

Software Engineering for Additive Manufacturing

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Software Engineering for Additive Manufacturing

Stephanie Rosenthal, PhD

Rick Kazman and Kurt Wallnau (SEI)

Megan Hofmann, Prof. Jennifer Mankoff,
Prof. Scott Hudson (CMU HCII)

3D Printing Enables Manufacturing in Remote Areas



The screenshot shows a web browser window with the address bar containing www.3dprintingfordefense.com. The page features a prominent red banner with the following text:

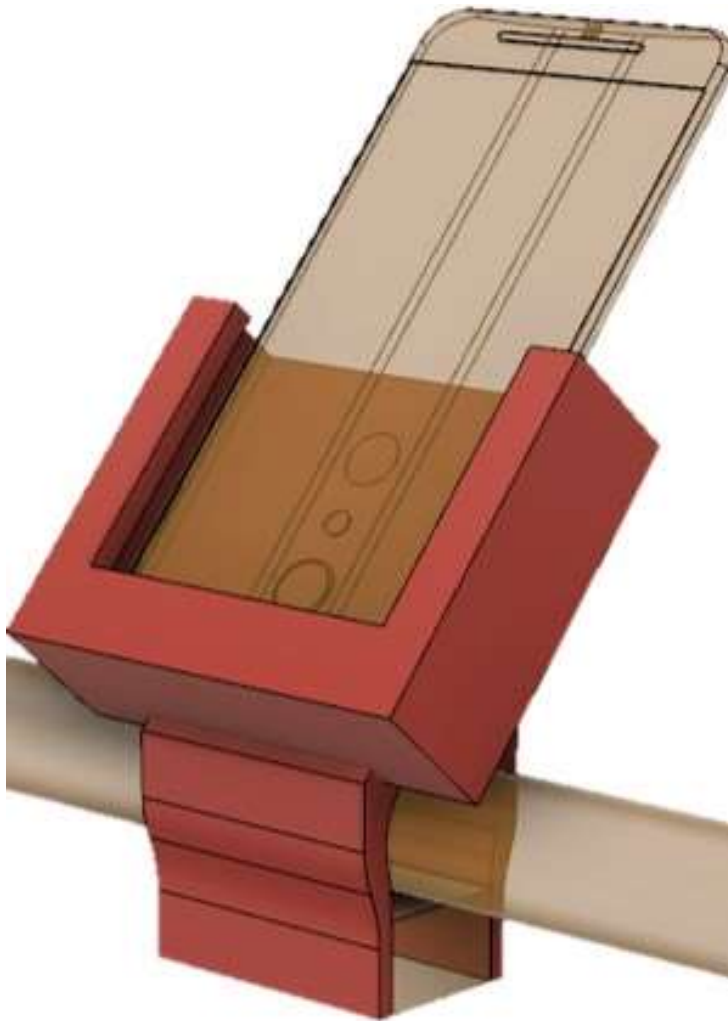
Additive Manufacturing
FOR DEFENSE AND GOVERNMENT

Revolutionizing Aerospace And Defense
Innovation, Production, Logistics, And Readiness

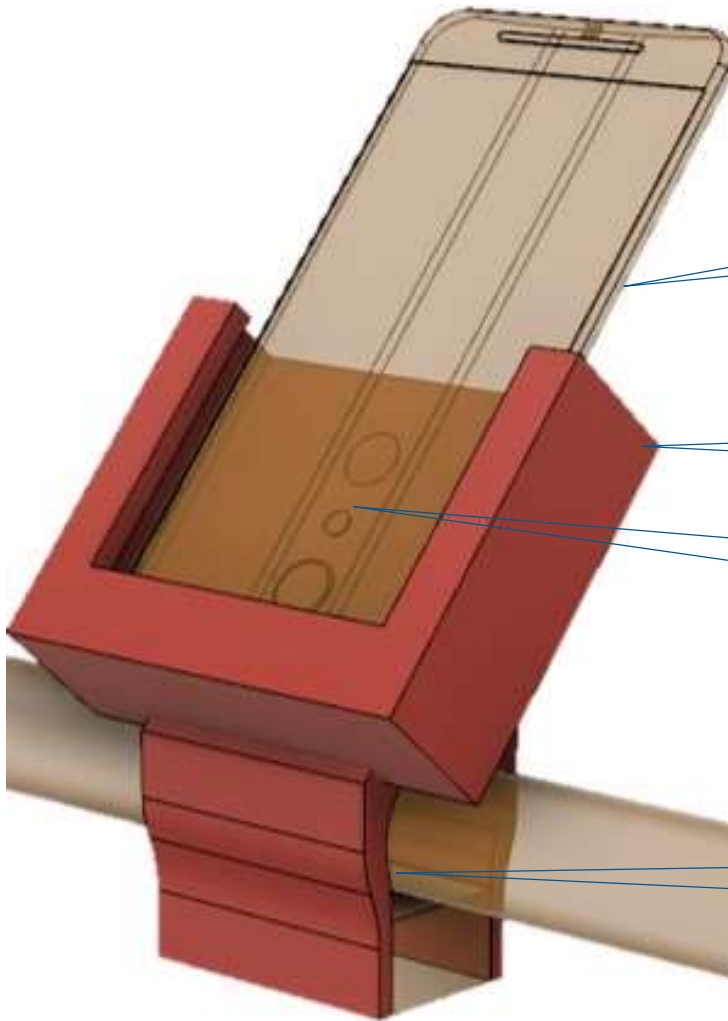
Washington, DC • November 15-16, 2016

Navigation links at the top right of the banner include: VISIT: WWW.TTCUS.COM / EMAIL US, and a SHARE button with social media icons for Facebook, Twitter, and Email.

3D Modeling for Additive Manufacturing



Why is 3D Modeling Hard?



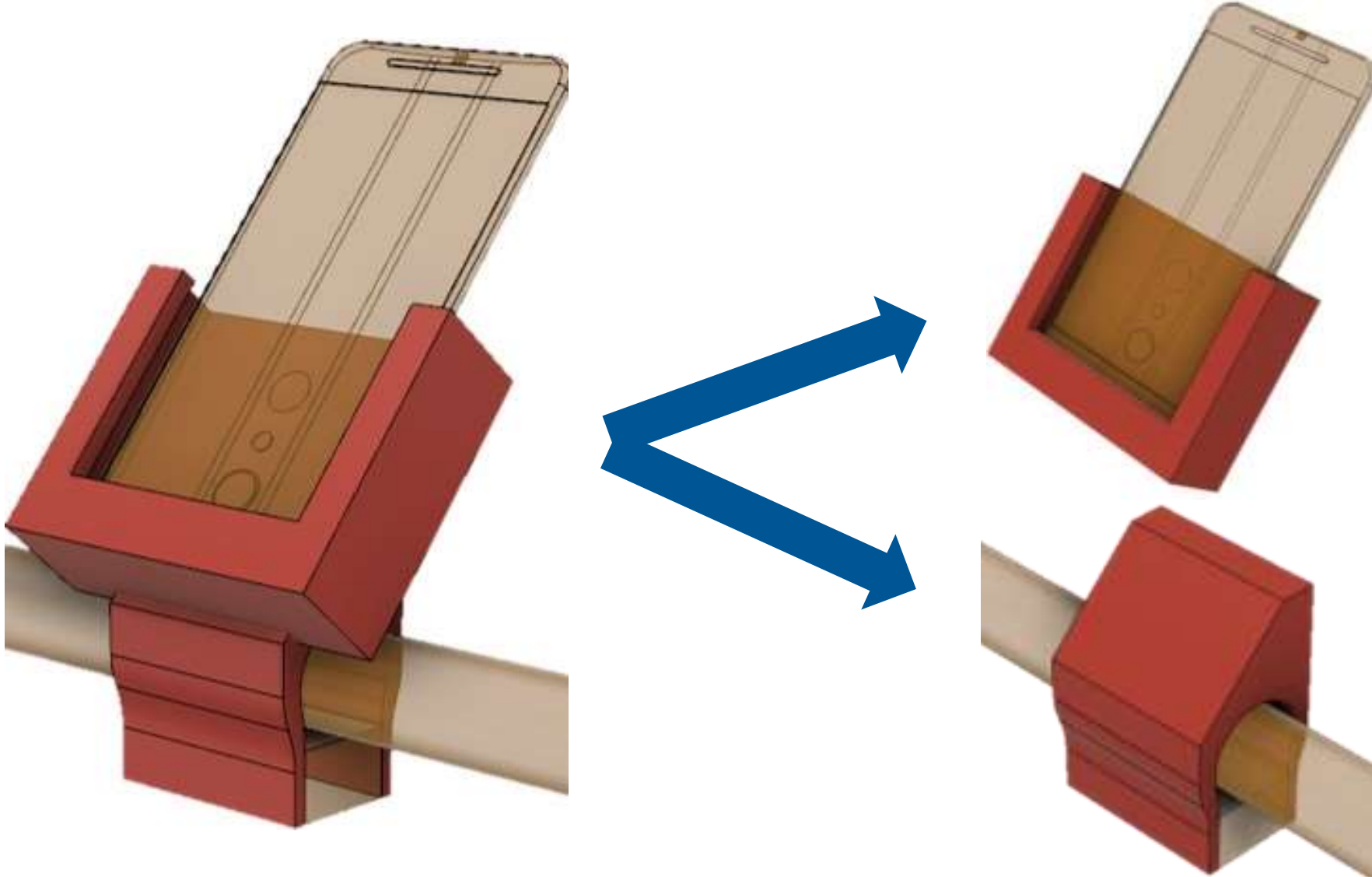
The model should fit tightly to the phone but not so tight that it does not fit

The print should be thick enough so that the object does not break with wear

The screen should be at a readable angle and should not be occluded

The clamp should fit tightly to the bar but not so tight that it does not fit

Functional Modularity of 3D Models



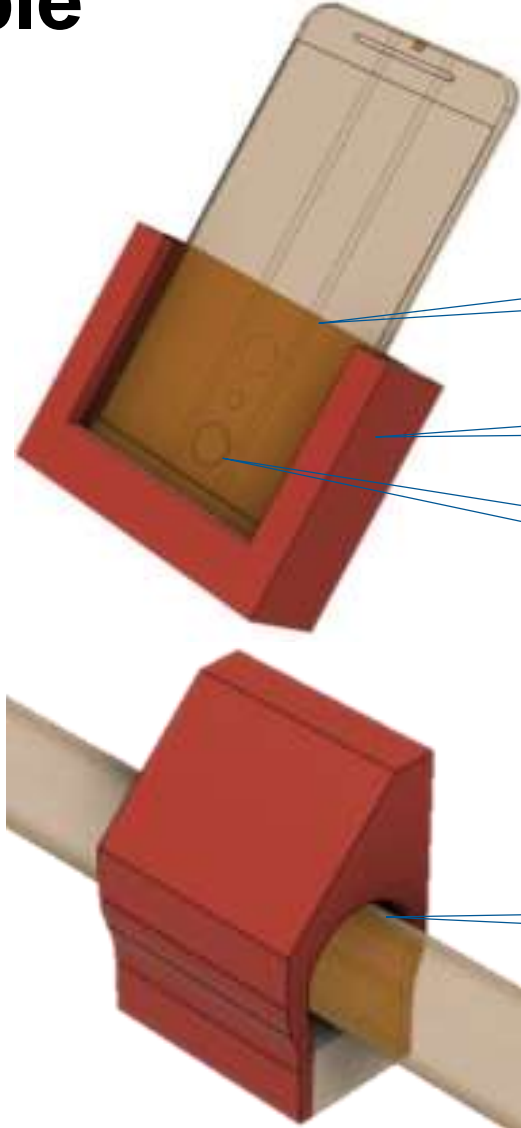
PARTs: Parameterizable Abstractions of Reusable Things



- 1) Allow modelers to decompose their complex models into components
- 2) Assign logic constraints to the geometry of the components to represent the modeler's intentions of how it is meant to interact with other models and physical objects
 - **Logical Assertions** – validatable rules about what components should look like and how they should be printed
 - **Integrators** – how to connect multiple models together (union, cut)

PARTs: Parameterizable Abstractions of Reusable Things

Example



The model should fit tightly to the phone but not so tight that it does not fit

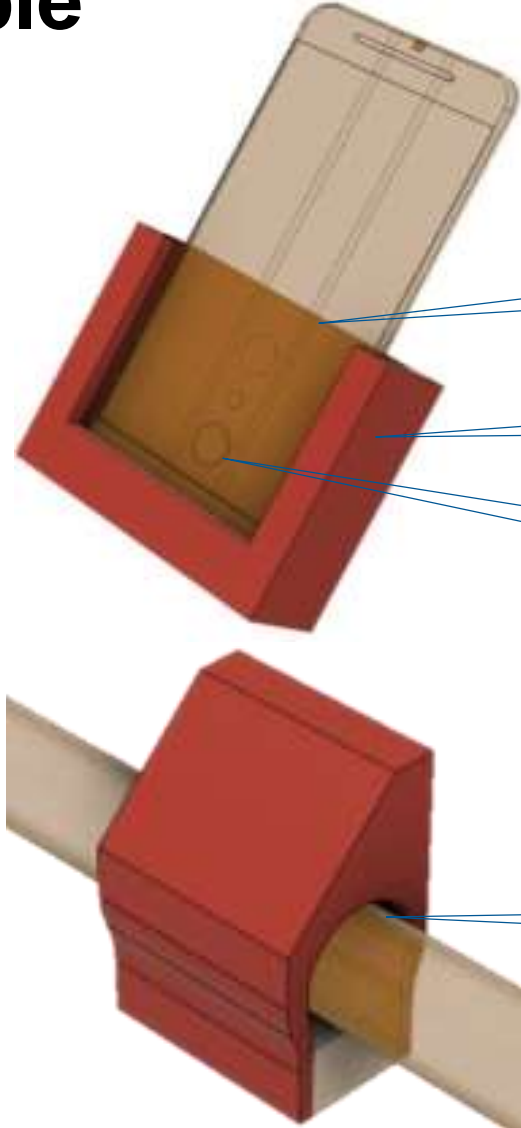
The print should be thick enough so that the object does not break with wear

The screen should be at a readable angle and should not be occluded

The clamp should fit tightly to the bar but not so tight that it does not fit

PARTs: Parameterizable Abstractions of Reusable Things

Example



Phone exterior + tolerance
= Model interior

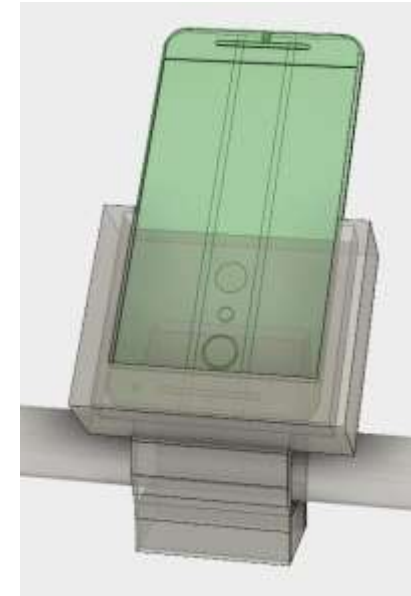
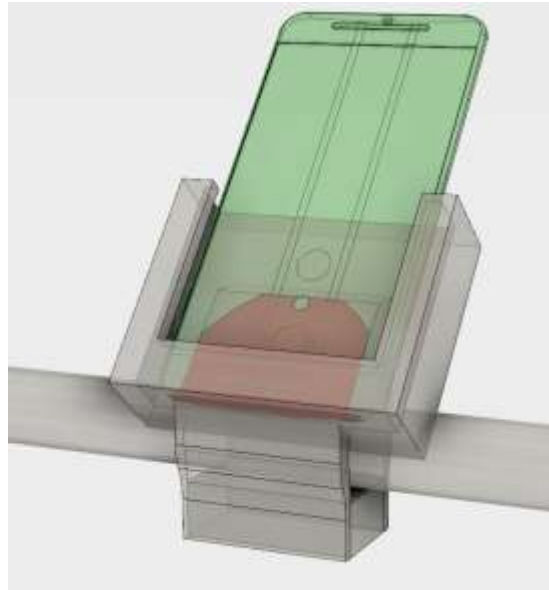
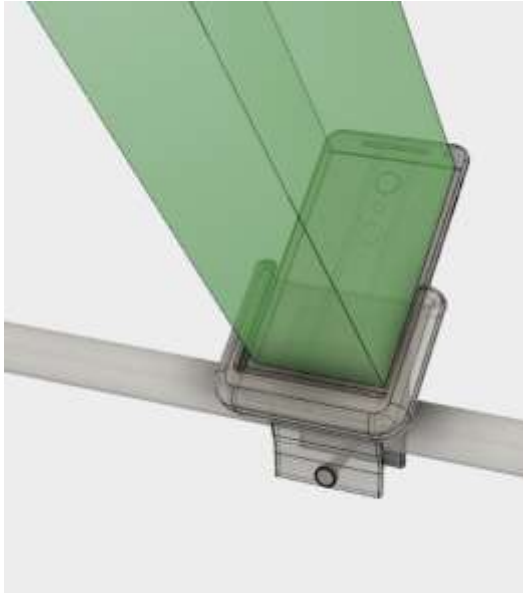
Model thickness > X mm

Phone screen + tolerance
= Model front

Bike radius + tolerance
= Clamp radius

PARTs: Parameterizable Abstractions of Reusable Things

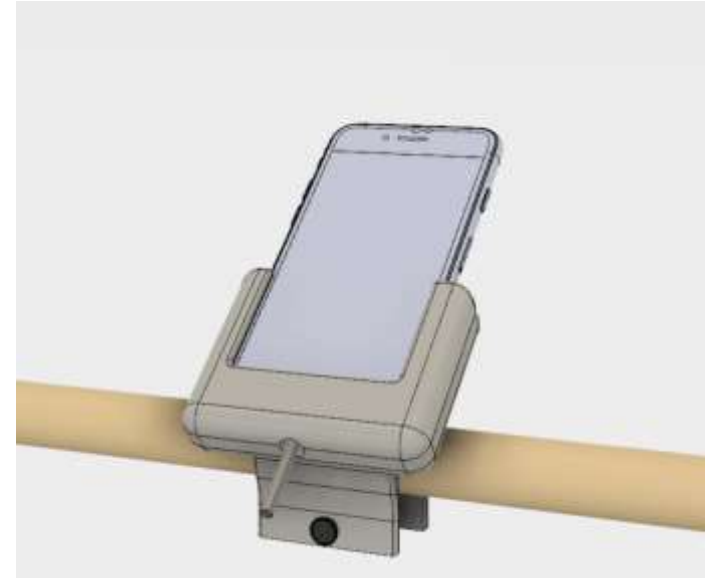
Example



Each assertion is verified and flagged as red in the model if it is invalid individually and/or when composed

Valid models meet all assertion requirements set by the modeler

PARTs Enable Modular Designs



Add a hole for headphones

Change the phone model
and handlebar width

PARTs Enable Modular Designs



Contributions:

- 1) Allow modelers to decompose their complex models into components
- 2) Assign logic constraints to the geometry of the components to represent the modeler's intentions of how it is meant to interact with other models and physical objects

Implemented in Fusion360 computer aided design CAD software

Next steps: apply and formalize other software properties for 3D models

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