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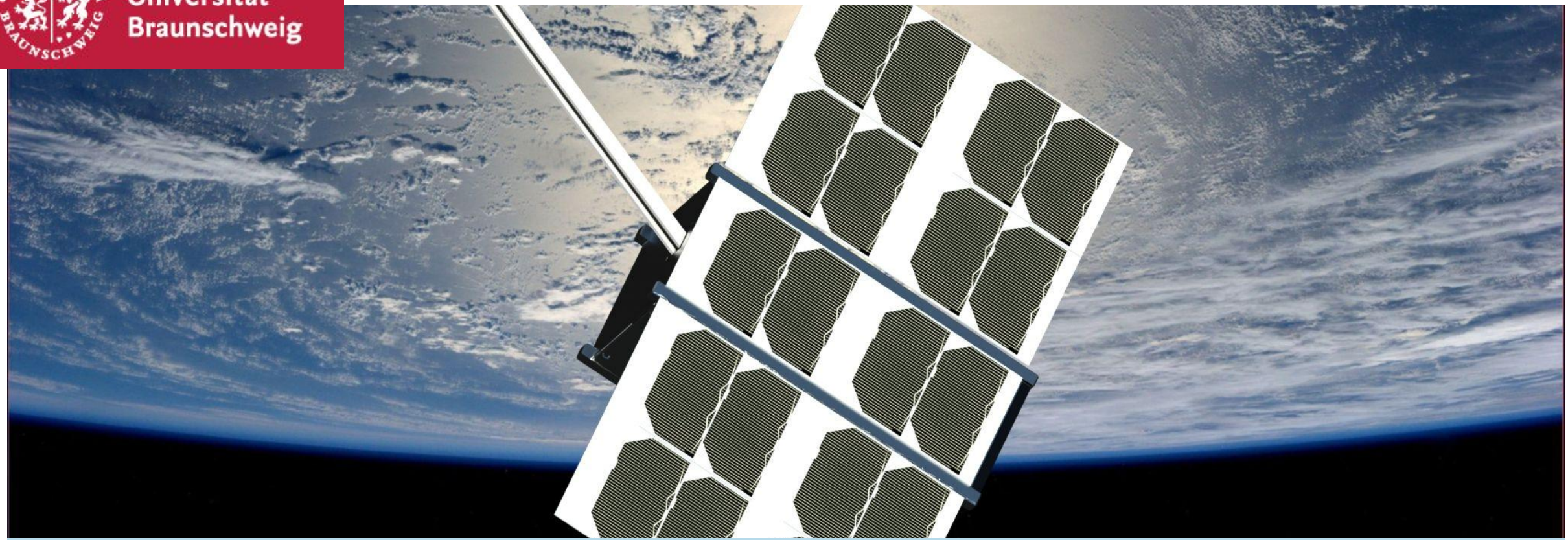


CSID 2022

Design of 3D-printing setup for in-space application

Janis Willger

Agenda:

1) Introduction and Motivation
2) Project description
3) 3D-printer design
4) Satellite configuration
5) Mission design
6) Conclusion and future work

1 Introduction and Motivation

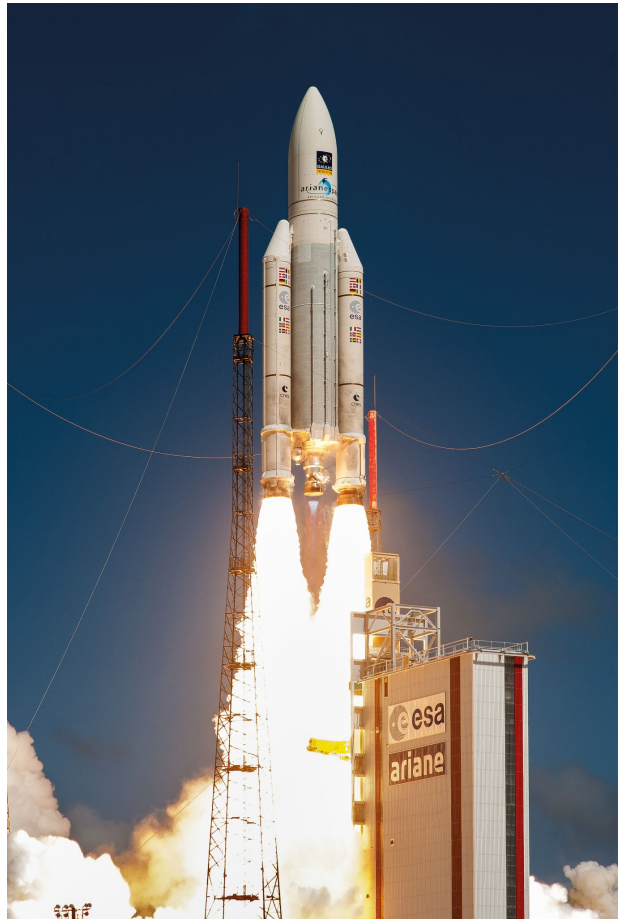
In-space manufacturing (ISM):

- More operation specific design
- Reduced mass
- Large-scale structures
- On-orbit repairs

Additive manufacturing (AM):

- High flexibility
- Low waste

▲ Ariane 5 fairing [1]



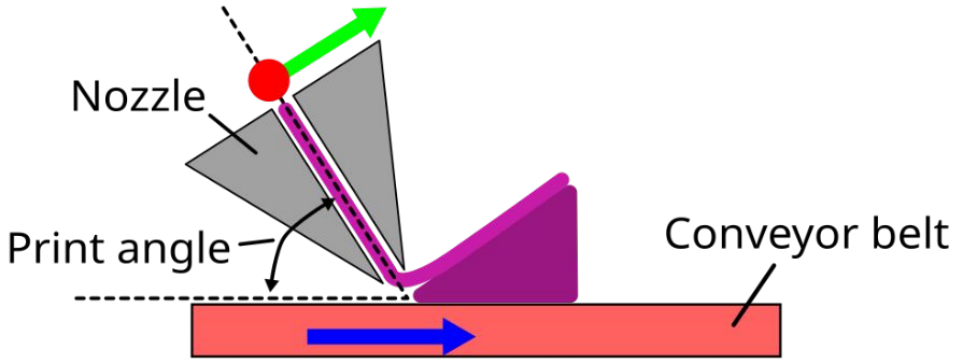
▲ Ariane 5 launch [2]

2 Project description

3D-printer design:

- Fused Filament Fabrication (FFF) printer with continuous printing capabilities
- Capable of processing polyether ether ketone (PEEK)
- 2U-Cubesat integration

Demonstrator mission in a 2U Cubesat

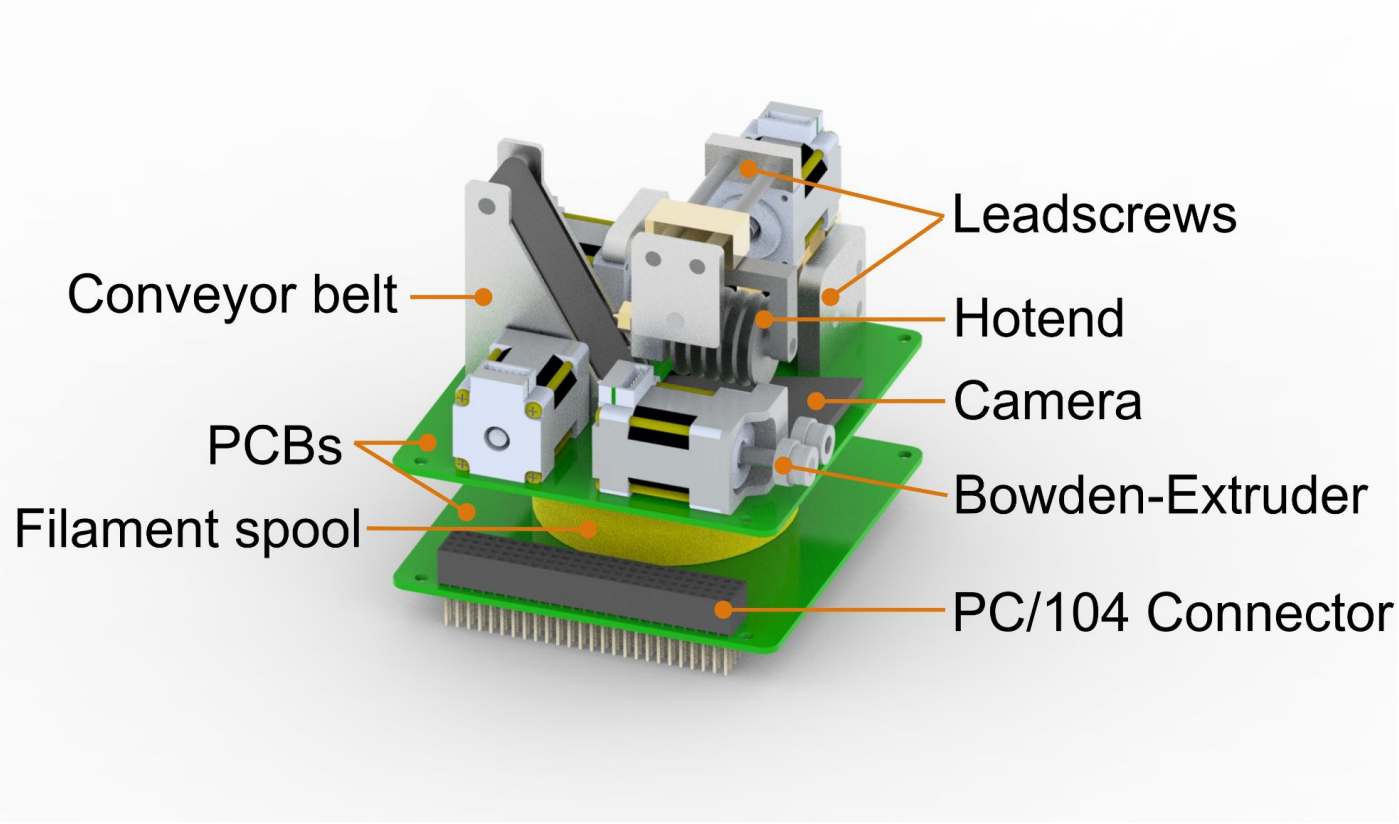


▲ Working principle of conveyor belt 3D printer

▲ 3D printed truss segment [3]

3 Printer design - Robotics and print-bed

Goal: Printing of a 1 cm × 1 cm × 100 cm structure made of PEEK



▲ Payload module housing the 3D-Printer and filament

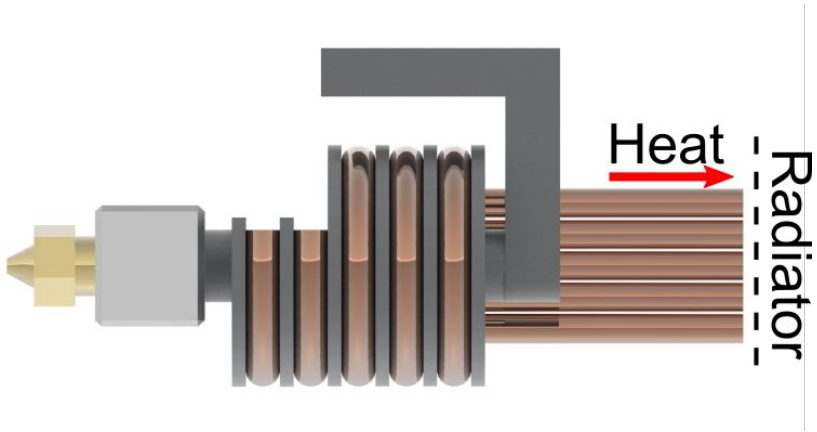
Robotics and print-bed:

- Printhead movement by **2 lead screws** driven by Nema 8 stepper motors
- Carbon fiber conveyor belt **angled at 30°** enables continuous printing
- ~5,35 W polyamide heater provides a print-bed temperature **>120°C**

3 Printer design - Hotend and axis of movement

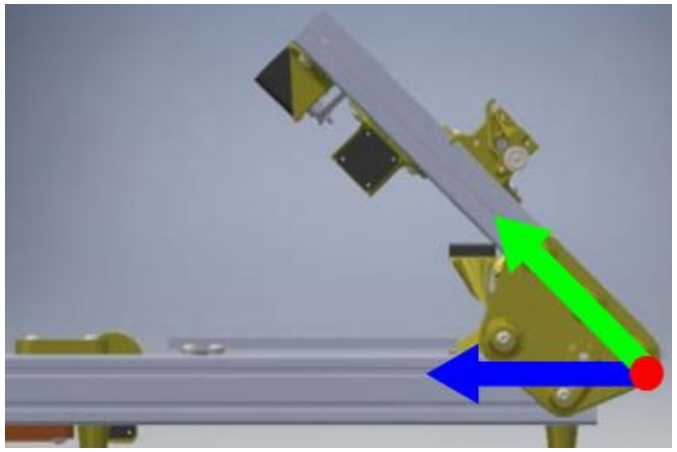
Hotend:

- Nozzle temperature **>400°C**
- Aluminum heat block with **9 W** ceramic heater and thermistor
- Heat dissipation through flexible heat straps and radiator on the outside

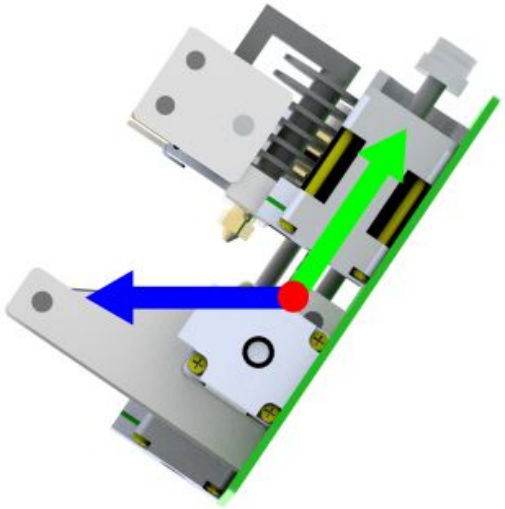


▲ Hotend design with heat straps

Axis of movement:



▲ Axis of movement in commercial 3D-printer [4]

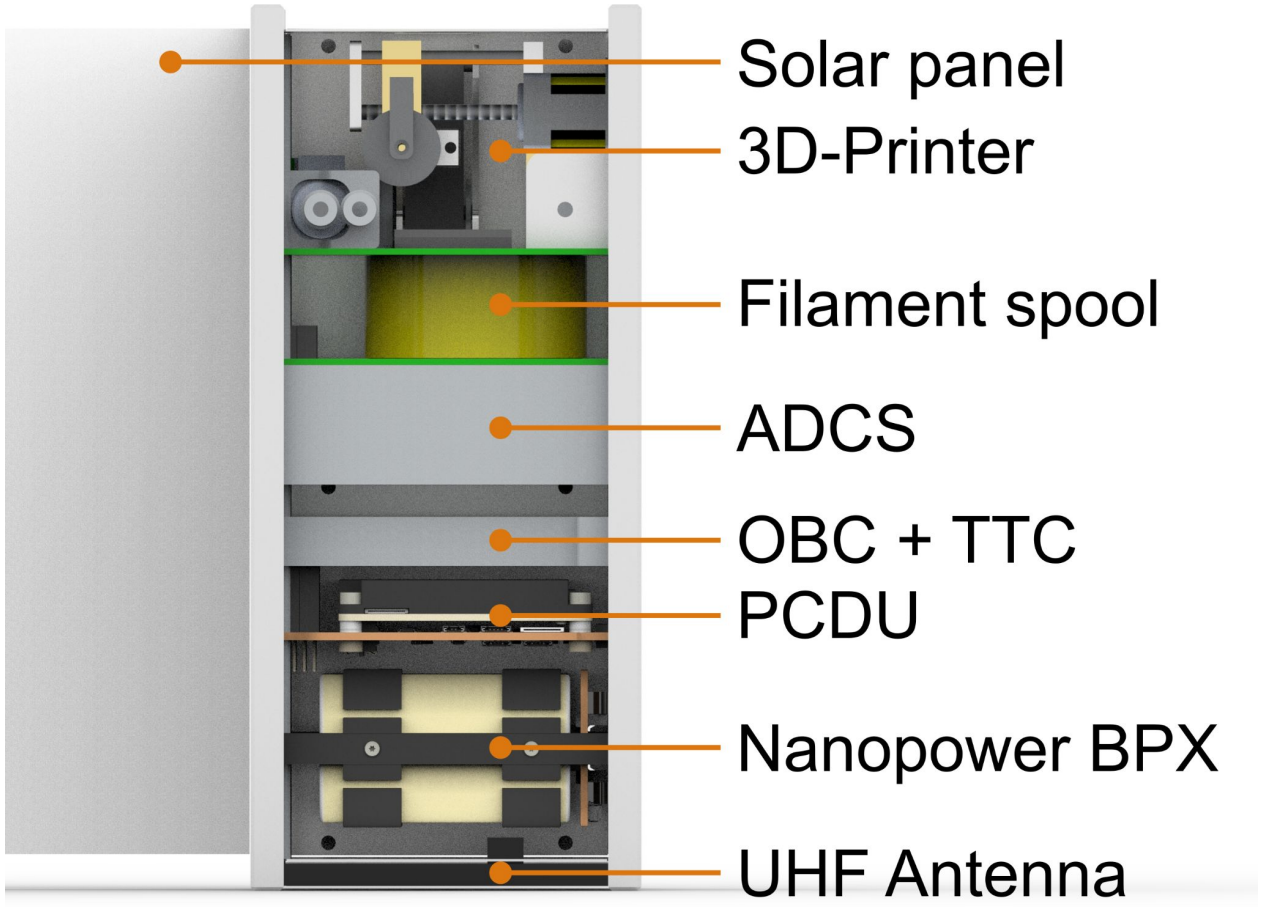


▲ Axis of movement in RFTP 3D-printer

4 Satellite configuration

Integration of the payload and the subsystems into a **2U-CubeSat**

- Usage of Commercial Off-the-Shelf (COTS) modules
- Print is pushed out through an opening in the top panel



▲ 2U-CubeSat subsystem integration

4 Satellite configuration - Attitude control

Attitude Determination and Control System (ADCS) needed for sun alignment

3D-printer applies significant torque on satellite

Hyperion Technologies iACS200:

- **3 Reaction wheels** for momentum storage
- **3 Magnetorquers** for momentum dumping
- Power consumption: **1.3 W**

▲ iACS200 fully integrated ADCS [5]

4 Satellite configuration - Electrical power system

Generation:

- Deployable solar panels with an area of 10U
- **23 W** max. power output

Storage:

- GomSpace NanoPower BPX
- 8 Li-Ion cells for a capacity of **77 Wh**

Conditioning and Distribution:

- GomSpace NanoPower P60 System
- 3 configurable output voltages

▲ CubeSat with deployed solar panels

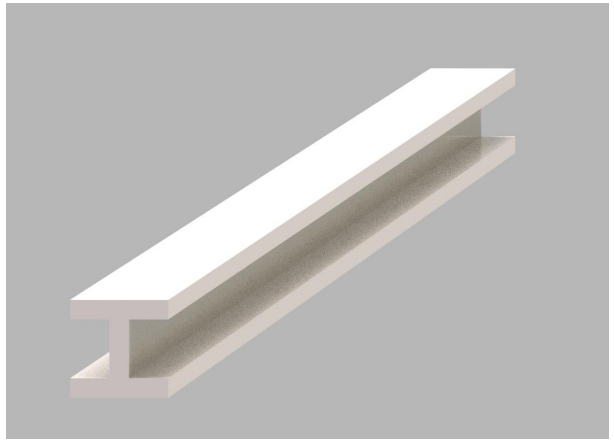
5 Mission design

Experiment schedule:

- Print duration: 25 h 10 min
- Hotend heat-up duration: 40 min [6]

- 5 print segments of ~5 h 42 min
- 4 charging segments of ~13 h 23 min

Duration of the experiment: ~82h



▲ 1 m long PEEK H-beam

▲ 3D printed truss segment [3]

Max. solar power	23.0 *W*
Min. OAP (above 300 *km*)	13.71 *W*
Power available at bus	12.34 *W*
Net power during print	−10.11 *W*
Net power during print pause	+4.24 *W*

▲ Power budget overview

6 Conclusion and future work

Conclusion:

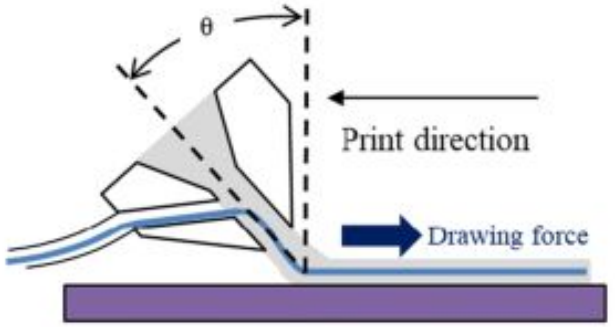
- FFF-Printer can be fitted into a 2U-Cubesat form factor
- Thermal control and power management of the payload remains a challenge
- CubeSats offer a great opportunity to test in-space manufacturing technologies

Next steps:

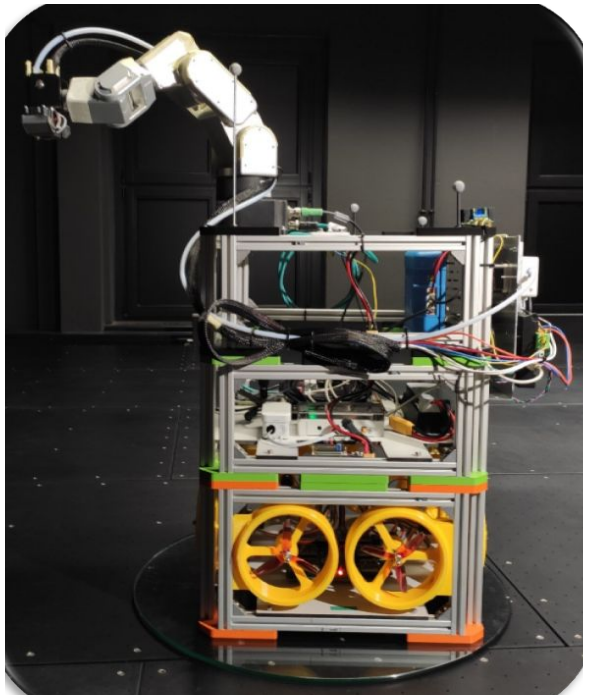
- Reevaluate the thermal control measures
- Optimization and prototyping of the 3D-printer

Outlook:

- Further research into on-orbit assembly
- Manufacturing of composite materials

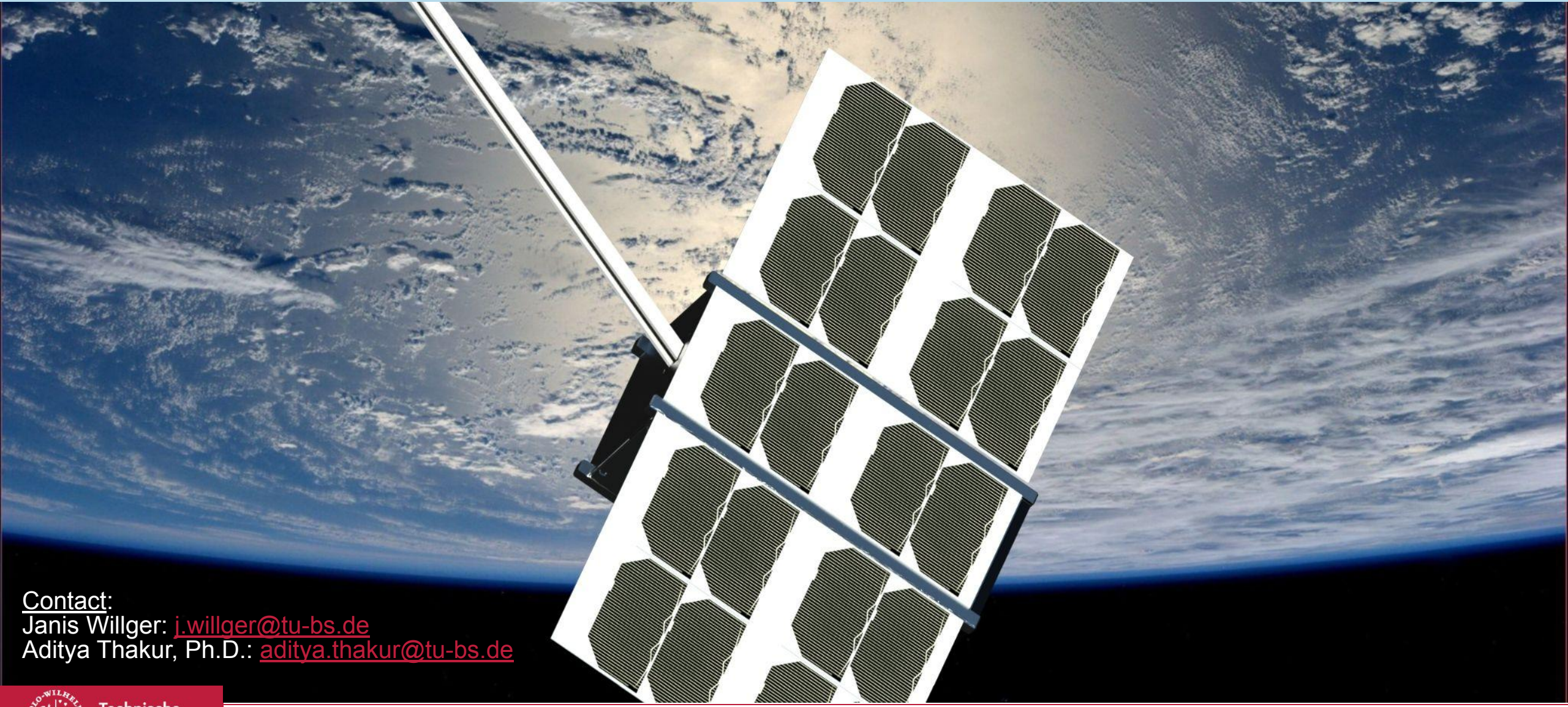


▲Manufacturing of composite materials [7]



▲”On-orbit” assembly experiment [8]

Thank you for your Attention!



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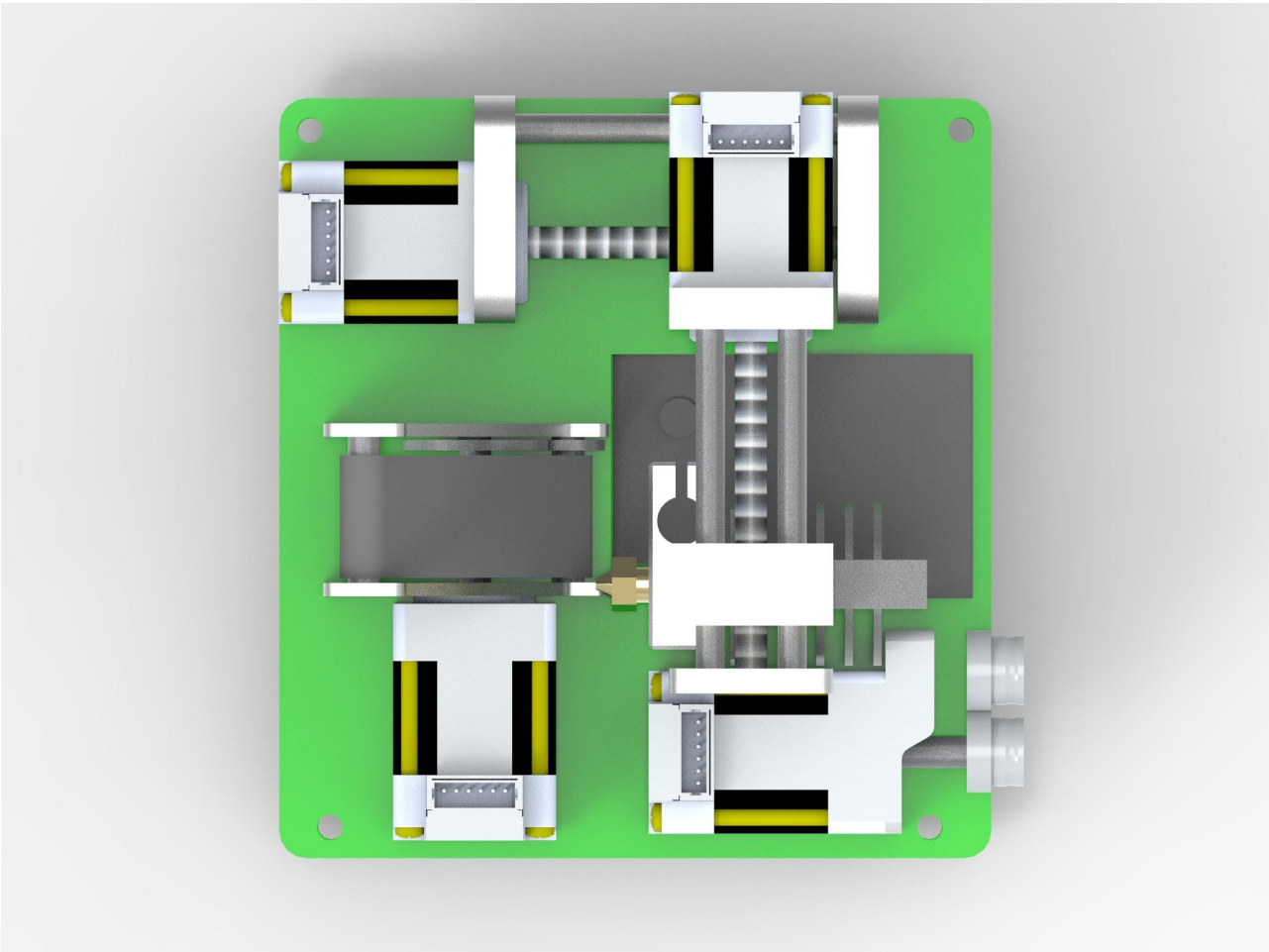
Appendix - A1

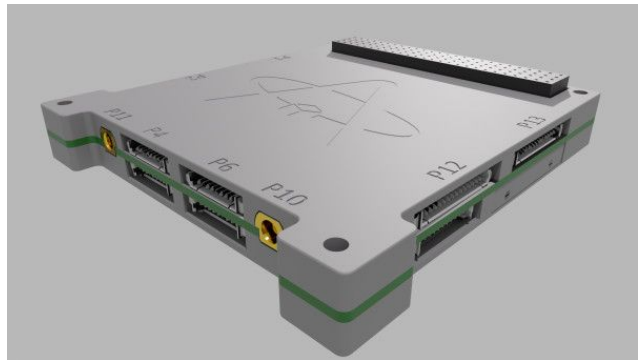


▲ 3D-printer module top view

Appendix - A2

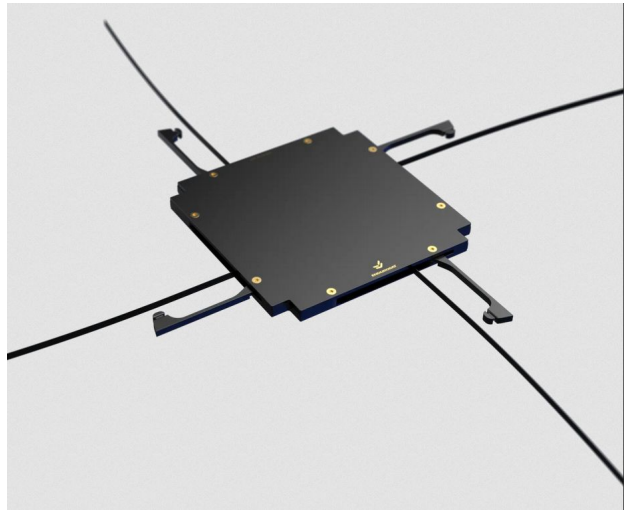
OBC and communication:

- Alén Space TRISKEL OBC with integrated UHF transceiver
- Transceiver: Data rates up to 19,2 kbps
- 0,5 W in normal use 5,2 W when transmitting data



▲ Alén Space TRISKEL OBC [9]

- Omnidirectional Endurosat UHF Antenna III
- Frequency: 435 - 438 MHz



▲ Endurosat UHF Antenna III [10]

Appendix - A3

Module/ Component	Number	Print mode		Print pause	
		Duty cycle [%]	Power [W]	Duty cycle [%]	Power [W]
ADCS	1	100	1,3	59,6	1,3
Antenna	1	100	0,005	100	0,005
OBC	1	100	0,4785 - 1,2375	100	0,4785
PCDU	1	100	0,294	100	0,294
Printbed heater	1	100	5,35	100	5,35
Printhead heater	1	100	9	0	0
Stepper motor	4 (3)	100	1,4	100	0,7
Transmitter	1	10	4,191	0	0
Total			22,4466		8,1023

▲ Power budget