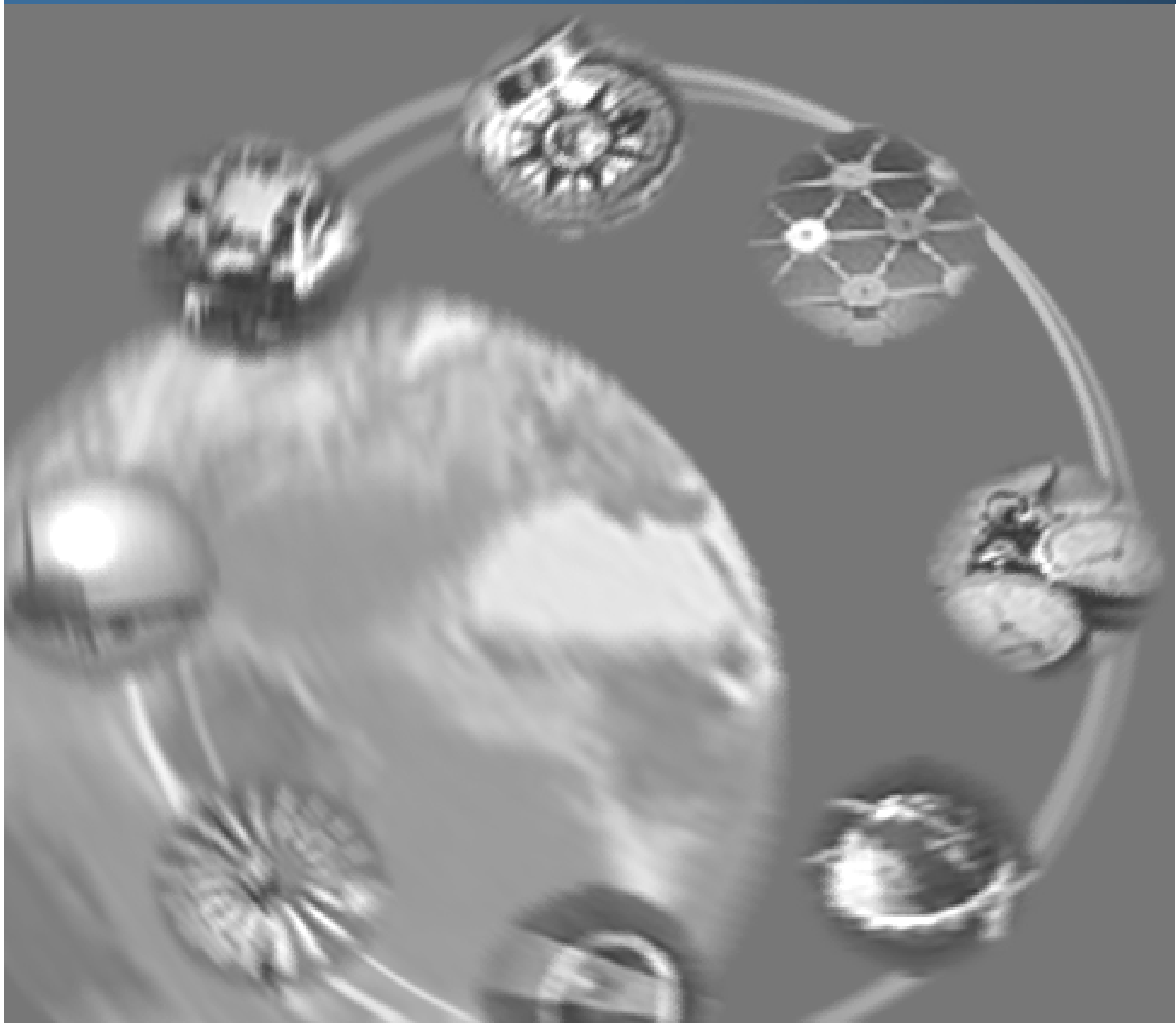
Product Specifications & Concept Generation

4013.315 Architectural Engineering System Design

April 22nd, 2009



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Product Specifications

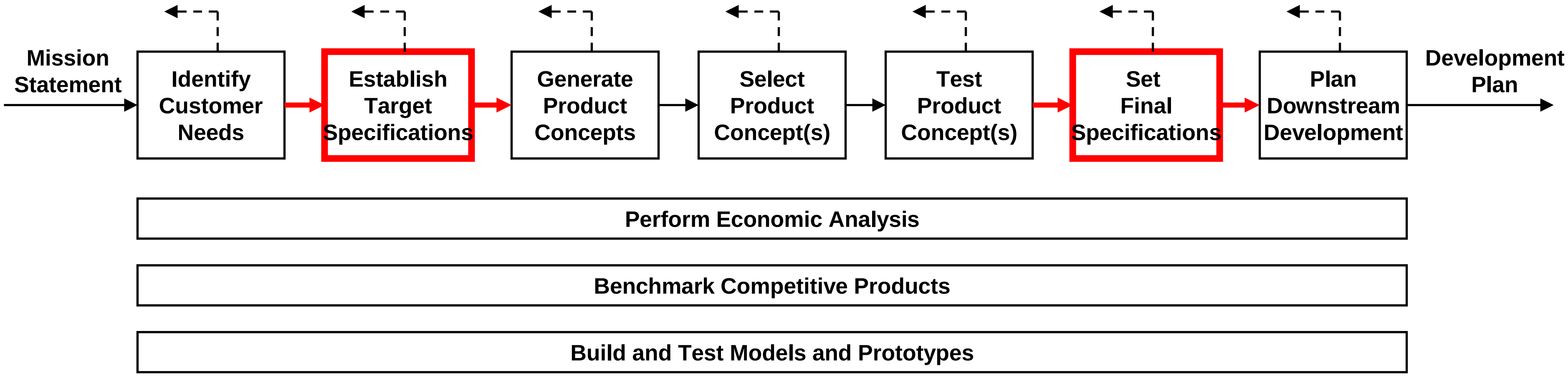
Teaching materials to accompany:

Product Design and Development
Karl T. Ulrich and Steven D. Eppinger
2nd Edition, Irwin McGraw-Hill, 2000.

Introduction/Overview

- What is a specification?
  - Translation of need expressed in language of customers to a <u>measurable</u> attribute.
  - Metric and value.
  - Measurable detail: *what* the product has to do, NOT *how* to address the customer needs

Concept Development Process



Target Specs

Based on customer needs and benchmarking

Final Specs

Based on selected concept, feasibility, models, testing, and trade-offs

The Product Specs Process

- Set Target Specifications
  - Based on customer needs and benchmarks
  - Develop metrics for each need
  - Set ideal and acceptable values
- Refine Specifications
  - Based on selected concept and feasibility testing
  - Technical modeling
  - <u>Trade-offs</u> are critical
- Reflect on the Results and the Process
  - Critical for ongoing improvement

Product Specifications Example: Mountain Bike Suspension Fork

Start with the Customer Needs

#	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

Establish Metrics and Units

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

Link Metrics to Needs

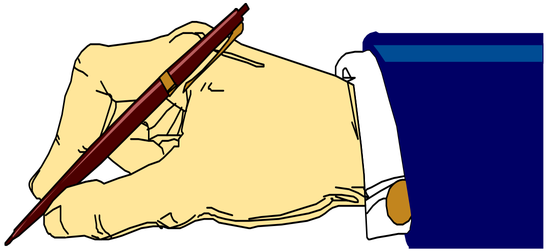
#	Need \ Metric	1 Attenuation from dropout to handlebar at 10hz	2 Spring pre-load	3 Maximum value from the Monster	4 Minimum descent time on test track	5 Damping coefficient adjustment range	6 Maximum travel (26in wheel)	7 Rake offset	8 Lateral stiffness at the tip	9 Total mass	10 Lateral stiffness at 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.																									•	•

Guidelines for listing metrics

Metrics should

- Be complete
  - Not always one-to-one need-metric matching
- Be dependent variables
  - To get the freedom to achieve the specifications using the best approach possible
  - E.g., mass of the fork (dependent), material of the fork (independent)
- Be practical
- Include the popular criteria for comparison in the market place

Metrics Exercise:
Ball Point Pen



Customer Need:

The pen writes smoothly.

Benchmark on Metrics

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

Assign Marginal and Ideal Values

	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

Develop technical models of the product

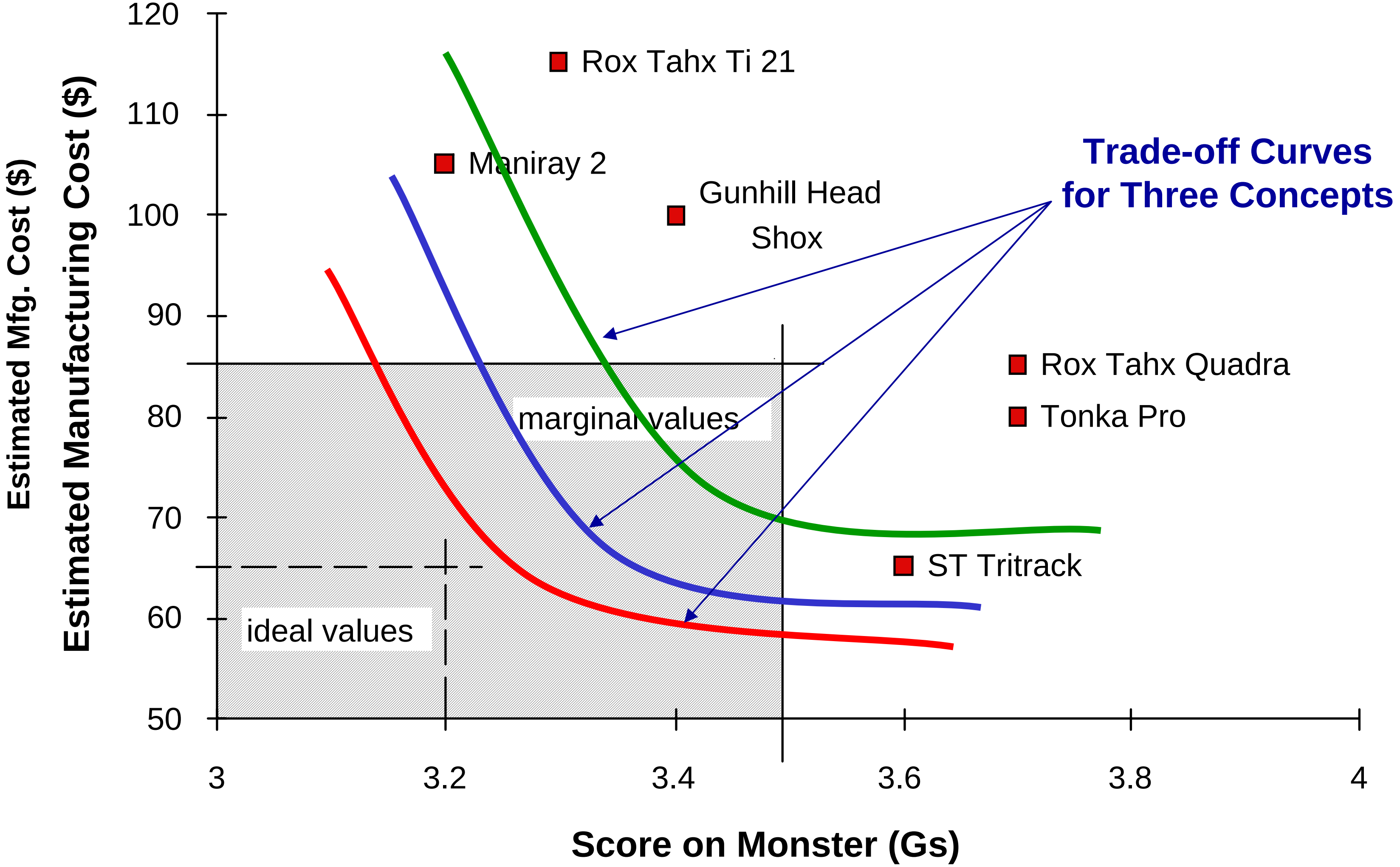
- Technical model: a tool for predicting the values of the metrics for a particular set of design decisions
- Either analytically or physically
- Several independent models, each corresponding to a set of the metrics, <u>more manageable</u> than one large integrated model
- Help predict whether any set of specifications is technically feasible by exploring different combinations of design variables

Develop a cost model of the product

- First estimation completed by drafting a bill of material and rough estimation of assembly and other manufacturing cost

- ‘What if’ cost analysis

Specification Trade-offs



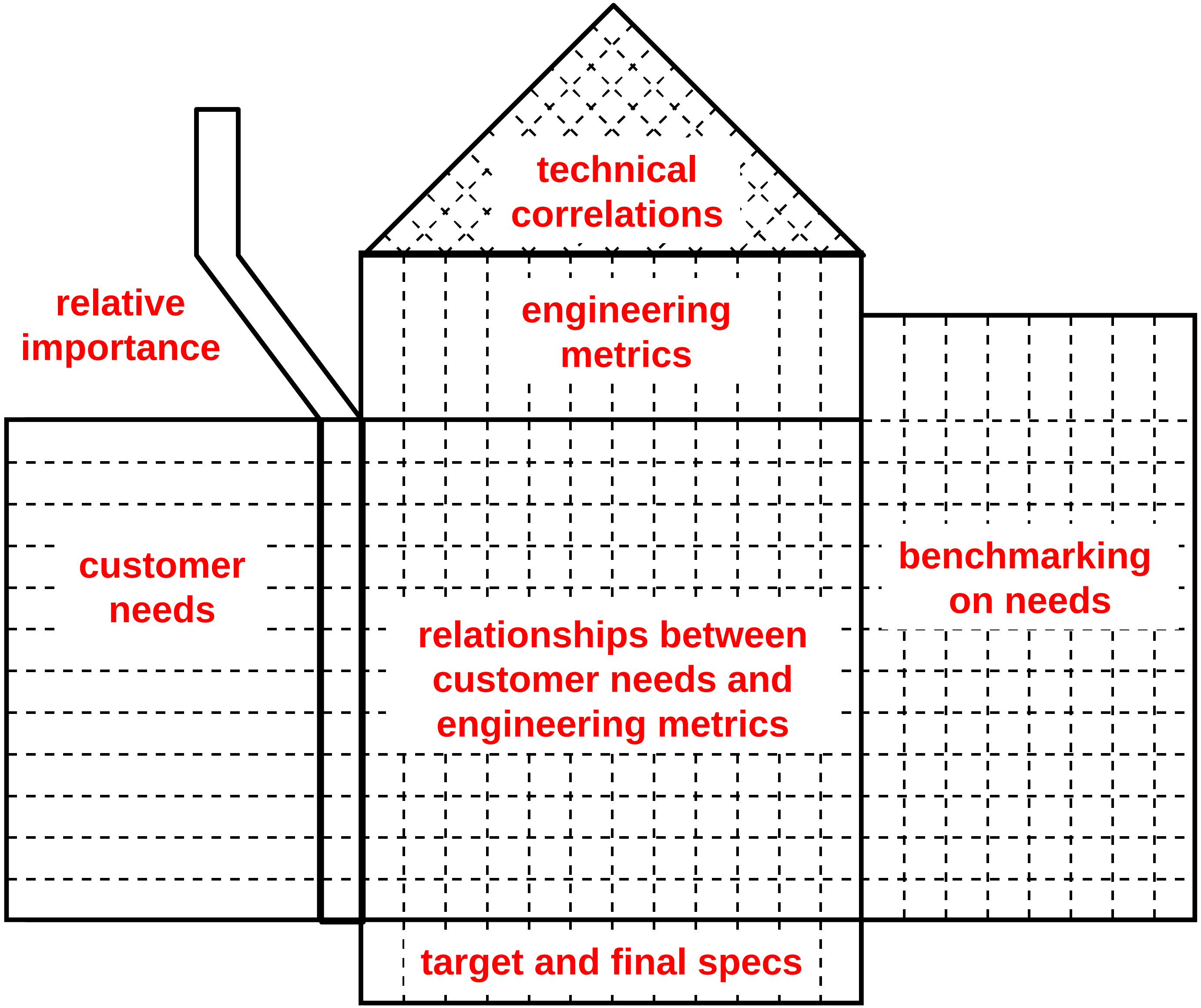
Competitive Map

Set Final Specifications

	METRIC	Units	Value
1	Attenuation from dropout to handlebar at 10hz	dB	>12
2	Spring pre-load	N	650
3	Maximum value from the Monster	g	<3.4
4	Minimum descent time on test track	s	<11.5
5	Damping coefficient adjustment range	N-s/m	>100
6	Maximum travel (26in wheel)	mm	43
7	Rake offset	mm	38
8	Lateral stiffness at the tip	kN/m	>75
9	Total mass	kg	<1.4
10	Lateral stiffness at brake pivots	kN/m	>425
11	Headset sizes	in	1.000 1.125
12	Steertube length	mm	150 170 190 210 230
13	Wheel sizes	list	26in
14	Maximum tire width	in	>1.75
15	Time to assemble to frame	s	<45
16	Fender compatibility	list	Zefal
17	Instills pride	subj	>4
18	Unit manufacturing cost	US$	<80
19	Time in spray chamber w/o water entry	s	>3600
20	Cycles in mud chamber w/o contamination	k-cycles	>25
21	Time to disassemble/assemble for maintenance	s	<200
22	Special tools required for maintenance	list	hex
23	UV test duration to degrade rubber parts	hours	>450
24	Monster cycles to failure	cycles	>500k
25	Japan Industrial Standards test	binary	pass
26	Bending strength (frontal loading)	MN	>100

Quality Function Deployment
(House of Quality)

생산관리시스템을 지원하는 설계/운용, 그리고 제품설계과정의 결과를 통해 정의된 소비자(고객)의 요구를 명확히 정의하기위해 설계된 방법이며 고객과 제품사이의 **Gap**을 제거하는 역할을 한다.



Concept Generation

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Chapter 7

Karl T. Ulrich and Steven D. Eppinger
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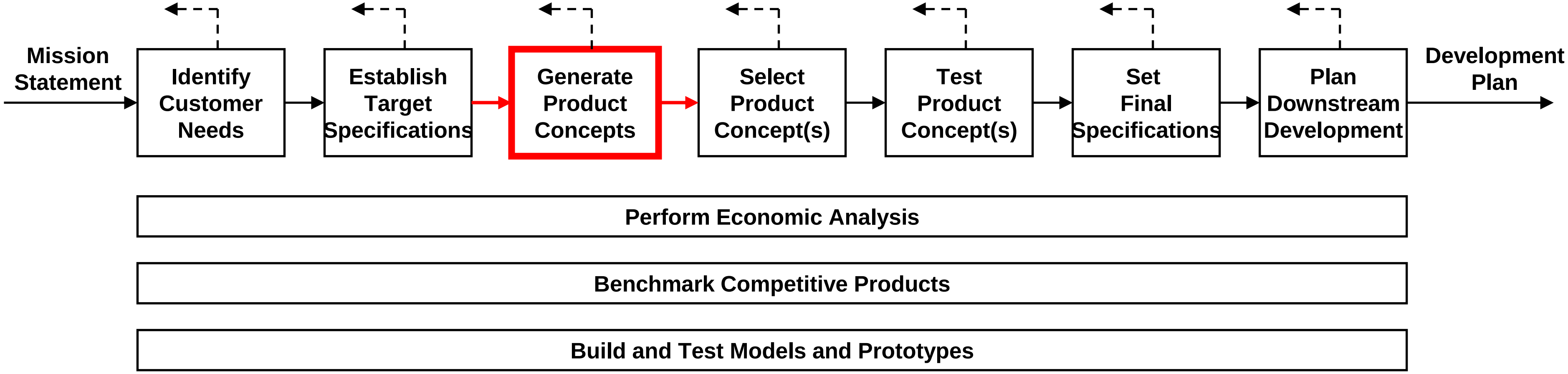
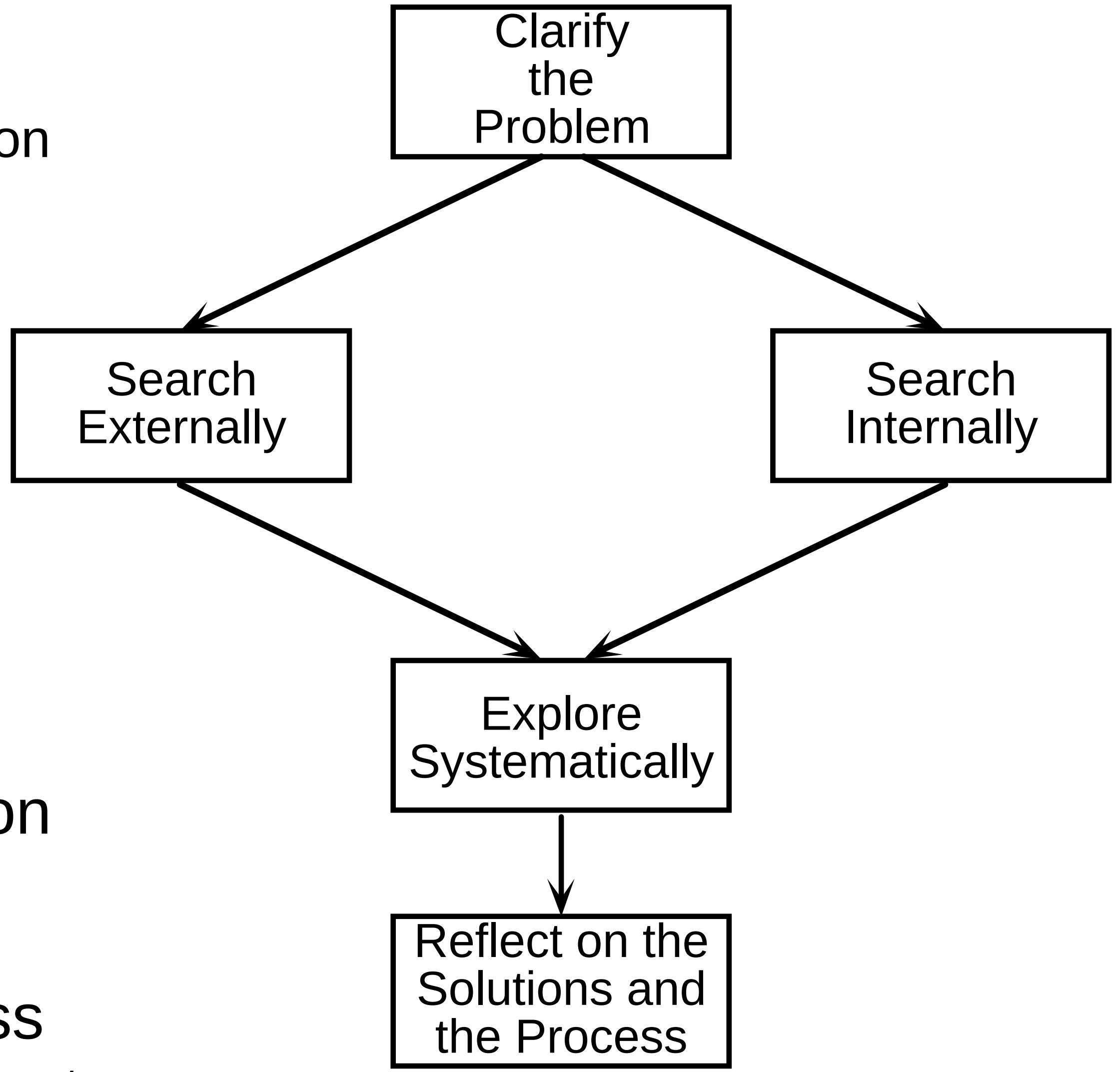
Concept Development Process



Concept Generation Process

- Clarify the Problem
  - Problem Decomposition
- External Search
  - Lead Users
  - Experts
  - Patents
  - Literature
  - Benchmarking
- Internal Search
  - Individual Methods
  - Group Methods
- Systematic Exploration
  - Classification Tree
  - Combination Table
- Reflect on the Process
  - Continuous Improvement



Principles

- **Functional Decomposition**
  Complex problems must be broken down into simpler constituent subproblems. This strategy is also useful for simple problems. The function diagram is useful for documenting this step.

- **Explore Solutions for the Subproblems**
  It is generally helpful to consider solutions to the subproblems in addition to (or instead of) the entire problem at once.

- **Explore Externally**
  It is essential to search for solutions from sources outside the team, such as lead users, experts, patents, literature, and competitive products.

- **Internal Concept Generation**
  brainstorming: analogies, wish and wonder, related stimuli, unrelated stimuli, goals, and the gallery method.

- **Balance Individual and Group Search**
  Individuals generate ideas more quickly than groups do, while the group interaction is critical for refinement, combination, and critique of the solution fragments.

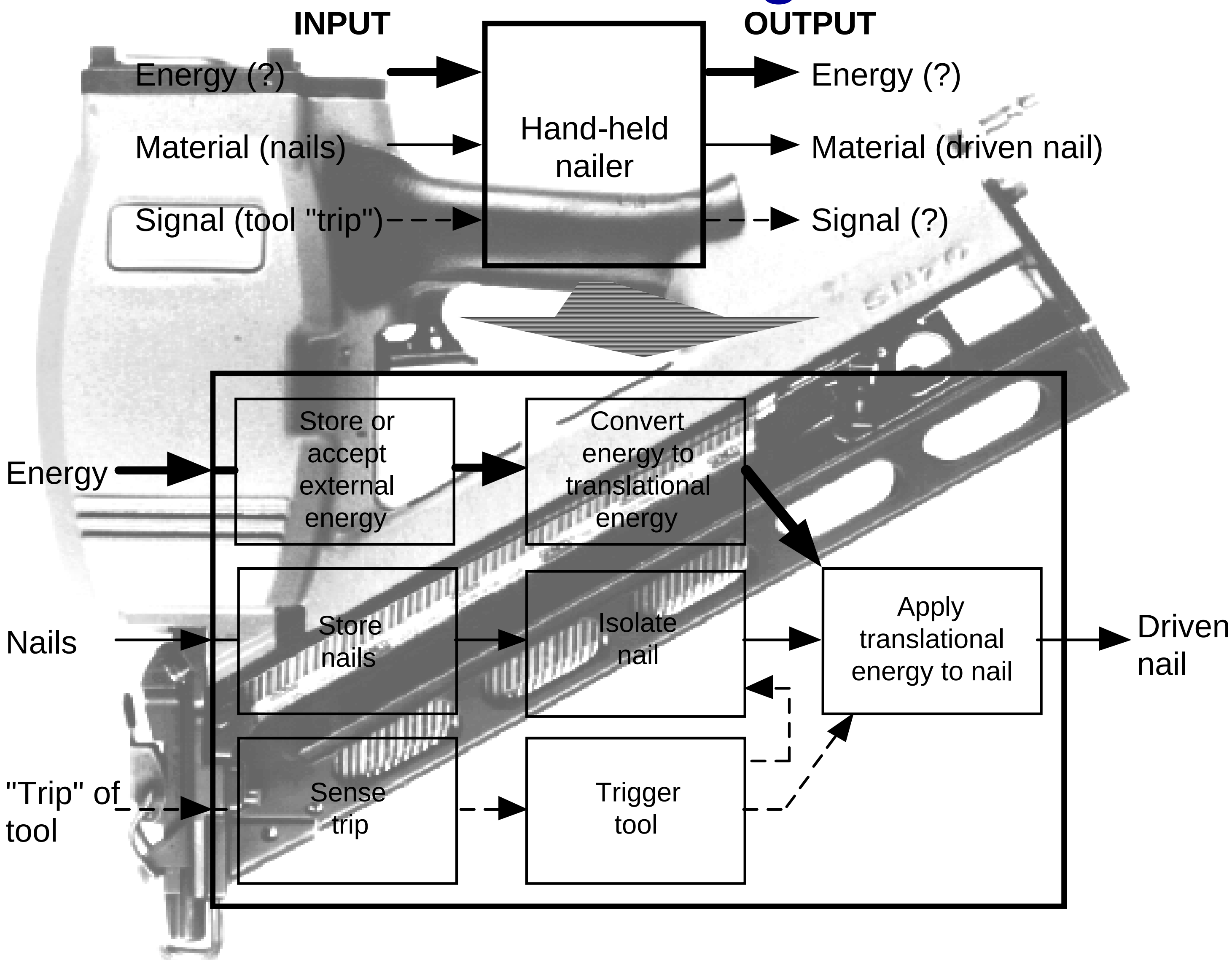
- **Quantity Breeds Quality**
  The team's best ideas are not likely to be found within the first few solutions considered. Rather, the best ideas are probably distributed uniformly over time.

- **Overlapping and Iteration**

- **Systematic Exploration**
  This step is particularly valuable when the problem has been successfully decomposed into subproblems.

- **Reflection**
  Encourage teams to reflect upon the process used and to improve upon it. Continuous improvement is an essential part of the product development process.

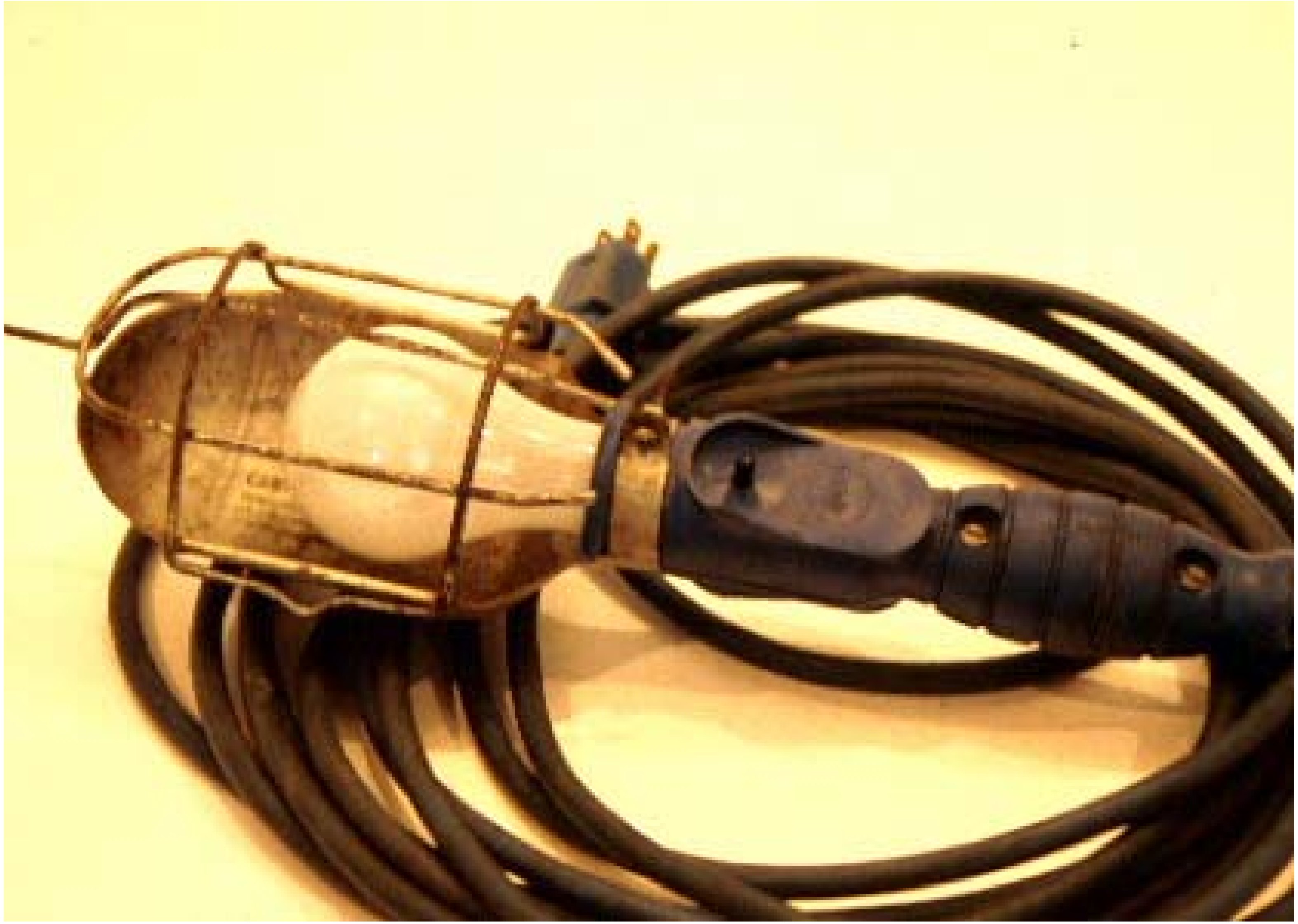
Problem Decomposition: Function Diagram



External Search:
Hints for Finding Related Solutions

- Lead Users
  - benefit from improvement
  - innovation source
- Benchmarking
  - competitive products
- Experts
  - technical experts
  - experienced customers
- Patents
  - search related inventions
- Literature
  - technical journals
  - trade literature

Capture Innovation from Lead Users: Utility Light Example

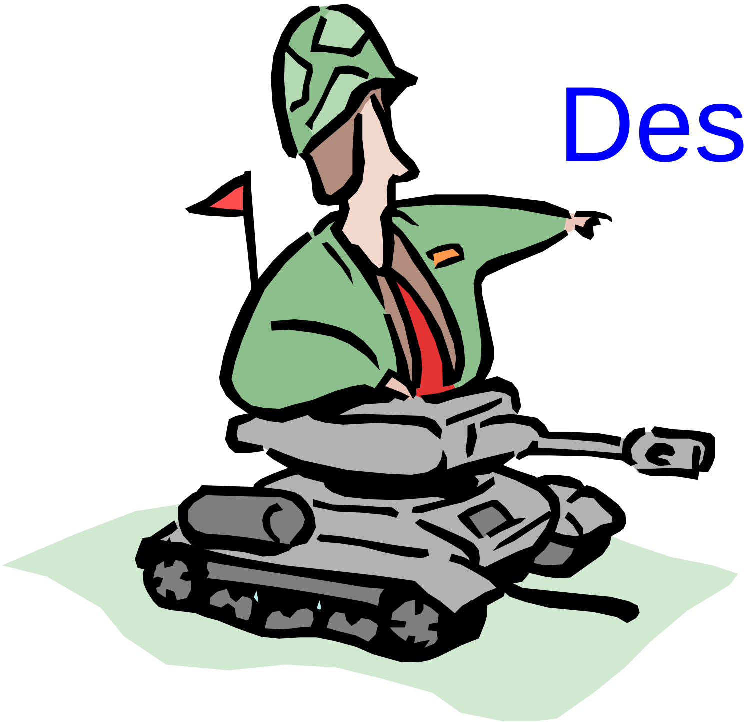


Internal Search:
Hints for Generating Many Concepts

- Suspend judgment
- Generate a lot of ideas
- Infeasible ideas are welcome
- Use graphical and physical media
- Make analogies
- Wish and wonder
- Solve the conflict
- Use related stimuli
- Use unrelated stimuli
- Set quantitative goals
- Use the gallery method
- Trade ideas in a group

Systematic Exploration:
Concept Combination Table

Convert Electrical Energy to Translational Energy	Accumulate Energy	Apply Translational Energy to Nail
rotary motor w/ transmission	spring	single impact
linear motor	moving mass	multiple impacts
solenoid		push nail
rail gun		



Design a better vegetable peeler!!!!

“none of the peelers works for everyone in every situation”

Customer Voice / Need

- "Carrots and potatoes are very different.“

  ➔ The peeler peels a variety of produce.
- "I cut myself with this one.“

  ➔The peeler is safe to use and store.
- "I just leave the skin on.“

  ➔ The peeler stays sharp or can be easily sharpened.
- "I'm left-handed. I use a knife."

  ➔The peeler can be used ambidextrously.

- "This one is fast, but it takes a lot off.“

  ➔ The peeler creates minimal waste.

- "Here's a rusty one.“

  ➔ The peeler is easy to clean.

- "This looked OK in the store."

  ➔ The peeler is durable.

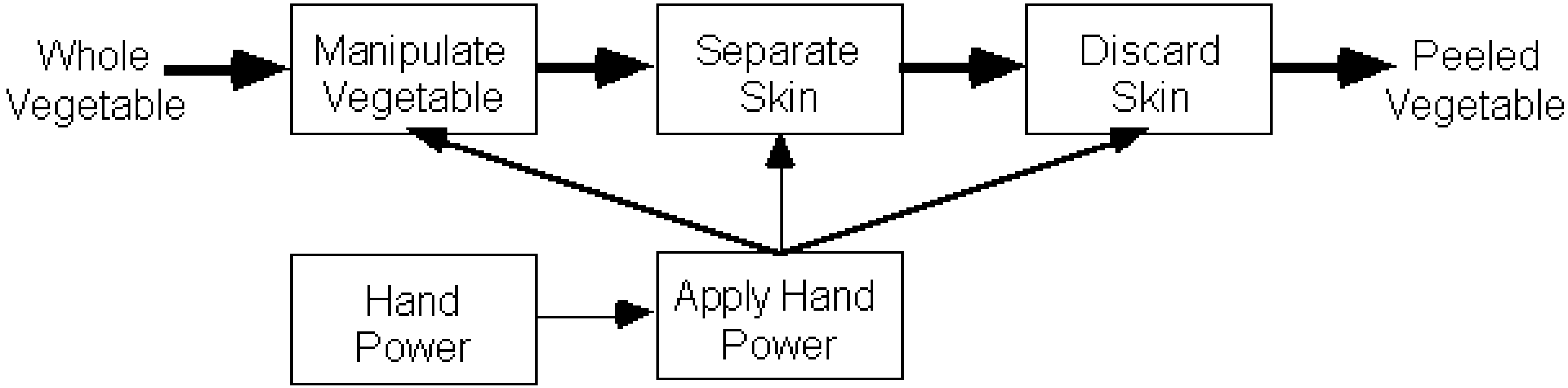
write down

a <u>function diagram</u>

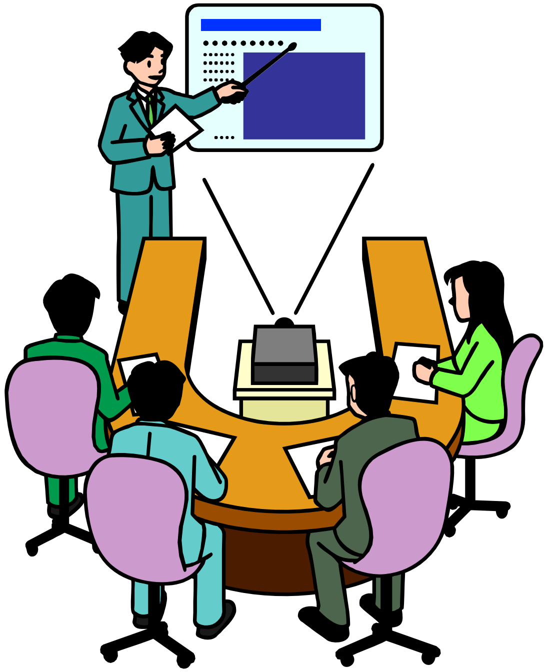
for the function "Peel produce for household

food preparation."

Function Diagram Example



Internal Search



Systematic Exploration

Process Reflection