ME4182: Capstone Design

Roger J. Jiao

Customer Needs and Requirement Analysis

- Product Development Process
- Customer Needs Identification
  - Product Definition
  - Requirement Analysis

Why today's topic on Requirement Analysis?

23:17:02

GEORGIA INSTITUTE OF TECHNOLOGY
George W. Woodruff School of Mechanical Engineering
ME 2110 - Creative Decisions and Design, Spring 2020

Final Design Project: Toy Story

A. Overview and Theme

The goal of this project is to use a structured design process to design, construct, build and test an autonomous system that will compete as a head-to-head competition. The theme of this competition is Toy Story. You and your team must rescue Woody and Buzz from the destructive Sid and return them to Andy before they get lost during the big move! In this competition, your team must rescue Buzz from the Aliens, help Buzz shoot the rocket to infinity and beyond, return RC cars to the Moving Truck, and return the toy to Andy's mansion. These tasks are described as the following text and pertain to the competition track depicted as Figure 1.

Figure 1. The competition arena

B. Primary Competition Parameters

Figure 2. The arena centerpiece (left) and competition item layout (right).

C. Competition Tasks and Competition Points

Rev. 2 (14 February 2020

Table 1. Scoring Detail

Task	Task	Competition Point Value
1	Launch	10 (successful deployment)
2	Rescue Buzz with the Claw	30 points for Buzz on fully/partially on team's starting zone 21 points for Buzz fully outside zone 2 9 points for Buzz partially outside zone 2 9 points for each Aliens fully inside zone 1 6 points for each Aliens partially inside zone 1 3 points for each Aliens fully outside of zone 2
3	Launch Rocket To Infinity and Beyond	21 points for rocket clearing 42 inches above competition floor + 31 points for highest rocket as round* + 11 points for second-highest rocket as round*
4	Return RC Cars to the Moving Truck	17 points per RC in team's marked quadrant
5	Return the Toy to Andy's Mansion	41 points for the toy in Andy's Mansion
6	Egress	2x points T4-T5 score for partial egress (from centre or start) 3x points T4-T5 for full egress (from centre and start)

* All rockets reaching 100 inches will receive 21+31 = 52 points.

Table 2. All Systems and Subsystems Competitions

Competition (type)	Week	Date	% of Final Grade
Competition 1 (robot)	8	February 25 - 28	5%
Competition 2 (robot)	10	March 10 - 13	5%
Qualifying (robot)	13	March 24 - 27	5%
Final (class-wide)	15	April 7	5%

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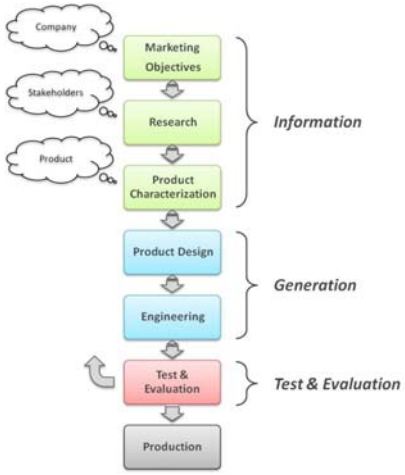
Product Development Process



General Product Development Process

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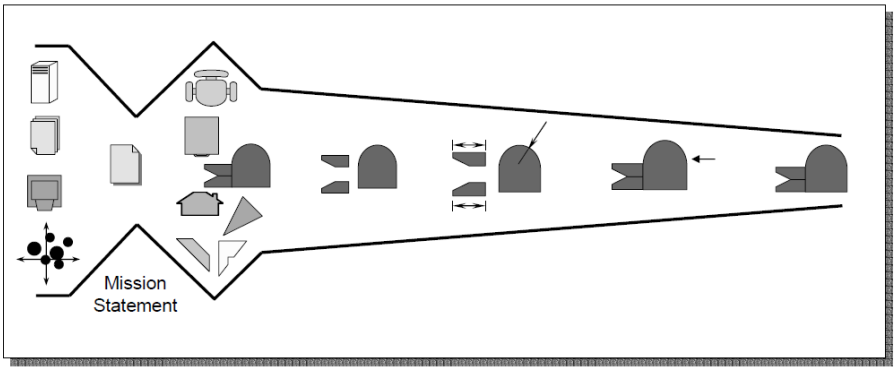

Product Planning	Concept Development	System-level Design	Detail Design	Testing and Refinement	Production Ramp-Up
Phase 0	**Phase 1**	**Phase 2**	**Phase 3**	**Phase 4**	**Phase 5**

(aka. Embodiment Design)

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Phase 0: Product Planning

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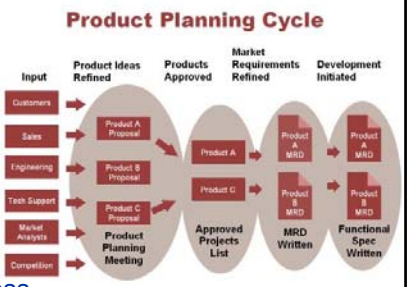
- To develop a product plan and project mission statements, a 5-step process can be used:
  - Identify opportunities.
  - Evaluate and prioritize projects.
  - Allocate resources and plan timing.
  - Complete pre-project planning.
  - Reflect on the results and the process



MRD - Market Requirements Document

- Though the process is presented as linear, the activities of evaluating projects and allocating resources can be iterative and even dynamic.

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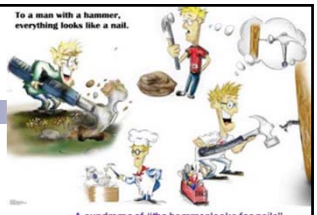
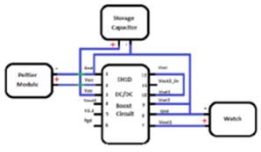
Identify opportunities!!



A syndrome of "the hammer looks for nails"

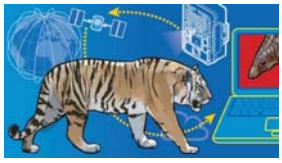
- One example in my capstone design class:
  - When brainstorming project ideas:
    - One student team proposed to extend their Heat Transfer Course Project to Design a Body Heat Powered Watch

Thermoelectric Watch



❖ How do you think about this idea for their capstone design?

Wildlife Conservation



You have to identify a compelling use case scenario that your product will uniquely excel!!

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ME 4182 - Product Definition

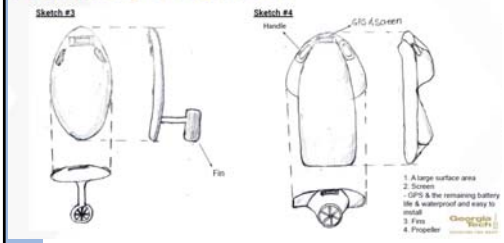
Team Sea: Week 5 Milestone Presentation

23:17:03

Members:
Eduardo Alfaro, David Montemayor, Maeve Gawryszewski, Bryan Santana, Jongsu Kim, Eric Pollock

Section K - Dr. Roger Jiao
February 4, 2020

Preliminary Design Ideas



Current Market Products

Yamaha Seascooter Line
For both recreational and professional divers.
Drawbacks
Geared toward underwater use and expensive.

PowerDolphin
Underwater Drone that takes pictures and videos.
Drawbacks
Not designed to rescue a person. Mostly used for recreational use.

Boost Surf Electric Fin
For professional surfers. Helps them to surf when a lack of large waves and enables them to surf at greater speeds.
Drawbacks
A permanent mount to a surfboard and is not easily removable. Not designed to rescue a person.

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Smart Drone Dispatching System for Harsh Last Mile Delivery

Eduardo Alfaro, David Montemayor, Maeve Gawryszewski, Eric Pollock, Jongsu Kim, Bryan Santana

Problem Statement

Most delivery services used today are limited to places only accessible by car. Our team's objective was to design an autonomous, unmanned, on-demand delivery ser

Project Goals

1. Choose and test a drone for autonomous missions.
2. Design a subsystem to be attached to the drone for carrying products.
3. Develop a phone application to receive orders and GPS coordinates.

Purchased drone to test the autonomous flight capabilities.

Final Subsystem Design

Subsystem consists of
- Sheet metal frame
- Compact Round-Face DC Motor
- 12V DC, 8574 rpm @ 2.62 in.-oz.
- Carabiner clip
- Shaft
- Hinges
- Rope/String

Drone With Subsystem

The final drone design consists of the DJI S900 with subsystem. Capable of a maximum takeoff weight of 18.1 pounds, this drone can deliver a product weighing 2.1 pounds.

Desired Drone Specs	
Diagonal Wheelbase	900 mm
ESC Current	40A
Motor KV	400 rpm/V
Max Takeoff Weight	18.1 lbs
Battery Life @12000mAh & 15-pound Takeoff Weight	18 min
Drone Weight (with subsystem)	16 lbs.

Drone "Tapfly" Function

- Draw a flight path on a map from point of origin to drop-off locations, back to origin
- Can set up multiple "drop-off" points making the process quicker and more efficient
- Implement function to a larger UAV in order to deliver more packages quicker

Application Development

- Android app captures last known location of user
- Loads data from database which contains 31 available items from 5 suppliers
- Allows users to input order information that is sent to database
- Date/time of order, order id, name, email, phone number, location & order details
- Integrates Google Maps API to visualize delivery and store address coordinates on map

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Phase 1: Concept Development

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- Sometimes called the ***Front-end*** process, and it demands more coordination among **functions**.
  - A concept is a description of the form, function, and features of a product and is often accompanied by:
    - a set of specifications,
    - an analysis of competitive products, and
    - an economic justification of the project.
  - The entire front-end process rarely proceed in a sequential manner, instead they may overlapped in time and iteration are often necessary.

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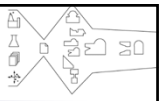
Phase 2: System-level Design



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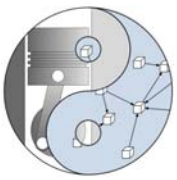
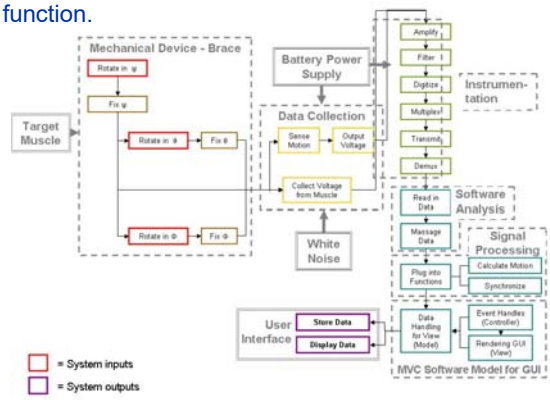
- Generate Product Architecture – aka. Embodiment Design
  - This consists of mappings of functional elements to physical elements.
  - Functional elements are the individual operations and transformations that contribute to the overall performance
  - Physical elements are the parts, components, and subassemblies that implement the product's function.





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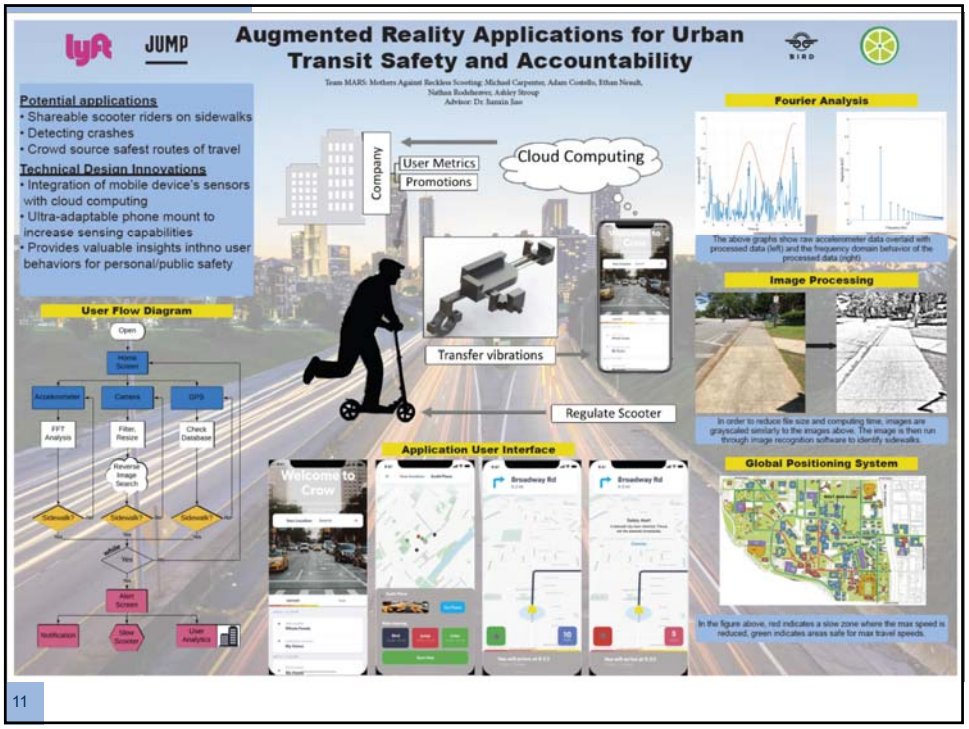

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(Product) System Architecture

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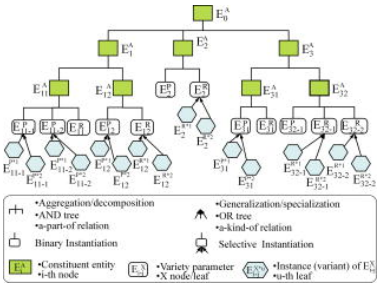
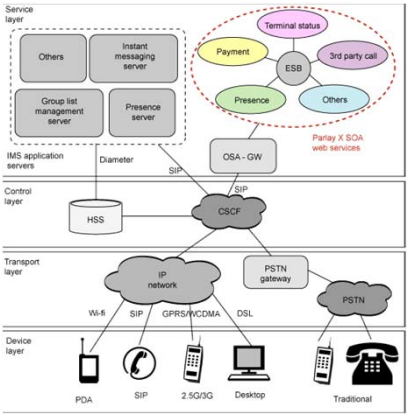
- Define major sub-systems and interfaces
- Develop plan for product option and extended product family
- Identify suppliers of key components
- Define final assembly schemes.





➔ Not the physical product structure; nor the assembly drawing!

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Urinary Tract Catheter Drainage Bag Notification System

PEEMINDER

Background

- 15-25% of hospital visits result in the patient receiving a urinary tract catheter
  - Comes fitted with a drainage bag that must be emptied
- Problems when not drained properly:
  - UTIs
  - Backflow
  - Sepsis
- Must be visually inspected to be changed
- Patients need discreet and reliable way of knowing when to empty the bag

System Architecture

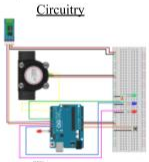
- **Product functions:**
  - Measure fluid
  - Interpret data
  - Relay information to user
- **Key performance aspects:**
  - Accurate reading of fluid flow level
  - Reliable connectivity between hardware and software
  - Notification system that can be amended to user specifications
- **Demonstration of proof of concept:**
  - Testing accuracy of fluid capacity readings

Design Innovation

- No existing products
- Development of Arduino circuitry and code
- Android Studio App that pairs with device
- Less than 5% Error in measurement readings
- Cost to produce 1 prototype: **$36.98**

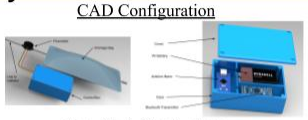
Data Flow Diagram

Circuitry



App Interface

CAD Configuration



Results & Conclusions

- **Device is 2% accurate in measuring output fluid volume**
  - Assumes constant flow
- **Future Applications**
  - Outpatient
  - Assisted living communities
  - Integrated hospital systems
- **Future product outlook**
  - External fluid flow sensor that can be clipped onto tubing and does not touch the urine
  - Developed application for different phones (i.e. iPhone, Androids, and text notification systems for brick phones)
    - Adjusted vibration or sound settings based on capacity of fluid bag

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ATMOSPHERIC MONITORING SYSTEM

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Jan Happel
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Georgia Tech Mechanical Engineering
The George W. Woodruff School of Mechanical Engineering

CENTER FOR SUSTAINABLE COMMUNITIES ATLANTA

green T

GOAL

01	02	03
Design, integrate, and install advanced instrumentation and equipment on a 140-ft tall cell tower	Collect long-term meteorological and atmospheric data.	Support academic research
Sensor comparison and selection	Tower sensor layout design	Real time acquisition and accessibility

PROBLEM

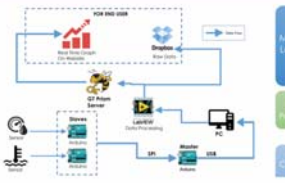
HOW TO DETERMINE THE BEST SENSOR?

Measurement Range
Accuracy
Operating Temperature Range
Response Time
Dimensions
Weight

HOW TO DETERMINE THE LOCATION?

Gas Density
Surrounding Environment
Characteristics of Subjects
Measurement Method

SOLUTION

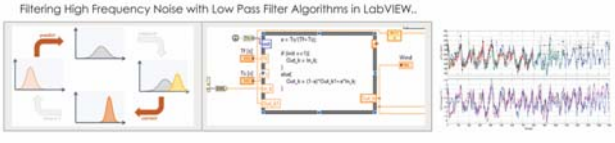


To apply all the sensors in the greenT system, we created sensor manuals for...

Humidity, Precipitation	Carbondioxide	Pellistor
Soil Temperature	Sonic Anonometer	Methane
Aerosol Spectrometer	Pyranometer	Wind Indicator

DATA PROCESSING

Filtering High Frequency Noise with Low Pass Filter Algorithms in LabVIEW..



Phase 3: Detail Design

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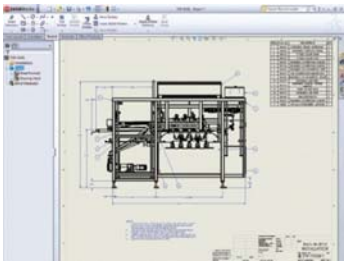
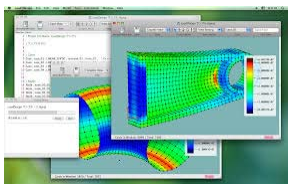
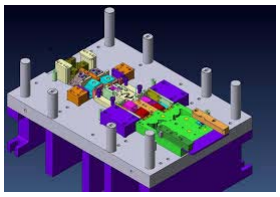
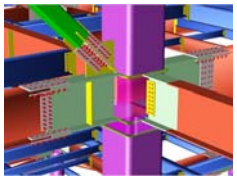
- Complete industrial and part design documentation
- Complete detail design of parts
  - define final geometry of parts
  - choose final material
  - assign tolerances
- Design tooling
- Define QA processes
- Begin procurement of long-lead tooling









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Phase 4: Testing and Refinement

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- Reliability, life and performance testing
- Obtain regulatory approvals
- Implement design changes

- Facilitate supplier ramp-up
- Refine fabrication and assembly processes
- Train workforce and suppliers
- Develop promotion and product launch materials
- Facilitate field testing

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Phase 5: Production Ramp-up

23:17:05

- Product is made using intended production system
- Work out remaining problems in the production processes
- Evaluate production output
- Transition to ongoing production is gradual and continuous.
- At some point in this transition, the product is launched and becomes available for widespread distribution.

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Summary

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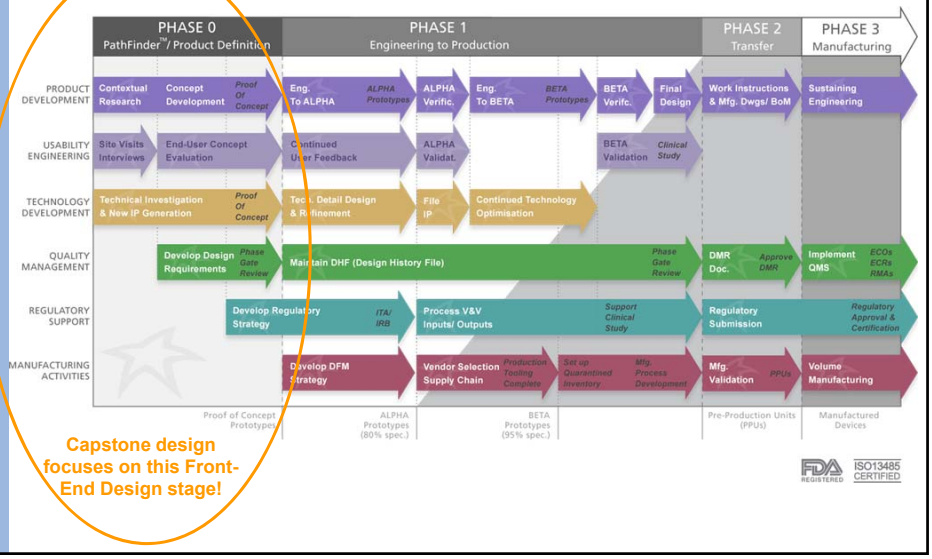

Capstone design focuses on this Front-End Design stage!

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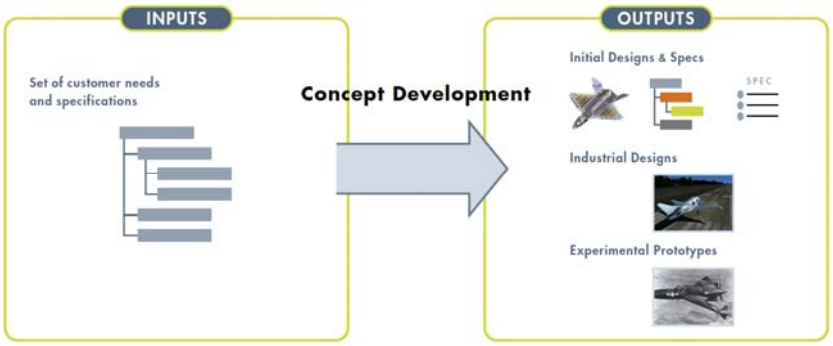
Customer Needs & Product Definition



Concept Development Process

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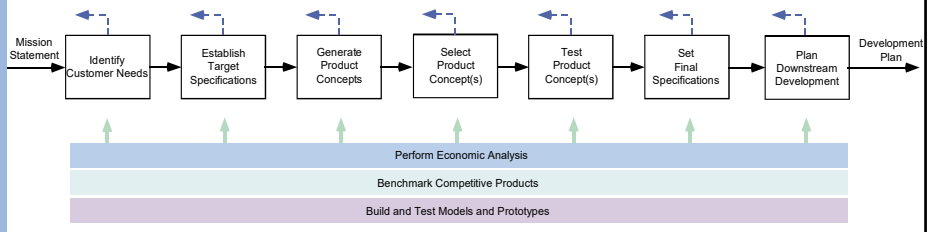
- The many Front-end activities in the concept development phase
  - Front-end of PD need not be a fuzzy process.
  - Structured methods exist for each process step
  - This is not strictly sequential - generally a parallel and iterative process.



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Identifying Customer Needs

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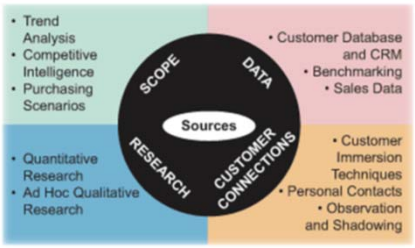
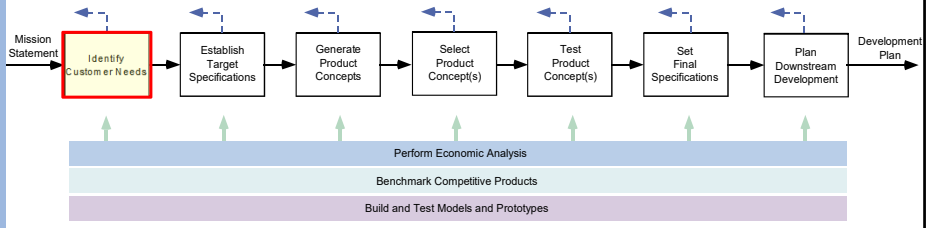
- Understand the customers needs.
- Effectively communicate it to the development team.
- Outputs a set of carefully constructed customer needs statements, organized in a hierarchical list with weightings.





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Establishing Target Specifications

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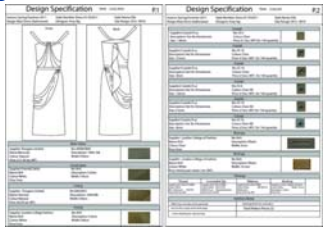
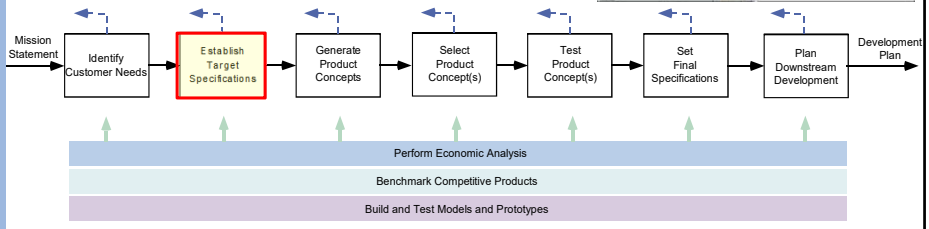
- Precise description of product
- Translate customer needs to technical terms
- Targets for the specifications are set early
- The output is a list of target specifications





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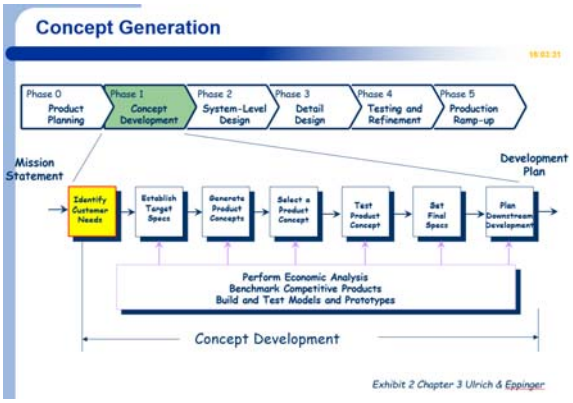
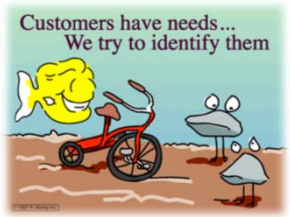
Identifying Customer Needs





Customer Needs Process

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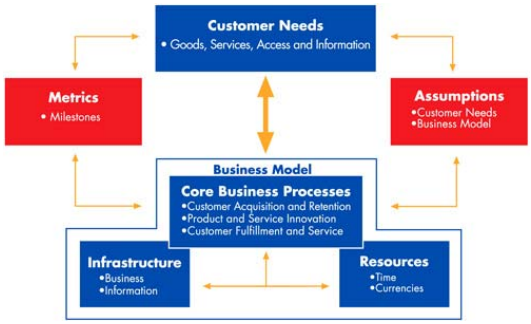
- Define the Scope
  - Mission Statement
- Gather Raw Data
  - Interviews
  - Focus Groups
  - Observation
- Interpret Raw Data
  - Need Statements
- Organize the Needs
  - Hierarchy
- Establish Importance
  - Surveys
  - Quantified Needs
- Reflect on the Process
  - Continuous Improvement



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Typical Procedure of Identifying Customer Needs

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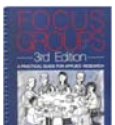
- Step 1. Gather Raw Data From Customers
  - Interview
  - Survey/Questionnaire
  - Focus groups
  - Observation
  - Lead users



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Typical Procedure of Identifying Customer Needs

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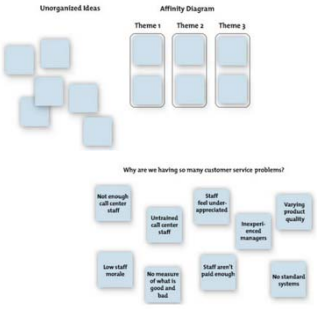
- Step 2. Interpret Raw Data in Terms of Customer Needs
  - **Affinity Diagram** (Also Known as the **K-J Method** or **Affinity Charts**)
  - Tutorials:
    - http://www.balancedscorecard.org/portals/0/pdf/affinity.pdf
    - https://www.moresteam.com/toolbox/affinity-diagram.cfm
    - http://asq.org/learn-about-quality/idea-creation-tools/overview/affinity.html
  - Free online tool for affinity diagramming: http://memosort.com/



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Typical Procedure of Identifying Customer Needs

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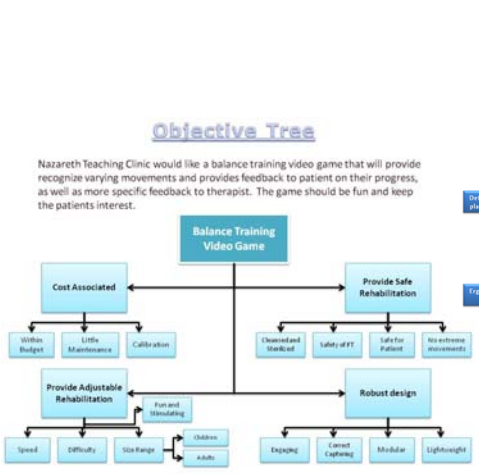
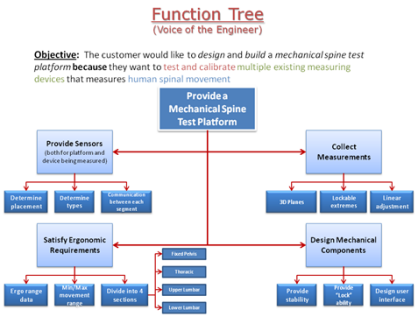
- Step 3. Organize the Needs into a Hierarchy





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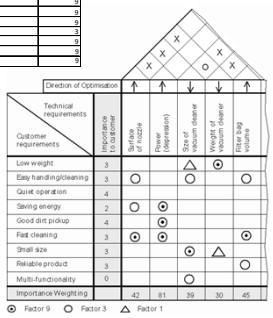
Typical Procedure of Identifying Customer Needs

23:17:07

- Step 4. Establish the Relative Importance of the Needs

Need	The Product	Needs to	Importance
1.1	Adjustability	Provide different speeds(reaction time) for varying levels of rehabilitation	9
1.2	Adjustability	Variable Distances	9
1.3	Adjustability	Fit Children (usually smaller than average)	3
1.4	Adjustability	Fit Adults (Max 330 lbs male)	3
1.5	Adjustability	Fit Patients sitting (Wheel chair)	9
2.2	Safety	Can be cleansed and sterilized	9
2.3	Safety	Can hold up to repetative use-safety of device	3
2.4	Safety	Can hold up to repetative use-safety of patient	9
3.1	Ease of Use - PT	Communicate easily with Physical Therapist	9
3.2	Ease of Use - PT	Provide Physical Therapist with an easy to understand Users Manual	9
3.3	Ease of Use - PT	Simple Assembly	3
3.3	Ease of Use	Easy Storage	9
3.4	Ease of Use	Doesn't take up a lot of space and can be in the gym area	9
3.5	Ease of Use	Easy to move(Portability)	9
3.6	Ease of Use	Simple Visual Feedback	9
3.7	Ease of Use	Simple Auditory Feedback	9
3.8	Ease of Use	Doesn't take a lot of strength to hit target	9
4.1	Cost	Fits within budget	3
4.2	Cost	Low cost repairs	9
5.1	Rehabilitation	Keeps patient's attention with fun and stimulating game	9
5.2	Rehabilitation	Provide PT with objective measure of patient progress	9



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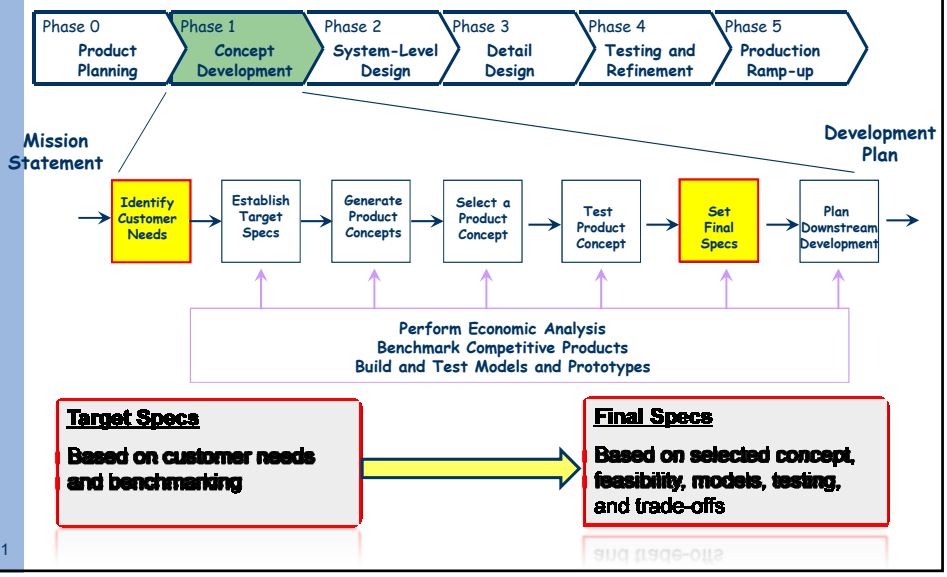
Product Definition → Specifications

	Commercial PSD-20RT	Commercial CN-80	Light Duty Healthcare LD-10H	Light Duty LD-10	Light Duty LD-5 Backpack
Service Rating:	Commercial	Commercial	Light Duty	Light Duty	Light Duty
Electric Power Required:	No	No	No	No	No
Power Source:	Carbon Dioxide (CO_2)	Nitrogen (N_2)	Carbon Dioxide (CO_2)	Carbon Dioxide (CO_2)	Carbon Dioxide (CO_2)
Removable Cylinder Patent-Pending Technology:	Yes	Yes	Yes	Yes	Yes
Patent-Pending Spray Design Type:	Continuous	Continuous	Intermittent	Intermittent	Intermittent
Total Spray Time between Refill:	90 minutes	45 minutes	45 minutes	45 minutes	25 minutes
Atomizing Spray Technology Type	Maximum Efficiency / Environmentally Responsible	Maximum Efficiency / Environmentally Responsible	High Volume / Low Pressure	High Volume / Low Pressure	High Volume / Low Pressure
Coverage Speed Sanitation:	2.76 seconds per square foot	2.76 seconds per square foot	3.45 seconds per square foot	3.45 seconds per square foot	3.45 seconds per square foot
Disinfection:	3.34 seconds per square foot	3.34 seconds per square foot	4.18 seconds per square foot	4.18 seconds per square foot	4.18 seconds per square foot
Sanitation:	1305 square feet per hour	1305 square feet per hour	1045 square feet per hour	1045 square feet per hour	1045 square feet per hour
Disinfection:	1080 square feet per hour	1080 square feet per hour	865 square feet per hour	865 square feet per hour	865 square feet per hour
Formula Usage Sanitation:	1.07 milliliters per square foot	1.07 milliliters per square foot	1.34 milliliters per square foot	1.34 milliliters per square foot	1.34 milliliters per square foot
Disinfection:	3.63 milliliters per square foot	3.63 milliliters per square foot	4.54 milliliters per square foot	4.54 milliliters per square foot	4.54 milliliters per square foot
Coverage Area Sanitation:	1960 sq. ft. per 20 lb. CO_2 cylinder	980 sq. ft. per 80 cf Nit. cylinder	785 sq. ft. per 10 lb. CO_2 cylinder	785 sq. ft. per 10 lb. CO_2 cylinder	390 sq. ft. per 5 lb. CO_2 cylinder
Disinfection:	1620 sq. ft. per 20 lb. CO_2 cylinder	810 sq. ft. per 80 cf Nit. cylinder	650 sq. ft. per 10 lb. CO_2 cylinder	650 sq. ft. per 10 lb. CO_2 cylinder	325 sq. ft. per 5 lb. CO_2 cylinder
Sanitation:	935 square feet per liter	935 square feet per liter	750 square feet per liter	750 square feet per liter	750 square feet per liter
Disinfection:	275 square feet per liter	275 square feet per liter	220 square feet per liter	220 square feet per liter	220 square feet per liter
Weight Full cylinder inserted:	92.0 lbs.	61.5 lbs.	43 lbs.	35.0 lbs.	24.0 lbs.
Empty cylinder inserted:	72.0 lbs.	53.0 lbs.	33.0 lbs.	25.0 lbs.	19.0 lbs.
Cylinder removed:	47.0 lbs.	10.5 lbs.	19.5 lbs.	10.5 lbs.	11.5 lbs.
Dimensions Width:	18.00 inches	13.50 inches	12.00 inches	13.50 inches	14.75 inches
Depth:	14.25 inches	9.50 inches	16.25 inches	9.50 inches	12.75 inches
Height:	52.00 inches	43" handle extended 28" handle retracted	41" handle extended 28" handle retracted	43" handle extended 28" handle retracted	43" handle extended 28" handle retracted

Concept Generation

23:17:07



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The Product Specs Process

23:17:08

- Set Target Specifications
  - Based on customer needs and benchmarks
  - Develop metrics for each need
  - Set ideal and acceptable values
- Refine Specifications: Ask "In terms of what" Questions!
  - Based on selected concept and feasibility testing
  - Technical modeling
  - Trade-offs are critical
- Reflect on the Results and the Process
  - Critical for ongoing improvement

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A Case Example of
Customer Need Identification and Product Specifications:

23:17:09

Mountain Bike Suspension Fork

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Start with the Customer Needs

23:17:09

#	NEED		Imp
1	The suspension	reduces vibration to the hands.	3
2	The suspension	allows easy traversal of slow, difficult terrain.	2
3	The suspension	enables high speed descents on bumpy trails.	5
4	The suspension	allows sensitivity adjustment.	3
5	The suspension	preserves the steering characteristics of the bike.	4
6	The suspension	remains rigid during hard cornering.	4
7	The suspension	is lightweight.	4
8	The suspension	provides stiff mounting points for the brakes.	2
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5
10	The suspension	is easy to install.	1
11	The suspension	works with fenders.	1
12	The suspension	instills pride.	5
13	The suspension	is affordable for an amateur enthusiast.	5
14	The suspension	is not contaminated by water.	5
15	The suspension	is not contaminated by grunge.	5
16	The suspension	can be easily accessed for maintenance.	3
17	The suspension	allows easy replacement of worn parts.	1
18	The suspension	can be maintained with readily available tools.	3
19	The suspension	lasts a long time.	5
20	The suspension	is safe in a crash.	5

Next…

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Establish Metrics and Units

23:17:10

Metric #	Need #s	Metric	Imp	Units
1	1,3	Attenuation from dropout to handlebar at 10hz	3	dB
2	2,6	Spring pre-load	3	N
3	1,3	Maximum value from the Monster	5	g
4	1,3	Minimum descent time on test track	5	s
5	4	Damping coefficient adjustment range	3	N-s/m
6	5	Maximum travel (26in wheel)	3	mm
7	5	Rake offset	3	mm
8	6	Lateral stiffness at the tip	3	kN/m
9	7	Total mass	4	kg
10	8	Lateral stiffness at brake pivots	2	kN/m
11	9	Headset sizes	5	in
12	9	Steertube length	5	mm
13	9	Wheel sizes	5	list
14	9	Maximum tire width	5	in
15	10	Time to assemble to frame	1	s
16	11	Fender compatibility	1	list
17	12	Instills pride	5	subj
18	13	Unit manufacturing cost	5	US$
19	14	Time in spray chamber w/o water entry	5	s
20	15	Cycles in mud chamber w/o contamination	5	k-cycles
21	16,17	Time to disassemble/assemble for maintenance	3	s
22	17,18	Special tools required for maintenance	3	list
23	19	UV test duration to degrade rubber parts	5	hours
24	19	Monster cycles to failure	5	cycles
25	20	Japan Industrial Standards test	5	binary
26	20	Bending strength (frontal loading)	5	MN

Next…

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Link Metrics to Needs

23:17:10

	Need \ Metric	1 Attenuation from dropout to handlebar at 10hz	2 Spring pre-load	3 Maximum value from the Monster	4 Minimum descent time on test track	5 Damping coefficient adjustment range	6 Maximum travel (26in wheel)	7 Rake offset	8 Lateral stiffness at the tip	9 Total mass	10 Lateral stiffness at brake pivots	11 Headset sizes	12 Steertube length	13 Wheel sizes	14 Maximum tire width	15 Time to assemble to frame	16 Fender compatibility	17 Instills pride	18 Unit manufacturing cost	19 Time in spray chamber w/o water entry	20 Cycles in mud chamber w/o contamination	21 Time to disassemble/assemble for maintenance	22 Special tools required for maintenance	23 UV test duration to degrade rubber parts	24 Monster cycles to failure	25 Japan Industrial Standards test	26 Bending strength (frontal loading)
1	reduces vibration to the hands.	•		•	•																						
2	allows easy traversal of slow, difficult terrain.		•																								
3	enables high speed descents on bumpy trails.	•		•	•																						
4	allows sensitivity adjustment.					•																					
5	preserves the steering characteristics of the bike.						•	•																			
6	remains rigid during hard cornering.		•						•																		
7	is lightweight.									•																	
8	provides stiff mounting points for the brakes.										•																
9	fits a wide variety of bikes, wheels, and tires.											•	•	•	•												
10	is easy to install.															•											
11	works with fenders.																•										
12	instills pride.																	•									
13	is affordable for an amateur enthusiast.																		•								
14	is not contaminated by water.																			•							
15	is not contaminated by grunge.																				•						
16	can be easily accessed for maintenance.																					•					
17	allows easy replacement of worn parts.																					•	•				
18	can be maintained with readily available tools.																						•				
19	lasts a long time.																							•	•		
20	is safe in a crash.																									•	•

Next…

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Benchmark on Customer Needs

23:17:11

#	NEED		Imp	ST Tritrack	Maniray 2	Rox Tahx Quadra	Rox Tahx Ti 21	Tonka Pro	Gunhill Head Shox
1	The suspension	reduces vibration to the hands.	3	•	••••	••	•••••	••	•••
2	The suspension	allows easy traversal of slow, difficult terrain.	2	••	••••	•••	•••••	•••	•••••
3	The suspension	enables high speed descents on bumpy trails.	5	•	•••••	••	•••••	••	•••
4	The suspension	allows sensitivity adjustment.	3	•	••••	••	•••••	••	•••
5	The suspension	preserves the steering characteristics of the bike.	4	••••	••	•	••	•••	•••••
6	The suspension	remains rigid during hard cornering.	4	•	•••	•	•••••	•	•••••
7	The suspension	is lightweight.	4	•	•••	•	•••	••••	•••••
8	The suspension	provides stiff mounting points for the brakes.	2	•	••••	•••	•••	••	•••••
9	The suspension	fits a wide variety of bikes, wheels, and tires.	5	••••	•••••	•••	•••••	•••	•
10	The suspension	is easy to install.	1	••••	•••••	••••	••••	•••••	•
11	The suspension	works with fenders.	1	•••	•	•	•	•	•••••
12	The suspension	instills pride.	5	•	••••	•••	•••••	•••	•••••
13	The suspension	is affordable for an amateur enthusiast.	5	•••••	•	•••	•	•••	••
14	The suspension	is not contaminated by water.	5	•	•••	••••	••••	••	•••••
15	The suspension	is not contaminated by grunge.	5	•	•••	•	••••	••	•••••
16	The suspension	can be easily accessed for maintenance.	3	••••	•••••	••••	••••	•••••	•
17	The suspension	allows easy replacement of worn parts.	1	••••	•••••	••••	••••	•••••	•
18	The suspension	can be maintained with readily available tools.	3	•••••	•••••	•••••	•••••	••	•
19	The suspension	lasts a long time.	5	•••••	•••••	•••••	•••	•••••	•
20	The suspension	is safe in a crash.	5	•••••	•••••	•••••	•••••	•••••	•••••

Next…

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Benchmark on Metrics

23:17:12

Metric #	Need #s	Metric	Imp	Units	ST Tritrack	Maniray 2	Rox Tahx Quadra	Rox Tahx Ti 21	Tonka Pro	Gunhill Head Shox
1	1,3	Attenuation from dropout to handlebar at 10hz	3	dB	8	15	10	15	9	13
2	2,6	Spring pre-load	3	N	550	760	500	710	480	680
3	1,3	Maximum value from the Monster	5	g	3.6	3.2	3.7	3.3	3.7	3.4
4	1,3	Minimum descent time on test track	5	s	13	11.3	12.6	11.2	13.2	11
5	4	Damping coefficient adjustment range	3	N-s/m	0	0	0	200	0	0
6	5	Maximum travel (26in wheel)	3	mm	28	48	43	46	33	38
7	5	Rake offset	3	mm	41.5	39	38	38	43.2	39
8	6	Lateral stiffness at the tip	3	kN/m	59	110	85	85	65	130
9	7	Total mass	4	kg	1.409	1.385	1.409	1.364	1.222	1.1
10	8	Lateral stiffness at brake pivots	2	kN/m	295	550	425	425	325	650
11	9	Headset sizes	5	in	1.000 1.125	1.000 1.125 1.250	1.000 1.125	1.000 1.125 1.250	1.000 1.125	NA
12	9	Steertube length	5	mm	150 180 210 230 255	140 165 190 215	150 170 190 210	150 170 190 210 230	150 190 210 220	NA
13	9	Wheel sizes	5	list	26in	26in	26in	26in 700C	26in	26in
14	9	Maximum tire width	5	in	1.5	1.75	1.5	1.75	1.5	1.5
15	10	Time to assemble to frame	1	s	35	35	45	45	35	85
16	11	Fender compatibility	1	list	Zefal	none	none	none	none	all
17	12	Instills pride	5	subj	1	4	3	5	3	5
18	13	Unit manufacturing cost	5	US$	65	105	85	115	80	100
19	14	Time in spray chamber w/o water entry	5	s	1300	2900	>3600	>3600	2300	>3600
20	15	Cycles in mud chamber w/o contamination	5	k-cycles	15	19	15	25	18	35
21	16,17	Time to disassemble/assemble for maintenance	3	s	160	245	215	245	200	425
22	17,18	Special tools required for maintenance	3	list	hex	hex	hex	hex	long hex	hex, pin wrnch
23	19	UV test duration to degrade rubber parts	5	hours	400+	250	400+	400+	400+	250
24	19	Monster cycles to failure	5	cycles	500k+	500k+	500k+	480k	500k+	330k
25	20	Japan Industrial Standards test	5	binary	pass	pass	pass	pass	pass	pass
26	20	Bending strength (frontal loading)	5	MN	55	89	75	75	62	102

Next…

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Assign Marginal and Ideal Values ➔ Requirement Specification

23:17:12

	Metric	Units	Marginal Value	Ideal Value
1	Attenuation from dropout to handlebar at 10hz	dB	>10	>15
2	Spring pre-load	N	480 - 800	650 - 700
3	Maximum value from the Monster	g	<3.5	<3.2
4	Minimum descent time on test track	s	<13.0	<11.0
5	Damping coefficient adjustment range	N-s/m	0	>200
6	Maximum travel (26in wheel)	mm	33 - 50	45
7	Rake offset	mm	37 - 45	38
8	Lateral stiffness at the tip	kN/m	>65	>130
9	Total mass	kg	<1.4	<1.1
10	Lateral stiffness at brake pivots	kN/m	>325	>650
11	Headset sizes	in	1.000 1.125	1.000 1.125 1.250
12	Steertube length	mm	150 170 190 210	150 170 190 210 230
13	Wheel sizes	list	26in	26in 700c
14	Maximum tire width	in	>1.5	>1.75
15	Time to assemble to frame	s	<60	<35
16	Fender compatibility	list	none	all
17	Instills pride	subj	>3	>5
18	Unit manufacturing cost	US$	<85	<65
19	Time in spray chamber w/o water entry	s	>2300	>3600
20	Cycles in mud chamber w/o contamination	k-cycles	>15	>35
21	Time to disassemble/assemble for maintenance	s	<300	<160
22	Special tools required for maintenance	list	hex	hex
23	UV test duration to degrade rubber parts	hours	>250	>450
24	Monster cycles to failure	cycles	>300k	>500k
25	Japan Industrial Standards test	binary	pass	pass
26	Bending strength (frontal loading)	MN	>70	>100

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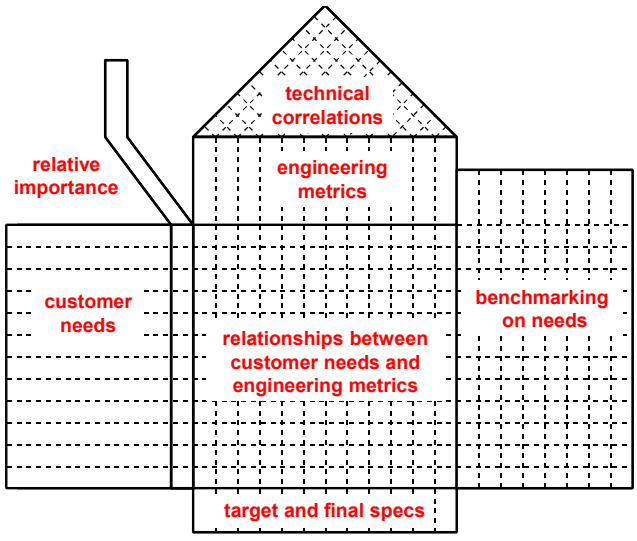
Quality Function Deployment (House of Quality)

23:17:13

- Tutorial: http://en.wikipedia.org/wiki/Quality_function_deployment



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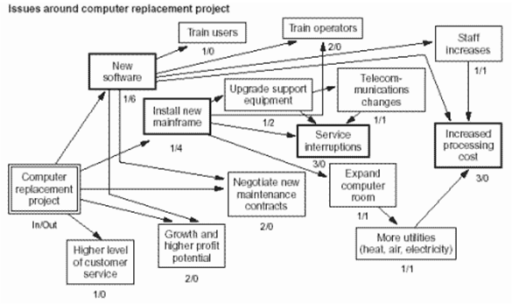
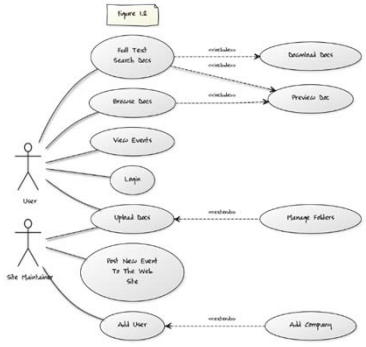
Requirement Analysis

Interactions/Interrelationships between Functions:

To describe how multiple functions work logically/interactively as a coherent system!



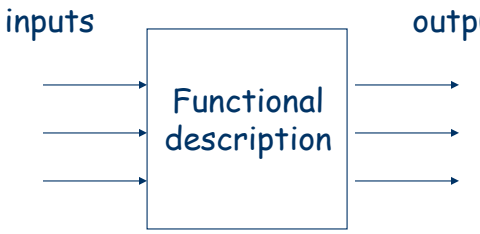


Function Decomposition

23:17:14

The goal of problem decomposition is to help identify the few critical functions for your design.

Every Product Function has a series of inputs and outputs that describe the behavior of the function.



Take a "systems" approach to design

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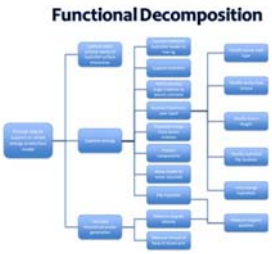
Step 1: Decompose Into Smaller Sub-Problems

23:17:14

- **Problem:** Most design challenges are too complex to be solved as a single problem.
- **Solution:** Divide into simpler, manageable subproblems, also called problem decomposition.
- **1. step:** represent problem as a black box operating on material, energy and signal flow
- **2. step:** functional decomposition by dividing the single black box into sub-functions to create a more specific description of the problem
  - **Goal:** to properly describe the functional elements without implying a specific technological working principle or a physical solution.
  - There is no single correct way of creating a function diagram or a functional decomposition.
  - It is best to create a number of drafts and then work to refine them into a single diagram..



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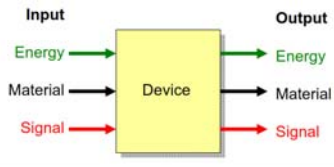
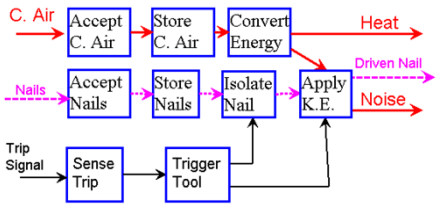
Function Structure Diagram

23:17:14

- Tutorial: http://npdbook.com/stages-of-the-design-process/function-structure-diagram/



Transfer and conversion of energy.
Movement of material within the system.
Control and feedback signals within the system.



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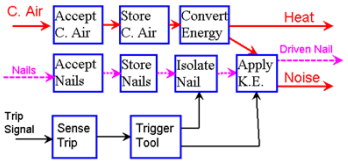
A Technique for Functional Decomposition & Analysis

23:17:14

- Follow the flows (energy, material and signal) and determine what operations are required
- Decomposition by Sequence of User Actions
  - Useful method for simple technical products
    - Example: Nail gun
      - Move tool to gross nailing position.
      - Position the tool precisely.
      - Trigger the tool.



- Decomposition by Key Customer Needs
  - Useful technique for products where form and shape are the primary design problem, not the working principle
    - Example: Nail Gun
      - Fires nails rapid succession.
      - Fits in tight spaces.
      - Has large nail capacity.
  - More examples for such products:
    - Storage container, toothbrush, ice cream scoop, etc.

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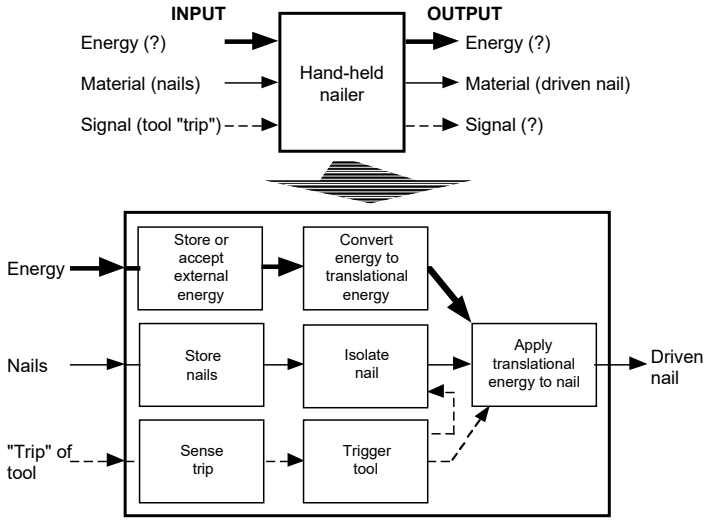
The Example of Designing a Hand-held Nailer

23:17:14



The design team decomposed the problem into several subproblems: Energy Source, Material (nails), Initiate action

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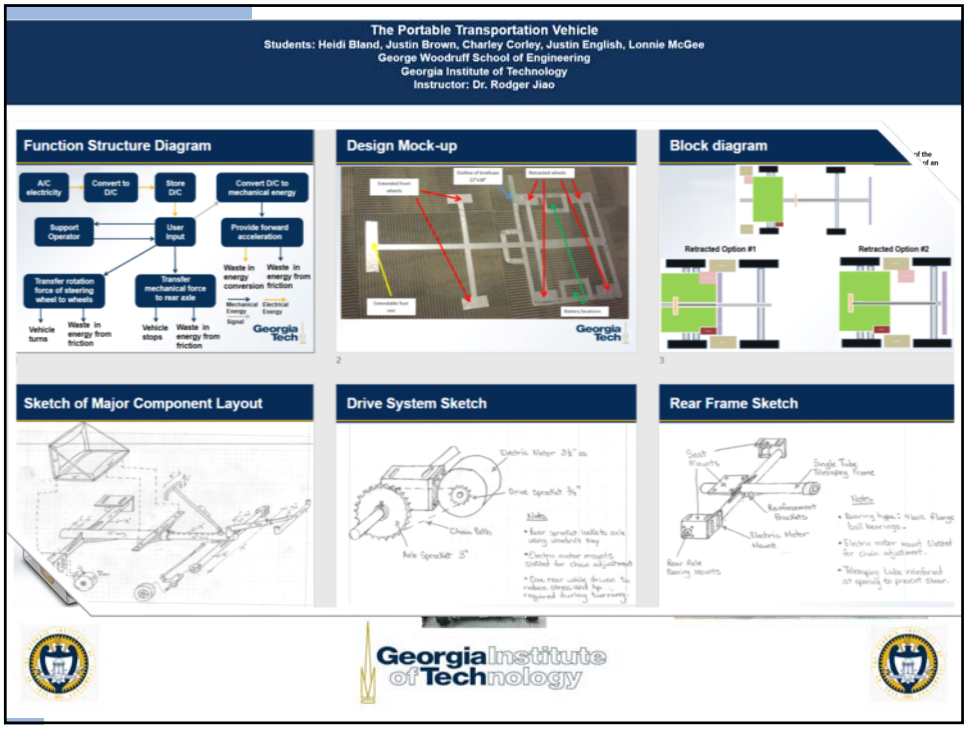


IDEF0 Functional Modeling

23:17:15

- Tutorial: http://www.idef.com/idef0.htm

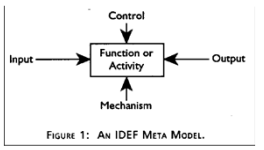
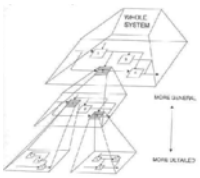
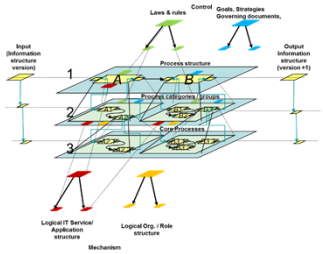
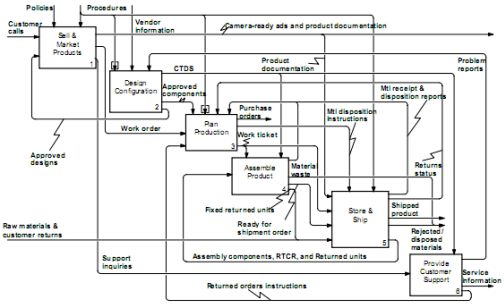
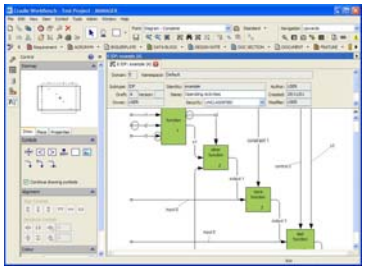


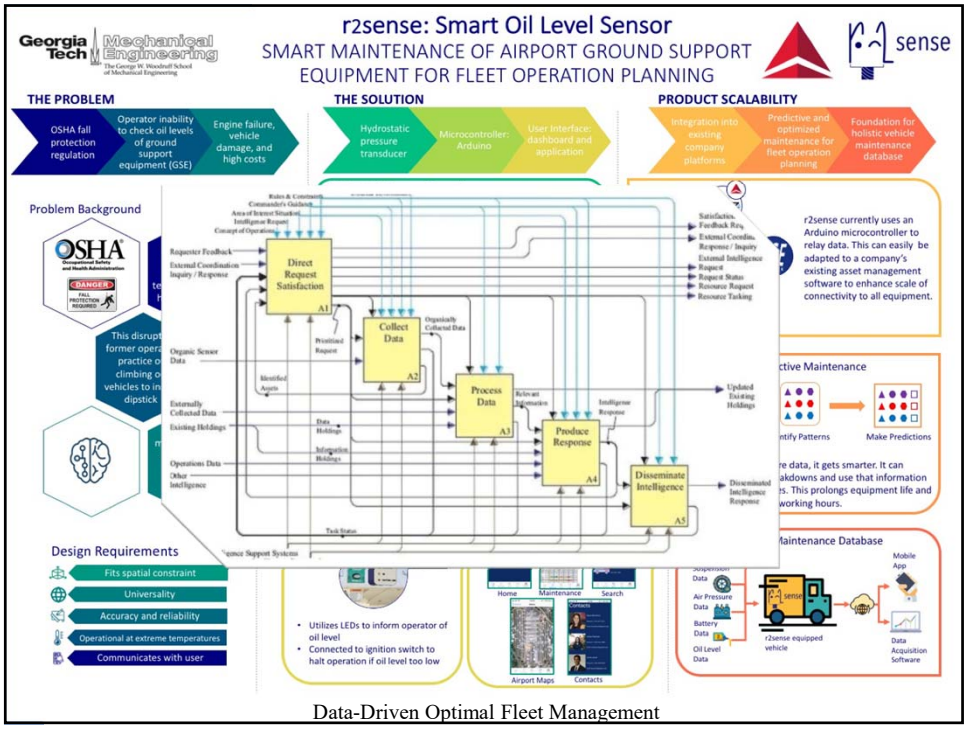
FIGURE 1: AN IDEF META MODEL.







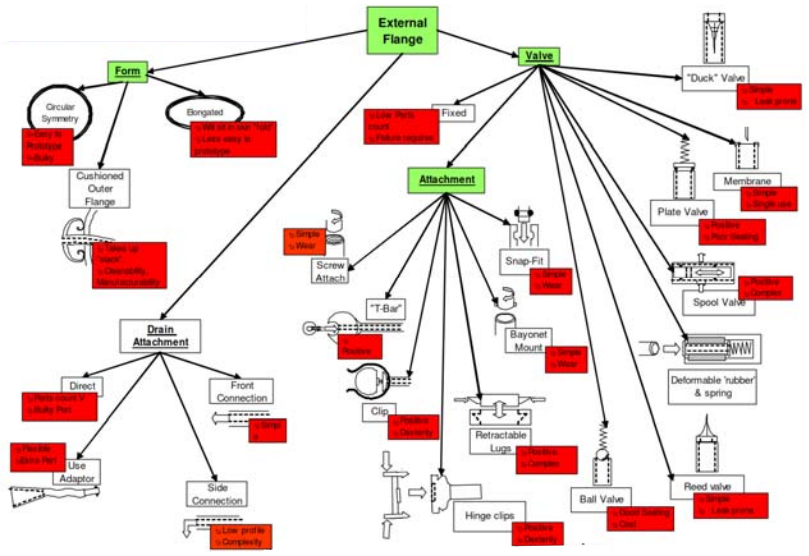




Data-Driven Optimal Fleet Management

Morph Charts

23:17:15



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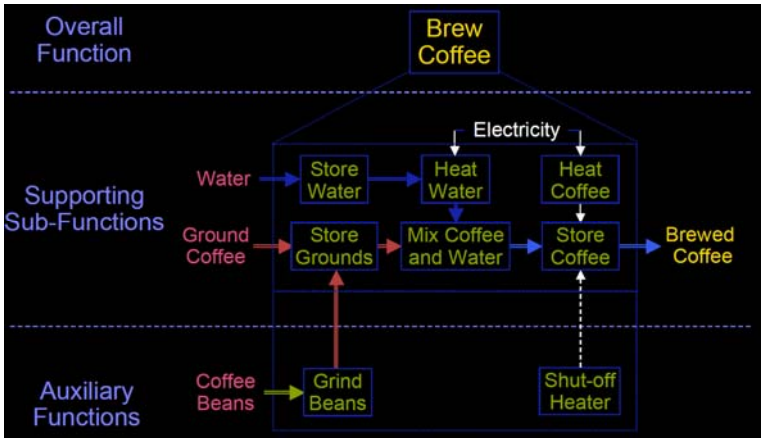
An Example of Coffee Maker

Function Decomposition

23:17:15



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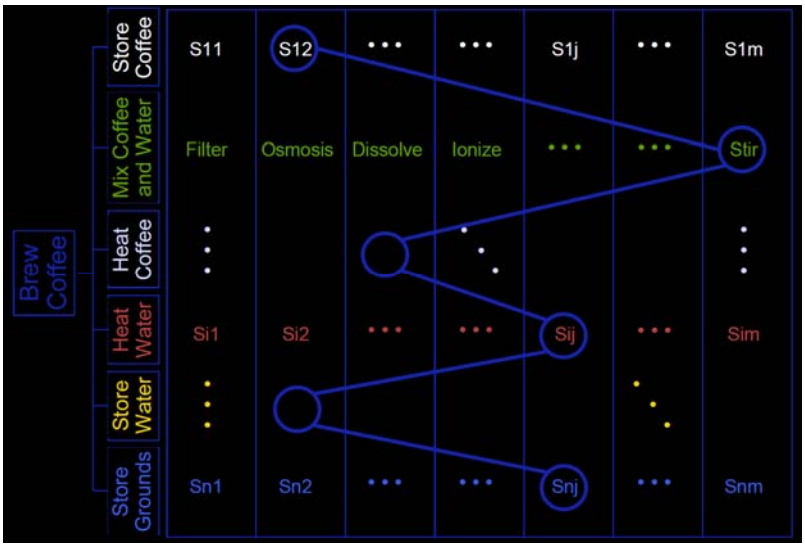
An Example of Coffee Maker

Morphologic Matrix

23:17:15



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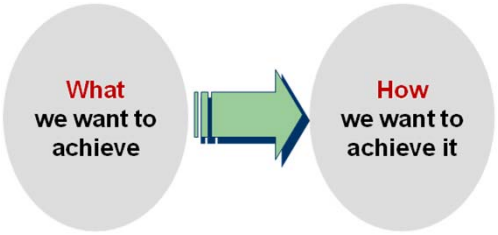
Summary

23:17:16



Essentially design is a *Mapping* between "*what* we want to achieve" and "*How* we want to achieve it"

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