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Combining Inventor and 3D Printing in Early Prototype Development

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Learning Objectives

- Discover where Inventor fits into the prototype development process
- Discover how 3D printing can accelerate the design review process
- Learn how using Inventor to continuously modify a model can save time on redesigning a part
- Learn how to identify the differences between design for manufacture and design for 3D print

Description

3D printing has revolutionized the design and manufacturing production workflow, making the creation of design prototypes as easy as pushing a button. Inventor software has been a central tool in this revolution, enabling designers and engineers to create and iterate their design faster than ever before. This course will step through the process of developing, printing, and iterating the design of a real product prototype. Quad copters and drones are used every day for a variety of purposes, from videography to inspecting large tanks. Many drones leave the blades exposed and a single hit into a surface can easily damage both the blades and the drone. Here you will step through the process of designing blade guards for a popular drone quadcopter, seeing the steps and different phases of the design used to create a 3D printable final product.

Your AU Expert

Steven attended Rochester Institute of Technology for film/animation and A-B Tech's Entrepreneurship program in 2011. In 1990, he founded Spectralight Images, LLC to produce 3D animation. Moving to Orlando, FL in 1990, he soon began teaching 3D at Seminole State College. In 1997, he opened Gallery 611 and formed the Orlando Visual Artists League in 2000, remaining president until 2004. In 1998, he became an Autodesk® training specialist, and has contributed to Autodesk's certified courseware for 9 releases of 3ds Max®. He was a co-developer of Autodesk's ACI Program, and Autodesk's 3ds Max® fundamental standards.

Now, he develops 3ds Max/Maya courseware for CAD Learning's online training, and has continued teaching end users, companies, Autodesk University, & others. Past trainees: Disney, Guess, US Army, and more. Spectra3D Technologies evolved out of Spectralight Images to provide 3D printer sales and support offering an array of 3D printers, design services and training.

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Introduction

Autodesk Inventor software has been the tool for the creation of a wide range of manufactured parts. From consumer products to industrial tooling, to assembly line fixtures, 3D design has been an integral part of reducing the overall time from concept to completion. With the introduction of 3D printing in the mid 1980's the process of developing real parts from 3D CAD models became less expensive with shorter delivery times. This change was quickly recognized by designers as a way to get their prototypes back in their hands for testing sooner and at a lower cost than going to a machine shop, or trying to make a simplified model in house. Soon, 3D printing would revolutionize the prototyping process altogether.

Overview of Prototype development process

Design and prototyping is an age old process that remained largely unchanged through the industrial revolution. The essence of prototyping begins with an idea. That idea can be a product, part or complete system. No matter what it is, the stage between the idea and the actual prototype has been the weak link in most development cycles.

There are several reasons to create a prototype. Whether you are creating a functional prototype, creating one to capture user experience, developing a visual model, or a proof of concept, the process involves physical model. That model begins as a concept, then must be made in some form to meet the requirements of the designer. These are not meant to be the production ready parts, but represent a physical version of the idea.

Traditional Prototyping



Traditional Prototype Process. (Image courtesy of MakerBot)

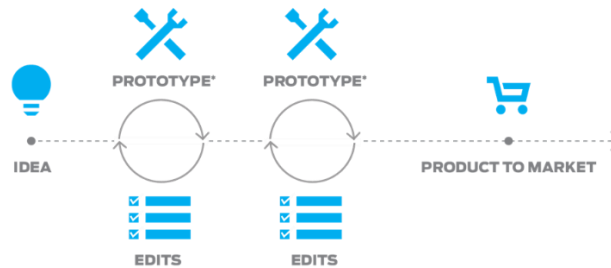
Traditional prototype creation can take days, even weeks to get a model built to specifications. Models were often made by hand from a variety of materials, like clay, paper, styrofoam and a host of other options. Ones that were machined, were made on lathes, or on more modern CNC machines.

The problem is the design process has to slow down to accommodate the prototype creation process, often leaving little time or money for redesigns and modifications. Cost is another issues that traditionally has limited the number of prototypes that can be created. Machining a part can cost hundreds if not thousands of dollars.

Once the prototype is created, it can be tested and reviewed, then compared to the desired result. Edits and changes are then incorporated into the design, and the process would start all over again, taking more time and financial resources. With the traditional method of prototype development many products get to market with flaws or design elements that are undesirable, or worse cause complete failures of shipping products.



Real-Time Prototyping (3D Printing)



Real-Time Prototype Process. (Image courtesy of MakerBot)

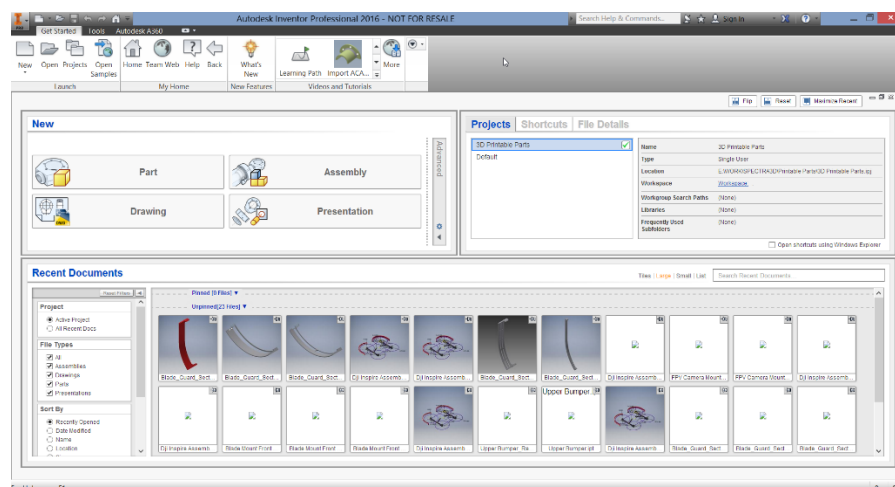
With the introduction of 3D printing into the design and engineering workplace, the prototyping process underwent a dramatic change. No longer would the prototyping process be the drag on the design of a part. Instead it would greatly enhance the process and reduce the time it took to get a part from the idea stage to the production stage.

Instead of weeks to get a prototype back from being created, it now takes hours or days. Not only is the time reduced, but what once cost hundreds or thousands of dollars, now costs significantly less, even just a few dollars. The reduced time and cost allows designers and engineers to work in near real-time, with the design and prototyping functions happening at nearly the same time.

Real-time prototyping, with only a few hours separating the design from the prototype, is radically changing how designers and engineers work from day to day. With 3D printing, often at or near a work area, a product that in the past may have undergone two or three prototypes, can now have a dozen or more prototypes created.

The increase in the number of prototypes and the reduction in cost has given designers and engineers a new found freedom. Combined with the power of Autodesk Inventor, and its powerful features, you are freed to create better, more tested designs than ever before.

Inventor in the prototype process



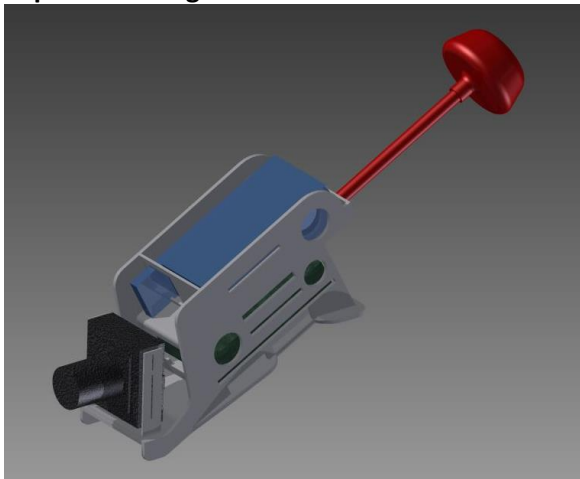
Autodesk Inventor



Computer assisted design has been evolving for more than half a century. Today's Autodesk Inventor software, while building on those early CAD programs, is a highly advanced design and engineering tool. Inventor can be used through all stages of the design process, from simple massing and form studies, to detailed simulation and analysis. Its advanced functions allow you to perform the entire engineering and virtual prototyping process in one software package.

While the advanced functions of Inventor are extremely useful in the overall engineering process, it is in conjunction with 3D printing where Inventor shines for rapid prototyping. Kinematic simulation and finite element analysis can make sure your parts will perform properly, they do not replace a physical part.

Aspects of design



FPV Mount for the DJI Inspire Quad Copter

One of the aspects of design is the idea of form versus function. A digital model can be rendered to make beautiful 3D images that look real. Kinematic simulation can show you if an assembly will work through a series of parameters; and finite element analysis can tell you if the material you are using for manufacturing will withstand the forces that are applied. But, none of this replaces a physical model.

The ability to 3D print a prototype is not a unique capability. It's the combination of Inventor's modeling tools and a 3D printer that create a powerful one-two punch for the engineer and designer. One, design the part; two, 3D print it and evaluate your design. Now you have the ability to touch the part, assembly multiple parts, and even create fully functioning prototypes from the 3D printed models.

Manufacturing vs. 3D printing

A question often asked is what's the difference between manufacturing a part and 3D printing a part?

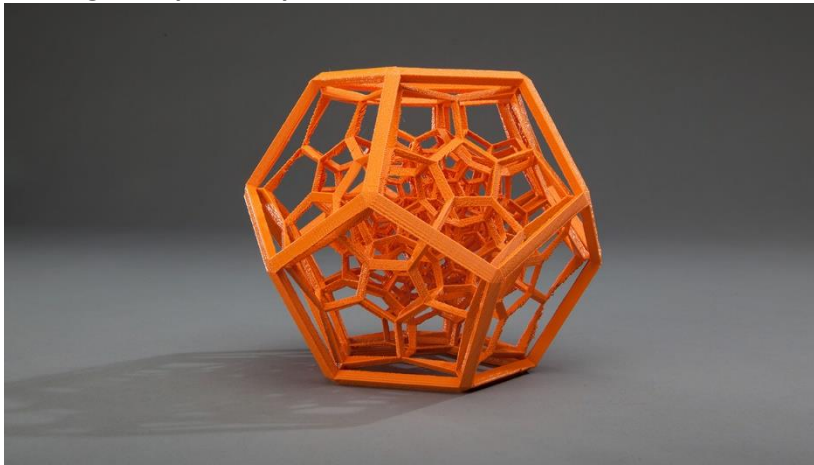
While manufacturing is a low cost way to make a large number of parts, for low run production, it can often be cost prohibitive. Manufacturing parts offers a way to mass produce parts that meet specific standards for material properties, tolerance and strength. And, even though the need for tooling, molds, and more, are costly, it is still the best way to make a million widgets with a low cost per part. The drawback is the design is locked in. Changing the design mid production can be both time consuming and costly.



3D Printing on the other hand has come a long way since the early days of Charles Hull's SLA printer. 3D printers are able to build parts using an ever increasing number of materials. Those materials range from basic PLA or ABS plastic to carbon fiber and a host of high strength metals. But it's not only the materials that make 3D printing an alternative to traditional manufacturing, the printers have been steadily getting faster and more capable.

A manufacturing revolution is in progress because of 3D printers and their ever increasing capabilities. Now, one person working from their house can be a mini manufacturing company. Taking orders and printing small run parts as effectively as large manufacturing firms. 3D printers also create a more flexible manufacturing environment, enabling designs to be easily changed and lowering costs for short run.

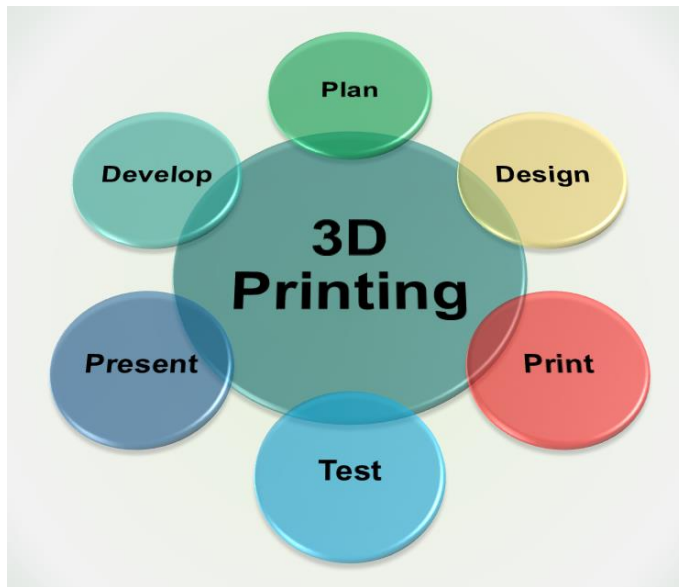
Printing an impossible part



The Impossible Part, courtesy of MakerBot

While 3d printers are beginning to enter the manufacturing space, they have one capability that no manufacturer has. They have the ability to 3D print models that would be impossible to manufacture using any traditional techniques. Since Inventor doesn't limit you to modeling only specific types of models, you are free to experiment. You can even print complete working assemblies in one print, no assembly required.

3D Printing and the prototype process



The process of developing a prototype is a critical step in the development of a product. Whether it's a product for manufacturing, or a one-off part for a project, prototyping is a step that should not be overlooked. Today, everyone can get access to a 3D printer, if it's not in your office, you can find one online through websites like 3D Hubs (www.3dhubs.com)

The 3D printing based approach to prototyping is to create as many design iterations as is needed to develop the design and perfect the product. Now, there's a practical limit to the number of design iterations you can run through. That will be determined by time, budget and other issues, like do you want the part to be put to use in the field or be reviewed by others for ergonomics and other factors.

Redesign

While working through the prototyping phase of the development process you may redesign a part several times for various reasons. The part shown below is the main mount for the blade guards for a DJI Inspire quad copter. This design was the initial prototype, printed from ABS on a Stratasys uPrint SE Plus 3D printer, that was field tested and evaluated.



Stratasys uPrint SE Plus, FDM 3D Printer



The feedback from initial flight tests determined the weight of the part was a factor. So the Inventor design was modified.



Initial Blade Mount Design, Revision 001

After some rework, a second prototype was 3D printed using the same uPrint 3D printer. While the weight was reduced, it was important to evaluate what else could be changed on the model in order to have it both function properly and be light weight. There's more work to do on this part yet!



Blade Mount, Revision 002

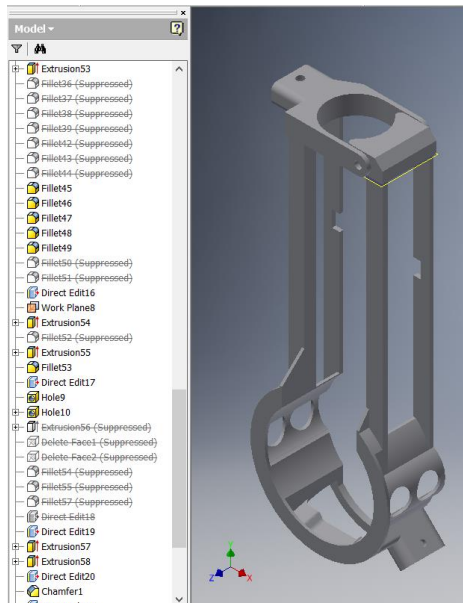
Modifying an existing model

When creating revisions to an existing part you have several choices as to how you work through the changes. If you are using a tool like Vault, tracking the revision of the part file is handled by vault. If you don't use Vault or some other management tool, you can use a simple file naming convention that works for your project. But that only deals with the file itself, not the geometry changes.

When you get the feedback from your prototype evaluations, there will need to be some simple, or dramatic geometry changes. This is where you have a few choices. One, you can start from a base model and rebuild it from scratch; a time consuming process. Second, you can use the existing model and use the tools available to modify the part as needed. For most designers, this is the preferred method. However, it's not without its drawbacks.

Modifying an existing model and have some unintended consequences. When suppressing and unsuppressing features, changes made up the hierarchy can cause modeling errors or even just break a feature altogether. By carefully modifying features, using the direct edit feature and adding additional features, you can make changes quickly and without causing errors.





Blade Mount, Revision 003

The Project



Project Overview

Contracted by a major energy company in North Carolina, the project was to design and 3D print blade guards for a DJI Inspire 1 quad copter. This copter was going to be used for inspecting the interior of larger boilers and other spaces with power plants. So we not only needed to protect the sides of the drone, we needed to protect the top as well.

Additionally the drone would be carrying a second FPV camera that had to be mounted to the top along with the battery and transmitter. This would require an FPV camera mount that fit under the top



bumper and mounted on the top of the fuselage. From the beginning, all the parts of the final design would need to be designed to be 3D printed as the final production method. Because of this, all the parts would need to fit within the build area of one of the three 3D printers available for the project.

DJI Inspire 1 Description

The DJI Inspire 1 quad copter is an aerial filmmaker's quad copter. It's designed to work with a swappable 4K video camera that uses active stabilization for rock solid video. The Inspire 1 has the ability to be flown by one person with a live view of the camera feed, or two people, one for flight and one for camera.

Project Requirements

The project requirements were based on the intended use of the quad copter when the blade guards were installed. The plan was to use it mainly for slow speed, indoor and outdoor visual inspections. Since the blades are exposed the bumpers did not need to handle major impacts, they just needed to protect the blades from coming in contact with a wall or other object.

Limitations

The main limitation is weight. Each ounce added to the Inspire reduces the flight time. Another issue is stability. How the quad copter would handle with the guards was a complete unknown, at least until the first prototype. Once the first design was printed and ready to fly, the design was based on the requirements and the design of the quad copter.

The Design Process

Designing the reference frame

In order to start the design process, it's a good idea to create a basic model of what the parts are going to be designed to. In this case, the entire quad copter was not needed, just the parts of the frame that needed to be referenced for modeling the blade guards and upper bumper. The first step is to capture reference imagery.

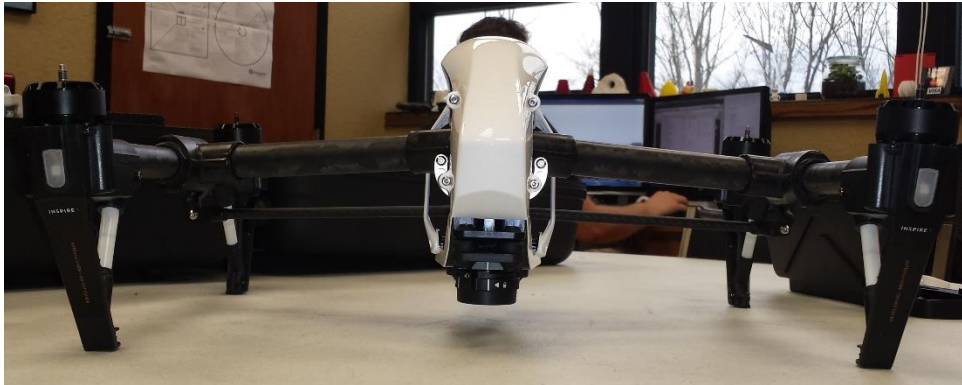
Capturing reference art

When capturing images for developing a reference model in Inventor, it's not critical that you take tens of photos from every angle. Just take the photos that will provide the details you need. In this case a top view, front view and close up views of the motor and crossbeam. If taken properly, reference art will make it possible to measure angles and distances.





Top View



Front View



Strut and Connector





Motor and Crossbeam

Measuring the quad copter

While reference photos are very useful for making rough measurements, it's still good to have photos with some type of measuring tape or ruler in them.



Side view with ruler.



Front view with ruler.

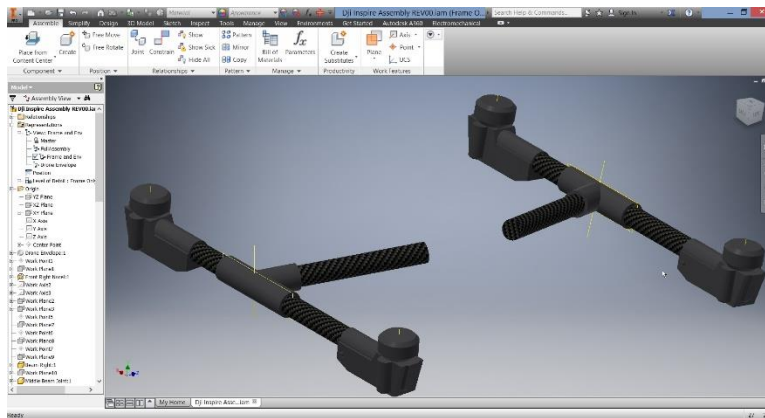
However, to get the dimensions accurate, it's best to use a set of calipers.



A Good set of Calipers can go a long way.

Developing a working assembly

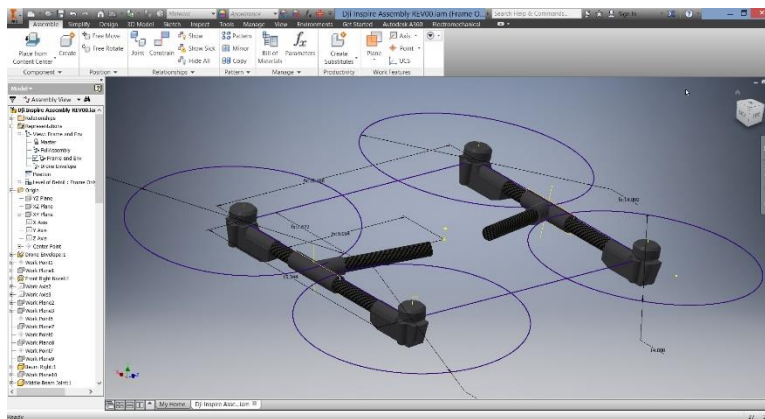
The first step was to create a reference model that could be used as the base from which to build the central hub and blade guards.



Essential parts of the quad copter.

Defining the blade envelope

The next step was to identify the range of the blades as they spin. This will give me the overall envelope of the quad copter in flight. It also defines the areas to avoid when designing the blade guards.

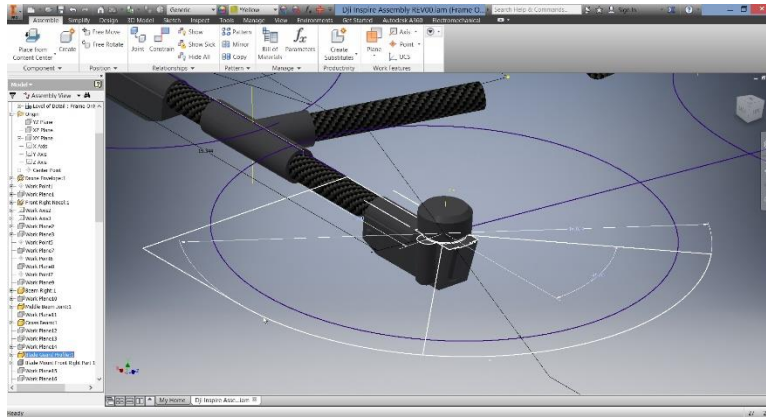


Blade envelopes in place.



Developing the Blade Guards

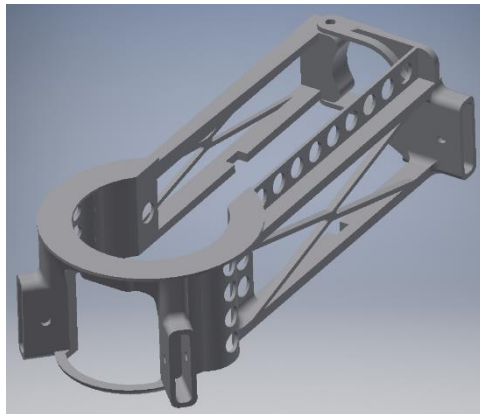
Once the basic frame components are in place and the blade envelope has been established, design of the guards can begin. The first element was a sketch to determine the size and basic design parameters of the guards and mounting area. The image below shows the sketch with some essential dimensions. This will be used as a reference for the rest of the design.



Blade guard layout sketch.

Blade Guard Mount

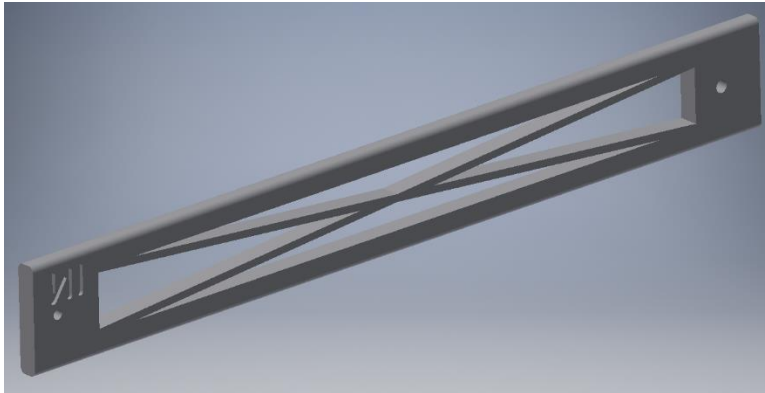
Establishing the design of the blade guard mount was the first priority, this would be the basis for the remaining components. The image below shows the first revision of the blade guard mount in place in Autodesk Inventor.



Blade Mount, Revision 001.

Support Struts

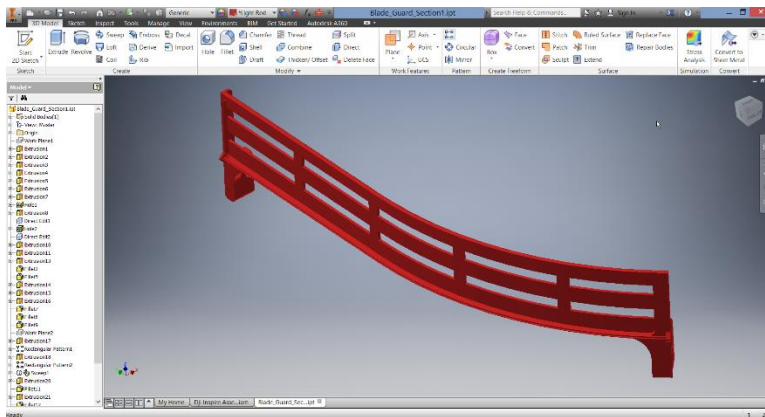
The support struts were designed as the second step. Adding the struts provided the mounting point and design for the blade guards.



Support Strut, Revision 001

First pass blade guards

Once the mount and struts were in place, the initial design of the blade guards could begin.



After the first blade guard was test printed, and weighed, updates to the guards were made before moving on to the next stage.



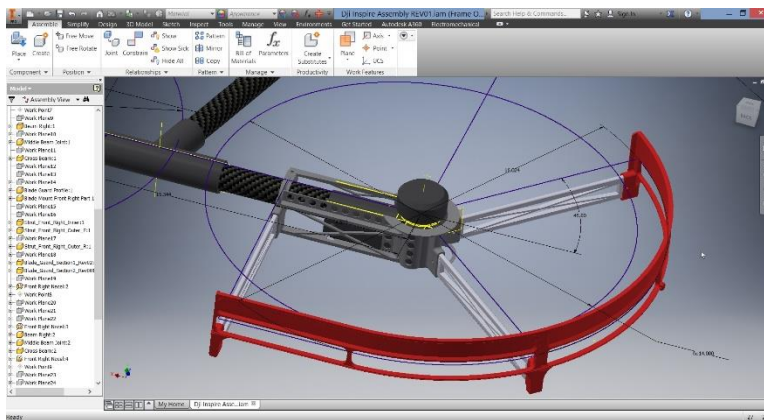
Blade Guard, Test 1



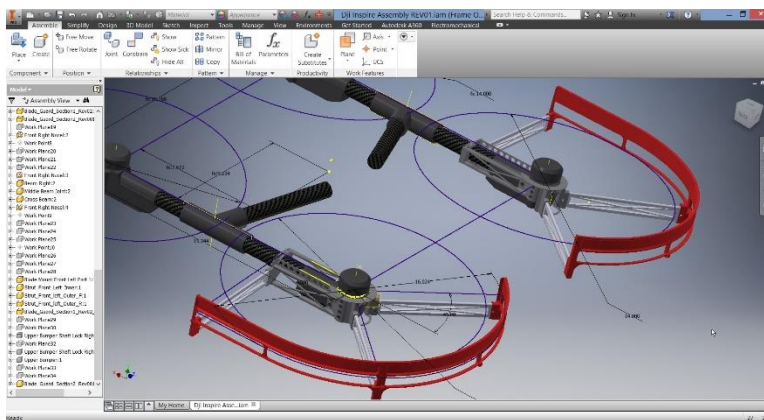
Blade Guard, Test 2

Creating the initial design

The next stage of the design was to put the assembly together and verify that the parts fit properly.



Once the parts are configured as an assembly, a mirrored version of the parts are needed for the opposite side of the quad copter. The mirrored parts will be exported along with the original parts.

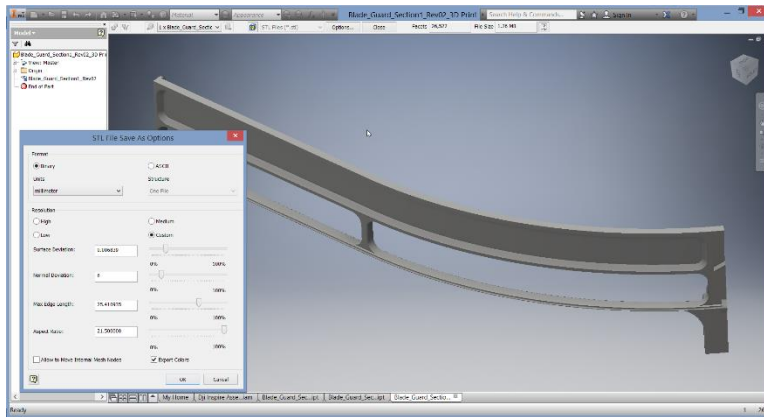


Half the model, ready to 3D print

Exporting the models

Once the initial design was to a point where it was ready for initial testing, the parts were ready to be printed for fit testing and if possible a first flight test. Autodesk Inventor provides several methods of getting a part out to a 3D printer.

The first method is to export the file directly as an STL file from the application menu. This method is the simplest to use, since all of the 3D printers that were used for printing the parts use their own slicer software.



The STL Export dialog

3D Printing the prototype

Once the designs are ready, the parts are printed. The parts were printed using several printers, a Stratasys uPrint SE Plus, MakerBot 5th generation, and a Fusion 3 Design F306. Each printer was chosen for a different reason for a different set of parts.



Primary Blade Guard Mount, printed with ABS on a uPrint SE Plus.



Blade Guard, printed with PLA on a MakerBot 5th Generation.

Test Fit and evaluation

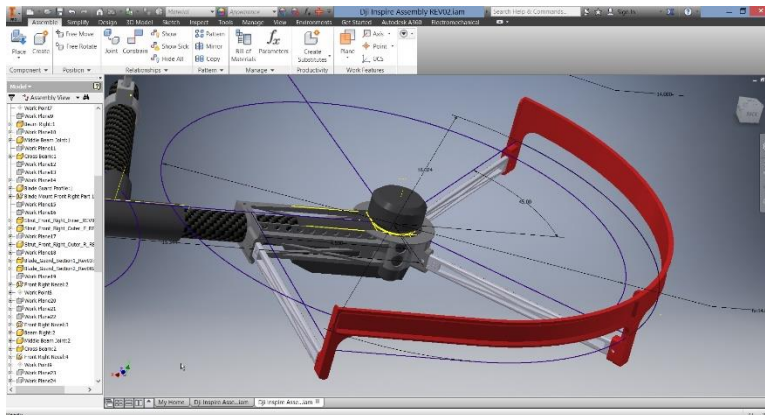
The first set of blade guards were printed, assembled and installed on the DJI Inspire 1 to ensure that the fit was good.



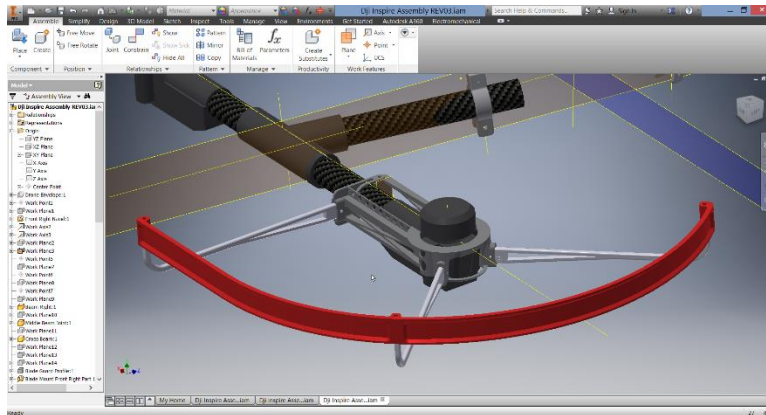
Test Installation

Redesign

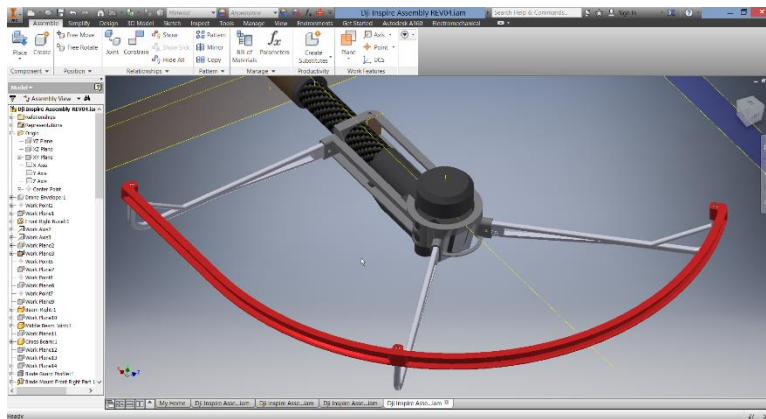
So far the blade guards have undergone several redesigns to make the assembly easier to install and remove from the quad copter as well as make the parts lighter without compromising the ability of the bumpers to protect the blades if they hit a wall at slow speed.



Second pass to reduce the weight of the assembly.



Third pass, reduce weight, change mounting of blade guards to support struts.



Fourth redesign, continue to reduce weight, strengthen support struts.

Other Drone Parts

Along with the blade guards, there were several other parts that needed to be designed and printed. One was the top bumper, this part was needed to keep the quad copter protected in case the drone was to bump up against the top of a tank or ceiling. Again, this is not designed to protect against a hard hit, but to keep the drone from being damaged if it bumped from the top.

The final part of the assembly is an FPV camera mount designed to be mounted to the upper fuselage of the quad copter body. This part needed to be able to hold several components related to the FPV camera. Those included, the camera, battery pack, transmitter and antenna. Along with the ability to hold the parts, and be securely mounted, it needed to fit within the protection of the upper bumper.

Top bumper

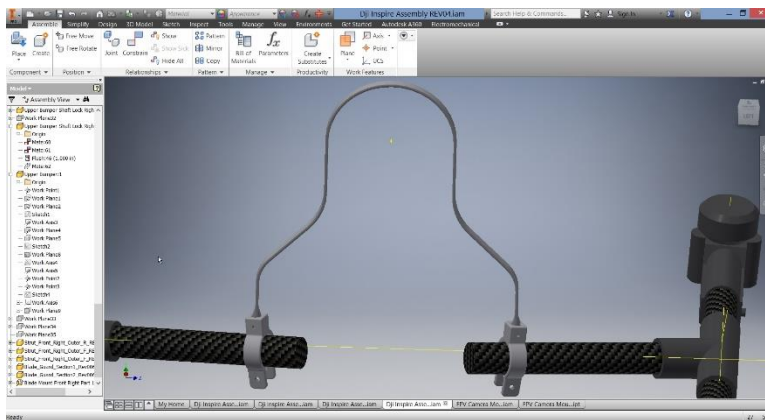
The top bumper was to be a fairly simple shape that would need to attach to the cross beams that went from the body of the drone to the beams that held the motors. The issue that was encountered was this quad copter has adjustable blade configurations, where the body can raise and lower in relationship to

the blades. This meant the upper bumper needed to be flexible enough to change along with the configuration of the quad copter.



Initial upper bumper design.

After some initial testing and review of the design, it was determined that a slight change was needed in order to allow for more flexibility and stability in the printed part. Since this needed to be flexible, it was printed using ABS on the uPrint SE Plus as one solid part.

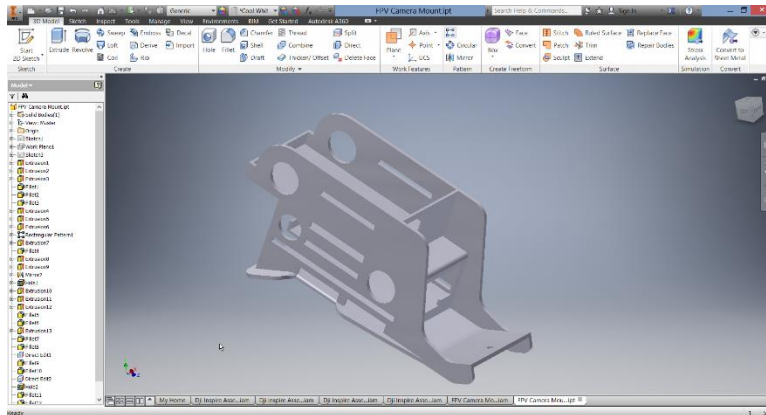


Bumper redesign.

FPV mount

The FPV mount was designed as one piece to make installation easier and make the overall part stronger at the same time.





Final design of the FPV mount.

Conclusion

With the availability of 3D printers for creating low cost prototypes and the power of Autodesk Inventor, you are able to create designs with a freedom like never before. The prototyping process has changed from a linear series of tasks, where time and cost were major factors; to parallel functions with the redesign process incorporated. You can iterate a design faster than ever before and make those changes easier than ever before with the power of Autodesk Inventor.



DJI Inspire Blade Guards and Bumper, Revision 001