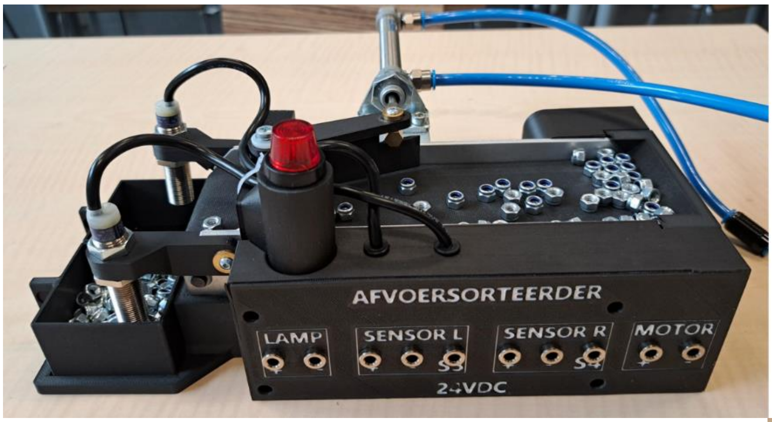
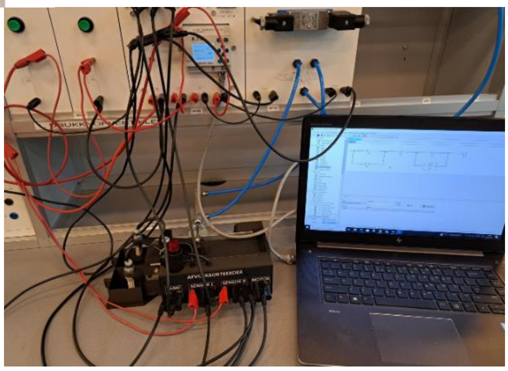
ONTWERPDOSSIER AFVOERSORTEERDER





[Filmpje Afvoersorteerder]

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Datum	17 mei 2024	
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Inhoudsopgave

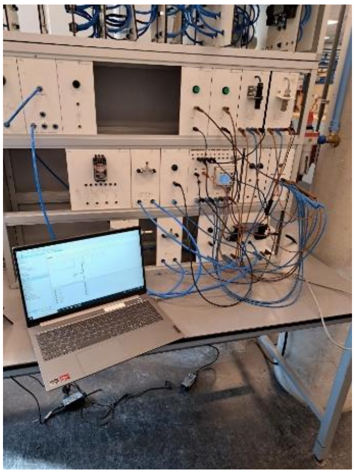
Inleiding

Ter afronding van mijn opleiding “Professionaliseringstraject PIE” moet een geïntegreerd onderwijsmiddel worden ontwikkeld en vervaardigd. **Dit dossier is aangepast n.a.v. van Criterium Gericht Interview (CGI) in juni 2023. De afwijzing hield voornamelijk in dat er sprake was reverse engineering van een CSPE-opdracht die niet expliciet in het dossier werd genoemd. In hoofdstuk 5 heb ik hierop gereflecteerd m.b.v. het model van Korthagen.**

Als onderwijsmiddel heb ik, in overleg met mijn collega’s en begeleidende docenten van Windesheim gekozen om een afvoersorteermachine te ontwikkelen en te maken. Het betreft een opdracht die reeds in ons PTA is opgenomen onder in de verplichte module “Besturen en Automatiseren”. Voor deze opdracht wordt rechtstreeks het blauwe onderdeel D van CSPE 2019 gebruikt.
https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf

De PTA-opdracht draagt nog thans de “Afvalsorteerder”. Wel willen we meer de nadruk leggen dat het apparaat gebruikt wordt om te waarborgen dat productieprocessen gecontinueerd worden in fabrieken, van bijvoorbeeld afvoer en collecteren van M4-moertjes. De naamgeving in ons PTA zal op termijn dan ook gewijzigd worden van “Afvalsorteerder” in “Afvoersorteerder”.

De aanleiding voor de keuze is dat leerlingen (KB-niveau) een schakelopdracht met een besturingsprogramma maken op het schakelbord en laptop, maar vaak moeilijk een voorstelling kunnen maken hoe een installatie er in het echt zou kunnen uitzien, laat staan de voordelen te bedenken bij automatisering. De huidige PTA-opdracht is het uitwerken van de genoemde opdracht. Bijgaand plaatje laat zien dat het geheel niet bepaald tot de verbeelding spreekt. Hierbij moet niet uit het oog verloren worden dat het juist aansluiten van stuurventielen, sensoren e.d. en programma-invoer een vast deel moet blijven uitmaken van de PTA-opdracht. M.a.w. niet een volautomatisch apparaat, met, bewijze van spreken, alleen aan/uitknop.



Figuur 1 Hoe de huidige uitvoering eruit ziet

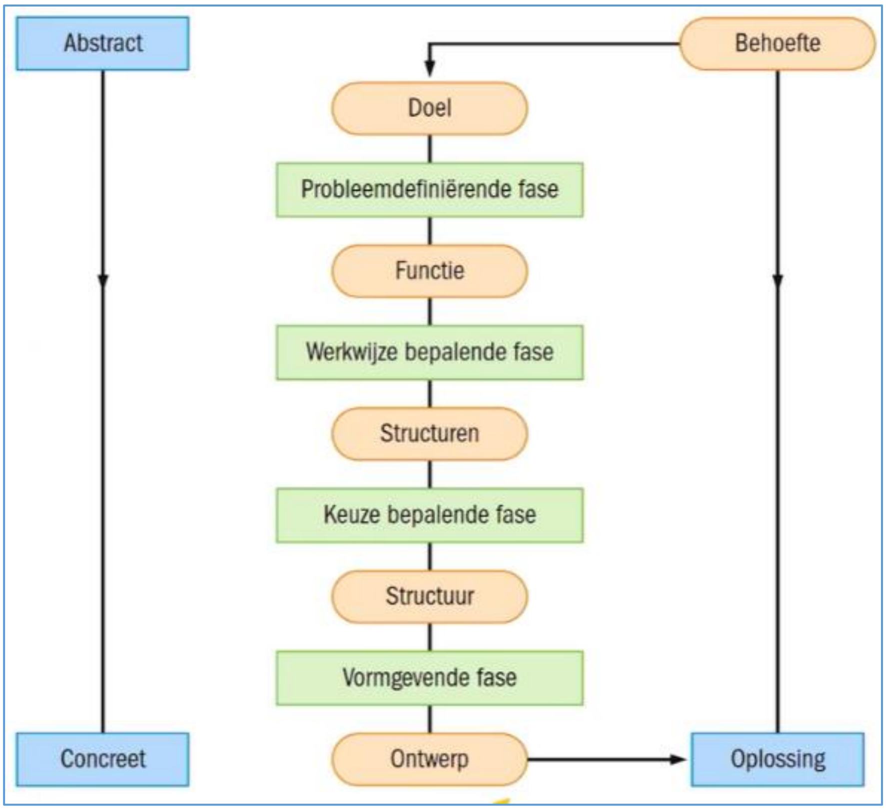
Daartoe ontsproot het idee een apparaat te ontwikkelen, waarmee de leerling daadwerkelijk ziet waarvoor zo’n de afvoersorteerder dient, dan alleen wat knopjes, sensoren, lampjes en een heen en weergaande luchtcilinder.

Bij het vervaardigen van de afvoersorteerder zijn twee van de drie PIE-vakbekwaamheden bevatten.

De afvoersorteerder zal ingezet worden ter afronding van een summatieve PTA-opdracht. Naast het fysieke product zal een duidelijk opdrachtomschrijving voor de leerlingen moeten komen, waarmee ze zelfstandig aan de slag gaan.

Ik heb de stappen uit het boek Basisboek Ontwerpen van Wim Zeiler gevolgd om zo mijn ontwerpdossier te maken. (Zeiler, 2014). Daarbij is het proces ingedeeld in de volgende fases: A - probleem definiërende fase. B - werkwijze bepalende fase. C - keuzebepalende fase. D - vormgevende fase. Hier is het eindproduct in werking te zien: Filmpje Afvoersorteerder

Vooraf gaand is een Plan Van Aanpak (PVA) gemaakt, die in bijlage H is opgenomen.



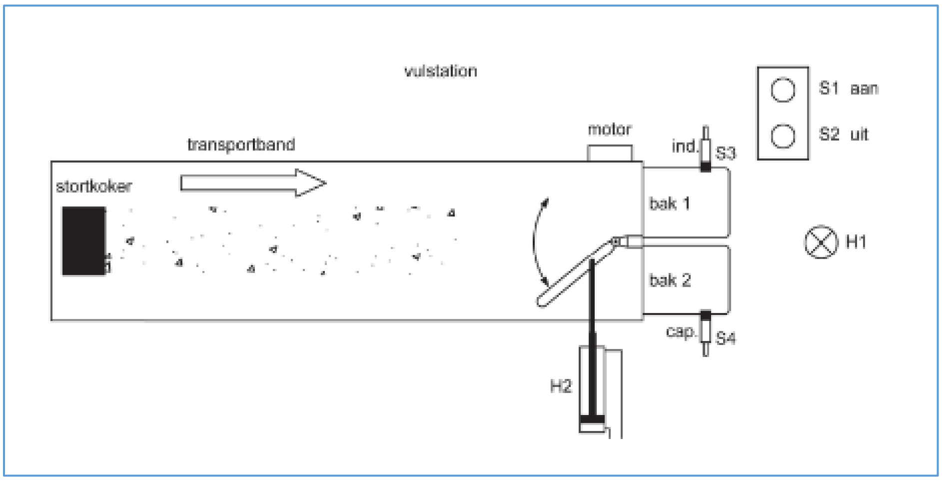
Figuur 2: Ontwerpfasering volgens Zeiler (Zeiler, 2014)

1. Probleem definiërende fase

1.1. Probleemstelling m.b.t. de huidige PTA-opdracht

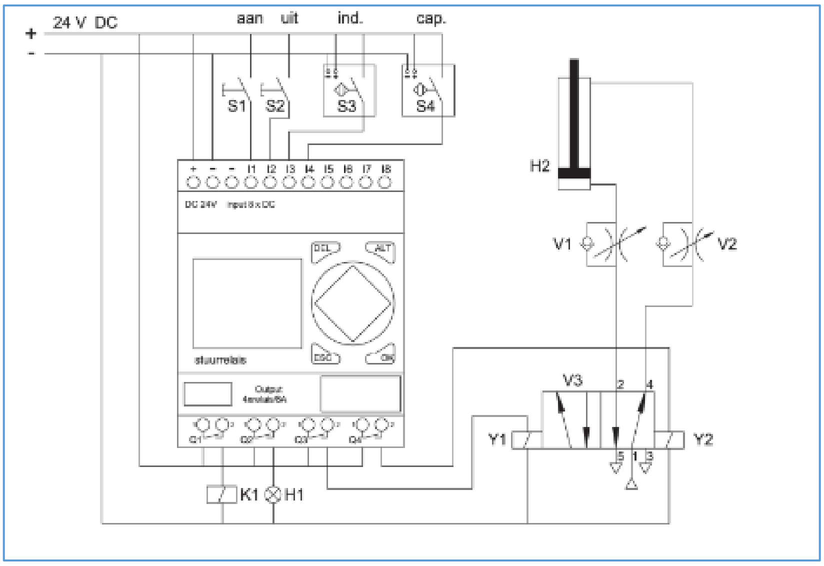
De werkelijke (hetzij onbewuste) opdrachtgevers zijn onze leerlingen. Ze geven dikwijls aan geen beeld te hebben waarom en hoe besturingstechniek, in het bedrijfsleven, wordt toegepast. Na een aantal formatieve opdrachten, zoals elektropneumatiek, programmeren en aansluiten van de EasyRelais, moeten de leerlingen de summatieve PTA-opdracht is de zogenaamde "Afvalsorteerder" voltooien. Dit is een opdracht waarvoor rechtstreeks het blauwe onderdeel D van het CSPE 2019 is gebruikt. https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf

Ondanks afbeelding in figuur 3 en de opdrachtomschrijving is het voor de leerlingen lastig zich een voorstelling te maken hoe een dergelijke installatie er in het echt zou kunnen uitzien en werken.

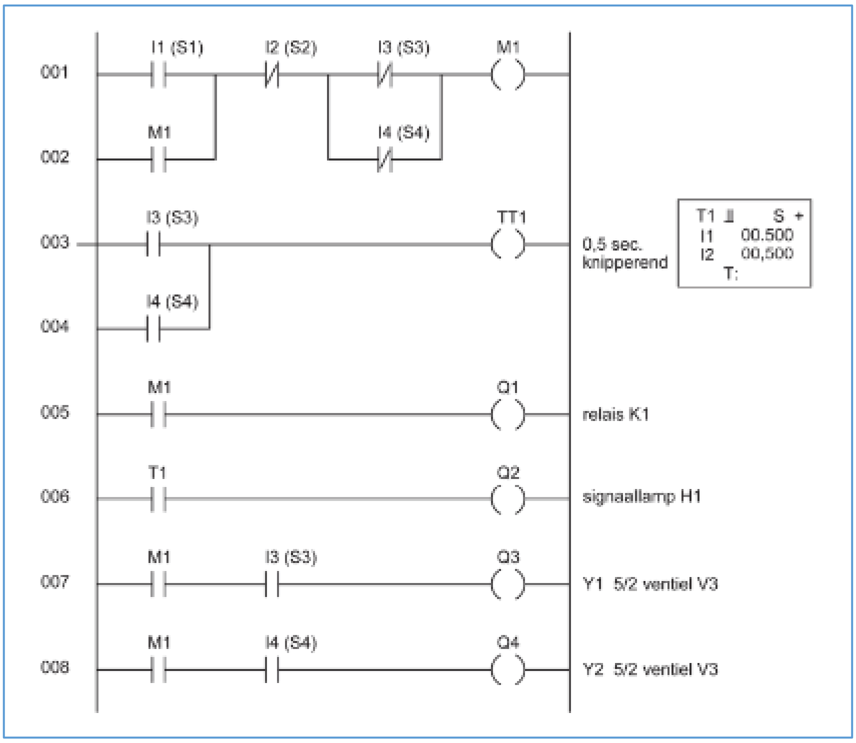


Figuur 3 De afvalsorteerder (College voor Toetsen en Examens, 2019) (bron CSPE 2019, onderdeel D Blauw)

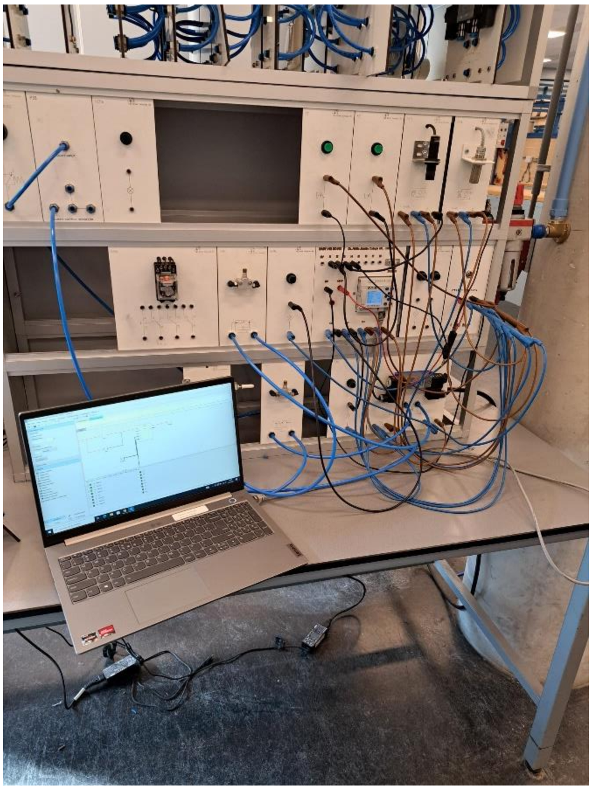
Het programmeren wordt vaak als lastig ervaren en de toepassing besturing en automatiseren, in het bedrijfsleven, zijn voor hen veelal abstract. Met een apparaat, die ook daadwerkelijk datgene doet, wat in de opdracht staat omschreven, zal het nut duidelijk worden en de materie beter beklijven.



Figuur 4: Elektro pneumatisch schema voor de afvalsorteerder (College voor Toetsen en Examens, 2019) ([bron CSPE 2019, onderdeel D Blauw](#))



Figuur 5: Ladderdiagram voor de afvalsorteerder (College voor Toetsen en Examens, 2019) ([bron CSPE 2019, onderdeel D Blauw](#))



Figuur 6: Zoals de opdracht nu in praktijk wordt uitgevoerd

Hierbij waren, voor mij, de 7 Hulpvragen (6 W's) van (Verhoeven, 2018) **een hulpvolle methode:**

Wie	Leerling.
Wat	Door abstractie onduidelijkheid over het nut bij de leerling.
Waar	Op de werkplekken/experimenteerborden waar de opdrachten worden uitgevoerd.
Wanneer	Bij het uitvoeren van de summatieve opdracht "Afvalsorteerder".
Waarom	Een aangesloten en geprogrammeerde EasyRelais met alleen actuatoren als schakelrelais, een signaal lamp en dubbelwerkende persluchtcilinder geeft geen duidelijk genoeg beeld over waar het voor dient. Ook de toepassing van de ingangssignalen m.b.v. capacitieve en/of inductieve sensoren spreken niet tot de verbeelding. Dus is een werkend apparaat nodig waarmee gedemonstreerd wordt, wat erna gebeurt als het eerst bakje volloopt, enz. ….
Waardoor	Leerlingen hebben (nog) geen excursie gehad bij een procesfabriek waar automatisering wordt toegepast. Naast technisch ook geen (volledig) beeld van economisch voordeel (humane arbeid versus automatisering/robotisering.

Naar (Verhoeven, 2018)

1.2. Doelstelling

Het ontwikkelen en maken van een leermiddel (afvoersorteerder) waarmee leerlingen bewust worden gemaakt van het nut en doel van besturingstechniek. Met dit middel leert de leerling het juist aansluiten en programmeren van de besturing. Ook worden de leerlingen in aanraking gebracht van professioneel 3D-printen, met versterkte composieten.

Zoals al eerder wordt de naam van huidige PTA-opdracht “Afvalsorteerder” gewijzigd in “Afvoersorteerder”. **Hiermee wordt de link gelegd dat een machine moertjes fabriceert, waarbij de eis is dat het proces continue moet doorgaan. Alleen als de operator verzaakt bij legen, zal het proces stoppen.**

De opdracht is bestemd voor PIE KB-leerlingen en gaat van de syllabus van de verplichte module “Besturen en Automatiseren” de volgende delen afdekken en kunnen als vaste eis worden beschouwd:

- Van deeltaak, P/PIE/3.1: 1, 2, 3, 4, 6, 7 en 8.
- Van deeltaak, P/PIE/3.3: 1 t/m 5.

Het programma van eisen zijn in navolgende paragraaf uitgezet. Belangrijkste (en dus vaste) eis is dat de te maken installatie direct ingezet kan worden voor het uitvoeren van onderdeel D, van CSPE 2019, die opgenomen is in ons PTA (Programma van Toetsing en Afsluiting) van de verplichte module Besturen en Automatiseren. https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf

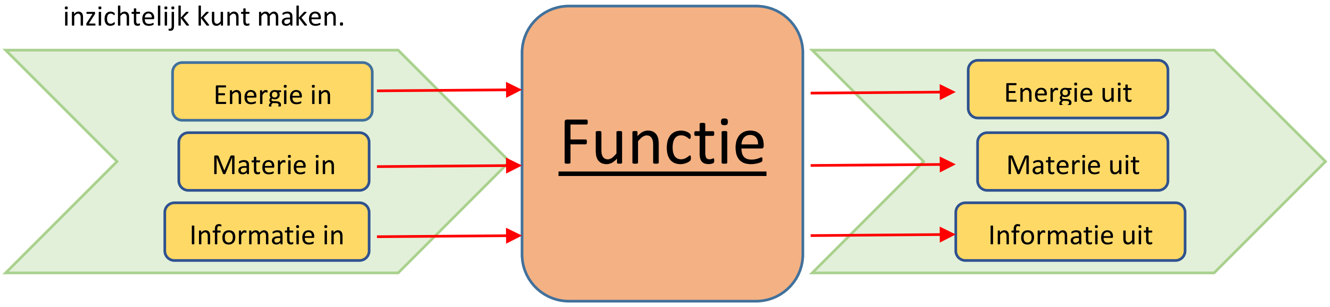
1.3. Programma van eisen

Functioneel	Fabricage	Programma van eisen	Vaste eis	Variabele eis	Wens	N.v.t.
X		De installatie moet geschikt zijn voor het uitvoeren van onderdeel D van CSPE 2019. Deze is opgenomen in het PTA van module Besturen en Automatiseren.	X			
	X	Idem.		X		
		• De opdracht moet de delen P/PIE/3.1 van Besturen en Automatiseren afdekken, op KB-niveau. Met de productieafvoerder moeten de volgende onderwijscomponenten uitgevoerd kunnen worden:				
X		1. Een pneumatische schakeling opbouwen.	X			
X		2. Een programmeerbare EasyRelais aansluiten en een programma invoeren.	X			
X		3. Sensoren en actuatoren kiezen en aansluiten.	X			
X		4. Een regelsysteem opbouwen, aansluiten en testen.	X			
		5. Een domotica-installatie opbouwen, aansluiten en testen.				X
X		6. Storingen en fouten zoeken en verhelpen in de opgebouwde schakeling.		X		
		7. Metingen uitvoeren aan een besturingsinstallatie.				X
		8. een verslag maken en de resultaten presenteren			X	
		• De opdracht moet de delen P/PIE/3.3 van Besturen en Automatiseren afdekken, op KB-niveau. Met de productieafvoerder moeten de volgende onderwijscomponenten uitgevoerd kunnen worden:				
X		1. Besturingscomponenten plaatsen aan de hand van een opstellingstekening.		X		
X		2. De besturingscomponenten bedraden en aansluiten aan de hand van een bedradingstekening.	X			
X	X	3. Een programma invoeren in een programmeerbaar relais.	X			
X		4. De automatische besturing testen.		X		
		5. De automatische besturing demonstreren en presenteren.	X			
X		De opdracht moet in 3 lesuren van 45 minuten gerealiseerd kunnen worden.	X			
X		100% van de productiedelen (moertjes) moeten tijdens transport aankomen.		X		
X		Afvoerproces mag niet stoppen moet continue doorgaan. (Door bijvoorbeeld productieafvoer automatisch in 2 stromen te kunnen leiden).	X			
X		Operator moet tijdig gewaarschuwd worden als het proces dreigt te stoppen.	X			
X		Als de operator verzaakt om tijdig in te grijpen, moet het proces alsnog stoppen.	X			
	X	Snelheid afvoertransport moet 50mm/s zijn.		X		
X		Veiligheid: afscherming van aandrijving.	X			
	X	Afmetingen afvoersorteerder: L x B x H = 300 x 100 x 100.		X		
	X	Gewicht ≤ 5kg.		X		
	X	Te maken met cataloguskoopdelen, 3D-printer, plaatdelen 2mm en inkoopdelen Brink Techniek BV.		X		
	X	De maakkosten mogen niet hoger dan €500,-.		X		
	X	De afvoersorteerder moet gemaakt kunnen worden in 3 maanden.		X		
	X	Bij een val van 1,5m geen ontzetschade aan de ophanging.		X		
X		Weinig onderhoud.		X		
	X	Defecte geraakte onderdelen moeten binnen 24 uren te vervangen zijn.		X		
X		Werking betrouwbaar.		X		
	X	Complexiteit onderdelen laag.		X		
	X	Zo weinig mogelijk onderdelen.		X		

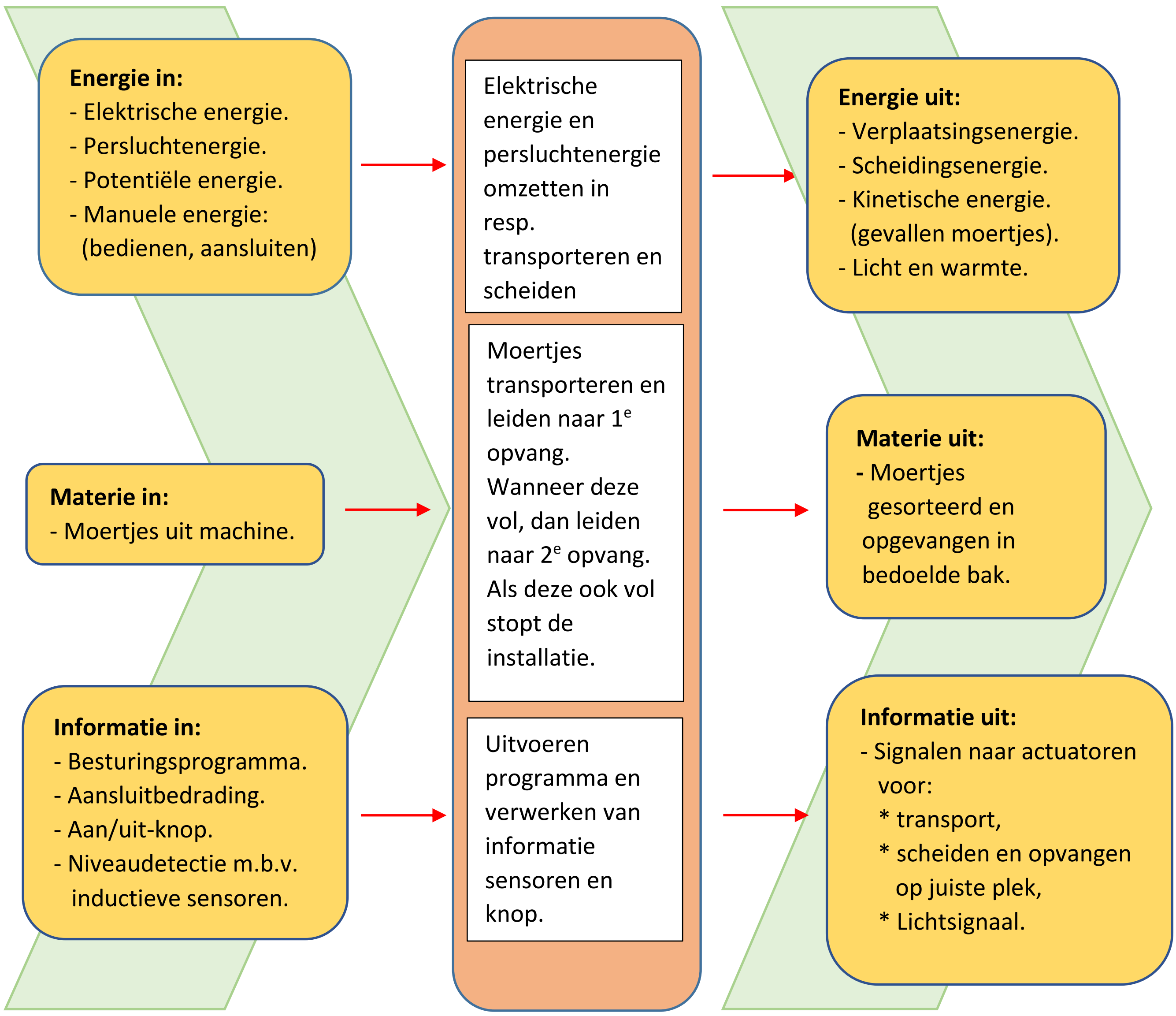
Naar (Zeiler, 2014)

1.4. MEI-diagram

In bijgaande MEI-diagram zijn de energie-omzettingen in kaart gebracht, waarmee helderheid gekregen wordt over de noodzakelijke functies. Hiervoor zijn figuren 3 gebruikt als leidraad (CSPE 2019, onderdeel D) https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf. Laten we wel wezen; het is mosterd na de maaltijd, maar het is wel interessant om te zien hoe zo'n diagram eruitziet in de gegeven situatie. M.a.w. hoe je de stromen inzichtelijk kunt maken.



Figuur 7: MEI-diagram algemeen (Zeiler, 2014)



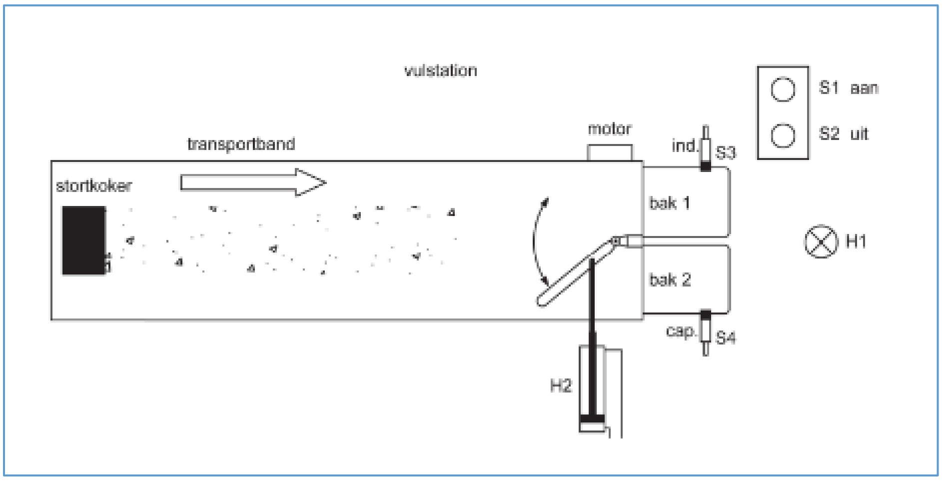
Figuur 8: Specifiek MEI-diagram naar (Zeiler, 2014)

2. Werkwijze bepalende fase

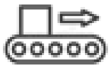
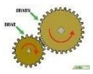
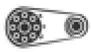
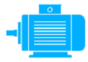
De functies volgen uit de opdracht https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf Nu kan er een morfologisch overzicht worden gemaakt. Hierbij heb ik 3 werkwijzen uitgezet.

2.1. Morfologische kaart

Omdat CSPE, onderdeel D, van 2019 wordt gebruikt, heb ik er niet voor gekozen om een geheel ander principe te gaan ontwikkelen, dan figuren 3, 4 en 5. Bijvoorbeeld: Het geleiden van schroefjes op de transportband naar de juiste bak zou namelijk ook op een andere wijze gedaan kunnen gaan, dan met een schuif die pneumatisch is aangedreven (bijvoorbeeld een kantelsysteem). Derhalve is dit (en andere principes) dan ook niet in de morfologische kaart opgenomen. M.a.w. een en ander is al reeds vastgelegd. Schematisch zal de afvoersorteerder er komen uit te zien als figuur 9. Er zullen zijframes nodig zijn waarin de motor, transportband, overbrenging en productscheiding zijn opgehangen.



Figuur 9 De afvalsorteerder (College voor Toetsen en Examens, 2019) (bron CSPE 2019, onderdeel D)

Transporteren moertjes	Flexibele Transportband 	Kettingband 	
Materiaal zijframes	Aluminium plaat	Verzinkte plaat	Kunststof 3D geprint
Materiaal omkasting	Aluminium plaat	Verzinkte plaat	Kunststof 3D geprint
Materiaal scheidingsschuif en opvangbakjes	Aluminium plaat	Verzinkte plaat	Kunststof 3D geprint
Materiaal transportrollen	Ø Messing	Ø automatenstaal	Kunststof 3D geprint met stalen asje
Signaallamp	Vast aan installatie	Los van installatie	
Instellen hoogte niveaudetectie S3 en S4	Statiefklem 	Schroefbeweging 	Scharnierend 
Overbrenging	Tandwielen 	Ketting 	Aandrijfriem 
Aandrijving	Brandstofmotor 	Elektromotor 	Luchtmotor 
Programmeren Easyrelais	Directe handmatige invoer. 	M.b.v. programma Easysoft easy	
Aansluiten bedrading sensoren, motor en signaallamp.	Krokodillebekjes op lipjes omkasting	Stekerbusjes in omkasting	
Keuzes die vastliggen n.a.v. CSPE-opdracht: • Programma. • Niveaudetectie. • In- en uitschakelen. • Lichtsignalering. • Pneumatische bediening schuif			

1	
2	
3	

3. Keuze bepalende fase

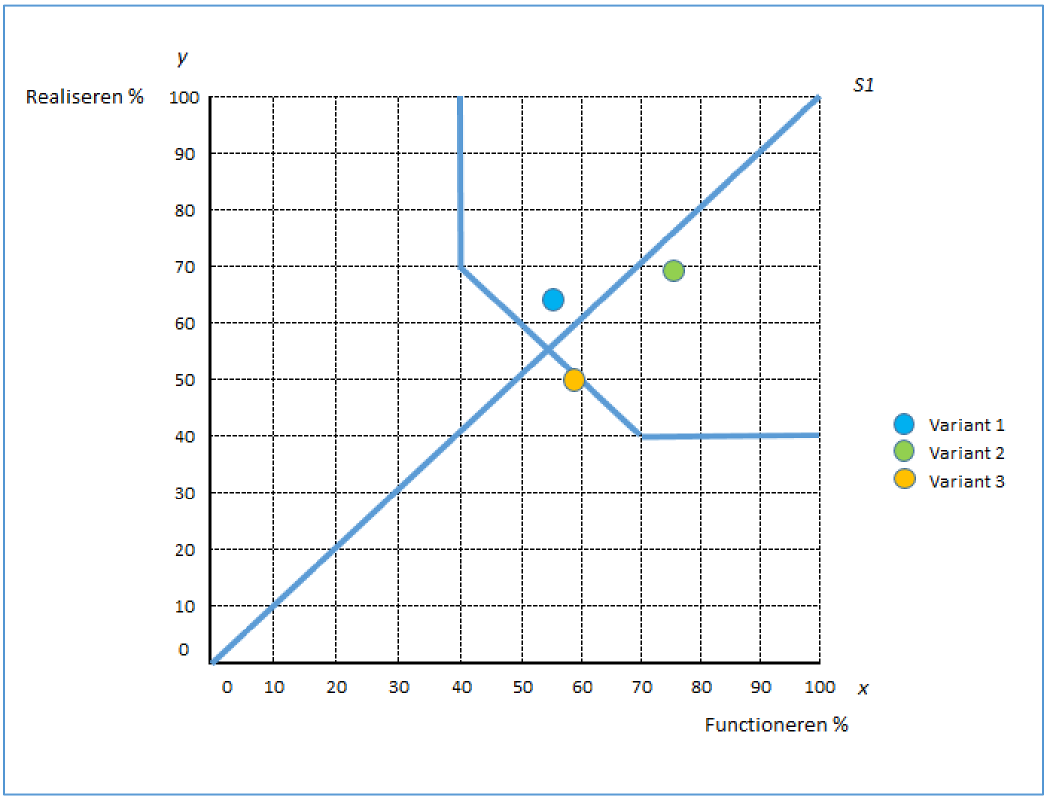
In deze fase wordt de keuze bepaald om door middel van het punten per werkwijze/uitvoering. Links staan de gebruikerseisen en rechts fabricage-eisen uiteengezet, wat als input in het S-diagram (Kesselring) zal dienen. Dit teneinde een verantwoorde en goede keuze te kunnen maken.

Gebruikerseisen	1	2	3	Ideaal	Fabricage-eisen	1	2	3	Ideaal
Makkelijk te handelen voor de leerling qua gewicht en afmetingen	2	3	2	4	Stijheid constructie m.b.t. buiging, wringing etc.	3	3	2	4
Opbouw en bedieningsgemak	1	3	2	4					
Syllabus: Geschikt voor opbouwen, aansluiten en testen	2	3	3	4	Defecte onderdelen kunnen binnen 24 uur gereproduceerd worden t.b.v. vervanging	1	3	1	4
Syllabus: Geschikt voor oefenen met storing en fouten zoeken	2	3	3	4	Fabricagekosten	3	2	2	4
Betrouwbare werking	3	3	1	4	Eenvoudige constructie	2	3	1	4
Veilig in gebruik	2	3	3	4	Eenvoudige montage	3	3	2	4
Weinig onderhoud	3	3	2	4	Toepassing inkoop/catalogusmaterialen	3	3	3	4
Werking moet tot de verbeelding spreken	3	3	3	4	Lage complexiteit onderdelen	3	2	3	4
Totaal X	18	24	19	32	Totaal Y	18	19	14	28
	56%	75%	59%	100%		64%	68%	50%	100%

Figuur 10: Beoordelingscriteria functioneren/gebruiken en realiseren/fabriceren

Bij het uitzetten van de drie werkwijzen blijkt variant 2 favoriet, met 75% gebruikerseisen en 68% fabricage-eisen. De S-lijn (S-1) is de 100% lijn en te zien is dat variant het dichtste bij deze ideale lijn zit.

Bovendien is te zien dat variant 3 buiten de grenswaarden (min. 40% per as en min 55% gecombineerd) valt en variant 1 op het randje zit.



Figuur 11: Kesselringmethode S-diagram

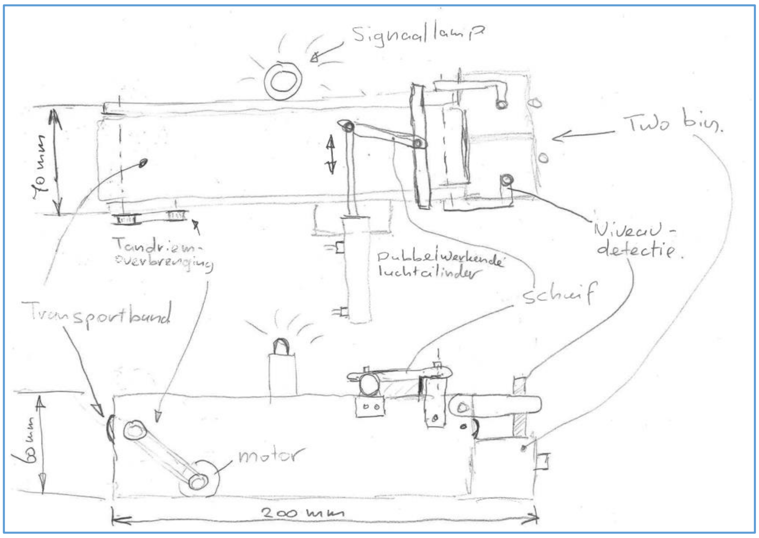
De methodieken hebben ertoe geleid dat de keus valt op variant 2 en dat ik kan starten met de realisatiefase.

4. Realisatiefase

Na de keuze gemaakt te hebben voor variant 2 is het tijd geworden om duidelijk te krijgen hoe het e.e.a. gerealiseerd moet worden.

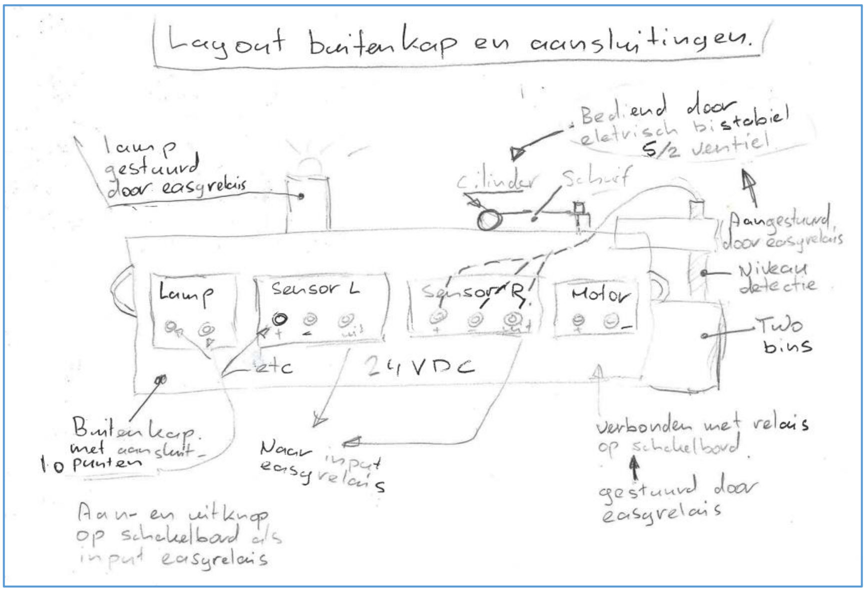
4.1. Schetsen

Uiteraard dient figuur 3, op bladzijde 7, hier als basis. De schetsen die hierop gemaakt zijn, dienen als input voor de CAD-tekeningen en inzicht te krijgen wat getekend en/of besteld moet worden.



Figuur 12: Schets boven- en zijaanzicht

In het programma van eisen hebben is duidelijk naar voren gekomen dat de afvoersorteerder geen kant- en klaar product moet worden, met, bij wijze van spreken, alleen een aan- uit knop. M.a.w. het correct aansluiten van de dubbelwerkende cilinder, het 5/2 bi-stabiel ventiel, aansluiten van sensoren, aansluiten van de signaallamp en het programmeren van de EasyRelais moet deel uitmaken van de opdracht. Aan de zijkant (o.i.d.) zal daarom een aansluitpaneel gerealiseerd moeten worden. Daartoe kwam de volgende schets tot stand.



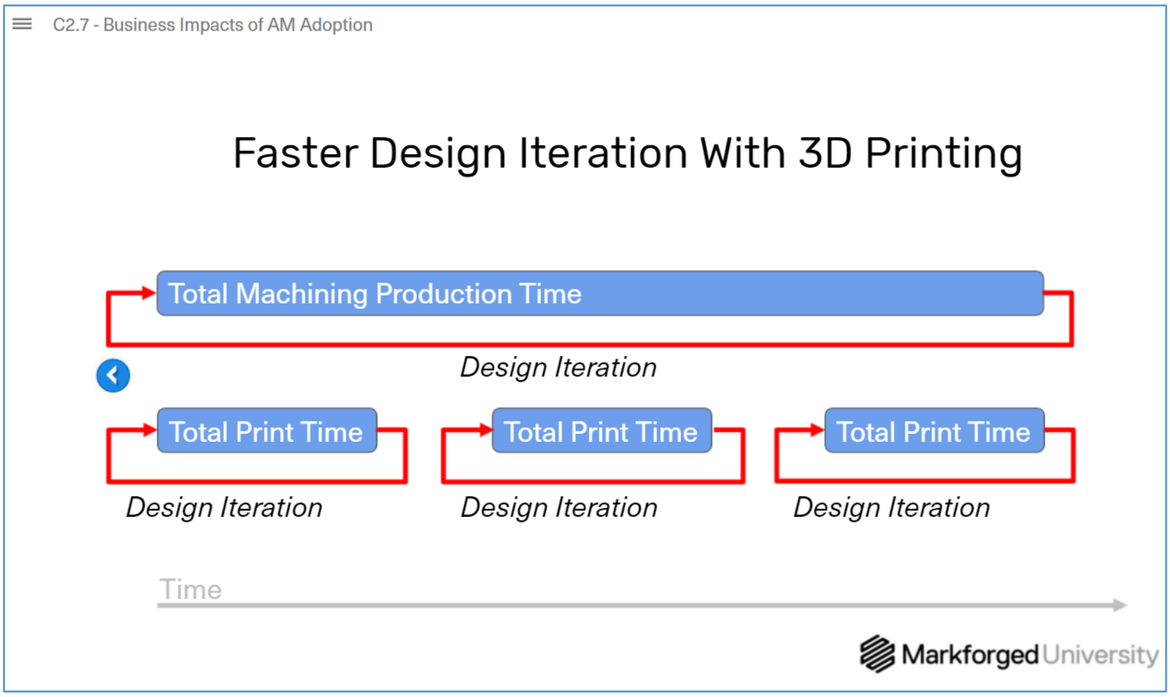
Figuur 13: Lay-out van de buitenkap en aansluitingen

4.2. Getekende 3D-modellen geprint

In de gekozen oplossing (variant 2) is opgenomen en gesteld dat defect geraakte onderdelen binnen 24h vervangen moeten kunnen worden (printer een nachtje laten draaien). Op onze deelschool is dit mogelijk, omdat we beschikken over 2 professionele printers waarmee onderdelen geprint kunnen worden, met treksterktes vergelijkbaar (of zelfs meer dan) van aluminium. Het betreft twee 3D-printers: “Onyx One” en de “Mark Two”, beide van het merk Markforged.

De Onyx One kan alleen het basis-filament Onyx verwerken en wordt **Fused Filament Fabrication (FFF)**. De Mark Two kan daarentegen ook versterkte vezels worden toevoegen en wordt **Continues Filament Fabrication (CFF)** genoemd. In de navolgende paragrafen 2.4.1 en 2.4.2 worden deze principes verder behandeld.

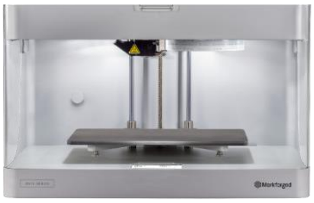
Bijkomend voordeel is dat, bij het ontwerpproces, snel beschikt kan worden over een aangepast product (iteratie): Sneller een definitief product, voor lagere kosten. Dit in vergelijking met bijvoorbeeld CNC-verspanen uit aluminium. Notie: Bij goede toepassing van versterkt materiaal, zijn bij 3D-printen zelfs hogere treksterktes mogelijk. Bijgaande figuur 14 komt uit de onlineopleiding “Markforged University Çomposites Training” die ik vorig jaar heb afgerond. In §4.3 licht ik dit verder toe.



Figuur 14: Met 3D-printen een snellere ontwerpiteratie (Hayford & Sapienza, 2021)

4.2.1. Bijzonderheden printer Onyx One (FFF)

De Onyx One werkt volgens het principe Fused Filament Fabrication (FFF). Kort gezegd houdt dit in dat er alleen basismateriaal Onyx kan worden verwerkt. De specificaties hiervan worden verder in deze § uiteengezet. Deze zijn opgehaald in: https://markforged.com/3d-printers/onyx-one. (Markforged, 2022). Via deze link is de data sheet te downloaden: F-PR-4011.pdf



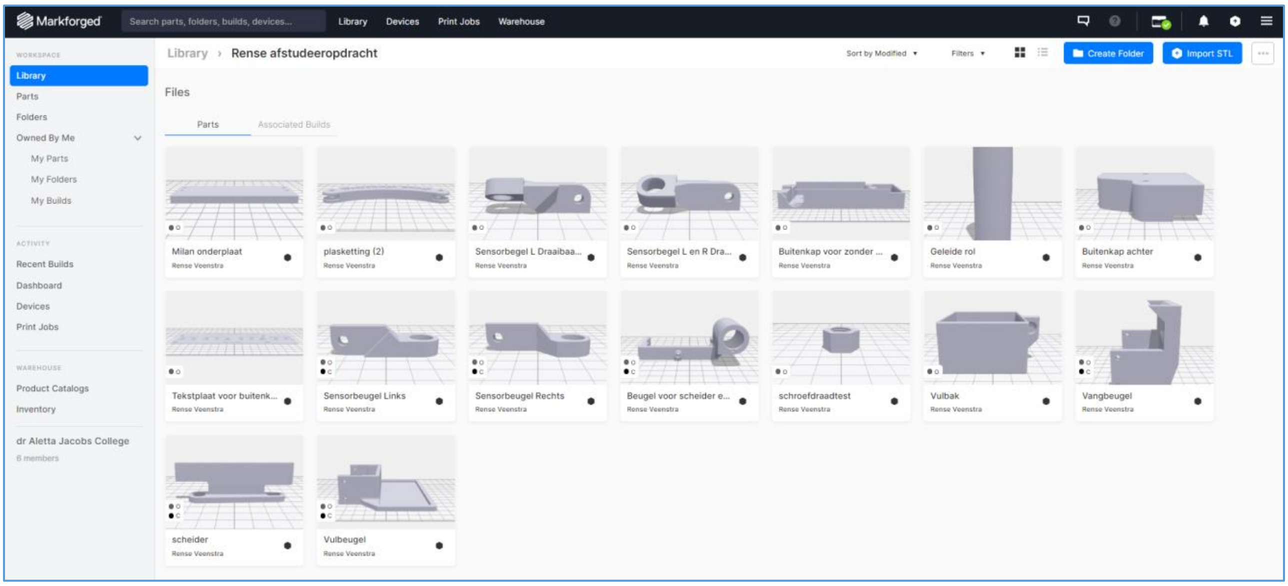
Figuur 15: Het instapmodel Onyx One (Markforged, 2022)

4.2.1.1. Specificaties Onyx One 3D-printer

- Merk / type: Markforged / Onyx One 3D
- Werkbereik X, Y, Z: 320mm x 132mm x 154mm
- Repeteernauwkeurigheid: 0,1 – 0,2mm
- Productiesnelheden Zie als voorbeeld figuren 2 en 3

4.2.1.2. Softwarematige aansturing

- Deze geschiedt d.m.v. een software-account https://www.eiger.io/library in de cloud, die zeer gemakkelijk te bedienen is. Een 3D-model getekend in een programma, zoals Solid Works, kan weg geschreven worden met de extensie **.STL**, die eenvoudig te importeren is in Eiger/Markforged. Figuur 16 laat mijn bibliotheek zien, in Eiger, van de geïmporteerde onderdelen die ik getekend heb in Solid Works. In § 4.2.5 worden deze nader uitgewerkt.
- In het programma Eiger kan er bijvoorbeeld gekozen worden voor honinggraatstructuur, lineaire structuur of volledig gevuld. Laagdiktes zijn instelbaar.



Figuur 16: Bibliotheek met geïmporteerde onderdelen in Eiger (Markforged, 2023)

4.2.1.3. Specificaties filament Onyx

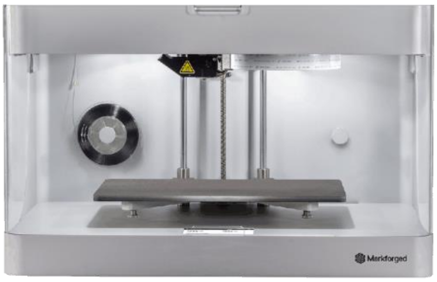
- Onyx is een composiet van PA6 en short cut-carbon fiber. Hierdoor is het niet alleen veel stijver dan standaard PA6, maar ook veel duurzamer en sterker.
  Ook heeft elk geprint product een perfecte zwart-satijnen finish door de toevoeging van het koolstof. Onyx is geschikt voor alle Markforged 3D printers en kan gebruikt worden in combinatie met alle Markforged CFF fibers (Markforged, 2022).
- Voor maximale treksterkte en belasting om zo onderdelen te produceren die sterker en duurzamer zijn dan aluminium.
  - Volgens de specificaties heeft het materiaal een treksterkte van 37 MPa. **Als je dit omrekent, komt dit overeen met 370kg/cm²** (Markforged, 2022)**.**

4.2.2. Bijzonderheden printer Mark Two (CFF)

De Mark Two is in grote lijnen dezelfde printer, ware het niet dat een tweede nozzle versterkte composieten kan toevoegen. Zie rol links in figuur 17. Dit proces wordt Continues Filament Fabrication (CCF) genoemd (Markforged, 2022).

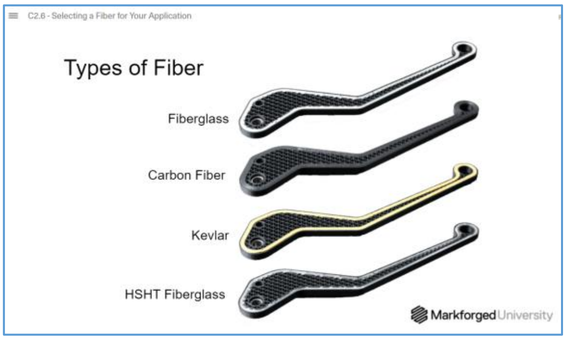
In de afbeelding is links de spoel te vinden Carbonmateriaal. Het basismateriaal Onyx wordt extern in een dry box afgewikkeld. De Onyx One kan alleen het basismateriaal Onyx verwerken. De Mark Two kan versterkte vezels toevoegen, te weten Fiberglass, Carbon Fiber, Kevlar en HSHT Fiberglass (High Strength High Temperature). (Markforged, 2022).

De specificaties en bijzonderheden zijn opgehaald in: https://markforged.com/3d-printers/mark-two. (Markforged, 2022) Via deze site is een data sheet te downloaden: [F-PR-2027.pdf](F-PR-2027.pdf)



Figuur 17 Markforged 3D-printer, type Mark Two (Markforged, 2022)

Uiteraard wordt de keuze van het toe te voegen composiet bepaald door de toepassing. Zo is Kevlar vele malen impactbestendiger dan Carbon.



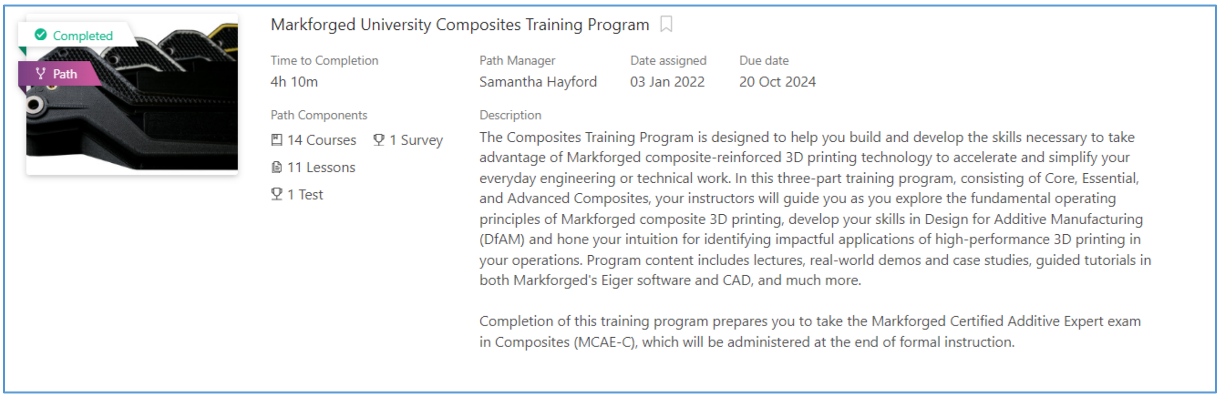
Figuur 18: Verschillende toe te voegen composieten (Hayford & Sapienza, 2021)

4.2.3. Scholing: University Composites Training Program

In het kader van regionale samenwerking zijn er meerdere scholen, in onze regio en nabijgelegen regio’s, die een printer van Markforged hebben aangeschaft. We hebben hier een voortrekkersrol in (Train de Trainer).

Daartoe heb ik de onlineopleiding “University Training Program”, met een aansluitend online examen afgerond. In bijlage I is een samenvatting van de gehele opleiding opgenomen (Hayford & Sapienza, 2021). Bijlage G laat het mijn behaalde certificaat zien.

De inhoud van de opleiding wordt in figuur 19 kort uiteengezet, met daaronder de vertaling in Nederlands.



Figuur 19: Inhoud van de opleiding University Composites Training Program (Hayford & Sapienza, 2021)

Markforged University Composites-trainingsprogramma

Het Composites-trainingsprogramma is ontworpen om u te helpen de vaardigheden op te bouwen en te ontwikkelen die nodig zijn om te profiteren van Markforged composiet versterkte 3D-printtechnologie om uw dagelijkse technische of technische werk te versnellen en te vereenvoudigen. In dit driedelige trainingsprogramma, bestaande uit Core, Essential en Advanced Composites, zullen uw instructeurs u begeleiden bij het verkennen van de fundamentele werkingsprincipes van Markforged composiet 3D-printen, het ontwikkelen van uw vaardigheden in Design for Additive Manufacturing (DfAM) en het aanscherpen van uw intuïtie voor het identificeren van impactvolle toepassingen van high-performance 3D-printen in uw activiteiten. De inhoud van het programma omvat lezingen, real-world demo's en casestudy's, begeleide tutorials in zowel Markforged's Eiger-software als CAD, en nog veel meer.

De voltooiing van dit trainingsprogramma bereidt u voor op het Markforged Certified Additive Expert-examen in Composites (MCAE-C), dat zal worden afgenomen aan het einde van de formele instructie.

Vertaling van figuur 19 (Hayford & Sapienza, 2021)

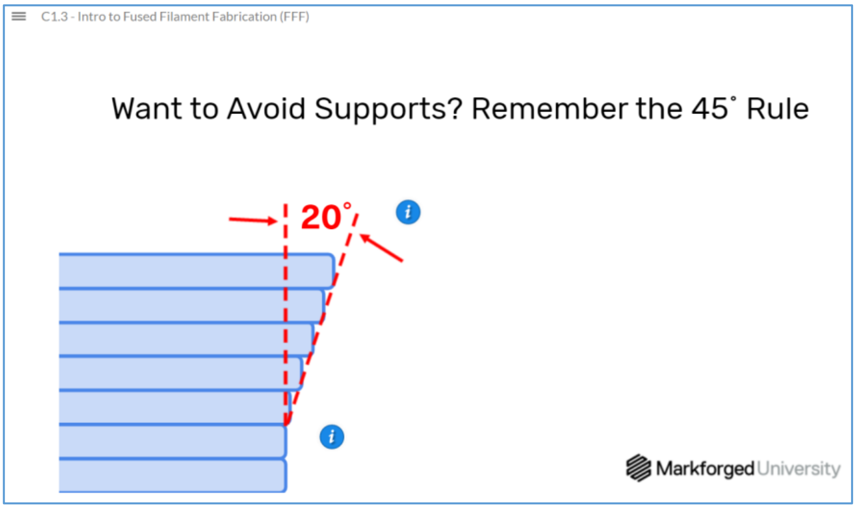
Uiteraard was de opleiding een welkome aanvulling voor ontwerpproces en kan dit dienen als opleiding van collega’s van andere scholen, in het kader van “Train de Trainer”.

In de navolgende paragrafen zijn een paar principes en regels m.b.t. tot 3D-printen opgenomen. In de opleiding is uiteraard veel meer te vinden, maar dit zijn belangrijkste aspecten.

4.2.3.1. Een paar 3D-print principes c.q. regels

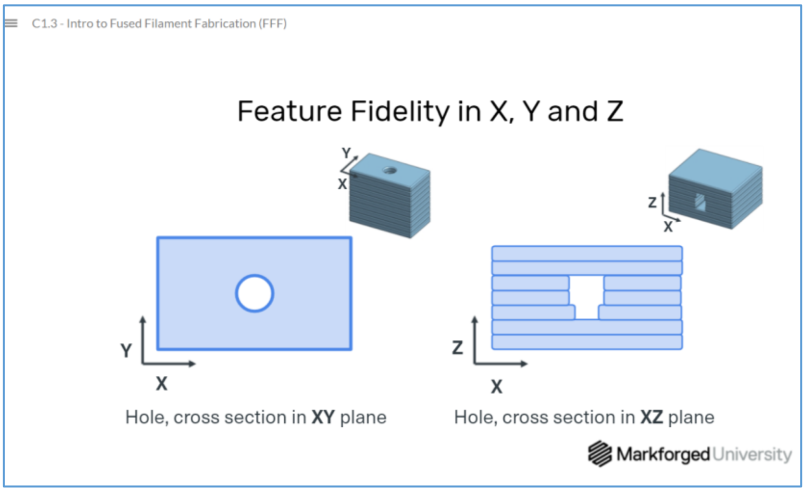
Om verspilling tegen te gaan is het van belang dat bij het ontwerp rekening wordt gehouden met de beperkingen en mogelijkheden bij 3D-printen. Het vergt dus een wijze van denken.

Zo kan gebruik van ondersteuningsmateriaal vermeden worden als de hoek in Z-richting ≤45°



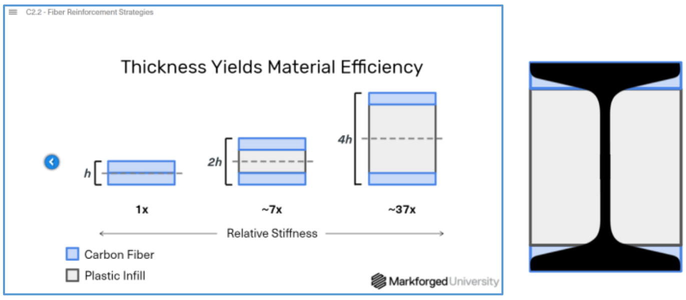
Figuur 20: Bij hoek ≤ 45° geen ondersteuningsmateriaal nodig (Hayford & Sapienza, 2021)

Een volgend aspect waar rekening mee dient te worden is dat de printer in laagjes/druppeltjes het product opbouwt, waardoor de Z-richting op het print-bed rekening worden gehouden dat de Z-richting de zwakste is. Het print-materiaal moet dan ook als een **anisotroop** beschouwd worden. De eigenschappen (in dit geval treksterkte als belangrijkste) zijn *niet* in iedere richting dezelfde zijn.



Figuur 21: Z-richting door anisotropie het zwakst (Hayford & Sapienza, 2021)

Verder is in figuur 18 te zien dat de composieten in de buitenste lagen gepositioneerd is, het zogenaamde sandwich panel. Dit noemen we concentrisch leggen (in Engels: Continues). Dit bespaart versterkt materiaal, terwijl de constructie stijf blijft. Ditzelfde principe wordt immers ook toegepast bij IPE- en HEB-balken. Ook kan er isotropisch gelegd worden (m.a.w. helemaal gevuld), maar kost veel meer versterkt materiaal.



Figuur 22: Voordelen van sandwichvorm: materiaalbesparing (Hayford & Sapienza, 2021)

In bijlage A heb ik een voorbeeldberekening van een traagheidsmoment van een balk en een I-vorm toegevoegd. Als naslagwerk heb ik het studieboek "Sterkteleer" (Bakker, 2005) geraadpleegd. Dit heb ik ook gedaan om mijn werktuigbouwkundige kennis weer eens op te frissen.

Ik kan verder op de materie ingaan maar zou het hierbij willen laten, omdat het m.i. niet meer toevoegt aan het ontwerpdossier. Boodschap is duidelijk: besparing van materiaal en net zo sterk.

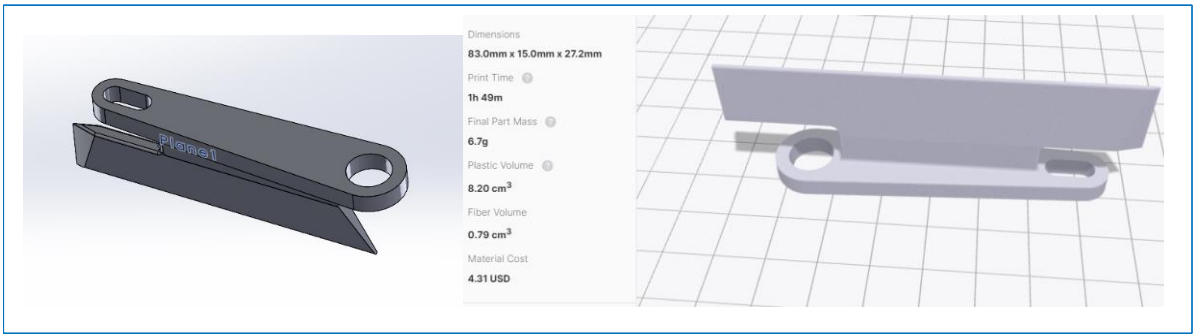
Zoals al eer genoemd zijn er verder nog talloze bijzonderheden, regels etc. te noemen, m.b.t. 3D-printen. In bijlage I is een samenvatting opgenomen van de gehele opleiding "Markforged University Composites Training Program".

4.2.4. Overzicht van 3D-geprinte CAD-onderdelen

In deze paragraaf is het overzicht opgenomen van alle onderdelen die ik getekend heb met Solid Works. Na gereed kunnen deze gemakkelijk weggeschreven worden als en STL-file, die in de cloud programma van Markforged (Eiger) gedownload kan worden.

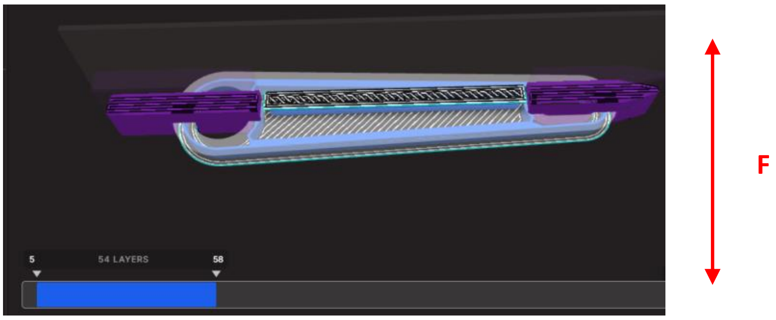
In dit programma kan keuzes worden gemaakt in printrichting, wel of niet toevoegen van versterkt materiaal, wanddiktes, vulwijze en dichtheid, e.d. In de komende afbeelding is links het CAD-model te zien en rechts een screenshot uit het printprogramma, waarin o.a. de materiaalkosten (USD) zijn weergegeven.

De sorteerschuif:



Figuur 23 SW-part en printbestand van de schuif

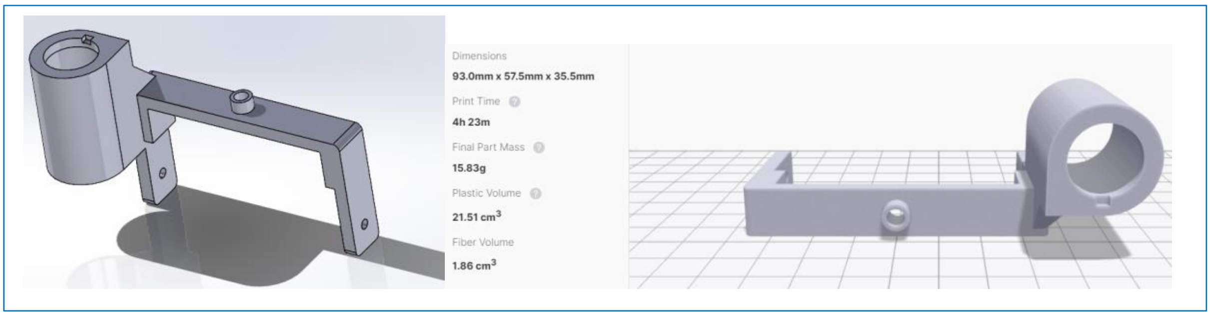
De schuif is geprint met Onyx als basismateriaal en versterkt met carbon, in concentrisch (sandwich) gelegd in de blauw aangegeven lagen 5 tot en met 58. Ook kan er gekozen worden



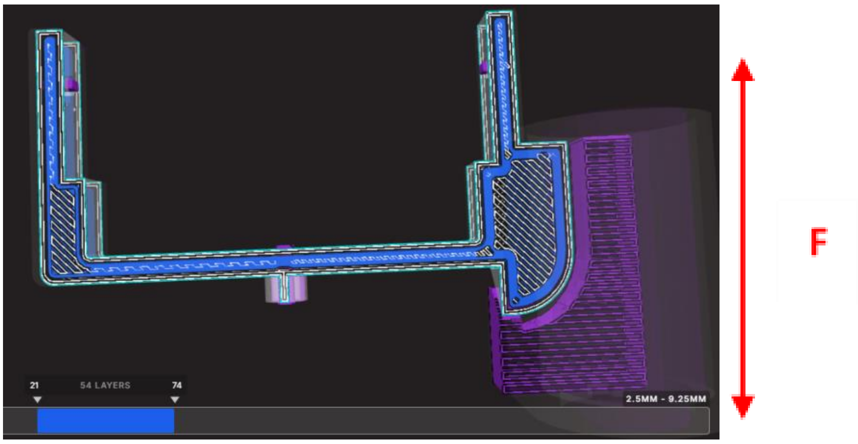
Figuur 24: Inwendige structuur van continue aangebracht carbon.

Dit laat zien dat printrichting wordt bepaald door de belastingsrichting.

Beugel voor schuif en lamp:



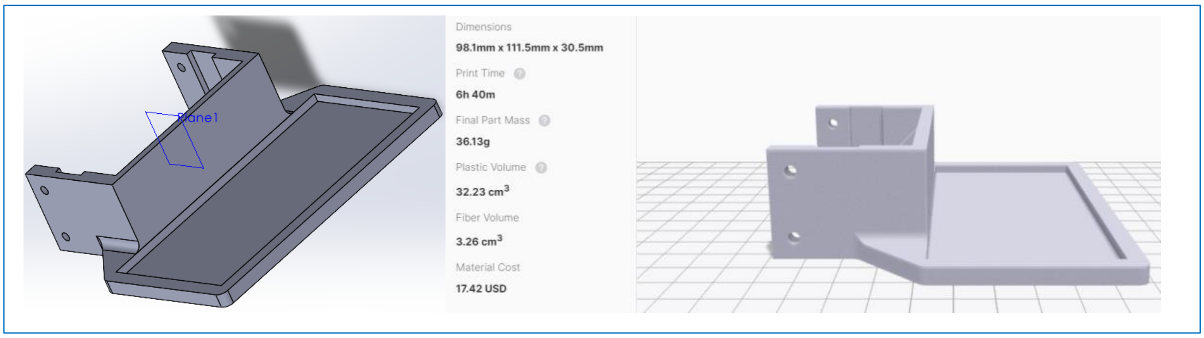
Hier hetzelfde principe. De belasting richting is niet zo zeer functioneel bepaald, maar meer "gebruiker" bepaald.



Figuur 25: Concentrische ligging carbon

Laadplateau:

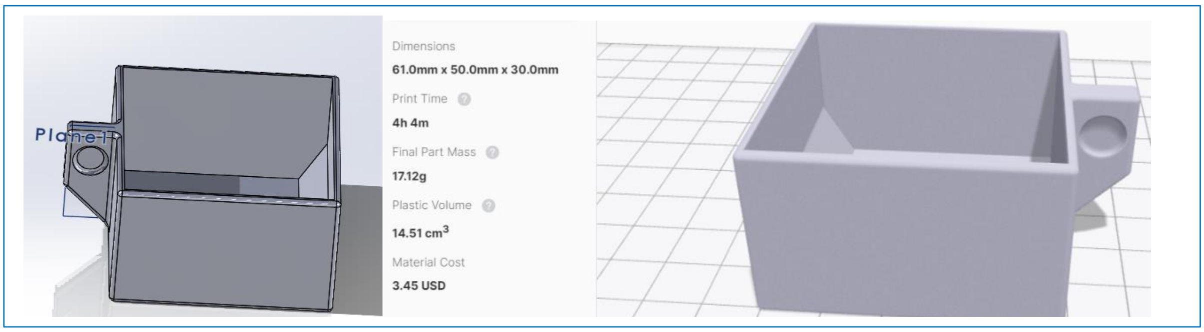
Dit onderdeel komt aan de voorzijde van de afsorteerder te zitten, waarop de 2 vulbakjes geplaatst kunnen worden.



Figuur 26: Laadplateau

Vulbak:

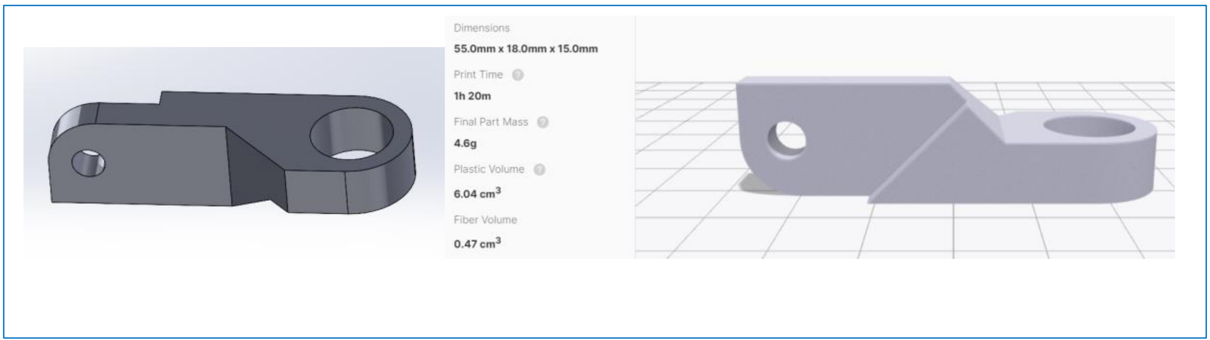
Ook alleen met Onyx geprint. 2 Bakjes zijn nodig die geplaatst kunnen worden op het laadplateau van de afvoersorteerder.



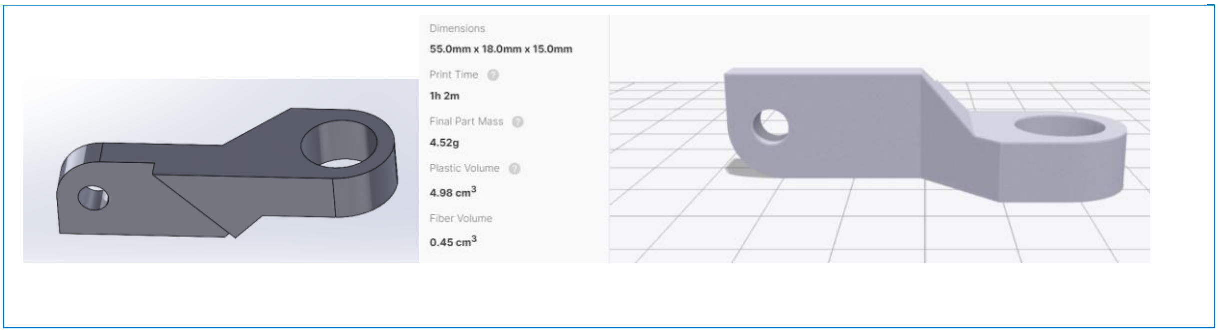
Figuur 27: Vulbak

Sensorbeugel Links en Rechts:

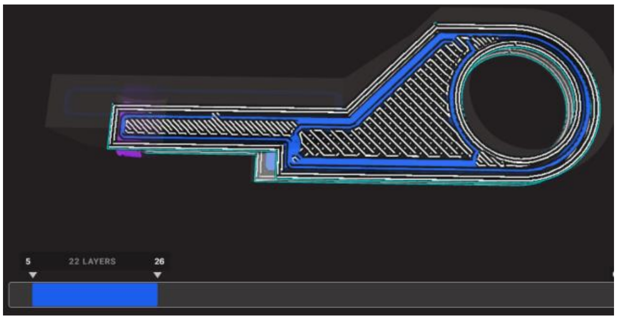
In het programma van eisen heb ik gesteld dat de sensoren in hoogte verstelbaar moeten zijn. Dit om de bakjes makkelijk te kunnen legen. In de morfologische kaart kwam naar voren dat een scharnierende de meest eenvoudige (en dus beste) oplossing is.



Figuur 28: Sensorbeugel Links



Figuur 29: Sensorbeugel Rechts



Figuur 30: Carbon continu gelegd

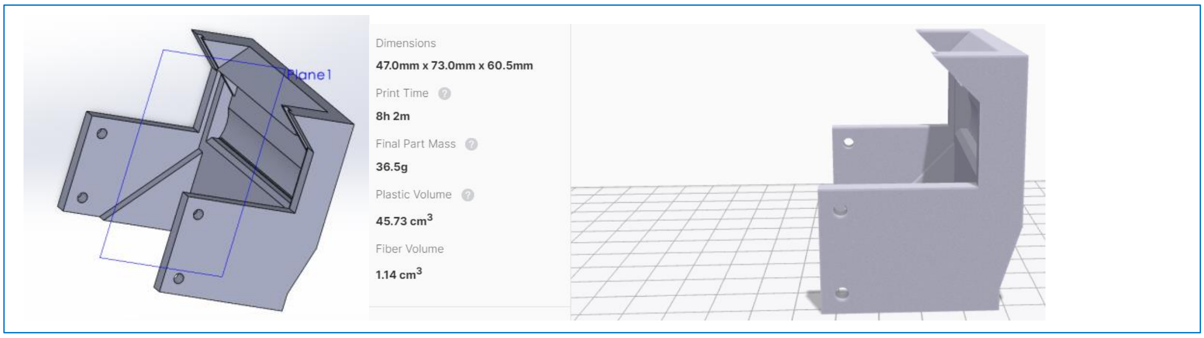
Hier hetzelfde principe. De belasting richting is niet zo zeer functioneel bepaald, maar meer "gebruiker" bepaald.

Verder heb ik van dit onderdeel een 2D-tekening gemaakt, die opgenomen is in bijlage B.

Niet van alle onderdelen heb ik werktekeningen gemaakt, omdat het m.i. niet echt wat toevoegt. Kwestie van keuzes maken, omwille de tijd. De CAD-modellen blijven sowieso in de cloud bewaard.

Opvangbeugel achter:

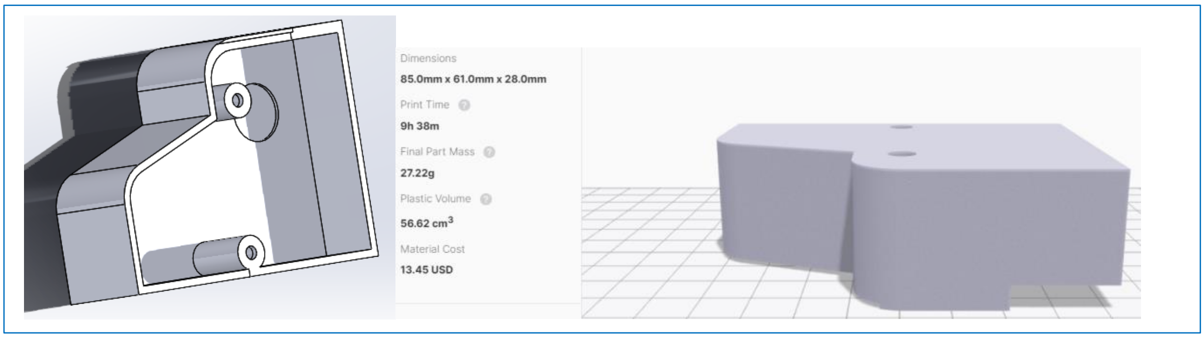
Om te voorkomen dat de moertjes aan begin van de transportband vallen, is deze vangbeugel gerealiseerd.



Figuur 31: Opvangbeugel

Afschermkap:

In het programma van eisen werd de afscherming, van welke overbrenging dan ook, als vaste eis beschouwd. Daartoe is dit kapje gerealiseerd, die de leerling moet beschermen tegen de gekozen tandriemoverbrenging.

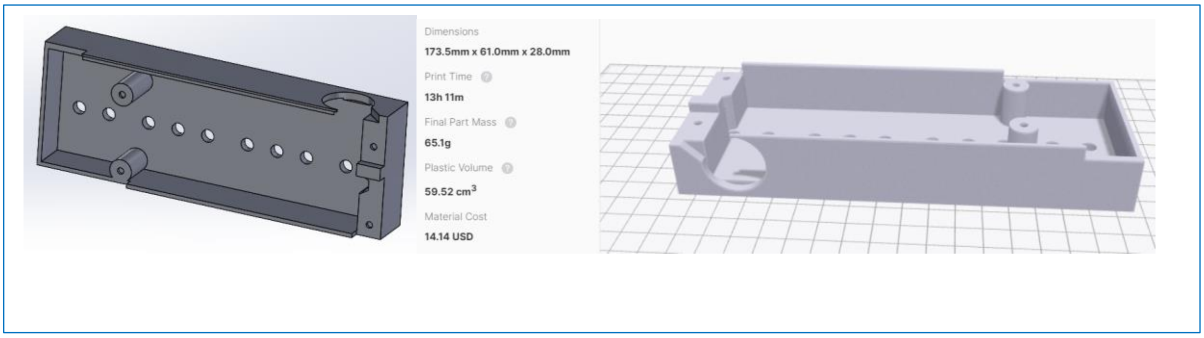


Figuur 32: Afschermkap aandrijving

Ook hier is alleen Onyx gebruikt.

Buitenkap voor aansluiten:

Deze kap wilde in aanvankelijk met holle zijde naar beneden printen, om tekst aan bovenzijde te kunnen realiseren. Dit zou veel ondersteuningsmateriaal hebben gekost.

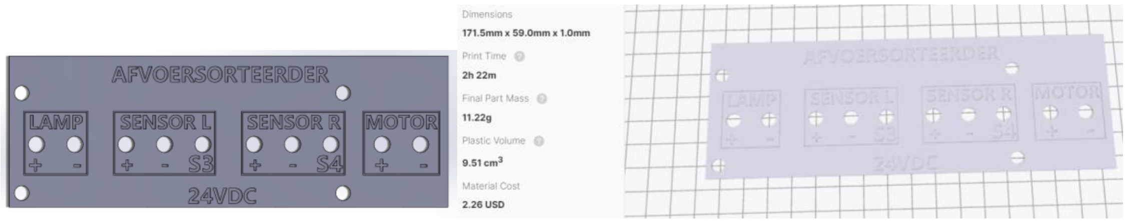


Figuur 33: Buitenkap voor aansluiten

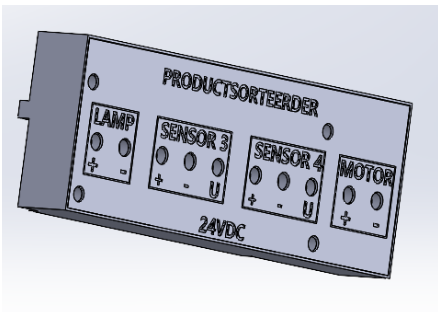
Daarom koos ik voor de volgende oplossing:

- Buitenkap op de kop printen zonder tekst.
- Tekstplaat printen.
    - Bij begin printen pauzeren en lakstift de tekst witten.
    - Verder printen.
- Daarna verlijmen met loctite.

Hiermee kon ik €20,- aan materiaal besparen.



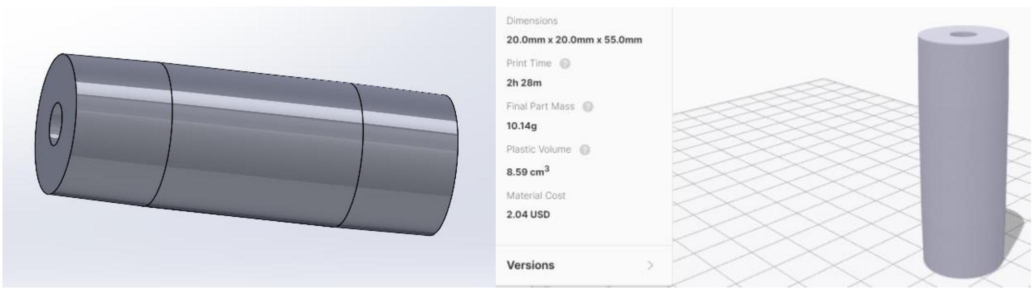
Figuur 34: Tekstplaat voor buitenkap



Figuur 35: Assembly van de compete buitenkap voor aansluiten

<u>Geleide- en aandrijfrol:</u>

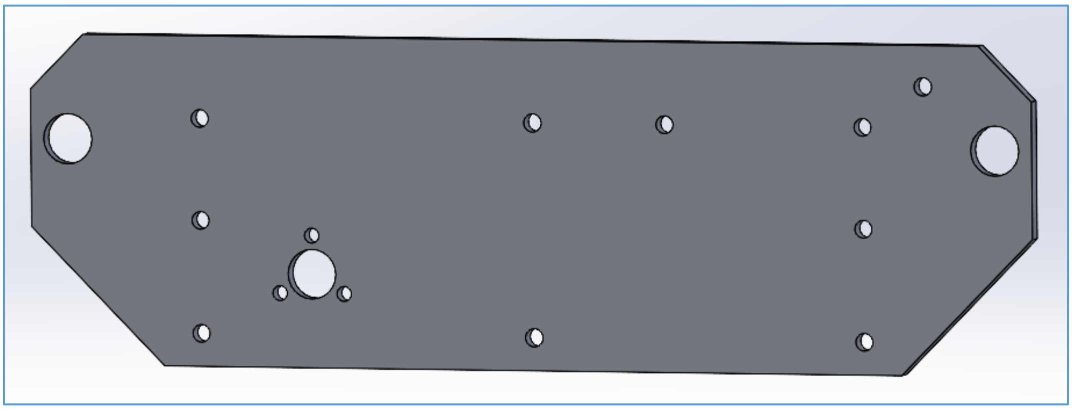
Hierop zitten wel rechten van Brink Techniek BV, maar we zouden deze kunnen printen voor €2,-. Inkoopsprijs is €9,50



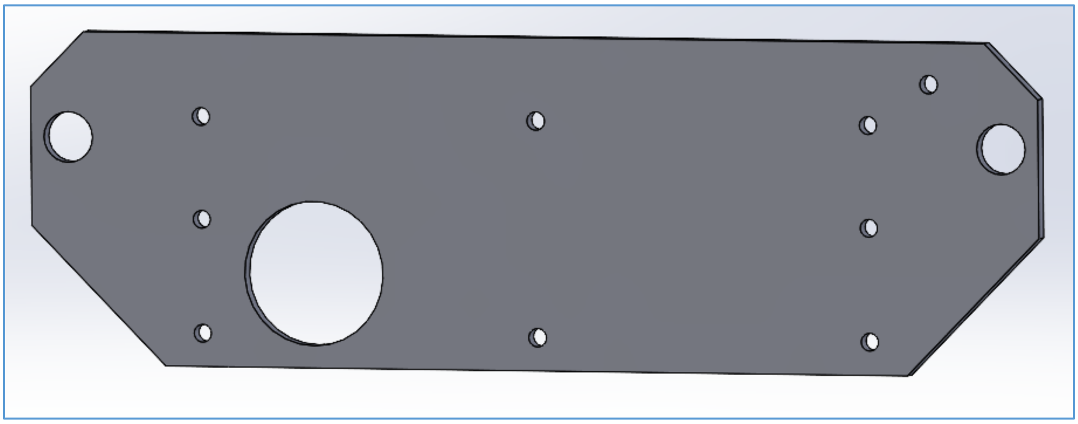
4.2.5. Overzicht van overige maakdelen

Linker en rechter zijframe:

Deze zijn gemaakt uit aluminiumplaat van 3mm.



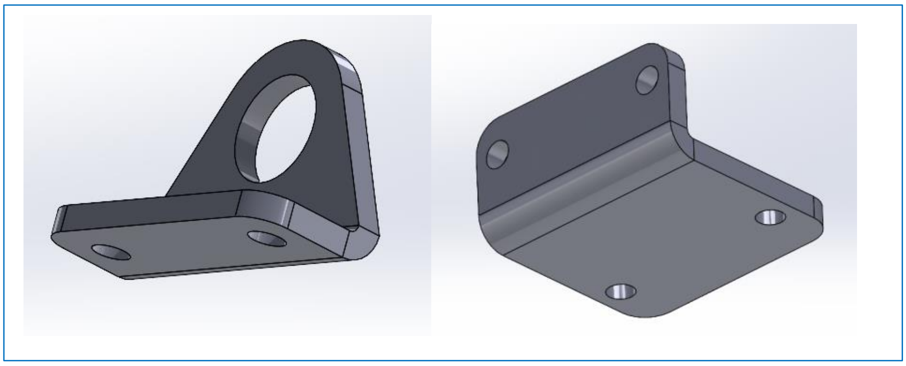
Figuur 36: Zijframe Links



Figuur 37: Zijframe Rechts

Ophanging / bevestiging van dubbelwerkende luchtcilinder:

Deze twee onderdelen zijn gemaakt uit senzimir verzinkte plaat van 3mm en zijn t.b.v. het bevestigen van de dubbelwerkende cilinder op het linker zijframe



Figuur 38 T.b.v. ophanging dubbelwerkende luchtcilinder

<u>Geleide- en lagerbusjes:</u>

Verder heb ik een aantal messingbusjes gedraaid, voor:

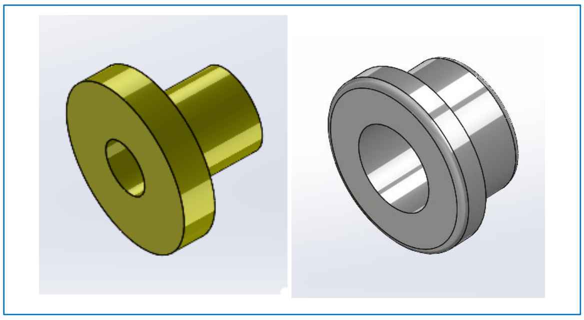
- Draaibare bevestiging van de schuif aan dubbelwerkende cilinder.
- Draaibare bevestiging van de sensorhouders.

Dit om “losdraaien” tijdens gebruik te voorkomen.

Rechts in de afbeelding is een glijlager te zien 6x9x6 voor lagering aandrijf- en geleide-rol. Deze heb ik weliswaar getekend, maar is ingekocht bij Brink Techniek BV.

Verder heb ik van dit onderdeel een 2D-tekening gemaakt, die opgenomen is in bijlage B.

Niet van alle onderdelen heb ik werktekeningen gemaakt, omdat het m.i. niet echt wat toevoegt. Kwestie van keuzes maken, omwille de tijd. De CAD-modellen blijven sowieso in cloud bewaard.

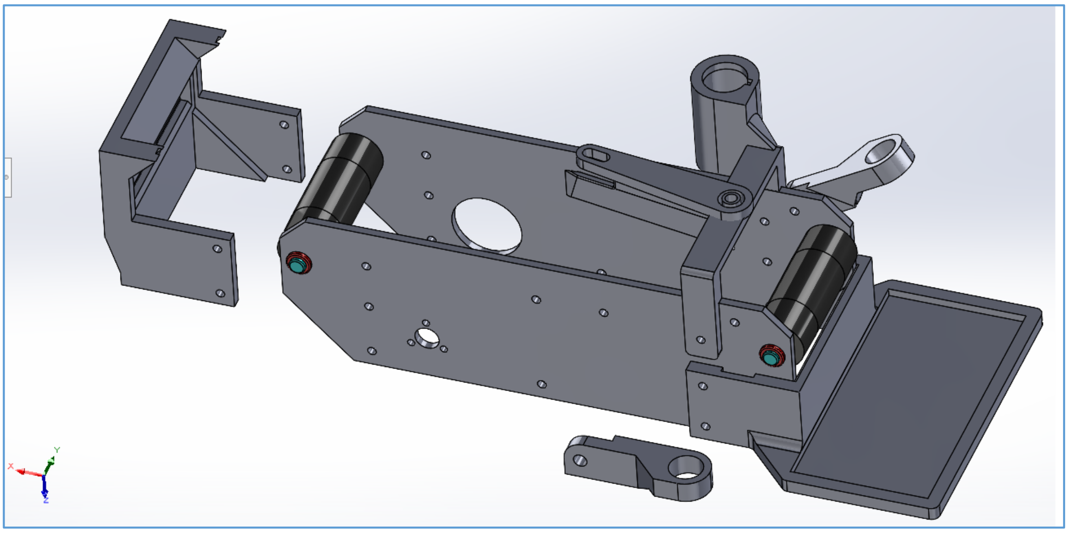


Figuur 39 Messingbus en PA-66 lagerbus.

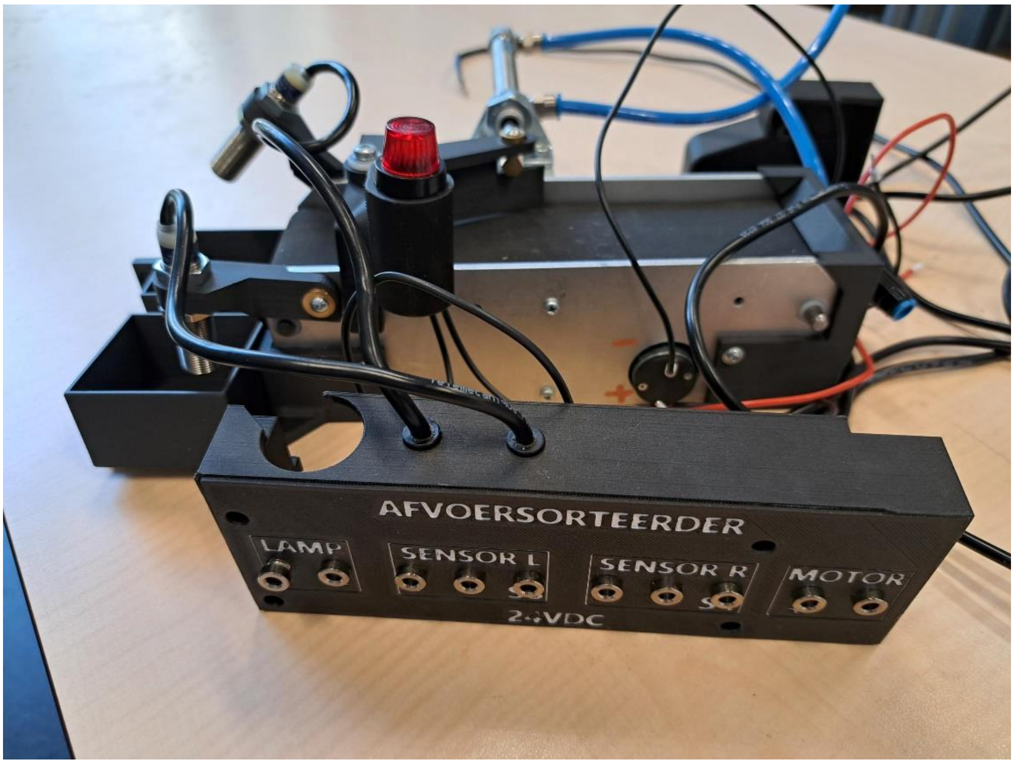
4.2.6. De assemblage (assembly)

Nadat alle onderdelen vervaardigd en ingekocht zijn, kon ik eindelijk starten met het assembleren.

De afbeelding laat een (gedeeltelijke) assembly in Solid Works zien. Verder heb ik de resterende tijd aangewend om de afvoersorteerder fysiek te assembleren.



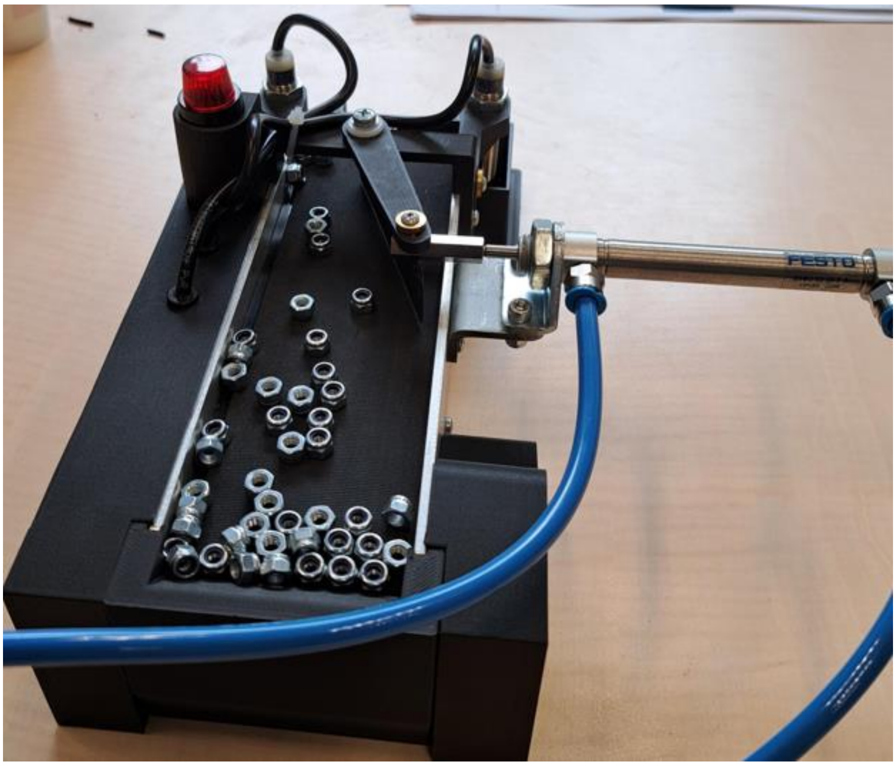
Figuur 40: Gedeeltelijke assembly in SW, in wording.

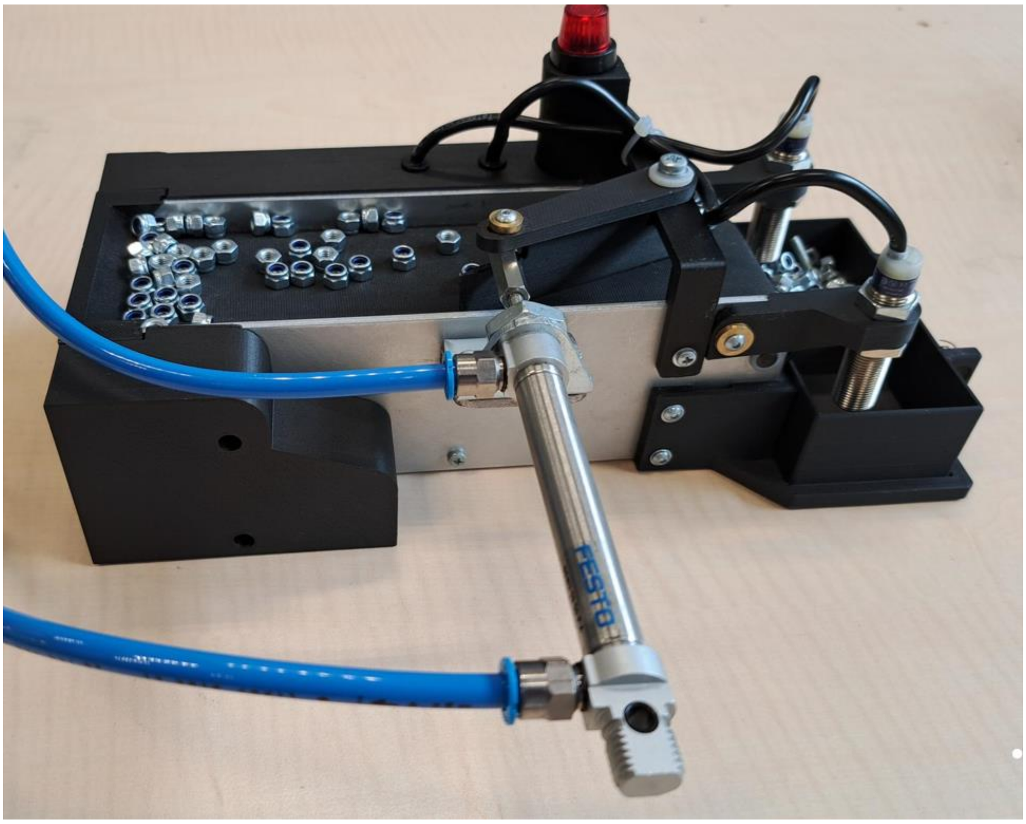


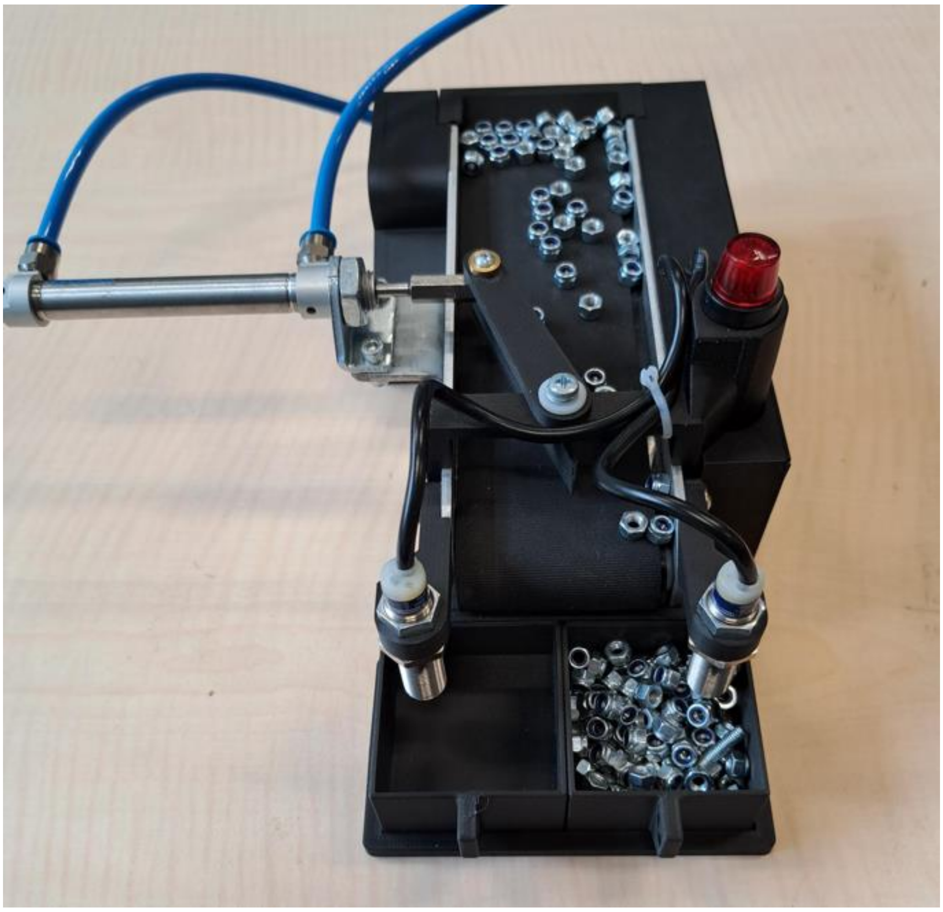
Figuur 41: Fysieke assemblage in progressie

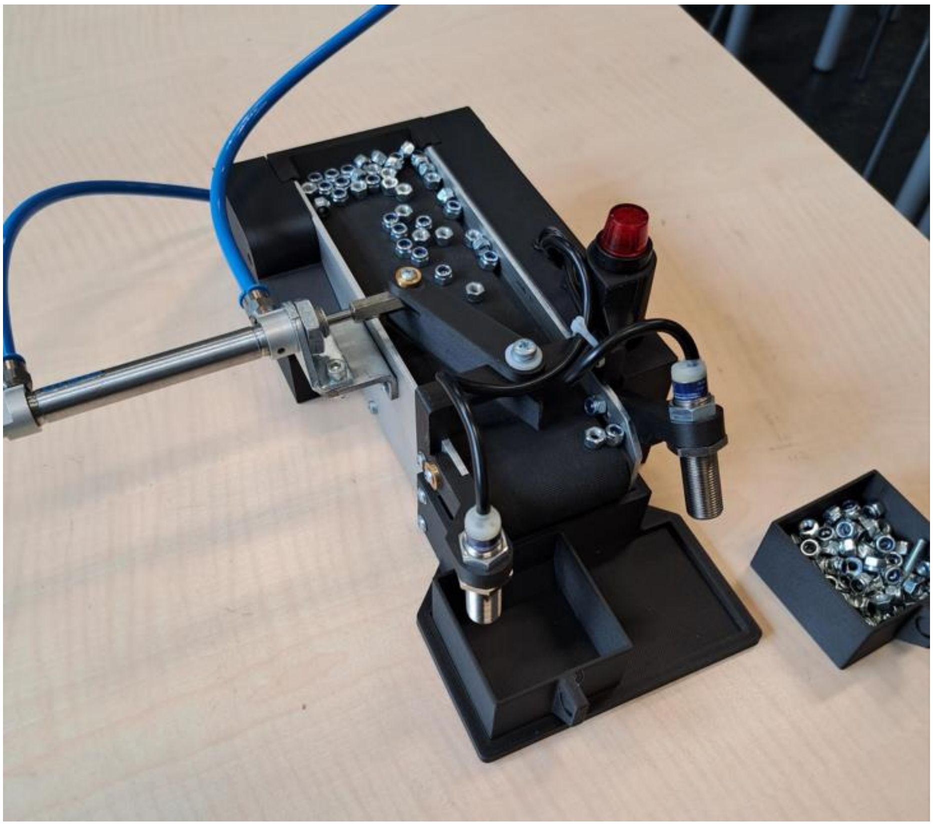
4.2.6.1. Foto's van gereed product

Bijgaand een fotocollage van het gerede product. De werking een aansluiting te zien in het filmpje:
Filmpje Afvoersorteerder




FESTO





Filmpje Afvoersorteerder

4.3. Complete stuklijst en kosten

Artikel	Benaming	Leverancier / gemaakt door	Aantal	Eenheidsprijs	Totaal
	Schuif, 3D-geprint	Rense Veenstra	1	€ 4,31	€ 4,31
	Beugel voor schuif en lamp, 3D-geprint	Rense Veenstra	1	€ 10,68	€ 10,68
	Laadplateau, 3D-geprint	Rense Veenstra	1	€ 17,42	€ 17,42
	Vulbak, 3D-geprint	Rense Veenstra	2	€ 3,45	€ 6,90
	Sensorhouder R, 3D-geprint	Rense Veenstra	1	€ 2,52	€ 2,52
	Sensorhouder L, 3D-geprint	Rense Veenstra	1	€ 2,52	€ 2,52
	Vangbeugel achter, 3D-geprint	Rense Veenstra	1	€ 14,28	€ 14,28
	Afschermkap, 3D-geprint	Rense Veenstra	1	€ 13,45	€ 13,45
	Buitenkap voor zonder tekst, 3D-geprint	Rense Veenstra	1	€ 14,45	€ 14,45
	Tekstplaat voor buitenkap, 3D-geprint	Rense Veenstra	1	€ 2,26	€ 2,26
	Geleiderol, 3D-geprint	Rense Veenstra	1	€ 2,04	€ 2,04
	Geleidebusje, gedraaid uit messing,	Rense Veenstra	3	€ 2,00	€ 6,00
	Ophanging voor dubbelwerkende cilinder, zincorplaat 2mm	Rense Veenstra	1	€ 1,50	€ 1,50
P02.03.300	Glijplaat 8mm PE 60mm Breed PE Zwart	Brink Techniek BV	1	€ 7,00	€ 7,00
P14.01.020	MAT-02H Elastische machineband LNGT 407 mm x BRDT 55 mm	Brink Techniek BV	1	€ 29,00	€ 29,00
P14.01.030	SYNCHROFLEX TANDRIEM 3326AT3/150W 6AT3/150	Brink Techniek BV	1	€ 7,00	€ 7,00
P14.01.031	SYNCHROFLEX RIEMSCHIJF 33110AT3/15-N2 10AT3/15-N2	Brink Techniek BV	2	€ 14,00	€ 28,00
P05.03.008.0610	Glijlagers 6x9x6, Materiaal: nylon-66 (PA-66)	Brink Techniek BV	5	€ 7,40	€ 37,00
P11.04.002	LAMP E10 24V 50MA E10 1,2W 404126	Brink Techniek BV	1	€ 1,80	€ 1,80
P11.02.001	Signaallamp armatuur Rafi rood lens	Brink Techniek BV	1	€ 3,95	€ 3,95
P09.50.008	Inductieve sensor type Bi1,5U-EG08-AP6XSchakelafstand 1,5mm	Brink Techniek BV	2	€ 45,00	€ 90,00
	Diverse schroeven, moeren etc.	Catalogusmateriaal	20	€ 0,05	€ 1,00
	Duurtule, rubber Ø 6mm	Catalogusmateriaal	2	€ 0,02	€ 0,04
P13.03.001	DC-Motor 24V + aandrijving 84:1	Brink Techniek BV	1	€ 165,00	€ 165,00
P65.01.0850D	DSNU-8-50-P-A DUBBELW.CILINDER	Brink Techniek BV	1	€ 21,25	€ 21,25
P03.01.17.006	Assen staal 6 mm.	Brink Techniek BV	2	€ 9,00	€ 18,00
P07.03.009	Blanke stekerbus 4 mm	Brink Techniek BV	10	€ 1,00	€ 10,00
	Diverse aansluitdraden	Catalogusmateriaal	4	€ 0,03	€ 0,12
P65.09.003	LBN-8/10 ONDERDEEL VOOR SCHARNIERBEVESTIGING	Brink Techniek BV	1	€ 3,30	€ 3,30
P65.09.002	Voetbevestiging HBN-8/10X2	Brink Techniek BV	1	€ 3,00	€ 3,00
	Totaal				**€ 523,79**

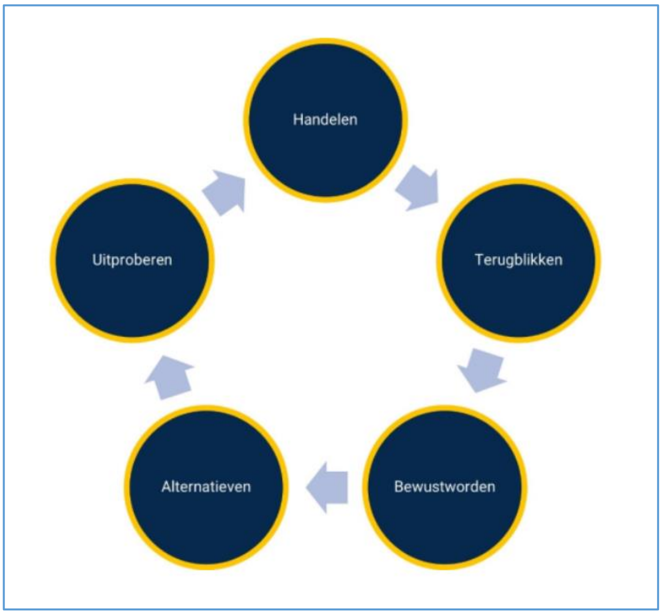
De daadwerkelijke kosten niet uit de hand gelopen. In mijn PVA had ik €500,- begroot.

5. Slot en reflectie volgens het model van Korthagen

Een belangrijk aspect in het uitvoeren van de integratieve opdracht is terugkijken op het hele proces. Wat heb ik ervan geleerd? Hoe zou ik zaken een volgende keer anders aanpakken? Maar nog belangrijker: wat heb ik eraan in de dagelijkse praktijk?

Daarom heb ik gekozen om op mijn handelen te reflecteren volgens het model van Korthagen (https://www.scriptium.nl/model-van-korthagen/)

Vaak zie je door terug te blikken pas in hoe het je afging, in plaats van op het moment zelf. Zonder te reflecteren zou je daar niet snel achter zijn gekomen. Het is dus zeer waardevol om terug te blikken op je handelen (Scriptium Excelente Onderwijshulp, 2014).



Figuur 42: Het model volgens Korthagen (Scriptium Excelente Onderwijshulp, 2014)

Ik heb gekozen voor dit model Het model van Korthagen omdat dit een reflectiecirkel. Na stap 5 kom je namelijk automatisch terug bij stap 1. Zo kun je het proces van reflectie opnieuw doorlopen. Hieronder zie je een handige visualisatie van het model (Scriptium Excelente Onderwijshulp, 2014):

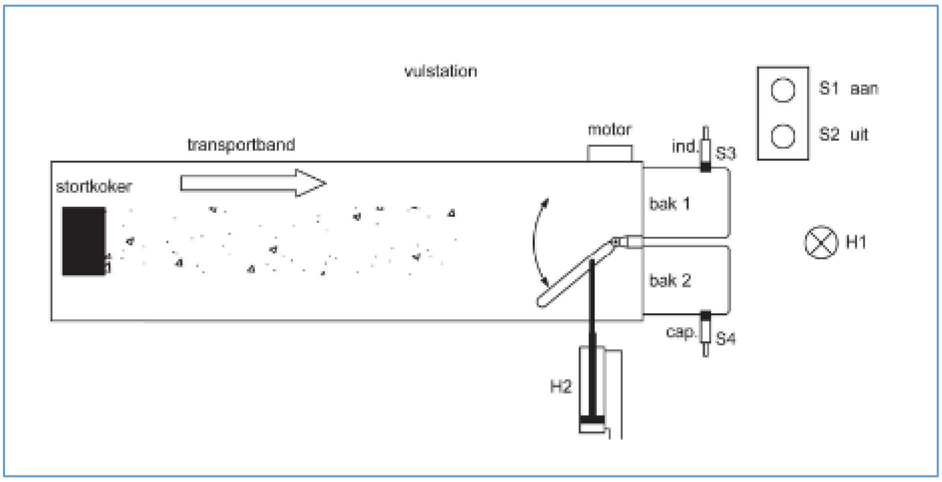
Handelen	Wat was de situatie? Wat wilde ik testen? Wat was mijn doel met de handeling? Wat waren de concrete acties die ik in die situatie heb ondernomen? Wat was het gevolg van mijn acties?
Terugblikken	Wat wilde ik doen? Wat zag ik? Wat heb ik gedaan? Wat dacht ik toen? Wat voelde ik op dat moment?
Bewustwording	Wat betekent het voor mij? Wat is het probleem? Wat heeft het probleem veroorzaakt?
Alternatieven	Welke alternatieven zie ik om het probleem op te lossen? Wat zijn de voor- en nadelen van die alternatieven? Wat wil ik de volgende keer anders aanpakken?
Uitproberen	Wat wil ik proberen? Wat wil ik uitproberen? Waar wil ik op letten?

(Scriptium Excelente Onderwijshulp, 2014)

5.1. Stap 1: Handelen

De werkelijke (hetzij onbewuste) opdrachtgevers zijn onze leerlingen. Ze geven dikwijls aan geen beeld te hebben waarom en hoe besturingstechniek, in het bedrijfsleven, wordt toegepast. Na een aantal formatieve opdrachten, zoals elektropneumatiek, programmeren en aansluiten van de EasyRelais, moet de leerlingen de summatieve PTA-opdracht is de zogenaamde “Afvalsorteerder” voltooien. Dit is een opdracht waarvoor rechtstreeks het blauwe onderdeel D van het CSPE 2019 wordt gebruikt. https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf

Ondanks afbeelding in figuur 3 en de opdrachtomschrijving is het voor de leerlingen lastig zich een voorstelling te maken hoe zoiets er in het echt zou kunnen uitzien en werken.



Figuur 3 De afvalsorteerder (College voor Toetsen en Examens, 2019) (bron CSPE 2019, onderdeel D Blauw)

Het programmeren wordt vaak als lastig ervaren en de toepassingen in het bedrijfsleven, zijn voor hen veelal abstract. Met een apparaat, die ook daadwerkelijk doet, wat in de opdracht staat omschreven, zal het nut duidelijk worden en de materie beter beklijven. Dit blijkt ook uit de eindgesprekken, die aan de opdracht verbonden zijn.

5.2. Stap 2: Terugblikken

Tijdens het uitwerken van mijn dossier had ik (onbewust) verzuimd duidelijk aan te geven dat het een CSPE-opdracht betrof die in ons PTA is opgenomen. Tijdens het Criterium Gericht Interview (CGI), in juni 2023, met de heren H. Spaan en H. Goes van Windesheim werd dit nadrukkelijk naar voren.

Daarnaast was de bronvermelding niet op orde.

Ook was het pijnlijk dat ik op de laatste dag nog het verplichte deel in mijn portfolio https://maken.wikiwijs.nl/?id=15&arrangement=198110 nog gecomplementeerd moest worden met het deel “Leeruitkomsten”.

Al met al was het gevolg dat opdracht werd afgewezen. Ik voelde me hierdoor behoorlijk bezwaard en verweet mezelf naïef te hebben gehandeld, zoals in bijgaande mail te lezen is:

5.3. Stap 3: Bewustwording

De afwijzing betekende dat het dossier moest worden herschreven en een volgend CGI pas in het volgende schooljaar aangevraagd kon worden.

Het probleem is ontstaan dat ik was te veel op de eindoplossing gericht was. Ik realiseer me dat het best lastig is om out of de box te denken; meerdere mogelijkheden onderzoeken.

Verder had ik me te weinig in de APA-normering verdiept en opdrachtomschrijving, m.b.t. leeruitkomsten verkeerd geïnterpreteerd c.q. niet goed gelezen.

Verder had ik meer trots moeten uitstralen en een filmpje moeten uploaden met bijvoorbeeld een leerling die de opdracht had voltooid en de werking demonstreerde.

5.4. Stap 4: Alternatieven

In het aangepaste dossier moet duidelijk naar voren komen dat CSPE-opdracht als uitgangspunt is genomen. Dit heeft tot gevolg dat de vast, variabele eisen herzien moeten worden en aansluitend een aanpassing van o.a. de morfologische kaart.

Gelukkig kreeg ik de gelegenheid om het hetzelfde eindproduct (Afvoersorteerder) en delen van het oude dossier te gebruiken.

5.5. Stap 5: Uitproberen

Het gevolg is dat ik bijgaand dossier heb aangepast en voornemens ben om een filmpje https://www.youtube.com/results?search_query=Rense+Veenstra up te loaden met een leerling die de opdracht heeft voltooid en de werking demonstreert.

Ik heb ervan geleerd een eventuele volgende keer me meer te verdiepen in de opdrachtomschrijving en correctere te werken volgens de APA-normering, **ook bij het ontwikkelen en uitwerken van nieuw lesmateriaal!**

5.6. Is het doel bereikt?

Toen de afvoersorteerder in wording was heb ik leerlingen het laten zien. Ook heb ik ze even laten stoeien met het halffabrikaat. Aansluiten motor en testen van de werking e.d. Daar kwamen nog wat dingetjes uit. Ontzettend leuk dat ze dan meedenken en er bruikbare tips naar boven kwamen.

De leerlingen waren oprecht geïnteresseerd en vroegen nadien regelmatig hoe het met mijn "projectje" ging en wanneer ze de opdracht ermee kunnen uitvoeren.

Alhoewel dat (op het moment van dit schrijven) de opdracht nog niet is ingezet, mag ik concluderen dat de afvoersorteerder tot de verbeelding zal spreken voor de rest van de leerlingen. Ook een aantal BB-leerlingen waren geïnteresseerd en wil hen daarom de gelegenheid geven deze uit te voeren als verdieping (het is immers een KB-opdracht).

Verder zijn de daadwerkelijke kosten van €538,- niet uit de hand gelopen. In mijn PVA had ik €500,-

In bijgaand filmpje is de aansluiting en werking van de afvoersorteerder te zien: https://www.youtube.com/results?search_query=Rense+Veenstra

5.7. Dankbetuigingen

Graag wil ik bedanken:

- De heren Evert Draaijer en Joost Brink van Brink Techniek BV hartelijk bedanken voor het meedenken, brainstormen en advies.
- Mijn directe PIE-collega's voor hun meedenken, brainstormen, advies en hun enthousiasme voor het uitwerken van de meer aansprekende opdracht:
        - Shurensly Chirino (technisch onderwijsassistent)
    - Chris Toren (docent PIE)
    - Ibrahim Uzel (docent PIE)
    - Rolf Ahlers (technisch onderwijsassistent)
    - Monika Smit (deelschoolleider vmbo)
- De begeleidende docenten:
    - Henk Spaan, Harrie Goes en Michel Greeven, voor hun heldere en pragmatische begeleiding. Altijd was er snel antwoord op terugbelverzoek en mail e.d., zodat ik weer snel verder kon.

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Bijlage A: Berekening traagheidsmoment

Bijlage A

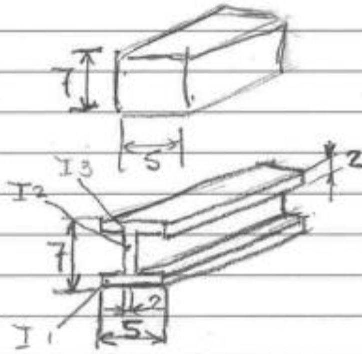
dr. ALETTA JACOBS COLLEGE
Scholengemeenschap voor praktijkonderwijs | vmbo | mavo | havo | atheneum | gymnasium

Naam: Rense Veenstra
Vak:
Datum: 13-6-2023 Klas:
Cijfer:

Voorbeeld berekening traagheidsmoment van massieve balk versus I-balk

* Massief $I = b.h^3/12 = 5.7^3/12$

$I = 143\ mm^4$



* I-balk $I_{tot.} = \Sigma(I_i + A_i d_i^2)$

Eerst zwaartepunt berekenen:

$$\bar{y} = \frac{\Sigma\, y_i . A_i}{\Sigma\, A_i} = \frac{(1 \times 10)+(5,5.10)+(6.10)}{10+10+10} = 4,2\ mm$$

$\bar{I}_1 = 5.2^3/12 = 3,34$ $A_1 = 10 mm^2$ $d_1 = |1-4,2| = 3,2$

$\bar{I}_2 = 2.5^3/12 = 20,8$ $A_2 = 10 mm^2$ $d_2 = |4,5-4,2| = 0,3$

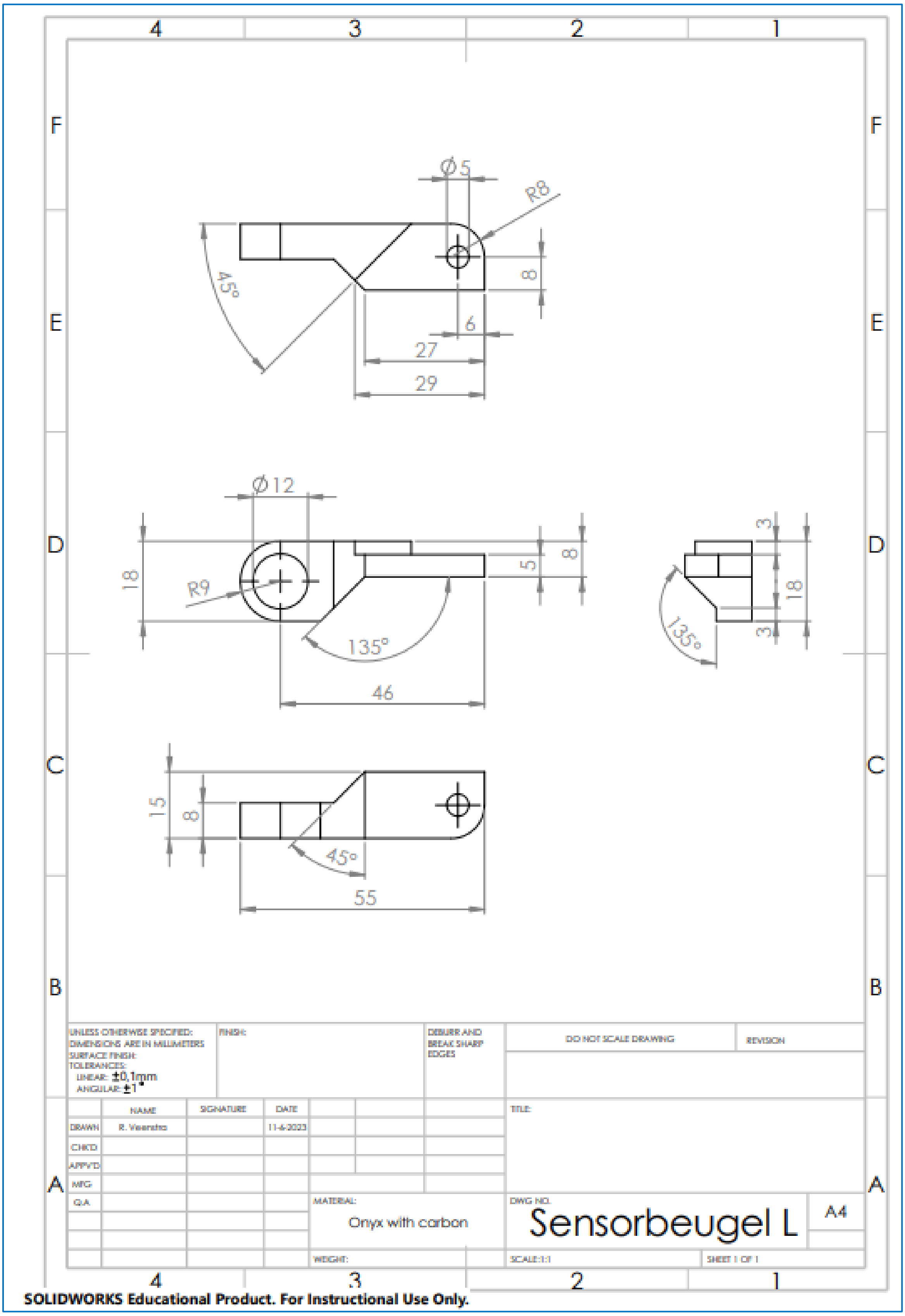
$\bar{I}_3 = 5.2^3/12 = 3,34$ $A_3 = 10 mm^2$ $d_3 = |6-4,2| = 1,8$

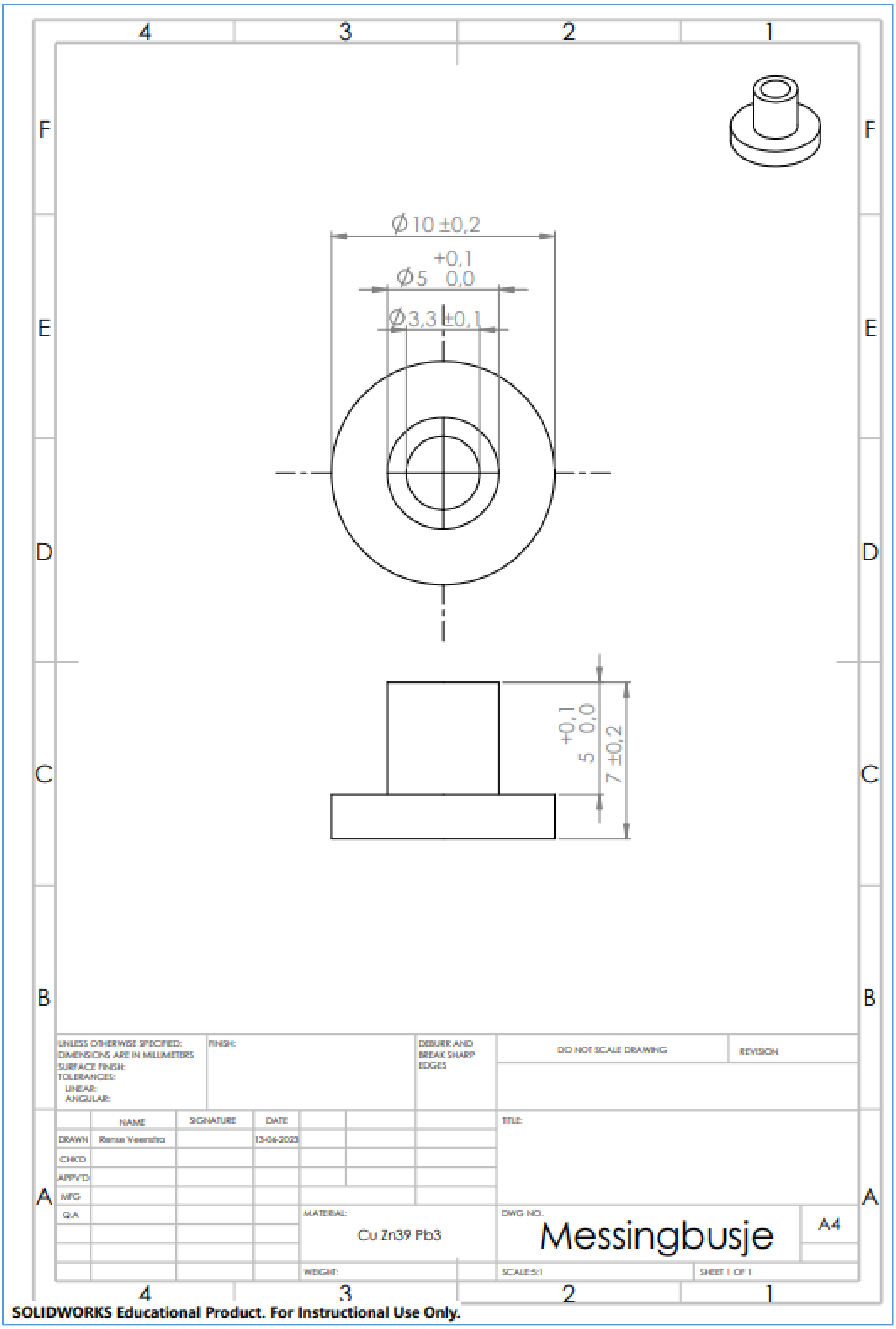
$$I_{tot.} = \Sigma(\bar{I}_i + A_i d_i^2)$$
$$= (\bar{I}_1 + A_1 d_1^2) + (\bar{I}_2 + A_2 d_2^2) + (\bar{I}_3 + A_3 d_3^2) =$$
$$= (3,34 + 10.3,2^2) + (20,8 + 10.0,3^2) + (3,34 + 10.1,8^2) =$$
$$= 105,74 + 21,7 + 33,4$$

I_{tot} 160,8 mm^4

Gebruikte bron: (Bakker, 2005)

Bijlage B: Enkele 2D-tekeningen





Ø10 ±0,2
Ø5 +0,1 0,0
Ø3,3 ±0,1
5 +0,1 0,0
7 ±0,2
UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION
NAME
SIGNATURE
DATE
DRAWN
Rense Veenstra
13-06-2023
CHK'D
APPV'D
MFG
Q.A
TITLE:
MATERIAL:
Cu Zn39 Pb3
DWG NO.
Messingbusje
A4
WEIGHT:
SCALE:5:1
SHEET 1 OF 1
SOLIDWORKS Educational Product. For Instructional Use Only.

Het programmeren en aansluiten van de AFVOERSORTEERDER

Naam leerling:____ Klas: ________________

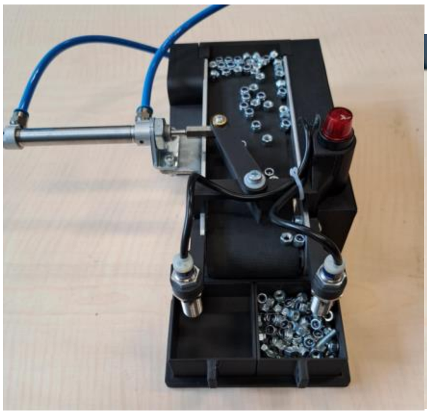
- Deze opdracht uit 6 delen waarmee je in totaal 20 punten kunt scoren. Voor elk opdrachtnummer staat hoeveel punten met een goede uitvoering behaald kunnen worden.
- Je krijgt 120 minuten om deze opdracht te maken.
- De opdracht is het deel D van het Centraal Schriftelijk en Praktisch Examen (CSPE) uit 2019. Hiermee kun je al een goede indruk krijgen hoe zo’n examen eruitziet.

Opdrachtdelen:

1	De afvoersorteerder aansluiten op het EasyRelais en bijgeleverde pneumatiekdelen
2	M.b.v. easysoft op laptop, invoeren van het programma in het EasyRelais.
3	Snelheidsregelventielen instellen.
4	Een waarheidstabel invullen.
5	Schriftelijke vragen beantwoorden.
6	De werking van de afvoersorteerder uitleggen en benoemen van de onderdelen aan de docent. Let erop dat op een nette manier doet (klantvriendelijk zijn).

(College voor Toetsen en Examens, 2019)

Hier zie je afbeeldingen van de afvoersorteerder



(College voor Toetsen en Examens, 2019)

Omschrijving van de opdracht:

Stel je voor dat je een monteur bent die afvoersorteerder gaat plaatsen en aansluiten bij een klant.

De klant is een bedrijf dat bevestigingsmateriaal produceert. Nu komen moertjes die uit de machine komen rechtstreeks in een opvangbak. Het probleem is dat het regelmatig voorkomt dat het productieproces stopgezet moet worden, omdat de (weer) opvangbak overstroomt.

Het bedrijf heeft de afvoersorteerder gekocht bij het bedrijf waar jij als monteur werkzaam bent. Met deze installatie willen ze voorkomen dat de productie iedere keer stopt en daarmee tijd en dus geld besparen.

- Jij bent, als monteur, niet alleen belangrijk om jouw vakmanschap, maar ook een belangrijk contactpersoon.:
  - De afvoersorteerder moet goed geprogrammeerd en aangesloten zijn.
  - Je moet duidelijk aan de klant kunnen uitleggen hoe de installatie werkt.

De werking van de afvoersorteerder:

- Met drukknop S1 schakel je de afvoersorteerder in en met S2 weer uit. M.a.w. de transportband wordt aangedreven door de elektromotor.
- De sensoren S3 en S4 reageren beide op metalen.
- Lamp H1 begint te knipperen als er een bak vol is en deze kan dan worden vervangen door een leeg exemplaar.
- Y1 en Y2 schakelen 5/2-ventiel (V3). Dit ventiel bedient cilinder H2 van de afvalsorteerder.
- De schuif van de afvoersorteerder zorgt voor de sturing van het schroot naar bak 1 of bak 2.
- Snelheidsregelventiel V1 en V2 regelen de snelheid van de schuif.
- Als beide bakken vol zijn, stopt de installatie.

Succes met de uitvoering!

(College voor Toetsen en Examens, 2019)

1. Aansluiten van de afvoersorteerder

De afvoersorteerder is uitgevoerd met:

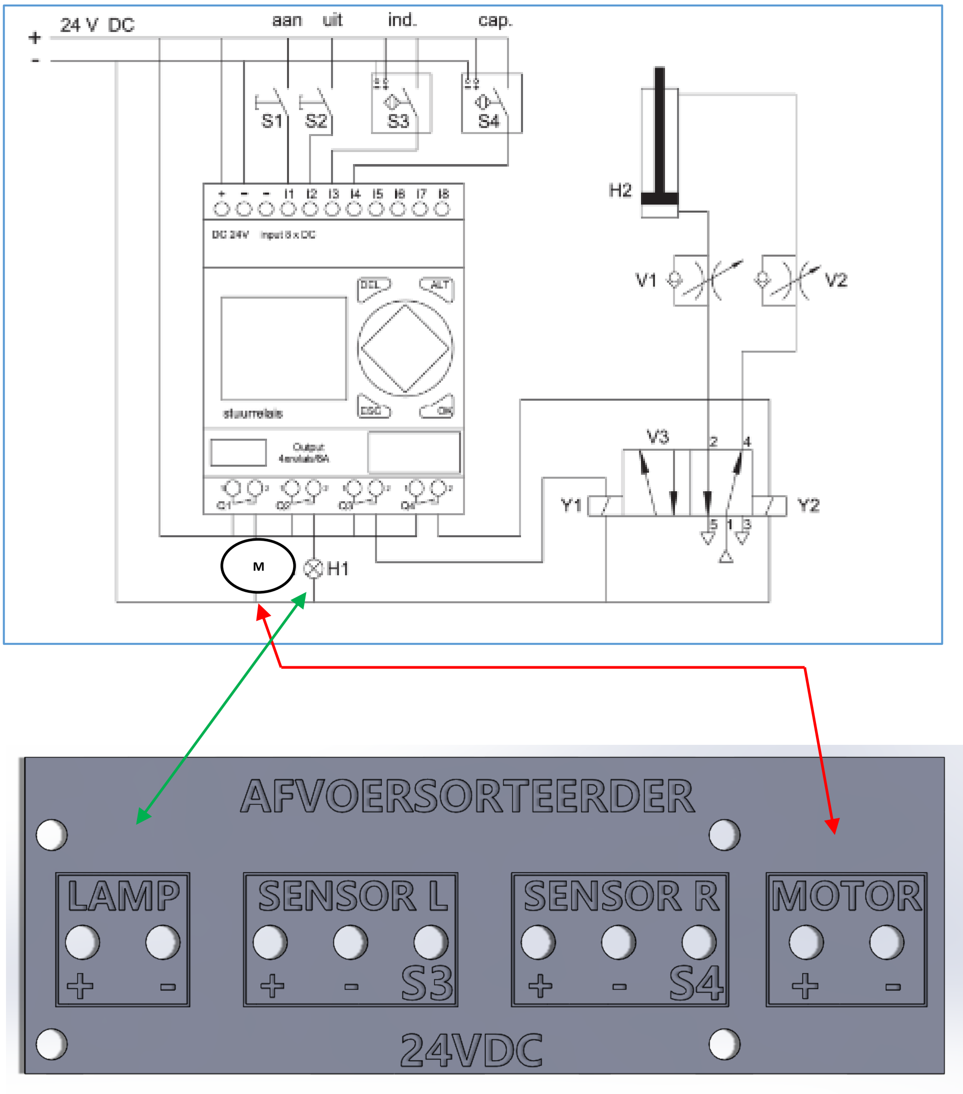
- Pneumatisch bediende schuif (H2),
- waarschuwingslamp (H1),
- transportband aangedreven door een elektromotor (M) en
- 2 inductieve sensoren (S3 en S4).

Wat extern moet worden aangesloten:

- Knop S1 voor inschakelen aan EasyRelais.
- Knop S2 voor uitschakelen aan EasyRelais.
- De inductieve sensoren van de afvoersorteerder aan het EasyRelais.
- De dubbelwerkende cilinder (H2) pneumatisch aansluiten, via de snelheidsregelventielen (V1 en V2) en het bi-stabiele elektrisch bediende 5/2 stuurventiel (V3). Deze is op zijn beurt weer aangesloten op het EasyRelais.
- Lamp (H1) van afvoersorteerder aansluiten op het EasyRelais.
- Motor (M) van afvoersorteerder aansluiten op het EasyRelais.

De uitvoering:

- Sluit de onderdelen aan volgens het elektro-pneumatisch schema op de volgende bladzijde.
- Vraag de docent om de schakeling te controleren.
- Als de schakeling niet juist is opgebouwd, mag je één keer proberen fouten te herstellen. Je kunt dan nog een deel van de punten behalen.
- Vraag de docent daarna om de schakeling en de werking opnieuw te controleren.
- Als de schakeling nu nog niet juist is opgebouwd, zal de docent dit voor je doen.
- Daarna kun je verder met de volgende opdracht: invoeren programma in EasyRelais.

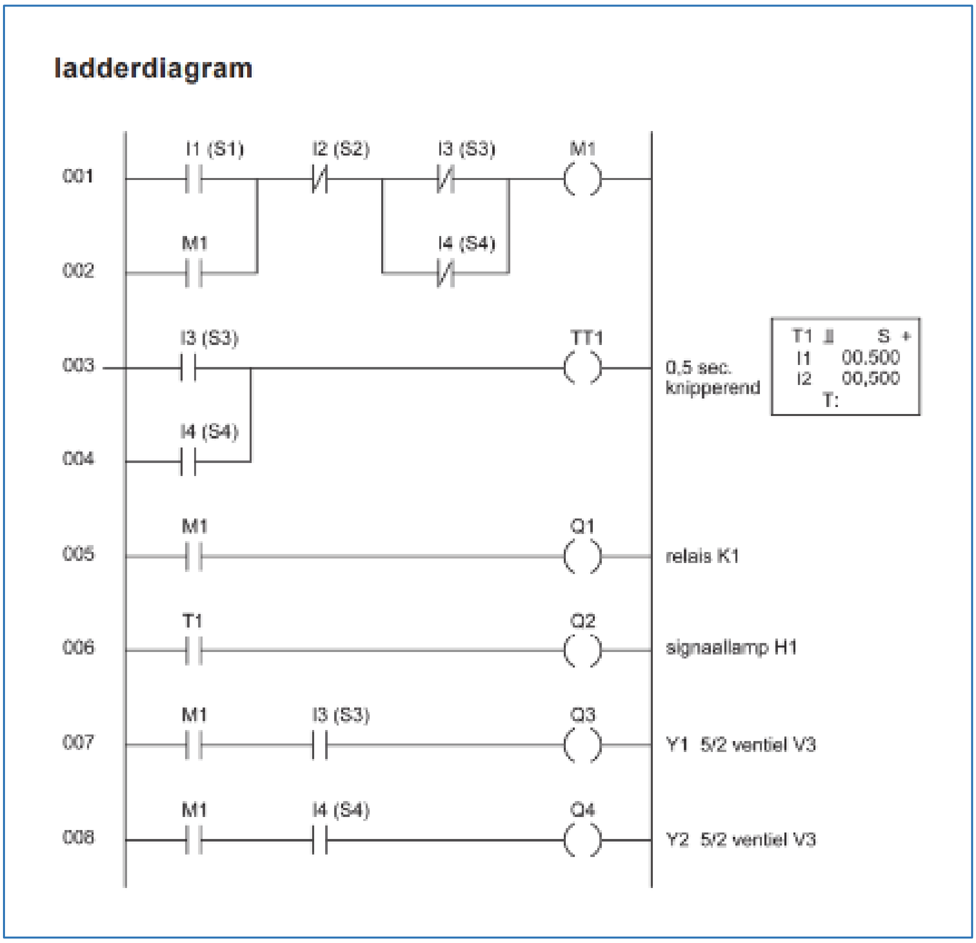


(College voor Toetsen en Examens, 2019)

(College voor Toetsen en Examens, 2019)

2. Programmeren van het EasyRelais

Je gaat nu het bijgaande programma/ladderdiagram m.b.v. easysoft maken en wegschrijven in het EasyRelais.



(College voor Toetsen en Examens, 2019)

De uitvoering:

- Lees eerst de bladzijden 47 t/m 54 door van **TRAININGSHANDBOEK EasySoft 7**
    - Voor het programmeren van de timer lees je bijlage B van deze opdracht door.
- Programmeer het stuurrelais volgens het bovenstaande ladderdiagram
- Vraag de docent om de werking van het programma te controleren.
- Als het EasyRelais niet juist is geprogrammeerd, mag je één keer proberen fouten te herstellen. Je kunt dan nog een deel van de punten behalen.
- Vraag de docent daarna om het programma en de werking opnieuw te controleren.
- Als het EasyRelais nog niet juist is geprogrammeerd, zal de docent dit voor je doen.
- Daarna ga je verder met het instellen van de snelheidsregelventielen.

(College voor Toetsen en Examens, 2019)

3. Instellen van de snelheidsregelventielen

De snelheidsregelventielen moeten juist worden ingesteld.

<u>De uitvoering:</u>

- Stel de snelheidsregelventielen zó in dat de cilinder vertraagd in- en uitgaat.
- Zorg ervoor dat de snelheid van de uitgaande slag ongeveer even groot is als de snelheid van de ingaande slag.
- Als je klaar bent vraag je de docent om de ingestelde snelheidsregelventielen te controleren.

(College voor Toetsen en Examens, 2019)

4. Invullen van het waarheidstabel

Vul de waarheidstabel voor de vul-installatie in.

Voordat je begint

- Bekijk nog eens het elektro-pneumatisch schema, het ladderdiagram en de tekst over de werking van de vul-installatie.
- Bekijk hieronder wanneer je een 0 en een 1 moet invullen.
  Je gebruikt de schakeling van opdracht 1 voor het invullen van de tabel.

De drukknop is bediend of de sensor is actief.	1
De drukknop is onbediend of de sensor is in rust.	0

De actuator is actief / de cilinder is uit.	1
De actuator is niet actief / de cilinder is in.	0

Uitvoering

- Vul de waarheidstabel in als je de volgende bediening uitvoert:
  stap 0: deze ruststand is al ingevuld
  stap 1: je houdt S1 ingedrukt (bediend)
  stap 2: je laat S1 los (onbediend)
  stap 3: je activeert S3 (met een metalen plaatje)
  stap 4: je haalt het plaatje bij S3 weer weg
  stap 5: je activeert S4 (met een metalen plaatje)
  stap 6: je haalt het plaatje bij S4 weer weg
  stap 7: je activeert S3 en S4 met een metalen plaatje
- Vul op elk stippellijntje onder actuatoren een 0 of een 1 in.

waarheidstabel

	sensoren				actuatoren		
	S1	S2	S3	S4	K1	H1	H2
stap 0 (ruststand)	0	0	0	0	0	0	0
stap 1	1	0	0	0	.....	.....	.....
stap 2	0	0	0	0	.....	.....	.....
stap 3	0	0	1	0	.....	.....	.....
stap 4	0	0	0	0	.....	.....	.....
stap 5	0	0	0	1	.....	.....	.....
stap 6	0	0	0	0	.....	.....	.....
stap 7	0	0	1	1	.....	.....	.....

(College voor Toetsen en Examens, 2019)

5. Schriftelijke vragen

Beantwoord de vragen over het elektro-pneumatisch schema en het programma van de vul-installatie.

vraag 1
Hoe heet het contact van drukknop S1?
- ☐ maakcontact
- ☐ verbreekcontact
- ☐ wisselcontact
- ☐ overneemcontact

vraag 2
Welke functie heeft contact M1 op regel 002?
- ☐ verbreekcontact
- ☐ wisselcontact
- ☐ overneemcontact
- ☐ vergrendelcontact

vraag 3
Op welke spanning moet het stuurrelais worden aangesloten?

.... volt

vraag 4
Moet het stuurrelais worden aangesloten op een wisselspanning of op een gelijkspanning?
- ☐ wisselspanning
- ☐ gelijkspanning

vraag 5
Wanneer gaat signaallamp H1 knipperen?

....

....

vraag 6
Wat gebeurt er als beide schrootbakken vol zijn?

....

(College voor Toetsen en Examens, 2019)

6. De werking van afvoersorteerder uitleggen aan de docent

Leg in een gesprek de werking van de elektro-pneumatische schakeling uit.

Voordat je begint
Bekijk nog een keer het elektro-pneumatisch schema en de werking van de schakeling.

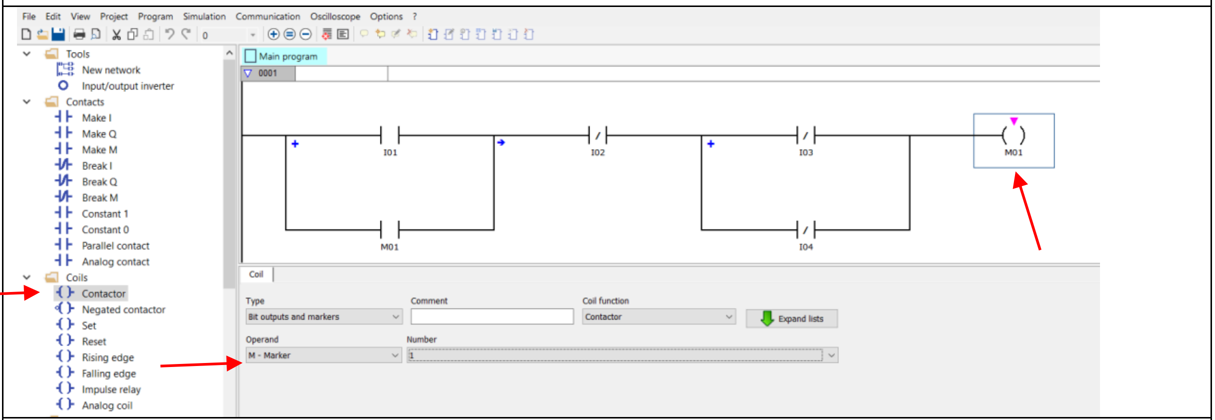
Uitvoering

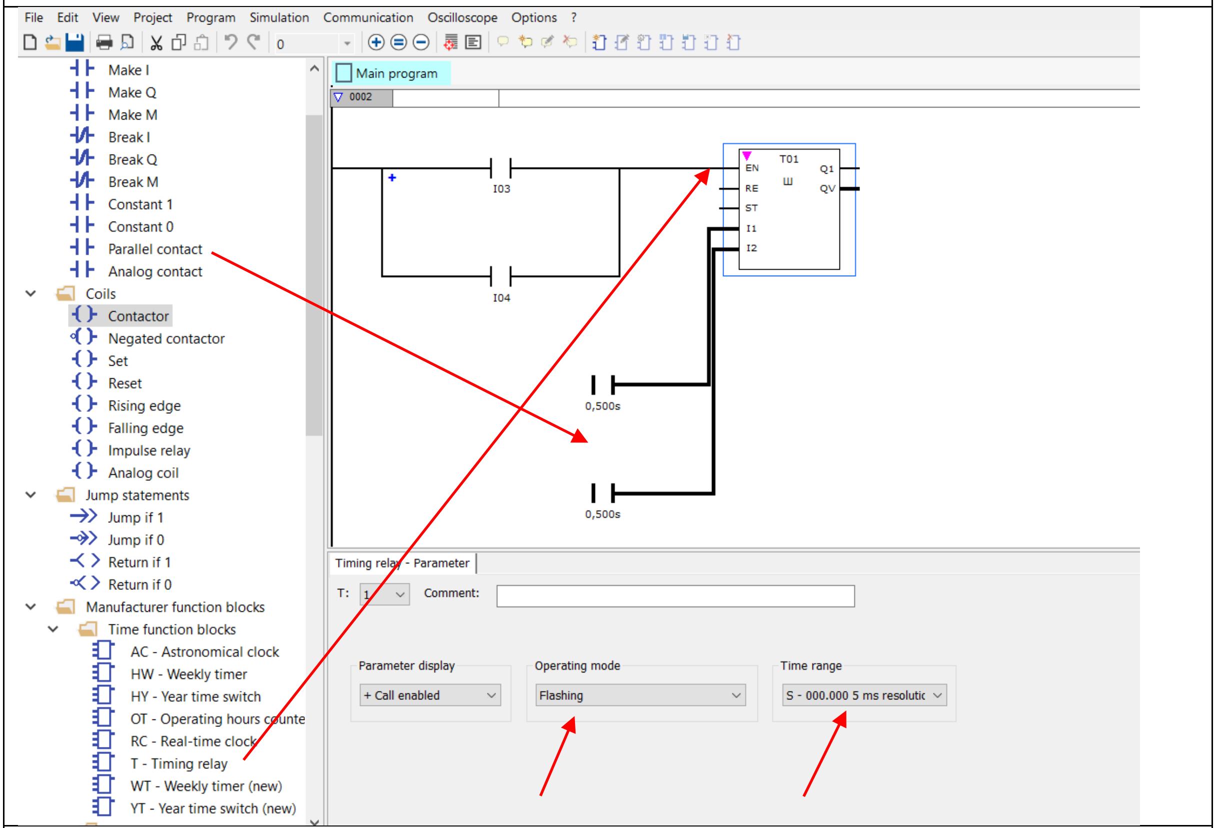
- Voer een gesprek met de examinator over de elektro-pneumatische schakeling.
- Tijdens het gesprek mag je alleen het schema en het ladderdiagram van **Bladzijden 4 en 5 gebruiken.**
- Leg duidelijk aan de examinator uit hoe de vul-installatie werkt. Leg ook het programma uit.
- Benoem bij je uitleg de onderdelen van de schakeling.

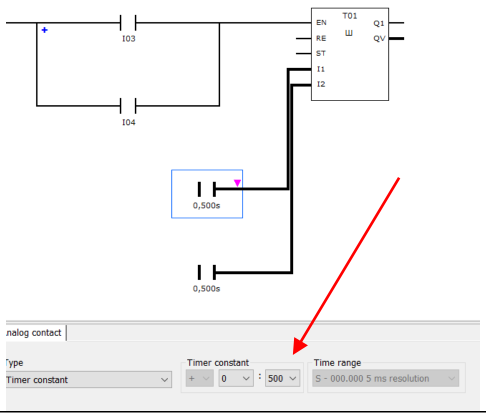
Let op: je wordt ook beoordeeld op gespreksvaardigheden. Wees klantvriendelijk en spreek duidelijk.

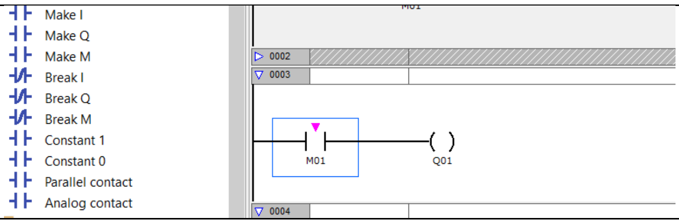
(College voor Toetsen en Examens, 2019)

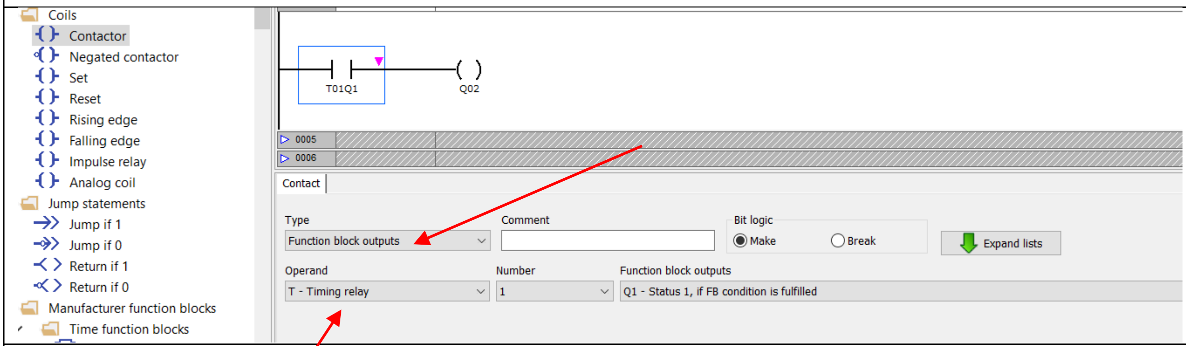
Bijlage A: Programmeren Afvoersorteerder in EasySoft (nakijkmodel)

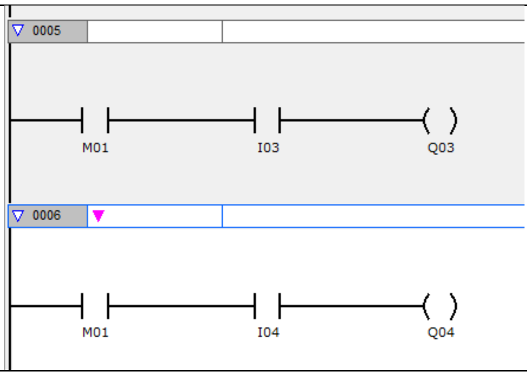





T01
EN
RE
ST
I1
I2
Q1
QV
I03
I04
0,500s
0,500s
Type
Timer constant
Timer constant
0
500
Time range
S - 000.000 5 ms resolution


Make I
Make Q
Make M
Break I
Break Q
Break M
Constant 1
Constant 0
Parallel contact
Analog contact
0002
0003
M01
Q01
0004

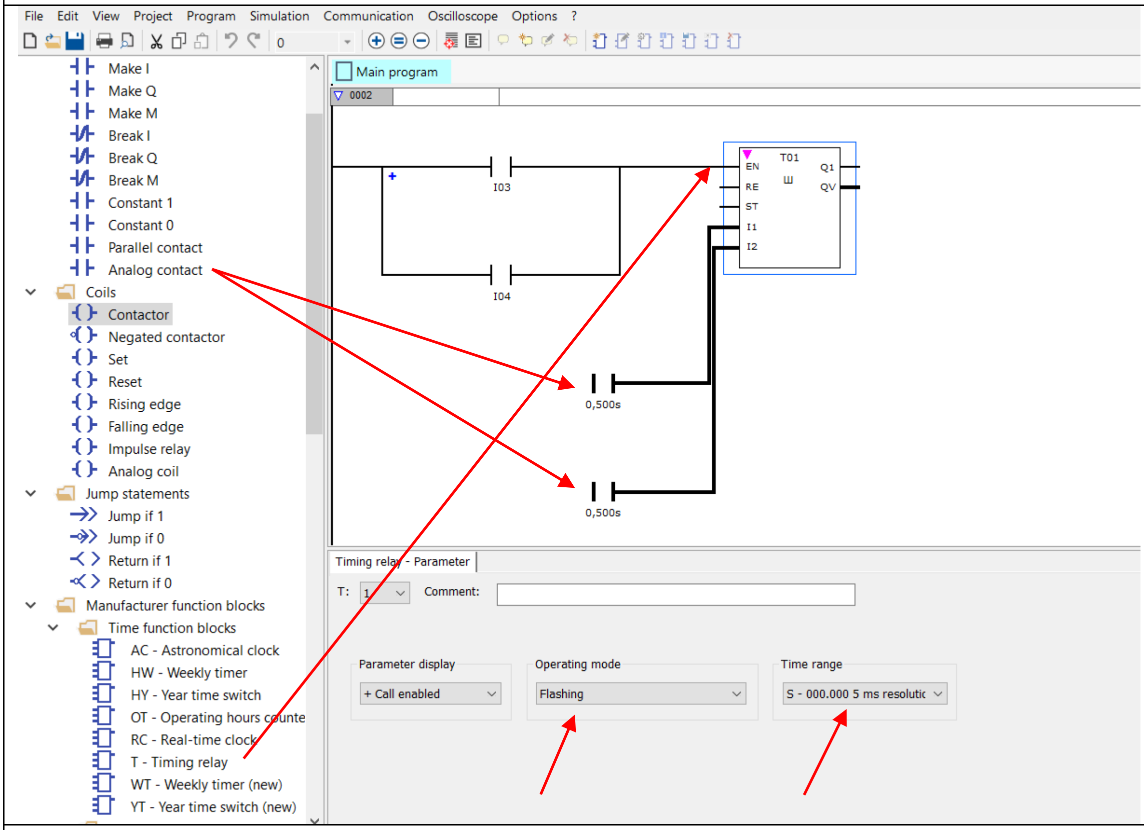

Coils
Contactor
Negated contactor
Set
Reset
Rising edge
Falling edge
Impulse relay
Analog coil
Jump statements
Jump if 1
Jump if 0
Return if 1
Return if 0
Manufacturer function blocks
Time function blocks
T01Q1
Q02
0005
0006
Contact
Type
Function block outputs
Comment
Bit logic
Make
Break
Expand lists
Operand
T - Timing relay
Number
1
Function block outputs
Q1 - Status 1, if FB condition is fulfilled


0005
M01
I03
Q03
0006
M01
I04
Q04

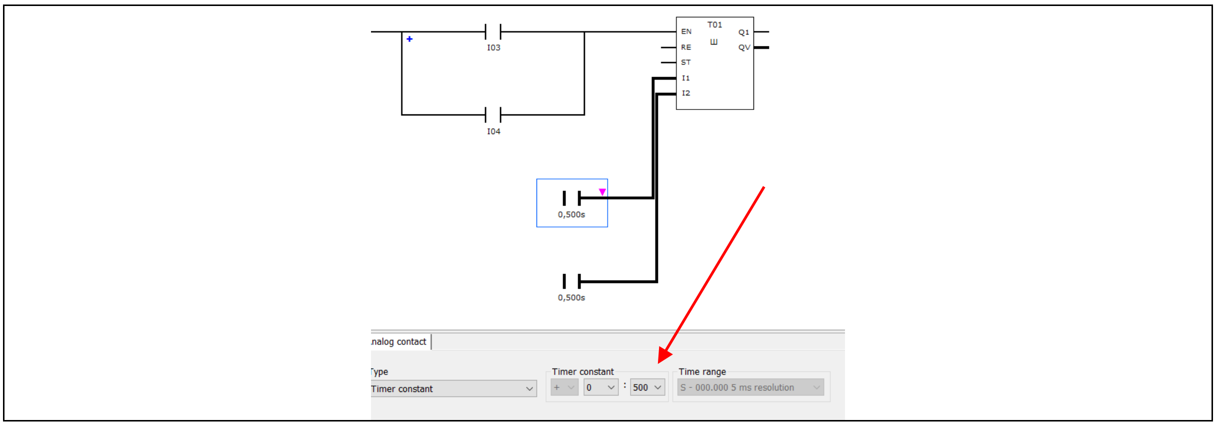
Bijlage B: Programmeren Timer

Lees eerst de bladzijden 47 t/m 54 door van **TRAININGSHANDBOEK EasySoft 7**

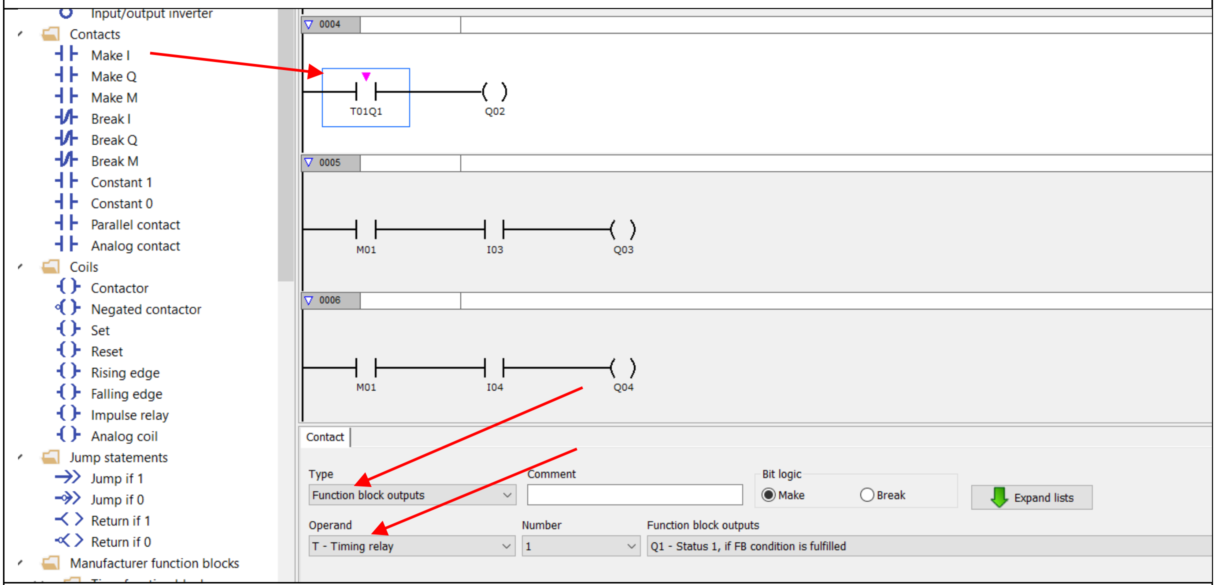
1e **Timing relay** plaatsen
2e **Operating mode** op “Flashing”
3e **Time range** op “5 ms resolution”
4e De analoge contacten plaatsen naar I1 en I2



5e Bij beide contacten de tijd ingeven



6e Plaatsen maakcontact “Make I”
7e **Type** op “Function block outputs”
8e **Operand** op “Timing relay”



Bijlage F: Screenshot uit feedback werkplekbeleider

Wat ziet u als sterke kwaliteiten van de deelnemer?

Kwaliteit	Toelichting
Betrouwbaar	Rense is eerlijk en integer en komt na wat afgesproken is.
Gedrevenheid	Rense is gepassioneerd, enthousiast en gemotiveerd.
Geduldig	Rense is iemand die onderwerpen meerdere malen uit kan leggen zonder dat het hem irriteert.
Betrokkenheid	Rense is zeer betrokken in het team, wil graag wat voor een ander doen en probeert anderen van dienst te zijn, dit wordt wel bevestigd door de relatie die Rense met de leerlingen heeft, deze is meer dan goed te noemen.

Op welke punten is nog ontwikkeling gewenst?

Kwaliteit	Toelichting
Perfectionistisch	Rense heeft wel eens de neiging om dingen te goed te willen doen, het oog voor detail is groot maar dit kan irritaties geven.
Gevoelsmens	Hoewel dit tevens een kracht is van Rense kan dit ook een valkuil zijn, denk aan een leerling die zijn dag niet heeft en er dat moment weinig aan te doen is je het persoonlijk aantrekt.
Bondigheid	Rense mag soms iets compacter zijn in zijn woorden.

EC PB

Pagina 11

Bijlage G: Markforged University Composites Course Certificate

Markforged University Composites Course Certificate

This is to certify that

Rense Veenstra

Has successfully completed

Markforged University Composites Course Final Assessment

On the date of

Dec 9, 2022

markforged

Certifying Agency

Erin Sapienza

Administration

PLAN VAN AANPAK

PROJECT AFVOERSORTEERDER

Naam student	Rense Veenstra	rense.veenstra@windesheim.nl
Datum	7 Maart 2024	
Plaats	Hoogezand	
Opdrachtgever	Dr. Aletta Jacobs College	
Professionaliseringstraject PIE	Integratief leermiddel	
Studentnummer	1073458	
Begeleidende docent	Henk Spaan	h.spaan@windesheim.nl
Begeleidende docent	Michel Greeven	m.greven@windesheim.nl

Inhoudsopgave

1. Achtergronden

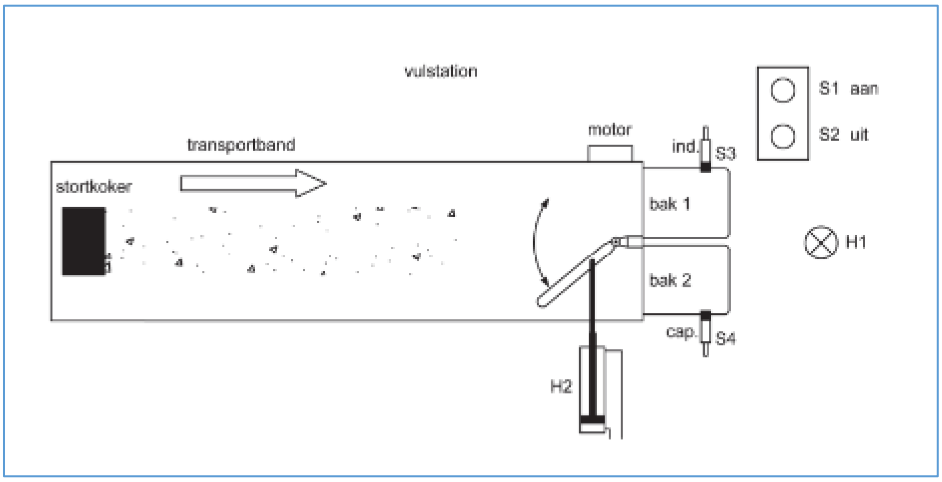
Ter voltooiing van mijn opleiding “Professionaliseringstraject PIE” moet er een integratieve opdracht worden uitgevoerd, waarbij minimaal 2 vakgebieden van het profiel PIE (Produceren, Installeren & Energie) in terug moeten komen. Daar het voor buitenstaanders m.i. de profielnaam niet altijd duidelijk is hebben we het in grote lijnen over:

- **Produceren**: Metaaltechnieken, zoals verspaning en plaatbewerking.
- **Installeren**: Drinkwater, sanitair en afvoer.
- **Energie**: Elektro- besturingstechniek.

1.1. Probleemstelling m.b.t. de huidige PTA-opdracht; Onderdeel D (blauw), CSPE 2019

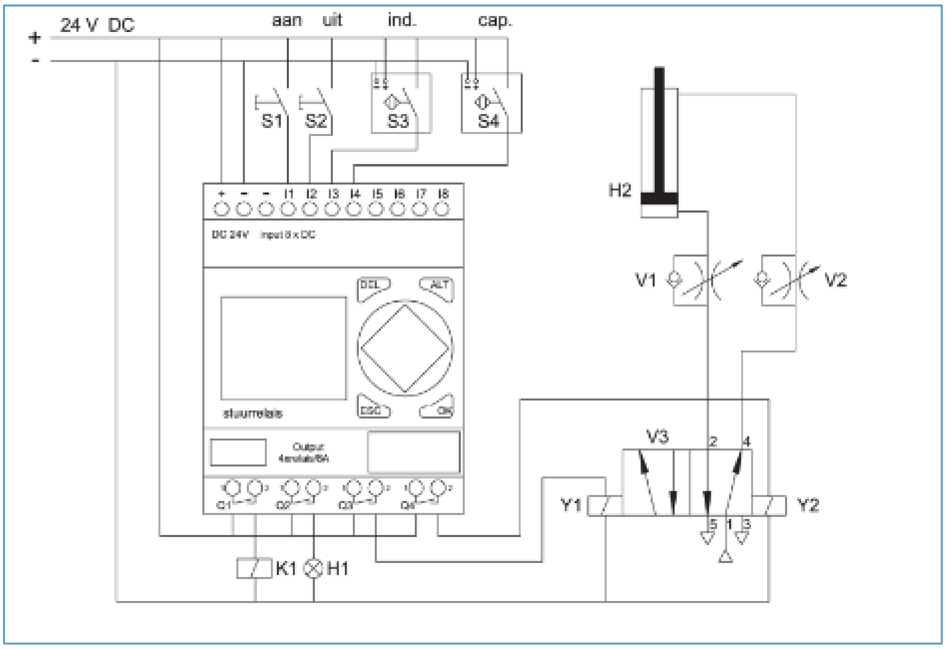
De werkelijke (hetzij onbewuste) opdrachtgevers zijn onze leerlingen. Ze geven dikwijls aan geen beeld te hebben waarom en hoe besturingstechniek, in het bedrijfsleven, wordt toegepast. Na een aantal formatieve opdrachten, zoals elektropneumatiek, programmeren en aansluiten van de EasyRelais, moet de leerlingen de summatieve PTA-opdracht is de zogenaamde “Afvalsorteerder” voltooien. Dit is een opdracht waarvoor rechtstreeks het blauwe onderdeel D van het CSPE 2019 wordt gebruikt. https://www.examenblad.nl/system/files/2019/profielen-vmbo/kp_1300_b_19_1_d_o.pdf

Ondanks afbeelding in figuur 3 en de opdrachtomschrijving is het voor de leerlingen lastig zich een voorstelling te maken hoe zoiets er in het echt zou kunnen uitzien en werken.

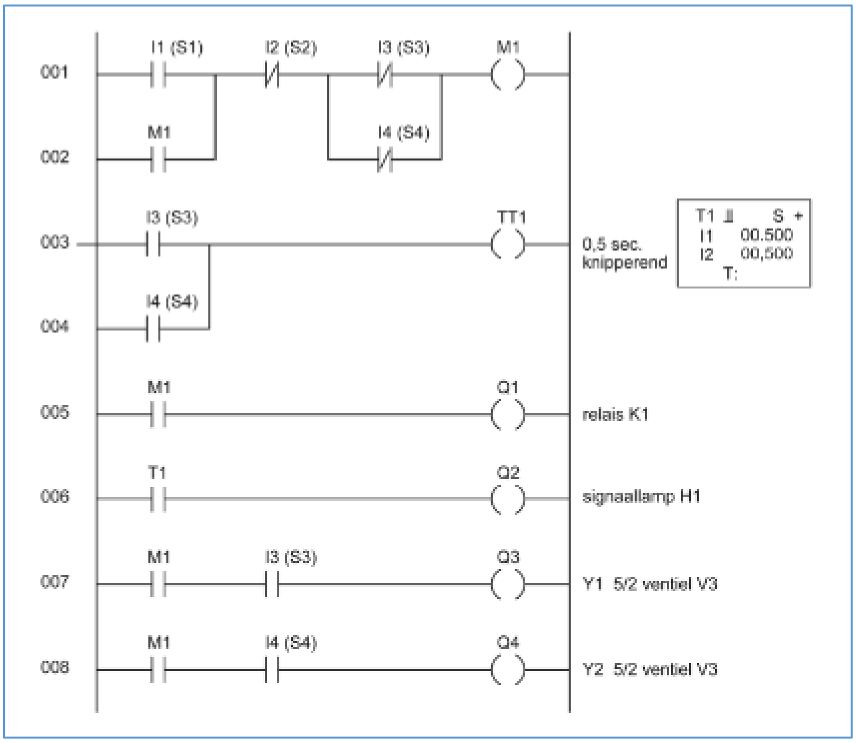


Figuur 3: De afvalsorteerder (College voor Toetsen en Examens, 2019) (bron CSPE 2019, onderdeel D Blauw)

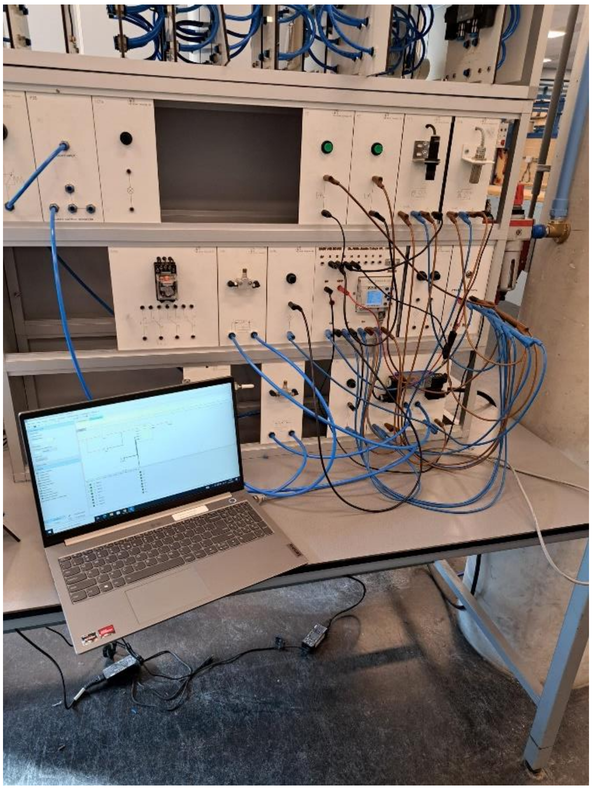
Het programmeren wordt vaak als lastig ervaren en de toepassingen in het bedrijfsleven, zijn voor hen veelal abstract. Met een apparaat, die ook daadwerkelijk doet, wat in de opdracht staat omschreven, zal het nut duidelijk worden en de materie beter beklijven.



Figuur 4: Elektro pneumatisch schema voor de afvalsorteerder (College voor Toetsen en Examens, 2019) ([bron CSPE 2019, onderdeel D Blauw]())



Figuur 5: Ladderdiagram voor de afvalsorteerder (College voor Toetsen en Examens, 2019) ([bron CSPE 2019, onderdeel D Blauw]())



Figuur 6: Zoals de opdracht nu in praktijk wordt uitgevoerd

Hierbij waren, voor mij, de 7 Hulpvragen (6 W's) van Verhoeven een hulpvolle methode (Verhoeven, 2018)**:**

Wie	Leerling.
Wat	Door abstractie onduidelijkheid over het nut bij de leerling.
Waar	Op de werkplekken/experimenteerborden waar de opdrachten worden uitgevoerd.
Wanneer	Bij het uitvoeren van de summatieve opdracht "Afvoersorteerder".
Waarom	Een aangesloten en geprogrammeerde EasyRelais met alleen actuatoren als schakelrelais, een signaal lamp en dubbelwerkende persluchtcilinder geeft geen duidelijk genoeg beeld over waar het voor dient. Ook de toepassing van de ingangssignalen m.b.v. capacitieve en/of inductieve sensoren spreken niet tot de verbeelding. Dus nodig is een werkend apparaat waarmee gedemonstreerd wordt, wat erna gebeurt als het eerst bakje volloopt, enz. ….
Waardoor	Leerlingen hebben (nog) geen excursie gehad bij een procesfabriek waar automatisering wordt toegepast. Naast technisch ook geen (volledig) beeld van economisch voordeel (humane arbeid versus automatisering/robotisering.

2. Projectresultaten

Waarom het project wordt geïnitieerd:

- Het bewust maken van het nut en doel van besturingstechniek bij onze PIE-leerlingen, die een aantal items gaan maken (3D-printen en metaaltechniek) en programmeren.

Daarom is gekozen voor het ontwikkelen en vervaardigen van een apparaat die afgeleid is van figuur 3. Wel willen we meer de nadruk leggen dat het apparaat gebruikt wordt om te waarborgen dat productieprocessen gecontinueerd worden, van bijvoorbeeld afvoer en collecteren van M4-moertjes. De naam zal op termijn dan ook gewijzigd worden, van “Afvalsorteerder”, in “Afvoersorteerder”.

2.1. Projectresultaat schoolopdracht Afvoersorteerder

SMART:

- **Specifiek:** In de Afvoersorteerder moeten 2 magazijnbakken geplaatst kunnen worden en er moet gesignaleerd worden wanneer de eerste bak vol is bouwblokjes. Vervolgens moet de installatie de afvoerstroom wijzigen naar de tweede bak. De installatie moet stoppen als de tweede bak ook vol is. Het programma voor de EasyRelaisbesturing wordt in de opdracht aangeleverd. De leerling moet een programma kunnen invoeren, niet te ontwerpen.
  - Het betreft hier een summatieve PTA-opdracht van de verplichte module 3 Besturen en Automatiseren, waar de leerlingen dus een cijfer mee scoren.
  - De opdracht is voor KB-niveau PIE. Deze is nu de opdracht “Afvalscheider” die in het volgende cohort “Afvoerafvoerder”
- **Meetbaar**: De leerling zal kunnen uitleggen waar de productie-afvoerder voor dient.
- **Aanwijsbaar/ Acceptabel**: Rense Veenstra is verantwoordelijk voor het eindresultaat, d.w.z. een afvoersorteerder ontwikkelen en fabriceren.
- **Realistisch**: De afvoersorteerder kan gemaakt worden met:
  - Catalogus inkoopdelen,
  - Machinepark beschikbaar en geschikt om de onderdelen te kunnen maken.
  - Een professionele 3D-printer is beschikbaar, waarmee met composiet versterkte materialen kan worden geprint, zoals carbon, kevlar en glasvezel.
- **Tijdgebonden**: De Productie-afvoerder moet voor 29 juni 2024 gereed zijn.

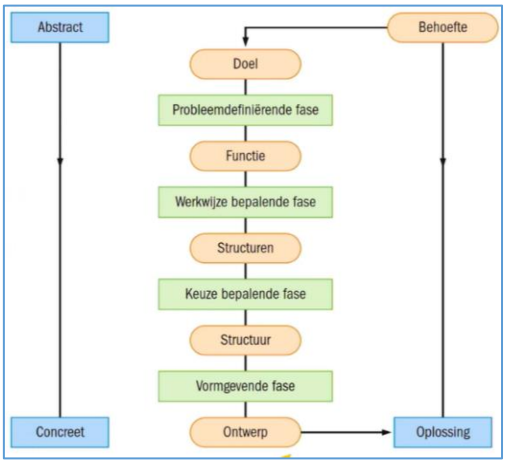
2.2. Programma van eisen

Functioneel	Fabricage	Programma van eisen	Vaste eis	Variabele eis	Wens	N.v.t.
X		De installatie moet geschikt zijn voor het uitvoeren van onderdeel D van CSPE 2019. Deze is opgenomen in het PTA van module Besturen en Automatiseren.	X			
	X	Idem.		X		
		• De opdracht moet de delen P/PIE/3.1 van Besturen en Automatiseren afdekken, op KB-niveau. Met de productieafvoerder moeten de volgende onderwijscomponenten uitgevoerd kunnen worden:				
X		9. Een pneumatische schakeling opbouwen.	X			
X		10. Een programmeerbare EasyRelais aansluiten en een programma invoeren.	X			
X		11. Sensoren en actuatoren kiezen en aansluiten.	X			
X		12. Een regelsysteem opbouwen, aansluiten en testen.	X			
		13. Een domotica-installatie opbouwen, aansluiten en testen.				X
X		14. Storingen en fouten zoeken en verhelpen in de opgebouwde schakeling.		X		
		15. Metingen uitvoeren aan een besturingsinstallatie.				X
		16. een verslag maken en de resultaten presenteren			X	
		• De opdracht moet de delen P/PIE/3.3 van Besturen en Automatiseren afdekken, op KB-niveau. Met de productieafvoerder moeten de volgende onderwijscomponenten uitgevoerd kunnen worden:				
X		6. Besturingscomponenten plaatsen aan de hand van een opstellingstekening.		X		
X		7. De besturingscomponenten bedraden en aansluiten aan de hand van een bedradingstekening.	X			
X	X	8. Een programma invoeren in een programmeerbaar relais.	X			
X		9. De automatische besturing testen.		X		
		10. De automatische besturing demonstreren en presenteren.	X			
X		De opdracht moet in 3 lesuren van 45 minuten gerealiseerd kunnen worden.	X			
X		100% van de productiedelen (moertjes) moeten tijdens transport aankomen.		X		
X		Afvoerproces mag niet stoppen moet continue doorgaan. (Door bijvoorbeeld productieafvoer automatisch in 2 stromen te kunnen leiden).	X			
X		Operator moet tijdig gewaarschuwd worden als het proces dreigt te stoppen.	X			
X		Als de operator verzaakt om tijdig in te grijpen, moet het proces alsnog stoppen.	X			
	X	Snelheid afvoertransport moet 50mm/s zijn.		X		
X		Veiligheid: afscherming van aandrijving.	X			
	X	Afmetingen afvoersorteerder: L x B x H = 300 x 100 x 100.		X		
	X	Gewicht $\leq$ 5kg.		X		
	X	Te maken met cataloguskoopdelen, 3D-printer, plaatdelen 2mm en inkoopdelen Brink Techniek BV.		X		
	X	De maakkosten mogen niet hoger dan €500,-.		X		
	X	De afvoersorteerder moet gemaakt kunnen worden in 3 maanden.		X		
	X	Bij een val van 1,5m geen ontzetschade aan de ophanging.		X		
X		Weinig onderhoud.		X		
	X	Defecte geraakte onderdelen moeten binnen 24 uren te vervangen zijn.		X		
X		Werking betrouwbaar.		X		
	X	Complexiteit onderdelen laag.		X		
	X	Zo weinig mogelijk onderdelen.		X		

Naar (Zeiler, 2014)

3. Projectactiviteiten

- Het maken en inleveren van dit PVA
  - GO afwachten, bij NOGO direct corrigeren,
- Het schrijven van het dossier en morfologische kaart.
  - Keuze van de morfologie.
- Ontwerpen van de afvoersorteerder.
- Inkopen van onderdelen.
- Het maken van de metaal- en 3D geprinte onderdelen.
- Het assembleren van de Afvoersorteerder.
- Testen van de afvoersorteerder > PDCA (Plan Do Check Action)
- Aanpassen van de afvoersorteerder.



Figuur 7: Ontwerpfasering volgens Zeiler (Zeiler, 2014)

Ik ga de stappen uit het boek Basisboek Ontwerpen van Wim Zeiler gevolgen om zo mijn ontwerpdossier te maken. Daarbij is het proces ingedeeld in de volgende fases: A - probleem definiërende fase. B - werkwijze bepalende fase. C - keuzebepalende fase. D - vormgevende fase (Zeiler, 2014).

4. Projectgrenzen

Zoals al omschreven in §2.2. blijft de afvoersorteerder beperkt tot de functies om hiermee de summatieve opdracht te kunnen realiseren, waarmee syllabusdelen P/PIE/3.1 en P/PIE/3.3 mee worden voldaan. Hieruit vloeien alleen de strikt noodzakelijke fabricage-eisen van de afvoersorteerder.

5. Tussenresultaten

- PVA klaar in week 10
- Dossier klaar in week 23
- Product klaar in week 22
- Eindassessment week 26

6. Kwaliteit

De afvoersorteerder moet hufter proof gemaakt worden. De ophanging moet dermate stijf geconstrueerd worden dat een valhoogte van 1.5 m geen schade geen ontzetschade ontstaat.

7. Projectorganisatie

Naam	functie	Projectactiviteiten.
Rense Veenstra	Docent PIE	Afstuderend d.m.v. dit project en alle verder genoemde activiteiten.
Rolf Ahlers	Technisch onderwijs assistent	Voor advies en assisteren bij fabriceren en assembleren.
Chris Toren	Docent PIE	Aanpassen van summatieve opdracht afvoersorteerder
Henk Spaan	Docentenopleider, Windesheim	Begeleiding
Monika Smit	Teamleider vmbo dr. AJC	Facilitering uren

8. Strokenplanning

Voor het maken van de strokenplanning heb ik gebruik gemaakt het model uit het boek “Projectmanagement” van Roel Grit

Project: **Datum opgesteld: 3 maart 2023** **Opgesteld door:** **Naam: Rense Veenstra**

Taak		**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**Tot**
Voorbereiding																											
PVA			8	2	7																						**17**
Afspraak Henk Spaan				4																							**4**
Uitvoering																											
Afspraak maken eind assessment							1																				**1**
Morfologische kaart						8																					**8**
Schrijven dossier								1	1	1	1	1	1	1	1	1	1	4									**14**
Ontwerpen van de afvoersorteerder							7	7	7																		**21**
Inkoopdelen					1					1	1																**3**
Metaalonderdelen										7	7	7															**21**
3D printen												1															**1**
Assembleren													8	8													**16**
Testen															8												**8**
Iteratie (PDCA)																8											**8**
Aanpassen summatieve opdracht afvoersorteerder																	8	4									**12**
Uitloop																			8	8							**16**
Afhandeling																											
Eindassessment																					8						**8**
Zomervakantie 24 juli dr. AJC																									V	V	
Onderwijsluwe weken Windesheim																									V	V	
Totaal			**8**	**6**	**8**	**8**	**8**	**8**	**8**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**9**	**8**	**8**	**8**	**8**						**158**

Gebruikte layout van (Grit, 2015)

9. Kosten en baten

De kosten zijn de investering van de manuren, inkoopdelen en materiaalkosten.

- De baten voor een fictief bedrijf zou een ferme kostenreductie zijn t.g.v. uitbannen van verspilling tijd door productiestagnatie. Hier wordt niet verder op ingegaan.
- Aangaande baten voor de onderwijscomponent zal de leerling, uit het voorgaande, het belang zien van automatiseren. Daarnaast zal leerlingen, m.b.v. de summatieve PTA-opdracht (als voorbeeld dienende) een beter beeld krijgen hoe automatisering toegaat in productie- en procesbedrijven. Een bezoek aan een dergelijk bedrijf kan/zal hiervan een deel uitmaken. Het zal een bijdrage leveren aan LOB (Loopbaanoriëntatie).
    - Zoals al aangehaald in §2.2 zijn de kosten geraamd op €500,-

10. Risico's

De reële risico's die genoemd moeten worden, worden gevormd door een ruim takenpakket, met nogal wat onverwachte wendingen.

- Ik ben mentor van een BB-klas, waar veel problemen spelen en waarmee veel (onverwachte/ incidentele) aandacht wordt gevergd.
- Naast PIE-docent ben Sectievoorzitter van PIE.
- Organisator van verschillende projecten, ter promotie van Techniek.
- 8 Uren (op de dinsdag) ben ik medewerker van het netwerkbureau PIT (Passie In Techniek), dat vanuit STO (Sterk Techniek Onderwijs). Het betreft hier samenwerking tussen de scholen Winkler Prins, te Veendam en dr. Aletta Jacobs College, te Hoogezand.
    - Het risico hierin is dat de programmamanager in december 2022 gestopt is en men met vragen bij mij terecht komen. Ook word ik door programmamanagers van andere STO-regio's beschouwd als de (tijdelijke) opvolger. Vergaderingen worden tijdens lesuren gepland, die ik dan weer moet cancelen. Er wordt gezegd dat ik dat zelf maar moet inschatten welke vergadering informatief belangrijk zijn, voor beide partijen. Ik heb de Directie al gevraagd hoe de opvolging van onze programmamanager geregeld wordt, maar we zijn inmiddels 2 maand verder en er is (zo ver ik weet) nog geen oplossing.

Verwijzingen PVA

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Grit, R. (2015). *Projectmanagement.* Groningen/Houten, The Netherlands: Noordhoff Uitgevers bv.

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Bijlage I: Samenvatting: Markforged University Composites Training Program

Inhoudsopgave

Introduction

Markforged University Composites Training Program

The Composites Training Program is designed to help you build and develop the skills necessary to take advantage of Markforged composite-reinforced 3D printing technology to accelerate and simplify your everyday engineering or technical work. In this three-part training program, consisting of Core, Essential, and Advanced Composites, your instructors will guide you as you explore the fundamental operating principles of Markforged composite 3D printing, develop your skills in Design for Additive Manufacturing (DfAM) and hone your intuition for identifying impactful applications of high-performance 3D printing in your operations. Program content includes lectures, real-world demos and case studies, guided tutorials in both Markforged's Eiger software and CAD, and much more.

Completion of this training program prepares you to take the Markforged Certified Additive Expert exam in Composites (MCAE-C), which will be administered at the end of formal instruction.

Markforged University Composites-trainingsprogramma
Het Composites-trainingsprogramma is ontworpen om u te helpen de vaardigheden op te bouwen en te ontwikkelen die nodig zijn om te profiteren van Markforged composiet versterkte 3D-printtechnologie om uw dagelijkse technische of technische werk te versnellen en te vereenvoudigen. In dit driedelige trainingsprogramma, bestaande uit Core, Essential en Advanced Composites, zullen uw instructeurs u begeleiden bij het verkennen van de fundamentele werkingsprincipes van Markforged composiet 3D-printen, het ontwikkelen van uw vaardigheden in Design for Additive Manufacturing (DfAM) en het aanscherpen van uw intuïtie voor het identificeren van impactvolle toepassingen van high-performance 3D-printen in uw activiteiten. De inhoud van het programma omvat lezingen, real-world demo's en casestudy's, begeleide tutorials in zowel Markforged's Eiger-software als CAD, en nog veel meer.

De voltooiing van dit trainingsprogramma bereidt u voor op het Markforged Certified Additive Expert-examen in Composites (MCAE-C), dat zal worden afgenomen aan het einde van de formele instructie.

Markforged Trainings center

https://markforged.litmos.com/home/dashboard

Showpad Web

rveenstra@aletta.nl

Ruben22!

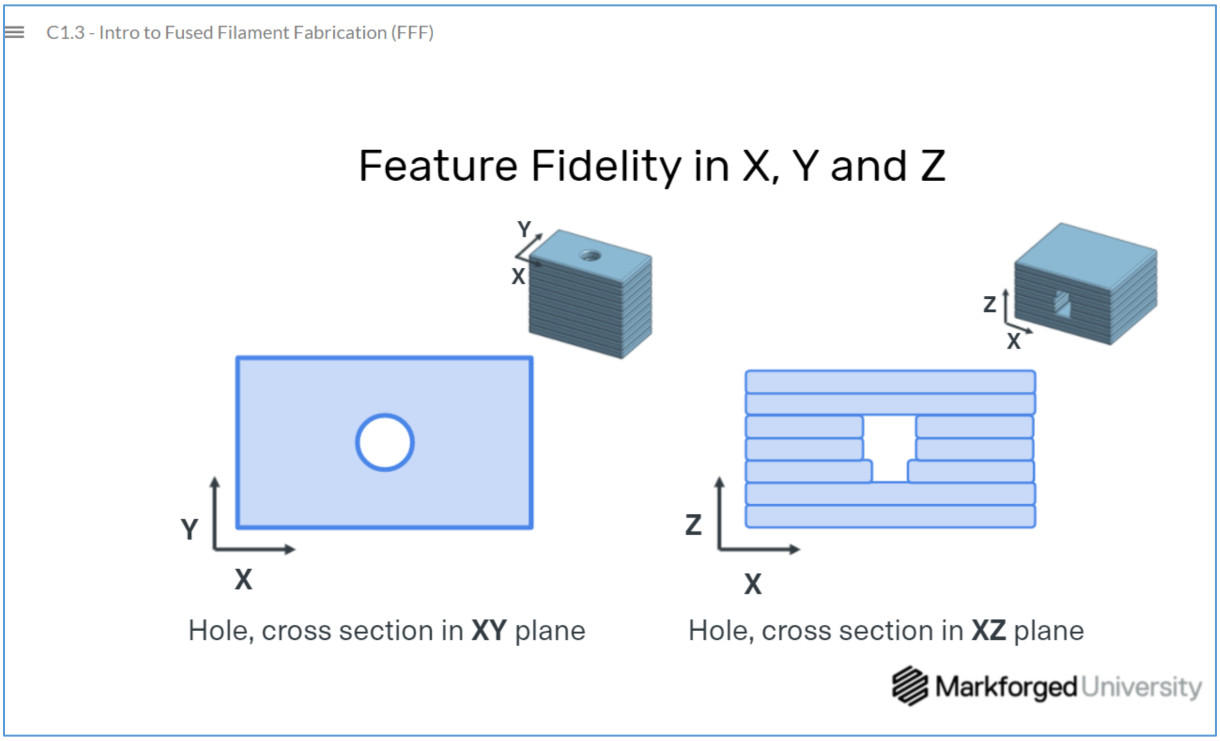
Metal

GO TO PATH

Markforged University Composites Course Pre-work

Markforged University Core Composites

C.1.3. Fused filament Fabrication (FFF)



C1.3 - Intro to Fused Filament Fabrication (FFF)

What about overhangs?

- 3D prints are built layer by layer on **top** of the preceding layer
- Cantilevered or overhanging features may be built on top of **supports**

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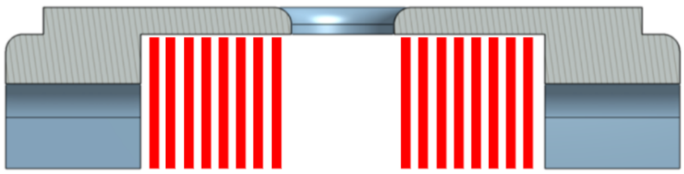
- Cantilevered = vrijdragend
- Preceding = voorgaande

C1.3 - Intro to Fused Filament Fabrication (FFF)

What about overhangs?



- 3D prints are built layer by layer on **top** of the preceding layer
- Cantilevered or overhanging features may be built on top of **supports**

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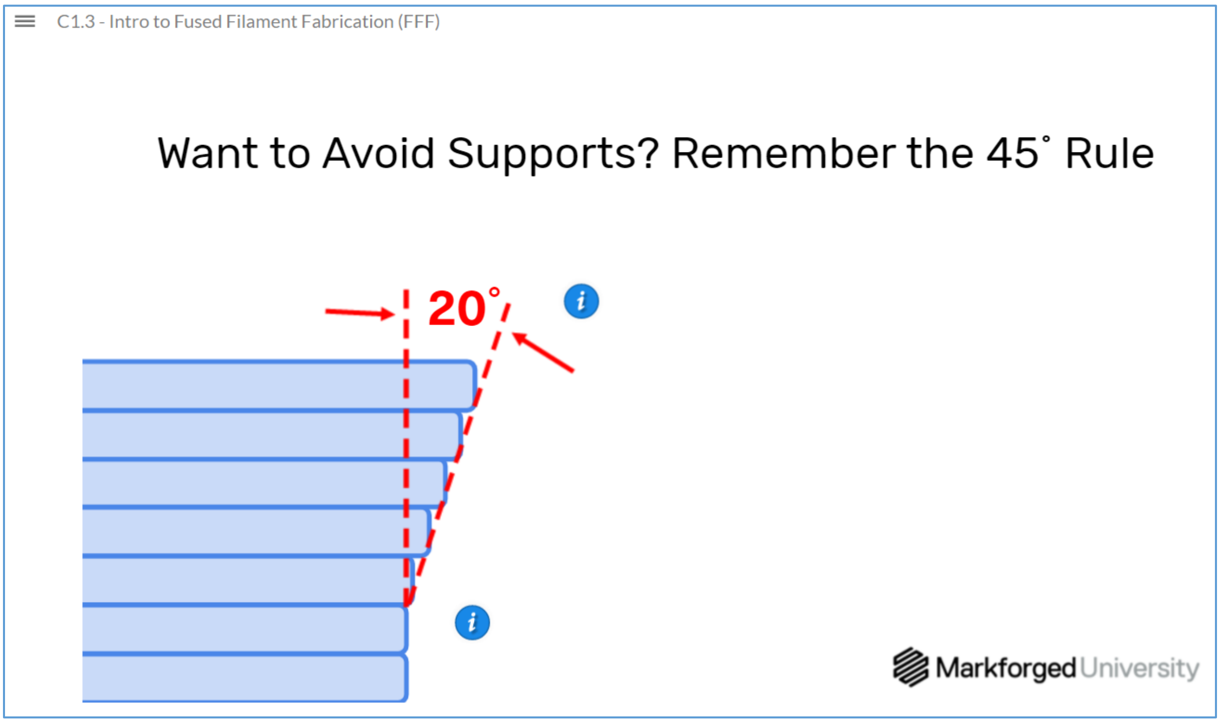
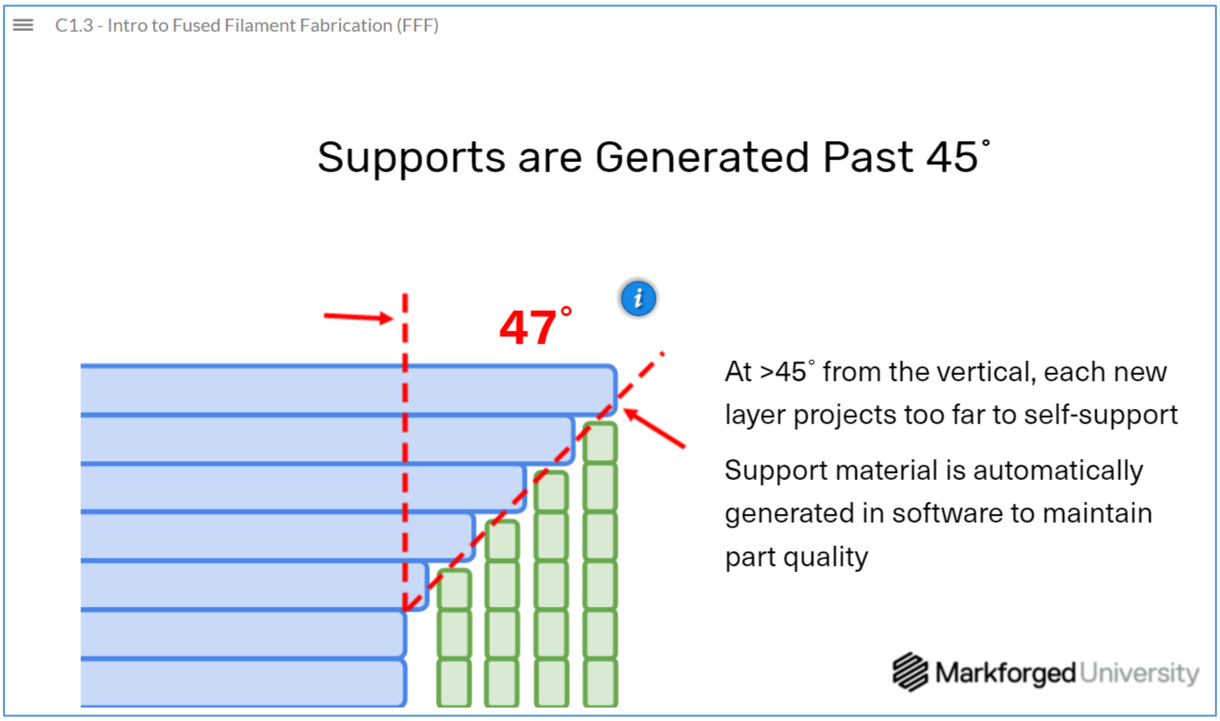
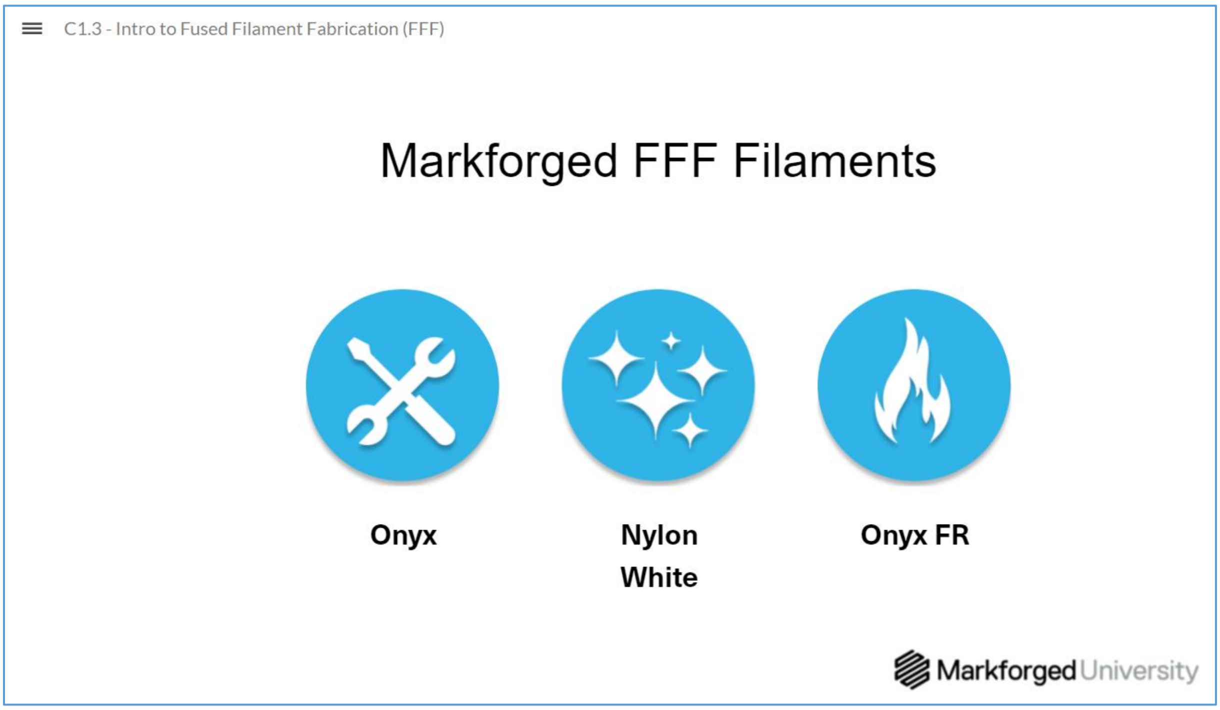
- Houd, bij CAD, rekening met printoriëntatie, om support material te reduceren.
- Idem: richting van belasting.



- Hoek <= 45°.

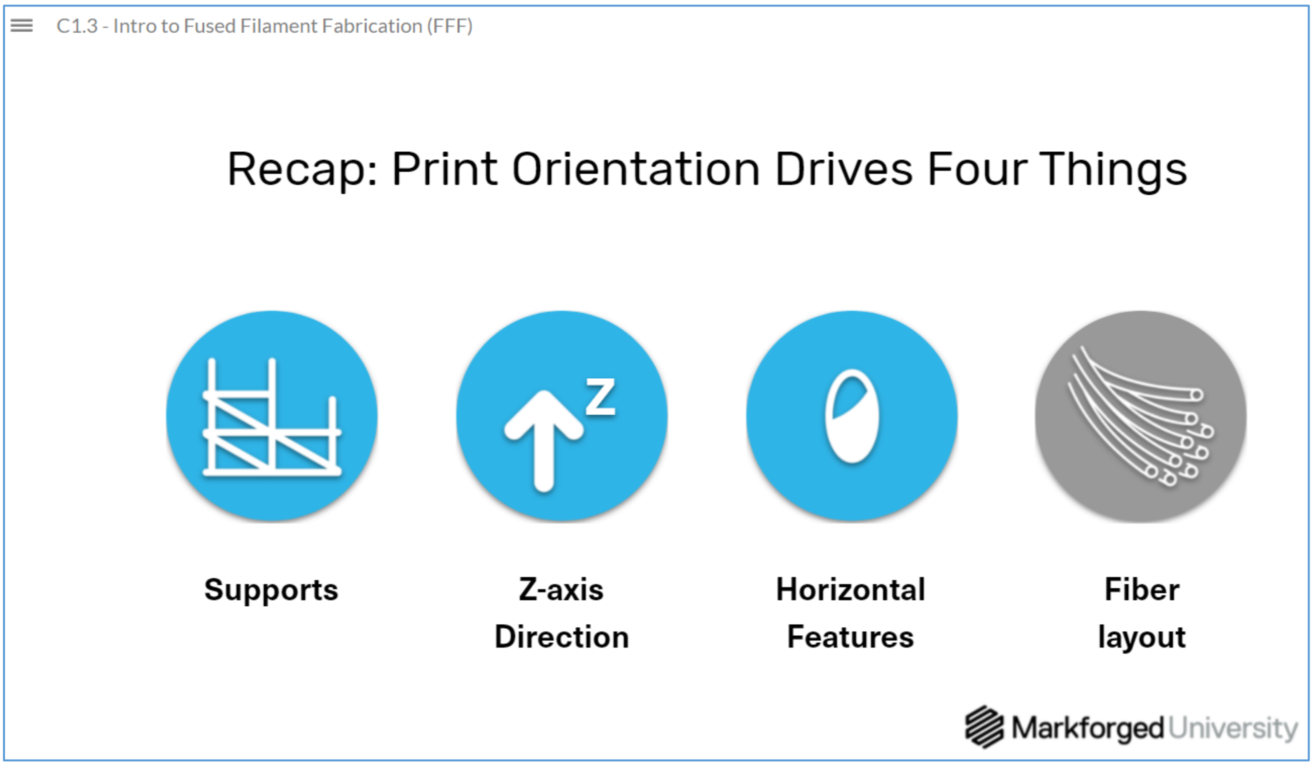


- Langere printtijd.
- Meer materiaalverbruik, door support.
- Dus duurder.



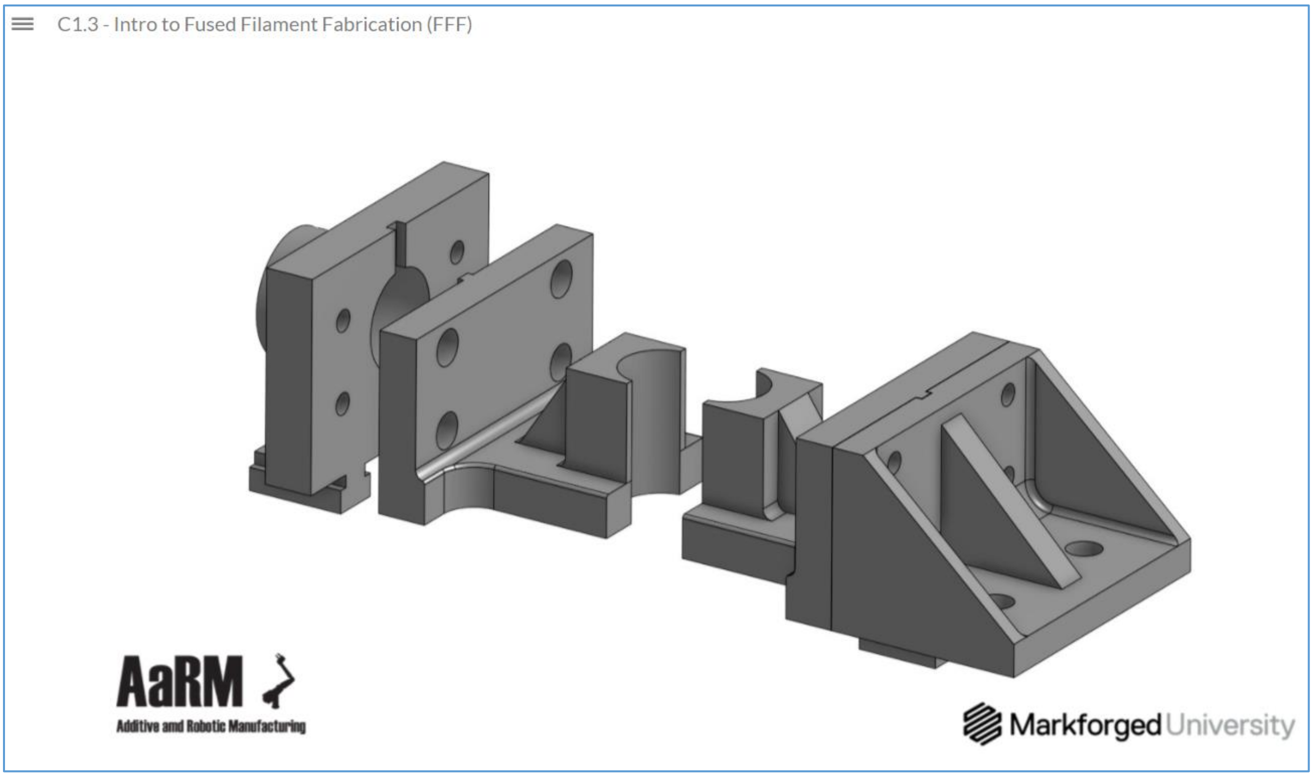
- Onyx: Carbon filled nylon.
  - Hoge taaiheid.
  - Afbuiging T?
  - Embrace??
  - Hoge nauwkeurigheid en oppervlaktegesteldheid.
  - Toepassingen:
    - Fixtures, prototypes.
    - Vervanging voor kunststoffen: Nylon en Delrin.

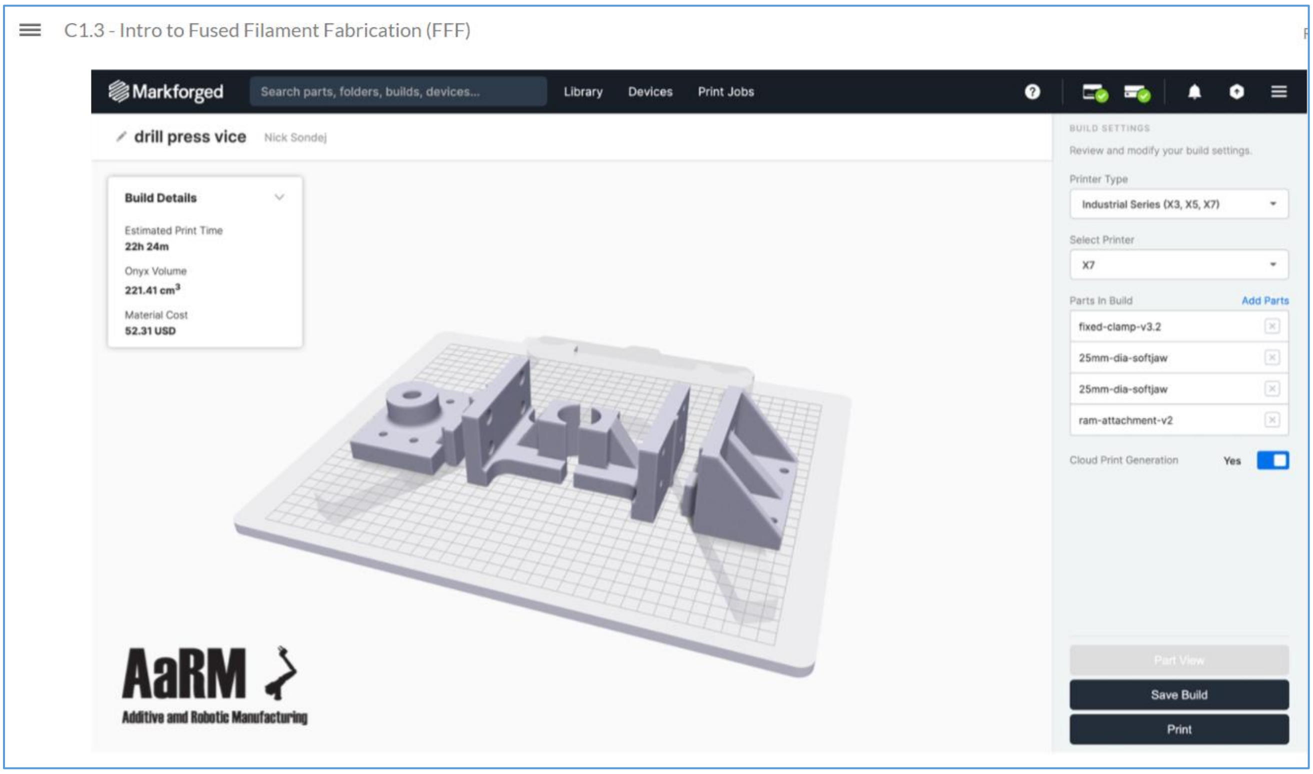
- Nylon White.
  - Unfilled material.
  - Geschikt voor modellen.
  - Lower friction properties,
  - Niet geschikt voor overhanging > 57° and thin parts.
  - Slippery surface finish.
- Onyx FR.
  - Low flamability.
  - Thickness of 3mm.
  - Toepassingen: Airospace, Defence and Transportation.
    - Exposing to high heat.
    - Bestand tegen combustion (verbranding): vonken en nabijheid van vlambooglassen.
  - Alleen voor industriële toepassingen.



Example: soft jaw construction with Onyx only


C1.3 - Intro to Fused Filament Fabrication (FFF)
Markforged University


C1.3 - Intro to Fused Filament Fabrication (FFF)
AaRM
Additive and Robotic Manufacturing
Markforged University



- Quick response tot he customer.

- Realise:
    - Higher strenght than credits you give for.
    - Reduce of material costs and production time.

C1.3 - Intro to Fused Filament Fabrication (FFF)

Module Review

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C1.3 - Intro to Fused Filament Fabrication (FFF)

Mark all answers which are aspects of the plastic FFF printing process that you need to consider when choosing a print orientation for a Markforged printer.

- [ ] Printhead location
- [x] Supports and their location
- [x] Z-axis strength
- [x] Horizontal features and their functional requirements
- [ ] Plastic FFF material selection

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C1.3 - Intro to Fused Filament Fabrication (FFF)

Mark all answers which are aspects of the plastic FFF printing process that you need to consider when choosing a print orien[...]

- [ ] Printhead
- [x] Supports a[...]
- [x] Z-axis stre[...]
- [x] Horizontal
- [ ] Plastic FFF material selection

Correct

You're correct – nicely done!

Continue

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C1.3 - Intro to Fused Filament Fabrication (FFF)

True/False: Markforged's Eiger software automatically generates support structures for any overhanging features with a surface tangent angle greater than 45˚ from the **vertical**.

- (•) True
- ( ) False

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C1.3 - Intro to Fused Filament Fabrication (FFF)

3D printed parts are **anisotropic**, which means that they...

- ○ don't absorb moisture readily
- ○ don't have a crystalline structure seen in isotropic plastics
- ◉ have different mechanical properties in different directions
- ○ perform best in outdoor environments near the Equator

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C1.3 - Intro to Fused Filament Fabrication (FFF)

Click on any geometry in this part which is an example of a **horizontal feature** whose functional requirements should be considered in the current print orientation.

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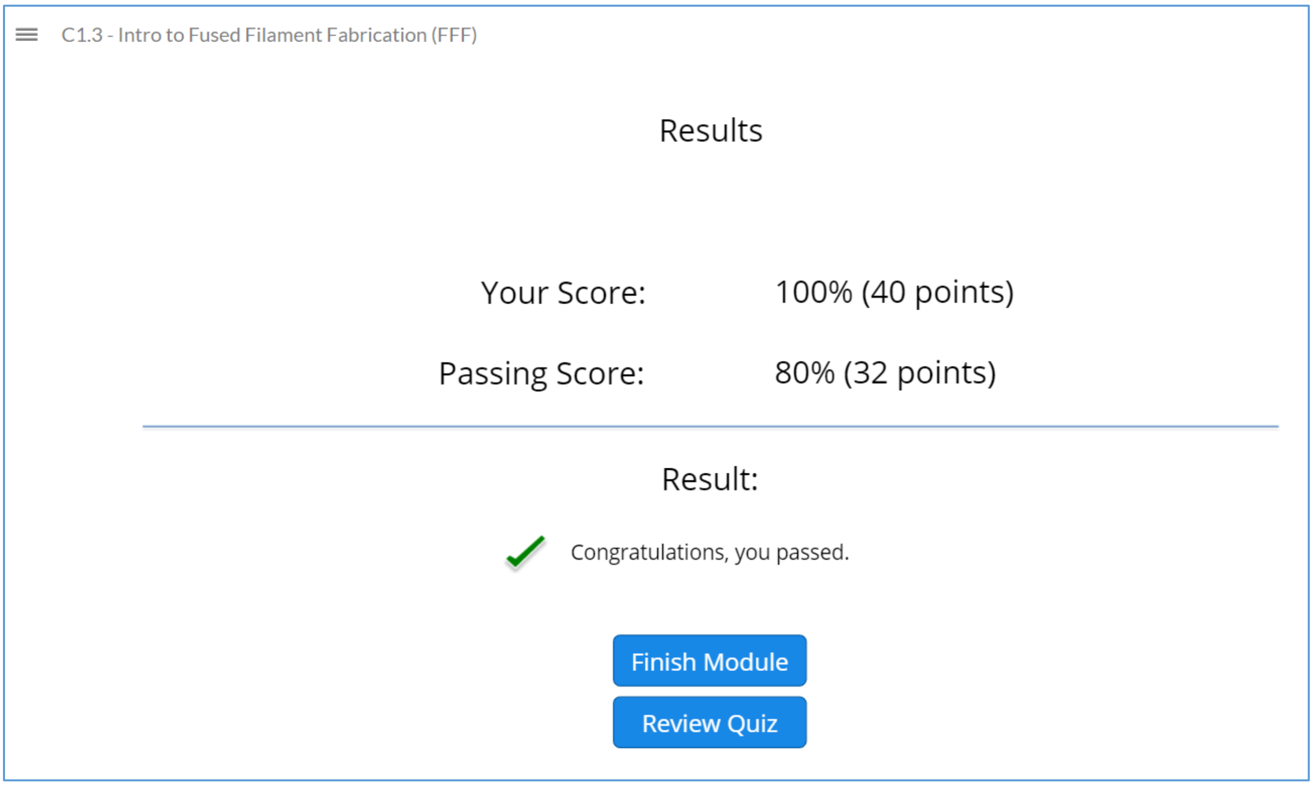
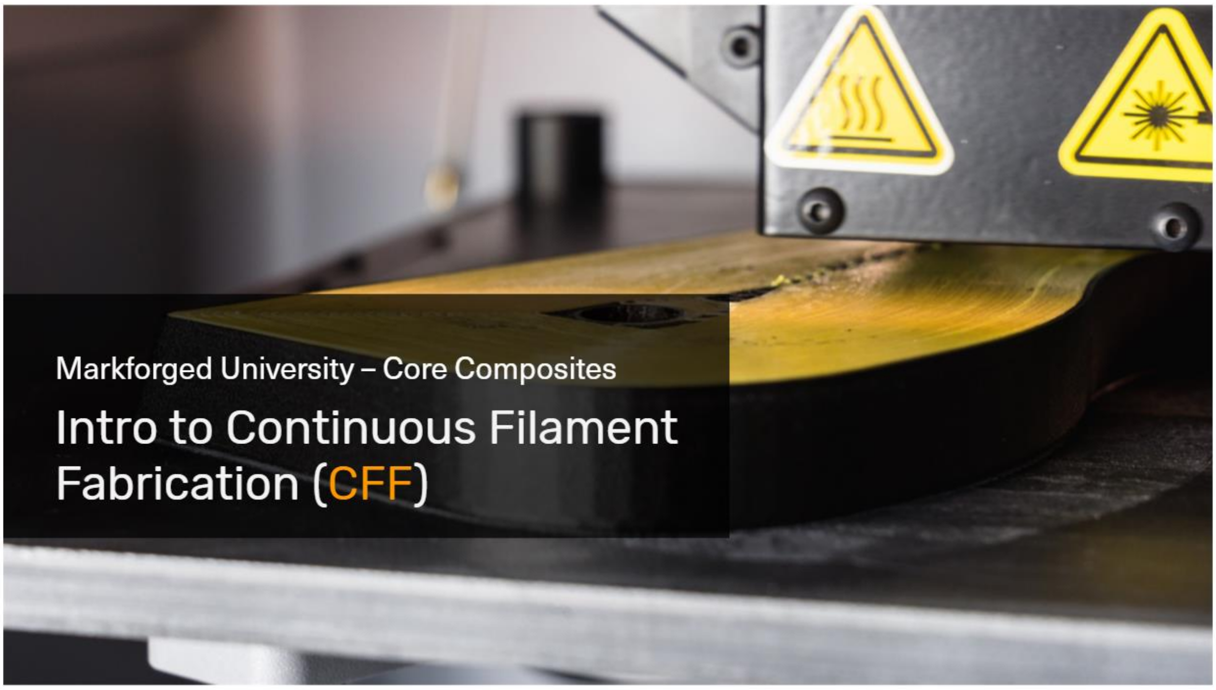
- Boven



C.1.4. Continues filament Fabrication (CFF)

C1.4 - Intro to Continuous Filament Fabrication (CFF)



C1.4 - Intro to Continuous Filament Fabrication (CFF)

Module Overview

CFF Process Overview

A Closer End-to-end Look at CFF

Mechanics of CFF Reinforcement in X, Y and Z

CFF in Practice

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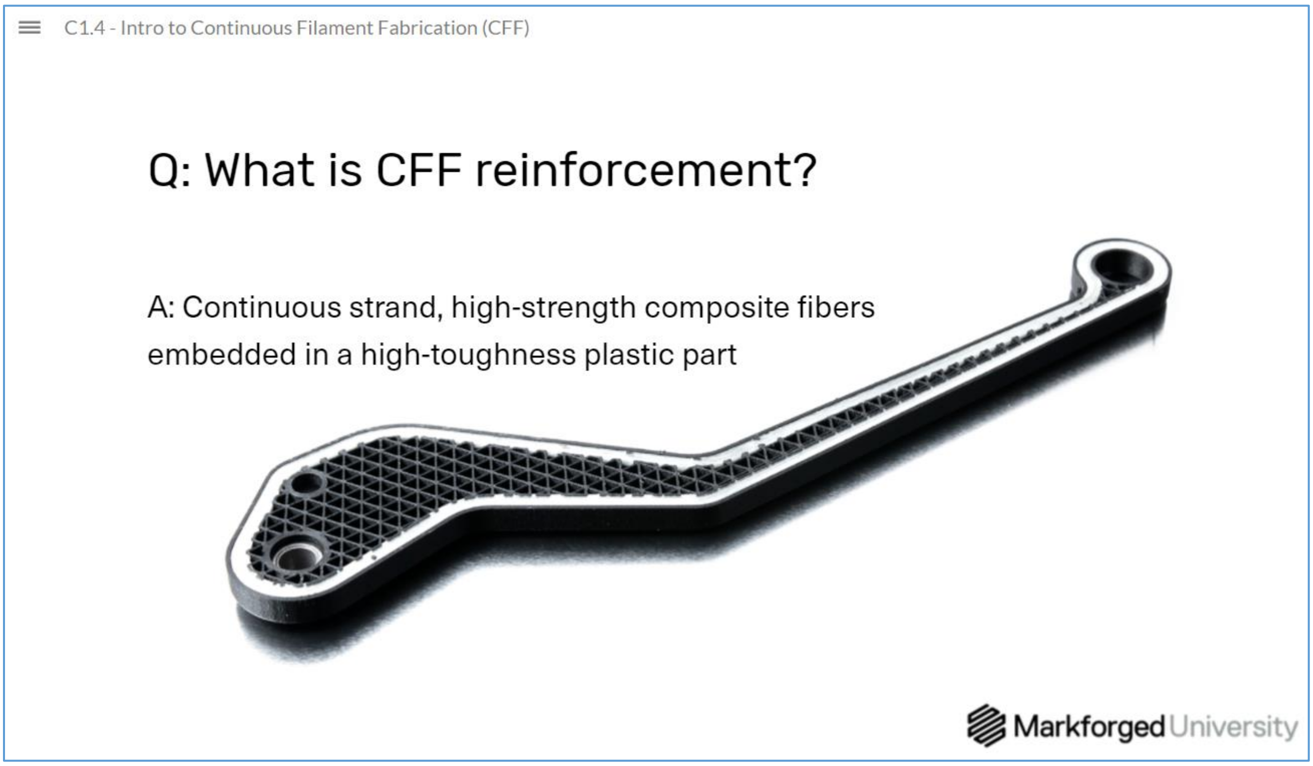
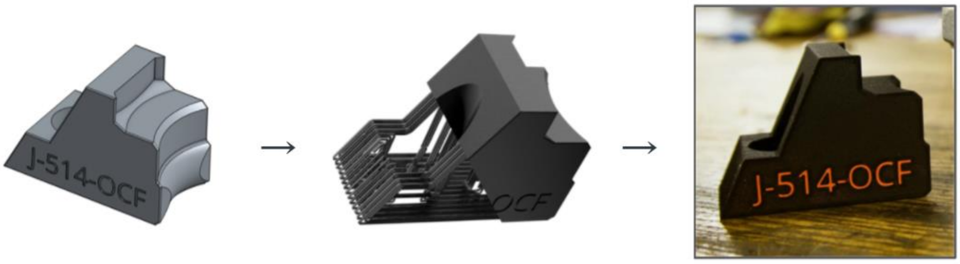


- Strand = Streng.

C1.4 - Intro to Continuous Filament Fabrication (CFF) RESOURCES

FFF+CFF Process Overview



CAD → Configure, Reinforce (CFF) & Slice → Part

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C1.4 - Intro to Continuous Filament Fabrication (CFF) RESOURCES

CFF produces parts which are true composites

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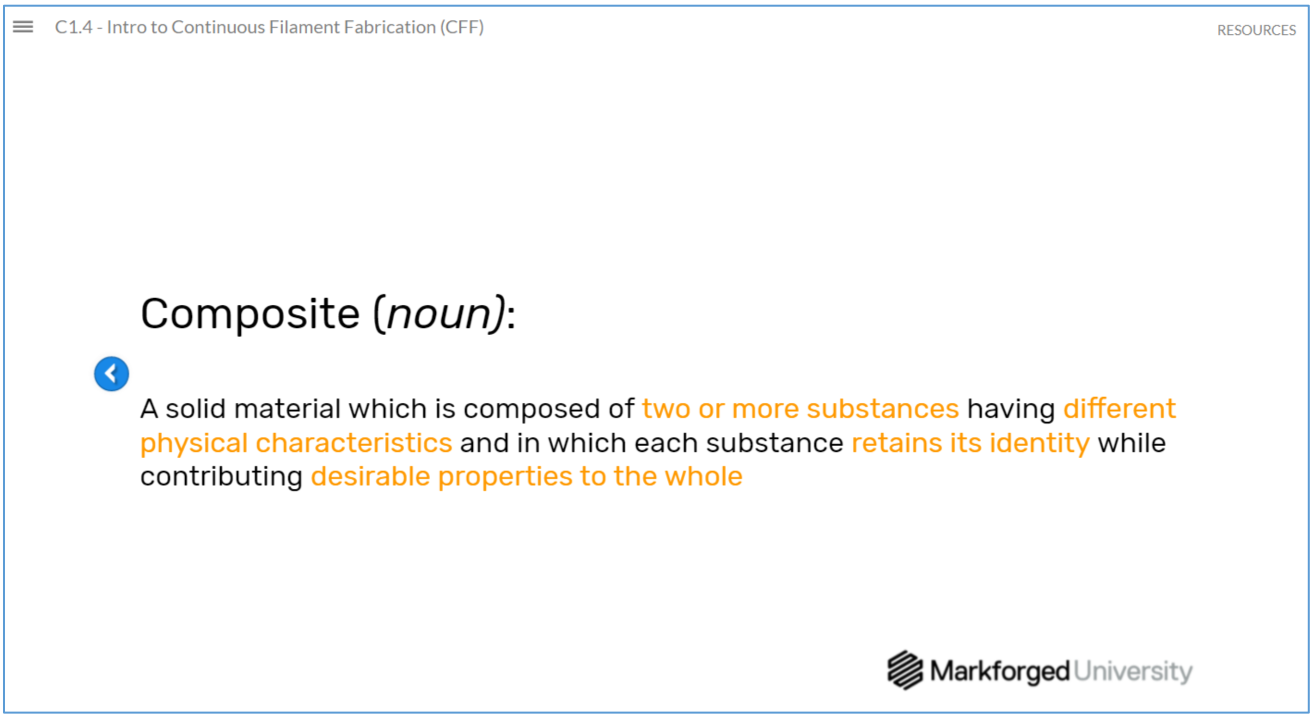
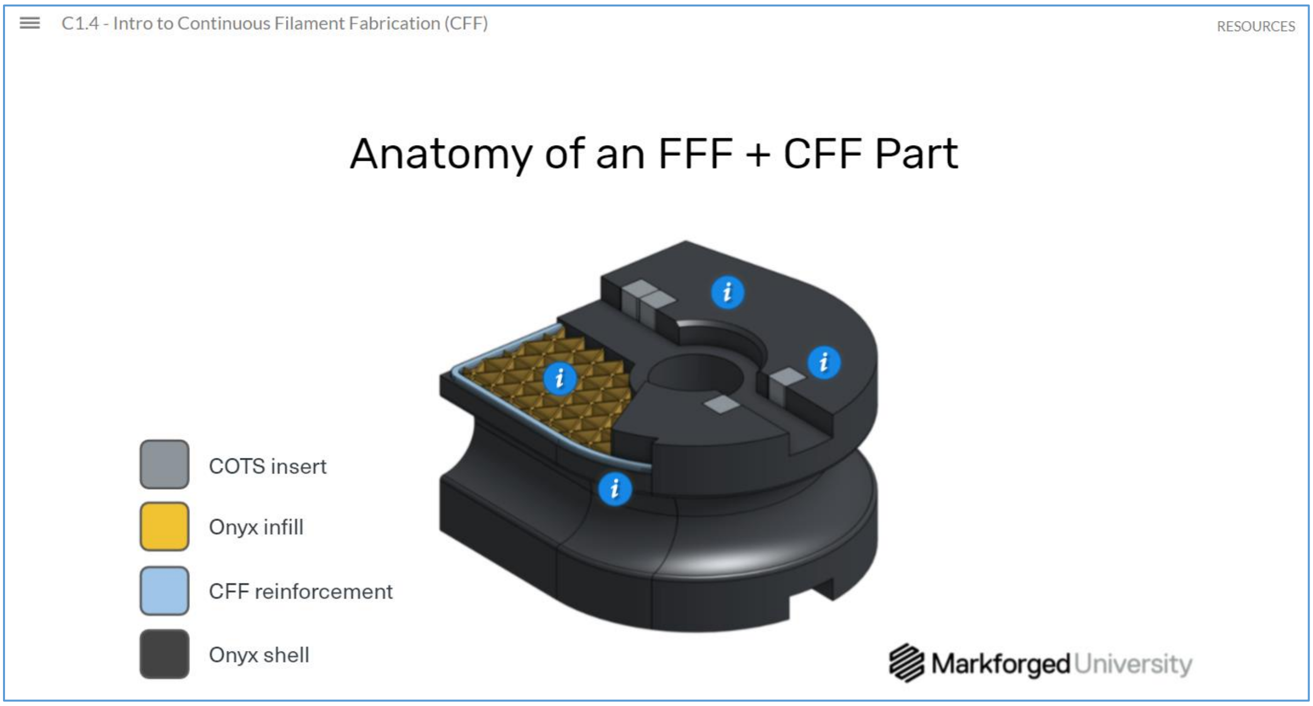
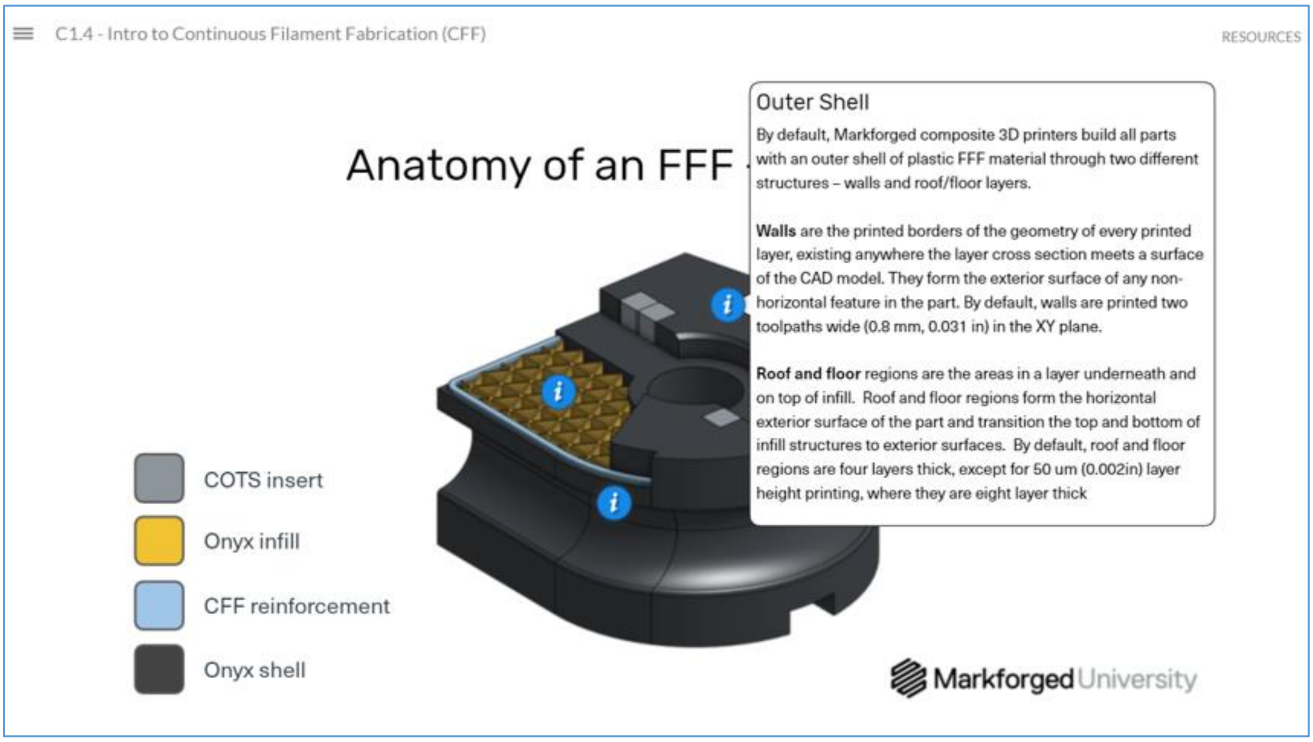
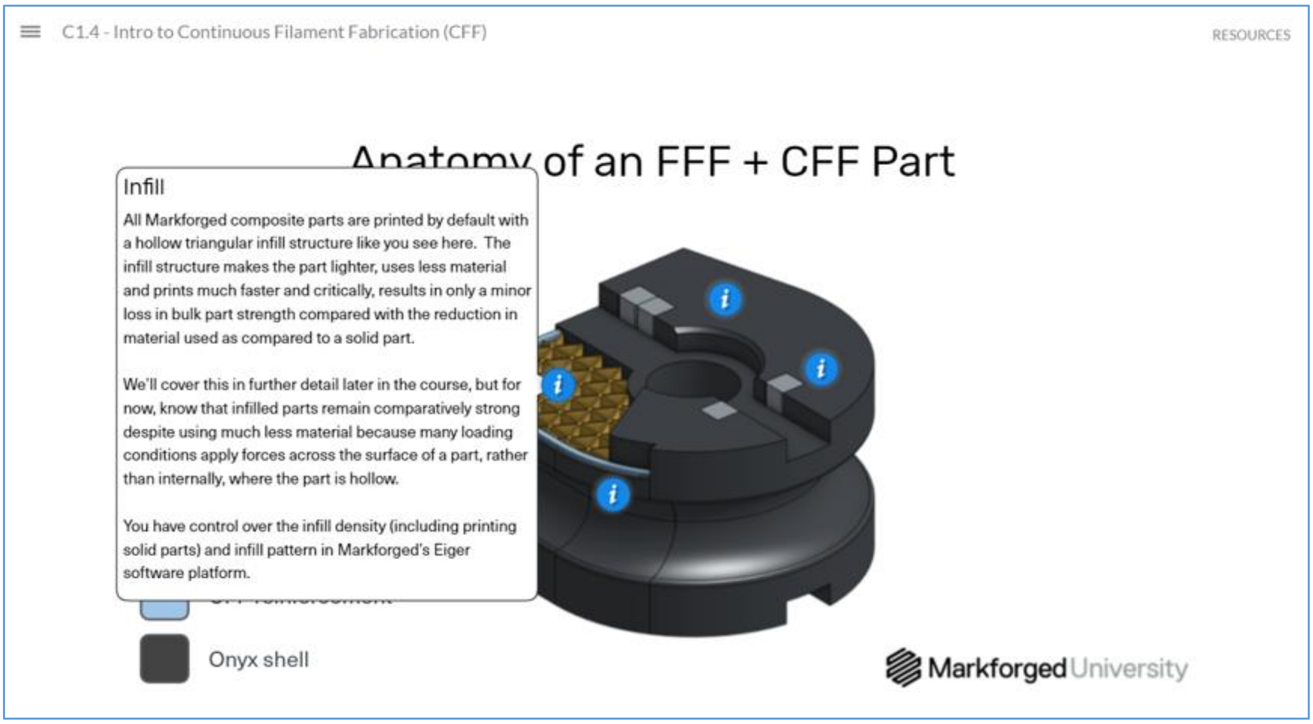


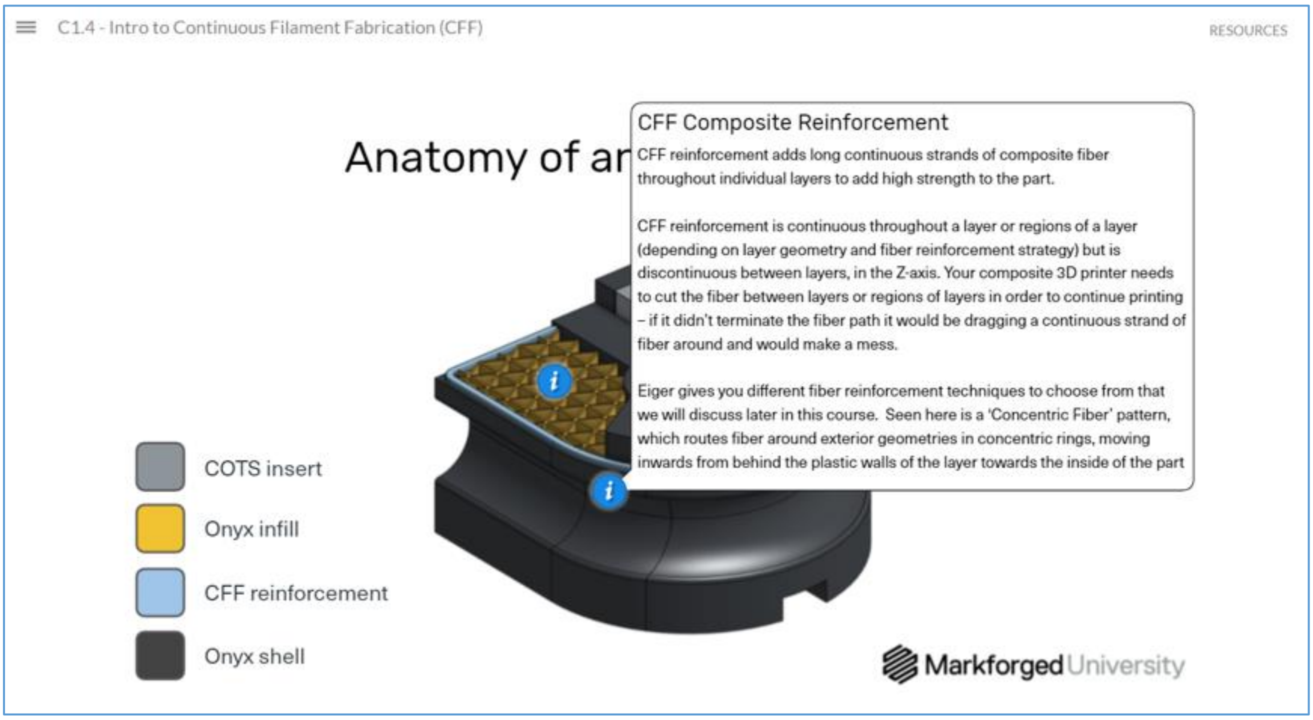
- Een vaste stof die is samengesteld uit twee of meer stoffen met verschillende fysieke kenmerken en waarbij elke stof zijn identiteit behoudt en tegelijkertijd gewenste eigenschappen aan het geheel toevoegt.



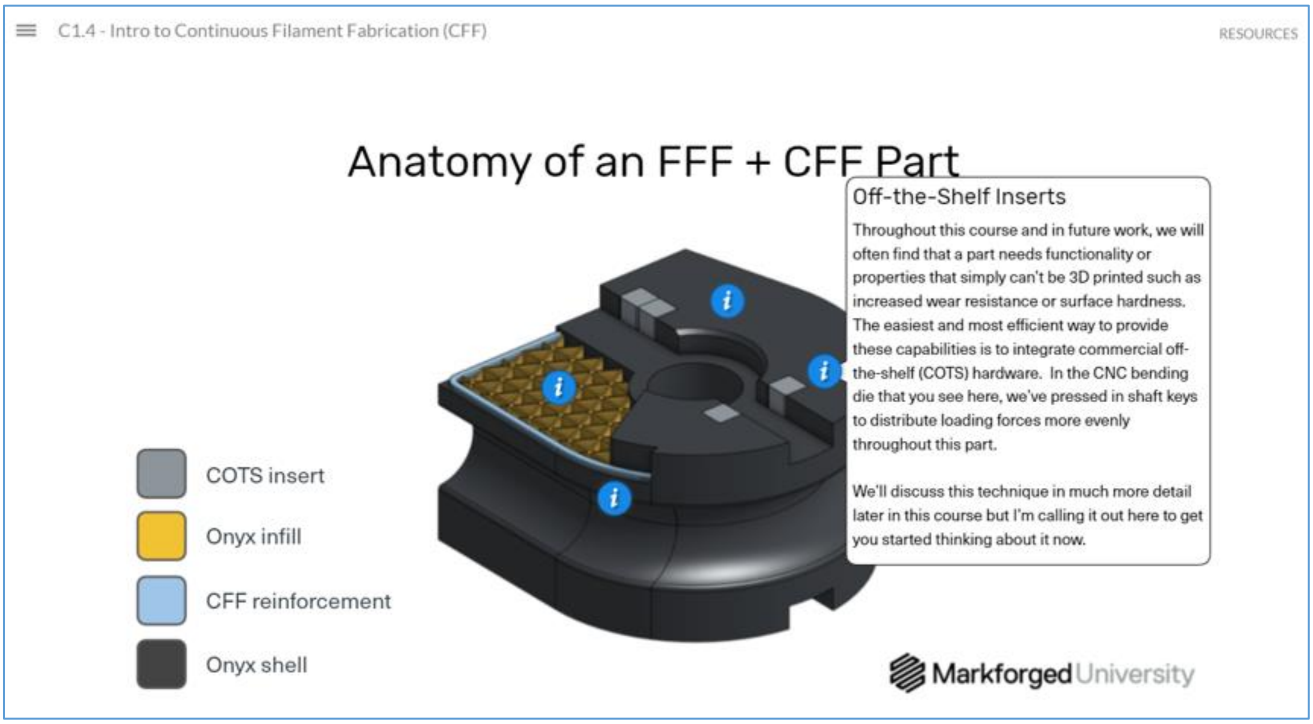


- Exterior = buitenkant





- Continuous strands?



C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

A Closer Look at the CFF Process

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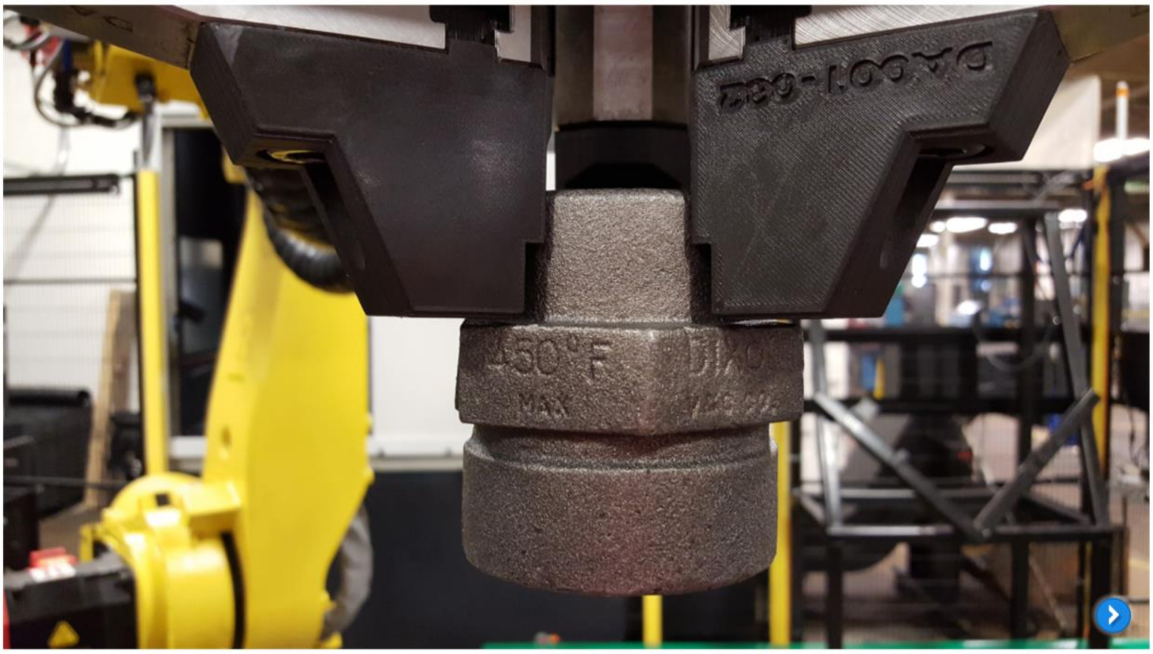
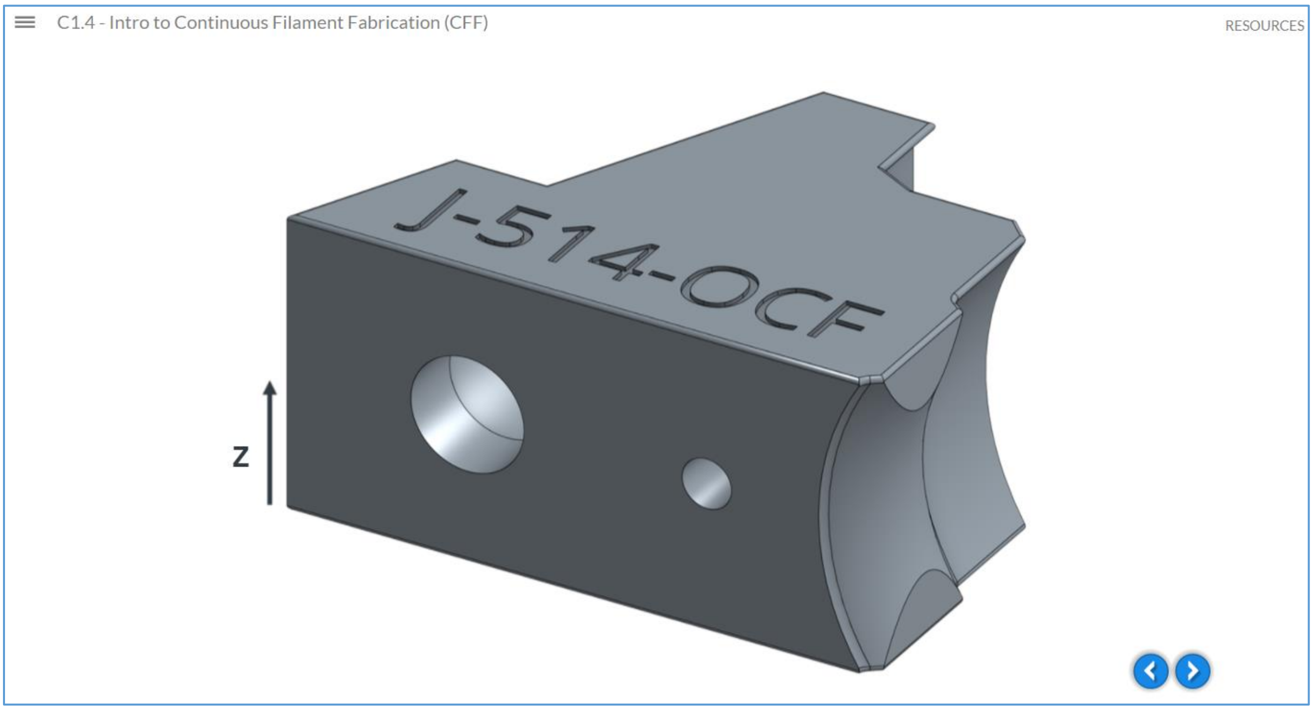
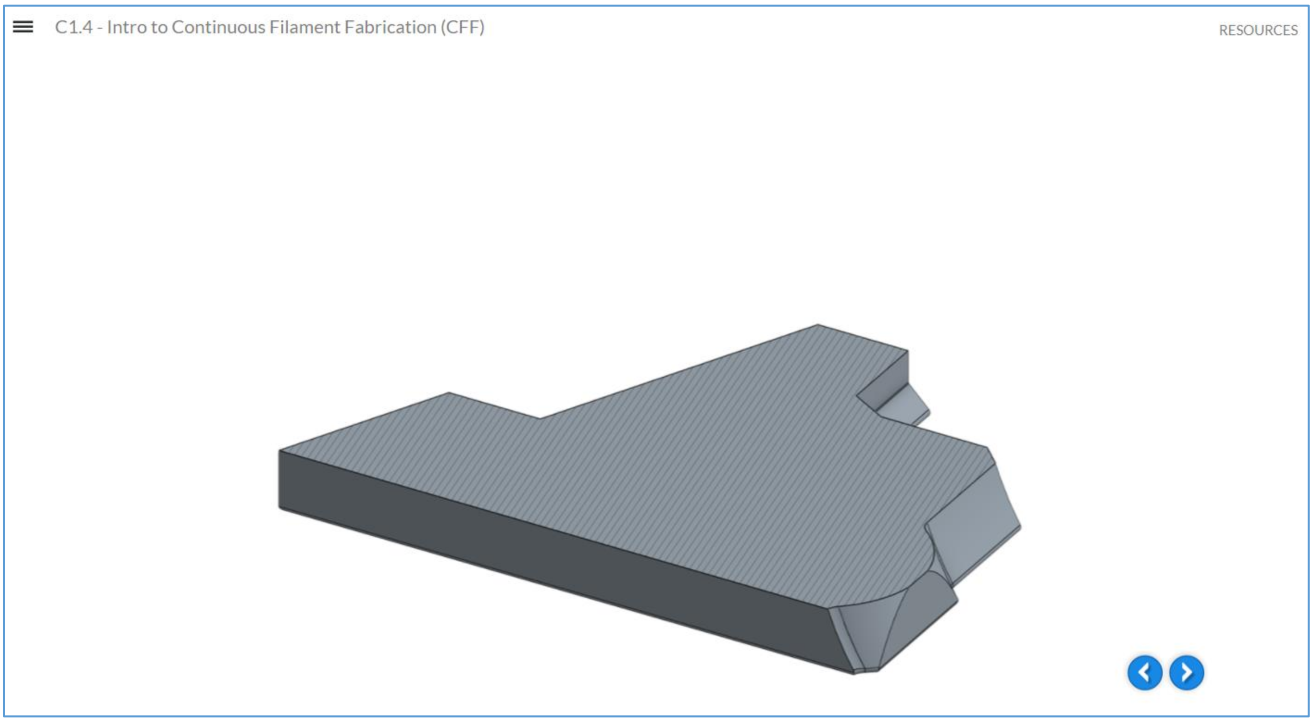
C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

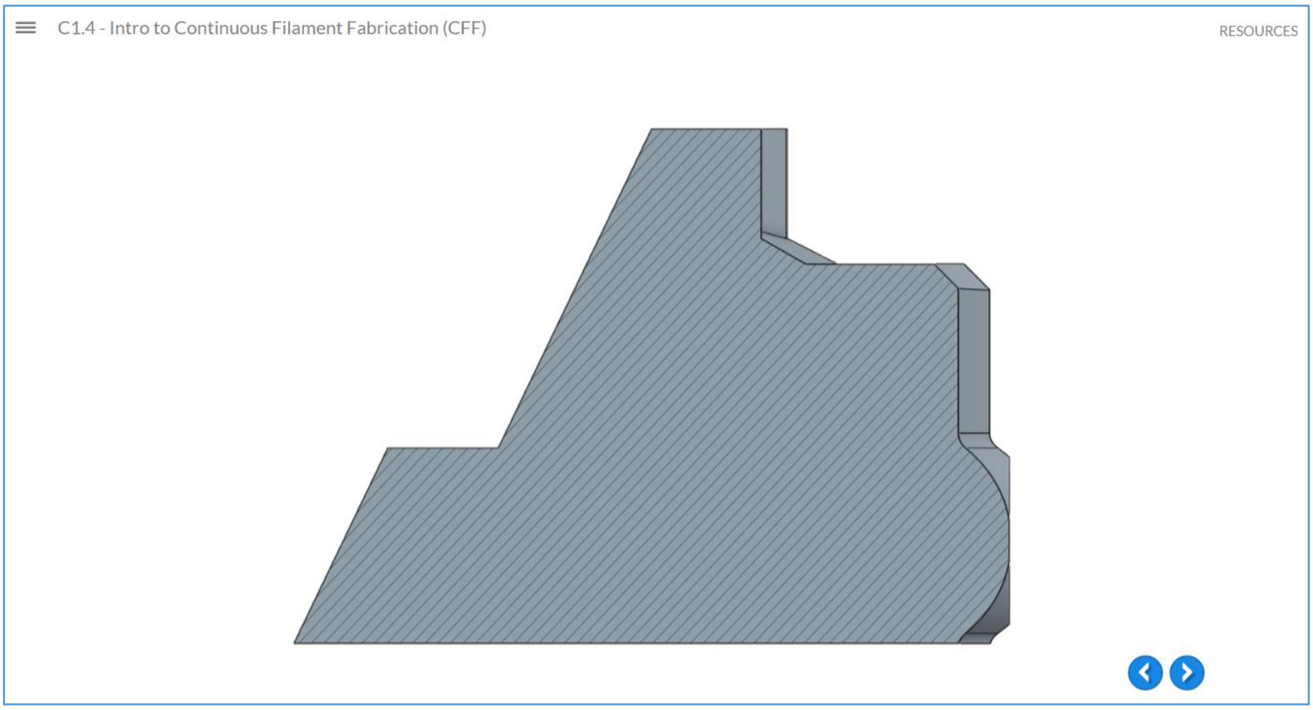


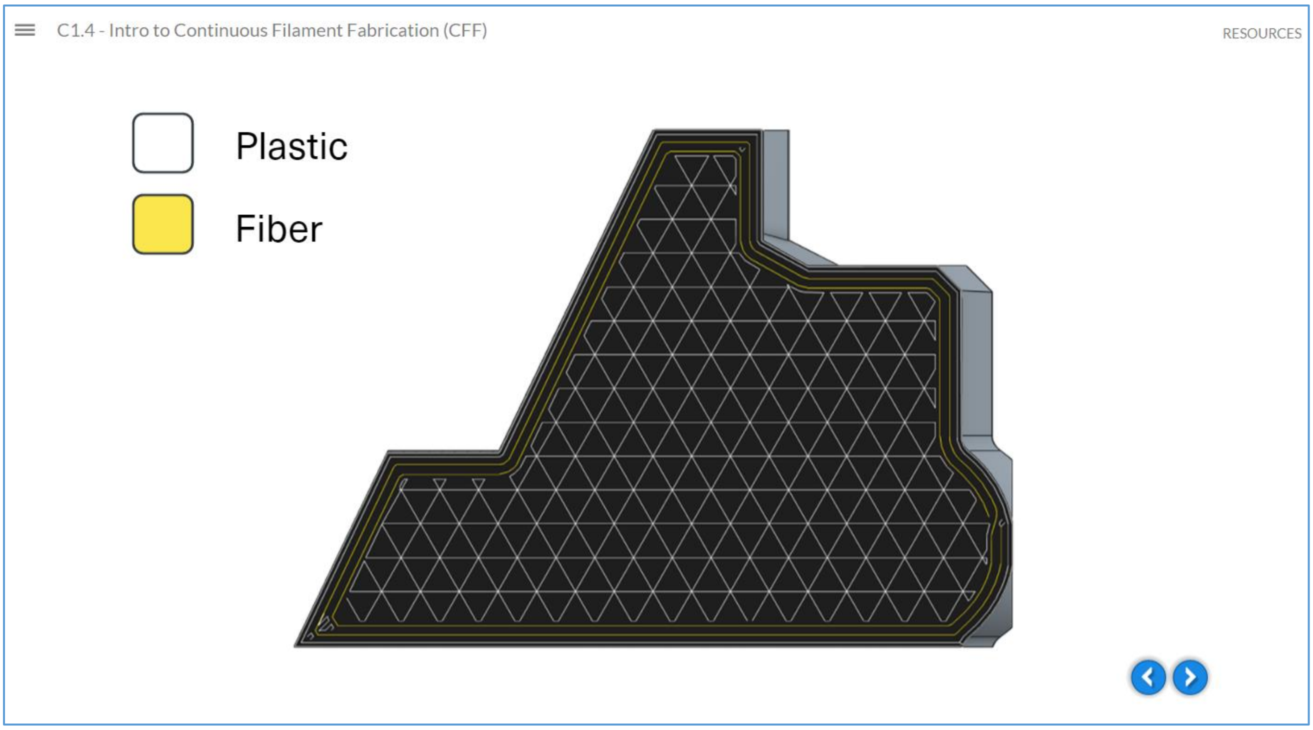


- Kiezen van de juiste oriëntatie.

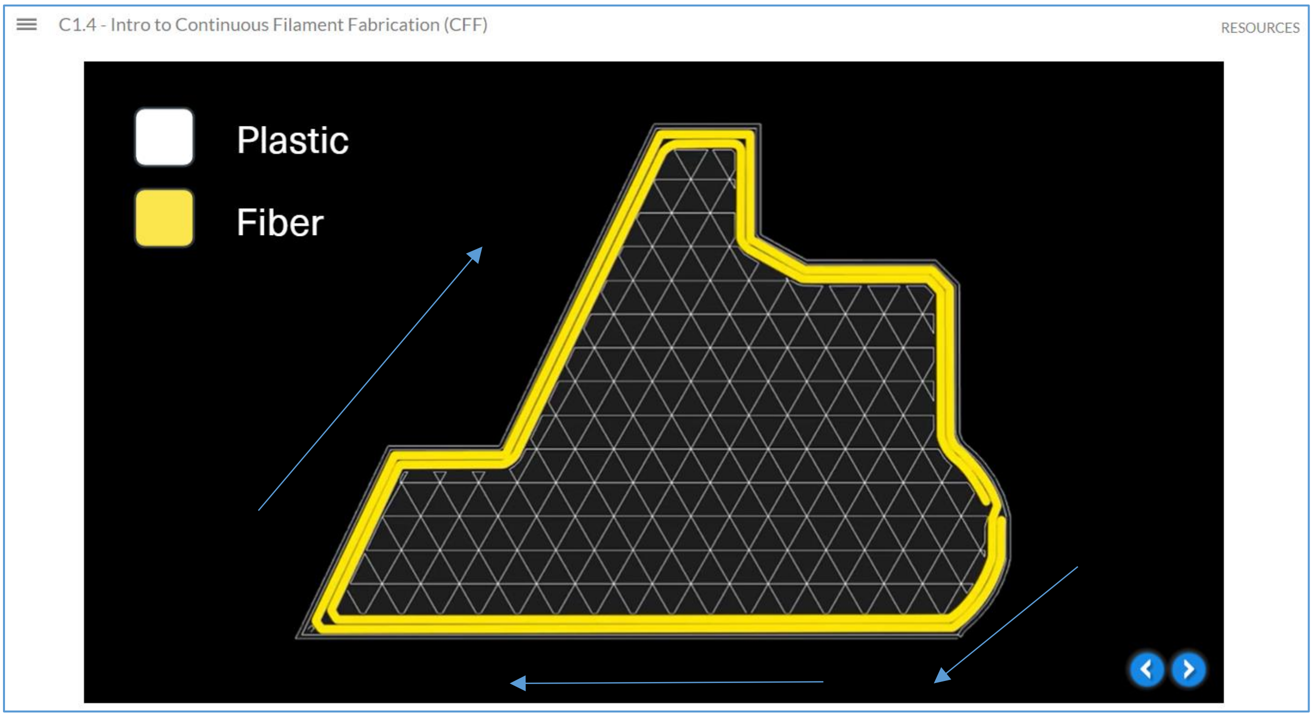


- Slice.


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES

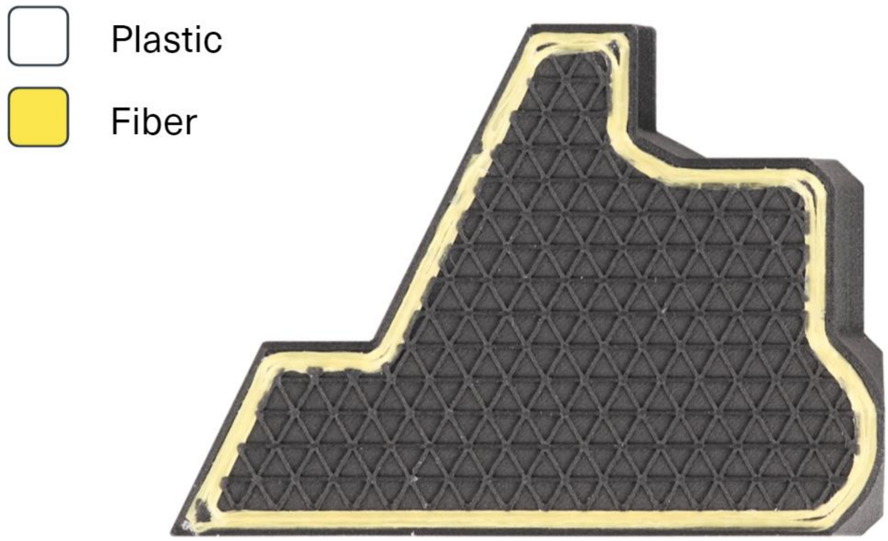

C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Plastic
Fiber


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Plastic
Fiber


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Plastic
Fiber

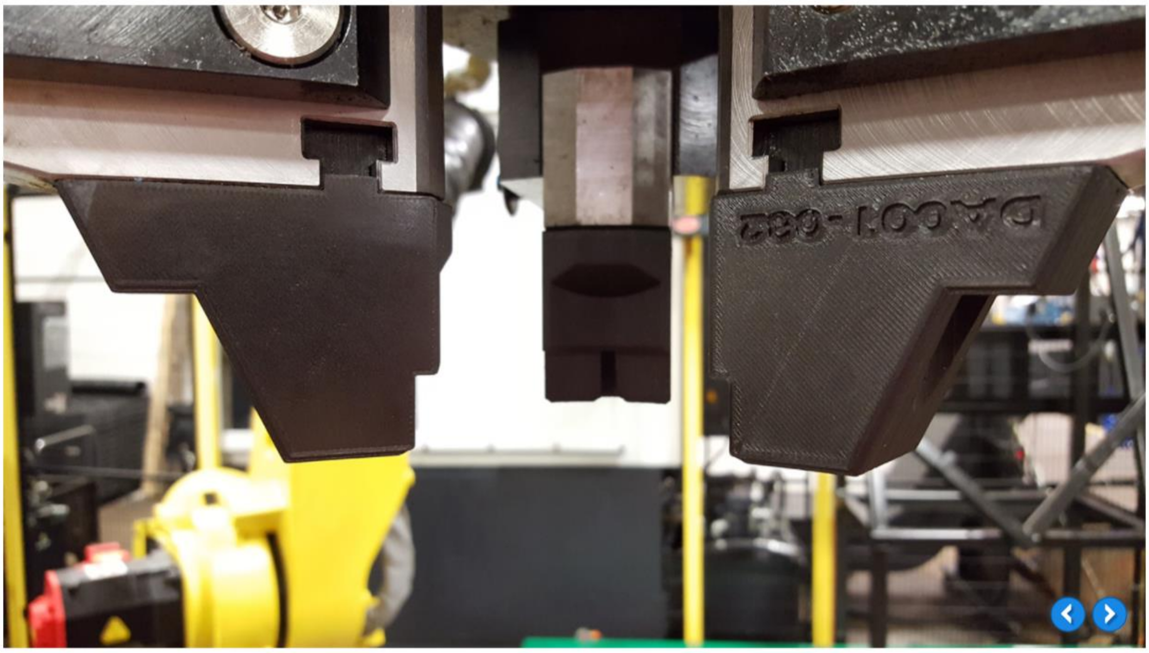
C1.4 - Intro to Continuous Filament Fabrication (CFF)

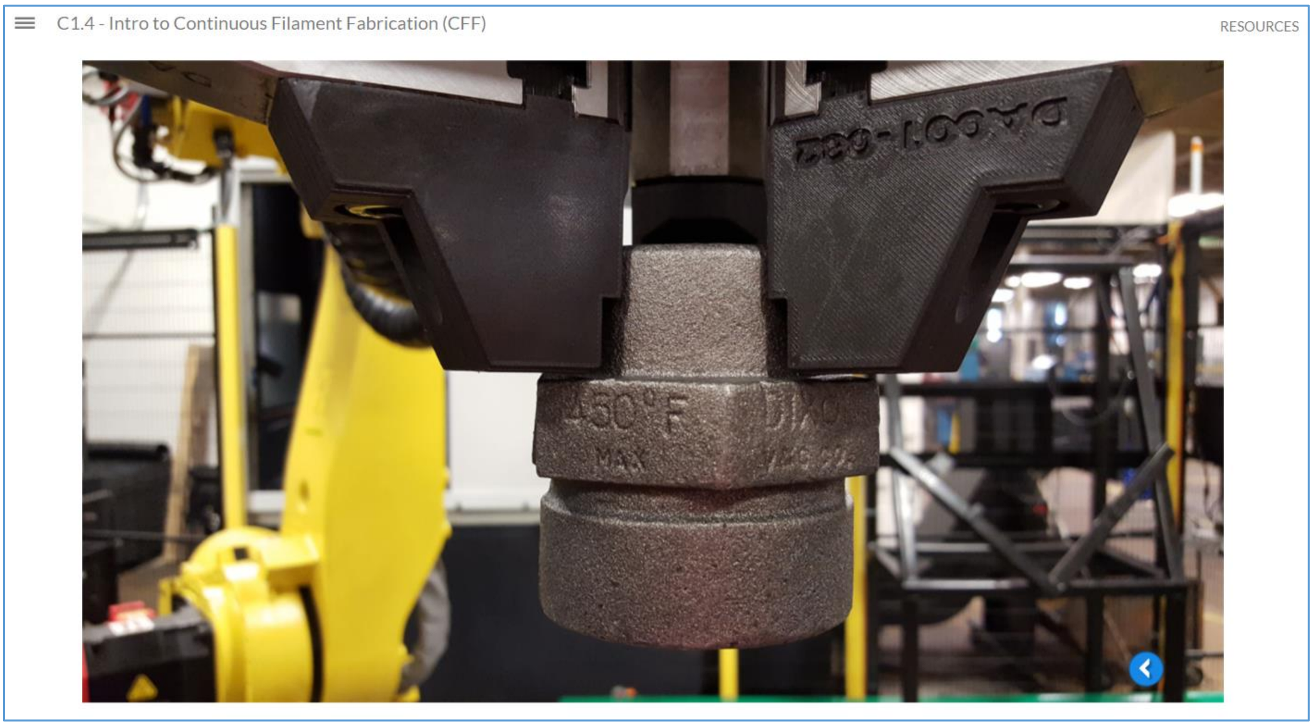
RESOURCES

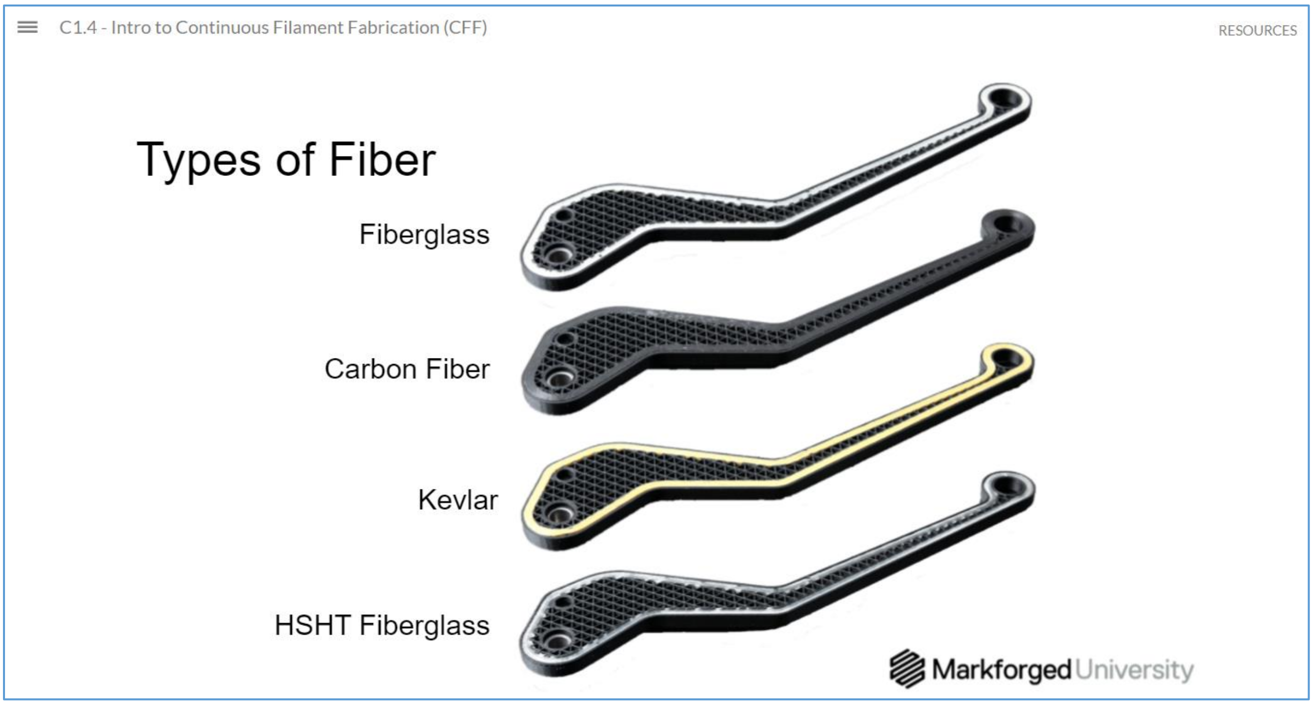


C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES




C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
450°F
MAX


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Types of Fiber
Fiberglass
Carbon Fiber
Kevlar
HSHT Fiberglass
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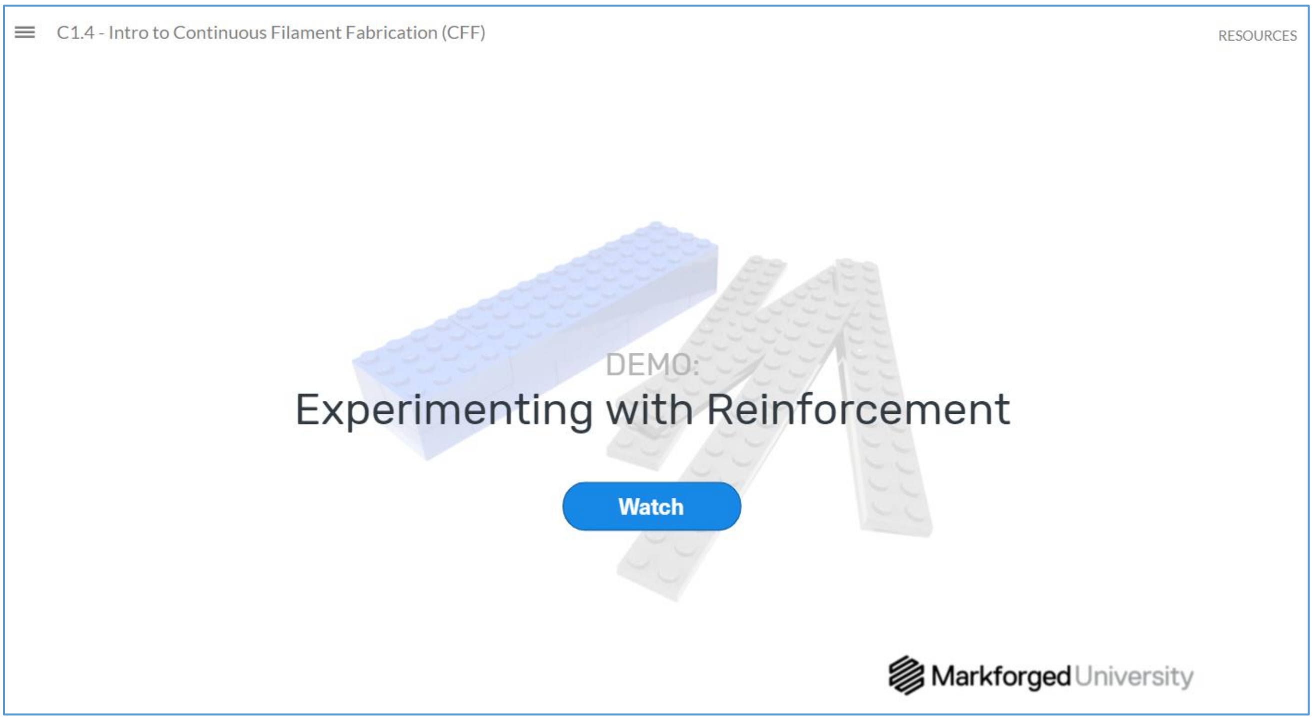
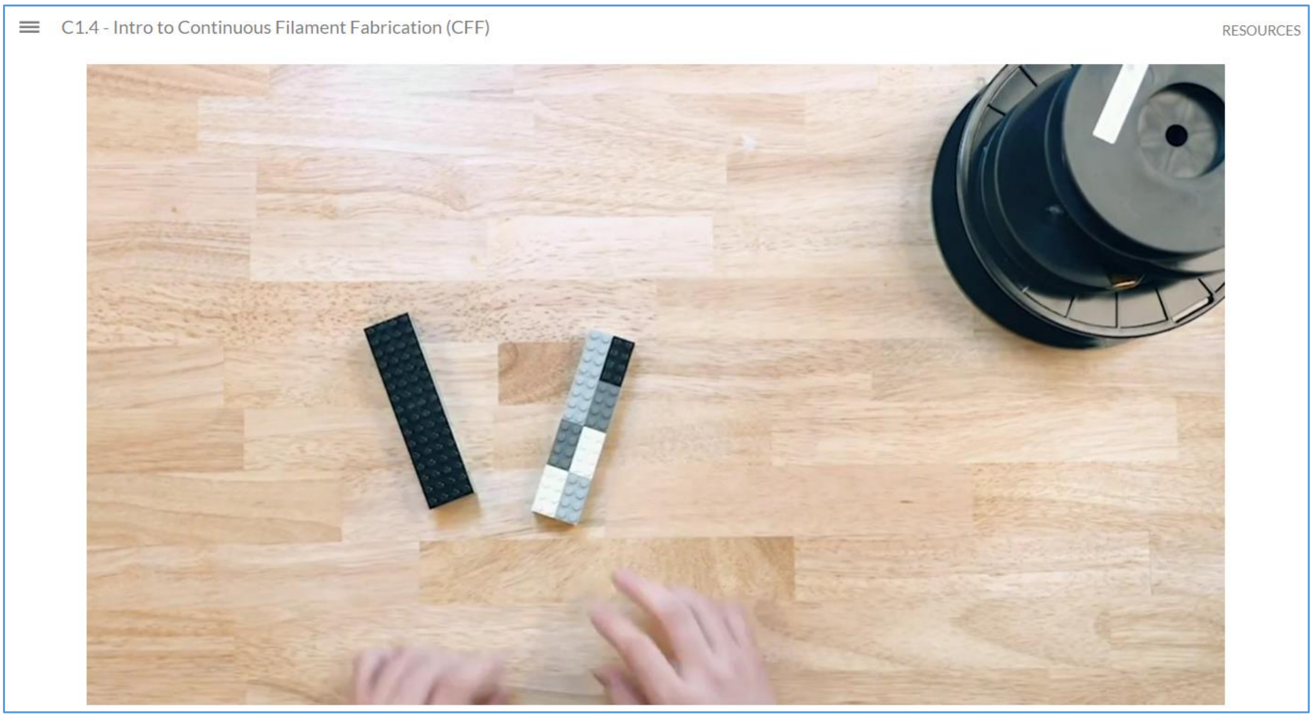
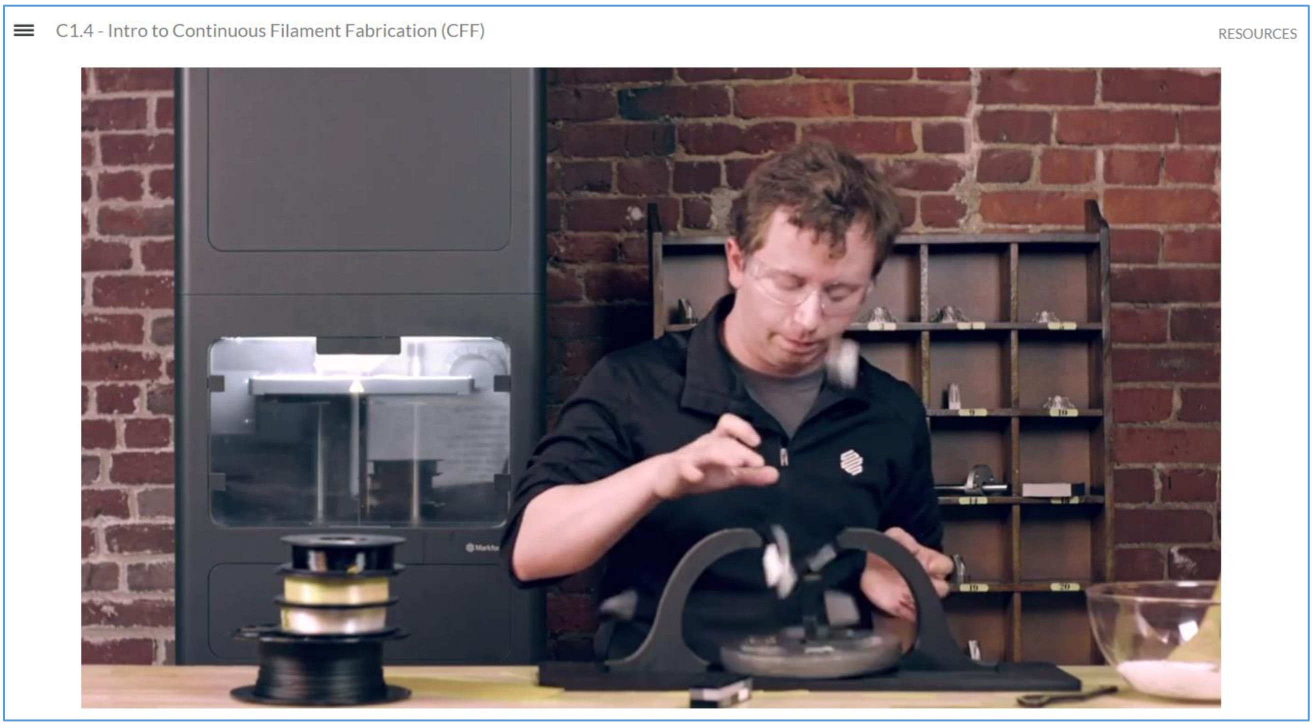
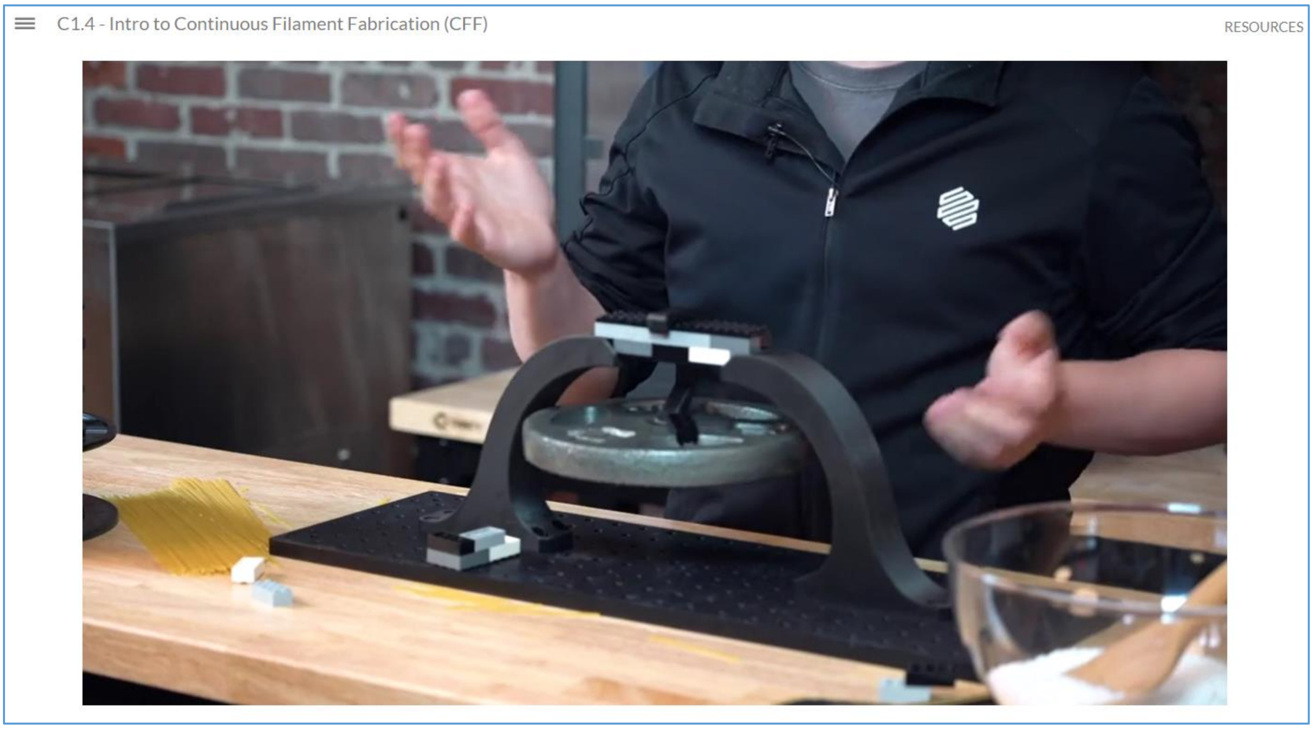

C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
DEMO:
Experimenting with Reinforcement
Watch
Markforged University


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES



- Chopped fibre part



- Part with Continuous layer: bottom and top.

C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

DISCUSSION:

How did the reinforcement change the part?

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C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

CFF has process limitations too…

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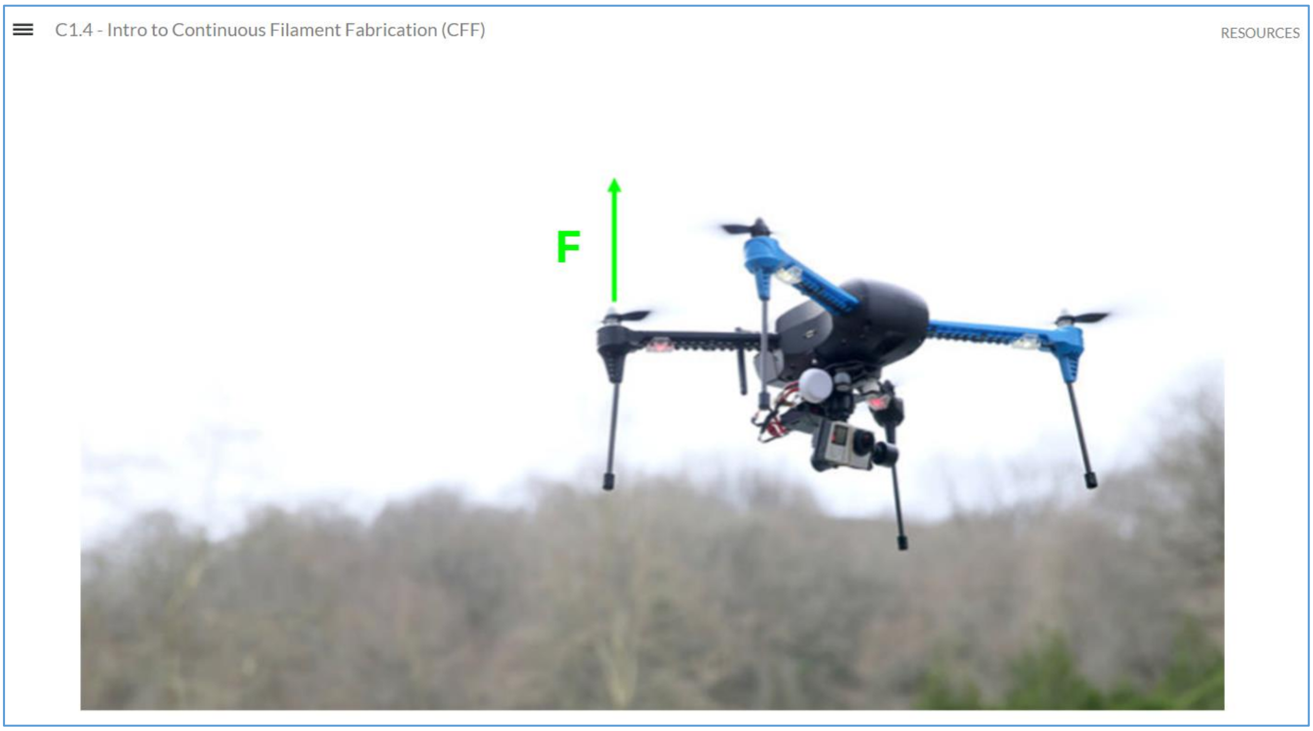
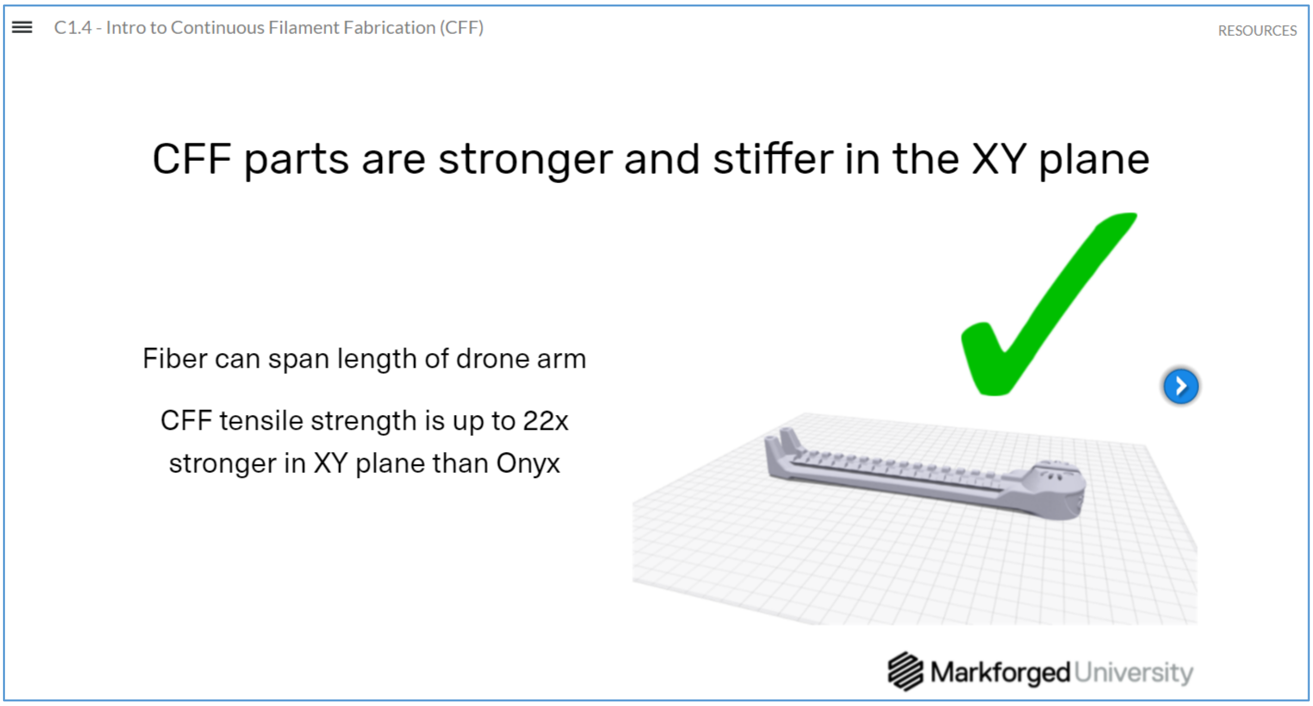
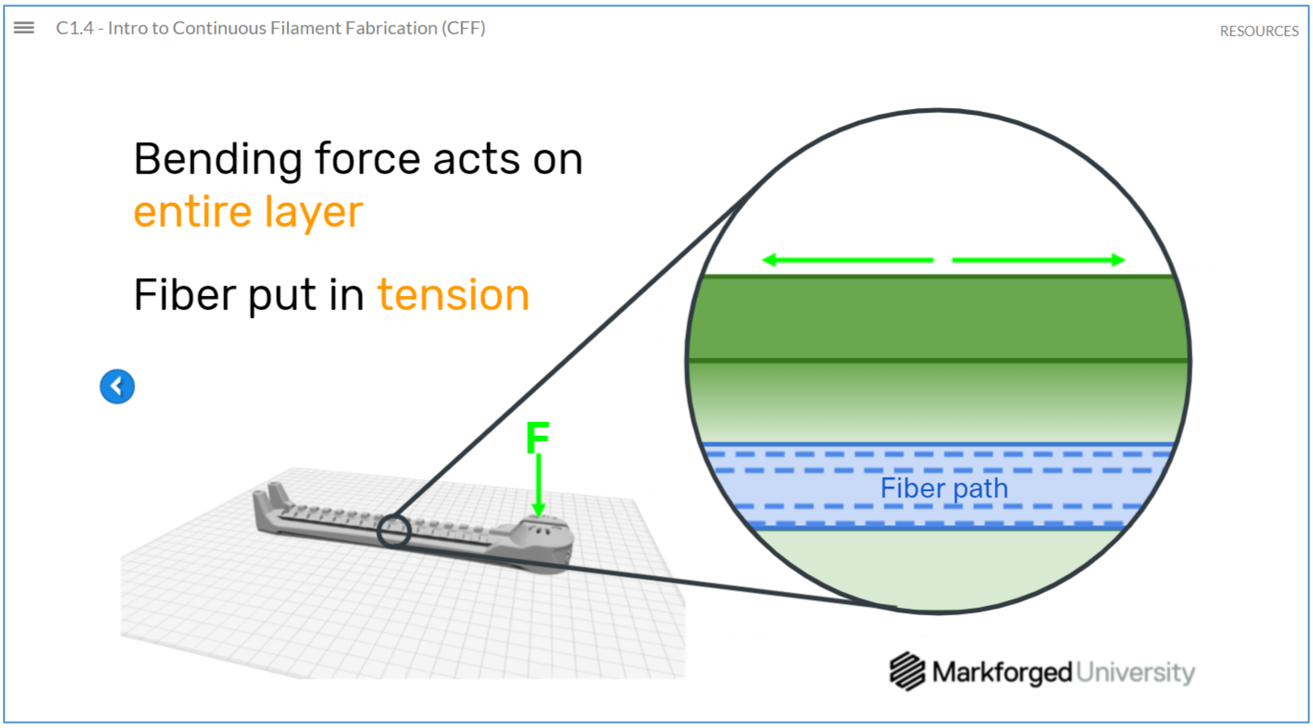
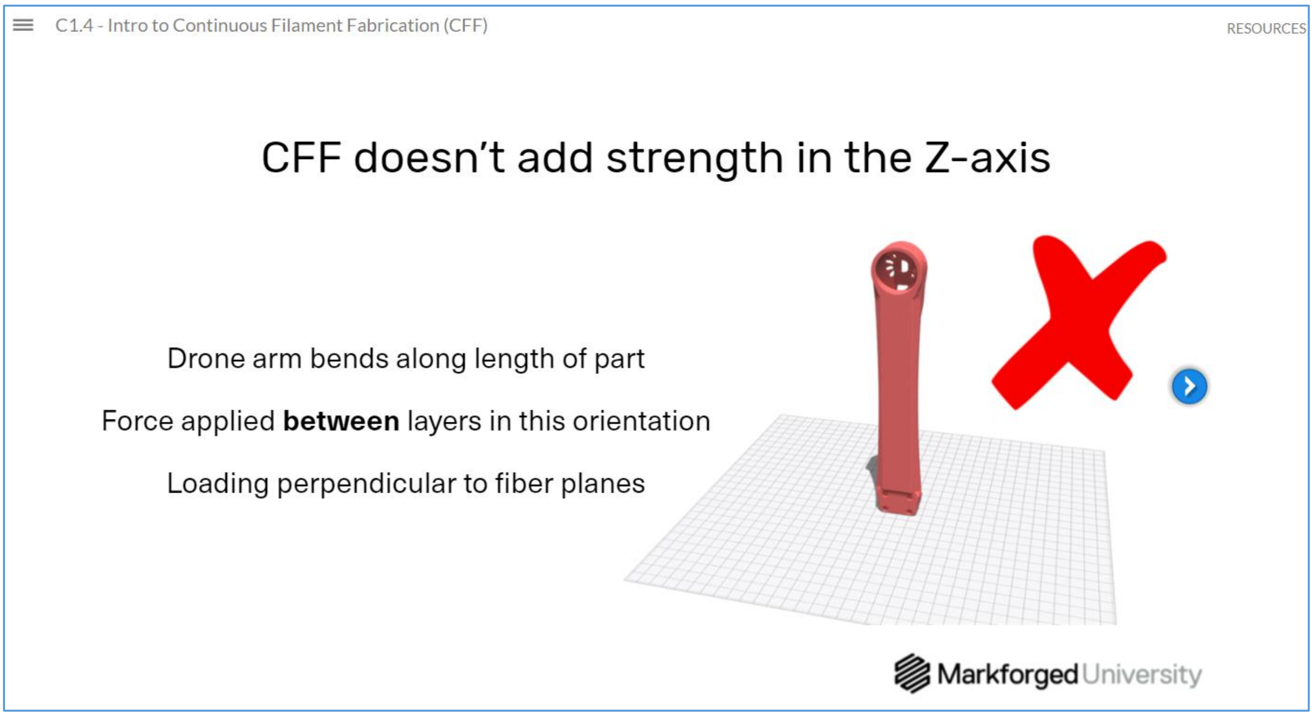


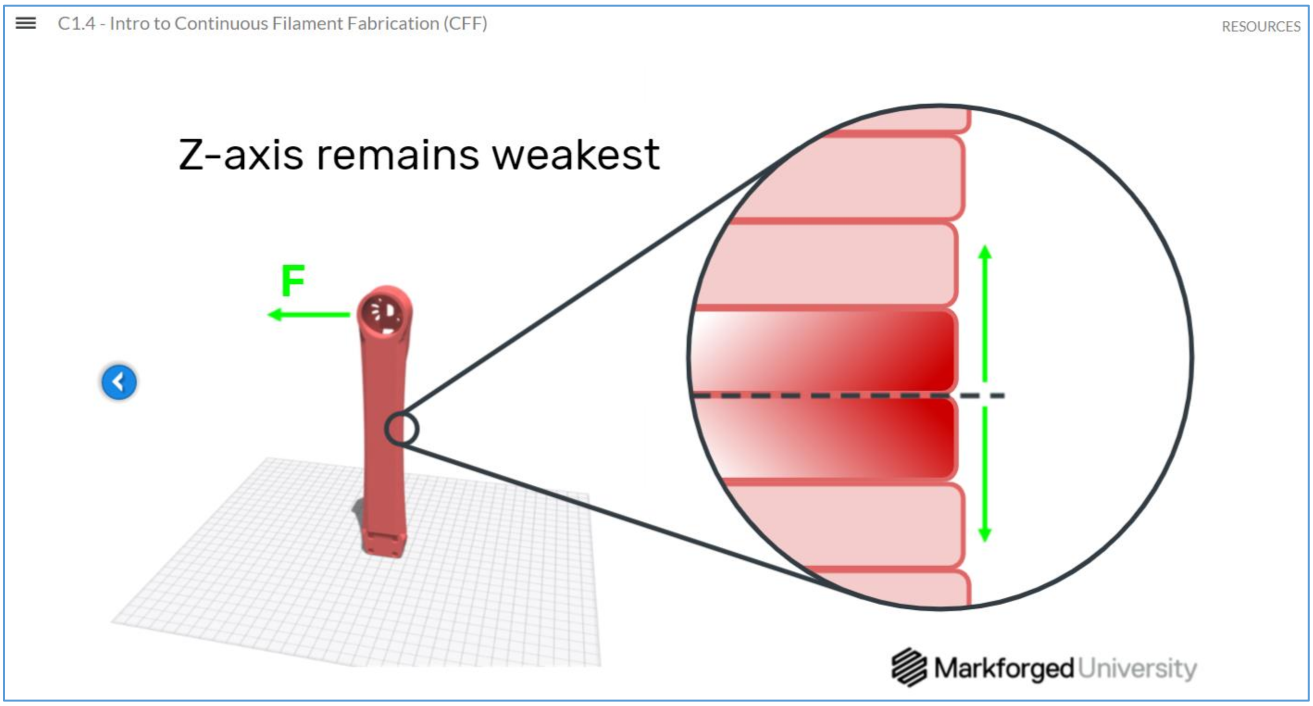


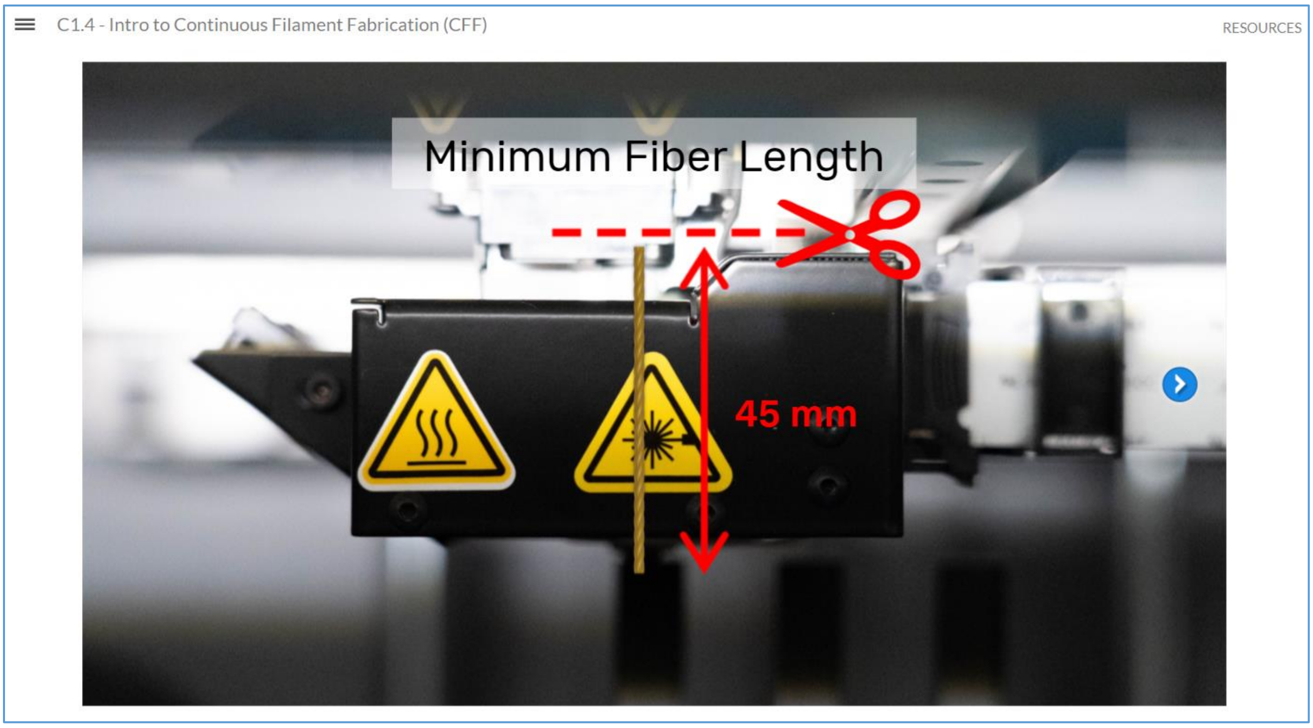
- Span = omspannen
- Tensile = treksterkte.



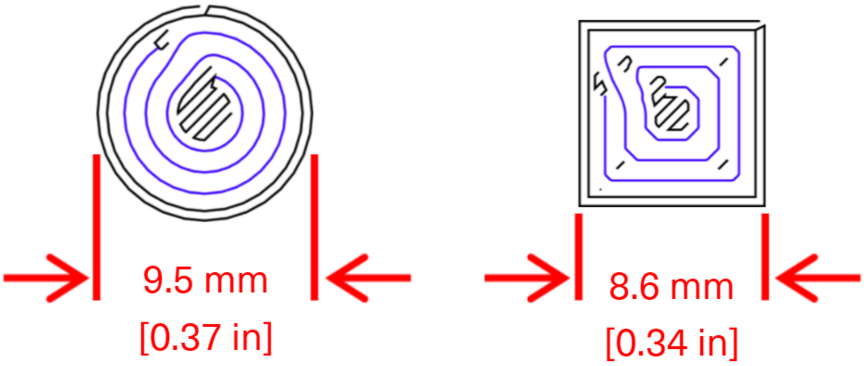


- CFF only in the XY plane.
- Perpendicular = loodrecht.
- Kracht uitgeoefend tussen lagen in deze oriëntatie, loodrecht op vezelvlakken.


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Z-axis remains weakest
F
Markforged University


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Minimum Fiber Length
45 mm

Smallest Reinforceable Area



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Minimum Diameters When Reinforcing a Hole

Three rings
D_3: 0.5 mm (0.020")

Two rings
D_2: 3.85 mm (0.152")

One ring
D_1: 12.16 mm (0.479")

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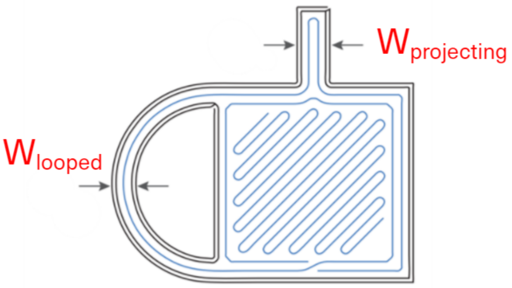
C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

Minimum Feature Sizes for Fiber in the XY Plane



Minimum fiber reinforcement feature width:

Projecting feature
W: 3.6 mm (0.15”)

Looped feature
W: 2.8 mm (0.11”)

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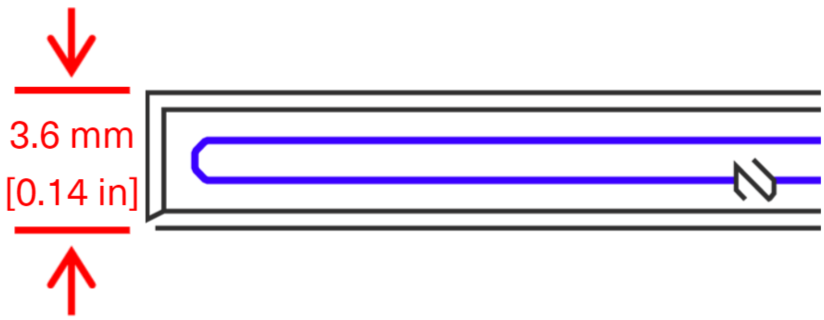
C1.4 - Intro to Continuous Filament Fabrication (CFF)

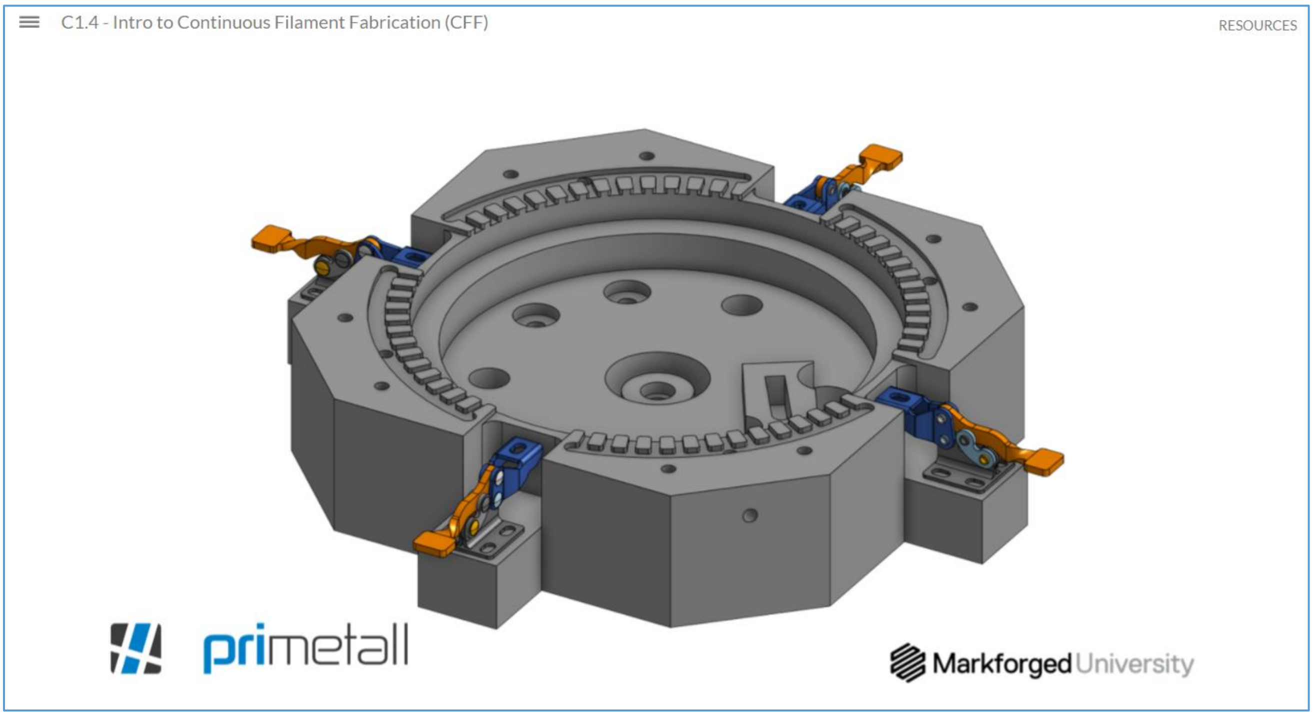
RESOURCES

CFF Fiber Can Bend 180˚

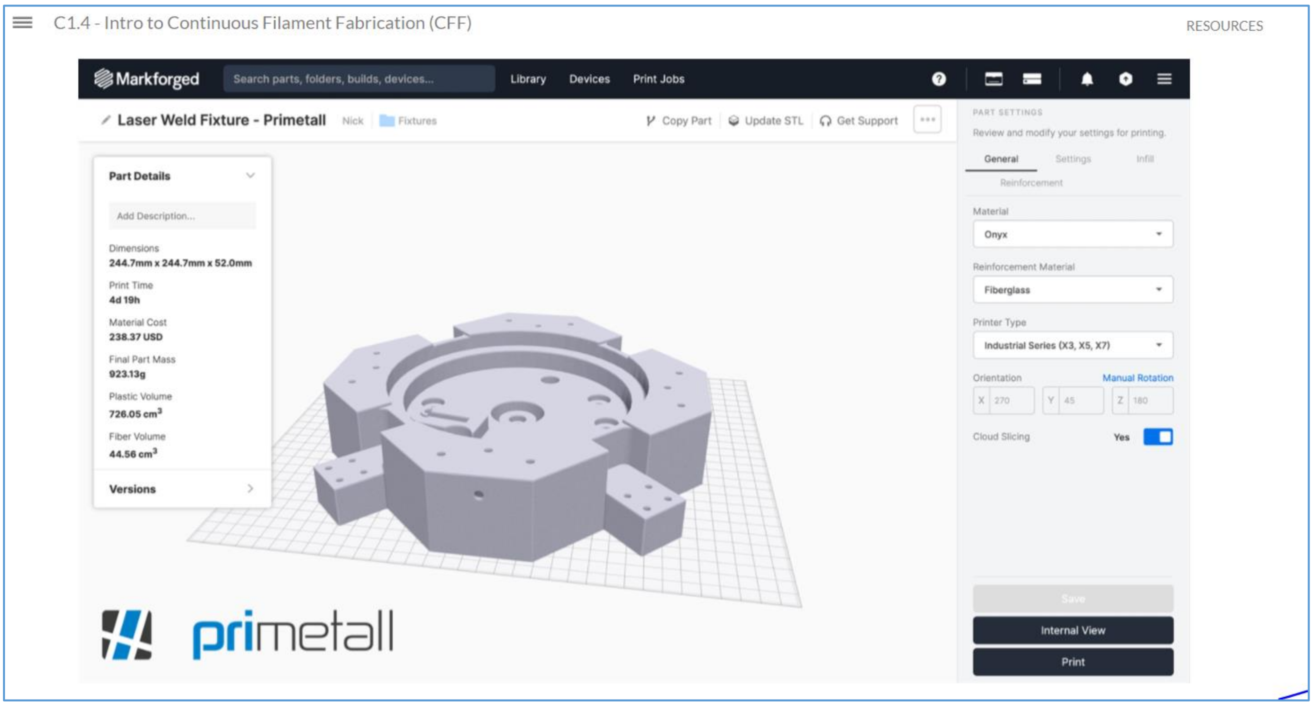


Markforged University

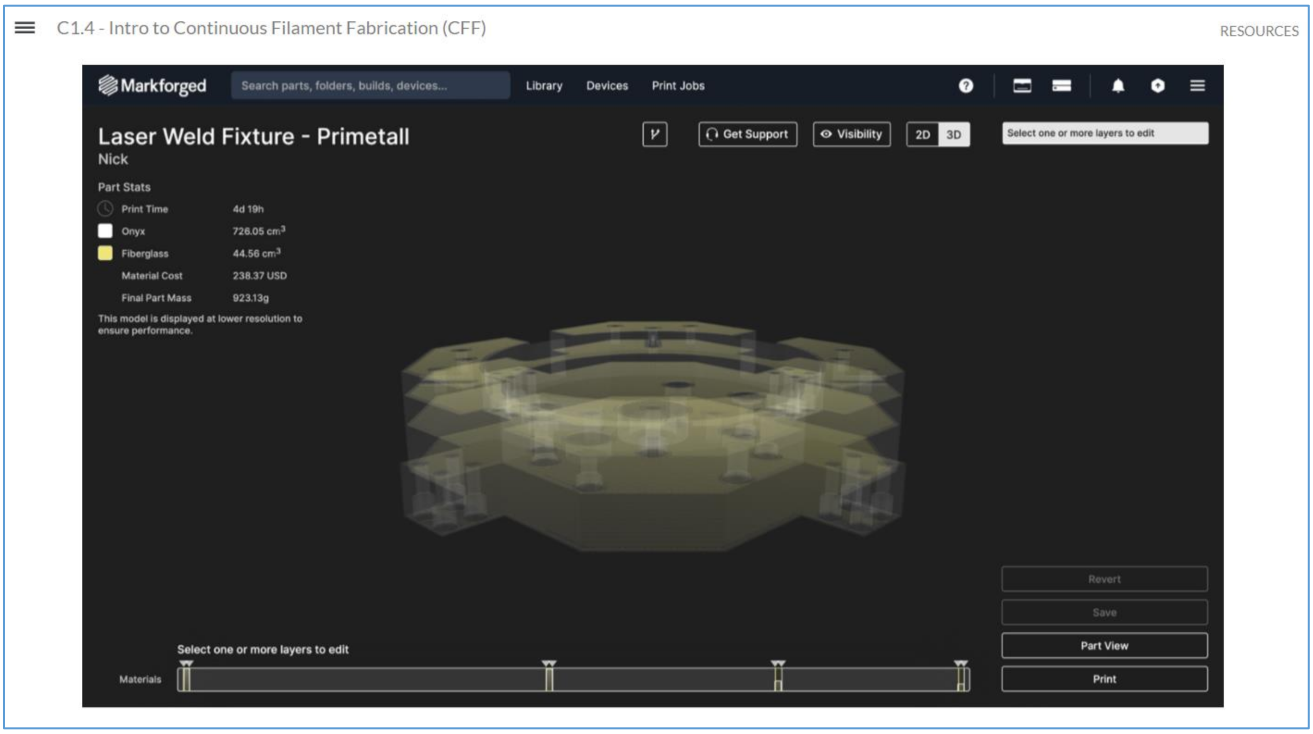
- Laserwelding fixtures.



- CAD-model.



- Upload in Eiger.
- Print time almost 5h.


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Laser Weld Fixture - Primetall
Nick
Get Support
Visibility
2D
3D
Select one or more layers to edit
Part Stats
Print Time 4d 19h
Onyx 726.05 cm³
Fiberglass 44.56 cm³
Material Cost 238.37 USD
Final Part Mass 923.13g
This model is displayed at lower resolution to ensure performance.
Revert
Save
Part View
Print
Select one or more layers to edit
Materials


C1.4 - Intro to Continuous Filament Fabrication (CFF)
RESOURCES
primetall
Markforged University

C.1.4. Design Guide: https://support.markforged.com/

- https://support.markforged.com/portal/s/

Module Review

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Which is stronger in the plane of a layer (XY plane), chopped fiber-filled plastics or continuous composite fiber reinforcement?

- (●) Continuous composite fibers (e.g. Carbon Fiber CFF filament)
- ( ) Neither, they have the same strength in the XY plane
- ( ) Chopped fiber-filled plastics (e.g. Onyx)

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C1.4 - Intro to Continuous Filament Fabrication (CFF) RESOURCES

True/False: You can print an entire part with just CFF composite filament.

- True
- False

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C1.4 - Intro to Continuous Filament Fabrication (CFF) RESOURCES

A plastic FFF 3D printed part keeps breaking under load between two of its layers (in the Z-axis). To potentially remedy the problem you should consider:

- Adding CFF fiber reinforcement around the region that is exhibiting failures, since CFF will make the part stronger in the Z-axis
- Giving up on the idea of 3D printing this part and just machining it instead
- Reorienting the part so that the forces are applied more in the XY-plane, and then adding CFF-reinforcement

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C1.4 - Intro to Continuous Filament Fabrication (CFF)

RESOURCES

Results

Your Score:	100% (40 points)
Passing Score:	80% (32 points)

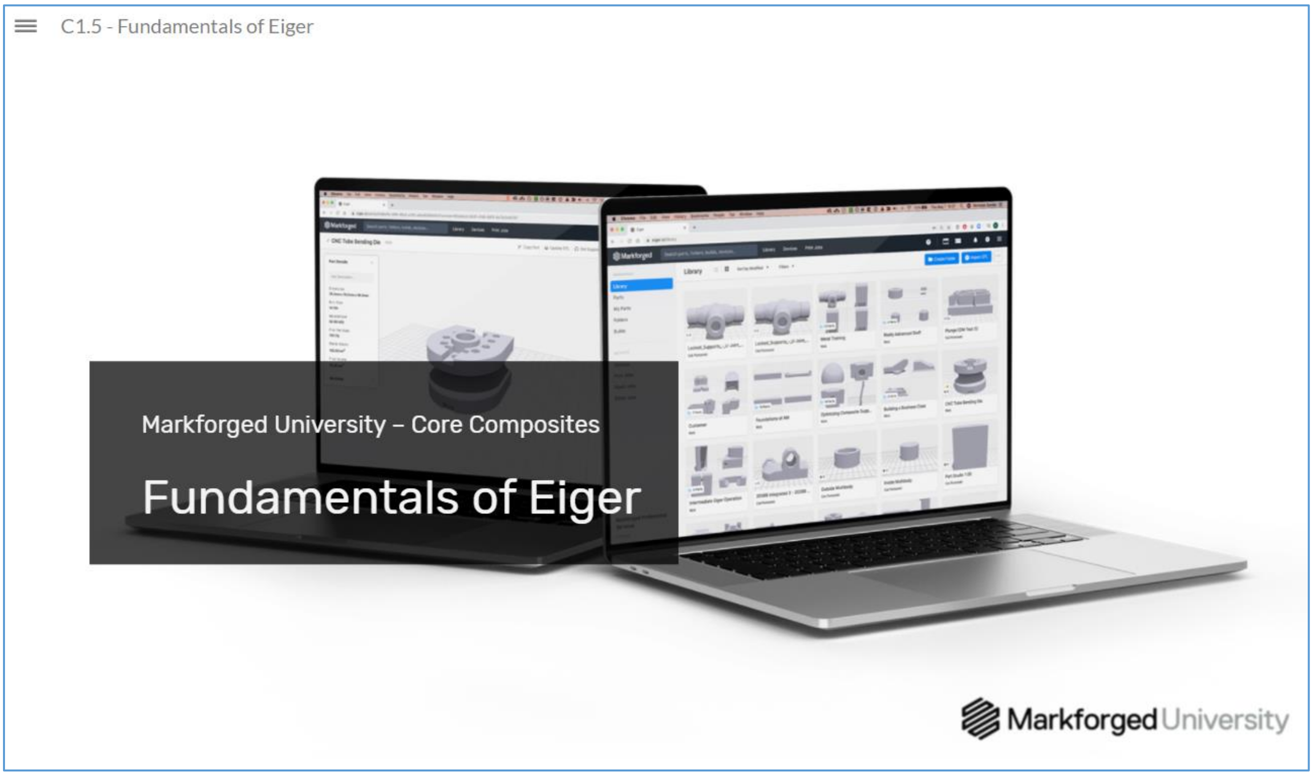
Result:

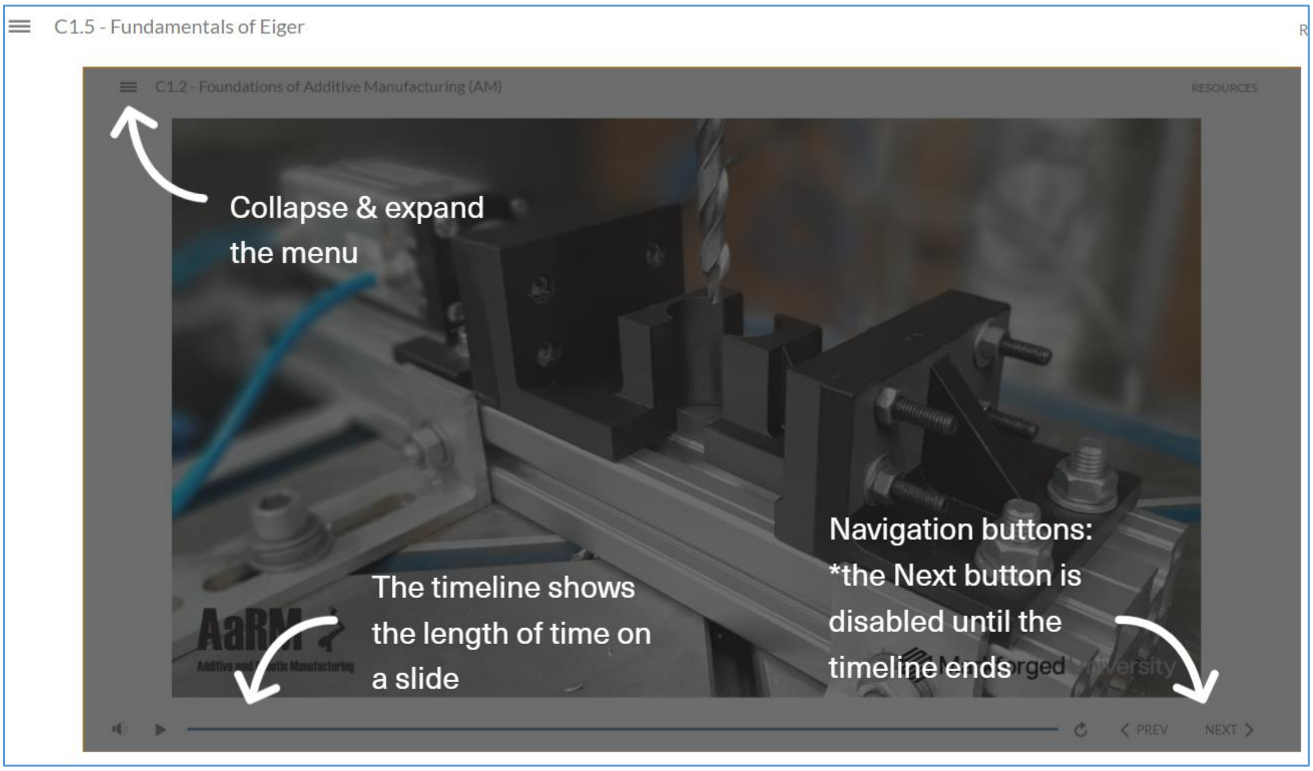
Congratulations, you passed.

Finish Module

Review Quiz

C.1.5. Fundamentals of Eiger





- Aanwijzingen spreken voor zich.

Module Overview

Basics of Slicing

Three Roles of Eiger

Getting to Know Your Way Around Eiger

Activity: STL-to-Print Eiger Workflow

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C1.5 - Fundamentals of Eiger

Review: 3D Printing Process

CAD

Configure & Slice

3D Print

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Review: 3D Printing Process

CAD → Configure & Slice → 3D Print

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C1.5 - Fundamentals of Eiger

Slicing Is Exactly What It Sounds Like

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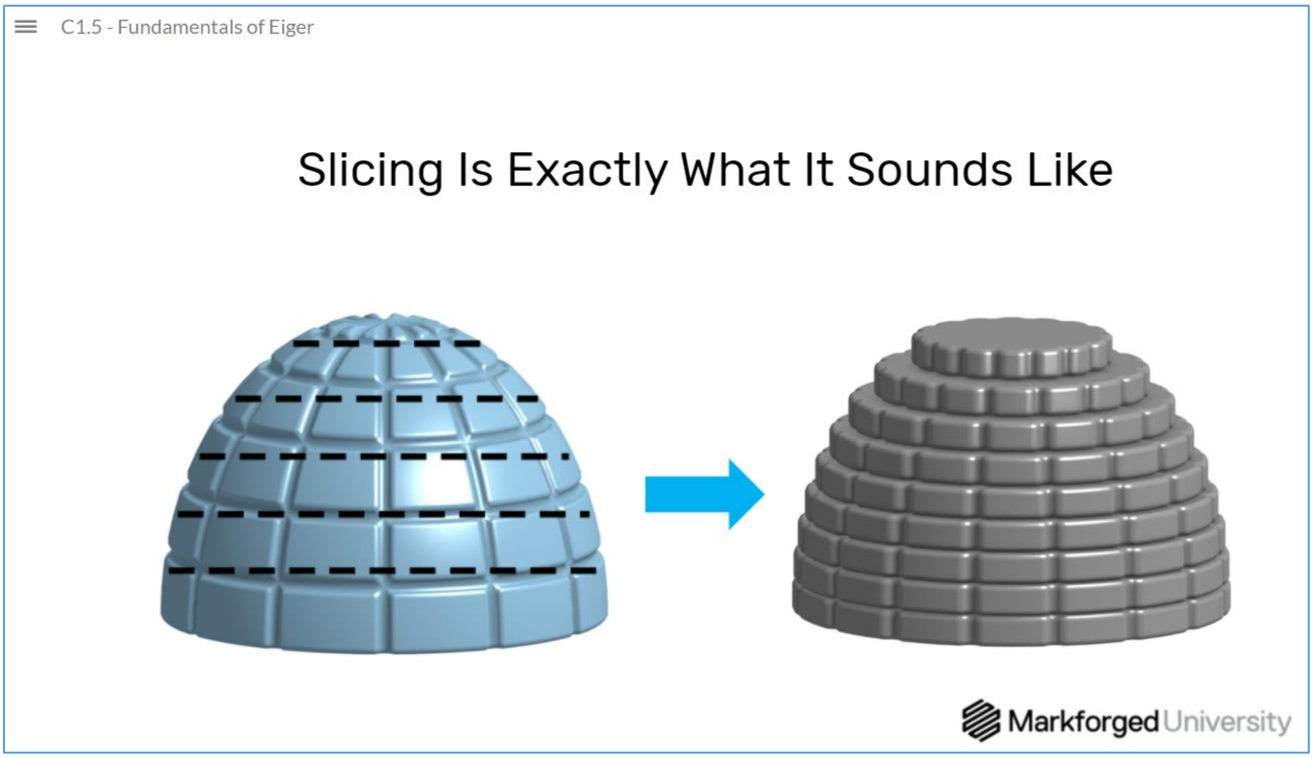
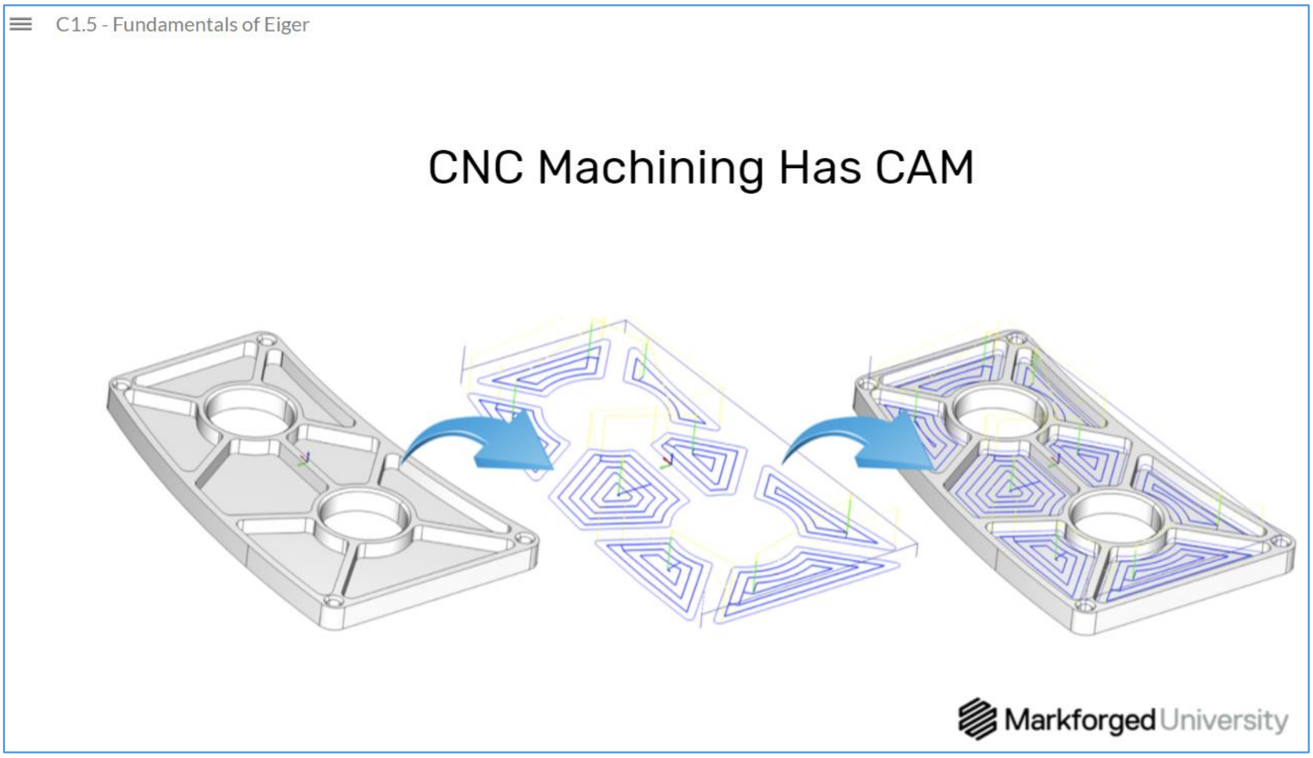
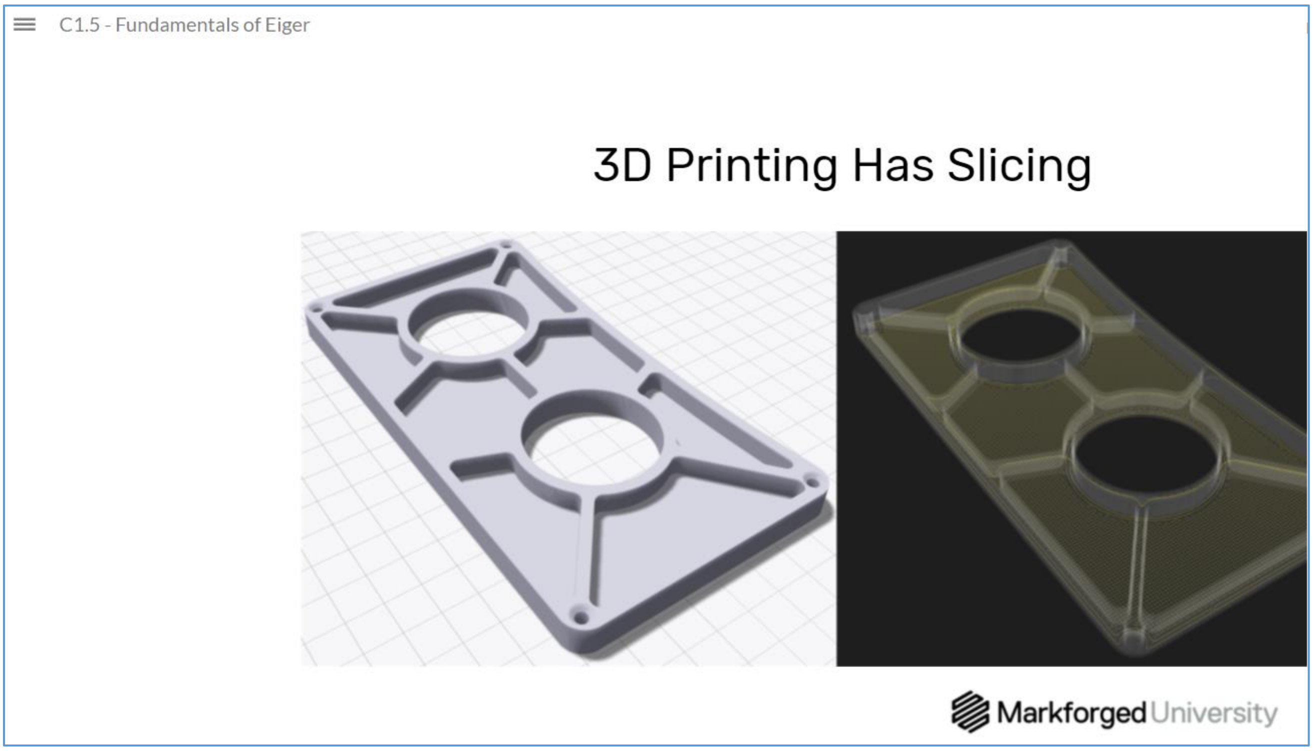
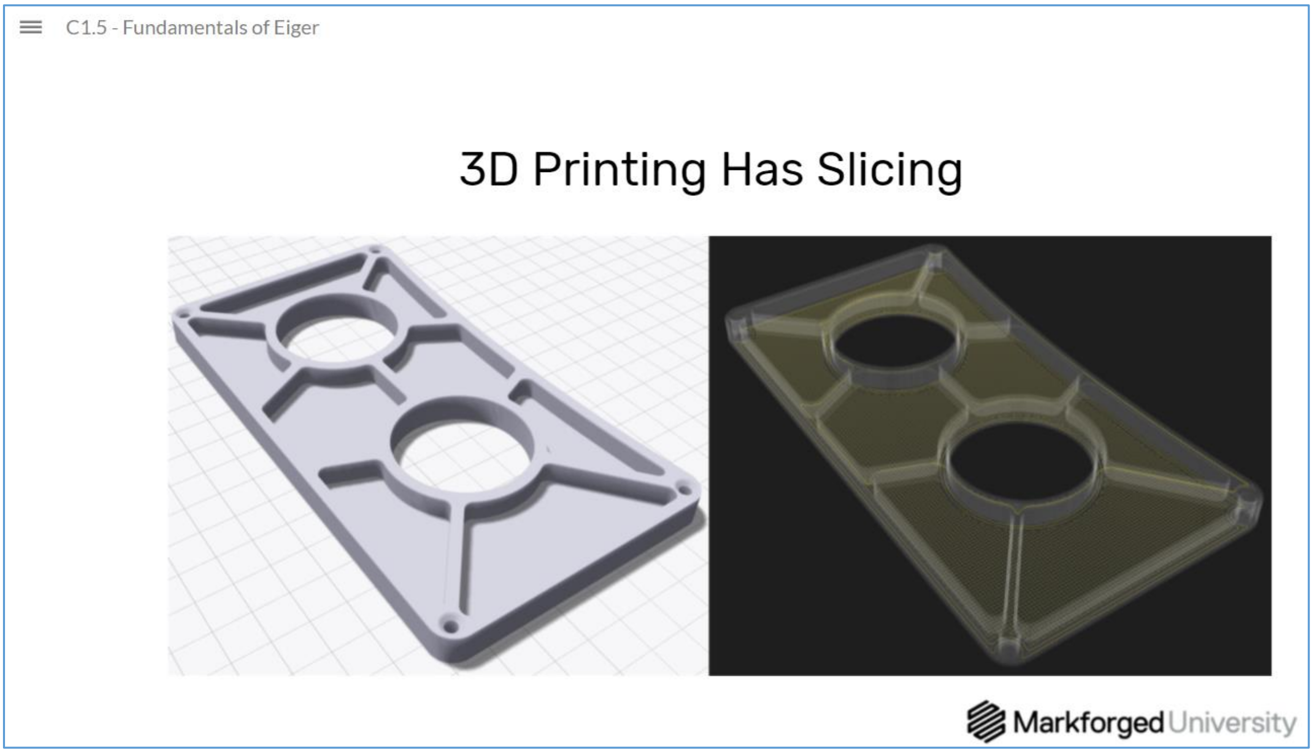


- Door de printlayers heeft een geprint model nooit een volledige gladde oppervlaktegesteldheid, zoals getekend in CAD.
- Fidelity = Betrouwbaarheid.
- Familiar proces toolpath simular to CNC-machining CAM.

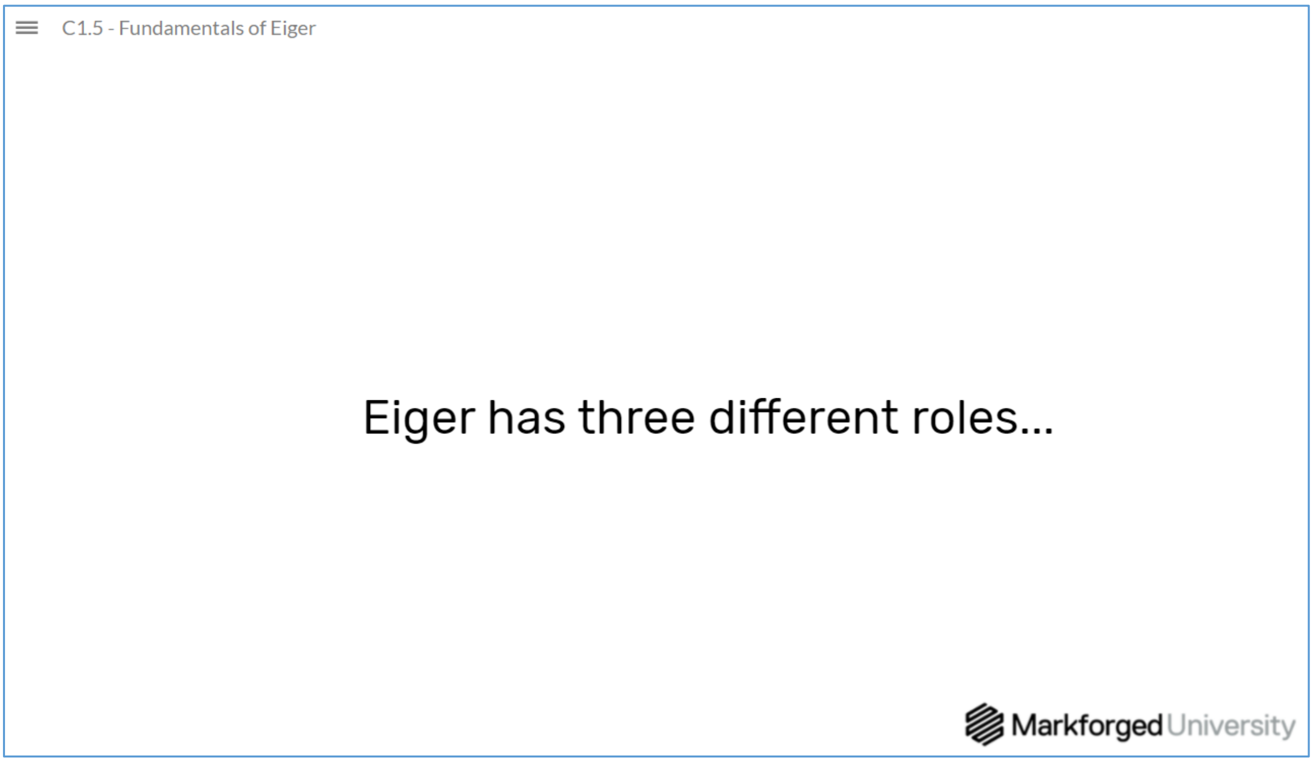


- CNC-machining programming requires a lot of manual work: Many variables are involved, like:
    - cutting tools.
    - Cutting speed as a result of workpiecematerial and also cutting tools.
    - Fixing workpieces on the mill.

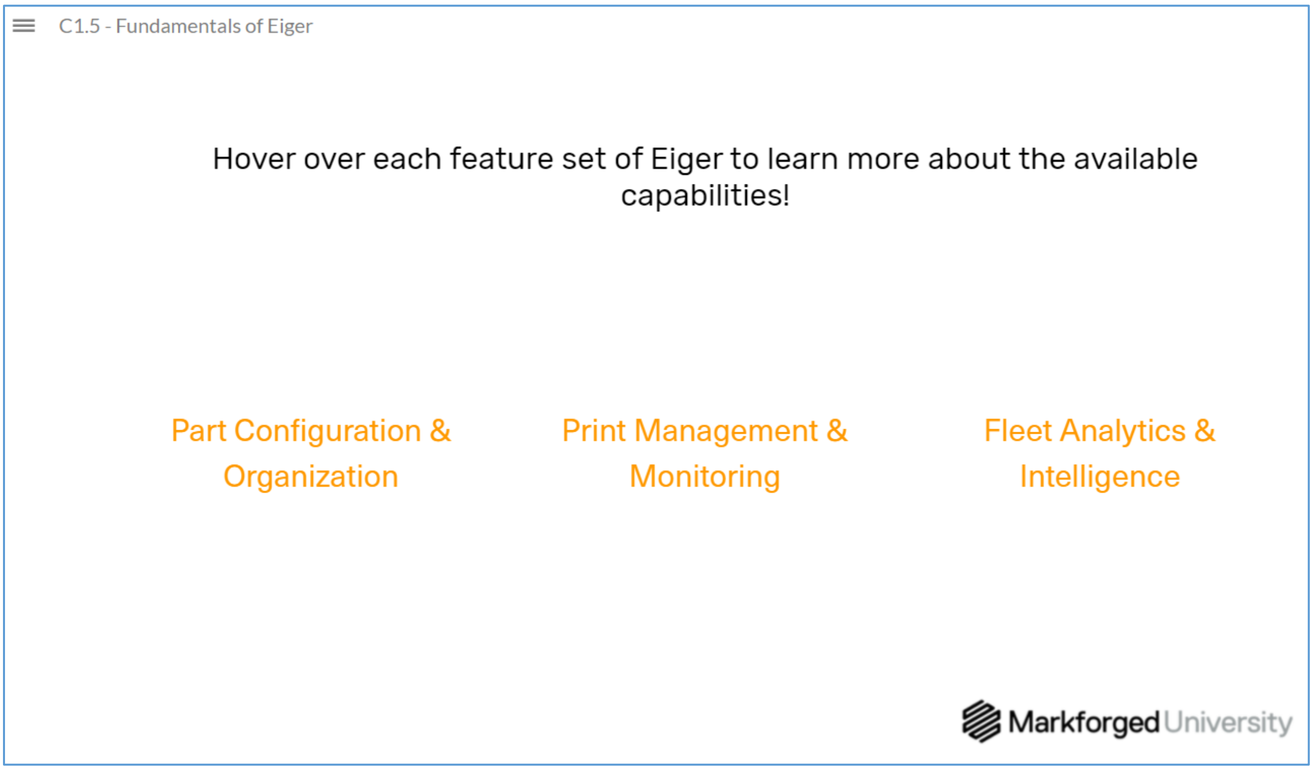




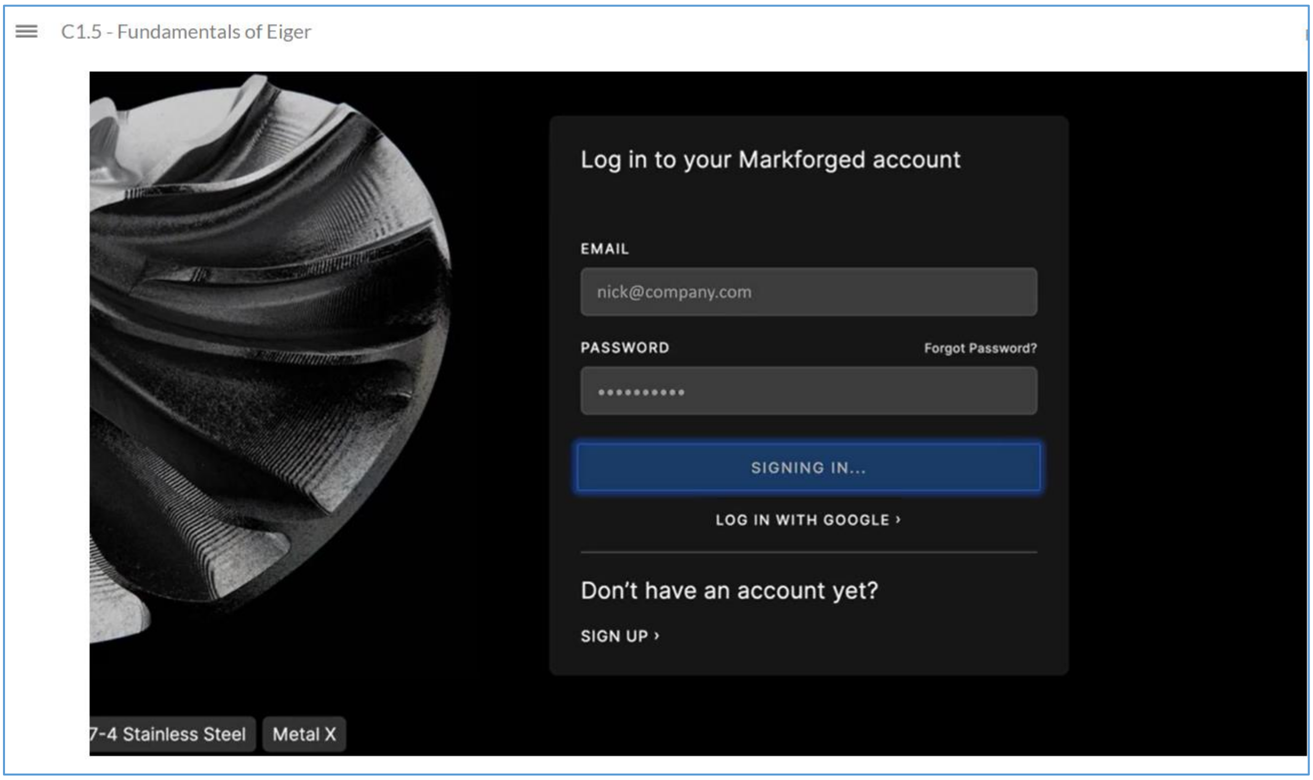
- Much more automatic workflow than CAM-software.
- Only one or two tools to control, wich are the plastic and fibre nozzles.
- Part is printed on the printbed.
- Most parts requires only a few minutes to configure and slice.
- You can leave the printer without supervision.

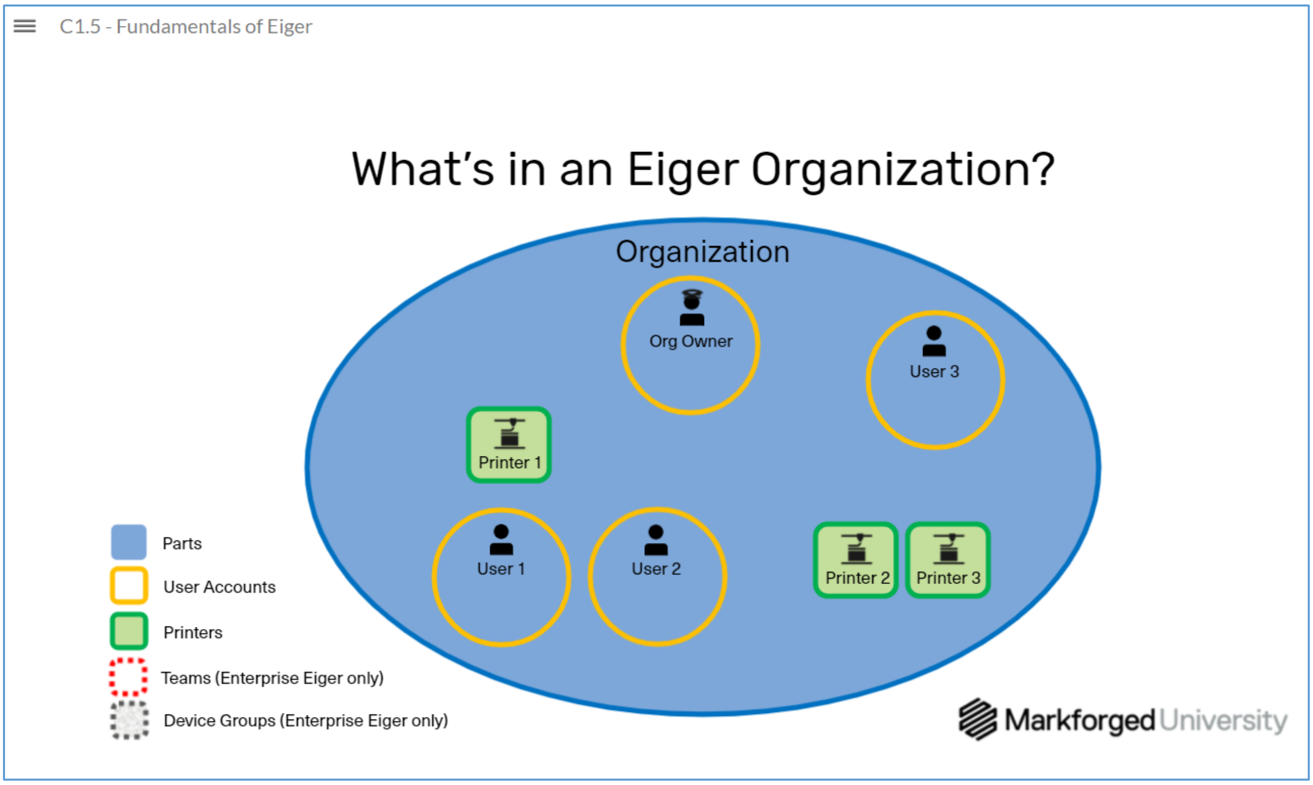


- Three different roles, wich slicing is one of them.

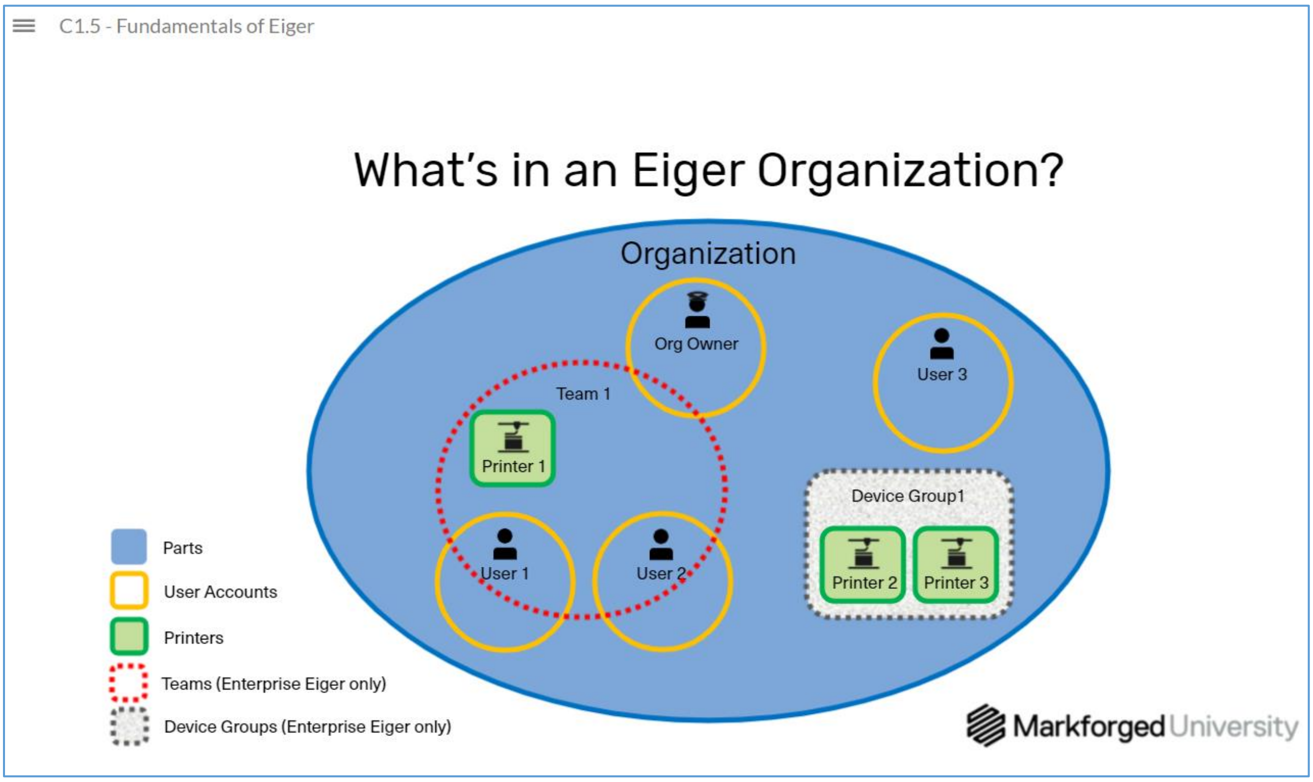


- Hover = zweven.

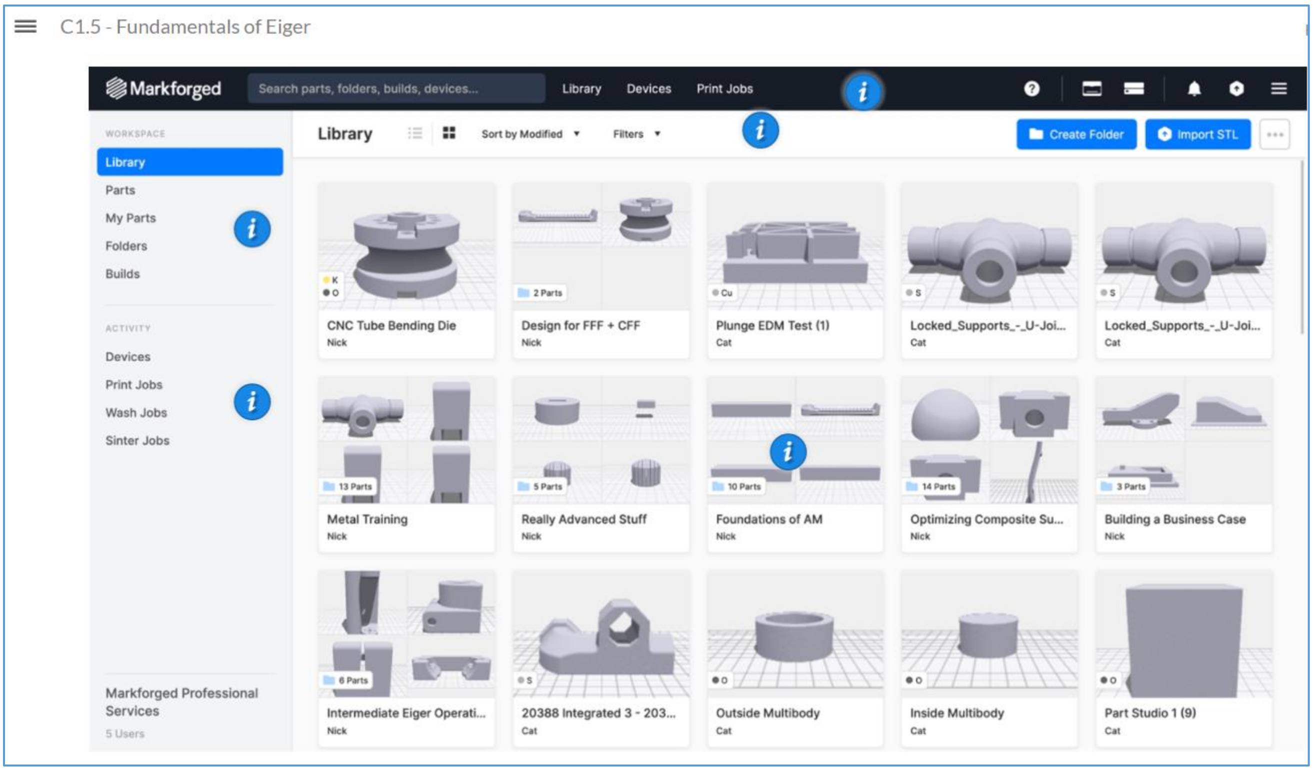




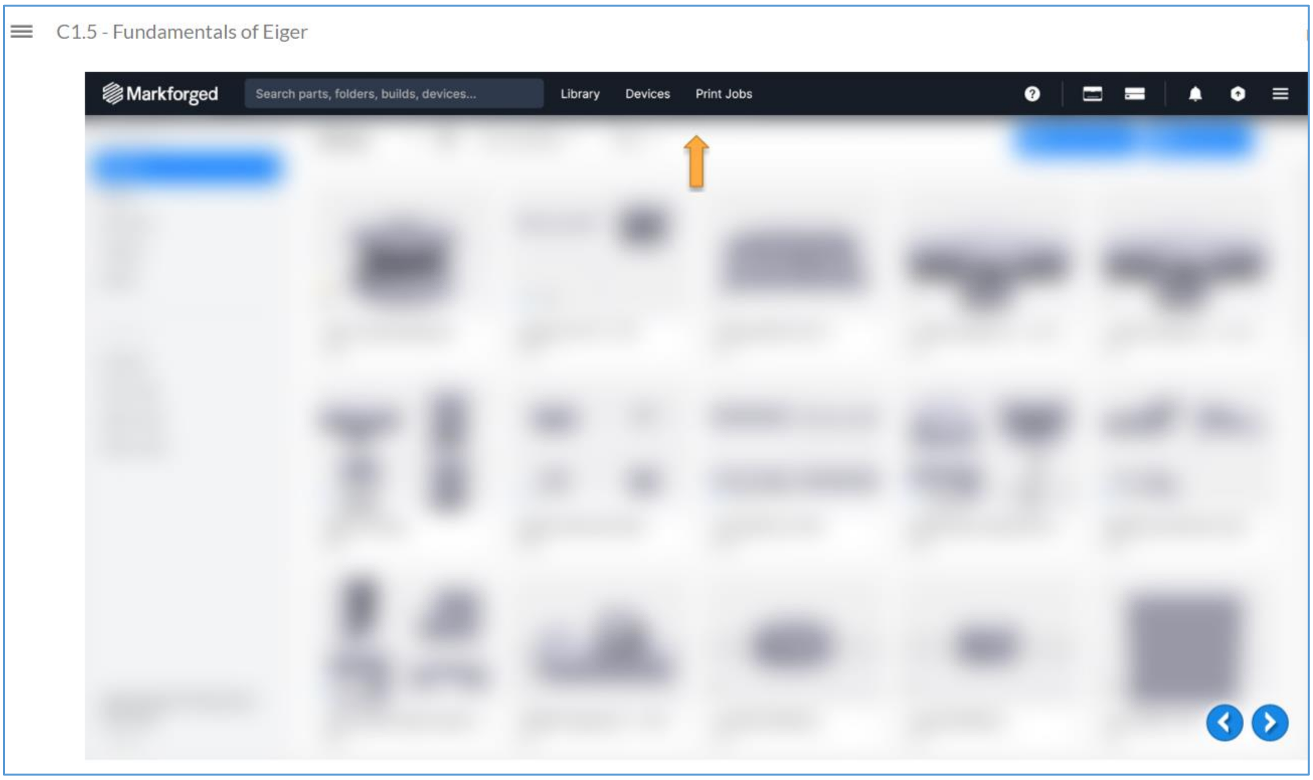
- Enterprise = Onderneming.



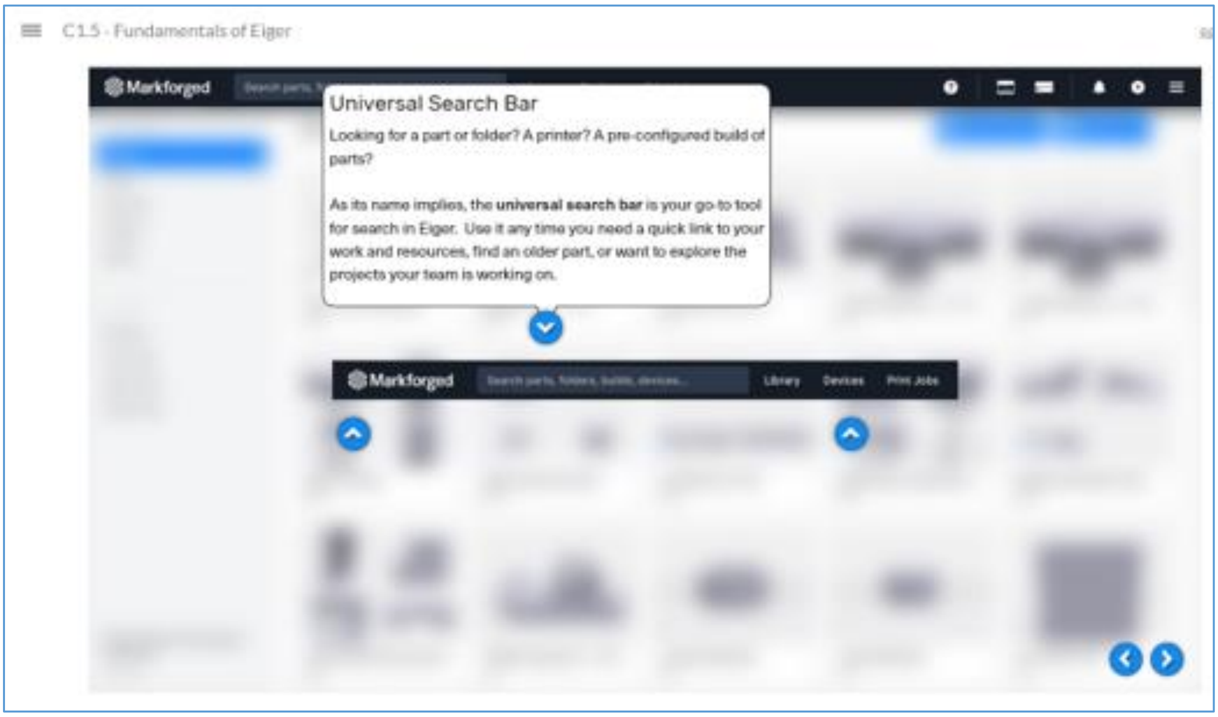
- Companies who subscribe (geabonneerd) has two extra levels to controle their organization:
  - Teams.
  - Device Groups. Apparaten.

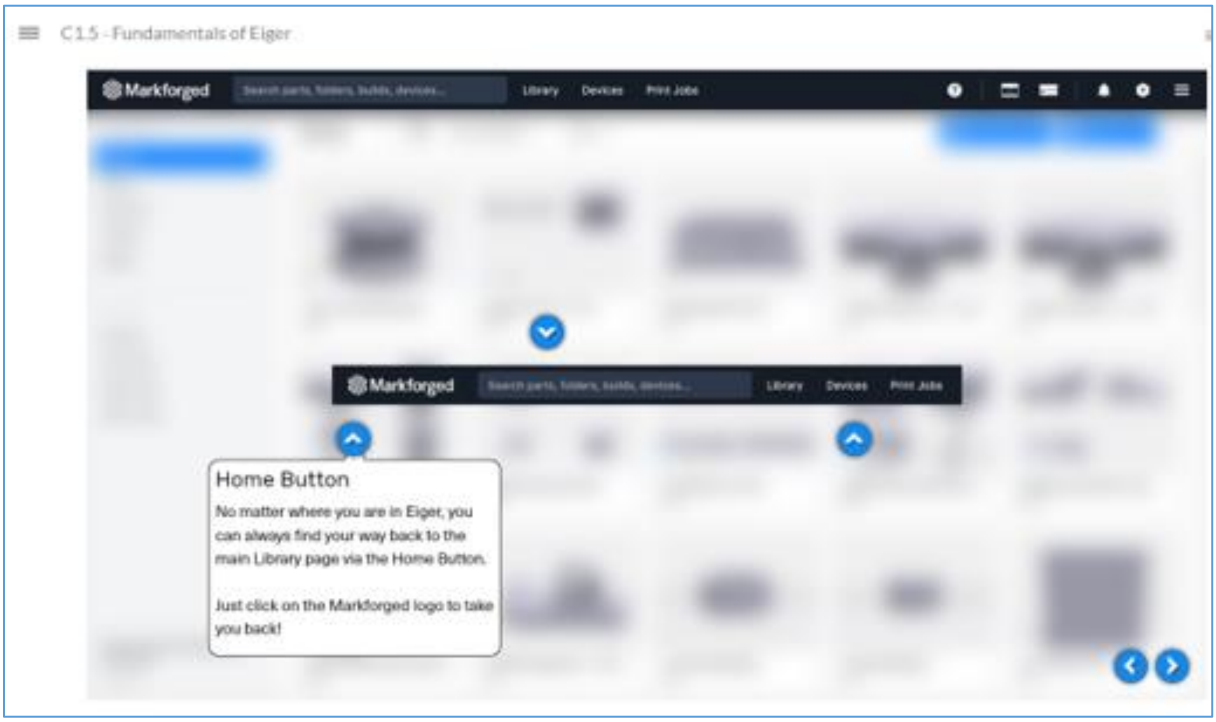


- **Navigating the Home Screen.**

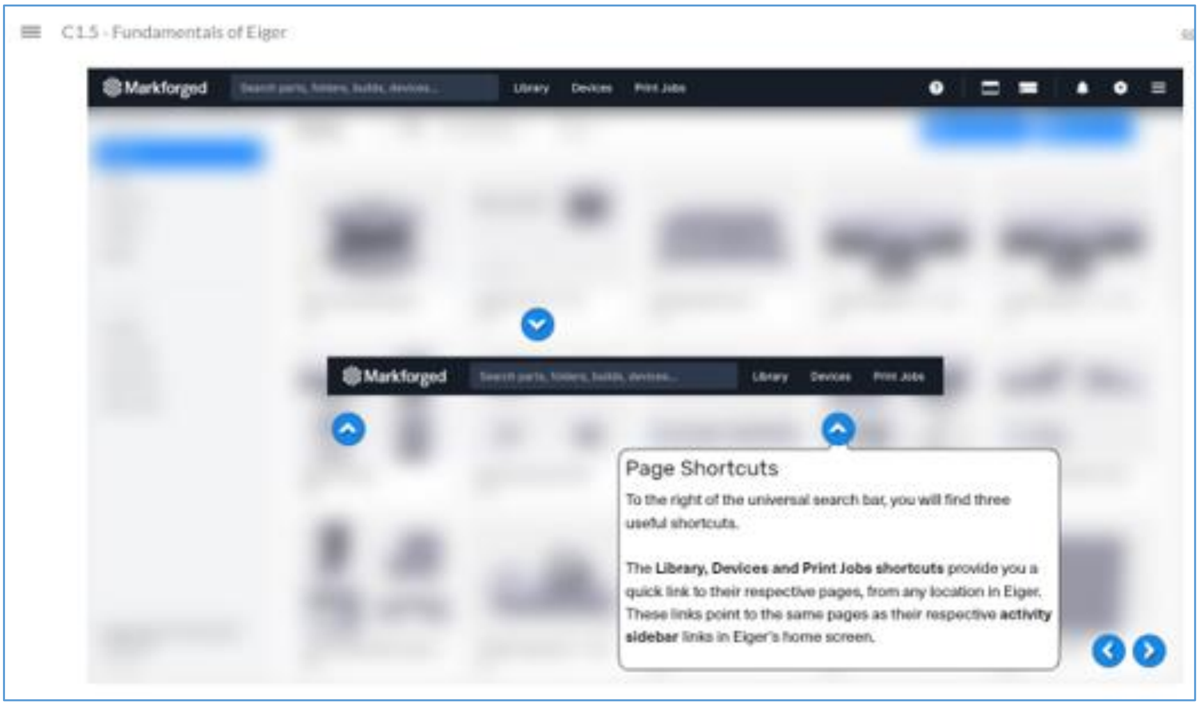


- **In-depth with the Nav Bar.**

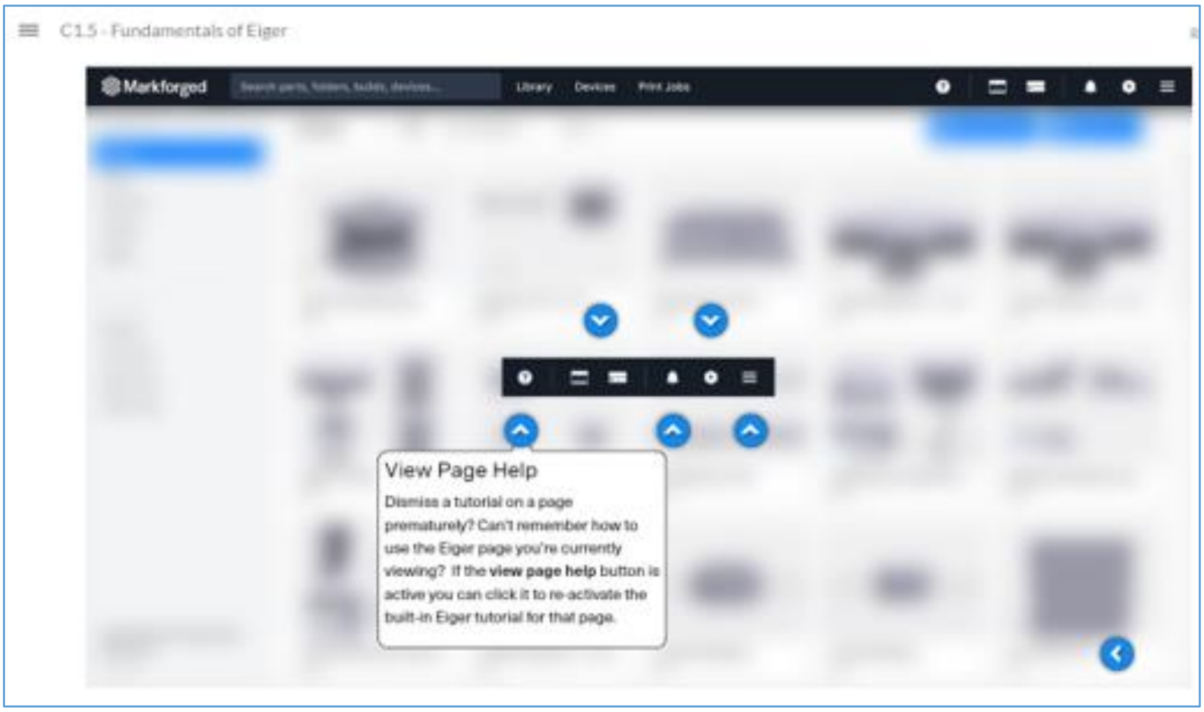




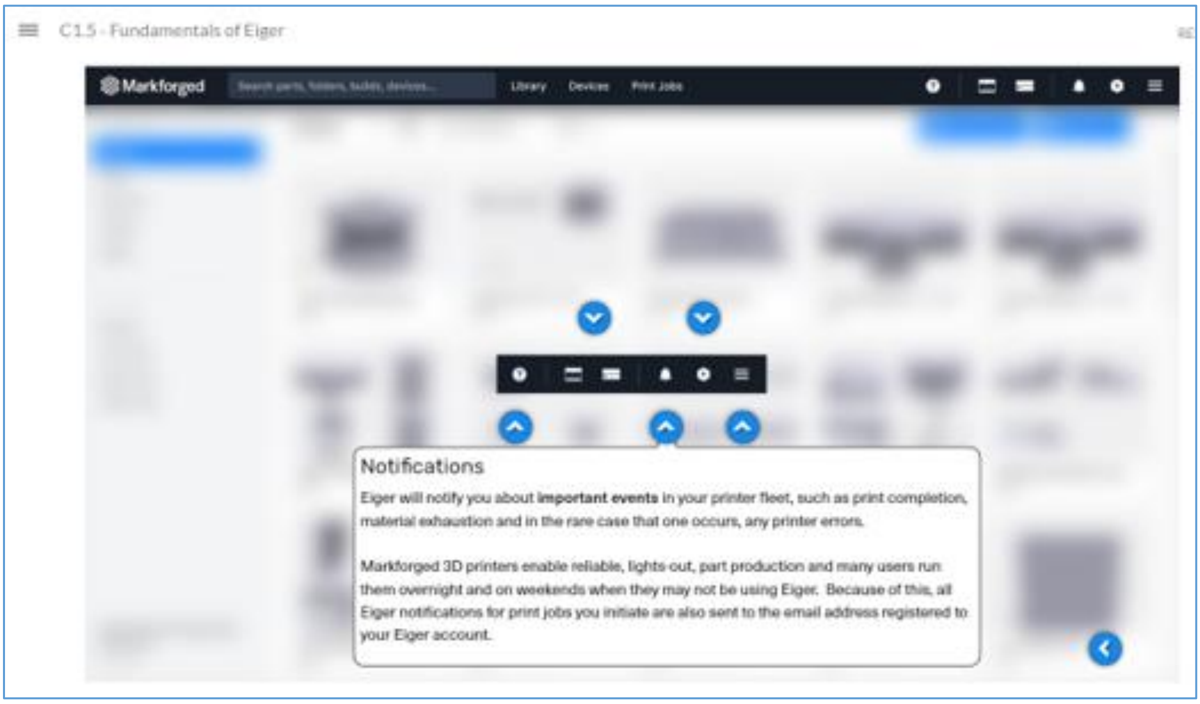
C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Home Button
No matter where you are in Eiger, you can always find your way back to the main Library page via the Home Button.
Just click on the Markforged logo to take you back!

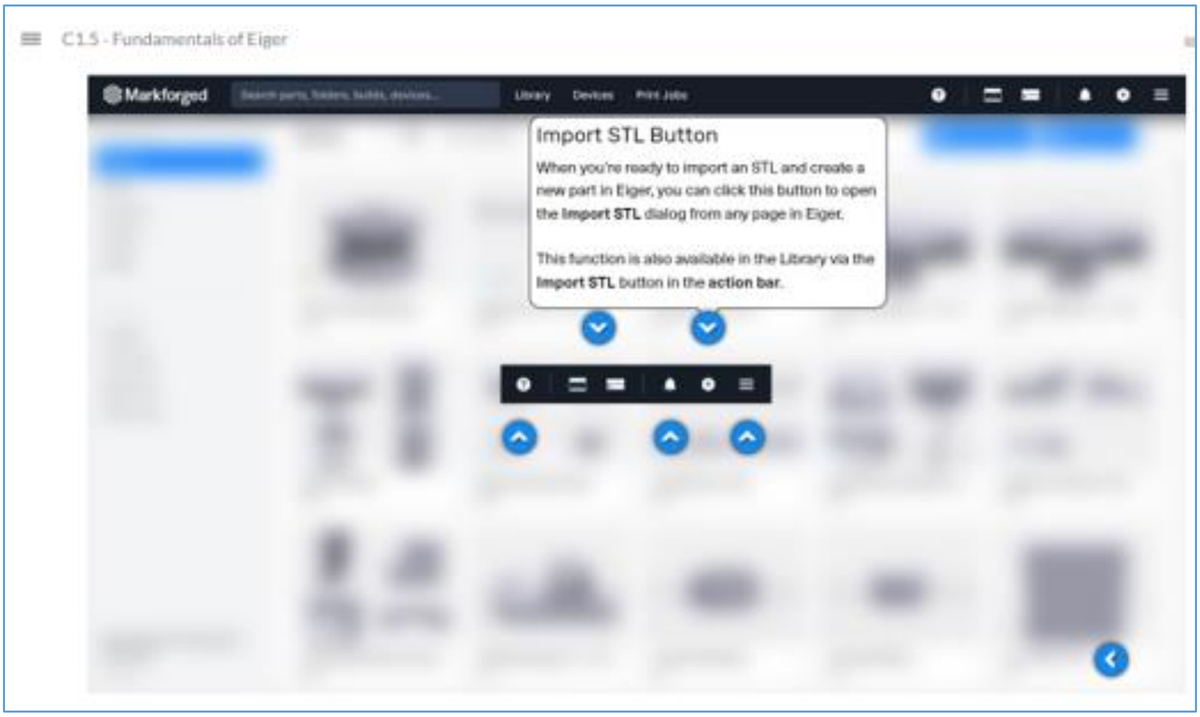


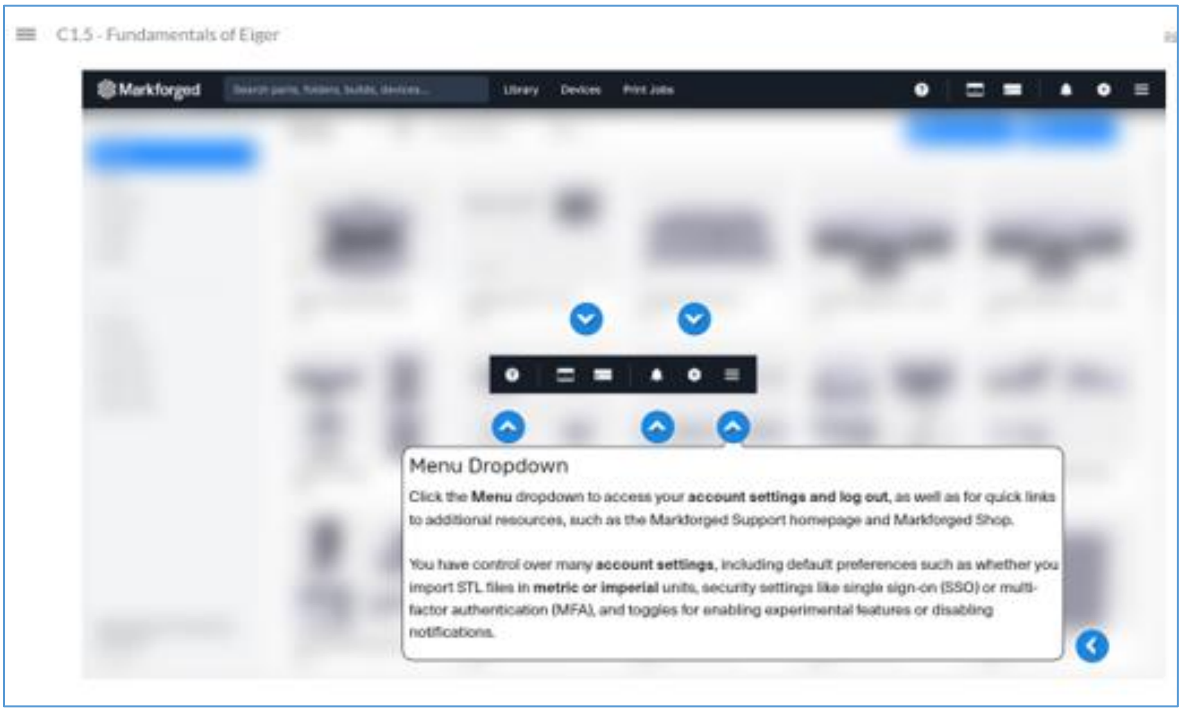
C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Page Shortcuts
To the right of the universal search bar, you will find three useful shortcuts.
The Library, Devices and Print Jobs shortcuts provide you a quick link to their respective pages, from any location in Eiger. These links point to the same pages as their respective activity sidebar links in Eiger's home screen.


C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
View Page Help
Dismiss a tutorial on a page prematurely? Can't remember how to use the Eiger page you're currently viewing? If the **view page help** button is active you can click it to re-activate the built-in Eiger tutorial for that page.

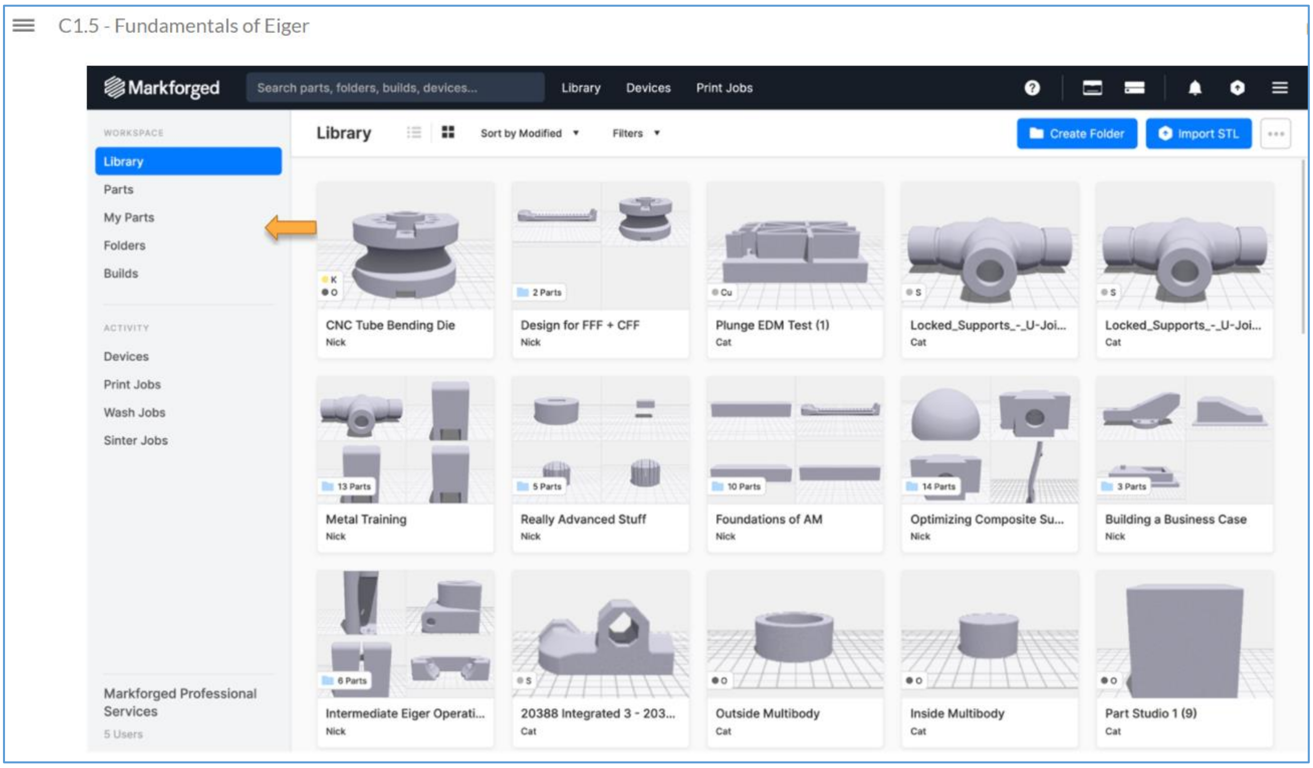

C1.5 - Fundamentals of Eiger
Markforged
Devices Dropdowns
Looking to quickly check the status of a device while remaining on the current Eiger page? You can use the **Printers** dropdown (left icon) to see a status overview of all Markforged 3D printers (composites or metal) in your organization. If you need more detailed insight into a device, just click on it to go to it's **device page**.
The devices dropdowns will update to reflect the devices registered to your organization. I have a Metal X system registered to my organization so you'll notice that I also have a **Sinters** dropdown (right icon) that lists the status of the Metal X system sintering furnaces in my organization.


C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Notifications
Eiger will notify you about important events in your printer fleet, such as print completion, material exhaustion and in the rare case that one occurs, any printer errors.
Markforged 3D printers enable reliable, lights-out, part production and many users run them overnight and on weekends when they may not be using Eiger. Because of this, all Eiger notifications for print jobs you initiate are also sent to the email address registered to your Eiger account.

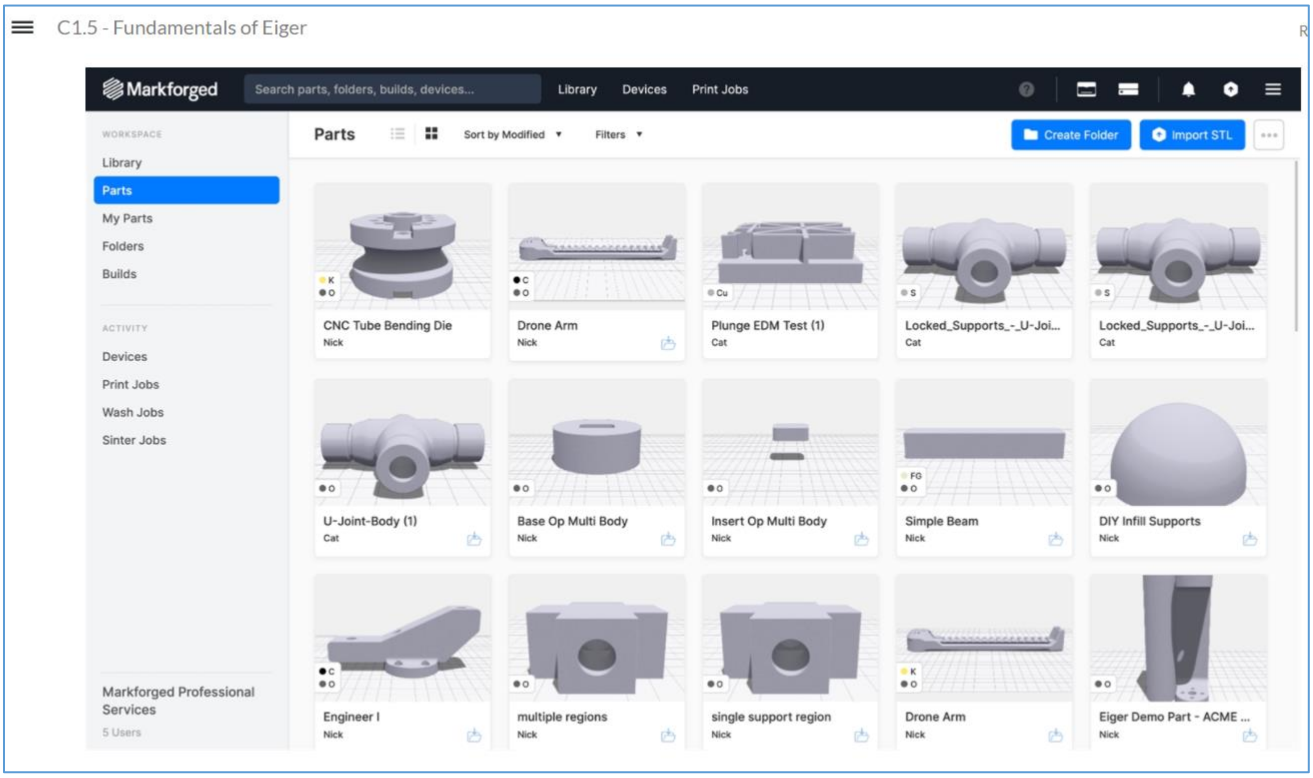

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Import STL Button
When you're ready to import an STL and create a new part in Eiger, you can click this button to open the Import STL dialog from any page in Eiger.
This function is also available in the Library via the Import STL button in the action bar.



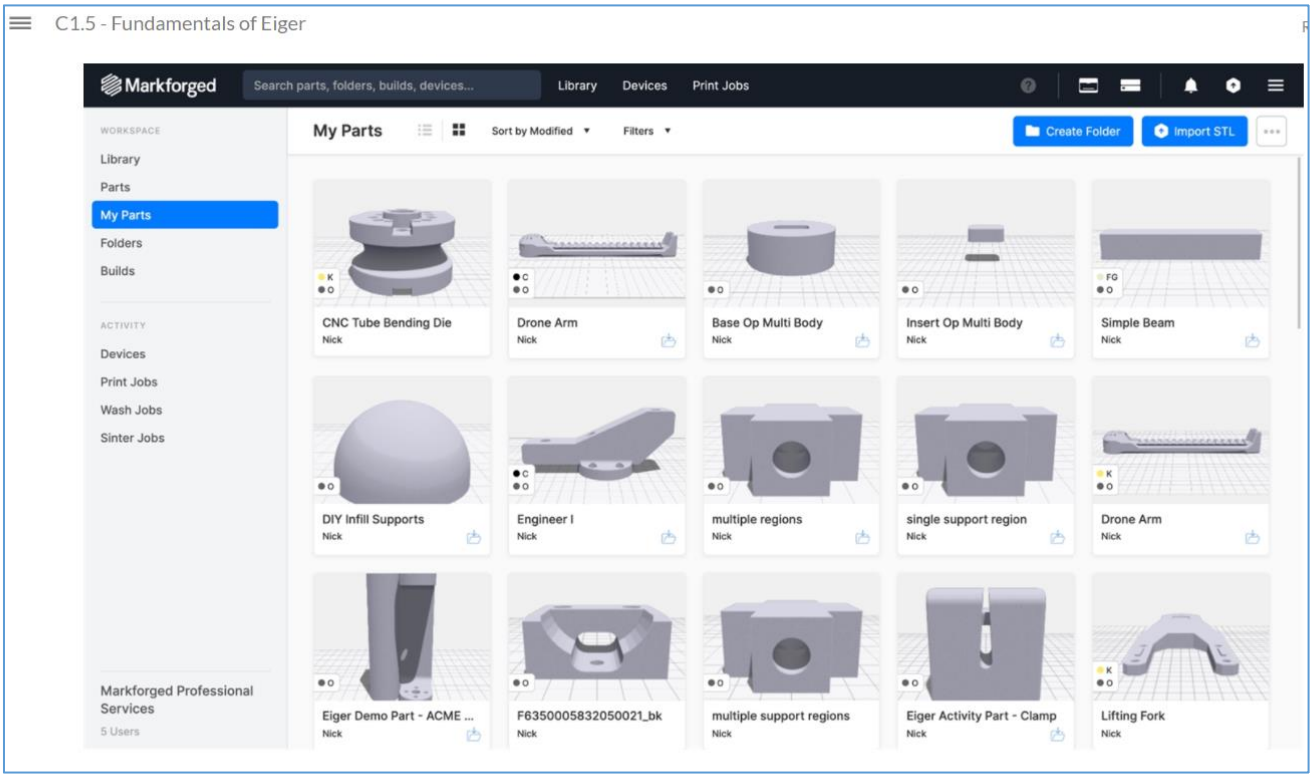
- **Additional resources: Aanvullende middelen.**



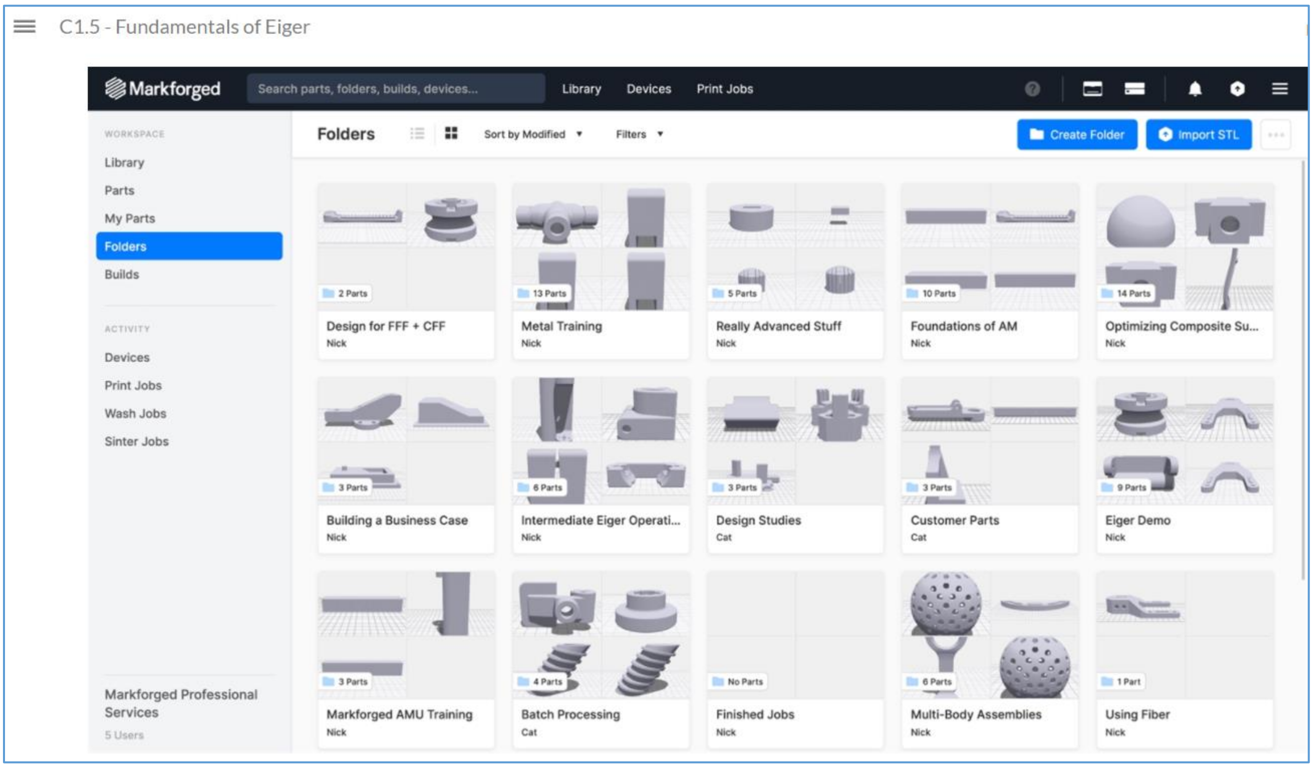
- **Exploring the Library with Workspace Views.**



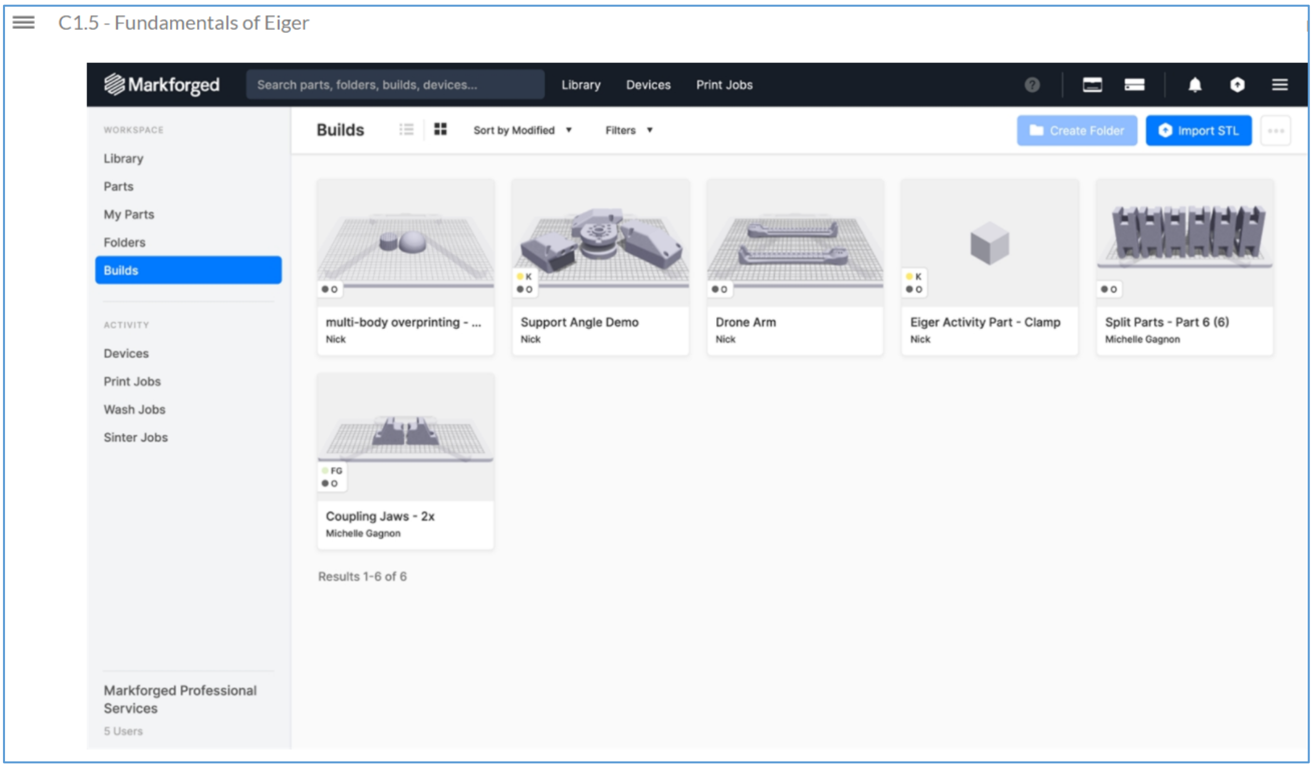
- Parts



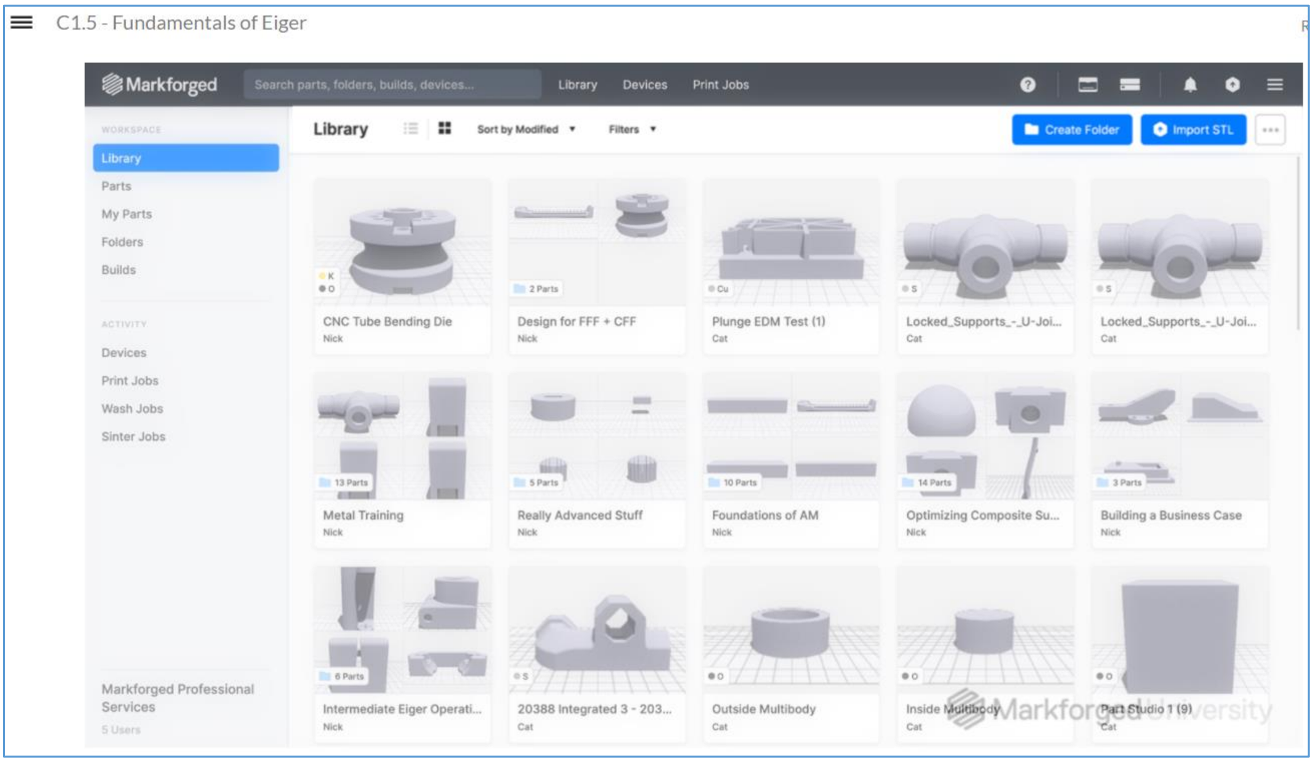
- My Parts



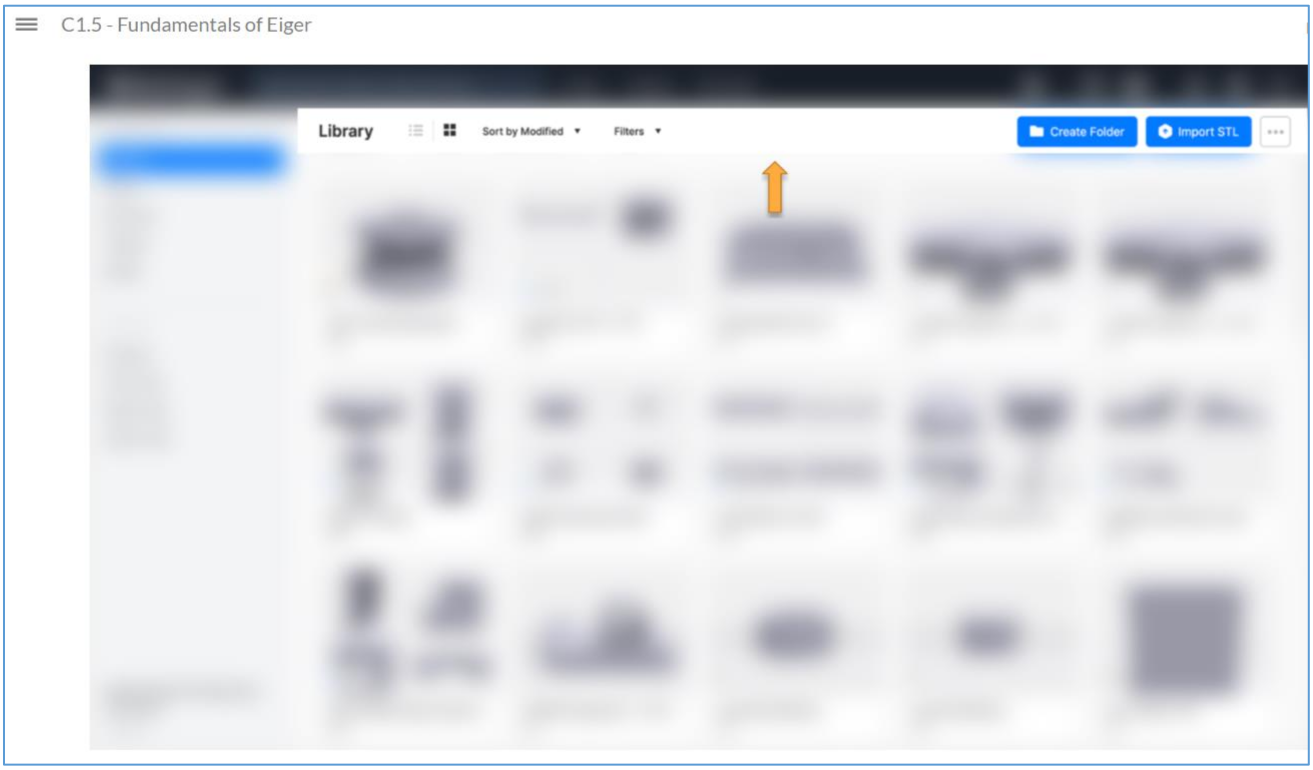
- Folders

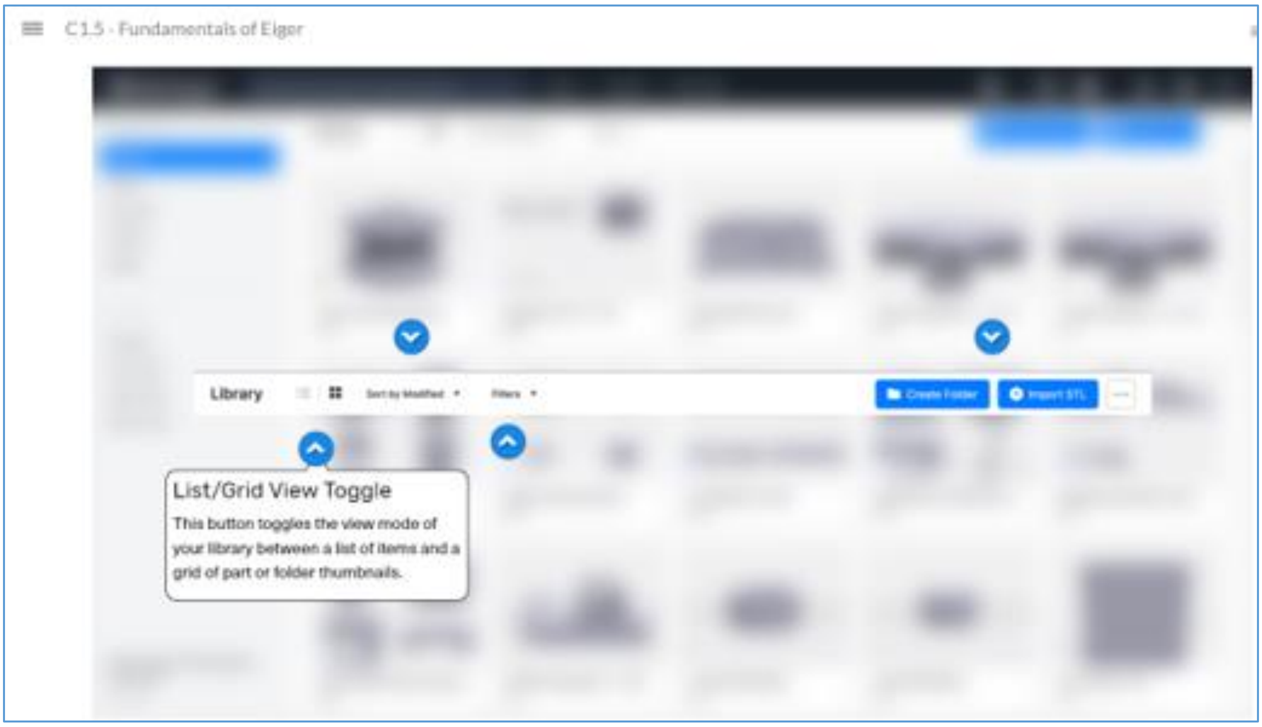


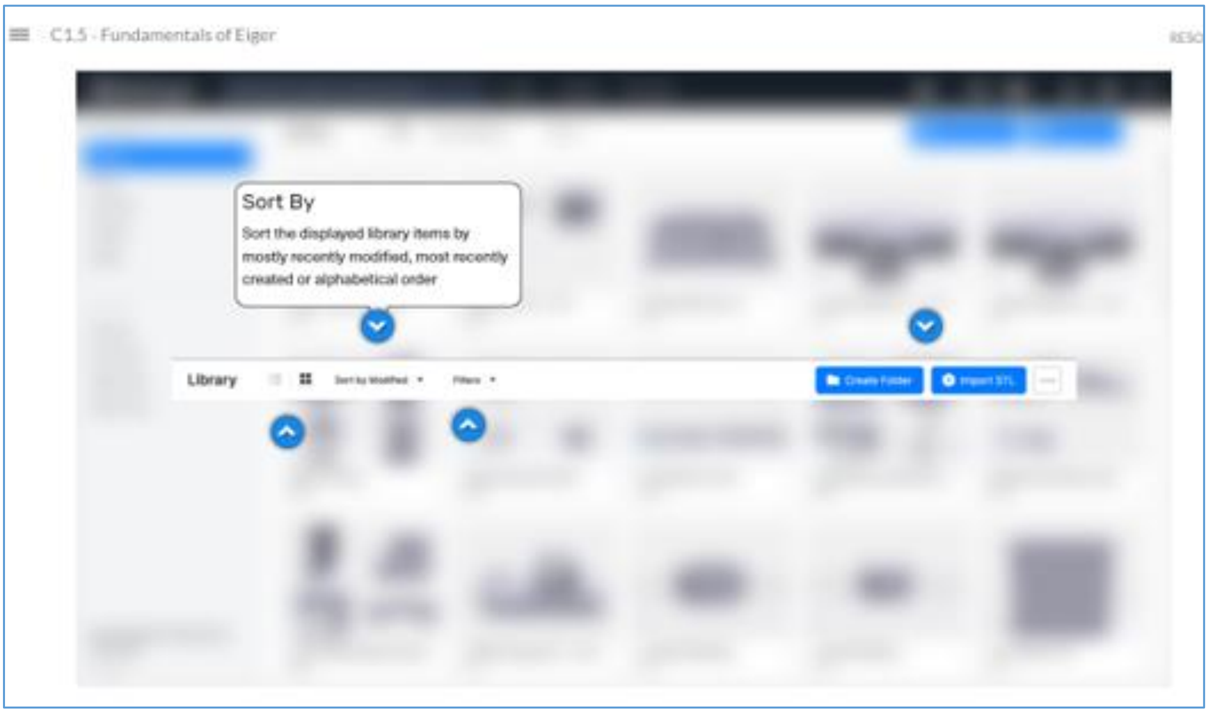
- Builds

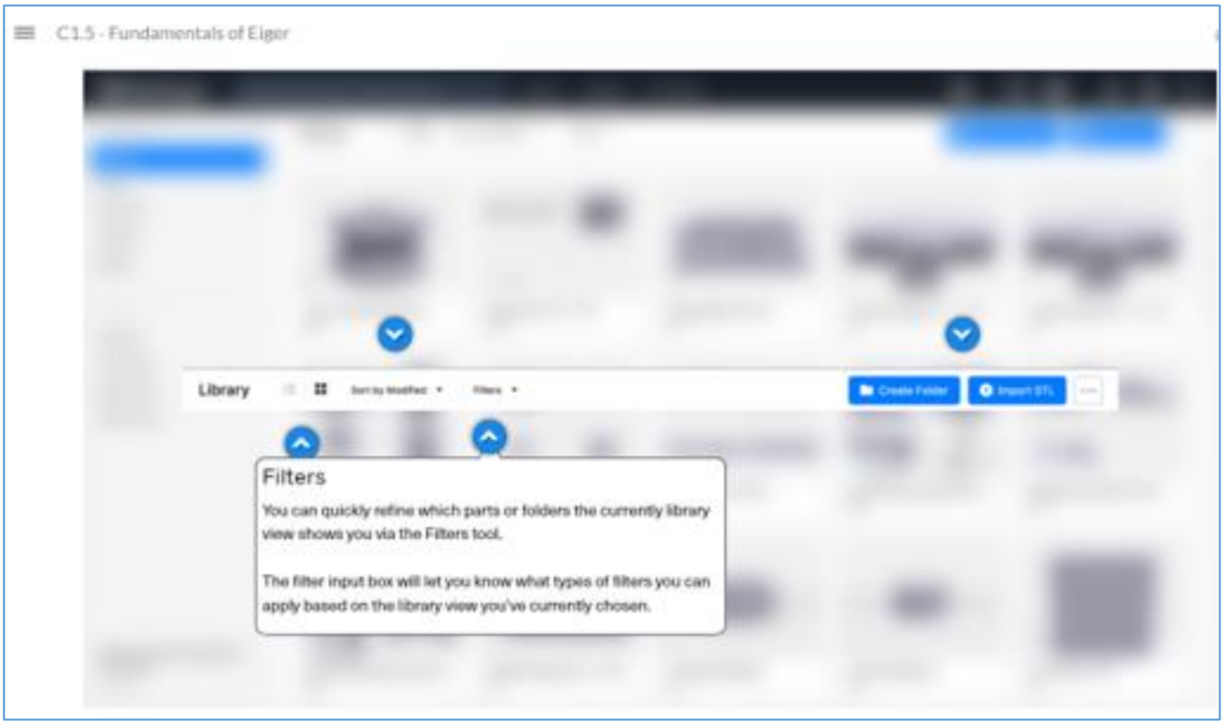


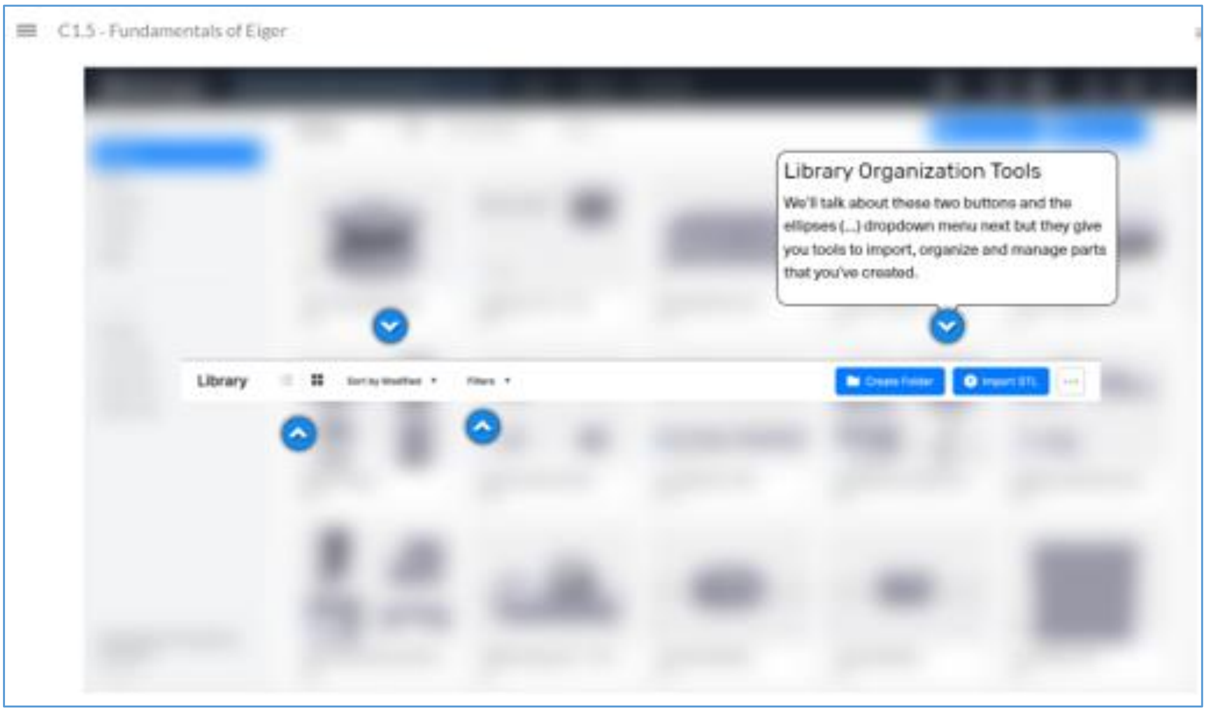
- **Take control with the Action Bar**

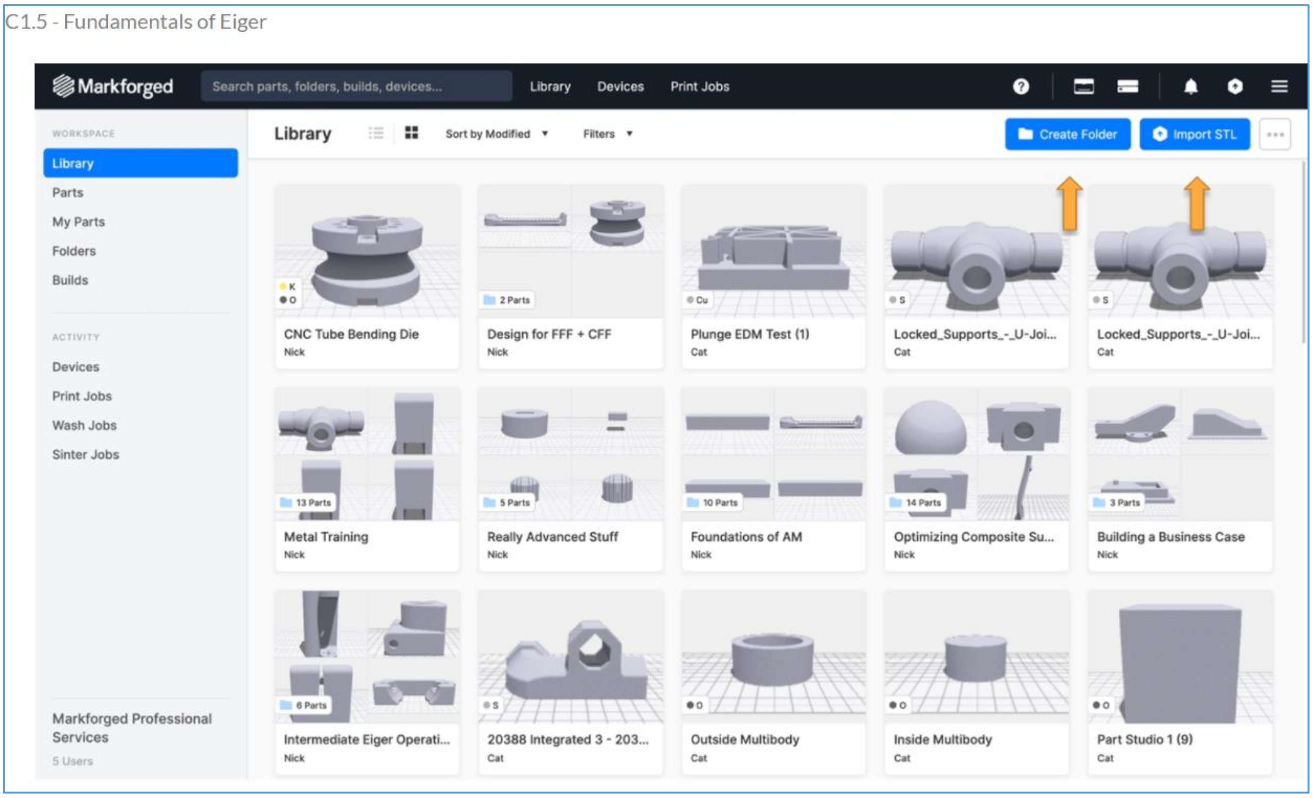

C1.5 - Fundamentals of Eiger
Library
Sort by Modified
Filters
Create Folder
Import STL


C1.5 - Fundamentals of Eiger
Library
Sort by Modified
Filters
Create Folder
Import STL
List/Grid View Toggle
This button toggles the view mode of your library between a list of items and a grid of part or folder thumbnails.

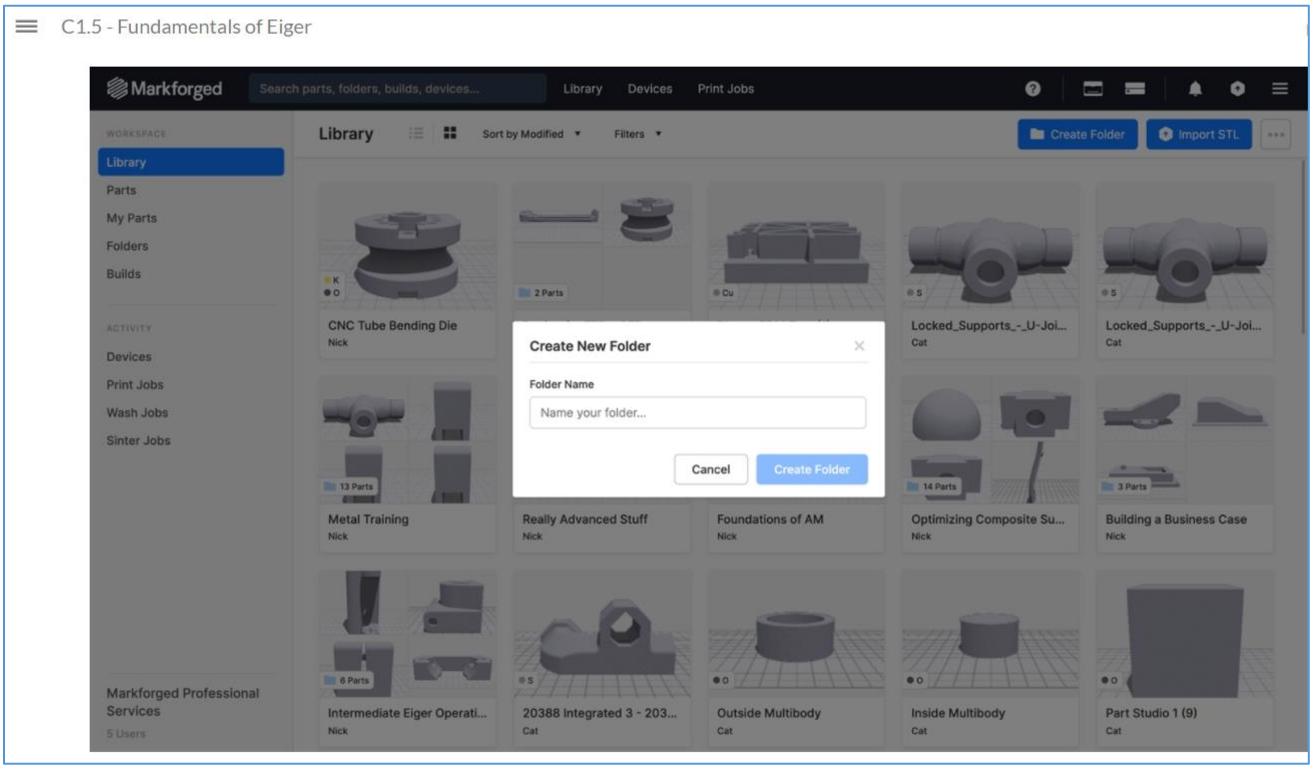

C1.5 - Fundamentals of Eiger
Sort By
Sort the displayed library items by mostly recently modified, most recently created or alphabetical order
Library
Create Folder
Import STL


C1.5 - Fundamentals of Eiger
Library
Create Folder
Import STL
Filters
You can quickly refine which parts or folders the currently library view shows you via the Filters tool.
The filter input box will let you know what types of filters you can apply based on the library view you've currently chosen.

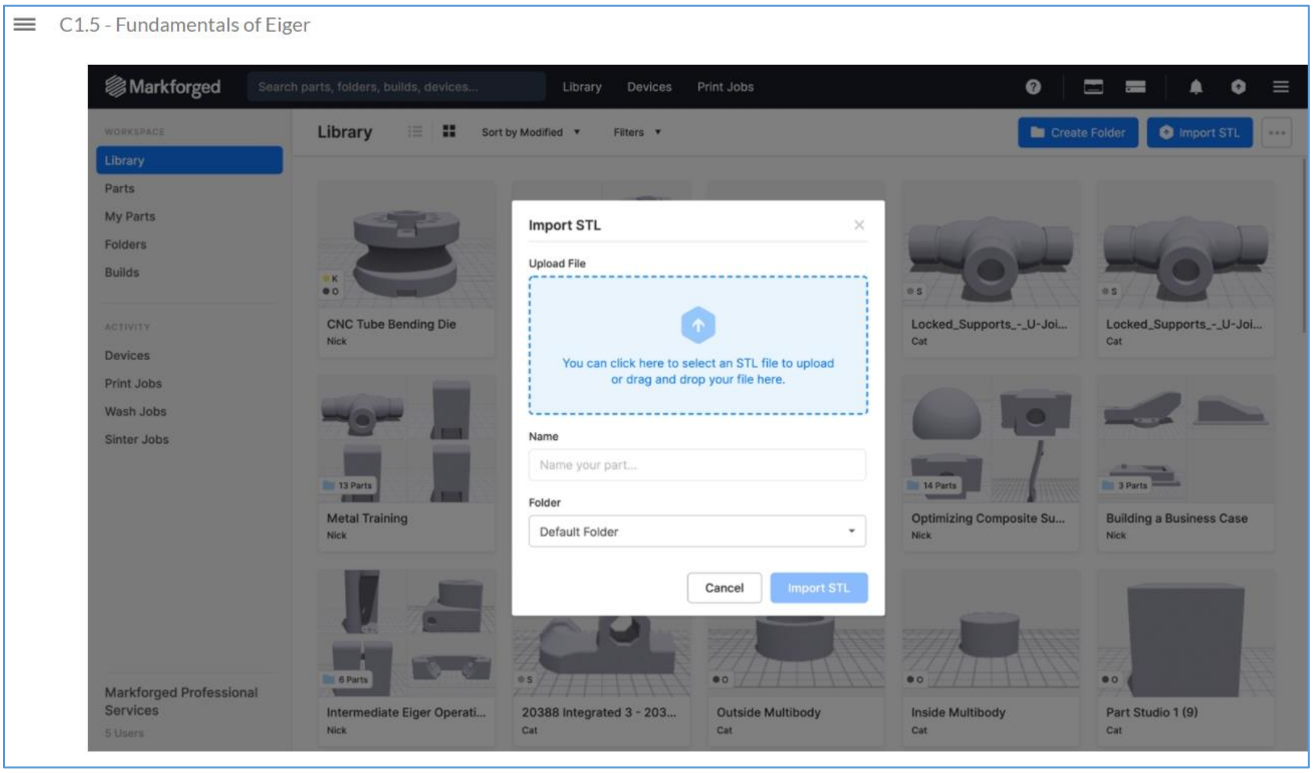




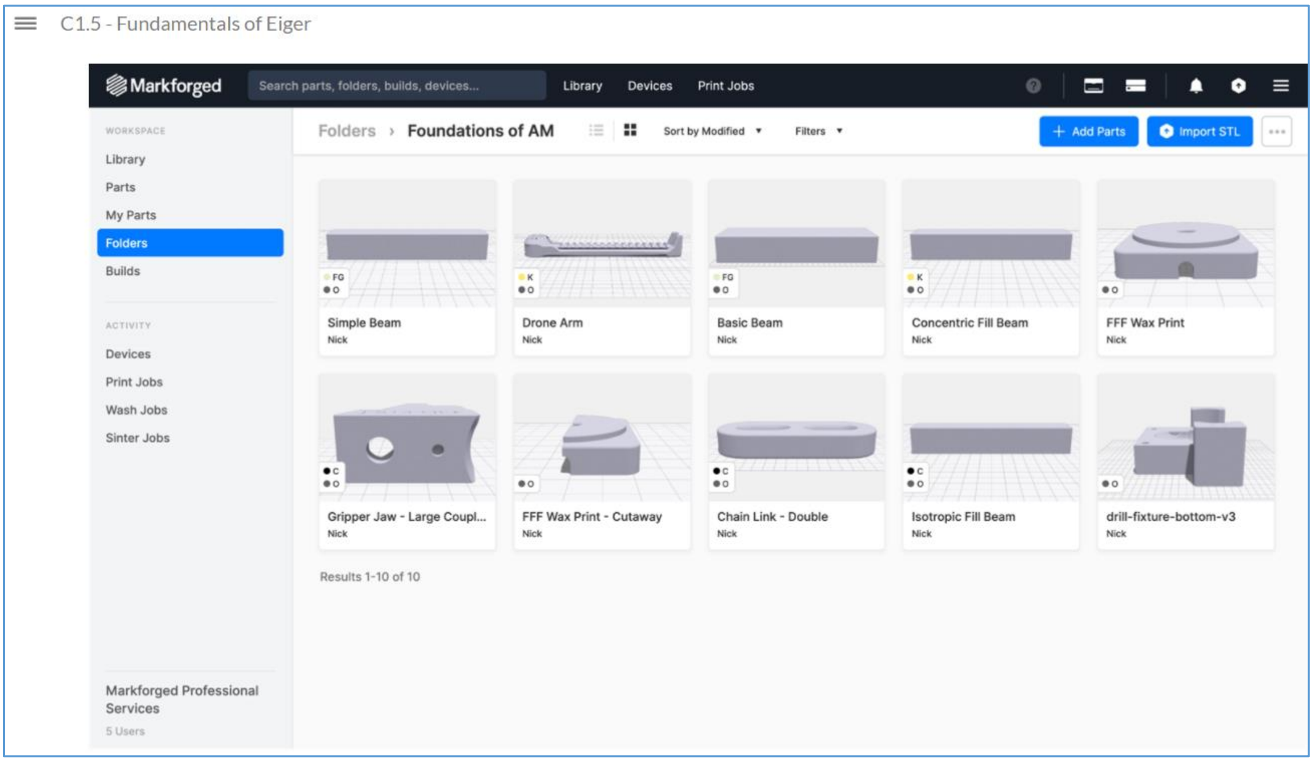
- **Keeping Organized in the Library**



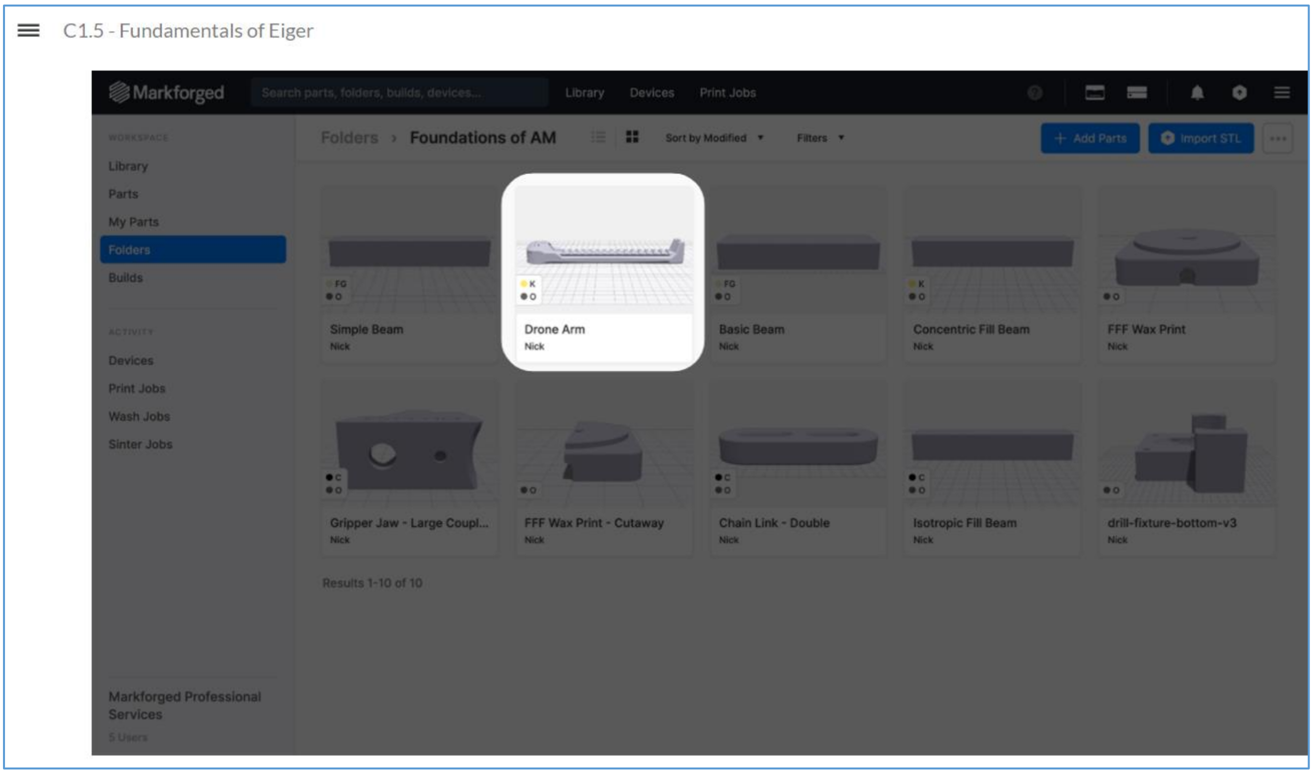
- Create folder



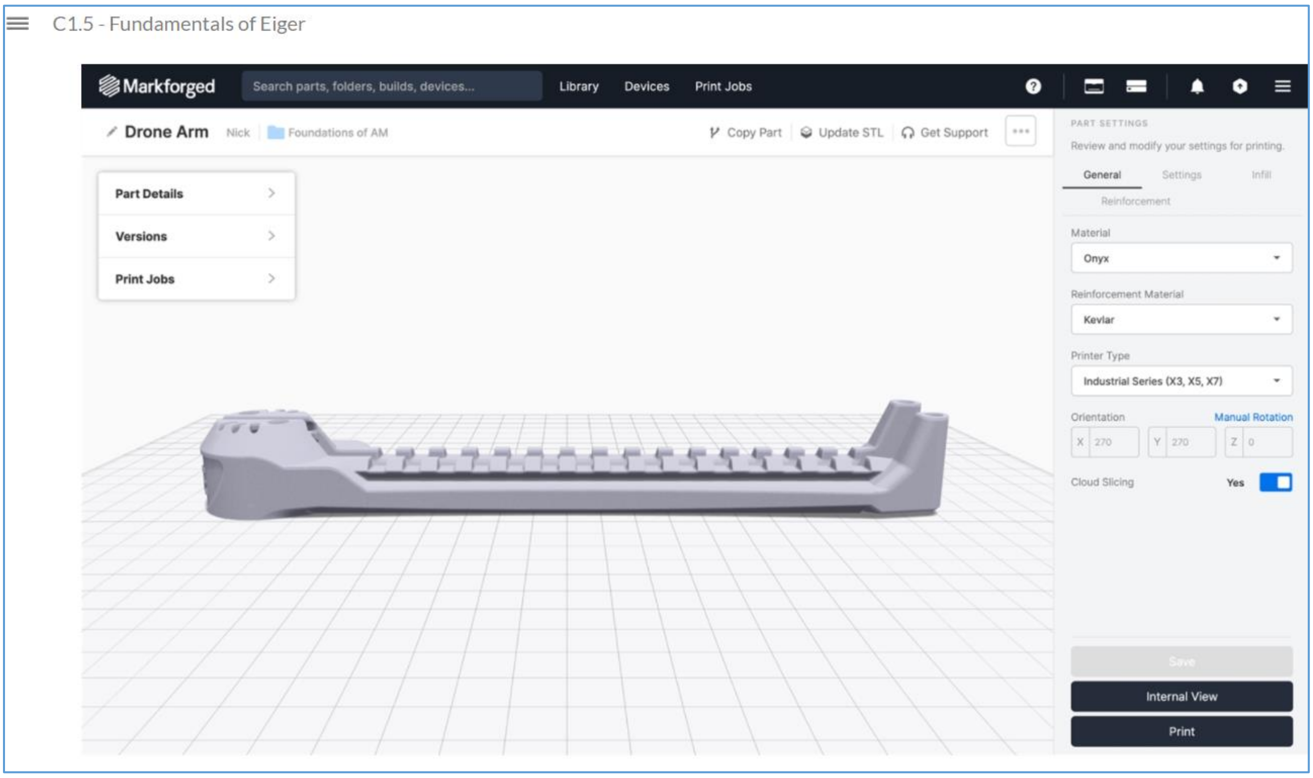
- Import STL

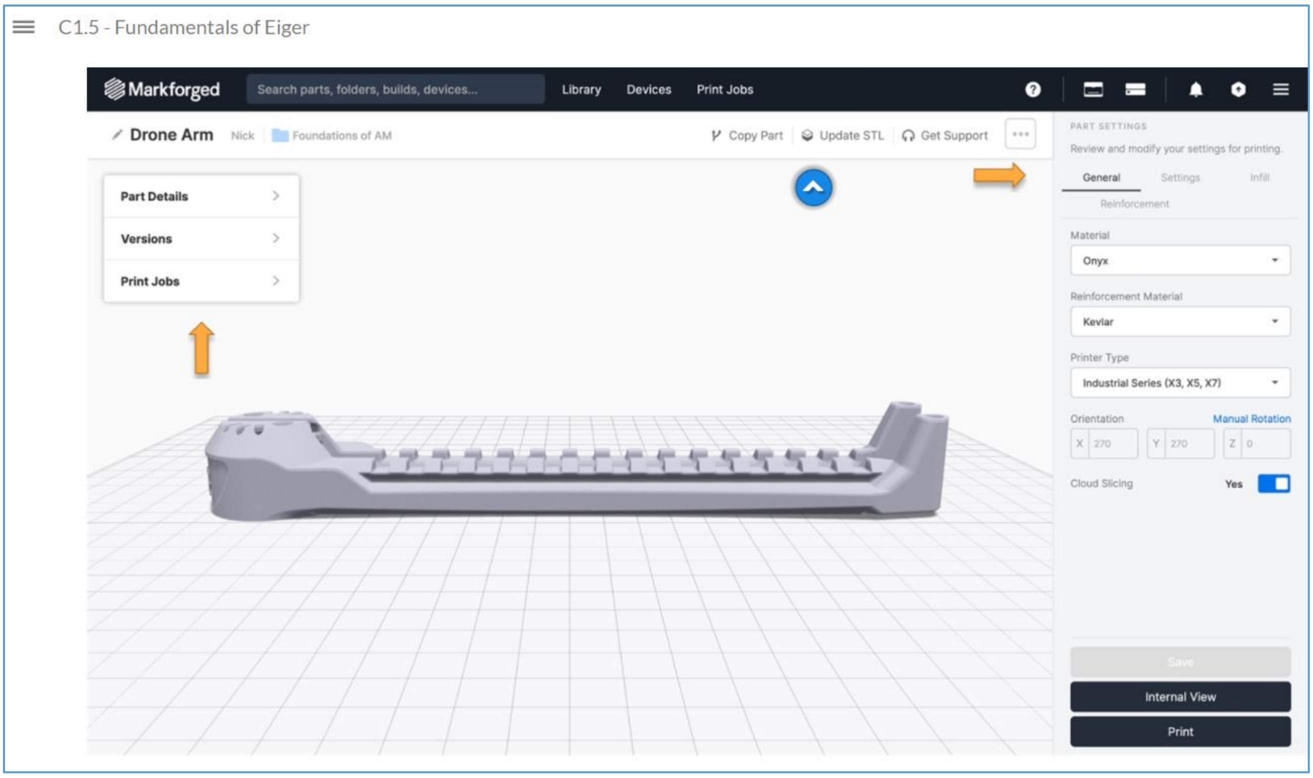


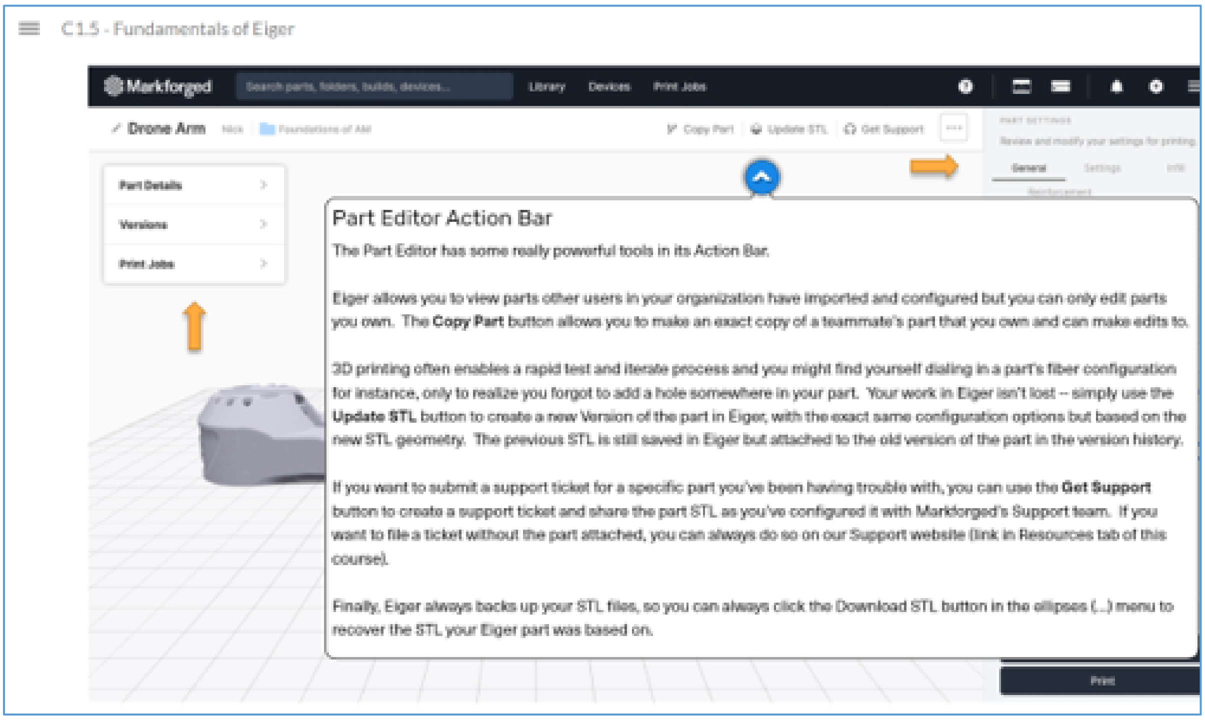
- **The Part Editor Page**



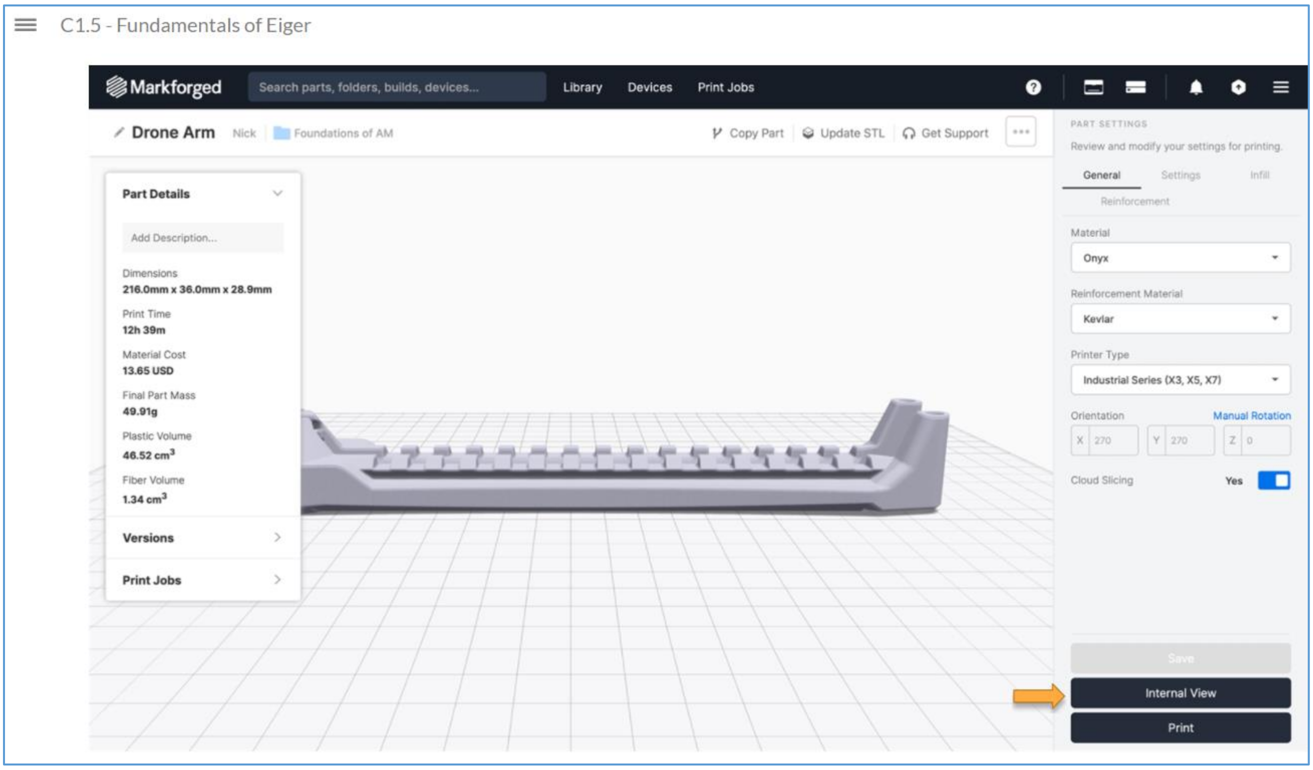
- Click on a Part (see highlighted)


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Foundations of AM
Copy Part
Update STL
Get Support
Part Details
Versions
Print Jobs
PART SETTINGS
Review and modify your settings for printing.
General
Settings
Infill
Reinforcement
Material
Onyx
Reinforcement Material
Kevlar
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Manual Rotation
X 270
Y 270
Z 0
Cloud Slicing
Yes
Save
Internal View
Print

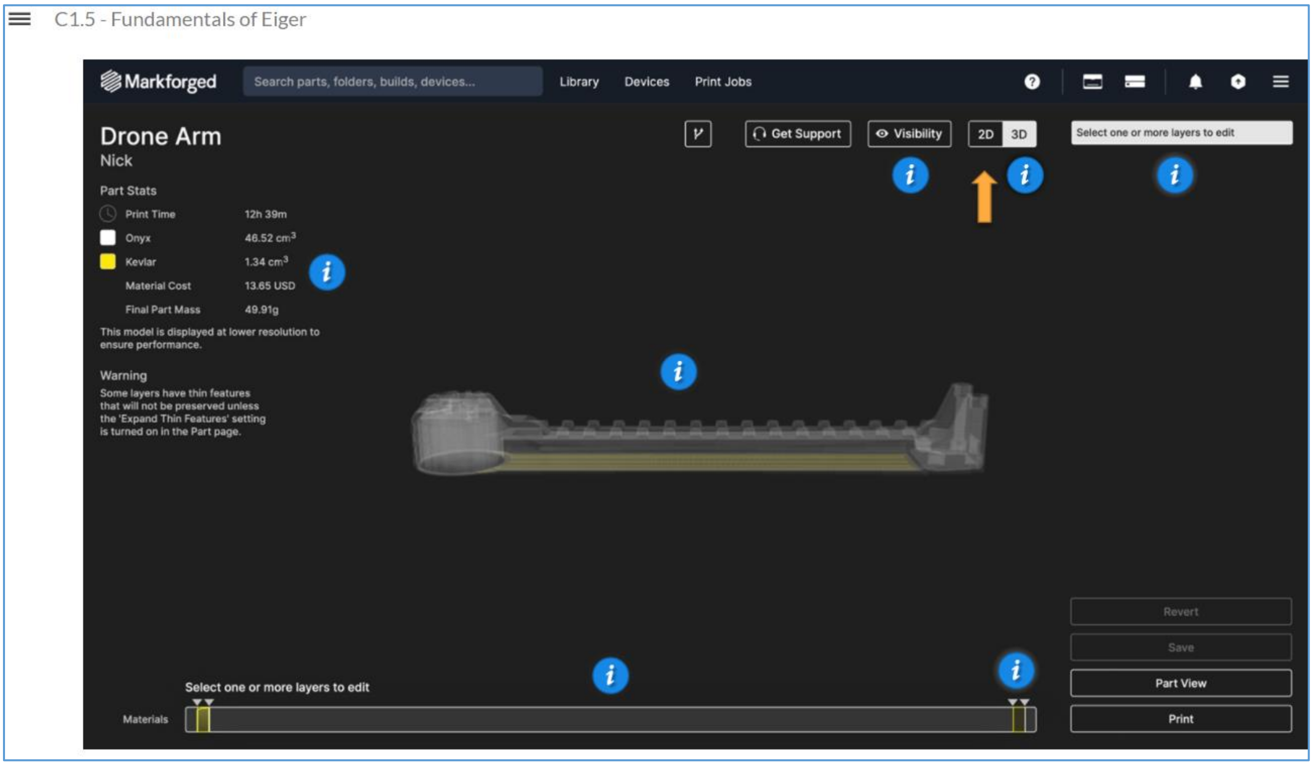

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Foundations of AM
Copy Part
Update STL
Get Support
Part Details
Versions
Print Jobs
PART SETTINGS
Review and modify your settings for printing.
General
Settings
Infill
Reinforcement
Material
Onyx
Reinforcement Material
Kevlar
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Manual Rotation
X 270
Y 270
Z 0
Cloud Slicing
Yes
Save
Internal View
Print



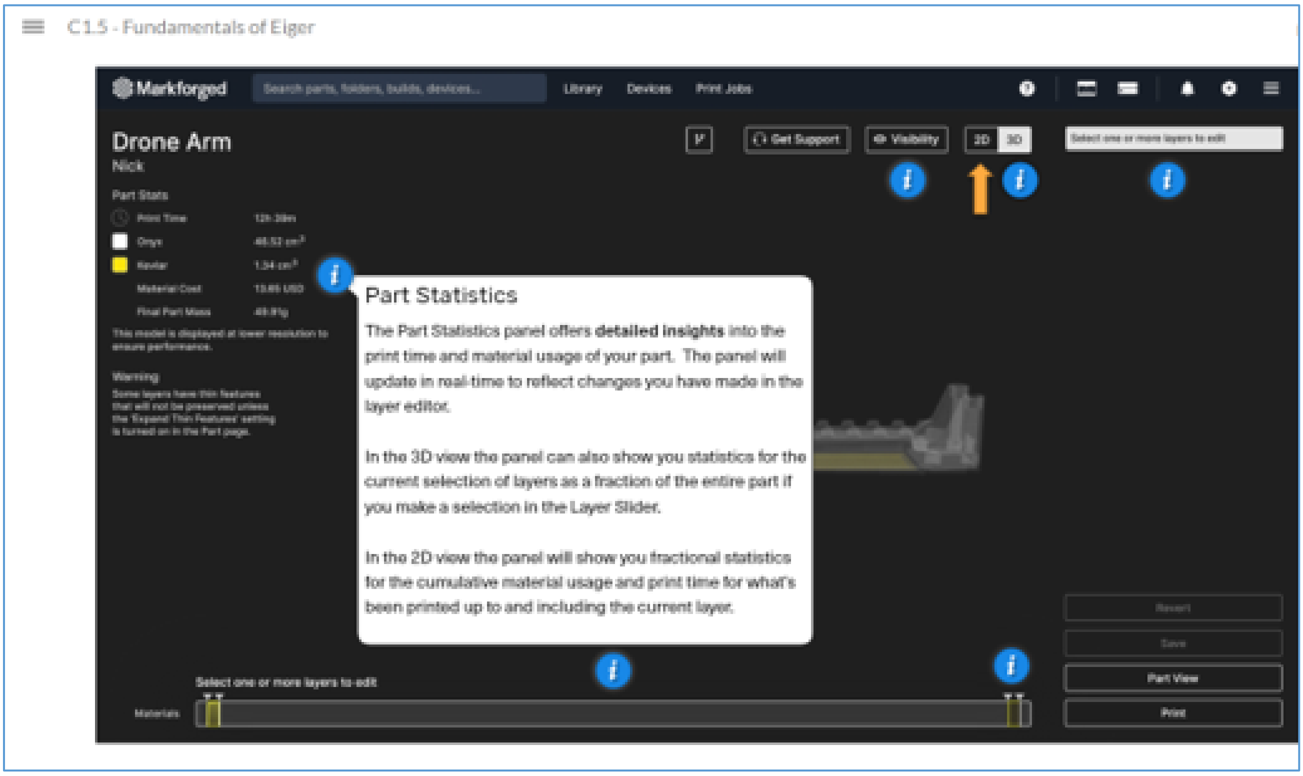
- Iterate = herhalen.
- Dialing = kiezen.

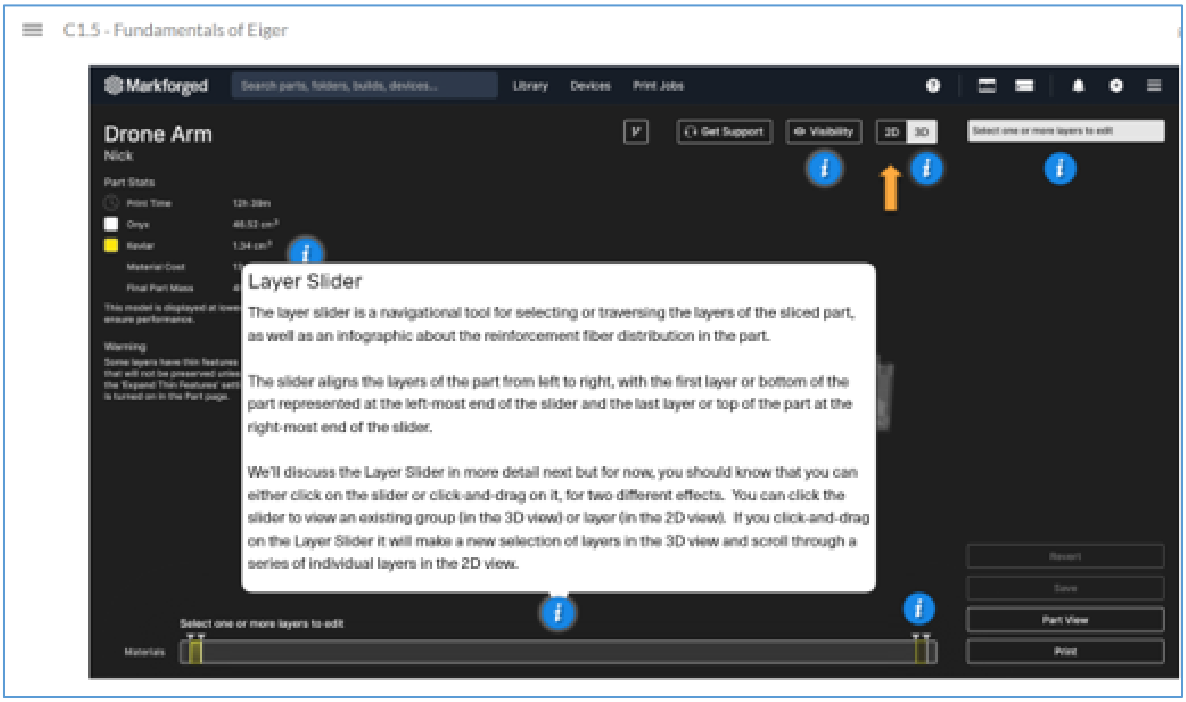


- **The Layer Editor: 2D and 3D views**

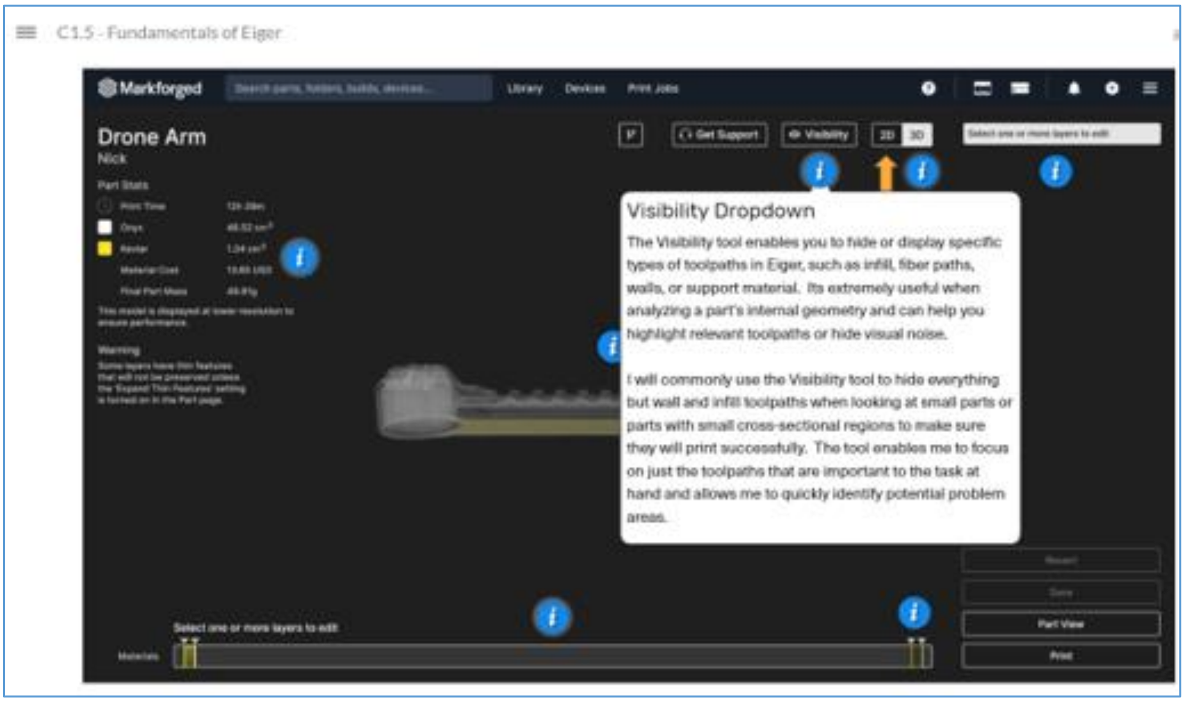


- Internal View

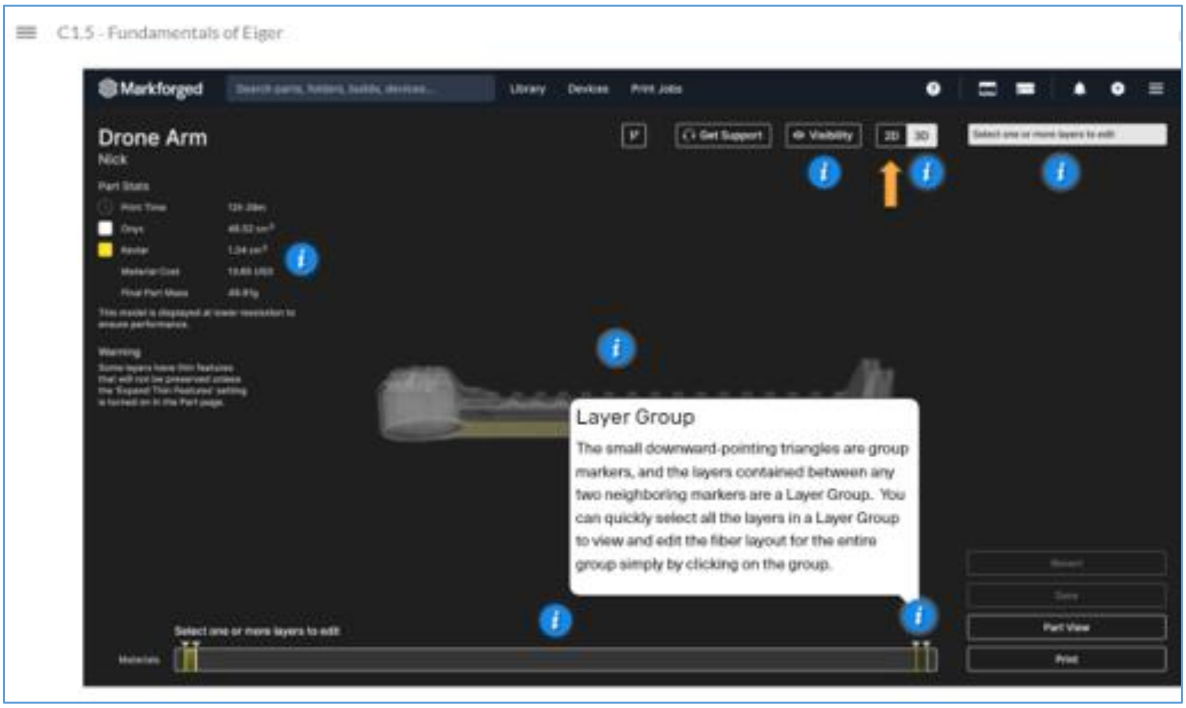


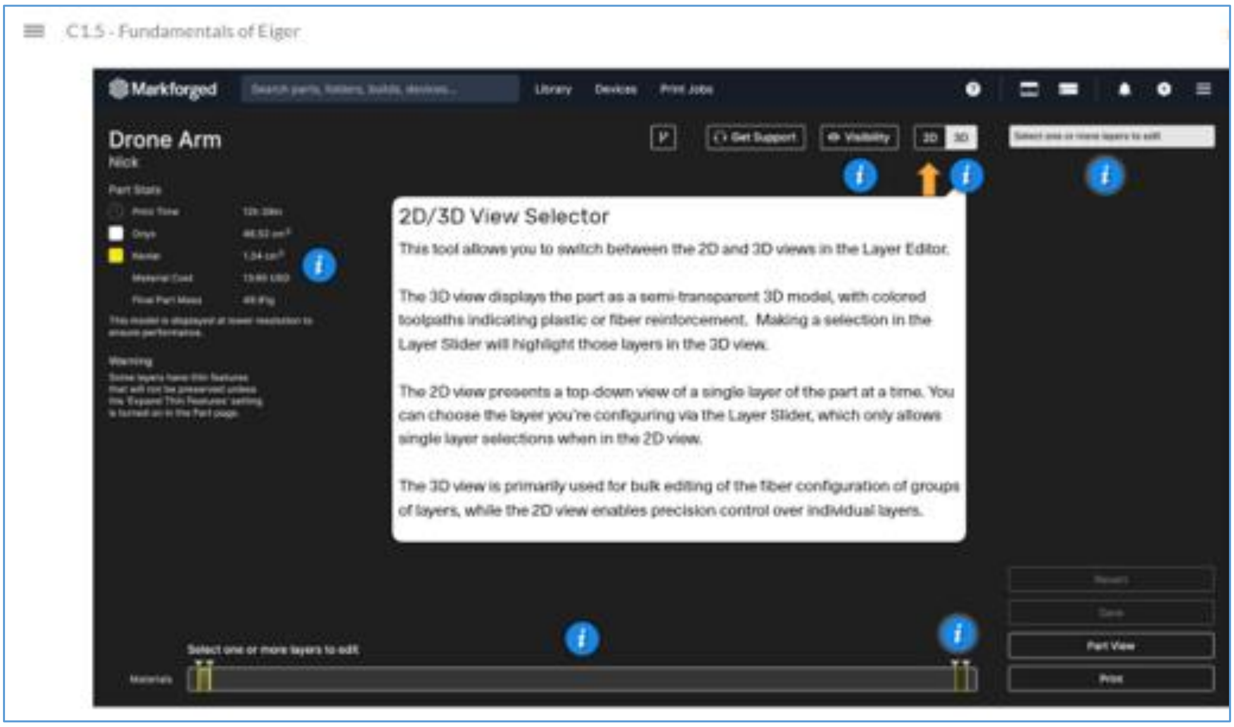

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Nick
Part Stats
Get Support
Visibility
2D
3D
Layer Slider
The layer slider is a navigational tool for selecting or traversing the layers of the sliced part, as well as an infographic about the reinforcement fiber distribution in the part.
The slider aligns the layers of the part from left to right, with the first layer or bottom of the part represented at the left-most end of the slider and the last layer or top of the part at the right-most end of the slider.
We'll discuss the Layer Slider in more detail next but for now, you should know that you can either click on the slider or click-and-drag on it, for two different effects. You can click the slider to view an existing group (in the 3D view) or layer (in the 2D view). If you click-and-drag on the Layer Slider it will make a new selection of layers in the 3D view and scroll through a series of individual layers in the 2D view.
Select one or more layers to edit
Part View
Print

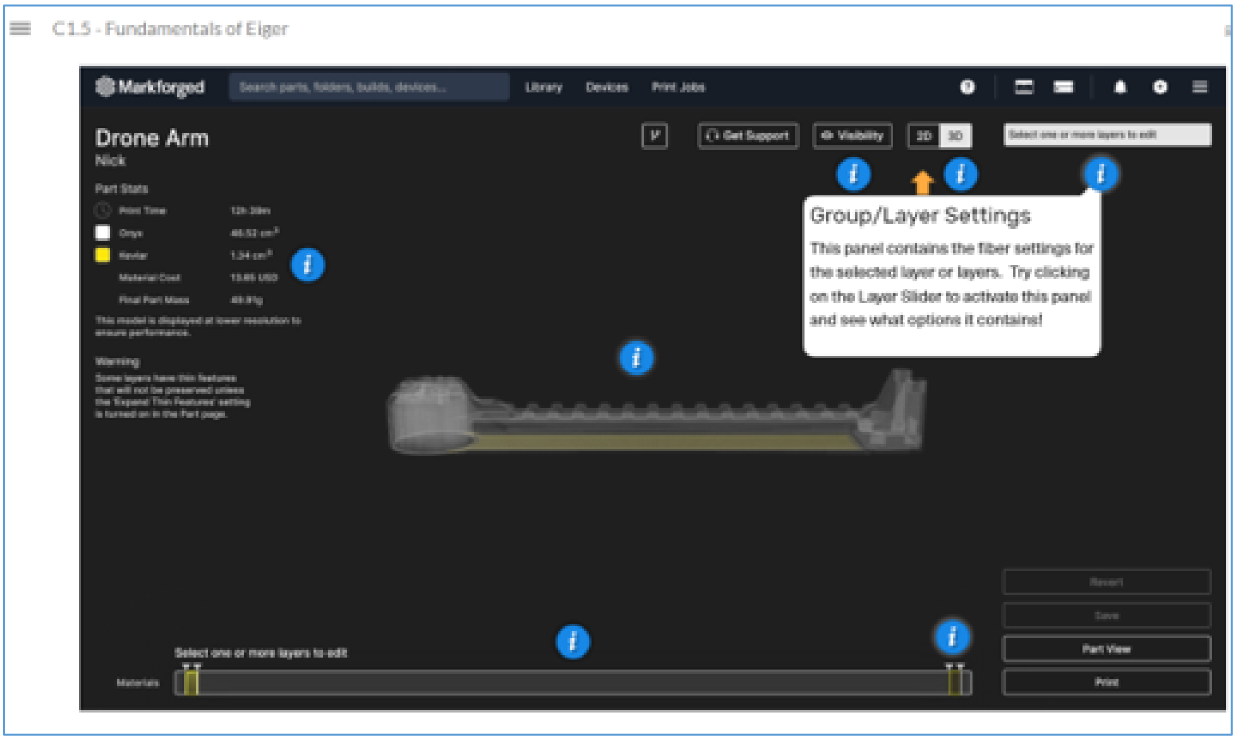

C1.5 - Fundamentals of Eiger
Markforged
Drone Arm
Nick
Part Stats
Part 3D Internal View
This is the 3D internal view of the drone arm we've been discussing. You'll notice immediately that it has a semi-transparent quality, kind of like an X-ray. This enables you to see the full geometry of the part (including internal regions that could be otherwise hidden from view) and identify where reinforcement fiber has been laid down.
The 3D internal view also makes it possible to visualize the structural layout of fiber in your part. We'll discuss this later but many times where fiber is placed is much more important than how much has been added
Select one or more layers to edit
Part View
Print

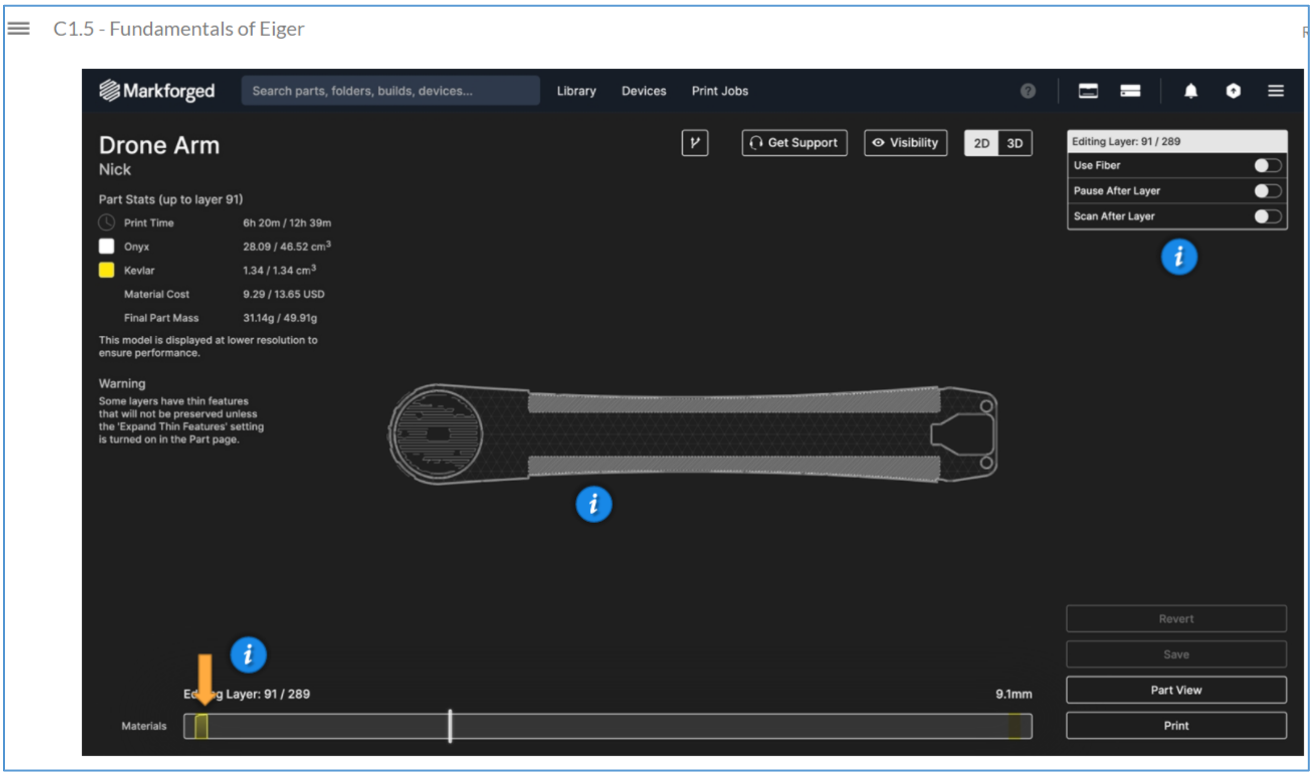


- Enables = Maakt het mogelijk….

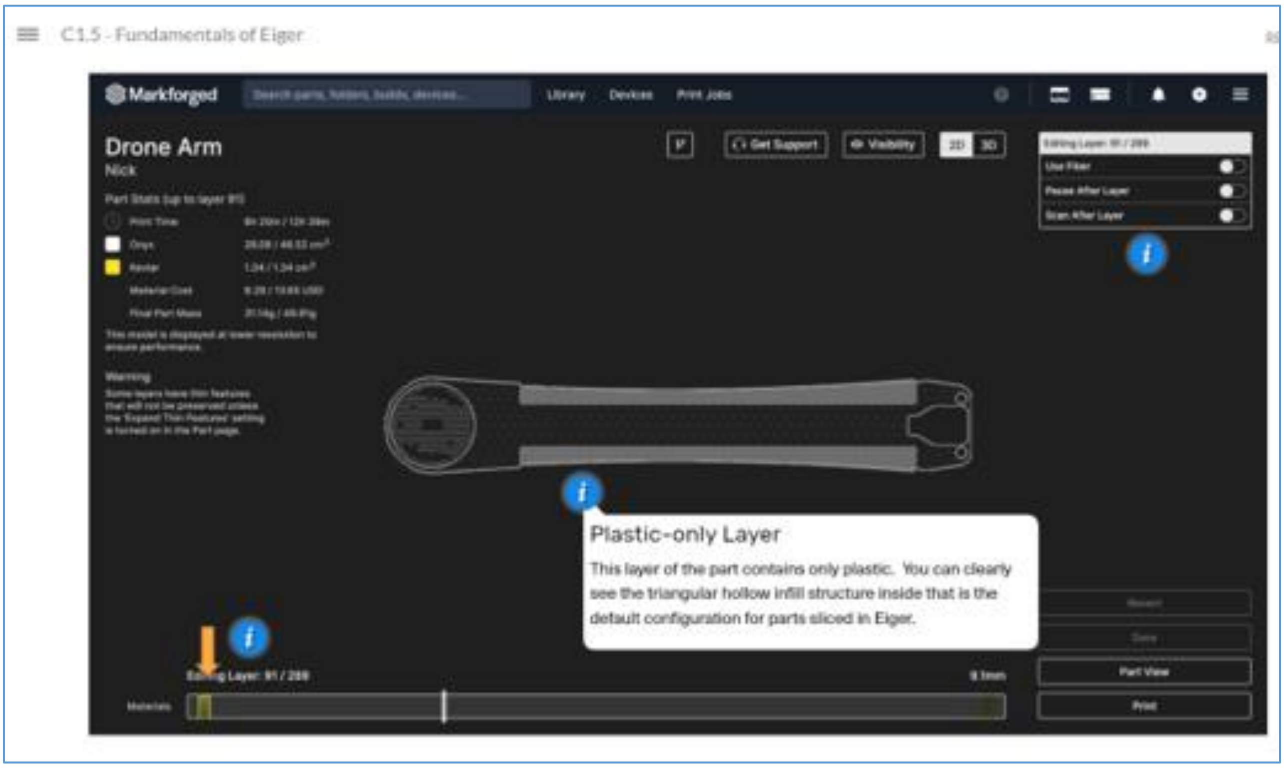


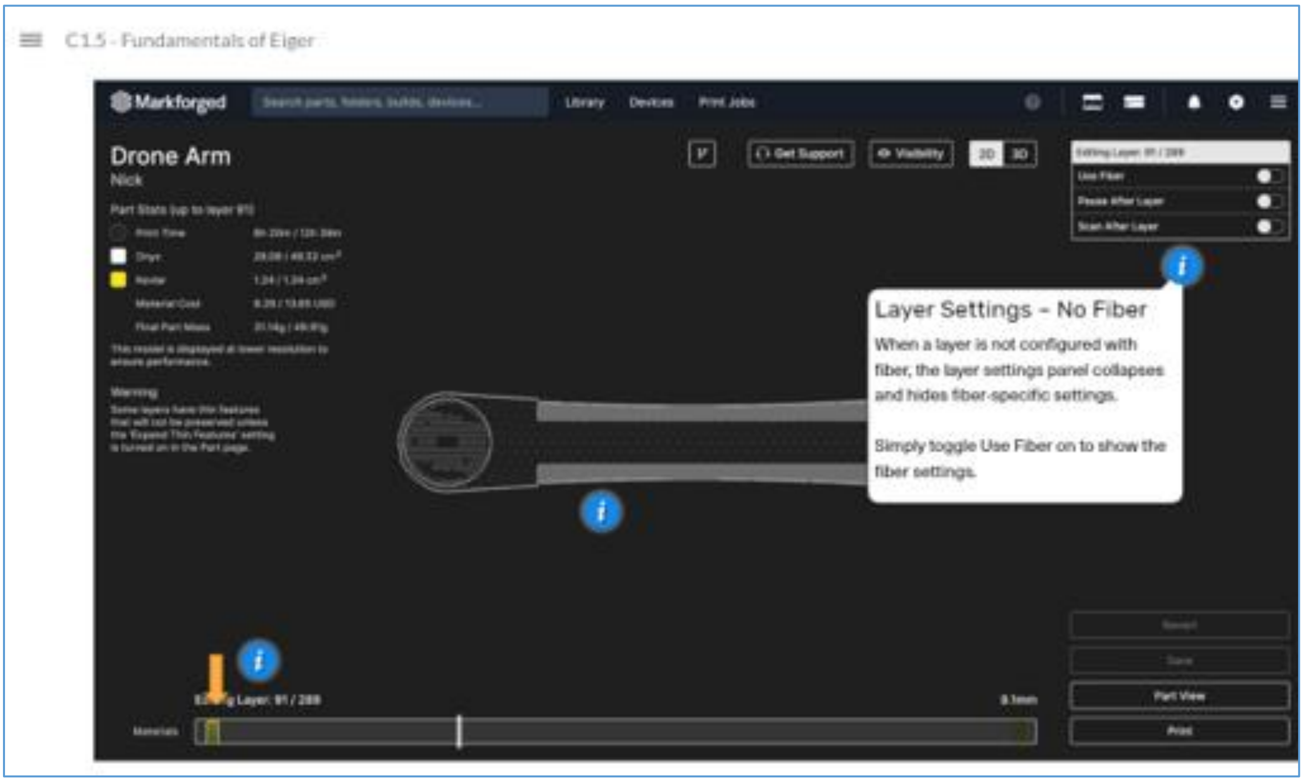

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Nick
Part Stats
Get Support
Visibility
2D
3D
2D/3D View Selector
This tool allows you to switch between the 2D and 3D views in the Layer Editor.
The 3D view displays the part as a semi-transparent 3D model, with colored toolpaths indicating plastic or fiber reinforcement. Making a selection in the Layer Slider will highlight those layers in the 3D view.
The 2D view presents a top-down view of a single layer of the part at a time. You can choose the layer you're configuring via the Layer Slider, which only allows single layer selections when in the 2D view.
The 3D view is primarily used for bulk editing of the fiber configuration of groups of layers, while the 2D view enables precision control over individual layers.
Select one or more layers to edit
Part View
Print

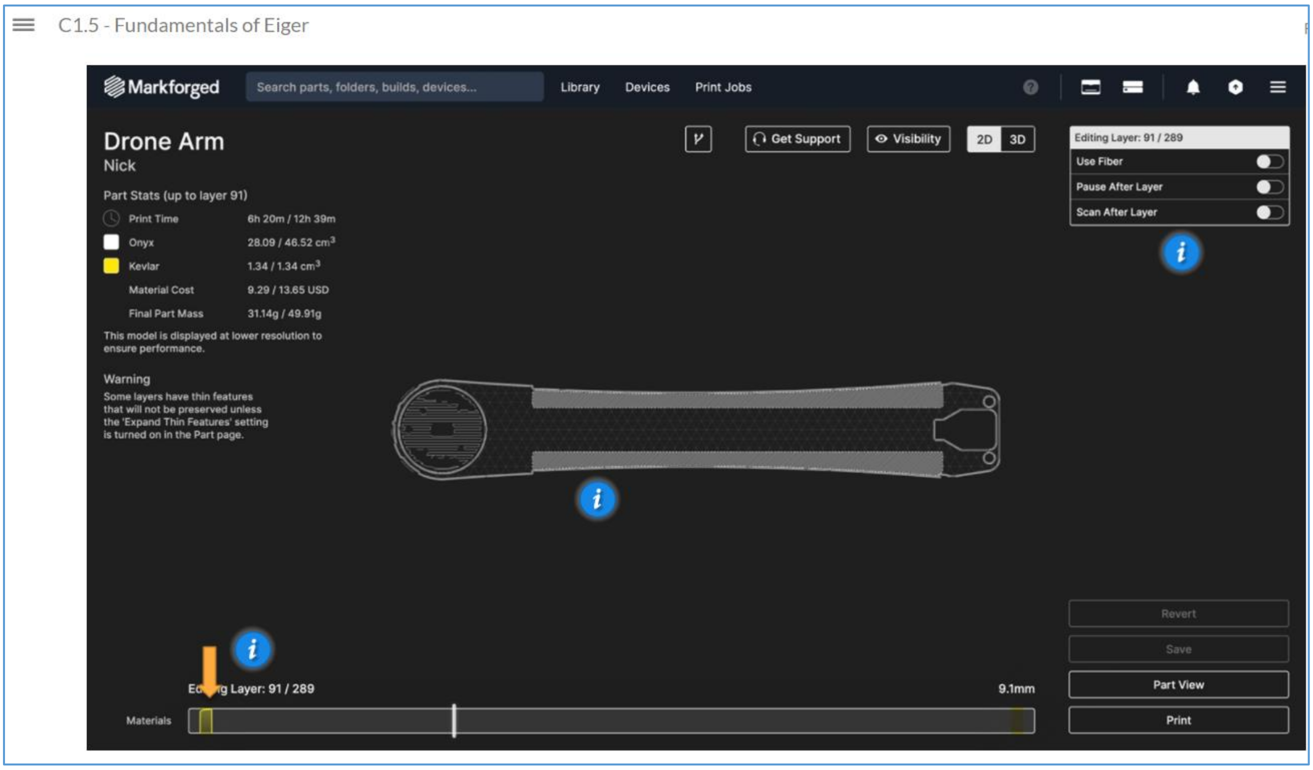

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Part Stats
Get Support
Visibility
2D
3D
Group/Layer Settings
This panel contains the fiber settings for the selected layer or layers. Try clicking on the Layer Slider to activate this panel and see what options it contains!
Select one or more layers to edit
Part View
Print

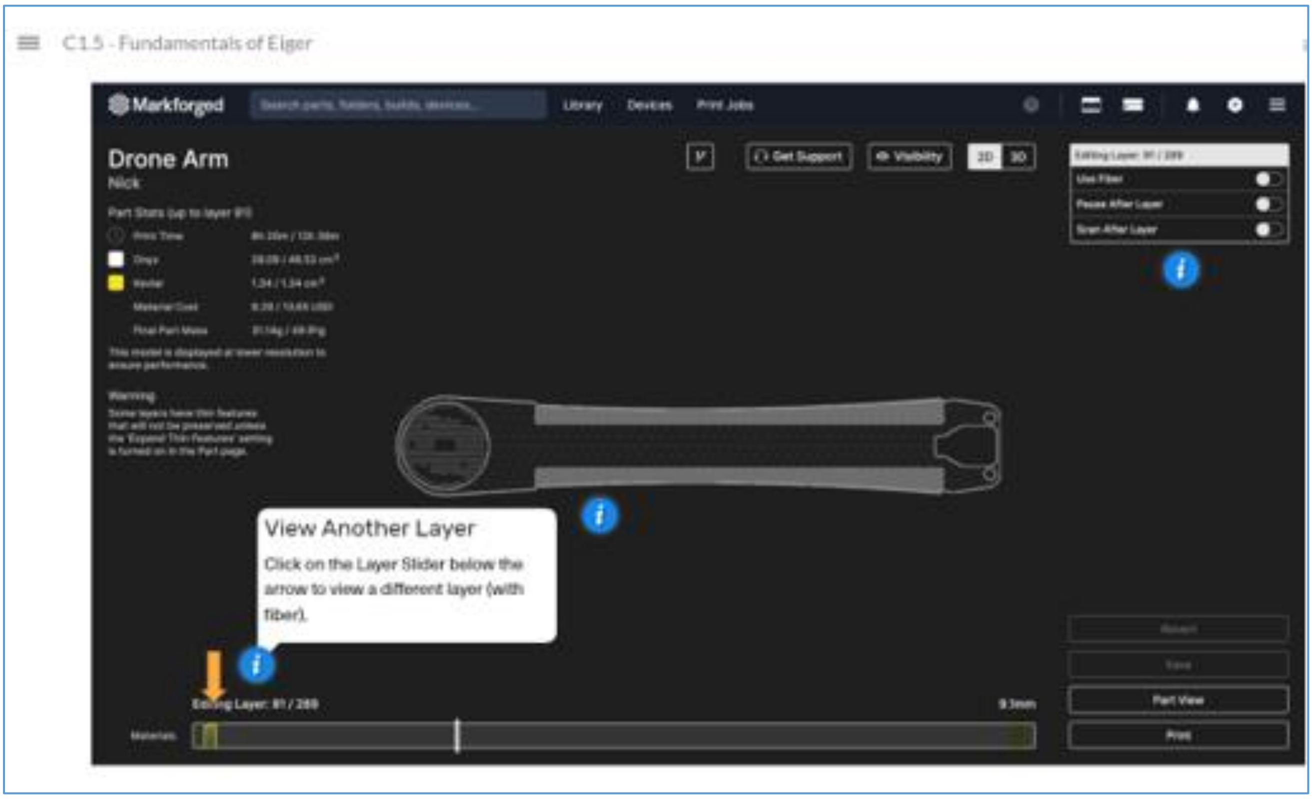

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Editing Layer: 91 / 289
Use Fiber
Pause After Layer
Scan After Layer
Part Stats (up to layer 91)
Print Time 6h 20m / 12h 39m
Onyx 28.09 / 46.52 cm³
Kevlar 1.34 / 1.34 cm³
Material Cost 9.29 / 13.65 USD
Final Part Mass 31.14g / 49.91g
This model is displayed at lower resolution to ensure performance.
Warning
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Revert
Save
Part View
Print
9.1mm
Materials

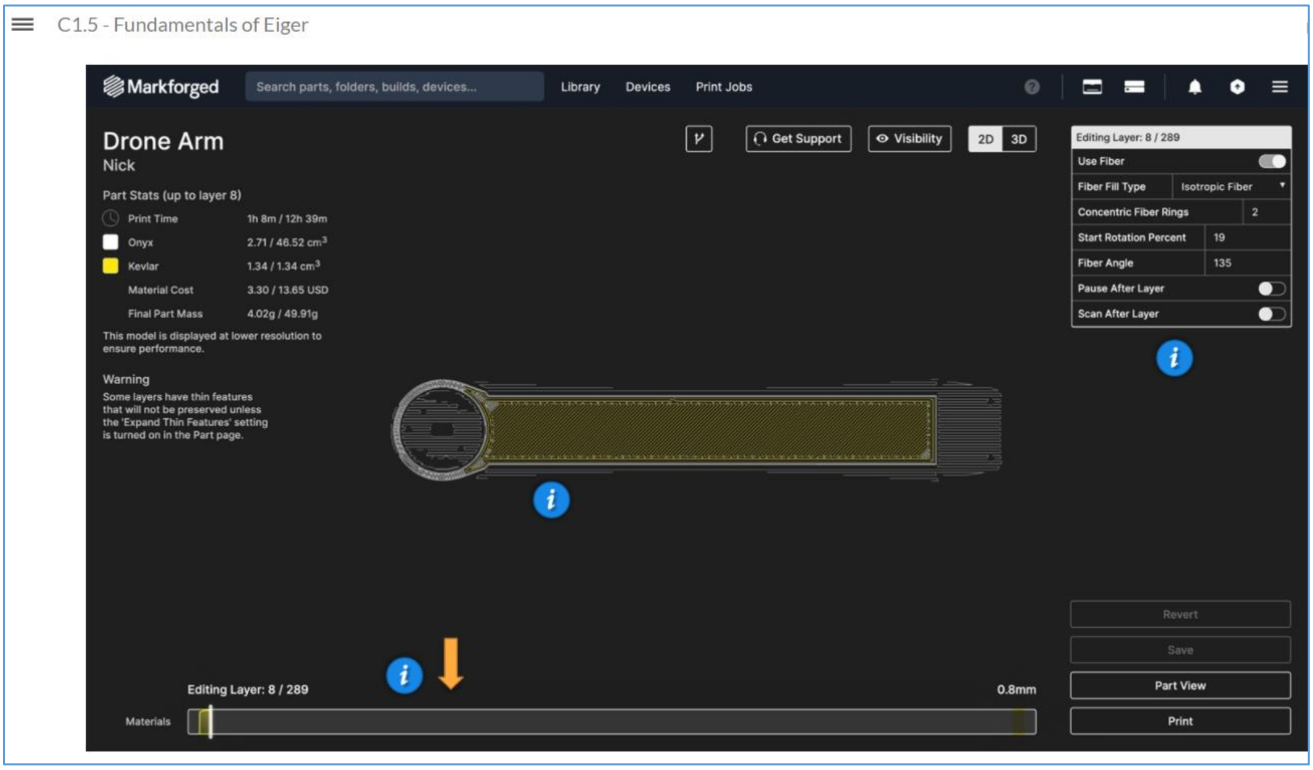
- 2D View.

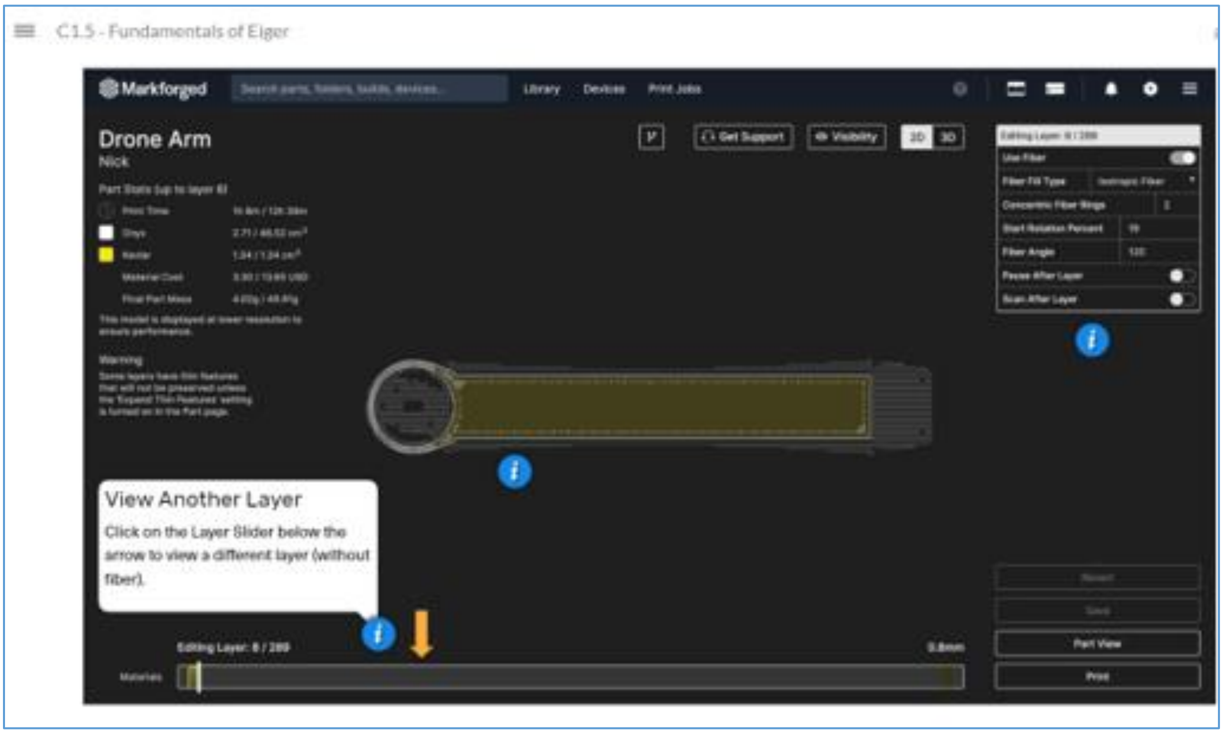

C1.5 - Fundamentals of Eiger
Markforged
Drone Arm
Nick
Plastic-only Layer
This layer of the part contains only plastic. You can clearly see the triangular hollow infill structure inside that is the default configuration for parts sliced in Eiger.

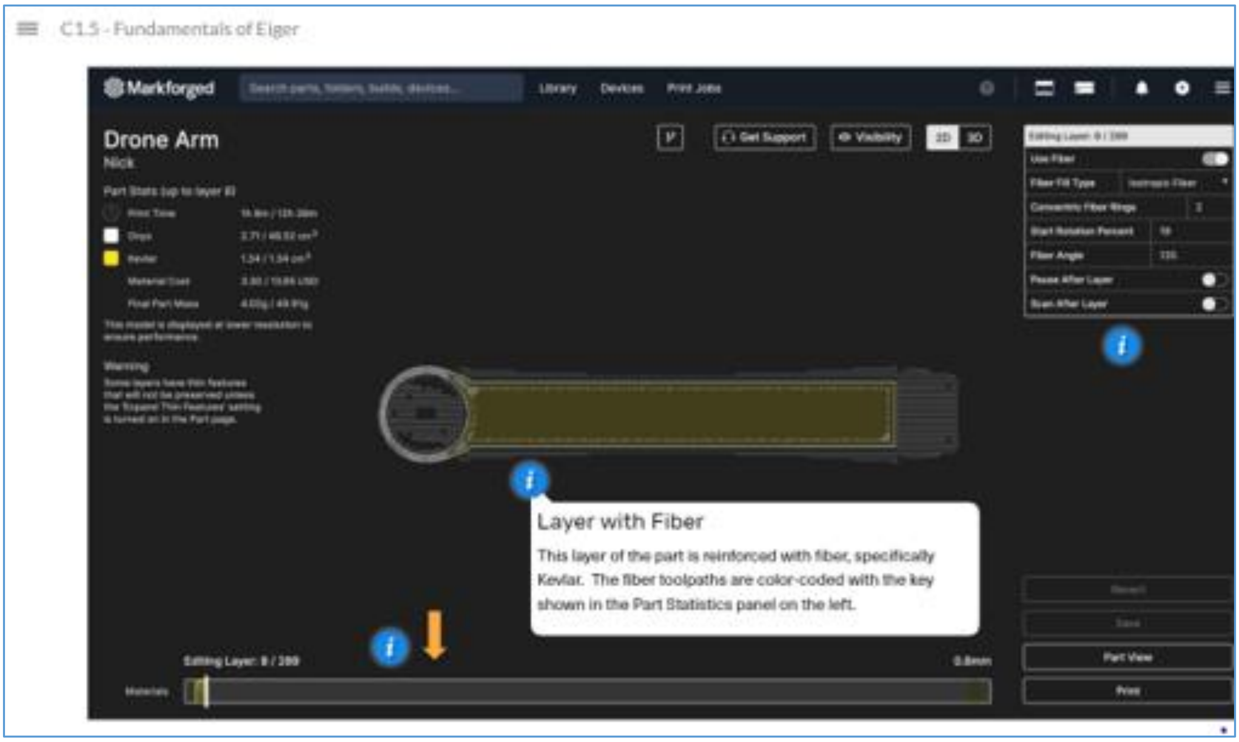

C1.5 - Fundamentals of Eiger
Markforged
Drone Arm
Nick
Layer Settings - No Fiber
When a layer is not configured with fiber, the layer settings panel collapses and hides fiber-specific settings.
Simply toggle Use Fiber on to show the fiber settings.

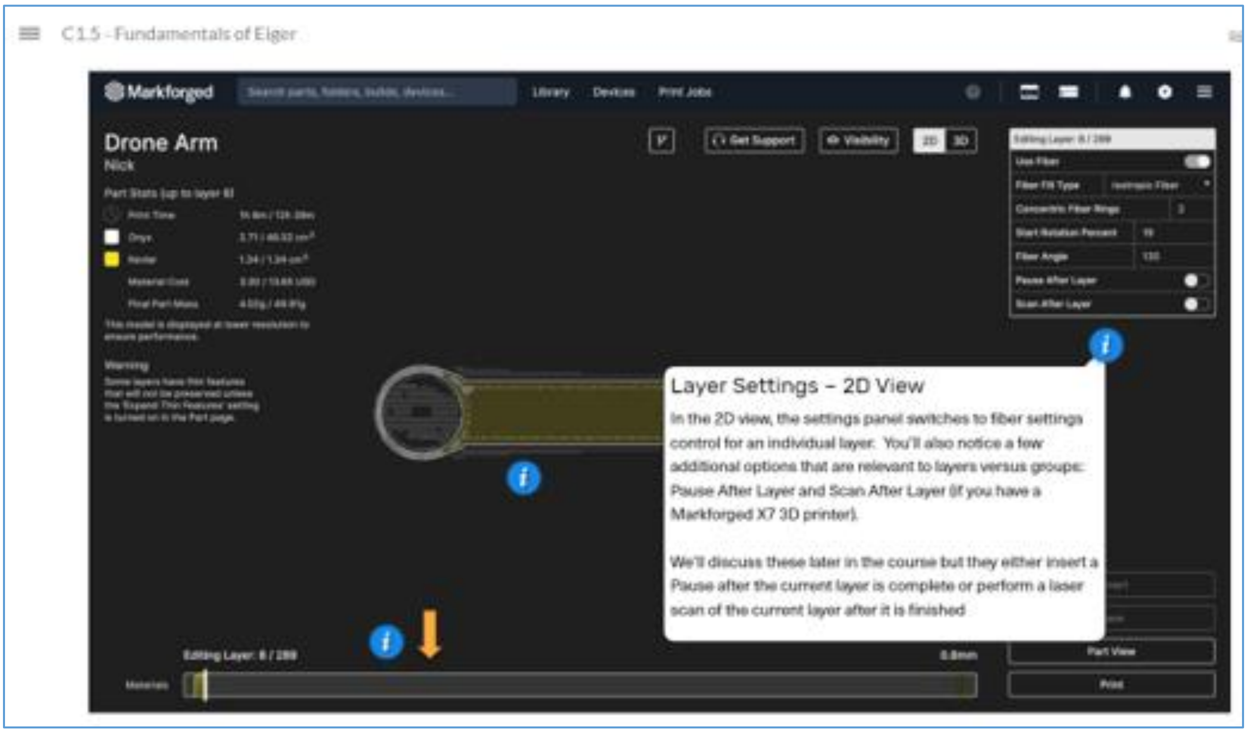

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Editing Layer: 91 / 289
Use Fiber
Pause After Layer
Scan After Layer
Part Stats (up to layer 91)
Print Time 6h 20m / 12h 39m
Onyx 28.09 / 46.52 cm³
Kevlar 1.34 / 1.34 cm³
Material Cost 9.29 / 13.65 USD
Final Part Mass 31.14g / 49.91g
This model is displayed at lower resolution to ensure performance.
Warning
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Revert
Save
Part View
Print
9.1mm
Materials

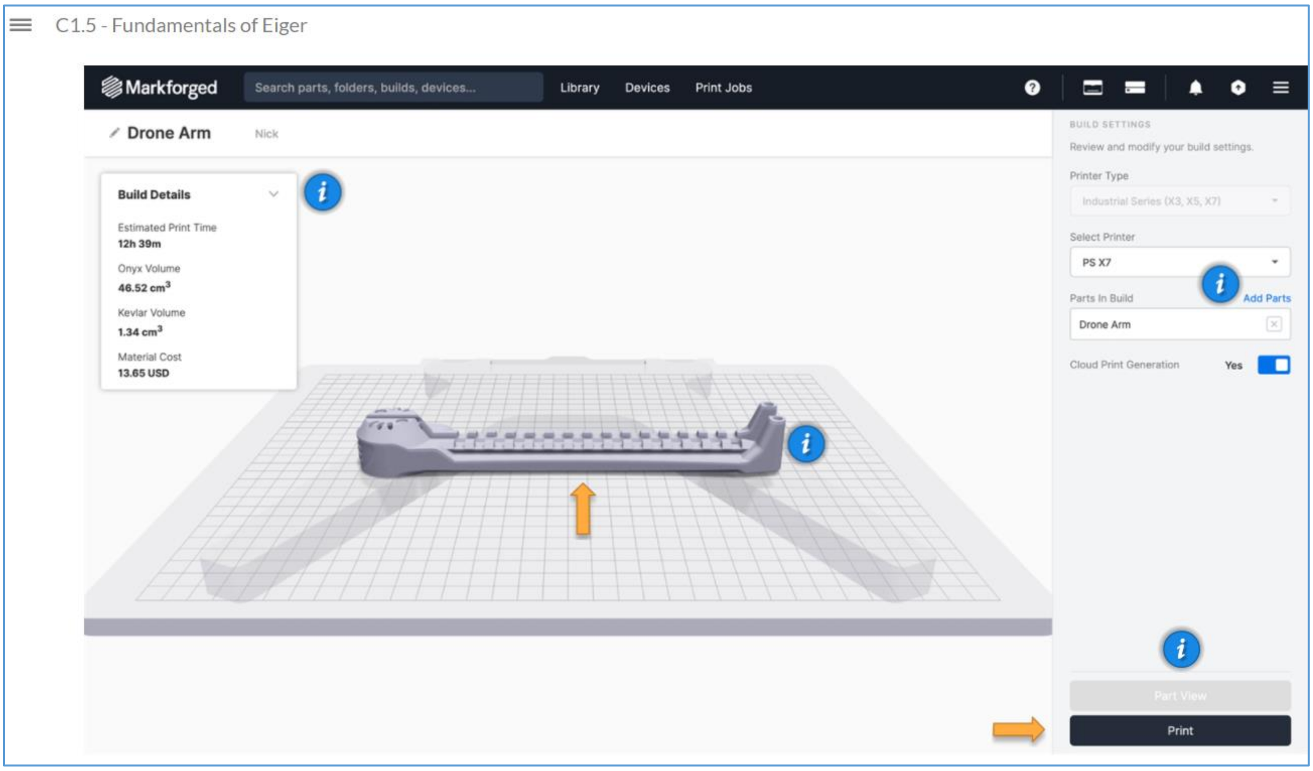

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Use Fiber
Pause After Layer
Scan After Layer
View Another Layer
Click on the Layer Slider below the arrow to view a different layer (with fiber).
Materials
Part View
Print


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 8)
Print Time 1h 8m / 12h 39m
Onyx 2.71 / 46.52 cm³
Kevlar 1.34 / 1.34 cm³
Material Cost 3.30 / 13.65 USD
Final Part Mass 4.02g / 49.91g
This model is displayed at lower resolution to ensure performance.
Warning
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Editing Layer: 8 / 289
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 19
Fiber Angle 135
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 8 / 289
0.8mm
Materials

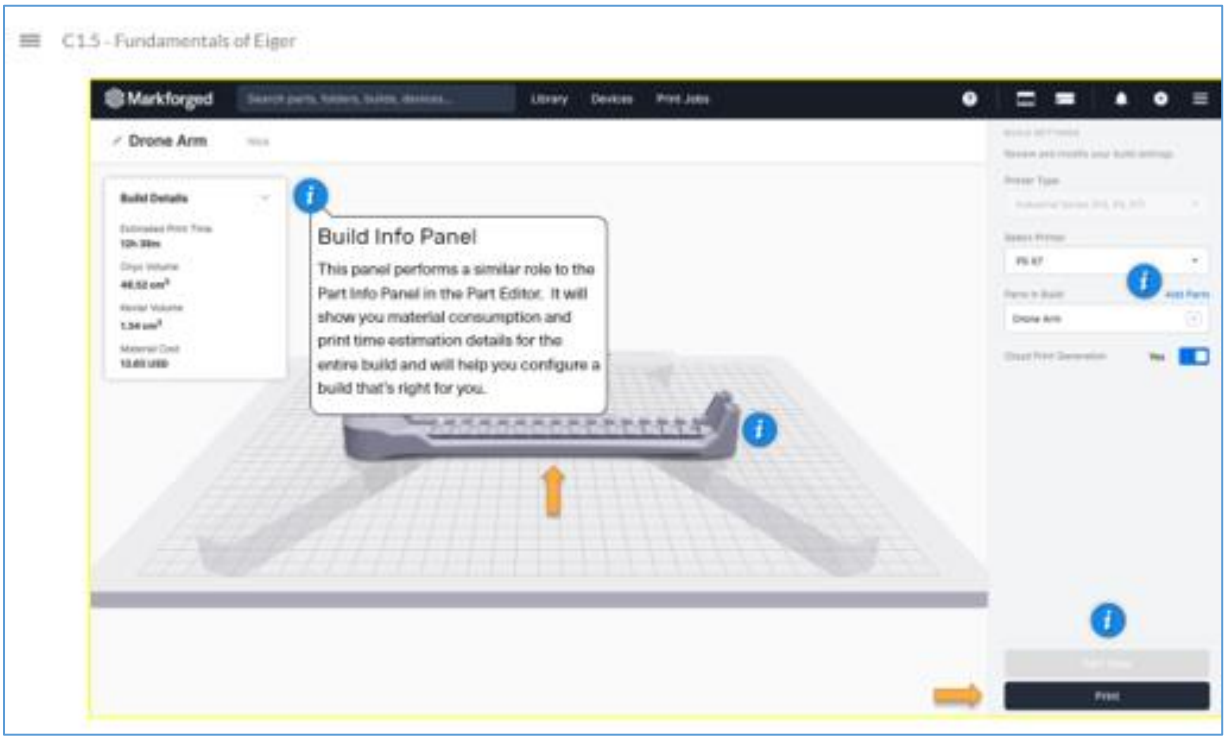

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
View Another Layer
Click on the Layer Slider below the arrow to view a different layer (without fiber).
Part View
Print

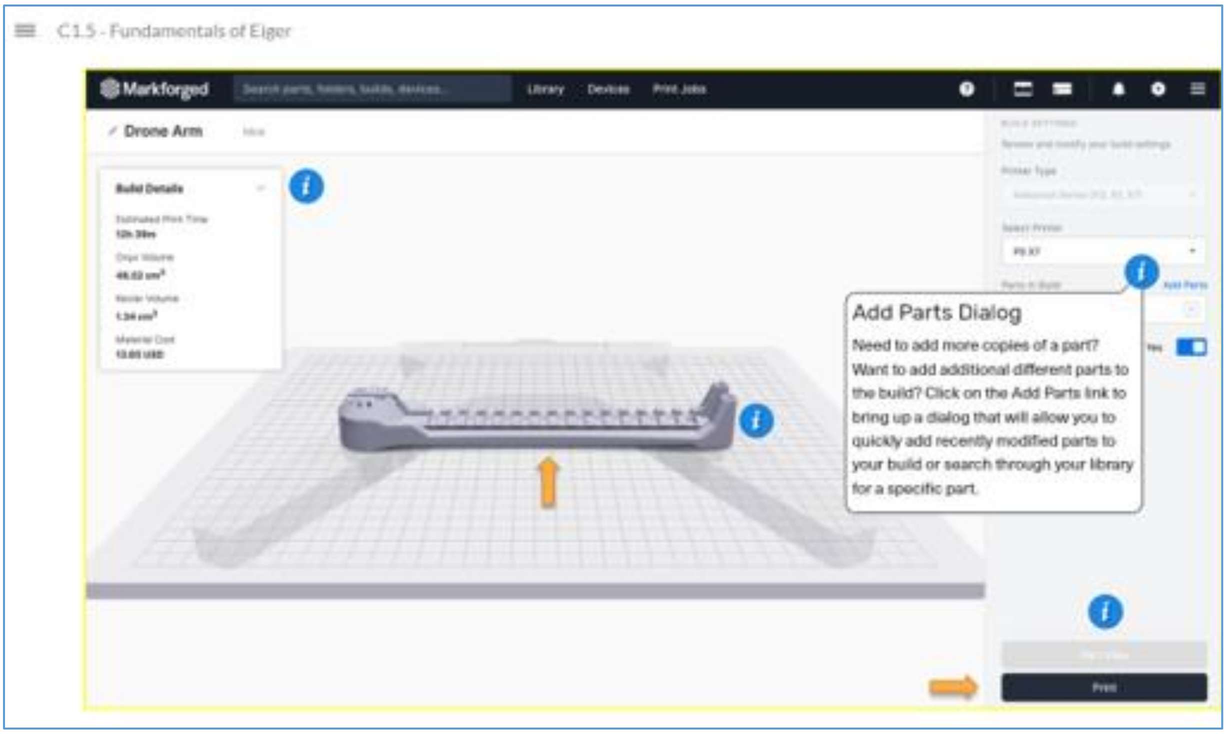

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Layer with Fiber
This layer of the part is reinforced with fiber, specifically Kevlar. The fiber toolpaths are color-coded with the key shown in the Part Statistics panel on the left.
Part View
Print

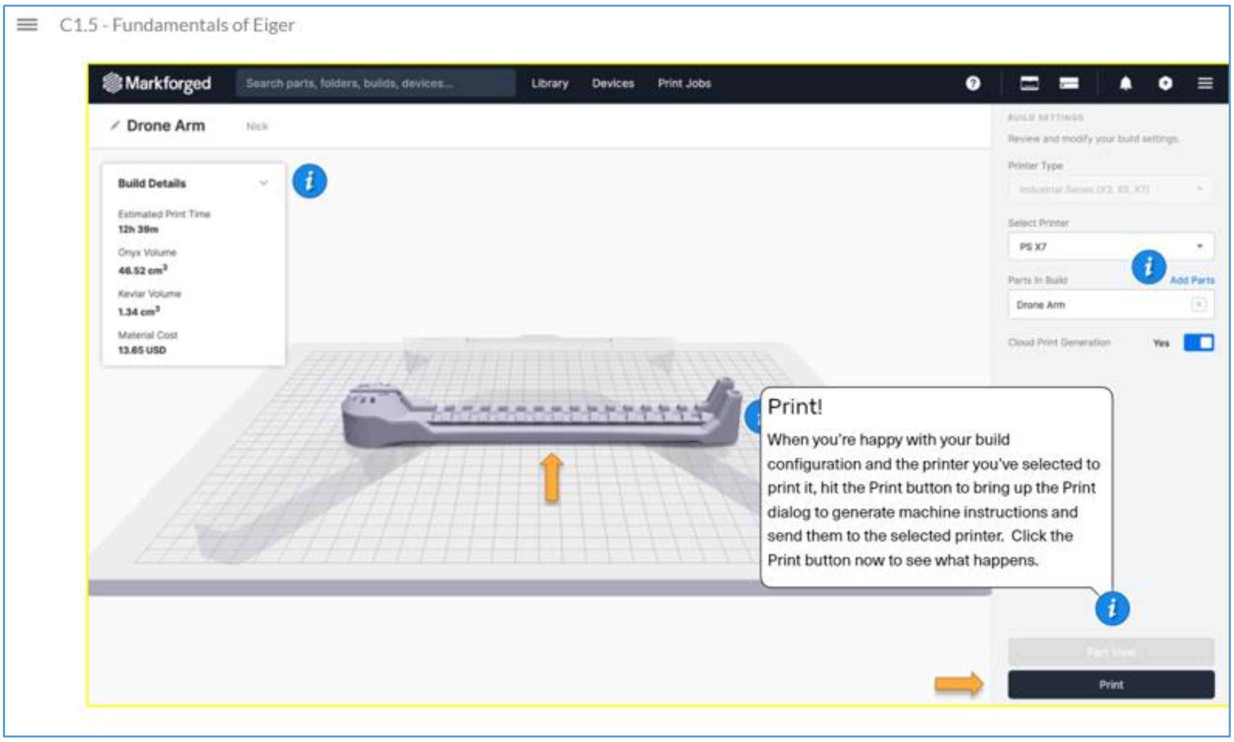


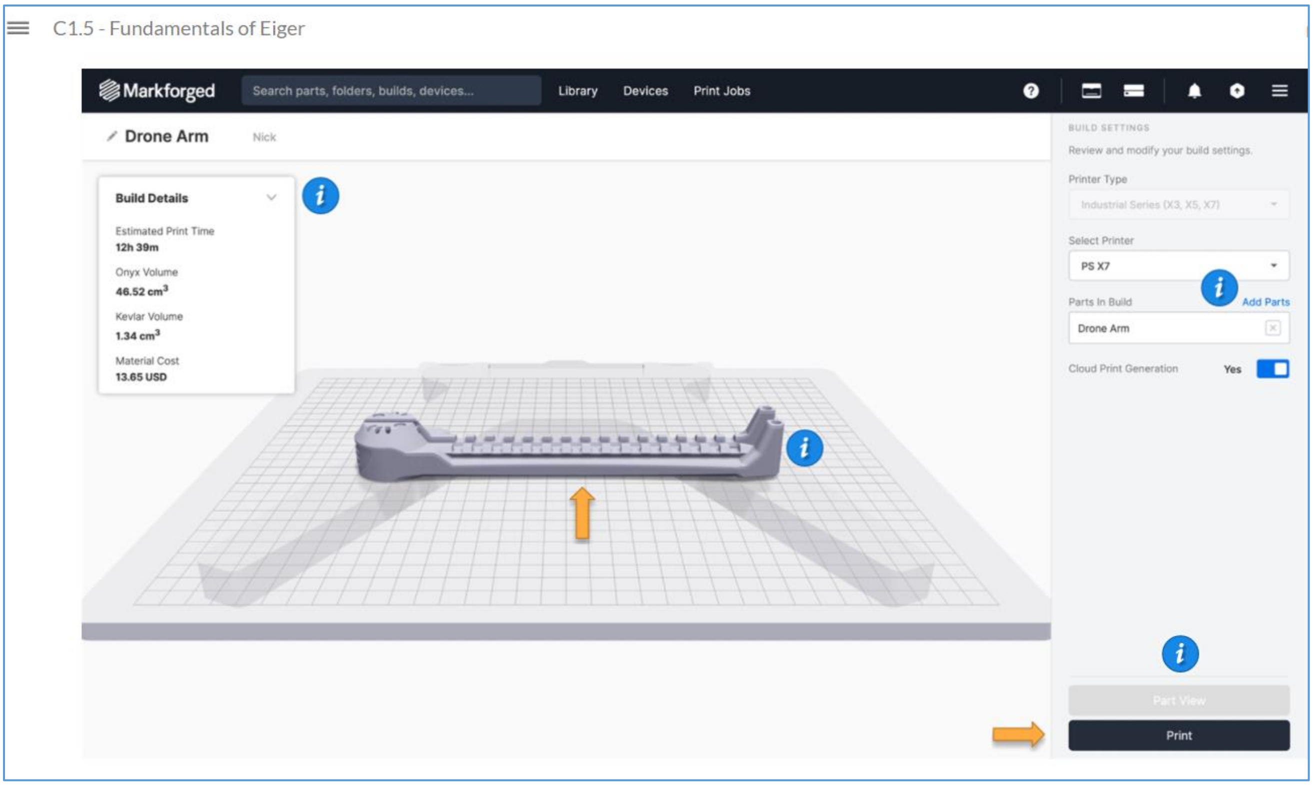


- **Setting up a Print in the Build Editor**

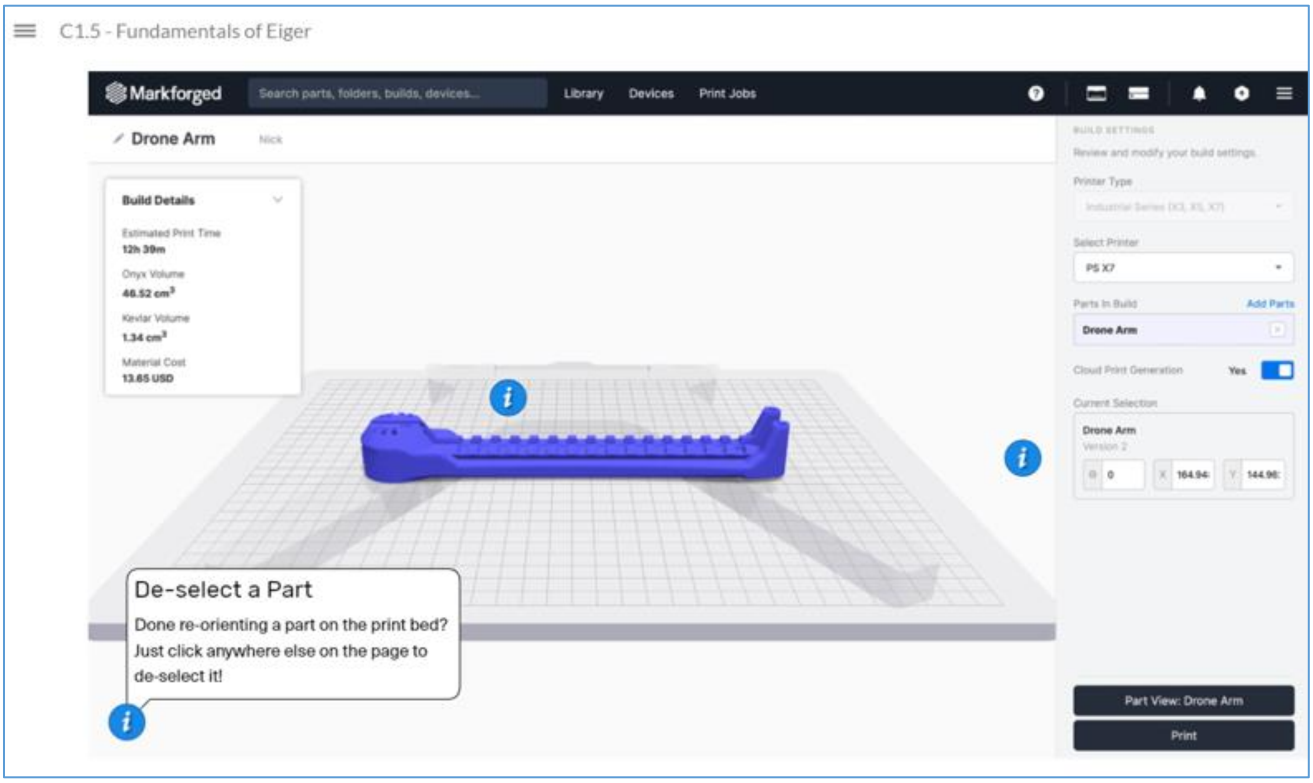

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Build Details
Build Info Panel
This panel performs a similar role to the Part Info Panel in the Part Editor. It will show you material consumption and print time estimation details for the entire build and will help you configure a build that's right for you.
Print

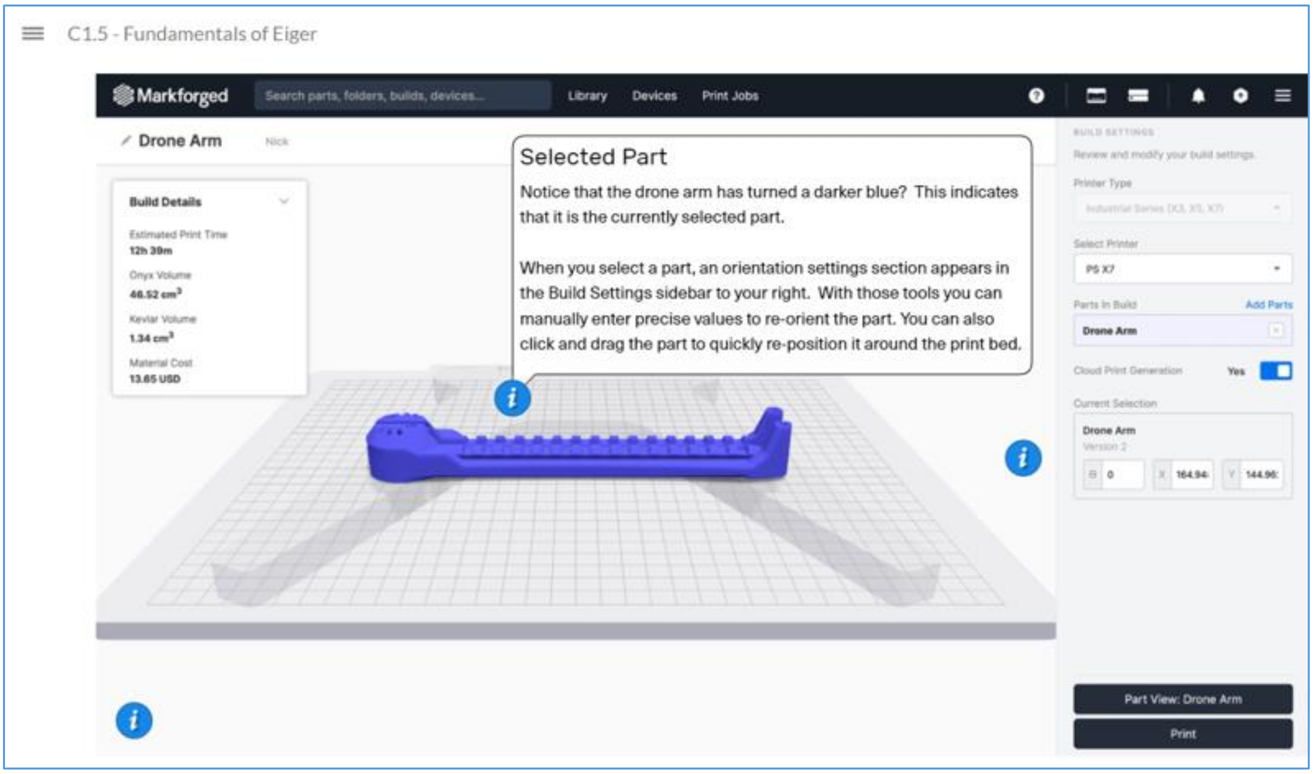

C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Drone Arm
Build Details
Add Parts Dialog
Need to add more copies of a part? Want to add additional different parts to the build? Click on the Add Parts link to bring up a dialog that will allow you to quickly add recently modified parts to your build or search through your library for a specific part.
Print

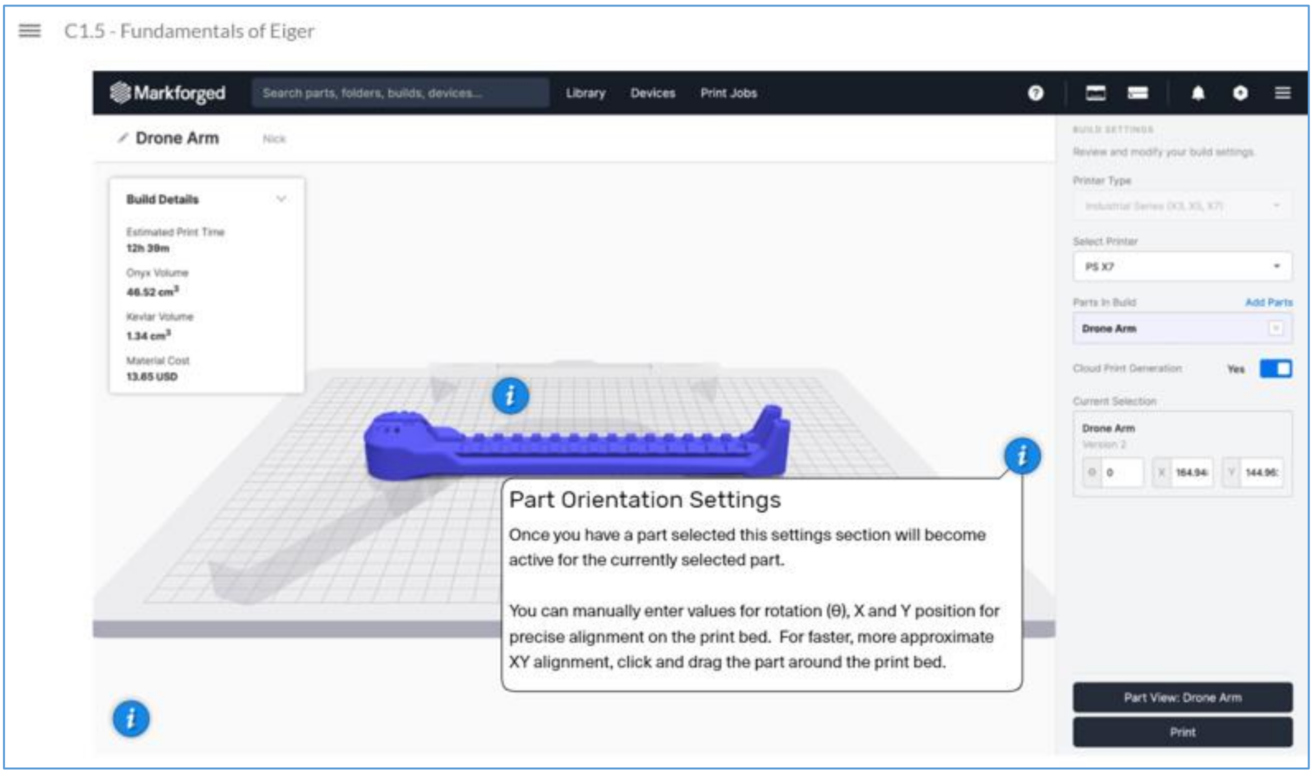


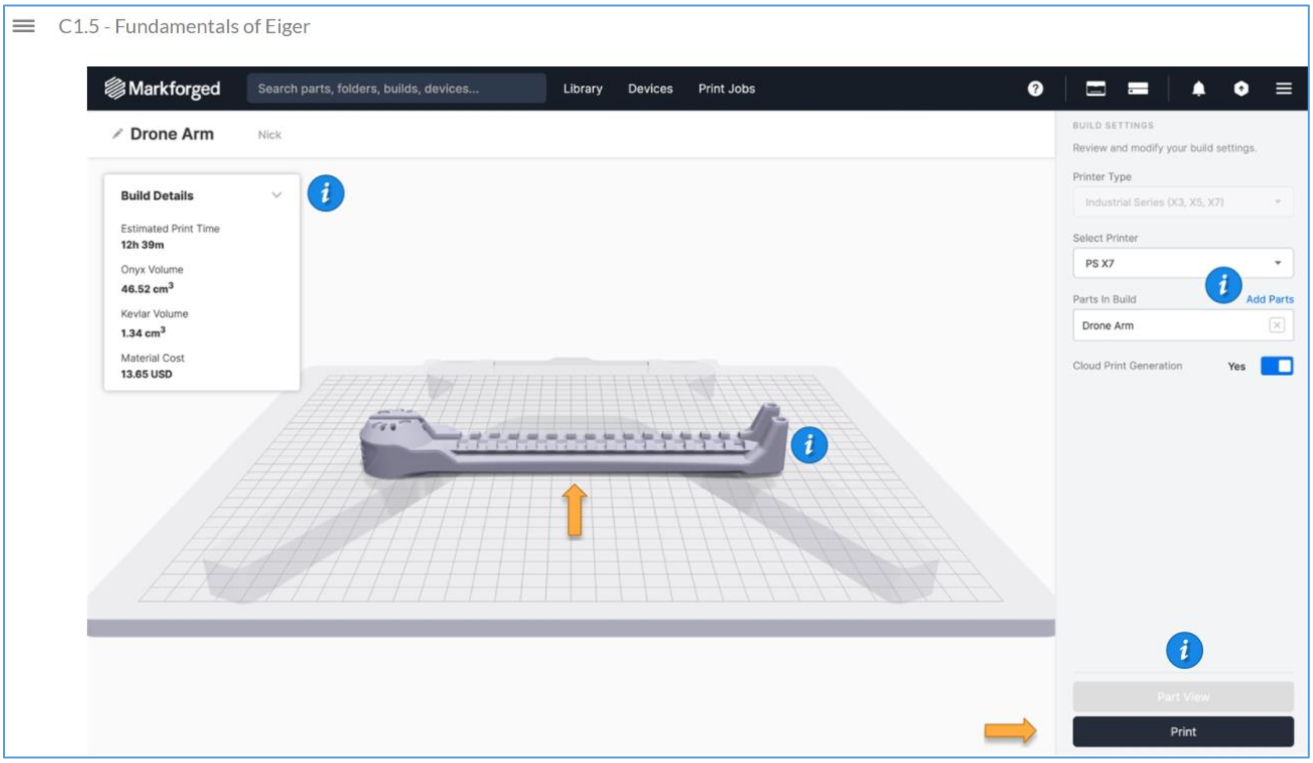


- Pijl bij Part.

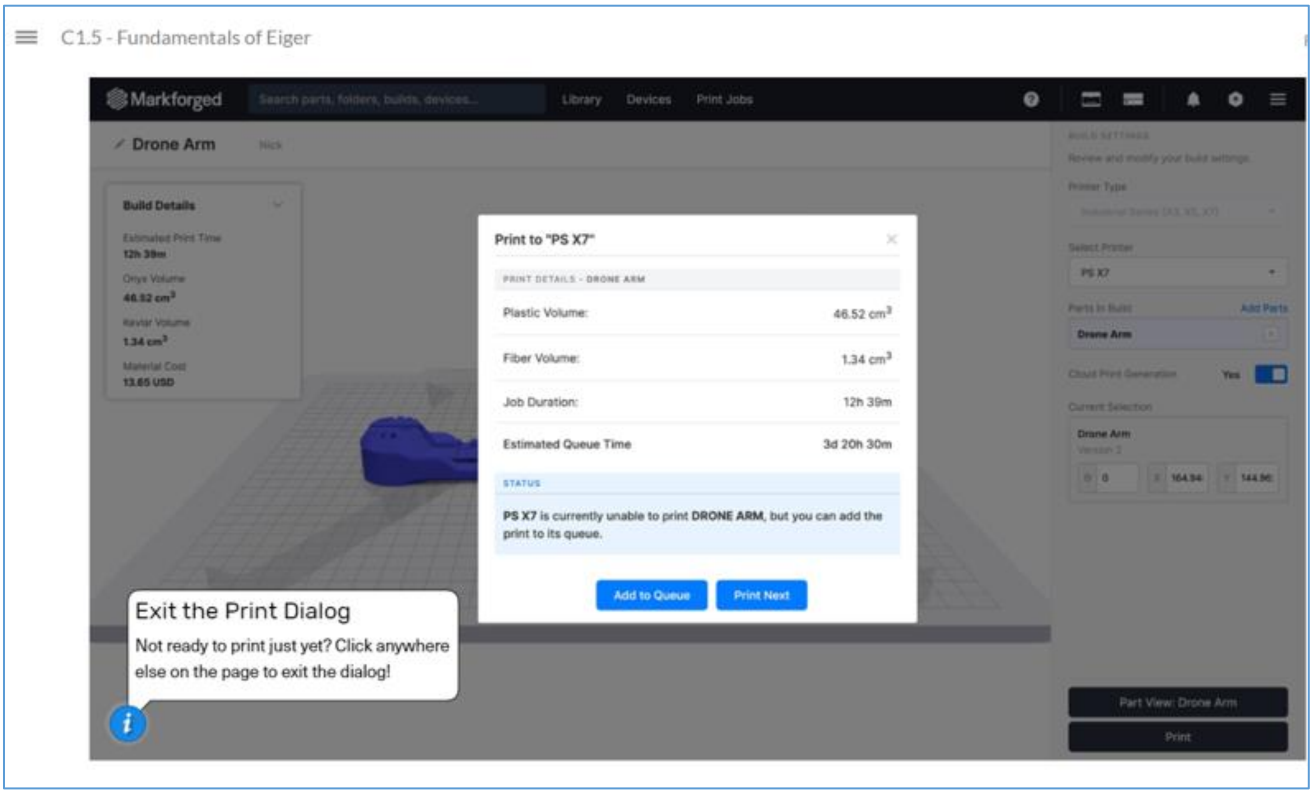

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Build Details
Estimated Print Time
12h 39m
Onyx Volume
46.52 cm³
Kevlar Volume
1.34 cm³
Material Cost
13.65 USD
Select Printer
FS X7
Parts In Build
Add Parts
Drone Arm
Cloud Print Generation
Yes
Current Selection
Drone Arm
De-select a Part
Done re-orienting a part on the print bed? Just click anywhere else on the page to de-select it!
Part View: Drone Arm
Print

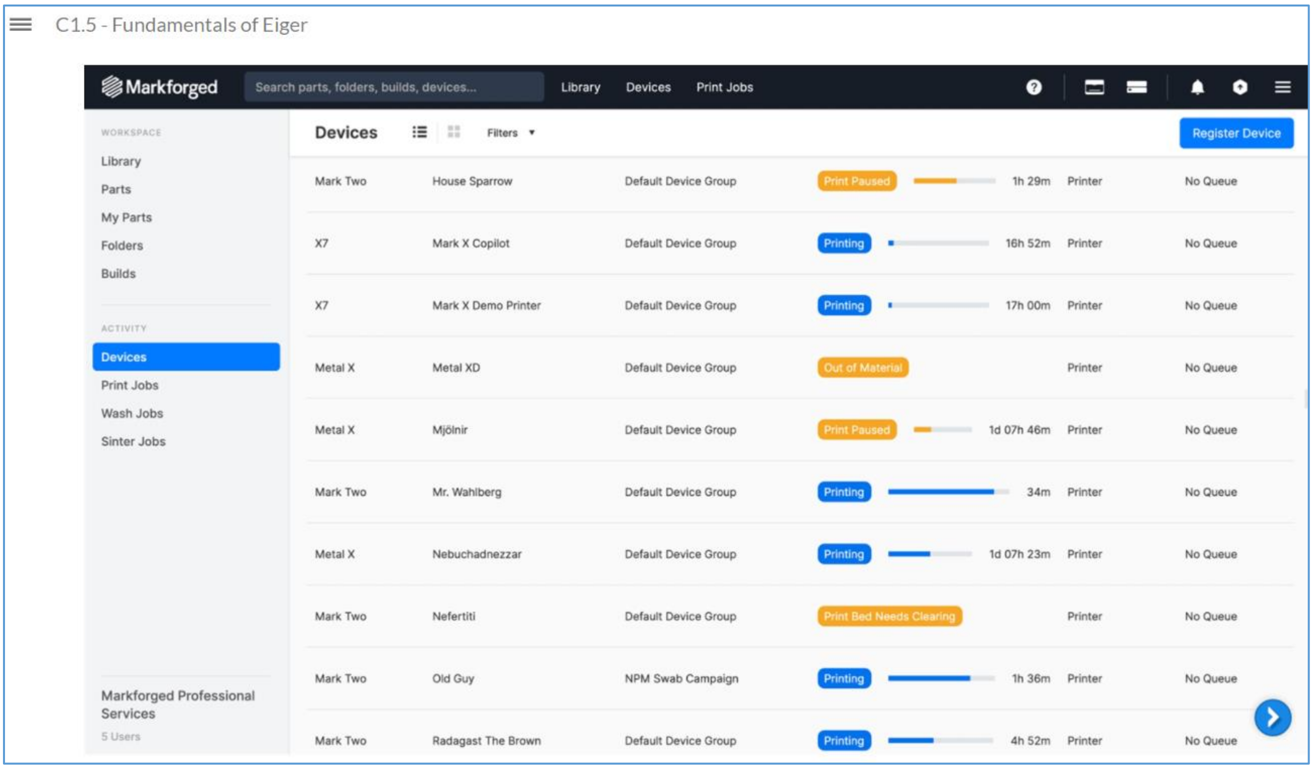

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Build Details
Estimated Print Time
12h 39m
Onyx Volume
46.52 cm³
Kevlar Volume
1.34 cm³
Material Cost
13.65 USD
Selected Part
Notice that the drone arm has turned a darker blue? This indicates that it is the currently selected part.
When you select a part, an orientation settings section appears in the Build Settings sidebar to your right. With those tools you can manually enter precise values to re-orient the part. You can also click and drag the part to quickly re-position it around the print bed.
Select Printer
FS X7
Parts In Build
Add Parts
Drone Arm
Cloud Print Generation
Yes
Current Selection
Drone Arm
Part View: Drone Arm
Print



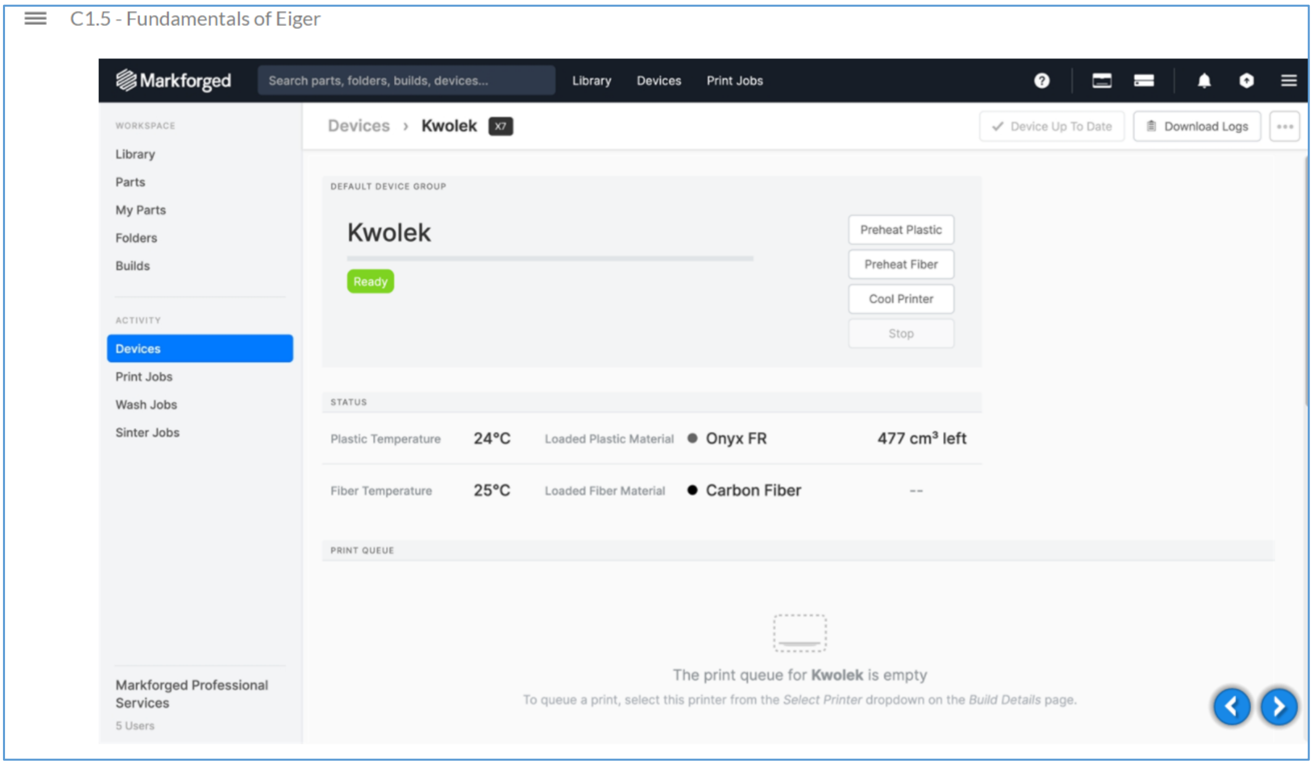


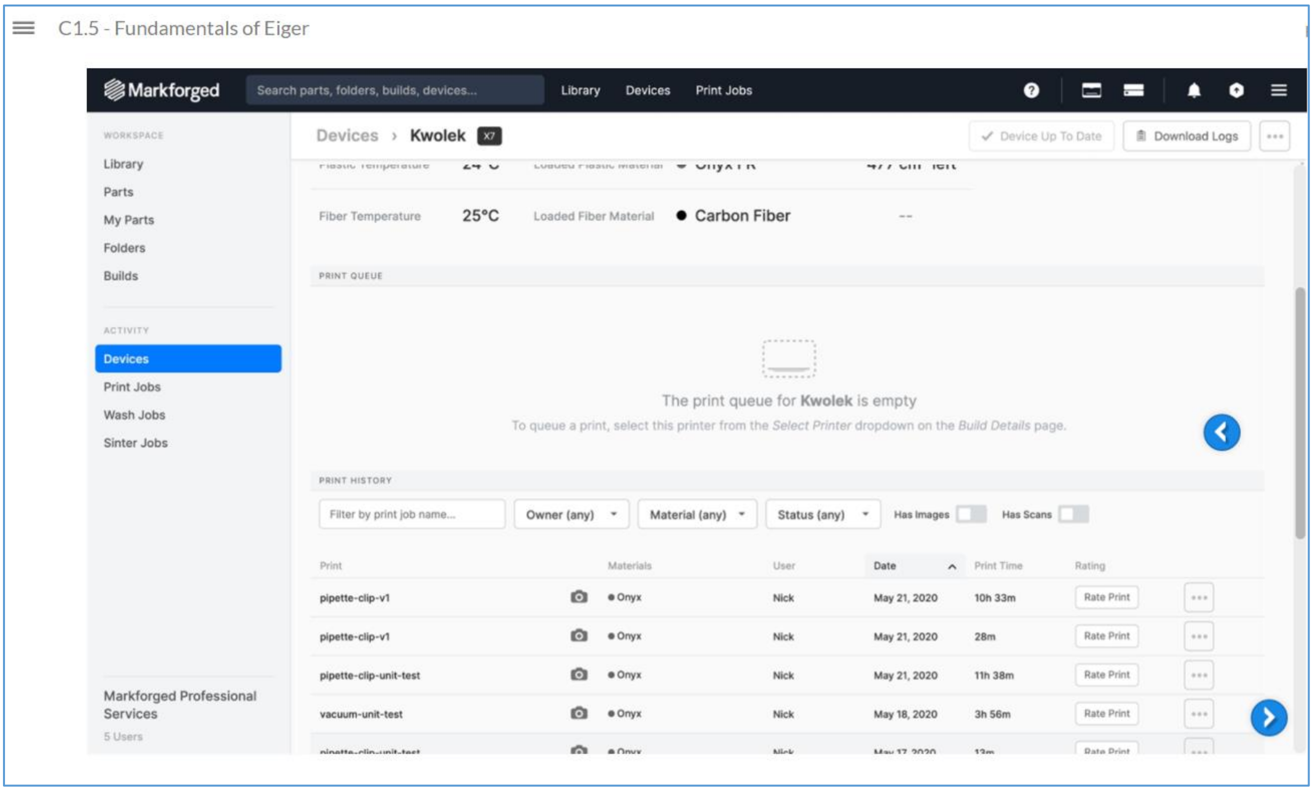
- Pijl bij Print.



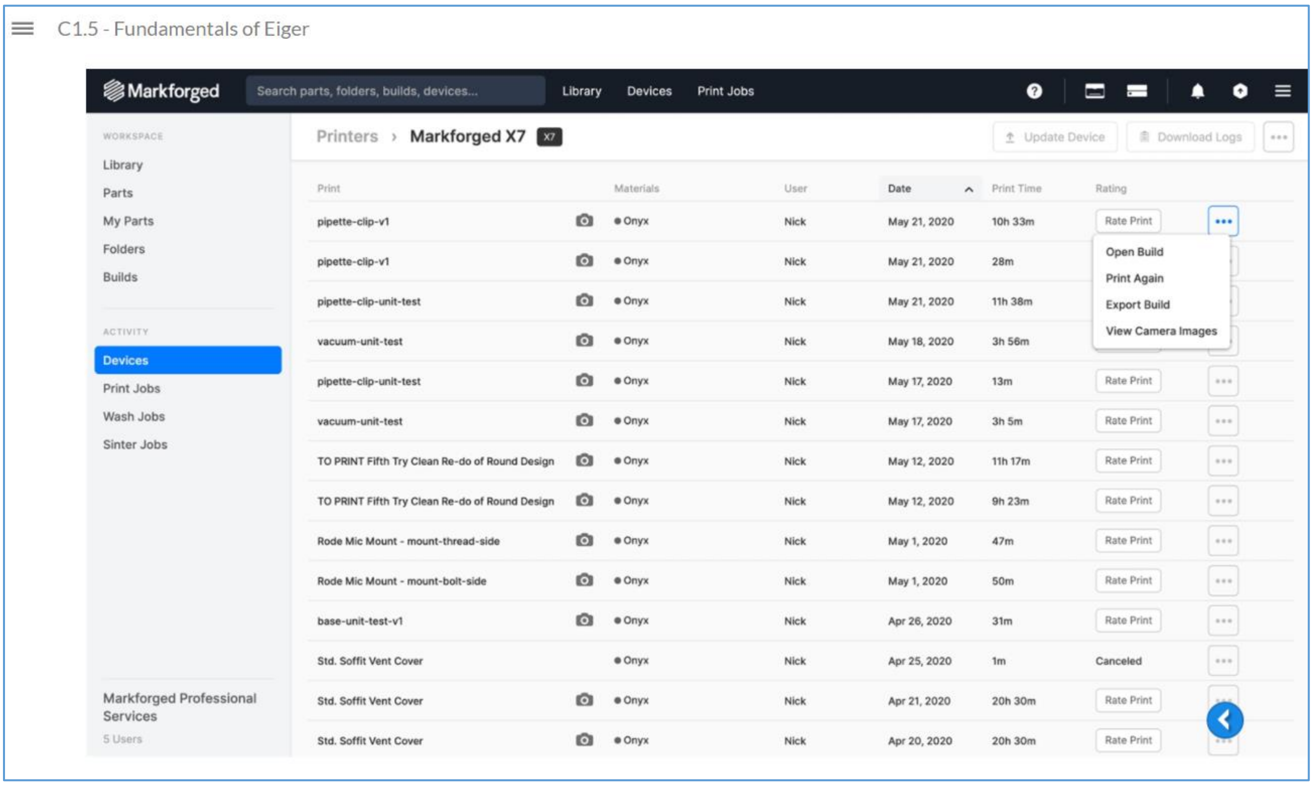


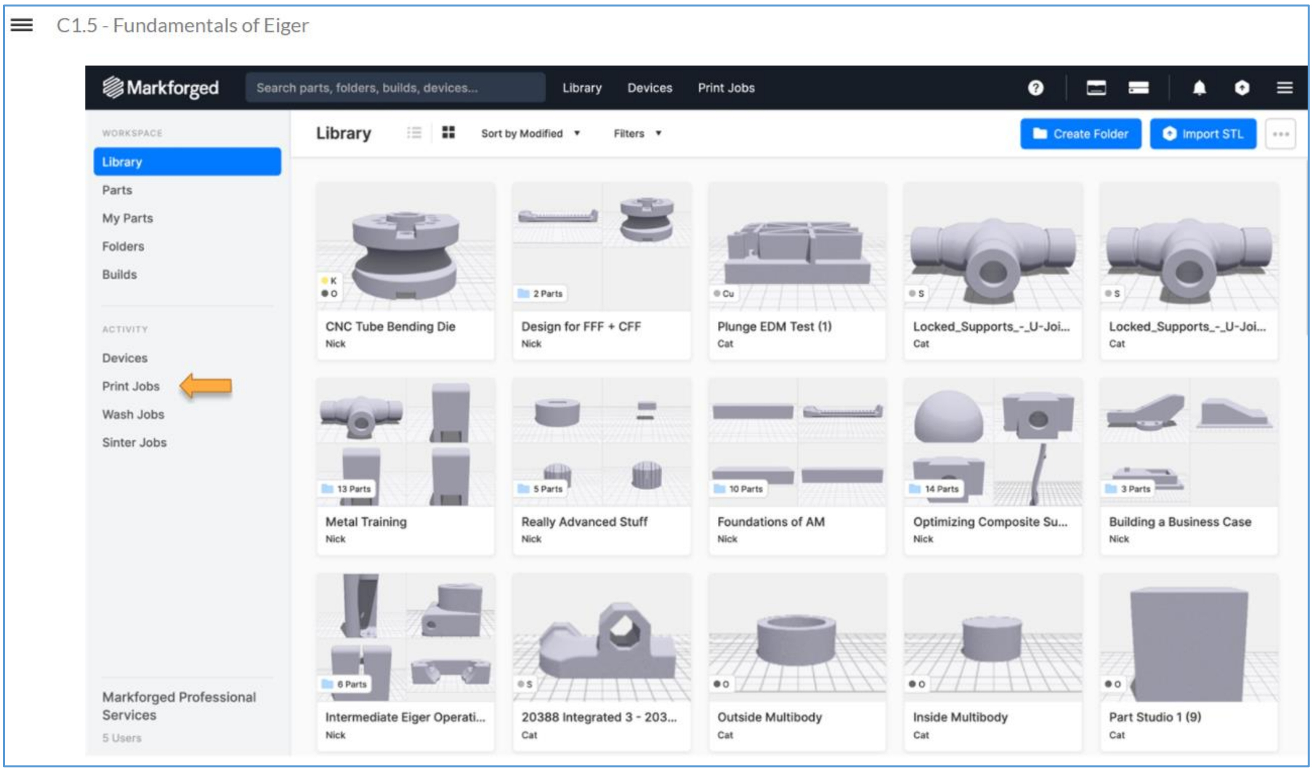
- **Fleet Status, the Devices Page and Detailed Device Info**



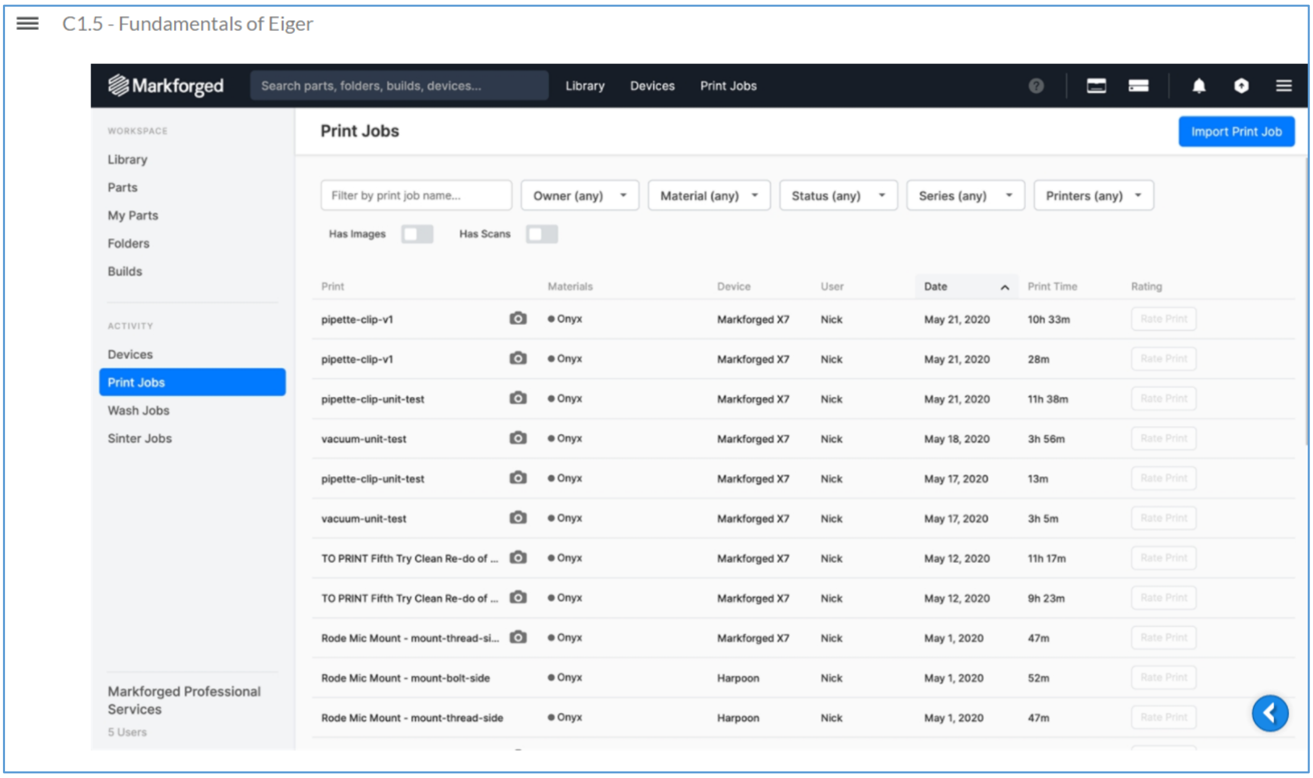


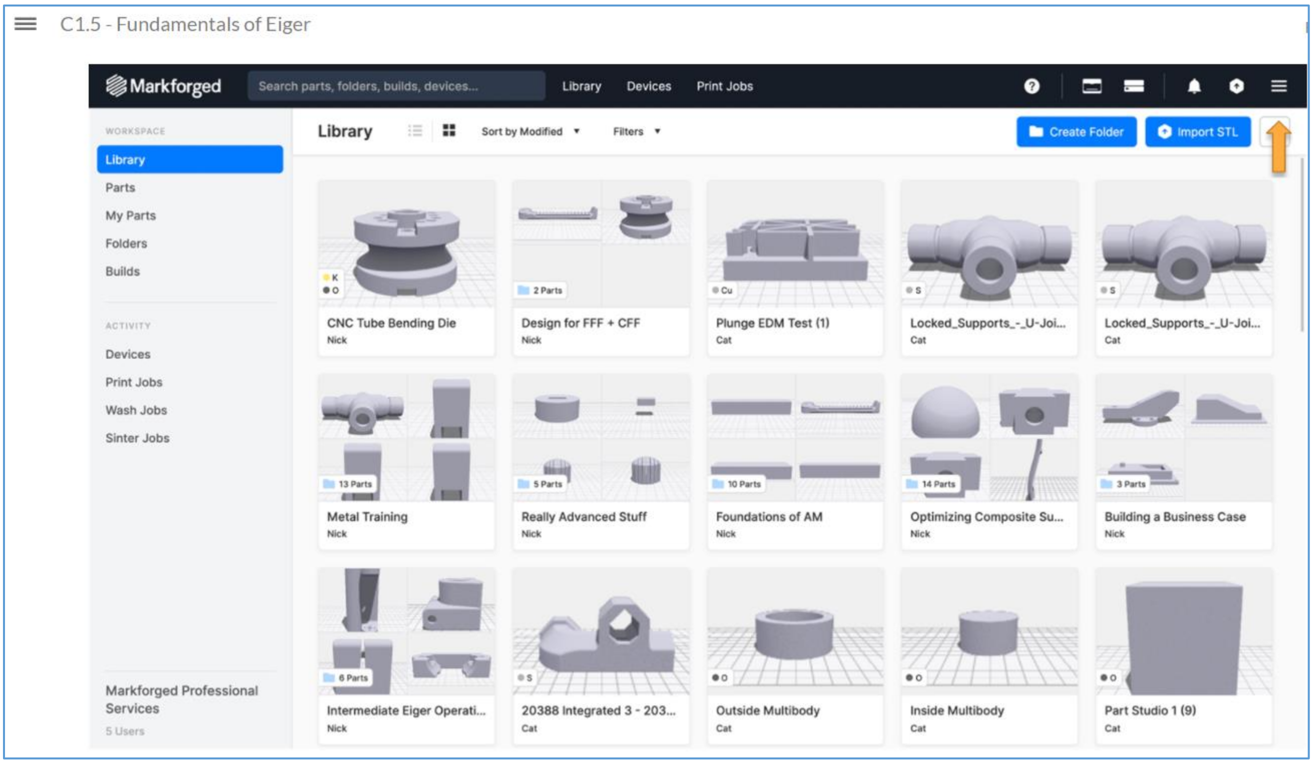
- Scrolling down.



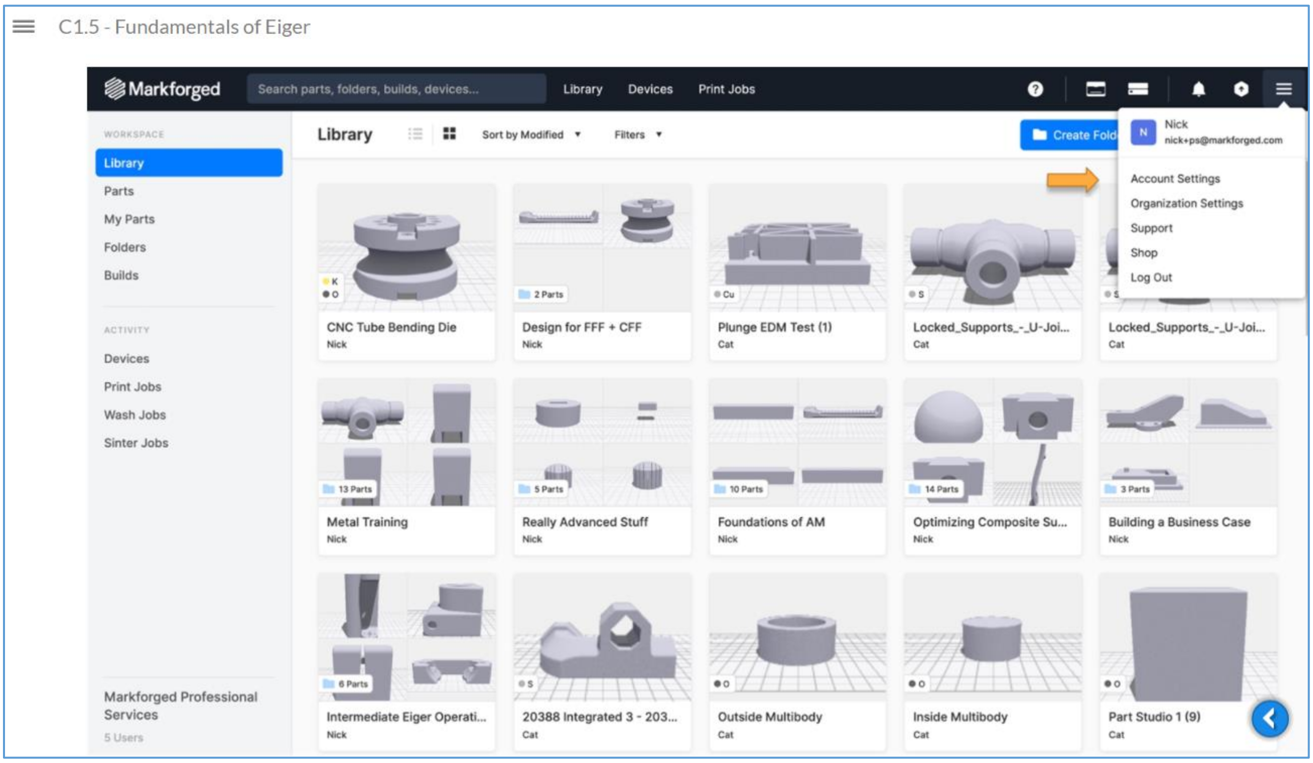


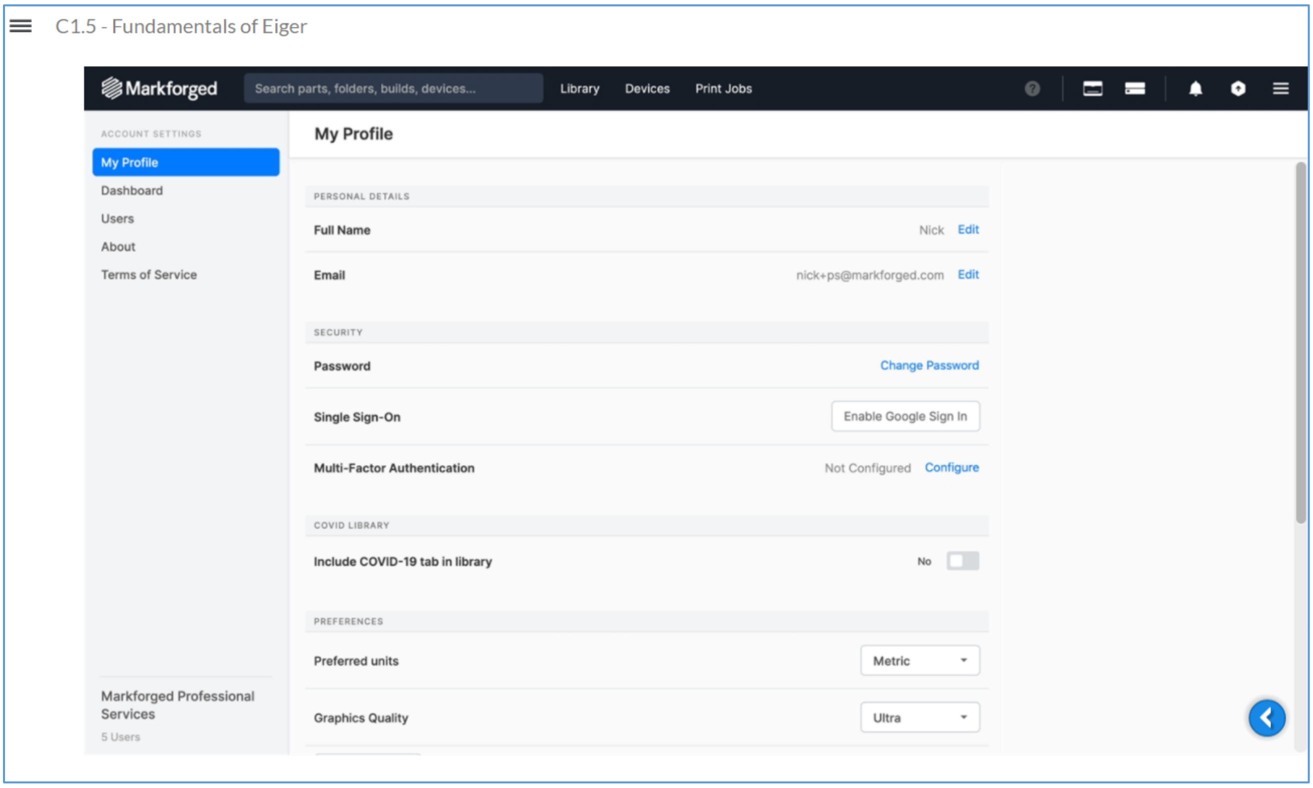
- **Organization Print History and the Print Jobs Page**

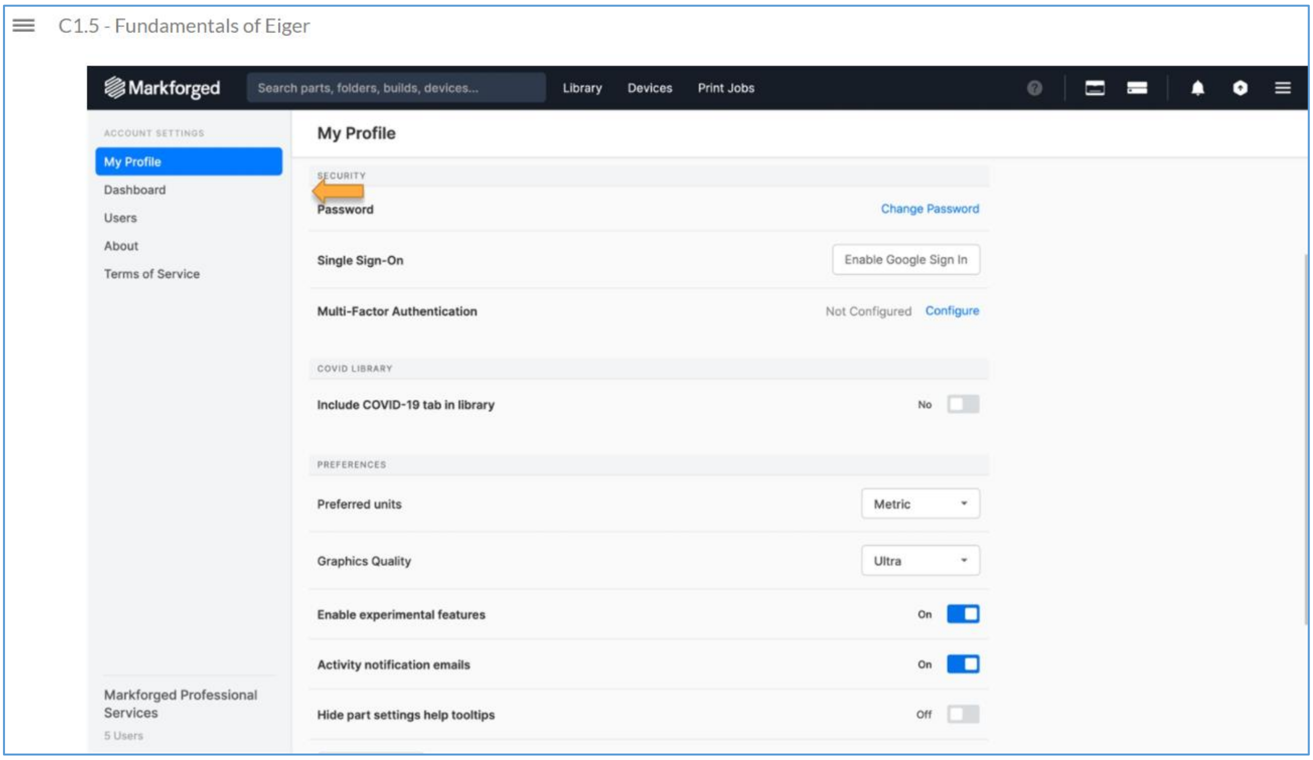




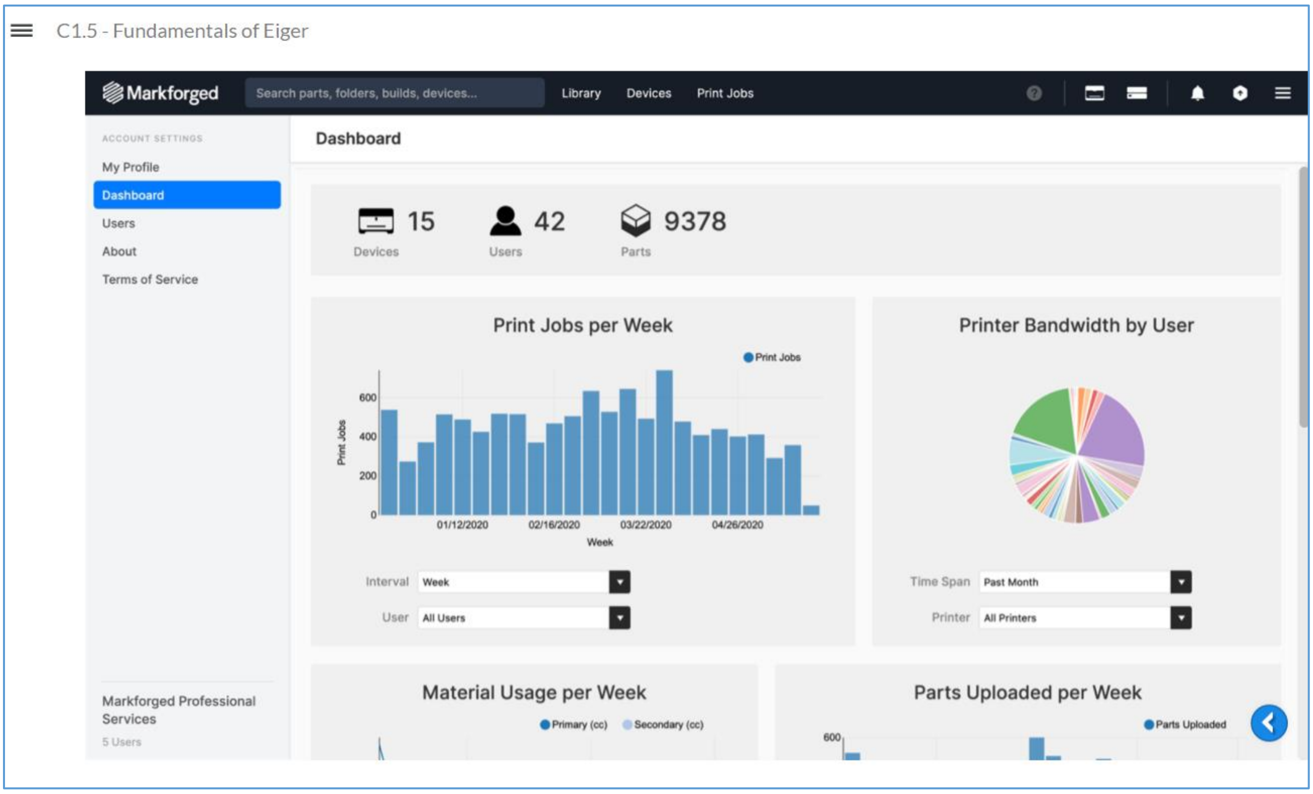
- **Personalizing Eiger with Account Settings**

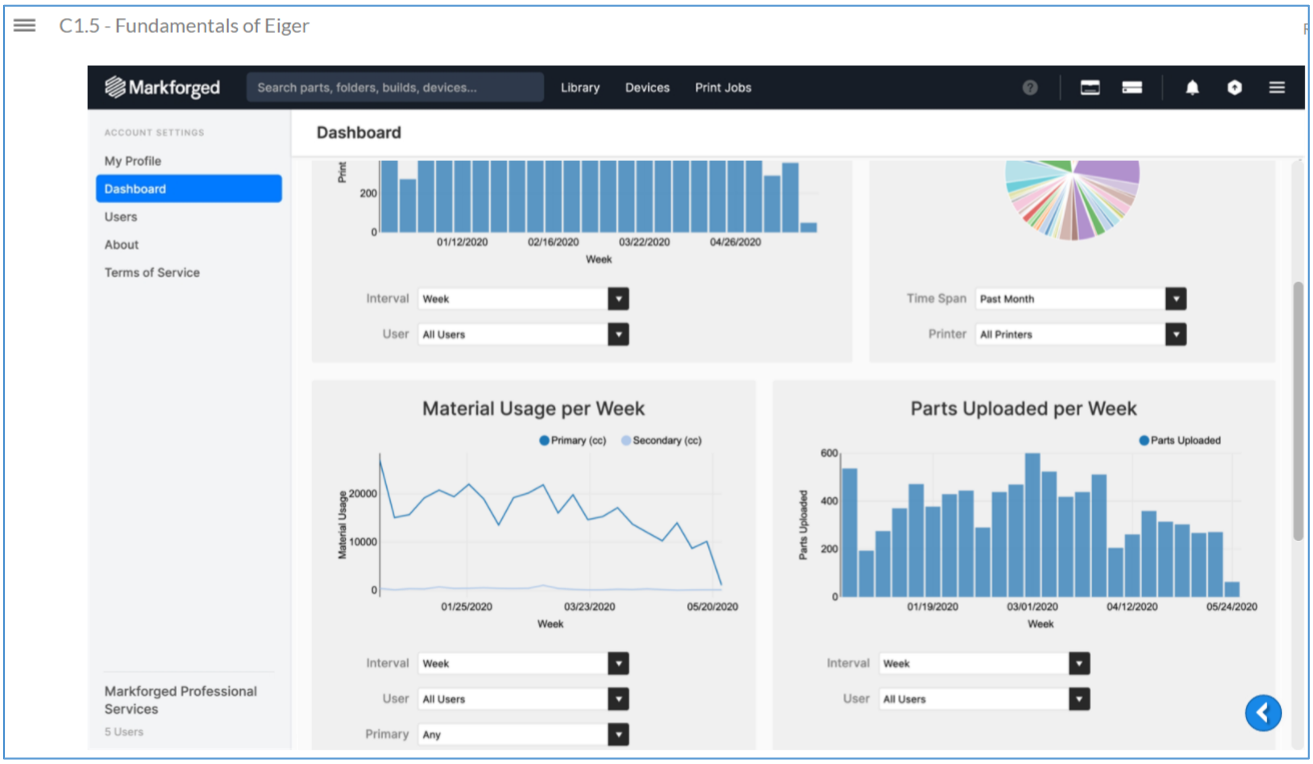

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Print Jobs
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Library
Sort by Modified
Filters
Create Folder
Nick
nick+ps@markforged.com
Account Settings
Organization Settings
Support
Shop
Log Out
CNC Tube Bending Die
Nick
Design for FFF + CFF
Nick
Plunge EDM Test (1)
Cat
Locked_Supports_-_U-Joi...
Cat
Locked_Supports_-_U-Joi...
Cat
Metal Training
Nick
Really Advanced Stuff
Nick
Foundations of AM
Nick
Optimizing Composite Su...
Nick
Building a Business Case
Nick
Intermediate Eiger Operati...
Nick
20388 Integrated 3 - 203...
Cat
Outside Multibody
Cat
Inside Multibody
Cat
Part Studio 1 (9)
Cat


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
ACCOUNT SETTINGS
My Profile
Dashboard
Users
About
Terms of Service
Markforged Professional Services
5 Users
My Profile
PERSONAL DETAILS
Full Name
Nick
Edit
Email
nick+ps@markforged.com
Edit
SECURITY
Password
Change Password
Single Sign-On
Enable Google Sign In
Multi-Factor Authentication
Not Configured
Configure
COVID LIBRARY
Include COVID-19 tab in library
No
PREFERENCES
Preferred units
Metric
Graphics Quality
Ultra

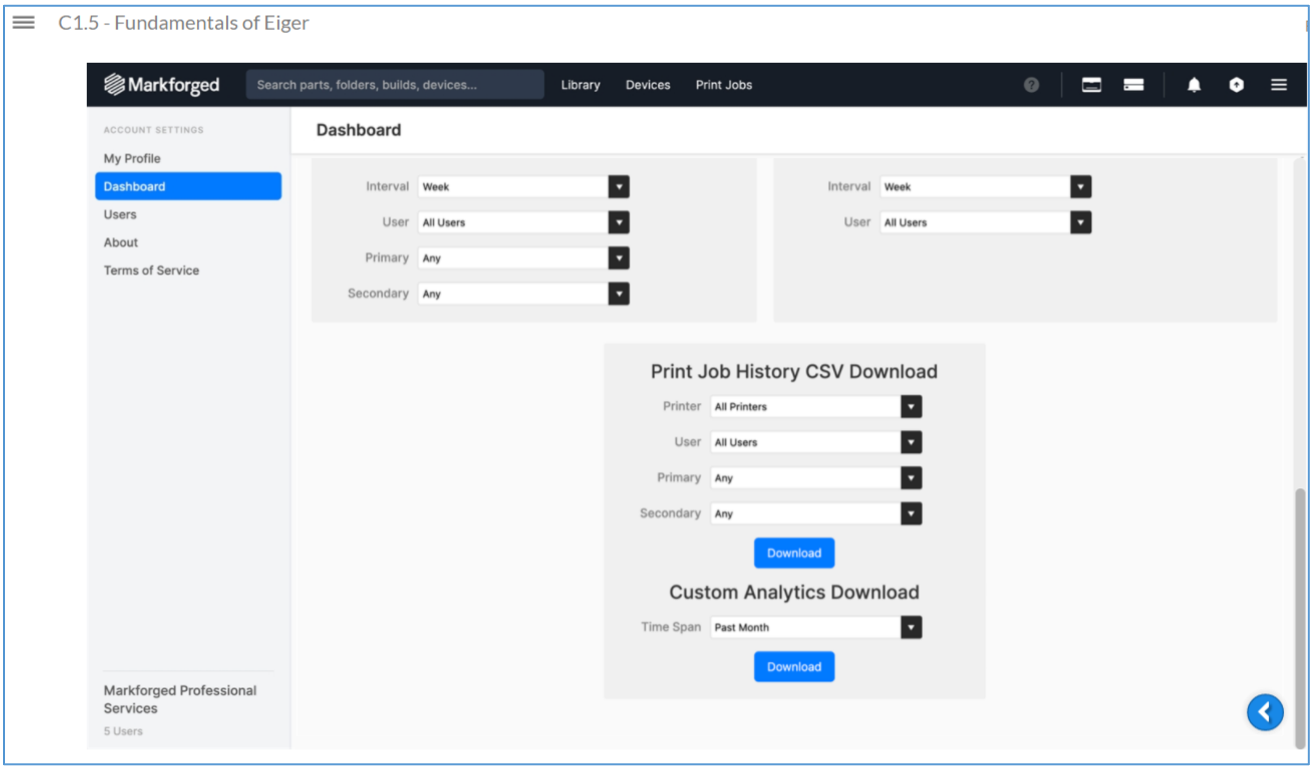


- **Organization Insights with the Dashboard**

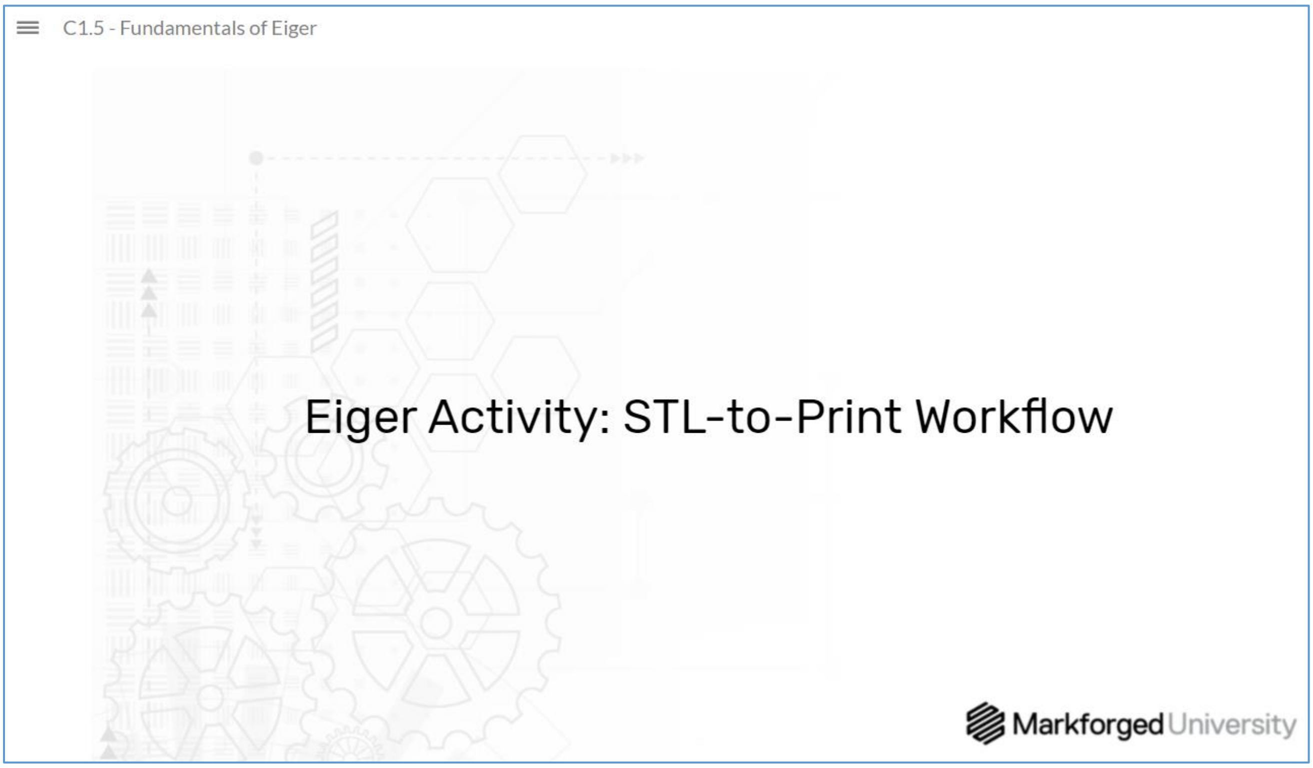




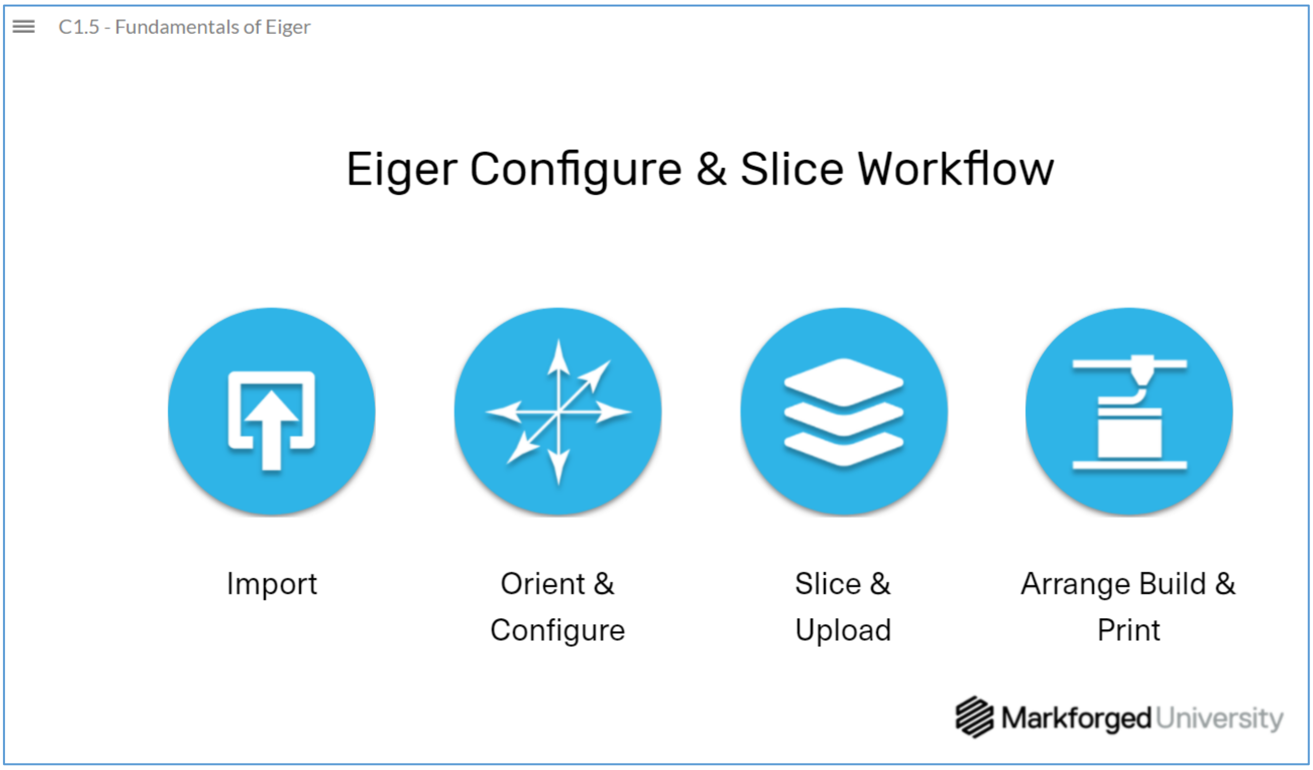
- Scrolling down…



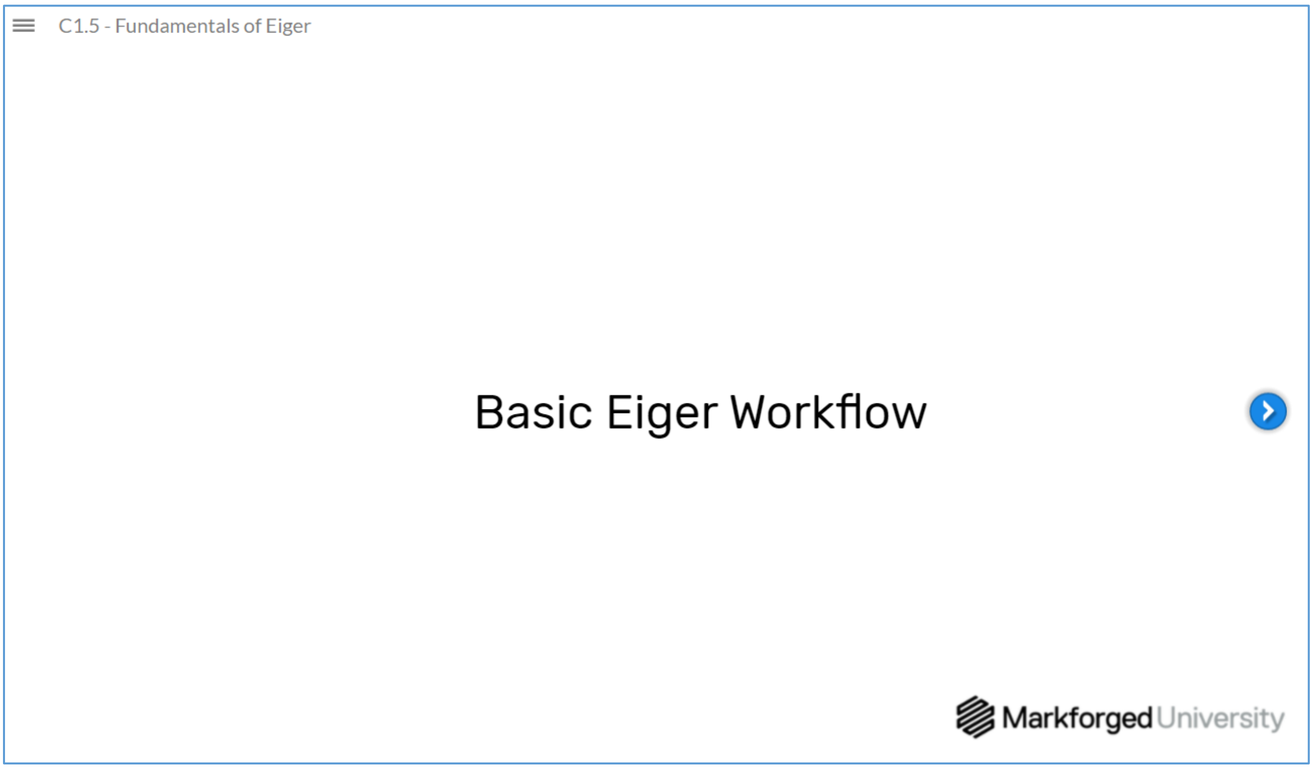
- Scrolling further down….



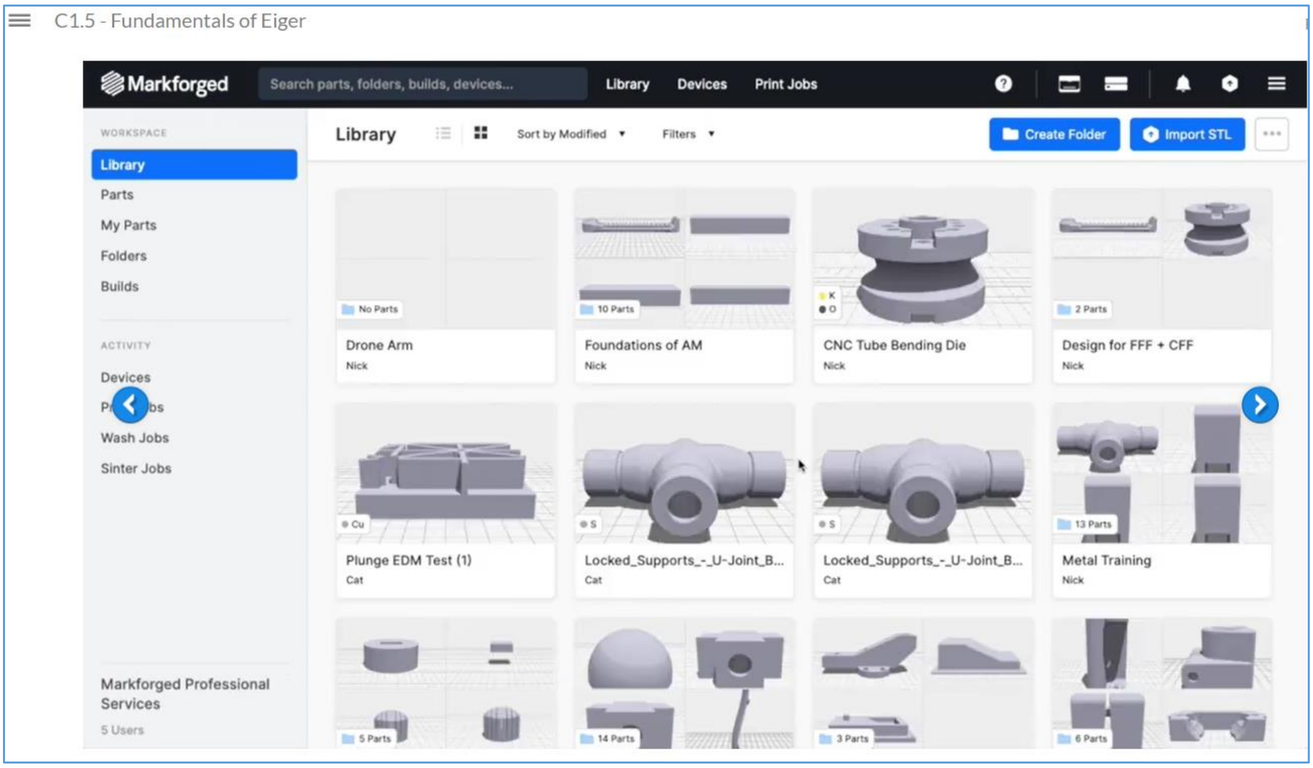
- **Activity: Basic Eiger Workflow**



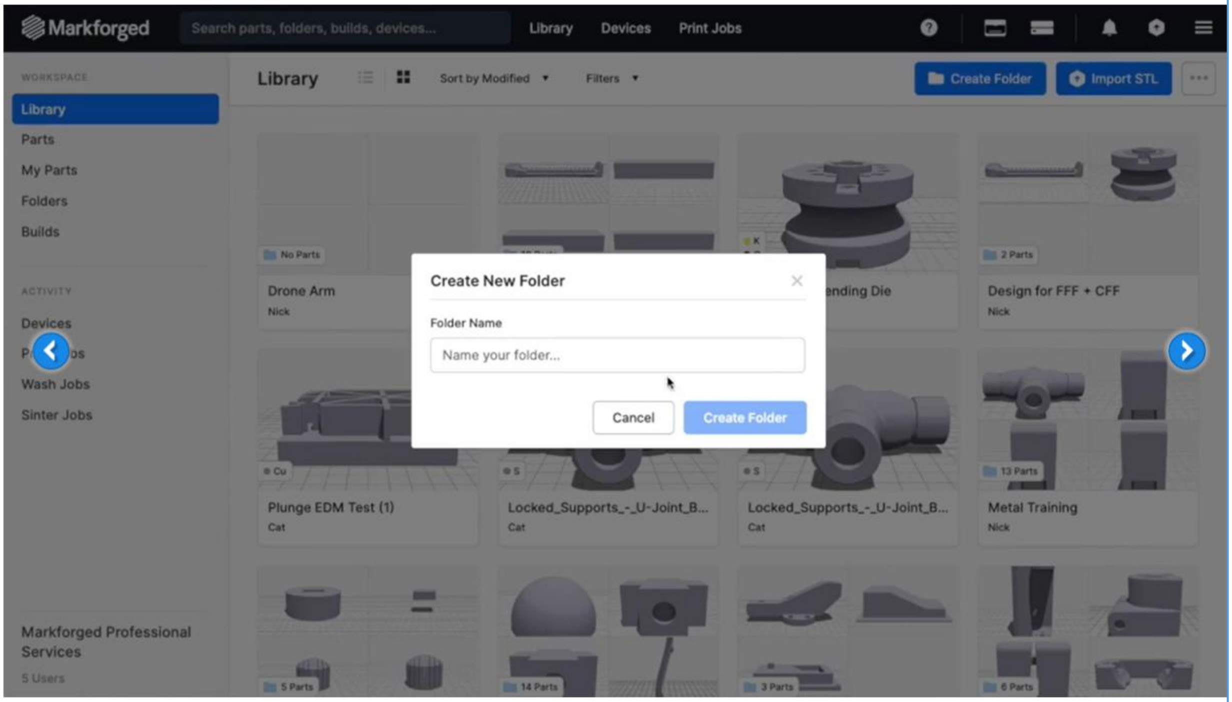
- **Eiger Configures & Slice Workflow**



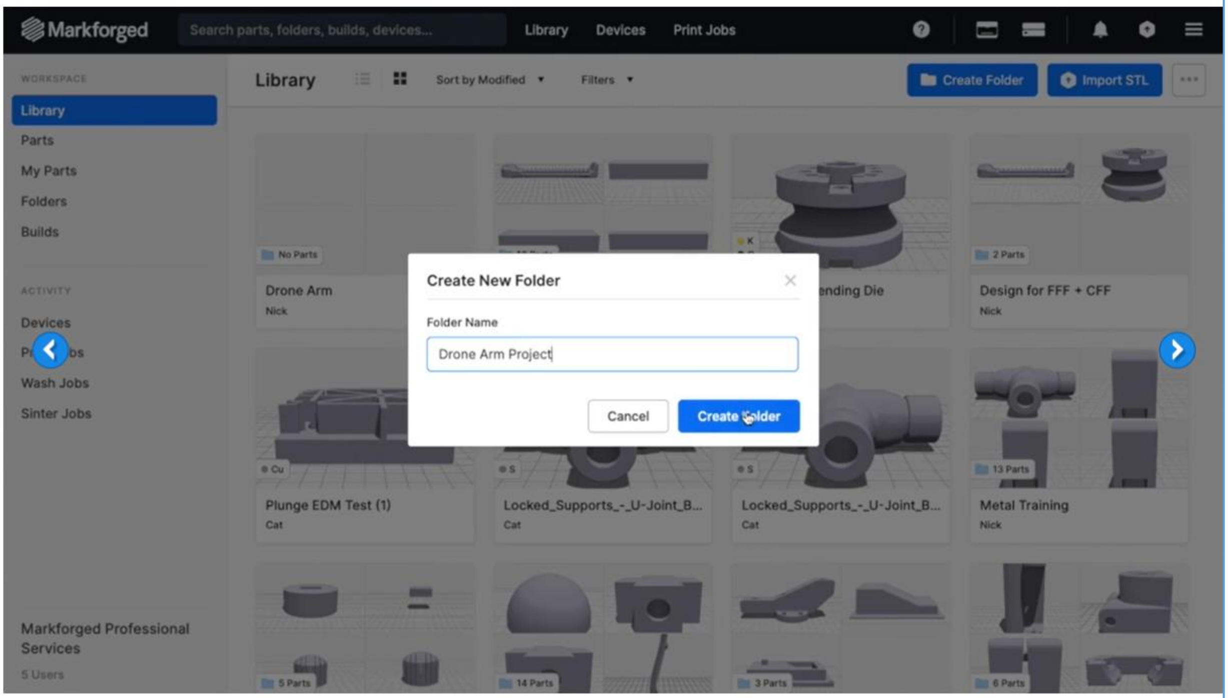
- **STL-to-Part Tutorial**

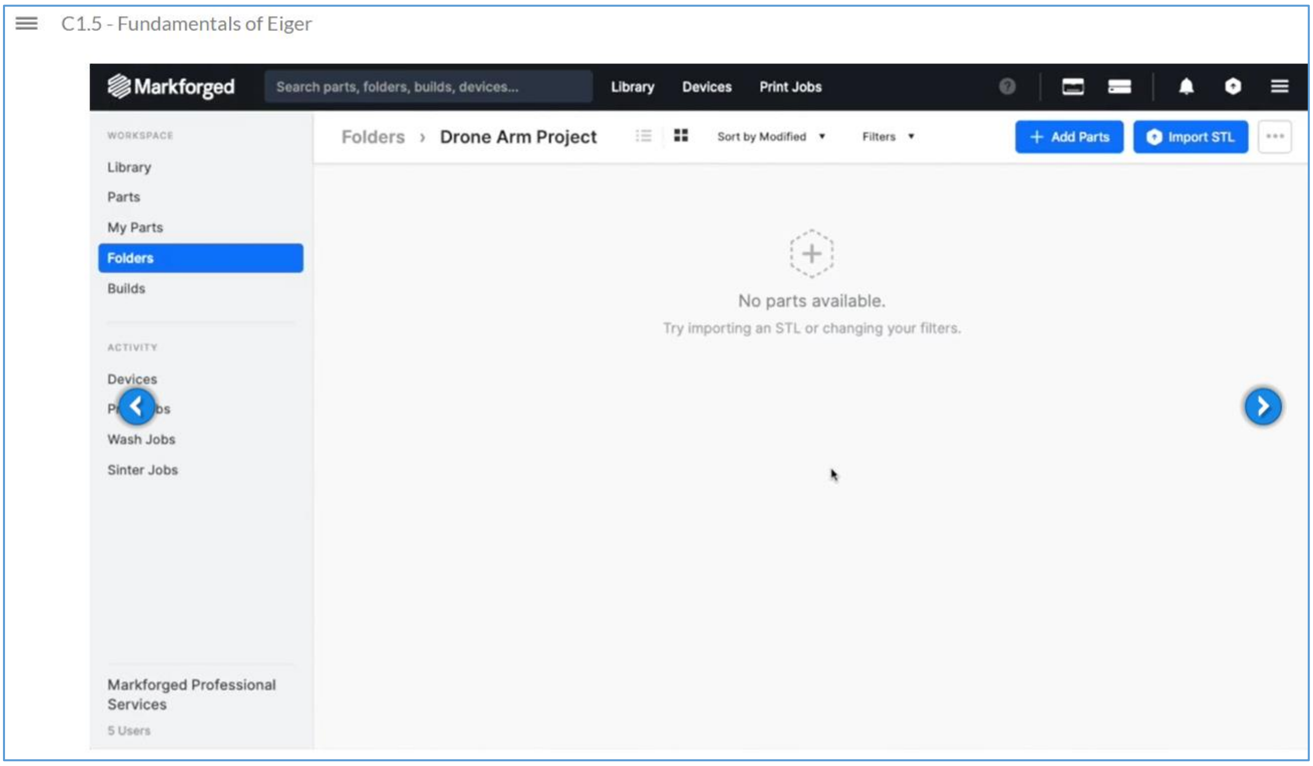


C1.5 - Fundamentals of Eiger

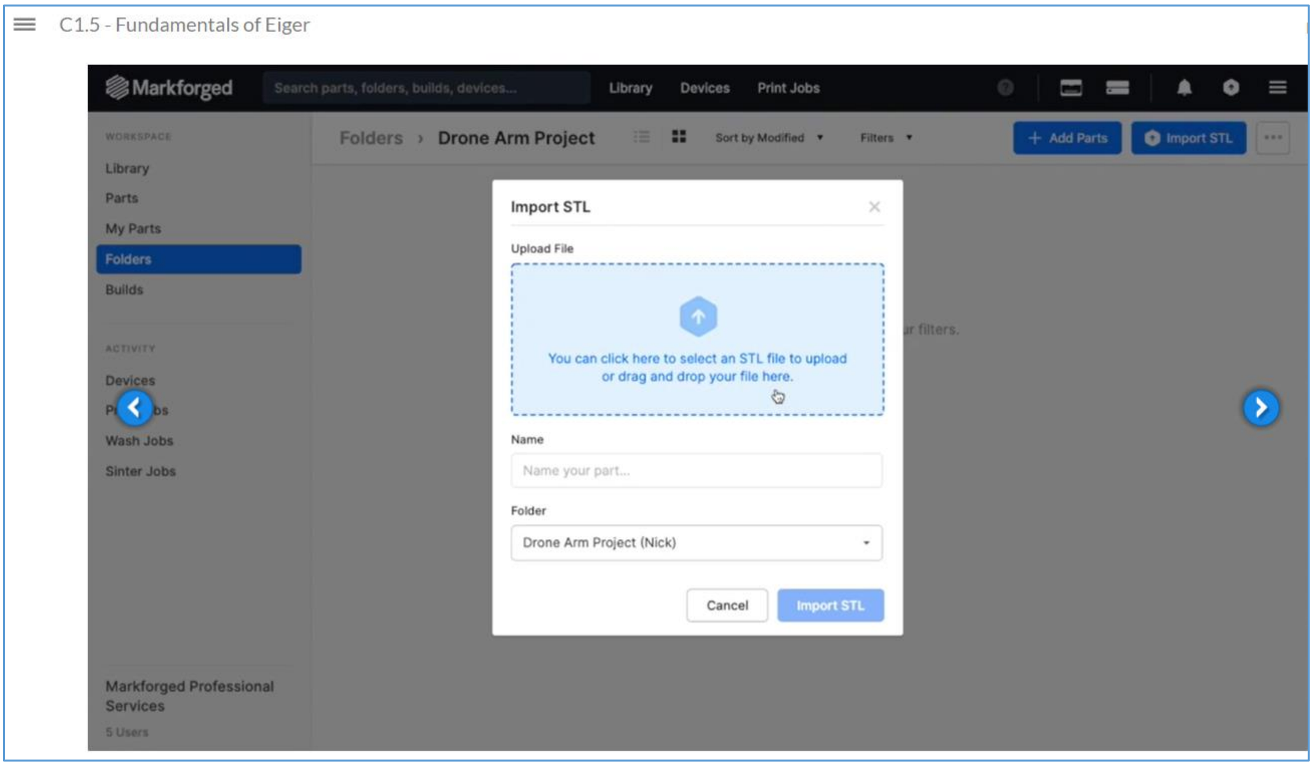


C1.5 - Fundamentals of Eiger

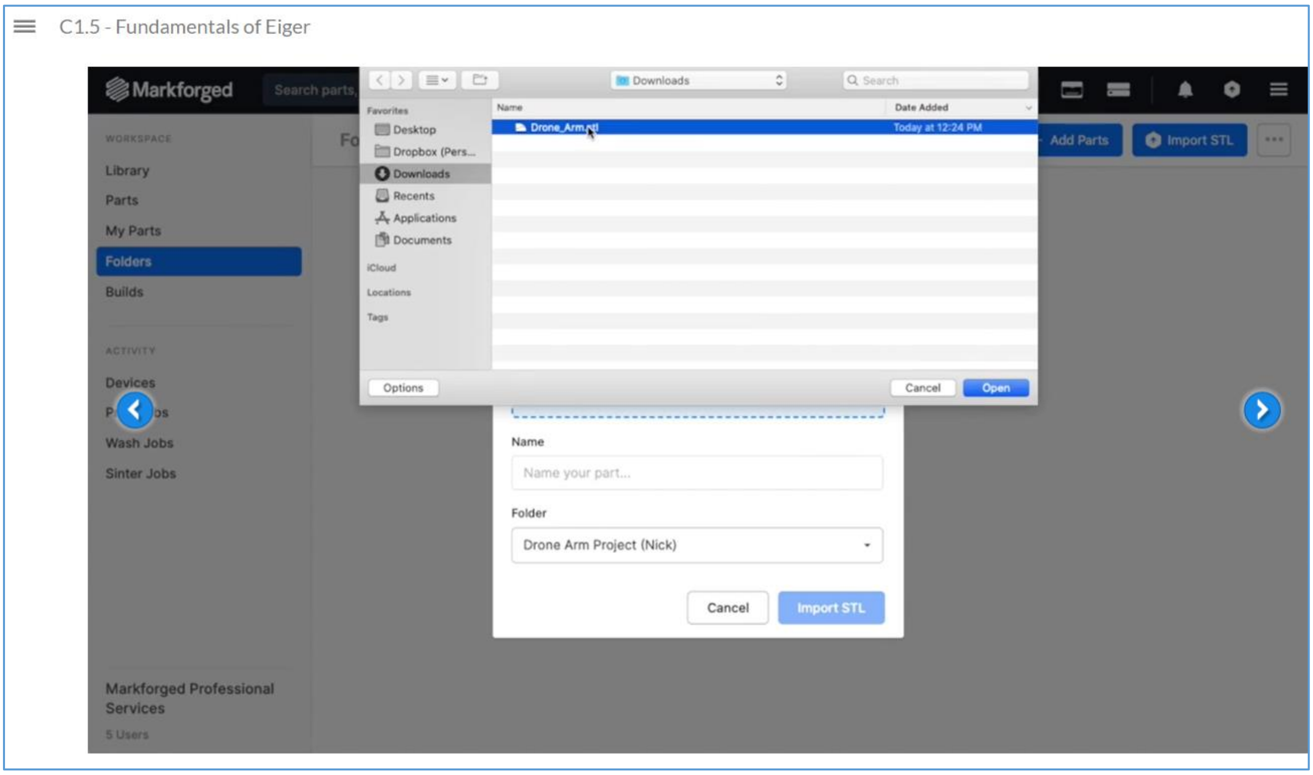


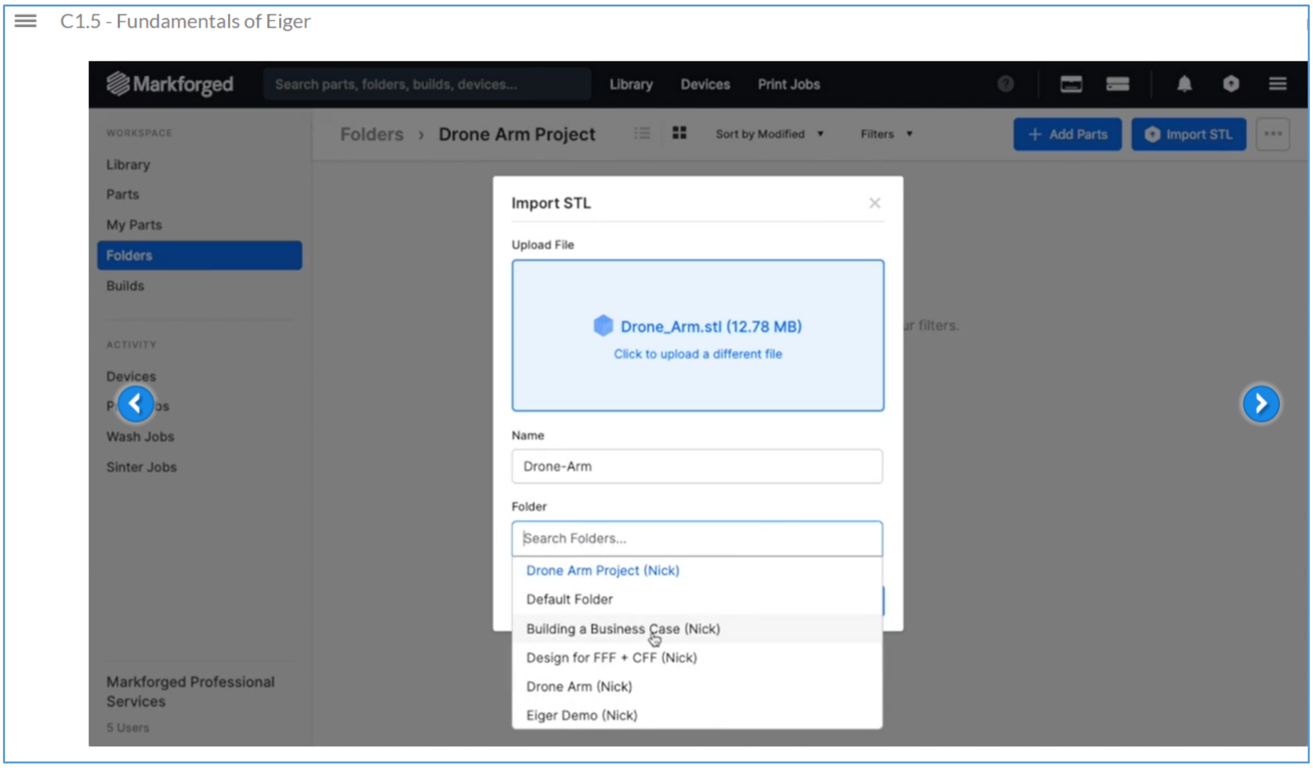


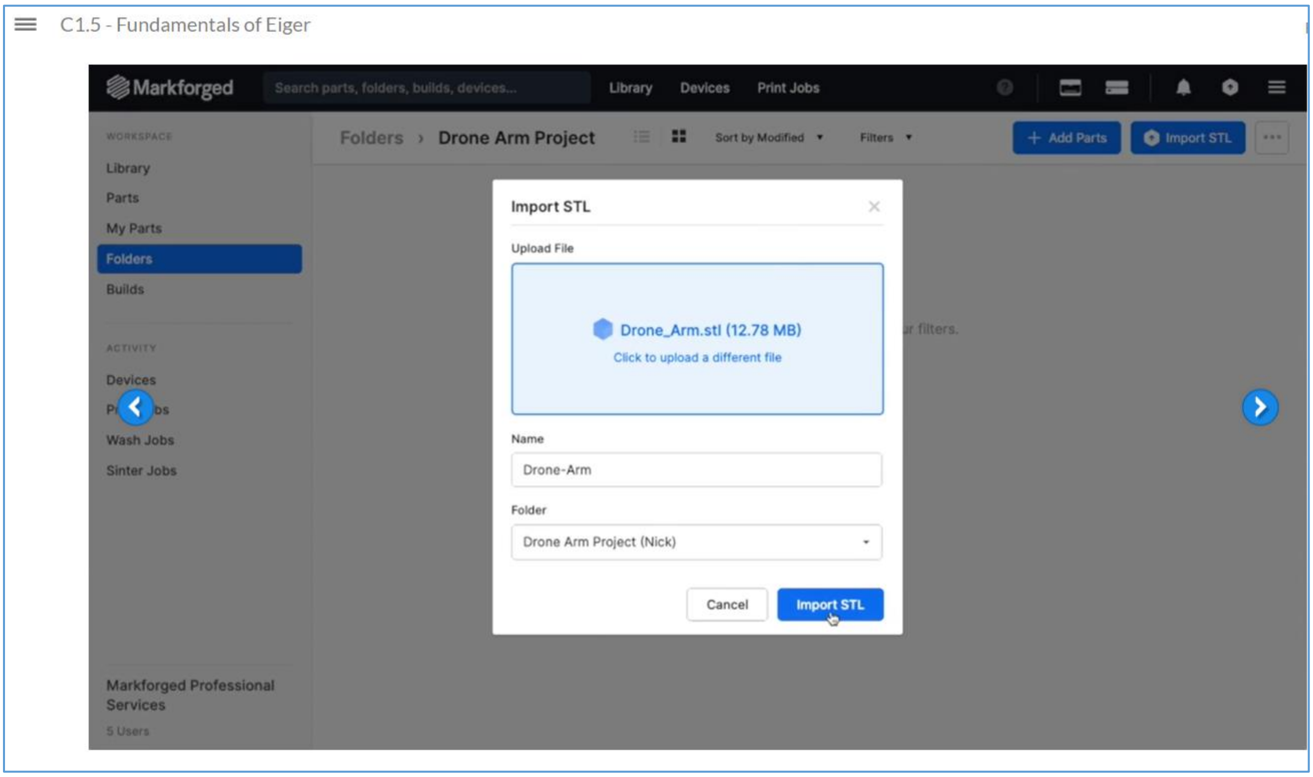
C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Folders › Drone Arm Project
Sort by Modified
Filters
Add Parts
Import STL
No parts available.
Try importing an STL or changing your filters.

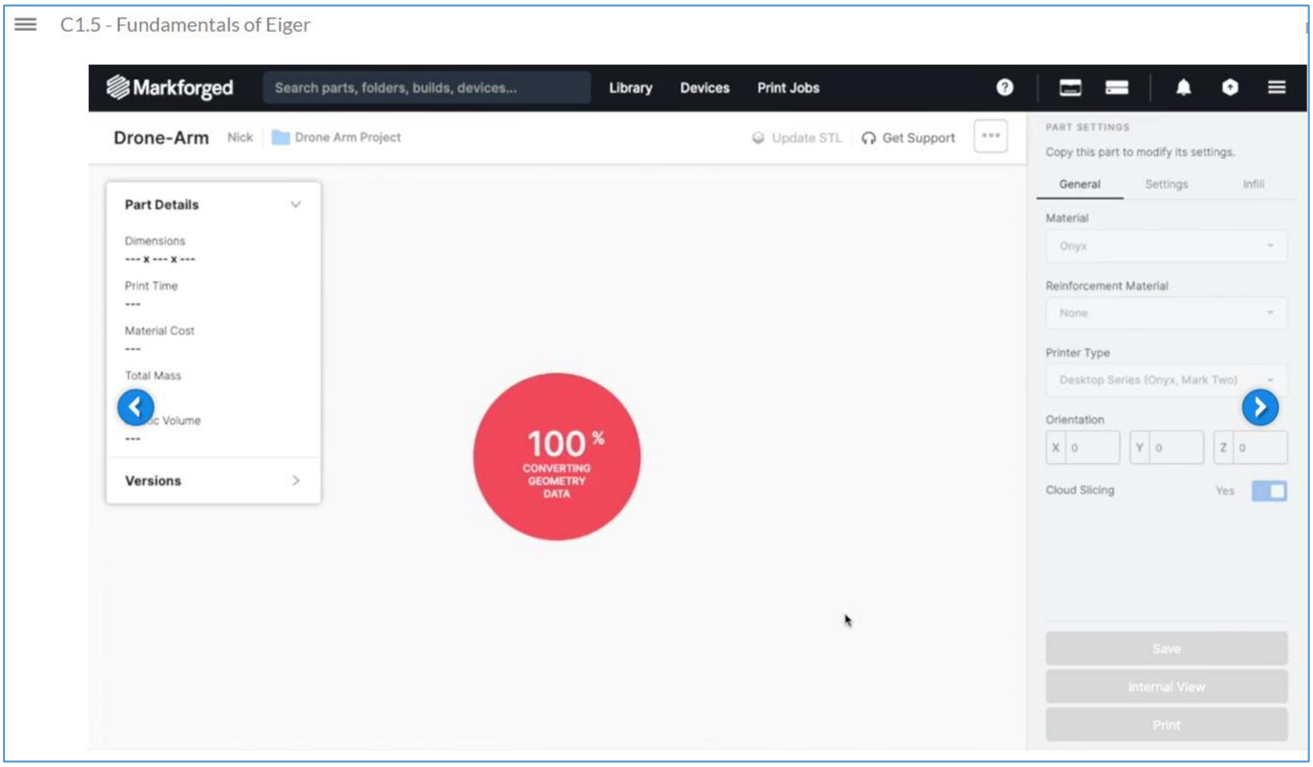


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Folders › Drone Arm Project
Import STL
Upload File
You can click here to select an STL file to upload
or drag and drop your file here.
Name
Name your part...
Folder
Drone Arm Project (Nick)
Cancel
Import STL


C1.5 - Fundamentals of Eiger
Markforged
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Downloads
Search
Favorites
Desktop
Dropbox (Pers...
Downloads
Recents
Applications
Documents
iCloud
Locations
Tags
Name
Date Added
Drone_Arm.stl
Today at 12:24 PM
Options
Cancel
Open
Add Parts
Import STL
Name
Name your part...
Folder
Drone Arm Project (Nick)
Cancel
Import STL


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Folders › Drone Arm Project
Sort by Modified
Filters
Add Parts
Import STL
Import STL
Upload File
Drone_Arm.stl (12.78 MB)
Click to upload a different file
Name
Drone-Arm
Folder
Search Folders...
Drone Arm Project (Nick)
Default Folder
Building a Business Case (Nick)
Design for FFF + CFF (Nick)
Drone Arm (Nick)
Eiger Demo (Nick)

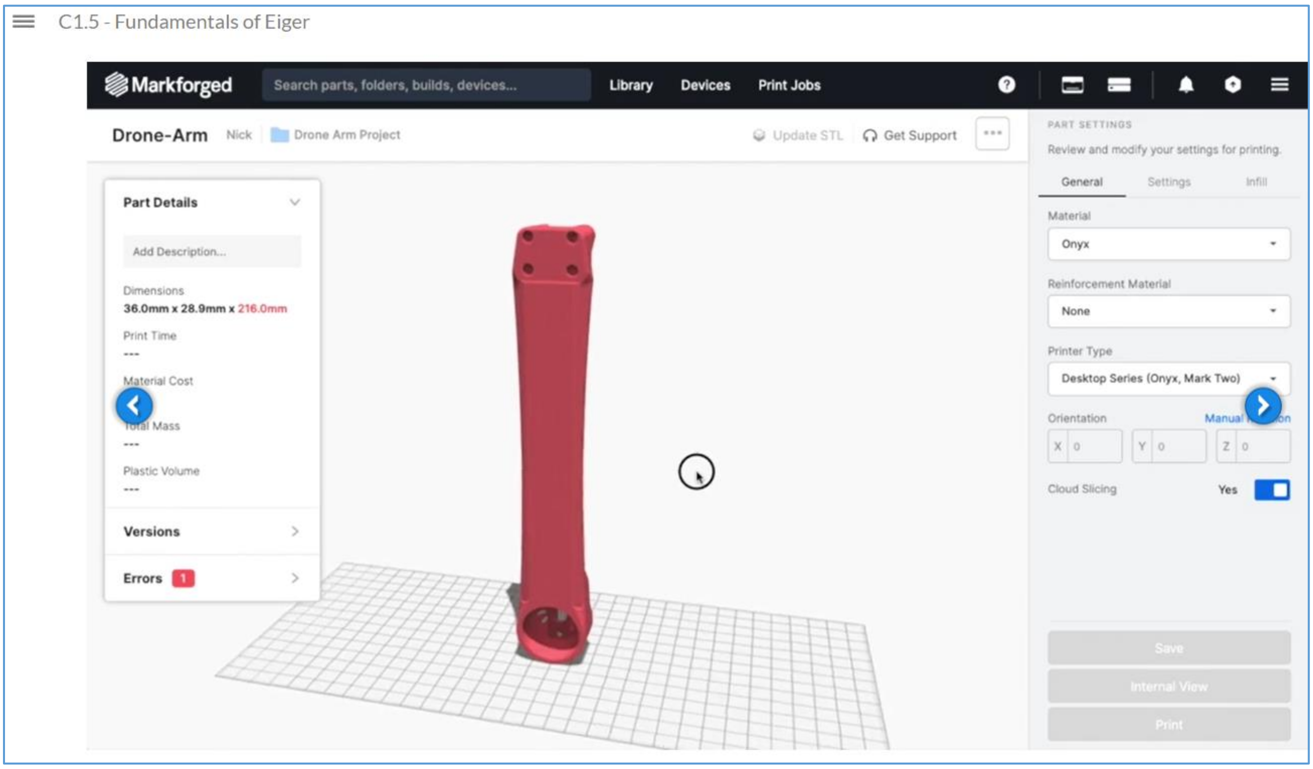

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Folders › Drone Arm Project
Sort by Modified
Filters
Add Parts
Import STL
Import STL
Upload File
Drone_Arm.stl (12.78 MB)
Click to upload a different file
Name
Drone-Arm
Folder
Drone Arm Project (Nick)
Cancel
Import STL


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Drone Arm Project
Update STL
Get Support
Part Details
Dimensions
--- x --- x ---
Print Time

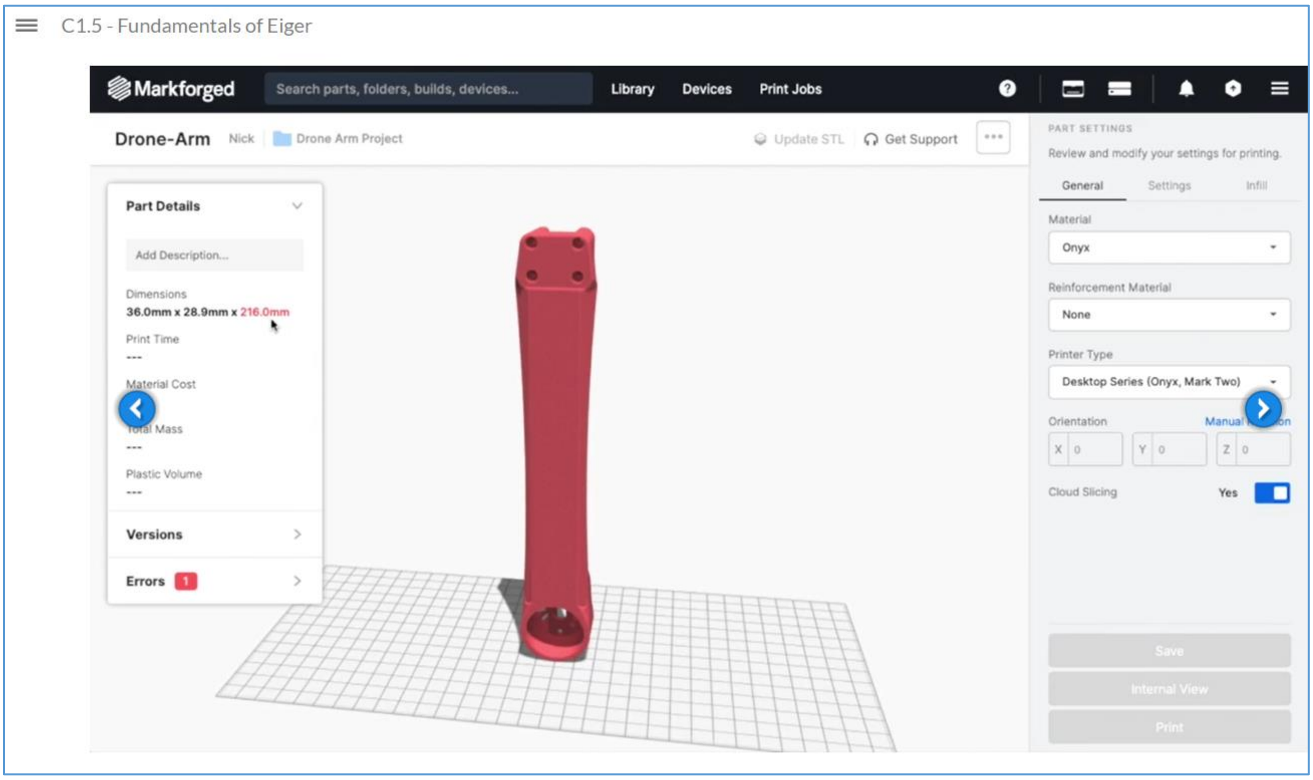
Material Cost

Total Mass

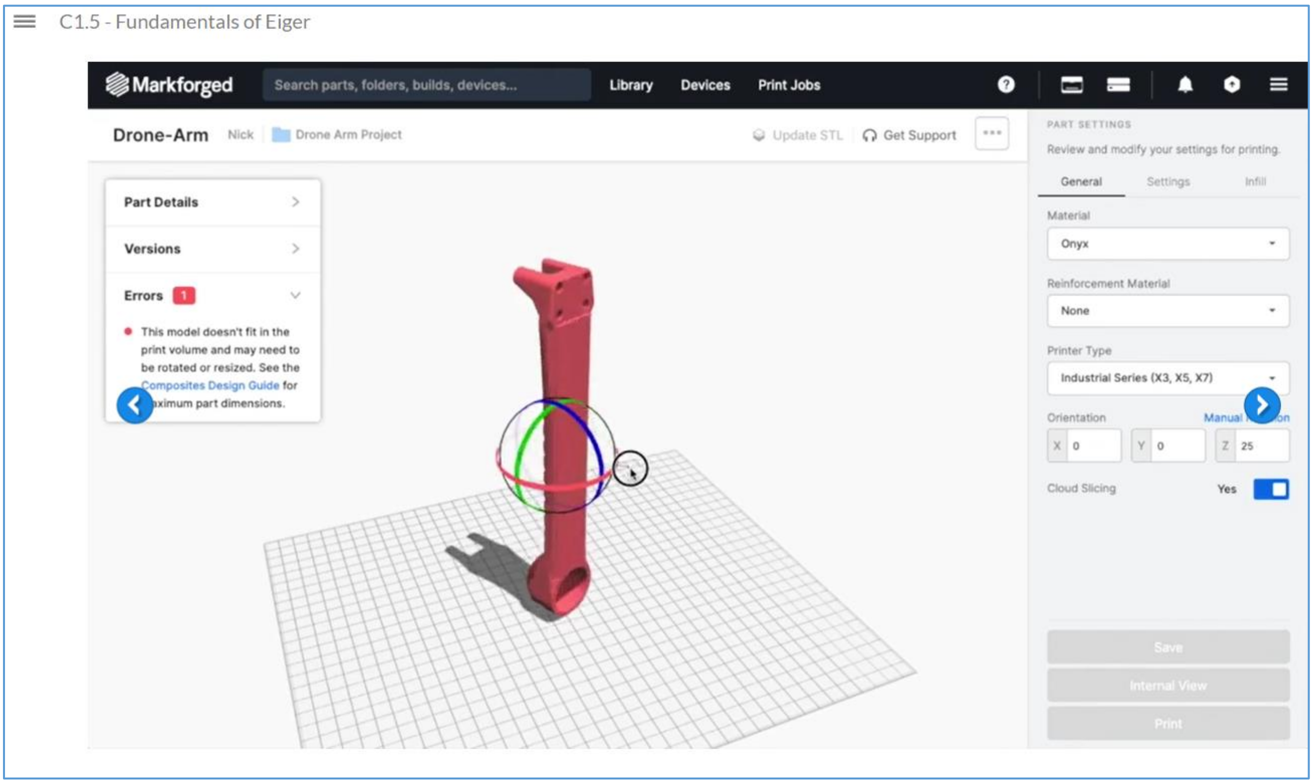
Versions
100 %
CONVERTING GEOMETRY DATA
PART SETTINGS
Copy this part to modify its settings.
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Desktop Series (Onyx, Mark Two)
Orientation
X 0
Y 0
Z 0
Cloud Slicing
Yes
Save
Internal View
Print



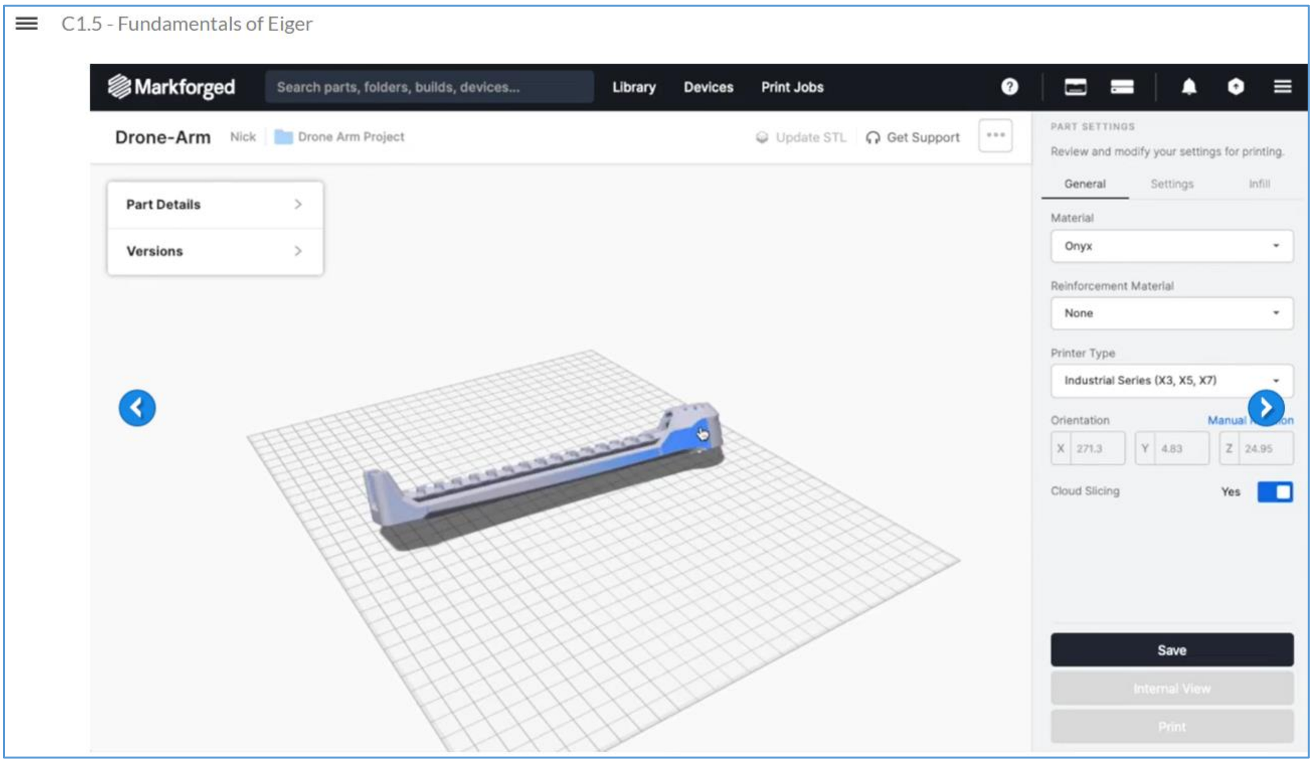
- Red: Something is wrong.



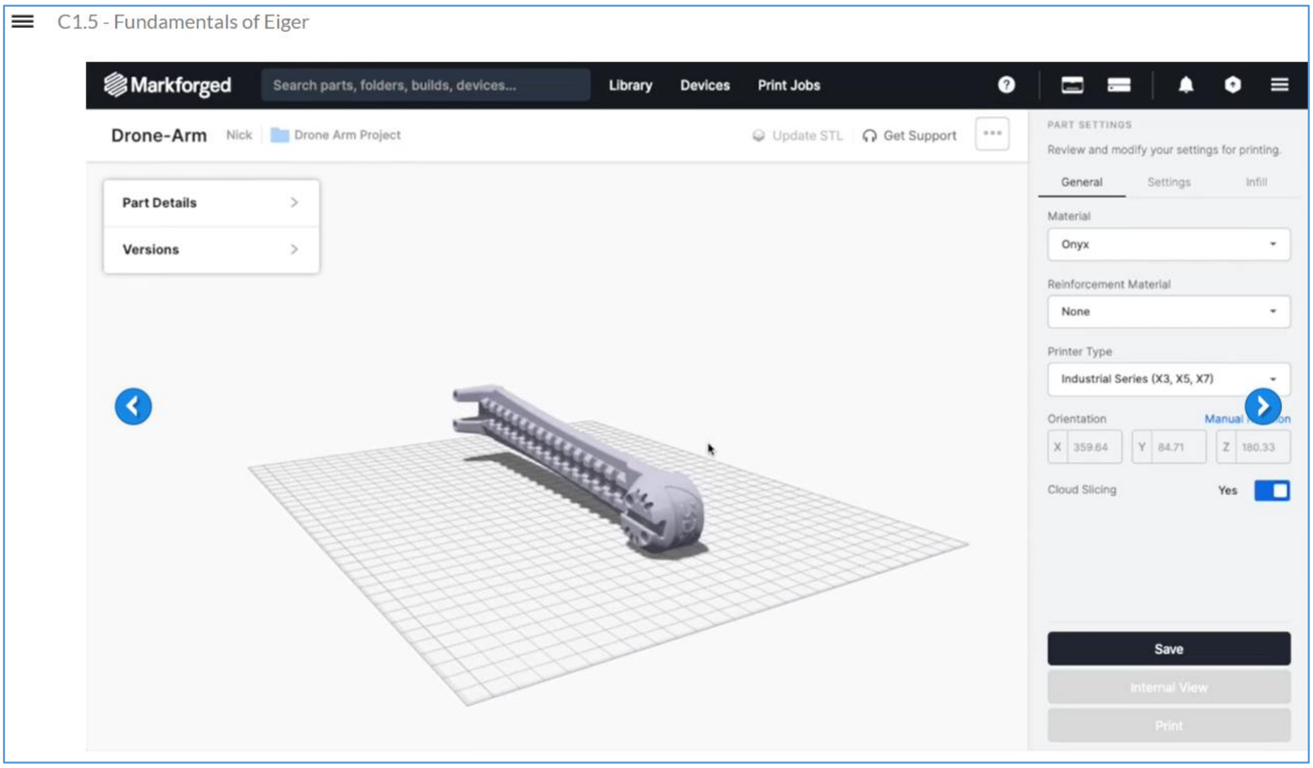
- Exceeds the size in Z-axis.



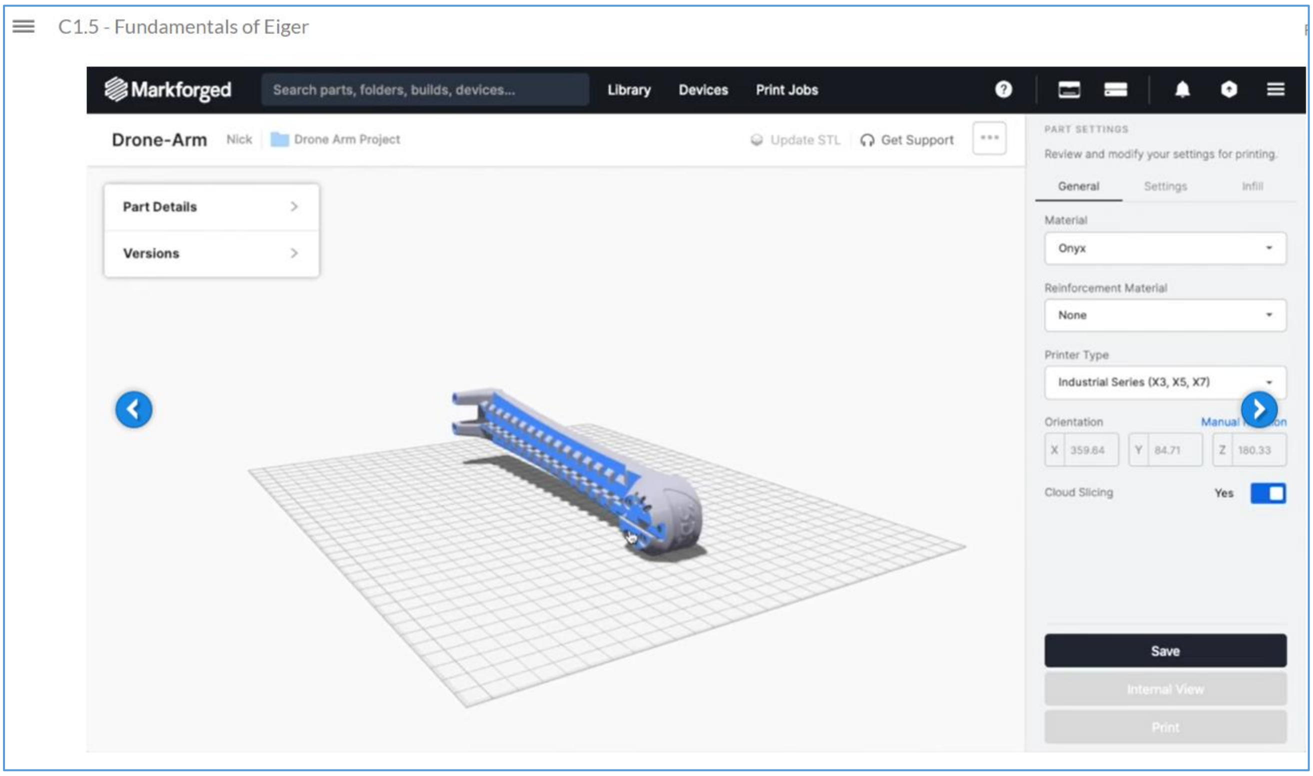
- Manual Orientation.



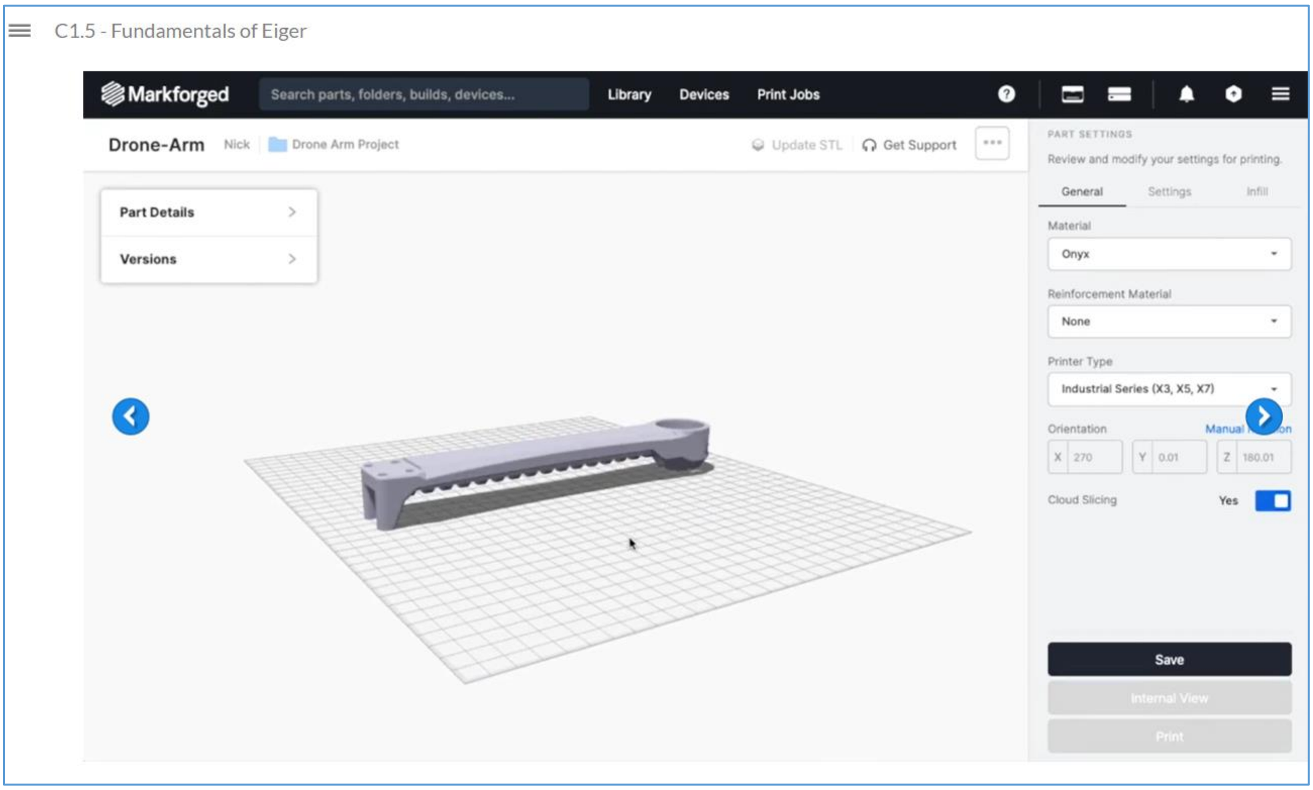
- Or click on surface you want to orientate parallel to.



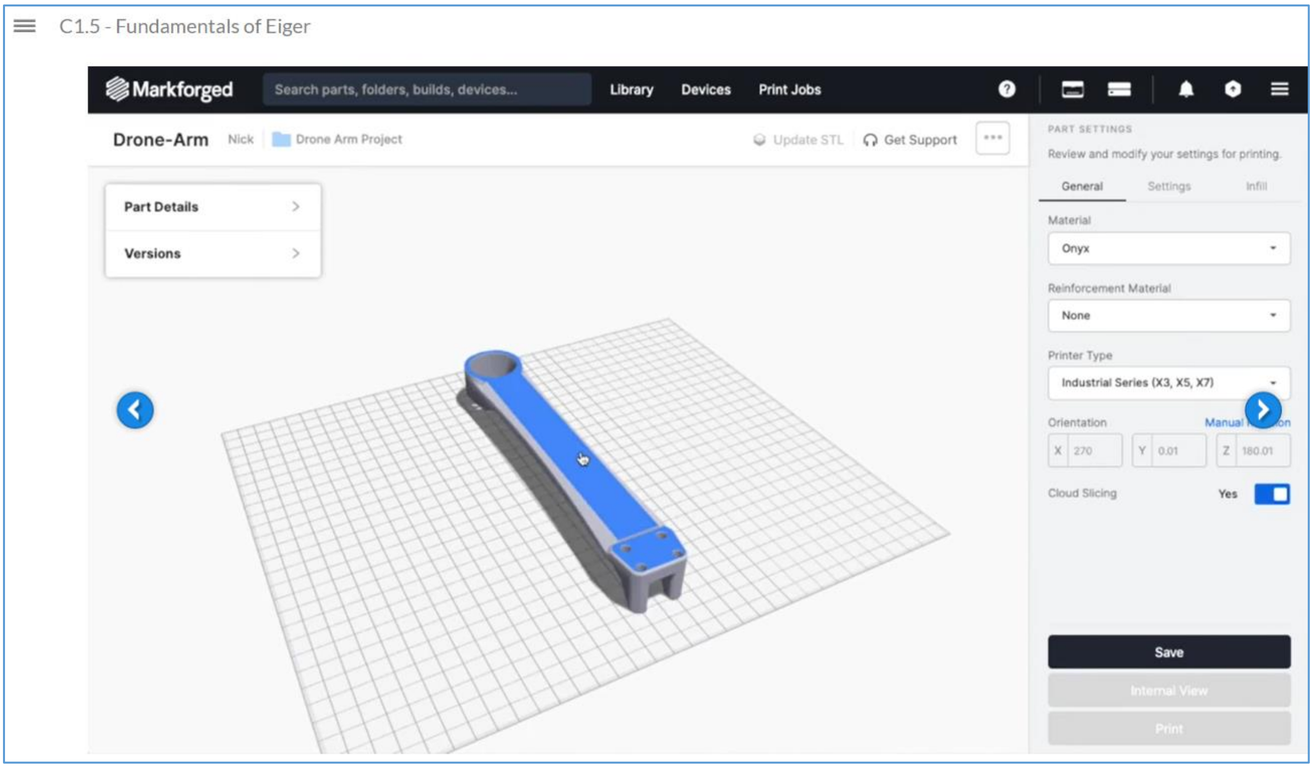
- And the orientated result….



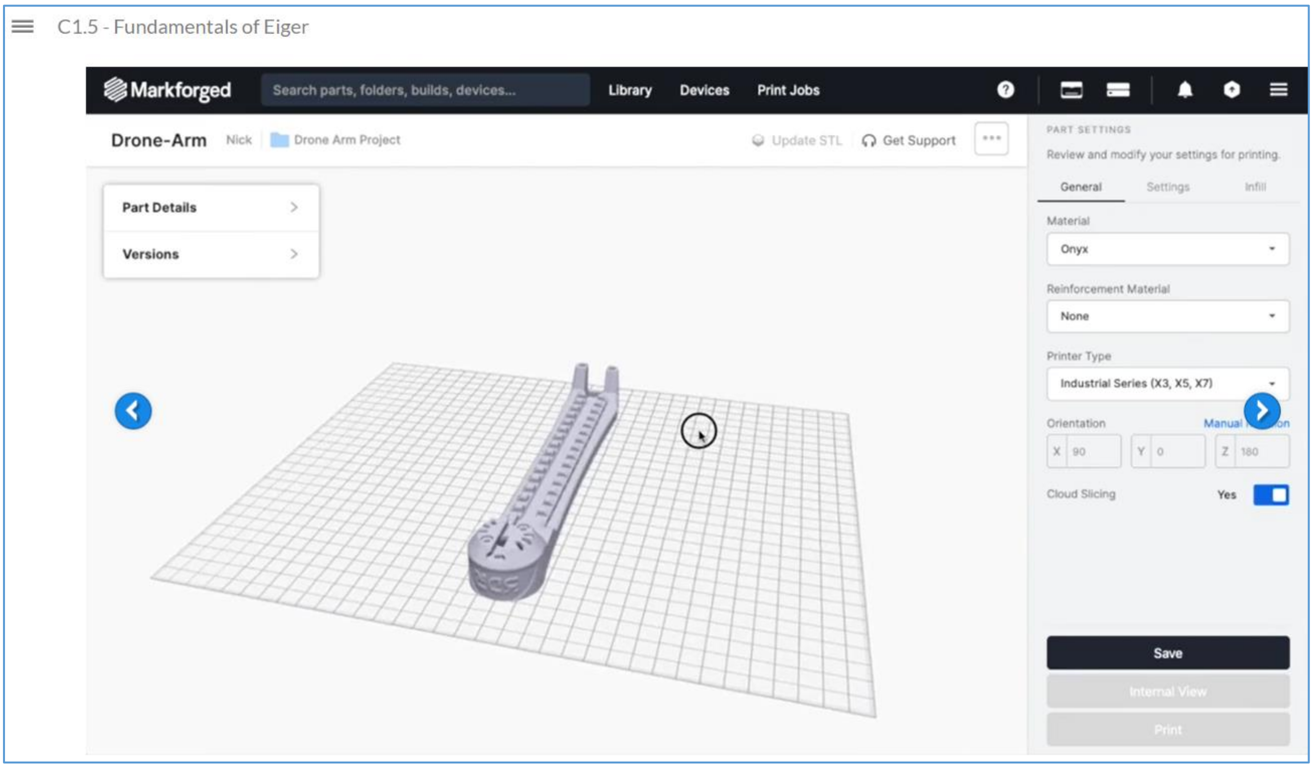
- Another orientation (see high lighted)…



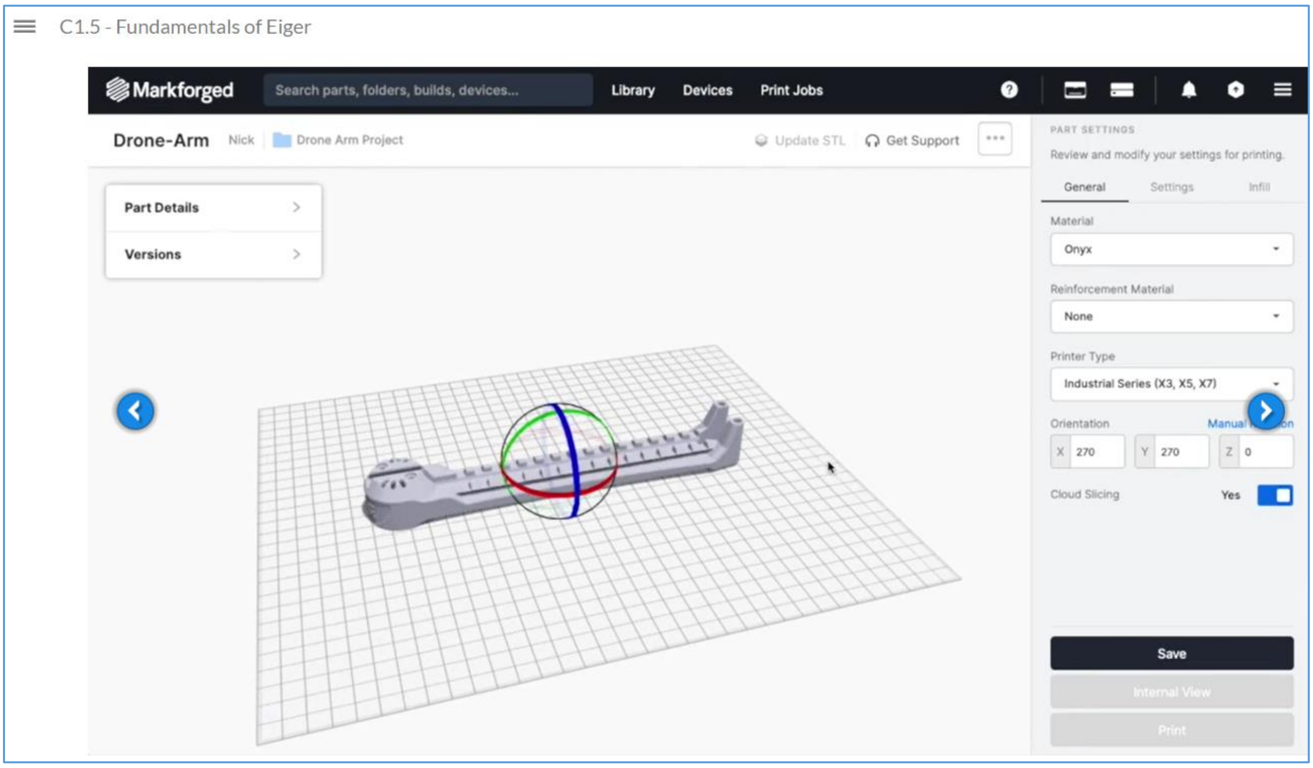
- And the result…
- Disadvantage: Lot of supportmaterial needed.

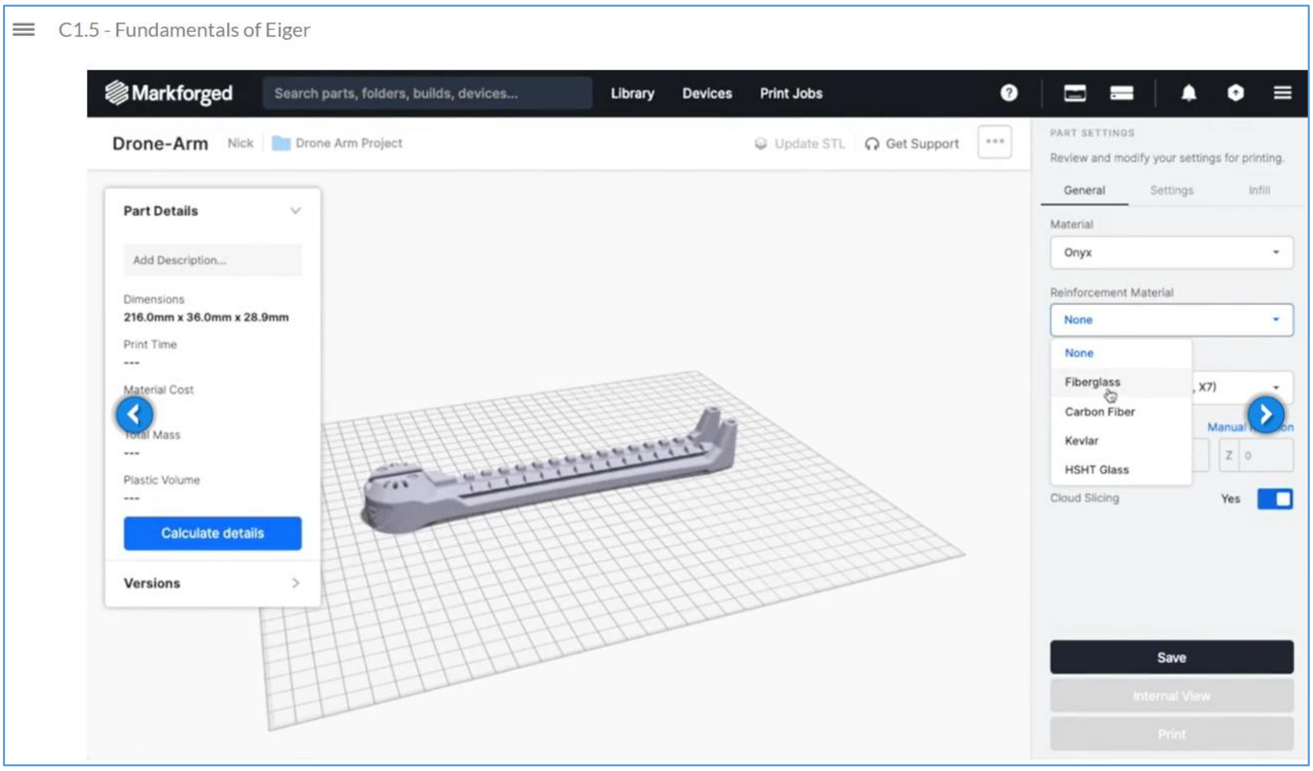


- To choose Opposite Direction by simply clicking

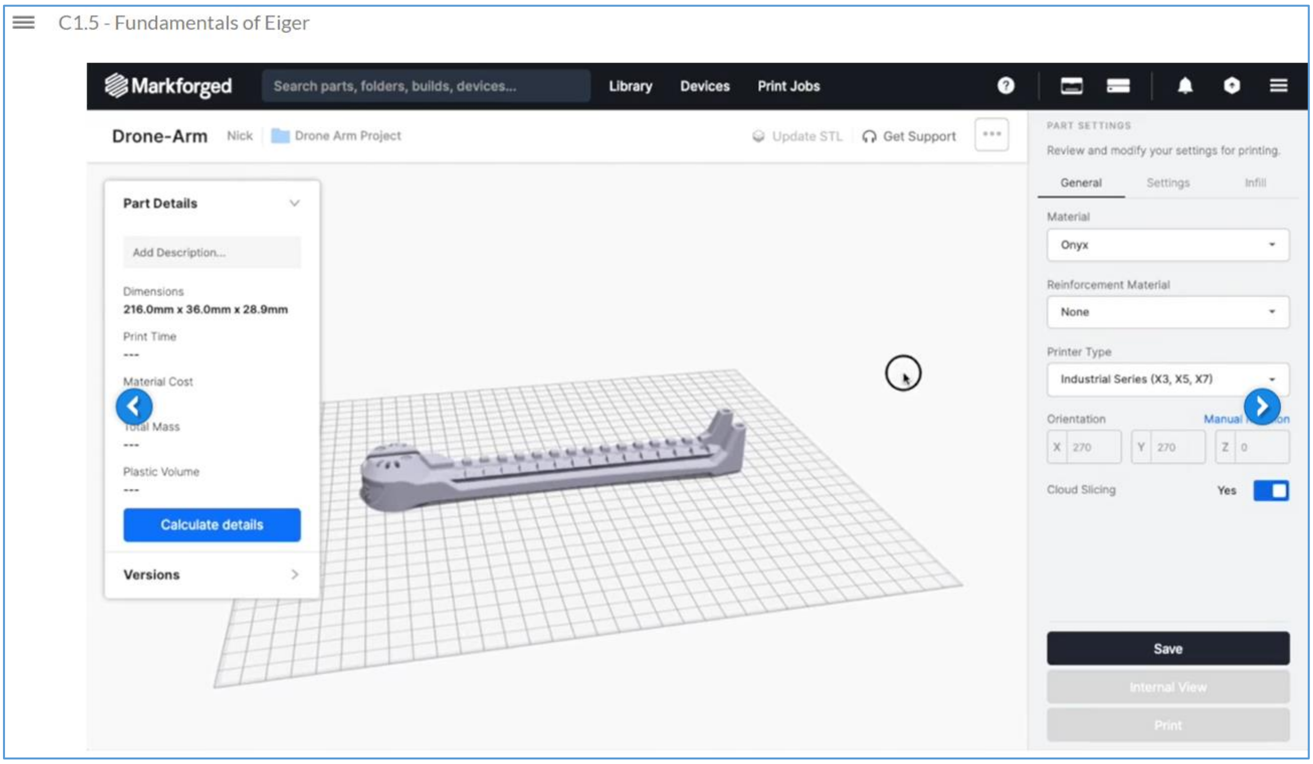


- And the result: Facing down.

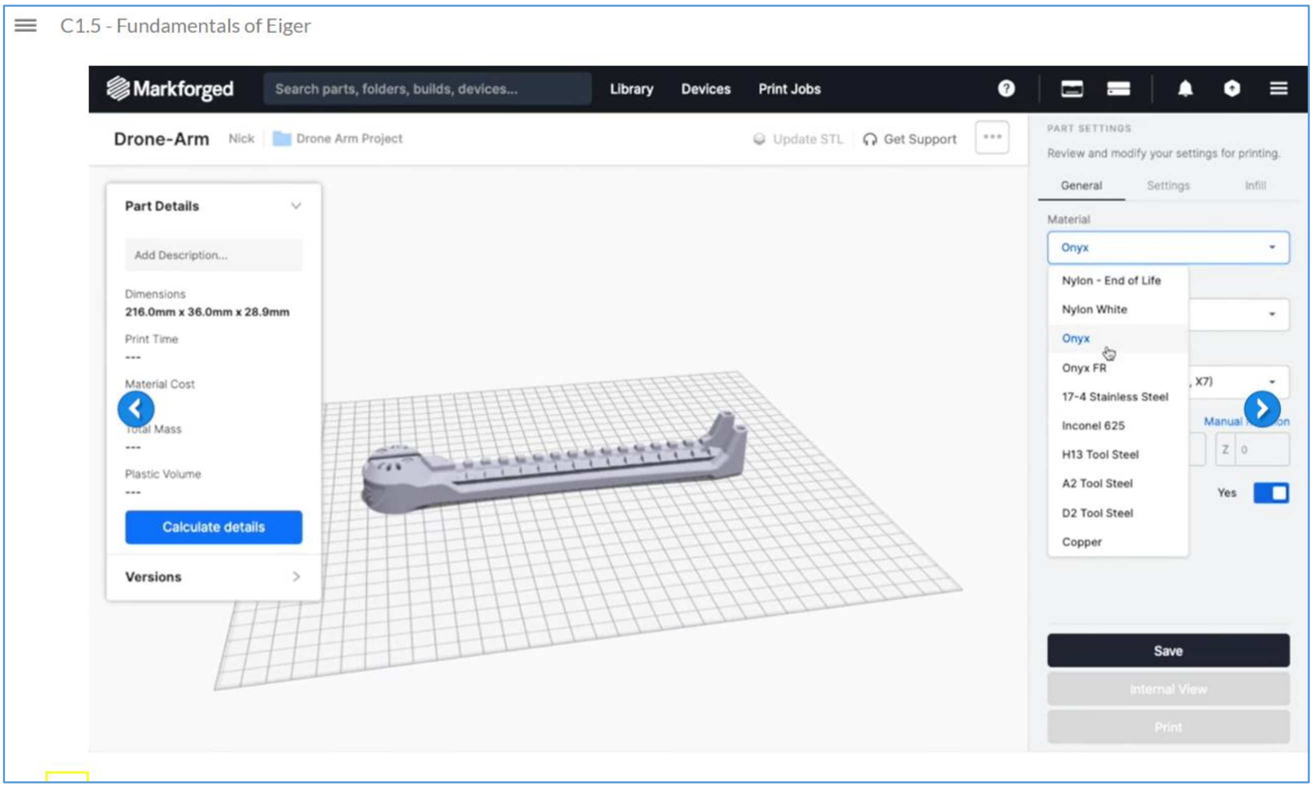




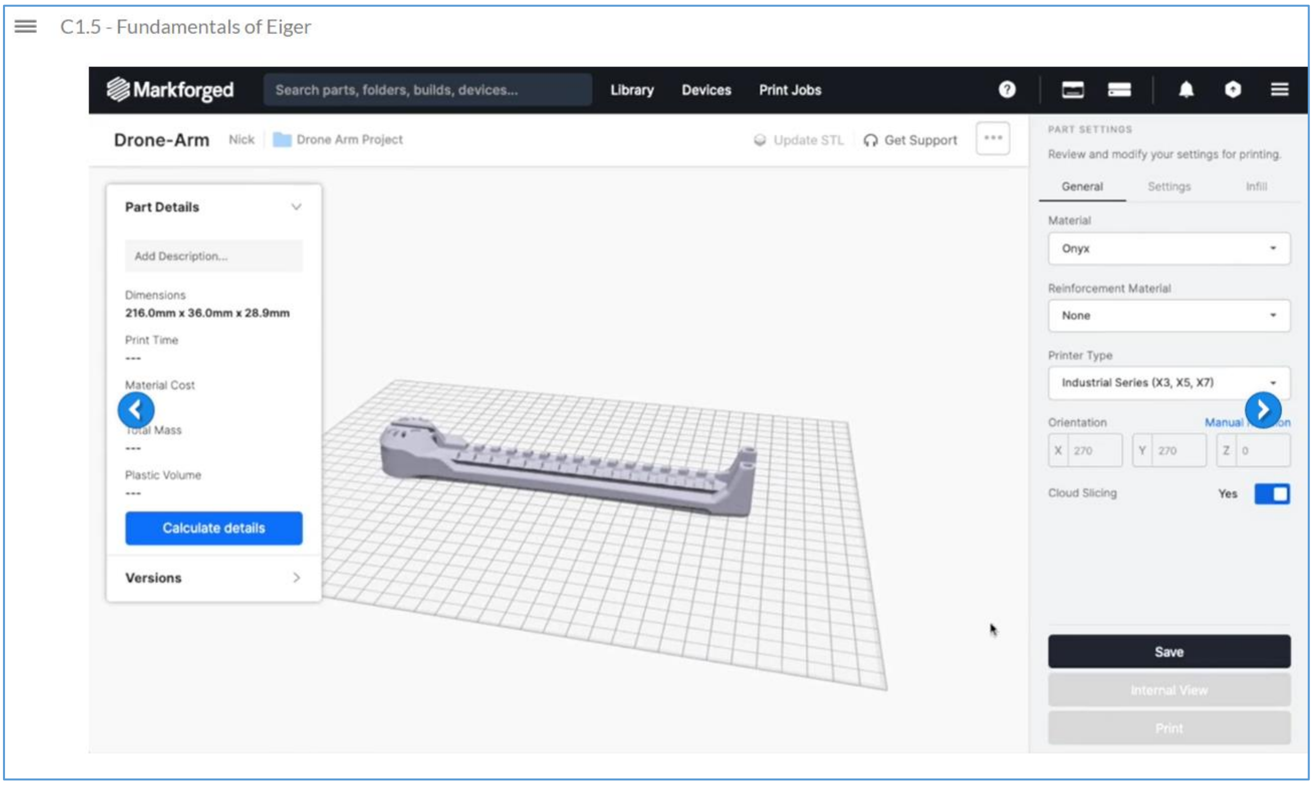
- At this point you can choose Reinforcement Material.



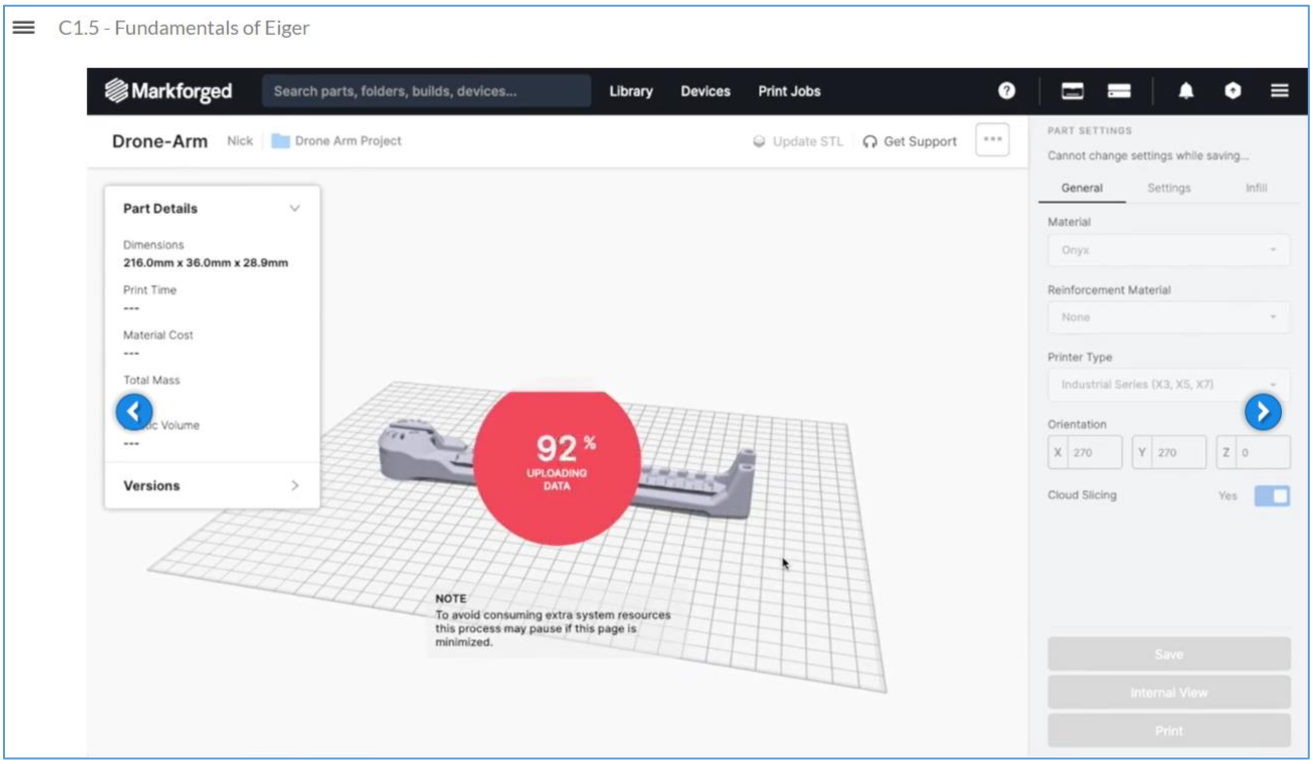
- In this case we use only Onyx Material.

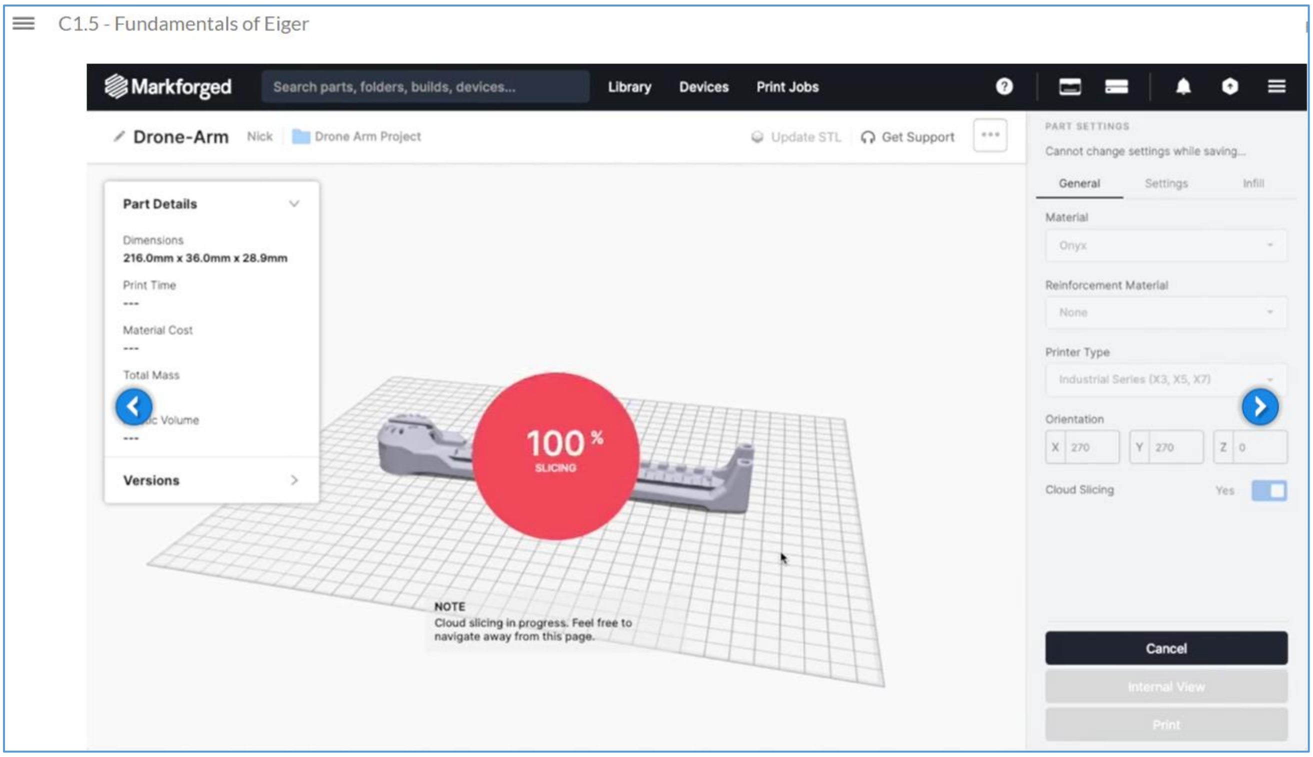


- In this case Onyx Material.

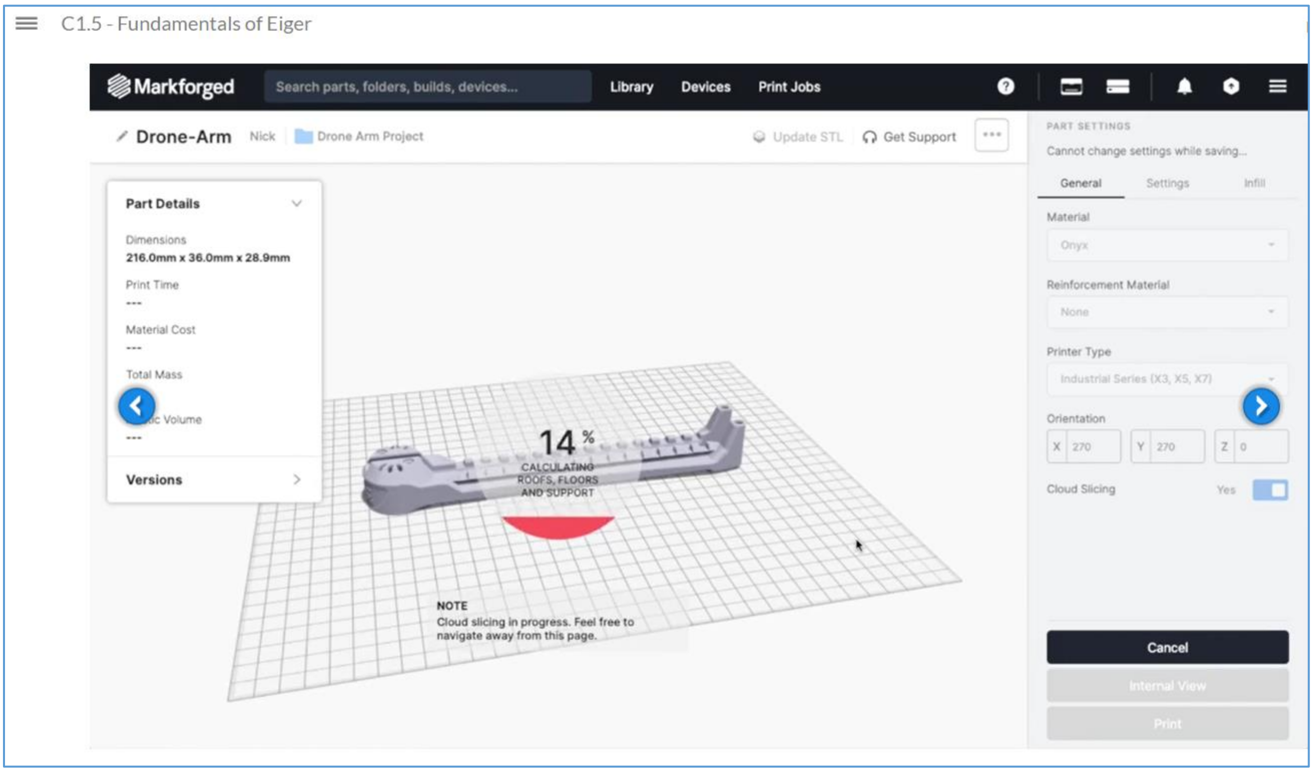


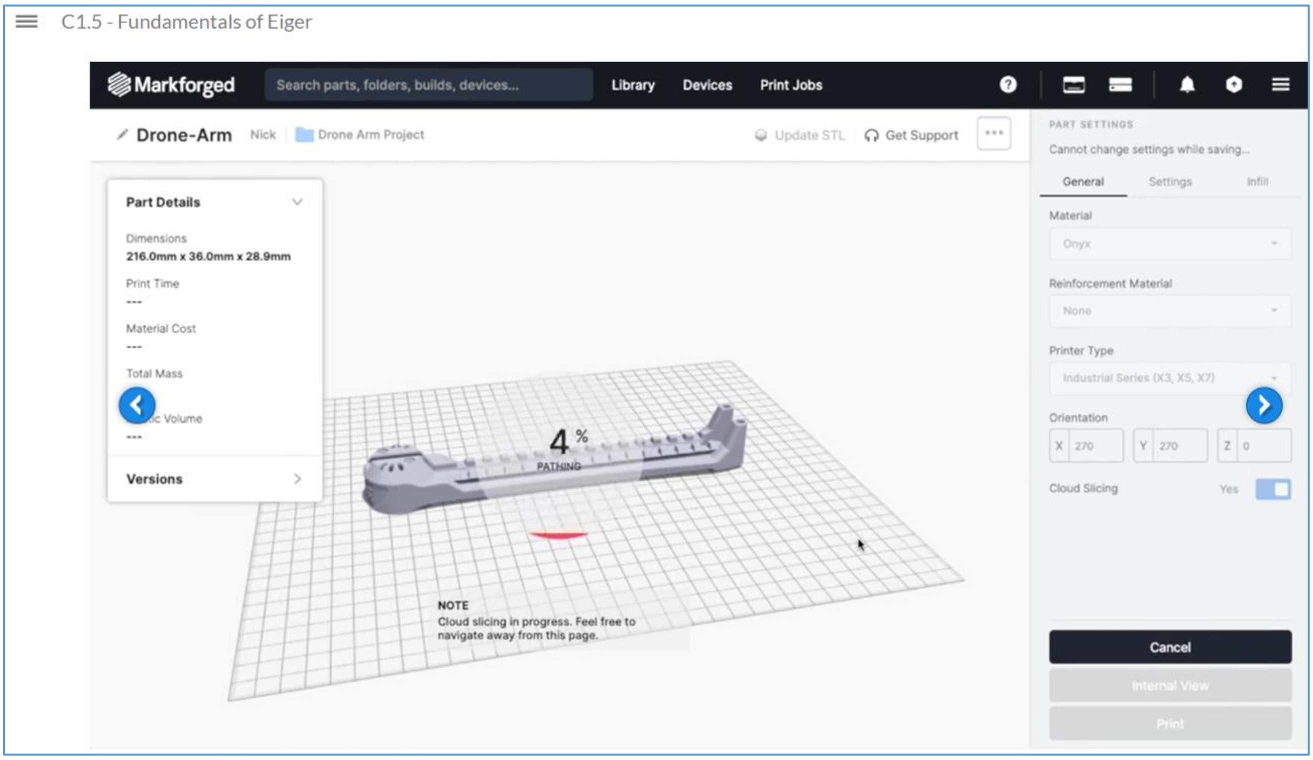
- Save this Configuration.

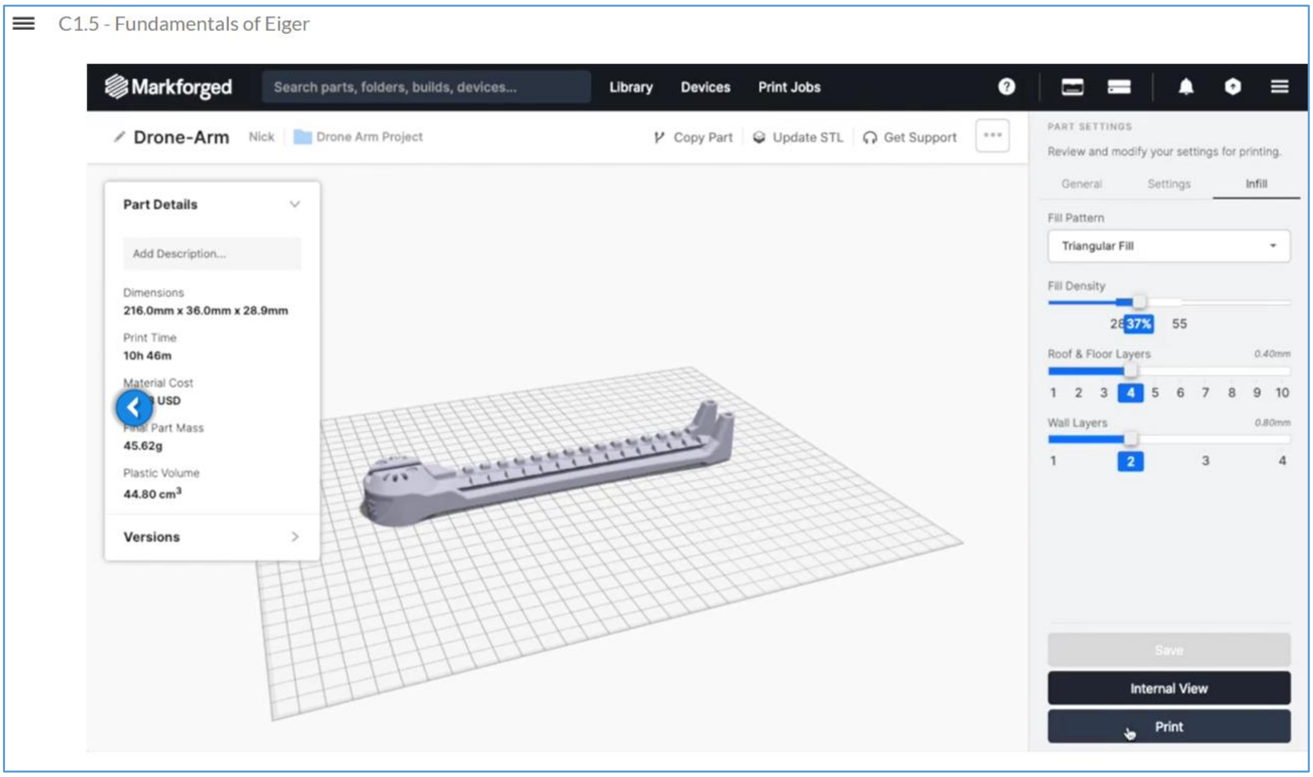

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Drone Arm Project
Update STL
Get Support
PART SETTINGS
Cannot change settings while saving...
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
X 270
Y 270
Z 0
Cloud Slicing
Yes
Save
Internal View
Print
Part Details
Dimensions
216.0mm x 36.0mm x 28.9mm
Print Time
Material Cost
Total Mass
Versions
92 %
UPLOADING DATA
NOTE
To avoid consuming extra system resources this process may pause if this page is minimized.


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Drone Arm Project
Update STL
Get Support
PART SETTINGS
Cannot change settings while saving...
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
X 270
Y 270
Z 0
Cloud Slicing
Yes
Cancel
Internal View
Print
Part Details
Dimensions
216.0mm x 36.0mm x 28.9mm
Print Time
Material Cost
Total Mass
Versions
100 %
SLICING
NOTE
Cloud slicing in progress. Feel free to navigate away from this page.

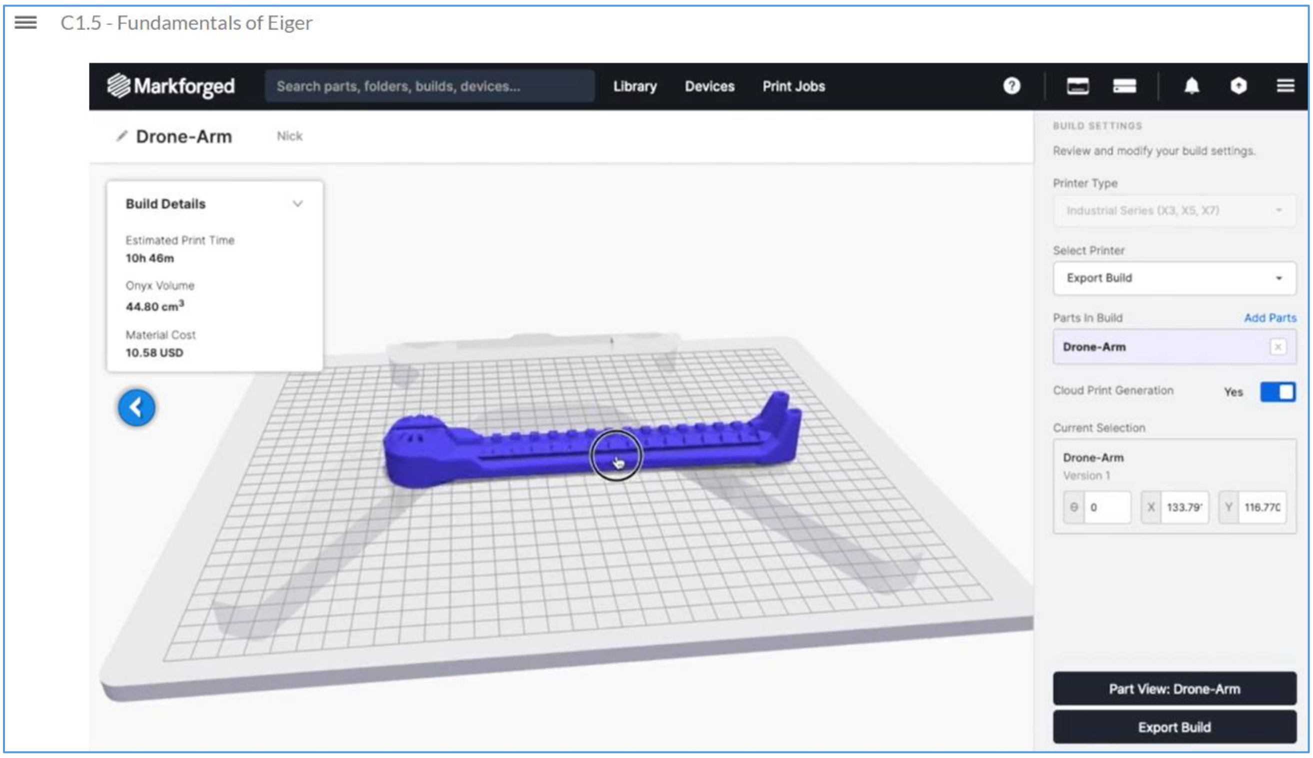
- Slicing.


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Drone Arm Project
Update STL
Get Support
Part Details
Dimensions
216.0mm x 36.0mm x 28.9mm
Print Time
Material Cost
Total Mass
Versions
14 %
CALCULATING ROOFS, FLOORS AND SUPPORT
NOTE
Cloud slicing in progress. Feel free to navigate away from this page.
PART SETTINGS
Cannot change settings while saving...
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Cloud Slicing
Yes
Cancel
Internal View
Print

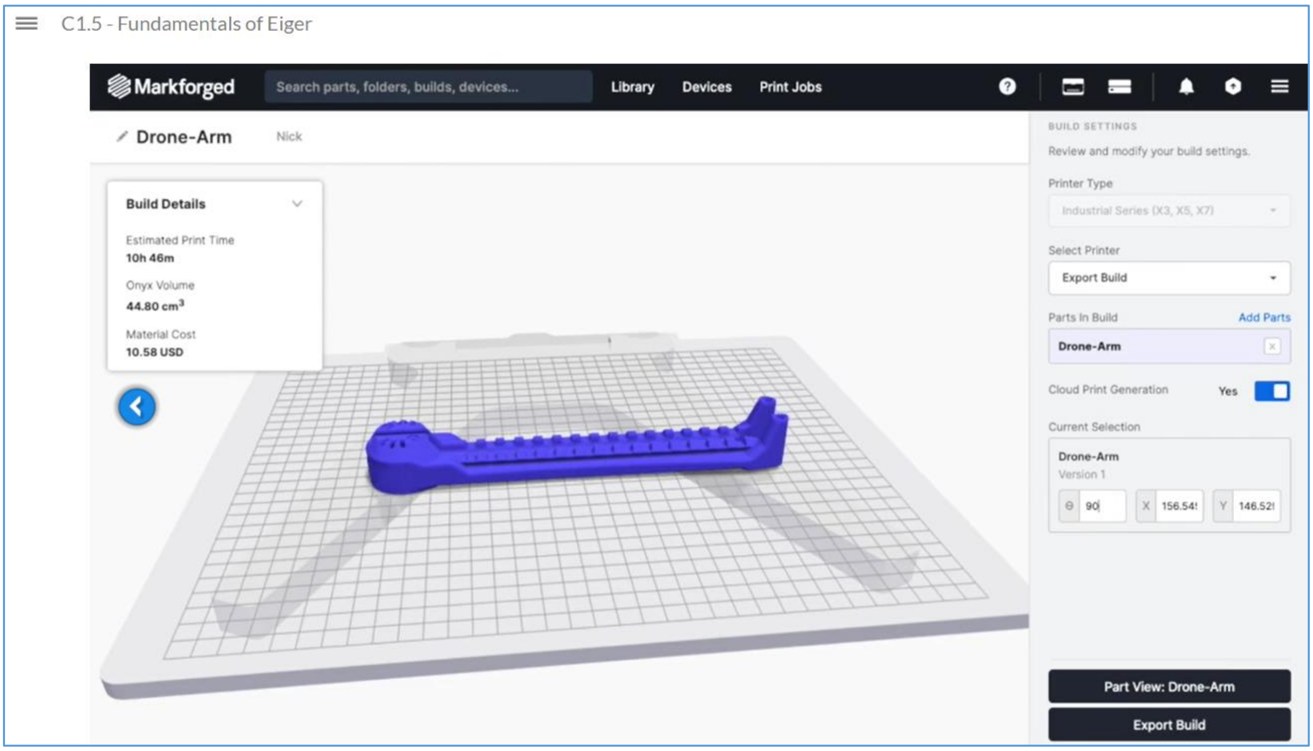

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Drone Arm Project
Update STL
Get Support
Part Details
Dimensions
216.0mm x 36.0mm x 28.9mm
Print Time
Material Cost
Total Mass
Versions
4 %
PATHING
NOTE
Cloud slicing in progress. Feel free to navigate away from this page.
PART SETTINGS
Cannot change settings while saving...
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Cloud Slicing
Yes
Cancel
Internal View
Print



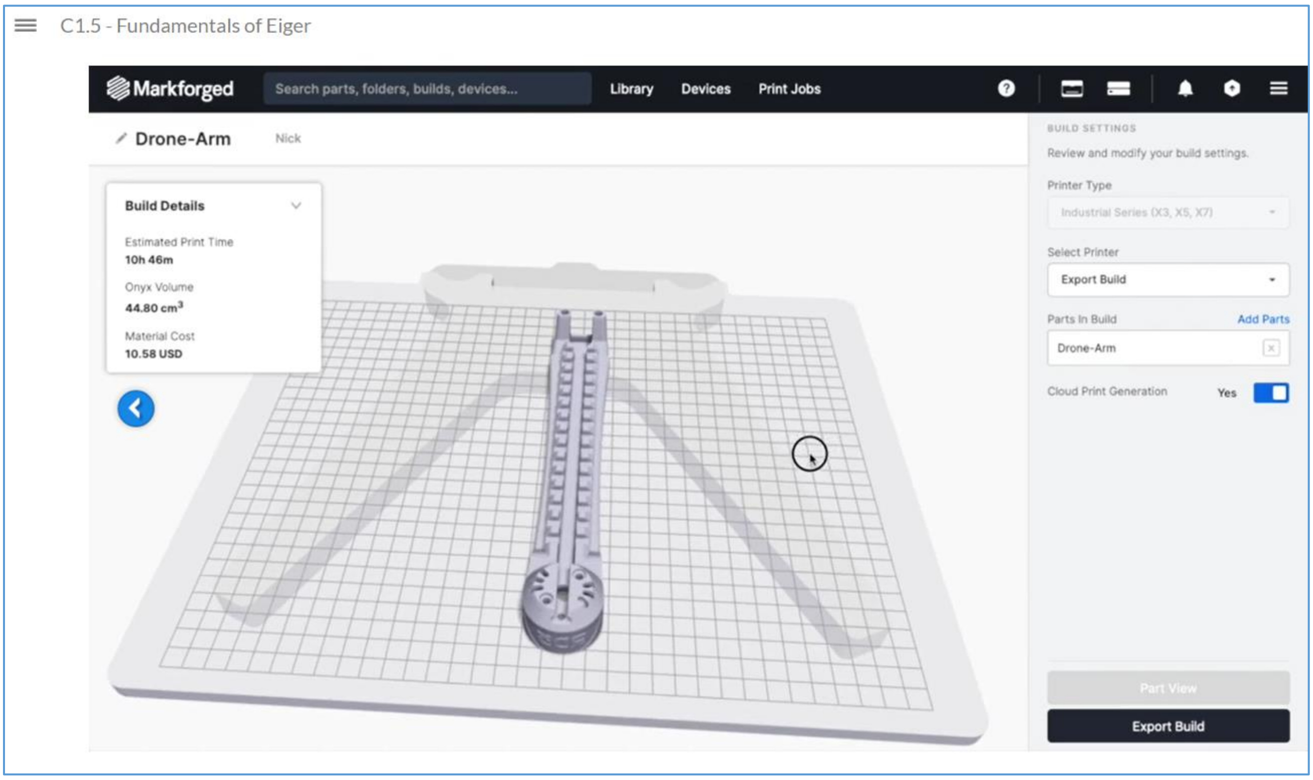
- Print the Drone Arm.



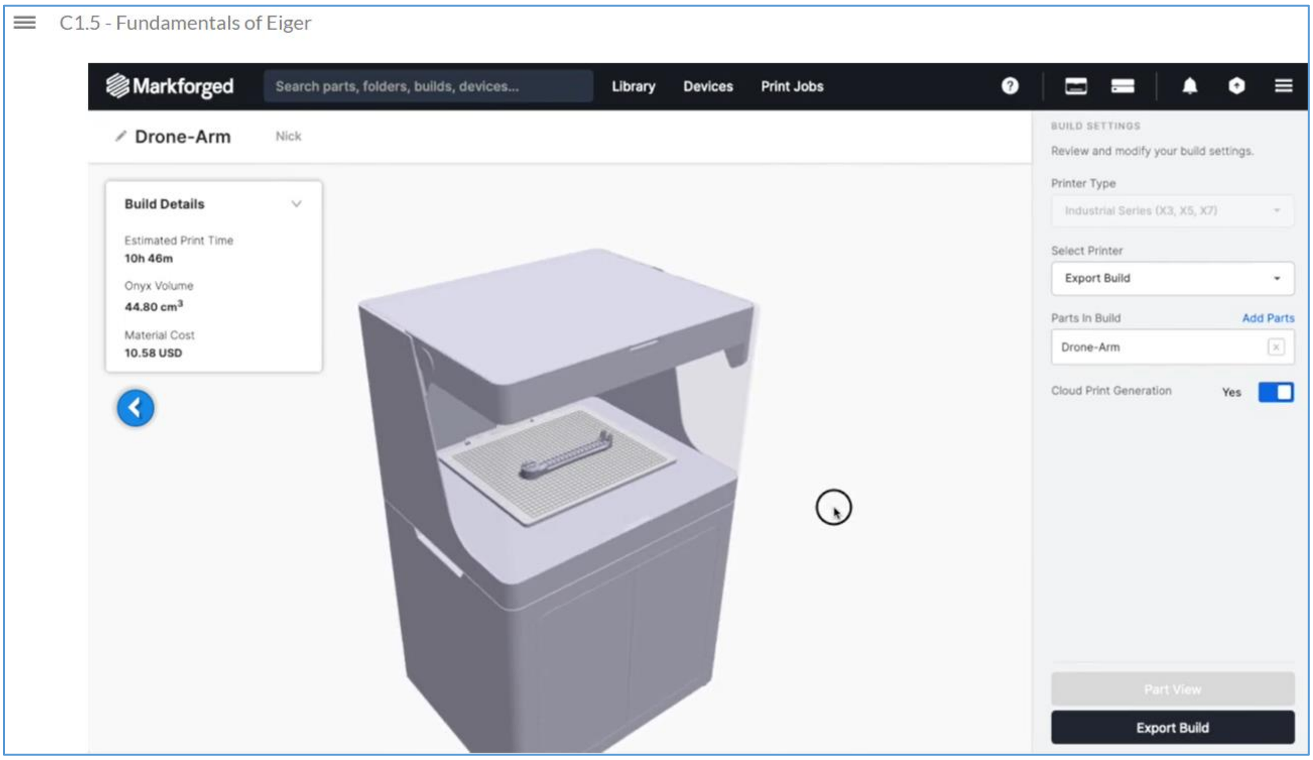
- Click and drag it for replacement on the printbed.



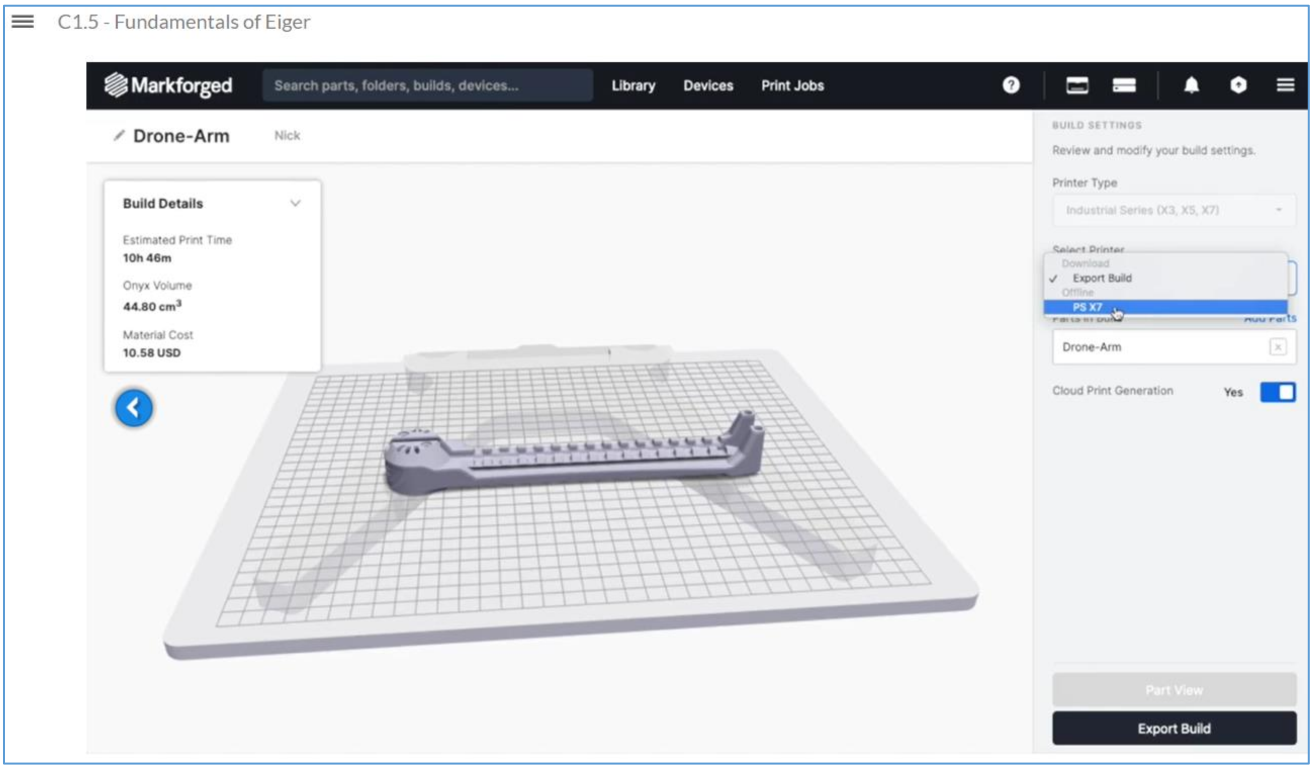
- Manually enter a value.



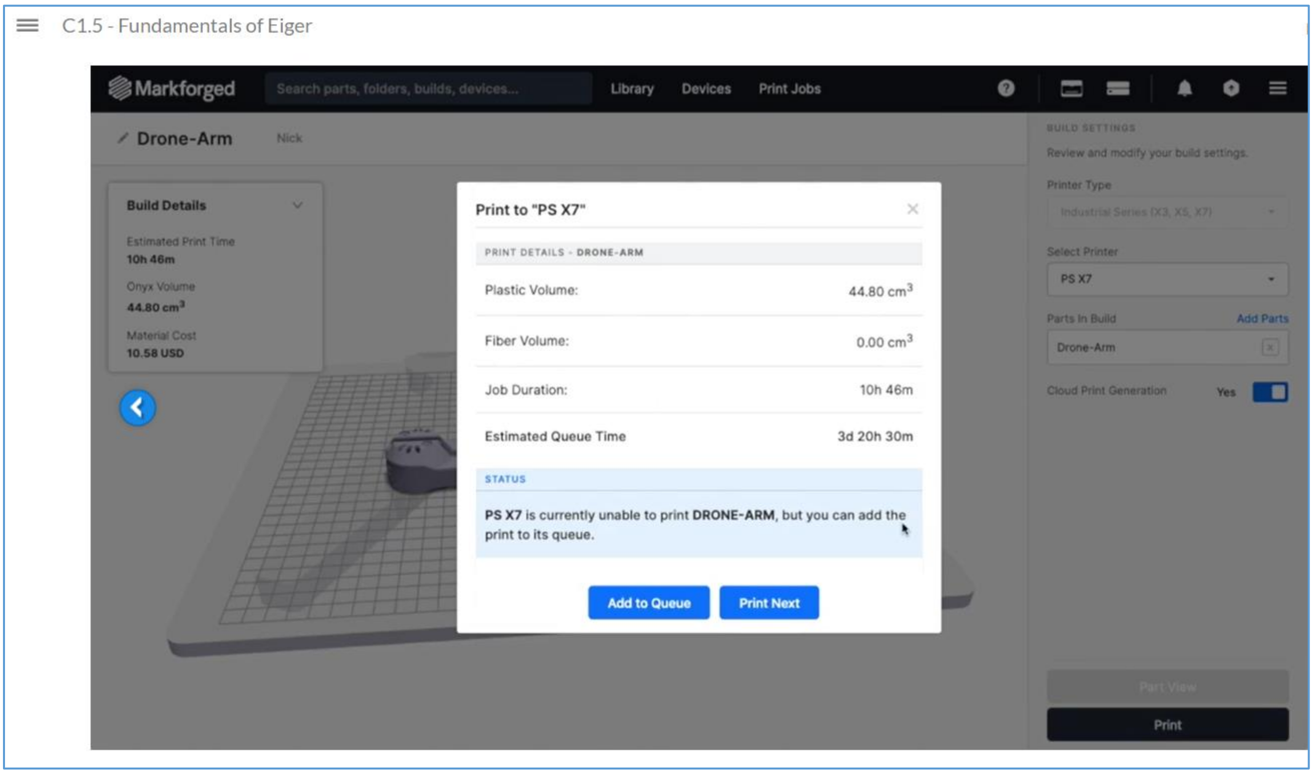
- And the result of 90 degrees turning.

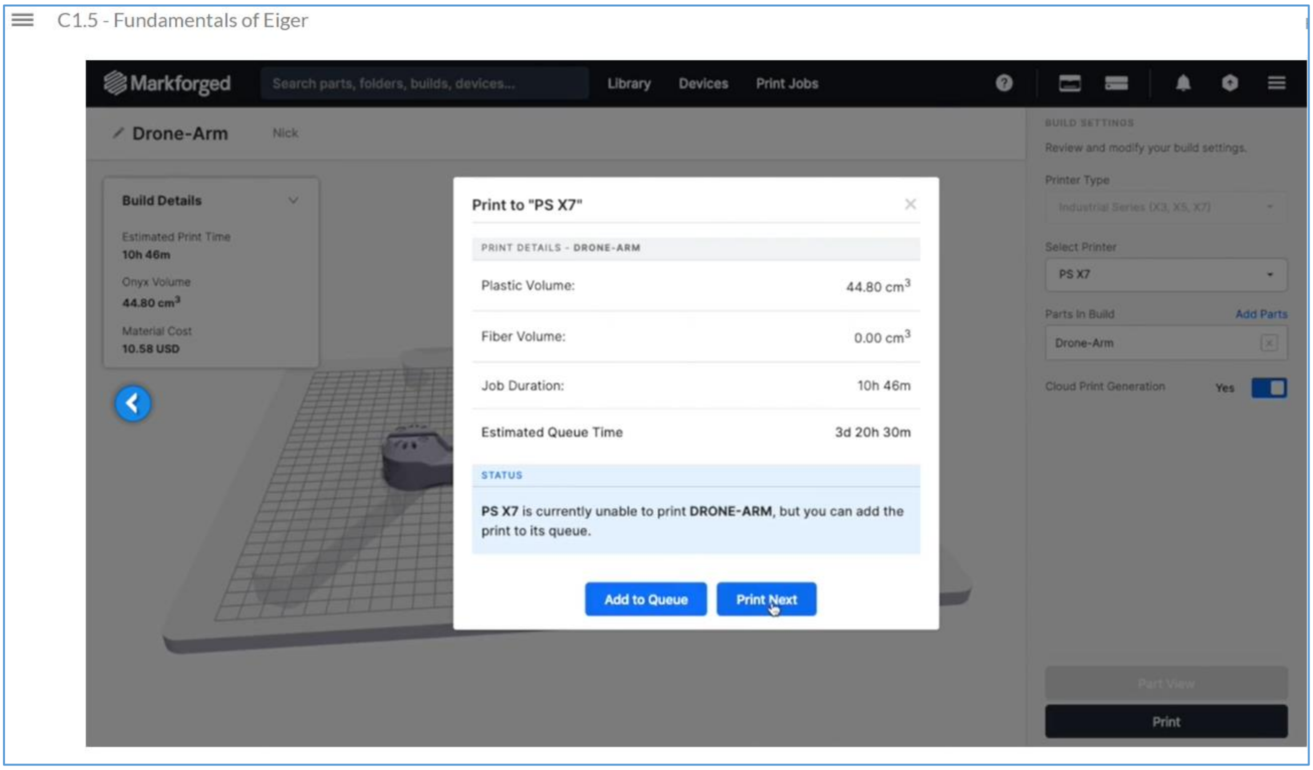


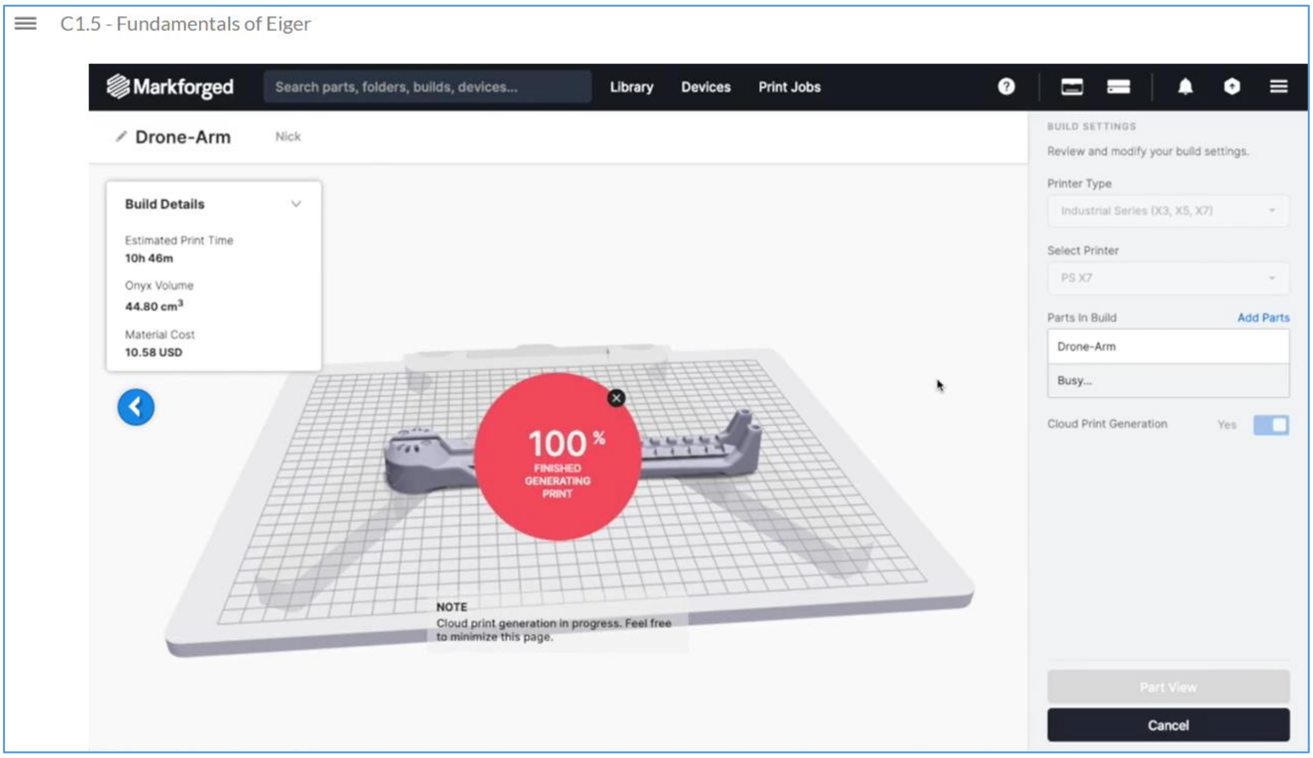
- Zooming In and Out.



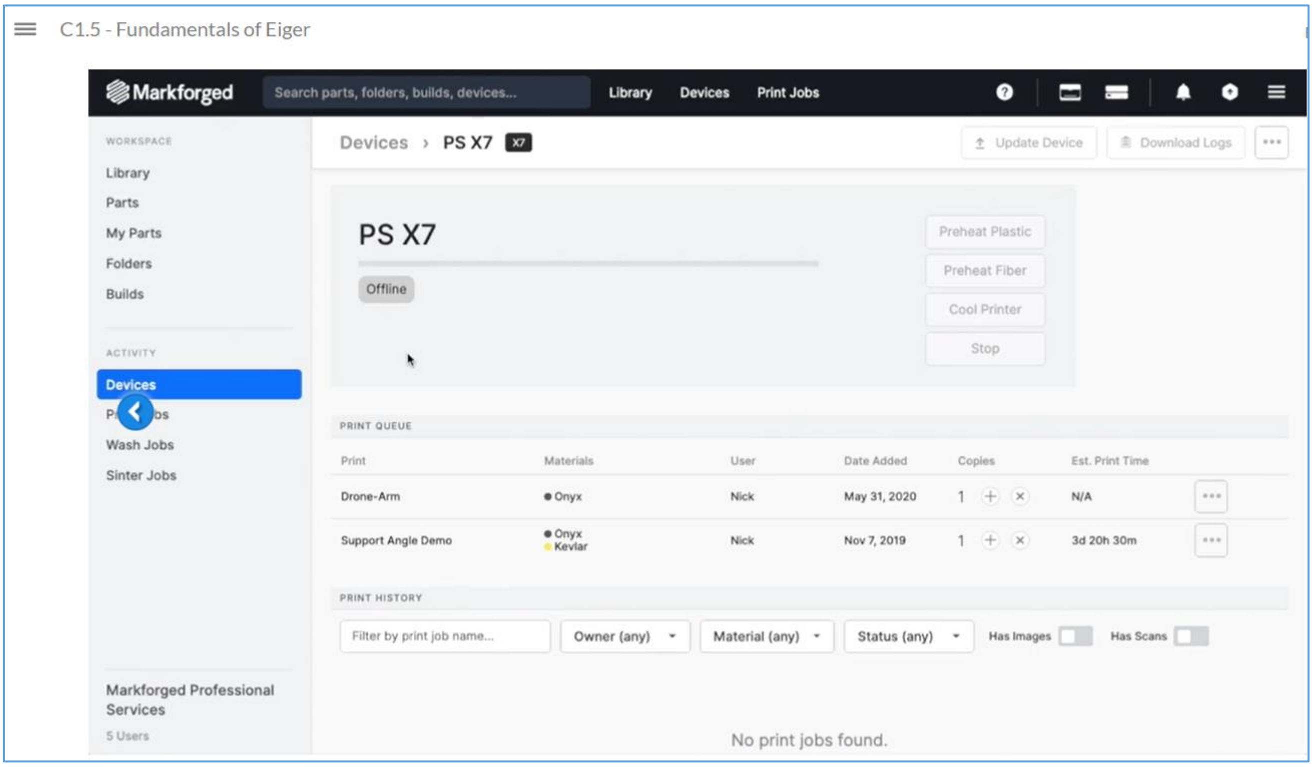
- Selecting the Printer you want to use.

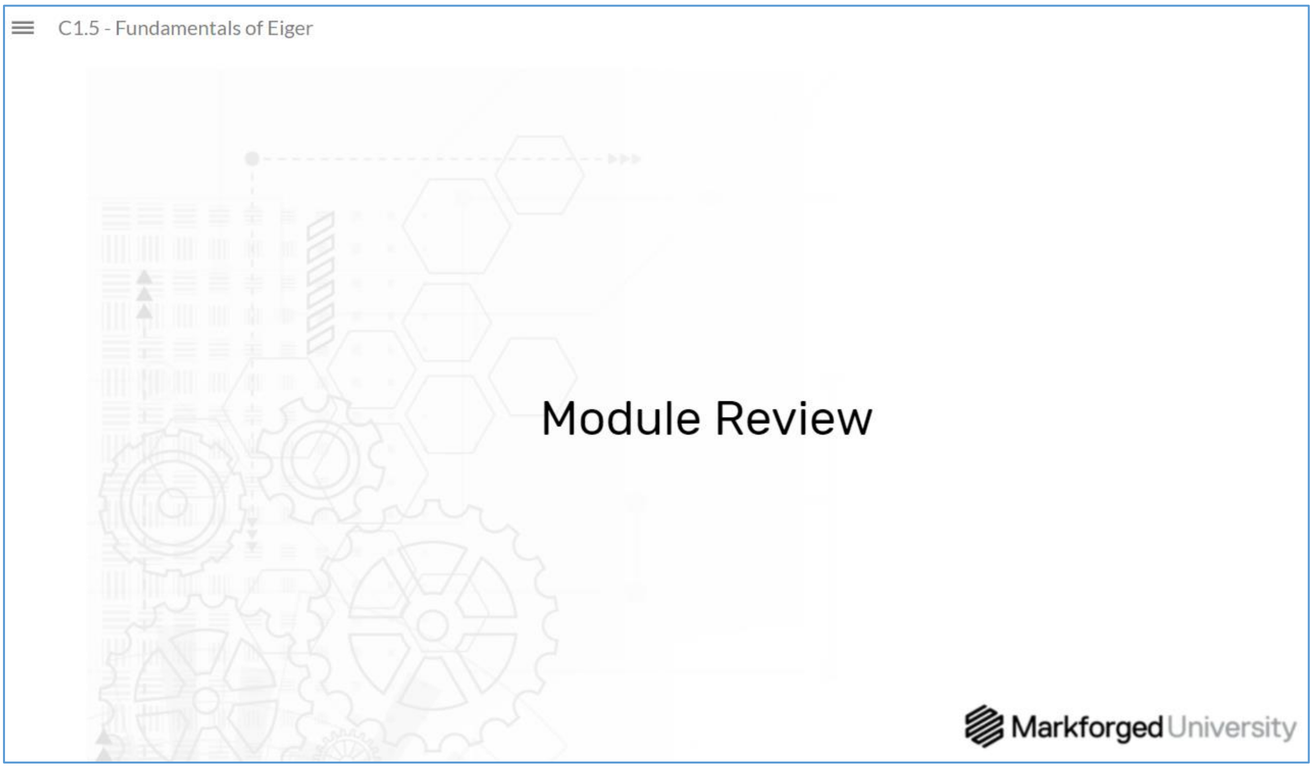

C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Build Details
Estimated Print Time
10h 46m
Onyx Volume
44.80 cm³
Material Cost
10.58 USD
Print to "PS X7"
PRINT DETAILS - DRONE-ARM
Plastic Volume: 44.80 cm³
Fiber Volume: 0.00 cm³
Job Duration: 10h 46m
Estimated Queue Time 3d 20h 30m
STATUS
PS X7 is currently unable to print DRONE-ARM, but you can add the print to its queue.
Add to Queue
Print Next
BUILD SETTINGS
Review and modify your build settings.
Printer Type
Industrial Series (X3, X5, X7)
Select Printer
PS X7
Parts In Build
Add Parts
Drone-Arm
Cloud Print Generation
Yes
Part View
Print


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Build Details
Estimated Print Time
10h 46m
Onyx Volume
44.80 cm³
Material Cost
10.58 USD
Print to "PS X7"
PRINT DETAILS - DRONE-ARM
Plastic Volume: 44.80 cm³
Fiber Volume: 0.00 cm³
Job Duration: 10h 46m
Estimated Queue Time 3d 20h 30m
STATUS
PS X7 is currently unable to print DRONE-ARM, but you can add the print to its queue.
Add to Queue
Print Next
BUILD SETTINGS
Review and modify your build settings.
Printer Type
Industrial Series (X3, X5, X7)
Select Printer
PS X7
Parts In Build
Add Parts
Drone-Arm
Cloud Print Generation
Yes
Part View
Print



- After “Printing Next”





- **Model Review**

C1.5 - Fundamentals of Eiger

Place the following steps in order for the CAD-to-part workflow of a CFF-reinforced 3D printed part.

1. Export the part as an STL and import it into Eiger
2. Sit back and relax while your part prints!
3. Orient the part and configure its materials and fiber layout
4. Design a part in CAD
5. Slice the part and send a print to an available 3D printer

Markforged University

Place the following steps in order for the CAD-to-part workflow of a CFF-reinforced 3D printed part.

1. Design a part in CAD
2. Export the part as an STL and import it into Eiger
3. Orient the part and configure its materials and fiber layout
4. Slice the part and send a print to an available 3D printer
5. Sit back and relax while your part prints!

Markforged University

C1.5 - Fundamentals of Eiger

Place the following steps in order for the CAD-to-part workflow of a CFF-reinforced 3D printed part.

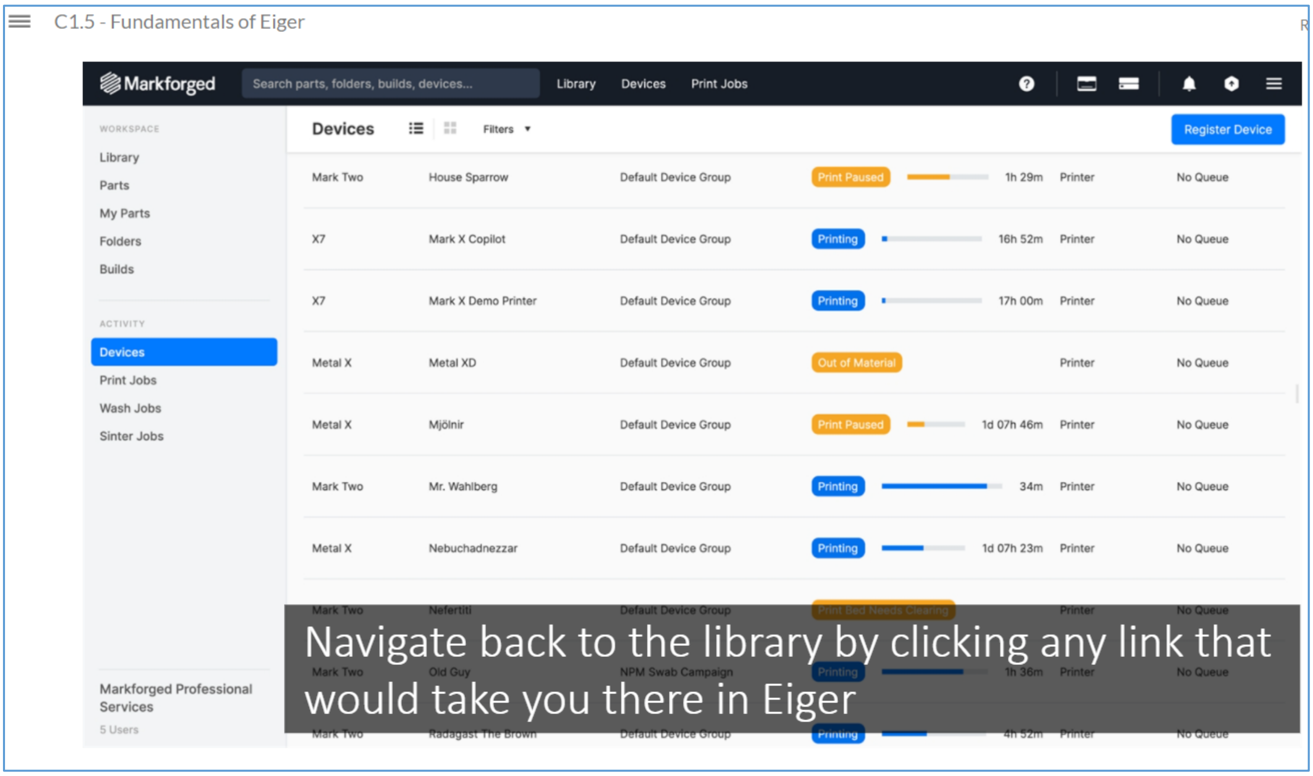
1. Design a
2. Export th
3. Orient the
4. Slice the
5. Sit back a

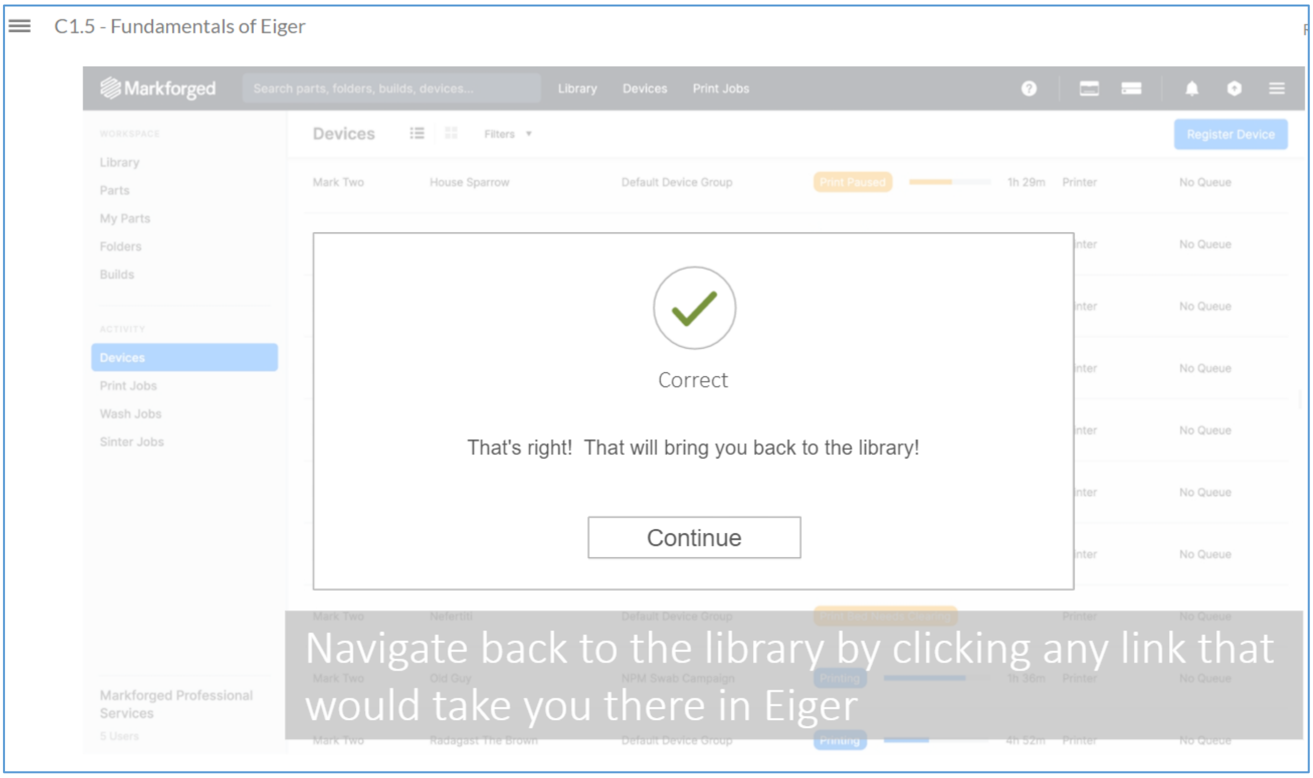
Correct

That's right! You selected the correct response.

Continue

Markforged University


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
WORKSPACE
Library
Parts
My Parts
Folders
Builds
ACTIVITY
Devices
Print Jobs
Wash Jobs
Sinter Jobs
Markforged Professional Services
5 Users
Devices
Filters
Register Device
Mark Two House Sparrow Default Device Group Print Paused 1h 29m Printer No Queue
X7 Mark X Copilot Default Device Group Printing 16h 52m Printer No Queue
X7 Mark X Demo Printer Default Device Group Printing 17h 00m Printer No Queue
Metal X Metal XD Default Device Group Out of Material Printer No Queue
Metal X Mjölnir Default Device Group Print Paused 1d 07h 46m Printer No Queue
Mark Two Mr. Wahlberg Default Device Group Printing 34m Printer No Queue
Metal X Nebuchadnezzar Default Device Group Printing 1d 07h 23m Printer No Queue
Navigate back to the library by clicking any link that would take you there in Eiger


C1.5 - Fundamentals of Eiger
Markforged
Library
Devices
Print Jobs
Devices
Register Device
Correct
That's right! That will bring you back to the library!
Continue
Navigate back to the library by clicking any link that would take you there in Eiger

C1.5 - Fundamentals of Eiger

Check all that can be contained in an Eiger Organization

- [ ] CFF filament spools
- [ ] CNC machining centers
- [x] Teams (Enterprise Eiger only)
- [x] Print history data
- [x] Oriented and configured parts
- [x] Printers
- [x] Users

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C1.5 - Fundamentals of Eiger

Check all that can be contained in an Eiger Organization

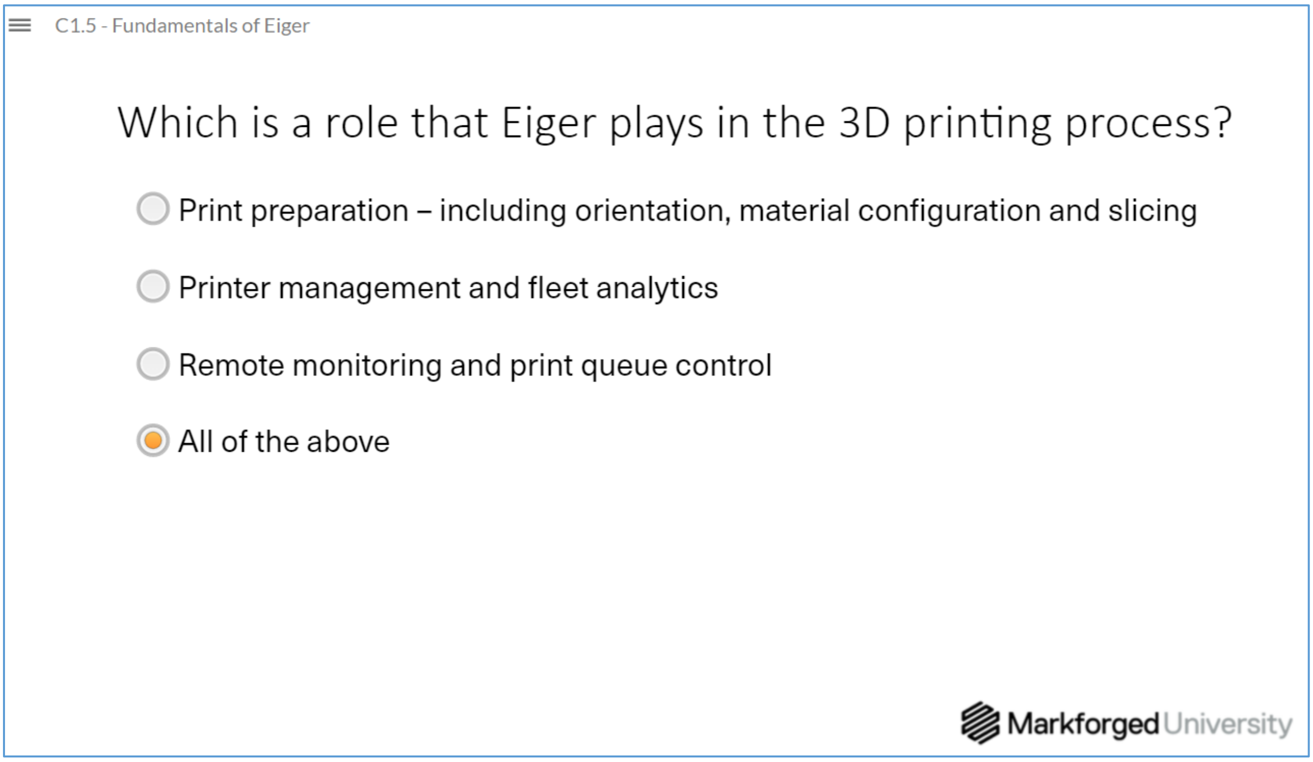
- [ ] CFF filament spools
- [ ] CNC mach
- [x] Teams (En
- [x] Print histo
- [x] Oriented a
- [x] Printers
- [x] Users

Correct

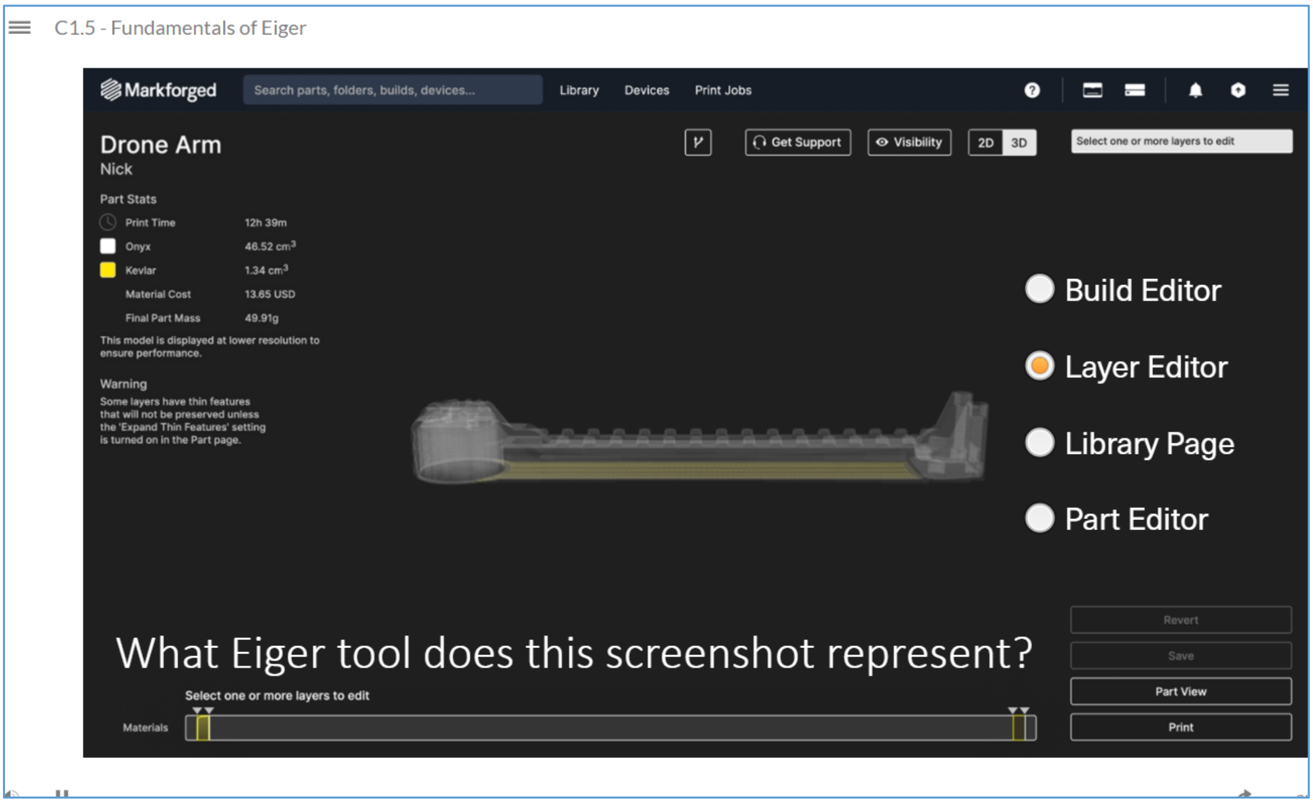
That's right! All of these are things that are part of an Eiger Organization.

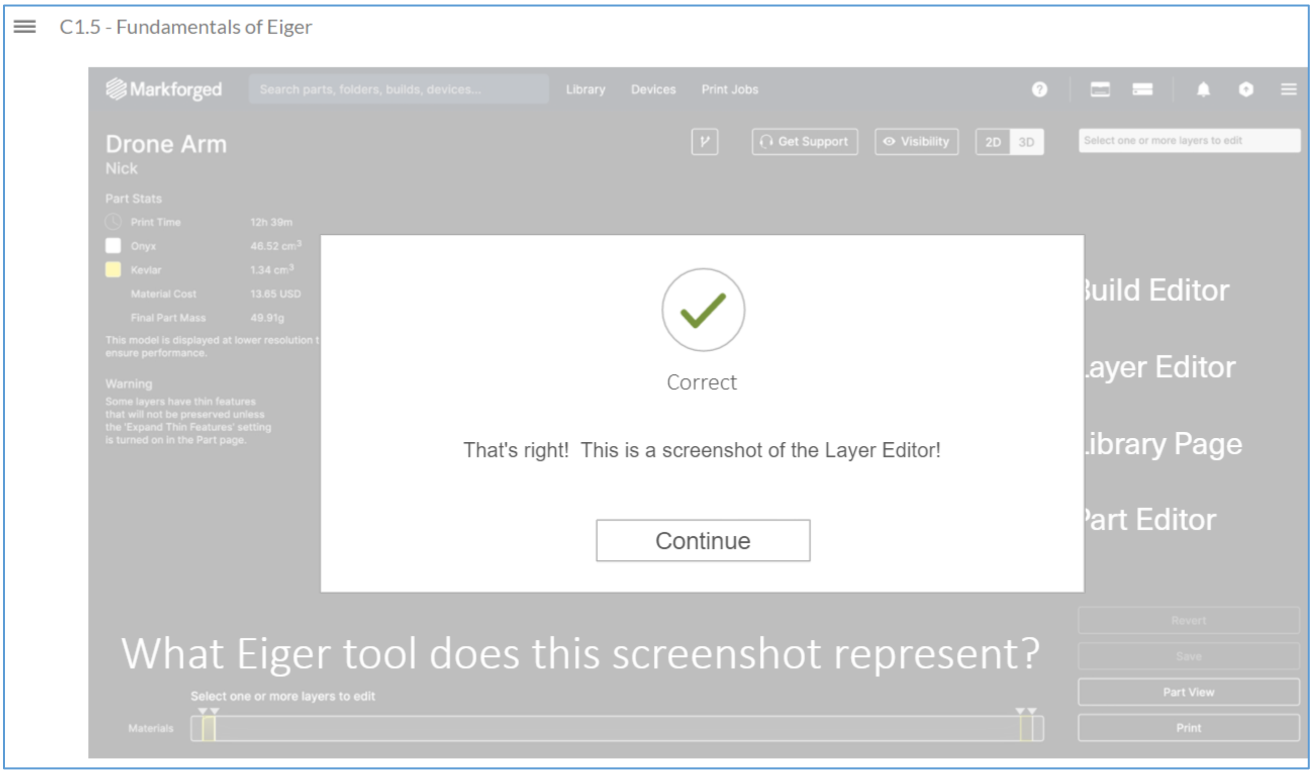
Continue

Markforged University


C1.5 - Fundamentals of Eiger
Which is a role that Eiger plays in the 3D printing process?
Print preparation – including orientation, material configuration and slicing
Printer management and fleet analytics
Remote monitoring and print queue control
All of the above
Markforged University


C1.5 - Fundamentals of Eiger
Which is a role that Eiger plays in the 3D printing process?
Print preparation – including orientation, material configuration and slicing
Correct
That's right! You selected the correct response.
Continue
Markforged University


C1.5 - Fundamentals of Eiger
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone Arm
Nick
Get Support
Visibility
2D
3D
Select one or more layers to edit
Part Stats
Print Time
12h 39m
Onyx
46.52 cm³
Kevlar
1.34 cm³
Material Cost
13.65 USD
Final Part Mass
49.91g
This model is displayed at lower resolution to ensure performance.
Warning
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Build Editor
Layer Editor
Library Page
Part Editor
What Eiger tool does this screenshot represent?
Revert
Save
Part View
Print
Materials


C1.5 - Fundamentals of Eiger
Correct
That's right! This is a screenshot of the Layer Editor!
Continue
What Eiger tool does this screenshot represent?

C1.5 - Fundamentals of Eiger

Results

Your Score: 100% (50 points)

Passing Score: 80% (40 points)

Result:

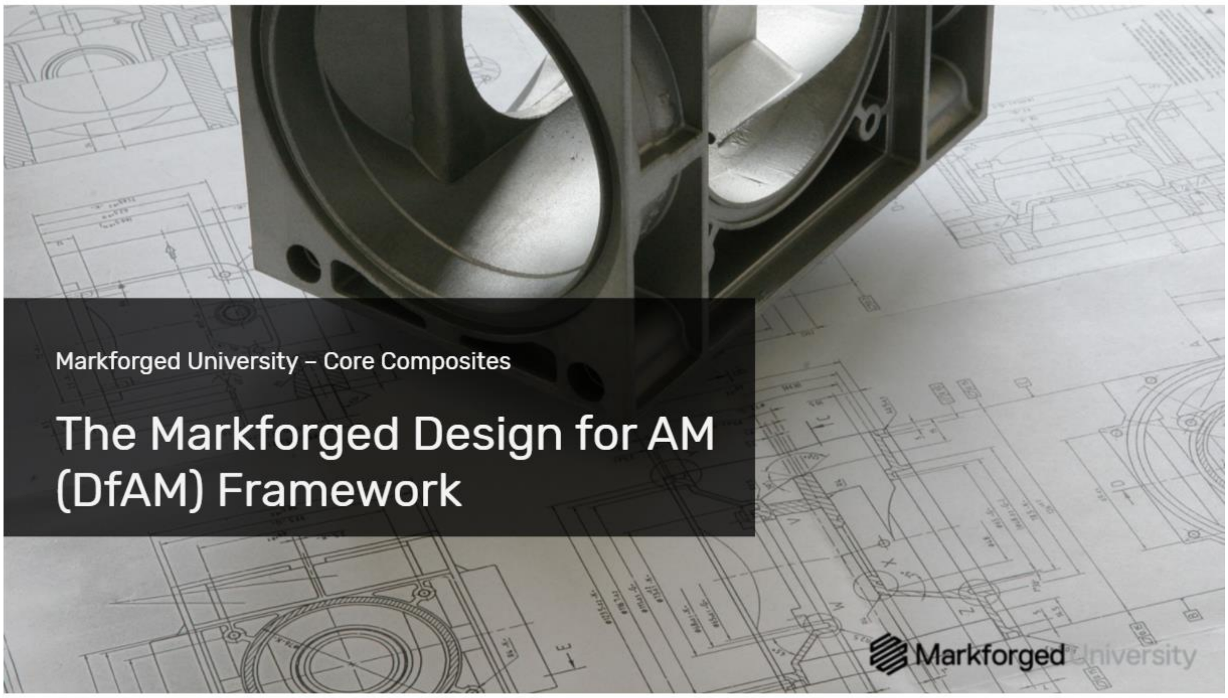
Congratulations, you passed.

Finish Module

Review Quiz

C.1.6. The Markforged Design for AM (DfAM) Framework

C1.6 - The Markforged Design for AM (DfAM) Framework



- AM = [Additive Manufacturing](#)

C1.6 - The Markforged Design for AM (DfAM) Framework

Module Overview

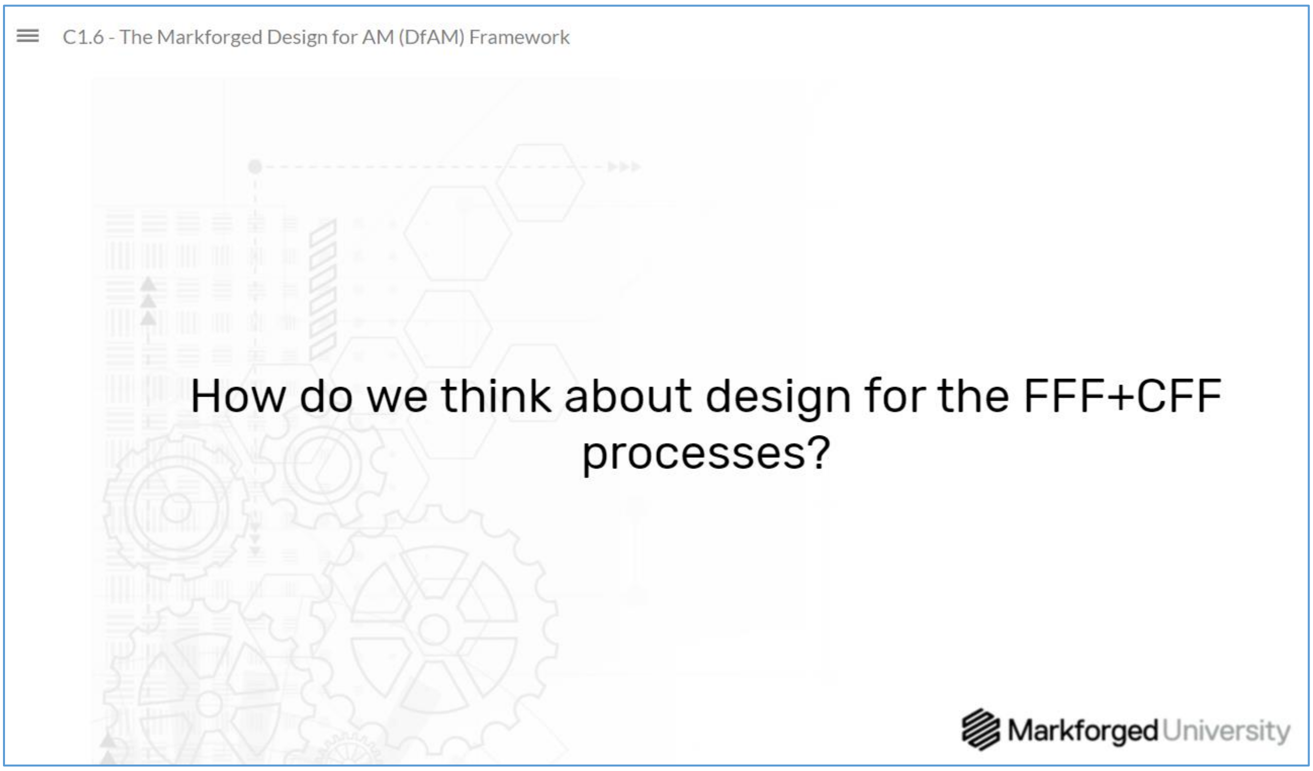
Intro to the Markforged DfAM Framework

Case Study: Dixon Valve and Coupling Co.

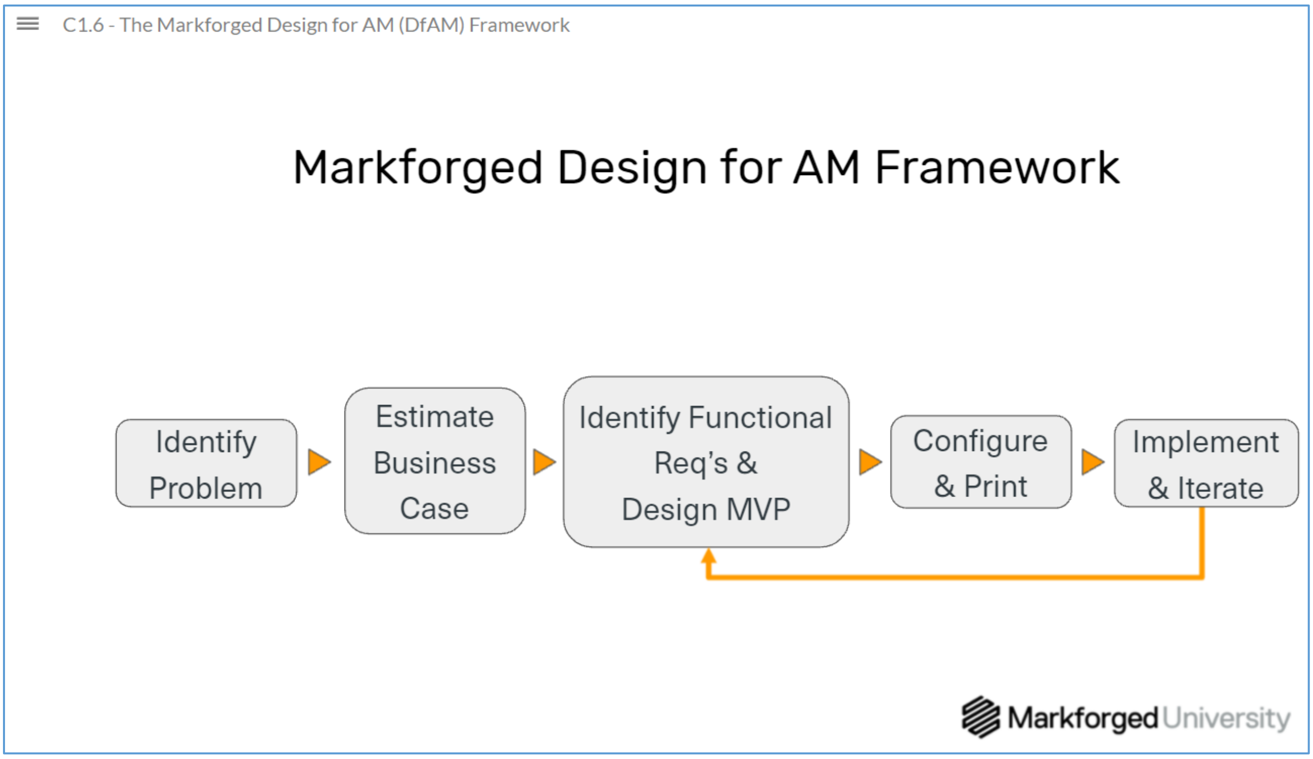
- Business Challenge
- Technical Hurdles
- Result and ROI

Markforged University

- **Model overview**

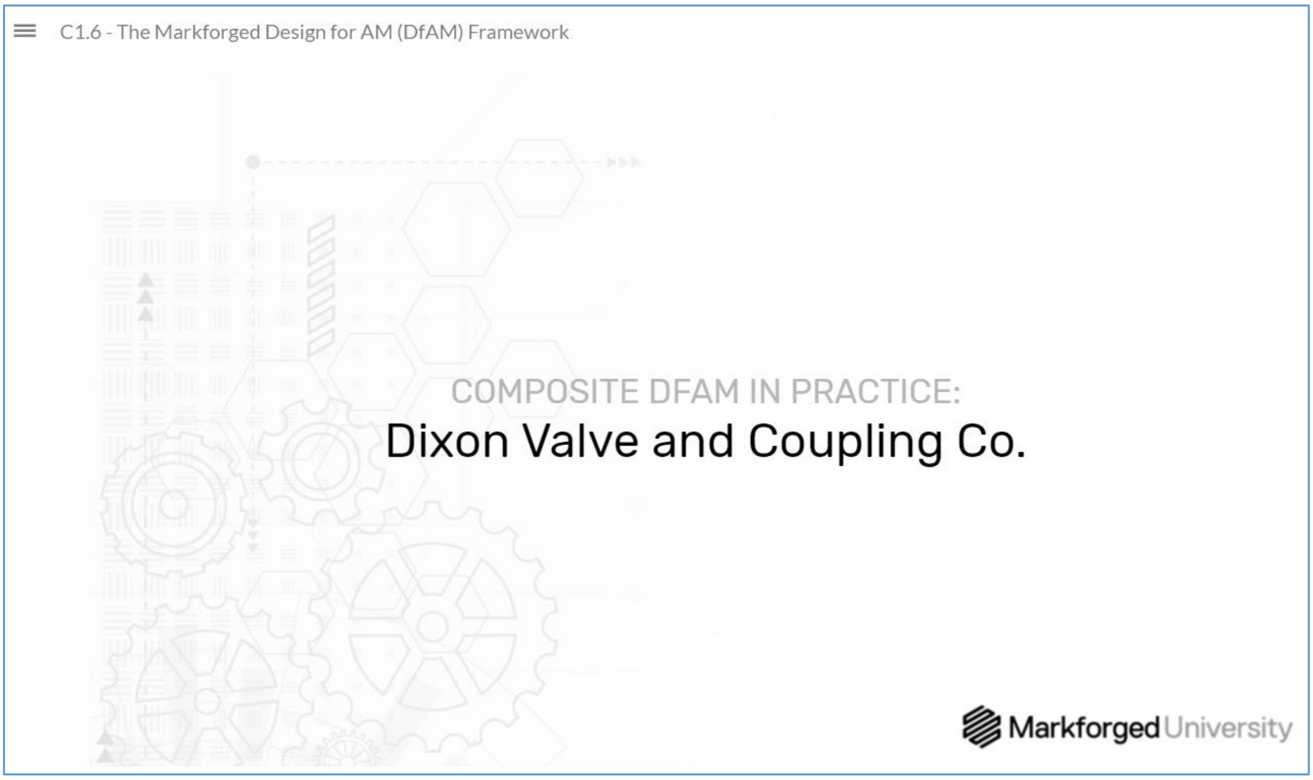


- **How do we think about design for the FFF+CFF processes?**

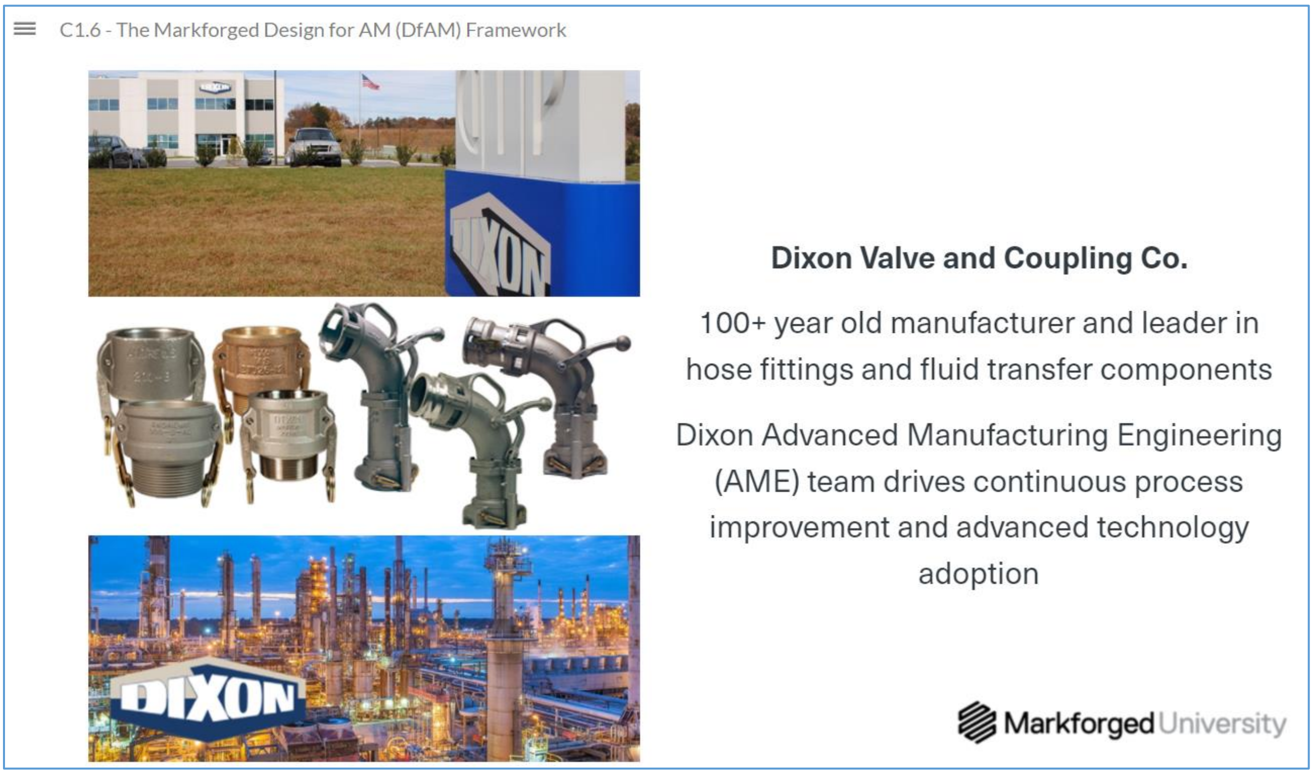


- **Markforged Design for AM Framework**

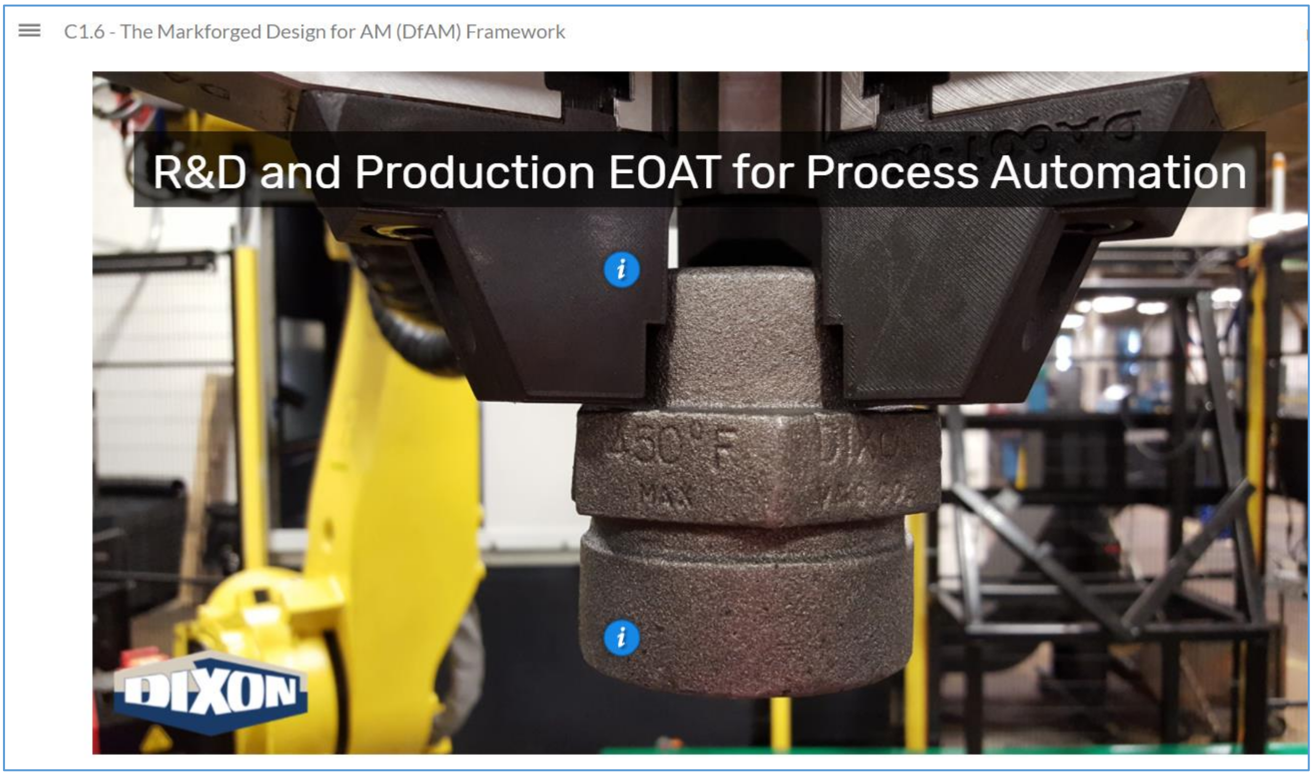
- Identify Problem: Bijvoorbeeld een onderdeel in een fabricageproces wat steeds stuk gaat. Je kan hem anders construeren of een beschermbumper of iets dergelijks maken. Dit om down time te verlagen.
- Schatten: Hoeveel heb je er nodig? In 1 keer, of verspreid over langer tijd? Misschien kiezen voor om het onderdeel anders te produceren (stel als er heel veel nodig hebt). Kortom: worden de kosten daadwerkelijk gereduceerd, met het printen van het onderdeel?
- MVP = Minimum viable product. Translate: Minimaal levensvatbaar product.
- Configure and Print: Oriantation? Reinforcement with wich material?
- Implement & Iterate (Iterate = herhalen = sequentieel = opeenvolgend). Als uit (destructieve) test blijkt dat het onderdeel bijvoorbeeld te zwak is: opnieuw configureren.



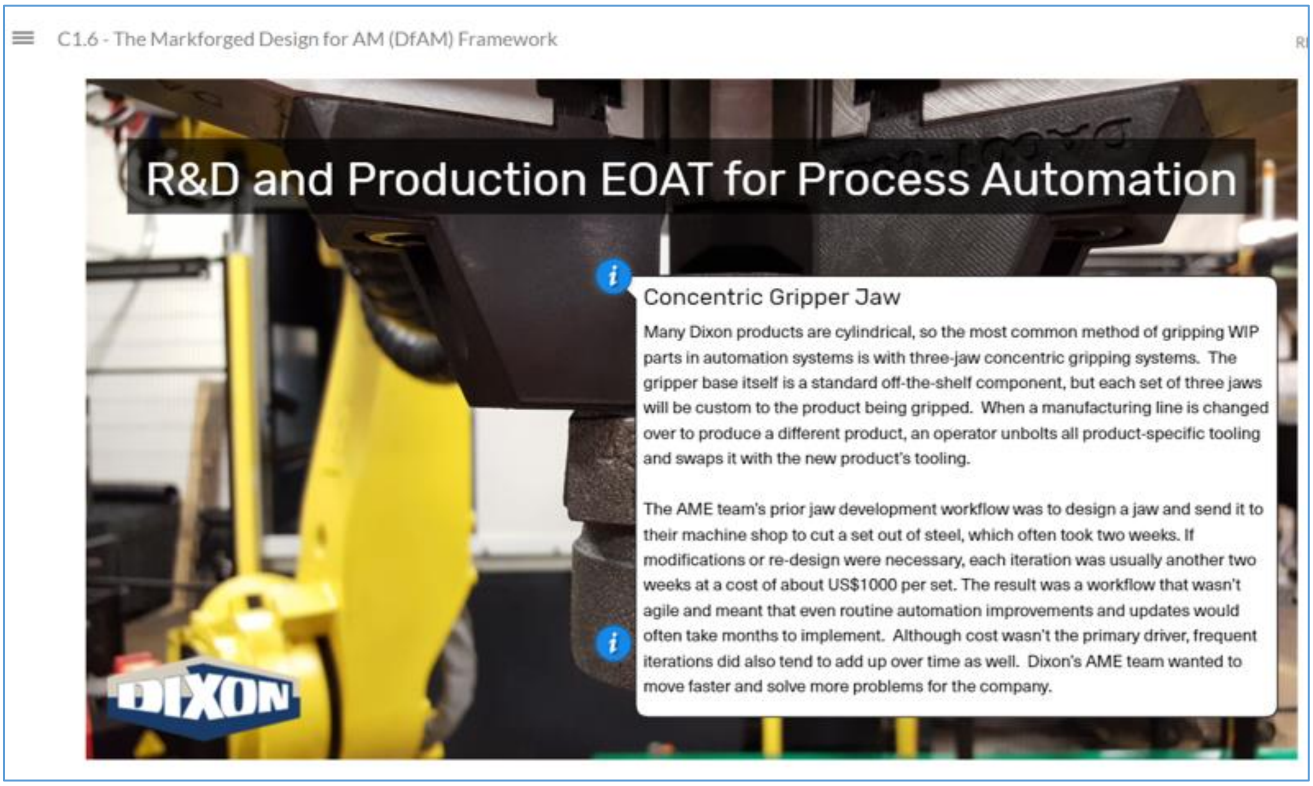
- **Markforged Design for AM Framwork**
  - Example.



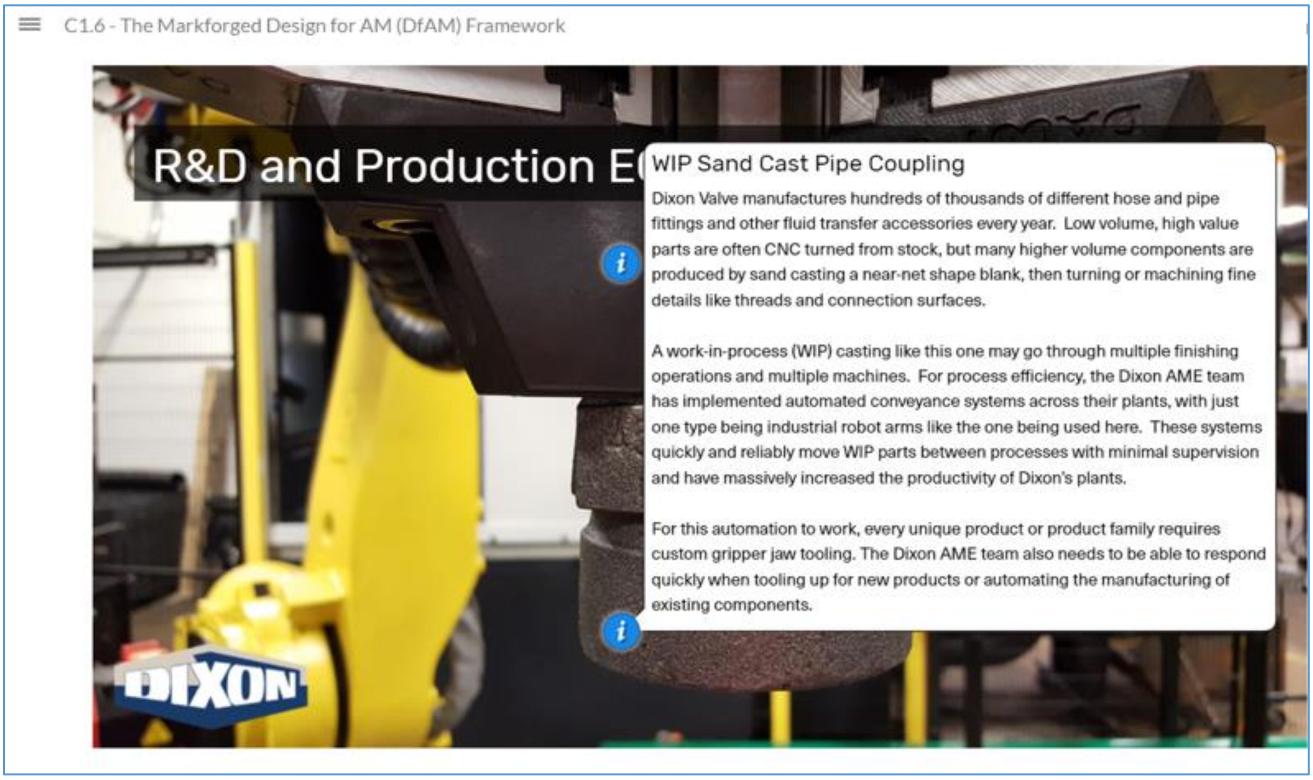
- **Dixon valve and the AME-team**

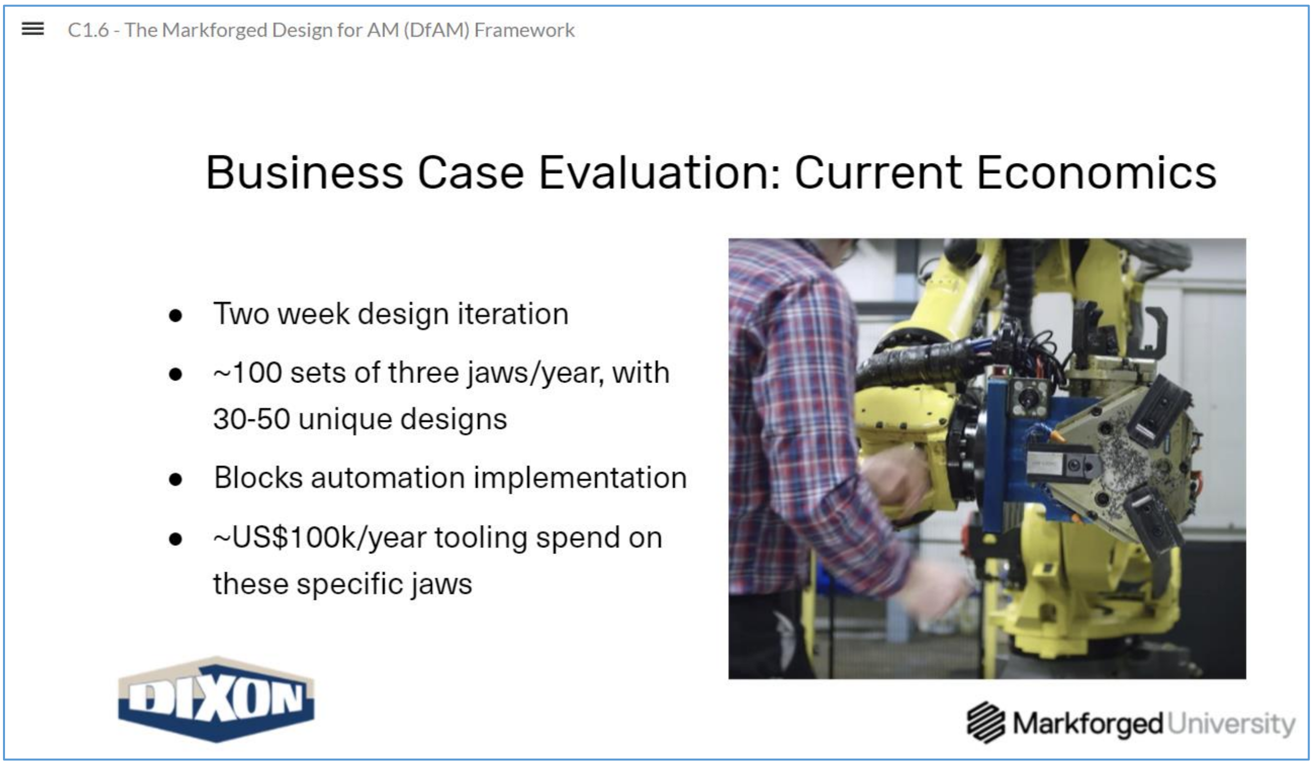


- **End-of-arm Tooling for Plant Automation**

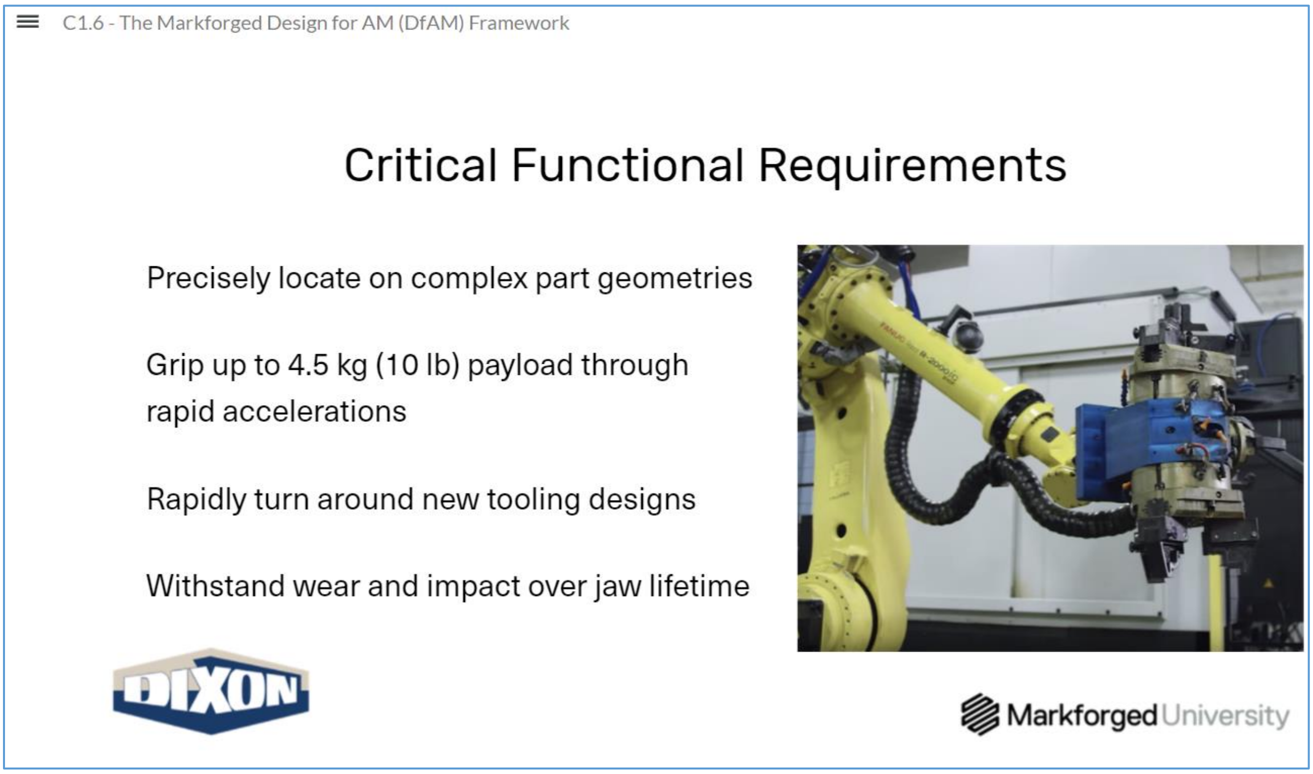


- Agile = Behendig
- Tend = neigen tot

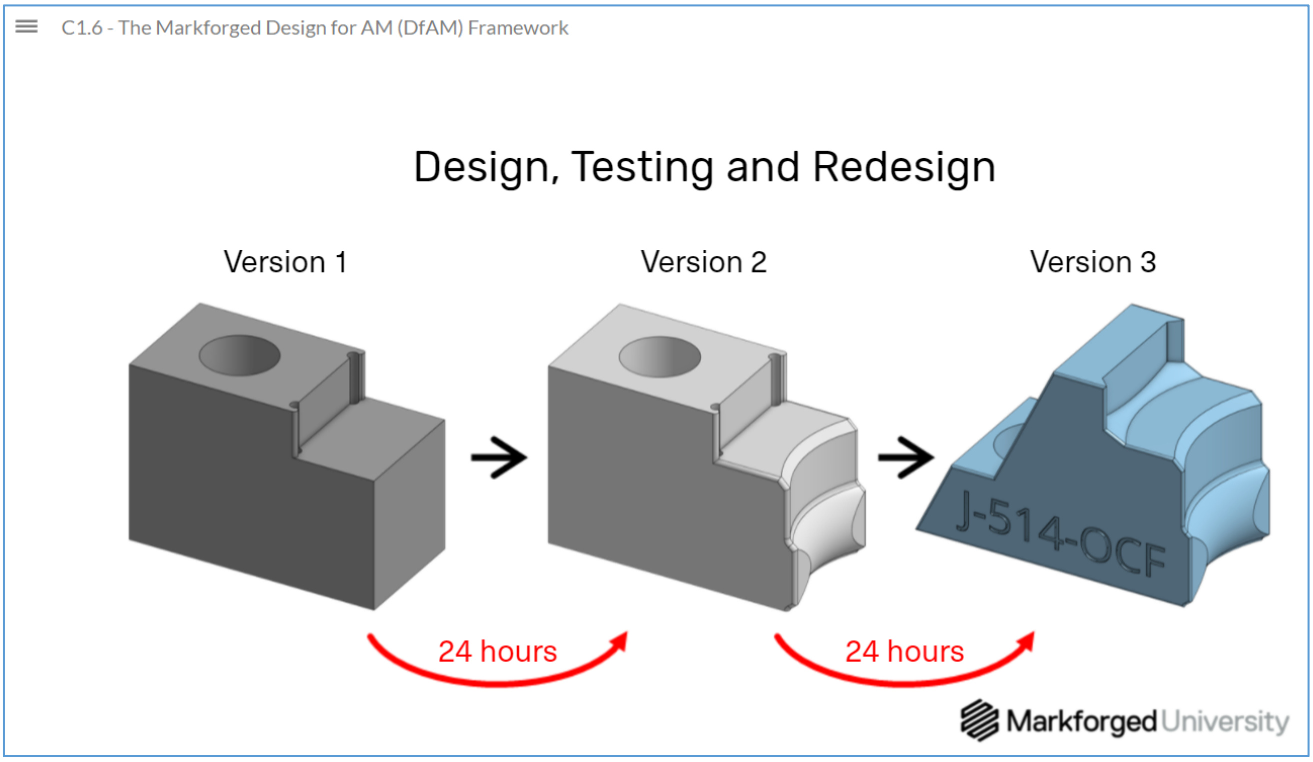




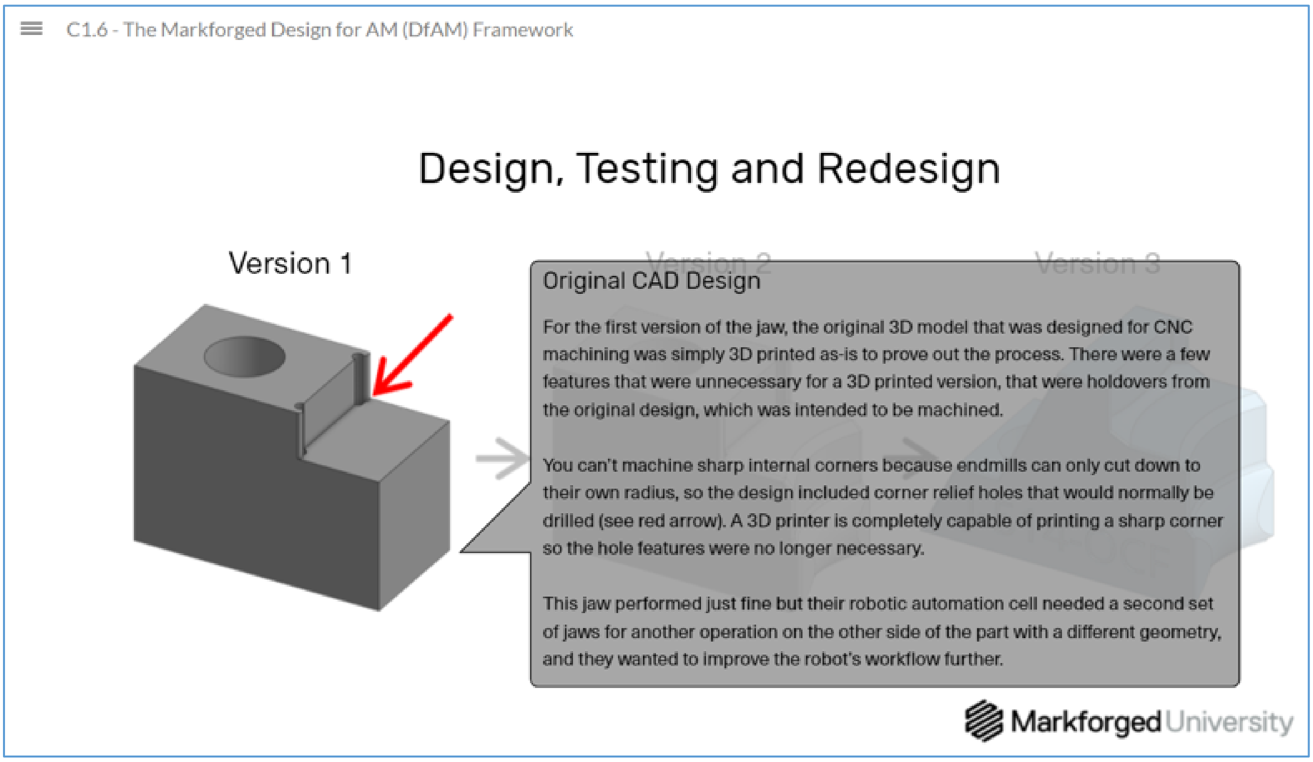
- **Business Case Evaluation**
    - Kostenreductie en levertijd van bijvoorbeeld 2 weken naar 24h.

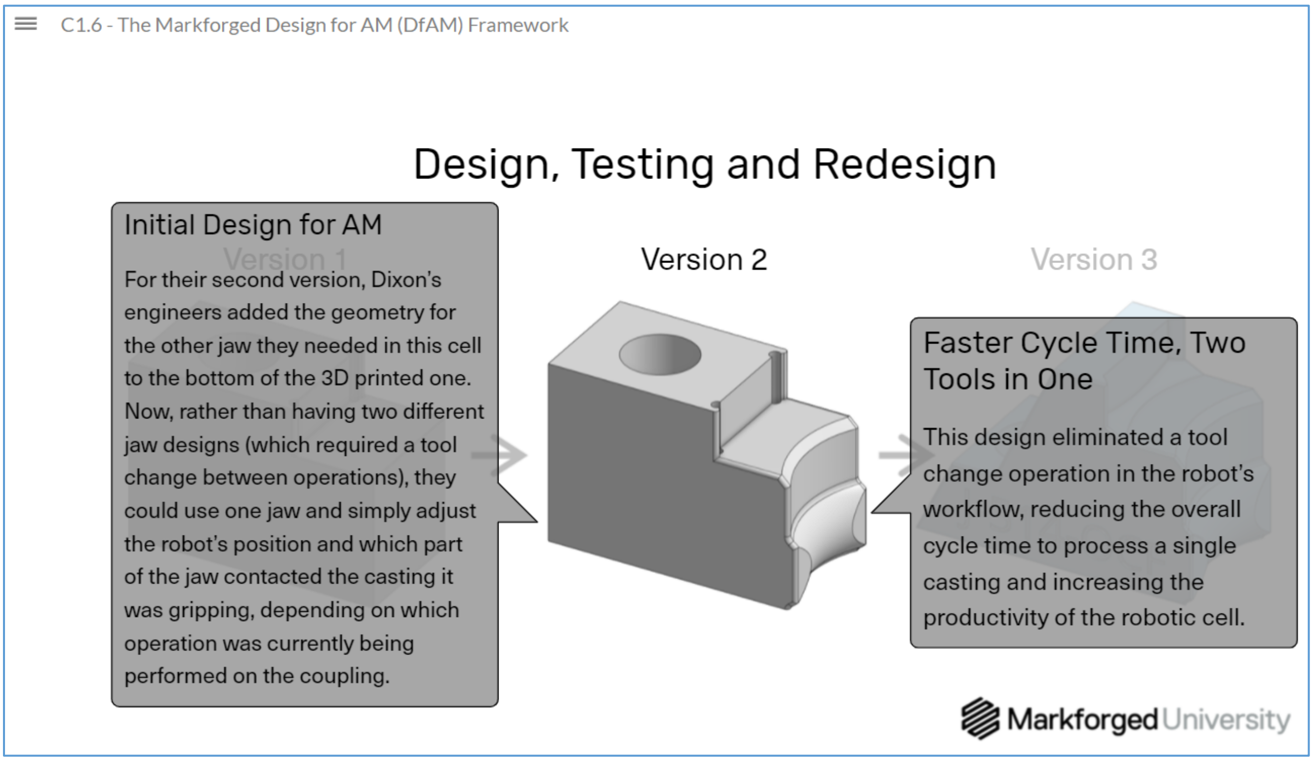


- **Core Functional Requirements**



- **Redesign and testing**
    - Each iteration is only one day.




C1.6 - The Markforged Design for AM (DfAM) Framework
Design, Testing and Redesign
Initial Design for AM
For their second version, Dixon's engineers added the geometry for the other jaw they needed in this cell to the bottom of the 3D printed one. Now, rather than having two different jaw designs (which required a tool change between operations), they could use one jaw and simply adjust the robot's position and which part of the jaw contacted the casting it was gripping, depending on which operation was currently being performed on the coupling.
Version 1
Version 2
Version 3
Faster Cycle Time, Two Tools in One
This design eliminated a tool change operation in the robot's workflow, reducing the overall cycle time to process a single casting and increasing the productivity of the robotic cell.
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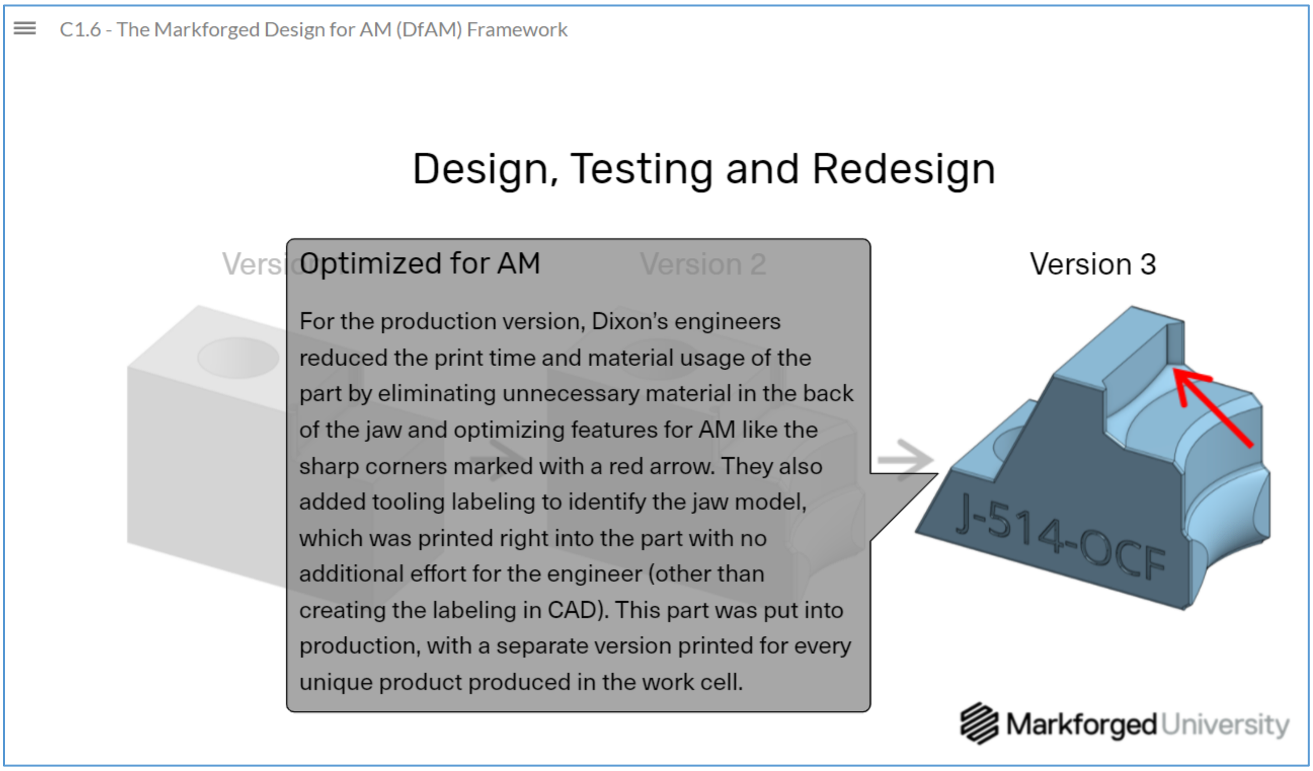
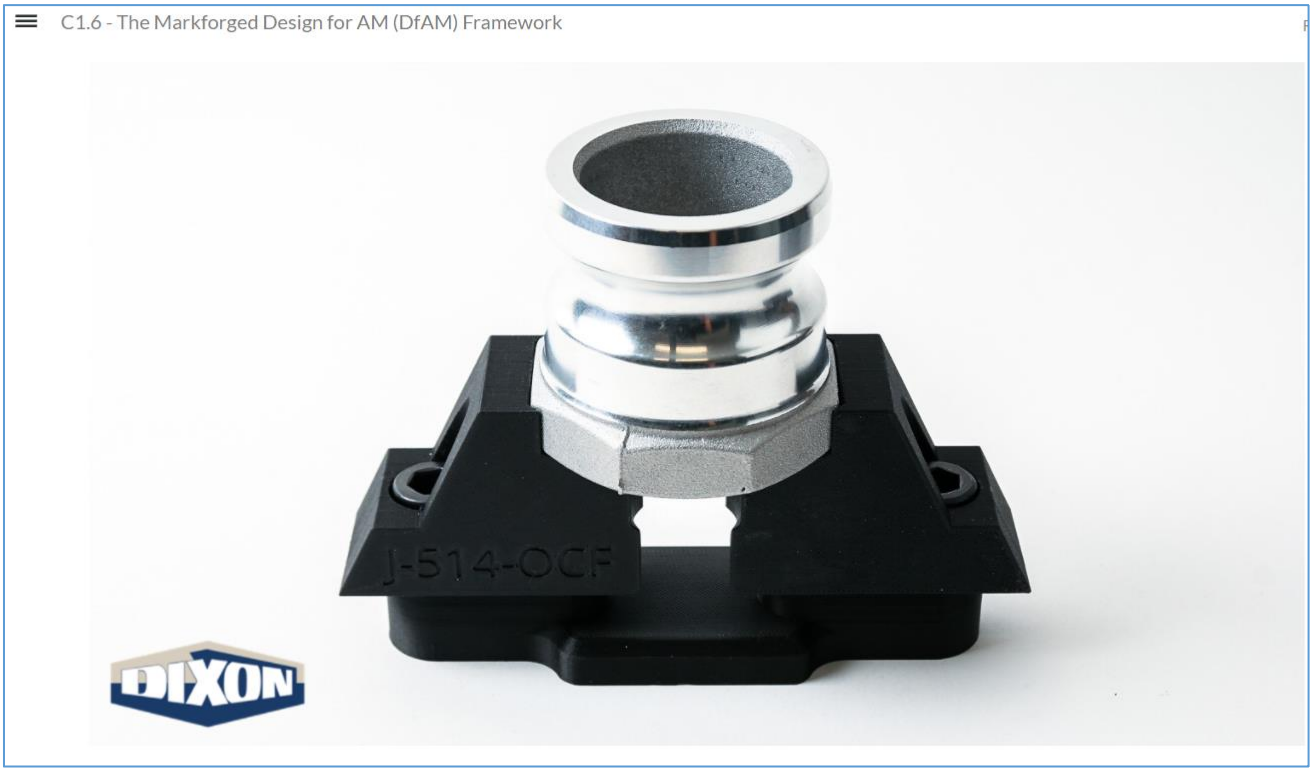

C1.6 - The Markforged Design for AM (DfAM) Framework
Design, Testing and Redesign
Optimized for AM
For the production version, Dixon's engineers reduced the print time and material usage of the part by eliminating unnecessary material in the back of the jaw and optimizing features for AM like the sharp corners marked with a red arrow. They also added tooling labeling to identify the jaw model, which was printed right into the part with no additional effort for the engineer (other than creating the labeling in CAD). This part was put into production, with a separate version printed for every unique product produced in the work cell.
Version 2
Version 3
J-514-OCF
Markforged University

- **Finished grippers**



C1.6 - The Markforged Design for AM (DfAM) Framework

ROI Metrics

Immediate Business Outcomes (per 3 jaw set):

	Traditional	Markforged	Change
Cost	$1000	$81	-92%
Lead Time	2 weeks	30 hours	-91%

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- **ROI Metrics**
  - Return On Investment.

C1.6 - The Markforged Design for AM (DfAM) Framework

ROI Metrics

Organizational Business Outcomes:

+ Process improvements with high value implemented weeks or months faster
+ Engineers give projects more intense focus with less context-switching penalties
+ Building an agile, 'fail-fast' engineering culture that's responsive and tests ideas quickly

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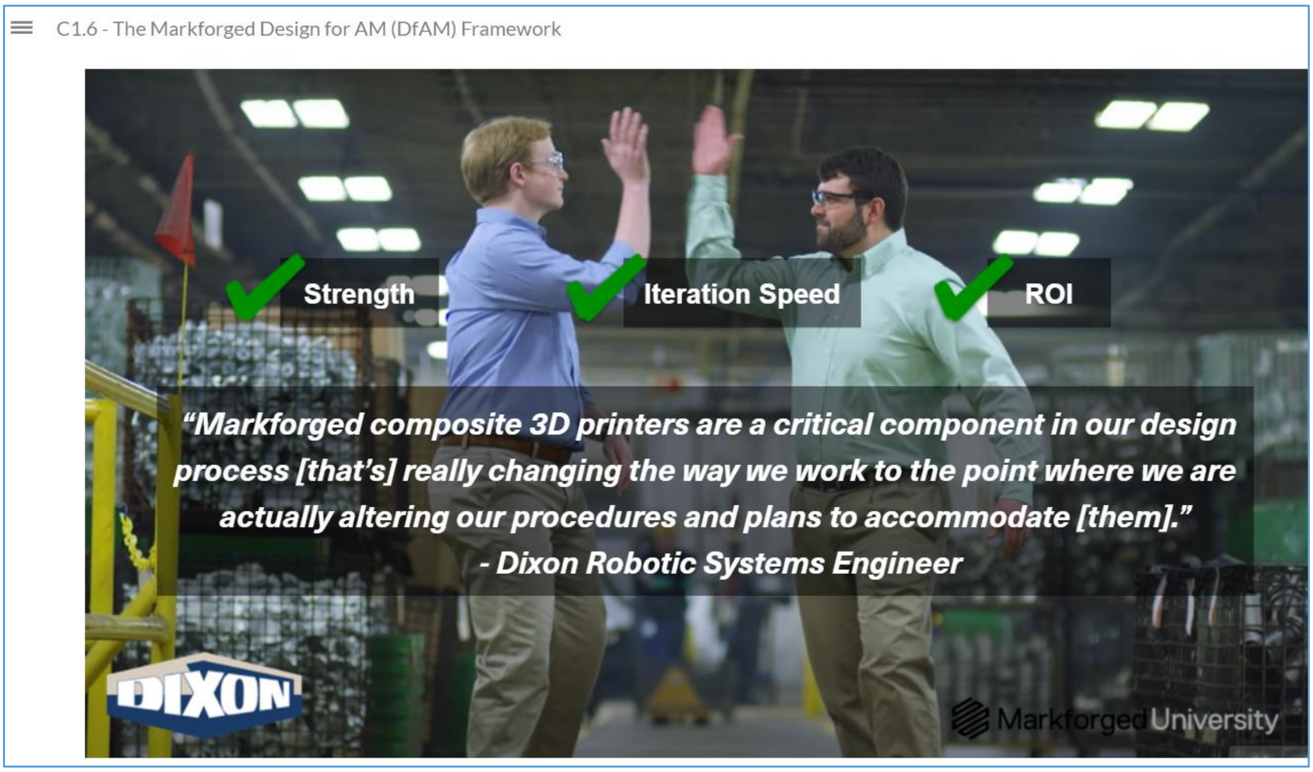
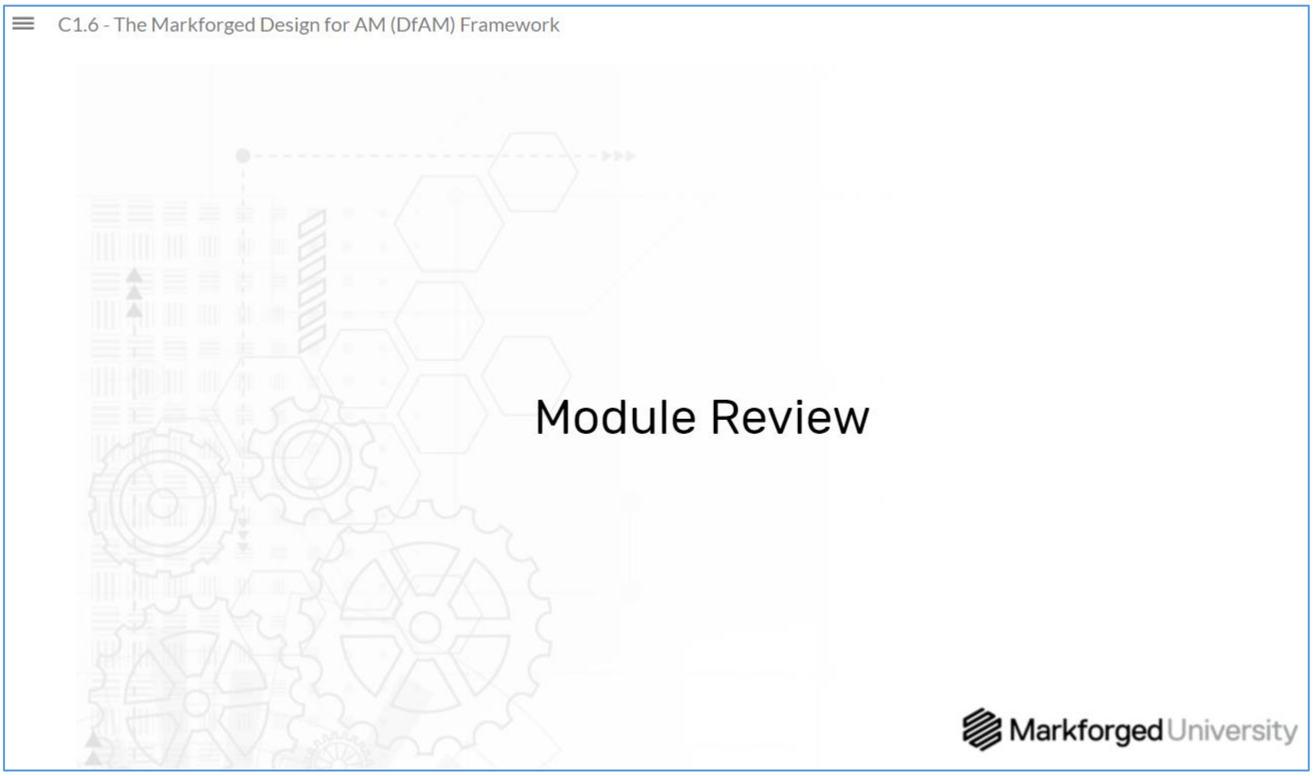
  - Agile = Weerbaar.



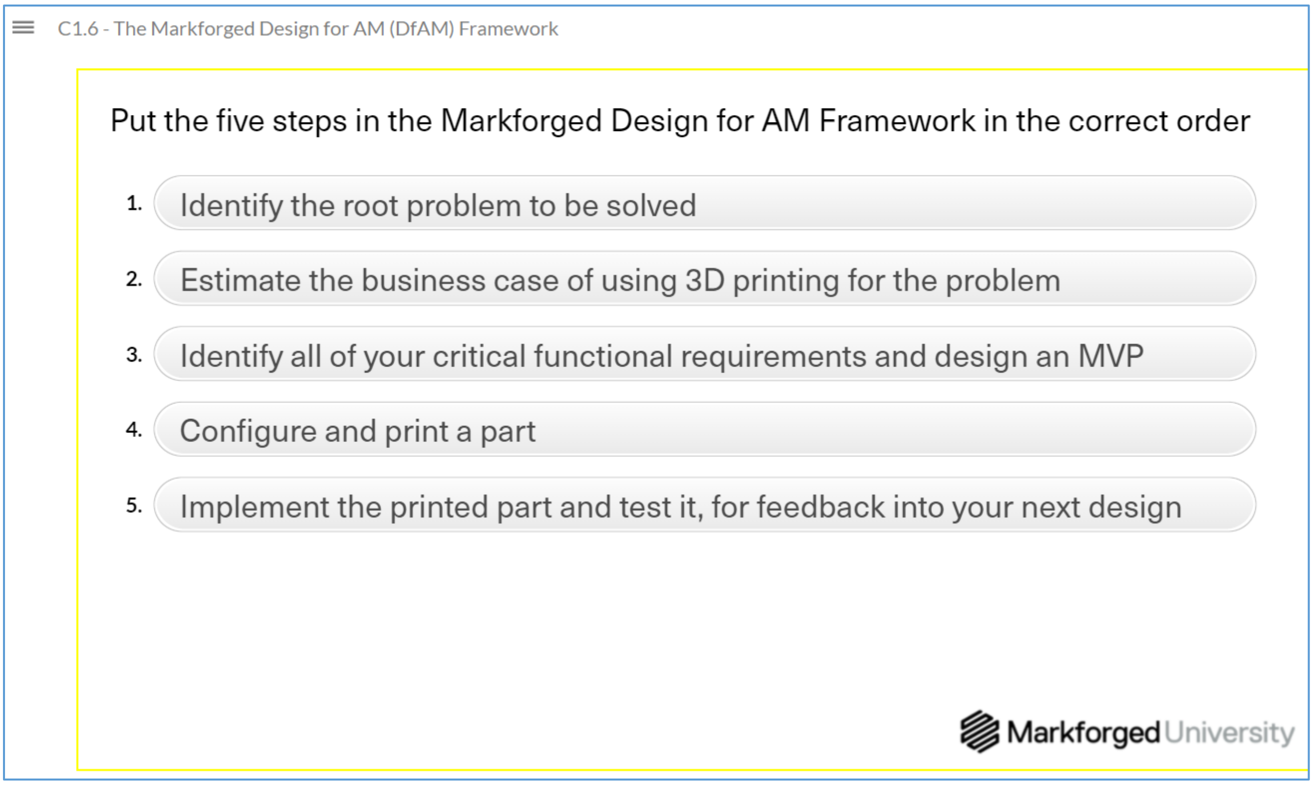
- **Project Recap**

Accommodate = aanpassen

Altering = wijzigen



- **Module Review**



C1.6 - The Markforged Design for AM (DfAM) Framework

Which is an example of an organizational-level business impact that Dixon Valve experienced as a result of integrating 3D printing into their engineering work?

- Fully identified functional requirements that are critical to a tool performing well
- A force applied across a small area of a fixture as a part dropped into it
- An engineering culture that encouraged fast prototyping and testing to get results quickly
- Large cost- and lead time-savings as a result of 3D printing their end-of-arm tooling

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C1.6 - The Markforged Design for AM (DfAM) Framework

True/False: When estimating the business case of using 3D printing to solve the problem at hand, we should develop a comprehensive ROI for every problem we're investigating.

- True
- False

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- Comprehensive = veelomvattend. Essentie van het verhaal is dat er geen uitgebreide ROI-onderzoek hoeft plaatst te vinden. Hier wordt immers ook gesproken over "estimating" hetgeen schatten betekent.

C1.6 - The Markforged Design for AM (DfAM) Framework

Results

Your Score:	100% (30 points)
Passing Score:	80% (24 points)

Result:

Congratulations, you passed.

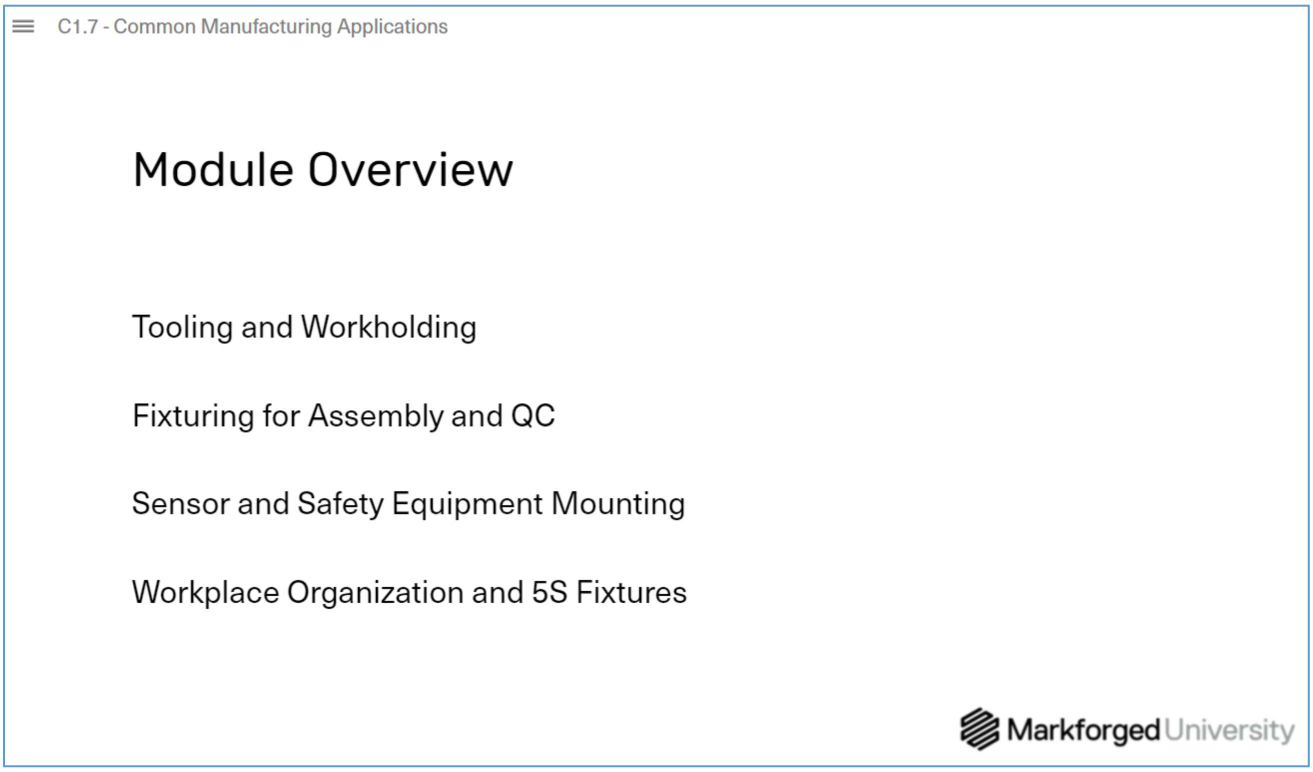
Finish Module

Review Quiz

C1.7 - Common Manufacturing Applications

C1.7 - Common Manufacturing Applications

- **Common Manufacturing Applications**



- **Module Overview**

- **Part 1: Tooling & Workholding**

C1.7 - Common Manufacturing Applications

Softjaws and Clamping

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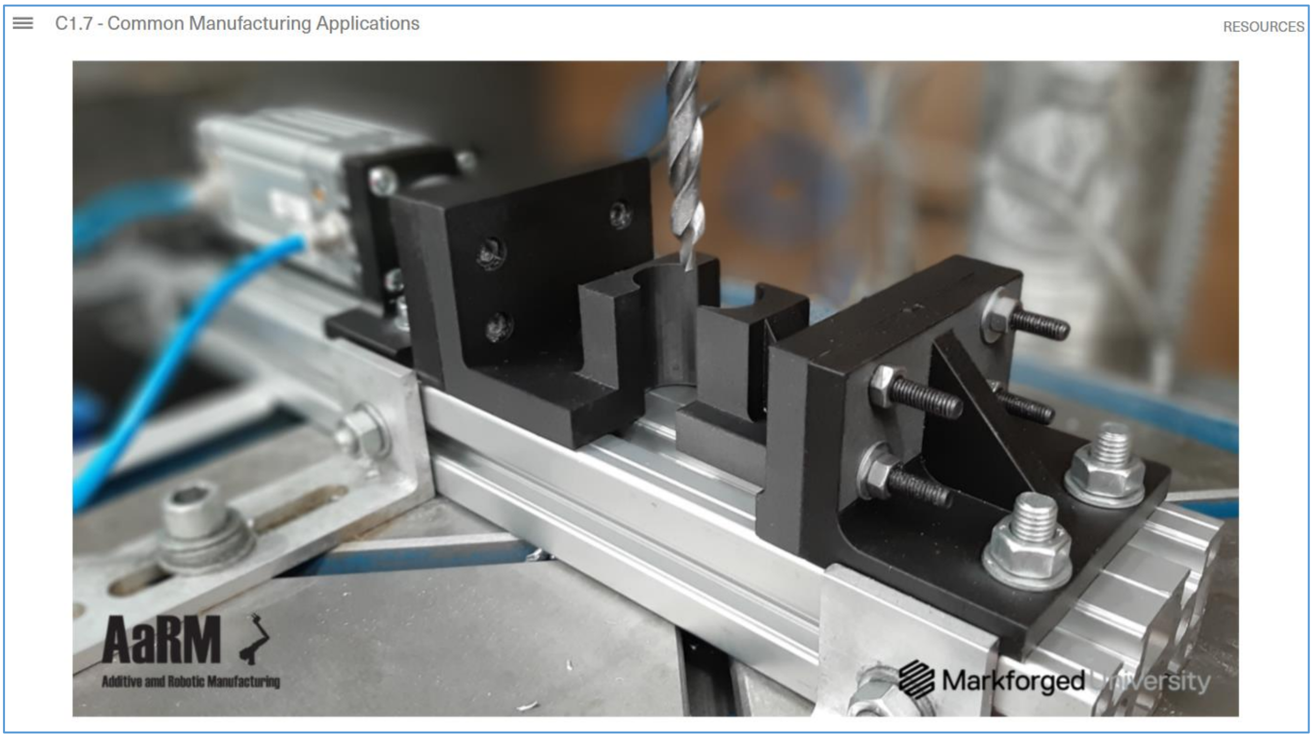
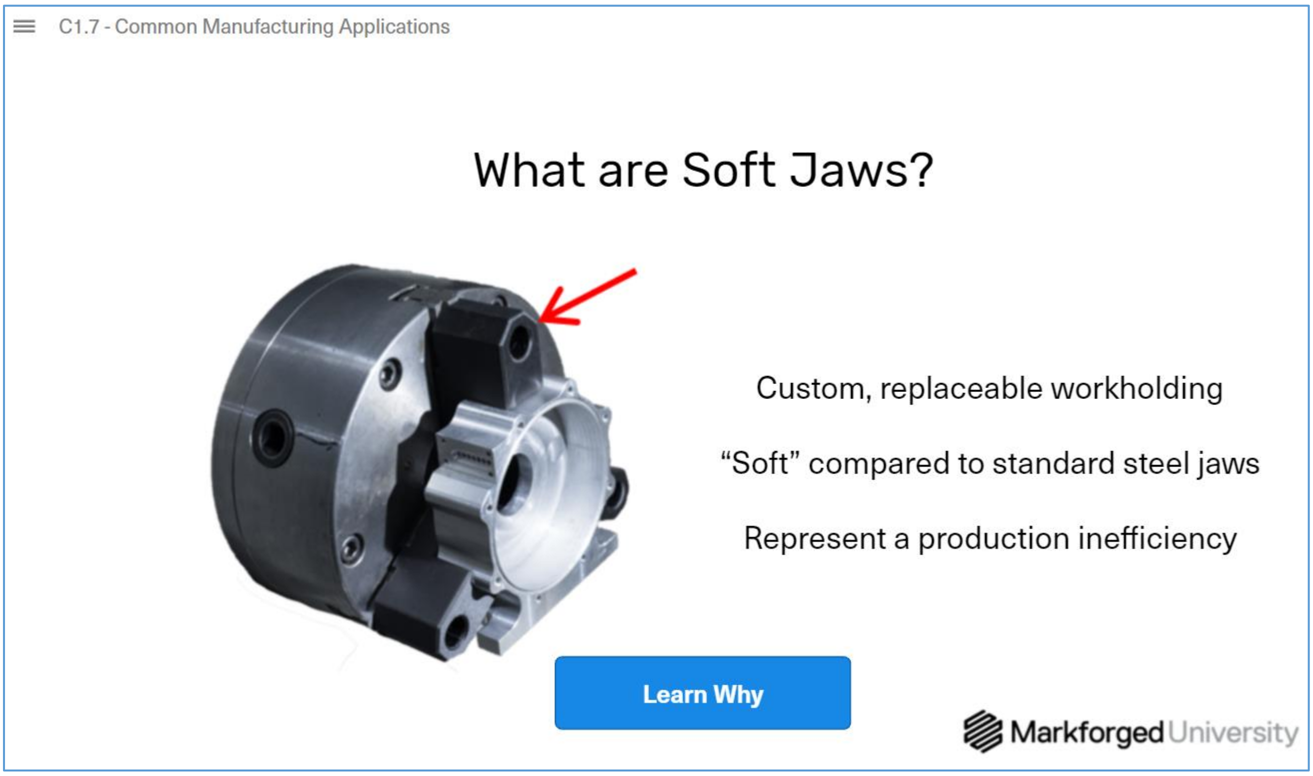
- **Softjaws and Clamping**

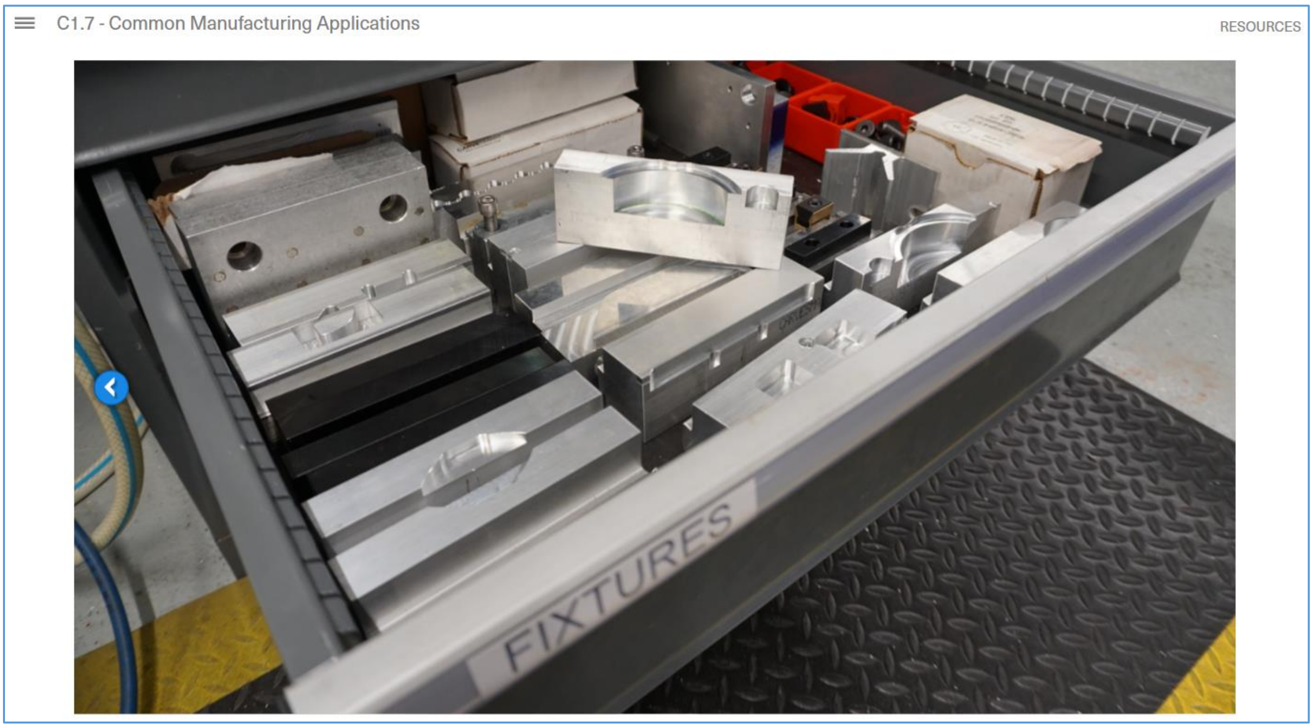


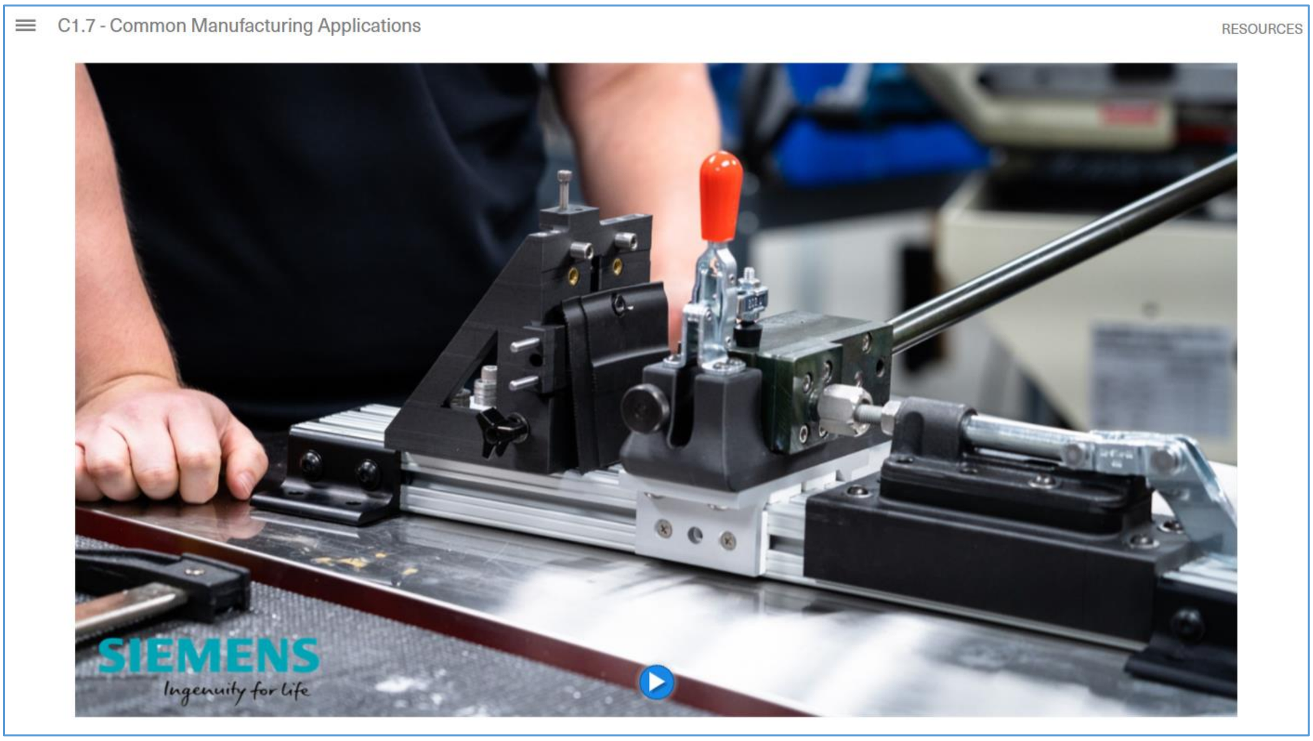
- **AaRM Clamping Jaws**



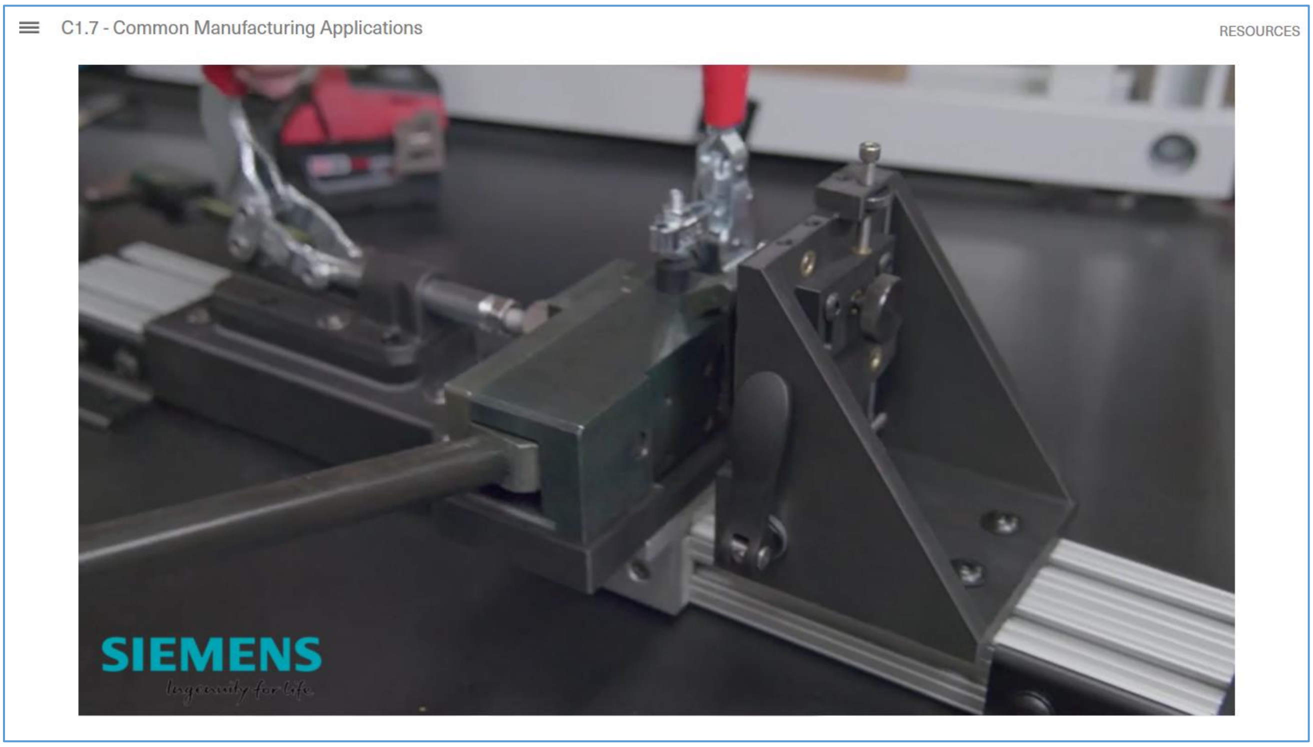
- **What are Soft Jaws?**

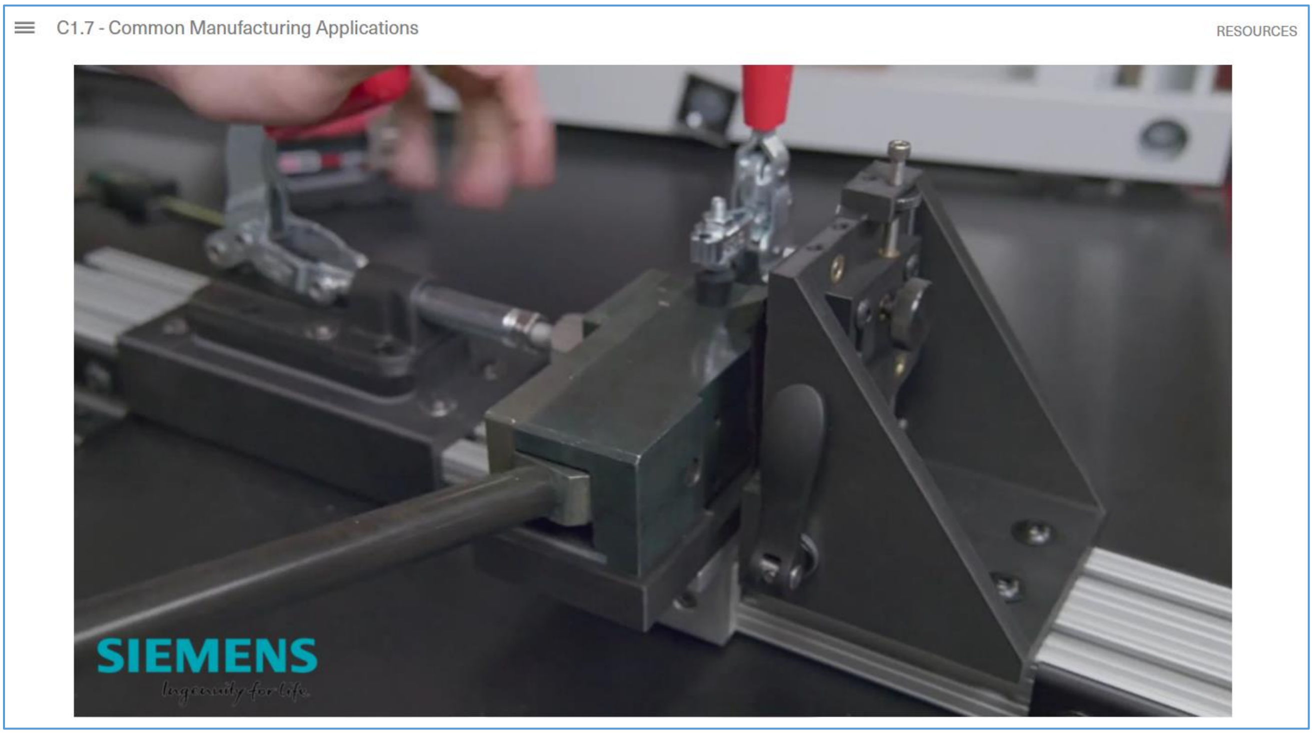
- **Where to Look for Softjaw Opportunity?**

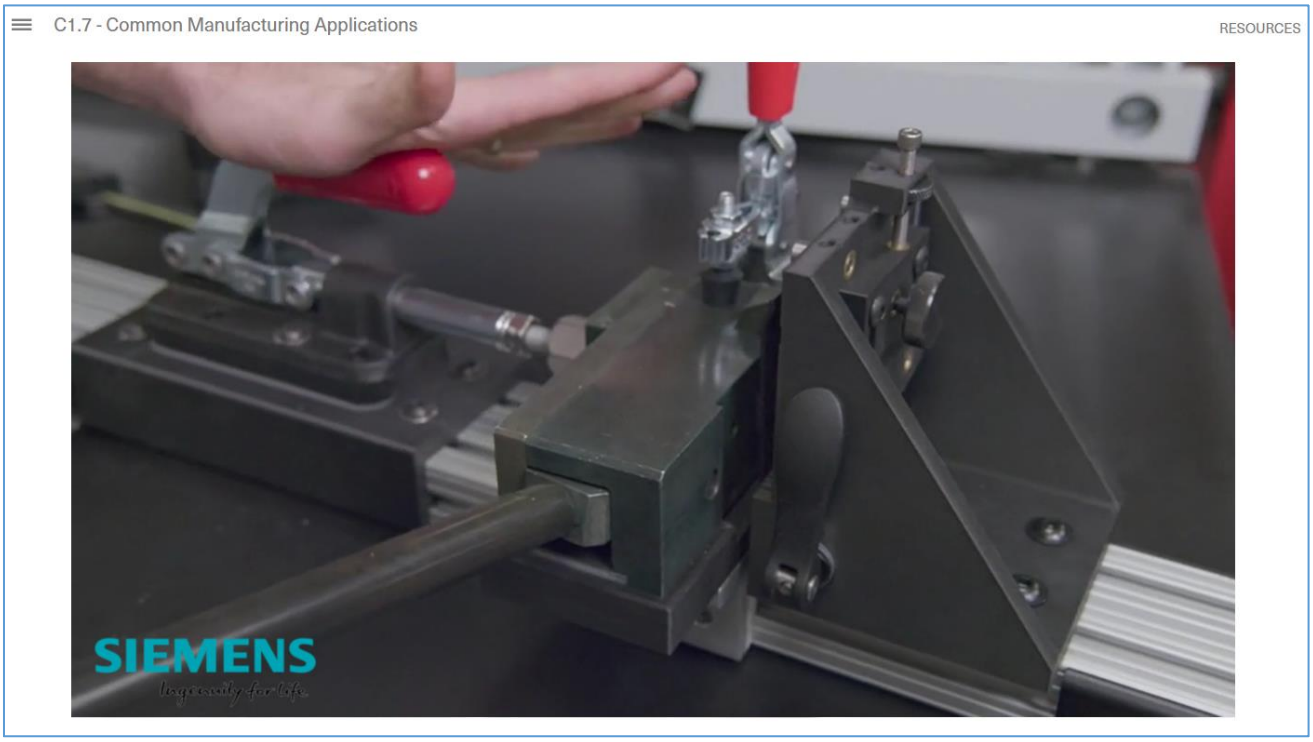


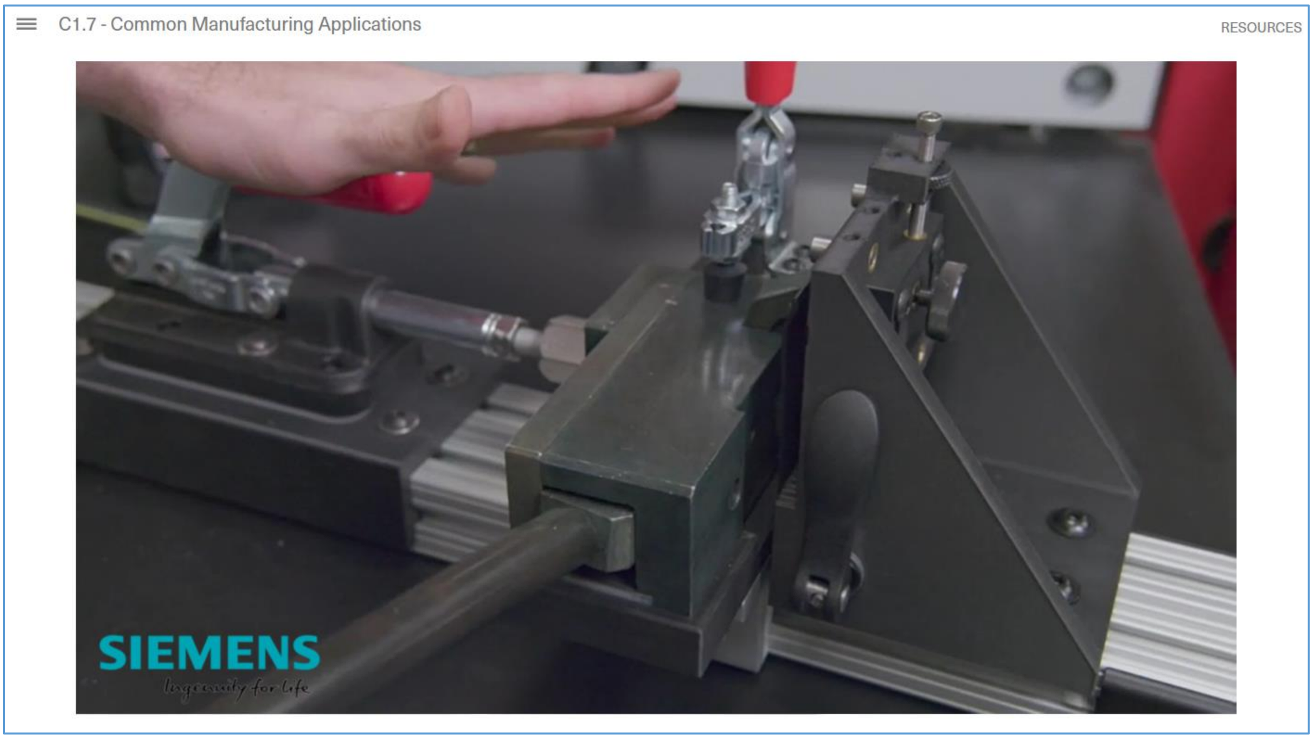


- **More Complex Clamp Tooling**
    - **Following images of clamping process**

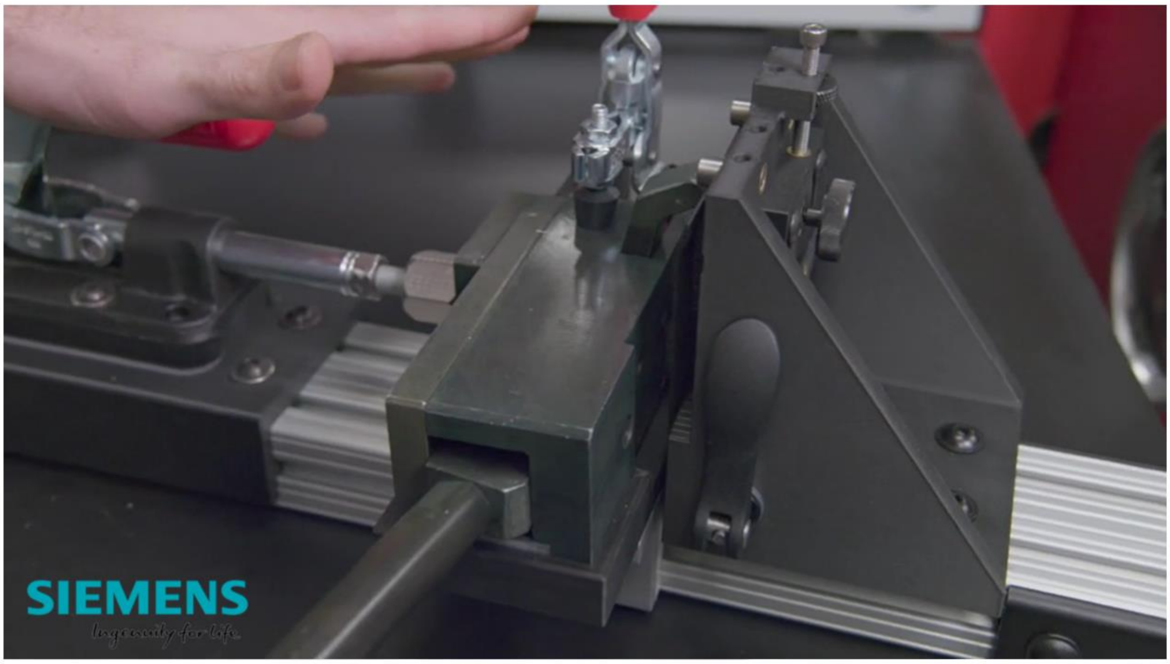

C1.7 - Common Manufacturing Applications
RESOURCES
SIEMENS


C1.7 - Common Manufacturing Applications
RESOURCES
SIEMENS

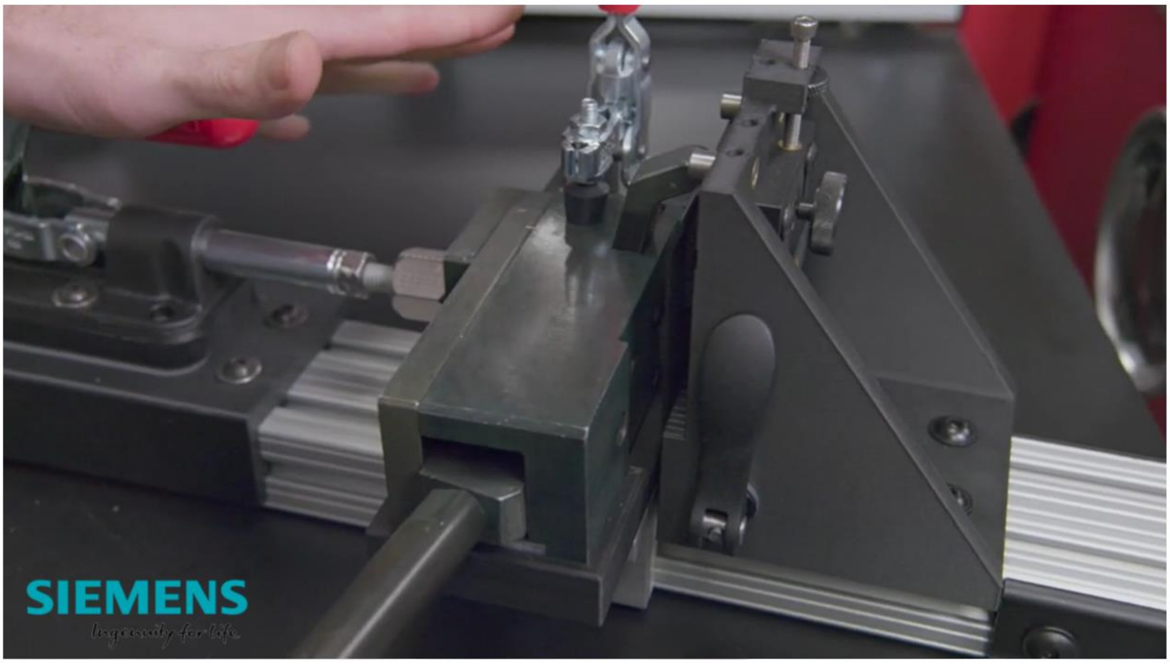

C1.7 - Common Manufacturing Applications
RESOURCES
SIEMENS
Ingenuity for life

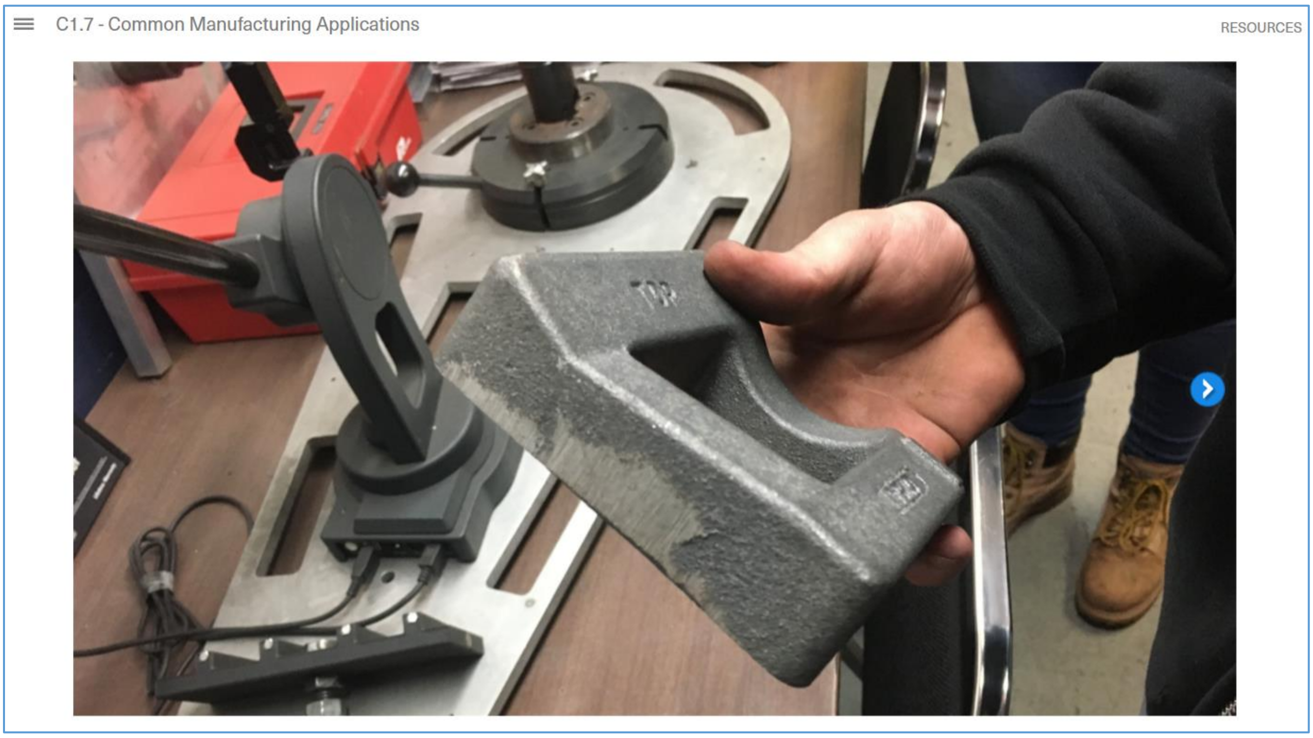

C1.7 - Common Manufacturing Applications
RESOURCES
SIEMENS
Ingenuity for life

C1.7 - Common Manufacturing Applications RESOURCES



C1.7 - Common Manufacturing Applications RESOURCES



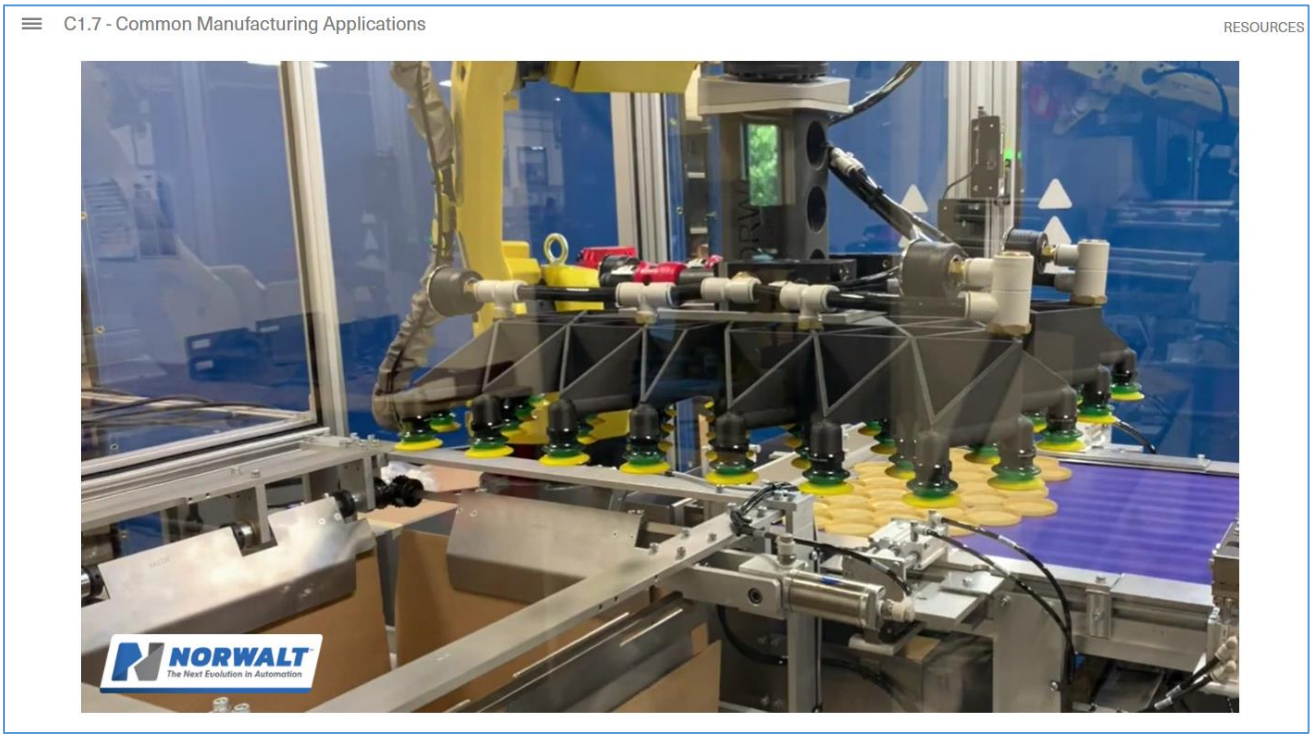


- **Robotic Grinding Fixture**

  - Original made of aluminium causes wear and tear reduces the live time of the fixture.
  - Interfering with the fixture (red arrow).

○

- **End-of-arm Tooling (EOAT) for Industrial Robots**



- **Vacuum Pick-and-Place: Norwalt Design**
    - Much lighter construction in stead of metal solutions.
    - Much more quickly accelarions and de-accelarations (massatraagheid? Mass Inertia?)
        - Gives much more productivity.

- **Unpowerd Cobot Gripper: Siemens**

- Een cobot of co-robot (van collaborative robot, meewerkende robot) is een robot die bedoeld is om samen te werken met mensen in een gemeenschappelijke werkomgeving. Een cobot verschilt daarmee van andere robots, die ontworpen zijn om zelfstandig of met beperkte begeleiding te opereren, zoals de meeste industriële robots tot 2010. Verder zijn cobots lichter, makkelijker verplaatsbaar en vaak goedkoper dan een grotere standaard industriële robot.

- **Vacuum EOAT – Packaging Automation**

C1.7 - Common Manufacturing Applications RESOURCES

Custom Tooling

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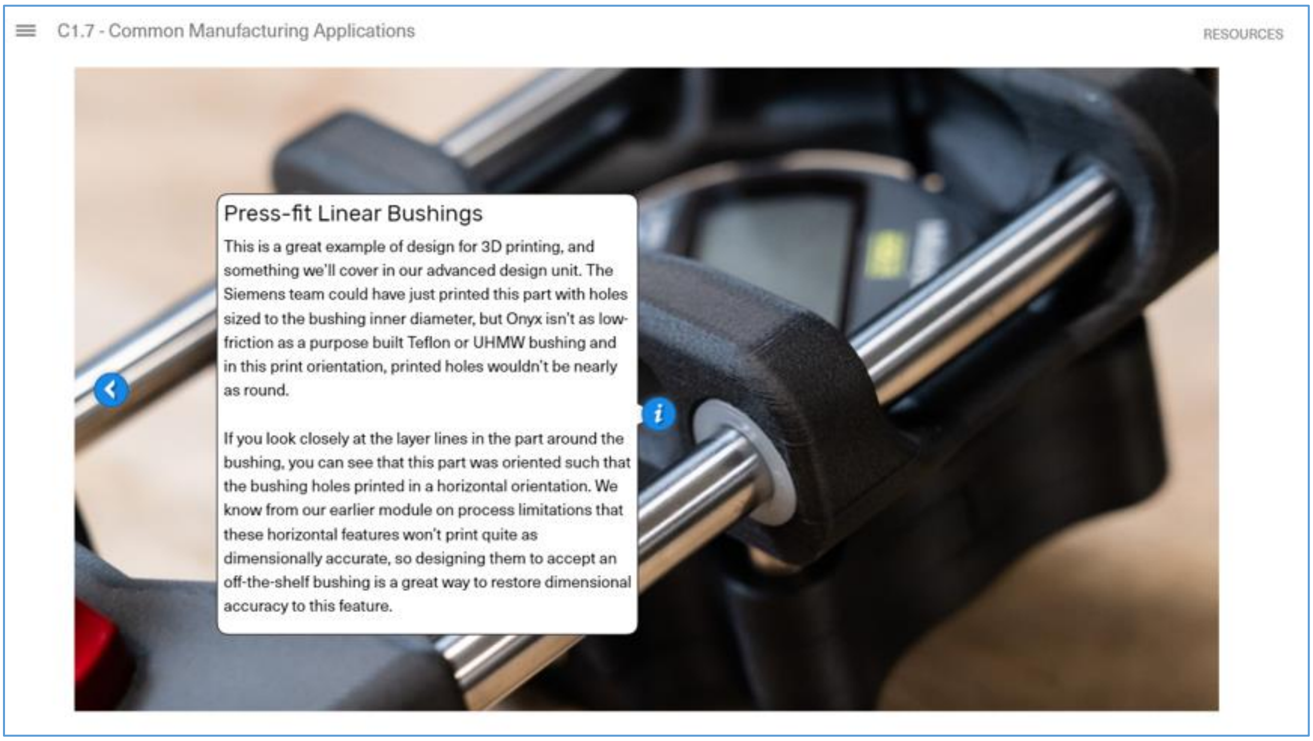
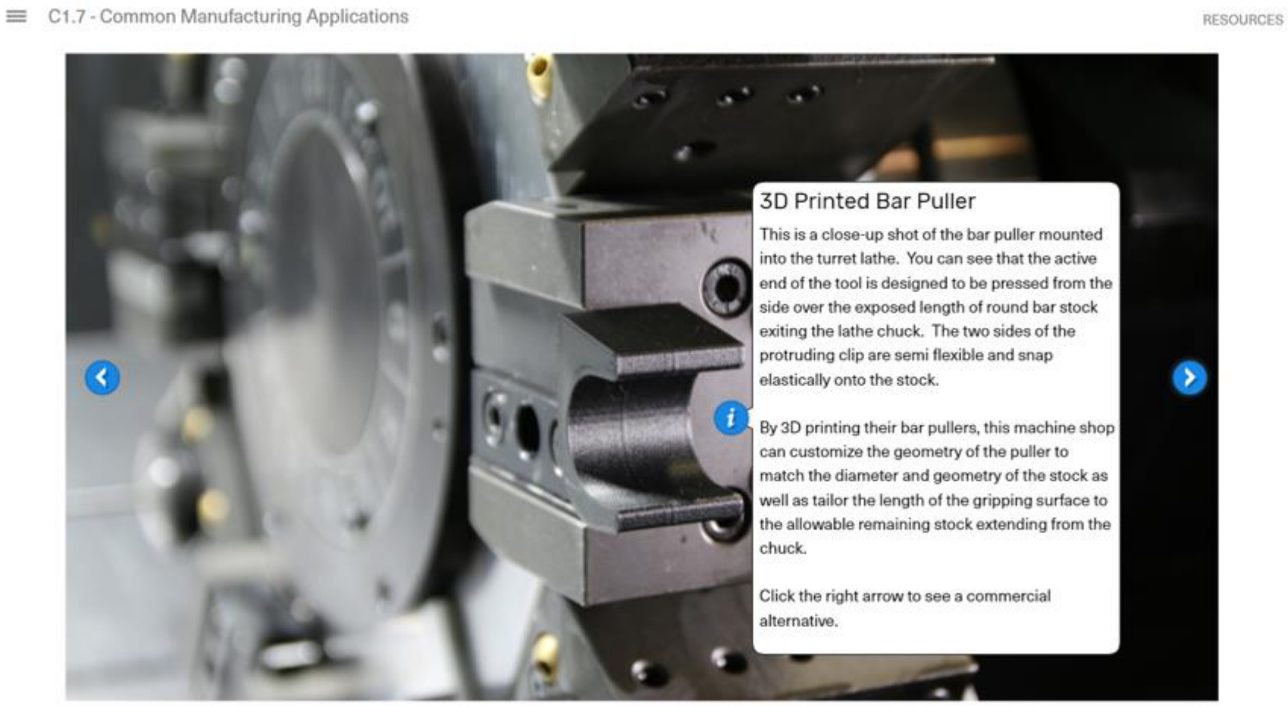
- **Custom Tooling**

C1.7 - Common Manufacturing Applications RESOURCES

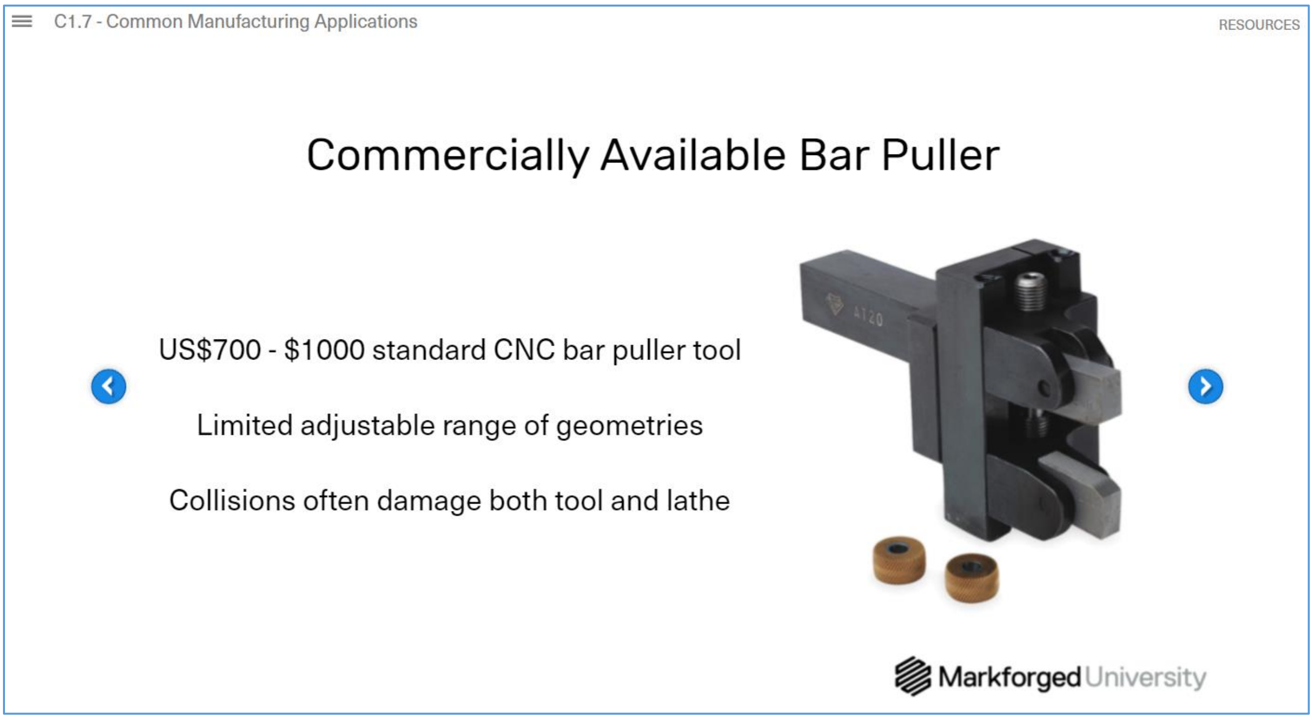
- **Inspection Tool Siemens**



- **CNC Lathe Bar Puller**



- Dit is een close-up van de staaftrekker die in de revolverdraaibank is gemonteerd. U kunt zien dat het actieve uiteinde van het gereedschap is ontworpen om vanaf de zijkant te worden gedrukt over de blootgestelde lengte van het ronde staafmateriaal dat de klauwplaat verlaat. De sleepzijden van de uitstekende clip zijn semi-flexibel en klikken elastisch op de kolf. Door hun staaftrekkers in 3D te printen, kan deze machinewerkplaats de geometrie van de trekker aanpassen aan de diameter en geometrie van de kolf en de lengte van het grijpoppervlak aanpassen aan de toegestane resterende voorraad die uit de spankop steekt.



- Printed with Onyx with fiber glass reïnforcement.
- Lower risk of damaging other parts of lathe by collision. The plastic gripper will break earlier.
- Much quicker redesigning of the model (available next morning).

- **Part 2: Fixtures**

C1.7 - Common Manufacturing Applications

Assembly and Quality Control Fixtures

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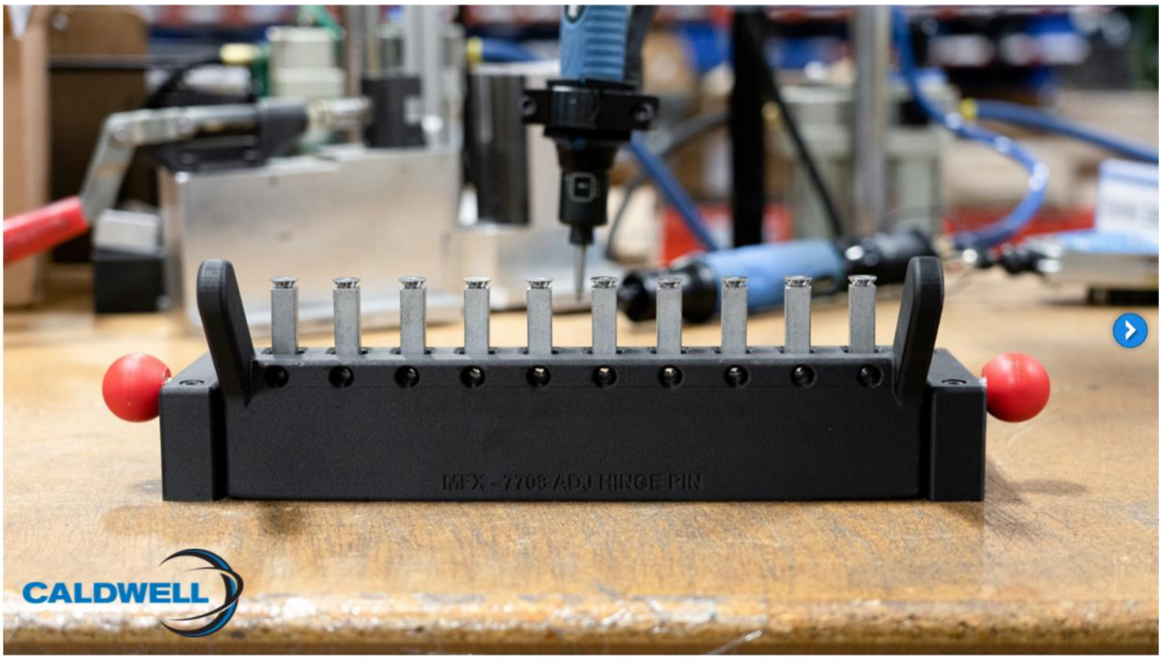
- **Assembly and Quality Control Fixtures**
    - Fixtures holds parts in position.

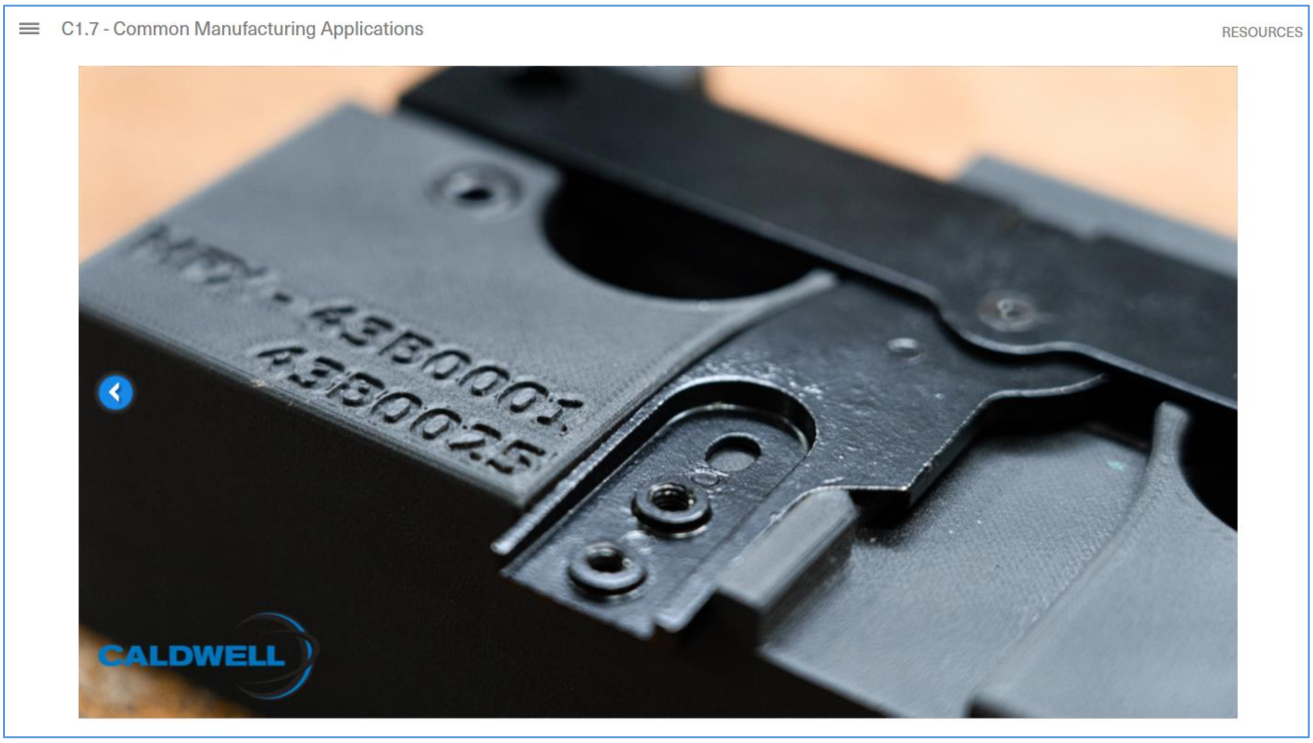
C1.7 - Common Manufacturing Applications

RESOURCES

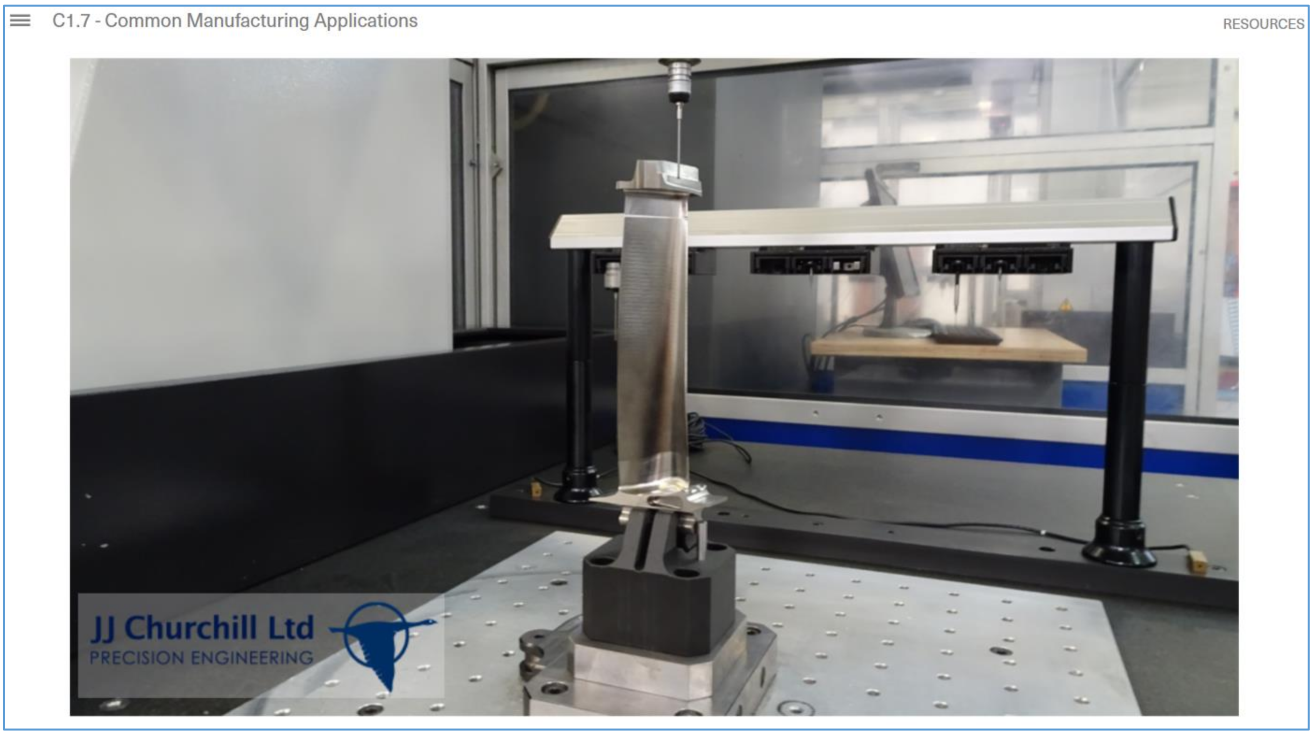


- **Assembly Fixtures – Caldwell Mfg.**

- Fixture for hinges, by using the cadmodel of the hinges.

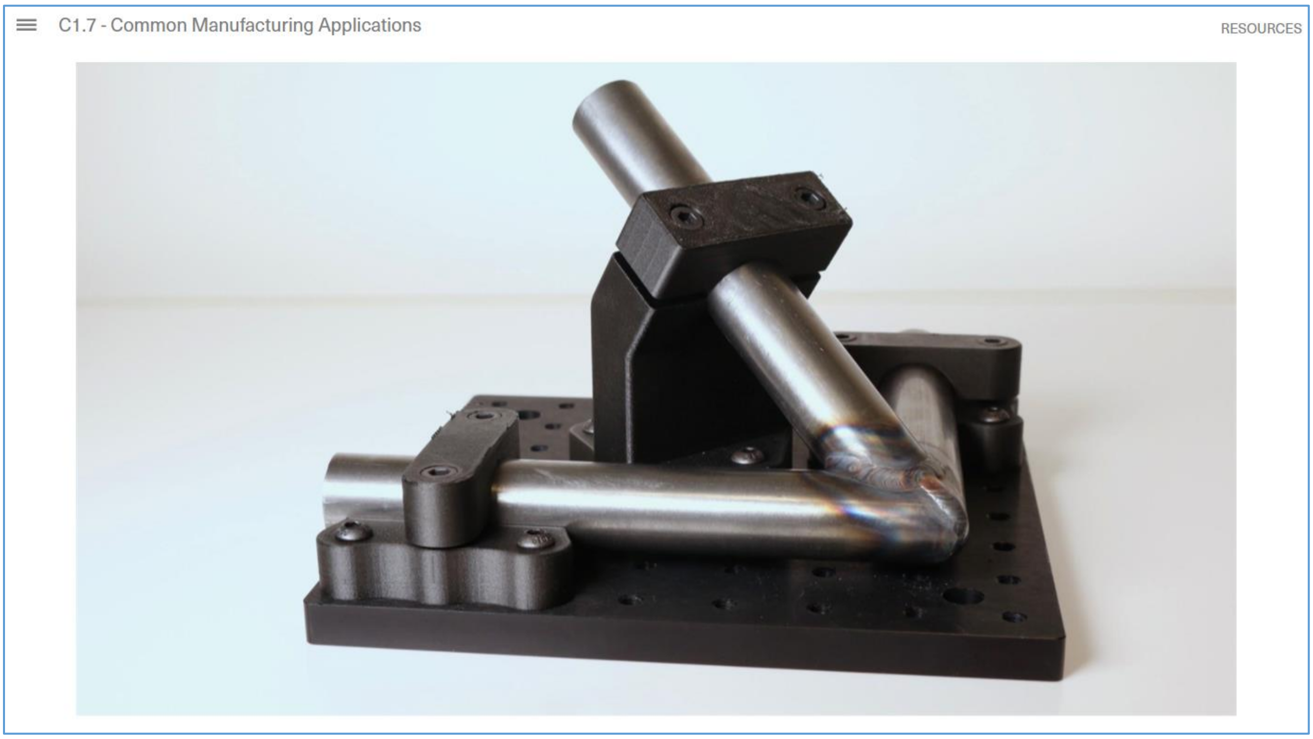


- Closer look of the fixture.

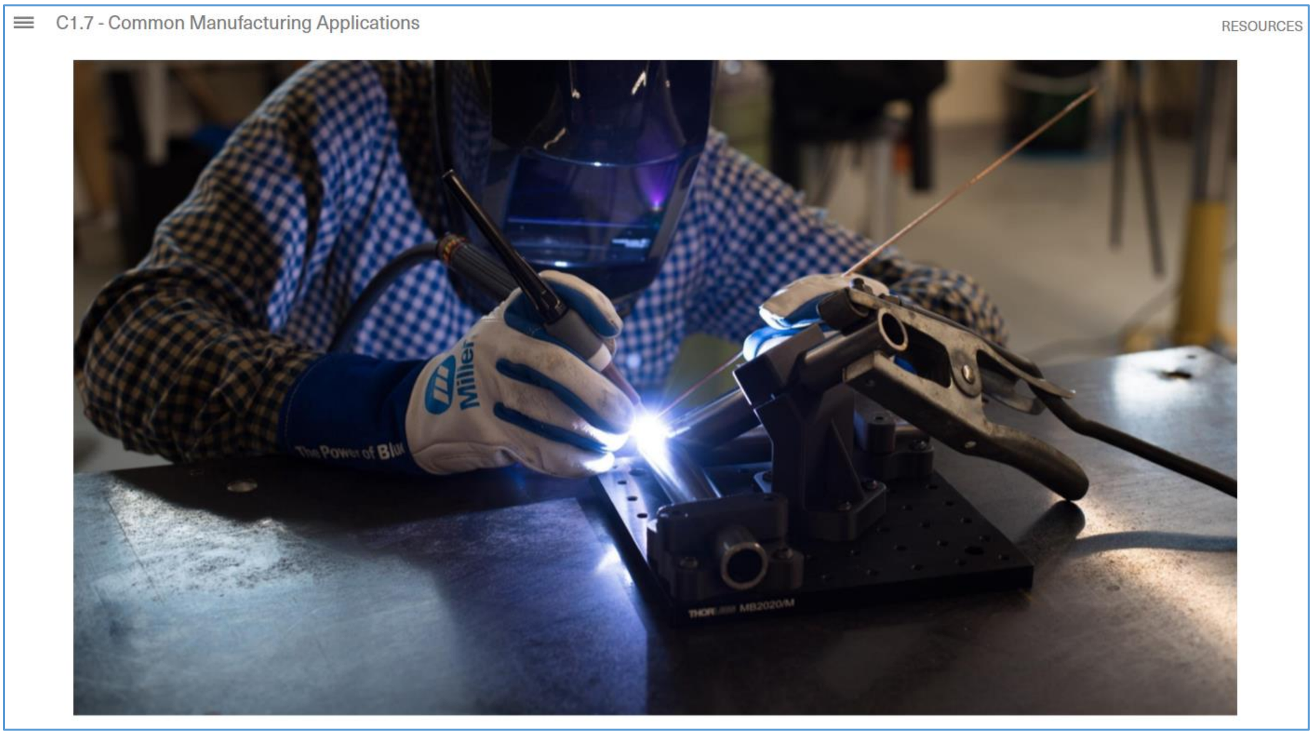


- **CMM fixturing – JJ Churchill Ltd**
  - CMM = Coordinate Measuring Machine

- **Welding Fixtures**
  - Despite the fact that the fixture needs to be far from the heat source, there are many applications for welding fixtures.



- **TIG Welding Fixture**
    - Rudimantary design: not a quick clamp and release mechanism and not for high volume use. But it is illustrate the concept.
    - Well away form the heatzone.
    - Gives plenty clearance for the welder to access to the join.
    - Closer to the heat section requires inserts



- **Laser Welding Fixture**

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RESOURCES

Machining Fixtures

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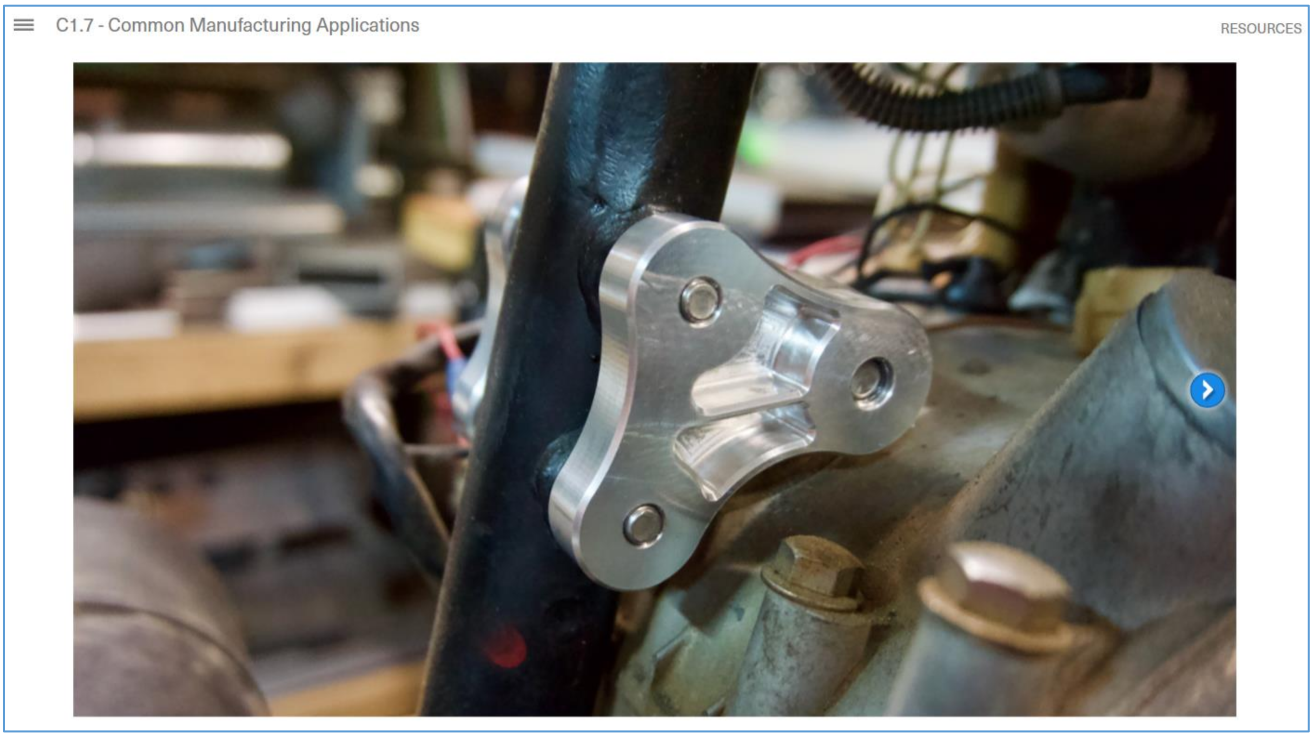
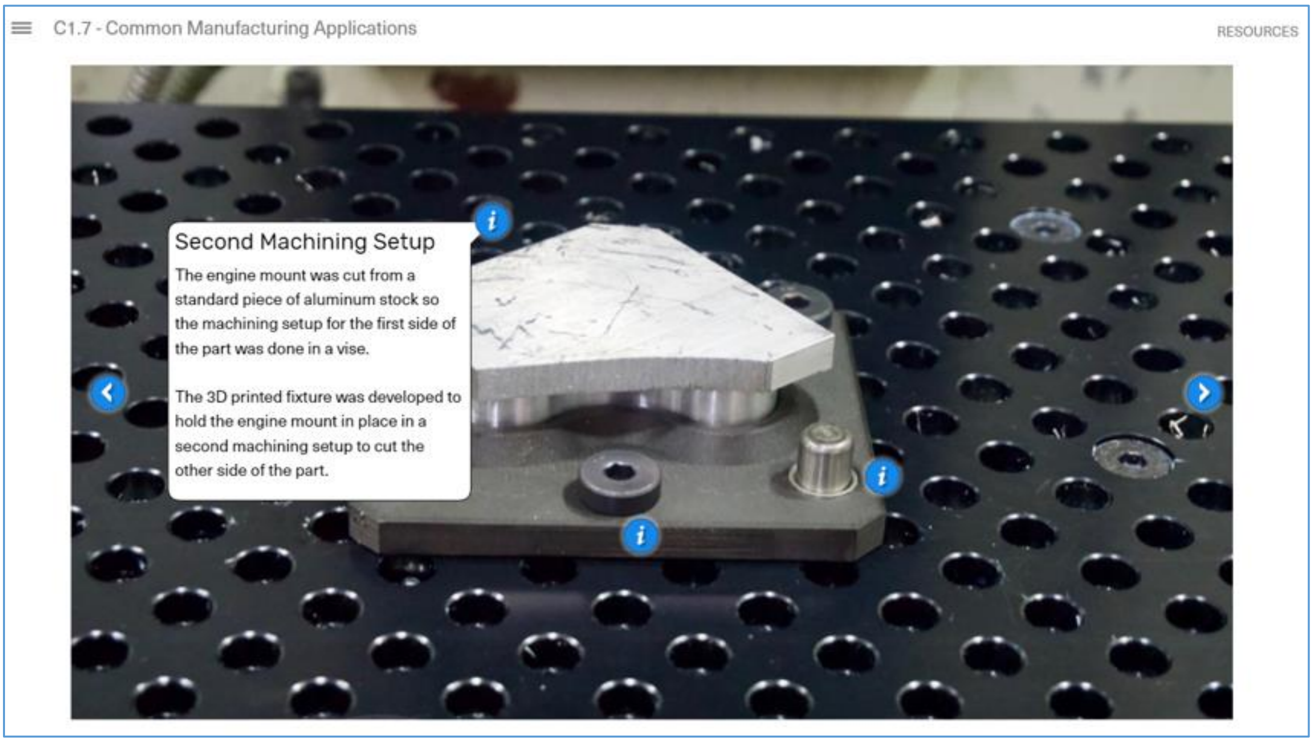
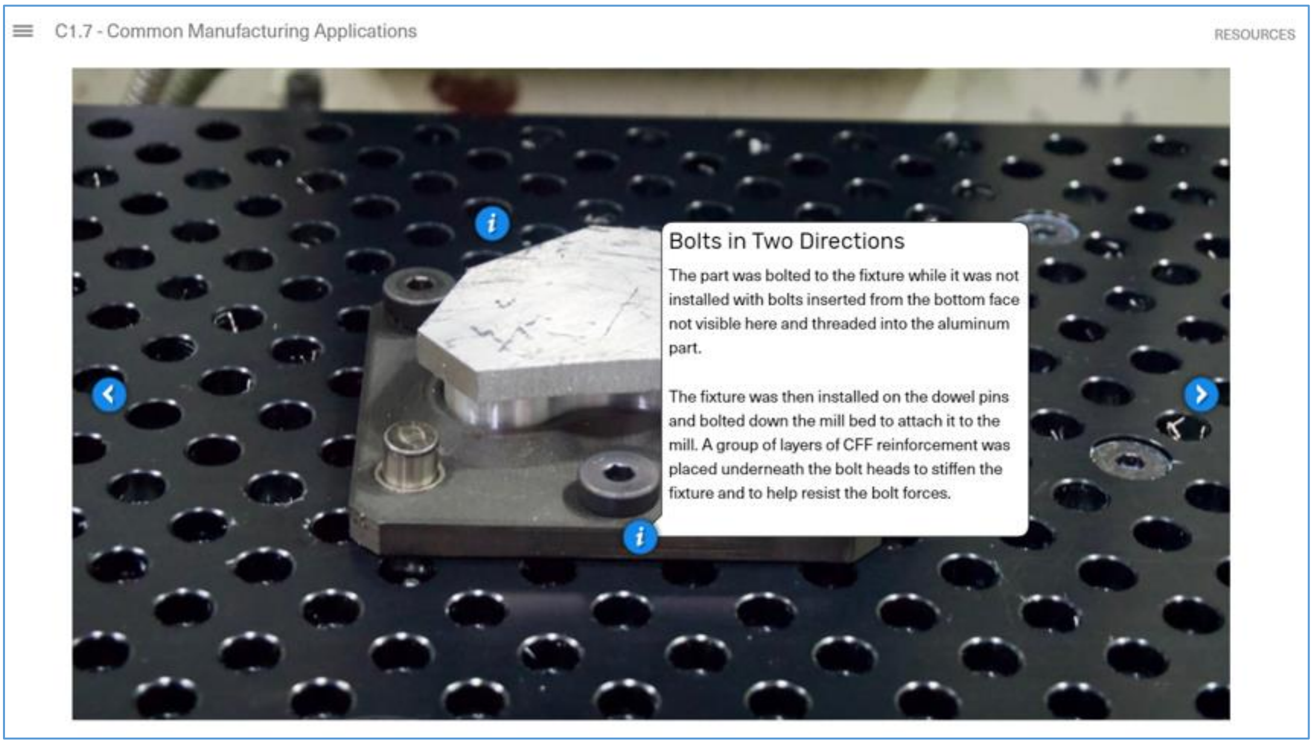
- **Machining Fixtures**



- **Motor Mount Machining Fixture**
  - For an old bike rebuilding.
  - Because of curve and other feature was not simple to hold during machining.
  - So they print a machining fixture of it.

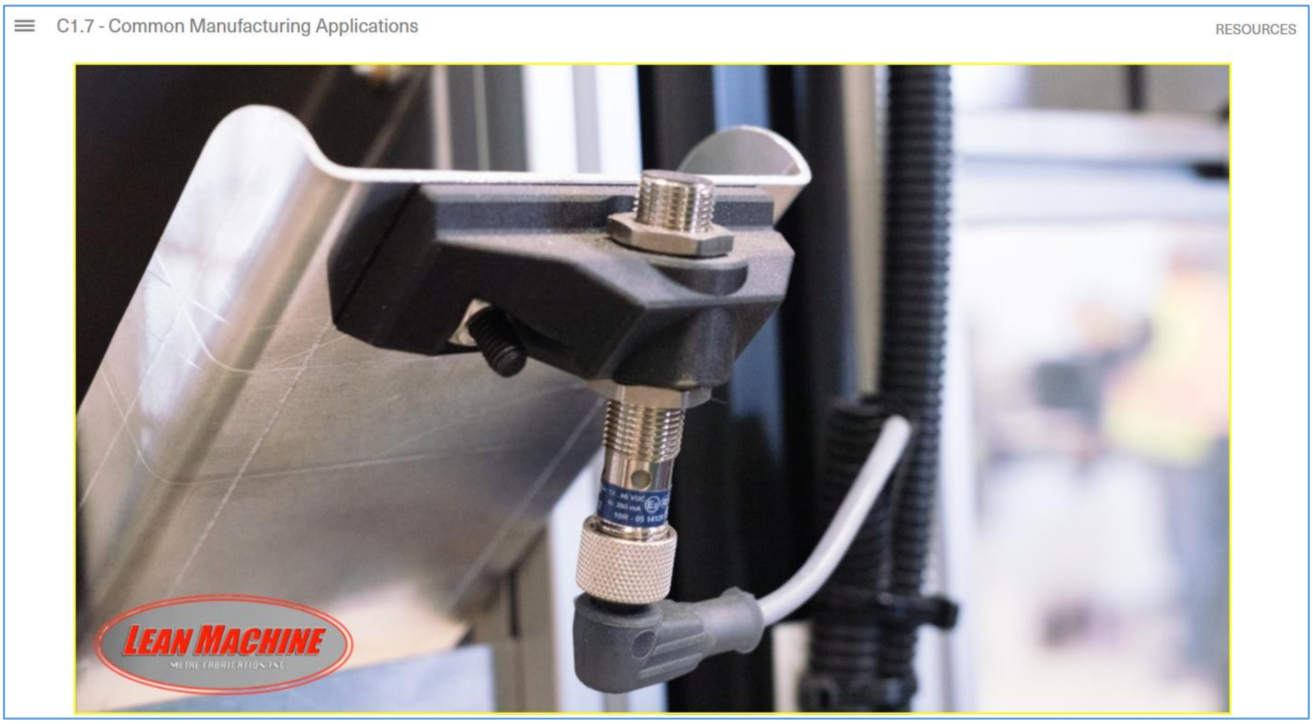


- Vise = Bankschroef

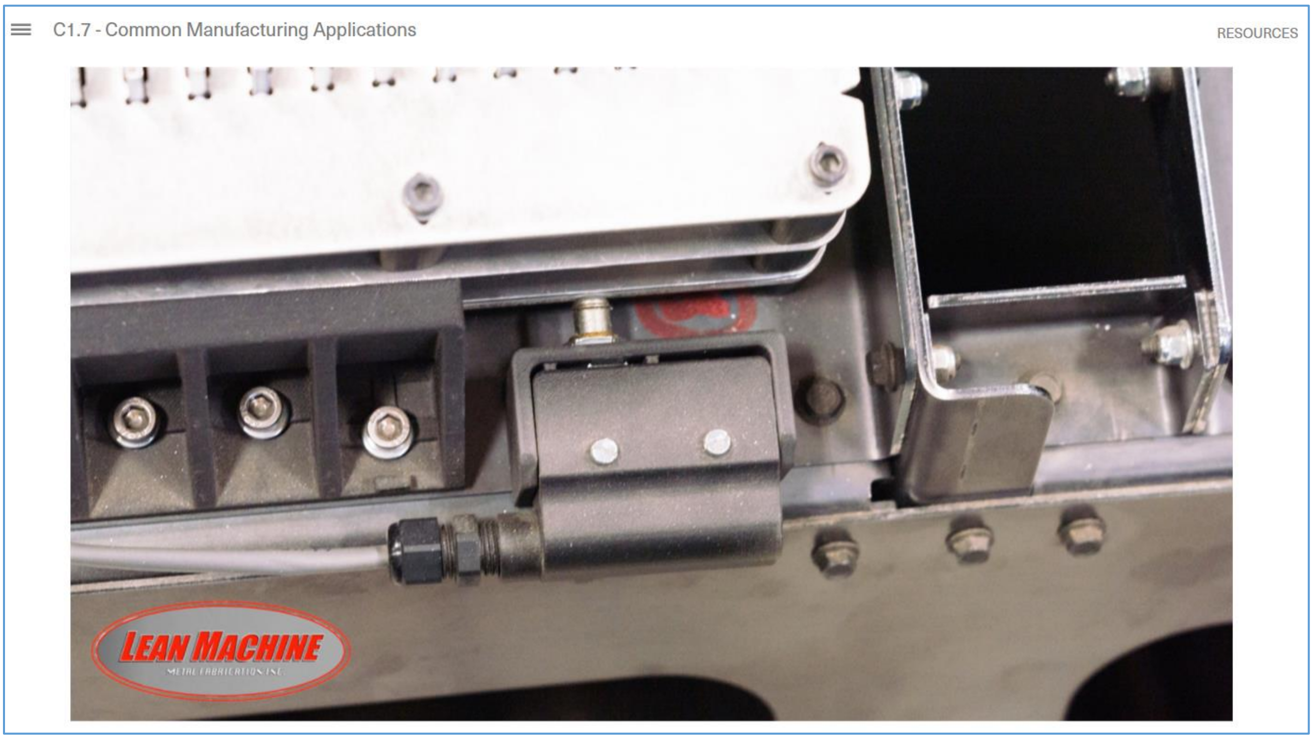


- Nylon will absord moisture in these conditions, but composite fiber will not.

- **Part 3: Sensor and Safety Equipment Mounting**

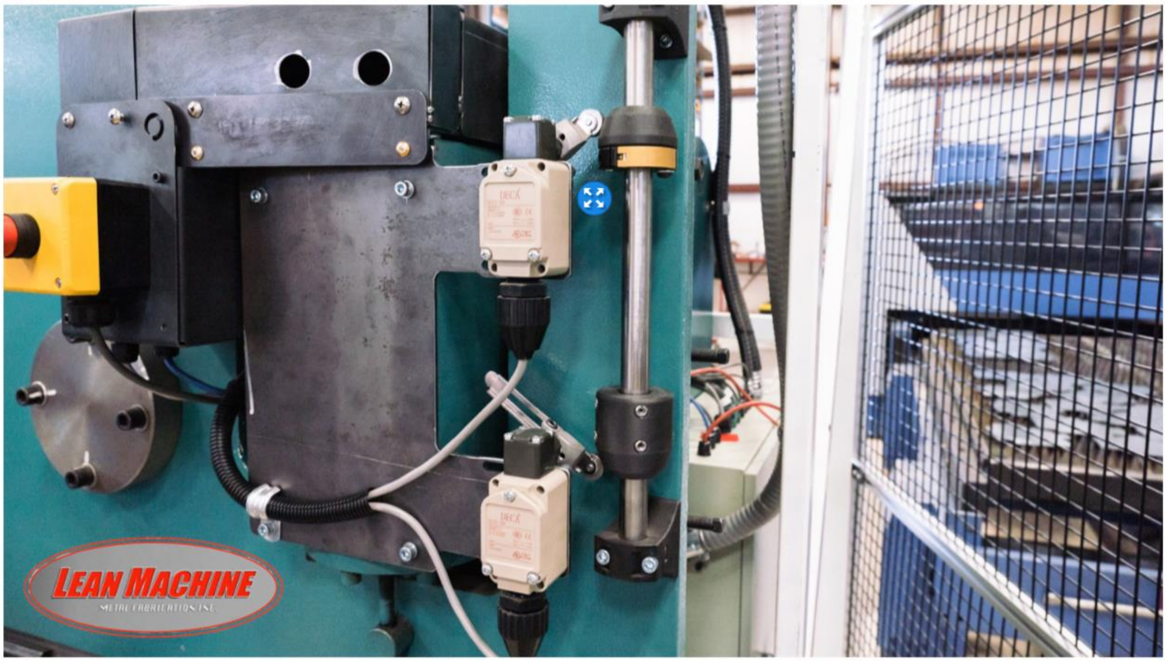


- **Proximity Sensor Bracket**
    - Proximity = nabijheid.



- **Contact Sensor**

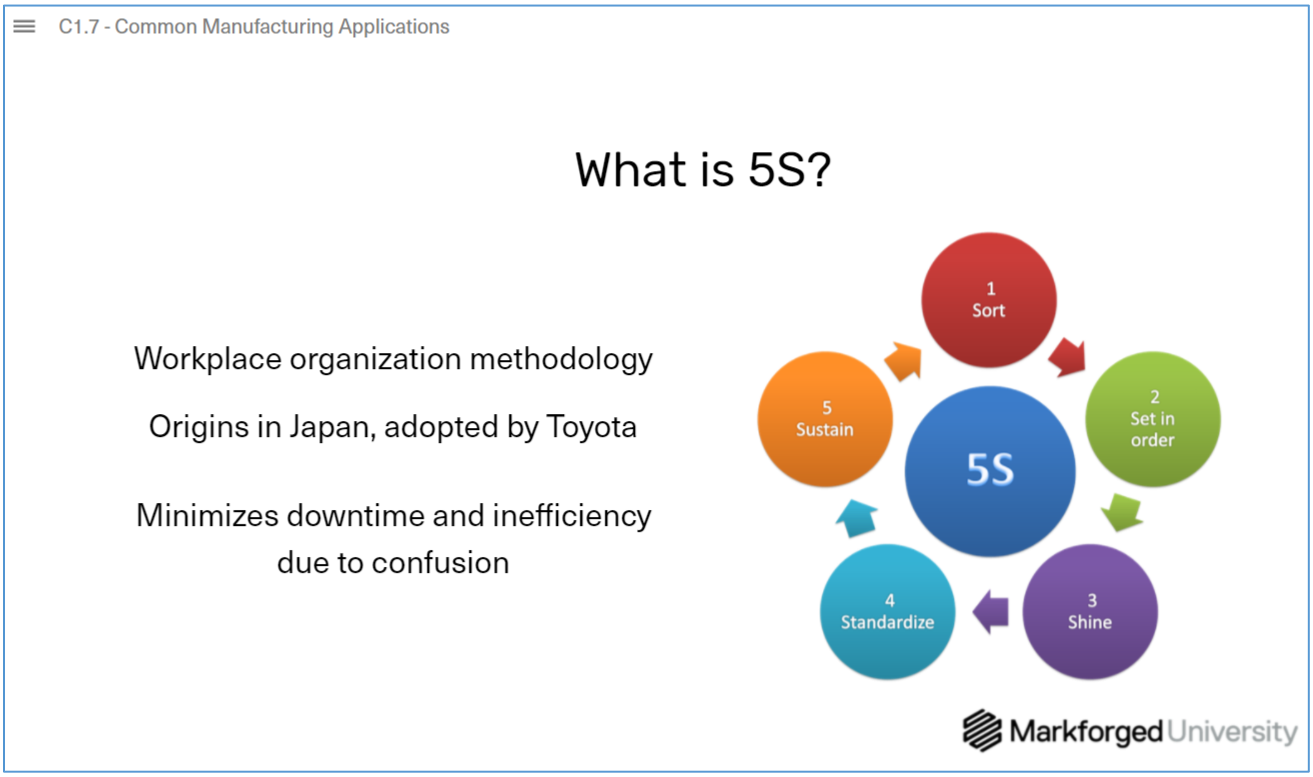
C1.7 - Common Manufacturing Applications RESOURCES



- **Updating Aging Equipment**
  - Backsite of a sheet metal press in an automatic workcell: Upper and lower extence for quicly adjustment traveldistance changing between different press operations.

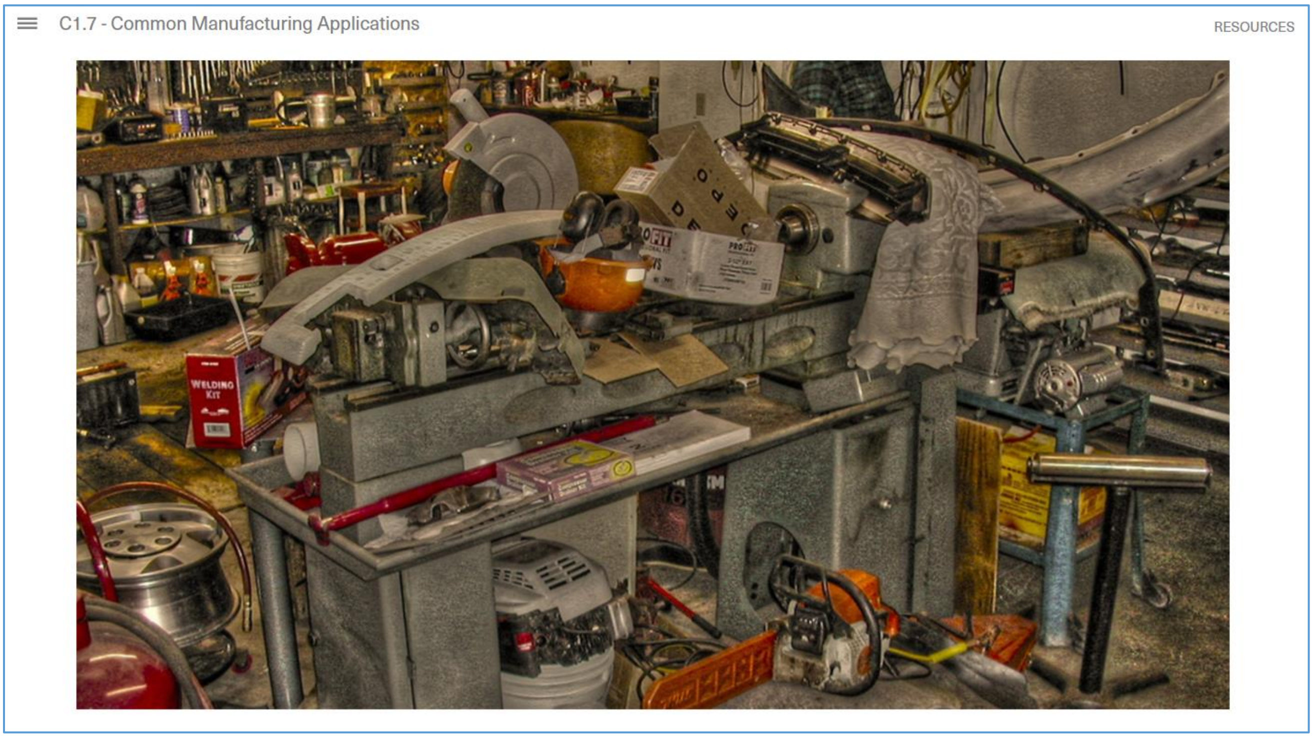
C1.7 - Common Manufacturing Applications RESOURCES

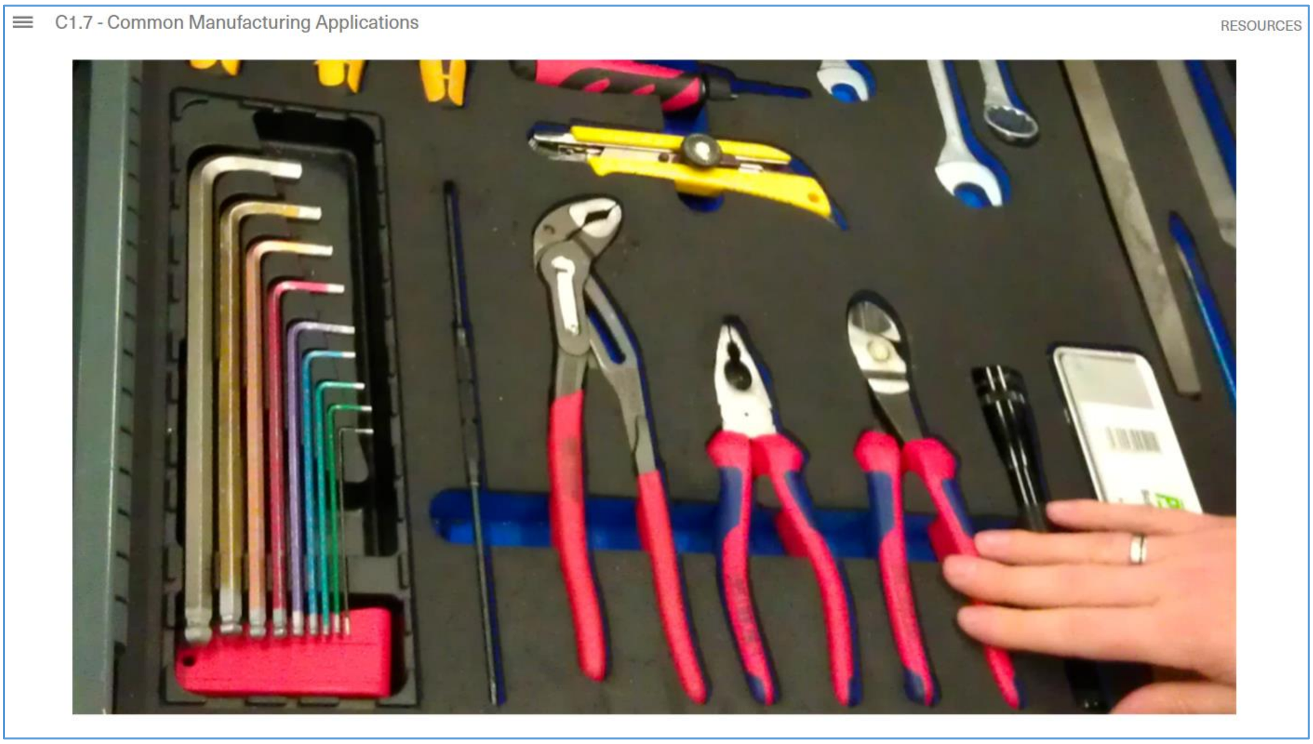
- **Part 4: Workplace Organization and 5S Systems**



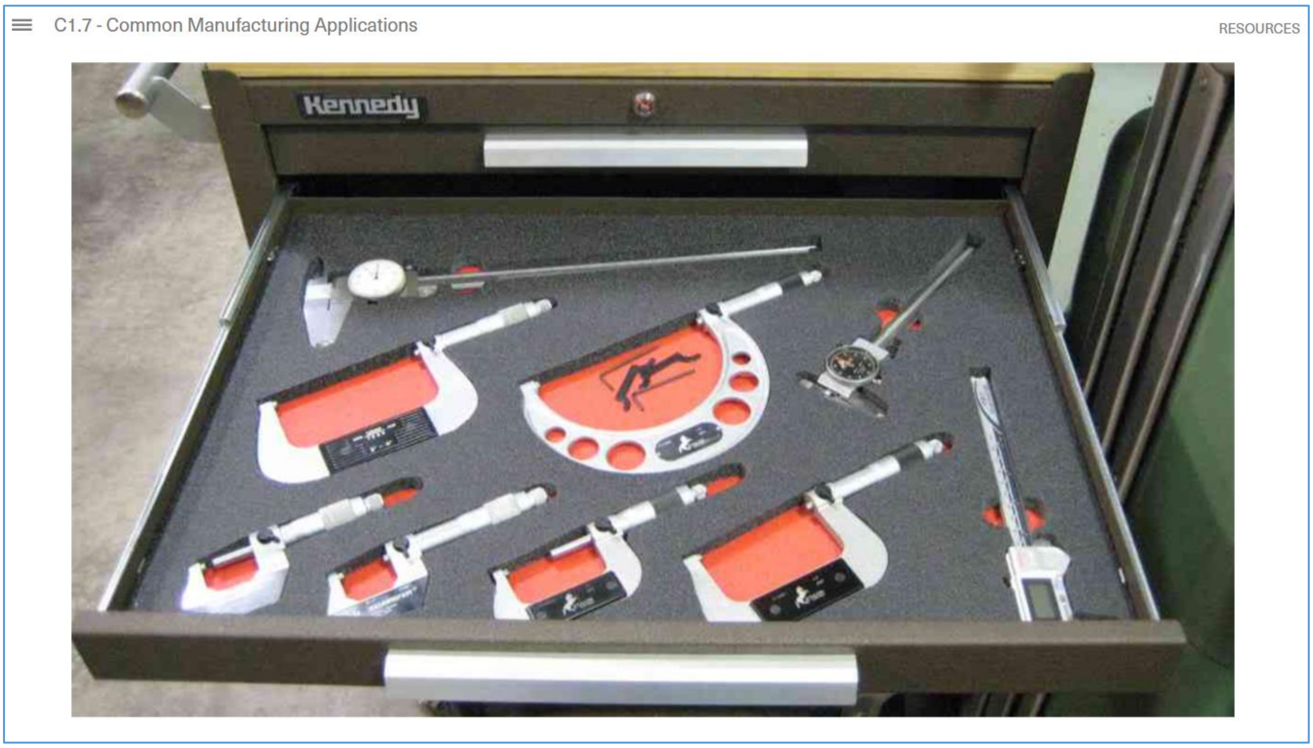
1. Scheiden
2. Schikken
3. Schoonmaken
4. Standaardiseren

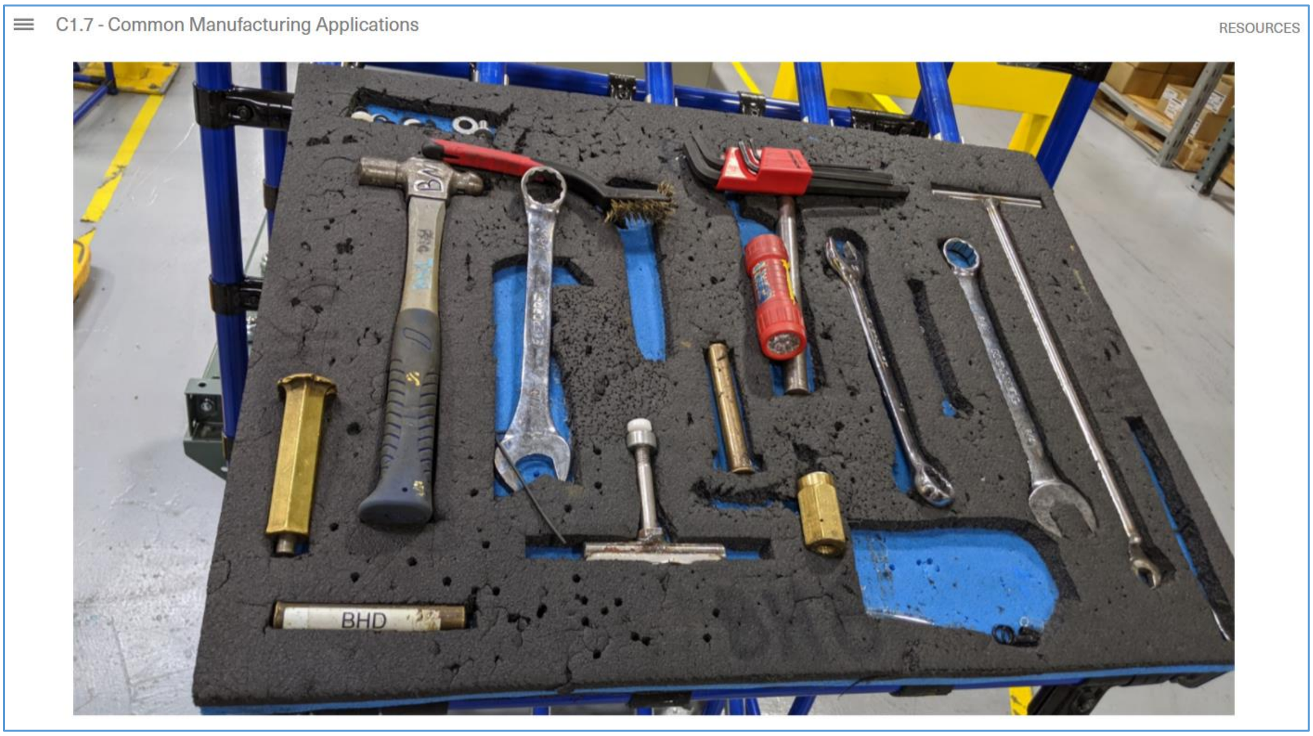
5. Standhouden of systematiseren





- **5S Tool Organizers**





- **Outdated 5S Tool Organizers**
    - Foam solutions will be damaged after wear and tear by aging of time.

C1.7 - Common Manufacturing Applications

RESOURCES

C1.7 - Common Manufacturing Applications

Change is the Downfall of 5S

Custom foam inserts for 5S organizers are great...until tools and needs change

Foam isn't modular, most facilities don't have tools to properly modify

Modular 3D printed 5S organizers enable future-proof continuous improvements

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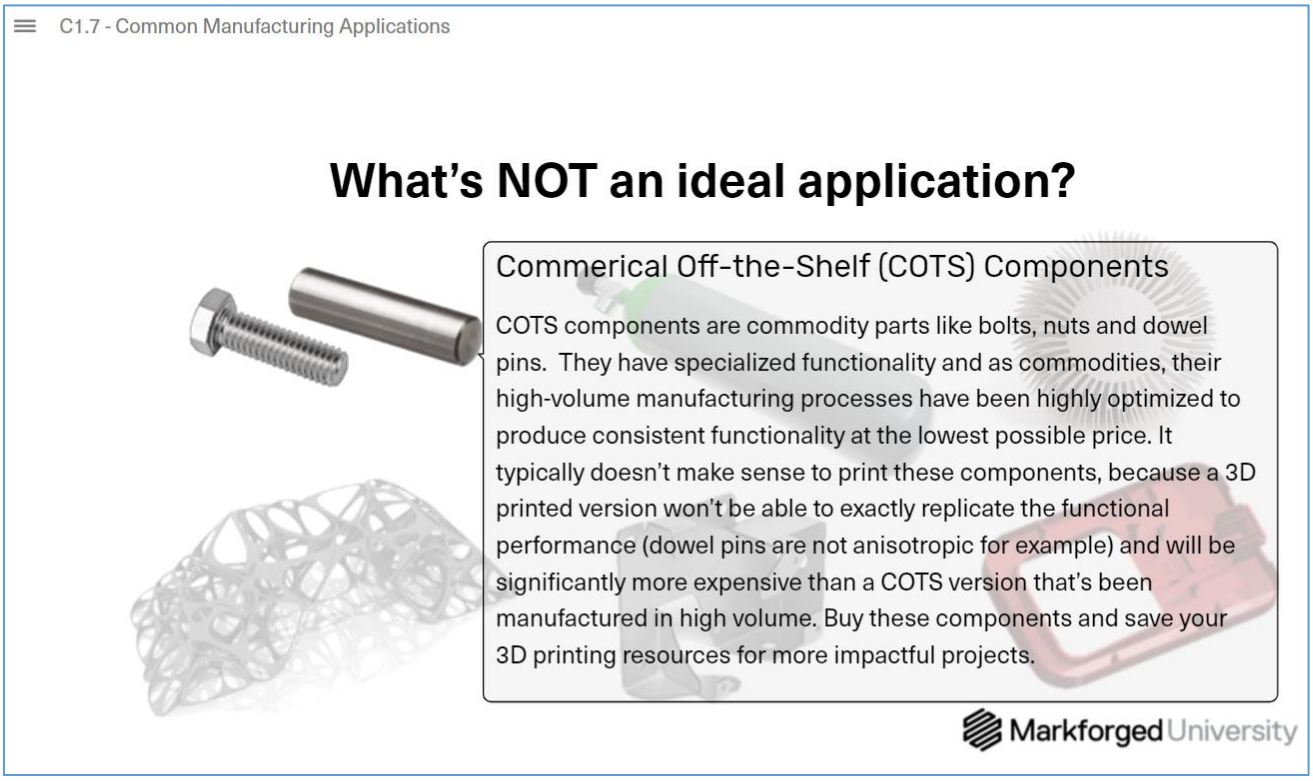
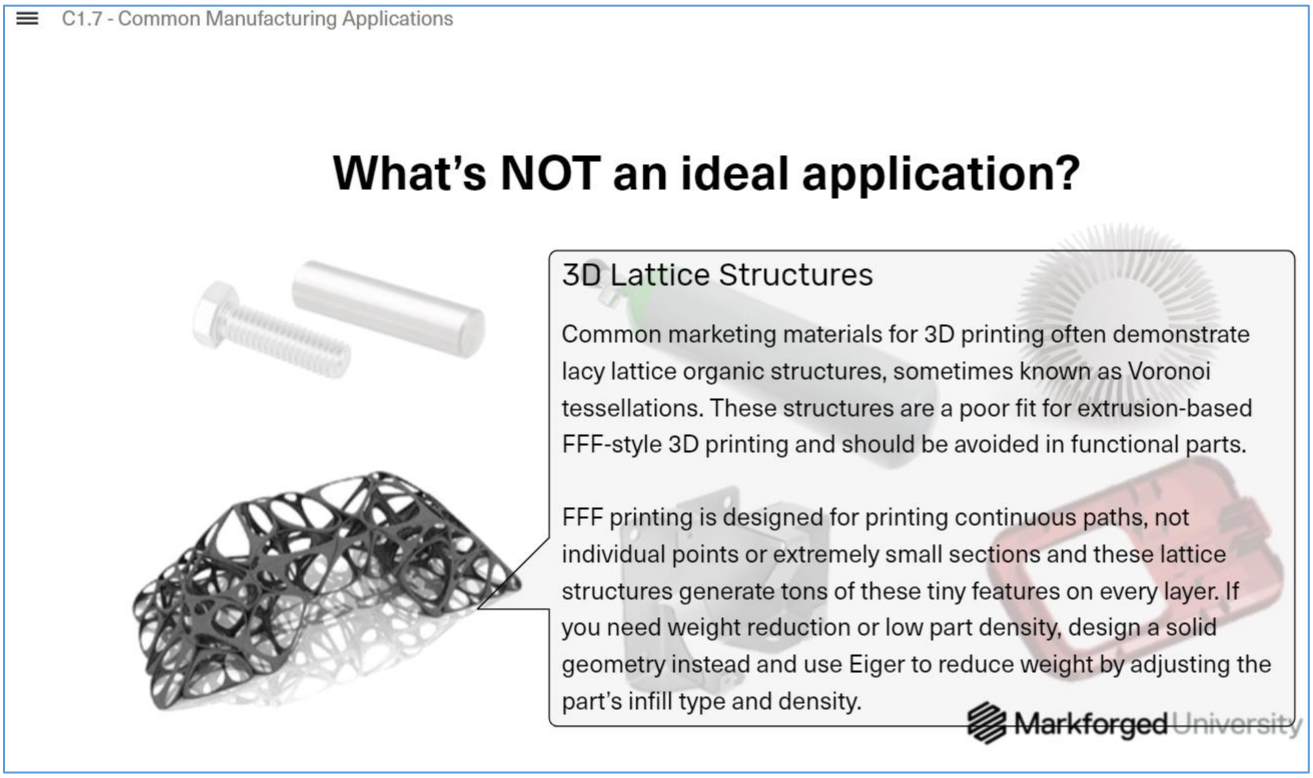
- **3D Printed Tool Holder**
    - When they update their calipers (new model) and the shape of the holder is not appropiate tot he new tool, only the single holder needs an update, not the intire shadowboard.

- **What's NOT ani deal application?**



- Commodity = Gemeengoed.



C1.7 - Common Manufacturing Applications

What's NOT an ideal application?

High-Pressure Vessels

3D printed parts SHOULD NOT be used to create static pressure vessels, especially for holding gaseous pressure that stores significant potential energy. Pressurized liquids and gases apply forces normal to the surface of their containers, and with 3D printing this means that the pressure will always be producing expansion forces in the Z-axis direction of the part that can cause failures between layers. The printed layer lines also serve as stress concentrators that aid in sudden crack initiation between layers. Should a crack develop, the pressure will cause it to propagate and the part will break, releasing the pressure and stored energy in an instant and often creating shrapnel from the part. 3D printed pressure vessels are extremely dangerous and should not be created.

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C1.7 - Common Manufacturing Applications

What's NOT an ideal application?

Extremely Fine Features (<0.5 mm [0.02 in])

Parts with microscopic or intricate features below this level tend to be a poor fit for extrusion 3D printing. Markforged composite printers print plastic in 0.4 mm [0.016 in] wide paths with layer heights ranging from 0.05-0.25 mm [0.002-0.01 in] which makes it difficult to accurately reproduce these fine features. Consider producing just the section of a part with these fine features with another process, like machining or wire EDM, then joining that with a larger 3D printed section to form an assembly.

If you do have to 3D print fine features, you'll get the highest resolution in the Z-axis, so features like tooling labeling will print with the highest fidelity if you place them on the vertical walls of a part versus the horizontal faces.

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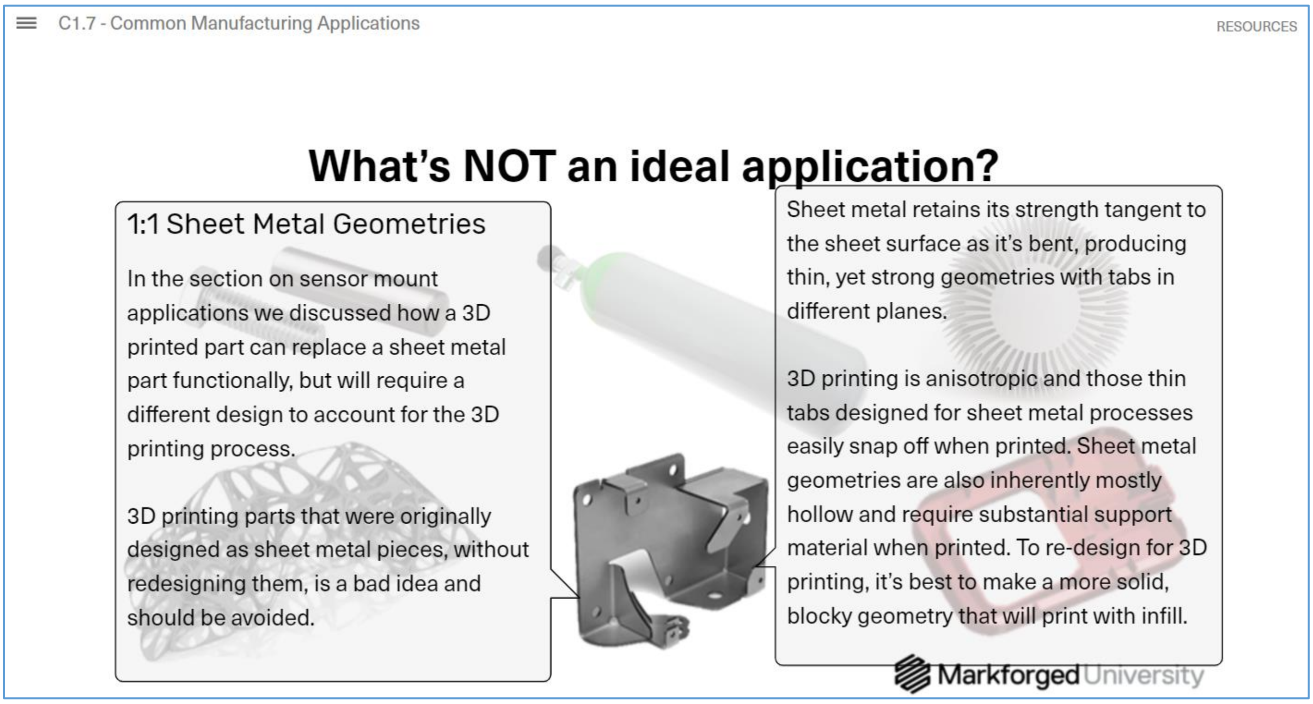
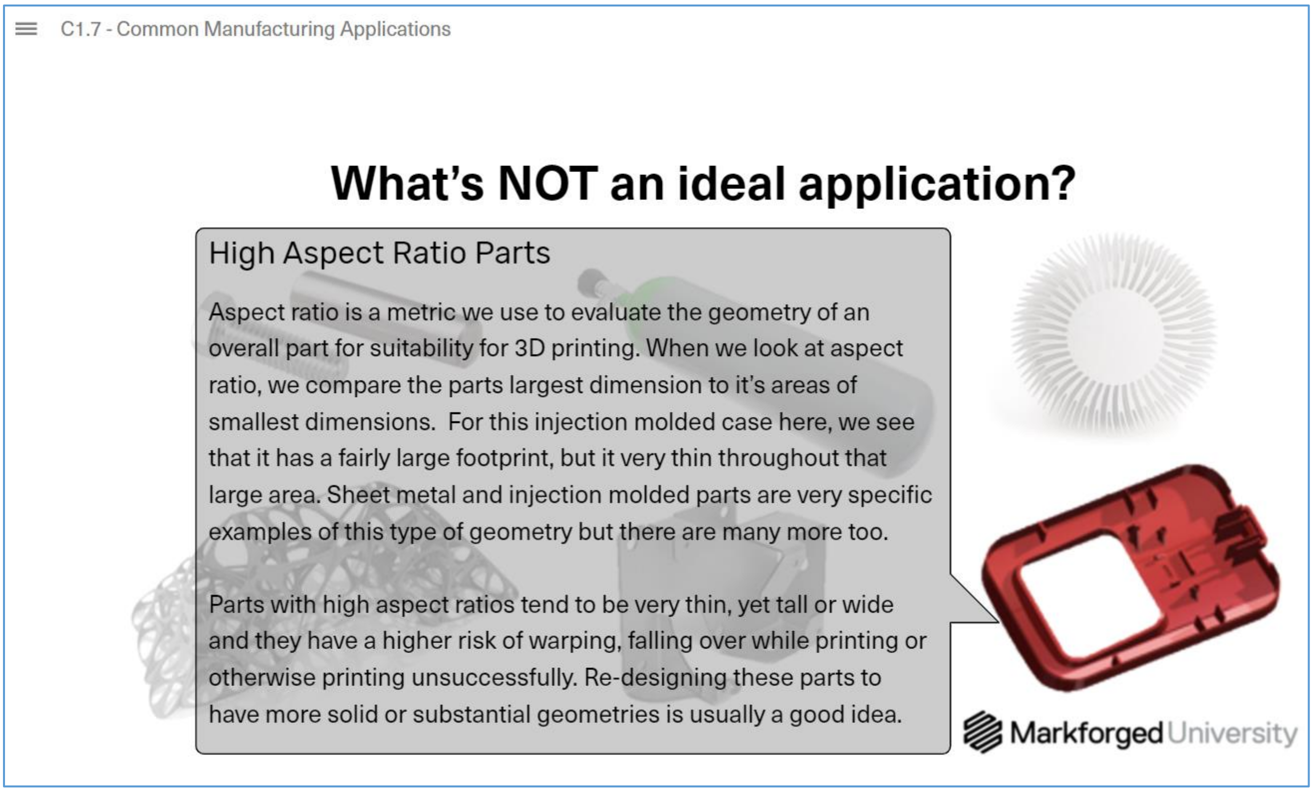




Aspect ratio is a metric we use to evaluate the geometry of an overall part for suitability for 3D printing. When we look at aspect ratio, we compare the parts largest dimension to it's areas of smallest dimensions. For this injection molded case here, we see that it has fairly large footprint, but it very thin throughout that large area. Sheet metal and injection molded parts are very specific examples of this type of geometry but there are many more too. Parts with high aspect ratios tend to be very thin, yet tall or wide and they have a higher risk of warping, falling over while printing or otherwise printing unsuccessfully. Re-designing these parts to have more solid or substantial geometries is usually a good idea.

Beeldverhouding is een maatstaf die we gebruiken om de geometrie van een algemeen onderdeel te evalueren op geschiktheid voor 3D-printen. Als we kijken naar de beeldverhouding, vergelijken we de grootste afmeting van de onderdelen met de gebieden met de kleinste afmetingen. Voor deze spuitgegoten behuizing zien we dat deze een vrij grote voetafdruk heeft, maar over dat grote gebied erg dun is. Plaatwerk en spuitgietonderdelen zijn zeer specifieke voorbeelden van dit soort geometrie, maar er zijn er nog veel meer. Onderdelen met hoge aspectverhoudingen zijn meestal erg dun, maar toch lang of breed en lopen een groter risico op kromtrekken, omvallen tijdens het afdrukken of op een andere manier zonder succes. Het opnieuw ontwerpen van deze onderdelen om meer solide of substantiële geometrieën te hebben, is meestal een goed idee.

- **Module Review**

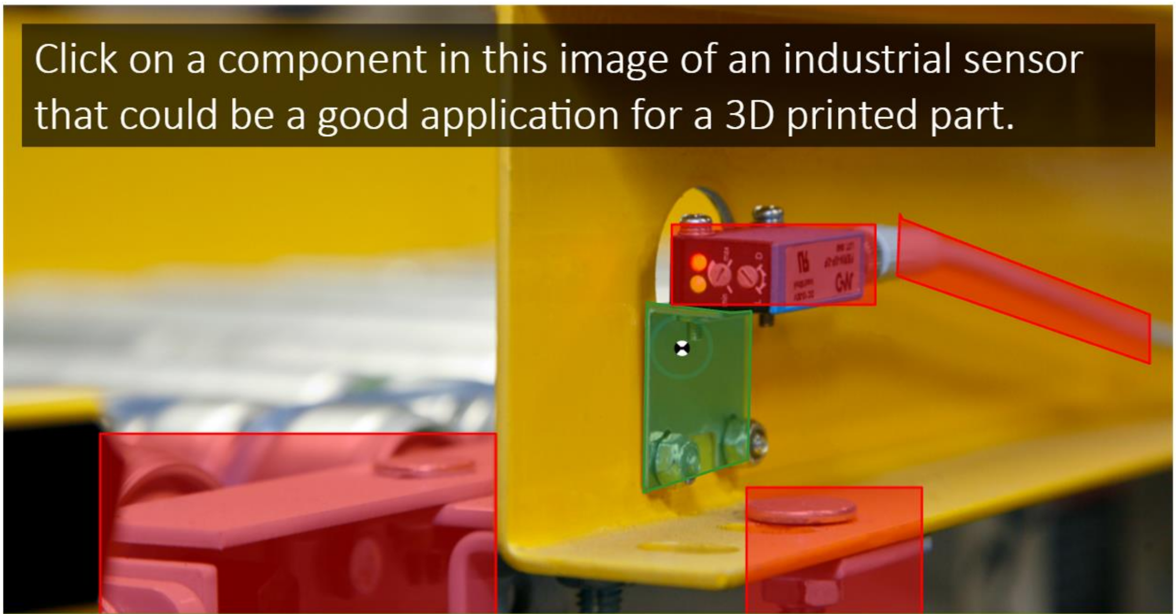
C1.7 - Common Manufacturing Applications RESOURCES

Mark all of the following that represent common manufacturing applications of Markforged composite 3D printed parts.

- [ ] Sand casting crucibles for containing molten steel
- [ ] Prototyping for injection molded parts
- [x] Fixtures for component assembly
- [x] Tooling and workholding
- [x] Workplace organization tools

Correct ×

C1.7 - Common Manufacturing Applications RESOURCES



Correct ×

C1.7 - Common Manufacturing Applications

RESOURCES

Which is a likely example of a non-ideal potential application of 3D printing with Markforged?

- A complex assembly fixture that was previously made from aluminum
- A tool holder for a pair of pliers to keep a work cell organized
- ✔ A prototype of a large, thin injection molded shell with flexible latches in different axes
- A pair of grippers for a cooperative industrial robot for a new product line

Correct ×

C1.7 - Common Manufacturing Applications

RESOURCES

True/False: You've designed a tool that's an assembly of custom parts, plus some nuts and bolts and a pair of linear rails for part of the tool to slide on. You have the CAD for every component and should 3D print the entire tool because that's the easiest way to produce a functional part.

- True
- ✔ False

Correct ×

C1.7 - Common Manufacturing Applications

Results

Your Score:	100% (40 points)
Passing Score:	80% (32 points)

Result:

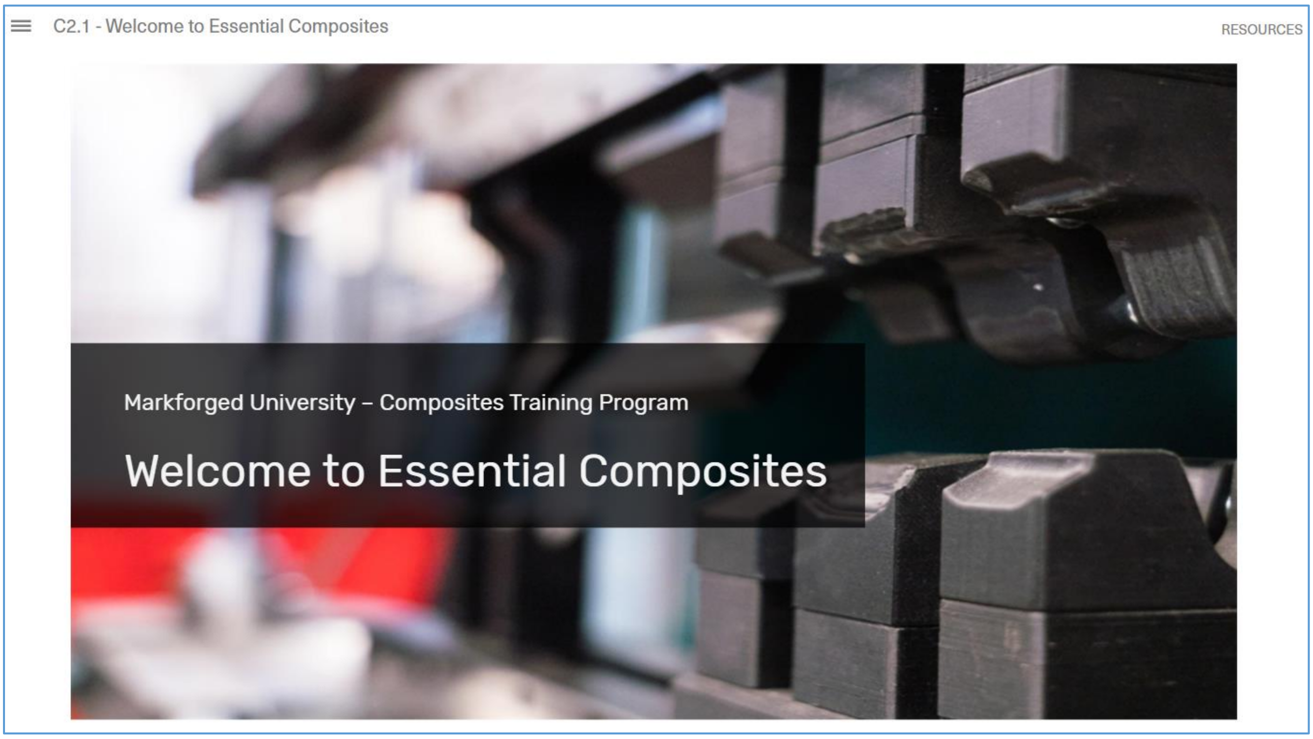
Congratulations, you passed.

Finish Module

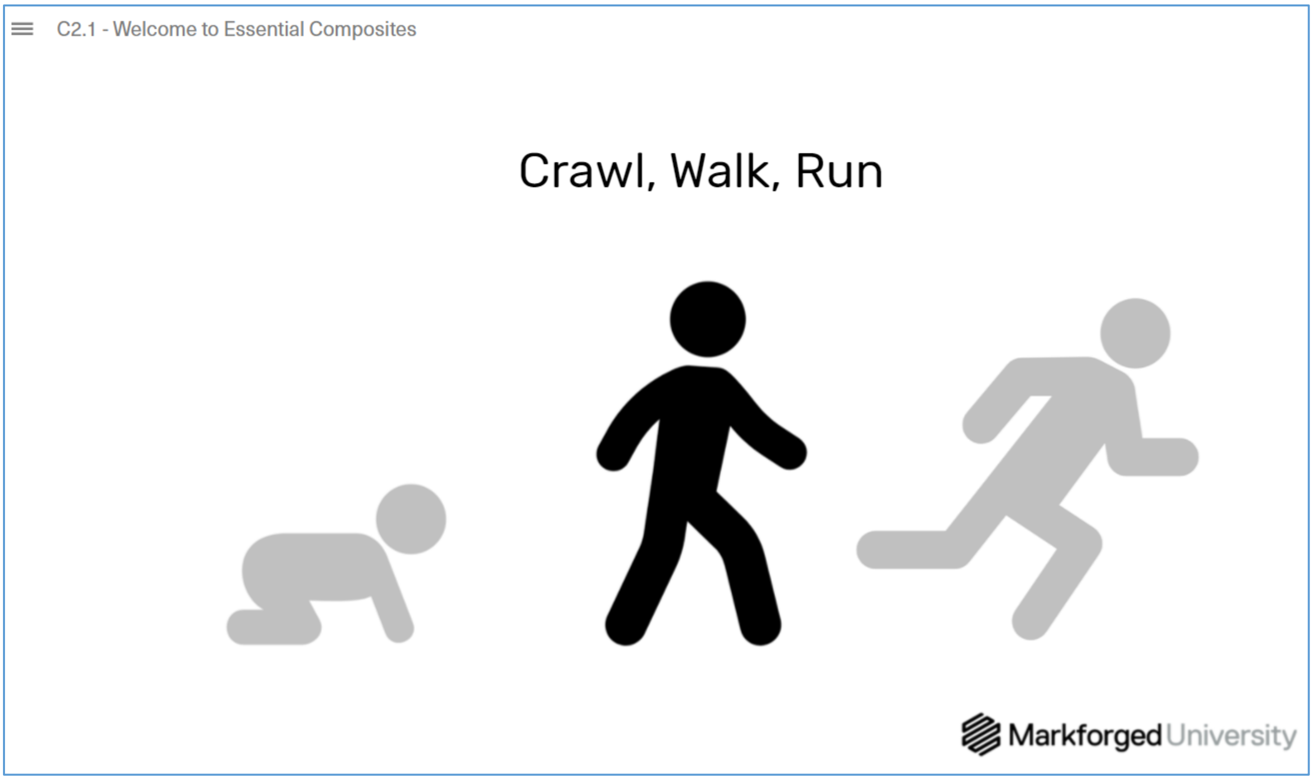
Review Quiz

Markforged University Essential Composites

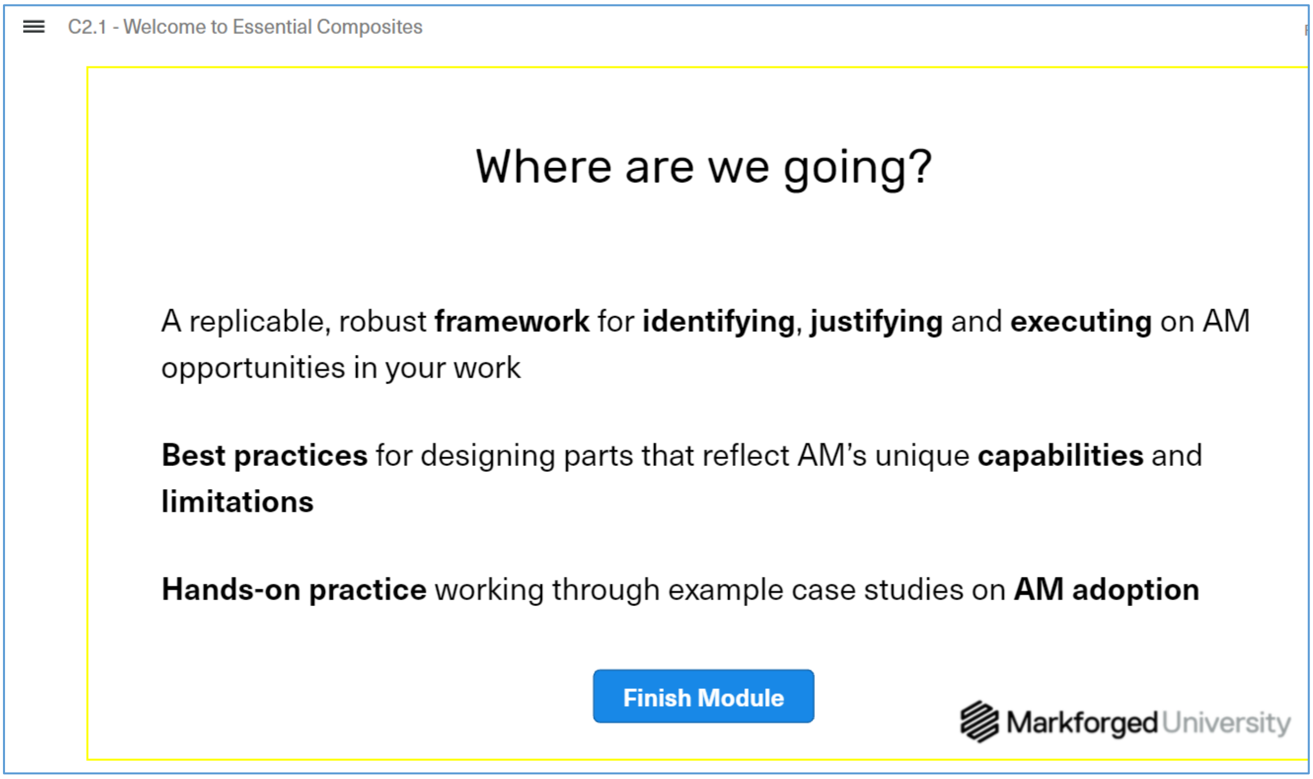
C2.1 – Welcome to Essential Composites



- **Welcome to Essential Composites**



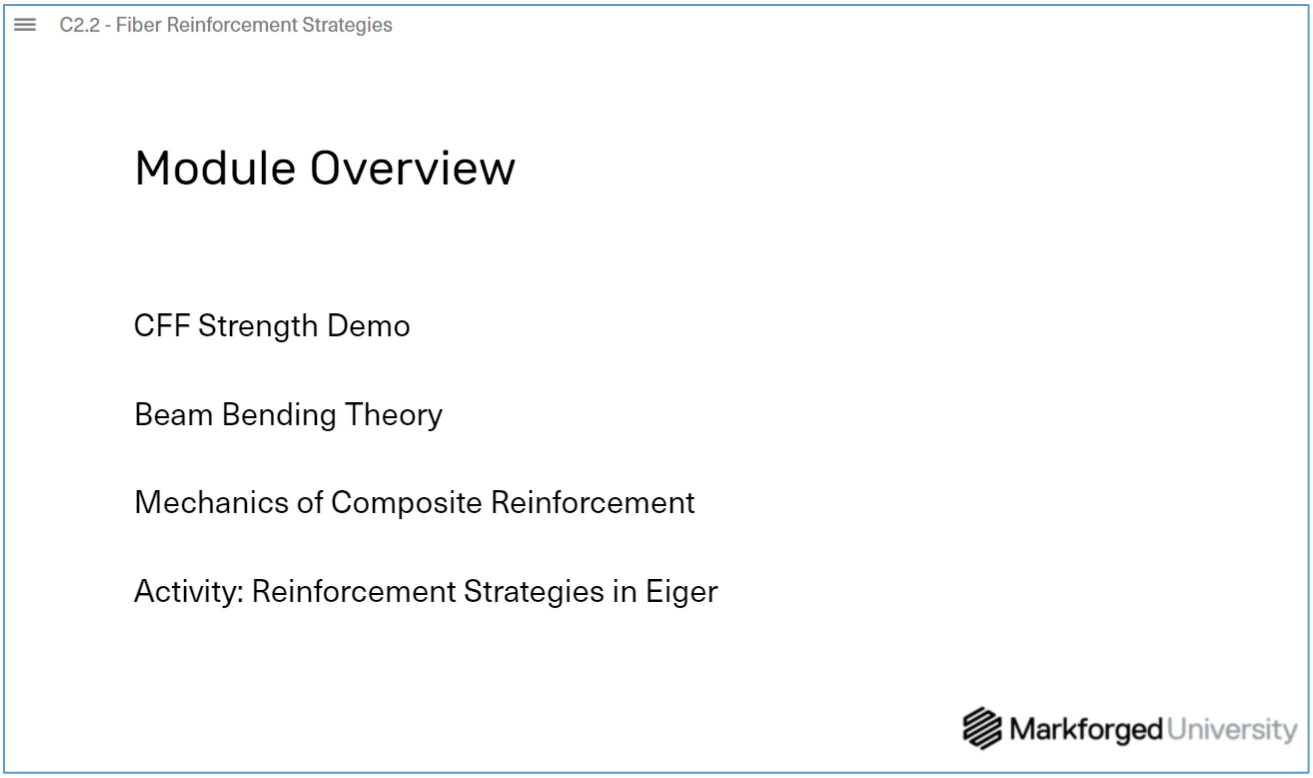
- **Crawl, Walk, Run**



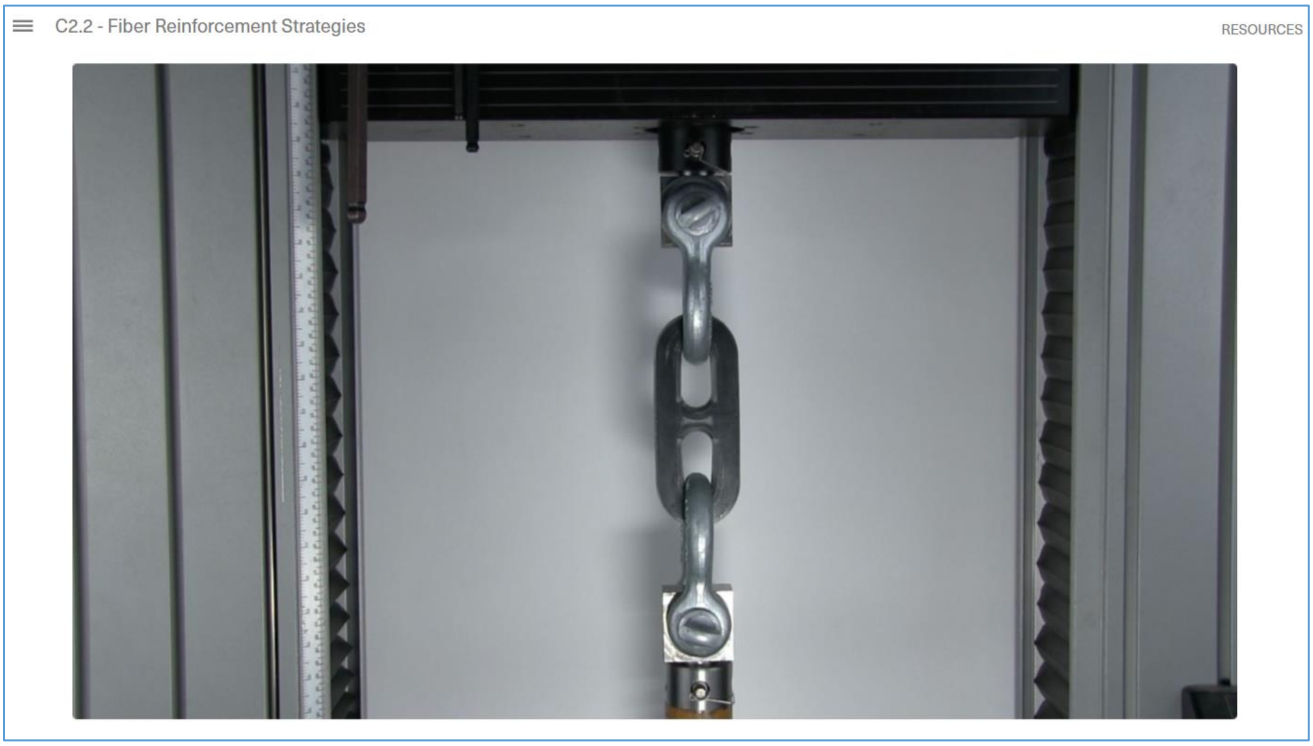
- **Where are we going?**

C2.2 – Fiber Reinforcement Strategies

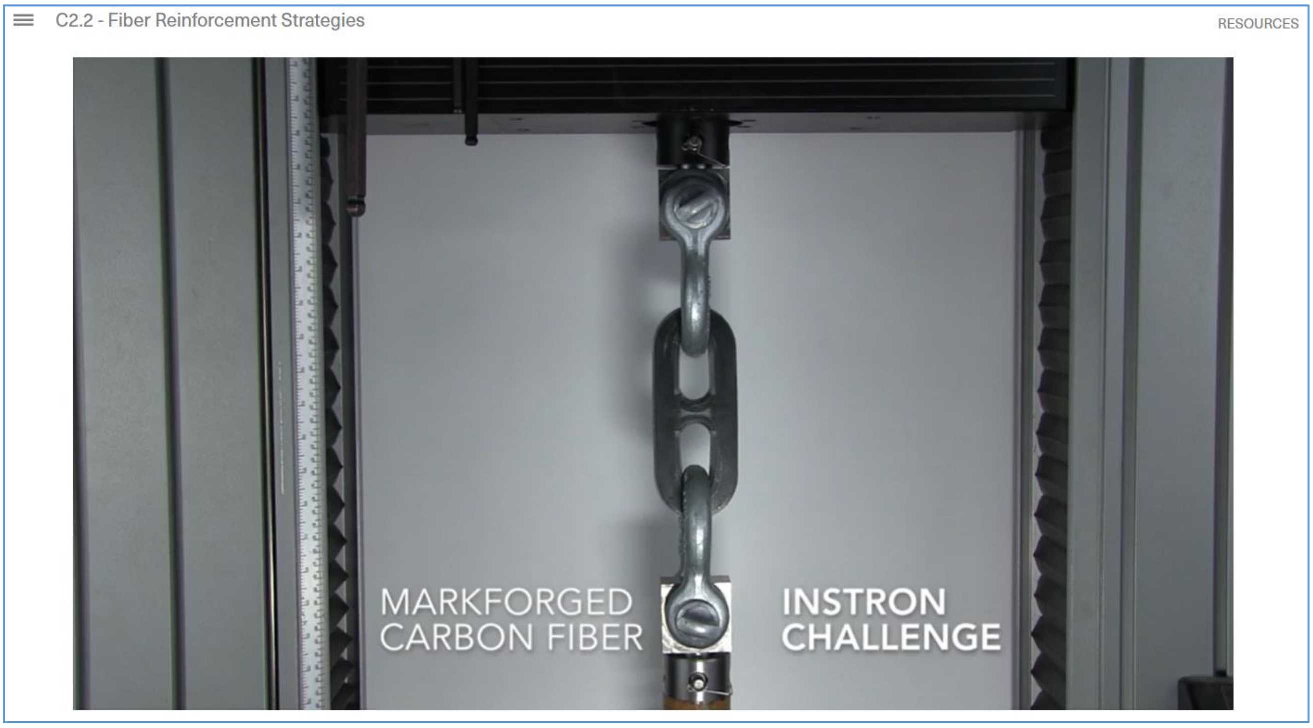
- **Fiber Reinforcement Strategies**

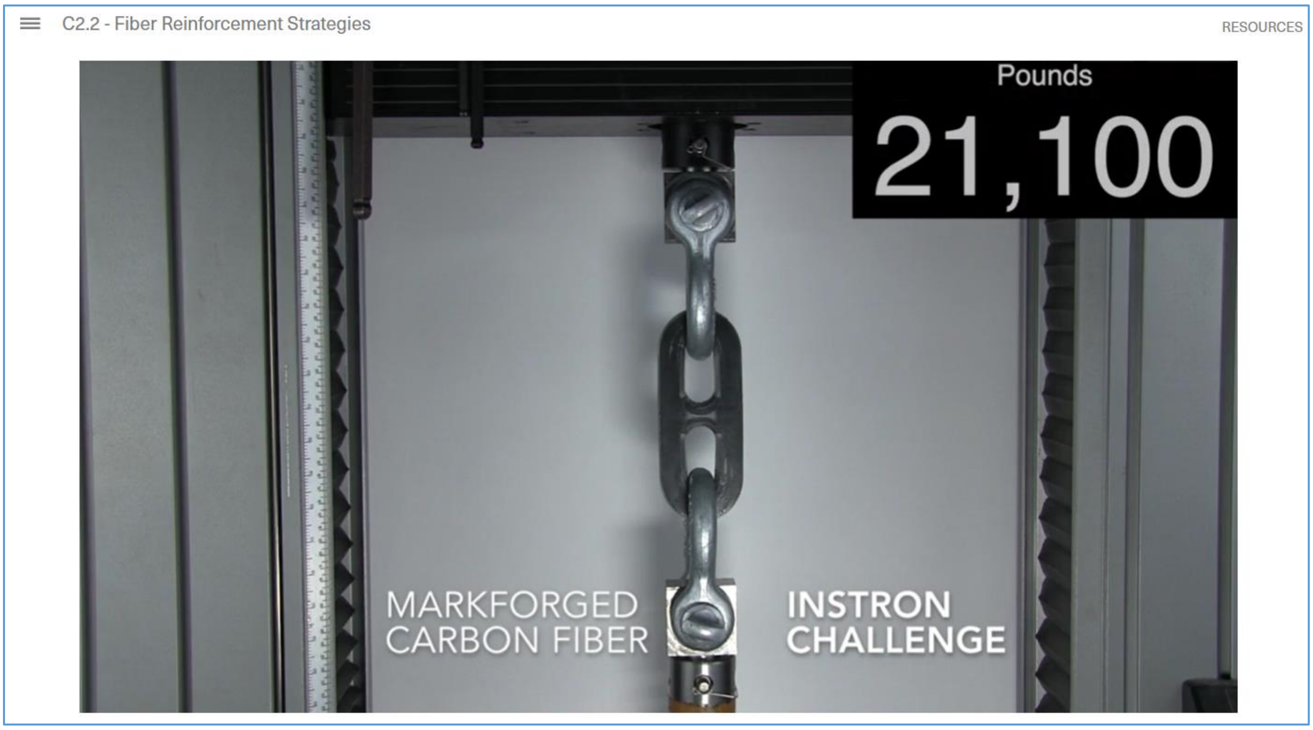


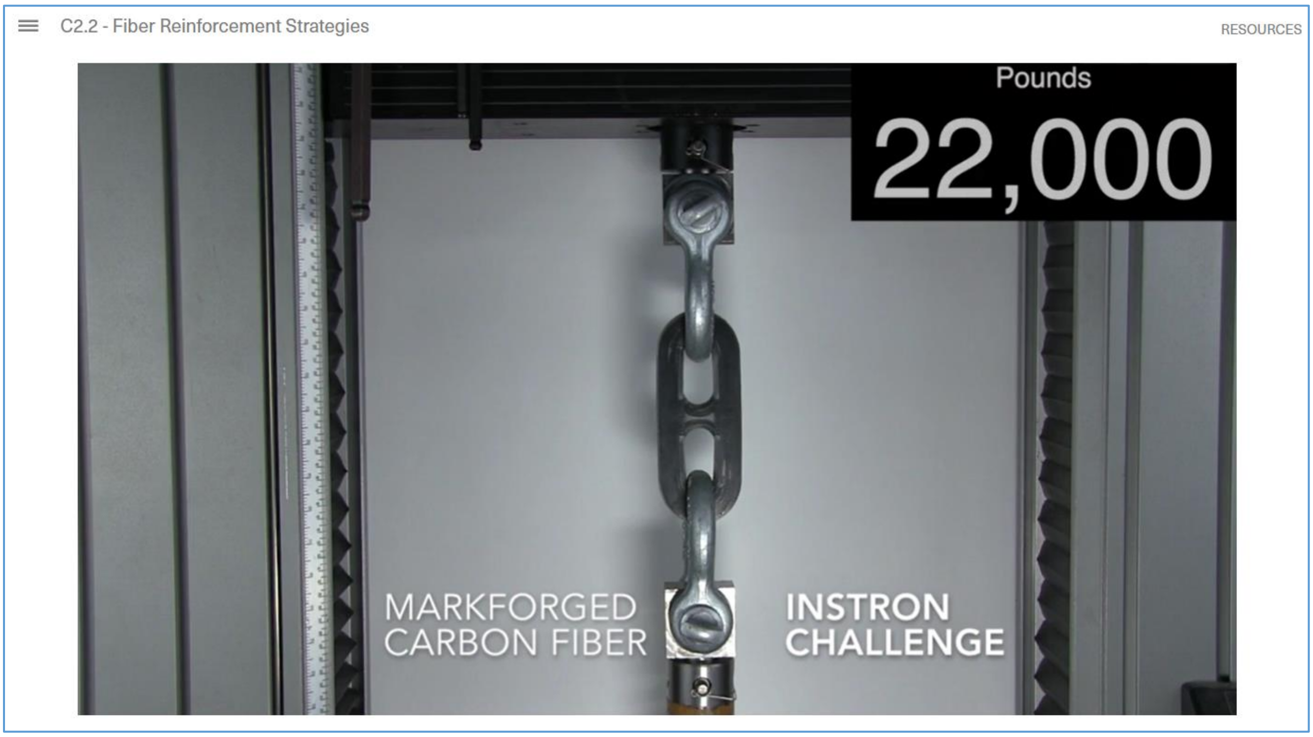
- **Module Overview**

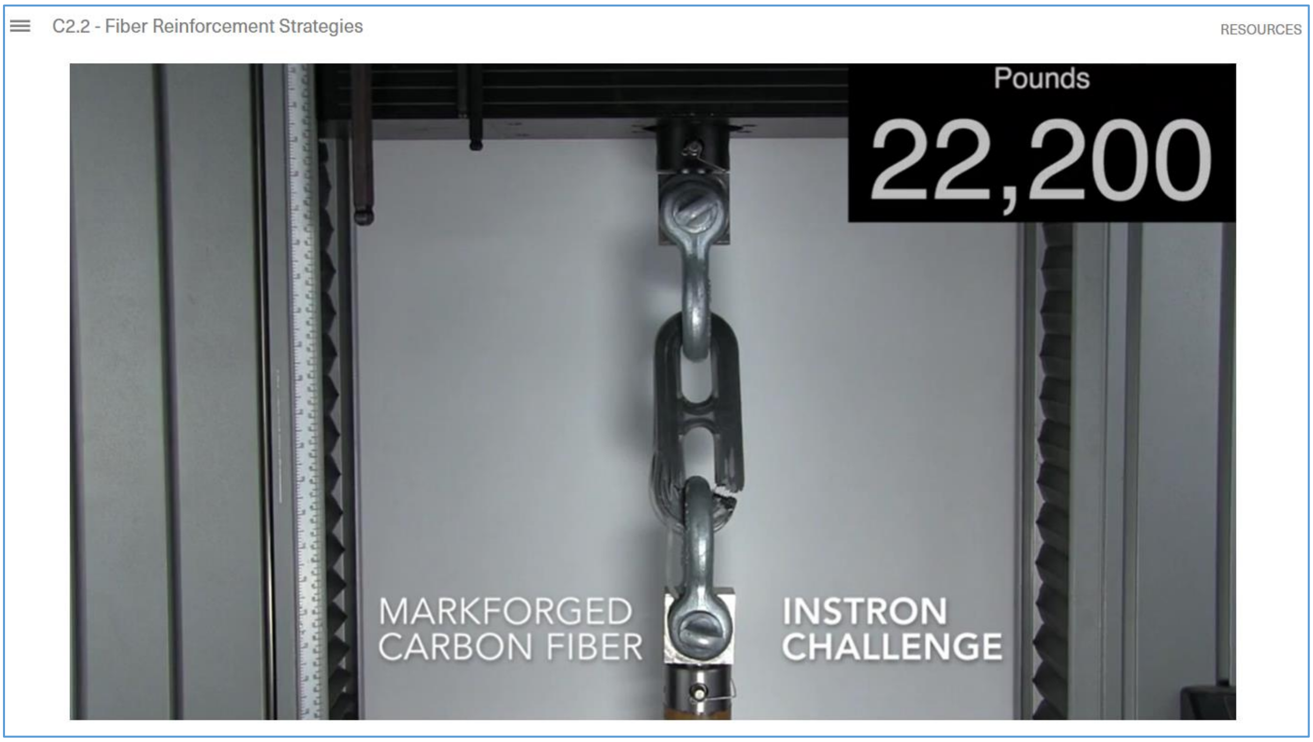


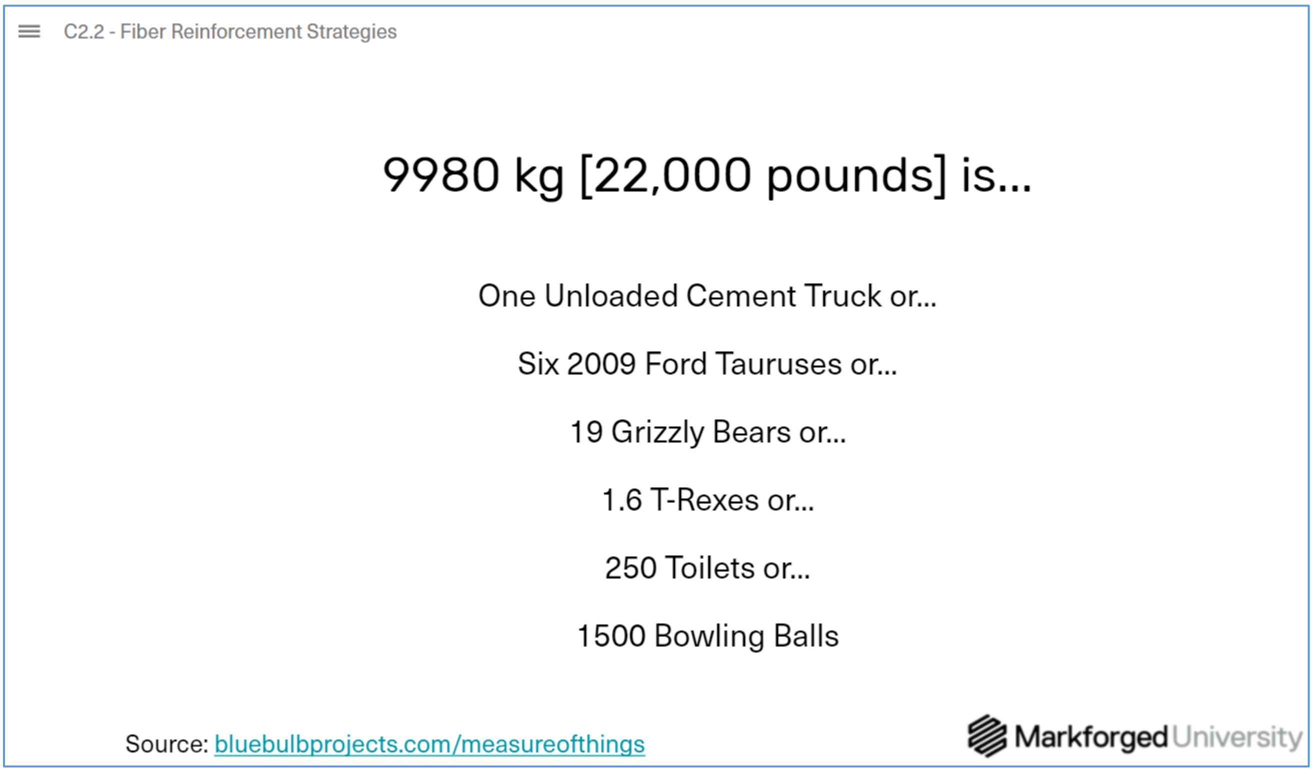
- **Video: The True Strength of Composites**


C2.2 - Fiber Reinforcement Strategies
RESOURCES
MARKFORGED
CARBON FIBER
INSTRON
CHALLENGE

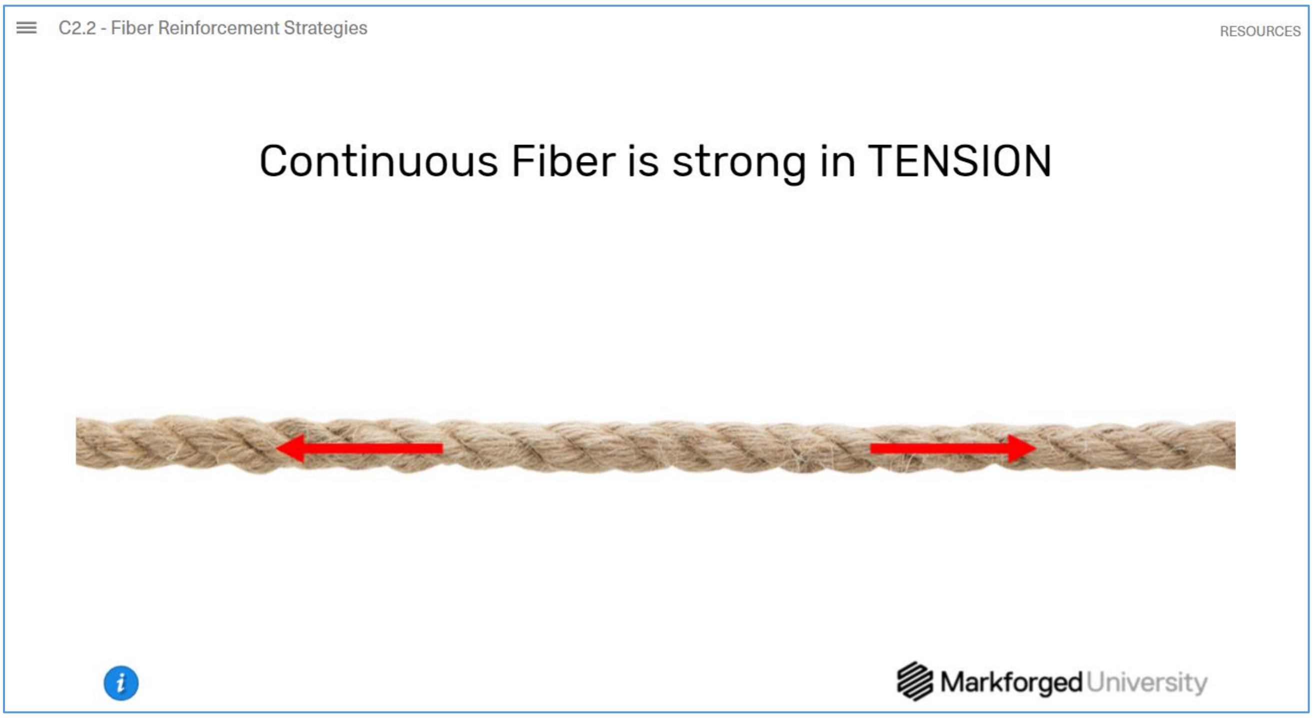

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Pounds
21,100
MARKFORGED
CARBON FIBER
INSTRON
CHALLENGE


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Pounds
22,000
MARKFORGED
CARBON FIBER
INSTRON
CHALLENGE

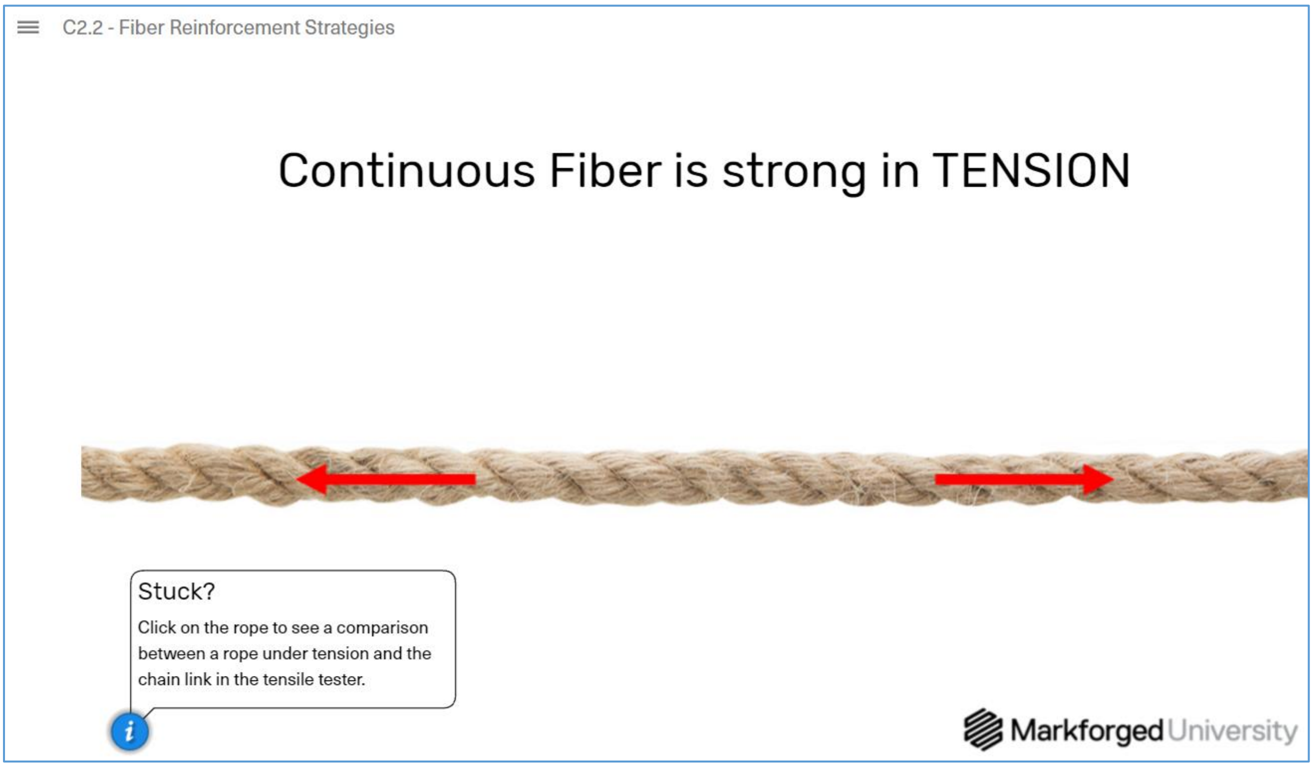

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Pounds
22,200
MARKFORGED
CARBON FIBER
INSTRON
CHALLENGE

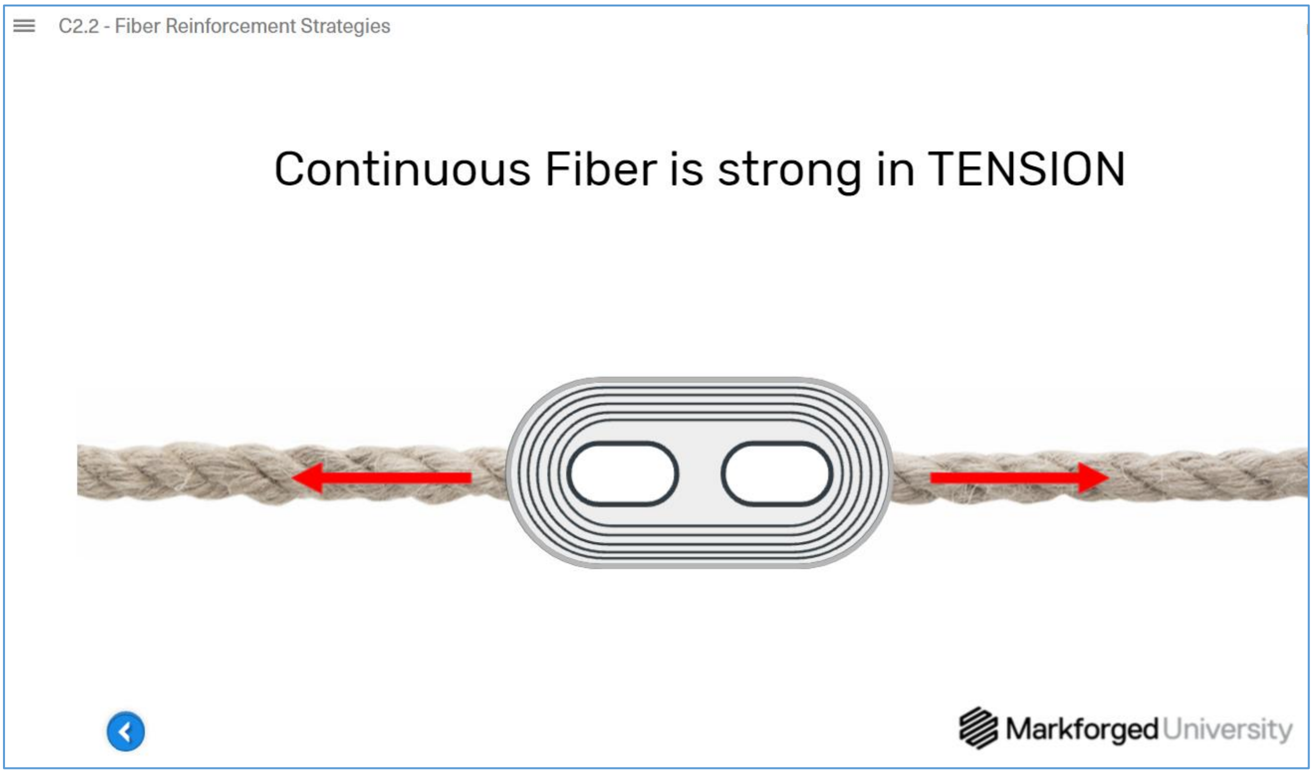


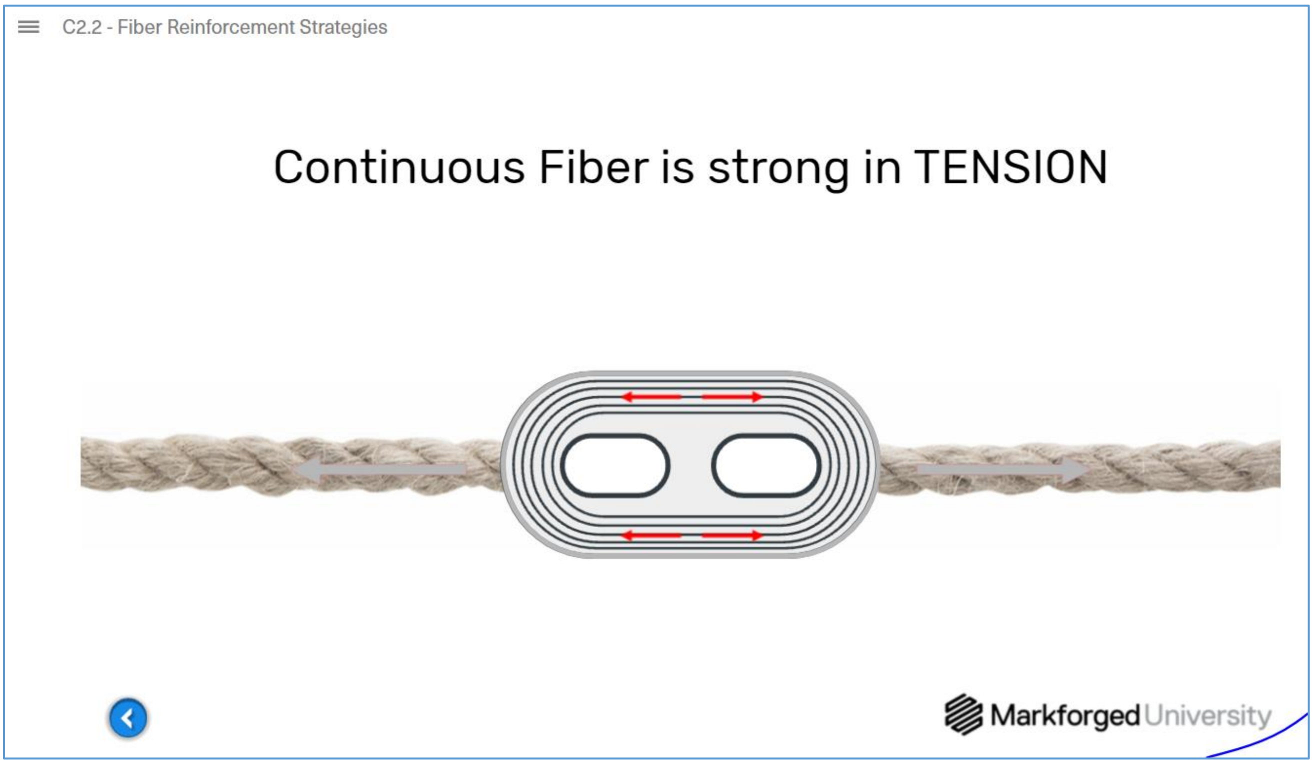
- **What is 22,000 Pounds?**
    - [The Measure of Things]



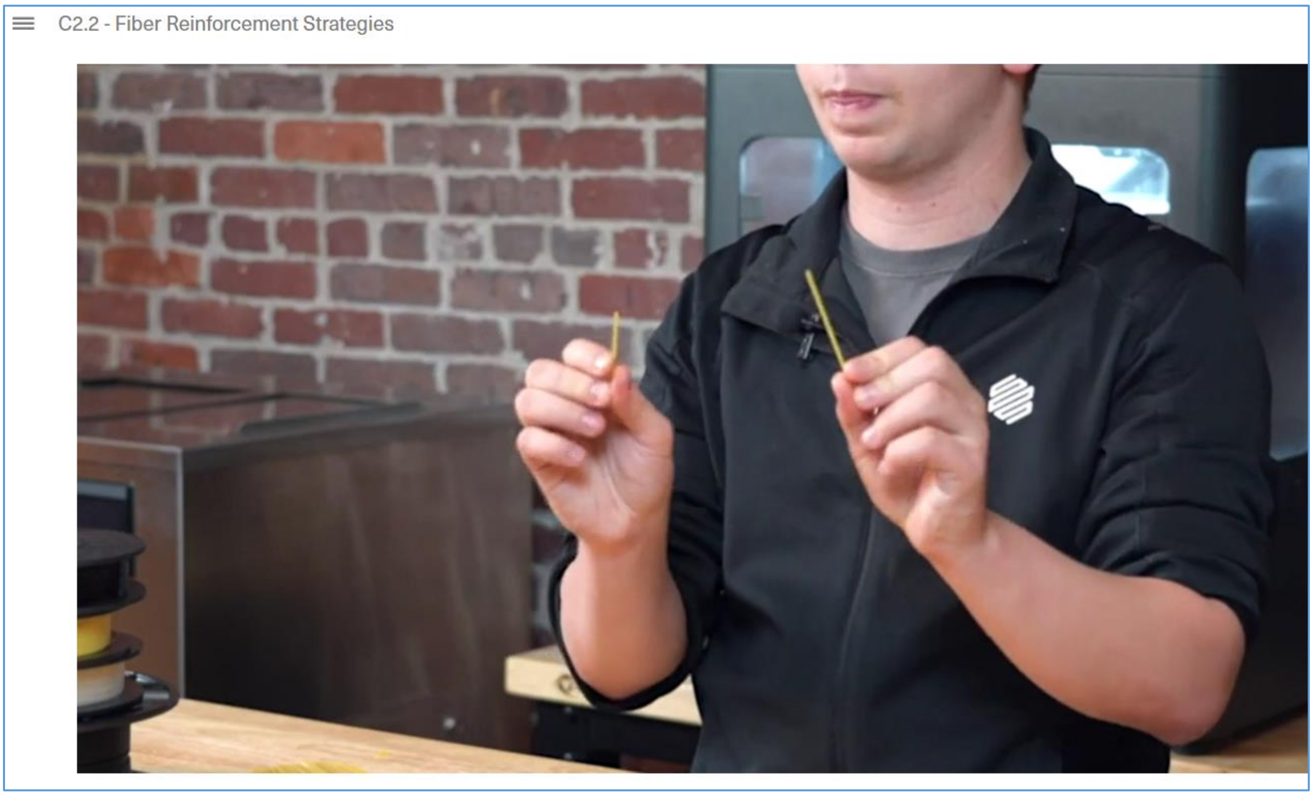
- **Continuous Fiber is strong in TENSION.**


C2.2 - Fiber Reinforcement Strategies
Continuous Fiber is strong in TENSION
Stuck?
Click on the rope to see a comparison between a rope under tension and the chain link in the tensile tester.
Markforged University

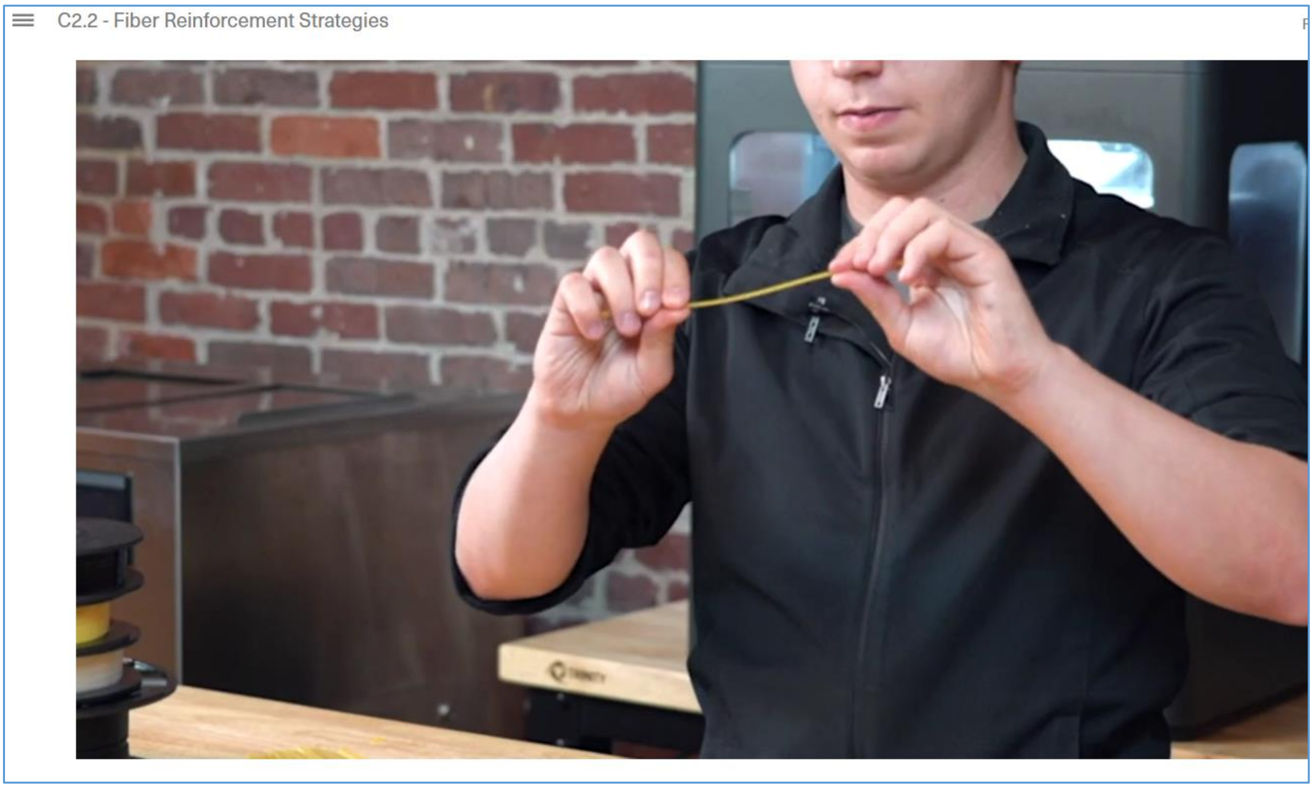

C2.2 - Fiber Reinforcement Strategies
Continuous Fiber is strong in TENSION
Markforged University



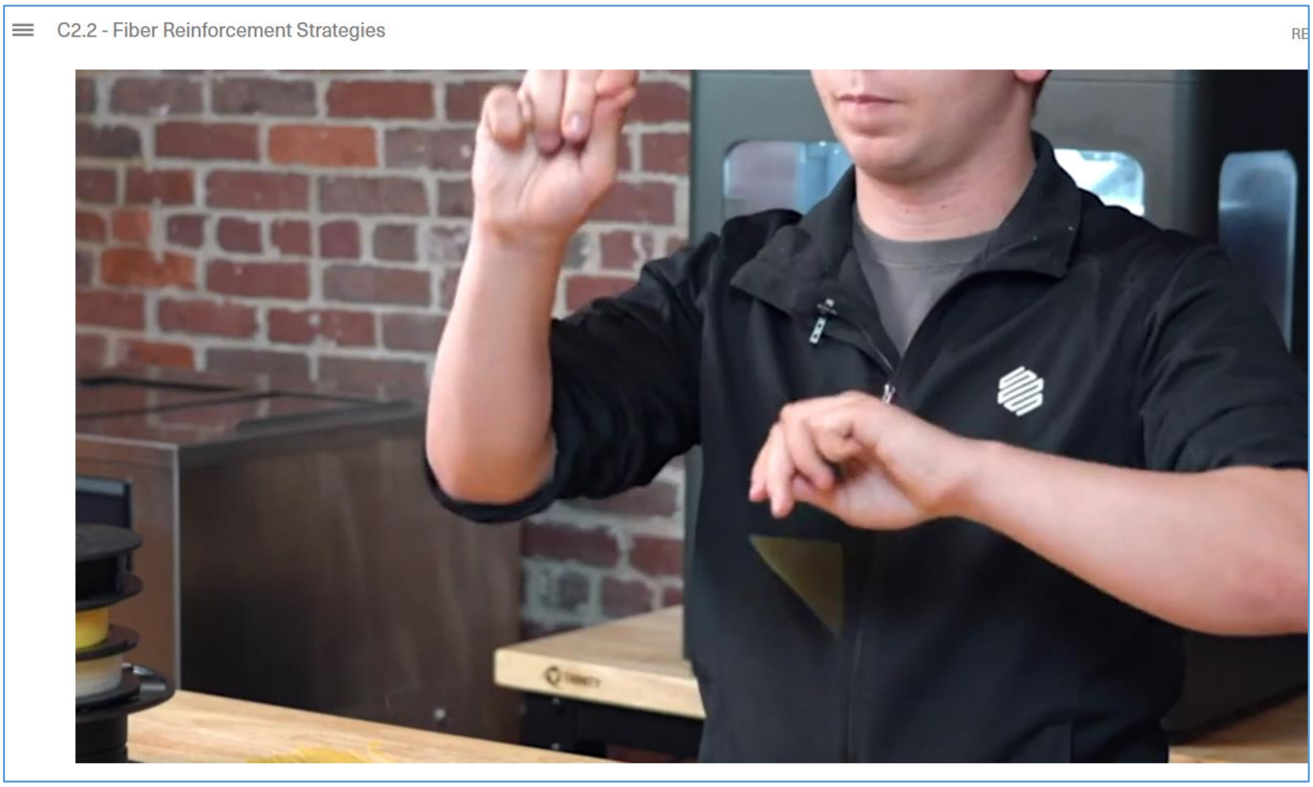
- **Activity: How Fiber Reacts to Applied Loads**



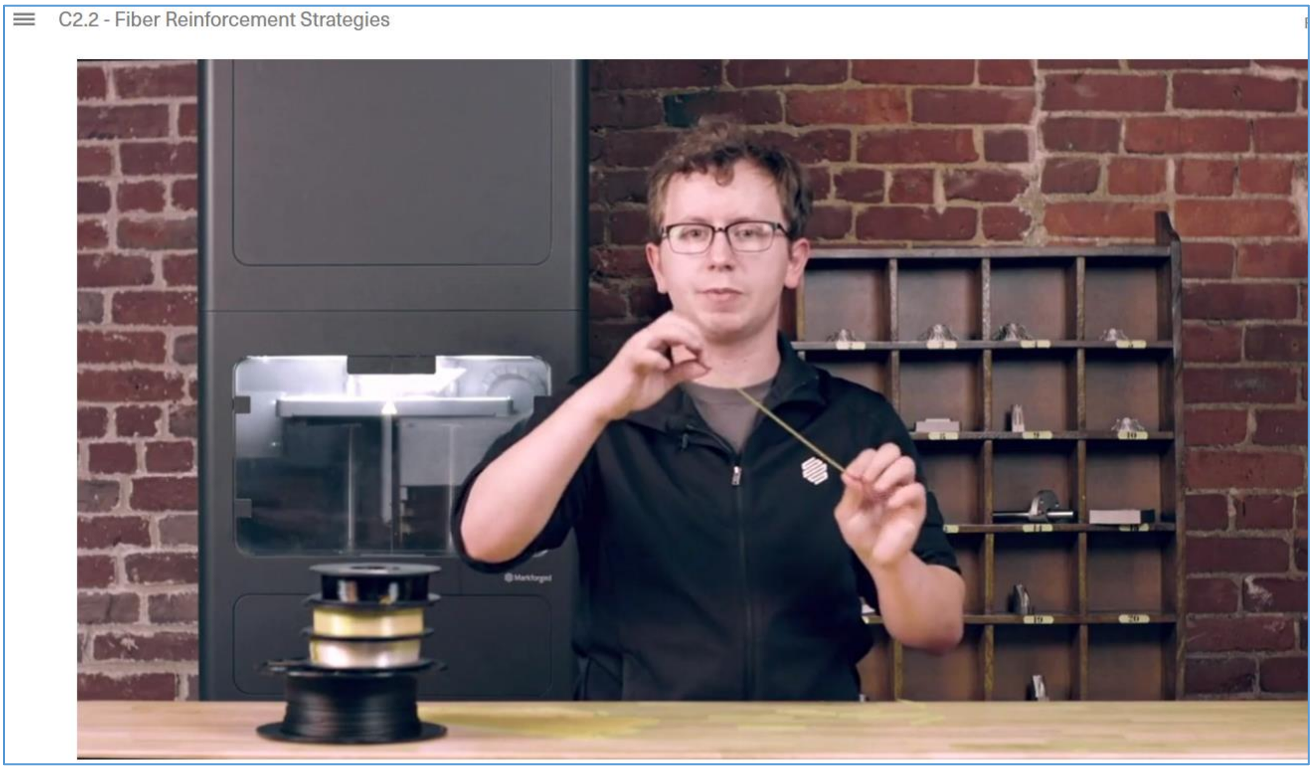
- Easily breaking by bending it.



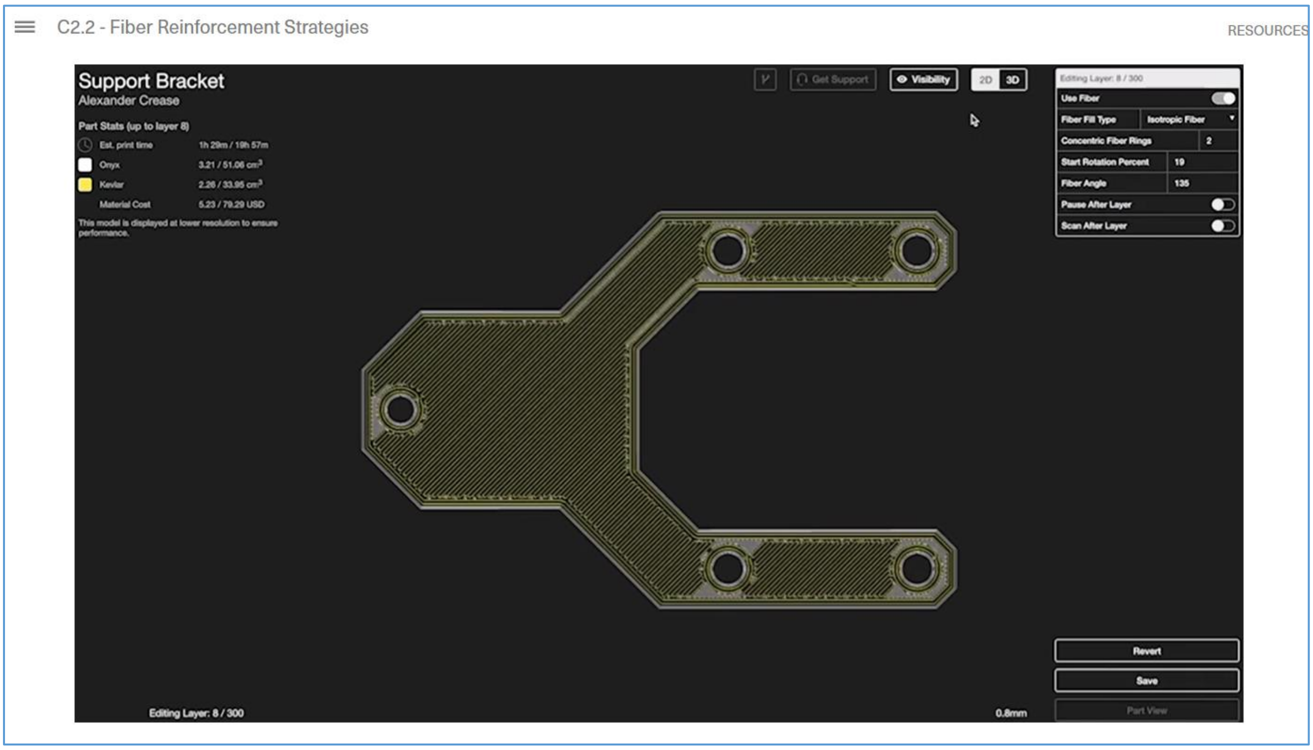
- Easily breaking by compressing it.

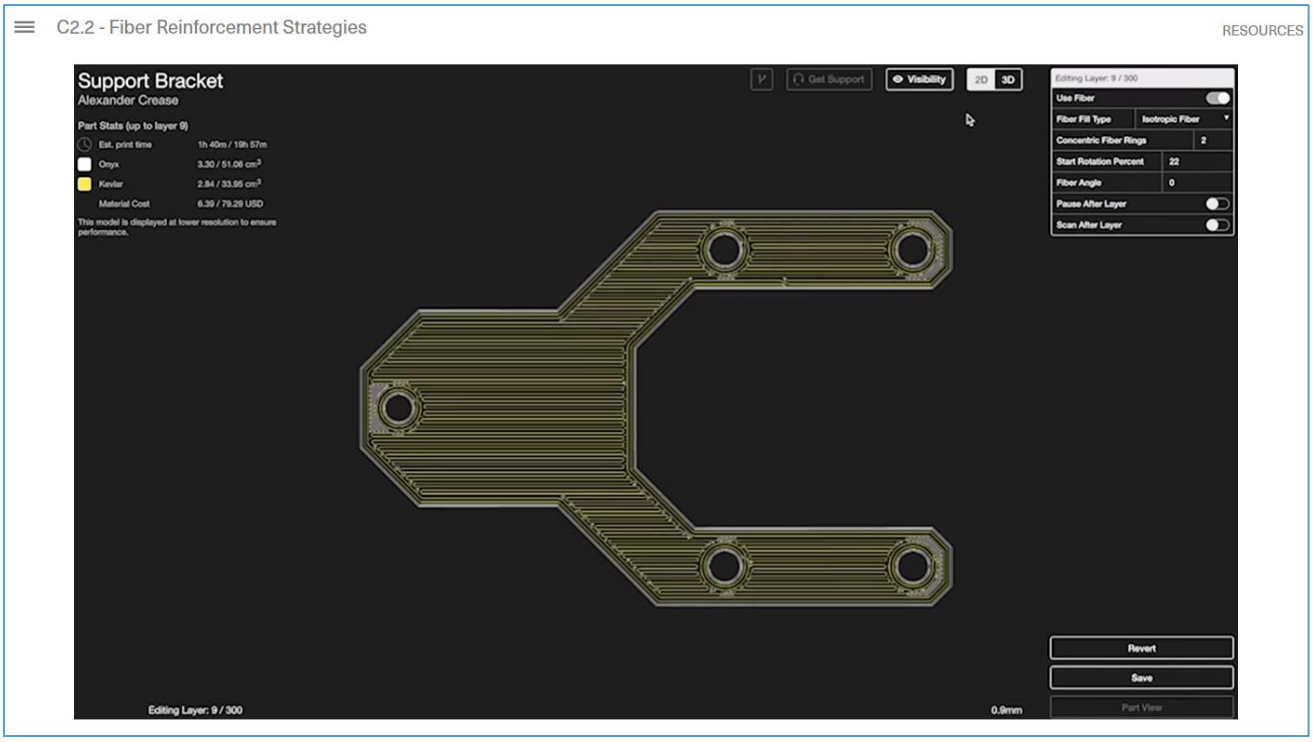


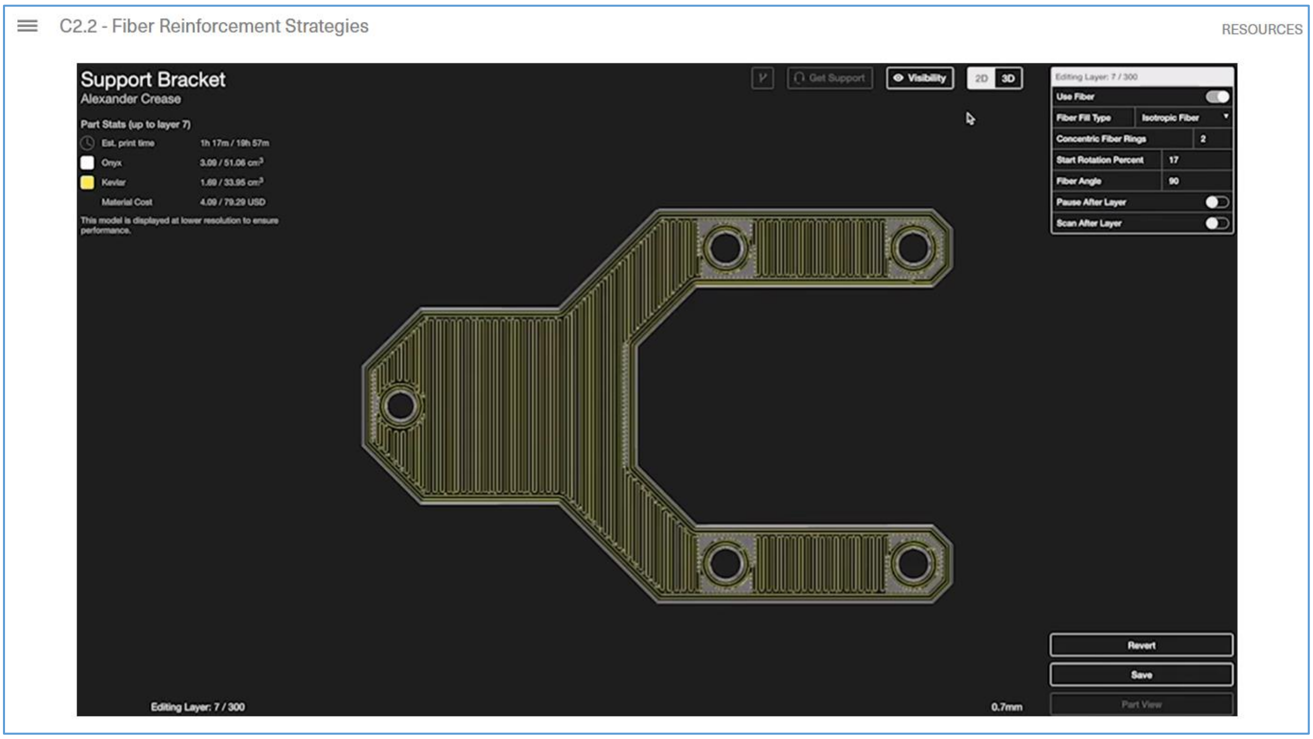
- Easily breaking by shearing it.

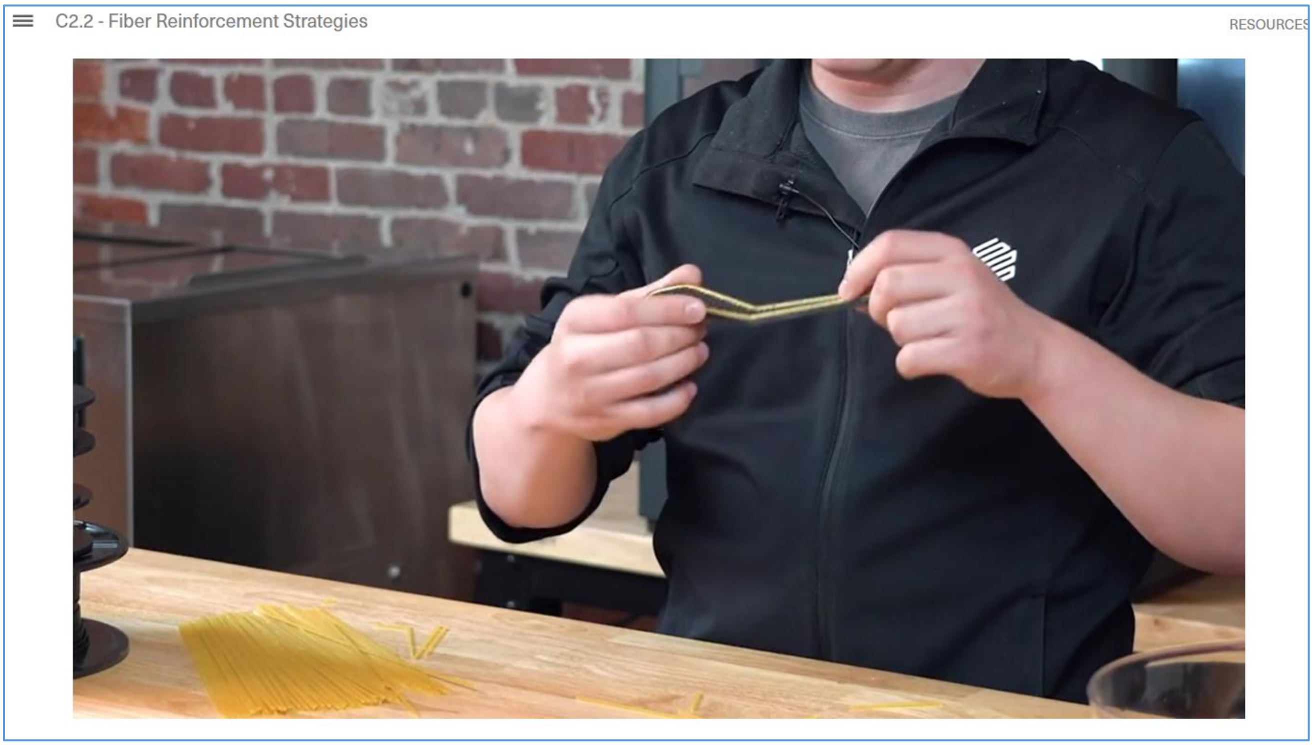


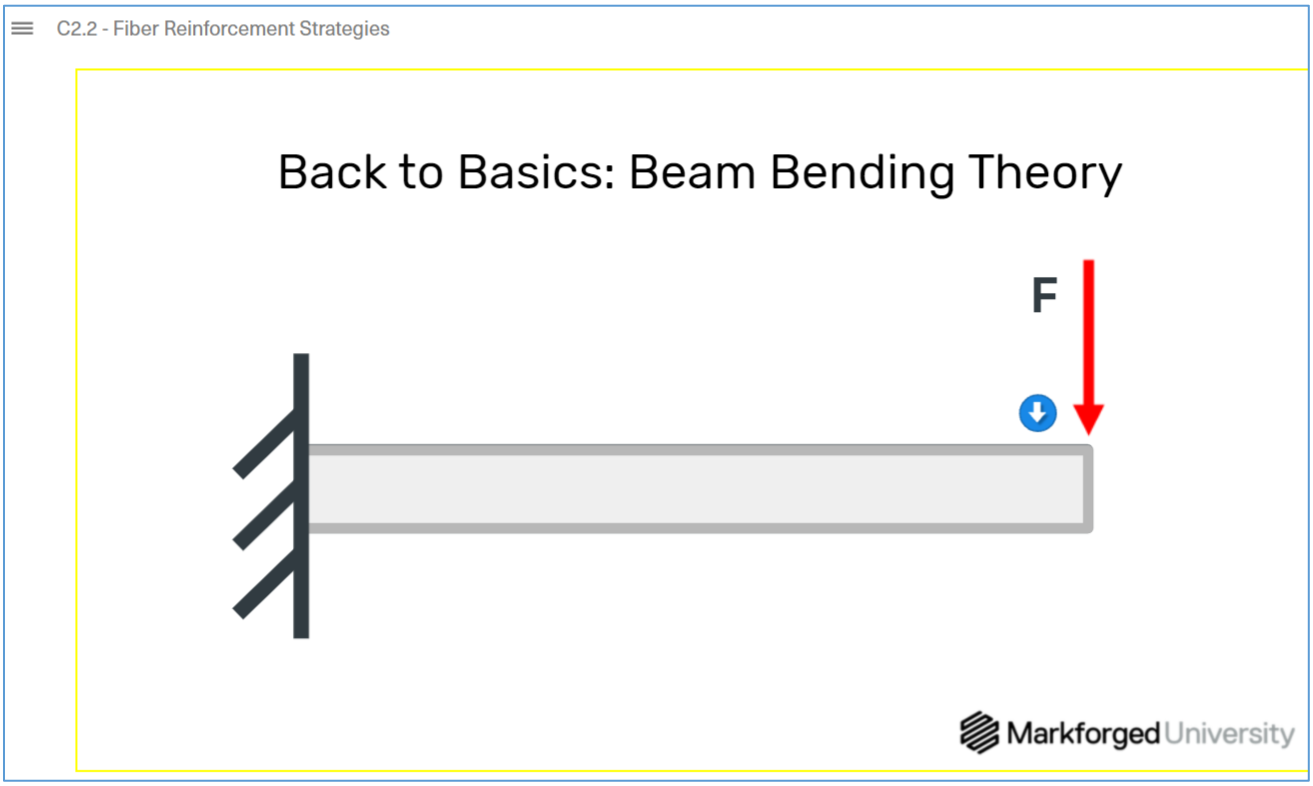
- But it takes lots of more force in tension by pulling on it.


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Support Bracket
Alexander Crease
Part Stats (up to layer 8)
Est. print time 1h 29m / 19h 57m
Onyx 3.21 / 51.06 cm³
Kevlar 2.26 / 33.95 cm³
Material Cost 5.23 / 79.29 USD
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 8 / 300
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings
2
Start Rotation Percent
19
Fiber Angle
135
Pause After Layer
Scan After Layer
Revert
Save
Part View
Editing Layer: 8 / 300
0.8mm

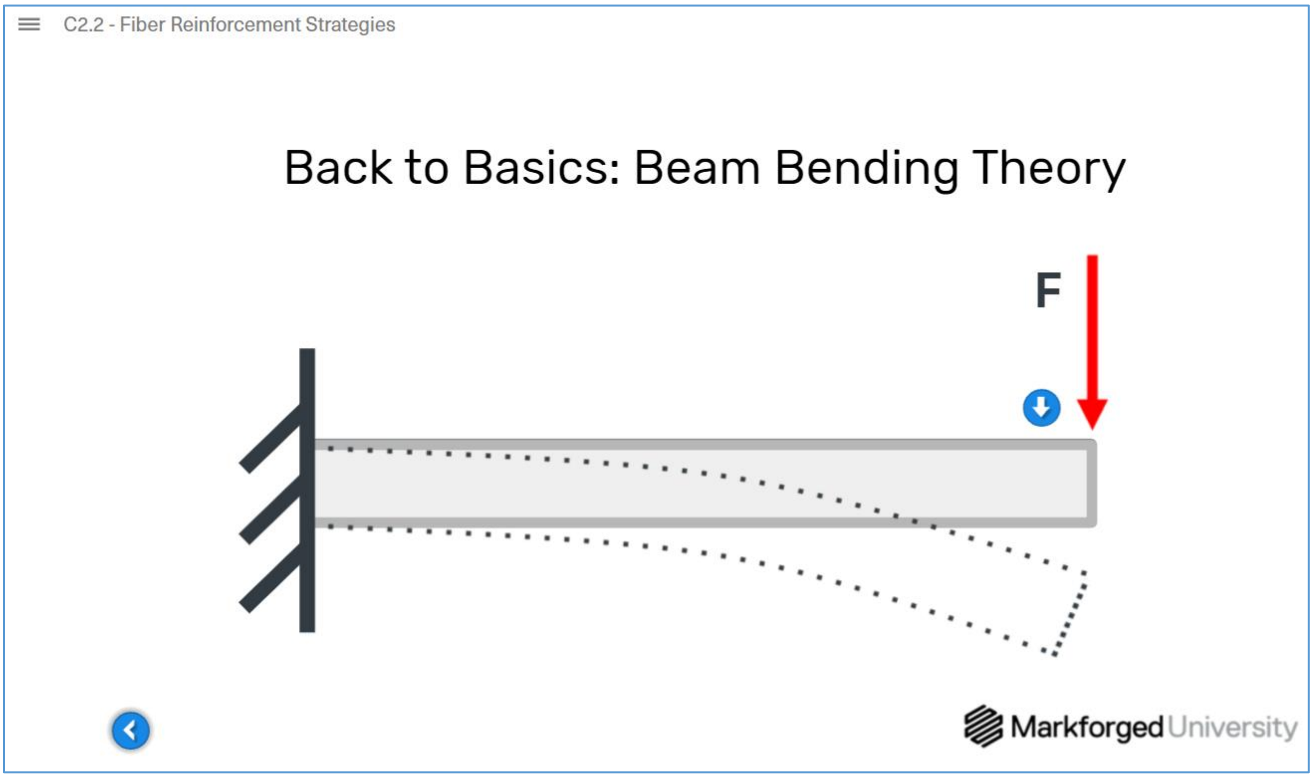

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Support Bracket
Alexander Crease
Part Stats (up to layer 9)
Est. print time 1h 40m / 19h 57m
Onyx 3.30 / 51.06 cm³
Kevlar 2.84 / 33.95 cm³
Material Cost 6.39 / 79.29 USD
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 9 / 300
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings
2
Start Rotation Percent
22
Fiber Angle
0
Pause After Layer
Scan After Layer
Revert
Save
Part View
Editing Layer: 9 / 300
0.9mm

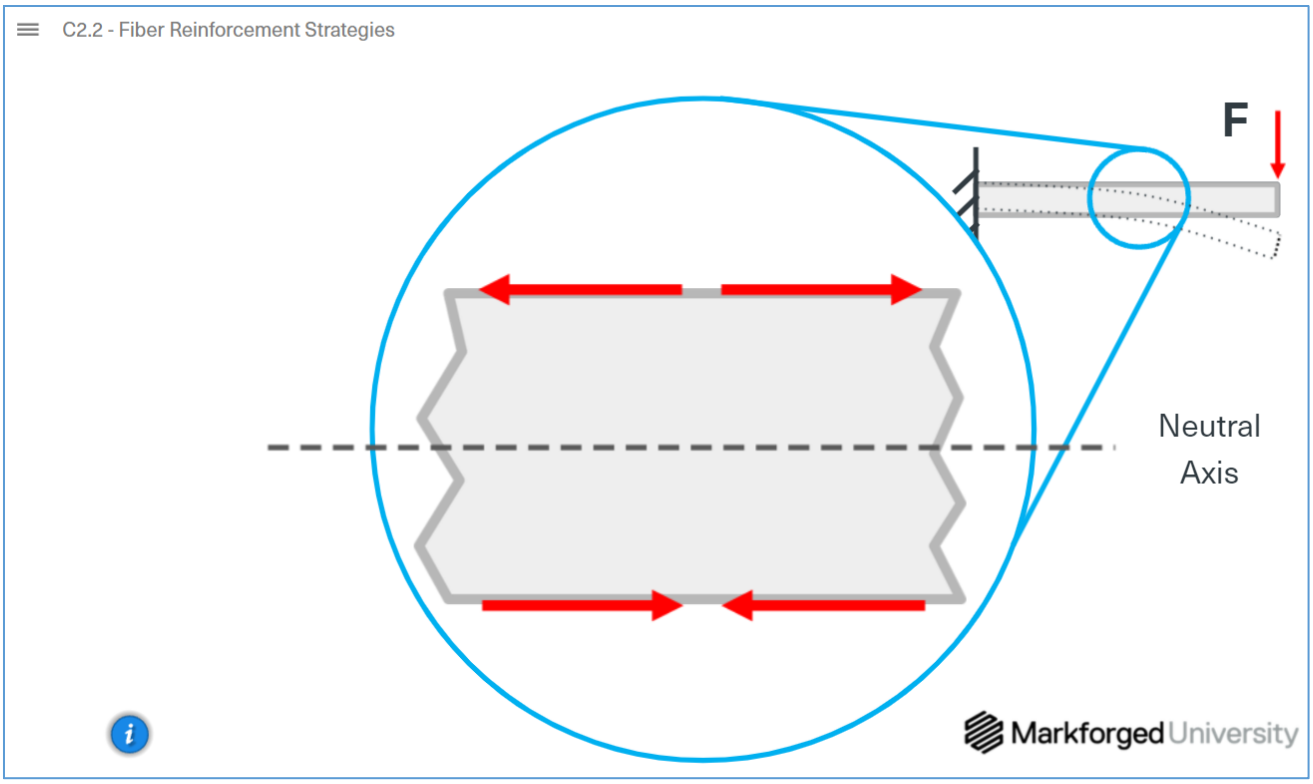

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Support Bracket
Alexander Crease
Part Stats (up to layer 7)
Est. print time 1h 17m / 19h 57m
Onyx 3.09 / 51.06 cm^3
Kevlar 1.69 / 33.95 cm^3
Material Cost 4.09 / 79.29 USD
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 7 / 300
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings
2
Start Rotation Percent
17
Fiber Angle
90
Pause After Layer
Scan After Layer
Revert
Save
Part View
Editing Layer: 7 / 300
0.7mm


C2.2 - Fiber Reinforcement Strategies
RESOURCES

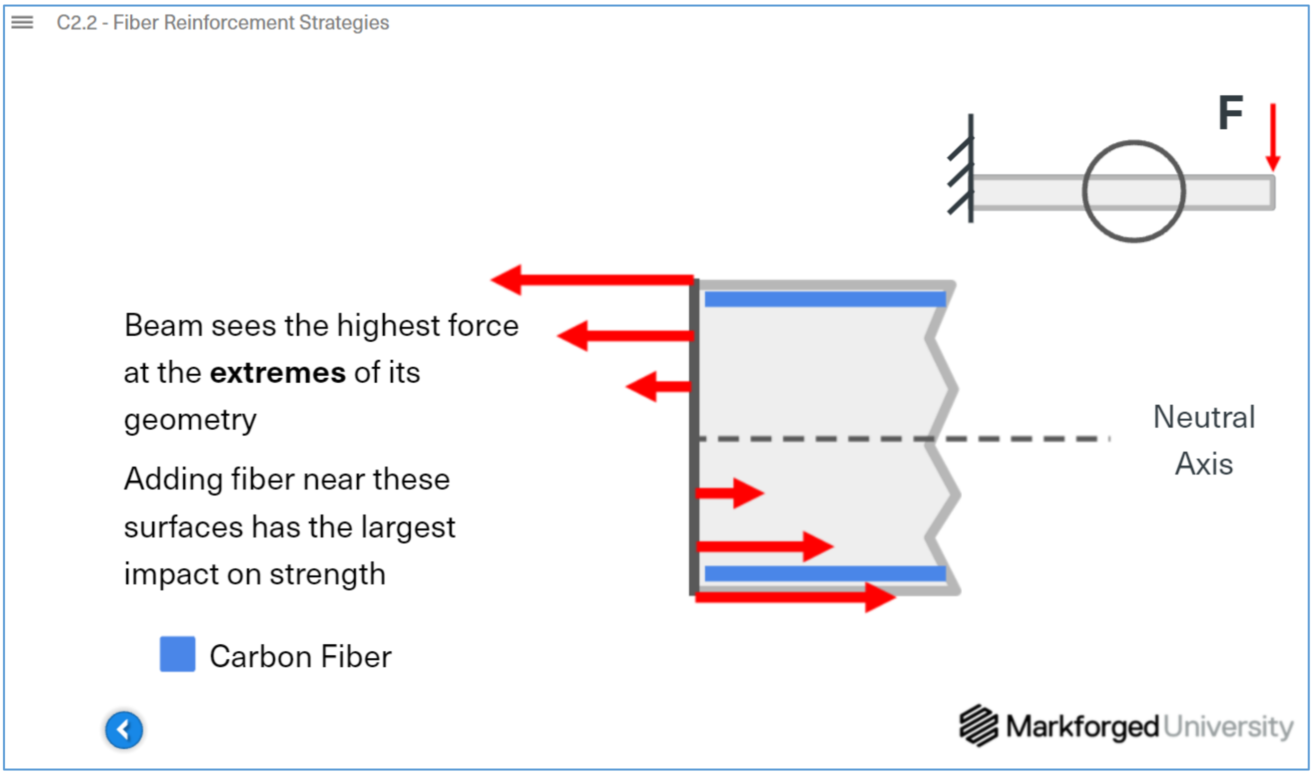


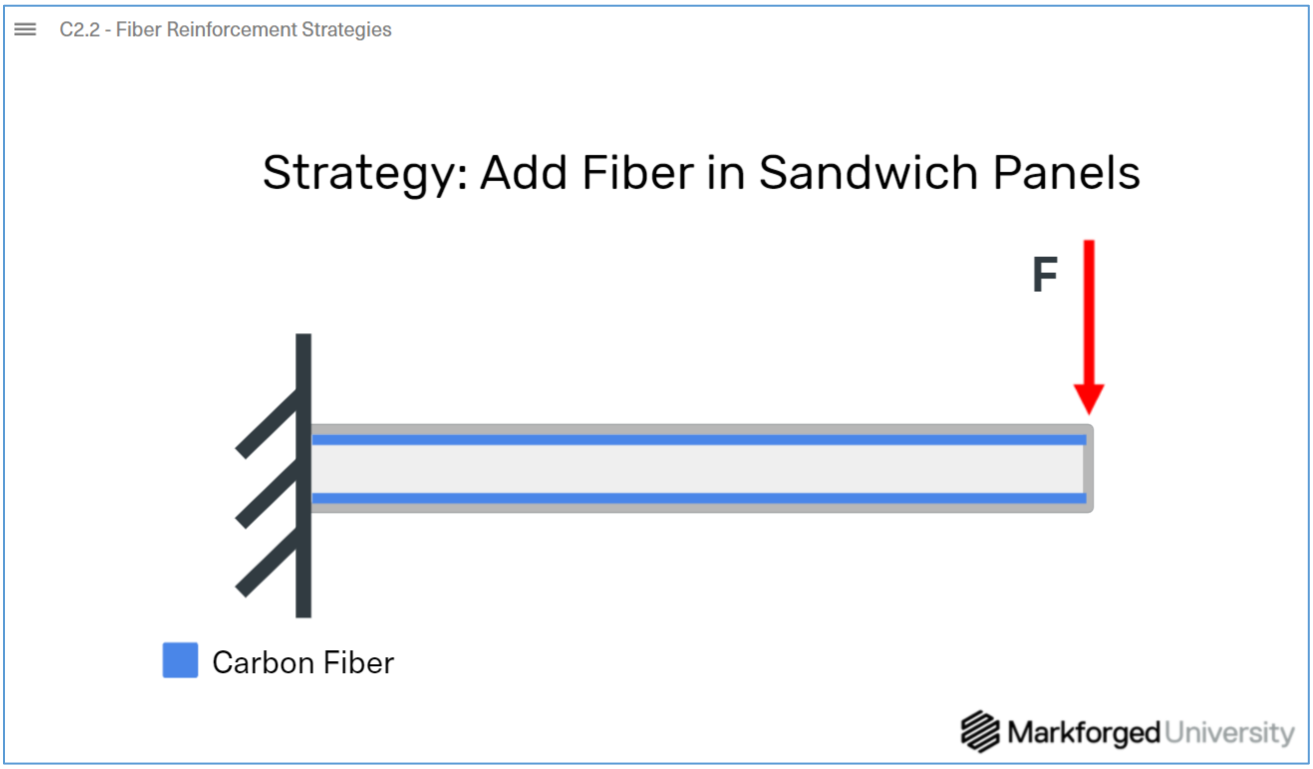
- **Back to basics: Beam Bending Theory**



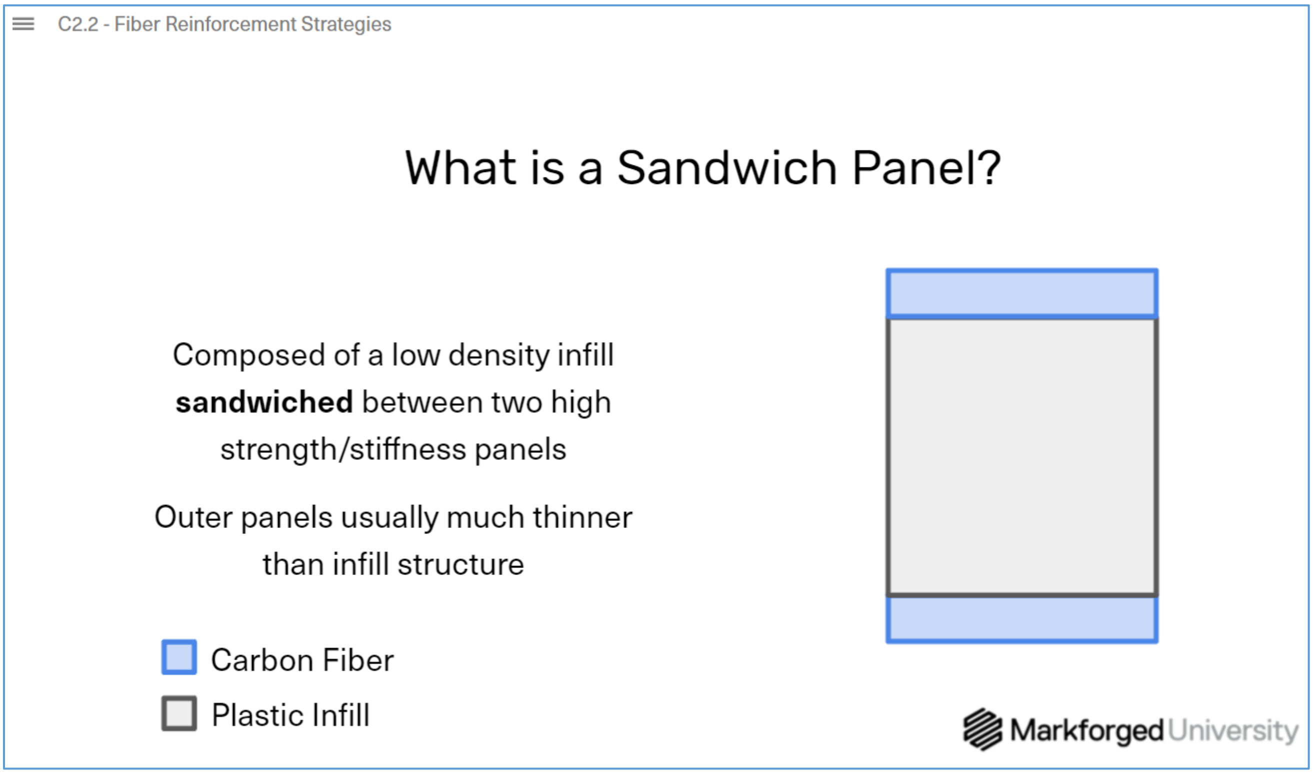


- **Internal Forces in a Beam**



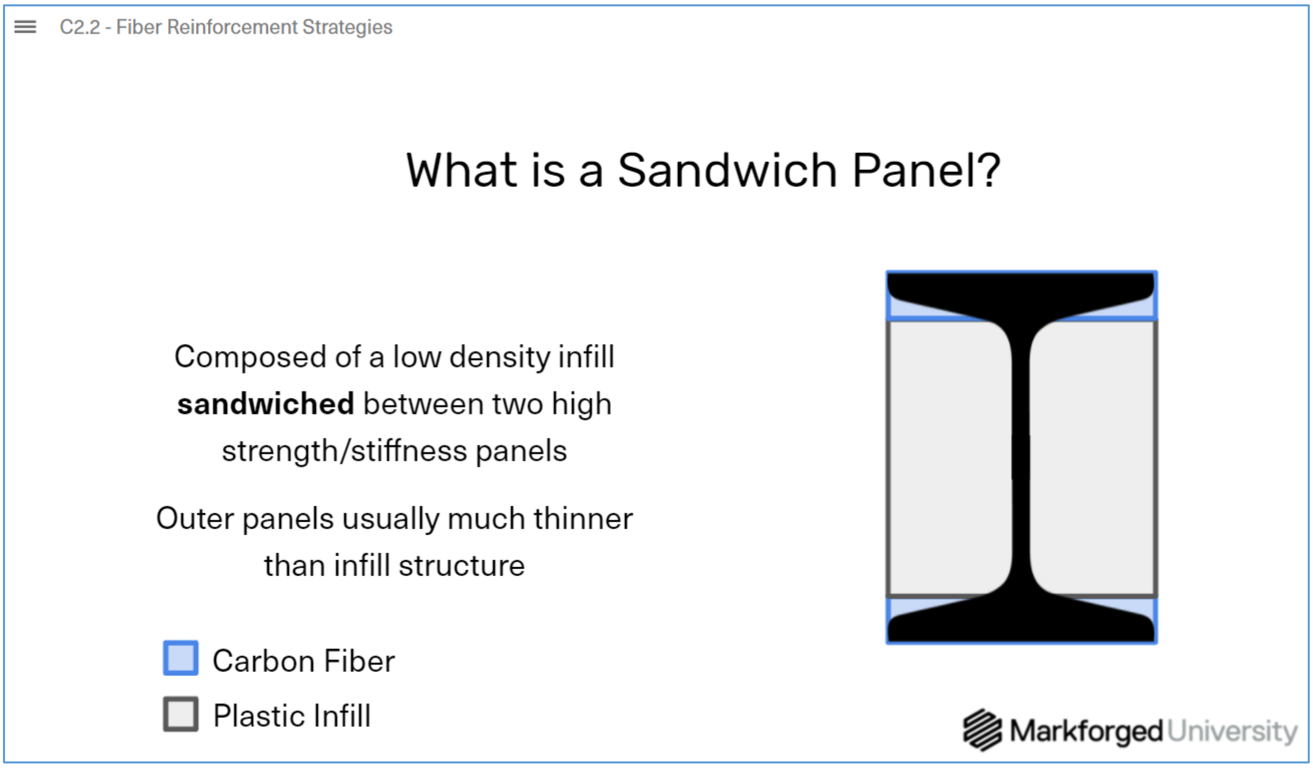


- **Add Fiber in Sandwich Panels**
    - Cheaper and faster printing, by using composite fyber sparenly, by adding in areas who has the most impact.

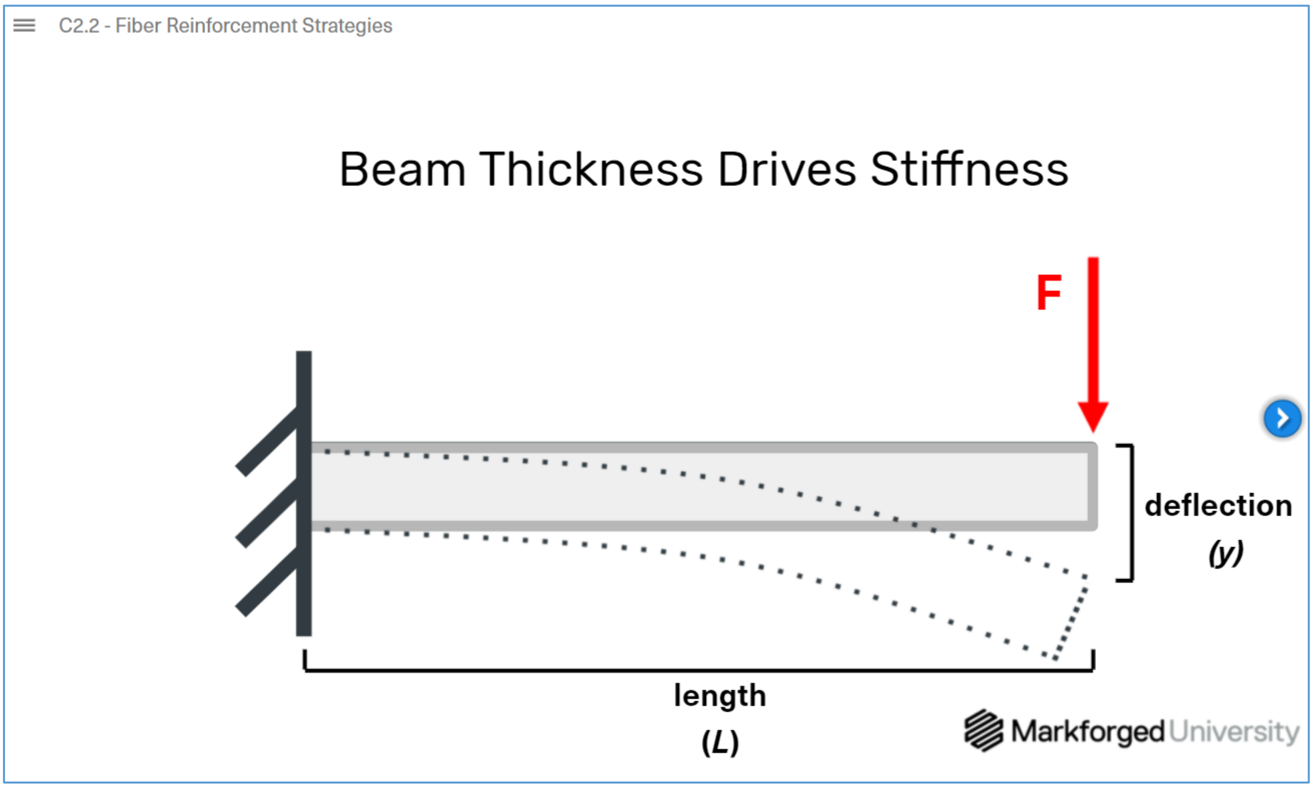


- **What is a Sandwich Panel?**
    - Keeping down cost and weight.

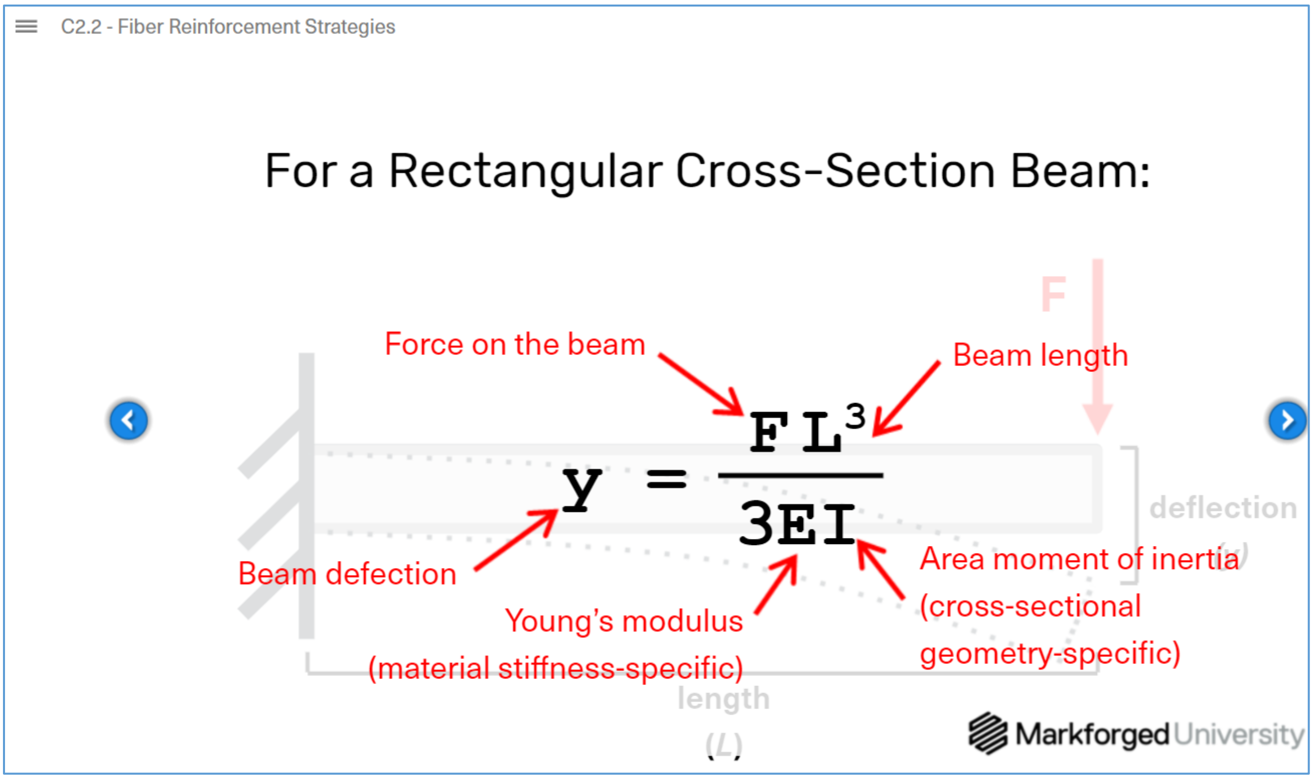
- Low infill structure (low density) with solid onyx-skin.

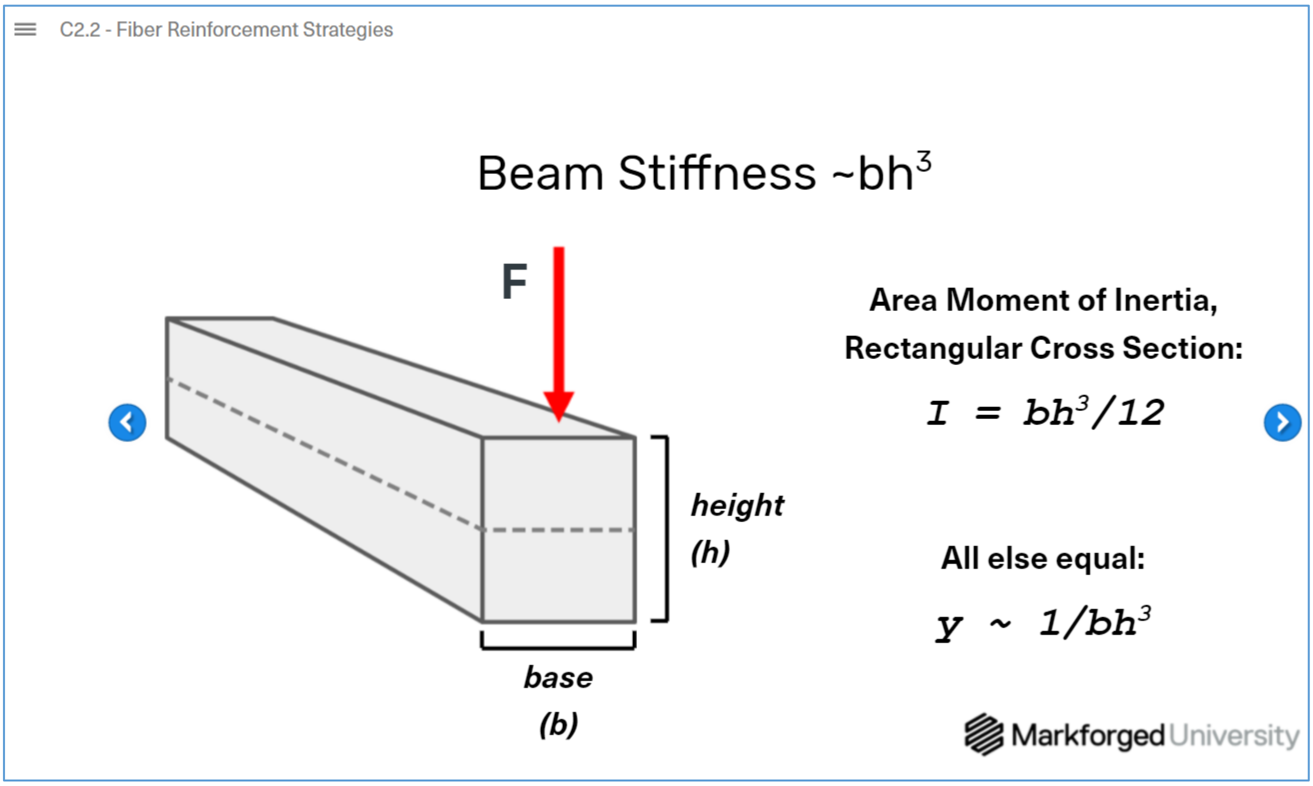


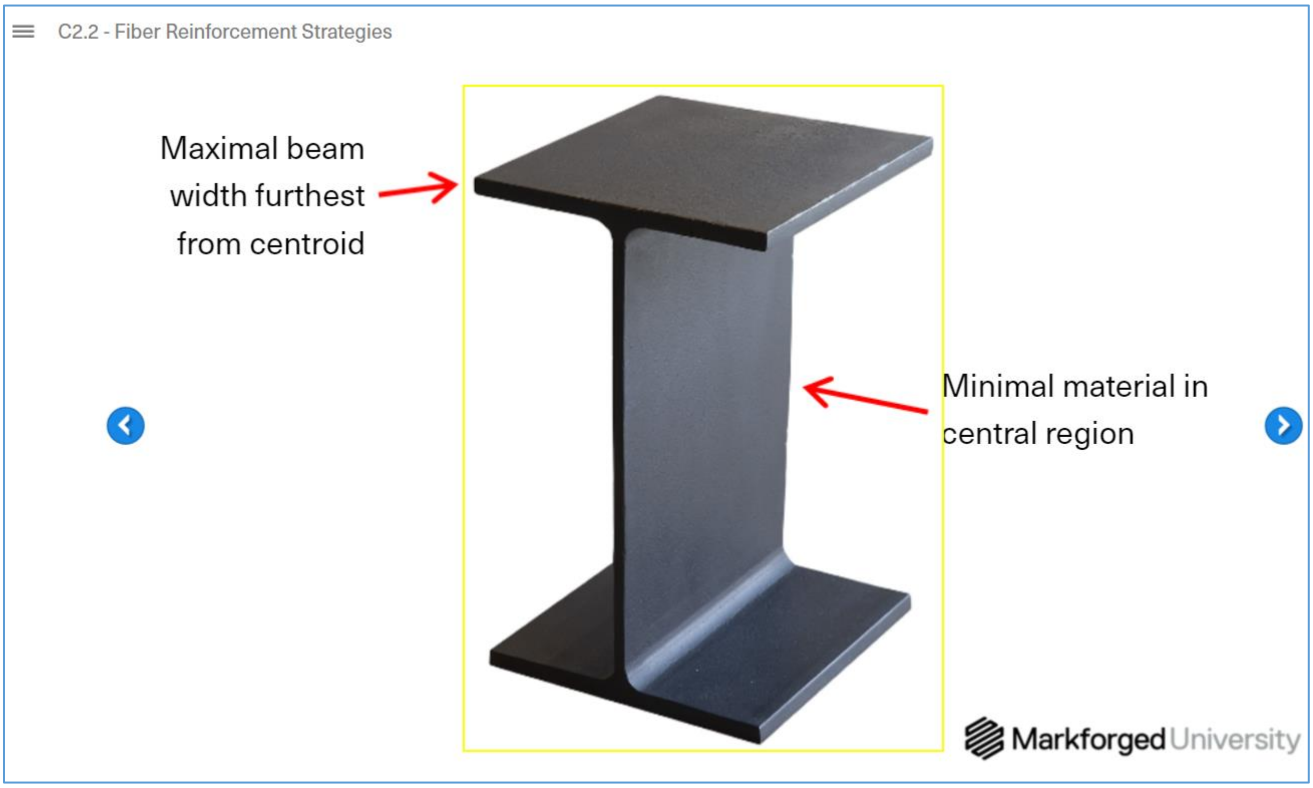
- An Example of a Sandwich Panel is an I-beam.



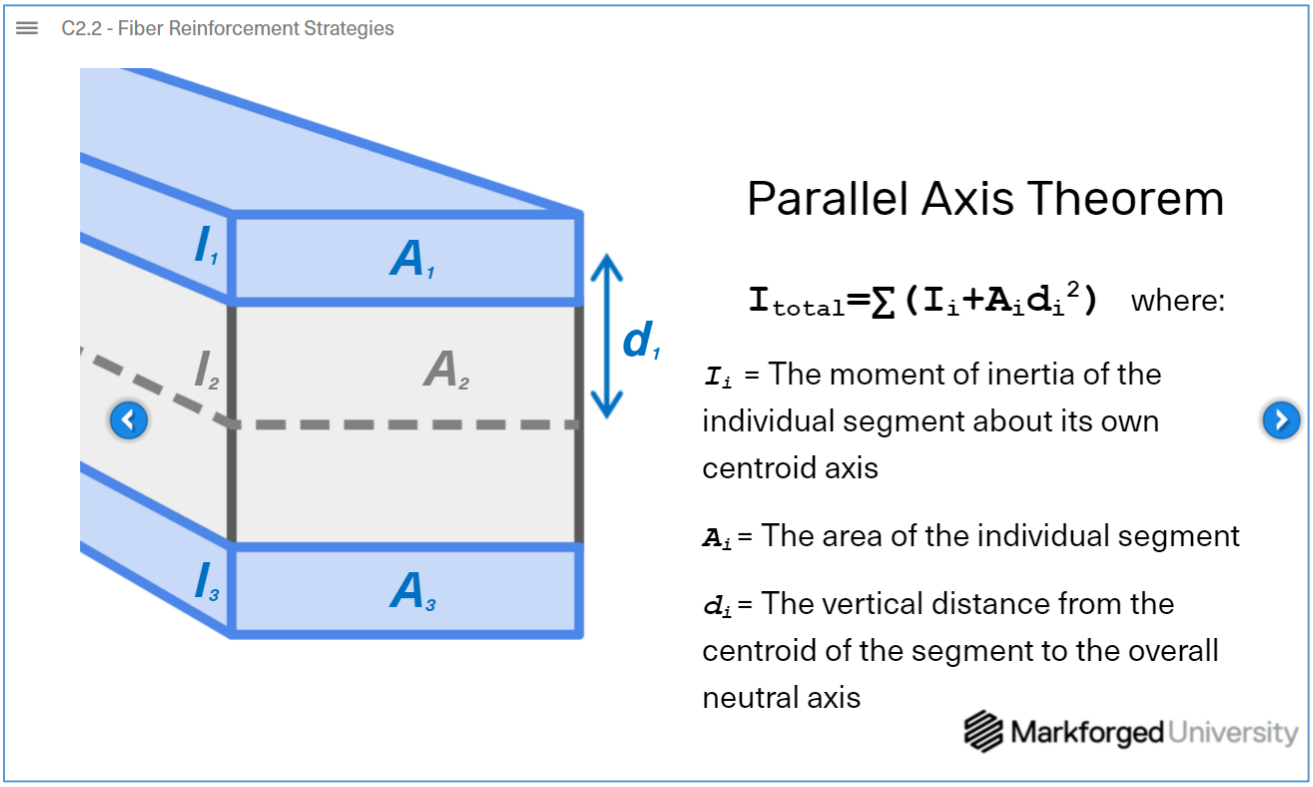
- **Beam Thickness matters**

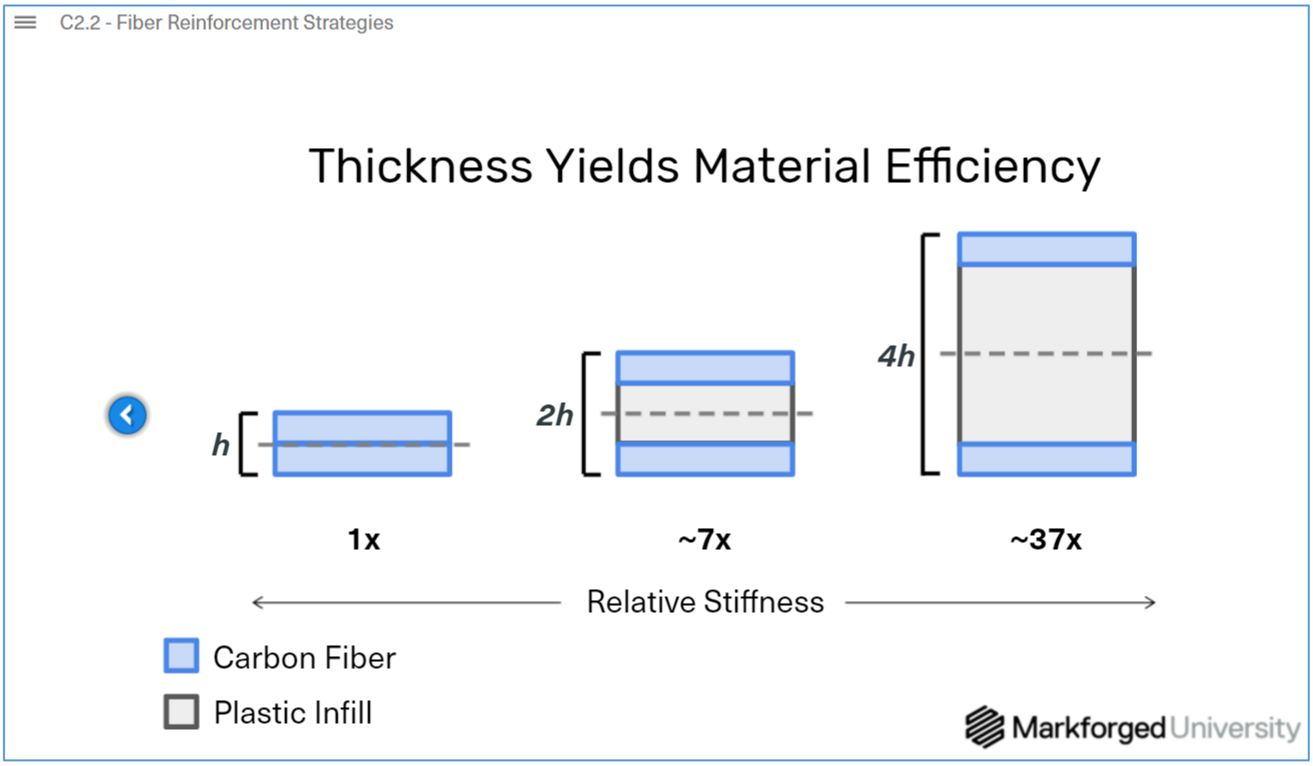




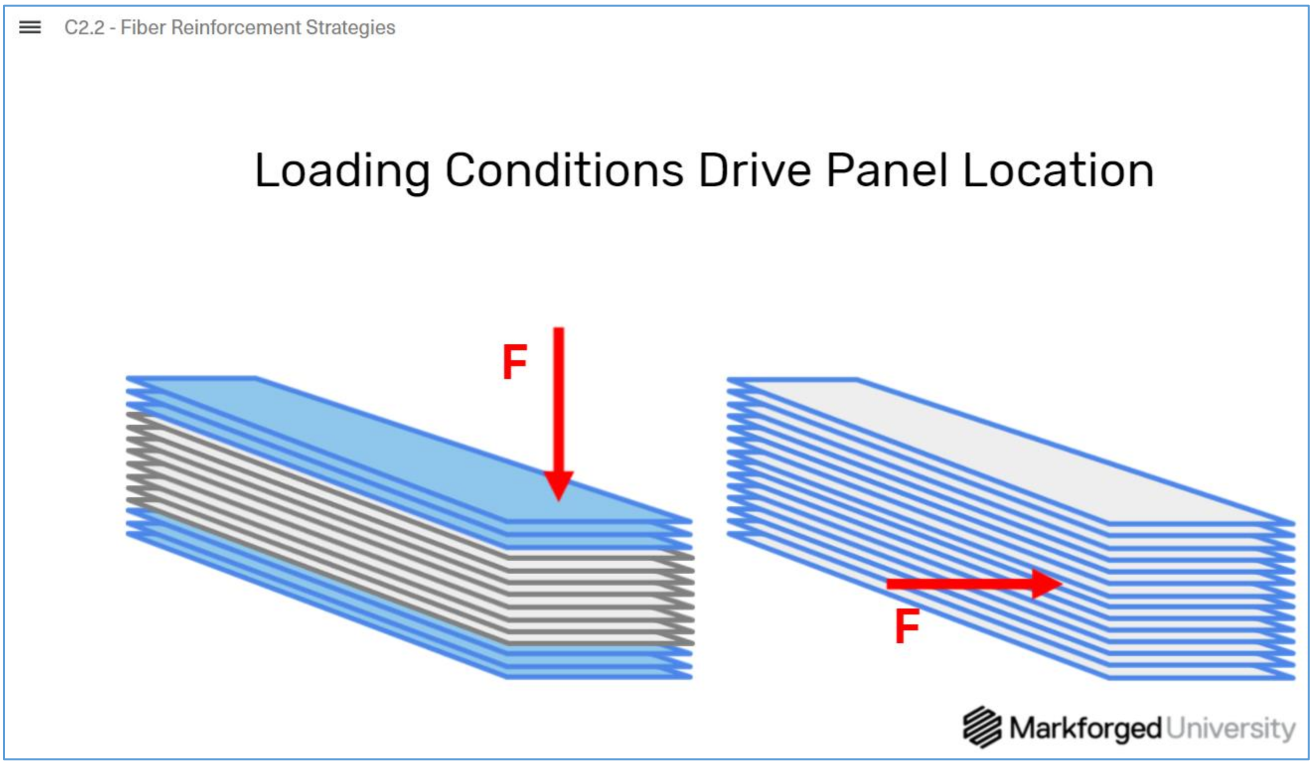


- Centroid = zwaartepunt

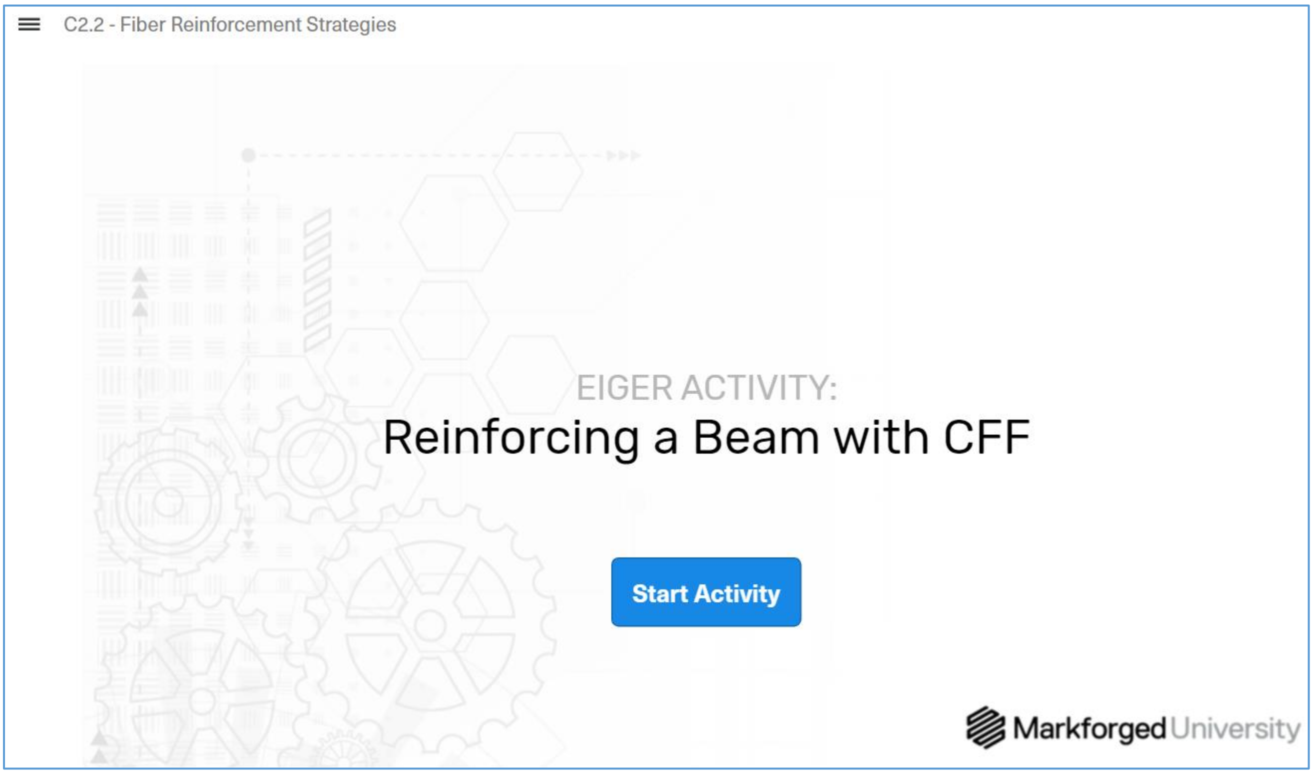




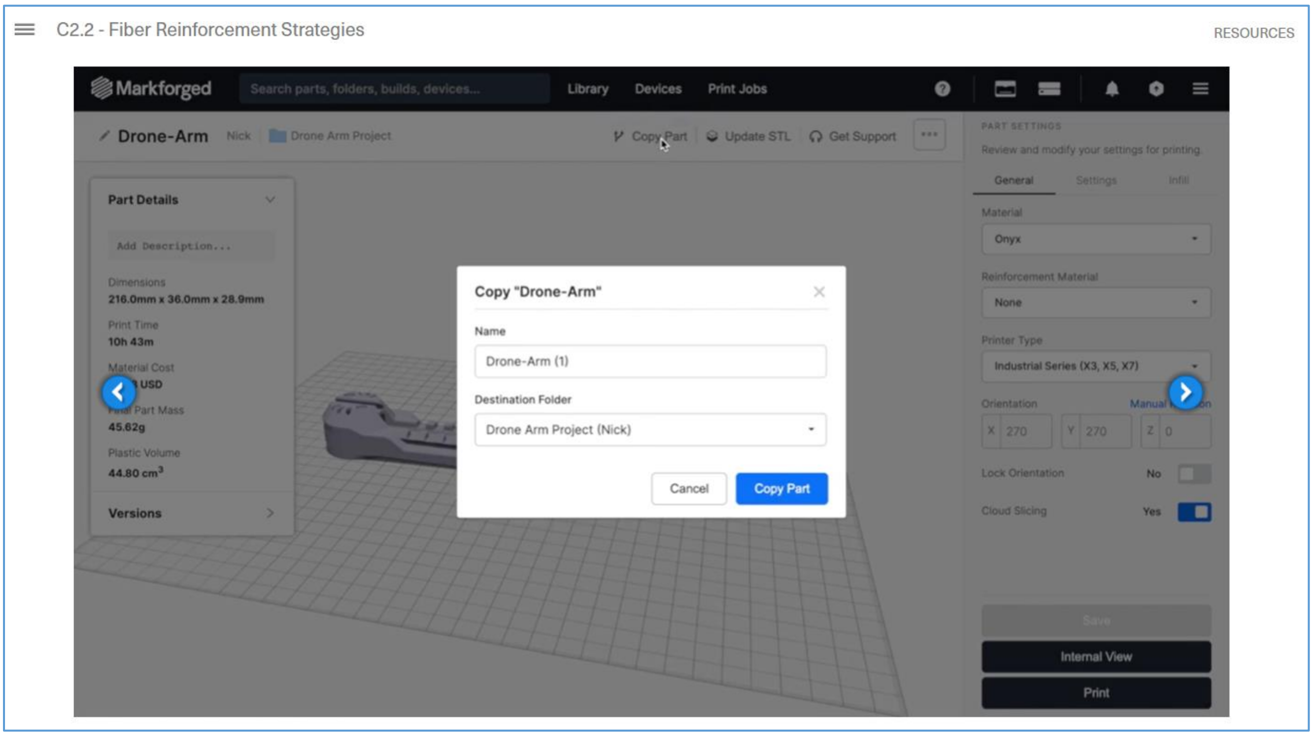
- Yield = Opbrengst.



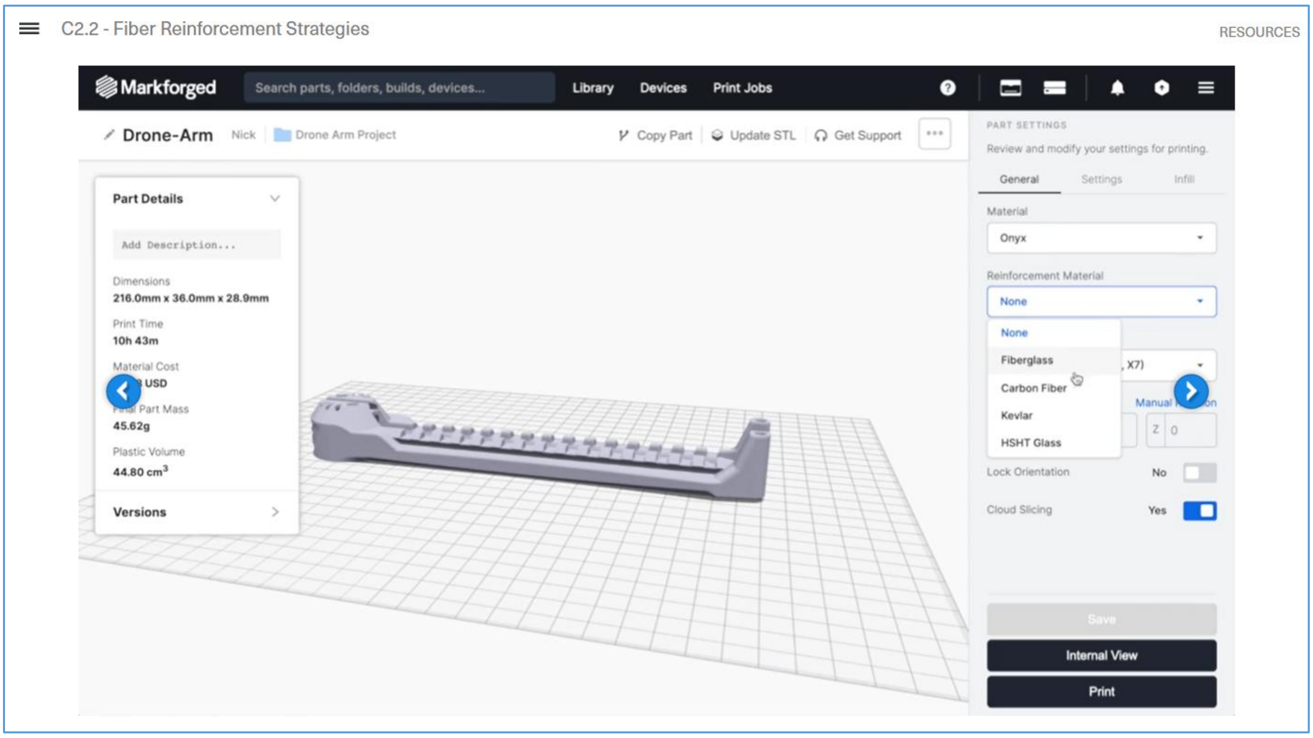
- **Loading Conditions Drive Reinforcement Location**



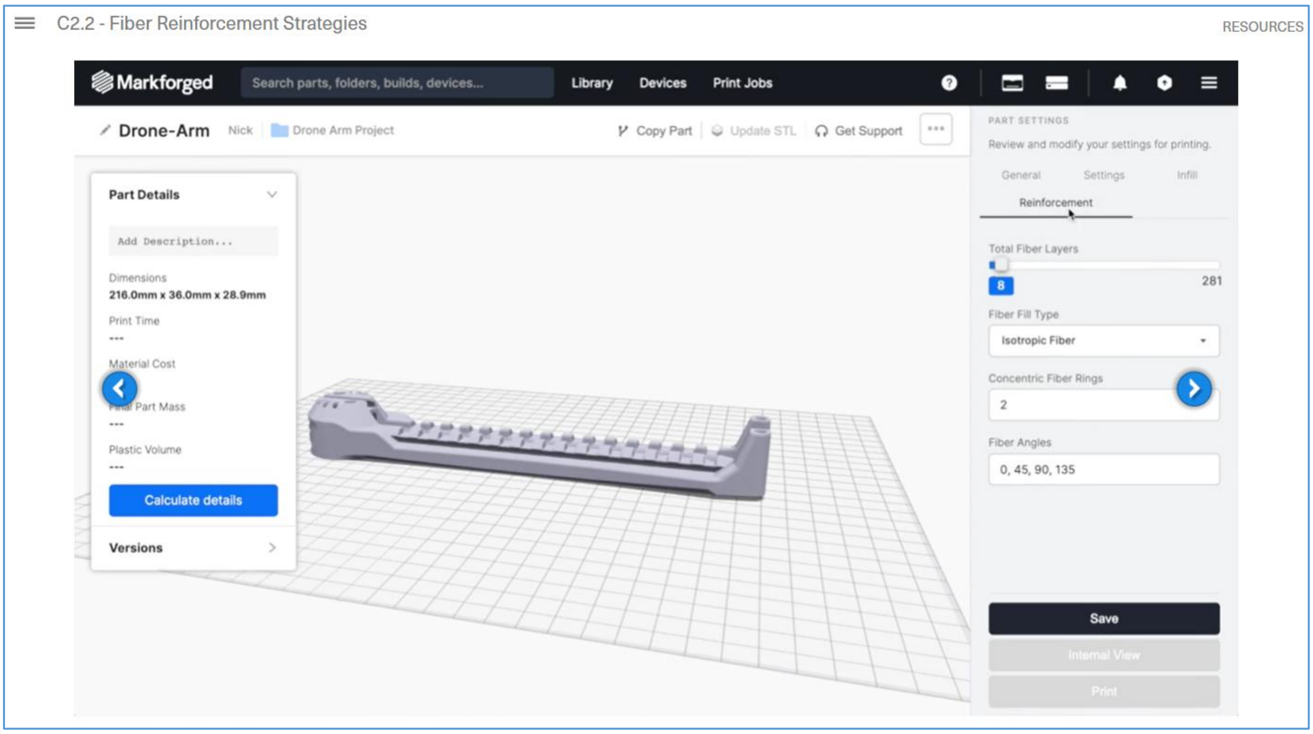
- **Activity: Reinforcing a Beam with CFF**

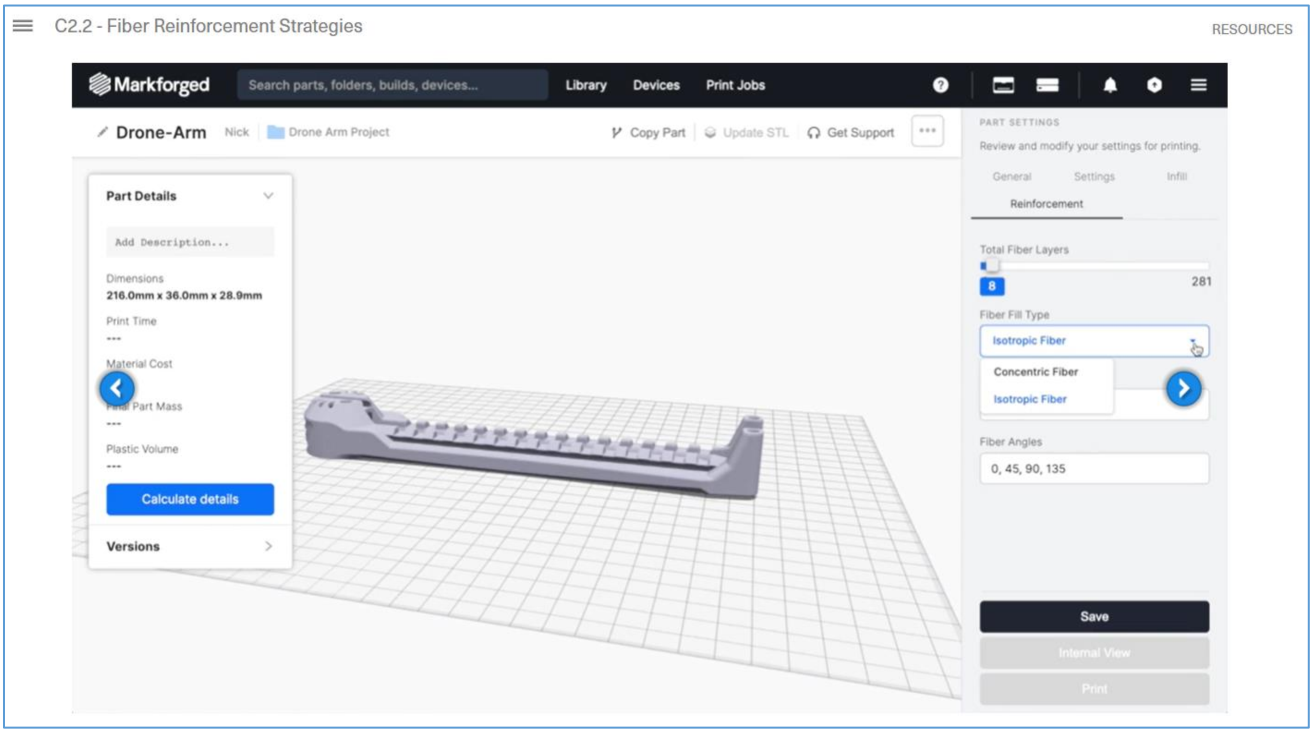


- Copy and new name.

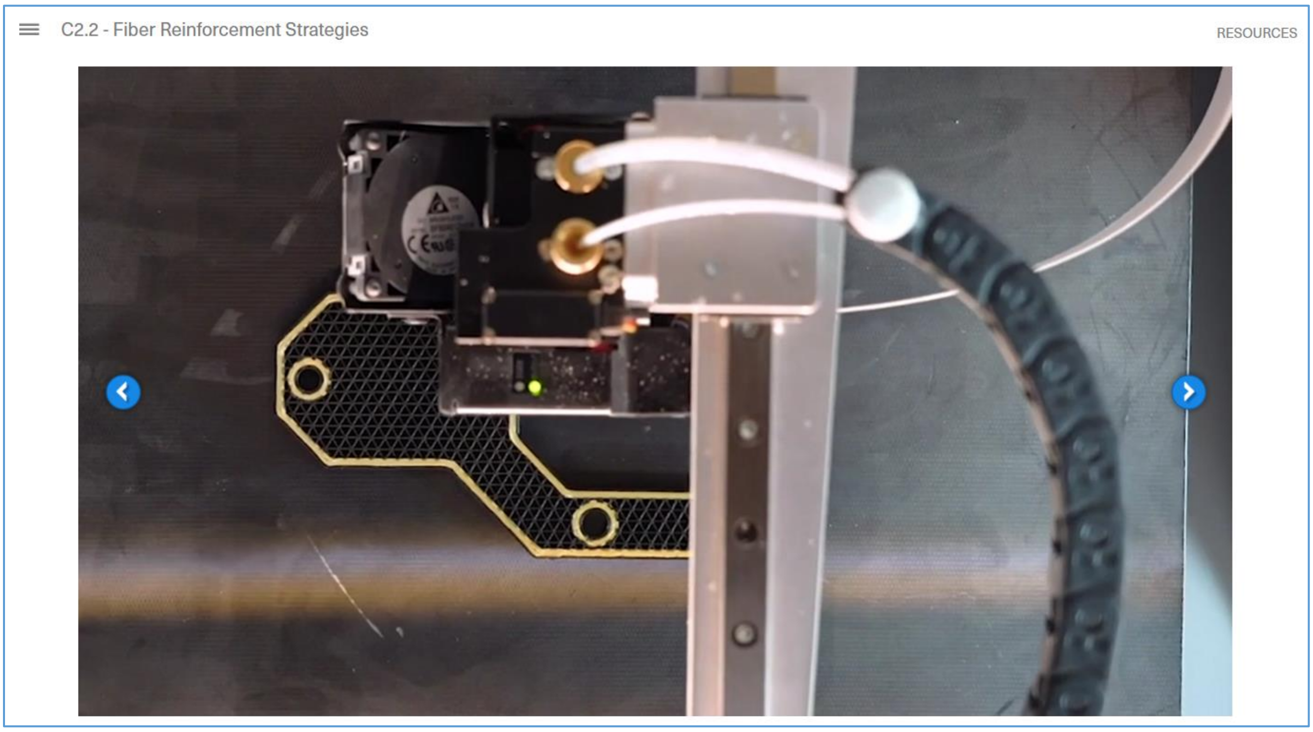


- Choose reinforcement material.
  - Note: Carbon prints thicker 125µm layerheight, than other fibers, that prints 100µm layerheight.

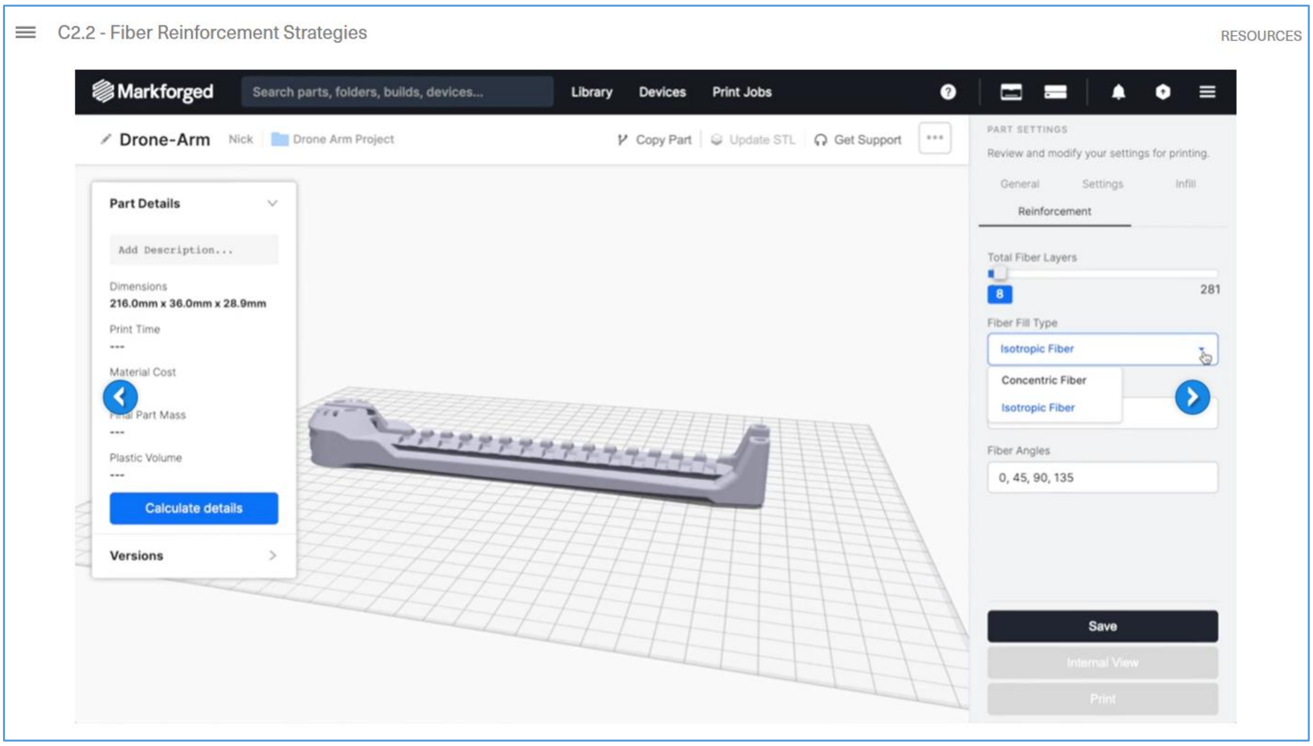




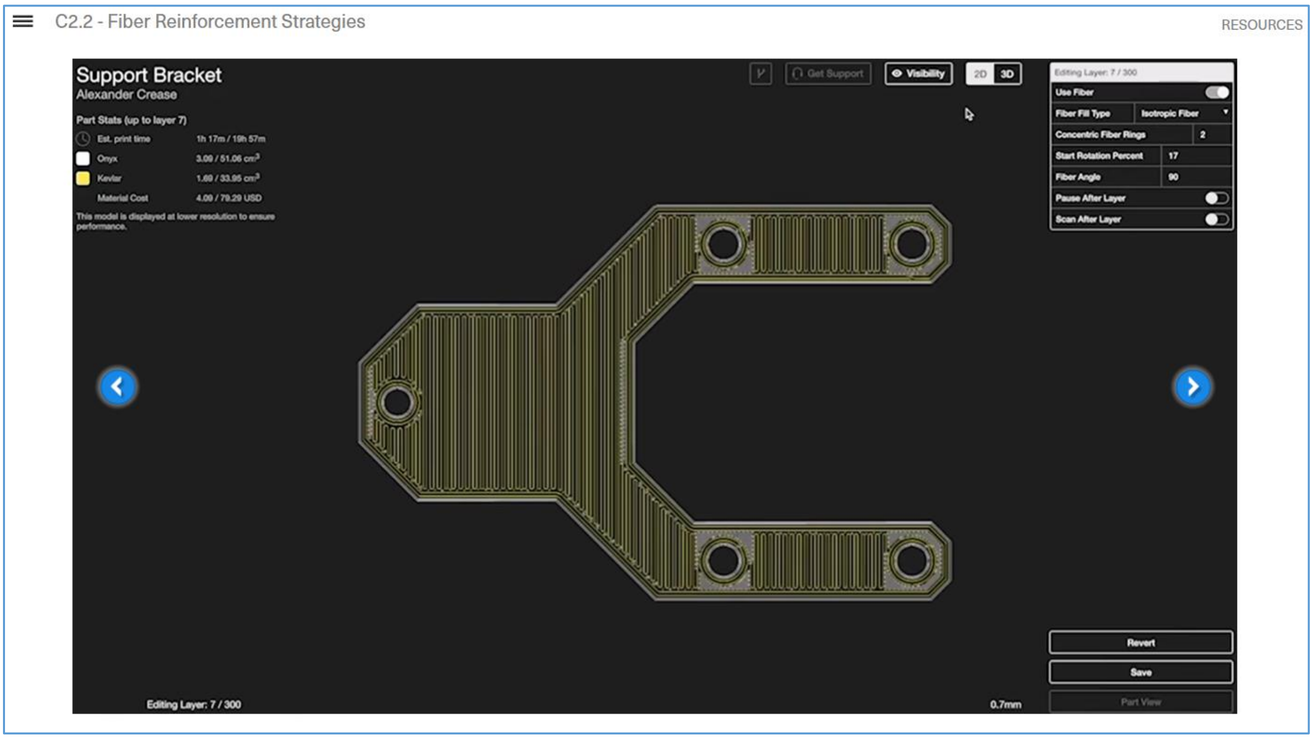
- Concetric Fiber

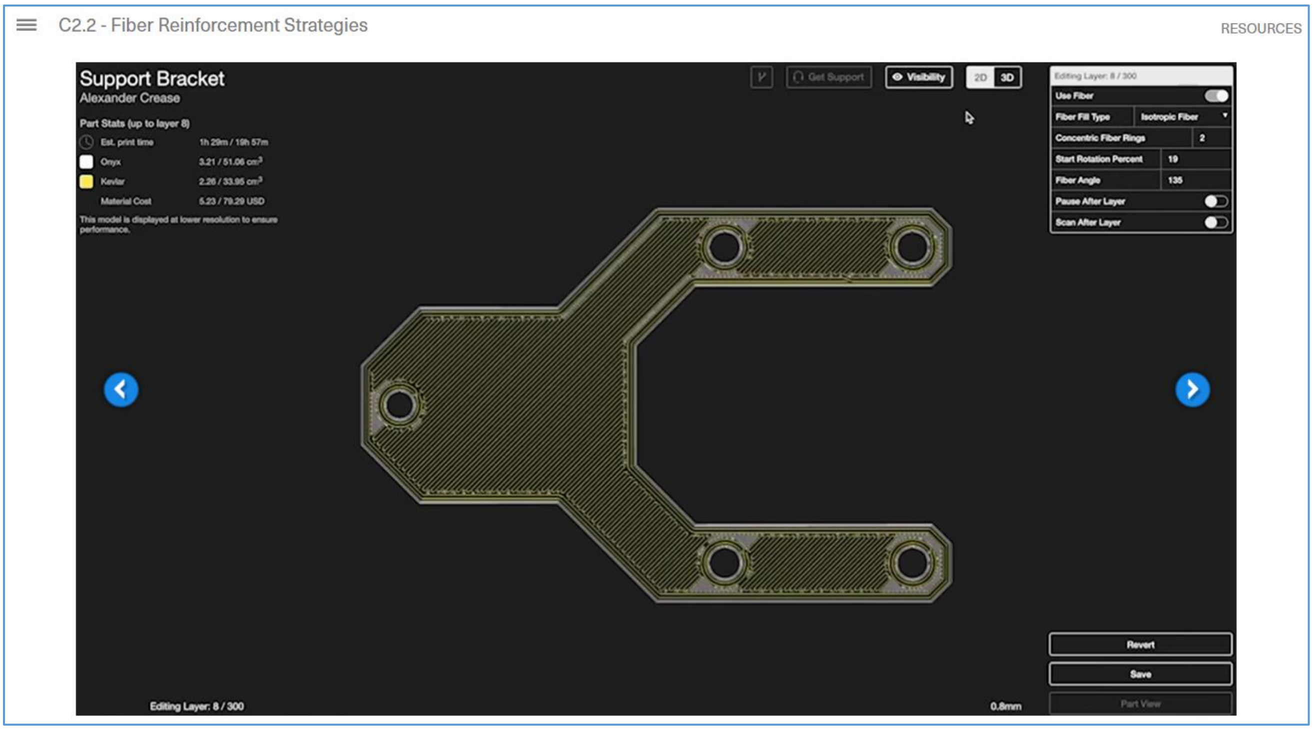


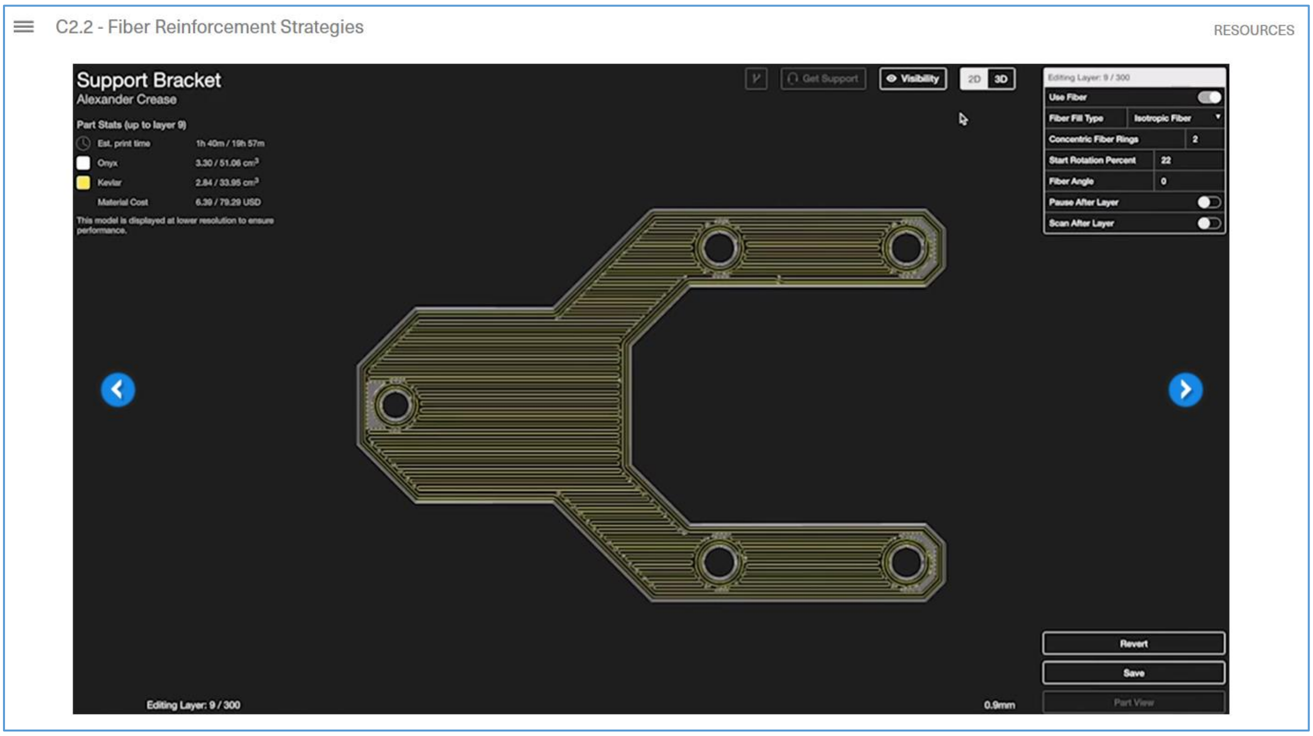
- Concentric Fiber

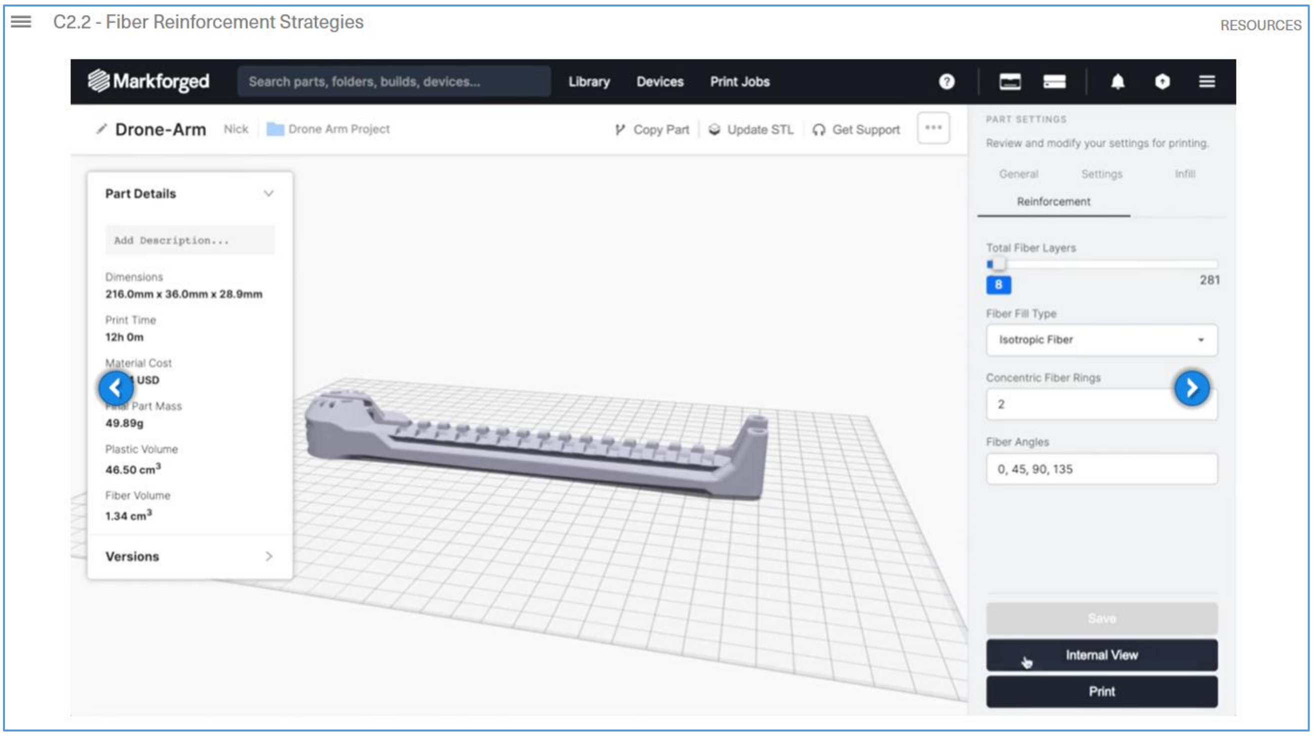


- Isotropic Fiber
  - Leads to more reinforcementmaterial and printtime.

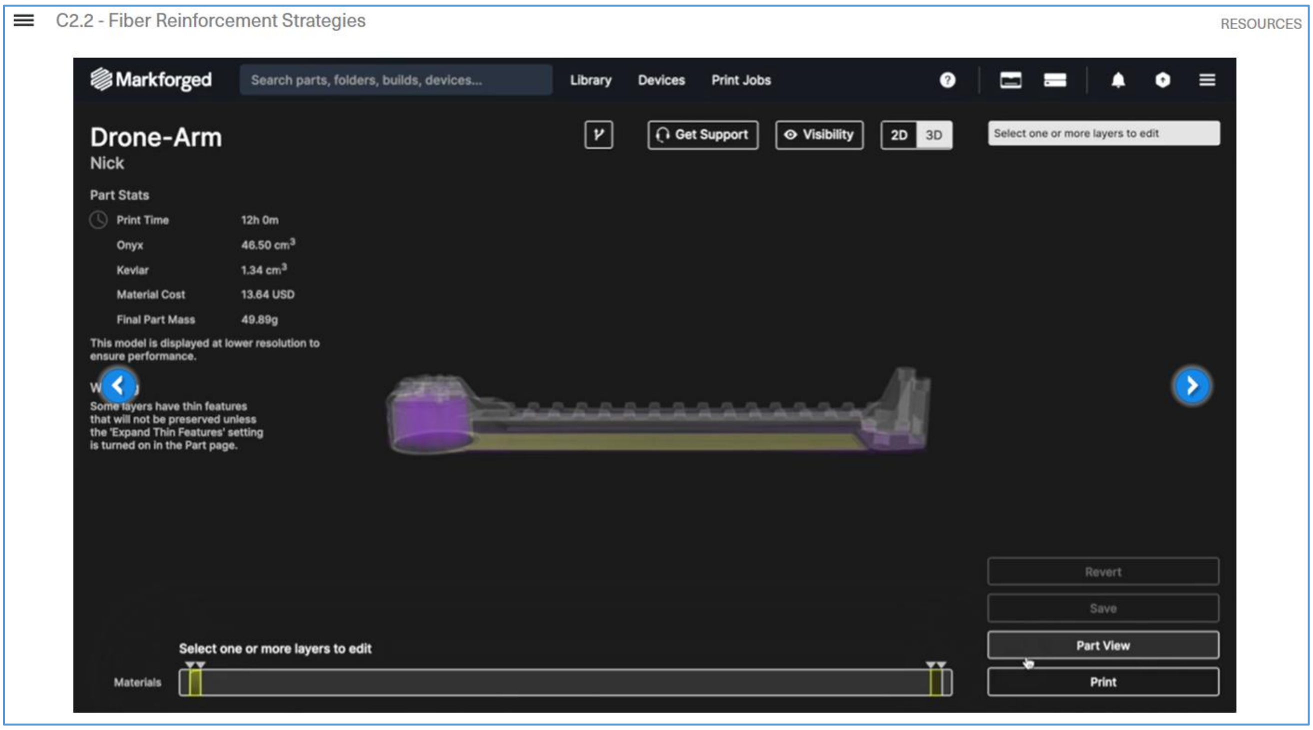

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Support Bracket
Alexander Crease
Part Stats (up to layer 7)
Est. print time 1h 17m / 19h 57m
Onyx 3.09 / 51.06 cm^3
Kevlar 1.60 / 33.95 cm^3
Material Cost 4.09 / 79.29 USD
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 7 / 300
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings
2
Start Rotation Percent
17
Fiber Angle
90
Pause After Layer
Scan After Layer
Revert
Save
Part View
Editing Layer: 7 / 300
0.7mm

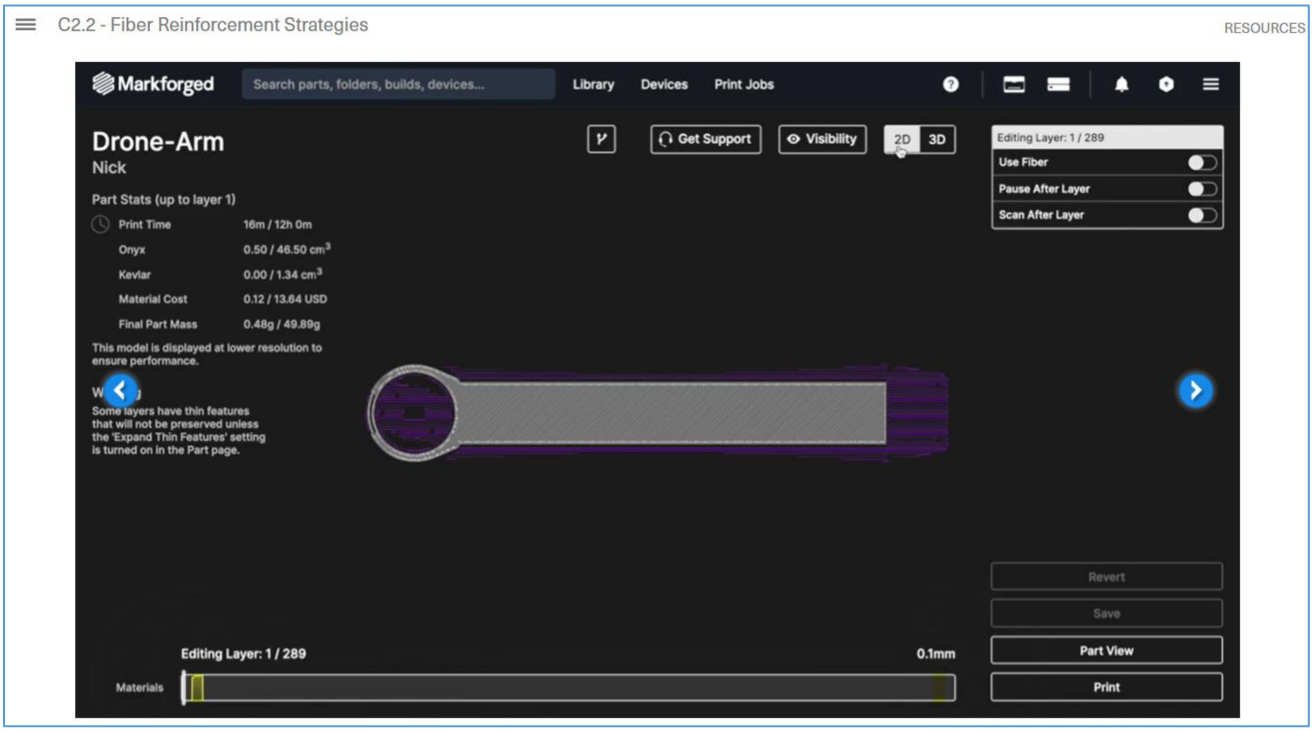

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Support Bracket
Alexander Crease
Part Stats (up to layer 8)
Est. print time 1h 29m / 19h 57m
Onyx 3.21 / 51.06 cm^3
Kevlar 2.26 / 33.95 cm^3
Material Cost 5.23 / 79.29 USD
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 8 / 300
Use Fiber
Fiber Fill Type
Isotropic Fiber
Concentric Fiber Rings
2
Start Rotation Percent
19
Fiber Angle
135
Pause After Layer
Scan After Layer
Revert
Save
Part View
Editing Layer: 8 / 300
0.8mm



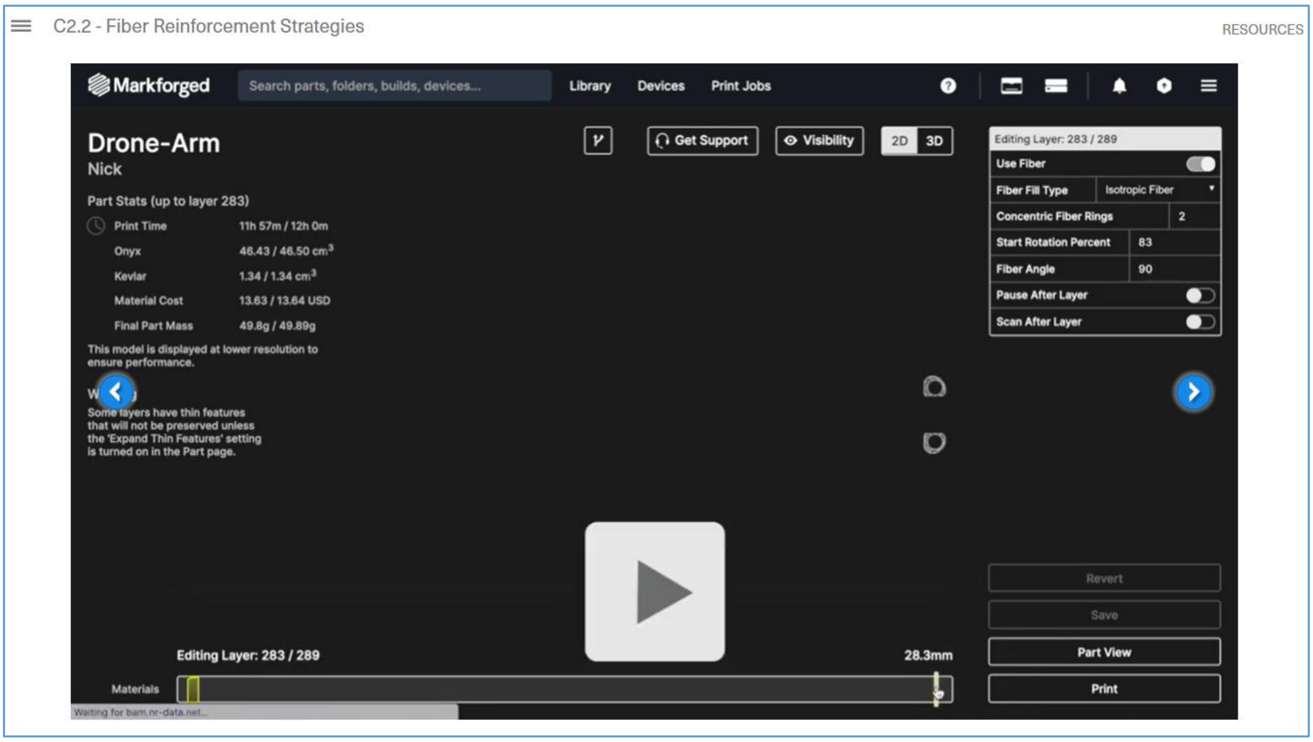


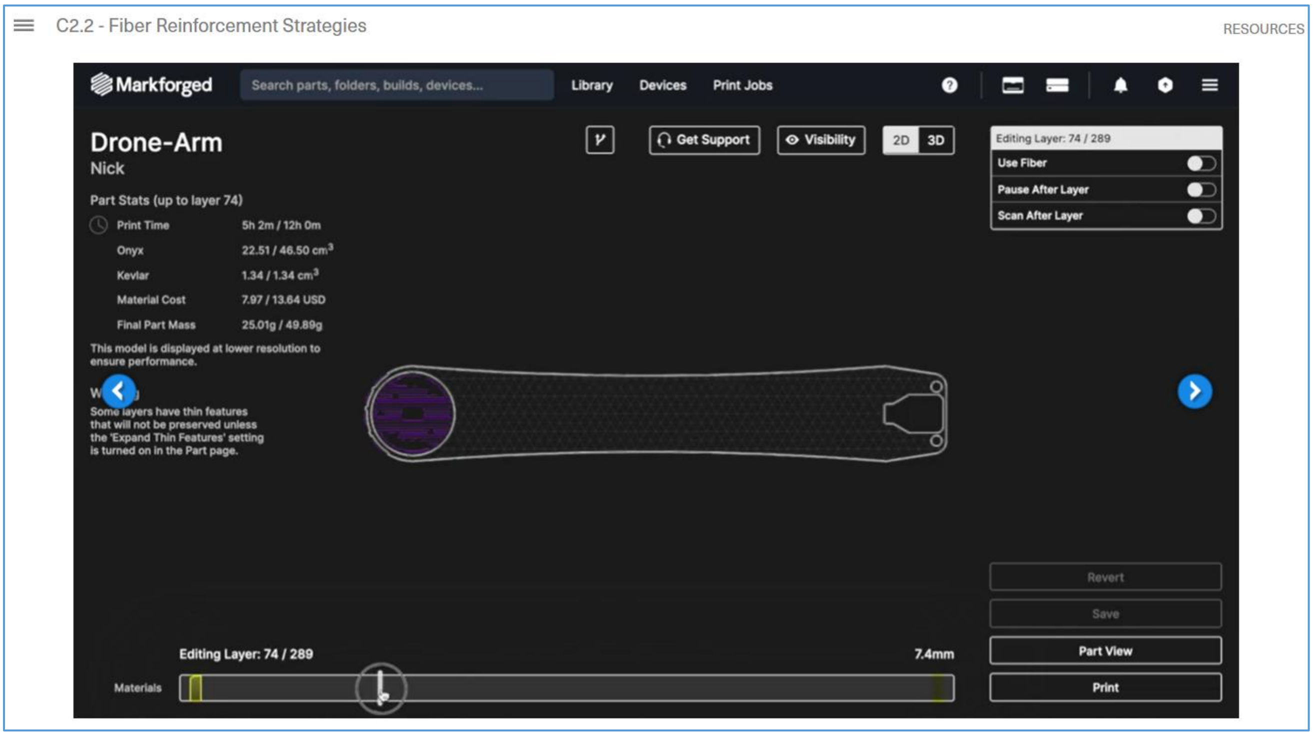
- Internal view: Click on Button Right beneath to get there.


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Select one or more layers to edit
Part Stats
Print Time 12h 0m
Onyx 46.50 cm³
Kevlar 1.34 cm³
Material Cost 13.64 USD
Final Part Mass 49.89g
This model is displayed at lower resolution to ensure performance.
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Revert
Save
Part View
Print
Select one or more layers to edit
Materials

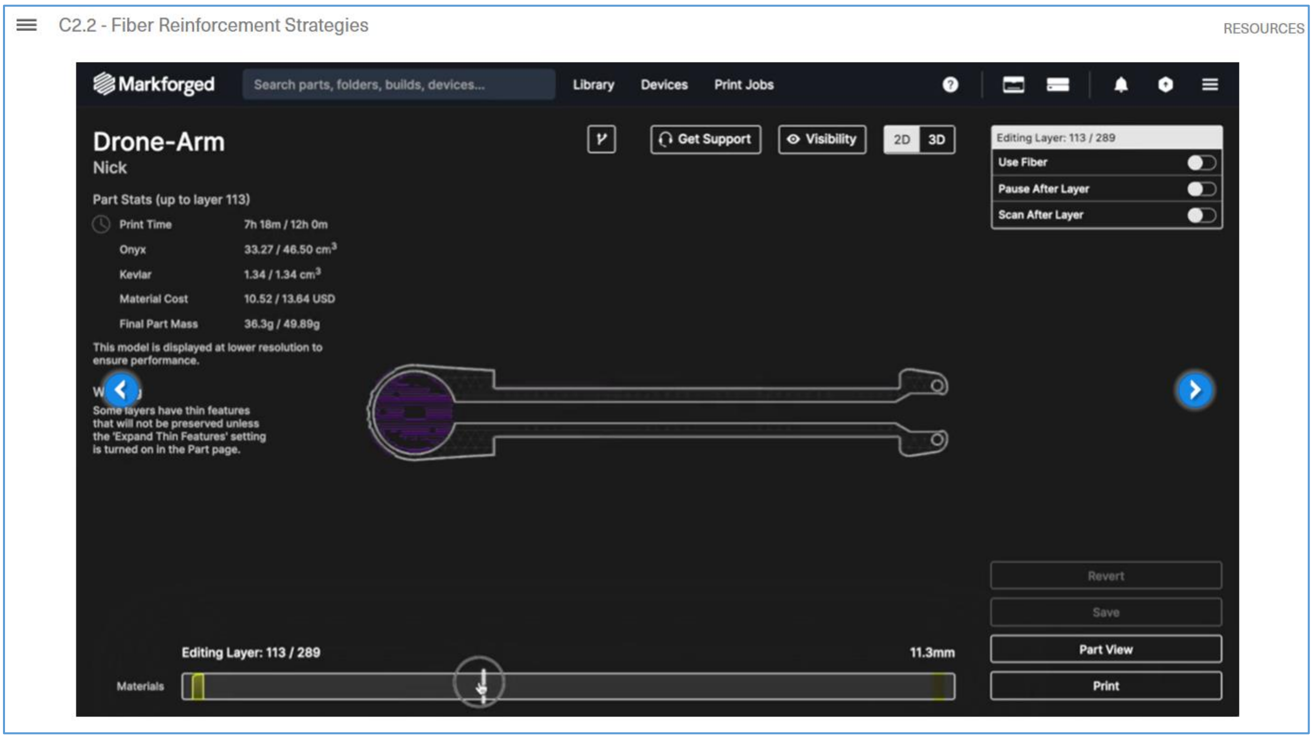

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Editing Layer: 1 / 289
Use Fiber
Pause After Layer
Scan After Layer
Part Stats (up to layer 1)
Print Time 16m / 12h 0m
Onyx 0.50 / 46.50 cm³
Kevlar 0.00 / 1.34 cm³
Material Cost 0.12 / 13.64 USD
Final Part Mass 0.48g / 49.89g
This model is displayed at lower resolution to ensure performance.
Some layers have thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Revert
Save
Part View
Print
Editing Layer: 1 / 289
0.1mm
Materials

- 2D view.

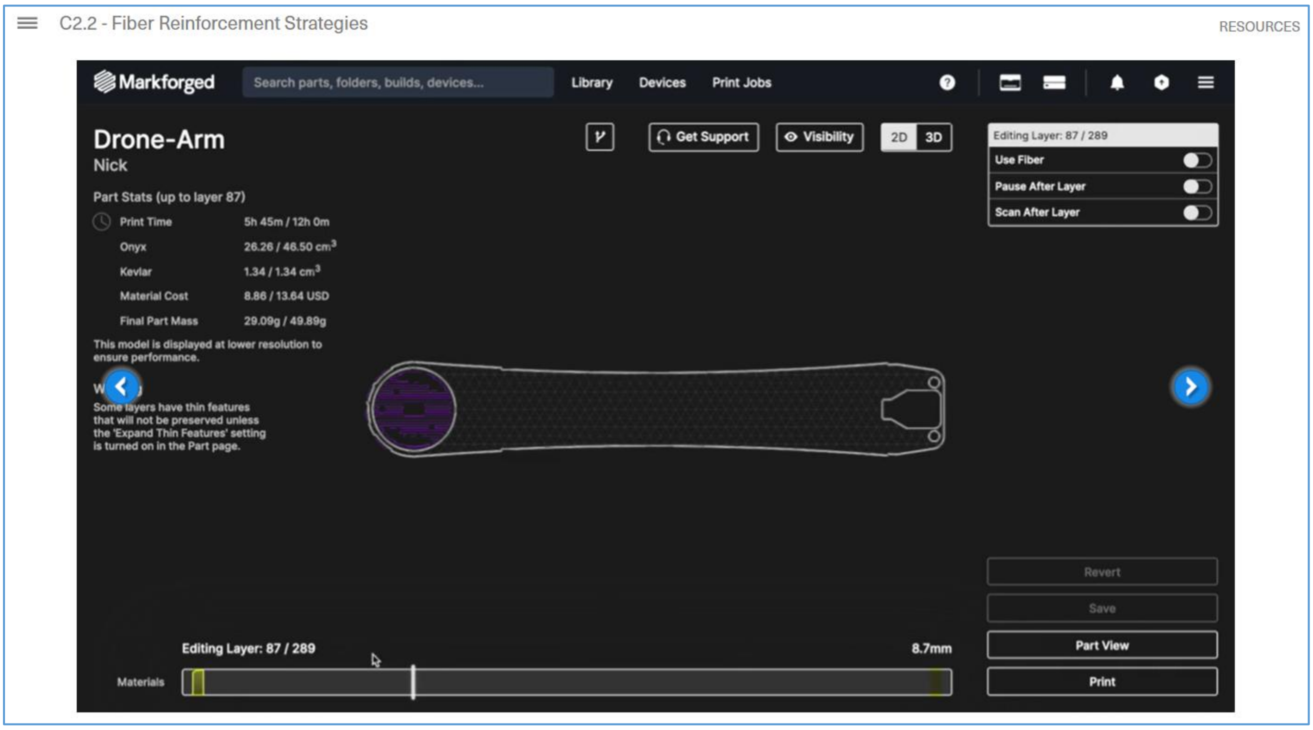




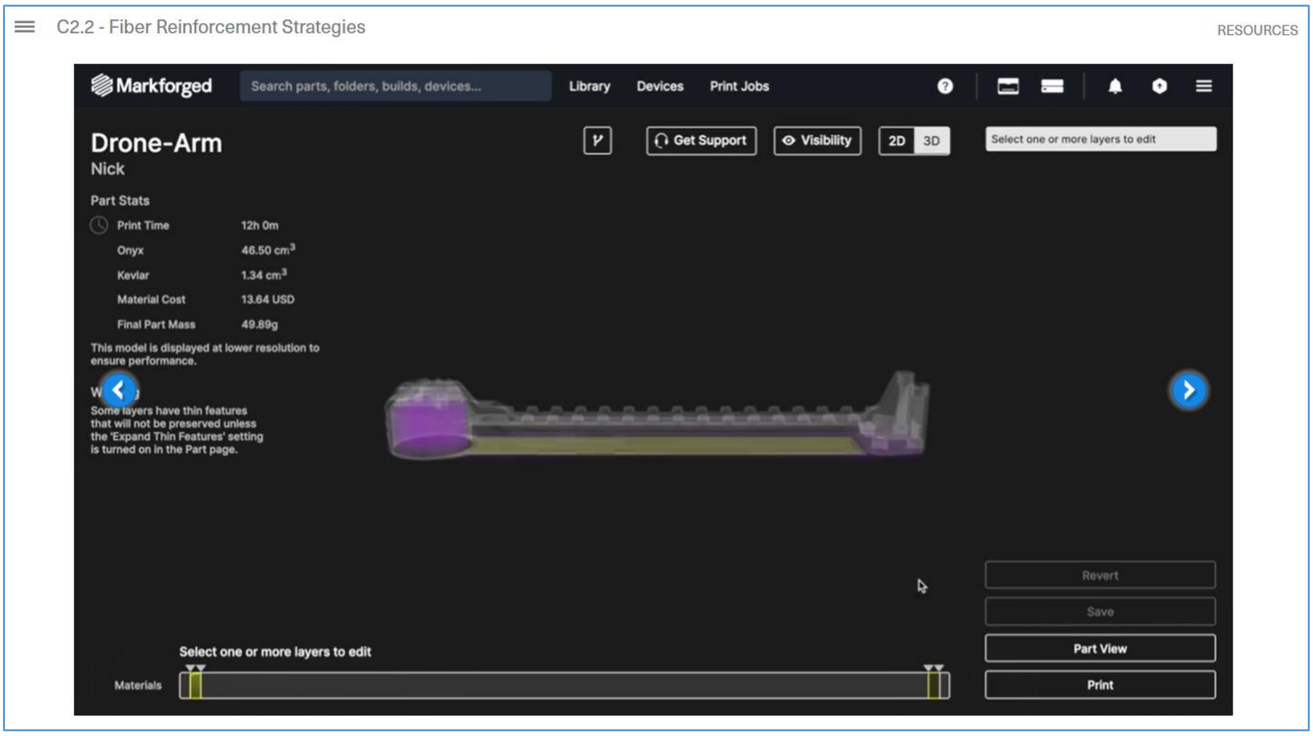
- Navigate down lower in the part.



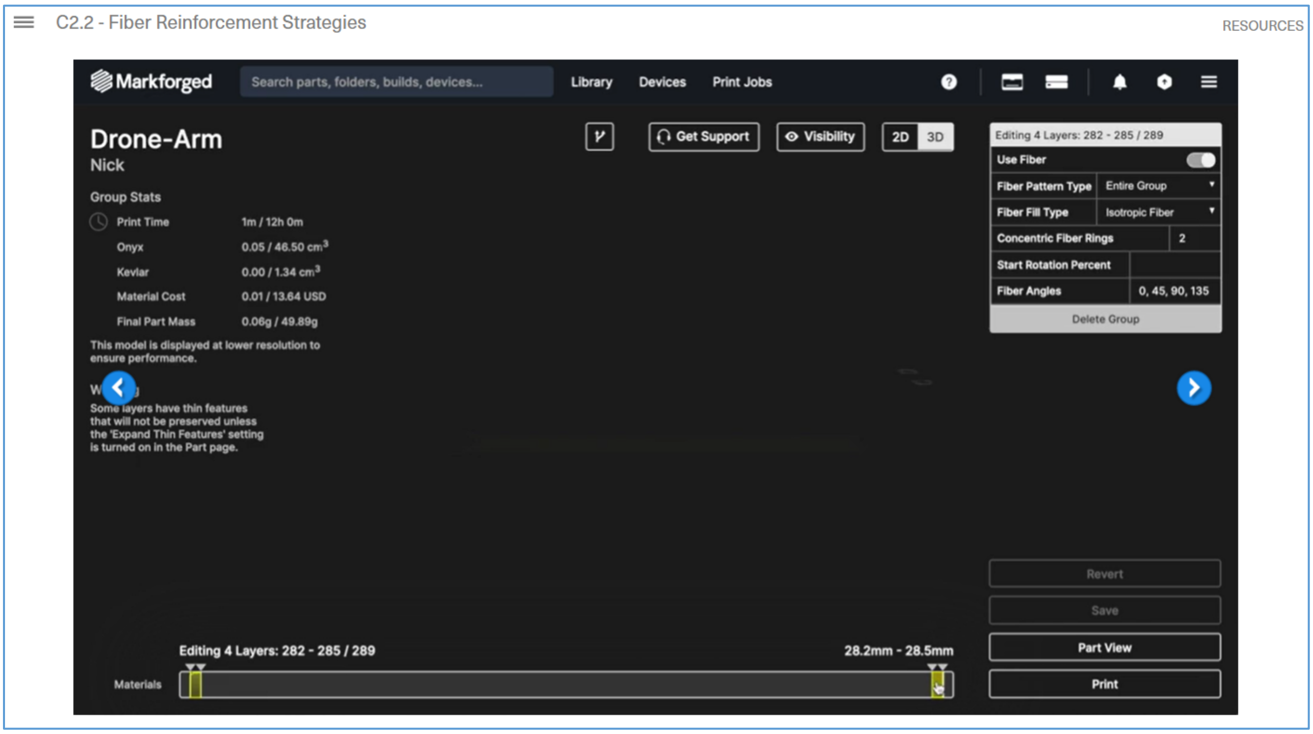
- For example: layer 113.



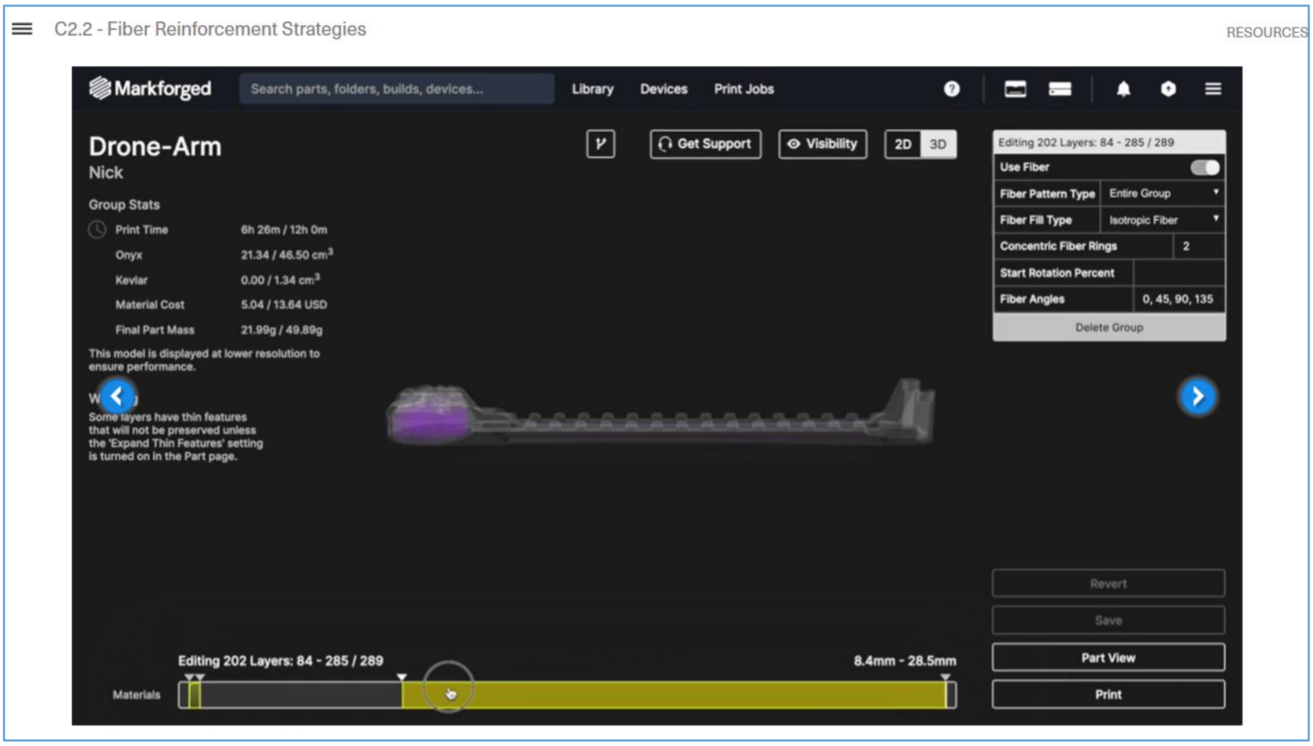
- The Layer beneath the first roof layer is (in this case) 87.



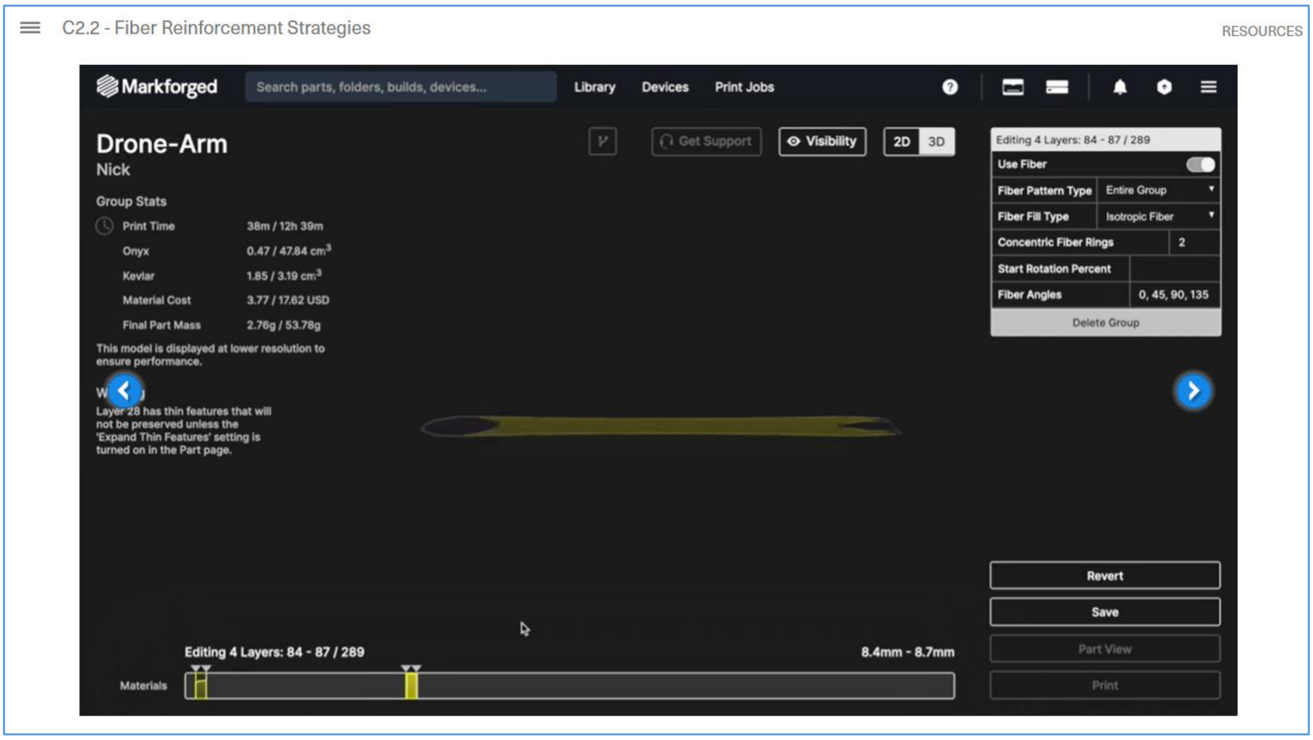
- Going back to the 3D layer view.



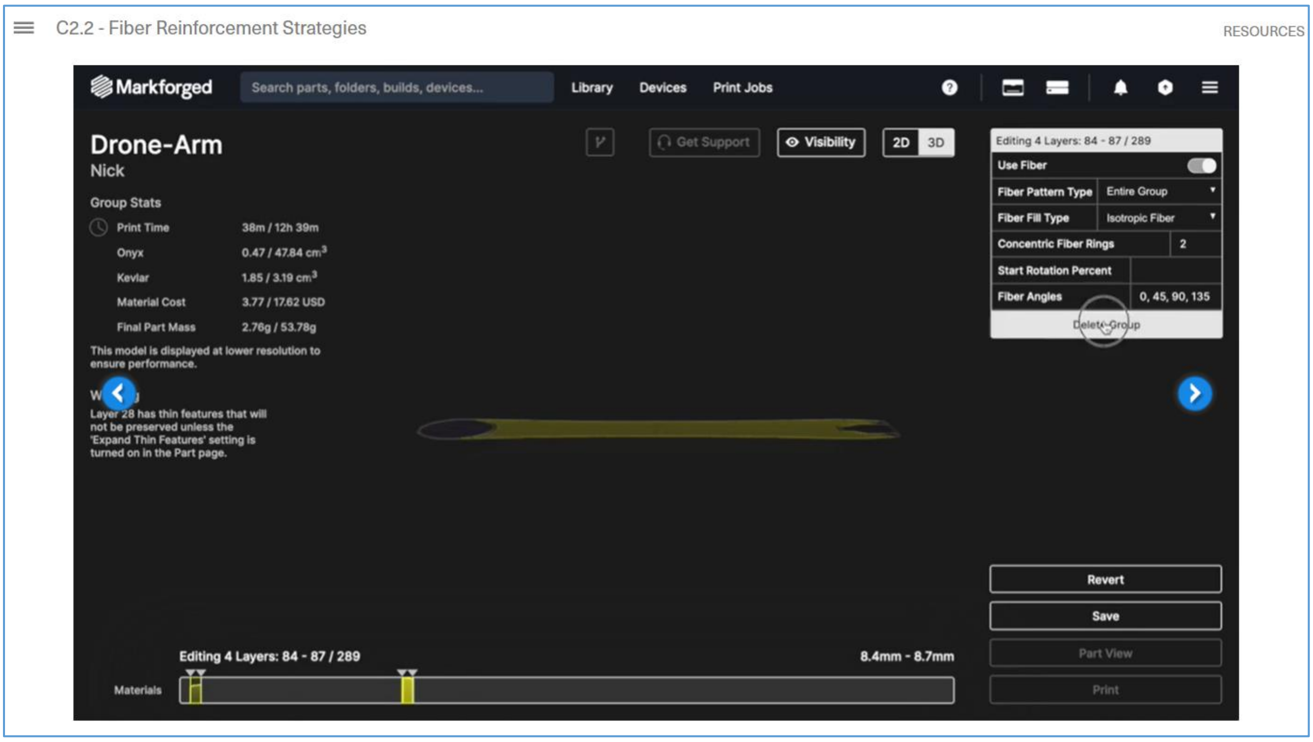
- Click on the top layer group.



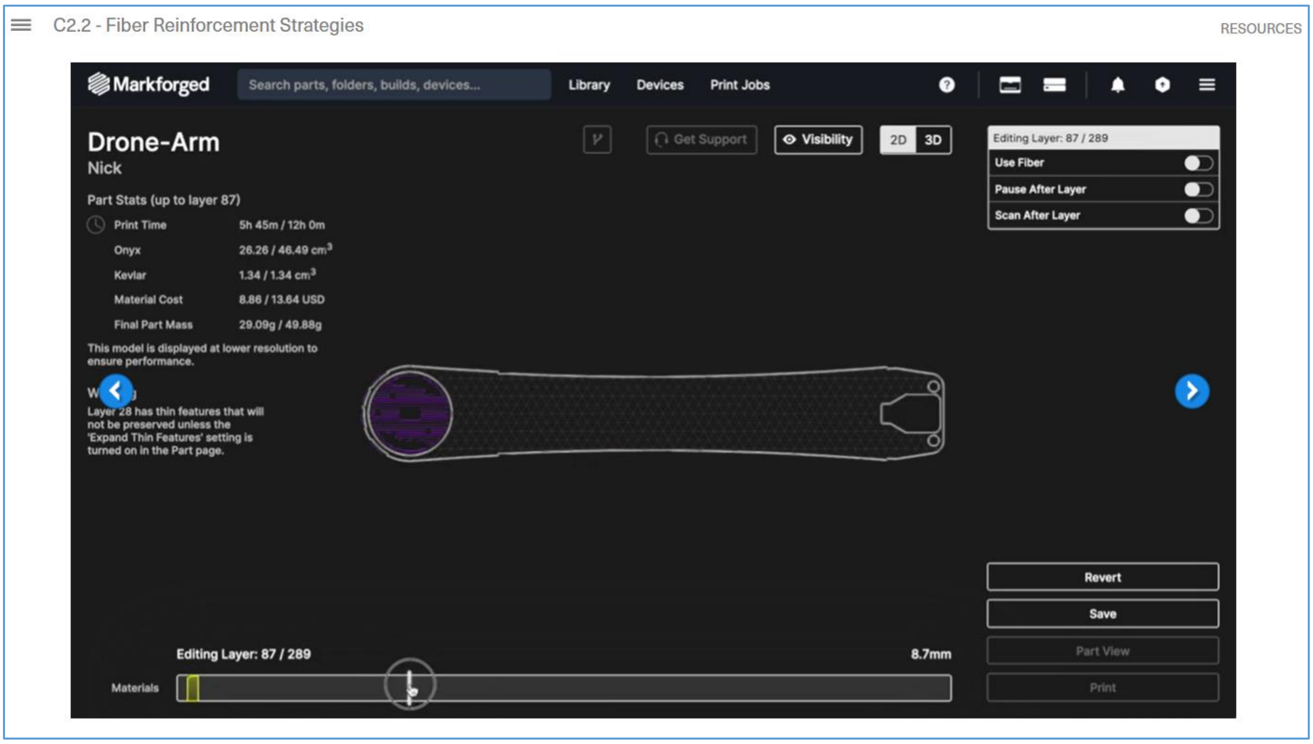
- For a default of 4 layers thick start on 84.



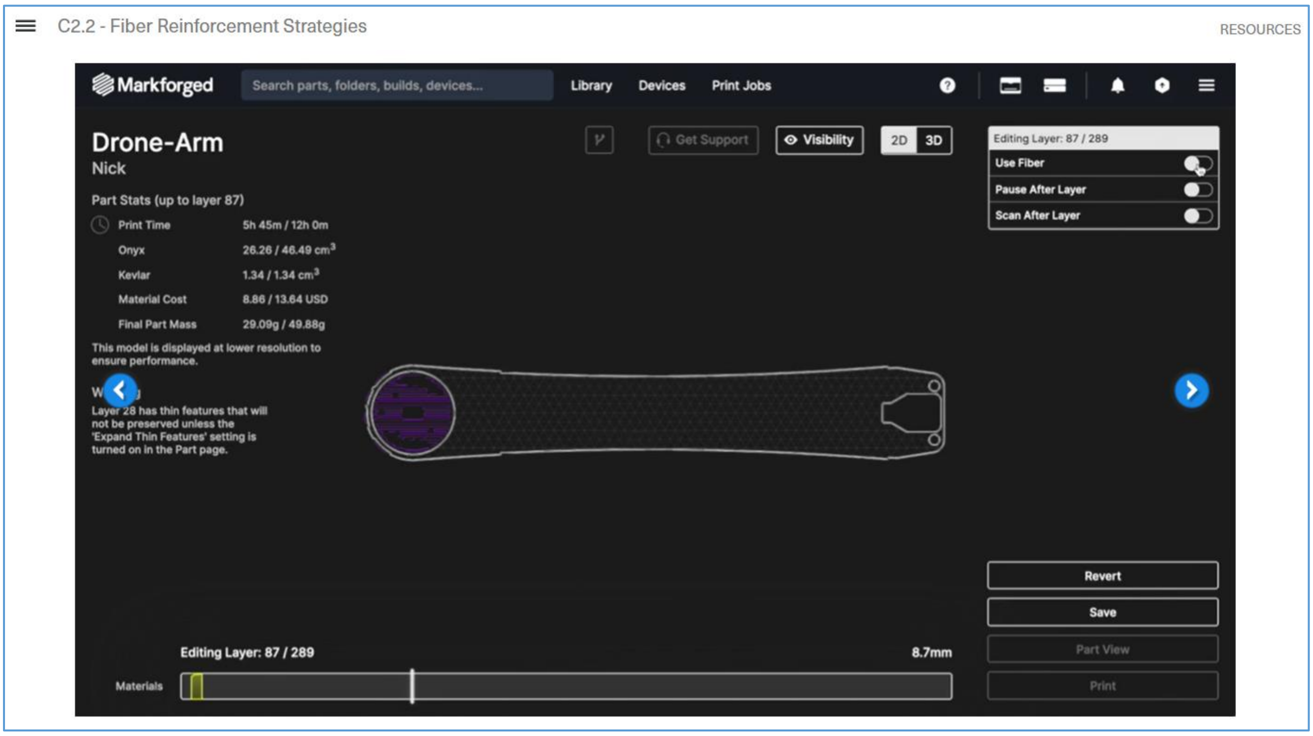
- Working with index handles is not a great strategy.
    - Tall part needs a lot of time to slice. **So instead something different.**



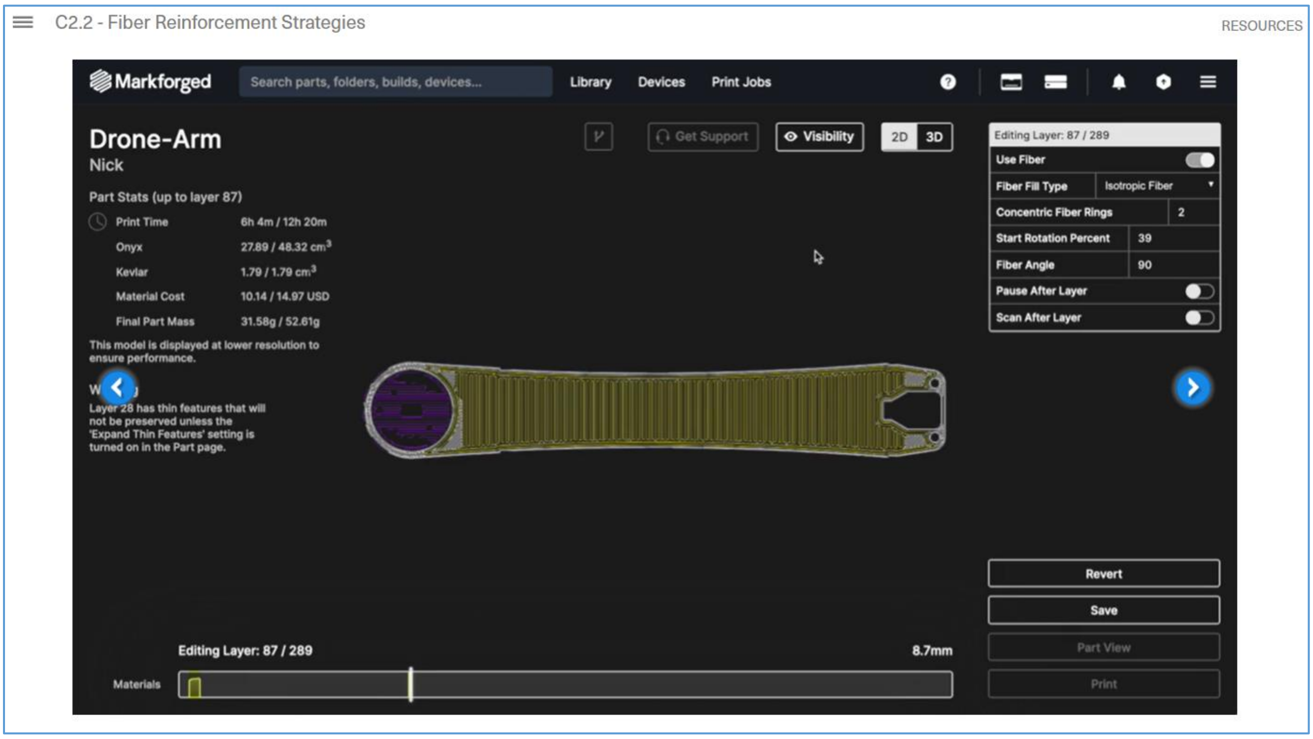
- To delete this: Click on bar and Delete Group.

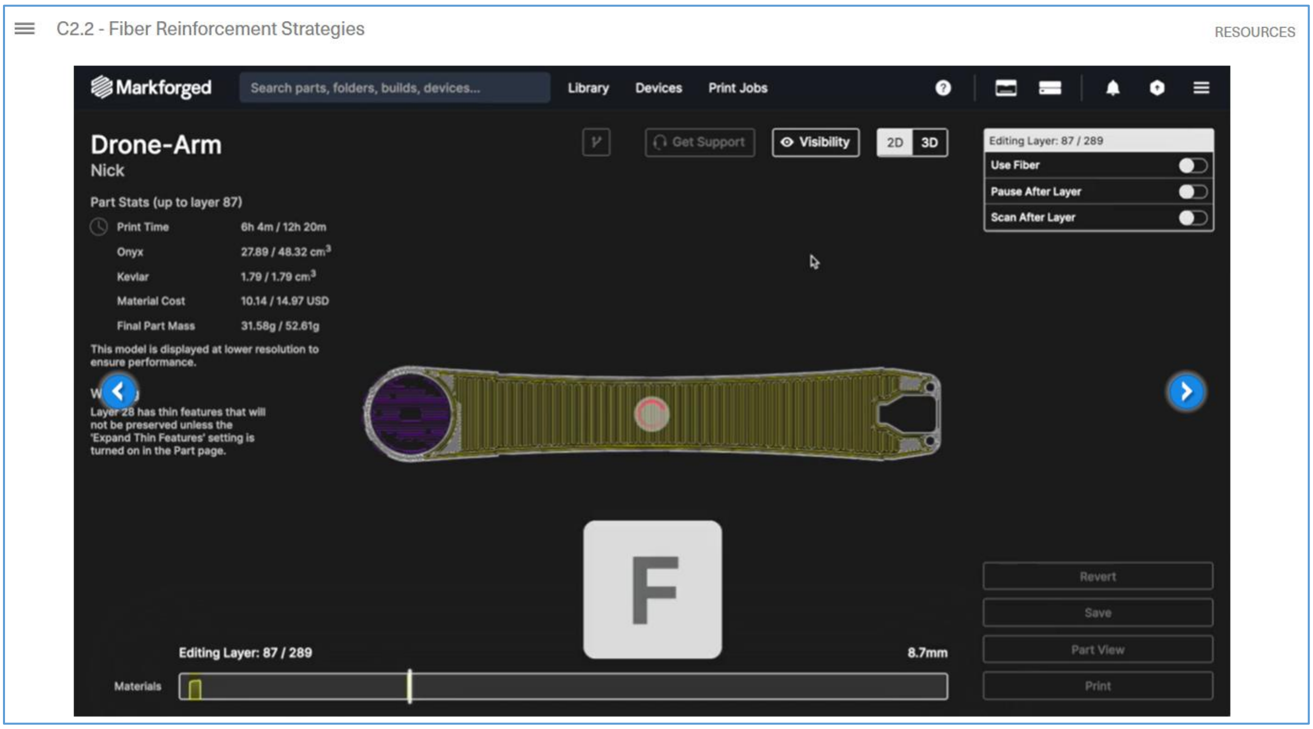


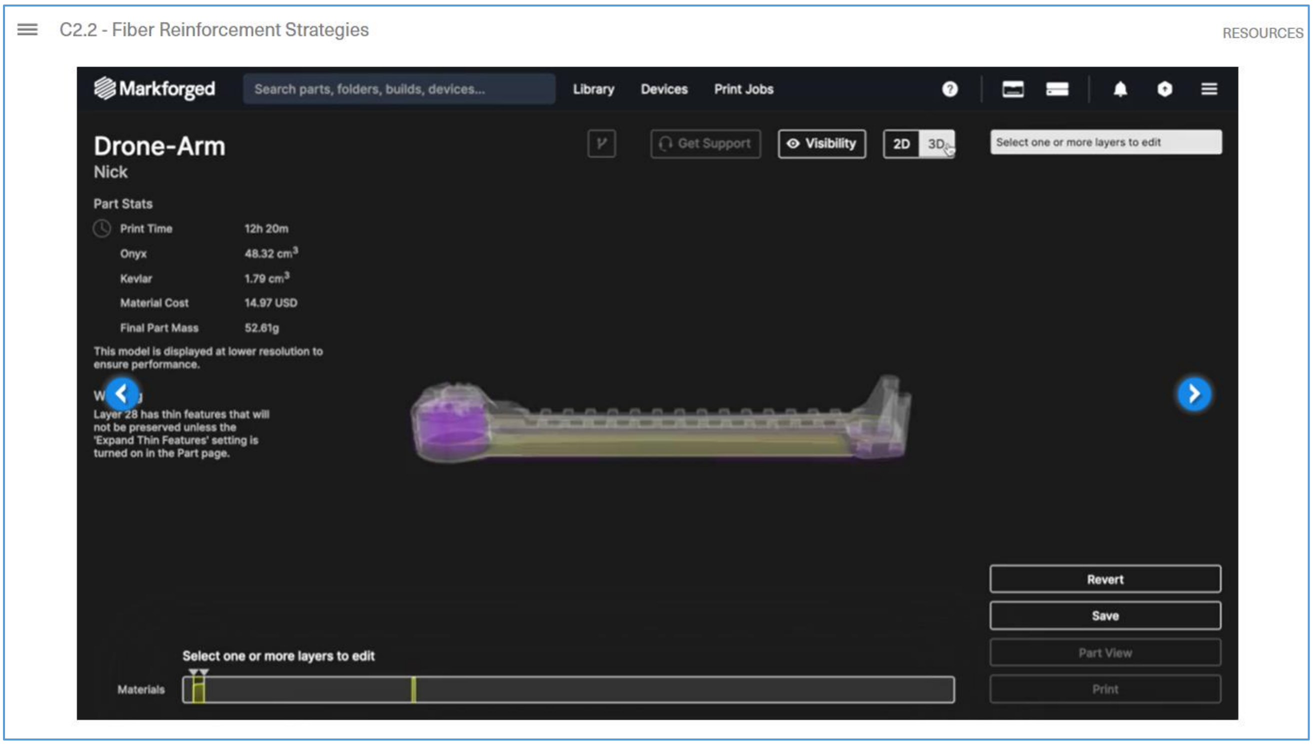
- 2D view and navigate to the layer you want


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 87)
Print Time 5h 45m / 12h 0m
Onyx 26.26 / 46.49 cm³
Kevlar 1.34 / 1.34 cm³
Material Cost 8.86 / 13.64 USD
Final Part Mass 29.09g / 49.88g
This model is displayed at lower resolution to ensure performance.
Layer 28 has thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Editing Layer: 87 / 289
Use Fiber
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 87 / 289
8.7mm
Materials

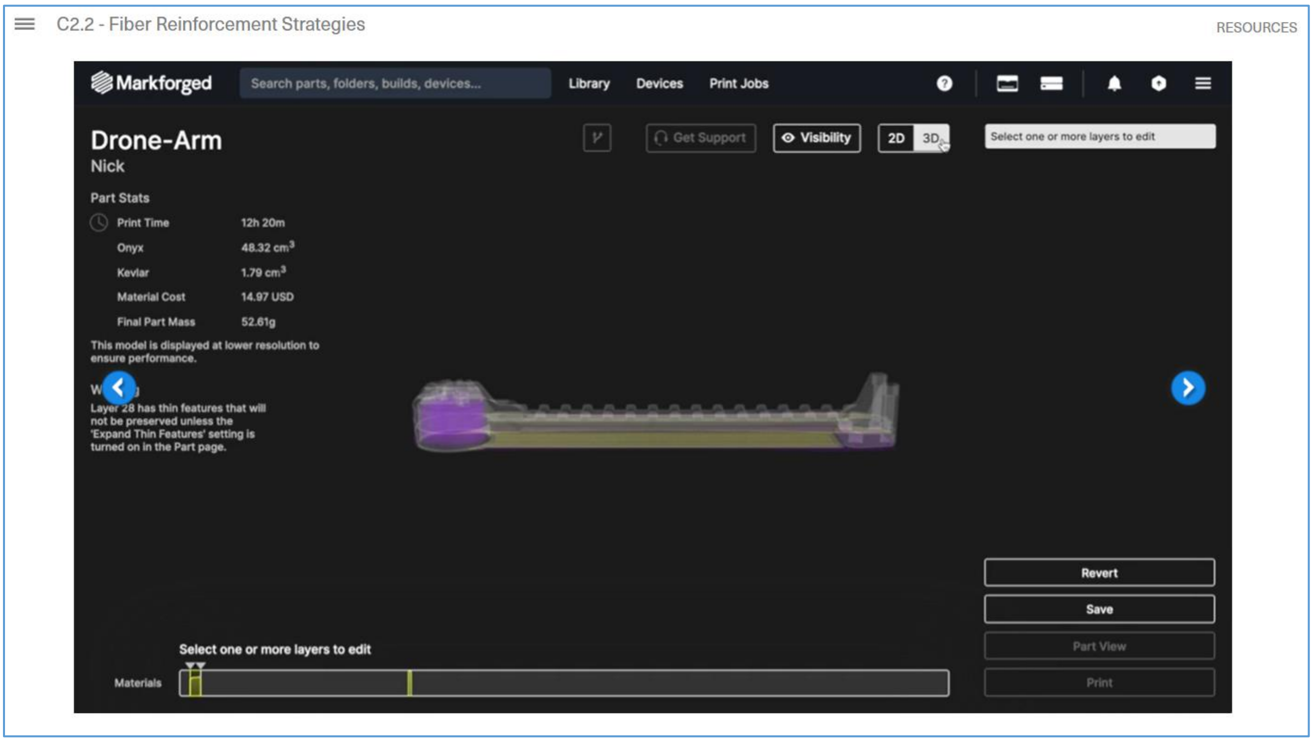
- Use Fiber.


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 87)
Print Time 6h 4m / 12h 20m
Onyx 27.89 / 48.32 cm³
Kevlar 1.79 / 1.79 cm³
Material Cost 10.14 / 14.97 USD
Final Part Mass 31.58g / 52.61g
This model is displayed at lower resolution to ensure performance.
Layer 28 has thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Editing Layer: 87 / 289
Use Fiber
Fiber Fill Type Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 39
Fiber Angle 90
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 87 / 289
8.7mm
Materials

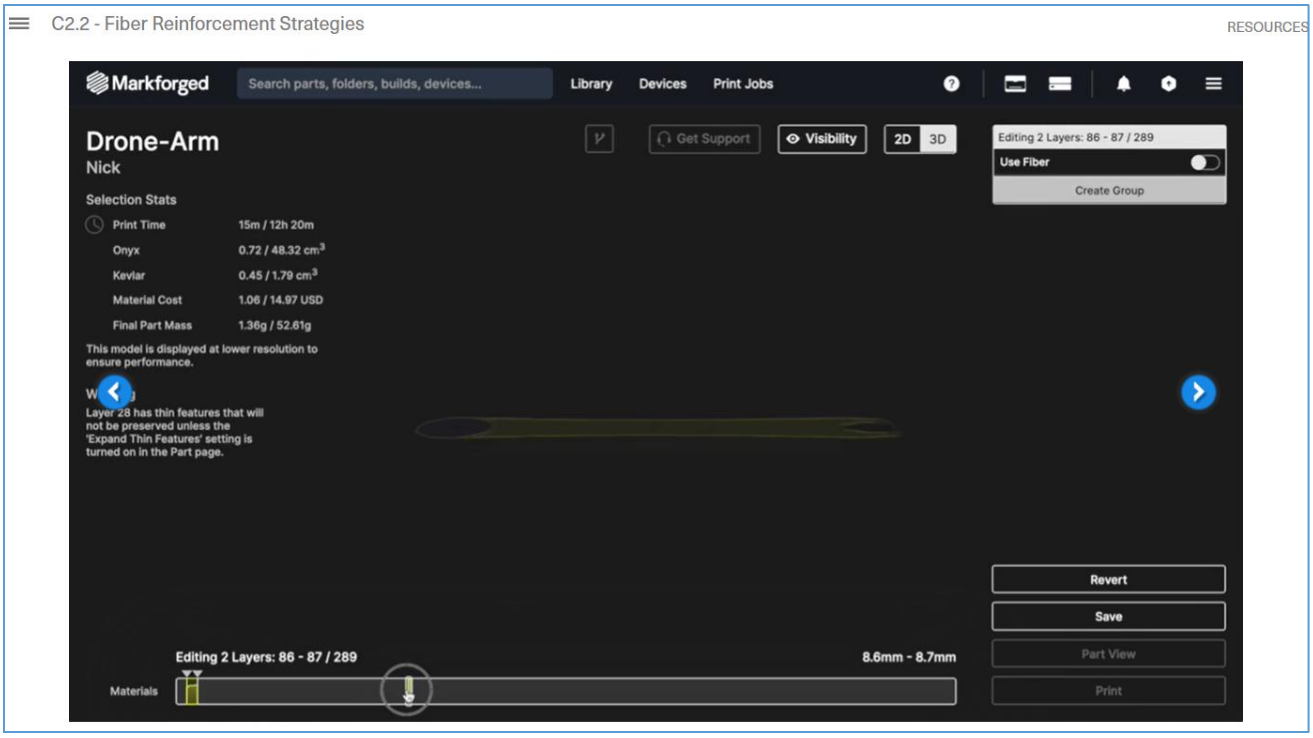




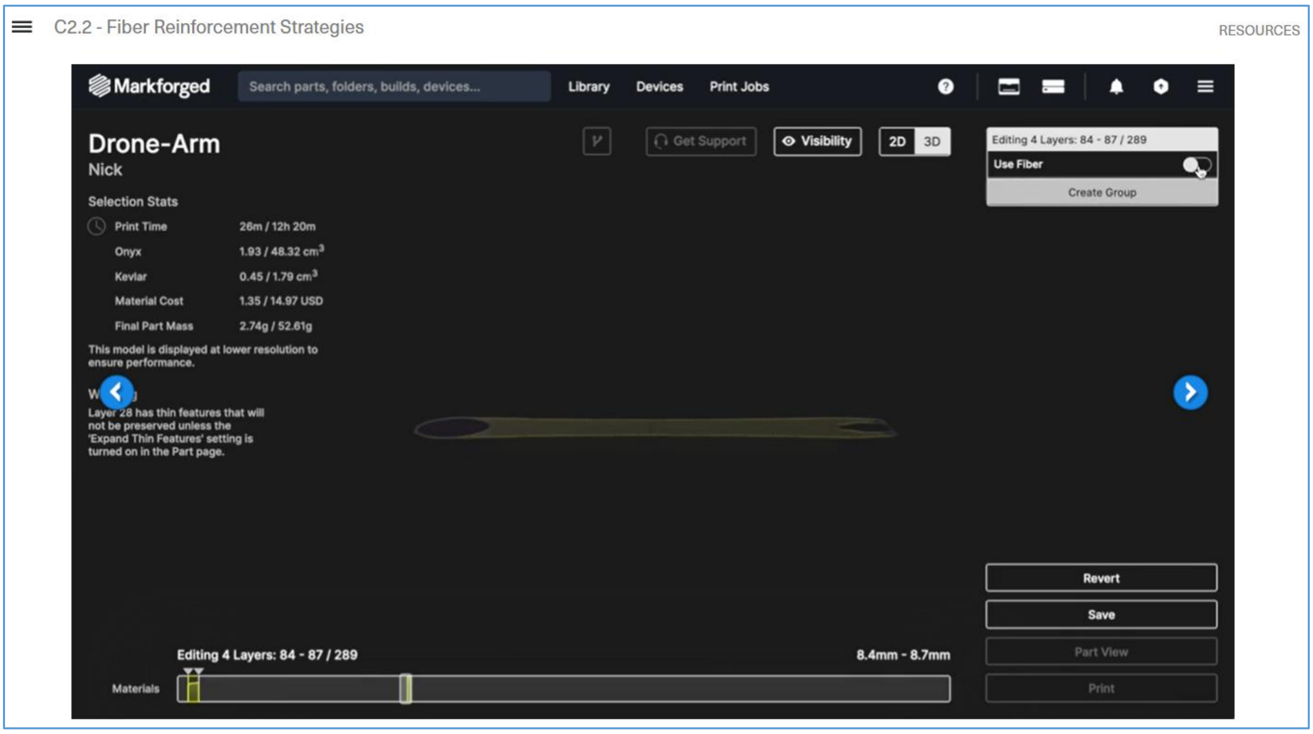
- Configure the top of the layer group > 3D.



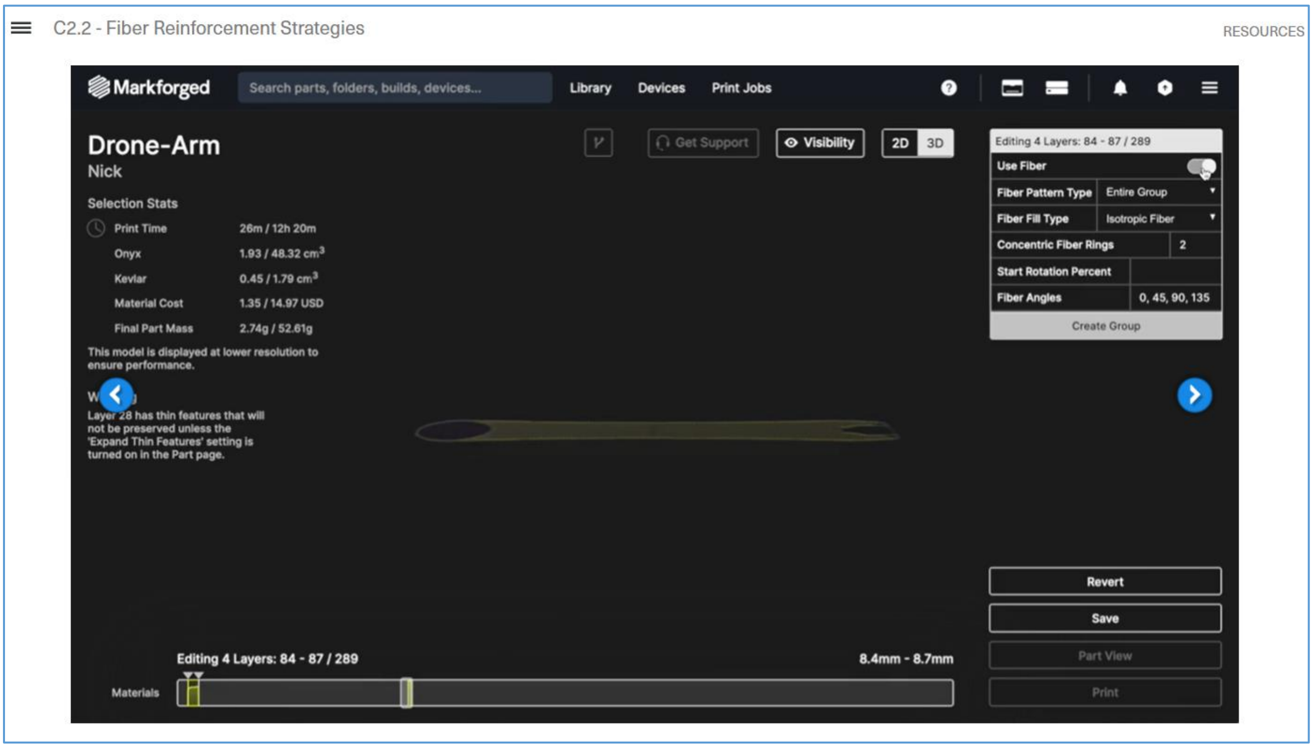
- The yellow indication is the layer we just added, at 87.
  - To use as a marker.

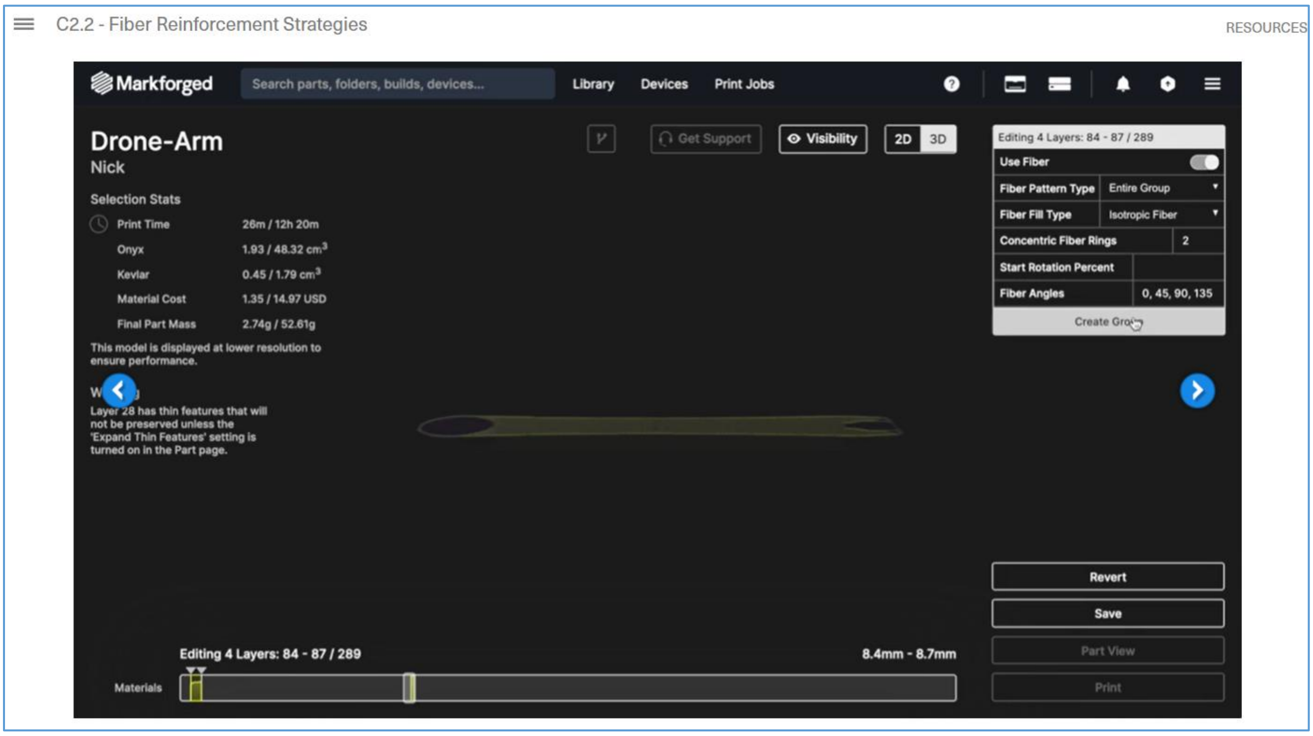


- Use as a marker for a new layer group.
  - Click and drag in layer bar.
  - And create a four layer selection.
  - This is a selection right now, not a group.

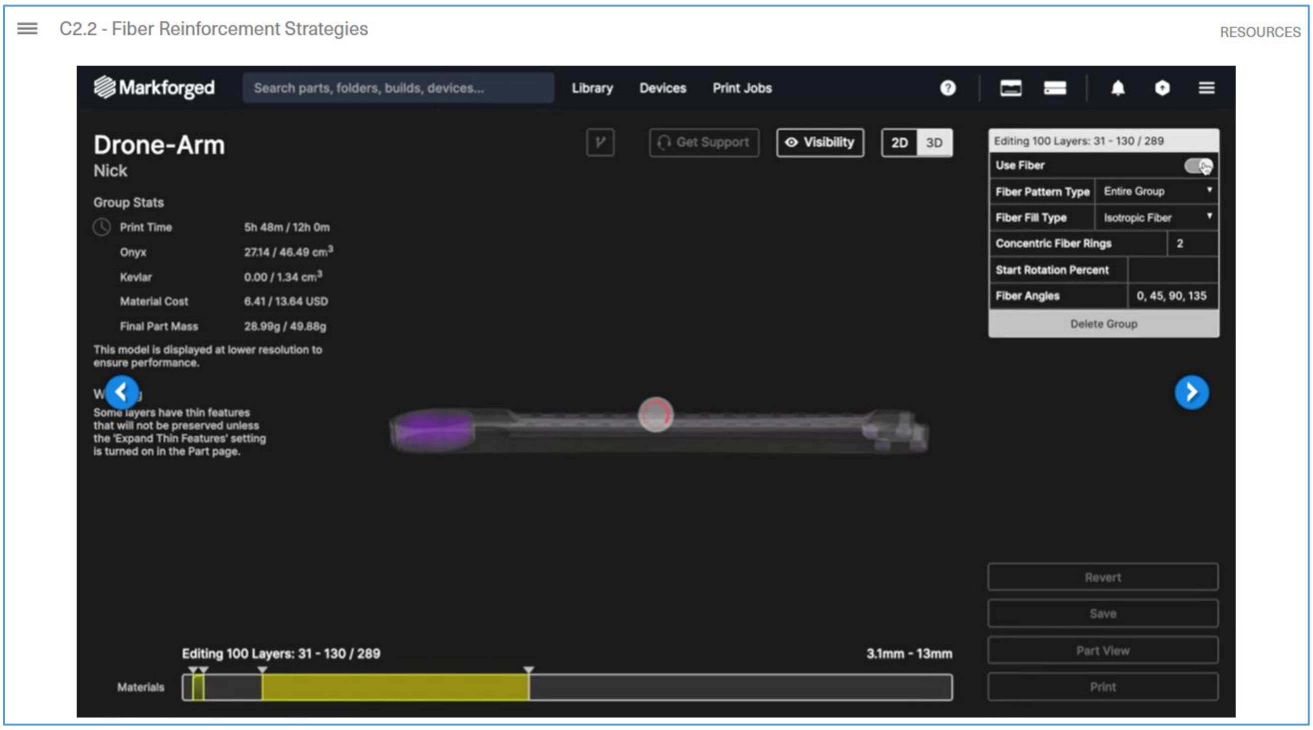


- Creating a group.

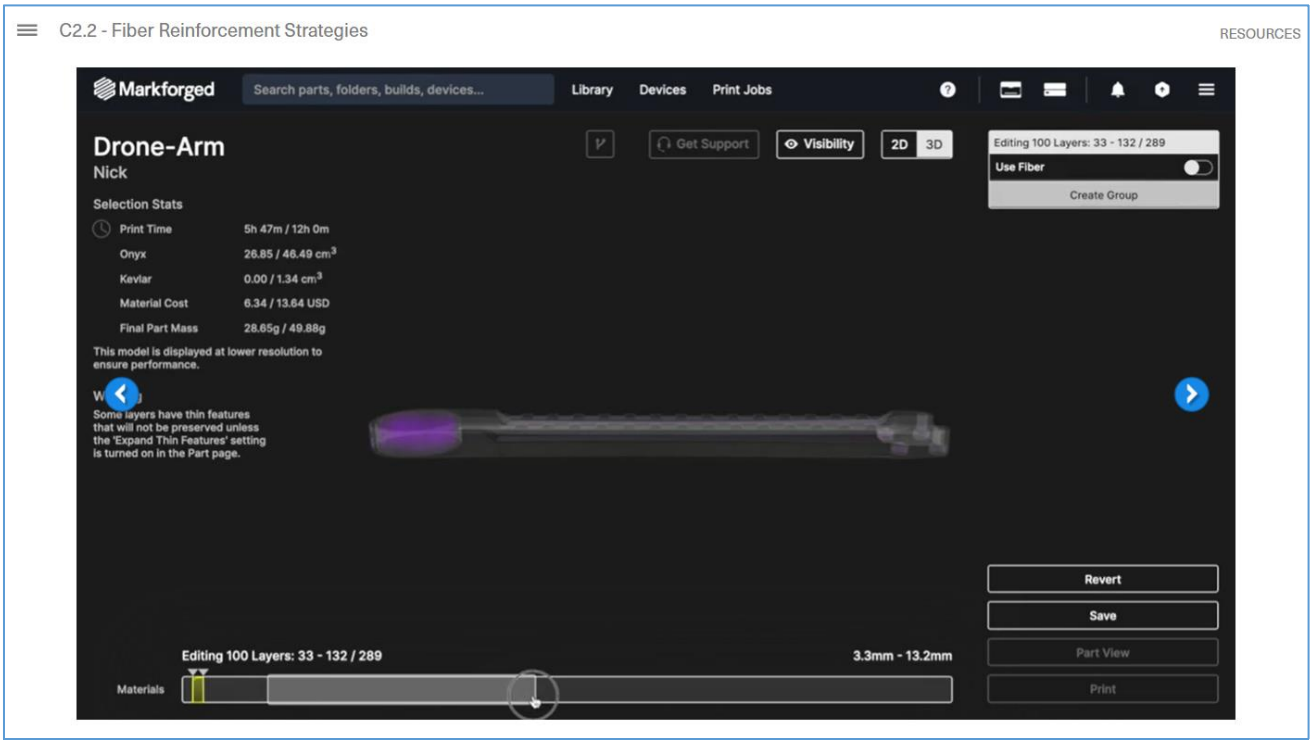




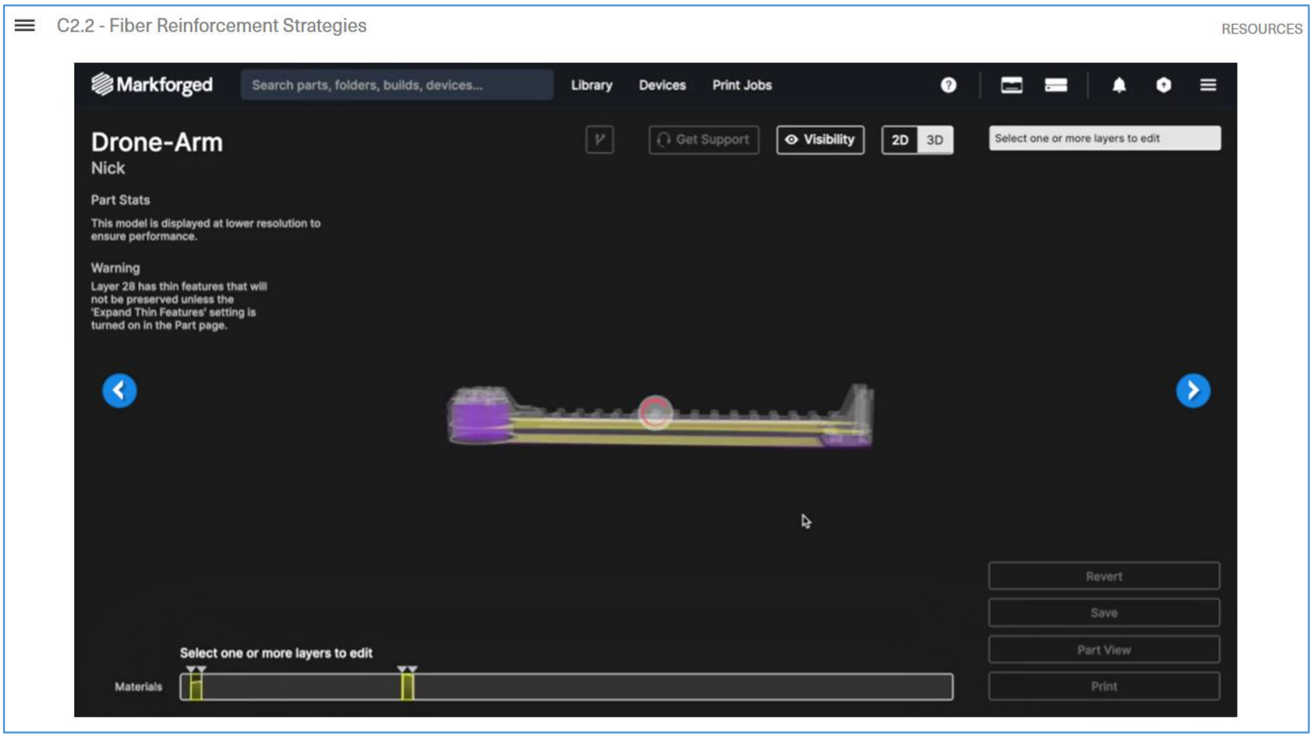
- Create Group Button.



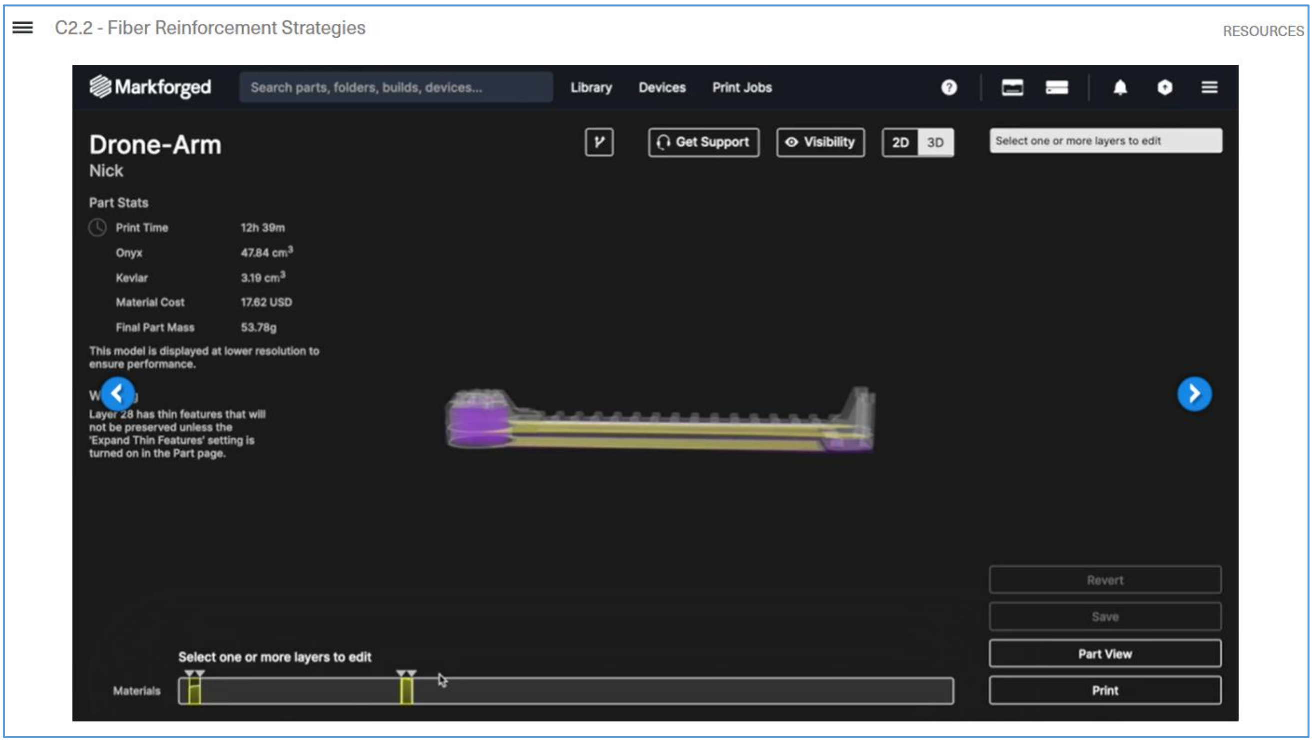
- Wrong Sequence if you want different fill type from the global default:
  - Make a layer selection.
  - Create a Group.
  - Then toggle fiber.
  - Than fill type (Concentric or Isotropic).
- Eiger will slice the entire group with the incorrect fill type, before it fill with the type you want.



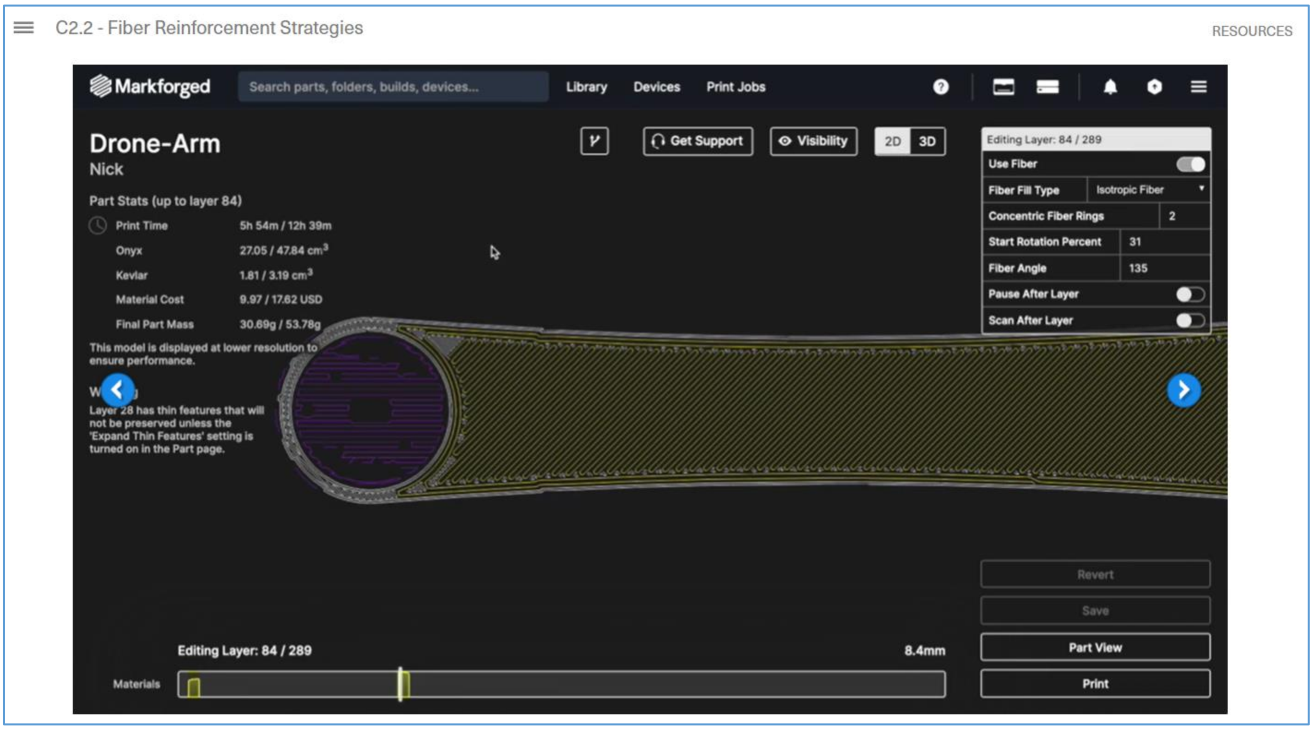
- Wright sequence:
  - Make a layer selection.
  - Toggle fiber.
  - Choose the fill type you want.
  - ONLY THAN CREATE THE GROUP.
- Eiger slice the group once.



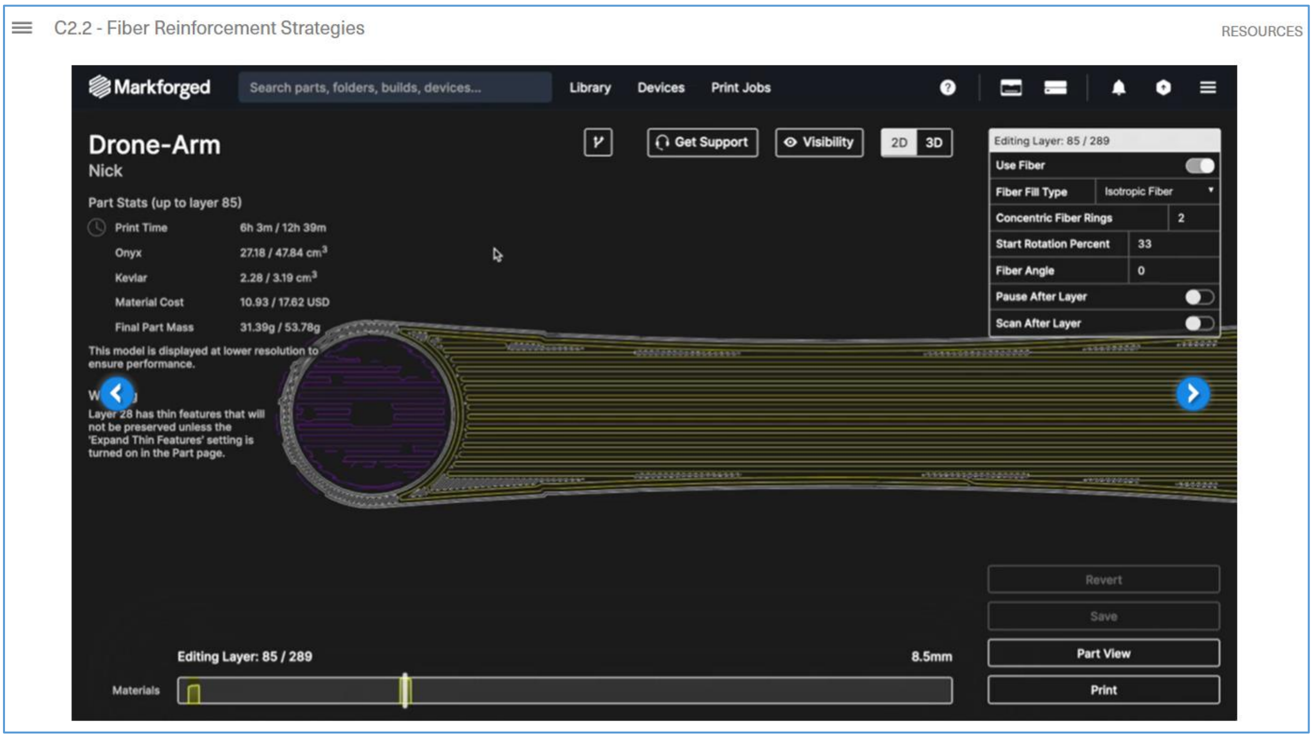
- And save your work.

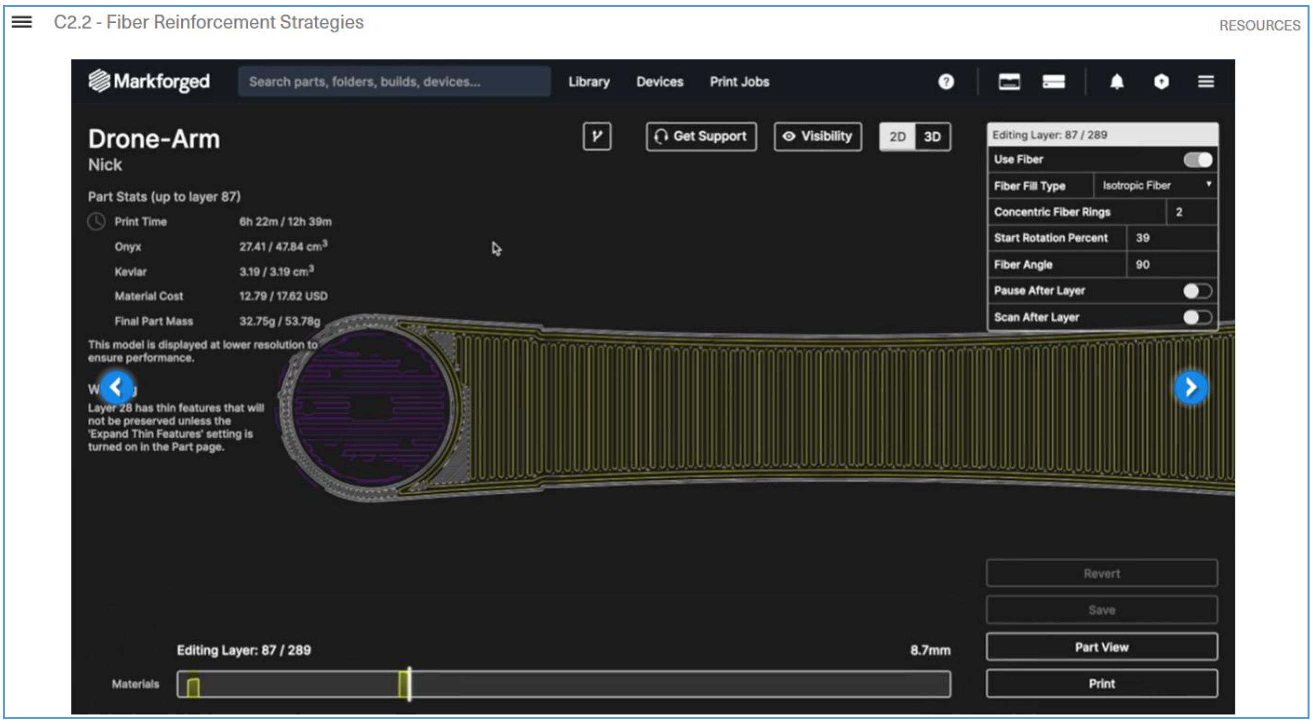


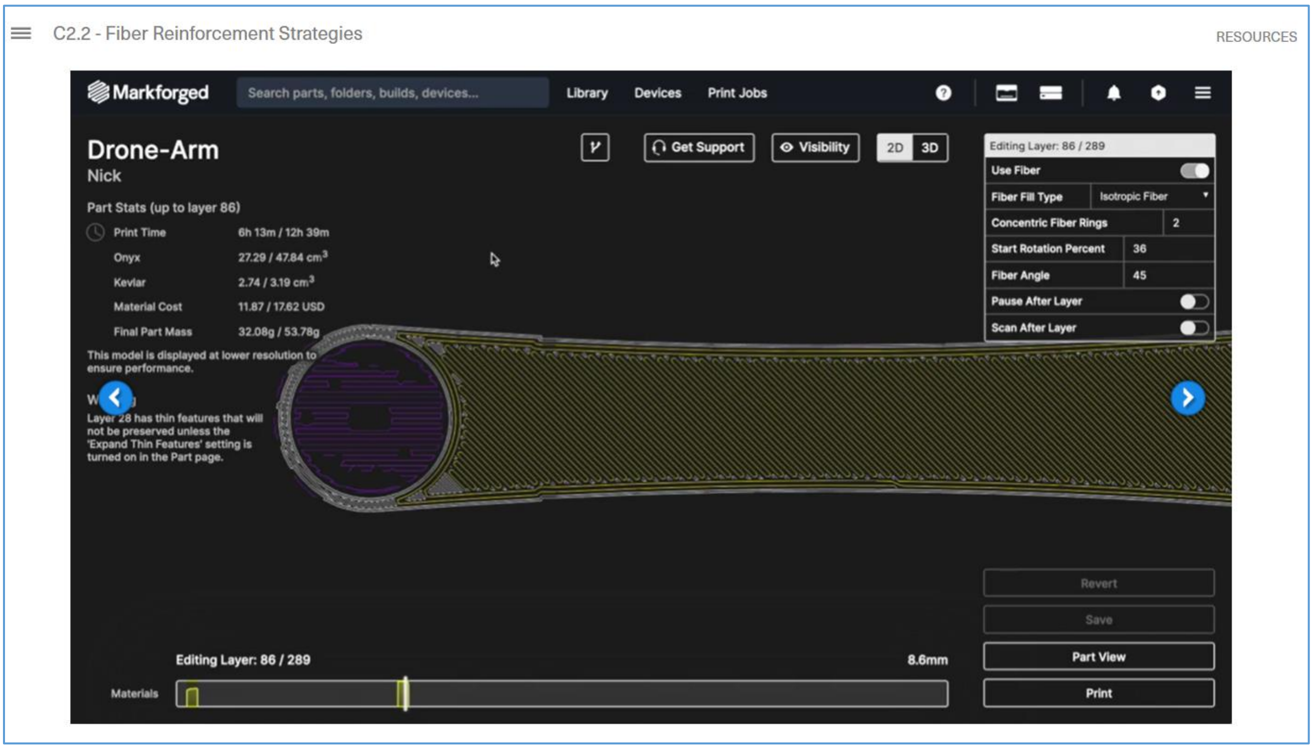
- Click on the group to select it.
  - It wasn't automatically created by Eiger.
  - Click on the upper group to select it.
  - Switch to 2D-view, that will take is to first layer in the group.

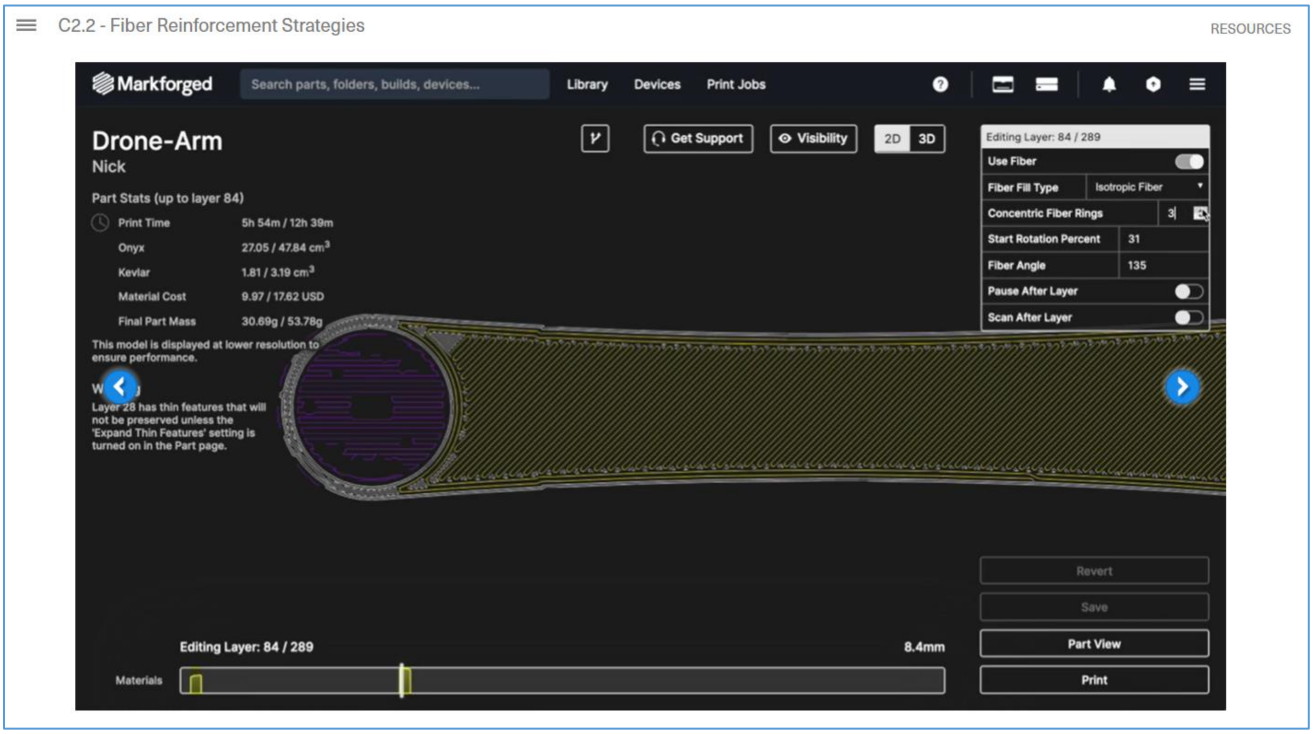


- Notice: Eiger rotates automatically the direction 45° each new layer.
  - Contoled by Fiber Angle in right box.

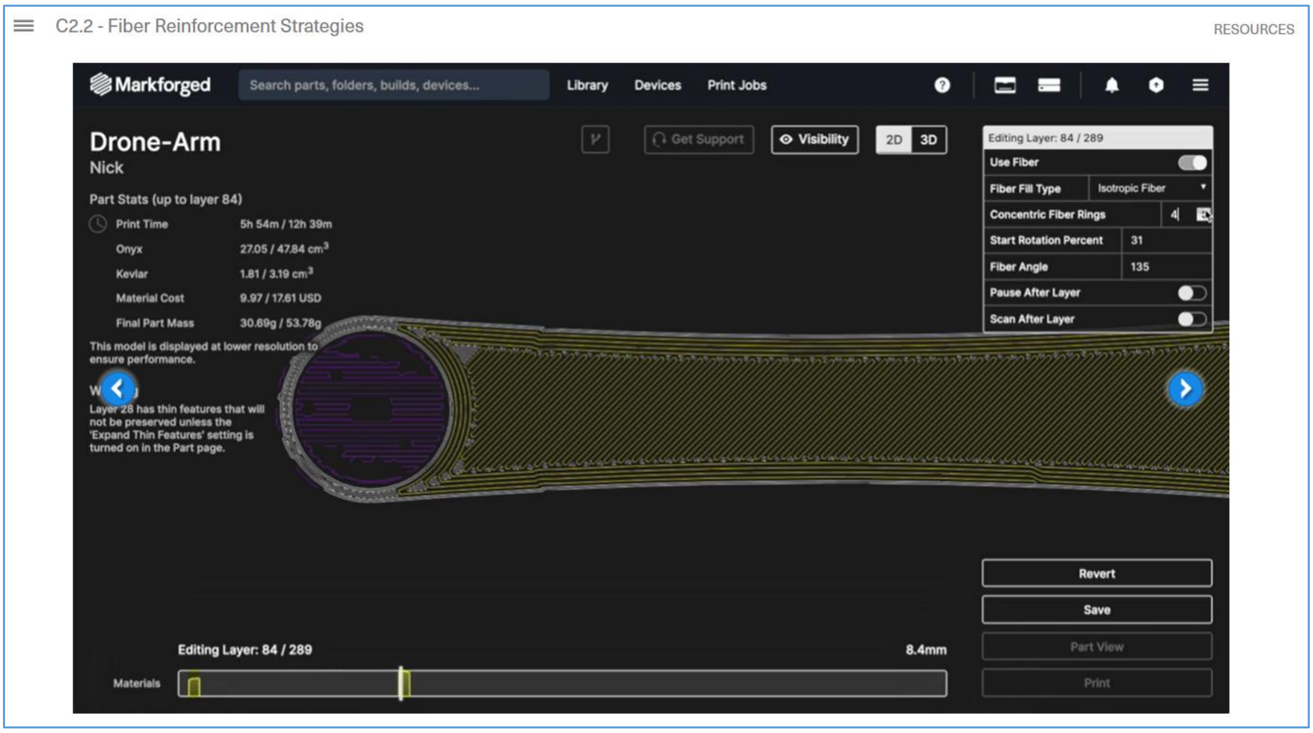

C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 85)
Print Time 6h 3m / 12h 39m
Onyx 27.18 / 47.84 cm³
Kevlar 2.28 / 3.19 cm³
Material Cost 10.93 / 17.62 USD
Final Part Mass 31.39g / 53.78g
This model is displayed at lower resolution to ensure performance.
Layer 28 has thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Editing Layer: 85 / 289
Use Fiber
Fiber Fill Type Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 33
Fiber Angle 0
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 85 / 289
8.5mm
Materials


C2.2 - Fiber Reinforcement Strategies
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Drone-Arm
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 87)
Print Time 6h 22m / 12h 39m
Onyx 27.41 / 47.84 cm³
Kevlar 3.19 / 3.19 cm³
Material Cost 12.79 / 17.62 USD
Final Part Mass 32.75g / 53.78g
This model is displayed at lower resolution to ensure performance.
Layer 28 has thin features that will not be preserved unless the 'Expand Thin Features' setting is turned on in the Part page.
Editing Layer: 87 / 289
Use Fiber
Fiber Fill Type Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 39
Fiber Angle 90
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 87 / 289
8.7mm
Materials

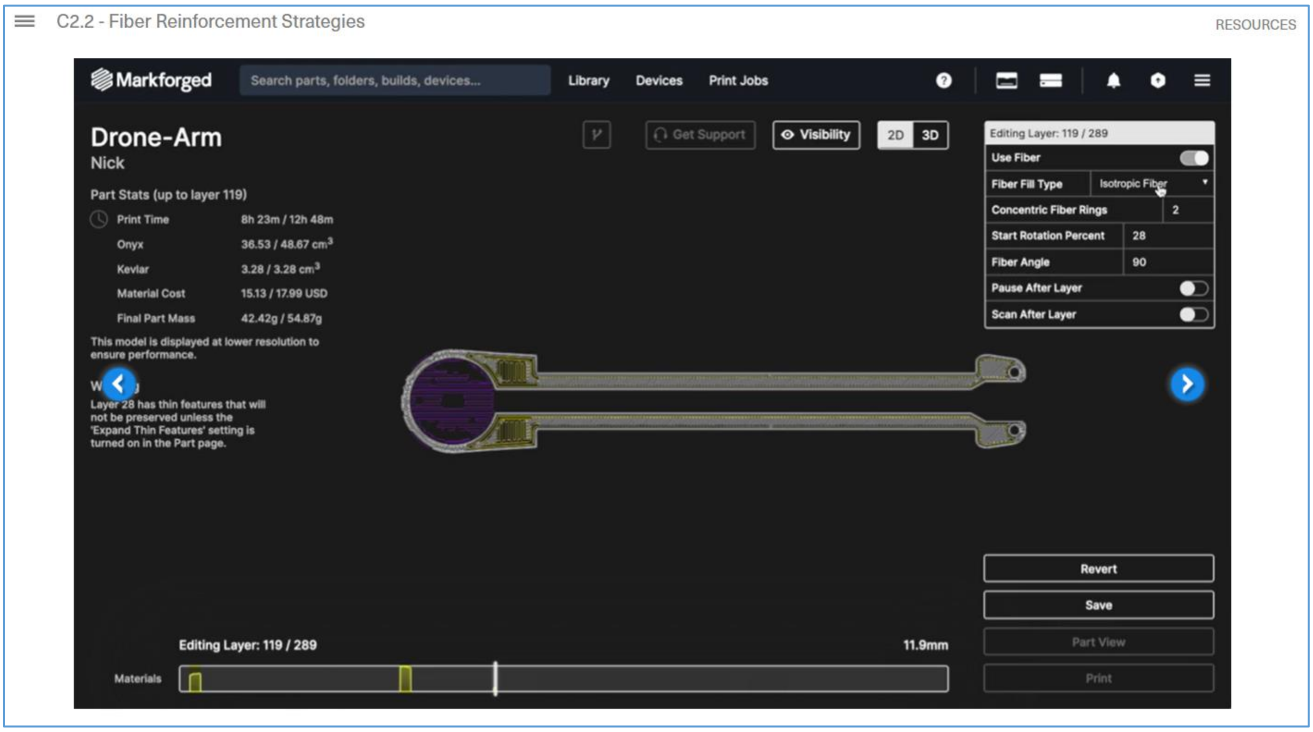




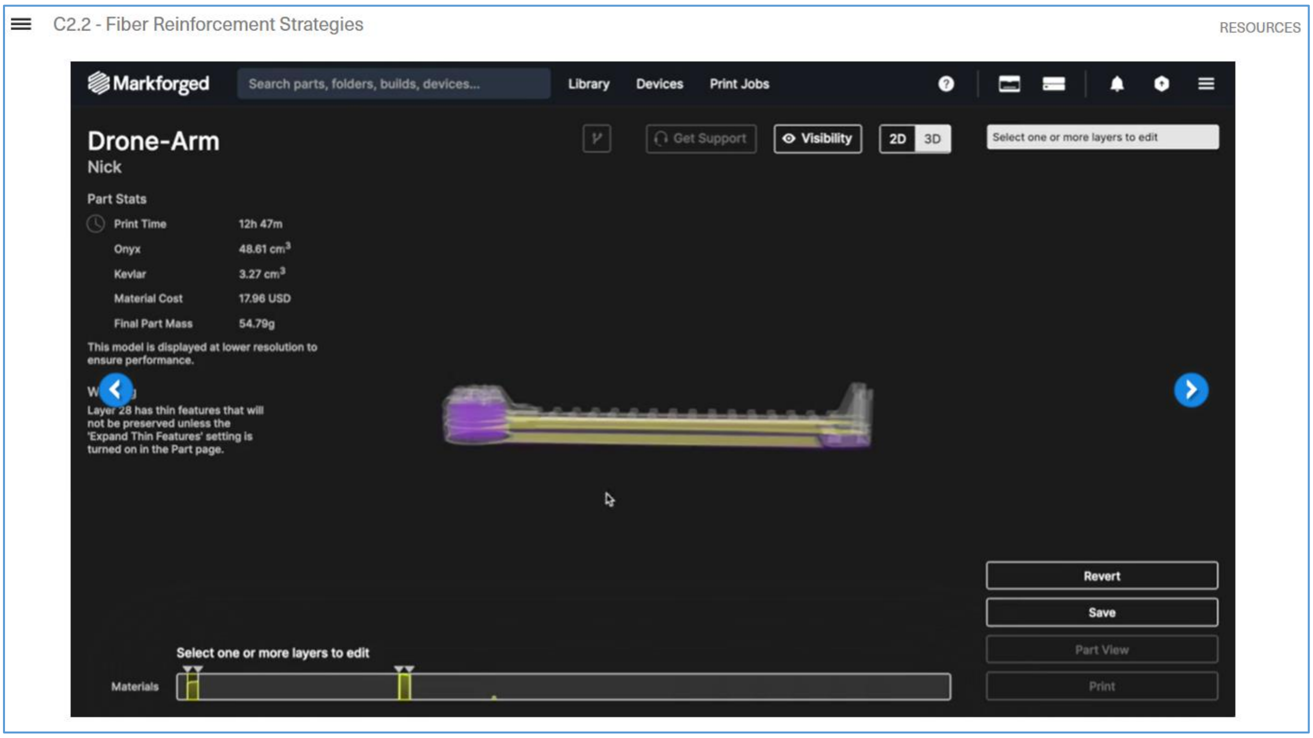
- You can also create Concentric Fiber Rings.



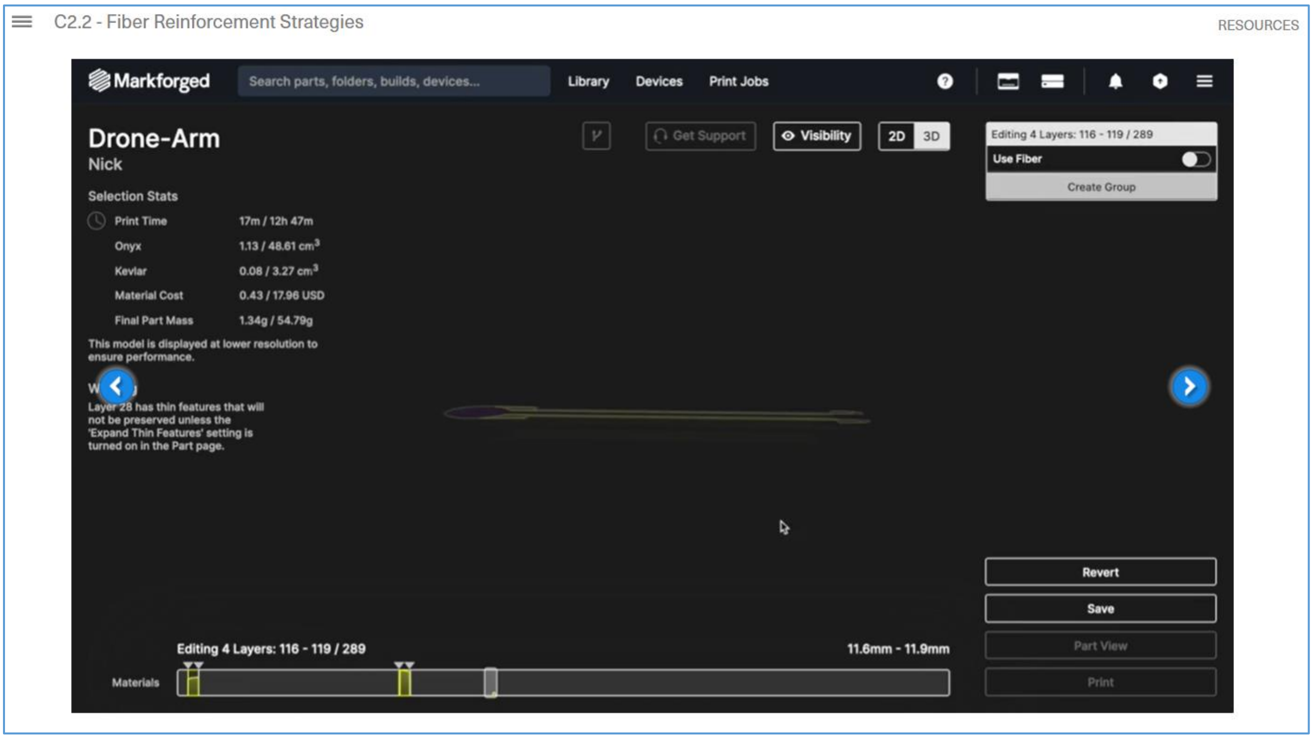
- Increasing the number of Rings.



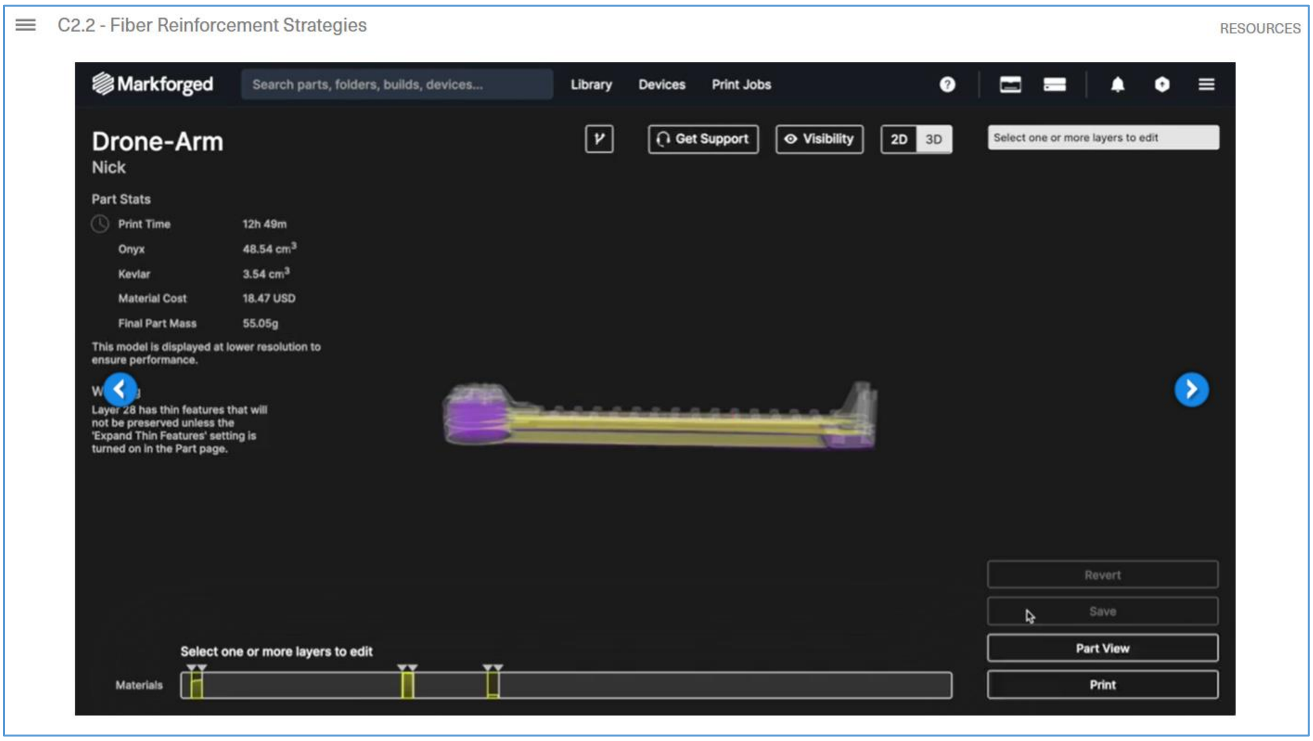
- In these layers the reinforcement does not very much.
  - So let us change it into Concentric Fiber.



- Use the same technique:
  - 3D-view
  - Yellow Indicator as a Starting Point.

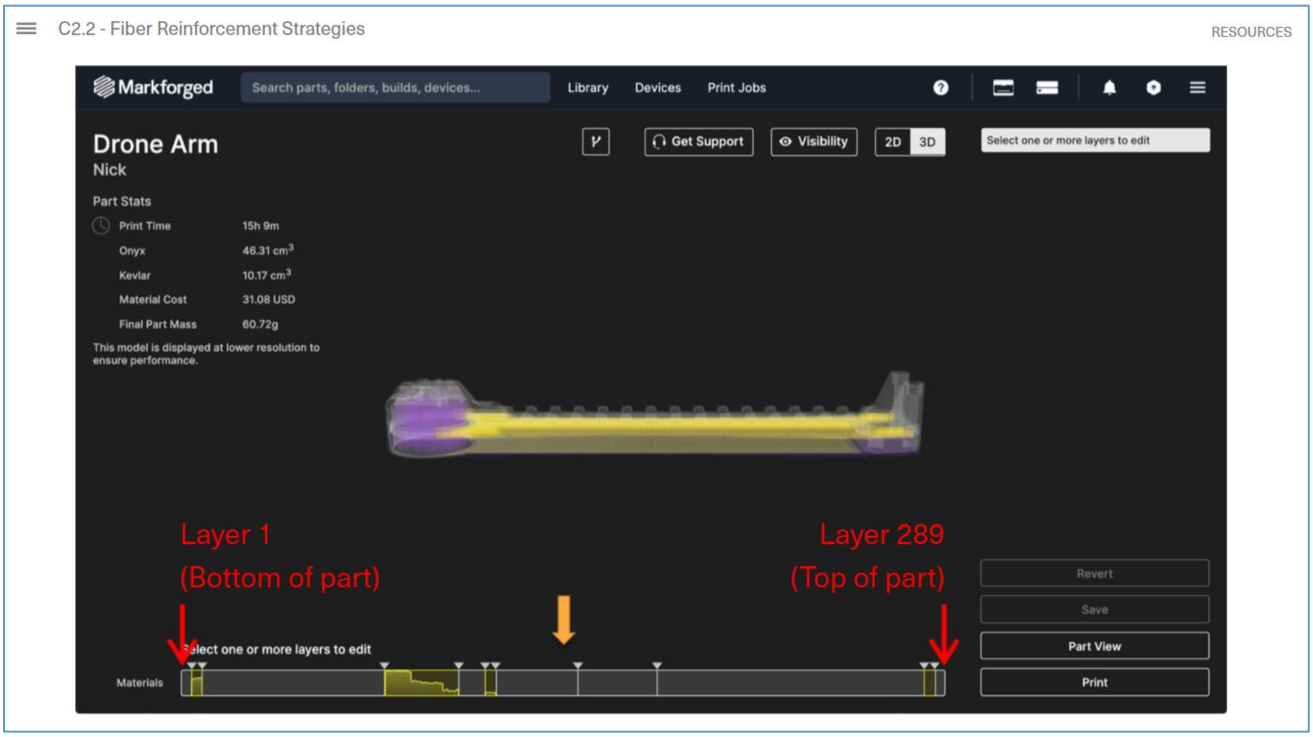


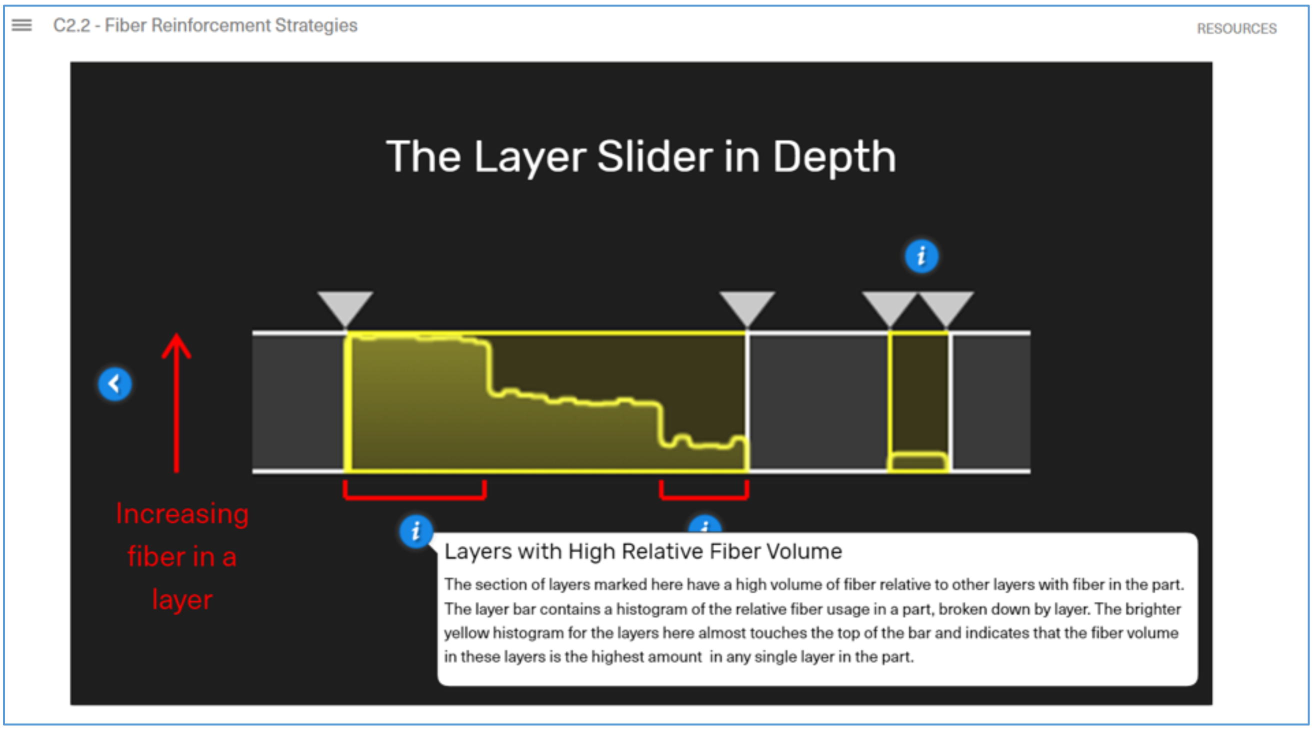
  - Select the layers first.
  - Toggle Fiber on.
  - Choose Fill Type.
  - Than Create the Group.

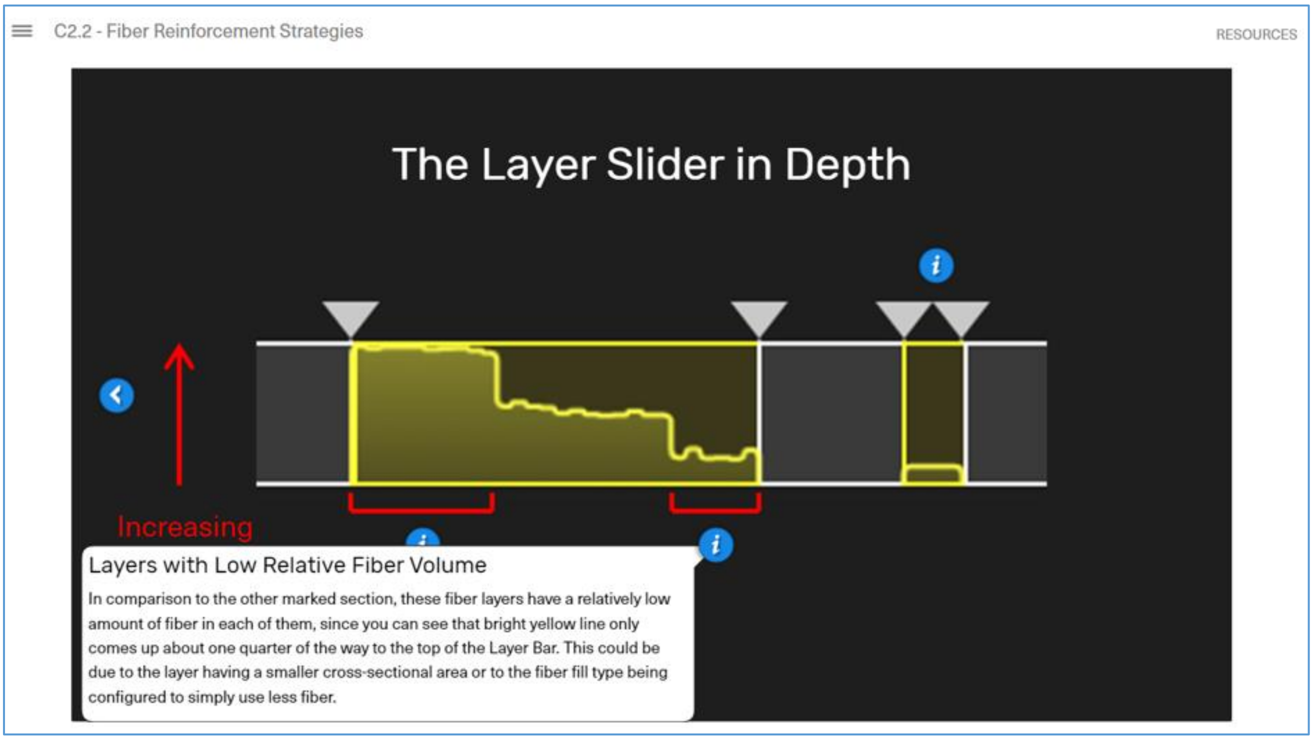


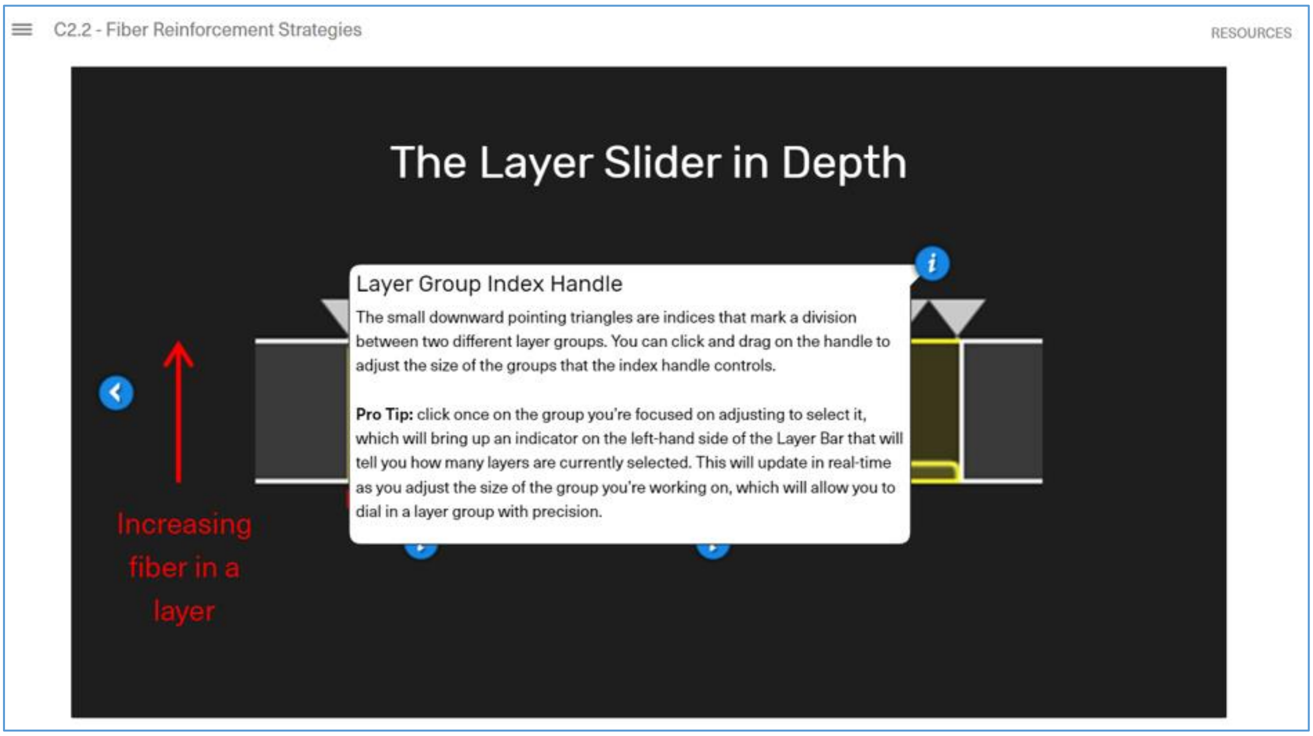
- Save your work.

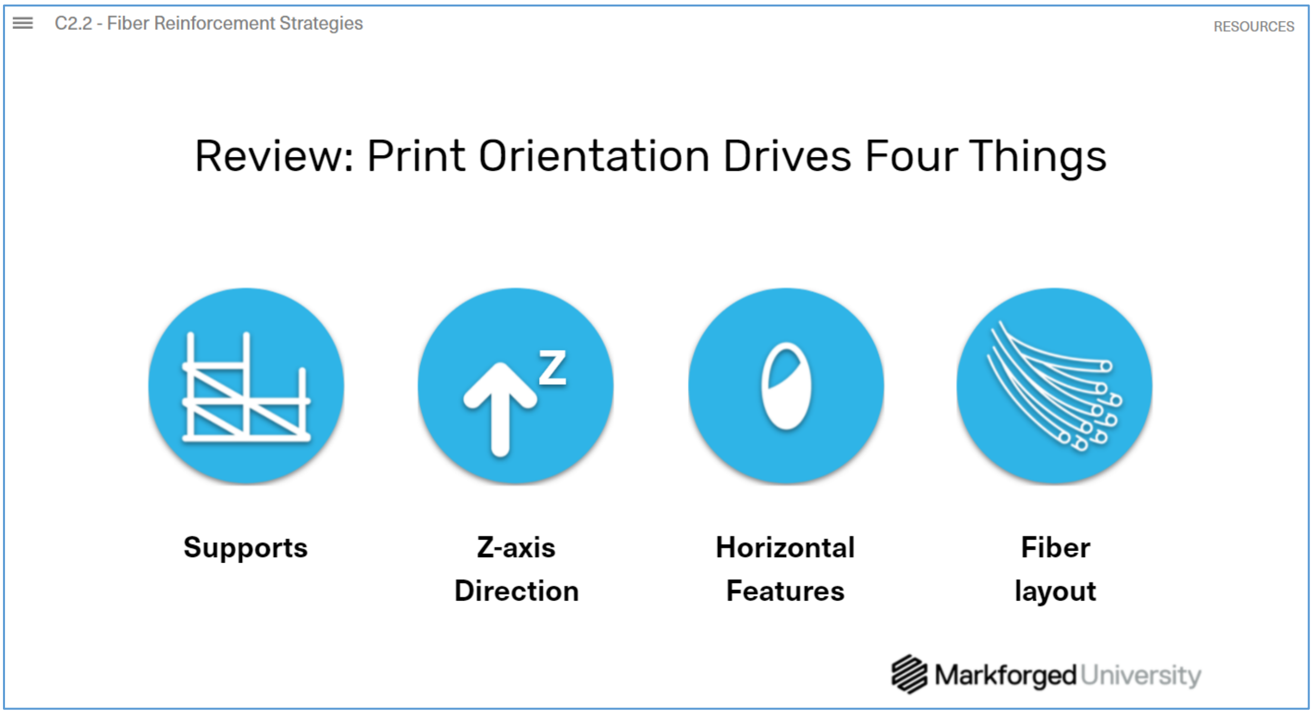
- **A Closer Look at The Layer Slider**



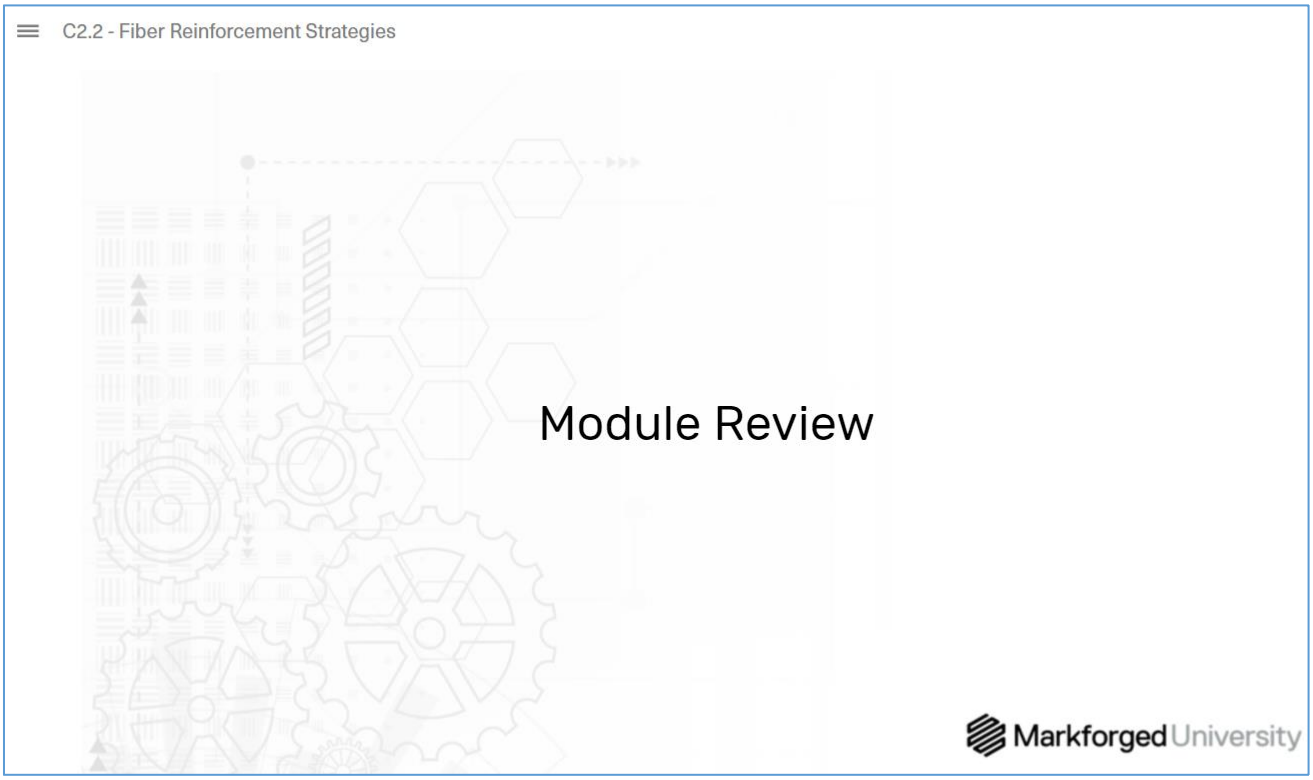

C2.2 - Fiber Reinforcement Strategies
RESOURCES
The Layer Slider in Depth
Increasing fiber in a layer
Layers with High Relative Fiber Volume
The section of layers marked here have a high volume of fiber relative to other layers with fiber in the part. The layer bar contains a histogram of the relative fiber usage in a part, broken down by layer. The brighter yellow histogram for the layers here almost touches the top of the bar and indicates that the fiber volume in these layers is the highest amount in any single layer in the part.


C2.2 - Fiber Reinforcement Strategies
RESOURCES
The Layer Slider in Depth
Increasing
Layers with Low Relative Fiber Volume
In comparison to the other marked section, these fiber layers have a relatively low amount of fiber in each of them, since you can see that bright yellow line only comes up about one quarter of the way to the top of the Layer Bar. This could be due to the layer having a smaller cross-sectional area or to the fiber fill type being configured to simply use less fiber.

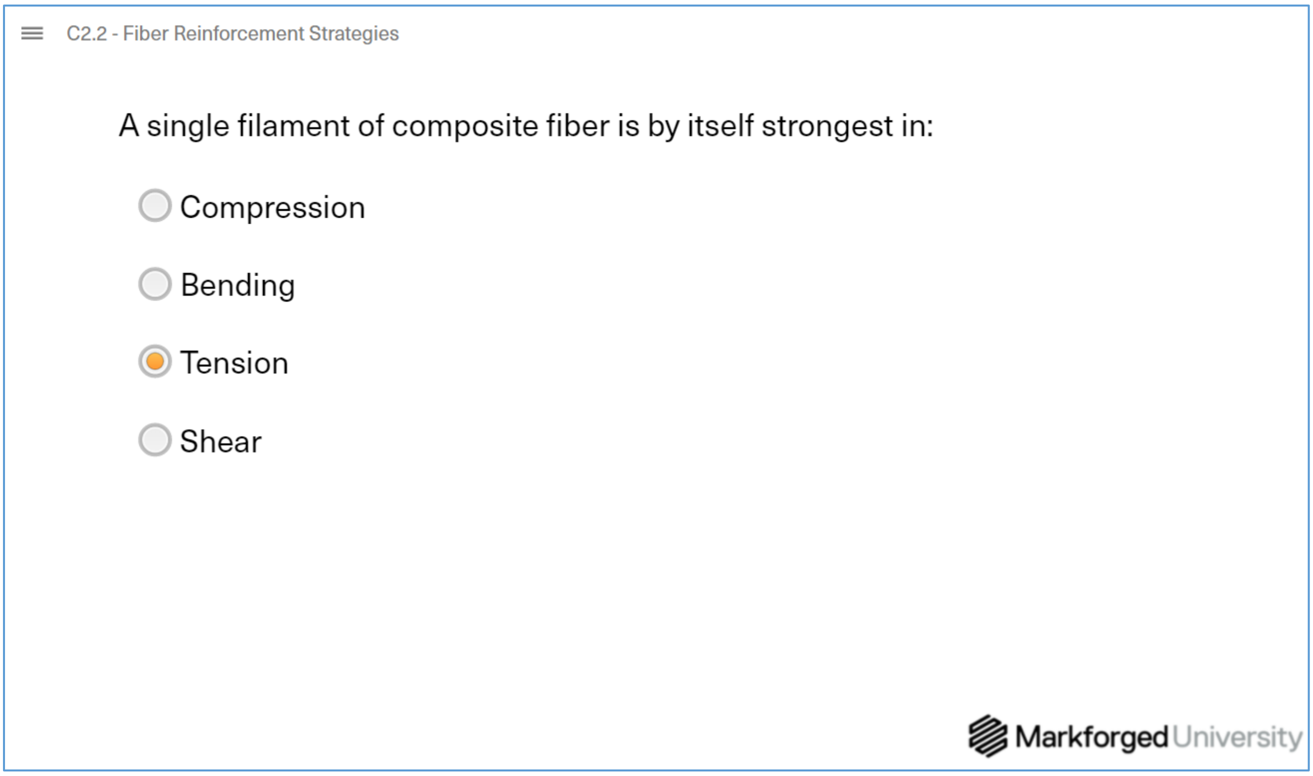




- **Review: Print Orientation Drives Four Things**



- **Module Review**



C2.2 - Fiber Reinforcement Strategies

Mark all of the following considerations that can be significantly influenced by changing the print orientation of a part.

- [ ] Plastic FFF material selection
- [x] Which features are printed as ‘horizontal features’
- [ ] The STL file size of the part
- [x] Where in the part you can lay fiber
- [x] The presence and amount of support structures

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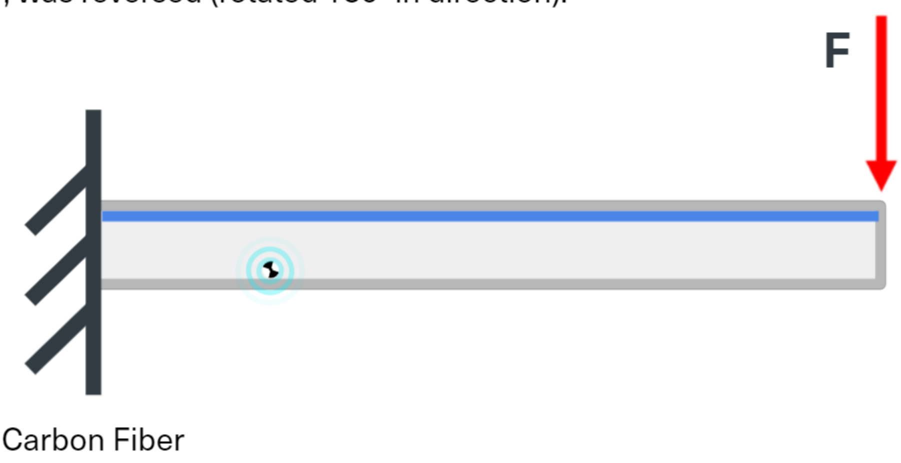
C2.2 - Fiber Reinforcement Strategies

Click on the area of this beam where you should add fiber, in order to complete the sandwich panel construction, and which would also be effective reinforcement if the force, F, was reversed (rotated 180° in direction).



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C2.2 - Fiber Reinforcement Strategies

True/False: A sandwich panel is an extremely lightweight and materially-efficient way to produce a high-strength and high-stiffness structure from multiple materials.

- (•) True
- ( ) False

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C2.2 - Fiber Reinforcement Strategies

Results

Your Score:	100% (40 points)
Passing Score:	80% (32 points)

Result:

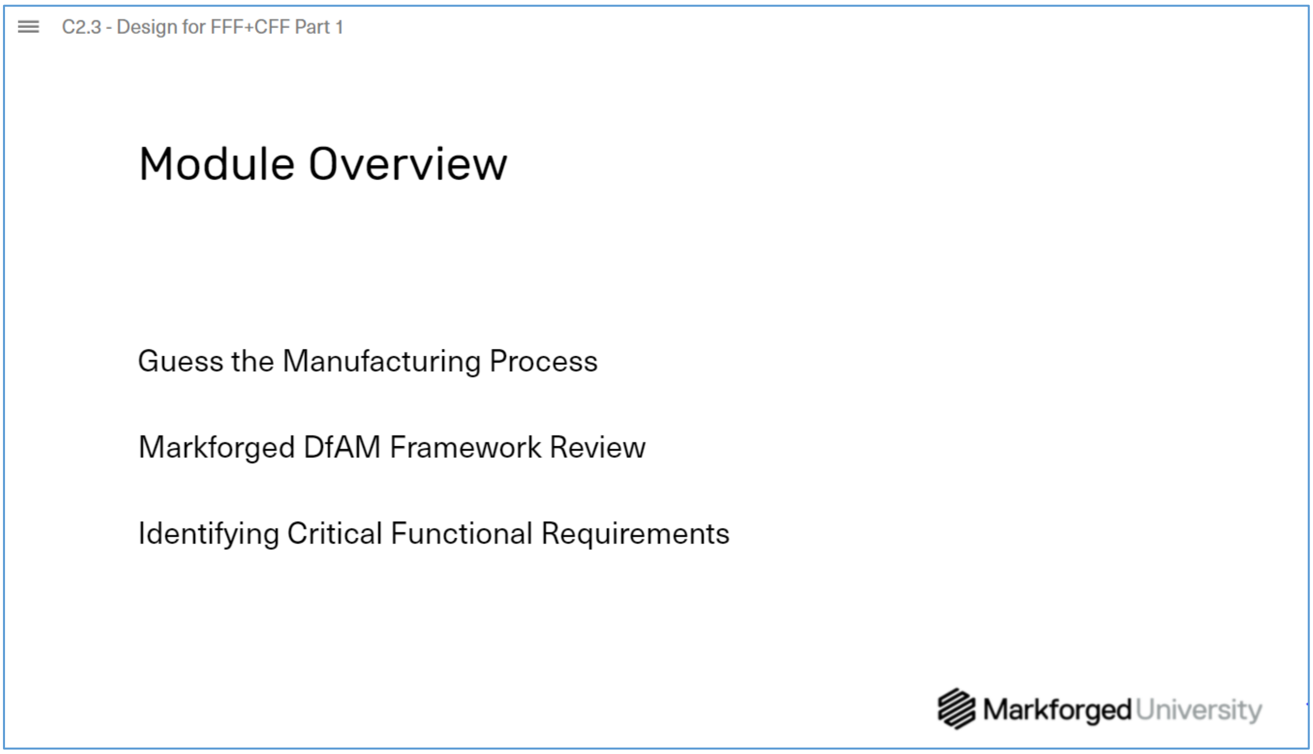
Congratulations, you passed.

Finish Module

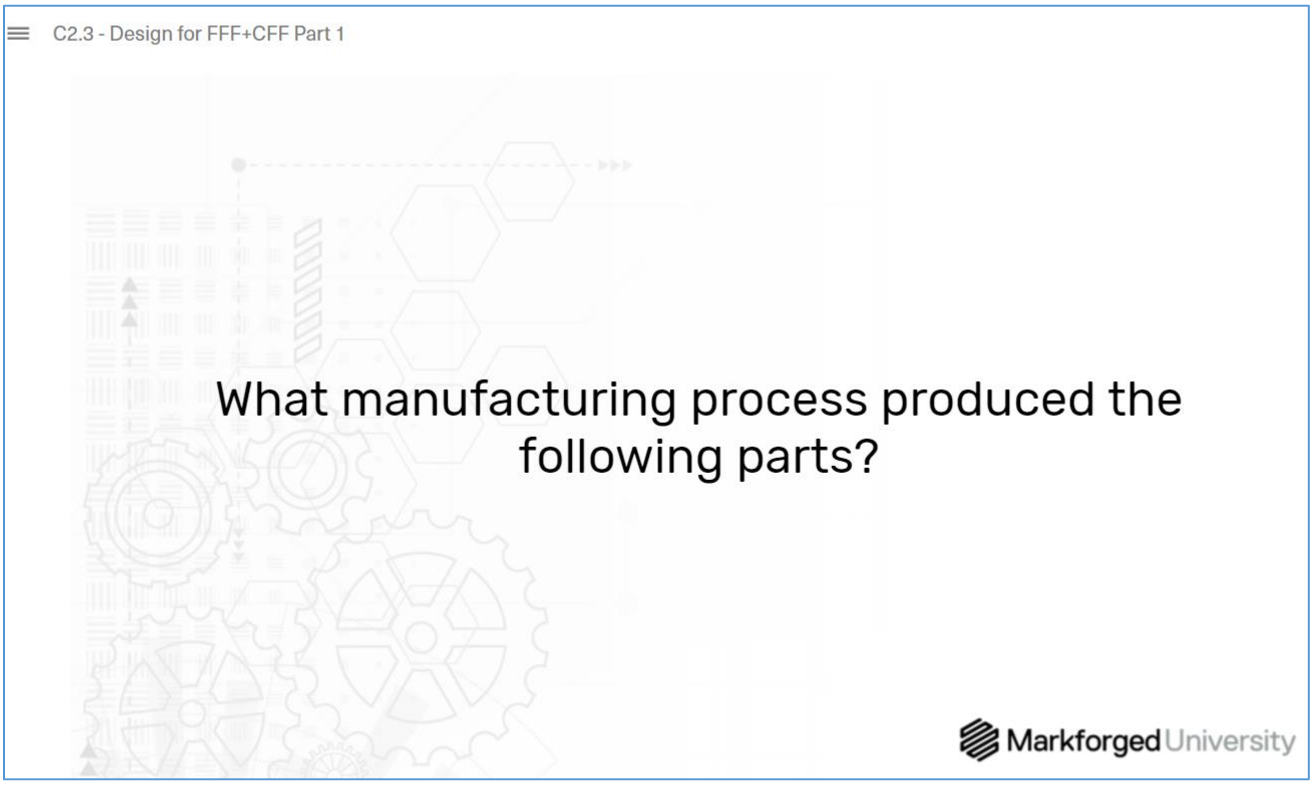
Review Quiz

C2.3 – Design for FFF and CFF Part 1

- **Design for FFF and CFF Part 1**

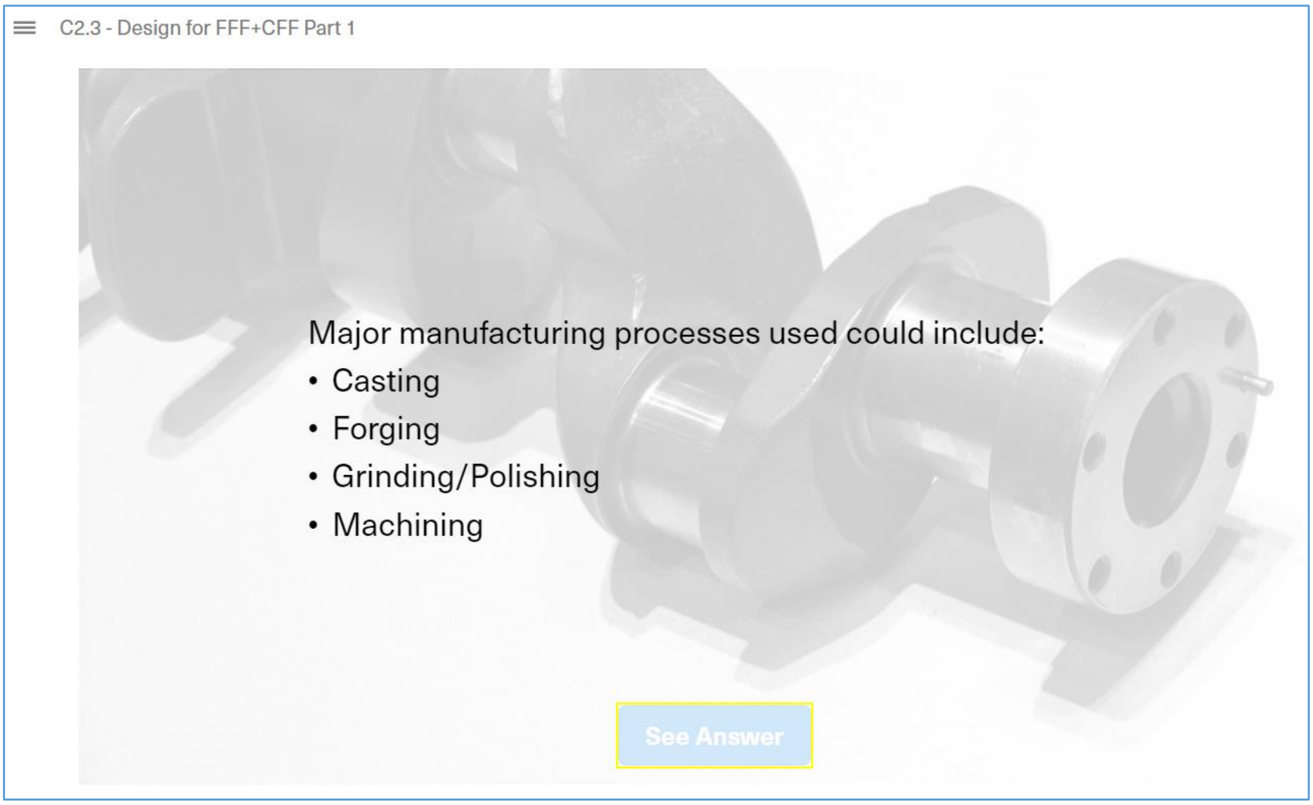


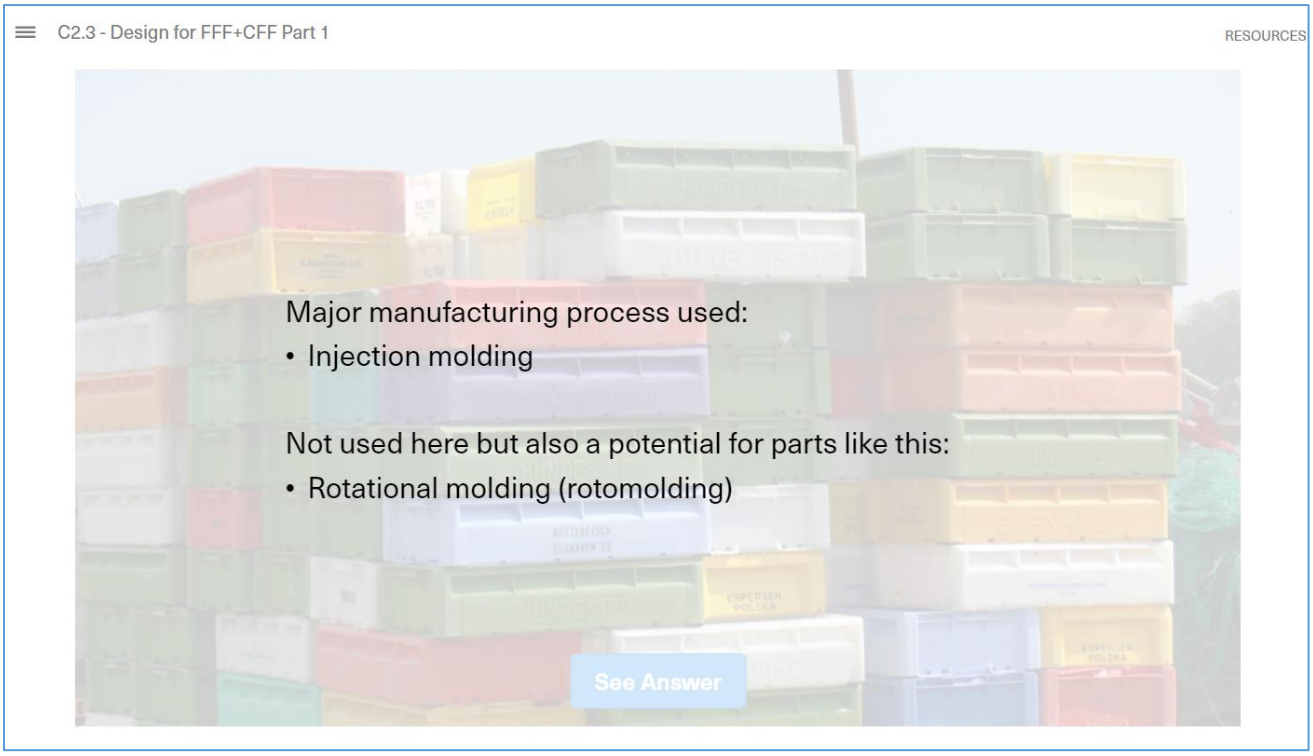
- **Module Overview**



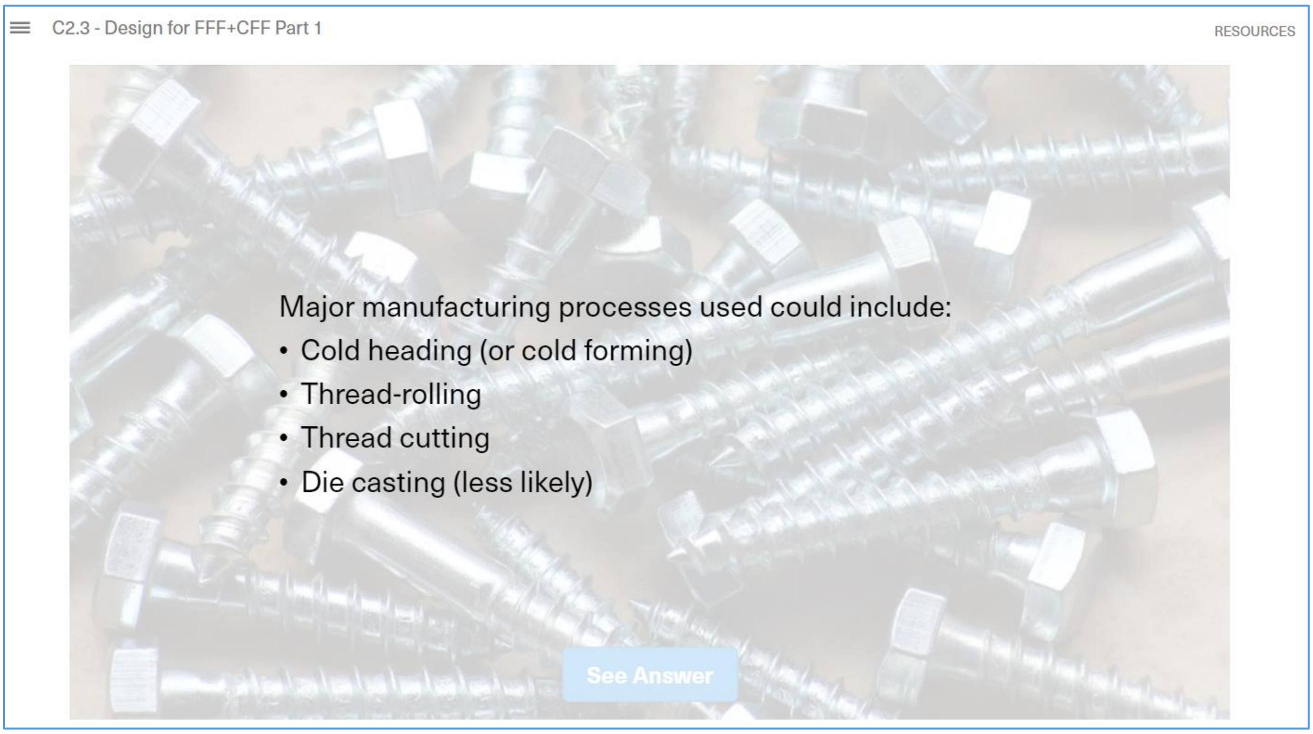
- **What's the Manufacturing Process?**

- **Example 1**


C2.3 - Design for FFF+CFF Part 1
Major manufacturing processes used could include:
• Casting
• Forging
• Grinding/Polishing
• Machining
See Answer


C2.3 - Design for FFF+CFF Part 1
RESOURCES
Major manufacturing process used:
• Injection molding
Not used here but also a potential for parts like this:
• Rotational molding (rotomolding)
See Answer

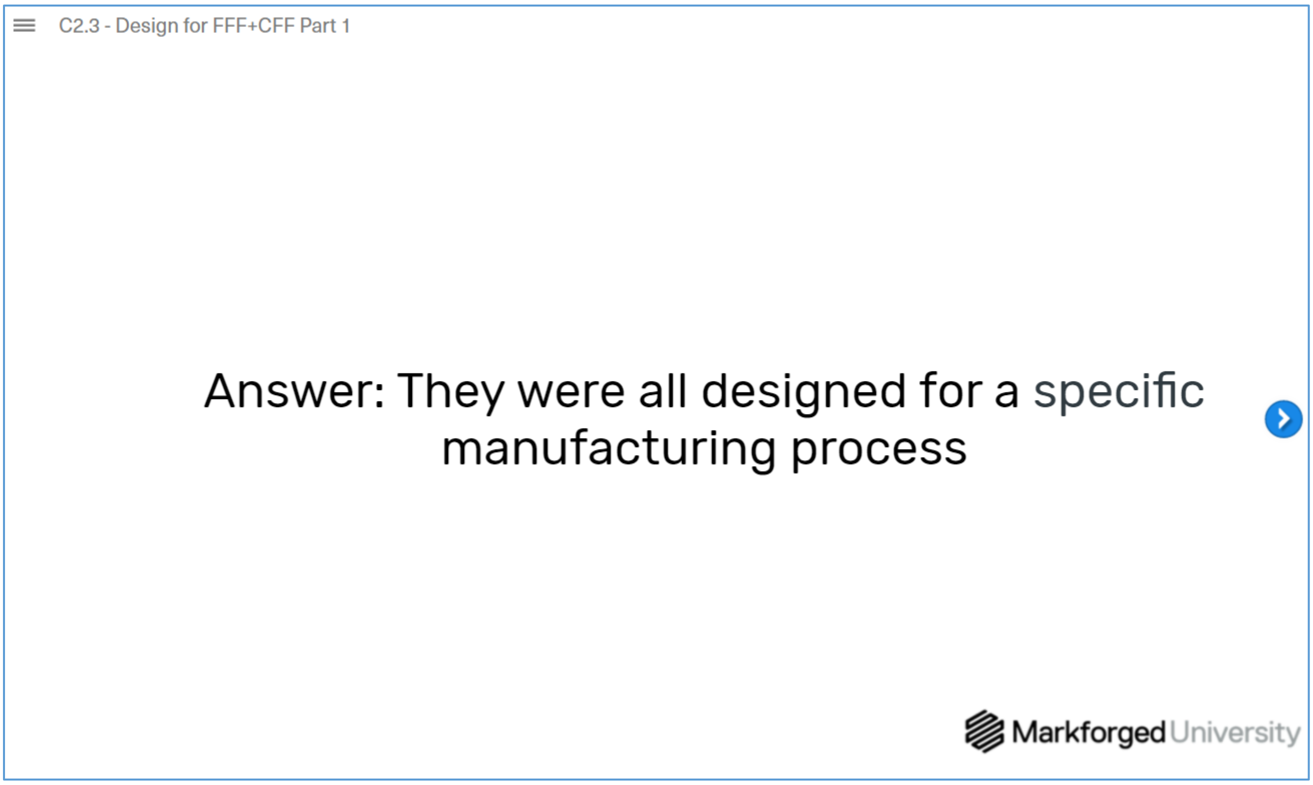
- **Example 2**



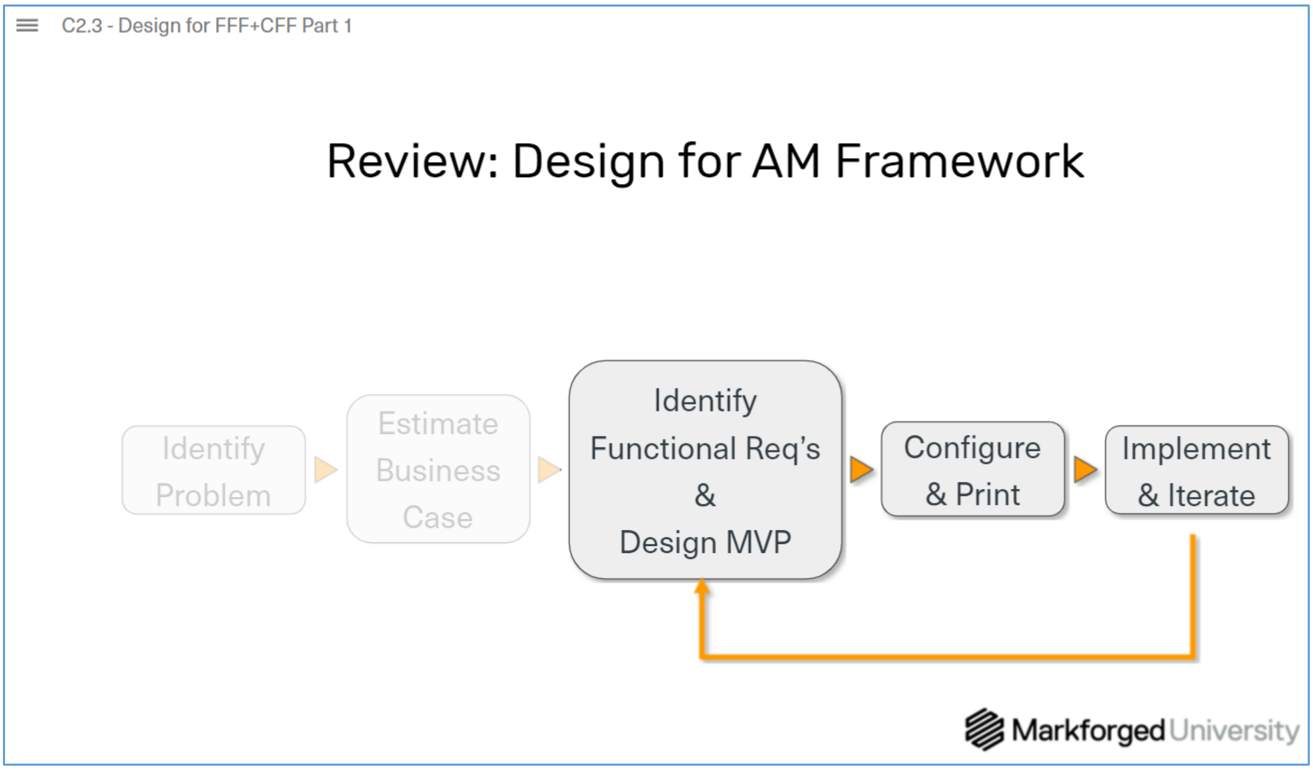
- **Example 3**

- **Example 4**

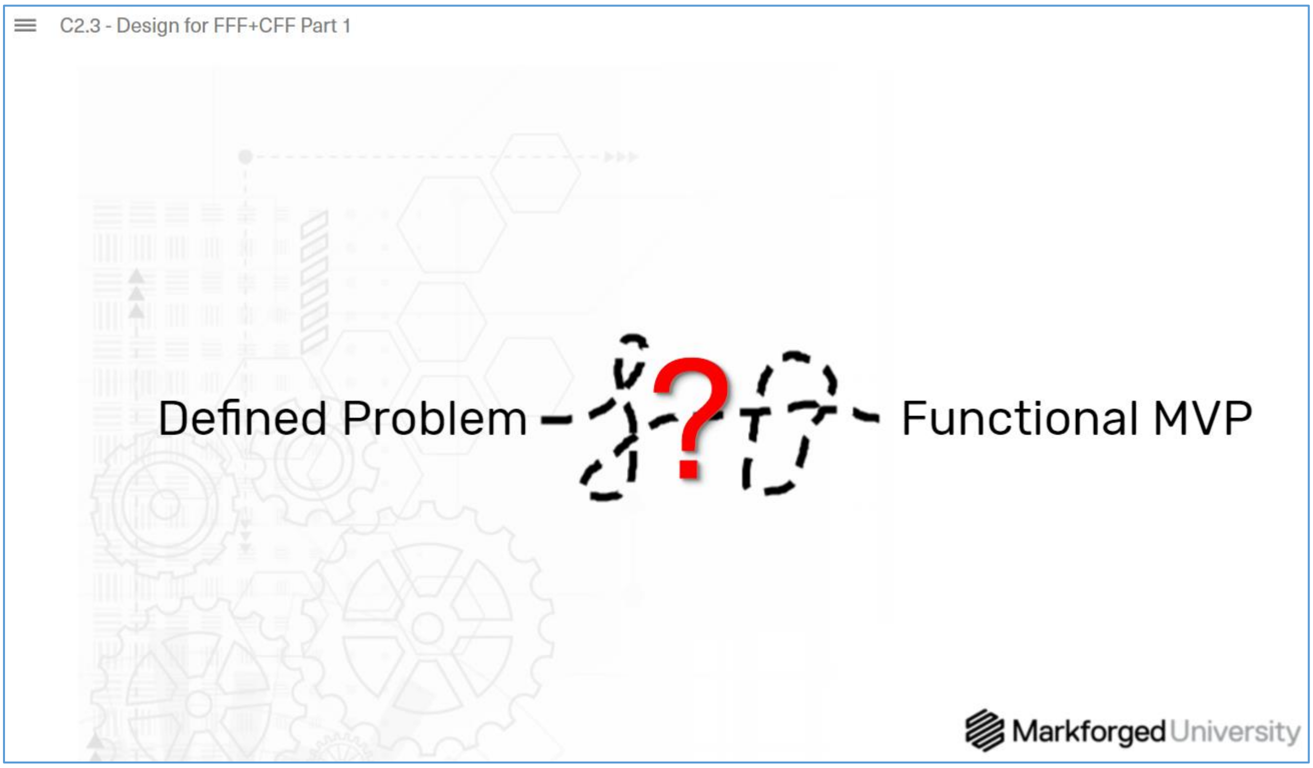
- **Recap: What Do These Parts in Common?**



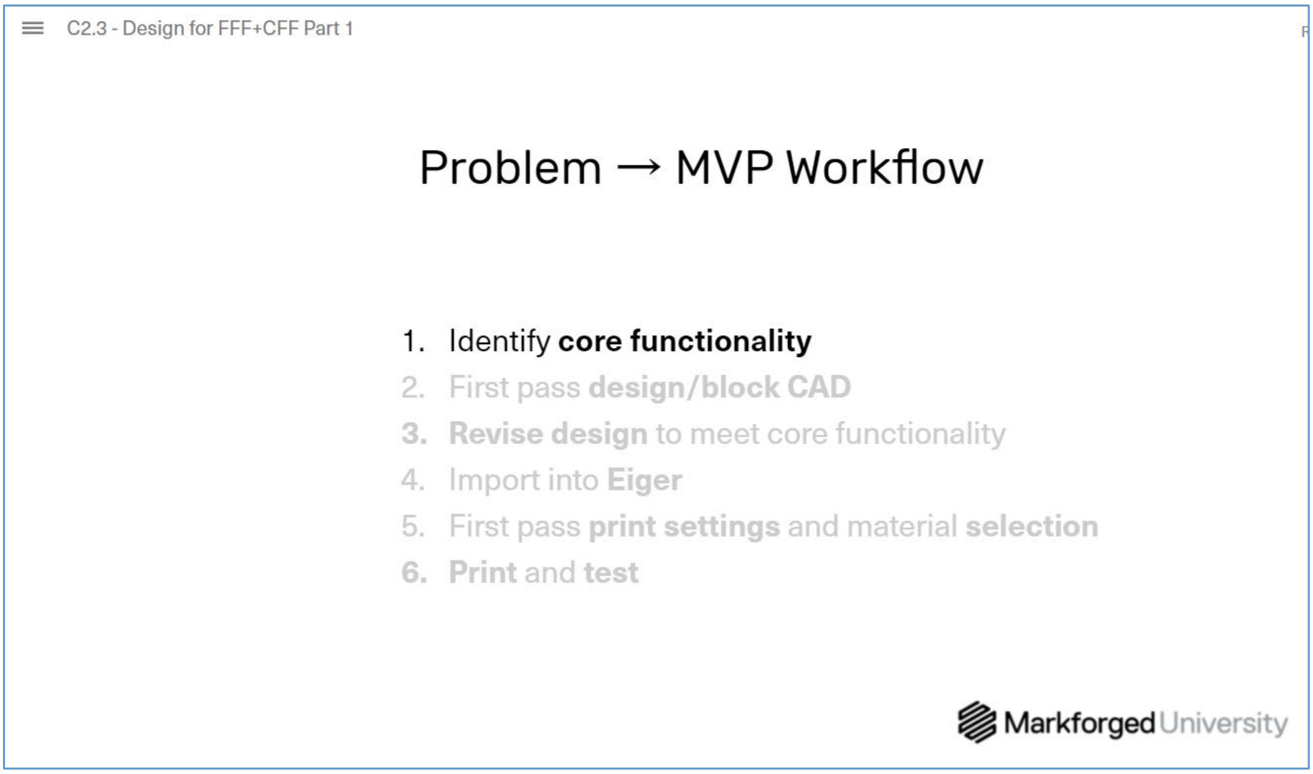
- **The Answer**



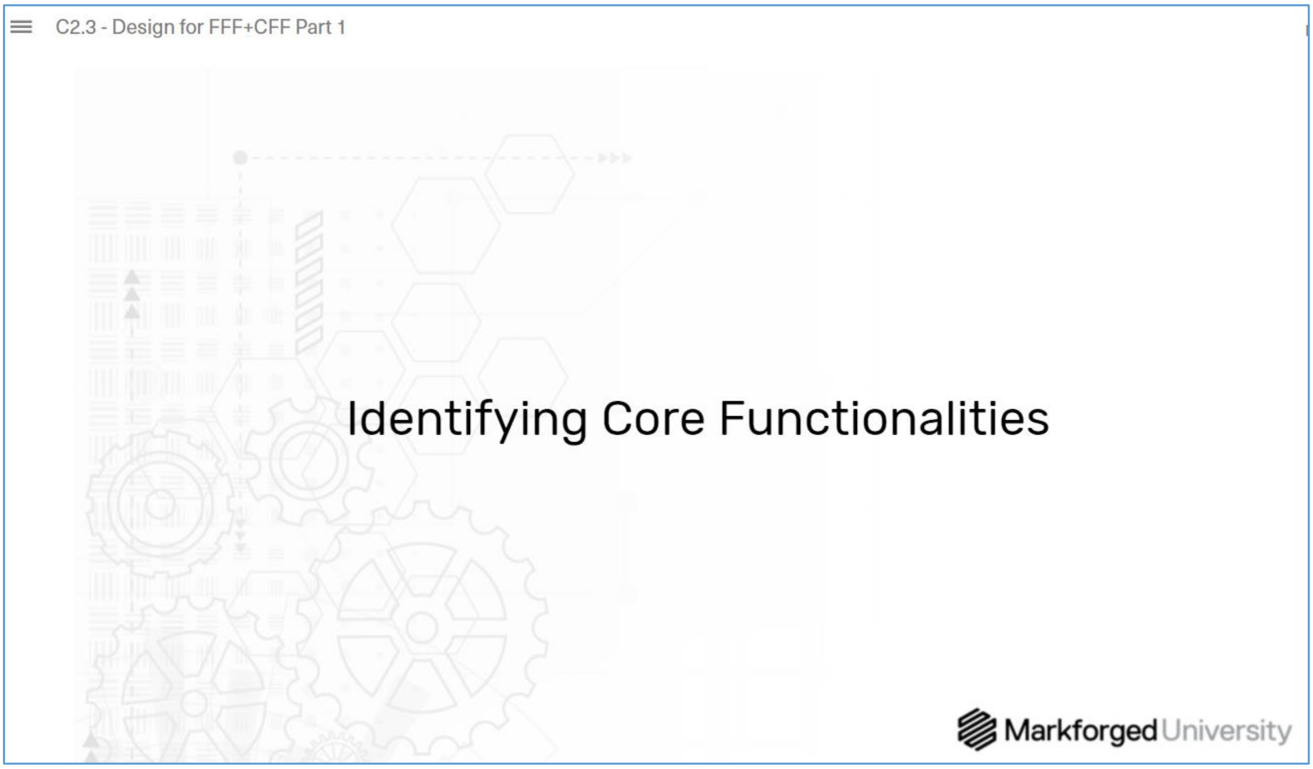
- **Review: Design for AM Framework**
    - Additive Manufacturing
    - MVP = Minimal Viable Product (V=levensvatbaar)
    - Iterate = herhalen



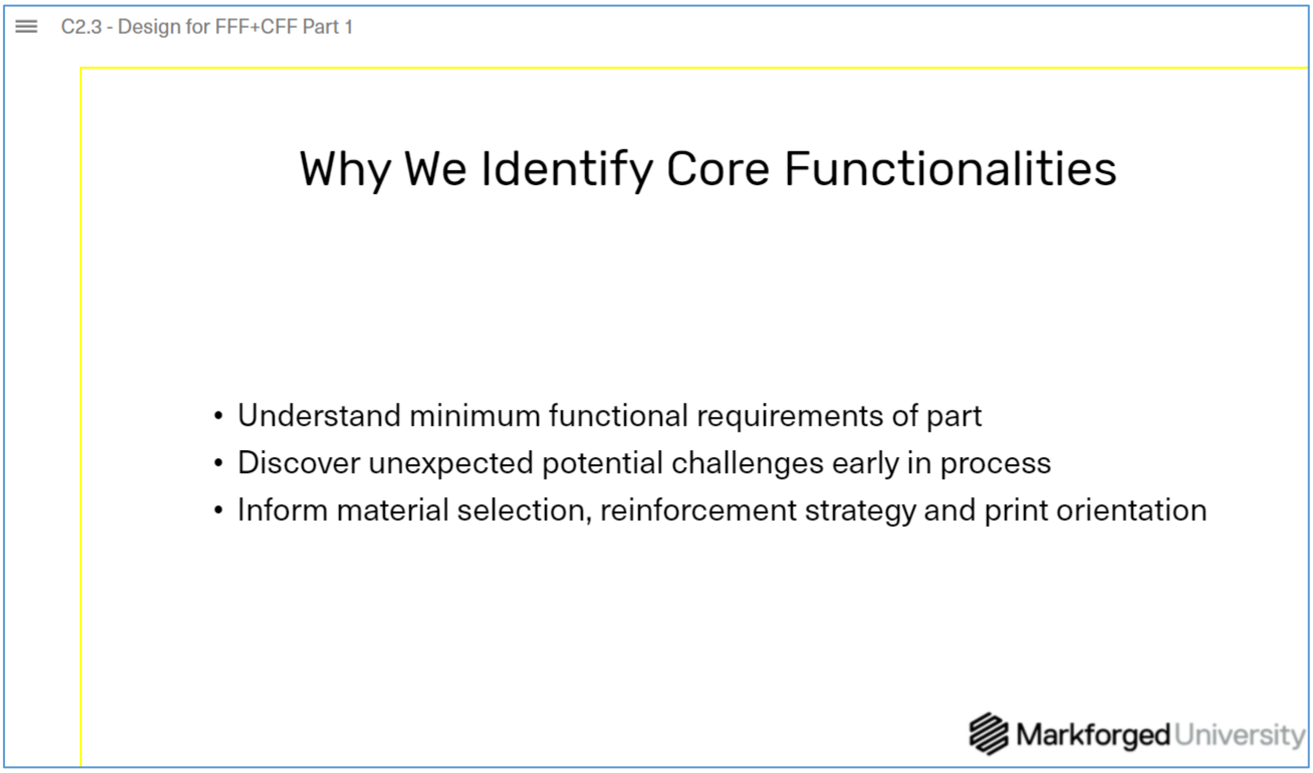
- **Defined Problem to Functional MVP**



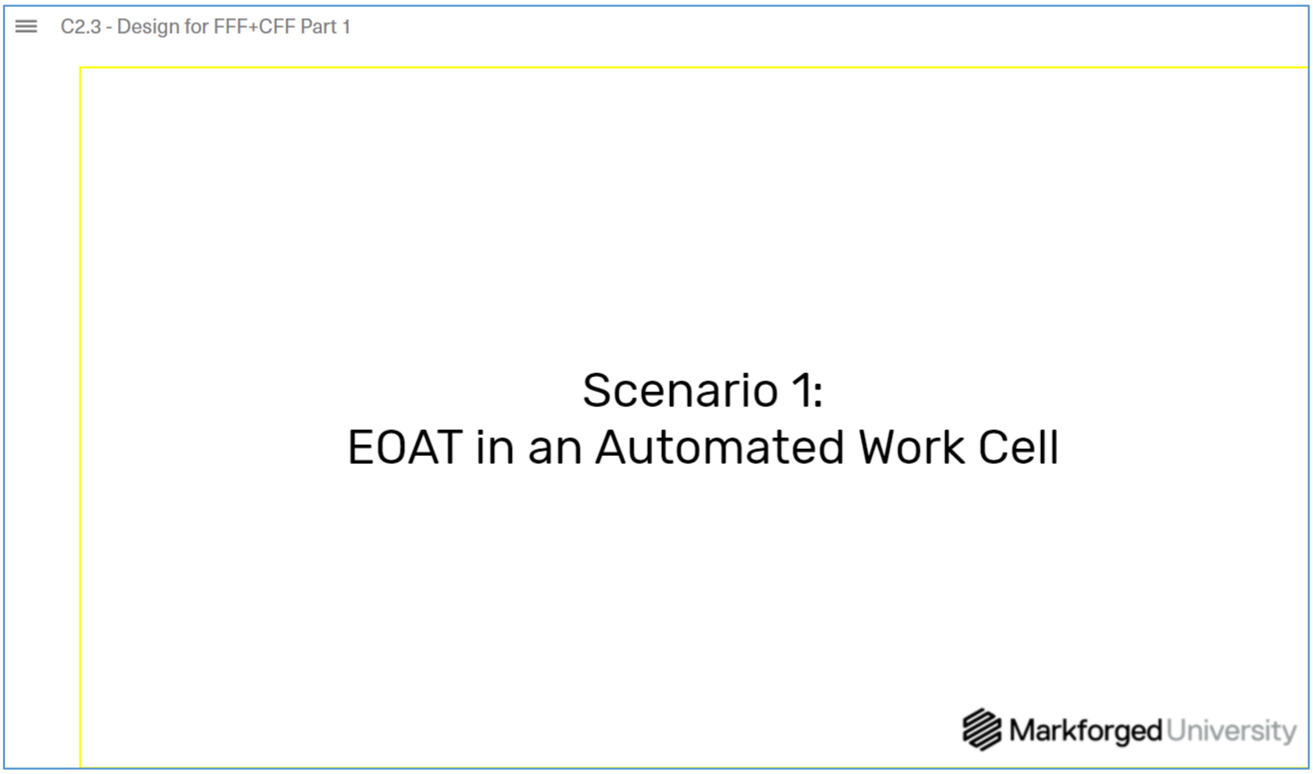
- **Problem → MVP Checklist**



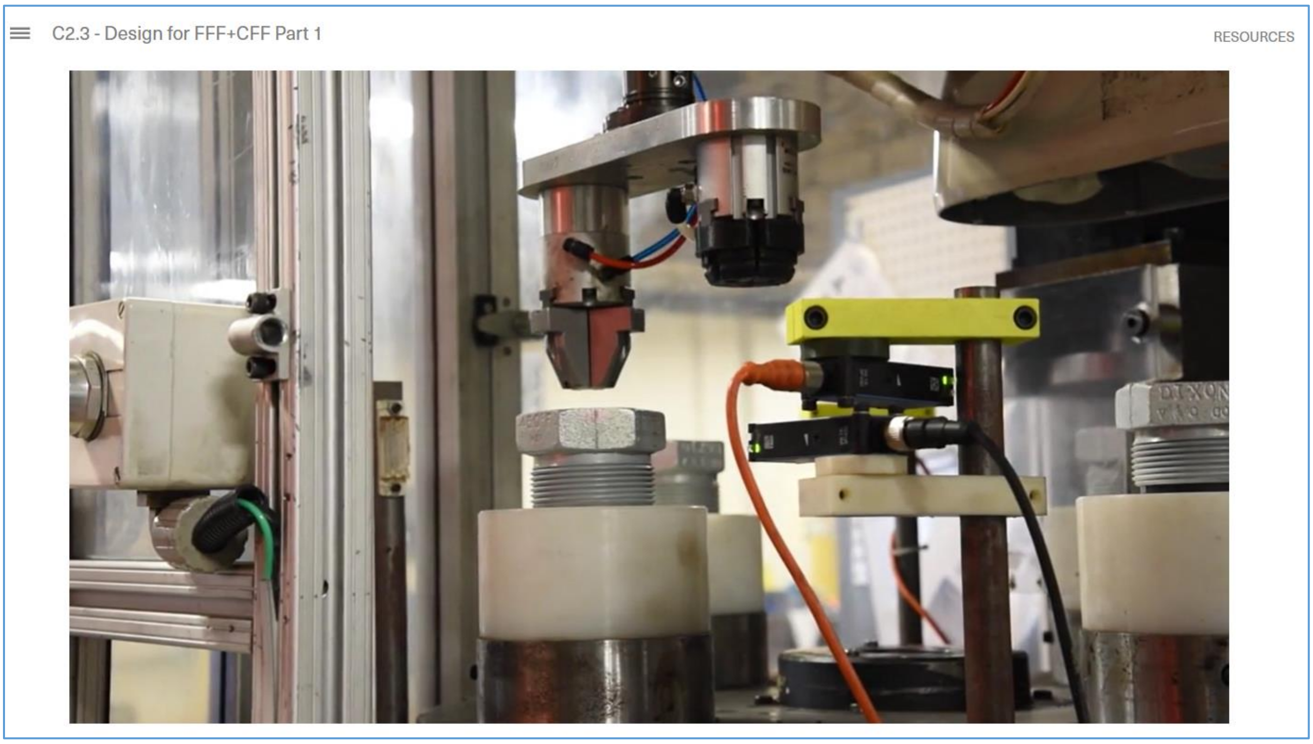
- **Identifying Core Functionalities**



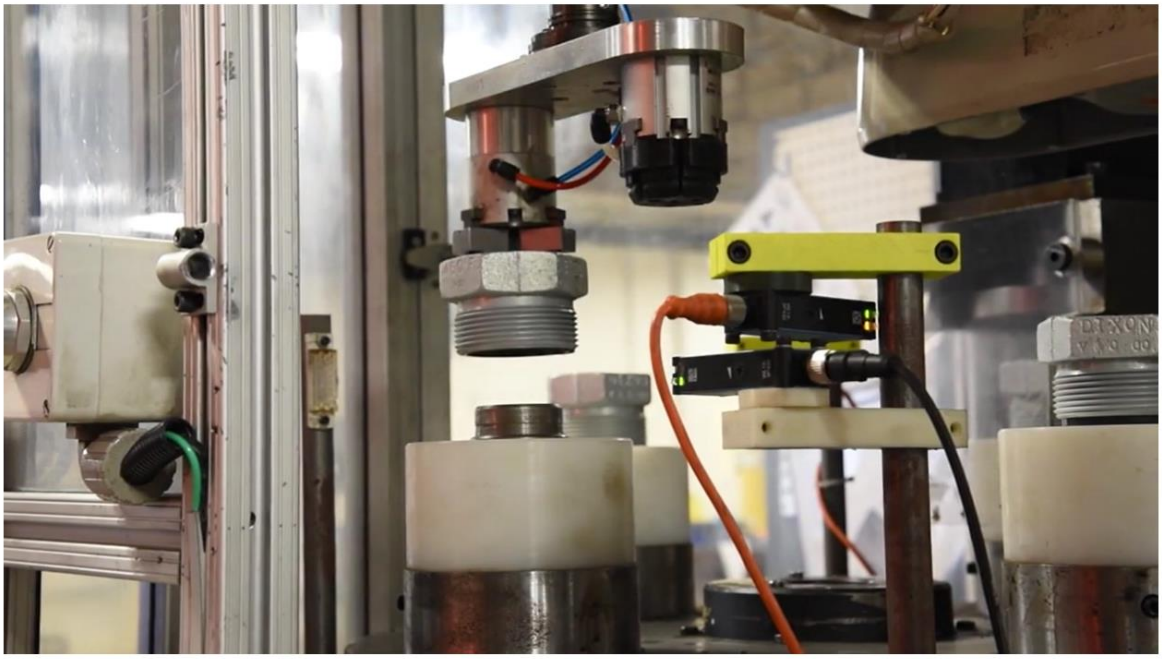
- **Why We Identify Core Functionalities**



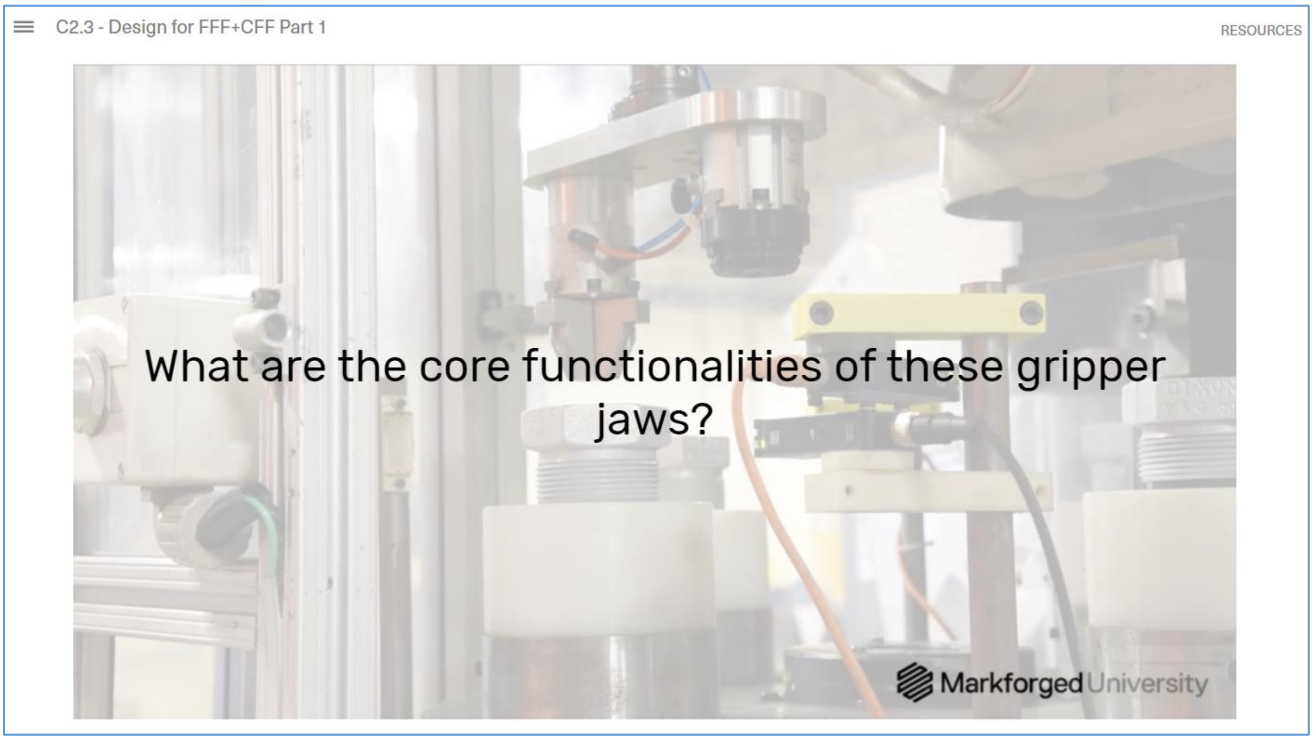
- **Scenario 1: Automation Cell**
    - EOAT = End of arm tooling



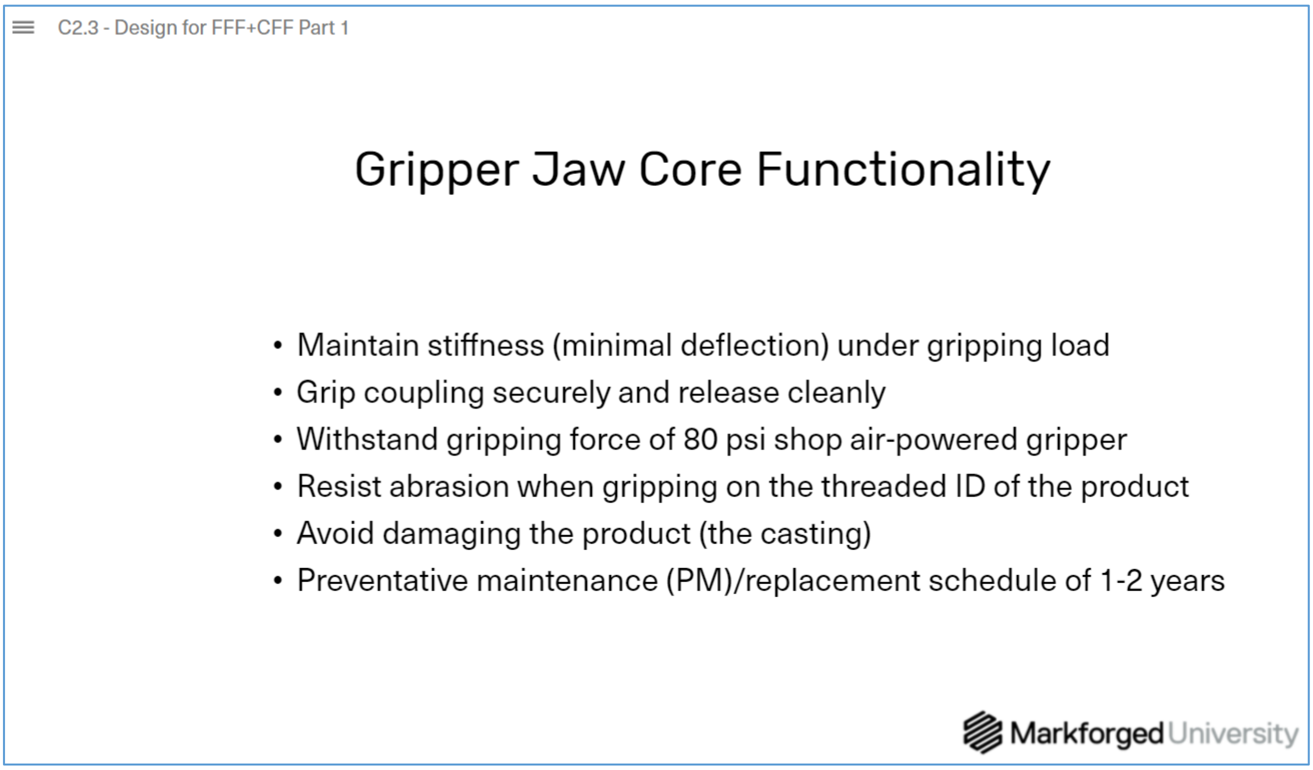
C2.3 - Design for FFF+CFF Part 1 RESOURCES



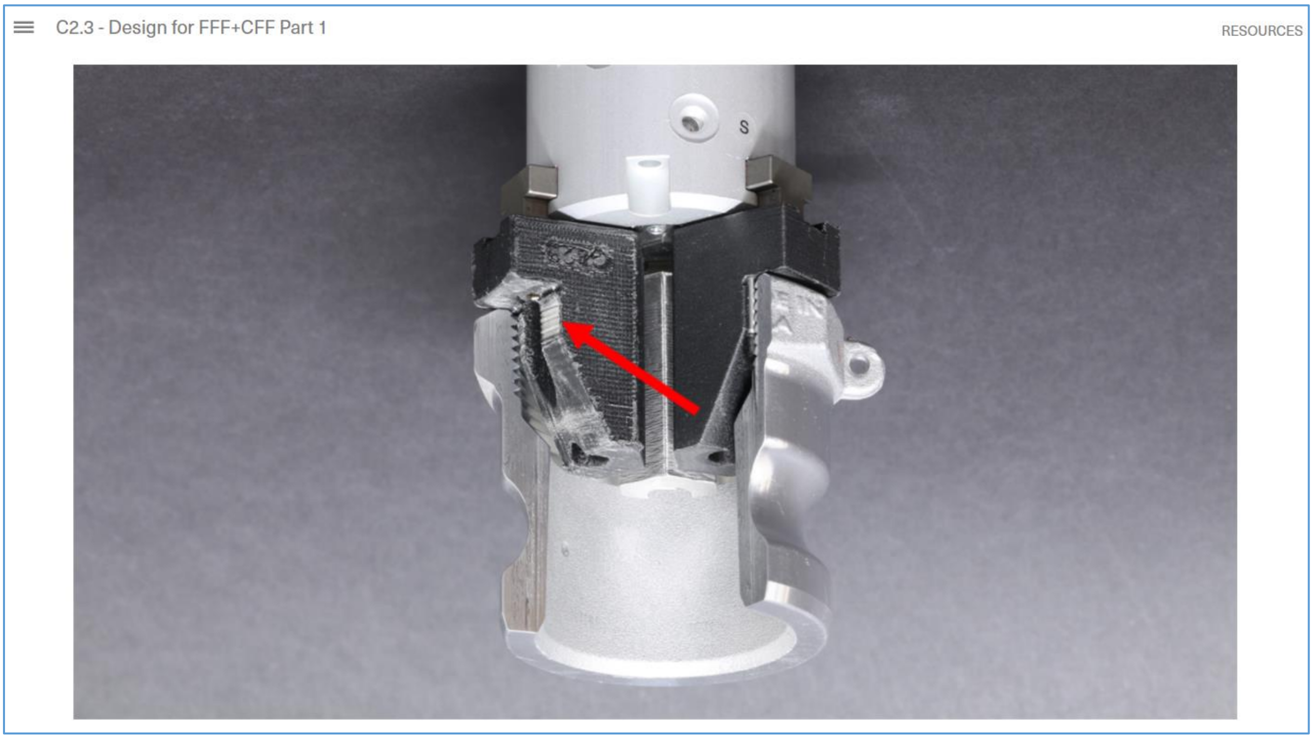
C2.3 - Design for FFF+CFF Part 1 RESOURCES



- **S1: What Are the Core Functionalities?**



- **Gripper Jaw Core Functionality**
    - Deflection = doorbuiging.
    - Abrasion = slijtage.



- **To be continued….**
    - Lot of wear and tear on onyx surface.

C2.3 - Design for FFF+CFF Part 1

Core Functions: Part Interactions

- Withstand contact forces
- Resist abrasive wear
- Distribute bolt forces

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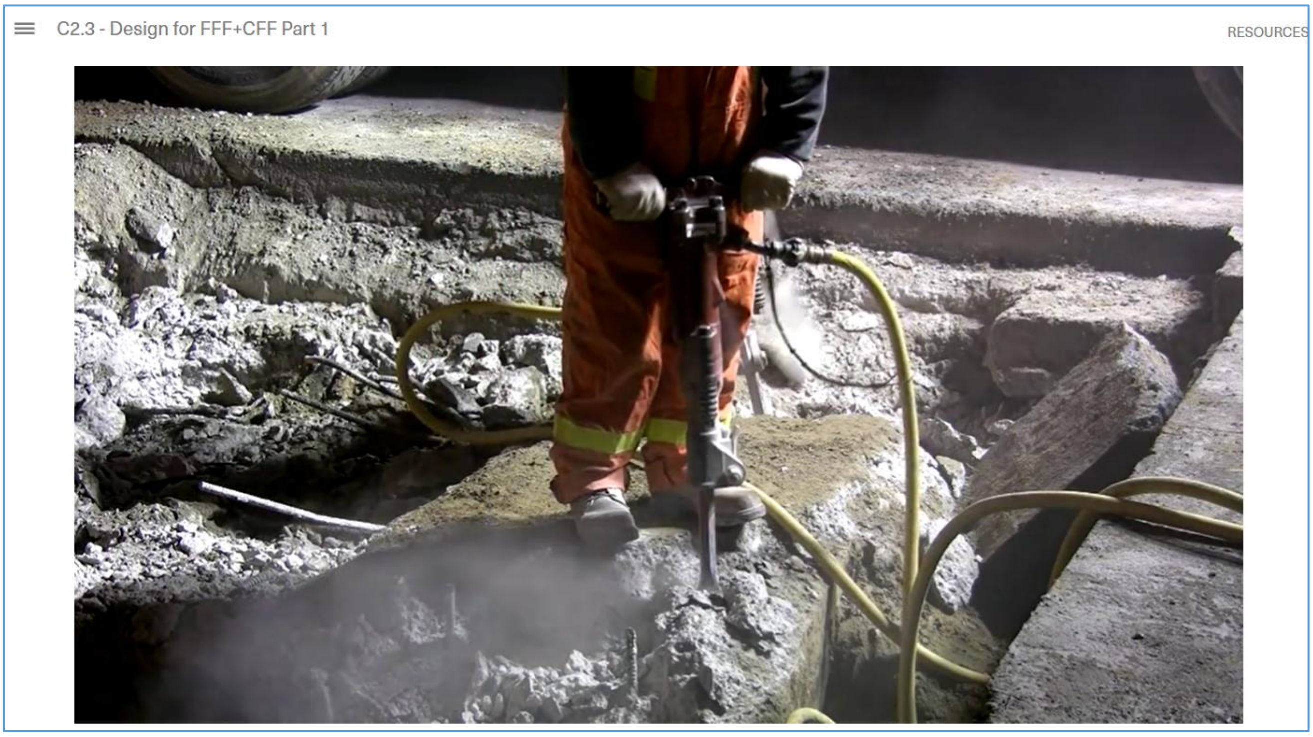
- **Core Functions: Part Interactions**

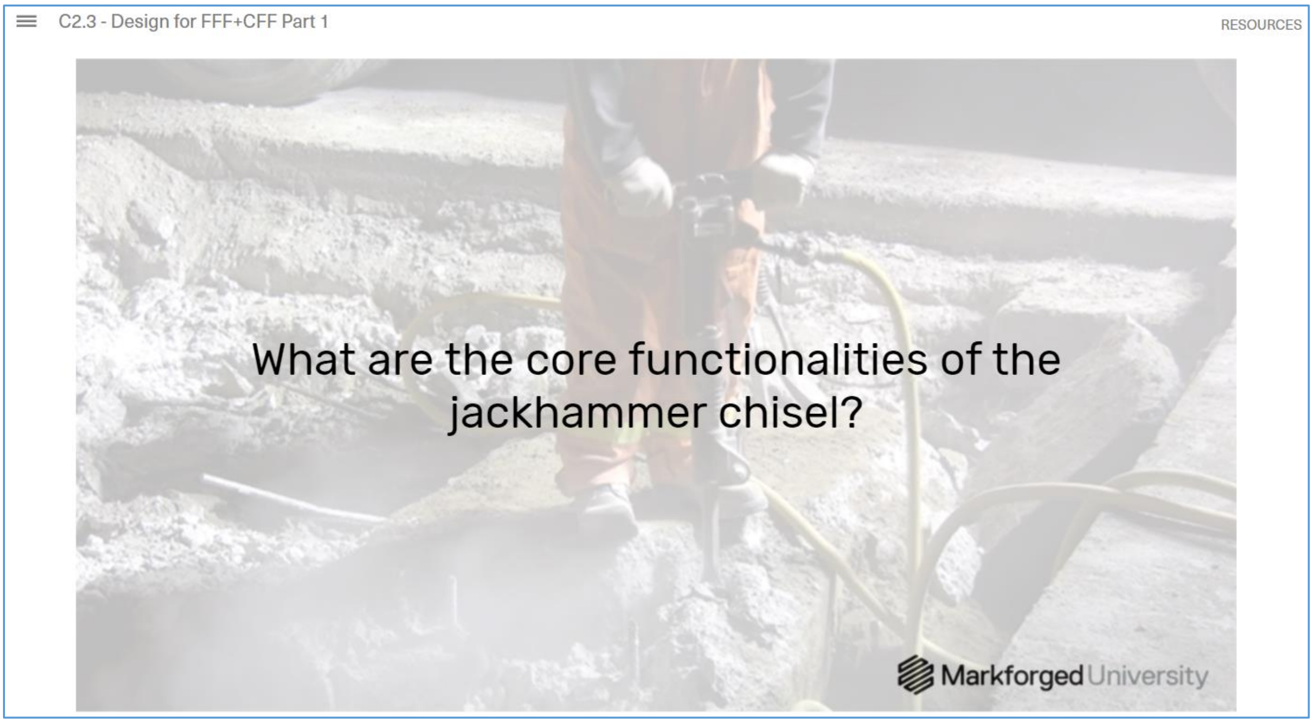
C2.3 - Design for FFF+CFF Part 1

Scenario 2: Jackhammer Chisel

Markforged University

- **Scenario 2: Jackhammer Chisel**





- **What Are The Core Functionalities?**

C2.3 - Design for FFF+CFF Part 1 RESOURCES

C2.3 - Design for FFF+CFF Part 1

Jackhammer Chisel Core Functionality

- Transmit high axial cyclic impact forces along chisel
- Resist bending force when operator performs prying motion
- Avoid deforming or shattering under load
- High wear resistance against concrete/pavement
- Resist corrosion in outdoor environments

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- **Jackhammer Chisel Core Functionality**

C2.3 - Design for FFF+CFF Part 1

Core Functions: Loading Conditions

- Type (point load, distributed, torque)
- Direction
- Magnitude
- Frequency
- Duration (impact, static)

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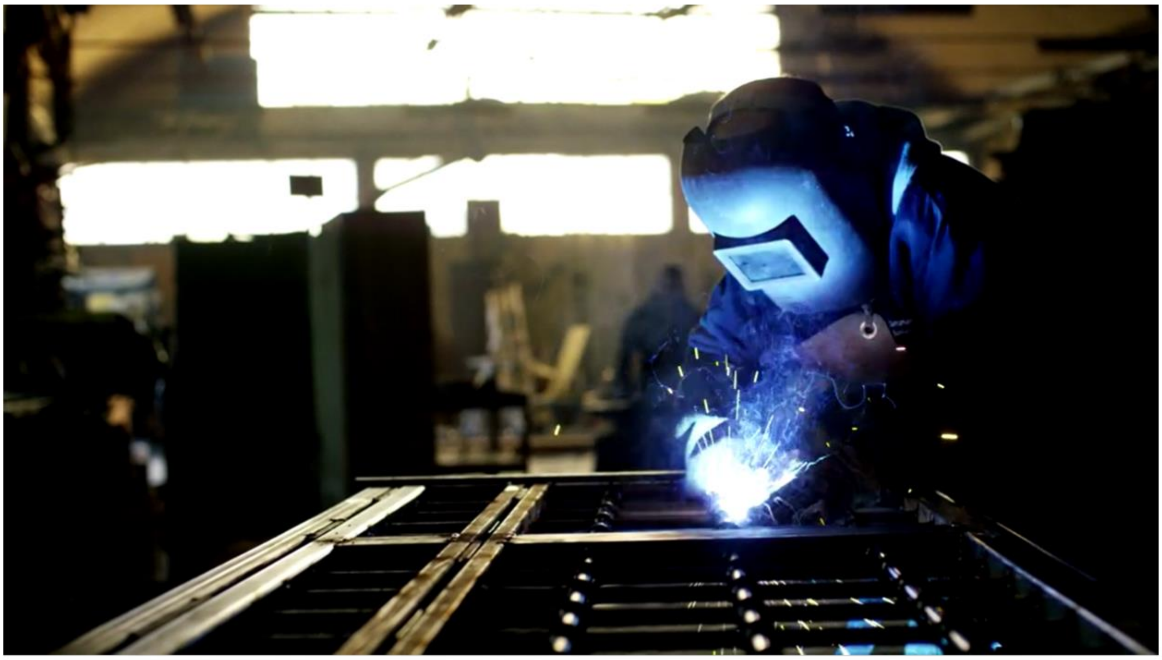
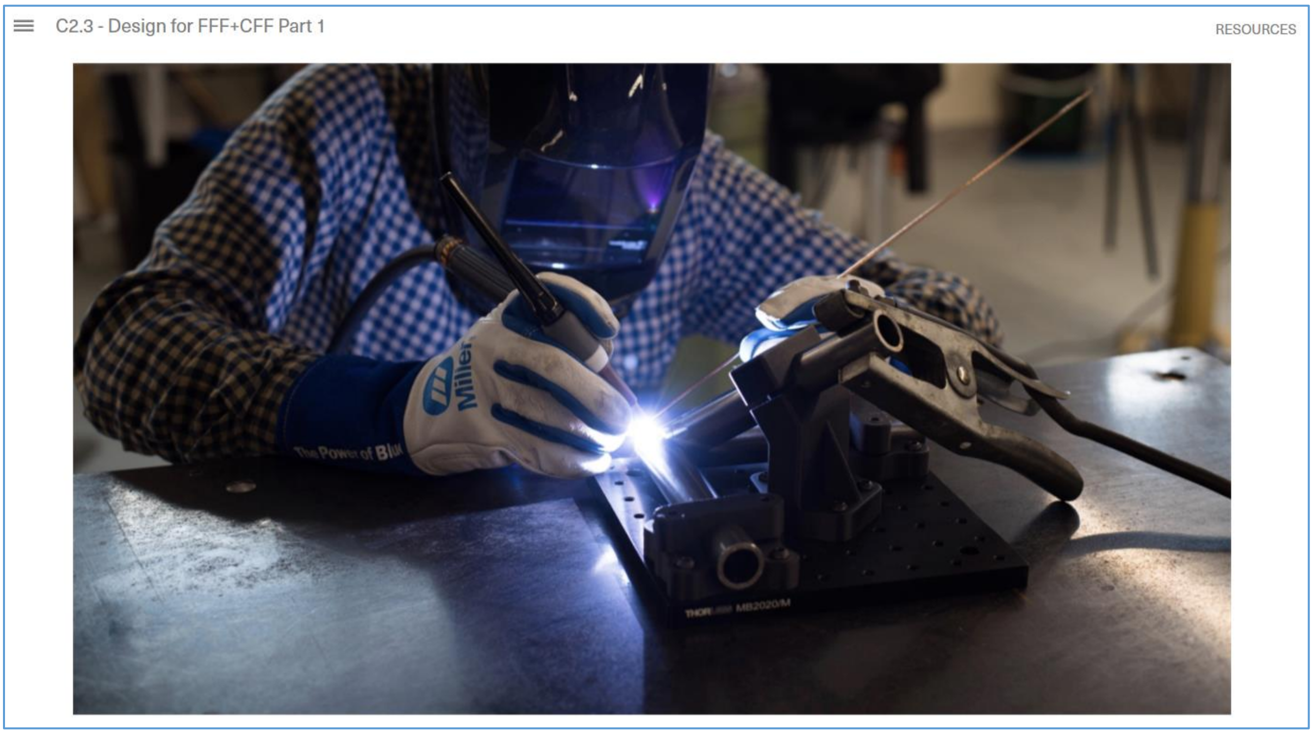
- **Core Functions: Loading Conditions**
  - Torque = Koppel. Magnitude = Grootte. Duration = looptijd.

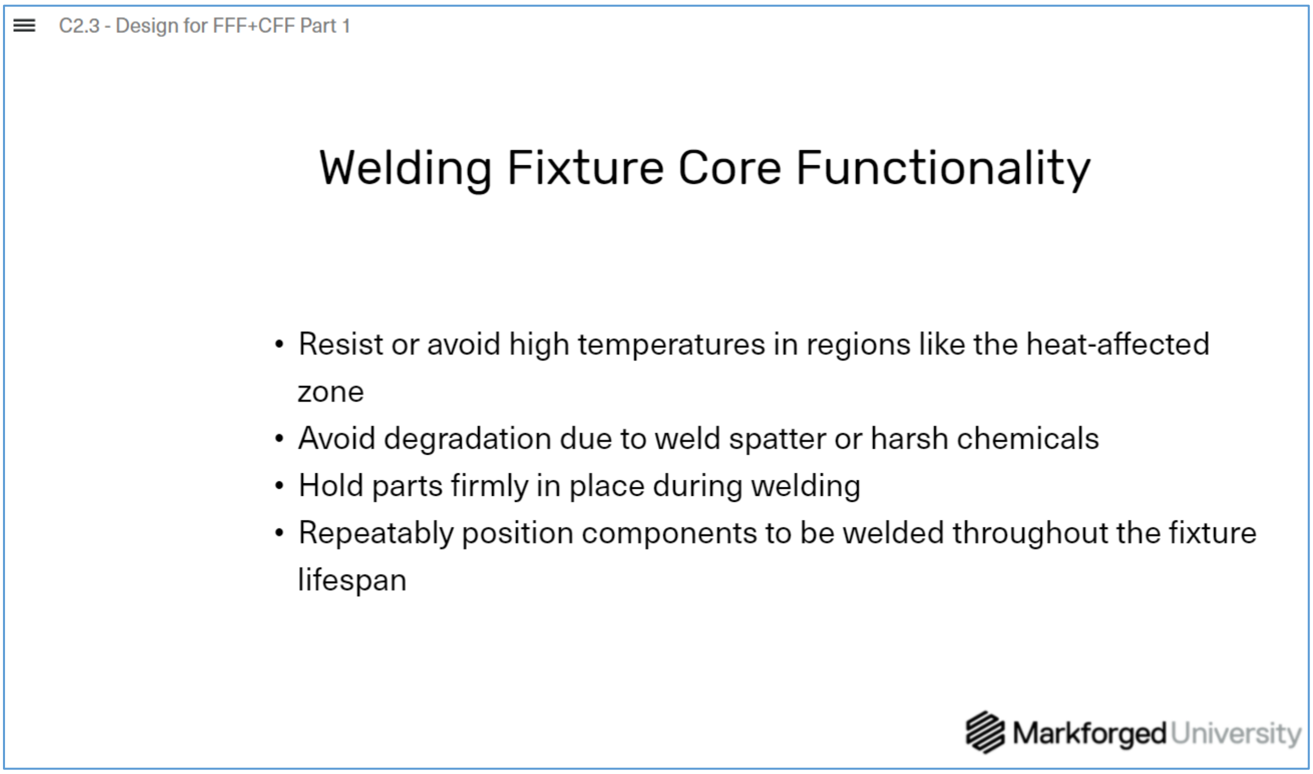
C2.3 - Design for FFF+CFF Part 1 RESOURCES



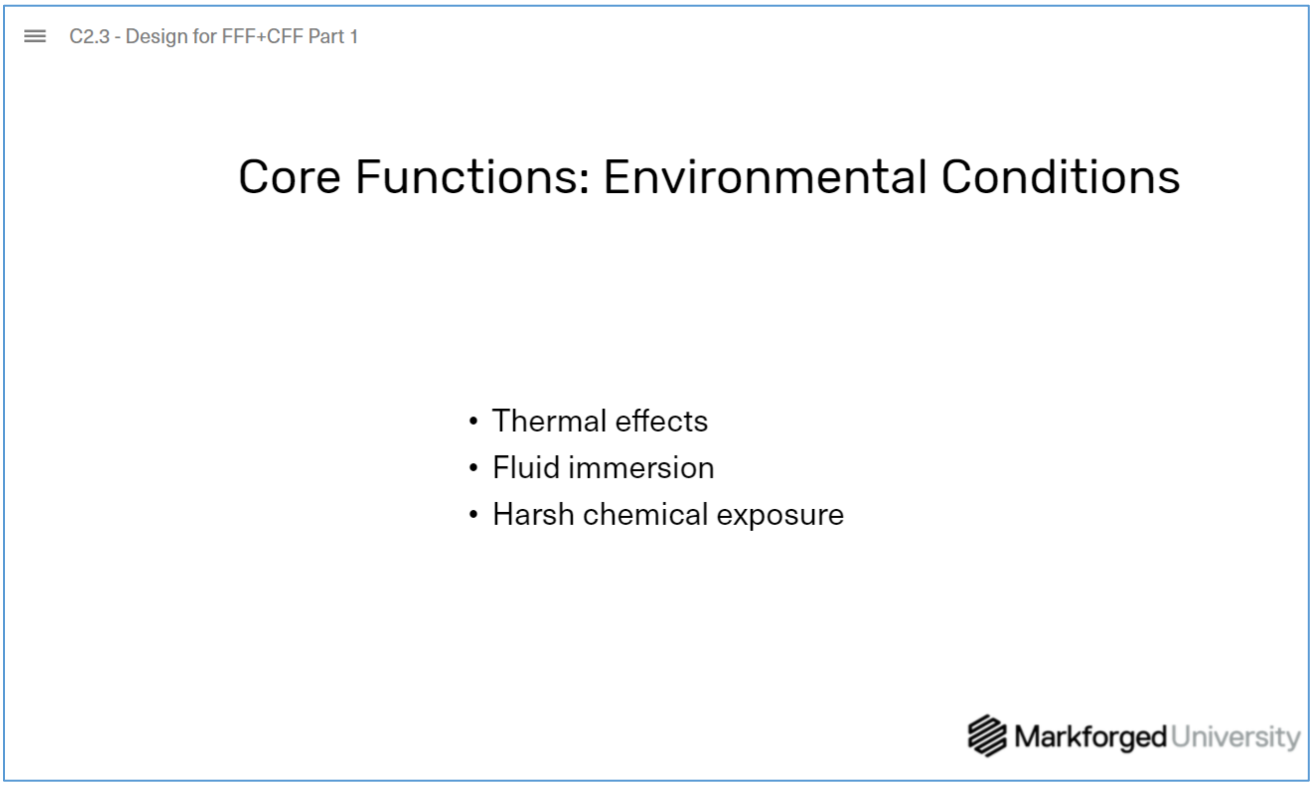
- **Scenario 3: Welding Fixture**



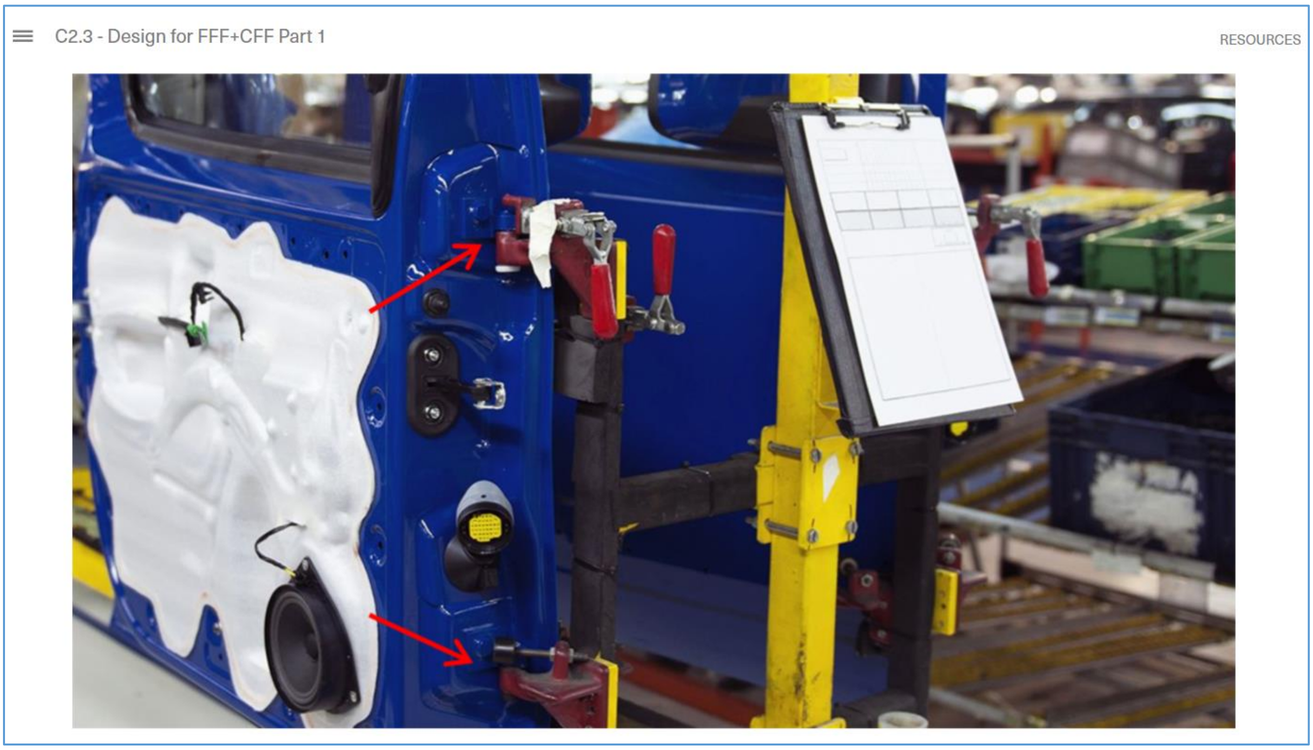
- **S3: What Are The Core Functionalities?**



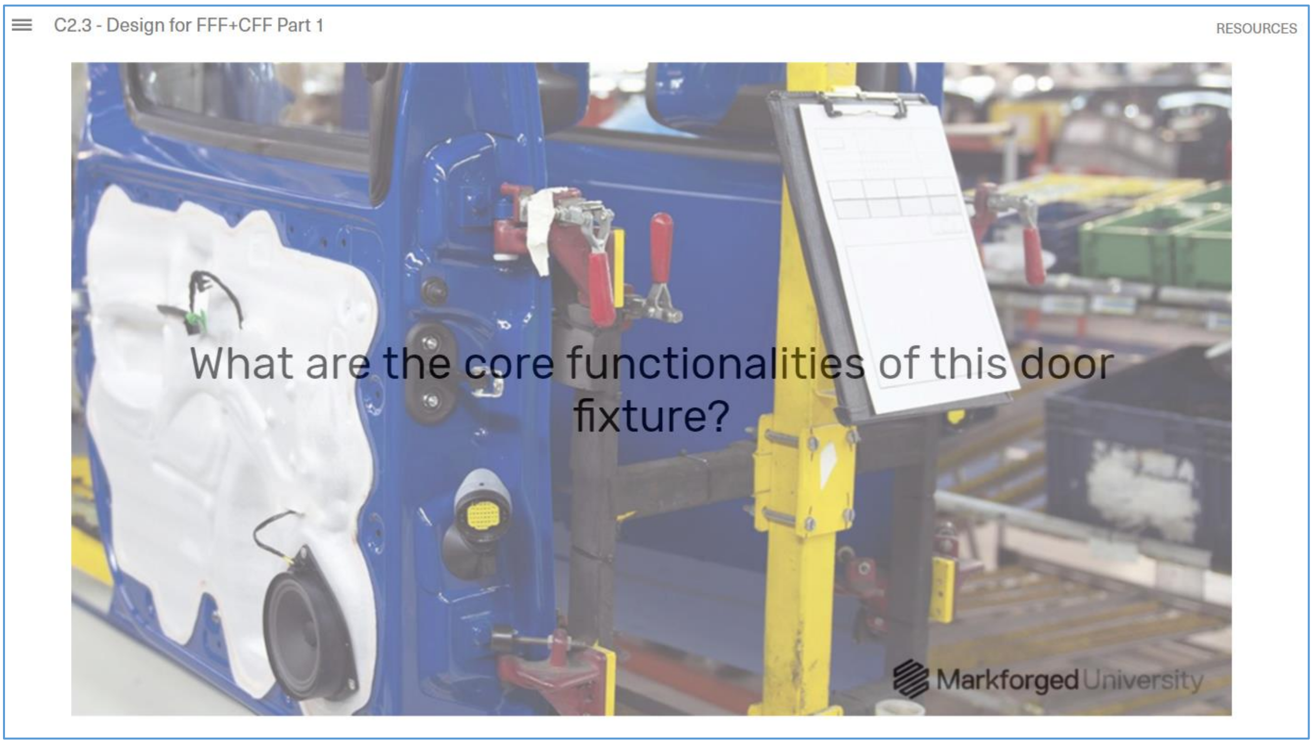
- **Welding Fixture Core Functionality**
    - Harsh chemicals = sterke zuren



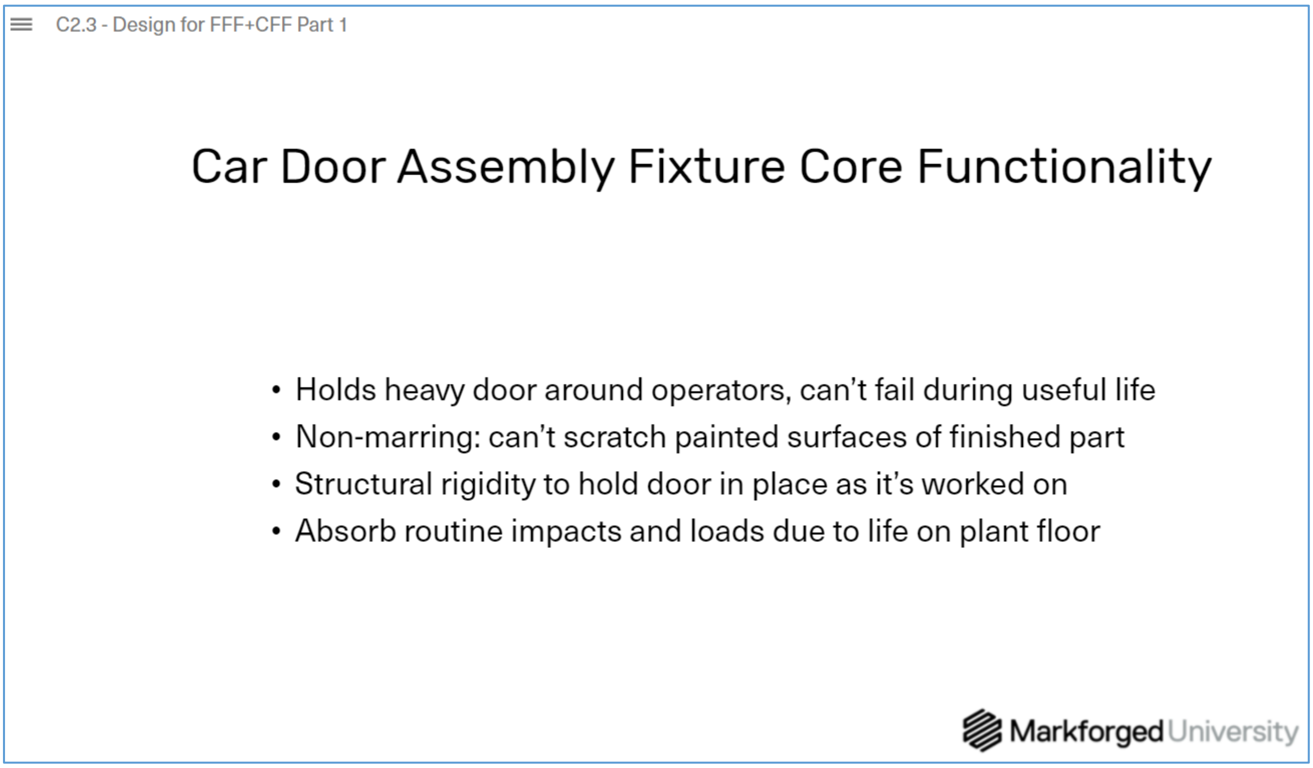
- **Core Functions: Environmental Conditions**



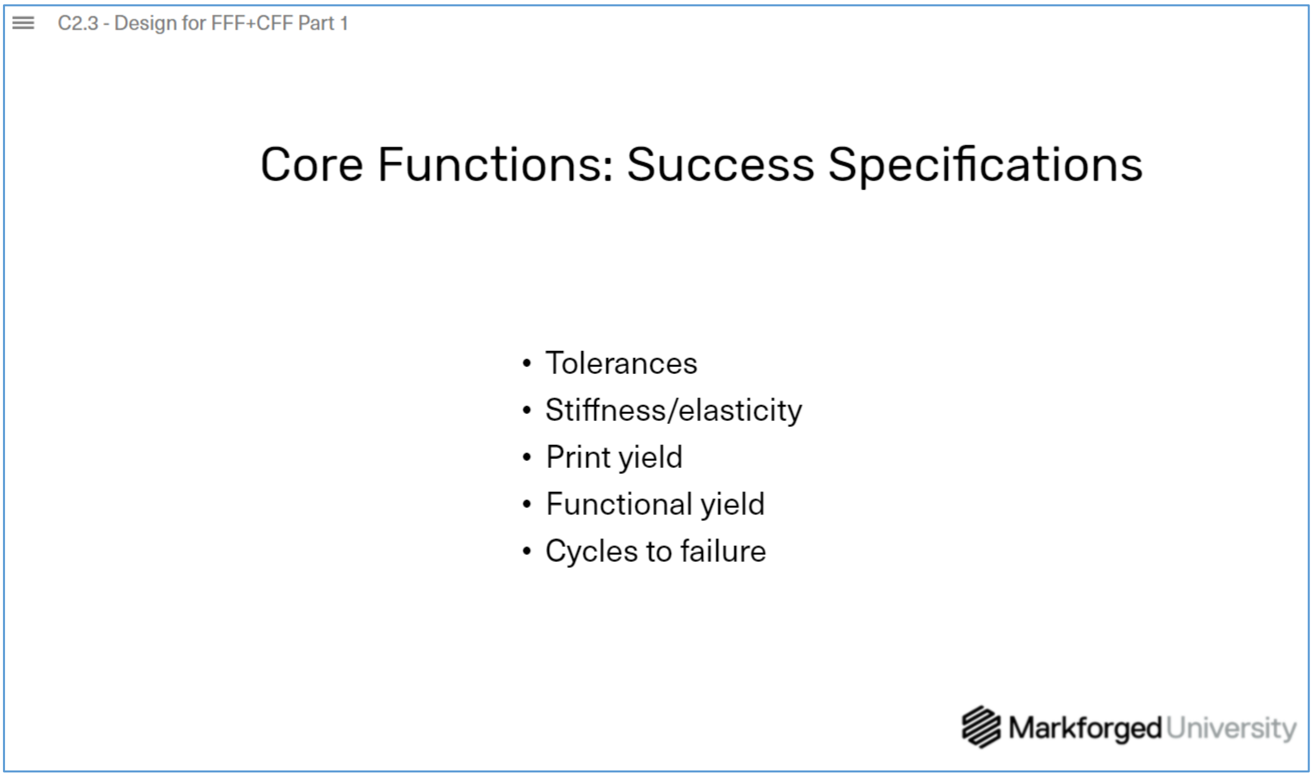
- **Scenario 4: Car Door Assembly Fixture**



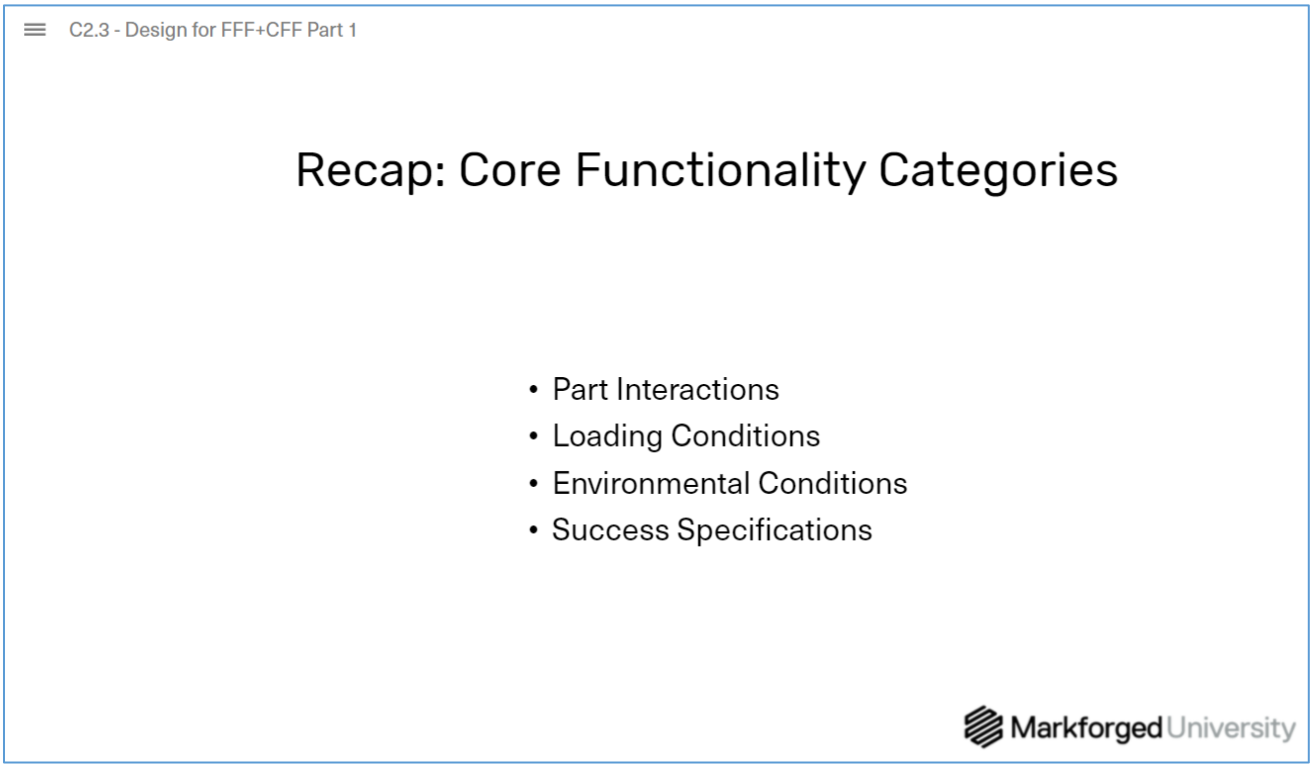
- **S4: What Are The Core Functionalities?**



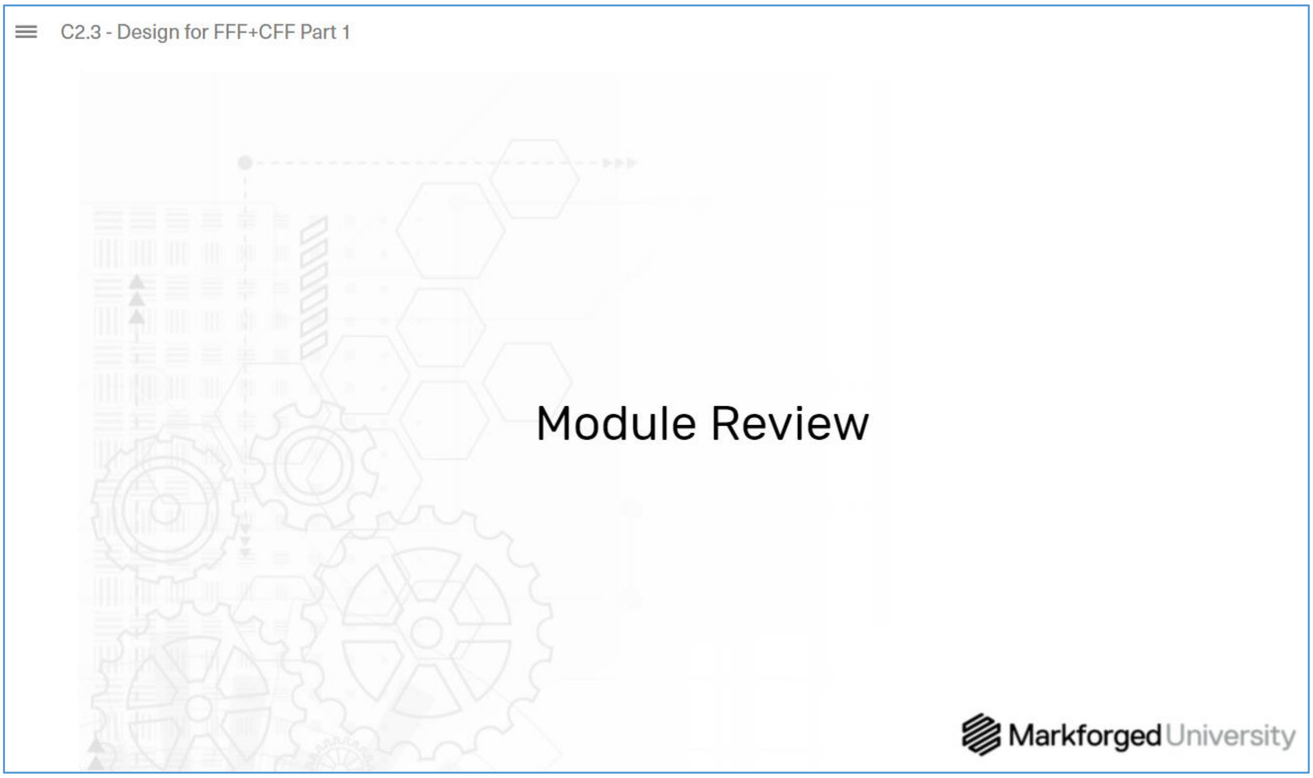
- **Car Door Assembly Fixture Core Functionality**
    - Around = in de omgeving van.
    - Non-marring = voorkomen beschadigingen / niet in de war brengen.
    - Rigidity = stijfheid.
    - Impact = Uitwerking, invloed of effect.
    - Load = Last.



- **Car Door Assembly Fixture Core Functionality**
    - Yield = opbrengst.



- **Review: Core Functionality Categories**
    - Loading Conditions = What type and directions of load.



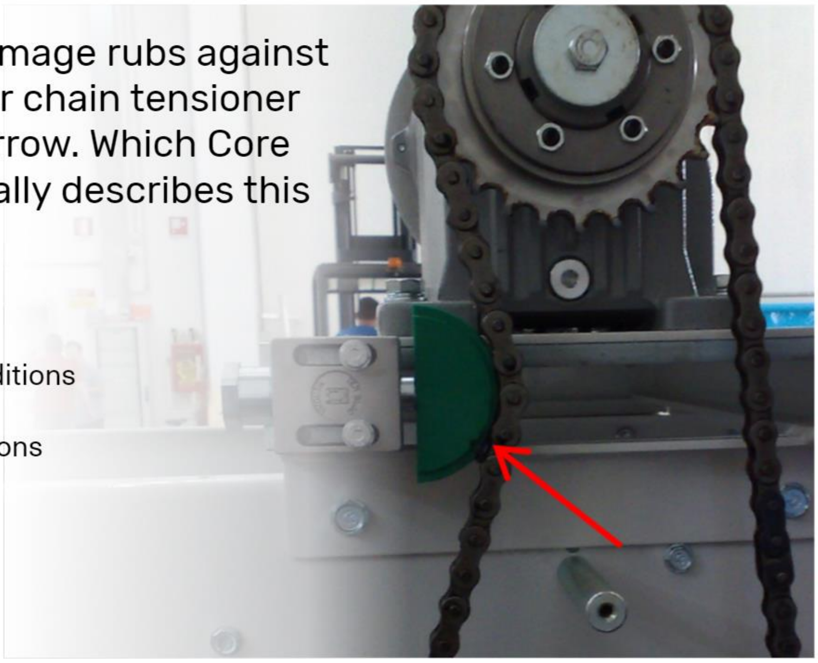
- **Module Review**

C2.3 - Design for FFF+CFF Part 1

RESOURCES

The chain in this image rubs against the green polymer chain tensioner marked with an arrow. Which Core Function specifically describes this contact?

- (●) Part Interactions
- ( ) Environmental Conditions
- ( ) Success Specifications
- ( ) Loading Conditions



C2.3 - Design for FFF+CFF Part 1

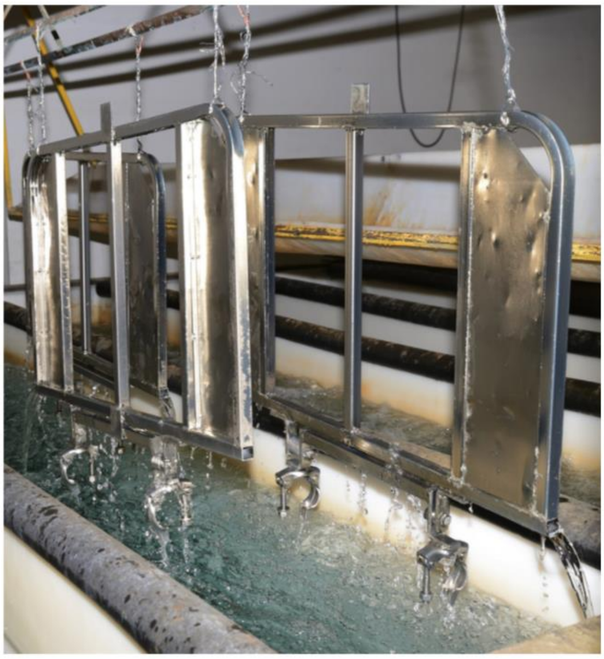
Put the following steps for taking a defined problem to a functional minimum viable part in order:

1. Identify core functionality
2. First pass design/existing CAD
3. Revise design to meet core functionality
4. Import into Eiger
5. First pass print settings and material selection
6. Print and test

C2.3 - Design for FFF+CFF Part 1

RESOURCES

What category of functional requirements would you be most concerned with if you were creating a fixture submersion in a chemical plating bath like this one?



- Part Interactions
- Loading Conditions
- Success Specifications
- Environmental Conditions

- Submersion = Onderdompeling

C2.3 - Design for FFF+CFF Part 1

Results

Your Score:	100% (30 points)
Passing Score:	80% (24 points)

Result:

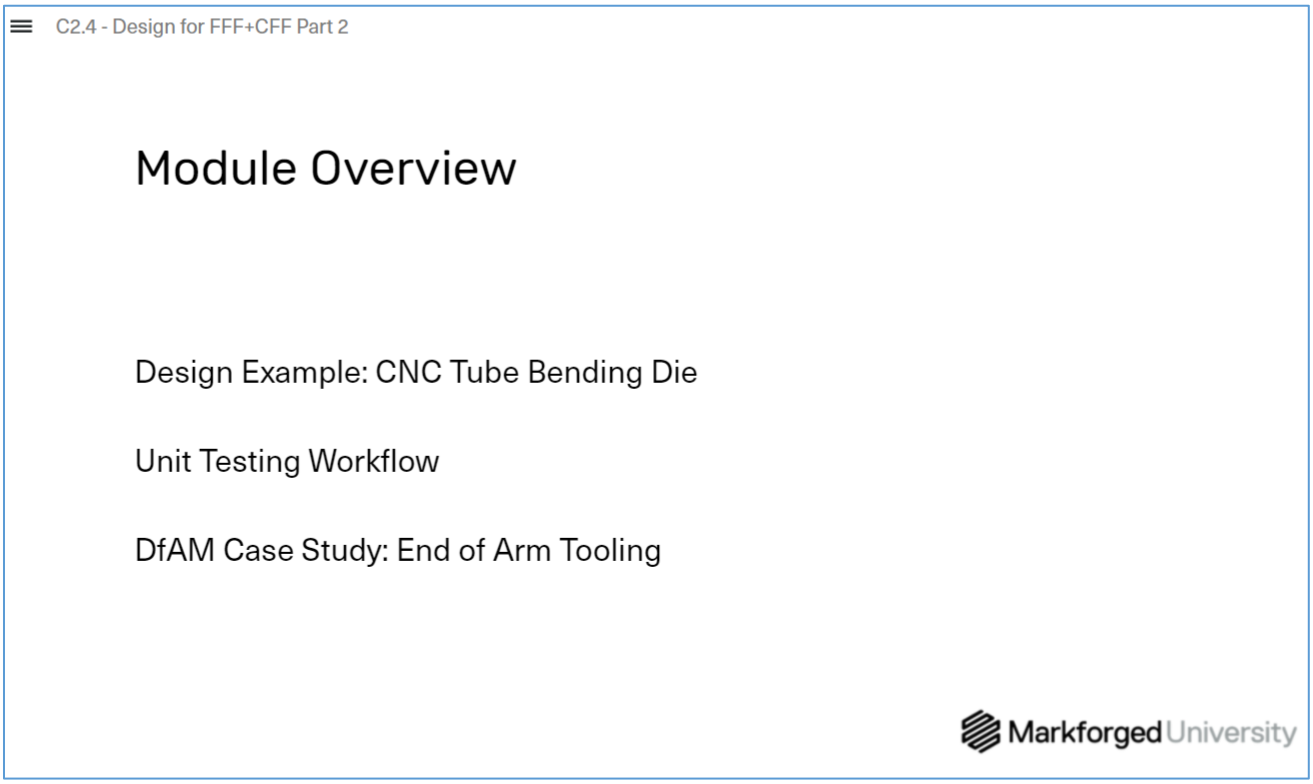
Congratulations, you passed.

Finish Module

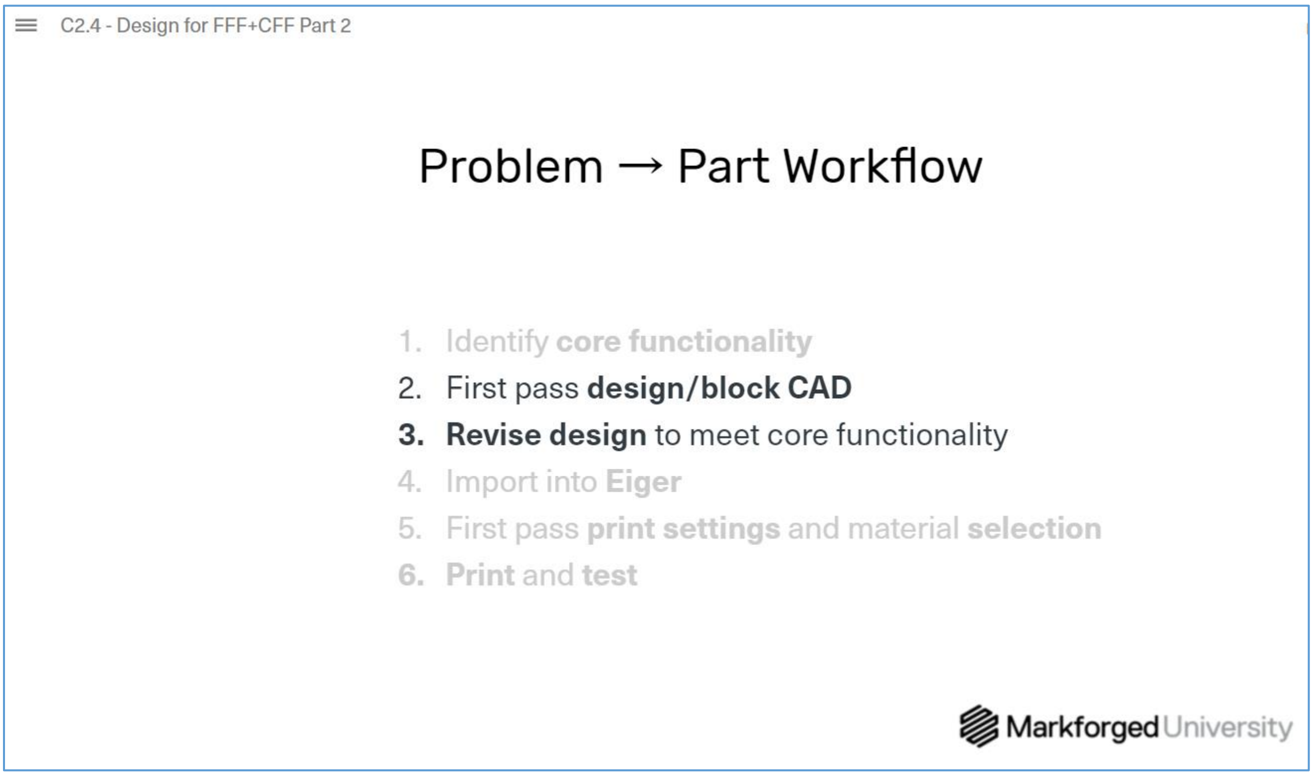
Review Quiz

C2.4 – Design for FFF and CFF Part 2

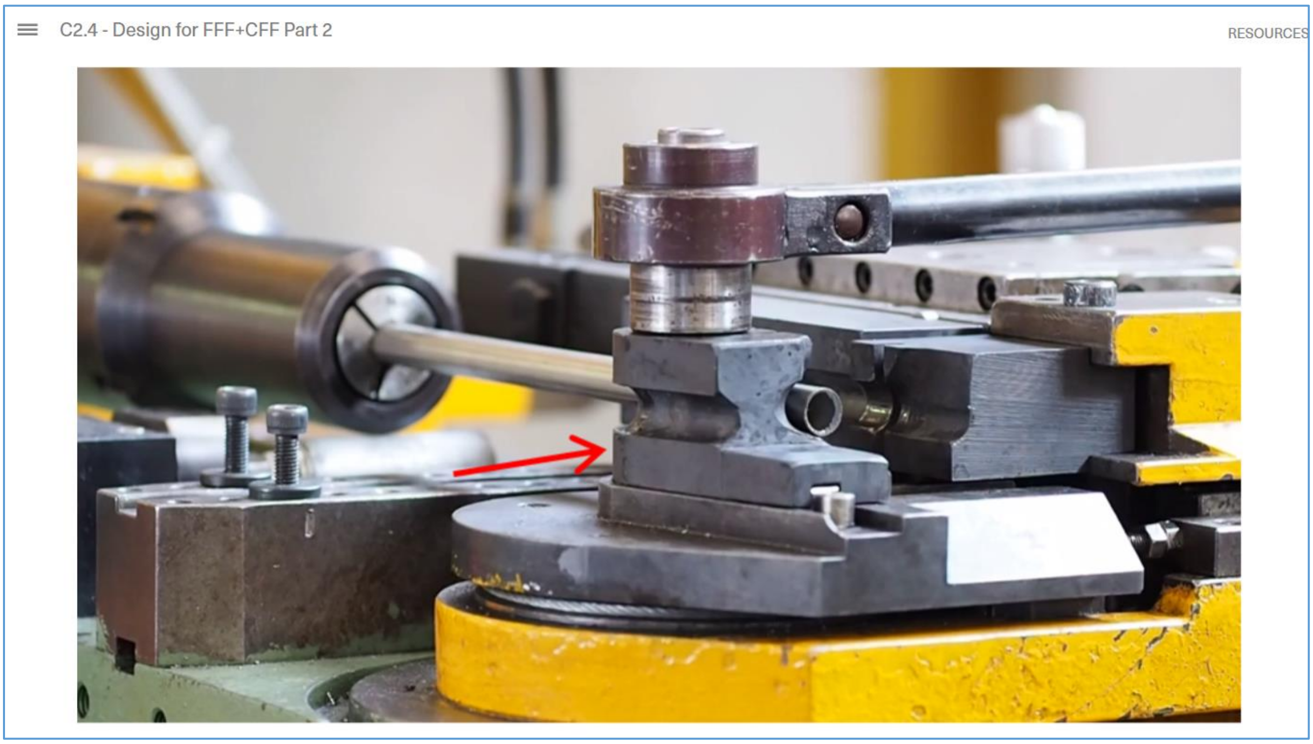
- **Design for FFF and CFF Part 2**



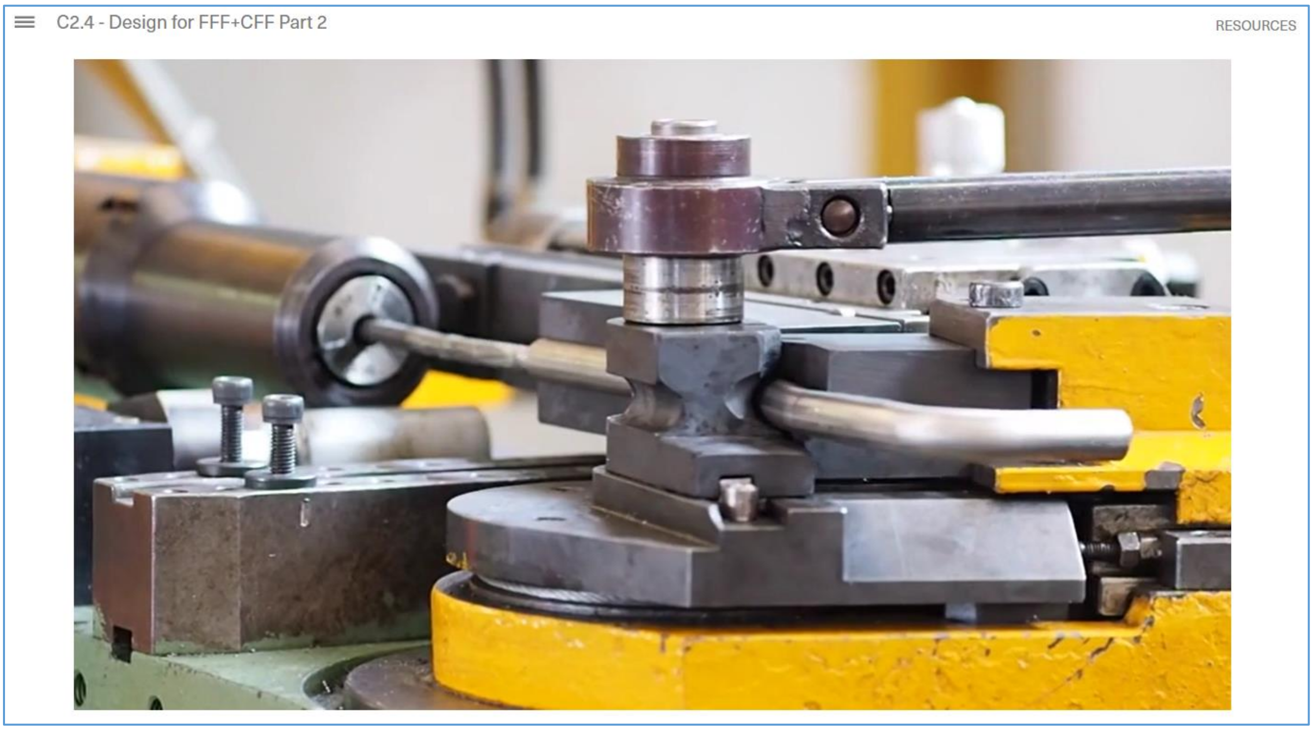
- **Module Overview**
  - DfAM = Design for Additive Manufacturing

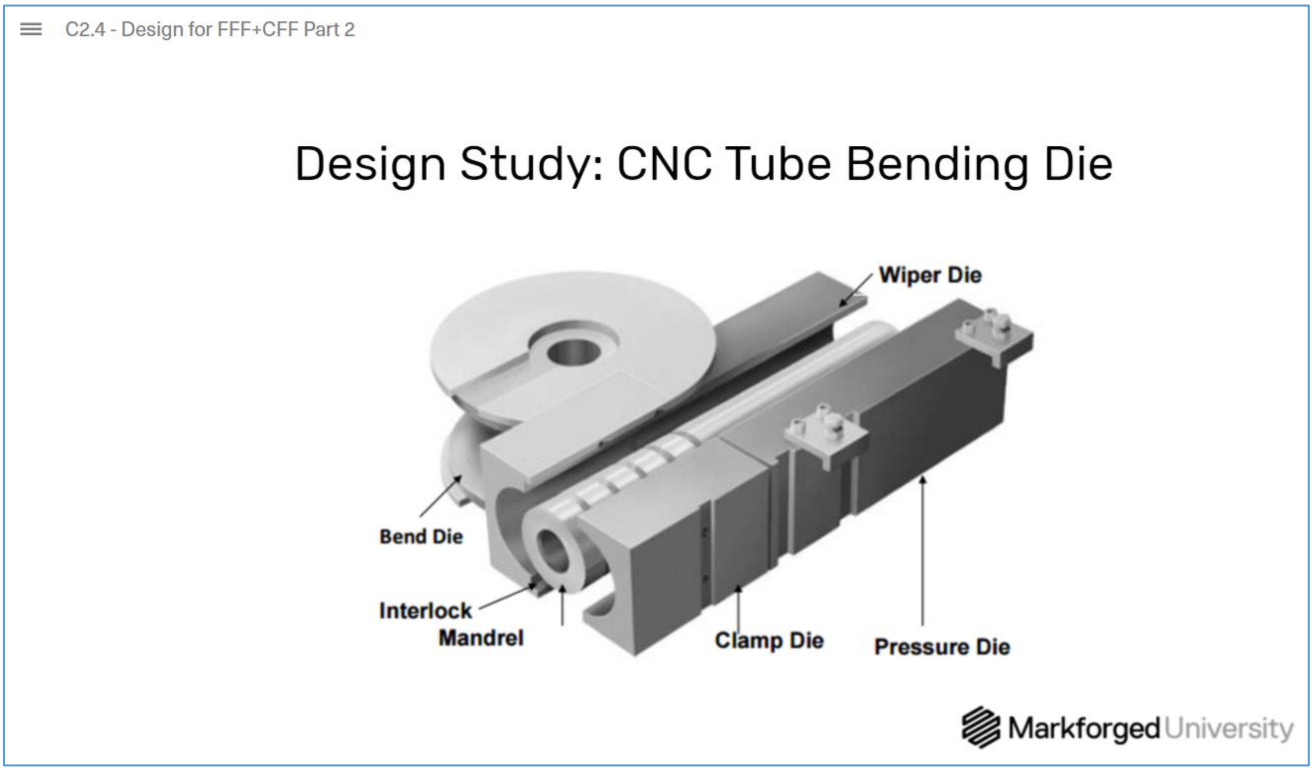


- **Step 2/3: Initial Designs and Design Revision**
  - Initial Design = Eerste ontwerp.



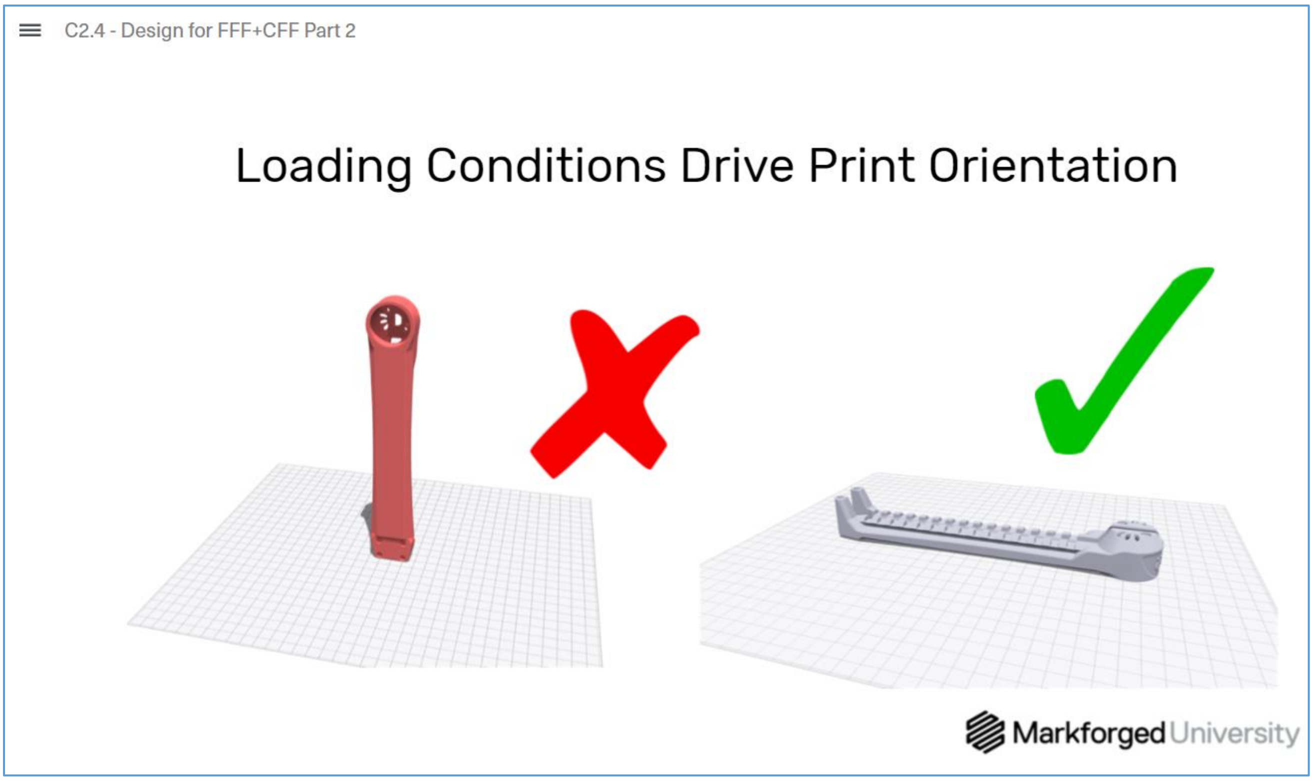
- **Video: CNC Tube Bending**
  - Lead Time = Doorlooptijd.

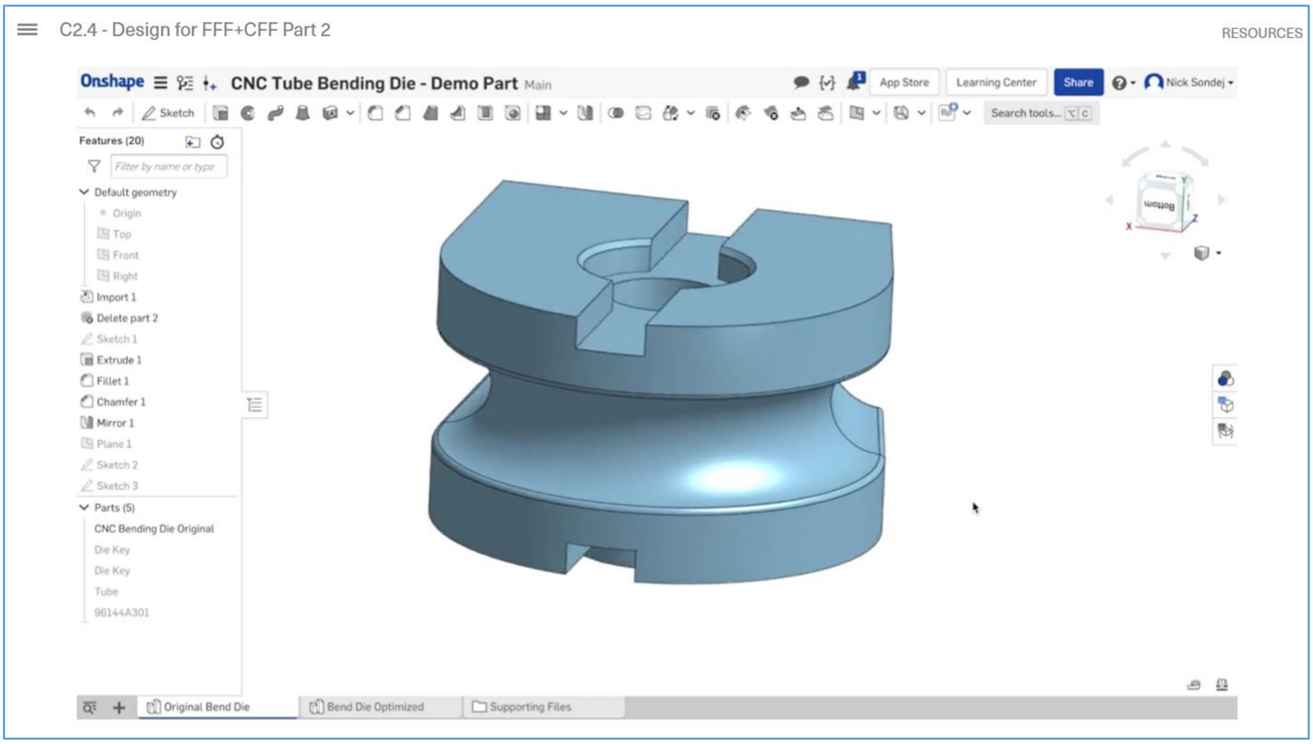




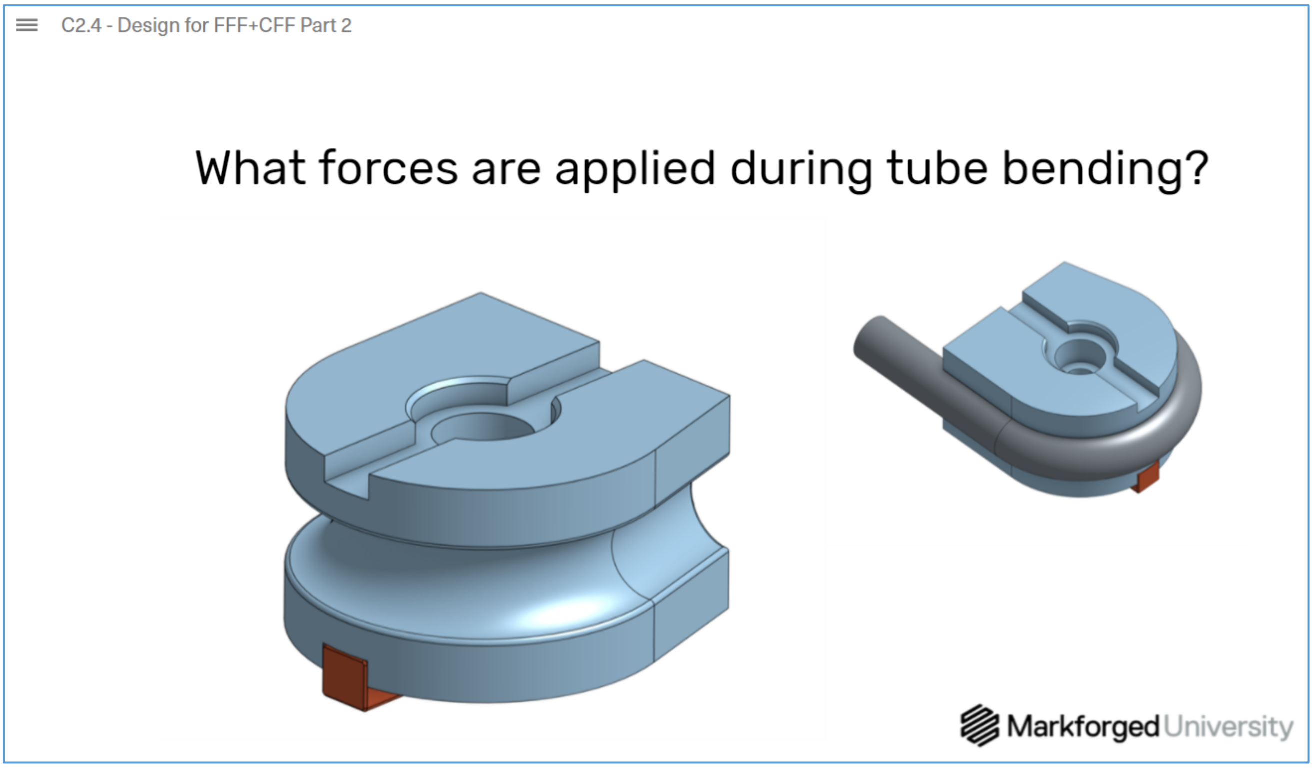
- **Design Study: CNC Tube Bending Die**
    - Vertaald uit het Engels-Een doorn, doorn of prieel is een zacht taps toelopende cilinder waartegen materiaal kan worden gesmeed of gevormd, of een van een flens voorziene of taps toelopende of van schroefdraad voorziene staaf die een werkstuk grijpt dat op een draaibank moet worden bewerkt.

- **Loading Conditions Drive Print Orientation**

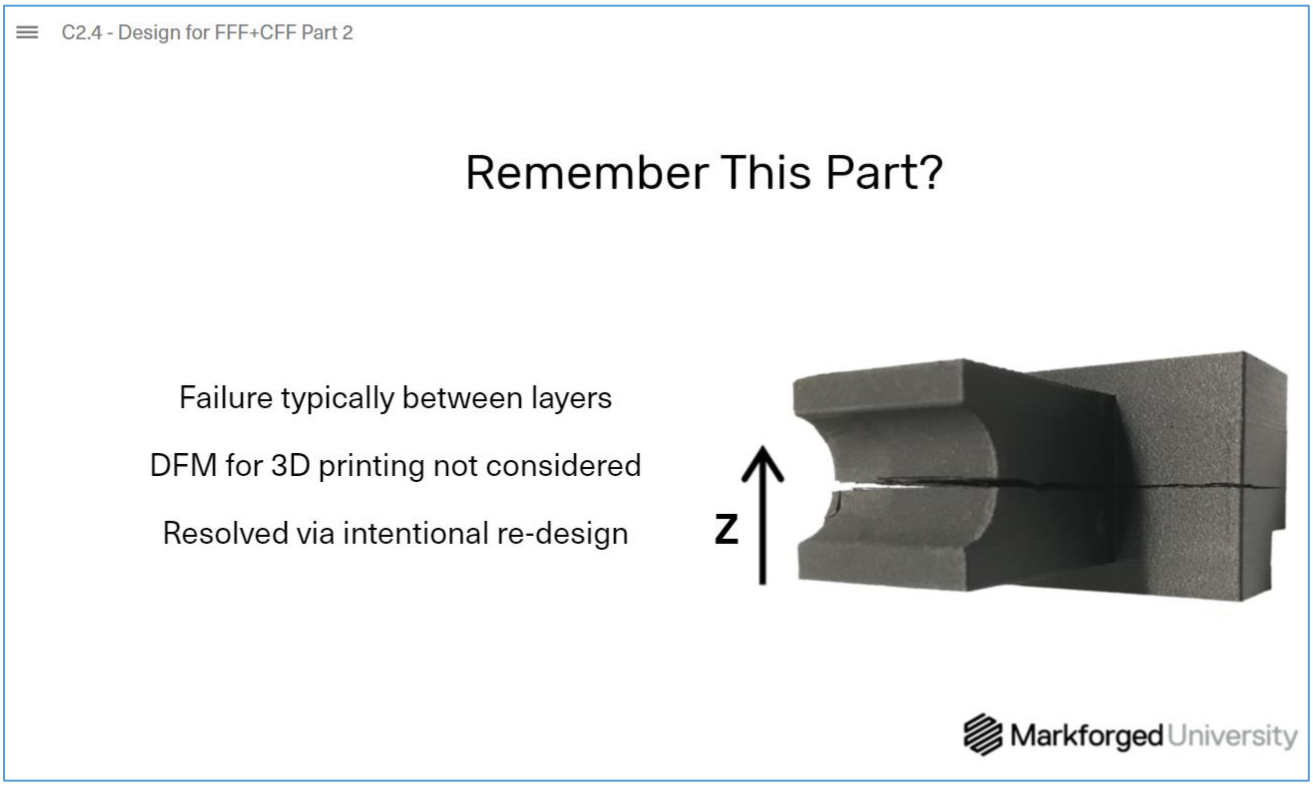




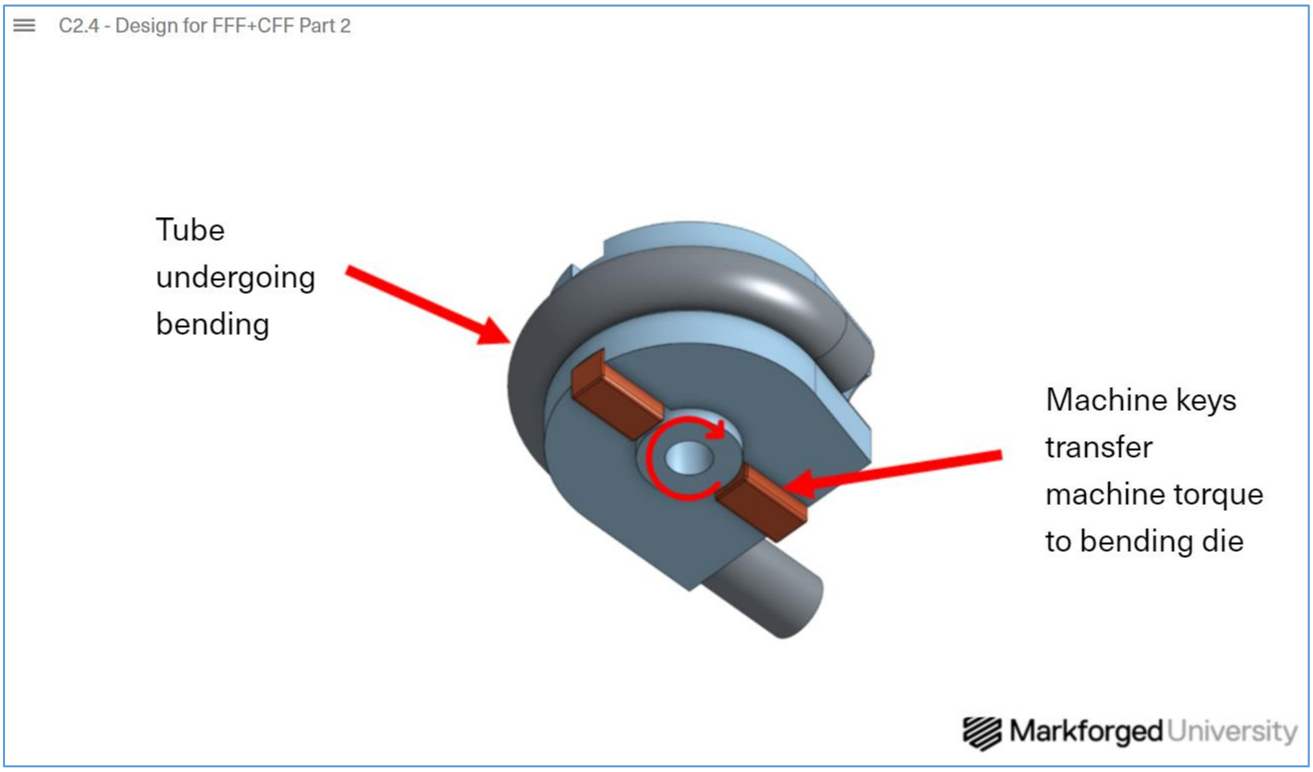
- **CAD Demo: Existing CAD Model**



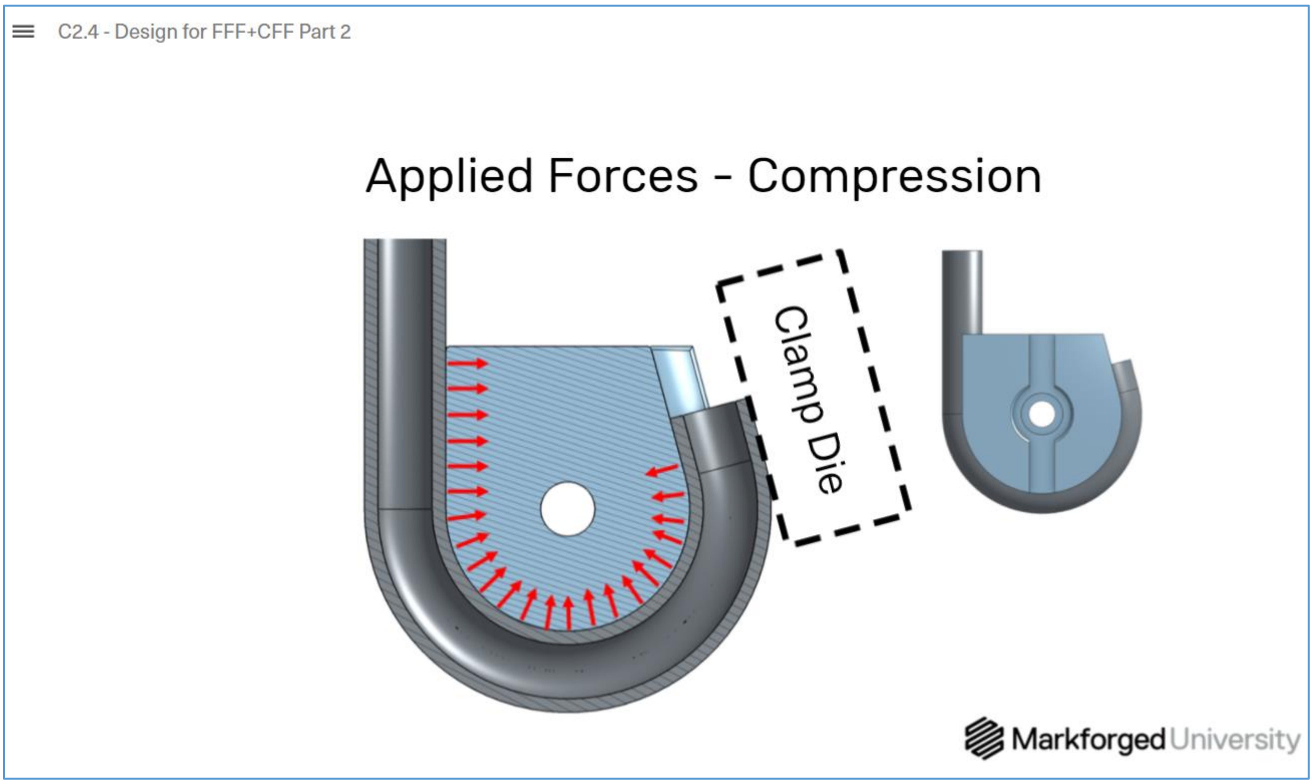
- **Tube Bending Forces**



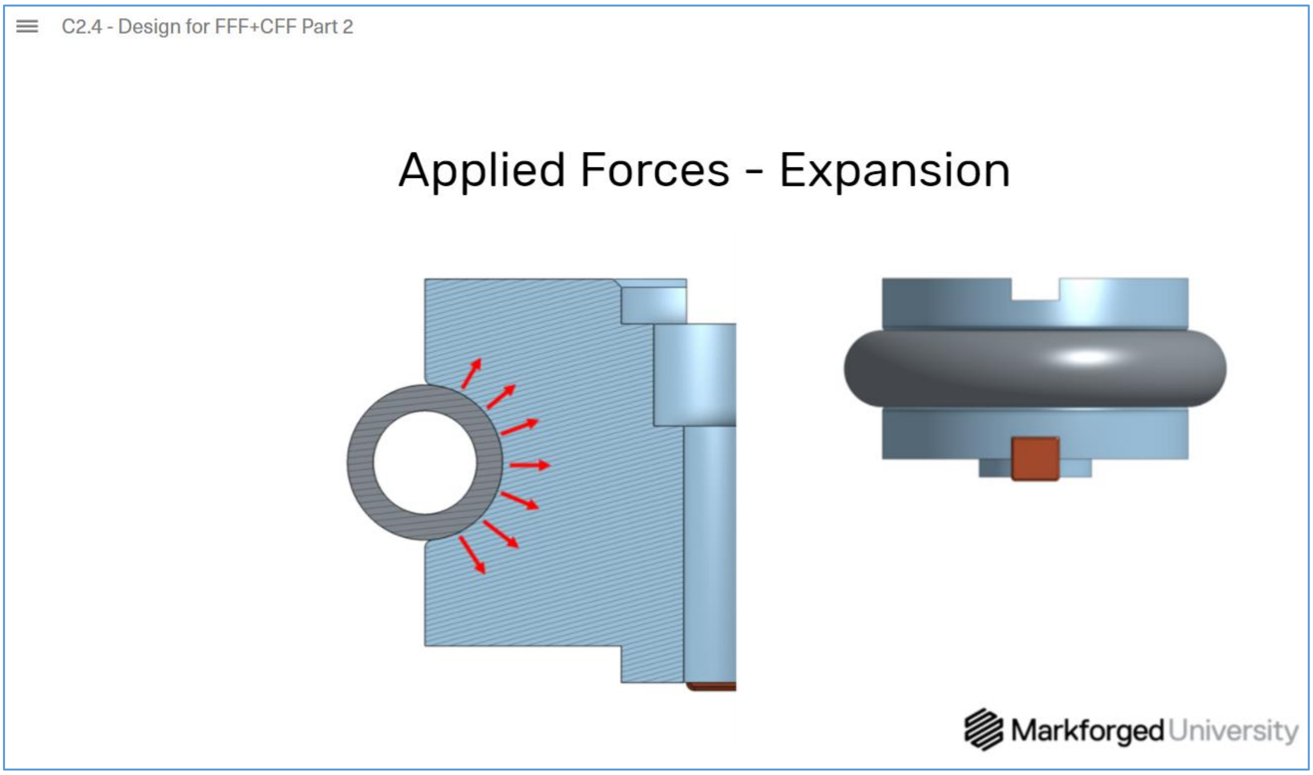
- **Remember This Part?**



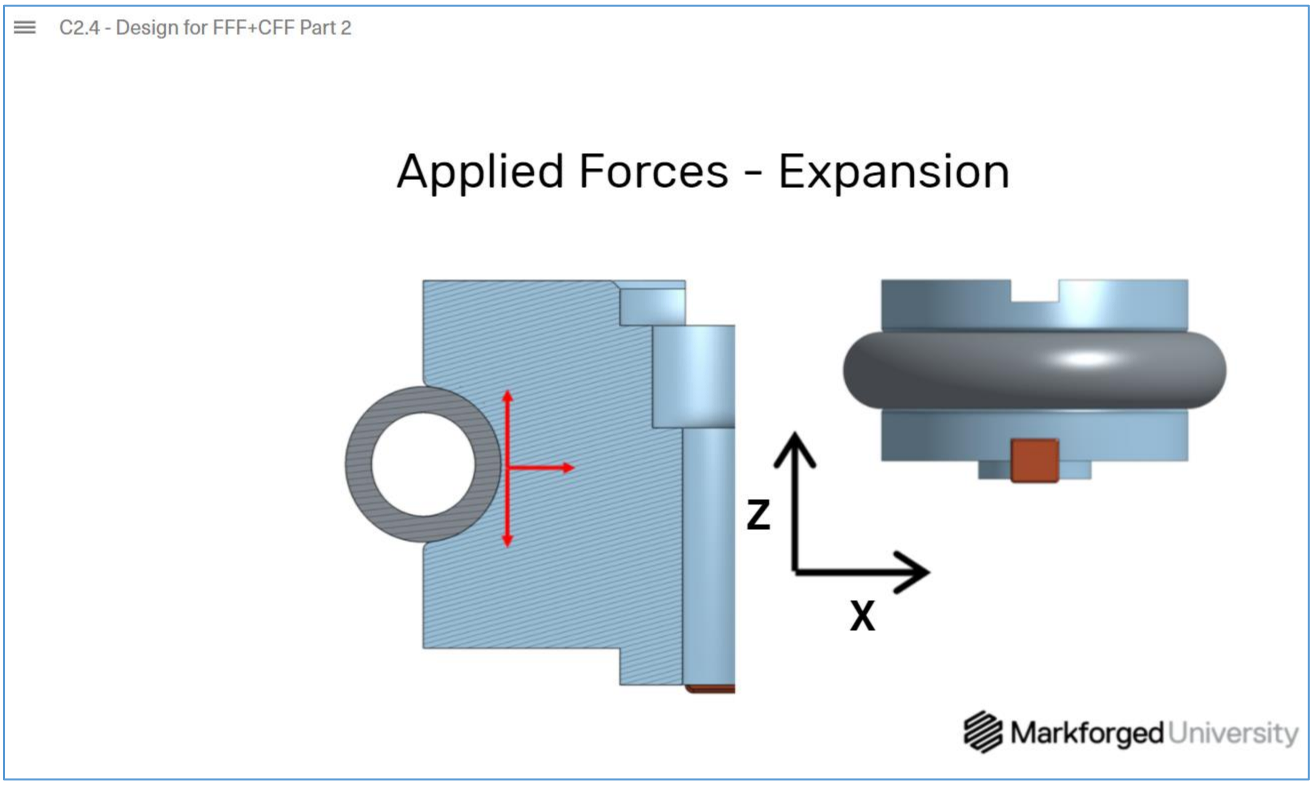
- **Operation of the Die**



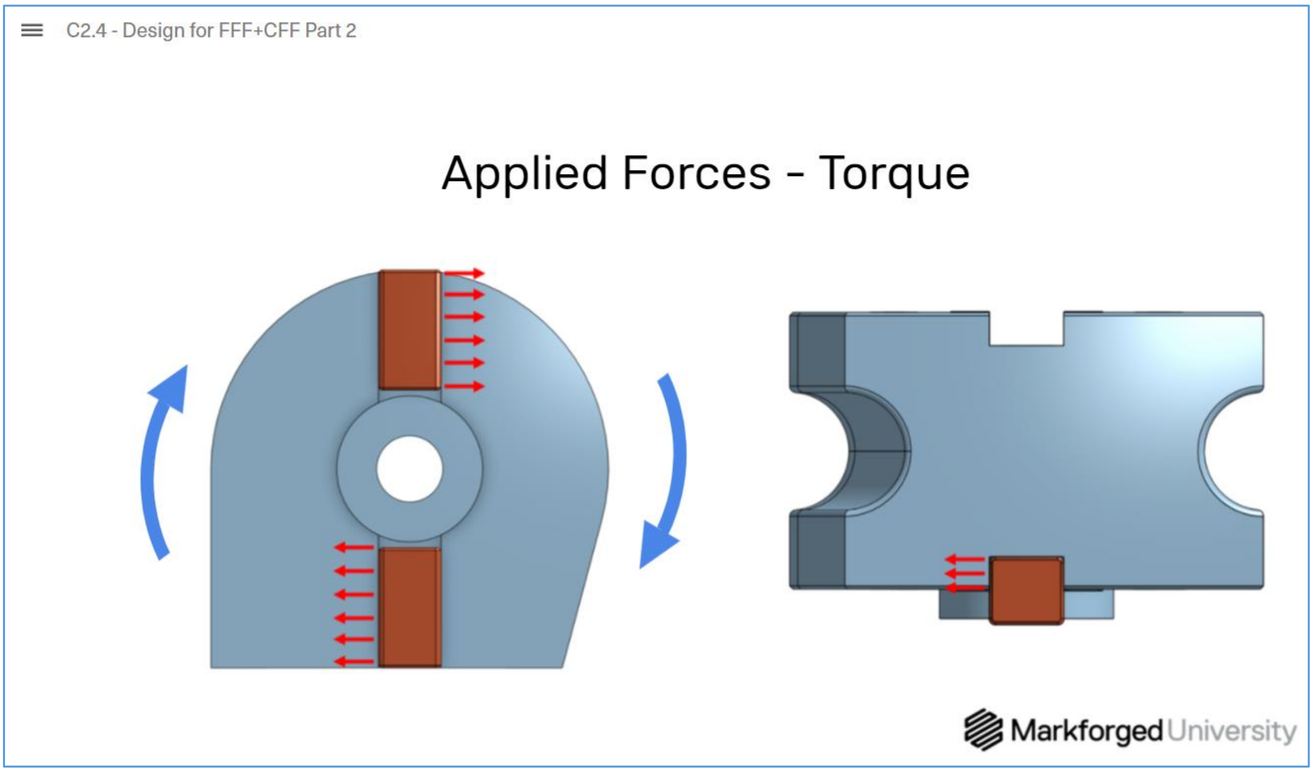
- **Applied Forces – Compression**



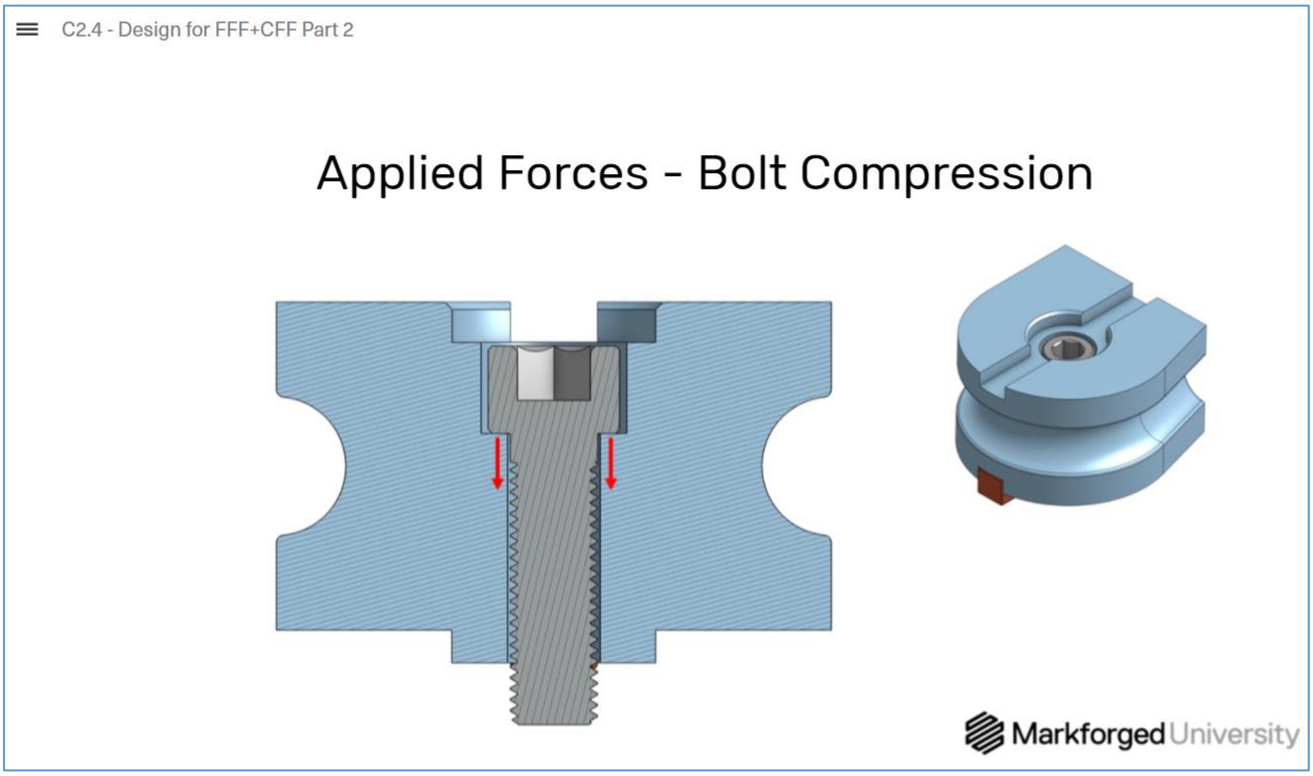
- **Applied Forces – Expansion**



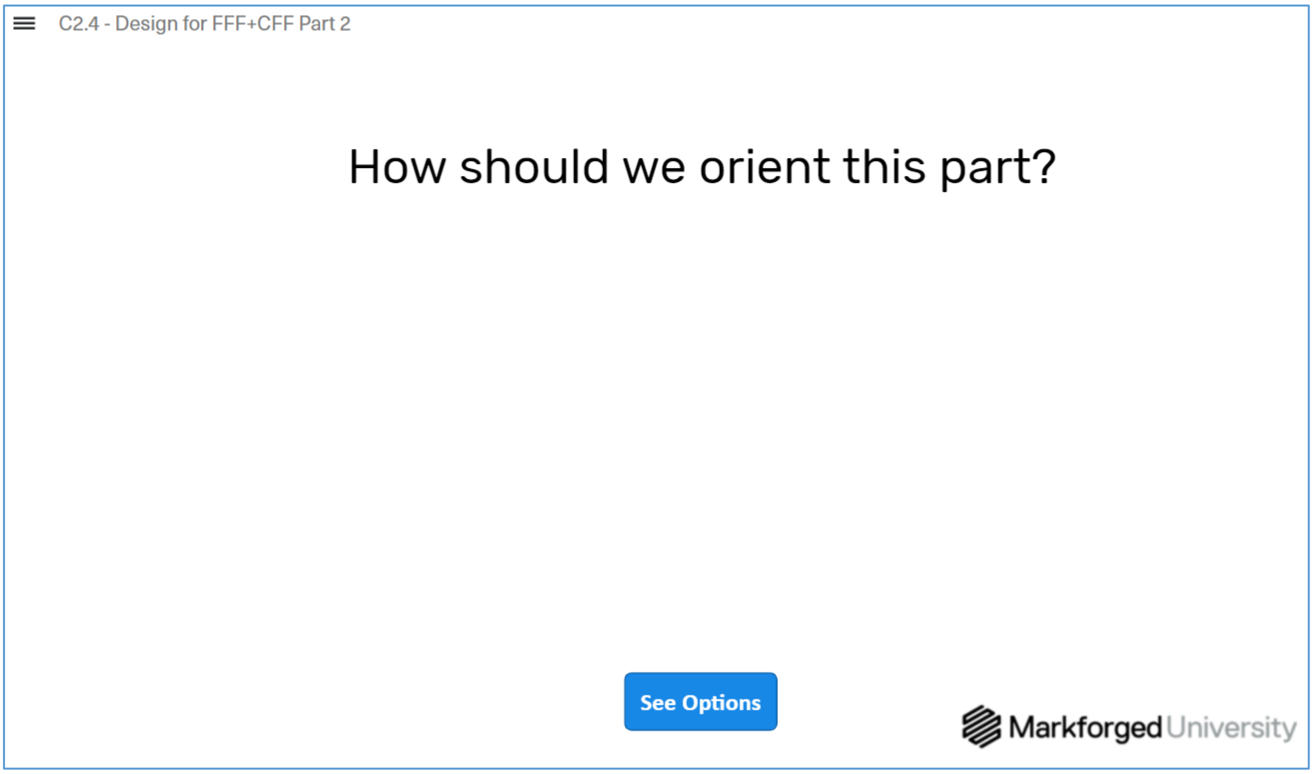
- Isotropic material: Crack between layers (Z-axis)



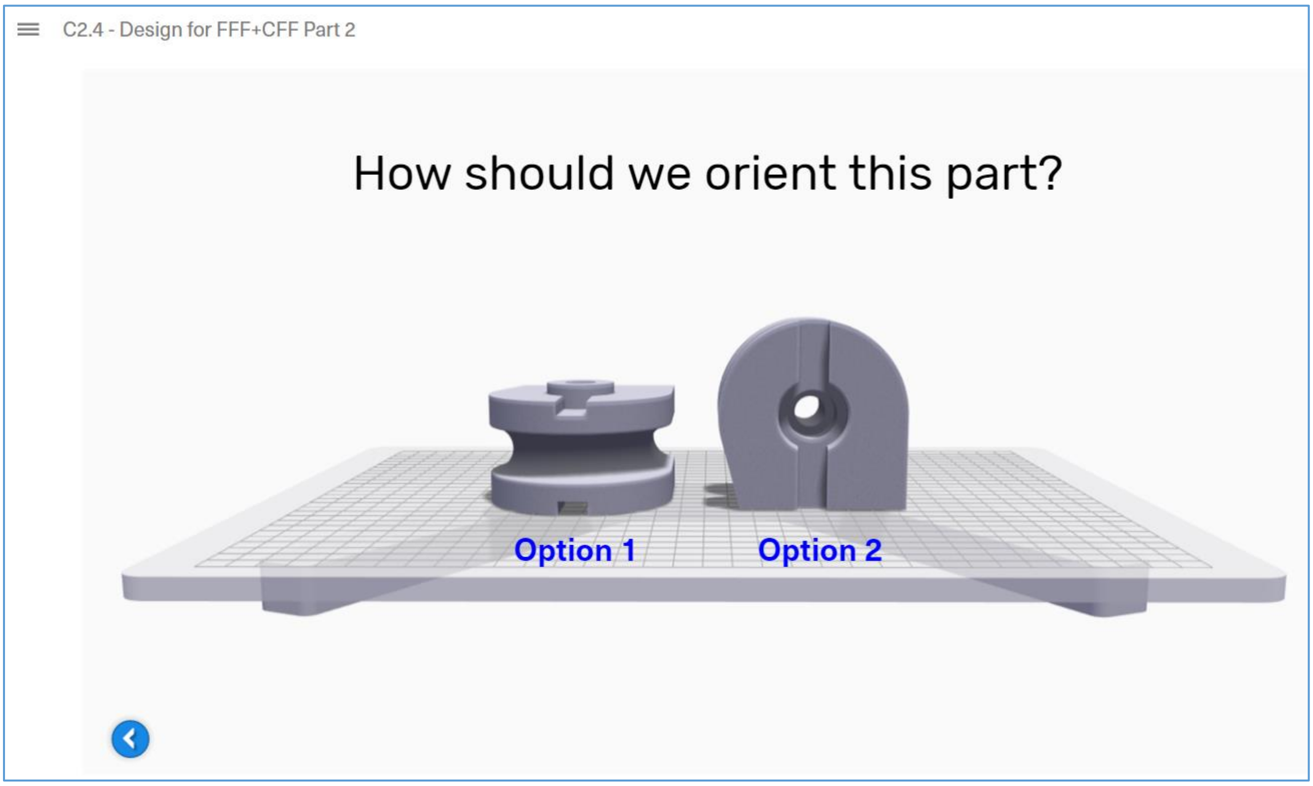
- **Applied Forces – Torque**

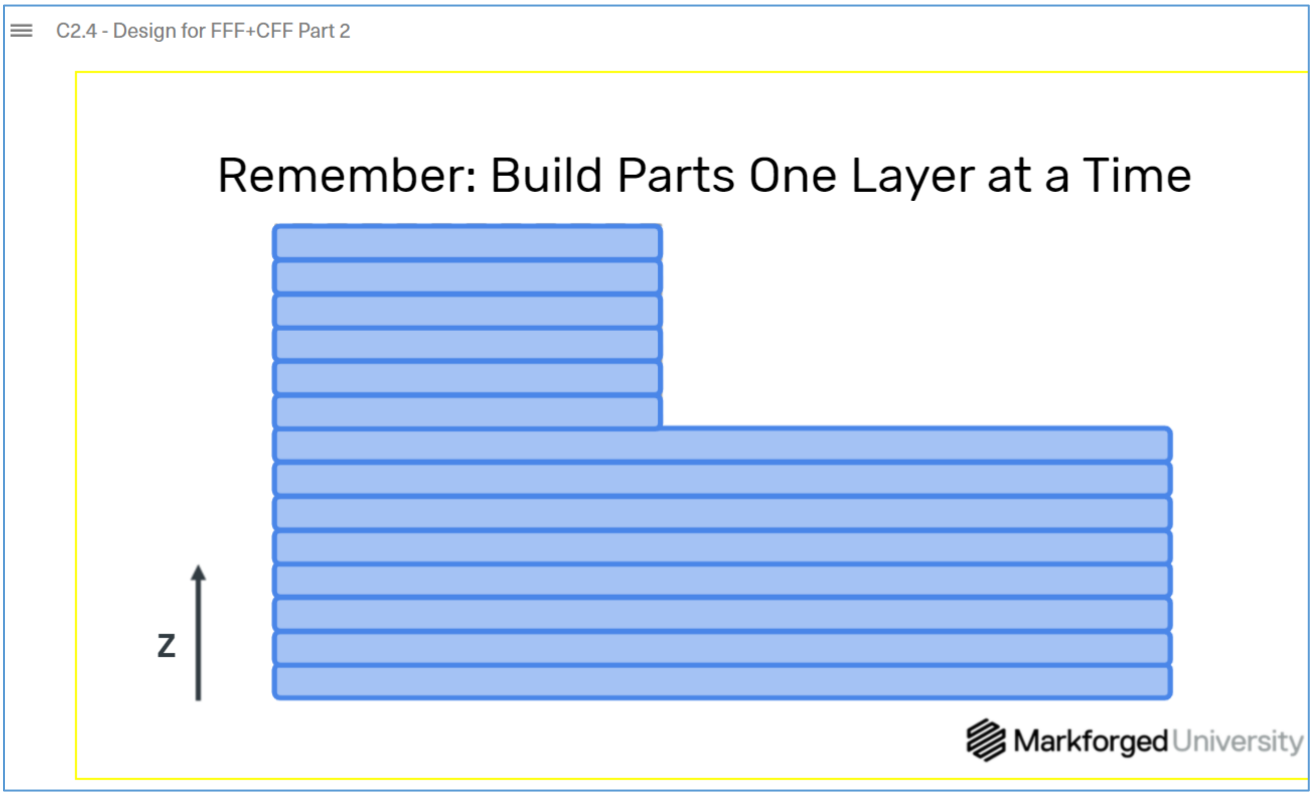


- **Applied Forces – Bolt Compression**

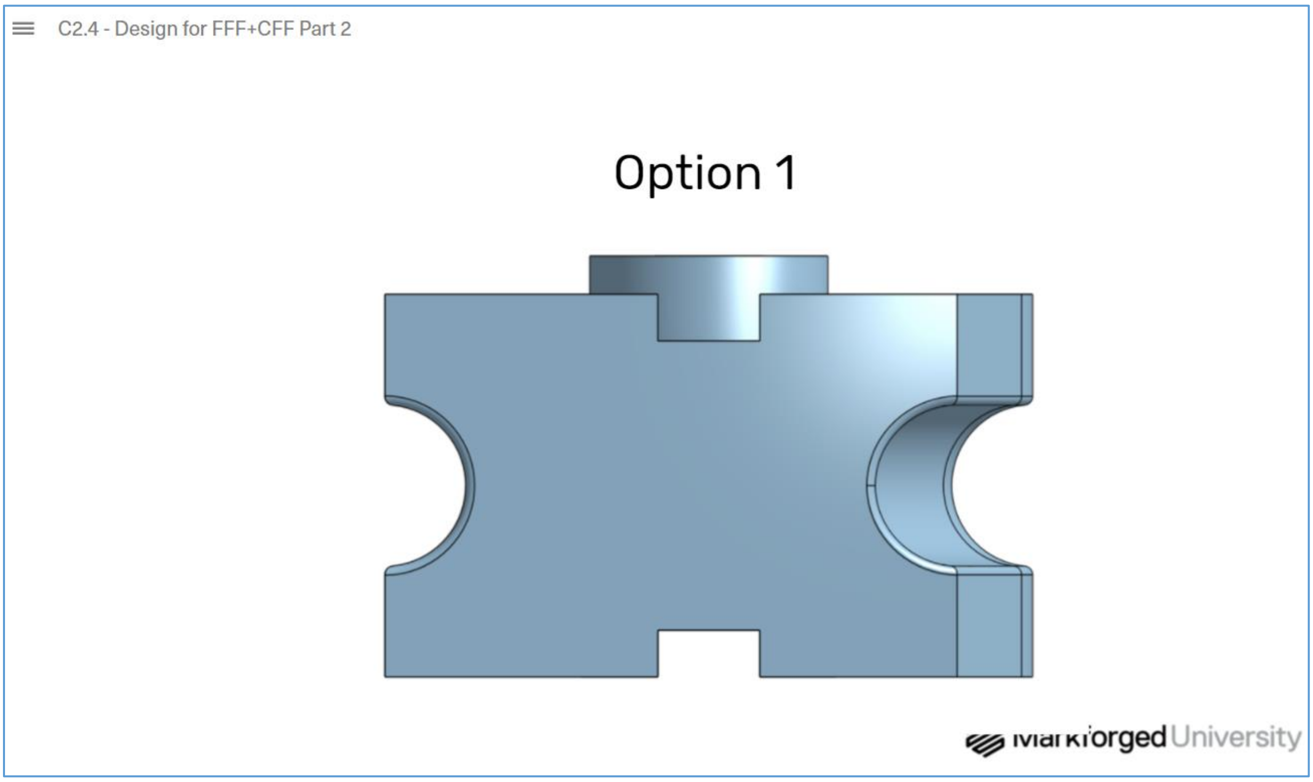


- **How should we orient this part?**

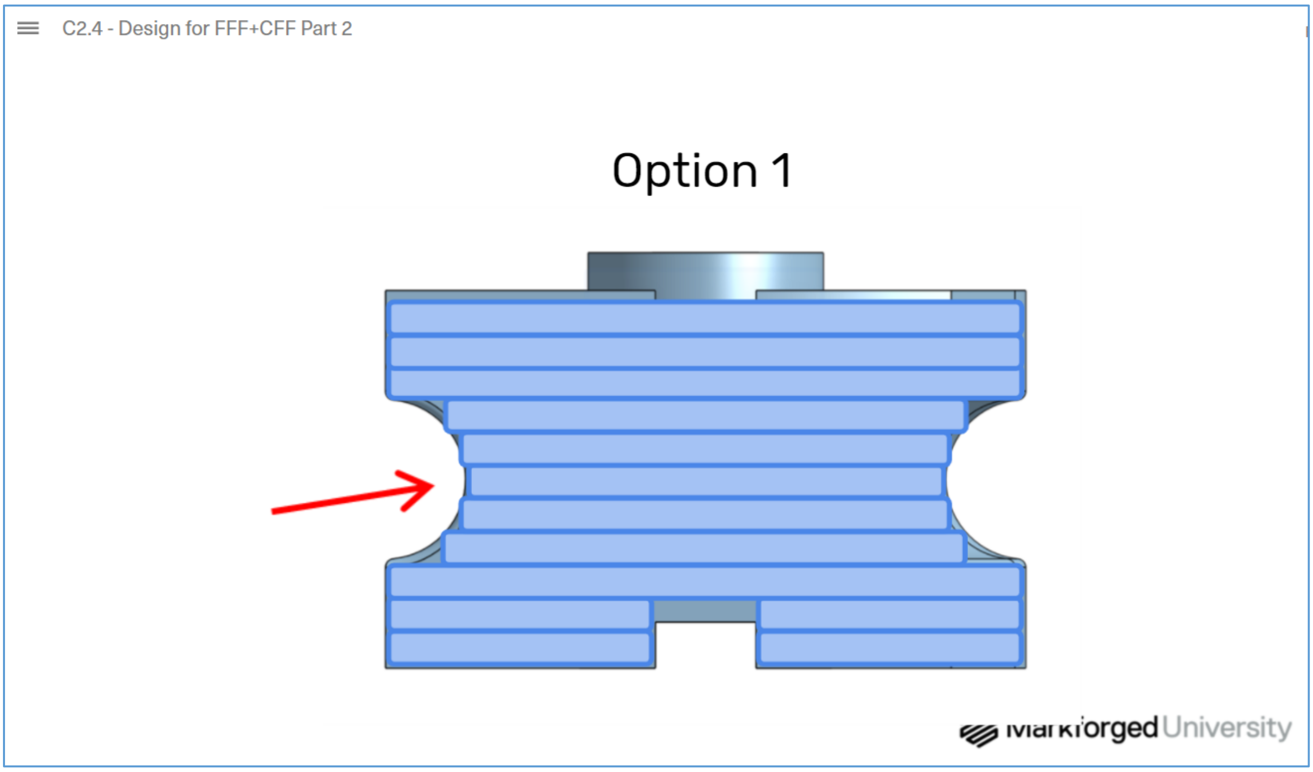


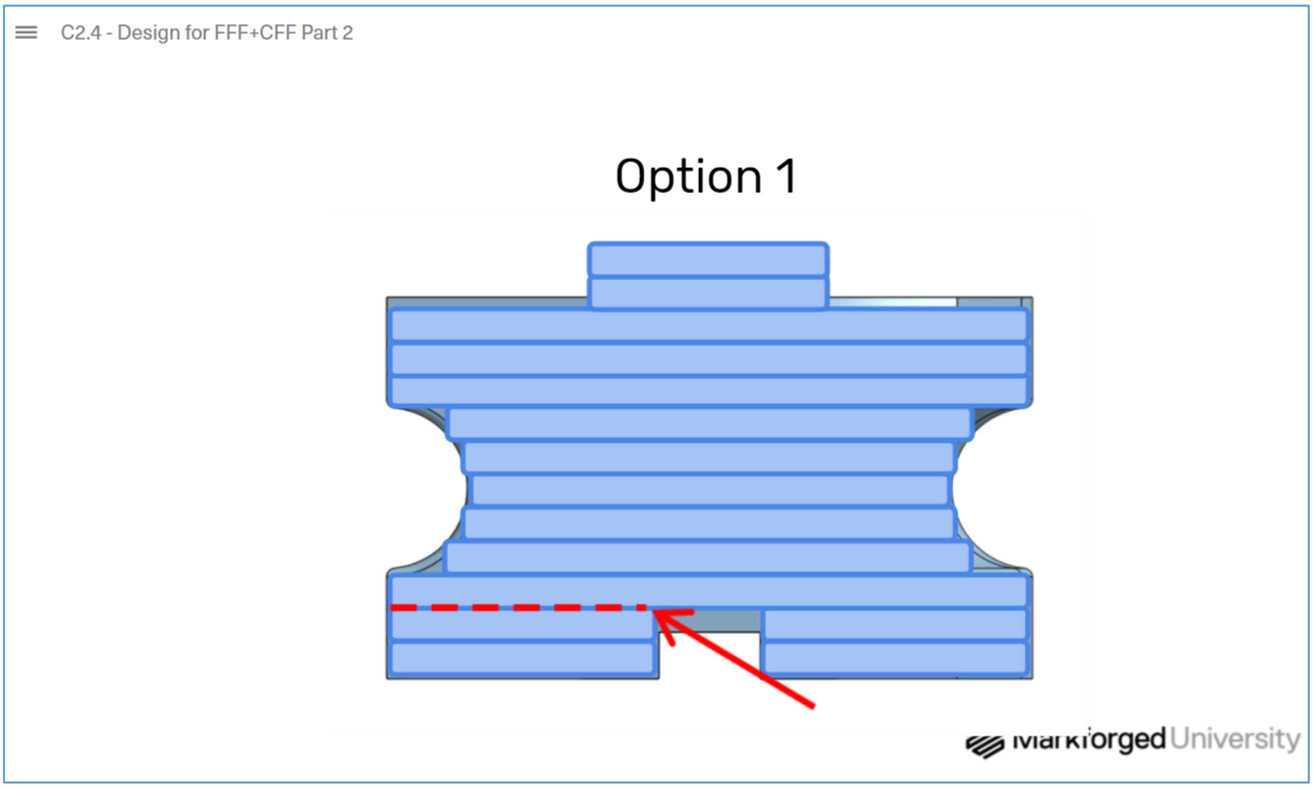


- **Remember: Build Parts One Layer at a Time**

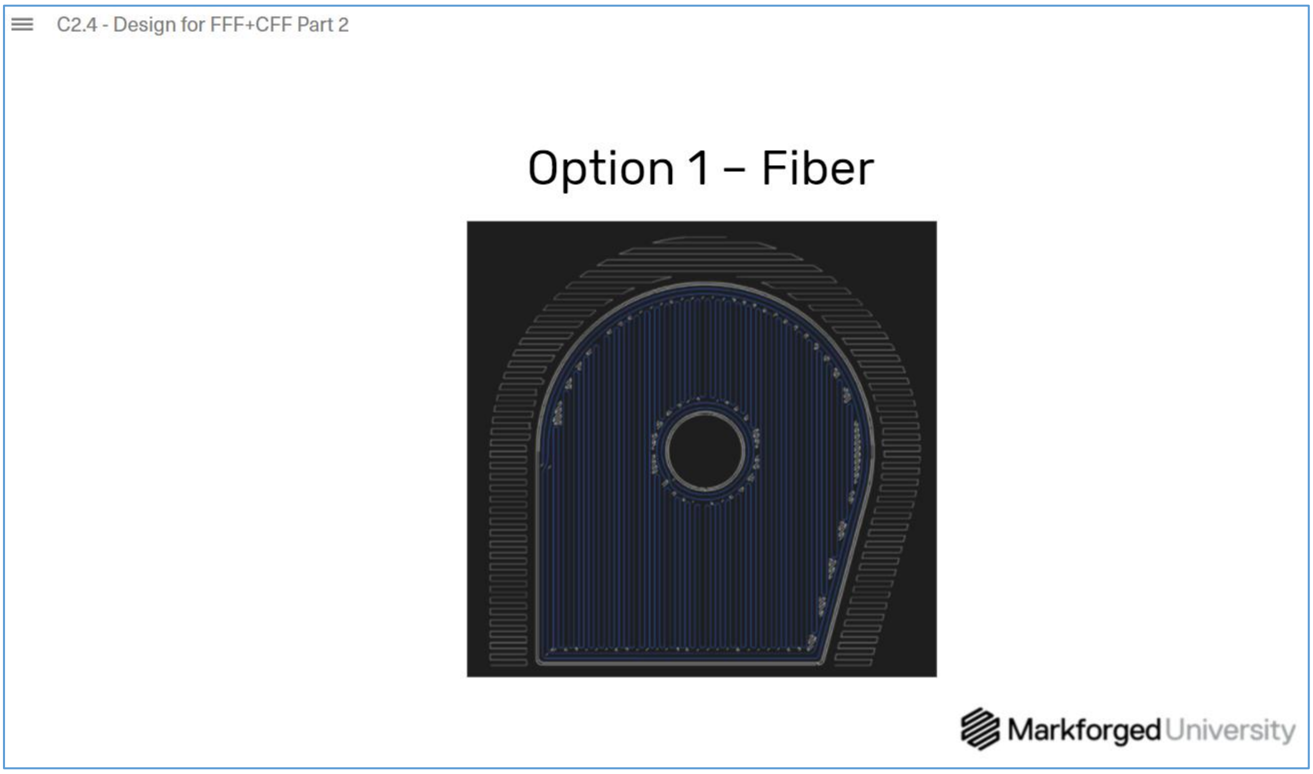


- **Option 1 – Print Construction**

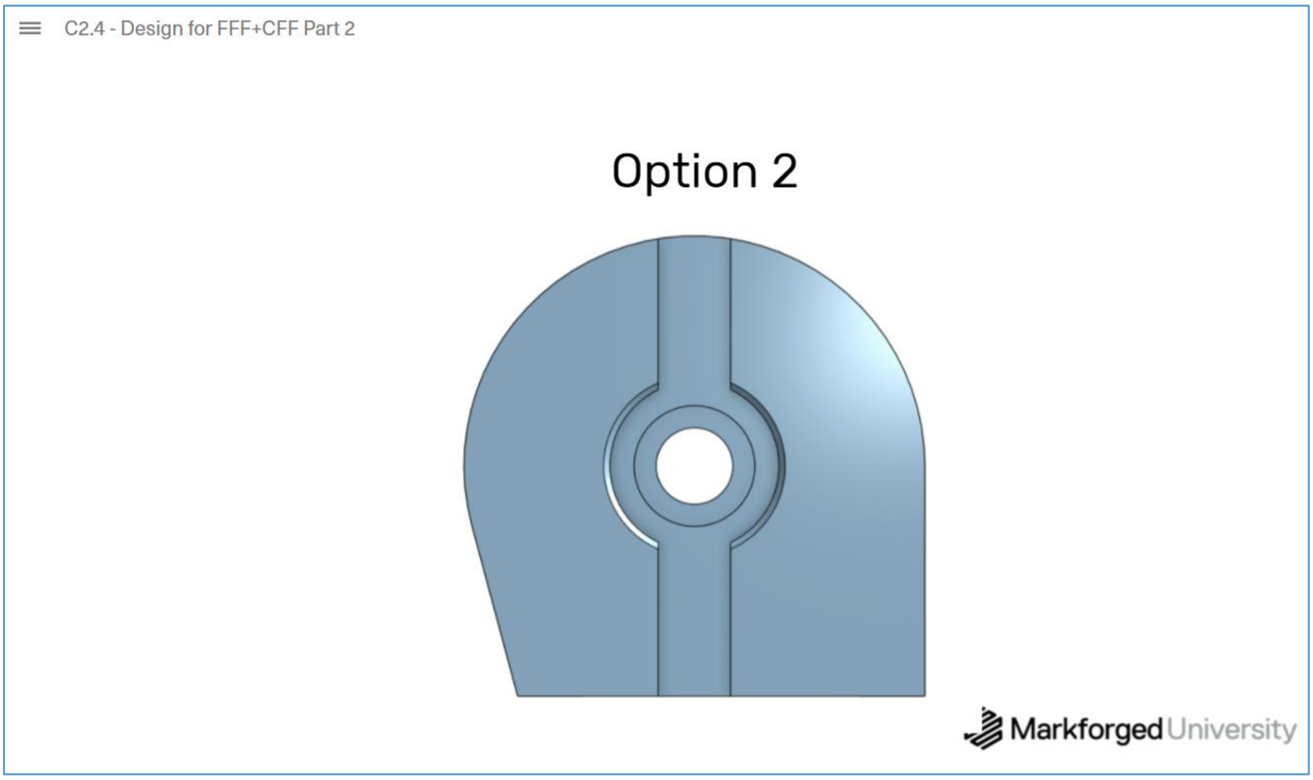




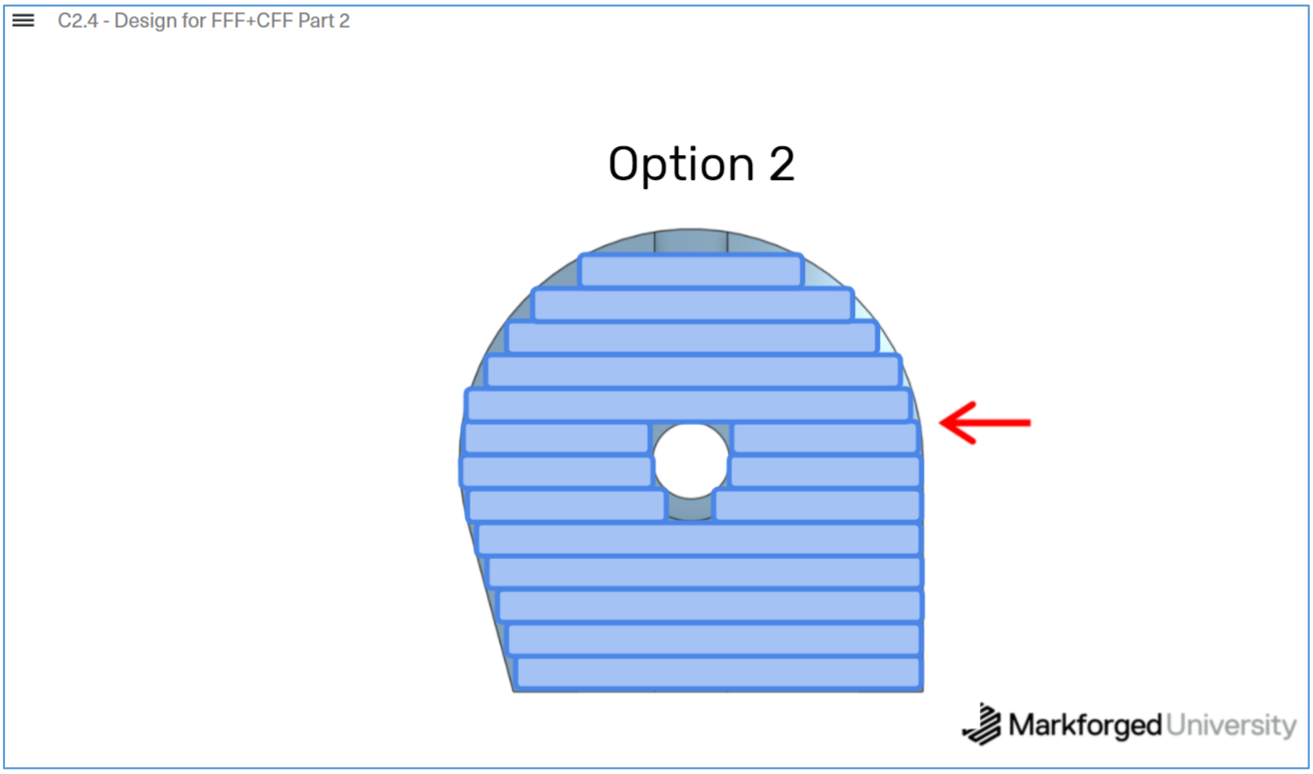
- Shear Force.



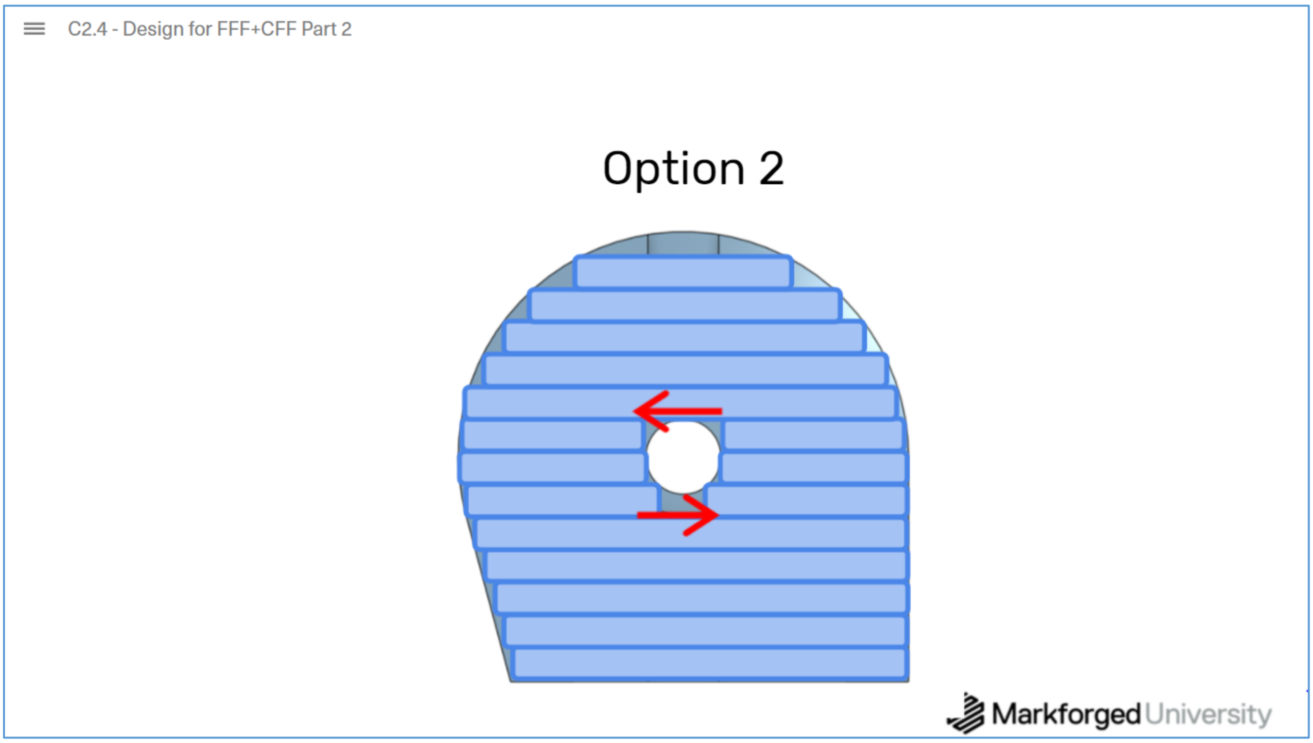
- **Option 1 – Fiber**

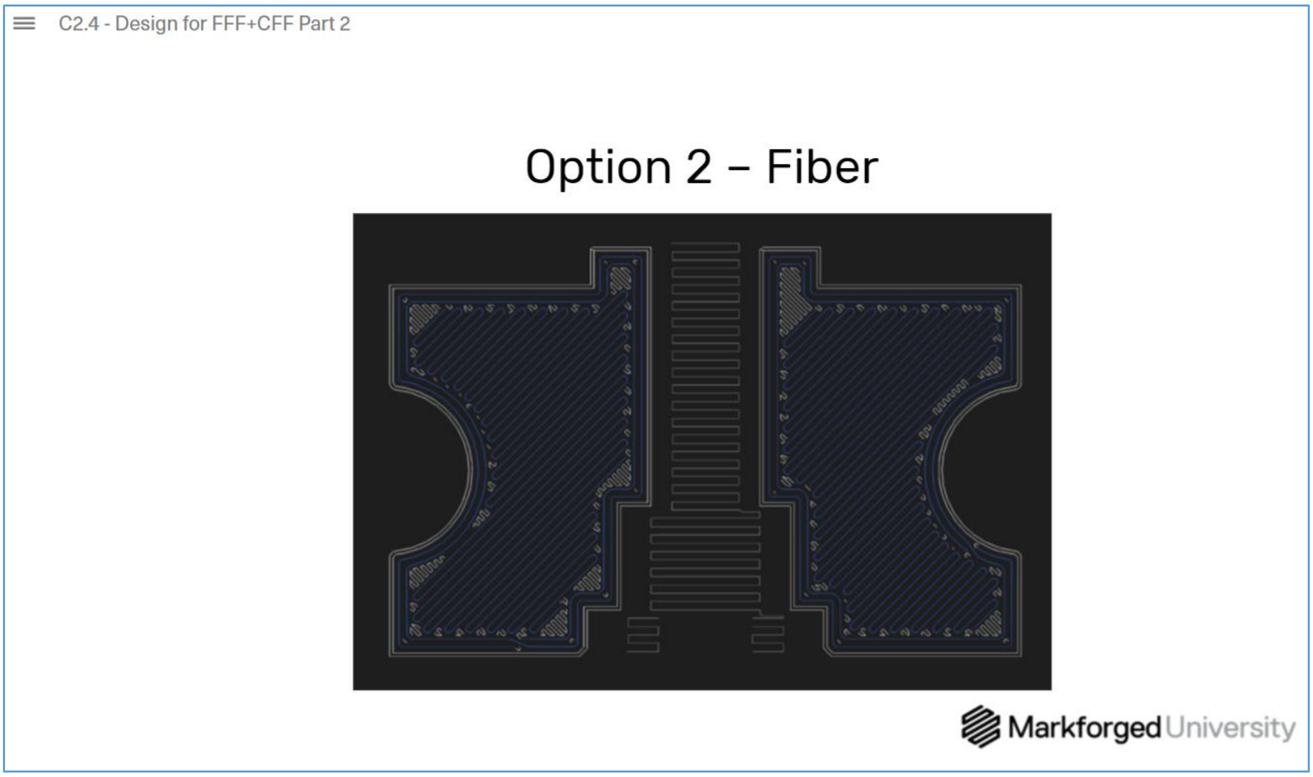


- **Option 2 – Print Construction**

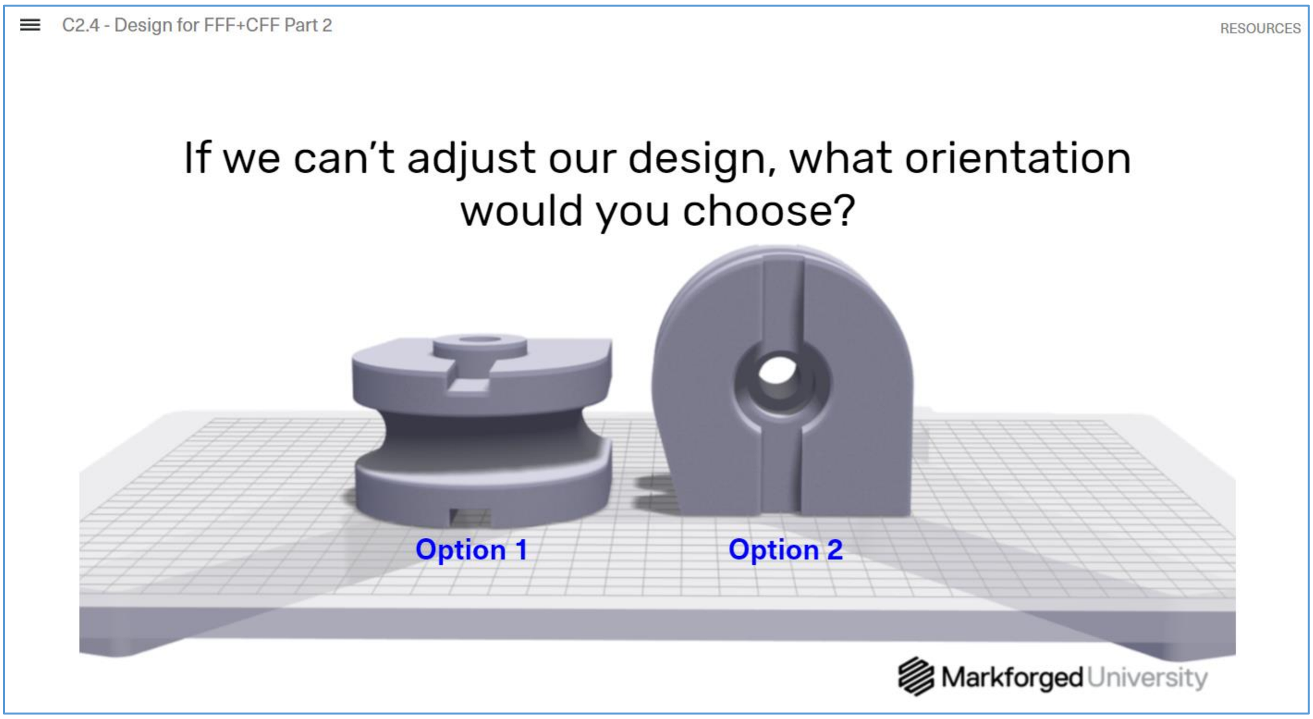


    - Shear Forces

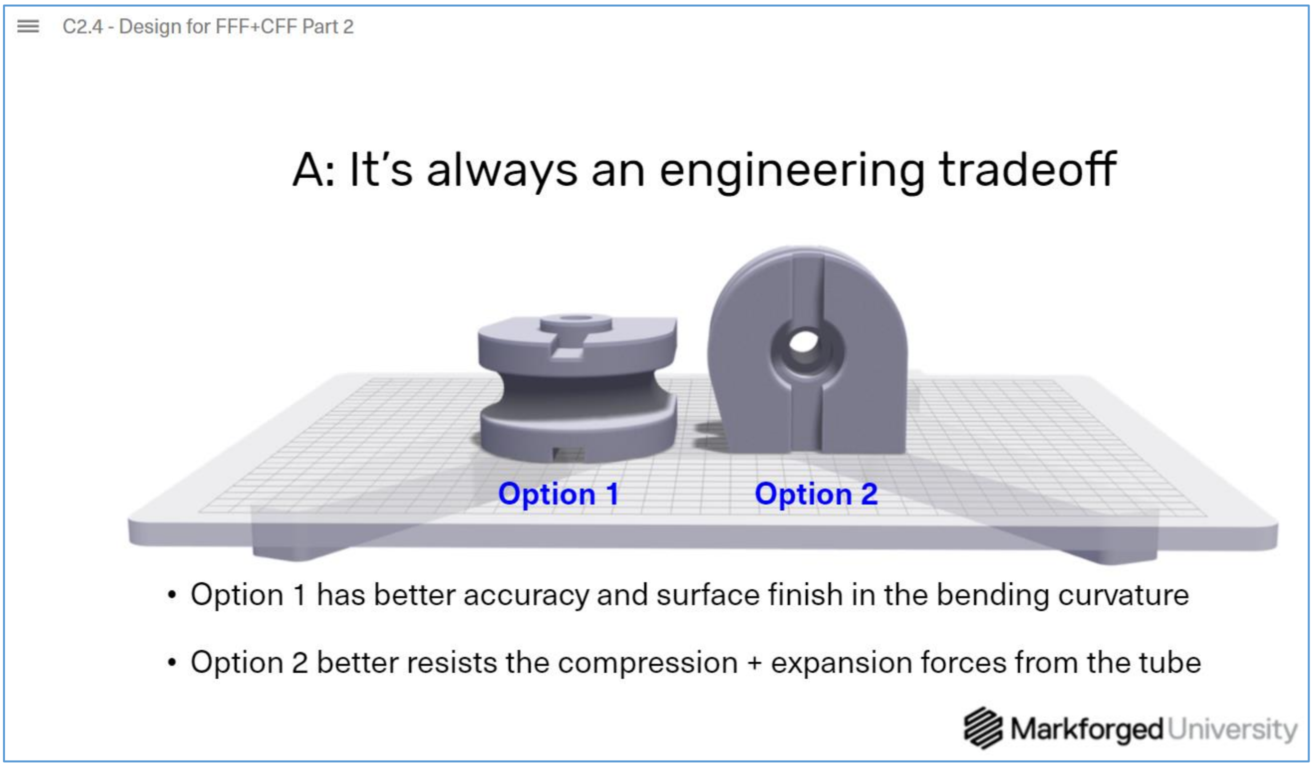




- **Option 2 – Fiber**

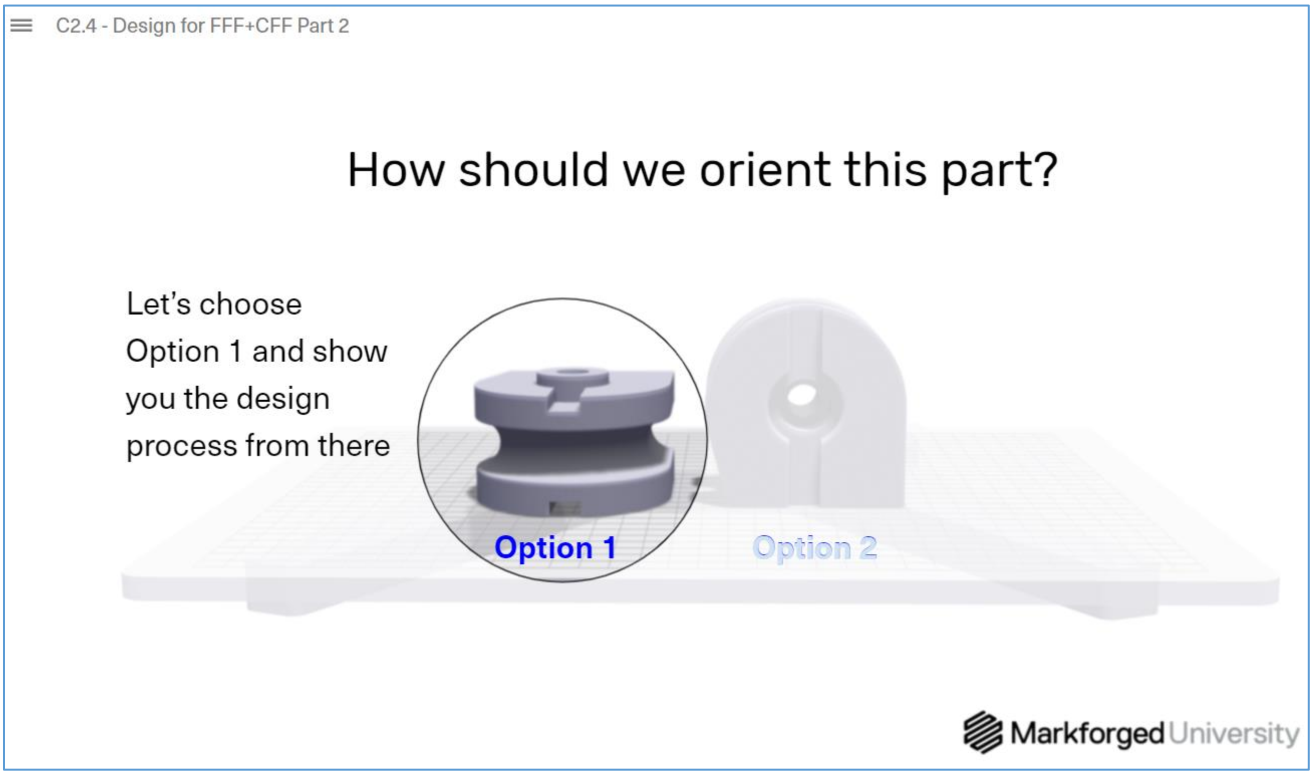


- **What Should We Choose?**

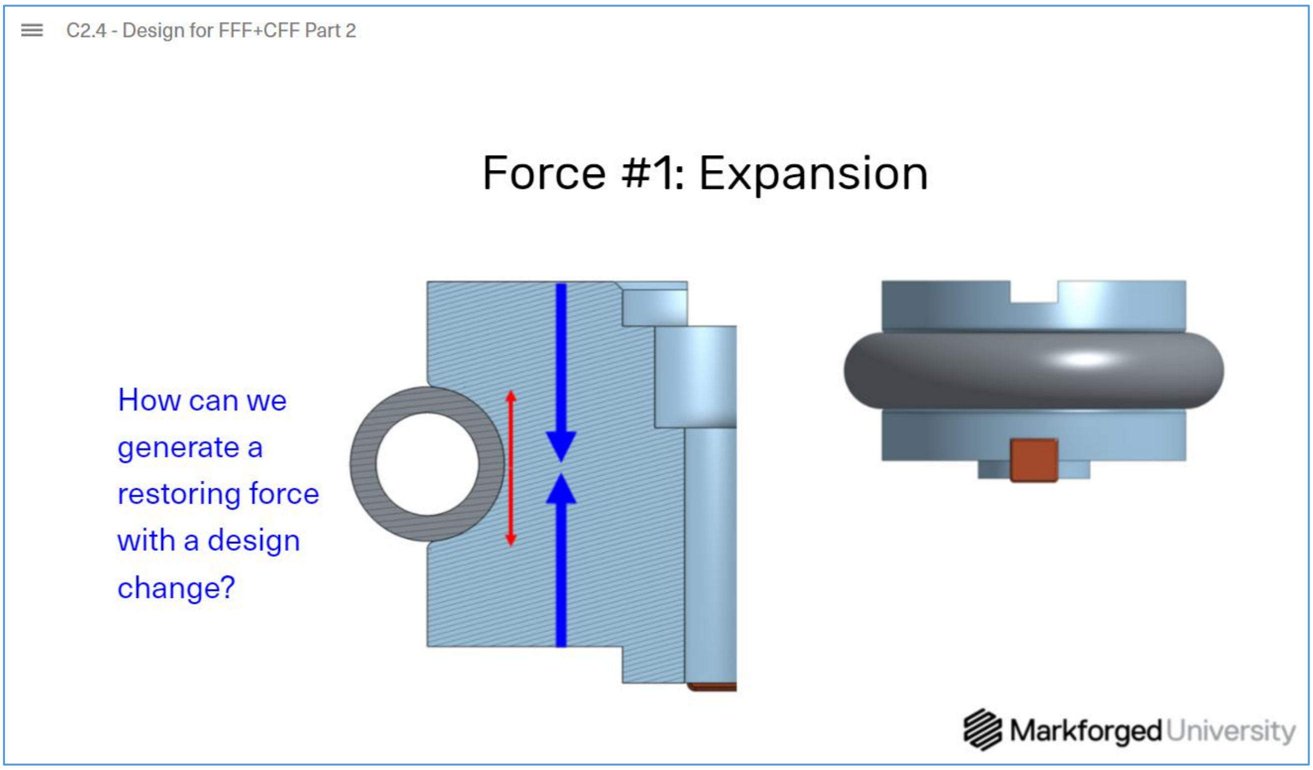


- **A: It's always an engineering tradeoff**
    - Tradeoff = Compromis
    - Curvature = Kromming

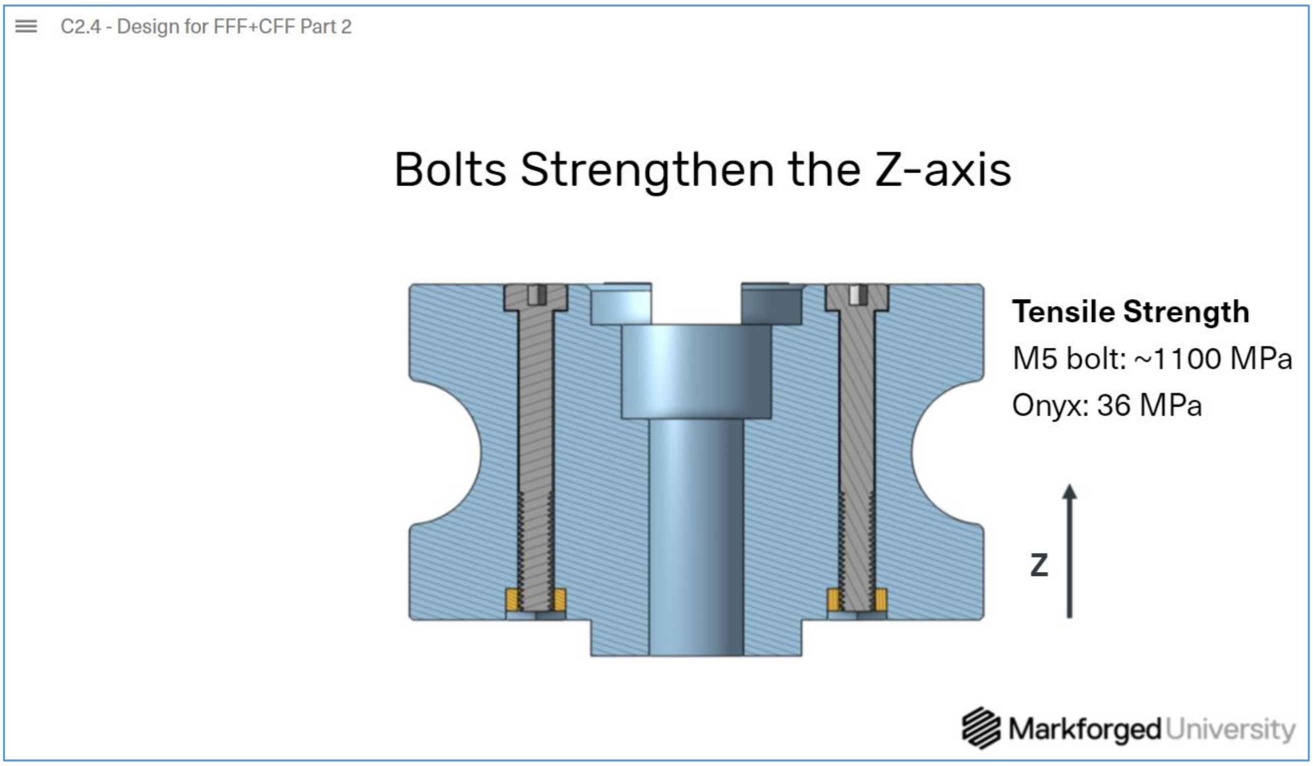
- **Now, let's adjust our design**



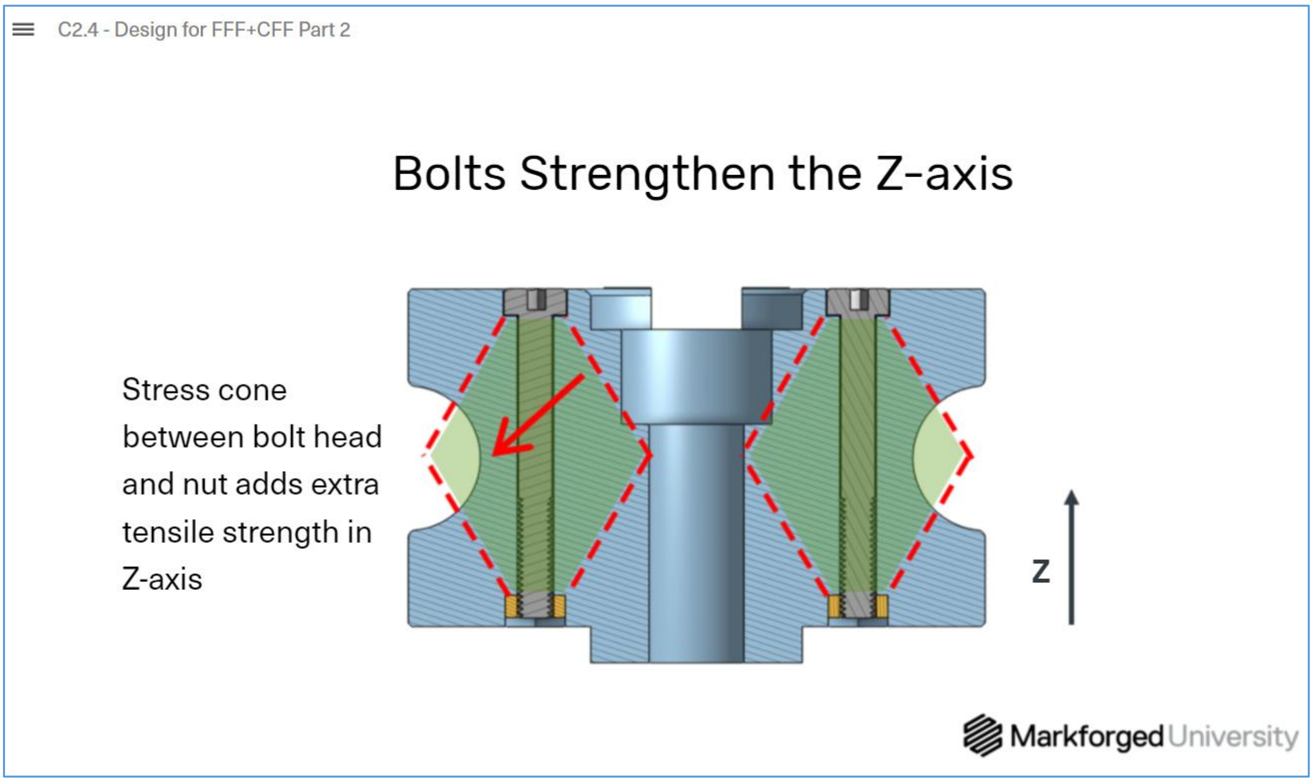
- **How should we orient this part?**



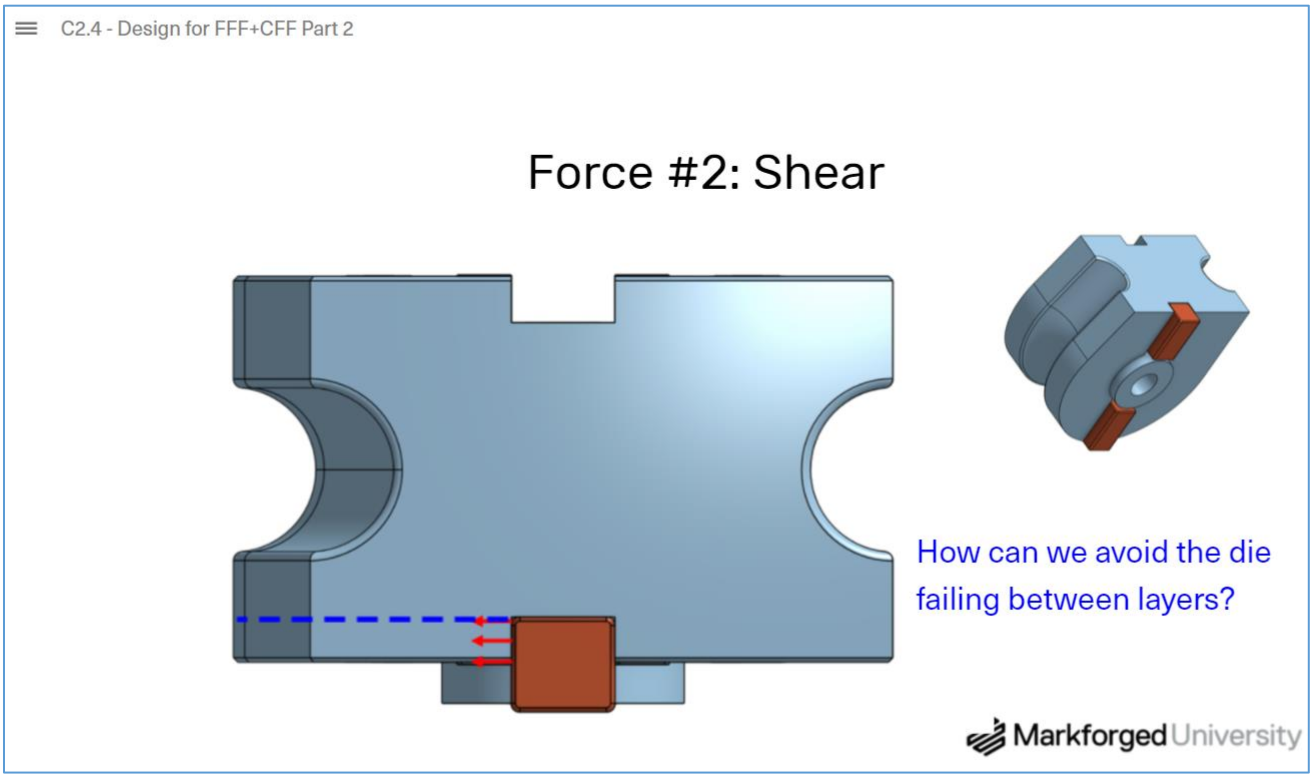
- **Force #1: Expansion**



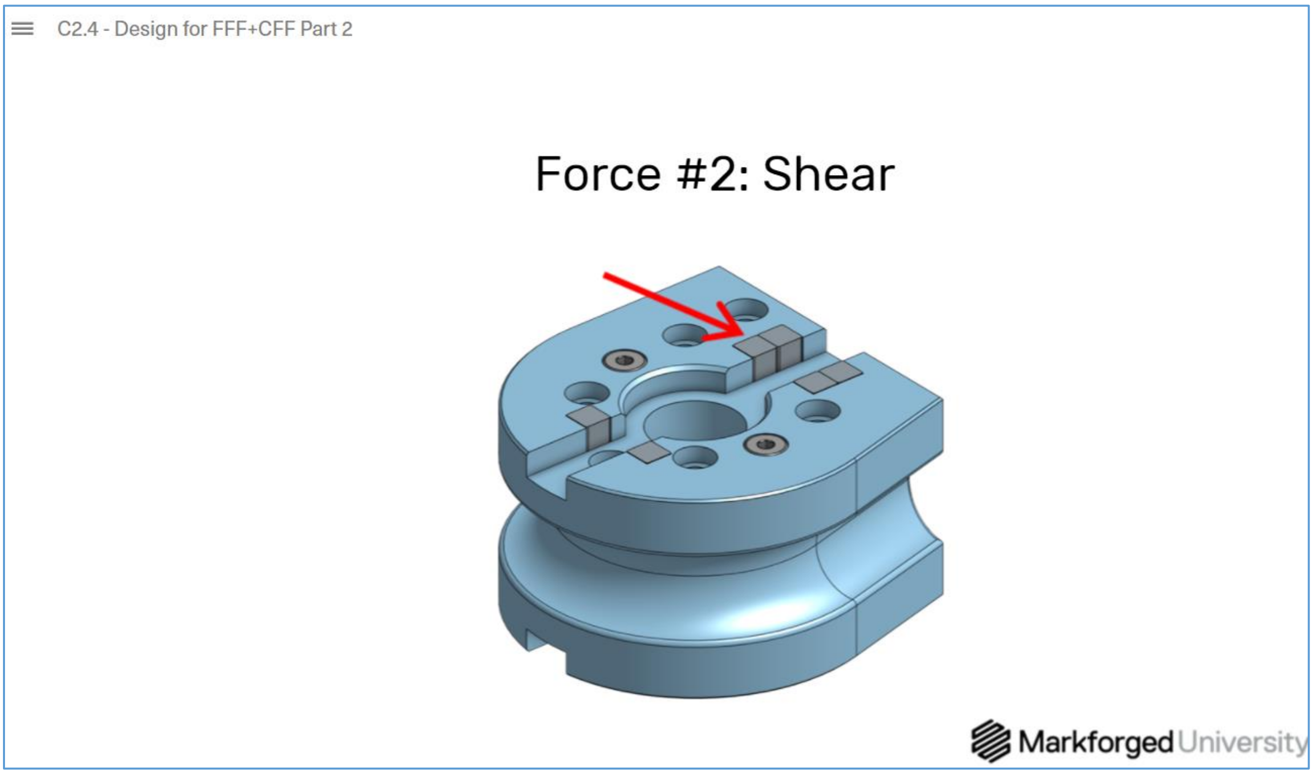
- **Bolts Strengthen the Z-axis**



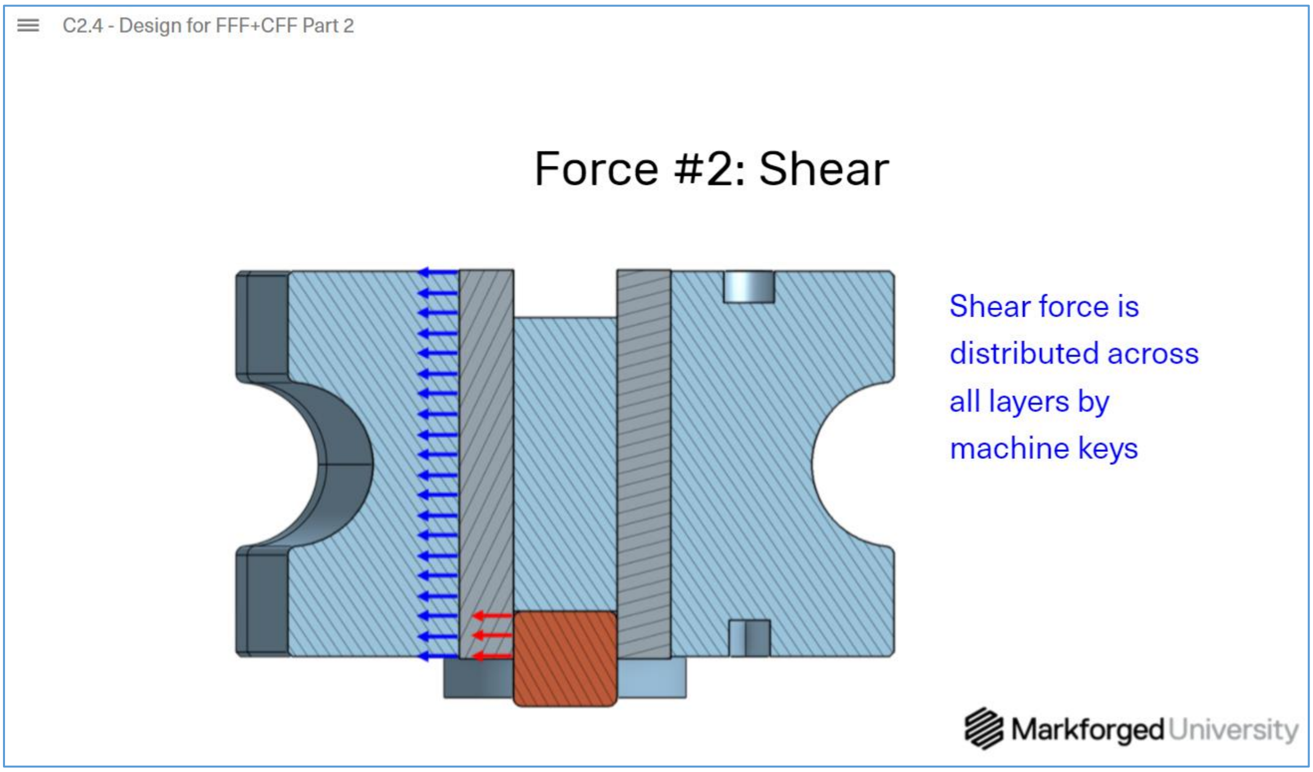
- Insure Area intending to reinforce falls within the cone

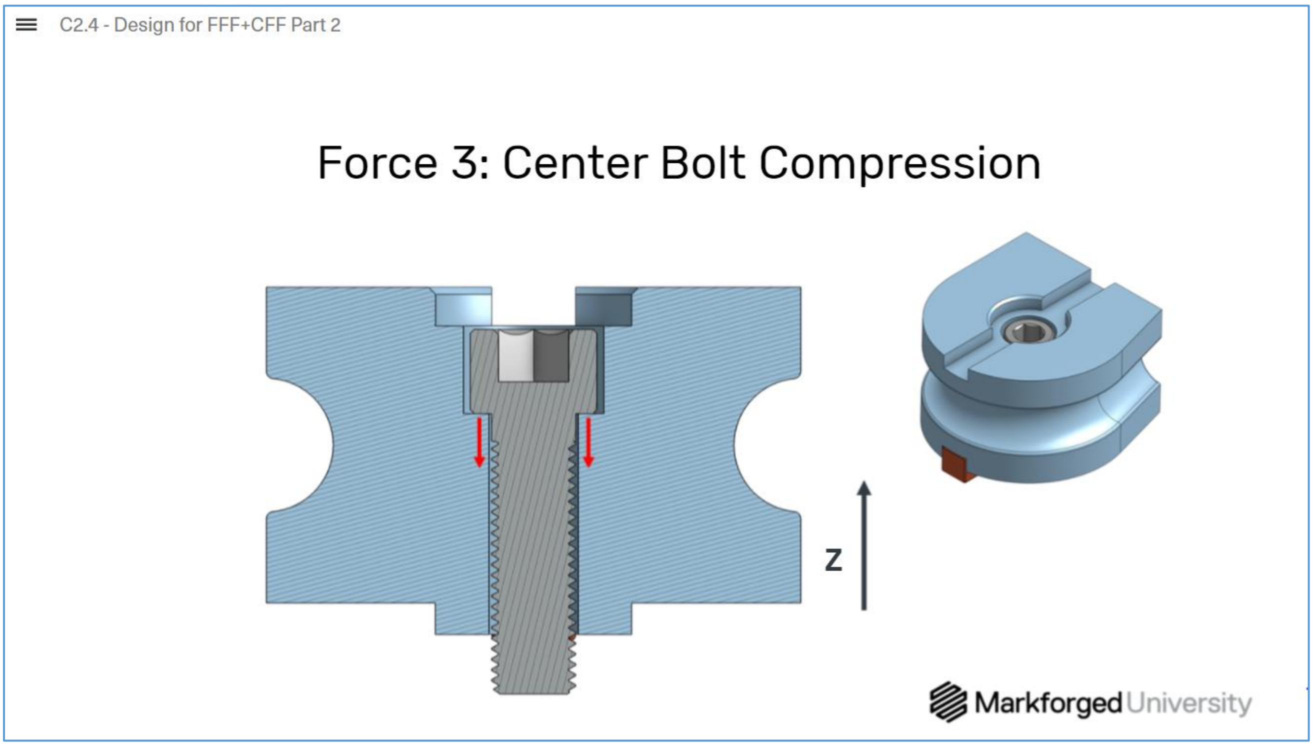


- **Force #2: Shear**

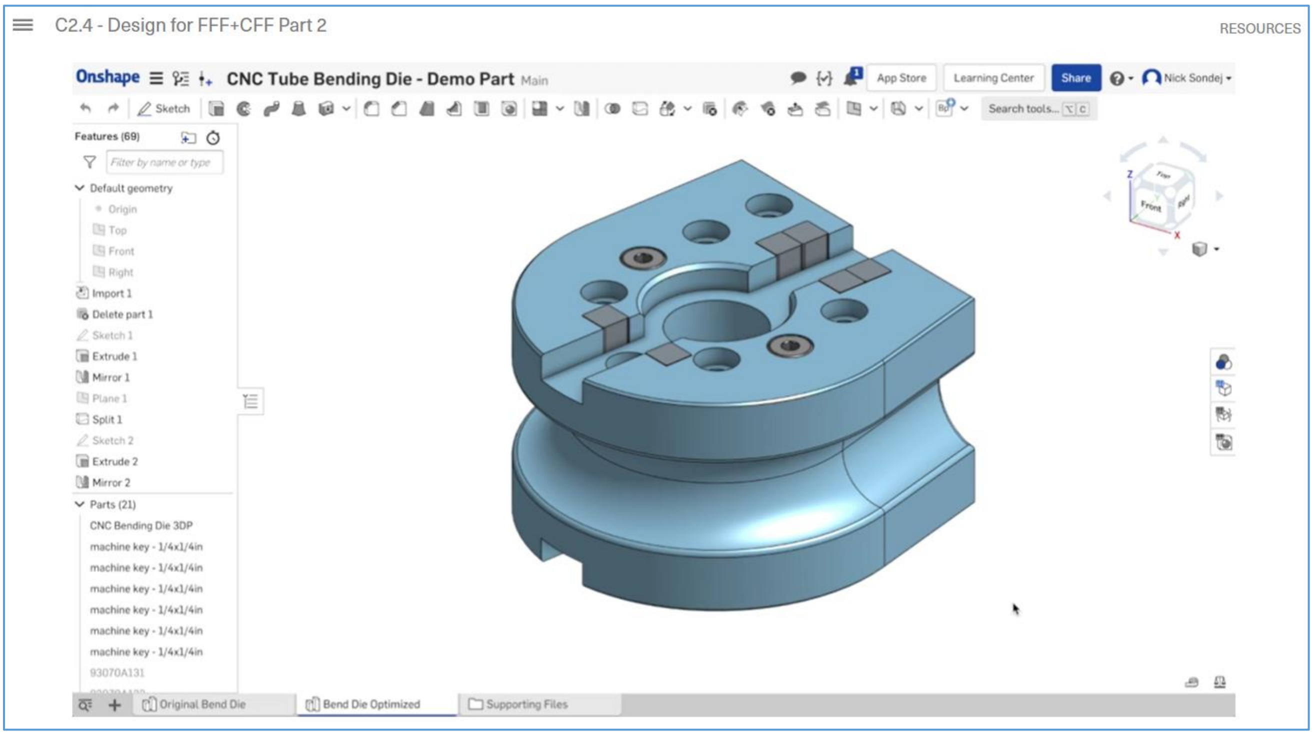


- **Steel Stock Distributes Shear Forces**
    - Shear Forces = Afschuifkrachten

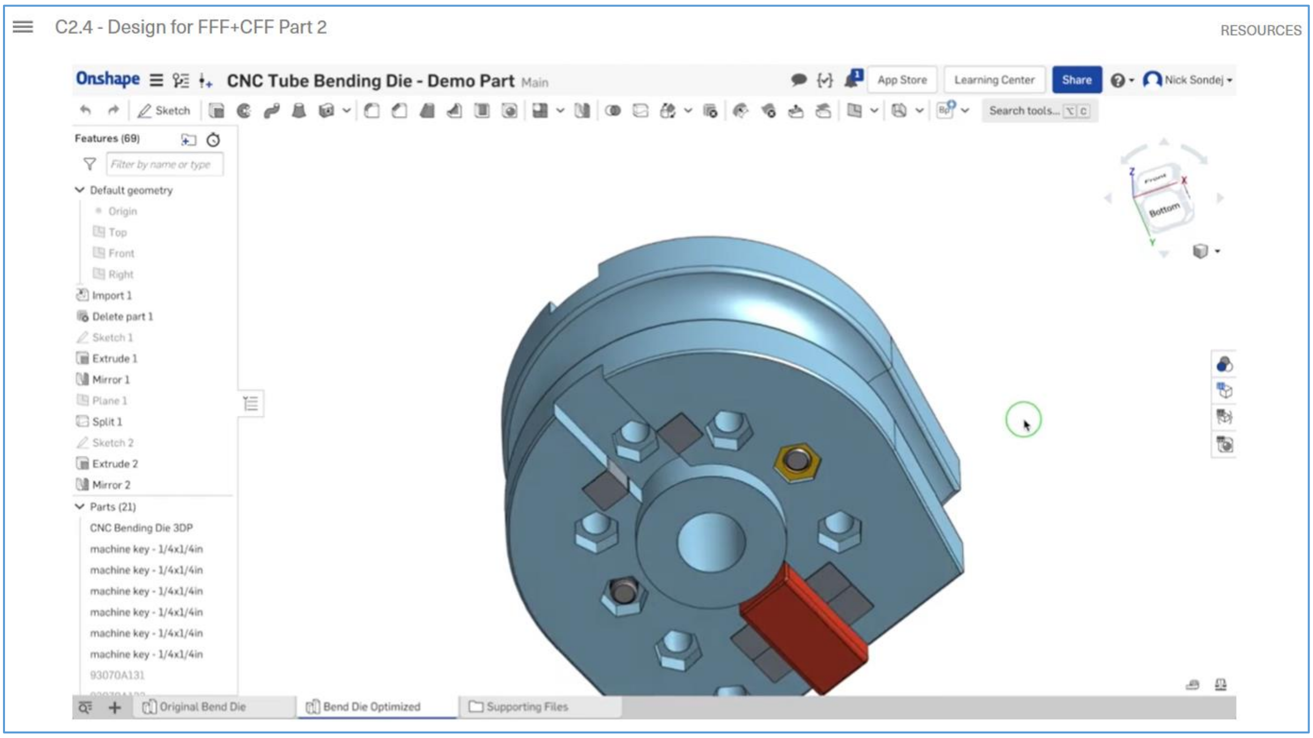




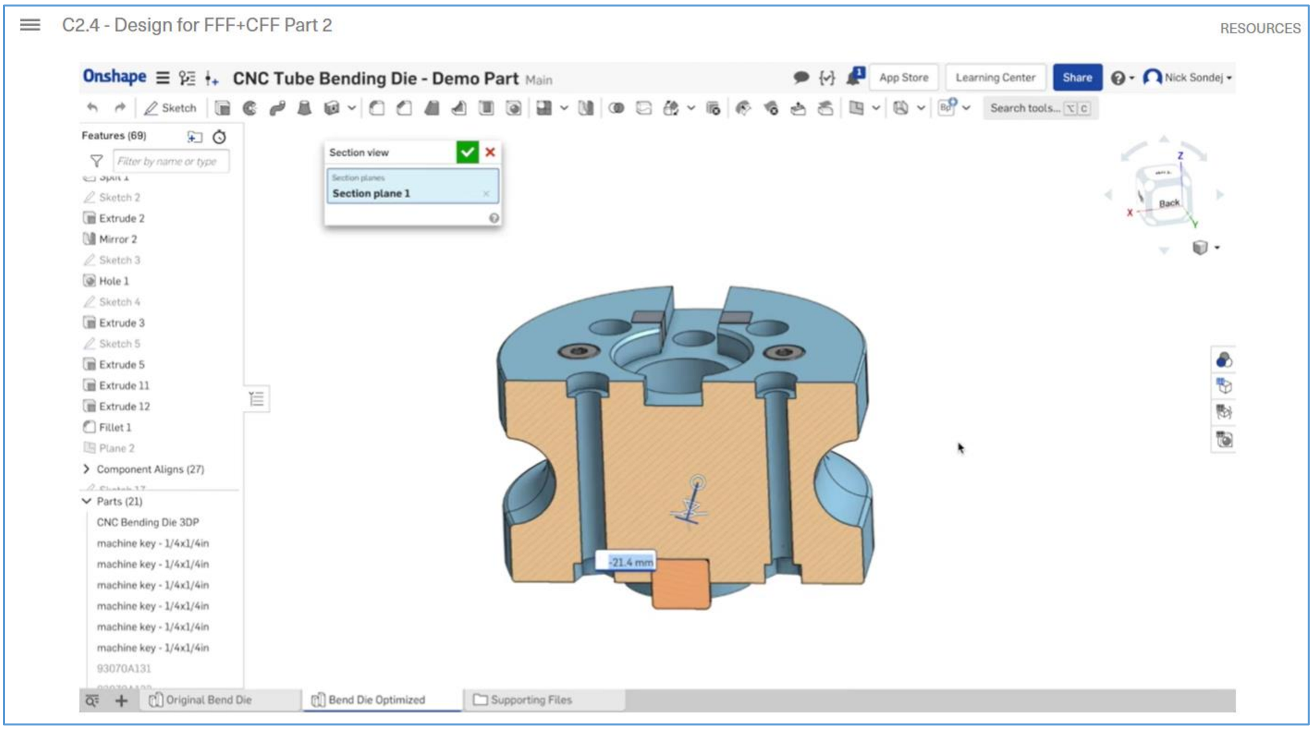
- **Force #3: Center Bolt Compression**
    - Could also redesign with a flanged bushing, but in this case not reallfpy necessary



- **CAD Demo: Revising an Existing Design**



C2.4 - Design for FFF+CFF Part 2
RESOURCES
Onshape
CNC Tube Bending Die - Demo Part Main
App Store
Learning Center
Share
Nick Sondej
Sketch
Search tools...
Features (69)
Filter by name or type
Default geometry
Origin
Top
Front
Right
Import 1
Delete part 1
Sketch 1
Extrude 1
Mirror 1
Plane 1
Split 1
Sketch 2
Extrude 2
Mirror 2
Parts (21)
CNC Bending Die 3DP
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
93070A131
Original Bend Die
Bend Die Optimized
Supporting Files



C2.4 - Design for FFF+CFF Part 2
RESOURCES
Onshape
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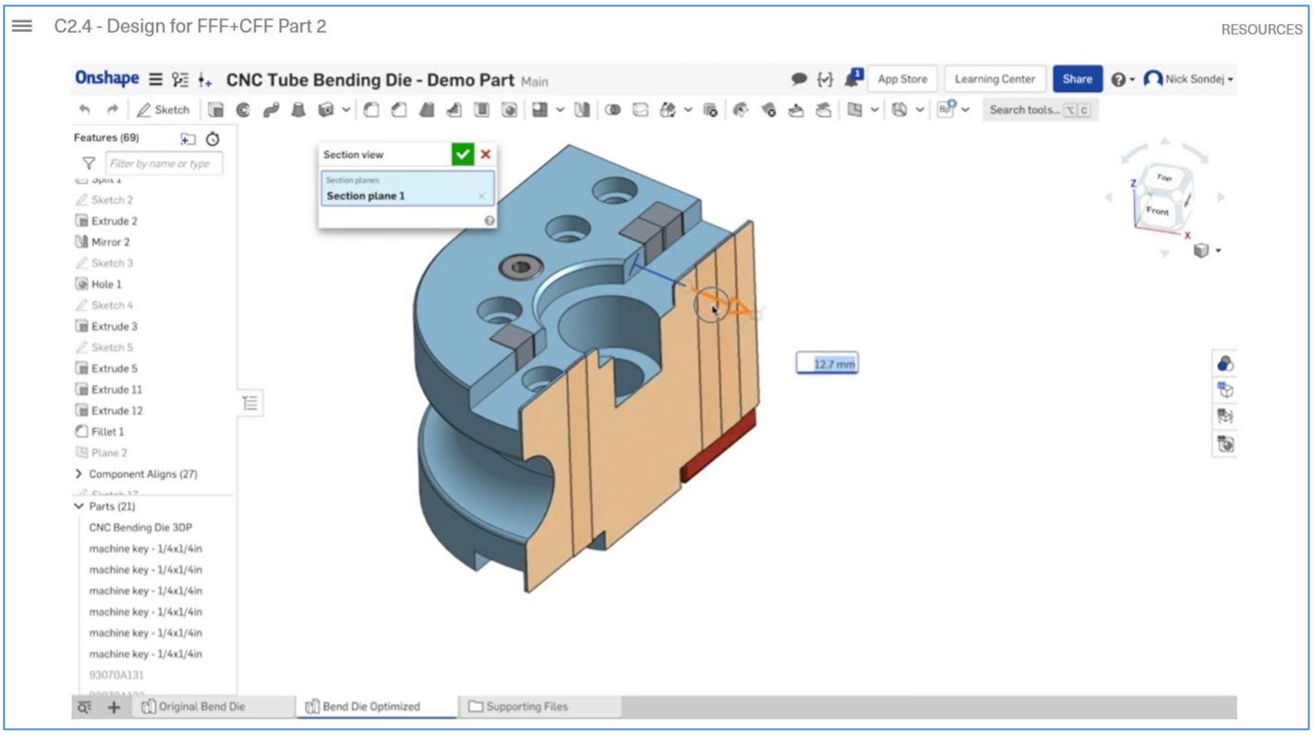
Nick Sondej
Sketch
Search tools...
Features (69)
Filter by name or type
Section view
Section planes
Section plane 1
Sketch 2
Extrude 2
Mirror 2
Sketch 3
Hole 1
Sketch 4
Extrude 3
Sketch 5
Extrude 5
Extrude 11
Extrude 12
Fillet 1
Plane 2
Component Aligns (27)
Parts (21)
CNC Bending Die 3DP
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
machine key - 1/4x1/4in
93070A131
-21.4 mm
Back
Original Bend Die
Bend Die Optimized
Supporting Files


C2.4 - Design for FFF+CFF Part 2
RESOURCES
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CNC Tube Bending Die - Demo Part
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Nick Sondej
Features (69)
Section view
Section plane 1
Sketch 2
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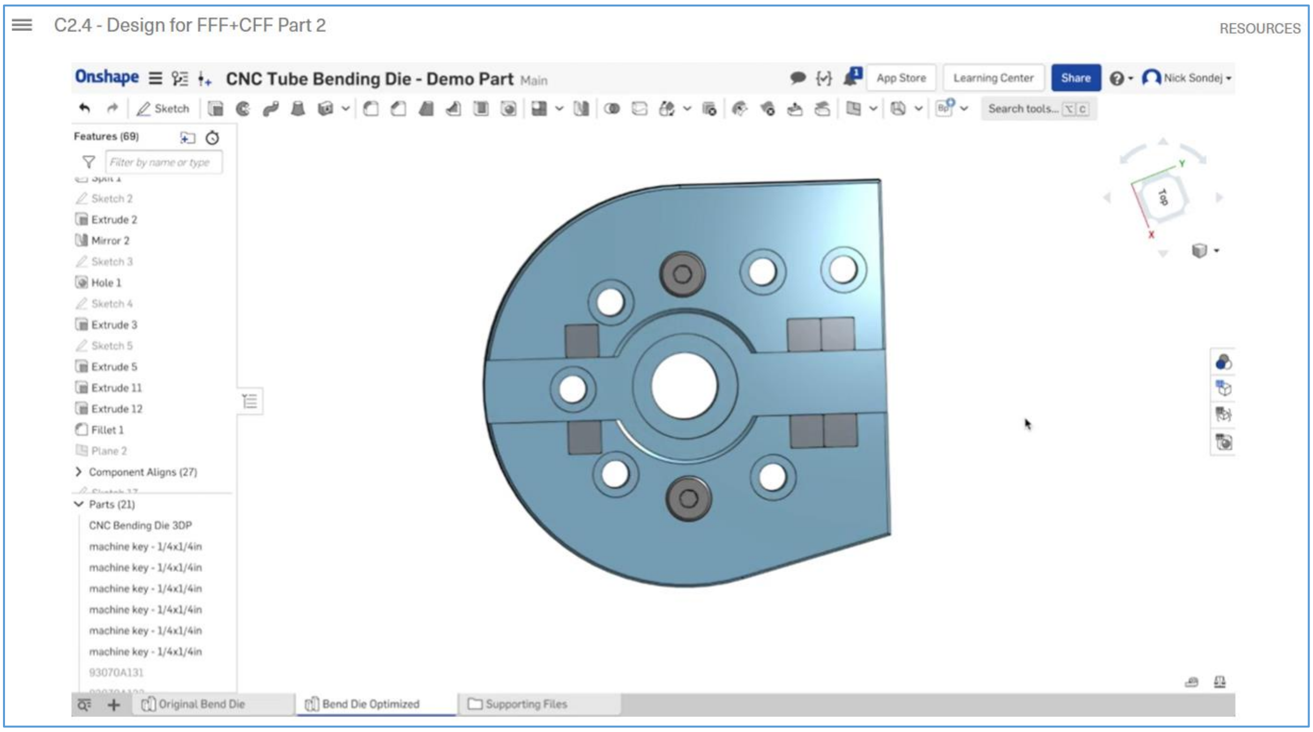
Sketch 4
Extrude 3
Sketch 5
Extrude 5
Extrude 11
Extrude 12
Fillet 1
Plane 2
Component Aligns (27)
Parts (21)
CNC Bending Die 3DP
machine key - 1/4x1/4in
93070A131
12.7 mm
Original Bend Die
Bend Die Optimized
Supporting Files


C2.4 - Design for FFF+CFF Part 2
RESOURCES
Onshape
CNC Tube Bending Die - Demo Part
App Store
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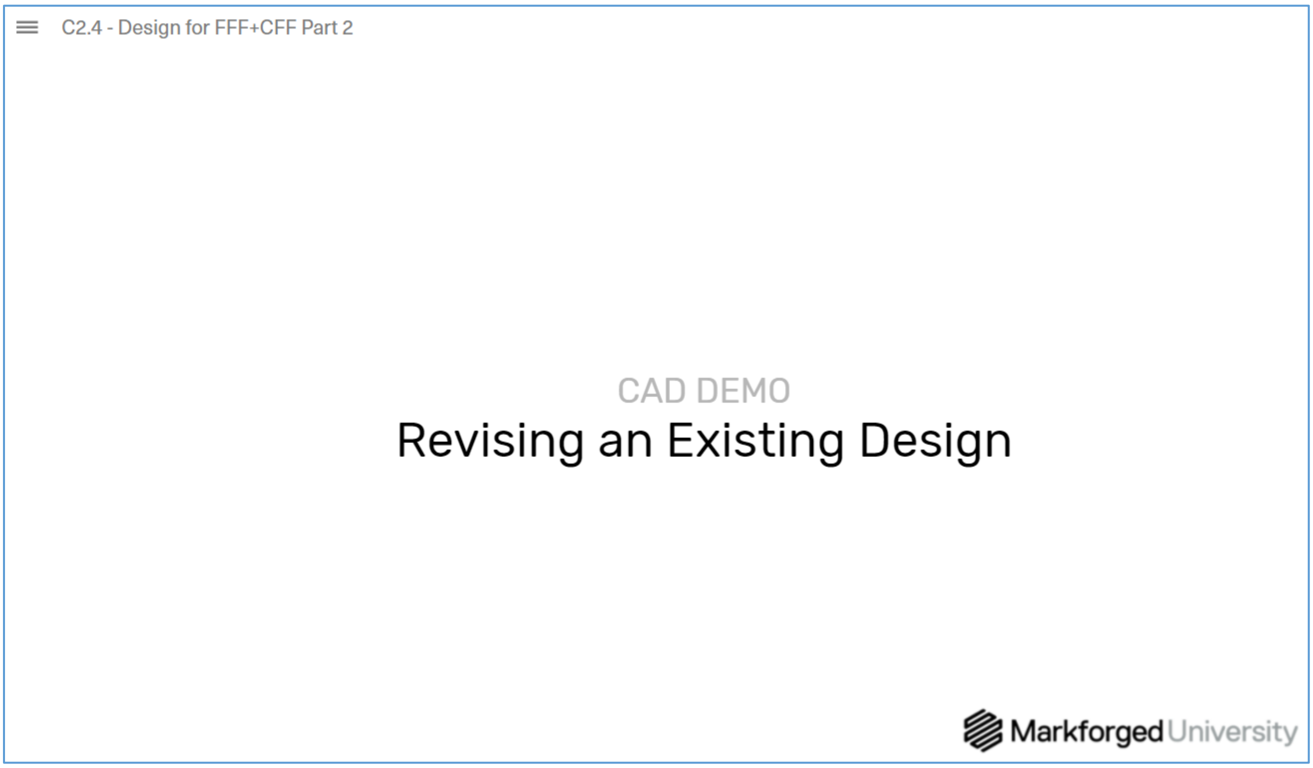
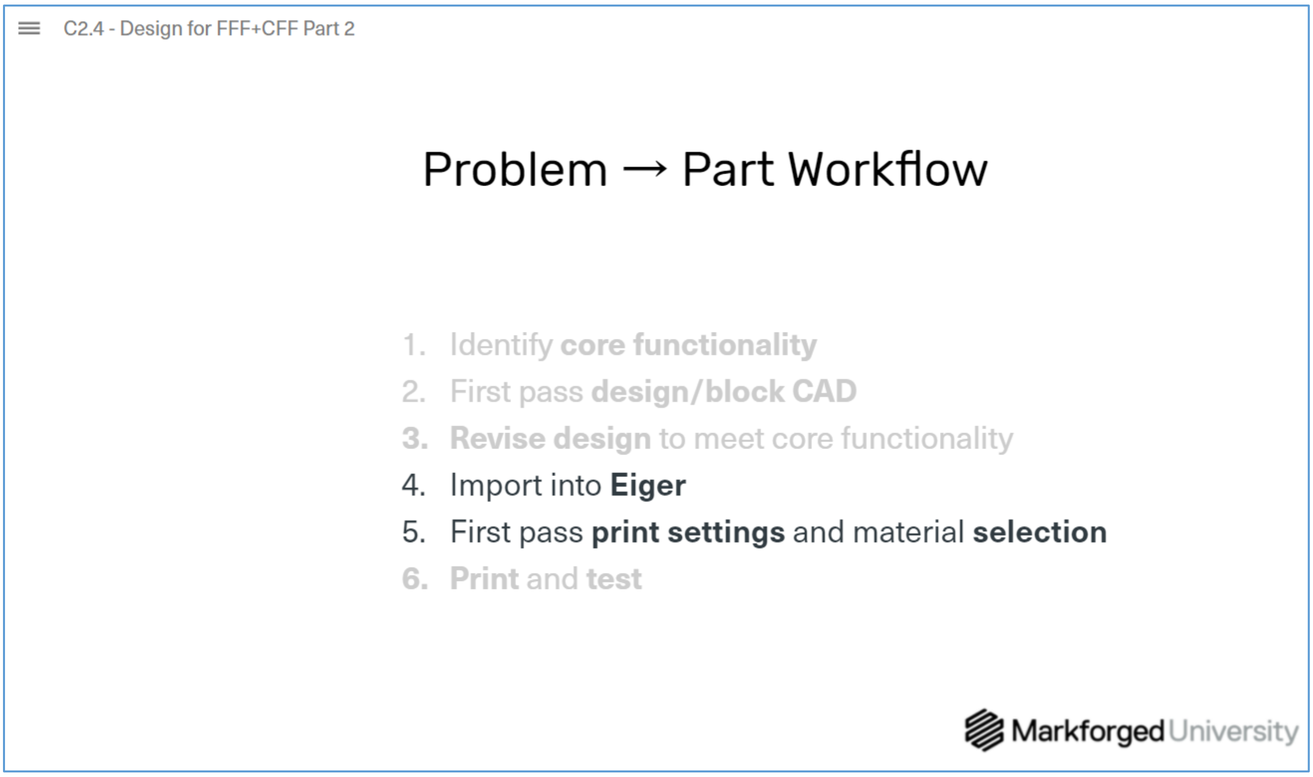
Nick Sondej
Features (69)
Sketch 2
Extrude 2
Mirror 2
Sketch 3
Hole 1
Sketch 4
Extrude 3
Sketch 5
Extrude 5
Extrude 11
Extrude 12
Fillet 1
Plane 2
Component Aligns (27)
Parts (21)
CNC Bending Die 3DP
machine key - 1/4x1/4in
93070A131
Original Bend Die
Bend Die Optimized
Supporting Files

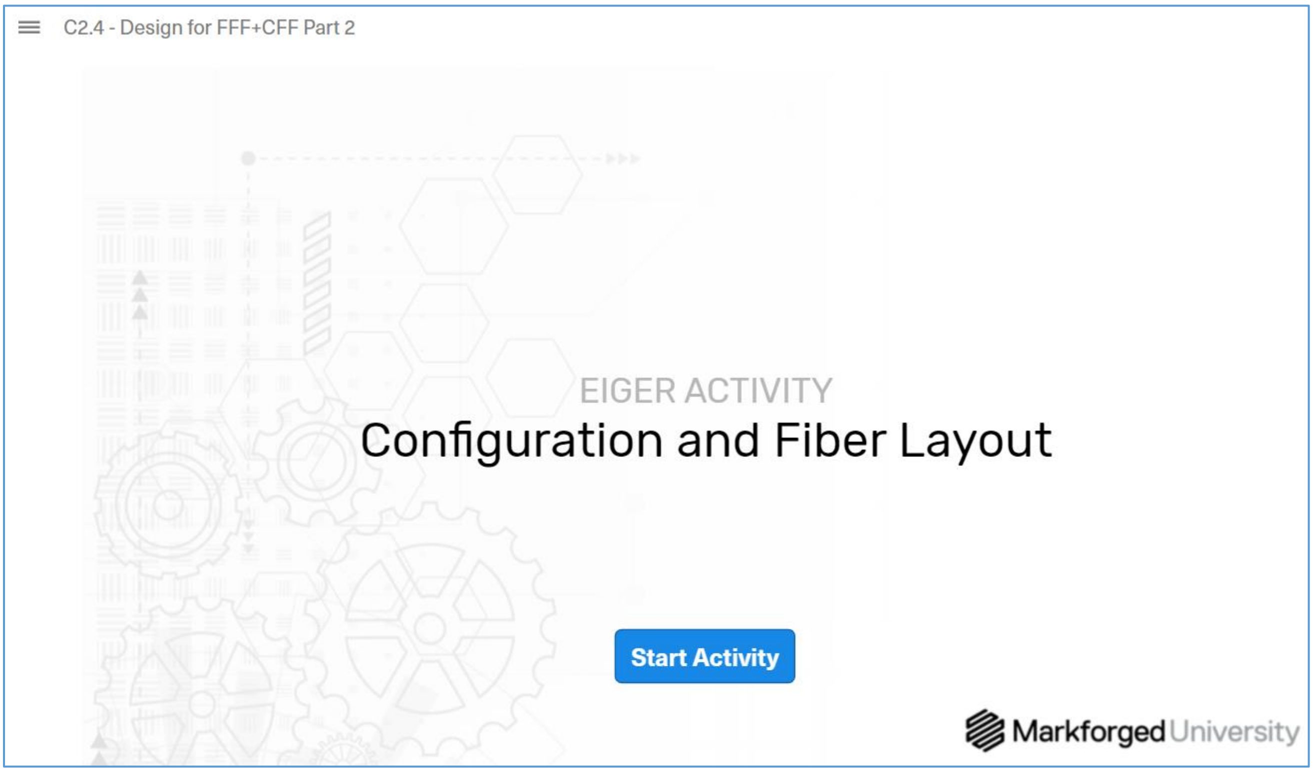
- Drive fit.



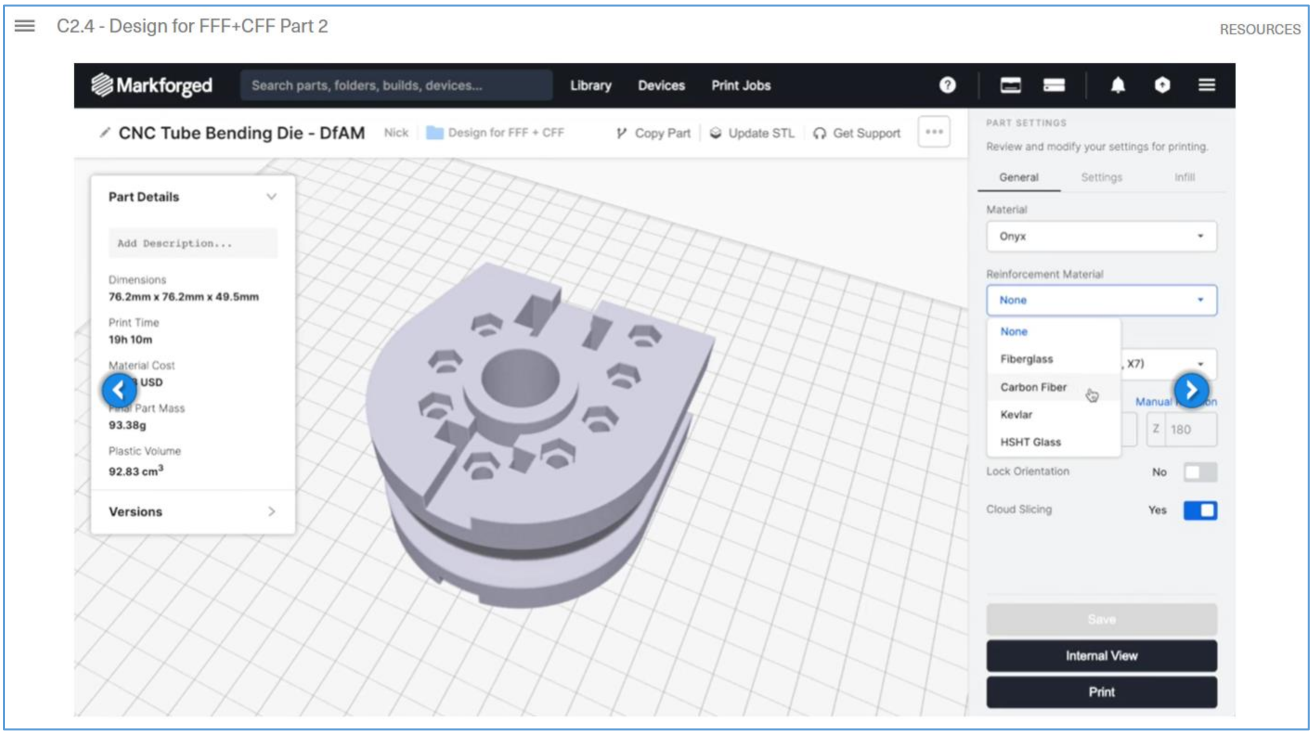
- **CAD Demo: Revising an Existing Design**



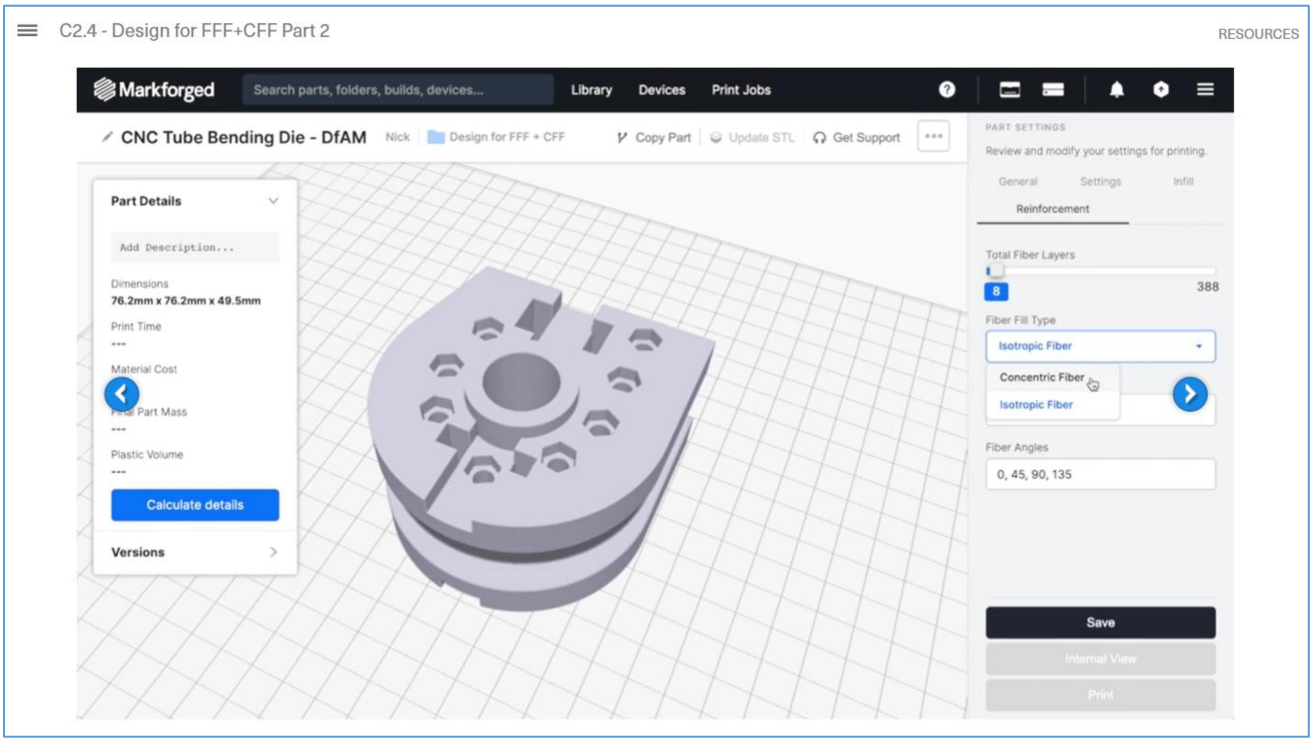
- **Step 4/5: Eiger Configuration**



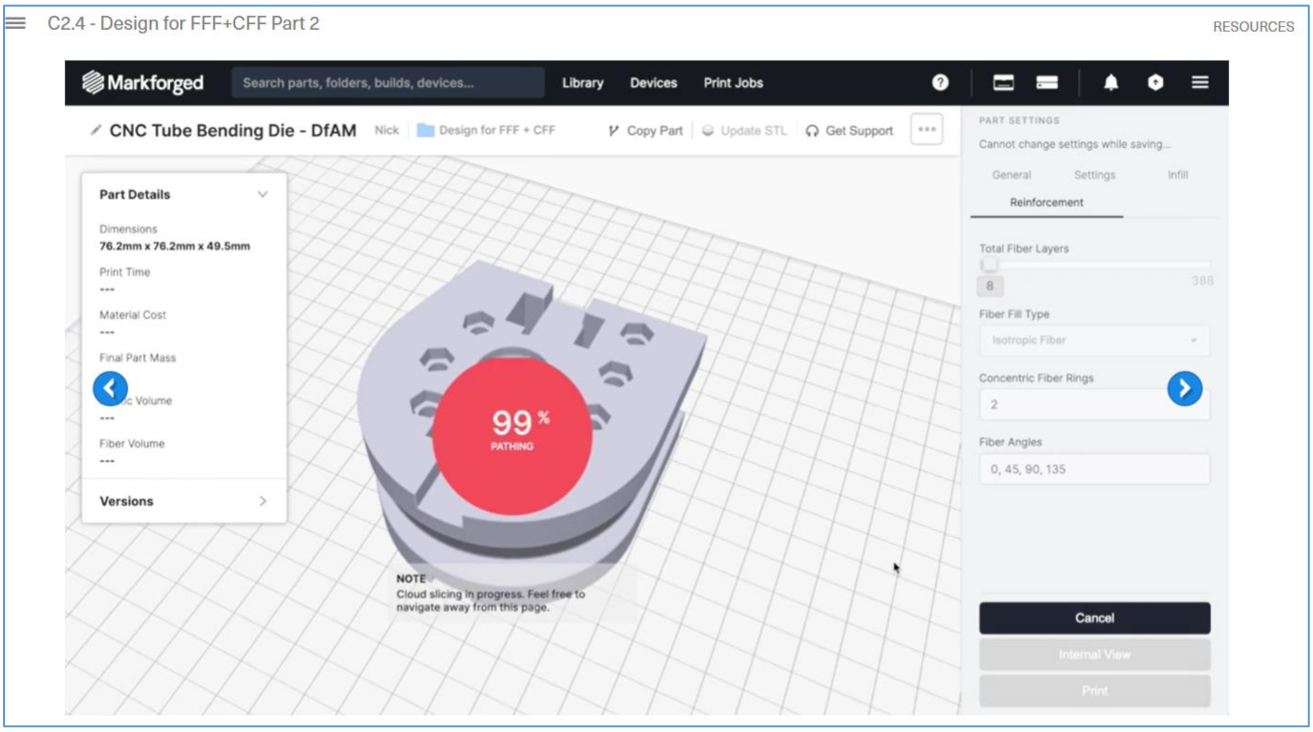
- **Eiger Activity: Configuration and Fiber Layout**



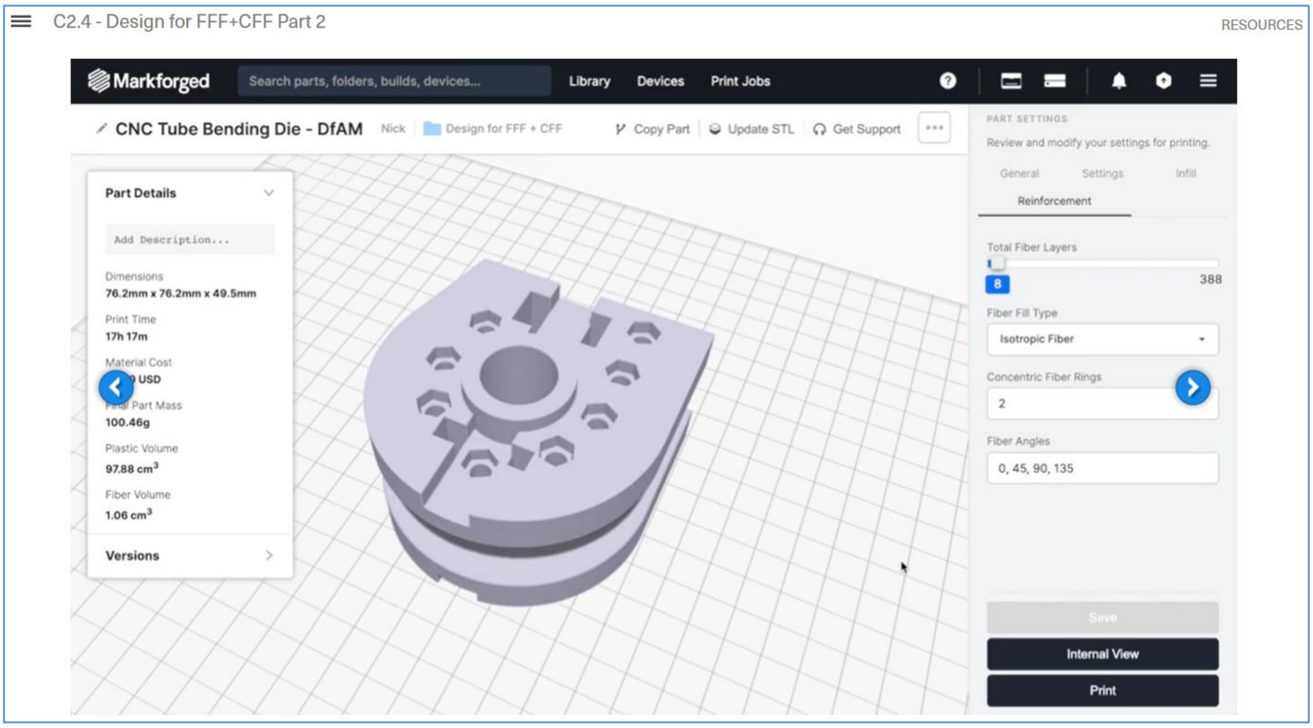
    ○ Reinforcement Material: Highest strength > Carbon Fiber



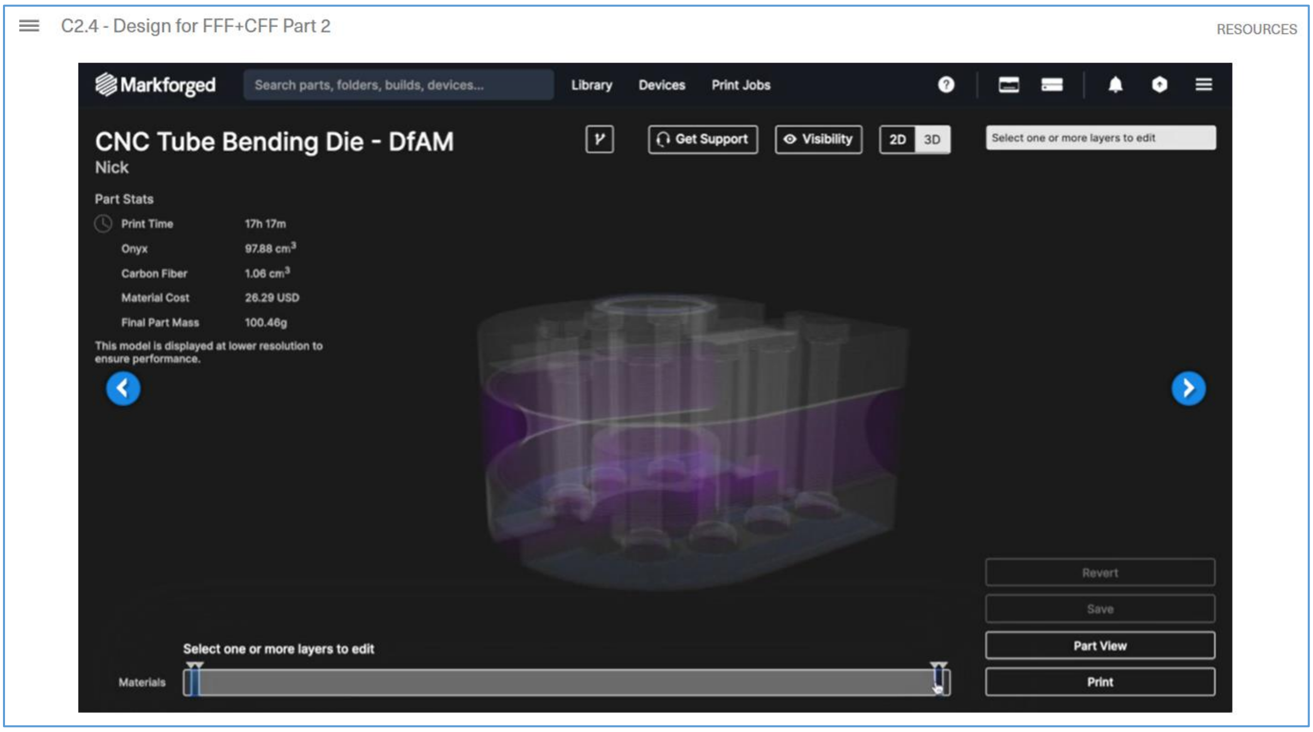
- Reinforcement: Isotropic Fiber



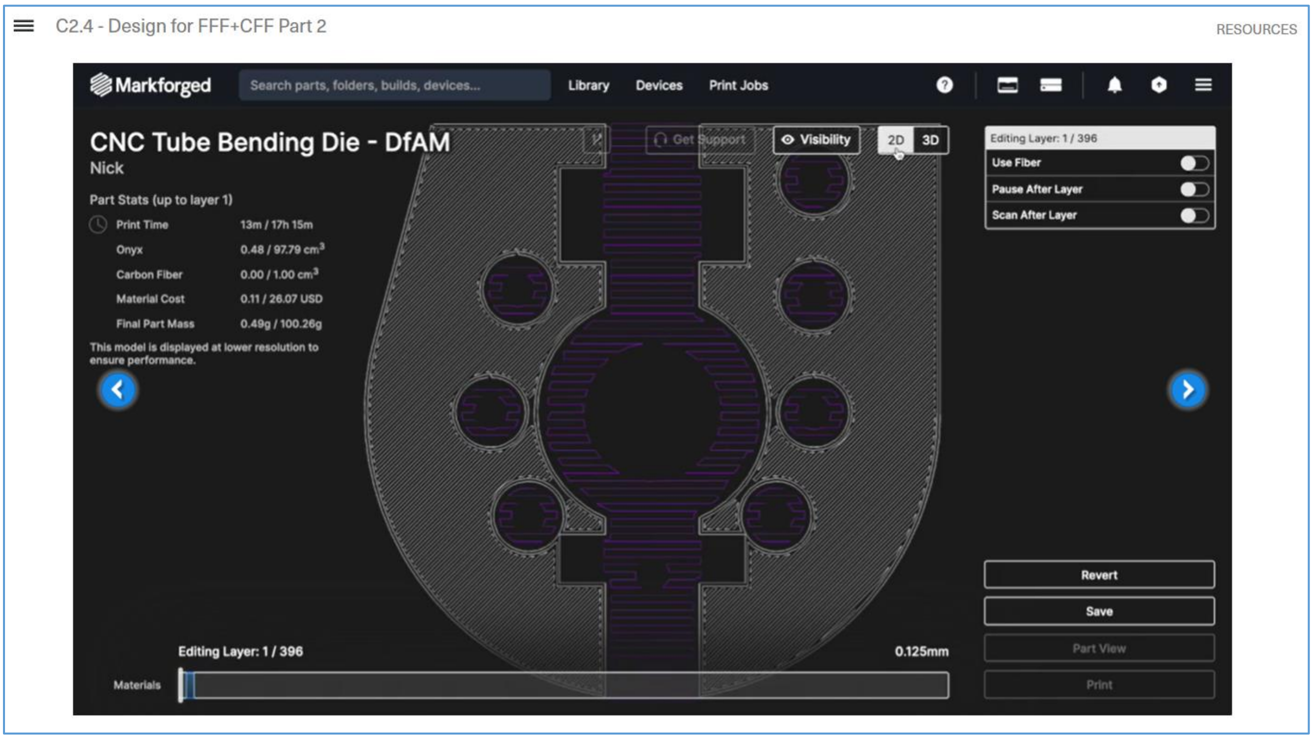
- Save it.



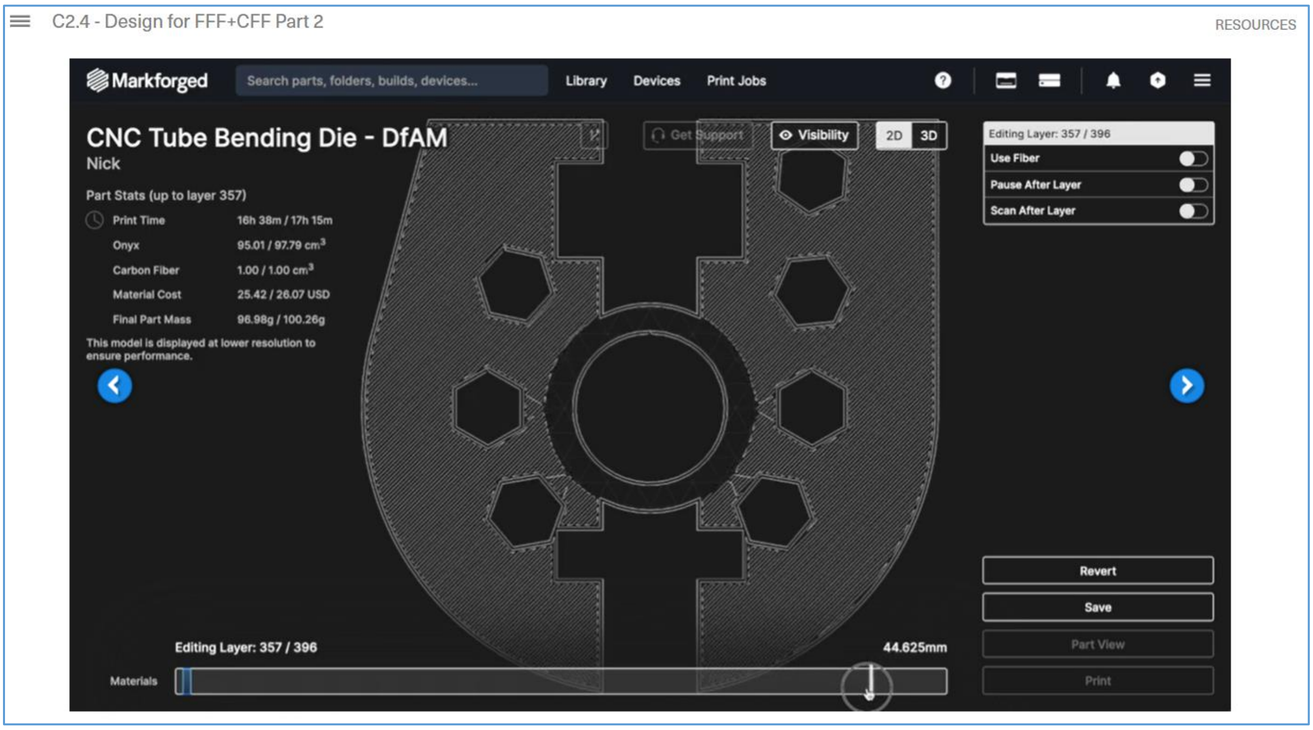
- Click on Internal View Button



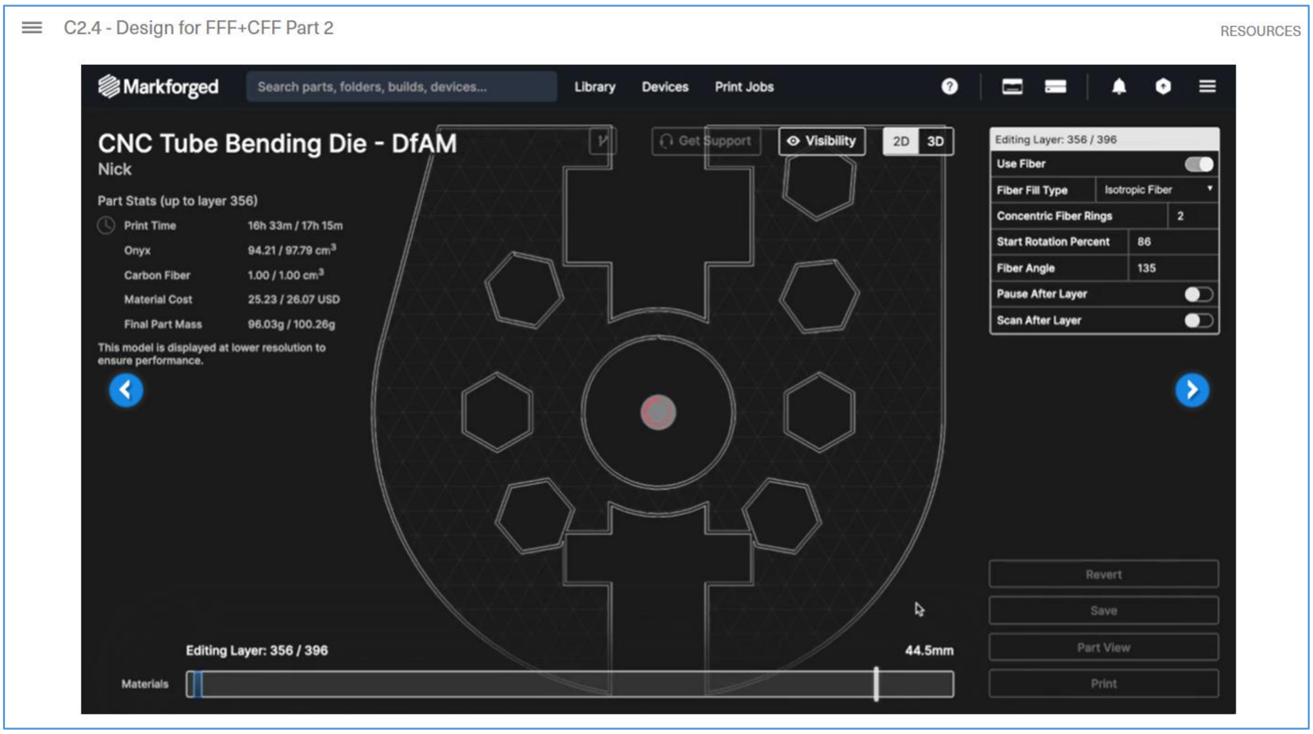
- Deleting a group (at the top).



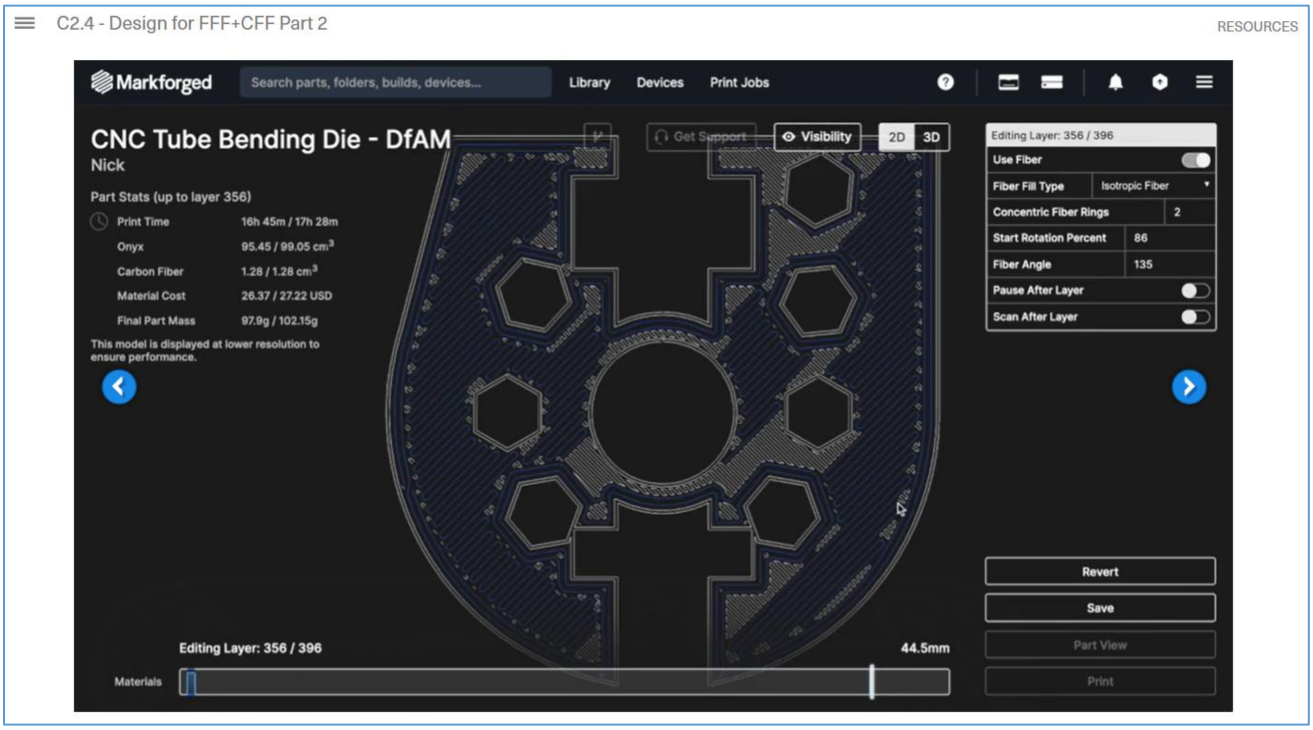
- Choose 2D view.



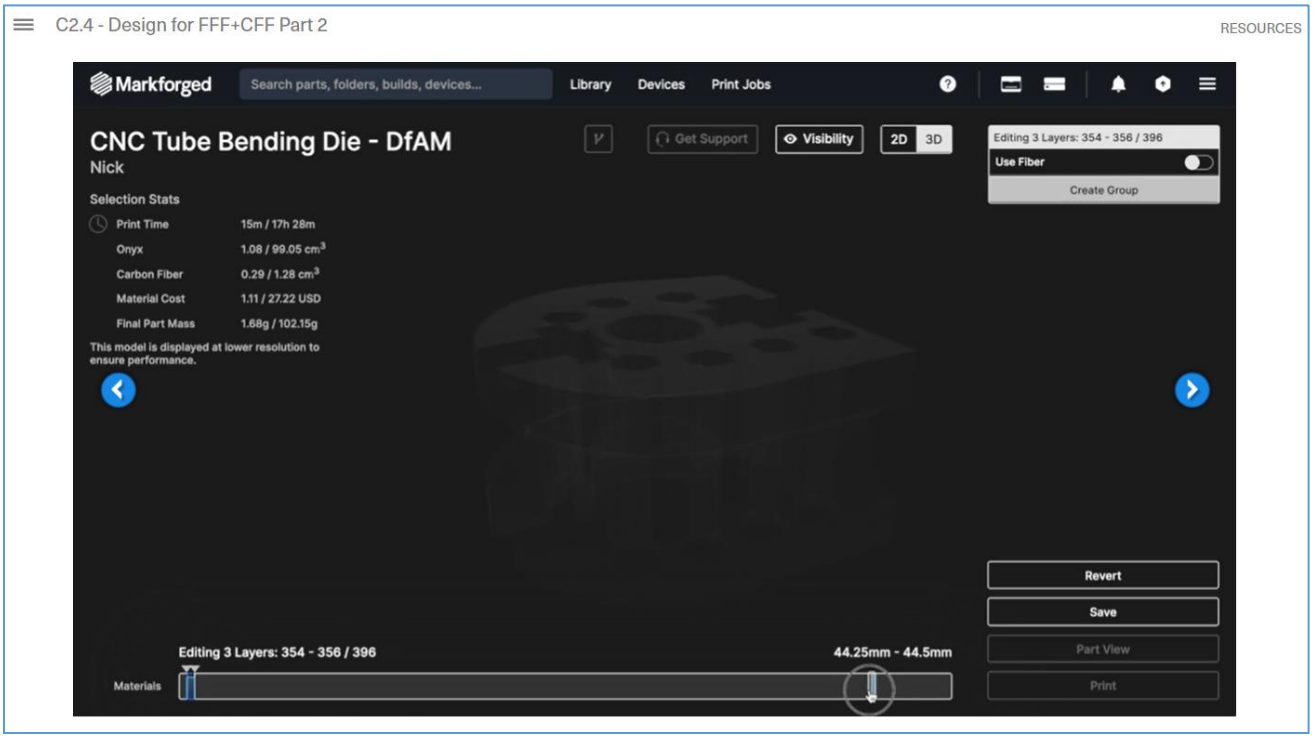
- Look for the Top of the Roof.



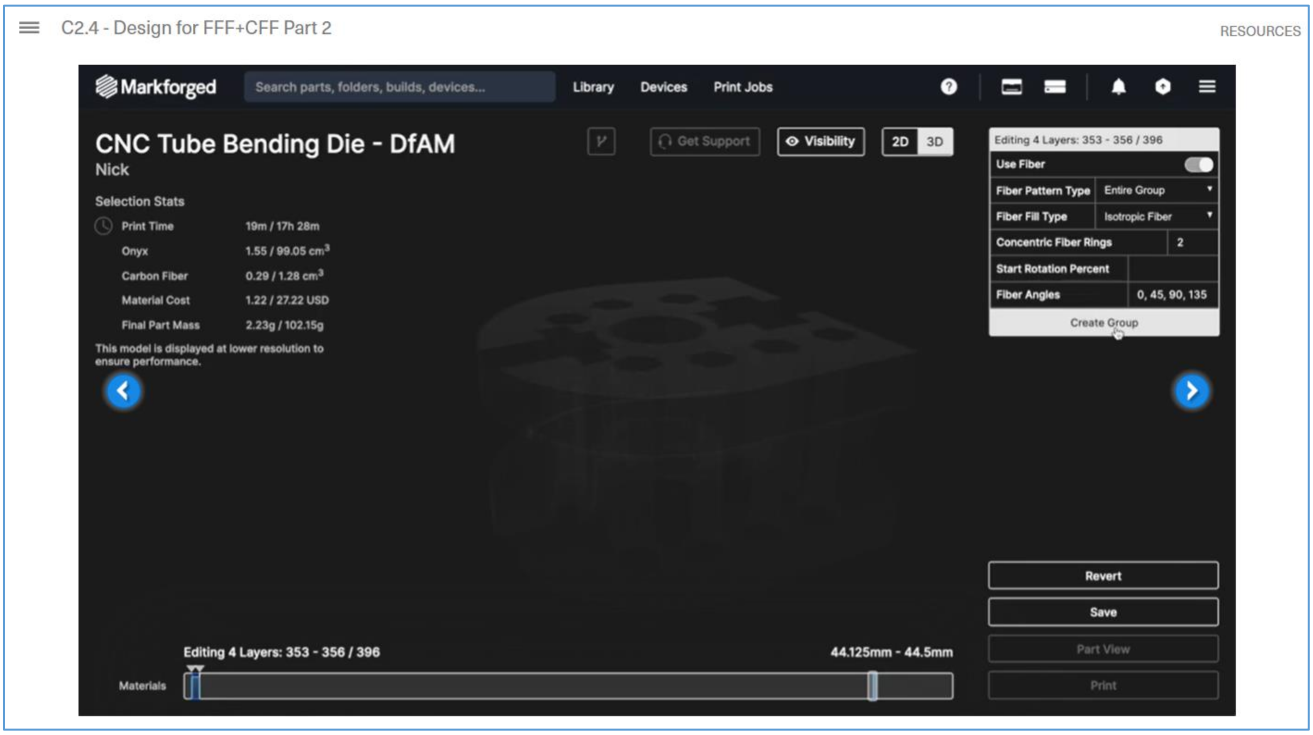
- Go a layer below the floorlayer.



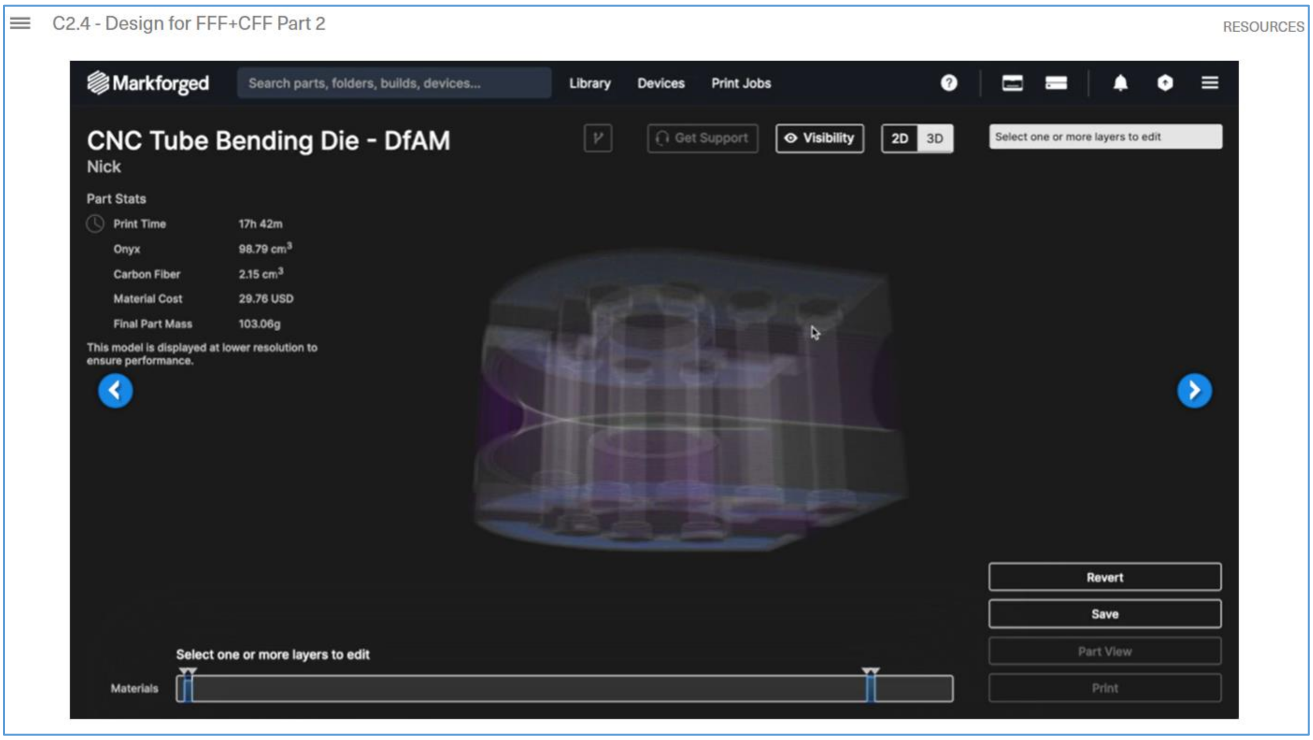
- Toggle on.



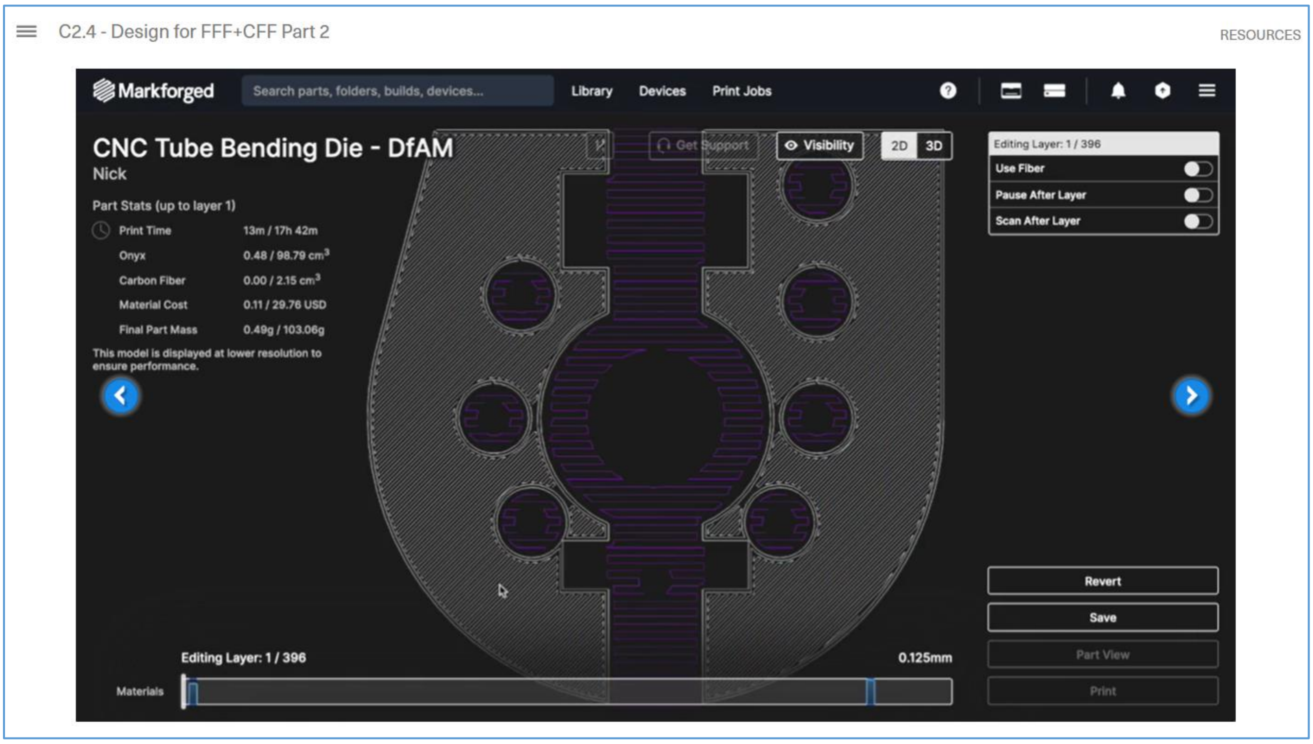
- Back in the 3D View: Drag down 4 layers for a selection.



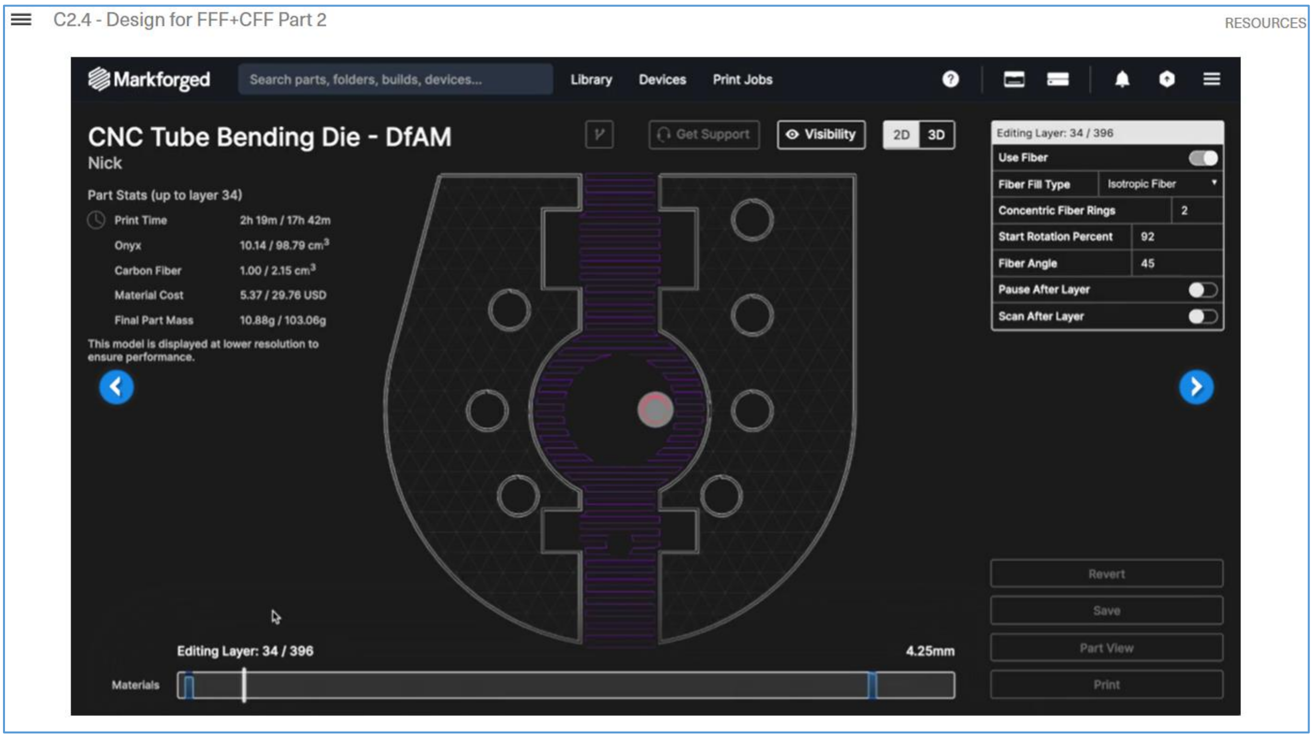
- Toggle Fiber on and create a Group.



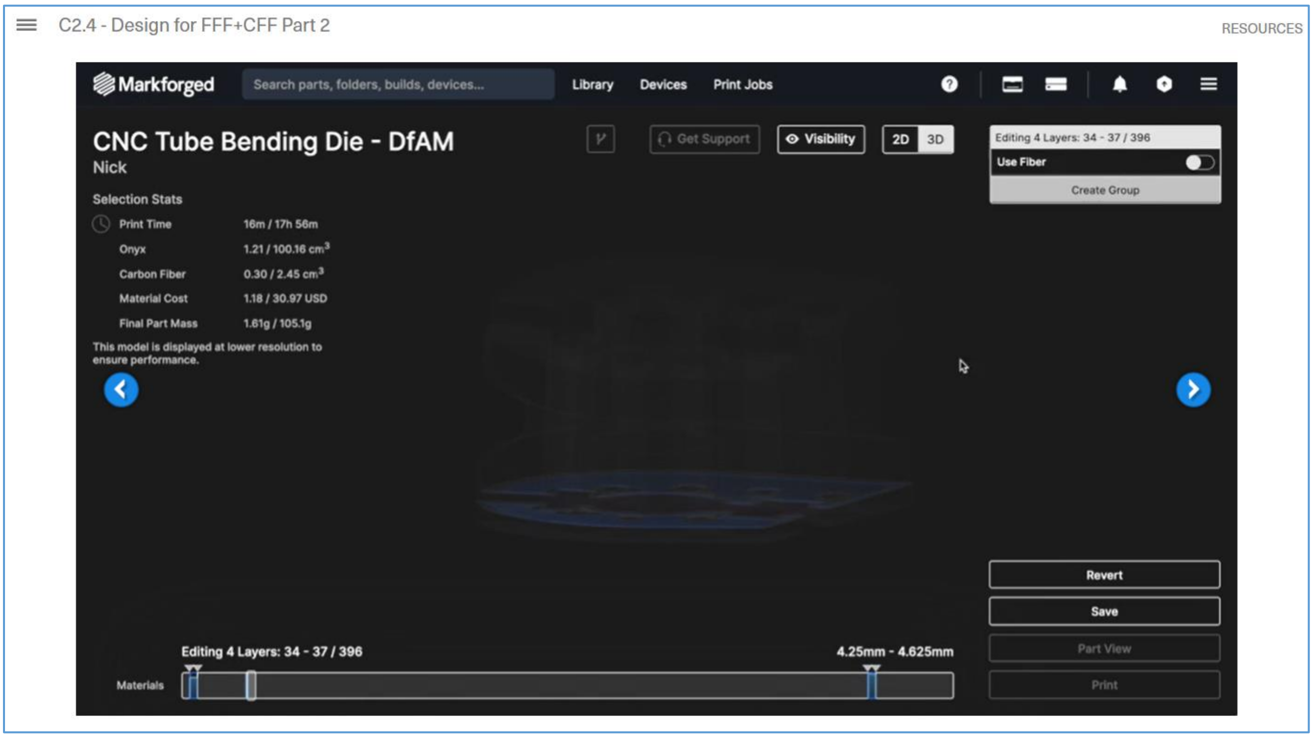
- Right arrow: Reinforcement like a washer, but simply built in the part.



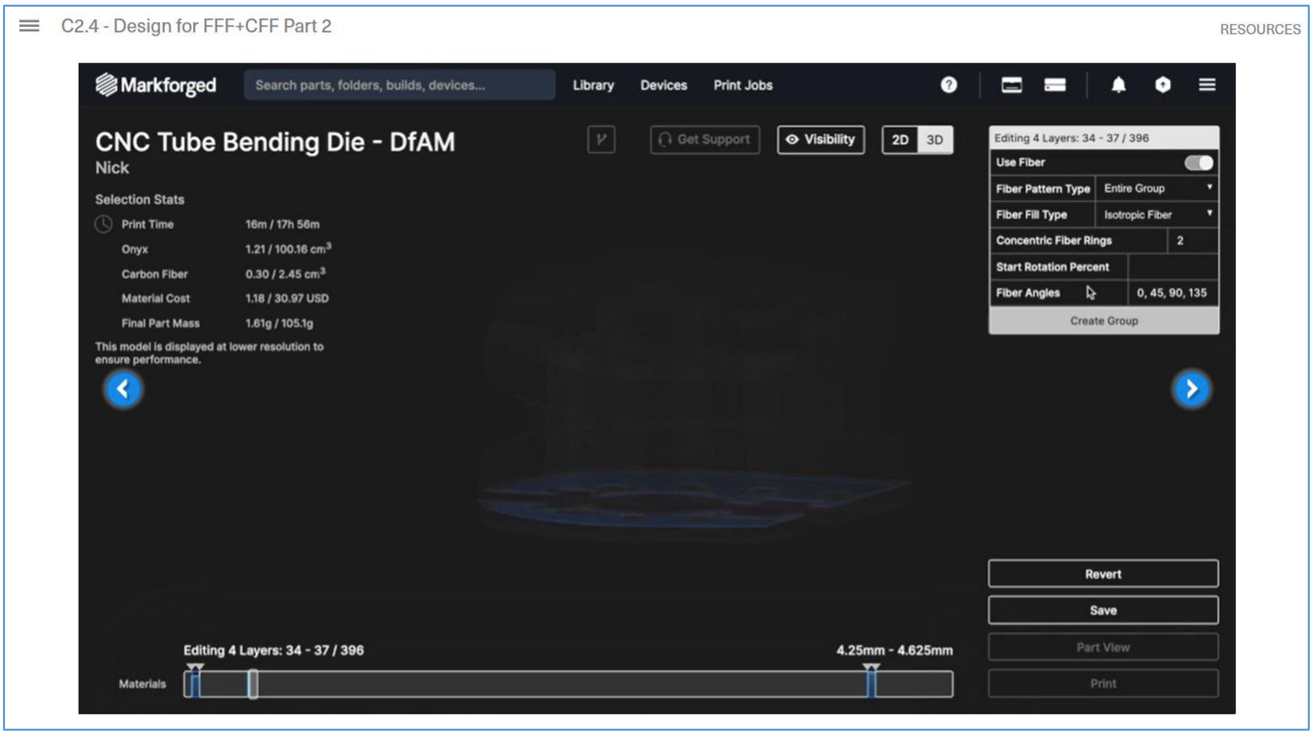
- 2D View > Look for the layer beneath the counter bore.



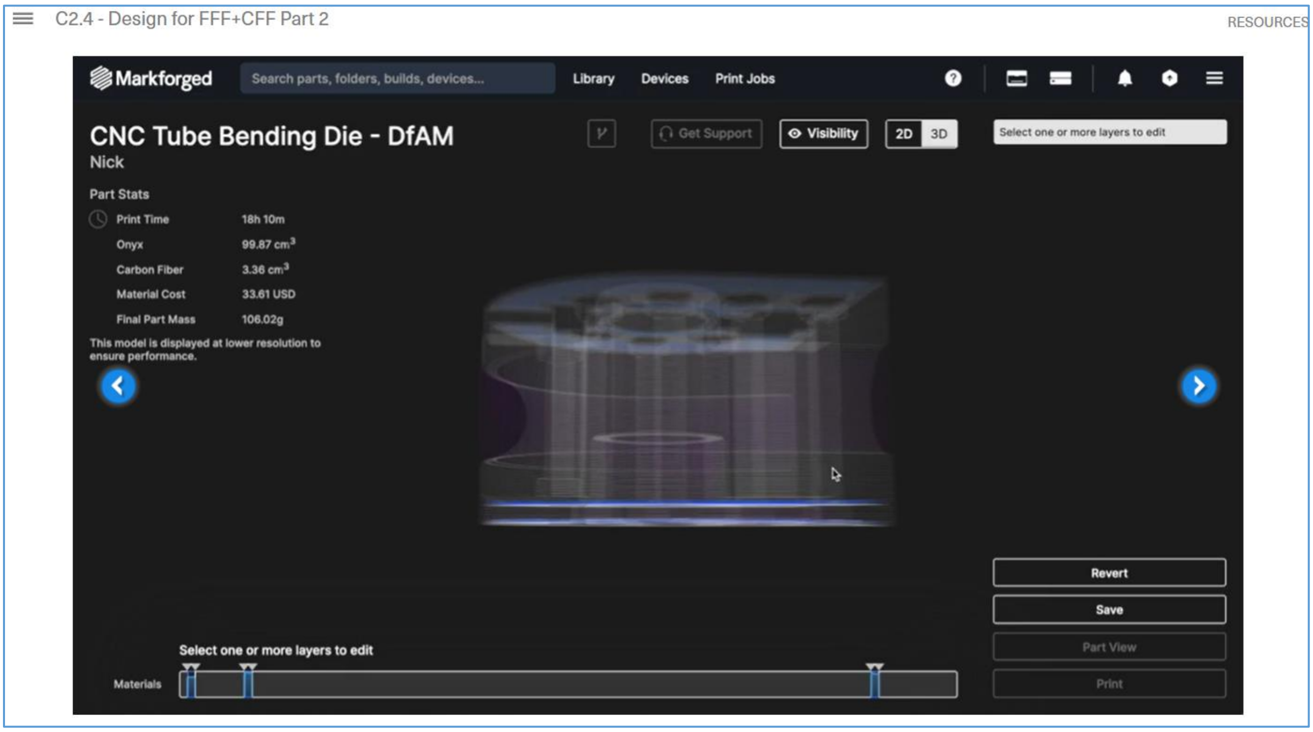
- Toggle Fiber on and go back in the 3D view



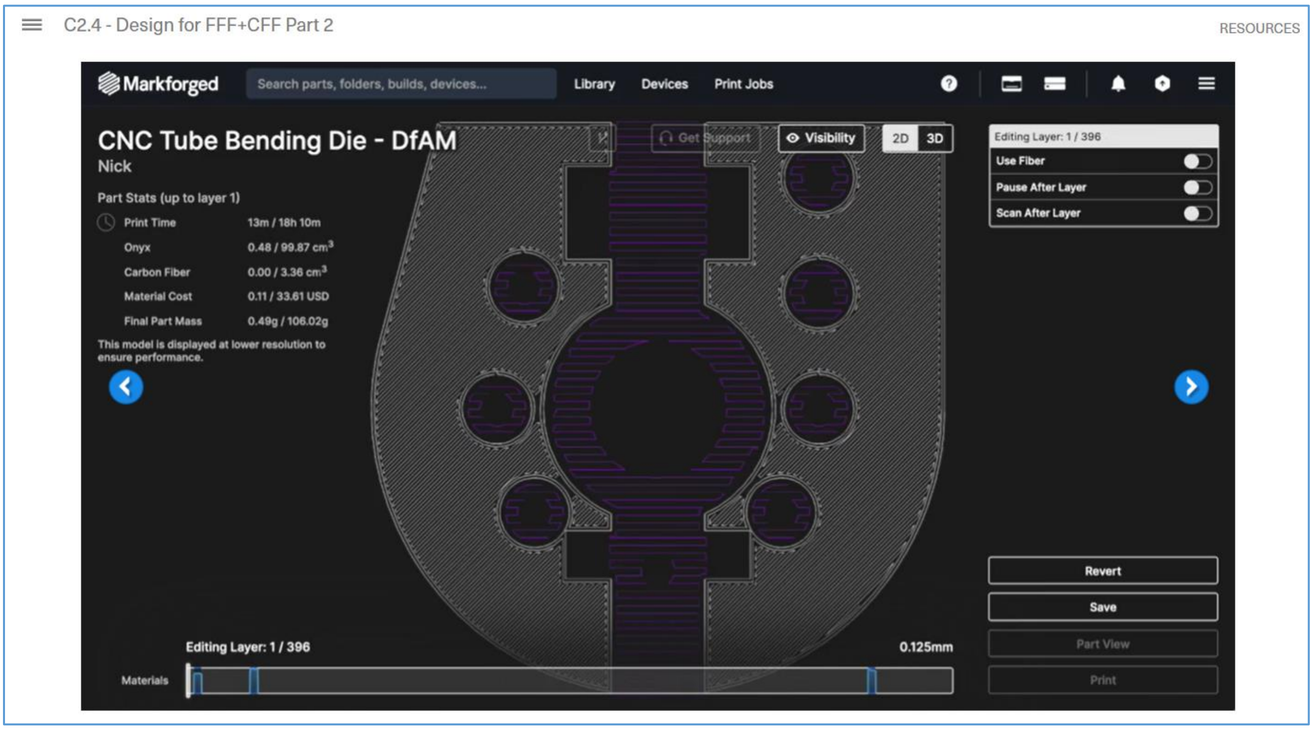
- In Layer slider and slide 4 layers



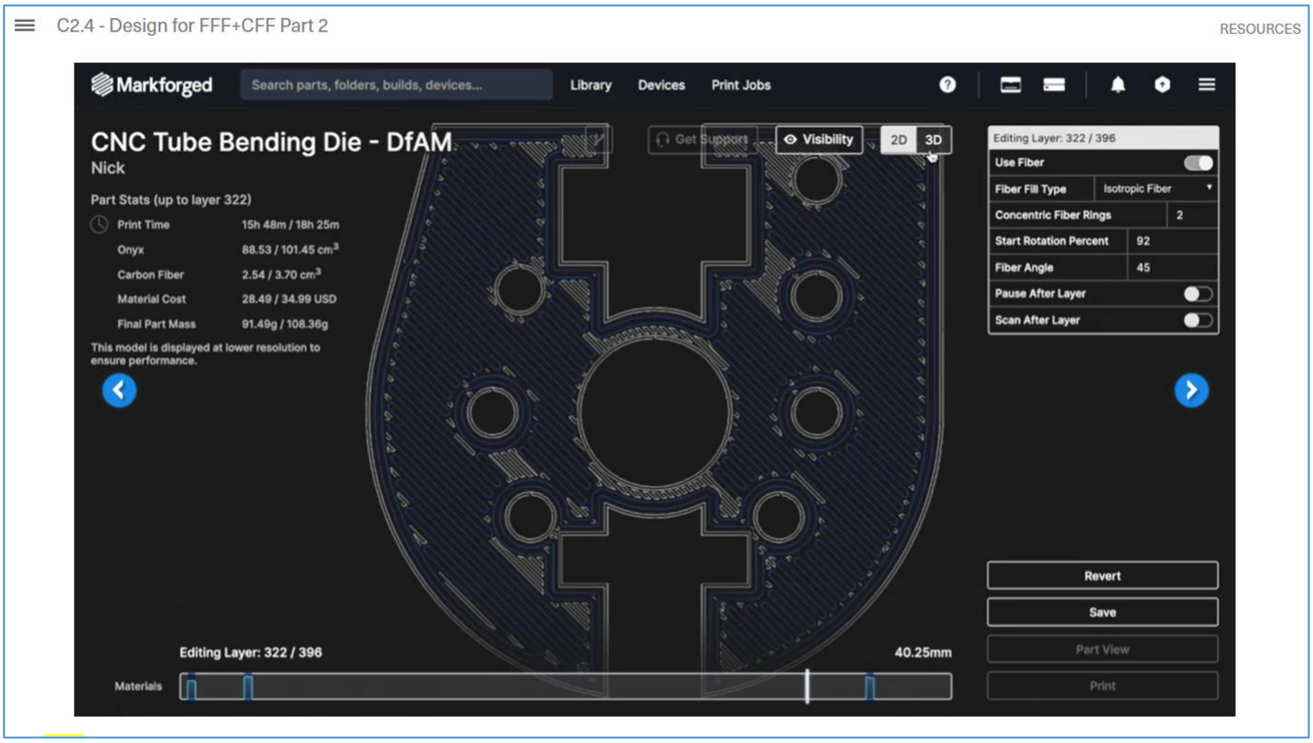
- And create the Group.



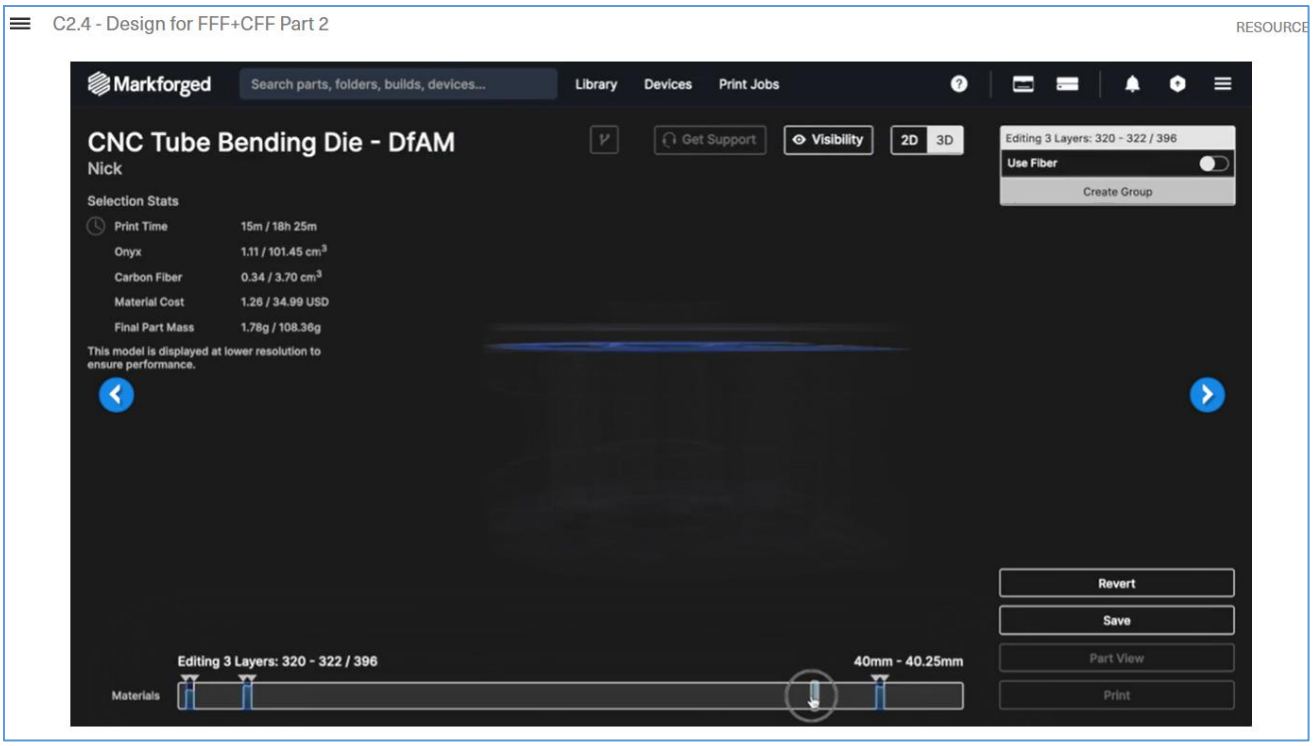
- Next we have to do the same thing underneath the nuts.



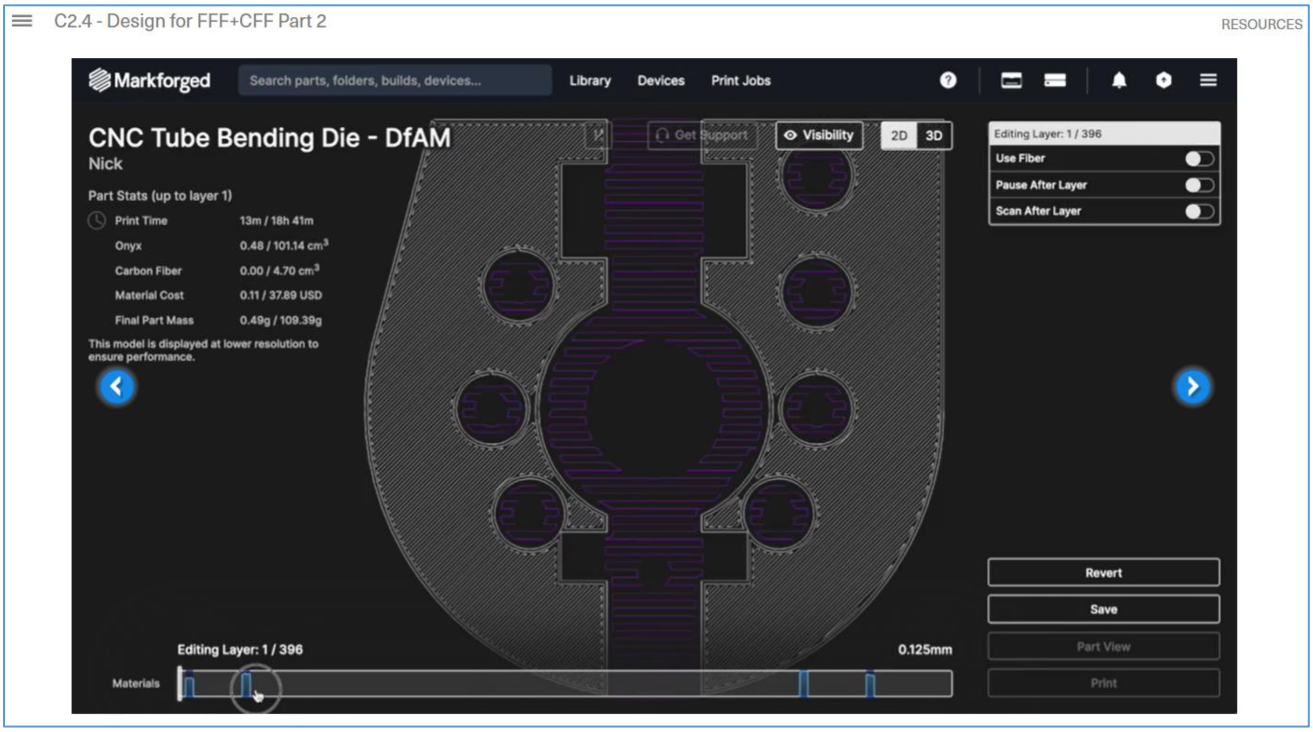
- Once again: Go into the 2D View.
- Drag the Layer Slider till you arrive at the first layer below roofing floor underneath the pockets for the captive nuts.



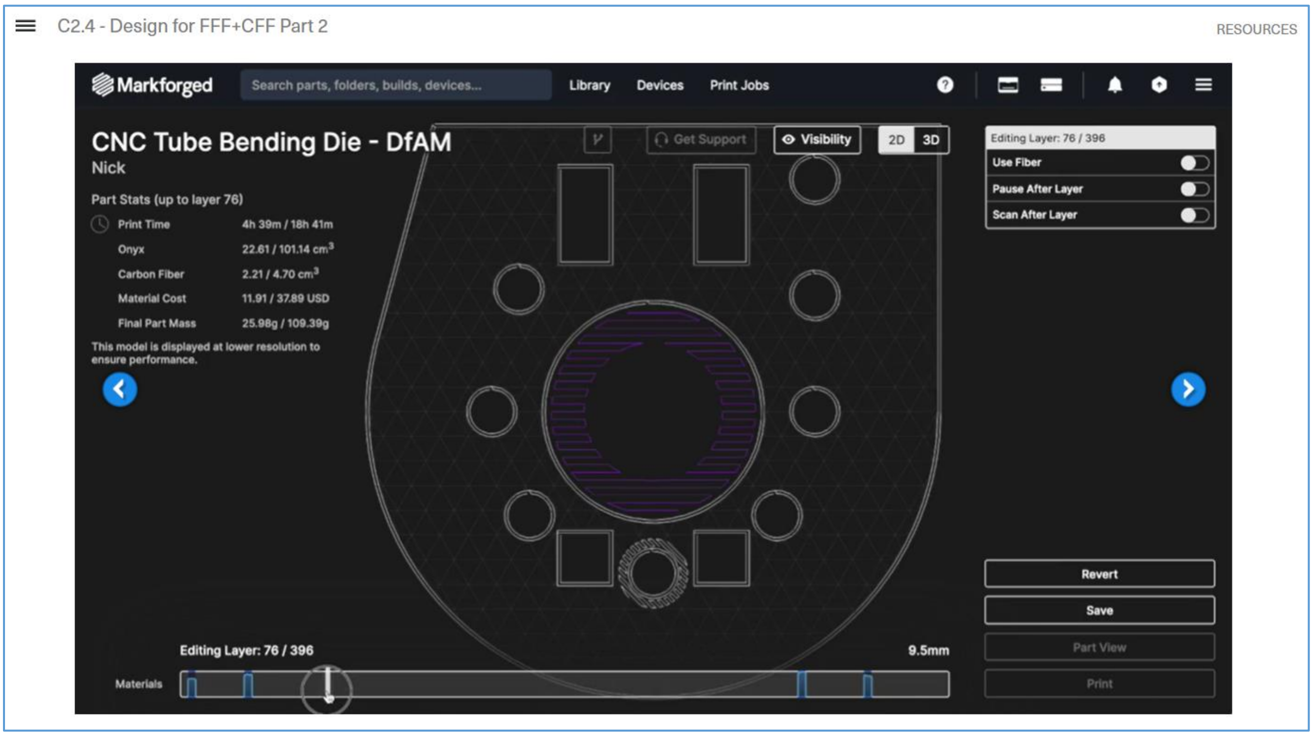
- Layer 322 and go back to the 3D View.



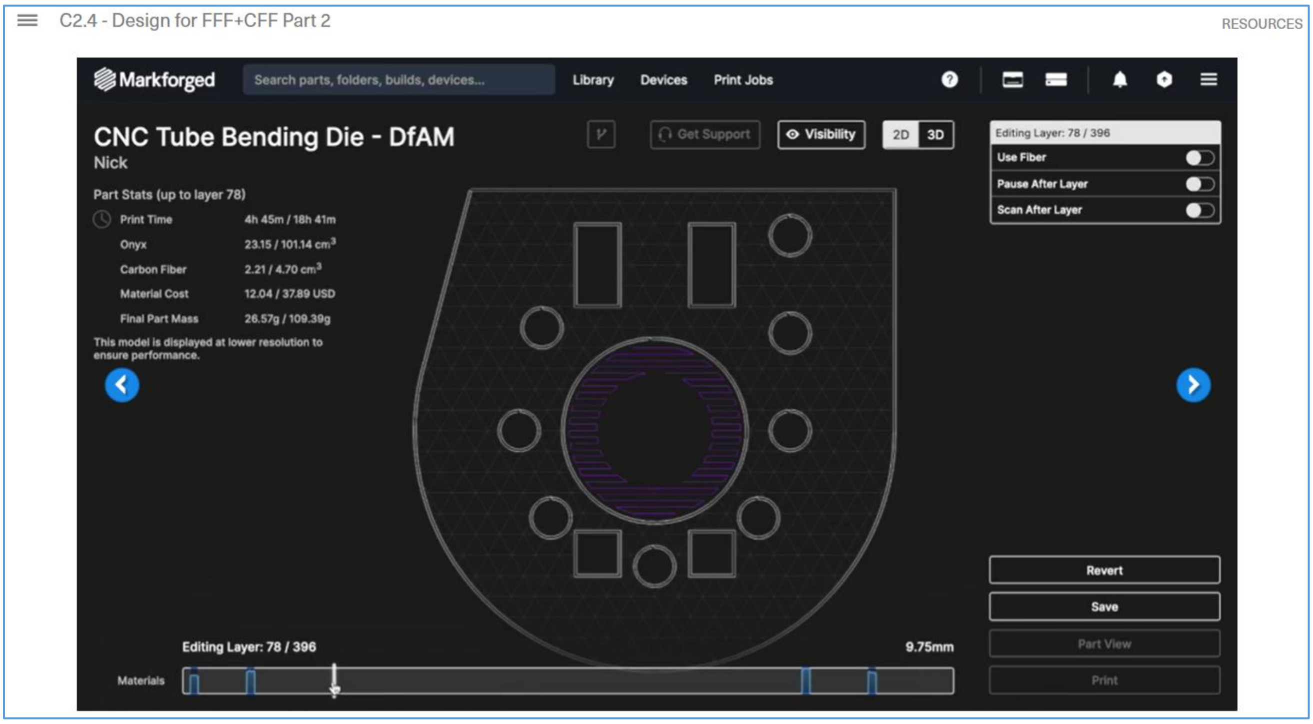
- Drag the slider 4 layers.
- Toggle Fiber on and Create a Group.



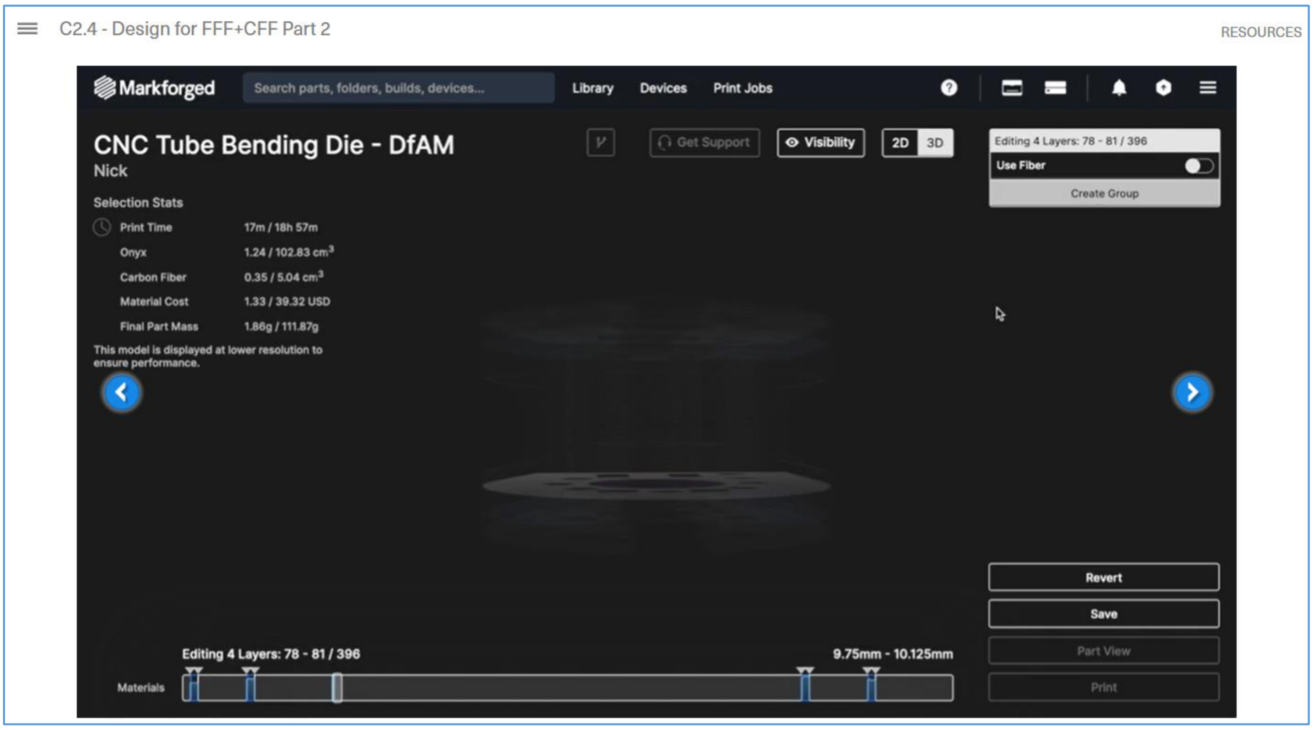
- Go back to the2D View.



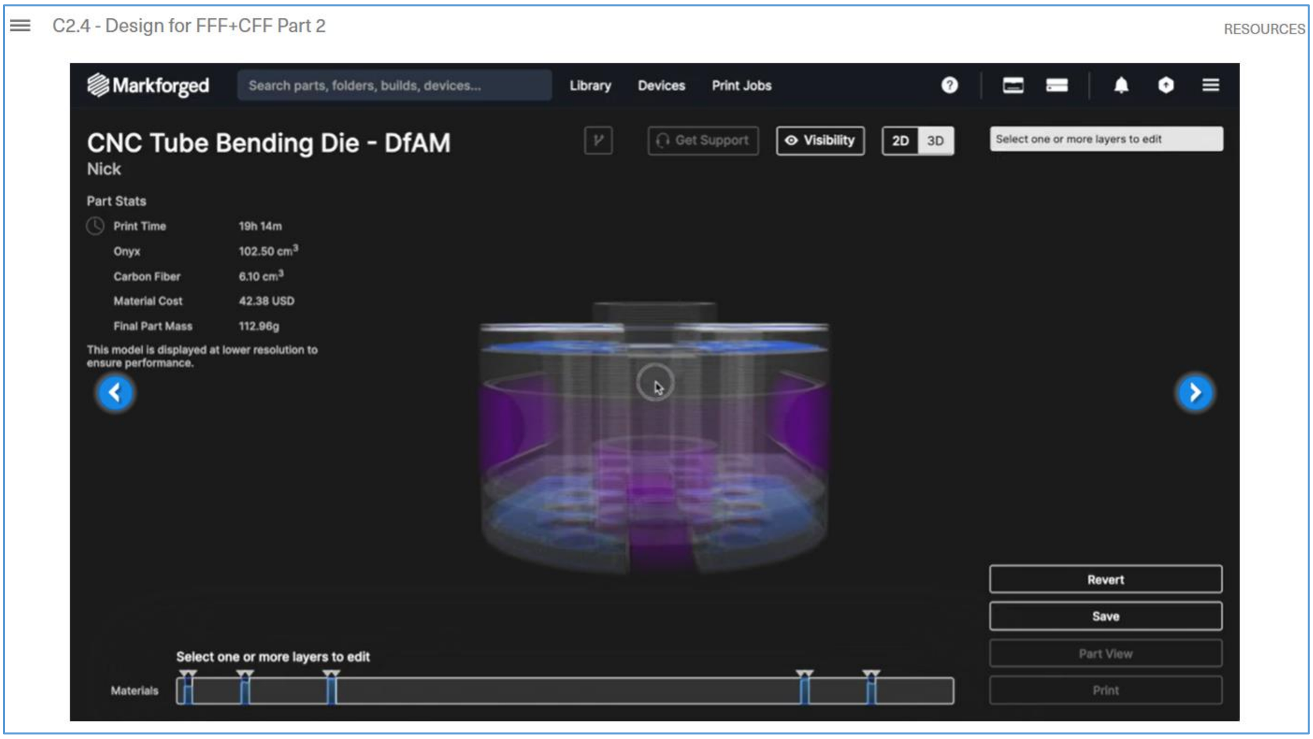
- Look for the roofing floor.



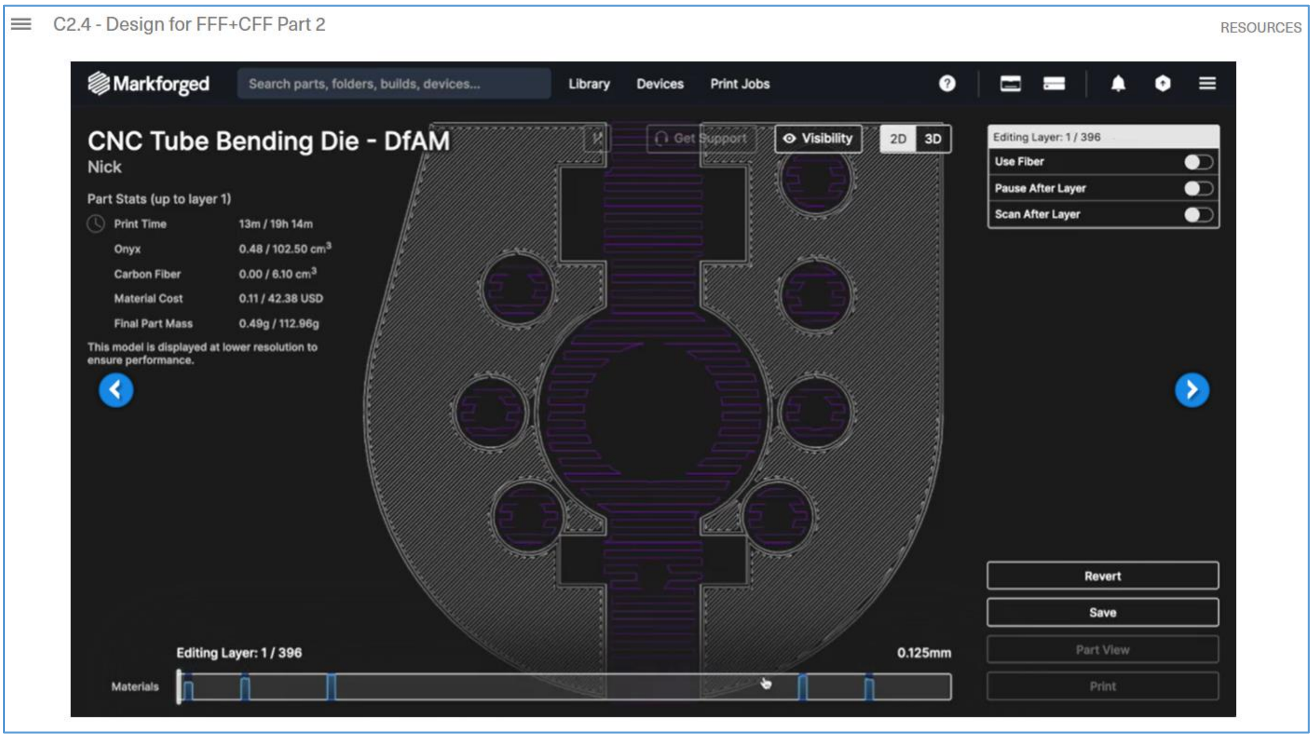
- To Layer 78 and toggle the Fiber on and go back to the 3D View.



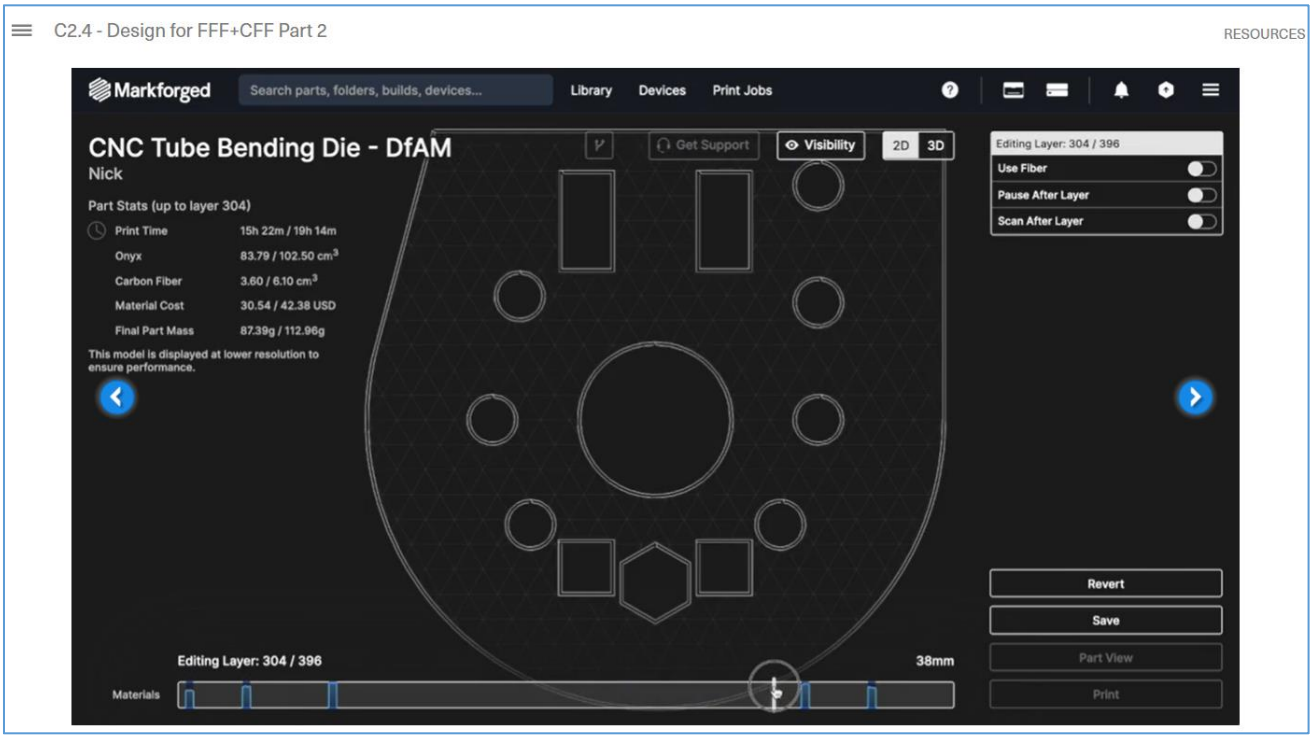
- Select Layer 78 to 81.
- Toggle Fiber on and Create the Group.



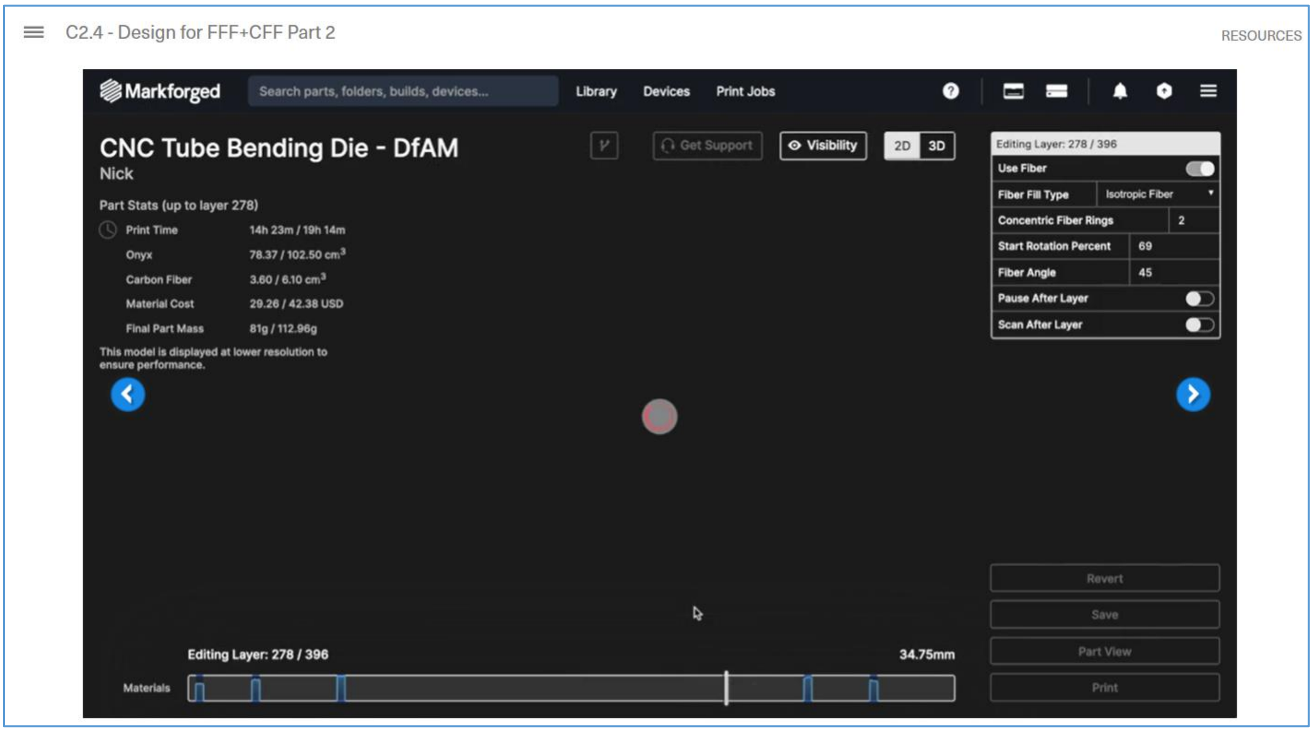
- Now the same thing for the top of the nut.



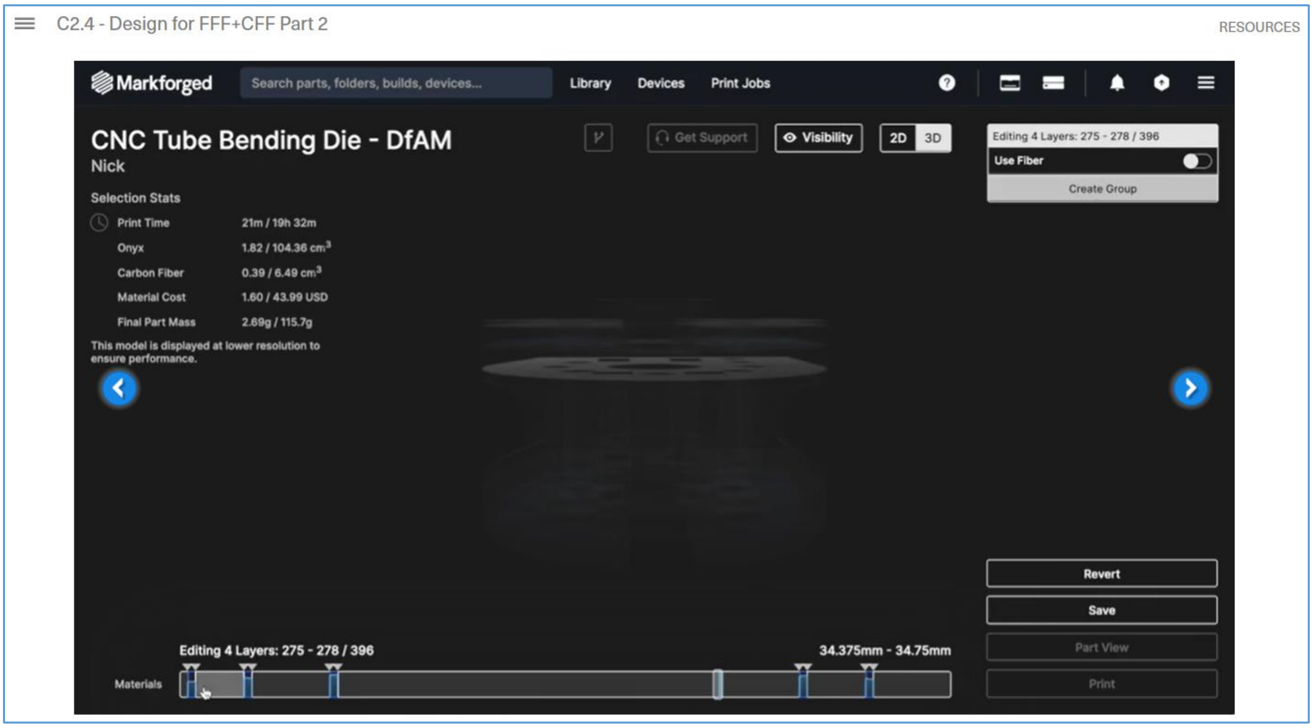
- Go back to the 2D View



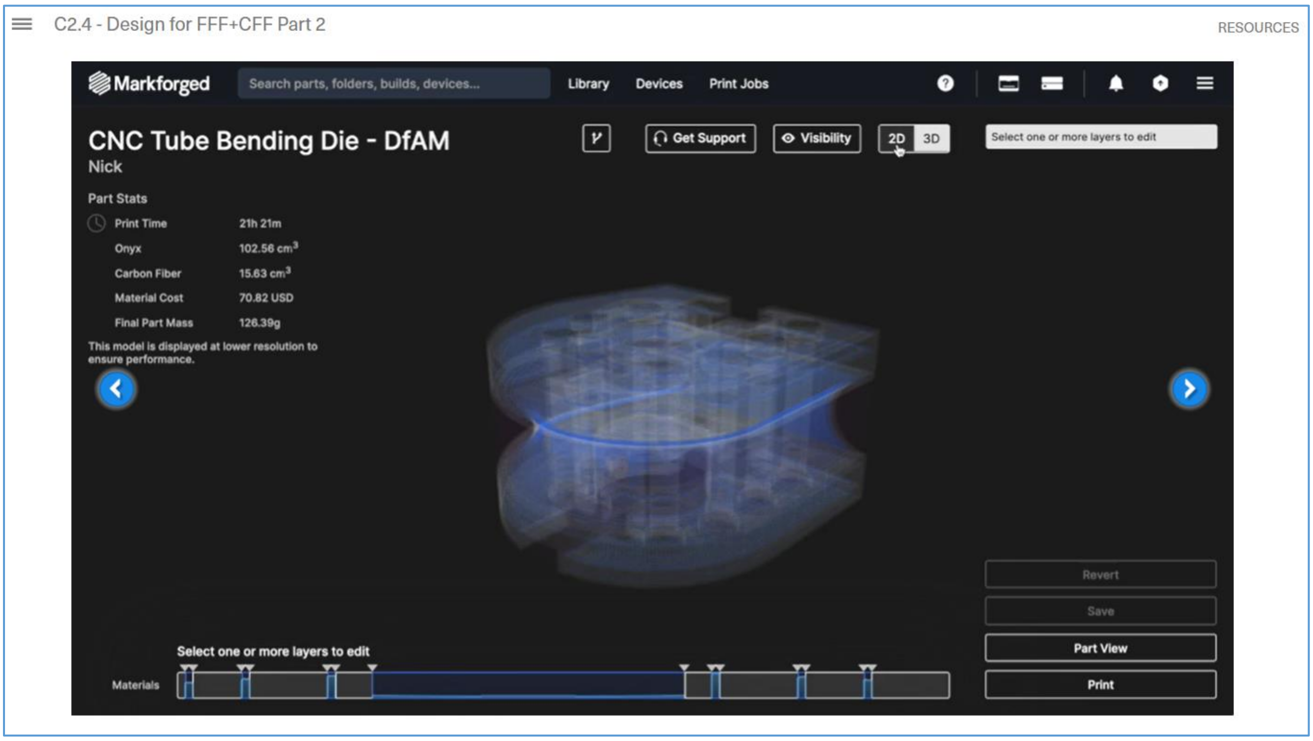
- and navigate to the layer I want.



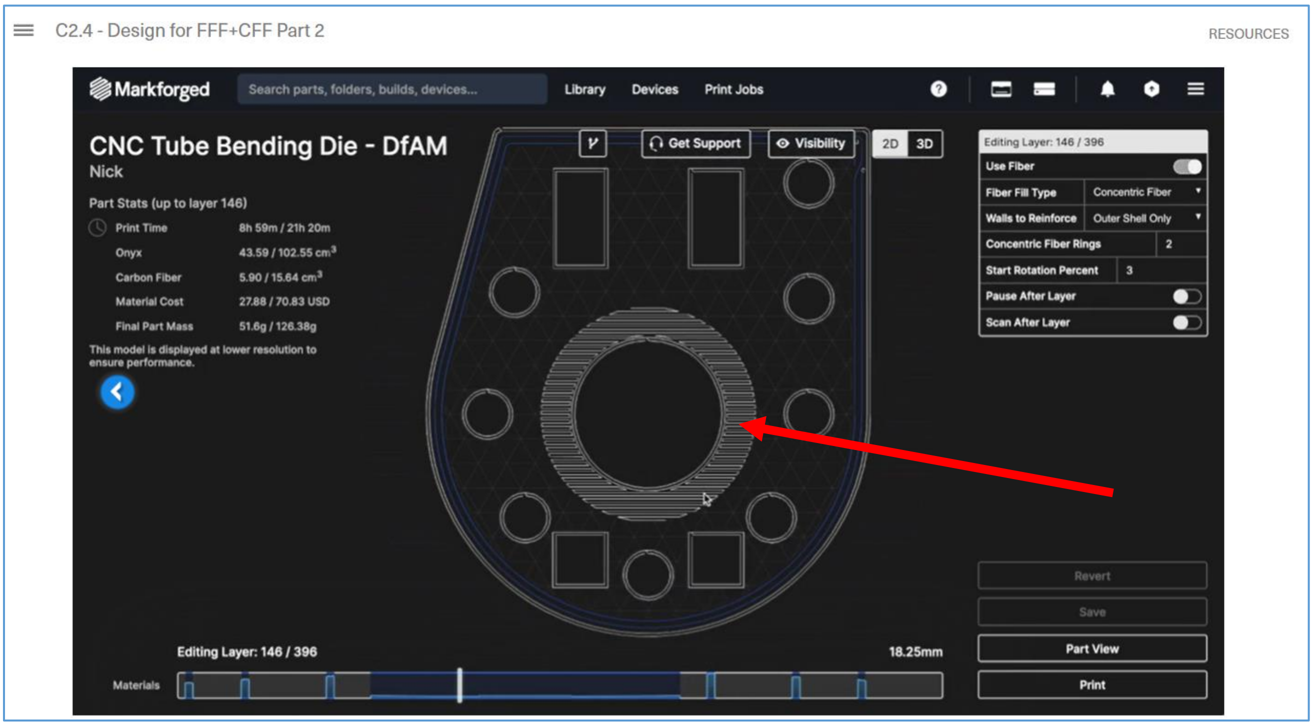
- Layer 78.
- Toggle Fiber on and go back to 3D View.



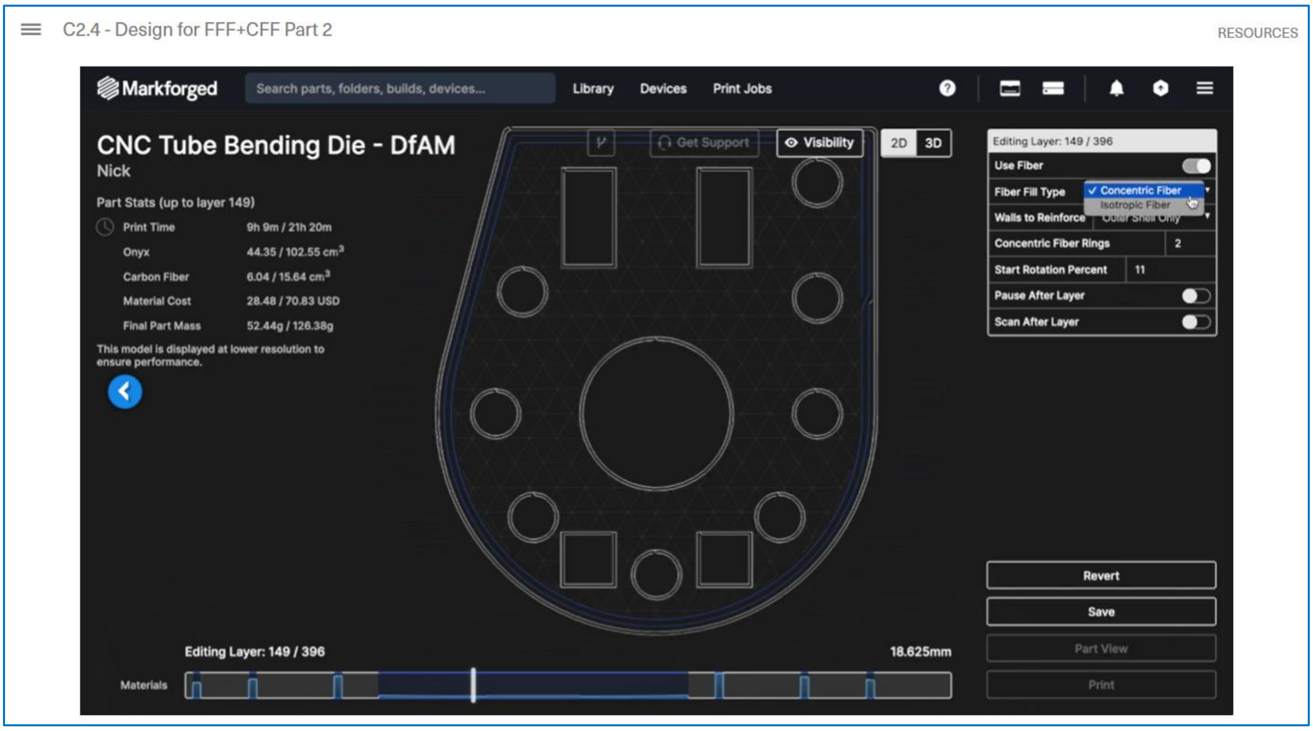
- Drag 4 layers with the slider.
- And create a group.
- Now, we fully reinforced underneath all the bolts and the nuts in this part a distribute out the compressive force to the bolts.



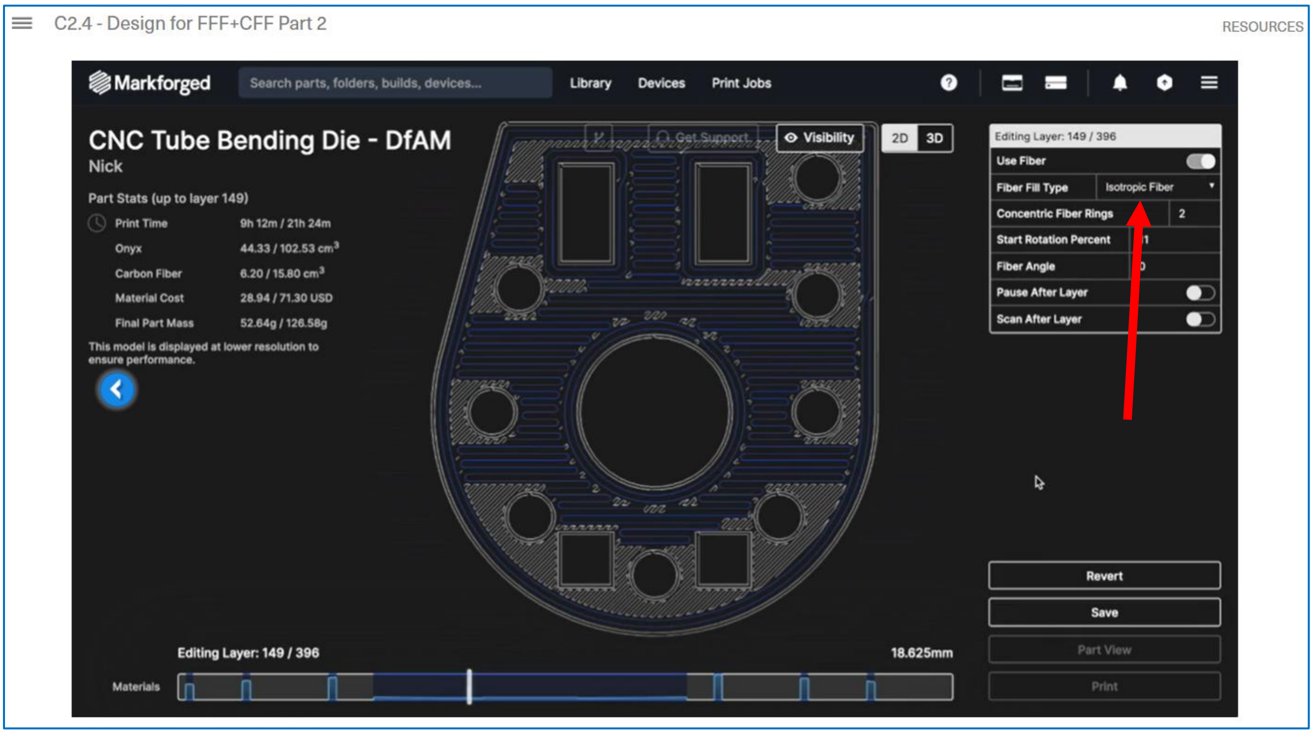
- Second right arrow:
  - Creating reinforcement for bolts due to compressionforce in the bolt/nut-holes. (in stead of using washers?) by laying a fiberlayer beneath the bolthead, to help to distribute the boltforce.



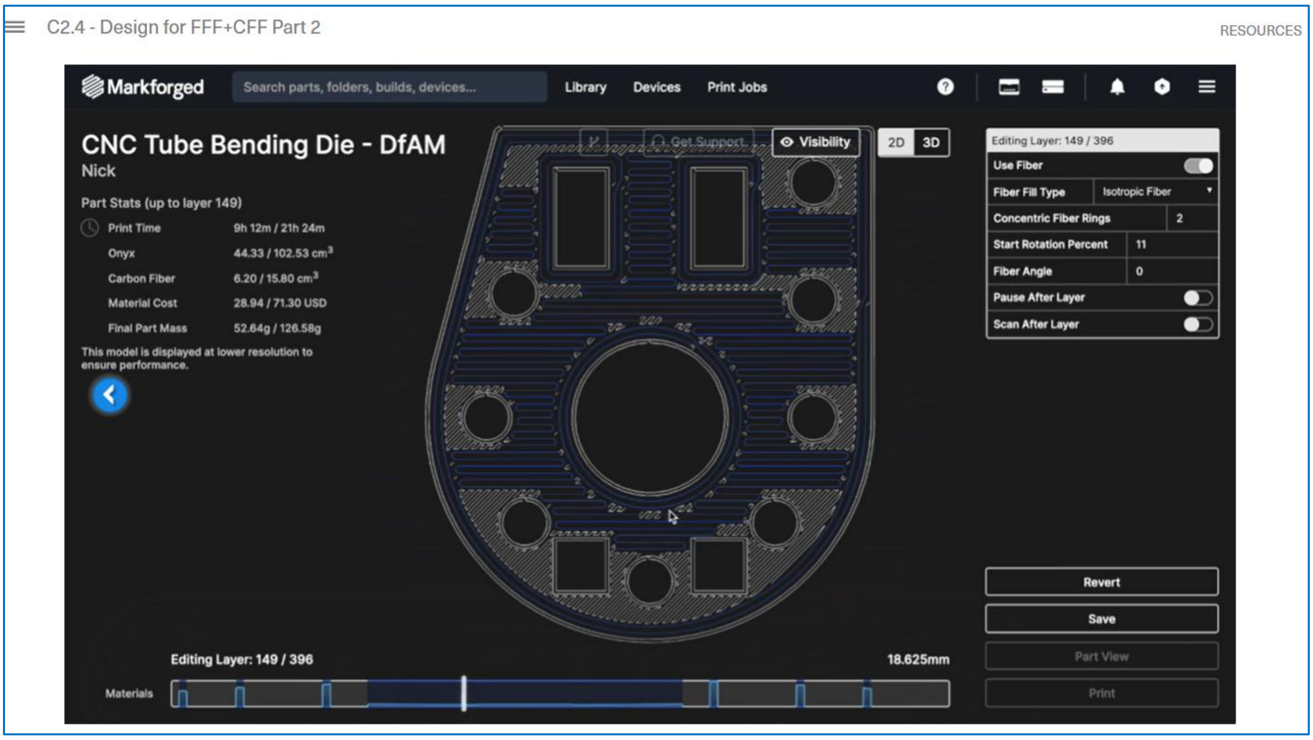
- Go to 2D and navigate to the floorlayer beneath the counterbore.
  - Layer 146.



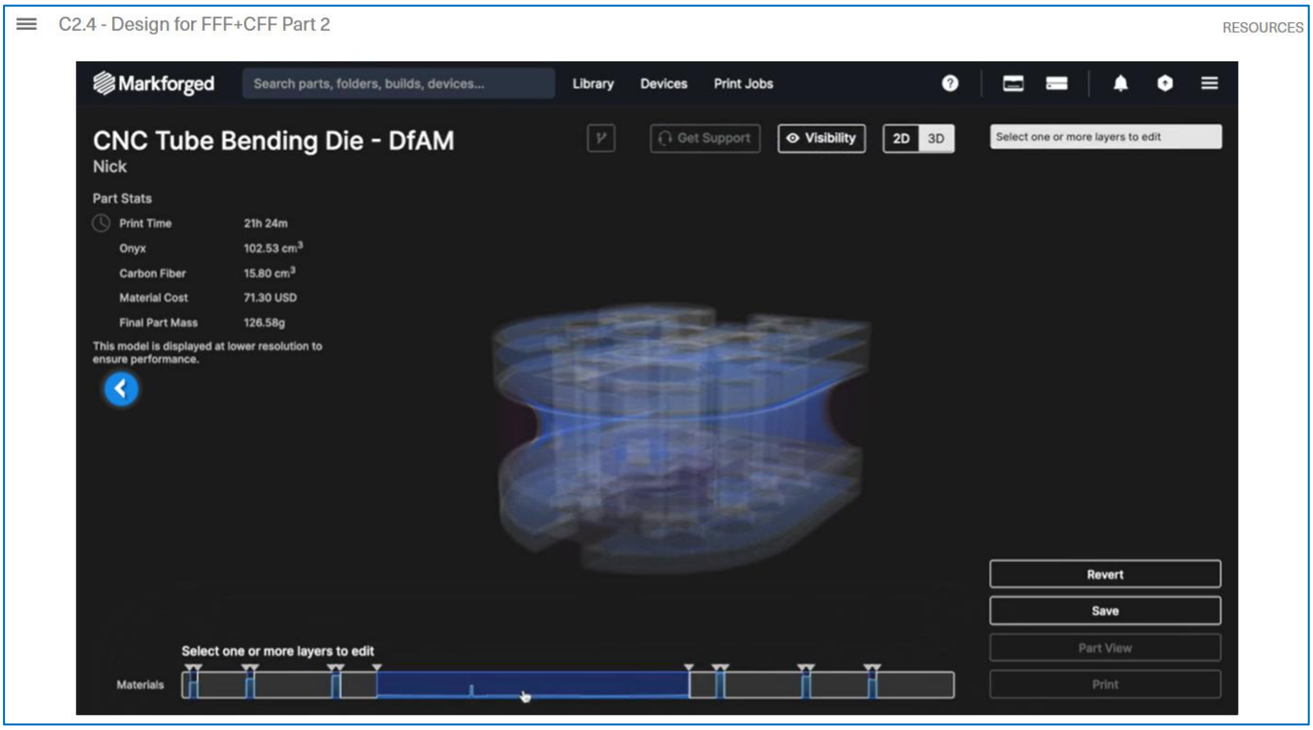
- Layer 149 is the first layer beneath the boltlayer.



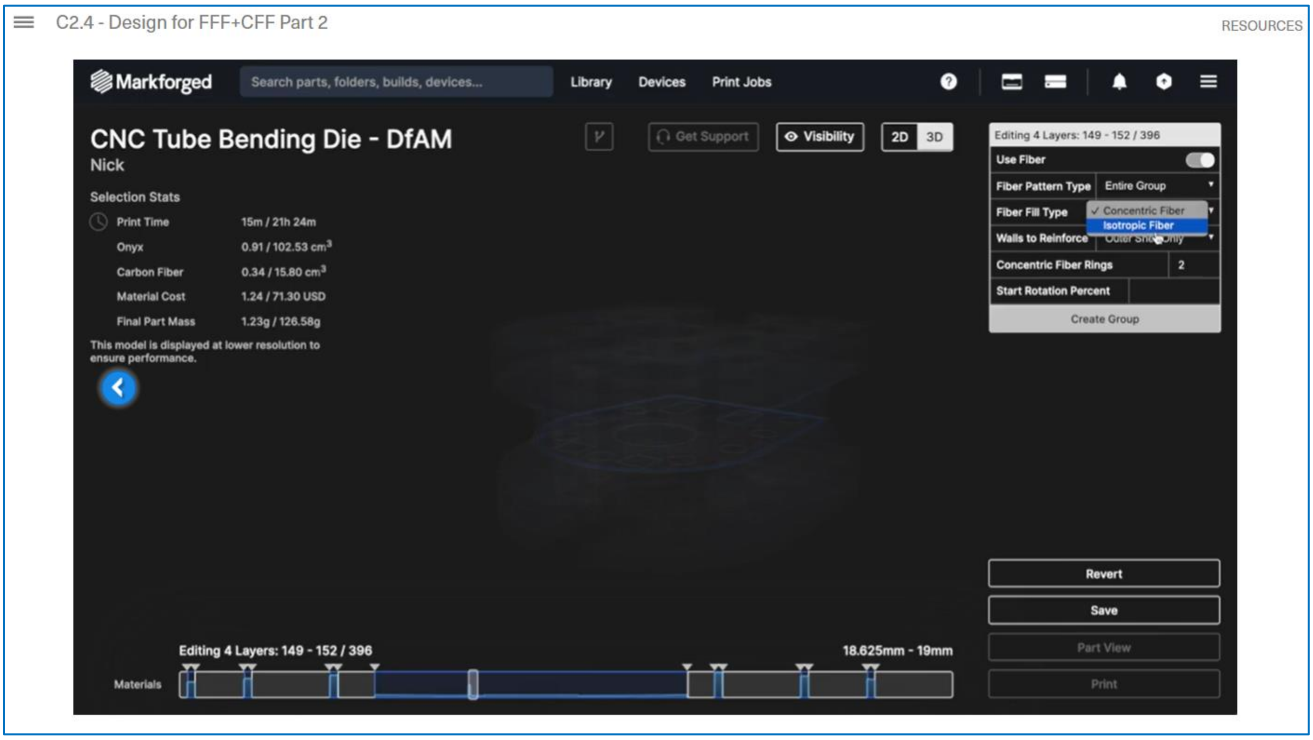
- Change the fiber type into Isotropic fiber.



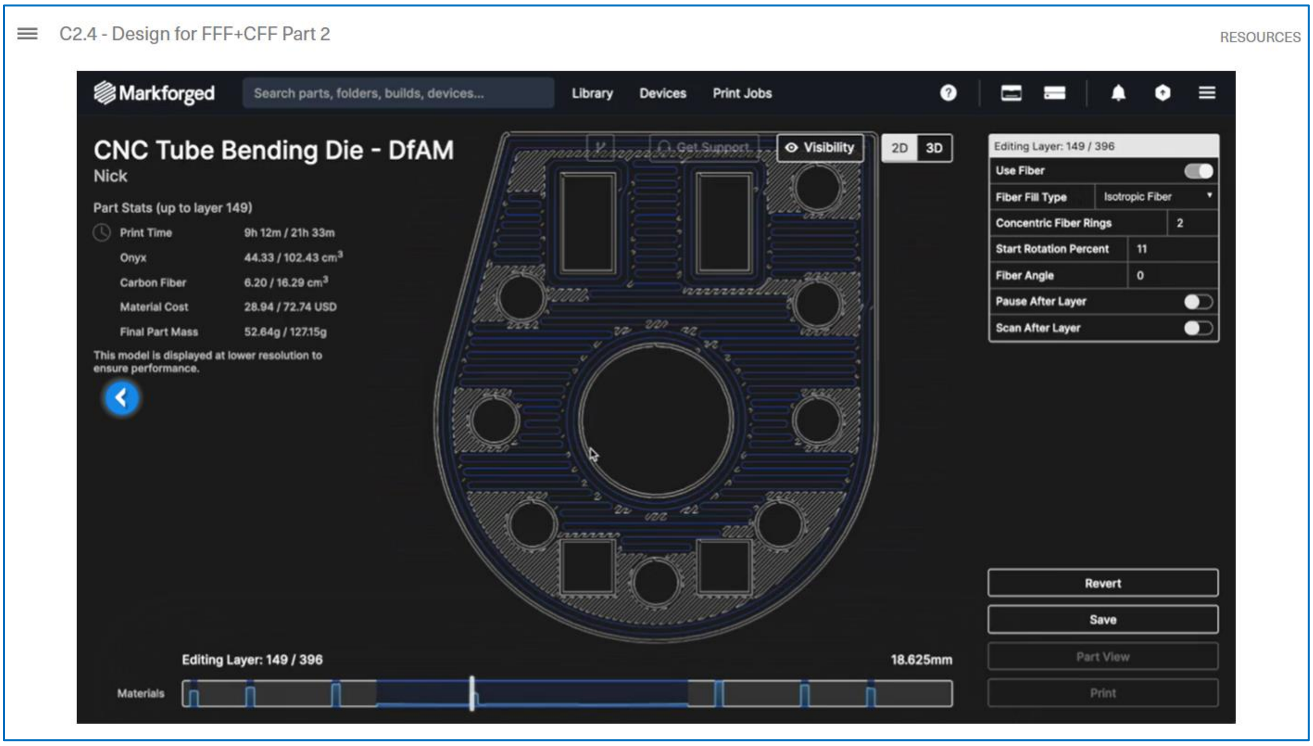
- Not an ideal scenario: Lot of cavities have not fiber.



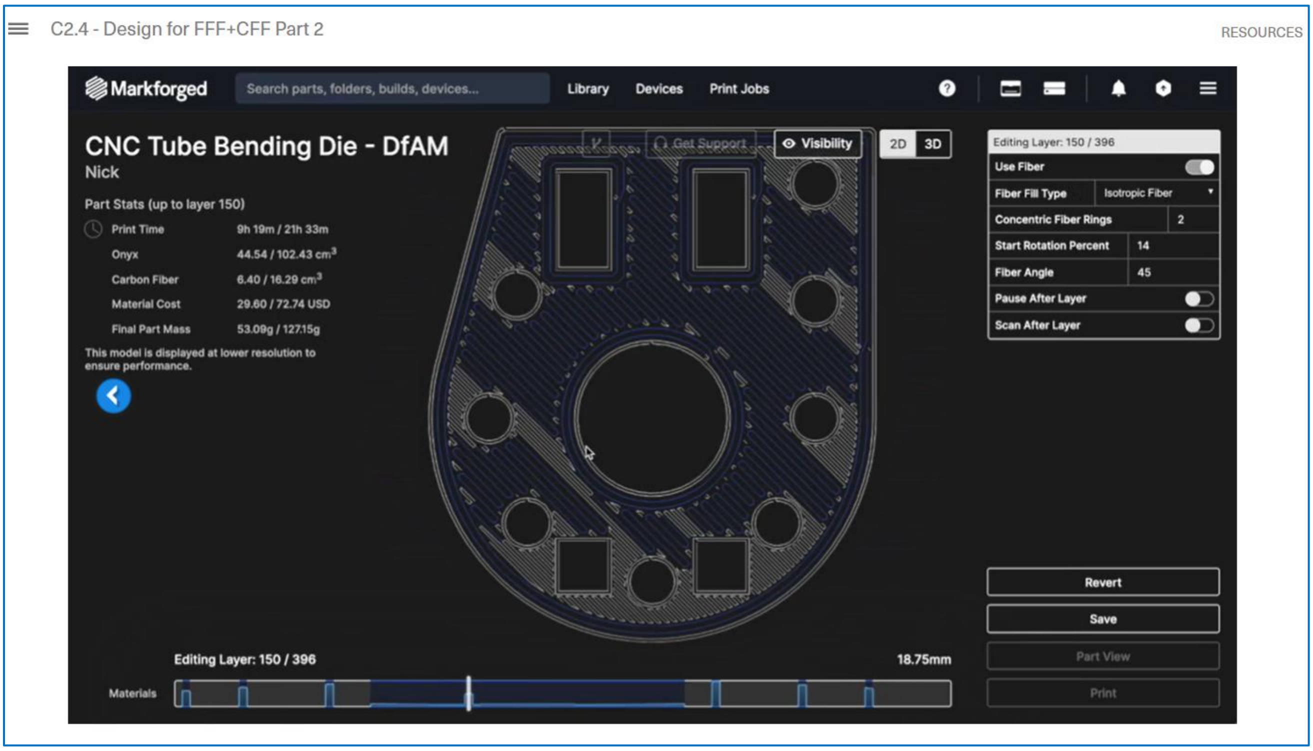
- Go back to the 3D-view.



- Start at layer 149 and move upwards to make 4 layers.
- Fiber layer on Isotropic Fiber.
- Update the fiber fill type and create the group.



- Go back to the 2D-view and notice the different layers in following images.



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RESOURCES
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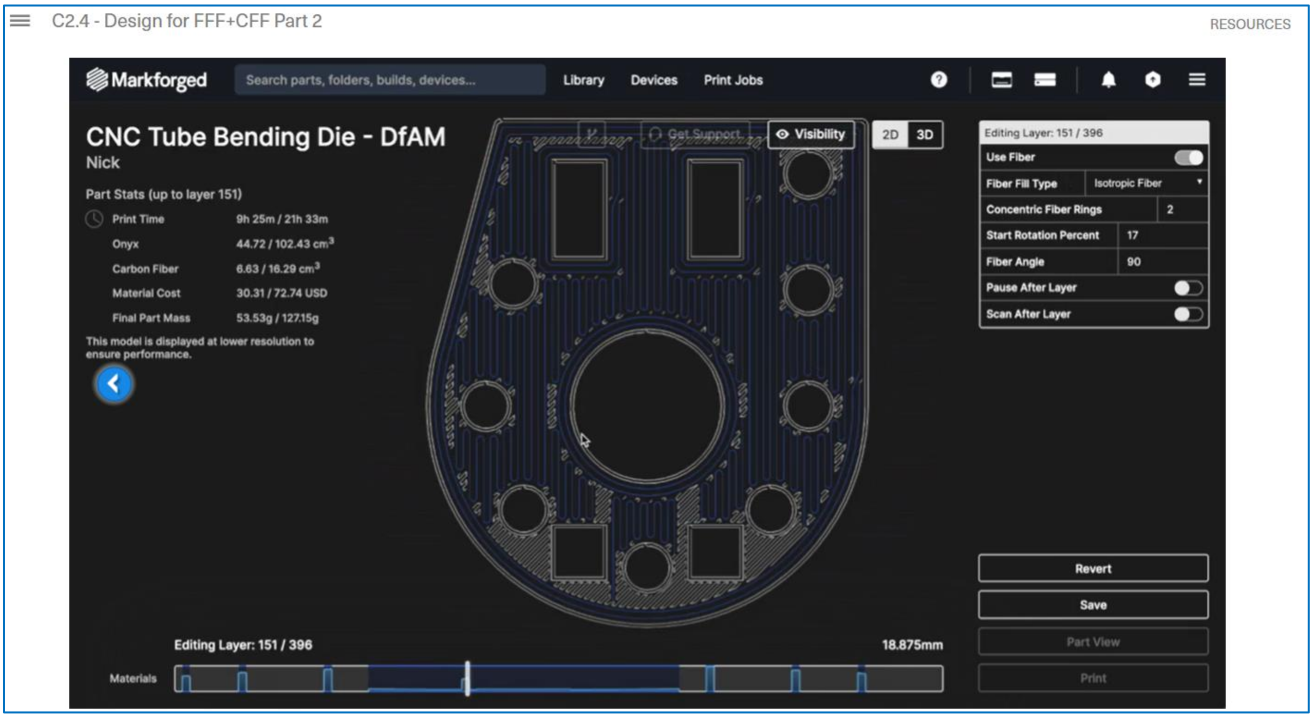
CNC Tube Bending Die - DfAM
Nick
Part Stats (up to layer 150)
Print Time 9h 19m / 21h 33m
Onyx 44.54 / 102.43 cm³
Carbon Fiber 6.40 / 16.29 cm³
Material Cost 29.60 / 72.74 USD
Final Part Mass 53.09g / 127.15g
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 150 / 396
Use Fiber
Fiber Fill Type Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 14
Fiber Angle 45
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 150 / 396
18.75mm
Materials



C2.4 - Design for FFF+CFF Part 2
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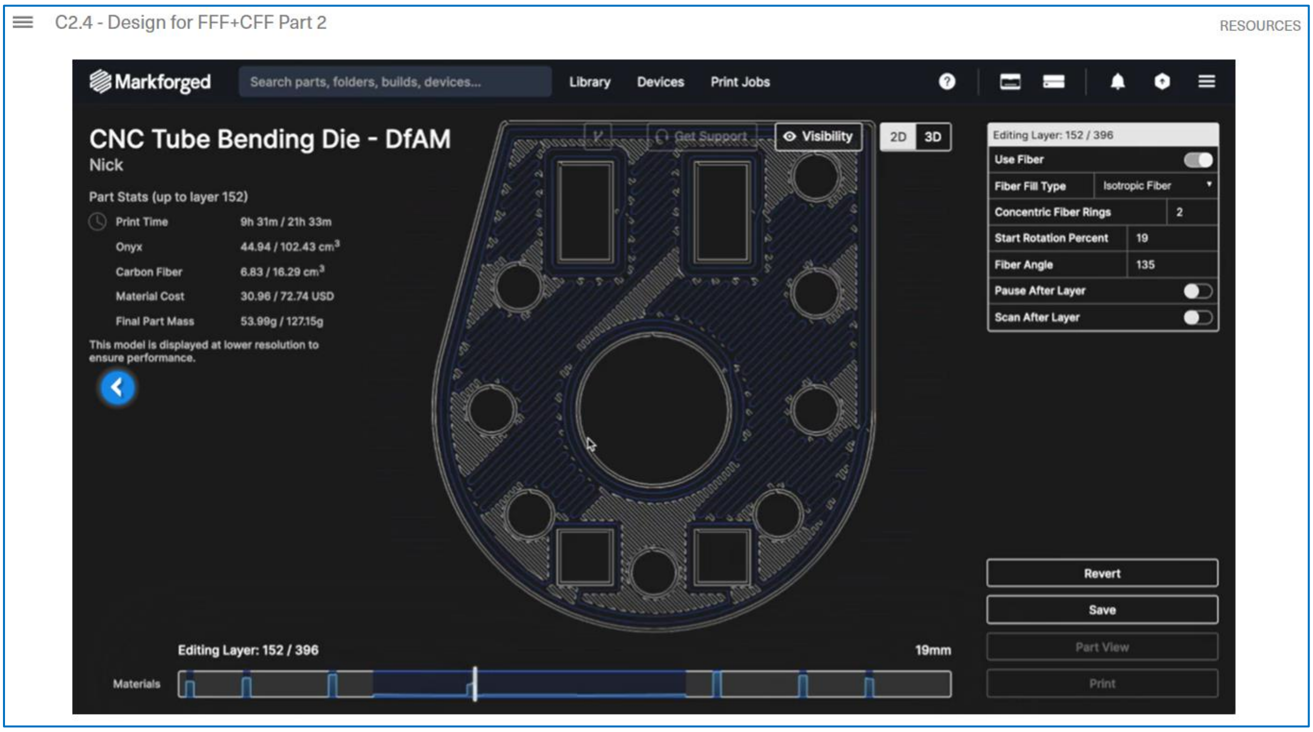
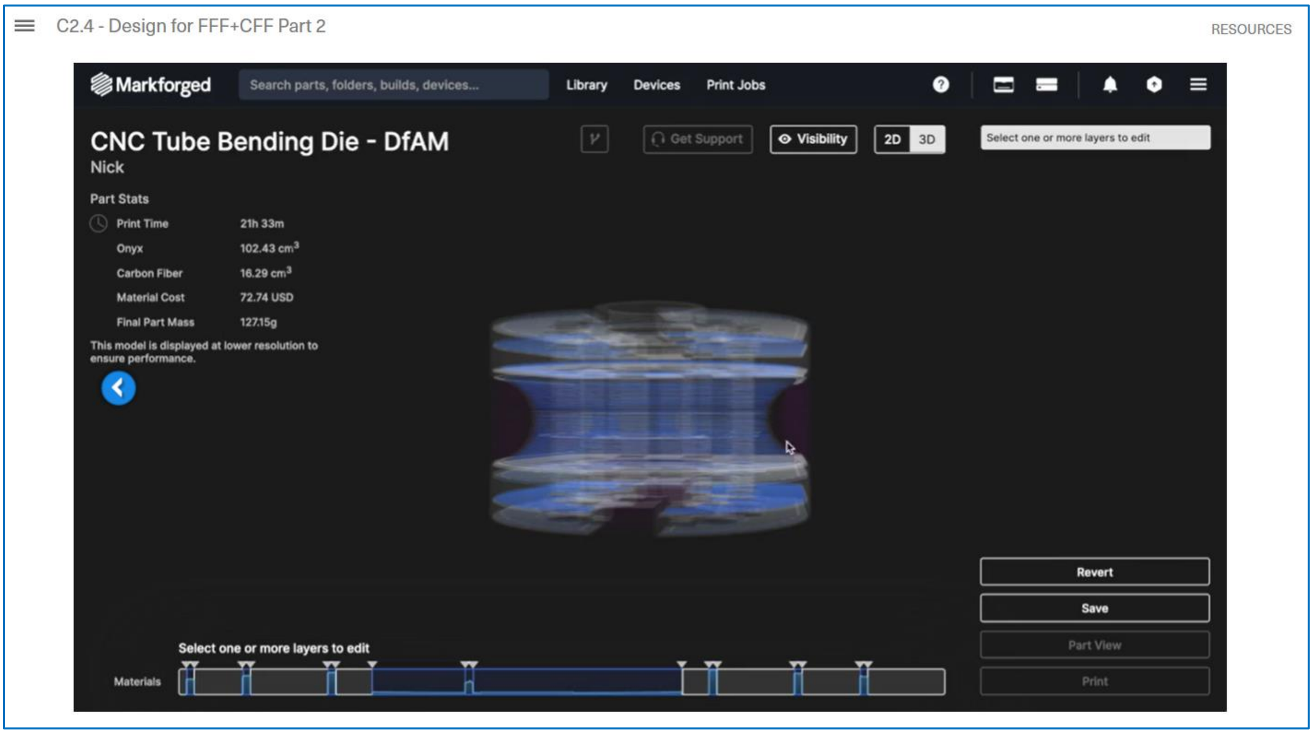
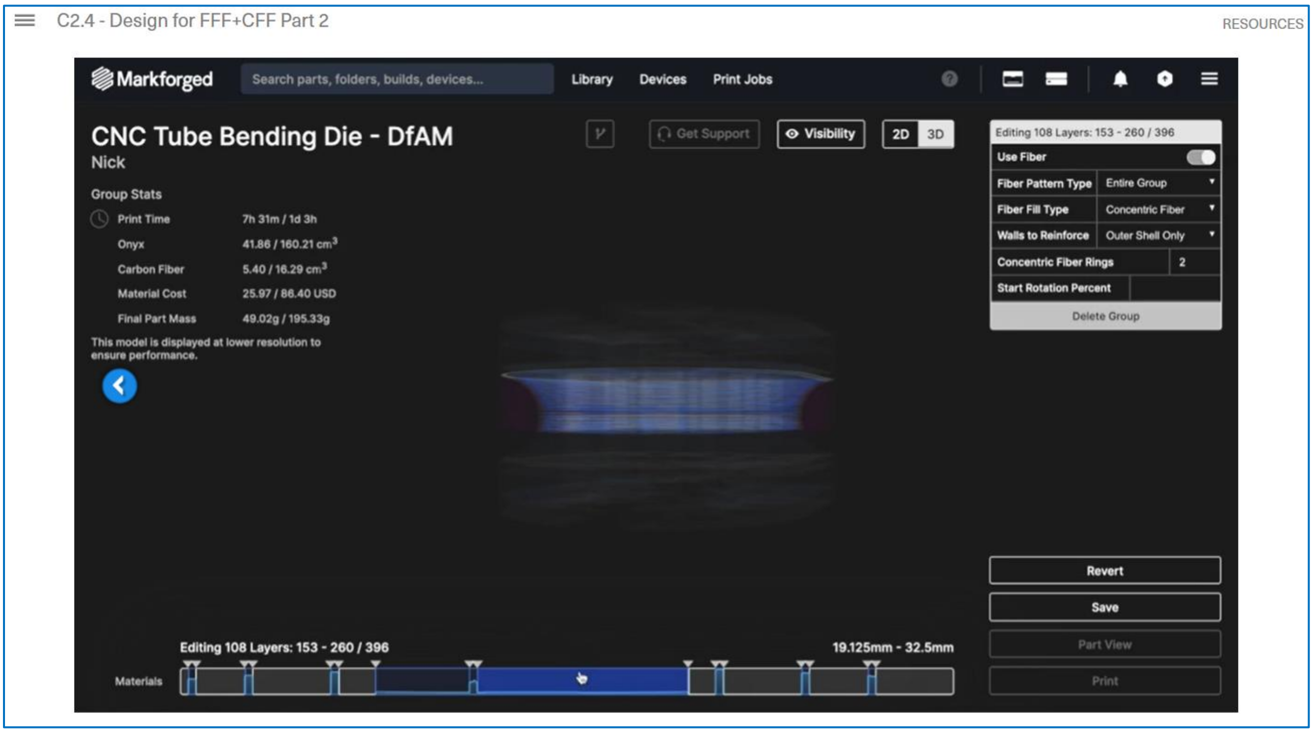
Print Jobs
CNC Tube Bending Die - DfAM
Nick
Part Stats (up to layer 151)
Print Time 9h 25m / 21h 33m
Onyx 44.72 / 102.43 cm³
Carbon Fiber 6.63 / 16.29 cm³
Material Cost 30.31 / 72.74 USD
Final Part Mass 53.53g / 127.15g
This model is displayed at lower resolution to ensure performance.
Get Support
Visibility
2D
3D
Editing Layer: 151 / 396
Use Fiber
Fiber Fill Type Isotropic Fiber
Concentric Fiber Rings 2
Start Rotation Percent 17
Fiber Angle 90
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 151 / 396
18.875mm
Materials

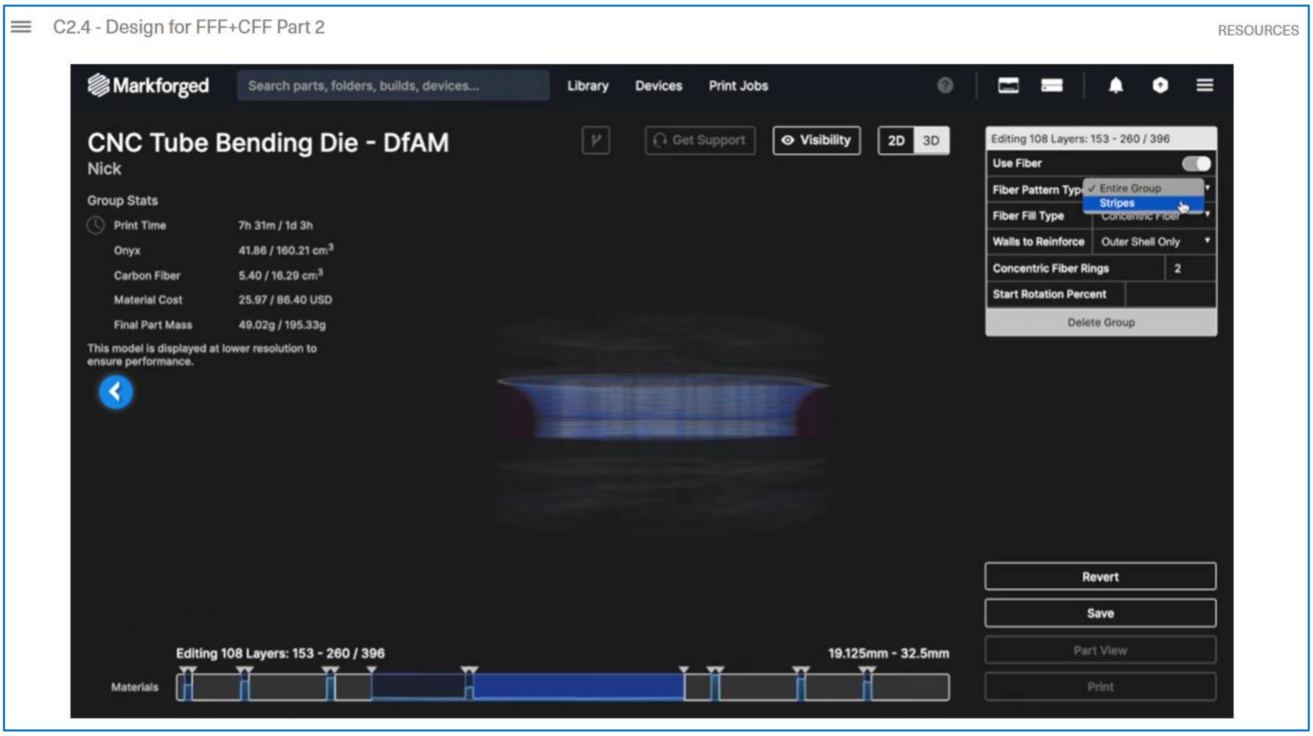




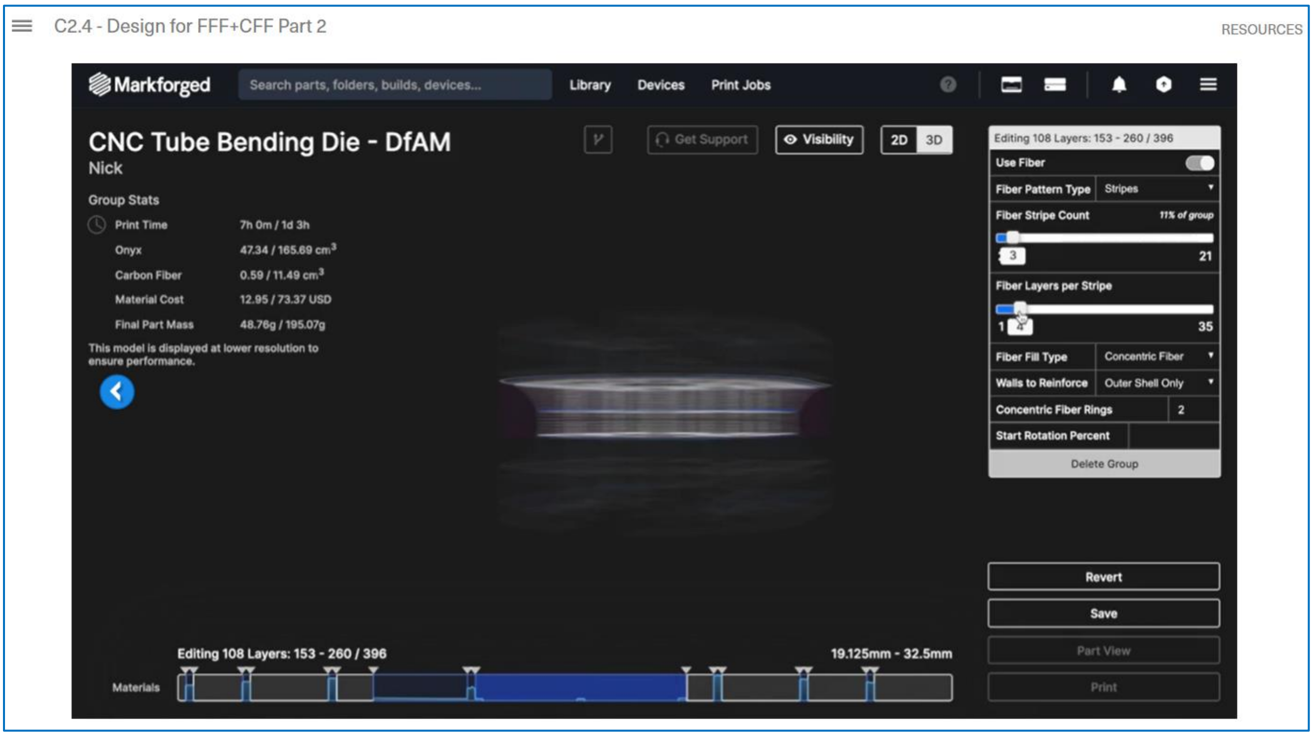
- The profile of the bend die.



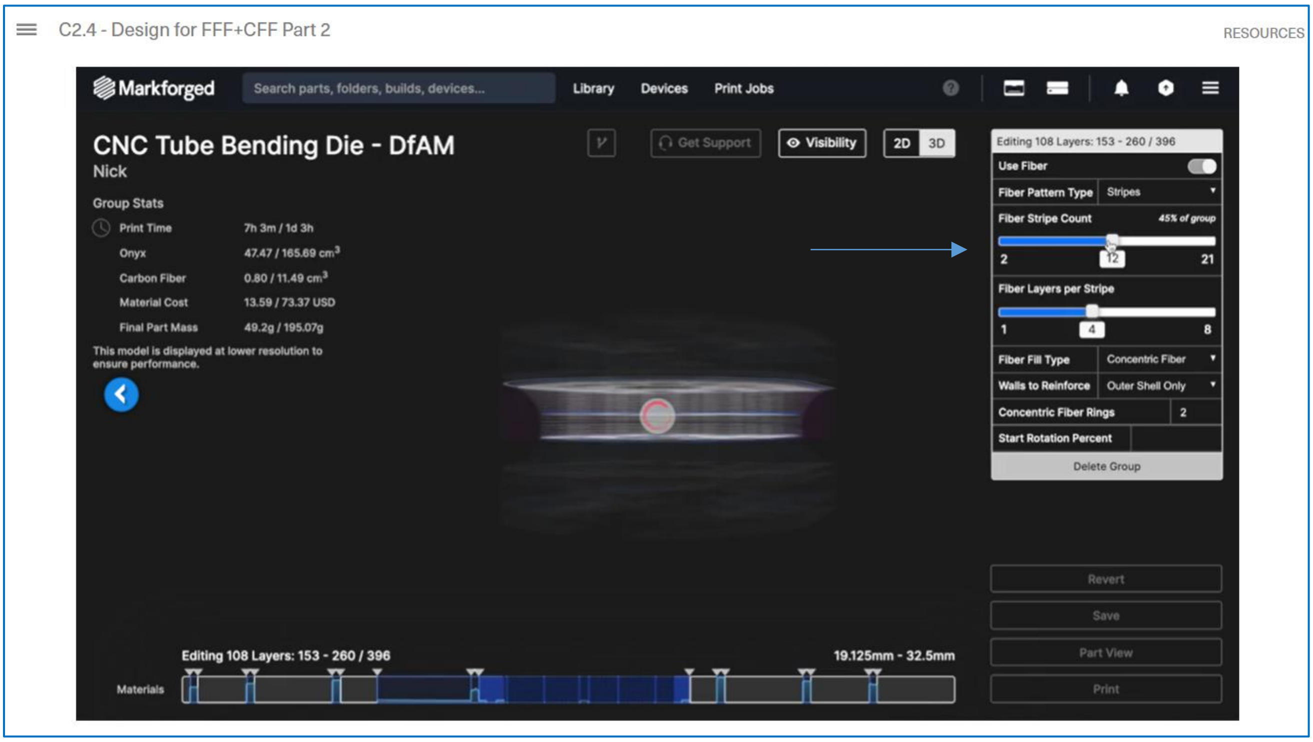
- Choose the layer groups in the bend path.



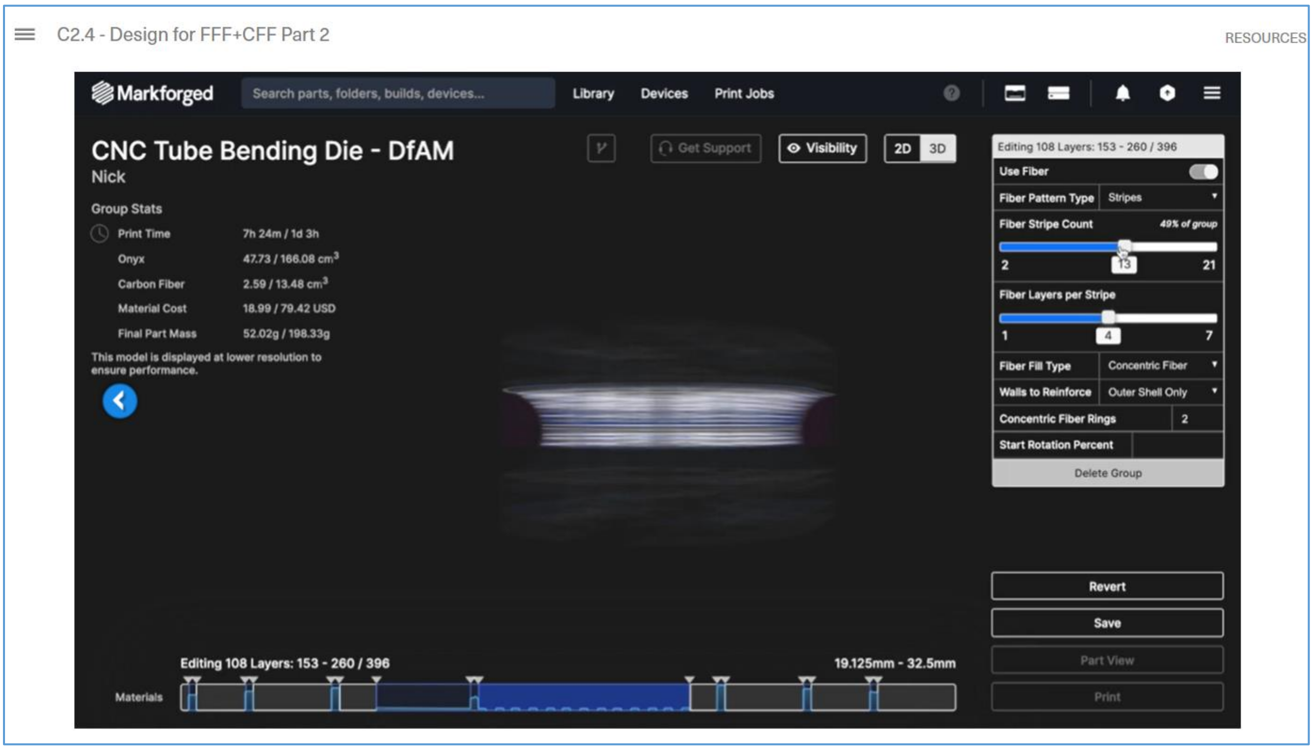
- Change the Fiber Type in Stripes.



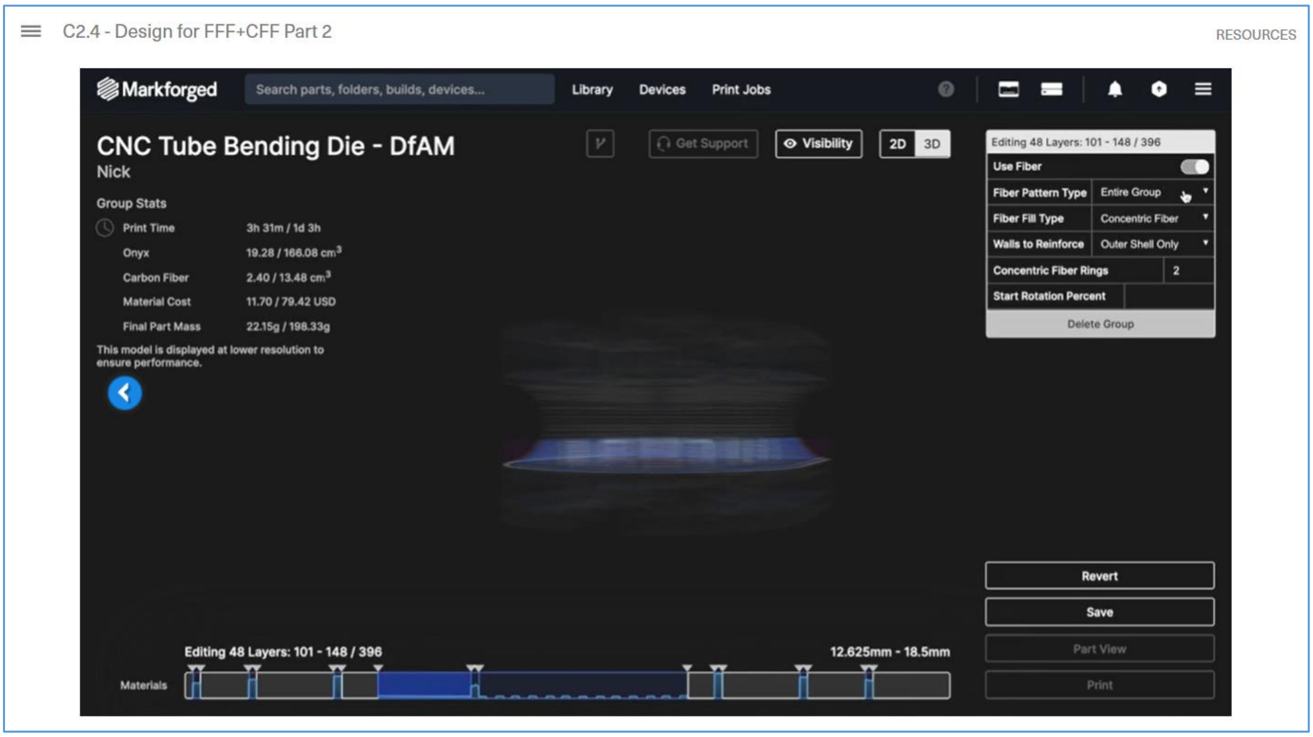
- Adjust Fiber Layer per Stripe.



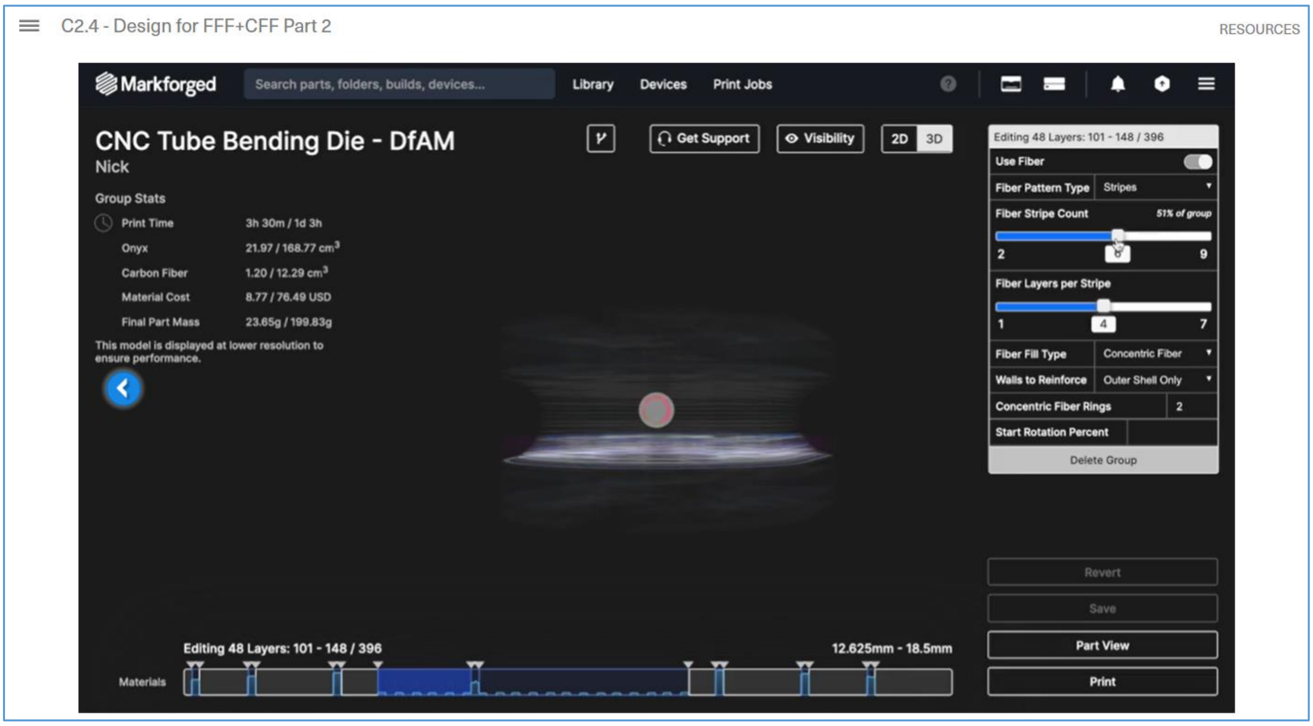
- Adjusting the slider



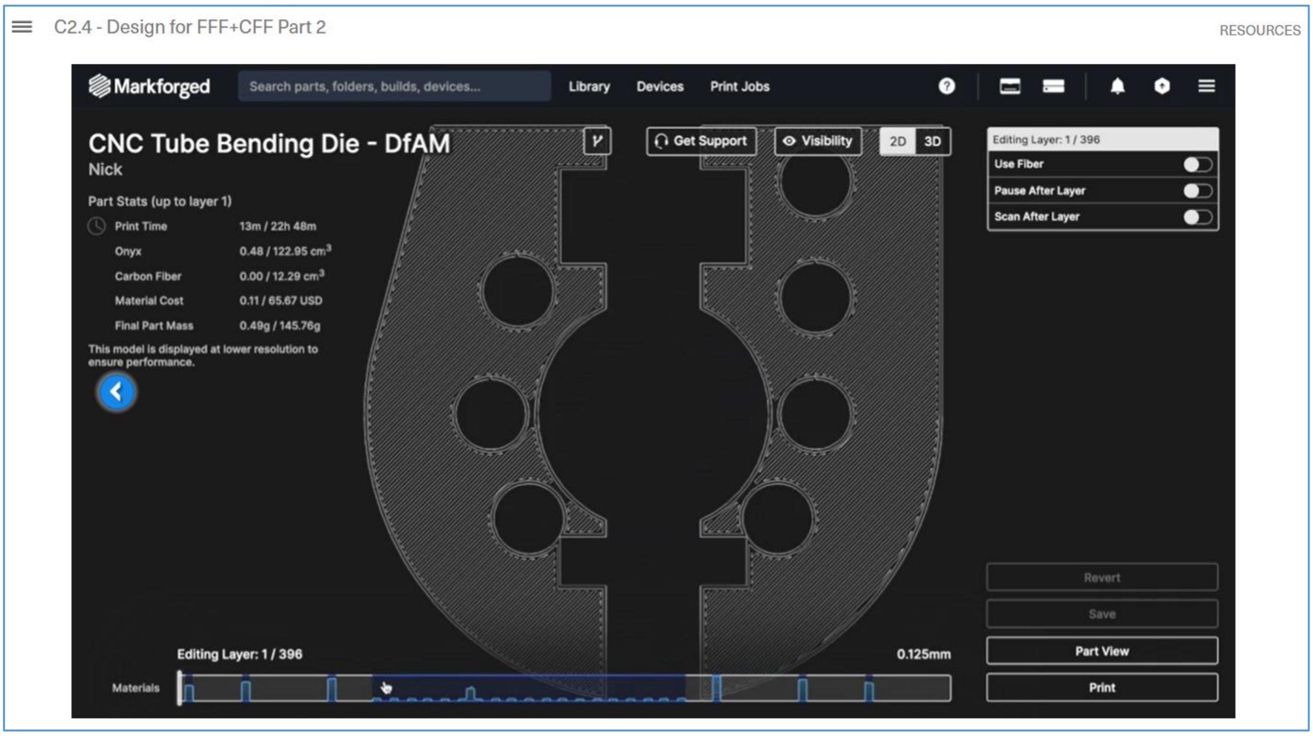
- To 13 Stripes.



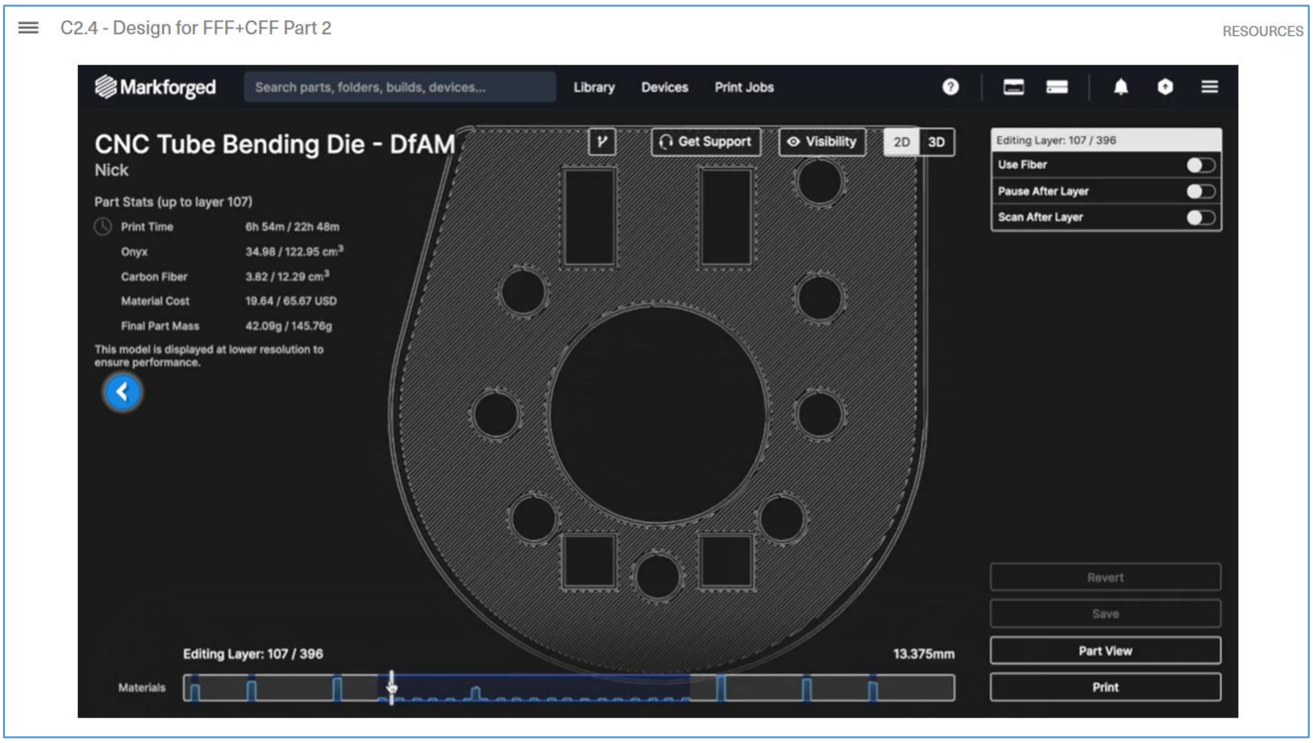
- The lower group and change its pattern type into stripes as well.



- Fiber layer per Stripe: 4 and Fiber Stripes Count: 6



- Go back to 2D-view how it looks to move the slider throw the layers. See next.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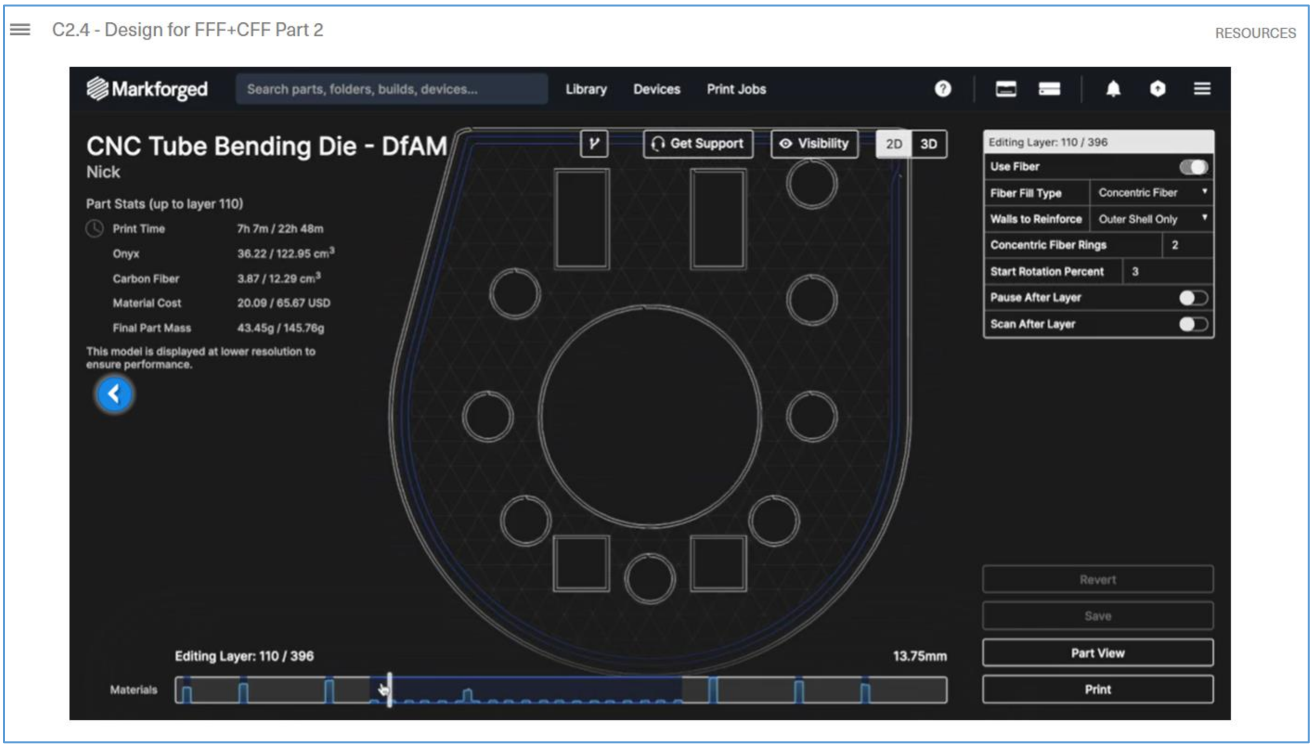
Visibility
2D
3D
Part Stats (up to layer 107)
Print Time 6h 54m / 22h 48m
Onyx 34.98 / 122.95 cm³
Carbon Fiber 3.82 / 12.29 cm³
Material Cost 19.64 / 65.67 USD
Final Part Mass 42.09g / 145.76g
This model is displayed at lower resolution to ensure performance.
Editing Layer: 107 / 396
Use Fiber
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 107 / 396
13.375mm
Materials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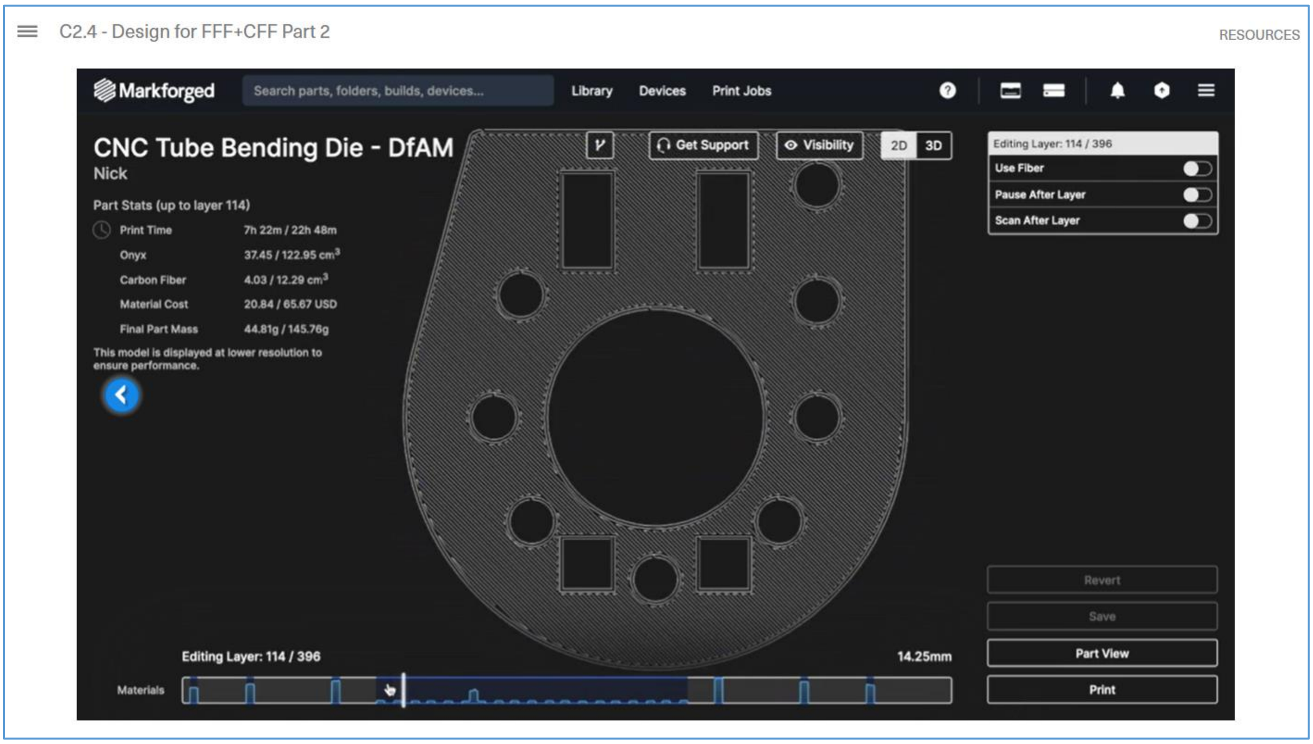
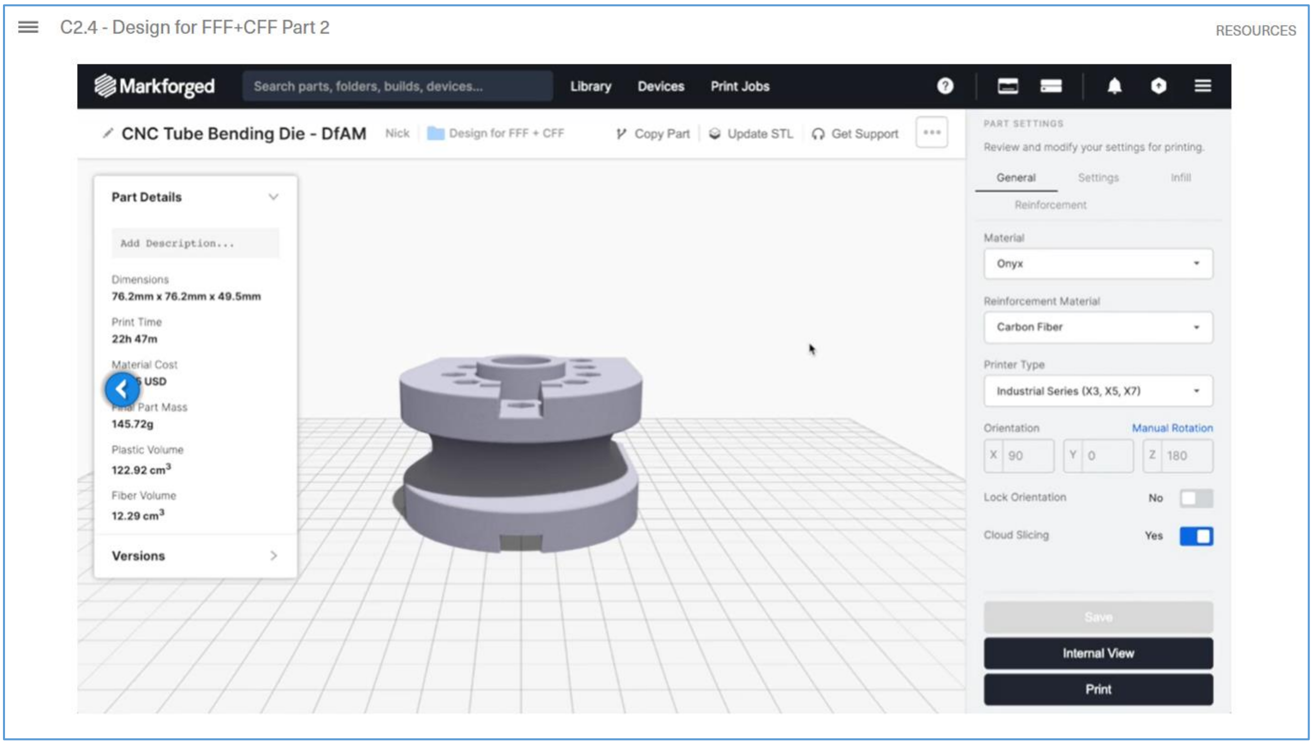
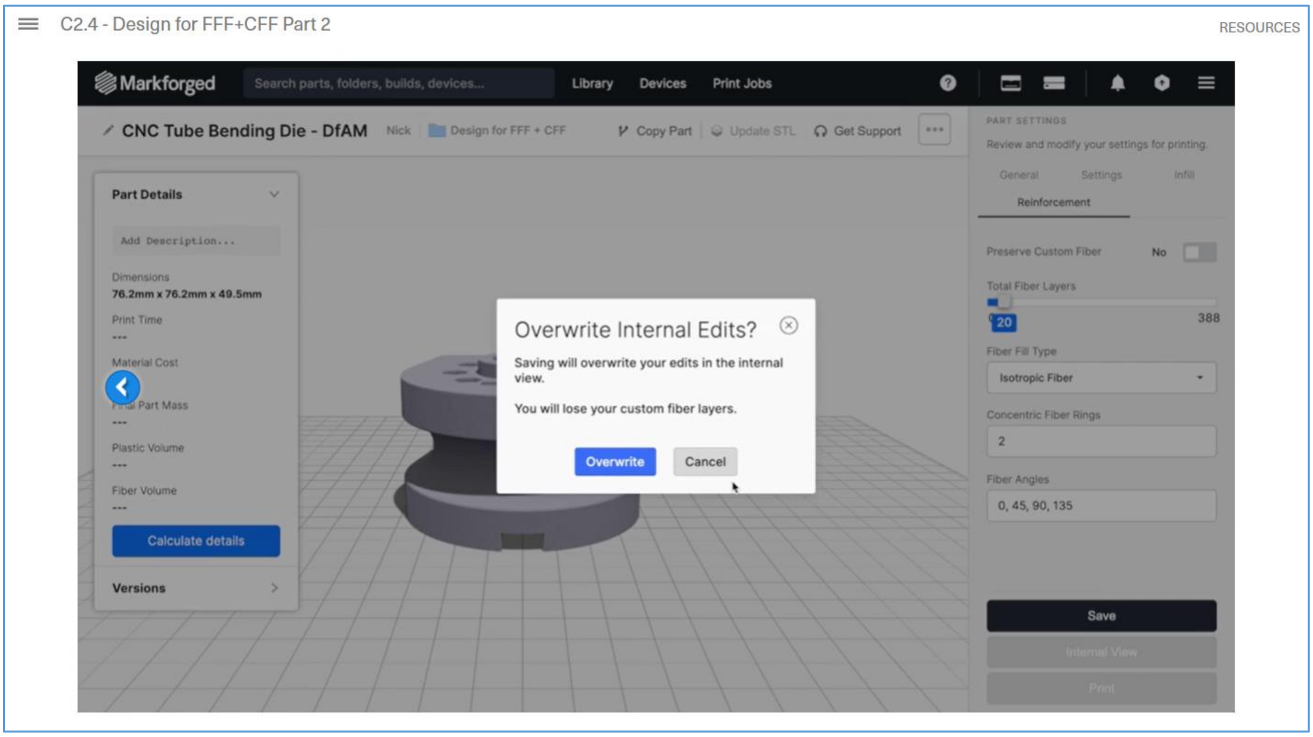
Devices
Print Jobs
CNC Tube Bending Die - DfAM
Nick
Get Support
Visibility
2D
3D
Part Stats (up to layer 110)
Print Time 7h 7m / 22h 48m
Onyx 36.22 / 122.95 cm³
Carbon Fiber 3.87 / 12.29 cm³
Material Cost 20.09 / 65.67 USD
Final Part Mass 43.45g / 145.76g
This model is displayed at lower resolution to ensure performance.
Editing Layer: 110 / 396
Use Fiber
Fiber Fill Type Concentric Fiber
Walls to Reinforce Outer Shell Only
Concentric Fiber Rings 2
Start Rotation Percent 3
Pause After Layer
Scan After Layer
Revert
Save
Part View
Print
Editing Layer: 110 / 396
13.75mm
Materials



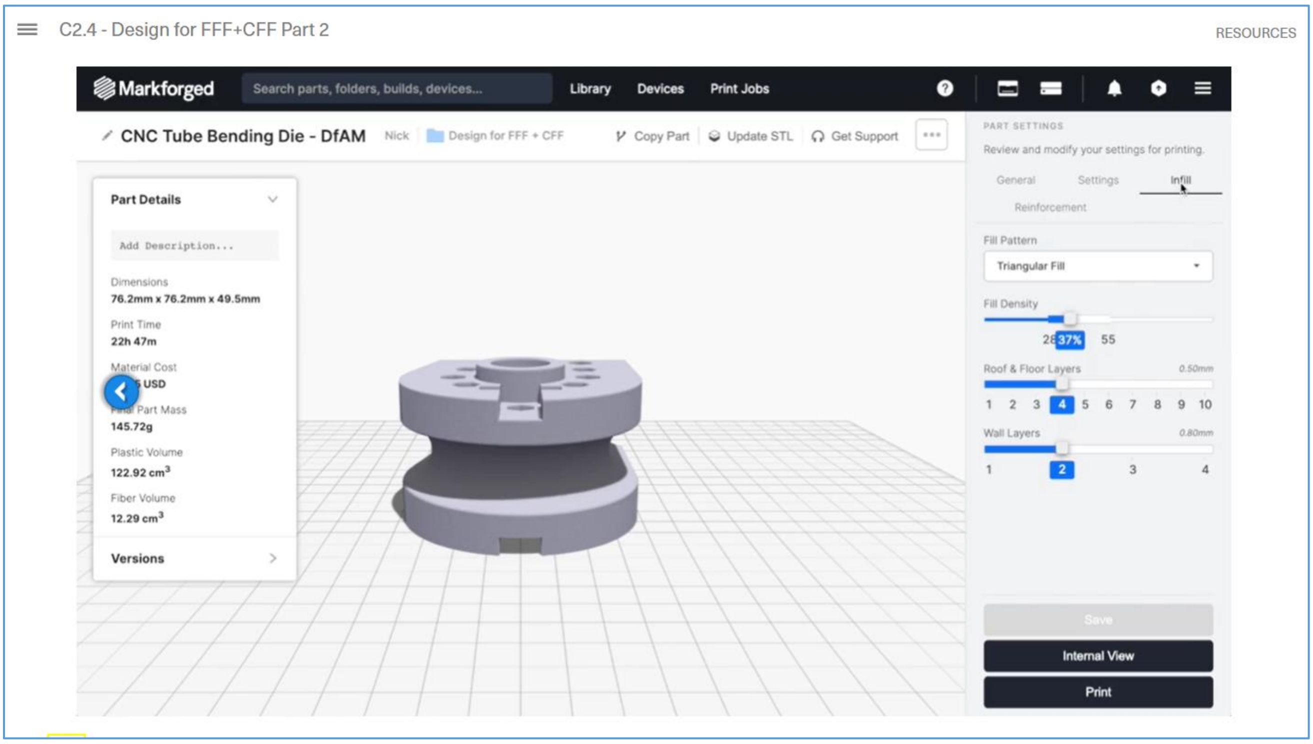
- Sections of solid roofs and floor layers.
- Save your work.



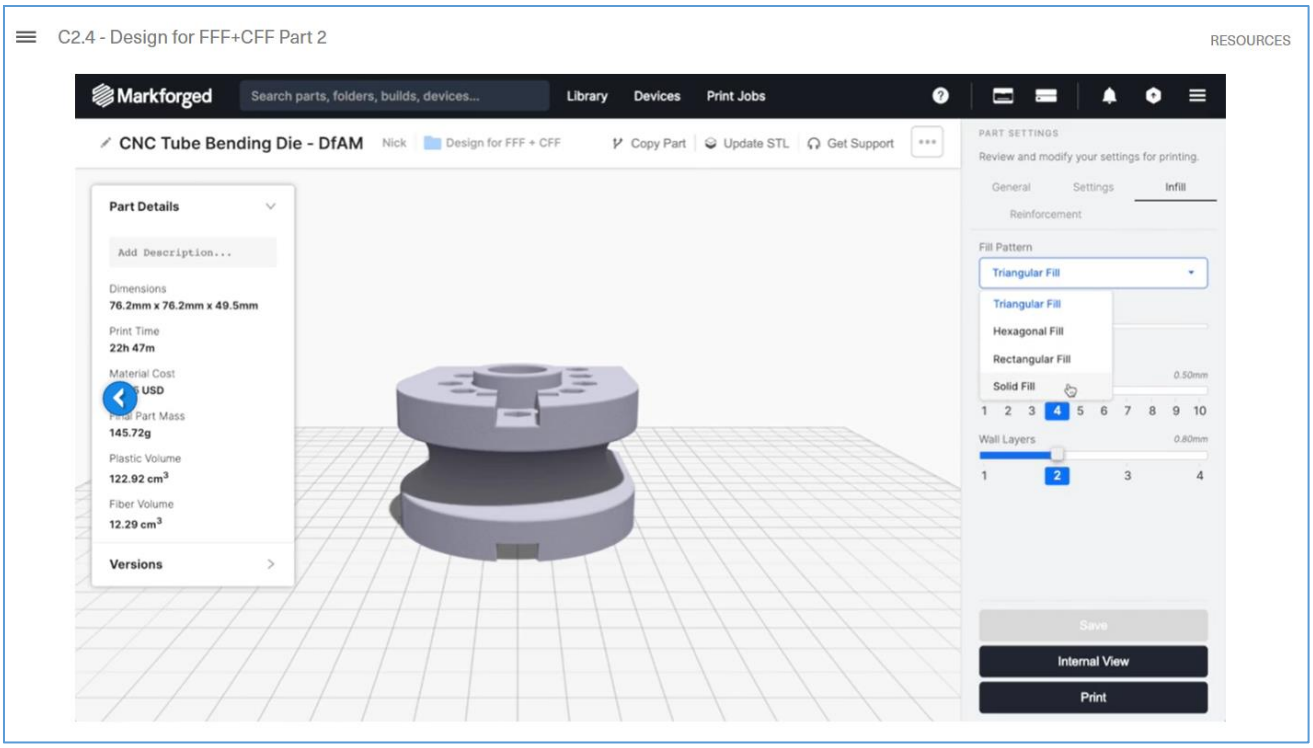
- Change infill pattern from rectangular to completely solid.



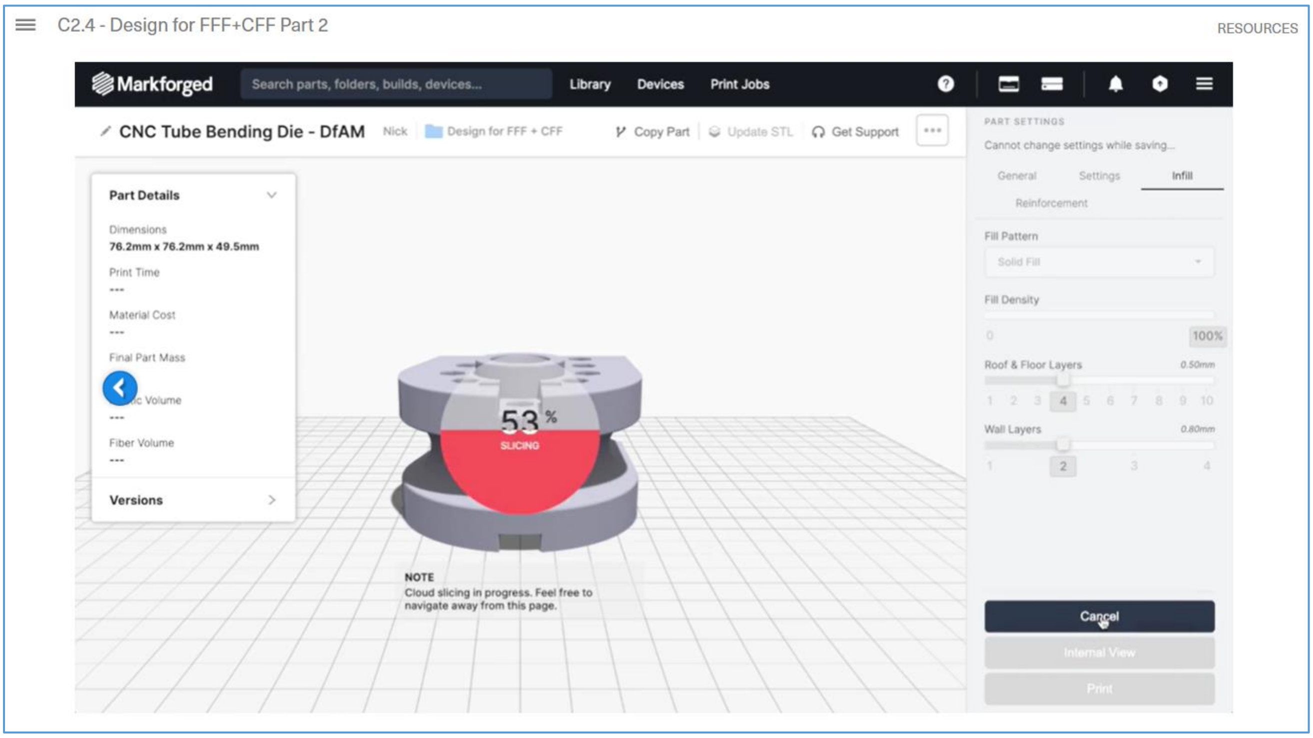
- We won't change the fiber configuration.



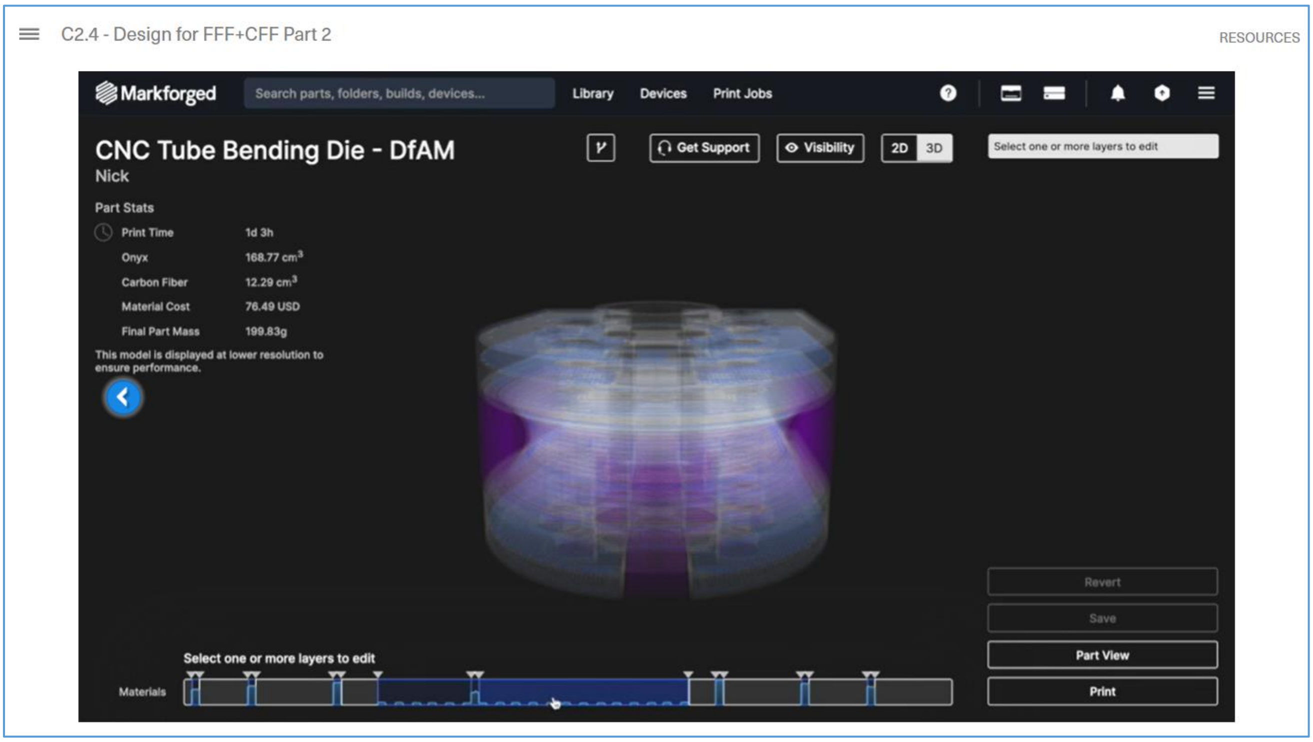
- Go to the Infill tab.



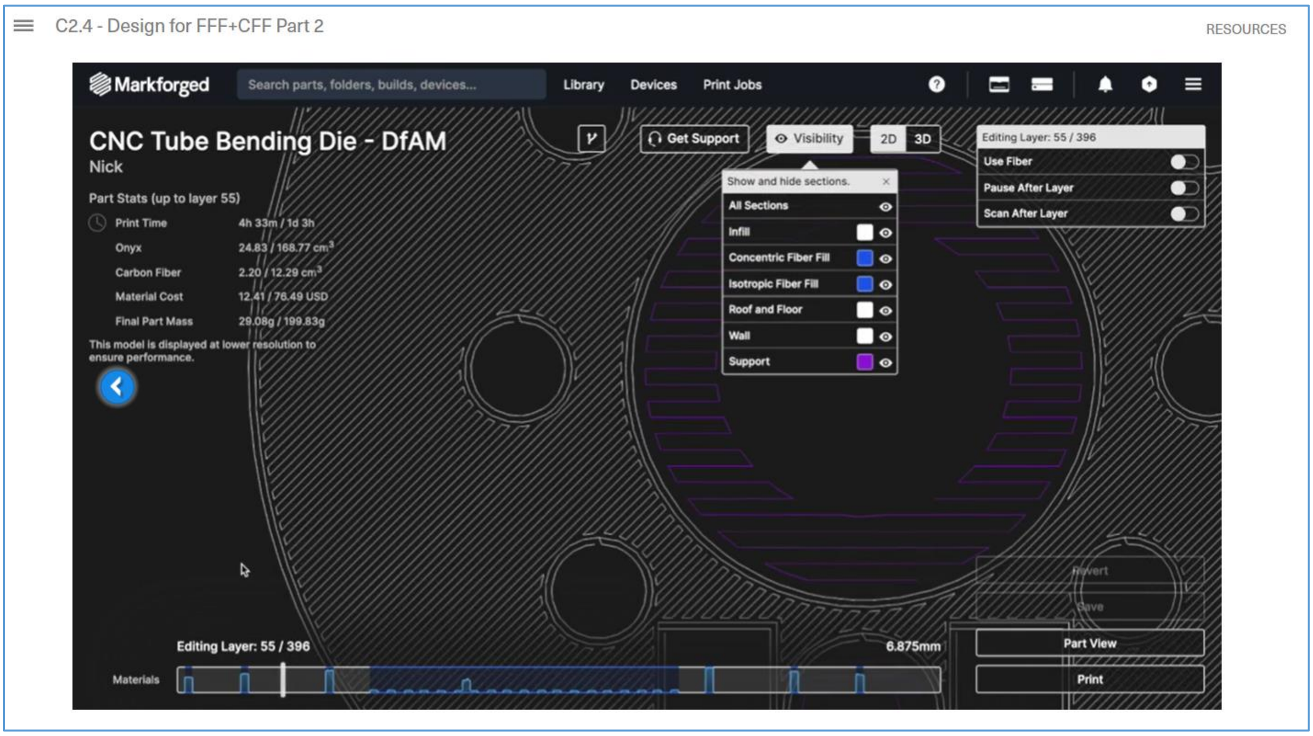
- Solid Fill.

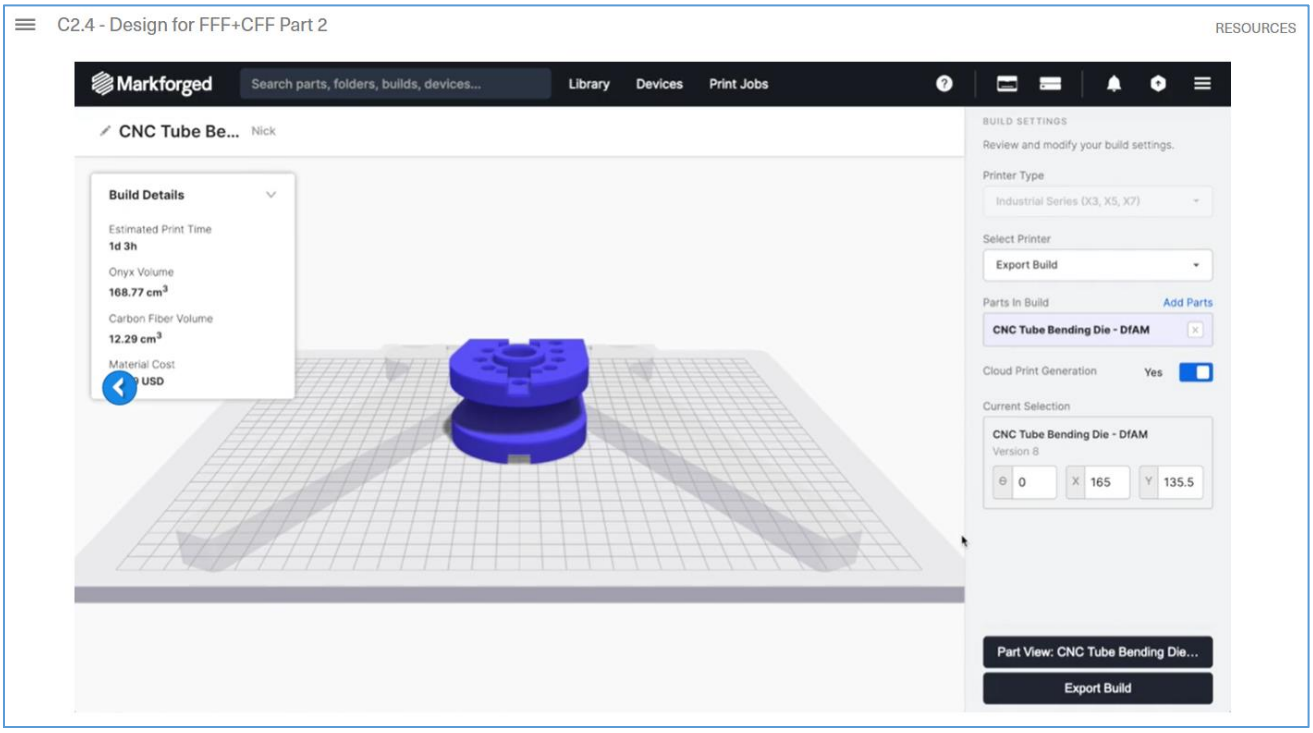


- This time no warning. The plastic infill type didn't change the fiber configuration.
- We can save our work, without worry.



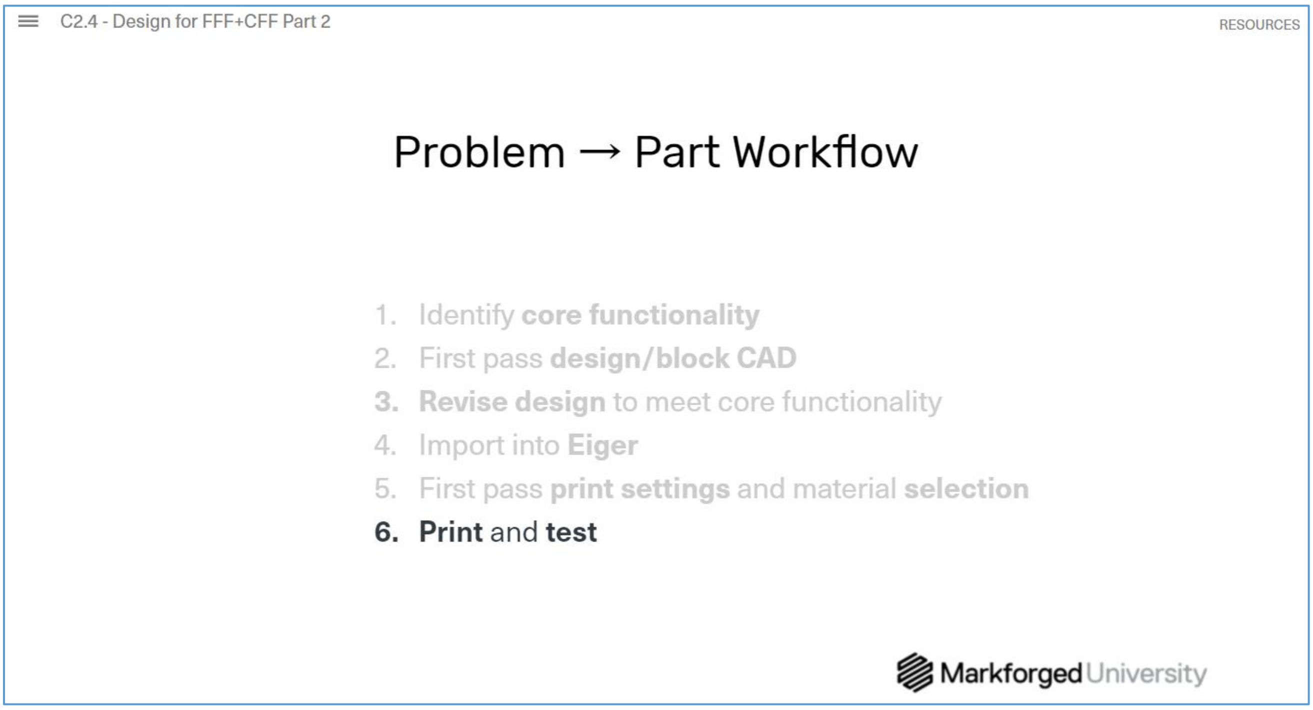
- Notice that all our fiber layer groups are preserved (beschermd).





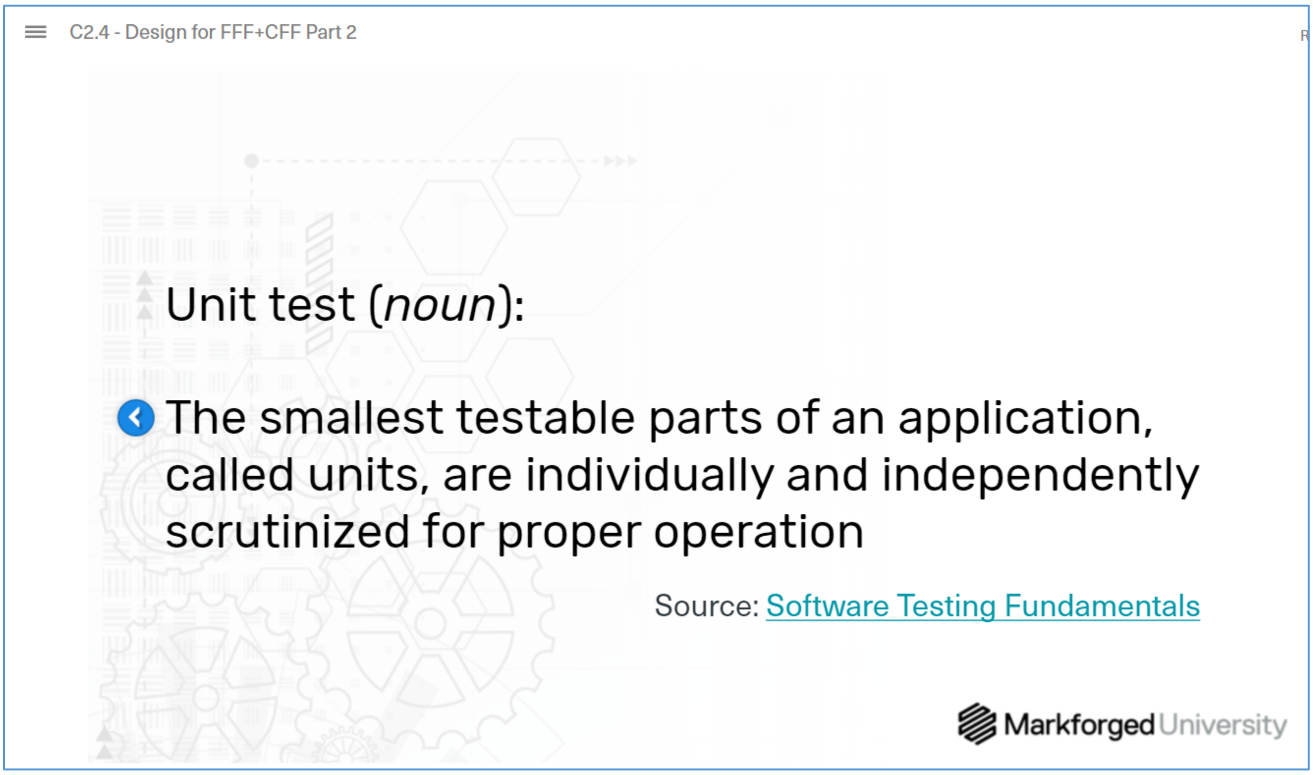
- The first print of a complex modified reinforced product.

- **Finished Bending Die**
  - With the bolts, nuts and the machine keys.
  - Lowering the costs and faster DfAM will give you advantage.



- **Step 6: Print and Test.**

- **Iterate faster with unit testing**

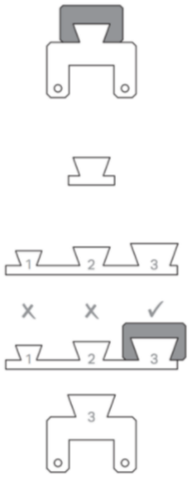


- Scrutinize = onderzoeken
- [Software Testing Fundamentals]

- **Demo: Unit Testing in Action**

C2.4 - Design for FFF+CFF Part 2

Unit Testing Workflow



1. Identify critical feature to test
2. Extrude-cut to smallest possible sub-section
3. Print a test piece with multiple configurations
4. Rapidly test iterations
5. Roll results back into larger model and print

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- **Unit Testing Workflow**

C2.4 - Design for FFF+CFF Part 2

Problem → Part Workflow

1. Identify **core functionality**
2. First pass **design/block CAD**
3. **Revise design** to meet core functionality
4. Import into **Eiger**
5. First pass **print settings** and material **selection**
6. **Print** and **test**

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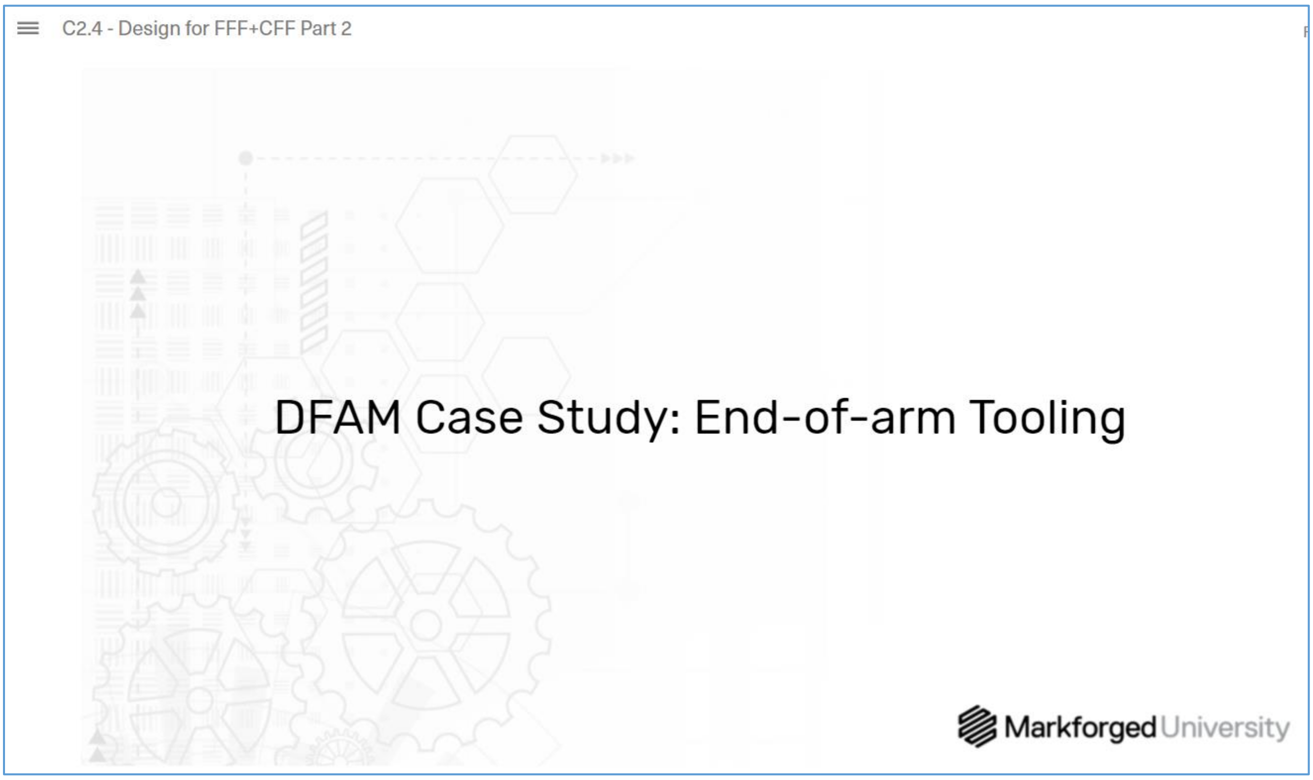
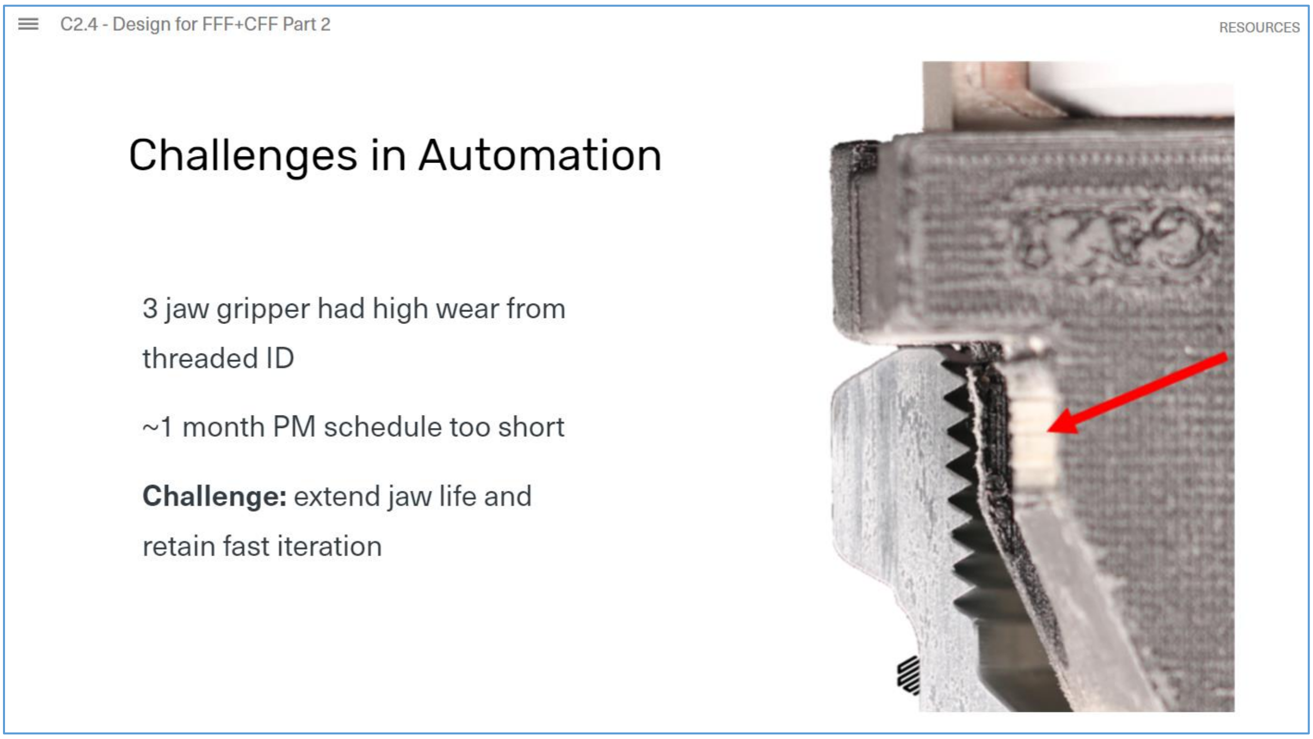
- **Recap: Problem to Part Workflow**

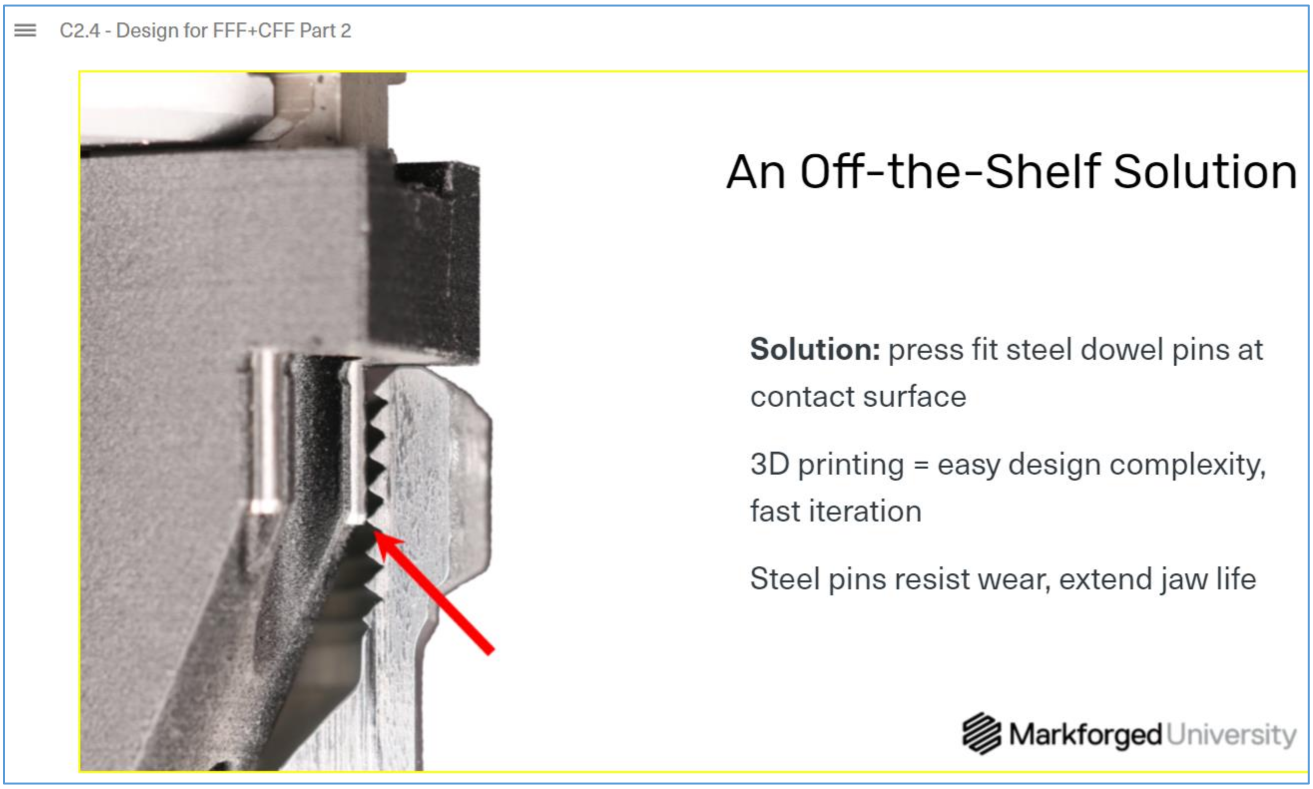


- **DFAM Case Study: End-of-arm-Tooling**

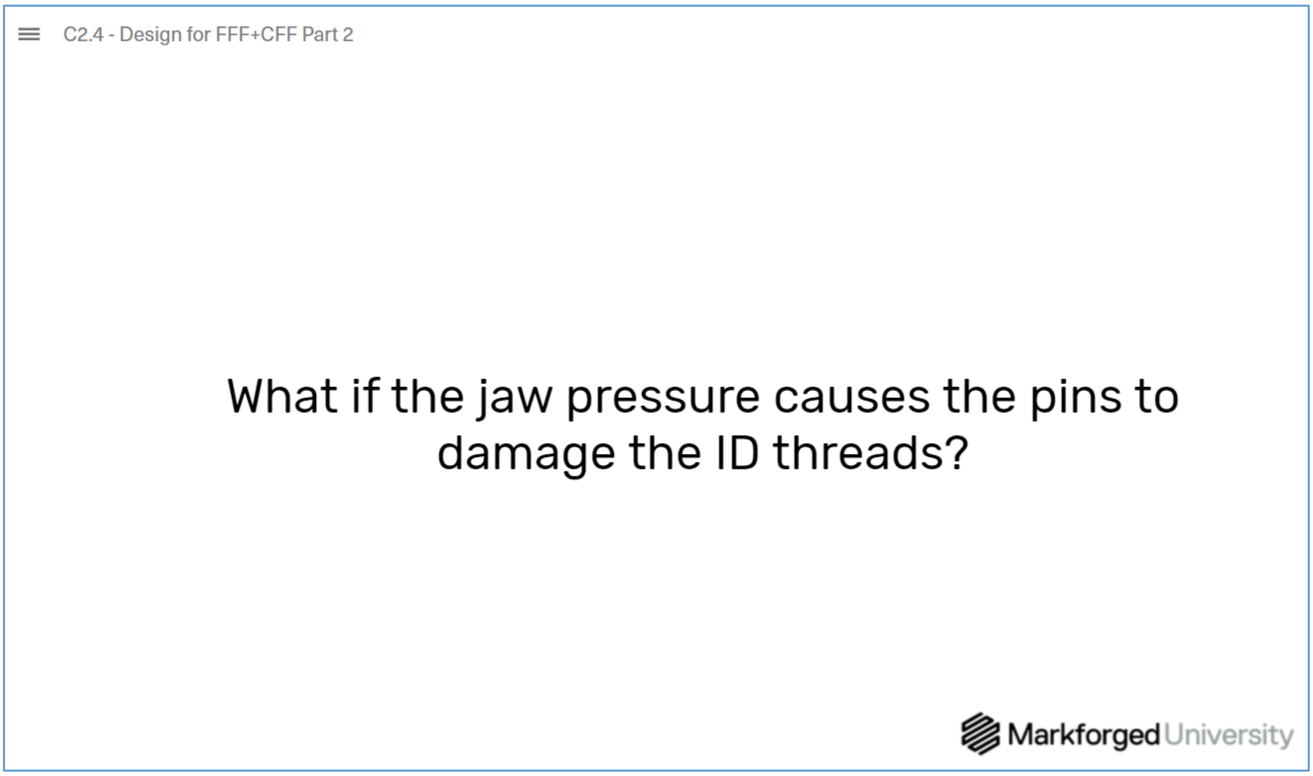
- **Video: Automated Assembly Work Cell**



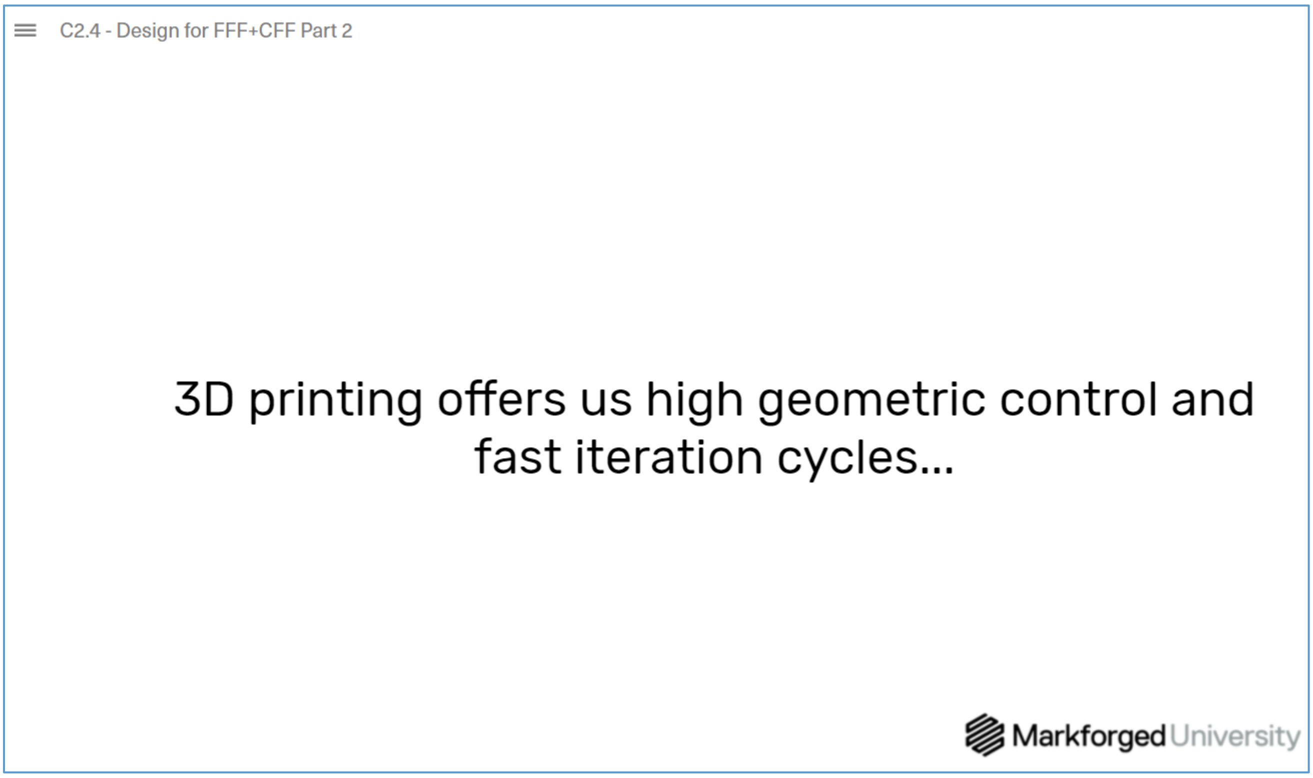
- **Challenges in Automation**

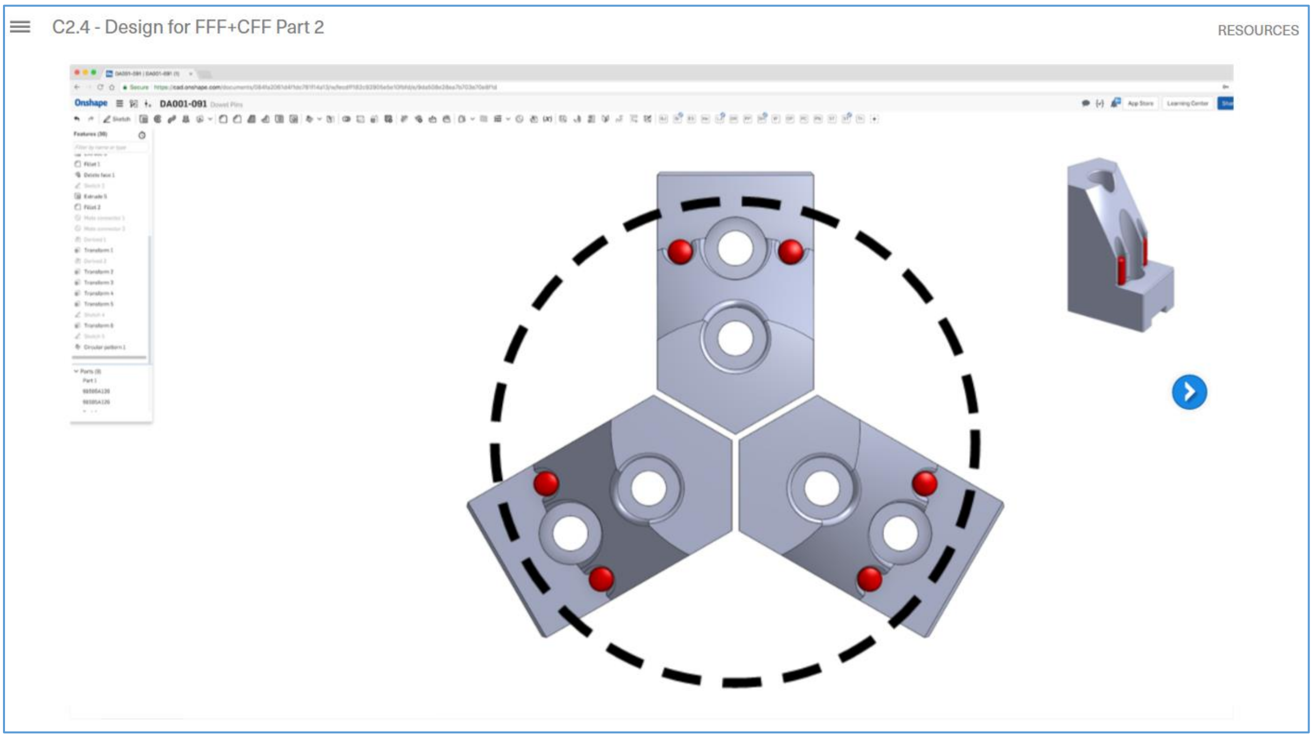


- **An OTS Solution**

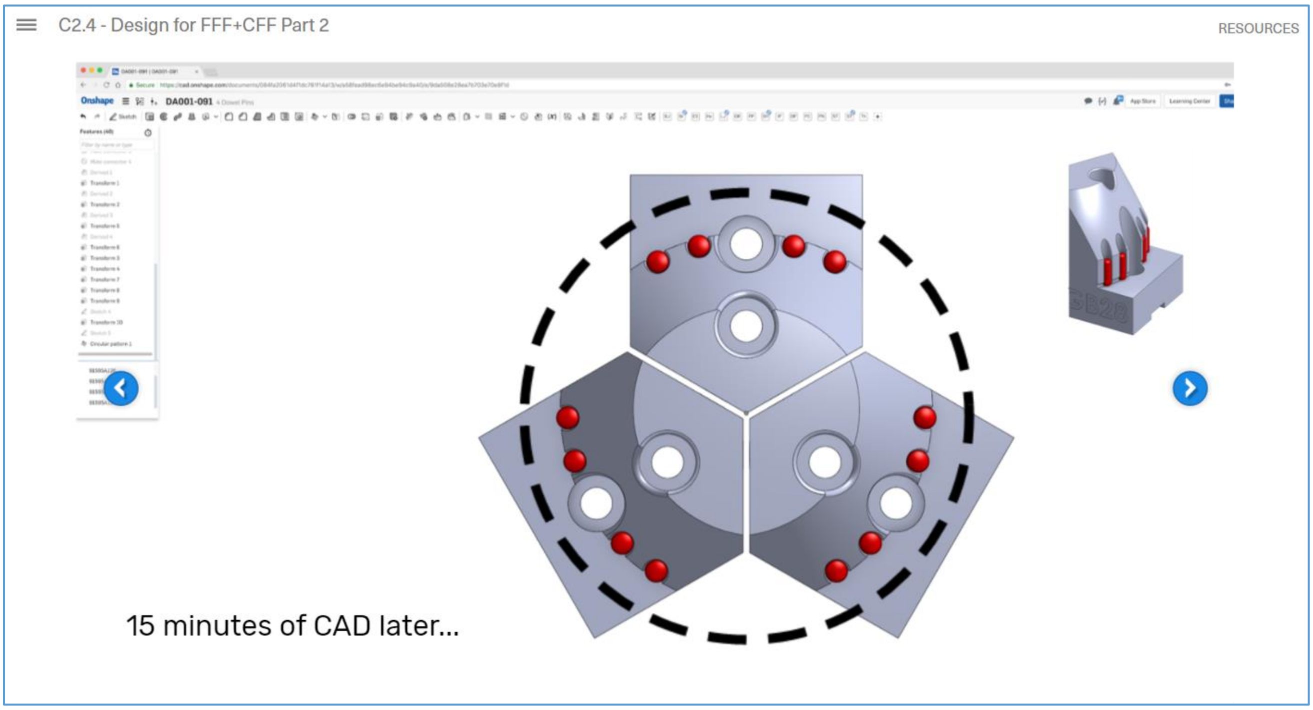


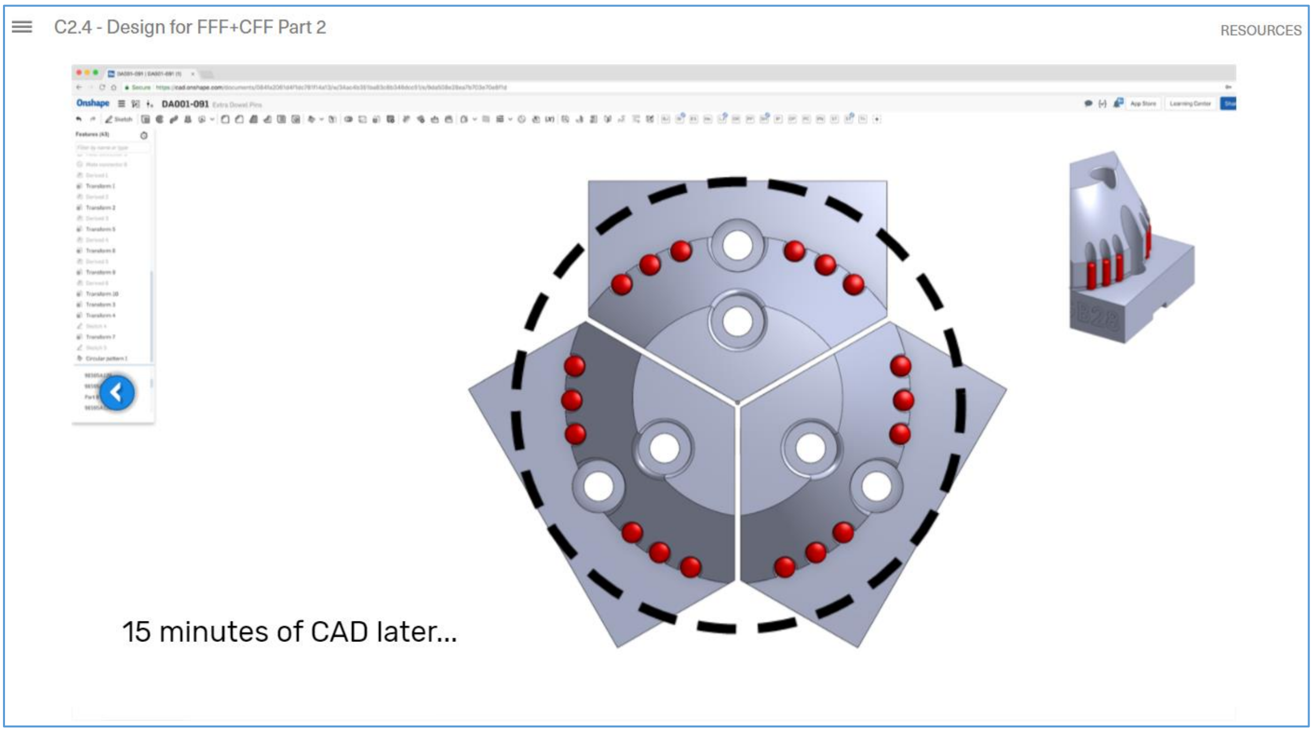
- **What if the jaw pressure causes the pins to damage the ID threads?**

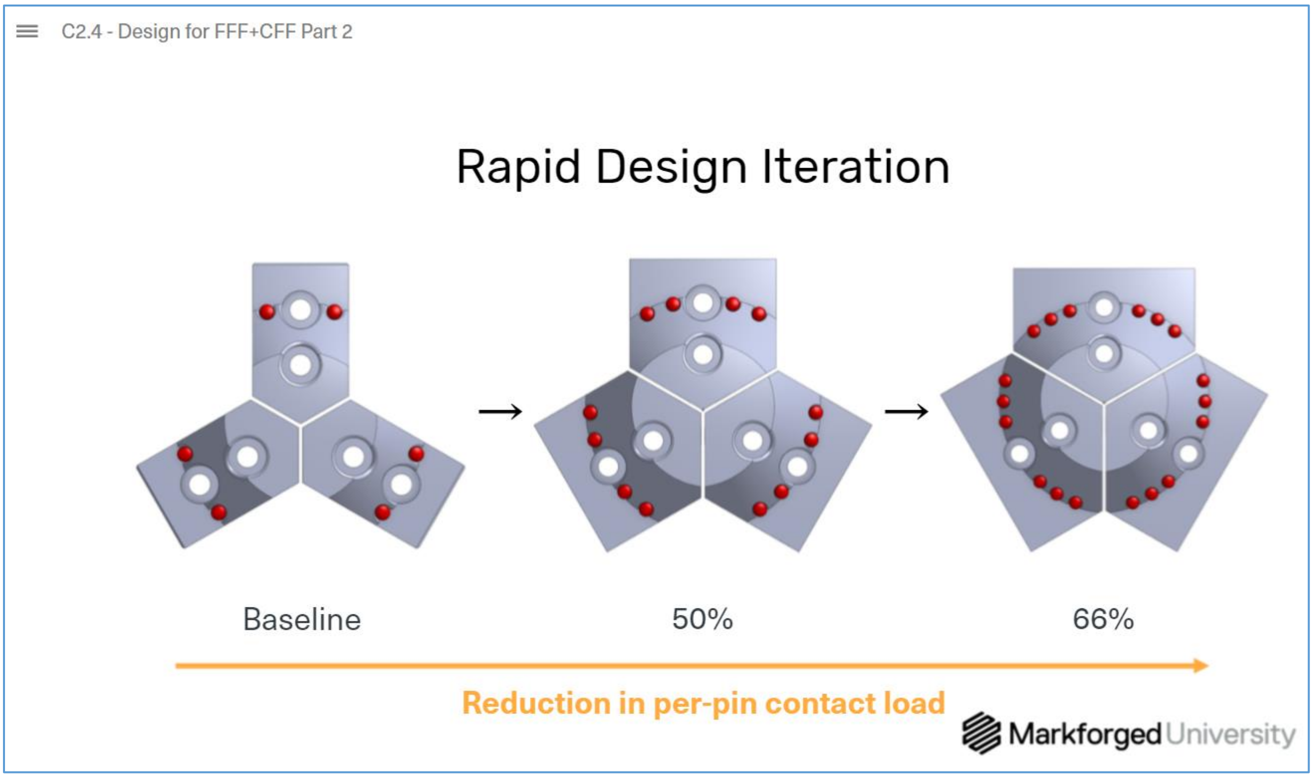




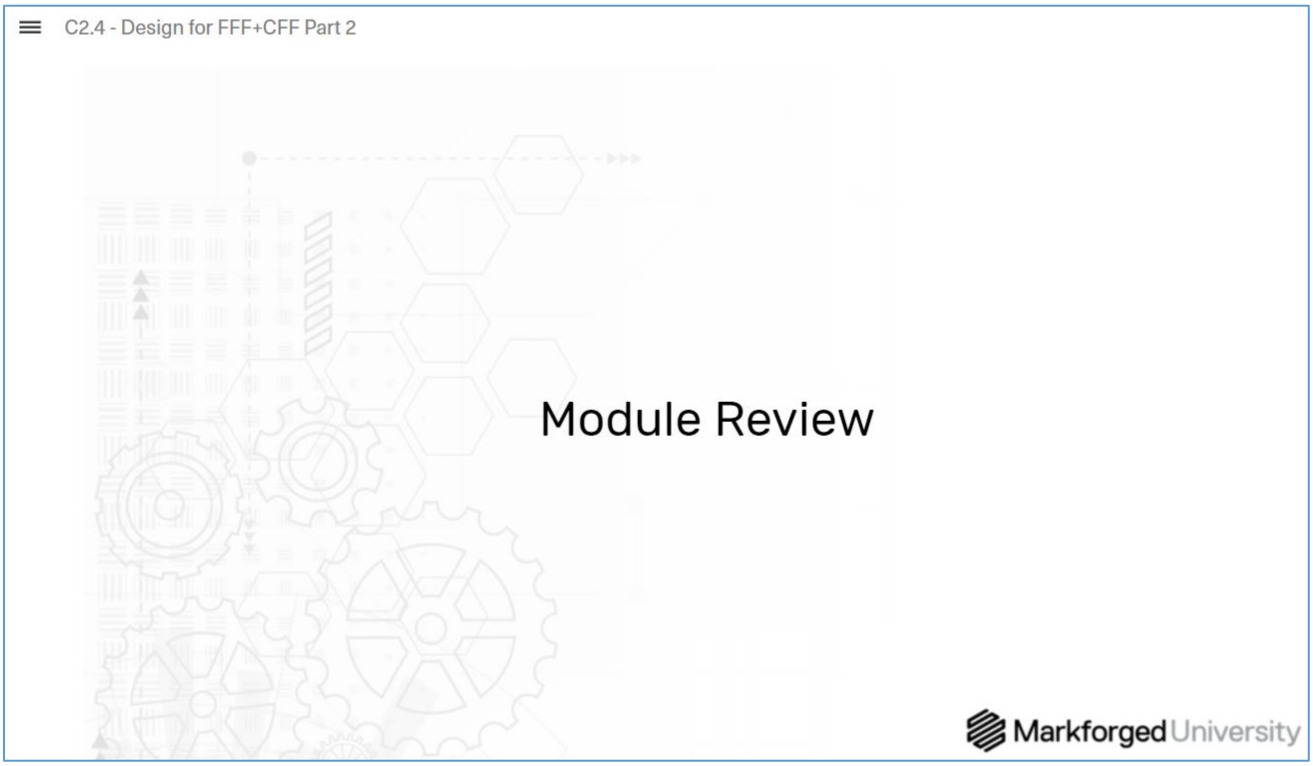
- **Iterating for Functionality**



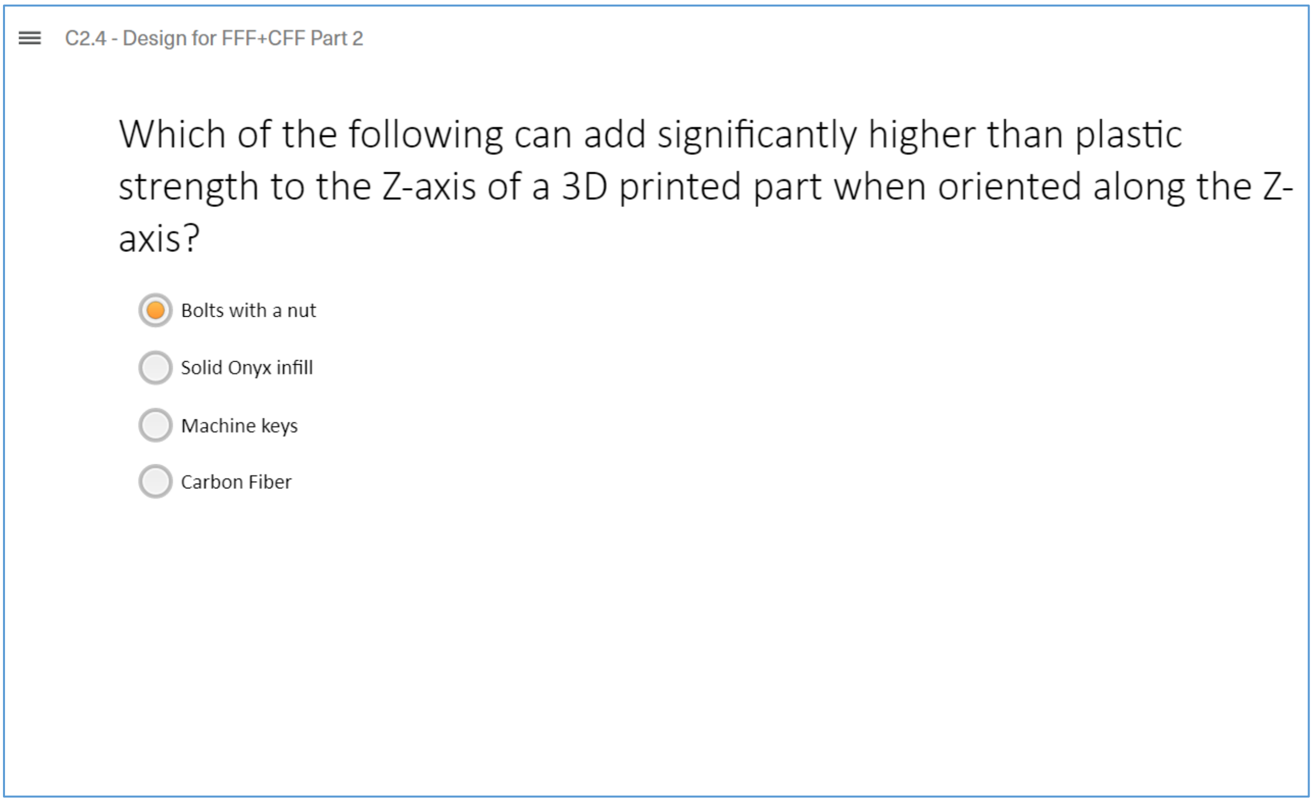




- **Rapid Design Iteration**



- **Model Review**



C2.4 - Design for FFF+CFF Part 2

Put the following steps in the Unit Testing Workflow in order

1. Identify a critical feature to test
2. Extrude-cut existing CAD to smallest possible sub-section OR design a test piece
3. Print a test piece with multiple configurations
4. Rapidly test iterations
5. Update results back into larger CAD model and print

C2.4 - Design for FFF+CFF Part 2

Incorporating commercial off-the-shelf (COTS) components into your 3D printed parts is a useful design strategy because...

- They're often cheap and readily available
- They add properties and capabilities not available in 3D printed materials
- All of the above
- They can be quickly assembled into the printed part

C2.4 - Design for FFF+CFF Part 2

Results

Your Score: 100% (30 points)

Passing Score: 80% (24 points)

Result:

Congratulations, you passed.

Finish Module

Review Quiz

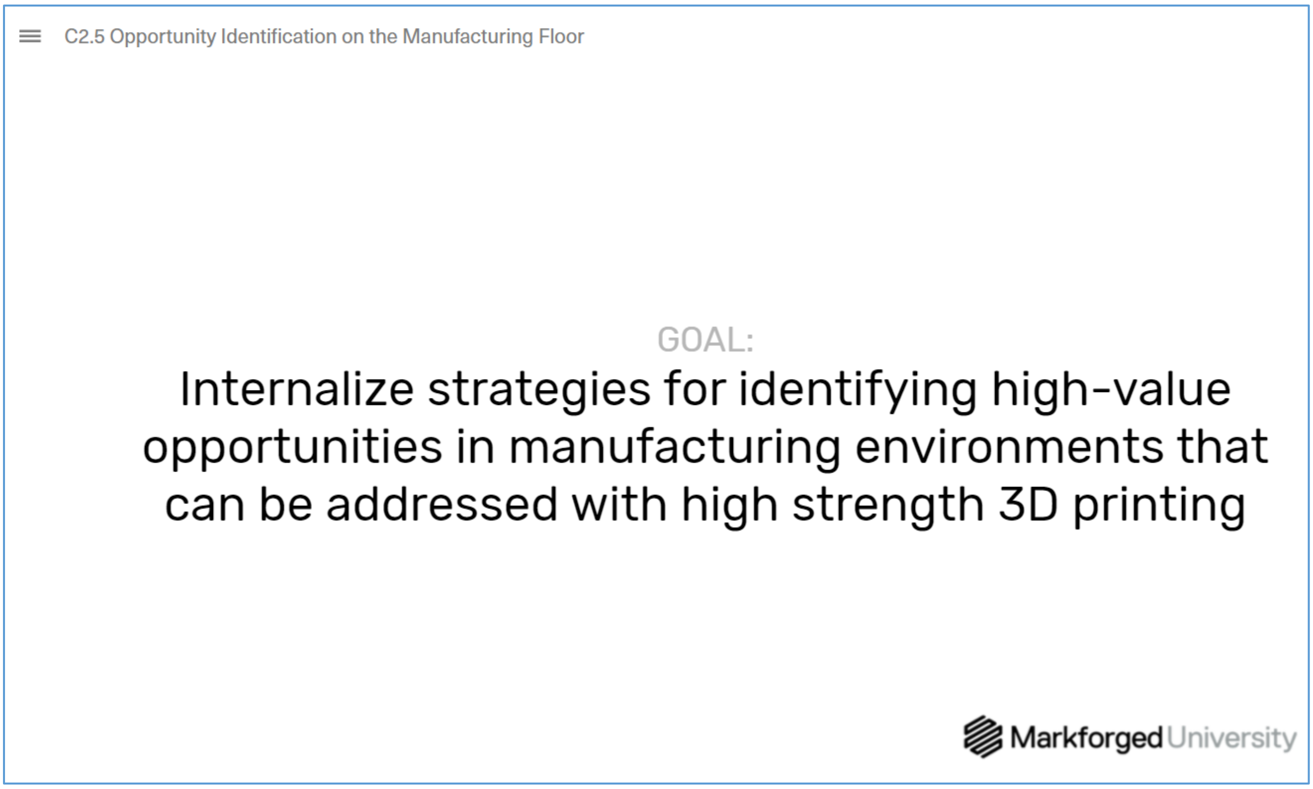
C2.5 – Opportunity Identification on the Manufacturing Floor

C2.5 Opportunity Identification on the Manufacturing Floor

RESOURCES

- **Opportunity Identification on the Manufacturing Floor**

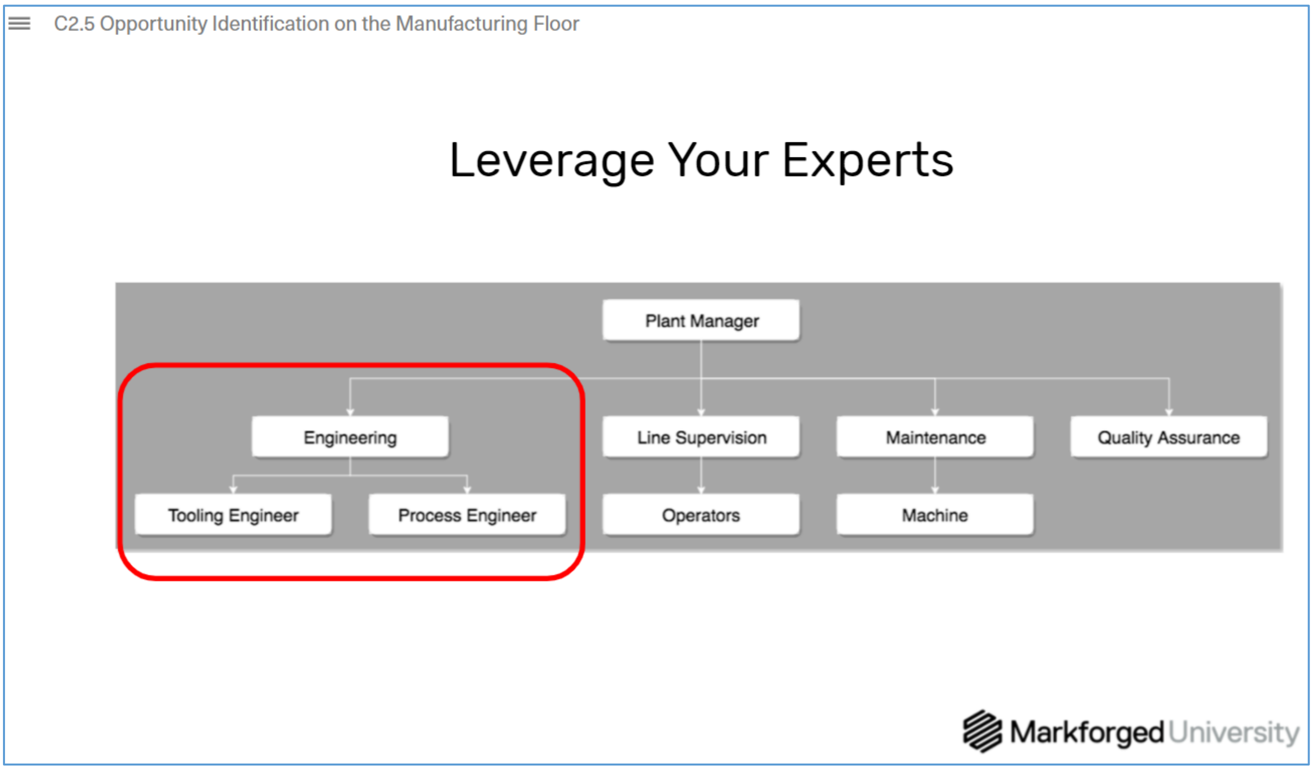
- **Model Overview**



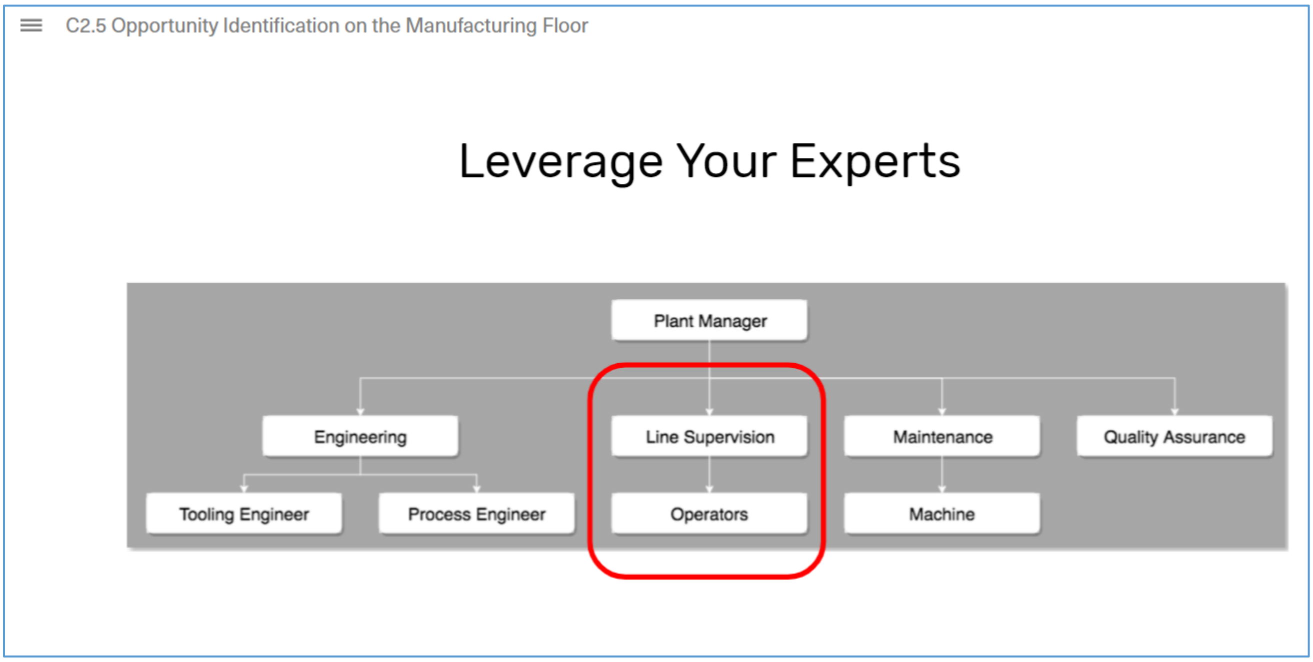
- **Module Goal**
    - Internalize = eigen maken.

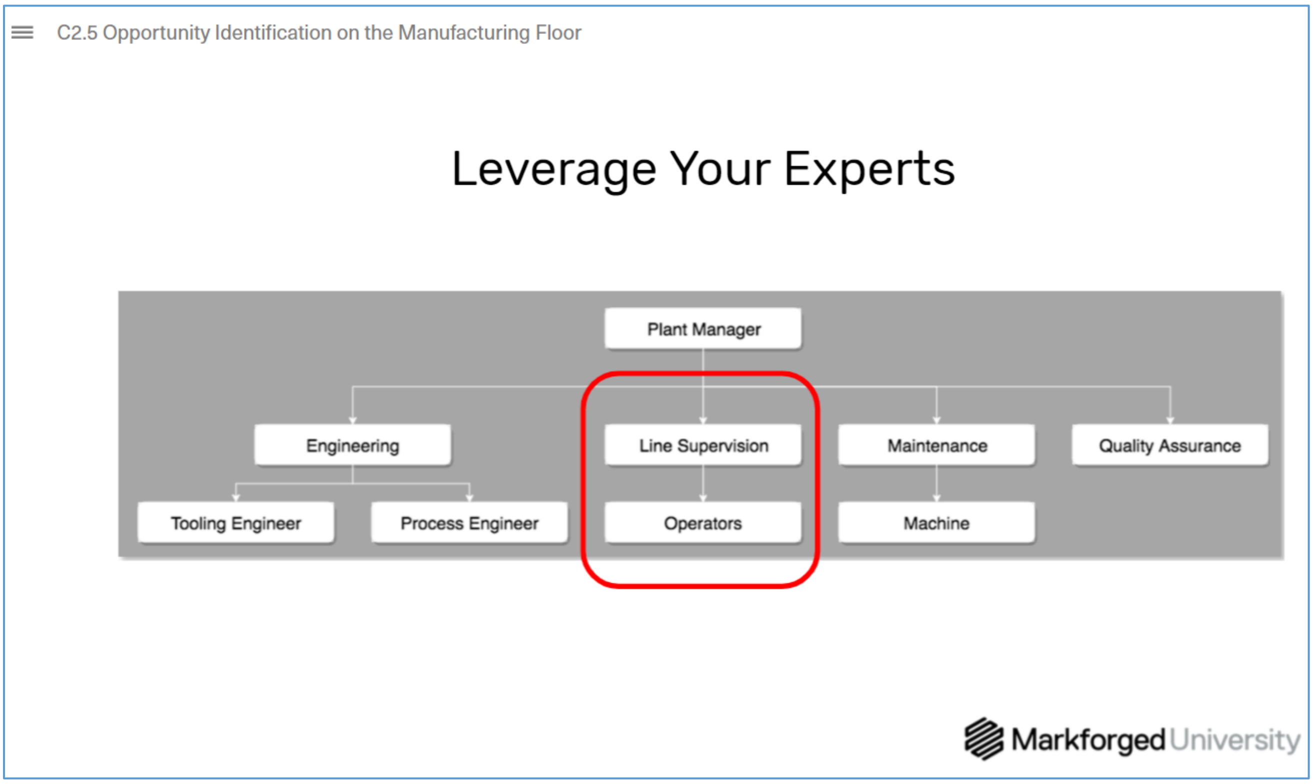
- **Key Takeaways**
    - Belangrijkste leerpunten.

- **"Who should I ask for help?"**

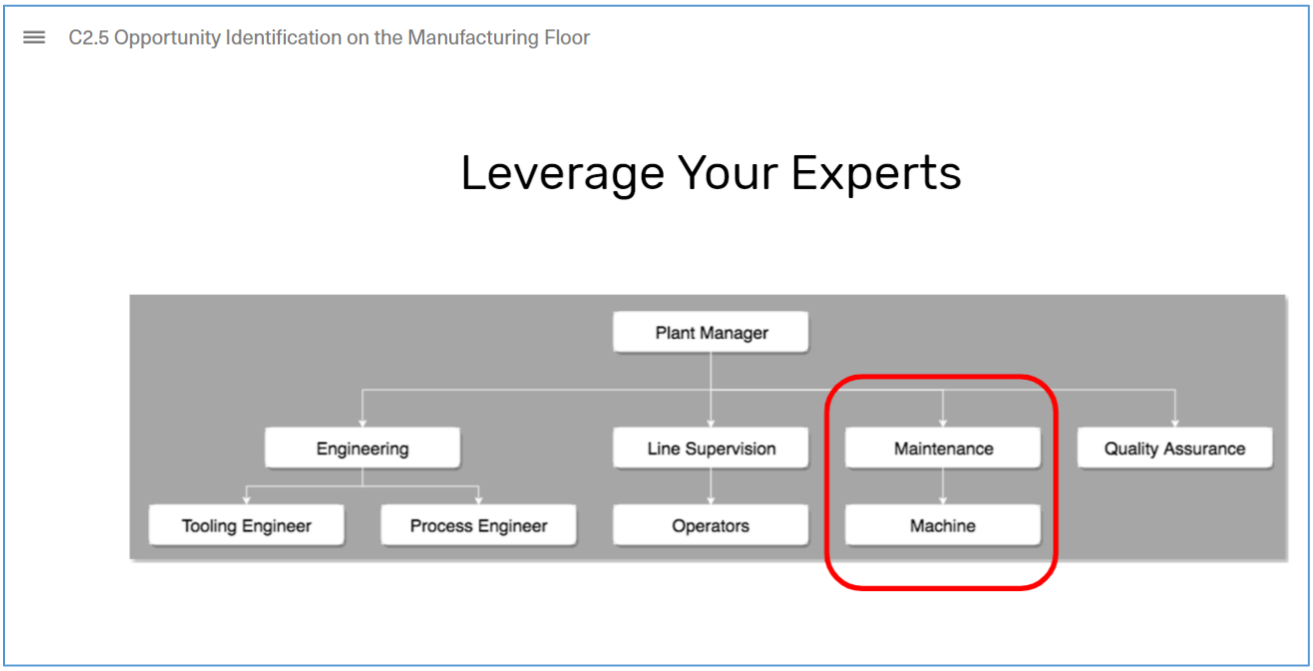


- **Leverage Your Experts**
  - Processes efficiency
  - Operations having trouble of it's bottlenecks
  - Consider what the blind spots are. The don't know operational challenges. That's an opportunity



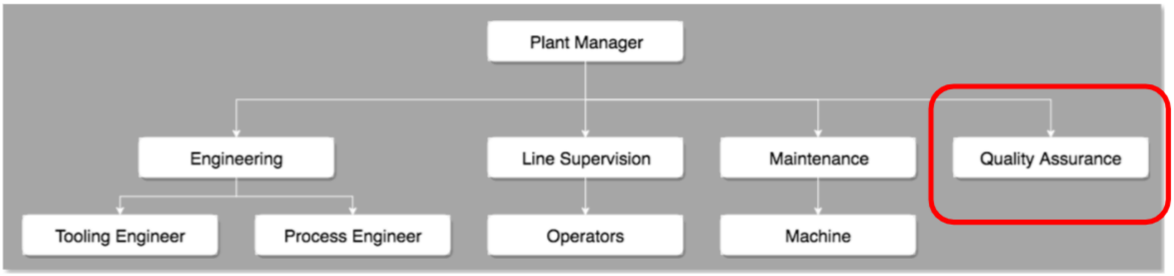


- Talk to the people who are closest to the manufacturing lines



C2.5 Opportunity Identification on the Manufacturing Floor

Leverage Your Experts



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C2.5 Opportunity Identification on the Manufacturing Floor

Three Search Strategies

Pain Points & Cost Drivers

Common Manufacturing Applications

Common Tooling & Fixtures Materials

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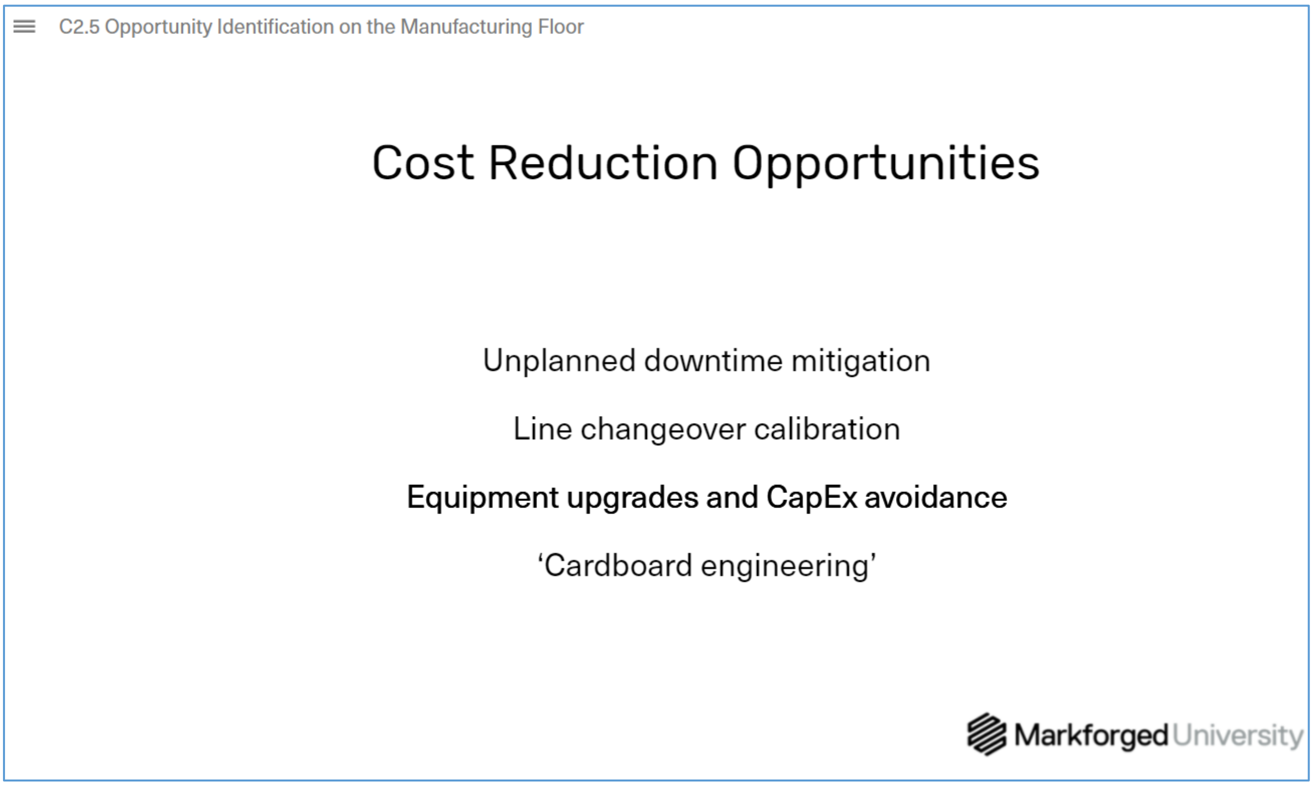
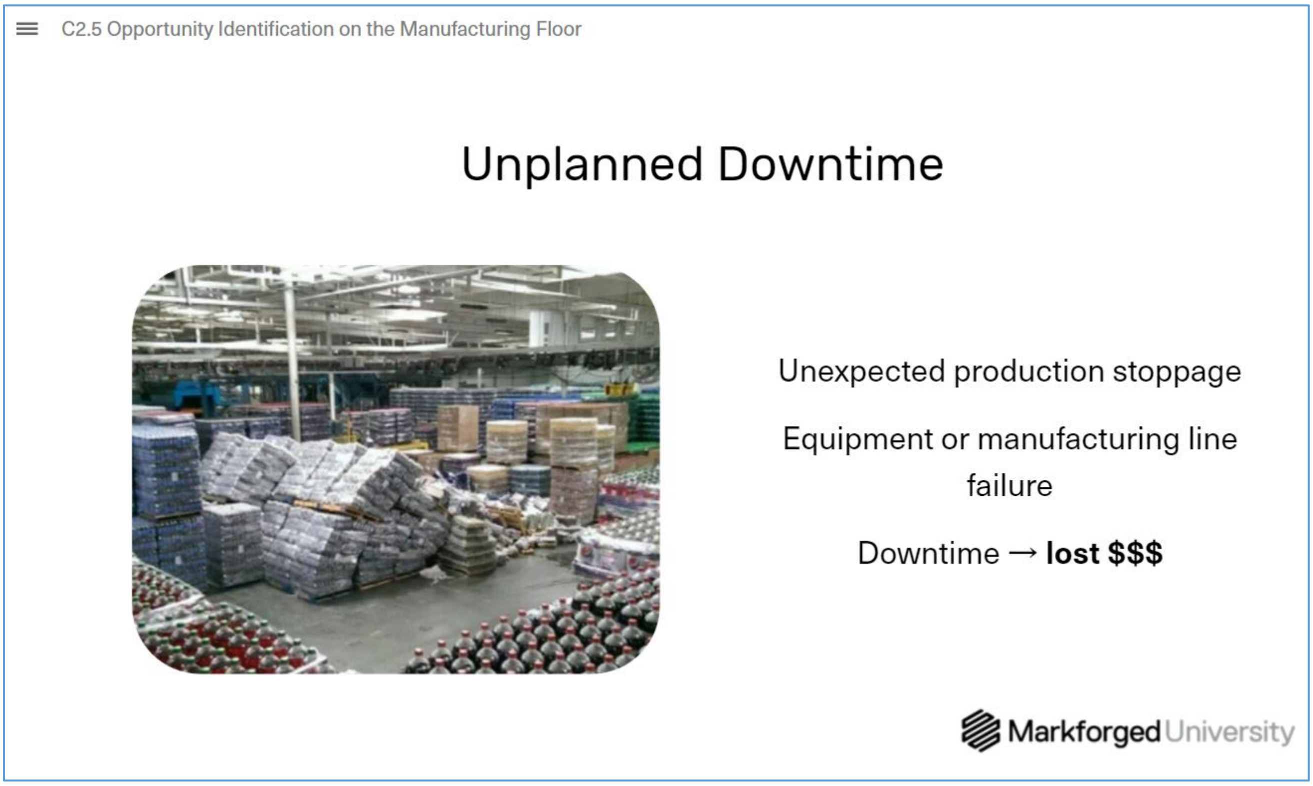
- **Three Search Strategies**

- **Pain Points & Cost Drivers**

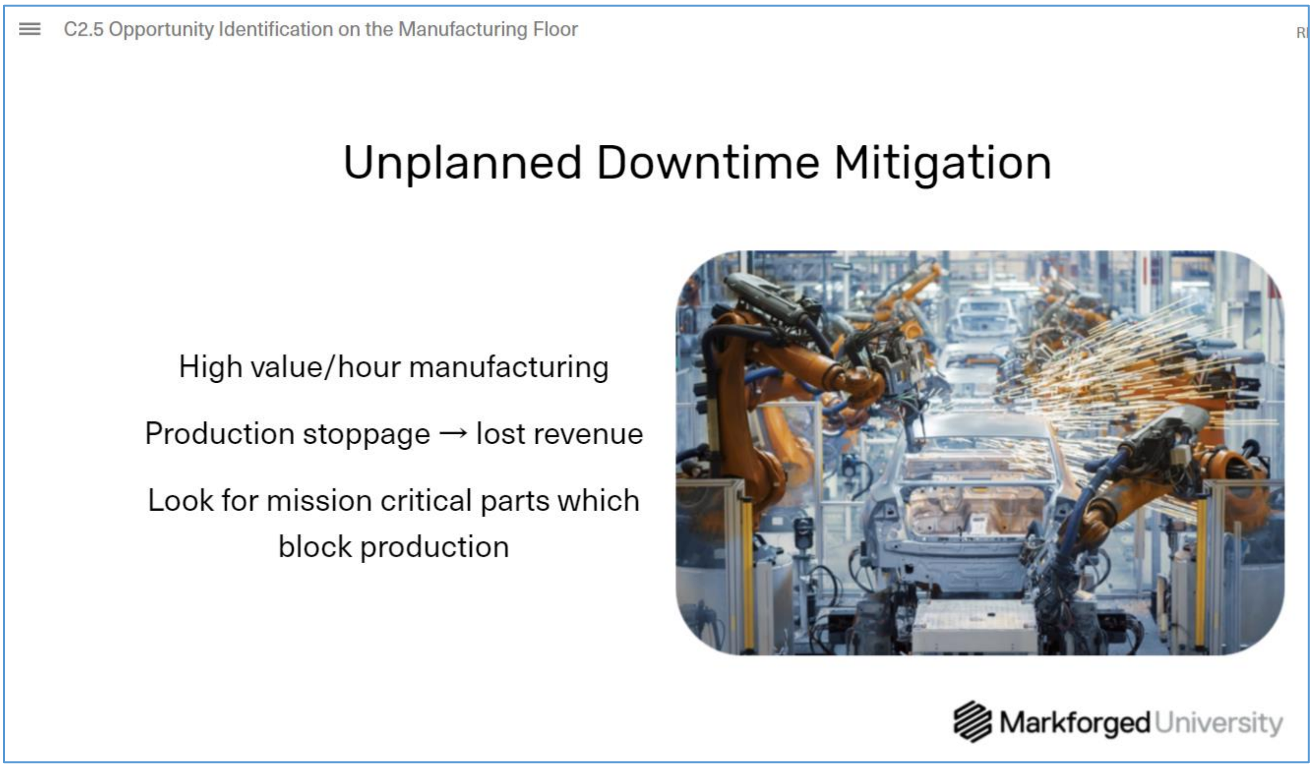
- **What Does it Cost?**
    - ROI = Return Of Investment



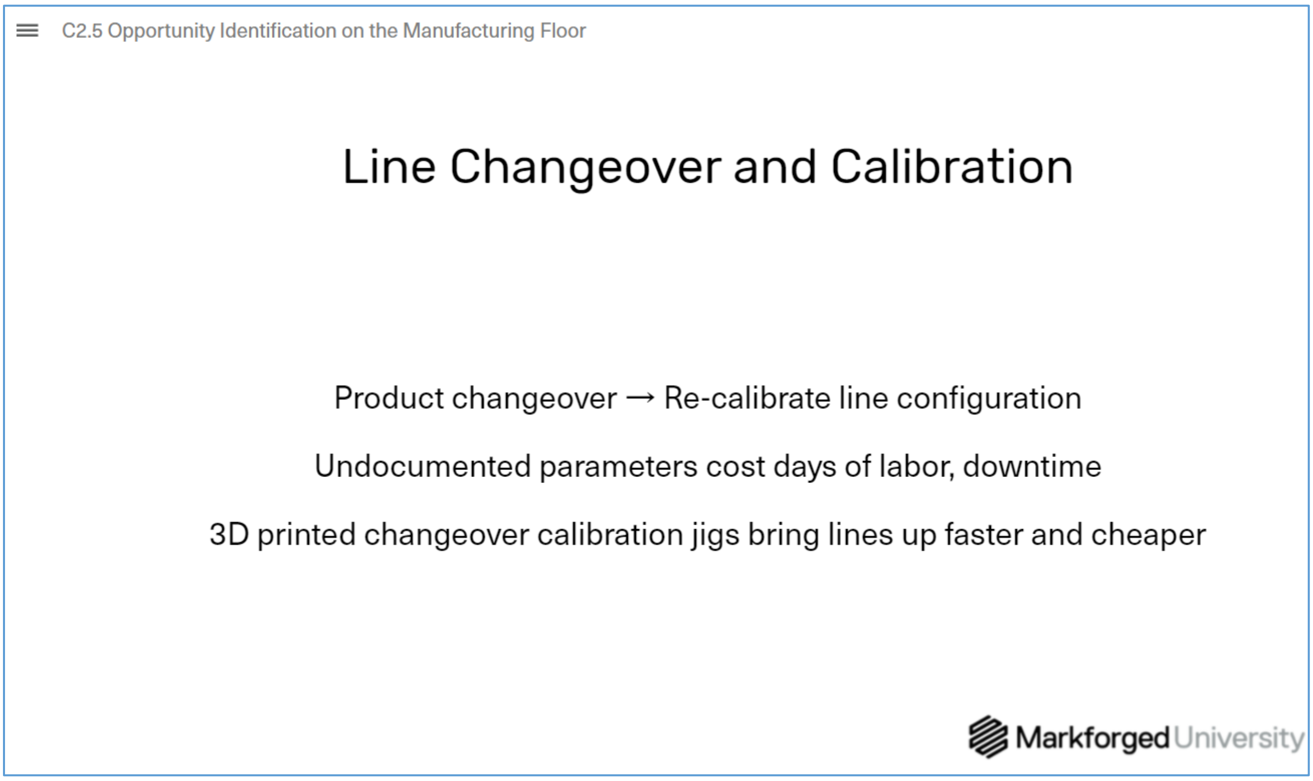
- **Cost Reduction Opportunities**
  - Mitigation = Verzachting. Effecten verminderen
  - Changeover = Omschakelen.



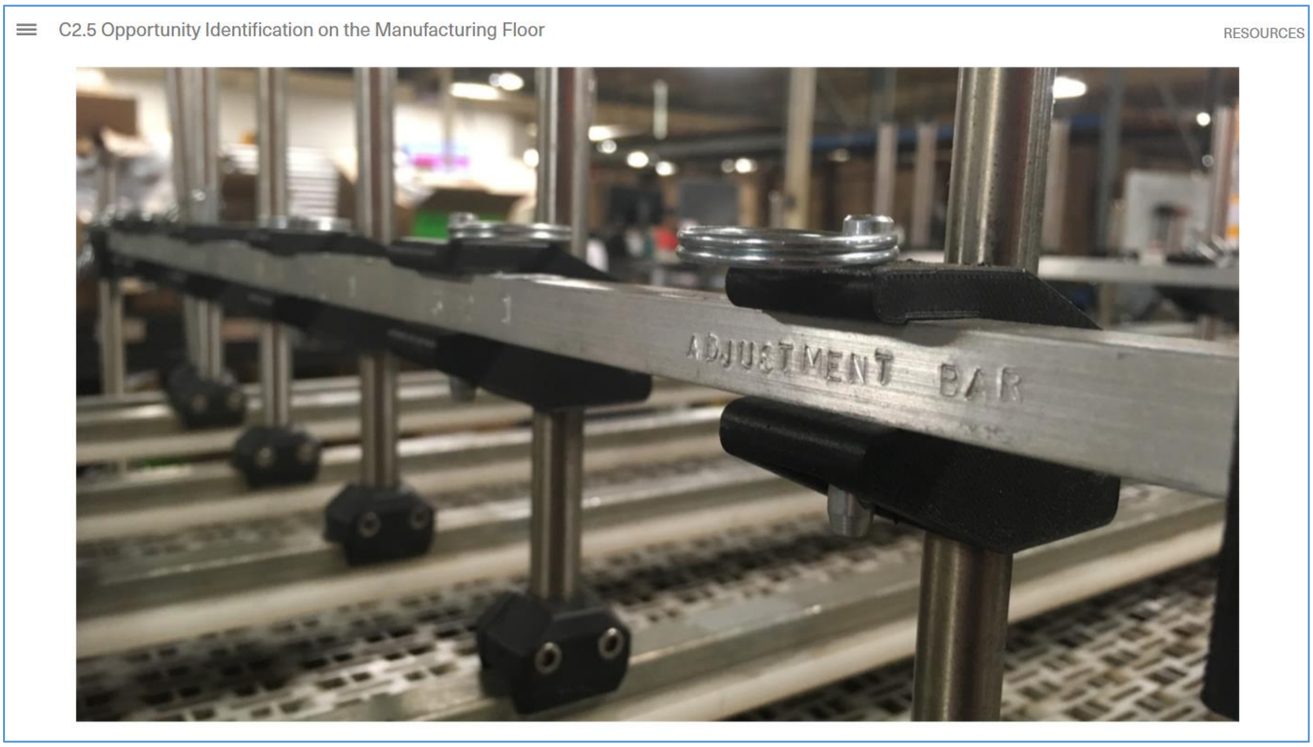
- **Unplanned Downtime**



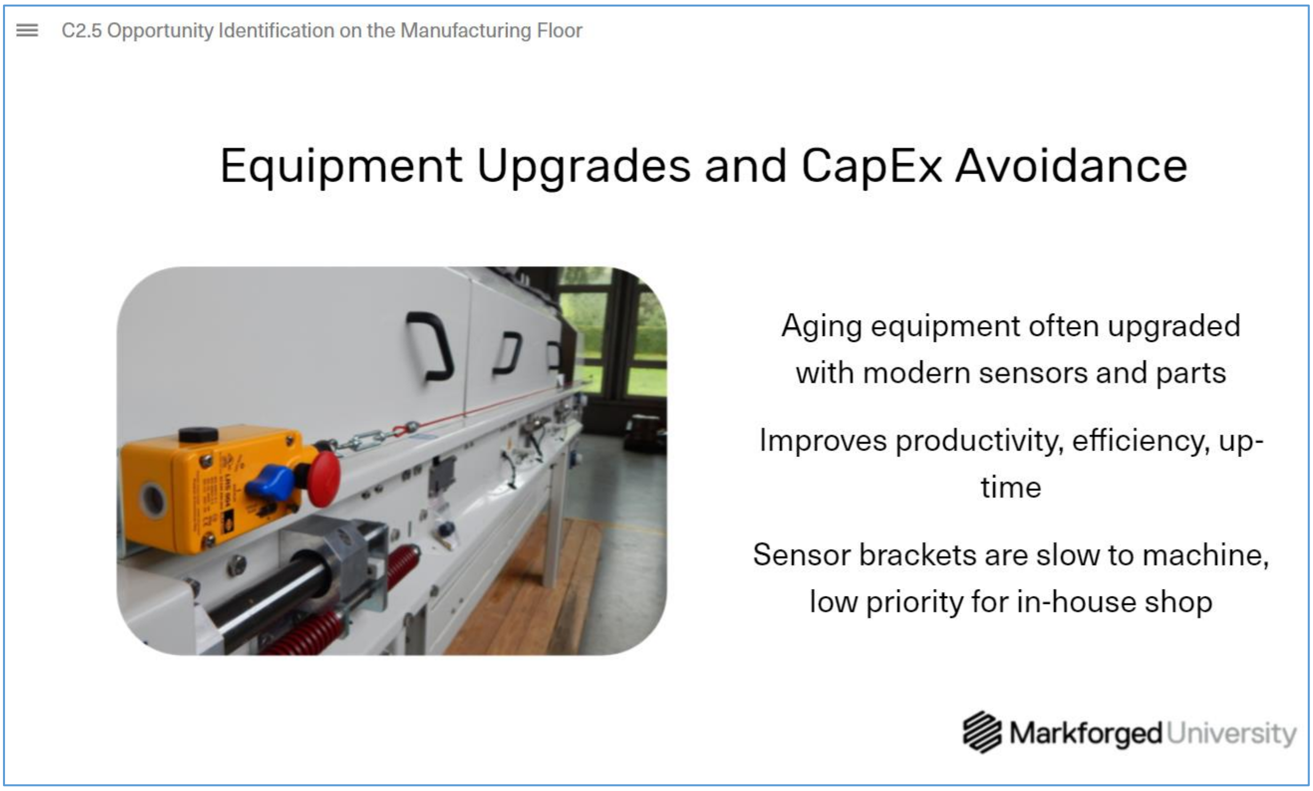
- **Unplanned Downtime Mitigation**
  - Revenue = winst



- **Line Changeover and Calibration**

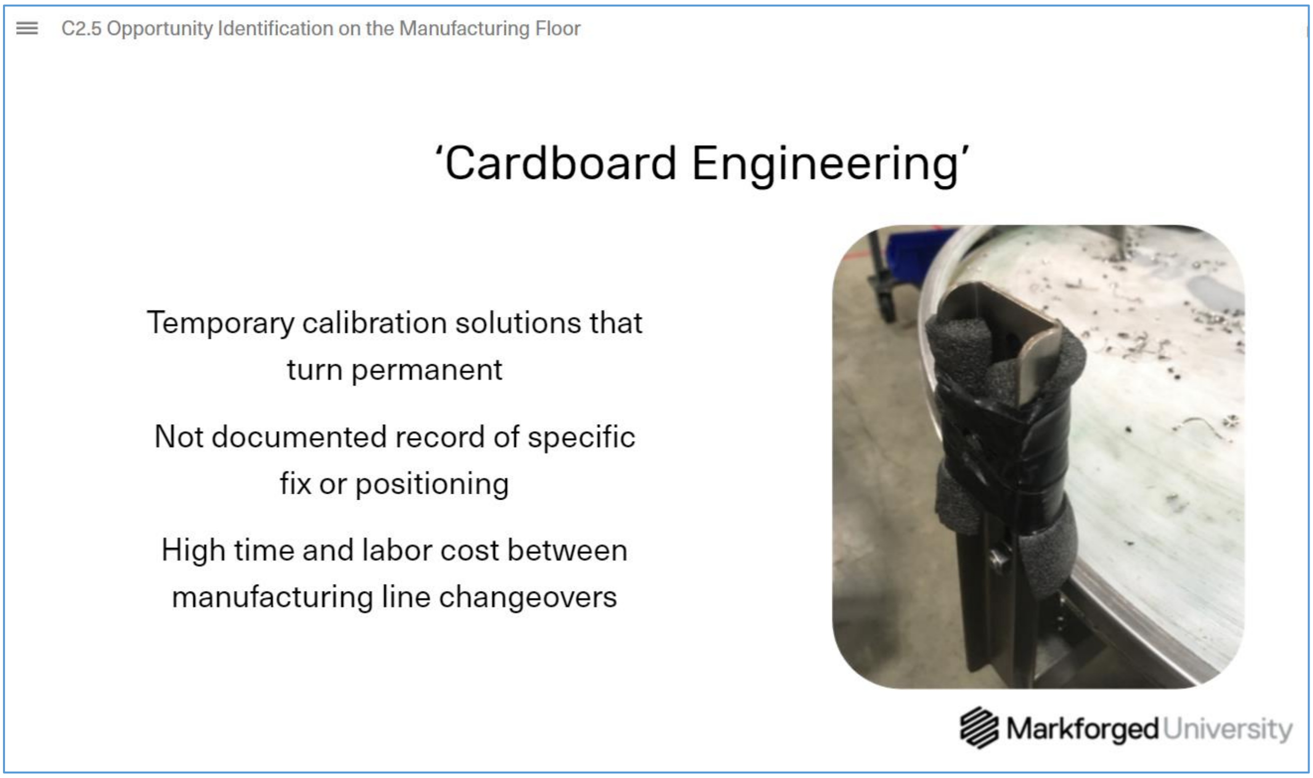


- **Example: Adjustable Conveyor Guide**



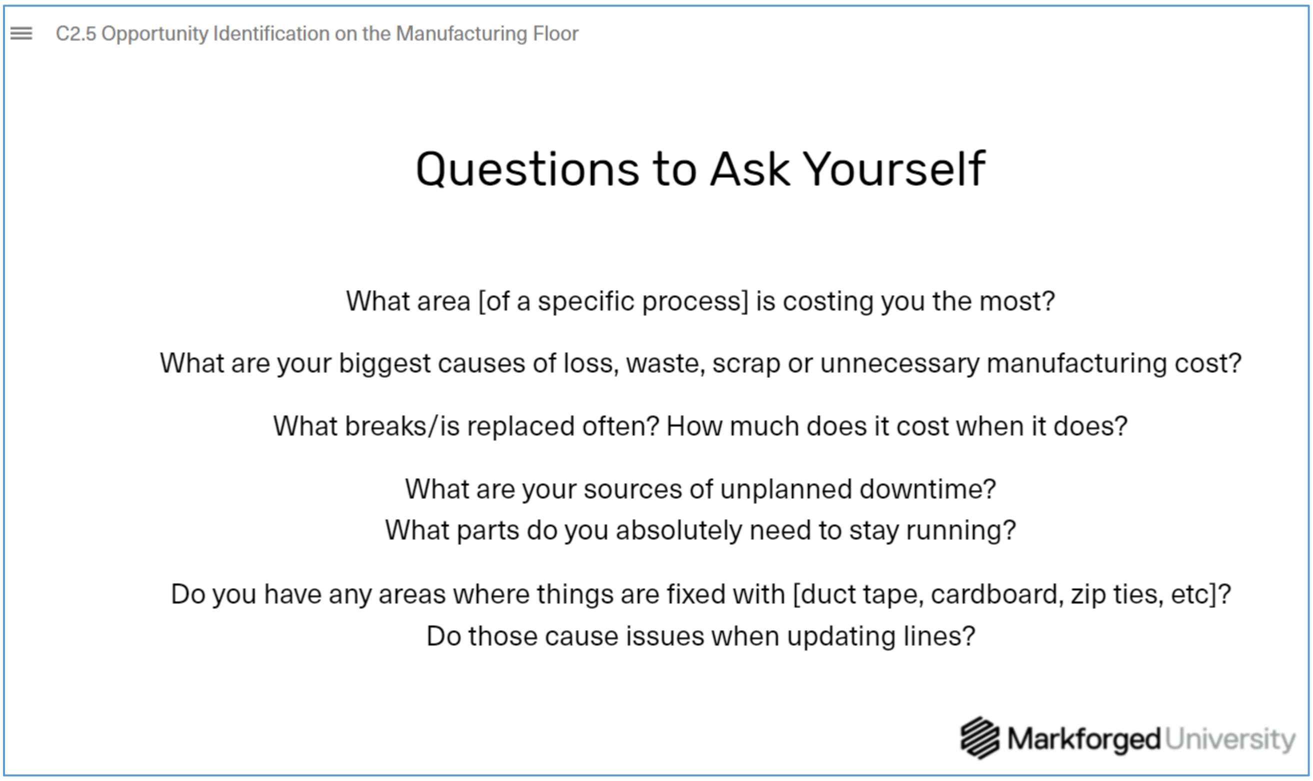
- **Equipment Upgrades and CapEx Avoidance**

- **Example: Adjustable Sensor Mount**



- **'Cardboard Engineering'**

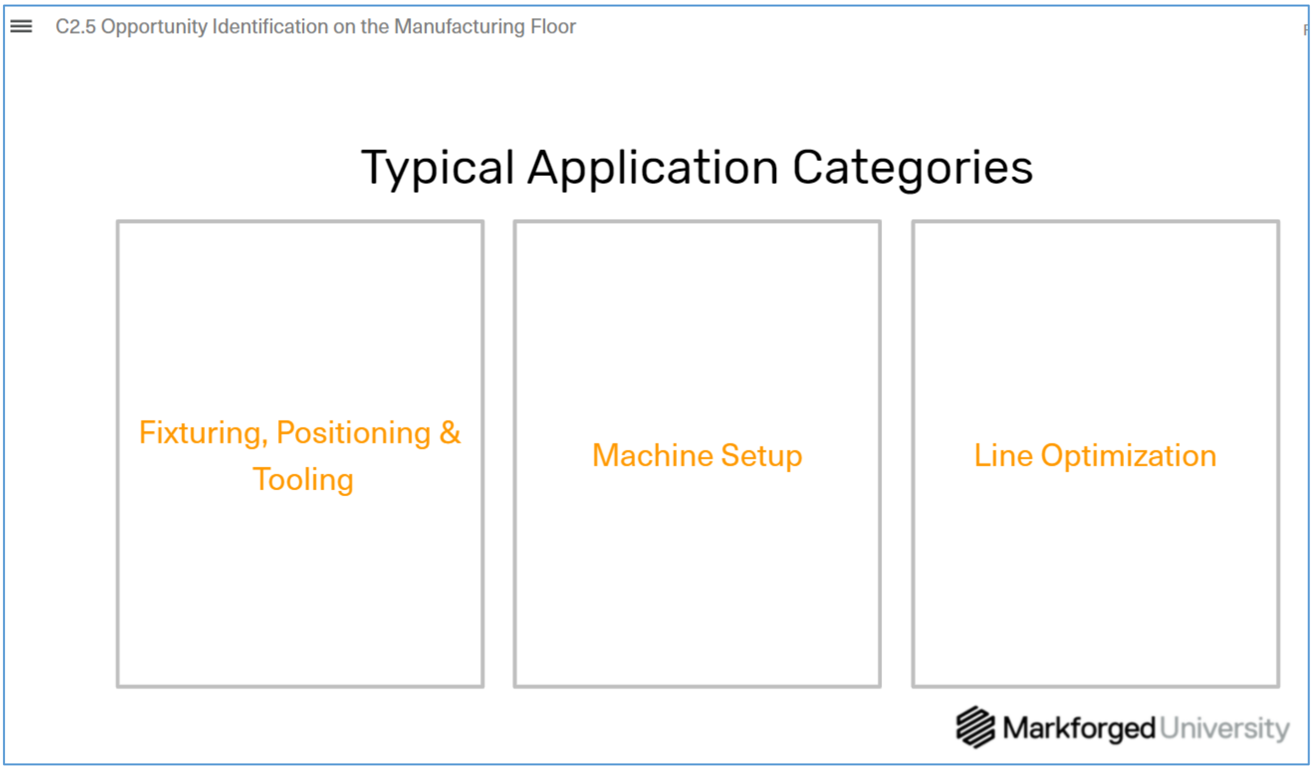
- **Example: Cardboard Engineering**



- **Questions to Ask Yourself**

- **Your Experts**

- **Common Manufacturing Applications**



- **Typical Application Categories**

Typical Application Categories

Fixturing, Positioning & Tooling

- Inspection and assembly fixtures
- Soft jaws
- Alignment features that are hard to machine

Machine Setup

Line Optimization

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Typical Application Categories

Fixturing, Positioning & Tooling

Machine Setup

- Calibration jigs
- Machine repair and maintenance tools
- Improved startup efficiency

Line Optimization

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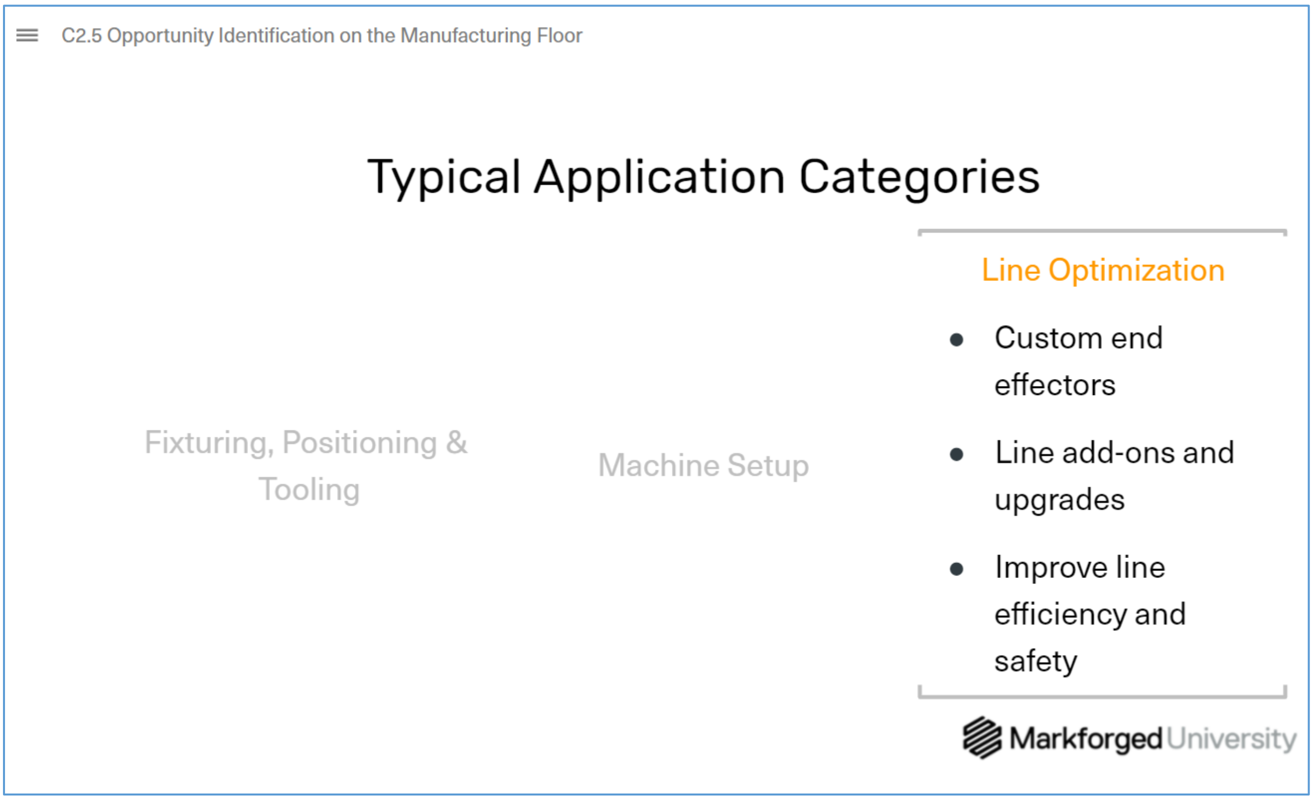
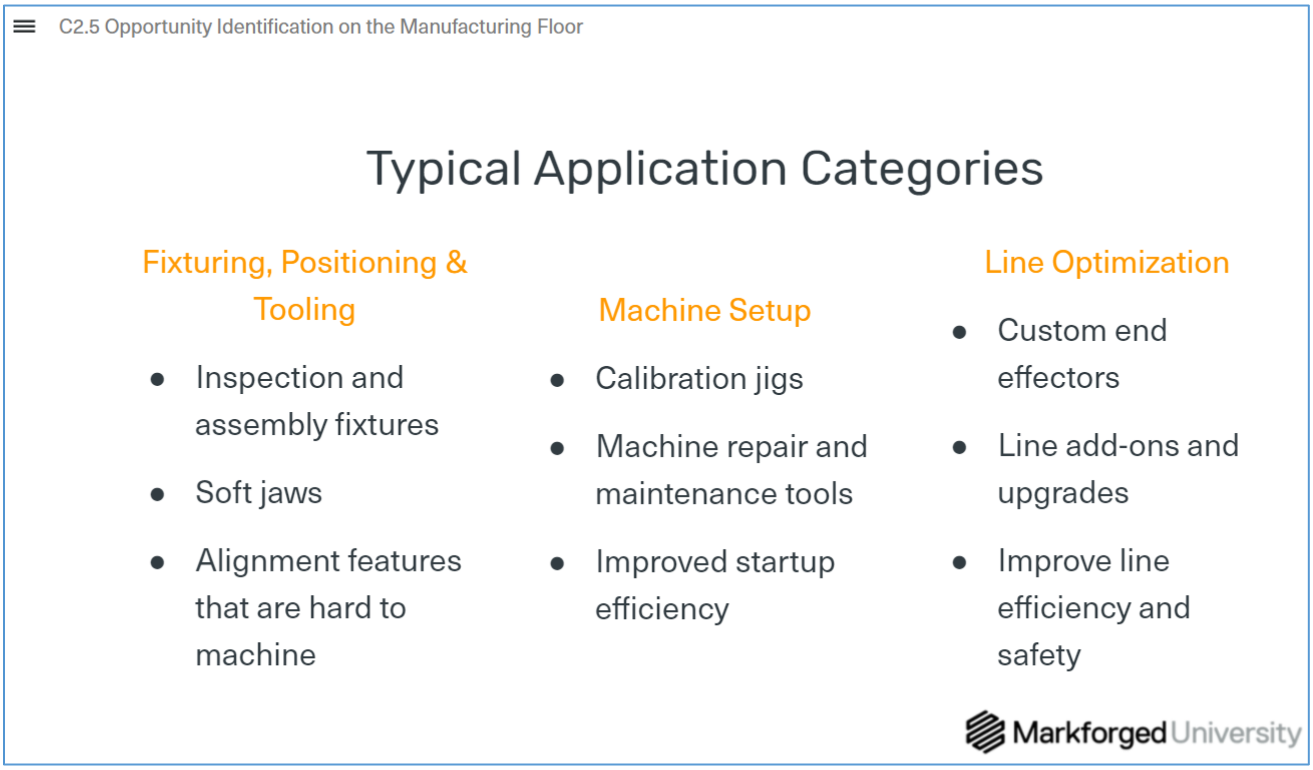
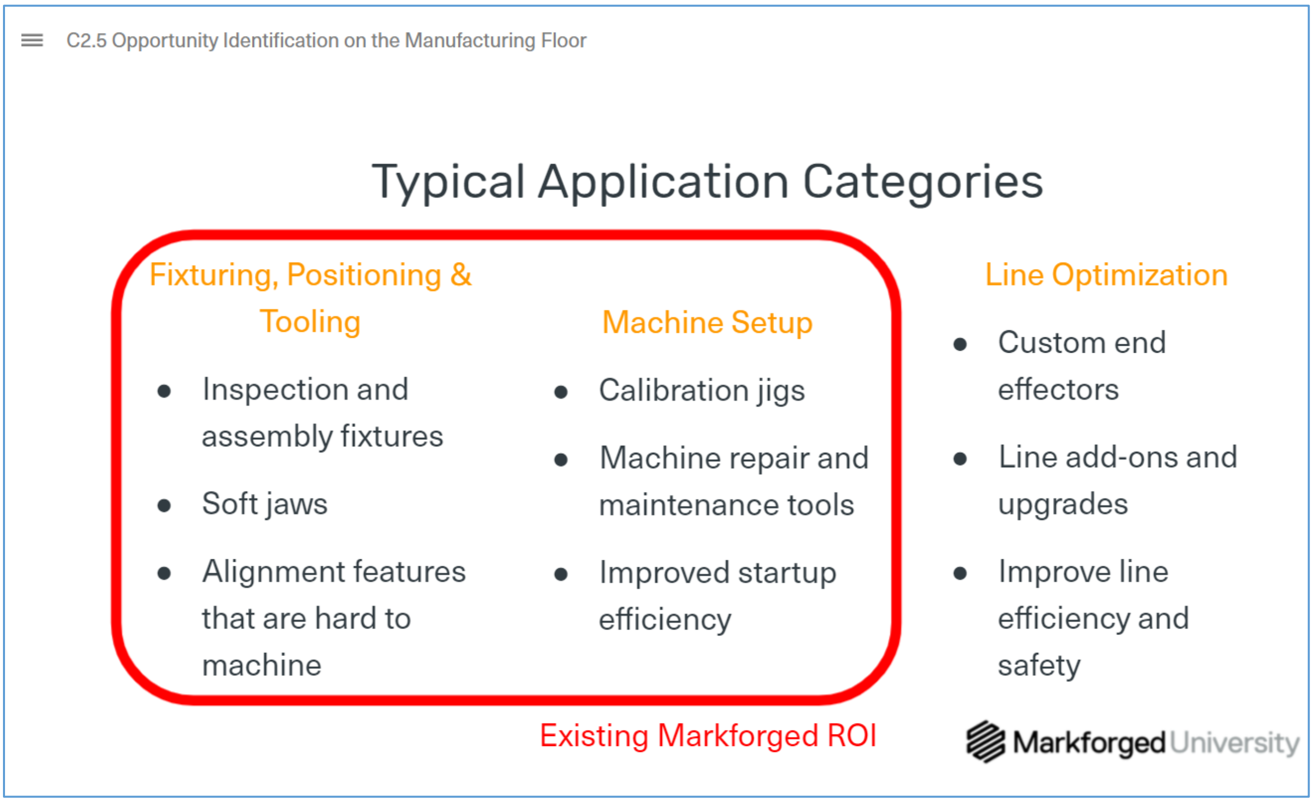
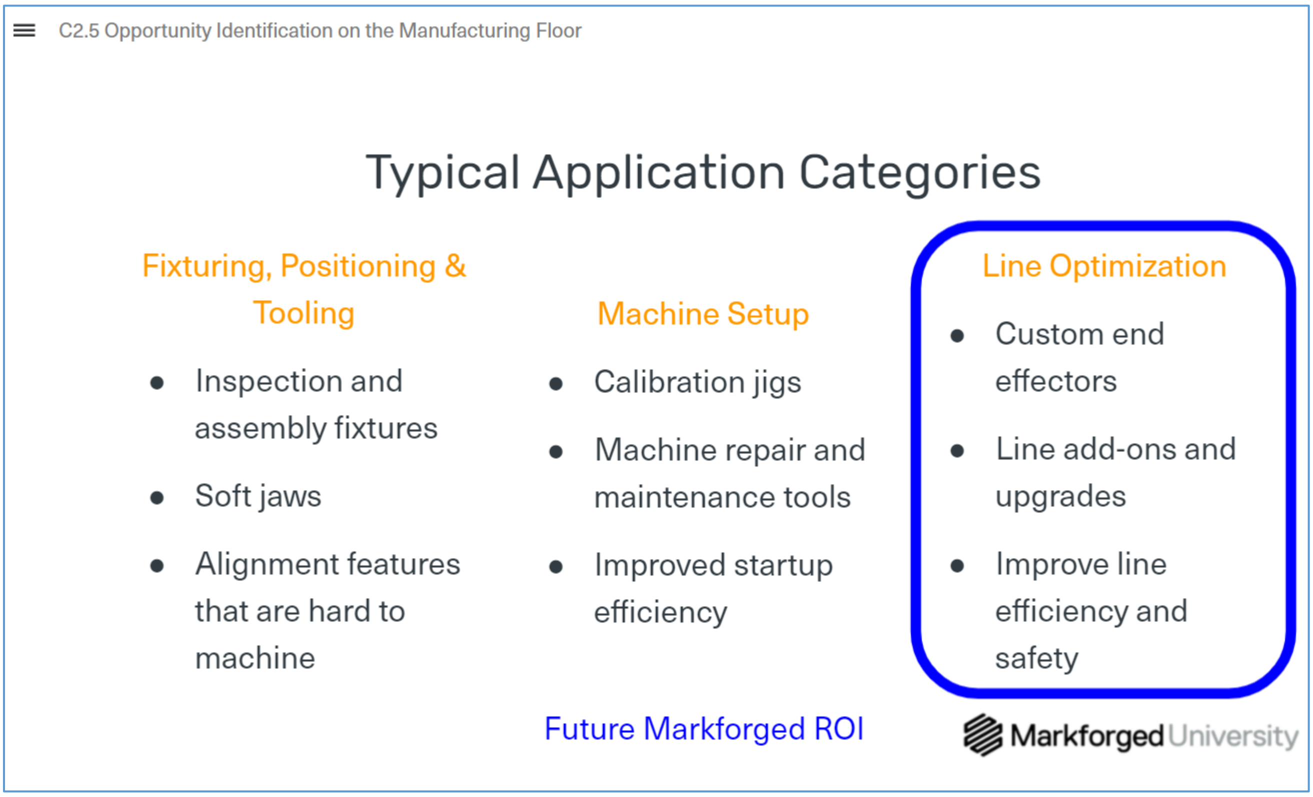




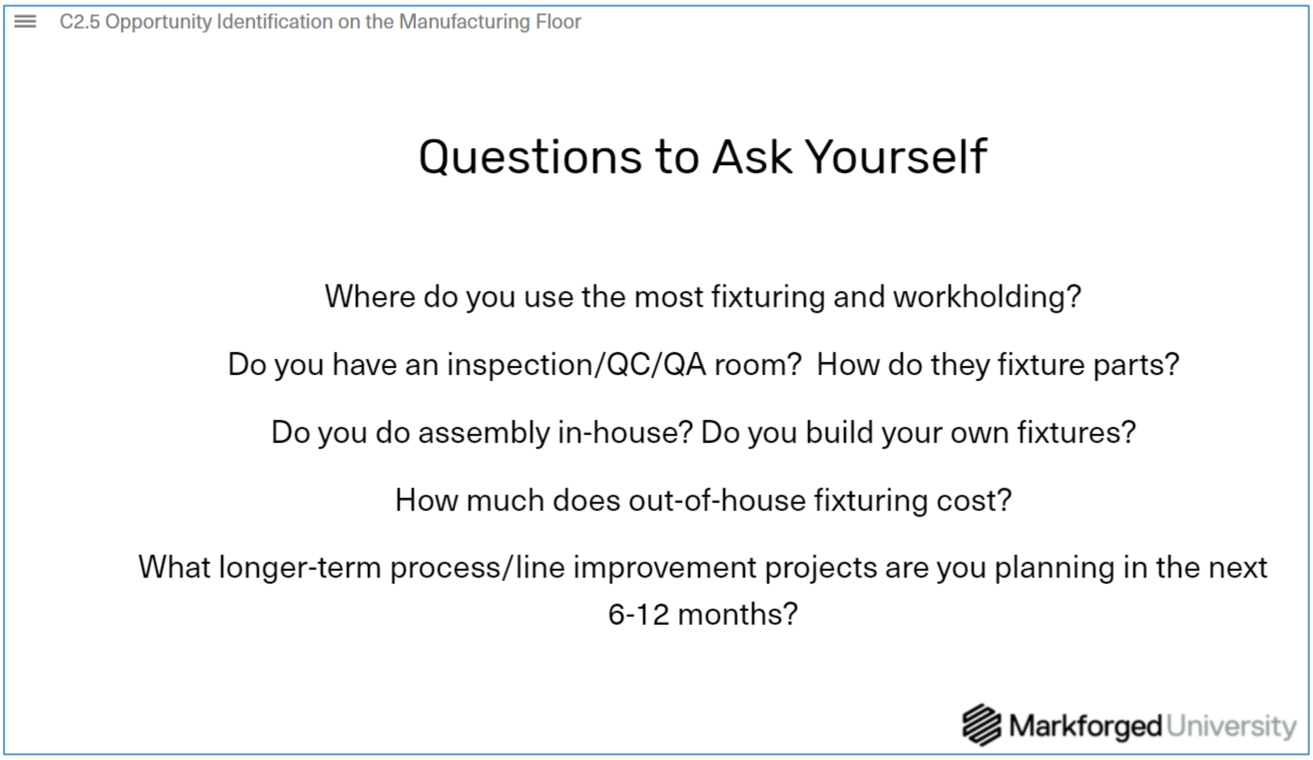
- **Immediate vs ROI**



- Immediate contribution to your operation and quickly ROI.



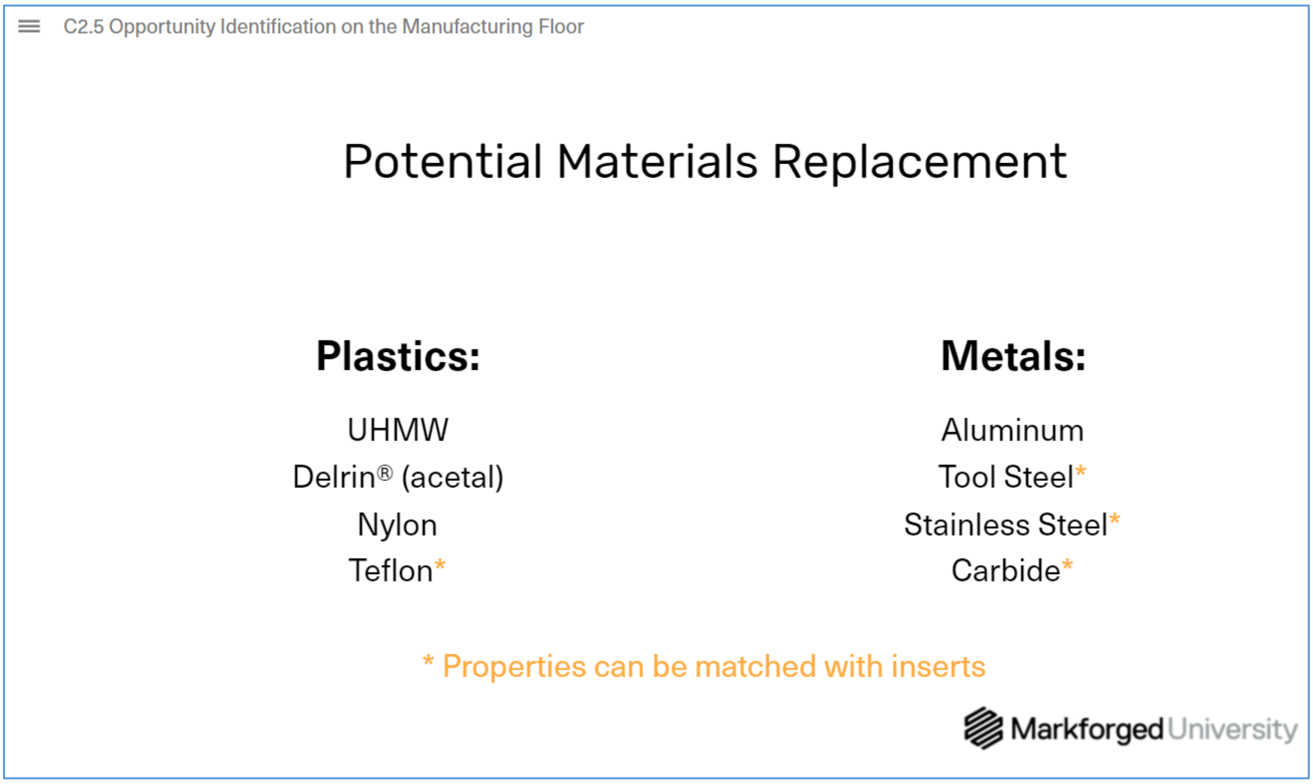
- Future



- **Questions to Ask Yourself**

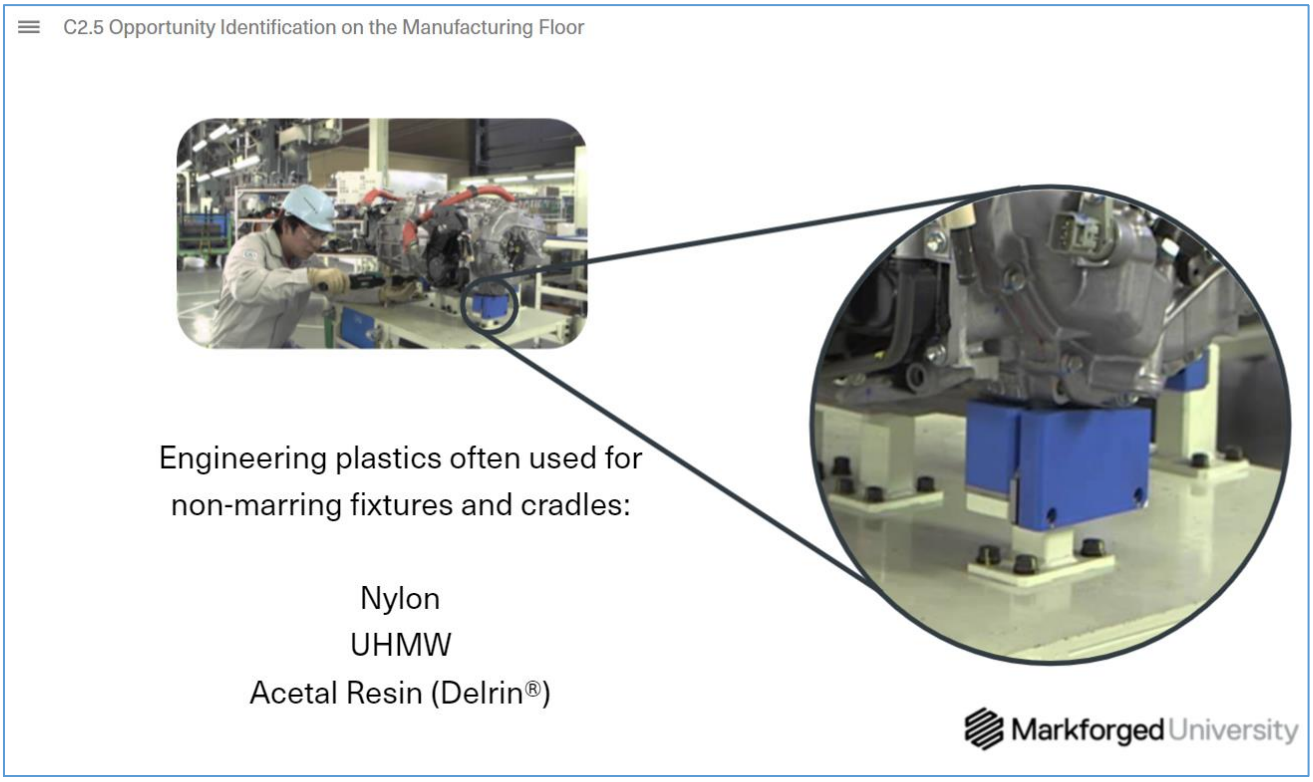
- **Your Experts: Searching by Application**

- **Common Materials**

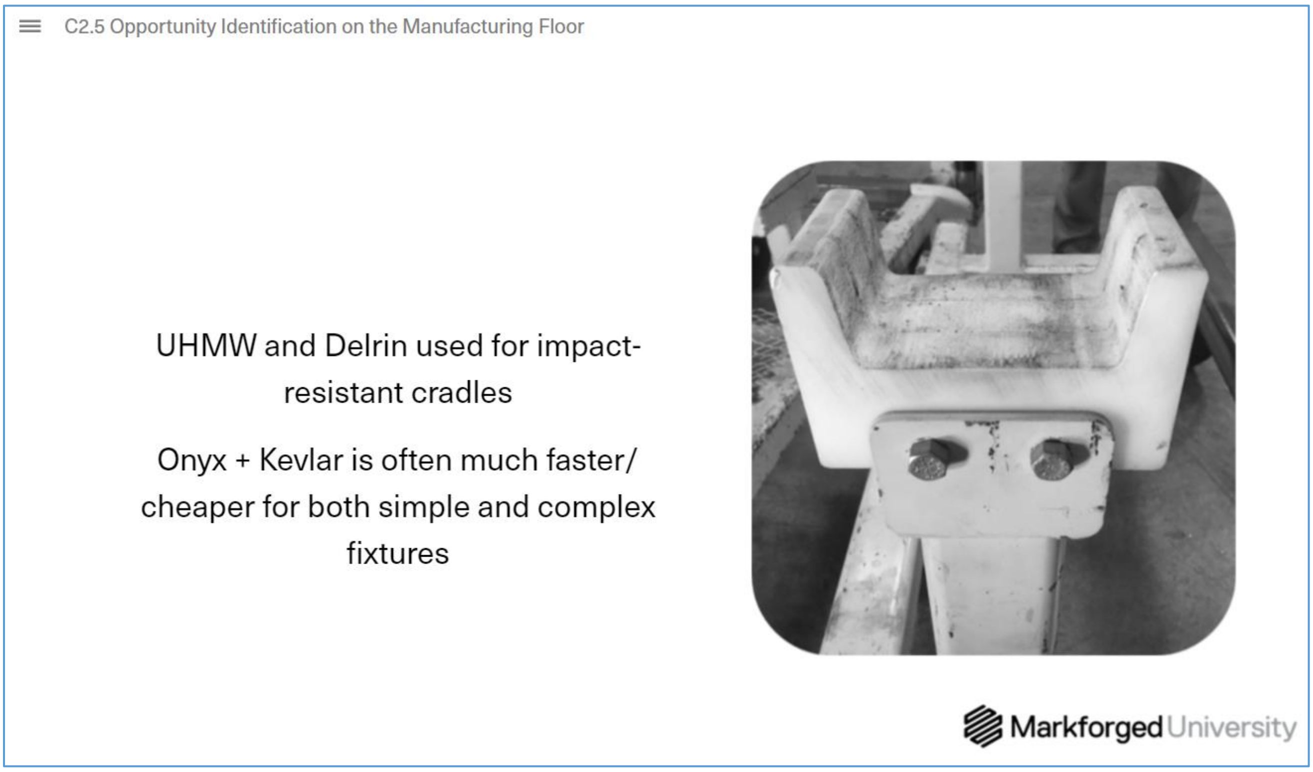


- **Potential Materials Replacement**

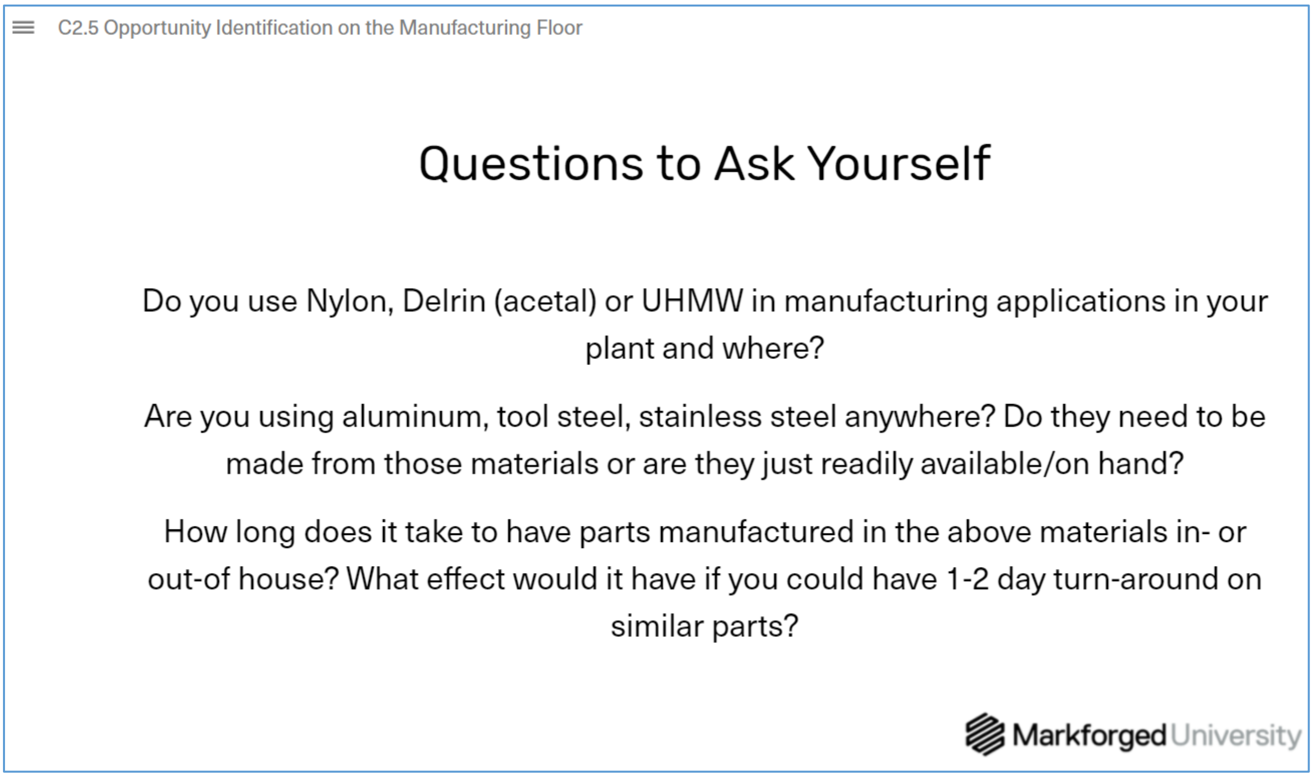
- **Manufacturing Plant Example**



- **Fixtures and Engineering Plastics**
    - Non-marring = not causing damage.
    - Cradles = wieg



- **Vehicle Carriage Fixture**

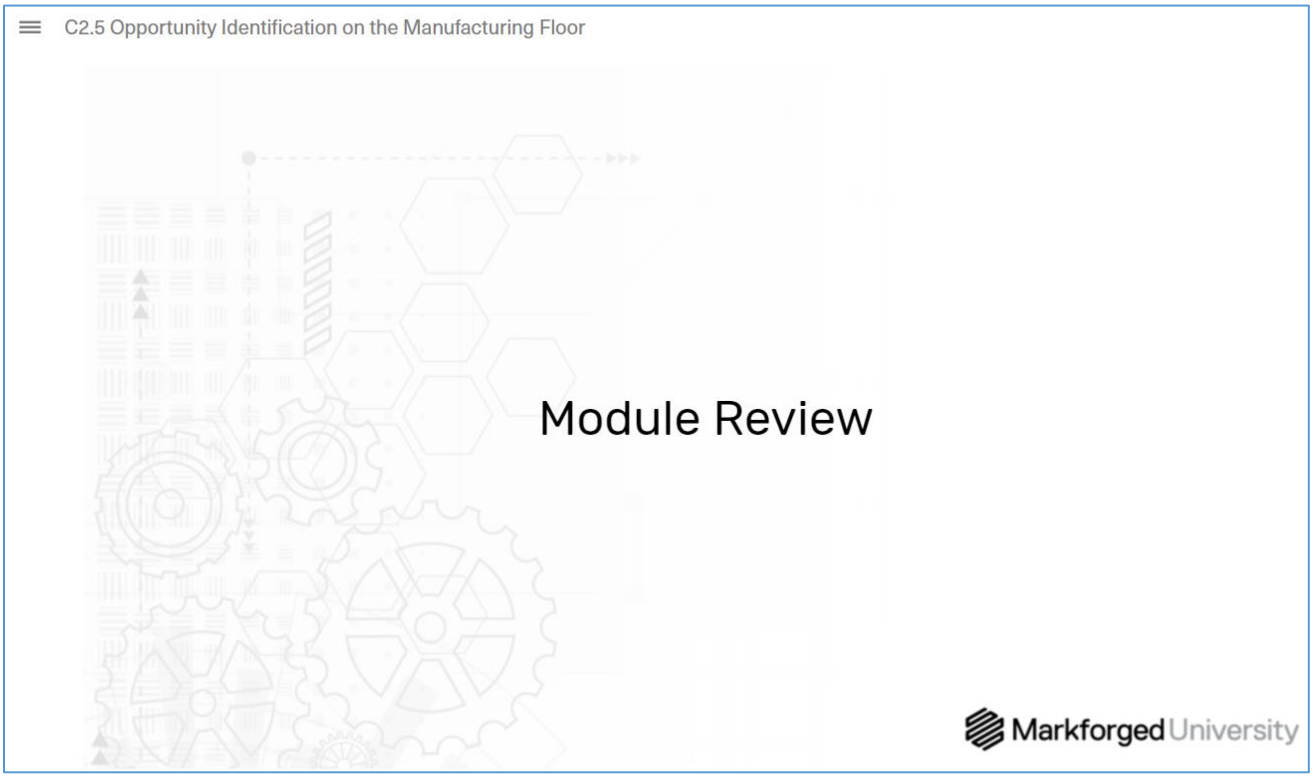


- **Questions to Ask Yourself**
    - Readily = Gemakkelijk

- **Your Experts: Searching By Materials**

- **Debrief: Your Opportunities**
    - Debrief = Nabespreking.

- **Review: Key Takeaways**



- **Module Review**

C2.5 Opportunity Identification on the Manufacturing Floor

Bringing a manufacturing line down for planned maintenance and re-configuration for making a different product type with it, is considered a form of:

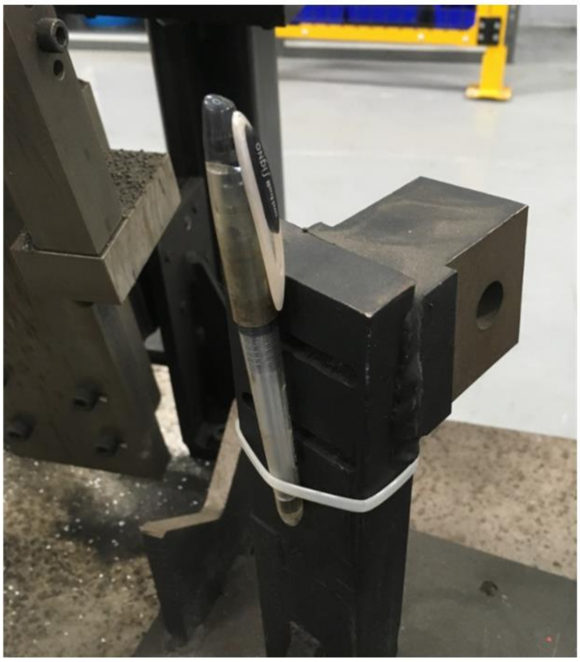
- 3D printing
- Manufacturing line changeover
- Scrap rate
- Unplanned downtime

C2.5 Opportunity Identification on the Manufacturing Floor

RESOURCES

What type of pain point or cost driver does this image of a fixture most directly represent?

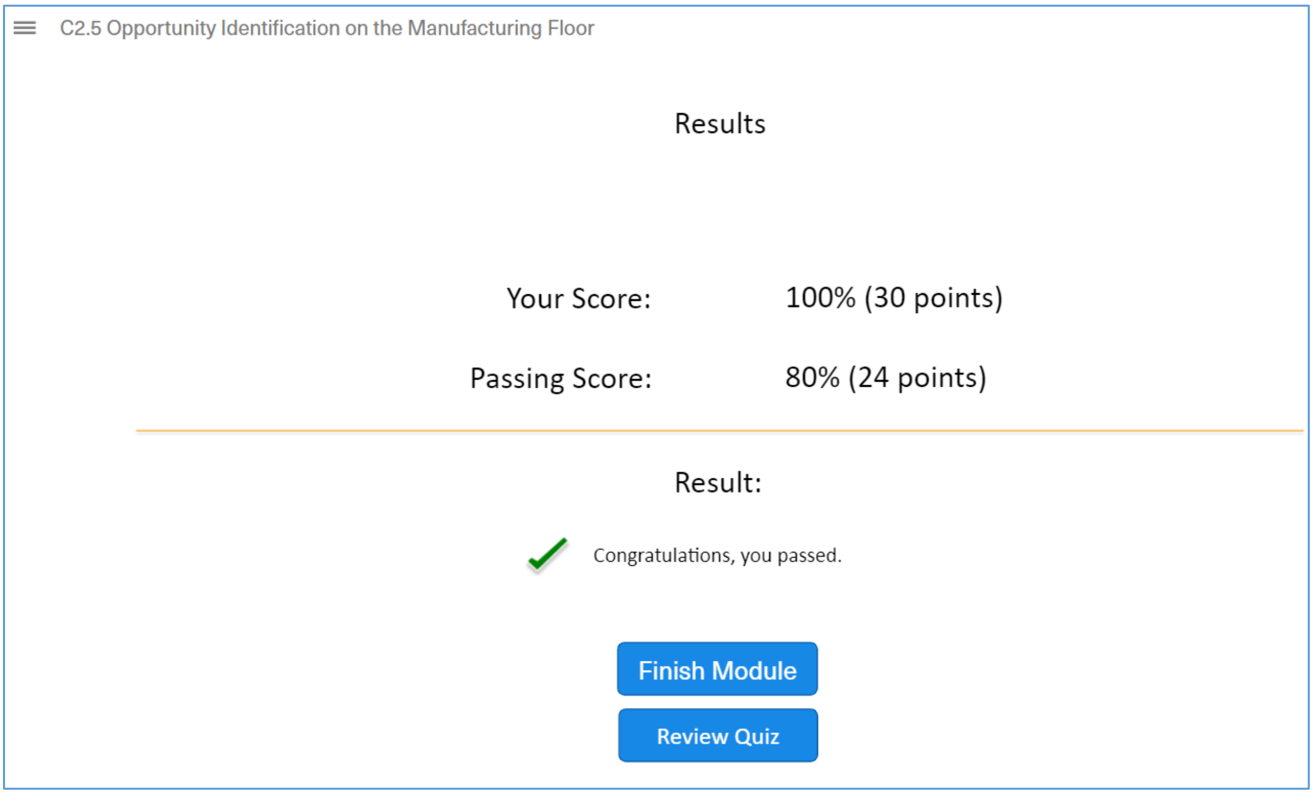
- Cardboard engineering
- Unplanned downtime
- Sensor mount hardware
- Line maintenance



C2.5 Opportunity Identification on the Manufacturing Floor

True/False: It can be possible to replace a custom fixture made from a harder material like tool steel with a composite-reinforced 3D printed part.

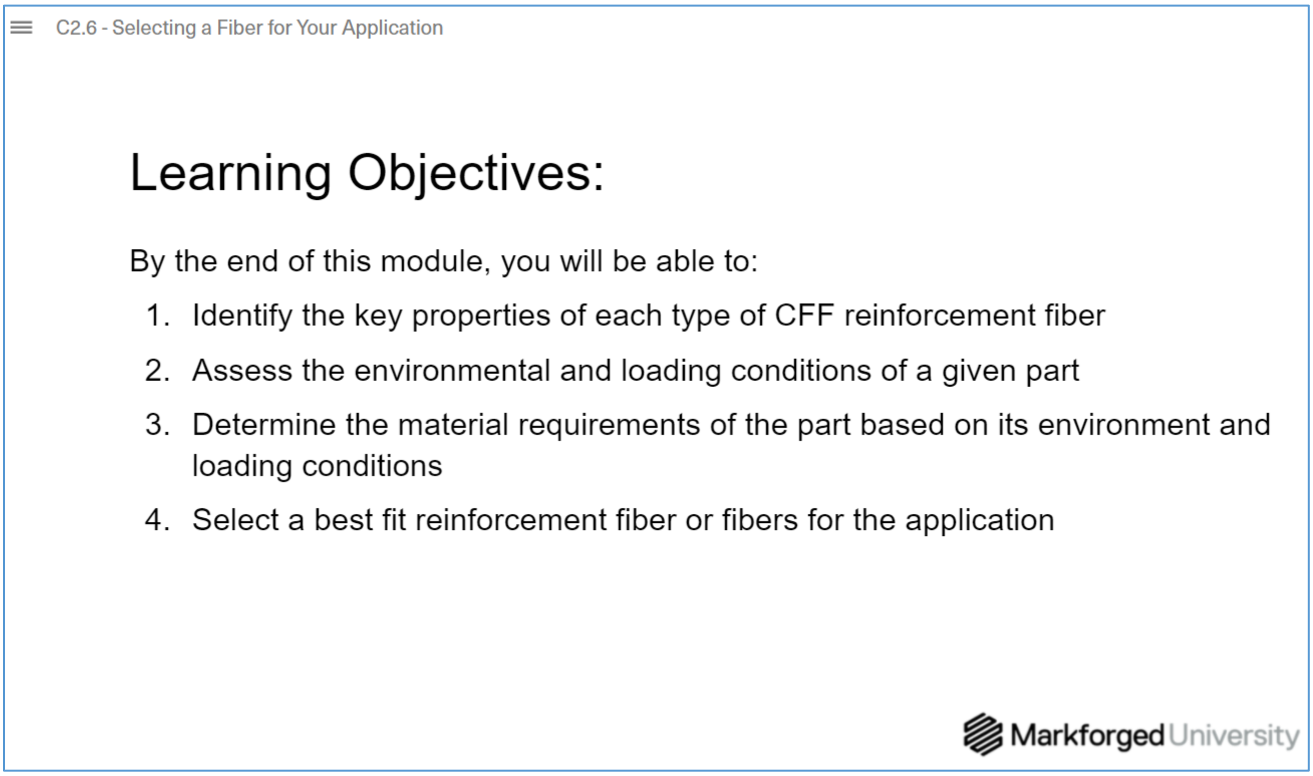
- True
- False



C2.6 – Selecting a Continuous Fiber for Your Application

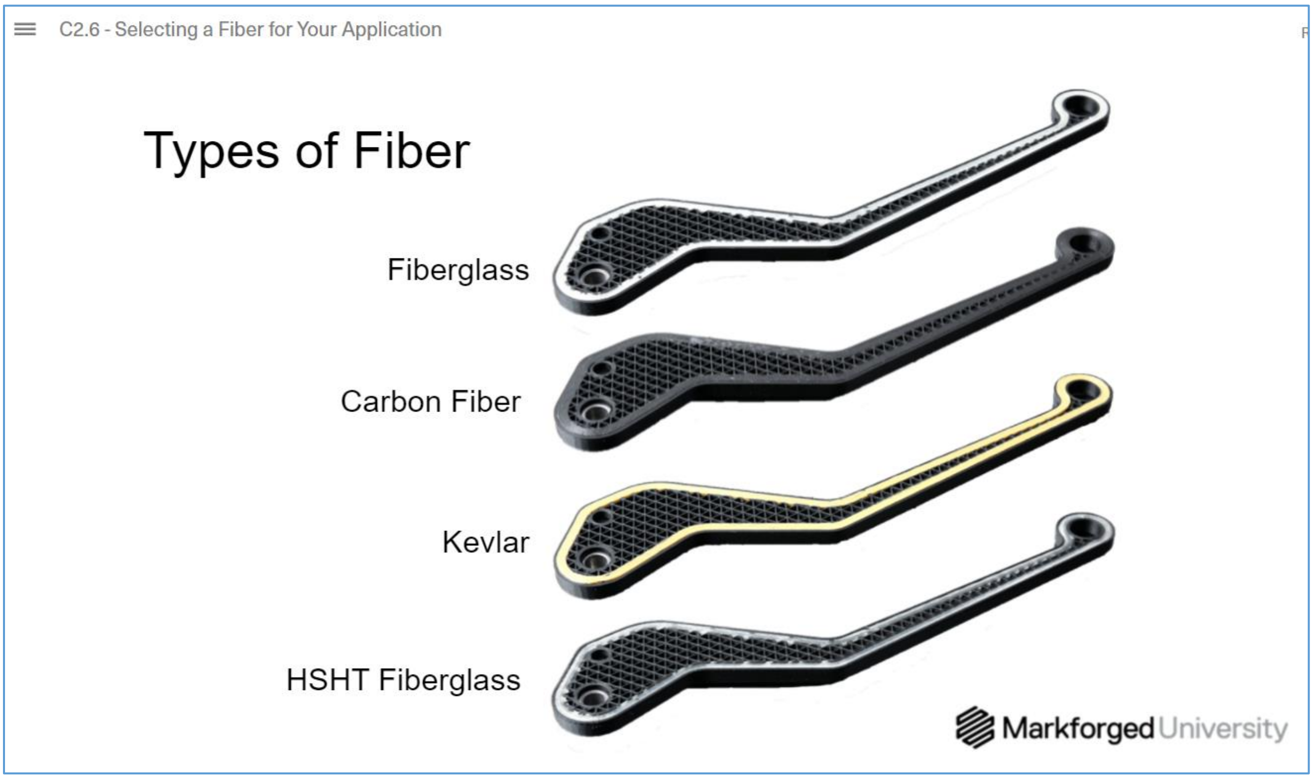
- **Selecting a Continuous Fiber for Your Application**

- **Module Overview**



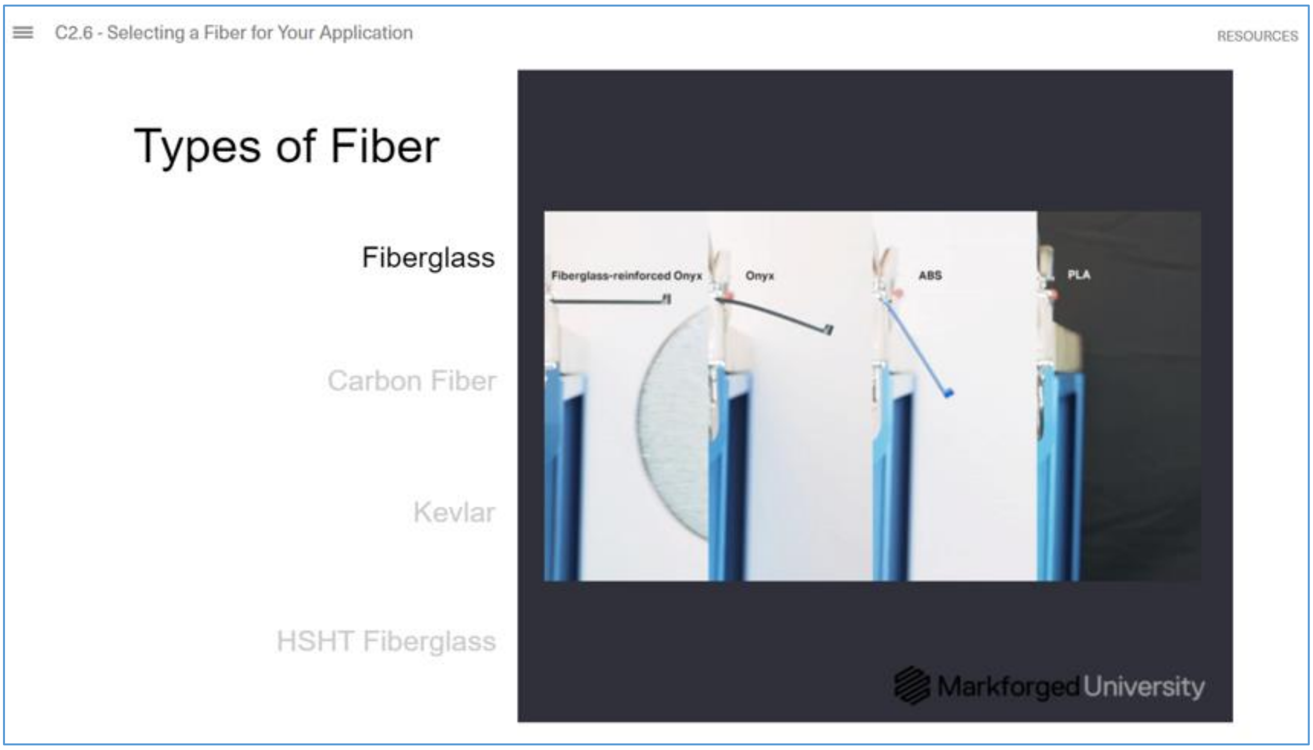
- **Learning Objectives:**
    - Assess = Schatten

- **What questions do we ask to evaluate a part?**
    - Which environment conditions?
    - Which loading conditions?
    - Onyx mold with high strength temperature HSHT (High Strength High Temperature) Fiberglass to meet the requirements.



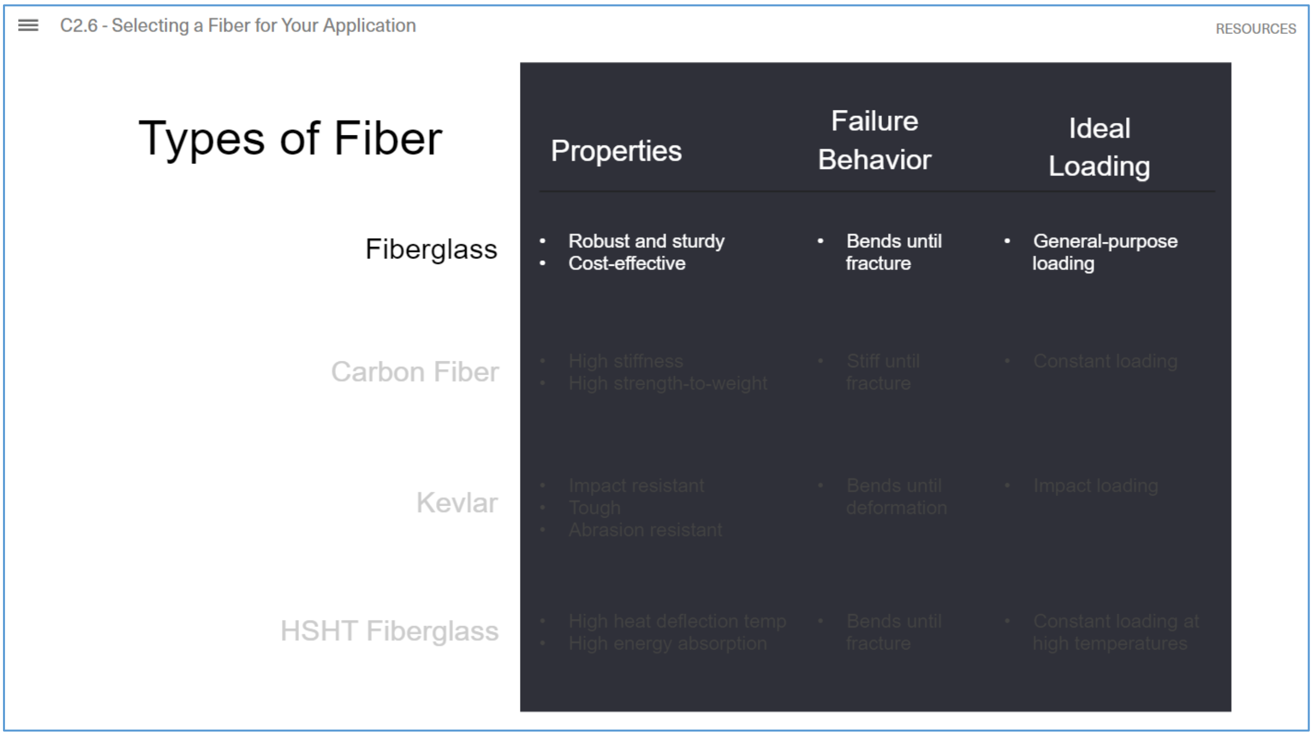
- **Types of Fiber**

- **Fiberglass in practice**

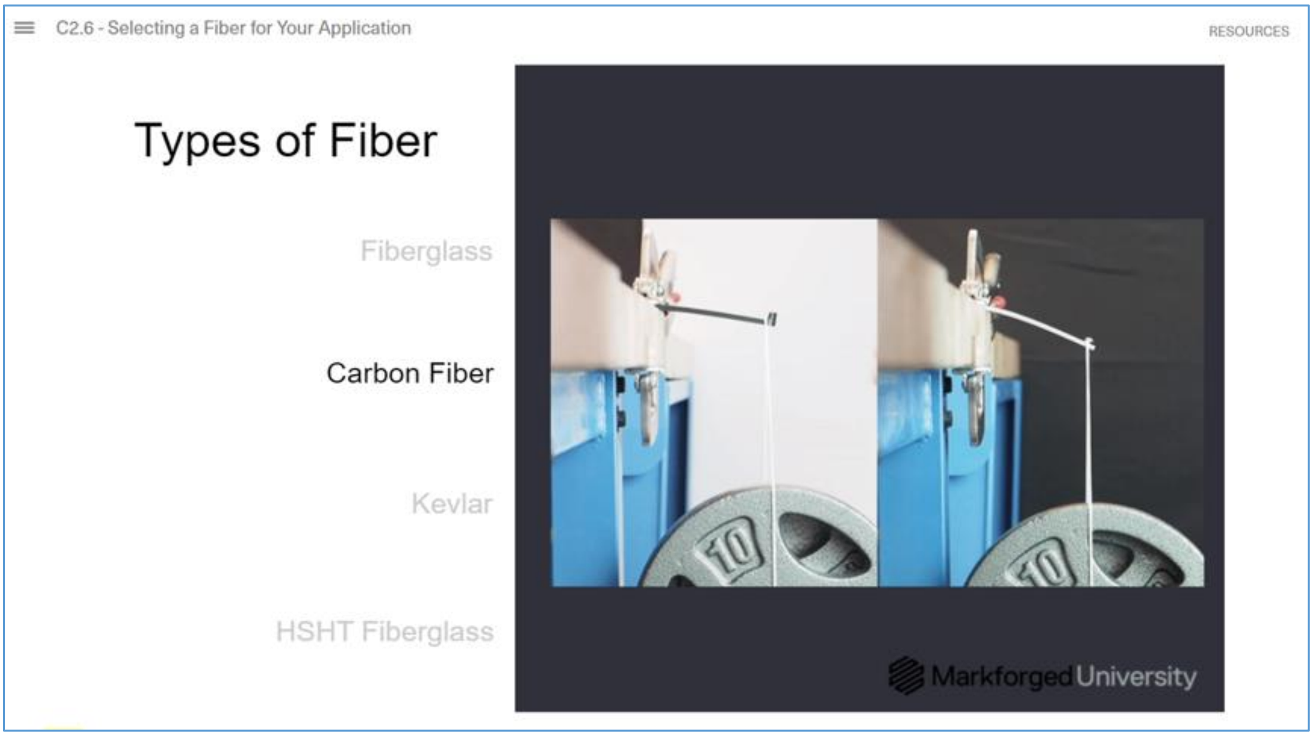


  - Beams with several material loaded by a 3kg weight.
  - The Fiberglass beam returns to its’ original shape.
  - Onyx does not completely returns to its’ position.

- ABS and PLA are completely overloaded.

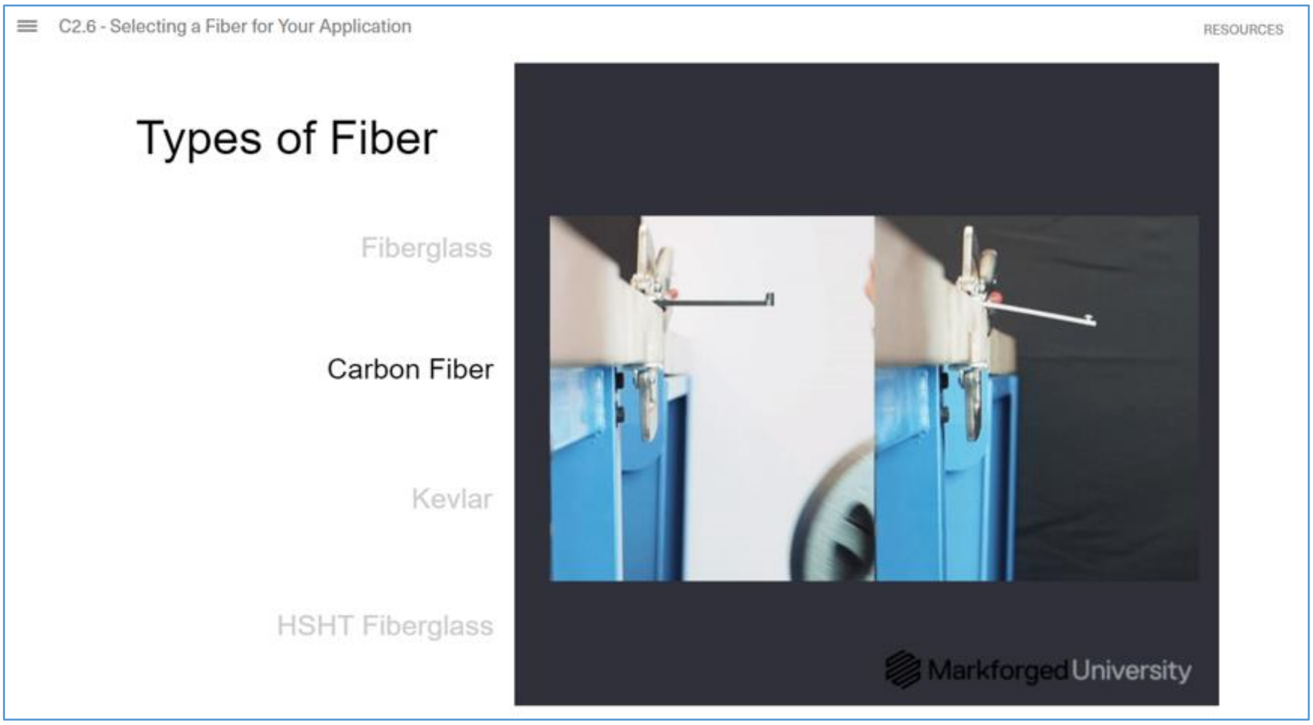


- **Fiberglass Properties**
  - In mass critical application is Carbon a better choice.
  - But it is a great default material.

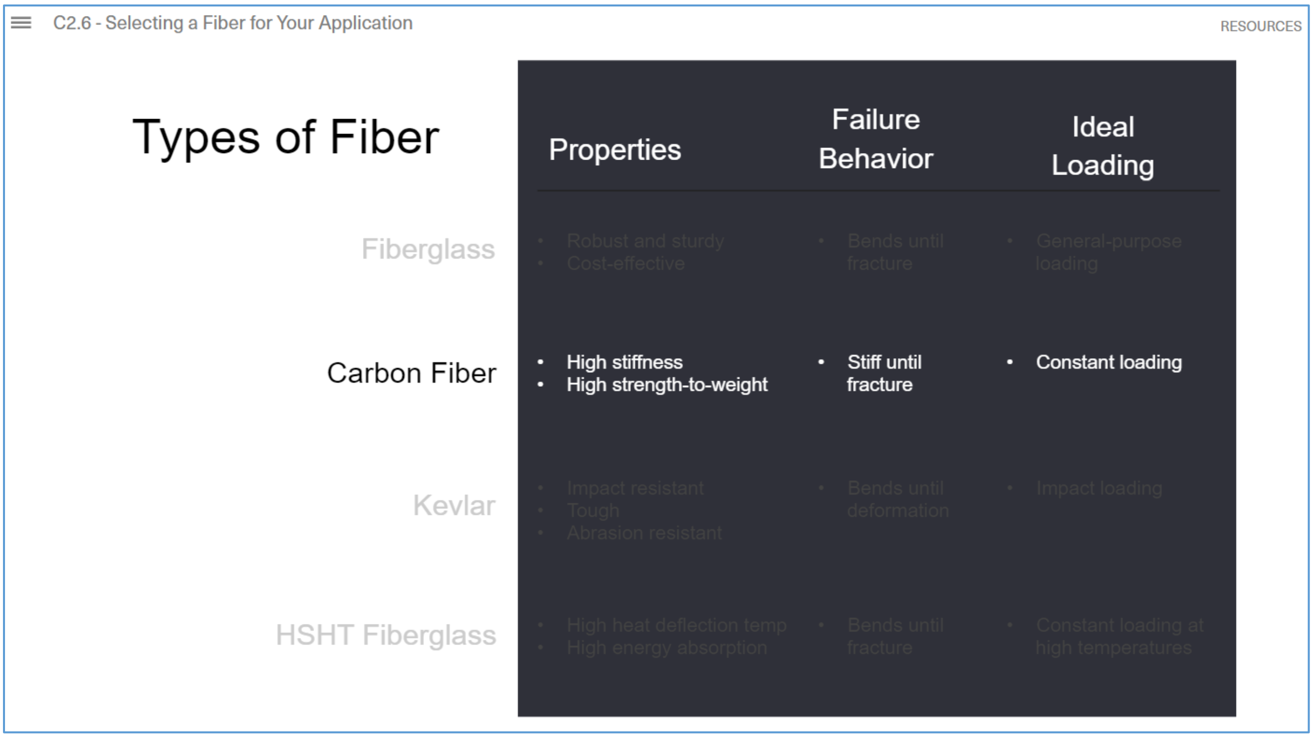


- **Carbon Fiber in Practice**
  - Strongest and stiffest material.

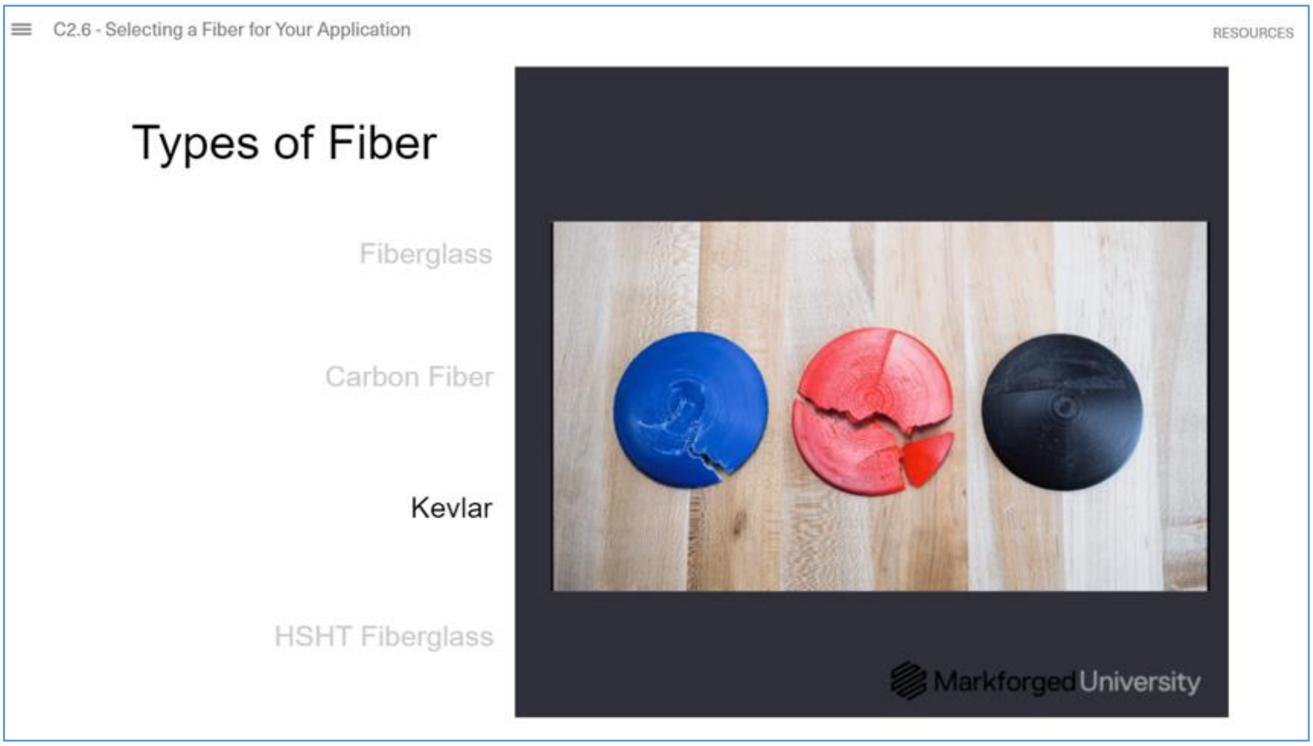
- Comparison: Left Onyx Carbon reinforced and right aluminum (with exact the same geometry).



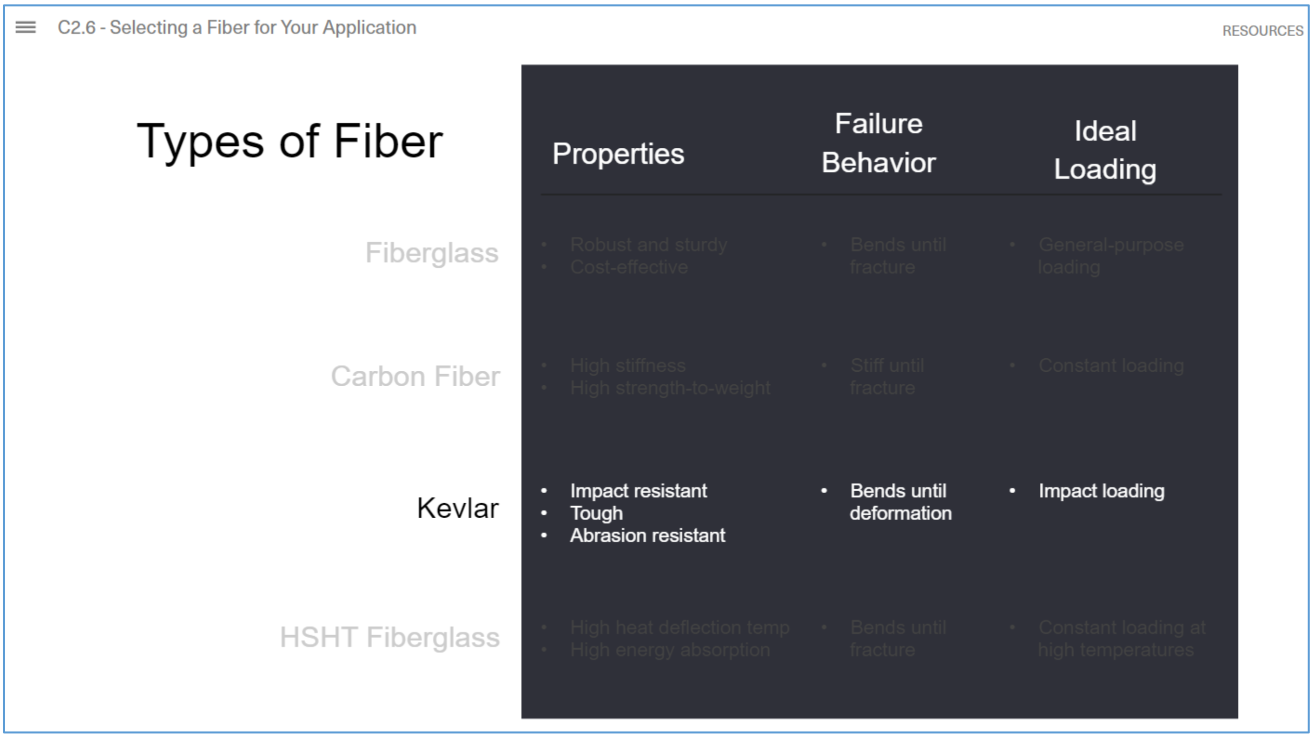
- Aluminum beam deforms.



- **Carbon Fiber Properties**
    - Applications: Drone arms, automation tooling, etc.
    - High stiffness is not at good absorb impact loading.
        - Needs more testing in high frequently loading conditions.



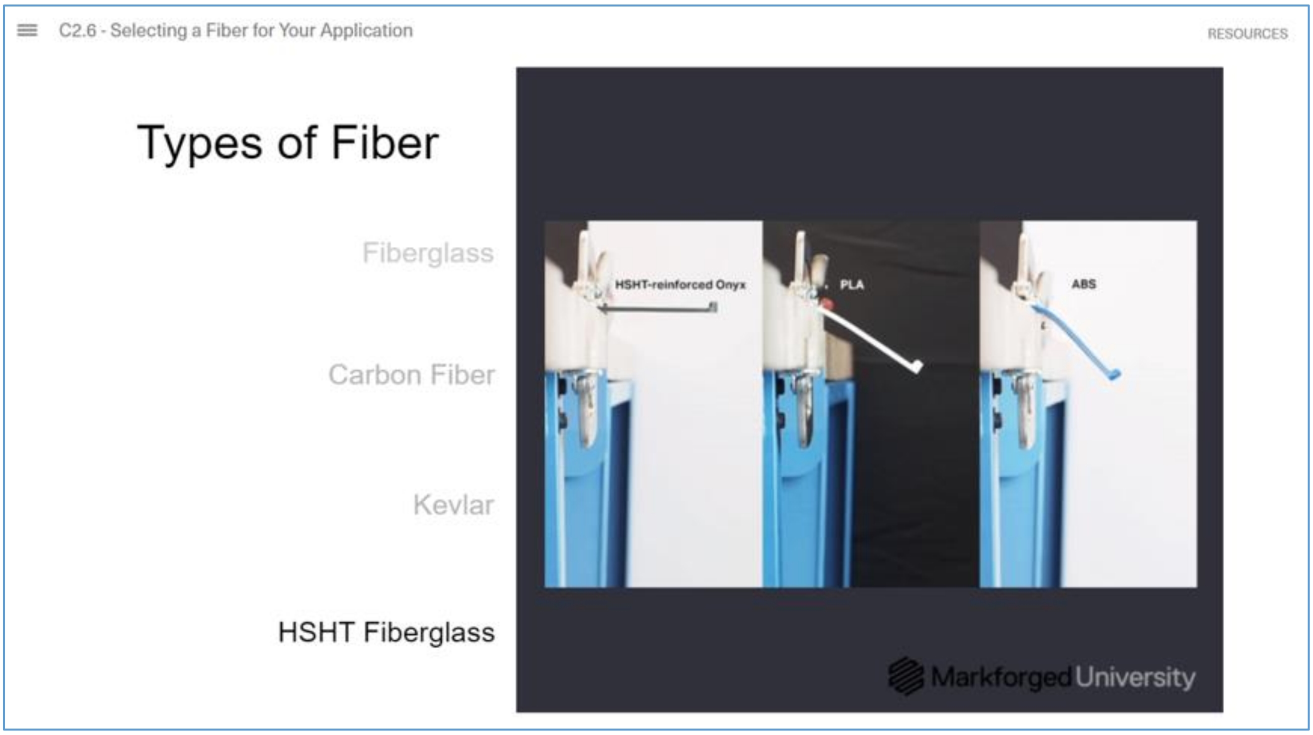
- **Kevlar in Practice**
    - Extremely impact resistant.
        - Comparison: ABS, PLA and Kevlar.



- **Kevlar Properties**
    - Abrasion = Slijtage.

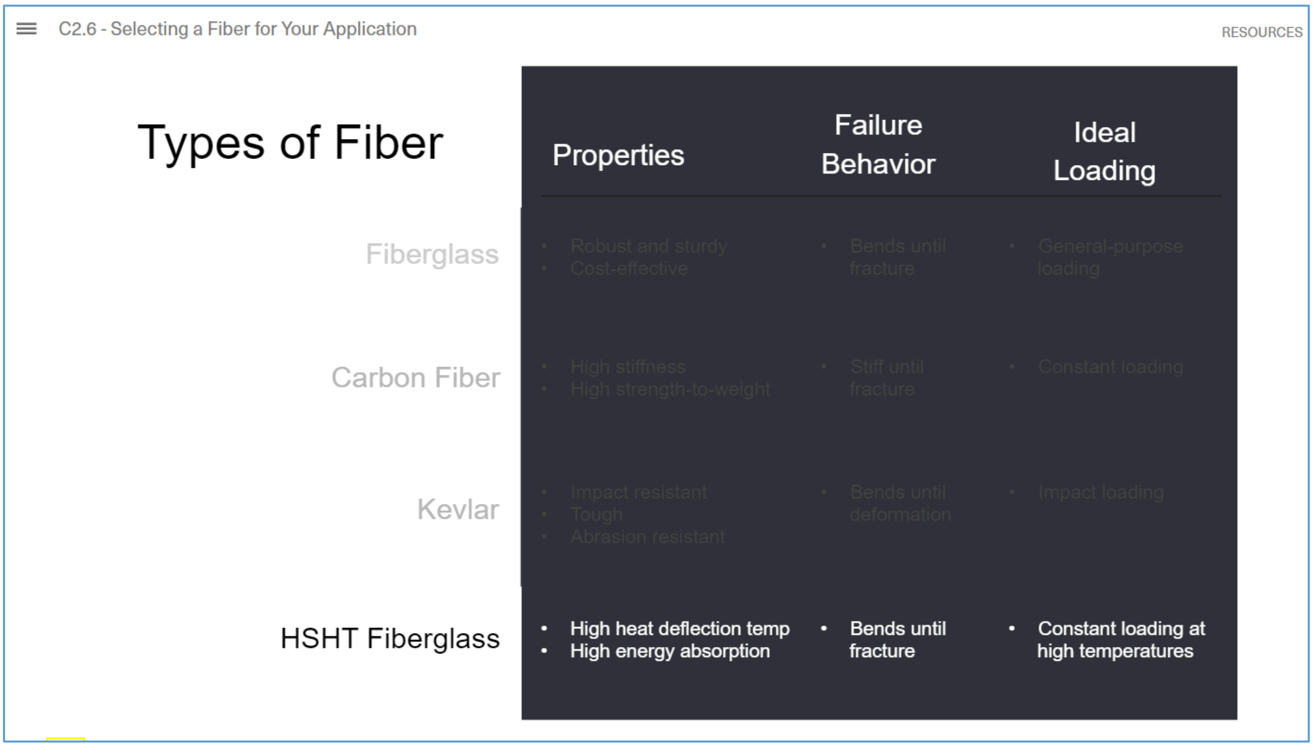
- Stress strain curves shows failing in 3 point bending for a half of load of carbon, for instance.
- Apllications: Reinforcing clamps rotating axis, soft jaws for CNC-lathes.

- **HSTS Fiberglass in Practice**

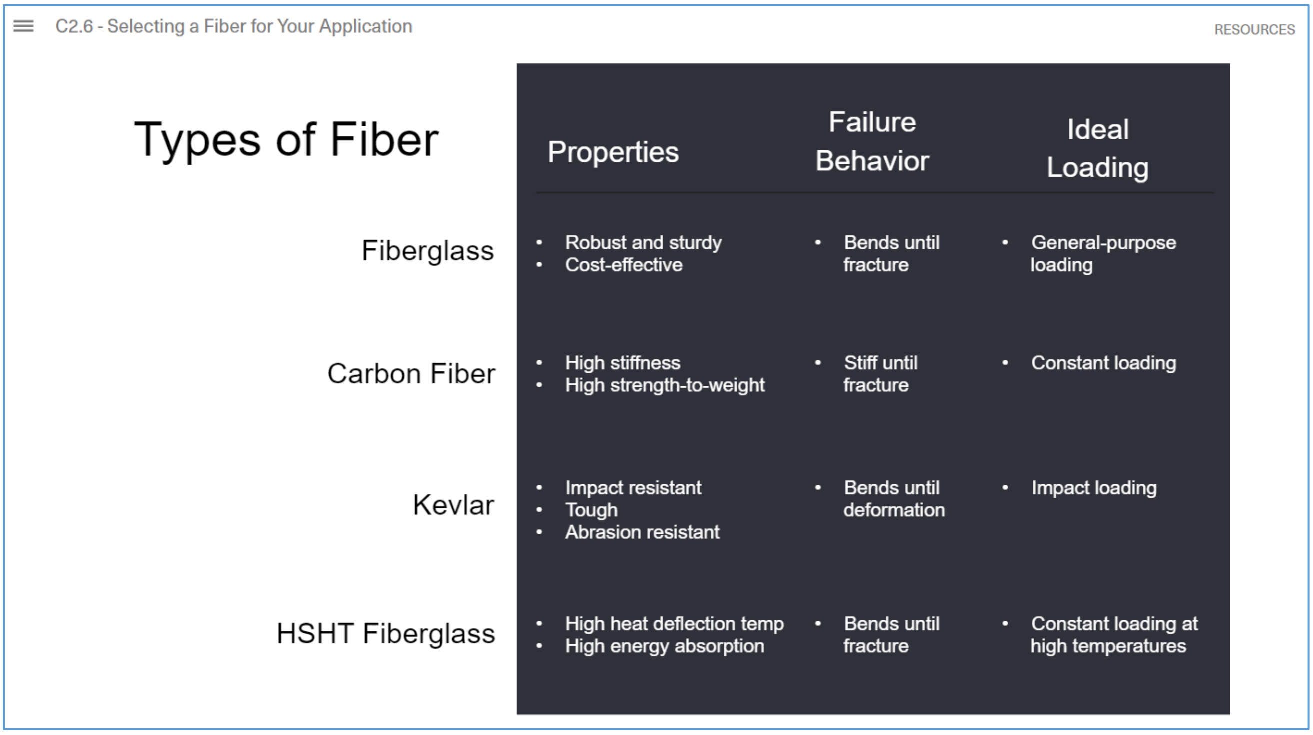


- Heated in an environmental chamber to 140 °C, for an hour, before applying load.

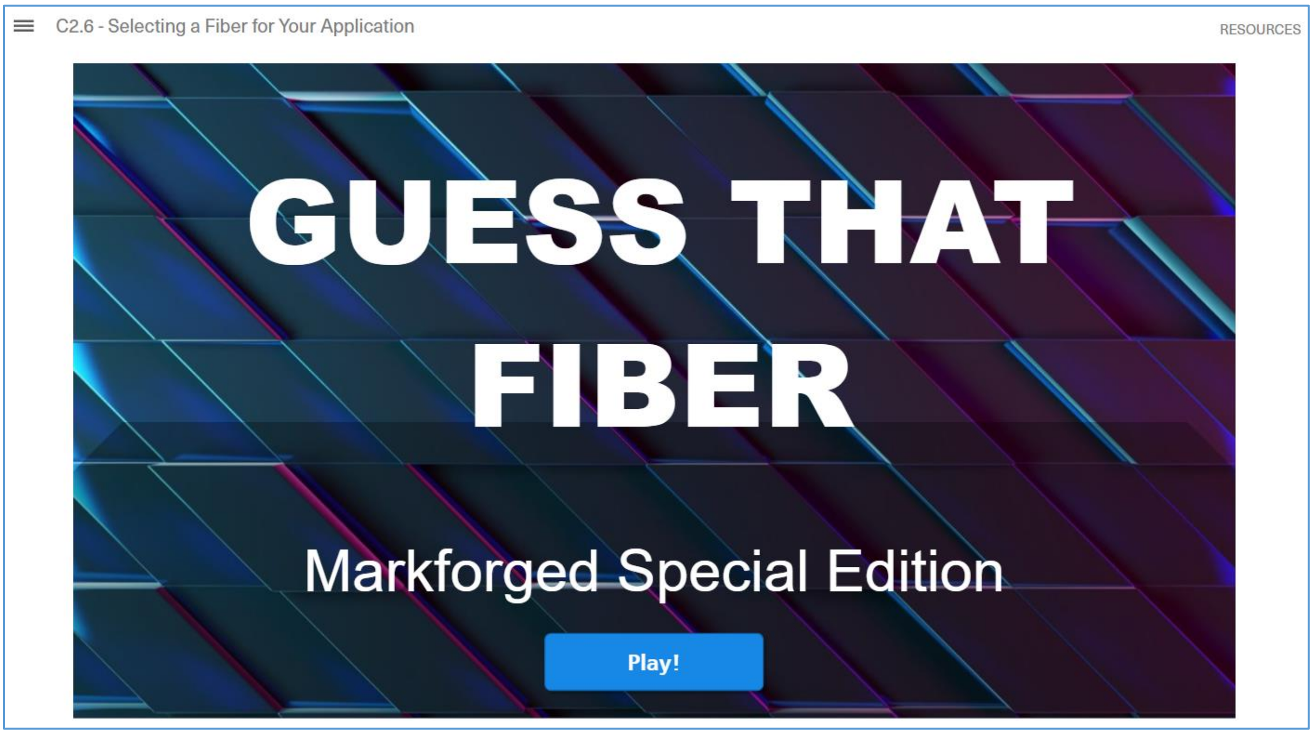
- Fiberglass beam just slightly bends and returns immediately to its’ original shape.
- PLA and ABS lost their stiffnesses.



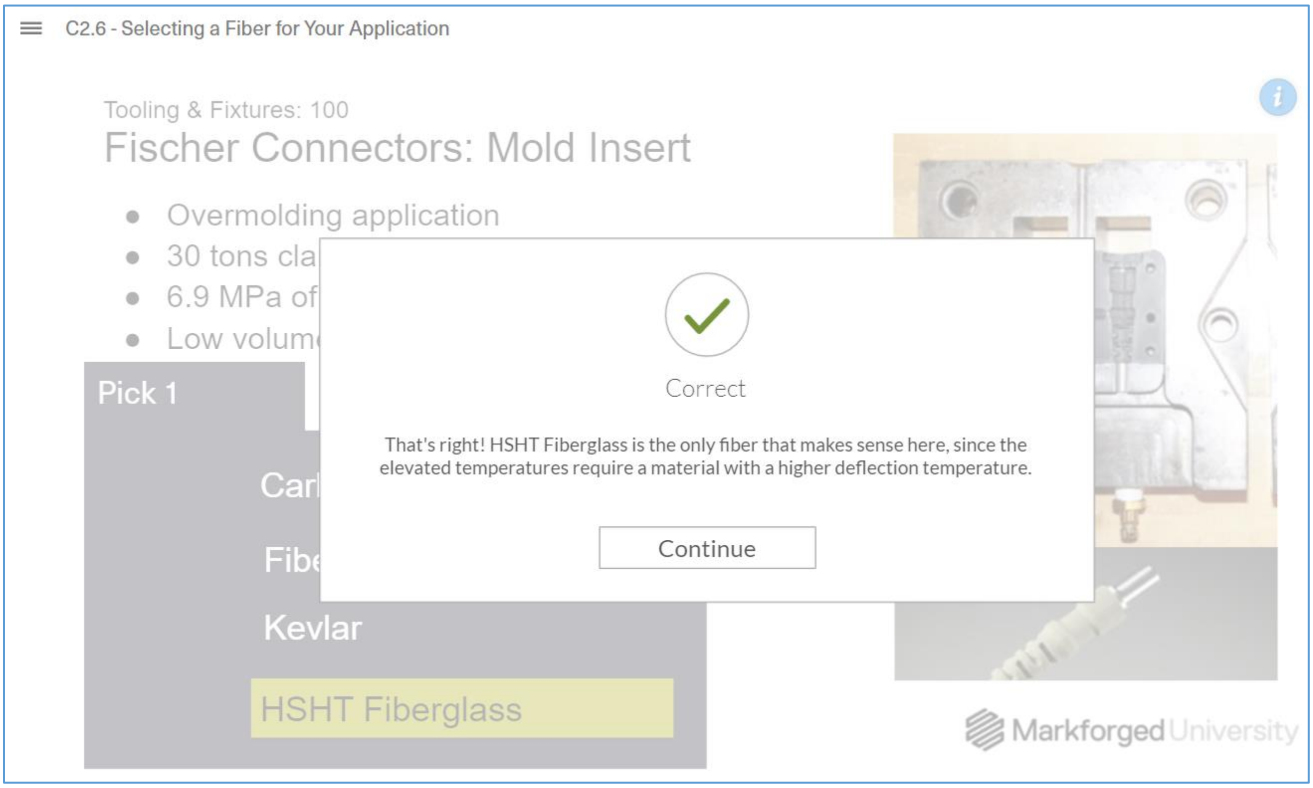
- **HSTS Fiberglass Properties**
    - Deflection = doorbuiging.
    - Print a little bit slower.



- **Recap: Continuous Fiber Properties**



- **Guess That Fiber**

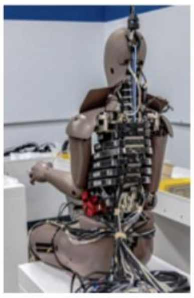


C2.6 - Selecting a Fiber for Your Application

RESOURCES

End Use: 200

Humanetics: Crash Test Dummy Ribs



- The ribs see some of the highest stresses during a crash
- Somewhat unknown loading directions
- Impact resistant
- Previous plastic iterations failed after 20 impacts

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Correct

C2.6 - Selecting a Fiber for Your Application

RESOURCES

Prototyping: 200

BattleBots Team Valkyrie: Skid Pad

- Attaches to the bottom of the blade
- Spins against the ground at 2000 RPM
- Support the weight of a 250 lb robot as one of three points of contact

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Correct

C2.6 - Selecting a Fiber for Your Application

RESOURCES

Prototyping: 300

Moterum Technologies: Stroke Mobility Device

- Support the weight of a person from multiple contact points
- Capable of handling gait-related loading conditions and impacts
- Light enough to not further impair gait

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Correct

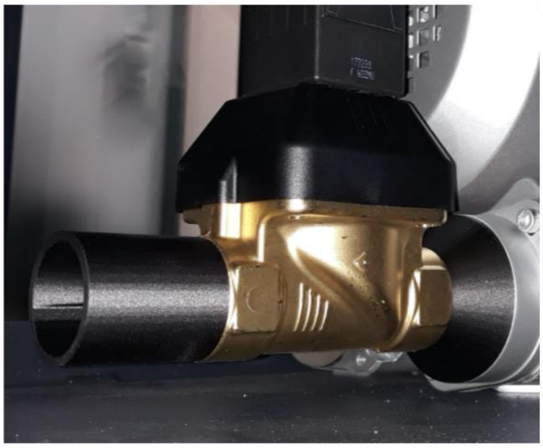
C2.6 - Selecting a Fiber for Your Application

RESOURCES

End Use: 100

BMF GMbH: Tube Extension

- Tube extension for sand blasting machine
- Needs to be wear resistant
- Low pressure
- Minimal loading



Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

C2.6 - Selecting a Fiber for Your Application RESOURCES

End Use: 300

Haddington Dynamics: Dexter Arm

- 7-axis robotic arm
- 50 micron joint precision
- 3kg payload
- 70 printed parts, focusing on arm segments

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Correct

C2.6 - Selecting a Fiber for Your Application RESOURCES

Tooling & Fixtures: 200

Primetall: Welding Fixture

- Zero-point clamping system for spot welding
- Durable, dimensionally stable
- Holding heavy steel while rotating at high speed
- Not a high load application

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Incorrect

C2.6 - Selecting a Fiber for Your Application

RESOURCES

Prototyping: 100

Surf Flex Lab: Surboard Fin

- Attaches to the bottom of the board
- Complex loading condition when in testing
- Marine application
- Needs to be strong and stiff

Pick 1

Carbon Fiber

Fiberglass

Kevlar

HSHT Fiberglass

Incorrect ×

C2.6 - Selecting a Fiber for Your Application

RESOURCES

Results

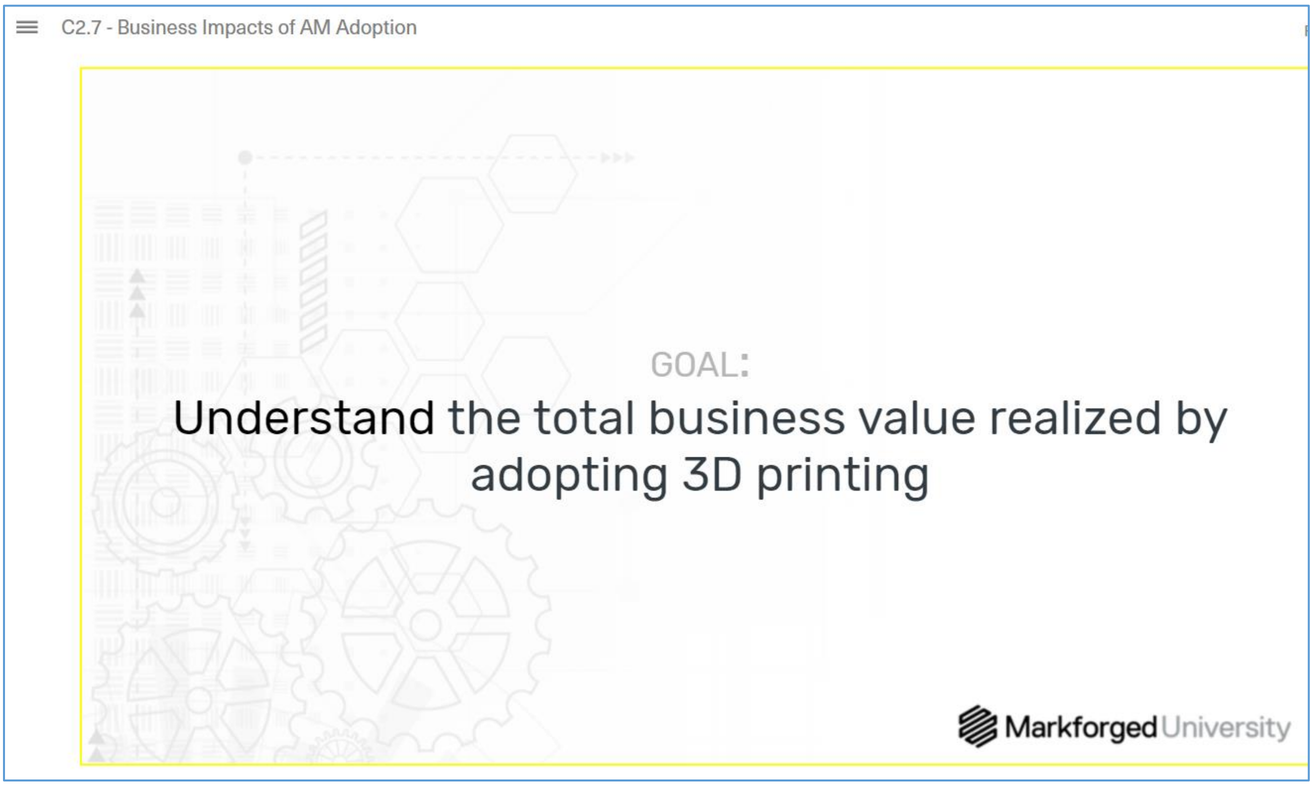
Your Score: **57.14% (40 points)**

Finish Module

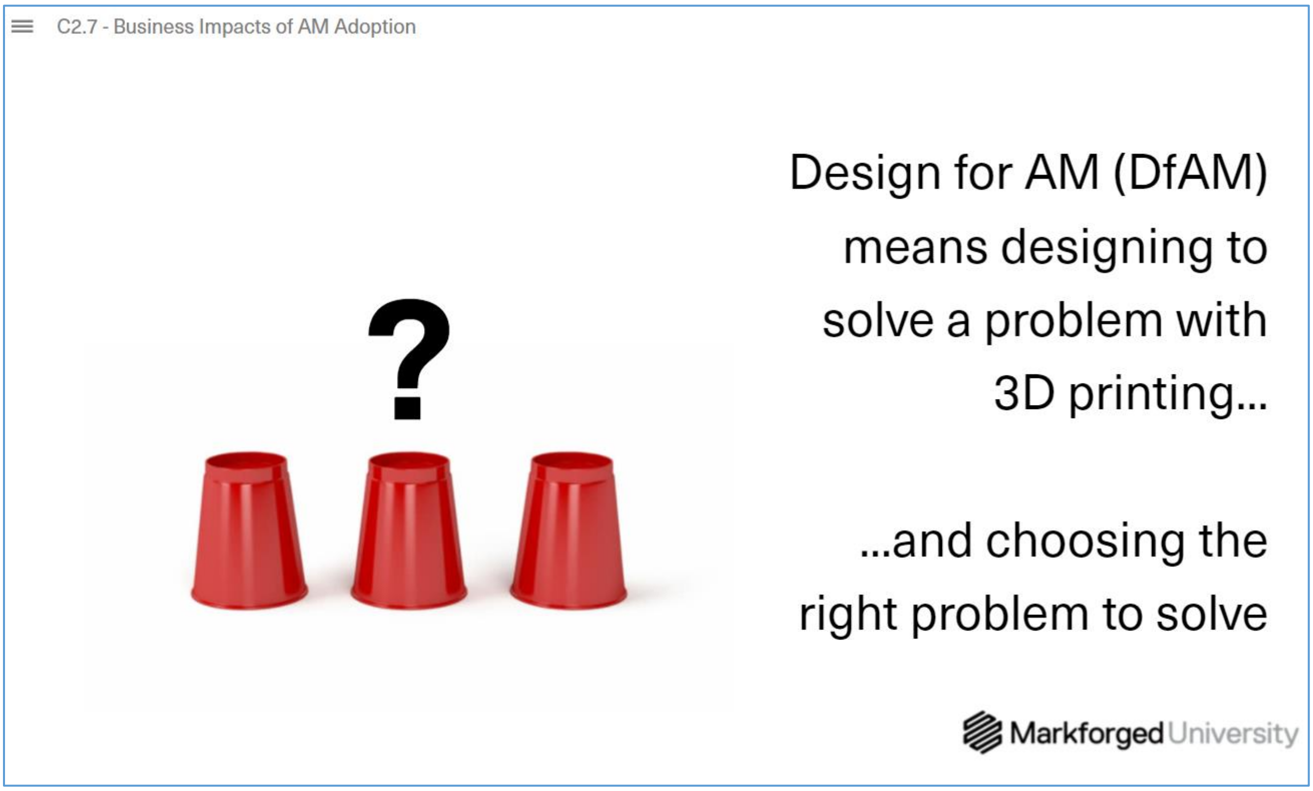
Review Quiz

C2.7 – Business Impacts of AM Adopotion

- **Business Impacts of AM Adoption**
    -

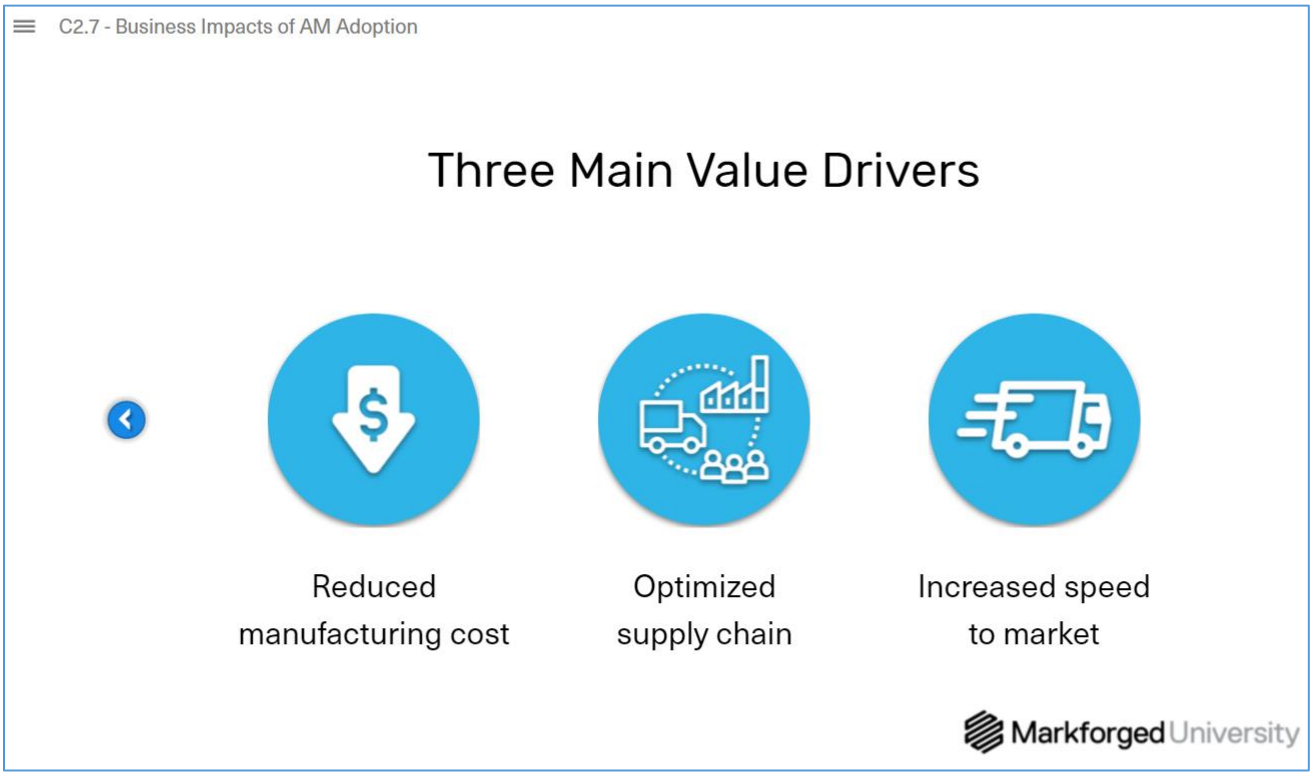


- **Its's All About the Total Value**
    - Comprehensive = samenhangend

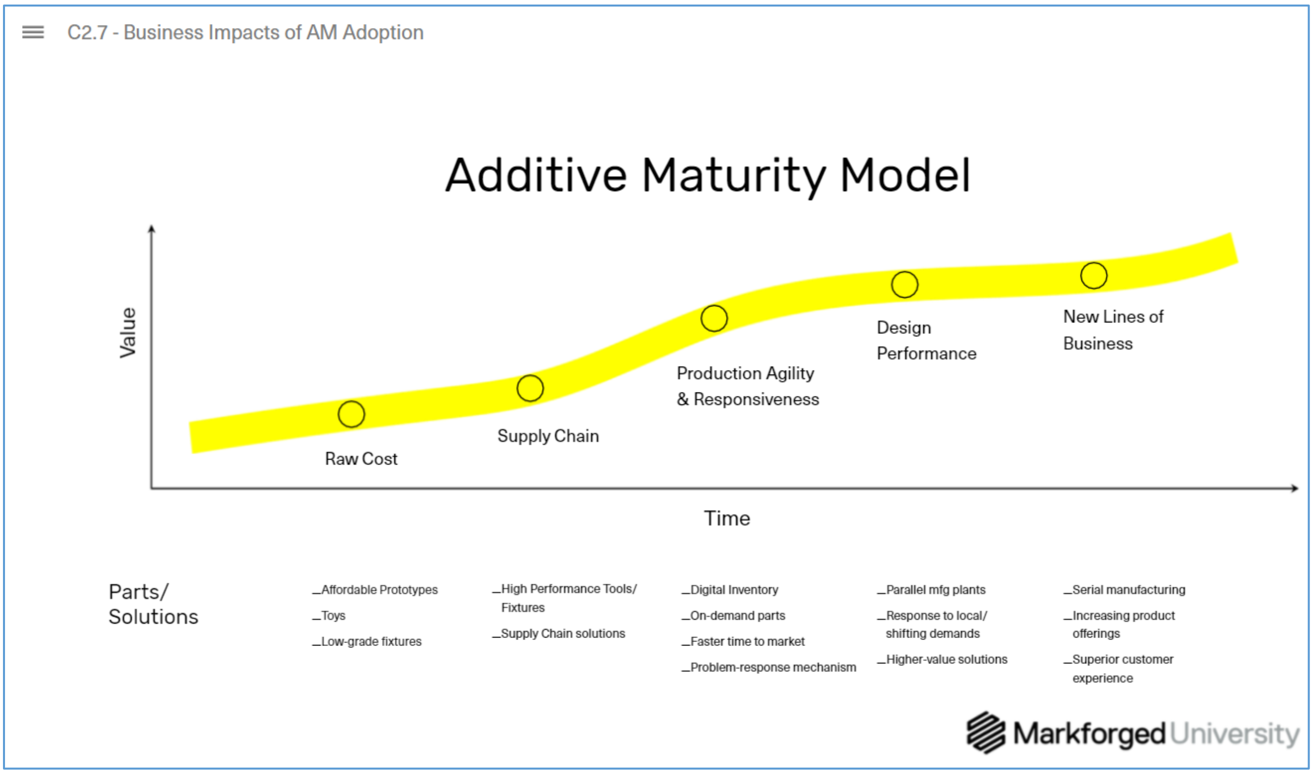


- **Choosing the Right Problem**

- **Business Impacts In Manufacturing**



- **Two Types of Impact**



- **AM Maturity Trajectory**
  - Maturity = Volwassenheid
  - Agility = Behendigheid
  - Responsiveness = Ontvankelijkheid
  - Increasing product offerings = Toename in offertes.

- Superior = betere

- **Immediate Impacts Revisited**
    - Revisited = Opnieuw bekeken

C2.7 - Business Impacts of AM Adoption

RESOURCES

Immediate Impacts Revisited

Immediate Business Outcomes (per 3 jaw set):

	Traditional	Markforged	Change
Cost	$1000	$81	-92%
Lead Time	2 weeks	30 hours	-91%

DIXON

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- Lead Time = Doorlooptijd

C2.7 - Business Impacts of AM Adoption

THEME:

Process improvements drive Organizational Impacts and result in larger, recurring benefits

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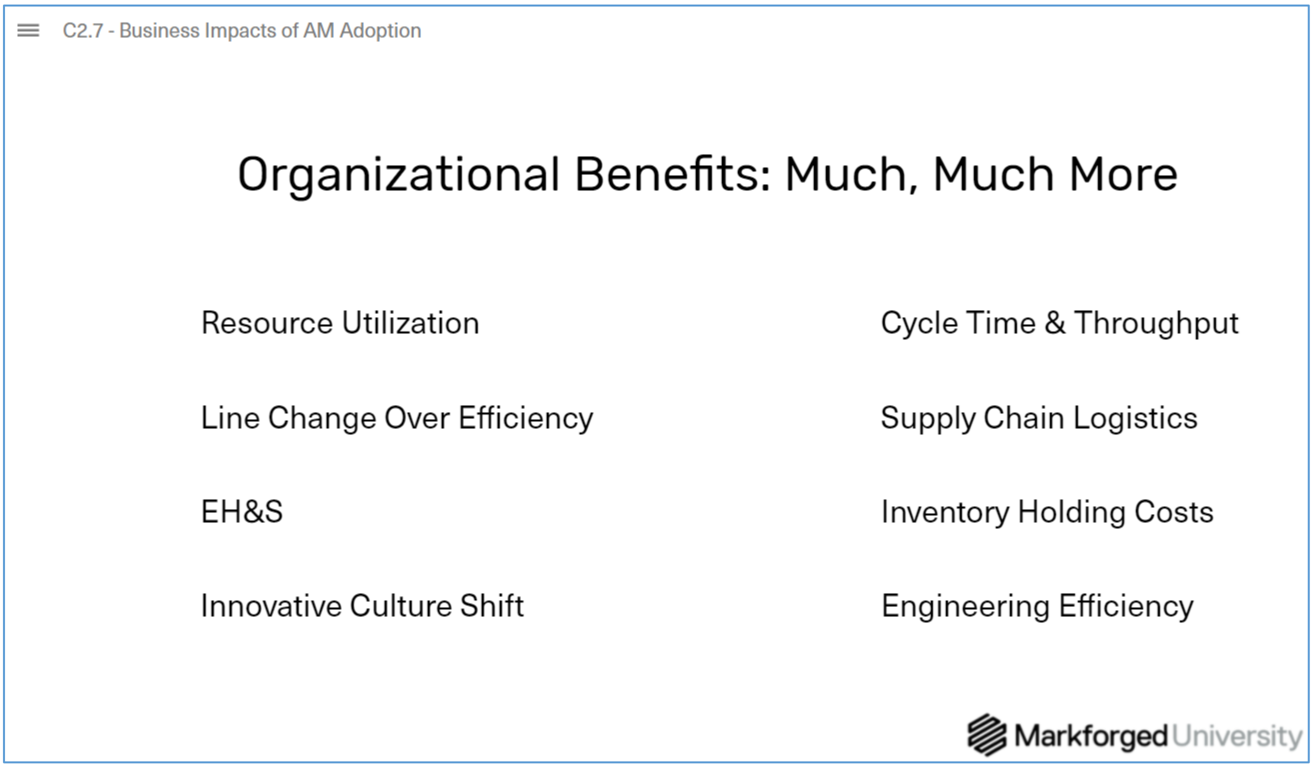
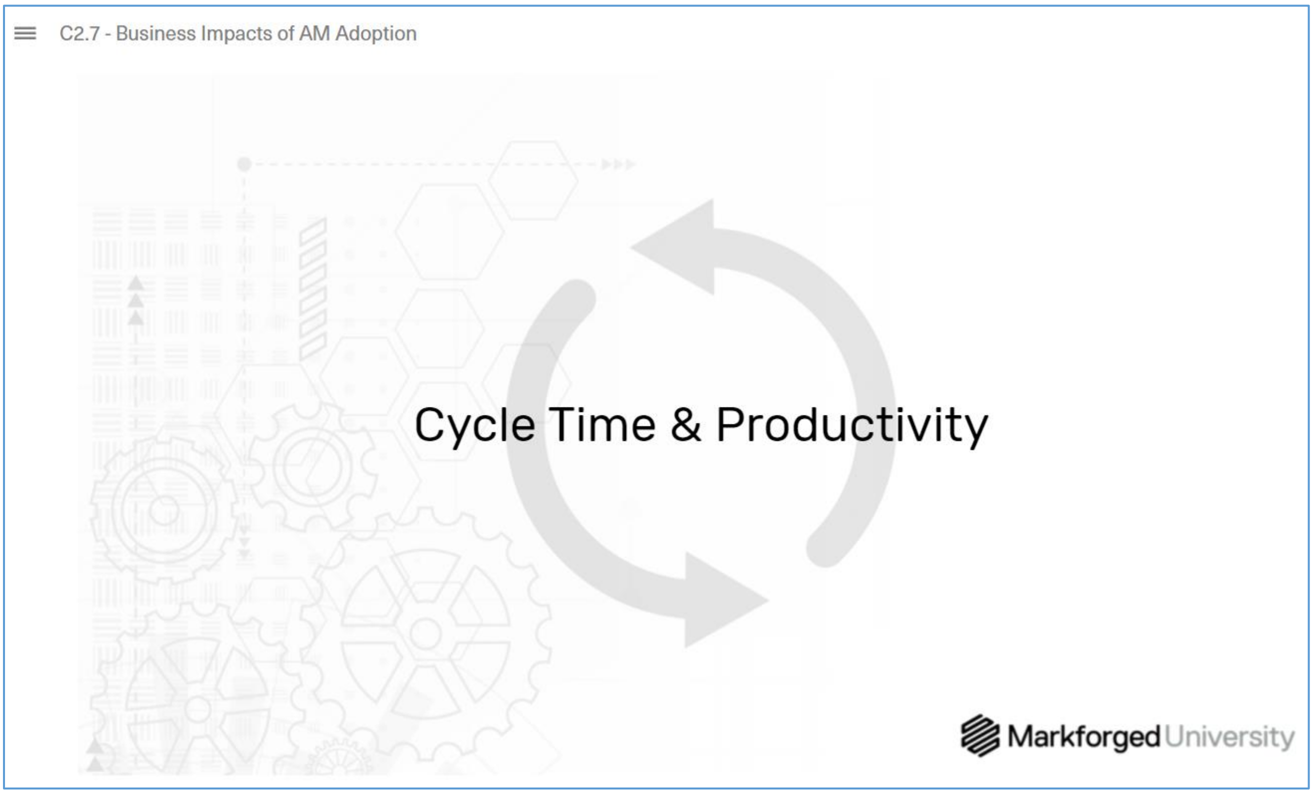
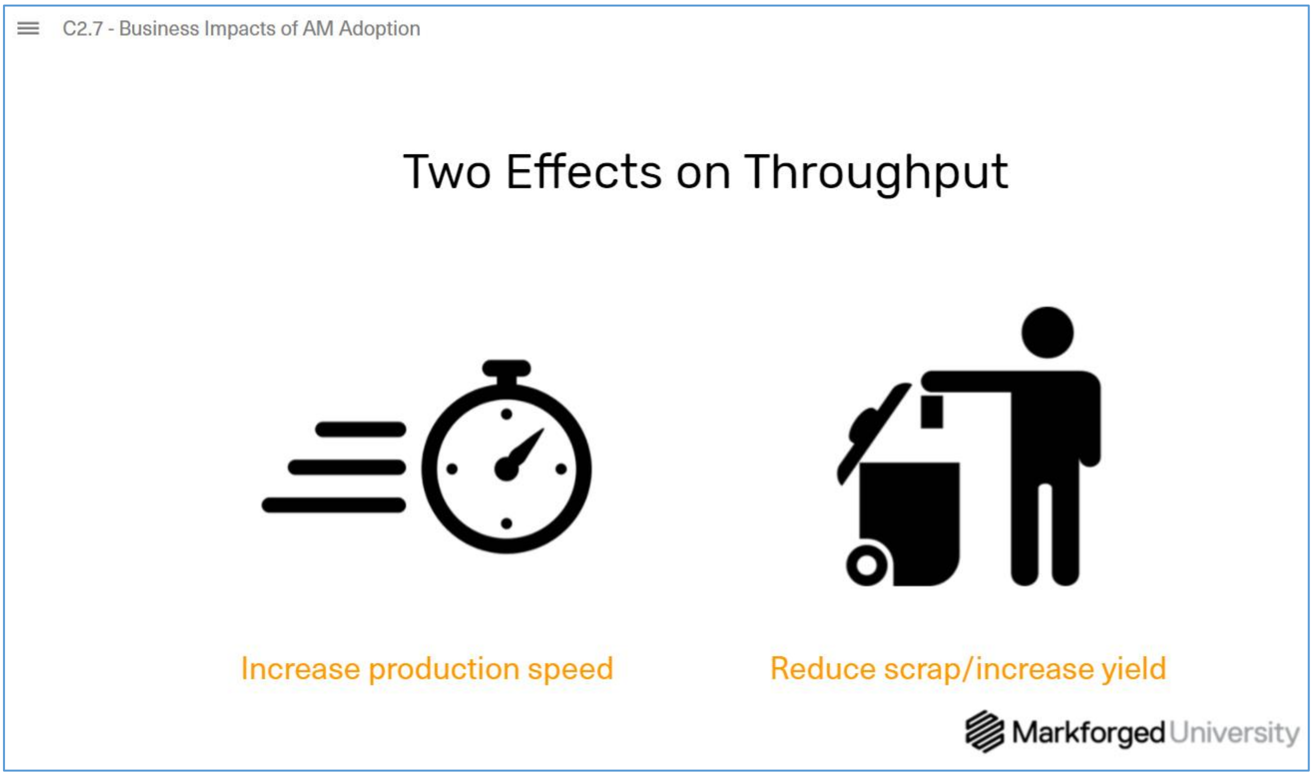
- **Organizational Benefits Are Greater**
    - Recurring = Terugkerend
    - Benefit = Voordeel



- **Organizational Benefits: Much, Much More**
    - Resource Utilization = Gebruik van hulpbronnen
    - EH&S = Environment, Health and Safety

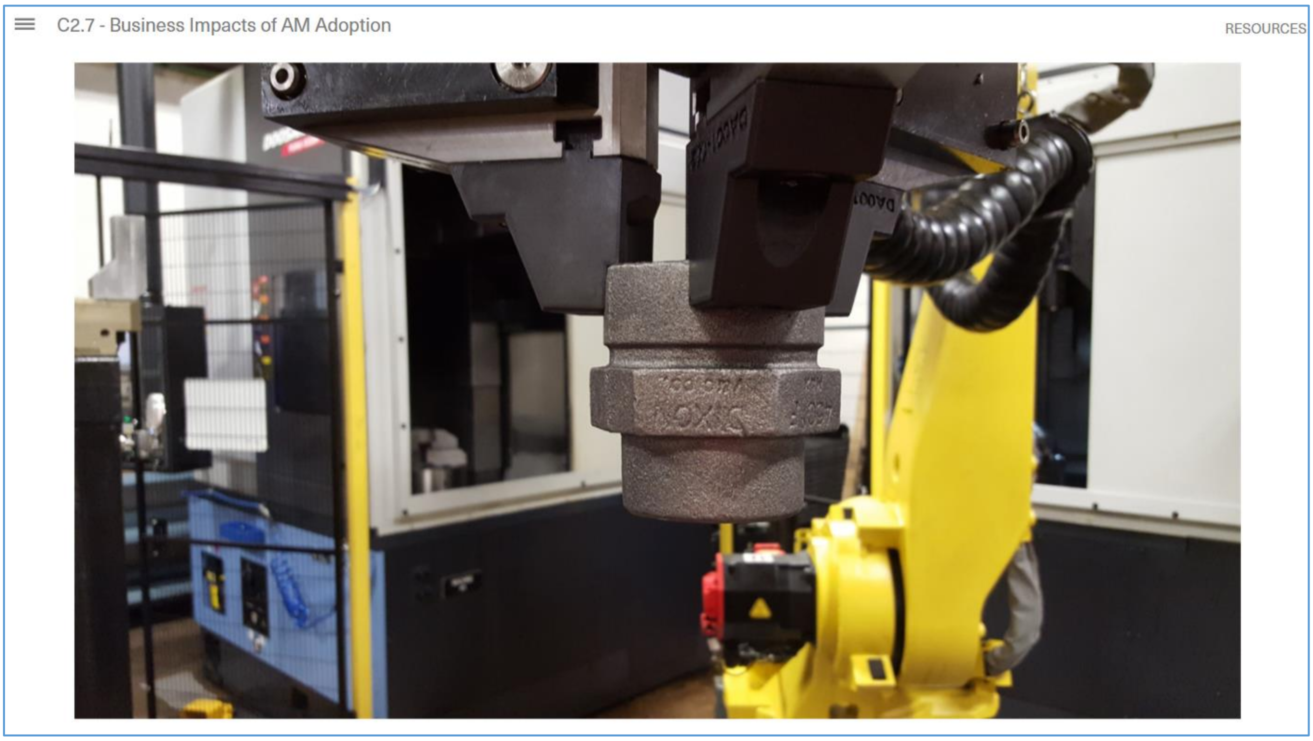


- **Cycle Time & Productivity**

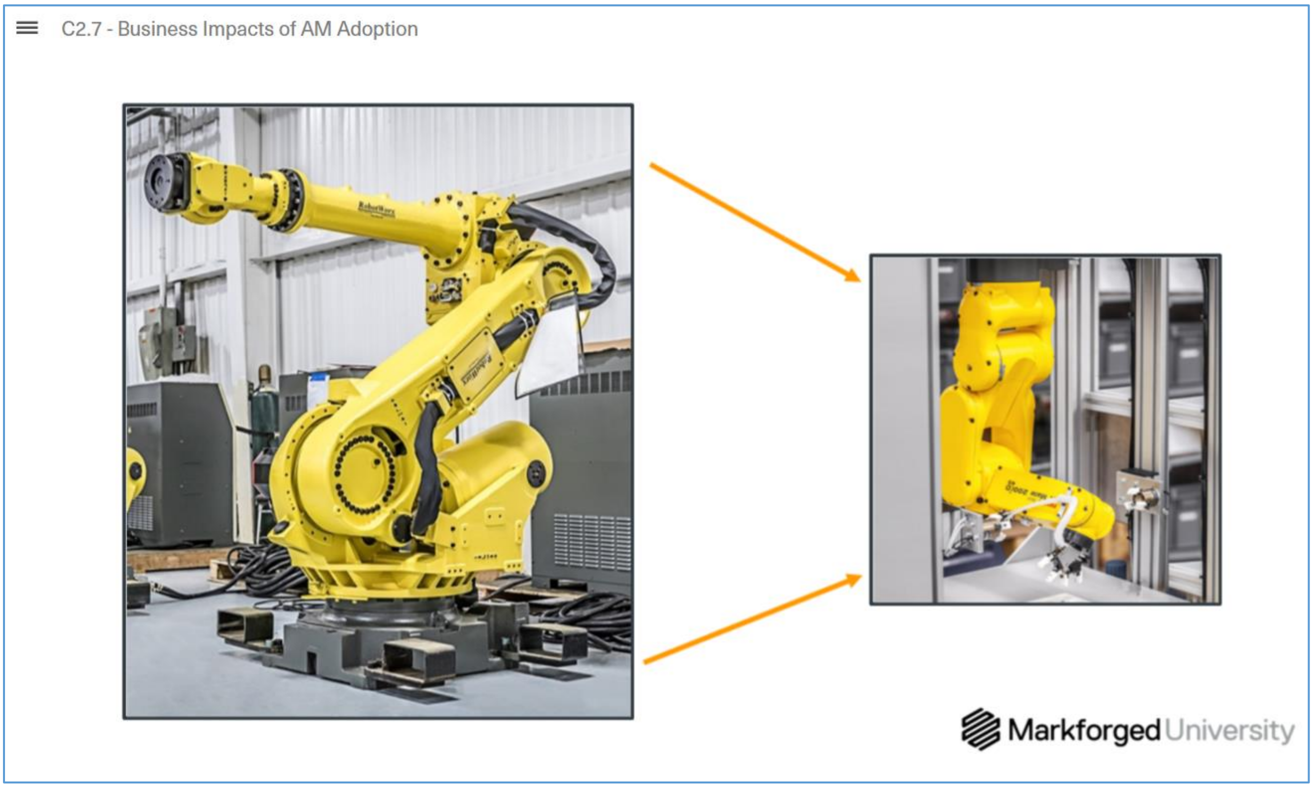


- **Two Effects on Throughput**
    - Throughput = Doorvoer

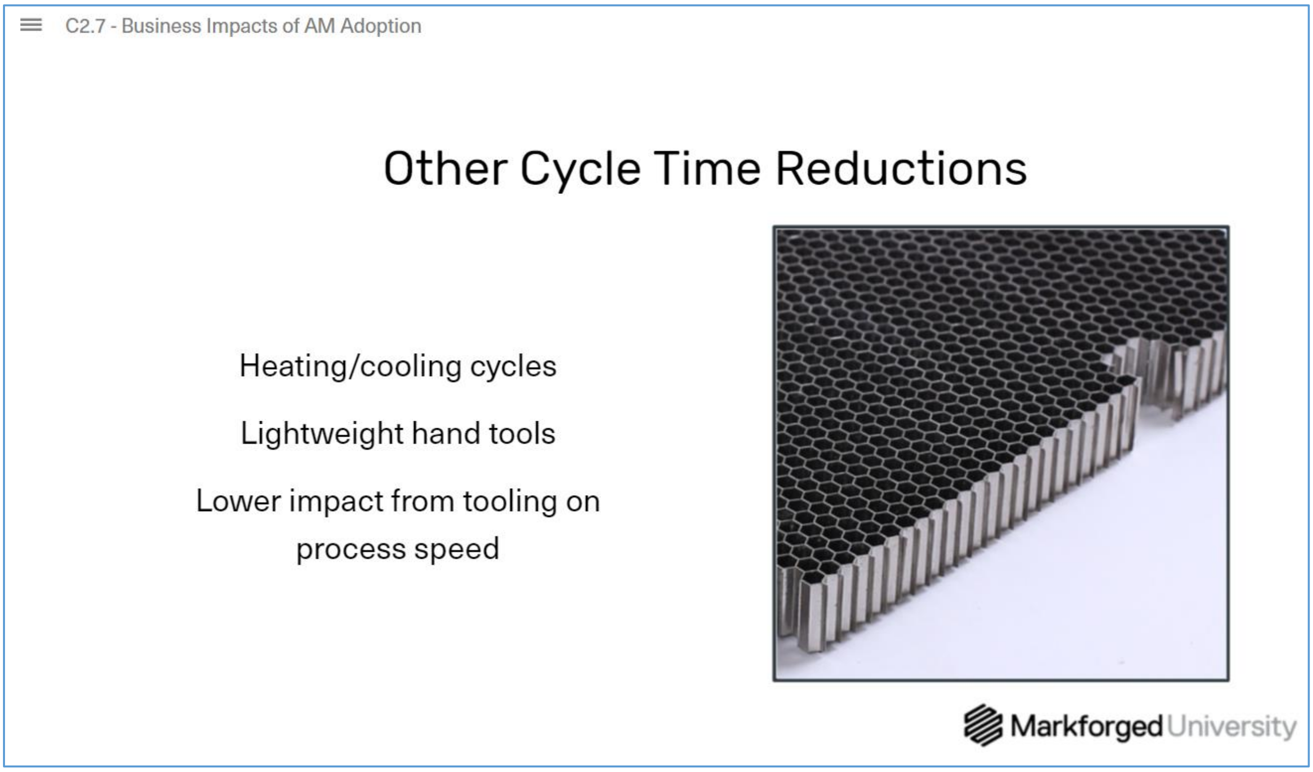
- **Poka yoke** is een Japanse term gebruikt in lean manufacturing en betekent zoveel als foutpreventie. Het is een methode om een productieproces zodanig te vormen dat het bijna onmogelijk wordt om fouten te maken. Een operatie wordt uitgevoerd op een manier dat de correcte handeling geforceerd wordt.



- **Reducing Cycle Time…and More!**
  - By using metal EOAT decreases the acceleration deceleration. By using lower weight plastics increases speed of movement.

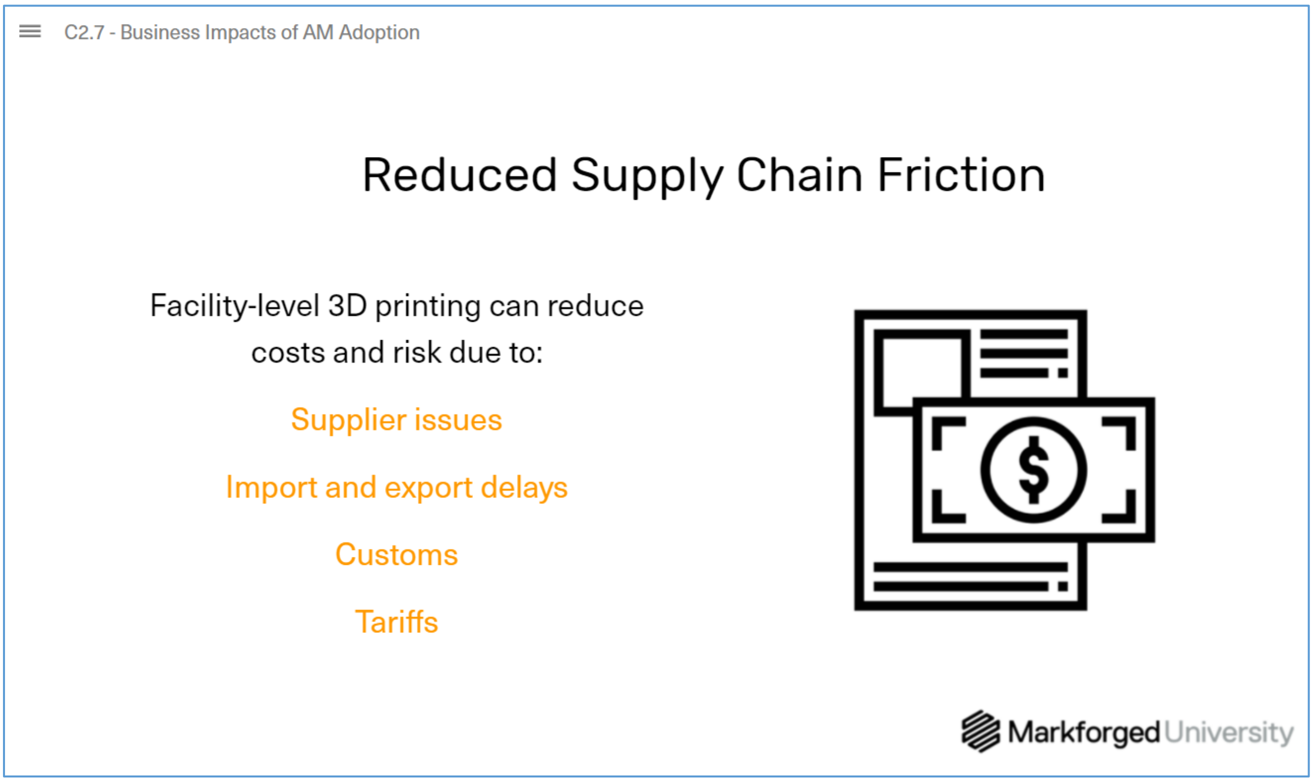


- Smaller and less expensive robots are required.

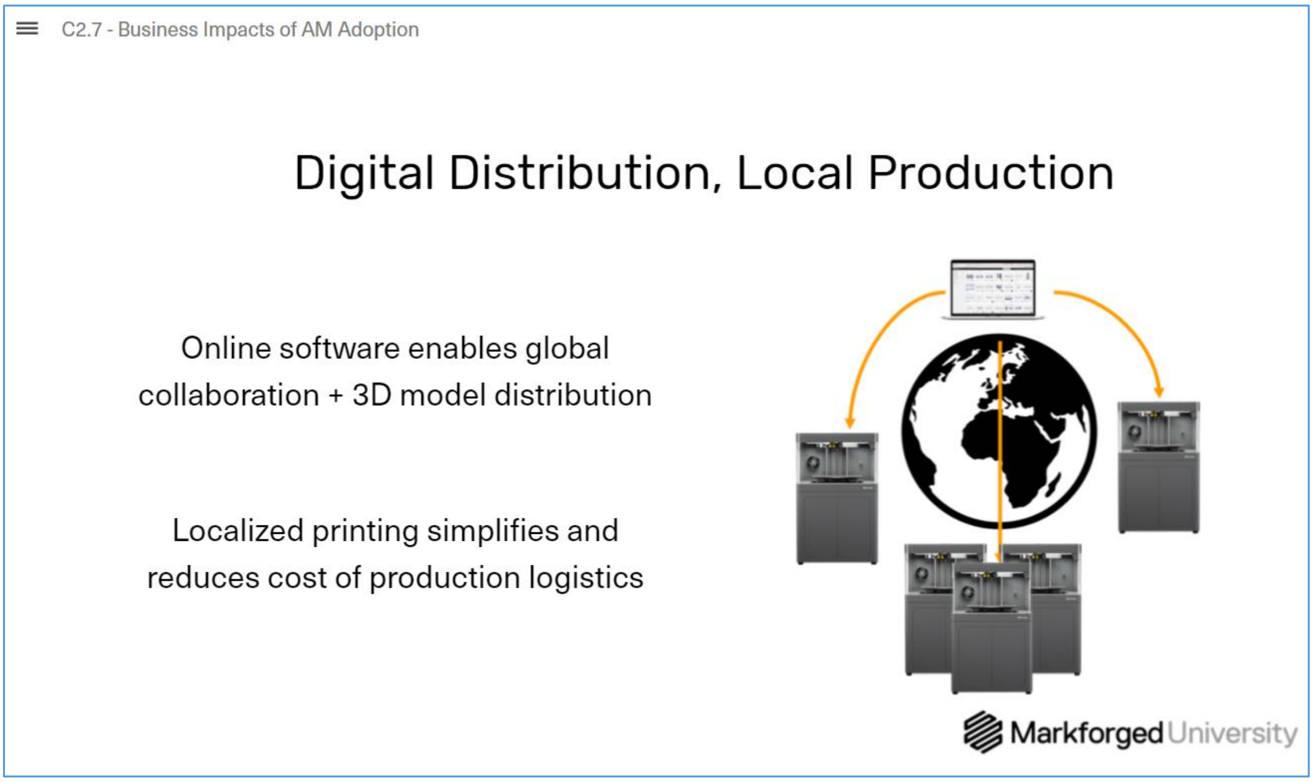


- **Other Cycle Time Reductions**

- **Supply Chain & Logistics Costs**
    - Bevoorradingsketen
    - Disruption = verstoring

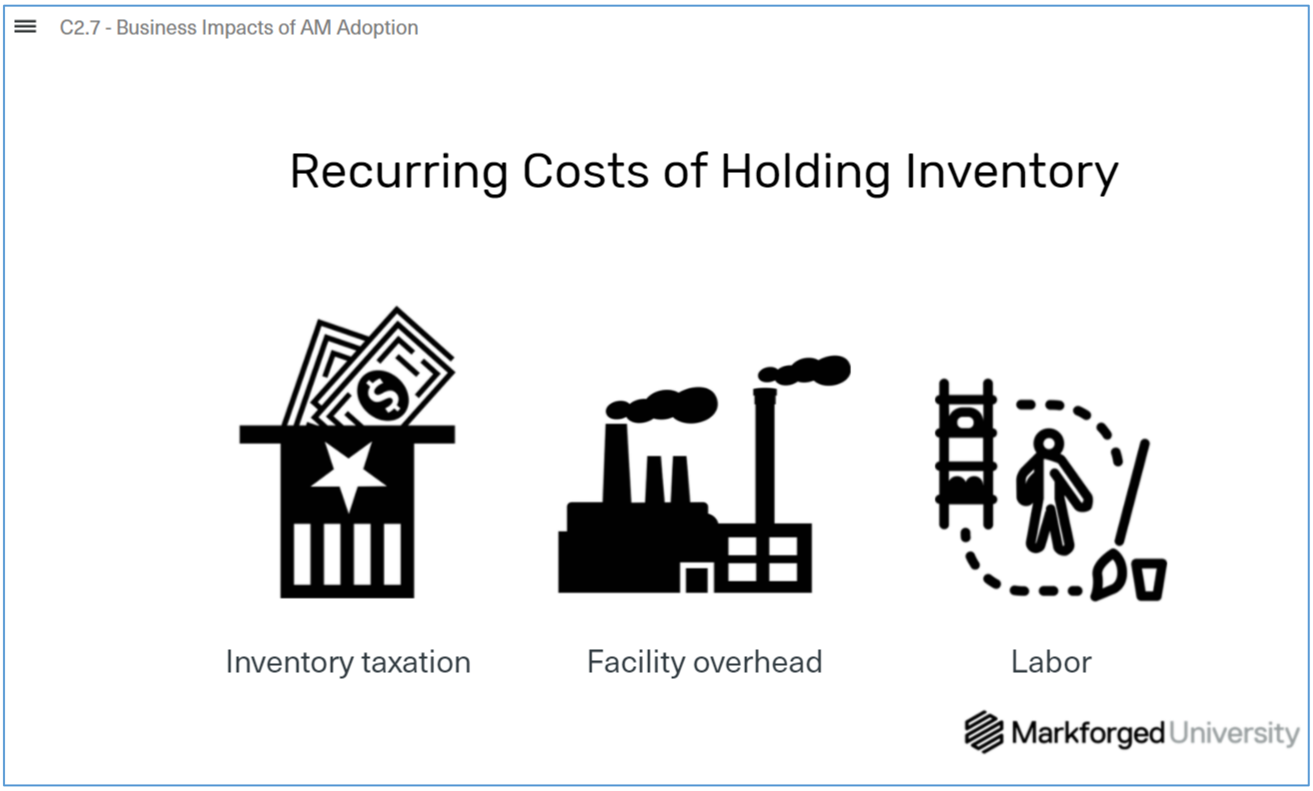


- **Reduced Supply Chain Friction**

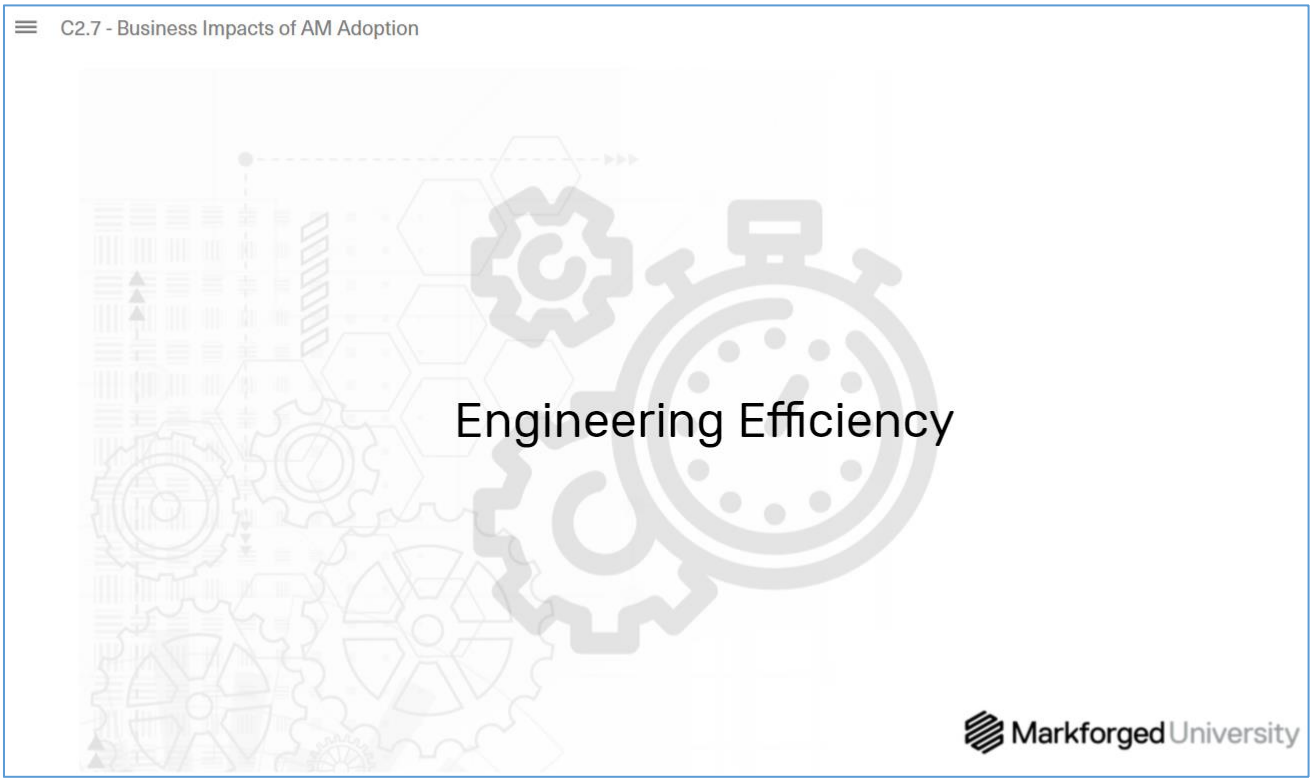


- **Digital Distribution, Local Production**

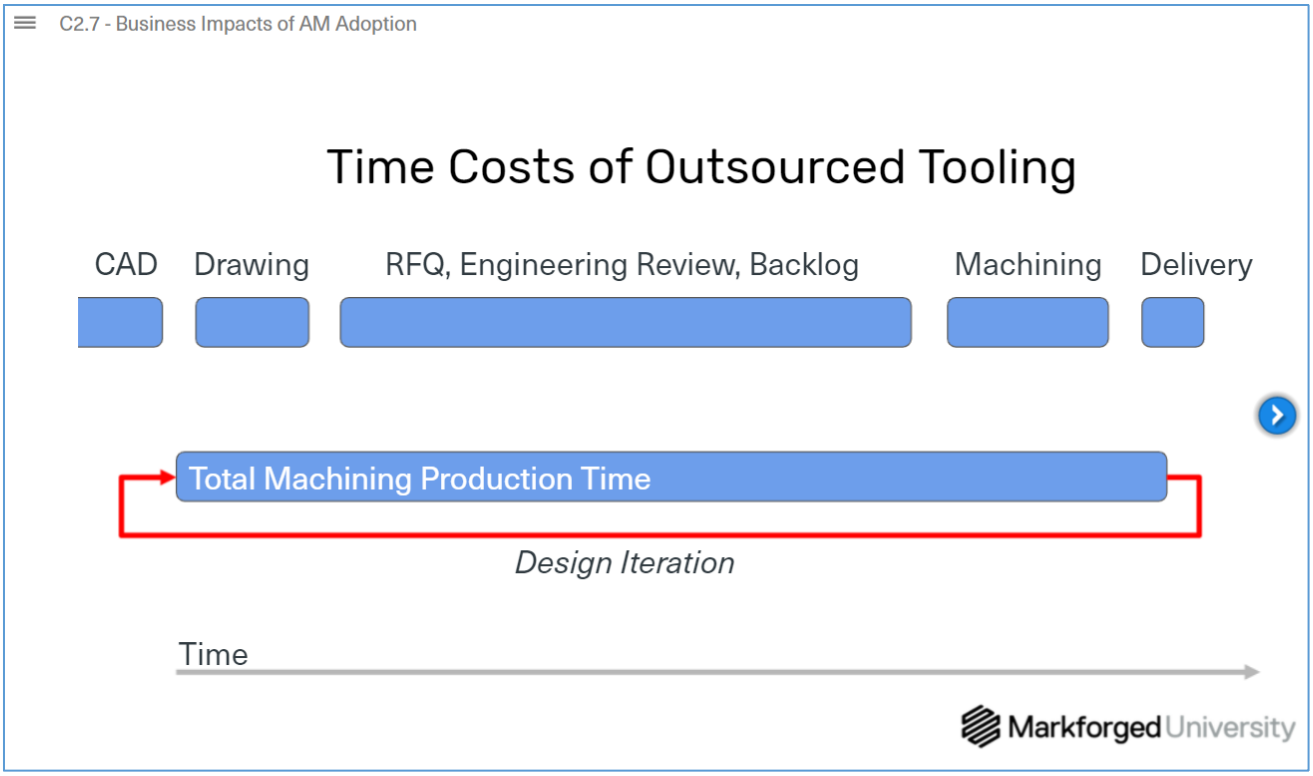
- **Inventory Holding Costs**
  - Voorraadkosten.



- **Recurring Costs of Holding Inventory**

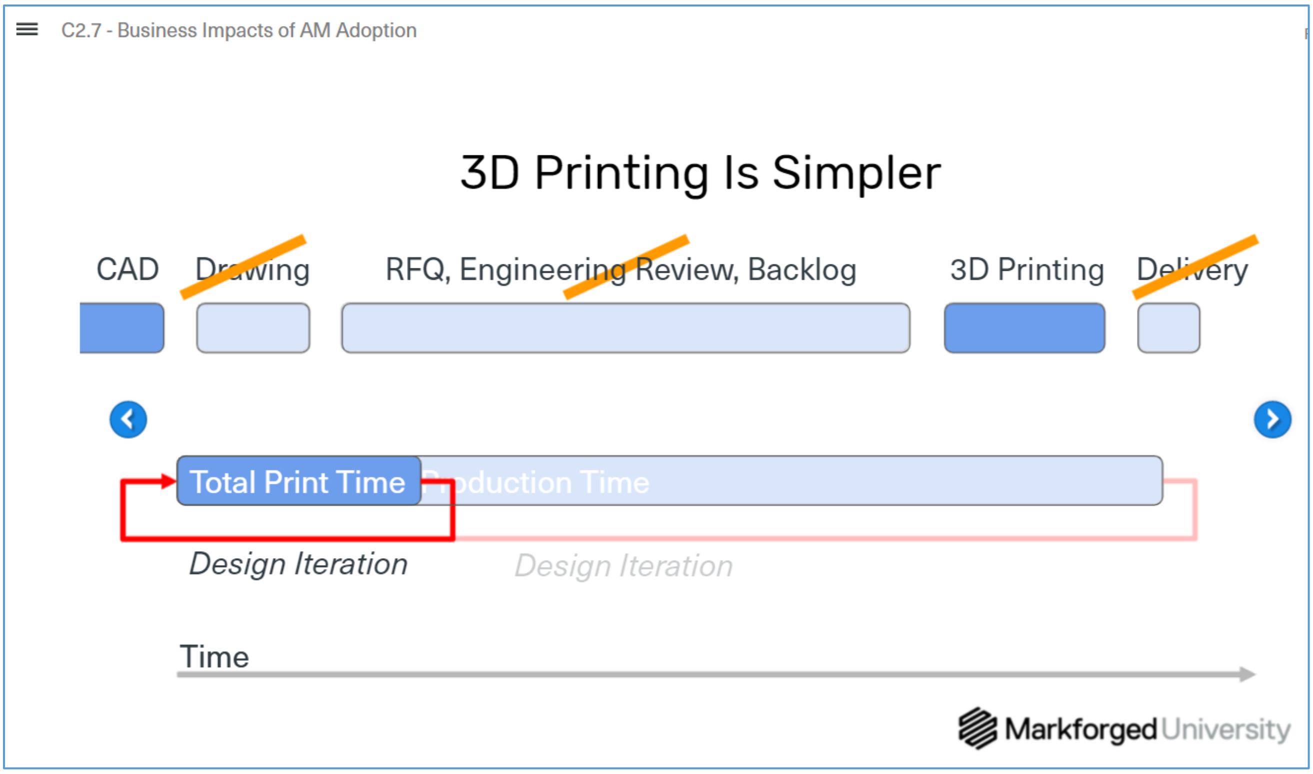


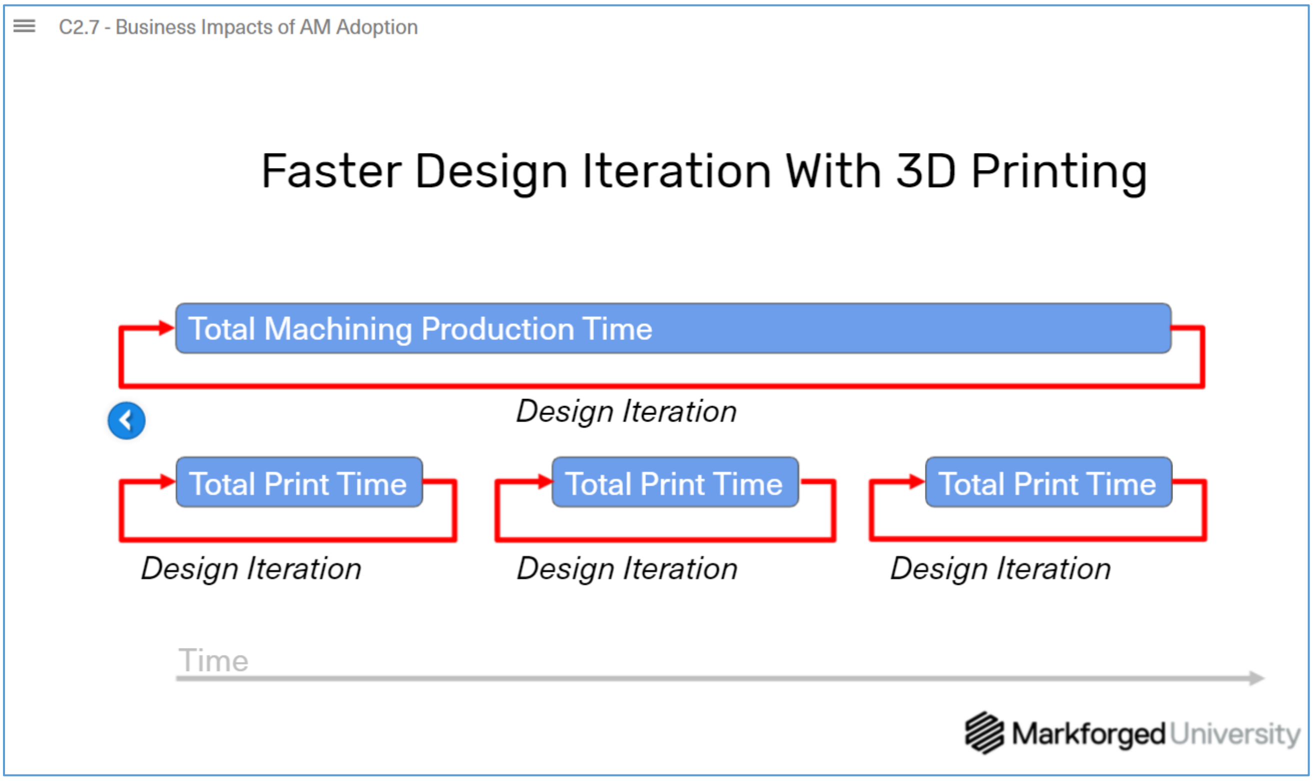
- **Engineering Efficiency**
    - Maturing tools faster with less effort
    - Maturing = Rijping (in deze context: op elkaar volgende verbeteringen).



- **Time Costs of Outsourced Tooling**

- RFQ = Request for Quote = Offerte aanvragen
- Backlog = Achterstand

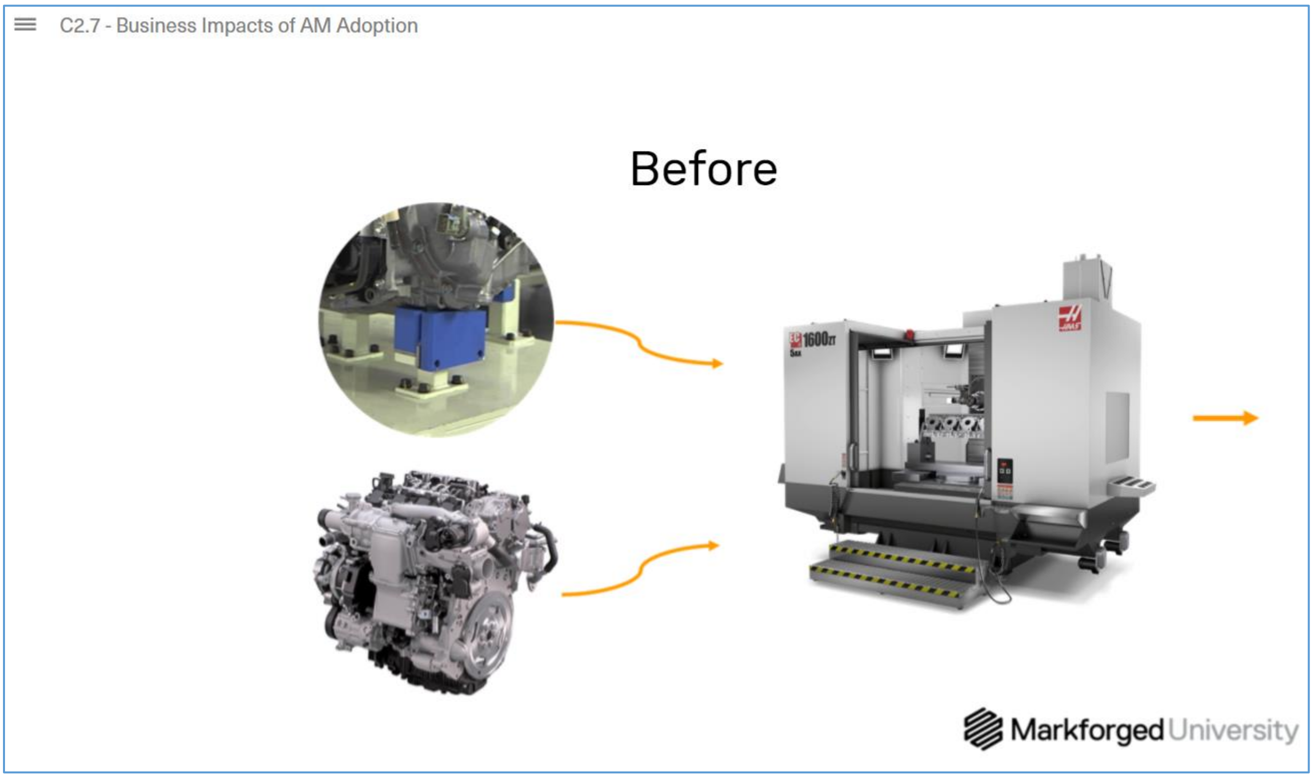




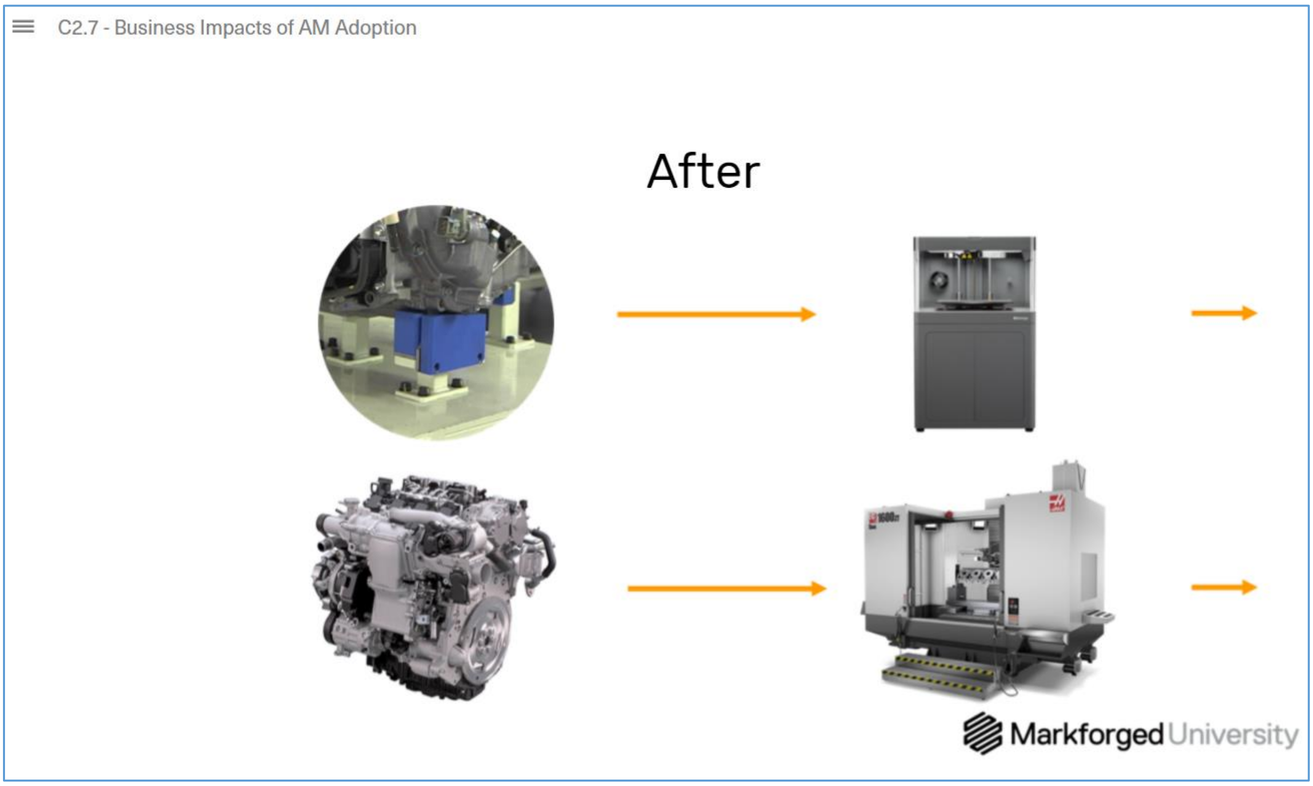
- More maturing of end product due to more iteration moments.

- **Resource Utilization Efficiency**
    - Efficiënt gebruik maken van hulpbronnen

- **Tools and Products**

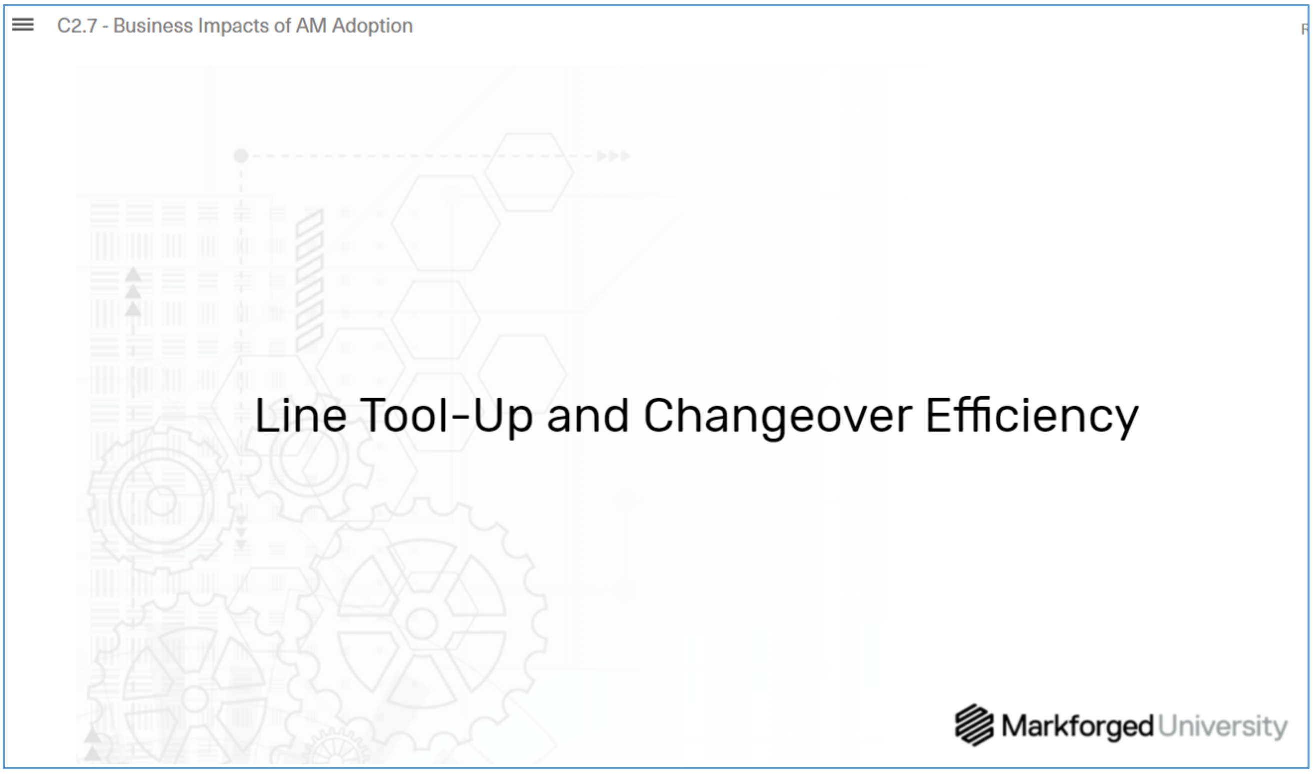


- **Before and After**
    - You can’t buy a CNC-machine to solve the problem

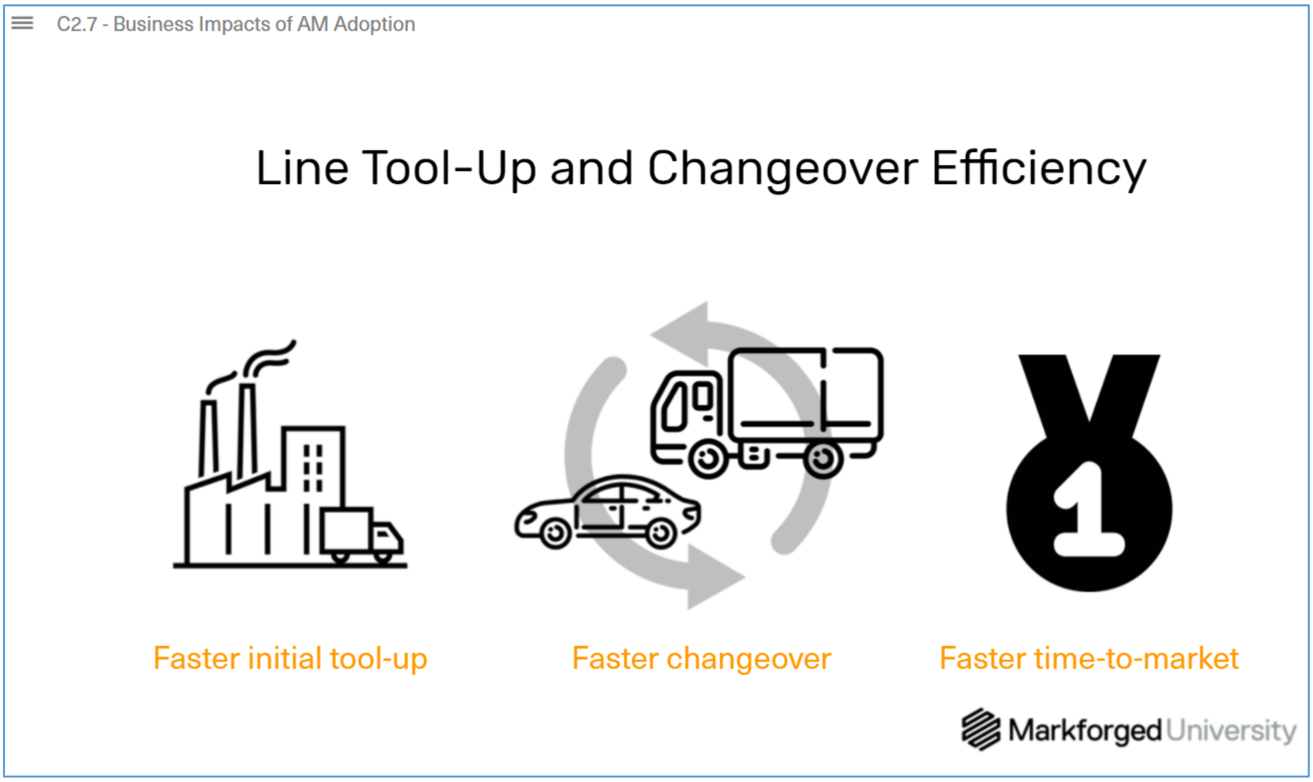


    - Production has the higher priority.
    - To add more CNC-machines is not an option (not only investment cost, also floorcapacity and laborcapacity.

- 3D printing of tooling creates more band width on CNC (by reducing demand on tooling needs). At the same time you have add significant production capacity.
    - 3D-printings works without supervision (produces through the night, without labor).
    - Achievement of highest value were each machine suited for.

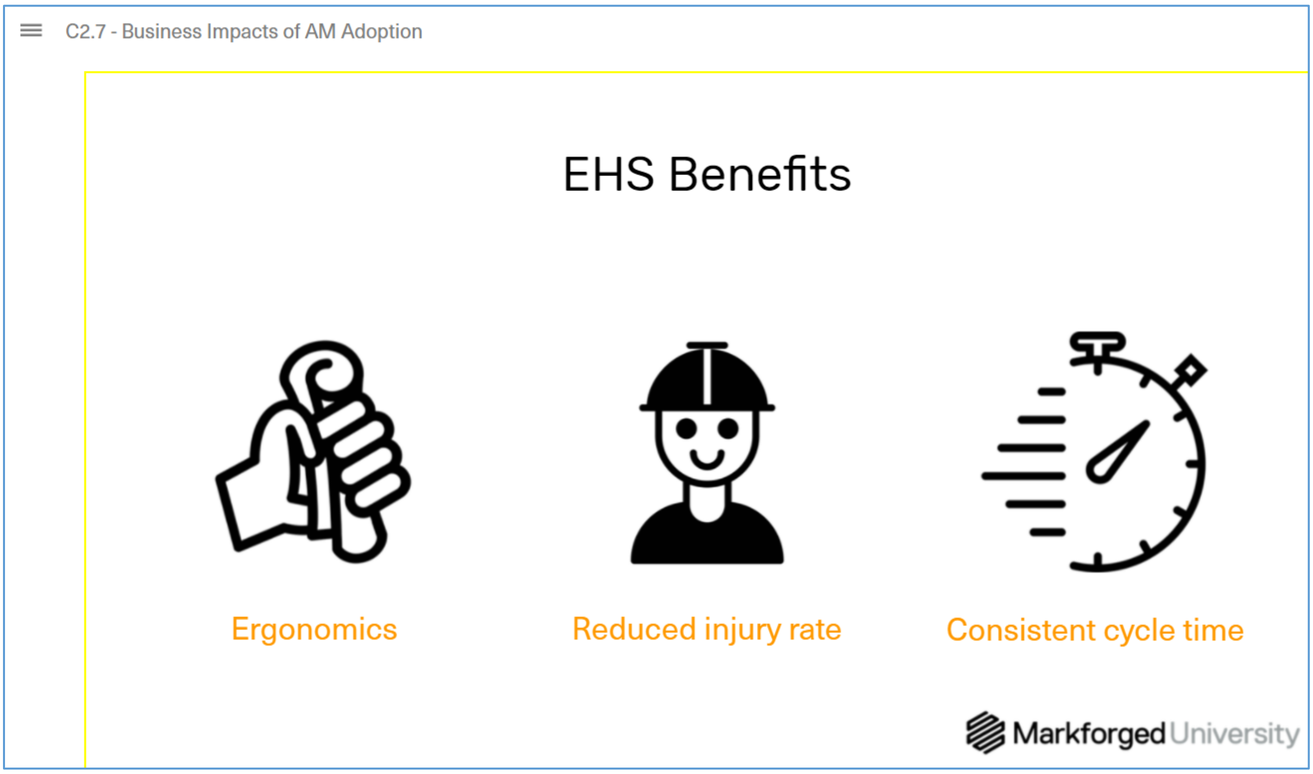


- **Line Tool-Up and Changeover Efficiency**



- **Line Tool-Up and Changeover Efficiency**

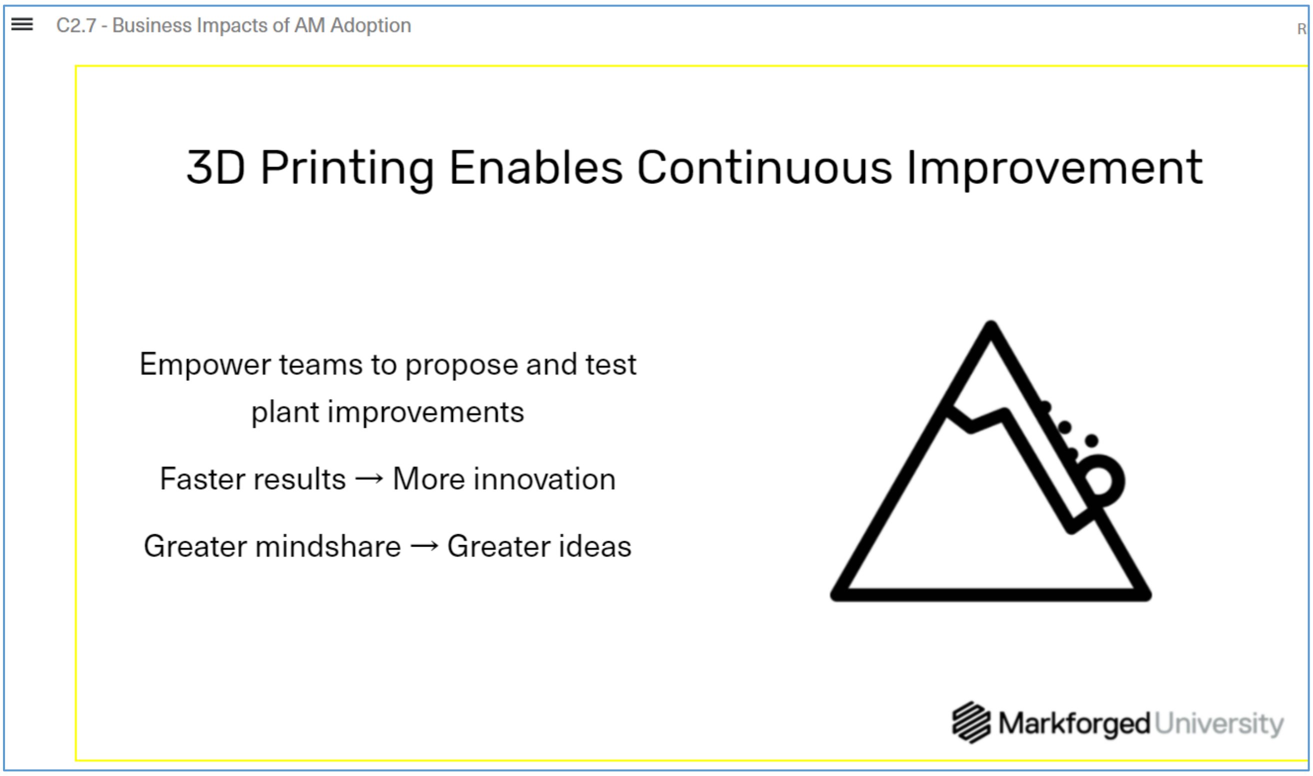
- **EHS Benefits**
    - Environment, Health & Safety



- **Better for Operators, Better for Business**
    - Example: Due to getting tired of the operator the cycle time will increase.

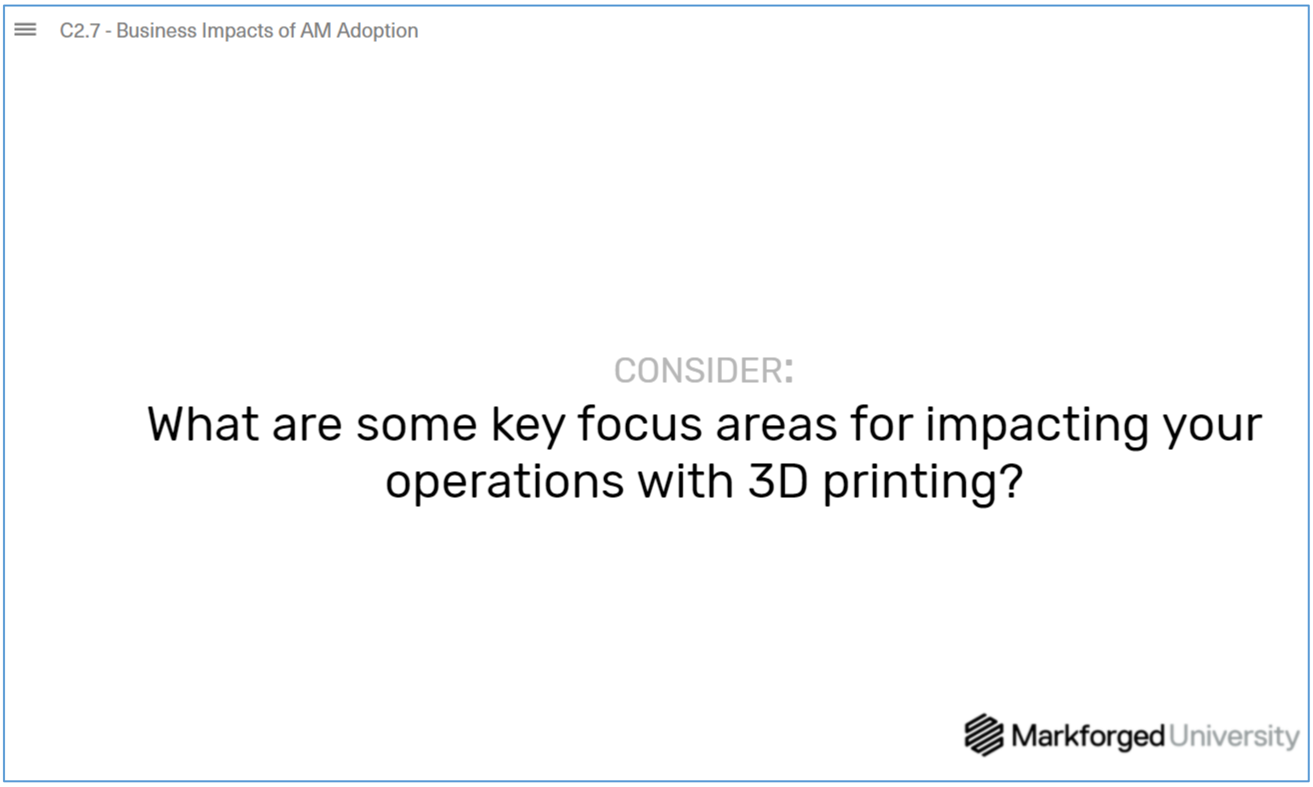
- Benefit for all!

- **Innovative Culture Shift**

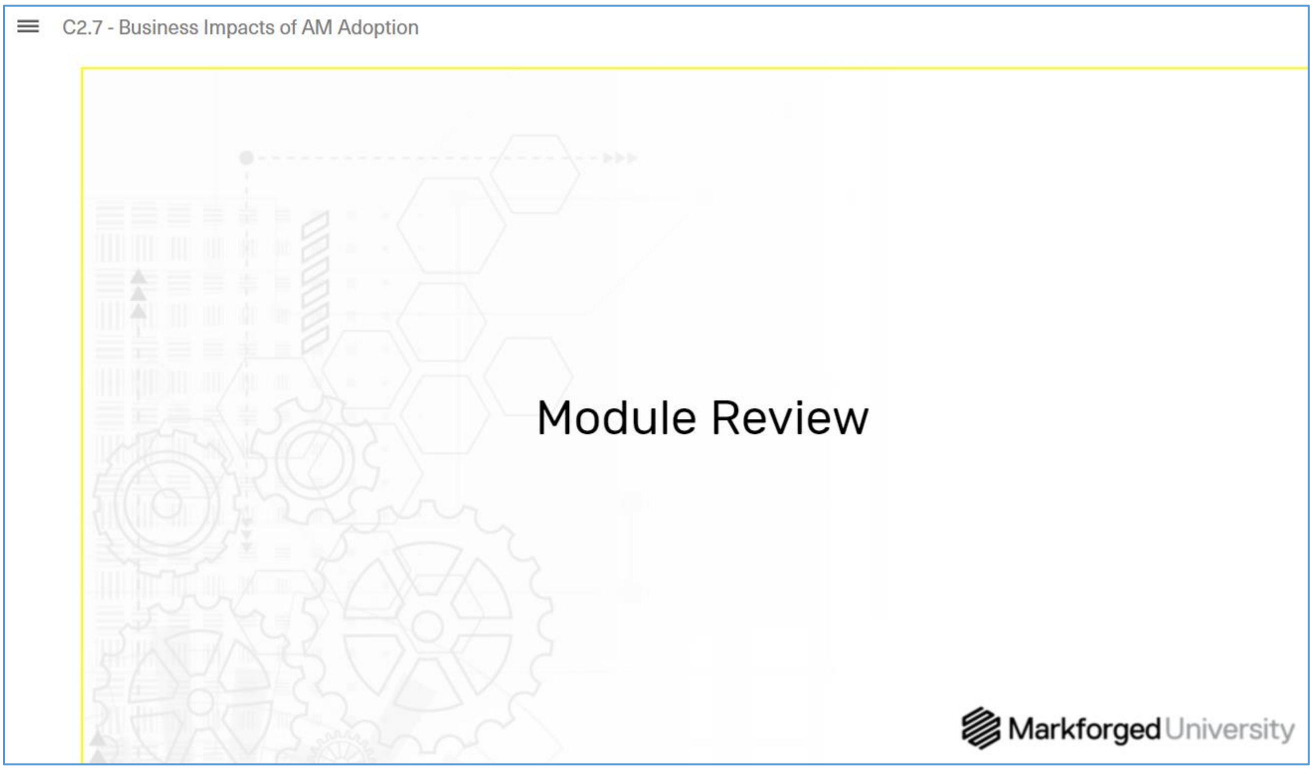


- **3D Printing Enables Continuous Improvement**

- **Recap: Organizational Impacts Dominate**



- **What Are Your Focus Areas?**
    - Wat zijn uw aandachtsgebieden?



- **Module Review**

Mark all the following which are examples of Organizational Impacts of AM adoption on a business.

- [x] Reducing the scrap rate in a process by 3% with a 3D printed alignment guide
- [x] Eliminating a recurring jam in a manufacturing line that caused downtime with a 3D printed guide rail
- [ ] Cutting the lead time of a machined part by 3 weeks by 3D printing it instead
- [ ] Saving $500 on every CMM fixture by 3D printing them instead of sending to a vendor

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C2.7 - Business Impacts of AM Adoption

A 3D printed tool which presents an operator with a set of the bolts they need in an assembly process, rather than requiring them to manually dig through a bin for them every time, is primarily an example of what kind of Organizational Impact?

- Vendor supply chain optimization
- Inventory holding cost reduction
- EHS improvements
- Reduced scrap rate

C2.7 - Business Impacts of AM Adoption

A fixture for holding a part in a gluing operation, that is performed at elevated temperature, was re-designed for 3D printing and with channels to allow conditioned airflow through to heat the part up faster beforehand and cool it down more quickly after adhesive application. What kind of organizational or operational impact describes the effect of these channels on the overall process.

- Reduced import duties
- Decreased cycle time
- Improved operator safety
- Inventory reduction via digital warehousing

C2.7 - Business Impacts of AM Adoption

Results

Your Score:	100% (30 points)
Passing Score:	80% (24 points)

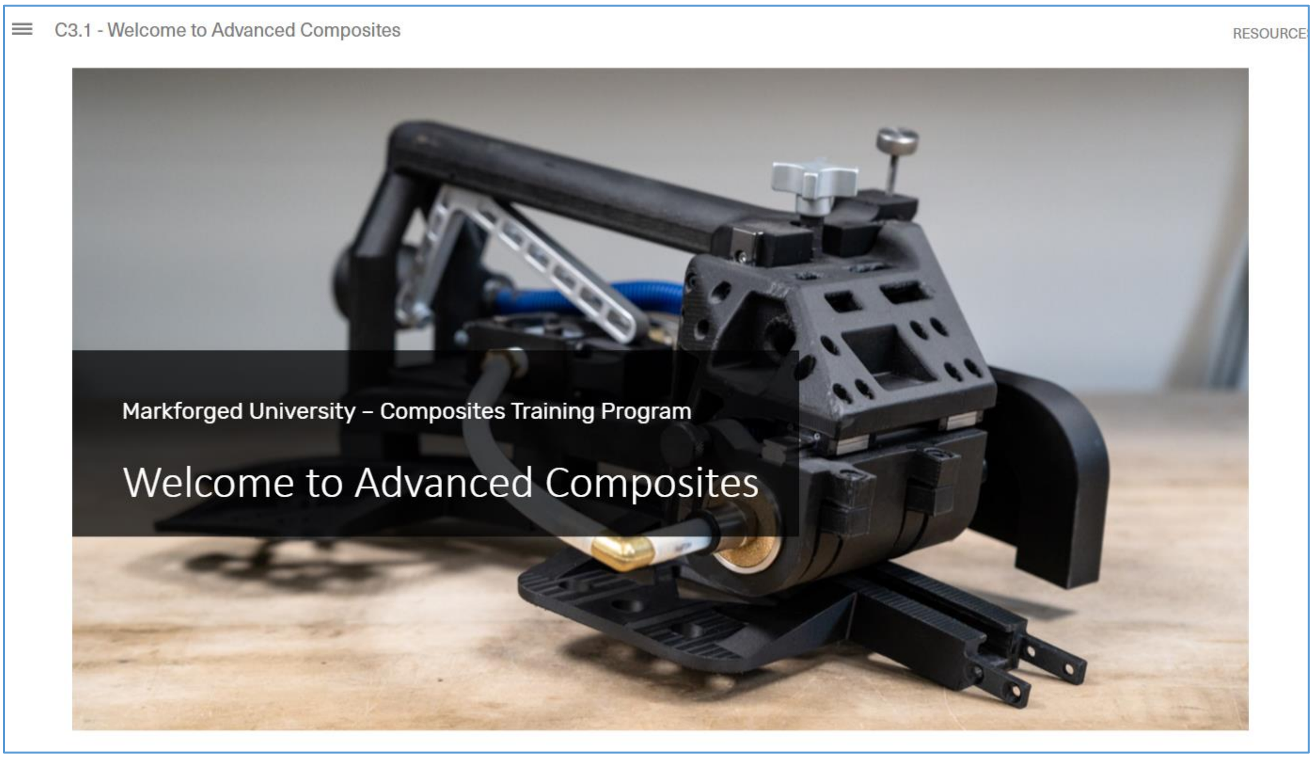
Result:

Congratulations, you passed.

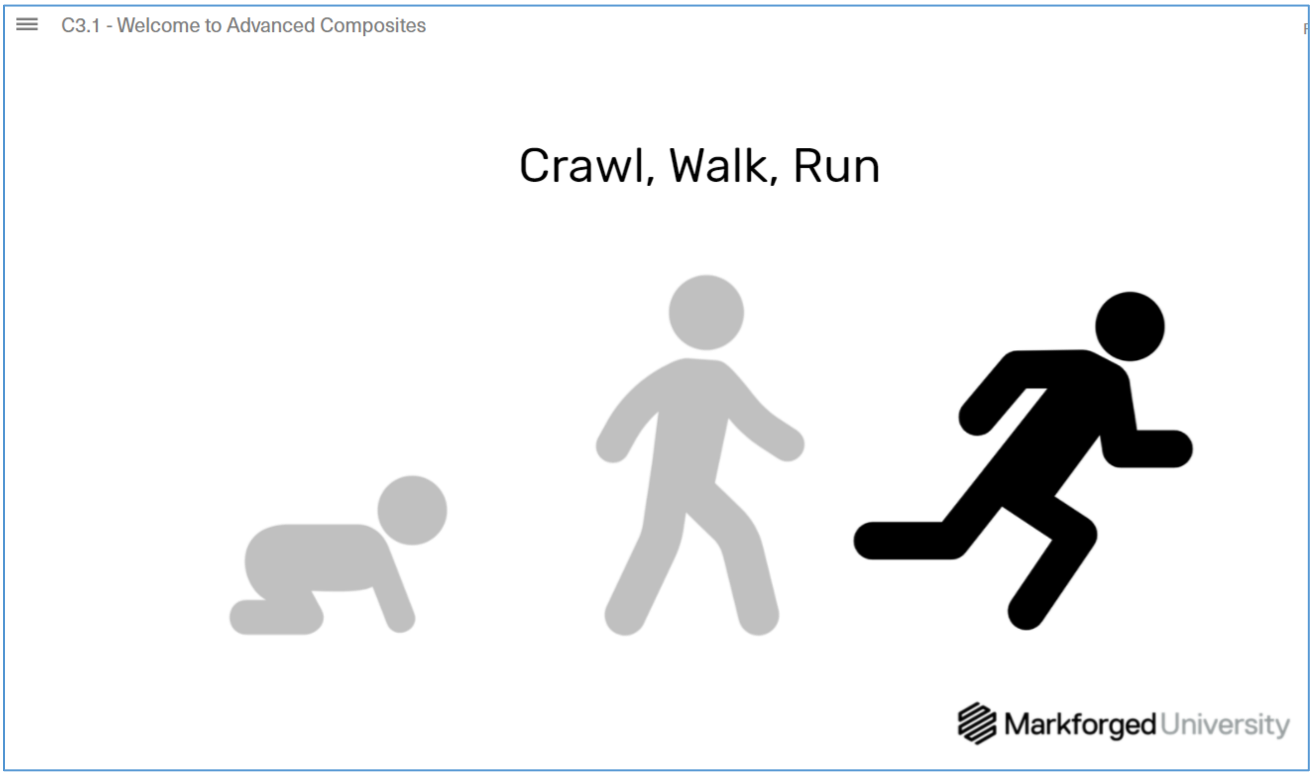
Finish Module

Review Quiz

Markforged University Advanced Composites

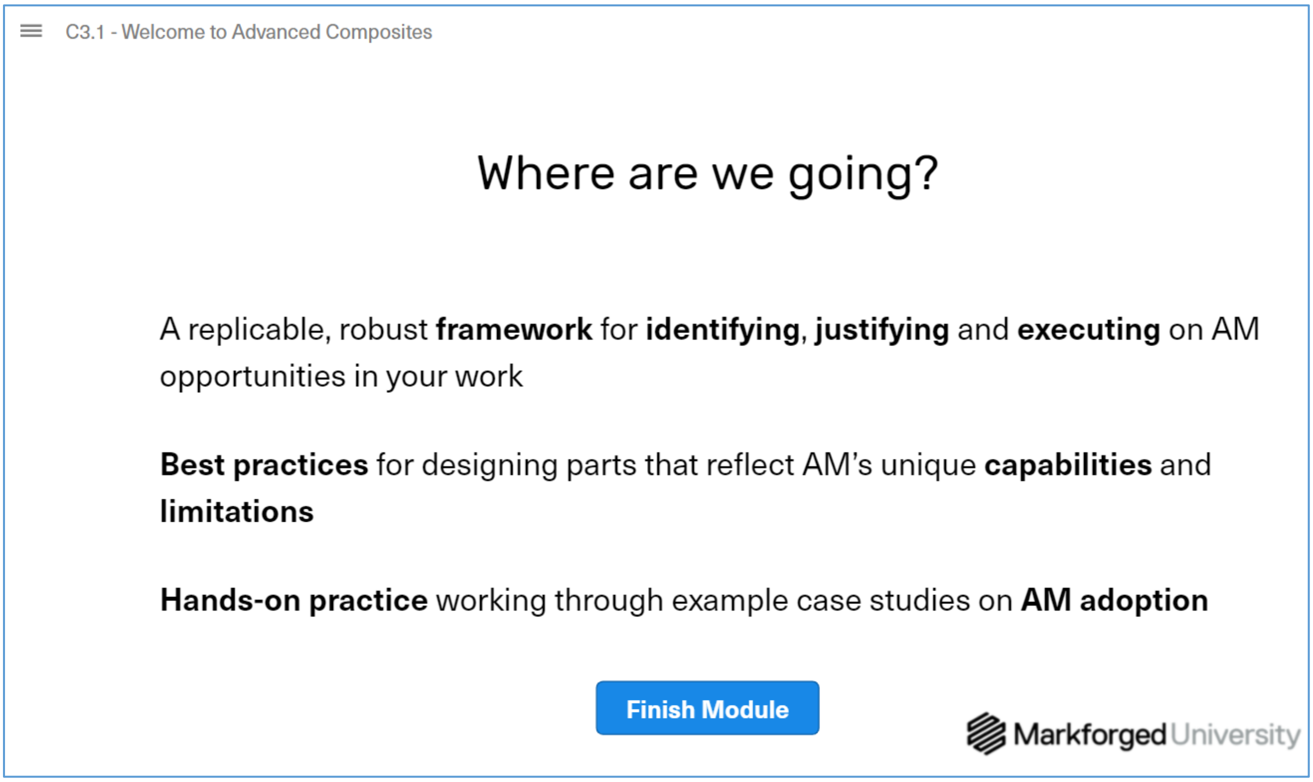


- **Welcome to Advanced Composites**



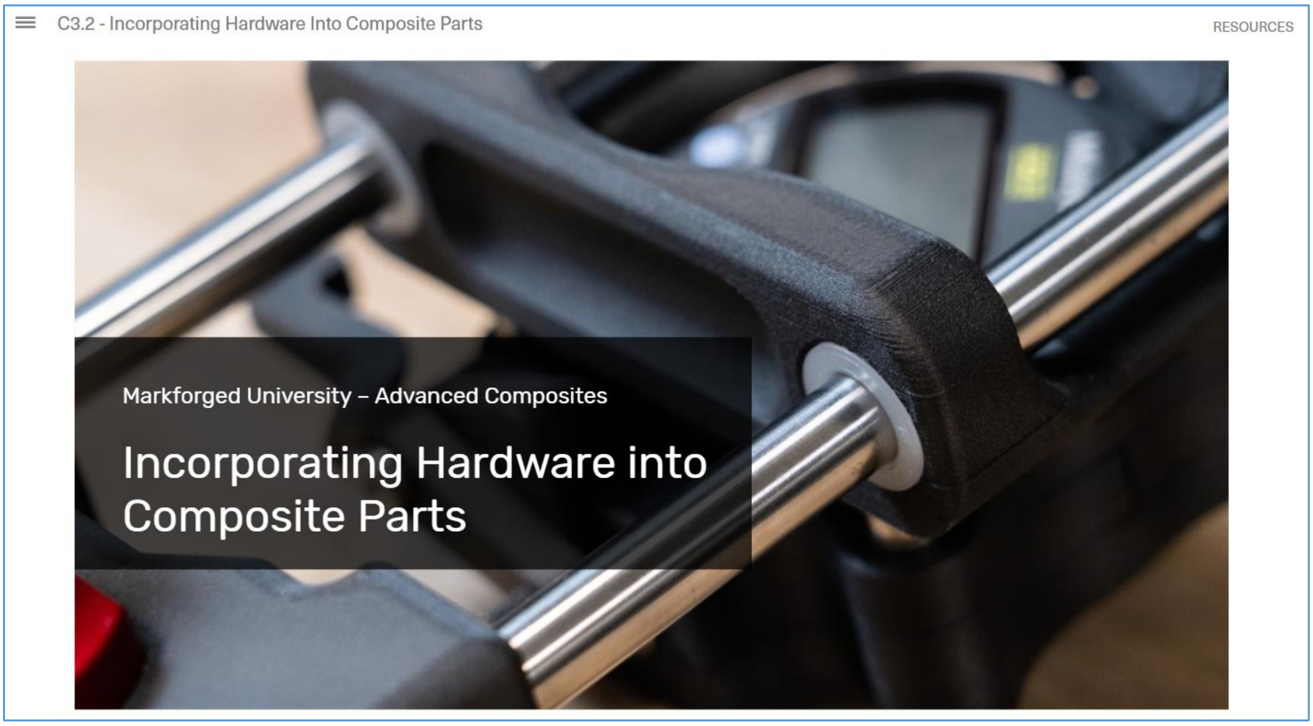
- **Welcome to Advanced C**

C3.1 – Welcome to Advanced Composites



- **Where are we going?**
  - **Replicable = repliceerbaar:** de mate waarin een andere onderzoeker dezelfde proefneming kan uitvoeren en dezelfde resultaten krijgt.
  - Best practice = Beste werkwijzen / optimale werkmethoden.

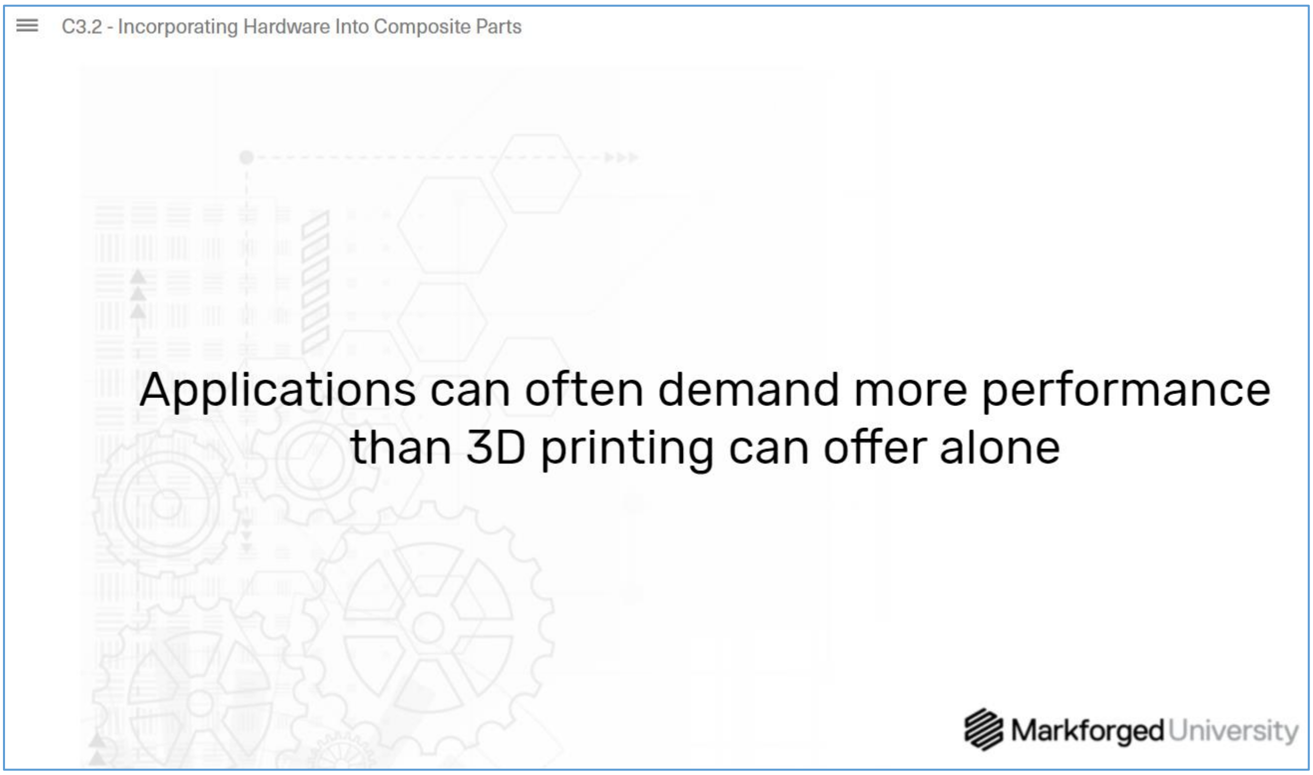
C3.2 – Incorporating Hardware Into Composite Parts



- **Incorporating Hardware into Composite Parts**
    -
    - Incorporating = opnemen
    - Off the shelf components = boutjes, moeren, kortom DIN-materiaal wat je op voorraad hebt liggen.

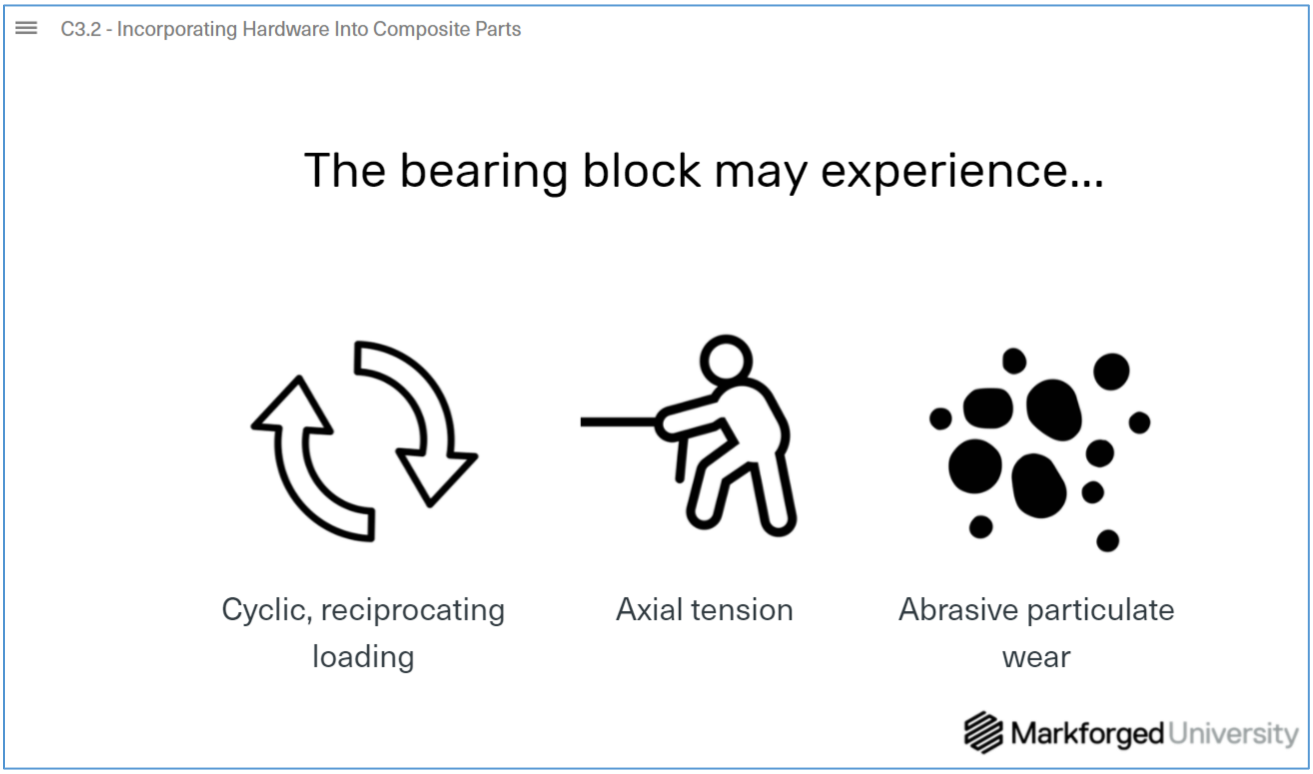
- **Module Overview**

- **Functional Requirements…Again!?!**

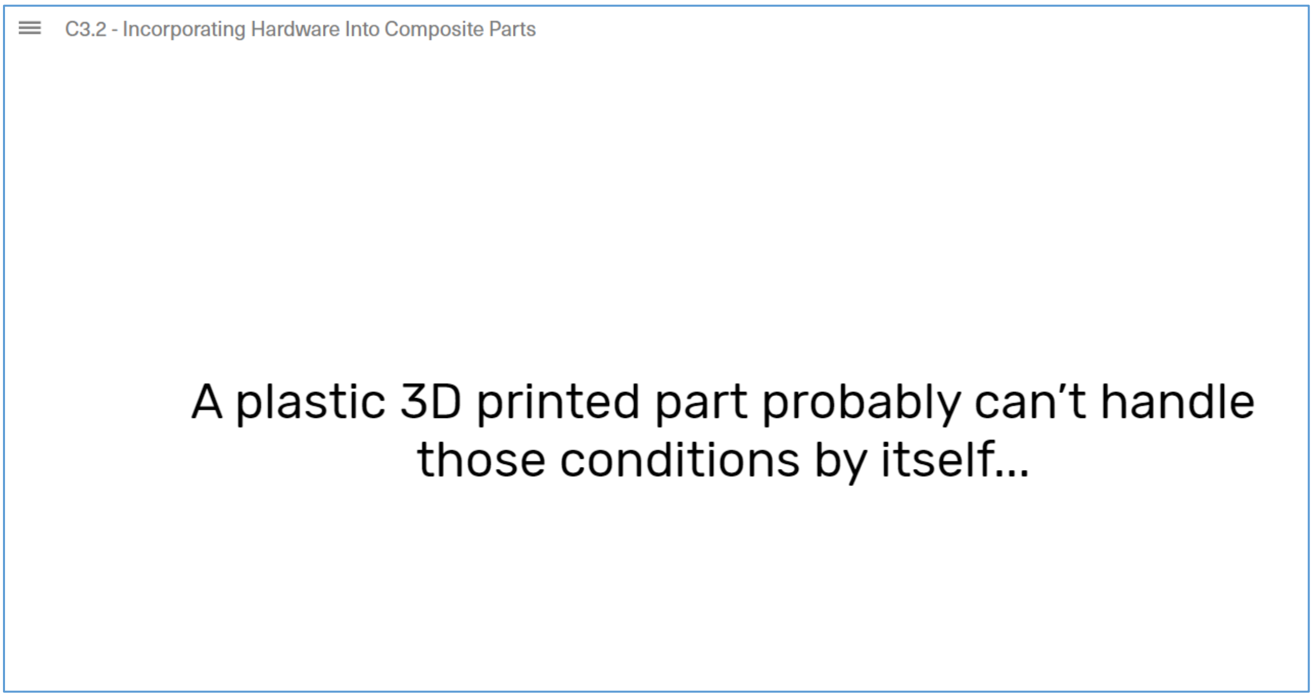


- **What are the functional requirements?**
    - Linear axis of a CNC-machine

- Bearing block of the ball screw.
- What kind of forces will take place?
- High level of replacing accuracy is needed.



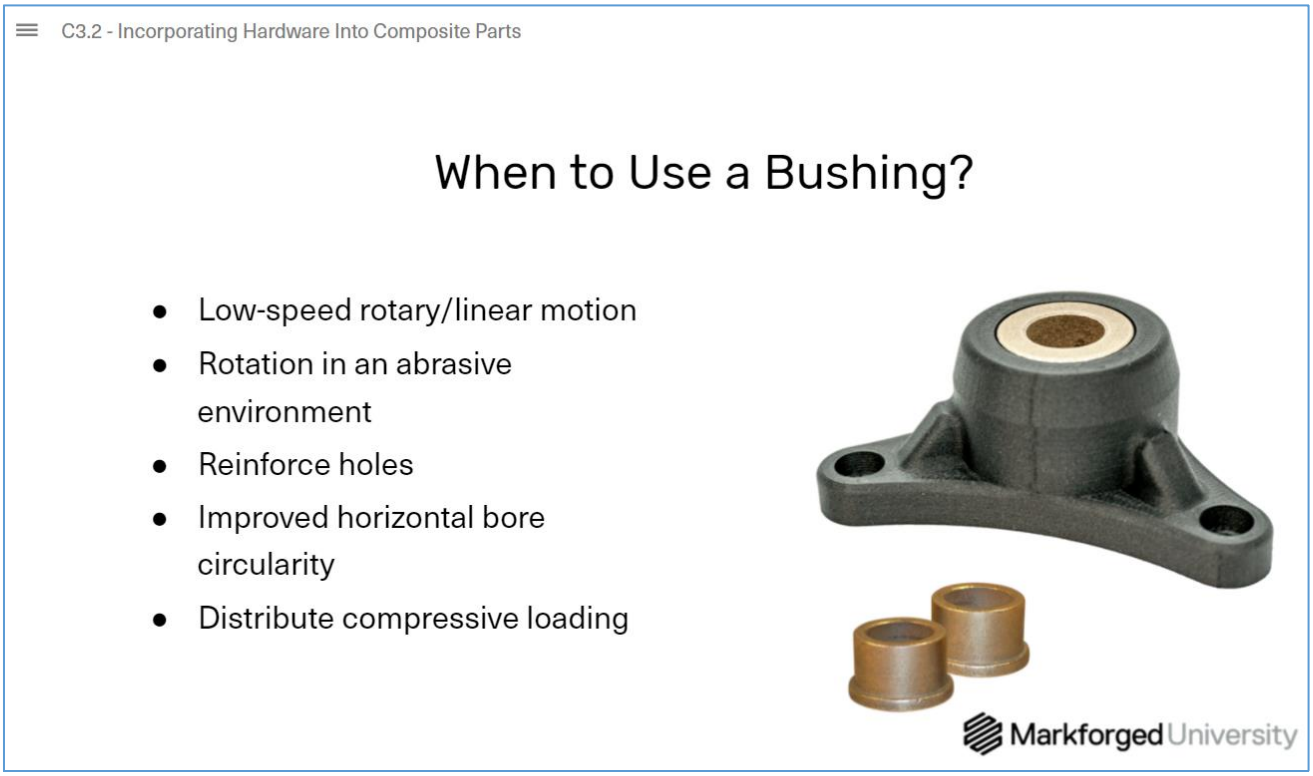
- **The bearing block may experience…**
  - Reciprocating = over en weer.
  - Abrasive = schurend.



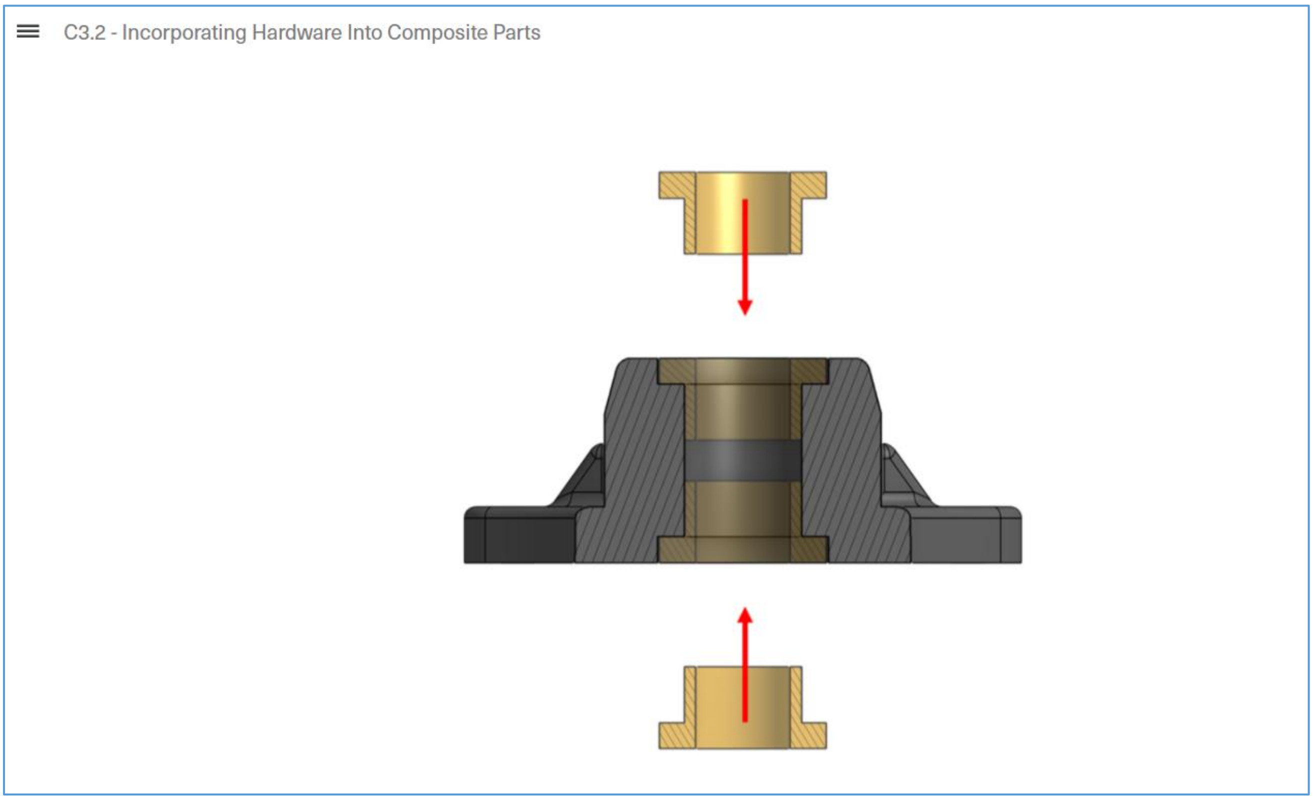
- **A plastic 3D printed part probably can’t handle those conditions by itself…**

- **Reinforce Holes with Bushings**

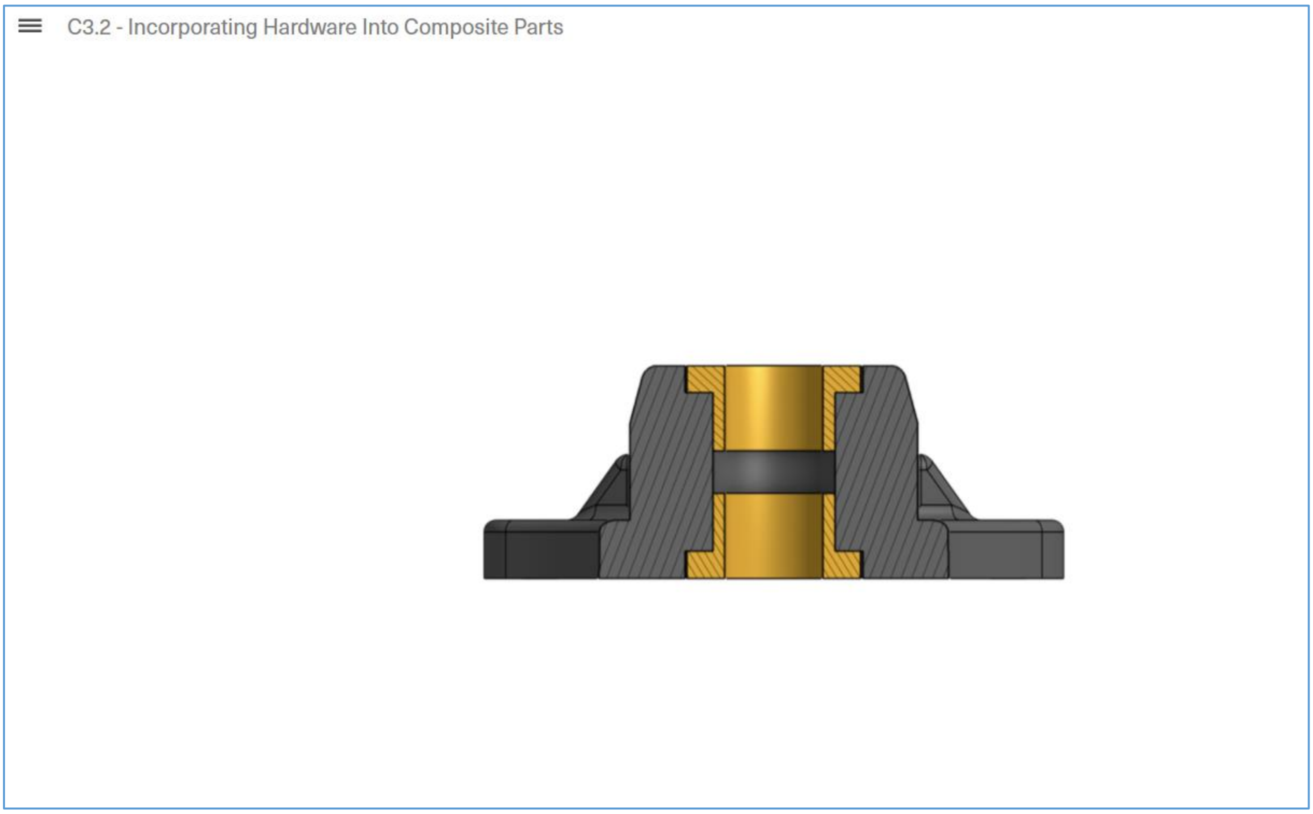
- **Sleeve Bearings/Bushings**
  - Wear resistant.
  - Low friction.
  - Self lubricating pressed in flanged fluid (oil) bearings

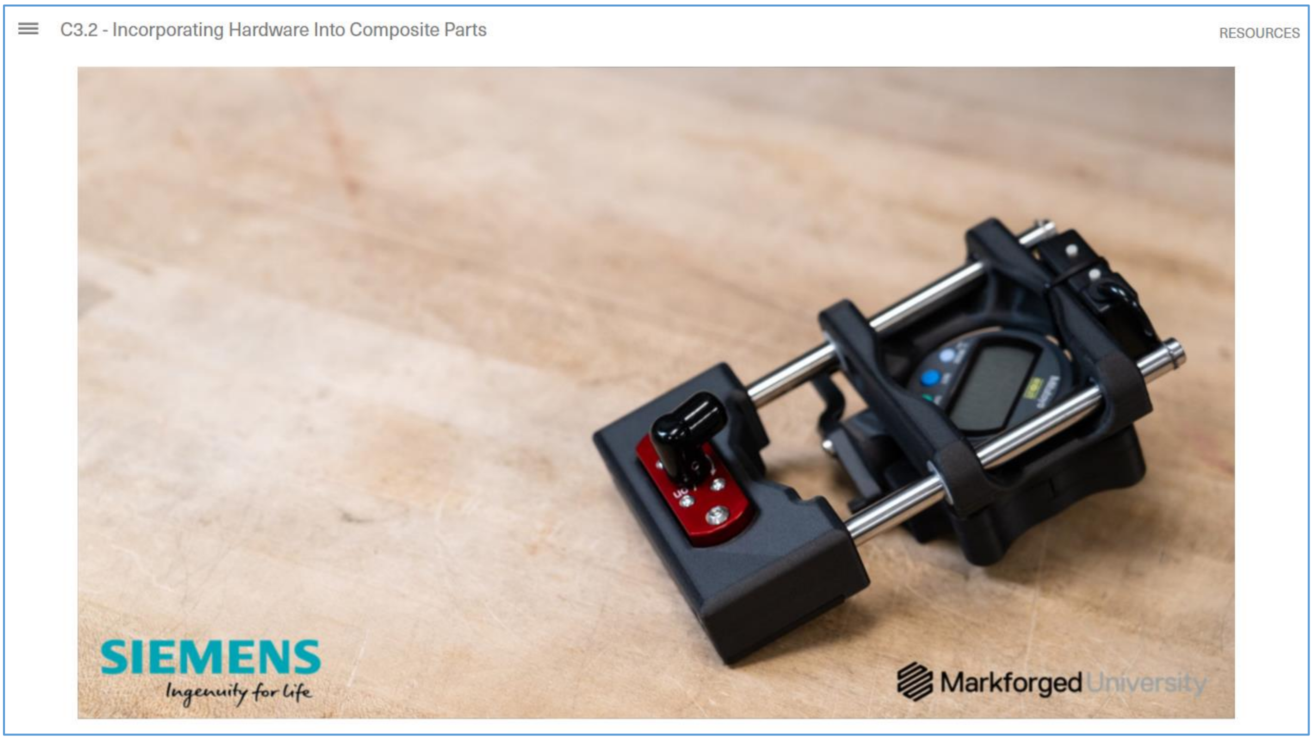


- **When to Use a Bushing?**
    - Distibute compressive loading = verdelen van de last.



- **A Bushing, Assembled**
    - Undersized press fit.

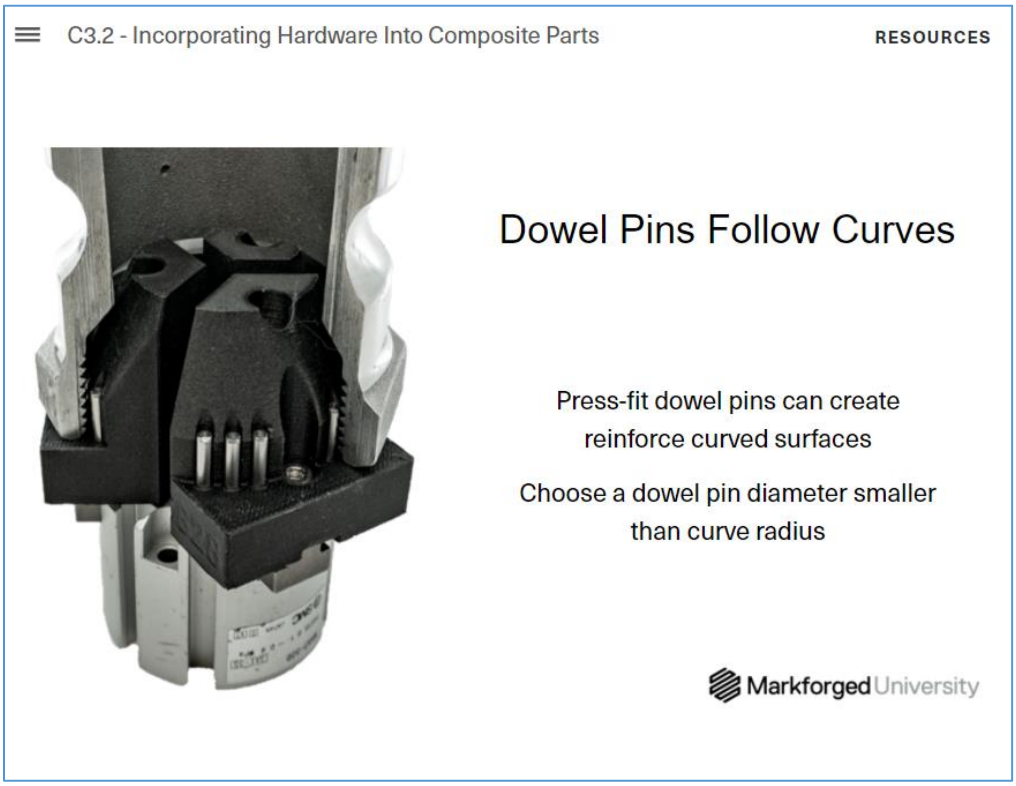




- **Example: Siemens Innovation Center**

- Press fit and low friction bushings.
- Take notice of the print orientation: Don't have to worry about the circularity

- **Abrasion Resistant Surfaces with Inserts**



- **Dowel Pins Follow Curves**
    - Dowel Pins < 10mm = Undersized hole sizes -0.1mm, or so.
    - Dowel Pins > 10mm = Undersized hole size by -1%.

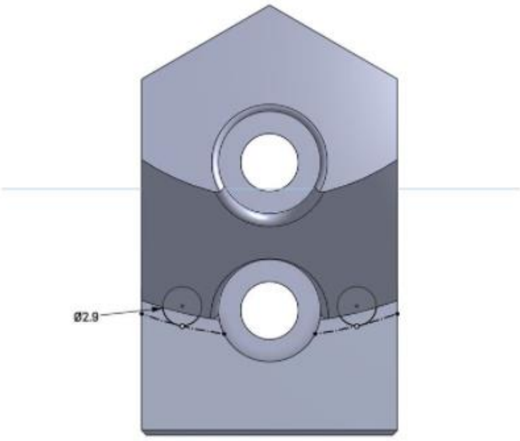
- **How to Design Dowel Pins In**

- Gripper jaws as an example

- Region to reinforce

- Cut the geometry

How to Design Dowel Pins In



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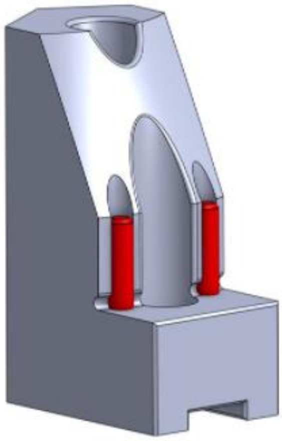
C3.2 - Incorporating Hardware Into Composite Parts RESOURCES

How to Design Dowel Pins In



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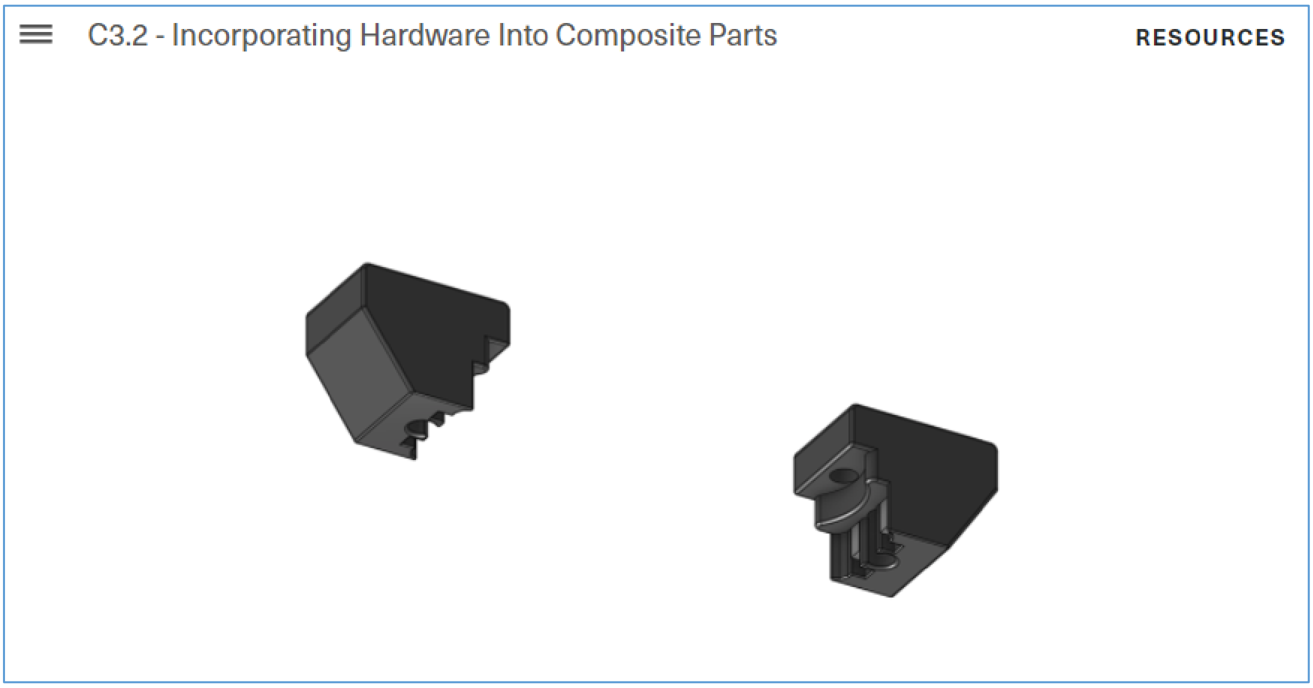
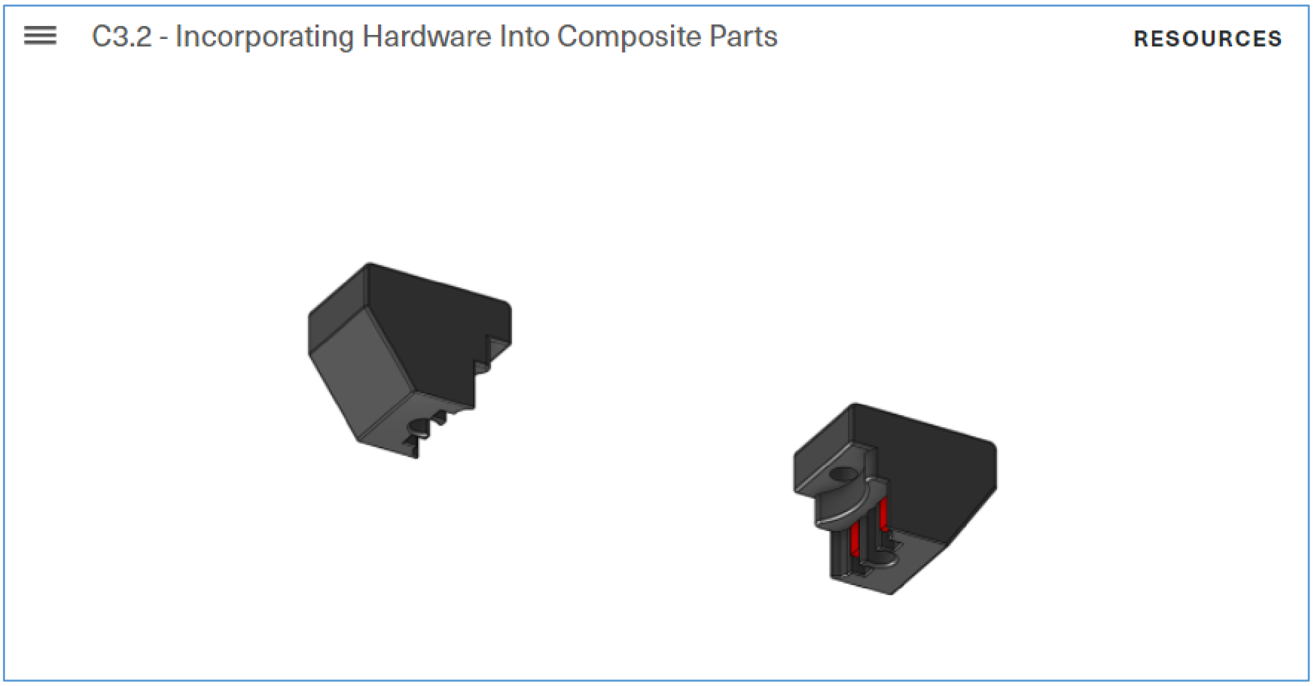
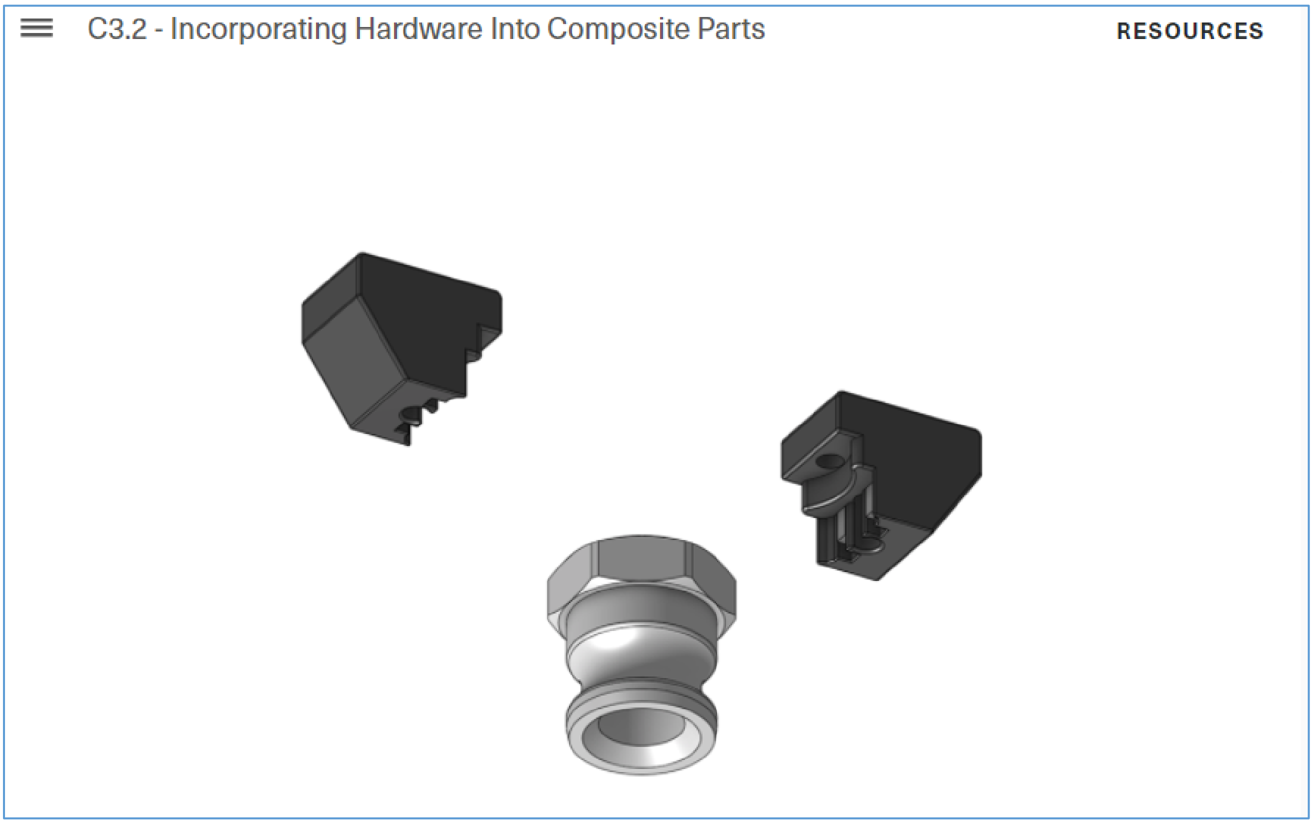
- **Machine Keys Create Flat Wear Pads**

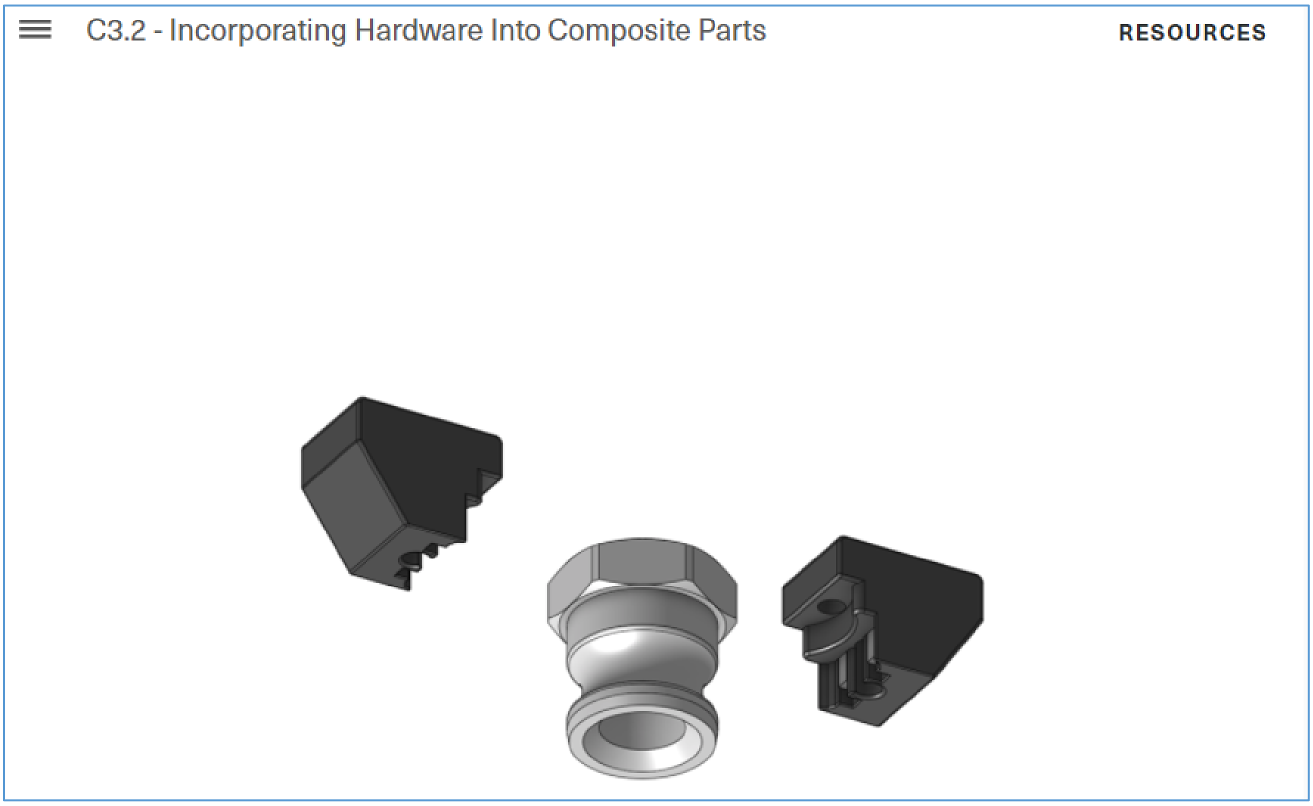
- **Easy Flat Contact Surfaces**

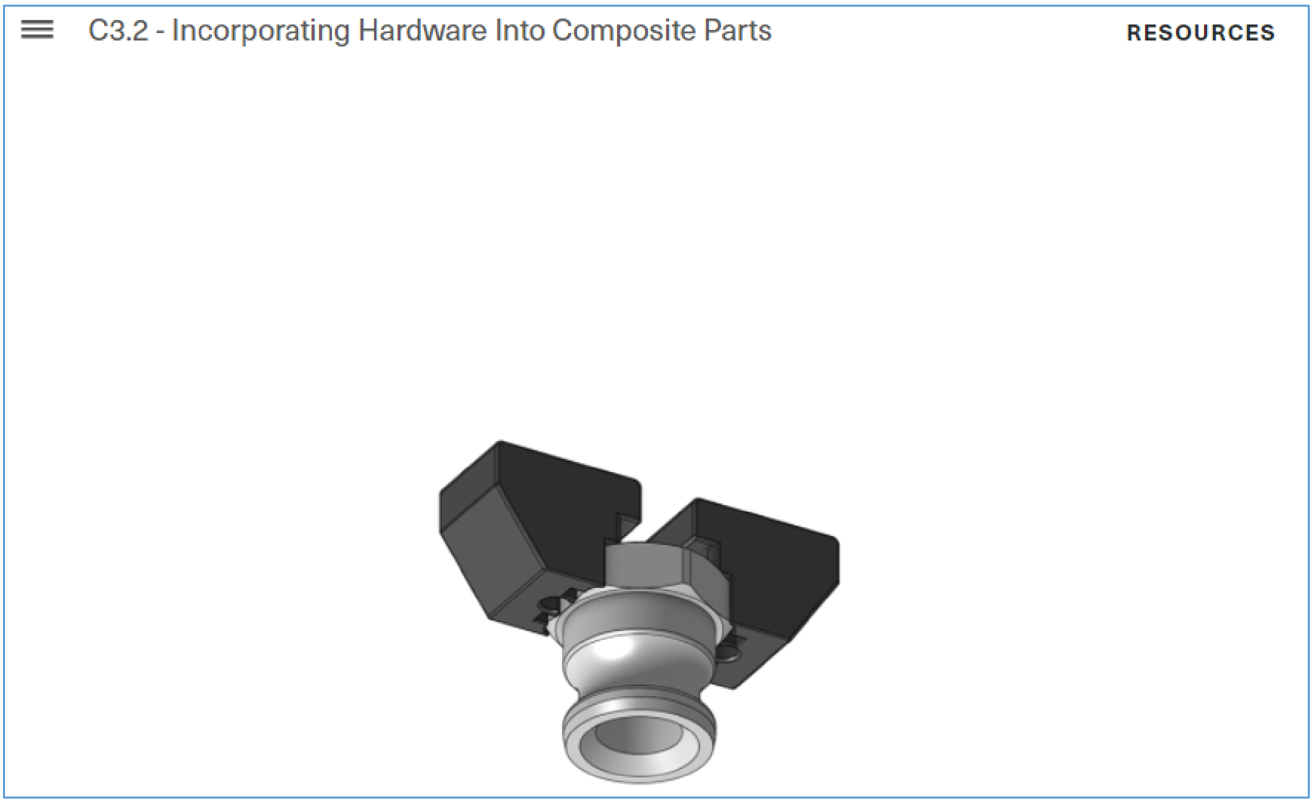


- **Reinforced Jaw in Action**

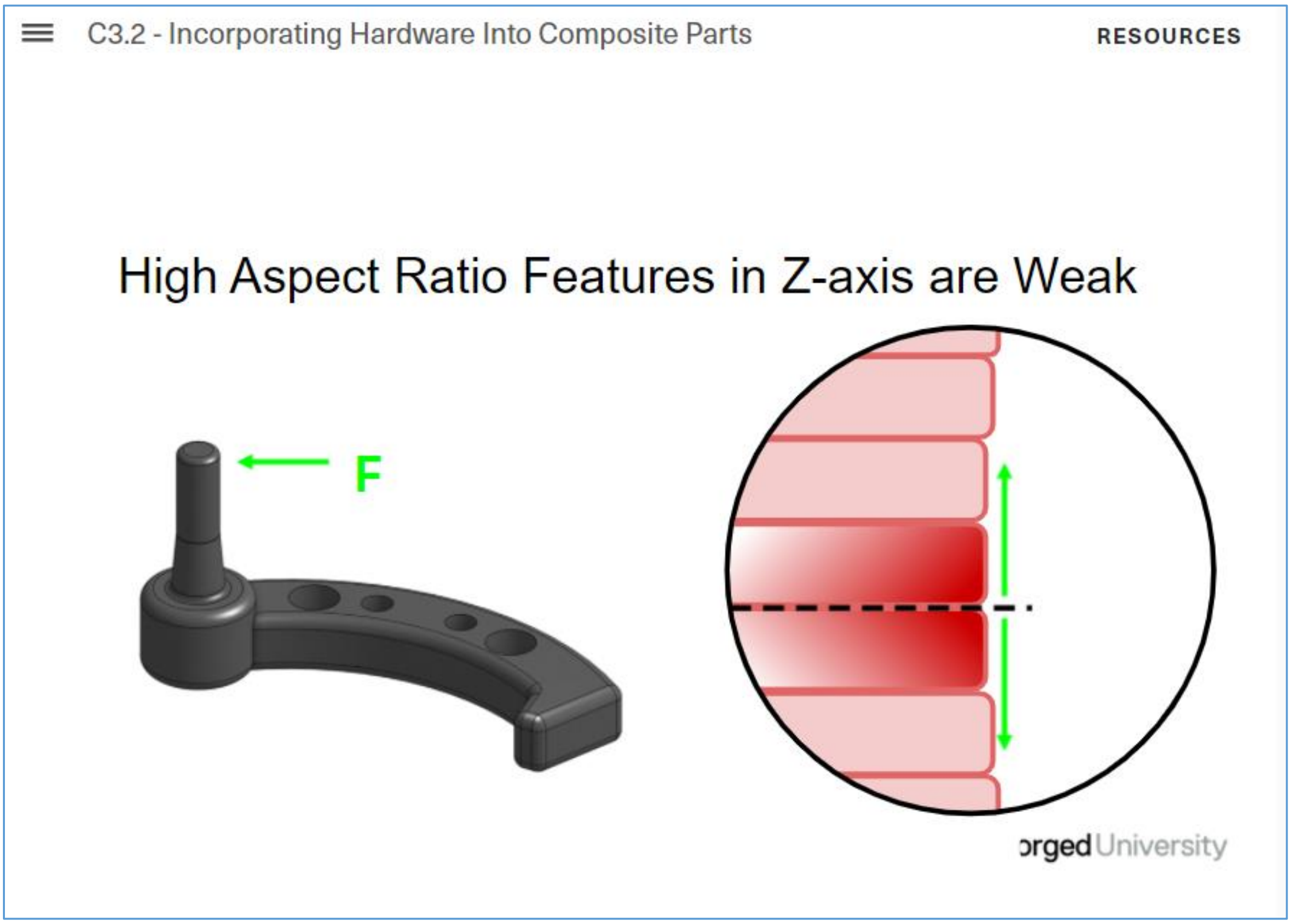



C3.2 - Incorporating Hardware Into Composite Parts
RESOURCES


C3.2 - Incorporating Hardware Into Composite Parts
RESOURCES



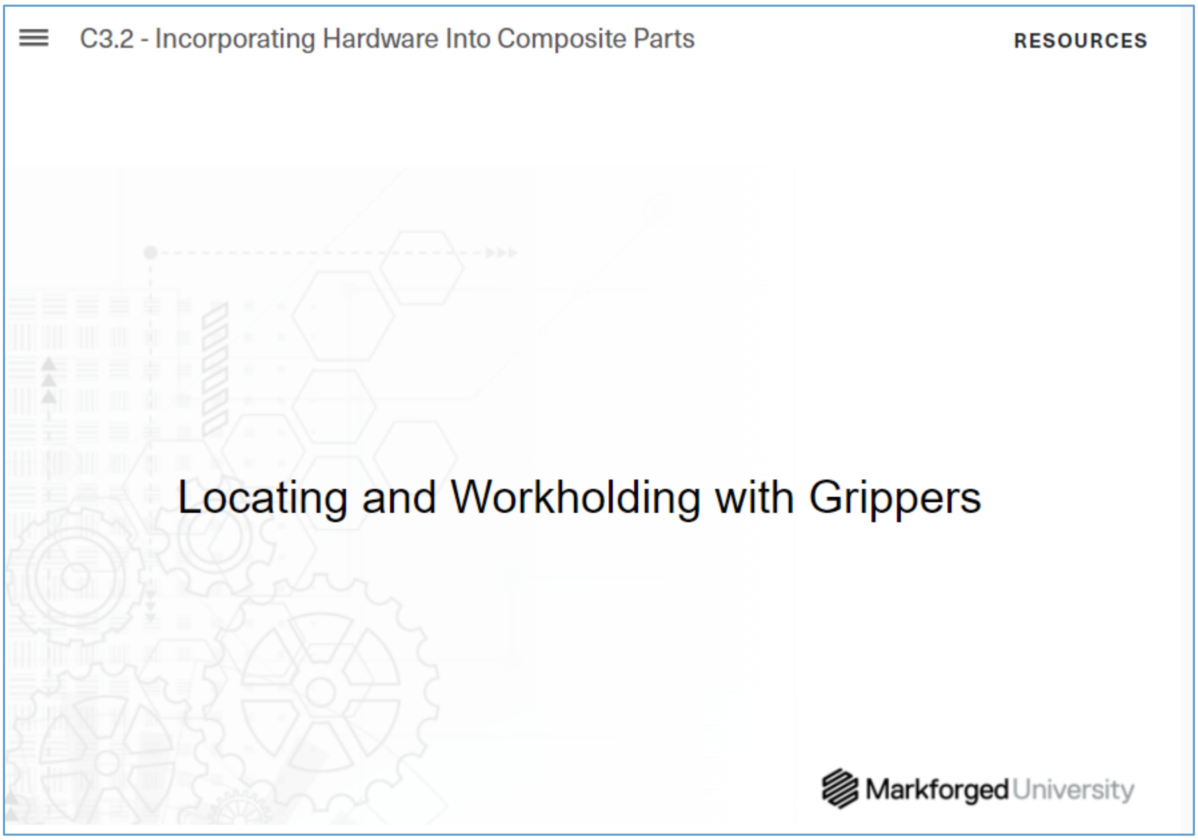
- **Reinforcing Z-axis Pillars**



- **High Aspect Ratio Features in Z-axis are Weak**

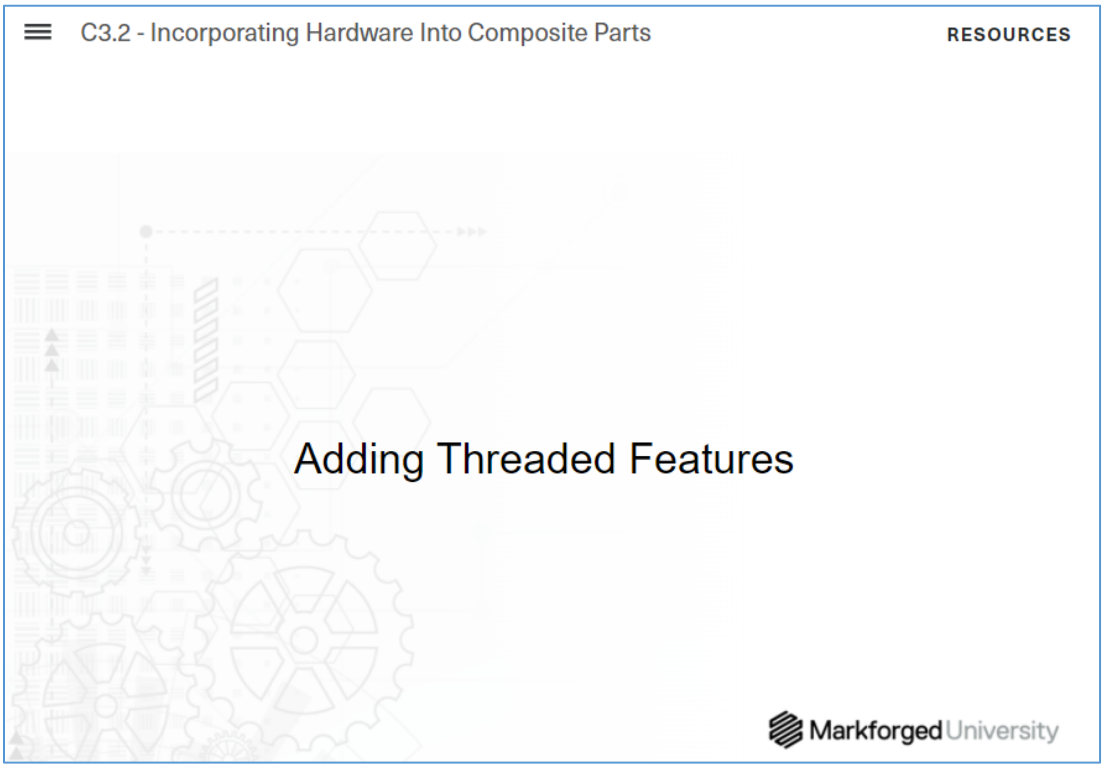
- **Example: Z-axis Reinforcement**
  - With a dowel pin.

  - Cross section.
  - Resisting bending and shear load (afschuifbelasting).

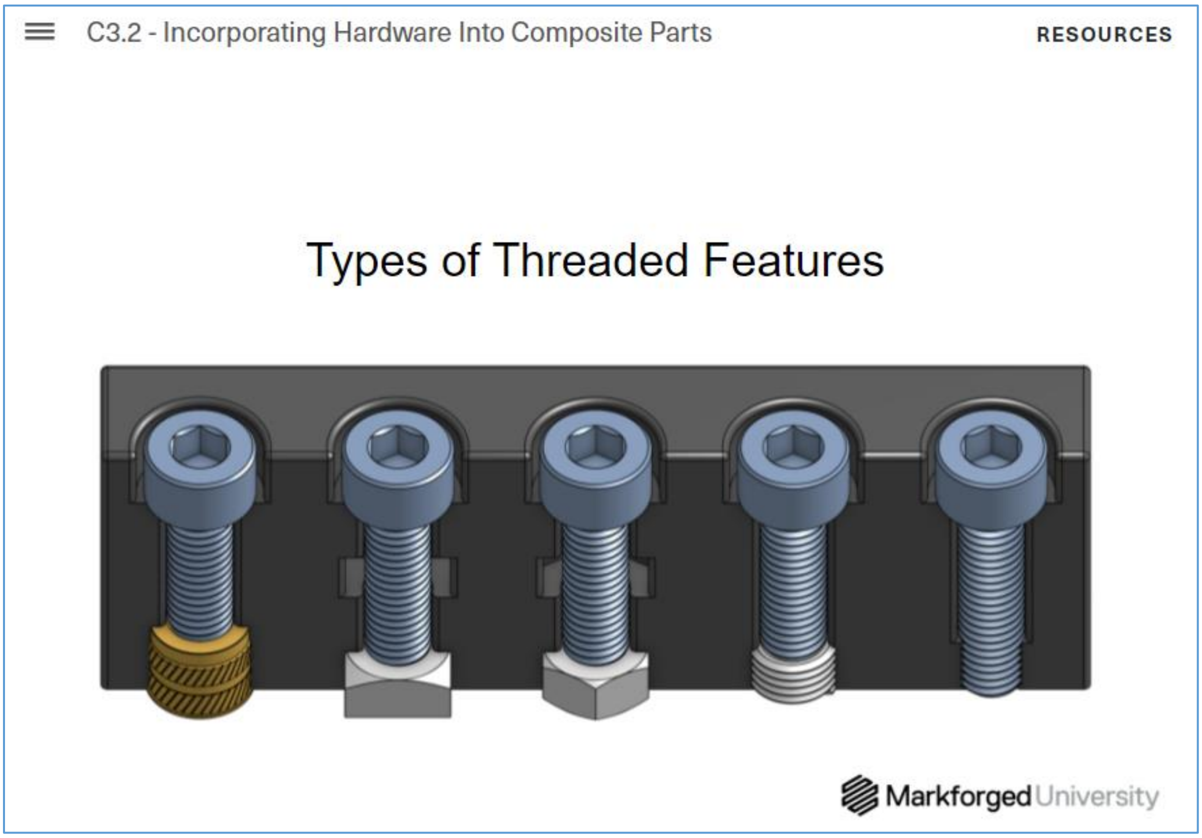


- **Locating and Workholding with Grippers**

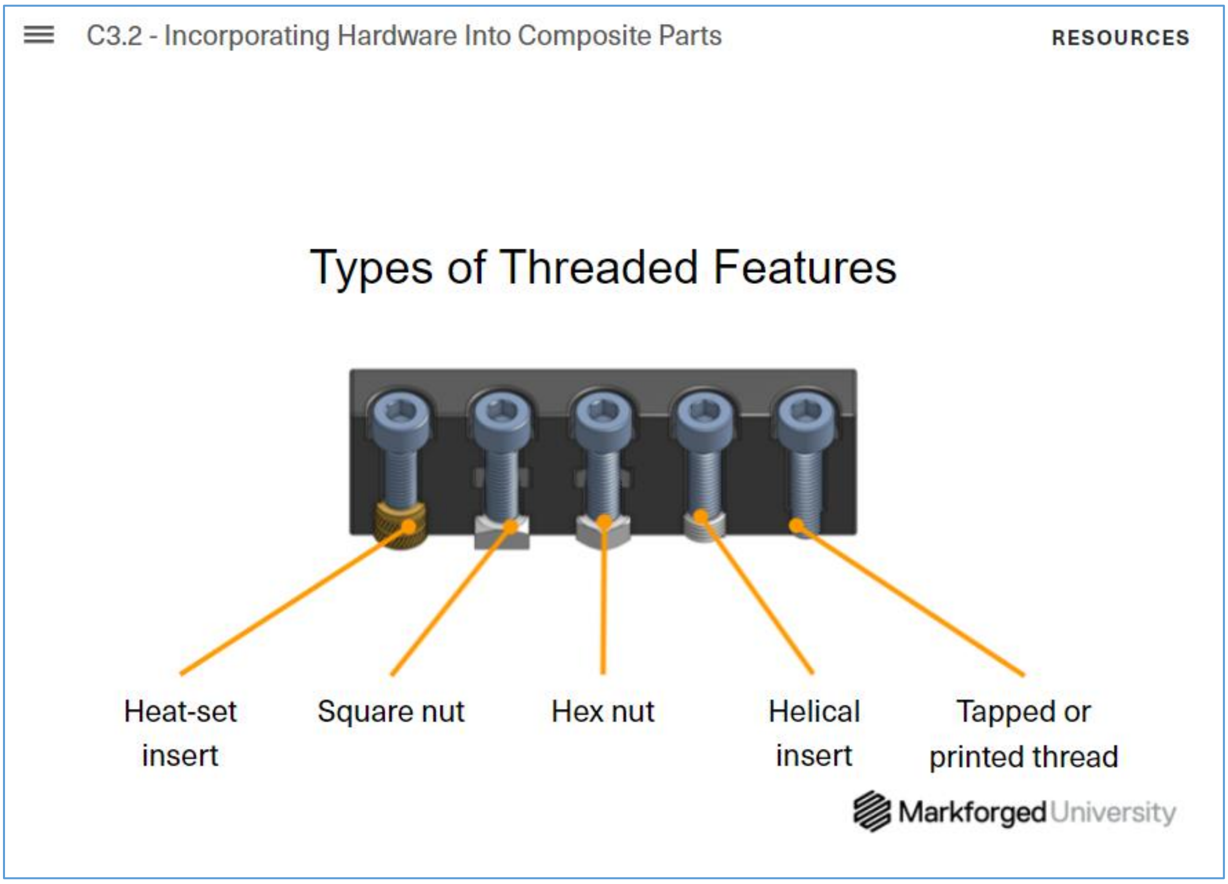
- **Fixture Grippers Bite Into A Workpiece**



- **Adding Threaded Features**



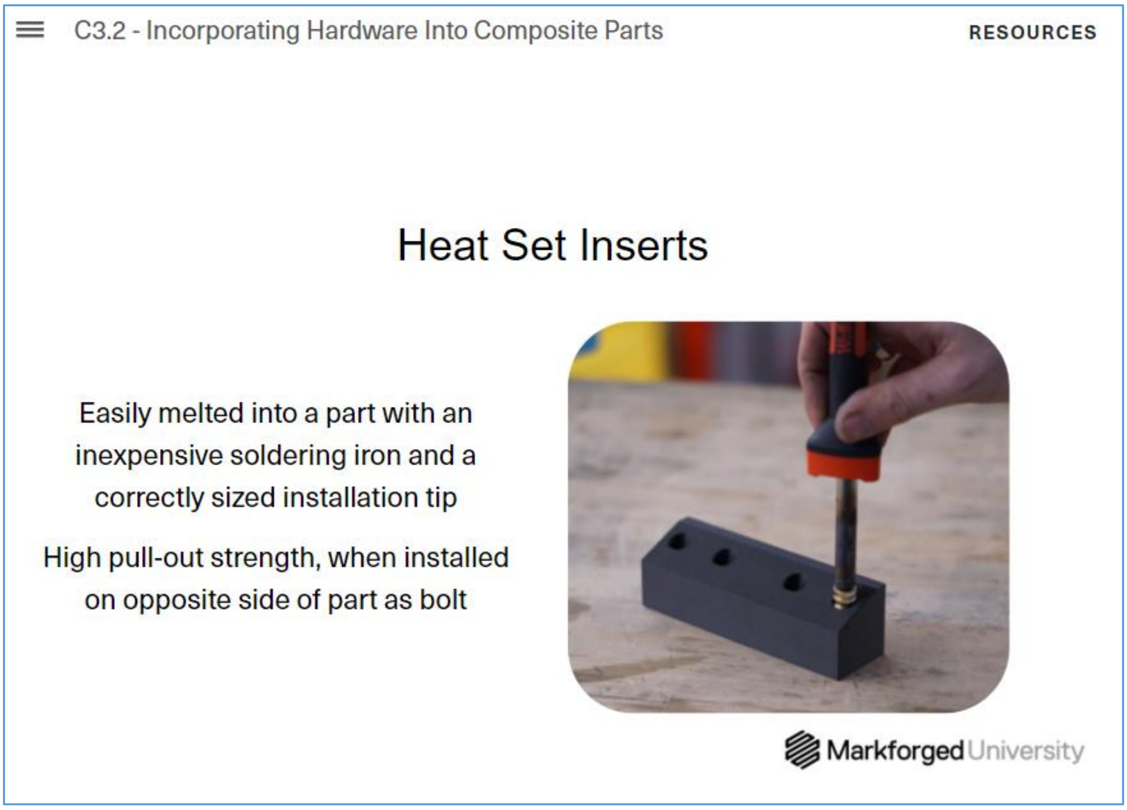
- **Threaded Features**

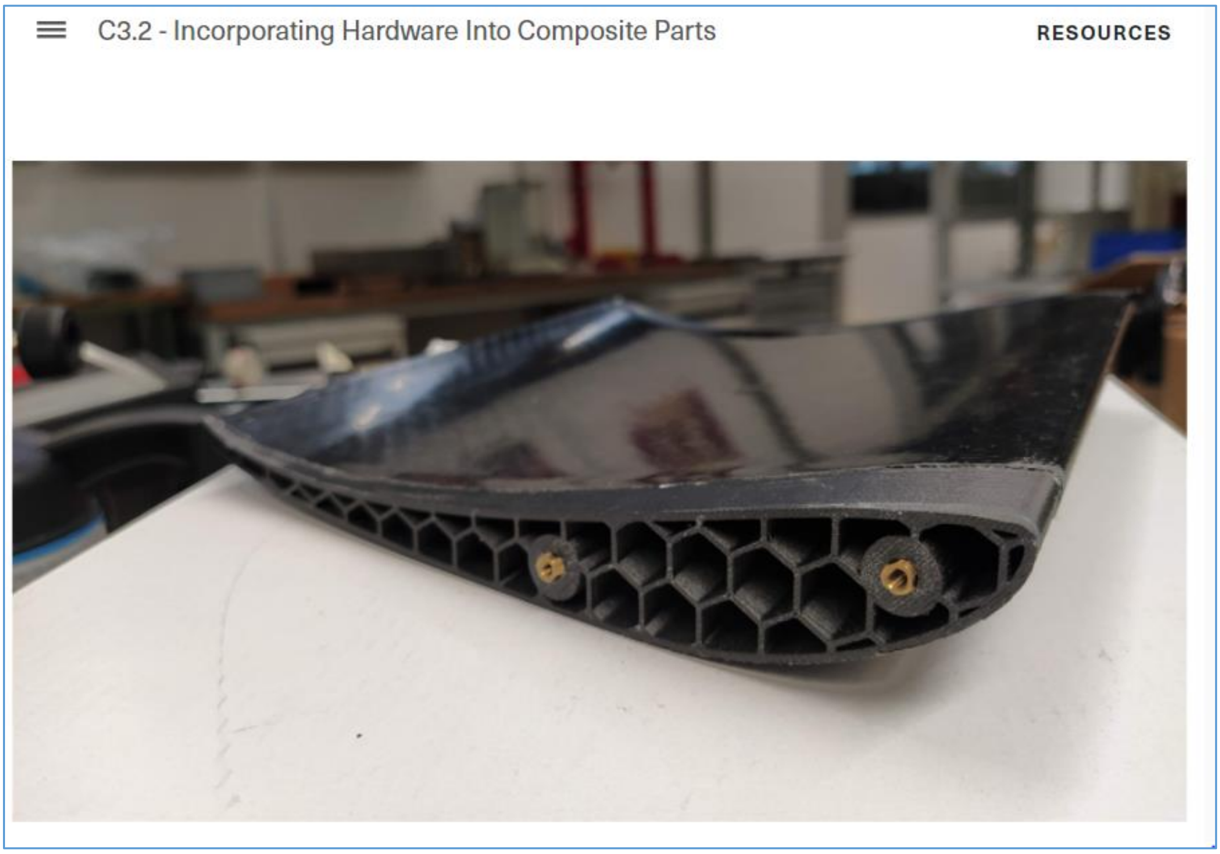


- Several types.

- **Threaded Features**
    - Right is de weakest solution.

- **Heat Set Inserts**

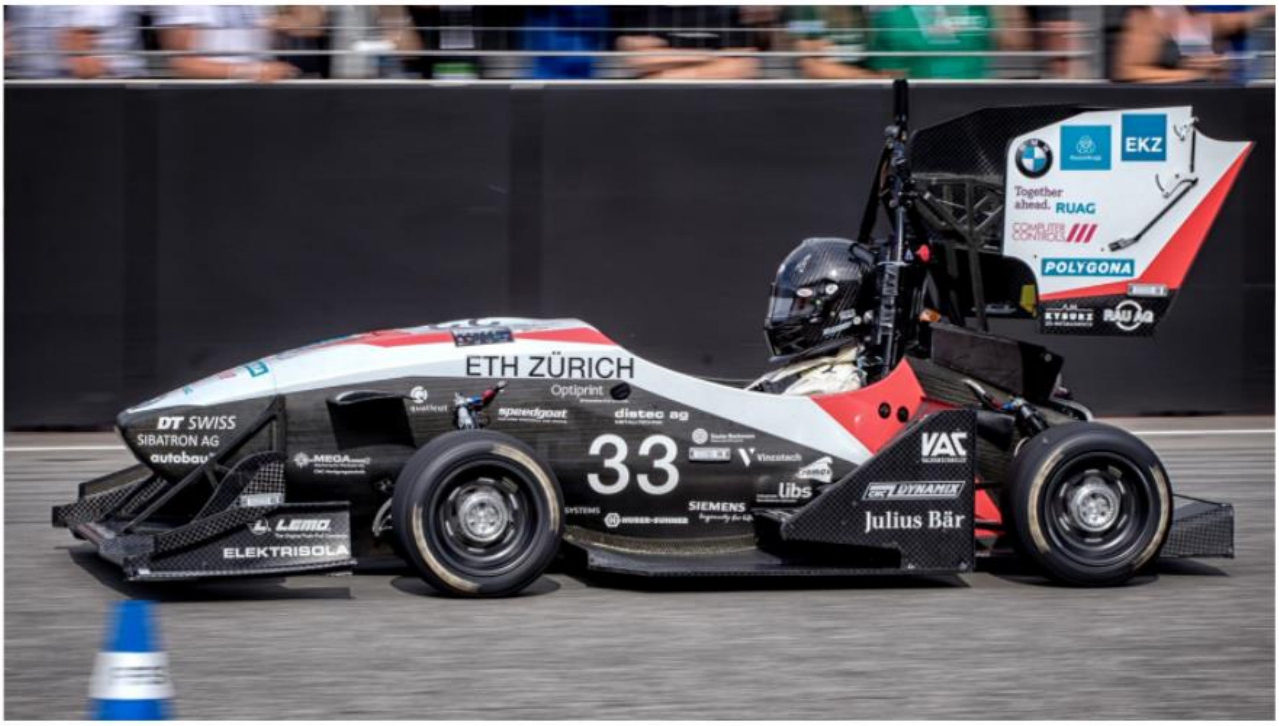


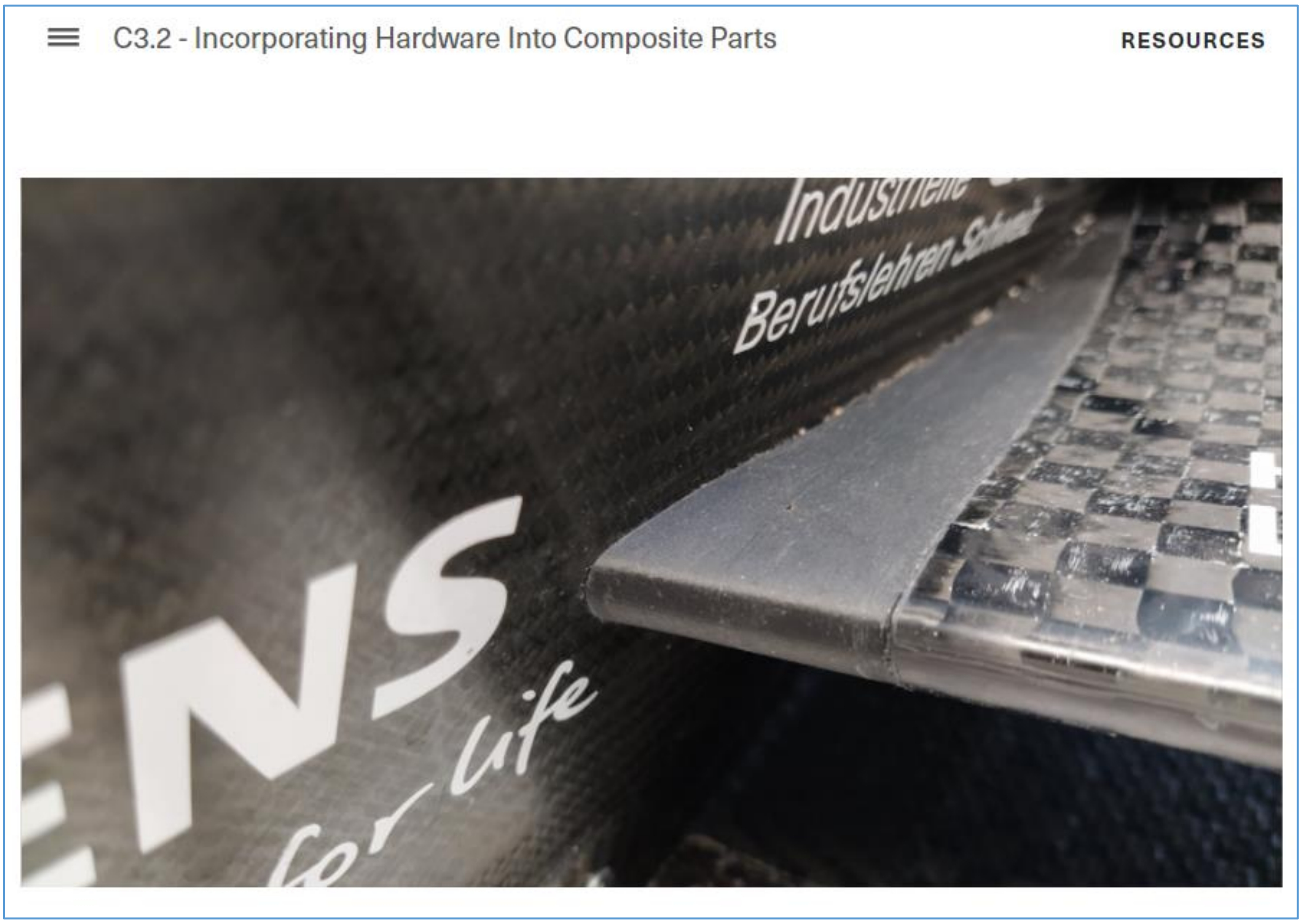


- **Example: AMC Racing Sidepod Wing**

C3.2 - Incorporating Hardware Into Composite Parts

RESOURCES

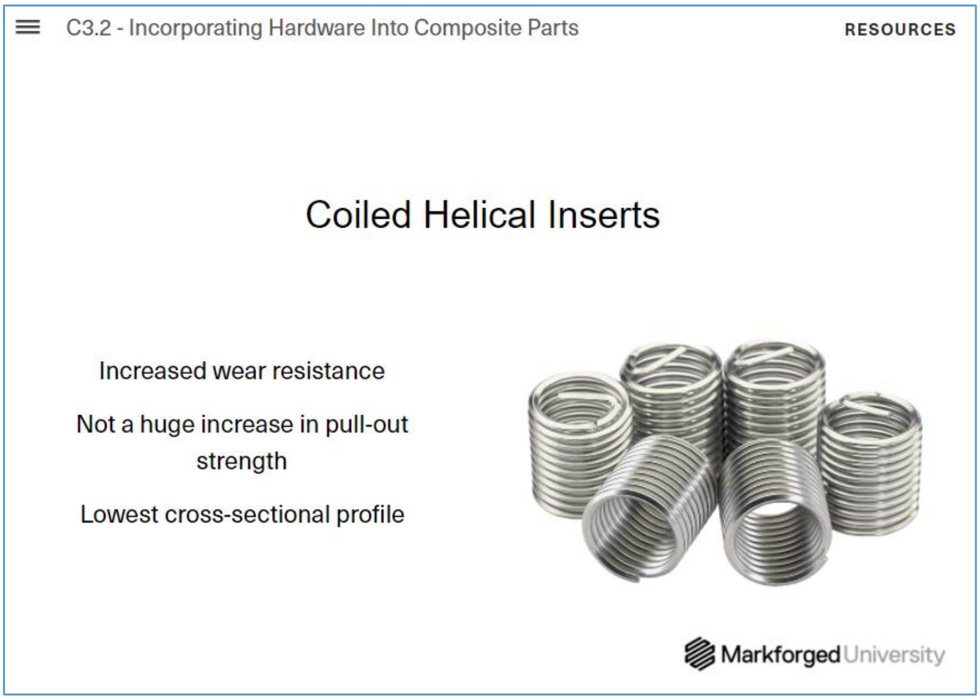




- **Captive Square or Hex Nuts**

- Captive = opgesloten
- Cavity = holte

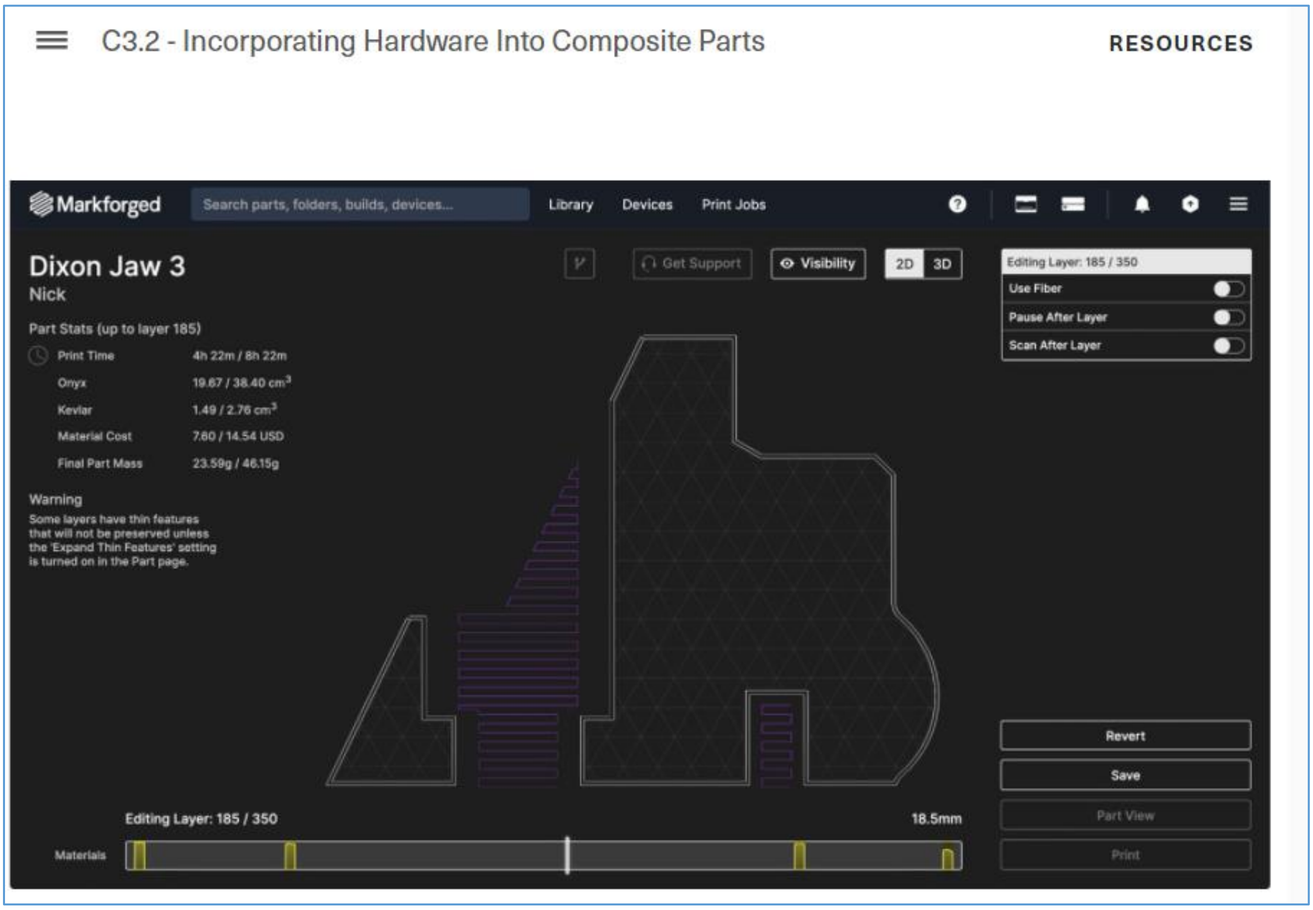
- **Captive Pockets Retain Nuts**
  - Retain = behouden.



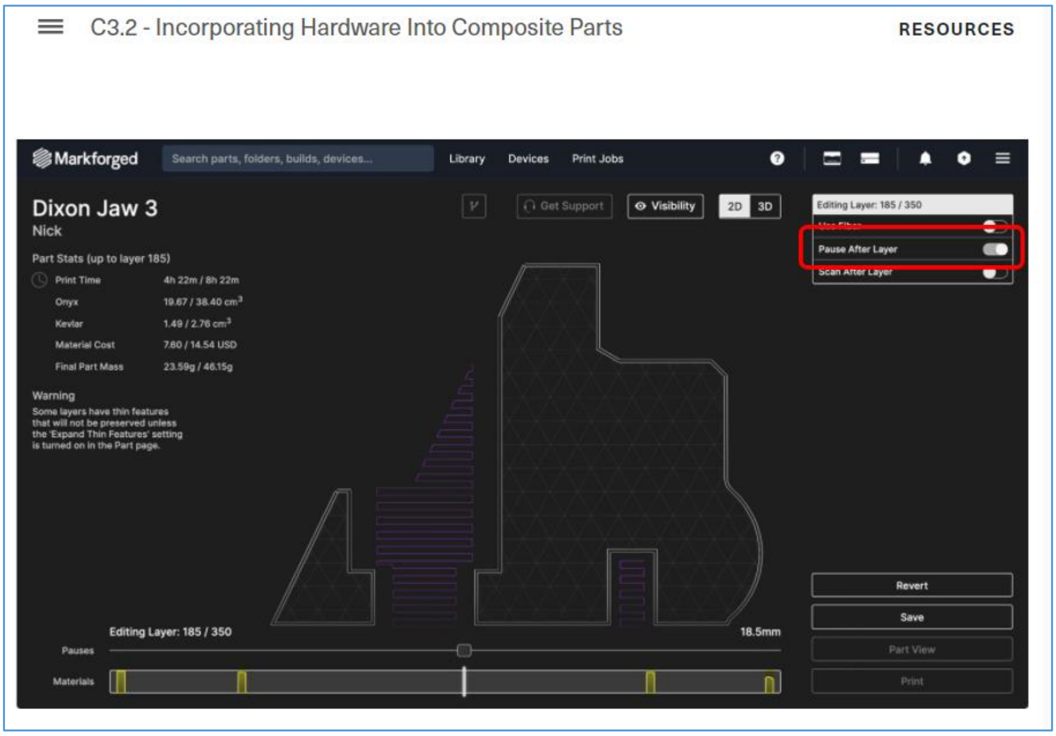
- **Threaded Features – Helical Inserts**
  - Not recommended.

- **Captive Hardware through Overprinting**

- **Overprinting Process**



- Pause in Layer editor

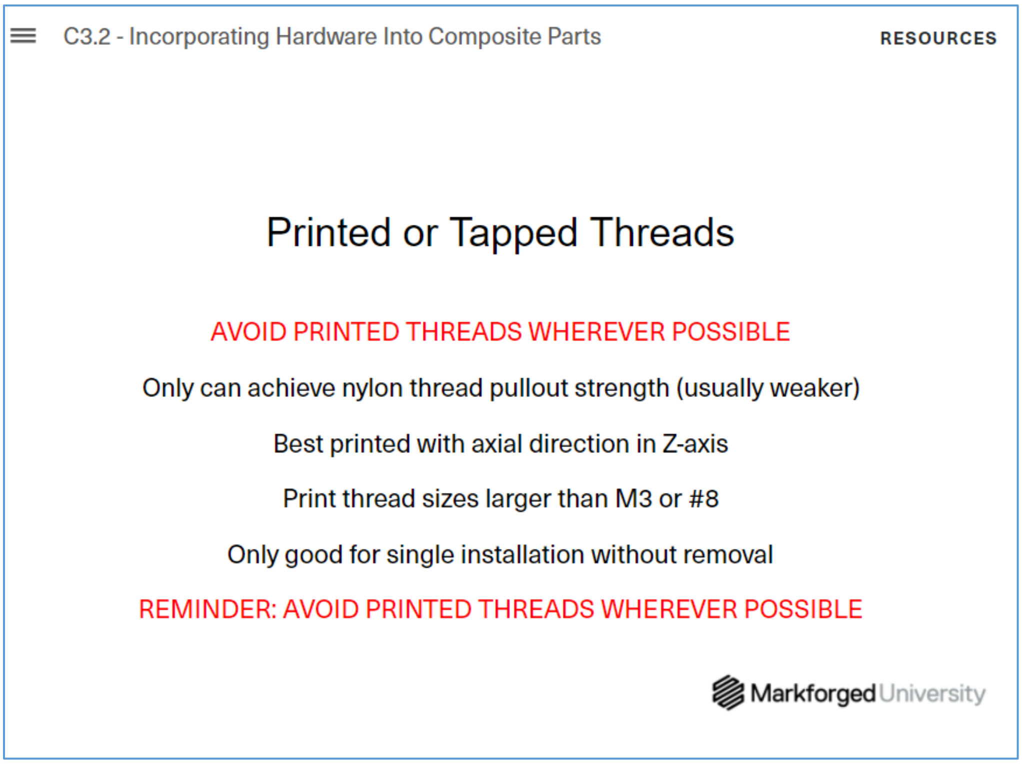


- The printer will automatically pause the printer and sends an e-mail.

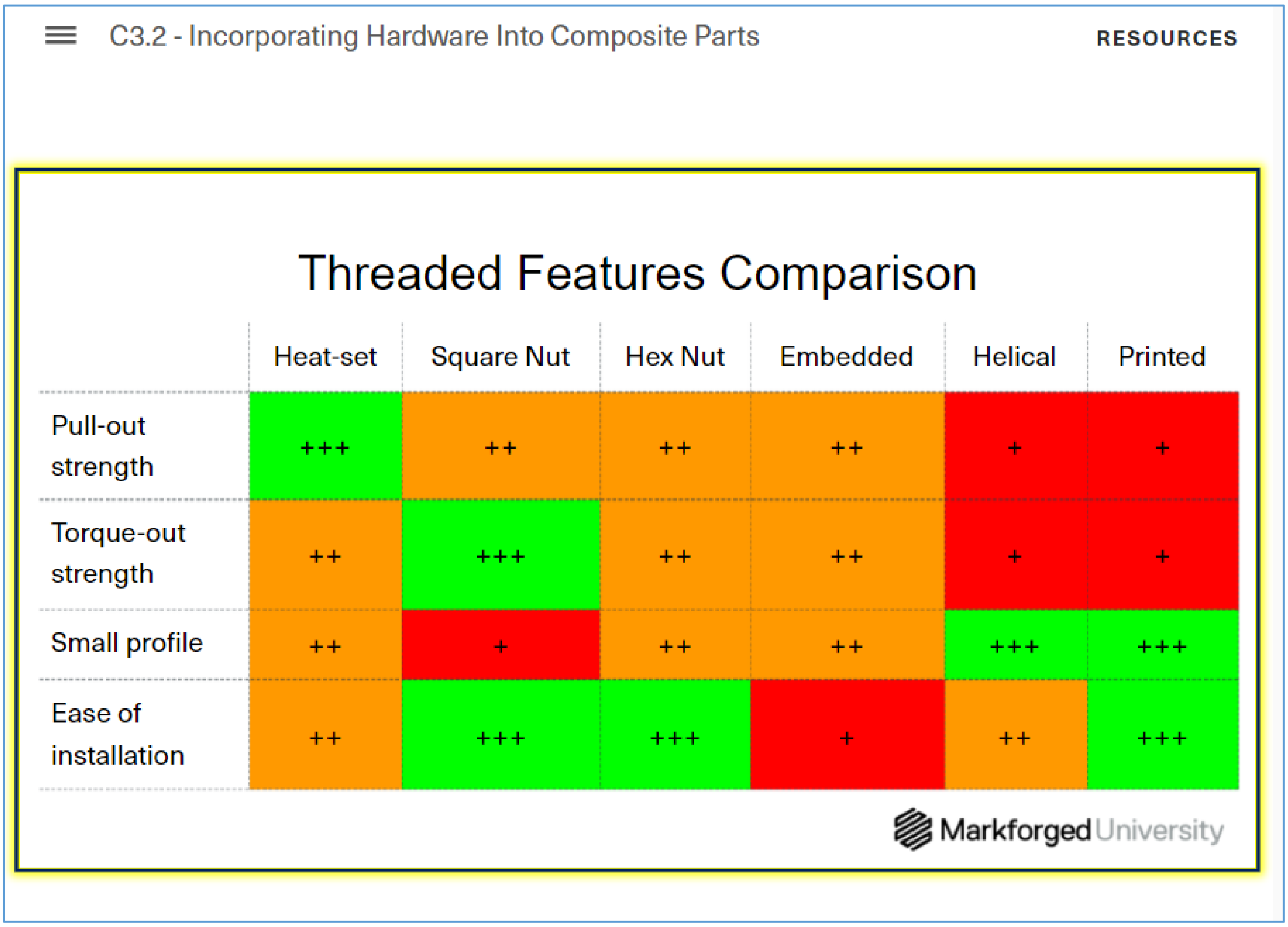
- Remove support material.
- Then add the inserts by using a little bit of the glue stick just at the top of the insert and at the metal part, because onyx will stick to the model otherwise.
- It is also important not apply glue on the axis infill the part. That will disrob the layer bounding and create weakness in the part.

- **Pros and Cons of Overprinting**

- Stray parts = verdwaalde / zoekgeraakte (of the shelf) onderdelen?
- Supervision is required to resume (hervatten): If you leave the printer pauses to long (more than 30 à 60 minutes) the chamber of the part will cool out, witch result in a weaker bound between the layer where paused at and the next layer. > Risk of failure of the application.



- **Printed or Tapped Threads**



	Heat-set	Square Nut	Hex Nut	Embedded	Helical	Printed
Pull-out strength	+++	++	++	++	+	+
Torque-out strength	++	+++	++	++	+	+
Small profile	++	+	++	++	+++	+++
Ease of installation	++	+++	+++	+	++	+++

- **Threaded Features Comparison**

- **Module Review**

C3.2 - Incorporating Hardware Into Composite Parts RESOURCES

Which of the following provides the highest pull-out strength threaded features among the option listed.

- Printed thread
- Tapped thread
- Coiled helical insert
- Square nut

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C3.2 - Incorporating Hardware Into Composite Parts RESOURCES

When attempting to add wear resistance to a flat surface of a part, we want to design in dowel pins to add a harder wear surface over a large contact area.

- True
- False

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C3.2 - Incorporating Hardware Into Composite Parts RESOURCES

Adding off-the-shelf hardware to a 3D printed part should be driven by:

- Lack of access to a CNC machine
- Part functional requirements
- The skill of the 3D printer operator
- A whim

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C3.2 - Incorporating Hardware Into Composite Parts RESOURCES

Results

Your Score:	100% (30 points)
Passing Score:	80% (24 points)

Result:

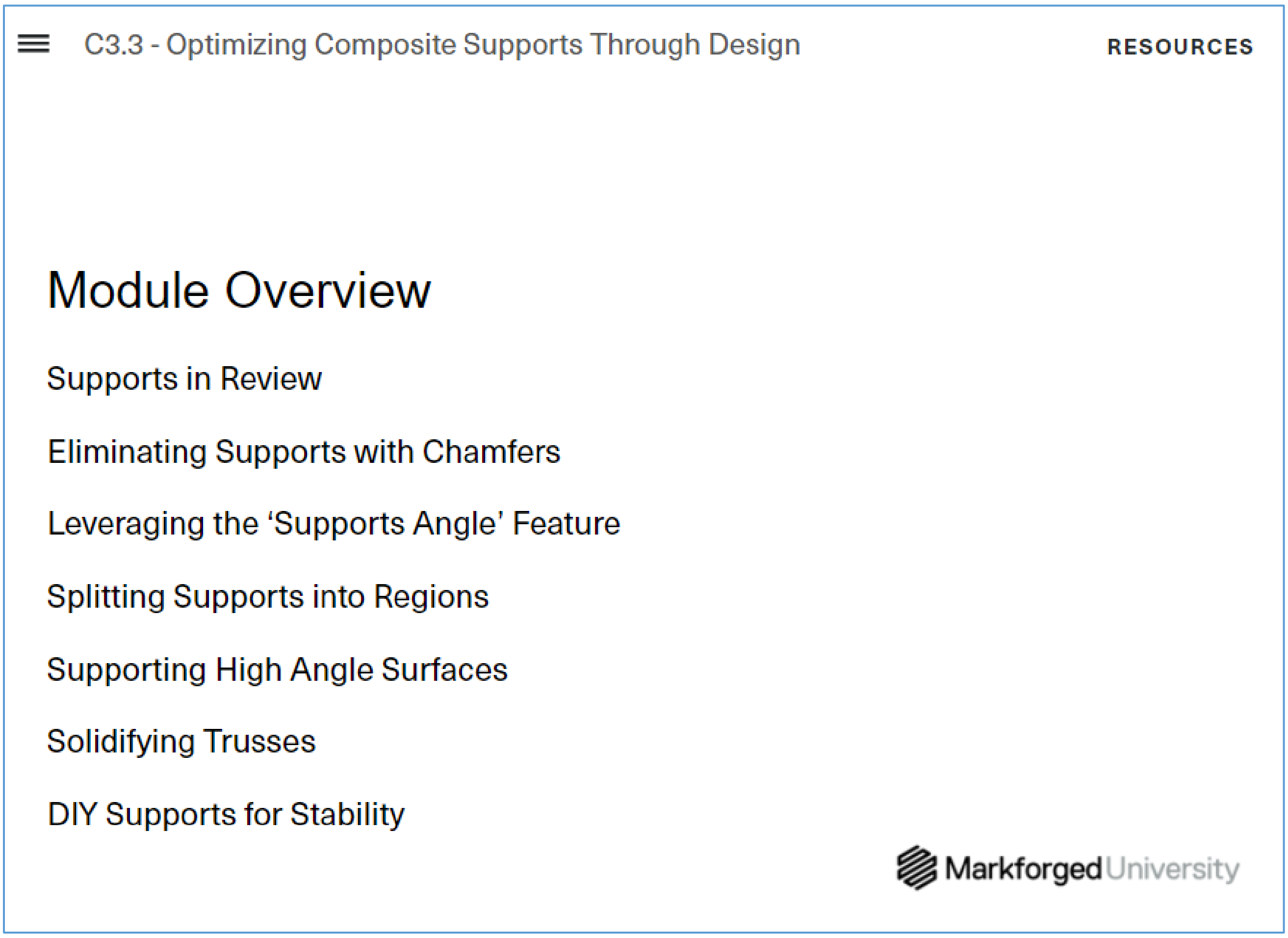
Congratulations, you passed.

Finish Module

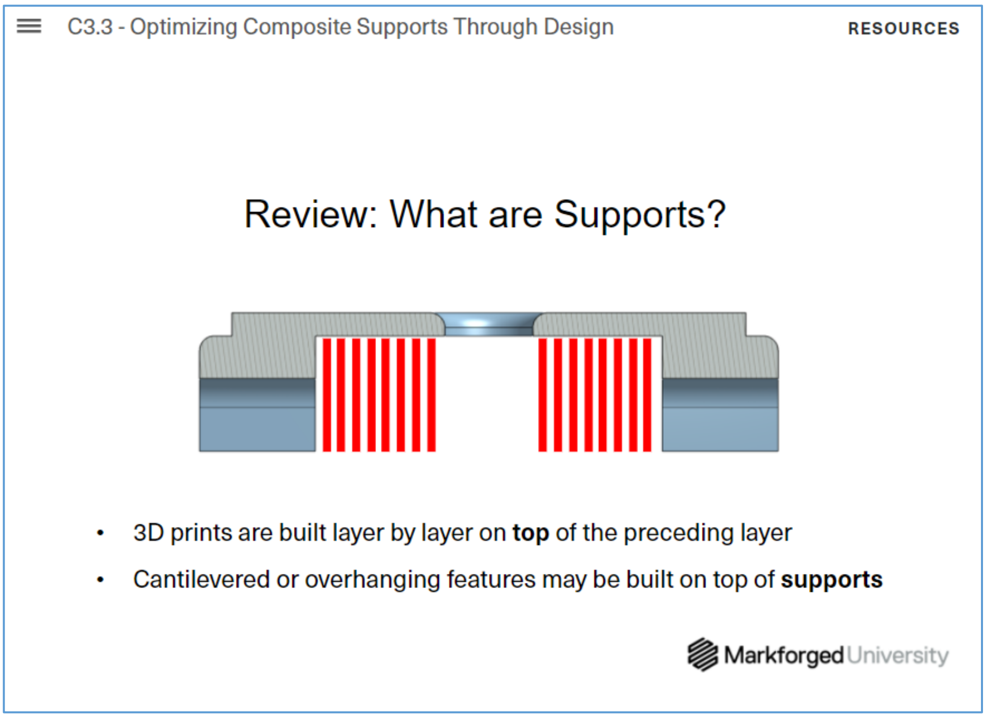
Review Quiz

C3.3 – Optimizing Composite Supports Through Design

- **Optimizing Composite Support Structures Through Design**
    - Samengestelde draagconstructies optimaliseren door middel van ontwerp.

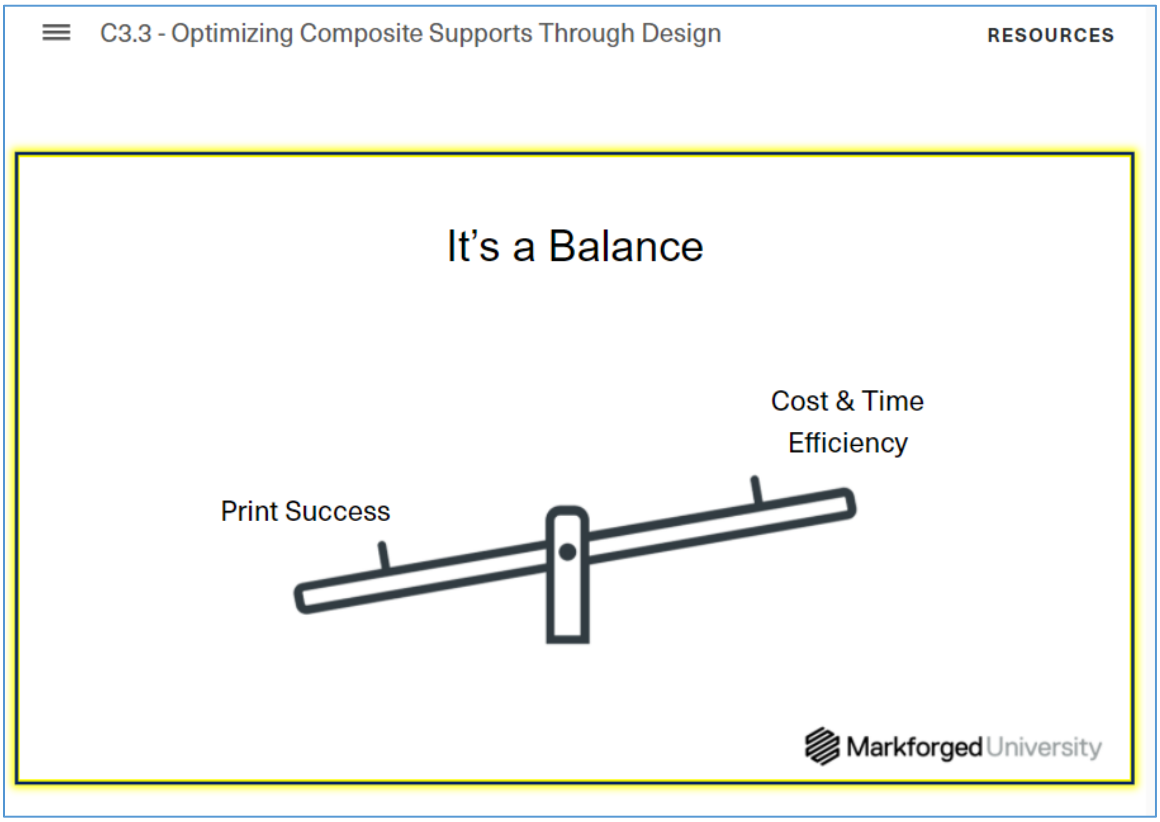


- **Module Overview**
    - Ondersteuning in beoordeling.
    - Het elimineren van steunen door met afschuiningen te werken.
    - Gebruikmakend van de functie 'ondersteuningshoek'.
    - Ondersteuningen opsplitsen in regio's.
    - Ondersteunende hoge hoek oppervlakken.
    - Stollende spanten.
    - DIY-ondersteuning voor stabiliteit (Do It Yourself)

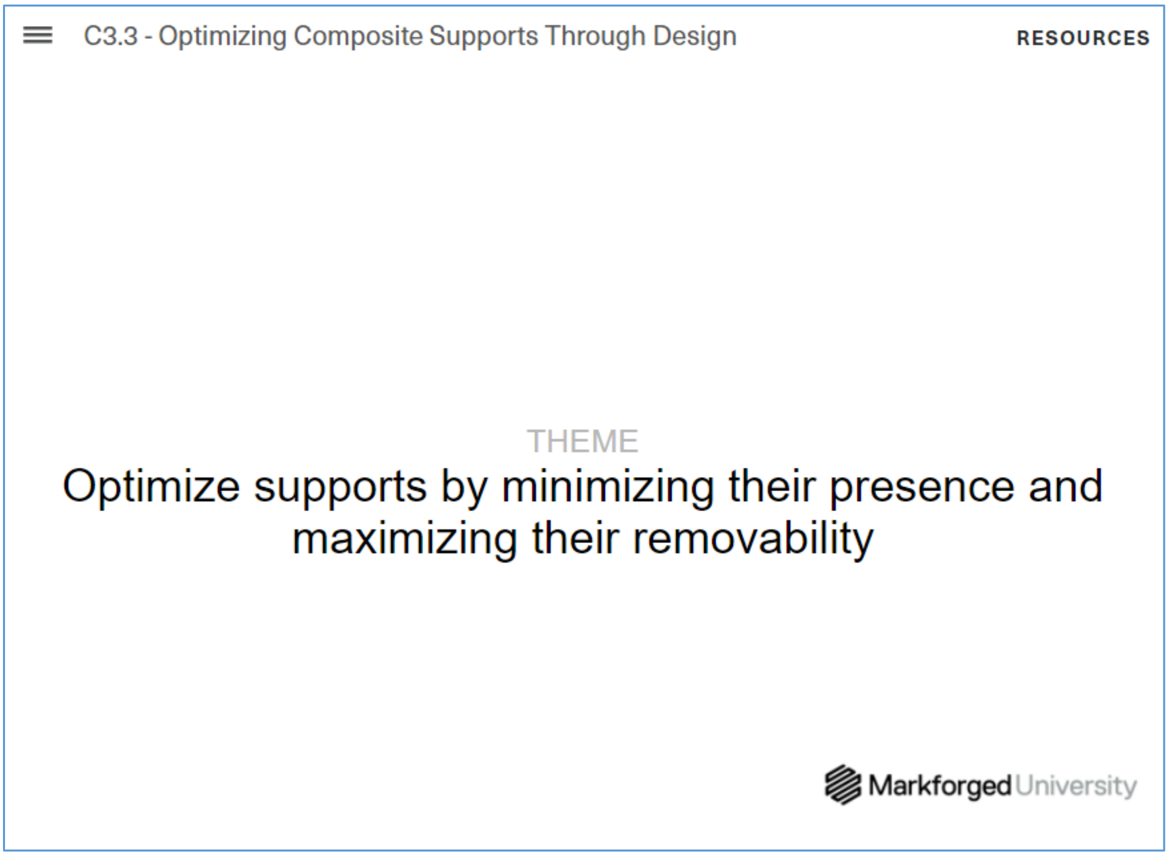


- **Review: What are Supports?**
    - Cantilevered = vrijdragend

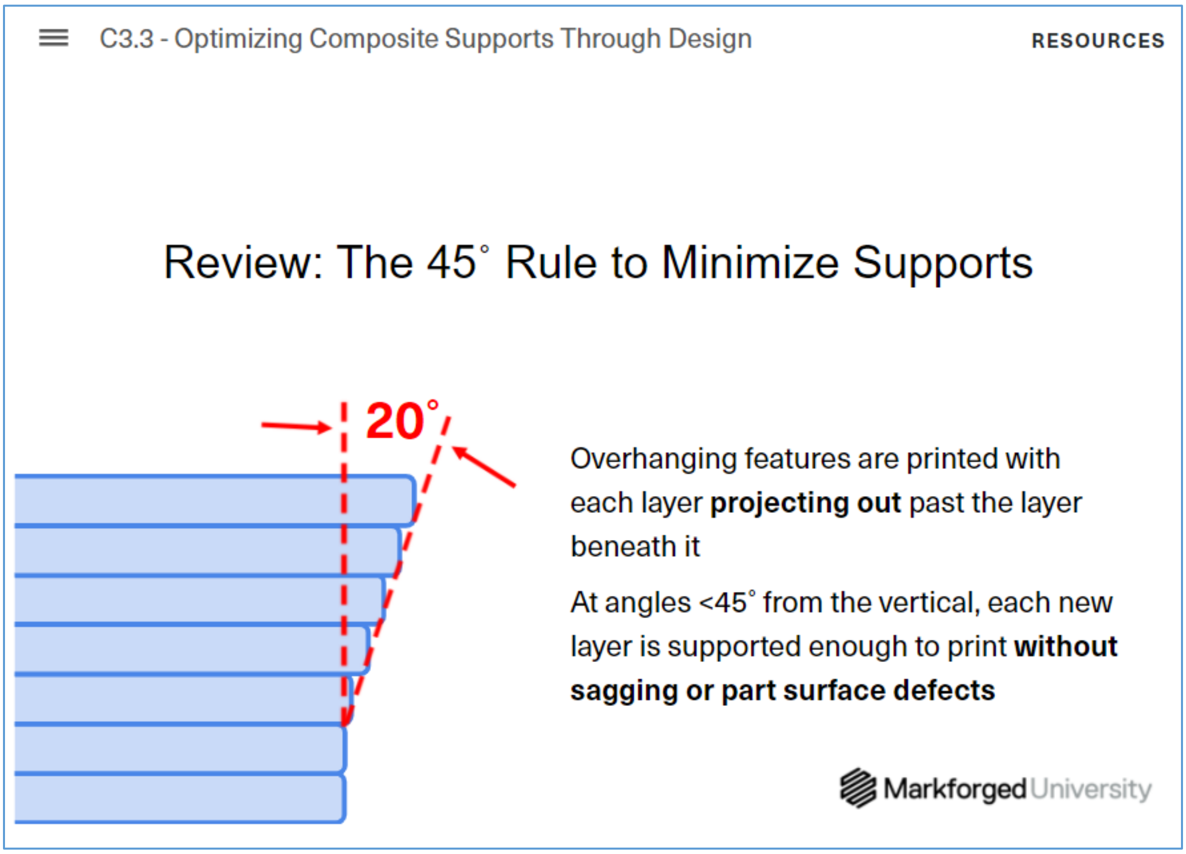
- **Review: What's Wrong With Supports?**



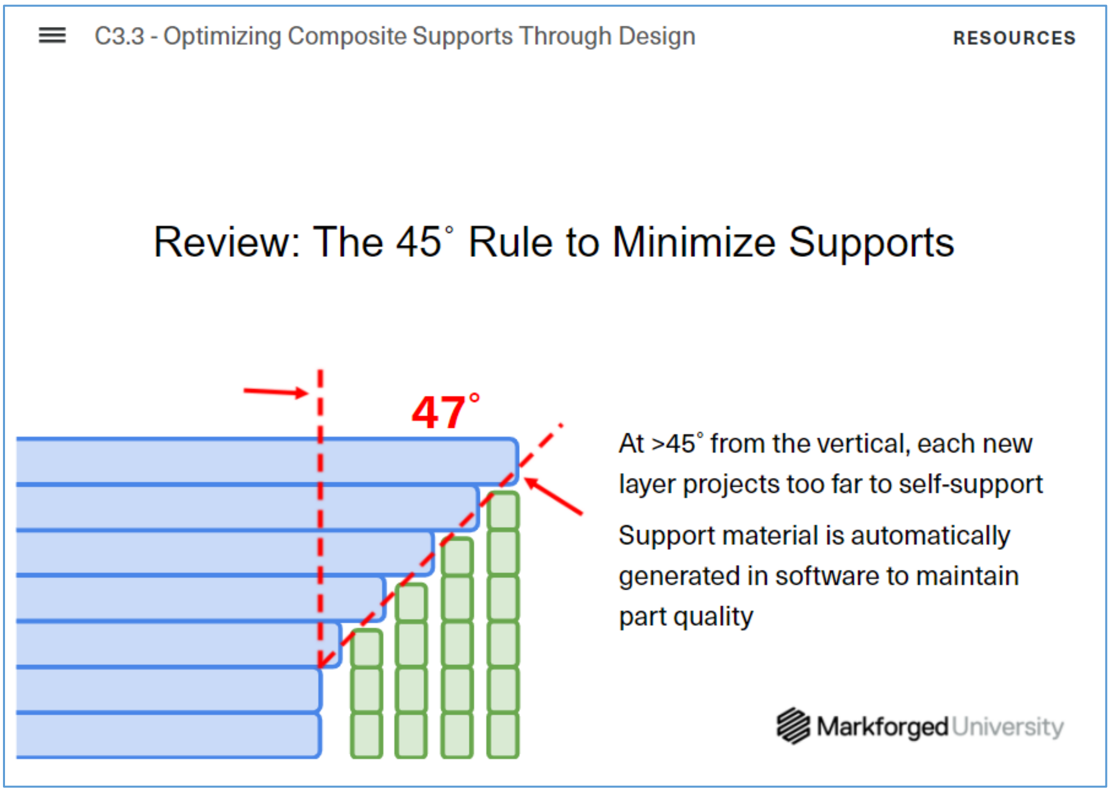
- **It’s a Balance**

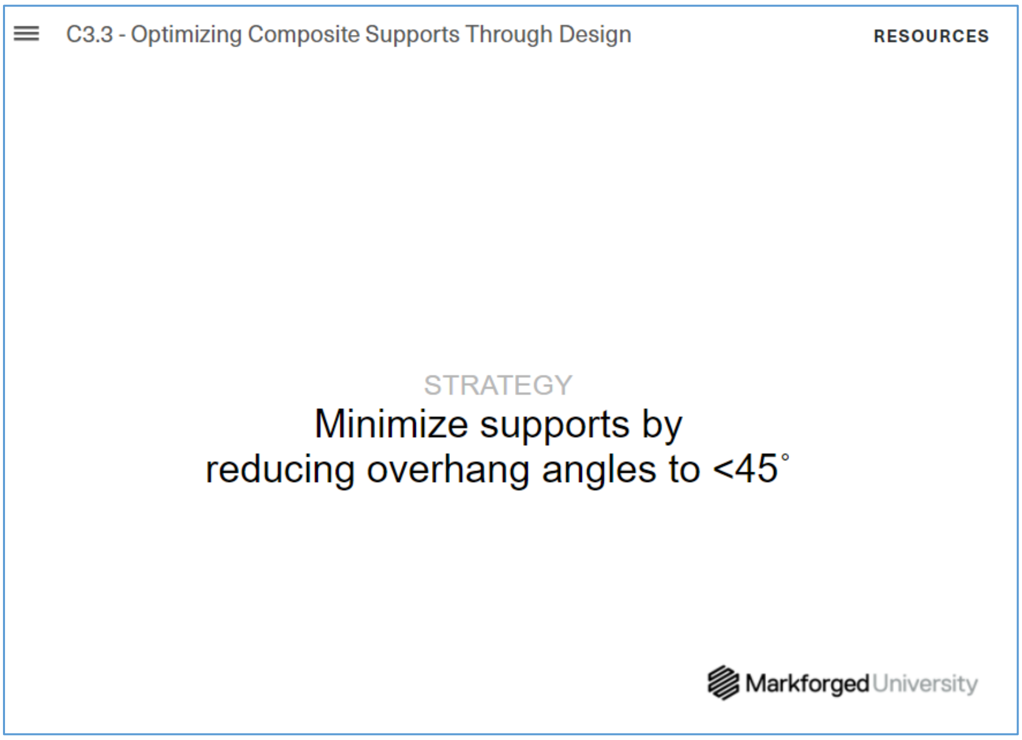


- **What Does Optimizing Supports Really Mean?**



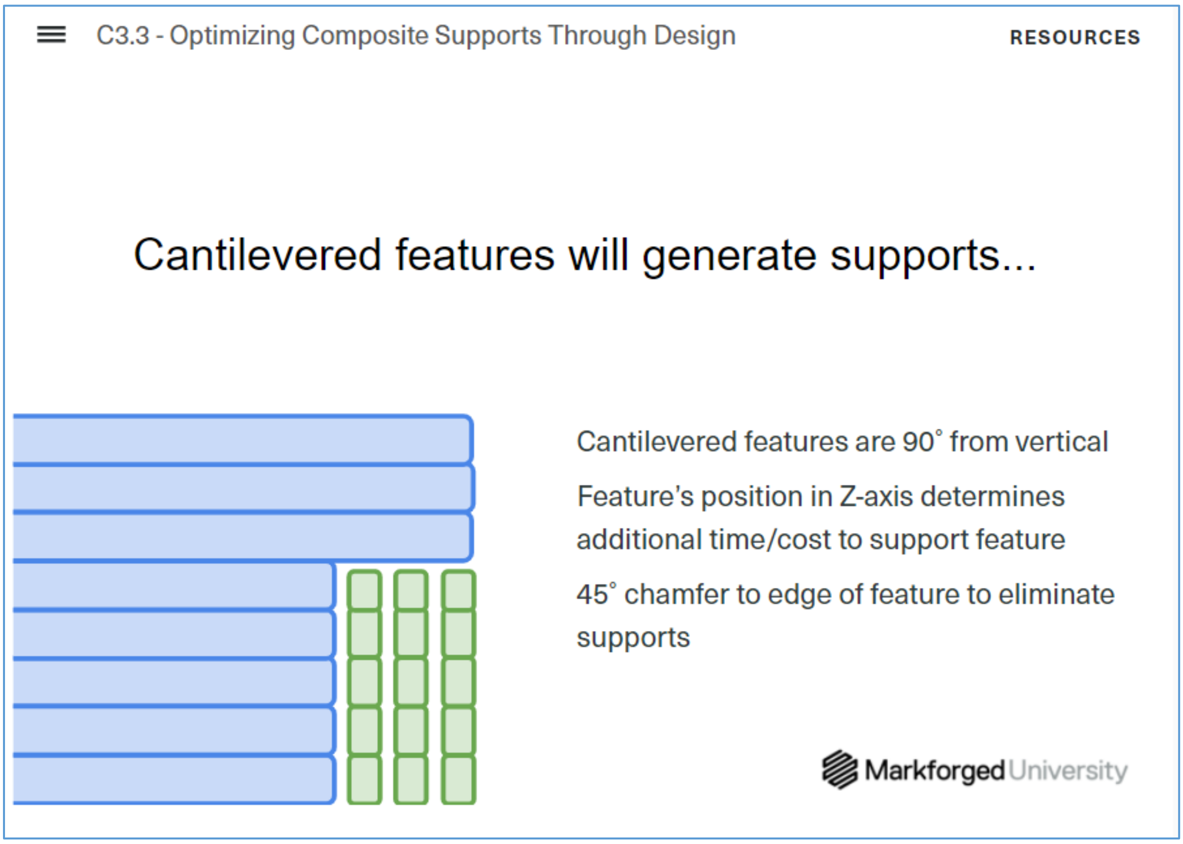
- **Review: The 45° Rule to Minimize Supports**
    - Sagging = doorzakken.



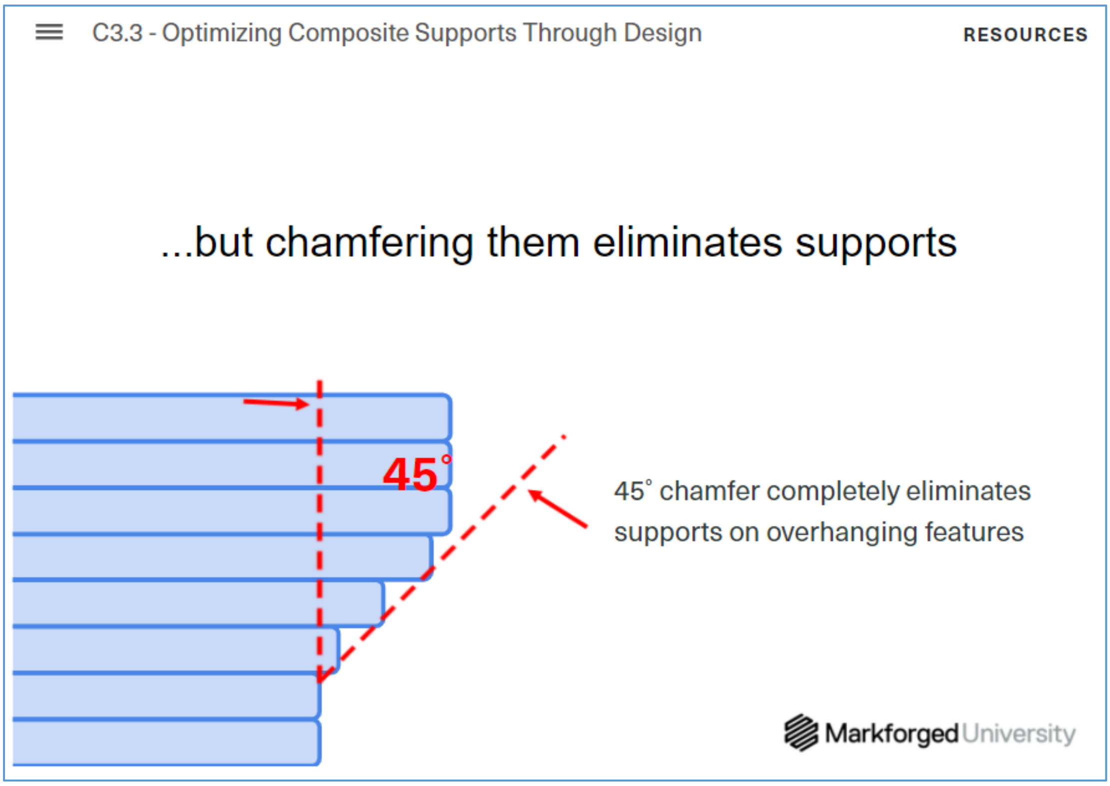


- **Principal Strategy: Reduce Overhanging Angles to <45°**

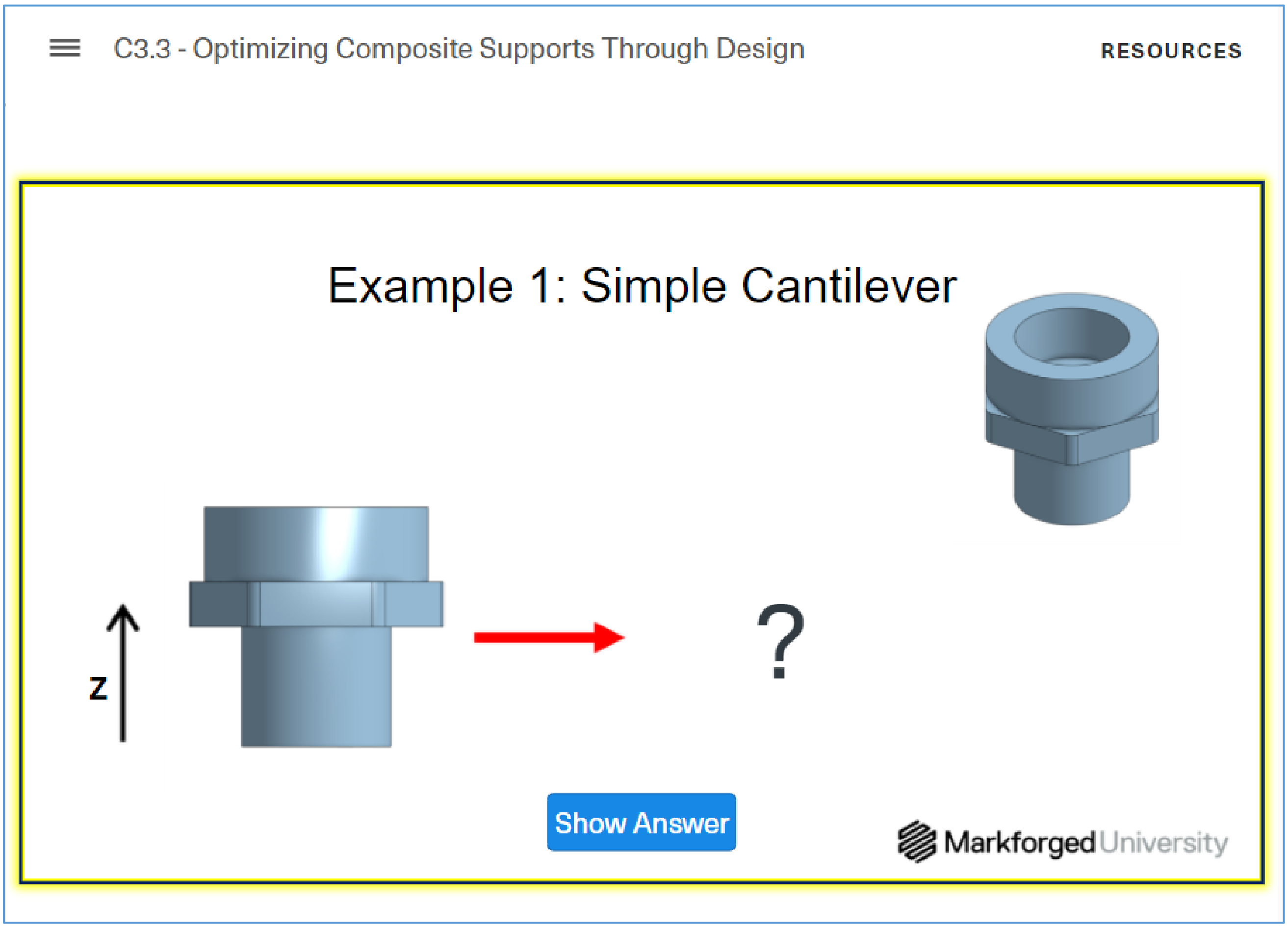
- **Eliminating Support with Chamers**



- **Cantilevered Features Generate Supports**



  - A Solution.


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Example 1: Simple Cantilever
z
?
Show Answer
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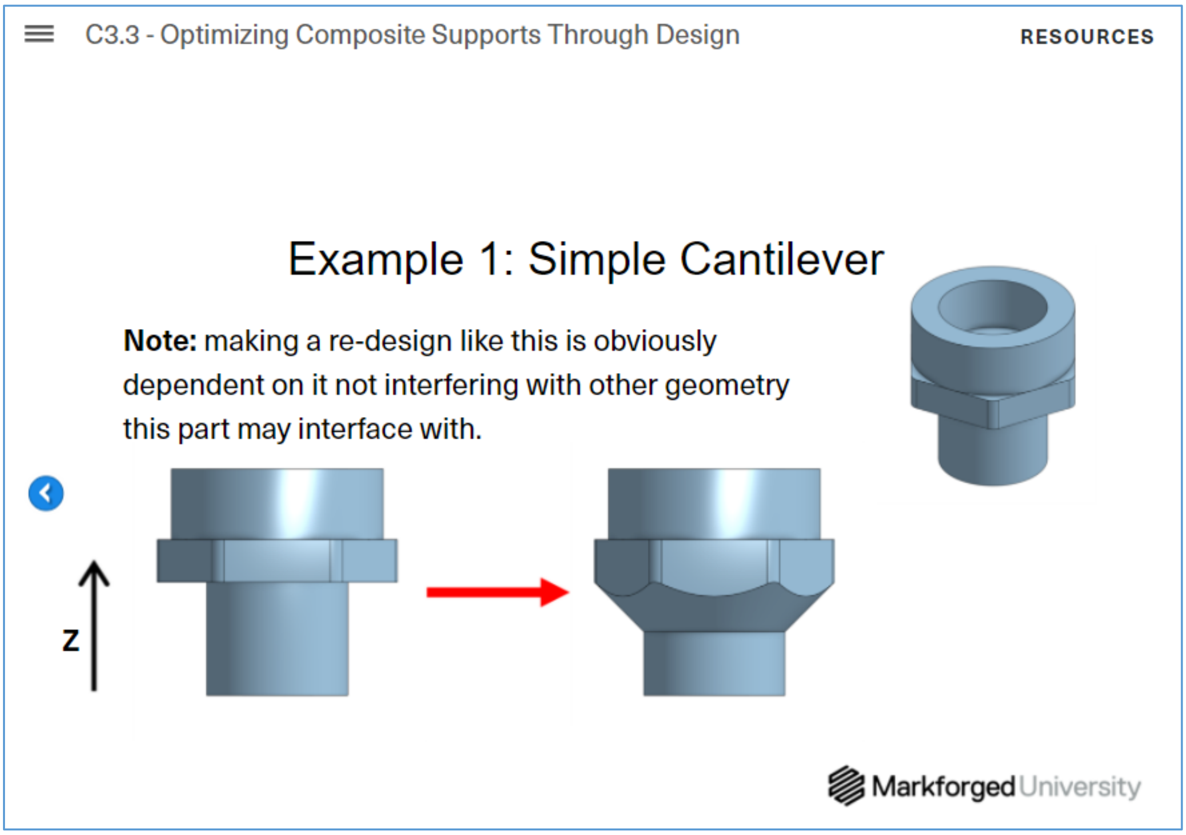
- **Example 1**


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Example 1: Simple Cantilever
Note: making a re-design like this is obviously dependent on it not interfering with other geometry this part may interface with.
Z
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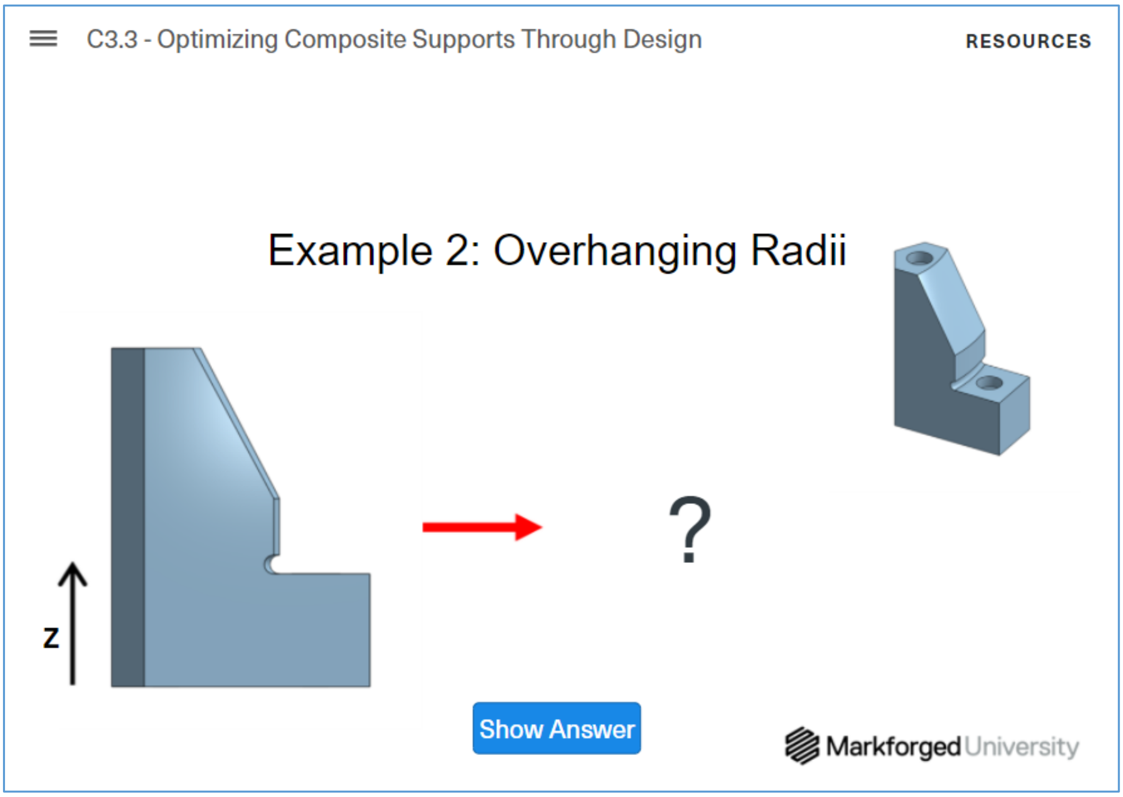
C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Example 2: Overhanging Radii
?
Z
Show Answer
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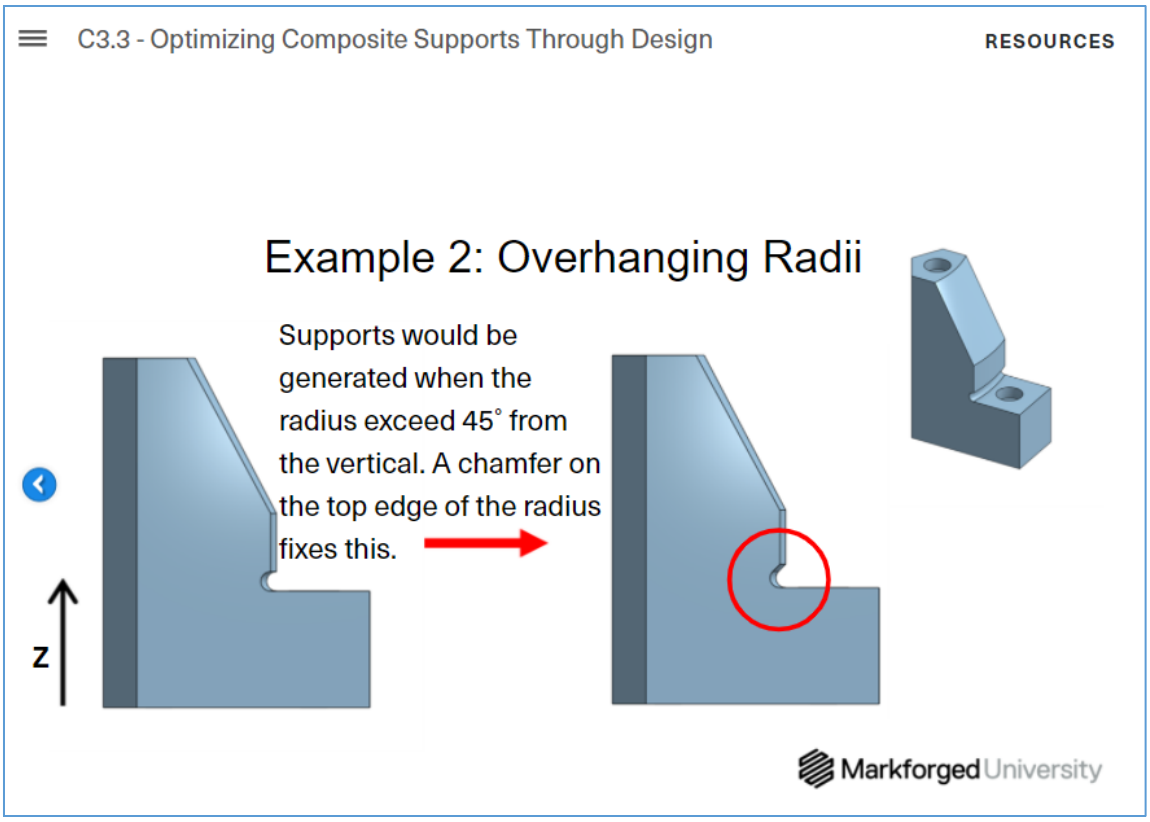
- **Example 2**


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Example 2: Overhanging Radii
Supports would be generated when the radius exceed 45˚ from the vertical. A chamfer on the top edge of the radius fixes this.
Z
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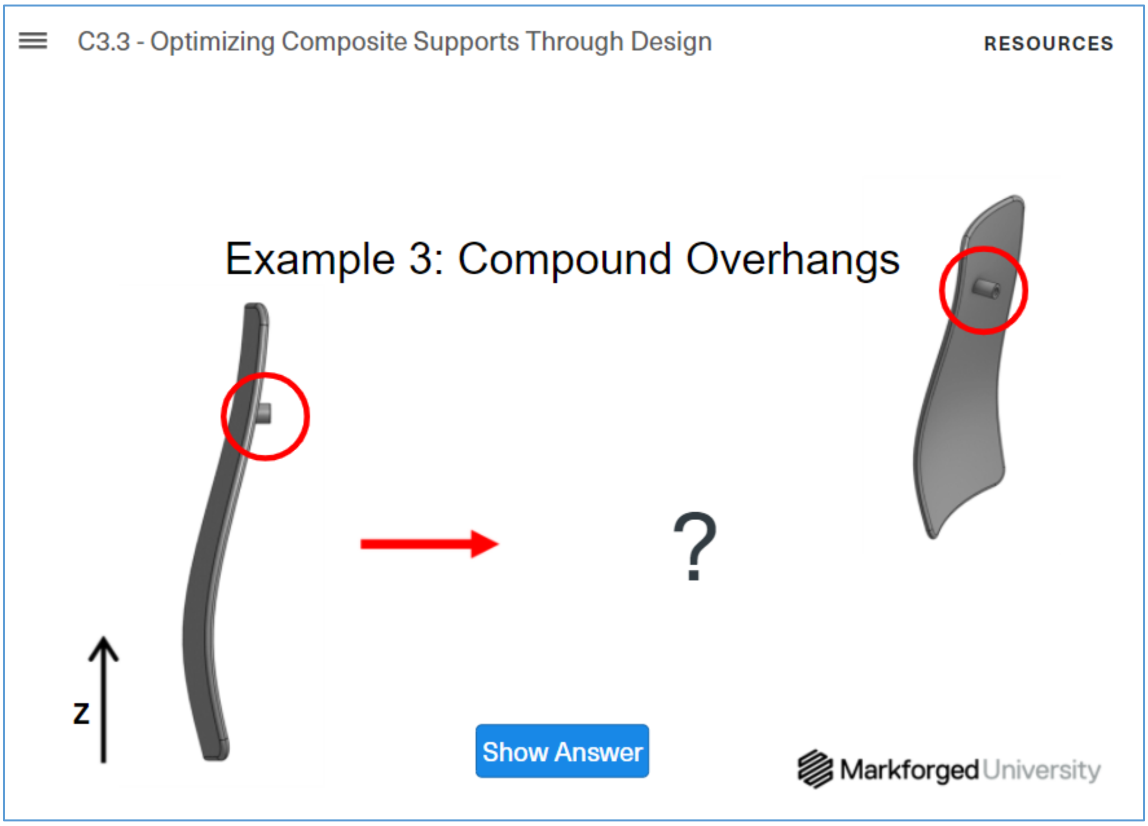
C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Example 3: Compound Overhangs
?
Z
Show Answer
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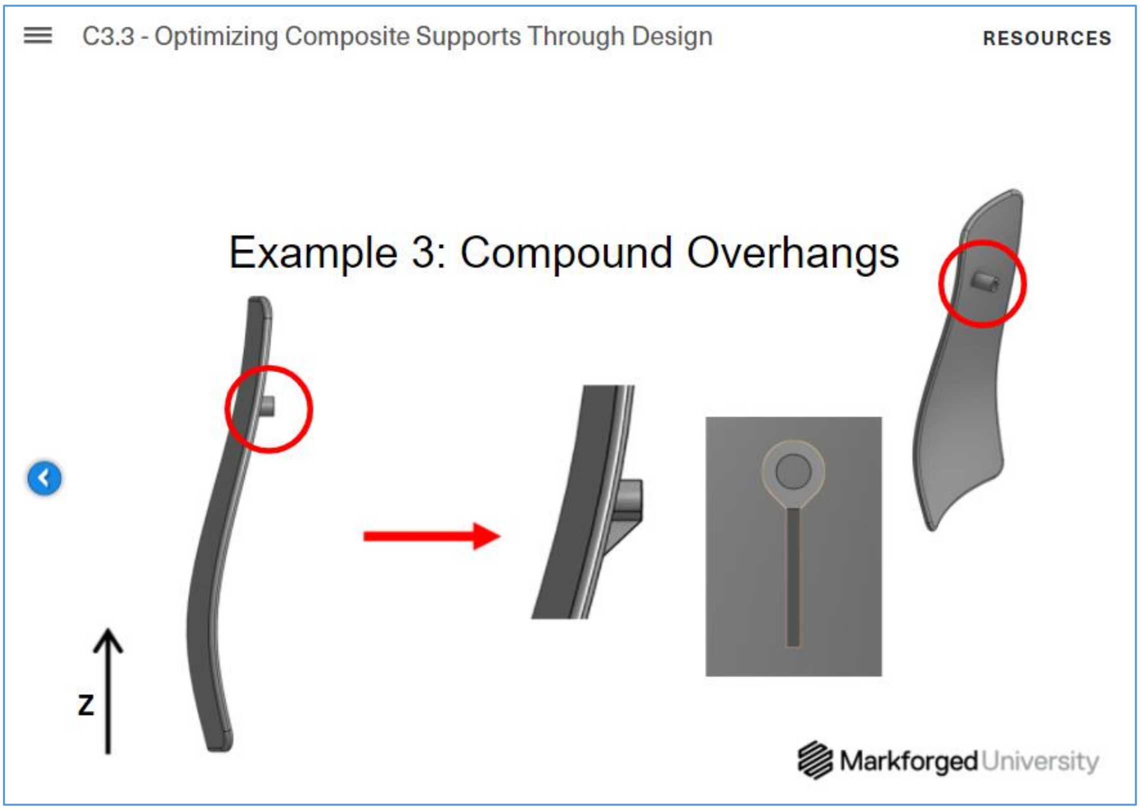
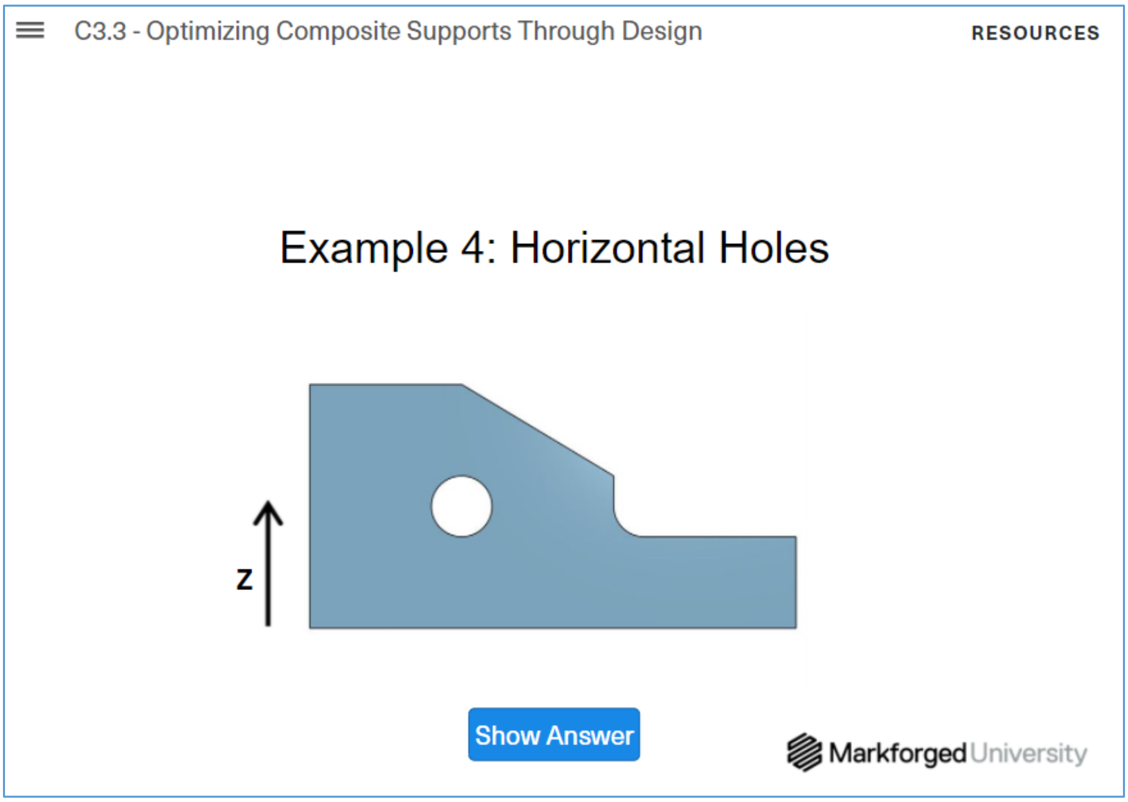
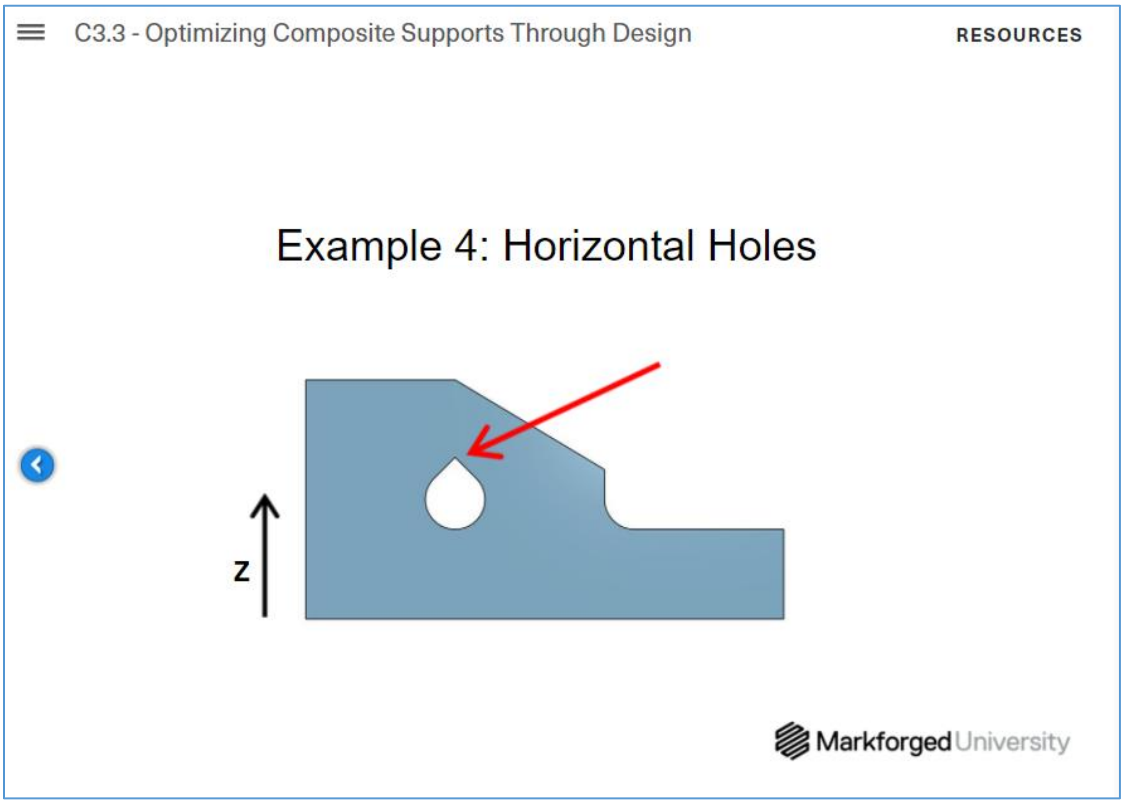
- **Example 3**



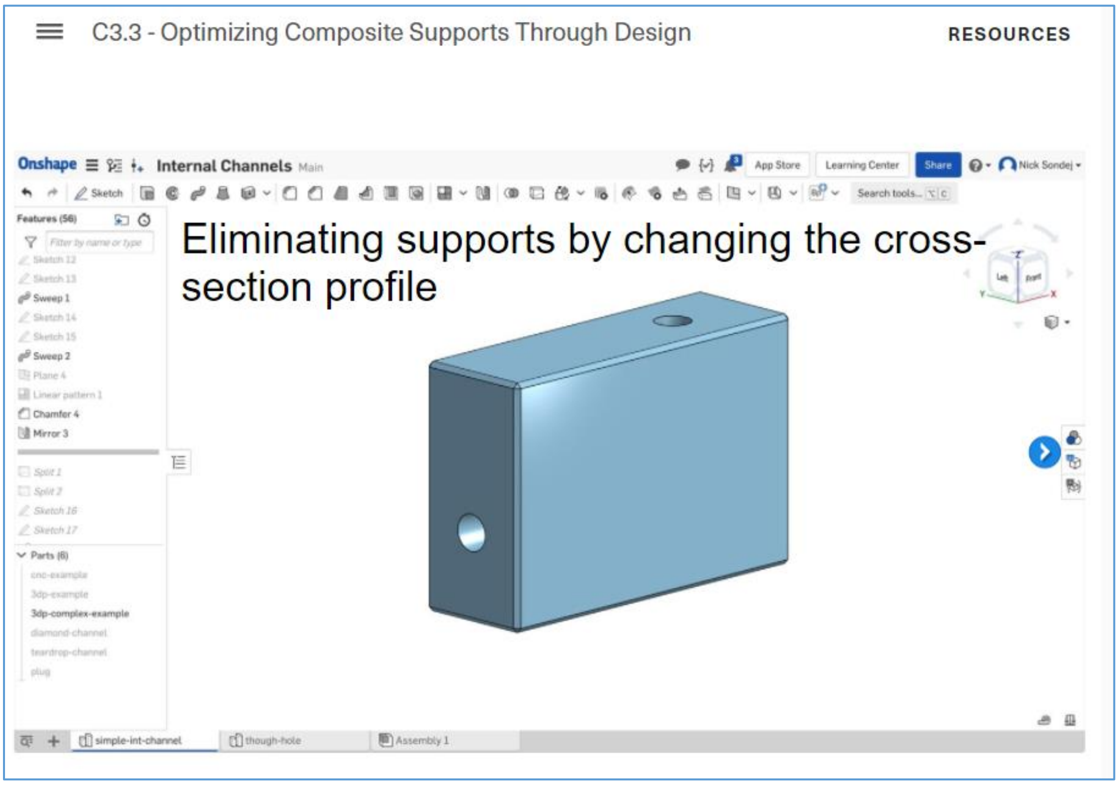
- Solution in 2 directions.



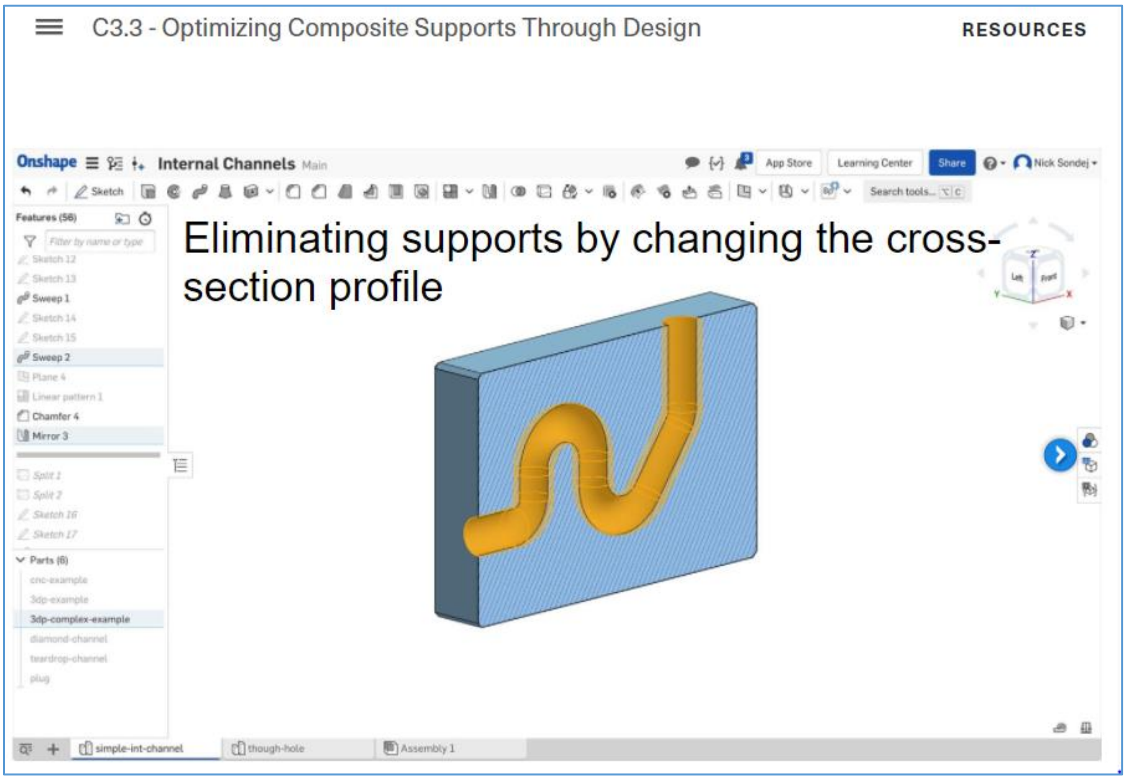
- **Example 4**

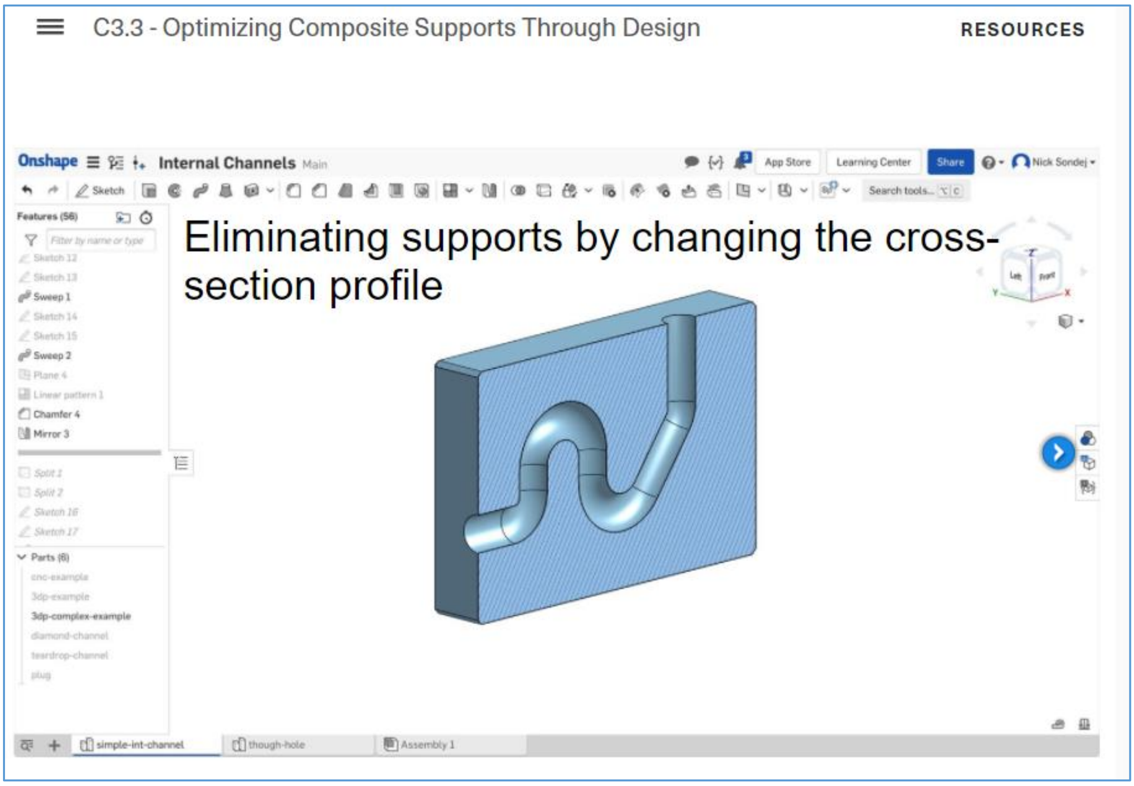


- Solution by teardrop shape



- **Why is a Hole Round?**


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Internal Channels Main
App Store
Learning Center
Share
Nick Sondej
Sketch
Search tools...
Features (56)
Filter by name or type
Sketch 12
Sketch 13
Sweep 1
Sketch 14
Sketch 15
Sweep 2
Plane 4
Linear pattern 1
Chamfer 4
Mirror 3
Split 1
Split 2
Sketch 16
Sketch 17
Parts (6)
cnc-example
3dp-example
3dp-complex-example
diamond-channel
teardrop-channel
plug
Eliminating supports by changing the cross-section profile
simple-int-channel
though-hole
Assembly 1


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Internal Channels Main
App Store
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Nick Sondej
Sketch
Search tools...
Features (56)
Filter by name or type
Sketch 12
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Parts (6)
cnc-example
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simple-int-channel
though-hole
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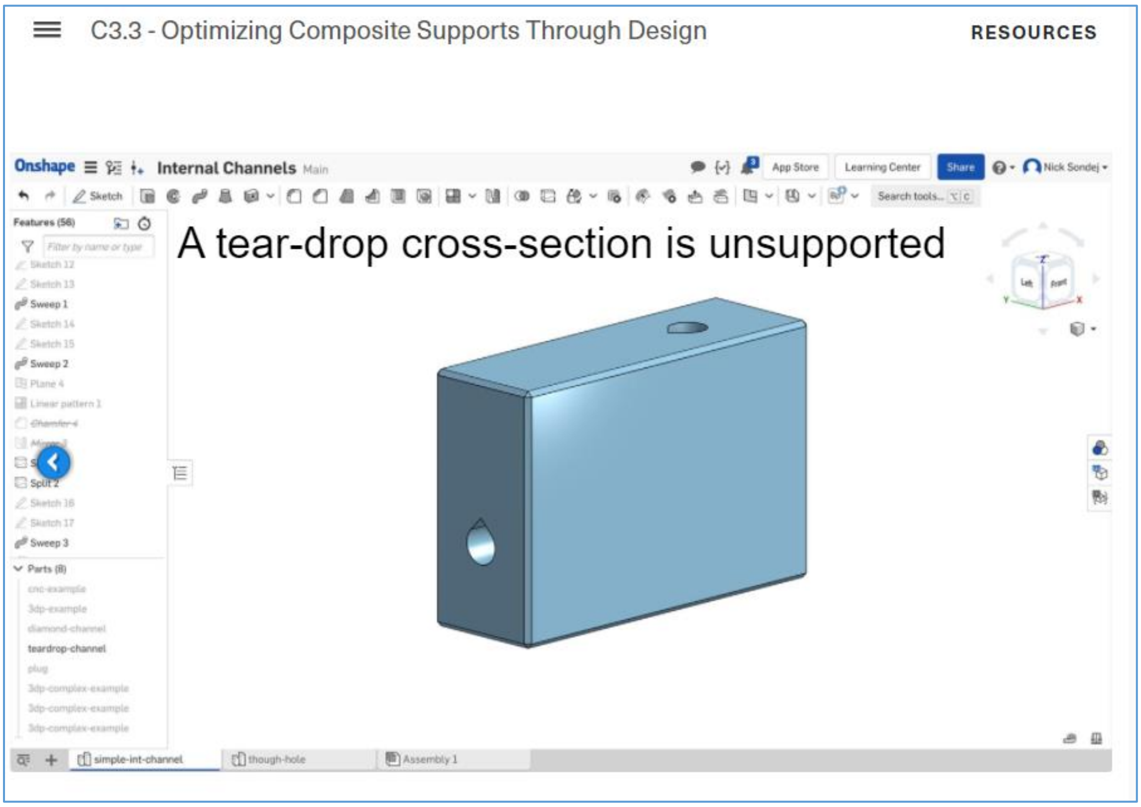
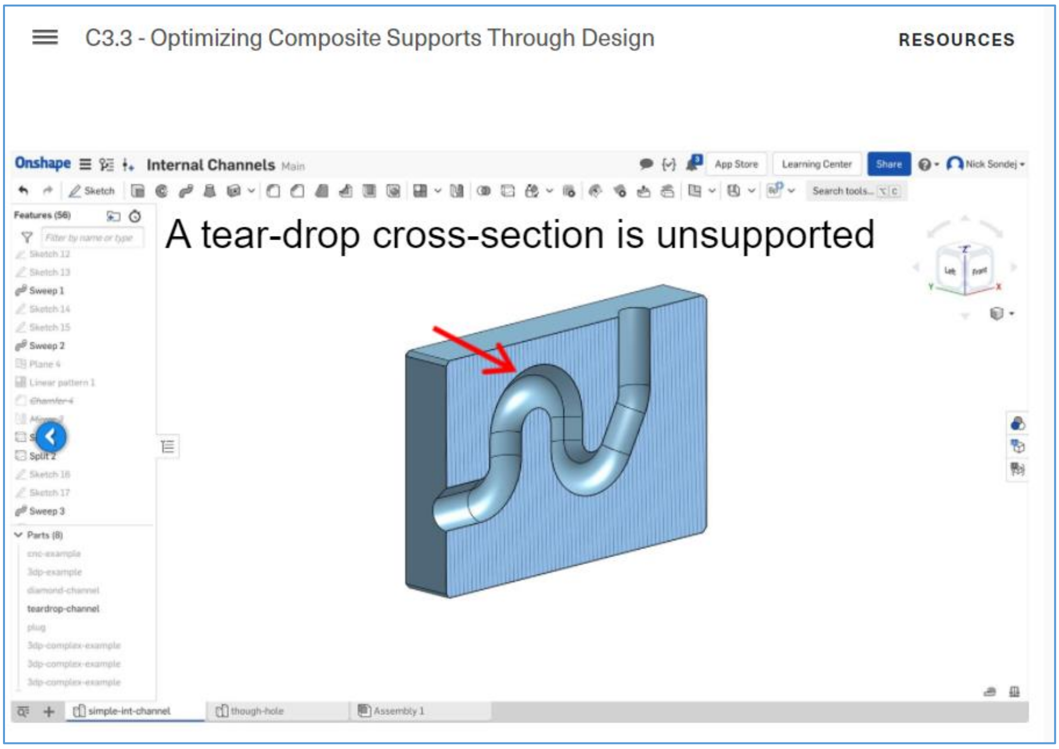
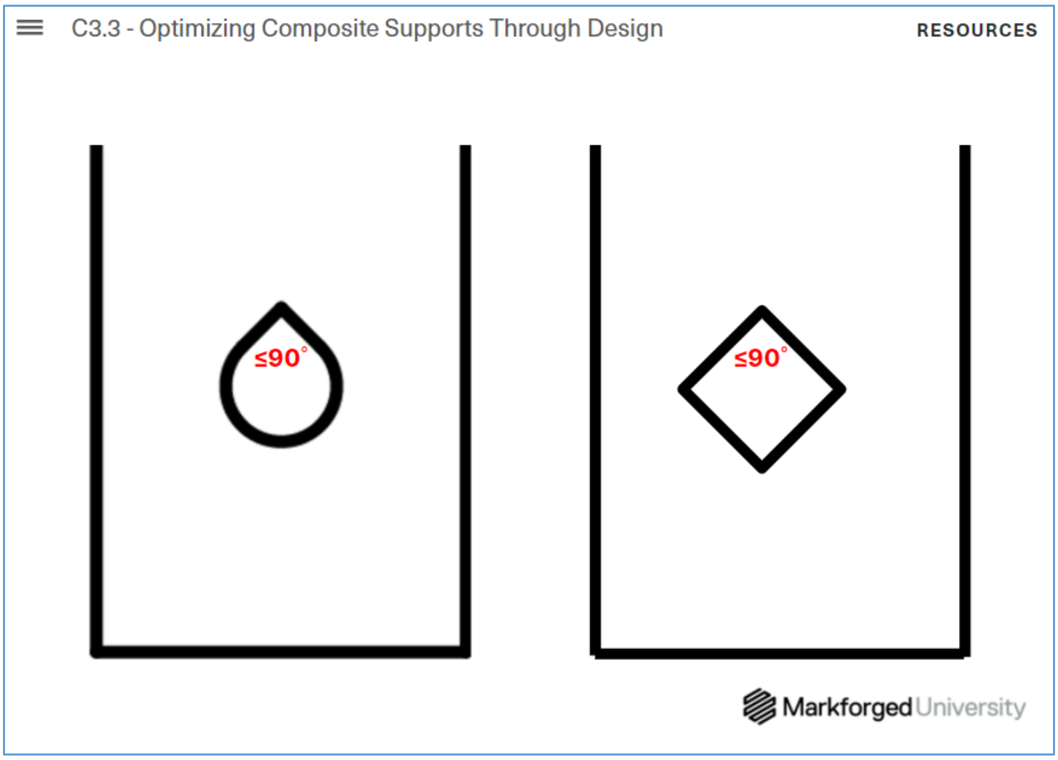
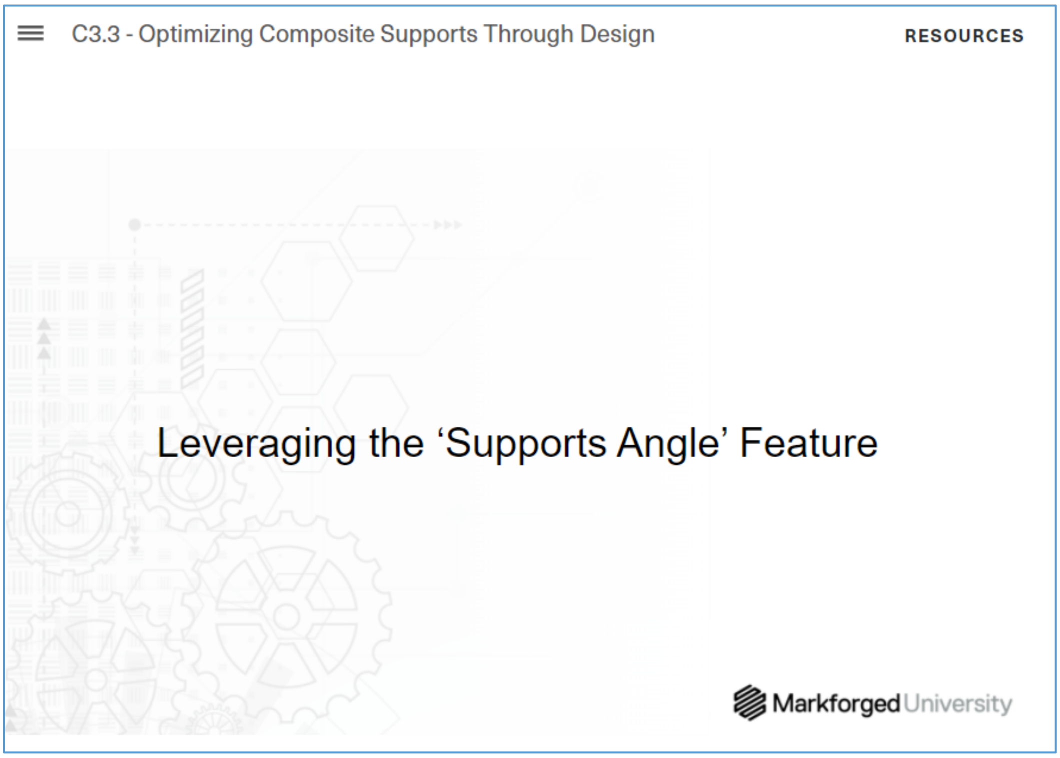

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Internal Channels
A tear-drop cross-section is unsupported
teardrop-channel
simple-int-channel


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Internal Channels
A tear-drop cross-section is unsupported
teardrop-channel
simple-int-channel

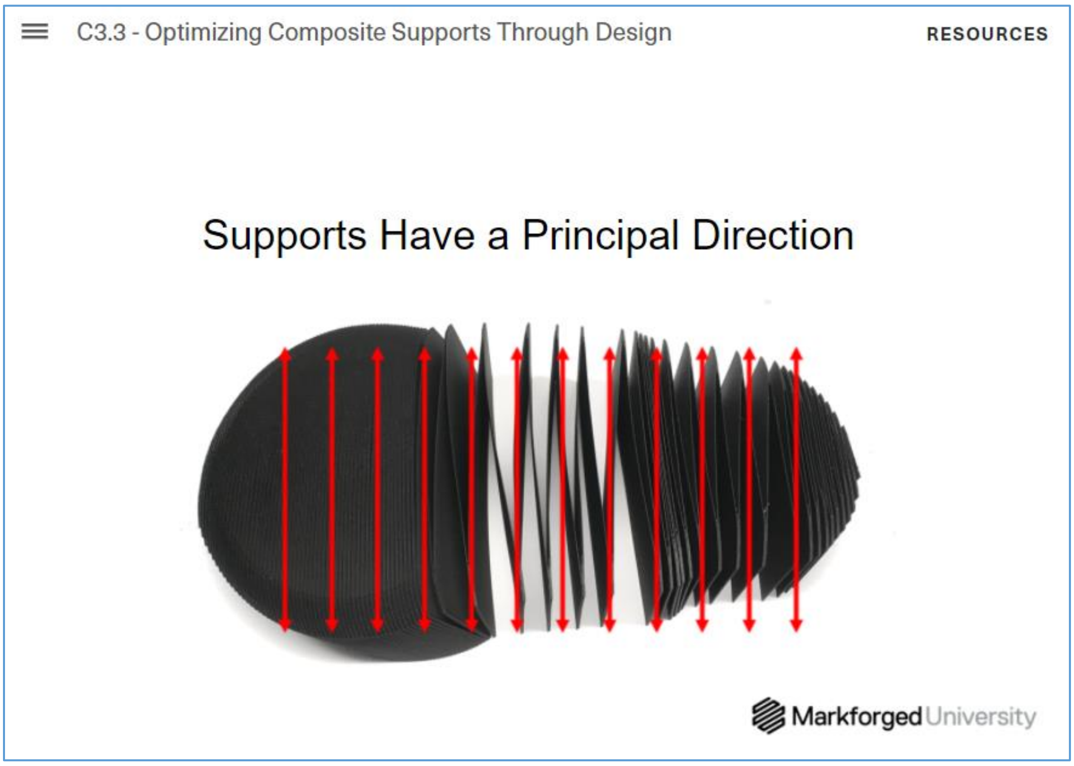


- **Different Profile Options**

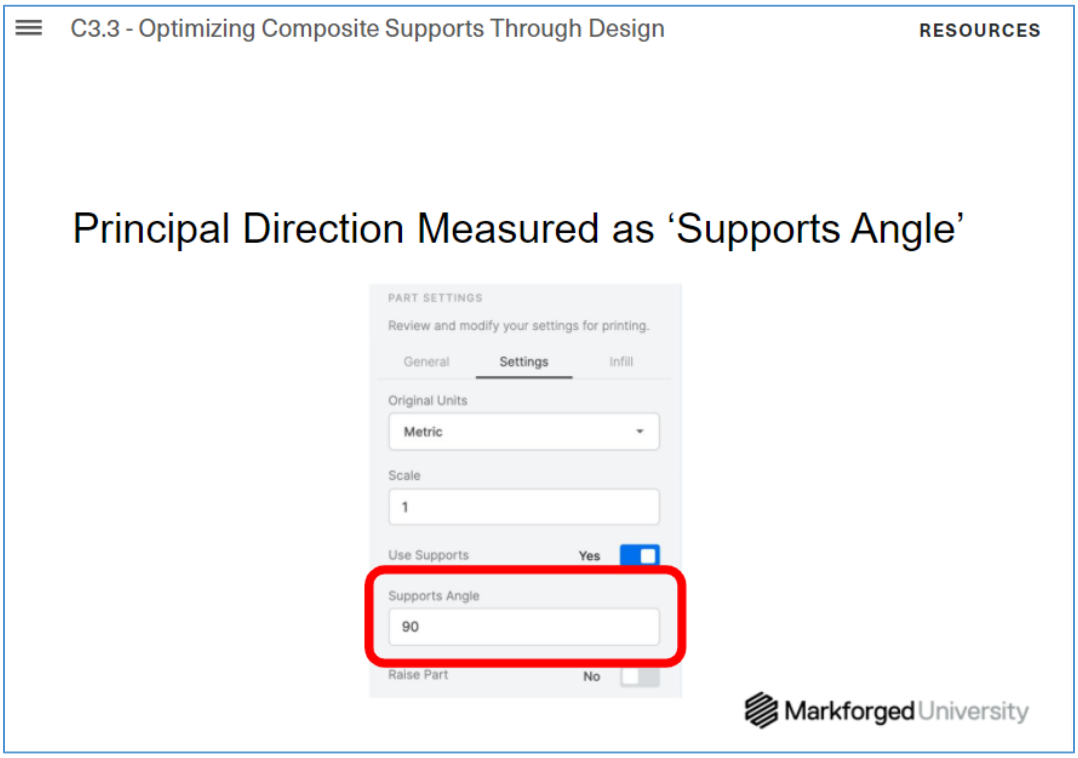


- **Leveraging the 'Support Angle" Feature**
    - Gebruikmaken van de functie 'Ondersteuningshoek

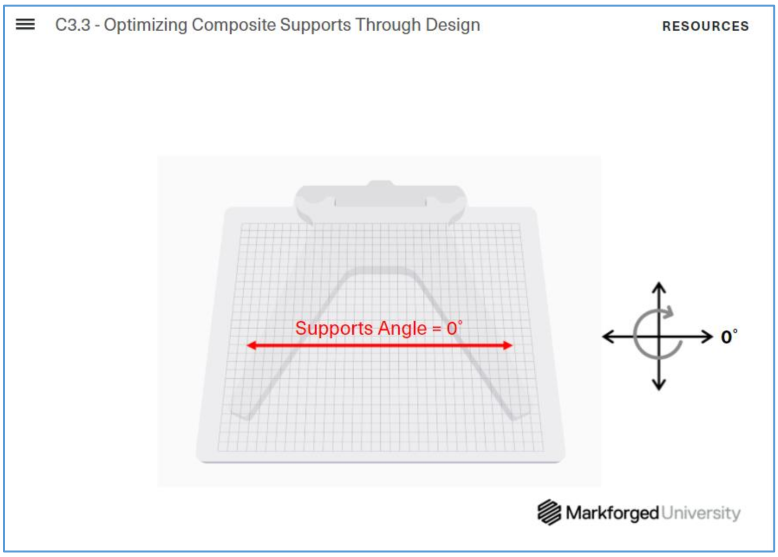
- **Supports Have a Principal Direction**
    - Steunen hebben een hoofdrichting.



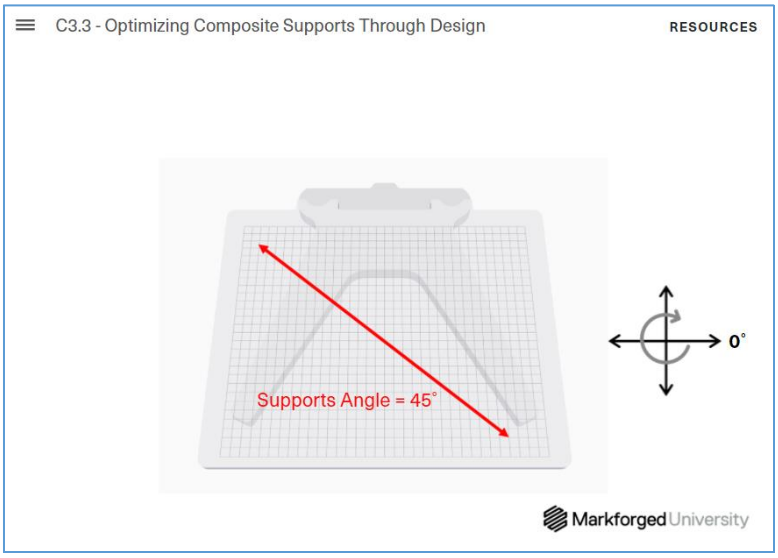
    - How this pattern is oriented can have an impact how easy or difficult on different reasons are to remove.



- Support Angle Feature.



- **The Supports Angle and the Print Bed**


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Supports Angle = 45˚
0˚
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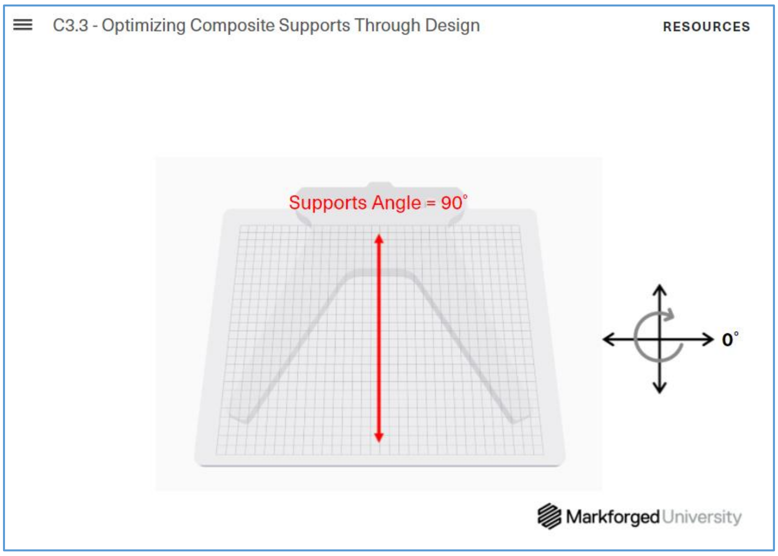
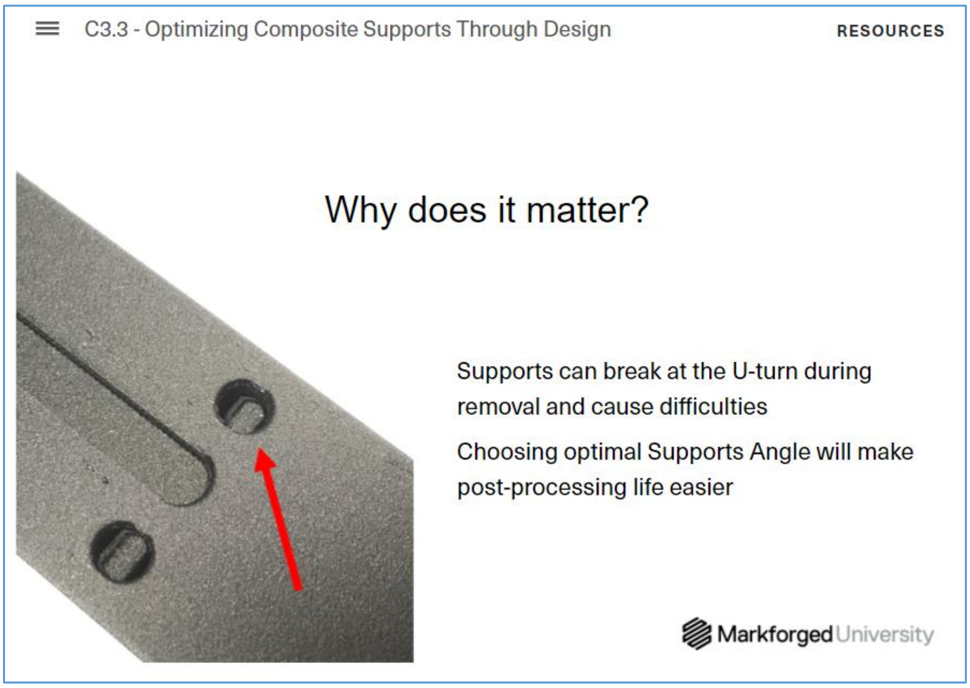
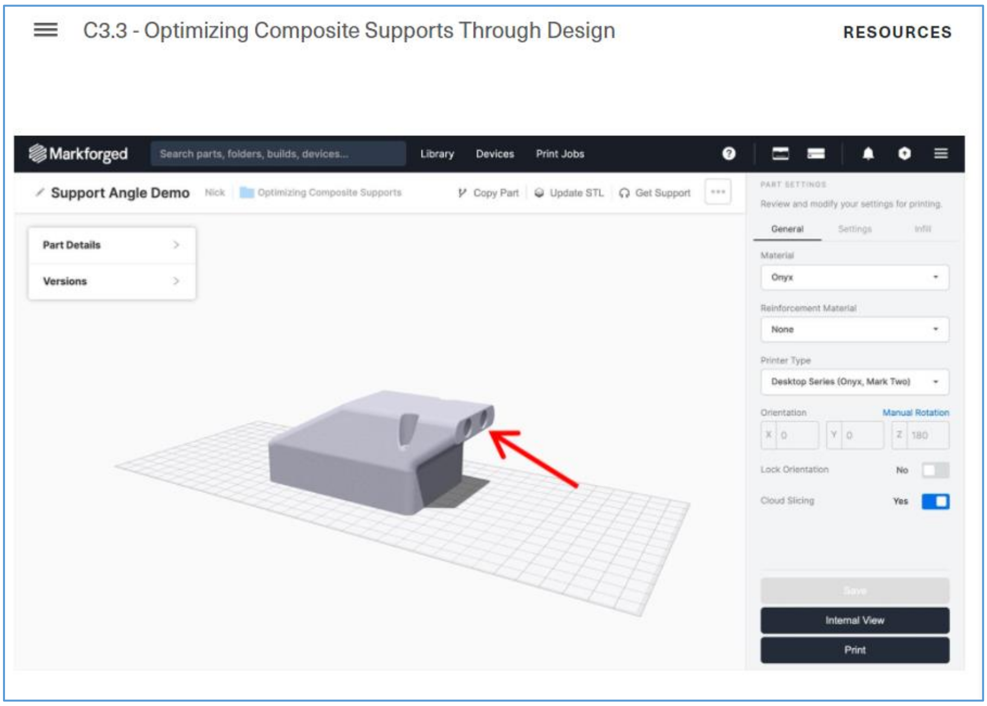

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Supports Angle = 90˚
0˚
Markforged University

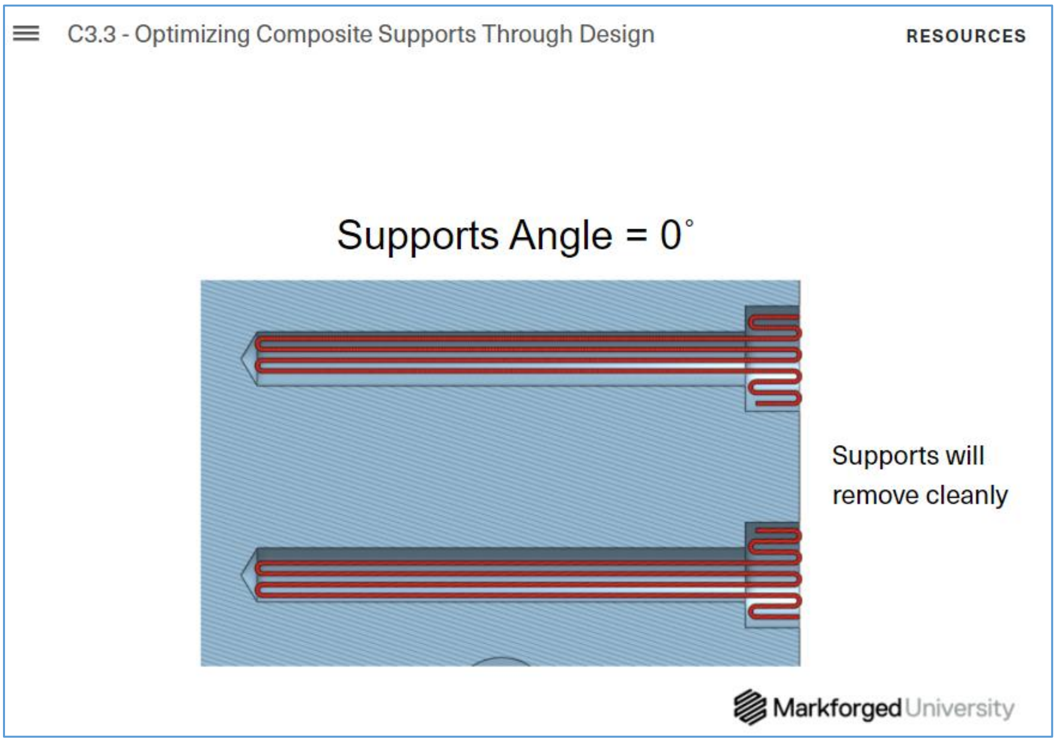


- **Why does it matter?**

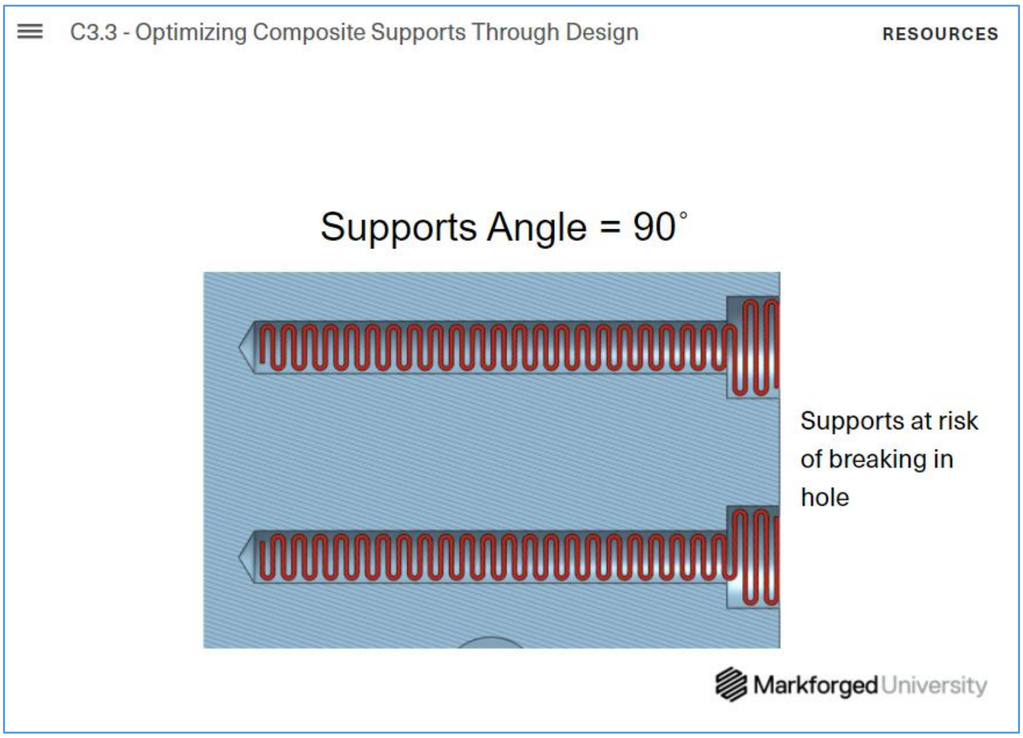
- **Strategy: Align Supports Axial to Holes.**



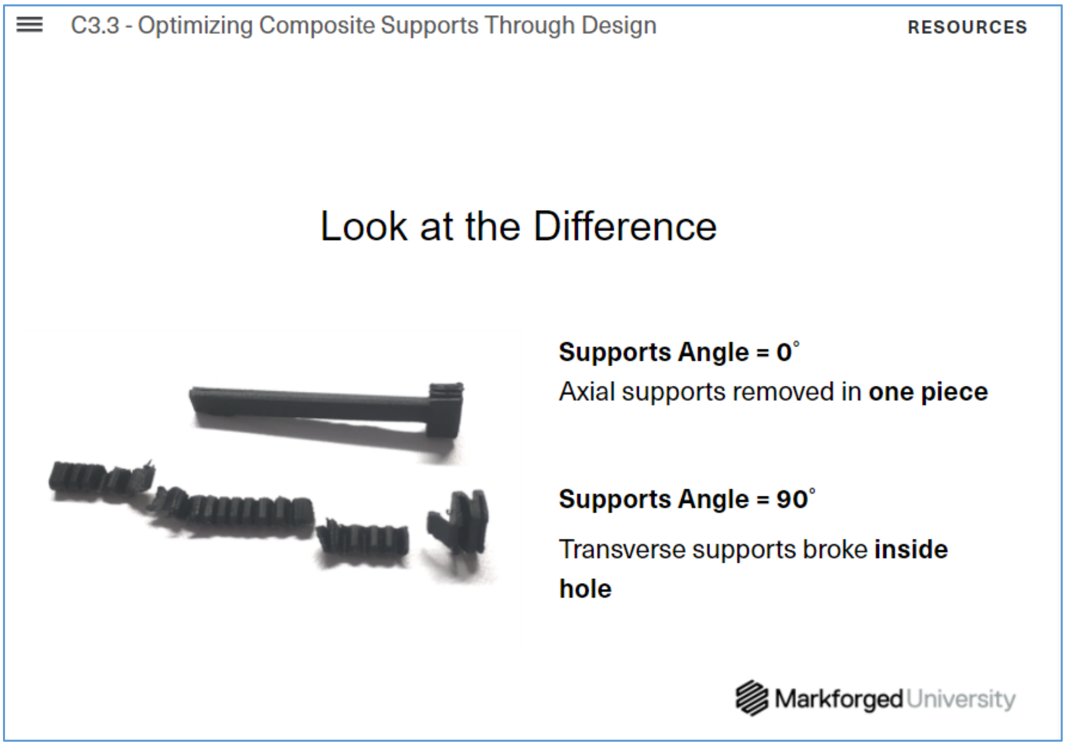
- **Example: Deep Horizontal Bores**



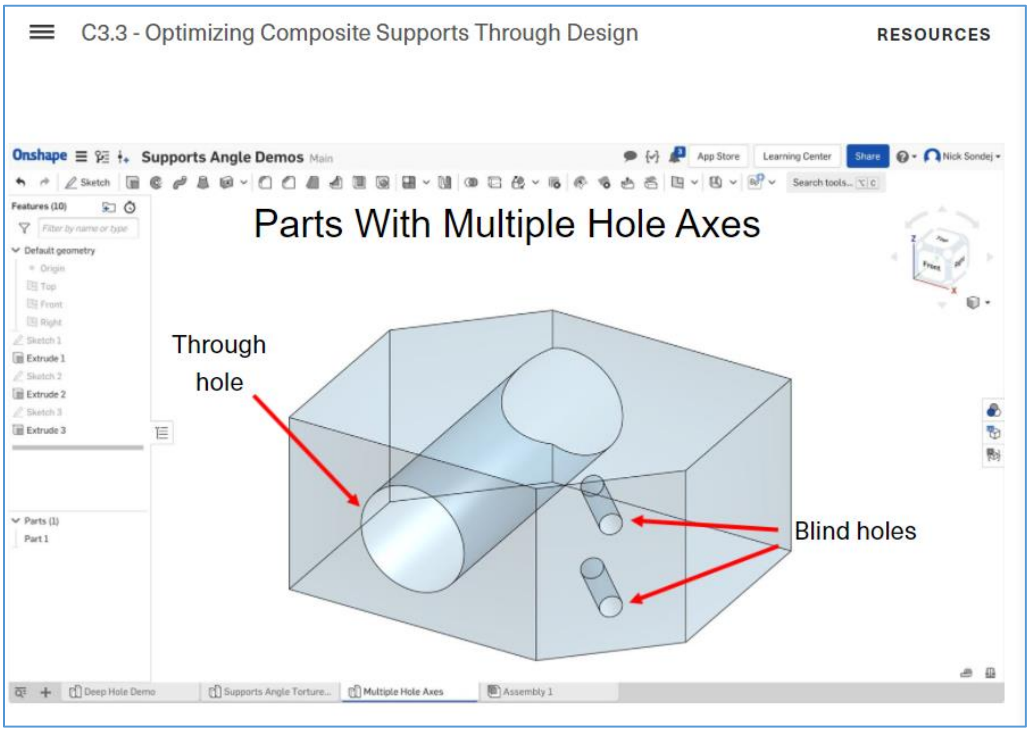
- **Supports Angle = 0°**
    - U-turn horizontal.
    - Easy to remove,.



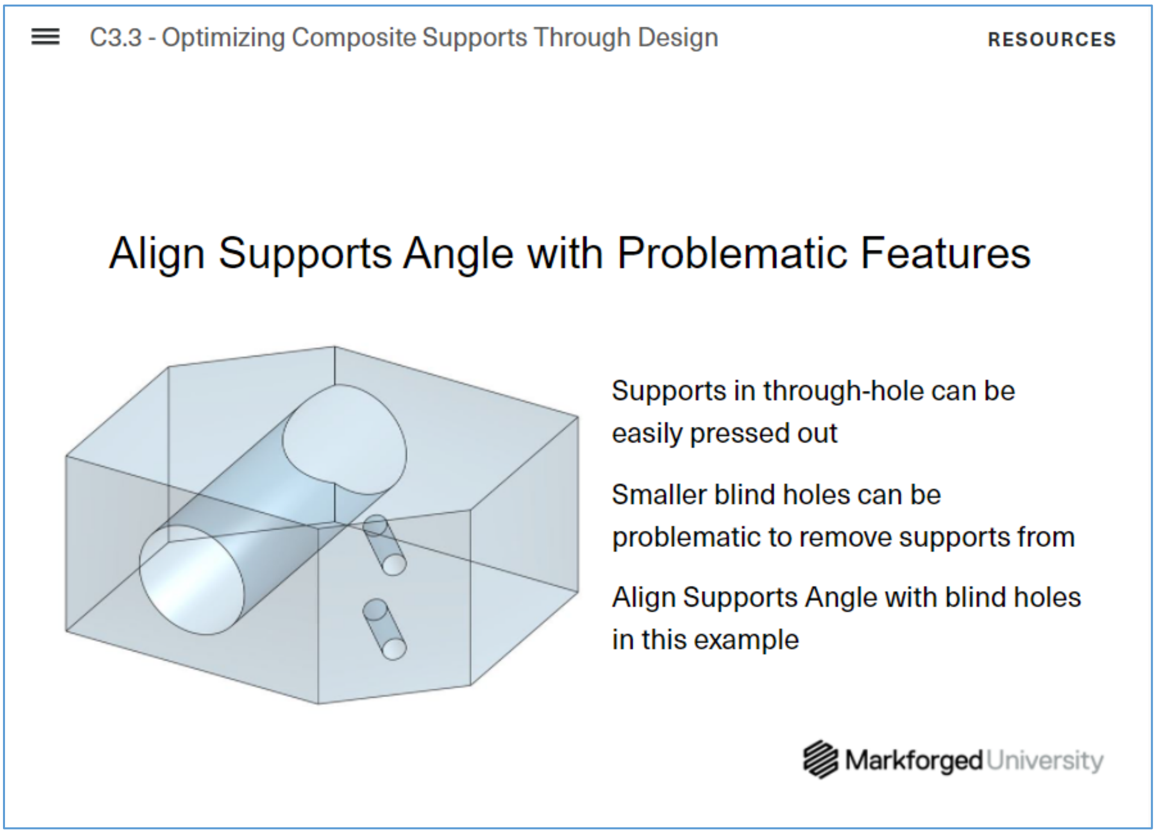
- **Supports Angle = 90°**
    - U-turn horizontal.
    - Hard to remove.



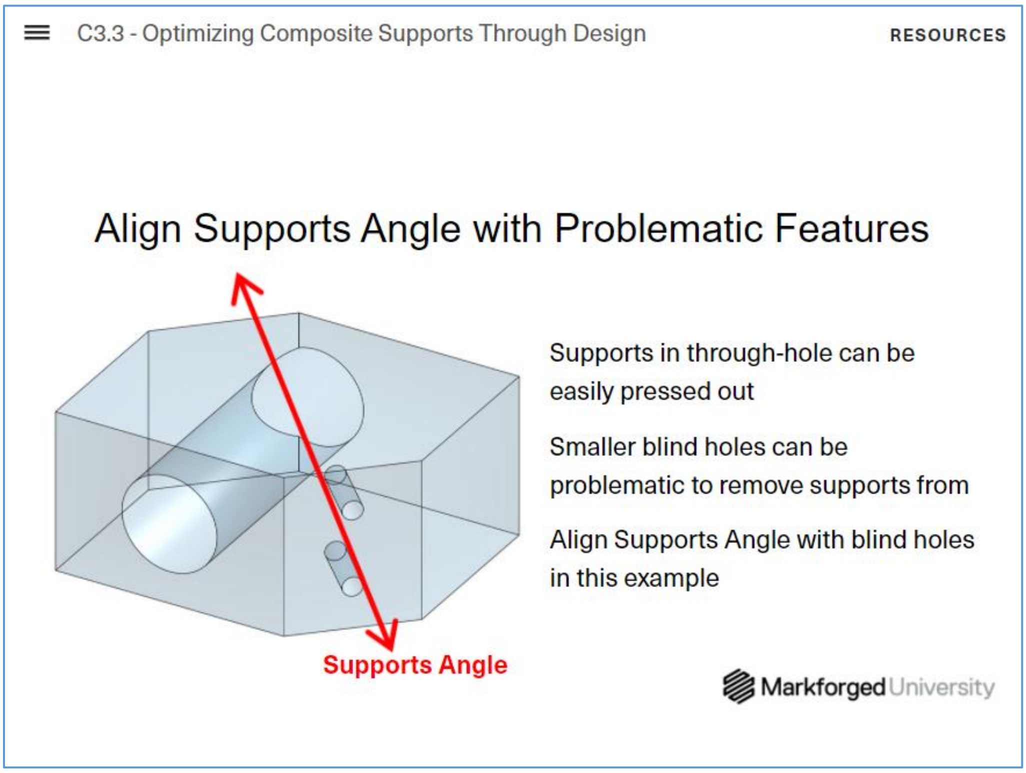
- **Look at the Difference**



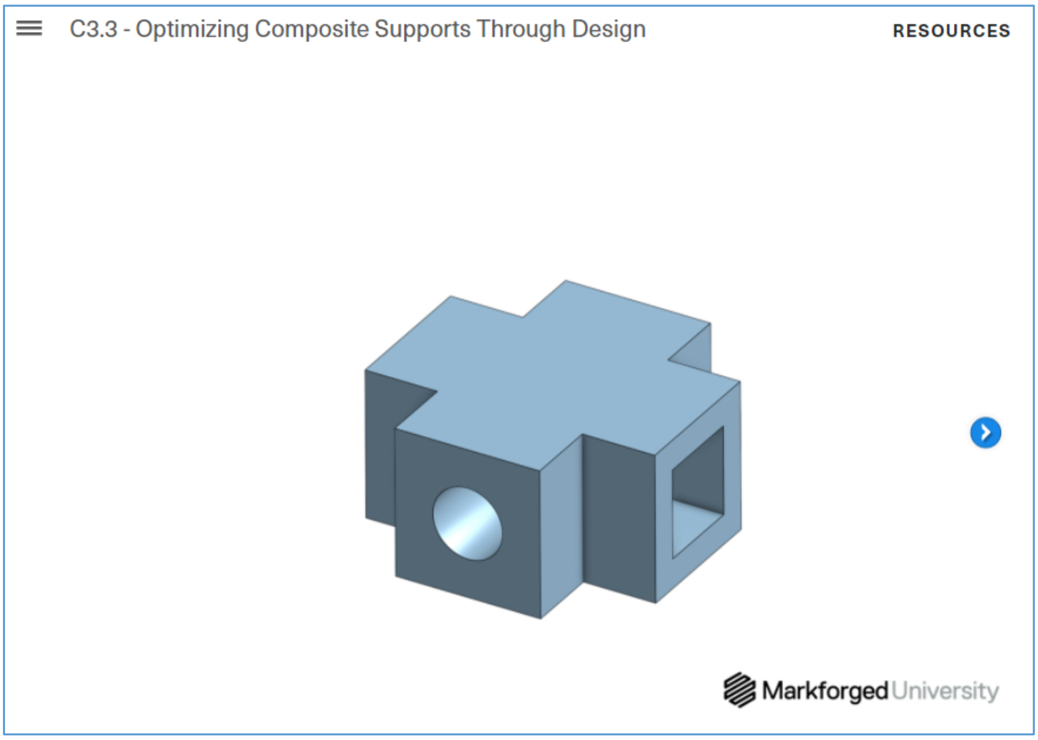
- **Parts With Multiple Hole Axes**



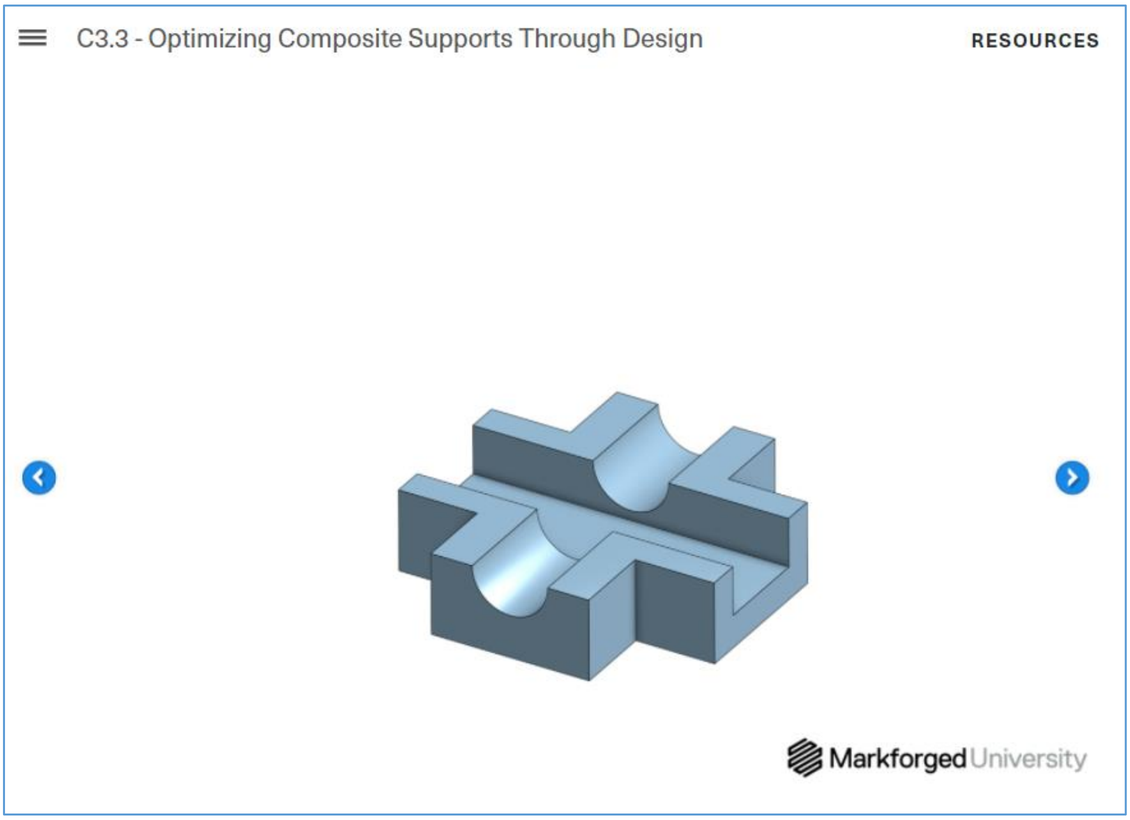
- **Align Supports Angle with Problematic Features**



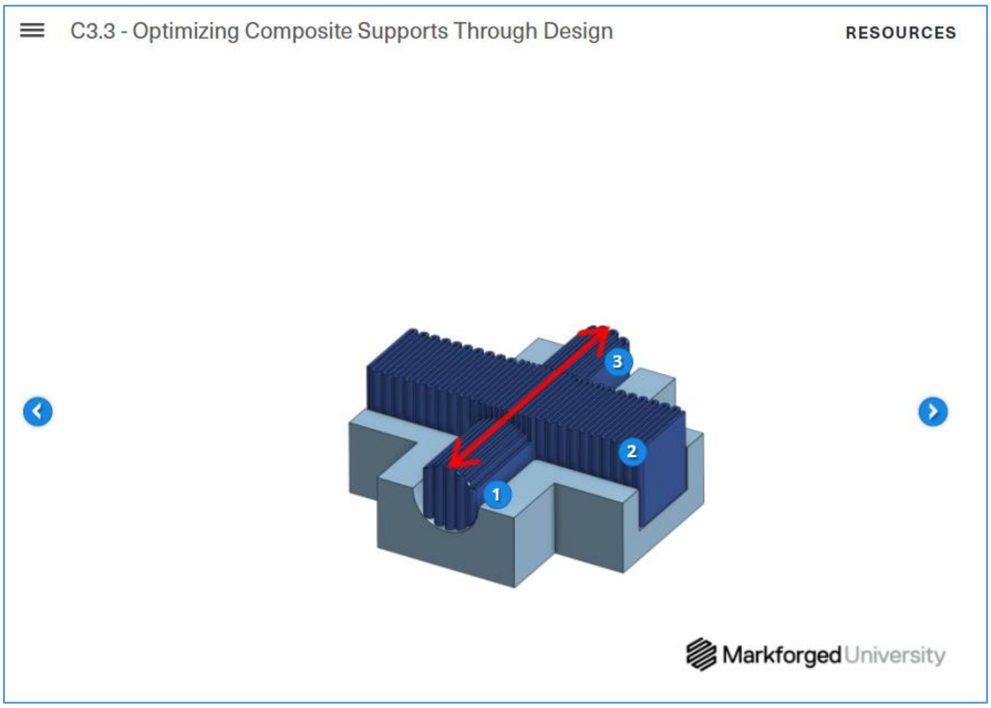
- **Improving Support Removal By Breaking Up Regions**

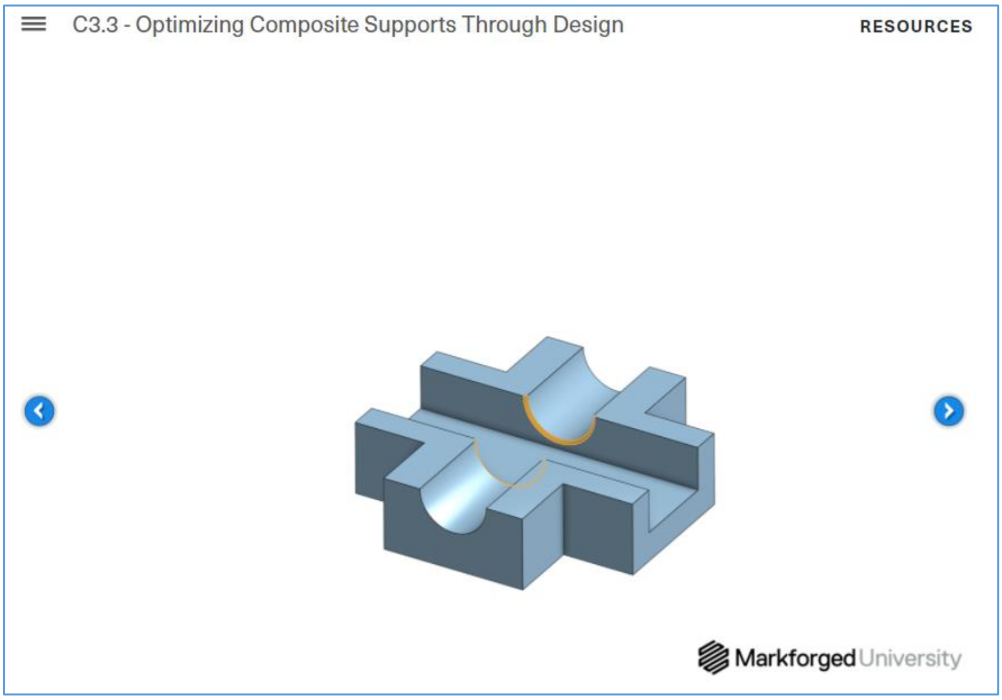


- **CAD Example**

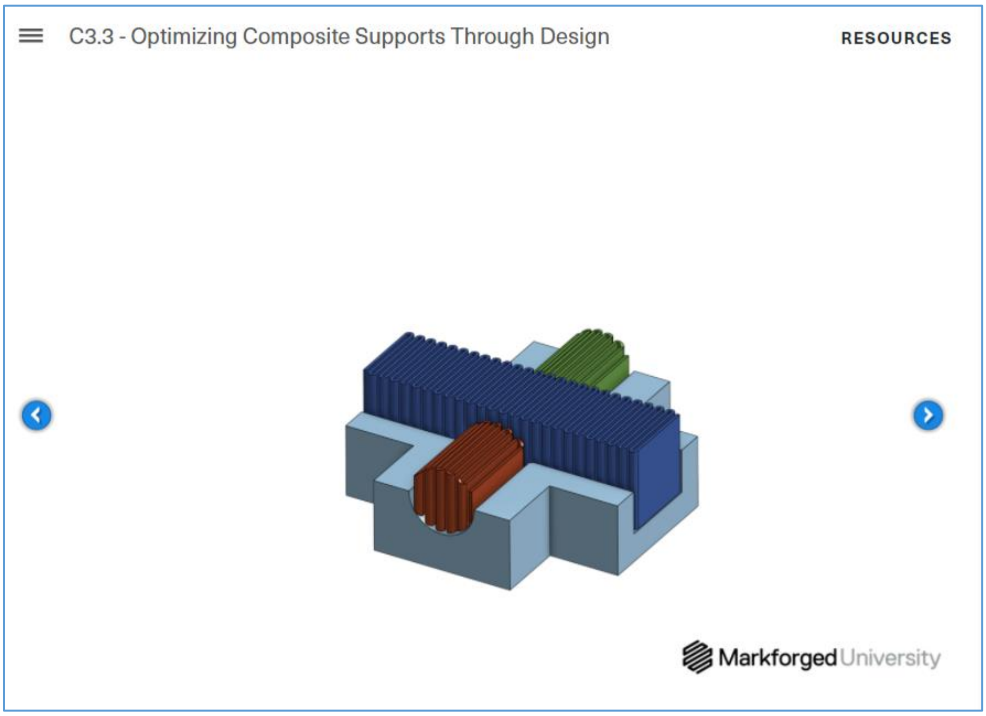


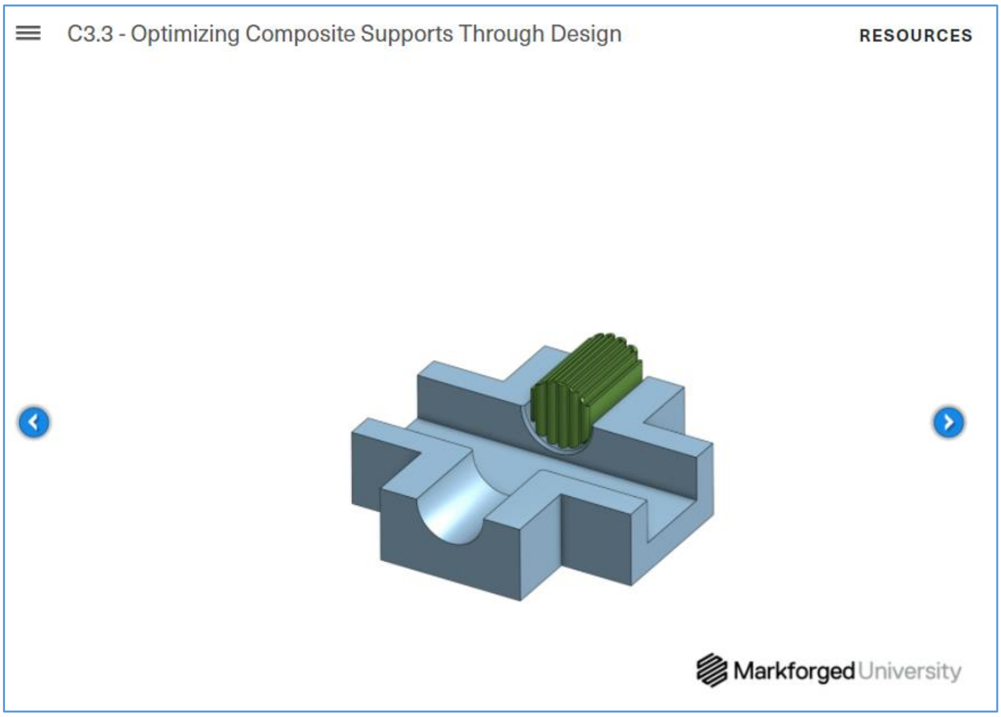
  - One circular bore and on square.
  - The diameter of the bore does not extend all the way the bottom of the square one.

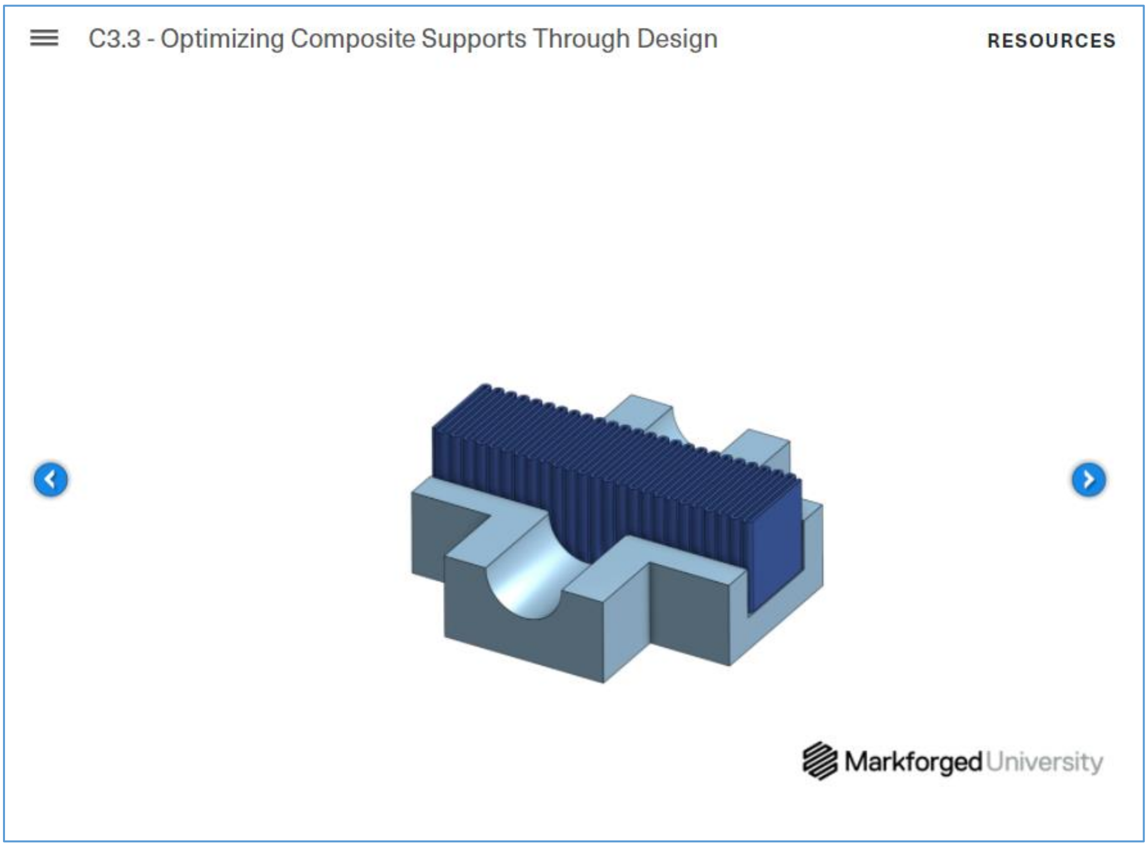


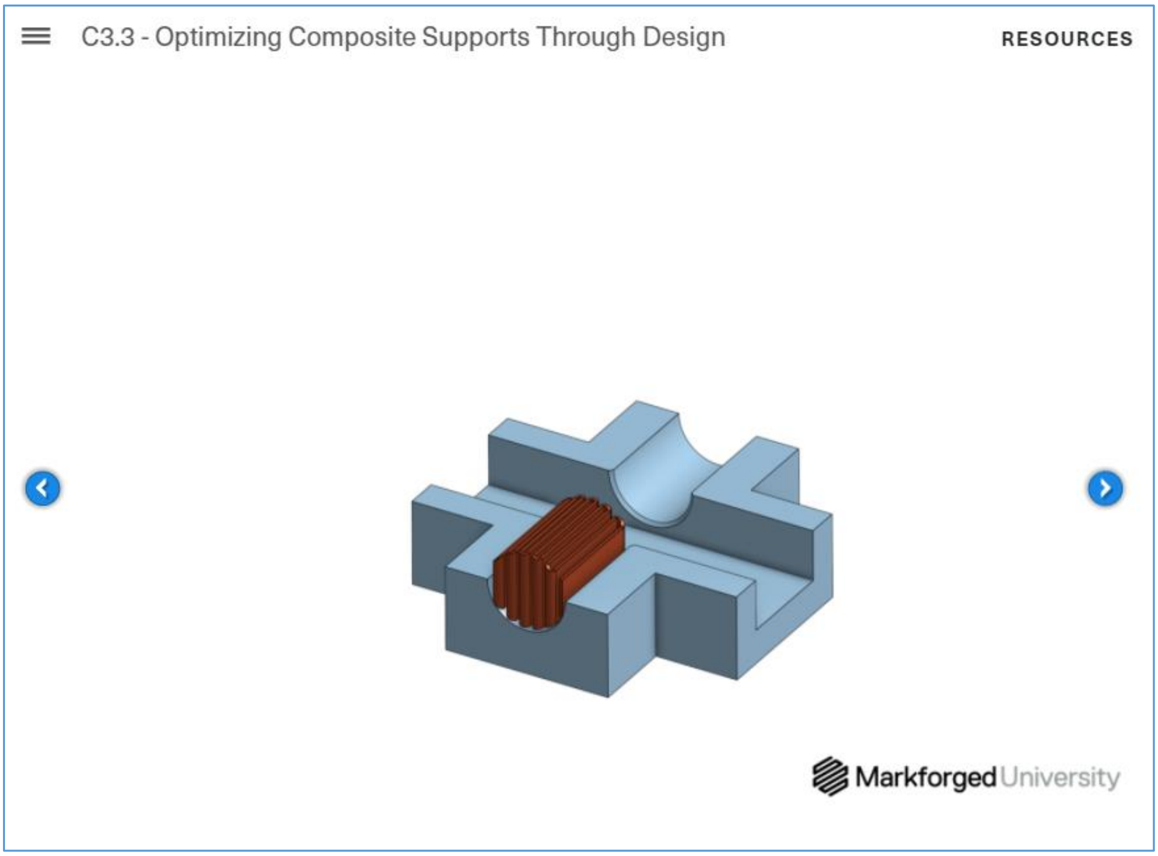


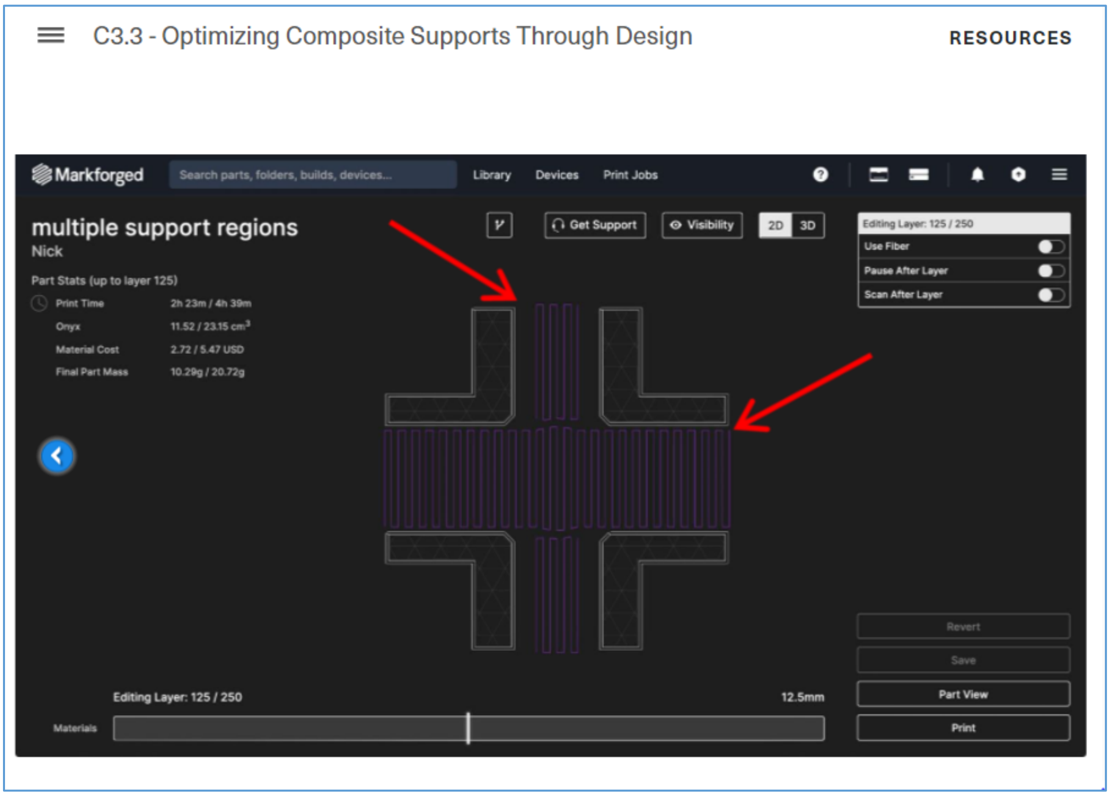
- Using chamfers will be the key to the solution.


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged University

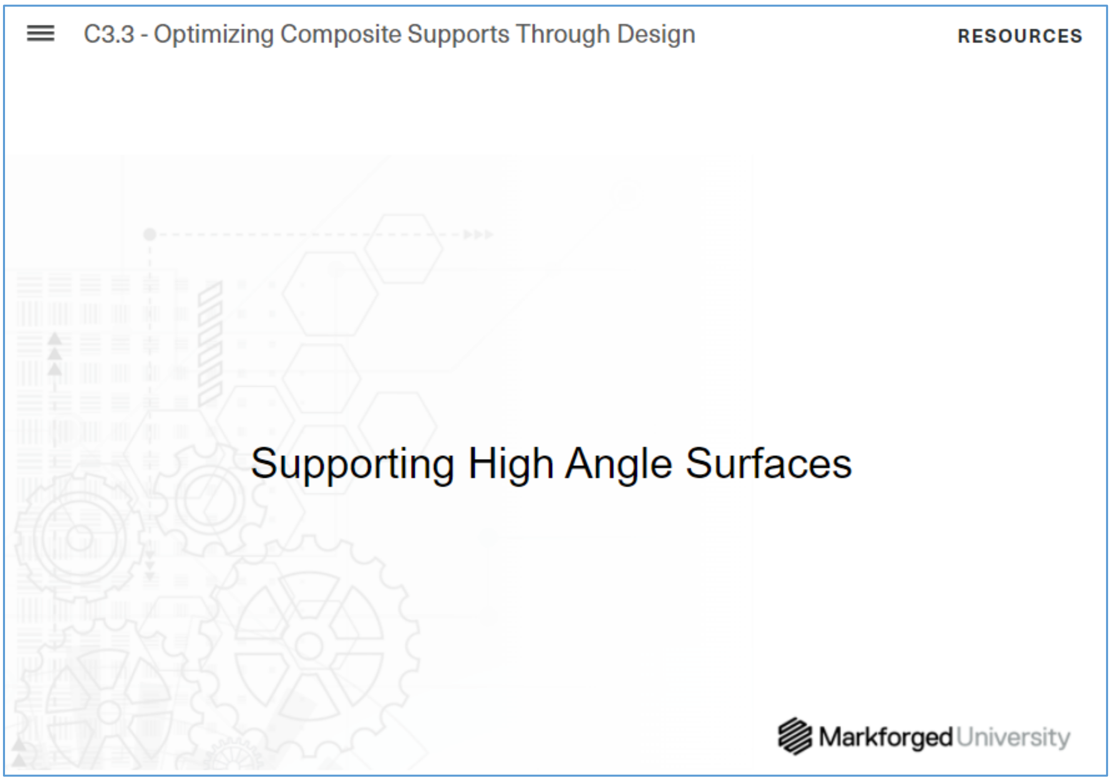

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged University


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged University

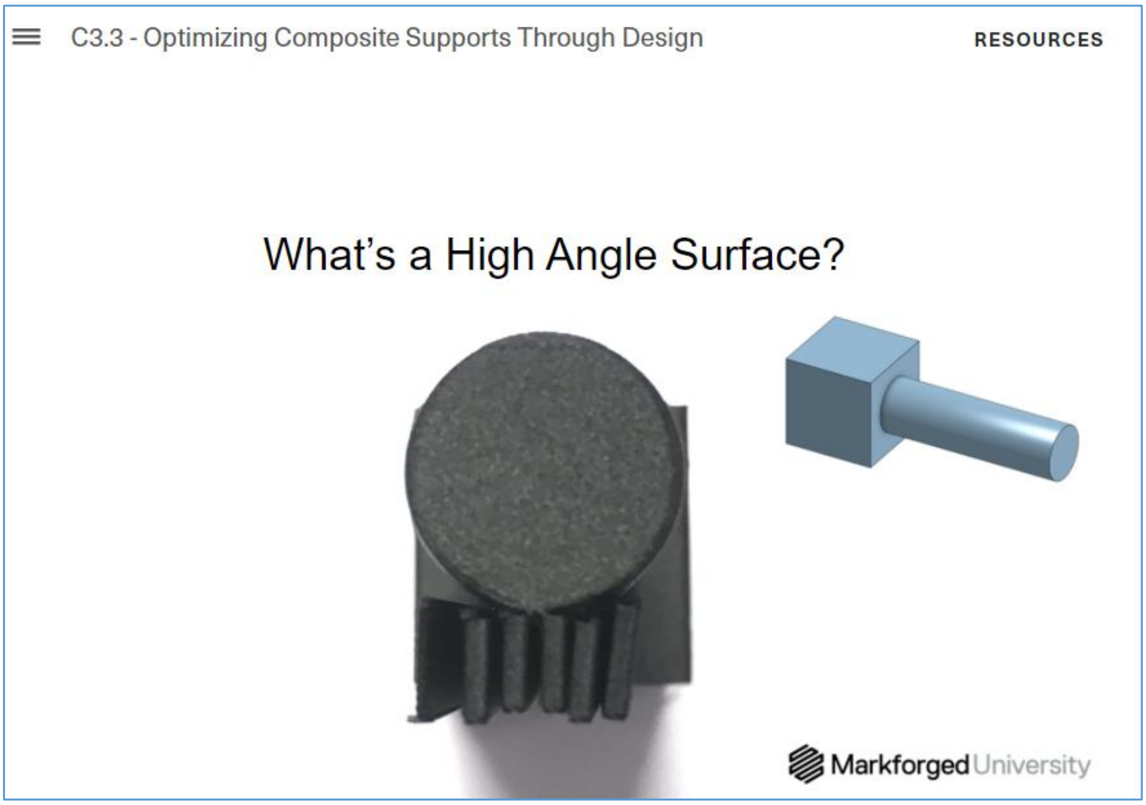

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged University



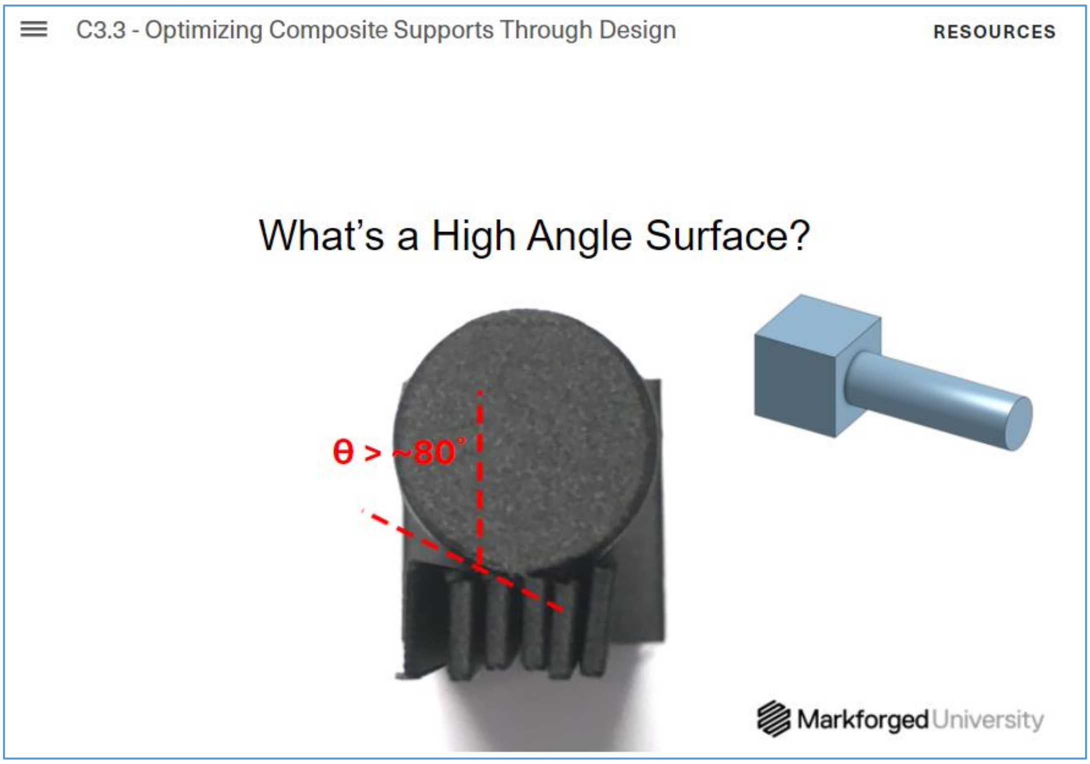
- Realized by using the chamfers.



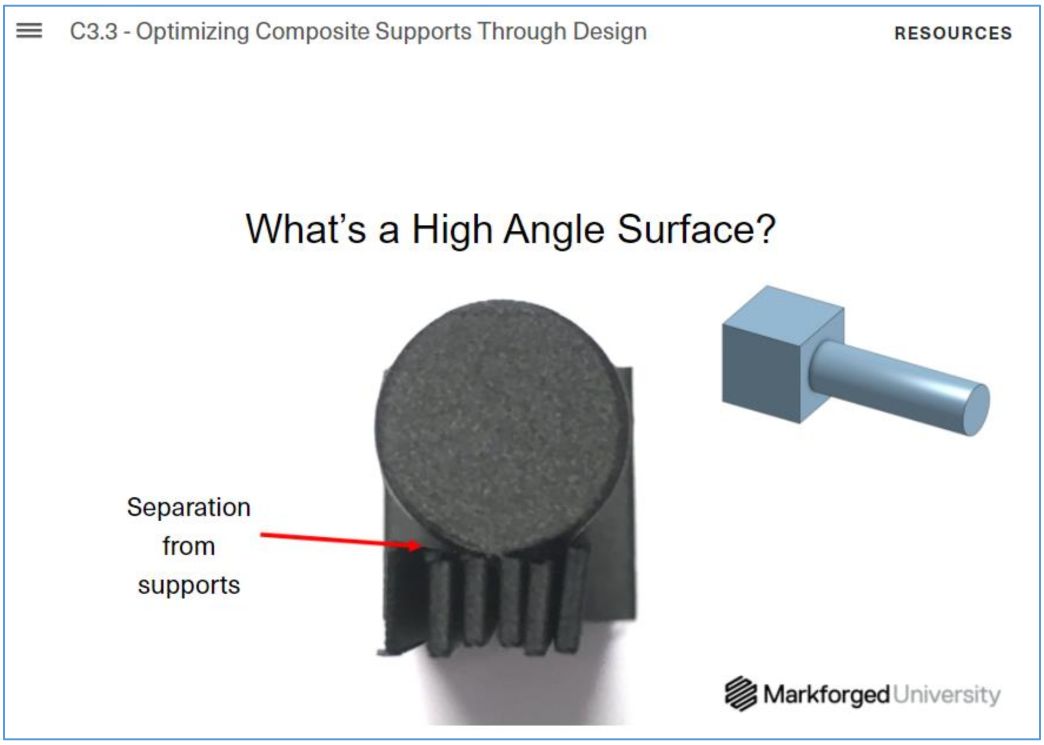
- **Supporting High Angle Surfaces**



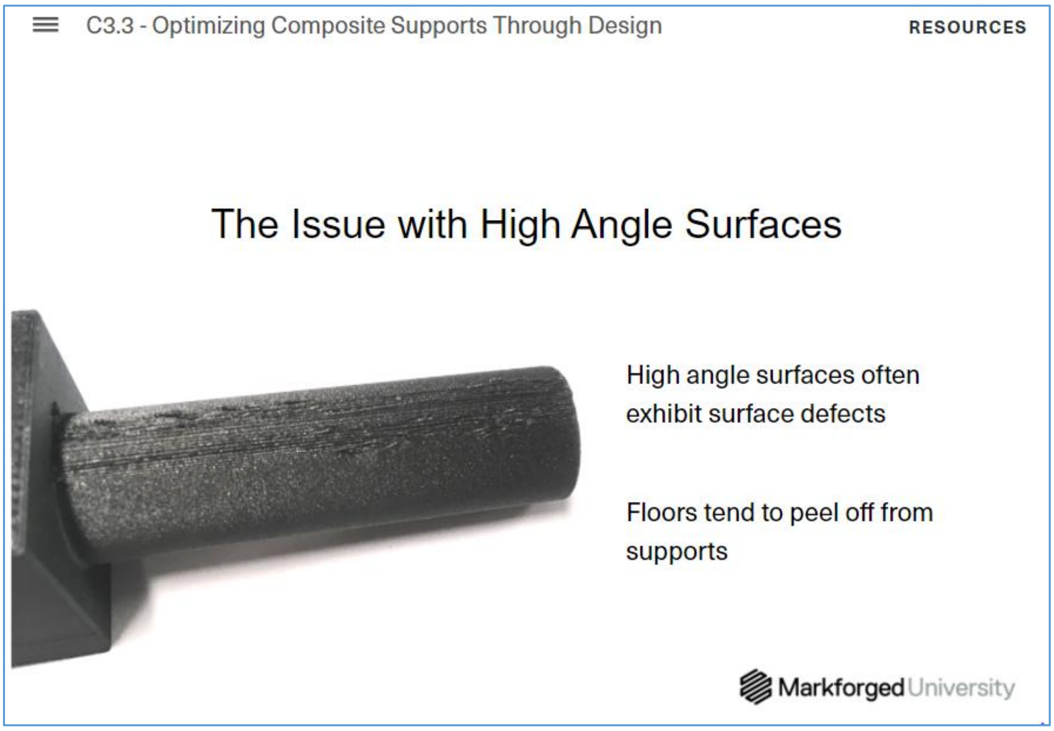
- **What's a High Single Surface?**



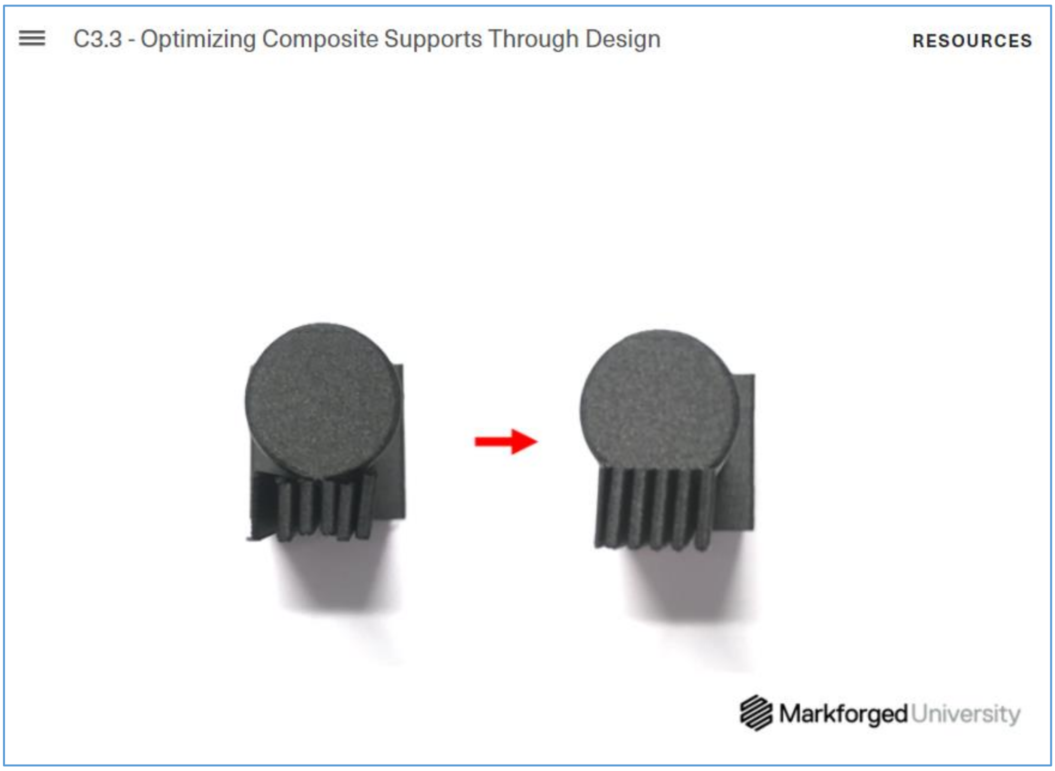
  - Pretty close to horizontal, but not quit.



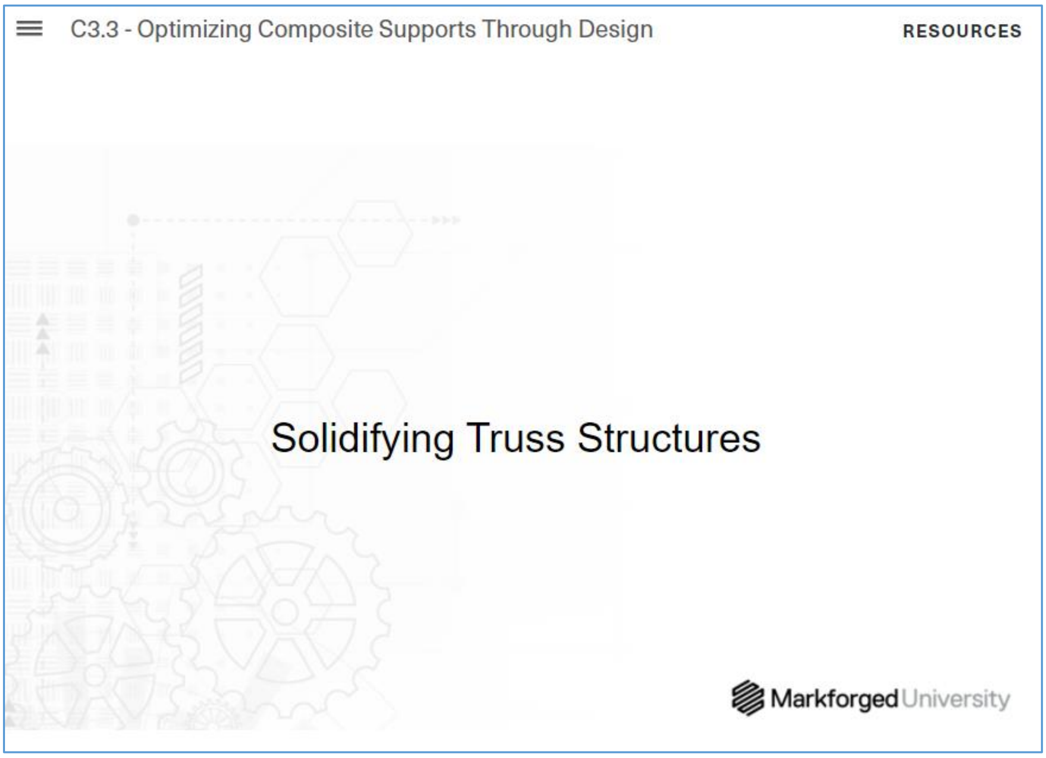
- Reduced part quality and increased surface defects.



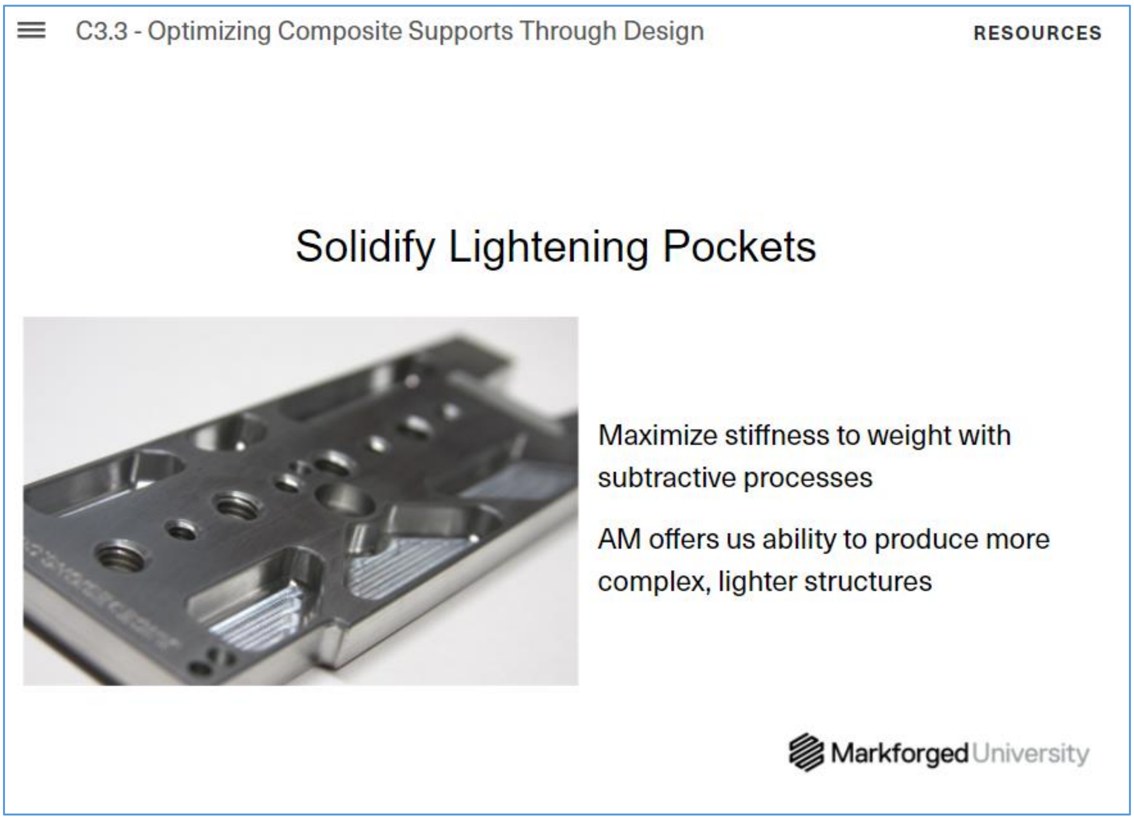
- **The Issue with High Angle Surfaces**
    - Exhibit =vertonen
    - Tend = de neiging tot.



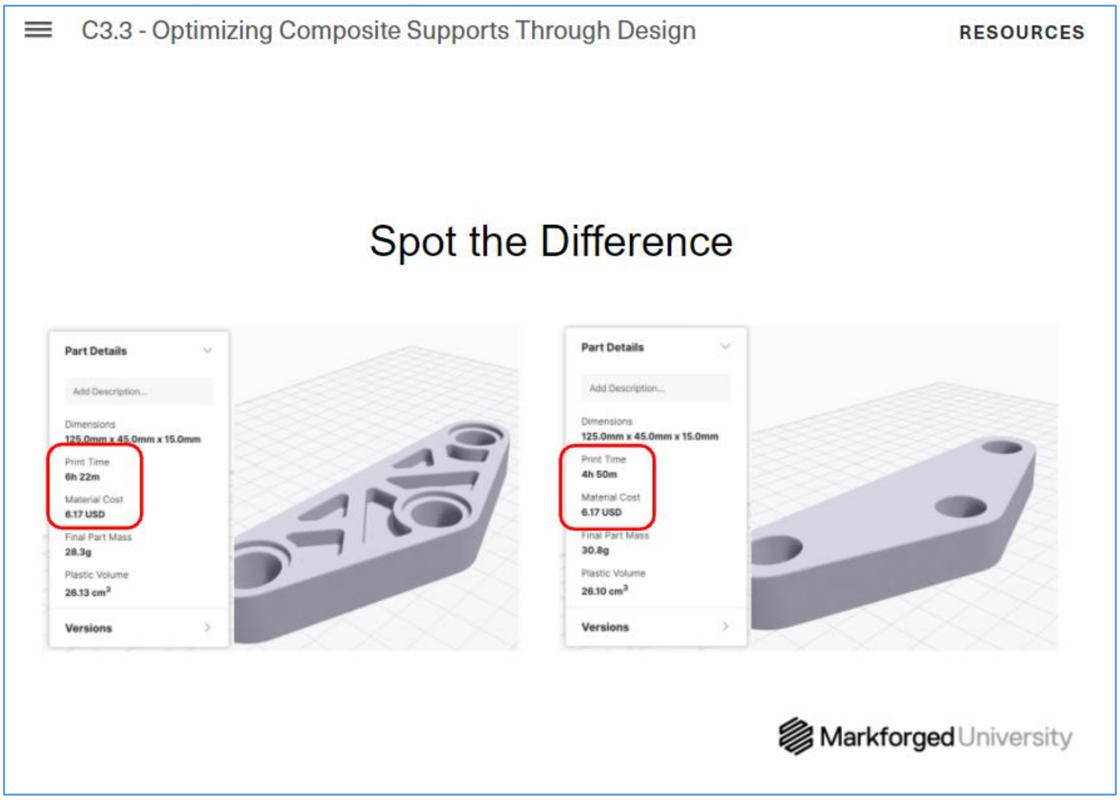
- **A potential Fix**



- **Solidifying Truss Structures**
    - Solidifying = verharden



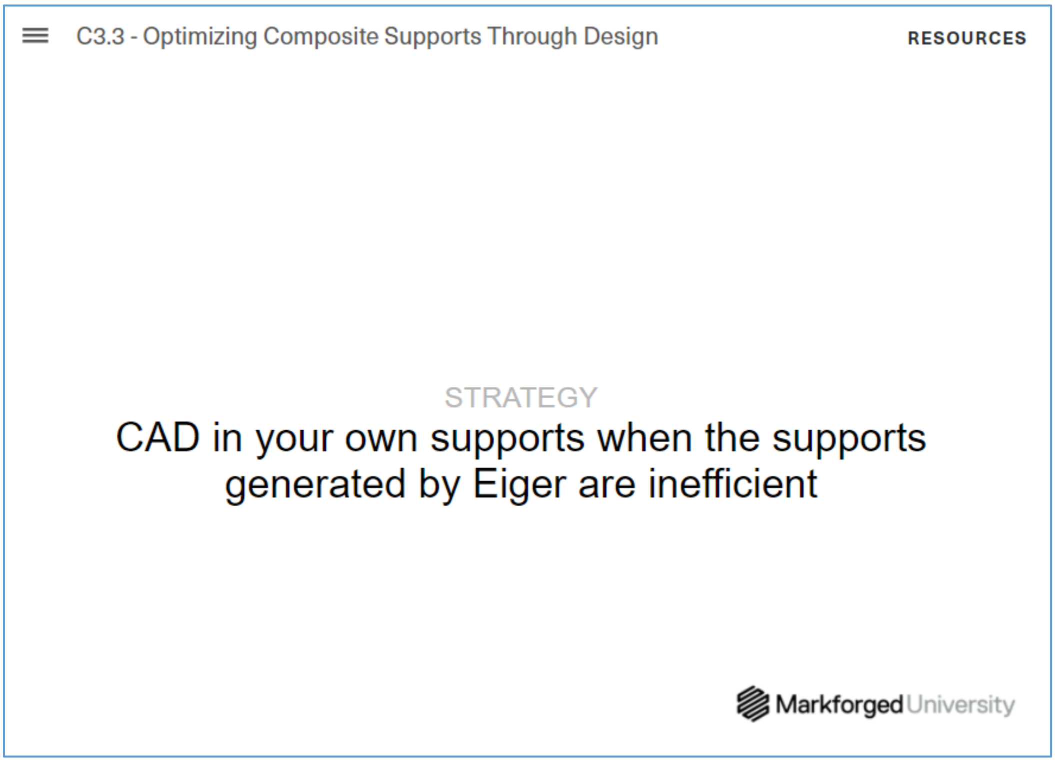
- **Lightening Pockets**
  - Subtractive = onttrekkend



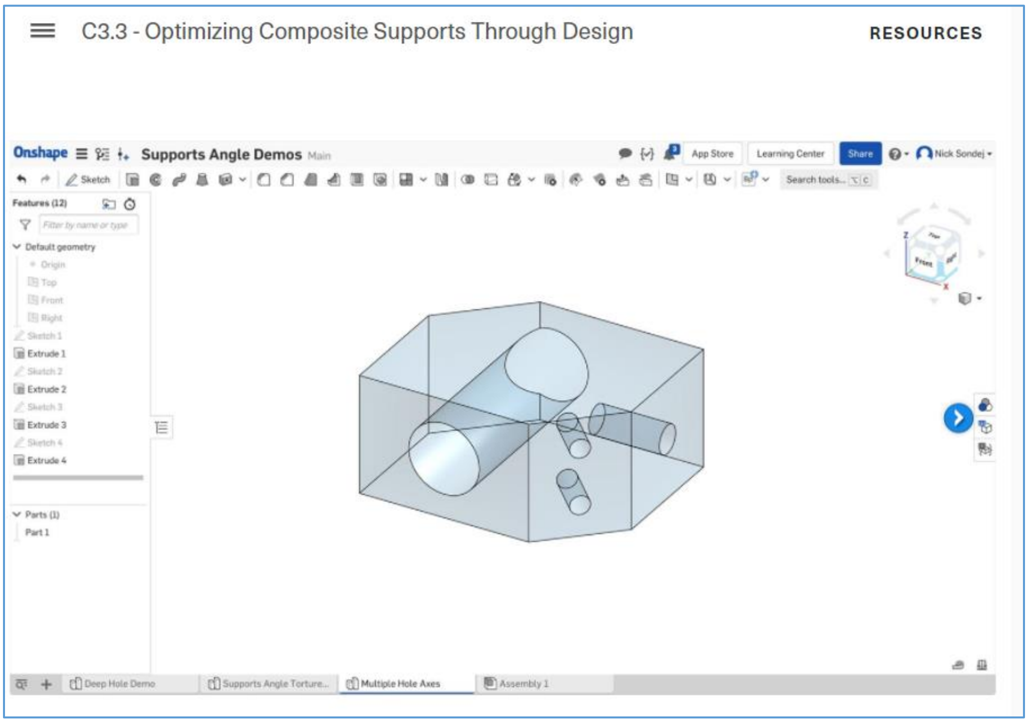
- **Spot the Difference**

- In case of a feature that was previously designed for machining. The right one requires less print time and is more solid. It turns out that the support structures of the left are unnecessary.

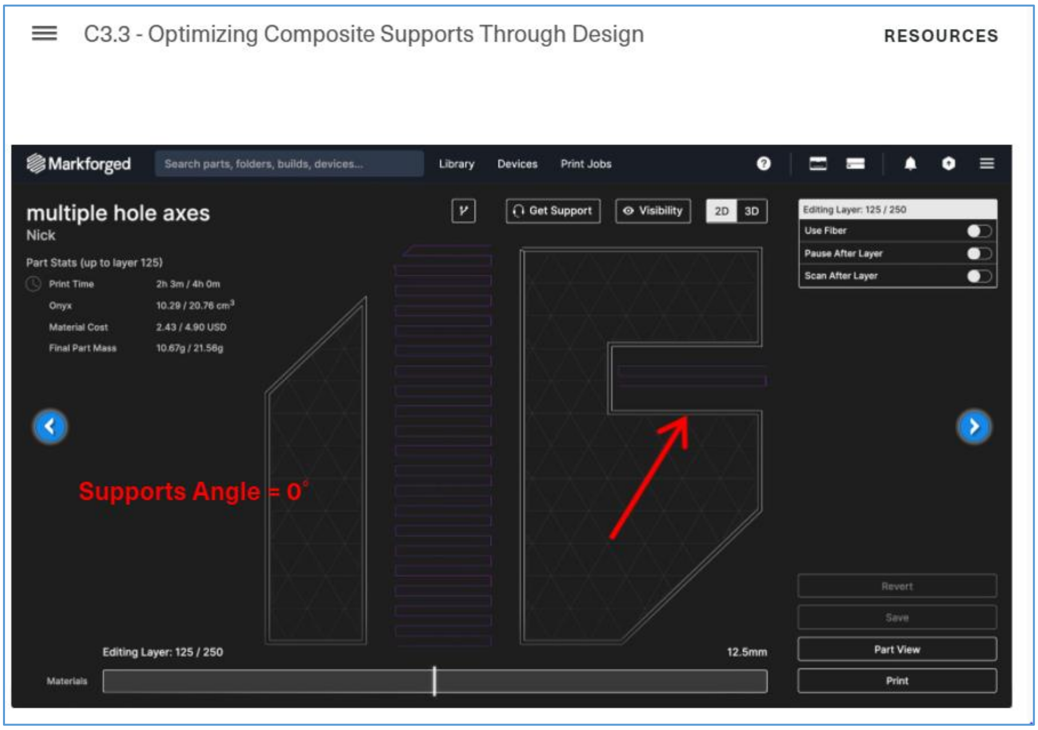
- **DIY Supports**

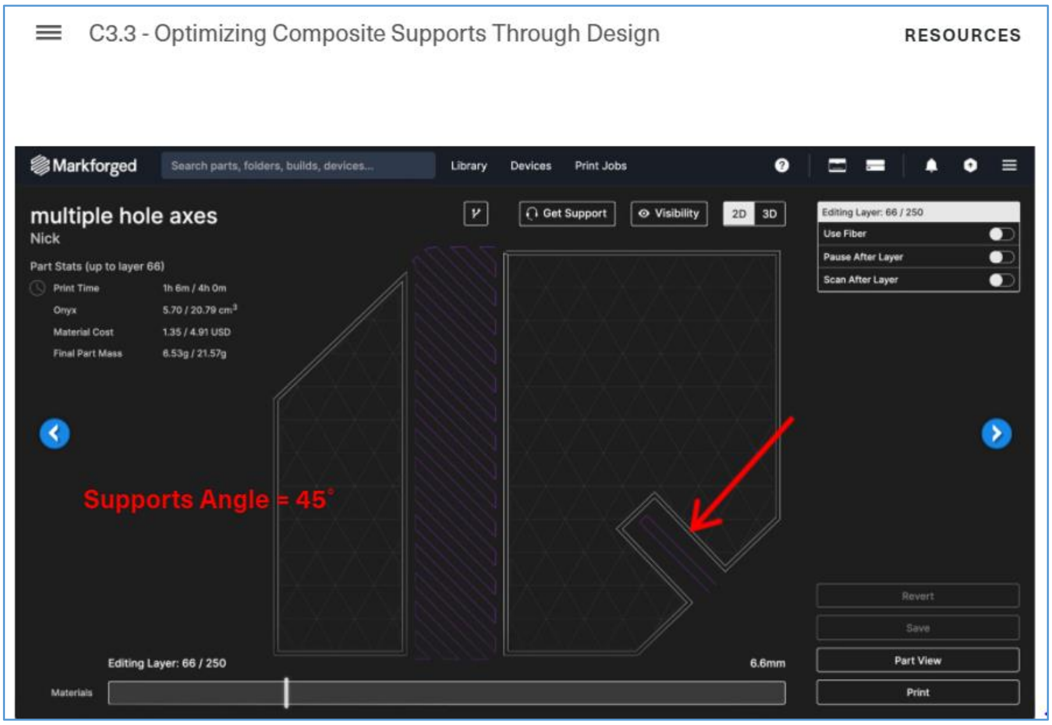


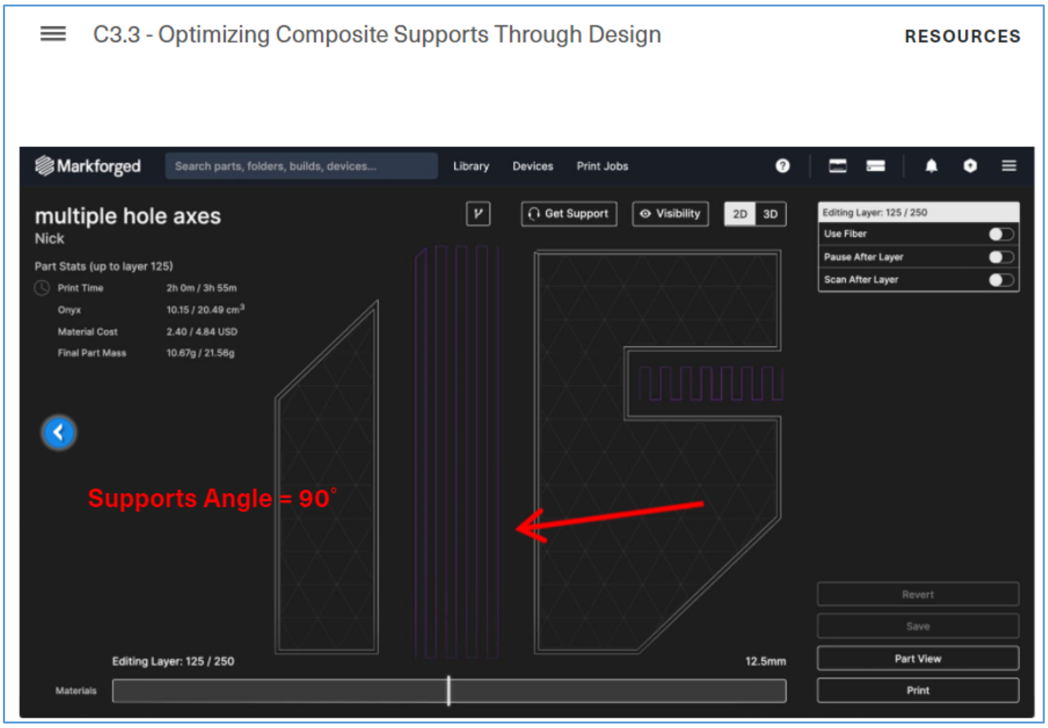
- **Strategy: Design Your Own Supports**

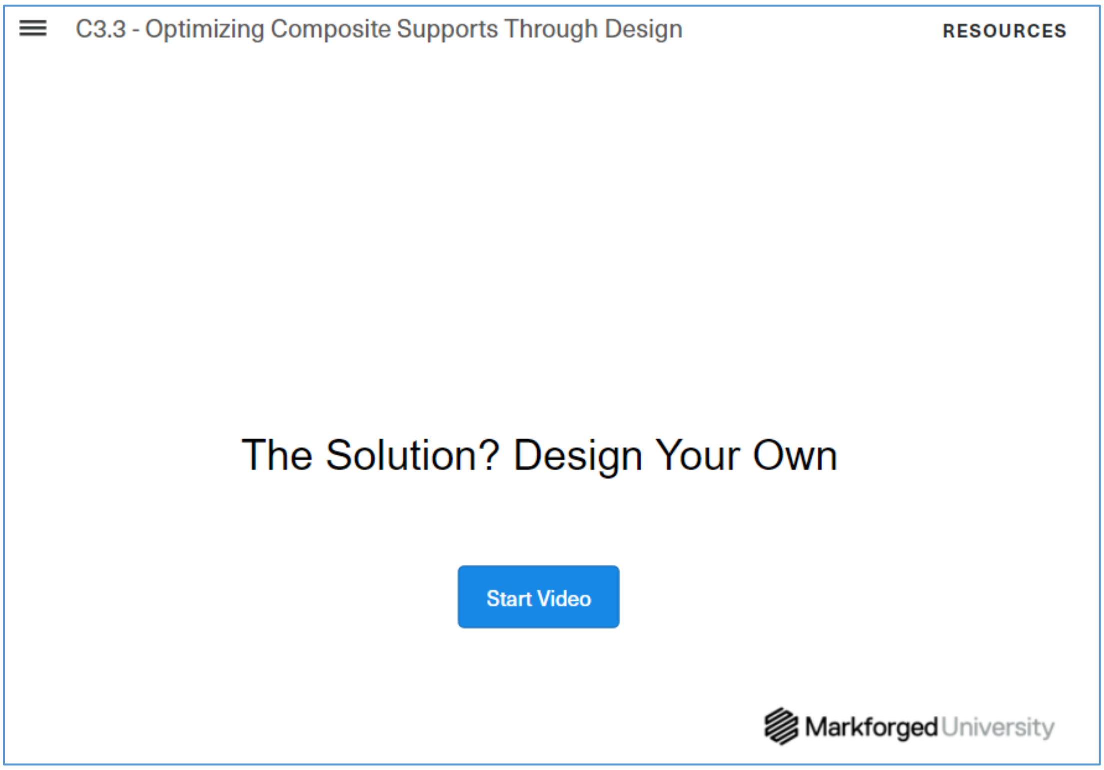


- **Example: DIY Supports**

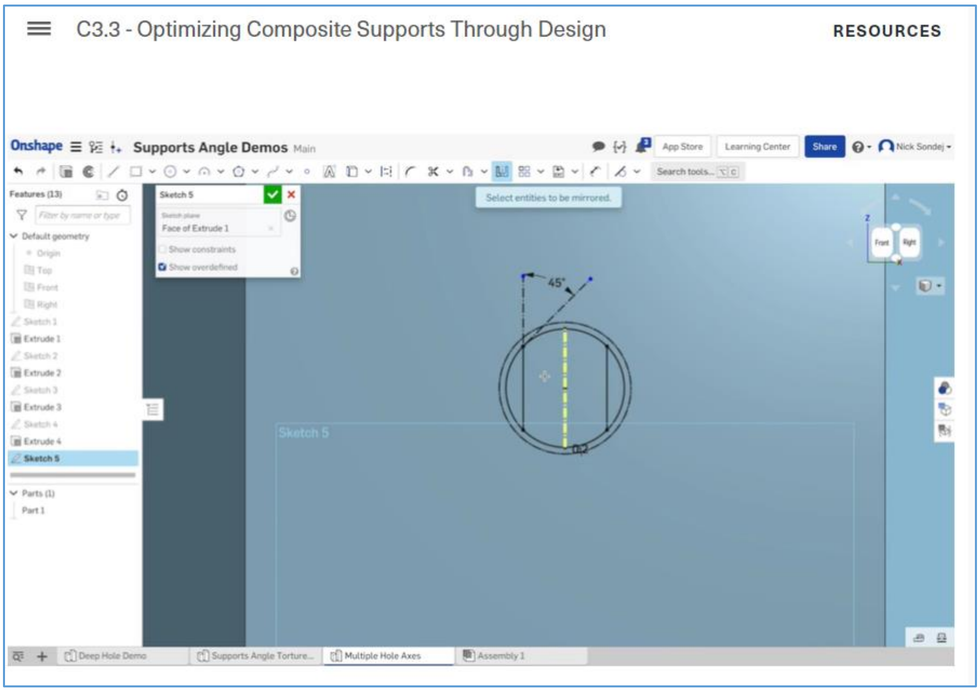


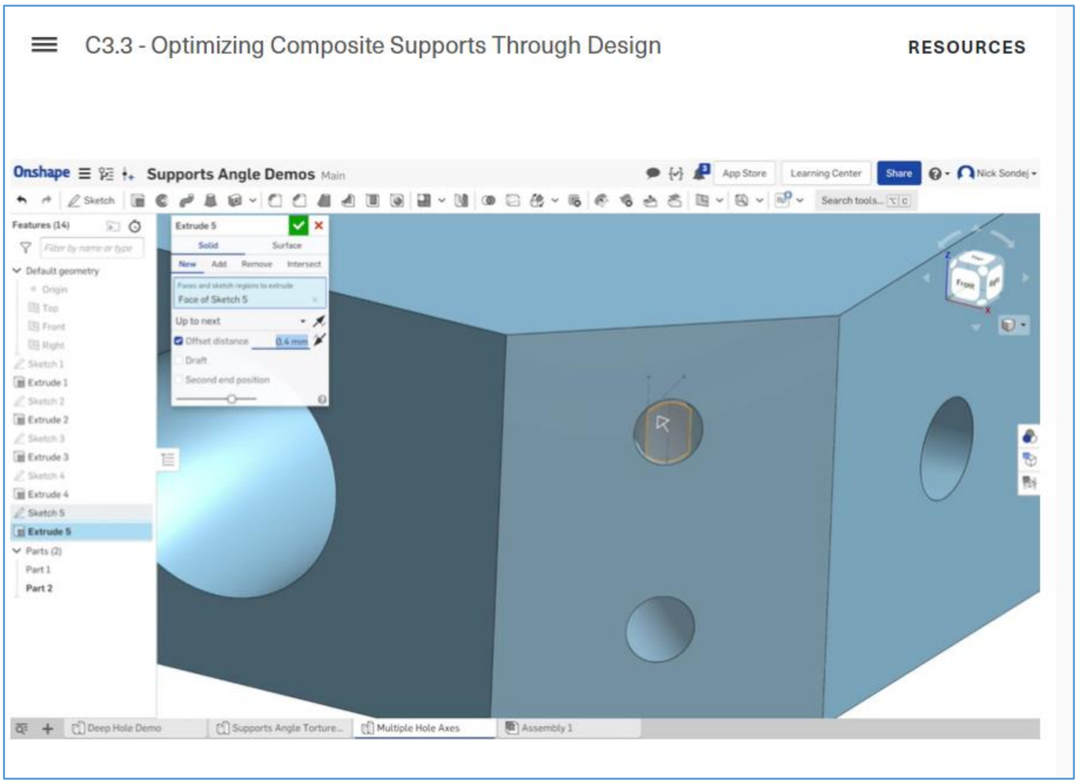

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
multiple hole axes
Nick
Get Support
Visibility
2D
3D
Editing Layer: 66 / 250
Use Fiber
Pause After Layer
Scan After Layer
Part Stats (up to layer 66)
Print Time
1h 6m / 4h 0m
Onyx
5.70 / 20.79 cm³
Material Cost
1.35 / 4.91 USD
Final Part Mass
6.53g / 21.57g
Supports Angle = 45˚
Revert
Save
Part View
Print
Editing Layer: 66 / 250
6.6mm
Materials


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
multiple hole axes
Nick
Get Support
Visibility
2D
3D
Editing Layer: 125 / 250
Use Fiber
Pause After Layer
Scan After Layer
Part Stats (up to layer 125)
Print Time
2h 0m / 3h 55m
Onyx
10.15 / 20.49 cm³
Material Cost
2.40 / 4.84 USD
Final Part Mass
10.67g / 21.56g
Supports Angle = 90˚
Revert
Save
Part View
Print
Editing Layer: 125 / 250
12.5mm
Materials

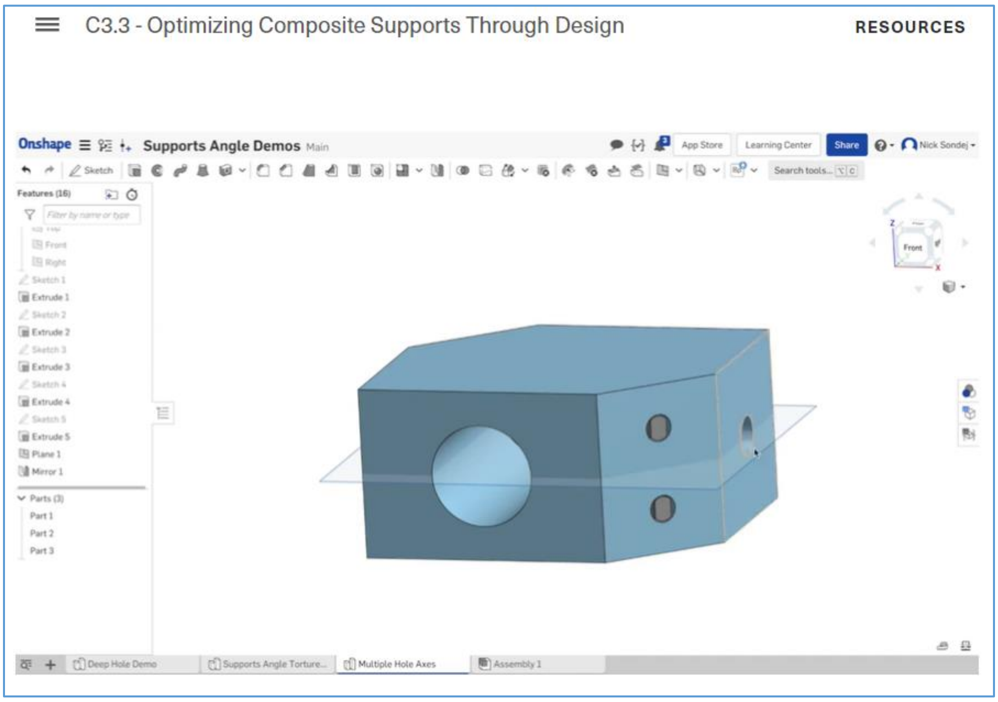


- **Video: Designing Your Own Supports**

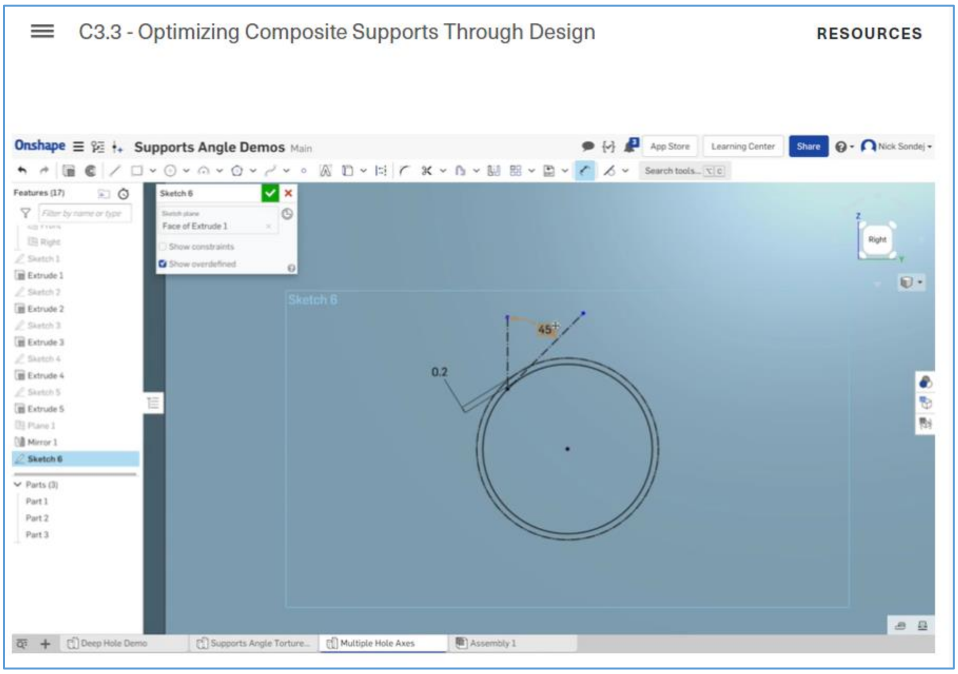


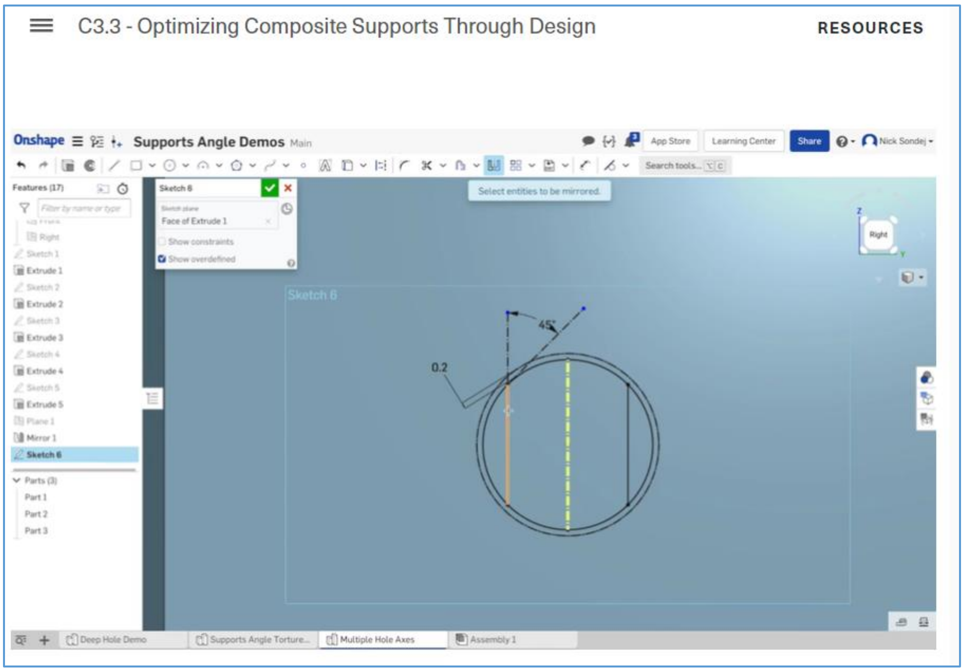


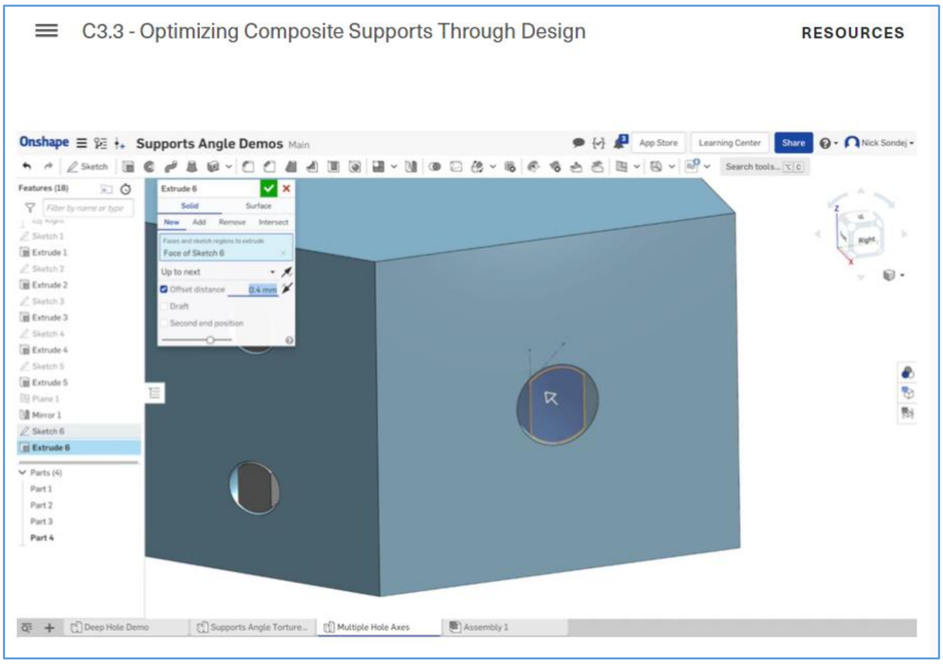
- Notice: Offset distance

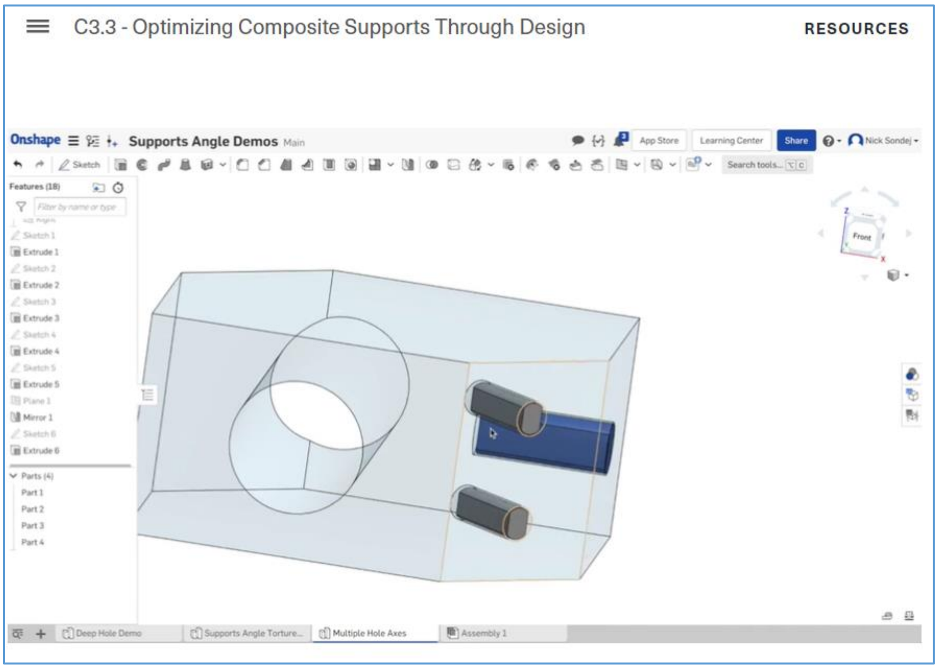


- Mirroring support feature over mid plane.

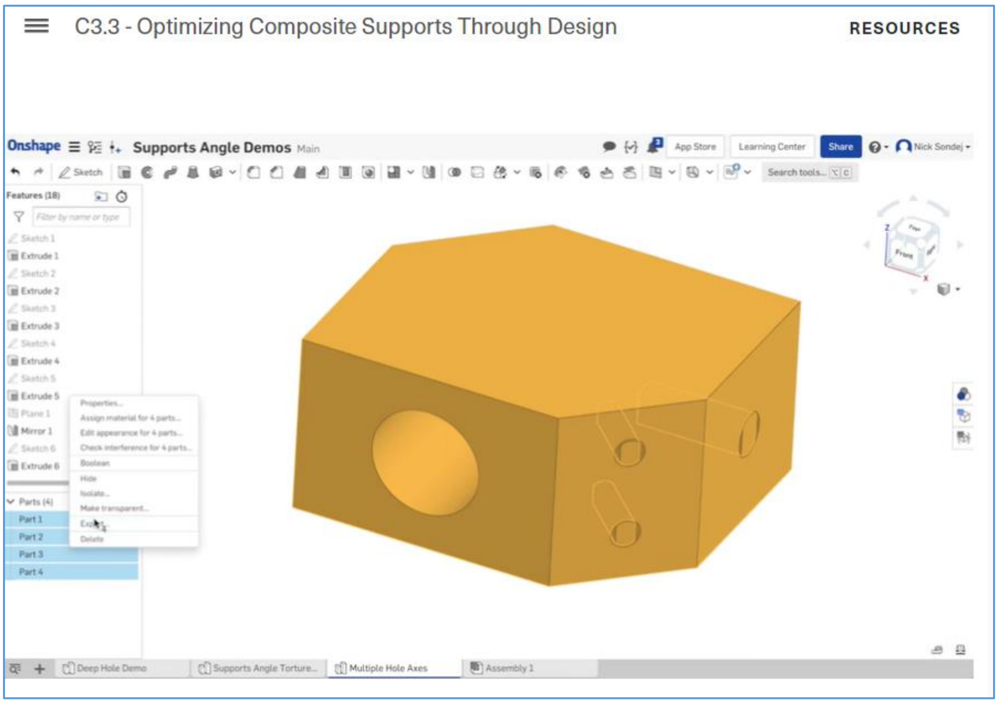

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Supports Angle Demos
Sketch 6
45°
0.2


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Onshape
Supports Angle Demos
Select entities to be mirrored.
Sketch 6
45°
0.2

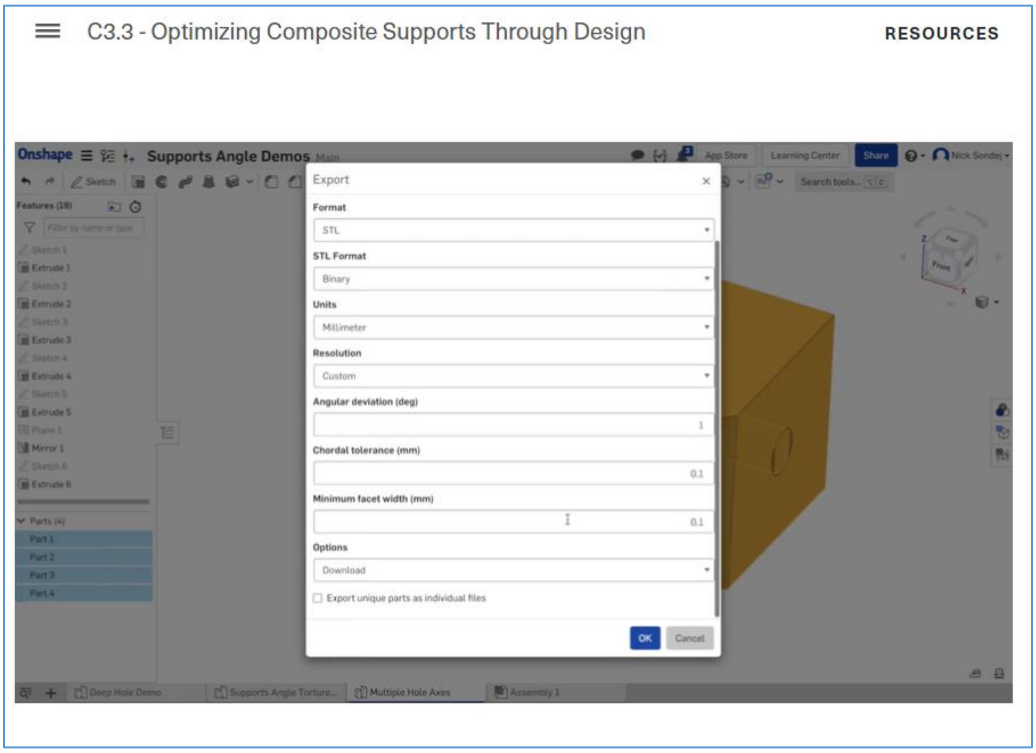




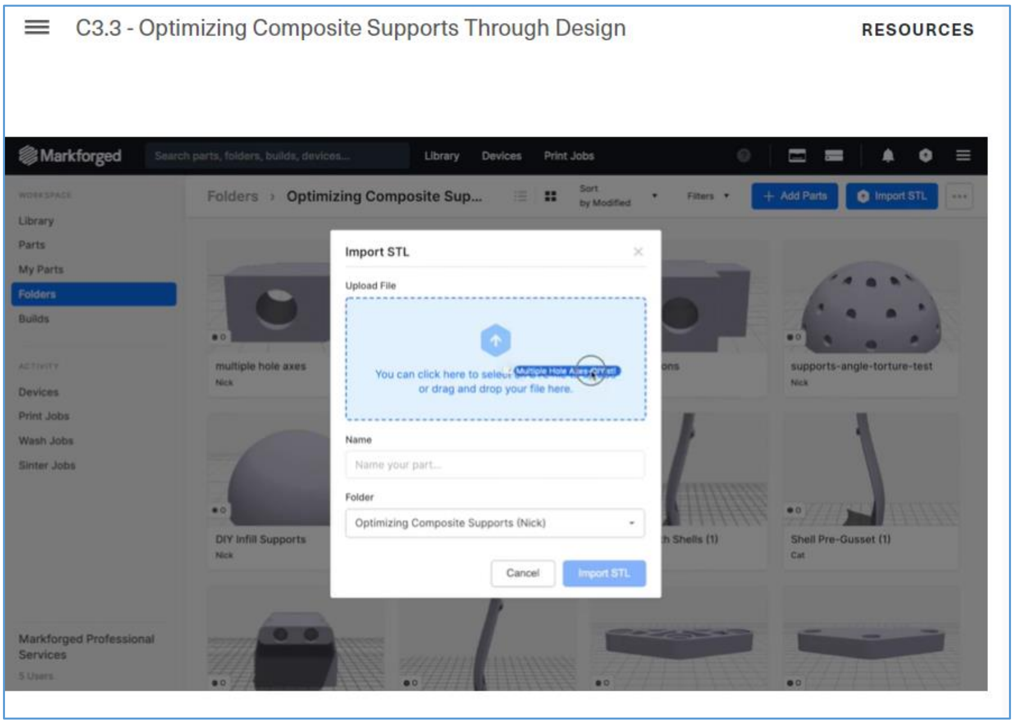
- Support does not touching the part at any point



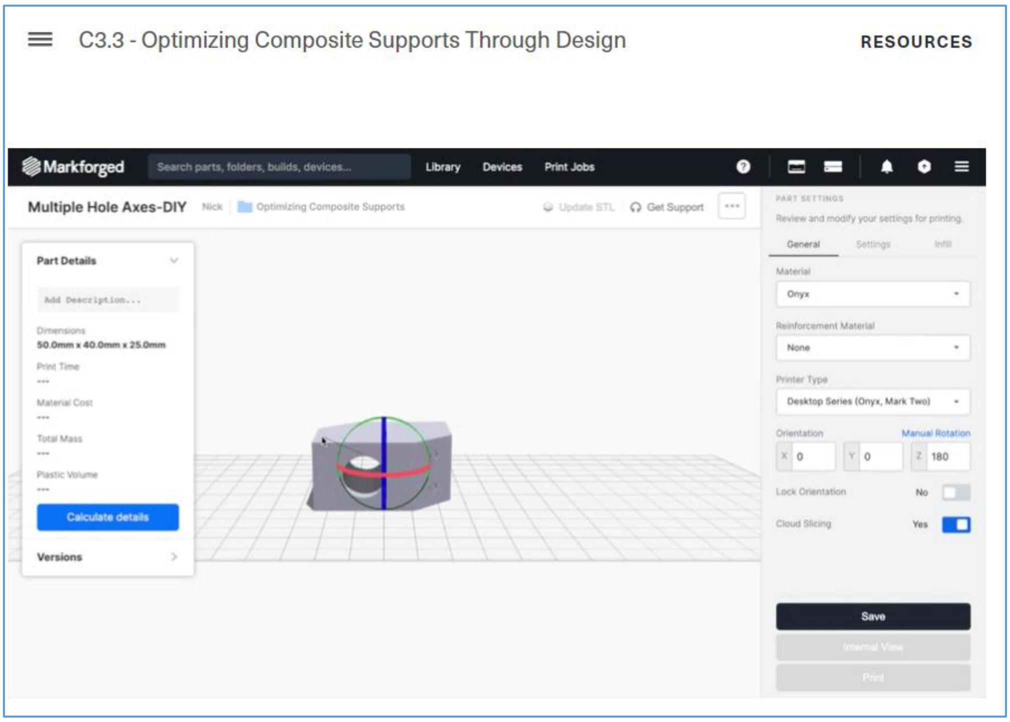
- Select all the bodies and export…

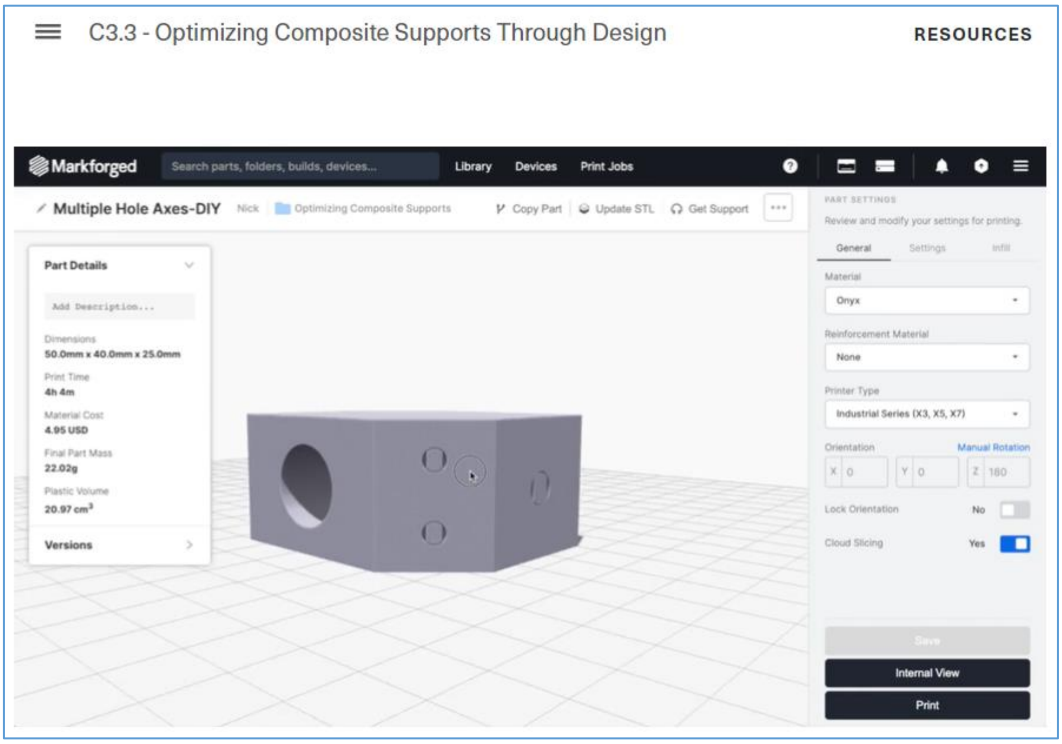


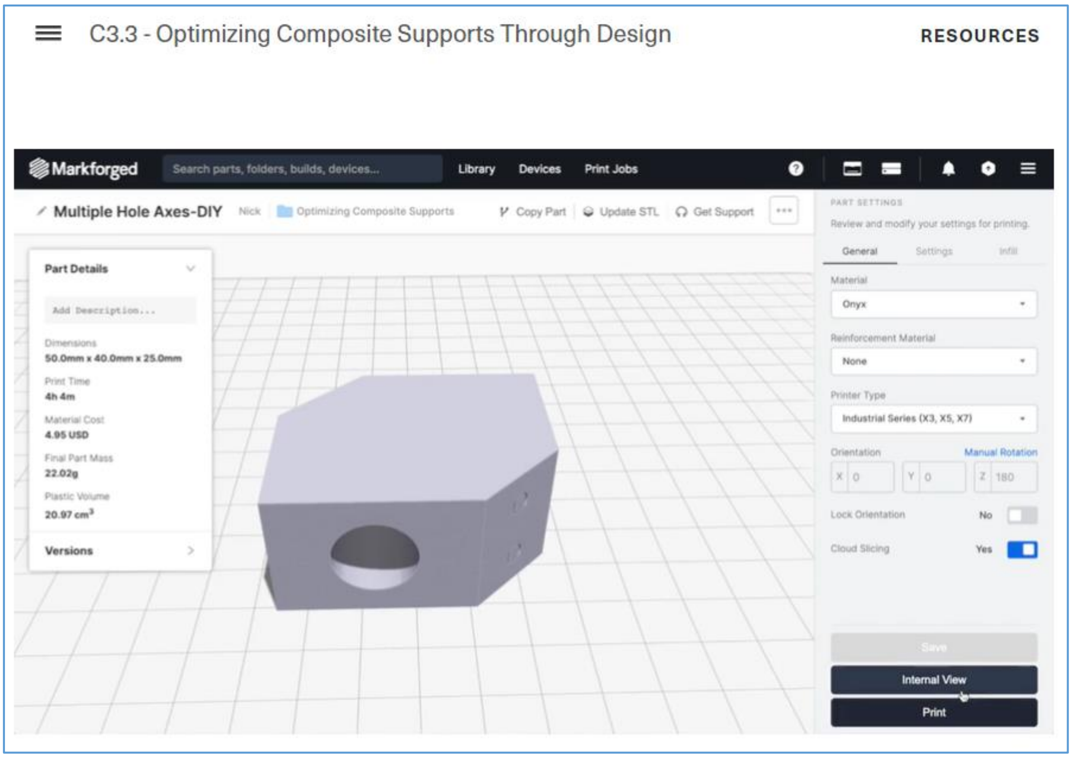
- ….. to a single STL.

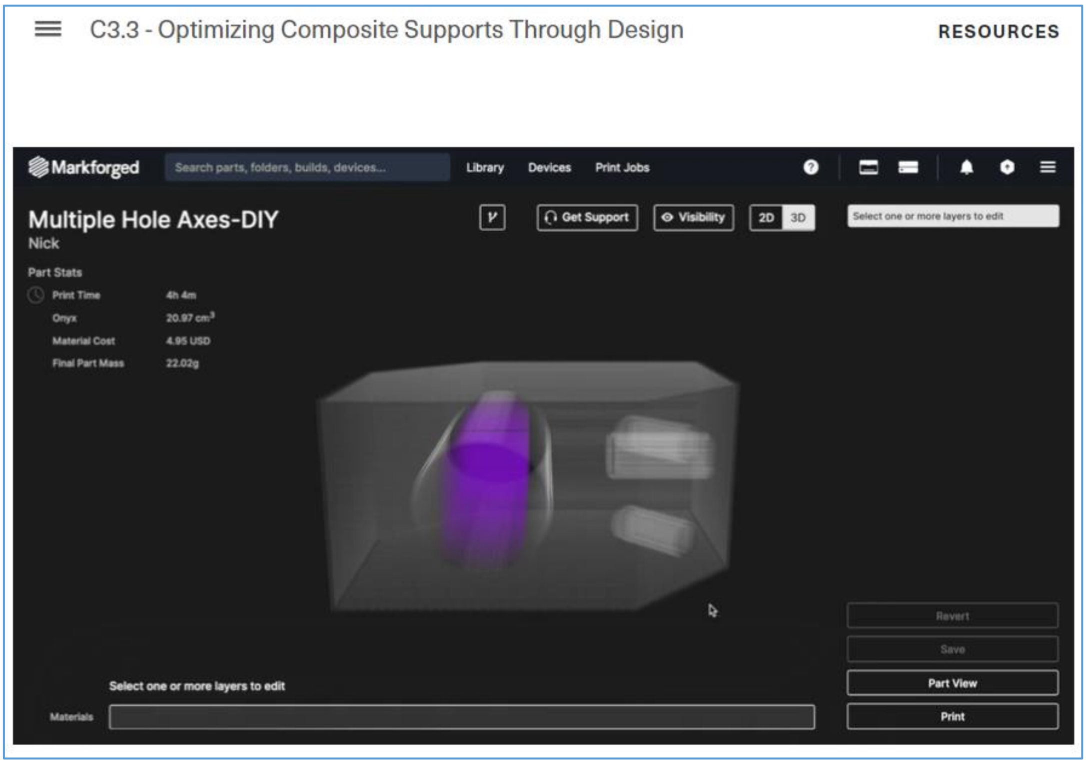


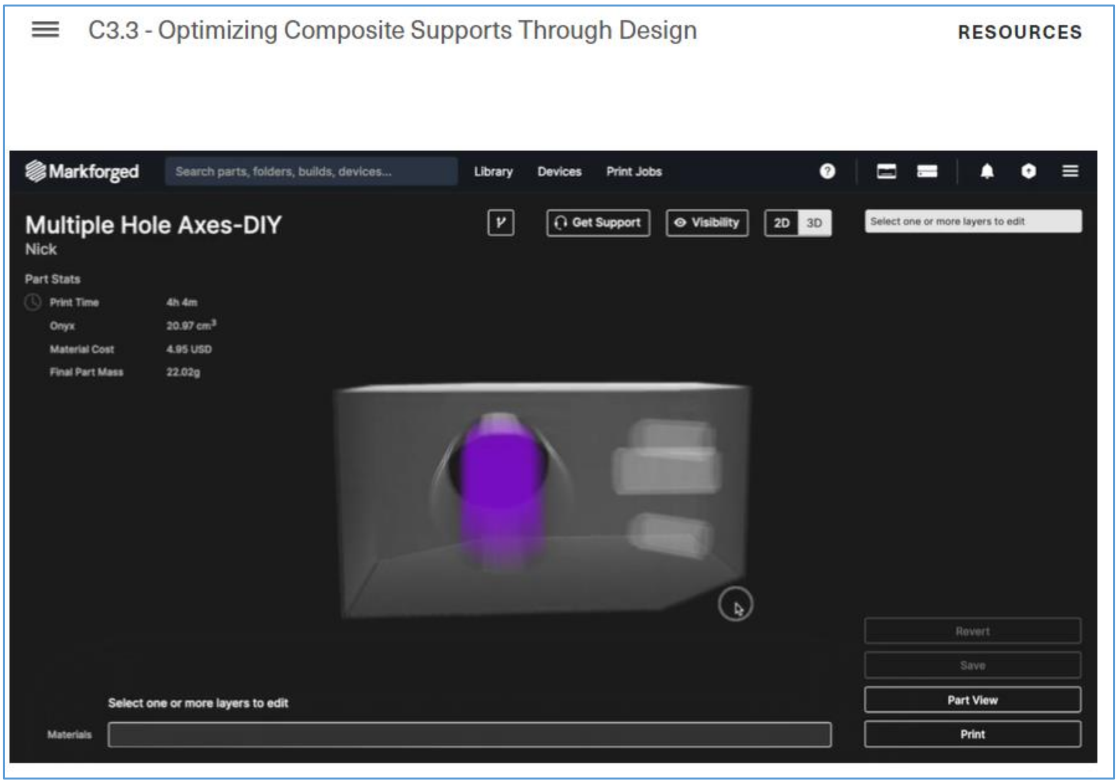
- Import the STL into Eiger.

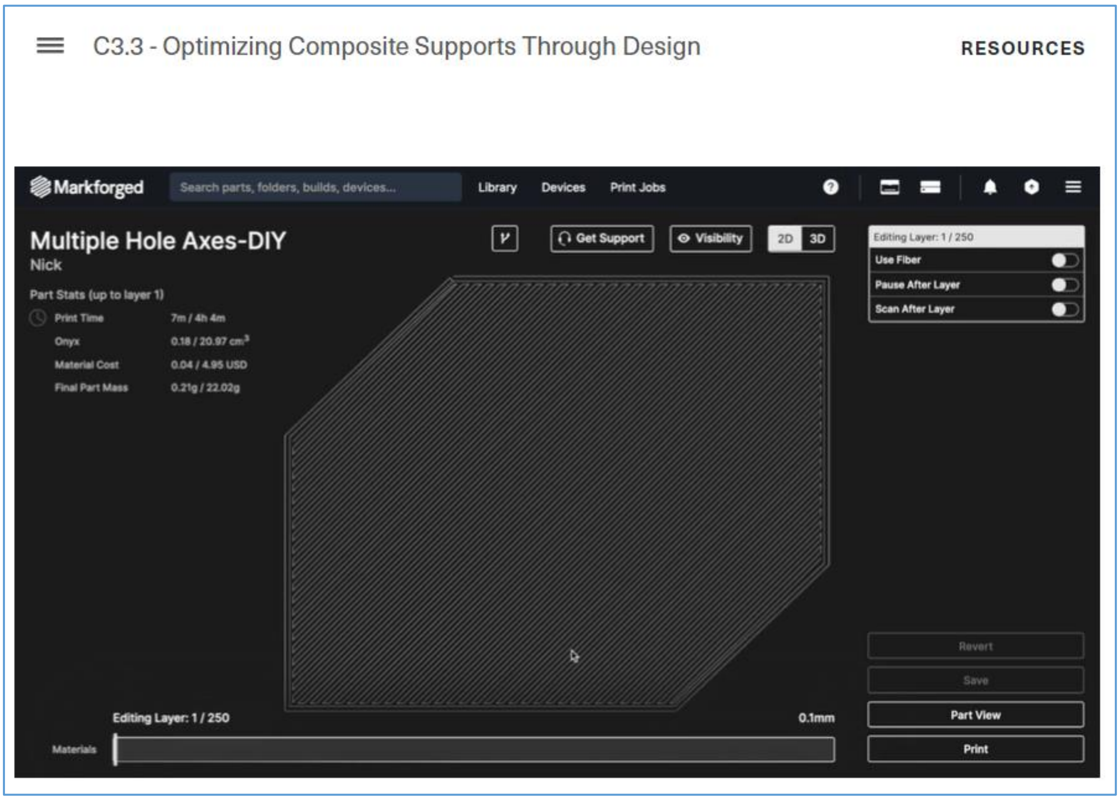


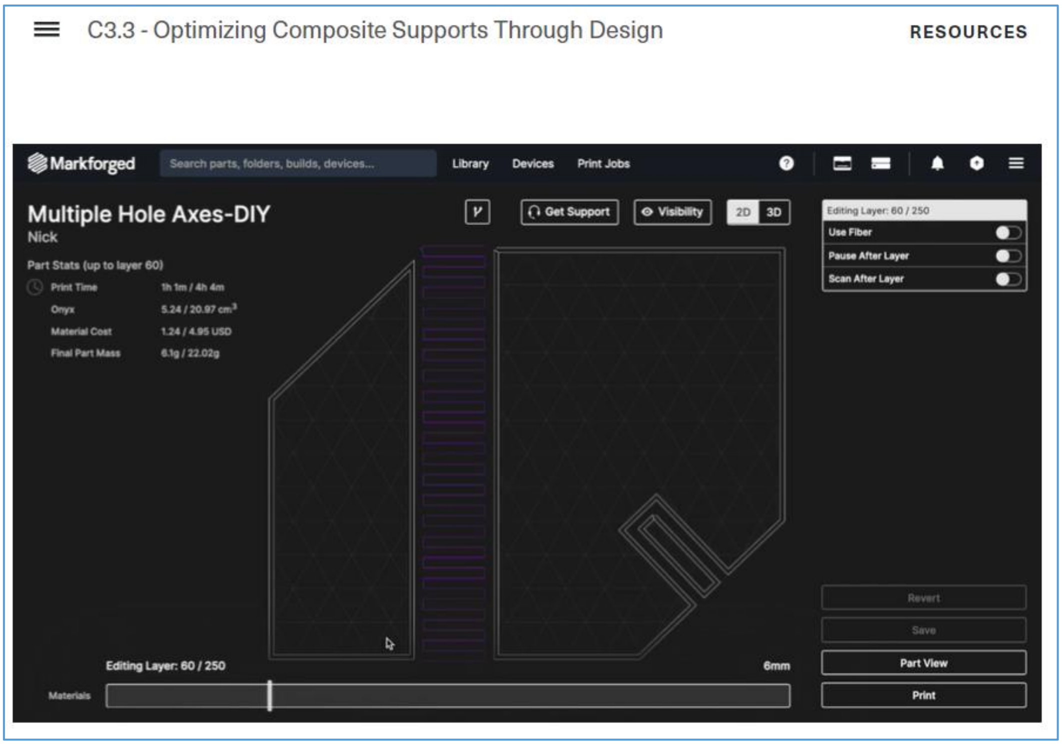

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Multiple Hole Axes-DIY
Nick
Optimizing Composite Supports
Copy Part
Update STL
Get Support
PART SETTINGS
Review and modify your settings for printing.
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Manual Rotation
X 0
Y 0
Z 180
Lock Orientation
No
Cloud Slicing
Yes
Save
Internal View
Print
Part Details
Add Description...
Dimensions
50.0mm x 40.0mm x 25.0mm
Print Time
4h 4m
Material Cost
4.95 USD
Final Part Mass
22.02g
Plastic Volume
20.97 cm³
Versions


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Multiple Hole Axes-DIY
Nick
Optimizing Composite Supports
Copy Part
Update STL
Get Support
PART SETTINGS
Review and modify your settings for printing.
General
Settings
Infill
Material
Onyx
Reinforcement Material
None
Printer Type
Industrial Series (X3, X5, X7)
Orientation
Manual Rotation
X 0
Y 0
Z 180
Lock Orientation
No
Cloud Slicing
Yes
Save
Internal View
Print
Part Details
Add Description...
Dimensions
50.0mm x 40.0mm x 25.0mm
Print Time
4h 4m
Material Cost
4.95 USD
Final Part Mass
22.02g
Plastic Volume
20.97 cm³
Versions

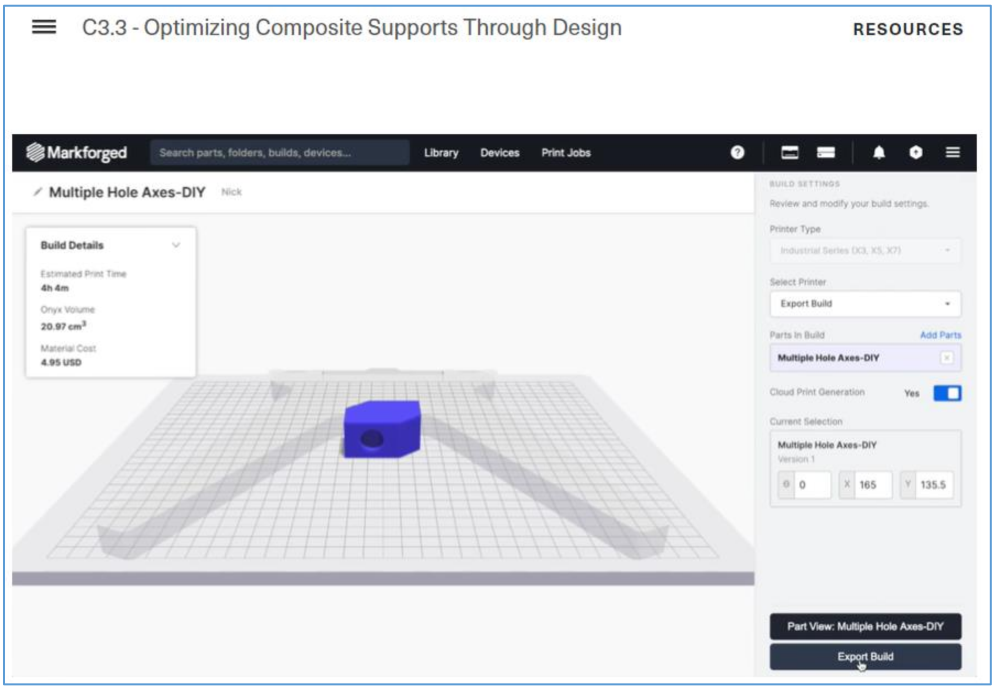

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Multiple Hole Axes-DIY
Nick
Get Support
Visibility
2D
3D
Select one or more layers to edit
Part Stats
Print Time
4h 4m
Onyx
20.97 cm³
Material Cost
4.95 USD
Final Part Mass
22.02g
Revert
Save
Part View
Print
Select one or more layers to edit
Materials


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Markforged
Search parts, folders, builds, devices...
Library
Devices
Print Jobs
Multiple Hole Axes-DIY
Nick
Get Support
Visibility
2D
3D
Select one or more layers to edit
Part Stats
Print Time
4h 4m
Onyx
20.97 cm³
Material Cost
4.95 USD
Final Part Mass
22.02g
Revert
Save
Part View
Print
Select one or more layers to edit
Materials

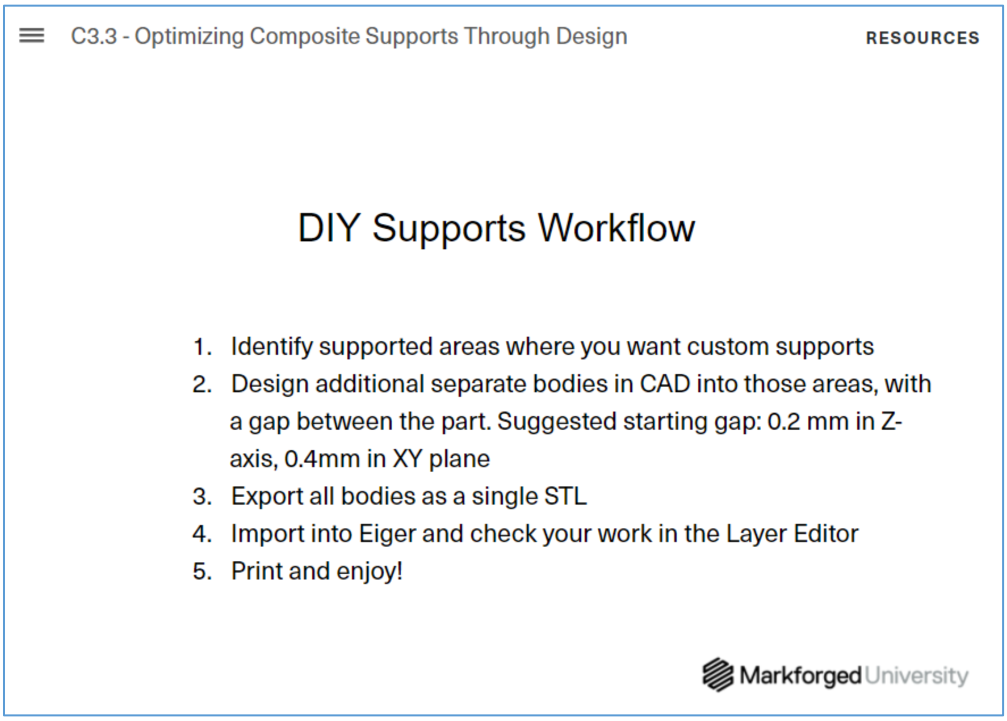




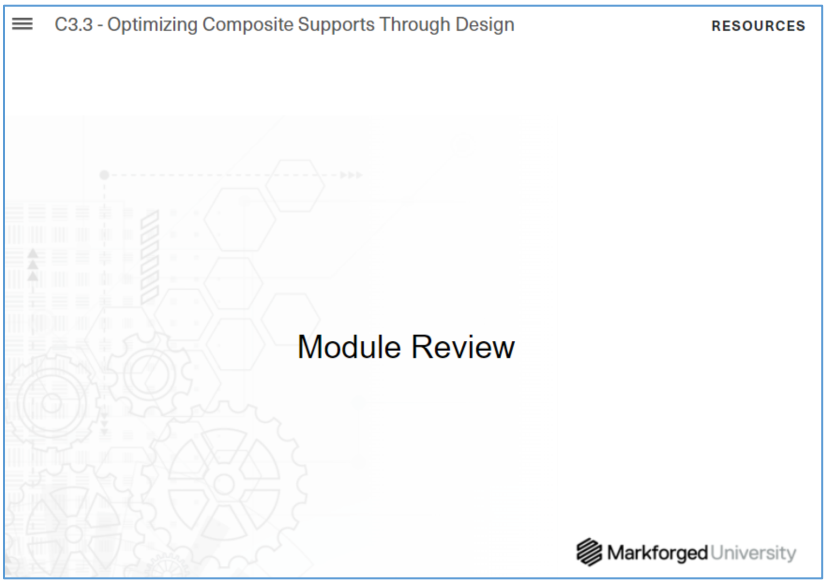
- You could change the support to 90° for a little easier remove of the support material, but it is a pretty large through hole, so you don't have to worry about it.



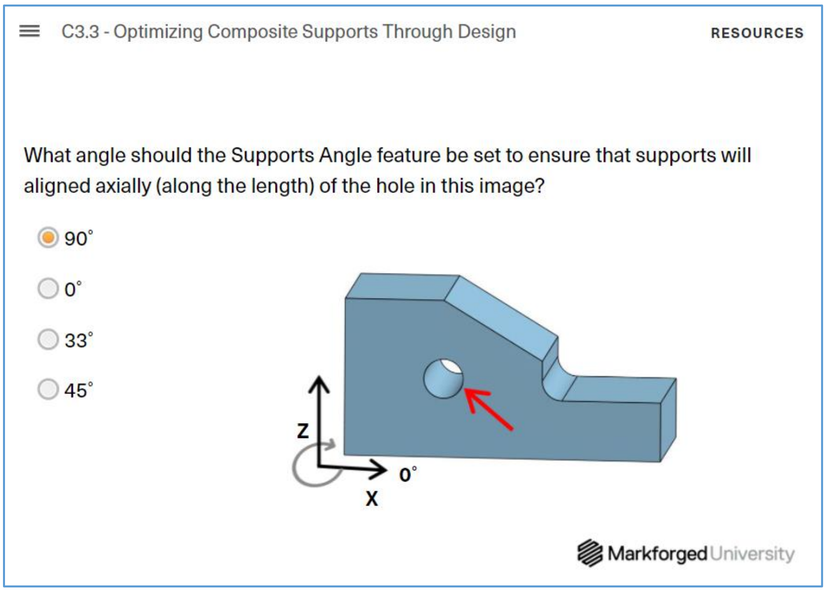
- And let us print!

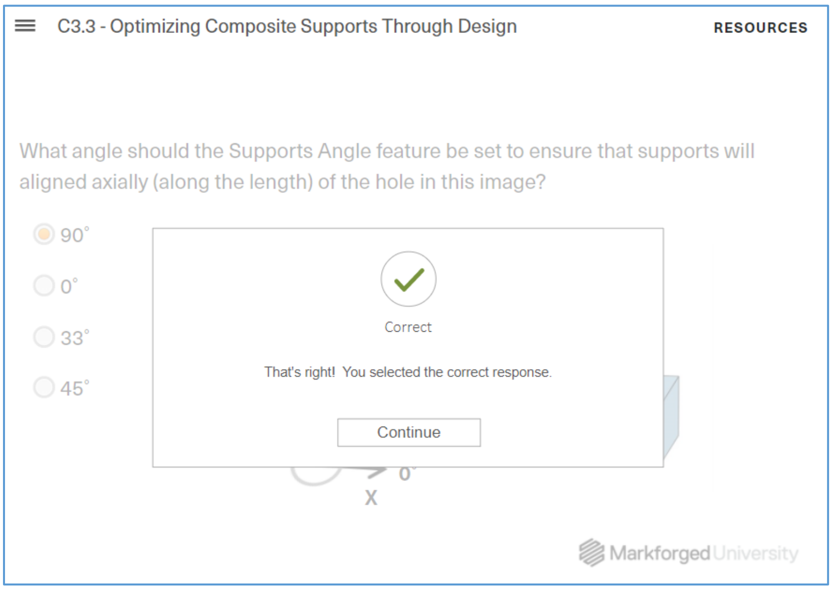


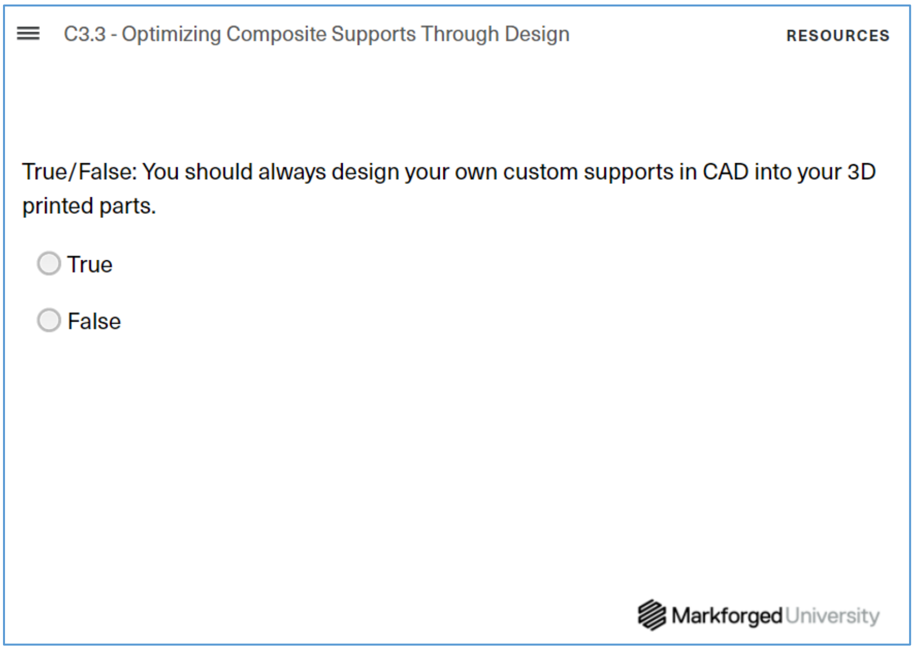
- **DIY Supports Workflow**



- **Module Review**




C3.3 - Optimizing Composite Supports Through Design
RESOURCES
What angle should the Supports Angle feature be set to ensure that supports will aligned axially (along the length) of the hole in this image?
90˚
0˚
33˚
45˚
Correct
That's right! You selected the correct response.
Continue
X
Markforged University


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
True/False: You should always design your own custom supports in CAD into your 3D printed parts.
True
False
Markforged University

C3.3 - Optimizing Composite Supports Through Design

RESOURCES

True/False: You should always design your own custom supports in CAD into your 3D printed parts.

- True
- False

Correct

That's right! We're all about efficient solutions here, and you should only spend time designing your own custom supports if you can't optimize the supports in a part with Eiger's existing support tools, which are much faster to use.

Continue

Markforged University

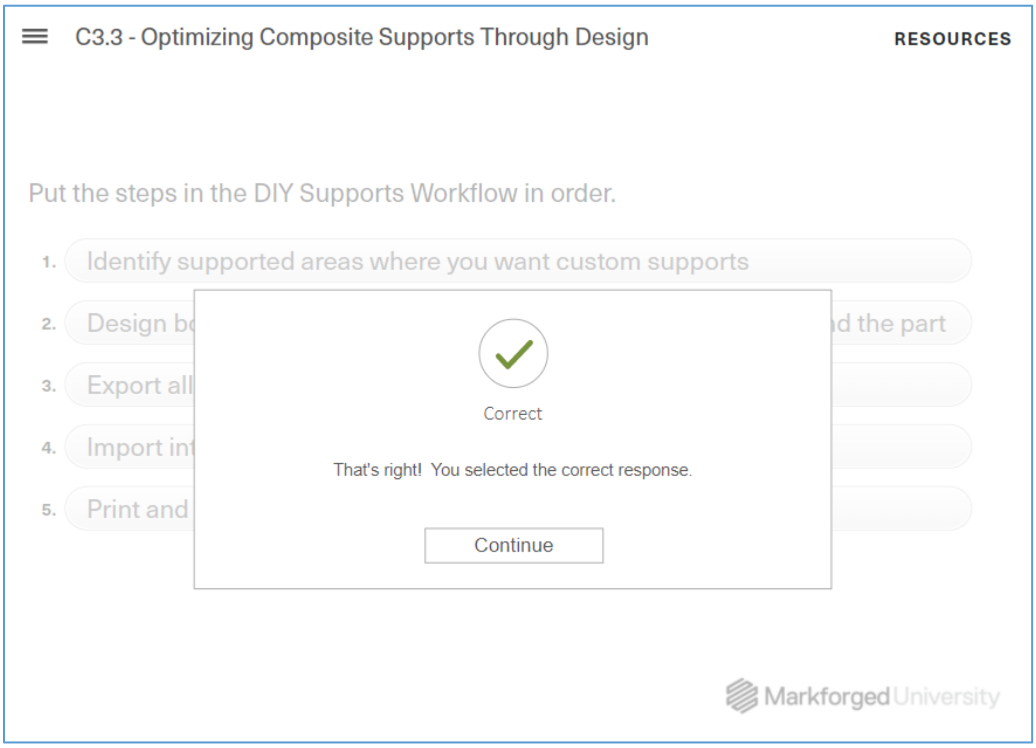
C3.3 - Optimizing Composite Supports Through Design

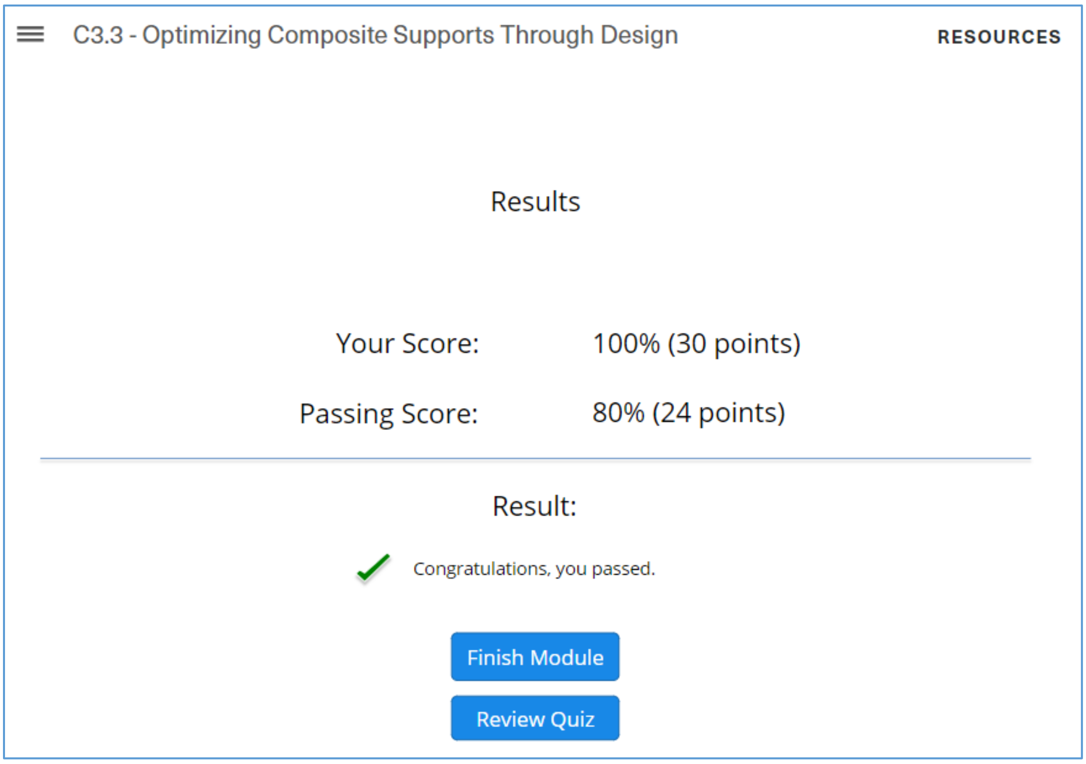
RESOURCES

Put the steps in the DIY Supports Workflow in order.

1. Identify supported areas where you want custom supports
2. Print and enjoy!
3. Design bodies in CAD in those areas, with a gap between them and the part
4. Export all bodies as a single STL
5. Import into Eiger and check your work in the Layer Editor

Markforged University

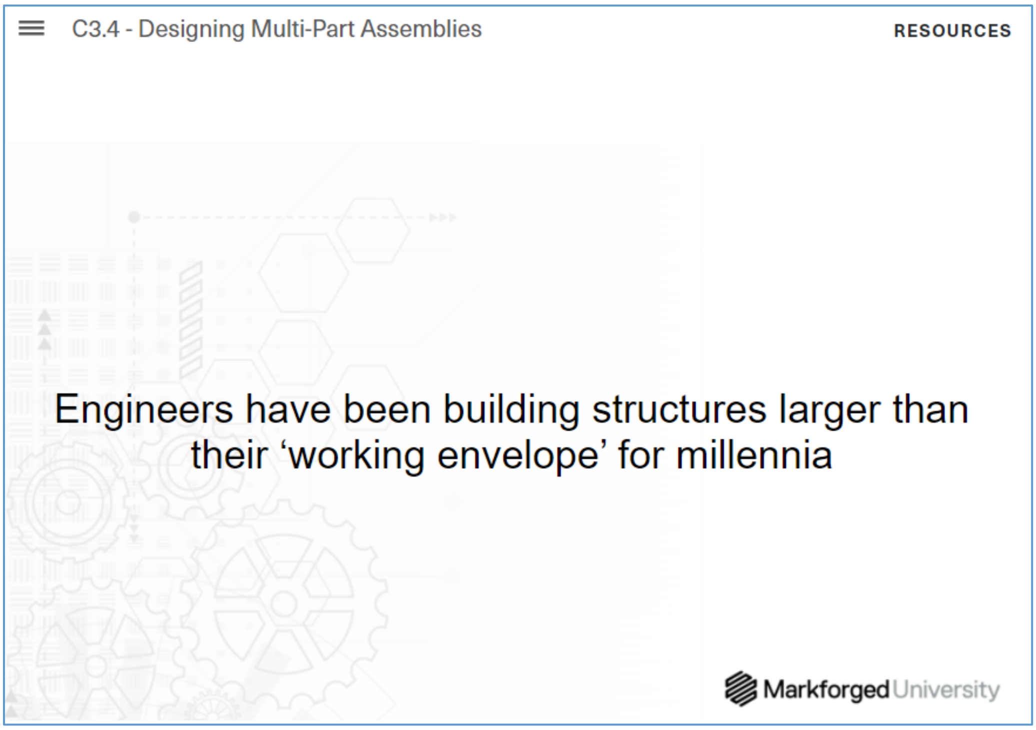

C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Put the steps in the DIY Supports Workflow in order.
1. Identify supported areas where you want custom supports
2. Design b
d the part
3. Export all
4. Import in
5. Print and
Correct
That's right! You selected the correct response.
Continue
Markforged University


C3.3 - Optimizing Composite Supports Through Design
RESOURCES
Results
Your Score: 100% (30 points)
Passing Score: 80% (24 points)
Result:
Congratulations, you passed.
Finish Module
Review Quiz

C3.4 – Designing Multi Part Assemblies

- **Designing Multi Part Assemblies**

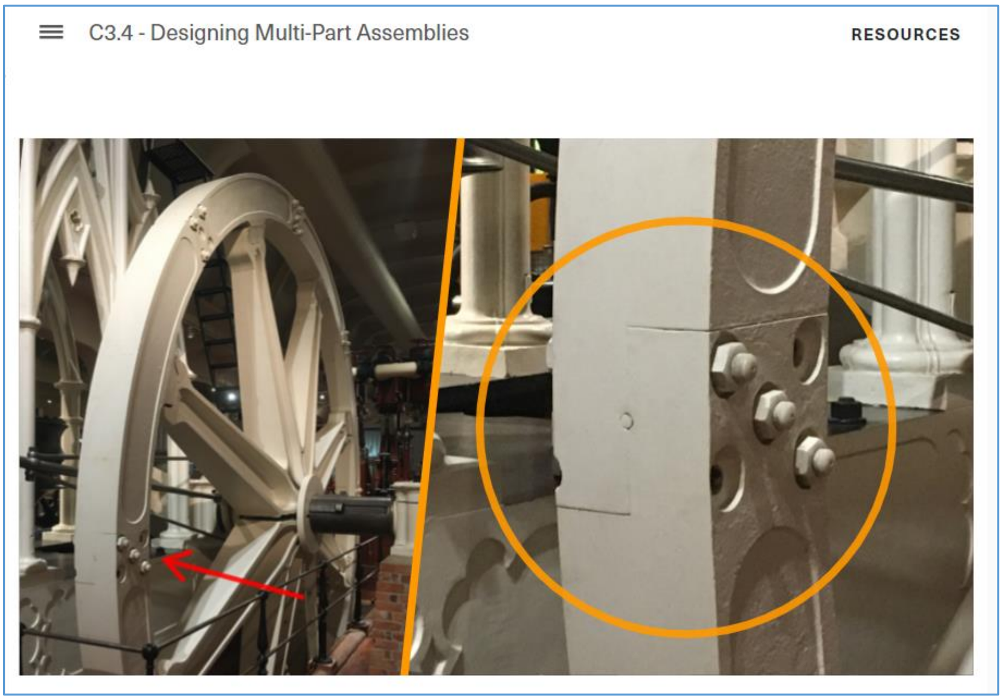
- **Module Overview**

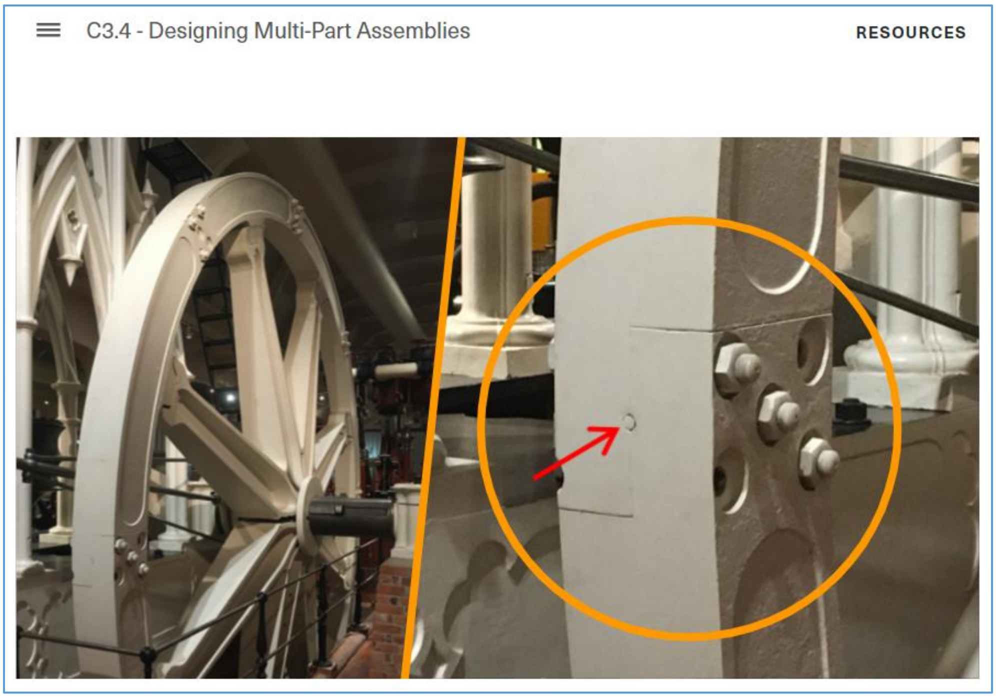


- **An Age-old Concept**
    - Example working envelope: A robot (arm) its range of movement.
    - Working envelope = The area in which a robot, or any part of one, can move around.

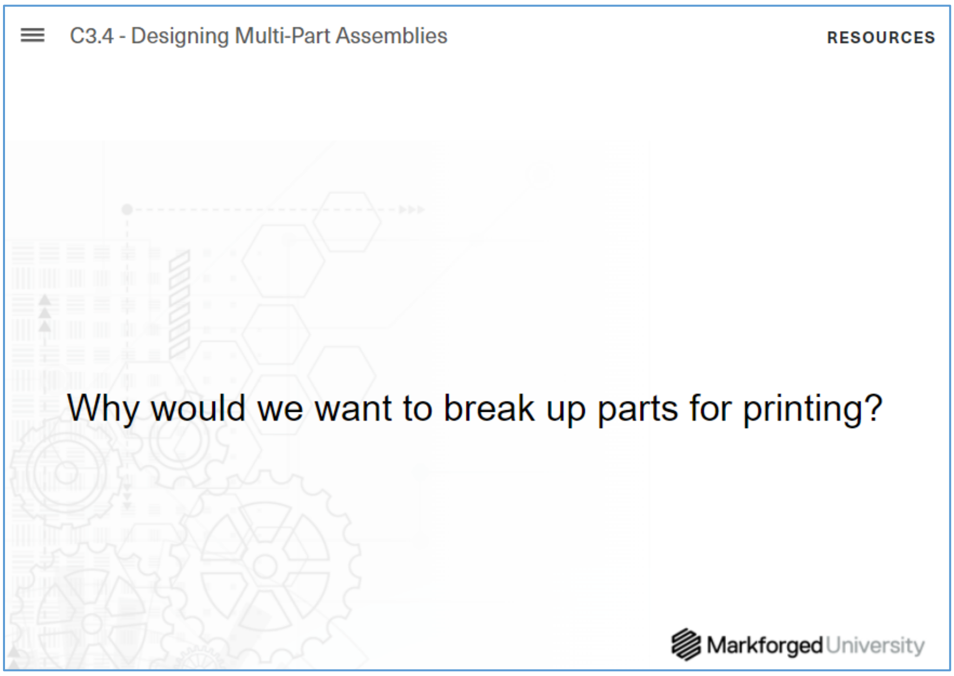
- **Example: Historical Multi-Part Assemblies**
    - The flywheel is probably 4 à 5 meters in diameter

    - A assemblies of same cast large segments. Too big to cast as a single piece.
        - To avoid deformations due to cooling down process, or simply too big to handle.

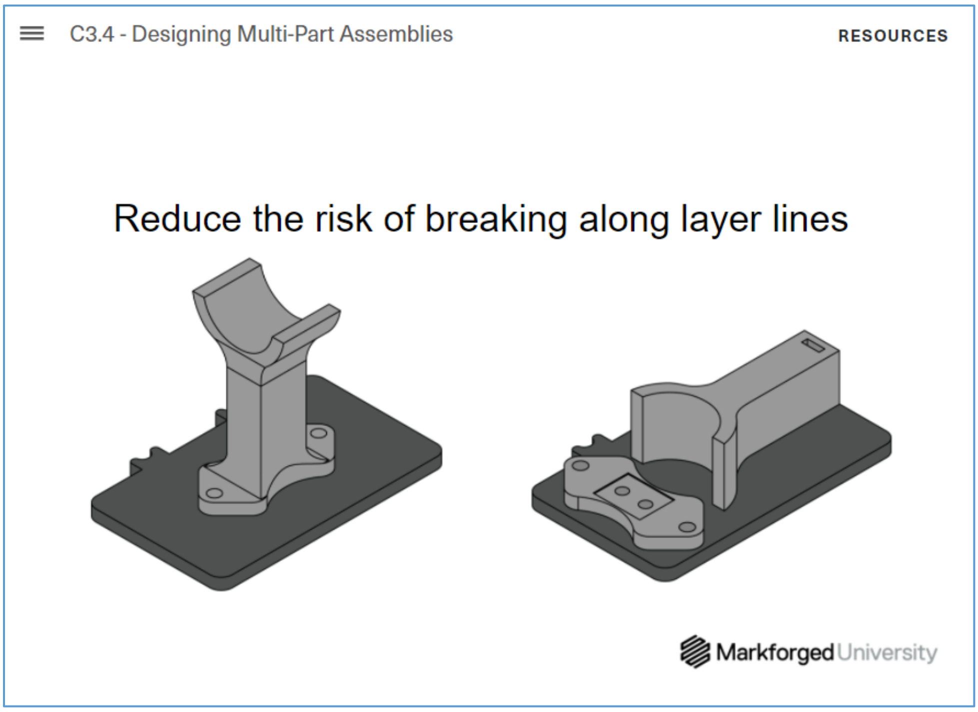




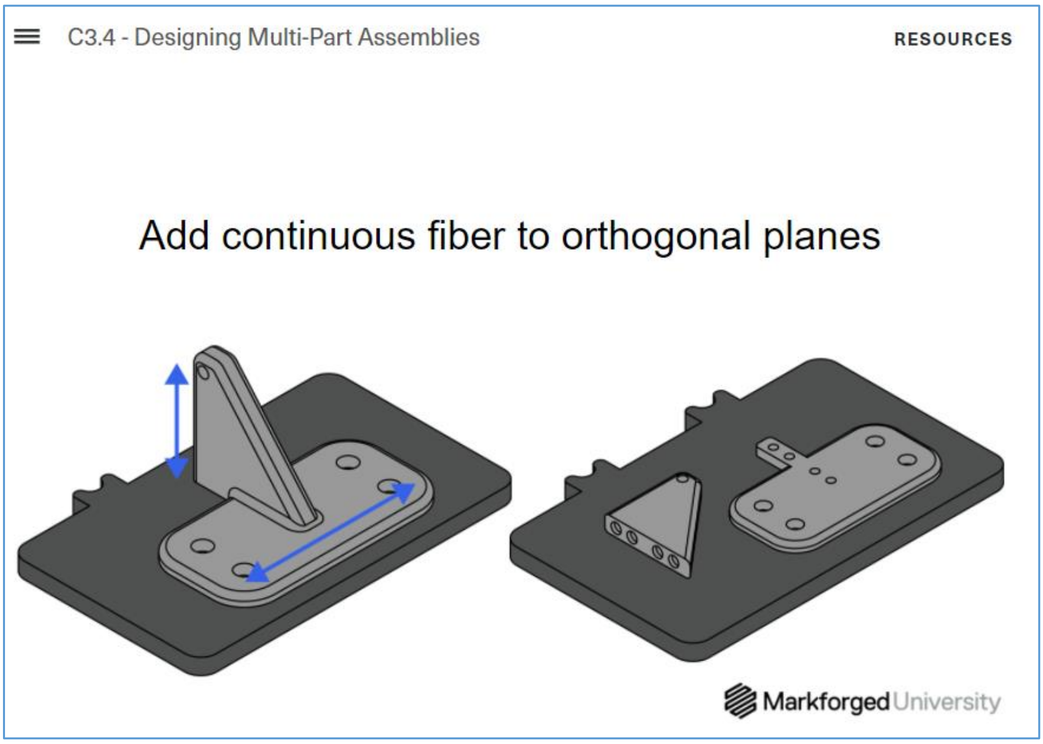
- A dowel pin in the lap joint to help align the pieces.
    - Meant as inspiration from.



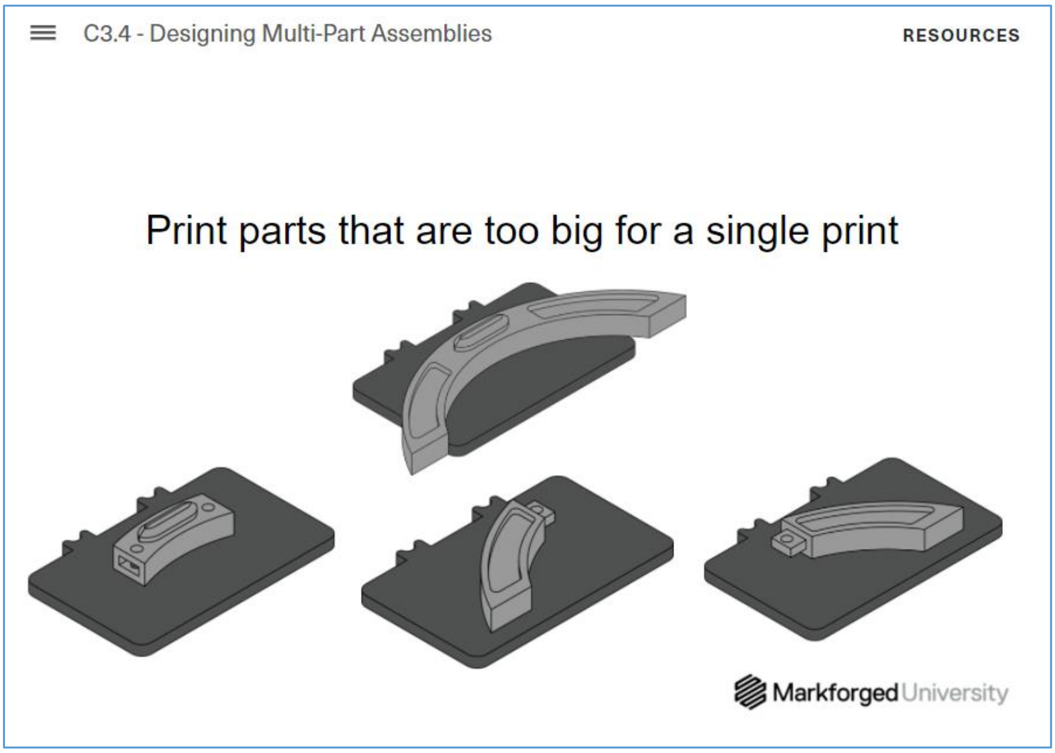
- **Why Split Up A Part?**



- **Z-axis Strength**
  - The weakest axis in 3D printed part is the Z-axis, or in between the layers.
  - The right alignment is easier to provide fiber.
  - The separate parts are bolted together afterwards.
  - By doing so the Z-axis weakness is completely eliminated.

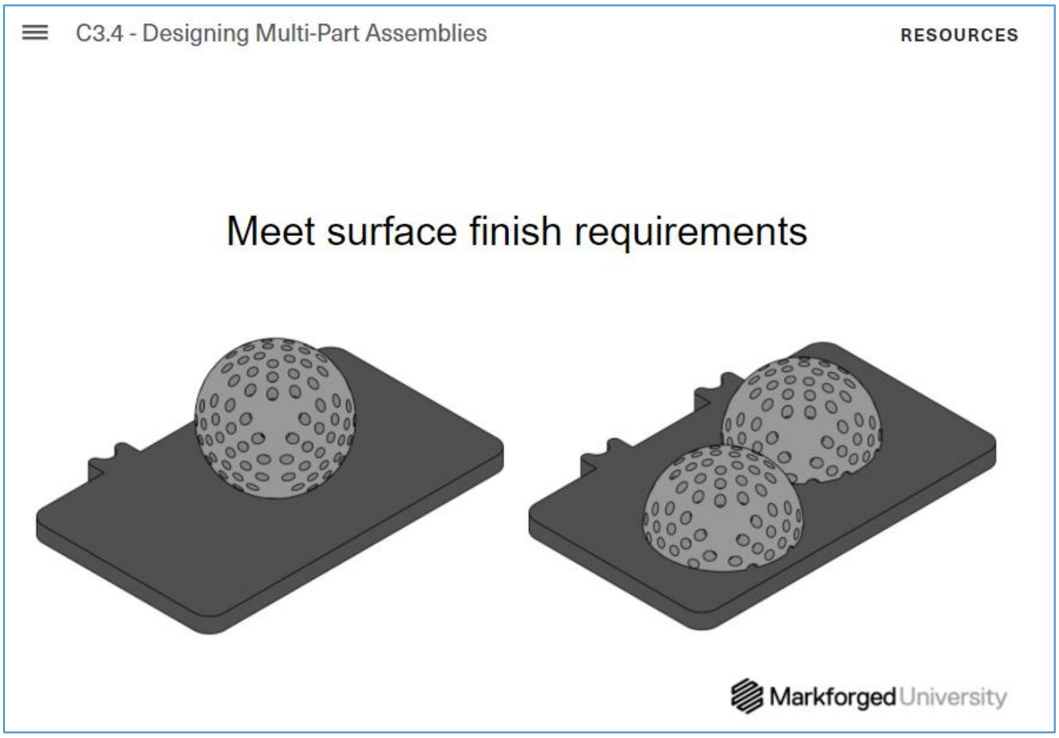


- **Fiber Layout**
  - Multiple non parallel planes we would to reinforce with fiber.
  - More easy to provide fiber and avoid Z-axis at the same time.
  - Orthogonal = Loodrecht op elkaar staand.
  - Assemblies with dowel pins to create strengthen and accurate alignment.

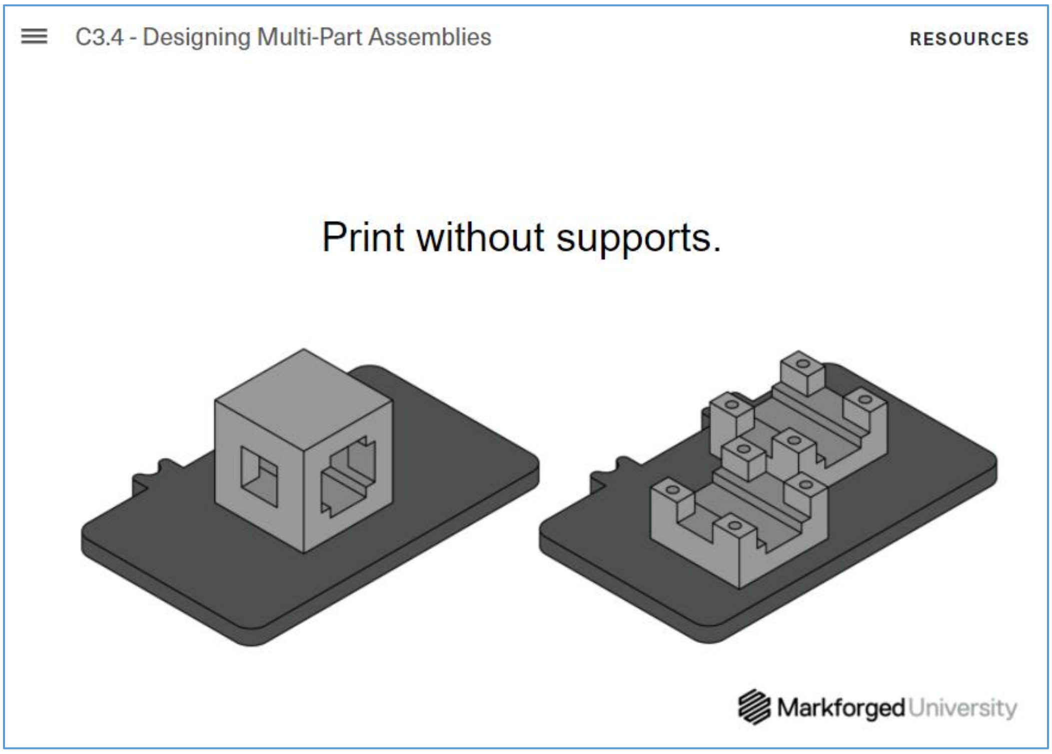


- **Over-sized Parts**

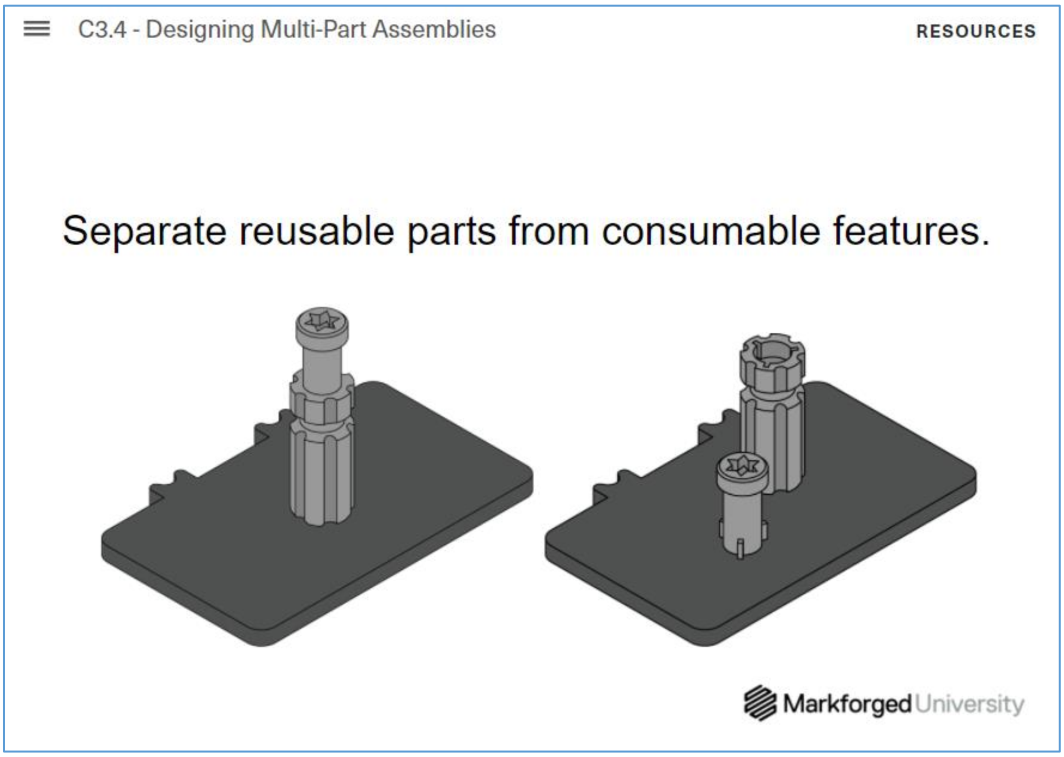
- Choose a affective joint strategy.



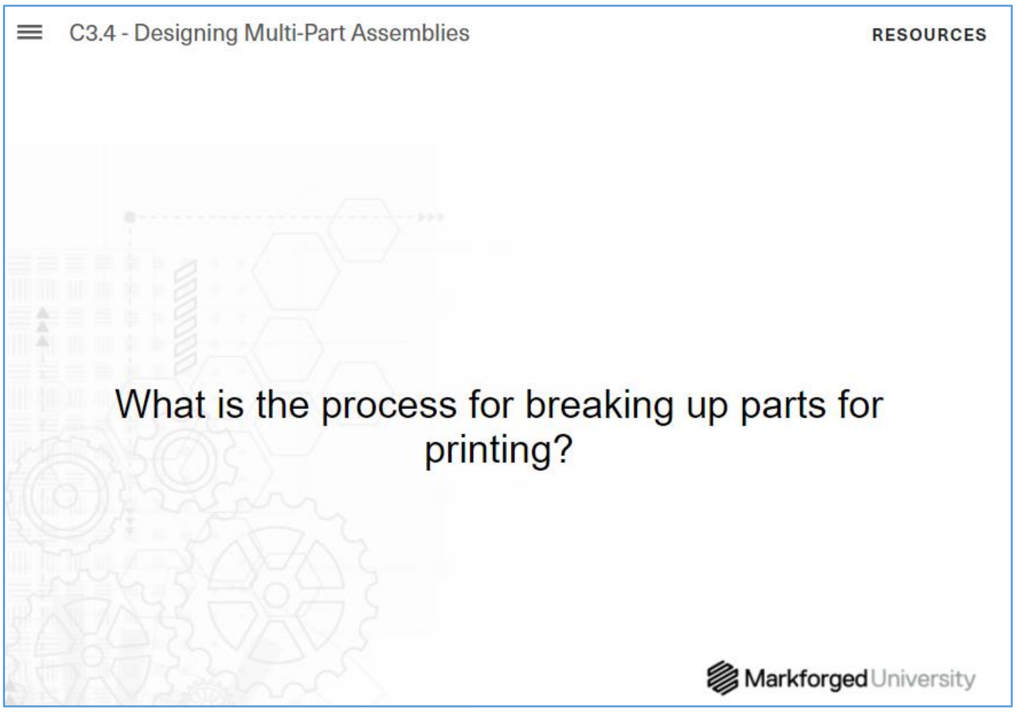
- **Maintaining Surface Finish**
    - Meet requirements = voldoen aan eisen.



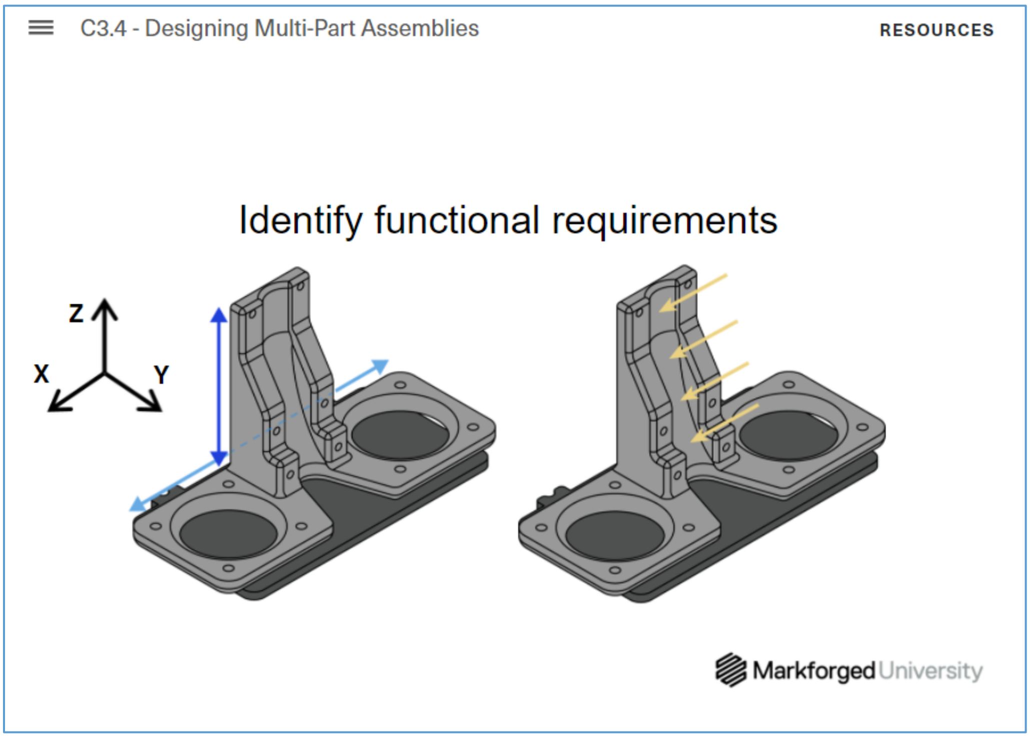
- **Support Reduction**



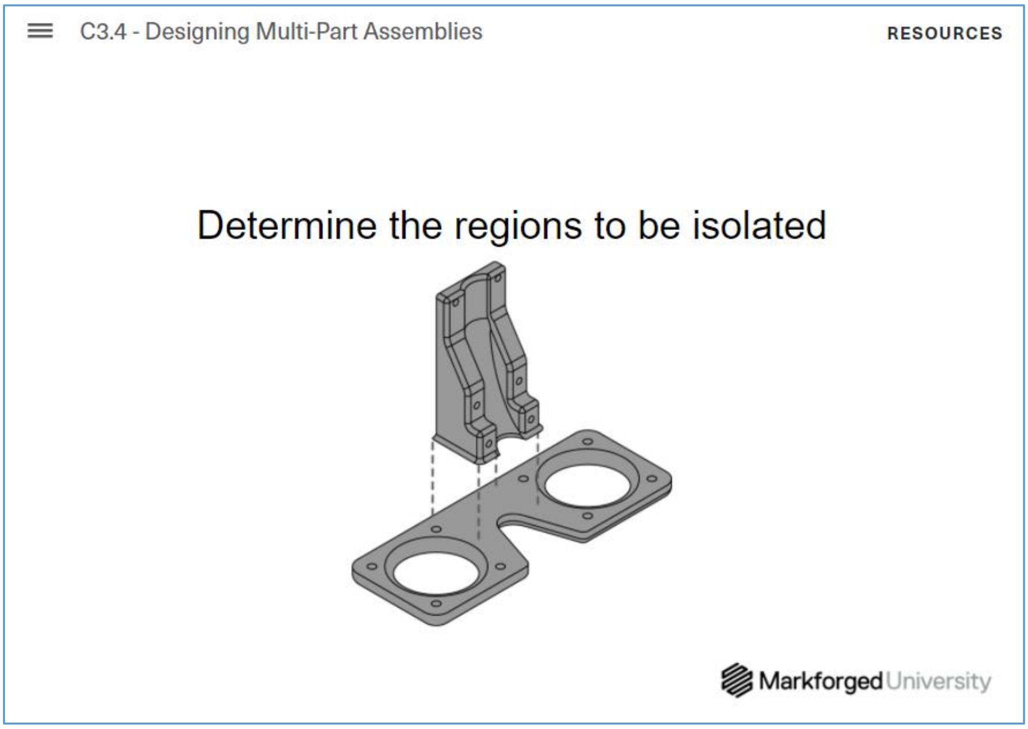
- **Design for Maintenance and Consumability**
    - Consumability = verbruik



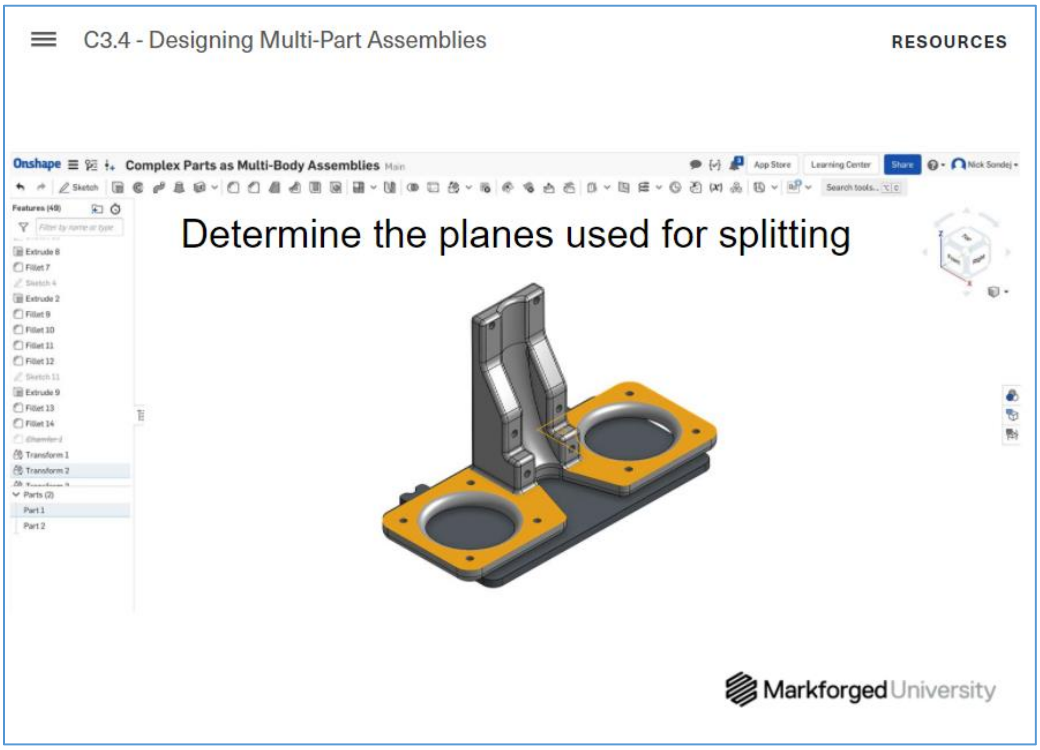
- **Multi-Part Assembly Process**



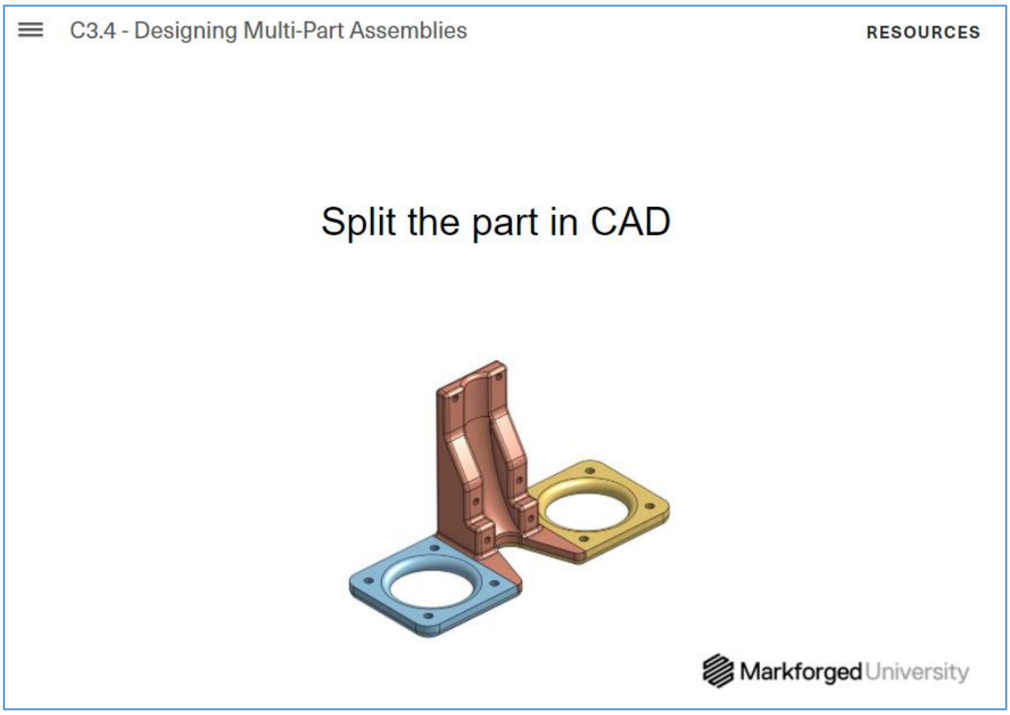
- **Identify Functional Requirements**
  - 2 Main planes requires strength: X-Y-plane and Z-Y-plane and are not parallel
  - So split up is needed for upper reason and size.



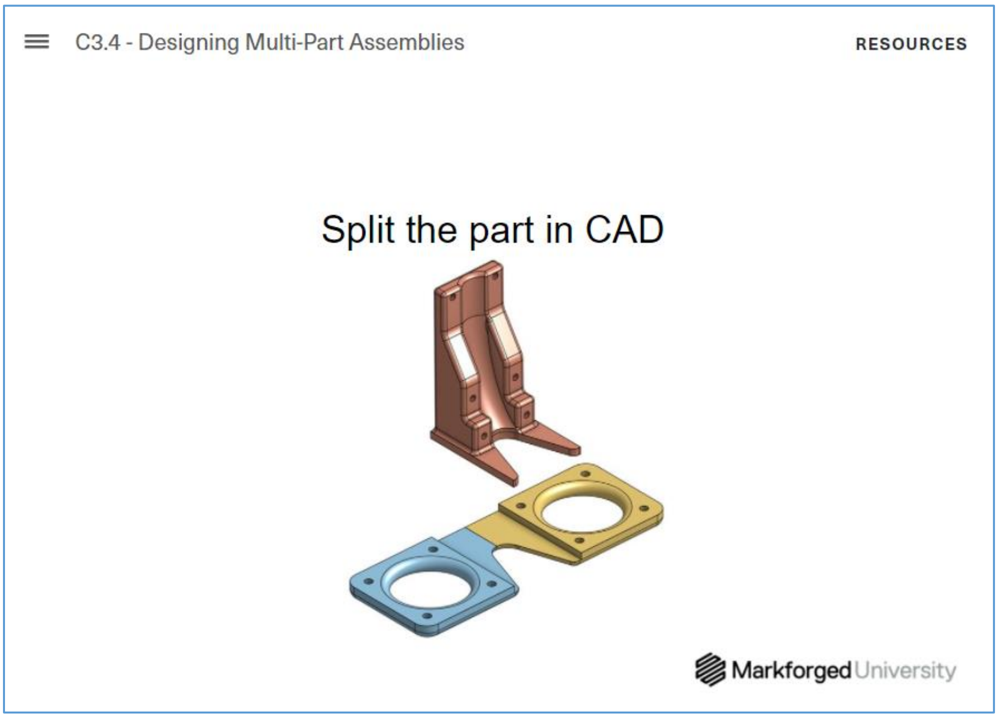
- **Determine Where to Split**



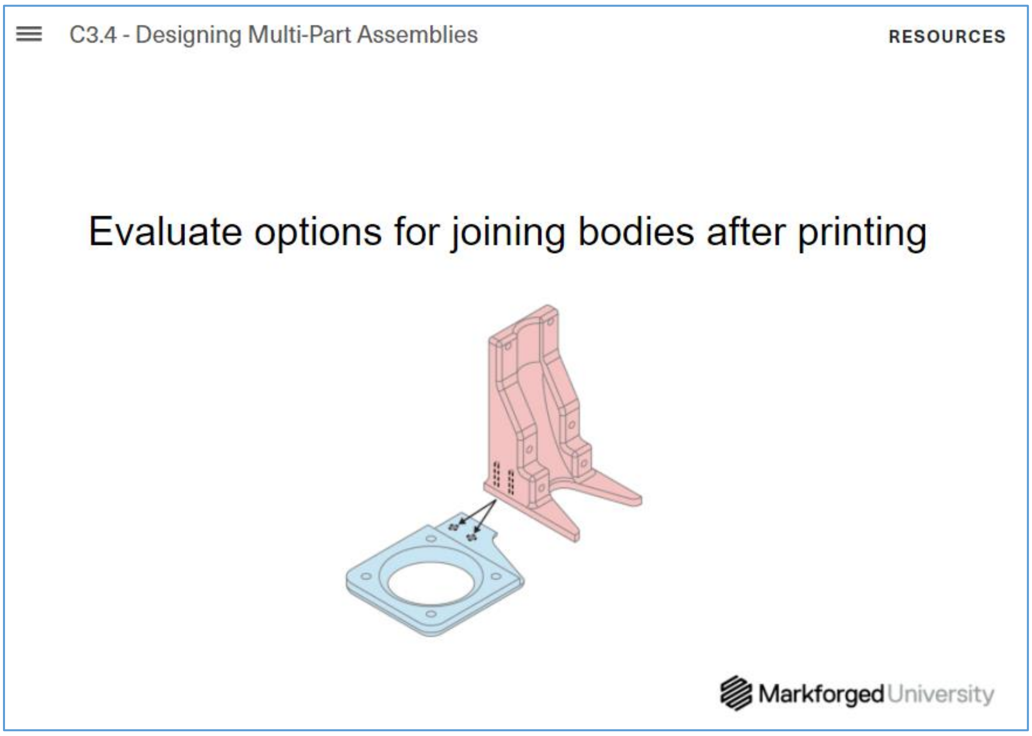
- **Identify Split Planes**
    - The bottom section is also too big.



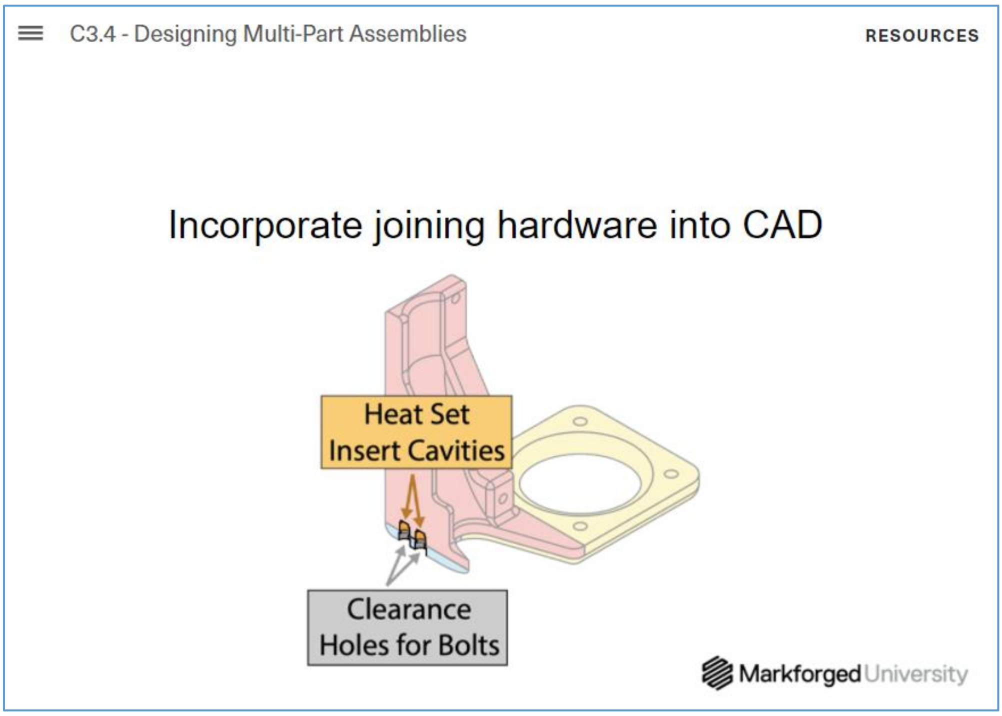
- **Split the Part into Pieces**



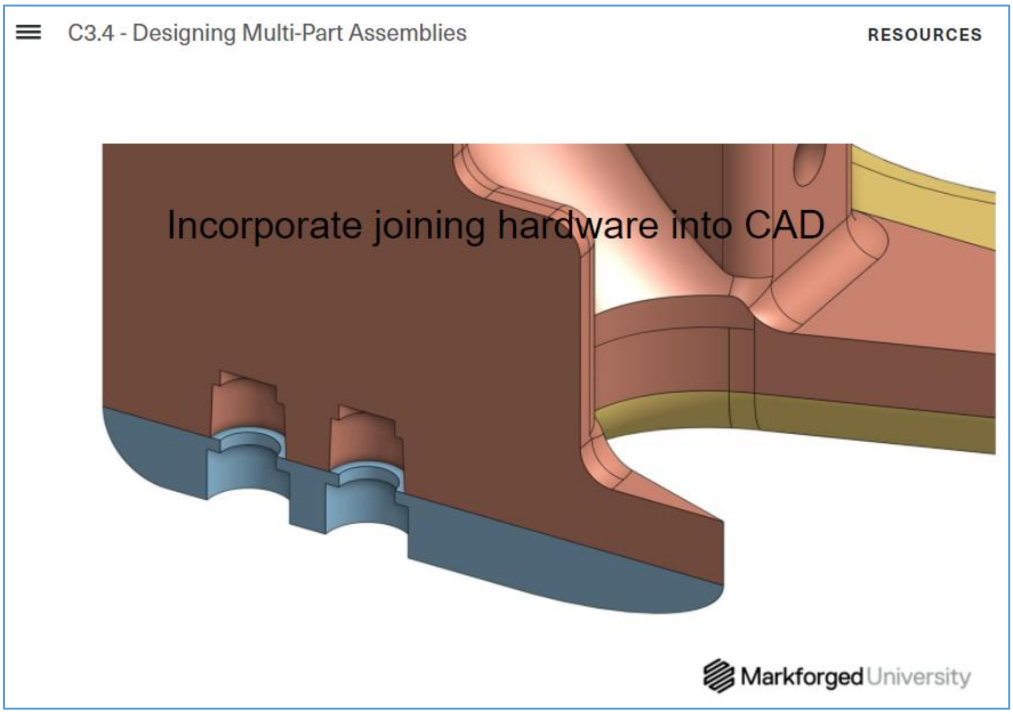
- 3 Pieces with lap joint.
- Oriented in a way to be best reinforced with composite fiber, in the way the best meet the functional requirements.
- First we have to make sure that the right way to join the parts back together is chosen.



- **Evaluate Joint Options**



- **Adjust CAD for Hardware**



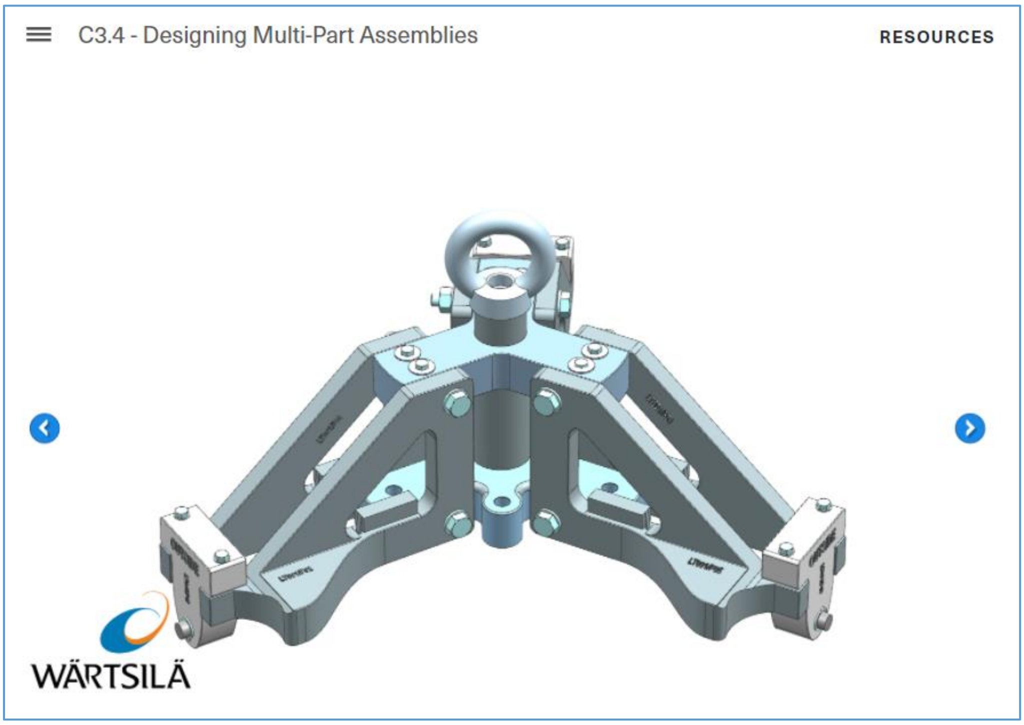
    - Taper Holes at the bottom of the upper part for heat inserts to be installed after printing.

- **Eiger Configuration**

- **Multi-Part Assemblies in the Real World**

- **Example: Siemens Saw Housing**

- **Example: Wärtsilä Lifting Tool**
  - Used for lifting 240kg engine pistons.
  - Tooling like this are extremely heavy requires 2 persons.



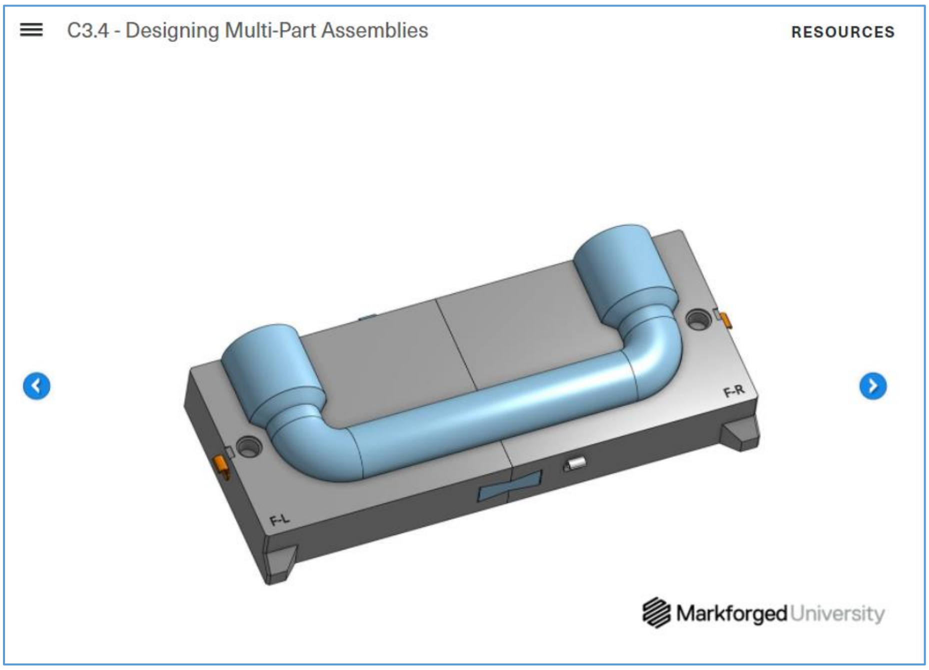
- The tool is able to lift 160kg as needed to and it actually the first 3D-printed CE-certified lifting tool in the world.

- **Example: Lean Machine Vise**
    - Vise = Bankschroef / machineklem

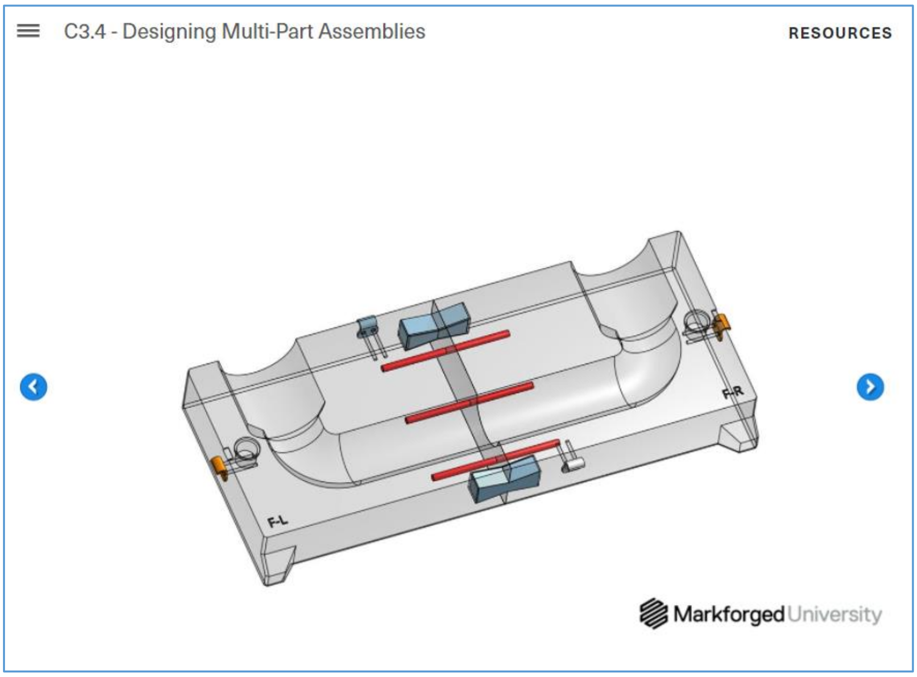
- Build end of a bed on long travel CNC-mills.
- It is much lighter and is therefore much lighter weight on the bed.
    - To avoid conditional wear during operating of the machine at the end of the bed.

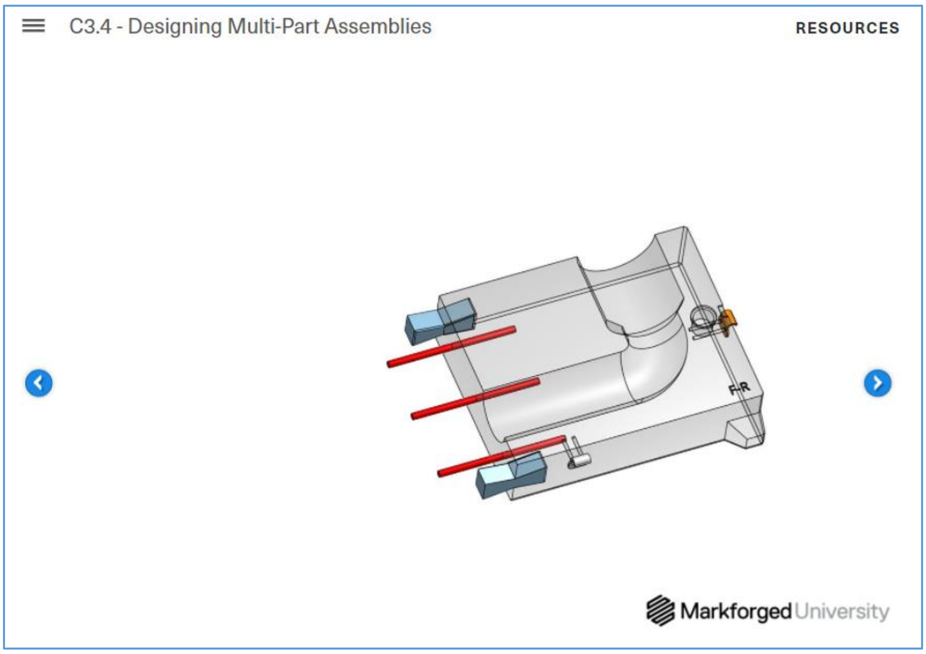
- **Example: Sand Casting Core Box**

    - Split up and joint together as an assembly

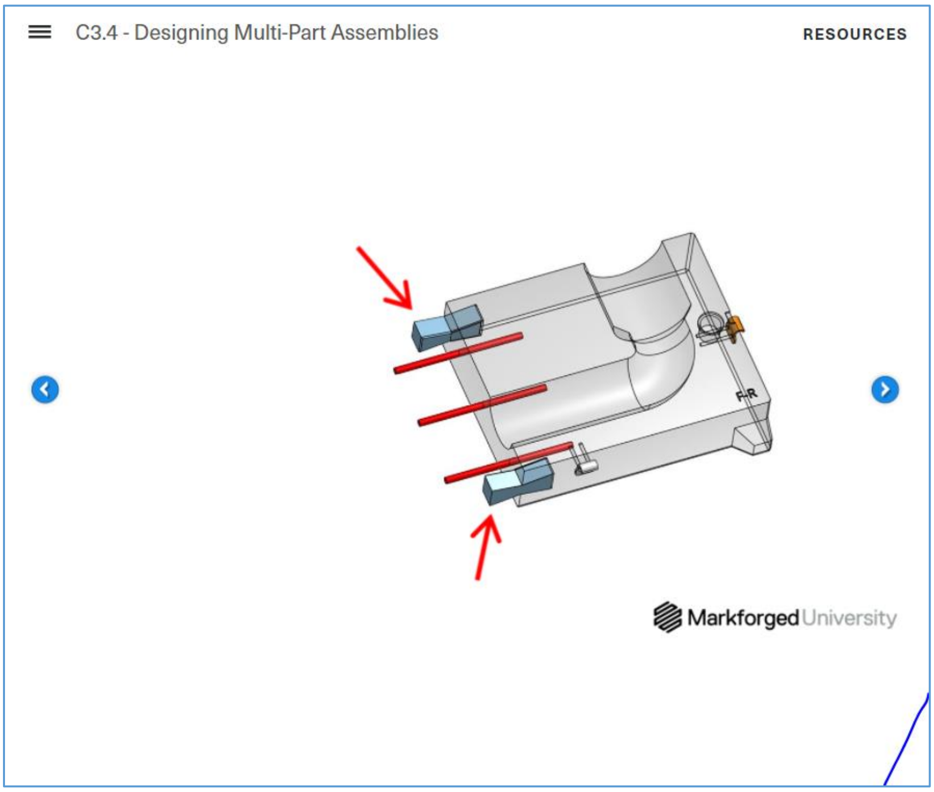


- CAD of the core box.

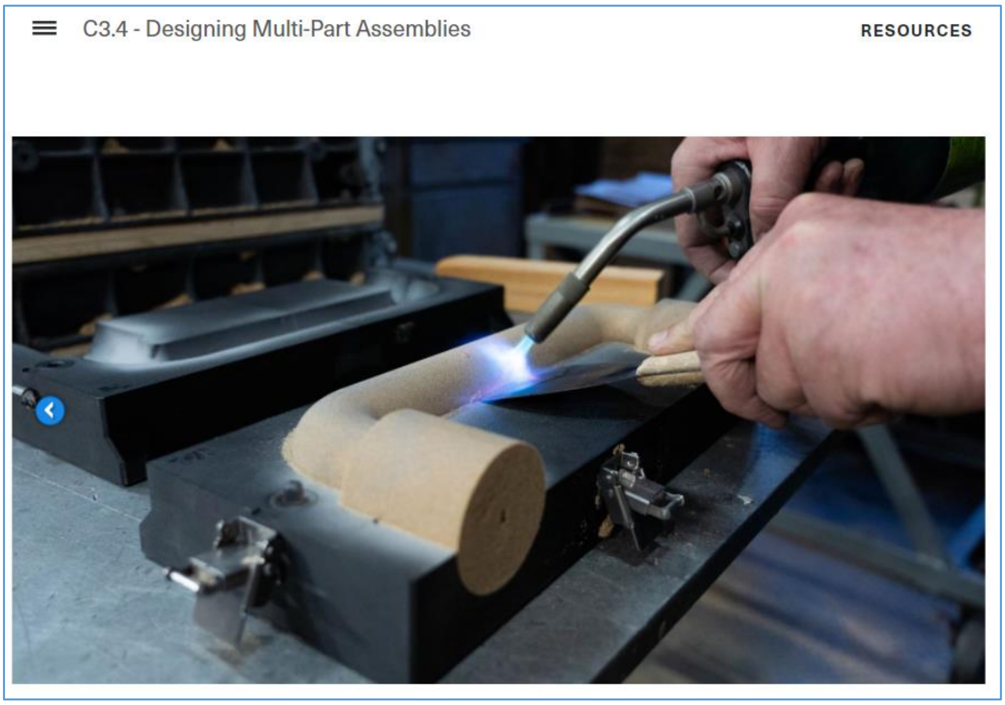


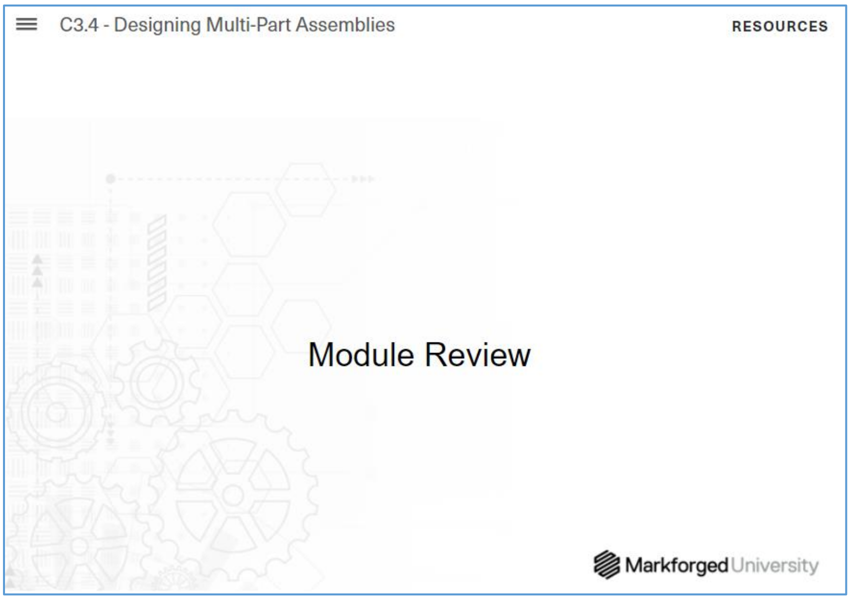


- Dowell pins



- Duck tailed inserts





- **Module Review**

C3.4 - Designing Multi-Part Assemblies RESOURCES

Which of the following is NOT a reason to split a part into smaller pieces and re-design it as an assembly of 3D printed parts?

- It's required to be able to machine parts after printing
- To add strength in multiple non-parallel planes
- Part is too large to fit on print bed
- Surface finish considerations

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C3.4 - Designing Multi-Part Assemblies RESOURCES

Which of the following is NOT a reason to split a part into smaller pieces and re-design it as an assembly of 3D printed parts?

- It's require
- To add str
- Part is too
- Surface fi

Correct

That's right! You selected the correct response.

Continue

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C3.4 - Designing Multi-Part Assemblies RESOURCES

Put the following steps for designing a multi-part assembly in order:

1. Split the part in CAD
2. Identify your functional requirements
3. Add design features for any hardware required to re-join the parts
4. Determine where the part needs to be split
5. Export each part individually as an STL and configure them in Eiger

C3.4 - Designing Multi-Part Assemblies RESOURCES

Put the following steps for designing a multi-part assembly in order:

1. Identify your functional requirements
2. Determin
3. Split the p
4. Add desig
5. Export ea ... er

Correct

That's right! You selected the correct response.

Continue

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C3.4 - Designing Multi-Part Assemblies

RESOURCES

True/False: The design strategy of building an assembly from a collection of parts is a brand-new process that has no historical design precedent.

- True
- False

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C3.4 - Designing Multi-Part Assemblies

RESOURCES

True/False: The design strategy of building an assembly from a collection of parts is a brand-new process that has no historical design precedent.

- True
- False

Correct

That's right! You selected the correct response.

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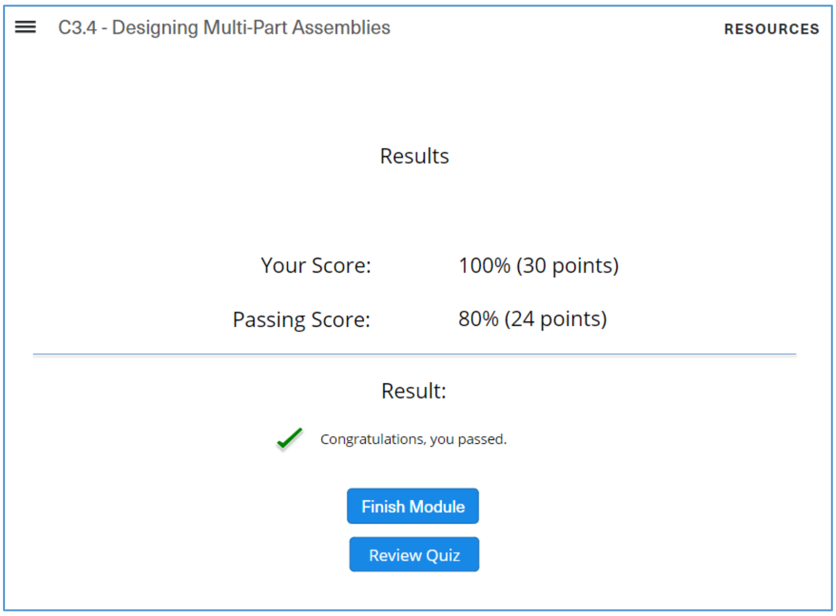
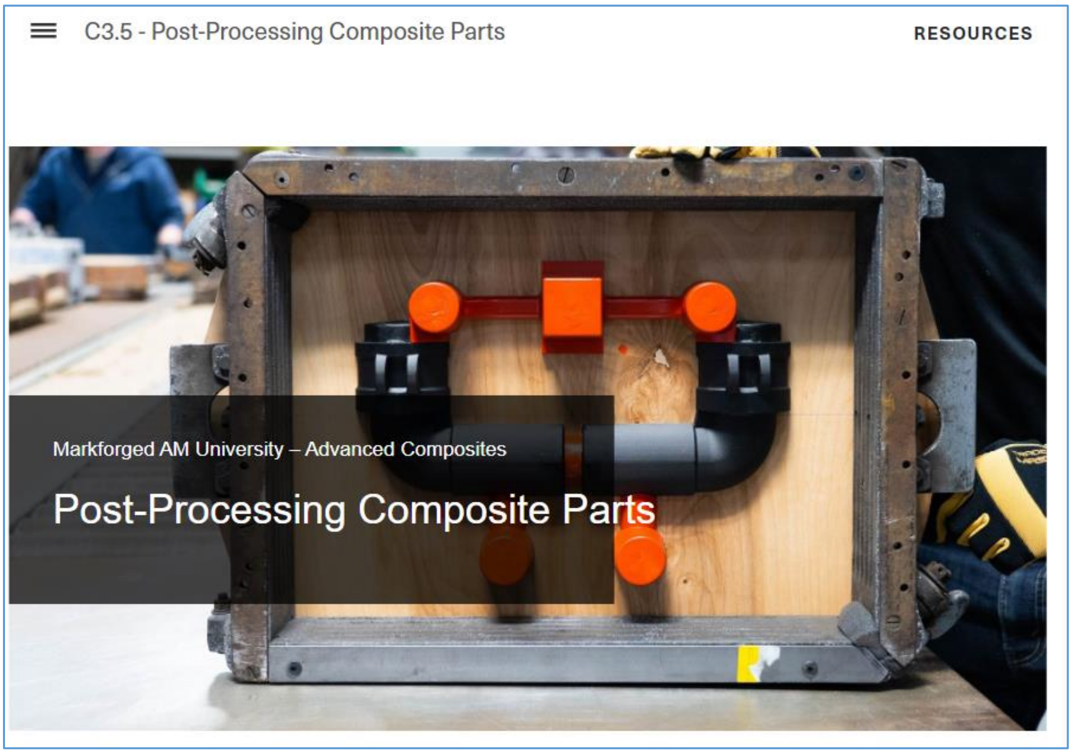
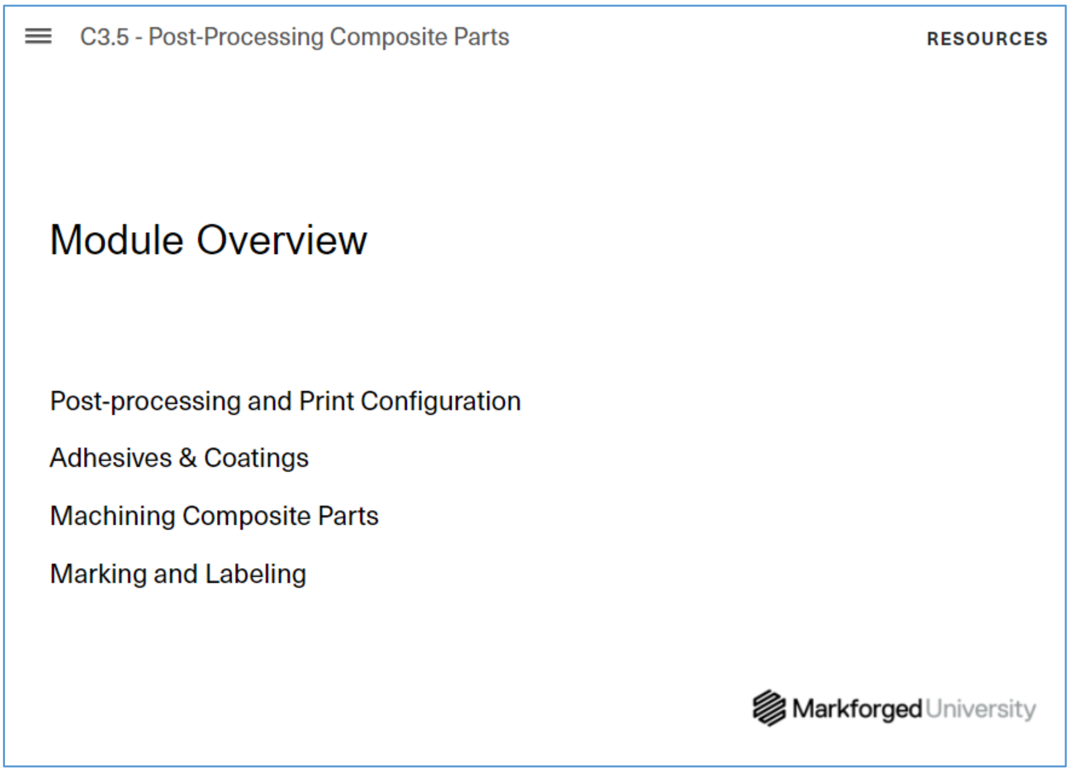


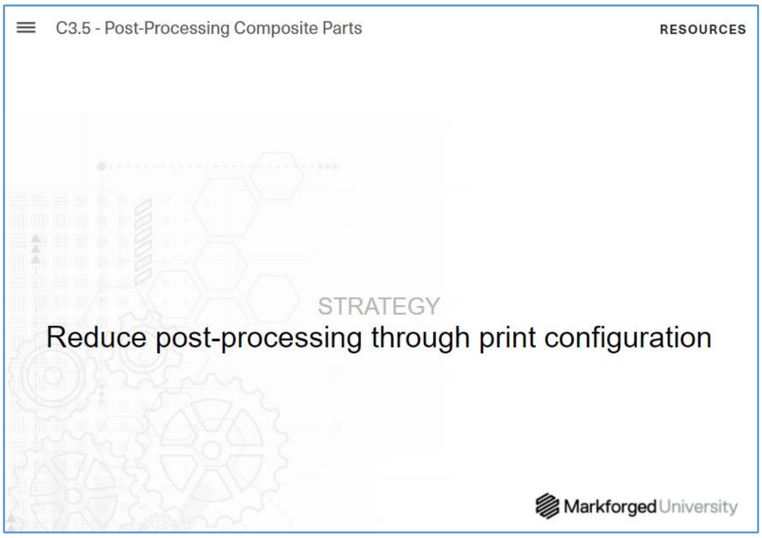
C3.5 – Post-Processing Composite Parts



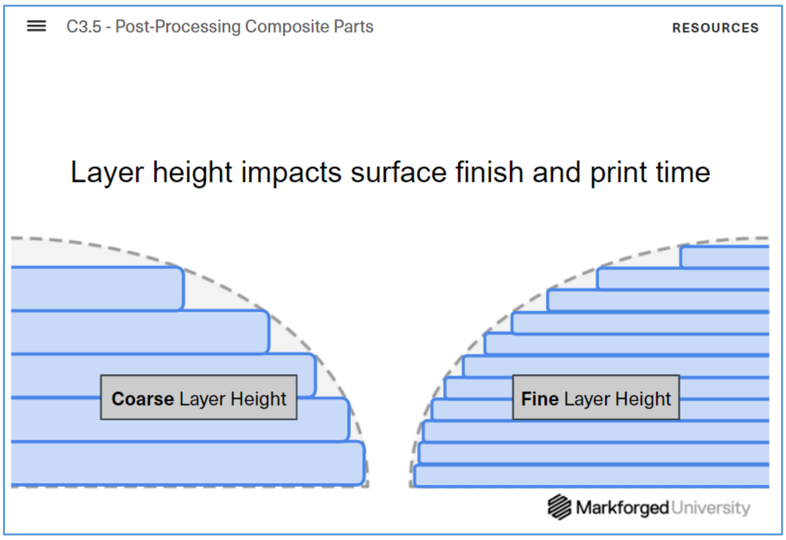
- **Post-Processing Composite Parts**



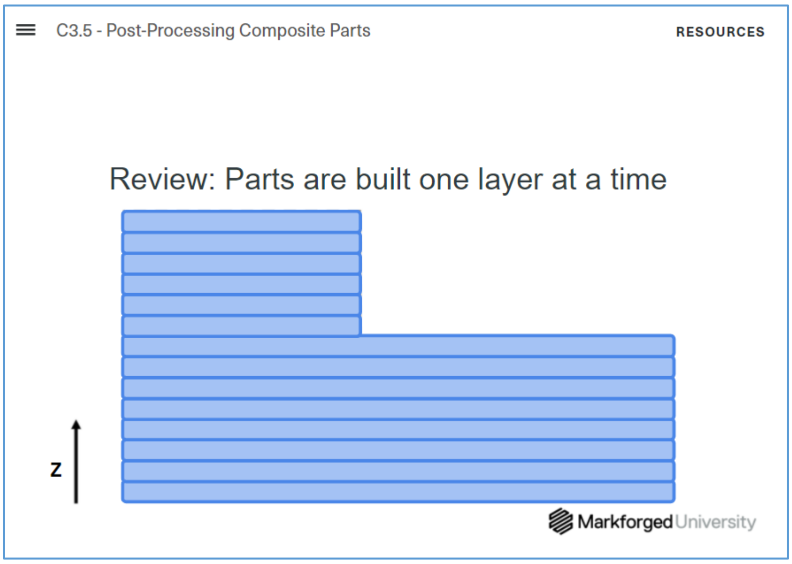
- **Module Overview**
    - Configureren is het samenstellen van een product uit verschillende basisbouwstenen, de keuze en schikking van componenten die samen een systeem met de gewenste functionaliteit moeten vormen.



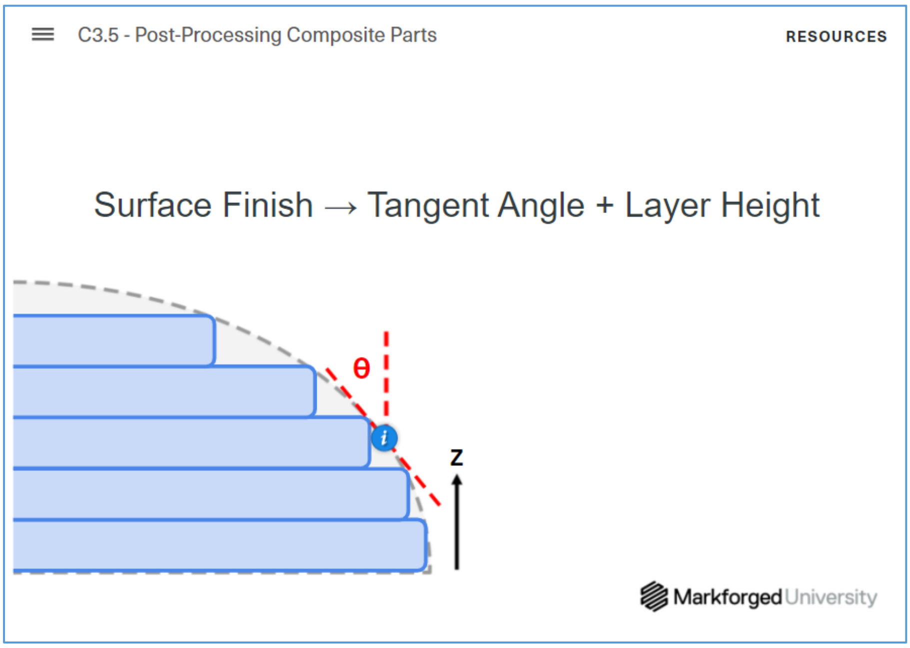
- **Reduce post-processing through print configuration**



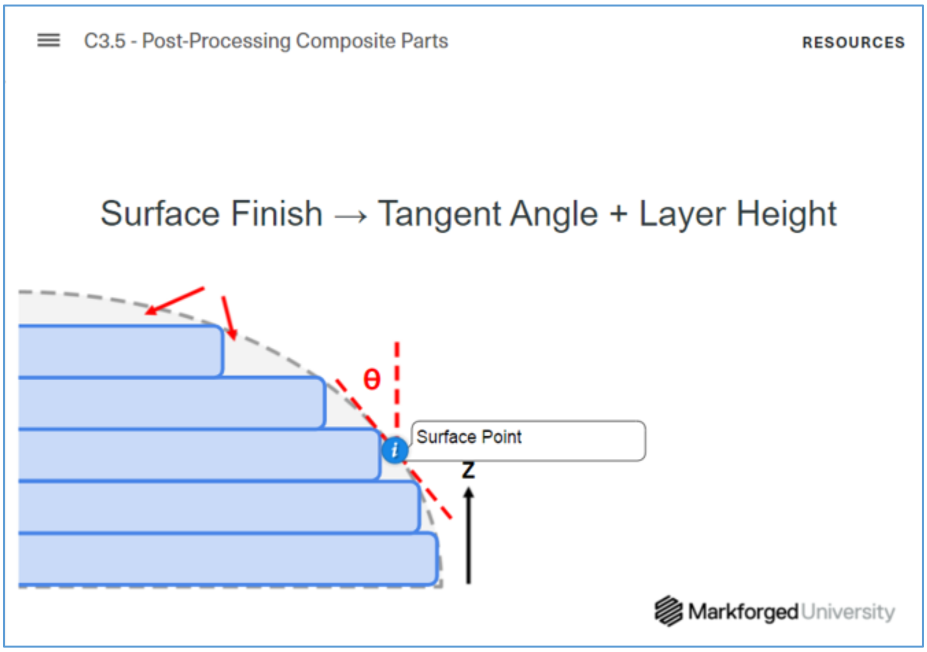
- **Layer height impacts surface finish and print time**

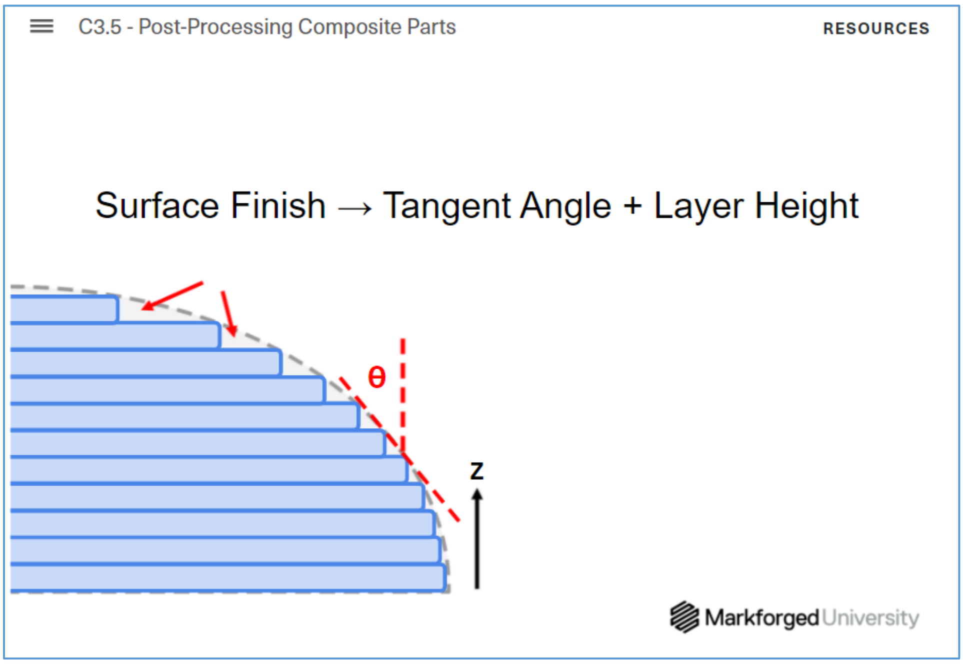


- **Review: Parts are built one layer at a time**

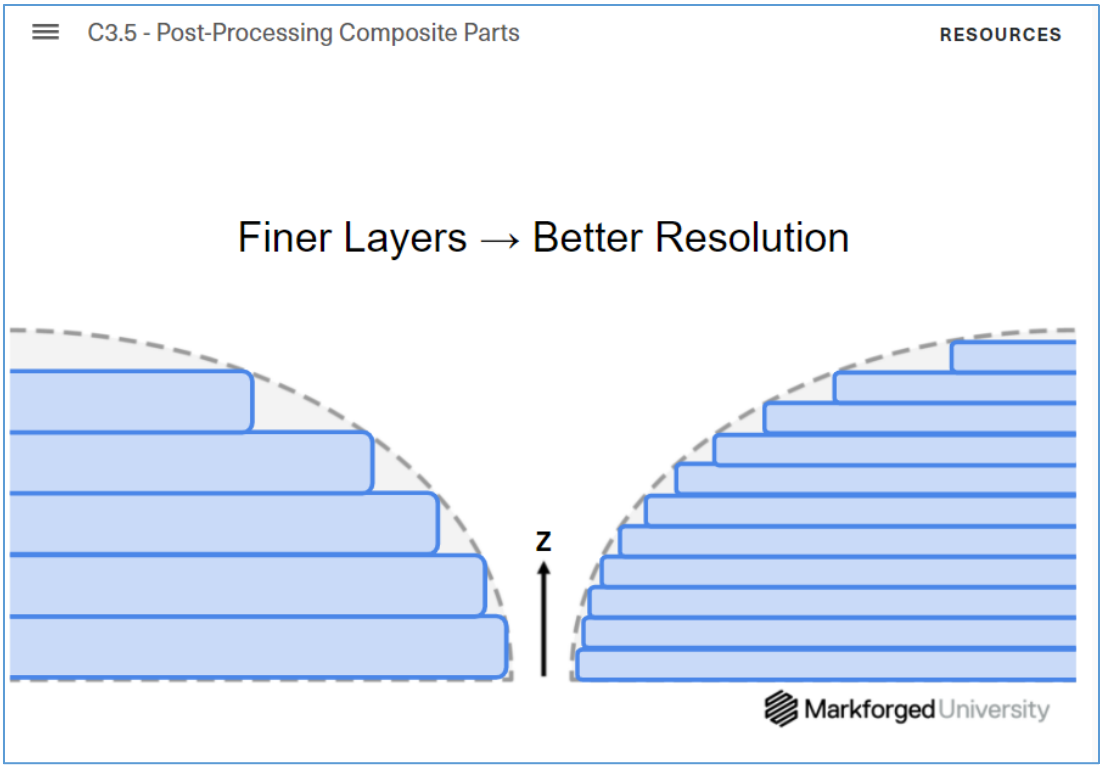


- **Service Finish at Thicker Layer Heights**

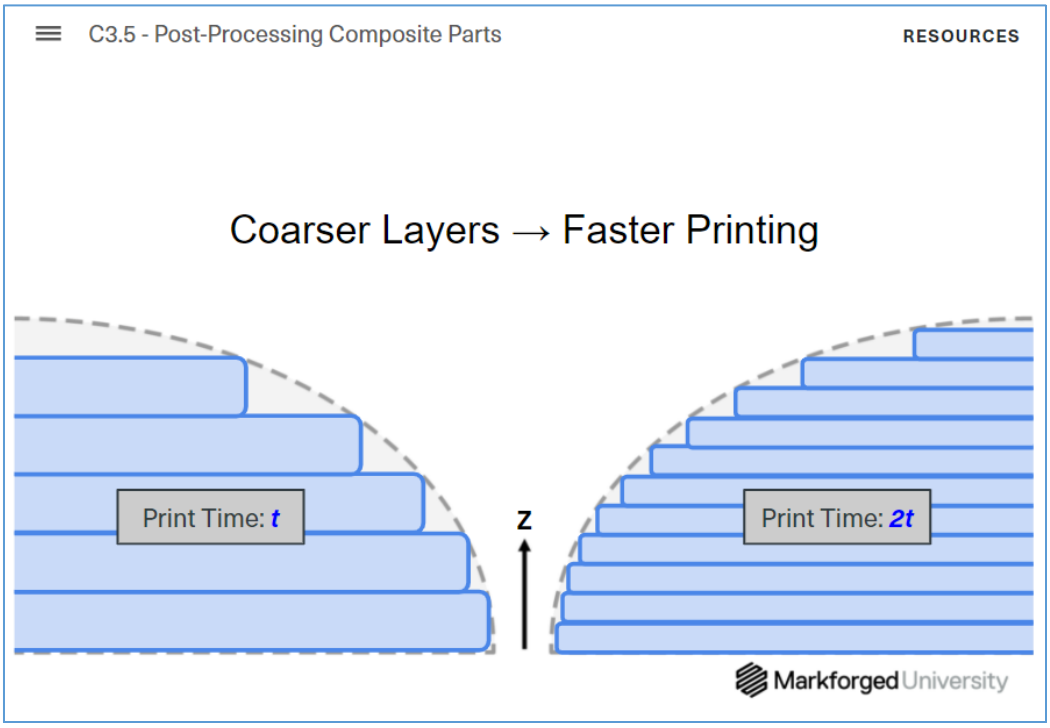




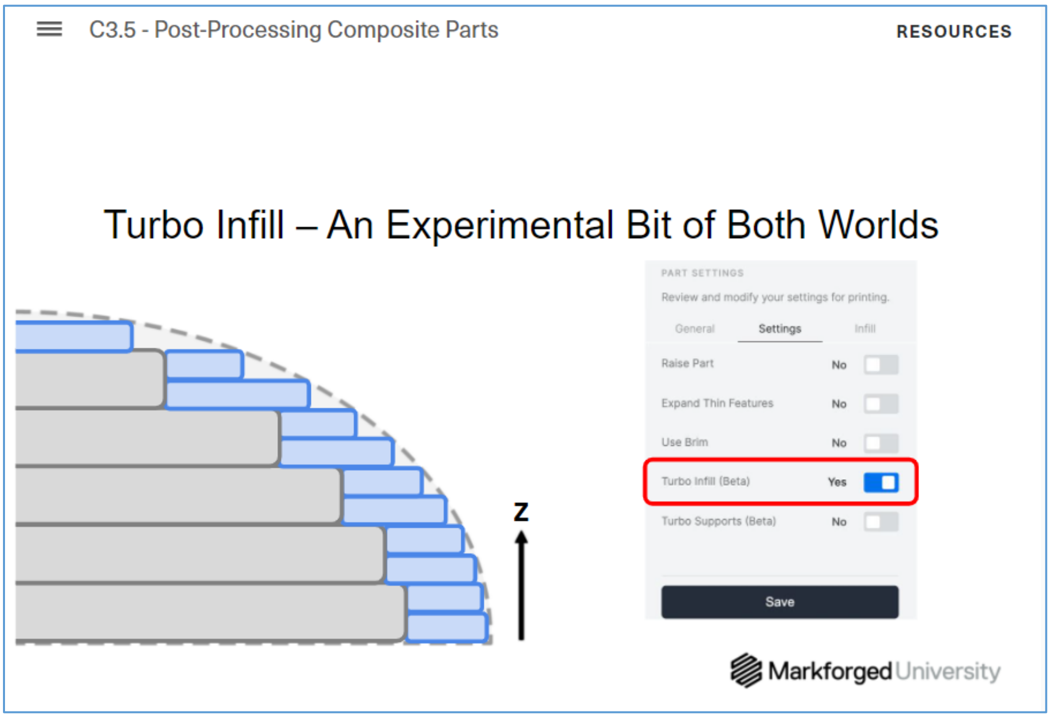
- **Service Finish at Thinner Layer Heights**
    - Is for plastic only. CFF composive fibre needs set layer height. So reinforce the part the layer height depends of the chosen fibre. 0.1mm Layer height for continues Kevlar and fibre glasses and 0.125mm for continues carbon fibre.



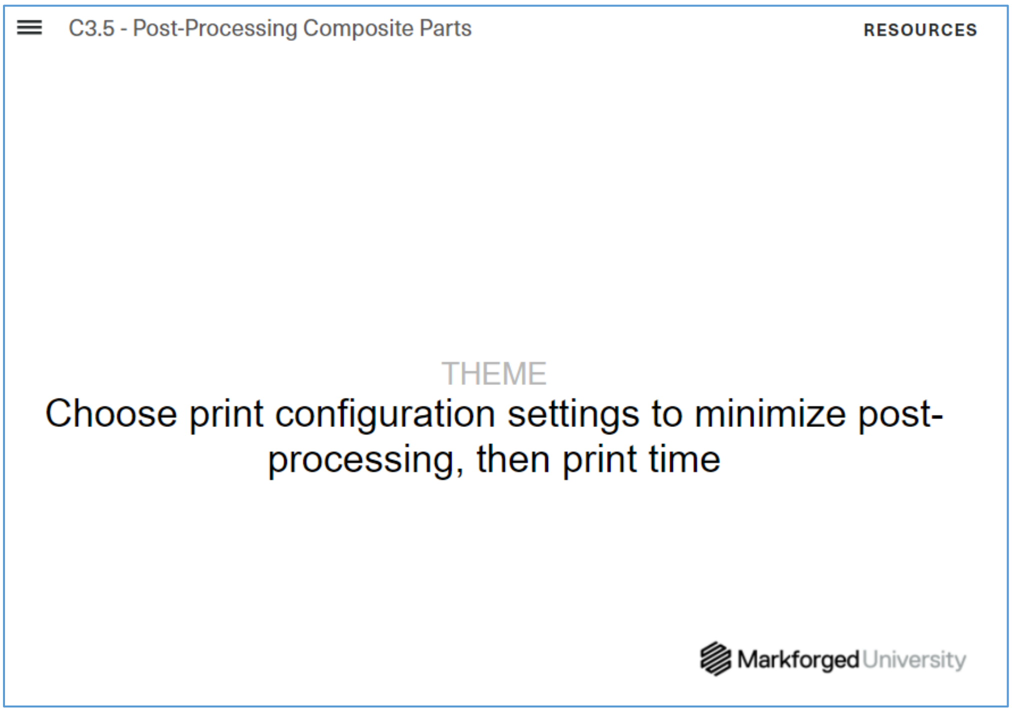
- **Finer Layers → Better Resolution**



- **Coarser Layers → Faster Printing**
    - Coarser = Grover.



- **Needed Faster? Try Turbo Infill**

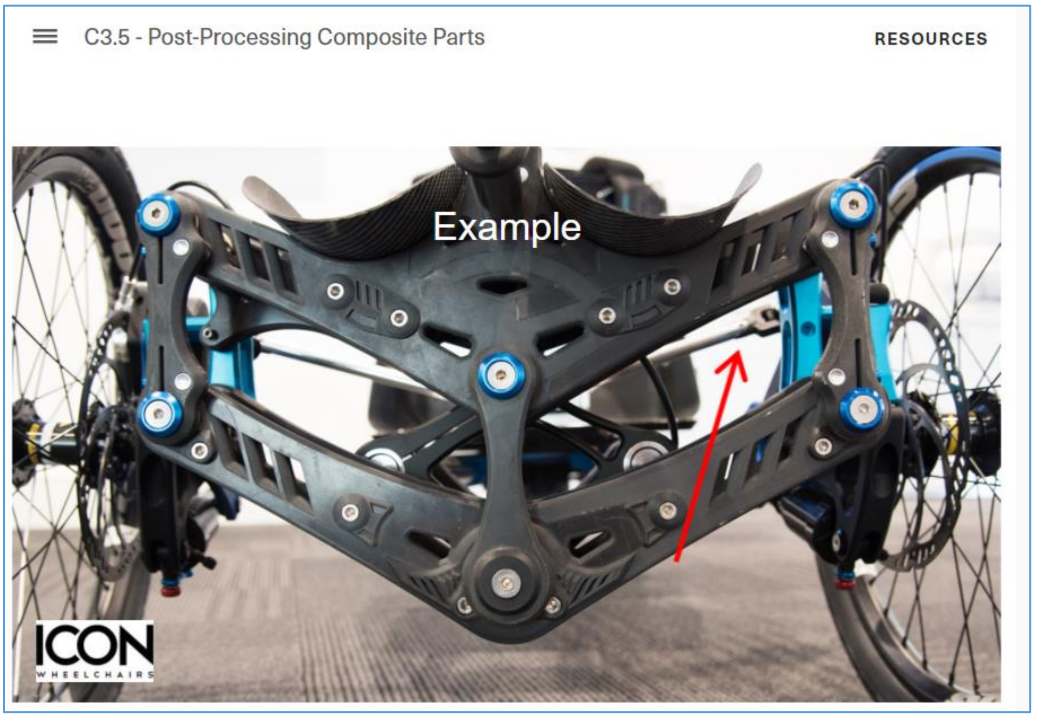


- **Theme: Minimizing Post-Processing**

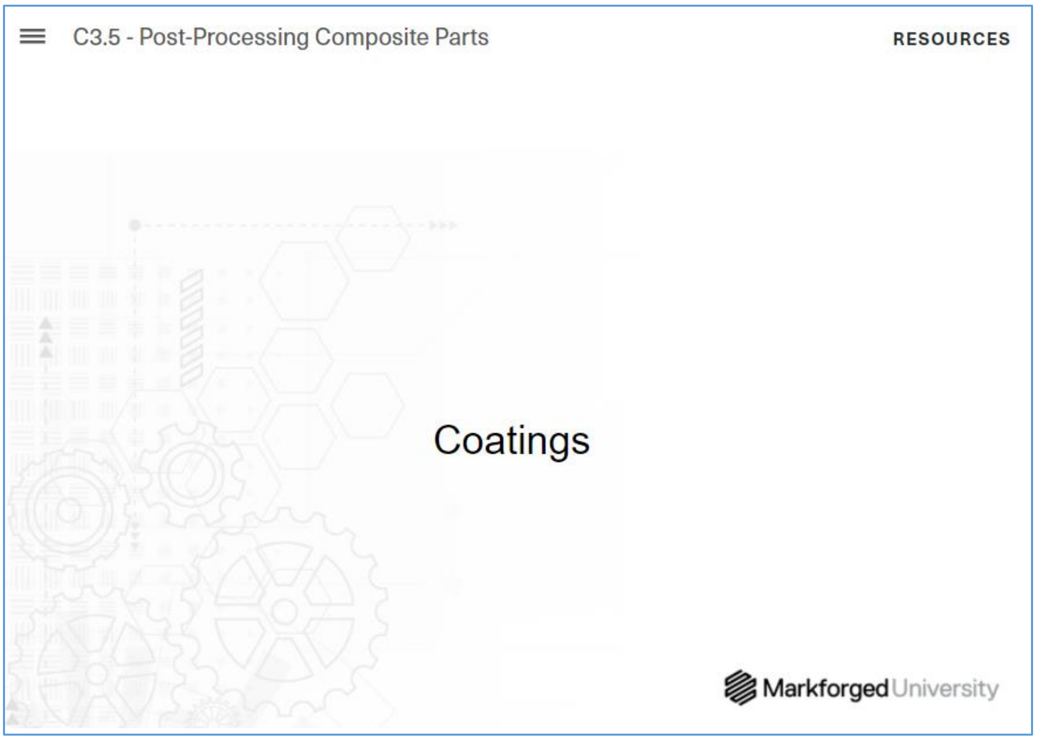
- **Adhesives**
    - Lijmen.

- **Onyx-Onyx Bonding**

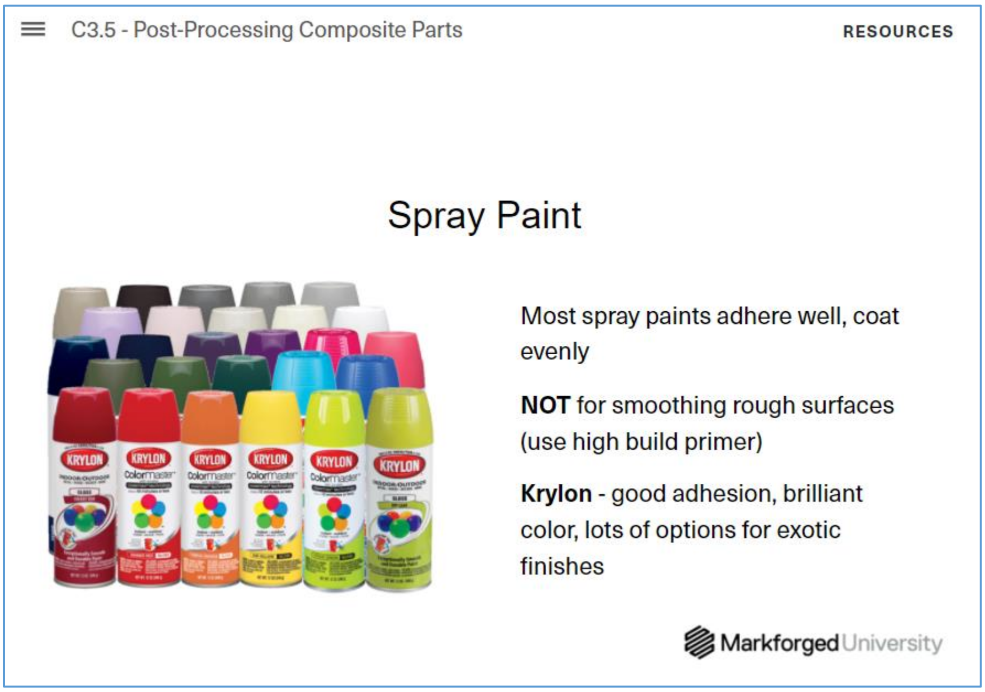
- **Onyx-Other Materials Bonding**



- **Example**
    - Control arms responsible for the rotation, like a car system.



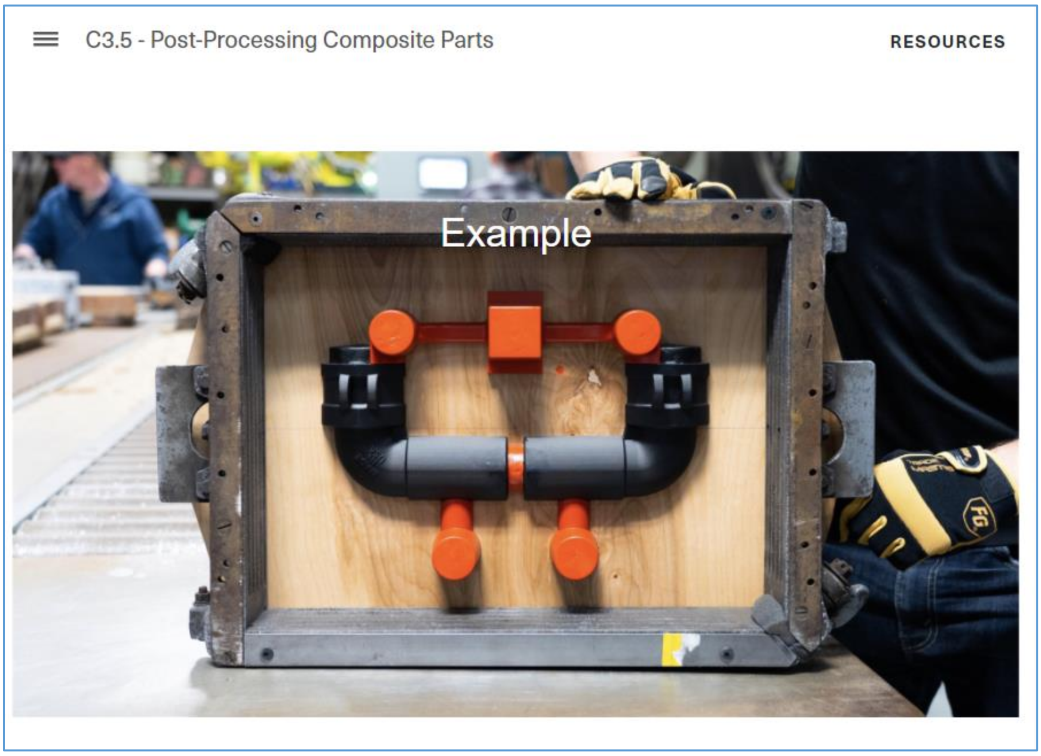
- **Coatings**



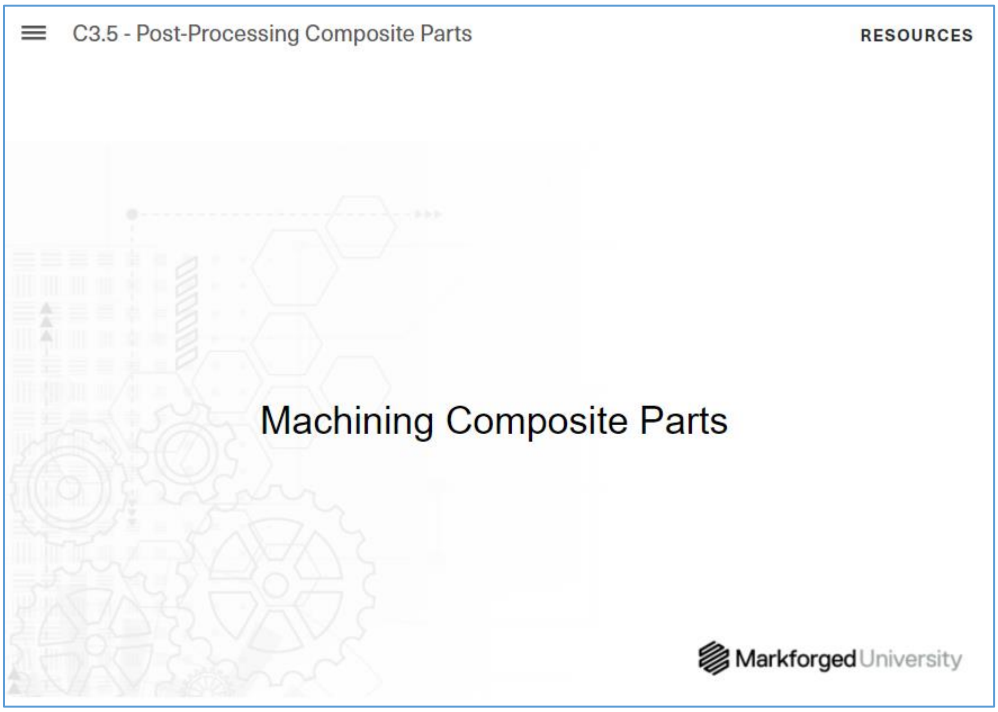
- **Spray Paint**

- **Filling in Rough Surfaces**

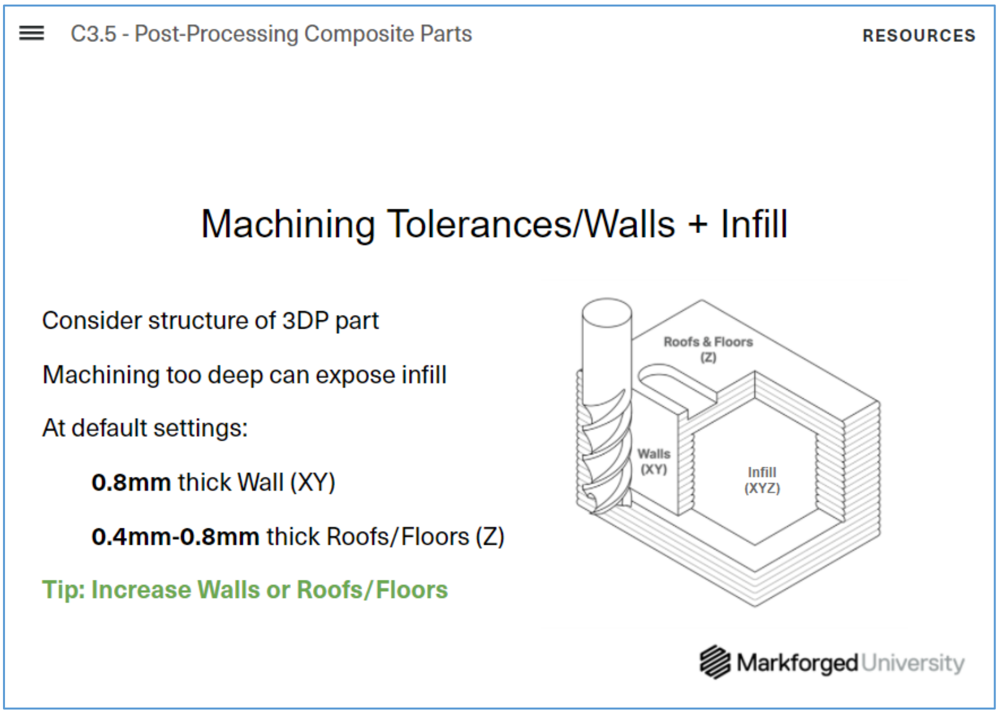
- **Water-resist/Vacuum Sealing**



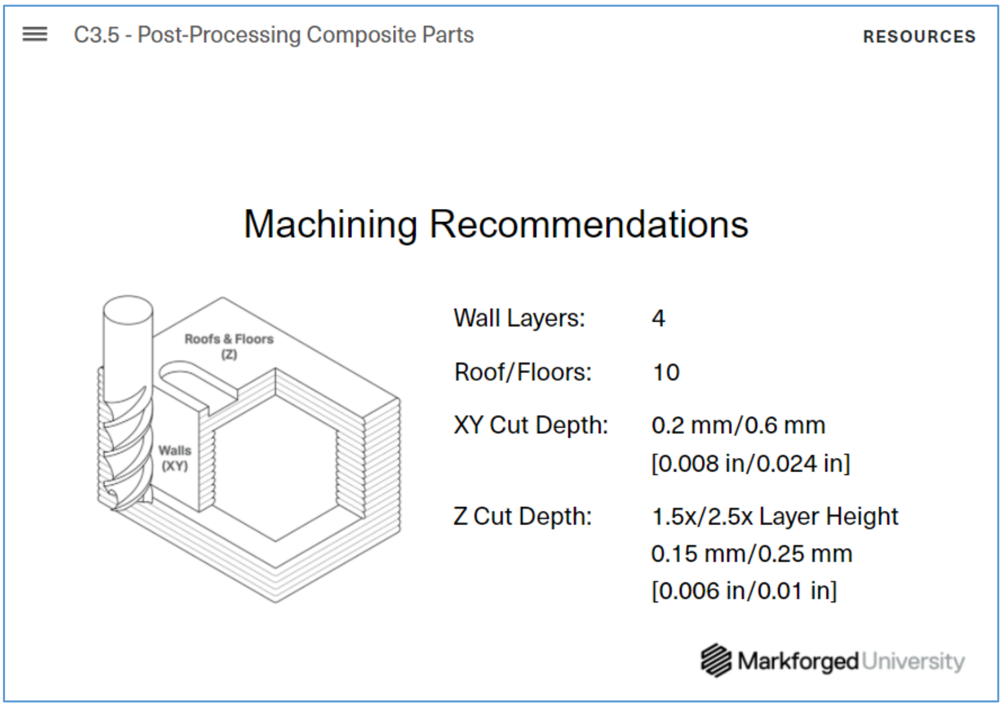
- **Example**
    - To improve the surface finish and also for easier removing from sand mold, without damaging.



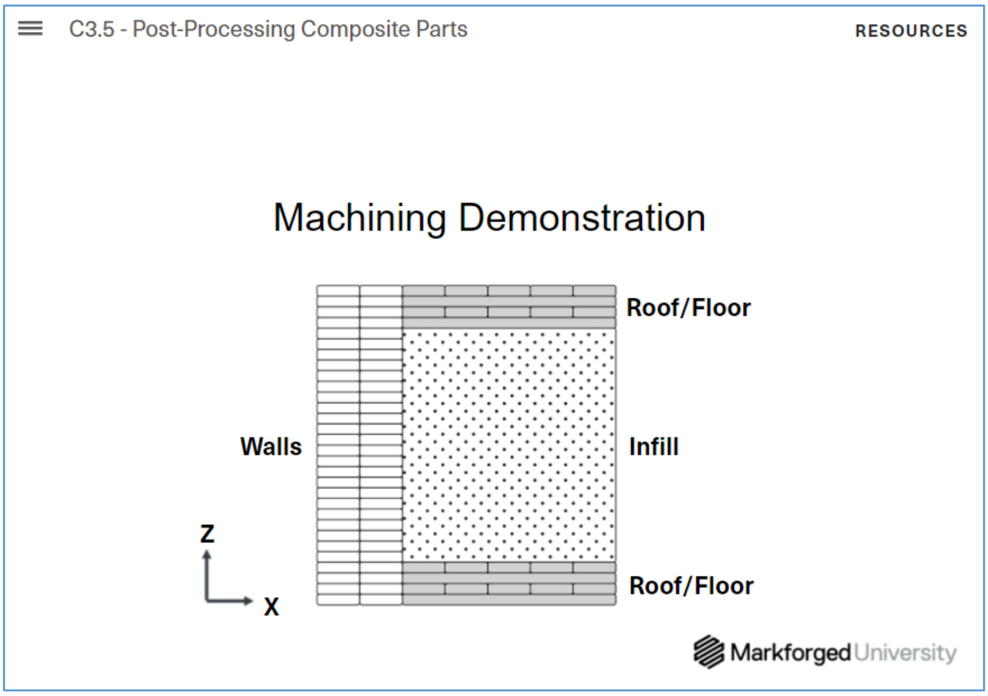
- **Machining Composite Parts**



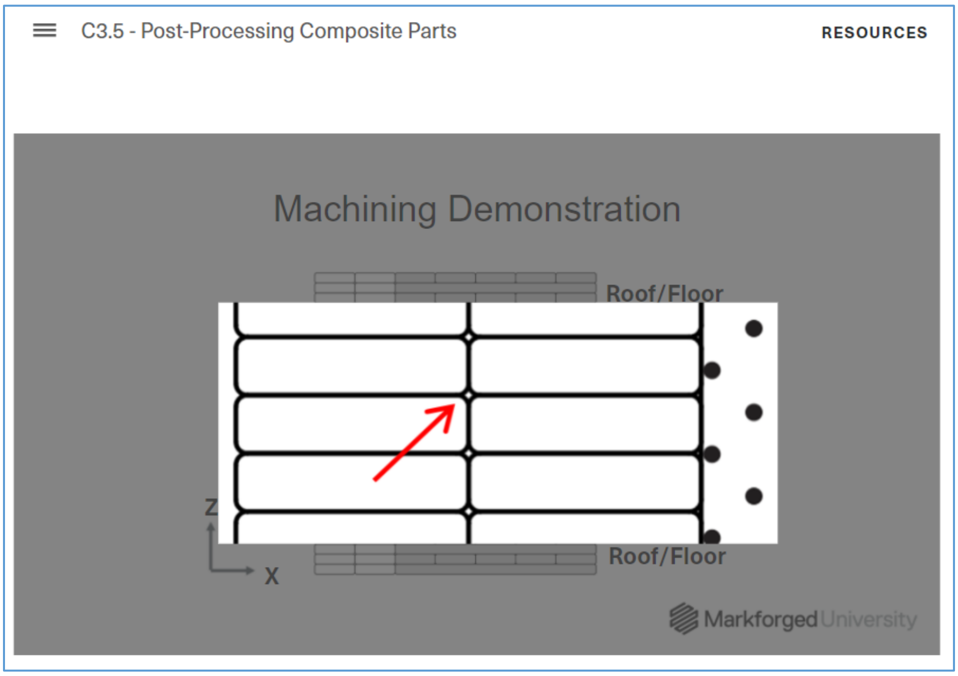
- **Machining Tolerance/Walls + Infill**
    - Expose = blootleggen



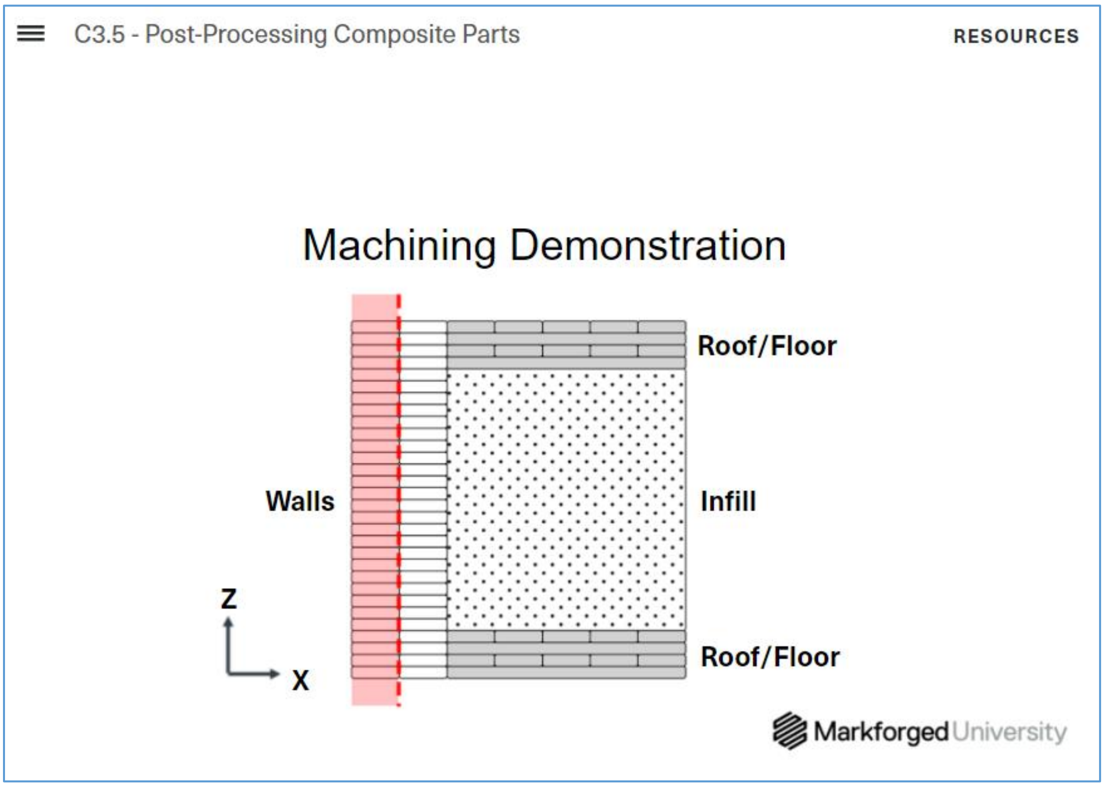
- **Machining Recommendations**



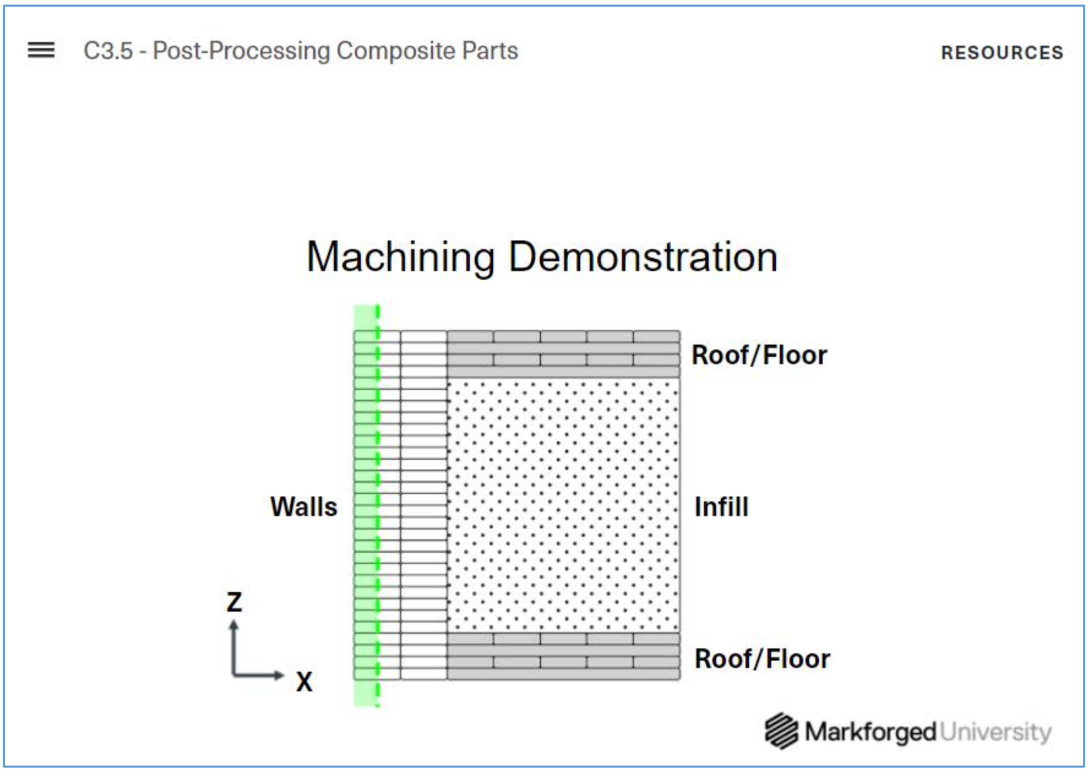
- **Machining Activity**



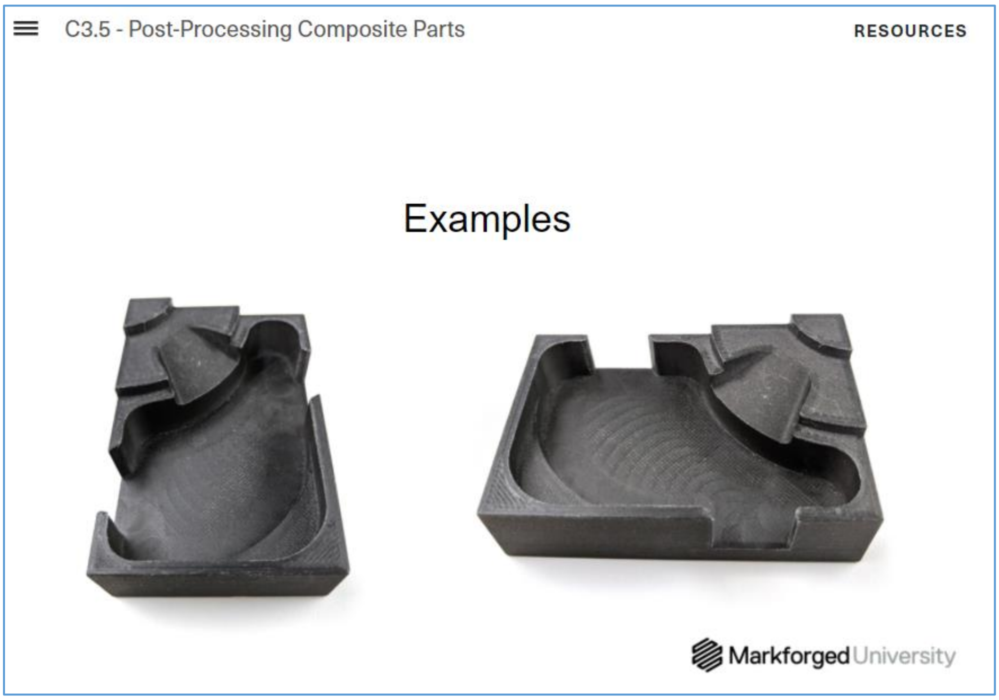
- Zooming in you can see a risk when you machining at this location.



- This toolpath is not what we want.



- We want the cutting toolpath in the middle of the wall.



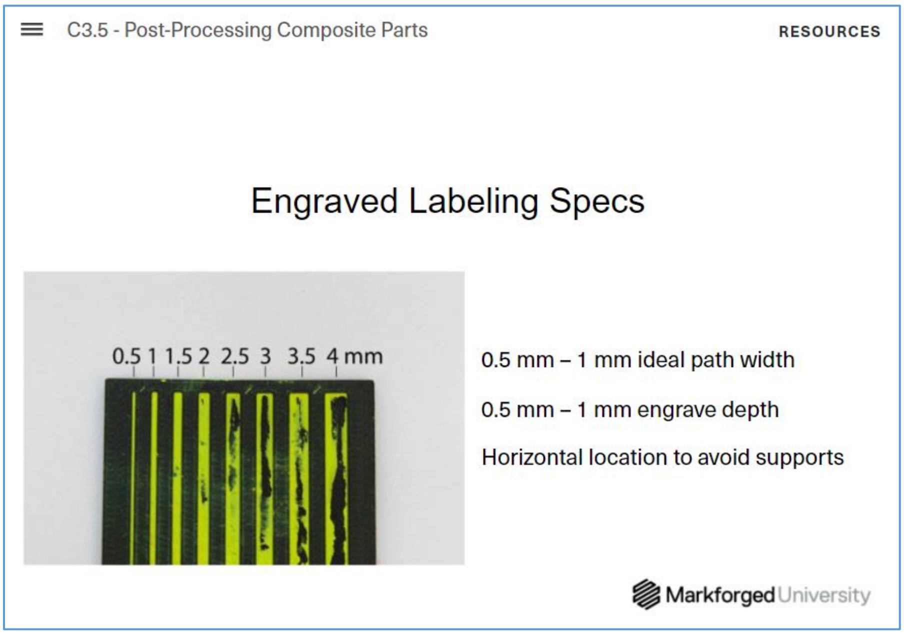
- **Examples**

- **Marking and Labeling**

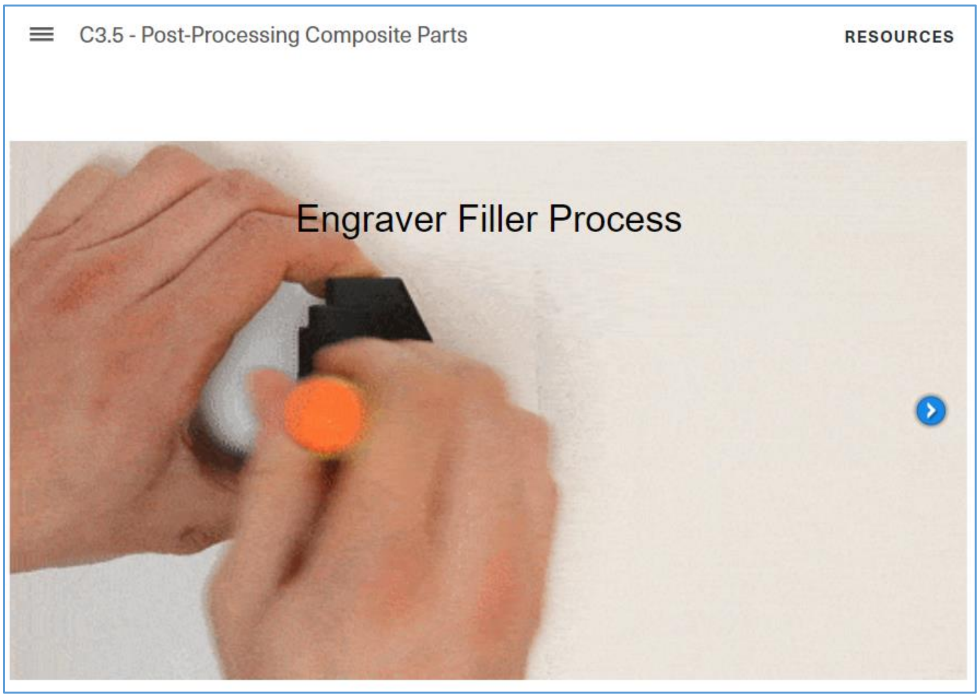
- **Metallic Sharpie (trademark) and Engrave**

- **Fiber Laser Marking**

- **Labeling with Engraving Filler**
    - https://www.amazon.com/s?k=engraving+filler&ref=nb_sb_noss_1
    - F Markal Paint Markers - Buy F Markal Paint Markers Online (markingpendepot.com)

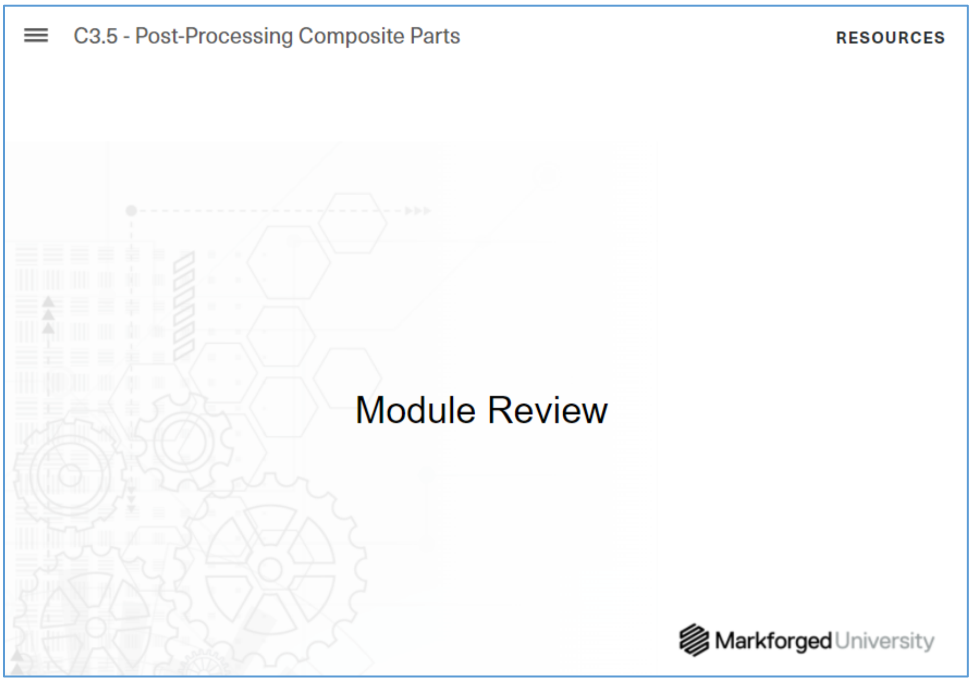


- **Engraved Labeling Specs**

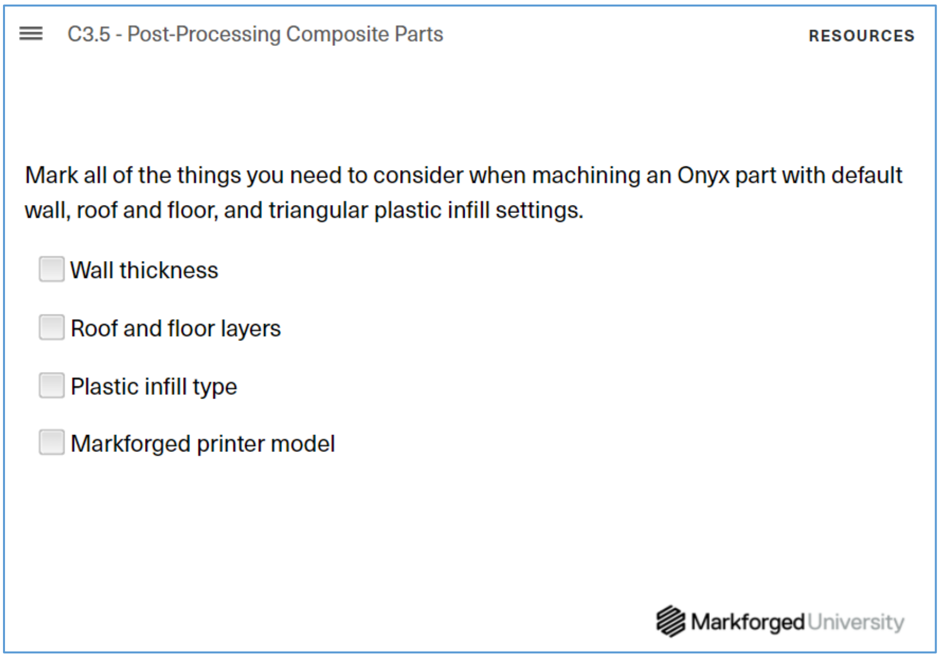



C3.5 - Post-Processing Composite Parts
RESOURCES
Engraver Filler Process
J-337-0CF


C3.5 - Post-Processing Composite Parts
RESOURCES
Finished Example
J-337-0CF
J-514-0CF
J-514-0CF



- **Module Review**



C3.5 - Post-Processing Composite Parts

RESOURCES

Mark all of the things you need to consider when machining an Onyx part with default wall, roof and floor, and triangular plastic infill settings.

- [x] Wall thickn
- [x] Roof and f
- [x] Plastic infi
- [ ] Markforge

Correct

That's right! You'll want to consider whether your part has a hollow infill and if it does how thick the walls and roof and floor layers are, to avoid breaking into the hollow infill of the part.

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C3.5 - Post-Processing Composite Parts

RESOURCES

True/False: Configuring a part to print with a thinner layer height will reduce the print time, since the thinner layers cool faster.

- True
- False

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C3.5 - Post-Processing Composite Parts

RESOURCES

True/False: Configuring a part to print with a thinner layer height will reduce the print time, since the thinner layers cool faster.

- True
- False

Correct

Correct! Printing a part with a thinner layer height will increase the print time since there are more layers to print. The thinner layer height will produce a smoother, higher resolution surface finish however.

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C3.5 - Post-Processing Composite Parts

RESOURCES

What is an effective technique to add high contrast labeling to a 3D printed part

- Fiber laser marking
- Running a metallic marker across engraved text
- Creating engraved text with a high contrast filler
- All of the above

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C3.5 - Post-Processing Composite Parts

RESOURCES

What is an effective technique to add high contrast labeling to a 3D printed part

- Fiber laser marking
- Running a
- Creating e
- All of the a

Correct

That's right! All of these can be effective techniques for adding highly visible labeling to a 3D printed part.

Continue

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C3.5 - Post-Processing Composite Parts

RESOURCES

True/False: The effects of a thinner layer height are most noticeable on areas of a part whose surface tangent angles are large (close to but less than 90° from the vertical)

- True
- False

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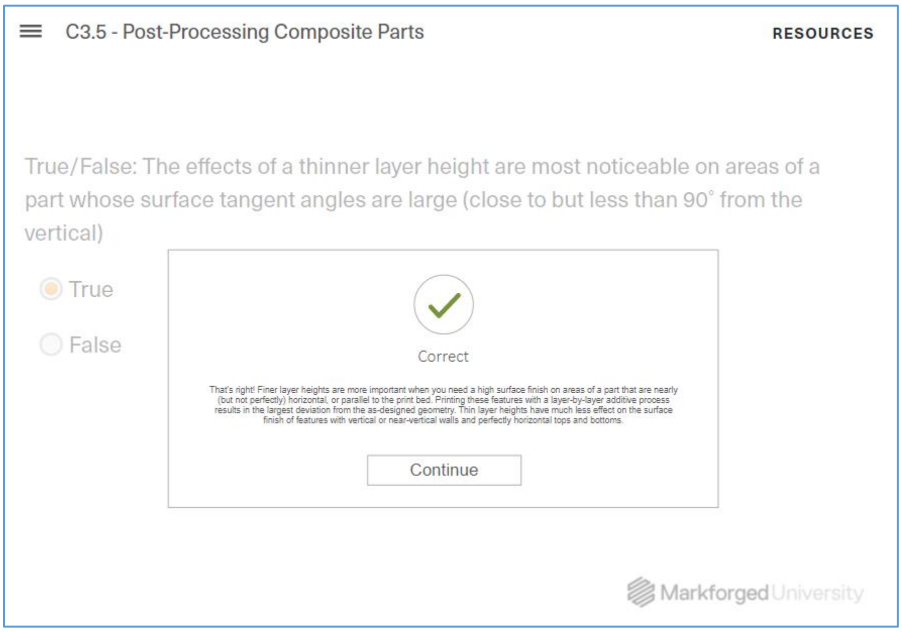
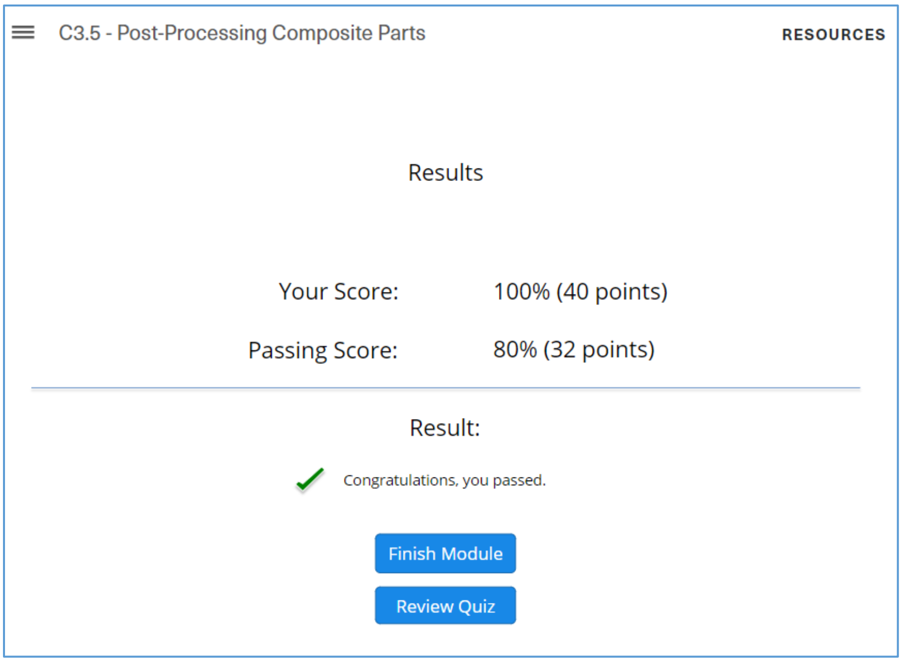

C3.5 - Post-Processing Composite Parts
RESOURCES
True/False: The effects of a thinner layer height are most noticeable on areas of a part whose surface tangent angles are large (close to but less than 90° from the vertical)
True
False
Correct
That's right! Finer layer heights are more important when you need a high surface finish on areas of a part that are nearly (but not perfectly) horizontal, or parallel to the print bed. Printing these features with a layer-by-layer additive process results in the largest deviation from the as-designed geometry. Thin layer heights have much less effect on the surface finish of features with vertical or near-vertical walls and perfectly horizontal tops and bottoms.
Continue
Markforged University


C3.5 - Post-Processing Composite Parts
RESOURCES
Results
Your Score: 100% (40 points)
Passing Score: 80% (32 points)
Result:
Congratulations, you passed.
Finish Module
Review Quiz

Software Updated on 2022-11-08

×

This release is focuses on improving new materials and expanding printer compatibility.

Industrial Printers:

Smooth TPU is now available on the web shop! Users can now print this high quality, flexible material on X3 (Gen 2), X5 (Gen 2), and X7 (Gen 2) printers or any industrial with an A3648 extruder installed. Make sure to read through the Getting Started with Smooth TPU guide before loading. Happy printing!

- S-TPU release for X3, X5, and X7 printers with an A3648 extruder.

Onyx Pro (Gen 2), Mark Two (Gen 2), Industrials:

- Improve P-PLA print reliability and reduce frequency of extrusion issues.
- Reduced time required for S-TPU pull routine.

FX20:

Close

Afgelopen CGI

RV Rense Veenstra (student)
Aan: Henk Spaan; Harrie Goes
Do 20-7-2023 12:59

Goedendag Henk,
Goedendag Harry,

N.a.v. de afgelopen CGI wil ik nog even reageren.

Ik laat het op het moment suprême misschien niet zo merken, maar het heeft me wel degelijk diep geraakt en dat ijlde nog (en nog). Ik erken de uitglijders die ik heb gemaakt en bedankt jullie voor de duidelijke feedback.

Ik moet zeggen dat het nog niet eens bewuste poging was om de boel te flessen, maar heb in mijn enthousiasme een verkeerde start gemaakt door direct met de vormgevende fase aan de slag te gaan. Ik ben gewoon dom geweest en zo voelt het ook.

Ik zal het PVA en het ontwikkeldossier conform jullie adviezen trachten aan te passen. Dit zal lastig zijn om dat de insteek en achtergrond een andere is. Daarom zit ik ook aan te denken een andere opdracht uit te werken, maar dat zou zonde zijn.

Ik wil nogmaals mijn excuses maken en betreur de gang van zaken (zoals het missen van de mails van Harry). Ik ben blij dat ik een nieuwe kans krijg. Zoals je (Henk) aangaf, zal dit na zomervakantie worden. Ik ben i.i.g. 100% gemotiveerd het volledig af te ronden.

Mijn vraag: Moet ik nog iets regelen om door te kunnen in het volgende schooljaar?

Mij rest nog jullie een fijne vakantie te wensen.

Met vriendelijke groeten,

Rense Veenstra
Studentnummer: 1073458