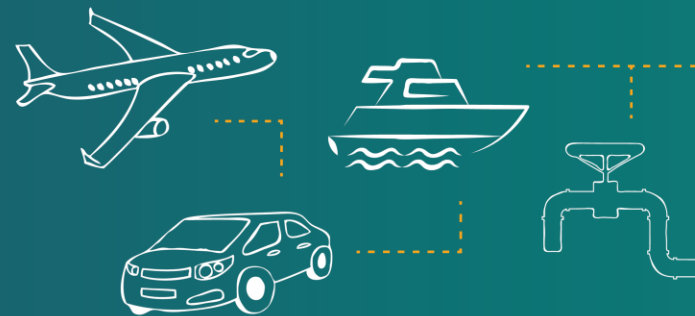




A NEW CAMX FOR A NEW TIME



COMBINED STRENGTH. UNSURPASSED INNOVATION

CAMX
THE COMPOSITES AND ADVANCED MATERIALS EXPO

SEPTEMBER 21-24

A VIRTUAL EXPERIENCE

2020



The background features a light gray grid of dotted lines. Scattered throughout are various technical icons in a light gray color, including a lightbulb, a microscope, a laptop, a tablet with a circuit diagram, a gear, a bicycle wheel, a person pointing at a screen with a gear, a robotic arm, a wrench, a car, an airplane, a wind turbine, and a speaker icon.

3D Modeling and Printing of Automated Fiber Placement Defects

Alex Brasington

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University of South Carolina
McNAIR Center, Department of Mechanical Engineering

Welcome Slide

- Alex Brasington
- UofSC McNAIR Aerospace Center
- Graduate researcher
- I am a part of Dr. Ramy Harik's New and Emerging X Technologies (neXt) research team
- My research focus is advanced manufacturing of composite materials (automated fiber placement)



A NEW CAMX
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CAMX 
September 21-24, 2020 / www.theC

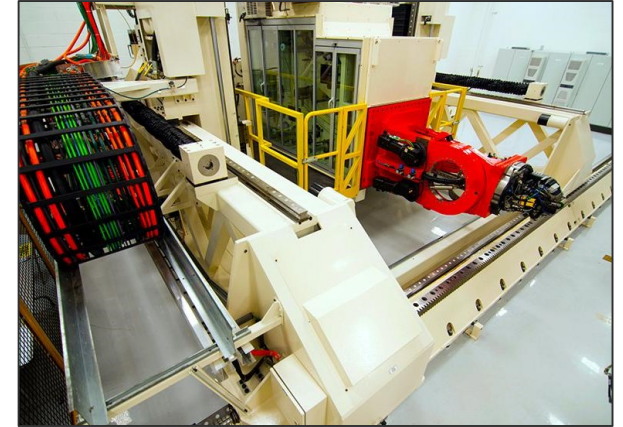
Outline

1. Introduction
2. Modelling
 1. Tool surface modeling
 2. Tow modeling
3. 3D printing
 1. Single print method
 2. Multiple print method
4. Completed Models
5. Model Dissemination
6. Conclusion



Introduction - AFP

- Composite manufacturing technique
- Often used to produce large aerospace structures
- Utilizes a robotic or gantry system and attached fiber placement head
- Growing technique being applied to new structures

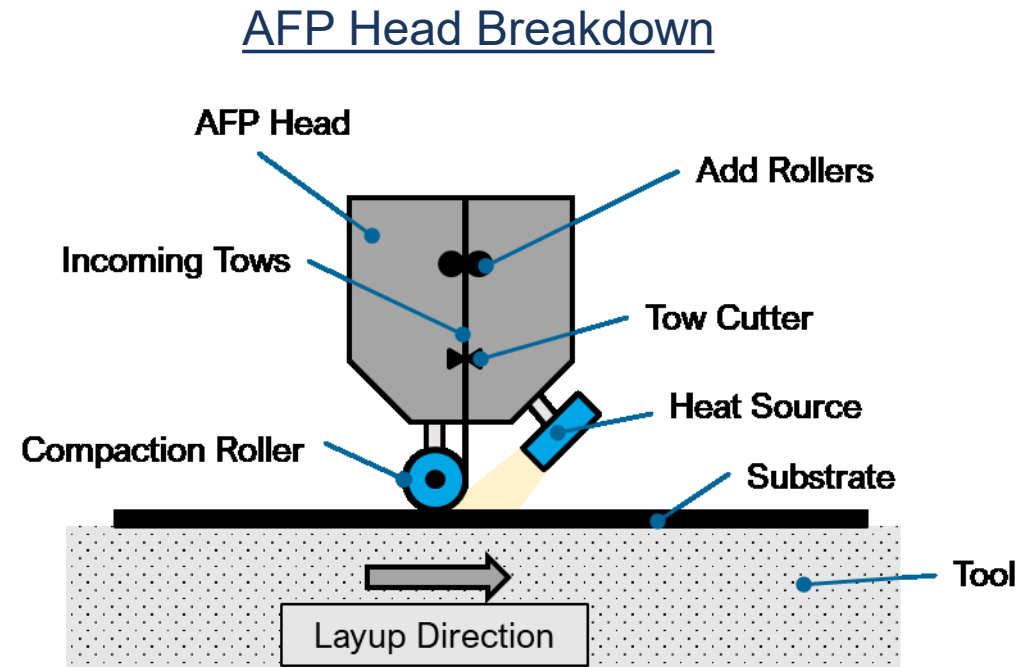


<https://www.nasa.gov/feature/nasas-advanced-composites-consortium-strengthens>



Introduction - AFP

- Strips of composite laid onto tool surface
- Heating mechanism used to ensure proper tackiness
- Compaction roller applies pressure directly after the heating
- Successive passes creates the laminate



Introduction - AFP Defects

- Main side effect of AFP is unavoidable defects
- Most of the inspection is done by a human
- Due to the large effect defects can have, understanding each is crucial
- Identification requires great deal of experience
- Hands on experience with the modeled defects aims to teach personnel characteristics of each defect



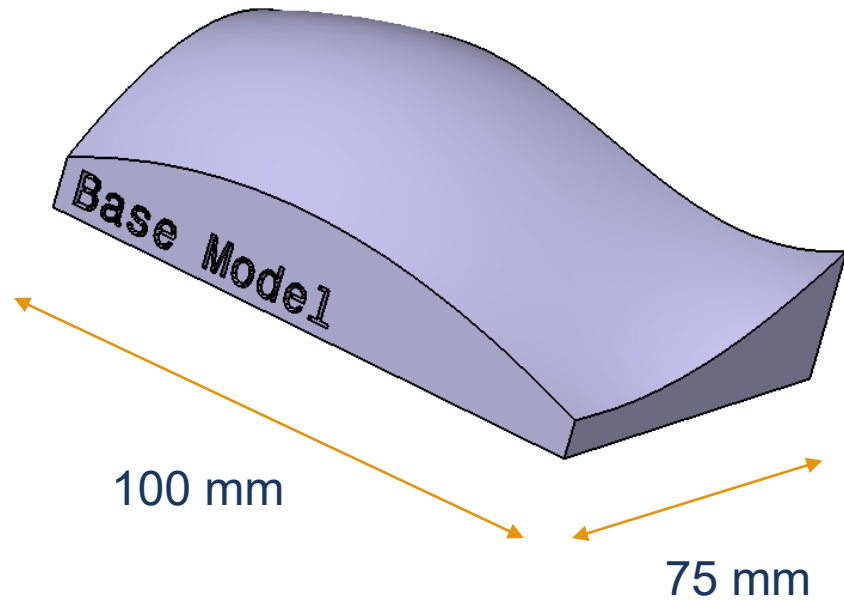
Introduction - AFP Defects

- 4 main categories
 - Position defects
 - Bonding defects
 - Tow defects
 - Foreign bodies
- Each defect is modeled

Defect	Category
Gap/overlap	1
Twist	1
Missing tow	1
Boundary coverage	1
Angle deviation	1
Wandering tow	1
Position error	1
Fold	2
Pucker	2
Wrinkle	2
Bridging	2
Loose tow	2
Splice	3
Foreign object debris	4



Tool Surface Modeling

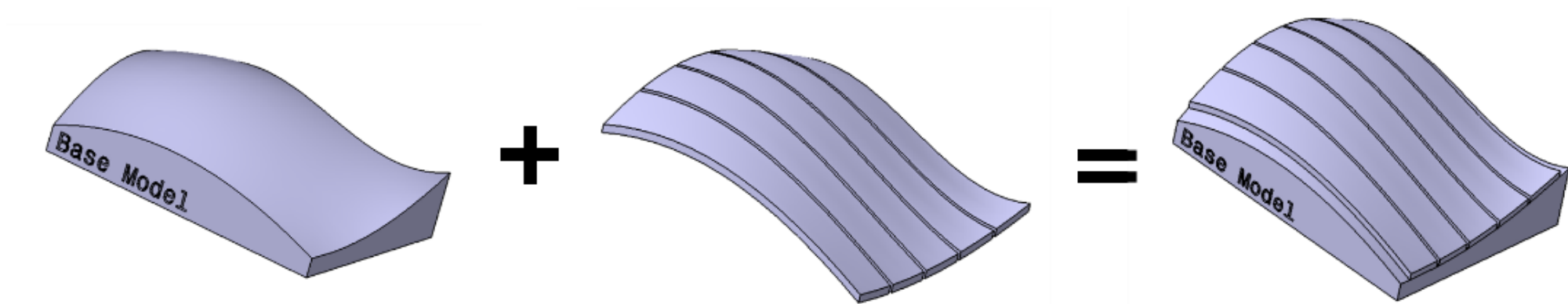


- Modelling began with tool surface
- Tool refers to the surface tools are placed onto
- Name of model is embossed on the side
- Geometry replicates a complex tool



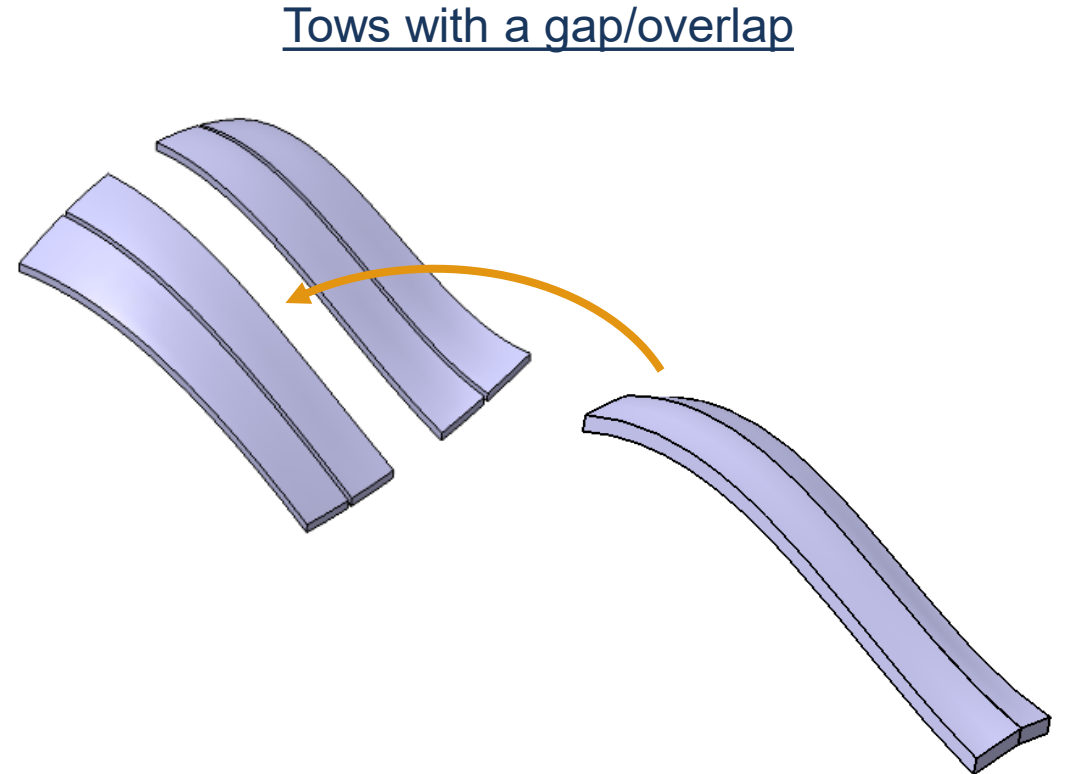
Tow Modeling

- Tows modeled following geometry of tool
- 5 large tows used to ease visualization
- Straight lines projected onto surface to form a closed curve
- Extruded vertically to create the thickness of the tows
- Tows can be contained in a single model or separate



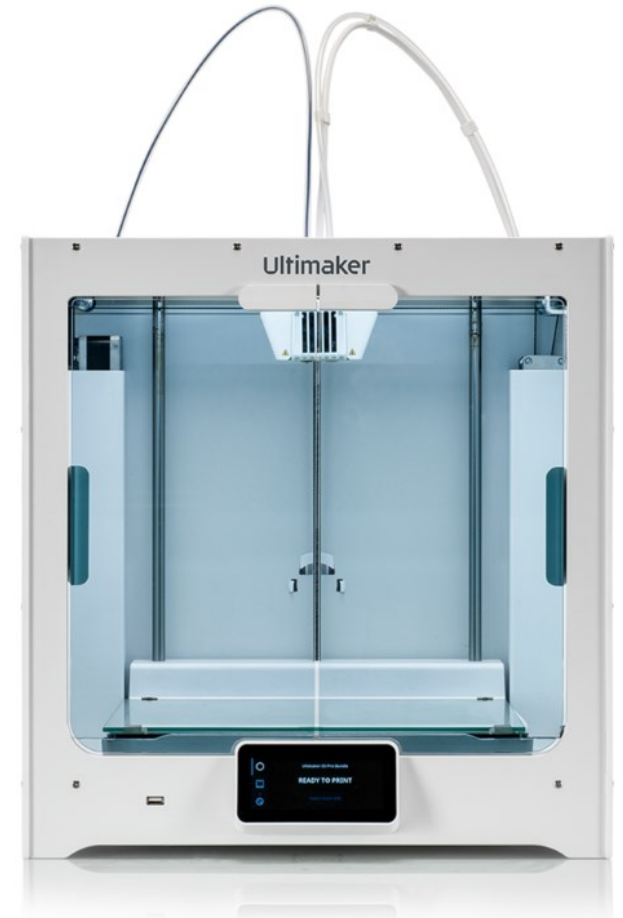
Tows with Defects

- Decide which tow is going to have the defect
- Create the preferred defect geometry
- Combine the defect and other tows with the base model



3D Printing

- 3D printing creates a hands-on experience
- Printing can be done with a single or multiple prints
- Printing was done using an Ultimaker S5
- Any printer and slicer can be used

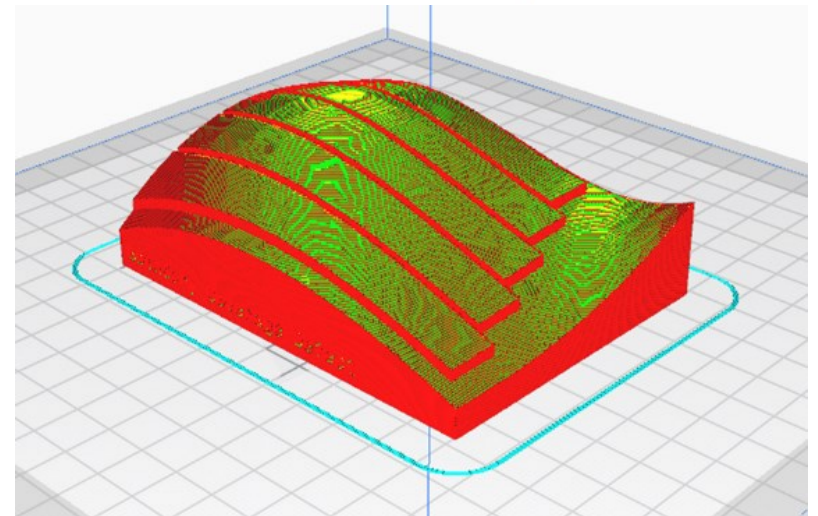
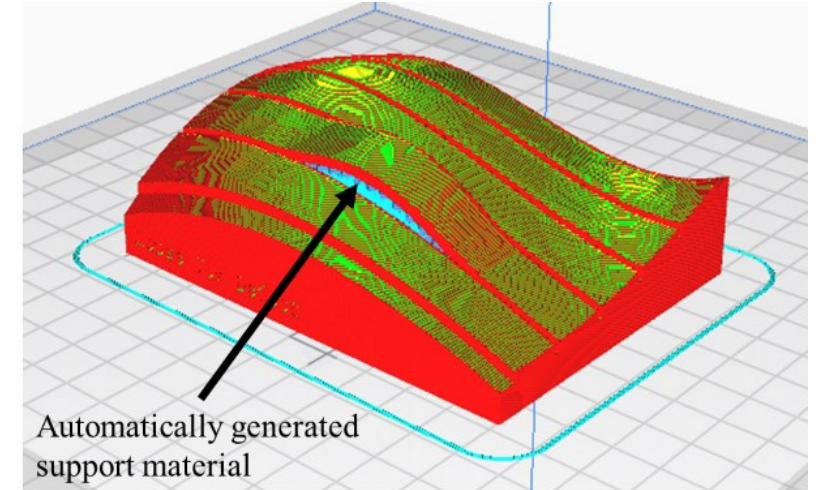


<https://ultimaker.com/3d-printers/ultimaker-s5>



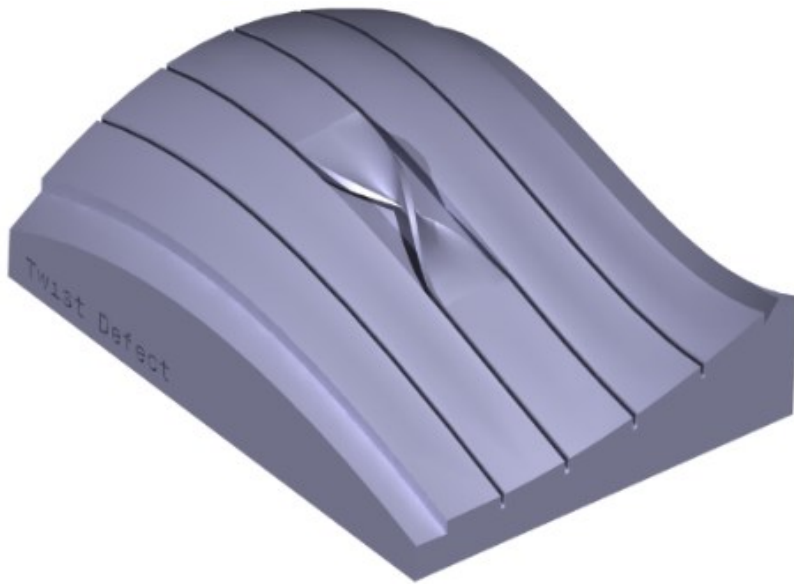
Single Print Method

- Tows and tool combined into single STL file
- Imported into slicer software
- Specific printer configuration properties are not required
- No support needed except for defects not in contact with tool
- Use slicer generated supports

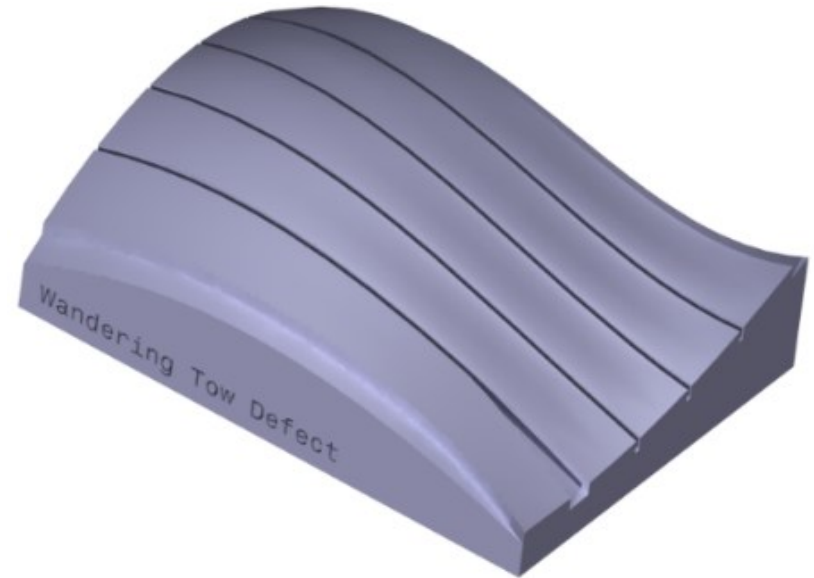


Single Print Method - Examples

- Faster and more efficient, however with most printers only a single color is possible and makes visualization harder



Twist defect

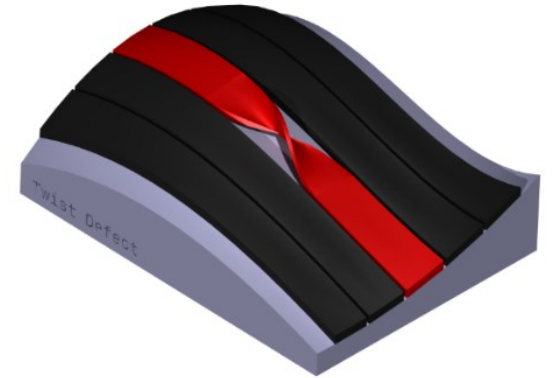


Wandering tow defect

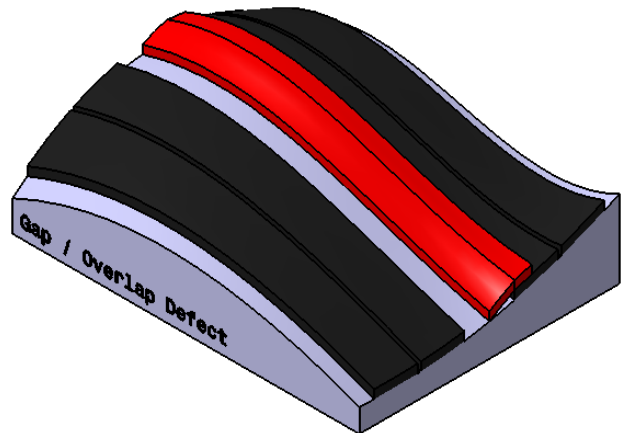


Multiple Prints Method

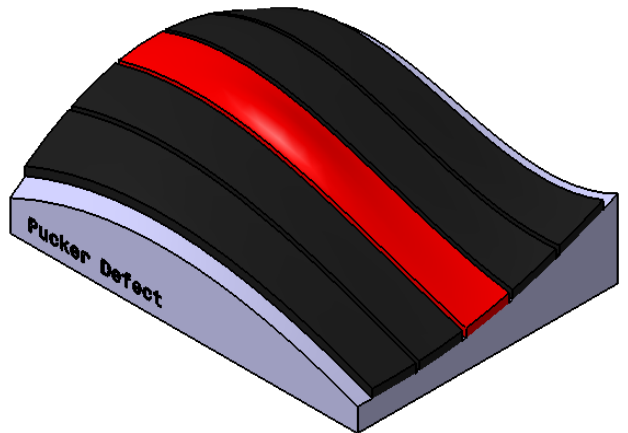
- More visually appealing and easier defect identification
- Base, non-defect tows, and defect tows printed with various colors to highlight defect
- Support material required based on part and positioning
- Each piece is assembled and glued together



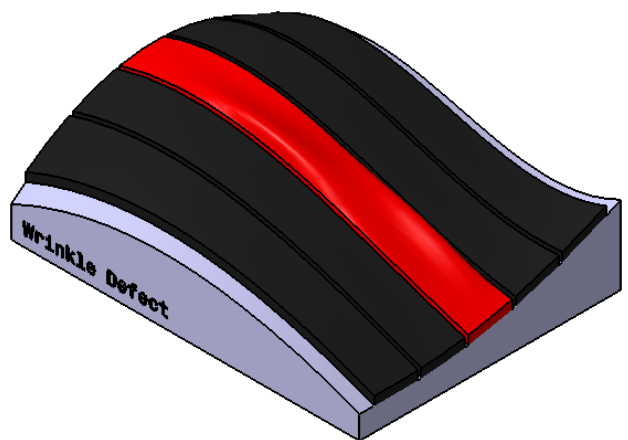
Completed Models



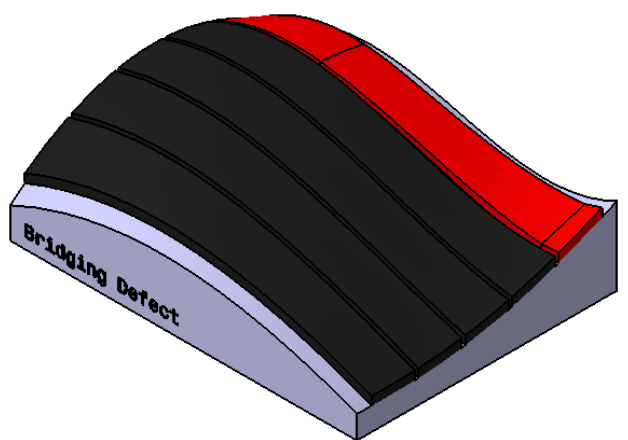
Gap / Overlap



Pucker



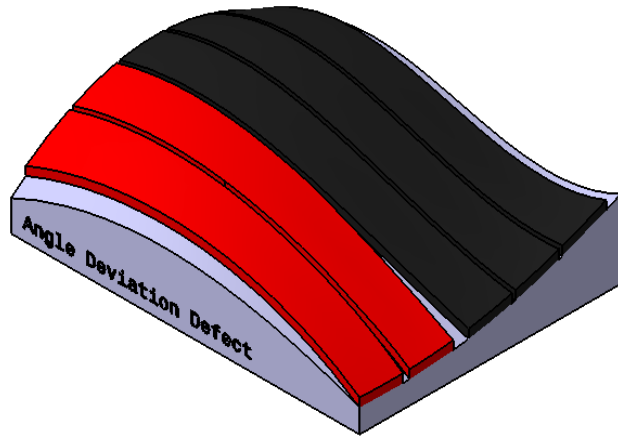
Wrinkle



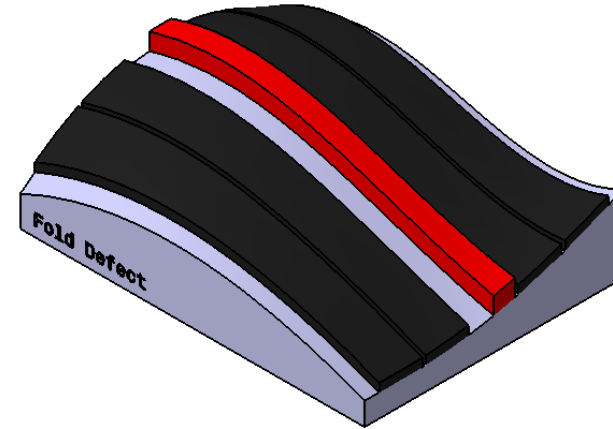
Bridging



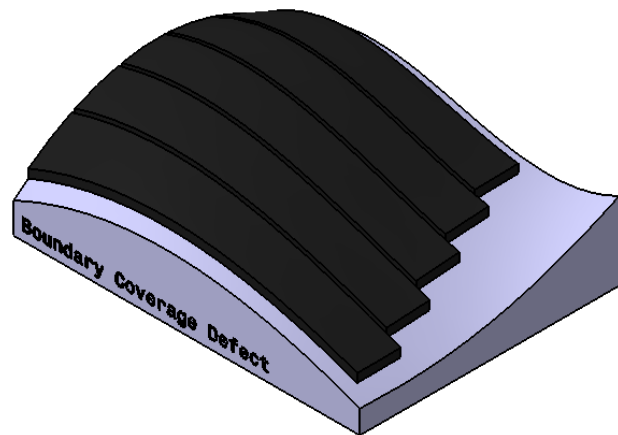
Completed Models



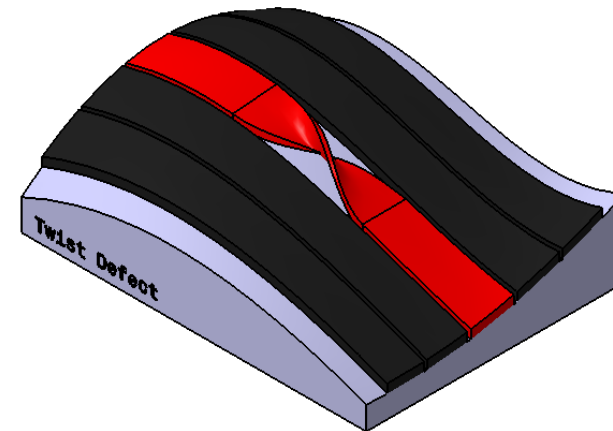
Angle Deviation



Fold



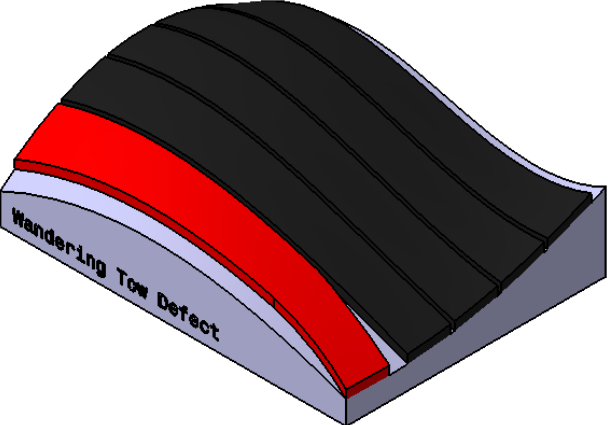
Boundary Coverage



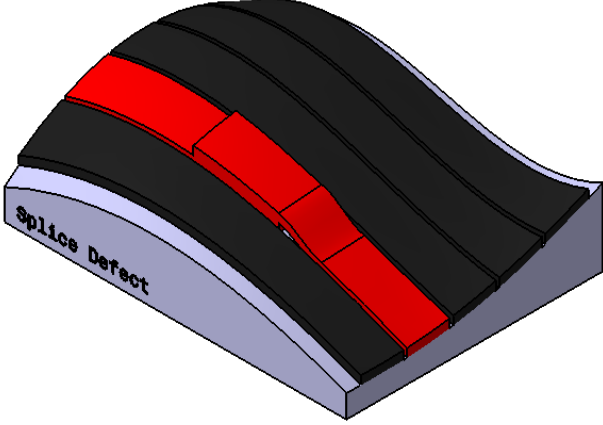
Twist



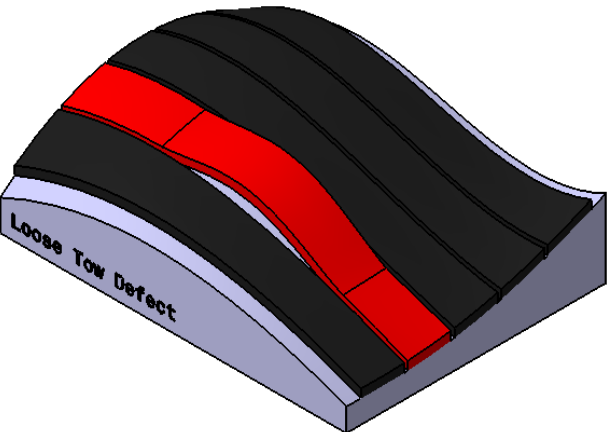
Completed Models



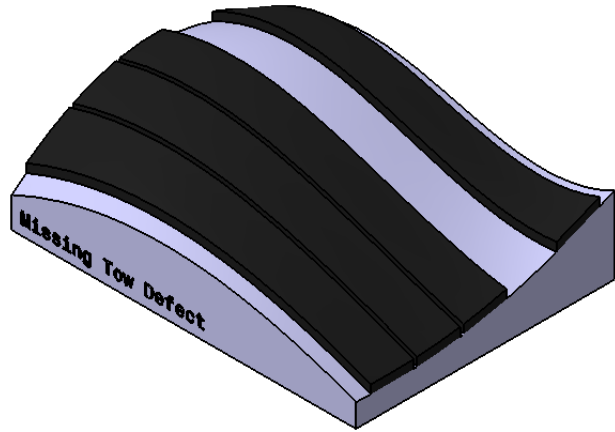
Wandering Tow



Splice



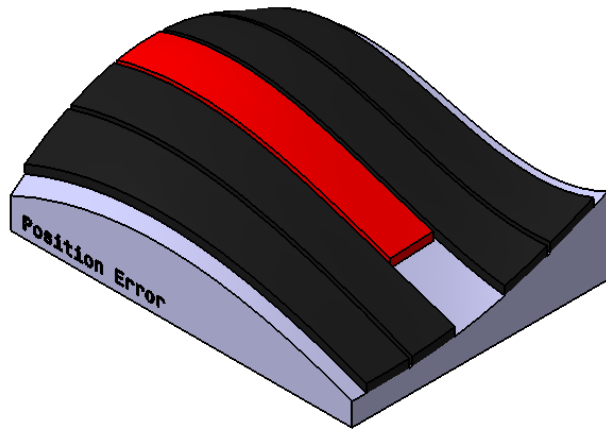
Loose Tow



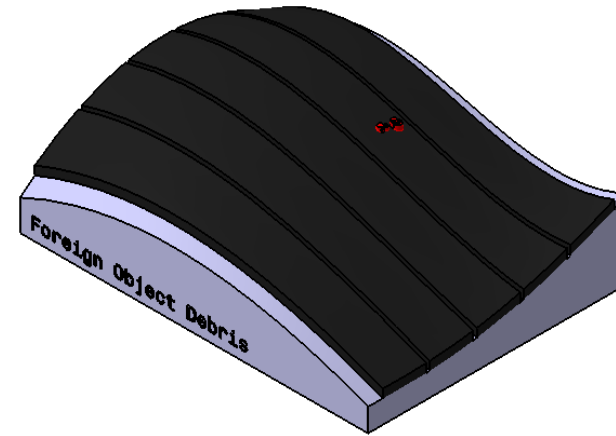
Missing Tow



Completed Models



Position Error



FOD




Model Dissemination

- Main goal of creation is to share with the public
- Anyone can view and print these models
- Visiting the following link will provide downloadable files
 - https://drive.google.com/file/d/1_mlr6cPgVzUw2Q60watgZ-FQHDa1nVqs/view?usp=sharing





Model Dissemination

10. Loose Tow 4 items

 prtTSloosetowmodelV01 - Base.stl

 prtTSloosetowmodelV01 - Defect.stl

 prtTSloosetowmodelV01 - Tows.stl

 prtTSloosetowmodelV01.stl



Model Dissemination

Tool surface

10. Loose Tow 4 items



prtTSloosetowmodelV01 - Base.stl



prtTSloosetowmodelV01 - Defect.stl



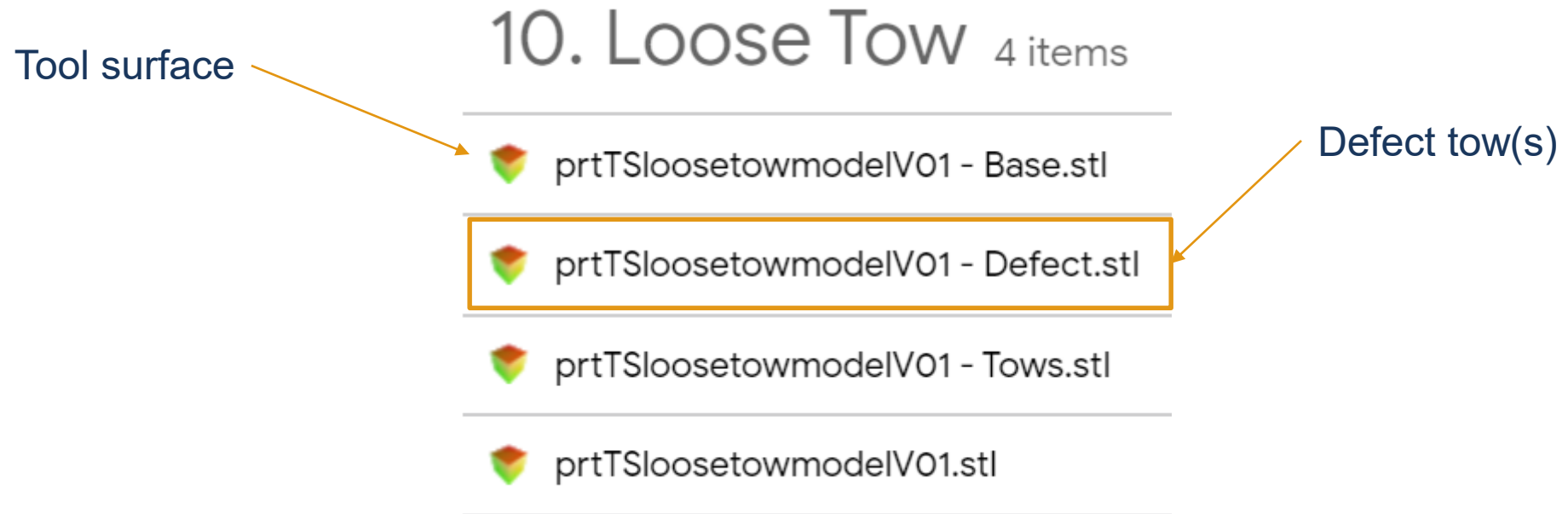
prtTSloosetowmodelV01 - Tows.stl



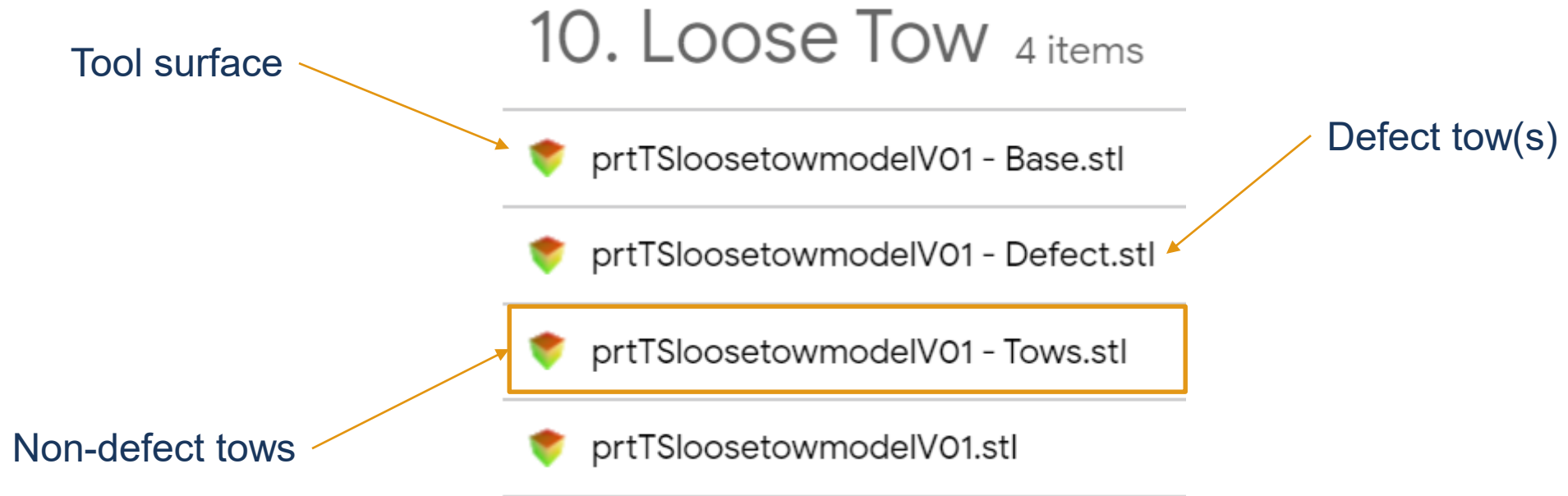
prtTSloosetowmodelV01.stl



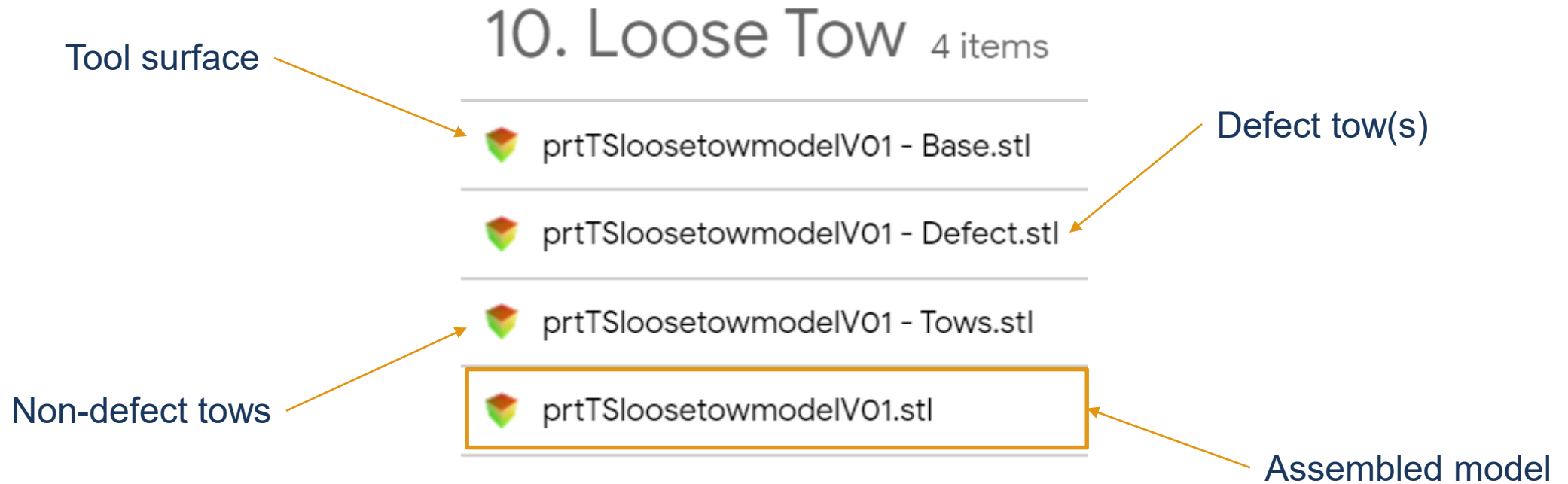
Model Dissemination



Model Dissemination



Model Dissemination



Conclusion

- 3D modeling and printing can play an integral role in spreading AFP knowledge
- No need for introducing defects with inspecting numerous AFP manufactured plies
- Exposing personnel to these models introduces the types of AFP defects
- Combining education gained with actual effect and significance of defects will broaden knowledge



**THANK YOU
FOR WATCHING**



SEPTEMBER 21-24

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2020

