



# 08. Quality Function Deployment

## NASA ESMD Capstone Design

developed by

**John K. Gershenson, Ph.D.**

Professor of Mechanical Engineering

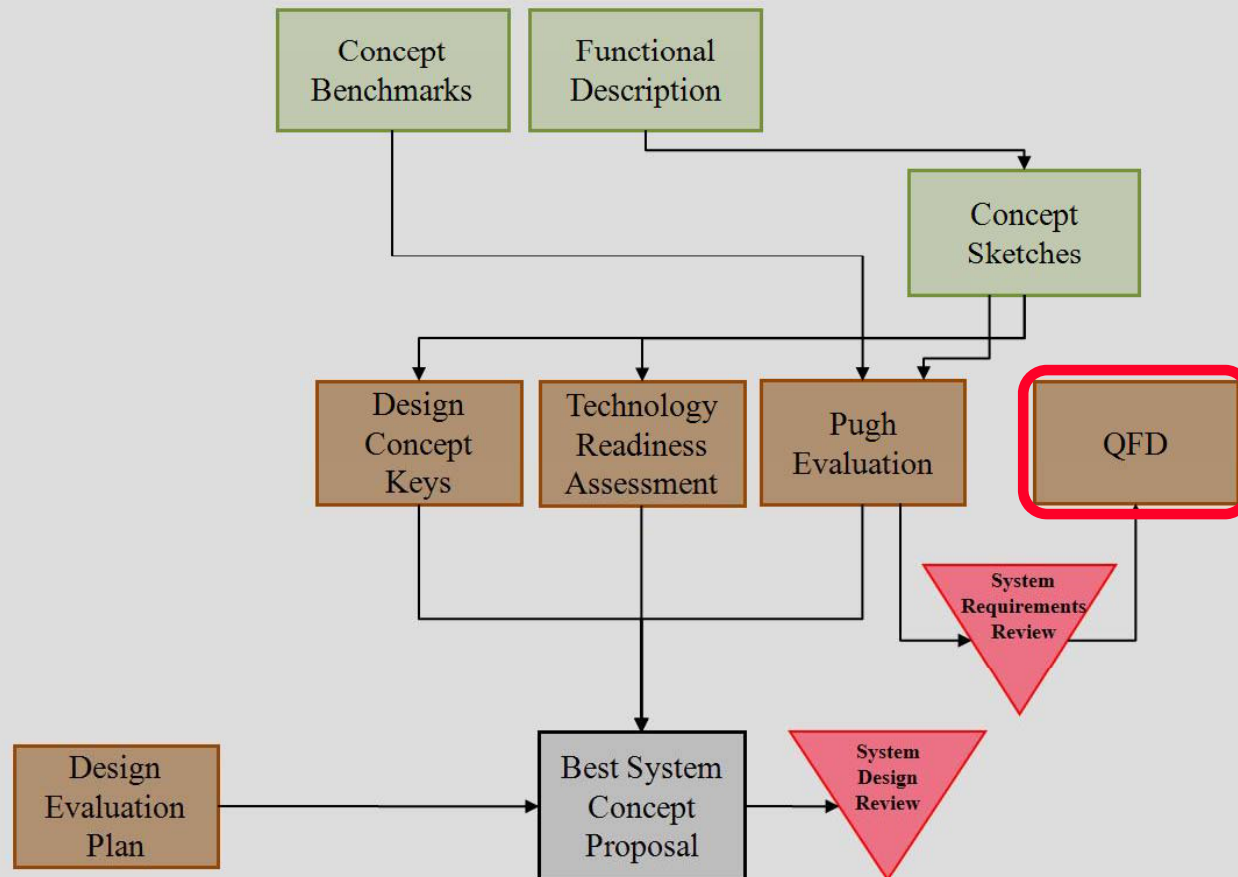
**MICHIGAN TECHNOLOGICAL UNIVERSITY**

and

Director

the**benshima**group

# Where in the Process?



## Phase A: Design Problem Analysis

# Project Tools Covered

## ◆ Quality Function Deployment

- A mechanism to ensure that the customer needs drive the entire product design and production process in the company, including market planning, product design and engineering, process development and prototype evaluation, as well as production, sales, and service.

(Lumsdaine *et al.*, 2006)

# Quality Function Deployment

- ◆ “Relating the voice of customer to design and manufacturing decisions”
- ◆ Quality
  - Satisfies the total needs of the customers
- ◆ Measure of quality
  - Difference between what the customers expect and what is provided
- ◆ Deployment of quality
  - All phases of a product’s life-cycle

# Quality Function Deployment

- ◆ Ensures(?) that the needs of the customer are understood
- ◆ Philosophy: products are customer driven, future products must offer “exciting quality,” think before you do
- ◆ Tool: House of Quality, NOT a magic box

# What Is QFD?

- ◆ Quality function deployment (QFD) is a continuous improvement tool that brings the voice of the customer into the design process
- ◆ It is a very structured team approach to quality control that offers many opportunities for creative thinking and brainstorming to achieve products that do not have any defects
- ◆ It is a comprehensive data base for continuous improvement and innovation

(Lumsdaine *et al.*, 2006)

# QFD Seeks to Answer ...

- ◆ What are the qualities the customer desires?
- ◆ What functions must the product serve, and what functions must we use to provide the product or service?
- ◆ Based on our available resources, how can we best provide what our customer wants?

(Lumsdaine *et al.*, 2006)

# History

- ◆ Early '60's (Demming) in US
- ◆ 1971: Kobe shipyards (Mitsubishi) and Japanese Society of Quality Control
- ◆ 1980's: Toyota - customer values
- ◆ Xerox 1980's and Ford 1984
- ◆ Toyota's famous rust study in 1978 was the result of QFD pointing to rust as a major competitive disadvantage for the company, with many complaints

# Benefits of QFD

- ◆ Shorter development cycles
- ◆ Trade-offs are made in design, rather than in the market
- ◆ Lower costs, increased productivity
- ◆ Documentation orientation
- ◆ Team involvement and commitment at the design stage

(Lumsdaine *et al.*, 2006)

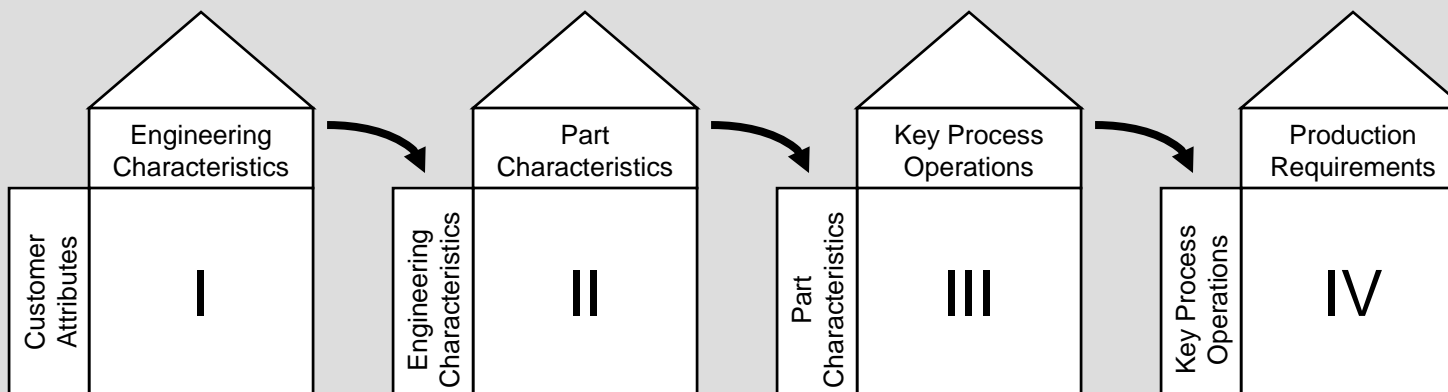
# QFD: Key Points

- ◆ Design – how do our capabilities match the customers' needs?
- ◆ Design – what trade-offs do we make in design?
- ◆ Process planning – key processes are identified in the process planning matrix
- ◆ Production planning – key process control items are identified in the production planning charts

(Lumsdaine *et al.*, 2006)

# QFD Phases

- ◆ Translate VOC through product development
- ◆ Requirements to metrics to part characteristics to process control to production planning

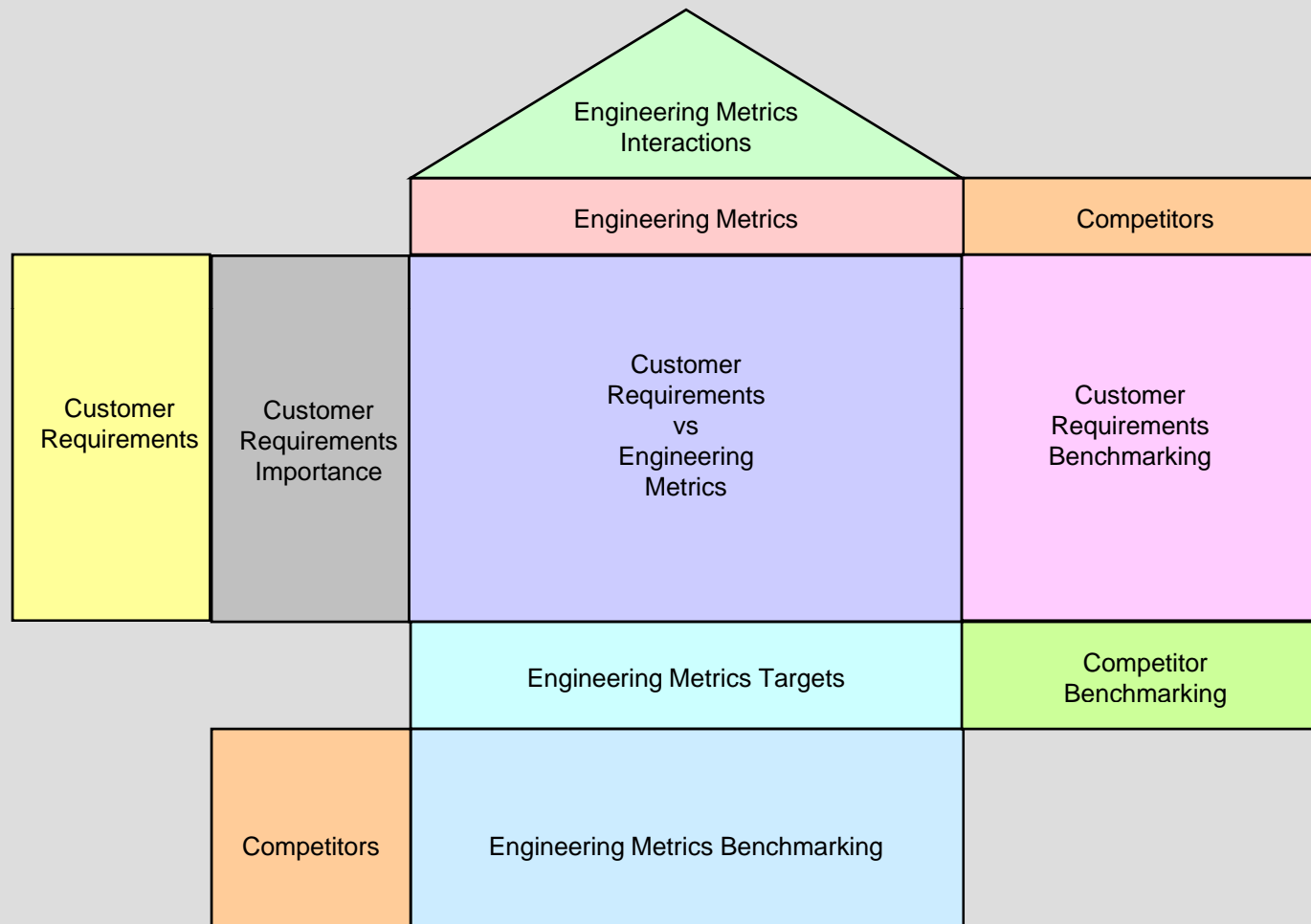


# QFD: The Visual Planning Matrix

- ◆ The House of Quality (the first of four QFD matrices) links
  - Customer Requirements
  - Design Requirements
  - Target Values
  - Competitive Performance

(Lumsdaine *et al.*, 2006)

# House of Quality



Airflow rate	0																			
Air temperature	--	0																		
Balance (torque)	+	0																		
Weight			++	0																
Size				+	+	0														
dB level	+									0										
Power consumption	+	++																		
# of switch settings																				
Direction of Improvement	nom	nom	dwn	dwn	dwn	dwn	dwn	dwn	dwn											

Customer Requirements	Customer Weights	Engineering Metrics							Customer Perception							
		Airflow rate	Air temperature	Balance (torque)	Weight	Size	dB level	Power consumption	# of switch settings	1 Worse	2	3	4	5 Better		
Dries Quickly	9	9	9											C	B	A
Operates Safely	3	1	9	3				1						A	B,C	
Comfortable to Hold	9		3	9	9	3								A	B	C
Quiet	3	3						9						A	B	C
Reliable	3	1	1					1						C	A	B
Inexpensive to operate	3							9							B	A,C
Portable	1				9	9								C	B	A
Easy to operate	1			3	3				3					C	B	A

Technical Targets		Airflow rate	Air temperature	Balance (torque)	Weight	Size	dB level	Power consumption	# of switch settings
		0.7 cu.ft./s min	180F After 2 s.	torque < 2 lb-in	< 1.5 lbs	< 8" x 6" x 4"	< 50 dB at 6"	< 1500 W	< 4

Technical Benchmarking		A	B	C	A	A	B	A	A
Better	5	A	B	C	A	A	B	A	A
	4	B	A	B	A	A	B	B	A
	3				B	B		B	C
	2	C	C	A	C	C	A	C	B
Worse	1				C			C	

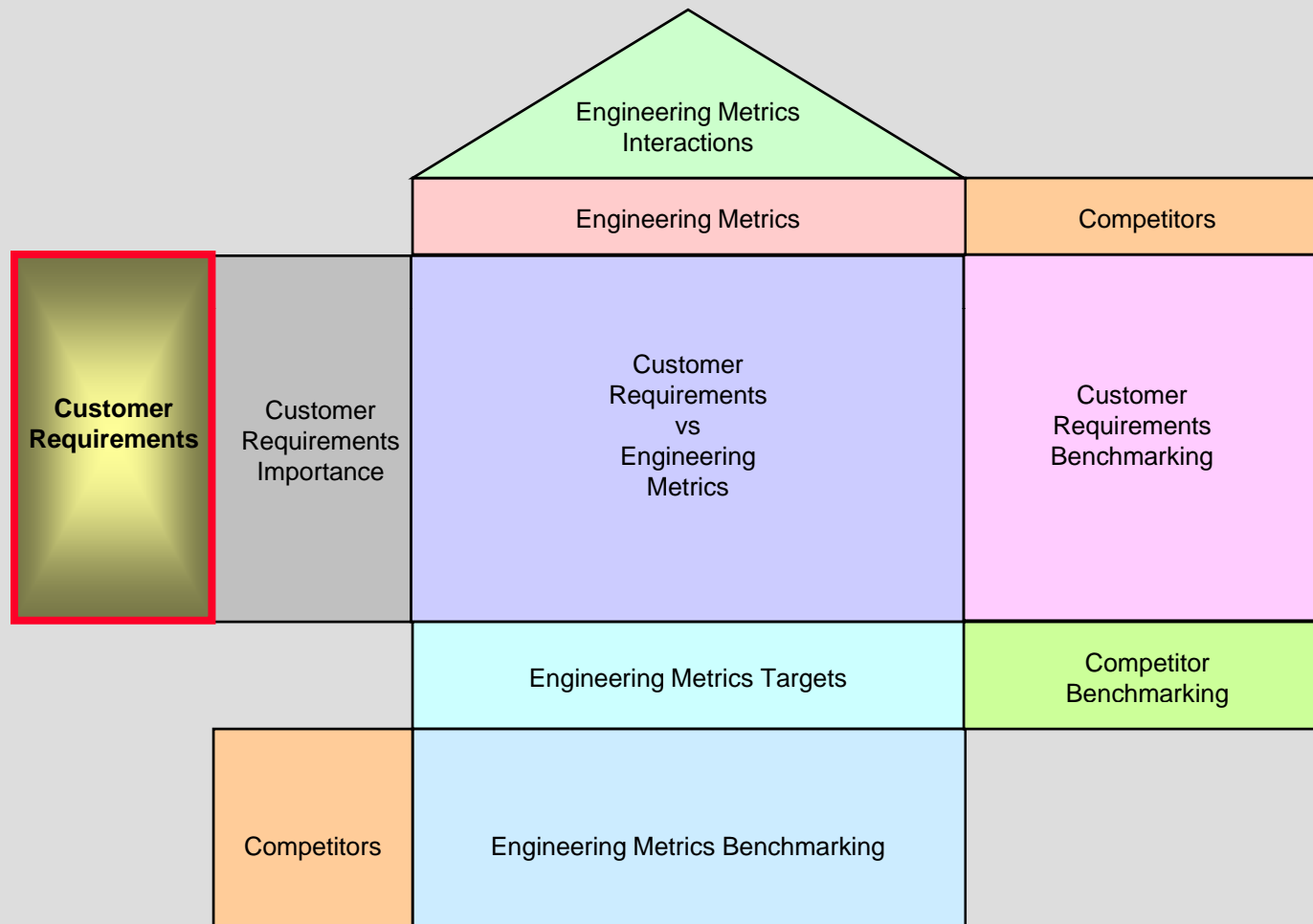
Raw score	96	138	93	93	36	33	27	3
Relative Weight	0.18	0.27	0.18	0.18	0.07	0.06	0.05	0.01

*A: KosDri Prototype  
B: HiDri 2500  
C: SuperStyle II*

# Phase I Example

# Customer Requirements

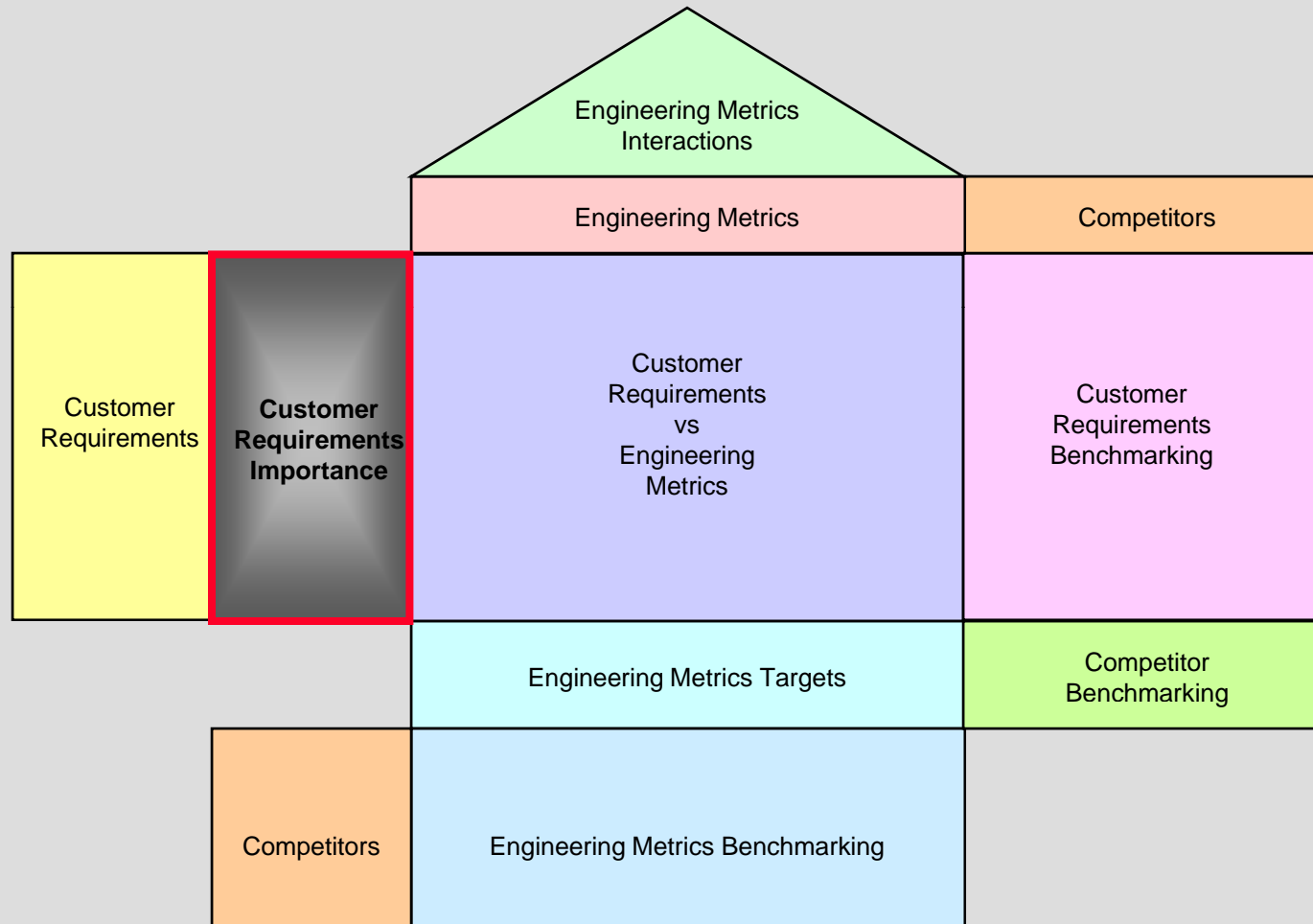


# The Customers' Voice

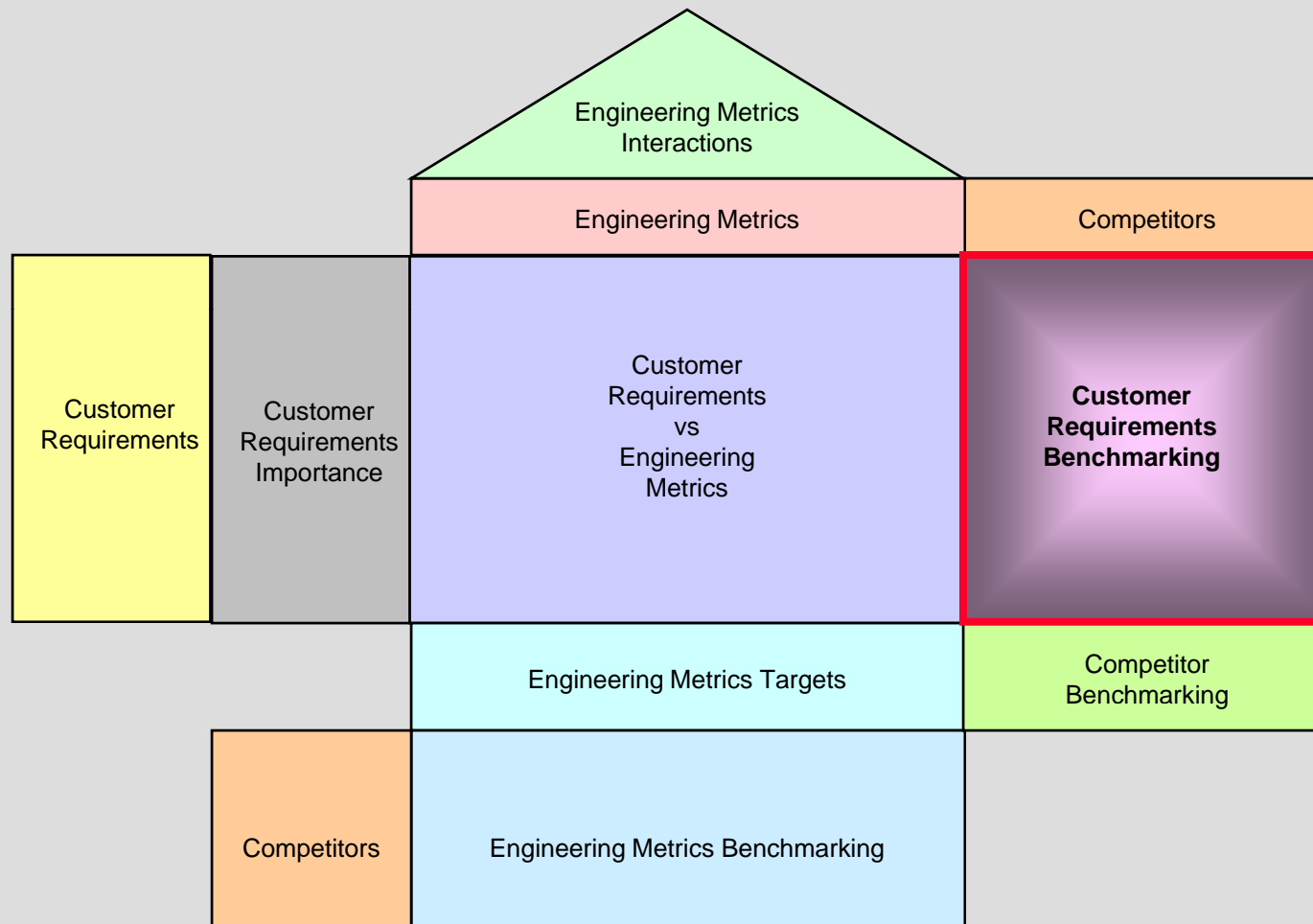
- ◆ From Weighted User Requirements
  - Solicited information
  - Unsolicited information
  - Quantitative information
  - Qualitative information
  - Structured information
  - Random information

(Lumsdaine *et al.*, 2006)

# Requirements Importance



# Requirements Benchmarking



# Requirements Benchmarking

- ◆ More *customers*, more time, more personal, more open-ended (with facilitation) leads to more knowledge
- ◆ Interviews, process participation (service, sales, design), participant observation

# QFD Tools

- ◆ Interrelationship diagram
  - Establishes relationships between and among causes
- ◆ Tree diagram
  - Classification tree of the ideas in the affinity diagram
- ◆ Matrix diagram
  - Maps the voice of the customer against the company capabilities required to meet the customer need

(Lumsdaine *et al.*, 2006)

# Relationships: Requirements versus Metrics

WHAT	HOW								
	○	●							
		○					△		
		△	○				△		
			○					●	
		○			○				
		●			○	●			
	●						△		●

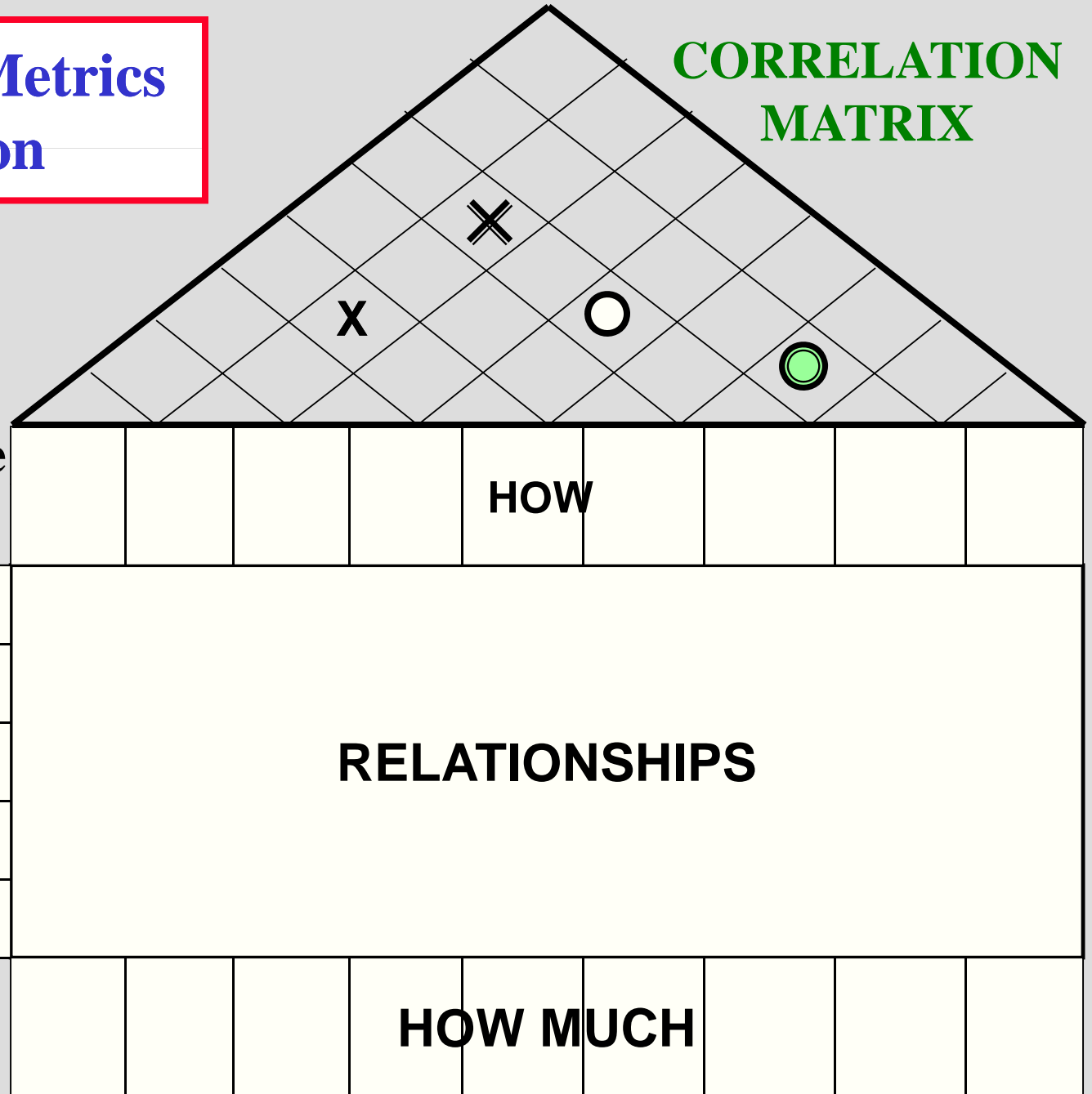
(Lumsdaine et al., 2006)

Relationships: △ Weak    ○ Medium    ● Strong

# Engineering Metrics Interaction

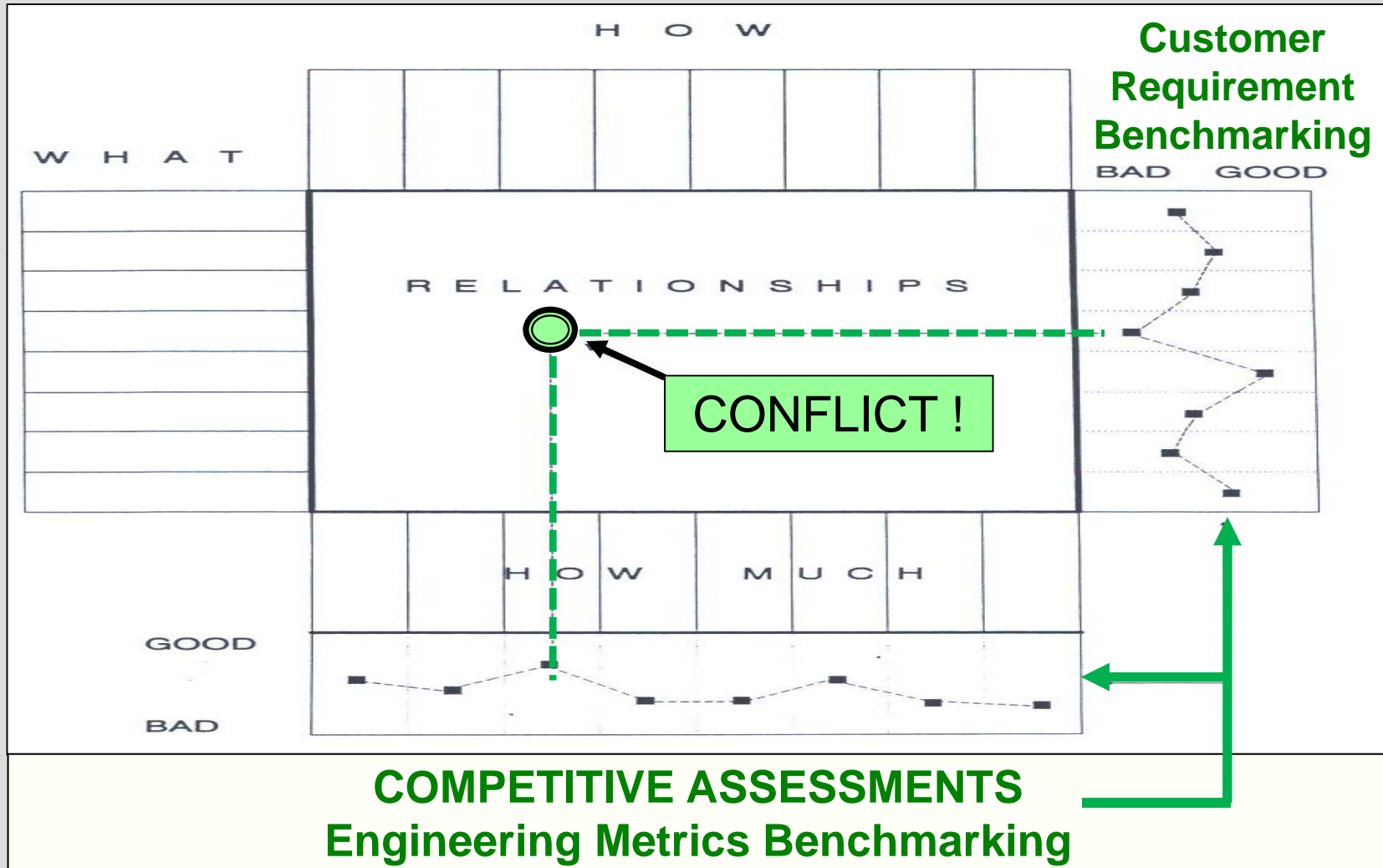
## CORRELATION MATRIX

- Strong Positive
- Positive
- ✕ Negative
- ✖ Strong Negative



(Lumsdaine *et al.*, 2006)

# Relationships: Requirements versus Metrics



# When is a Conflicting Relationship a Plus?

- ◆ When conflicting requirements for an important product feature cannot be resolved, this presents an opportunity for creative problem solving, the development of new technology, and subsequent innovation in company's effort to achieve highest quality at the lowest cost

(Lumsdaine *et al.*, 2006)



## Establish the Company Measures (HOW's)

- ◆ Customer wants must be translated into characteristics that are measurable
- ◆ These incorporate the design objectives or requirements
- ◆ This is a crucial step in QFD, deserving major study and development, so that the voice of the customer is not lost and the design requirements truly reflect the customer wants

(Lumsdaine *et al.*, 2006)

# Conduct Technical Competitive Benchmark Studies

- ◆ Comparative testing of this type is normally done by a company's laboratory
- ◆ The team should spend preparatory time with the lab personnel who will conduct the study
- ◆ They need to be familiar with the company measures the team has established
- ◆ It may not be possible to develop data for all measures

(Lumsdaine *et al.*, 2006)

# Complete Relationship Matrix of Customer Wants versus Company Measures

- ◆ This is a vital step in the QFD process
- ◆ Look for the direct relationship of how well the company measure satisfies the customer wants
- ◆ The symbols used indicate a strong, medium, or weak relationship
- ◆ Most teams find that filling the matrix in a column-wise manner works best

(Lumsdaine *et al.*, 2006)

## Establish Preliminary Targets for Company Measures

- ◆ Targets are the level of performance which the team believes is required to achieve customer satisfaction
- ◆ Traditionally, design specifications reflect the judgment of the engineer and include the capabilities of the manufacturing process

(Lumsdaine *et al.*, 2006)

# Complete the Correlation Matrix

- ◆ Orientation values indicate the direction for optimization
  - Maximize (tensile strength, reliability)
  - Minimize (wear, fade, water leak amount)
  - Target (material stretch, operating effort)

(Lumsdaine *et al.*, 2006)

# Analysis of Completed QFD Chart

- ◆ Blank rows
  - No company measures address this customer want
  - If it is important, identify design requirements
- ◆ Blank columns
  - These may be necessary for the product but do not directly relate to any customer want
  - Remove from QFD matrix but reserve for subsequent use (see Column 12)

(Lumsdaine *et al.*, 2006)

# Analysis of Completed QFD Chart

## ◆ Conflicts

- If your customer rates your product good, but your engineering competitive assessment does not have a good rating, this could mean that you do not fully understand your customer demand and competitive assessment, or you don't have a strong relationship

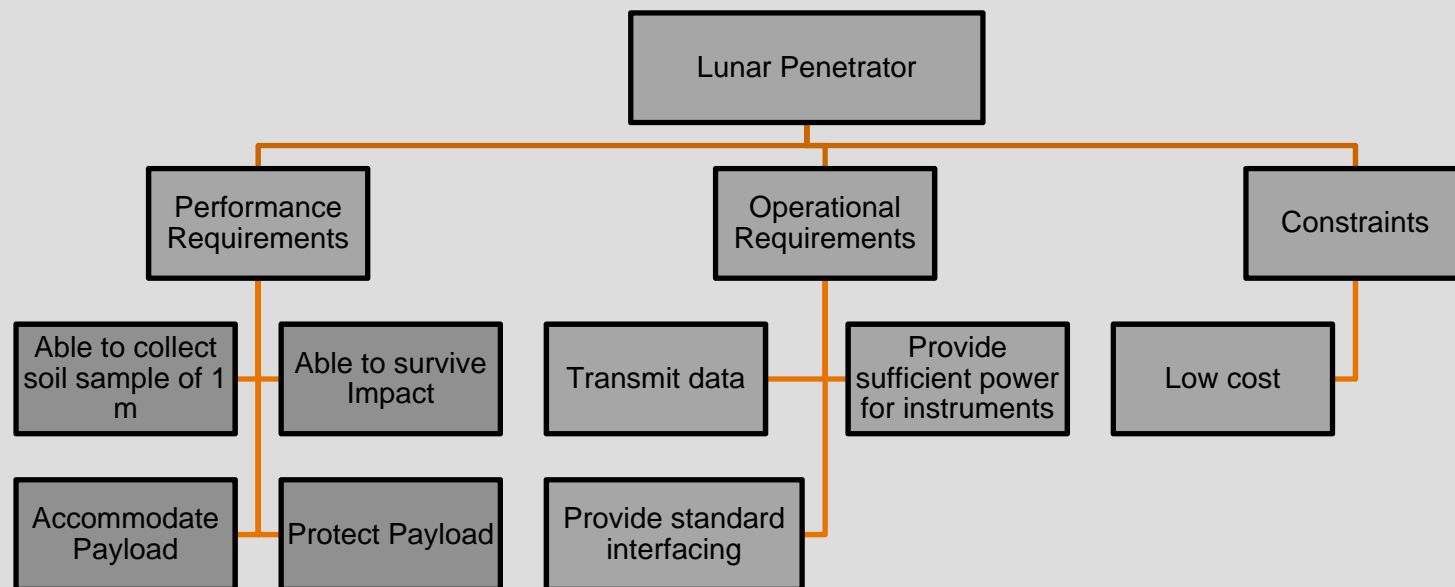
(Lumsdaine *et al.*, 2006)

# Quality Function Deployment (QFD) – Lunar Penetrator



# QFD – Tree Diagram

- ◆ Customer requirements are identified using pre-phase A documents and forming Affinity and Tree Diagrams



# QFD – Requirement Weighting

- ◆ Weights are assigned to the requirements in agreement with the views of the customers

Customer Needs	Customer Weights
Able to collect 1m of soil sample	5
Survive impact	5
Accommodate payload	4
Protect payload	5
Transmit data	5
Provide sufficient power for instruments	3
Standard interfacing with data equipment	3



# QFD – Customer Opinion Survey

- ◆ Quantify customer requirement priorities and perception of existing products and place on the right side of the house

Customer Opinion Survey					
	Poor	Acceptable		Excellent	
	1	2	3	4	5
		B	C		A
				C	A, B
		C		A	B
			B	C	A
				B	A, C
		A, C		B	
		C	A	B	

Survey Legend	
<b>A</b>	Current product
<b>B</b>	Competitor B
<b>C</b>	Competitor C



# QFD – Technical Requirements

- ◆ Voice of the company: describe product in terms of your design team using measurable characteristics

Technical Requirements							
Vibration isolation	Length of the penetrator	Shock load limit	Data transfer rate	Battery power	Number of connectors	Impact force	Angle of impact



# QFD – Interrelationship Matrix

- ◆ Describe interrelationship between customer requirements and technical characteristics using symbols

		Technical Requirements							
Customer Needs	Customer Weights	Vibration isolation	Length of the penetrator	Shock load limit	Data transfer rate	Battery power	Number of connectors	Impact force	Angle of impact
Able to collect 1m of soil sample	5	▲	●					■	
Survive impact	5	●		●				●	●
Accommodate payload	4	▲	■			▲	●		
Protect payload	5	●		▲				■	
Transmit data	5				●	■			
Provide sufficient power for instruments	3				■	●			
Standard interfacing with data equipment	3						●		

Interrelationship Matrix Symbols	
●	Strong Interrelationship - 9
■	Moderate Interrelationship - 4
▲	Weak Interrelationship - 1



# QFD - Roof

- ◆ Fill out the roof to find out where the technical requirements characterizing the product support or impede each other

Length of the penetrator									
Shock load limit									
Data transfer rate									
Battery power	-	+		+					
Number of connectors			+						
Impact force	-		-	+					
Angle of impact		+		-				-	
Vibration isolation			-		+			-	

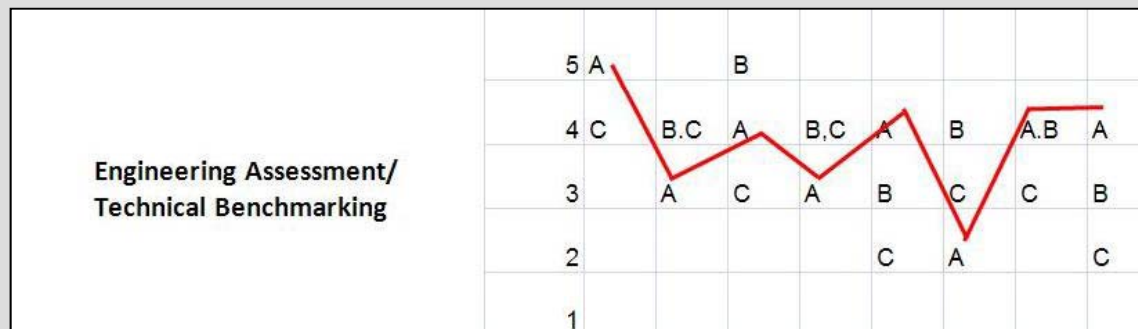
  

Technical Requirements							
Vibration isolation	Length of the penetrator	Shock load limit	Data transfer rate	Battery power	Number of connectors	Impact force	Angle of impact



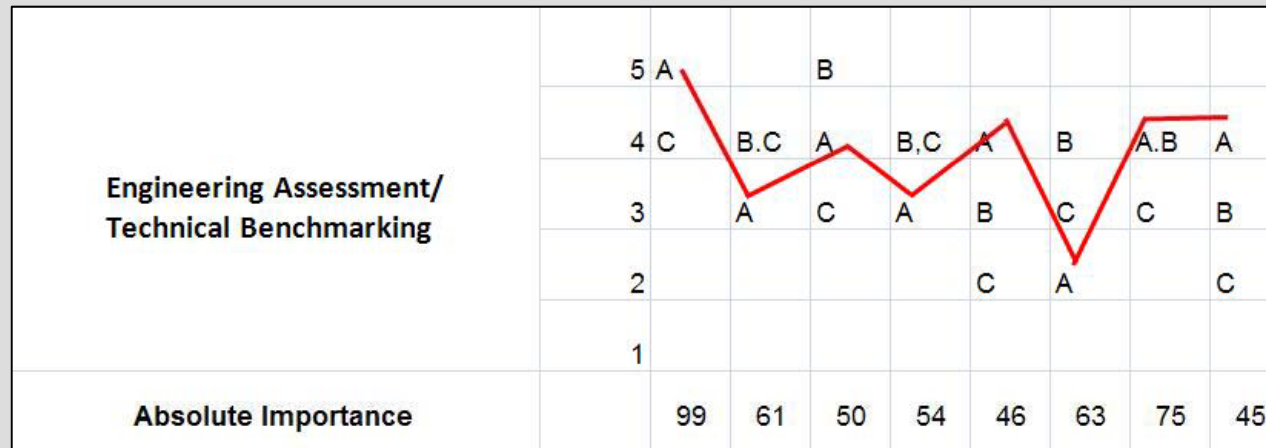
# QFD – Technical Benchmarking

- ◆ Carry out technical benchmarking to find out relative technical position of existing product and determine target level of performance to be achieved by new product



# QFD – Technical Priorities

- ◆ Fill bottom of the house by stating the technical priorities (absolute importance of each tech requirement in meeting needs)
- ◆ Multiply interrelationship points with customer weights for all technical requirements



# QFD – Engineering Target Values

- ◆ Set engineering target values to be met by new design

Technical Requirement Units	Lbs, deflection	Metres	Newtons	Bits/sec	Ampere-hrs(A-h)	Qty	G's	Degrees
Technical Requiriement Targets	<6"	1.7	350	9600	100	5	8000	90



# QFD- Lunar Penetrator

Quality Function Deployment (QFD)- Lunar Penetrator									
Length of the penetrator									
Shock load limit									
Data transfer rate									
Battery power	-	+		+					
Number of connectors				+					
Impact force	-		-	+					
Angle of impact		+		-				-	
Vibration isolation			-		+			-	

Technical Requirements										Customer Opinion Survey				
Customer Needs	Customer Weights	Vibration isolation	Length of the penetrator	Shock load limit	Data transfer rate	Battery power	Number of connectors	Impact force	Angle of impact	1 Poor	2	3 Acceptable	4	5 Excellent
Able to collect 1m of soil sample	5	▲	●					■			B	C		A
Survive impact	5	●		●				●	●				C	A, B
Accommodate payload	4	▲	■			▲	●				C		A	B
Protect payload	5	●		▲				■				B	C	A
Transmit data	5				●	■							B	A, C
Provide sufficient power for instruments	3				■	●						A, C		B
Standard interfacing with data equipment	3						●				C	A		B

Technical Requirement Units	Lbs. deflection	Metres	Newtons	Bits/sec	Ampere-hrs(A-h)	Qty	G's	Degrees
Technical Requirement Targets	<6"	1.7	350	9600	100	5	8000	90

Engineering Assessment/ Technical Benchmarking	5	4	3	2	1
A					
B					
C					
A, B, C					
A, B, C					
A, B, C					
A, B, C					
A, B, C					
A, B, C					
A, B, C					

Absolute Importance	99	61	50	54	46	63	75	45
---------------------	----	----	----	----	----	----	----	----

Interrelationship Matrix Symbols	
●	Strong Interrelationship - 9
■	Moderate Interrelationship - 4
▲	Weak Interrelationship - 1





# 08. Quality Function Deployment

## NASA ESMD Capstone Design

developed by

**John K. Gershenson, Ph.D.**

Professor of Mechanical Engineering

**MICHIGAN TECHNOLOGICAL UNIVERSITY**

and

Director

the**benshima**group

