Building Functional 3d-Printable Lab Equipment Using Fusion 360

Carlo Quinonez

Director of Research, FATHOM

CHANGING THE WAY PRODUCTS ARE DESIGNED & MANUFACTURED

Inc. 5000 AMERICA'S FASTEST GROWING PRIVATE COMPANIES

Oakland 510.281.9000 // Seattle 206.582.1062 // studiofathom.com

TOPICS

1

Background

- FATHOM & Carlo
- 3D-Printable Lab Equipment

2

Practical Complexity

- Value of Complexity
- Practical Examples of Complexity

3

Conclusions

- Next steps
- Future perspective

BACKGROUND

FATHOM & CARLO

FATHOM IS...

Leveraging its expertise in 3D printing and additive manufacturing to help its customers innovate faster and more efficiently.

Helping companies put satellites into orbit, electric cars on freeways, and a full spectrum of devices into people's hands, homes and even their bodies.

Using its expertise for serious digital manufacturing.

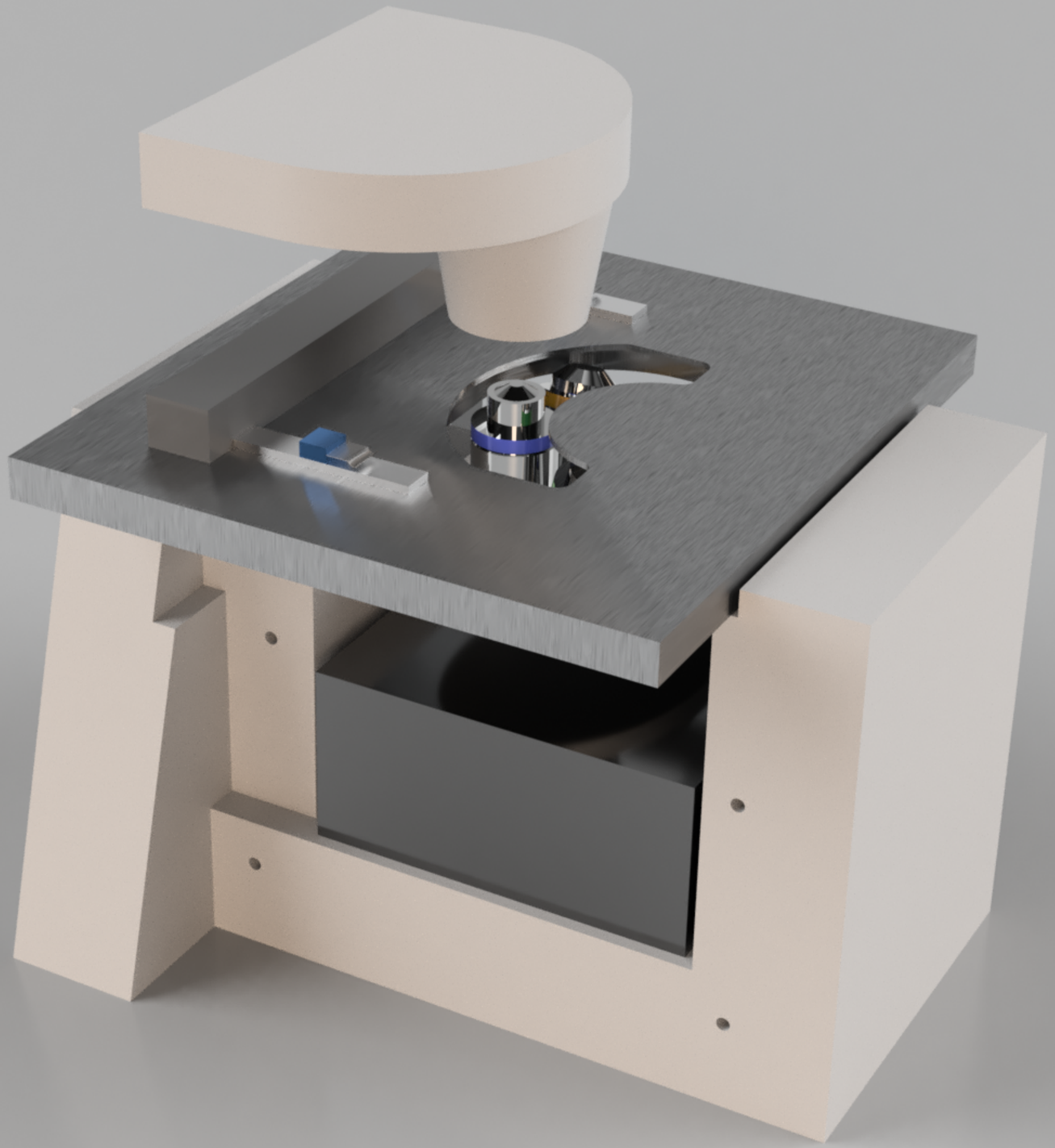
FATHOM offers professional 3D printers and manufacturing systems, prototyping and advanced manufacturing services, with design and engineering resources in support of these.

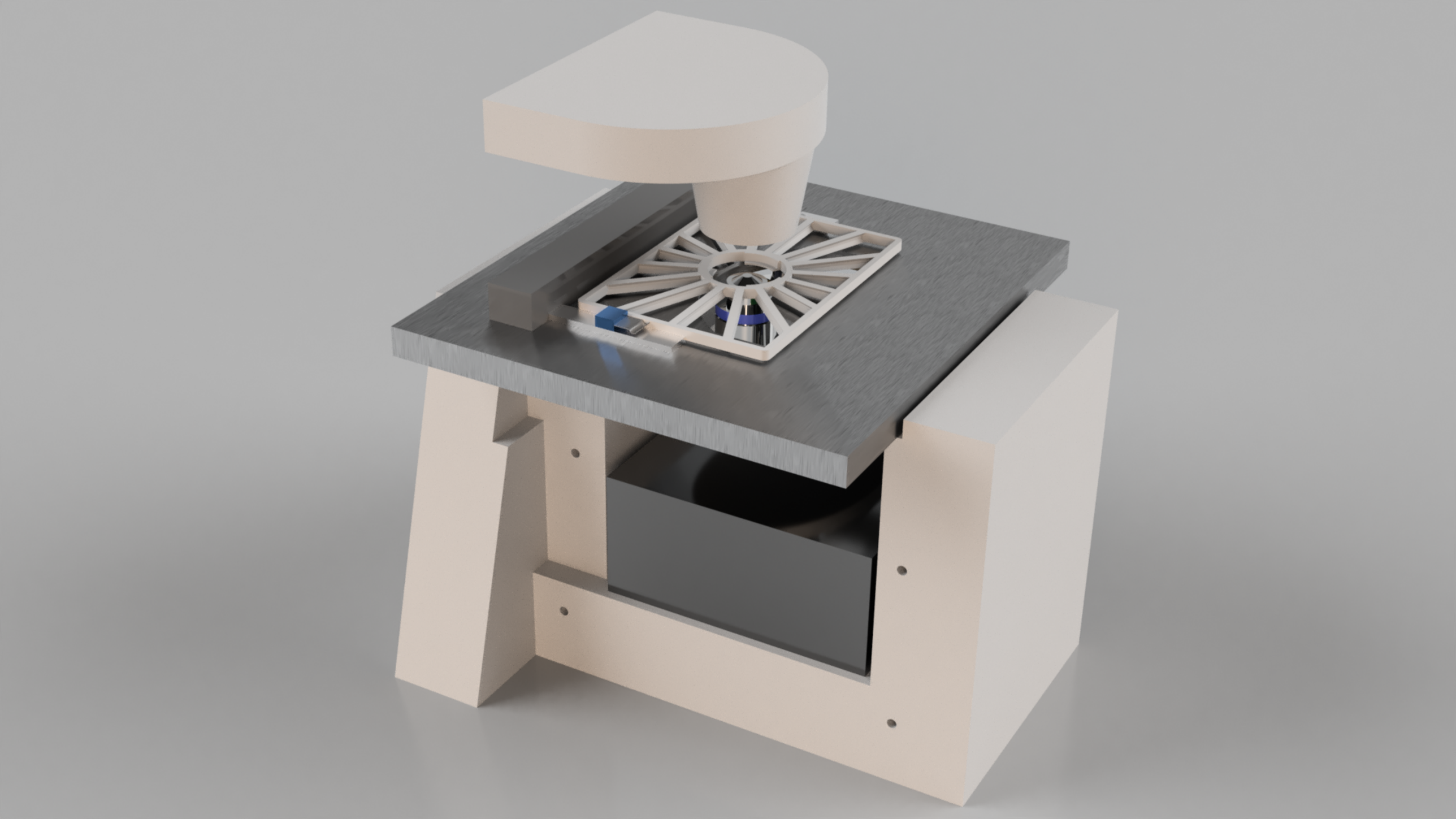
AWARDS & RECOGNITION

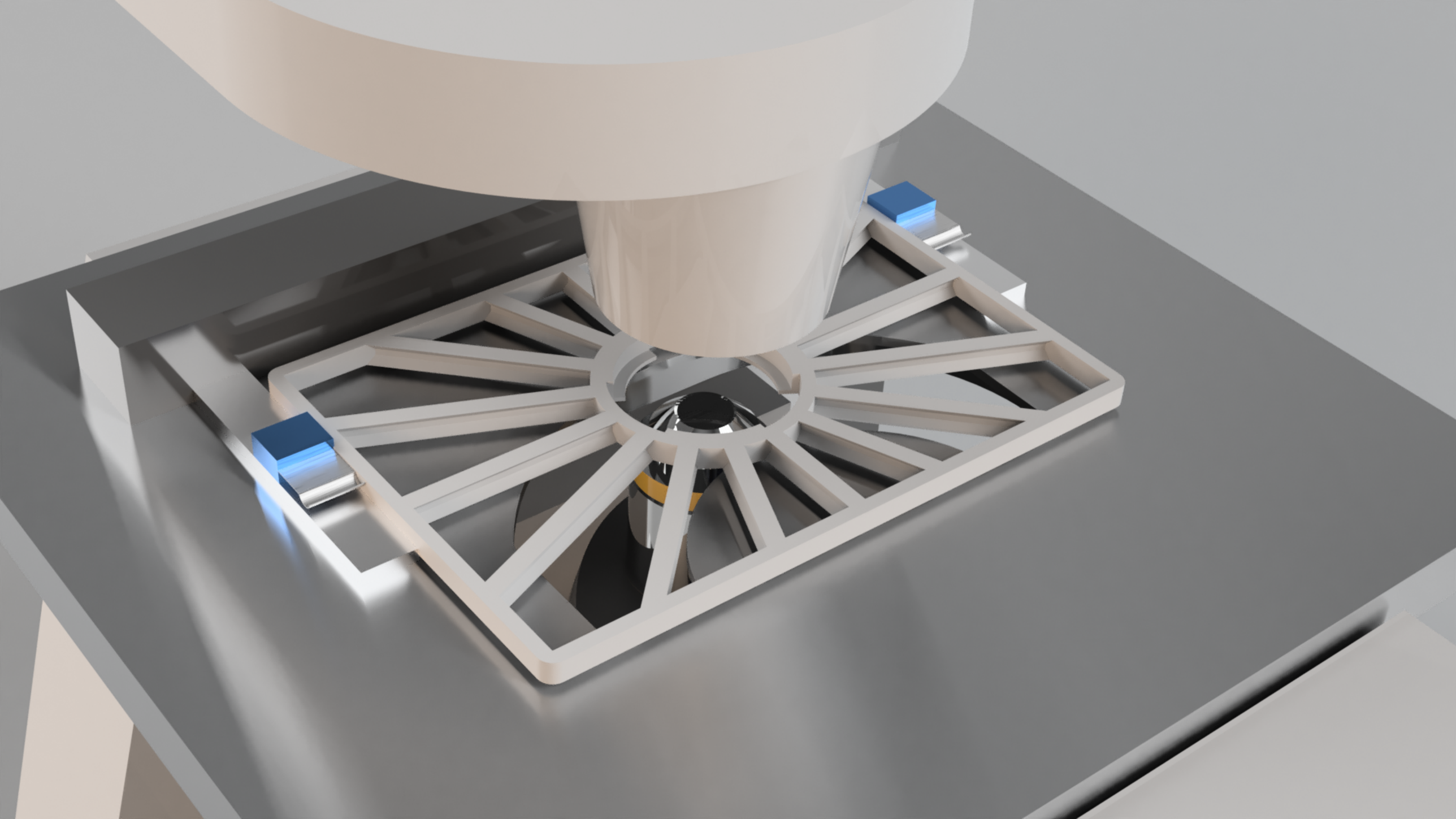
- Stratasys/Objet Top Reseller [2009-2015]
- INC 500|5000 Ranking [2013-2015]
  - NO. 369 and NO. 1312
- ICIC Inner City Ranking [2014]
  - NO. 1 in MFG and NO. 2 Overall
- SF Business Times [2013-2015]
  - NO. 39 and NO. 32
- Champions of Manufacturing Summit [2015]
- East Bay Innovations Award [2015]
  - Advanced Manufacturing Category
- East Bay Innovations Award [2015]
  - Advanced Manufacturing Category

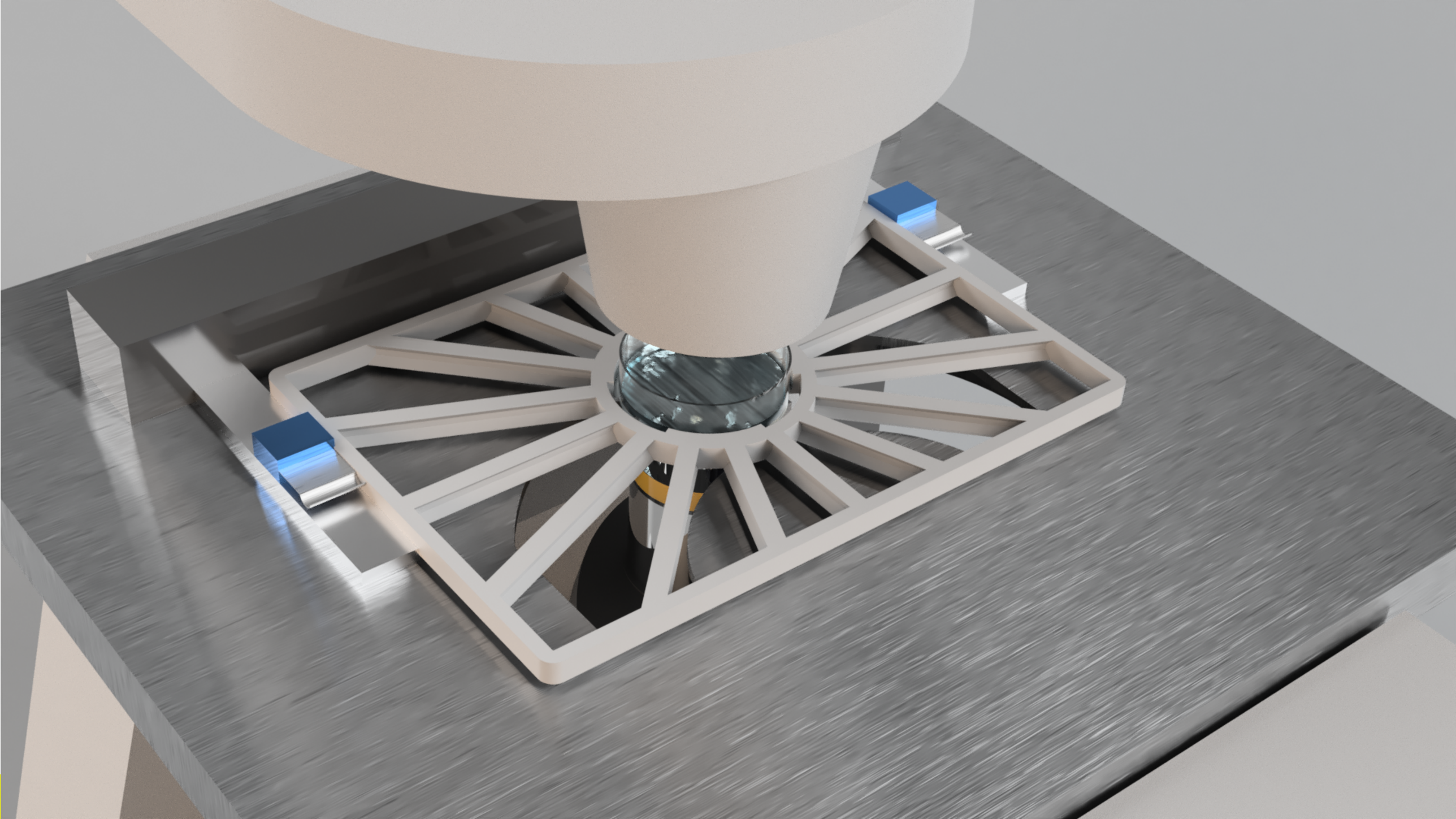
CARLO QUIÑONÉZ
DIRECTOR OF RESEARCH

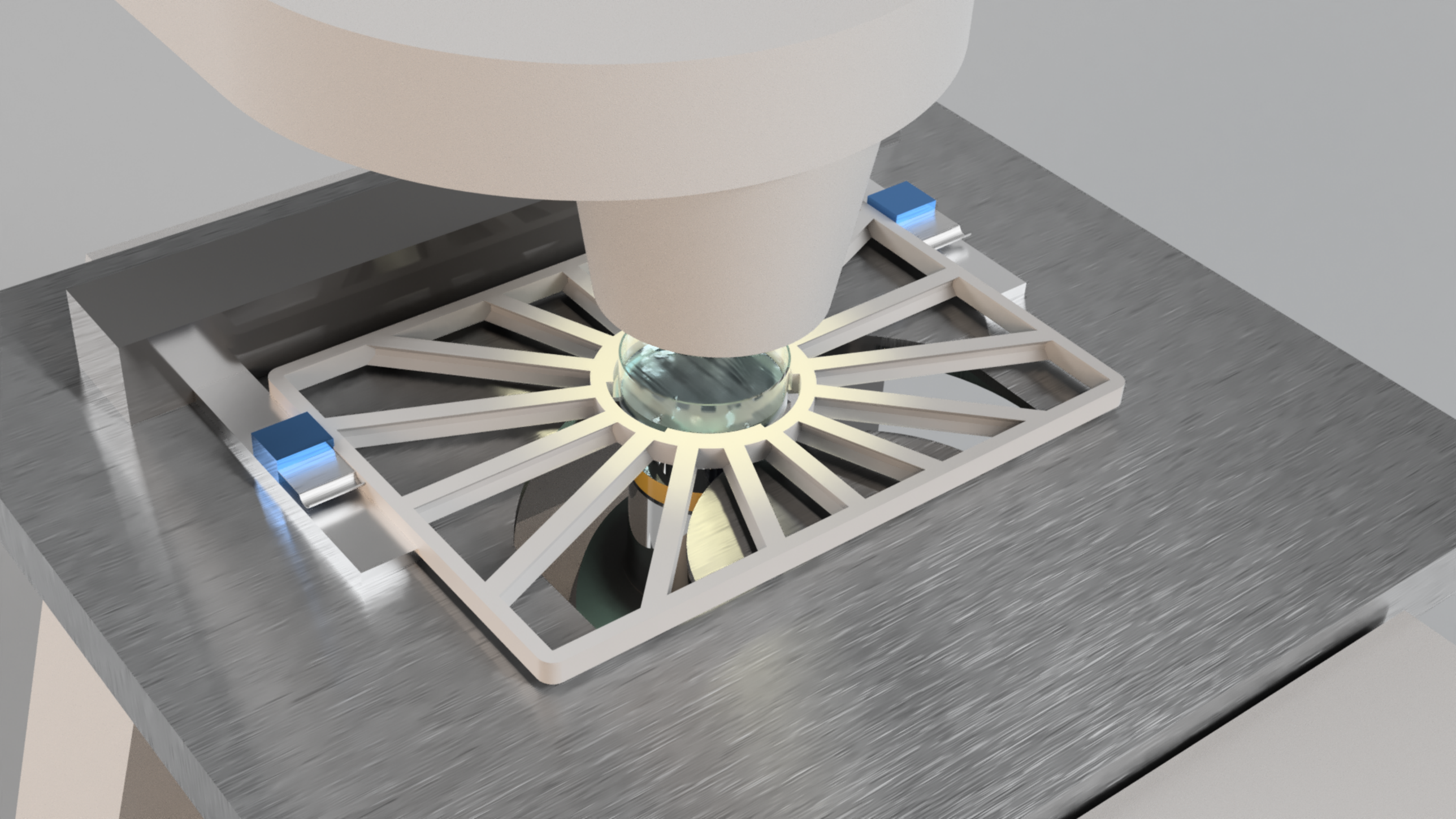
- Passion for science and engineering
- Academic experience
  - Biology PhD from California Institute of Technology in 2003
  - Focused on building tools for scientists
- Industrial experience
  - Over 10 years working on design/build teams
  - First used 3d-printing on projects in 2004

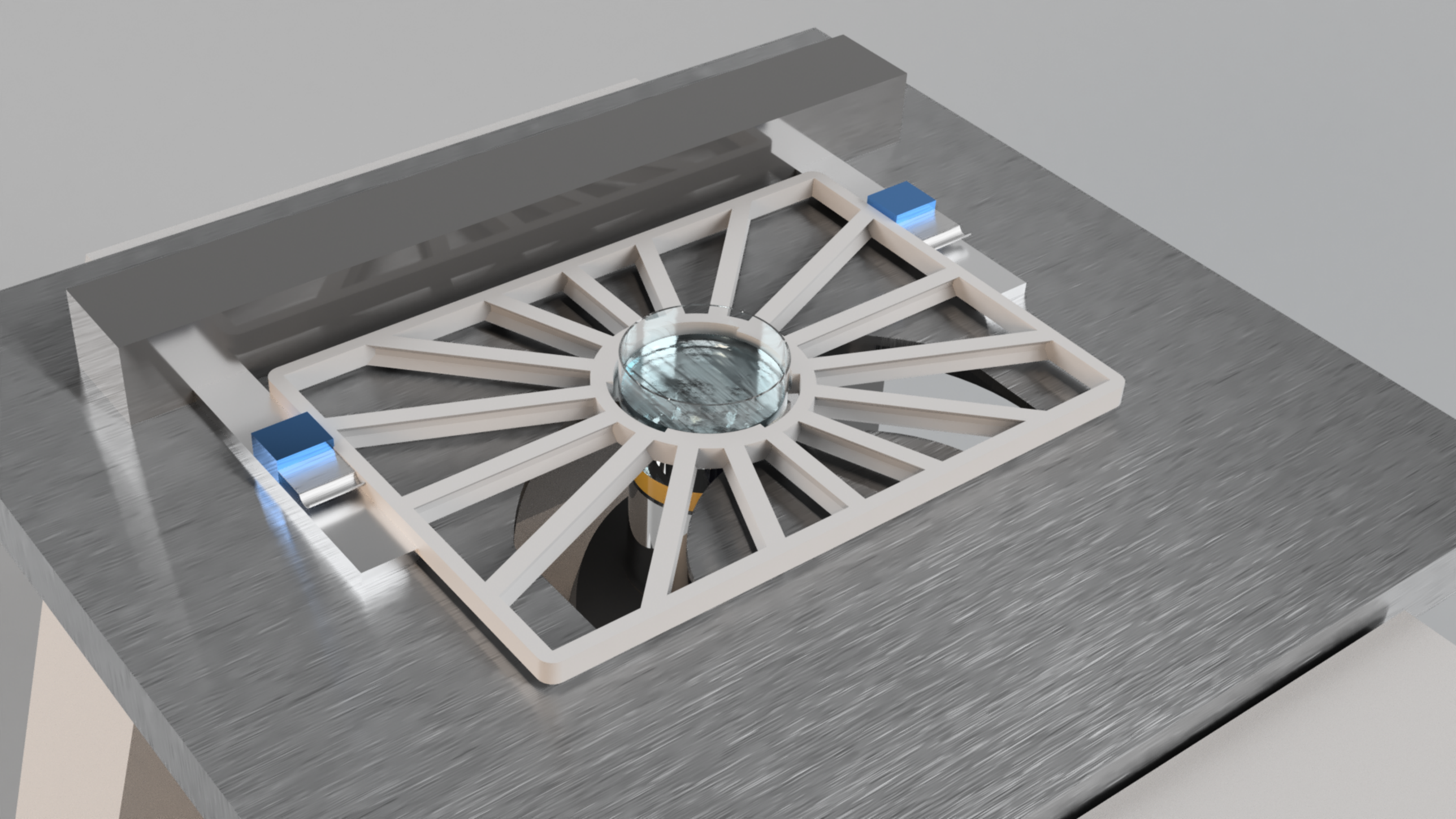


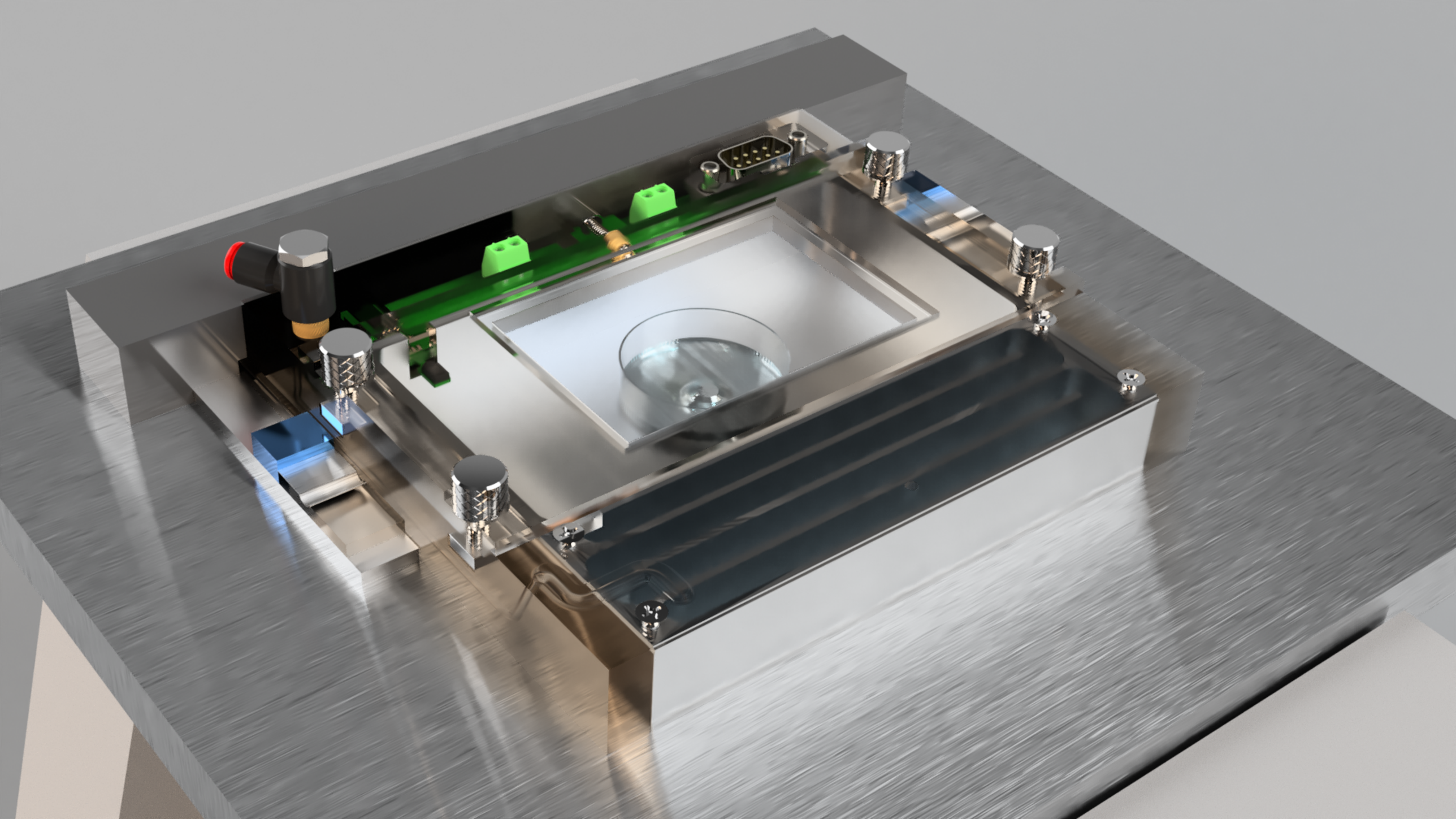








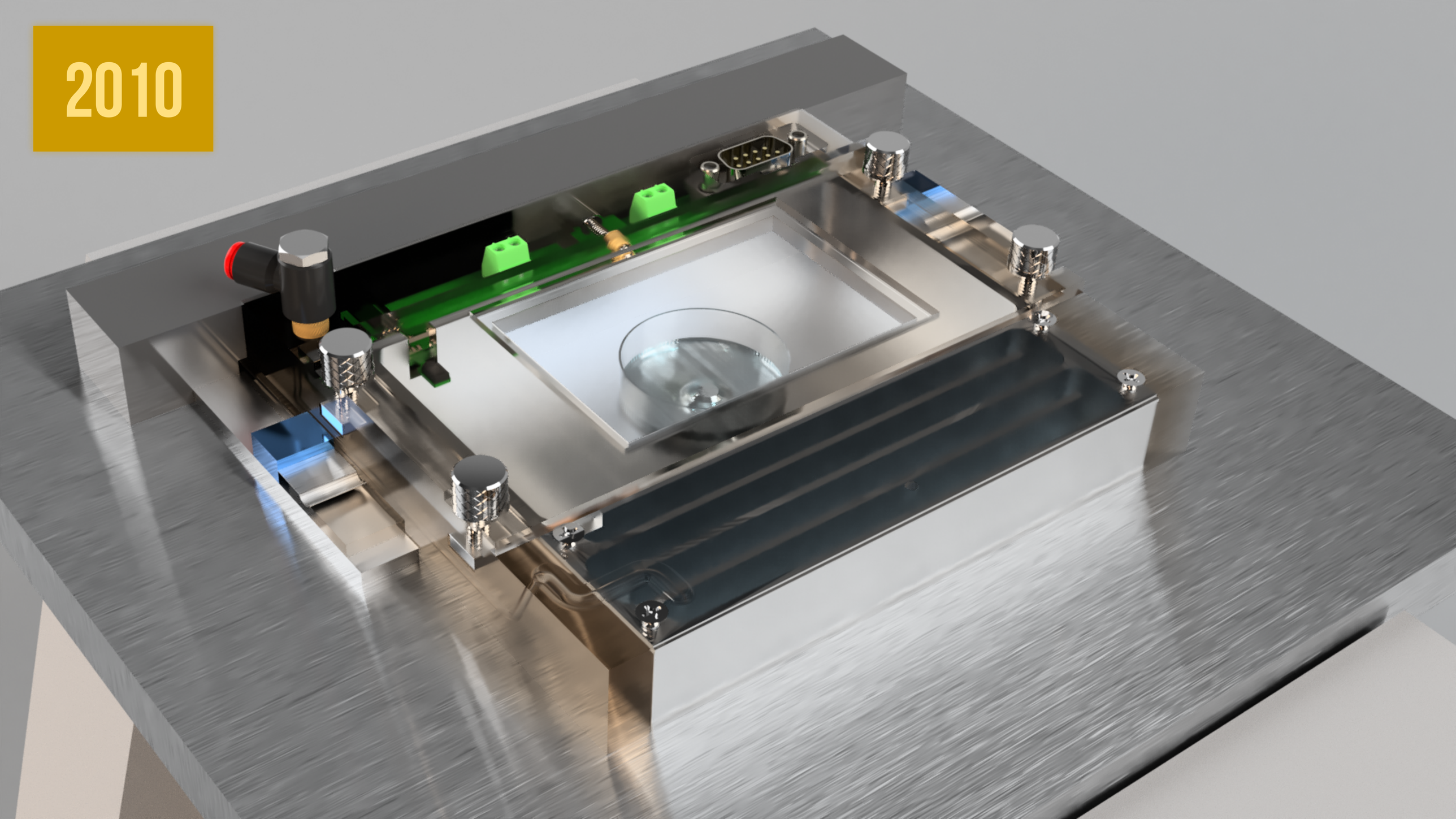




BACKGROUND

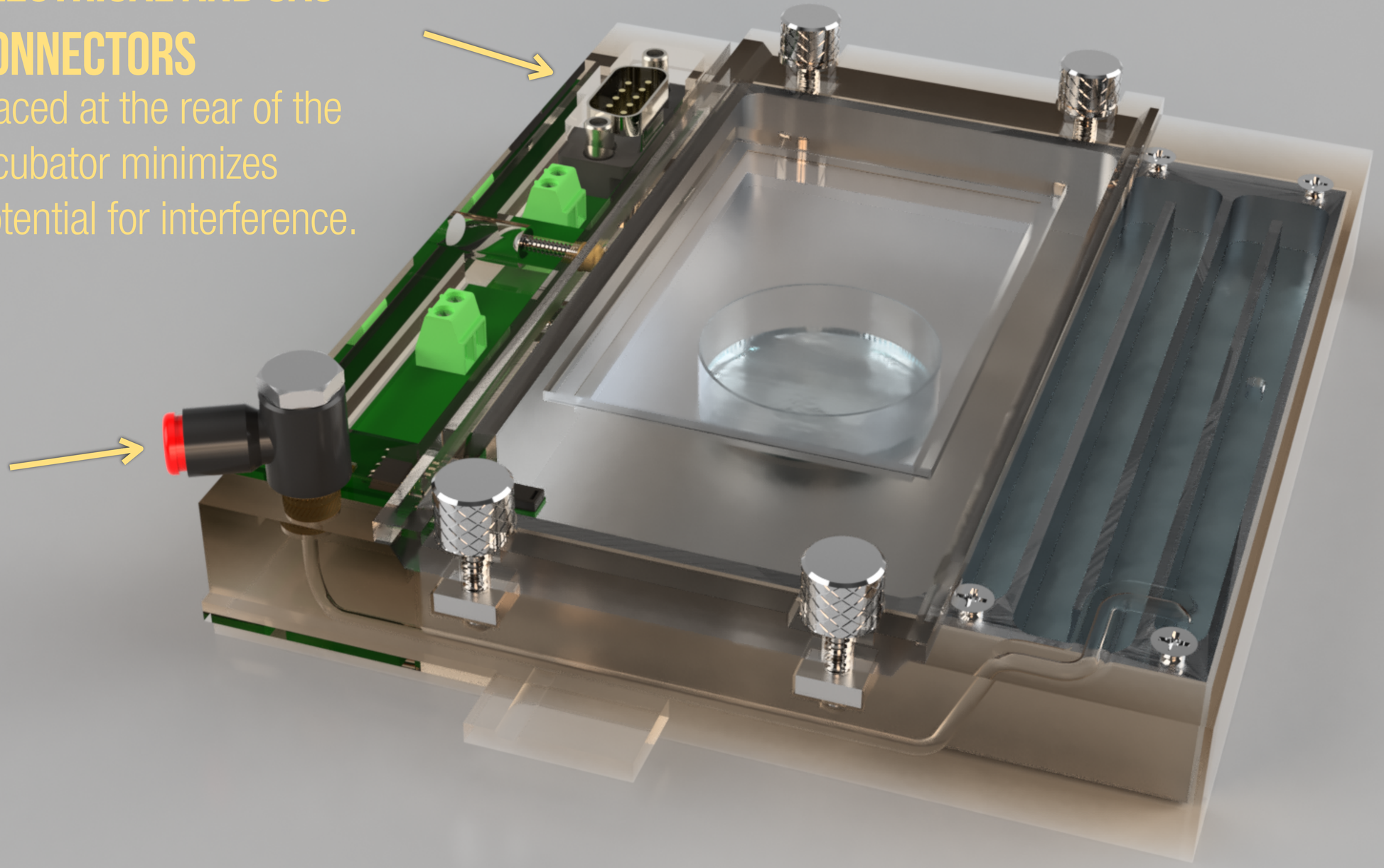
3D-PRINTABLE LAB INCUBATORS

2010



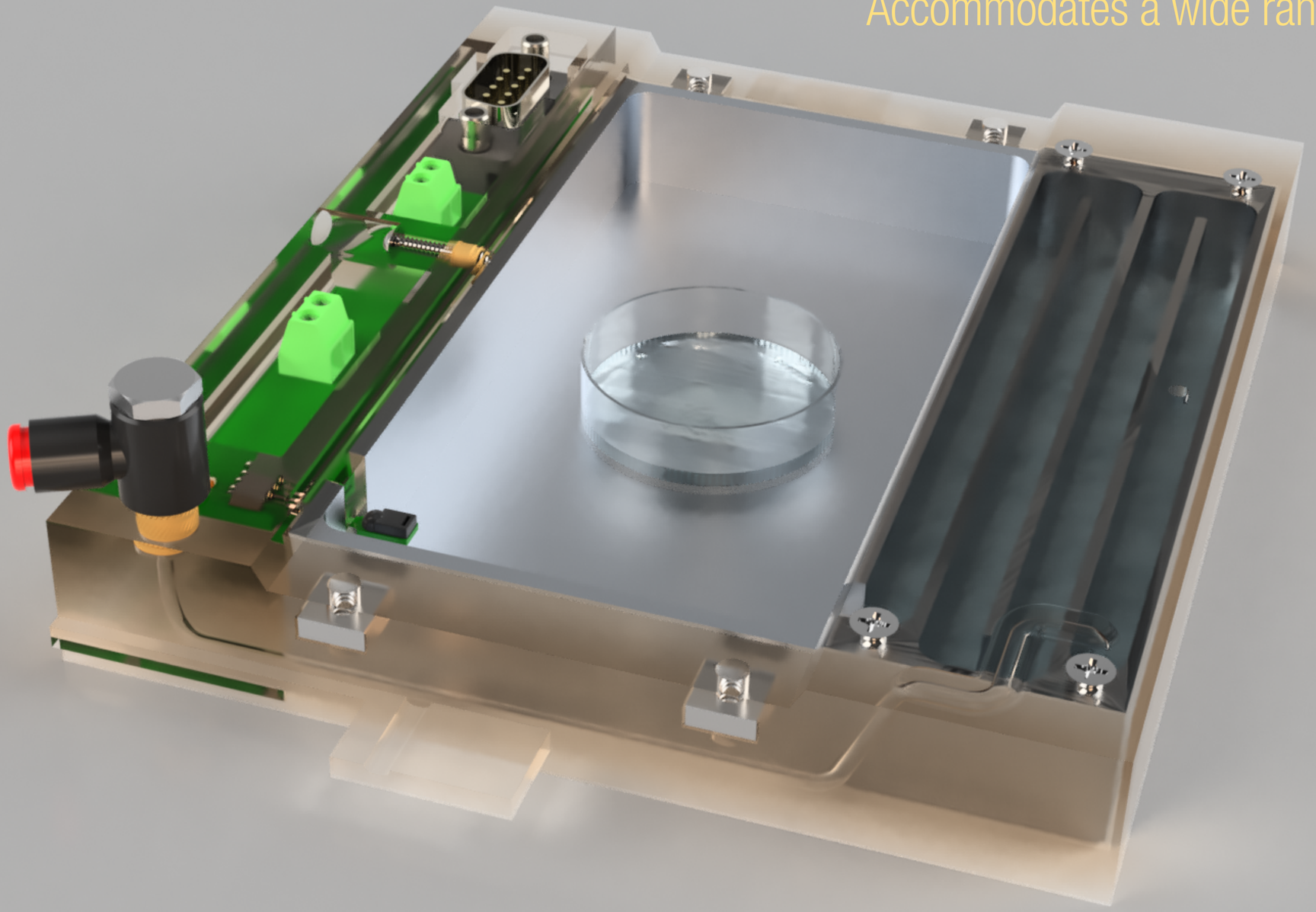
ELECTRICAL AND GAS CONNECTORS

Placed at the rear of the incubator minimizes potential for interference.



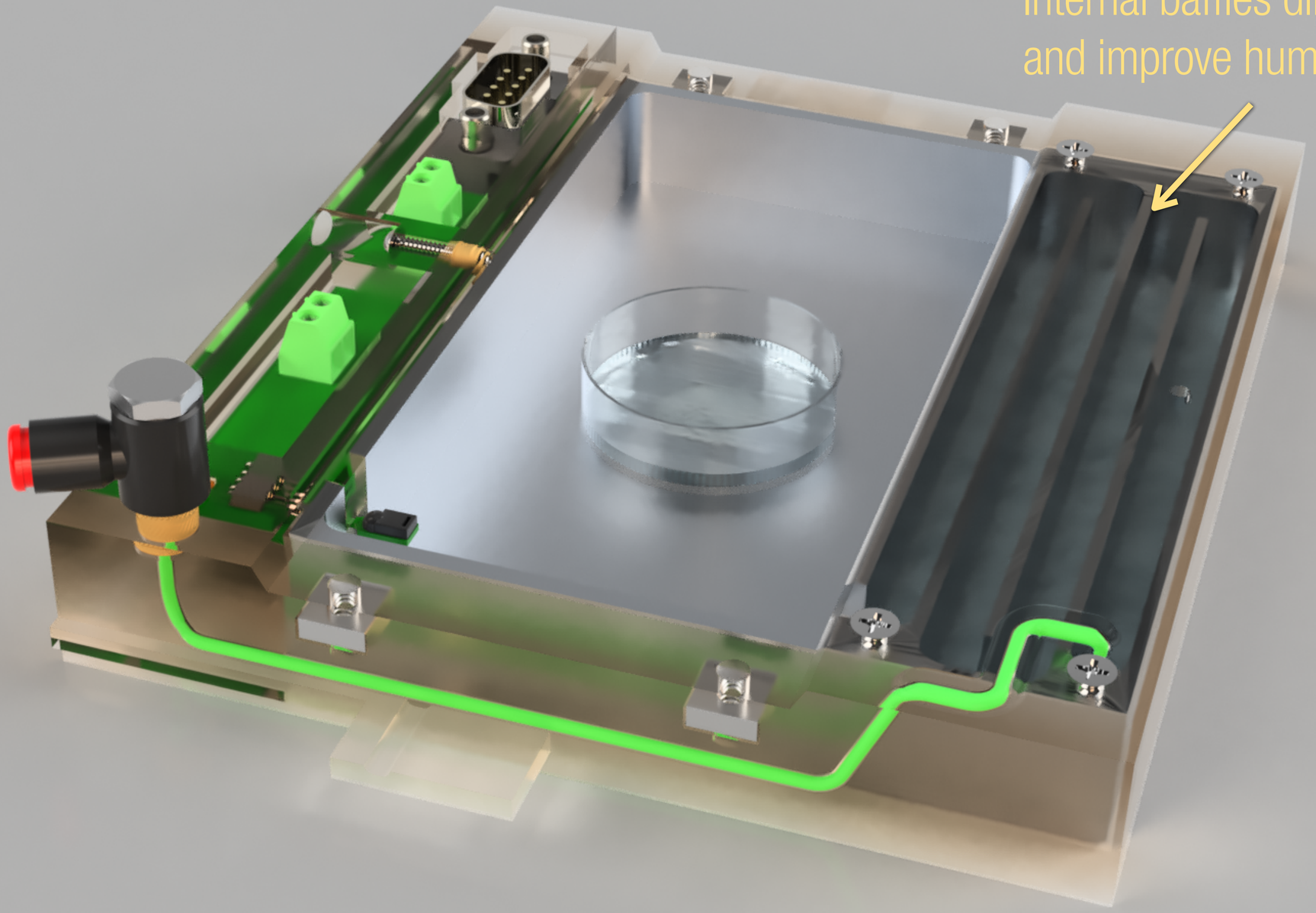
VERSATILE SAMPLE CHAMBER

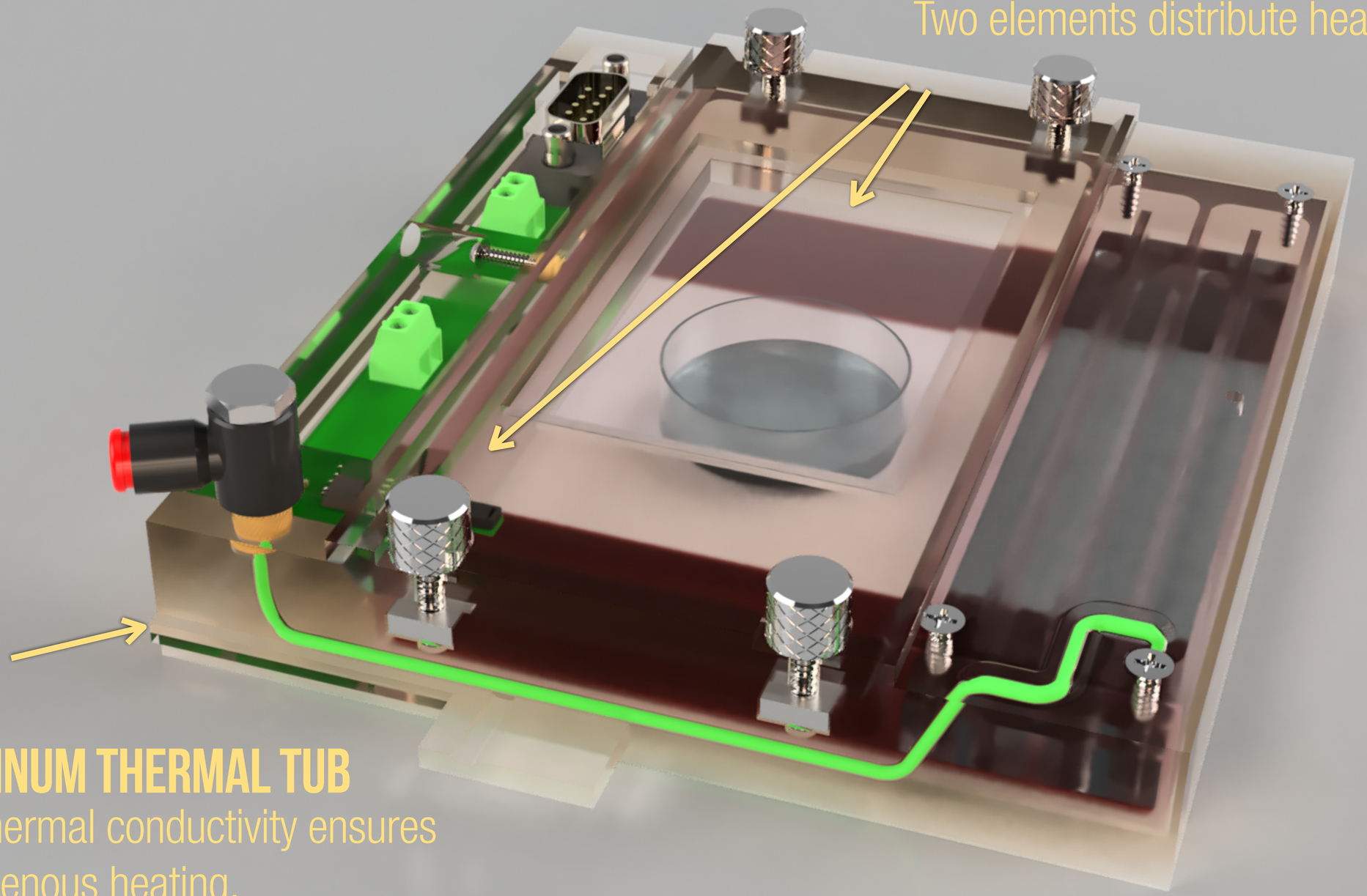
Accommodates a wide range of sample sizes.



HUMIDIFICATION

Internal baffles direct the gas flow and improve humidification efficiency.





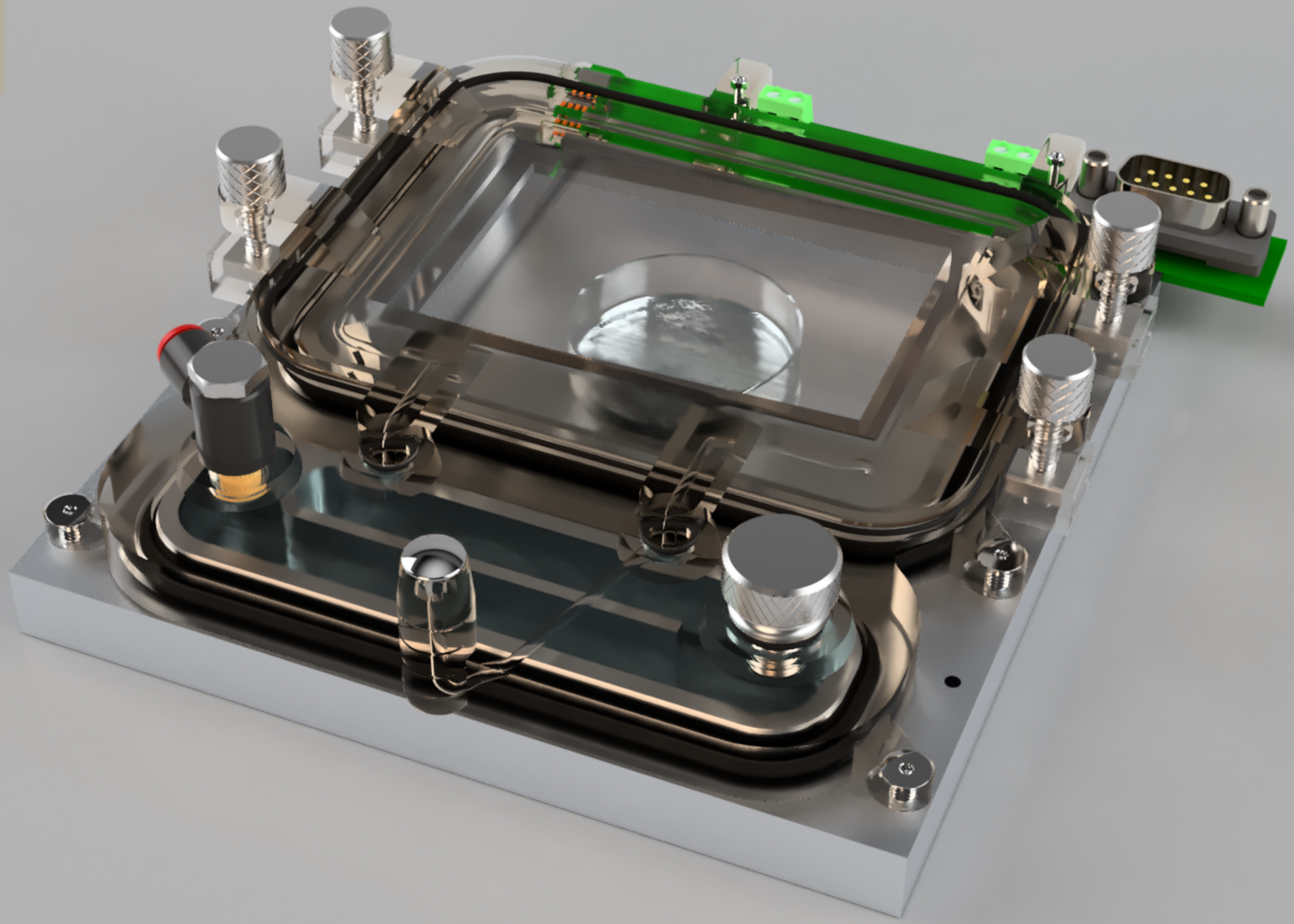
FOIL HEATERS

Two elements distribute heat more evenly.

ALUMINUM THERMAL TUB

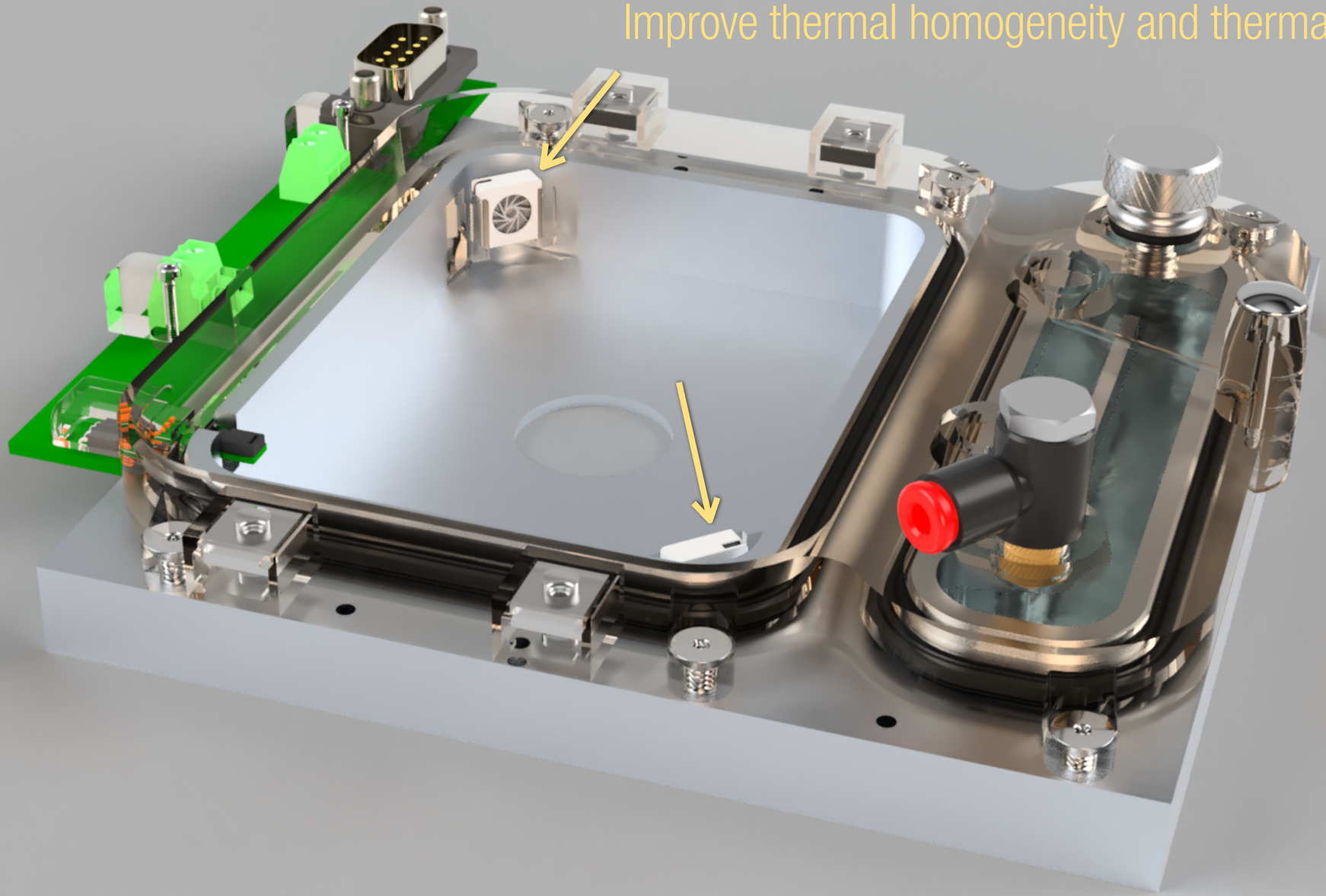
High thermal conductivity ensures homogenous heating.

2011



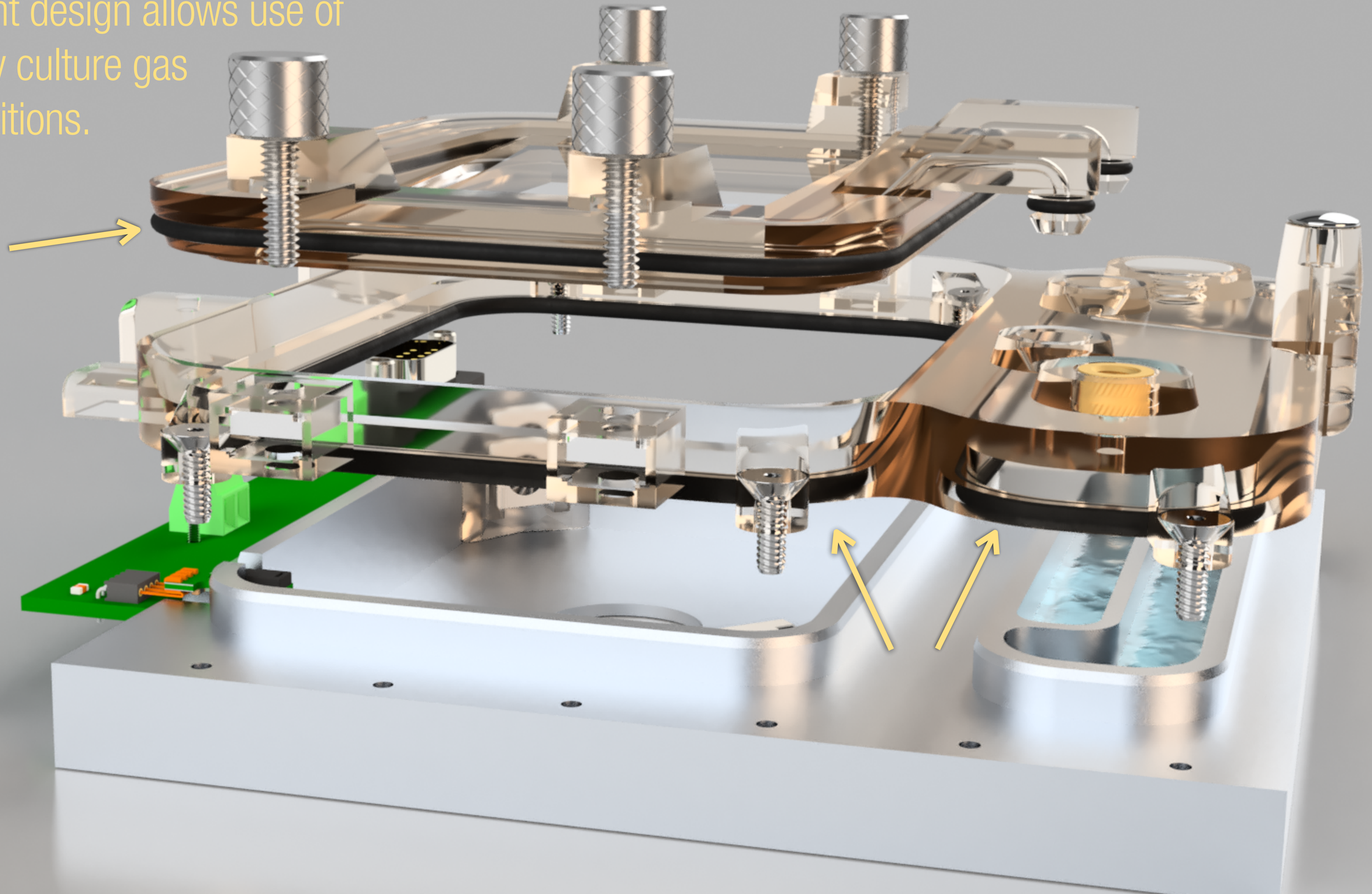
STIRRER FANS

Improve thermal homogeneity and thermal equilibration times.



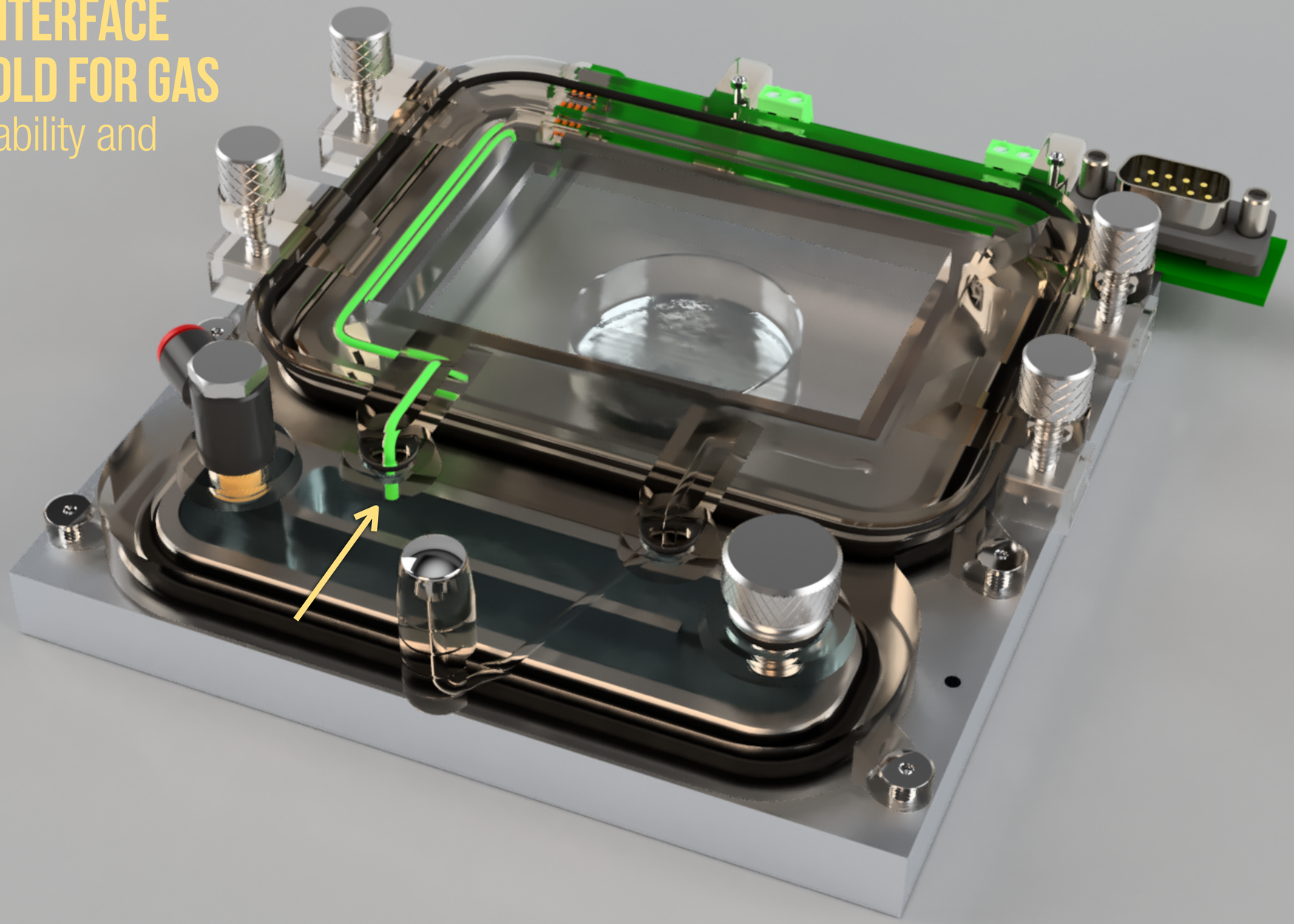
ORING SEALS

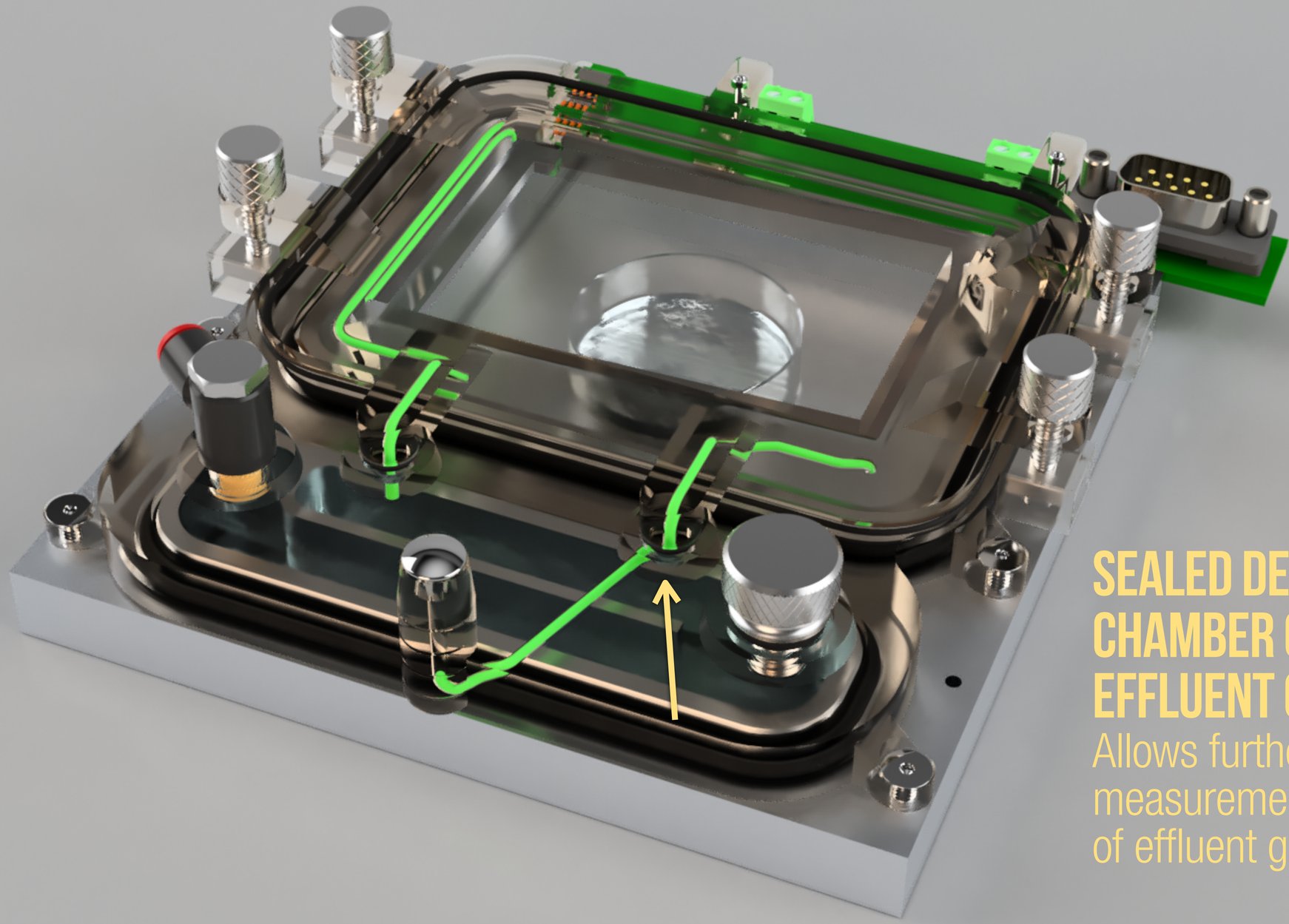
Gas-tight design allows use of arbitrary culture gas compositions.



INTEGRAL INTERFACE AND MANIFOLD FOR GAS

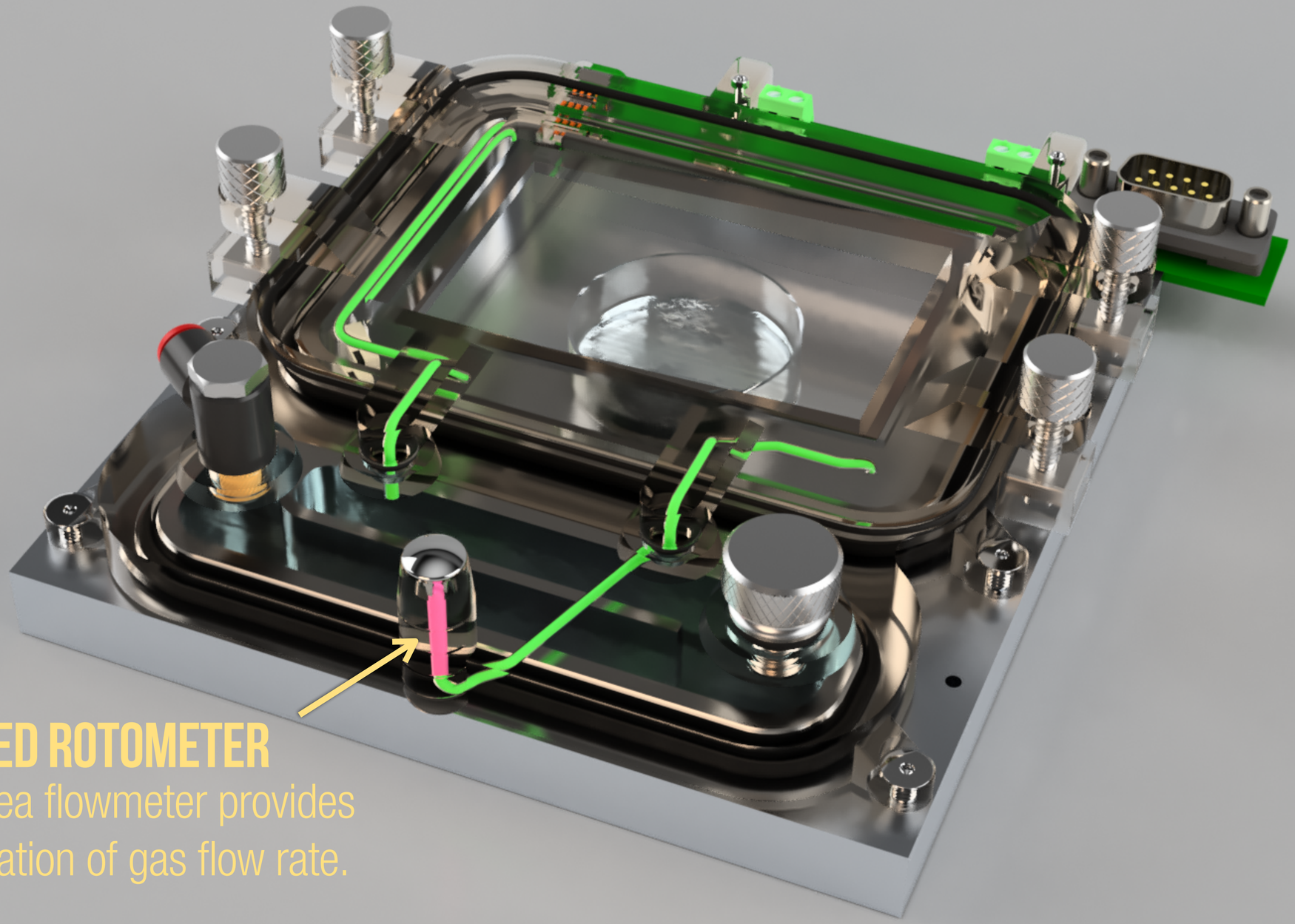
Improves reliability and serviceability.





SEALED DESIGN OF CHAMBER CAPTURES EFFLUENT GASSES

Allows further processing, measurement or sampling of effluent gases.



3D-PRINTED ROTOMETER

Variable-area flowmeter provides visual indication of gas flow rate.

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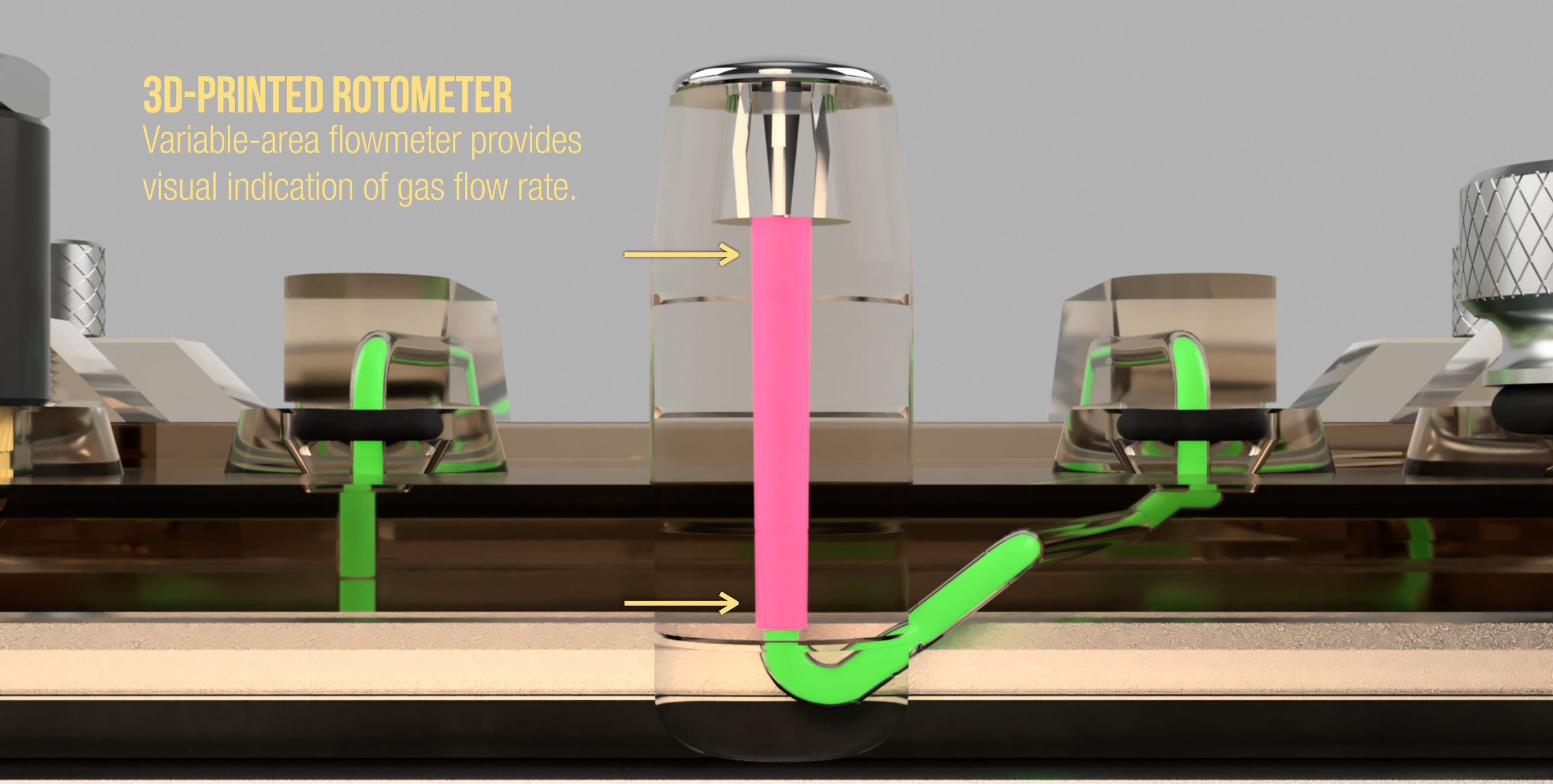

3D-PRINTED ROTOMETER

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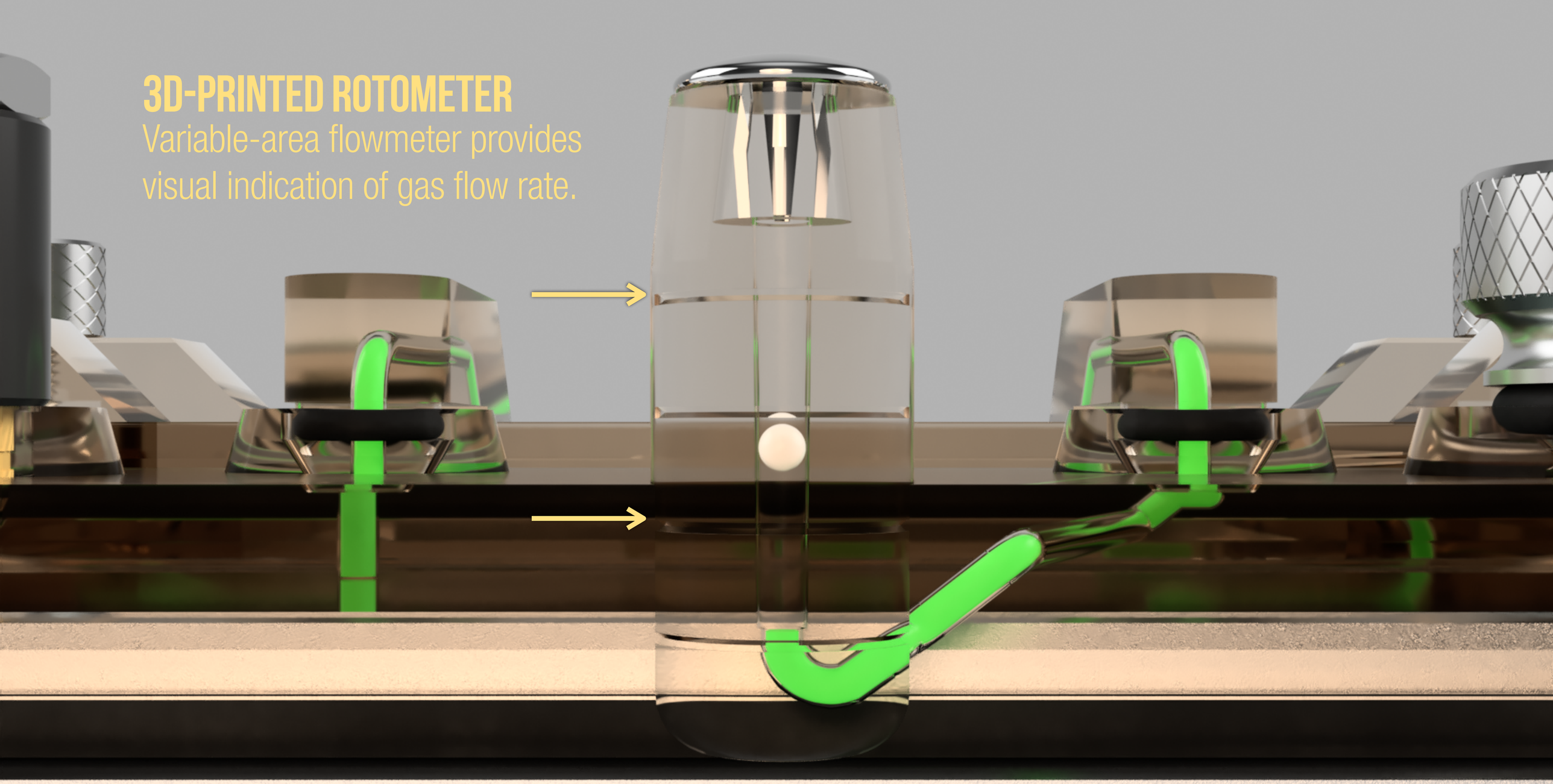
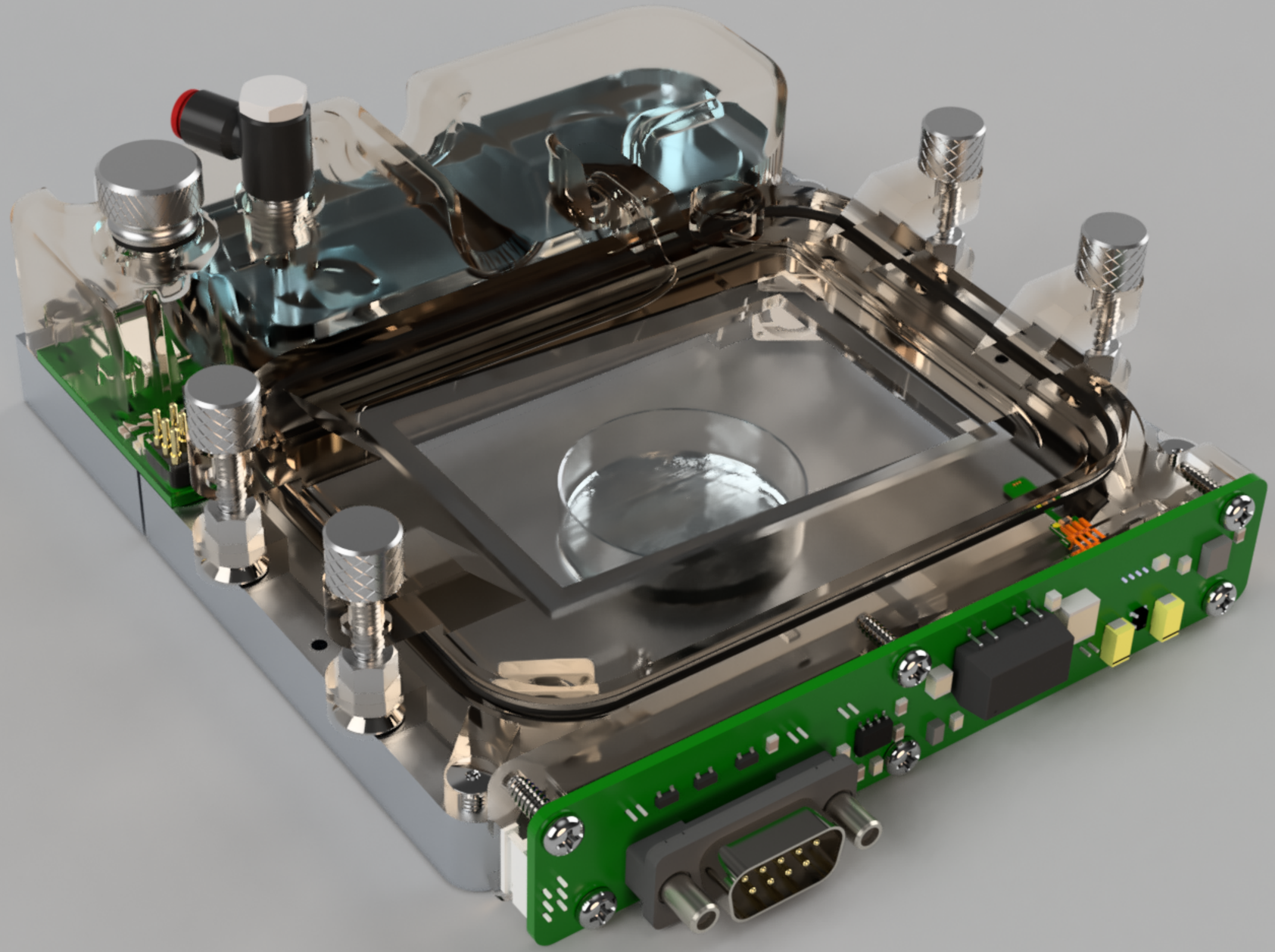
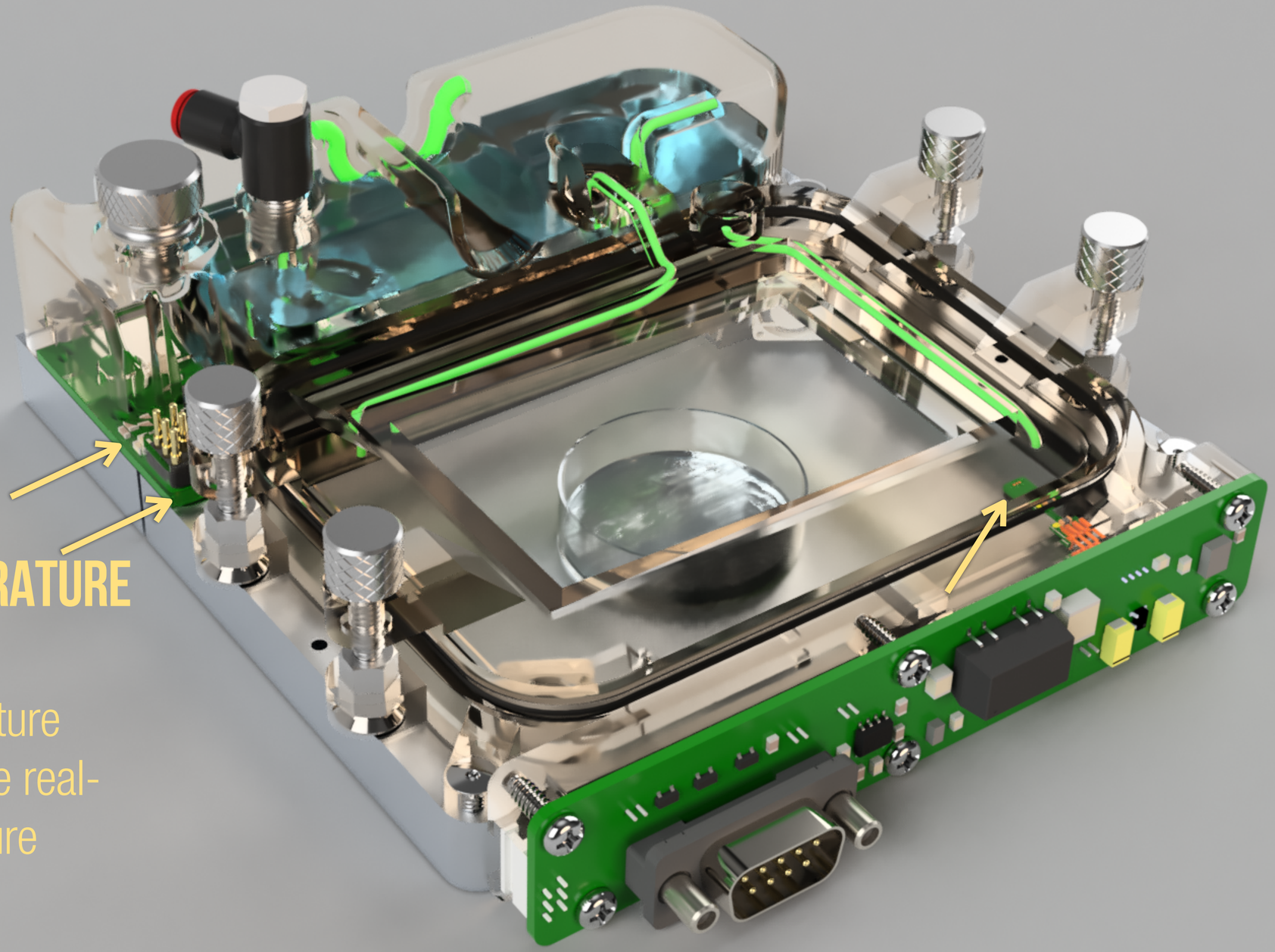


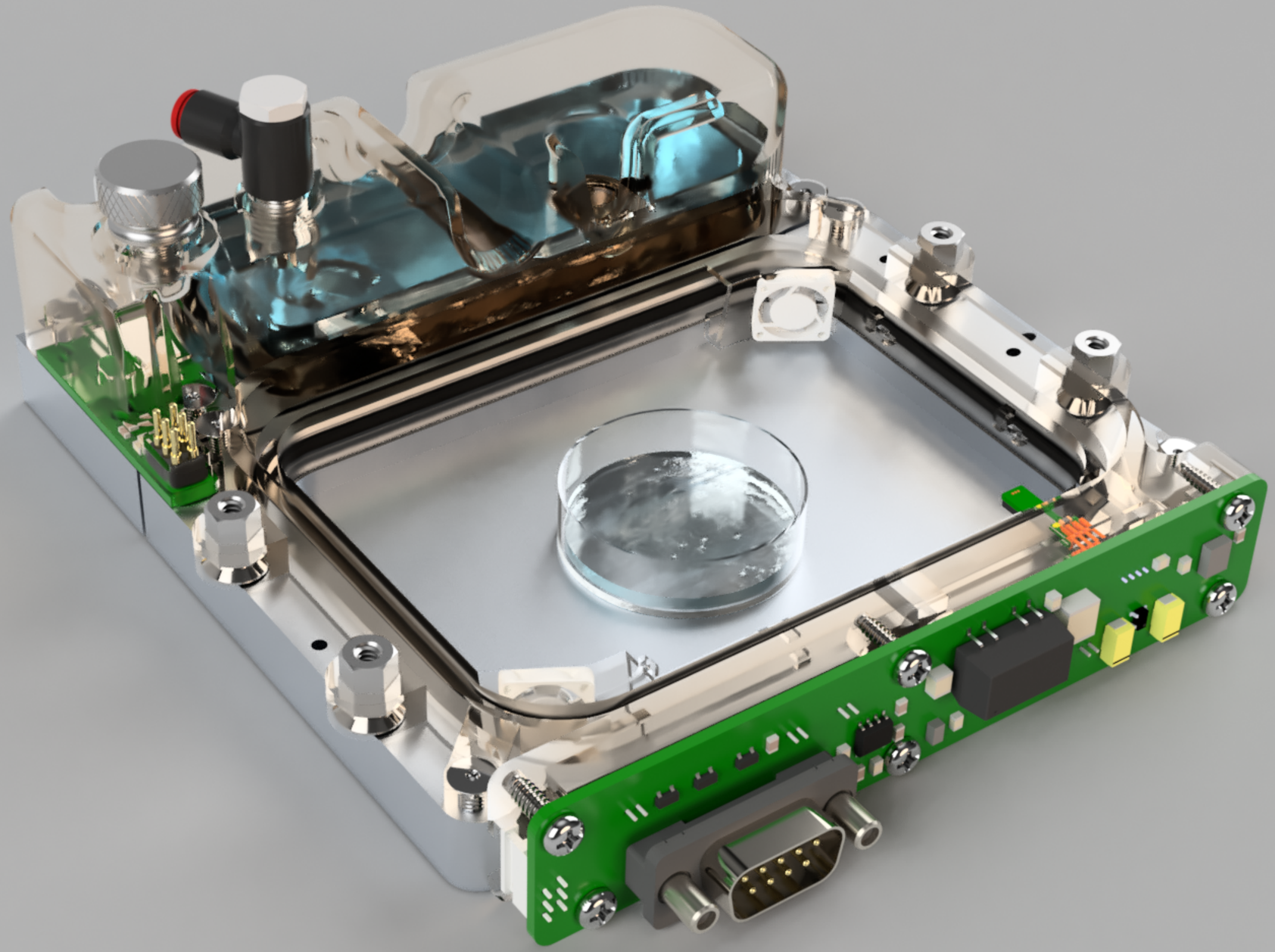
2012

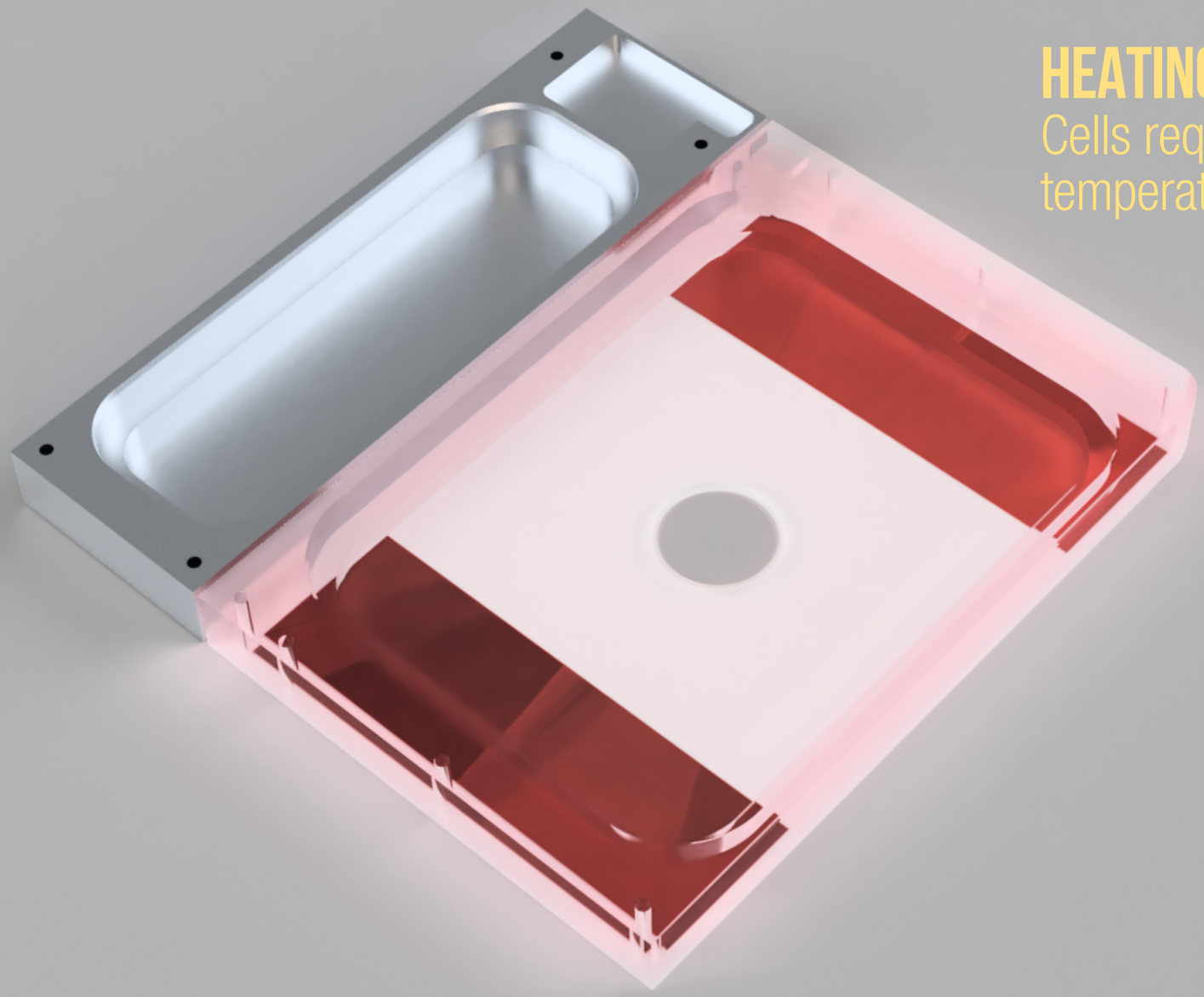




DUAL TEMPERATURE ZONES

Three temperature sensors provide real-time temperature feedback.



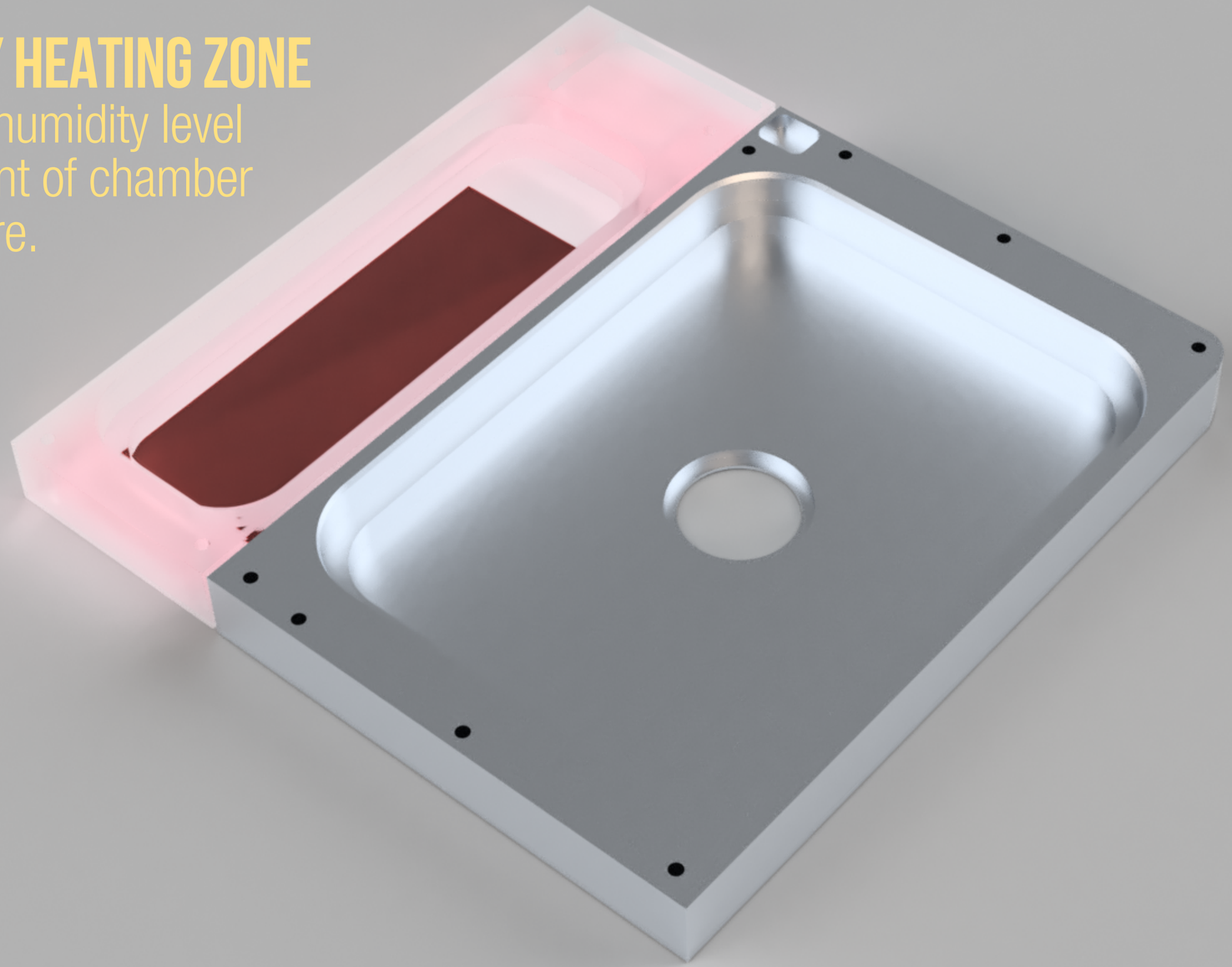


HEATING ZONE FOR CELLS

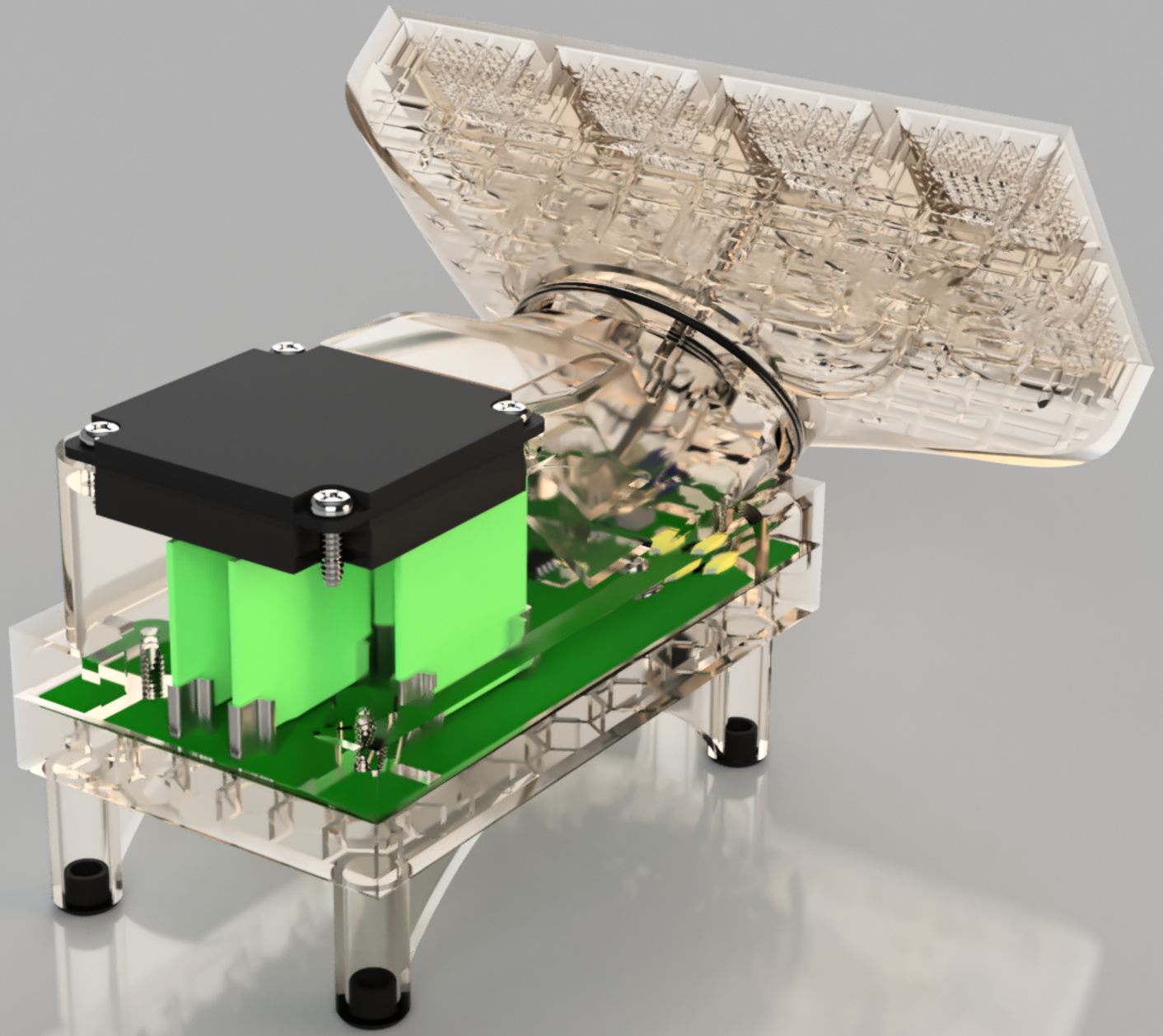
Cells require careful temperature regulation.

HUMIDITY HEATING ZONE

Control of humidity level independent of chamber temperature.

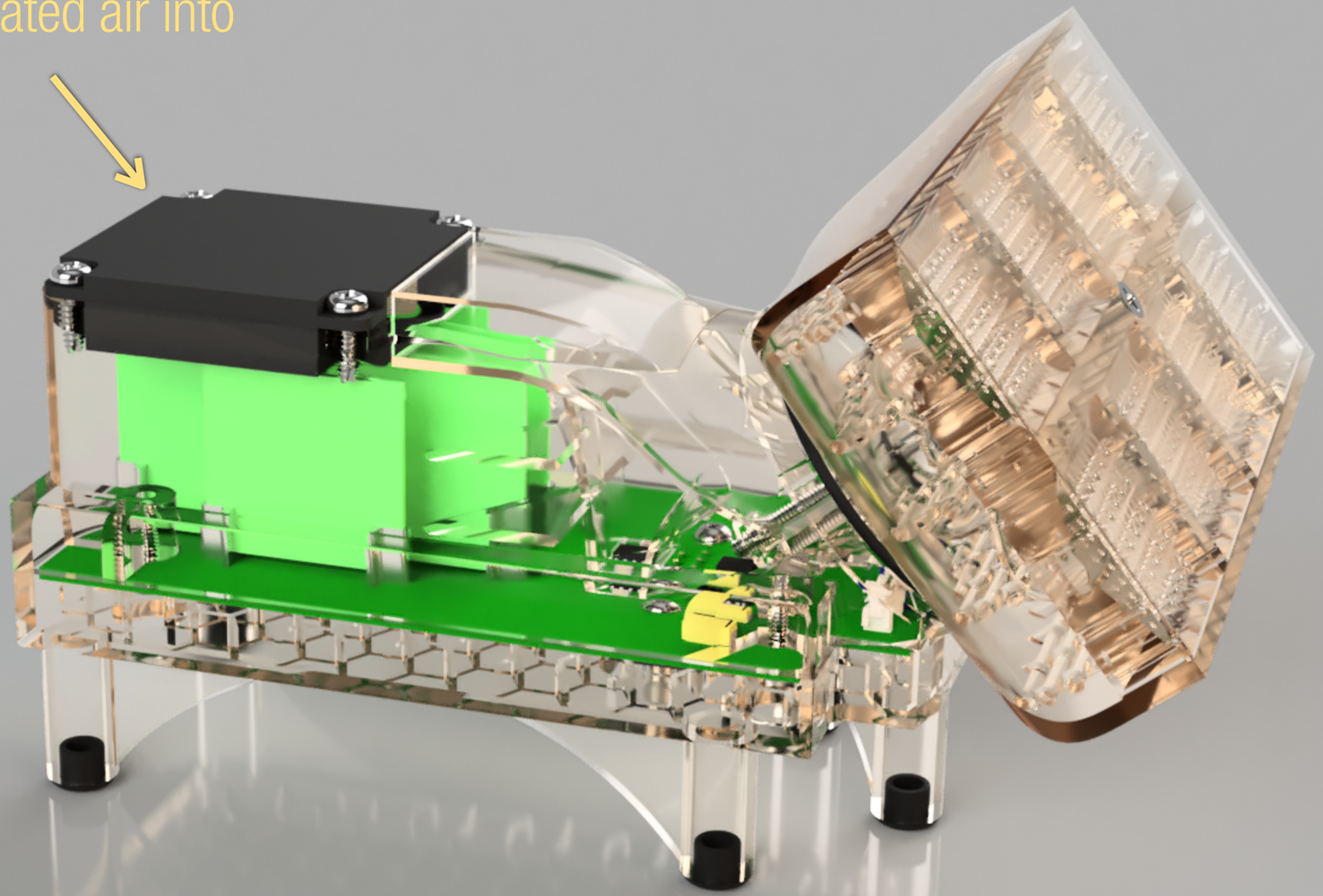


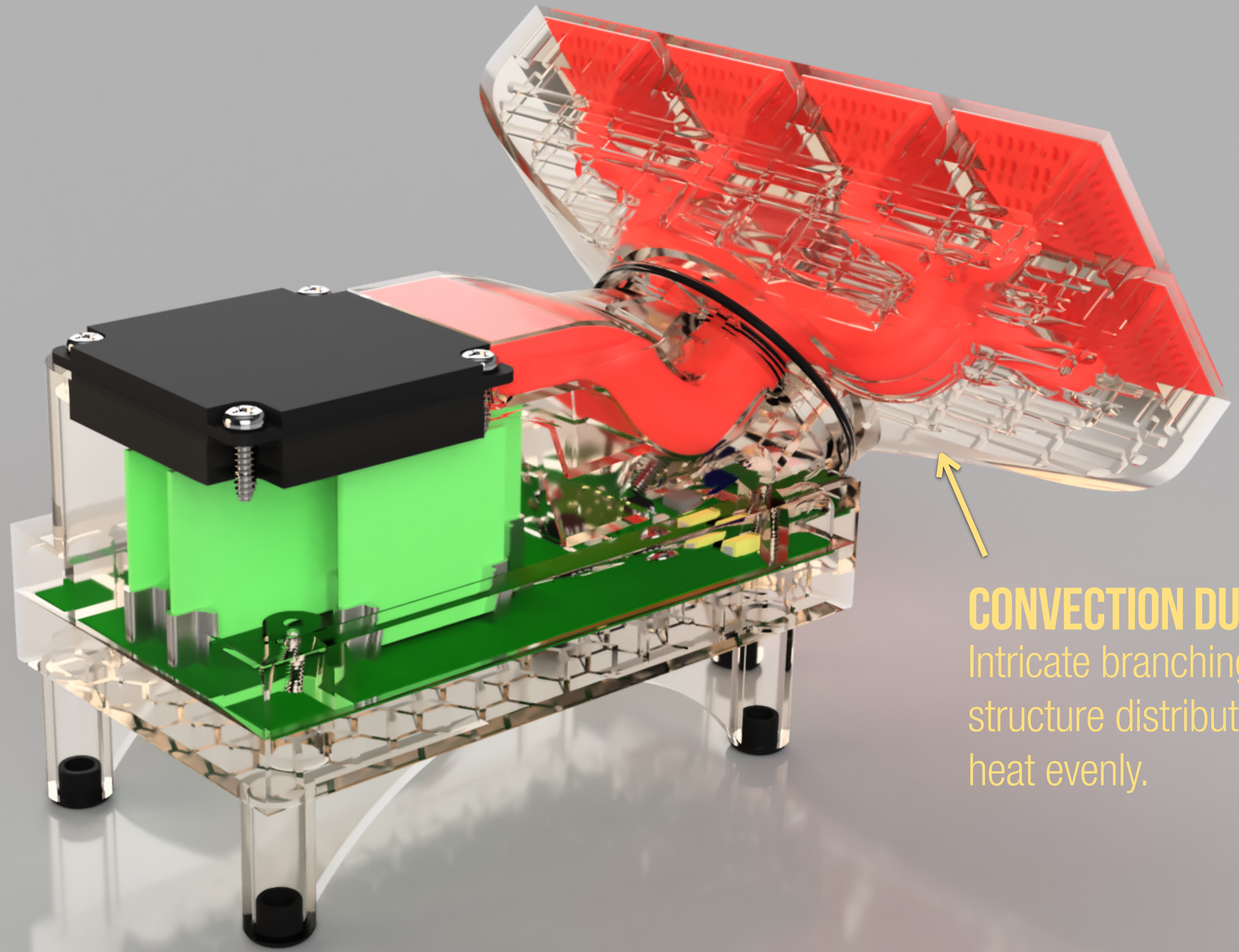
2014



BLOWER

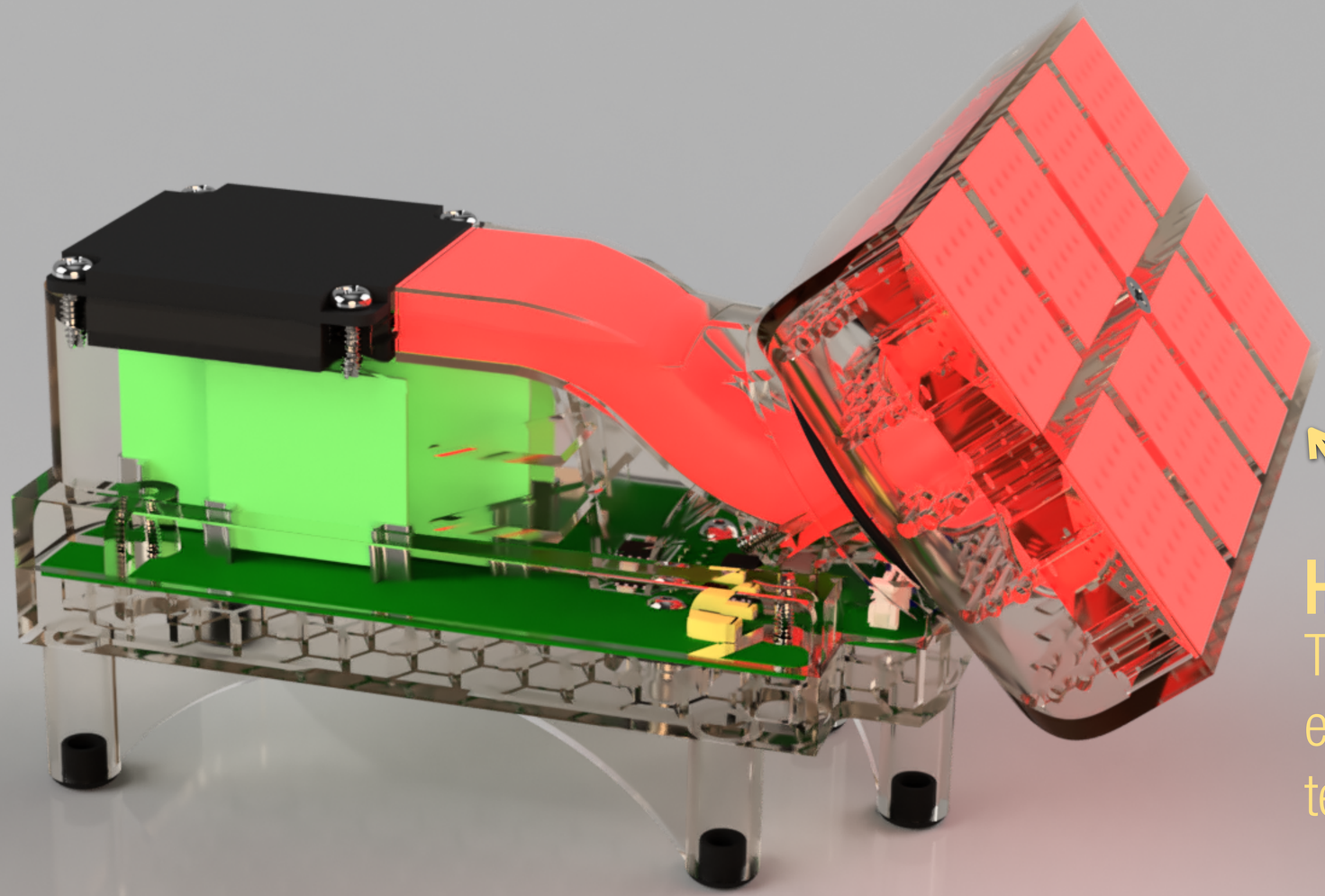
Forces heated air into ductwork





CONVECTION DUCTS

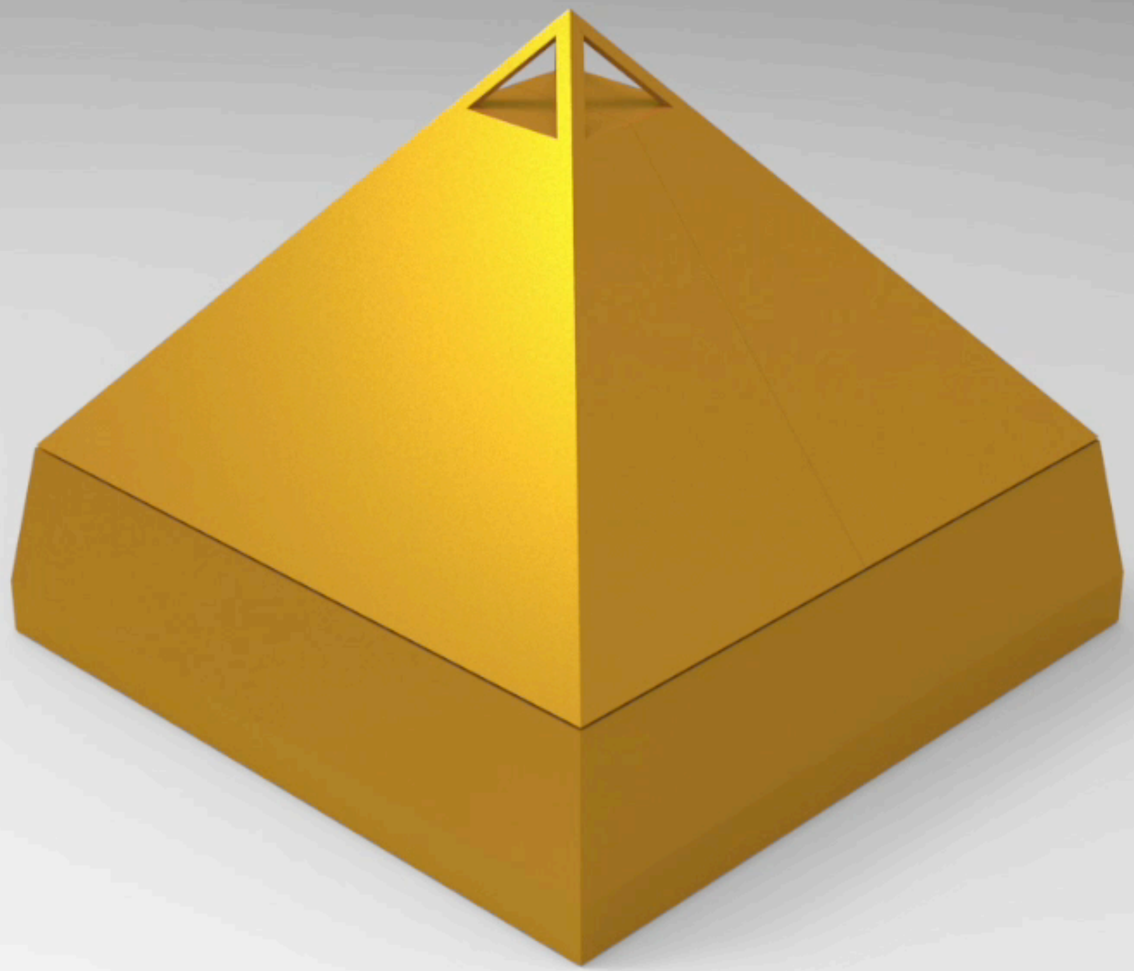
Intricate branching structure distributes heat evenly.

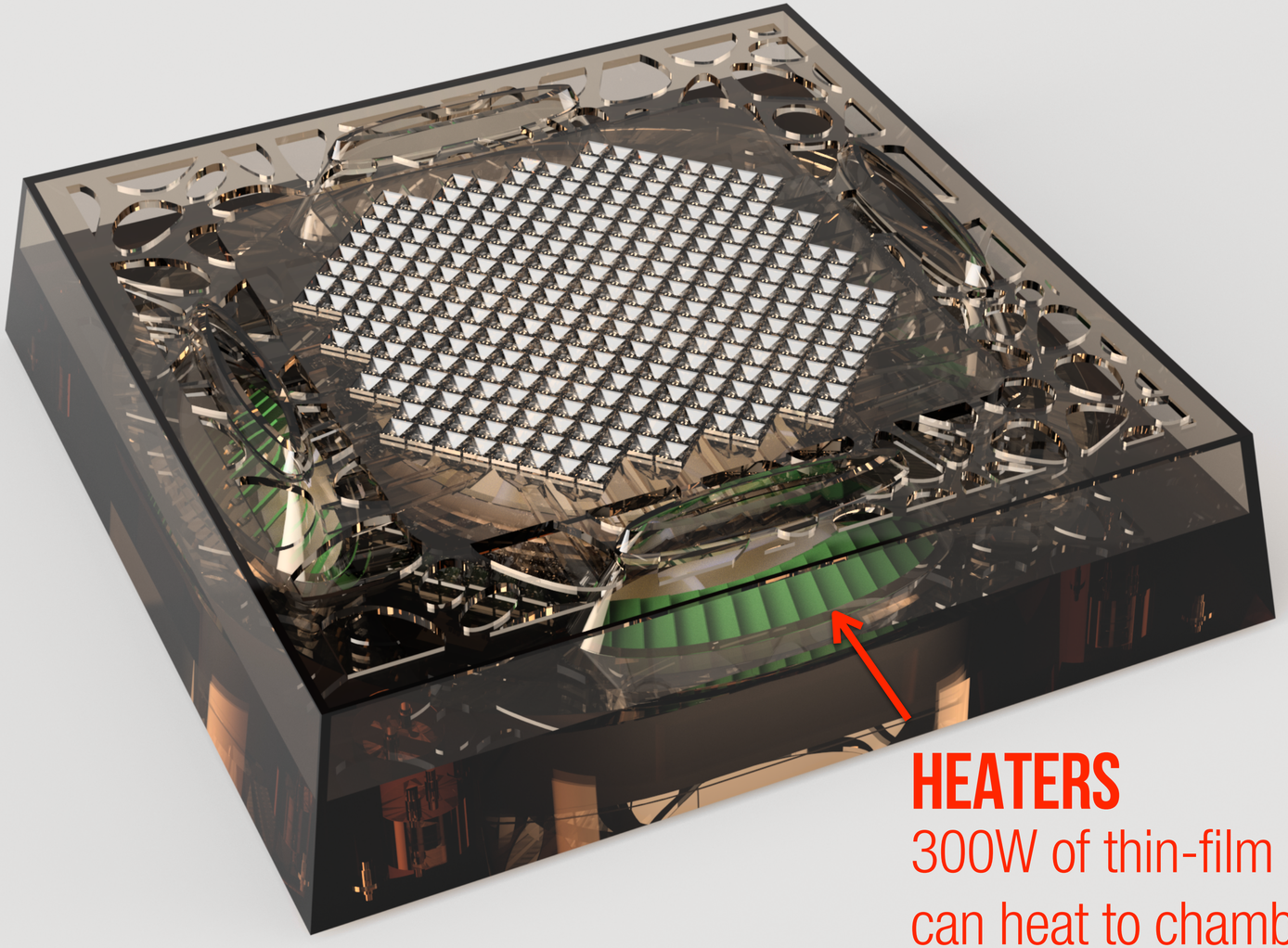


HOT PLATE HEAD

The target surface is the easiest to control temperature-wise.

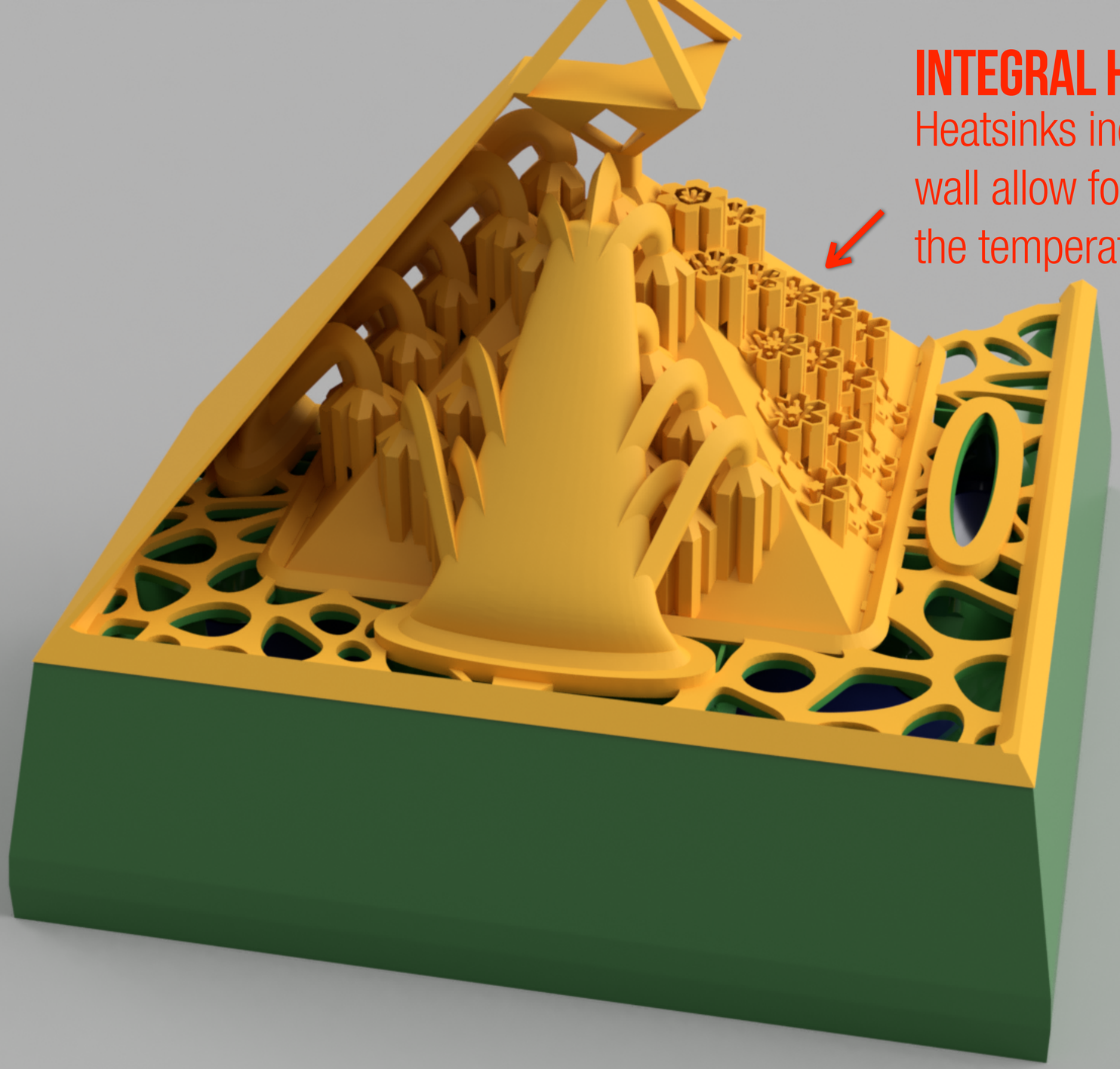
2015





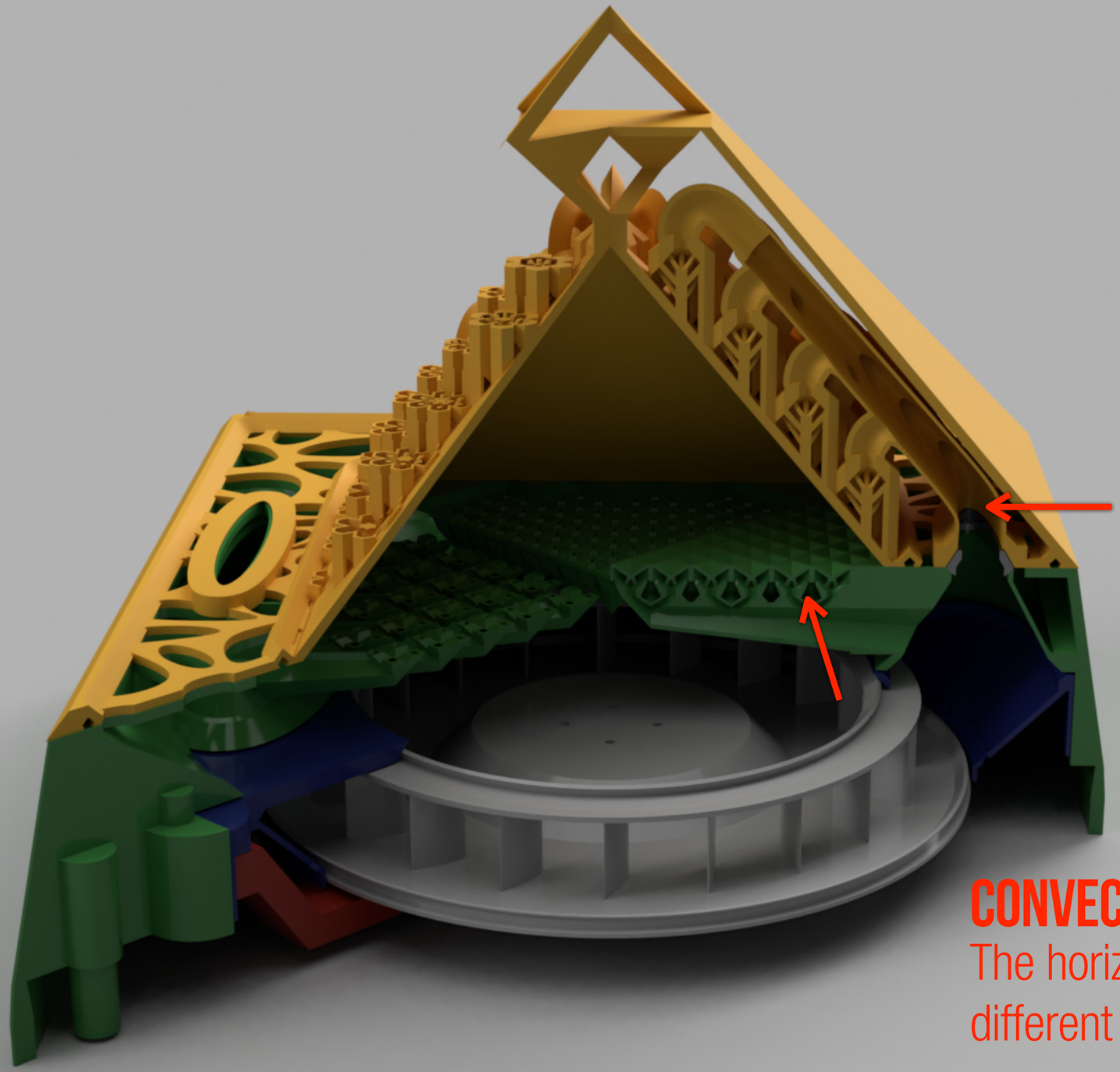
HEATERS

300W of thin-film heaters can heat to chamber to over 200°C.



INTEGRAL HEATSINKS

Heatsinks incorporated in the design of wall allow for efficient and rapid control of the temperature



CONVECTIVE DUCTS

The horizontal ductwork is very different than the sloping ductwork

PRACTICAL COMPLEXITY

VALUE OF COMPLEXITY

COMPLEX AS PRACTICAL
MEASURING GEOMETRIC COMPLEXITY

- Spies Ratio[1]
  - Bounding box is defined as smallest primitive that contains the part.
- Part-Complexity Evaluation Model[2]
  - Originally used to rate complexity of STLs, where N_{faces} was the number of facets. Here we're using the number of B-rep faces as N_{faces}.
- Mean Connectivity Value
  - The average fraction of interior voxels that can be "seen" by a voxel on the surface of a part.

$$\frac{V_{PART}}{V_{BOUNDING\ BOX}}$$

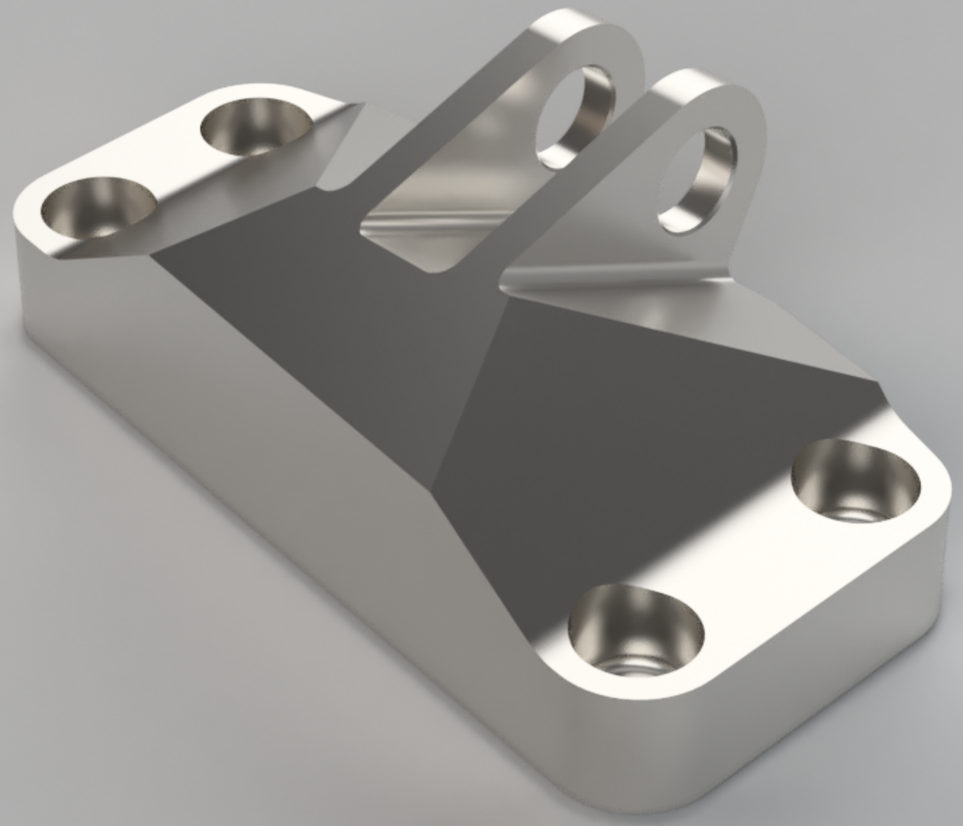
$$\frac{N_{FACES} * SA_{PART}}{V_{PART}}$$

$$\sum_{I=1}^{N} \frac{VC_I}{N}$$

1. Spies, K. (1957). Die Zwischenformen beim Gesenkschmieden und ihre Herstellung durch Formwalzen (Doctoral thesis). Springer-Verlag; Düsseldorf.

2. Valentan B., Brajlih T., Drstvešnek I., & J. Balič (2012). Development of a part-complexity evaluation model for application in additive fabrication technologies. Strojniški vestnik-Journal of Mechanical Engineering, 57 (10), 709-718.

ORIGINAL DESIGN



2,089 g

68 PCEM value

LAST PLACE FINALIST

424 g

533 PCEM value

6TH PLACE

422 g

499 PCEM value

5TH PLACE

499 g

1,020 PCEM value

4TH PLACE

403 g
3,313 PCEM value

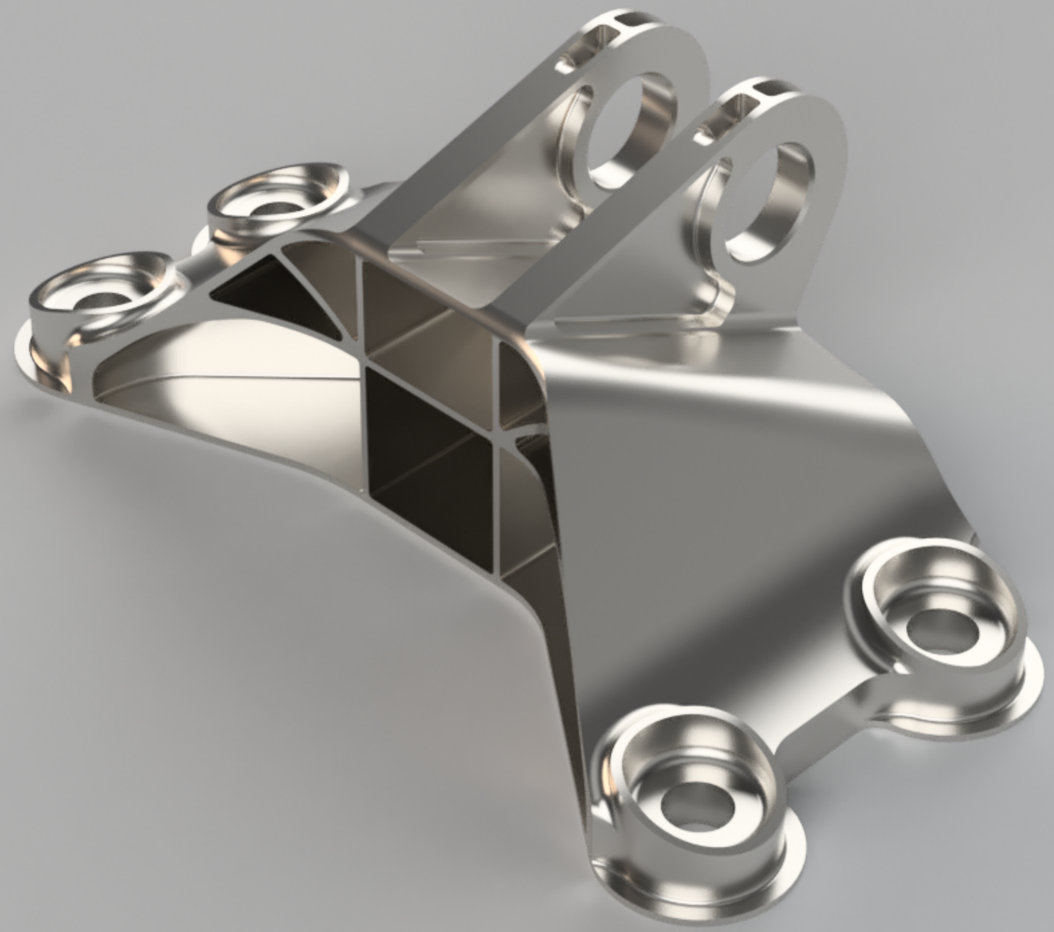
3RD PLACE

392 g
1,475 PCEM value

2ND PLACE

371 g
2,465 PCEM value

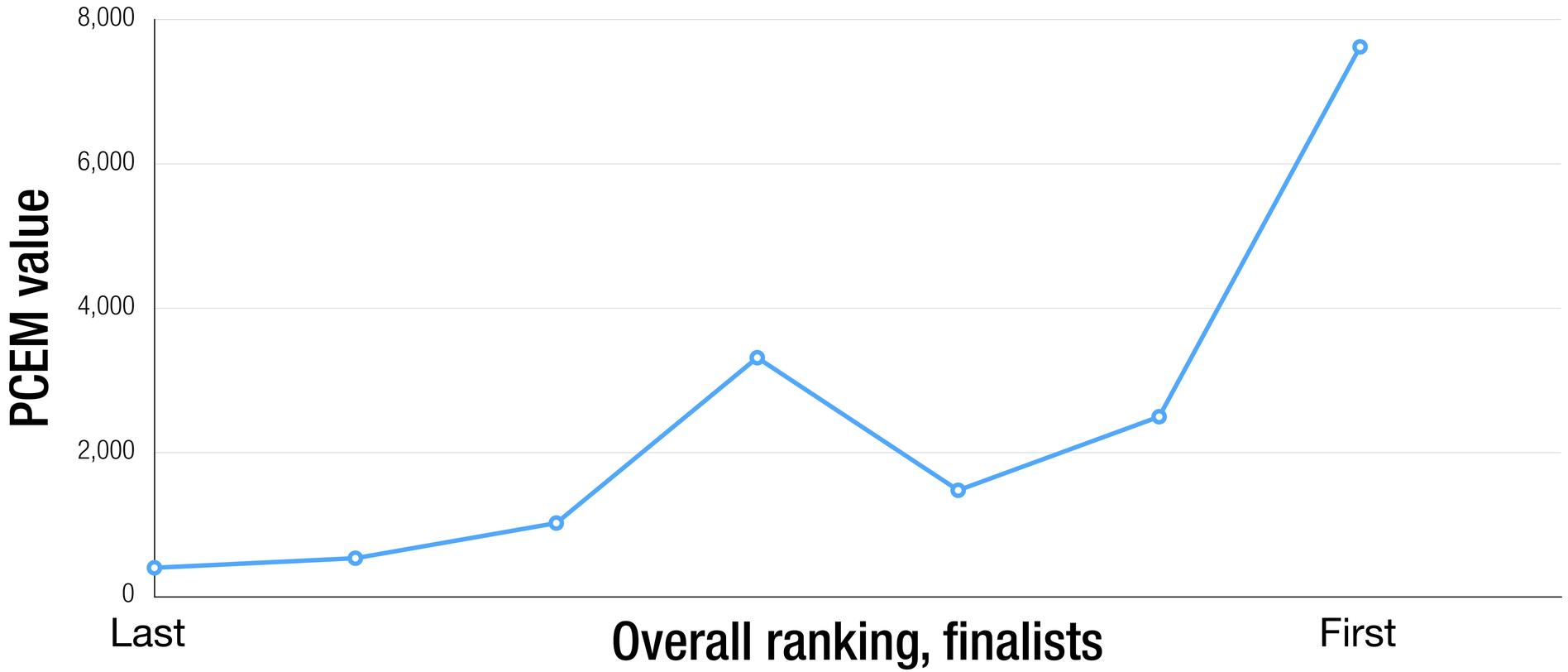
1ST PLACE WINNER



337 g

7,623 PCEM value

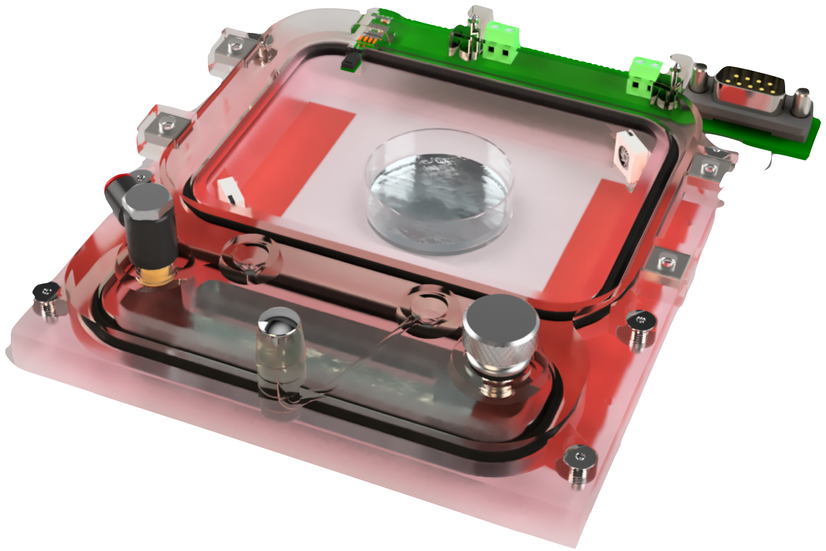
DESIGNING FOR ADDITIVE
COMPLEXITY IS A GOOD THING



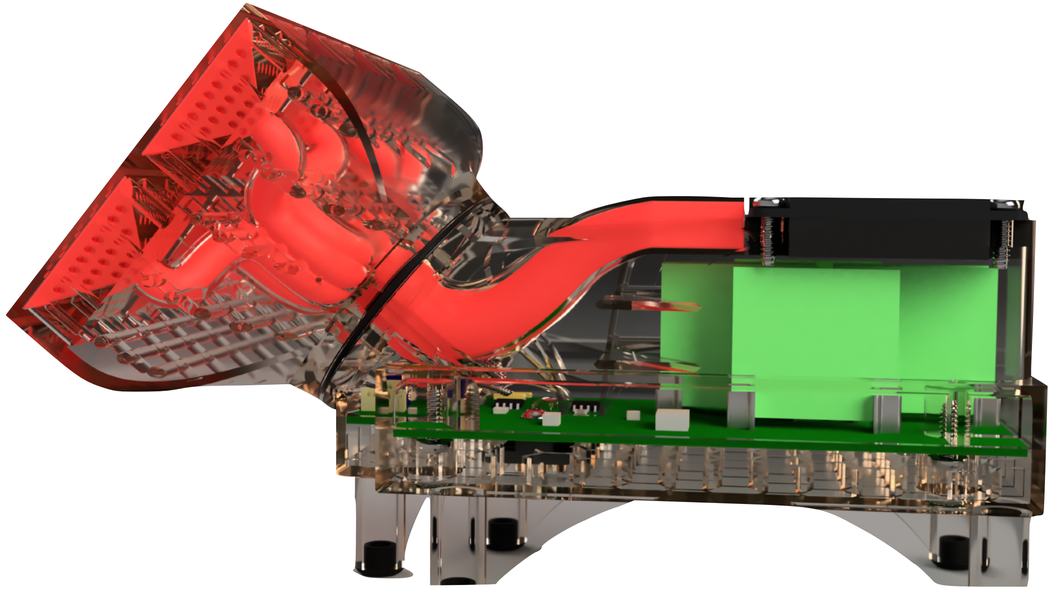
PRACTICAL COMPLEXITY

PRACTICAL EXAMPLES OF COMPLEXITY

HARNESSING COMPLEXITY
OVERCOMING POOR THERMAL CONDUCTIVITY

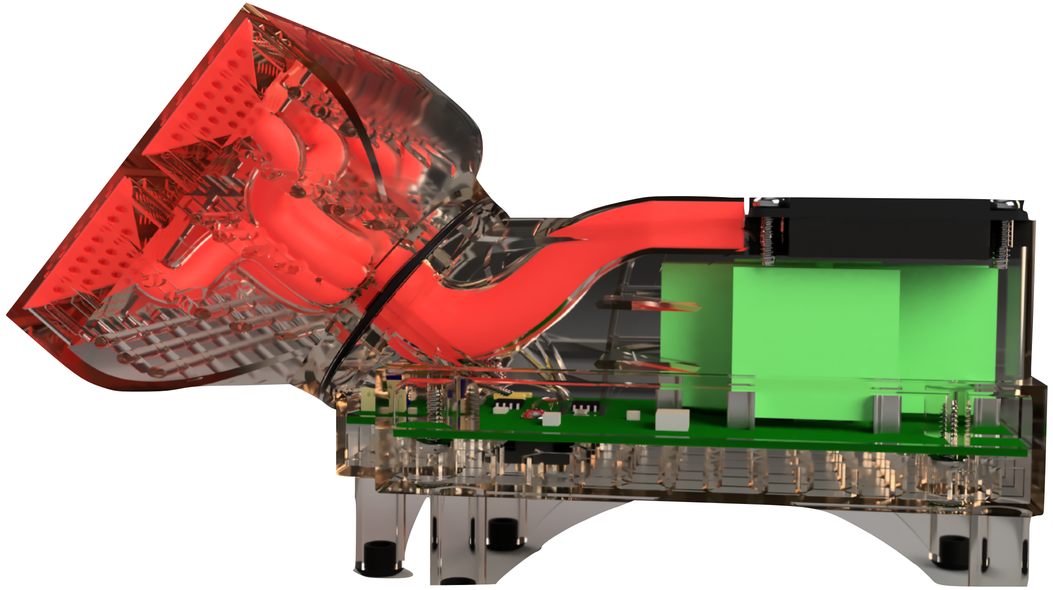


~580 for thermal tub



~32k

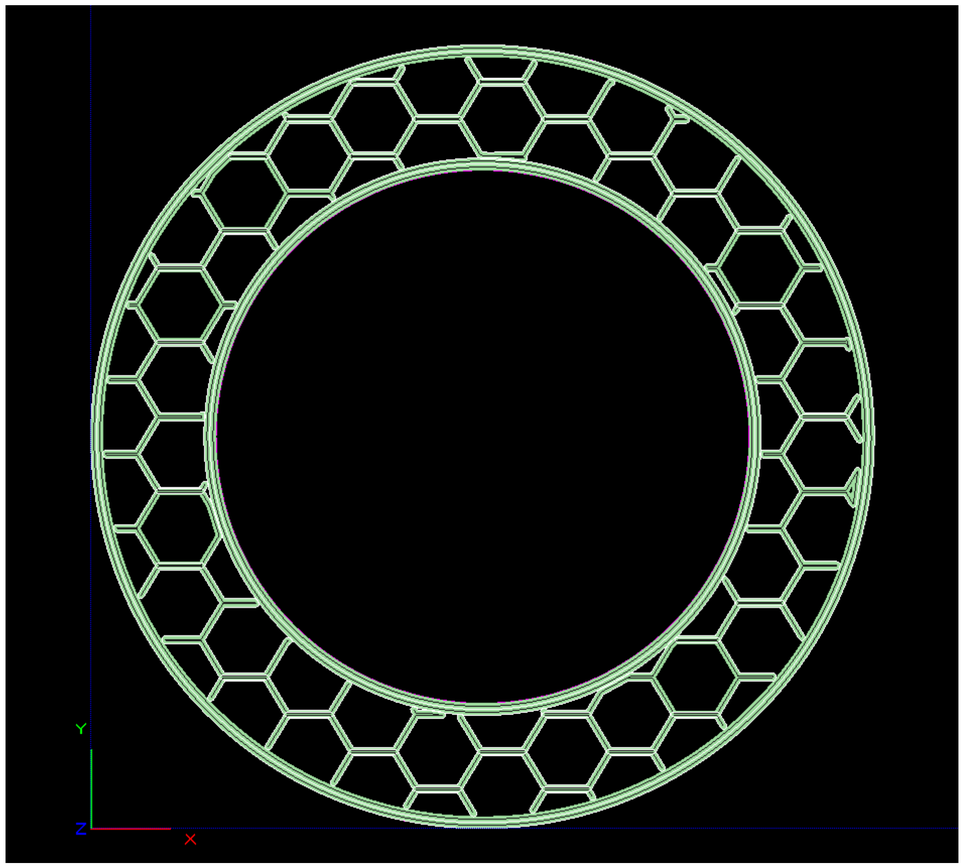
HARNESSING COMPLEXITY
OVERCOMING LOW SPECIFIC HEAT AND GRAVITY

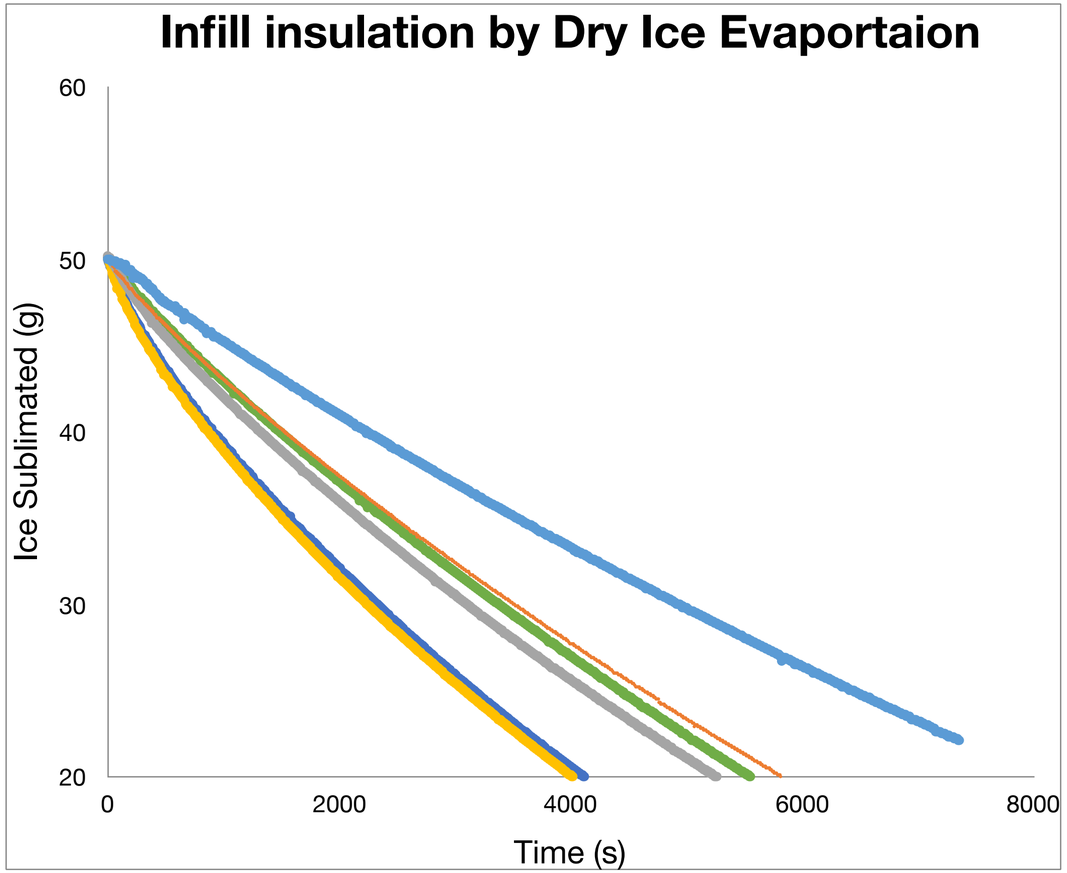


~3.5k (chamber and floor)

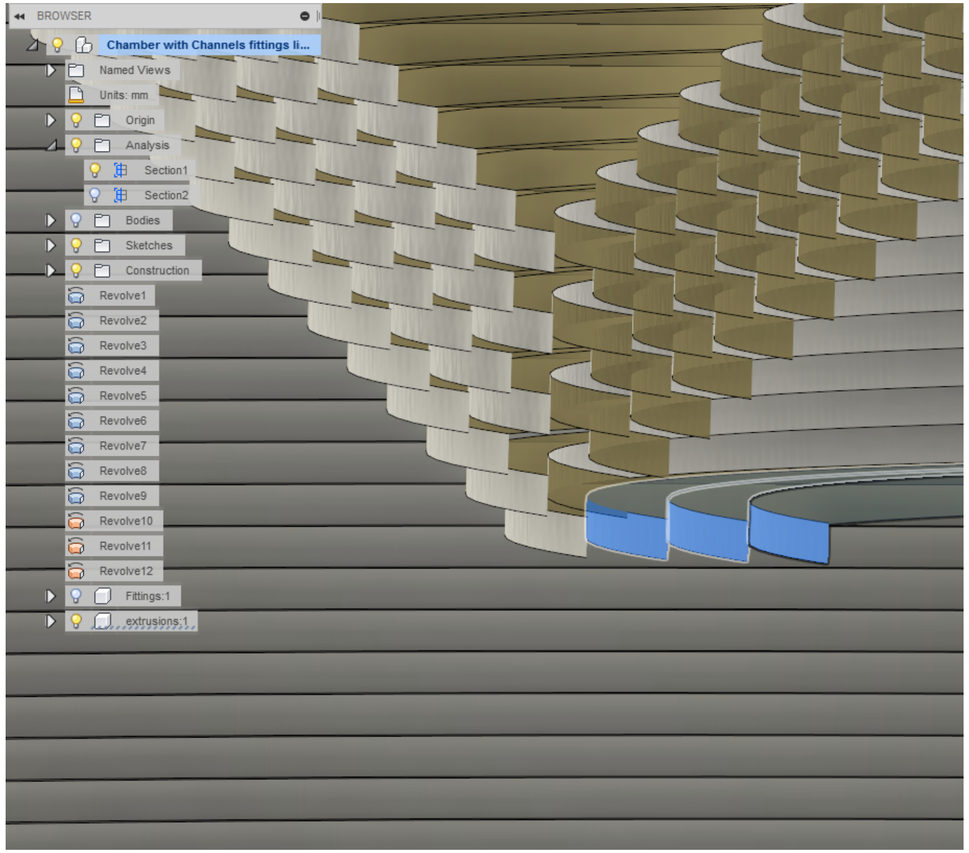
~32k

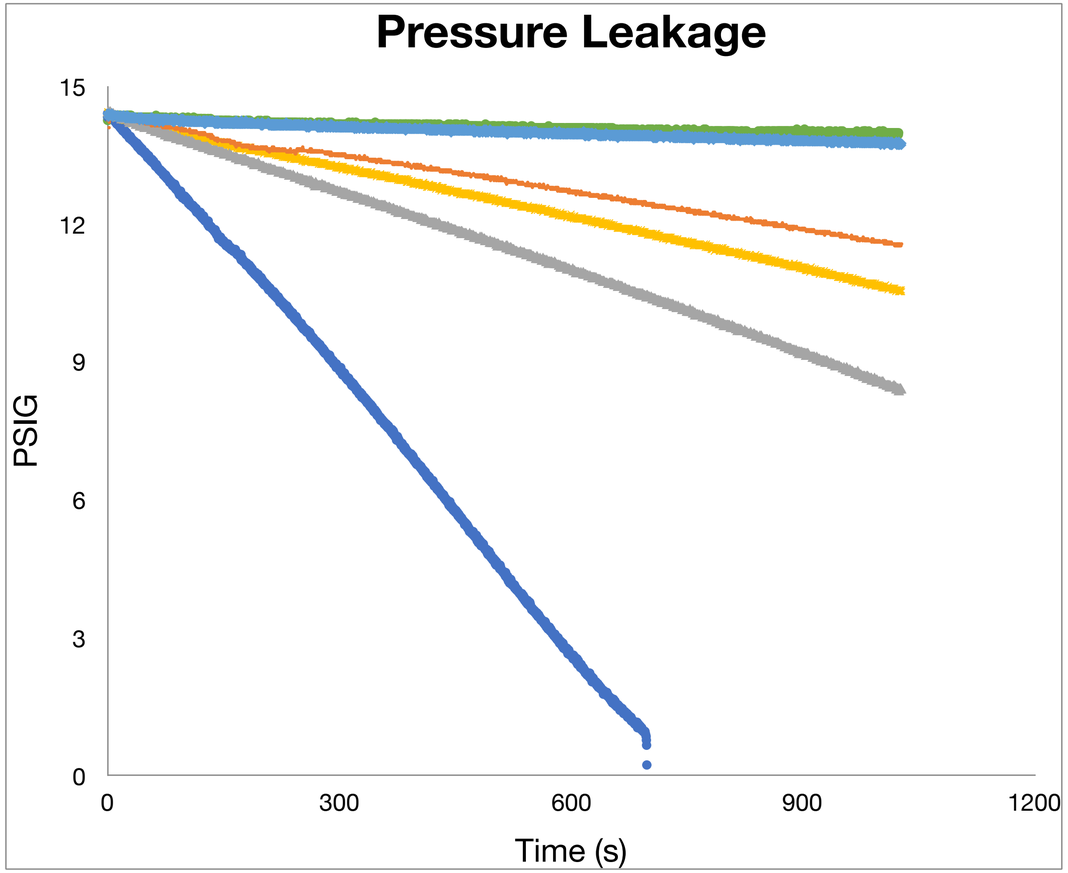
HARNESSING COMPLEXITY
IMPROVING THERMAL INSULATION





HARNESSING COMPLEXITY MAKING AIRTIGHT PARTS





CONCLUSIONS

NEXT STEPS

PROJECT **CRUCIBLE**

Rendering by Roberto Ziche in the
Rendering As a Service group at Autodesk

LIGHTWEIGHT INNOVATION

- Open-source hardware design
- Academia is perfect incubator
  - They already have a strong culture of sharing
  - They are technically sophisticated
  - Their needs are poorly met by commercial solutions
  - The applications are low volume, high value

CONCLUSIONS

FUTURE PERSPECTIVE

THE 1ST RULE OF (CONVENTIONAL) ENGINEERING IS...

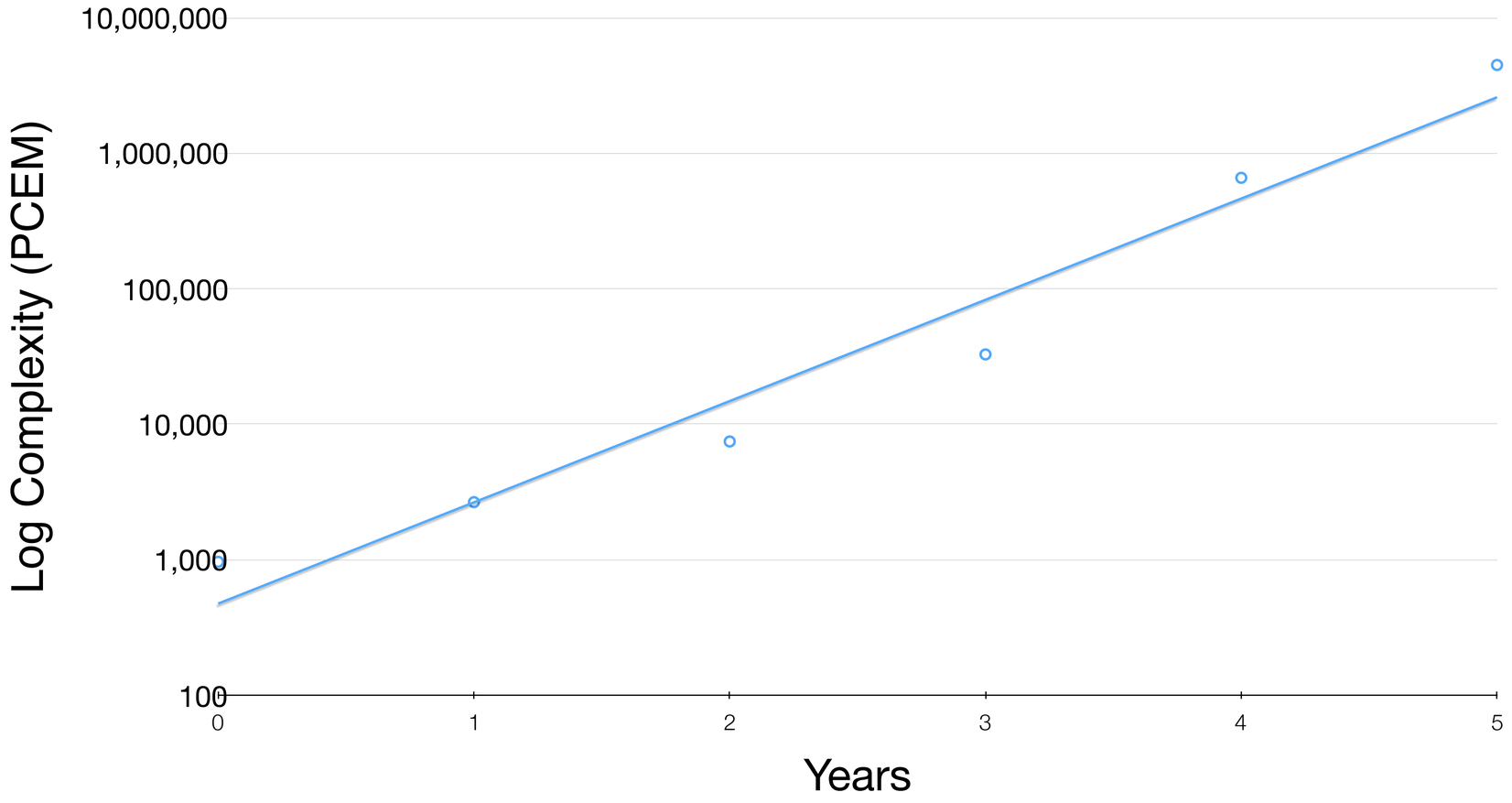
KISS

BUT THE 1ST RULE FOR (ADDITIVE) ENGINEERING SHOULD BE....

CAP

THE FUTURE OF COMPLEXITY IN THE ADDITIVE ERA

A NEW MOORE'S LAW FOR CAD



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