Continuous Analysis within 3D-Printed Structures Using In-Chamber Sensors

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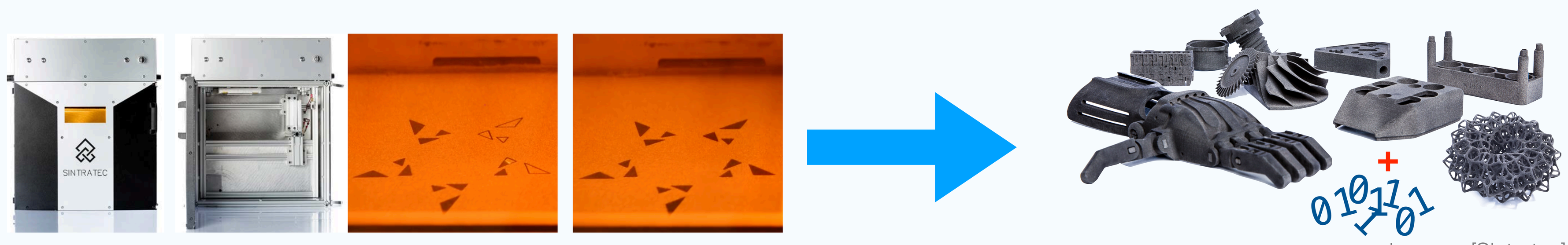
Abstract

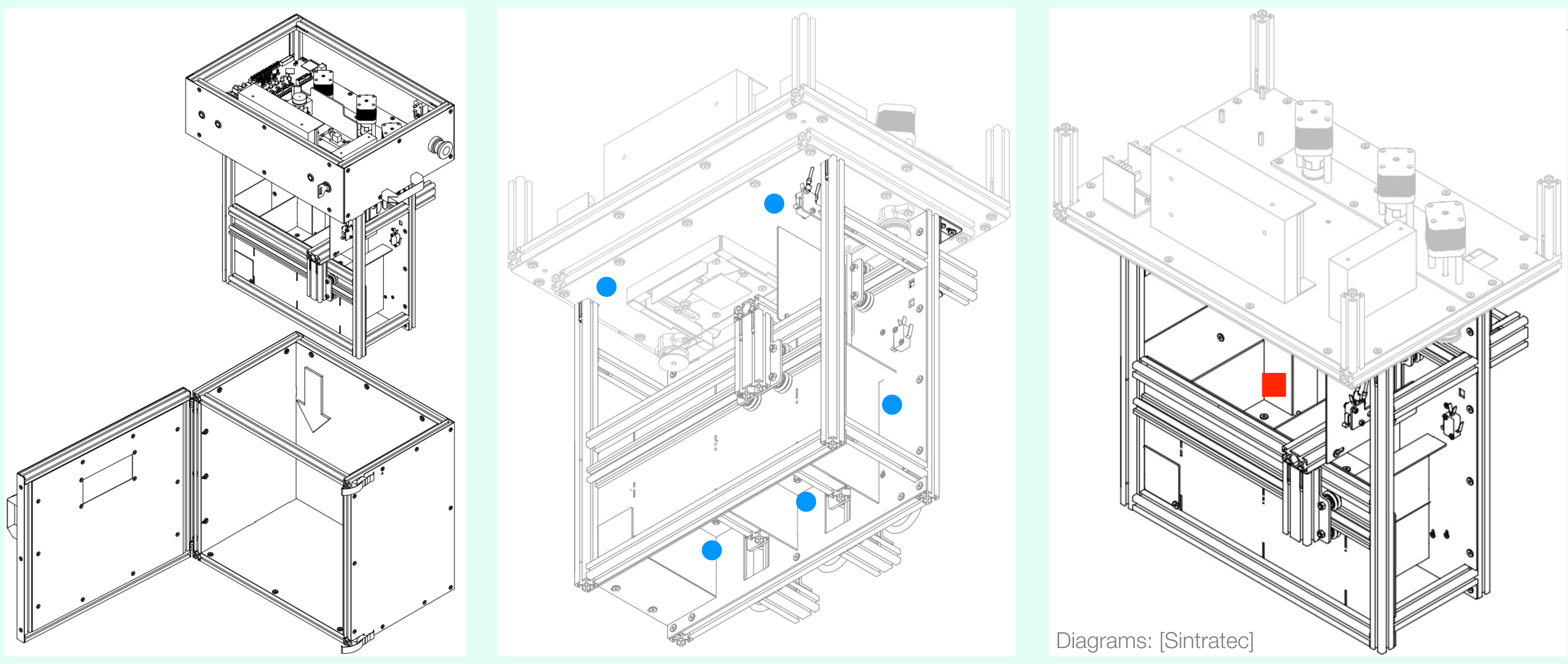
We are investigating how to efficiently and accurately measure per-layer chemical composition and build chamber conditions, *in situ,* for objects manufactured by selective laser sintering (SLS). Our investigation is a first step towards integrating sensors into the powder bed and eventually into parts themselves.



② Approach

Monitor build material properties using three complementary sensing modalities: ❶ 12-band visible/NIR spectrometer in 450 nm–850 nm wavelength range; ❷ 248-band NIR spectrometer in 900 nm–1700 nm range; ❸ Build surface temperature at 64 points.

Monitor build chamber conditions using five sensing modalities: ❶ temperature, ❷ humidity, ❸ barometric pressure, ❹ CO_2, and ❺ airborne volatile organic compounds.



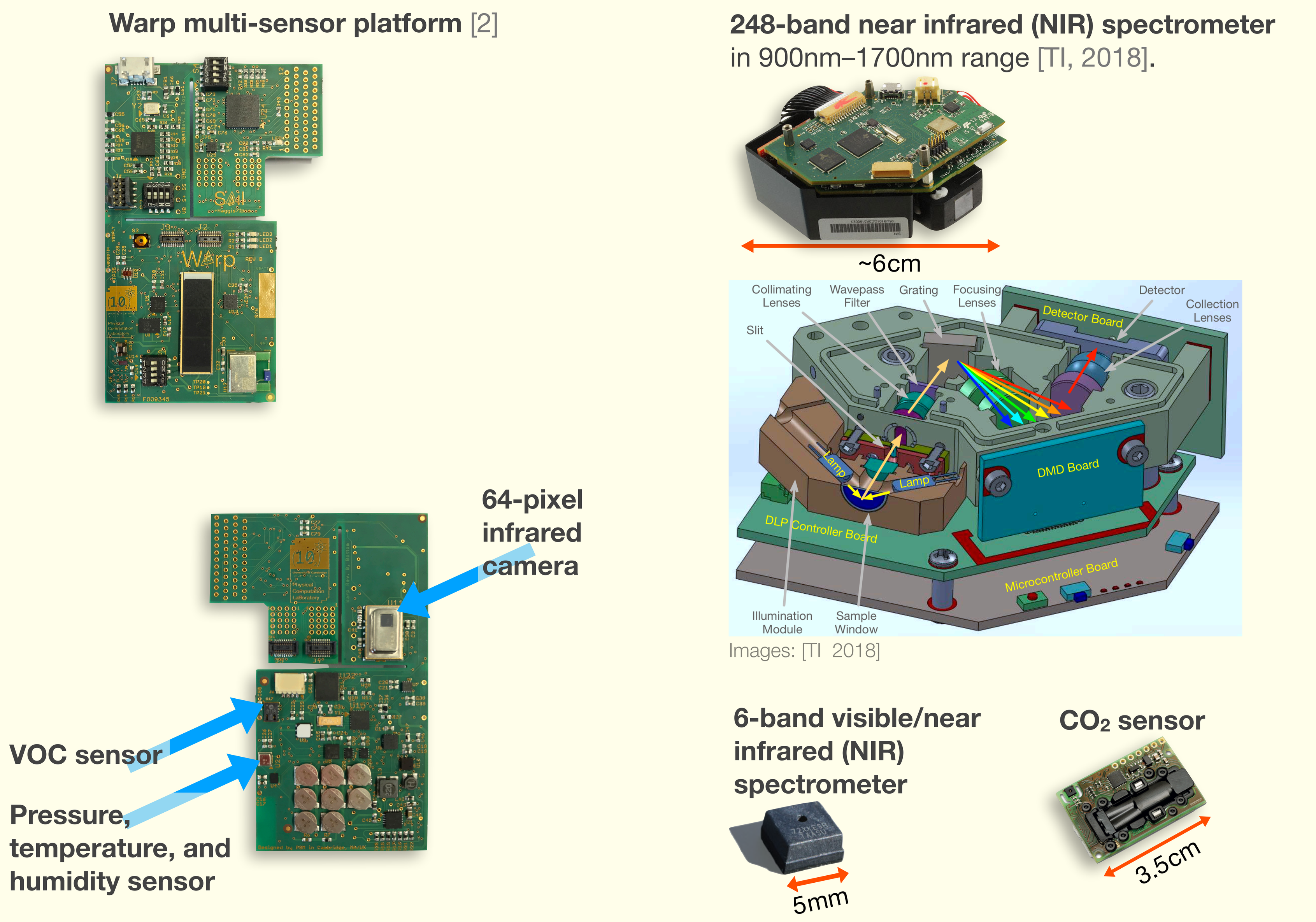
Nylon SLS System Diagram | ●: Build chamber sensing | ■: Build material sensing

① Objective

In-process materials composition sensing for Nylon selective laser sintering (Nylon SLS): To understand whether low-cost sensors provide sufficient accuracy to monitor per-layer build material composition and build chamber properties during the additive manufacturing (AM) process.

The results of the project will make it possible, for the first time, to have a per-object "digital birth certificate" detailing the entire volumetric / per-layer build process and object parameters, for each Nylon SLS AM part produced.

③ Sensors and sensor signal processing



④ Planned outcomes

❶ **New methods** for using low-cost sensors integrated into AM systems for in-process **material characterization** and **build chamber monitoring**.

❷ **Open dataset** from materials characterization that captures noise properties of sensors. Potentially useful for machine learning from the data [1].

❸ **Open platform** (hardware and software) that other research groups can use.

❹ **Concepts for generative documentation** and visualization from sensor data.

⑤ Project timeline

Official project start: April 2018

Project duration: 8 months

Status: Testbed/apparatus construction

⑥ New research directions which this feasibility study enables

❶ Monitor powder bed properties (e.g., compaction, flow, temperature distributions) with **in-powder sensors**. Significant research challenges in energy-efficient signal processing, sensor platform miniaturization, in-situ machine learning on miniature in-powder sensors, and more. Complements existing research on in situ metrology for metal powder bed fusion [3].

❷ Monitor object properties (e.g., stress concentrations) over lifetime of use, with **in-object sensors**. Will require fundamental new understanding for in situ sensor signal processing, localization of sensors, and new approaches to extracting in-situ-processed sensor data.

References:

[1] P. Green, K. Black, and C. Sutcliffe, "Towards Additive Manufacturing Process Control using Semi-Supervised Learning". *Connected Everything Feasibility Study*, January 2017.

[2] P. Stanley-Marbell and M. Rinard, "A Hardware Platform for Efficient Multi-Modal Sensing with Adaptive Approximation", *arXiv preprint arXiv:1804.09241*, 2018.

[3] P. Bidare, R.R.J. Maier, R.J. Beck, J.D. Shephard, A.J. Moore, "An open-architecture metal powder bed fusion system for in-situ process measurements", *Additive Manufacturing*, Volume 16, 2017, Pages 177-185.

connected everything
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