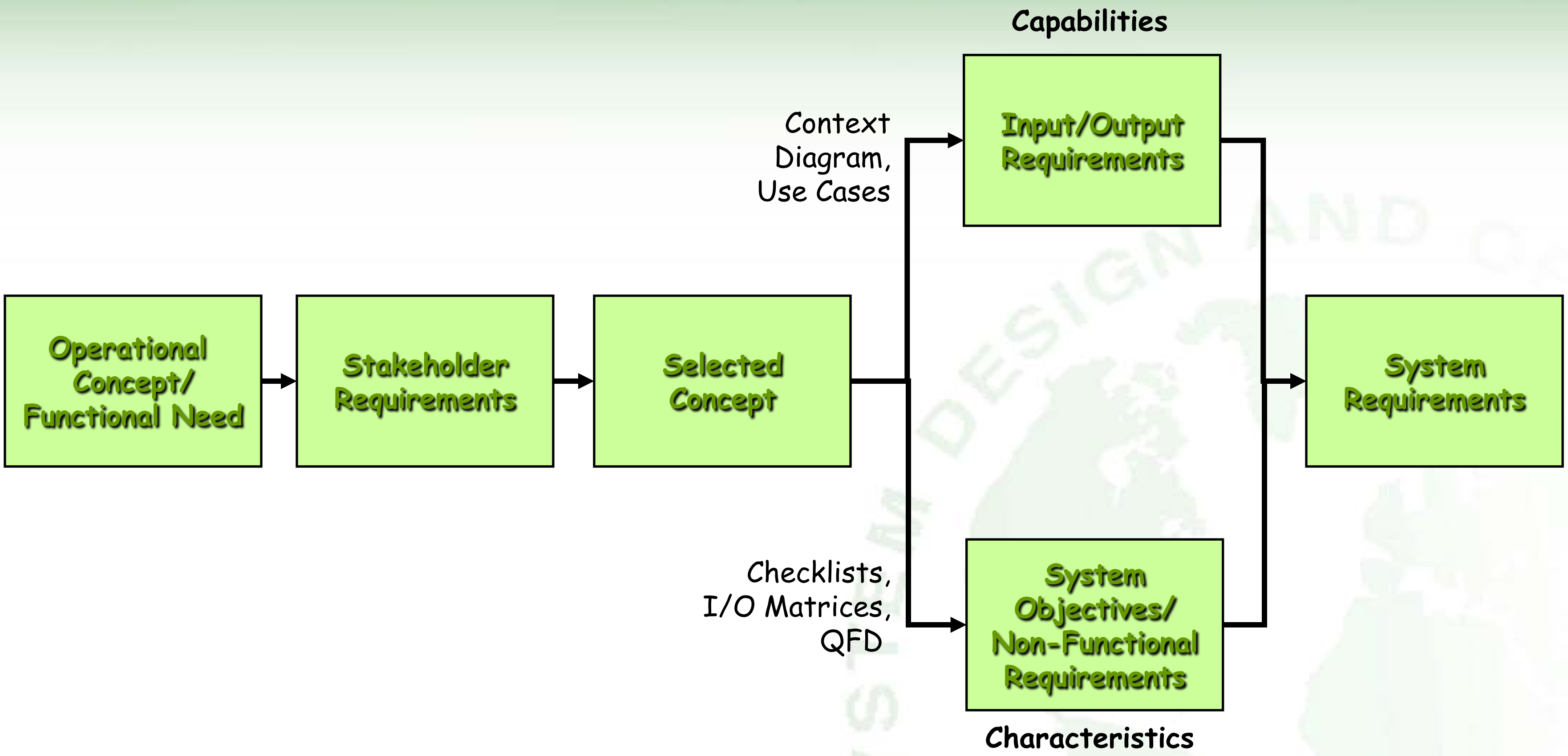
Turning Fuzzy Expectations Into Engineering Reality: Quality Function Deployment

Module 6

Requirements development: Stakeholder expectations synthesis

- Two categories of Stakeholder Expectations
  - **Capabilities**: These are expectations that reflect functions or system behavior desired by the stakeholders
    - For an Automatic Teller Machine: Ability to withdraw and deposit money 24 hours a day; Check account balances; Transfer funds between accounts, etc.
  - **Characteristics**: These are requirements that reflect system attributes or properties
    - For an Automatic Teller Machine: Quality, reliability, safety, security, cost, aesthetics, performance, accuracy, compliance with standards and protocols, etc.

Requirements development follows a two-pronged approach for completeness



Requirements development: Stakeholder expectations synthesis

Examples of "Capability" Expectations

- The F-35 Joint Strike Fighter must be highly survivable against current air-to-air threats
- The Airborne Laser must be highly lethal against current tactical ballistic missiles in the boost phase
- The FalconSat 5 spacecraft must have a useful life of X years

How do we turn these fuzzy expectations into "Concrete" Design Requirements?

Another Example: *"Cell Phone Must Feel Good in the Hand"*

- **Nokia engineers were challenged by a requirement for a new mobile phone. Customers had told them the phone had to *"feel good in the hand."***

- **They brainstormed a number of design parameters that might lead to a phone that satisfied the requirement:**
  - ***"Length, width, depth, weight, center of gravity, curvature, surface roughness, thermal conductivity, …"***

- **They recognized that considerable effort would be required to determine the correlations and establish the objectives.**
  - ***Prototyping, benchmarking, etc.***

Number of tools are useful in defining system objectives and non-functional requirements

Methods and Tools for developing design requirements from Characteristic expectations:

- **Checklists and Hierarchies (For Legacy Systems. I.e. cars)**
- **Input-Output Matrices**
- **Quality Function Deployment**
- **A Host of Other Elemental Activities Pertaining to Customer Surveys, Benchmarking, Competition Analysis, etc.**

Quality Function Deployment (QFD) is useful in developing non-functional requirements

Quality Function Deployment is a Design Practice Used to Facilitate Translation of Stakeholder **Characteristics** into System **Objectives and Specifications** at Each Stage of the System Design and Development Process

Objective of the QFD Method:

Make the "Voice of the Customer" an Integral Part of the Research, Design, and Development Activities. This is Accomplished Through the Development of Multiple and Linked QFD Matrices

Quality Function Deployment (QFD) History

- Developed in 1966 by Dr. Yoji Akao, to combine the concepts of Quality Assurance with Function Deployment

He called it a “method to transform user demands into design quality, to deploy the functions forming quality, and to deploy methods for achieving the design quality into subsystems and component parts, and ultimately to specific elements of the manufacturing process.”

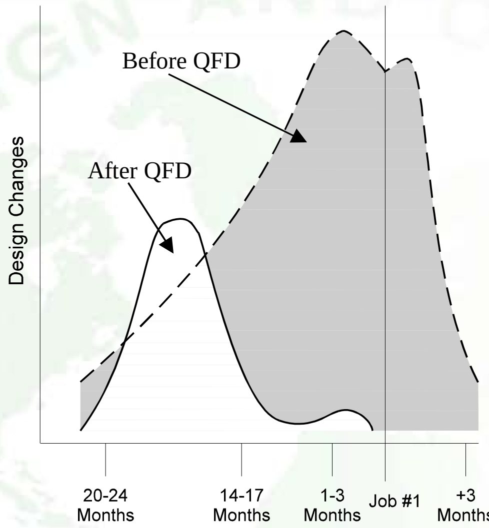
- “House of Quality” first used on a Mitsubishi heavy oil tanker in 1972

- QFD used in projects such as the F-35 Joint Strike Fighter

Ref: Wikipedia

QFD has been shown to significantly enhance the system design process

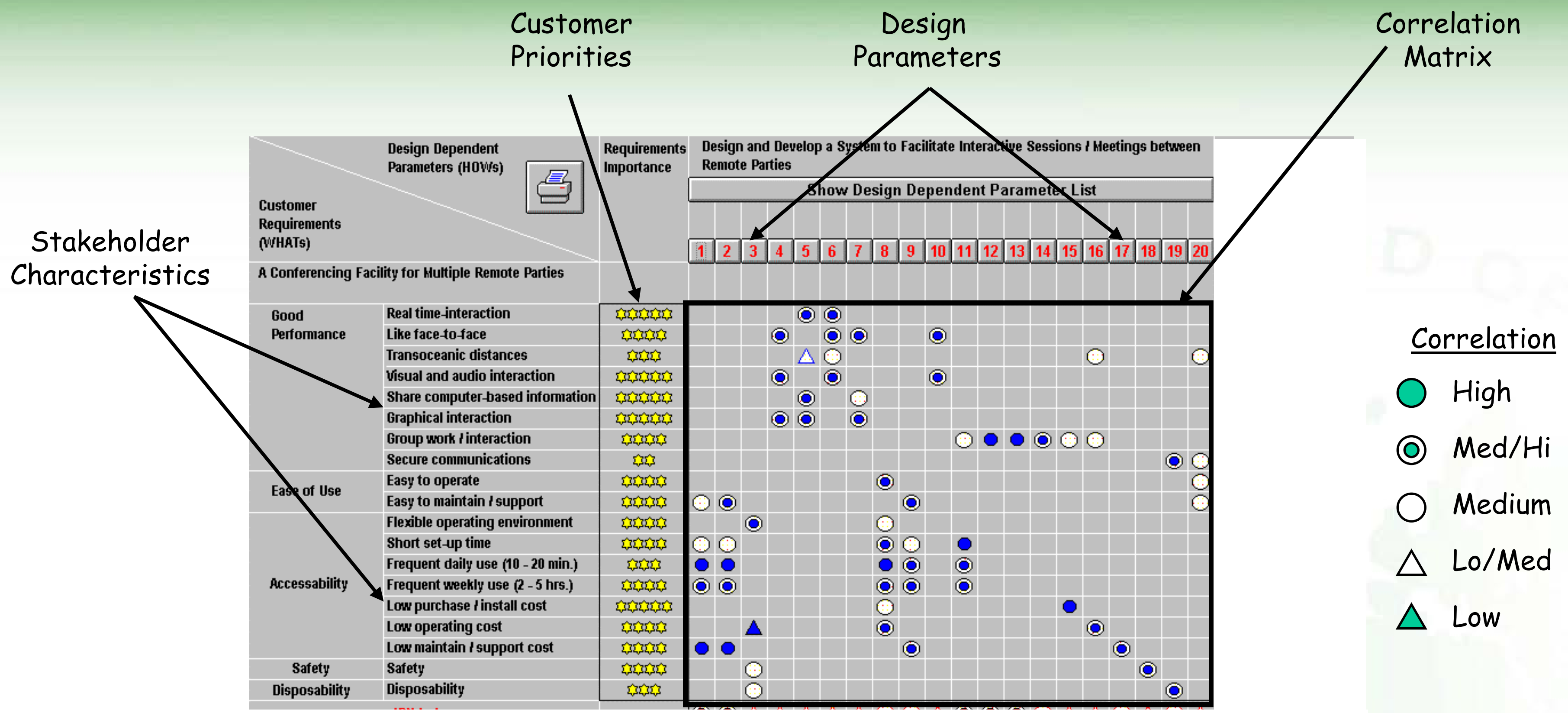
- From Industry Week (Nov. 1, 1993; v242, n21)
  - According to a survey included in this publication, organizations applying Quality Function Deployment (QFD) for the identification and analysis of product requirements realized
    - 30% to 50% reduction in engineering charges;
    - 30% to 50% reduction in design cycle time;
    - 20% to 60% reduction in start-up costs; and
    - 30% to 50% reduction in time to market.
  - Du Pont's Beech Street Engineering Center Group, Wilmington, DE. Reports a 75% reduction in product design cycle time after making QFD an integral part of a newly revamped design structure.
  - Ford Motor company adopted it in 1984, and by 1988 it was being implemented on 50 different applications



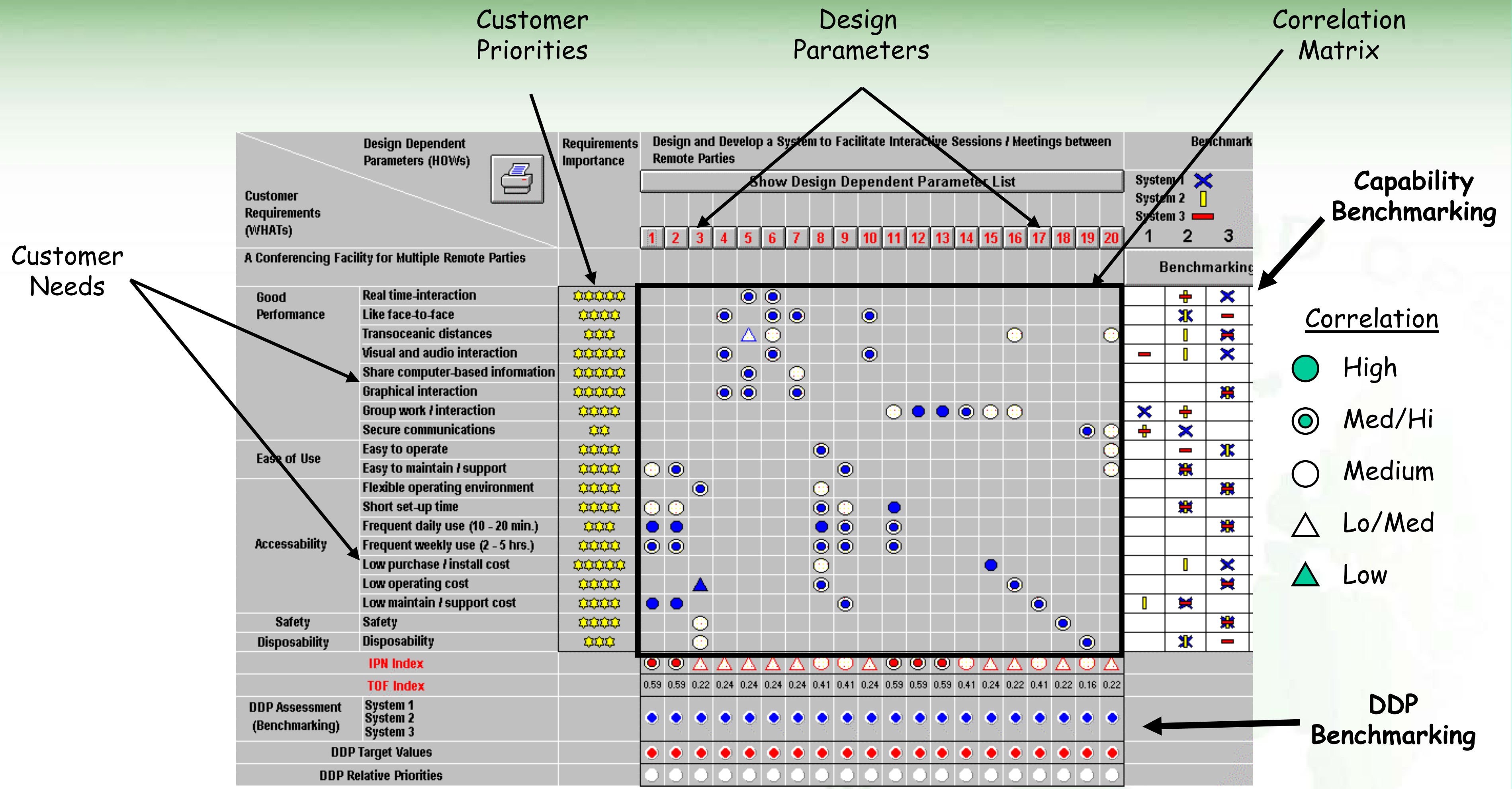
Design Changes Before and After Implementing QFD (Reported by Toyota)

Leverage QFD, in conjunction with own Heuristics...

Sample Quality Function Deployment (QFD) Matrix



Sample Quality Function Deployment (QFD) Matrix

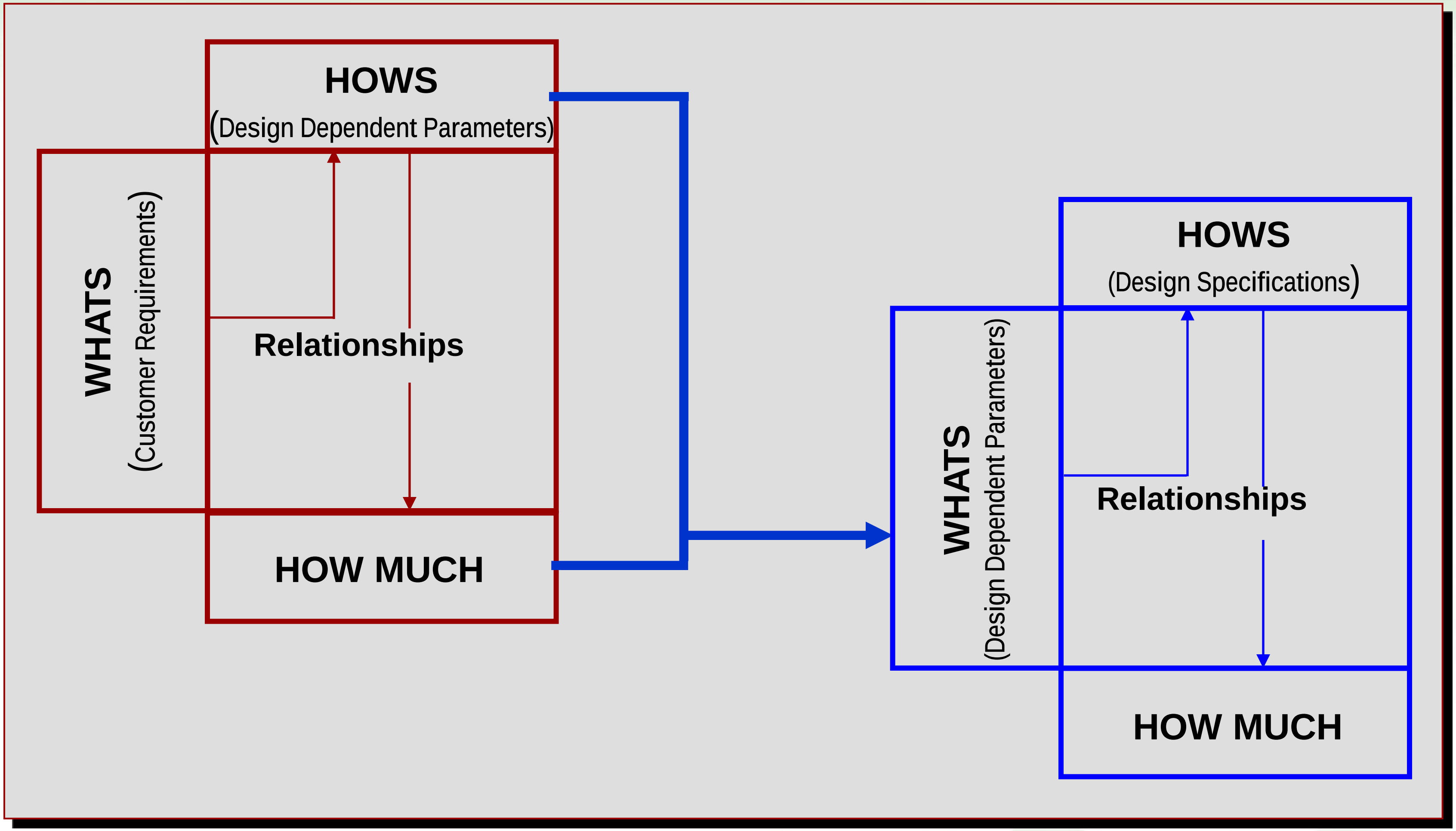


Quality Function Deployment (QFD):
Multiple "Houses of Quality"

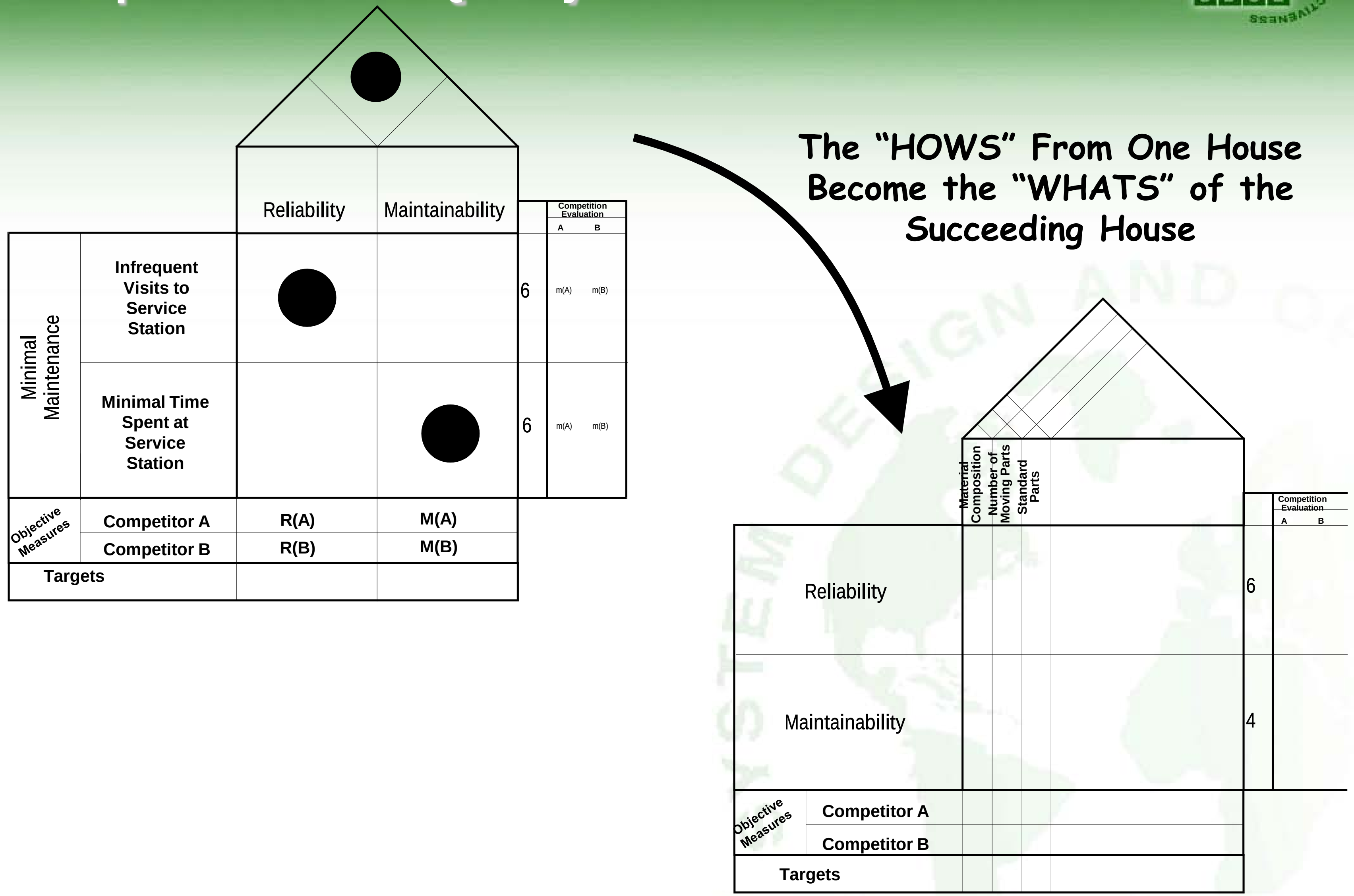
- Multiple, Linked "Houses of Quality" Are Often Developed in Order to:
  - Ensure the "Voice of the Customer" Plays a Consistent Role throughout the Design and Development Process
  - Maintain Traceability With Customer Needs and Requirements

- The "HOWS" in One QFD Matrix Become the "WHATS" in the Subsequent Matrix

Quality Function Deployment (QFD):
Example of multiple "Houses of Quality"



Quality Function Deployment (QFD):
Multiple "Houses of Quality"



Special Exercise

High-G Entertainment System for Uncle Cliff's!

The Design Concept: A Roller-Coaster

Stakeholder Expectations:

1. Be safe
2. Be fun to ride
3. Provide vertical acceleration
4. Provide horizontal acceleration
5. Have a loop-the-loop
6. Allow quick loading/unloading of cars
7. Initial Cost < $2M
8. Operations costs < $200K / yr
9. Have accommodation for up to 40 passengers at a time
10. Fit within a 100 m x 75 m area

Your Challenge

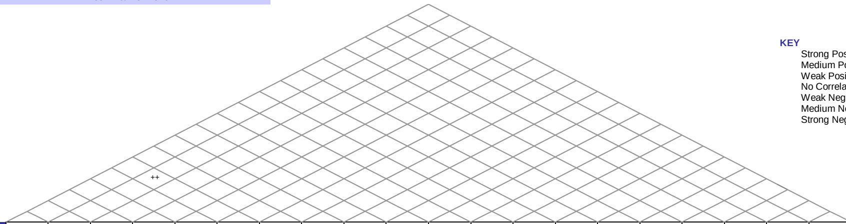
Using QFD, Determine a set of Design Objectives for Stakeholder Expectations 1, 2 and 7

1. **Be safe**
2. **Be fun to ride**
7. **Initial cost < $2M**

Project Name: Enter Name Here

First House

Interactions



KEY

Strong Positive Correlation	+++
Medium Positive Correlation	++
Weak Positive Correlation	+
No Correlation	
Weak Negative Correlation	-
Medium Negative Correlation	- -
Strong Negative Correlation	- - -

Roller Coaster for Uncle Cliff's

HOWs - System Objectives

Customer and Competitive Evaluation

ale: 1 Bad; 5 Go

WHATs - Stakeholder Characteristics		Importance: 5 High	Big Bad Wolf	Mind Eraser			
	Be Safe	5	4	4			
	Be Fun To Ride	4	3	4			
	Initial Cost < $2M	3	2	3			

Feature Raw Score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feature Rank	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Deployment Priorities

Key

Strong Positive Correlation	+++
Medium Positive Correlation	++
Weak Positive Correlation	+
No correlation	
Strong Negative Correlation	-
Medium Negative Correlation	- -
Weak Negative Correlation	- - -

Project Name: Enter Name Here

Second House

KEY

Key	
Strong Positive Correlation	+++
Medium Positive Correlation	++
Weak Positive Correlation	+
No Correlation	
Weak Negative Correlation	-
Medium Negative Correlation	- -
Strong Negative Correlation	- - -

Interactions

HOWs - Component Specifications

Customer and Competitive Evaluation

WHATs - System Objectives																					Priority from First House	Importance: 5 High, 1 Low	Scale: 1 Bad, 5 Good				
Provide Accommodation																					1	1					
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Feature Raw Score	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Feature Rank	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Deployment Priorities

Key

1	Strong Positive Correlation	+++
2	Medium Positive Correlation	++
3	Weak Positive Correlation	+
4	No correlation	
5	Strong Negative Correlation	-
6	Medium Negative Correlation	- -
7	Weak Negative Correlation	- - -

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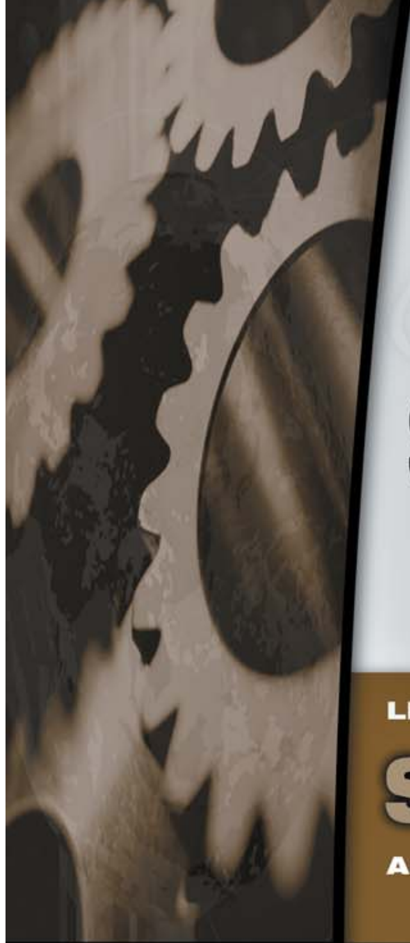
The Fellows serve in an advisory capacity with regard to curriculum development, program design, doctoral committees, research and project ideas, and program assessment.



GRADUATE CERTIFICATE IN

SSE SPACE SYSTEMS ENGINEERING

LEADING TO A MASTER'S DEGREE IN

SYSTEMS ENGINEERING

An offering of the School of Systems and Enterprises at Stevens Institute of Technology

In today's space-related enterprises, change is the only constant. From market and technological changes to policy and budgetary uncertainty, the space industry has been faced with increasing challenges that transcend technical boundaries. To fully utilize existing opportunities and explore new ones within a modern space-centric enterprise, it is crucial to have both the technical knowledge necessary to design cutting edge space missions and associated products, as well as, the systems knowledge that is required to operate in an increasingly complex business and policy environment.

The Stevens Graduate Certificate in Space Systems Engineering, and the Master's Degree in Systems Engineering allow professionals working in government and private space-related enterprises to combine a robust technical education in space systems design and development, key space system engineering processes and tools, with a holistic understanding of systems engineering principles. This combination provides them with a unique advantage that is hard to come by anywhere else.

Partnering with TSTI, the leading educational institute for technical mission analysis and design, the Stevens Institute of Technology's School of Systems and Enterprises has created a unique program geared towards professionals currently working in the space industry or those interested in careers in space systems. This unique program by one of the foremost technological institutes in the United States will provide experienced professionals with the edge needed to excel in this increasingly complex and competitive industry.

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Institute of Technology

COURSES

GRADUATE CERTIFICATE IN SPACE SYSTEMS ENGINEERING

SYS/SDOE 632

Designing Space Missions and Systems

This course examines real-world space missions and systems design. Taking a process-oriented approach, the course starts with basic mission objectives and examines the principles and practical methods for mission design and operations in depth. Interactive discussions focus on key system engineering issues like initial requirements definition, operations concept development, architecture trade-offs, payload design, bus sizing, subsystem definition, system manufacturing, verification and operations. This course provides the end-to-end technical space system engineering information necessary to manage the technical baseline of a project. Over 800 equations, rules of thumb and security checks are provided.

SYS/SDOE 633

Mission and System Design Verification and Validation (V&V)

This course provide hands-on opportunities to apply key principles of space systems engineering. In this course, participants are given a set of customer expectations in the form of broad mission objectives. Using state-of-the-industry mission design and analysis tools, participants apply systems engineering processes to define top-level system requirements, design key elements and conclude with a system design review. Then, participants experience system realization processes first-hand by integrating, verifying, validating and delivering the shoe box-sized satellite. From the part-level to the system-level, participants implement a rigorous assembly, integration, verification and validation plan on space hardware/software applying "test like you fly, fly like you test" principles.

SYS/SDOE 625

Fundamentals of Systems Engineering

This module presents the fundamental principles and processes for designing effective systems, including how to determine customer needs, how to distinguish between needs and solutions, and how to translate customer requirements into design specifications. The focus is on designing systems that not only provide the required capabilities, but that are reliable, supportable and maintainable throughout their life-cycle. The course concludes with a Systems Requirements Review (SRR) in which students present their class projects.

SYS/SDOE 650

System Architecture and Design

This module presents the fundamentals of system architecting, including practical heuristics for developing good architectures. It extends the systems engineering process introduced in SYS/SDOE 625 through functional analysis, decomposition and requirements flow-down. The implications of open systems architectures and the use of commercial technologies and standards (COTS) are explicitly addressed, as are the linkages between the early architectural decisions, driven by customer requirements and the concept of operations, and system operational and support costs.
Prerequisite:
SYS/SDOE 625.

This certificate in Space Systems Engineering integrates crucial activities spanning the entire life cycle. Information and capabilities are learned by participants in hands-on space system and mission design assignments focusing on: operations concept development, space system architecture, verification and validation, as well as key system engineering processes and tools. These four courses provide the backbone for the development of solid space system engineers.

Intended Audience

This Graduate Certificate in Space Systems is relevant for professionals with other advanced degrees who wish to complement their existing knowledge and skills base to include state of the art spacecraft systems and mission analysis design combined with a holistic systems engineering and architecture perspective. This flexible Graduate Certificate is offered in short, focused sessions that minimize interference with work-related responsibilities. The capabilities learned can be applied to a Master's in Space System Engineering.

Please visit our website at: **www.stevens.edu/SPACE**

MASTER'S PROGRAM

MASTER'S DEGREE IN SYSTEMS ENGINEERING

The Graduate Certificate in Space Systems Engineering can be used as a stepping stone towards a Master's Degree in Systems Engineering. The Master's Degree in Systems Engineering requires 10 courses (equivalent to 30 credits). At least 3 credits, and up to 6 credits, must be applied towards a project or a thesis.

Required Courses

Required courses for the Space Systems Engineering Graduate Certificate (4 courses, 12 credits)

SYS/SDOE 632: Designing Space Missions and Systems
SYS/SDOE 633: Mission and System Design Verification and Validation
SYS/SDOE 625: Fundamentals of Systems Engineering
SYS/SDOE 650: System Architecture and Design

Required Courses to complete core course requirements for a Master's Degree in Systems Engineering.

The above 4-course sequence satisfies the core course requirements for a Master's Degree in Systems Engineering. In addition, candidates must take EM/SDOE 612 - Project Management of Complex Systems, SYS/SDOE 605 - Systems Integration, plus one course from the Space Concentration Electives, and one course from the Systems Concentration Electives. Students must also take either SYS 800 - Special Topics in Systems Engineering and one faculty advisor approved elective, or SYS 900 - Thesis in Systems Engineering.

Elective Courses

Students must take one course from each of the Concentrations listed below.

Space Concentration Electives

SYS/SDOE 635: Human Spaceflight
SYS/SDOE 636: Space Launch and Transportation Systems
SYS/SDOE 637: Cost-Effective Space Mission Operations
SYS/SDOE 638: Crew Exploration and Vehicle Design Exercise

Systems Concentration Electives

SYS/SDOE 611: Modeling and Simulation
SYS/SDOE 645: Design for System Reliability, Maintainability, & Supportability
SYS/SDOE 660: Decision and Risk Analysis

The electives listed here are for illustrative purposes only. Additional electives from other engineering disciplines and management are also available to students. Please see the Program website for a listing at www.stevens.edu/xxx. Selection of electives must be approved and coordinated with the faculty advisor.

Project or Thesis Courses

Students have an option of working on a project (3 credit hours) or a thesis (6 credit hours) to complete the requirements for a Master's Degree in Systems Engineering. Project or Thesis work must be coordinated with a faculty advisor.

SYS 800: Special Topics in Systems Engineering (3 credit hours for a Project), OR
SYS 900: Thesis in Systems Engineering (6 credit hours for a Thesis)

All courses in this Program are taught in a modular format and many are also taught in an online format.

Modular Format

Pre-Module Readings: Candidates will receive module related readings in advance as preparation for the module week.

Module Week: Intense week-long lectures and group exercises

Module Homework Assignment and Project (10 Weeks): Candidates have 10 weeks to complete the Module Homework Assignment and Project. Faculty support is provided during these 10 weeks.

Online Format

Online courses are run in an asynchronous format. Candidates are often required to collaborate with each other and complete weekly assignments. Online courses run on a traditional semester schedule spread over 15 weeks.