UCI Samueli School of Engineering
Department of Mechanical and Aerospace Engineering

Siemens NX: Project Y

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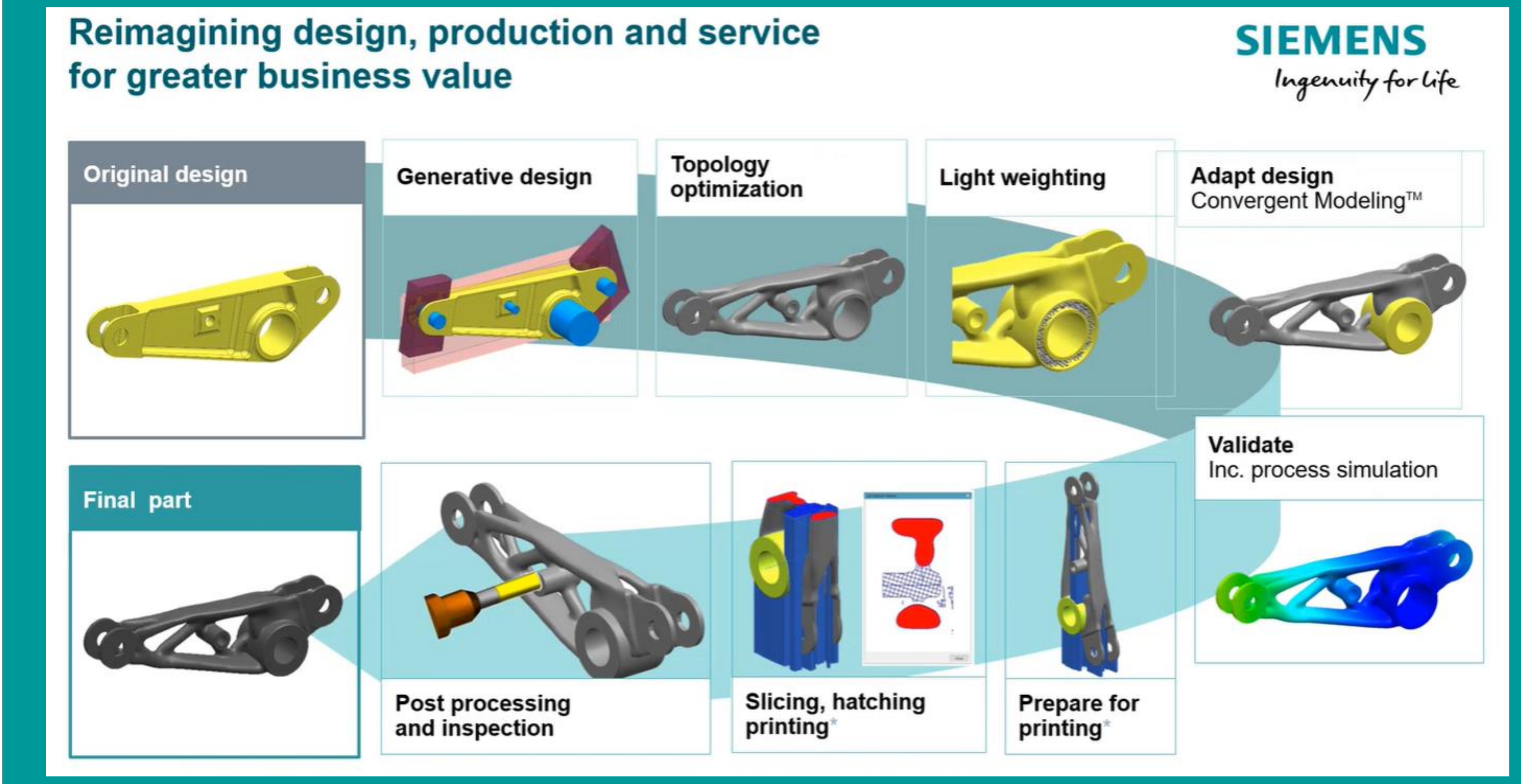
SIEMENS NX

Background

Siemens has partnered with UCI to work with senior-level MAE students to introduce the scope of digital twin and additive manufacturing as well as providing them with hands on experience through their own CAD software, NX.

Objectives and Goals

Topics such as generative engineering, topology optimization, virtual manufacturing, finite element analysis, and convergent modeling are covered in this capstone project. Objectives include using these additive design features and manufacturability concepts to further address additive design goals such as light weighting, strength-to-weight ratio, and custom material properties. With a goal of being NX certified by the end of Spring 2021.

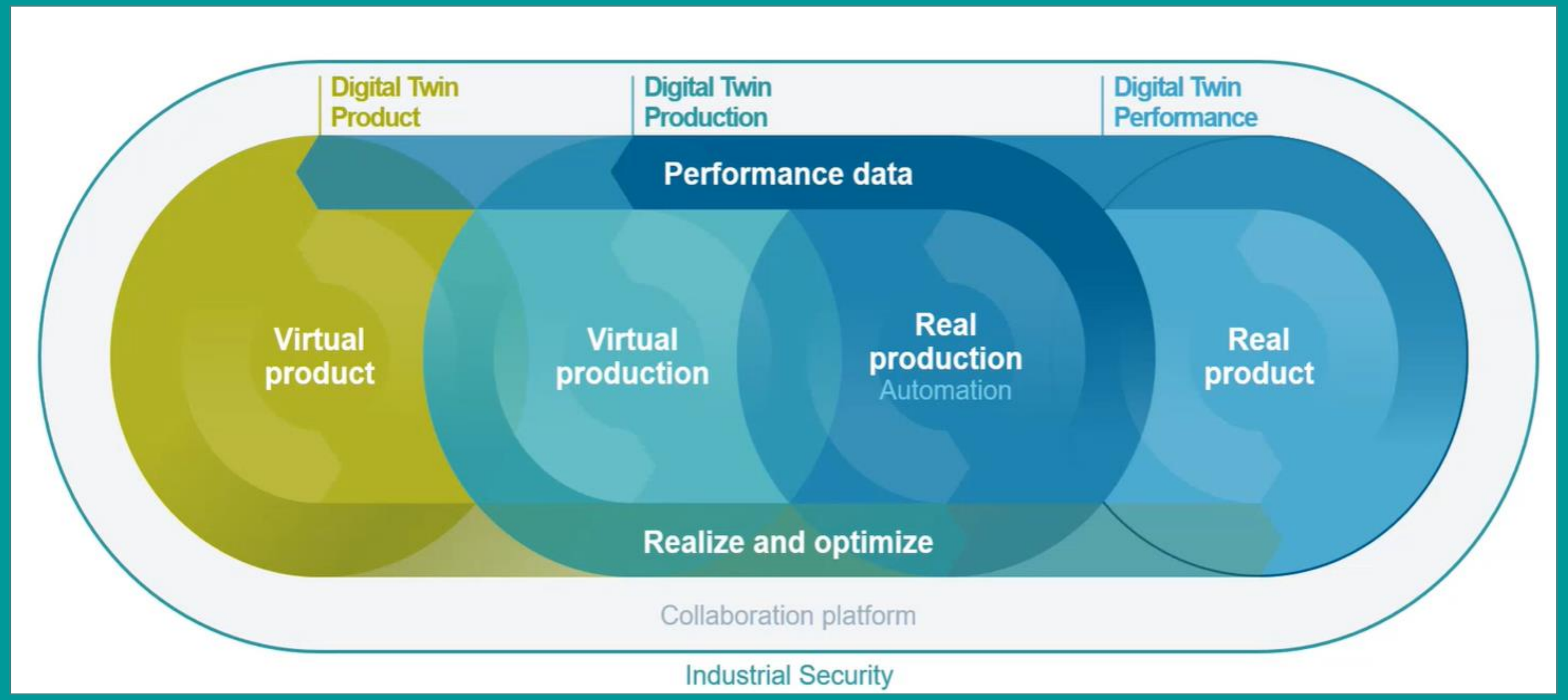


Assigned Tasks

The loading conditions and range of motion of the bellcrank must be identified. After establishing boundary conditions, Siemens NX will be used to model the component, employing generative engineering and topology optimization to prepare the part for additive manufacturing. Static and dynamic analysis will be performed to ensure the part can withstand the given loads. The manufacturing process will be simulated and optimized within NX before proceeding to actual manufacturing.

Digital Twin

A digital twin is the generation or collection of digital data representing a physical object. The concept of digital twin has its roots in engineering and the creation of engineering drawings/graphics.



Siemens

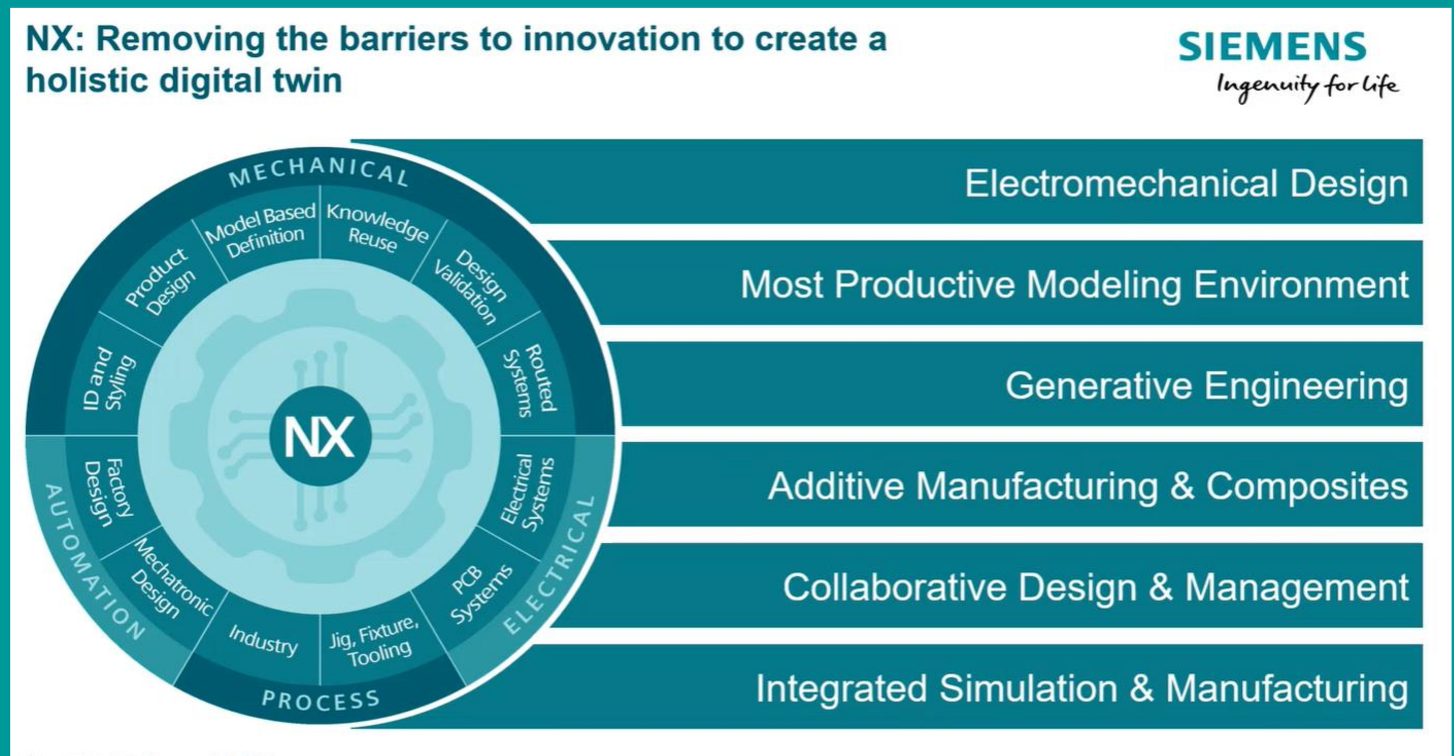
Siemens is a multinational manufacturing company known for its contributions to the healthcare, software, infrastructure, and energy industries. Siemens focuses on the digitization and automation for the manufacturing industry.

Additive Manufacturing

Additive manufacturing, more commonly known as 3D Printing, has recently advancing with hobbyist and industry use. More companies are turning to it as a viable option for producing components as it allows for the creation of lighter and stronger parts making it desirable in the aerospace, defense, medical and automotive industries. Popular additive manufacturing methods include material extrusion for hobby printers and powder bed fusion for industry applications.

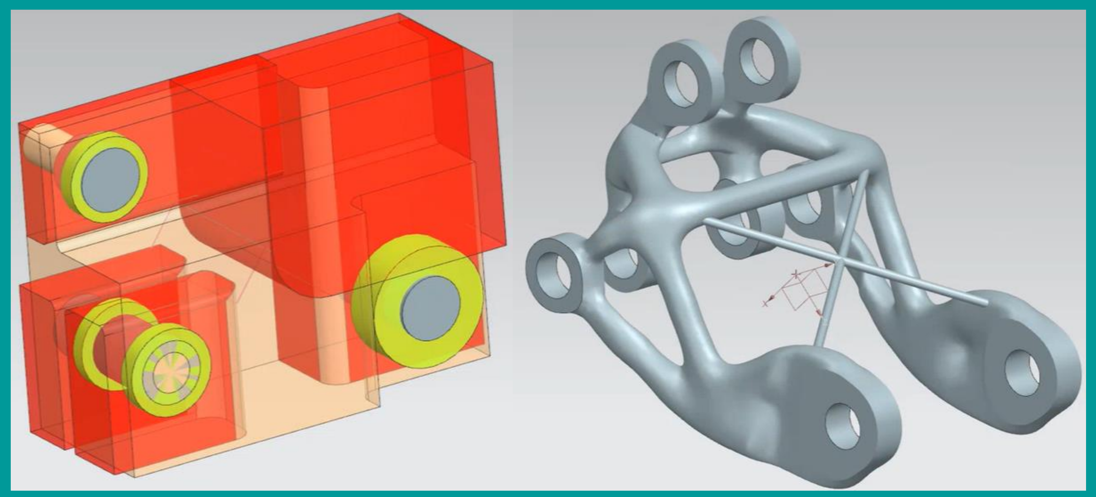
NX

NX is an integrated CAD/CAM/CAE program owned by Siemens. NX simplifies the job of an engineer by providing a platform that integrates modeling, simulation, and virtual production all in one environment. Users can use NX to validate their designs and check if they are compliance to the requirements to make informed decisions. In addition, NX allows users to create prototype and manufacture products using additive manufacturing at a faster rate and and cheaper cost.



Topology Optimization

Topology optimization is one of the many features offered in the NX suite, and is utilized for design of additive manufactured parts. The main goal of implementing topology optimization is to create a model that fits within the design space/constraints and is lightweight with a high strength to weight ratio. The geometry produced is typically organic in nature and can be tested under several load cases. This feature as mentioned helps reimagine products by reducing weight (material), product personalization, and expanding performance.



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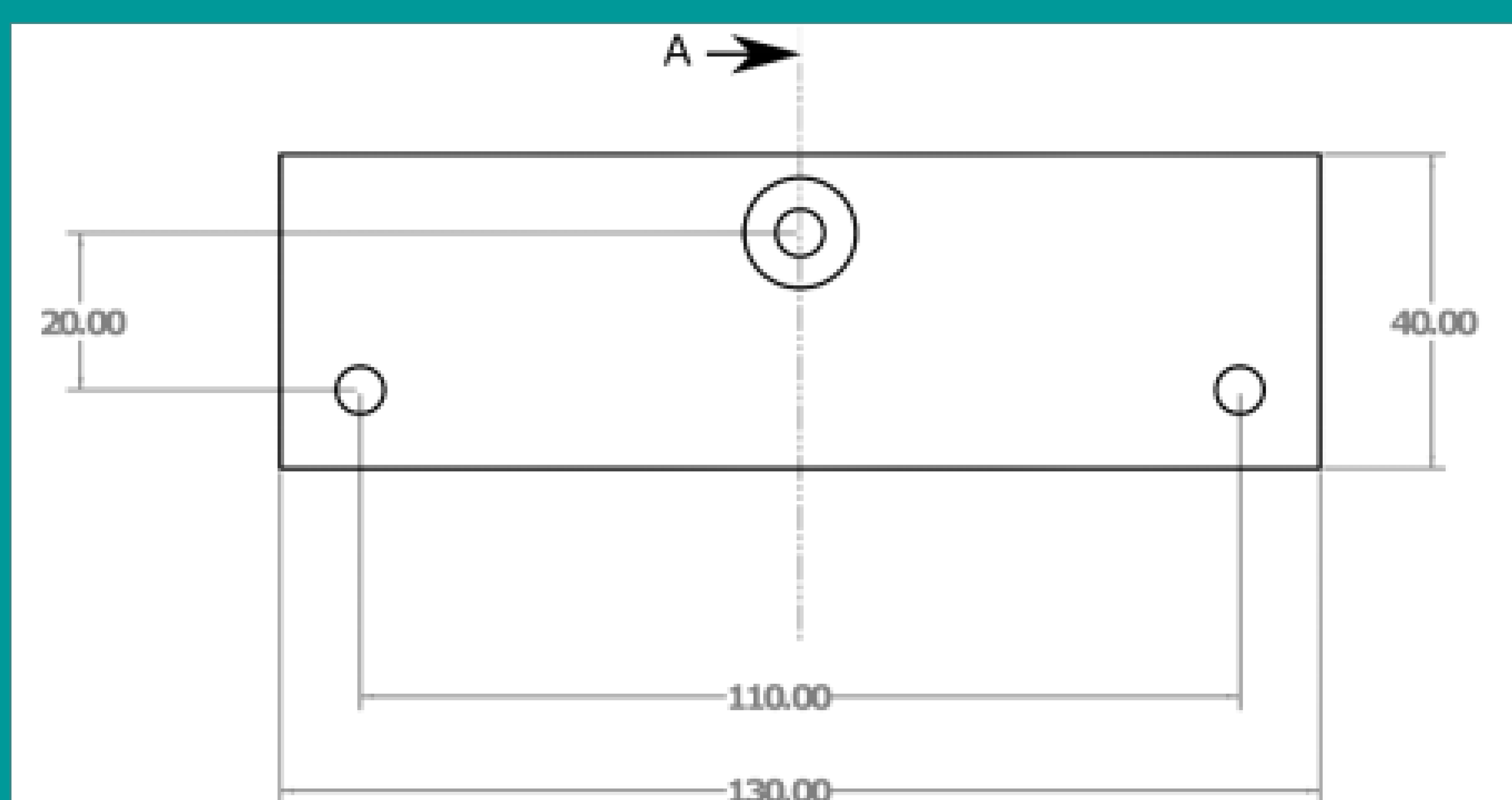
Projects

During the training of NX, the team was tasked with a few design challenges in order to learn and implement NX features. We were to utilize NX to create a Linear Actuator Bracket, and then a Bell-crank actuator for the elevators of a small plane.

Bracket

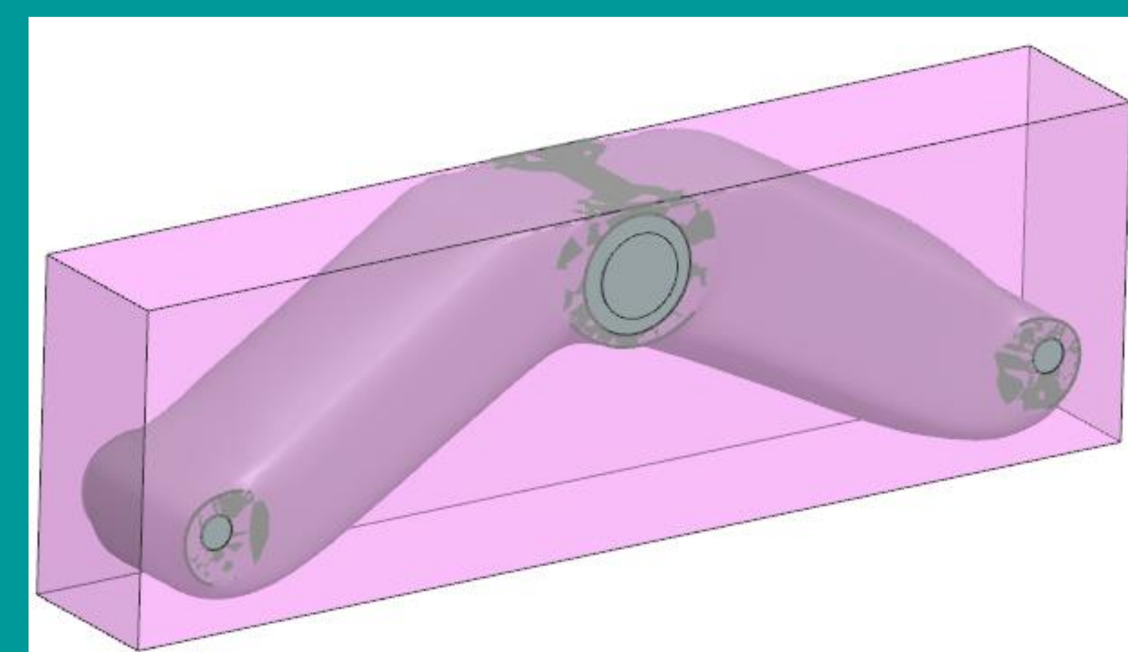
We were given parameters and the design space of the Linear Actuator Bracket. The maximum normal reaction force of this linear actuator is 100 N and a lateral force creates a twisting moment of 50 N-m at the base of the actuator. The distance between the internal faces of the slot in the base of the actuator is 22 mm. Because the motion planning requires allowing the actuator to move 30 degrees back and forth from the vertical position, the hole supporting the actuator should be equipped with flanged sleeve bearings. With all of these parameters and the design space given, we can use Topology Optimization to transform the rectangular prism to more efficient shape.



The bracket will be supported at two points using two dowels of diameter from 4 mm to 6 mm. The goal of the design is to try to maximize the ratio of the normal load, 100 N, to the bar weight while minimizing the deflection to below 2 mm.

Topology Optimization

Utilizing NX optimization, each of the members of the team created brackets of various shapes and strengths. With the constraints and parameters, each engineer had an interpretation of the best design. The figure below shows the before and after transformation of the topology optimization. From the geometric pink prism to more efficient and organic shape.



Multi-inkjet Fusion

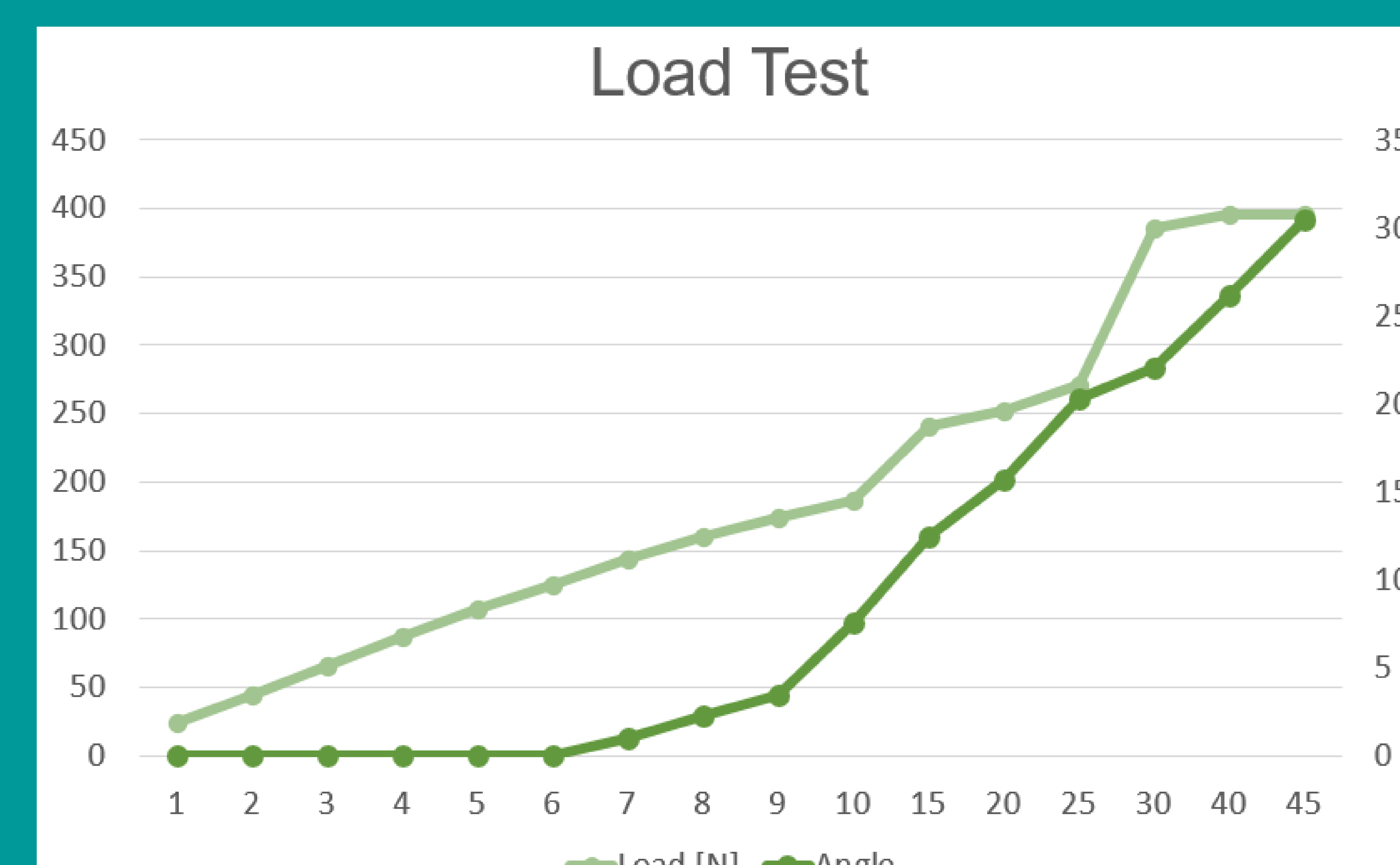
Multi-inkjet fusion (MJF) 3D printer was utilized to manufacture the parts that were designed. The material used was powdered nylon. MJF was used in this application because topology optimization often creates parts that are complex and intricate. The MJF printers can print multiple parts in great detail. MJF printers also offers isotropic material properties as suppose to the more common printers that deposits materials in a pattern that have anisotropic properties.

Testing Rig

When designing the bracket, a testing rig also had to be designed in order to experiment with the performance of the part. The test rig consist of aluminum frames and stainless steel rods that will provide support. The test rig will be mounted to an s-beam stainless steel load cell. The load will be manually applied with a hand crank.

Testing Results

During load tests, the comparison of the angle of displacement is paired against the force measured by the load cell. The various designs had each of their strengths and weaknesses. Some designs had more resistance against torsion while some had better axial resistance.



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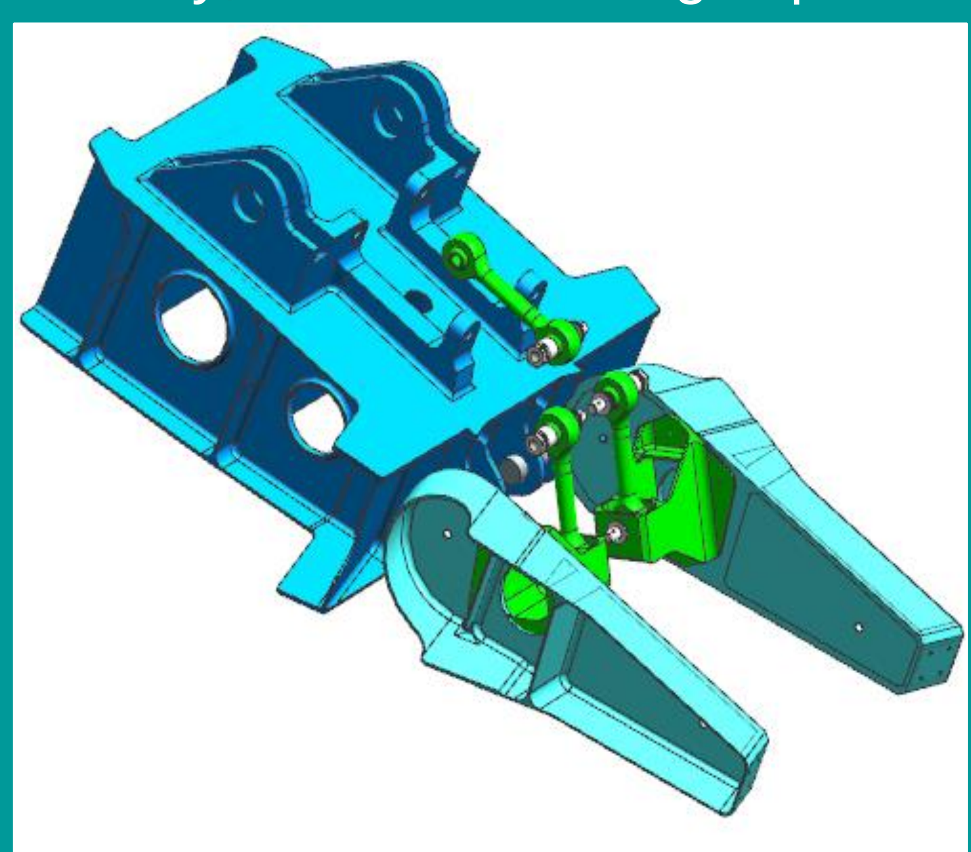
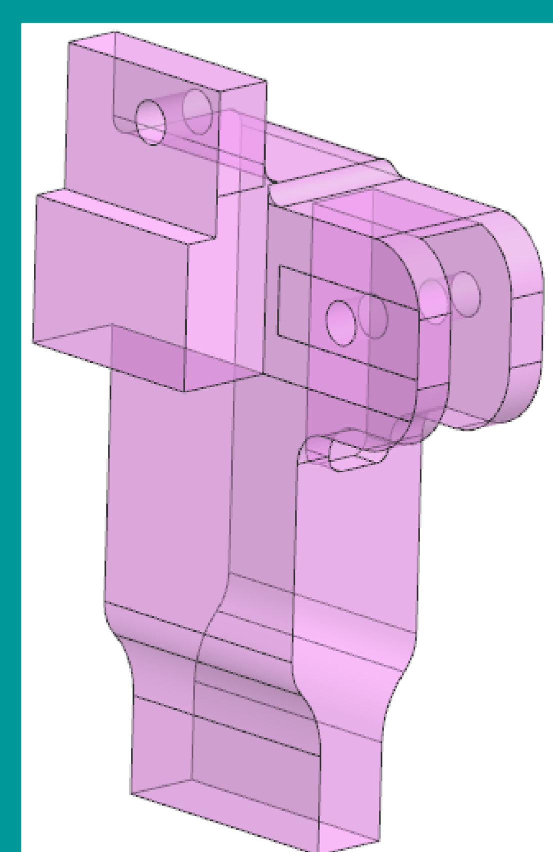
Elevator Bell-crank

Plane elevators control the pitch of the aircraft by deflecting up and down, creating a pressure difference around its flight control surface. The elevator bell-crank is for the Cessna 182 aircraft. The bell crank is responsible for articulating the elevator of the plane which must be able to deflect 22 degrees downward and 25 degrees upwards from its neutral position. The bell crank must withstand the given 550 Newton loads on each of the joints with specified vectors, mass must be under 0.17 kg, and must have a detailed manufacturing plan. As per FAA standards, a factor of safety of at least 1.5 must be achieved.

Elevator Mechanism

The elevator mechanism assembly was provided to allow the creation of the design space. By evaluating the assembly, the correct design space can be drawn.



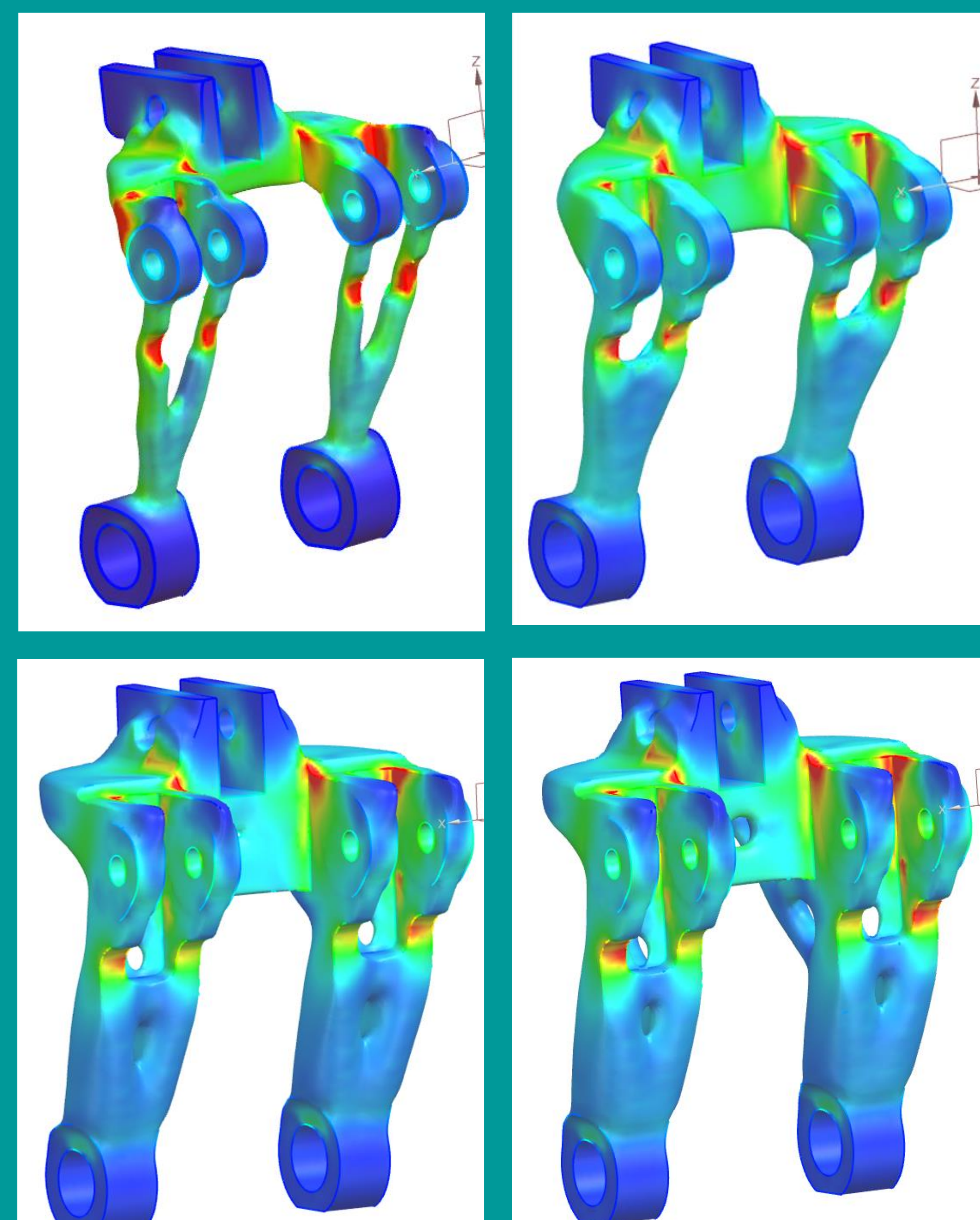


Design Plan

Siemens NX will be used to model, simulate the physical performance, and virtually manufacture the component, consisting of a bell crank mechanism, before proceeding to actual manufacturing. Generative engineering and topology optimization will be employed to create models that is both lightweight and capable of withstanding the loads required for it to be considered safe.

Topology Optimization

Utilizing NX topology optimization, each of the members on the team created brackets of various shapes and strengths. With the given constraints and parameters provided by Siemens, optimized bell-cranks were created using materials ranging from metals to polymers. The load case consisted of 550 N along with fixed and pinned boundary conditions as the mounting holes. The bell-crank was optimized to be additively manufactured, lightweight, and high strength-to-weight ratio.



Top left: 316L Stainless Steel
Top right: Aluminum Alloy AlSi10Mg
Bottom left: Ultem 9089 (Polyetherimide)
Bottom right: Nylon PA12

Material Comparison

Comparing the results of each material's simulation, we can compare the performances to analyze the best material to manufacture the bell-crank.

Material	Max VM Stress (MPa)	Max Displacement (mm)	Weight (kg)	Material Cost (Dollars)
Stainless Steel	27.9	0.0028	0.3441	$130.76
Aluminum Alloys	15.3	0.019	0.1967	$23.61
Ultem 9085	11.7	0.396	0.1216	$30.40
Nylon PA12	10.3	0.223	0.1173	$18.66

Results & Conclusion

The aluminum alloy is the better choice. Although the Nylon is the most lightweight, aluminum will be more reliable than the polymer when dealing with sustained loads and dynamic movement. The aluminum alloy remains lightweight while having about ten times less displacement than the Nylon bellcrank.

Material Criteria	Importance (1-4)	Stainless Steel	Aluminum Alloys	Ultem 9085	Nylon PA12
Stress	1	3	3	3	3
Displacement	3	3	3	1	1
Weight	4	0	2	3	3
Cost	2	0	3	2	3
Manufacturability	3	3	3	2	2
Totals		**9**	**14**	**11**	**12**