

CONCEPT SELECTION

Elec 4309 Senior Design

Wendell H Chun

Sept. 14, 2017



College of Engineering
and Applied Science

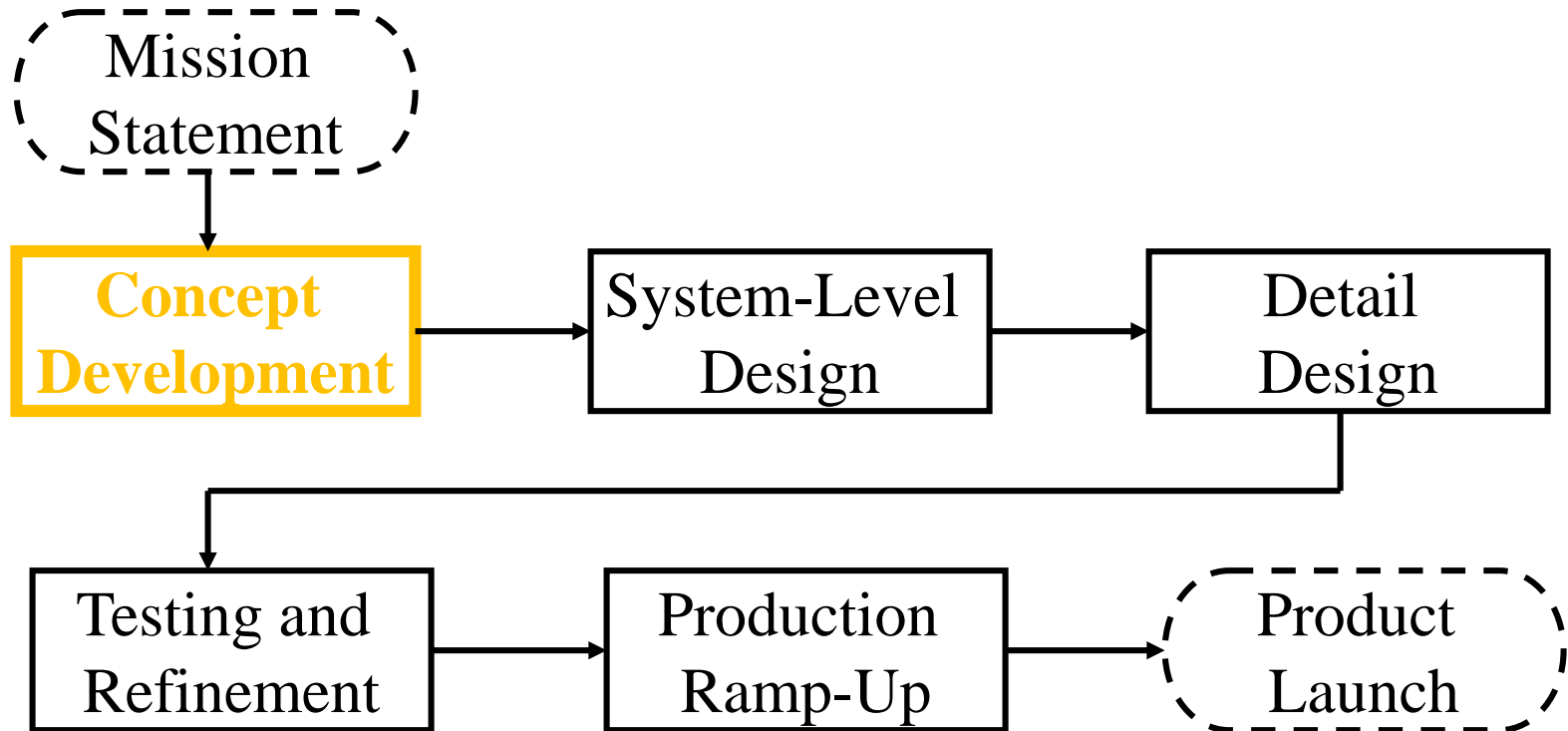
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October 3 Presentation

- Problem
- Requirements/Constraints/Standards
- Conceptualization
 - Brainstorm
 - Function-Means Tree
 - Mind Map
 - Morphological Chart
 - TRIZ
 - 6 Hats
- Down Select Concept
- Marketing Brochure
- Team
 - GANNT Chart (from Work Breakdown Structure) or
 - Project Schedule (for this semester)



Concept Selection

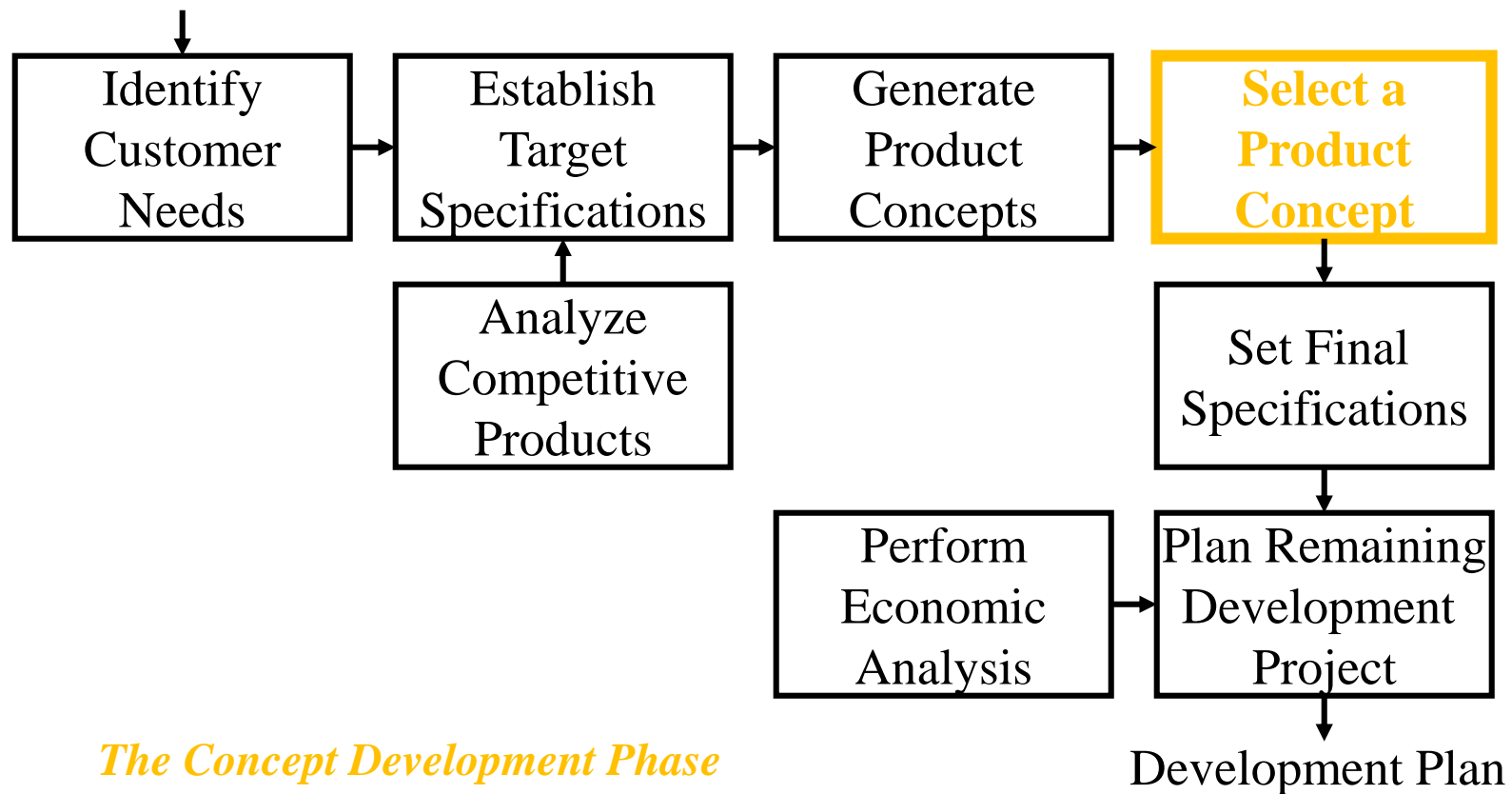


A Generic Product Development Process



Concept Selection

Mission Statement
Or Problem



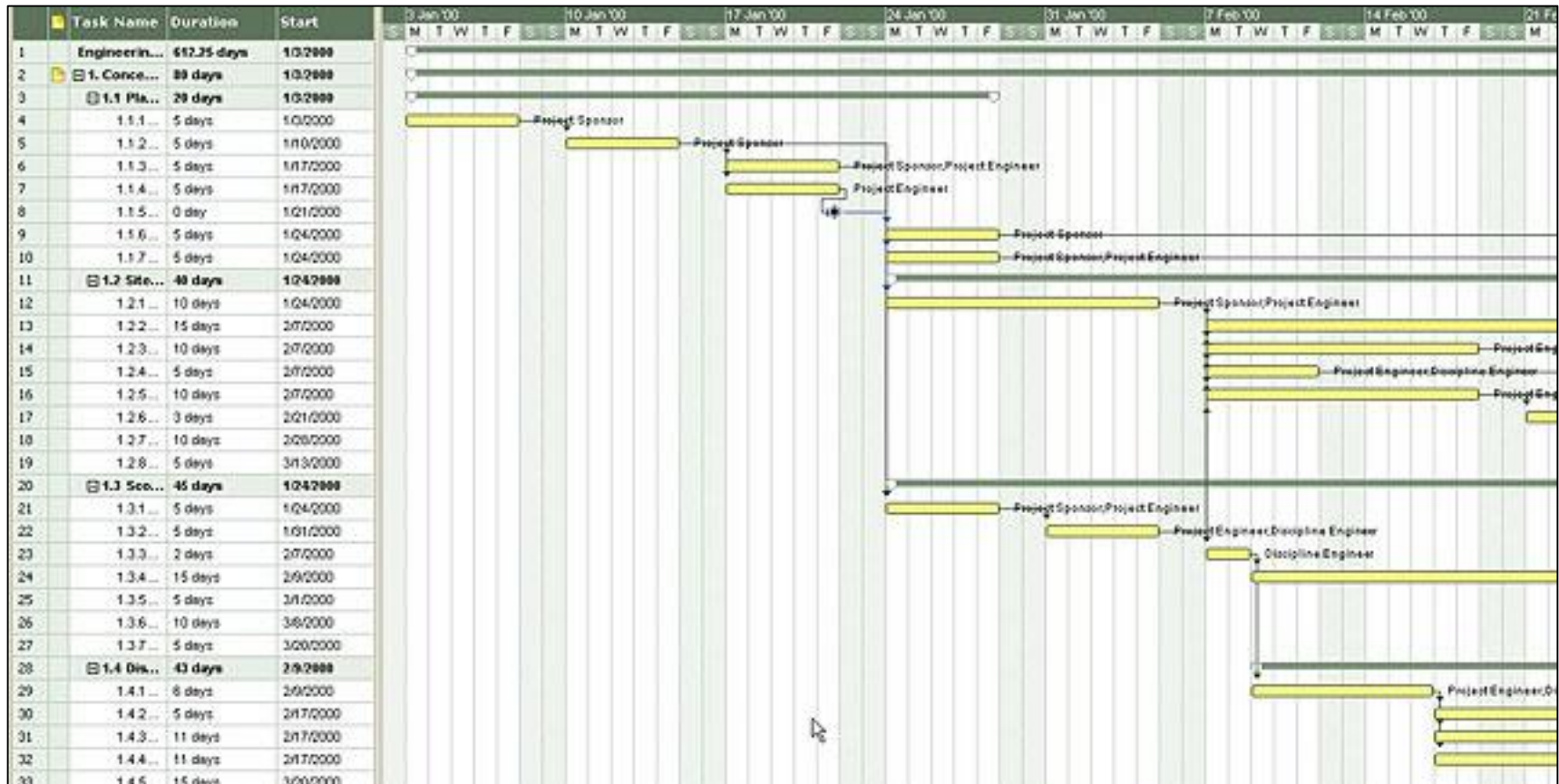
The Concept Development Phase



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Gantt Chart Example



Concept Selection

- Concept selection is the process of evaluating concepts with respect to the customer needs and other criteria, comparing the relative strengths and weaknesses of the concepts, and selecting one or more concepts for further investigation.
- We will focus here on the selection of an overall product concept. However, the method presented can also be used later in the development process when the team must select sub-system concepts, components, and production processes.



Concept Selection

- Although concept selection is ultimately a convergent process, it is frequently an iterative convergent-divergent process and may not produce a dominant concept immediately.
 - A large set of concepts is initially windowed down to a smaller set, but these concepts may subsequently be combined and improved to temporarily enlarge the set of concepts under consideration.
 - Through several iterations a dominant concept is finally chosen.



Concept Selection

- All teams use some method for choosing a concept.
- The methods vary in their effectiveness and include the following:
 - External decision.
 - Product champion.
 - Intuition.
 - Multi-voting.
 - Pros and cons.
 - Prototype and test.
 - ***Decision matrices.***



Concept Selection

- A structured method offers several benefits:
 - A customer-focused product.
 - A competitive design.
 - Better product-process coordination.
 - Reduced time to product introduction.
 - Effective group decision making.
 - Documentation of the decision process.
 - Better team buy-in on the decision.



Stuart Pugh's Perspective

- *“One thing is certain: It is extremely easy to select the wrong concept and difficult to select the best one. If the wrong one is chosen, the design may be said to suffer from conceptual weakness, and the design may be said to be conceptually vulnerable.”*
- *“Conceptual weakness in any design usually manifests itself in two ways:*



Stuart Pugh's Perspective

- *The final chosen concept is weak due to lack of thoroughness in conceptual approach. Thereafter, no amount of attention to detail requirements, technical requirements, and the like will recoup the situation.*
- *The final chosen concept is strong and the best possible within the constraints, but, due to lack of thoroughness in conceptual approach and selection, alternatives suggested, say, by others, cannot be refuted by sound technical argument and debate. In other words, the concept is the best available, it is strong, but the reasons for its strength are not known or fully understood.”*



Stuart Pugh's Perspective

- *“So here we have, by definition, two cases of conceptual weakness – the former being truly weak, the latter being strong but lacking thoroughness in approach and apparently weak.”*
- *“Bear in mind that in the absolute sense it is impossible to evolve and evaluate all possible solutions to a particular problem. In order to minimize the possibility of the wrong choice of concept, it becomes essential to carry out concept formulation and evaluation in a progressive and disciplined manner.”*



Overview of the Concept Selection Methodology

- We will consider here a two-stage concept selection methodology, although the first stage may suffice for simple design decisions.
- The first stage is called *concept screening* and the second stage is called *concept scoring*.
- Each stage is supported by a decision matrix which is used by the team to rate, rank, and select the best concept(s).



Overview of the Concept Selection Methodology

- **Concept screening:**

- The method that we are going to use was developed by Stuart Pugh in the 1980s and is often called the *Pugh Concept Selection Method*.
- It is a quick, approximate evaluation aimed at producing a few viable alternatives.

- **Concept scoring:**

- It is a more careful analysis of these relatively few concepts in order to choose the single concept most likely to lead to product success.



Overview of the Concept Selection Methodology

- During the concept screening stage, rough initial concepts are evaluated relative to a common reference concept using the concept screening matrix.
- At this preliminary stage, a coarse comparative system is used since detailed quantitative comparisons are difficult to obtain and may be misleading.
- After some alternatives are eliminated, the team may choose to move on to the concept scoring stage.

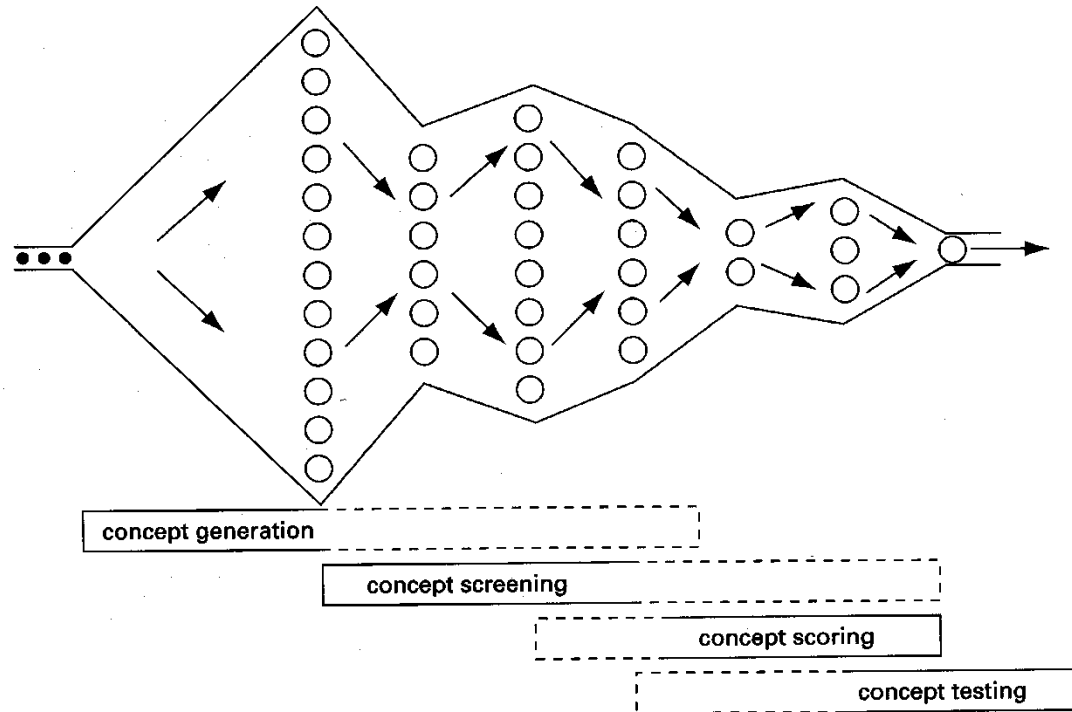


Overview of the Concept Selection Methodology

- During the concept scoring stage, the team members conduct a more detailed analysis and a finer quantitative evaluation of the remaining concepts using the concept scoring matrix as a guide.
- Throughout the screening and scoring process, several iterations may be performed, with new alternatives arising from the combination of the features of several concepts.



Overview of the Concept Selection Methodology



Concept selection is an iterative process closely related to concept generation and testing. The concept screening and scoring methods help the team refine and improve the concepts, leading to one or more promising concepts upon which further testing and development activities will be focused.



Overview of the Concept Selection Methodology

- Both stages, concept screening and concept scoring, follow a six step process which leads the team through the concept selection activity.
- These steps are:
 1. Prepare the selection matrix.
 2. Rate the concepts.
 3. Rank the concepts.
 4. Combine and improve the concepts.
 5. Select one or more concepts.
 6. Reflect on the results and the process.



Overview of the Concept Selection Methodology

- Now we will consider in more detail each step of the methodology using an example



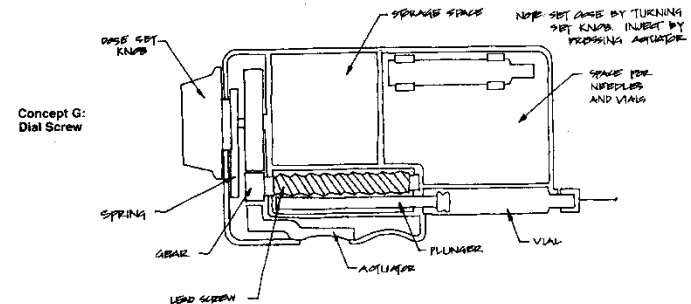
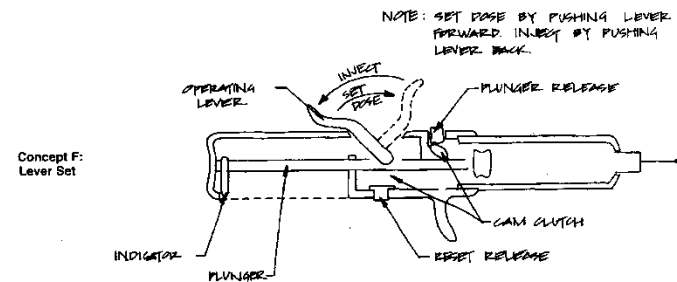
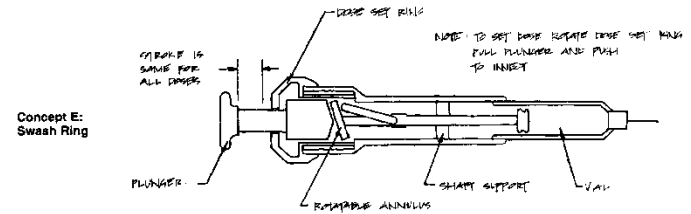
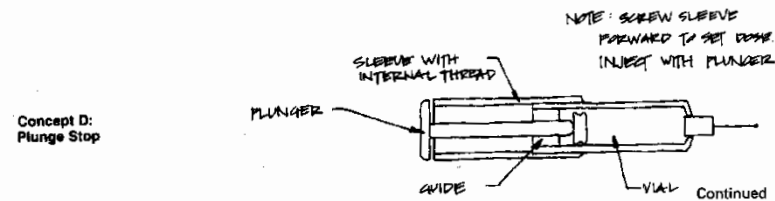
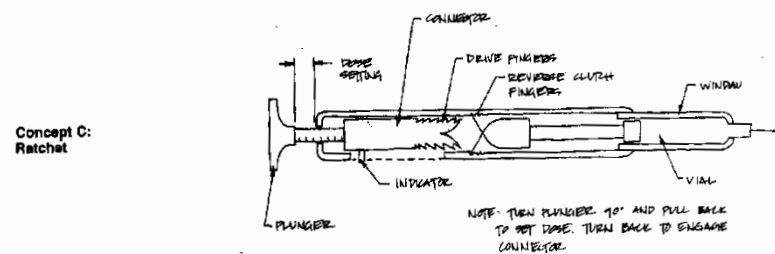
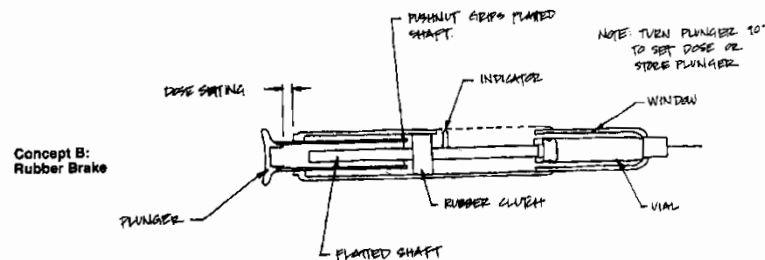
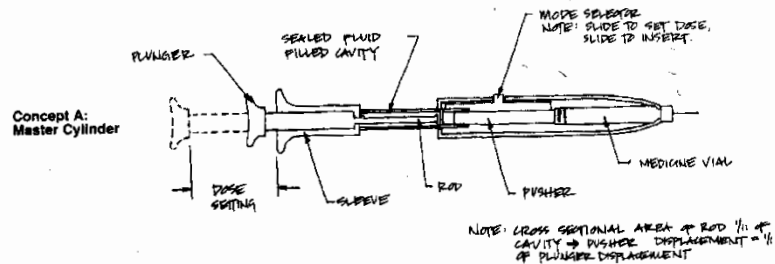
Concept Screening



The Concepts

- The product for this example is an outpatient syringe.
- Concept generation led to seven possible concepts shown in the next slide





1. Prepare the Selection Matrix

- The inputs for the matrix are:

Rows → Selection criteria.
Columns → Concepts generated by the team.

- All the concepts generated by the team should be presented at the same level of detail (using both a written description and a graphical representation) to allow a meaningful comparison and an unbiased selection.
- If the team is considering more than about 12 concepts, the *multi-vote* technique may be used to quickly choose a dozen or so concepts to be evaluated.



1. Prepare the Selection Matrix

- The selection criteria:
 - Are usually expressed at a high level of abstraction and typically include from 5 to 10 dimensions.
 - Should be able to differentiate among the concepts.
 - Should not include many relatively unimportant criteria because each criterion is given equal weight.
- The selection criteria are chosen based on:
 - Customer needs (usually some of the primary needs) that the team has identified.
 - Needs of the enterprise (such as low manufacturing cost or minimal risk of product liability).



1. Prepare the Selection Matrix

- The team chooses a concept to become the benchmark, or *reference concept*, against which all other concepts are rated.
- The reference concept can be:
 - An industry standard.
 - A straightforward concept with which all the team members are very familiar.
 - A commercially available product.
 - A best-in-class benchmark product that the team has studied.
 - An early generation of the product.



1. Prepare the Selection Matrix

- Any one of the concepts under consideration.
- A combination of subsystems assembled to represent the best features of different products.



1. Prepare the Selection Matrix

Selection Criteria for the Syringe

For the syringe example, the selection criteria were chosen and a matrix was created. Concept D was chosen as the reference concept since they feel they know the most about this concept. The next slide shows the result of this step.



1. Prepare the Selection Matrix

Selection Criteria for the Syringe

Selection Criteria	Concepts						
	A Master Cylinder	B Rubber Brake	C Ratchet	D (Reference) Plunge Stop	E Swash Ring	F Lever Set	G Dial Screw
Ease of handling Ease of use Readability of settings Dose metering accuracy Durability Ease of manufacture Portability							
Sum +’s Sum 0’s Sum –’s							
Net Score Rank Continue?							



2. Rate the Concepts

- A relative score of *“better than” (+)*, *“same as” (0)*, or *“worse than” (-)* is placed in each cell of the matrix to represent how each concept rates in comparison to the reference concept for each particular criterion.
- At this stage in the design process, each concept is just a general notion of the ultimate product, and more detailed ratings are usually meaningless.
- When available, objective metrics can be used as the basis for rating a concept. These metrics help to minimize the judgmental nature of the rating process.



2. Rate the Concepts

- Absent of objective metrics, ratings are established by team consensus (or other methods such as secret ballot)
- At this point the team may decide that some selection criteria need further investigation and analysis.



2. Rate the Concepts “Syringe Example”

- The next slide shows the matrix for the syringe example with the concepts rated



2. Rate the Concepts

“Syringe Example”

Selection Criteria	Concepts						
	A Master Cylinder	B Rubber Brake	C Ratchet	D (Reference) Plunge Stop	E Swash Ring	F Lever Set	G Dial Screw
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +’s							
Sum 0’s							
Sum –’s							
Net Score							
Rank							
Continue?							



3. Rank the Concepts

- The team sums the number of “better than,” “same as,” and “worse than” scores and enters the sum for each category in the lower rows of the matrix.
- Next, a net score can be calculated by subtracting the number of “worse than” ratings from the “better than” ratings.
- Finally, the team rank-orders the concepts.



3. Rank the Concepts

- At this point the team can identify one or more criteria which really seem to differentiate the concepts.



3. Rank the Concepts

“Syringe Example”

- The next slide shows the syringe example with the concepts ranked. Notice how ties are handled.



3. Rank the Concepts

“Syringe Example”

Selection Criteria	Concepts						
	A Master Cylinder	B Rubber Brake	C Ratchet	D (Reference) Plunge Stop	E Swash Ring	F Lever Set	G Dial Screw
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +’s	2	1	1	0	2	2	1
Sum 0’s	5	4	3	7	4	3	5
Sum –’s	0	2	3	0	1	2	1
Net Score	2	–1	–2	0	1	0	0
Rank	1	6	7	3	2	3	3
Continue?							



4. Combine and Improve the Concepts

- At this stage the team tries to combine and improve the concepts.
- Improvement:
 - Applicable to a generally good concept that is degraded by one bad feature.
 - The idea is to make minor modifications to improve the concept while still preserving a distinction from other concepts.



4. Combine and Improve the Concepts “Syringe Example”

- The team developing the syringe decides which concepts to combine and improve as shown in the next several slides



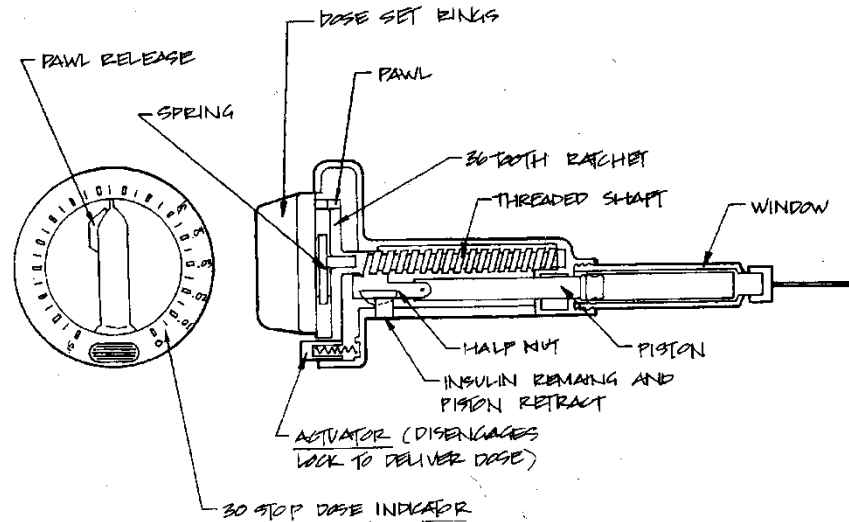
4. Combine and Improve the Concepts

“Syringe Example”

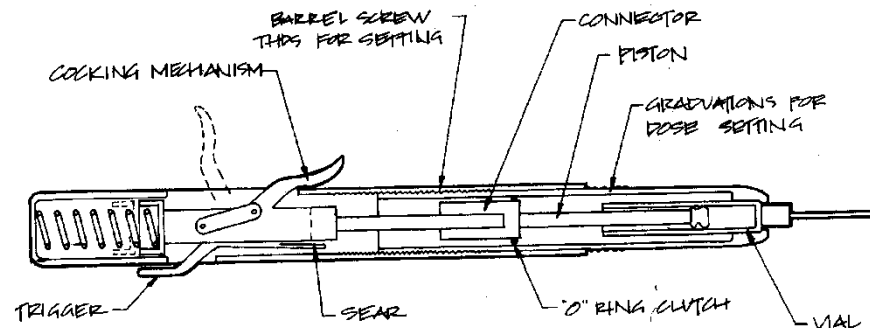
Selection Criteria	Concepts						
	A Master Cylinder	B Rubber Brake	C Ratchet	D (Reference) Plunge Stop	E Swash Ring	F Lever Set	G Dial Screw
Ease of handling	0	0	–	0	0	–	–
Ease of use	0	–	–	0	0	+	0
Readability of settings	0	0	+	0	+	0	+
Dose metering accuracy	0	0	0	0	–	0	0
Durability	0	0	0	0	0	+	0
Ease of manufacture	+	–	–	0	0	–	0
Portability	+	+	0	0	+	0	0
Sum +’s	2	1	1	0	2	2	1
Sum 0’s	5	4	3	7	4	3	5
Sum –’s	0	2	3	0	1	2	1
Net Score	2	–1	–2	0	1	0	0
Rank	1	6	7	3	2	3	3
Continue?	Yes	No	No	Combine	Yes	Combine	Revise



Concept G+:
Dial Screw+



Concept DF:
Lever Stop



5. Select One or More Concepts

- The team members decide which concepts are to be selected for further refinement and analysis.
- The number of concepts selected for further review will be limited by team resources (personnel, money, and time).
- The team must decide whether another round of concept screening will be performed or whether concept scoring will be applied next.



5. Select One or More Concepts

“Syringe Example”

- The syringe development team decides four concepts (A, DF, E, and G+) will be taken to the Concept Scoring Phase for further comparison



Concept Scoring



1. Prepare the Selection Matrix

- A computer spreadsheet is the best format to facilitate ranking and sensitivity analysis.
- The inputs for the matrix are:

Rows → Selection criteria.
Columns → Concepts that have been identified for analysis.

- The concepts have typically been refined to some extent after the concept screening stage and may be expressed in more detail.



1. Prepare the Selection Matrix

- Usually the team adds more detail to the selection criteria. (Instead of using some of the primary needs, the team may use some of the secondary or tertiary needs).
- The team also adds importance weights to each one of the selection criterion.
- Several different schemes can be used to weigh the selection criteria such as assigning an importance value from 1 to 5, or allocating 100 percentage points among them.



1. Prepare the Selection Matrix

- The importance weights are often determined subjectively by team consensus.
- As in the concept screening stage, the team identifies a reference concept.



2. Rate the Concepts

- Because of the need for additional resolution to distinguish among the competing concepts, a finer scale must be used to rate the concepts.
- A scale from 1 to 5 is recommended:
 - 1 → Much worse than the reference.
 - 2 → Worse than the reference.
 - 3 → Same as the reference.
 - 4 → Better than the reference.
 - 5 → Much better than the reference.



2. Rate the Concepts

- A single reference concept can be used for the comparative ratings. However, this is not always appropriate.
- Unless the reference concept is of average performance relative to all the criteria, the use of the same reference concept for the evaluation of each criterion will lead to “scale compression” for some of the criteria.
- To avoid scale compression, the best alternative is to use different reference points for the various selection criteria.



2. Rate the Concepts

- The reference points may come from several of the concepts under consideration, from the comparative benchmarking analysis, from the target values of the product specifications, or other means.
- The reference points for each criterion must be well understood to facilitate direct one-to-one comparisons.
- Using multiple reference points does not prevent the team from designating one concept as the overall reference for the purposes of ensuring that the selected concept is competitive relative to this benchmark.



3. Rank the Concepts

- Weighted scores are calculated by multiplying the raw scores by the criteria weights.
- The total score for each concept is the sum of the weighted scores:

$$S_j = \sum_{i=1}^n w_i r_{ij}$$



3. Rank the Concepts

- n = number of criteria.
- w_i = weighting for the i th criterion.
- r_{ij} = raw rating of concept j for the i th criterion.
- S_j = total score for concept j .
- Finally, each concept is given a rank corresponding to its total score.



4. Combine and Improve the Concepts

- As in the concept screening stage, the team looks for changes or combinations that improve concepts.
- Some of the most creative refinements and improvements can occur during the concept selection process as the team realizes the inherent strengths and weaknesses of certain features of the product concepts.



5. Select One or More Concepts

- The final selection is not simply a question of choosing the concept that achieves the highest ranking after a first pass through the process.
- The team should explore in detail this initial evaluation by conducting a sensitivity analysis.
- By investigating the sensitivity of the ranking to variations in a particular rating, the team members can assess whether uncertainty about a particular rating has a large impact on their choice.



5. Select One or More Concepts

- In some instances, the team may select a lower-scoring concept about which there is little uncertainty instead of a higher-scoring concept that may possibly prove to be unworkable or less desirable as they learn more about it.
- Notice that given the resolution of the scoring system, small differences are generally not significant.
- The team may decide to select the top two or more concepts. These concepts may be further developed, prototyped, and tested to obtain customer feedback.



5. Select One or More Concepts

- If necessary, the team may also create two or more scoring matrices with different weightings in order to obtain the concept ranking for different market segments.



Concept Scoring

“Syringe Example”

- Continuing our syringe example, the next slide show the result of concept scoring for the syringe example



Concept Scoring

“Syringe Example”

		Concepts							
		A (Reference) Master Cylinder		DF Lever Stop		E Swash Ring		G+ Dial Screw+	
Selection Criteria	Weight	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Ease of handling	5%	3	0.15	3	0.15	4	0.2	4	0.2
Ease of use	15%	3	0.45	4	0.6	4	0.6	3	0.45
Readability of settings	10%	2	0.2	3	0.3	5	0.5	5	0.5
Dose metering accuracy	25%	3	0.75	3	0.75	2	0.5	3	0.75
Durability	15%	2	0.3	5	0.75	4	0.6	3	0.45
Ease of manufacture	20%	3	0.6	3	0.6	2	0.4	2	0.4
Portability	10%	3	0.3	3	0.3	3	0.3	3	0.3
	Total Score	2.75		3.45		3.10		3.05	
	Rank	4		1		2		3	
	Continue?	No		Develop		No		No	



Final Remarks on Concept Generation and Selection

- Keep in mind Stuart Pugh's advice:
 - *“In order to minimize the possibility of the wrong choice of concept, it becomes essential to carry out concept formulation and evaluation in a progressive and disciplined manner.”*

