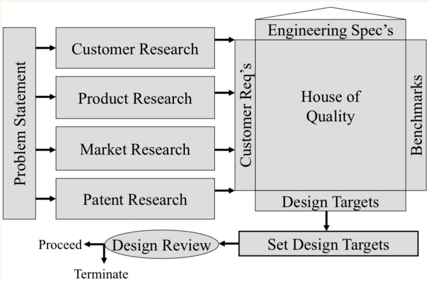
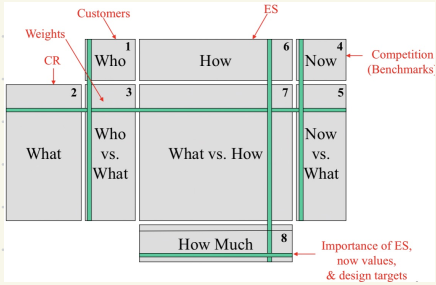
/MENG

Quality Function Deployment

- Products should reflect customers' desires
- Translating consumer requirements into engineering specifications





1. Identify customers - not only end users - govt regulations, vendors, etc
2. Determine customer requirements (CR)
3. Distribute 100pts by importance by CR
4. Identify competition
5. Evaluate whether competition meets benchmarks
6. Generate engineering requirements (ER)
7. Numerically rate CR correlation to ES - 0, 1, 3, or 9
8. Set ES targets (to make customers delighted) & thresholds (to make customers not disgusted)

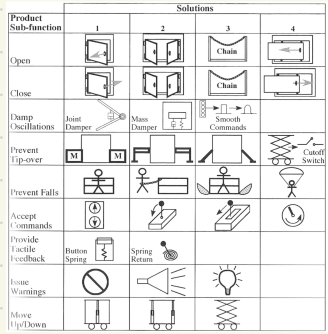
Functional Decomposition

- At the root is the function of the device
- Break the function into subfunctions
    - What lower-level functions must happen for parent function to occur?
    - At least 2 subfunctions per function

Concept Design

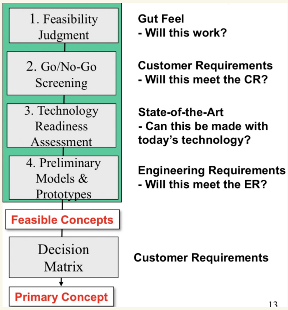
1 CONCEPT GENERATION

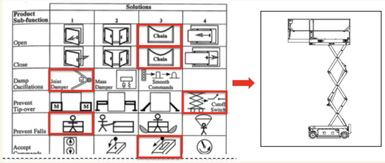
- Brainwriting, Scamper, morphological method, etc.
  - Morphological method: generate n concepts for each function



2 EVALUATION

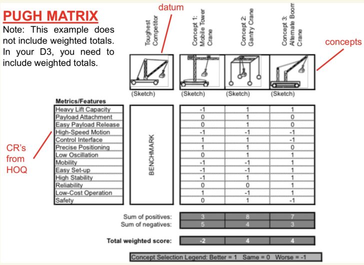
- Determine feasibility of each concept
- Combine function concepts into product concepts





3 DECISION MATRIX

- Compare fulfillment of customer requirements to existing benchmark, weighting results by importance of CRs

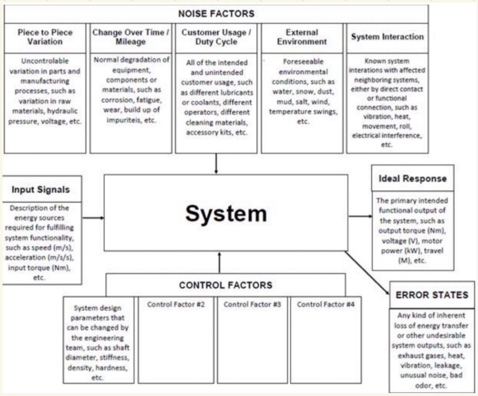


Metrics/Features	Toughest Competitor	Concept 1: Mobile Tower Crane	Concept 2: Gantry Crane	Concept 3: Alternate Boom Crane
Heavy Lift Capacity	BENCHMARK	-1	1	1
Payload Attachment		0	1	0
Easy Payload Release		0	1	0
High-Speed Motion		-1	-1	-1
Control Interface		1	1	-1
Precise Positioning		1	1	0
Low Oscillation		0	1	1
Mobility		-1	-1	1
Easy Set-up		-1	-1	1
High Stability		-1	1	1
Reliability		0	0	1
Low-Cost Operation		1	-1	1
Safety		0	1	-1
Sum of positives:		3	8	7
Sum of negatives:		5	4	3
Total weighted score:		-2	4	4

Failure Modes & Effects Analysis

- Failure modes are the ways in which a design could fail
  - E.g. loosening, short circuit, corrosion, thermal expansion
  - You can determine failure modes per function

P-DIAGRAMS



FMEA PROCEDURE

1. Determine failure modes
2. Determine severity, occurrence, & detection ratings (1-5)
   - Severity: How much a failure affects customer
   - Occurrence: How likely a failure is to occur
   - Detection: How likely controls will catch failure before it occurs
3. Risk priority number $= S \times O \times D$

Engineering Modeling

1. Formulate a question

2. Develop a list of assumptions

3. Develop a model
   - Physical model, CAD model, mathematical analysis, computer analysis

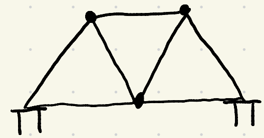
Ex. CubeSat drop problem

- Assumptions
  - CubeSat is a square (4-bar truss)
  - CubeSat falls on corner - do scenarios for all possibilities!
- Free Body Diagram
- Math calculations

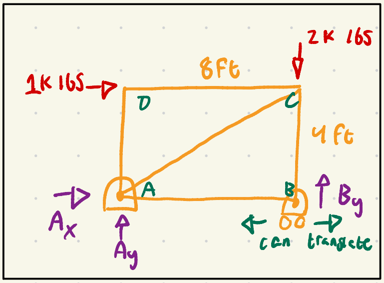
Truss Analysis

▷ ASSUMPTIONS

- Truss members are connected at ends only
- Truss members are connected by frictionless joints
- Trusses are loaded only at joints
- Members themselves are weightless



▷ METHOD OF JOINTS



Equilibrium equations for entire body

$\rightarrow \sum F_x = 0 \quad \rightarrow 1000\ lb + A_x = 0$

$\uparrow \sum F_y = 0 \quad \rightarrow -2000 + A_y + B_y = 0$

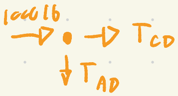
$\circlearrowleft \sum M_A = 0 \quad \rightarrow -1000(4) - 2000(8) + B_y(8) = 0$

moment of inertia around A

$$\left.\begin{aligned} A_x &= -1000\ lb \\ B_y &= 2500\ lb \\ A_y &= -500\ lb \end{aligned}\right.$$

FBD Pins

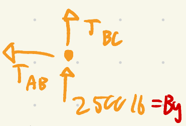
D:



$1000 + T_{CD} = 0$

$-T_{AD} = 0$

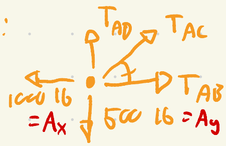
B:



$-T_{AB} = 0$

$T_{BC} + 2500 = 0$

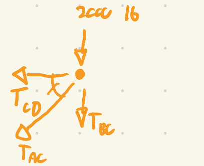
A:



$T_{AB} + T_{AC}\cos\theta - 1000 = 0$

$T_{AD} + T_{AC}\sin\theta - 500 = 0$

C:



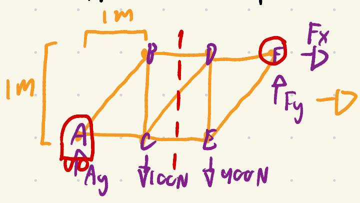
$-T_{CD} - T_{AC}\cos\theta = 0$

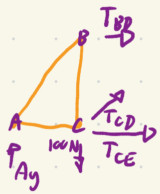
$-2000 - T_{BC} - T_{AC}\sin\theta = 0$

SOLVE for all T forces!

▷ METHOD OF SECTIONS

- You can split trusses into sections to make analysis easier
- A virtual cut must pass through the member of interest
- A cut can pass through 3 members max (3 unknowns)





$$\Sigma F_x = T_{BD} + T_{CE} + T_{CD}\cos 45^\circ = 0$$

$$\Sigma F_y = T_{CD}\sin 45^\circ - 100\,N + A_y = 0$$

$$\Sigma M_A = -100(1) + T_{CD}\sin(45^\circ)(1) - T_{BD}(1) = 0$$

Design for Assembly

- Assembly steps
  - Retrieve parts from storage
  - Handle parts (orient, etc)
  - Mate/insert components

▷ GUIDELINES

1. Minimize component count
2. Minimize use of fasteners
3. Design a "base" to locate other components
4. Avoid base repositioning
5. Make assembly sequence/order efficient
6. Avoid part tangling/jamming during retrieval
7. Design for method of assembly (manual, robot, specialized)
8. Design for end-to-end symmetry
9. Design for symmetry about axis of insertion
10. Make non-symmetric parts clearly asymmetric
11. Mate from one rather than many directions
12. Use chamfers to guide insertion

Statistics

Sample value x

Points in population N

Points in sample n

Population average μ

Sample average $\bar{x}$

Population standard deviation σ

Sample standard deviation S

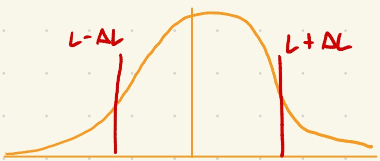
Unbiased stdev

$$S_{n-1}^2 = \frac{\sum (x_i - \bar{x})^2}{n-1}$$

- For a part with tolerances, we assume inconsistencies fall in a normal distribution.

tolerance

$L \pm \Delta L$



- When parts stack up, you have to combine tolerances.

$$\Delta L^2 = \sum \left(\frac{\partial L}{\partial L_i} \right)^2 \Delta L_i^2$$