



Utilizing advanced manufacturing technologies to enhance legacy production techniques for next generation personal protective equipment

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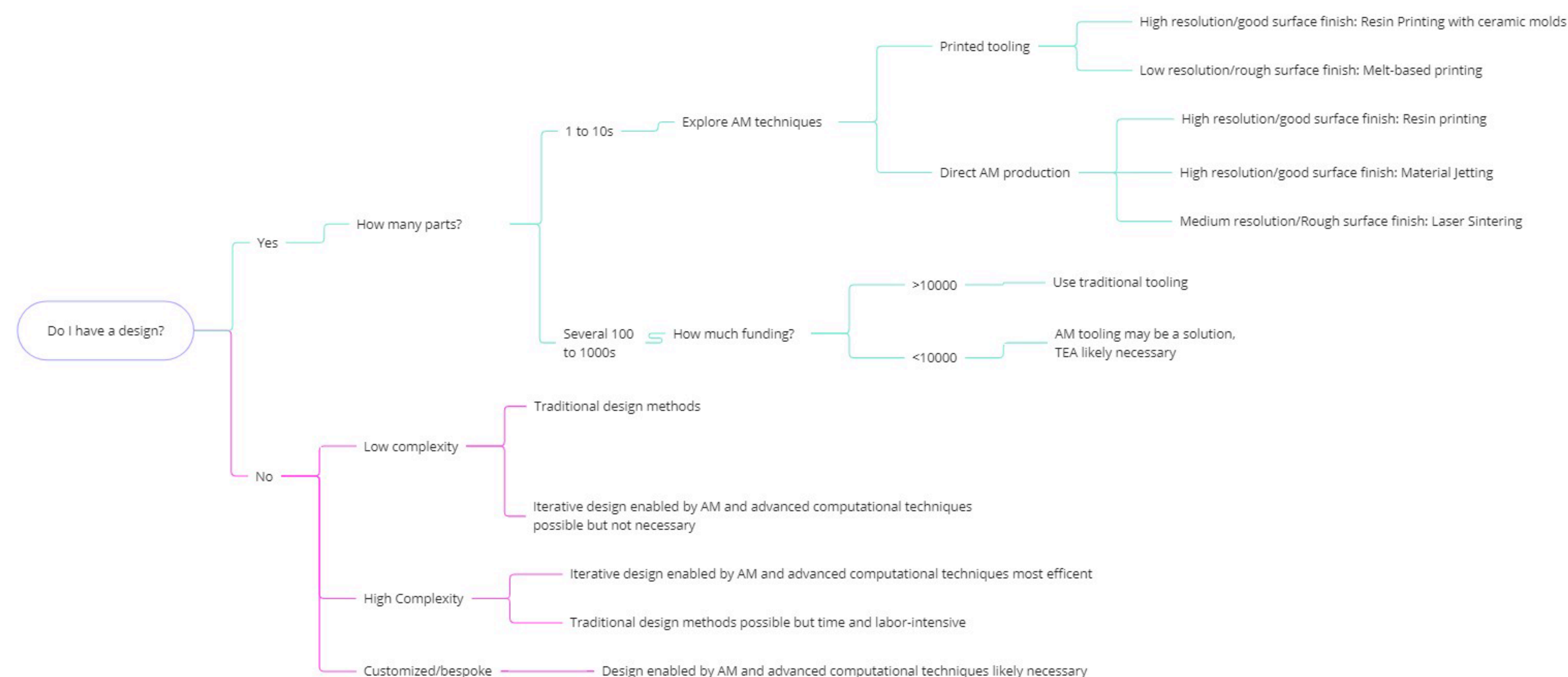
Introduction

Additive manufacturing (AM) and associated computational techniques have significantly enhanced our ability to prototype and produce versatile, innovative product concepts with shapes and material systems previously unachievable through legacy techniques like injection molding. Unfortunately, unique demands of CBRN protection have slowed wide adoption of AM technologies for personal protective equipment. DEVCOM CBC's additive manufacturing strategy considers adoption of AM and related advanced manufacturing technologies as both primary manufacturing methods and as technology enablers, bridging gaps and enhancing the utility of legacy manufacturing. The goal of this presentation is to introduce the advanced manufacturing landscape and demonstrate use cases to demonstrate the new realm of the possible enabled by emerging technology.

Additive Manufacturing

AM is a powerful tool, but successful implementation requires understanding the pros and cons of each method and judicious application. AM is not a hammer, and every problem is not a nail. The workflow below has been developed to guide R&D teams to decide when to implement AM in their processes.

AM Decision Tree



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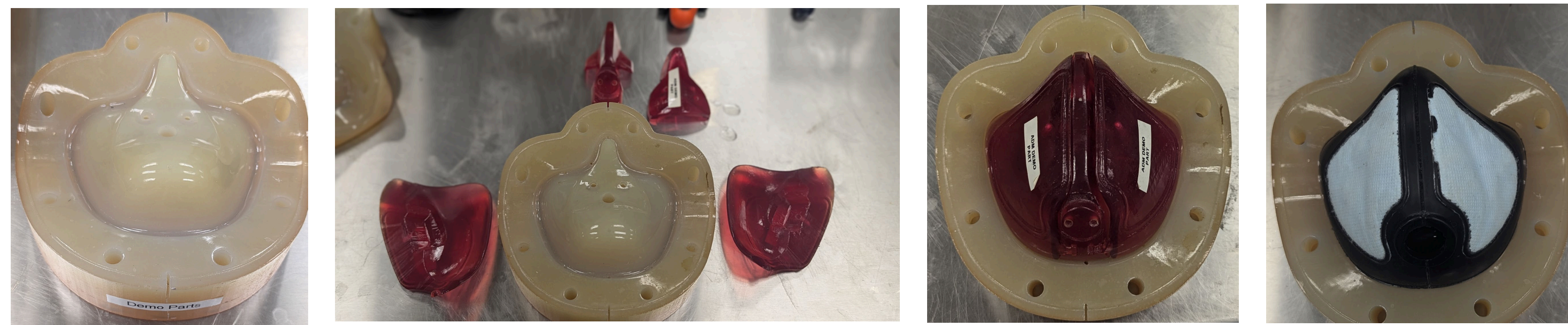
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Additive Manufacturing cont'd

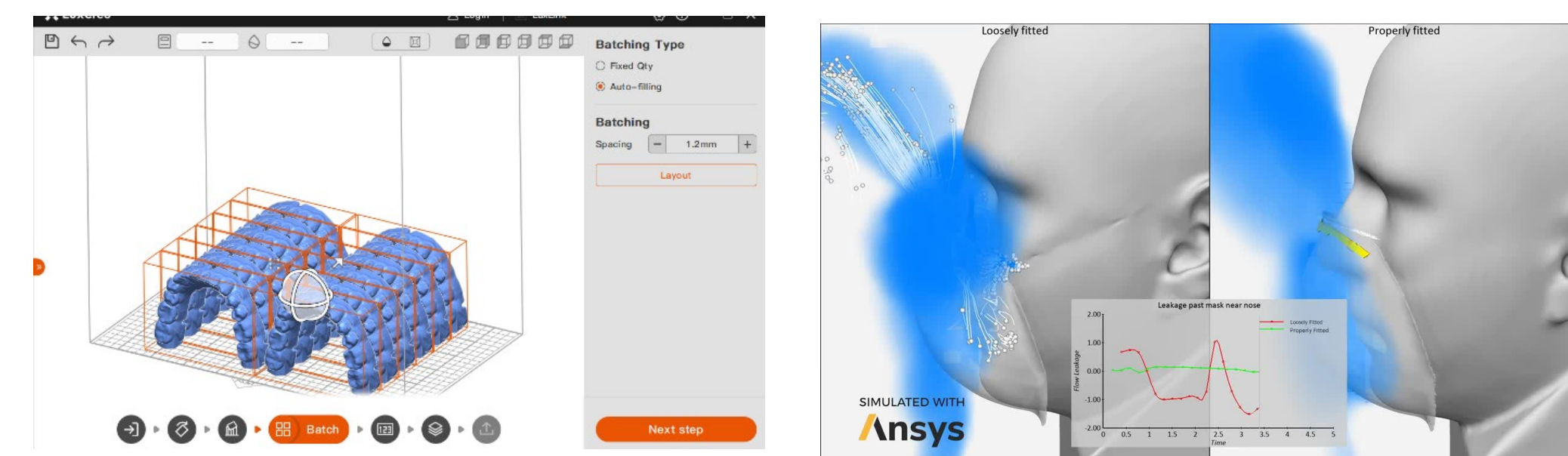
Sample Use Case: 3D Printed Mask Molds

3D printing-enabled production of a multi-material mask. A mold with removable inserts was printed from resin. The multipart mold allowed for insertion of filter media during production. Overall, the mold cost <\$1000 in materials and less than a day of production, contrasted with <\$10,000 and multiple weeks for traditional steel tooling. Pictured **below** is the multipart mold and the finished mask concept.



Computational Techniques

Design, processing, and characterization via computational tools continues to improve and become more powerful. Use of these techniques allows for better prototyping and modeling, making design iterations simpler and faster.



Left: Luxdesign by LuxCreo is latticing software for use with additive manufacturing systems that utilizes implicit modeling concepts to aid in design of parts.

Right: Ansys Fluent allows for modeling of parts, including computational fluid dynamics to show airflow in masks.

Sample Use Case: Using 2D Images to Custom Fit Masks

Image analysis and learning tools trained on large datasets can significantly enhance design and customization without even needing the user to be present. Utilizing face landmark detection tools, 2D images can be converted to 3D maps and printed or cast to produce accurate models of an individual's facial structure, allowing for mass customization without the user being present.



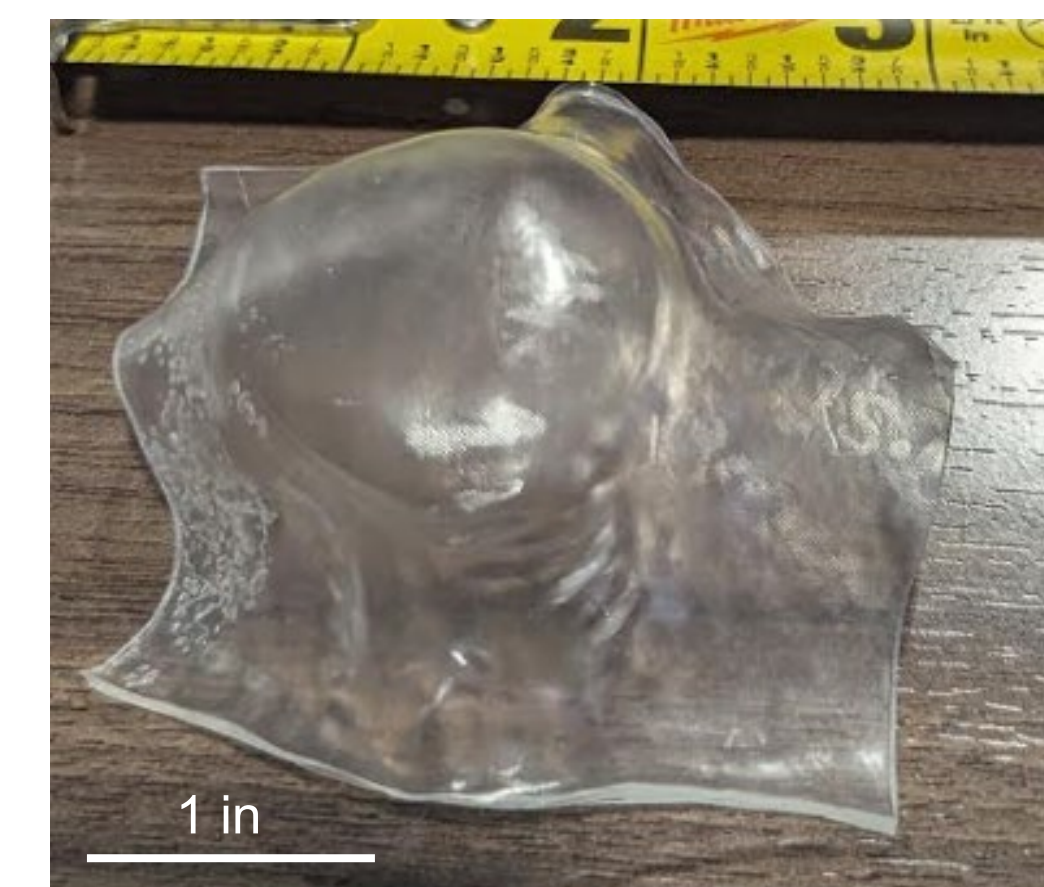
Left: Facial feature mapping via Google Mediapipe (https://ai.google.dev/edge/mediapipe/solutions/vision/face_detector) **Right:** Pressure-sensing head forms utilizing 3D printed "skulls" overlaid with sensor pads and cast silicone to provide more realistic response when fitted with PPE .

Advanced Materials

New materials development and formulation/compounding enabled by automated and combinatorial techniques can significantly speed discovery of materials with unique, tailored properties. Coupled with advanced manufacturing techniques, the design space for new personal protective equipment becomes nearly infinite.

Sample Use Case: Thermoformable Butyl Rubber

Applying polymer physics principles, confining polyisobutylene between layers of styrene-isobutylene-styrene (SIBS) obviates the need to vulcanize rubber. The multilayered material still provides barrier protection but can be thermoformed to achieve desired shape. Moreover, the SIBS provides a comfortable, non-tacky surface appropriate for skin contact. This material can be used in a variety of manufacturing products and can be reformed, whereas traditional PIB products are generally limited to high temperature injection molding where they are irreversibly crosslinked.



Thermoformed multilayered SIBS-PIB-SIBS

Conclusions

The wealth of new manufacturing techniques, computer-aided design and analysis software, and access to AI/ML tools provides powerful pathways for designing the next generation of personal protective equipment. Coupling these tools with new materials development, PPE concepts no longer are bound by old constraints. The community must adopt these new techniques and must revise its conception of the realm of the possible.

Given advances in materials and manufacturing, consider: If all material and processing constraints are removed, what would our PPE look like? How will it be different from now? How can our design concepts change now that we have a new toolset?

Acknowledgements: R&D funding for this program was provided by JSTO (Dr. Kendra McCoy). The authors would like to express our thanks to our partners at Harrisburg University (LJ Holmes), IC3D (Michael Cao, Luke DeBruin, Matt Organiscak) and the Senior Capstone team at Texas A&M University (Tyler Corazao, Salem Smith, Sofia Torres). The views expressed in this abstract are those of the authors and do not necessarily reflect the official policy or position of the Department of Defense or the U.S. Government.

