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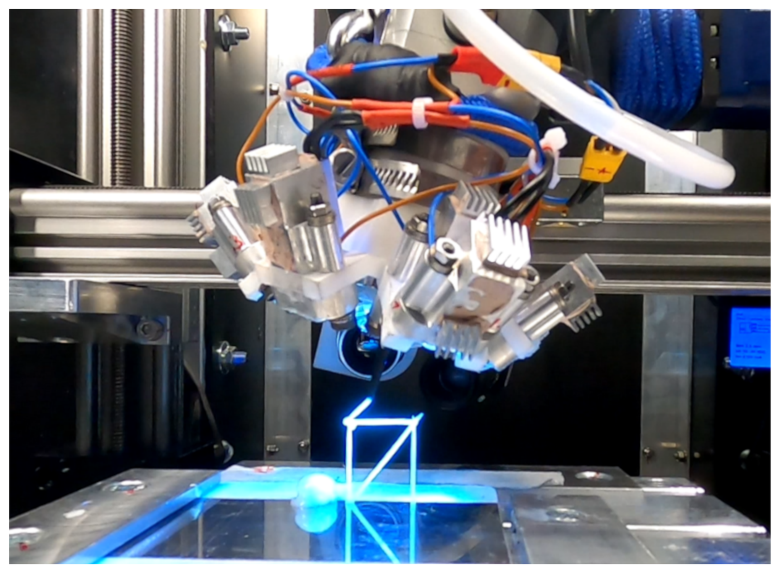
In-Orbit Demonstration of an In-Space Manufactured Selfie Stick for SmallSats

Abstract

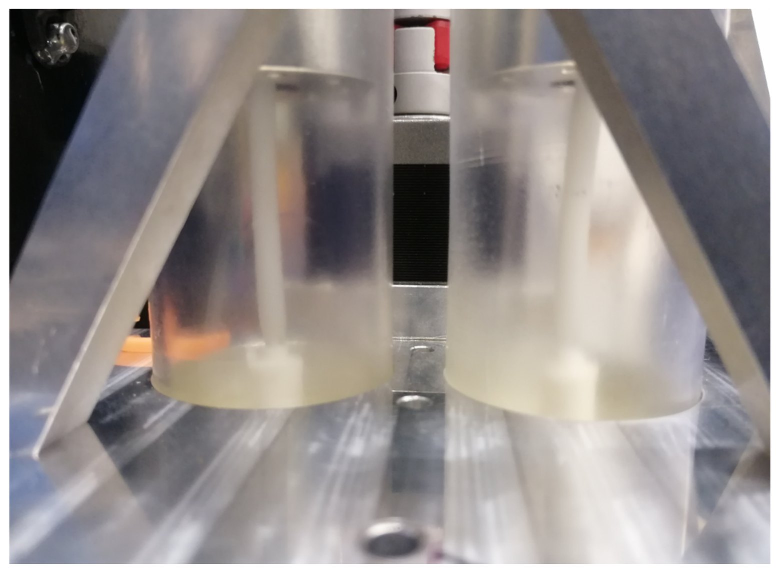
The poster presents a **demonstration mission** of an **in-space manufacturing** technology to extrude tube-shaped photopolymer **boom structures for satellites**. On the end of the boom a camera will be mounted to simulate a payload and to observe the manufacturing process. The boom is **manufactured in a continuous motion** and therefore higher manufacturing speeds are archivable than by comparable additive manufacturing methods. The photopolymer curing mechanism makes the process **energy- and packaging efficient** which enables in-space manufacturing also for small satellites.
In-space manufacturing will be one of the key technologies for the future space economy. **Large and lightweight** structures can be manufactured **on demand**, to safe volume and costs at launch. Compared to deployable structures, which are commonly used on spacecraft, in-space manufacturing **enables a large scalability** and **low development costs**. The demonstrator will be mounted on the upper stage of the HyImpulse SL1 rocket which is scheduled to **launch in the fourth quarter of 2025.**

Previous Work

Besides of laboratory experiments and test setups experiments on two parabolic flight campaigns were conducted to investigate the influence of gravity on the material as well as on the manufacturing process. During the campaigns, 180 experiments under lunar, Martian and zero gravity could be realized. In conclusion, the influence of reduced gravity on the process has no negative effect and higher printing speeds are possible [1]. During a sounding rocket campaign four experiments have been performed on the extrusion and curing of the photopolymer in an altitude of ~90 km. In parallel, the same tests were carried out on the ground. Shape artifacts were observed in the specimens produced in flight caused by the reduced atmospheric pressure. These artifacts could be avoided by the implementation of various measures on the process.



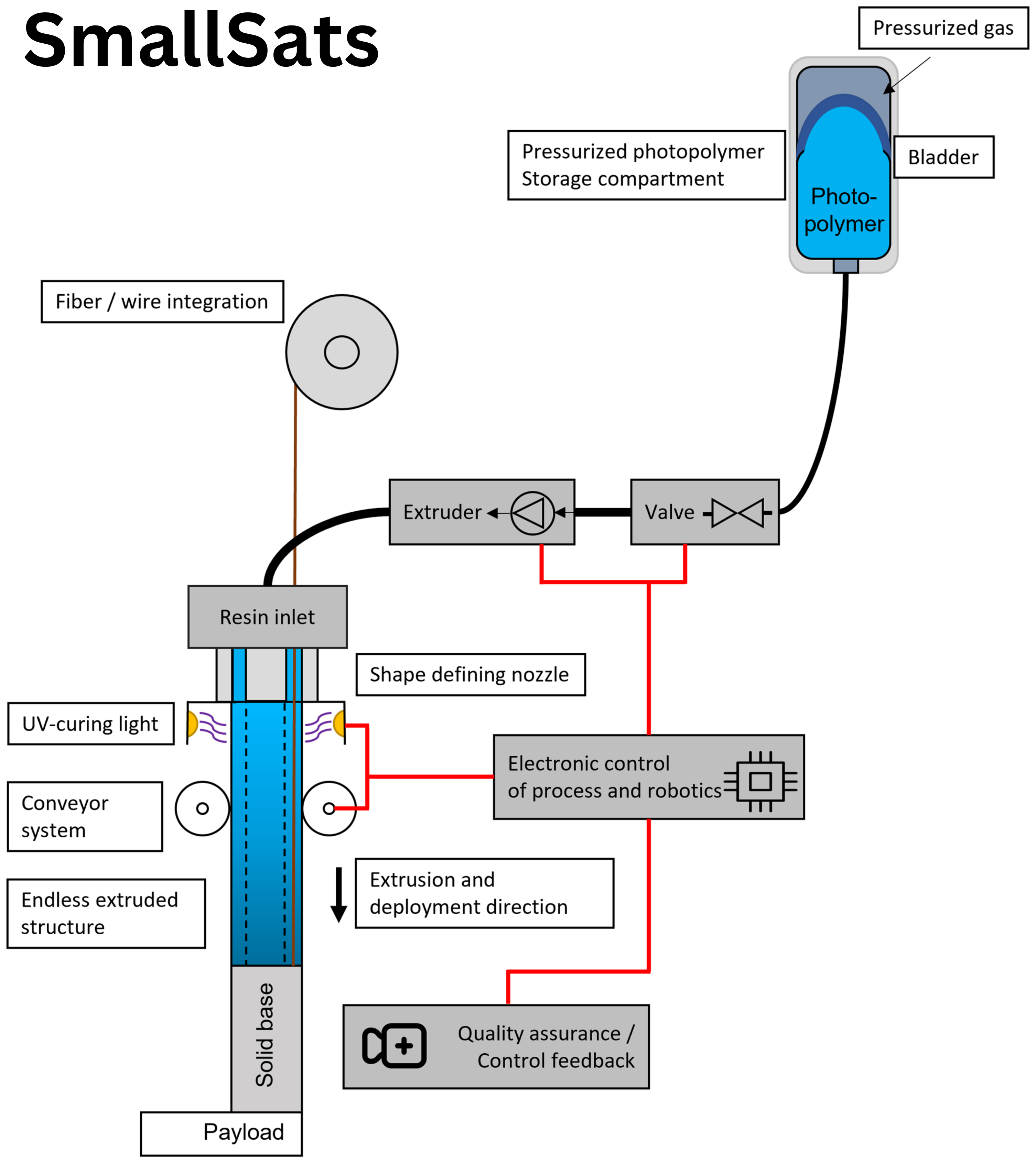
Truss made during parabolic flight (0g)



Rod shaped specimen made during sounding rocket flight

In-Orbit Demonstration

With the maiden flight of the HyImpulse SL1 rocket in Q4 2025 the first in-space manufactured photopolymer structure will be demonstrated. During the flight the experiment stays mounted on the satellite interface plate of the upper stage. After the second stage reaches the orbit and all customer satellites are deployed, the in-space manufacturing experiment will start. Over a few orbits a boom will be "printed" into free space and the process will be monitored by cameras mounted on the upper stage.
In addition, the camera mounted on the tip of the printed boom, is recording the process and shows the possibility of the integration of electrical wires for data communication in the tube. At the end of the extrusion process, the resin inside the nozzle will be cured as well and therefore a strong bond to the satellite will be enabled.
SL1 has a payload capacity of 500 kg to a 400 km SSO.



Schematic overview of subsystems and principle of operation

Setup

With the Photopolymer Extrusion, infinite tube-shaped booms can be manufactured in a continuous motion (Figure 1). For this, a liquid photopolymer, stored in a tank, is dispensed via an extruder though a die that defines the final shape. On the outlet of the die, uv-LEDs are located, to initiate the curing of the photopolymer into a solid. A conveyor system supports the manufactured element mechanically and controls the manufacturing speed. The camera is mounted on a solid base that is used as a defined starting point for manufacturing. Due to the possibility of integrating fibers or wires into the tube, a high mechanical stiffness as well as integrated data lines for communication are conceivable.

Tube nozzle during extrusion and curing

Challenges

The manufacturing of external space structures is expected to be heavily influenced by the harsh environmental conditions in space. This interaction will be different during manufacturing were the resin is initially still in a liquid state.
It is expected that these are the three dominant influences during manufacuturing:

Absence of Gravity:
In microgravity, the influence of the surface tension of the liquid resin behaves differently than on earth. In experiments on parabolic flights, however, this has not shown any major issues [1].

Vacuum:
Vacuum can cause the liquid resin to boil, and a high outgassing rate occurs. In addition, the resin needs to be properly degassed beforehand, since small bubbles mixed into the resin do increase in volume dramatically when exposed to vacuum [2].

Large Temperature Fluctuation:
During every orbit the manufactured structure experiences large temperature fluctuations. This causes internal stress on the structure.

After manufacturing, the polymer structure is expected to suffer long-term damage from uv-light, atomic oxygen, or large temperature fluctuations.

References:
[1] Kringer, M., Frey, M., Böhrer, C. & Pietras, M. Direct Extrusion of Photopolymers (DREPP): Influence of Microgravity on an In-Space Manufacturing Method. Front. Space Technol.; 10.3389/frspt.2022.899242 (2022).
[2] Kizito, J., Balasubramaniam, R., Nahra, H., Agui, J. & Troung, D. Vapor-Gas Bubble Evolution and Growth in Extremely Viscous Fluids under Vacuum. In 47th AIAA Aerospace Sciences Meeting including The New Horizons Forum and Aerospace Exposition (American Institute of Aeronautics and Astronautics, Reston, Virigina, 2009).

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