  - "Method of scenario selection …was clear."
  - "I feel my brain become flexible…is best"
  - "Action Flow around VOS, Scenario…is clear"
  - "Divide and conquer…is useful."
  - "Vox framework…is useful."

Tool Voting



When Design Teams make Breakthroughs

Legend A: Aha O: Oops E: Eureka

		Teams											
Workshops	Methods	A1	A2	B1	B2	C1	C2	D1	D2	E1	E2	F1	F2
WS #1	Scenario Graph							A					
	CVCA				A								
	OPM 0, 1												
	Observation/Interview	O						O	A,E	A,O,E		O,E	E
	Brainstorming	A	A					A				A	
	Value Graph						A						
			O*			A*							
WS #2	Scenario Prototyping								E			O	
	QFD												
	Morph	E		A									A
	Pugh	E	E	A			O						
	DSM												
						O,E*					A*		
WS #3	NPV			O	P					O	O		O
	Scorecarding												
	System Architecture						E						
WS #4	DFV												
	DOE												
	DA-NPV			E	O								
WS #5	DFC				E						E		
	Eureka												

Conclusion

Proposed

- Framework and methods to design systems with under-defined project scope
  - Analyzed 32 industry-sponsored projects
  - 6 W framework for product definition phase
  - New methods: Scenario Graph, Scenario Menu
- Language for multidisciplinary design teams
  - Amorphous (Under-defined): 3 W's or less are well-defined.
  - Scenario: A *set of Who, What, Where and When*
- Statistical validation model for design methods

Helped 70+ team projects

- Implemented in 28 projects from industry, academia
  - 25 ME317, 37 ALPS SDM, 5 retrospective studies
- Integrated in Toshiba DFSS training module
  - 2 Innovation projects

Future Work

- Better metrics (survey)
- Controlled Experiment Design – Qualitative or Quantitative

Acknowledgement

Committee Members	Kosuke Ishii, Ken Waldron, Kurt Beiter, Hau Lee, Seungjin Whang, Raymond Levitt
Affiliates	Keio, Toshiba, SLAC, GE, GSCMF
MML Members	Whit, Jenny, Sandi, Sam, Karthik, Kenij, Tomaru, Brent, Tae, Seung, Larry, Peter, Tina, Kash, Tak, Ken, Sam, Toshi, Yoda, Rashida, Cona, Satch, Copper
Family & Friends	Lily, Parents, Siblings, KME

Q&A

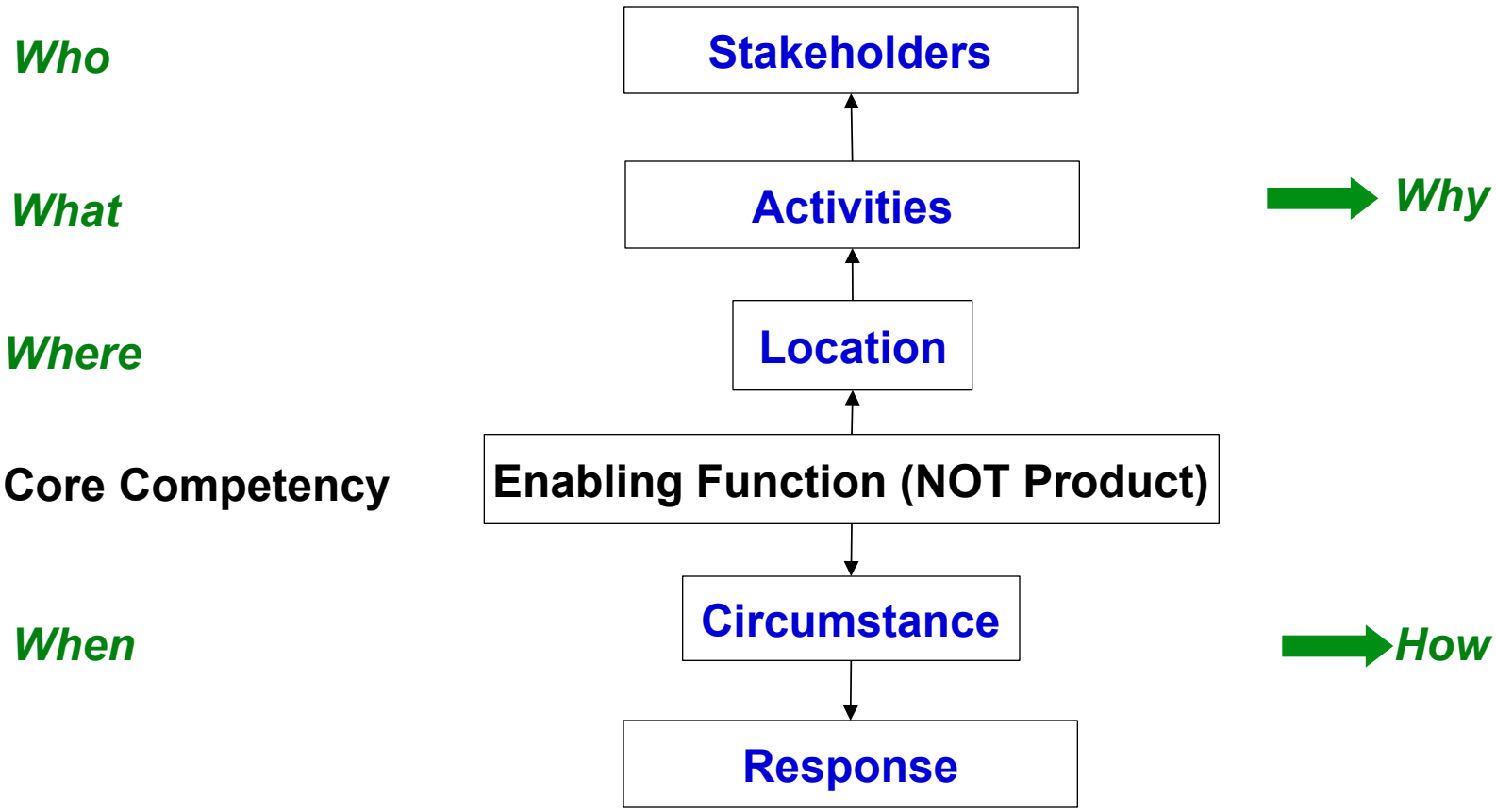


Table 1 9 Types derived from 40 Cases in the Customer Contact Expansion Model

Type	A	C	T	Num	Product-based Services[6)]
1	M	S	S	1	Elevator maintenance
2	S	M	S	5	Electronic money by RFID, document outsourcing, PDP information service, PFI, railway information service
3	S	S	M	6	Ringing melody service, DVD contents recommendation, telematics, automatic ticket gate information service, music download, electricity usage monitoring service
4	M	S	-	9	Maintenance services (exposure equipment, security system, ATM, parking facility, water and sewerage system, gas turbine, physical distribution system), coating system management, POS system support
5	S	M	-	5	ESCO, residential property maintenance, coating system outsourcing, rental washing machine, aircraft engine leasing
6	S	-	M	6	Housing improvement service, PDP-based meeting support system, information system by construction company, maintenance portal site, mobile phone solution, management consulting by manufacturer
7	M	-	-	4	Cement solution, chemical goods maintenance, seismic diagnosis, aircraft information service
8	-	M	-	2	Financial service, rental PC
9	-	-	M	2	One-stop mobile phone solution, industrial gas distribution system

(A: Adjustment expansion, C: Commitment expansion, T: Territory expansion, Num: Number of cases, M: main feature, S: subsidiary feature)

Table 3 8 Elementary Service Function Templates in Customer Contact Expansion Model

Expansion Type	Elementary Function	Explanation
Adjustment Expansion	Consulting	Consulting services to teach customers how they can make better use of the product
	Customizing	Customizing services to improve the product so that customers can make better use of it.
	Downtime and Risk Reduction	Maintenance services to reduce downtime and related risks by using monitoring information of the product.
Commitment Expansion	Financial Risk Reduction	Risk reduction services to take over financial risks (e.g. repair cost and investment risk) in place of customers.
	Social Risk Reduction	Risk reduction services to take over social risks (social responsibility) in place of customers.
	Operational Efficiency	Operation services to operate the product efficiently in place of customers.
Territory Expansion	Seamless Services	Related services necessary to solve customers' problems with the product, which are seamlessly provided.
	Rich Content	Content delivery and updating services by a platform connected to the products, where the content is processed in the product.

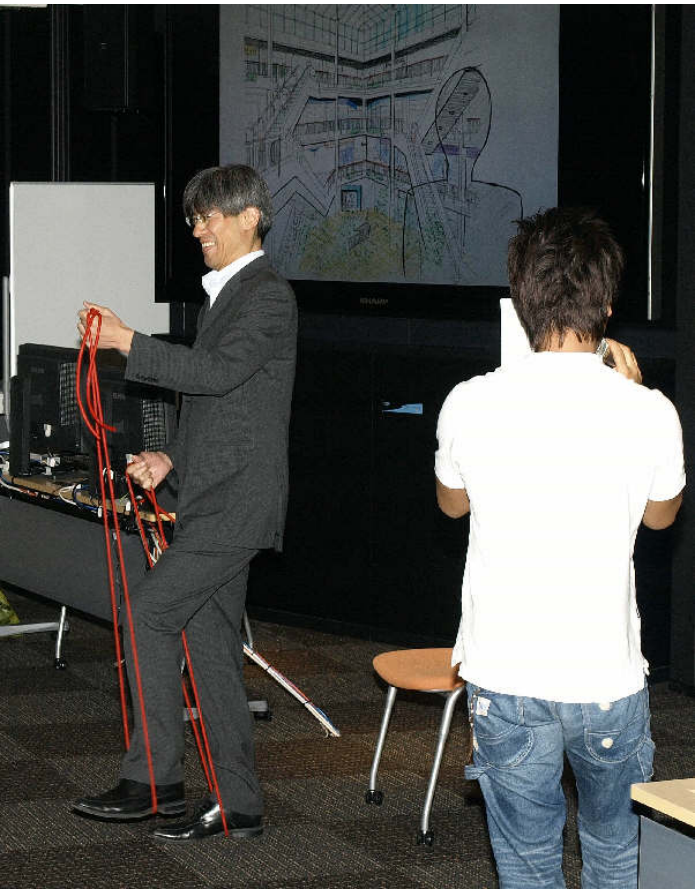
- **Based on Cognitive Science and Psychology**
  - ☛ **Mindmap (Buzan)**
  - ☛ **Diagrams (Tversky, Tufte)**
  - ☛ **Semantic, Neural Network (Richens, Collins)**

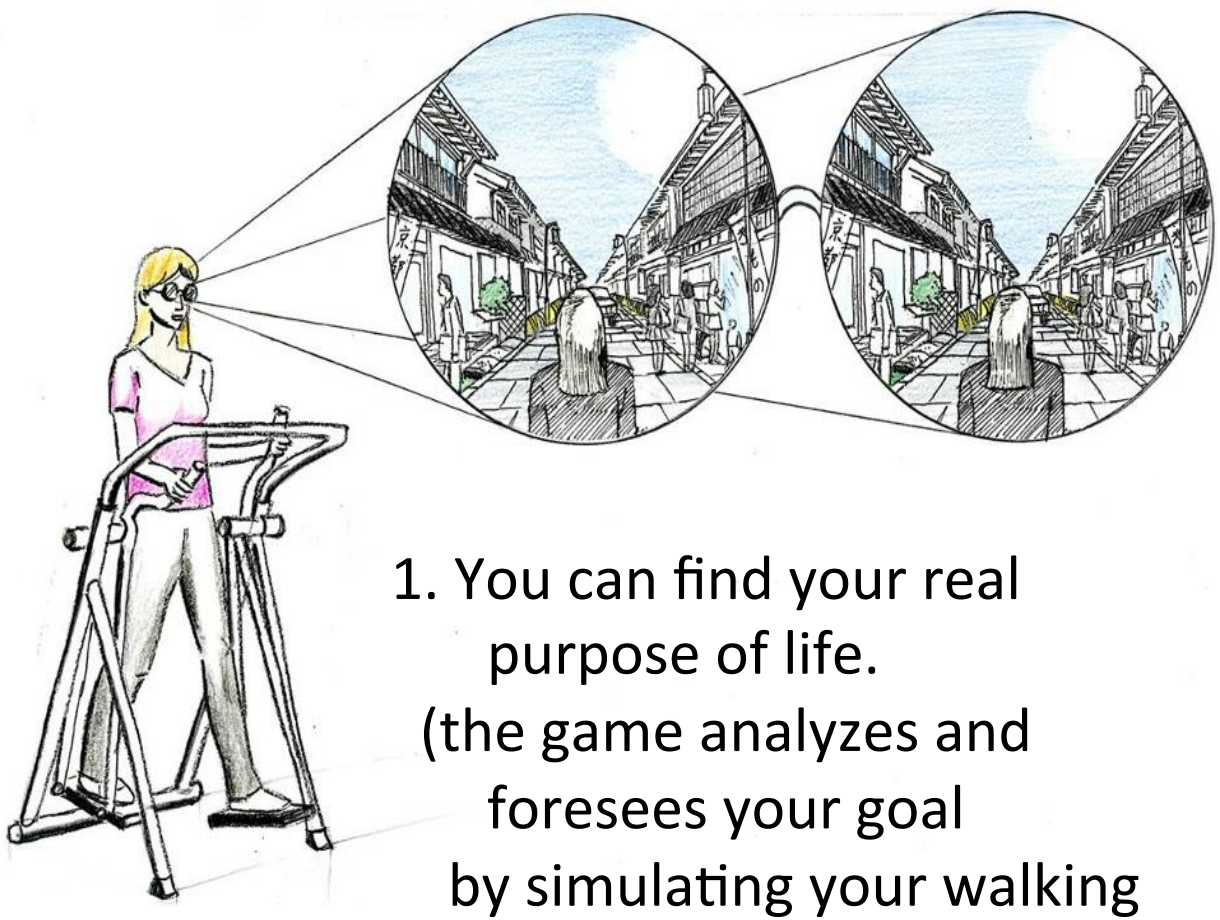
Research Progress

1st Research	Framework / Tools	Case Studies	Publications
Design for Service Innovation	Definitions DfSI Scenario Graph 1.0 Dynamic CVCA Fishbone Diagram	Apple iPod+iTunes Mobile Radiography Aircraft Engine Service Interactive TV	DfSI - TBD SG - IDETC IPSJ, AI, PICMET

2nd Research	Framework / Tools	Case Studies	Publications
Scenario-based approach for amorphous systems design	Dynamic CVCA 2.0 Scenario Graph 2.0 Function-Solution Elem.	GE Healthcare Toshiba IT Toshiba Infra PD Transportation	Framework-IMECE SG 2.0 - TBD IJST

Creating: It's My Life
Bodystorming + Scenario





1. You can find your real purpose of life.
(the game analyzes and foresees your goal by simulating your walking habit).
2. You can walk anywhere you want and have fun.

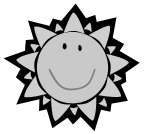
Functions and Requirements

- Affinitized into 5 functions
- Used 5 main functions as morph keys
  - Assess which information is needed
  - Find the source of the information
  - Retrieve the information
  - Transfer the information to “Butler” terminal
  - Deliver information to user

From Scenarios to Functions

Extract functions from detailed scenarios or Value Graph

- Generation
- Organization

When	Where	Who		
		 Mr. Oda	 Ms. Oda	 Mr. Tama
Morning	Home			
	Train	What		
	Road			
	Restaurant			
Afternoon	Home			
	Train	What		
	Road			
	Restaurant			
Evening	Home			
	Train	What		
	Road			
	Restaurant			

Scenario-based Design for Amorphous Systems is based on dfX Framework

Voice of X	*VOX Analysis*
Scenarios	***Scenario Graph*** ***Pugh Selection*** ***Scenario Prototyping Rapidly***
Functions / Requirements	*Value Graph* *(QFD / CWA)*
Concepts	*Morph Concept Generation* *Function-Sol. Elem. Map* *Architectural View*
Business Model / Roadmap	***Dynamic CVCA*** *Puppy Dog-Muscular Lion*
Validation	*NPV / (Scorecarding)*

Actual process was iterative

ME317, MML, Stanford

150 user scenarios

informal selection

10 user scenarios

sponsor consensus

4 user scenarios

expansion

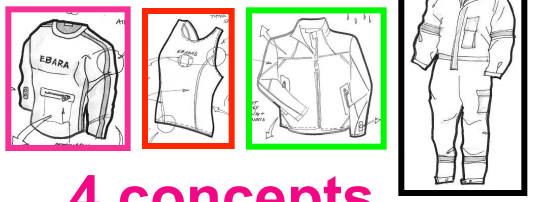
– **Temperature Regulation**
  - **Heated/Cooled Clothing**: Temperature adjusted by the user
  - **Medical Heating of Extremities**: Device to heat fingers and toes to counter effects of Reynaud's Condition
  - **Athletic Cooling**: Cooling of internal core of athletes through localized heating in hands, which increases performance
– **Water Filtration**
  - **Standard Handheld**: Baseline filtration at bacteria level
  - **Ultra Filtration**: Secondary and tertiary water filtration
  - **Extractor & Filter**: For use in arid regions w/ out water supply
– **Restoration of Circulation**
  - **Post Surgery Atrophy** - Restore circulation for medical use
  - **Laziness** – For sitting at desk, on couch in front of the TV
– **Prevention of repetitive stress wrist injuries**

9 user scenarios

Pugh: market

1 user scenario

Morph: VOC + function



4 concepts

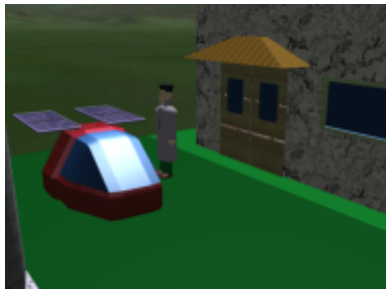
Pugh: product

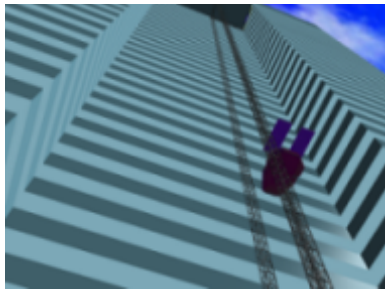
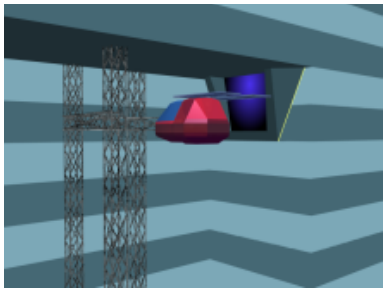
1 concept

Source: ME317, MML, Stanford

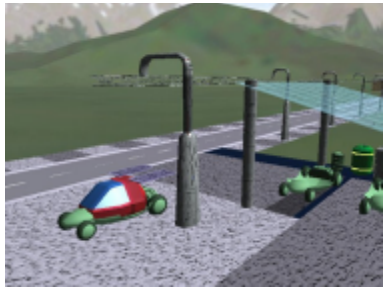
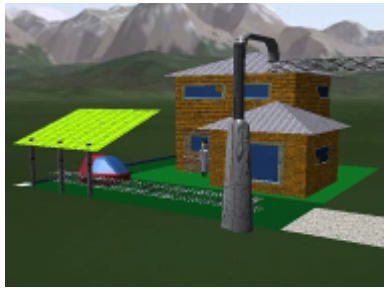
Infrastructure: “Magic Carpet”

- Commute (Home – Office)

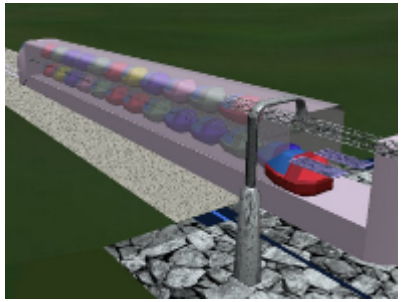
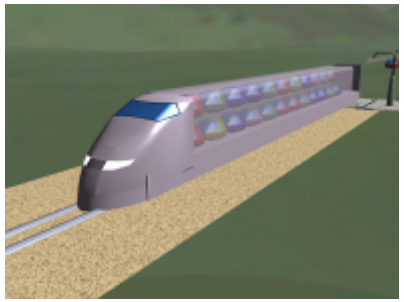


- Shopping in the suburbs


- Family trip


By S.Sekimoto, Toshiba Sigma Consut.
Stanford NPI Roundtable, July 16, 2008

Scenario Menu (Morph)

- Who, What, Where, When
- What: Active Verb + Noun Format
  - ☛Interview, observe domain experts, potential customers

Who	      
Where	  
What	  
When	   Help! 

Source: ME317, MML, Stanford

Scenario Selection

Multiple Iterations of Pugh selection

- Used business criteria to chose "Butler" concept
  - Potential Market Size
  - Degree of Need
  - Leveraging Core Competency
  - Competition

Source: Wikipedia, TDFSS Workshop, 2007

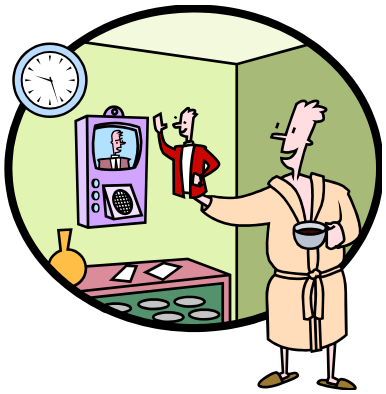
Criteria	Scenarios								
	The newest interested news, stock, etc. are extracted.	It is automatic and makes a selling point of an auction.	Information for enjoying oneself (a book, TV, movie)	Support of a dress and makeup	Its information on surrounding is collected automatically and taught (confusion, traffic, and course information).	meeting: Secretary-role (it contains privately)	Automatic creation of the minutes	Store information which suited liking	Automatic arrangement of data (it is the same also at home)
Market size (potential)	S	−	DATUM	−	S	S	S	S	S
Size of needs (concerned with a life and a life)	+	−		+	+	+	+	S	+
Wants (the degree of charm of a function)	+	+		+	S	+	−	S	−
Technical implementability (a technical core コンピ war	S	−		−	+	S	−	S	−
Technical predominancy	S	S		S	+	S	+	+	S
Business model implementability (a sales channel, part	S	−		S	+	−	+	S	−
Business model predominancy	S	S		−	+	−	S	+	S
(legal) Risk	+	−		+	+	−	+	+	−
sigma of +	0	0	0	0	0	0	0	0	0
sigma of −	0	0	0	0	0	0	0	0	0
sigma of S	0	0	0	0	0	0	0	0	0
Overall	0	0	0	0	0	0	0	0	0

Source: ME317, MML, Stanford

From Scenarios to Functions

Affinitized into 5 functions morph keys

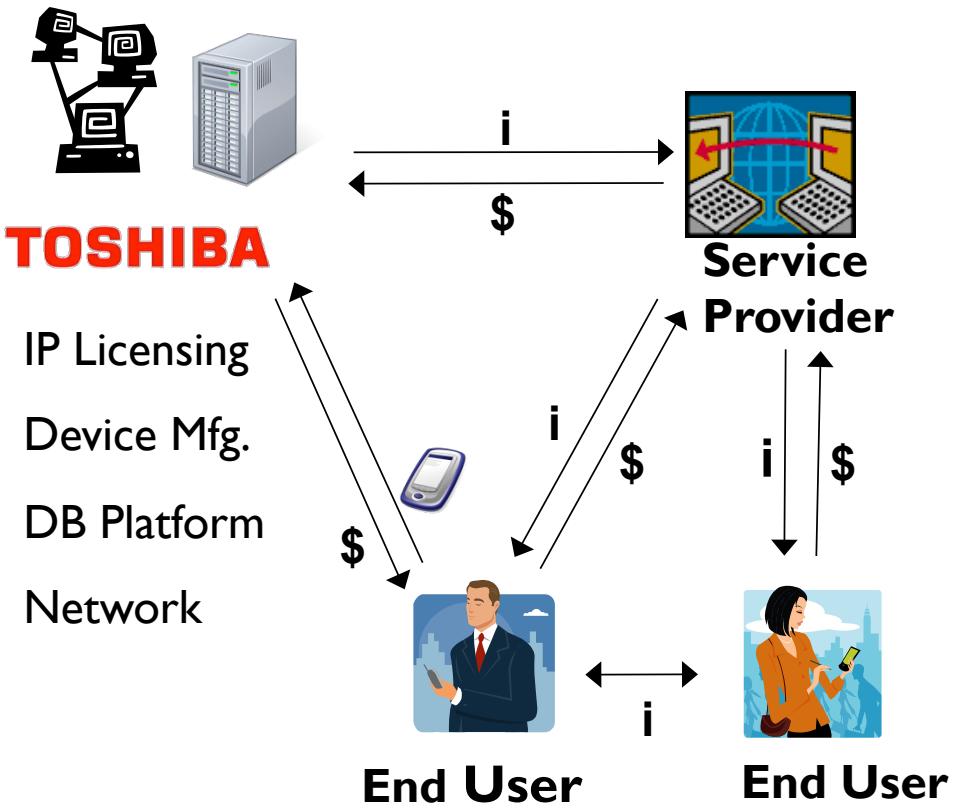
- Assess which information is needed
- Find the source of the information
- Retrieve the information
- Transfer the information to "Butler" terminal
- Deliver information to user



When	Where	Who		
		Mr. Oda 	Ms. Oda 	Mr. Tama 
Morning 	Home 	Wakes up Watches TV Reads Newspaper Takes shower Gets dressed Eats breakfast Checks Email	Wakes up **What** Get dressed Cooks breakfast Gives allowance	Wakes up Checks security Watches TV Reads Newspaper Takes shower Gets dressed Eats breakfast Checks Email

Dynamic CVCA: "Butler" Case

1. Current CVCA → 2. Set Direction → 3. Add Value → 4. Add Paths, Customers



Ref: Stanford-DFACE WS#4

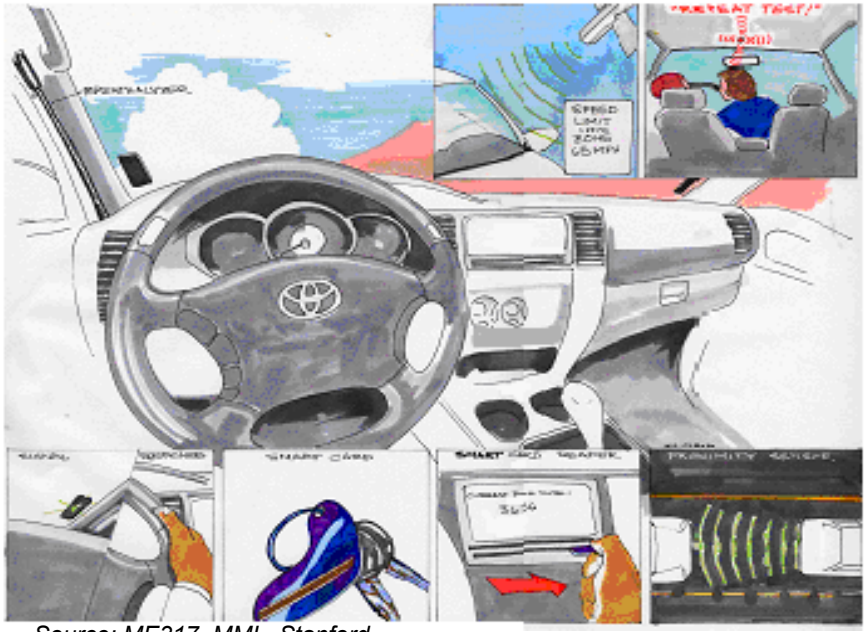
Dynamic CVCA:
A different tree for a different fruit

- **How is the company going to make money?**
  - ☛ **Transform business model**

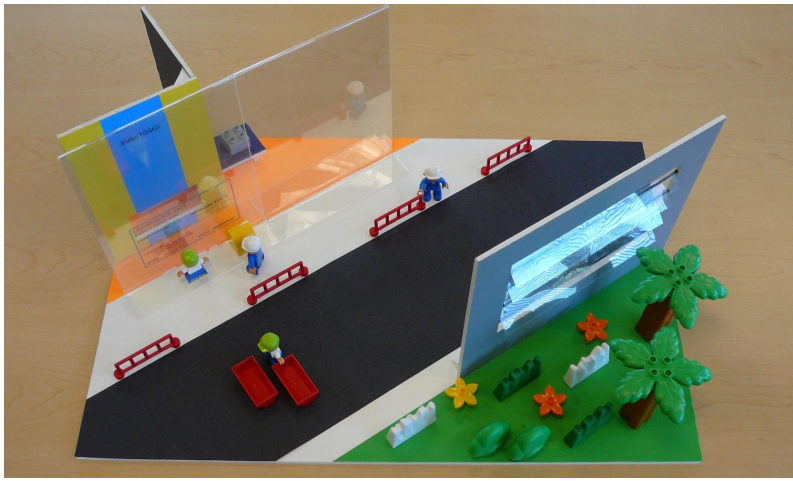
1. Current CVCA	2. Set Direction	3. Add Value	4. Add Paths, Customers
Understand the current business model, core competency	Follow business roadmap	Add new products or services that are of value to current customers	Add new supply chain paths to deliver products, services, and collect money Extend customer relationships

Scenario Prototyping Rapidly

- **quick and inexpensive (LOW TECH!)**
  - Story-boards
  - Videos & Movies
  - Role-playing, skits
  - Bodystorming
  - Mock-up, scale modeling



Source: ME317, MML, Stanford



Validation

Qualitative Analysis

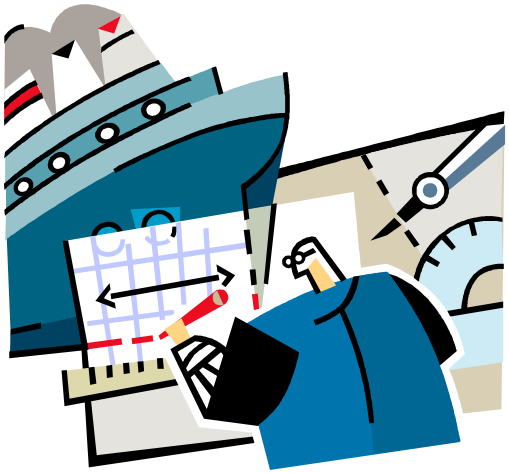
- Interviews

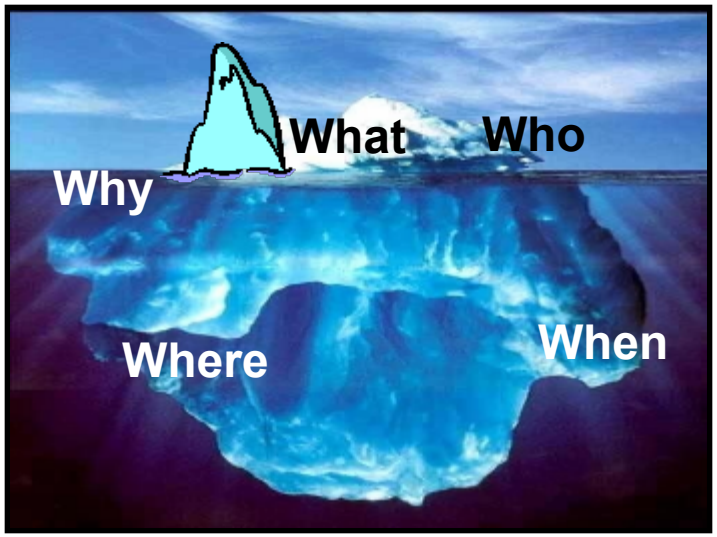
Quantitative Analysis

- Statistical validation model for design methods
- Surveyed level of understanding of project scope

Context is important!

- **Complete Description: 6W's**
  - Scenario Graph: Where, When, Who, What
  - CVCA: Who
  - Value Graph: Why,How

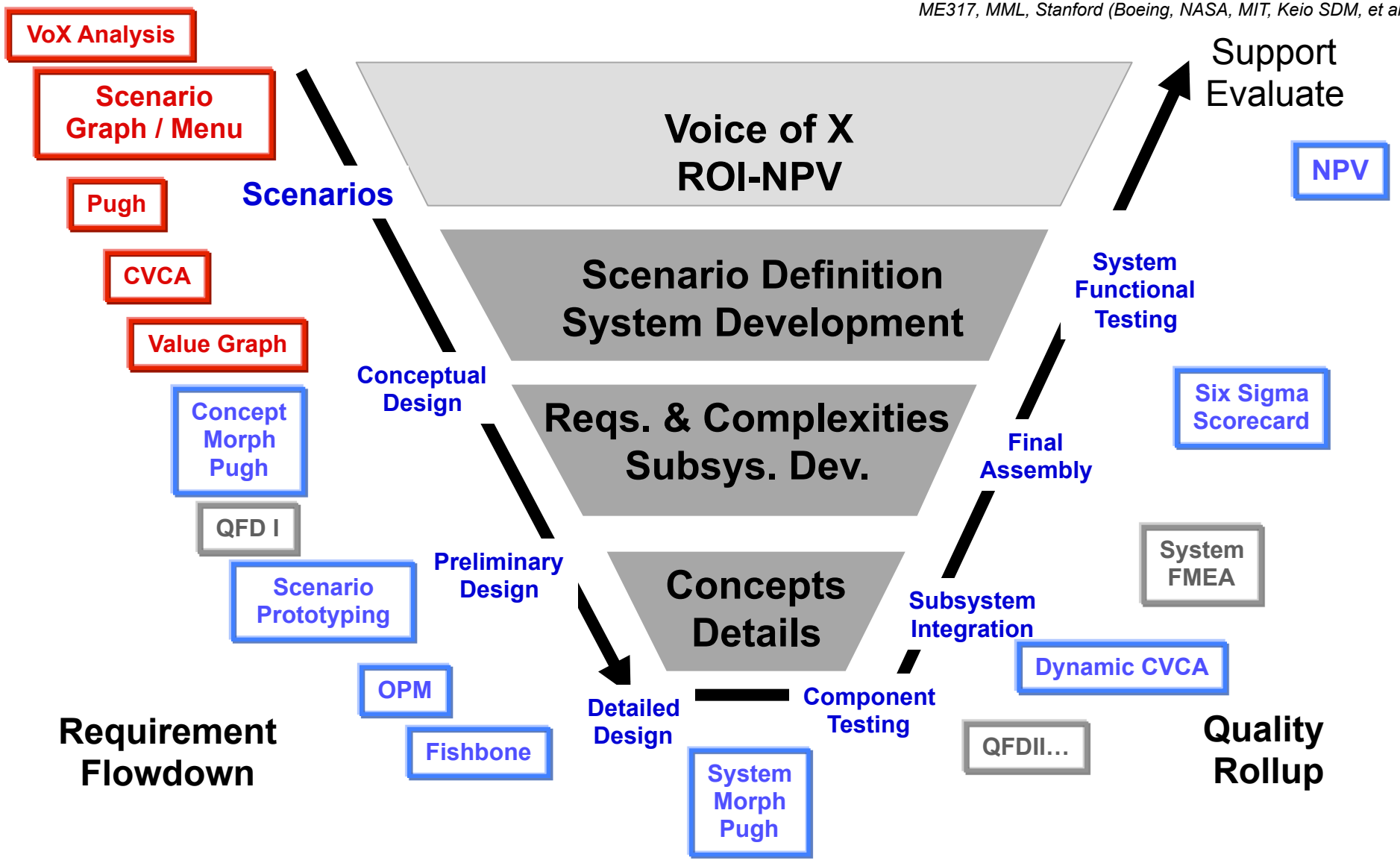




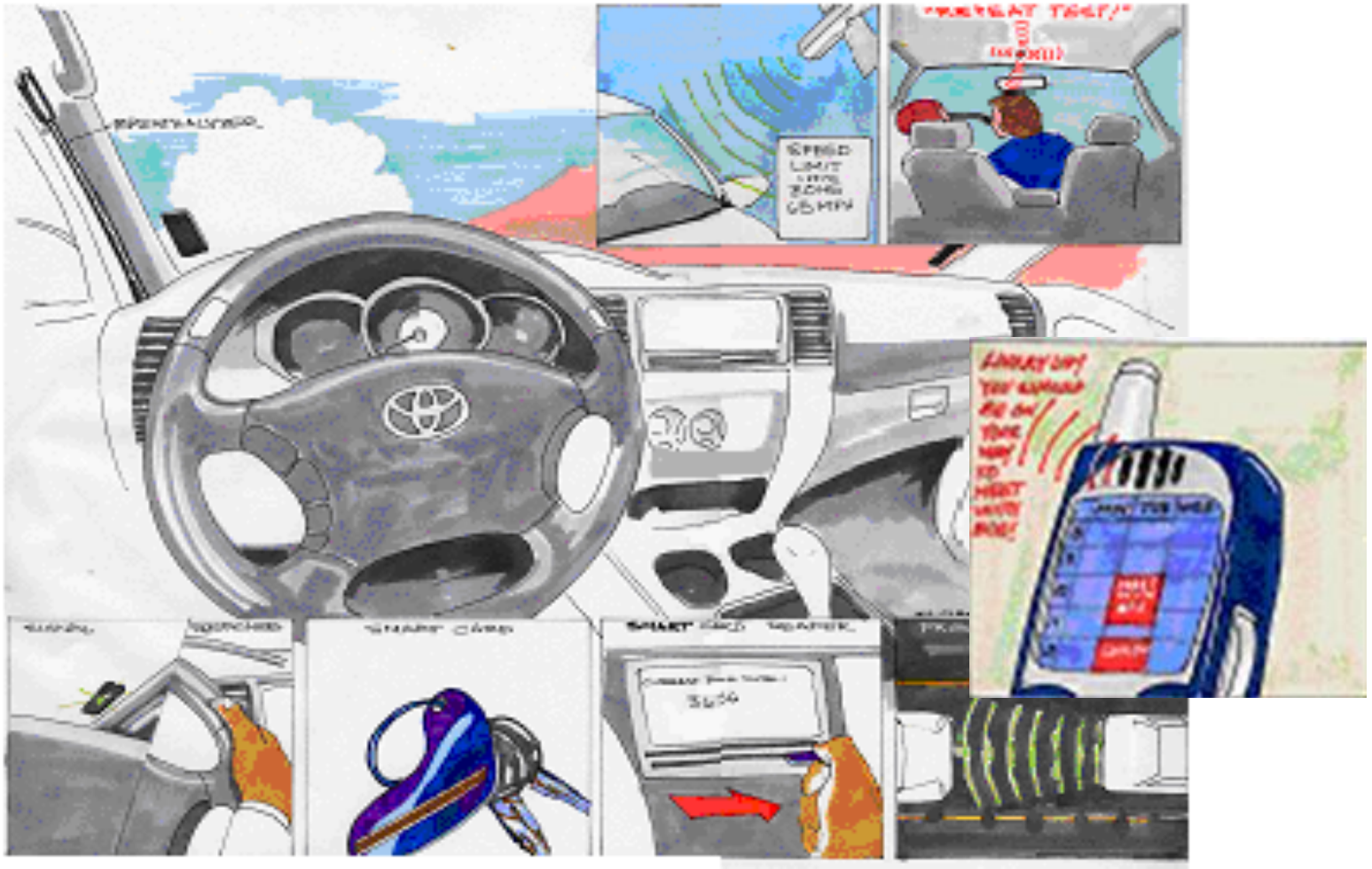
Reference: http://redstatepatriot.com

Scenario-based tools in the V

ME317, MML, Stanford (Boeing, NASA, MIT, Keio SDM, et al.)



Systems-oriented Product: "Changing Driving Manners"



Source: ME317, 2003, MML, Stanford

Engineers taught to focus on FUNCTIONS

Example of an Infocus Multimedia Projector

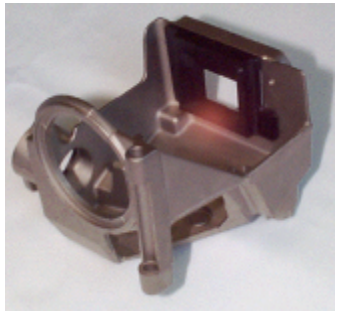
$$Weight = Y = F(\bar{x})$$

$$= w_{SA_1} + w_{SA_2} + \ldots$$

System Level

Setup Time	<30 *sec*
Weight	<4 *kg*
Physical Volume	ℓ = 305 *mm* *w* = 230 *mm* *h* = 100 *mm*
Surface Temperature	<50 *°C*
MTBF	>50,000 *hrs*
Image Brightness	>700 *lum*
Operating Noise	<40 *dB*
Contrast Ratio	400:1
Image Resolution	800x600
Audio Quality	50-6000 *Hz*
Audio Volume	1 *W*
Cost	< $2000

Projector Structure Tree

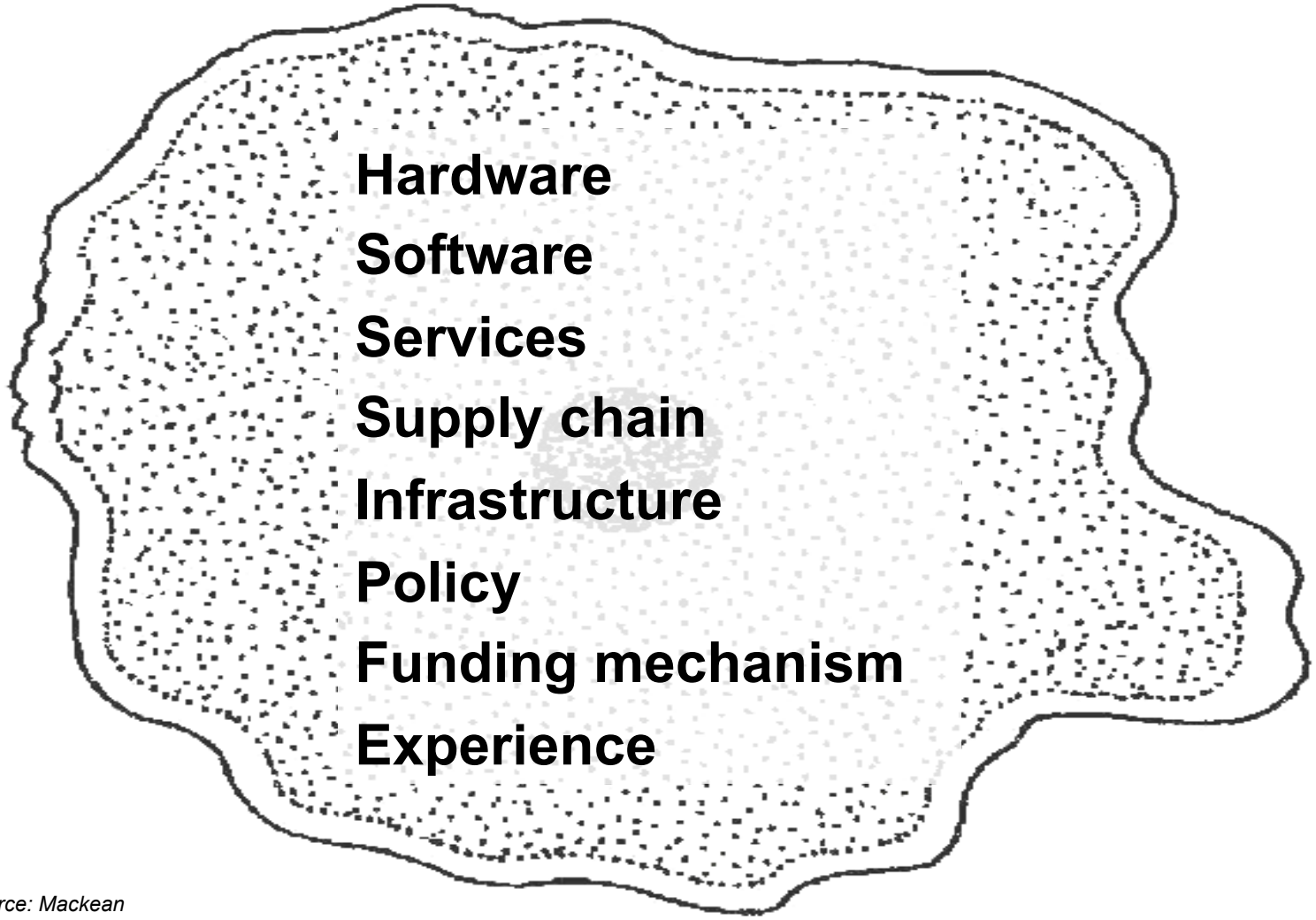


- Projector
  - Lower Housing Sub Assy
  - DMD & Formatter
  - Optical Engine S/A
    - Optical Components
    - Projection Lens
    - Color Wheel Casting
    - DMD Casting
    - Mechanical Components
  - Controller Board
  - Lamp & Reflector S/A
    - Bulb
    - Heat Shield
  - Power Supply S/A
  - Keypad Board
  - Fan S/A's
  - Housing S/A's
    - Front Bezel Assy
    - Top Cover Assy
    - Rear Bezel Assy
    - Bulb Access Door Assy
      - Door
      - Captured Screws
    - Focus Ring
    - Lens Cap
  - Speaker S/A
  - Accessories
  - Bag

- **Development team may set sub-assembly weight targets**
- **For Optical Engine: < 1 kg**

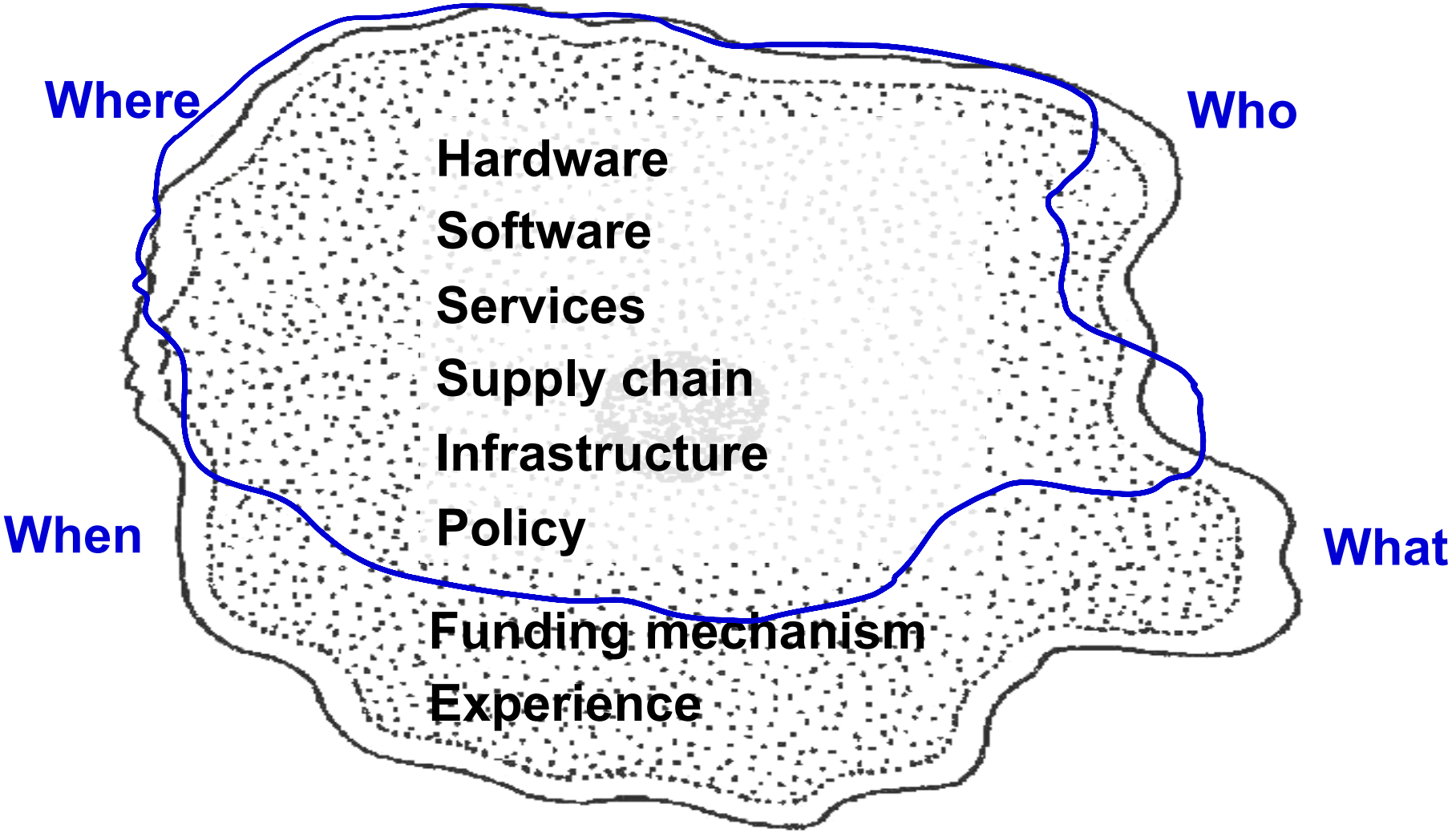
Source: ME317, MML, Stanford

Products became systems-oriented, project scopes became under-defined



Amoeba Figure Source: Mackean

Scenario defines boundaries of an under-defined system



Simplified Project Flowchart

Value of Customer

Voice of Society

Key Theme

Scenario

Function Deployment

Concept Generation / Selection

Business Model

Society = Users / Non-users Technology trend Economy, Ecology, Politics, etc.

By S.Sekimoto, Toshiba Sigma Consut.
Stanford NPI Roundtable, July 16, 2008

Case Study 1: From Portable X-ray Machine to Battlefield Mobile Radiography

Portable X-ray Machine

Source: GEHealthcare

Battlefield Tele-Radiology

Scenario Graph

Who, What, Where, When, Why, How

Who Patient Radiologist Medic Physician

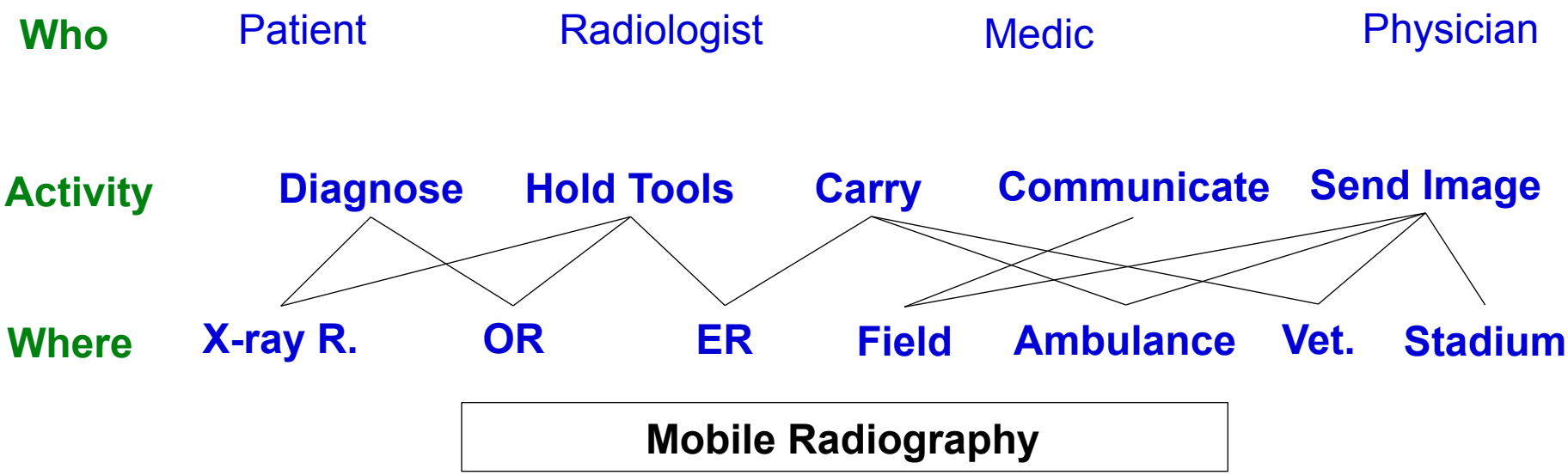
What d Image

Where

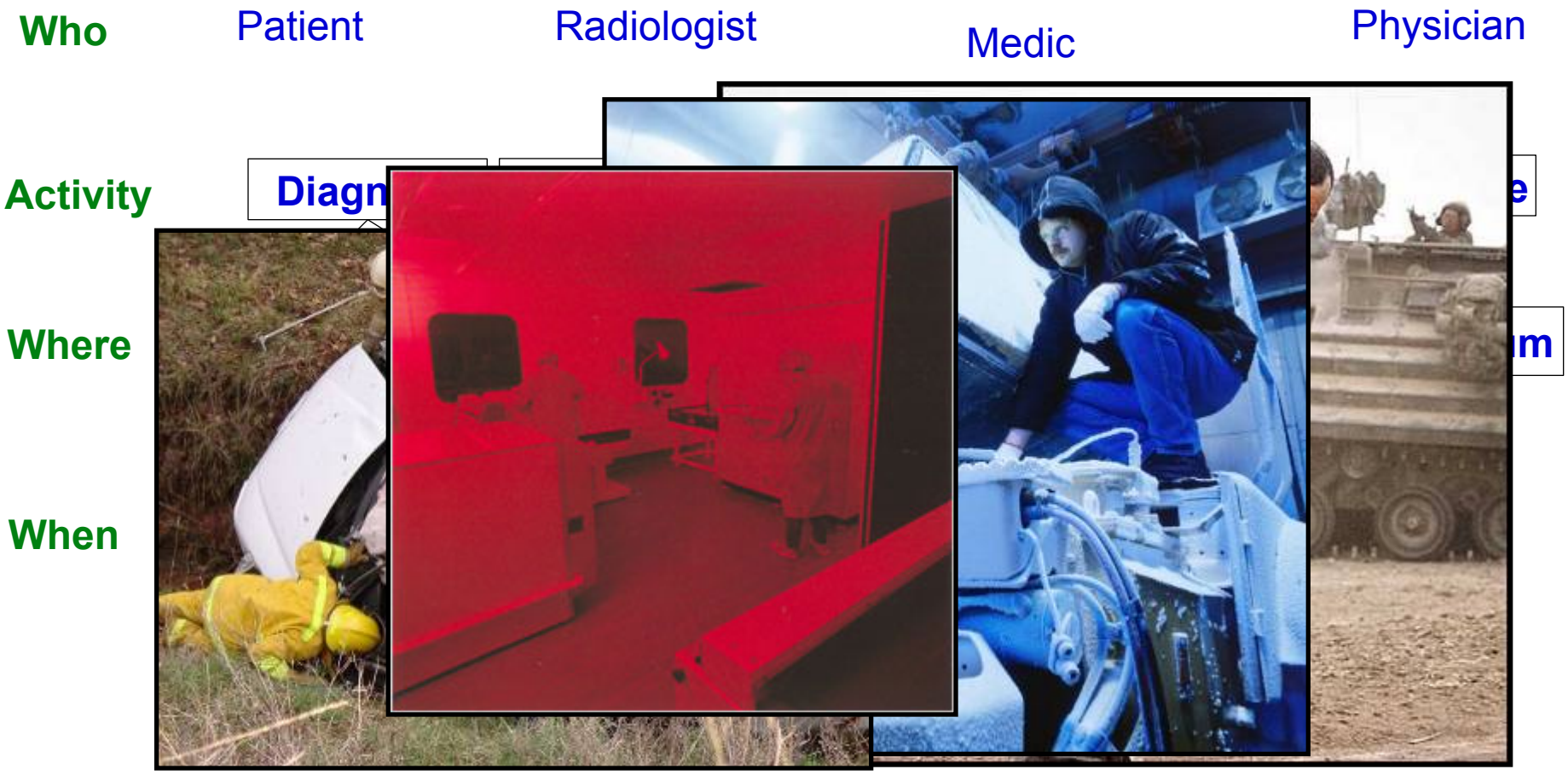
Source: http://redstatepatriot.com, jolaroo.com, wvucc.com, larrymulvile.com, ambulance.union.rpi.edu

Scenario Graph

- Link the W's using semantics

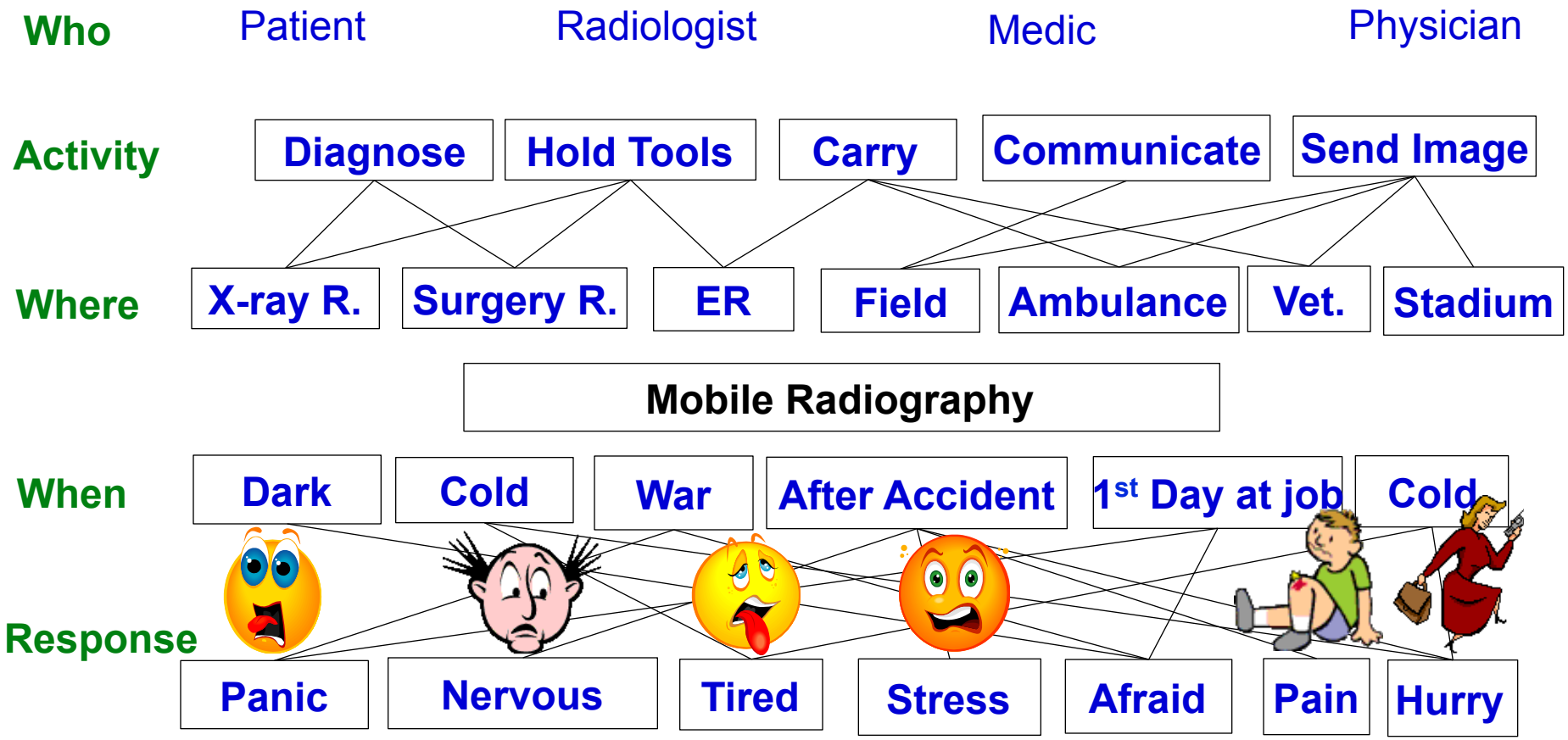


Scenario Graph



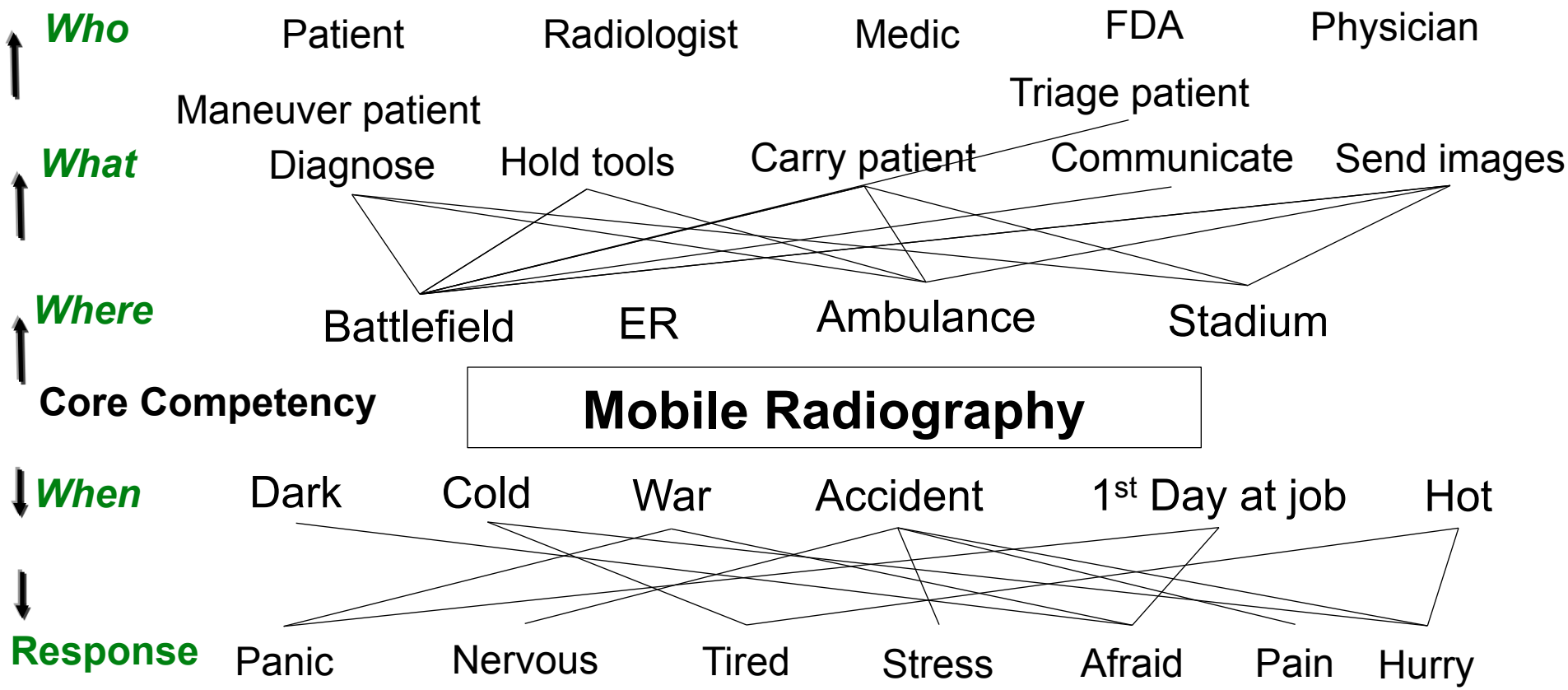
Scenario Graph

- Scenario Graph – Who, What, Where, When, Why, How



Source: http://redstatepatriot.com, jolaroo.com, wvucc.com, larrymulvile.com, ambulance.union.rpi.edu

Scenario Graph



Source: Kim, 2008, Scenario-based Design For Amorphous Systems, ASME IMECE 2008

Scenario Selection: Pugh

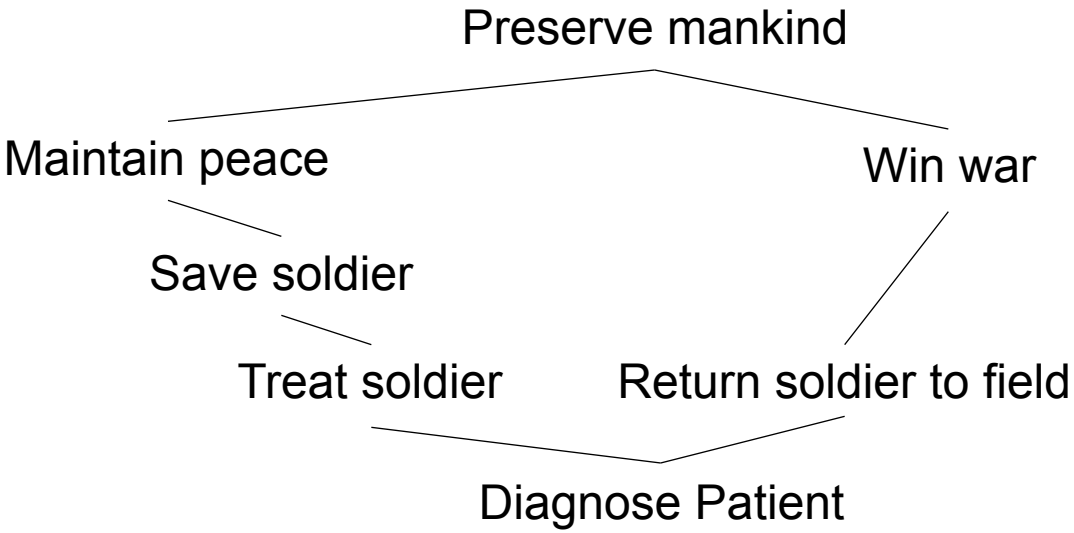
Multiple iterations of Pugh selection

☛ Used business criteria to chose "Battlefield Scenario."

Criteria	Scenarios			
	Ambulance	Battlefield	Hospital	Stadium
Potential Market Size	+	+		+
Degree of Need		+		
Leverage on Core Competency		+		
Competition	-			+
Management		+		+
			DATUM	
+	1	4		3
-	-1			

Extracting Customer Requirements

Why – Customer Requirements



WHY (Value)

Mobile Radiography in Battlefield

Requirements

Easy to use (move) Reliable Safe Fast Diagnosis

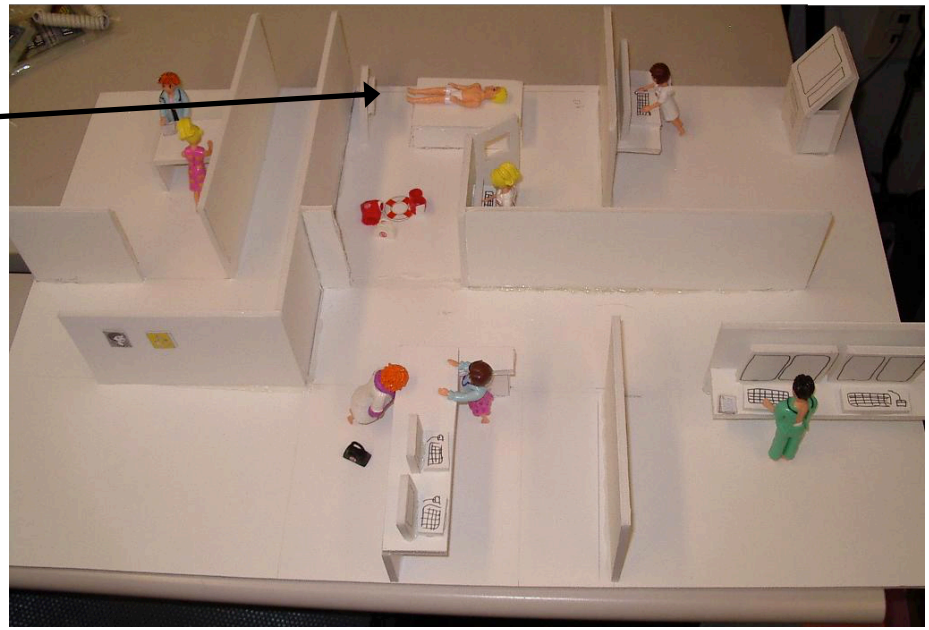
Metrics

Weight # of Functions MTBF Errors Radiation

Scenario Prototyping

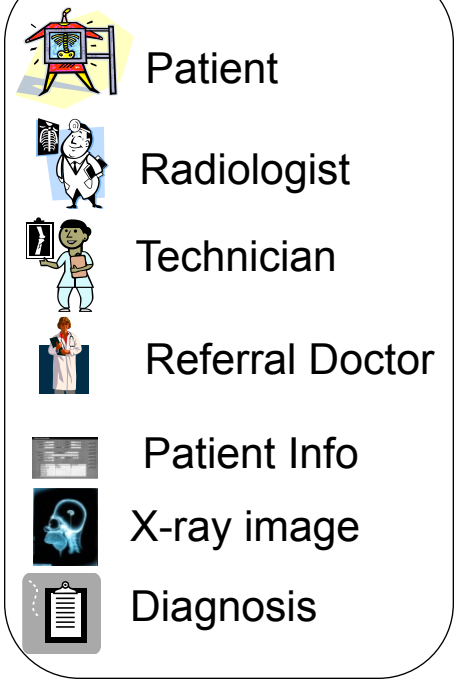
Scaled Physical Mockup + Scenario

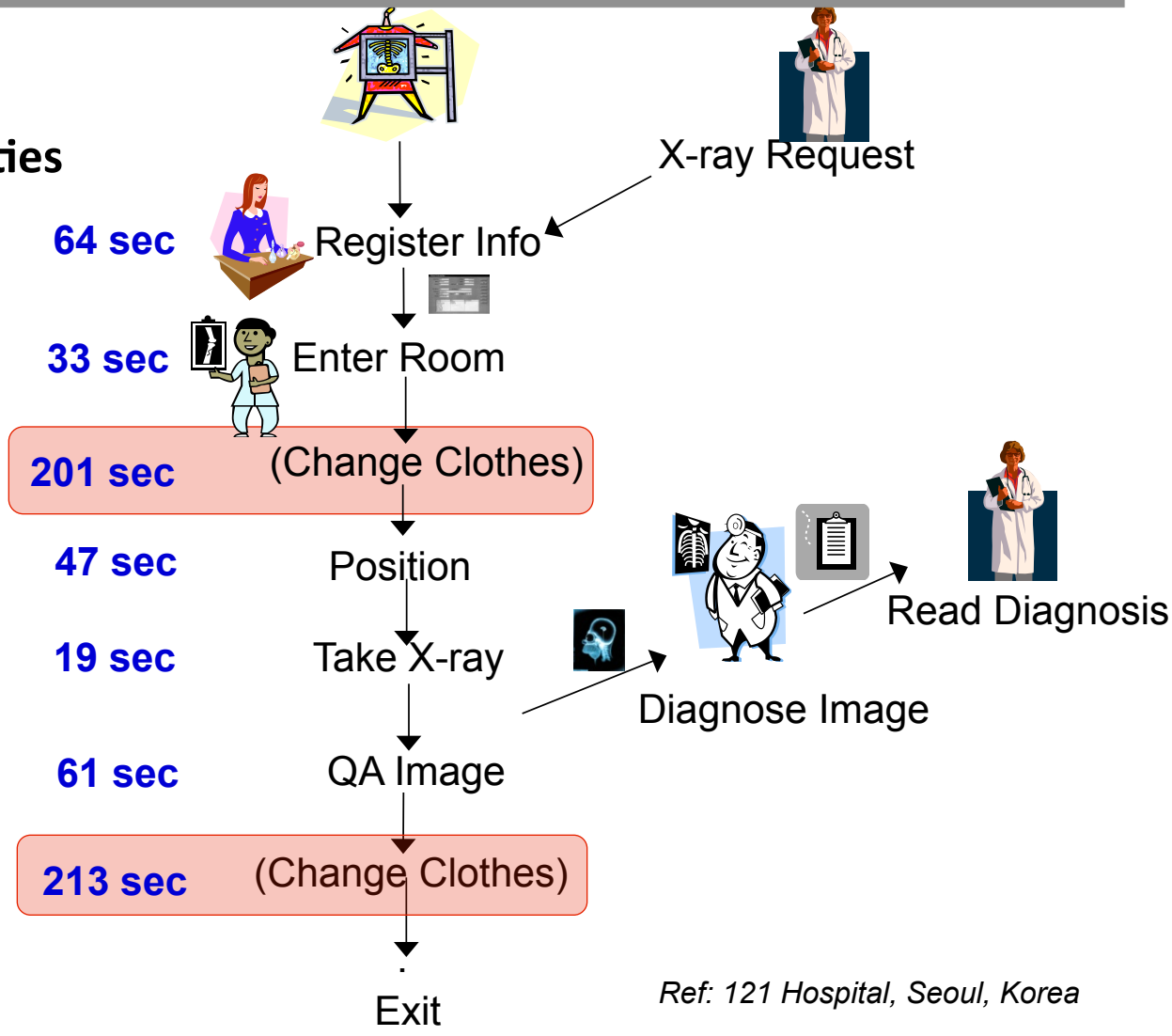
- **Role-playing Scenario with the stakeholders**
- **Quick and inexpensive**
  - Story-boards
  - Videos & Movies
  - Role-playing, skits
  - Bodystorming
  - Mock-up, scale modeling



Fishbone Diagram
Service Process

- **Service Process**
  - Participants, Activities
  - Pareto Analysis
  - Errorproofing



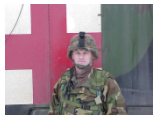


Ref: 121 Hospital, Seoul, Korea

Fishbone Diagram
Battefield Mobile Radiography

Service Process

Receive request



X-ray Request

426 sec  Reach Patient

24 sec Prepare Patient

Read Patient's Info 65 sec

15 sec (Expose Wound)

Diagnose Image 157 sec

10 sec Position

Write Diagnosis 320 sec

20 sec Take X-ray

Send Diagnosis sec

5 sec QA Image

25 sec (Cover Wound)

Read Diagnosis 38 sec

Send Patient

Ref: 2FSB, 2ID, TDC, Korea

Patient

Radiologist

Technician

Referral physician

Patient Info

X-ray image

Diagnosis

Extract Functions from Scenarios

Tabularize activities from Scenario Graph

- Organize by When, Where, Who, and What
- Use active verb + noun for activities
- Affinitize into functions

Source: Kim, MML, Stanford

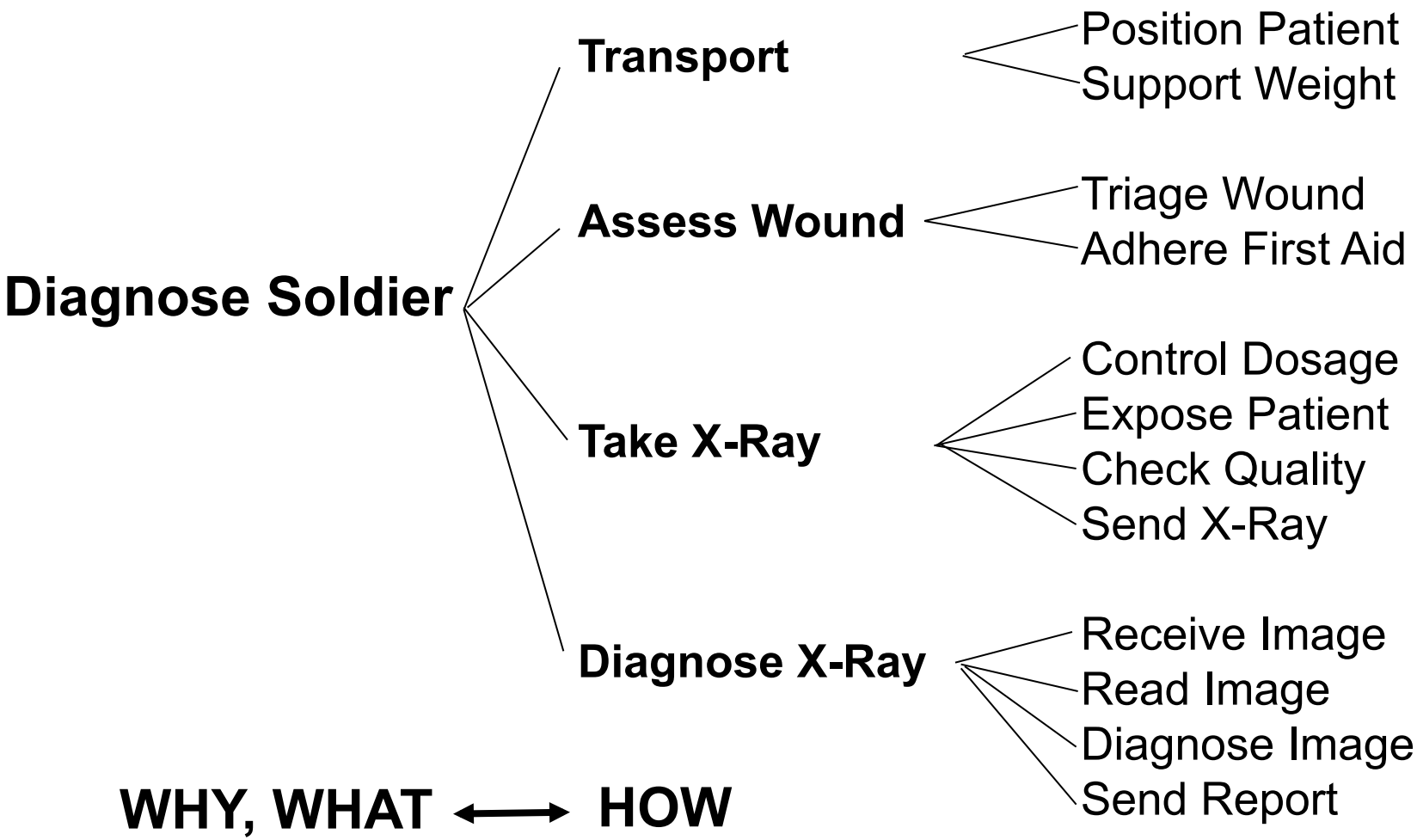
When	Where	Who		
		Medic	X-ray tech	Radiologist
War	Battlefield	Triage patient Adhere first aid Carry patient Reports injury		
	Station 1		Position patient Educate patient Maneuver xray Process image QA image Send image	
	Station 2			Receive request Receive image Read symptoms Inspect image Diagnose image Write diagnosis Send diagnosis

What

Source: Kim, 2008, Scenario-based Design For Amorphous Systems, ASME IMECE 2008

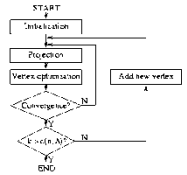
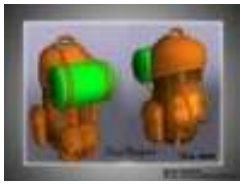
Function Tree: Mobile Radiography

- Look at the function hierarchy



WHY, WHAT ⟷ HOW

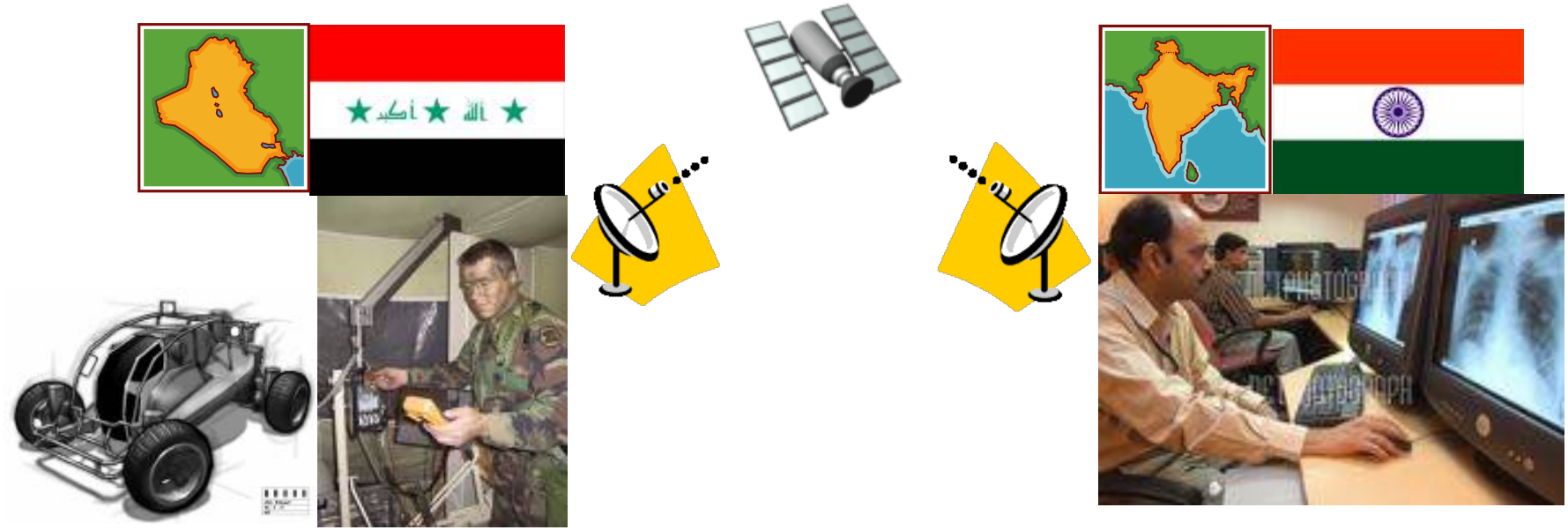
Concept Generation: Morpholgical Analysis

Customer Values	Solution Elements		
Reliable	 Maintenance Education	 Remote Diagnostics	 Parts Delivery
Fast (Diagnosis)	 Satellite Transmission	  Global Diagnostics	  Auto Diagnosis
Mobile	 Backpack Module	 X-ray Mobile	 Portable, Self Power

Tele-radiology Service in the Battlefield

Satellite Diagnostic Service

- 24/7 Radiography Assist Service – Tele-radiology
- Remote Maintenance Diagnostics



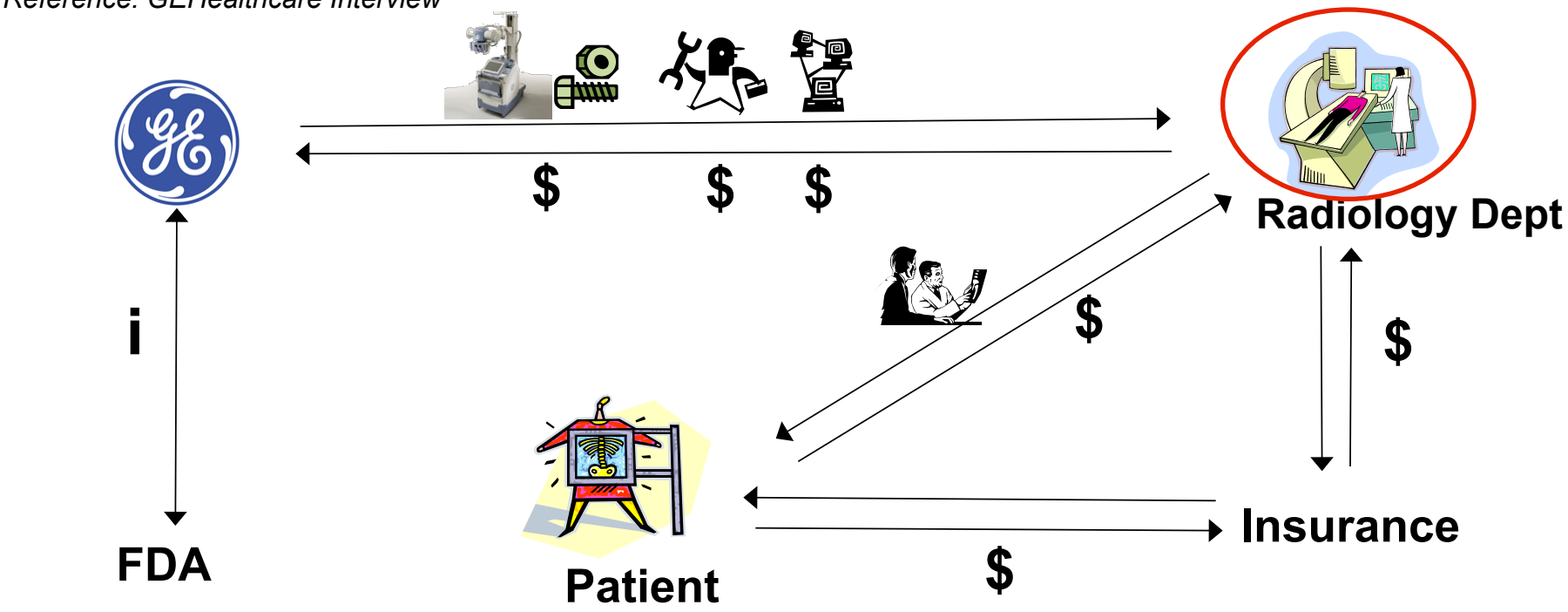
Source: http://www.3dactionplanet.com/breed/images/vehicles/_buggy3.jpg

Dynamic CVCA : Healthcare

Find New ways to deliver Value:

- Customer Value: Reduce cost/ time/ error, Improve survival rates
- Products: X-ray machine, Peripherals, Network
- Service: Maintenance, Realtime-Diagnostics & Assistance

Reference: GEHealthcare Interview

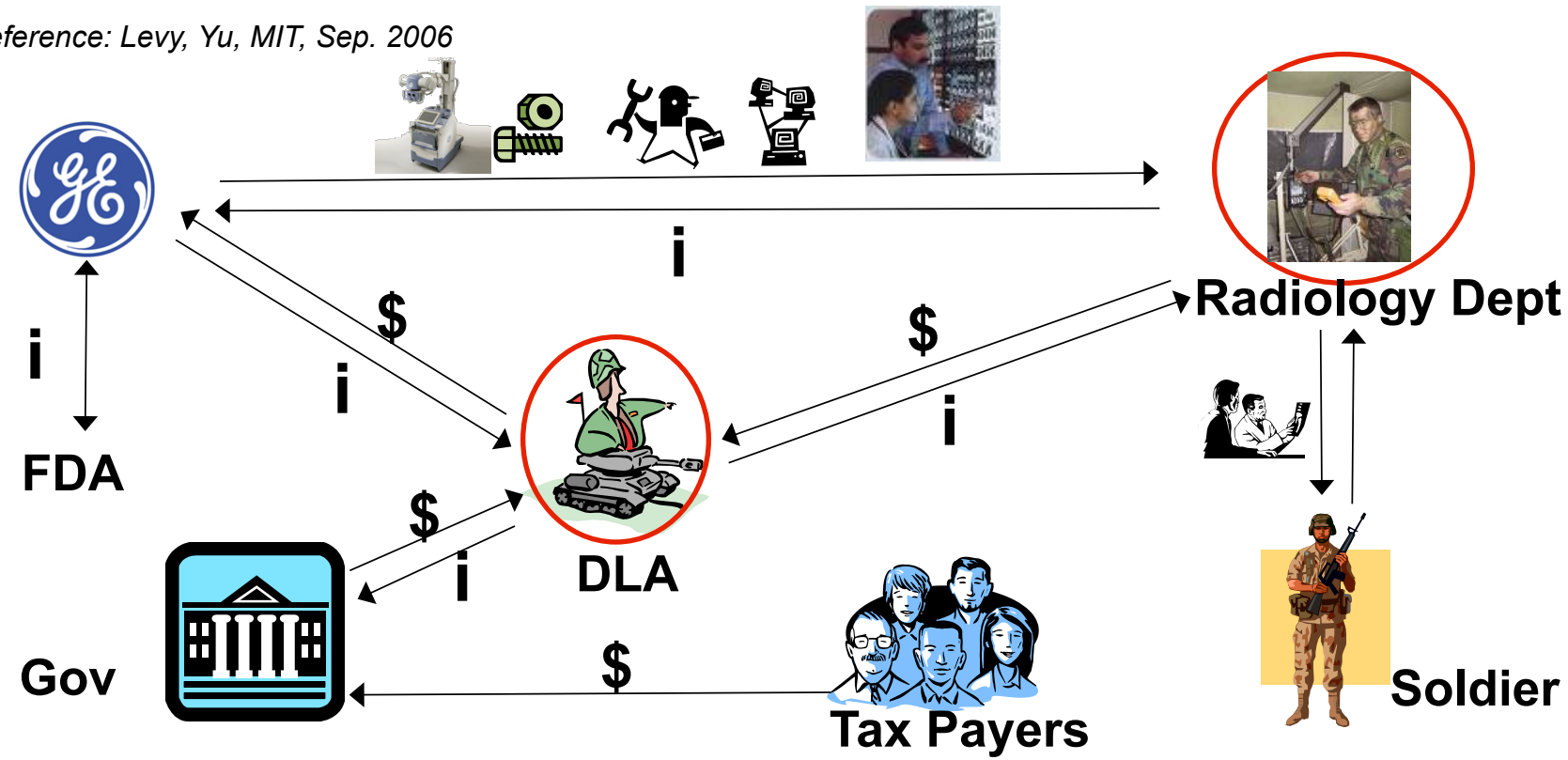


Dynamic CVCA: Military Contracts

Find New ways to deliver Value:

- Customer Value: Reduce cost/ time/ error, Improve survival rates
- Products: X-ray machine, Peripherals, Network
- Service: Maintenance, Remote Radiography, Diagnostics

Reference: Levy, Yu, MIT, Sep. 2006



Patterns of Transformation

1. Current CVCA → 2. Set Direction → 3. Add Value → 4. Add Paths, Customers

8 Elementary Service Function Templates

- Consulting
- Customizing
- Downtime and risk reduction
- Financial risk reduction
- Social risk reduction
- Operational efficiency
- Seamless services
- Rich content

Expansion Type	Elementary Function	Explanation
Adjustment Expansion	Consulting	Consulting services to teach customers how they can make better use of the product
	Customizing	Customizing services to improve the product so that customers can make better use of it
	Downtime and Risk Reduction	Maintenance services to reduce downtime and related risks by using monitoring information of the product.
	Financial Risk Reduction	Risk reduction services to take over financial risks (e.g. repair cost and investment risk) in place of customers.
	Social Risk Reduction	Risk reduction services to take over social risks (social responsibility) in place of customers.
Concurrent Expansion	Operational Efficiency	Operation services to operate the product efficiently in place of customers.
Territory Expansion	Seamless Services	Related services necessary to solve customers' problems with the product, which are seamlessly provided.
	Rich Content	Content delivery and updating services by a platform connected to the products, where the content is processed in the product.

Ref: Uchihira, Kim et al, 2007