

Reverse Engineering



Objective

I have written this short paper with the hope that the next time you have a reverse engineering problem you will have some new ideas as to how it can be tackled.

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What is Reverse Engineering?

Reverse Engineering is a process where we study a product so that we can extract design information.

Now it would not be surprising if your mind at this point has made the leap to China and their attitude to IP protection...



Take the new “Land Wing X7” which looks very much like somebody has reversed engineered a Range Rover... I wish to assure you that I am not talking about this type of reverse engineering.

The tools that I use are instead aimed at helping businesses recover legitimate technical information.

Common issues I have encountered with clients in the past include:

- acquiring the intellectual property rights for a product only to find key manufacturing information is missing
- realising that manufacturing information was never created
- drawings and CAD data being lost/damaged
- fabricators going bankrupt and taking with them key information
- trying to design a new part that must integrate with a product for which technical information is unavailable

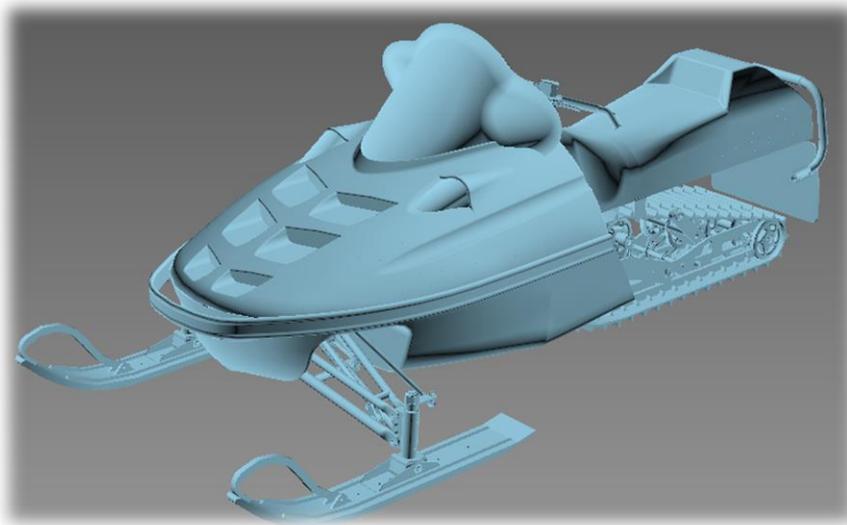
To give you an idea of what can be done this short paper briefly covers five reverse engineering tools;

1. *Digital Clay*
2. *Technical Surfacing*
3. *Photogrammetry*
4. *Point Clouds*
5. *Working from Real Life*

The first tool we start with is not particularly common but I have found it to be extremely useful...

1. Reverse Engineering with Digital Clay

When a client has legacy CAD data for a product that is in an unusable state then digital clay can help.



For the snowmobile above I need to make some quick changes to the bodywork but we have neither the manufacturing drawings nor the original CAD files. We do however have one very large .STL file for the entire assembly.

Unfortunately .STL files are not designed for editing so the best approach I have found for fast conceptual work is to convert them into digital clay.

I start by using Autodesk Mudbox to replace the triangular mesh of the .STL model with a clean quad mesh. I will then fix any errors that might have occurred in the mesh conversion process by hand.

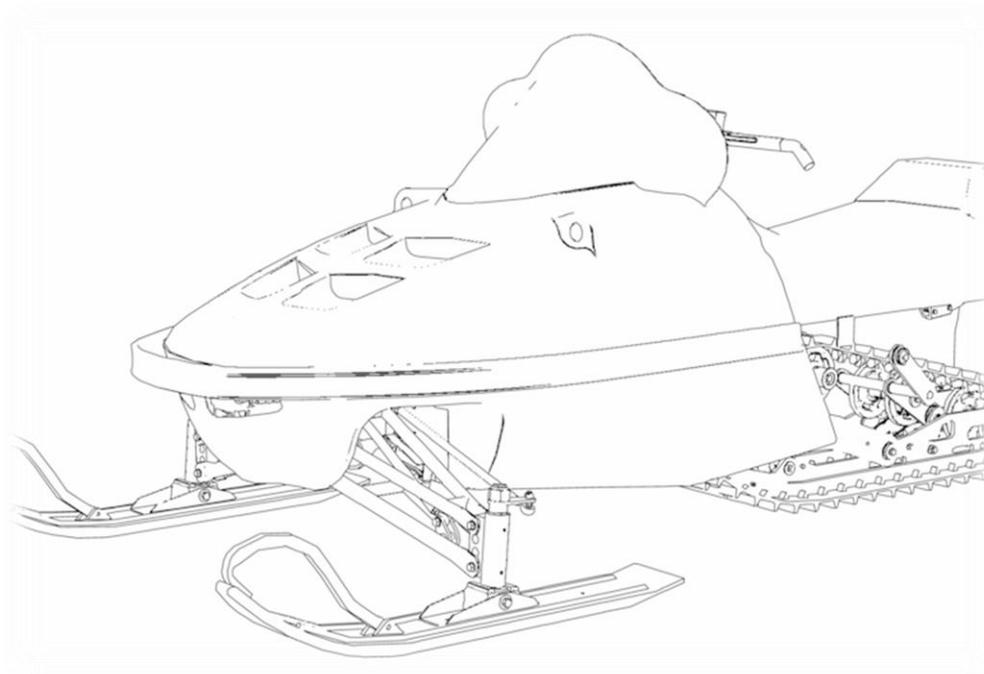


In this quick example the lower two pockets on the bonnet need to be removed.

To achieve this I use digital clay in much the same way as traditional clay, placing it into the two pockets whereupon I can then blend it into the main surface.



From starting with poor quality CAD data we have been able to extract out enough information to generate a new design concept.



Summary: *If you have 3D data of any kind that needs to be changed then clay sculpting offers a fast and flexible approach.*

Once we are happy with a concept we can use the digital clay file as a reference for Technical Surfacing. This is the next technique to be covered...

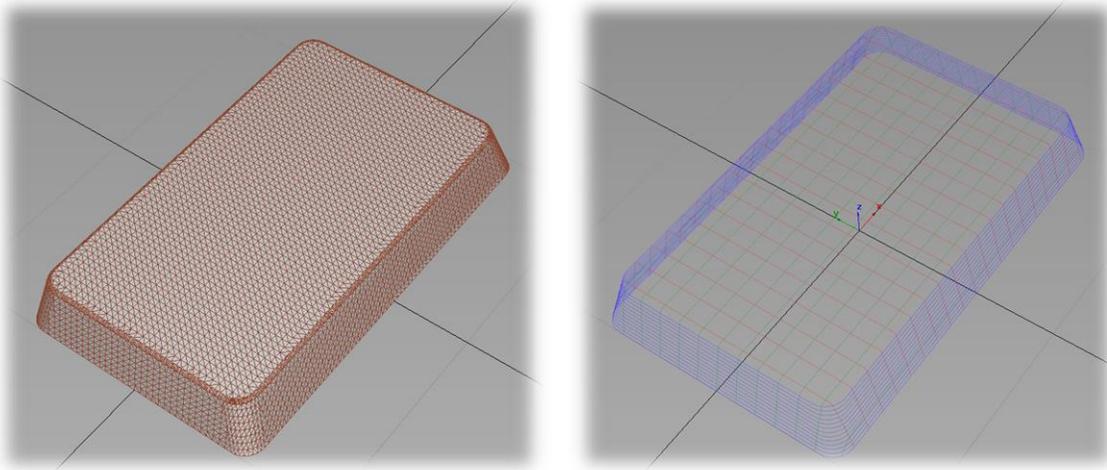
2. Technical Surfacing

Once we have a shape established, be it from digital clay or a 3D scan, we can embark on a process of reverse engineering the surfaces.

Technical surfacing is a process whereby we aim for the highest surface quality that we can achieve.

A high quality surface is important on any product when the surfaces will be seen or touched by a customer. Essentially we want surfaces that are both accurate and seamless.

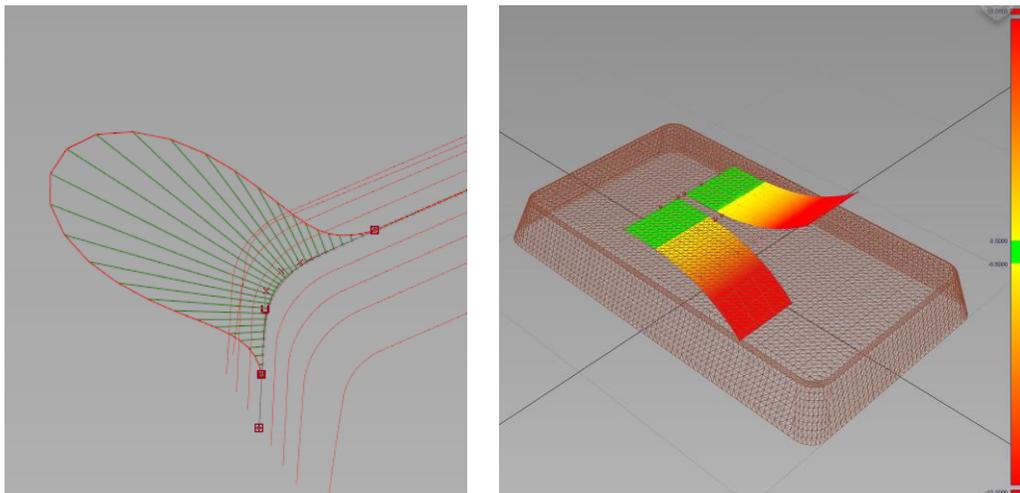
In this example I am using a STL file that I have imported into Autodesk Alias. I started by projecting reference lines over the imported 3D file.



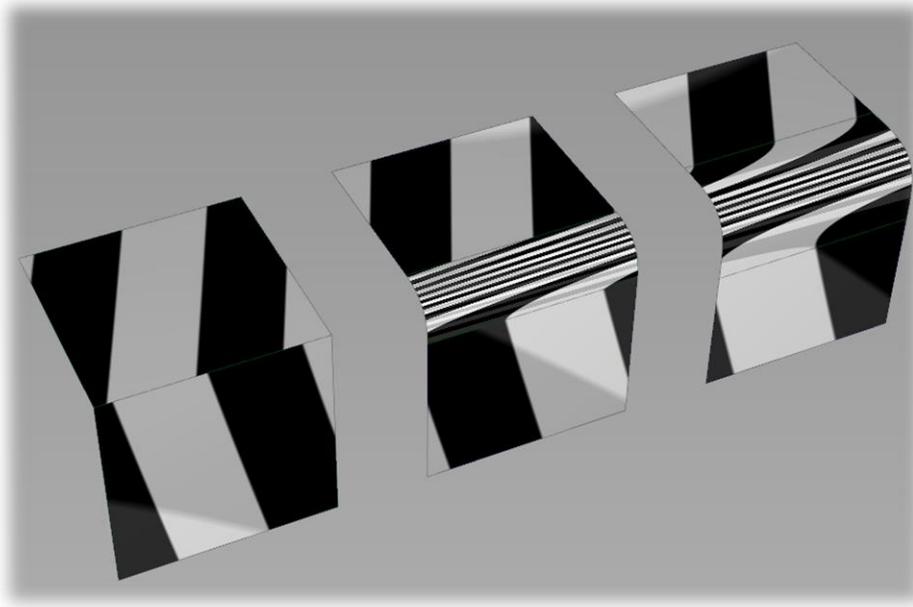
The network of reference lines is then used to build and position the new surfaces.

As I work I will be making checks with respect to both curvature and deviation. We want the surfaces to flow smoothly and to lie within an established tolerance range of the reference model.

In the quick illustration below you can see how the two surfaces move from being acceptable (*green*) within the 1mm tolerance range I have established to then falling outside of it (*red*).

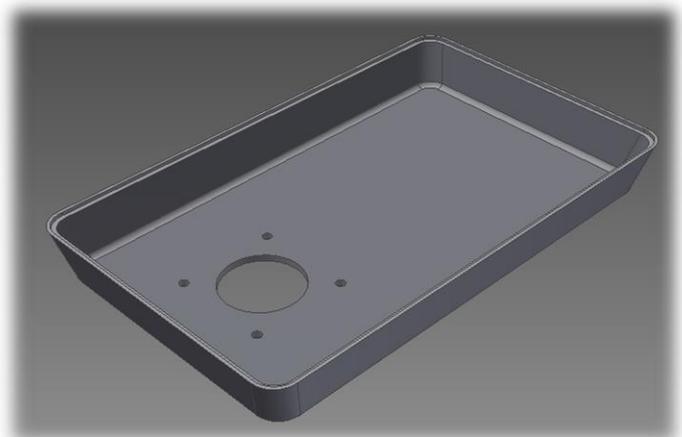
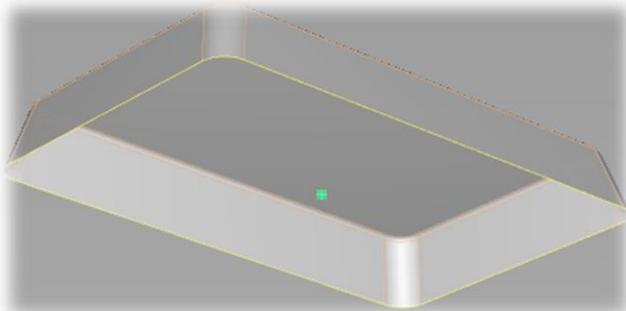


Once the surface patches for the part have been created I will evaluate their quality by analysing what are known as 'zebra stripes'. This technique is used to pick up any slight imperfections or errors.



Once I am happy with the work I will stitch all of the surfaces together, perform an export check and then save the file in a neutral format so that it is ready to be used by any standard CAD software.

Once we have exported the surface model into say Solidworks or Inventor we can then add in any controlled features to meet the quality and precision demanded by the customer.



Summary: Technical surfacing is a complex process where we create a set of high quality surfaces that are ready for manufacturing. In this example I worked off a STL file but it could just as easily be from a 3D scan.

A cost effective approach to 3D scanning is covered next...

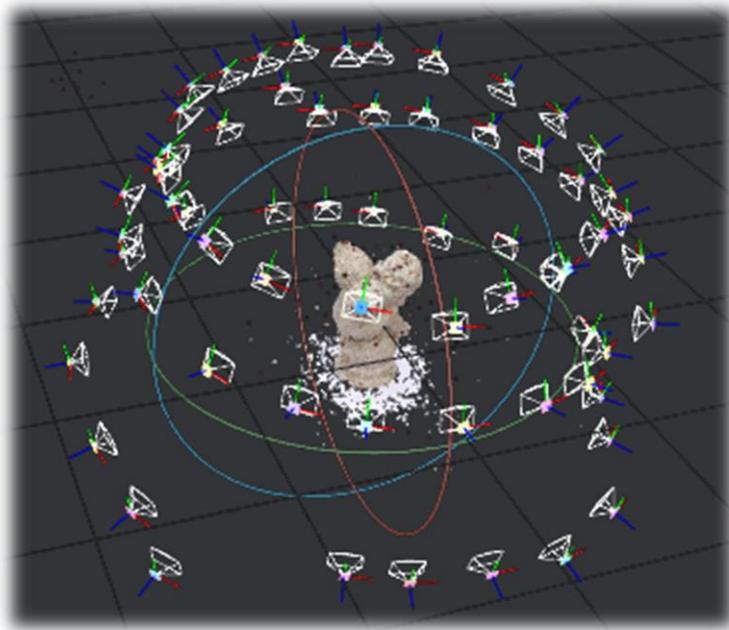
3. Reverse Engineering with Photogrammetry

Photogrammetry is a low cost technique that allows us to create a 3D file from a series of photographs.

In this example 65 overlapping photographs have been taken around a garden ornament using a standard 35mm digital camera.



The photogrammetry software I use establishes the original camera location for each photograph and by way of a clever algorithm pieces together a 3D model.



Note how the resultant highly accurate 3D file shown below also incorporates the original material texture.

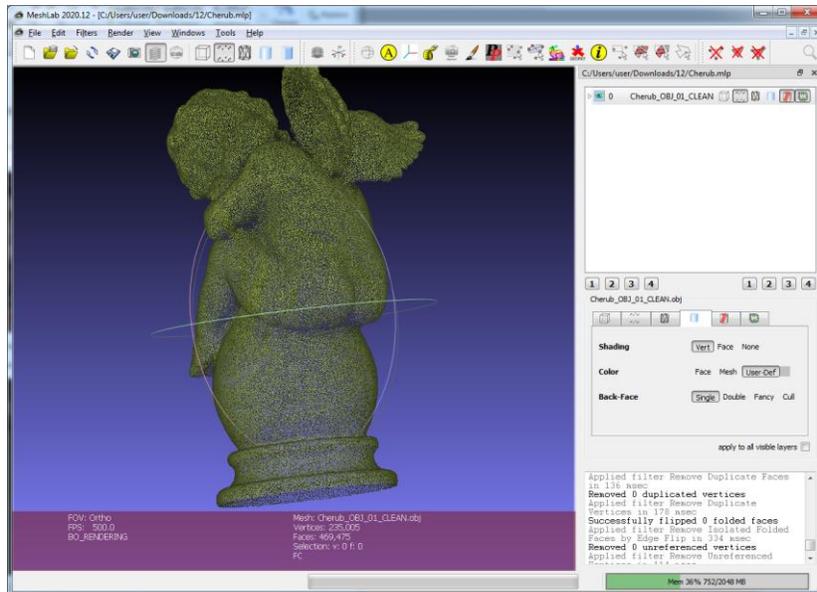


Now that we have a digital copy of the garden ornament we can manipulate it any way that we require. Let us say that we want to manufacture the ornament but we don't wish to include the wings.

I start by identifying areas of the photogrammetry mesh that have small errors.



I then use the full range of mesh cleaning algorithms found in MeshLab to fix the problems.



Once I have a clean mesh I transfer over to Autodesk Mudbox and use a series of digital clay techniques to make the required changes.



In this case I simply had to remove the wings and sculpt new detail into the back of the cherub.

The digital clay sculpture is now ready for its final stages of refinement where I would adjust and smooth the model until I am happy with the surface quality.

Summary: Photogrammetry can be conducted with the phone in your pocket so it is easy to see that this approach is both an inexpensive and extremely powerful way of converting real life objects into digital 3D data. The dedicated hardware of laser scanning will offer higher levels of accuracy but it comes at a cost.

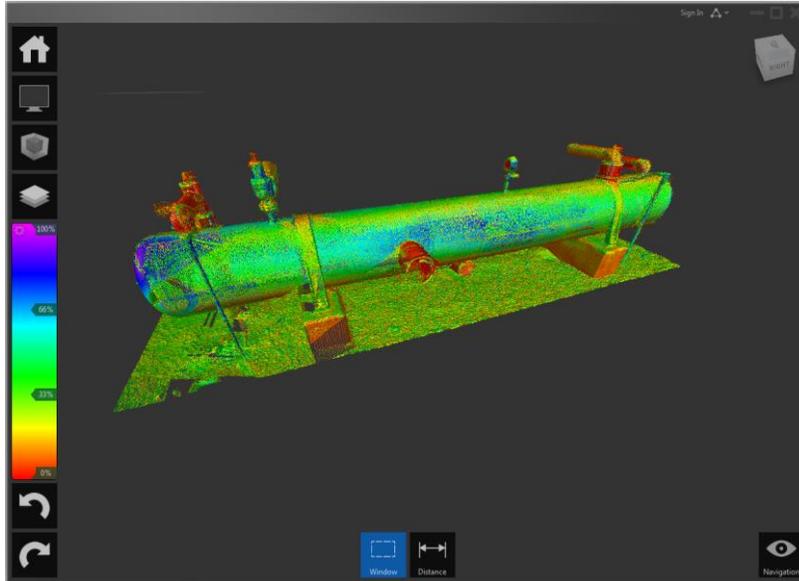
If you have a very large object then perhaps consider the use of Point Clouds...

4. Reverse Engineering from a Point Cloud

Point clouds are the output of a laser scan. They are made up of a collection of points in digital space which are defined by their XYZ coordinates.

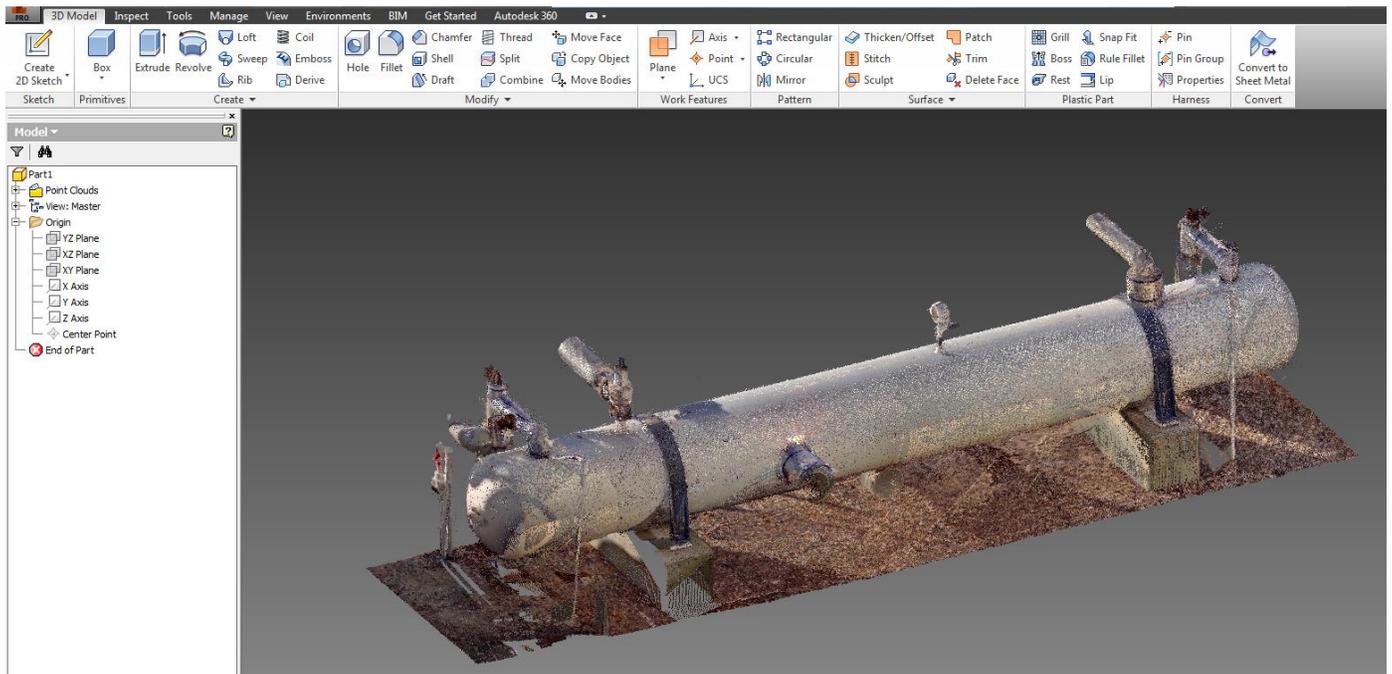
In the example below we have a point cloud for a large pressure vessel that I have imported into Autodesk Recap¹.

1. Supported file formats: .rcs / .fls / .fws / .lsp / .pts / .ptg / .ptx / .zfs / .zfp / .las / .xyz / .txt / .asc / .cl3 / .e57 / .rds / .pcg / .xyb



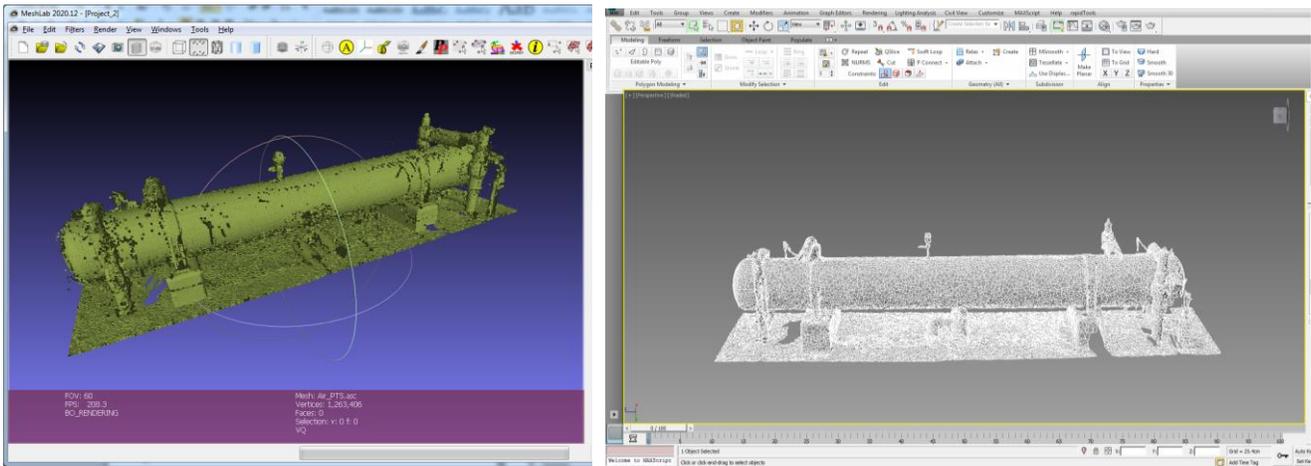
I will process this information in Recap in order to then transfer it into Autodesk Inventor.

Whilst this approach gives me a 3D underlay to design new components against, it does not let me select or directly measure from the point cloud. This means that I have to design by eye alone.

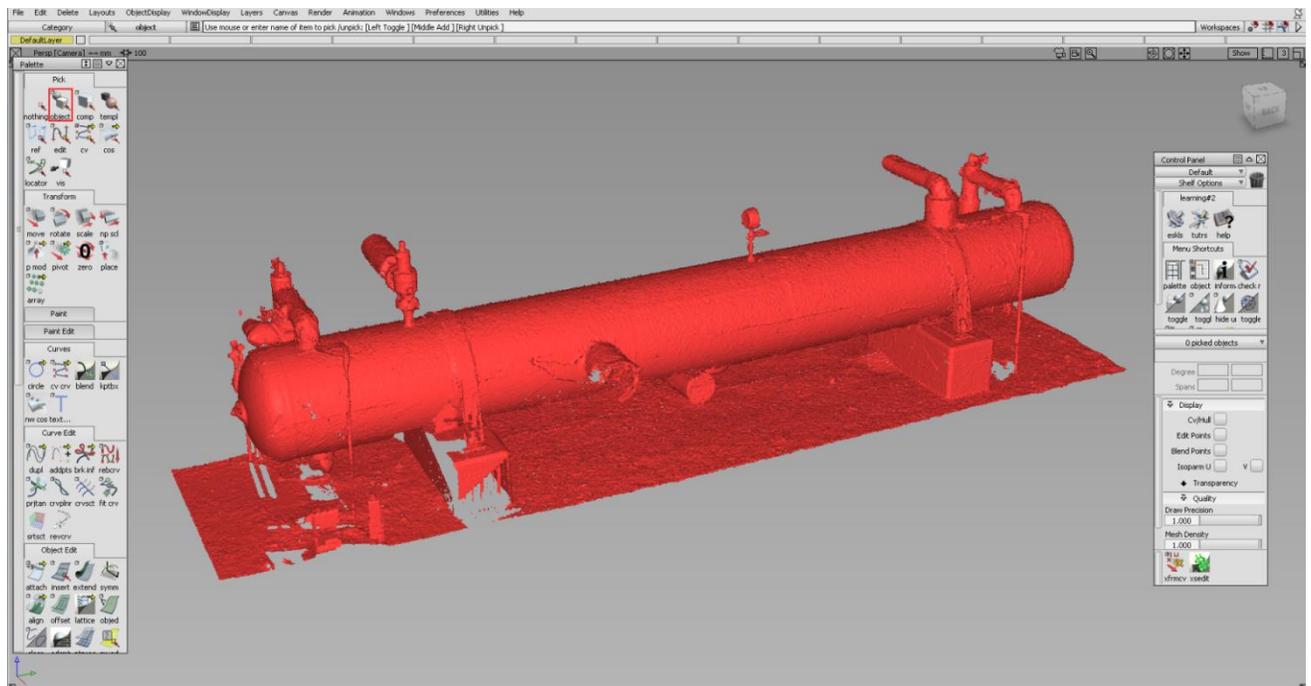


If I am interested in a higher level of accuracy then the best approach I have found is to convert the point cloud into a mesh.

For this work I use MeshLab in combination with 3ds Max to reduce the resultant complexity of the mesh.



I will then import the optimised mesh into Autodesk Alias which I have found to be the easiest tool for taking accurate measurements.



Summary: From football stadiums to sailing yachts the only limit on what you can scan with point clouds is your imagination.

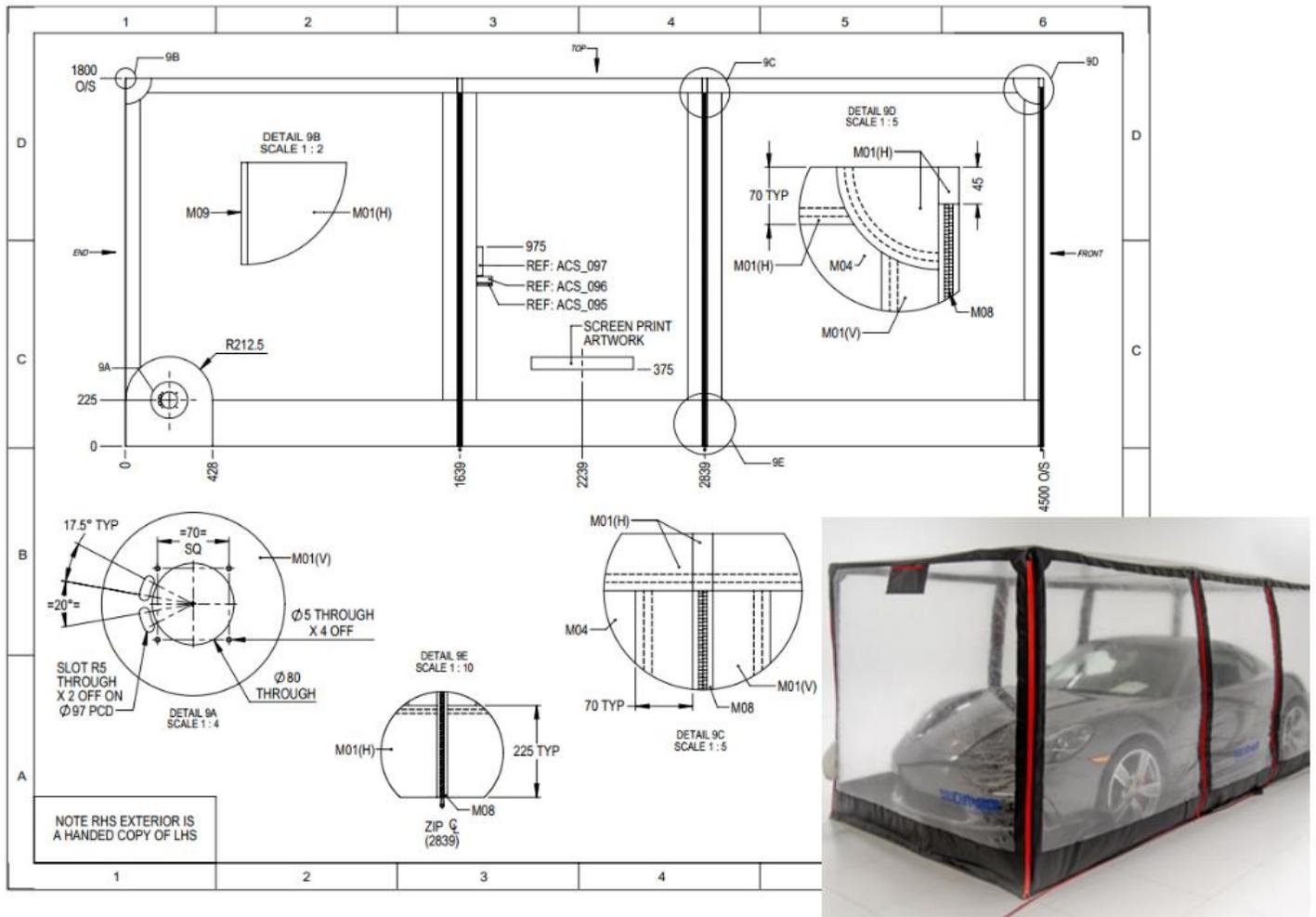
Laser scanners that are used to create point clouds are available for hire. Alternatively a number of companies in the United Kingdom and the Republic of Ireland can perform this type of work.

The final tool is for objects that need parameters other than their dimensions to be established...

5. Reverse Engineering from Real Life

There are many occasions when a client finds that they do not have the manufacturing drawings for their product.

The example below shows a car storage system that had been developed in tandem with a fabricator. Unfortunately manufacturing drawings had never been created.



I was able to take apart the product and then by reviewing each and every component I was able to understand both how it worked and how it had been designed.

Direct measurements and materials analysis led to new set of engineering drawings.

Summary: *If you have lost the original drawings for your product then don't worry.*

If I can have a sample delivered there is a good chance I can reverse engineer it and create a new manufacturing drawing pack for you.

Thanks for taking the time to read this short paper.

If you have a mechanical design problem that you would like to discuss then get in touch today:

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