DFSS - Design for Six Sigma:
Shifting from Deterministic Design to Probabilistic Design

Presentation to University of Sofia - Bulgaria

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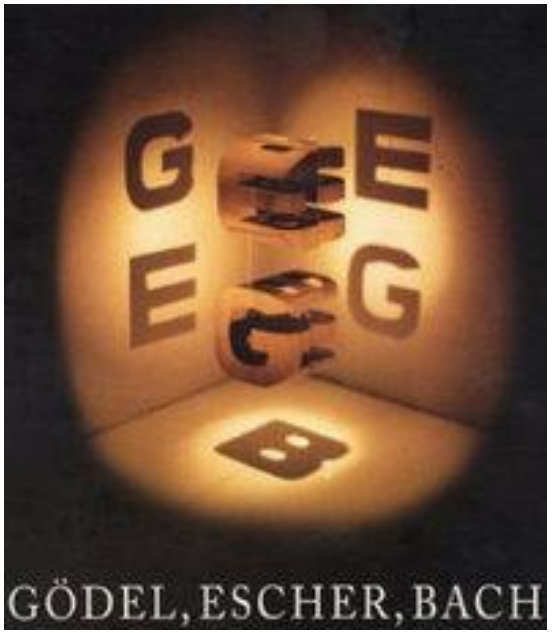
The Multifaceted nature of Six Sigma



Six Sigma is a philosophy, a measure, and a methodology that provides businesses with a perspective and tools to achieve new levels of performance in both services and products.

Six Sigma as a (Management) Philosophy

Six Sigma as a philosophy helps companies achieve very low defects per million opportunities over long-term exposure.

"...this Six Sigma journey will change the paradigm from fixing products so they are perfect to fixing processes so that they produce nothing but perfection, or close to it." *- Jack Welch*

"It is a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimize waste and resources while increasing customer satisfaction."

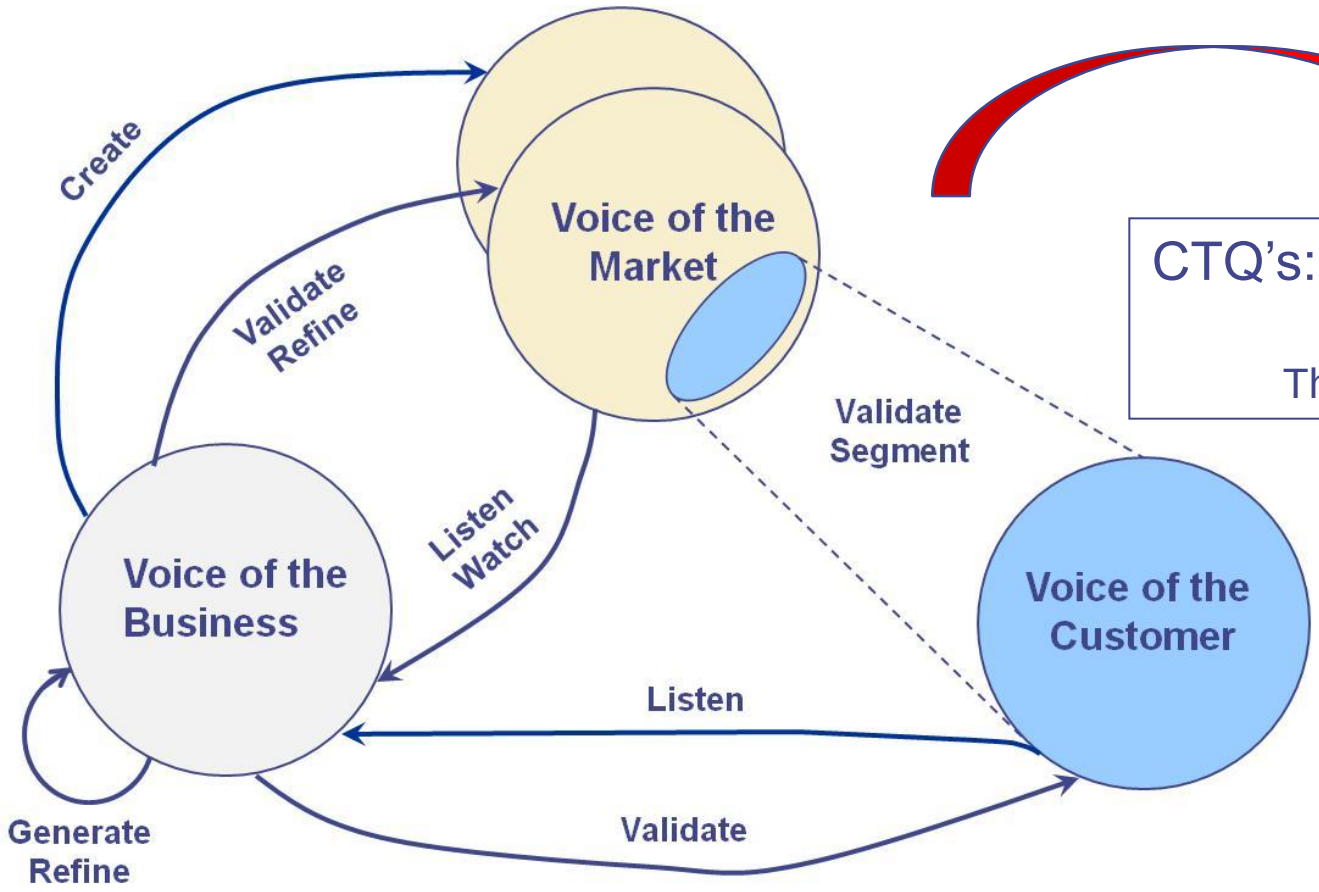
taken from "Six Sigma: The Breakthrough Management Strategy Revolutionizing the World's Top Corporations", 2000, Mikel Harry, Ph.D., and Richard Schroeder

Six Sigma is more than Quality, it is a way of doing business

Six Sigma – focus on Process Improvement

- Six Sigma is a process-focused approach to achieving new levels of performance throughout any business or organisation
- In Six Sigma the focus is on process improvement to increase capability and reduce variation
- The process is considered as a system of inputs, activities, and outputs. It provides a holistic approach to all factors and the way they interact to create value or waste
- The few vital inputs are chosen from the entire system of "controllable" and "noise" variables, and the focus of improvement is controlling these inputs

Six Sigma – Creating Value



CTQ's: Critical To Quality

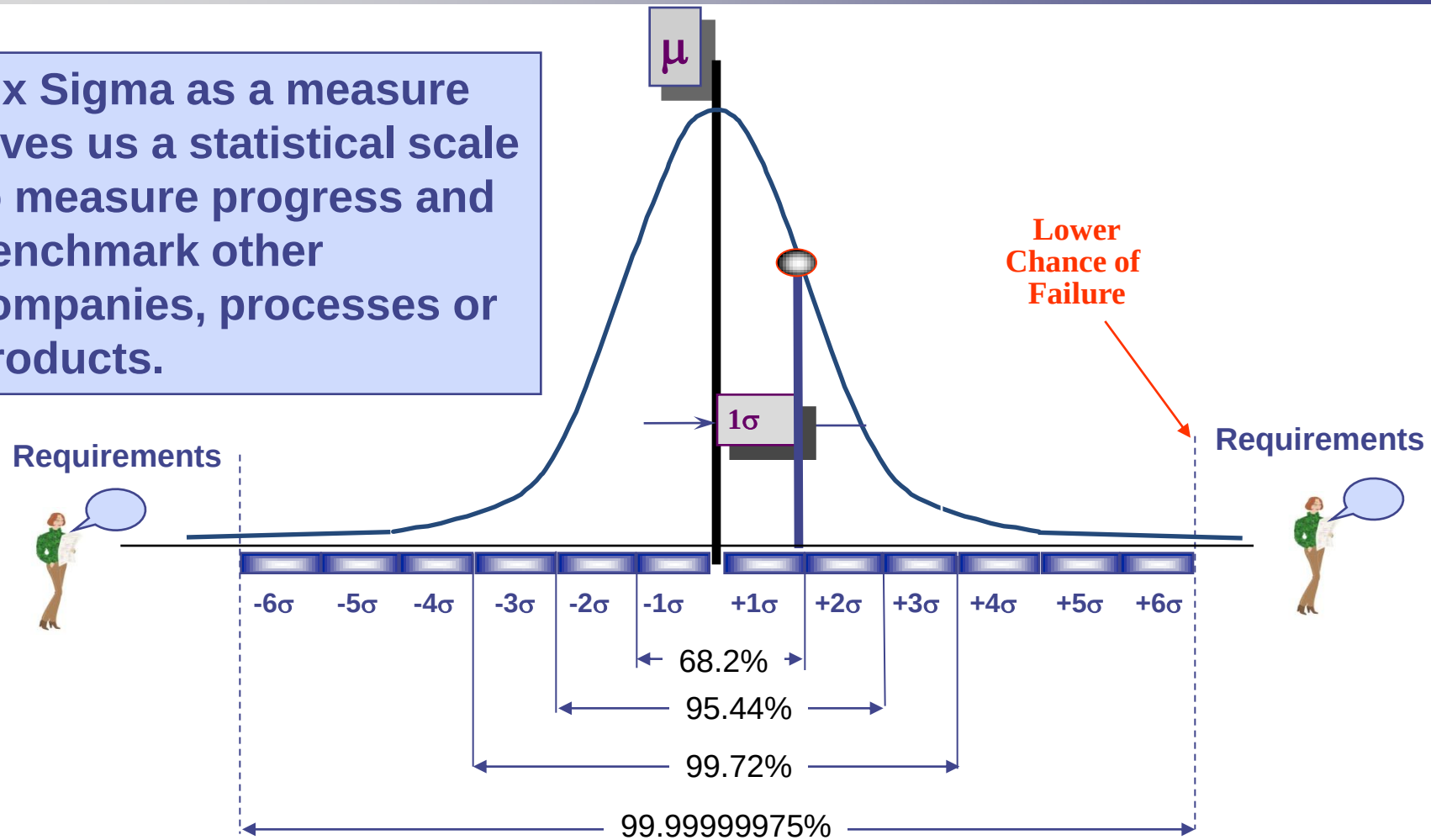
The Pareto Effect

*Six Sigma, is "**the degree of confidence a customer has that his (or her) product and service-related expectations will be met by the producer.**"*

Michael J. Harry & J. Ronald Lawson, *"Six Sigma Producibility Analysis and Process Characterization*," Addison-Wesley Publishing Company, Inc., 1992

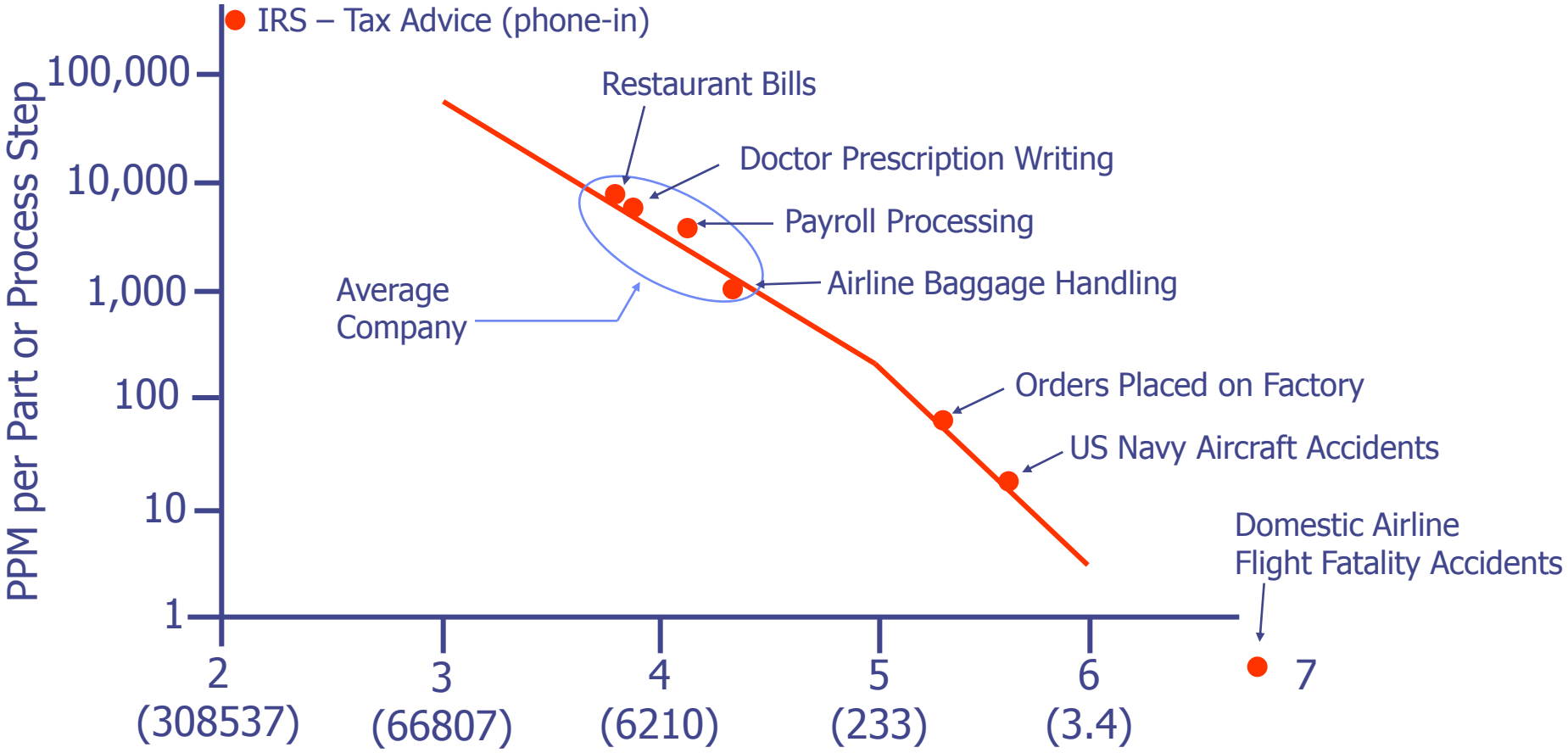
Six Sigma - As a measure

Six Sigma as a measure gives us a statistical scale to measure progress and benchmark other companies, processes or products.



Six Sigma implies a process where any value outside the specifications is an extremely rare occurrence

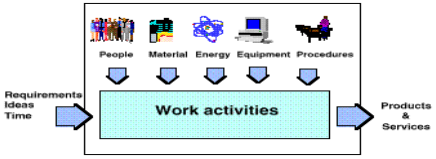
Six Sigma Levels



Keep in mind, the number of "sigmas" depends on the type of business and criticality.

[Harry 00]

Six Sigma – as a Measure



Voice of the Process

High Capability

Lower Specification Limit

Upper Specification Limit

Low Capability

Lower Specification Limit

Upper Specification Limit

Lower Specification Limit

Upper Specification Limit

Lower Specification Limit

Upper Specification Limit

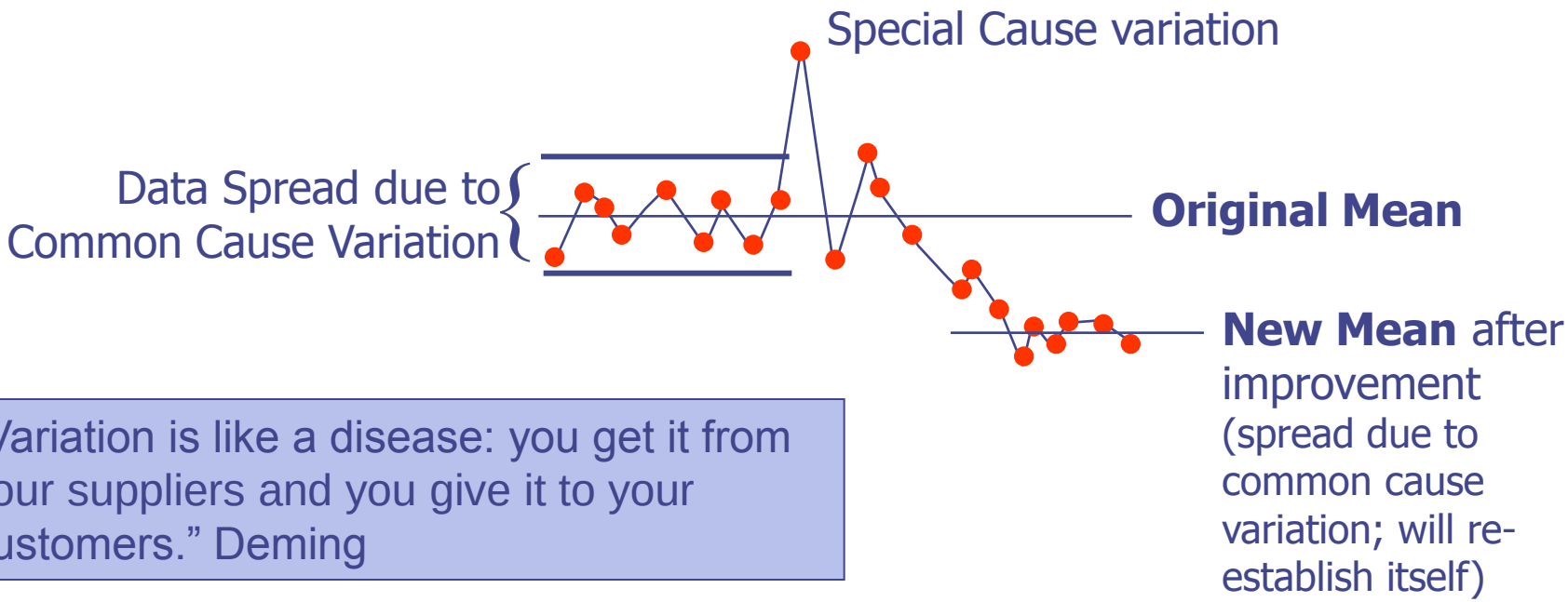
Capable Process

Not capable Process

Get the two Voices (VOC & VOP) into alignment

Statistical Thinking

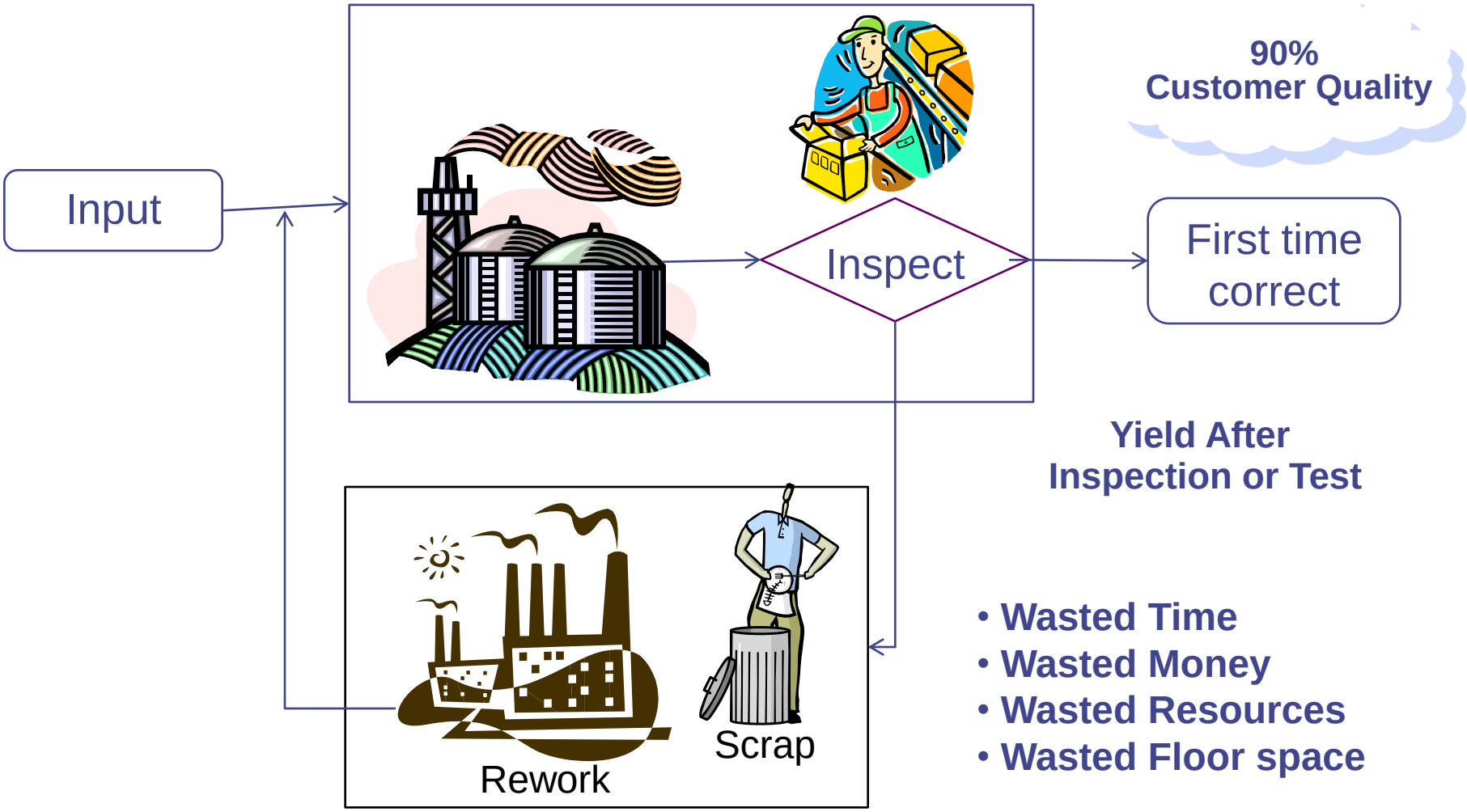
- **All work is process**
- **Variation exists in any process**
- **Knowledge and management of variation are key to succeed in process improvement**
- **Provides feedback loops**



"Variation is like a disease: you get it from your suppliers and you give it to your customers." Deming

[ASQ 00][Penn 03]

Hidden Factory



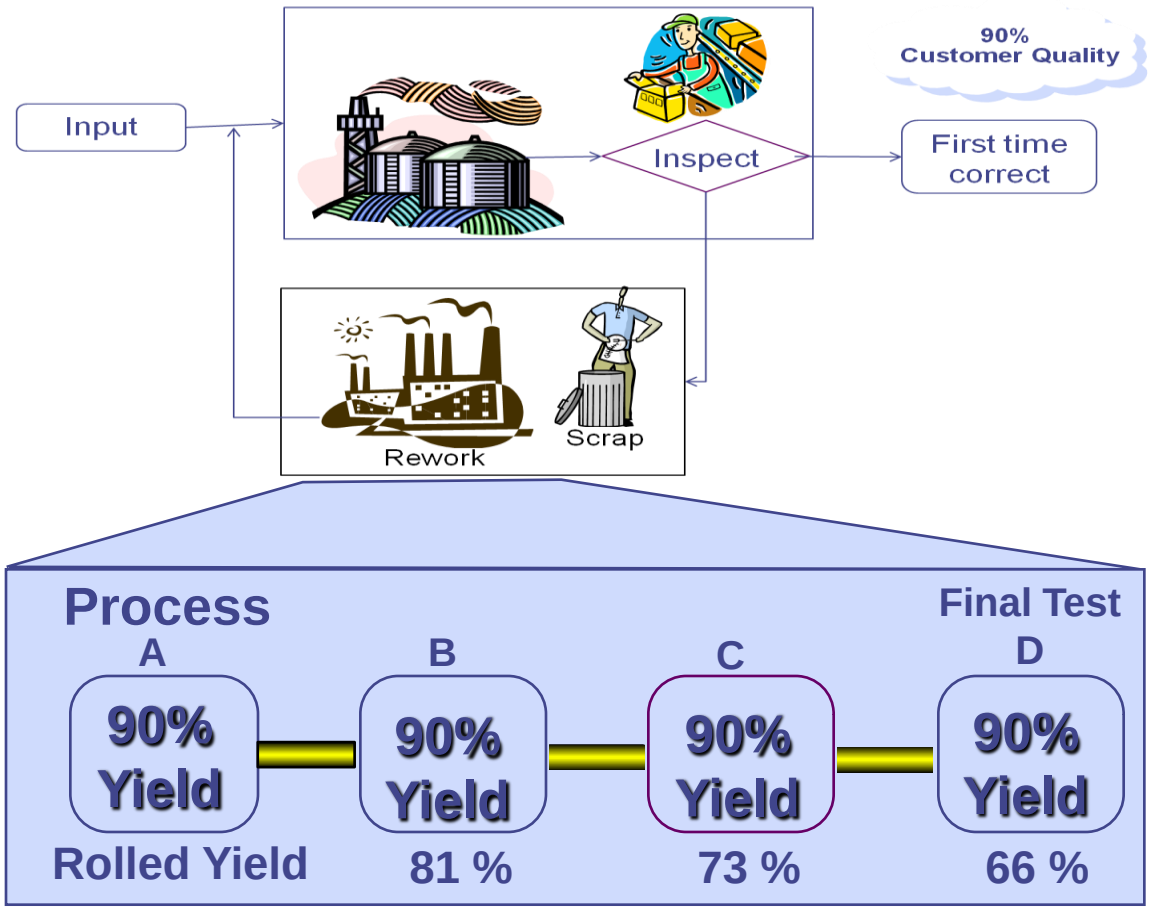
90% Customer Quality

Yield After Inspection or Test

- **Wasted Time**
- **Wasted Money**
- **Wasted Resources**
- **Wasted Floor space**

Manufacturing Variation Causes A "Hidden Factory"
Increased Cost - Lost Capacity

Hidden Factory



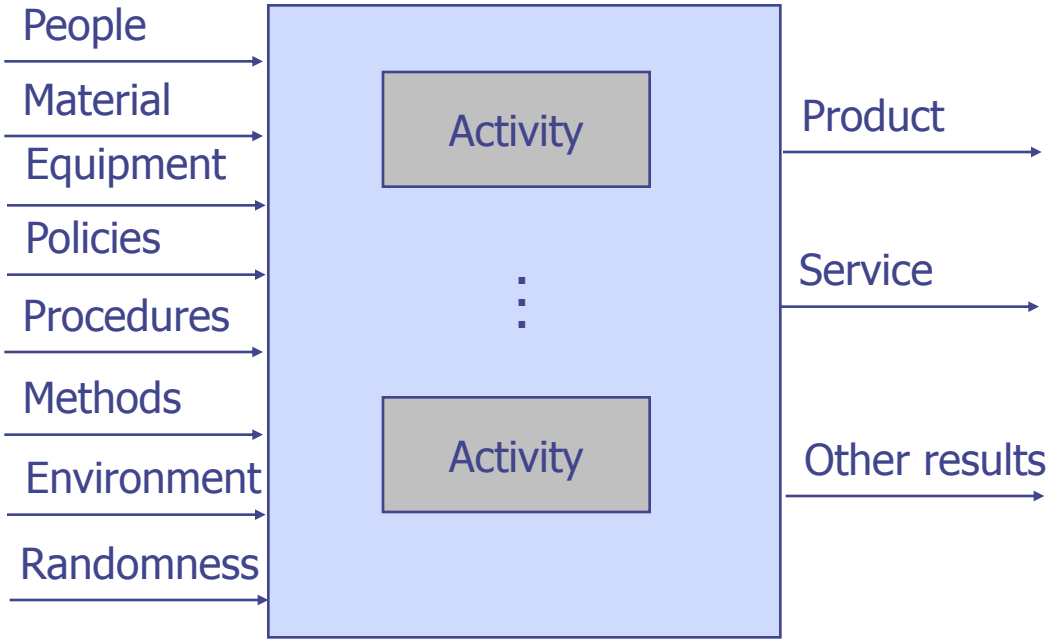
Rolled-Throughput Yield

66% ≠ 90%

Classical First-Time Yield

DPMO forces you to look at the “hidden factory” where expediting, rework and delays occur, but would likely not show up in classical yield metrics. The resulting detail from DPMO determinations can then help to prioritize where improvements can be made.

Define a problem statistically



$$Y = F(X_1 \ldots X_n)$$

Y	$X_1 \ldots X_n$
Dependent	Independent
Output	Input-Process
Effect	Cause
Symptom	Problem
Monitor	Control

Find and control the critical X's

The framework contains two roadmaps for problem solving

DMAIC - Define, Measure, Analyse, Improve, Control

Improve the capability of existing processes, products and services

Systematic defect elimination and waste reduction

Based on statistical techniques

DFSS - Design For Six Sigma

Create new products, processes and services at ensure that quality is built-in by design and not through Testing)

Systematic Innovation and creativity

Based on non-deterministic and probabilistic techniques for risk modelling and management

Six Sigma Roadmaps

DESIGN

VERIFY

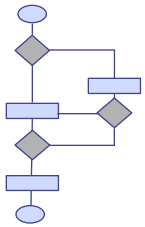
DEFINE

MEASURE

ANALYSE

IMPROVE

CONTROL



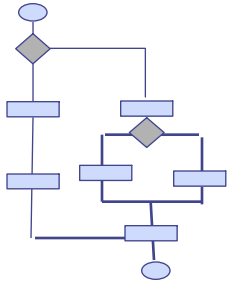
Y

X_1
X_2
X_3
X_n

f

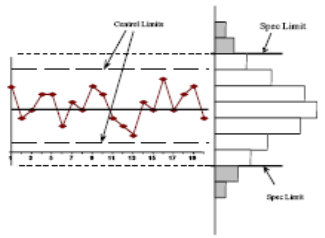
Y

$Y=f(X_1, X_2,..,X_n)+\varepsilon$



$Y=f(X_1, X_2,..,X_n)+\varepsilon$

X_1 X_2 X_3 X_n



Six Sigma is applicable to both, Process and Product, but some of the tools may differ

Six Sigma – as an organisational infrastructure

Executives
- Own vision, direction, integration, results
- Lead change

Project Team members
- Part-time
- Project-specific

Champions
- Project owner
- Implement solutions
- Black Belt managers

All employees
- Understand vision
- Apply concepts

Green Belts
- Part-time
- Help Black Belts

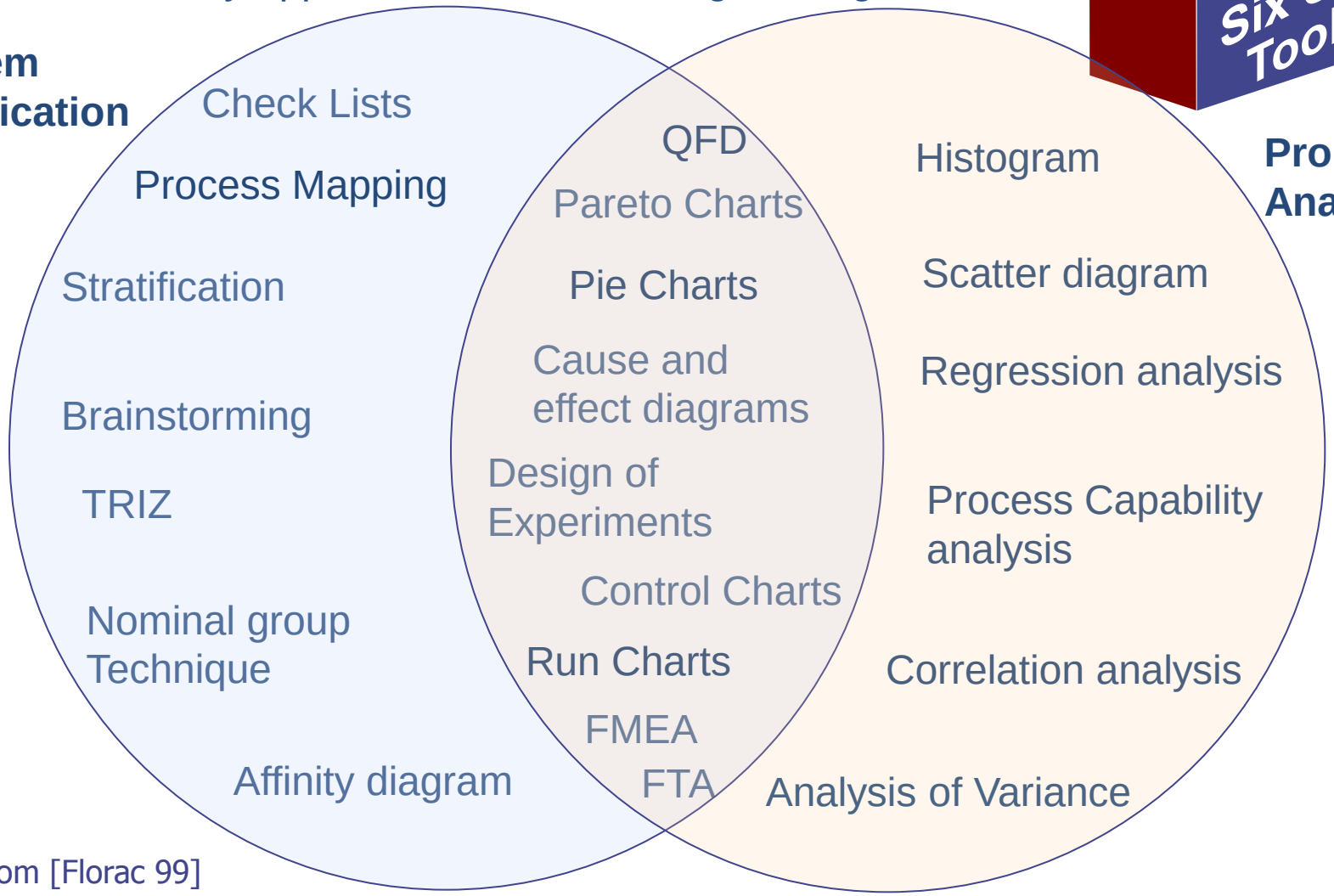
Master Black Belts
- Full time
- Train and coach
- Statistical problem solving experts

Black Belts
- Devote 50% - 100% of time to BB activities
- Facilitate and practice problem solving
- Train and coach Green Belts and project teams

Source: ASQ, Six Sigma Business Excellence

Six Sigma – as a toolset

The majority of techniques of Quality Management and Six Sigma are directly applicable to software engineering



Adopted from [Florac 99]

Adapted by RO from CMU/SEI-97-HB-003

Design Activity

" Everyone designs who devises courses of action aimed at changing existing situations into preferred ones " – **Herbert Simon**

- **Designing is a type of cognitive activity**
- **Designing is specifying**
  - Work with multiple representations.
  - Representations give structure and focus.
  - Representations provide for reflection on the state of the design
- **Designing is stealing**
  - Domain knowledge is reused
  - Creativity is based on analogical reasoning

Integration is the hardest part of design

- **Design is a Social Process**
  - Collaboration
  - Negotiation
  - User Participation

Past, Present, Future

- Design lives everywhere, in all of us.
- Specifically, in the "users".
- People commit everyday little acts of design by adapting systems to their needs.

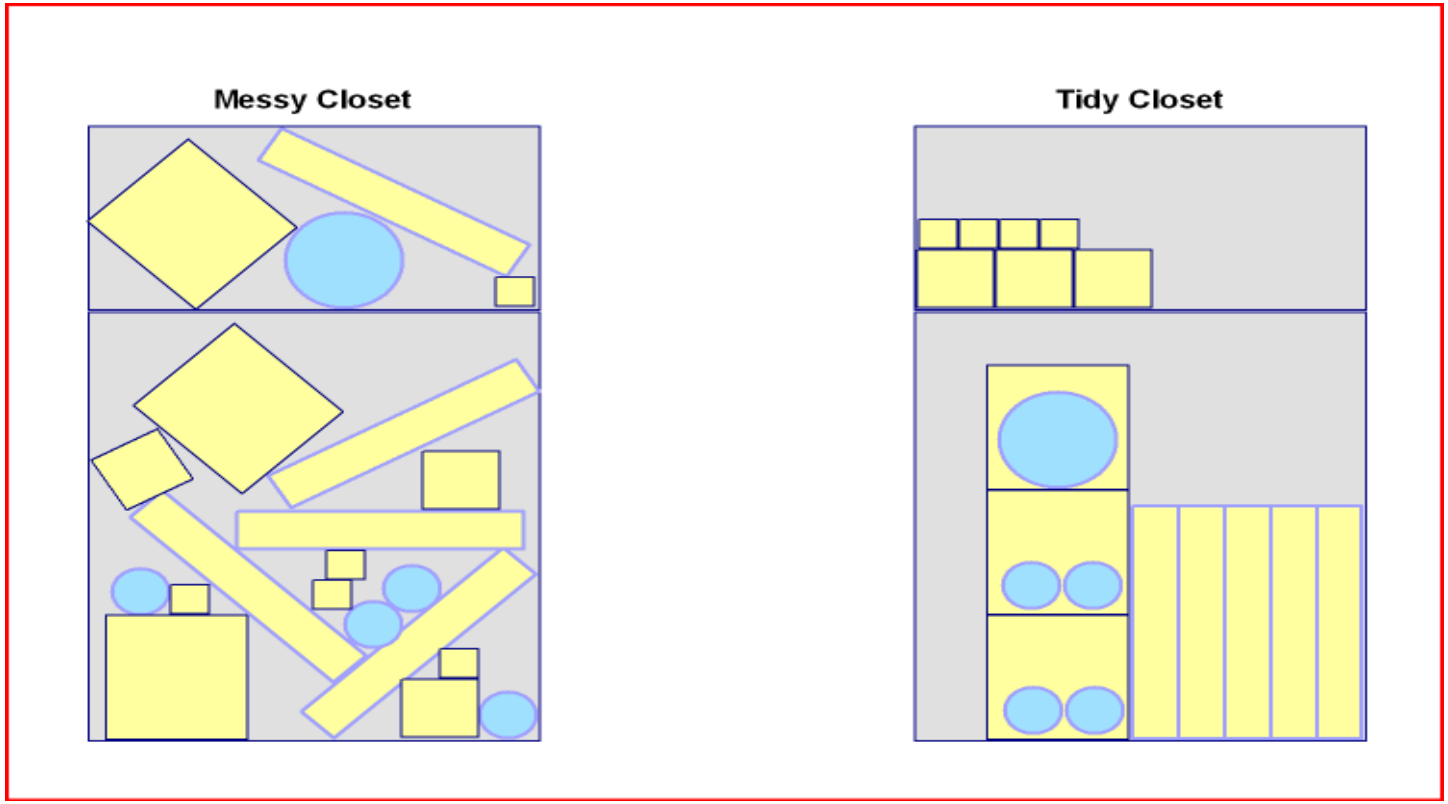
Design – State of the art

- We do not have the knowledge or the mechanisms to determine the most appropriate design methods and techniques.
- We do not have the measurements needed to evaluate and compare possible design alternatives with any confidence.
- We are still at the stage of maturity that is nearer to that of a craft than an engineering discipline.
- While we can often tell from experience that design X is better than design Y…
- We do these judgments from the standpoint of an art critic, not from the standpoint of an engineering discipline based on well understood measures derived from a well established theoretical basis.

We tend to be very religious about our design choice, techniques and methods…

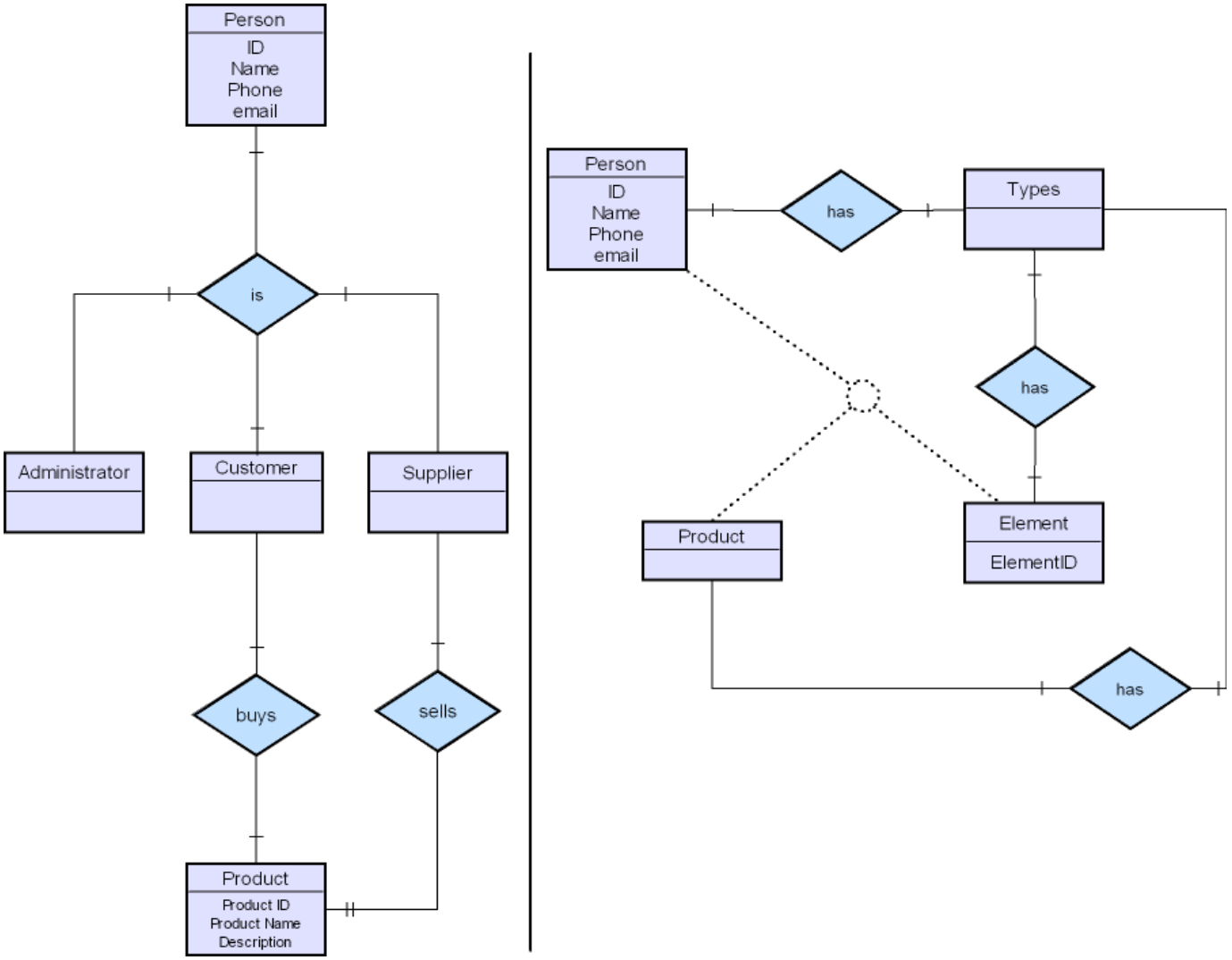
What are the CTQs of a good design?

- What is a good design? What are the characteristics of a good design?



What are these CTQs of a good Design

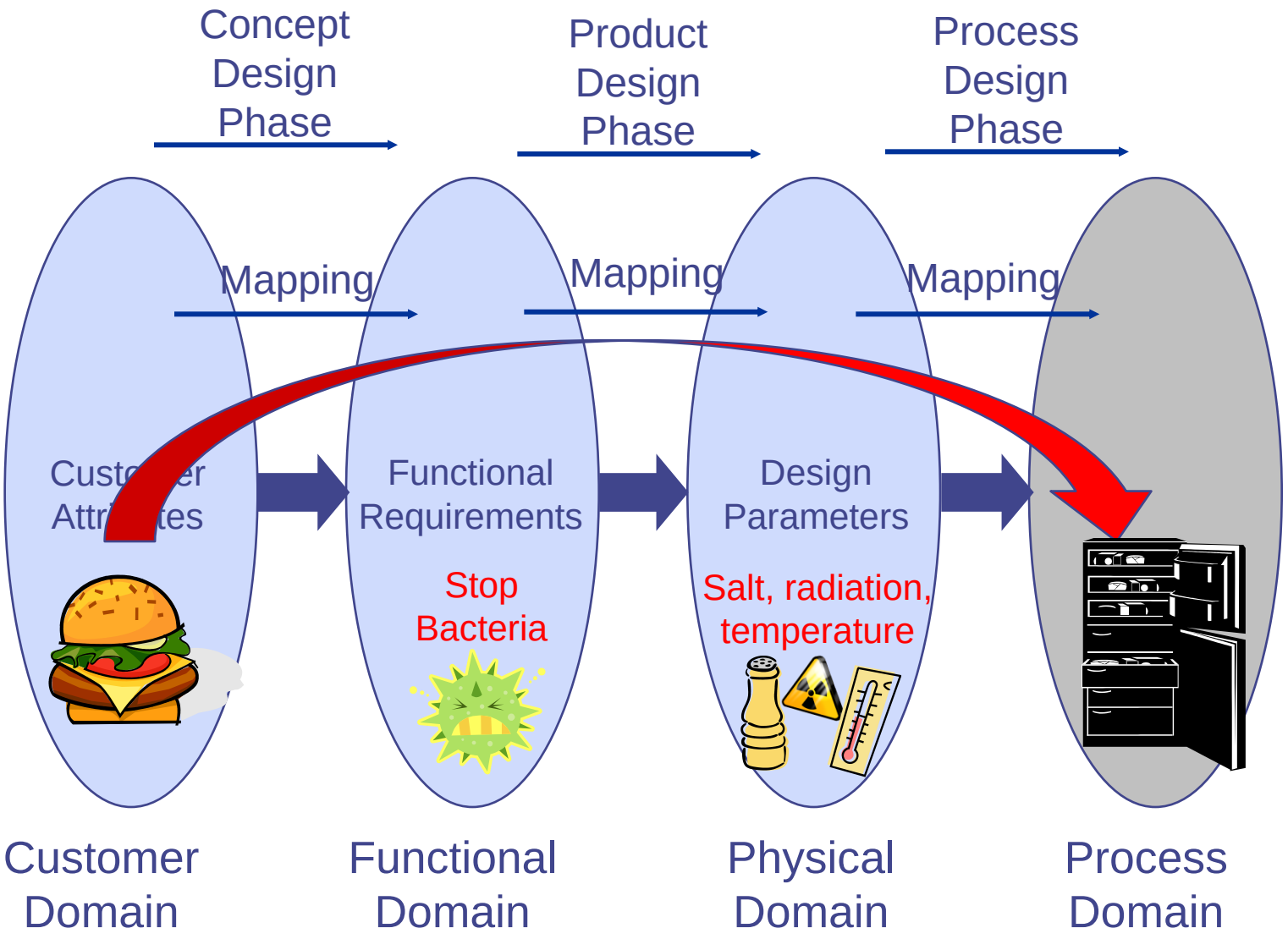
- What would you say of these two design options?



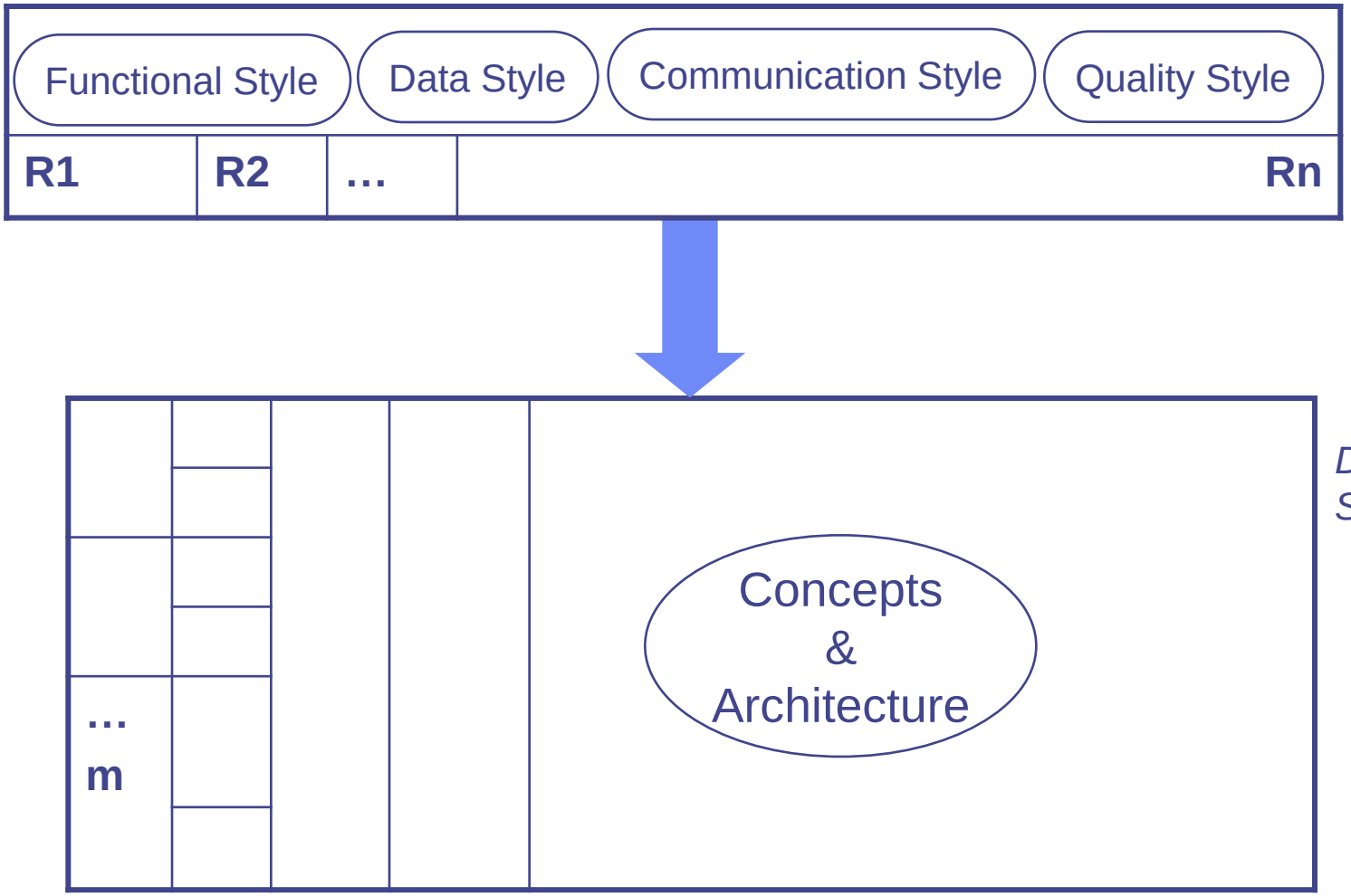
Case study

- you buy a hamburger and bring it home for your dinner
- at home, you receive a call from a friend and decide to go to the restaurant together
- what are you going to do with your hamburger?

Jumping to Solution Space



From Problem Space to Solution Space

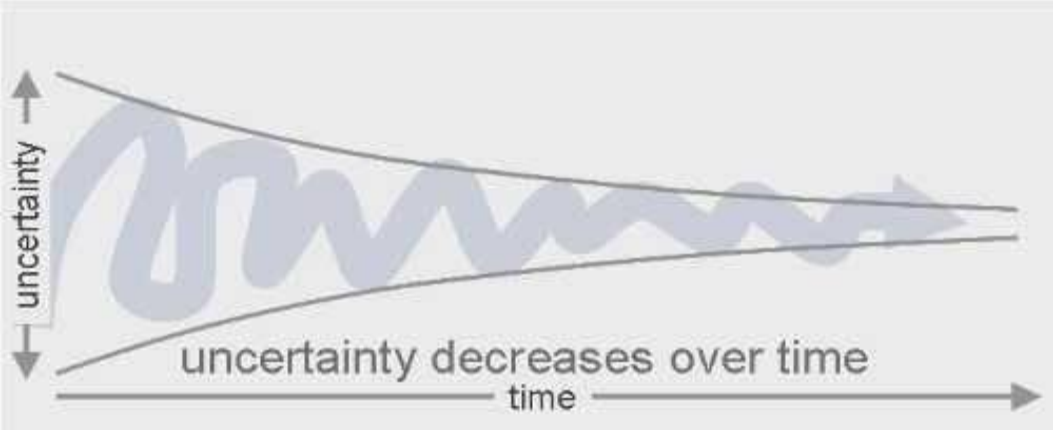


Design is essentially a decision-making process

Decision & Risks

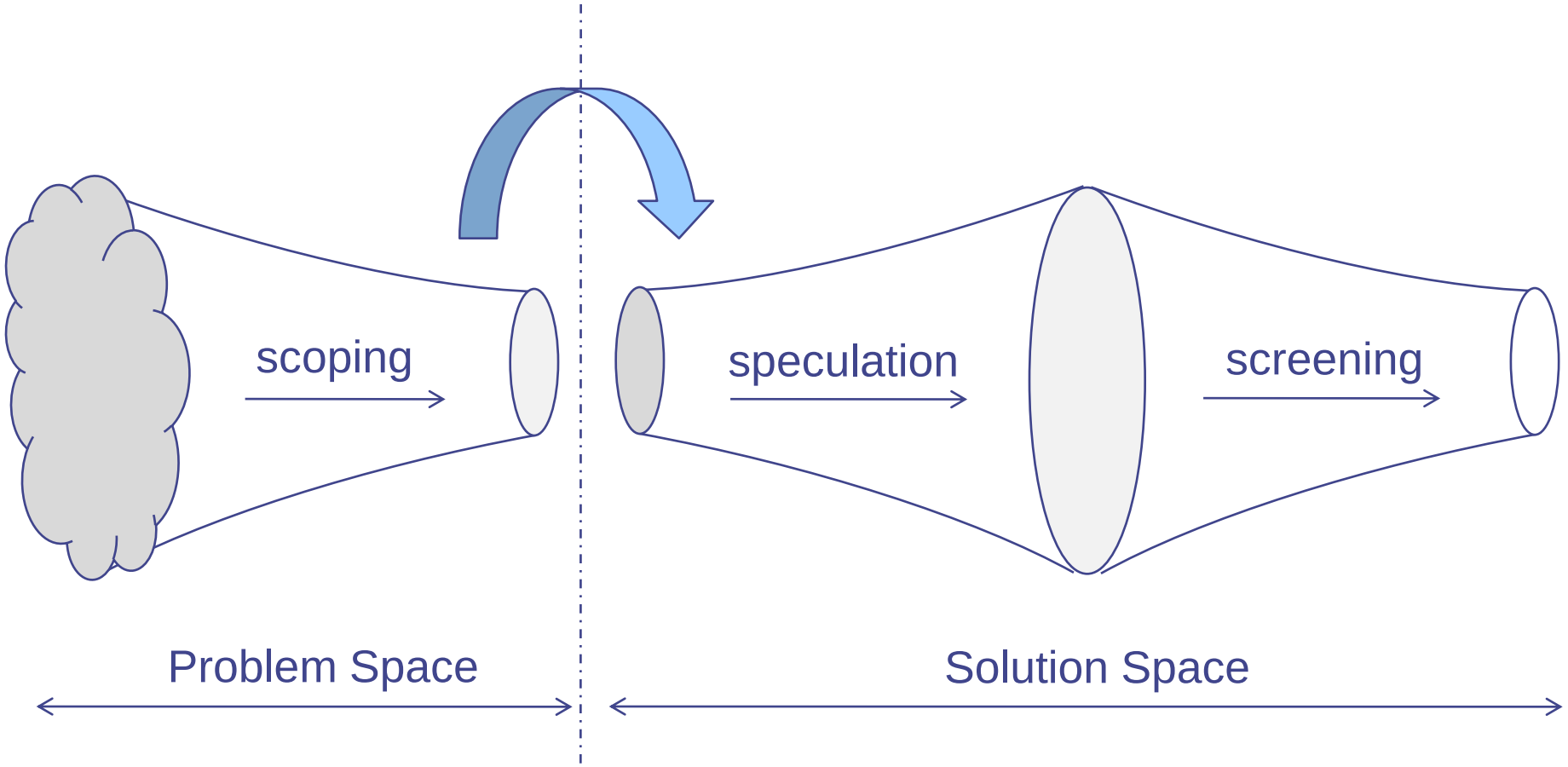
- **Rule:**
  - The quality of decisions cannot consistently rise above the quality of information upon which those decisions are made

- **Corollary**
  - Considering time constraints, there is never enough time to make a no-risk decision



A Design Process is essentially a Risk Management process

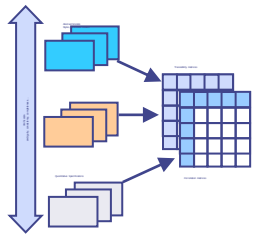
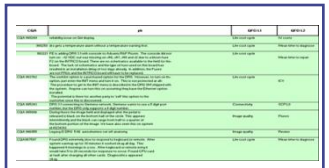
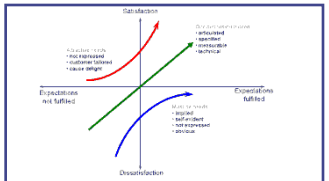
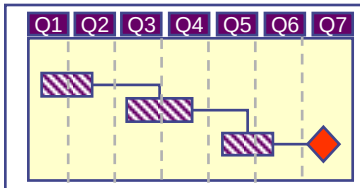
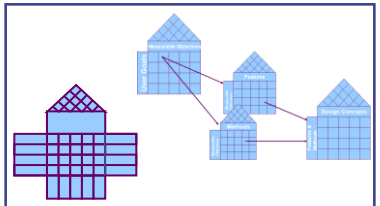
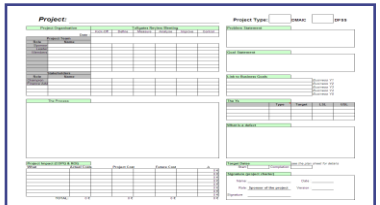
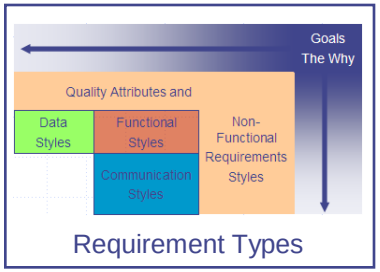
From the Problem Space to the Solution Space



Breakthrough innovation across the entire process

Define Phase

Project / Req

Key activities	Potential Tools and Techniques	Key Deliverables
1. Define the Project Charter 2. Identify the Project Scope and goals 3. Select the Project Life Cycle 4. Define Initial Budget, Resources, timelines 5. Define the Initial Business Case 6. Estimate ROI and Added Values 7. Understand initial an potential VOC 8. Develop Initial System/Process concept Identify Stakeholders 9. Identify Organisation Change Plan 10. Define Communication Plan 11. Identify Initial Risks 12. Tollgate Review	 Problem Statement And Goals  Concepts  Risk Register  Req. Significance  Project Plan  QFD planning  Project Charter  Requirement Types	1. Draft Project Charter 2. Business case 3. Project objective 4. Project Scope 5. Project Plan 6. Initial Risk Register 7. Communication Plan

Why Requirements Engineering is difficult

- **Many requirements are created, not found.**
  - Users, buyers, even developers may be unknown.
- **Inconsistency must be tolerated…for a while.**
  - We don't always understand everything about the real world that we need to know
  - We may understand a lot, but we cannot express everything that we know
  - We may think we understand a lot, but our understanding may be wrong
- **Little or no agreement on requirements**
  - Even the simple word "requirements" means different things to different people.
  - Stakeholders have conflicting objectives.
  - Unprioritised Requirements - "They're all important, or I wouldn't have given them to you."
- **Requirements evolve during and after development.**
  - Volatile or rapidly changing requirements

"Our plan is to lead the public to new products rather than ask them what they want. The public does not know what is possible, we do"

Akia Morita, founder of Sony Corporation

"The customer doesn't generally know what is needed and neither does anyone else! The initial requirements are therefore wrong and will change."

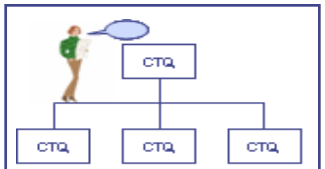
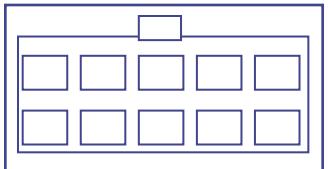
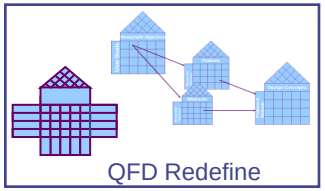
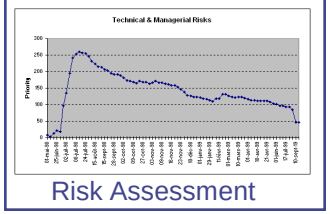
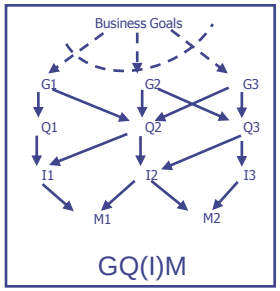
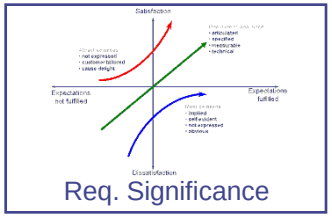
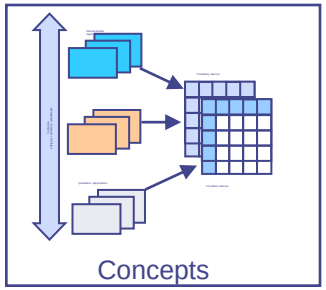
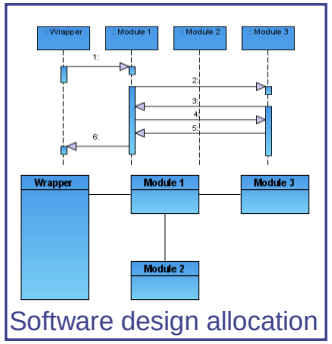
W. Humphrey

"Users are tremendously un-self-aware . . . Software sucks because users demand it to."

Mhyrvold

Measure Phase

Requirements

Key activities	Potential Tools and Techniques	Key Deliverables
1. Identify Stakeholders, Users and Customers 2. Refine the VOC 3. Translate the VOC 4. Define Measures for CTQs 5. Define the Measurement Framework 6. Prioritise CTQs 7. Define Goals 8. Re-assess Risks 9. Tollgate Review	 CTQ Flow down  Affinity diagram  QFD Redefine  Risk Assessment  GQ(I)M  Req. Significance  Concepts  Software design allocation	1. Customers/Stakeholders & segmentation 2. Actual Voice of Customer 3. Competitive benchmarking 4. System Requirements 5. CTQs clearly defined and prioritised 6. CTQ and requirement measures definition

Design For Six Sigma

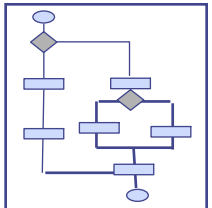
ANALYSE Phase

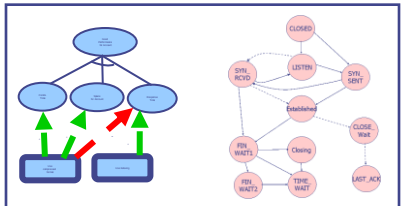
Concepts

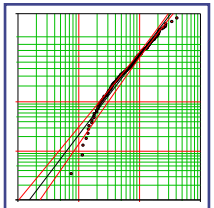
Key activities

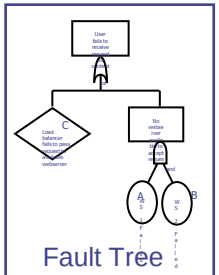
1. Identify Key Functions or Activities
2. Prioritise Functions or Activities
3. Generate Conceptual design and Models
4. Define conceptual design elements and parameters
5. Evaluate and analyse concepts and models
6. Reassess Risks
7. Tollgate review

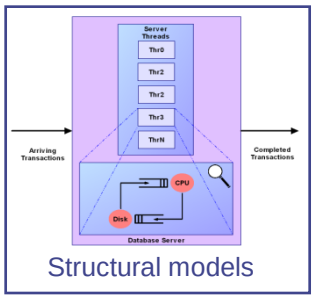
Potential Tools and Techniques

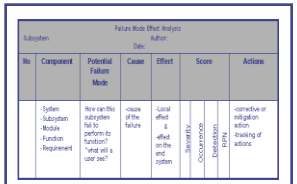

Functional Flowchart

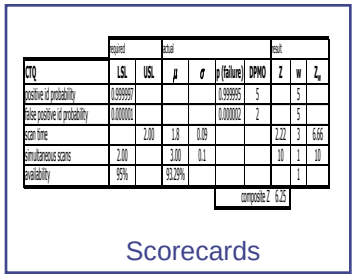

Design Analysis Model

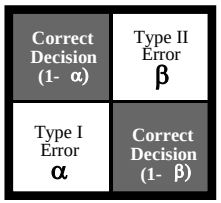

SW Reliability Analysis


Fault Tree

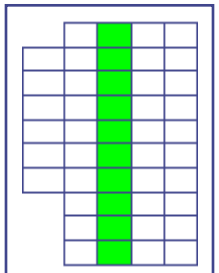

Structural models


Software FMEA


Scorecards



Hypothesis Tests


PUGH Matrix

Key Deliverables

1. Conceptual models and designs
2. Design parameters definition
3. Functions and capabilities specification
4. Conceptual Design "Best-Fit" selection
5. Functional capability assessment
6. System characteristics (performance) scorecards

Design For Six Sigma

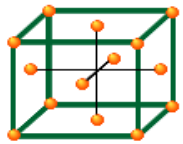
DESIGN Phase

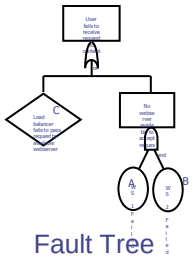
System

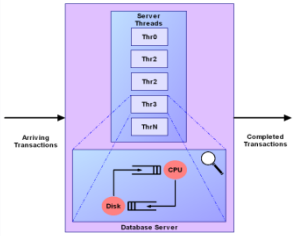
Key activities

1. Identify and prioritise Nth level Design Requirements
2. Develop Nth level Design Requirements
3. Develop Nth level Design
4. Develop Quantitative models
5. Evaluate (design) alternatives
6. Select solution
7. Verify/Review Nth level Design
8. N=N+1
9. Mitigate Risks
10. Develop the system
11. Tollgate Review

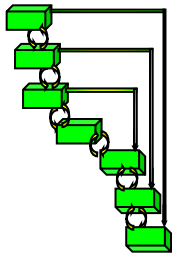
Potential Tools and Techniques

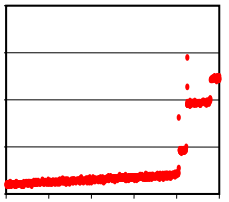

Software DOE

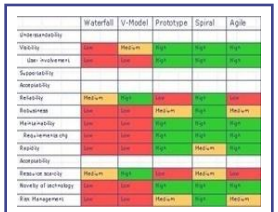

Fault Tree



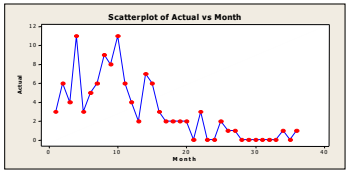
Structural models


Software Process Capability

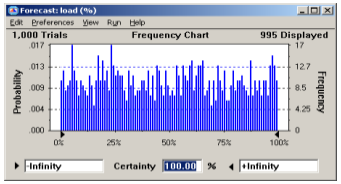

Monte Carlo Simulation



Process Model



Reliability Growth Model



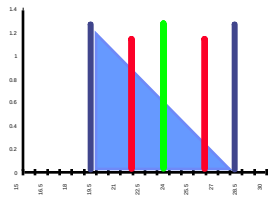
Predictive Model

Key Deliverables

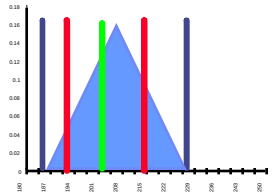
1. Detailed system design
2. Detailed function and capabilities mapping
3. Refined System characteristics (performance) scorecards
4. Verified System

What Are Simulations?

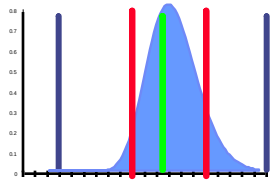
Input Parameters



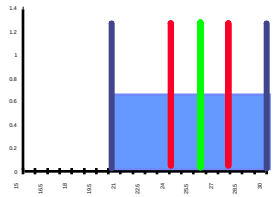
A



B

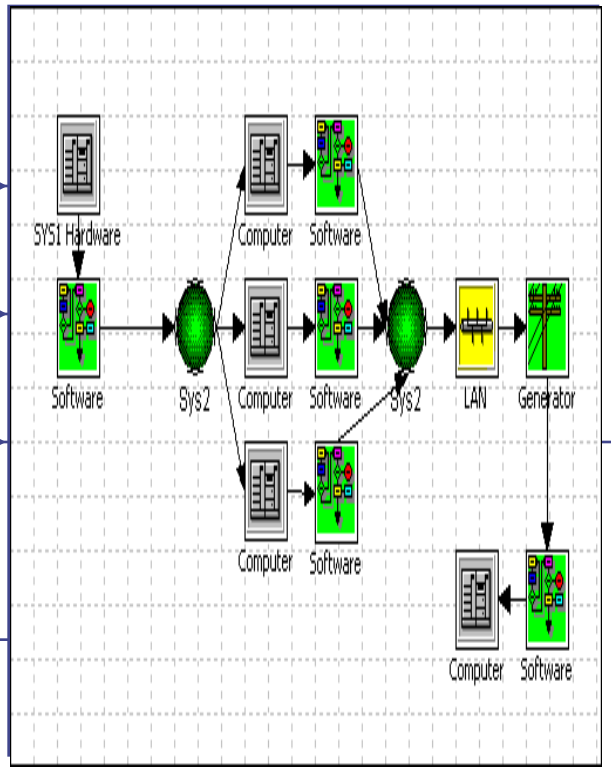


C



D

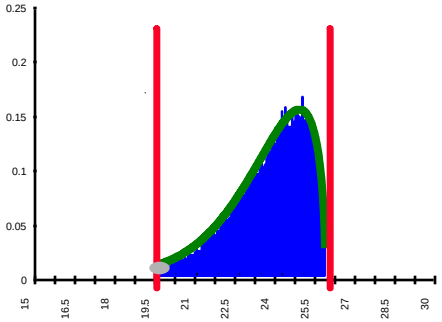
Model



Response

$Y = f(A, B, C..., J)$

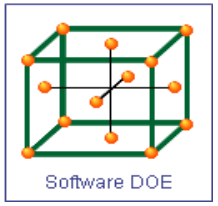
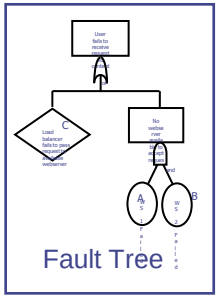
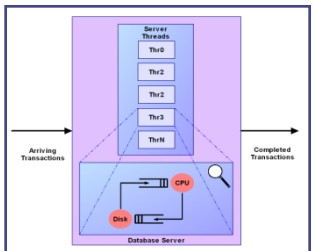
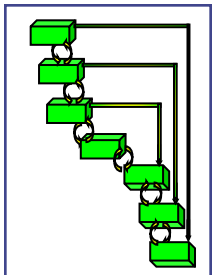
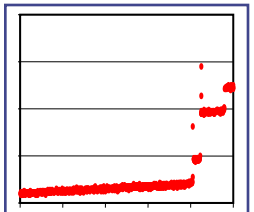
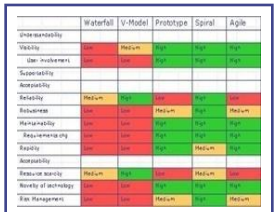
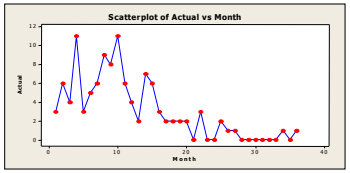
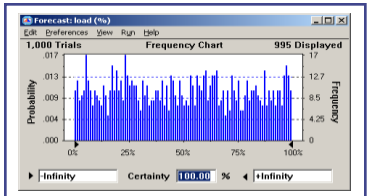
Y



Process and methods of experimenting with a model to analyse performance and behavior of inputs in a system

Optimize Phase

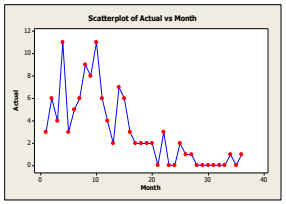
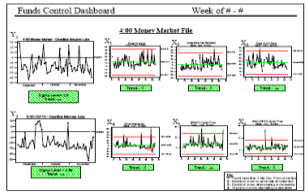
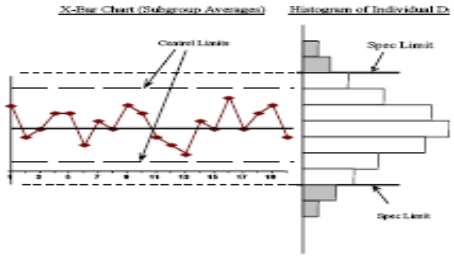
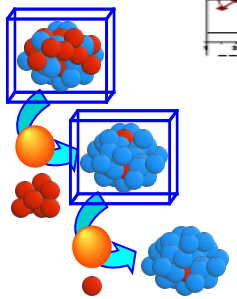
Performance

Key activities	Potential Tools and Techniques	Key Deliverables
1. Assess performance capabilities to achieve critical design parameters and meet CTQ limits 2. Optimize design to minimize sensitivity of CTQs to environment and noise factors 3. Design for robust performance and reliability 4. Error proofing 5. Establish statistical tolerancing 6. Optimize sigma and cost 7. Mitigate Risks 8. Commission and startup 9. Tollgate Review	 Software DOE  Fault Tree  Structural models  Software Process Capability  Monte Carlo Simulation  Process Model  Reliability Growth Model  Predictive Model	1. Detailed system design 2. Detailed function and capabilities mapping 3. Refined System characteristics (performance) scorecards 4. Verified System

VERIFY & Validate Phase

Performance

To Validate the system performance in full-scale or near full scale environment. To implement control and usage measurements. Develop transition plan to system owners and The objective of this phase and to package lessons learned.

Key activities	Potential Tools and Techniques	Key Deliverables
Validate System design performance Implement Ongoing and usage Measurements Develop Transition Plan Compare Estimates versus Actual Package Lessons Learned Close Project	  Reliability growth models Stress Test, scalability test   	Usage measurement Design Transitioned Validated system Score Cards System Owner Transition Plan Build & Control Documentation Lessons Learned Training Project Completion Reward & Recognition