TEXAS
The University of Texas at Austin

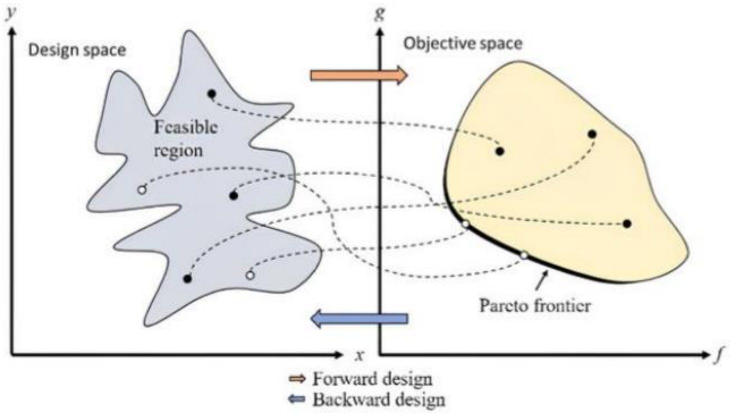
EDUCATING DESIGNERS FOR GENERATIVE ENGINEERING

LEARNING GOAL 3

Chapter: Traditional Design
Learning Objectives: 1) Define traditional design; 2) Define a problem within a traditional design paradigm; 3) Explore with the traditional design paradigm; 4) Evaluate designs made in traditional design; 5) Iterate within traditional design

Design Space and Objective Space

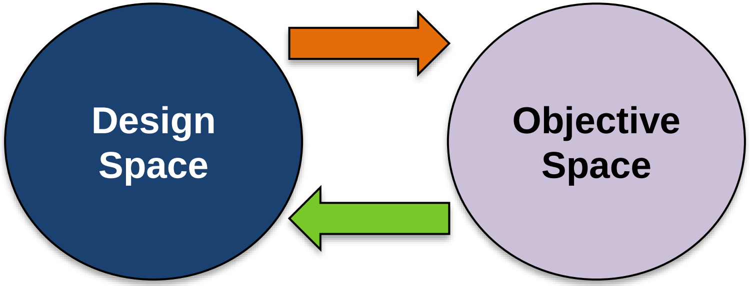
- **Design Space**
  - Defined by the **constraints**.
  - Represents all the possible designs.
  - Captures all the allowable variation in the design parameters.
- **Objective Space**
  - Defined by the design **objectives**.
  - Specifies which designs perform best, according to the given objectives/criteria.



Forward Design and Backward Design

- **Forward Design**
  - Moves from the **design space** to the **objective space**.
  - Involves creating a design that adheres to the design **constraints** and evaluating how well it meets the **objectives**.
  - Favored in **Traditional Design (TD)** and **Parametric Design (PD).**

- **Backward Design**
  - Moves from the **objective space** to the **design space**.
  - Involves creating a design that meets the **objectives** well and checking whether it adheres to the design **constraints**.
  - Favored in **Generative Design (GD).**

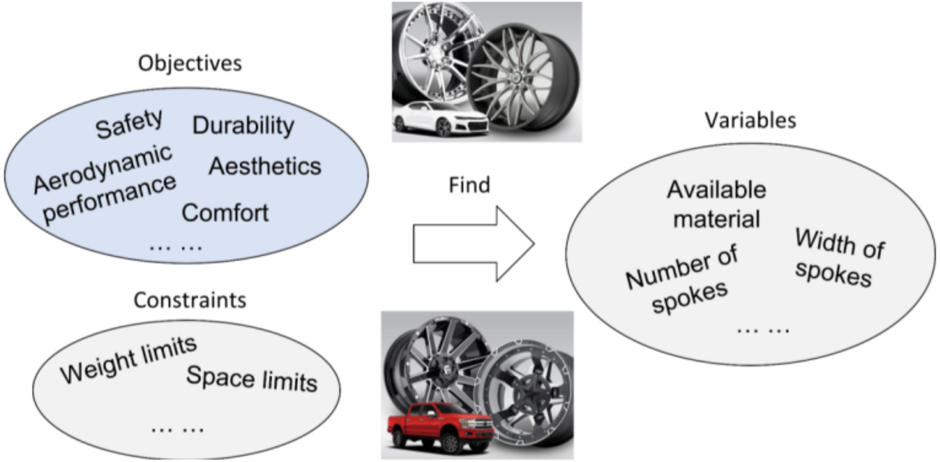


Problem Definition

- Assume you are hired to design a wheel for a car.
- How would you start?
  - By coming up with several high-performance concepts? (**objective**-focused)
  - By asking the client what their constraints are? (**constraint**-focused)

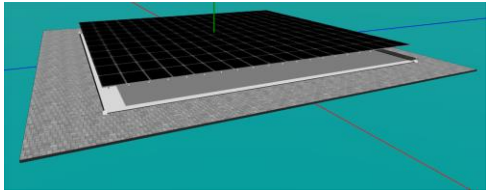
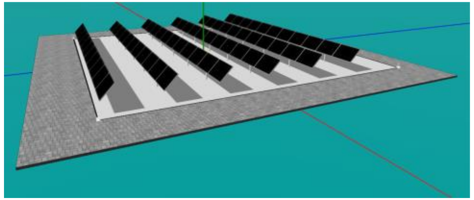
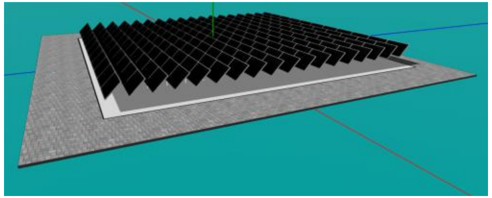

Problem Definition

- Both **constraints** and **objectives** are essential. You cannot fully understand a problem without understanding both.
- This allows you to define the design space and its constituent **variables**.



Practice Example: Solar Farm Design

- Assume you have been hired to design a solar farm on a university campus.
  - What **design objectives** might your client (the university) have?
  - What **design constraints** might exist?
  - What are some possible **design variables?**

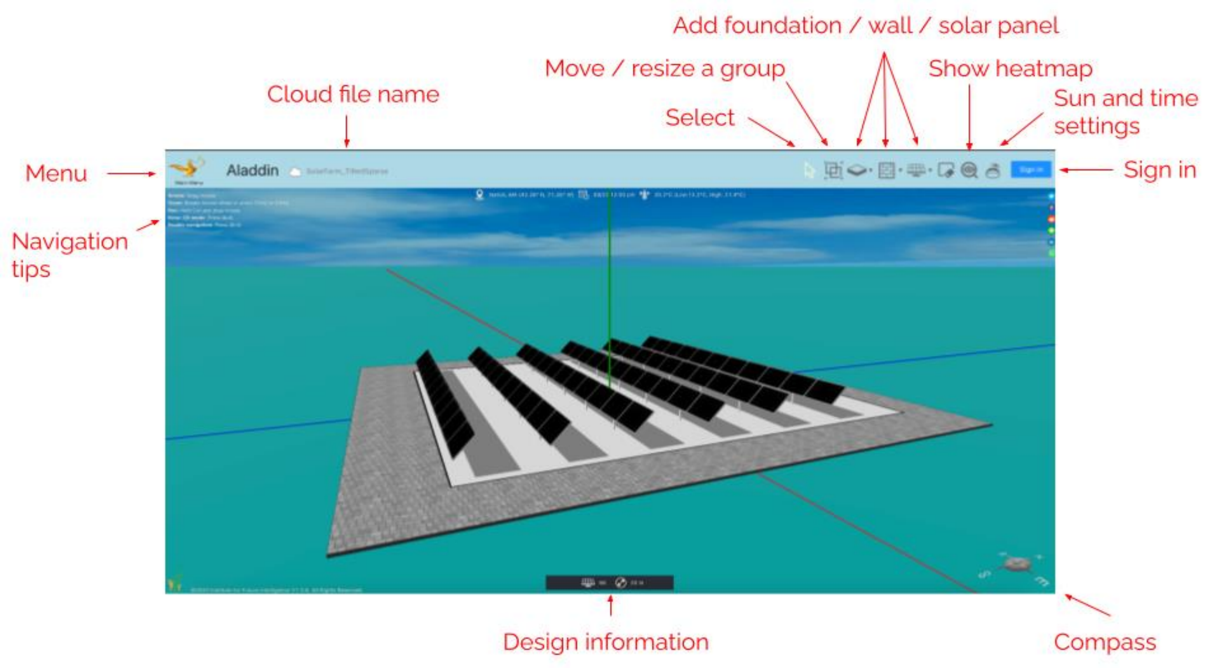




Practice Example: Solar Farm Design

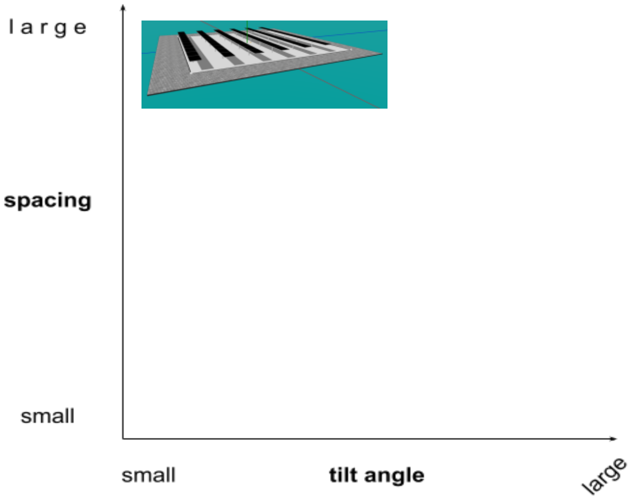
- Our design objectives:
  - **Maximize the energy output**
  - Minimize the cost
- Our design constraints:
  - Budget (maximum allowable cost)
  - Land allotted (maximum allowable area)
  - Location (number of sunny days per year, shadows from hills or buildings, etc.)
- Our design variables:
  - **Spacing (distance between the rows)**
  - **Tilt angle of the solar panels**

Practice Example: Solar Farm Design

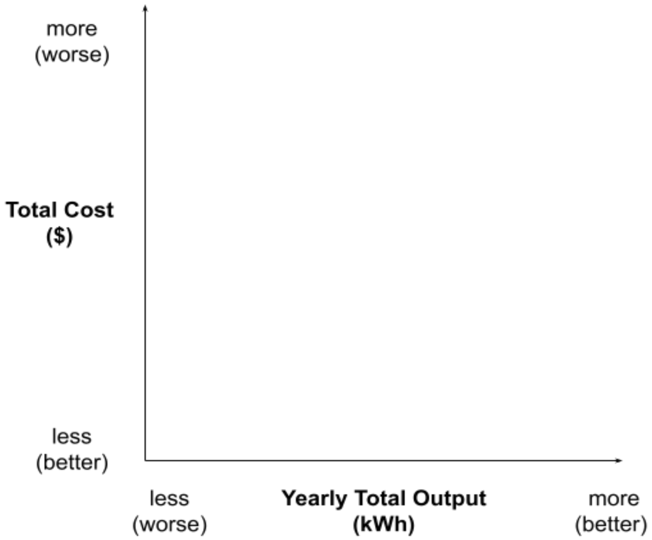
***Aladdin:* Quick Start**



Practice Example: Solar Farm Design



Design space



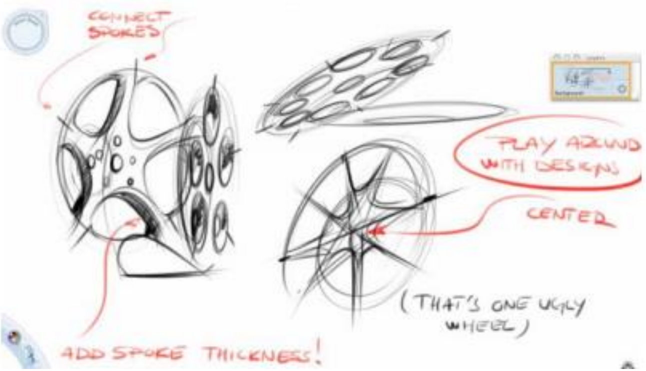
Objective space

Organize your design concepts here using the variables

Organize your design concepts by their performance (objectives) here

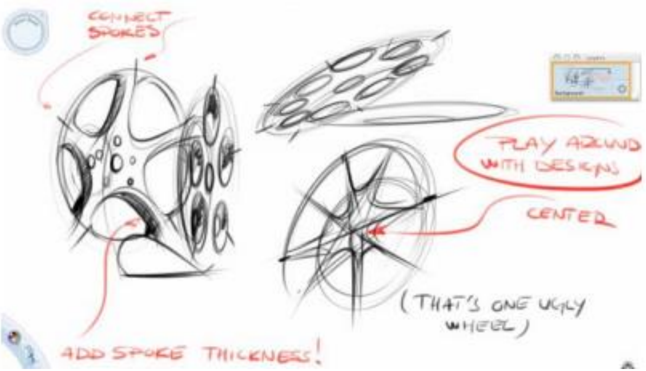
Exploration

- Exploration involves varying the **design space variables** to determine how they impact performance, according to the **objectives**.
- Returning to the wheel design example:
  - What would be the effect of using aluminum instead of steel?
  - What would be the effect of making the spokes thinner?



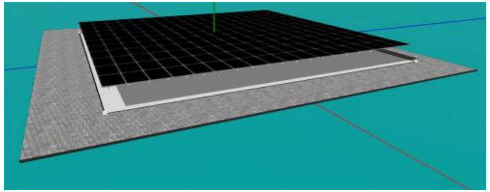
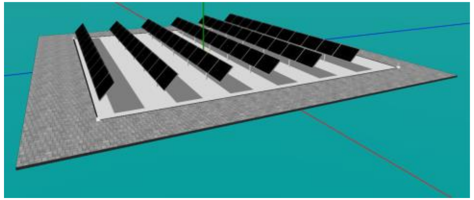
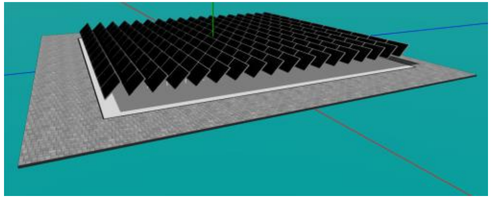
Exploration

- Taking a **divergent** approach to design exploration is often useful.
- This involves creating very different designs.
- This allows you to explore the **edges** of the design space.



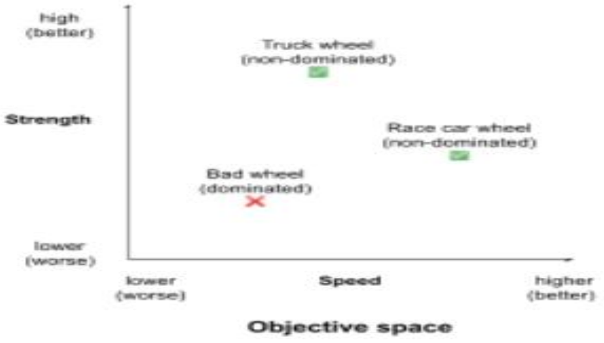
Practice Example: Solar Farm Design

- We’ve given you one example solar farm design in Aladdin.
- Try to make something very different. What is this an example of?
- Then, try to make a third design that is different from the first two.

Evaluation

- **Evaluation** is the process of classifying designs as **dominated** or **non-dominated** and then removing **dominated** designs.
    - If Design 1 performs worse than Design 2 on all **objective** metrics, then Design 1 is **dominated**.
    - If Design 2 is not outperformed on all **objective** metrics by any known design, then Design 2 is **non-dominated**.



Evaluation

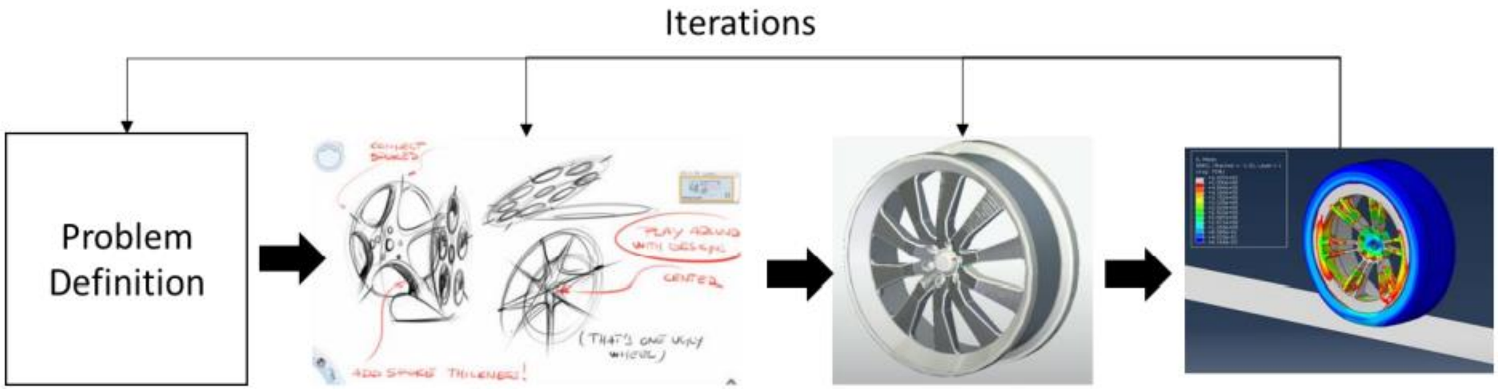
- All of the **non-dominated** designs in the design space form the **Pareto Front**.
  - A solution lies on the **Pareto Front** if its performance according to one **objective** cannot be improved without worsening its performance with respect to another **objective**.
- These designs have different **variable** values and may perform differently on a given **objective** metric. This introduces **trade-offs**.
  - For example, one wheel design may offer the highest strength, while another offers the lowest cost.

Practice Example: Solar Farm Design

- Next, you'll evaluate your solar farm designs.
  - Yearly Total Output (kWh), yearly average output (kWh)
  - Cost (USD), Profit (USD)
- You'll likely notice that the ones that produce the highest output aren't the same ones that produce the highest profit.
  - Which designs are non-dominated?
  - Are any designs dominated?
  - How would you choose which design is best?

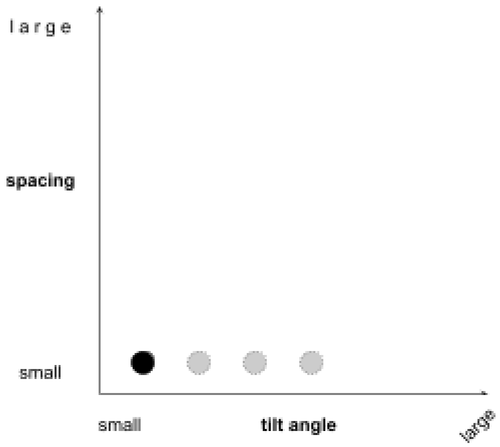
Iteration

- Iterating involves making small changes to dominated designs (identified through **exploration** and **evaluation**), to (hopefully) further improve their performance.

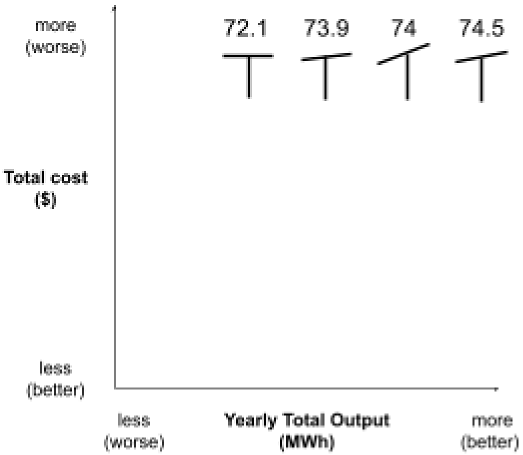


Practice Example: Solar Farm Design

During the iteration step, we can pick one of the non-dominated designs and change the tilt angle slightly. What is the effect on the yearly total output?



Design space



Objective space

Summary

In **Traditional Design (TD)**, you:

- First, develop a complete picture of the design problem by defining your **objectives**, **constraints**, and **variables**.
- Create several design concepts that adhere to the **constraints**.
- Develop an understanding of how changing the **variables** affects the design performance.
- Determine which designs are **non-dominated** and which are **dominated**.
- Make slight changes to **dominated design(s)**, with the aim of further improving their performance.

END