TEXAS
The University of Texas at Austin

EDUCATING DESIGNERS FOR GENERATIVE ENGINEERING

LEARNING GOAL 1

Chapter: Preface

Learning Objectives: 1) The design process; 2) three design paradigms; 3) relation between paradigms (design evolution).

Design Process

Process – sequence of steps taken to achieve an end; for example, following a recipe to prepare a meal.

Design Process – the steps taken by the designer to design an object or experience to fill a need.

Real world problem – traveling across a body of water

Goal – Design and build a structure to enable travel

Constraints – Natural water and land formations; existing city infrastructure

Solution – A bridge!

Evaluation – Safety; travelers per year

Design - clear goals and objective evaluation metrics.

Design vs. Art Processes

Design Process – the steps taken by the designer to design an object or experience to fill a need.

Design – clear goals and objective evaluation metrics.

Art Process – the steps taken by the artist to express emotions or themes that are important.

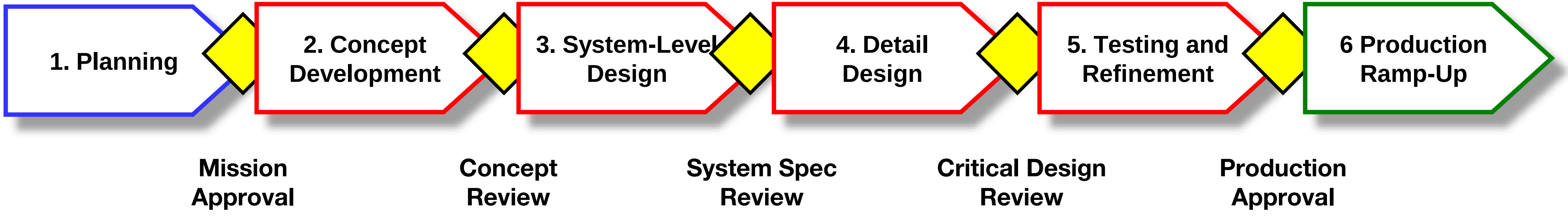
Art – no clear goals and evaluation can be a matter of taste.

Design Process

The **Design Process** changes based on different problems to be solved or tools used to solve them.

Designers use abstract **design process models** to loosely describe the phases/steps of a typical design process.

Generic 6-phase Product Design Process*:

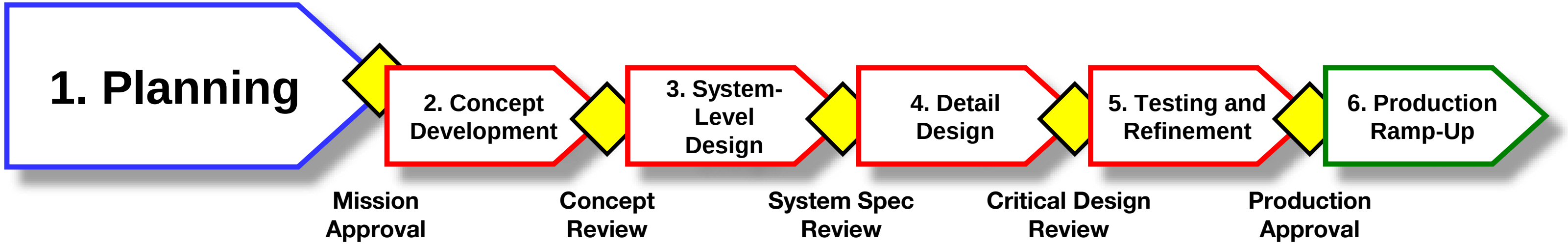


Ulrich, K. T., Eppinger, S. D., & Yang, M. C., (2020). *Product design and development*. McGraw-Hill.

1. Planning; 6-phase Design Process

- "Phase Zero;" this generally occurs before product development begins.
- Includes opportunity/market identification and technology/market assessments.

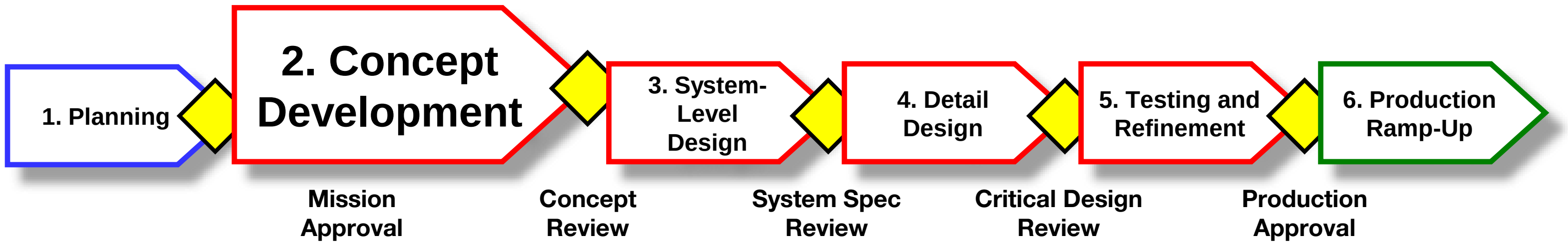
❖ *Output*: **Project mission statement** – specifies target market, business goals, and constraints.



2. Concept Development; 6-phase Design Process

- Market (identified in Planning stage) needs are identified, and
- Alternative product concepts are created and evaluated to
- Select one or more concepts for further development.

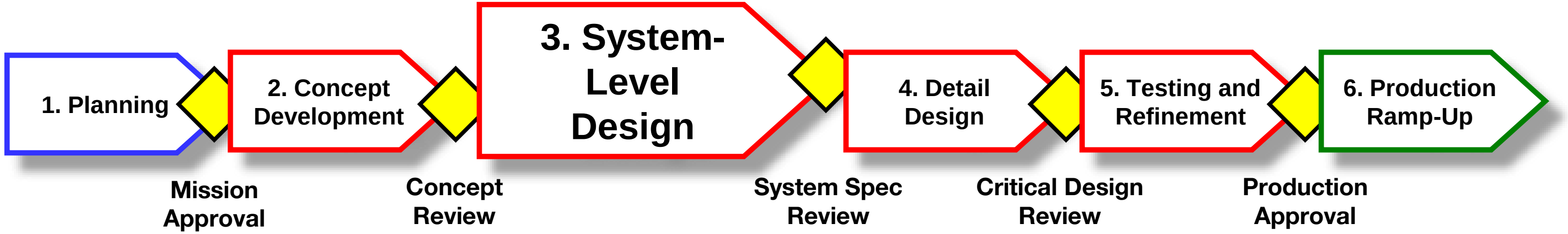
❖ *Output*: Concept(s) for further testing - description of product form/function/features and mission statement.



3. System-Level Design; 6-phase Design Process

- Defining problem architecture,
- Decomposing product into subsystems and components, and
- Preliminary design of key components.

❖ *Output*: Geometric product layout, subsystem description(s), and preliminary manufacturing/assembly process.



4. Detail Design; 6-phase Design Process

- Complete specification of all problem variables (geometry, materials, tolerance of parts), and acquisition of all needed materials. Key Issues:
  1. Material selection,
  2. Production cost,
  3. Robust performance.

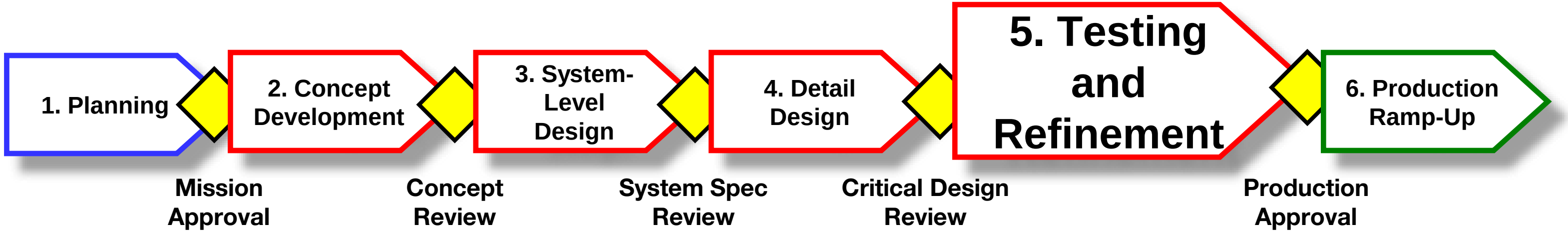
❖ *Output*: **control documentation** of the product, includes (for each part of the design) – geometric description, material acquisition and usage, production supply chain, and assembly.

5. Testing and Refinement; 6-phase Design Process

- Construction and evaluation of multiple preproduction versions of the product.

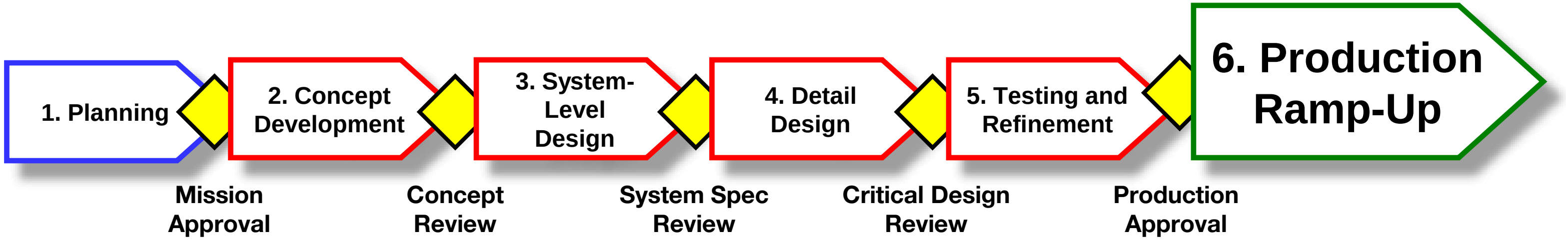
i. **Alpha prototypes** - uses production intent parts but preliminary production processes.
   - ❖ *Output*: Evaluate & determine the acceptable alpha prototype(s) to promote to the next phase,

ii. **Beta prototypes** - uses production intent parts and intended final production processes but with preliminary assembly process.
   - ❖ *Output*: Identify performance and reliability concerns to address for the final product design.



6. Production Ramp-Up; 6-phase Design Process

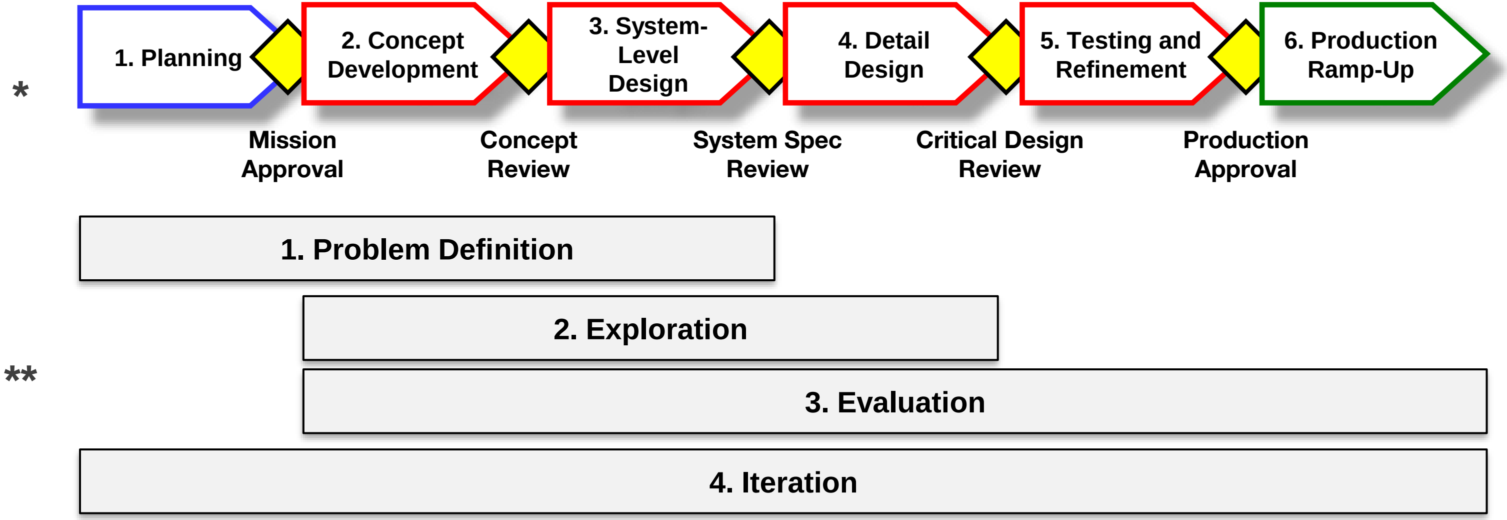
- Designed product is manufactured and assembled via intended final production system.
  - ❖ *Output 1*: Train the workforce,
  - ❖ *Output 2*: Identify any remaining manufacturing/production issues.
- Build up to product **launching**.
- Postlaunch project review – optional commercial and technical assessment



Design Process

Generic 6-phase Design Process*

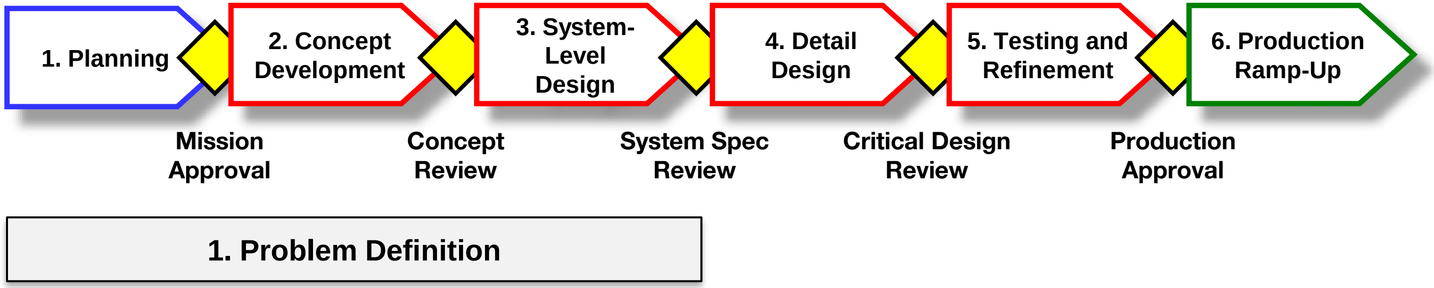
Curriculum Four-Step Design Process**:



1. Problem Definition; Four-Step Design Process

- Problem/opportunity identification (*Planning* phase),
- Technology/market assessments (*Concept Development* phase), and
- Identifying/defining the relationships between <u>key</u> variables (*Systems-Level Design* phase)

❖ *Output*: Design space definition via objectives and constraints.

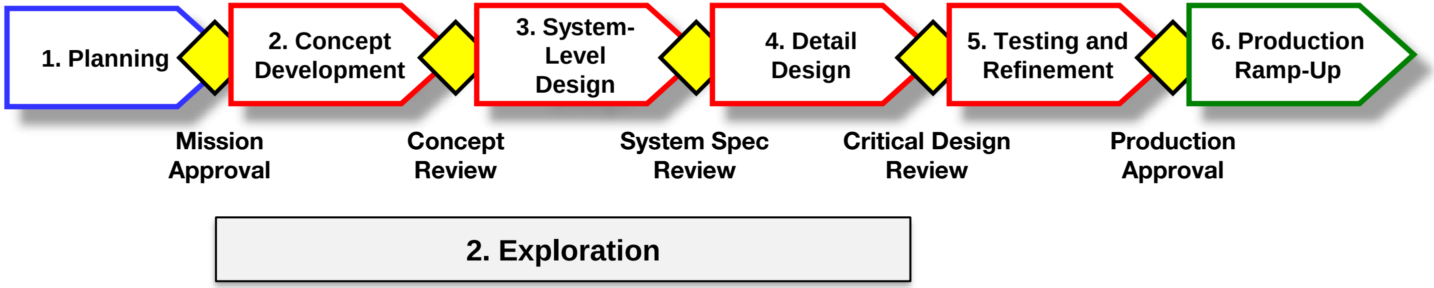


2. Exploration; Four-Step Design Process

- Generate alternative product concepts to establish relationships between variables/constraints and objectives (*Concept Development* phase).

❖ *Output*: Develop alternate concept(s) for further testing.

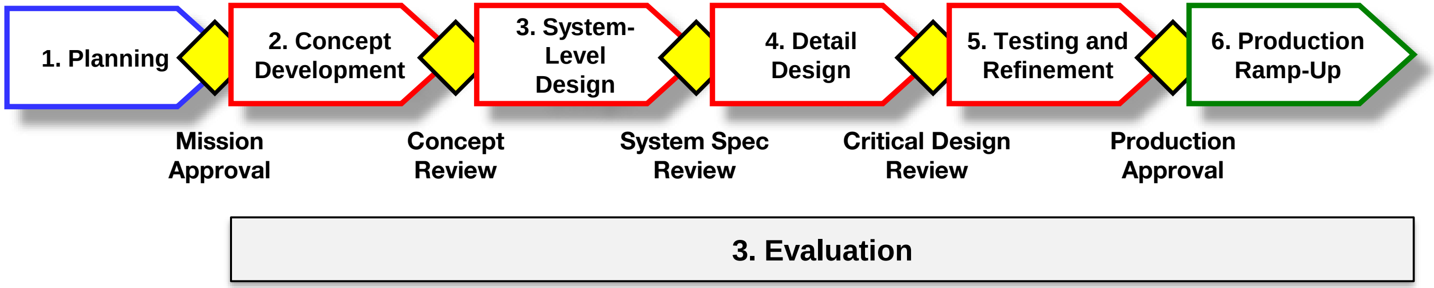
- Informs outputs from *System-Level Design* (defining problem architecture and subsystems) and *Detail Design* (variable specification and material usage) phases.



3. Evaluation; Four-Step Design Process

- Evaluate cost and preliminary performance of design concepts (*Concept Development*, *System-Level Design*, *Detail Design*),
  - Compare performance of competing design concepts,
- Compare alpha and beta prototype performance to target performance (*Testing and Refinement*),
- Evaluate production system and conduct a postlaunch project review (*Production Ramp-Up*).

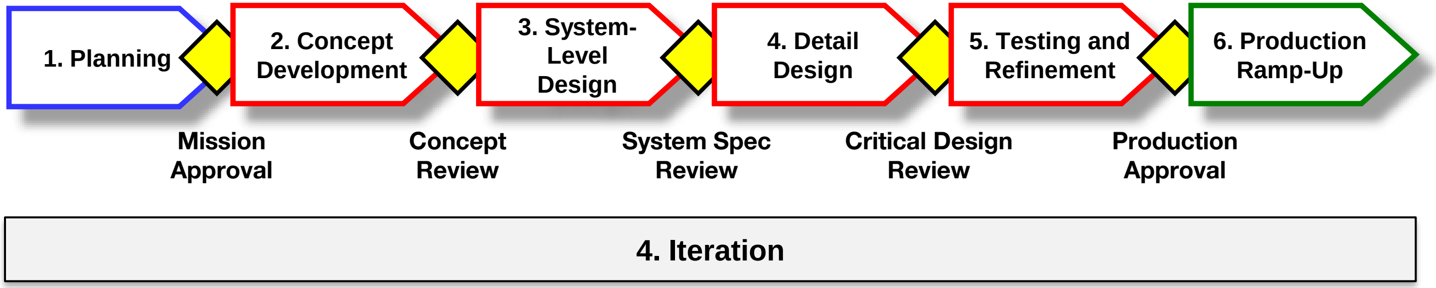
❖ *Output*: Performance documentation.



4. Iteration; Four-Step Design Process

- **Inter-stage** iteration – Using information from one stage to inform later plans in another stage, e.g., Evaluating performance during *Testing and Refinement* to guide further *Concept Development*.
- **Intra-stage** iteration – Using information from one stage to inform later plans within that stage, e.g., Merging insights from client interviews and market identification during *Planning*.

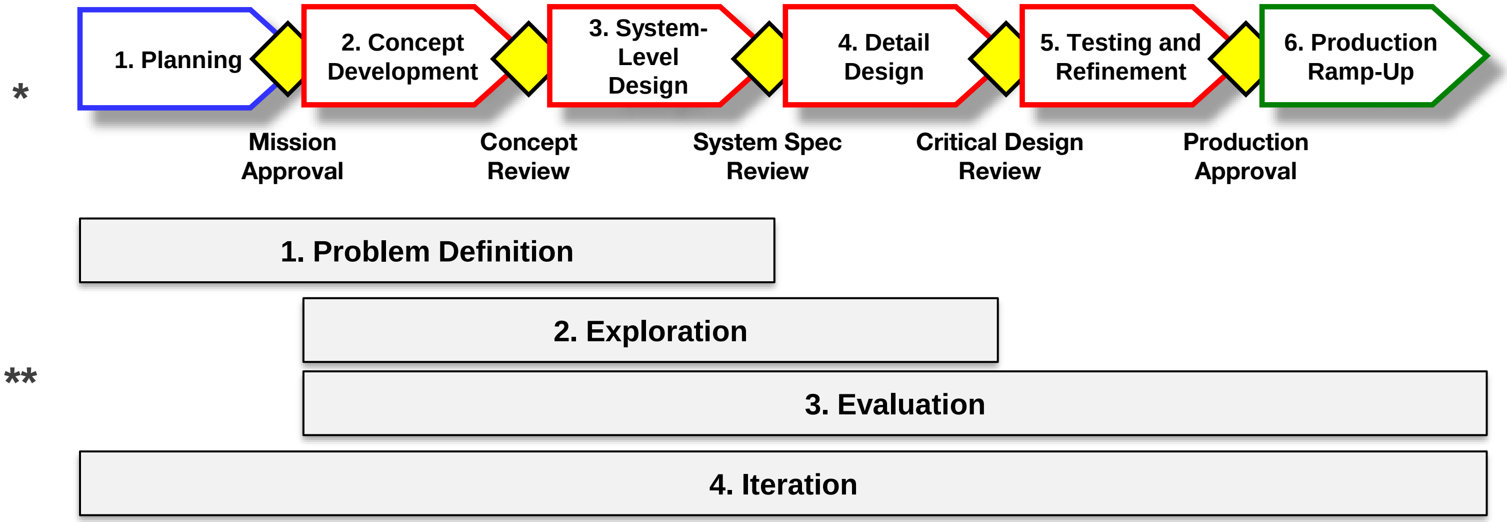
❖ *Output*: Plans for refining the design; **a to-do list**!



Design Process

Generic 6-phase Design Process*

Curriculum Four-Step Design Process**:

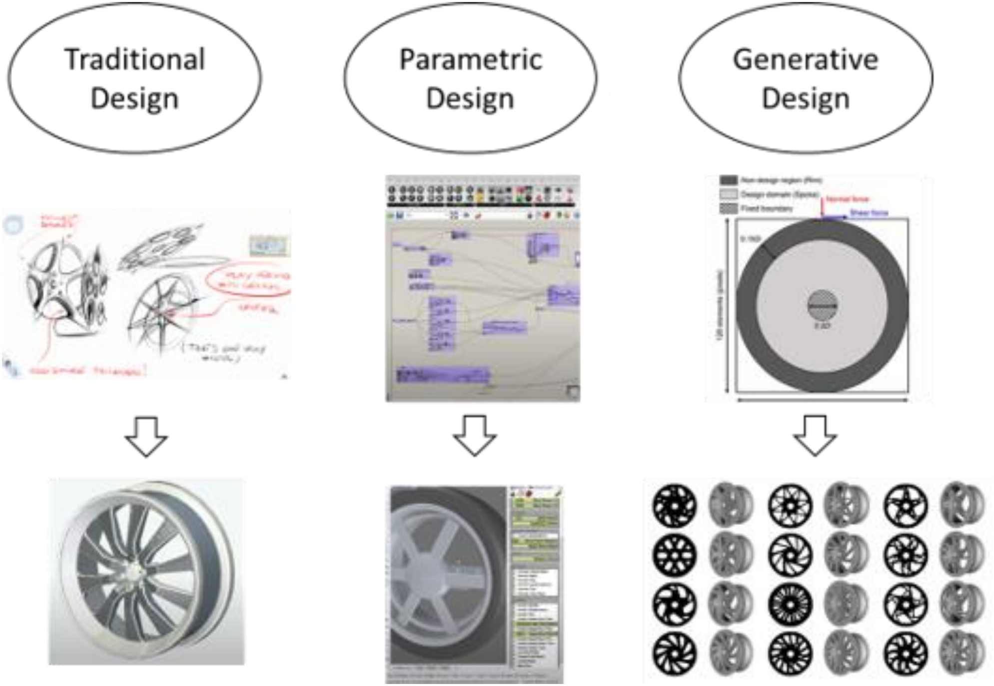


Design Paradigms

Paradigm – *pattern* (Greek, loose translation); collections of ideas that shape thought and action.

Design Paradigm – framework for understanding and approaching the design process.
Three major paradigms include:

- **Traditional Design** – manual design
- **Parametric Design** – type of computational design
- **Generative Design** – design with generative AI



Traditional Design Paradigm

Traditional/Manual Design – established practices for engineering design; emphasizes human cognition, manual action, and human driven iteration.

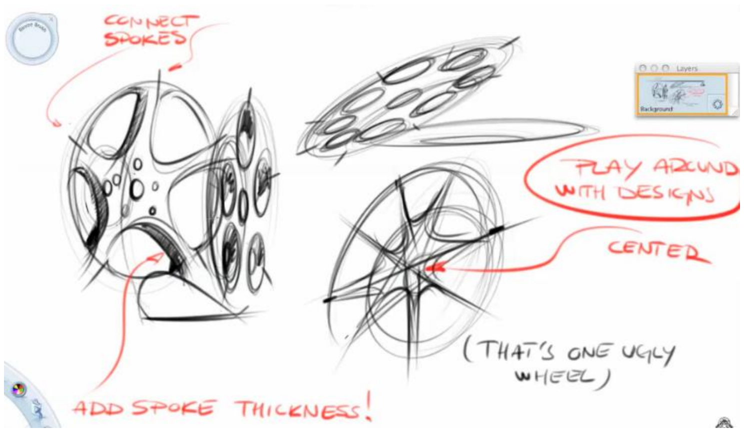


Image: Sketch of an idea for a car wheel design. Traditional designers often begin idea generation by loosely sketching whichever ideas first come to mind. This is influenced by the designer's skills, previous experiences, and intuition.

Image: CAD model of a car wheel. Computer-aided design can aid human-driven manual design phases, including conceptualization and evaluation.

Parametric Design Paradigm

Parametric Design – introduces computational artificial intelligence (AI) algorithms which allow the designer to define parameter relationships to computationally generate a corresponding design.

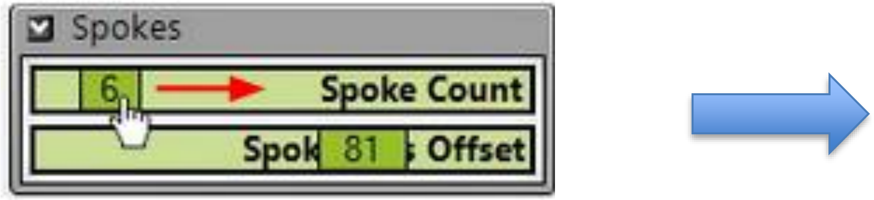


Image: Car wheel design based on parameters. Parametric design lets the designer define relationships or "rules" between variables and computationally generate the corresponding design for further refinement.

Image: CAD models of different car wheels. Parametric design allows the designer to test many ideas in a short amount of time.

Generative Design Paradigm

Generative Design – extends the role of AI to generate up to thousands of design options for the human to evaluate and refine.

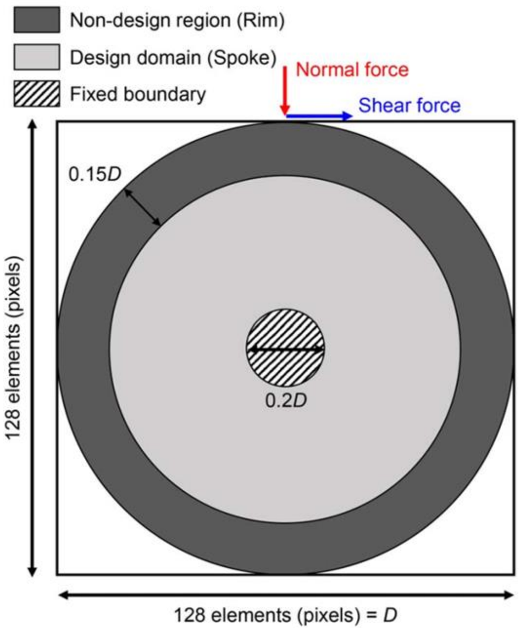


Image: Car wheel geometry.
Generative design often requires the designer to computationally define the geometry of the object being designed. Early GD stages may also include defining equations for performance metrics, such as car wheel stiffness.

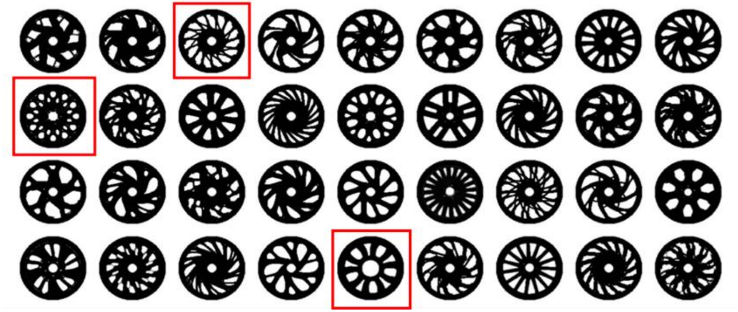
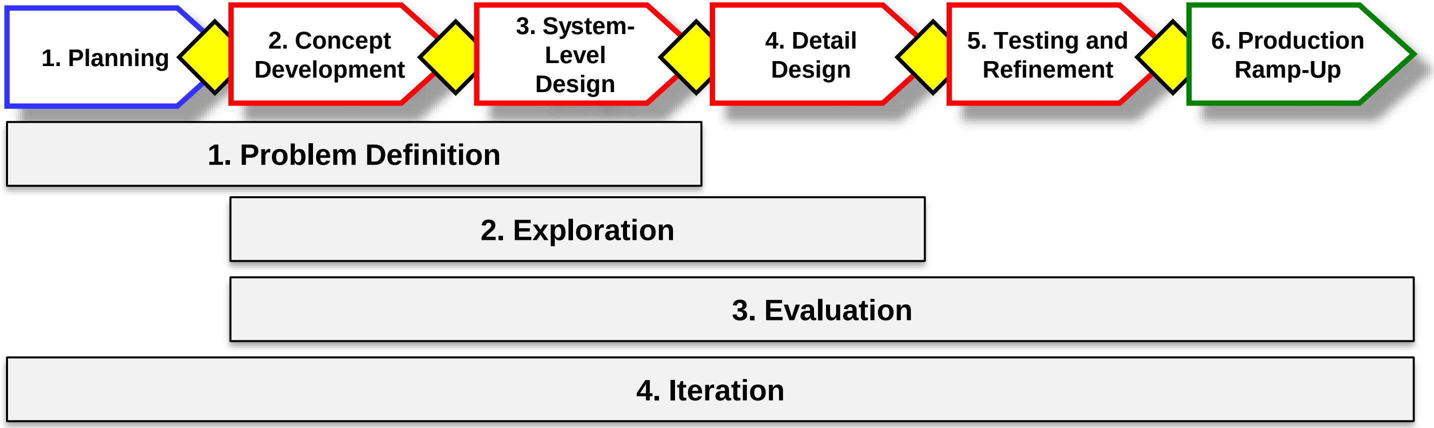


Image: CAD models of different car wheels.
Generative Design automatically explores every possible solution via computational methods.

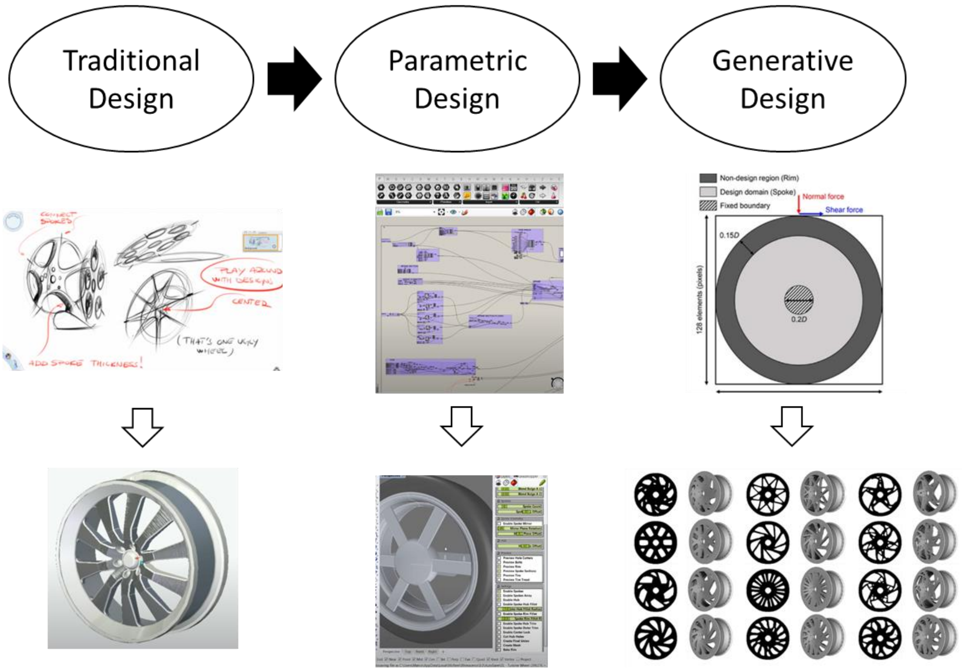


	1. Problem Definition	**2. Exploration**	**3. Evaluation**	**4. Iteration**
Traditional/Manual Design	*Ill-defined problem statement/design space*	*Design Space*	*Human-driven*	*Human-driven*
Parametric Design	*Requires well-defined (computational) problem statement/design space*	*Design Space*	*Human-driven*	*Human-driven*
Generative Design	*can use AI for all of it*	*Objective Space*	*AI-driven during exploration; human-driven of AI designs*	*Human-driven*

Design Evolution

Design Evolution – Technological development leads to the progression from traditional design, to parametric design, to generative design.

Paradigms are **not mutually exclusive**, and designers often use multiple paradigms throughout the design process.



Each paradigm builds upon computational abilities from the previous paradigm to expand the limits of design.

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