AUTODESK UNIVERSITY

Using Advanced Features in Generative Design



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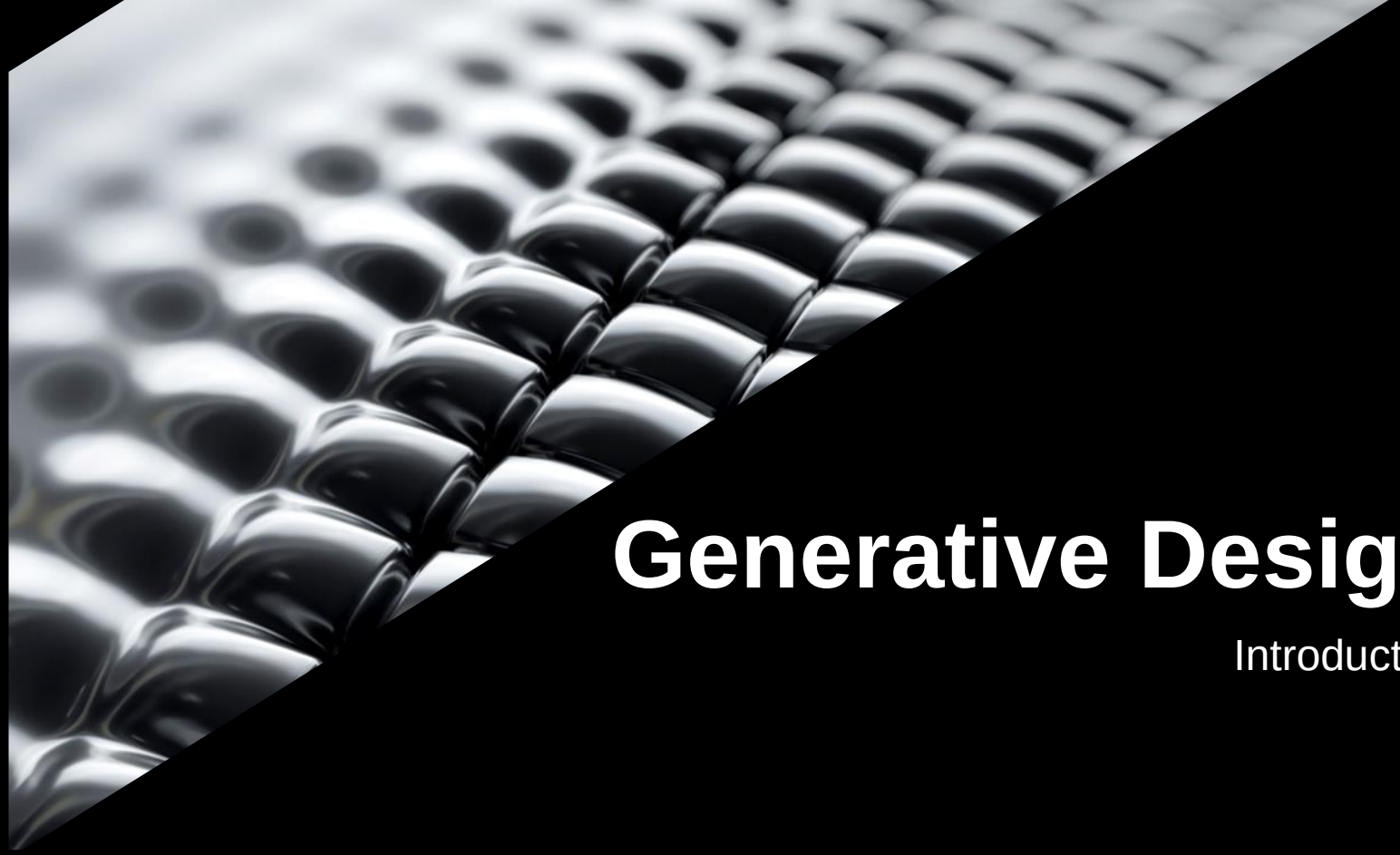
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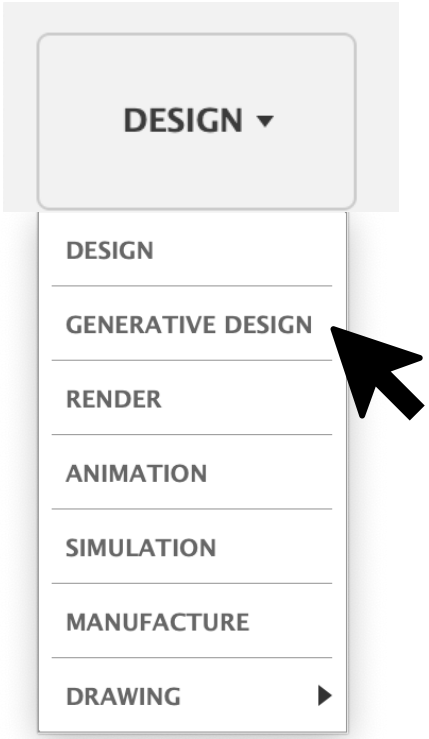
Generative Design

Introduction

What is Generative Design?

- Generative design is a **design exploration** technology available **in Fusion 360**

- Simultaneously generate multiple CAD-ready solutions based on real-world manufacturing constraints, cost evaluation and product performance requirements



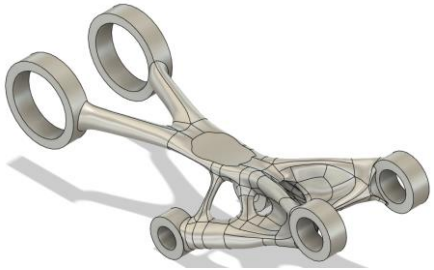
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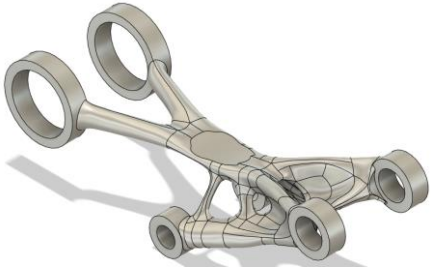
Traditional Design



CAD

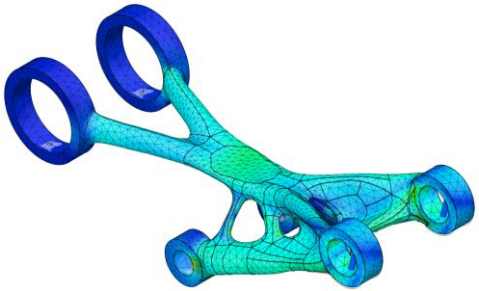
Computer Aided Design

Traditional Design



CAD

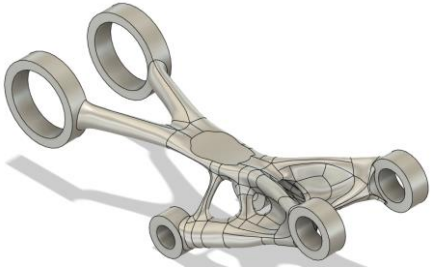
Computer Aided Design



CAE

Computer Aided Engineering

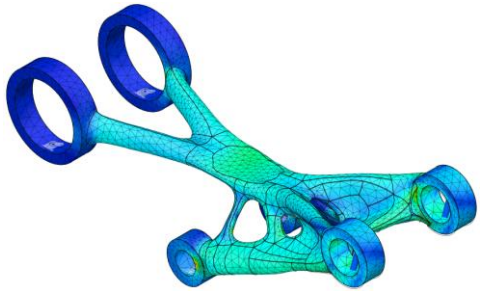
Traditional Design



CAD

Computer Aided Design

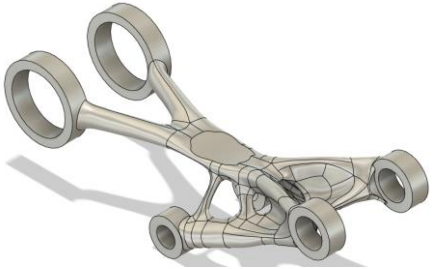




CAE

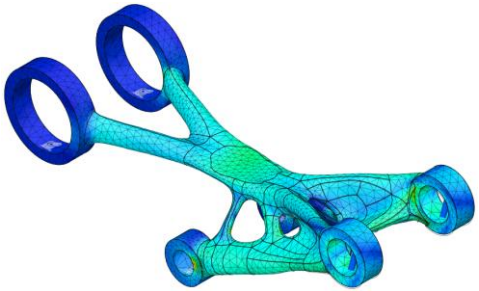
Computer Aided Engineering

Traditional Design



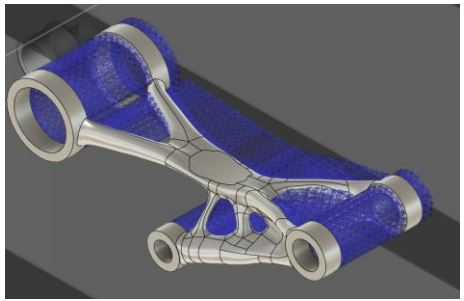
CAD

Computer Aided Design



CAE

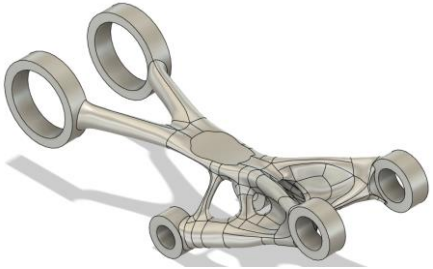
Computer Aided Engineering



CAM

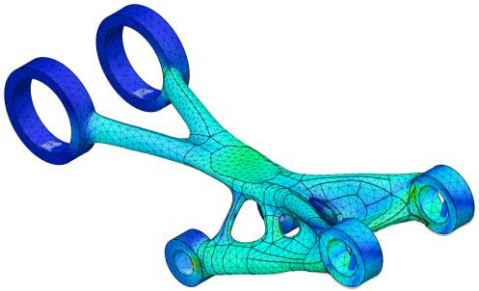
Computer Aided Manufacturing

Traditional Design



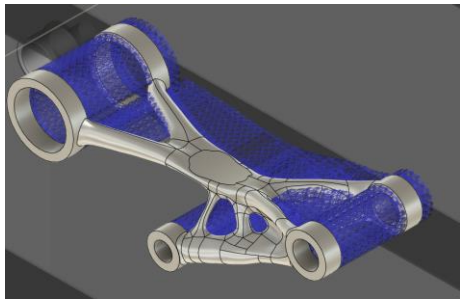
CAD

Computer Aided Design



CAE

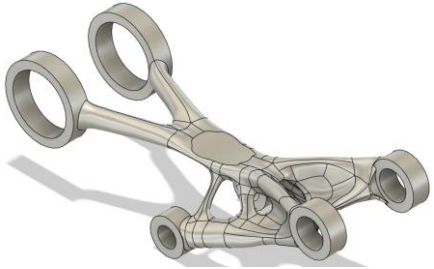
Computer Aided Engineering



CAM

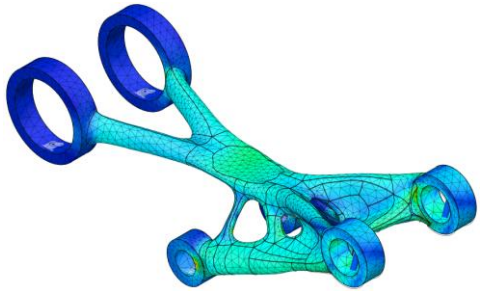
Computer Aided Manufacturing

Traditional Design



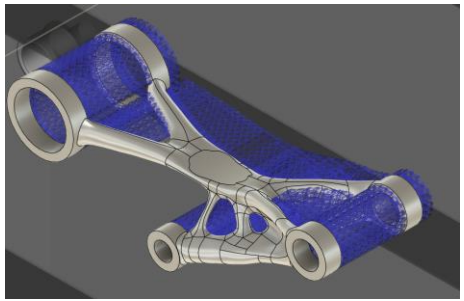
CAD

Computer Aided Design



CAE

Computer Aided Engineering



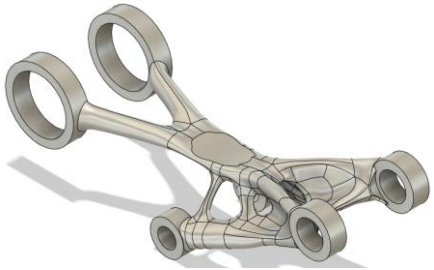
CAM

Computer Aided Manufacturing



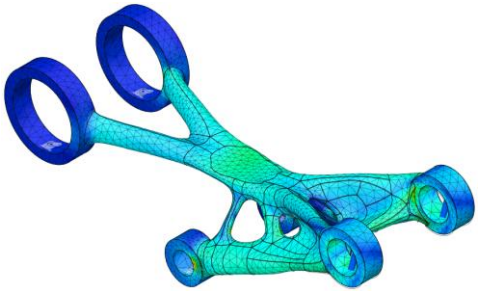
Manufacture

Traditional Design



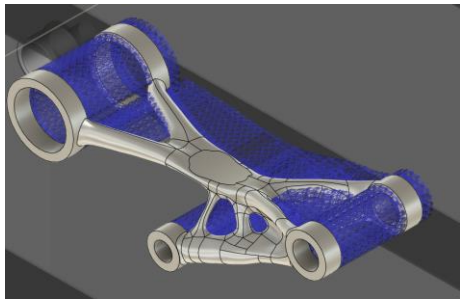
CAD

Computer Aided Design



CAE

Computer Aided Engineering



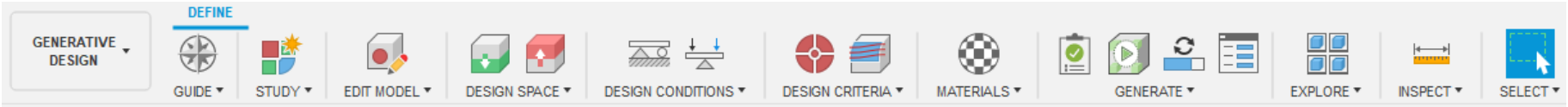
CAM

Computer Aided Manufacturing

Generative Design

Workflow

- Generative Design requires few steps:



  - Create Generative Study
  - Define Preserve geometry
    - Optionally Obstacle or/and Starting Shape
  - Assign Boundary Conditions
    - Loads
    - Constraints
  - Select Material
  - Define Manufacturing method
  - Set Objectives
  - Adjust resolution
  - Check potential warnings
  - Generate study
  - Explore results
  - Export design
  - Validate design

Standard Features



Design control

- Preserve geometry
- Obstacle geometry
- Starting Shape
- Obstacle Offset
- Manufacturing Methods
  - Unrestricted
  - Additive
  - 2 axis cutting
  - 2.5 / 3 / 5 axis milling



Boundary Condition

- Loads:
  - Force
  - Pressure
  - Moment
  - Bearing
- Constraints:
  - Fixed
  - Pin
  - Frictionless



Objective Limits

- Mass Target
- Safety Factor



Advanced Features

Introduction

Preview Technology

Generative Design introduces additional advanced features thru several preview options:

- Experimental Generative Solvers & Features
  - Enables advanced functionality
- Die Casting
  - Enables additional manufacturing method
- Fluid Path
  - Enables generation of a flow path optimized for pressure drop based on your geometric and performance requirements

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Advanced Features



Design control

- Symmetry
- Manufacturing Methods
  - Die Casting



Boundary Condition

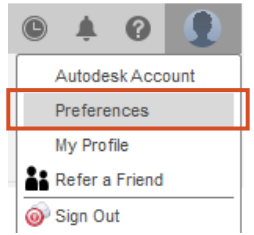
- Remote loads
- Remote constraints
- Point Mass
- Remove Rigid Body Modes



Objective Limits

- Frequency
- Buckling
- Displacement limits

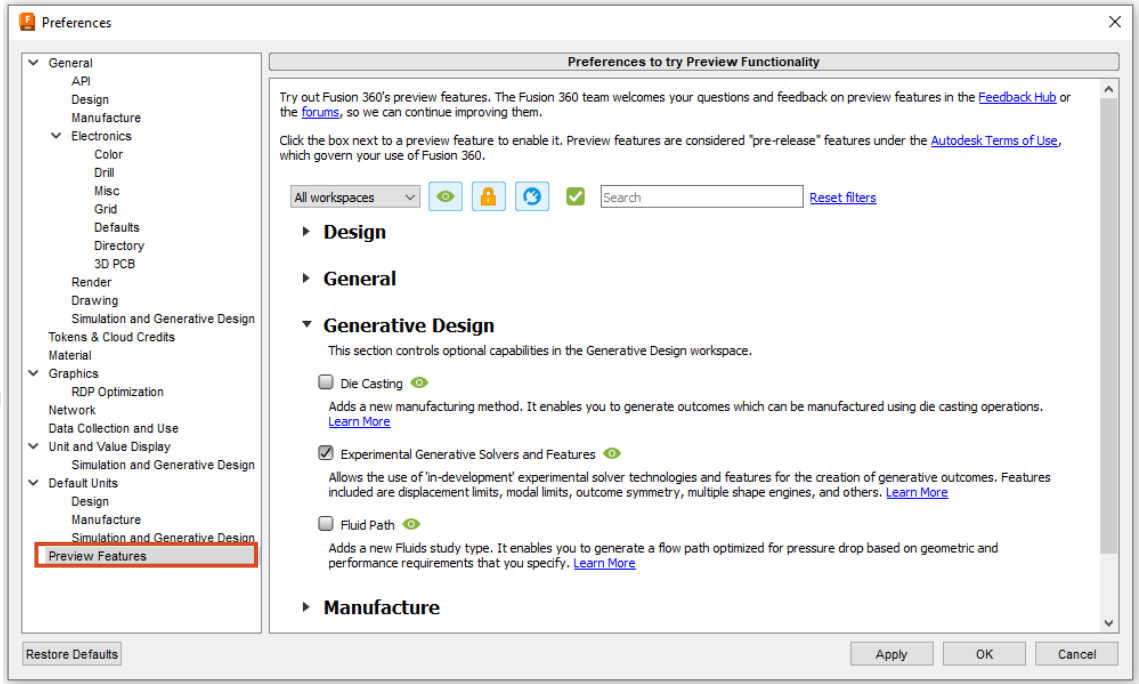
How to enable Preview Features?



Preview Features are available for all Generative Design users.

To enable Preview Features:

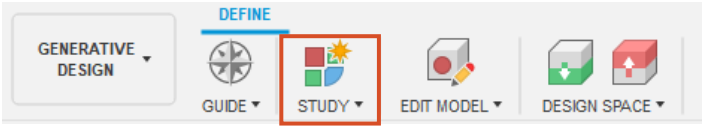
- Open **Preferences**
- In the **Preferences** dialog, in the left panel, select **Preview Features**
- In the right panel, expand **Generative Design** section
- Select the **Preview** you wish to enable
- Apply changes

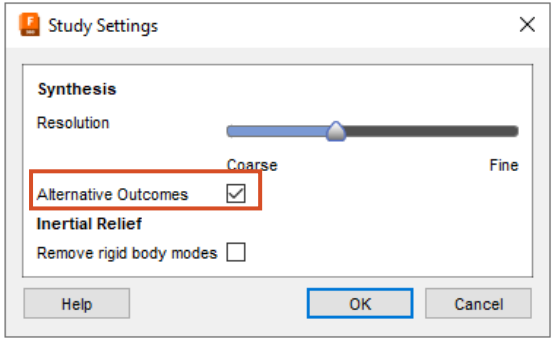


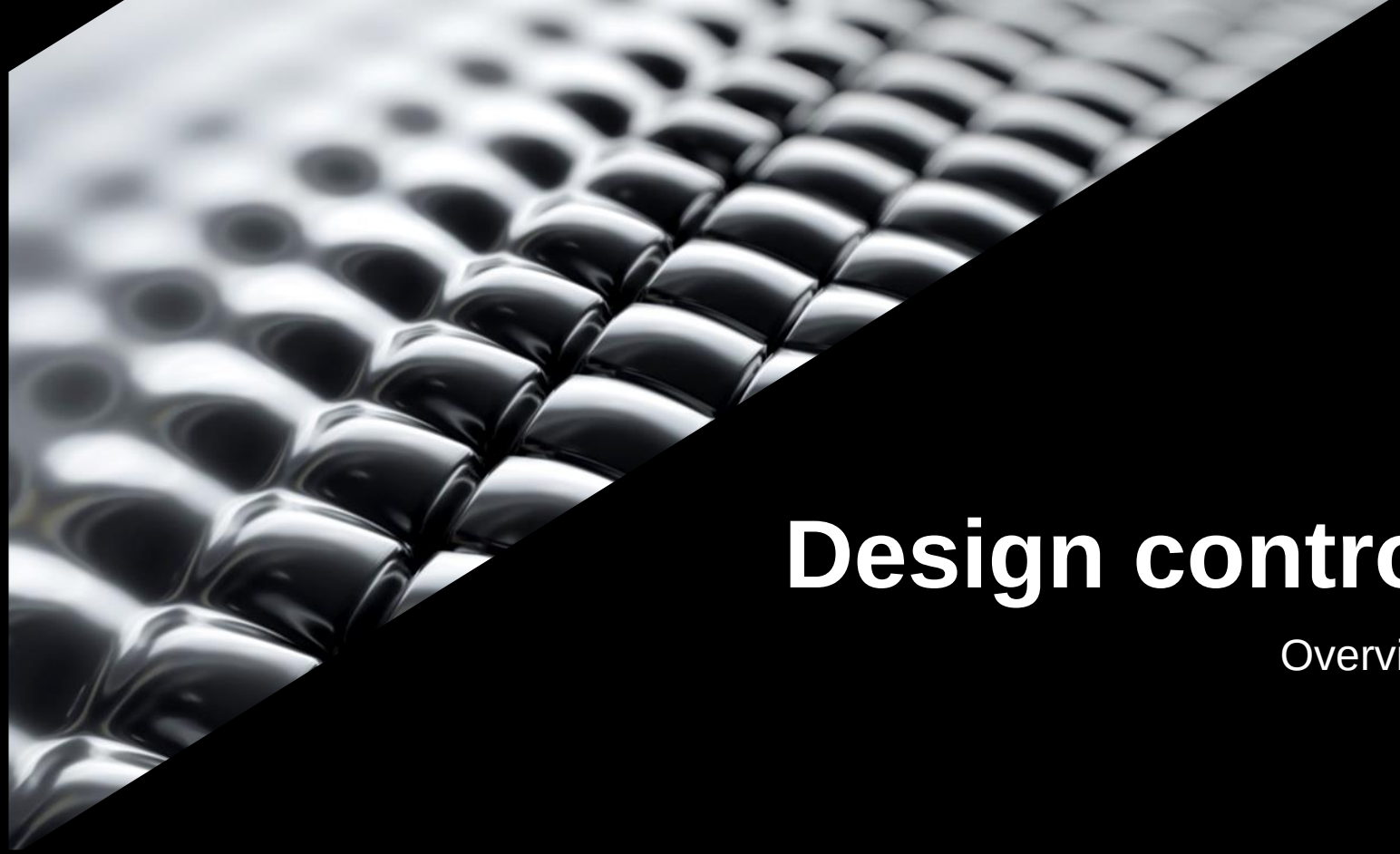
Alternative Outcomes

Experimental Generative Solvers & Features enables additional option under Study Settings called **Alternative Outcomes**.

Alternative Outcomes checked, can provide additional outcomes depending on setup configuration.





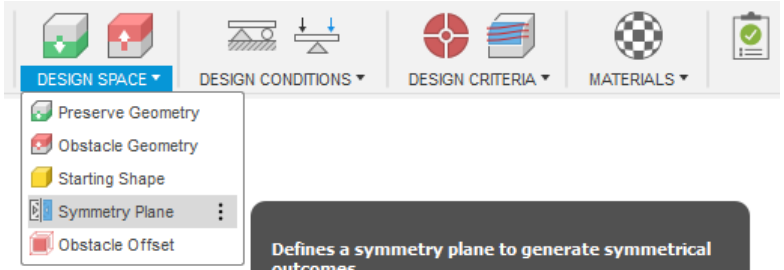


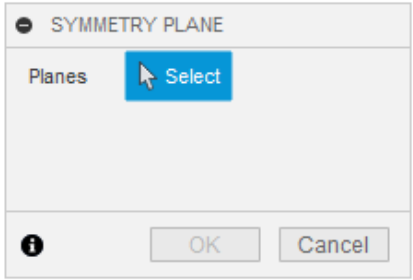
Design control

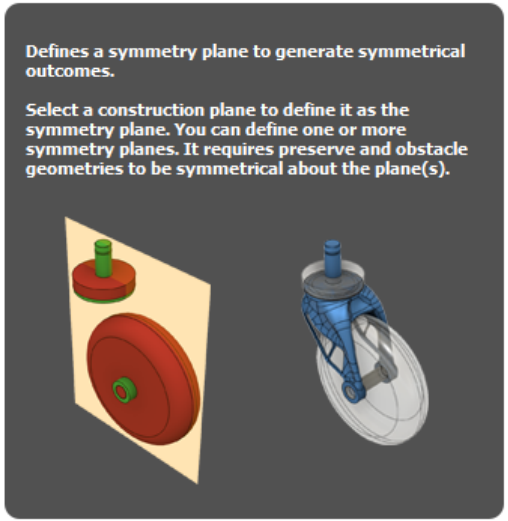
Overview

Symmetry

- Application
  - Drive shape generation by enforcing symmetrical design
  - Application of symmetry constraints in final design (T-Spline edit mode)



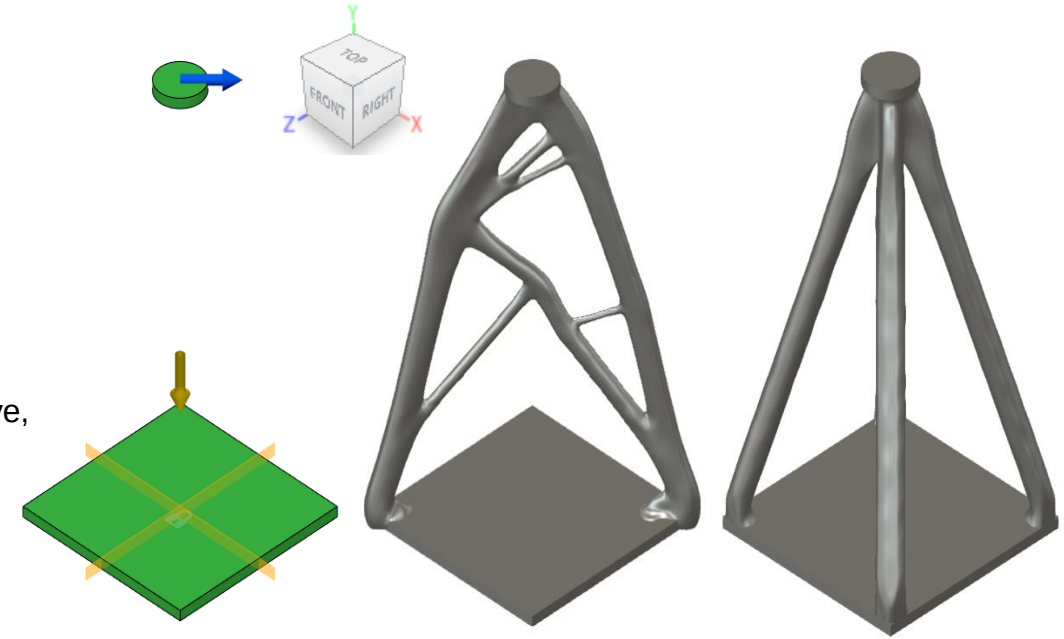




- How to use it?
  - Go to **Design Space** section
  - Select **Symmetry Plane**
  - Choose construction planes in your model
  - **Accept** your selection

Symmetry

- Requirements
  - Up to 3 symmetry planes
  - Symmetry planes must be orthogonal
  - Setup (preserves and obstacles) needs to be symmetrical
  - Loads and constraints can be unsymmetrical
  - Some manufacturing settings can be contradictory to symmetry settings
  - Symmetry is supported for Unrestricted, Additive, 3-axis milling and 5-axis milling manufacturing method
- Good practice
  - Use symmetric setup (preserve geometry, obstacle and starting shape)
  - Verify symmetrical setup thru Pre-check

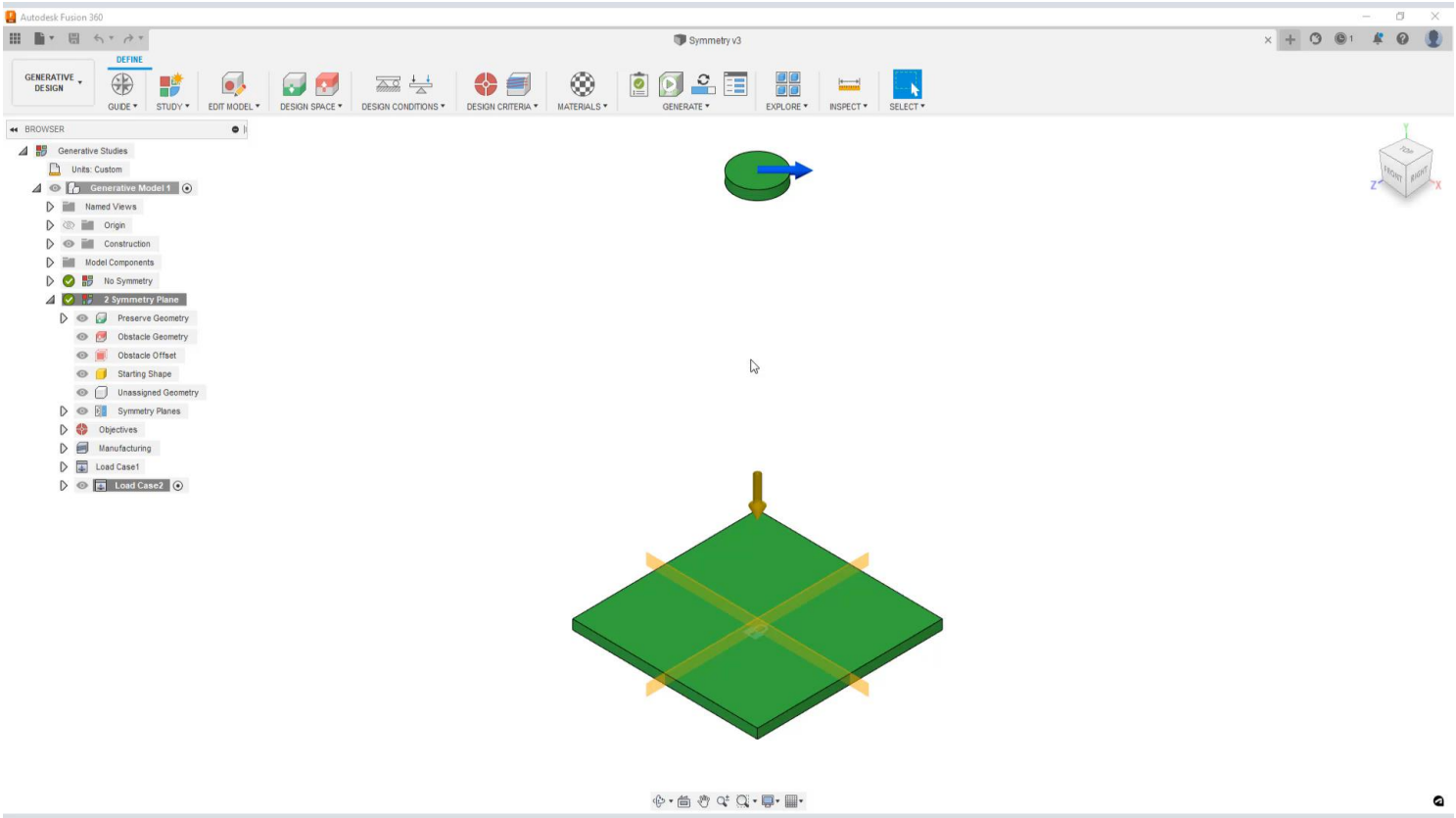


Setup

No symmetry planes

2 symmetry planes (XY & YZ)

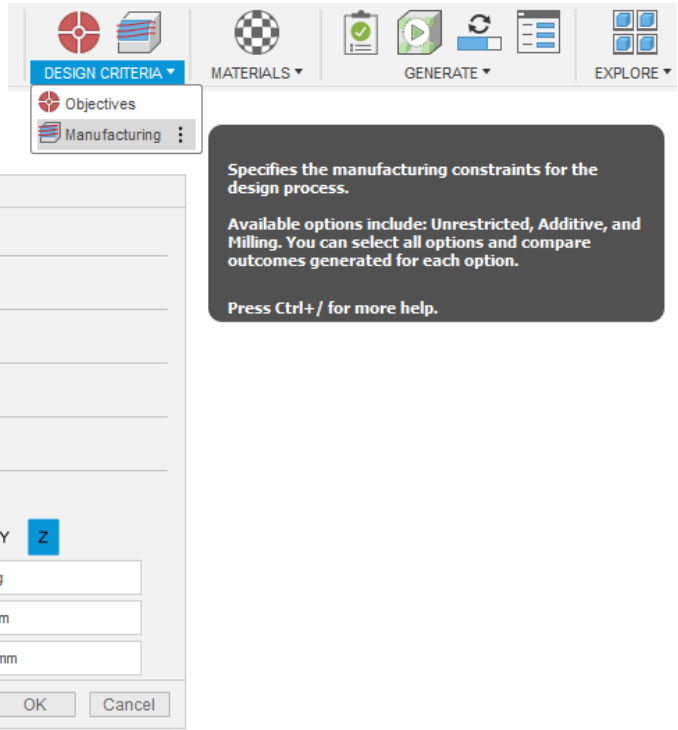
Symmetry


Autodesk Fusion 360
Symmetry v3
GENERATIVE DESIGN
DEFINE
GUIDE
STUDY
EDIT MODEL
DESIGN SPACE
DESIGN CONDITIONS
DESIGN CRITERIA
MATERIALS
GENERATE
EXPLORE
INSPECT
SELECT
BROWSER
Generative Studies
Units: Custom
Generative Model 1
Named Views
Origin
Construction
Model Components
No Symmetry
2 Symmetry Plane
Preserve Geometry
Obstacle Geometry
Obstacle Offset
Starting Shape
Unassigned Geometry
Symmetry Planes
Objectives
Manufacturing
Load Case1
Load Case2

Die Casting

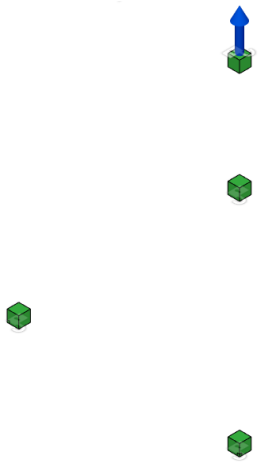
- Application
  - Create a design applicable for Die Casting manufacturing

- How to use it?
  - Go to **Design Criteria**
  - Select **Manufacturing**
  - Enable **Die Casting**
  - Setup your **manufacturing method**
    - Minimum Draft Angle
    - Minimum Thickness
    - Maximum Thickness
  - **Accept** your selection

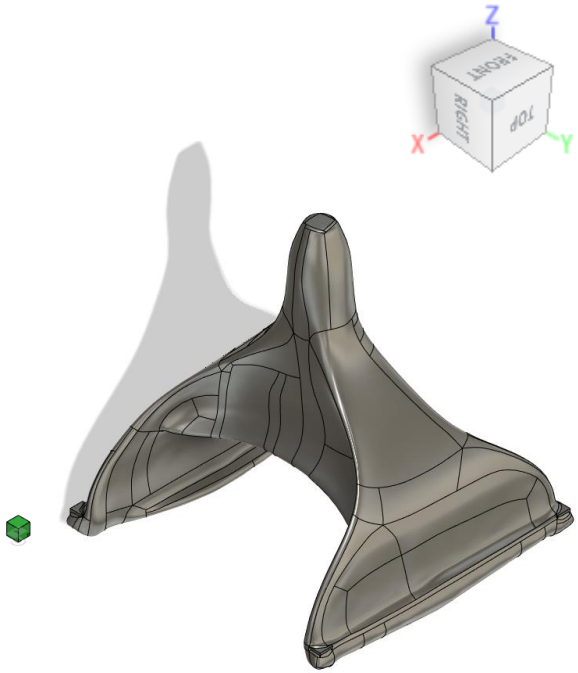


Die Casting

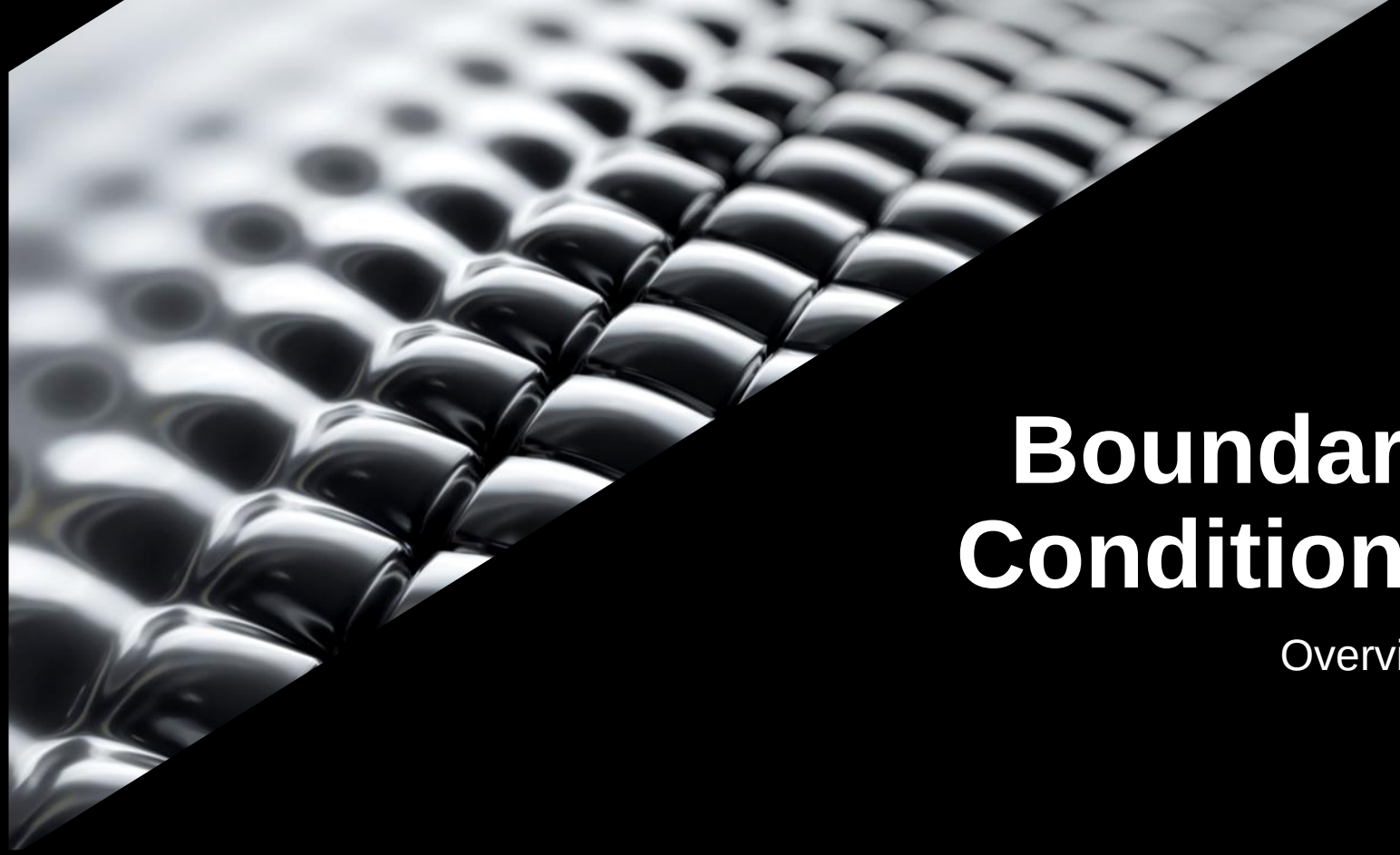
- Requirements
  - Setup must be Die Casting “friendly”
  - Some of advanced features are not supported together with Die Casting
    - Symmetry
    - Remote loads
    - Remote constraints
    - Point mass
    - Remove Rigid Body modes
- Good practice
  - Your entry setup must be possible to obtain thru Die Casting manufacturing



Setup



Die Casting result
Direction +X-X

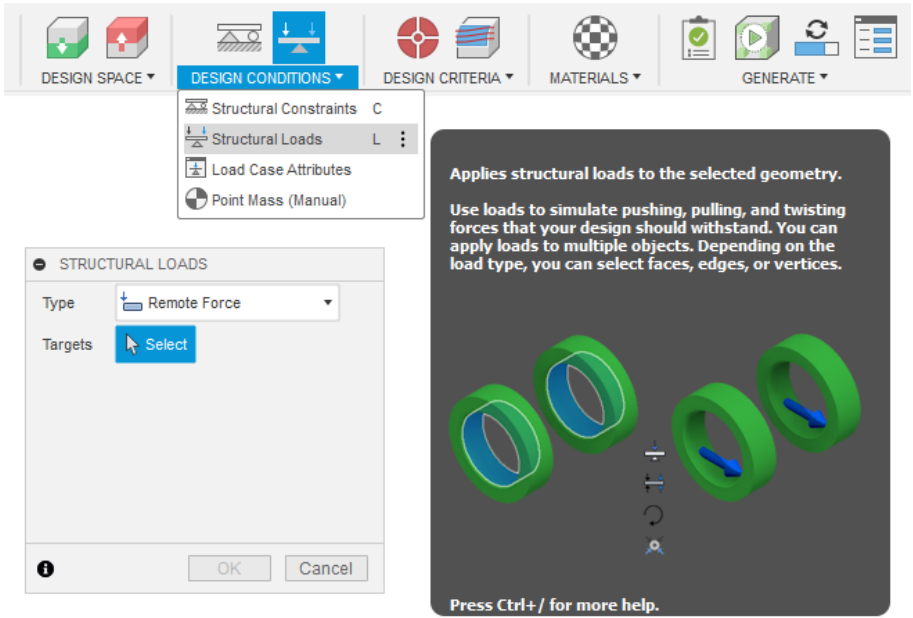


Boundary Conditions

Overview

Remote Loads

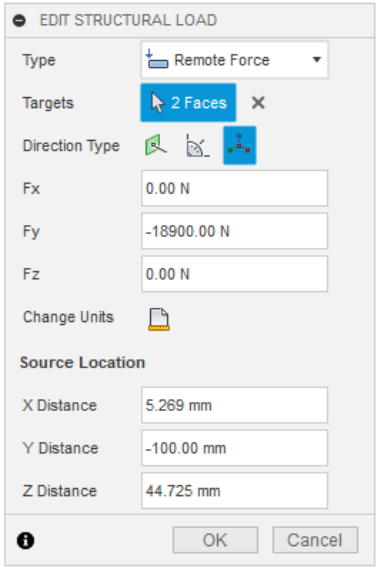
- Application
  - Define point loads that are not directly on the preserves
  - Commonly used for simulation of assemblies
- How to use it?
  - Go to **Design Conditions**
  - Choose **Structural Loads**
  - Select up **Remote Force** or **Remote Moment** thru dialog drop down menu
  - Select target and input desired load
  - **Accept** your selection

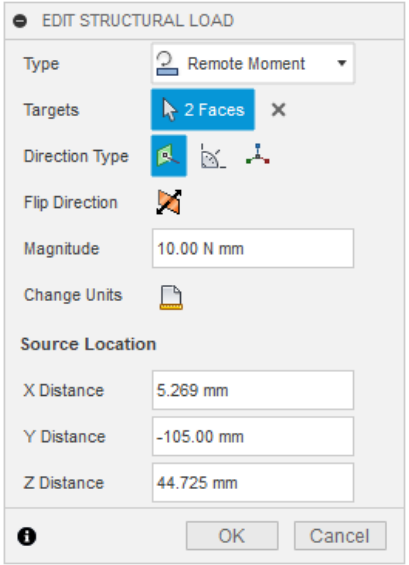


Remote Loads

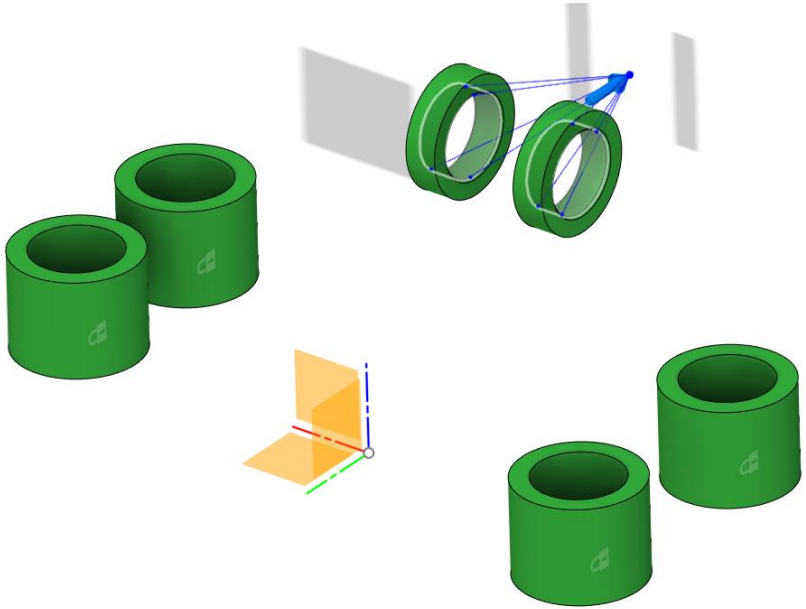
- Requirements
  - Force and Moment loads are supported
  - Only Faces can be choosen as target
  - Points, edges, bodies are not supported

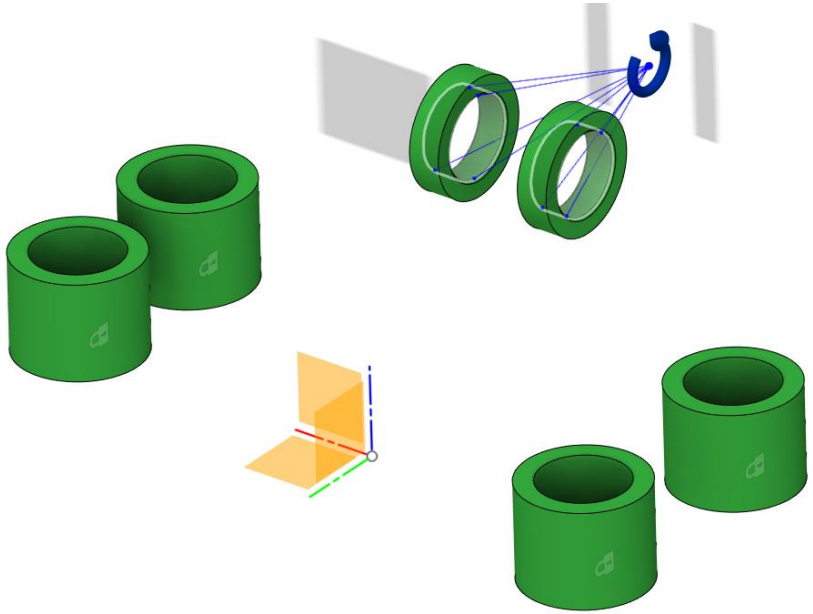
- Good practice
  - Remote loads should be realistic
  - Avoid relatively small loads as it may lead to disconnections
  - Avoid self canceling (opposite direction, same magnitude) loads on same preserves





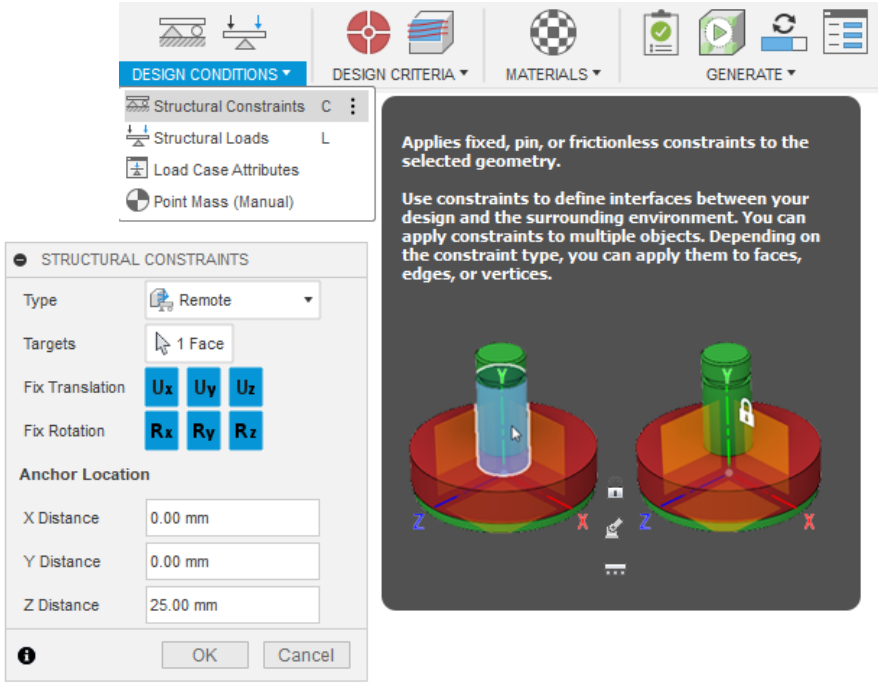
Remote Loads





Remote Constraints

- Application
  - Define constraints that are not directly on the preserves
  - Define joint like connection
  - Commonly used for simulation of assemblies
- How to use it?
  - Go to **Design Conditions**
  - Choose **Structural Constraints**
  - Select up **Remote Constraints** thru dialog drop down menu
  - Select **Target** and apply **Degree of Freedom**
  - Select **Anchor Location**
  - **Accept** your selection



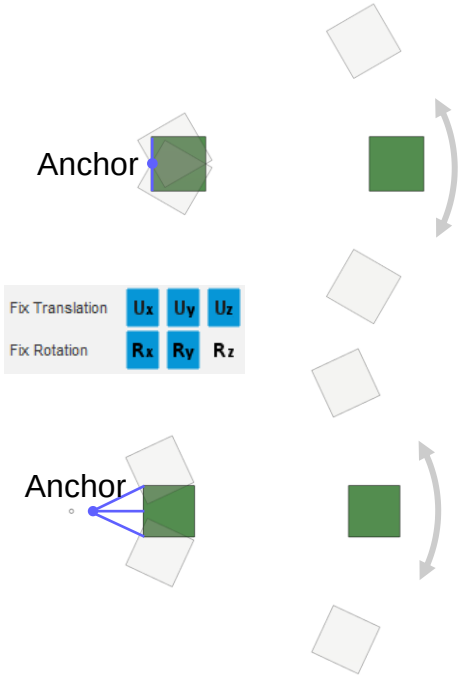
Remote Constraints

- Requirements
  - Only Faces can be choosen as target
  - Points, edges, bodies are not supported
- Good practice
  - Selection of Degrees of Freedom should be done with caution

Remote Constraints



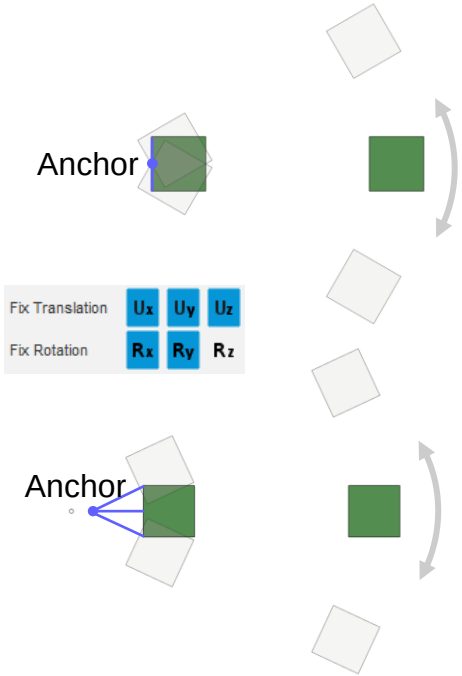
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- Good practice
  - Selection of Degrees of Freedom should be done with caution



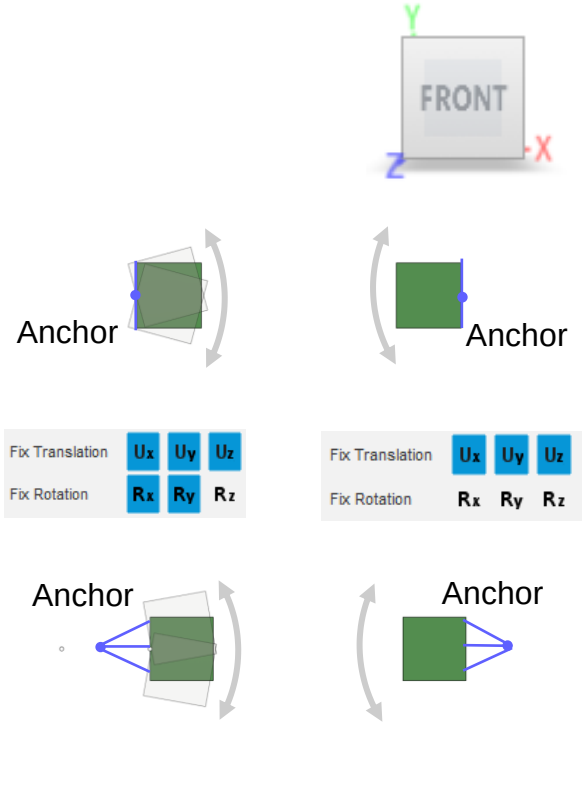
Setup won't run correctly as it is **NOT** fully constraint

Remote Constraints

- Requirements
  - Only Faces can be choosen as target
  - Points, edges, bodies are not supported
- Good practice
  - Selection of Degrees of Freedom should be done with caution



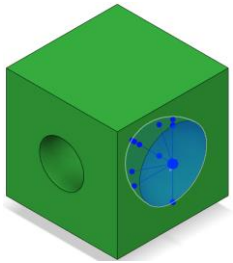
Setup won't run correctly as it is **NOT** fully constraint



Setup fully constrained

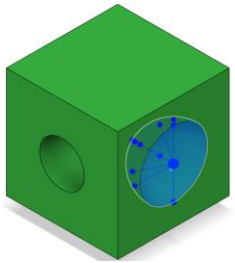
Remote Constraints

Fixed



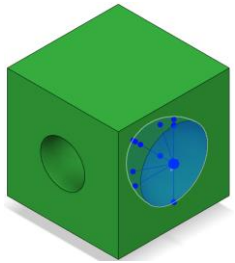
Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

No rotations

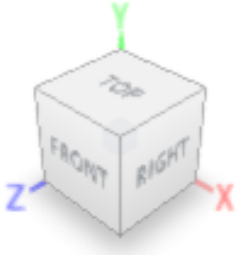


Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

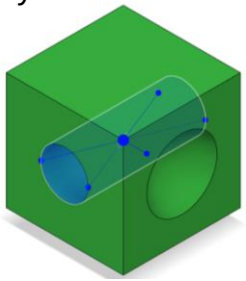
Ball Joint



Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

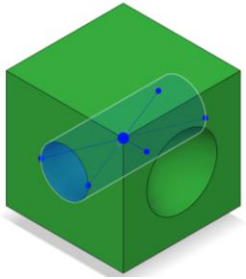


Cylindrical Joint



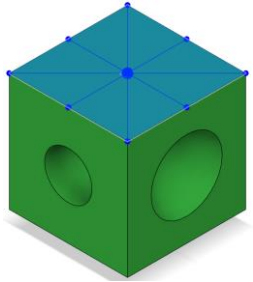
Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

Revolute Joint



Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

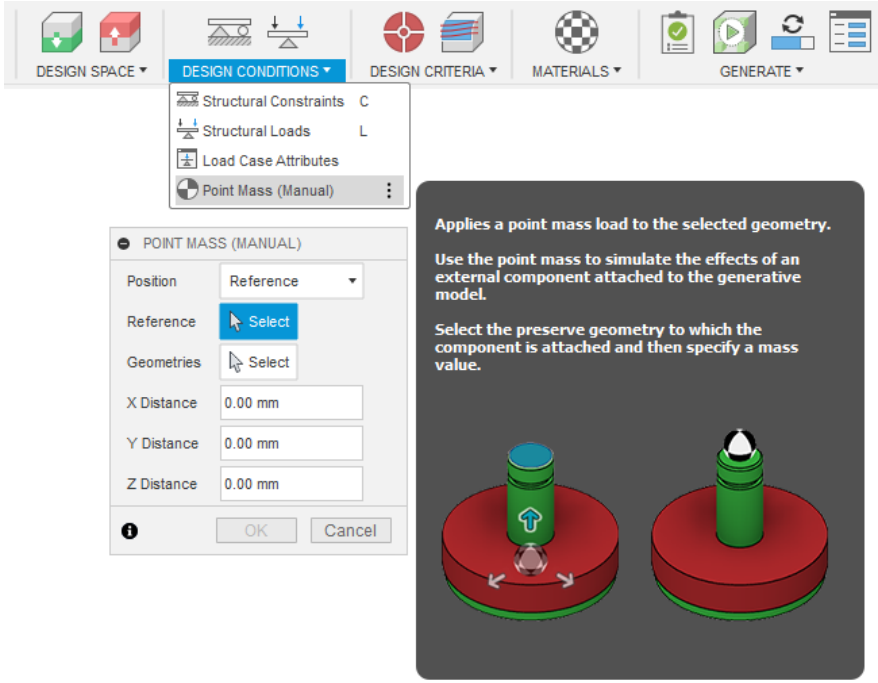
Frictionless



Fix Translation	Ux	Uy	Uz
Fix Rotation	Rx	Ry	Rz

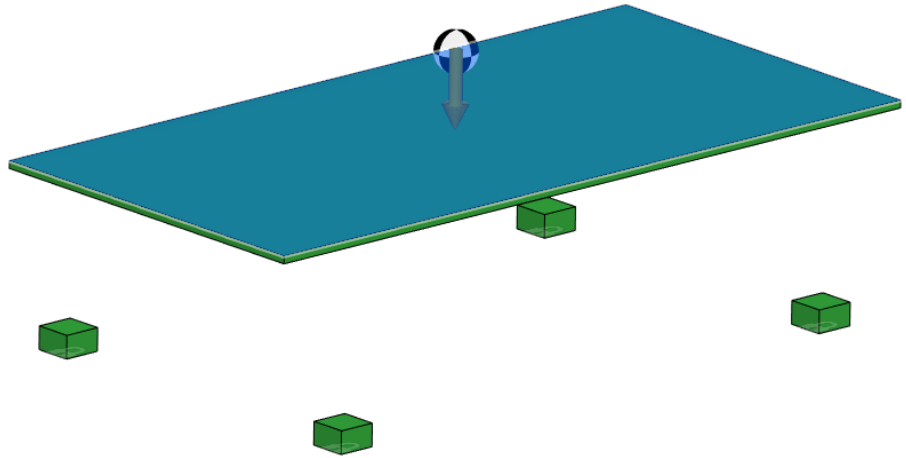
Point Mass

- Application
  - Represents the effects of an external component attached to the generative model
- How to use it?
  - Go to **Design Conditions**
  - Choose **Point Mass**
  - Set up **Point Mass** thru dialog
    - Define Position
    - Choose Preserve to which point mass is connected
    - Define Mass
  - **Accept** your selection



Point Mass

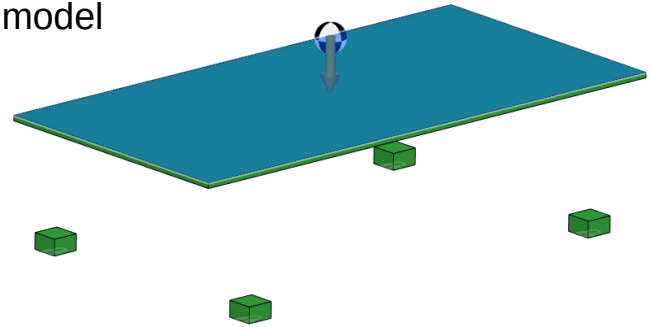
- Requirements
  - Point Mass has an effect only if:
    - Loadcase contains Gravity Load
    - Loadcase contains Frequency limit
  - Point masses will not affect the mass target or mass minimization values

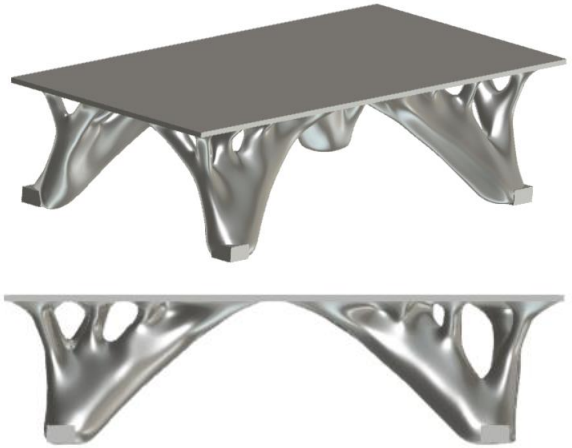


- Good practice
  - Point mass should be realistic
  - Point mass should not have significant impact on stiffness

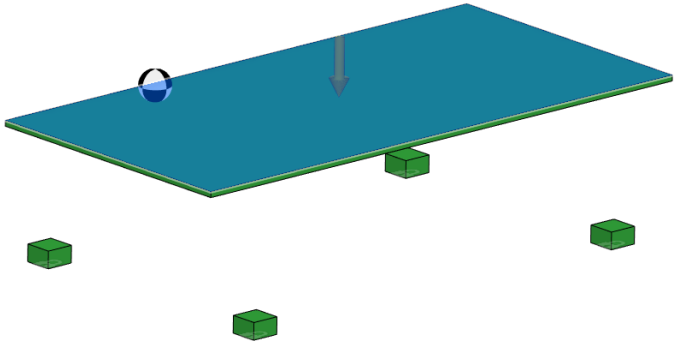
Point Mass

- Point Mass at the center of table model





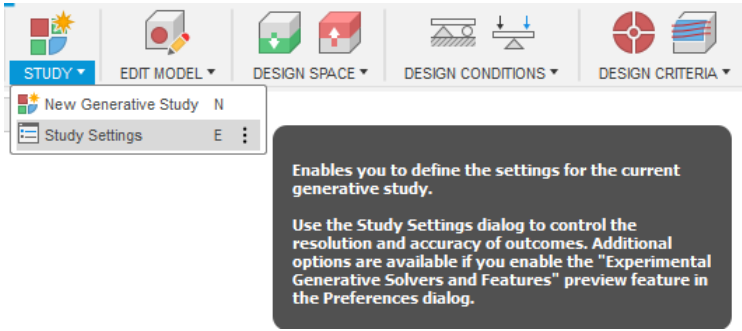
- Point Mass near the edge of table model



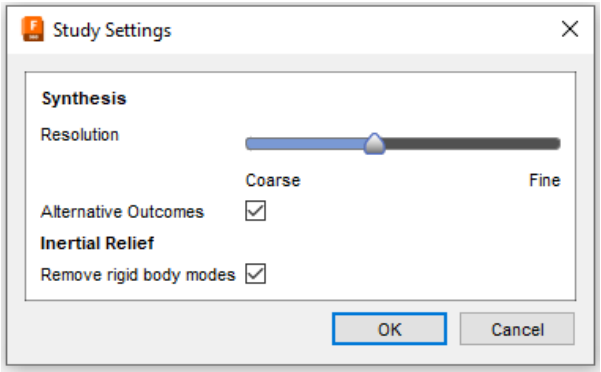


Remove Rigid Body Mode

- Application
  - Stabilize generative study when model is not entirely constrained
  - Commonly used for simulation of assemblies

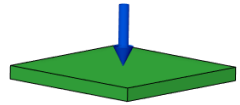


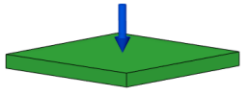
- How to use it?
  - Go to **Study**
  - Choose **Study Settings**
  - Check **Remove rigid body modes** box
  - **Accept** your selection



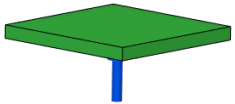
Remove Rigid Body Mode

- Requirements
  - It is recommended to use this feature without constraints
  - The sum of loads equals to or is close to zero (loads are balanced)
- Good practice
  - Instead of constraints please us all known forces (contact forces, reaction forces etc) to stabilize your model
  - Make sure that the loads are balanced in the direction where the constraints are applied

















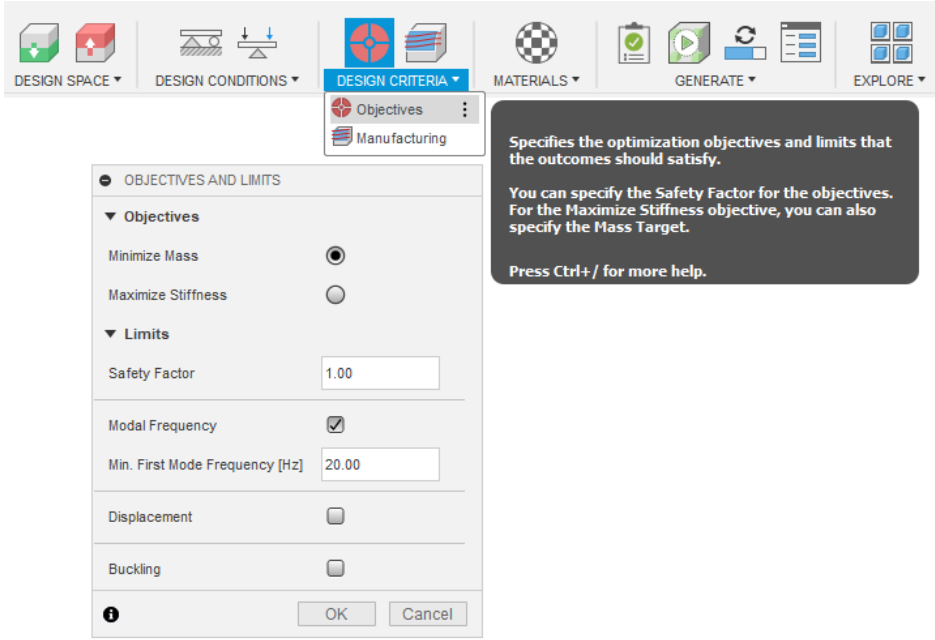
Objective Limits

Overview

Frequency

- Application
  - Prevent resonance phenomena in designed part by including limit of first natural frequency

- How to use it?
  - Go to **Design Criteria**
  - Choose **Objectives**
  - Check **Modal Frequency** option under **Limits** section
  - Set up **Minimal First Mode Frequency [Hz]**
  - **Accept** your selection



Frequency

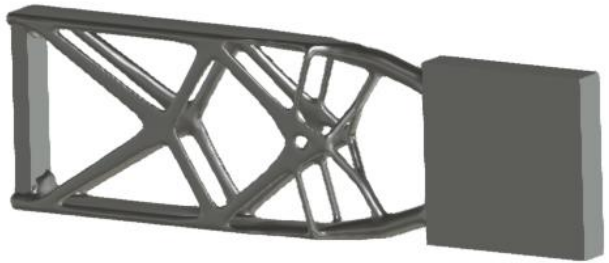
- Requirements
  - Only First Natural Mode is supported
  - Frequency must be applied in [Hz] units
  - Expect longer runtime
- Good practice
  - Select minimum first mode frequency to be higher than excitation frequencies

Setup



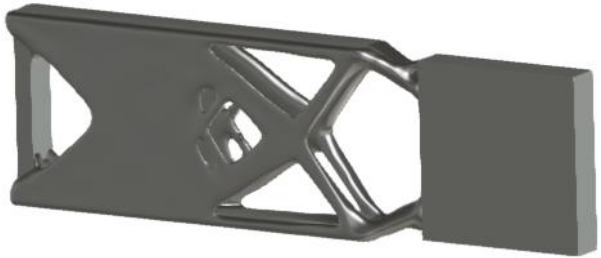
No Frequency limit

First Mode = 314 [Hz]



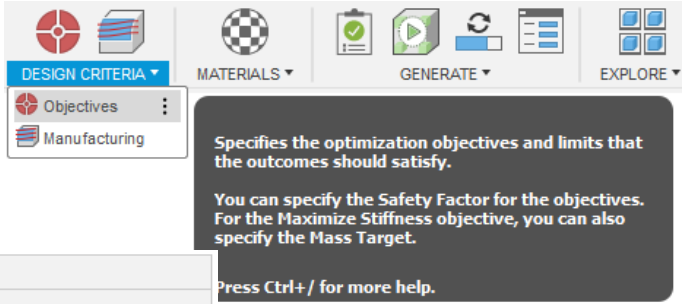
Frequency limit = 500 [Hz]

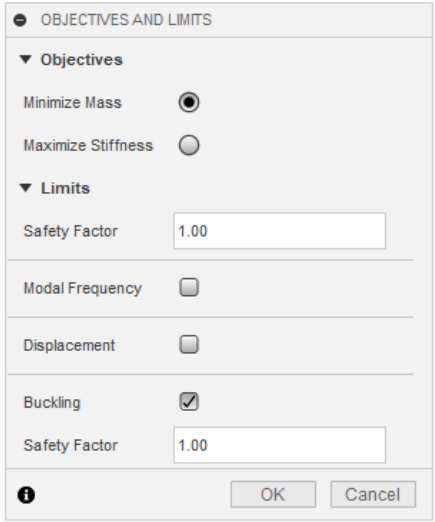
First Mode = 508 [Hz]



Buckling

- Application
  - Prevent loss of stability of a design under compression loading
- How to use it?
  - Go to **Design Criteria**
  - Choose **Objectives**
  - Check **Buckling** option under **Limits** section
  - Set up **Safety Factor**
  - **Accept** your selection

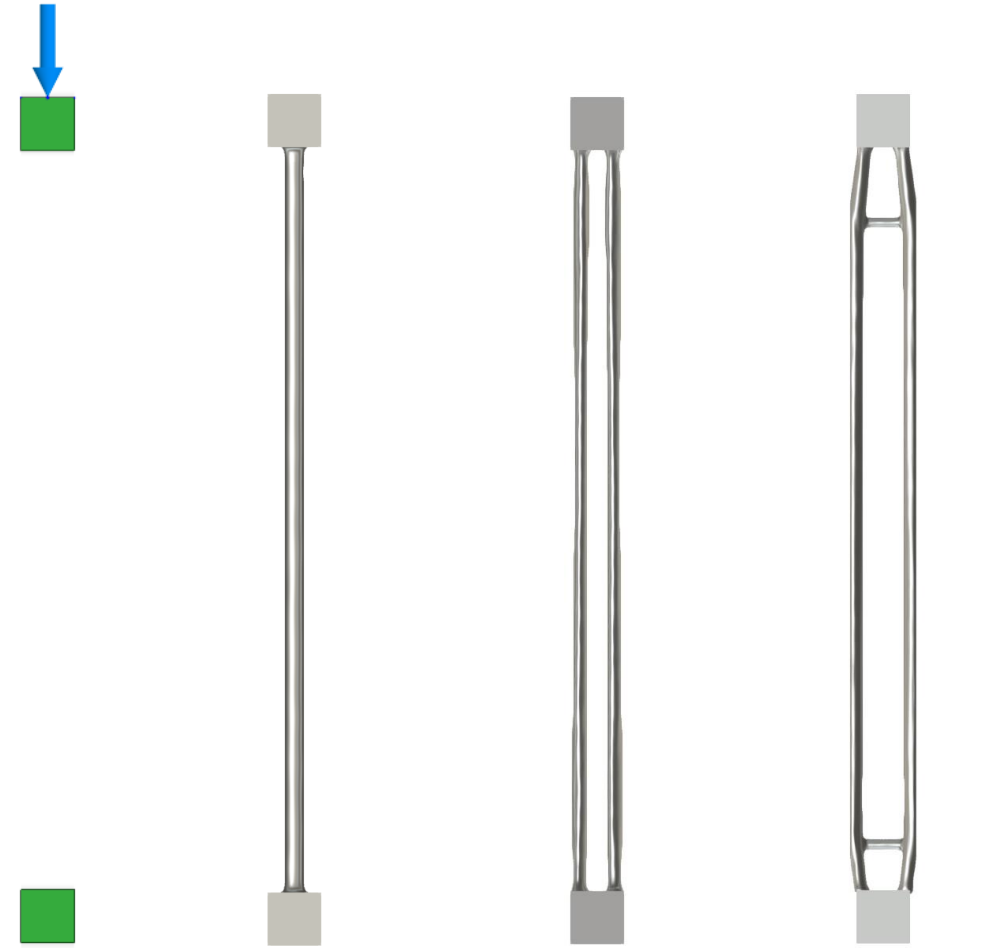




Buckling

- Requirements
  - Only one loadcase is supported
  - Expect longer runtime

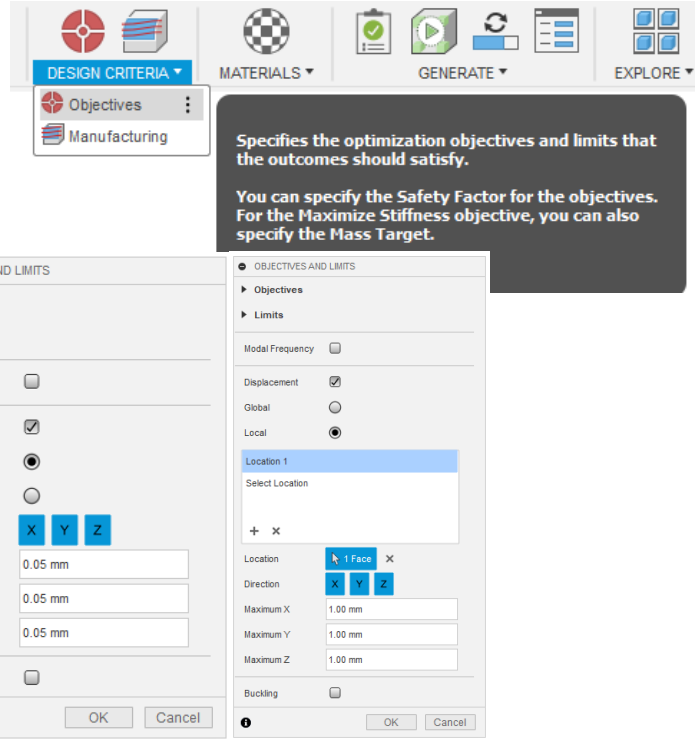
- Good practice
  - Due to limit of single load case per generation, it is advised to choose the most critical load case for your design



Displacement Limit

- Application
  - Set maximum displacement limit for your generative design outcome

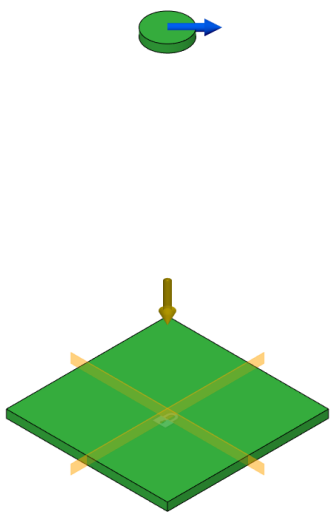
- How to use it?
  - Go to **Design Criteria**
  - Choose **Objectives**
  - Check **Displacement** option under **Limits** section
  - Set up **Global** or **Local** limit
    - Select surface / edge / point if local limit is used
    - Set direction
    - Set allowed maximum displacement
  - **Accept** your selection



Displacement Limit

- Requirements
  - Displacement limit can be
    - Global
    - Local

- Good practice
  - Displacements limits should be realistic
  - Avoid too small displacements limits as it might prevent material reduction
  - In case where many displacement limits are needed, consider using global limit



Setup



No Displacement Limit

Mass = 0.37 kg

Max global displacement
0.113 mm



Displacement Limit

0.025 mm in each global direction

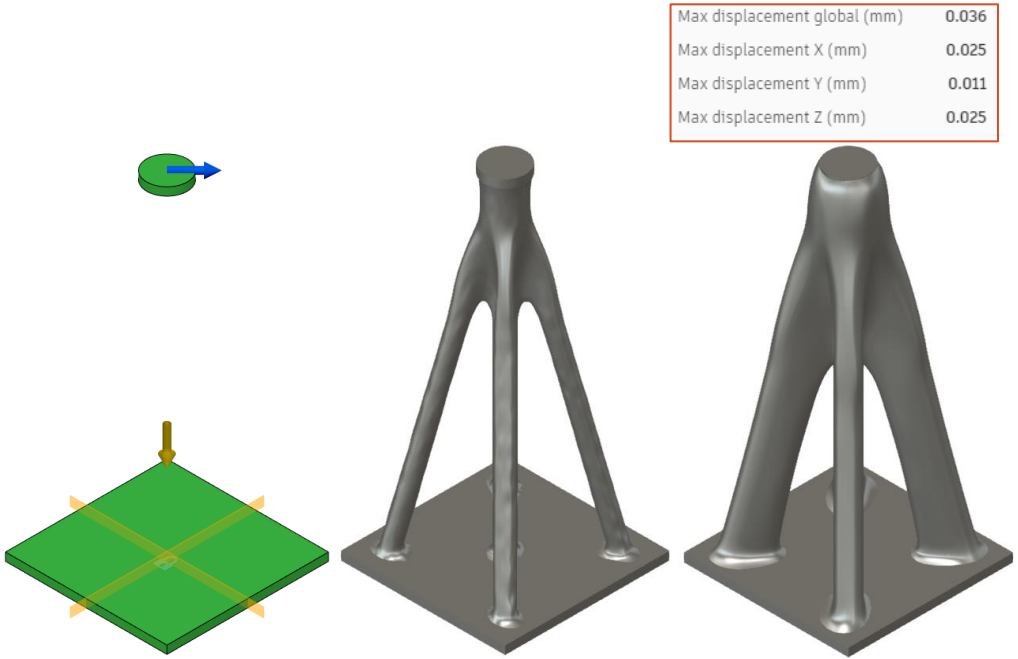
Mass = 0.71 kg

Max global displacement
0.036 mm

Displacement Limit

- Requirements
  - Displacement limit can be
    - Global
    - Local

- Good practice
  - Displacements limits should be realistic
  - Avoid too small displacements limits as it might prevent material reduction
  - In case where many displacement limits are needed, consider using global limit



Setup

No Displacement Limit

Mass = 0.37 kg

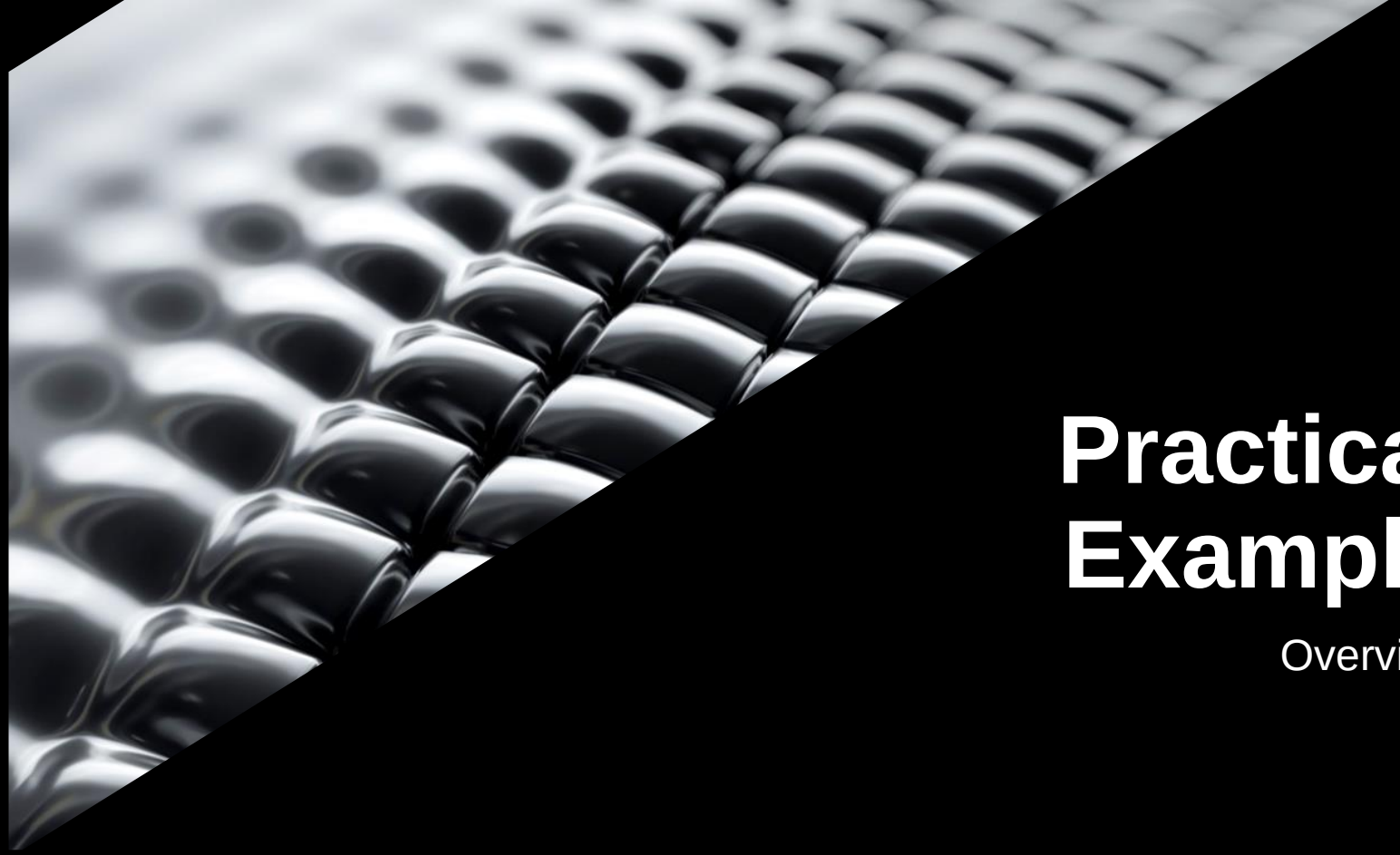
Max global displacement 0.113 mm

Displacement Limit

0.025 mm in each global direction

Mass = 0.71 kg

Max global displacement 0.036 mm



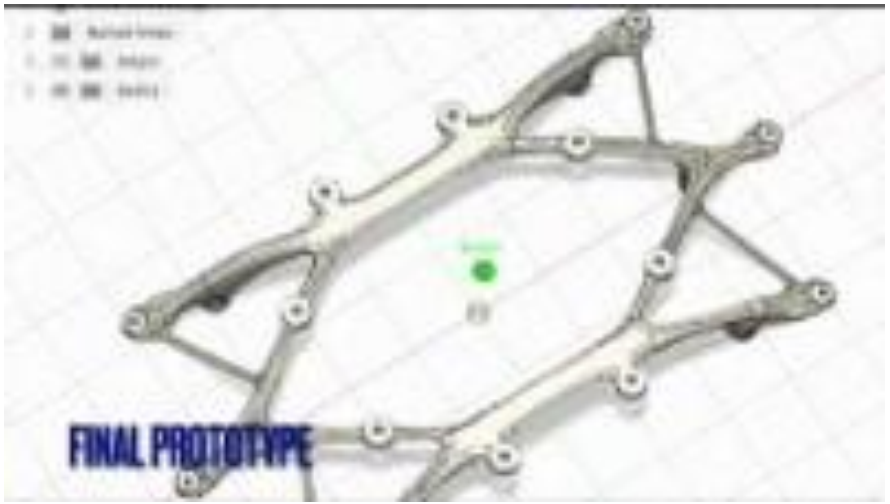
Practical Example

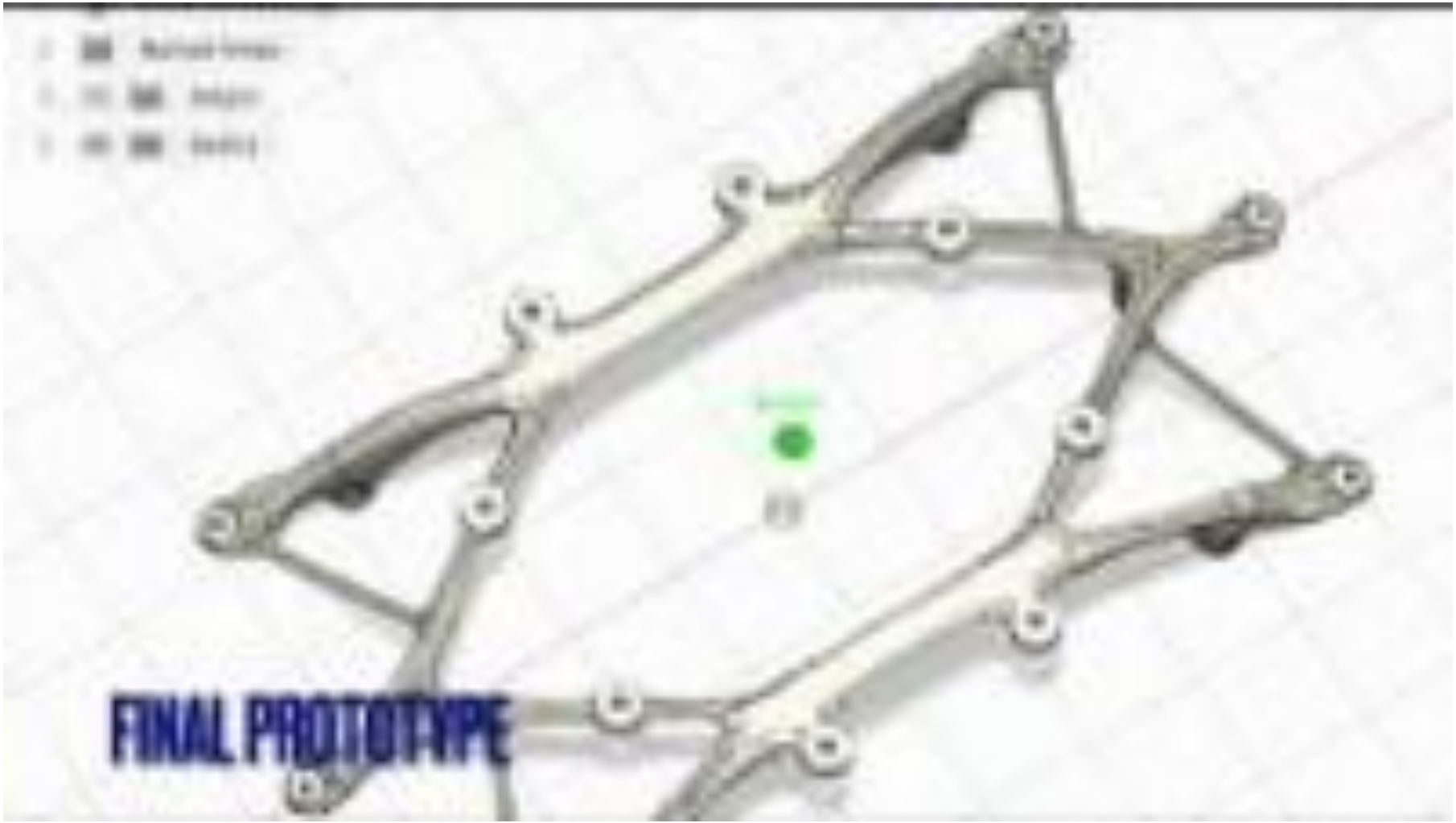
Overview

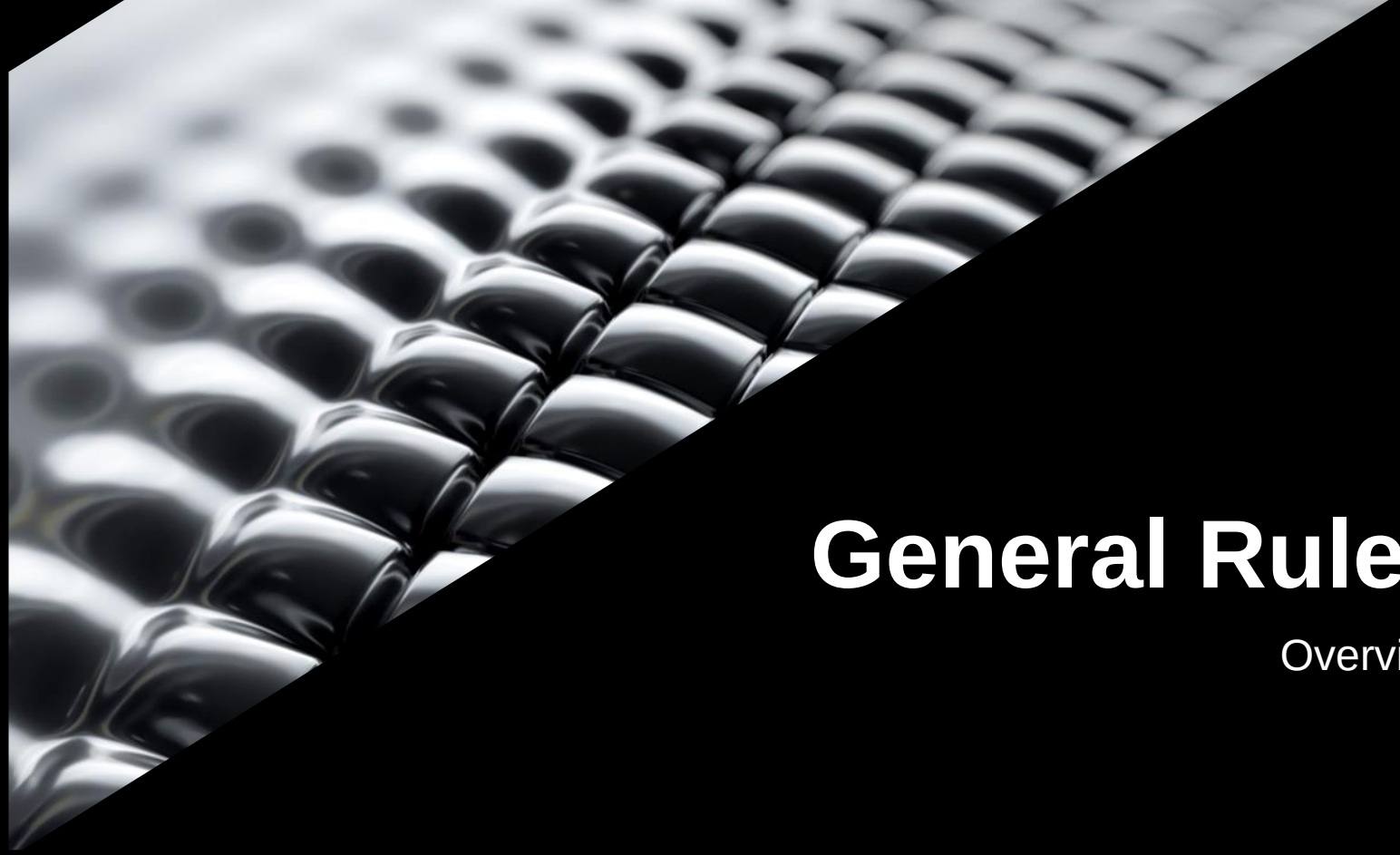
Practical Example

- **Tittle:** Optimized Space Telescope Structure: Penn State Capstone Video
- **Authors:** Penn State Students Gracie Chiodo, Jennifer Aklilu, Yanen Huang, and Luke Fichner
- **Description:** This video summaries the Capstone project completed by these Penn State Engineering students for Spring Semester 2022. The sponsors for this capstone project are Autodesk, Inc and NASA. Autodesk is a software company that created the software named Fusion360 which was utilized for this project. NASA is providing the design challenge itself, which is to build a detector bench that will be a piece of the Star-X space telescope being built. The video describes the design, build, and testing of a telescope structure created by the Penn State students.
- **Source:** YouTube

  https://www.youtube.com/watch?v=Mrgi7d6RQH4&list=FLJDT-JWi_K1w--_y0c0Bm1Q




FINAL PROTOTYPE



General Rules

Overview

General good practice

- Investigate model carefully for any Pre-Check warnings. Any warning can have a direct effect on result
- Use Previewer for validation of your setup
- Preserve, Obstacles and Starting Shape
  - Avoid relatively small / thin geometries
  - Ensure realistic "line of sight“ between all preserve geometry
  - Avoid interference between preserves and obstacles
  - Use starting shape to drive your design
  - Avoid thin starting shape
  - Starting Shape must be connected to preserves
  - Avoid unnecessary detail (i.e. engraved part numbers, complex geometry)
- Material
  - Use realistic material data
- Boundary conditions
  - Loads and constraints should be realistic
  - Avoid low loaded unloaded setups
  - Resultant load at given preserve should be a nonzero value
  - Avoid loads on small area
- Manufacturing methods
  - Not every setup is valid for each manufacturing method
  - Tool dimension should be reasonable compared to user setup
  - Ensure that obstacles are not preventing material removal
- Resolution
  - Change resolution based on your setup. Complex setups need higher resolution
  - Accurate resolution does not guarantee better results



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