Andover Robotics Team Training Series

IX. Robust Design

The 4 Steps of Project Management

STEP 1 – Establish The Objective

- capture the requirement
- define the strategy

STEP 2 – Plan The Project

- determine tasks
- allocate resources
- establish timing plan

STEP 3 – Implement The Project

- execute the plan
- monitor progress and adjust resources

STEP 4 – Wrap up Project

- deliver product
- establish lessons learned and best practices

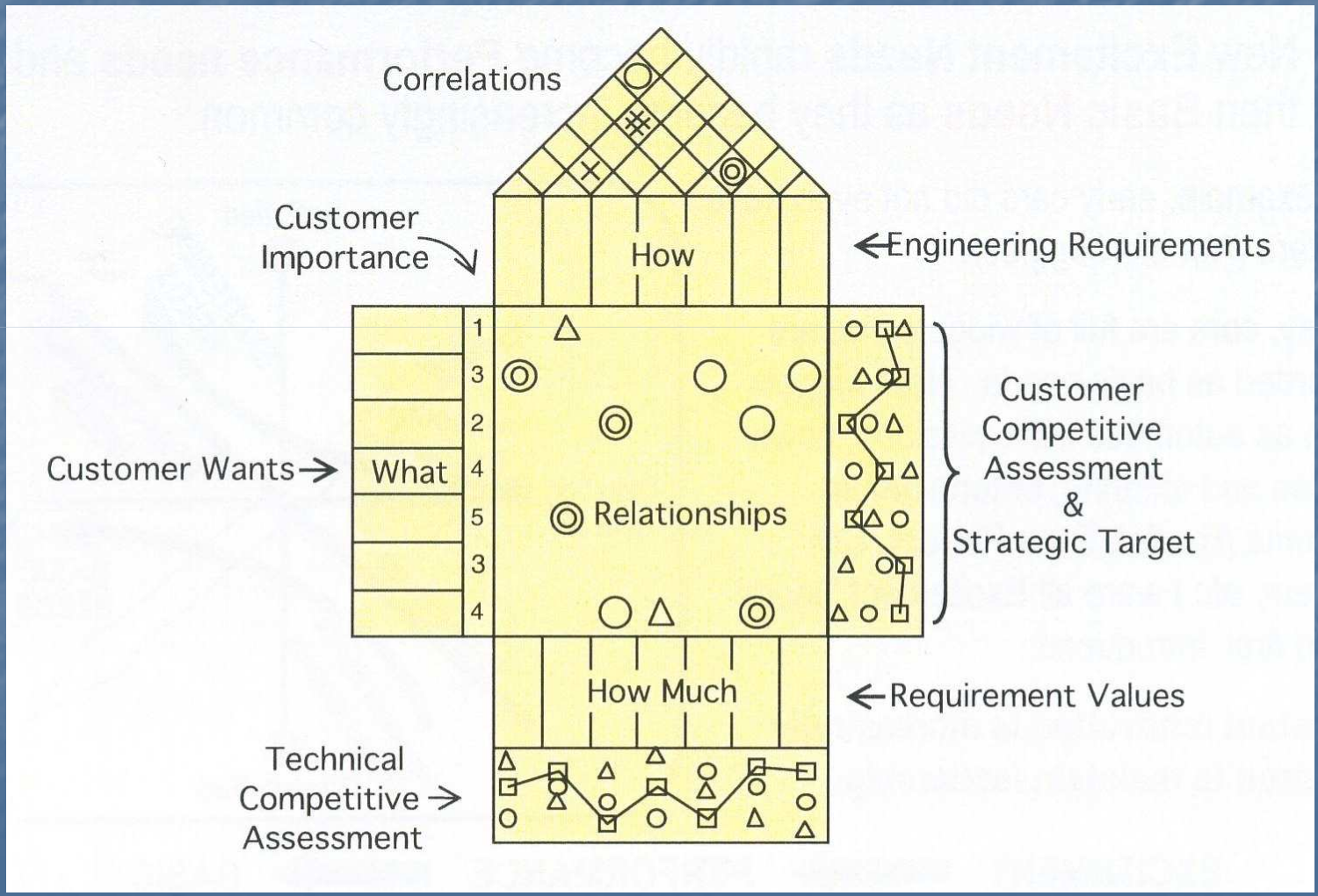
Ideal FIRST Robot Design Process

1. Understand the rules
2. Analyze the game, examine all possible scoring and defensive scenario
3. Play mock-up game
4. List the tasks, no robot talk, no design talk
5. Note cost (game play effort, time)
6. Note benefit (points reward/deny, reversible?)
7. Rank based on cost/benefit
8. Brainstorm chokehold strategy if any
9. The ranked list of tasks becomes the Customer Wants, sometimes known as the Voice of the Customer (VOC)

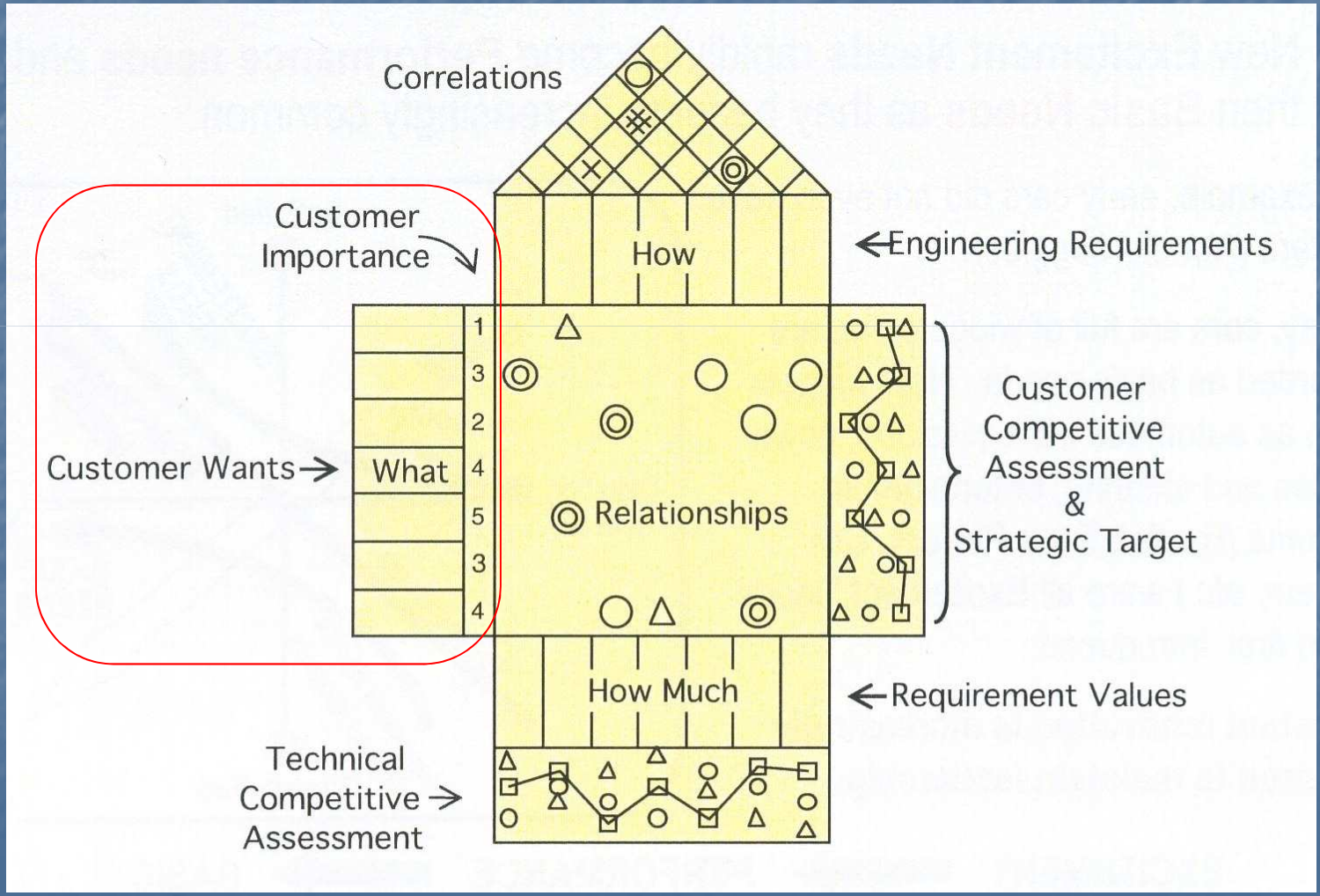
Ideal FIRST Robot Design Process (cont.)

10. Translate Customer Wants into appropriate Engineering Requirements using Quality Function Deployment (QFD)
11. Generate Design Concepts based on Engineering Requirements
12. Select Concept based on function, cost, weight, build time, risks, durability, ease of repair and WOW factor using Pugh Concept Selection or Decision Matrix
13. Run full system test to failure and improve design
14. Develop list of spare parts for replacement

Quality Function Deployment



House of Quality

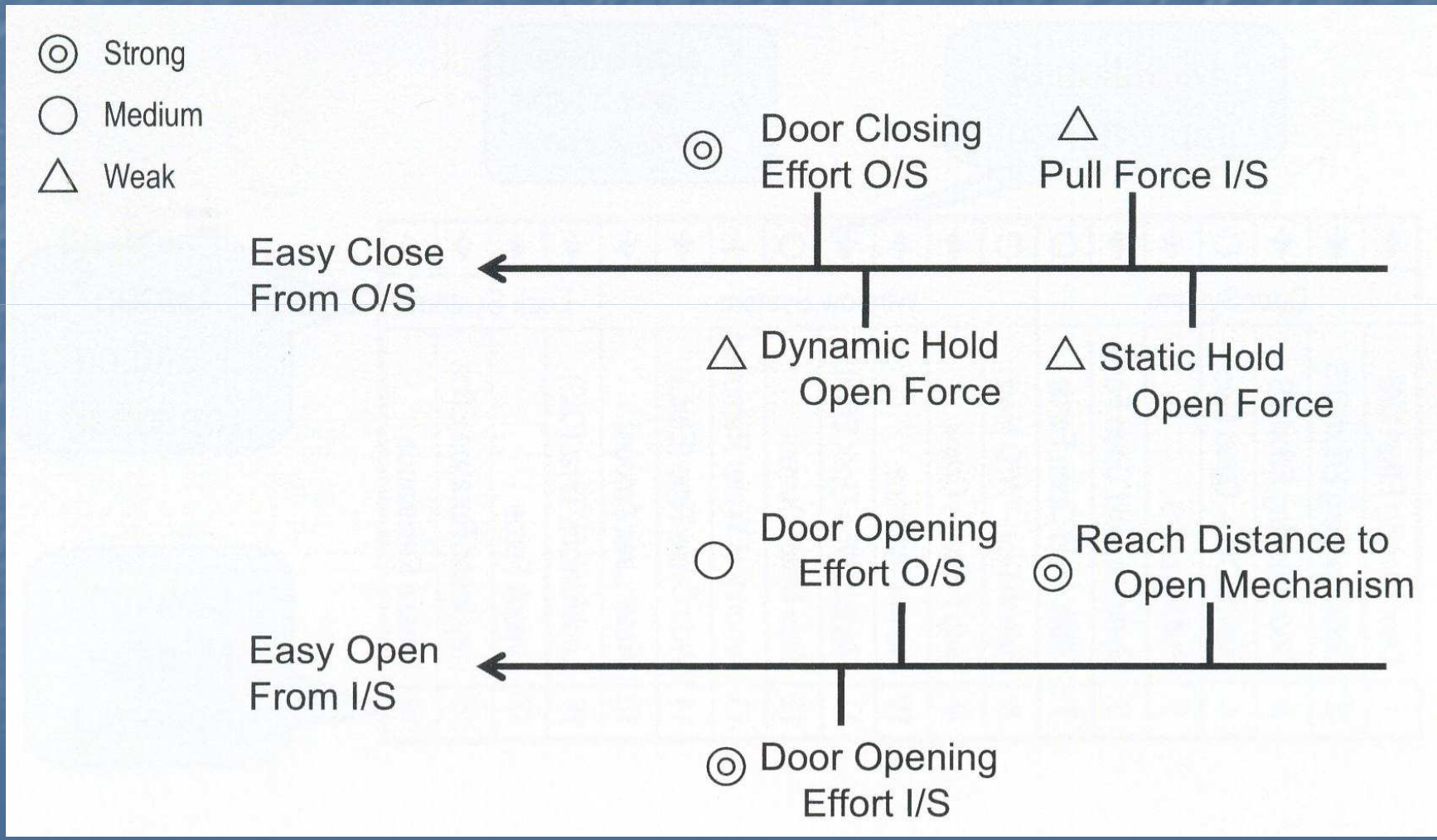


Customer Wants

1	Easy to Open/Close	Easy Close From O/S	5
2		Easy Open From O/S	4
3		Easy Open From I/S	3
4		Easy Close From I/S	4
5		Stays Open in Check Pos.	3
6		Handle Looks Nice	2
7	Window Operates Easily	Crank-Easy to Reach	4
8		Crank-Easy to Grasp/Hold	3
9		Easy to Operate (Manual)	3
10		Wipes Dry	2
11		Operated Rapidly (Elect)	2
12		Doesn't Leak Water	5
13	Lock Latch Easily	Lock Knobs Oper. Easily	4
14		Latch Lasts Long Time	4
15		Key Operates Easily	3
16		Doesn't Freeze	4

importance

Translate Customer Wants into Engineering Language



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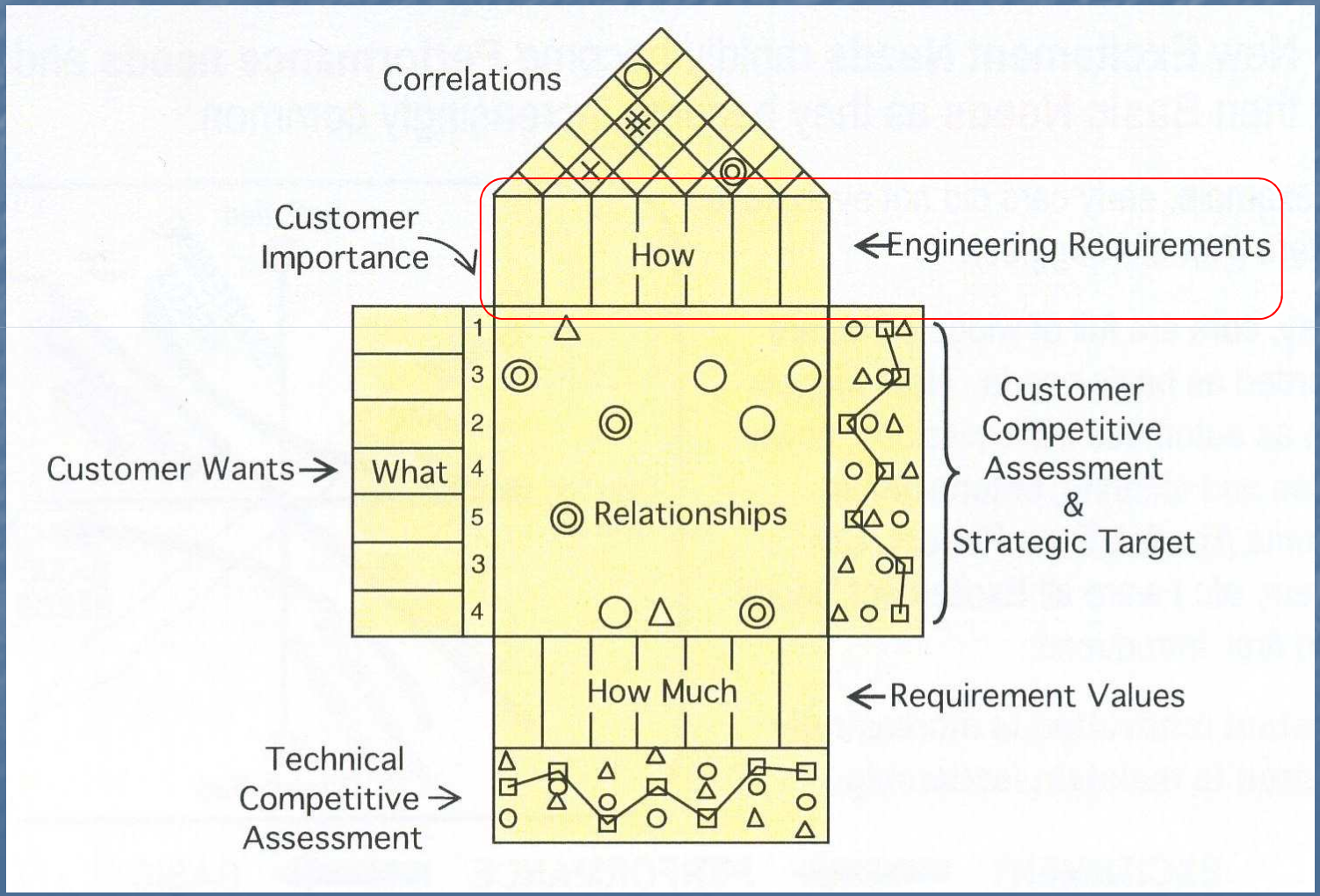
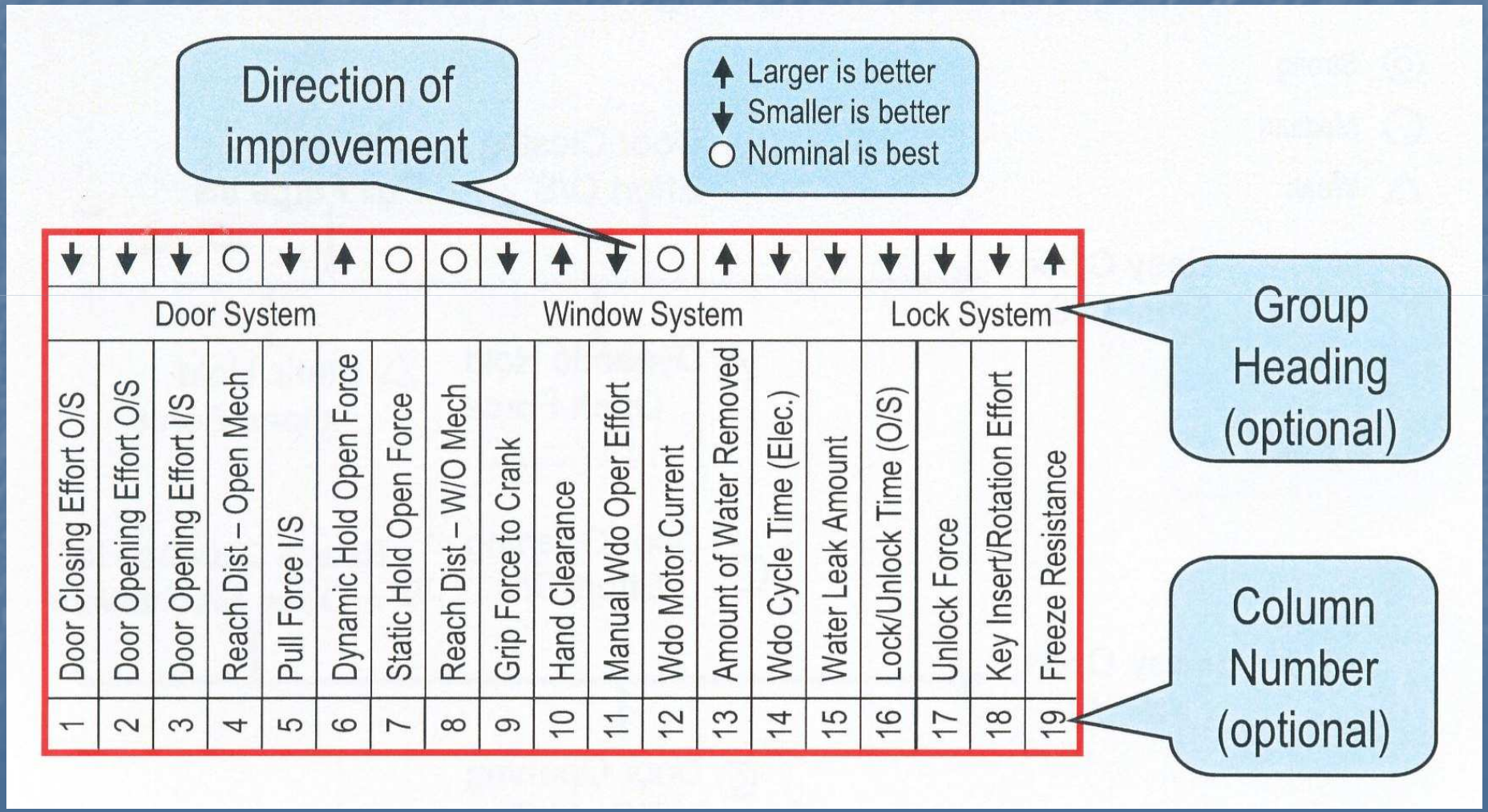


Add Engineering Requirements



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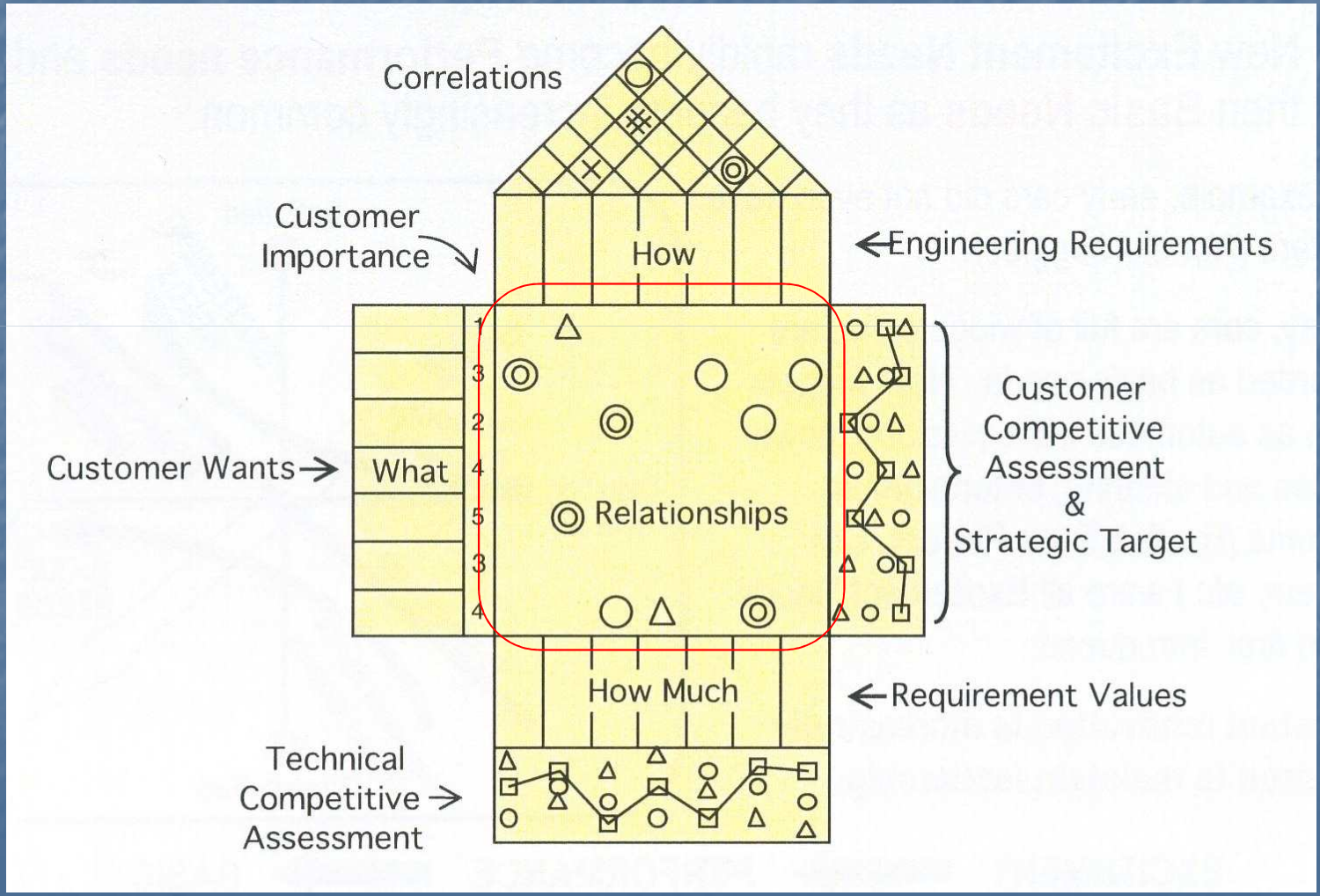


Symbols for Relationship Matrix

- The relationship matrix is completed using the best judgment of the team. It is not a vote, but rather a technical decision. There are no absolute rules for this, but the following may be helpful:

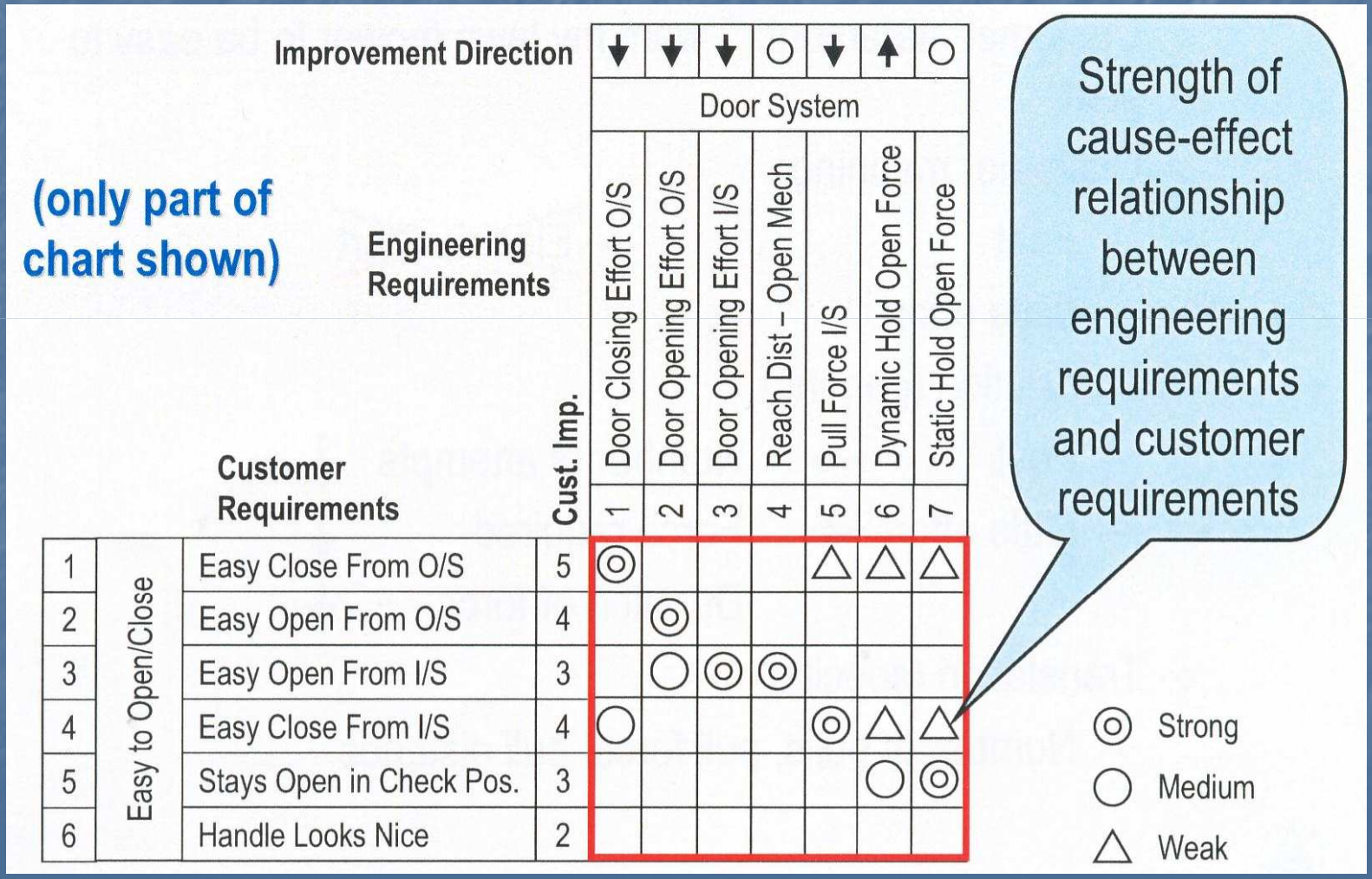
◎ – Use the double circle (strong relationship) where the engineering requirement is a primary driver for the customer requirement.

○ – Use the single circle (medium relationship) where the engineering requirement clearly has some influence on the customer requirement, but is not a primary driver.

△ – Use the triangle (weak relationship) where the engineering requirement may have some degree of influence.

It's a good idea to document your thinking as you proceed!

Fill In Relationship Matrix



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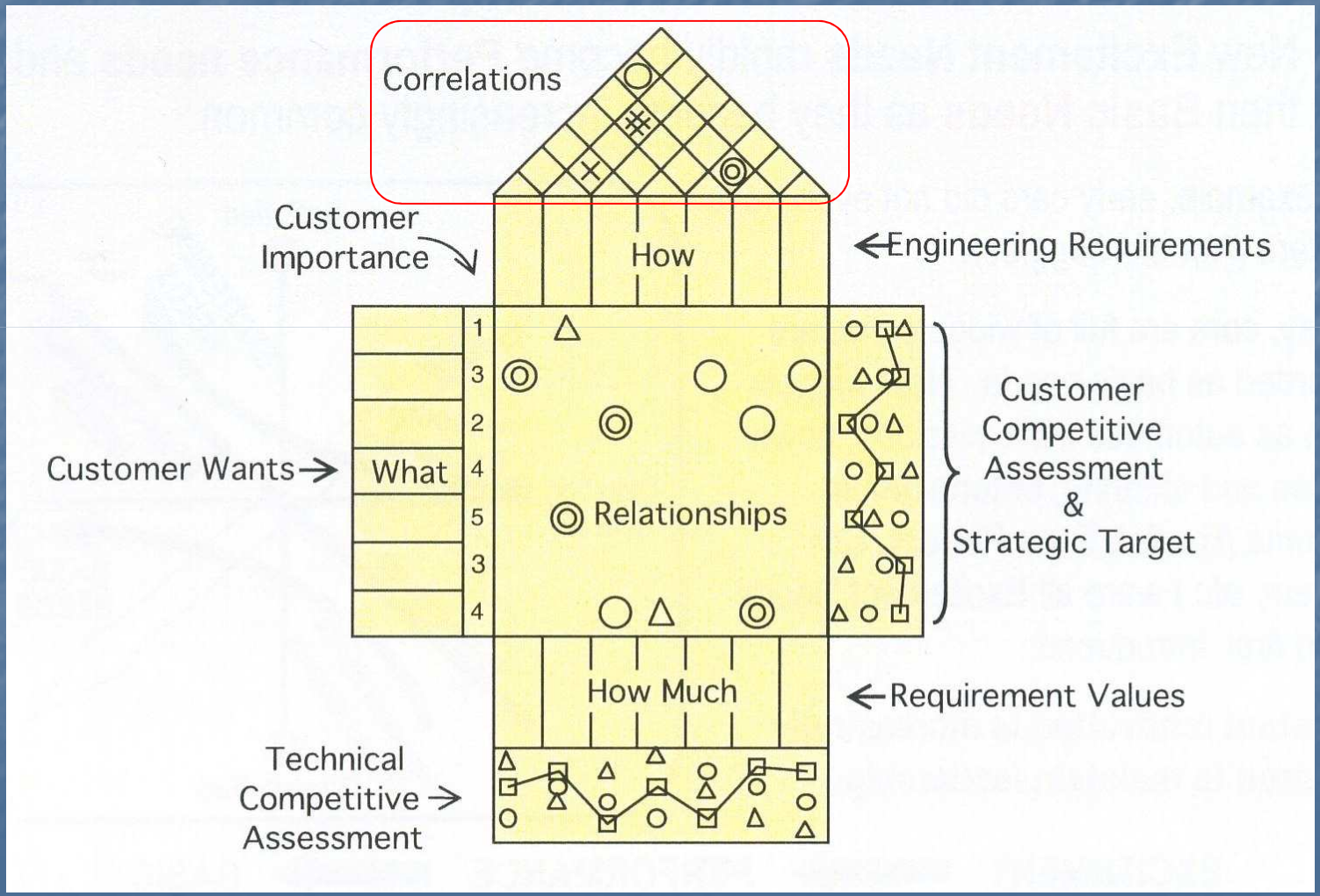
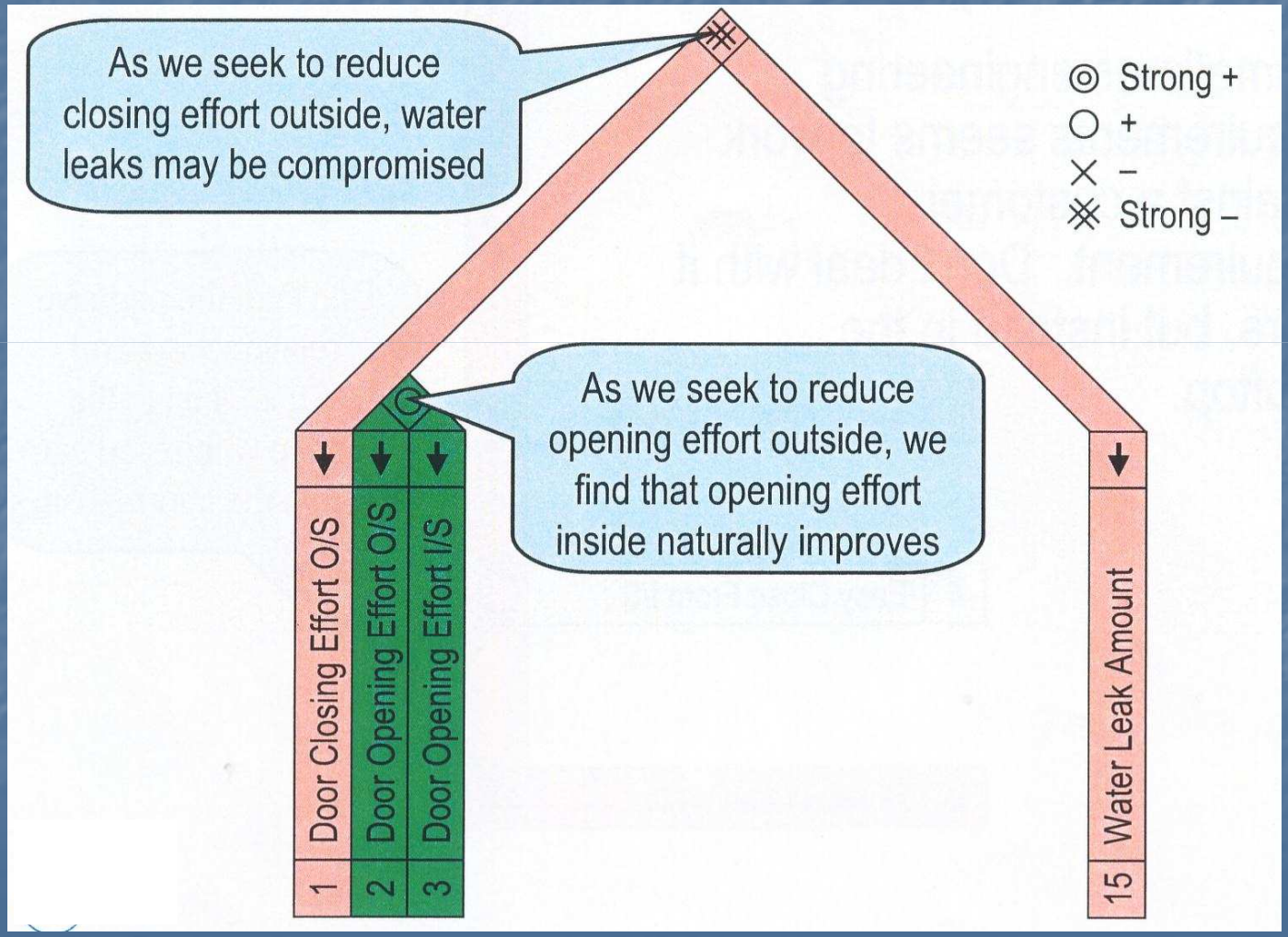


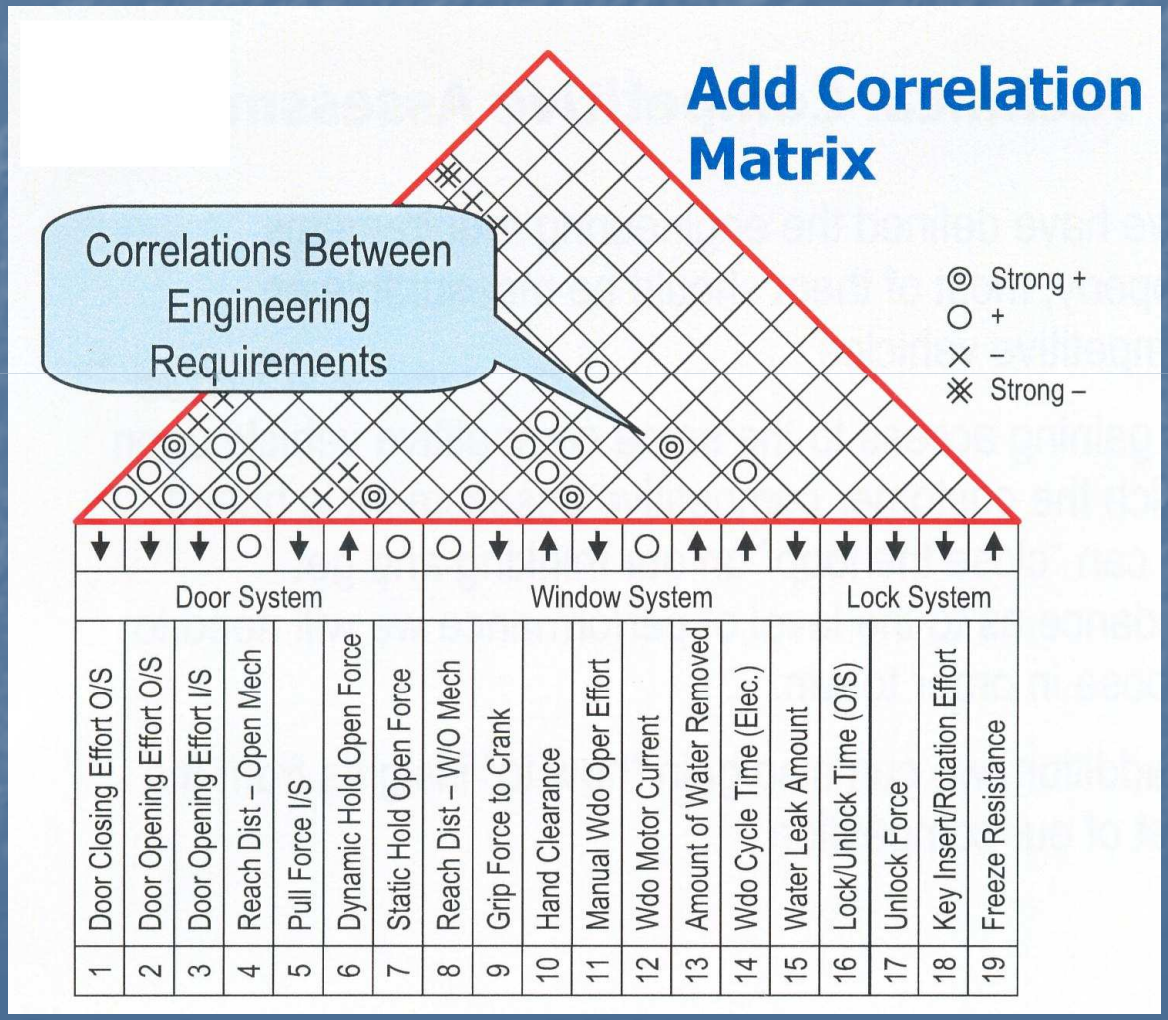
Symbols for Correlation Matrix

- While we may develop the engineering requirements as a set of individual specifications, there often are related to each other.
- For instance:
  - as we seek to improve door closing effort, we may find that leak resistance is compromised. Such cases, where the engineering requirements work against each other, are called negative correlations, shown with a cross or double cross, depending upon the strength of the adverse correlation.
  - As we seek to improve door opening effort from the outside, we may find that door opening effort from the inside improves as well. This is a positive correlation, shown as a circle or double circle
- The correlation matrix is used to show the relationship between pairs of engineering requirements.

Fill In Correlations



Fill In Correlation Matrix



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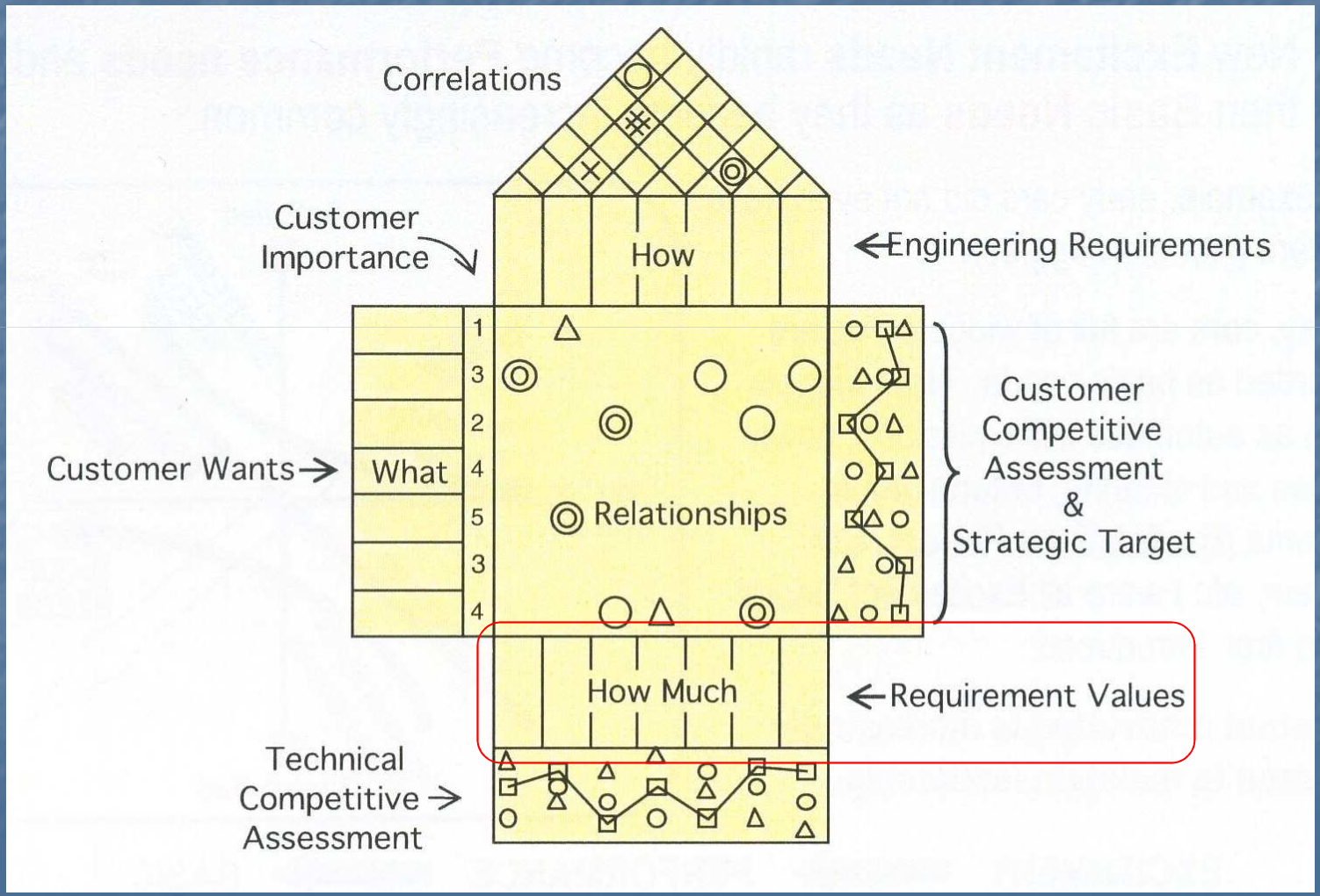
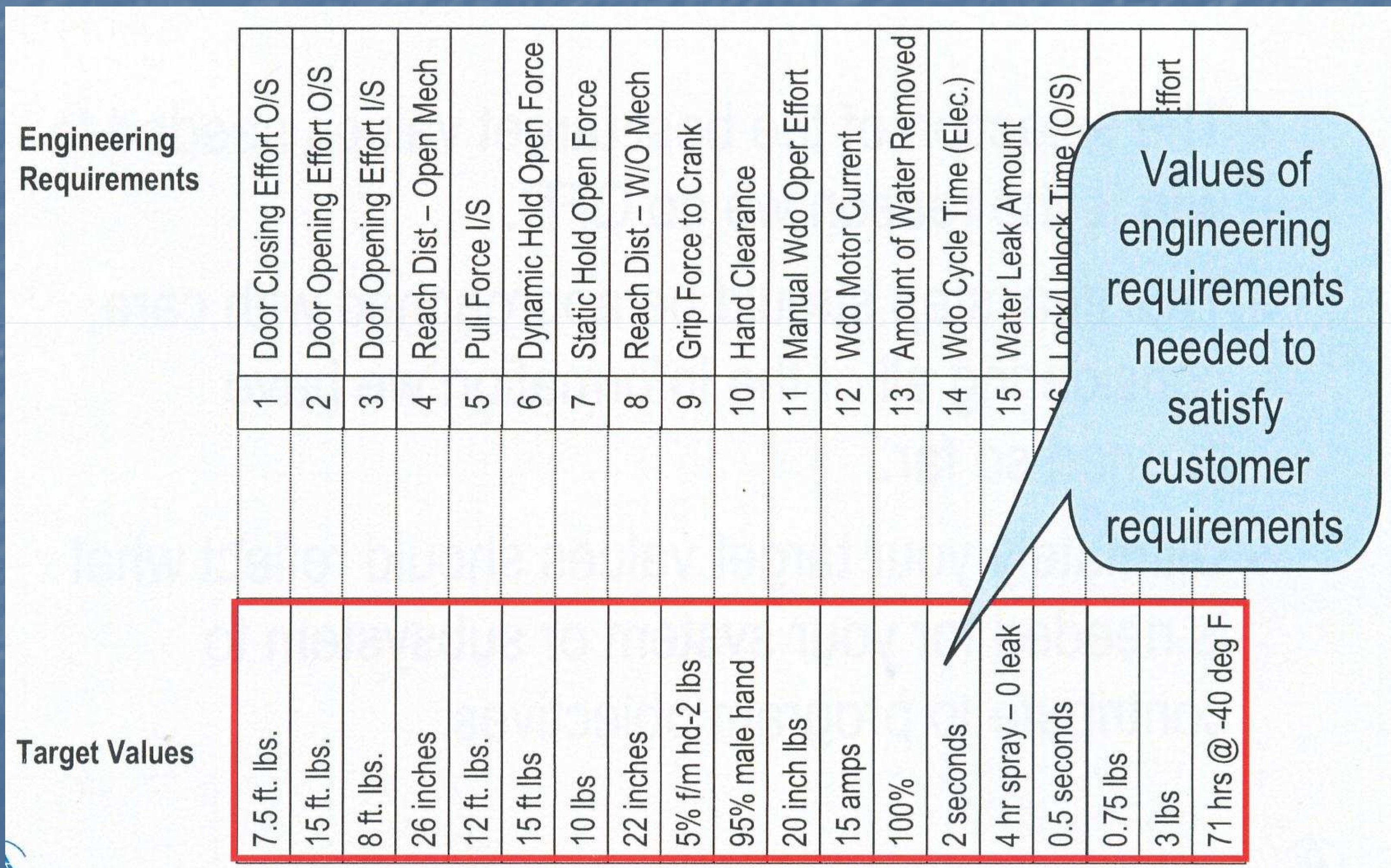
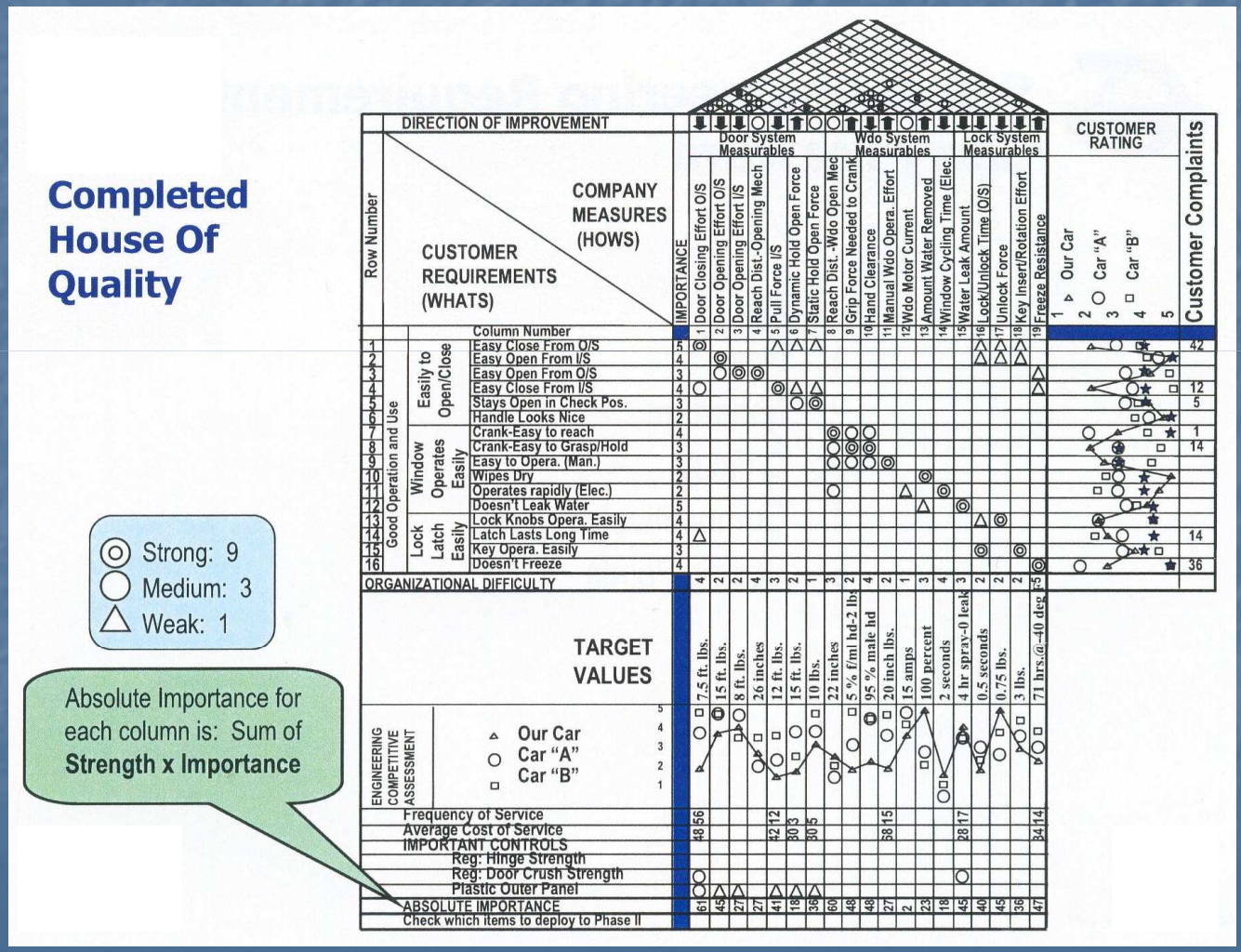


Add Target Values



	Engineering Requirements	Target Values
1	Door Closing Effort O/S	7.5 ft. lbs.
2	Door Opening Effort O/S	15 ft. lbs.
3	Door Opening Effort I/S	8 ft. lbs.
4	Reach Dist – Open Mech	26 inches
5	Pull Force I/S	12 ft. lbs.
6	Dynamic Hold Open Force	15 ft lbs
7	Static Hold Open Force	10 lbs
8	Reach Dist – W/O Mech	22 inches
9	Grip Force to Crank	5% f/m hd-2 lbs
10	Hand Clearance	95% male hand
11	Manual Wdo Oper Effort	20 inch lbs
12	Wdo Motor Current	15 amps
13	Amount of Water Removed	100%
14	Wdo Cycle Time (Elec.)	2 seconds
15	Water Leak Amount	4 hr spray – 0 leak
16	Lock/Unlock Time (O/S)	0.5 seconds
[illegible]	[illegible]	0.75 lbs
[illegible]	[illegible] Effort	3 lbs
		71 hrs @ -40 deg F

Completed House of Quality



Pugh Concept Selection

CRITERIA \ CONCEPT	1	2	3	4	5	6	7
Closing Effort		+	+	+	+	S	+
Durometer		+	+	+	+	–	+
Compression Set		+	+	+	+	+	+
Meet Freeze Test		S	S	–	S	+	S
Durability		S	S	S	S	–	–
Section Change @ Radius		–	S	+	+	+	+
Squeak		S	S	S	S	S	S
Water Leak		S	S	+	+	S	+
Wind Noise		–	S	+	+	S	+
Pleasing to Customer		S	S	S	+	S	S
Accommodate Mfg Var		S	S	+	S	S	–
Process Capability		S	–	–	–	+	–
Cost		S	S	–	–	S	–
# Installation Operations		S	S	–	–	S	S
R and R for Repair		S	S	–	–	+	S
Robustness		–	S	+	+	S	+
TOTAL +		3	3	8	8	5	7
TOTAL –		3	1	5	4	2	4

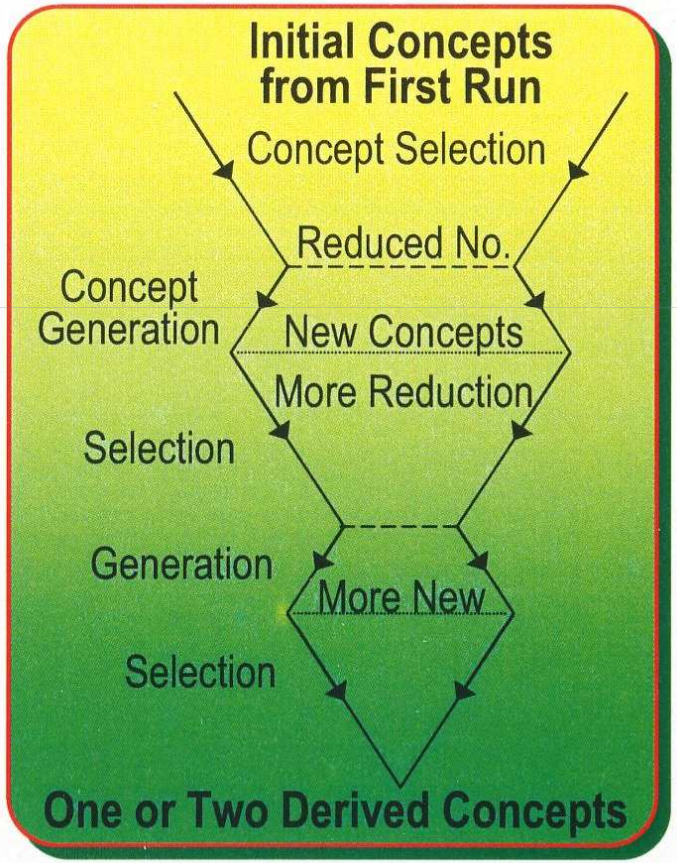
DATUM

Conduct Controlled Convergence Runs

Controlled Convergence is a powerful methodology that intertwines Generation, Synthesis, and Selection in ways that strengthen both Creativity and Analysis.

Controlled Convergence is simultaneously a synthesis and selection process. It fosters synthesis of the best attributes of several designs into new design Concepts.

- It involves alternate convergent *(analysis)* and divergent *(synthesis)* thinking
- It helps the team to attack weaknesses and enhance strengths
- As team members learn more and gain new insights, they will consistently derive and create new, stronger Concepts



Decision Matrix

		Sub-Teams							
Attribute	Weight	Blue		Red		Black		White	
		Simple robot, known designs, can score well and defend OK.		Complex robot, stretch designs, does all functions well if they work.		Simple robot, no risks, using easiest designs.		Complex robot, very risky designs, can do it all if it works.	
	1-5	Rank 1-5		Rank 1-5		Rank 1-5		Rank 1-5	
Speed	4	4	16	5	20	2	8	5	20
Power	4	3	12	4	16	4	16	5	20
Score-ability	5	4	20	5	25	3	15	5	25
Reliability	5	5	25	2	10	5	25	1	5
Defense	3	2	6	4	12	5	15	5	15
Easy to build	5	5	25	2	10	5	25	1	5
Innovation	2	2	4	4	8	1	2	5	10
Wow	2	2	4	4	8	1	2	5	10
Total points			**112**		**109**		**108**		**110**