ESD.33 -- Systems Engineering

Session #7
~~Pugh Concept Selection~~

Controlled Convergence

Dan Frey

Plan for the Session

➡ Notes on exam #1
- Summary of last session -- QFD
- Brainstorming (ideas from IDEO)
- Pugh Concept Selection
  - What is it for?
  - How do you use it?
  - Critique
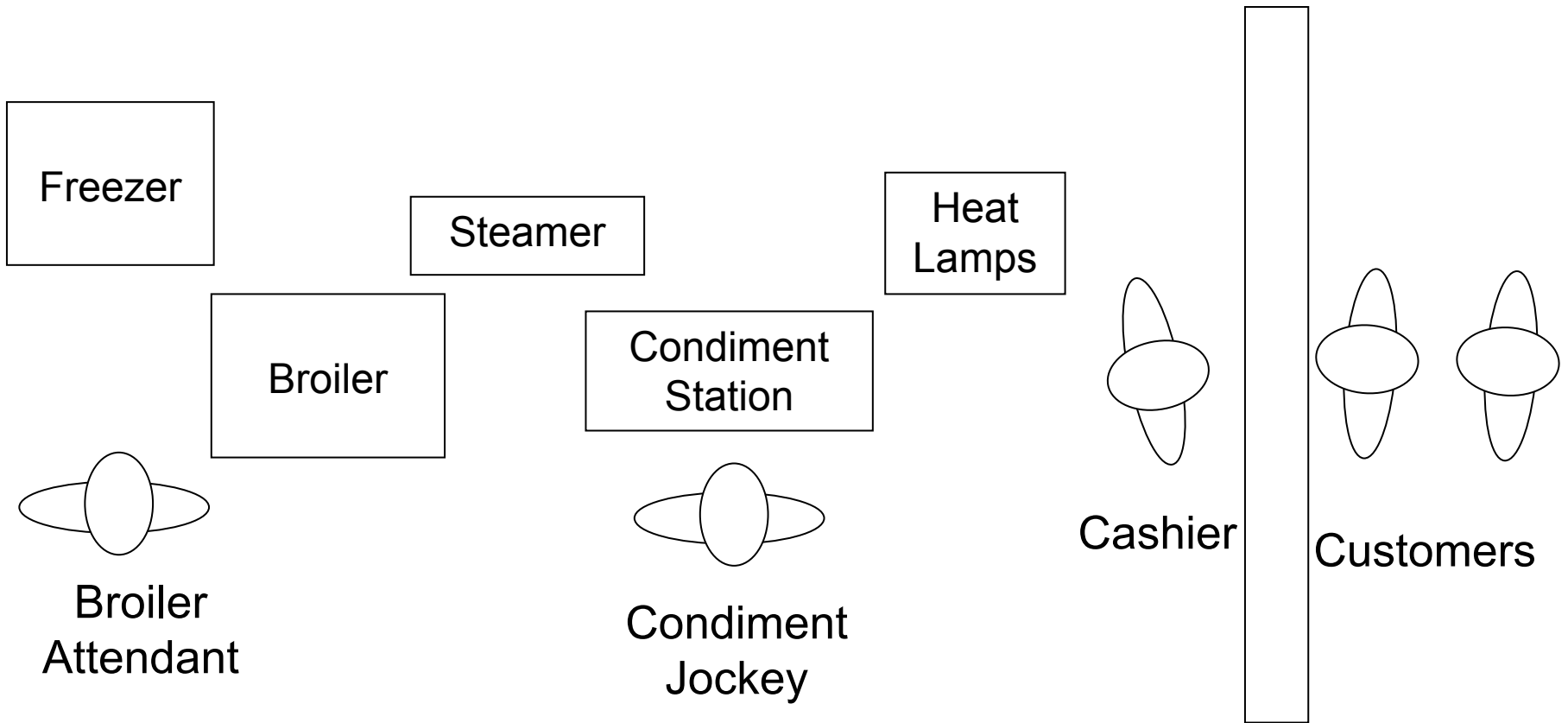- Next steps

Preliminary Feedback on Exam #1

- Most people seem to be doing very well
- Some people seemed to run into a time crunch (my theory is that #1 + open book caused the time problem)
- I will do my best to account for the time issue in final grading, but I do suggest preparing differently for the next exam
- There were a few points I obviously should have emphasized more clearly

Short Answers

- How is kaizen related to flow? (HP video)
- If a design has more DPs than FRs it is a _____ design and the extra DP contributes needlessly to _____.
- A decoupled design must have its DPs set in a _____.
- "Remove" rather than "scrape" ice. Or better yet, maintain a clear view.

Burger Czar
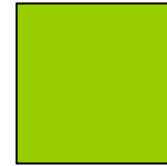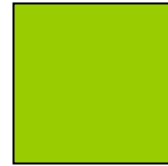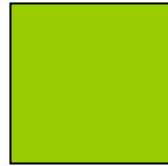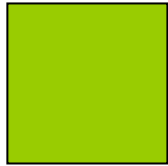# "where the burgers are"

Freezer

Steamer

Heat Lamps

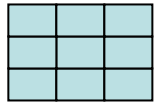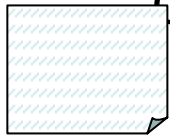Broiler

Condiment Station

Cashier

Customers

Broiler Attendant

Condiment Jockey

Push Systems –

Order arrives at the front of the system and is produced in the economical order quantity.
Q. How long did it take for the order to go through the system?

Time = 0
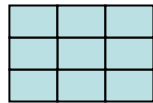
Time = 1
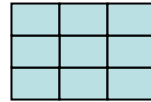
Time = 2
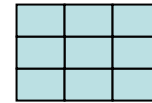
Time = 3
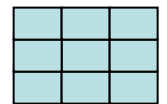
Time = 4

Pull Systems-

The order arrives at the end of the line and is "pulled" out of the system. WIP between the machines allows quick completion.
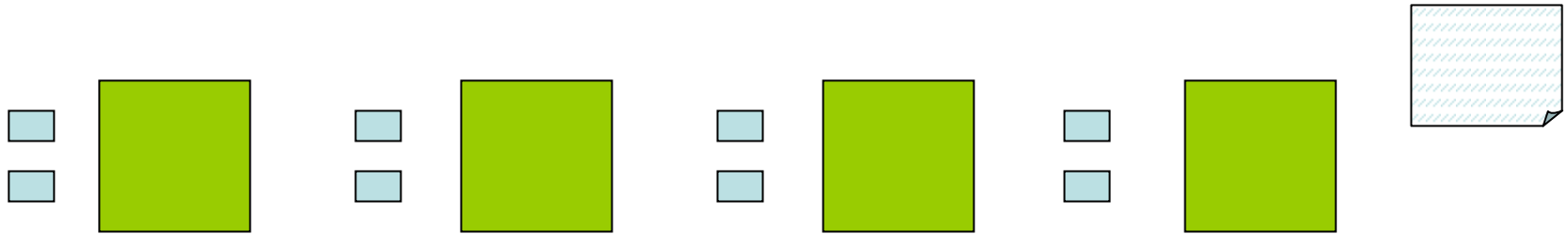
Pros and Cons;

Pull can fill small orders quickly, but must keep inventory for all part types. Design can help here but not in all cases.

No Silver Bullet

- People are selecting a variety of frameworks (both "useful" and "not so useful")
- People are talking about what they know
- The results are very good

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"Rooms" in the House of Quality
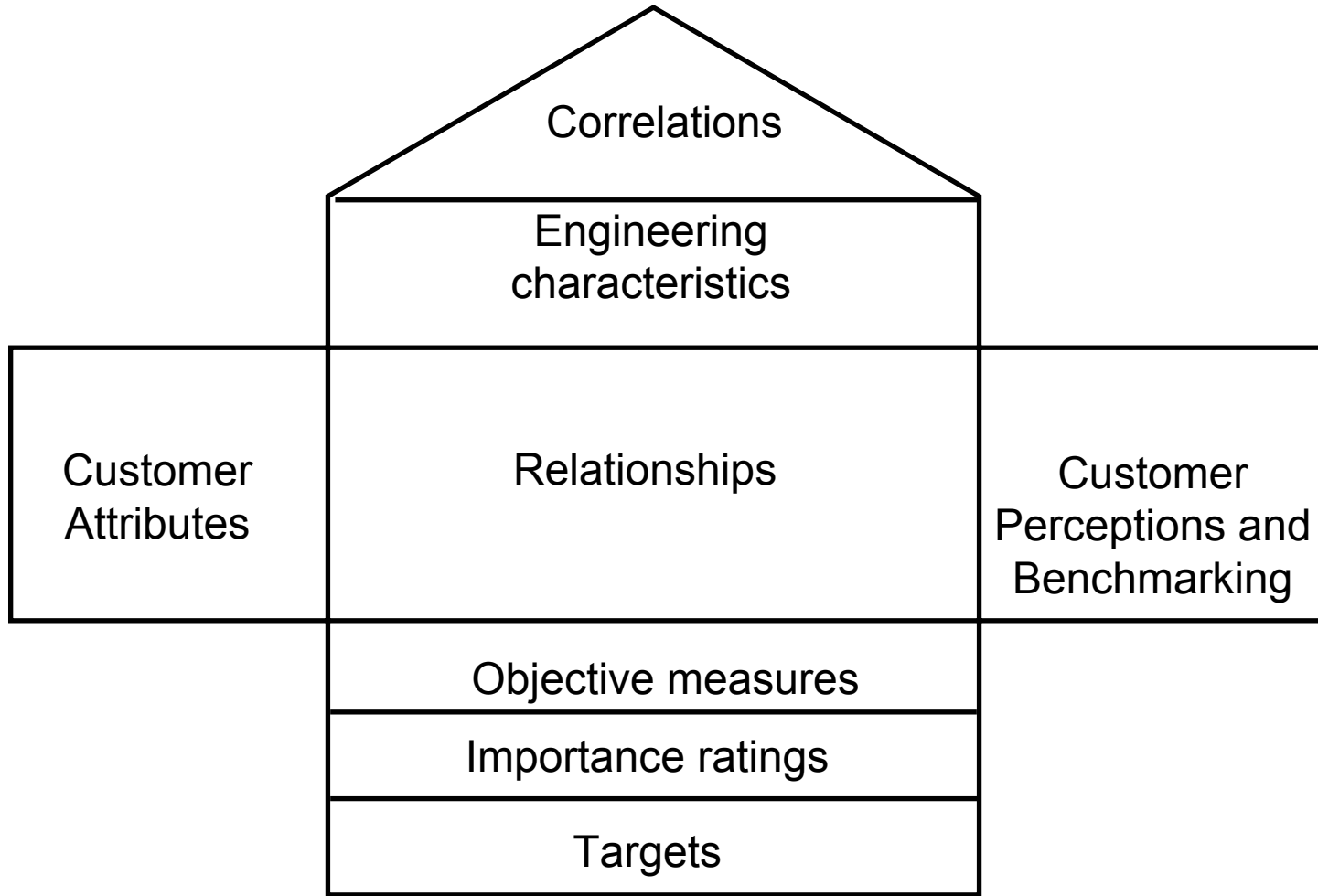
Figure adapted from Lou Cohen.

What is the QFD for?

QFD is for

- Coordinating skills within an organization
  - Serves as a lingua franca
  - Helps break down the functional silos
  - Encourages real teamwork
- Designing goods that customers want to purchase
  - Creates external focus
  - Provides immersion in the specifications
- Target setting for mature products

QFD is NOT for

- Automatic decision making
  - "the house absolves no one of the responsibility of making tough decisions"
- Implementing a quick fix
  - "None of this is simple…"
  - "An elegant idea ultimately decays into process…"
  - "What is also not simple is creating an organization capable of absorbing elegant ideas"
- More difficult to use for highly novel / unprecedented functions

Hauser and Clausing, 1988, "The House of Quality", *Harvard Business Review.*

Quality Function Deployment Summary

- "… can break down functional barriers and encourage teamwork …"
- "The house relives no one of the responsibility of making the tough decisions"
- Many of the most effective companies use QFD
- Surveys suggest that QFD provides long term competitive advantages
- The arguments against QFD so far seem weak

Controlled Convergence

- This is Pugh's vision of the conceptual phase of design
- Takes us from a specification to a concept
- Convergent and divergent thinking equally important

Front-end design work — e.g., QFD

PDS — specification

Concept generation — e.g., brain-storming

Initial number of concepts based on PDS

Apply controlled convergence (CC)

Initial number reduced

Apply concept generation (CG)

New ones added

CC

CG — Further reduction (FR)
Further addition (FA)

CC

CG — FR
FA

CC
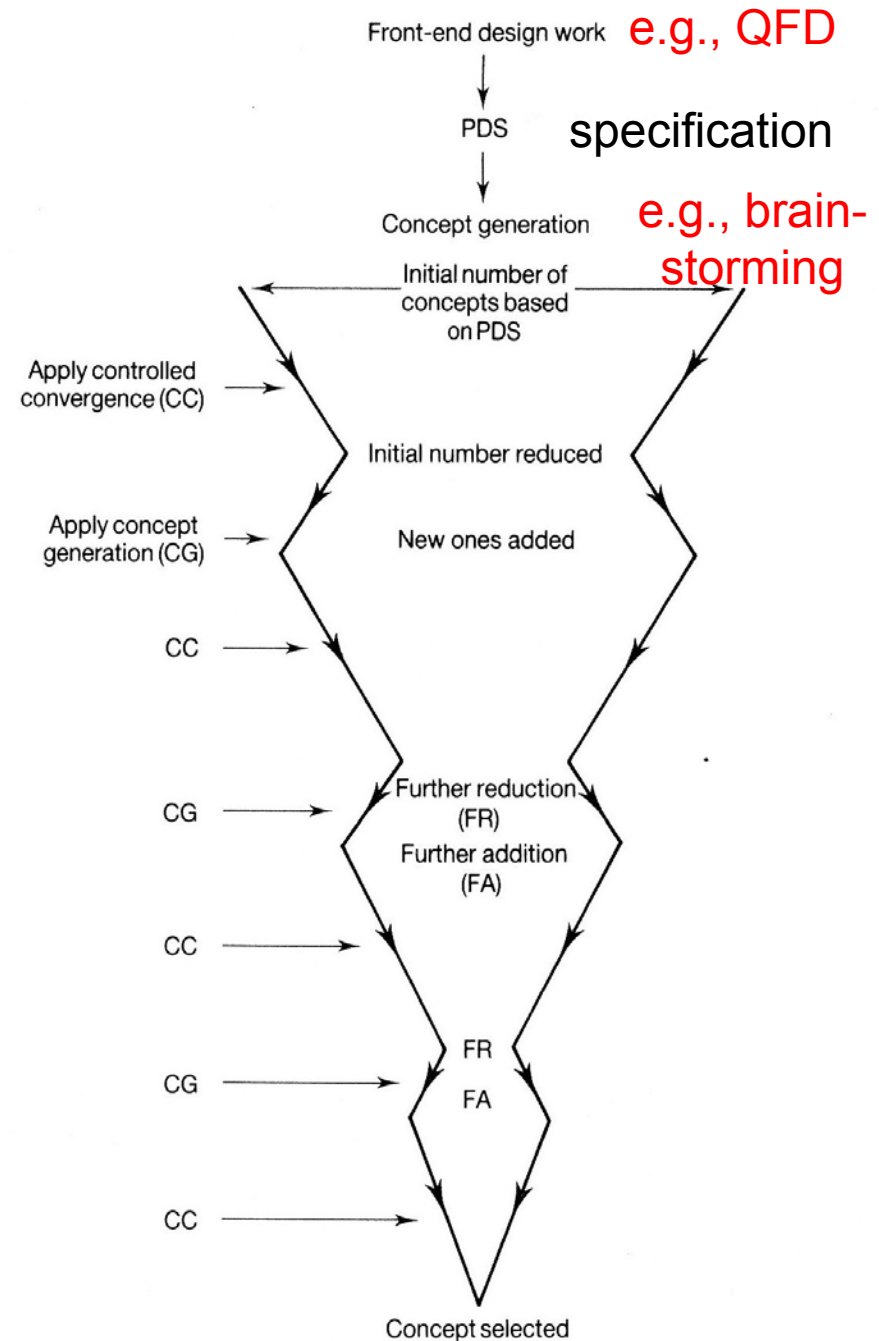
Concept selected

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Kelley, Tom. *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*. New York: Doubleday, 2001.

By the general manager of IDEO --

America's top design firm.

This book describes the processes

and practices that keep IDEO

creative and vibrant.

IDEO Brainstorming

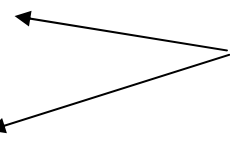- A group problem solving technique that involves spontaneous contribution of ideas from all members of the group

Composing the Brainstorming Group

- Get a range of expertise and perspectives
  - Software / hardware
  - Marketing, engineering, maintenance, sales
  - Engineers, scientists, linguists, artists
- Include the client if possible
- Enough people to maintain momentum
- Small enough that all are engaged
  - 5 to 7 people

Preparing for the Brainstorm

- Understand the problem
- Gather background info

The House of Quality!!

- Set up the room
  - Everyone around one table
  - Stacks of 8.5X11 plain paper
  - Whiteboards or easels and markers
  - Props (hardware, technologies)
  - Food and drink

The Five Rules of the Brainstorm

- Defer judgment ⟵   What did Pugh say about this?
- Build upon the ideas of others
- One conversation at a time
- Stay focuses on the topic
- Encourage wild ideas

Recording Ideas

- Record EVERY idea
- Make a good picture of the idea
  - This is helpful for the Pugh matrix later
- Headlining (choose a descriptive name)
- Shoot for a large number (100 in one hour)

Some Brainstorming Tricks to Try

- Analogy (nature, other technologies, …)
- Inversion
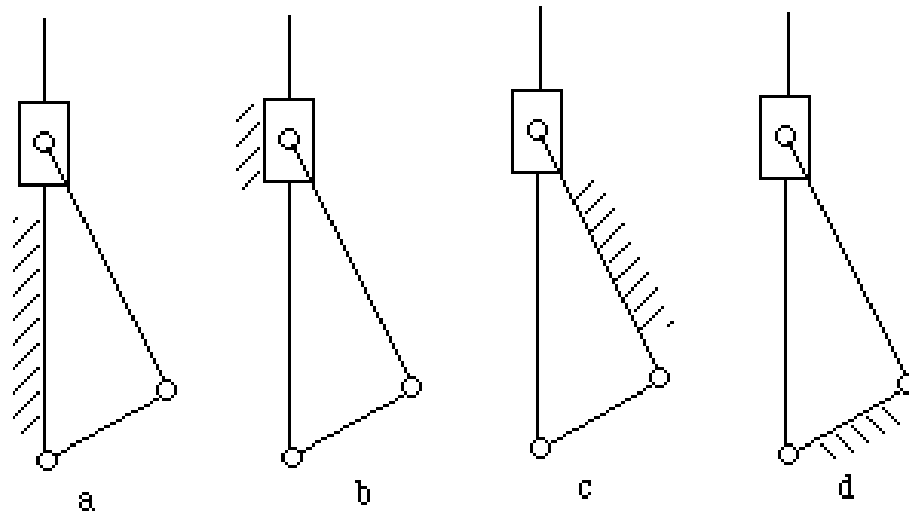
- Combination
- Checklists (TRIZ is essentially a well designed checklist, more in session #8)

Plan for the Session
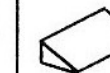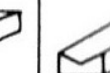
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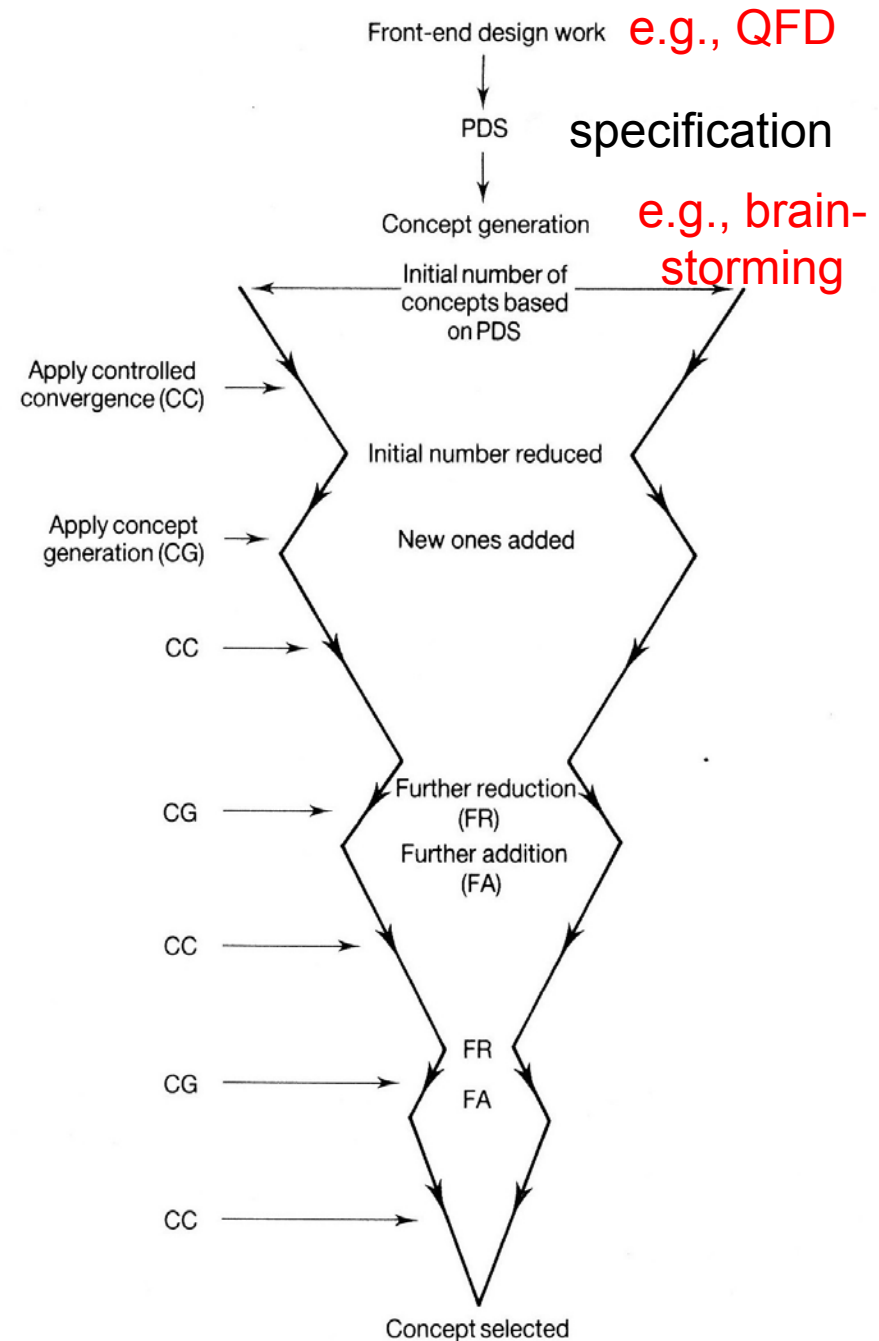- Summary of last session -- QFD
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Evaluation Matrix

Concept / Criteria	1	2	3	4	5	6	7	8	9	10	11
A	+	−	+	−	+	−	D	−	+	+	+
B	+	S	+	S	−	−		+	−	+	−
C	−	+	−	−	S	S	A	+	S	−	−
D	−	+	+	−	S	+		S	−	−	S
E	+	−	+	−	S	+	T	S	+	+	+
F	−	−	S	+	+	−		+	−	+	S
Σ+	3	2	4	1	2	2	U	3	2	4	2
Σ−	3	3	1	4	1	3		1	3	2	2
ΣS	0	1	1	1	3	1	M		1	0	2

The First Run

- Generate multiple solutions to same problem spec.
- Depict the solutions (sketches)
- Form the matrix
- Choose criteria (and <u>clarify</u> them)
- Choose datum (pick one of the 'best' solutions)
- Insert comparisons (+, S, -), form sums thereof
- Look at strongest concepts, try to reverse negatives (combine with complementary concepts)
- Look at weaker concepts, try to improve them
- Eliminate the weakest remaining concepts

The Second Run

- Strengthen the best concept<u>s</u> from first run
  - This is substantial engineering work
  - More detailed descriptions will emerge
  - Note the plural – develop multiple concepts
- Expand evaluation criteria
- Choose new datum (pick one of the 'best' solutions)
- Insert comparisons (+, S, -), form sums thereof
- Seek agreement among team on the best concept
- Further phases may be required to obtain convergence
- "…experience has shown that, almost without exception, the results of Phases I and II will be confirmed…"

Some Challenges

- "people who have a lot of experience … exhibit an impatience 'to get on with it' and may consider that the procedure holds them back…"

- "strong willed individuals who have a lot of experience and whose initial concepts have not emerged in the final selection … commence a defense based on emotion, experience, and bluster…"

Role of the Facilitator

- Controls the flow / pace of the session
- Records the results (creates the matrix)
- Maintains a tight discipline on the participants
  - Comparison to the datum concept
  - Preventing tangents
  - Encourages clarification of criteria
  - Encourages clarification of concepts
- Seeks opportunities for divergence (hybrids)

What is the Pugh Matrix for?
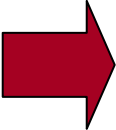
The Pugh matrix <u>is</u> for

- Structuring and representing an evaluation procedure
  - Serves as common visual
  - Provides a discipline
  - Helps break down self-sealing behavior
  - Encourages real teamwork
- Convergence
  - Eliminates weaker ideas
  - Retains a set of strong concepts
- Divergence
  - Helps to identify opportunities for combination

The Pugh matrix <u>is NOT</u> for

- Automatic decision making
  - "the scores or numbers … are for guidance only and must not be summed algebraically."
  - "it avoids the rigidity and false confidence of rating/weighting matrices"
- Completely controlling the process
  - "… stimulates creative unconstrained thinking due to its <u>lack of rigorous structure</u>"
- Trade studies
  - More on this today

Pugh, Stuart, 1991, *Total Design*, Addison-Wesley, New York.

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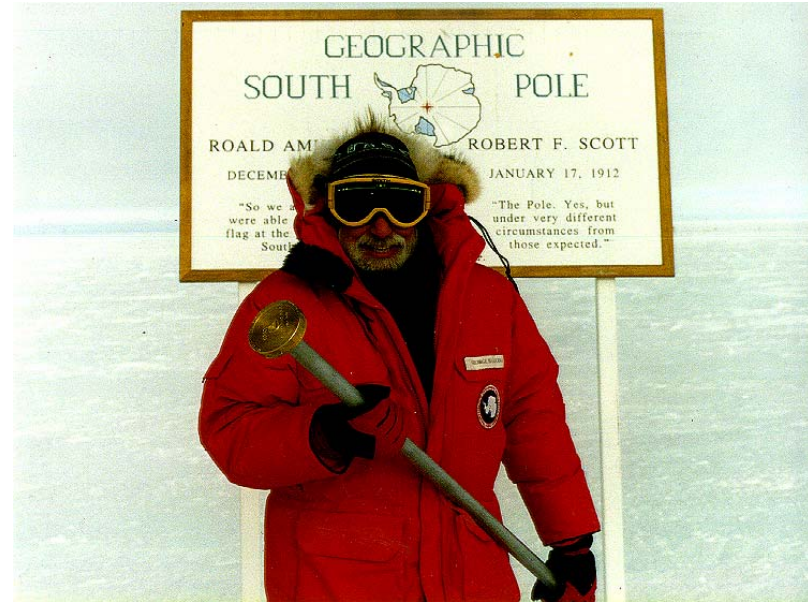- Pugh Concept Selection
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Engineering Design is "Science" Too

George A. Hazelrigg

Program Director, Manufacturing Machines and Equipment
Division of Design, Manufacture, and Industrial Innovation
National Science Foundation

Arrow's Impossibility Theorem

- ## Given the choice between *x*, *y* and *z*, a group preference should satisfy conditions:
  - If everyone in the group prefers *x* over *y*, the group preference should be for *x* over *y*
  - If the group preference is for *x* over *y* and for *y* over *z*, then the group preference should be for *x* over *z*
  - If the group must choose between *x* and *y*, their preference should not depend upon whether *z* exists or not
  - There shouldn't be a dictator in the group, i.e., the preferences of each individual in the group should count

- ## Arrow's Impossibility Theorem: no method of preference aggregation meets these conditions

"Enabling the nation's future through discovery, learning, and innovation."

By design, this vision captures the dynamism that has shaped NSF's history. It's no accident that terms like discovery, learning, and innovation are all resting side-by-side in the same set of words. You'll see them again later when we focus on engineering.
An our strategic goals to fulfill the mission in three words: People, Ideas and Tools. And order is important!

A big mistake

To think that you can make an optimal decision for a group

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Another big mistake

To think that an optimal product design is comprised of optimized product attributes

Customer	Attribute					
	Size		Shape		Color	
	Large	Small	Flat	Bumpy	Red	Green
John	Hate	Great	Great	OK	Great	OK
Pam	Great	OK	Hate	Great	Great	OK
Trevor	Great	OK	Great	OK	Hate	Great
Preference	Large		Flat		Red	

Potential market: LFR 0, SBG 3   SBG is clearly a better design than LFR

Multiplicative Utilities

Customer	Attribute Utility					
	Size		Color		Shape	
	Large, L	Small, S	Red, R	Green, G	Flat, F	Bumpy,B
Tom	0	1	1	.9	1	.9
Pat	1	.9	0	1	1	.9
Jan	1	.9	1	.9	0	1

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Pugh phew

Attribute	Product Design							
	LRF	SGB	SGF	SRB	SRF	LGB	LGF	LRB
Size	L	-	-	-	-	0	0	0
Color	R	-	-	0	0	-	-	0
Shape	F	-	0	-	0	-		-
Tom	0	.81	.9	.9	1	0	0	0
Pat	0	.81	.9	0	0	.9	1	0
Jan	0	.81	0	.9	0	.9	0	1
Pot Mkt	0	3	2	2	1	2	1	1

Pugh selection is exactly opposite, it has rank ordered designs precisely wrong

Summary

- QFD helps with the front end
- Then a large number of concepts are needed
- Pugh controlled convergence helps with the convergent and divergent process
- Enhances creativity, communication, and builds consensus
- Don't over emphasize numbers
- Do be aware of how product attributes combine

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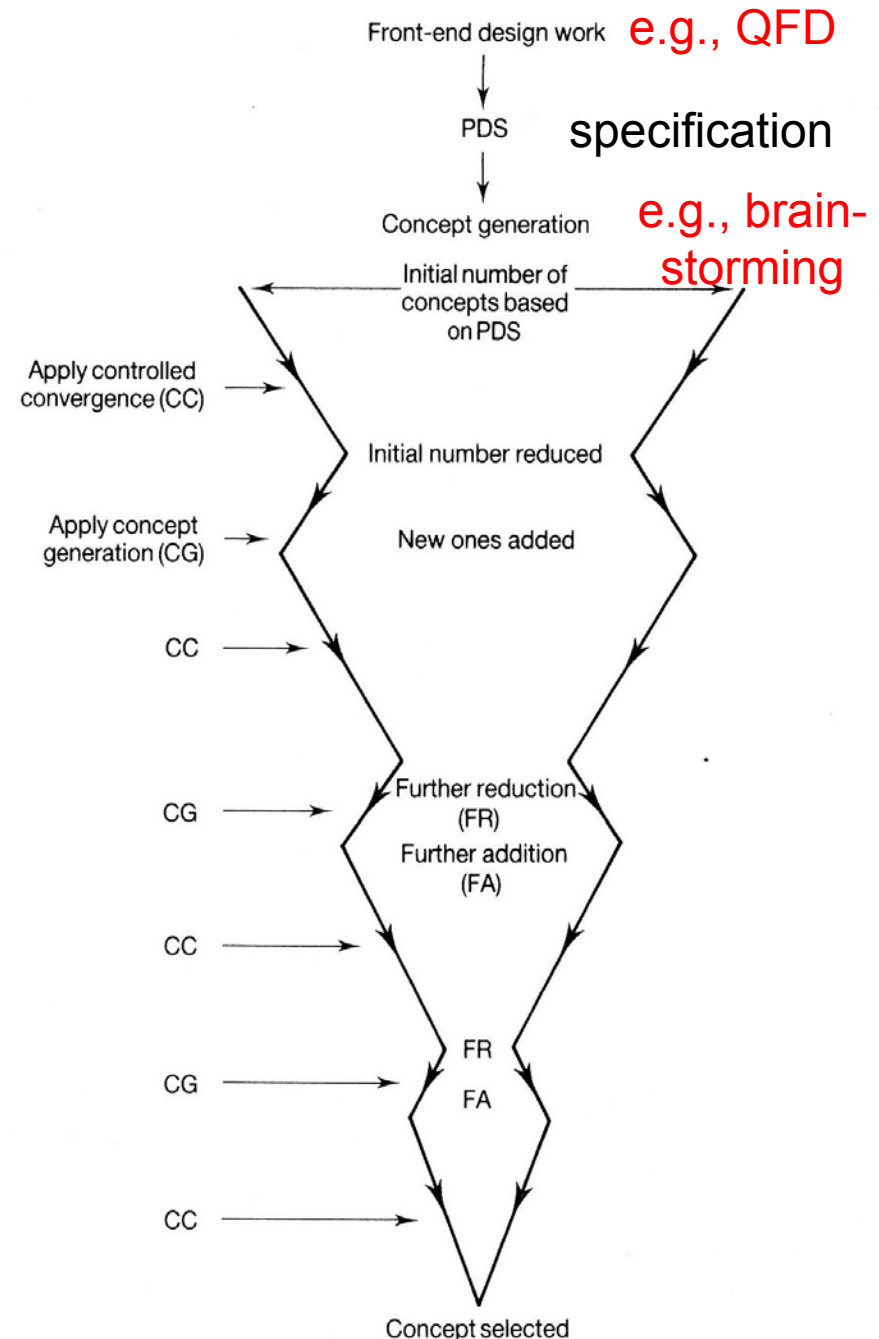
Next Steps

- You can download HW #4
  - Due 8:30AM Tues 6 July
- See you at Thursday's session
  - On the topic "Effective Innovation"
  - 8:30AM Thursday, 1 July
- No reading assignment for Thursday
  - But you can pre-view the slides