Examples of when 3D printing repair is good

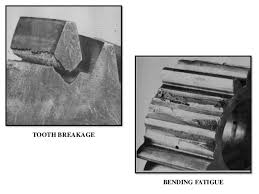
This website has a multitude of ways 3d printed stuff are used in the industrial world:

<https://amfg.ai/industrial-applications-of-3d-printing-the-ultimate-guide/>

1. 3D-printed Rutherford rocket engine: It is a reusable 3D printed rocket so we can figure out areas on it that would need to be repaired
   1. <https://www.forbes.com/sites/elizabethhowell1/2019/07/09/rocket-lab-completes-100th-3d-printed-rocket-engine/#31fe69cf51c7>
   2. <https://amfg.ai/2019/08/28/application-spotlight-3d-printed-rockets-and-the-future-of-spacecraft-manufacturing/>
2. Arevo is making carbon-fibre bike frames for a large portion of their bikes so if we can find areas on a bike that might fail theres a good example
   1. <https://amfg.ai/2019/08/01/3d-printing-for-bike-manufacturing-application-spotlight/>
   2. Common bike damage:
   3. 

* For the bike frame this article backs up why the 2 most common points of failure they test are tensile and 3 point bending which would back up why we would want to do 3 point bending. <http://userweb.eng.gla.ac.uk/philip.harrison/Teaching/2011%20Weikeong%20Teng/Weikeong%20teng_0703555_FYP%20report.pdf>
* For the rocket engine, this article backs up why we should test bending since it is one of the first things they run tests and is a common source of failure <https://strives-uploads-prod.s3.us-gov-west-1.amazonaws.com/19900016050/19900016050.pdf?AWSAccessKeyId=AKIASEVSKC45ZTTM42XZ&Expires=1601931336&Signature=OlIQsY6rUFXLdRP5LSAVY58XiBI%3D>

Gears common failures:



Wind turbine common wear and tear damage:



**Brendans notes**

Big question: why repair these parts when we can just replace them. It would probably take longer to repair them than to replace them.

Are there are situations in which the reusability would have a greater influence than the practicality of simply changing out the part? If 3D printing is so easy then in what scenario would we need to use another 3D printer to repair it, why not just change out that part

General thoughts

-Wind turbines/other airfoils like wings (might be hard to repair with 3d printing)

-Gear teeth damage (a chip in gear teeth, or even a missing tooth)

Actual research

-StrataSys Direct Manufacturing does a lot of work for the aerospace industry in terms of 3D printing.

* LS, **FDM**, DMLS, and casting

StrataSys mission statement and applications (taken from their website)

Improve product efficiency and flight performance while simplifying inventory with strong, lightweight components 3D printed on-demand.

Common Applications

Internal:

* Air filter boxes
* Bezels
* Brackets
* Custom cosmetic interior components
* Display shrouds
* Environmental control system ducting
* Fuel tanks
* Housings and enclosures
  + snap-fits
* Oil tanks
* Clips & clamps
* Knobs & buttons
* Windshield defogger duct nozzles

External:

* Battery compartments
* Camera mount and gimbal
* Clips & clamps
* Component connectors
* Electrical housings
* Payload enclosures
* Plenums
* Shrouds and closeouts
* FOD covers
* Propulsion components
* Rocket motors
* Fuel injectors
* Thrusters
* Combustion chambers

<https://www.stratasysdirect.com/industries/aerospace>

\*Possible question we may face is why would they repair a damaged aerospace structure. Aerospace is a very specific field where safety is extremely important, so printing over a damaged part may not be the best idea from a safety standpoint.

<https://amfg.ai/industrial-applications-of-3d-printing-the-ultimate-guide/>

Aerospace industry uses 3d printing for prototypes mostly, but wall panels are printed with FDM and used in flight. \*Probably won’t even be damaged

**NASA Zero-G 3D Printing**

[https://strives-uploads-prod.s3.us-gov-west-1.amazonaws.com/20140012888/20140012888.pdf?AWSAccessKeyId=AKIASEVSKC45ZTTM42XZ&Expires=1603071141&Signature=AdduY1VYeq%2BYEN%2F3wwZ7%2FpFizQ8%3](https://strives-uploads-prod.s3.us-gov-west-1.amazonaws.com/20140012888/20140012888.pdf?AWSAccessKeyId=AKIASEVSKC45ZTTM42XZ&Expires=1603071141&Signature=AdduY1VYeq%2BYEN%2F3wwZ7%2FpFizQ8%253)

* Based on the Problem Resolution and Corresponding Action (PRACA) database maintained by
* NASA on the ISS, approximately 28.6% of parts that require replacement are plastics and composites.
* These parts include **gaskets, hoses, valves seals, retainer brackets, and lubricants**.
* Being able to repair or replace these parts in space by 3D printing would save the money and time it would take to send replacements on a launch
* The ability to create makeshift replacement parts while waiting for resupply could prevent flight experiments from losing critical operation time

**Types of ISS Damage**

- <https://www.universetoday.com/101567/how-micrometeoroid-impacts-pose-a-danger-for-todays-spacewalk/>

- <https://www.hou.usra.edu/meetings/orbitaldebris2019/orbital2019paper/pdf/6001.pdf>

- Spacewalk danger to astronauts:

o Micrometeoroid impacts leave small but very sharp craters on the handrails attached to the outside of the ISS.

o These craters can injure the astronauts if they are sharp enough to tear through the gloves of their suits.

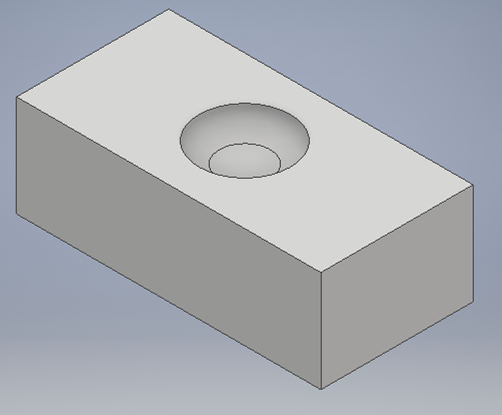
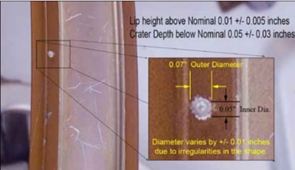
o NASA’s solution so far has been focused on designing thicker and stronger gloves, not repairing the handrails.

- Other common damage to the ISS:

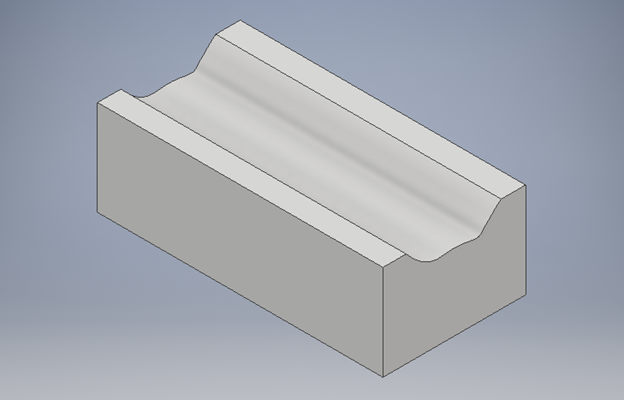
o Tears in the radiator panel from debris impacts

o Impact craters on shields

o Tears in solar array wings

****

Handrail damage on ISS Possible test design sample

****

Radiator damage on ISS Possible test sample design

**Applications in Oceanography**

* [**https://www.sciencedirect.com/science/article/pii/S2211122016300093**](https://www.sciencedirect.com/science/article/pii/S2211122016300093)
* FDM 3D printingis used to build nylon specimens for impact testing
* 3D printing is used to reinforce existing parts and build new parts, so developing a method to repair these parts using 3D printing would be efficient
* 