

CPS500004

## Extreme Optimisation - An adventure with Fusion 360 Generative Design

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### Learning Objectives

- Understand some of the benefits and challenges of using Fusion 360 Generative Design for a real-world application.
- Recognise the key steps in the Generative Design workflow.
- Identify types of components that would make good candidates for Generative Design.
- Avoid common mistakes when tackling their first Generative Design project

### Description

The Gavisgon electric longboard project started back in 2018 when a German CNC machine vendor donated a longboard deck machined from billet aluminium, on the condition that I "do something cool with it." I got to work with Fusion 360 to design an electric skateboard. This class will walk you through my design journey for the key component, the rear truck that the drive assembly is mounted to. Beginning with a customised off-the-shelf part, then iterating through a generatively designed 3-axis CNC machined version, and finally a 5-axis CNC machined version.

### Speaker(s)

Gavin is currently employed by NZ's largest Autodesk reseller in a split role between technical support/consulting and software development. His foci are primarily Fusion 360, Inventor, and Vault. Before becoming a Technical Consultant, he spent about 10 years using Inventor, Vault and various CAM packages as a mechanical designer. Gavin has worked in a variety of industries including Aerospace, Defense, Consumer Products, and materials handling equipment for everything from logging/mining to food. In these areas he has designed machinery, equipment and products involving a huge variety of materials and manufacturing processes. Gavin places utmost emphasis on manufacturability in the design work he does, as a result of having always worked very closely with the manufacturing environment. This has taught him to adapt and calibrate his digital-prototyping tools to give real-world results. Gavin has recently completed his Autodesk Generative Design Certification <https://coursera.org/verify/XF3XEURGLQZZ>

## Intro to Generative Design

While technologies for designing and making things have improved an almost immeasurable amount, at a high-level the process has changed very little. Generally we start with a problem, conceive a solution, create a prototype, and then iterate on the design until we achieve an outcome that solves our challenge efficiently. We've gotten pretty fancy lately with this, and started to simulate things digitally to avoid having to make large numbers of physical iterations.

Generative design takes us into a whole new paradigm. We are rethinking the role of the designer. This new role put more emphasis on defining the problem, in terms of options. We then hand the problem over to a computer, and ask it to come up with suitable solutions to our problem. Where it differs the most is that the designer no longer has to conceive the form of the result, and can instead focus on the technical details such as loading conditions, materials, manufacturing methods.

## Gavisgon – An Electric Longboard



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This project began when I was lucky enough to be given an aluminium longboard deck, at a trade show in Chicago. I converted it to an electric longboard with (mostly) off-the-shelf parts, and rode it for approximately 300 km, before the drive belt shredded. Realising that this was caused by a belt misalignment issue caused by a poor interface, I decided to use the generative design technology inside Fusion 360 to come up with a better solution. Build logs are available here: [Longboard](#), and [GD Truck](#)

## Benefits and challenges

The skateboard truck is not a commercial product, but it was the first real world application of Generative Design that I had tackled. I learnt some things along the way that gave me some insight into when I may and may not choose generative design for real products. While it gives huge benefits in terms of optimisation for things like lightweighting of components, and the ability to reduce part count in assemblies, it's not a silver bullet.

The big benefits for me were that I ended up with a beautiful looking part, that is very unique, which meets my design criteria very efficiently, and I learnt a lot of things along the way.

The downsides were mainly around time and cost. For complex scenarios, the processing time to generate the outcomes can be quite long, and many iterations were required to get geometry that I was happy with. The process of cleaning up the freeform body, while powerful, was time-consuming. Finally, the organic nature of the geometry proved to be quite a challenge for generating two paths for the CNC machine to cut the part.

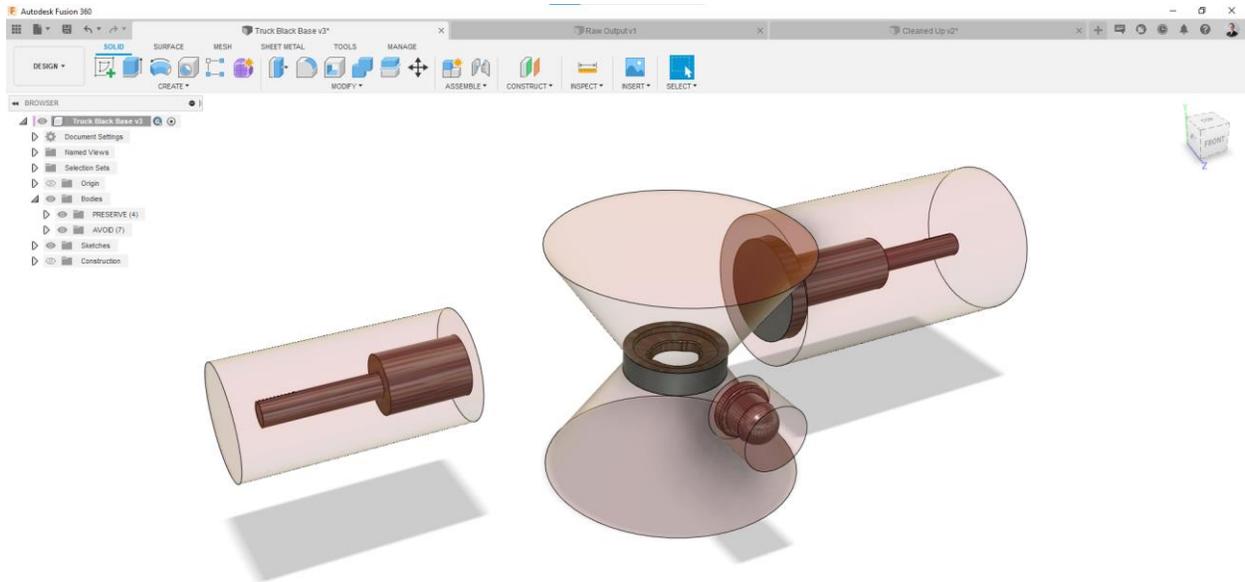
## Key Steps

At a high-level, the process can be broken down into these steps:

- Create / Modify the relevant geometry
- Configure the Study Definition
- Review the outcomes and select a solution
- Cleanup the output / prepare for manufacture

The next few pages will show these steps in a little more detail

## Geometry

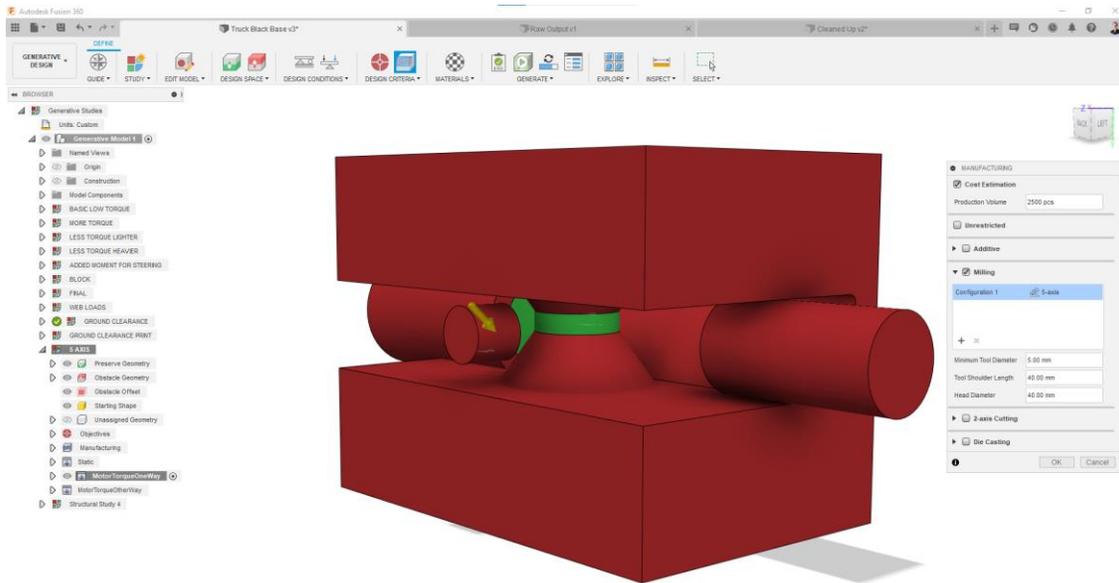


Using traditional solid modeling tools inside the fusion 360 design workspace, bodies can be created to represent geometry that needs to appear in the final outcome, but also volumes that need to be avoided. Additionally, you can create a starting volume to guide the initial shape.

When defining these volumes, it can be helpful to think of them as preserve and obstacle volumes. The structure that grows in the generative design process, will stick to the preserve regions and avoid the obstacle geometry. You need to think about allowing clearance for moving parts, tools etc. If you run a study and end up with a geometry that you don't like the look of, you can always come back and add some obstacle geometry to guide the shape a little further.

It also pays to remember to do boolean subtractions in overlapping bodies, to expose faces that you need the structure to adhere to.

## Study Definition



The generative design workspace, which is where you create the study definition, is probably the area that will require the most learning, When getting started with Generative Design.

You typically work from left to right along the ribbon. When you first enter the Design workspace, a new study has already been created for you, which just requires configuration. If you want to explore other scenarios, you can create as many parallel studies as you like.

The model button takes you into a special solid modelling area, where changes to the existing geometry or creation of new geometry, only exist for the generative design workspace. This can be useful when creating generative design components in the context of a larger design.

The Design Space ribbon panel has the tools you need for selecting the various bodies that represent the Preserve, Obstacle, and Initial volumes. It's very easy to choose the type you want, and then select the bodies by simply picking them in the graphics window.

For those familiar with finite element analysis, the next two panels will have a familiar feel about them. Here you define the loads, and constraints that affect your component. The biggest difference here, is that you have the ability to define the manufacturing criteria, in terms of methods and technologies available to you. This is one of the real strengths of generative design inside fusion 360. If you're not sure whether to 3D-print or CNC machine a component, the outcomes that are generated can help to make this decision.

Finally you can run an automated check to ensure you have define all the required parameters, and then submit your study to be processed in the cloud.

## Review / Select Outcomes

| Outcome                         | Status    | Material                       | Orientation  | Manufacturing method | Visual similarity | Production volume (pcs.) | Piece part cost | Fully burdened cost | Volume (mm <sup>3</sup> ) | Mass (kg) | Max von Mises stress (MPa) | Factor of safety limit | Min factor of safety | Max displacement global (mm) |
|---------------------------------|-----------|--------------------------------|--------------|----------------------|-------------------|--------------------------|-----------------|---------------------|---------------------------|-----------|----------------------------|------------------------|----------------------|------------------------------|
| Structural Study 1 - Outcome 6  | Converged | Aluminum AISI10Mg              | Unrestricted | 5 axis milling       | Group 1           | -                        | -               | -                   | 8.134e+6                  | 21.734    | 1.1                        | 2                      | 216.15               | 0                            |
| Structural Study 1 - Outcome 2  | Converged | Aluminum 6061                  | Unrestricted | 5 axis milling       | Group 1           | -                        | -               | -                   | 8.135e+6                  | 21.964    | 1.1                        | 2                      | 266.22               | 0                            |
| Structural Study 1 - Outcome 3  | Converged | Aluminum 6061                  | Unrestricted | 5 axis milling       | Group 1           | -                        | -               | -                   | 8.135e+6                  | 21.964    | 1.1                        | 2                      | 266.22               | 0                            |
| Structural Study 1 - Outcome 4  | Completed | Aluminum AISI10Mg              | -            | Unrestricted         | Unique            | -                        | -               | -                   | 8.11e+6                   | 21.654    | 0.9                        | 2                      | 254.89               | 0                            |
| Structural Study 1 - Outcome 9  | Converged | Aluminum AISI10Mg              | Z+           | Additive             | Group 3           | -                        | -               | -                   | 8.189e+6                  | 21.864    | 1.5                        | 2                      | 163.31               | 0                            |
| Structural Study 1 - Outcome 10 | Converged | Orgasol® Invent Smooth - PA 12 | Z-           | 3 axis milling       | Group 2           | -                        | -               | -                   | 5.048e+7                  | 48.464    | 0.4                        | 2                      | 134.2                | 0.02                         |
|                                 | Converged | Orgasol® Invent Smooth - PA 12 | Unrestricted | 5 axis milling       | Group 1           | -                        | -               | -                   | 8.132e+6                  | 7.807     | 1                          | 2                      | 47.8                 | 0.13                         |

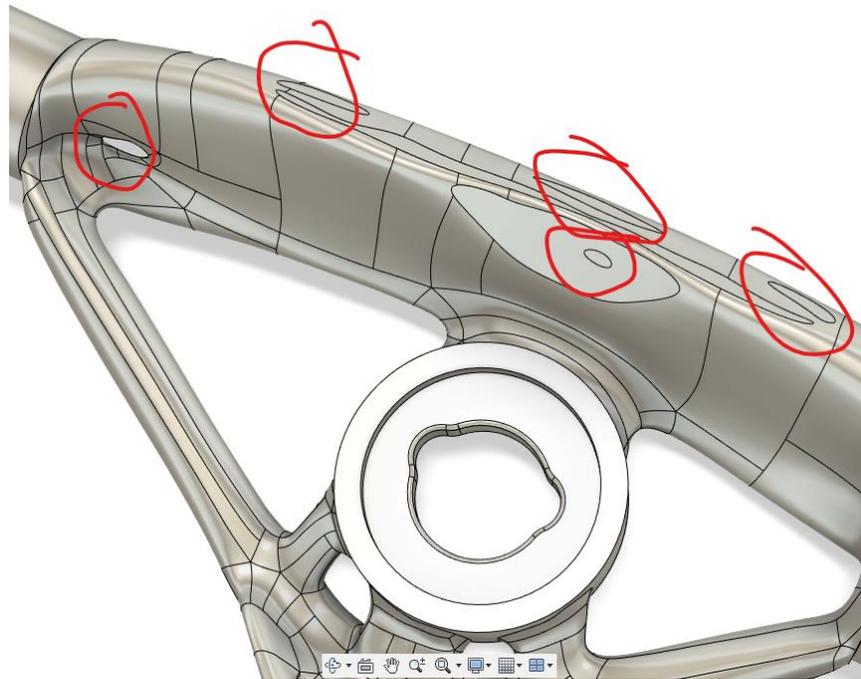
Outcome selection is really the fun part of the process. Here you get to see the various solutions, and review them with a broad range of tools that allow you to compare them against each other, using a variety of metrics.

You don't need to wait until the solutions are complete to see the direction the geometry is heading. Within a few minutes of submitting the study you'll see the early iterations of the design start to take shape.

The outcomes are generated to provide all the permutations of the various materials and manufacturing methods that you chose. This means that the more materials and manufacturing methods you choose, the more outcomes you'll have to sort through.

Once you have chosen your favorite design, you can download it as either a solid model, or a mesh body. The solid option uses freeform volumes, which are much nicer to work with in post processing workflows.

## Cleanup / Prep for Manufacture



While the exported freeform body will generally have pretty clean surface is, it may still require some refinement for aesthetic reasons, or ease of machining or printing. The freeform editing tools in Fusion 360 provide a convenient way to manipulate these surfaces while still maintaining good continuity. On the skateboard truck I patched some holes, adjusted some areas where the freeform body mates with the preserve geometry, and bevelled some edges to make them look more refined.

The final stage before manufacturing, is to generate the CNC toolpaths and machine code. Using the Manufacture workspace inside Fusion 360, toolpaths for roughing, finishing, and drilling can be generated and simulated to produce a quality manufacturing plan. In the case of skateboard truck, I spent upwards of 40 hours producing a program that I felt confident to use. This is something to be aware of, and is one of the costs of producing parts with complex organic type surfaces.

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## Good Candidates for GD Components

When starting out with generative design it can be quite difficult to know whether a particular design challenge would be a good fit for the technology. The ideal components right now, are going to be lower volume, higher value parts, that require a highly efficient usage of material in terms of strength-to-mass. As the technology improves, we should expect to see the amount of time taken to generate outcomes reduce, and that combined with improvements in both additive and subtractive manufacturing methods, will make this way of designing components more and more economical.

## Things to Watch Out For

Some small details can have big effects on productivity when using generative design. Getting to know and avoid these traps, will save you a lot of time.

Firstly, the Synthesis Resolution setting has a big effect on generation time for the outcomes. The setting is found under the Study dropdown on the ribbon, and controls the coarseness of the mesh that is used in generating the geometry. It's good practice to start with a coarser setting, and run additional solves with finer and finer settings until you achieve the outcome you desire.

Spend time thinking about the obstacle geometry, and imagine where the volume will grow. If you rush this step, and then run a solve that takes 12 hours, you will be very frustrated when you see that geometry has grown over an important mating interface. The preview tool can be very useful here, to generate a very rough volume that will give you some idea of what could happen in the final solve.

When performing cleanup on the freeform body, be careful of manipulations that pull the surface away from the preserve geometry that they should intersect with. If there are any gaps, no matter how small, when exiting the freeform environment, the solid will fail to build. This can be a very time-consuming problem to fix.

## Conclusion

Generative design can be a very exciting and rewarding technology to use can equally be frustrating and difficult. I encourage you to persevere and get over the initial learning curve and believe you will be rewarded for your efforts. Thank you for attending my session.