

Generative Design Helps Students Improve Their Career Prospects

Prof Dr. Zhang Dong

Liang Jingkan

South China University of Technology

Robotlab



Prof Dr. Zhang Dong

Director of Robotic Lab of South China
University of Technology

South China University of Technology (SCUT)



华南理工大学
South China University of Technology



South China University of Technology



- Ranks 22nd in China and first in South China

South China University of Technology (SCUT)



华南理工大学
South China University of Technology



South China University of Technology (SCUT)



华南理工大学
South China University of Technology

About us

- Ranks 22nd in China and first in South China
- Strong influence on South China Industry
- No.1 employment rate in south China

Top 1% of the country

Architecture

Mechanical engineering

Management science and
engineering

Top 1‰ in the world

Engineering

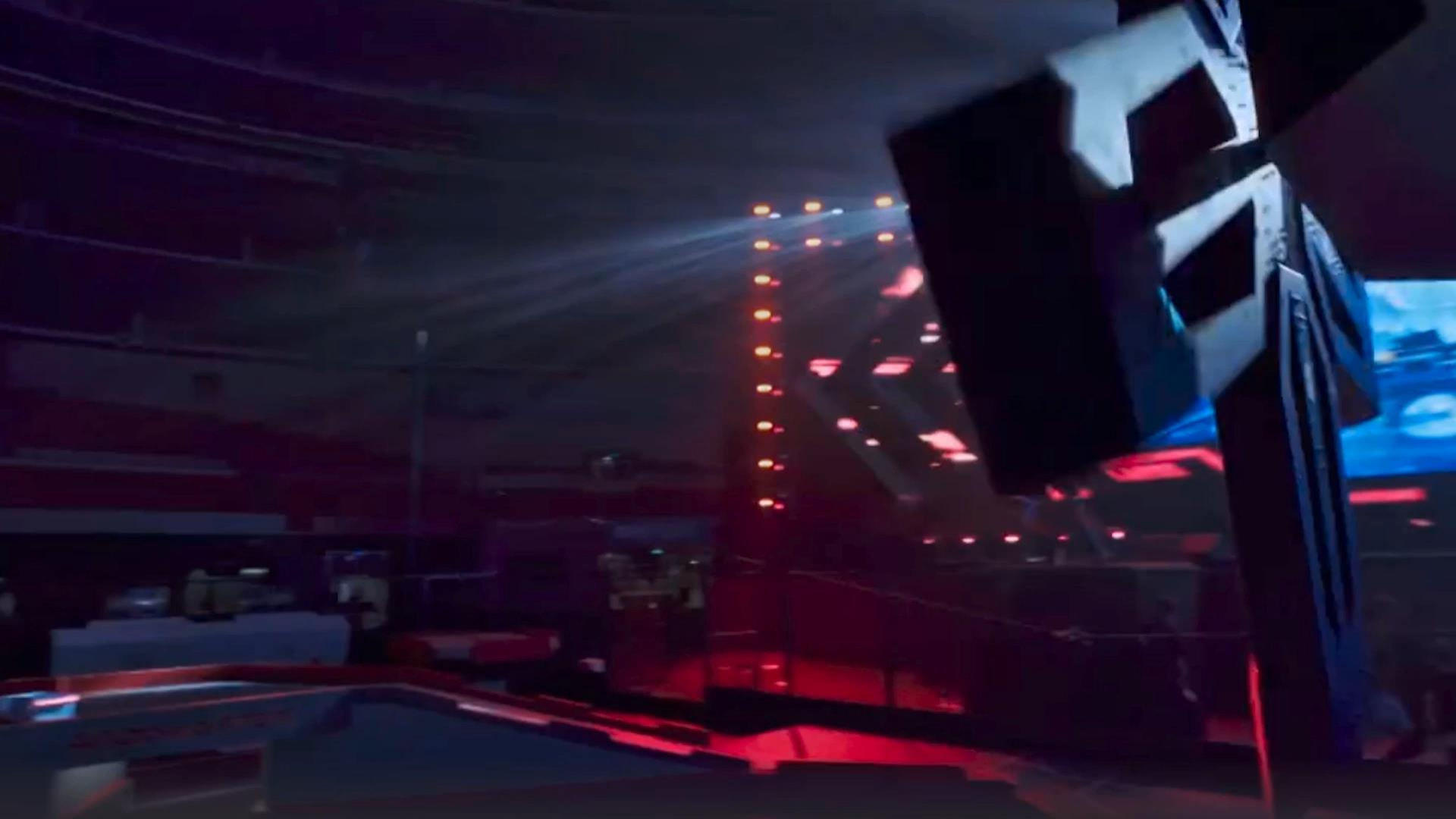
materials science

chemistry

agricultural science

SCUT Robotic lab







Robot Lab

South China University of Technology



Set up in 2000

Over 60 members

The biggest undergraduate lab

General Situation

Available to all the undergraduates in the school, Robot Lab is an innovation base, focusing on Robomaster, Robocon, Robot Business Plan Competition and other high level events. Robot Lab is committed to provide a superior science and technology activity platform for the students.



SCUT Robot Lab

About us

Practical
innovation &
training base

Scientific &
technological
platform

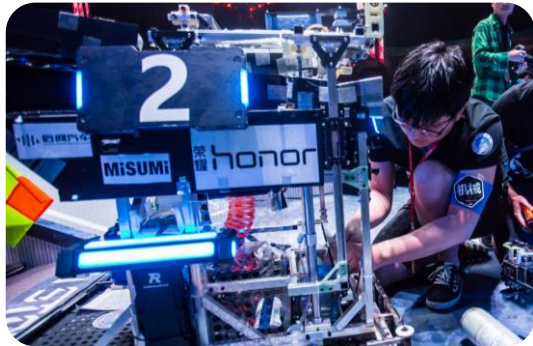
With sound
management
system



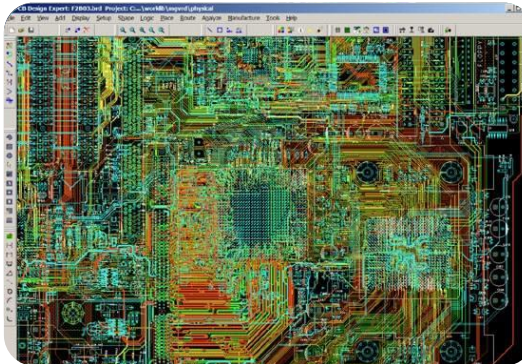
SCUT Robot Lab - Activities

based on competitions & guided by projects.

Robotics Competition



Electronics Competition



Entrepreneurship Race



Science and Technology
Competition Award

200+

Innovation companies
hatched out

11

Outstanding mechanical and
electrical talents cultivated

700+

Founded in 2000 as the largest undergraduate laboratory of South
China University of Technology



National
Patents

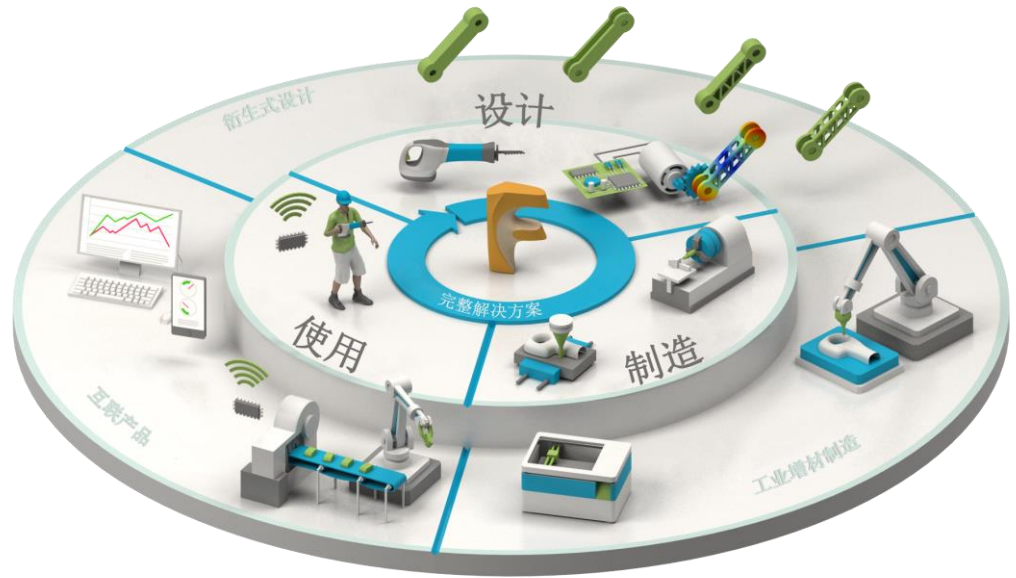
358

Cooperation
platforms

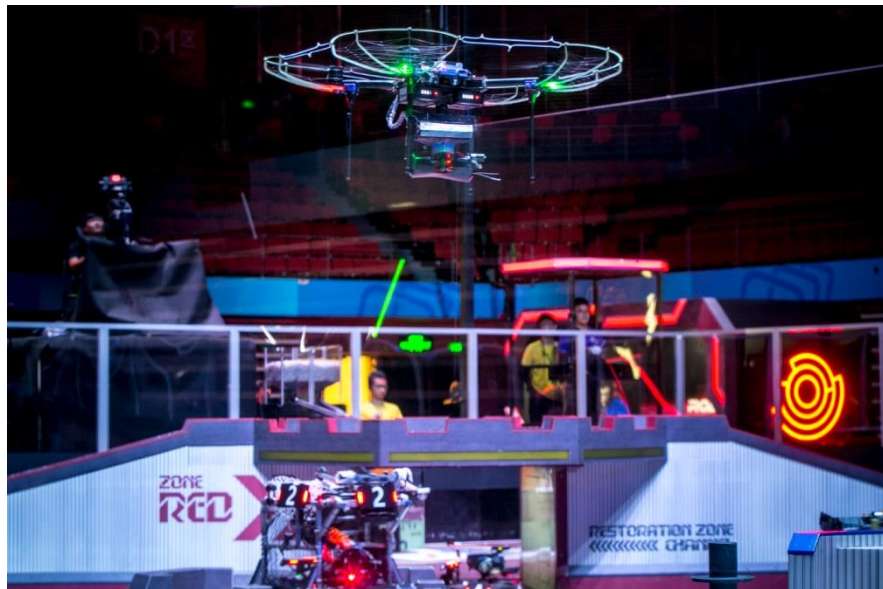
10+

Cooperation platforms

The laboratory establishes partnerships and cooperation platforms with industry-leading companies. The companies provide the lab with materials, technology, extensive internship, practice, and technical exchange opportunities. And Autodesk is one of the companies that provide us with great support.



Competition Awards



2016 National
Division Champion

2019 National
Division Champion



Competition Awards



2018
Final Champion

2017
Final Champion



New technology research program

Generative design



MVP 华南理工大学 华南虎

操作手 努尔兰 桑木哈尔

研发代表 范传融

4 步兵

击杀	1
助攻	1
基地伤害	15
机器人伤害	400
能量机关	0
发弹（小）	273

Stabilizer mount of infantry robot

New technology research program

Generative design



2019 Autodesk AU Technical Reports



The application paper was published in the well-known British technical journal——
International Design Engineer



Liang Jingkang

co-speaker

Mechanical team member of Robot Lab of
South China University of Technology

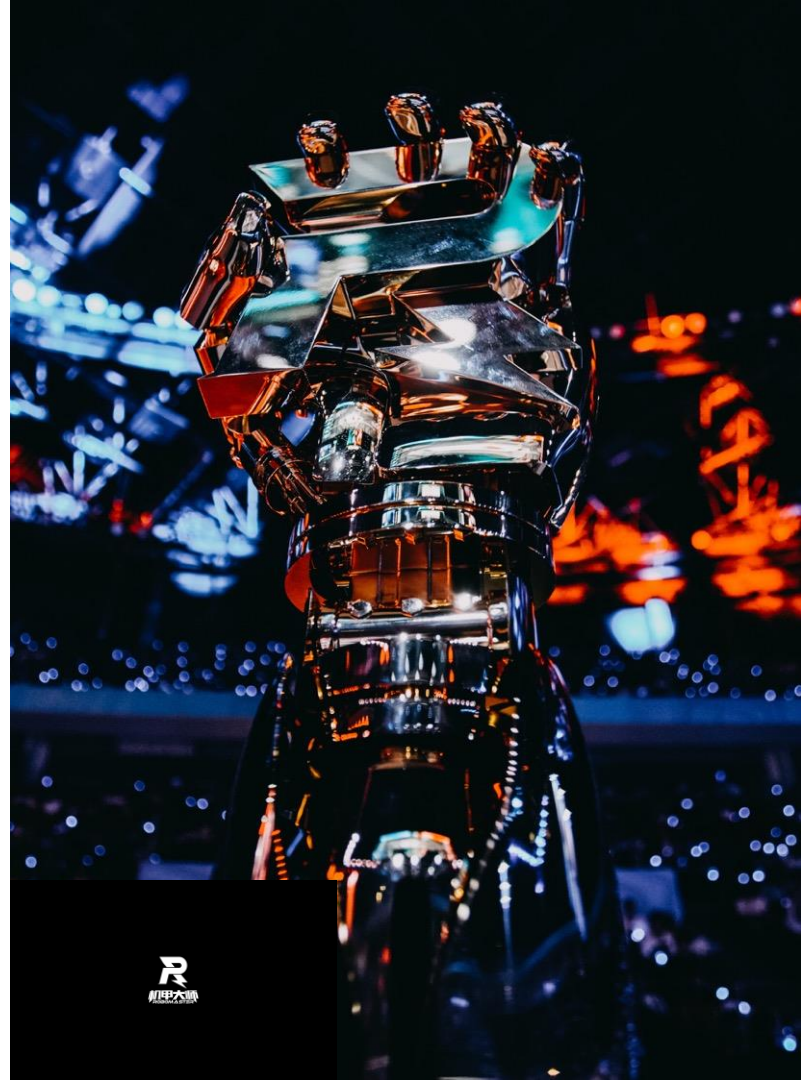
Infantry Robot of Robomaster





Introduction of Robomaster

- The world's **leading college robotics competition**
- Independently held by **DJI**
- Build a contemporary engineer star and lead the dream of scientific and technological innovation
- Conform to the trend of science and technology education and artificial intelligence
- It's a combination of **technology** and **entertainment**
- **the first robotic tactical shooting battles competition in the world**



Introduction of Robomaster

The most extensive robotics competition in colleges and universities

≈400

College

>20,000

College students

10+

Host cities



Introduction of Robomaster


We get good results every year

Southern Division Champion in 2016 and 2019, Final Champion in 2017 and 2018





Challenges we encountered

A photograph of two male students in a laboratory or workshop setting, focused on assembling or repairing a small robot. The student on the left is wearing a white t-shirt and black shorts, while the student on the right is wearing a blue long-sleeved shirt and black pants. They are both crouching on the floor, working on a robot that has a large white number '4' on its side. The robot appears to be a custom-built device with various electronic components and wheels. In the background, other students are visible at their desks, some working on laptops. The environment is a typical school or university lab with wooden desks, chairs, and various equipment.

而给步兵机器人减重



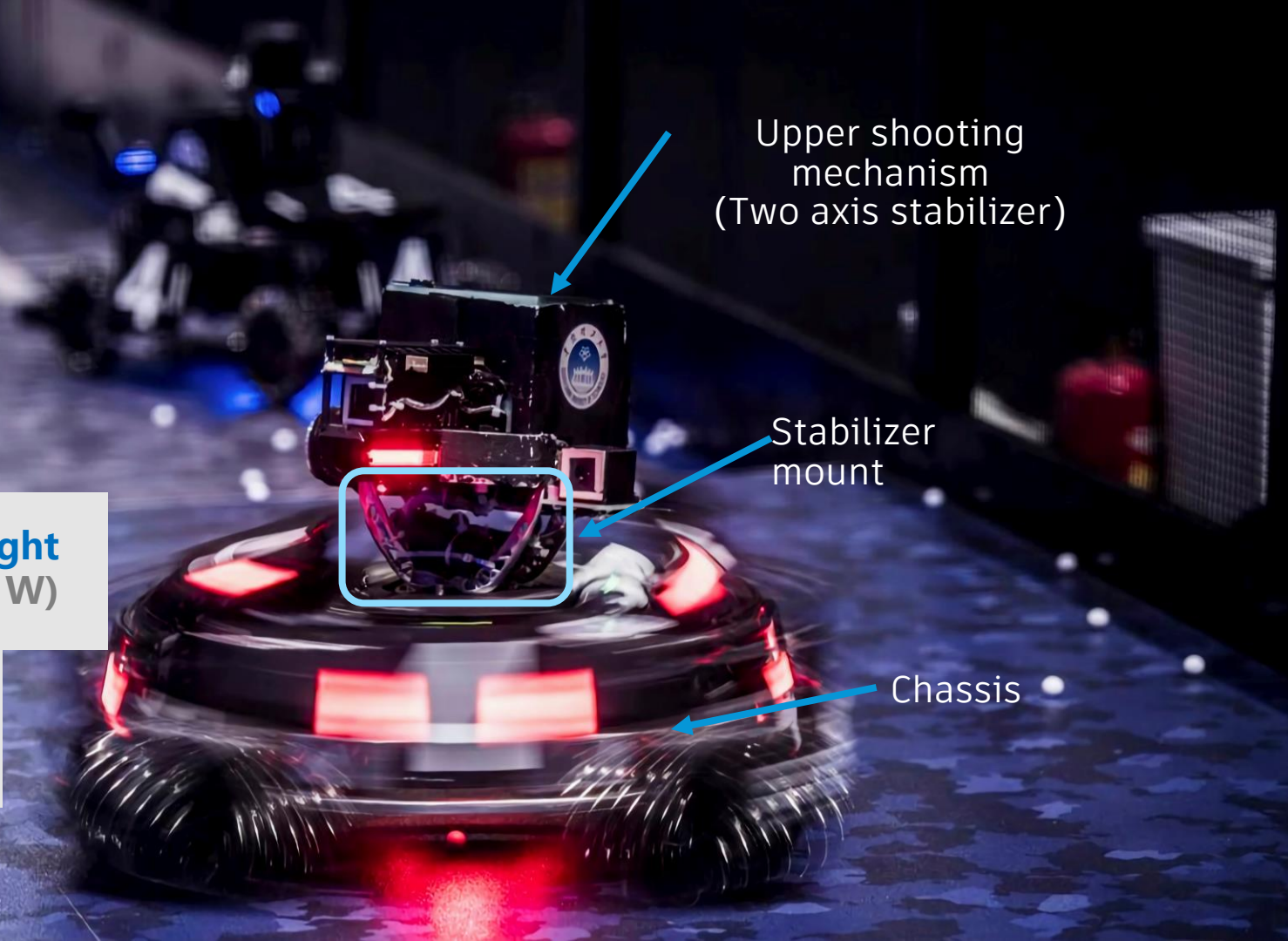
Rules: limited weight
and power(80 W)

lighter=faster

Upper shooting
mechanism
(Two axis stabilizer)

Stabilizer
mount

Chassis



Original design compared to generative design

Original design

Design method: People subjective design

Limits: materials, manufacturing methods, experience of designer

Disadvantages: numbers of parts, difficult to be assembled, no scientific ways for lightweight



Generative design + additive manufacturing

Design method:

Automatic computer iteration

Limits: boundary conditions set by designer

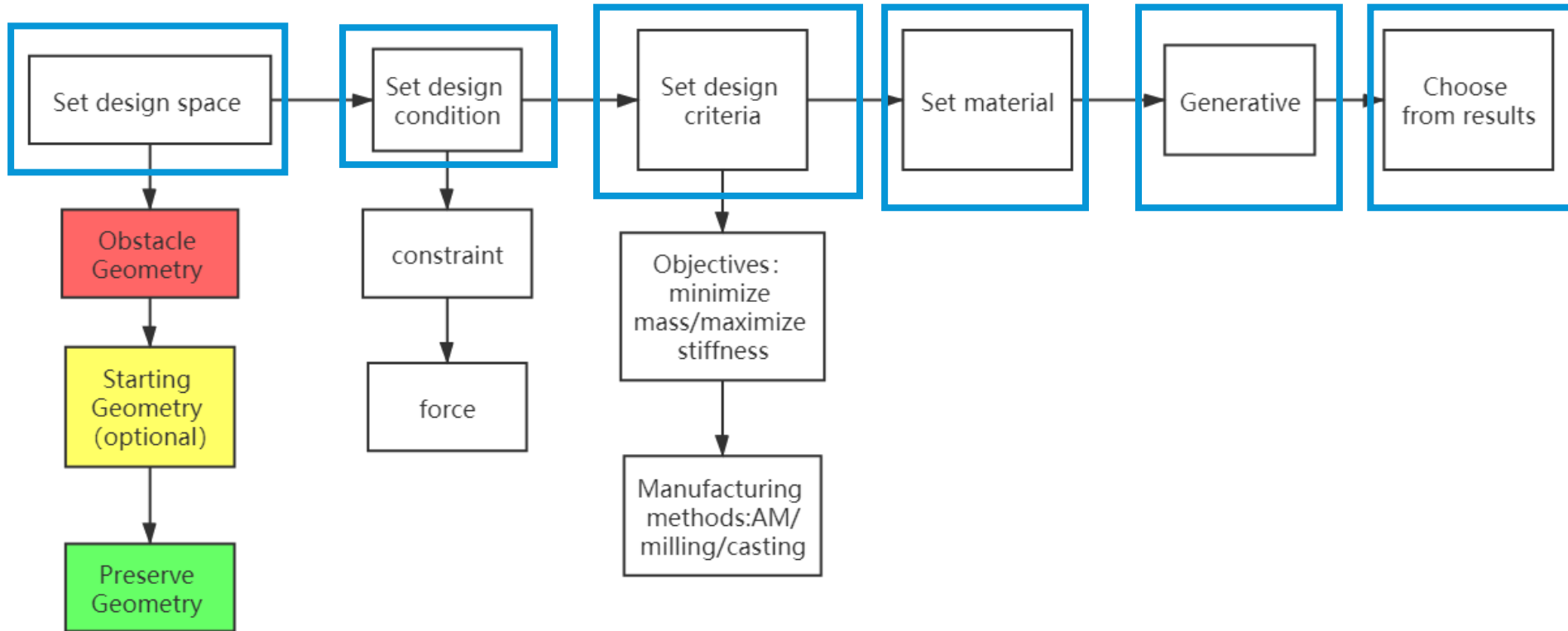
Advantages: only 1 single part, no need be assembled, scientific lightweight design





Design steps

Design workflow



Lightweight the Head Support of the Infantry Robot---boundary condition

Design space

The screenshot displays the Generative Design software interface. The top toolbar includes various tools, with the 'DESIGN SPACE' tool highlighted by a green box. The left sidebar shows a tree view of the model components, including 'Generative Model 1' and 'Load Case6'. The main workspace shows a 3D model of a robot head support, which is a yellow structure with a red cylindrical rod passing through it. The model is shown in three different states: 'Obstacle Geometry' (red), 'Starting Geometry' (yellow), and 'Preserve Geometry' (green). The 'Obstacle Geometry' state shows the robot head support with a red cylindrical rod passing through it. The 'Starting Geometry' state shows the robot head support without the rod. The 'Preserve Geometry' state shows the robot head support with the rod, but the rod is highlighted in green, indicating it is part of the preserve geometry.

Generative Design

GUIDE STUDY EDIT MODEL DESIGN SPACE DESIGN CONDITIONS DESIGN CRITERIA MATERIALS GENERATE EXPLORE INSPECT SELECT

BROWSER

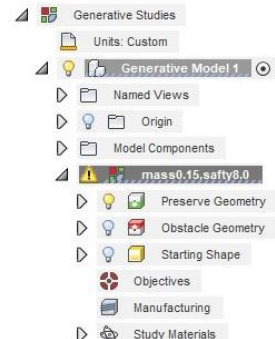
Generative Studies

Units: Custom

Generative Model 1

- Named Views
- Origin
- Model Components
 - mass0.15,saftey8.0
 - mass0.15,saftey8,nostarting
 - mass0.15,saftey10.0
 - mass0.17,saftey8.0
 - mass0.17,saftey8. 1mm
 - Preserve Geometry
 - 3 bodies
 - Obstacle Geometry
 - 9 bodies
 - Starting Shape
 - Body1
 - Objectives
 - Manufacturing
 - Study Materials
 - Load Case1
 - Load Case2
 - Load Case3
 - Load Case4
 - Load Case5
 - Load Case6


Design conditions




The screenshot shows the 'Load Case6' configuration in ANSYS Workbench. The 'Loads' section is expanded, showing 'Gravity', 'Force16', 'Force17', and 'Force18'. The 'Constraints' section is also expanded, showing 'Fixed6'. The 'Supports' section is partially visible at the bottom, showing 'mass0.15,safty8,nostarting', 'mass0.15,safty10.0', 'mass0.17,safty8.0', and 'mass0.17,safty8.0 - 1mm'.

A 3D CAD model of a green mechanical part, possibly a bracket or a housing. It features a central circular hole and several smaller circular features on its top and side surfaces. A blue cylindrical component is shown inserted into one of the side holes, demonstrating a fit or assembly.

A yellow pushpin is pinned to the top of the page.



Fix



Lightweight the Head Support of the Infantry Robot---boundary condition

Design criteria

GENERATIVE DESIGN

GUIDE

STUDY

EDIT MODEL

DESIGN SPACE

DESIGN CONDITIONS

DESIGN CRITERIA

MATERIALS

GENERATE

EXPLORE

INSPECT

SELECT

OBJECTIVES AND LIMITS

Objectives

Minimize Mass

Maximize Stiffness

Limits

Safety Factor

8.00

OK

Cancel

OBJECTIVES AND LIMITS

Objectives

Minimize Mass

Maximize Stiffness

Limits

Safety Factor

8.00

Mass Target

0.15 kg

OK

Cancel

MANUFACTURING

Unrestricted

Additive

Overhang Angle

45.0 deg

Minimum Thickness

6.00 mm

Milling

Configuration 1

3-axis

Configuration 2

5-axis

Minimum Tool Diameter

10.00 mm

Tool Shoulder Length

40.00 mm

Head Diameter

150.00 mm

2-axis Cutting

Cutting Direction

X

Y

Z

Die Casting

Ejection Direction

X

Y

Z

Minimum Draft Angle

3.0 deg

Minimum Thickness

1.50 mm

Maximum Thickness

13.00 mm

OK

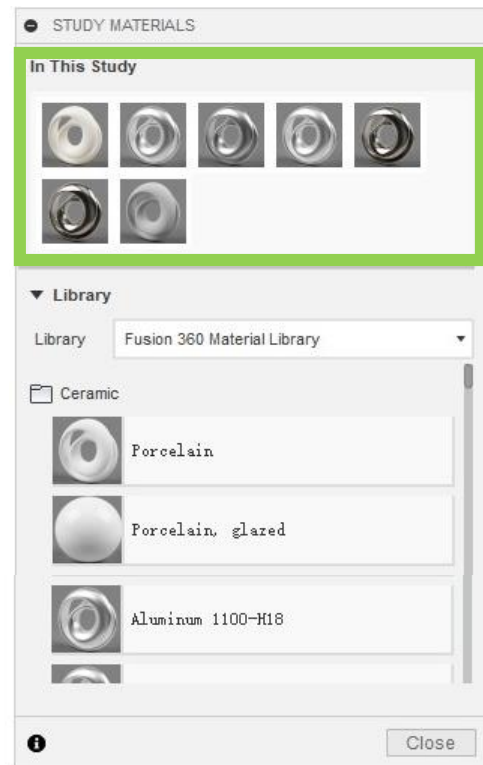
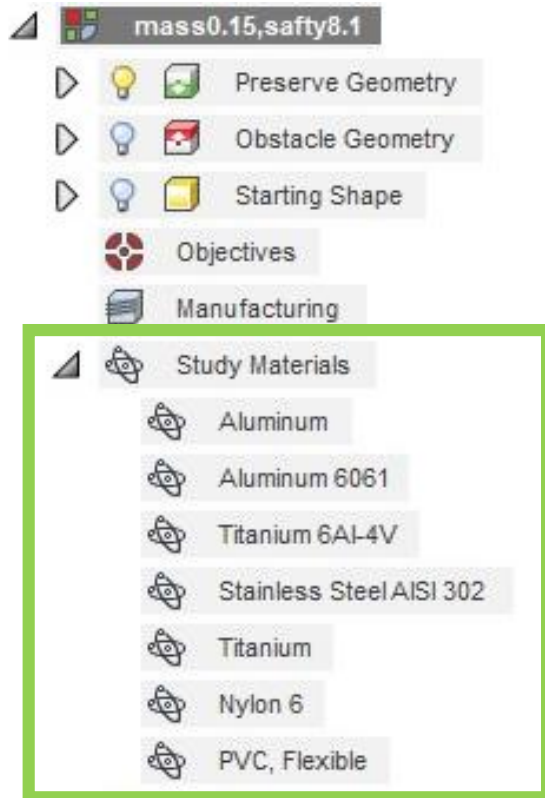
Cancel

Objectives and Limits

Manufacturing

Lightweight the Head Support of the Infantry Robot---boundary condition

Materials



Lightweight the Head Support of the Infantry Robot---boundary condition



Pre-Check

Ready to Generate with Warnings

The missing input may impact your results.

- ⚠ 2-Axis Cutting doesn't support preserve bodies of different height. Consider modifying 'Preserve Geometry'.
- ⚠ The Milling 'Head Diameter' is large comparing to the model size. Review the Milling settings, model size and units.

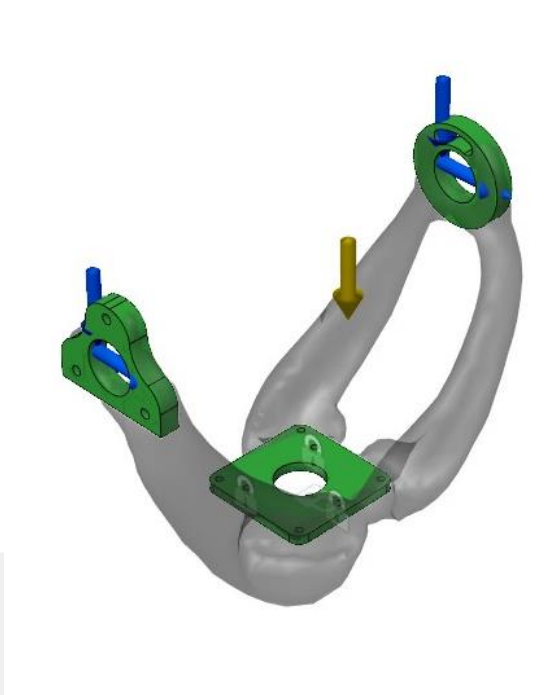
Close

Ready to Generate

The study setup has all the information required.

OK

Pre-Review



Generative

Generate

STUDIES OF THE ACTIVE DOCUMENT

Study	Status	Cloud Credits
<input type="checkbox"/> Generative Model 1 - mass0.15,safety8.0 Generative • Why can't I generate outcomes?	Error • Repair	
<input type="checkbox"/> Generative Model 1 - mass0.15,safety8,nostarting Generative • Why can't I generate outcomes?	Solved	
<input type="checkbox"/> Generative Model 1 - mass0.15,safety10.0 Generative • Why can't I generate outcomes?	Solved	
<input type="checkbox"/> Generative Model 1 - mass0.17,safety8.0 Generative • Why can't I generate outcomes?	Solved	
<input checked="" type="checkbox"/> Generative Model 1 - mass0.17,safety8, 1mm Generative	Ready	
<input checked="" type="checkbox"/> Generative Model 1 - mass0.15,safety8.1 Generative	Ready	25

CLOUD CREDITS

BUY CREDITS • HISTORY • FAQ

Required	Available	Will Remain
25	7818	7793

The document is modified. A new version will be created before generating.

Generate 1 Study Close

Lightweight the Head Support of the Infantry Robot--interpretation of results



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



mass0.15,safte8,nostarting - 0...
Converged



8.0 - Outcome 4
Converged



mass0.15,safte8.0 - Outcome 5
Converged



mass0.15,safte8.0 - Outcome 6
Converged



mass0.15,safte8.0 - Outcome 7
Converged



mass0.15,safte8.0 - Outcome 8
Converged

Lightweight the Head Support of the Infantry Robot--interpretation of results

GENERATIVE DESIGN

GUIDE

STUDY

EDIT MODEL

DESIGN SPACE

DESIGN CONDITIONS

DESIGN CRITERIA

MATERIALS

GENERATE

EXPLORE

INSPECT

SELECT

EXPLORE

DISPLAY

FINISH EXPLORE

Outcome filters

Processing status

☒ Converged

☒ Completed

Study

☒ mass0.15,safty8,n...

☒ mass0.15,safty8.0

☒ mass0.15,safty10.0

☒ mass0.17,safty8,...

☒ mass0.17,safty8.0

Design file

☒ Created from outcome

☒ Not created from outcome

Manufacturing method

☒ Unrestricted

☒ Additive

Objective ranges

Reset

Volume (mm³)

3.39e+4

4.347e+5

Mass (kg)

0.15

0.361

Maximum displacement (mm)

0.03

3.41

Maximum von Mises stress (MPa)

2

110.3

Minimum factor of safety


8

18.61


infrantry_support_part_1metal 80 outcomes 67 converged 13 completed

Sort by Study


mass0.15,safty8,nostarting




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...



mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...




mass0.15,safty8,nostarting - 0...


mass0.15,safty8.0




mass0.15,safty8.0 - Outcome 1




mass0.15,safty8.0 - Outcome 2




mass0.15,safty8.0 - Outcome 3




mass0.15,safty8.0 - Outcome 4




mass0.15,safty8.0 - Outcome 5



mass0.15,safty8.0 - Outcome 6

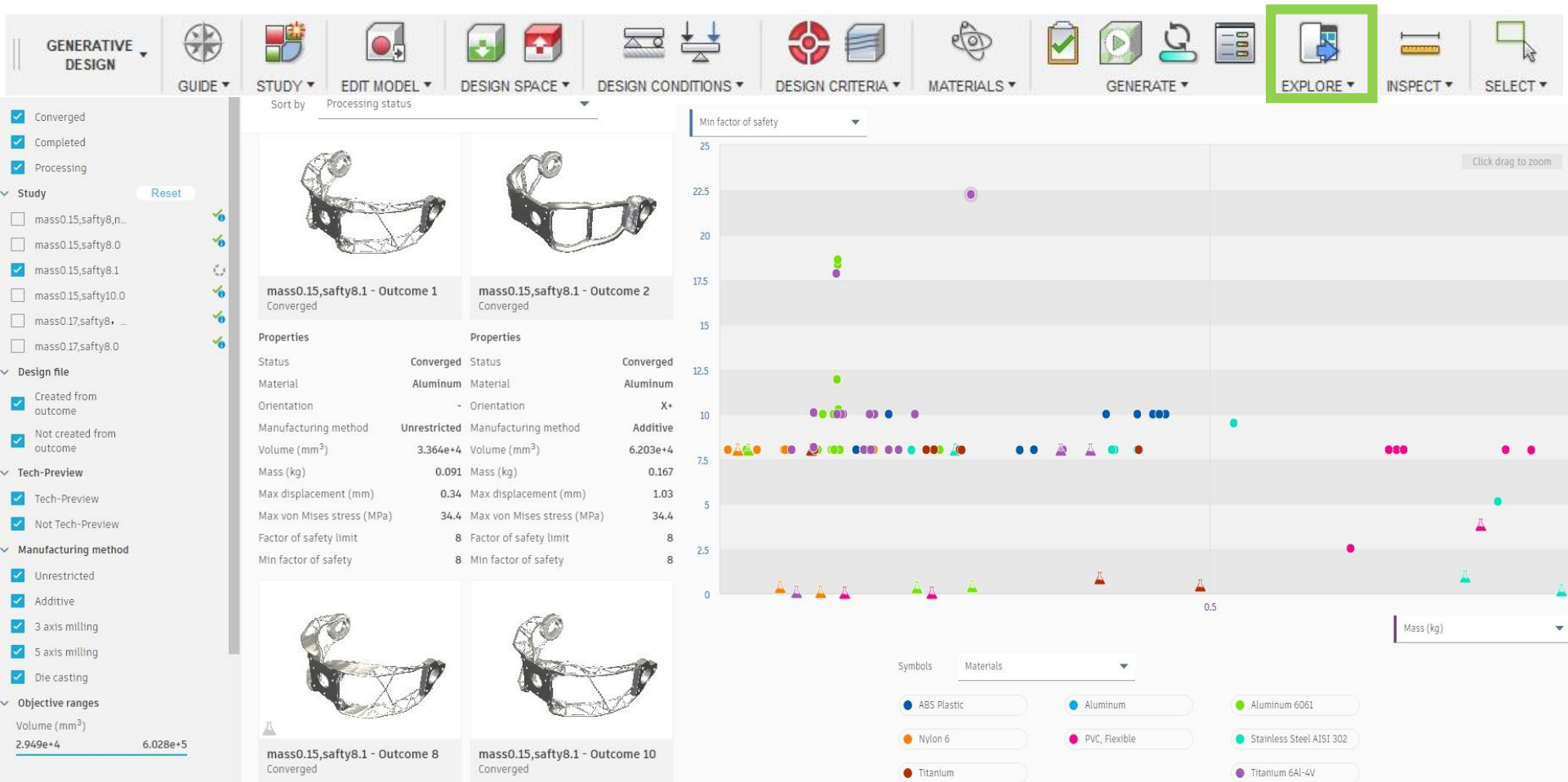


mass0.15,safty8.0 - Outcome 7



mass0.15,safty8.0 - Outcome 8

Lightweight the Head Support of the Infantry Robot--interpretation of results



Lightweight the Head Support of the Infantry Robot--interpretation of results

GENERATIVE DESIGN

GUIDE

STUDY

EDIT MODEL

DESIGN SPACE

DESIGN CONDITIONS

DESIGN CRITERIA















MATERIALS

GENERATE

EXPLORE

INSPECT

SELECT

	mass0.15,saftey8.1 - Outcome 55	Converged	PVC, Flexible	Unrestricted
	mass0.15,saftey8.1 - Outcome 56	Converged	PVC, Flexible	Additive
	mass0.15,saftey8.1 - Outcome 57	Converged	PVC, Flexible	Additive
	mass0.15,saftey8.1 - Outcome 60	Converged	PVC, Flexible	5 axis milling
	mass0.15,saftey8.1 - Outcome 7		Aluminum	Die casting
	mass0.15,saftey8.1 - Outcome 9		Aluminum	Die casting
	mass0.15,saftey8.1 - Outcome 16		Aluminum 6061	Die casting
	mass0.15,saftey8.1 - Outcome 18		Aluminum 6061	Die casting
	mass0.15,saftey8.1 - Outcome 25		Titanium 6Al-4V	Die casting

Converged—
Results that
meet the
requirements

Completed—
Results to
be discarded

Lightweight the Head Support of the Infantry Robot--interpretation of results

mass0.15,safty8.1 - Outcome 17



mass0.15,safty8.1 - Outcome 6



mass0.15,safty8.1 - Outcome 46



mass0.15,safty8.1 - Outcome 48



mass0.15,safty8.1 - Outcome ...
Iteration 15 (final)

Properties

Status	Converged
Material	Nylon 6
Orientation	-
Manufacturing method	Unrestricted
Volume (mm ³)	6.651e+4
Mass (kg)	0.074
Max displacement (mm)	1.55
Max von Mises stress (MPa)	8.8
Factor of safety limit	8
Min factor of safety	8

Lightweight the Head Support of the Infantry

增材制造 Additive

Outcome 6
Material: Aluminum 6061
Weight: 151g
Factor of Safety : 8.01



5轴CNC 5-Axis Milling

Outcome 15
Material: Aluminum 6061
Weight: 168
Factor of Safety : 8.02



3轴CNC 3-Axis Milling

Outcome 50
Material: Nylon 6
Weight: 203g
Factor of Safety: 8



铸件 Die Casting

Outcome 17
Material: Aluminum 6061
Weight: 92g
Factor of Safety : 8



Lightweight the Head Support of the Infantry --Iterations

Additive Manufacturing

Number of Iterations: 19

Properties

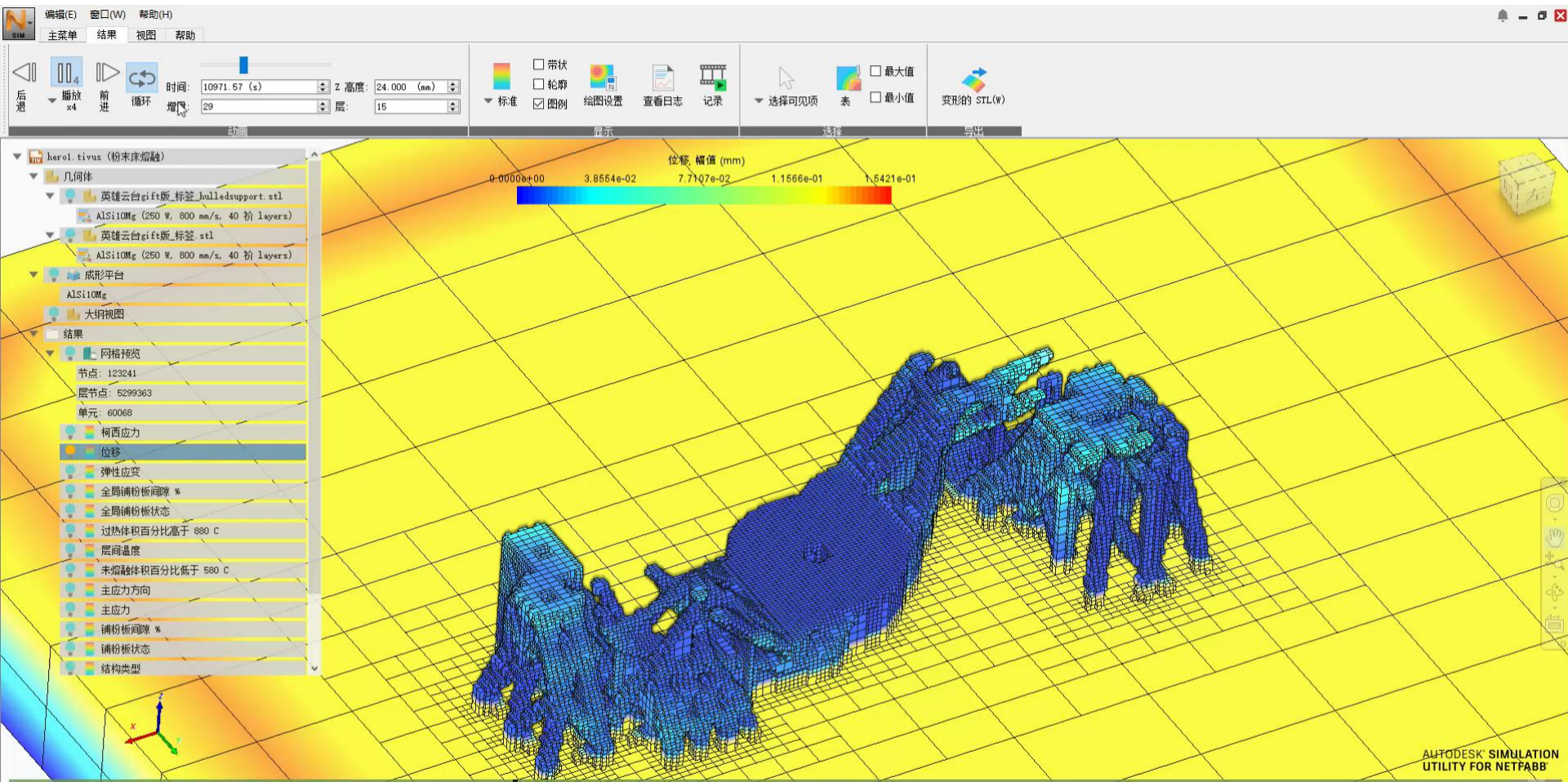
Status	Converged
Material	Aluminum 6061
Orientation	-
Manufacturing method	Unrestricted
Volume (mm ³)	5.601e+4
Mass (kg)	0.151
Max displacement (mm)	0.16
Max von Mises stress (MPa)	34.3
Factor of safety limit	8
Min factor of safety	8.01



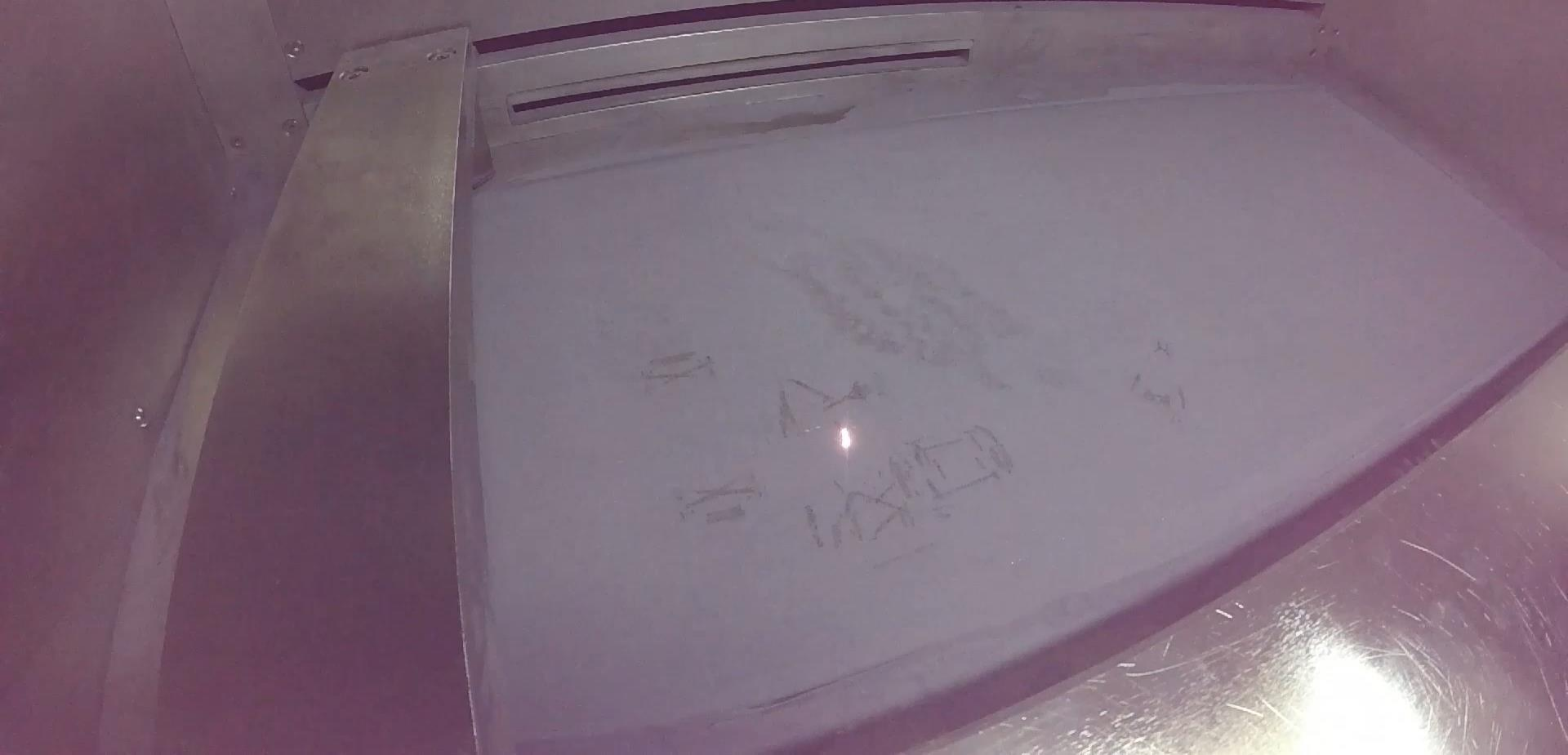


Manufacturing process

3D printing simulation



Metal 3D printing (SLM)



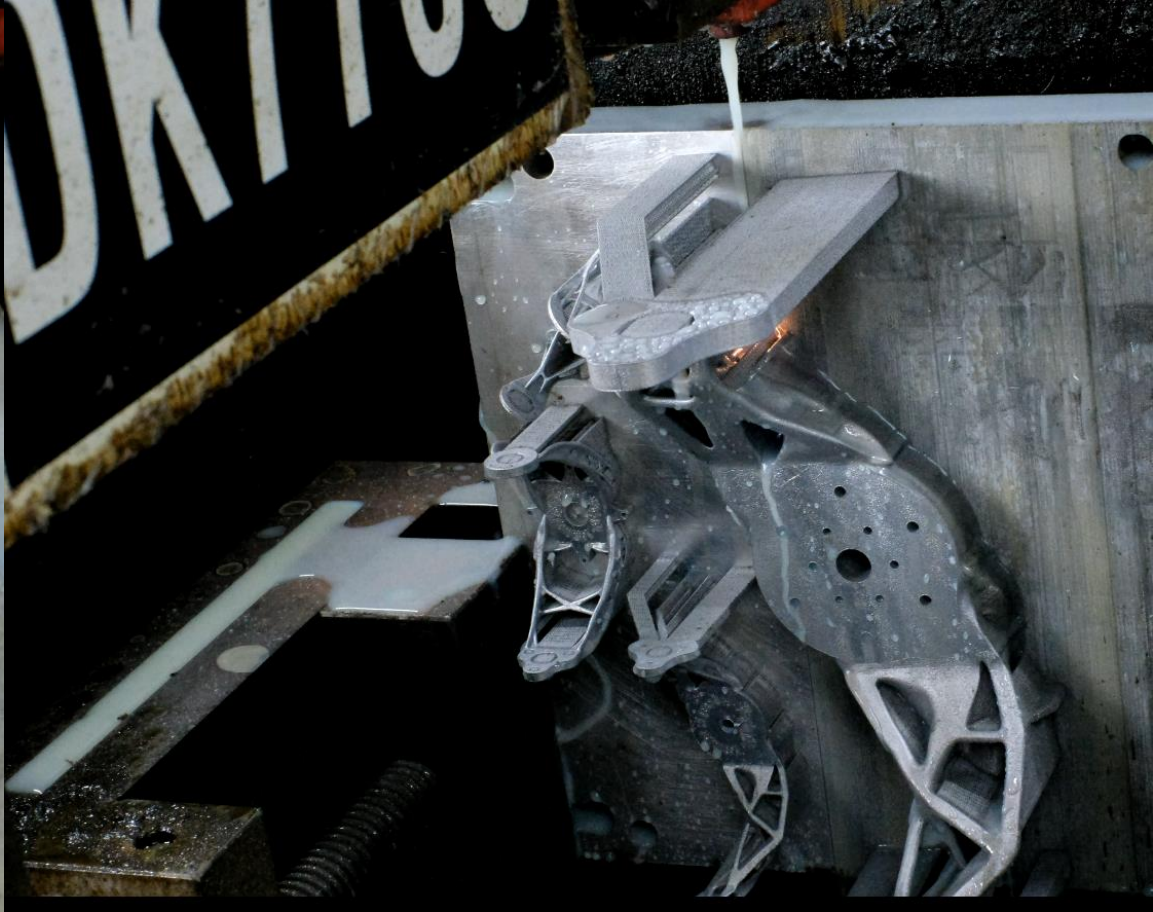
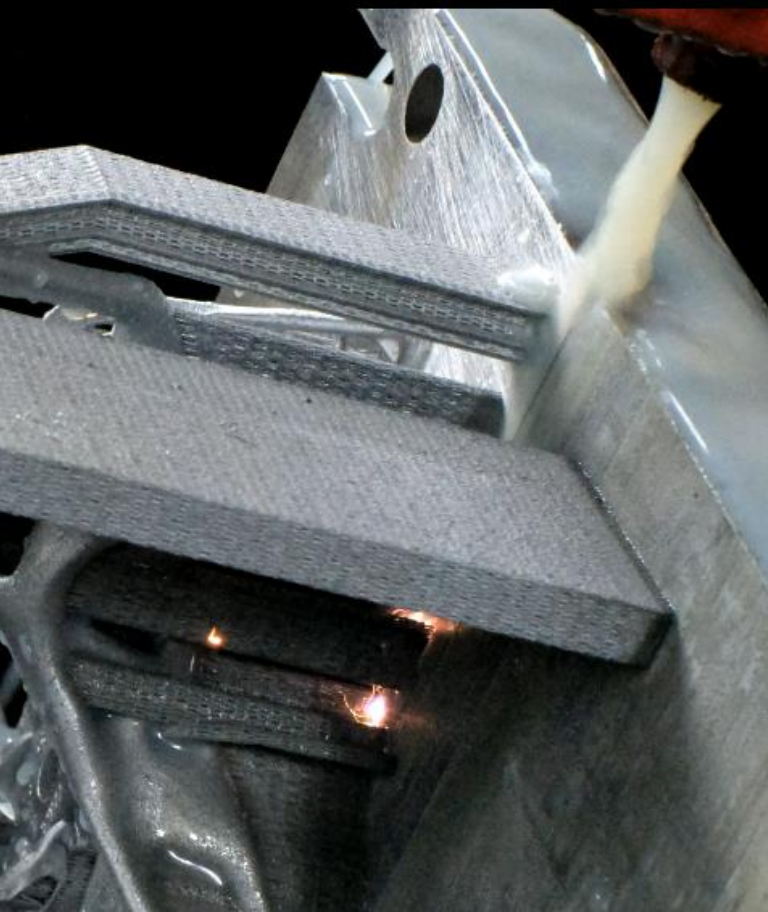




Heat treatment (annealing)



Wire Electrical Discharge Machining



Sanding and sand-blasting





Additive Manufactured by Farsoon
Material: AlSi10Mg



Test results

Lightweight the Head Support of the Infantry Robot–Physical Tests

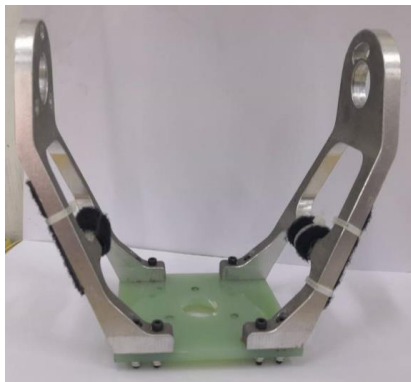
Original Design

Manufacturing: CNC & Assembly

Materials: Aluminum alloy + Glass fiber plate

Number of parts: 27

Weight: 295g



Generative Design V1

Manufacturing: Additive

Materials: Resin

Number of parts: 1

Weight: 120g

Lighter: 59%

Physical Test: Fail



Generative Design V4

Manufacturing: Additive

Materials: Nylon

Number of parts: 1

Weight: 135g

Lighter: 54%

Physical Test: Fail



Generative Design V6

Manufacturing: Additive

Materials: Aluminum 6061

Number of parts: 1

Weight: 170g

Lighter: 42%

Physical Test: Success



DOUBLE KILL



MVP



华南理工大学
华南虎



3

步兵

操作手
曾国立



研发代表
范传融

击杀

5

助攻

0

基地伤害

880

机器人伤害

1081

能量机关

0

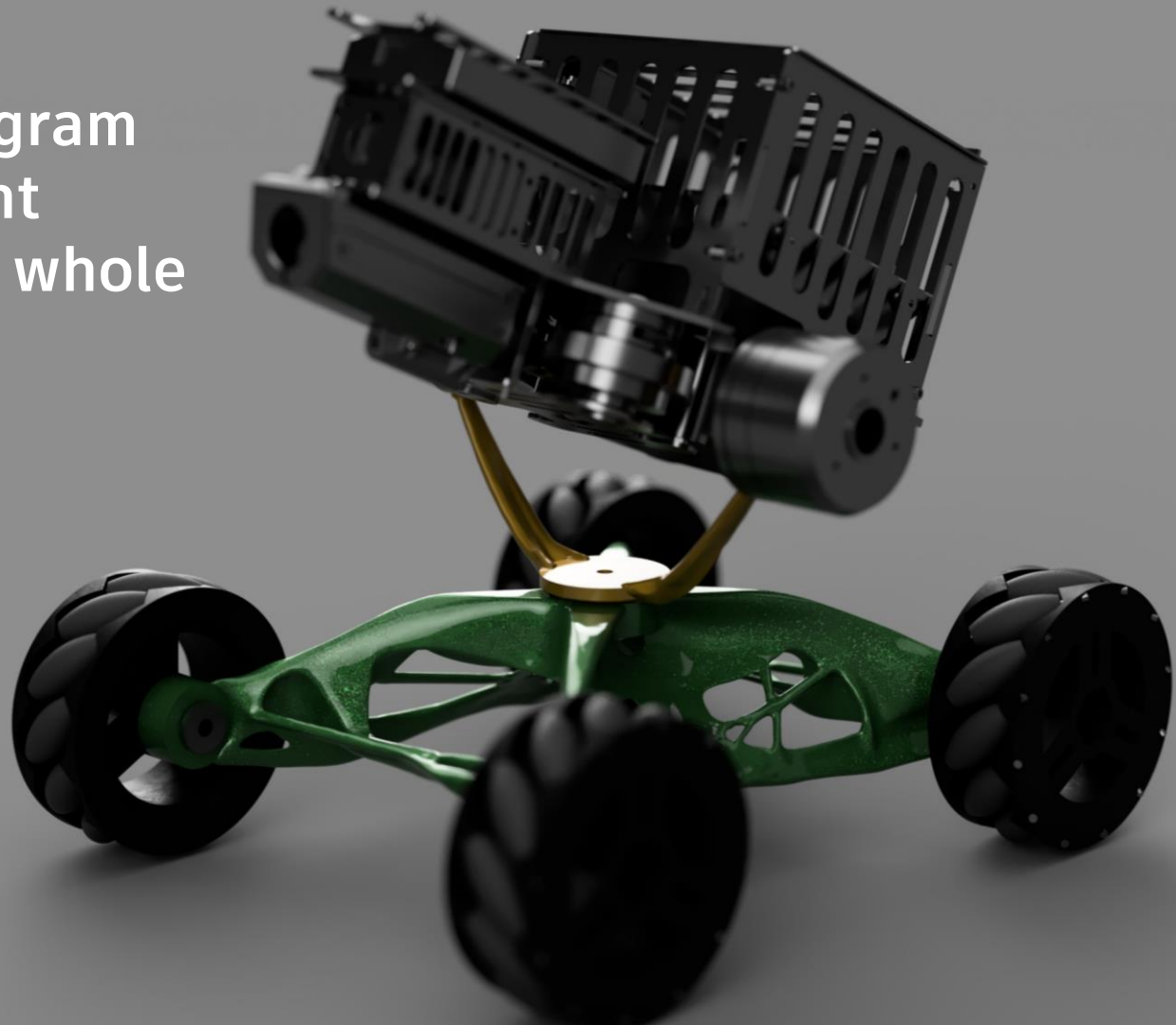
发弹（小）

421

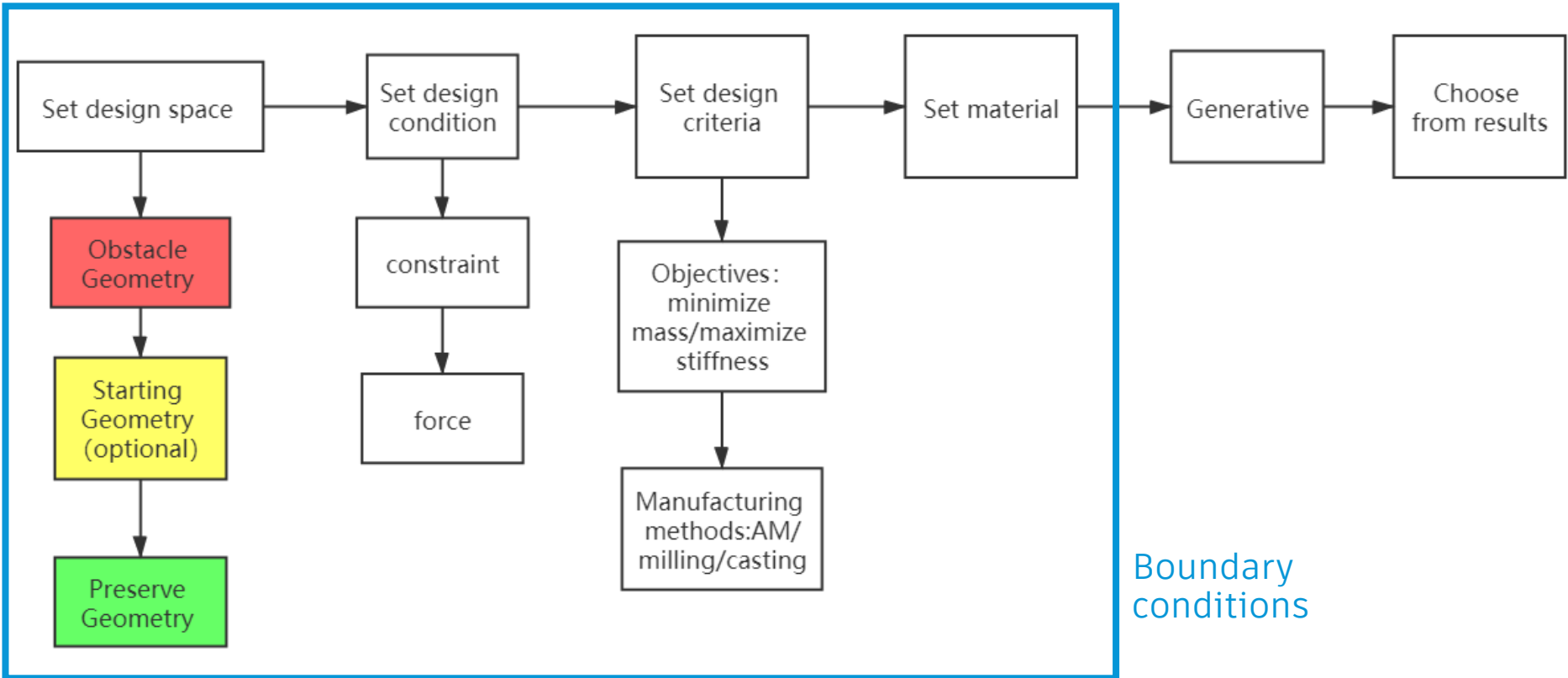
The background is an abstract composition of light blue and white geometric shapes. On the left, a large, curved, light blue shape resembles a stylized 'C' or a wing. To its right, a series of vertical, slightly curved white bars of varying heights create a sense of depth and rhythm. In the foreground, a blue, curved surface with fine, parallel lines suggests a textured or ribbed material. A white, semi-transparent trapezoidal box is positioned in the upper-middle section, containing the text.

Light weight of the whole robot

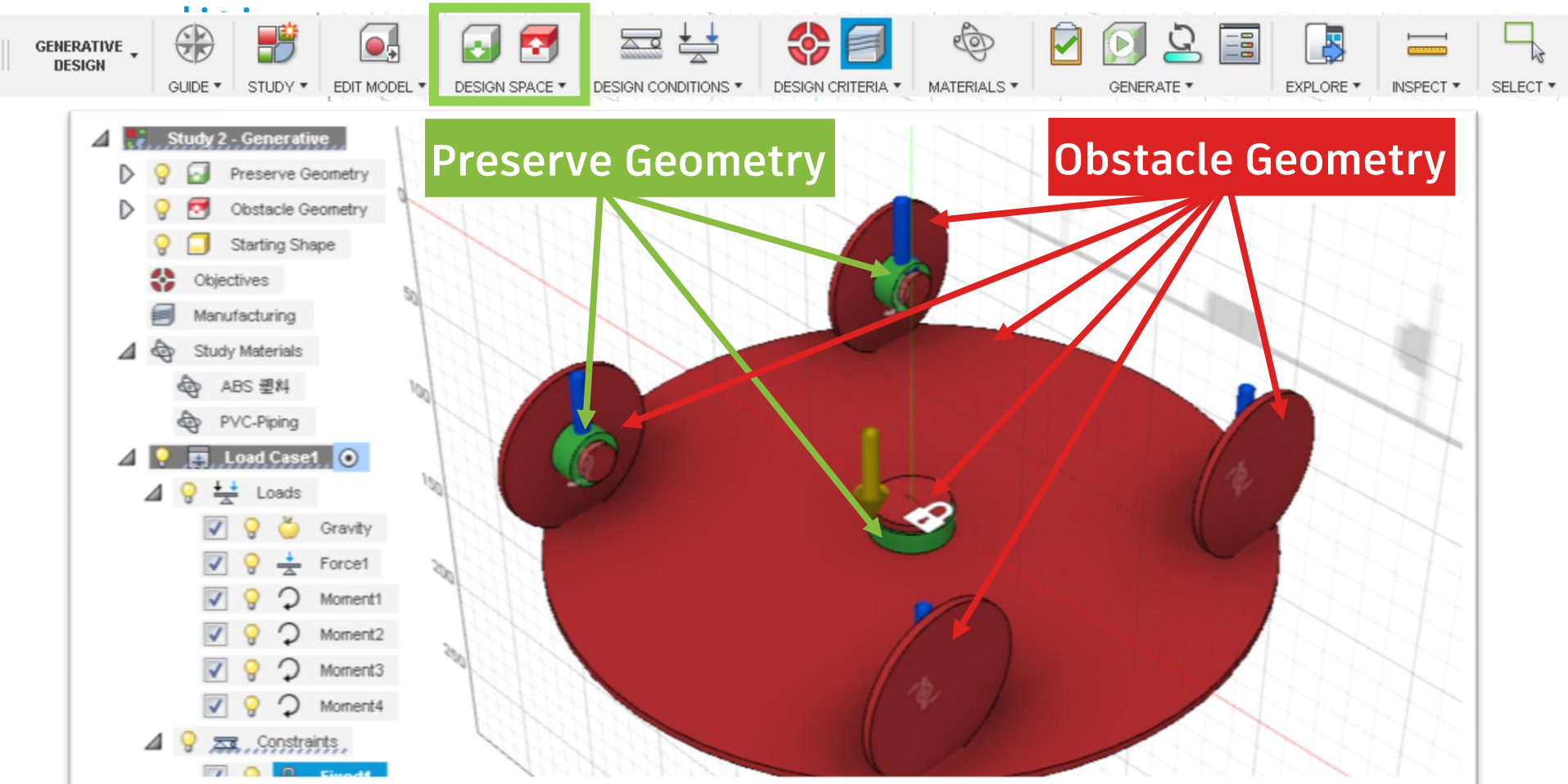
Research program
about the light
weight of the whole
robot



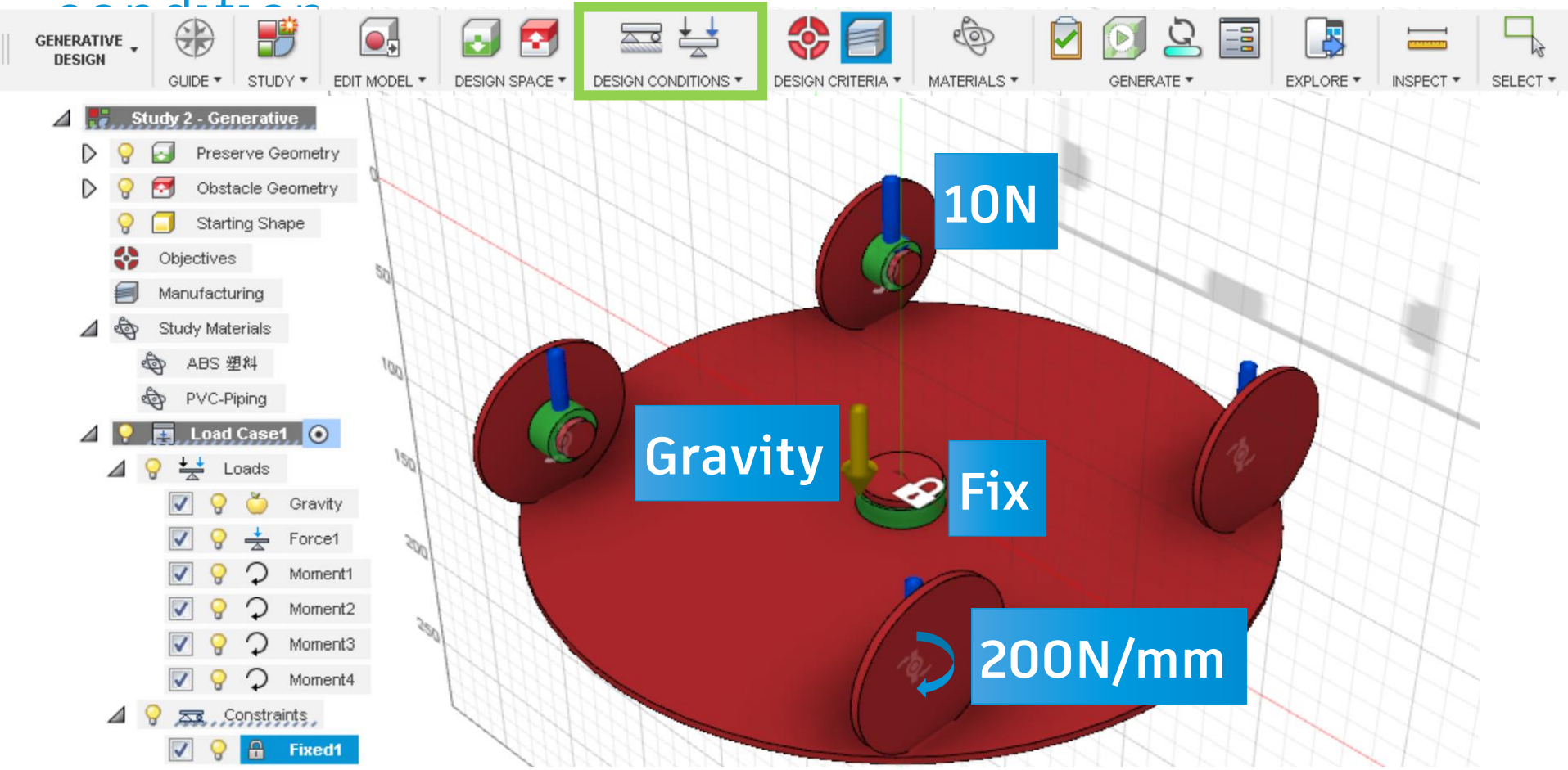
Design workflow



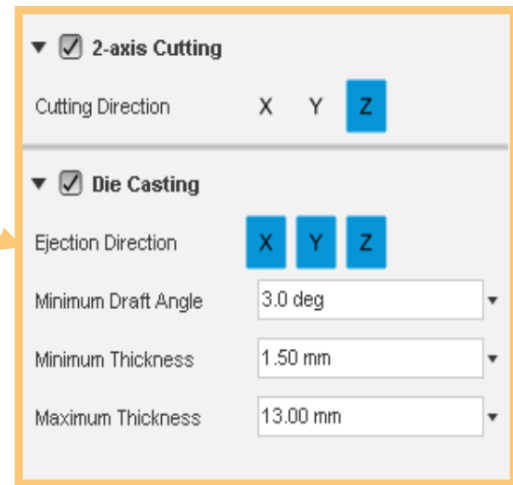
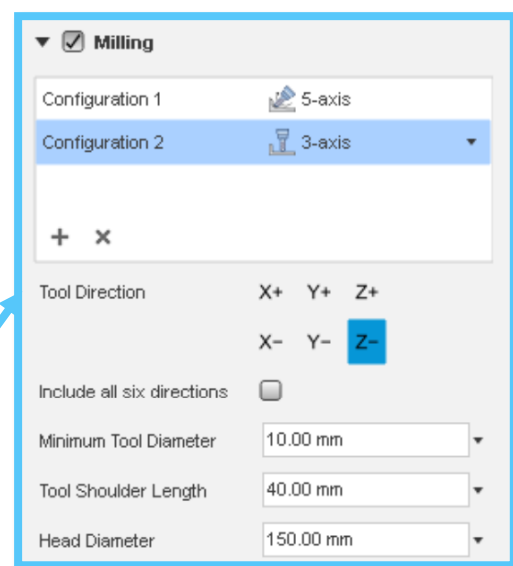
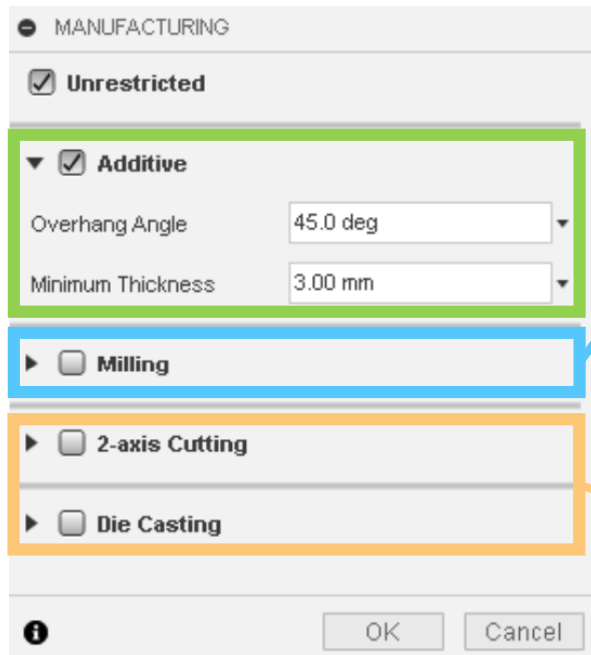
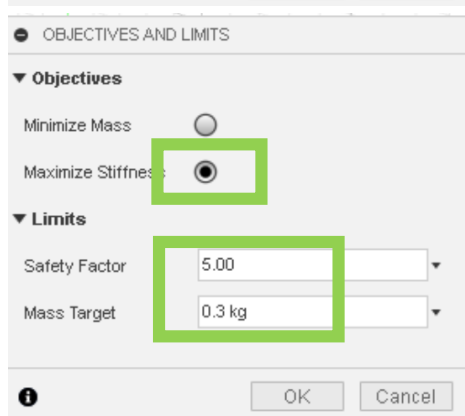
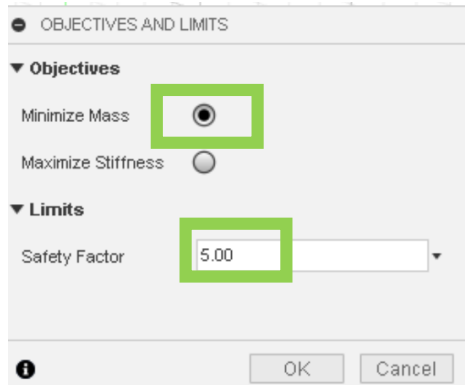
Light weight of the whole robot--boundary



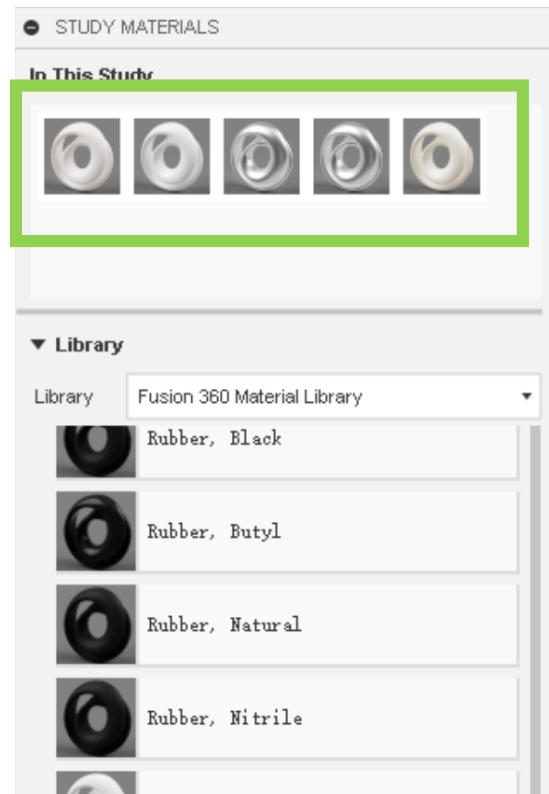
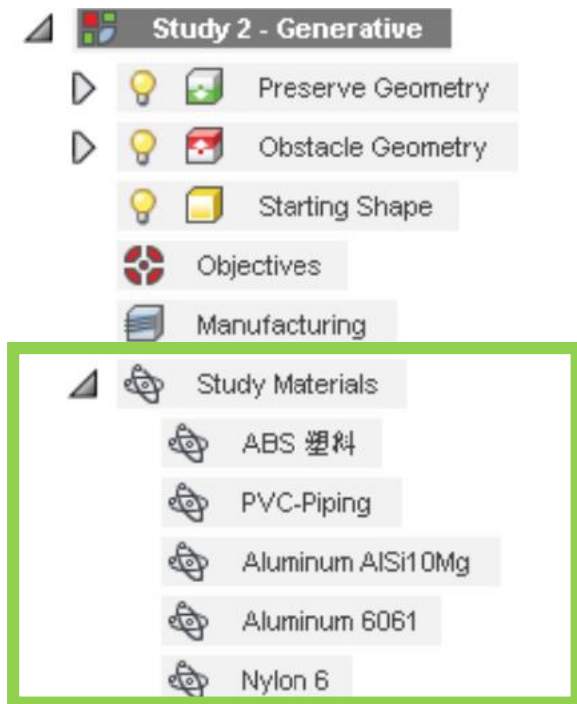
Light weight of the whole robot--boundary



Light weight of the whole robot



Light weight of the whole robot--boundary



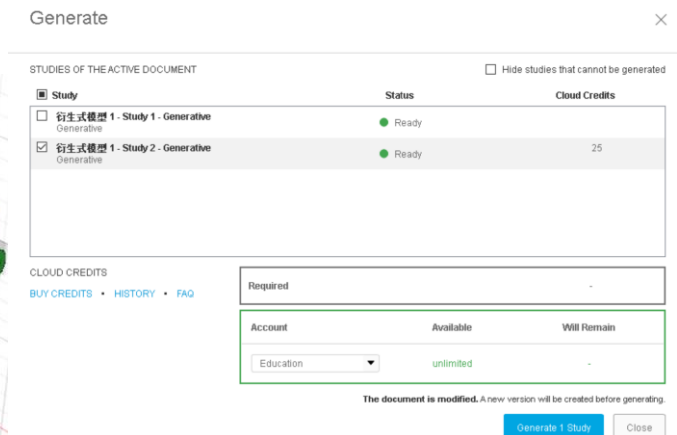
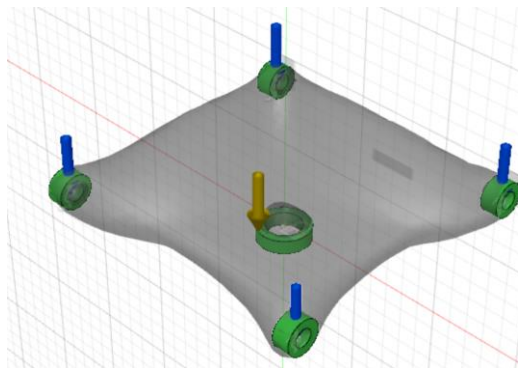
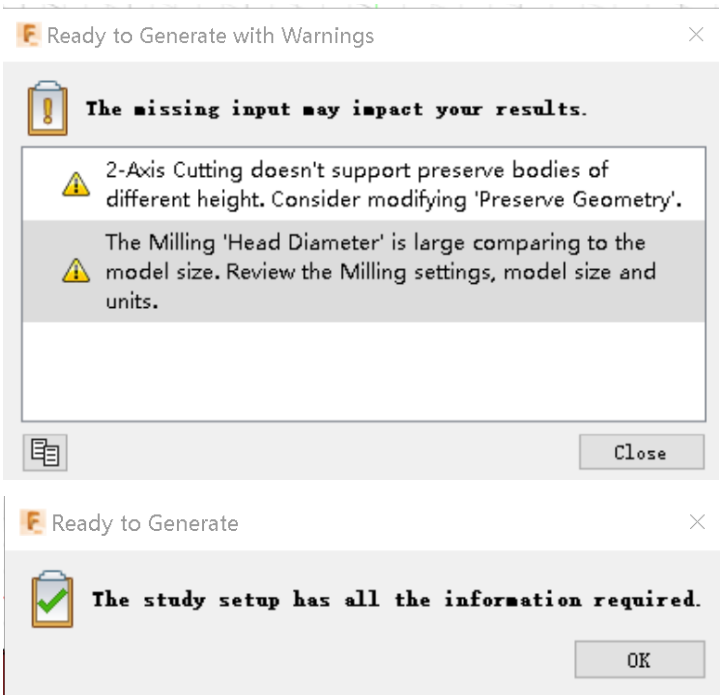
Light weight of the whole robot--boundary



Pre-Check

Pre-Review

Generative





2

4

4

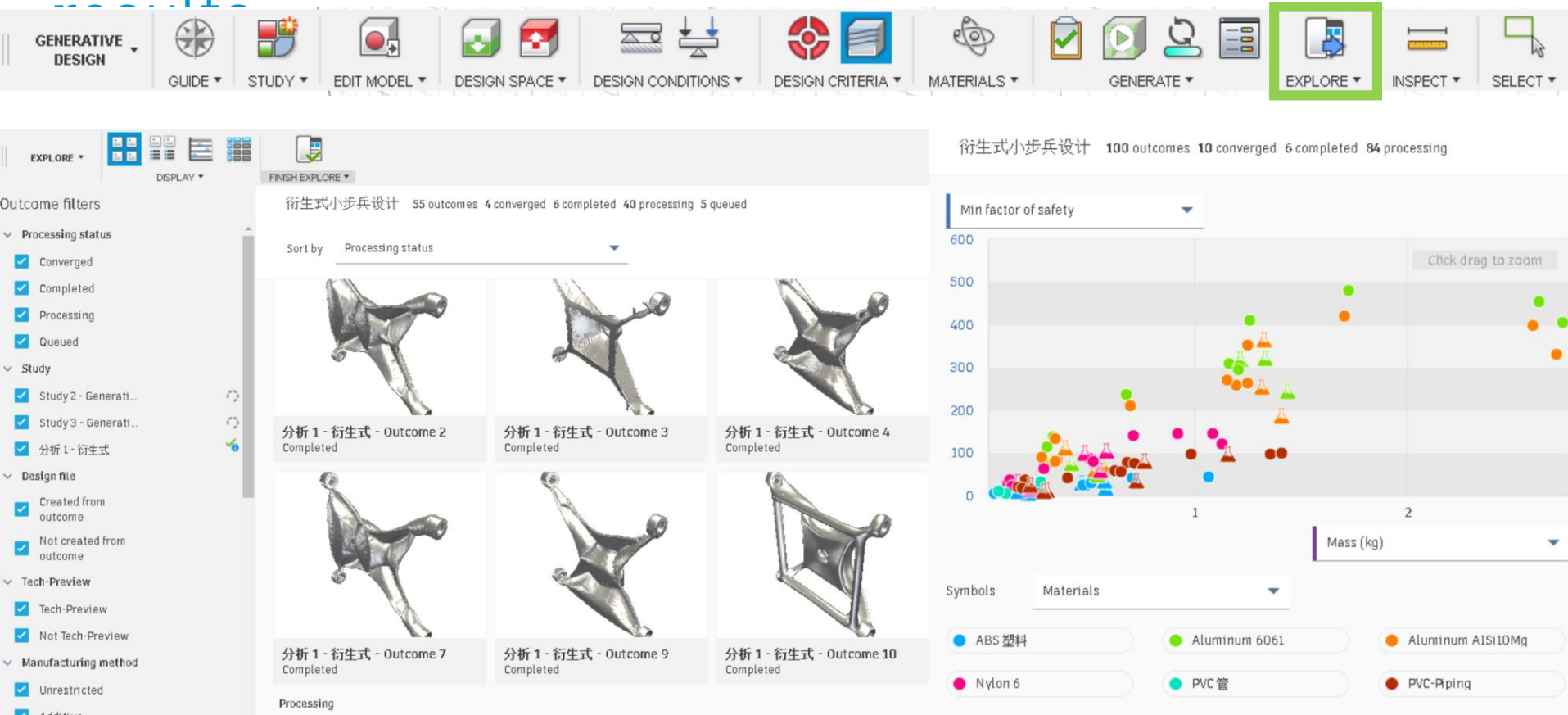
4

Study 2 - Generative - Outcome -
Converged

Study 2 - Generative Distance











10

Light weight of the whole robot--interpretation of



Light weight of the whole robot--interpretation of

衍生式小步兵设计V3 12 outcomes 5 converged 7 completed

Name	Tech-Preview	Processing status ↓	Material	Manufacturing method	Volume (mm ³)
 分析 1 - 衍生式 - Outcome 1		Converged	ABS 塑料	Unrestricted	4.816e+4
 分析 1 - 衍生式 - Outcome 5		Converged	ABS 塑料	3 axis milling	5.598e+4
 分析 1 - 衍生式 - Outcome 6		Converged	ABS 塑料	5 axis milling	5.655e+4
 分析 1 - 衍生式 - Outcome 7		Converged	丙烯酸树脂	Unrestricted	4.815e+4
 分析 1 - 衍生式 - Outcome 11		Converged	丙烯酸树脂	3 axis milling	5.756e+4
 分析 1 - 衍生式 - Outcome 2		Completed	ABS 塑料	Additive	5.687e+4
 分析 1 - 衍生式 - Outcome 3		Completed	ABS 塑料	Additive	4.848e+4
 分析 1 - 衍生式 - Outcome 4		Completed	ABS 塑料	Additive	5.841e+4
 分析 1 - 衍生式 - Outcome 8		Completed	丙烯酸树脂	Additive	5.246e+4
 分析 1 - 衍生式 - Outcome 9		Completed	丙烯酸树脂	Additive	4.801e+4

Converged

Completed

Light weight of the whole robot--iterations

3轴CNC

3-Axis

iterations: 55

Outcome 11

Material: resin

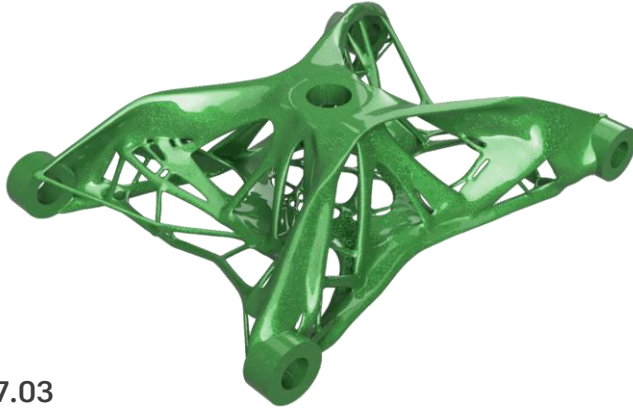
Weight: 68g

Factor of Safety: 11.12



Light weight of the whole robot

3D打印 Additive



Outcome 1
Material: ABS
Weight: 51g
Factor of Safety : 7.03

5轴CNC 5-Axis



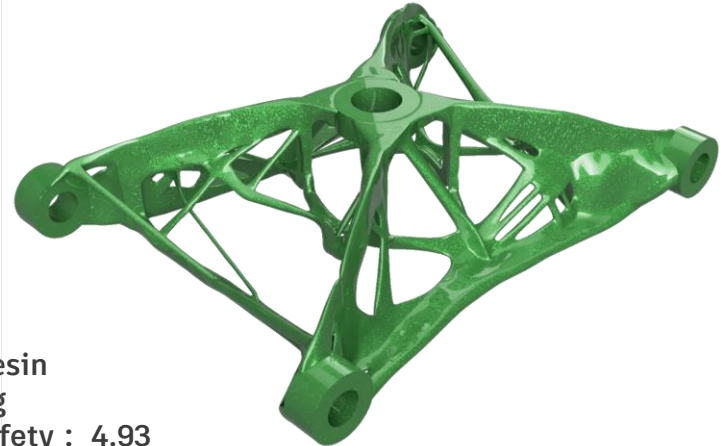
Outcome 15
Material: resin
Weight: 68
Factor of Safety : 8.72

3轴CNC 3-Axis

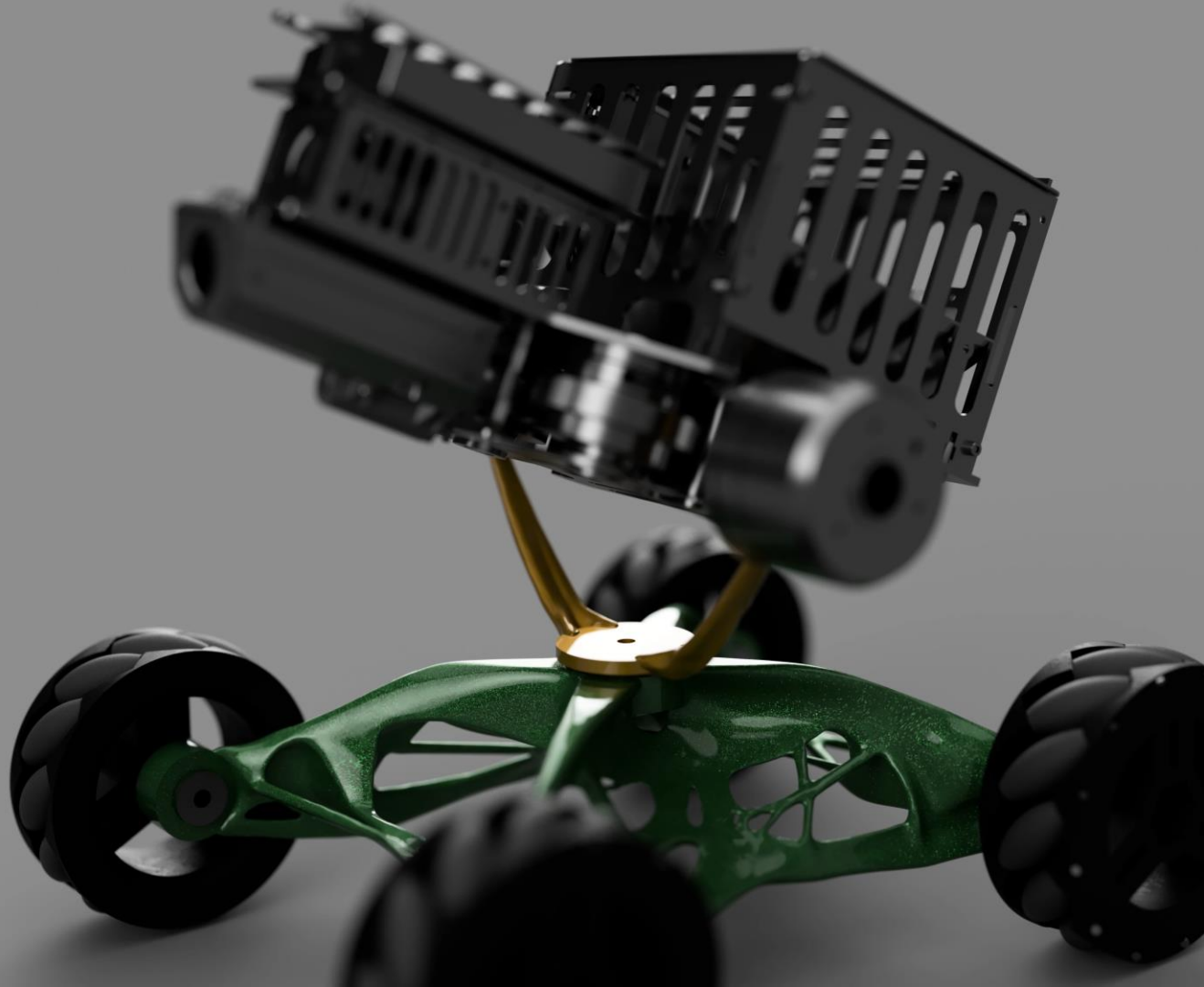


Outcome 11
Material: resin
Weight: 68g
Factor of Safety: 11.12

铸件 Casting



Outcome 17
Material: resin
Weight: 57g
Factor of Safety : 4.93





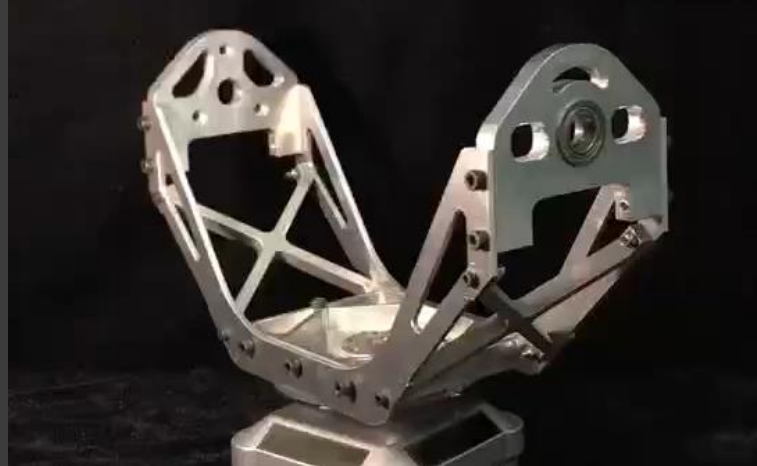
Other examples

Lightweight the Head Support of the Hero Robot

From **37** parts to **ONE Part**

46% Mass Reduction

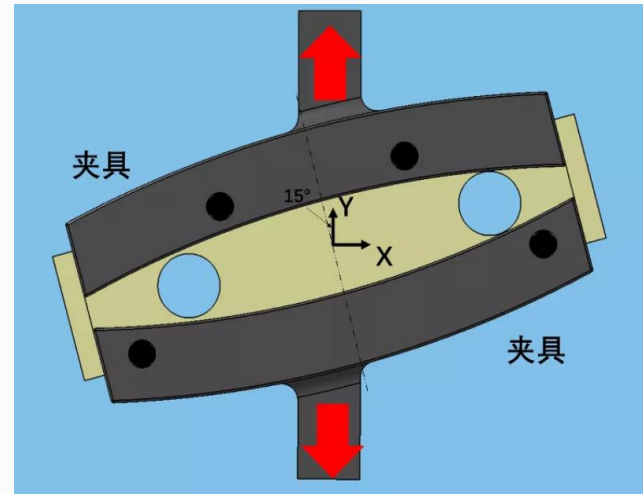
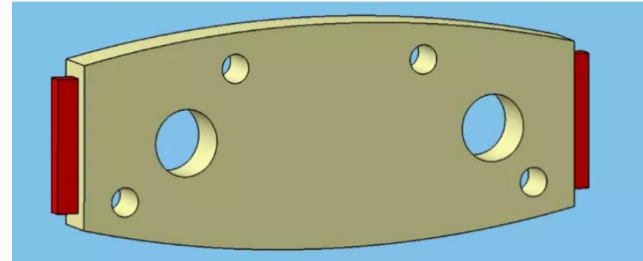
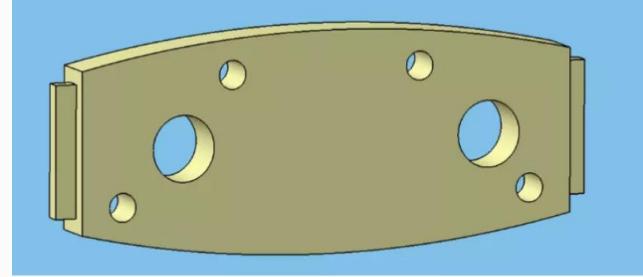
- Faster and nimbler
- SCUT won the Champion of South China.
- MVP in the Robomaster South China competition area.



Lightweight the spacecraft ribbed plate

50% Mass Reduction

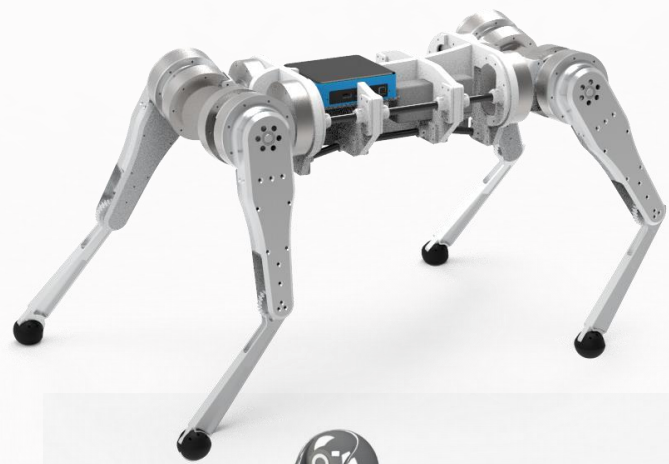
- Lighter and save more fuel
- Environmentally friendly



Lightweight the legs of quadruped Robot

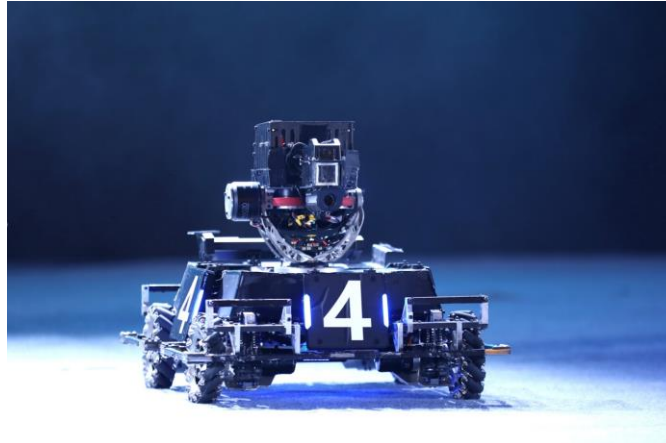
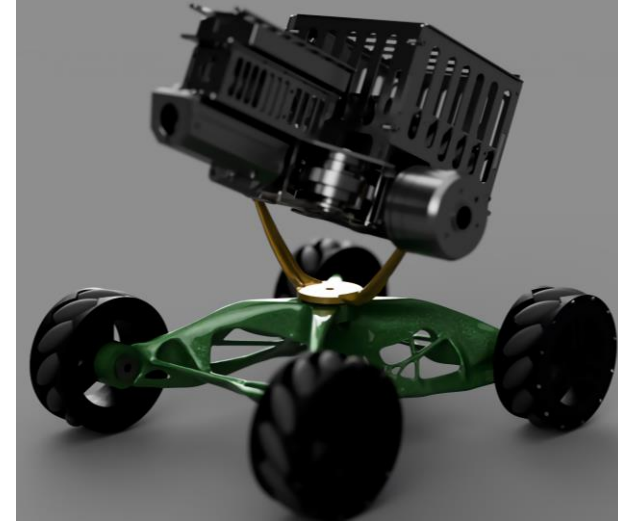
42% Mass Reduction

- Faster and nimbler
- Longer battery life
- Won the first prize of Robocon 2020 China



Conclusion

- Can be easily made through additive manufacturing while CNC cannot
- 30% lighter of the whole robot if each parts are generative design and 3d printed
- production in one single piece help enhancing the structural strength, reduces the material waste and entire iterative cost by 80%



Our stories
To be continue



Autodesk 和 Autodesk 标识是 Autodesk, Inc. 和/或其子公司和/或其关联公司在美国和/或其他国家或地区的注册商标或商标。所有其他品牌名称、产品名称或者商标均属于其各自的所有者。Autodesk 保留随时调整产品和服务、产品规格以及建议零售价的权利，恕不另行通知，同时 Autodesk 对于此文档中可能出现的文字印刷或图形错误不承担任何责任。