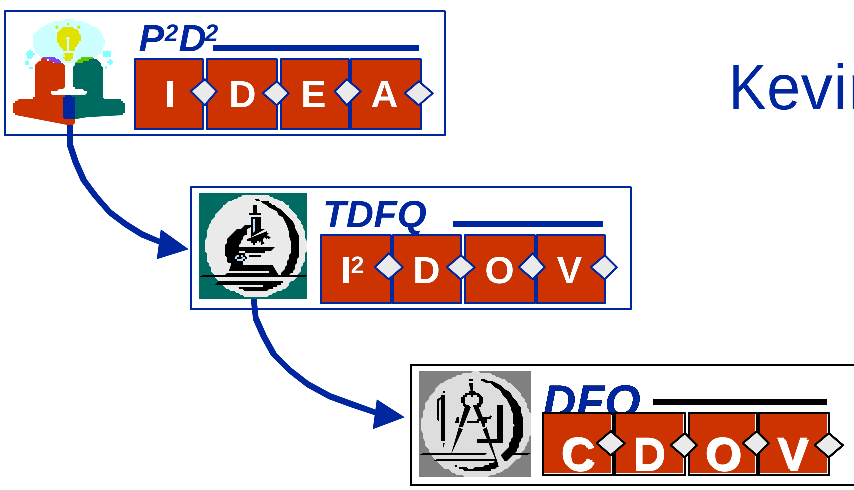
How to Use Tools to Enable Lean Product Development



Kevin Otto

PRODUCT GENESIS
Strategic Product Development Partners

PDSS

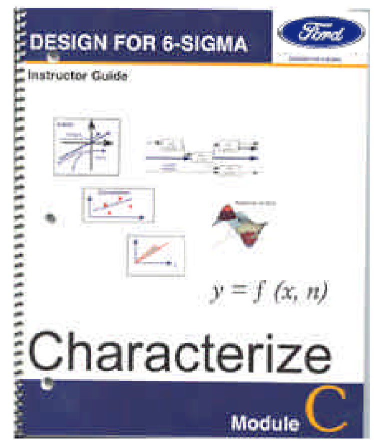
Center for Innovation in Product Development
MIT

Kevin Otto

- Product Genesis Inc. (www.productgenesis.com)
  - Complete outsourced R&D
  - Vice President, Leveraged Development

- Product Development Systems and Solutions Inc. (www.pdssinc.com)
  - Focus on R&D improvement
  - Principle Consultant
  - TDFSS, DFSS Master Black Belt

- Massachusetts Institute of Technology
  - Previously Associate Professor of Mech. Eng.
  - Center for Innovation in Product Development



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My Perspective…

- What does "lean" mean for product development?
  - Value stream mapping – right data
  - Flow – flow of correct decisions
  - No rework – stop undoing made decisions
- Great. How do I do it?
  - All the process mapping, restructuring, teaming
  - Start enabling your engineers to provide options
  - **Stop your engineers from providing simply single-point designs, requirements, ...**

Part of the Value

The cost of fixing a single defect:

- $35 during the design phase
- $177 before procurement
- $368 before production
- $17,000 before shipment
- $690,000 on customer site

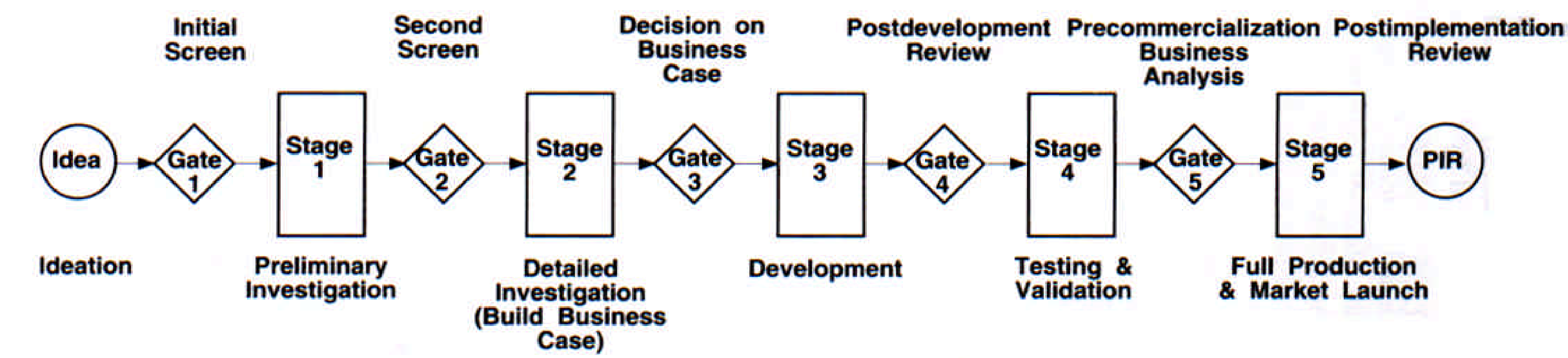
RICOH Image Communication

Mr. Hiroshi Hamada, President of Ricoh

Source: *European Community Quarterly Review*, Third Quarter 1996

R&D - Typical Phase Gate Development

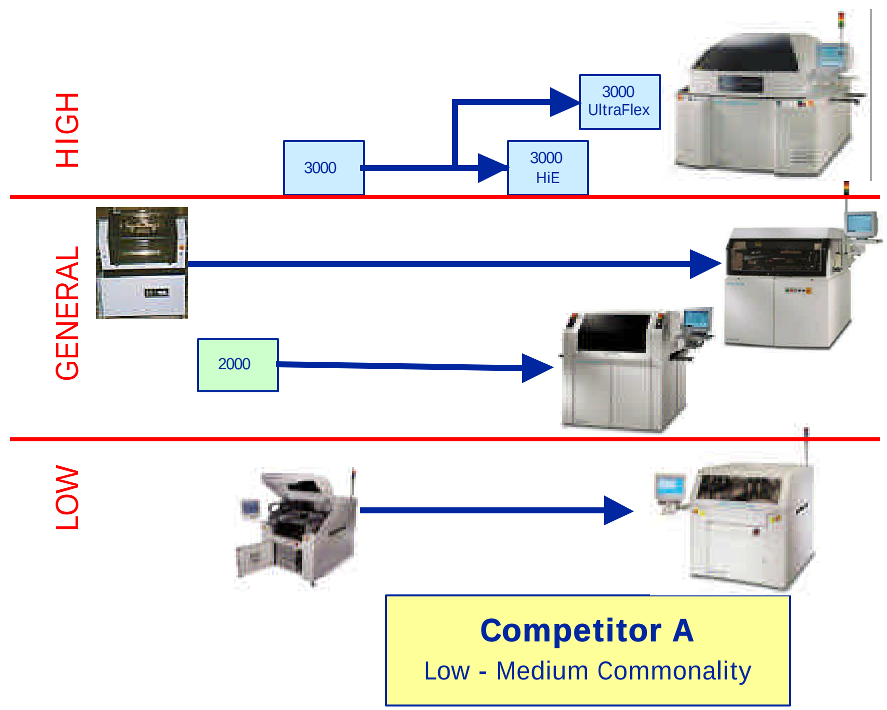
Figure 5.4: A Generic Stage-Gate New Product Process (Cooper)

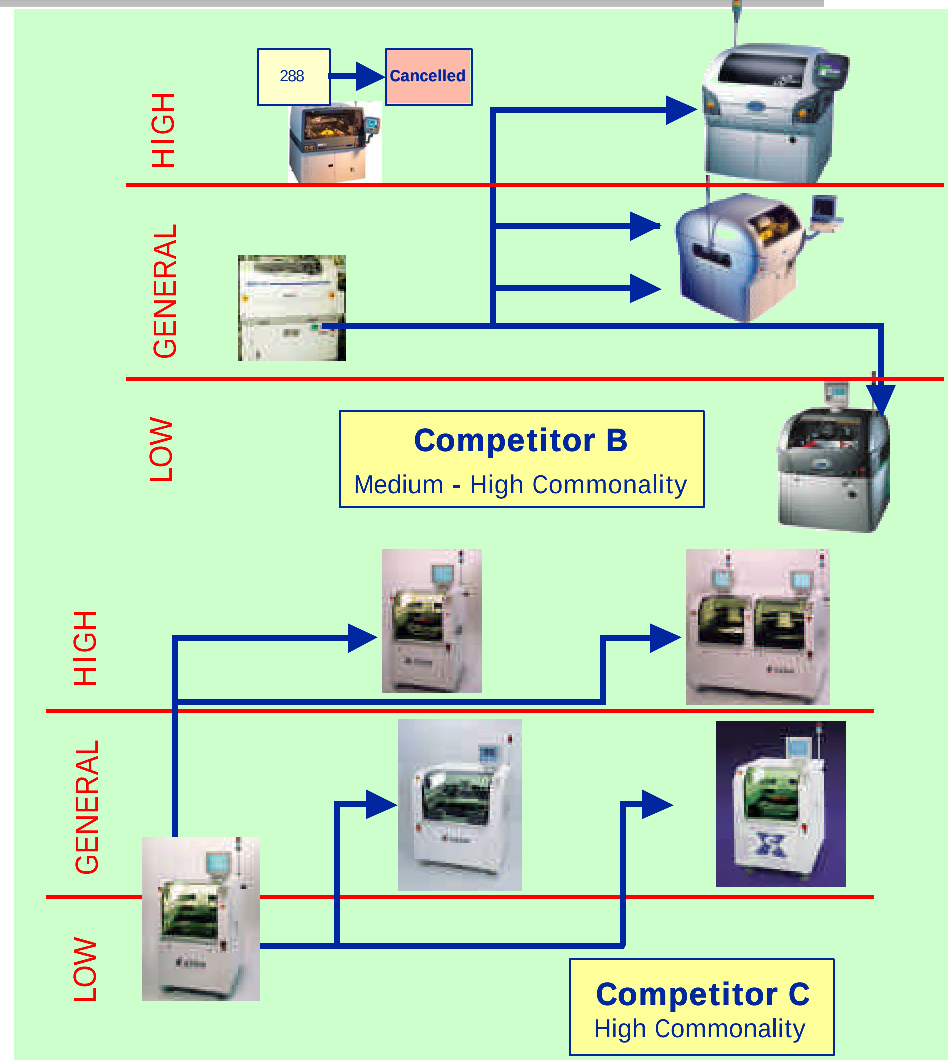


But really, there are three distinct activities happening

1. Product Portfolio Definition and Launch Planning
2. Technology Development
3. Product Commercialization

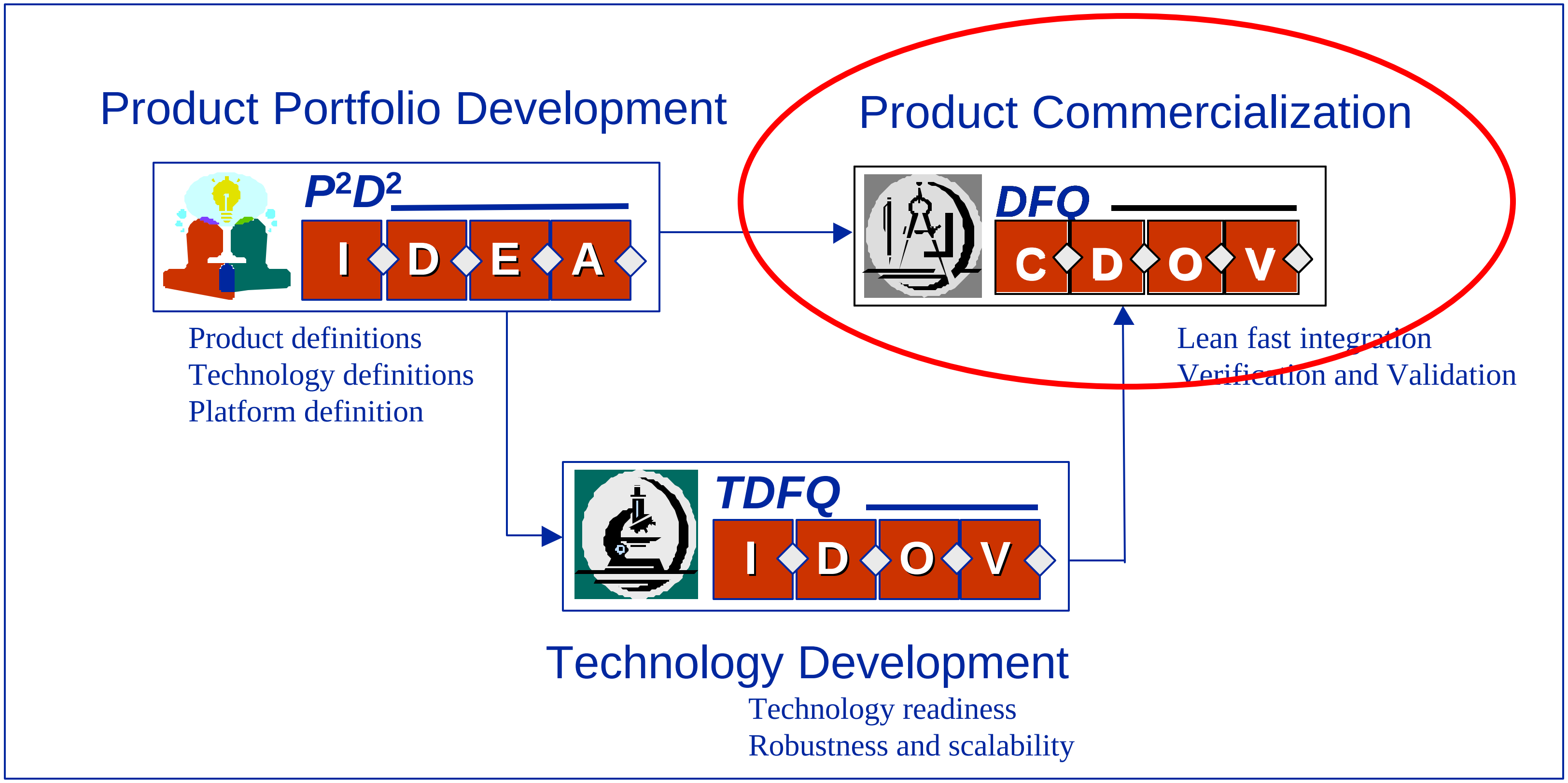
Screen Printer Industry





Portfolio configuration impacts cost, not just product configuration.

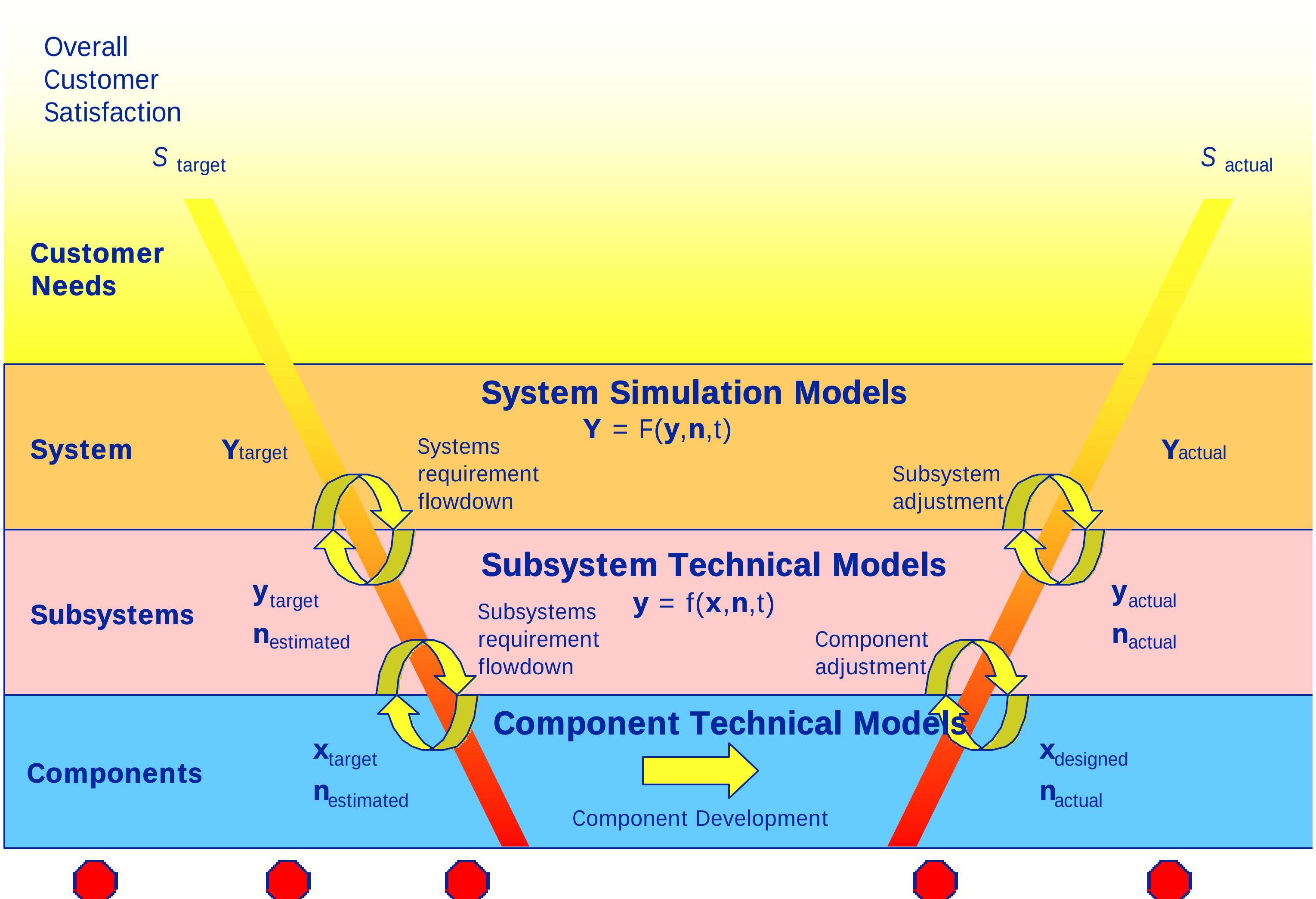
Effective Research & Development

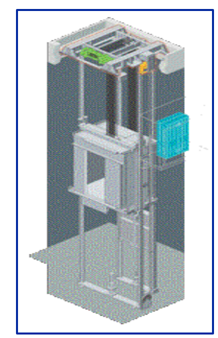


Tools & Best Practices

- You generate increased value through a unique set of design & statistical tools...
- Tools that are focused on developing...
  - the right DATA within each Phase of Product Development!
  - the right DATA to enable clarity in decision making
  - the right DATA to reduce risk though identification & management during Gate Reviews

Working the Systems Vee





CTF Metrics - Scorecards

CTF Output (Y)

CTF Output Variability

Performance		Transfer Function		Specification			Estimates Based on Mean Condition of x's and n's Listed Below: Predicted Performance Capability				6^{σ} Score		
Characteristic	Units	Y/N	Formula (enter below)	Target	USL	LSL	mean: μ	s.d.: σ	Short/Long	Confidence	z	σ-shift	DPM
Voltage	V	Y	2	2	2.1	1.9	2	0.008654			11.55	0.00	0.0

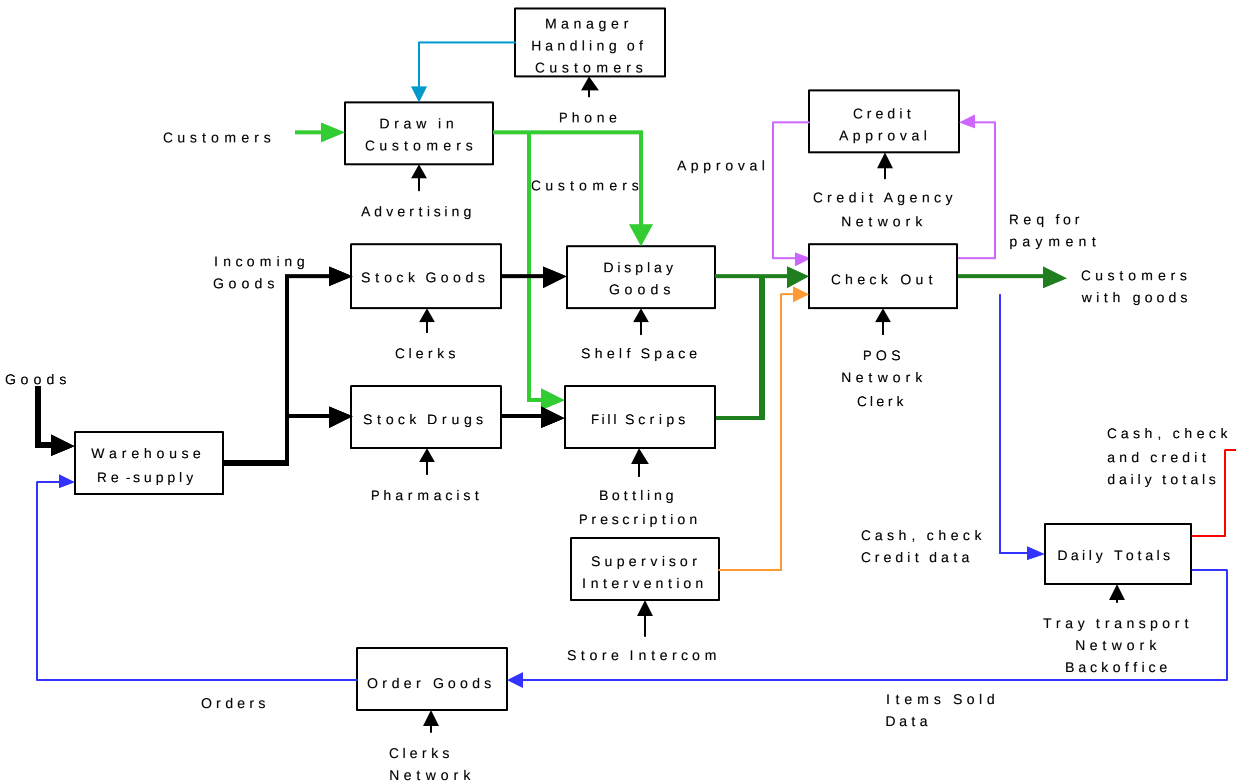
x's, Input Control Factors

	Variables		Range		Contribution to Variability		Specification		Sample/Database Statistics				6^{σ} Score		
No	Characteristic	Units	Min	Max	Sensitivity	%	USL	LSL	mean: μ	s.d.: σ	Short/Long	Confidence	z	σ-shift	DPM
1	X1	ohms	20	500	0	0.00%			20	0.04899			-408.25		1000000.0
2	X2	ohms	2	50	-0.3108194	32.03%			6.433029	0.015758			-408.25		1000000.0
3	X3	ohms	2	50	0.4176437	32.04%			4.788771	0.01173			-408.25		1000000.0
4	X4	volts	1.2	30	0	0.00%			30	0.03873			-774.60		1000000.0
5	X5	ohms	2	50	0	0.00%			2	0.004899			-408.25		1000000.0
6	X6	ohms			0.7444038	32.04%			2.686714	0.006581			-408.25		1000000.0
7	I	amp			-10.449776	3.89%			0	0.000163			0.00		933192.8
8															
9															
10															
11															
12															
13															
14															

Control factors (x)

Control factor Variability

Start with the Customer's System



Where is the value?

Added Revenue $= CNfR\,(r_2 - r_1)$			
C	Average customer transaction	dollars	$9.00
N	Number of customer transactions per year	count	600,000
f	Fraction of customers paying via e-payment	percent	40%
R	Prime Rate	percent	4%
r_2	System reliability of bank-to-checkout using Avaya equipment	percent	99.999%
r_1	System reliability of bank-to-checkout using non-Avaya equipment	percent	99.919%
			$69
Reduced Expense $= nRt$			
n	Number of failures per year	count	1
R	Labor rate	$/hr	$60.00
t	Time to deal with each failure	hr	6
			$360
		Client Value of Avaya Solution:	$429

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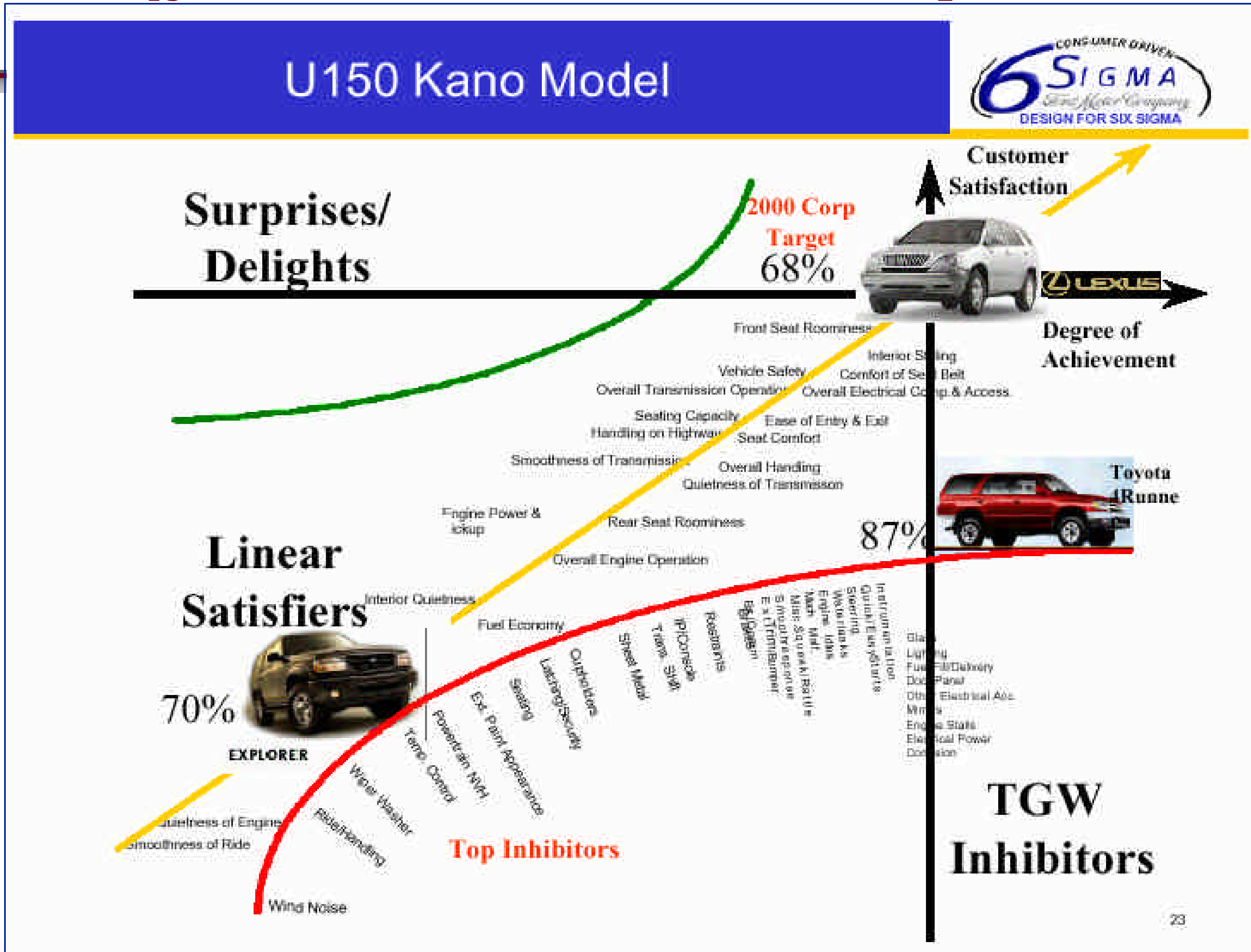
Identify Critical Customer Requirements



Develop Quality & Predictability through the Identification & Measurement of Critical Functions…

Focus on variation in the context of the **Laws of Conservation of Energy & Mass**

Variation in **Energy** Flow & Transformations

WHAT exactly do we measure?

These are *leading indicators* of reliability & quality

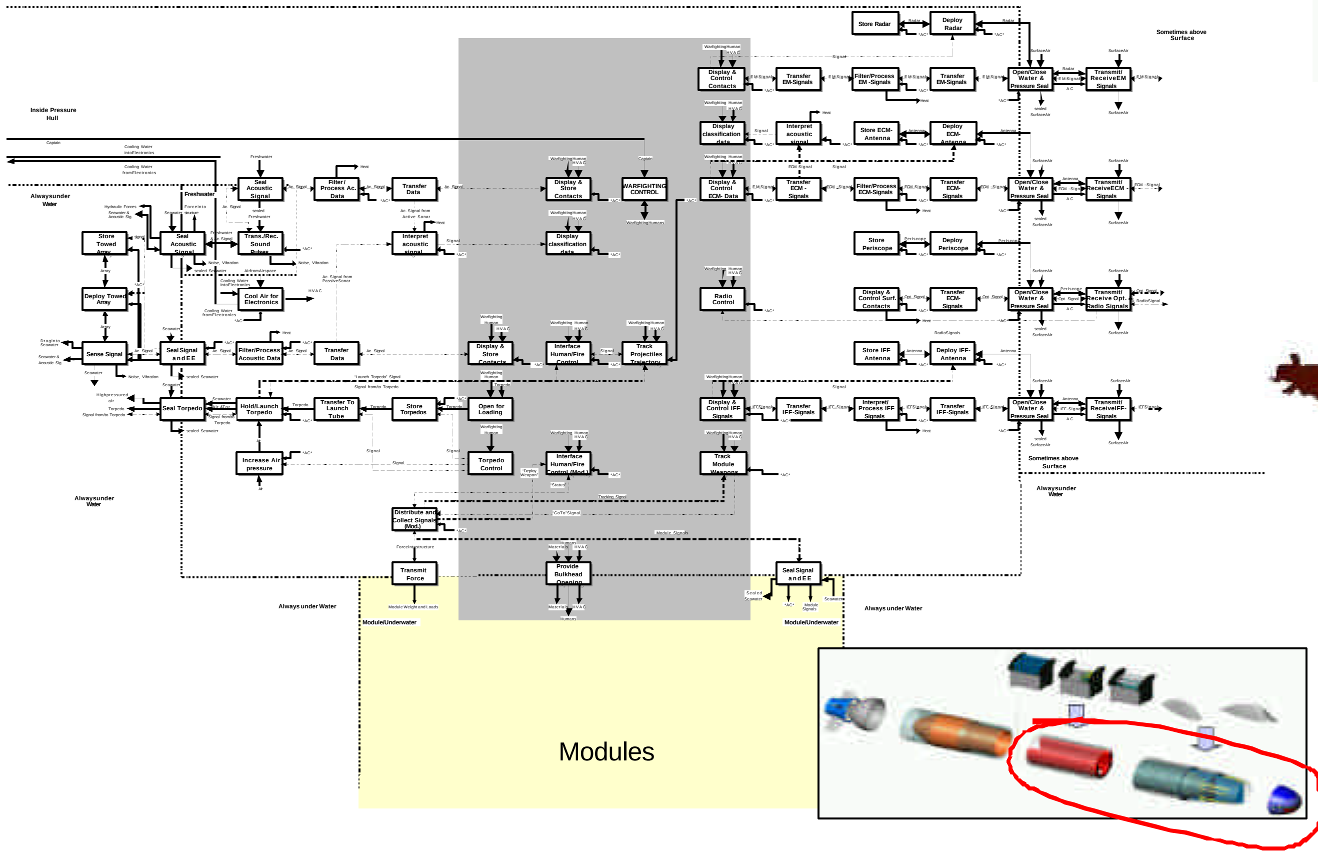
Variation in **Mass** Flow & Transformations

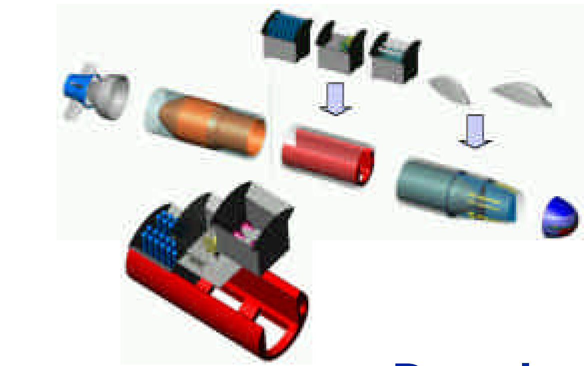
Variation in **Information** Flow & Transformations

"Statistical Engineering"

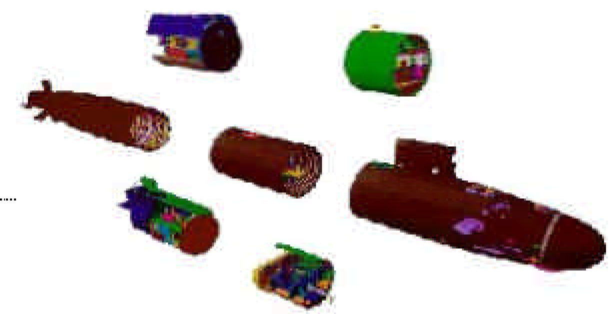
System Block Diagrams

… complete with flows of the physics!

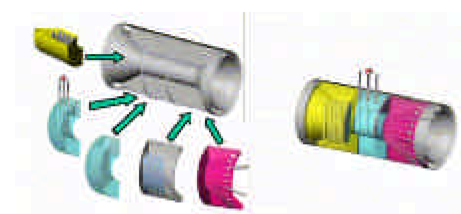




Drop In



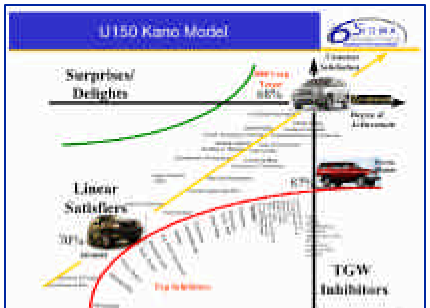
Weld In



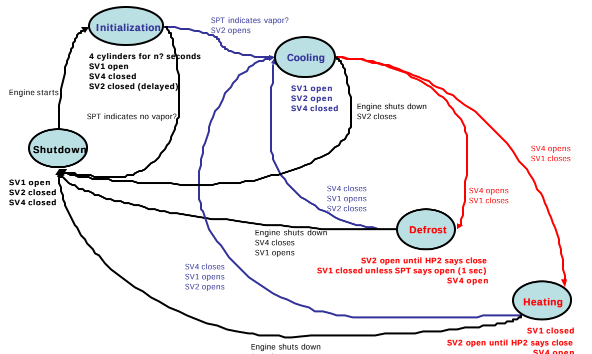
You have a mapping from top level requirements to these flows

Bolt On

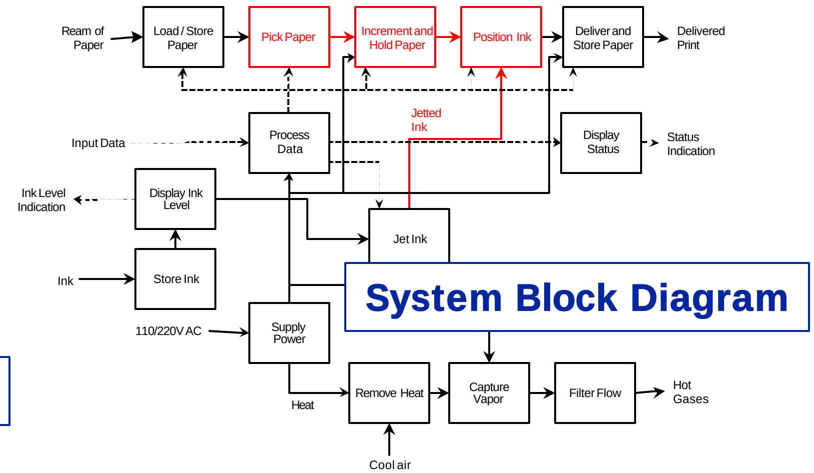
Potential FMEA and RCA



Customer Needs



Customer / Product States



System Block Diagram

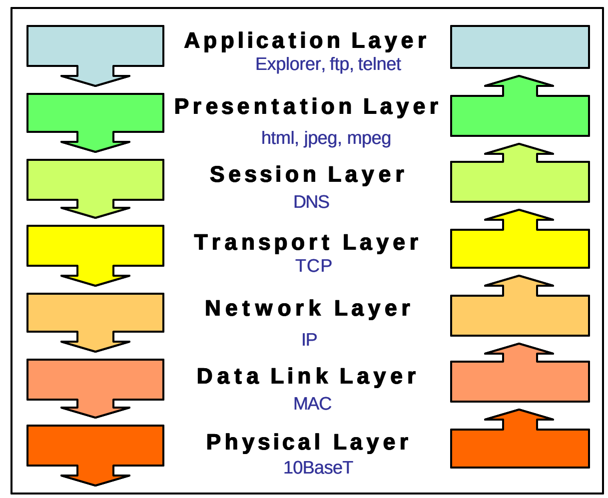
Item Function	Potential Failure Mode	Potential Effect(s) of Failure	Sev	Class	Potential Cause(s) of Failure	Occur	Current Design Controls	Detect	RPN	Recommended Action(s)	Responsibility and Target Completion Date	Action Results: Actions Taken	Sev	Occur	Detec	RPN
									0							0

FMEA everything: business plan, requirements, concept, schedule, ...
This generates requirements to metrics to models to ...

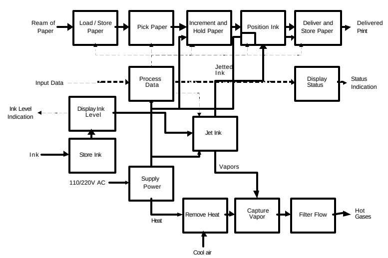
Interface Definition

- Each module has
  - Flows at boundary
  - Attachments
- These require definition
  - Fixed standards
  - Exchange standards
- Incorporate robustness at the interface!
  - Scalable parameters
  - Robustness parameters

	Paper Handling	Cartridge	Print Handling	Electronics	Air Handling
Paper Handling	X	Aligned paper	Paper advance	Paper position	
Cartridge		X	Jetted Ink	Cartridge position	Ink heat
Print Handling			X	Paper position	Ink heat
Electronics	Paper advance	Ink commands		X	12 V
Air Handling		Cool air	Cool air	Cool air	X

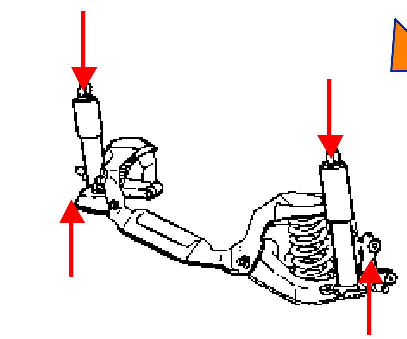


Generate y=f(x) Relationships



Function	y	WT	Flow (M, E, or I)	*Element (Part)*
Insulate air	Cooling Time	5	Heat (E)	*Sidewall, Mouth, Lid*
Contain Coffee	% Volume Lost	5	Coffee (M)	*Side, Lid*
Contain Coffee	Delta Height	5	Coffee (M)	*Sidewall*
Import surface	Base Width	5	Surface (M)	*Base*
Stabilize Forces	Moment about Base	5	Forces (E)	*Base*
Insulate hand	Boundary Temp.	4	Heat (E)	*Sidewall*
Hold Coffee	Cup Volume	3	Coffee (M)	Sidewall
Hold Coffee	Cup Diameter	3	Coffee (M)	Sidewall
Insulate air	Coffee Temp	2	Heat (E)	Sidewall, Mouth, Lid

Y **flows**



Function	y	WT	Flow (M, E, or I)			*x,n*			
Insulate air	Cooling Time	5	Heat (E)	A_{out}	A_{in}	r_{out}	r_{in}	k_{cup}	h_{in}
				h_{out}	T_{coff}	T_{air}	m_{coff}	$C_{p,coff}$	
⋮	⋮	⋮	⋮	⋮					

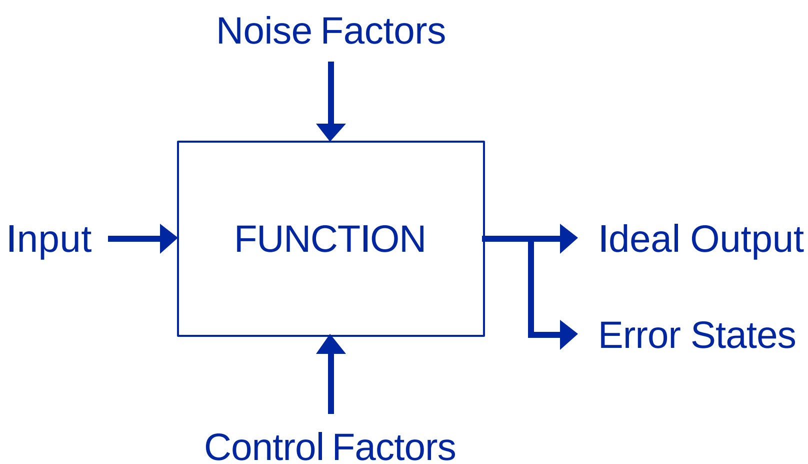
Y ***x*'s and *n*'s**

Now go model or experiment

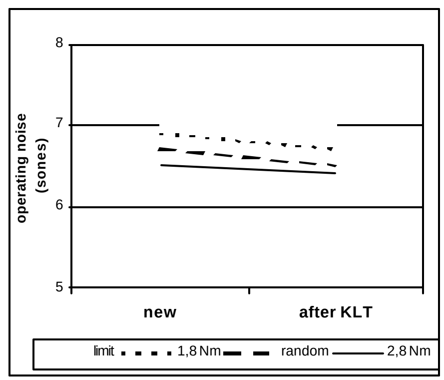
Robust Design on Subsystems

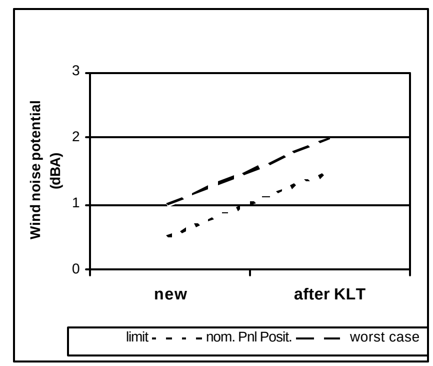
Function	y	WT	Flow (M, E, or I)			x,n			
Insulate air	Cooling Time	5	Heat (E)	A_{out}	A_{in}	r_{out}	r_{in}	k_{cup}	h_{in}
				h_{out}	T_{coff}	T_{air}	m_{coff}	$C_{p,coff}$	
⋮	⋮	⋮	⋮	⋮					

L_{12}	N_A	N_B	N_C	N_D	N_E	N_F	N_G	N_H	N_I	N_J	N_K	Y_1	Y_2	…	Y_n
1	1	1	1	1	1	1	1	1	1	1	1				
2	1	1	1	1	1	2	2	2	2	2	2				
3	1	2	2	2	2	1	1	1	2	2	2				
4	1	2	1	2	2	1	2	2	1	1	2				
5	1	1	2	1	2	2	1	2	1	2	1				
6	1	1	2	2	1	2	2	1	2	1	1				
7	2	2	2	2	1	1	2	2	1	2	1				
8	2	2	2	1	2	2	2	1	1	1	2				
9	2	1	1	2	2	2	1	2	2	1	1				
10	2	1	2	1	1	1	1	2	2	1	2				
11	2	2	1	2	1	2	1	1	1	2	2				
12	2	2	1	1	2	1	2	1	2	2	1				



$$y=f(x)$$





... only then do reliability tests at the system level

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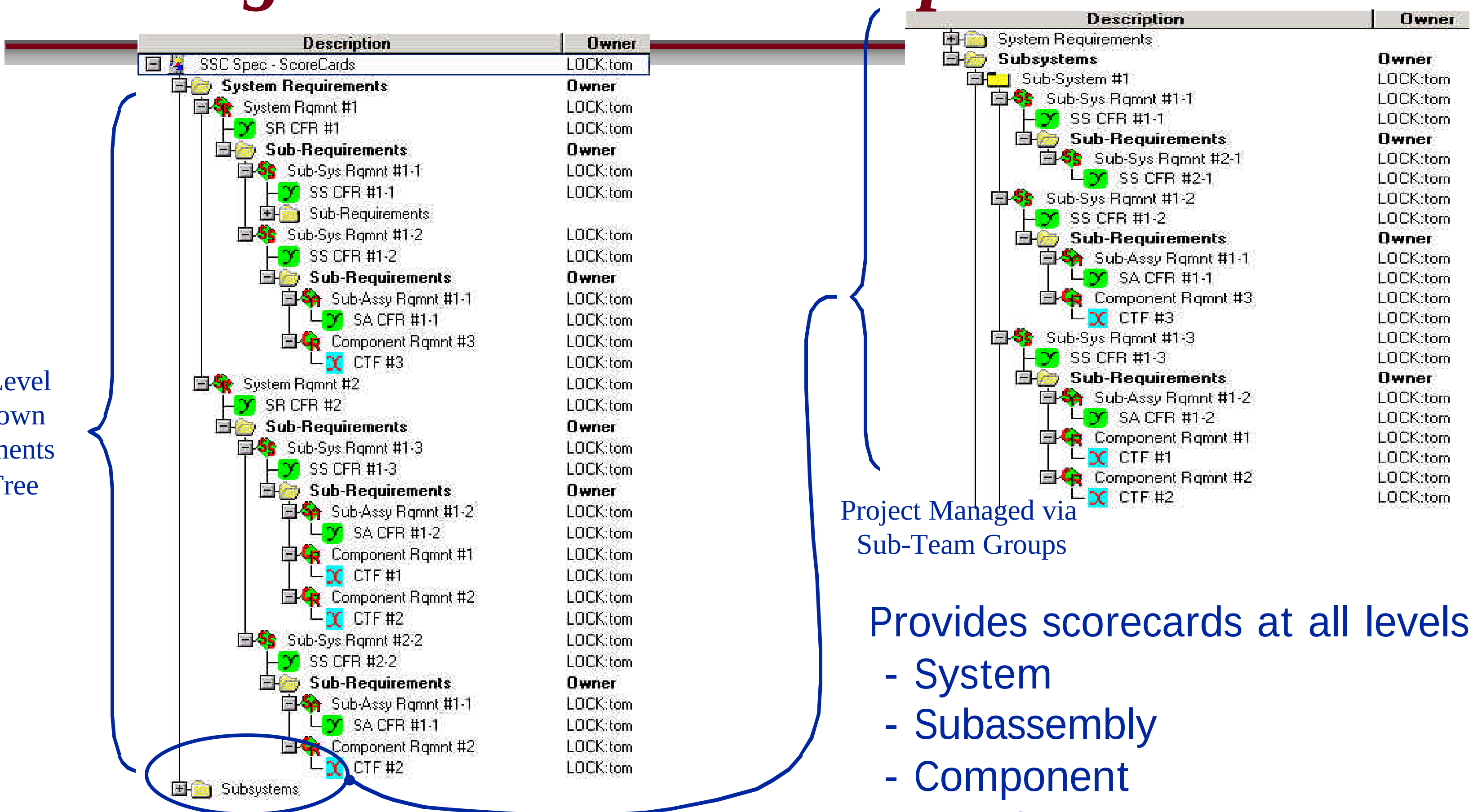
Cognition Corp's Six Sigma Cockpit: Linking Critical Relationships



Project Level Flow Down Requirements & CP Tree

Project Managed via Sub-Team Groups

Provides scorecards at all levels
- System
- Subassembly
- Component
- Function

Cognition Corporation

DFSS Critcial Parameter Management --- System Requirement & System Level CFR Score Card

Project Name: SSC Spec - ScoreCards **Project ID#:** SSC-Spec-SC1.0 **Date:** 3/1/2002

System Requirement	System Level CFR (Y)	Owner	T/F ?	Requirement Target Value			Design Model Prediction					Production Capability Prediction				Validation Test Data					
							CGI-DMP:					CGI-PCP:				CGI-VTD:					
				Lower Limit	Nominal	Upper Limit	Nominal	Mean	Std. Dev.	Cp	Cpk	Mean	Std. Dev.	Cp	Cpk	Mean	Std. Dev.	Cp	Cpk	COV	S/N
System Rqmnt #1	SR CFR #1	tom	N																		
System Rqmnt #2	SR CFR #2	tom	N																		

Reinforce Data Based Gate Progression

Concept → Gate 1 → Design → Gate 2 → Optimize → Gate 3 → Capability → Gate 4 → Launch

Product Concept
Bus. Strategy, Family Plans. VOC, Platform & Tech. Concepts

Design Developed
FMEA, Mod. Design, DOE Modeling, MSA, …

Design Optimized
Robust Design, RSM

Design Capable
Sens. & Cap. Analysis, Stress Testing, M-V

Critical Parameter Management

Scorecards help determine Phase advancement (Rank & Risk Assessment)

Gate 1	Rank	Risk
Item	Score	
Strategy	95	
Bus. Case	88	
Concept Engineering	91	
CPM	91	
DFQ Score	91.2	

Gate 2	Rank	Risk
Item	Score	
FMEA	95	
DOE & Models	88	
System Arch	91	
Flexibility	91	
DFQ Score	91.2	

Gate 3	Rank	Risk
Item	Score	
Noise Char.	95	
Robust Design	88	
Integration Plan	91	
Analytical & Exp. Sensitivity	91	
DFQ Score	91.2	

Gate 4	Rank	Risk
Item	Score	
System Stress Testing	95	
Reliability Assessment	88	
Capability Analysis	91	
Process CPM	91	
DFQ Score	91.2	

Areas to become Proficient

A	Overview & Exercise	Lean Development Process & Project Mgt.	VOC Gathering & KJ Methods	System Architecting	QFD & Reqts Document Methods	Planning Systems Integration: Design Flexibility and Risk	Pugh Process: Concept Evaluation & Selection
B	FMEA & Top-down functional RCA	DFMA Design for Lean Production	Critical Parameter Mgt.	Hypothesis Testing & Confidence Intervals	ANOVA Measurement System Analysis	Model Maturity Assessment	Monte Carlo Simulation
C	Regression	Basic DOE	Advanced DOE	Robust Design & Dynamic Methods	Tolerance Optimization	RSM & Multiple Y Optimization	Technology & Process Capability
D	Reliability Modeling	System Variation Stress Tests	HALT Tests	ALT tests & Warrantee Guarantee	Production & Supply Chain CPM	Statistical Process Control	DMAIC & Lean Production Methods Overview

This Generates Results

- ROI's conservatively > 10X are typical
- Shorter time to market
- Improved Gate Decision Making
- Quality improvements
- Clarity of process