MECHANICAL DESIGN & ANALYSIS

LoSiento

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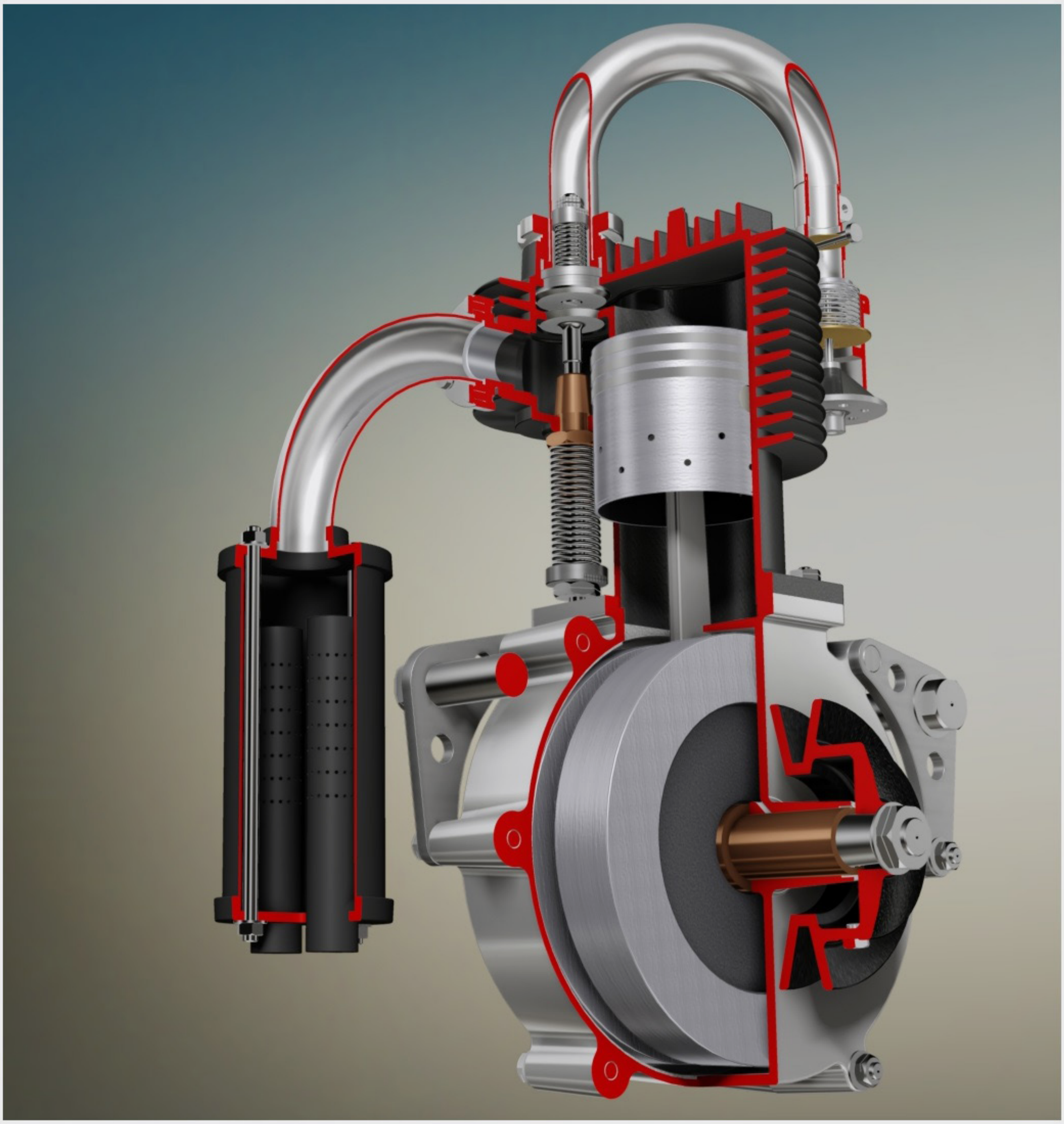


Sectional rendering of a 3.5hp motorcycle engine

"It has been a real pleasure to work with Andy, his great care to detail and commitment to follow up on those details, not only have provided for a great job done, but also has set the high level of professionalism. I will work with Andy again, and also highly recommend him."

Josef @ Alcobendas, Entrepreneur

"Andy worked quickly and helpfully on our project going the extra mile to ensure it was what we needed."

Dylan @ Woodview Electronics Ltd

WELCOME

I understand that commissioning design work can be an intimidating process as reputations, money and even jobs can all be put on the line.

The purpose of this brochure is to give you the confidence that you will be working with the correct partner on your next mechanical engineering project.

With that all said I wish you all the best and I hope that we can work together in the near future.

Regards,

ANDY REYNOLDS BENG (HONS)
Director of LoSiento

CONTENTS

SECTION 1 - WHO AM I AND HOW CAN **WE WORK TOGETHER**

WHO AM I?

My name is Andy Reynolds and I am a freelance mechanical design engineer.

My great grandfather was the last of a generation of blacksmiths; his son – my grandfather – trained as an engineer then started and ran a factory making fibreglass body shells for sports cars until the oil crisis of the 1970's closed that down. My other grandfather spent his life as a time served shipwright in the docks of Birkenhead. So if you believe like me that characteristics can in fact be passed down through the generations, then I think it was inevitable that I would become an engineer.

I spent countless hours as a child using my father's tools to take anything I could lay my hands on apart, then trying - with varying degrees of success - to put them back together. I have always been fascinated by how things worked, so much so that by the age of 14 I had managed to gain an amateur radio license.

After obtaining my degree I wanted to see as much of the world as I could. I rode the motorcycle I owned at the time around Europe then after selling it to pay for a flight I travelled to Guatemala to work for a company running mountain bike tours. Upon my return I cycled from England to Turkey and then worked out in Australia for a year to raise the funds for an even longer adventure when I cycled from England to New Zealand.

Upon returning to the United Kingdom I moved into industry, starting out as a draughtsman for a multinational scientific equipment manufacturer based in the midlands. After a few years of learning the ropes I was left with the feeling that to become a good design engineer I needed to expose myself to different challenges, so I took the gamble to leave permanent employment and become a contracting design engineer.

I started contracting in the renewable energy sector and within a short period of time I was lucky enough to be approached on a regular basis to do all manner of design jobs. These jobs varied in their levels of complexity but no two were ever the same.

The need for continuous learning and the opportunity to work on some really interesting projects are the parts of the job that I still enjoy the most and as a result I found myself gravitating towards freelancing which is where I find myself today.

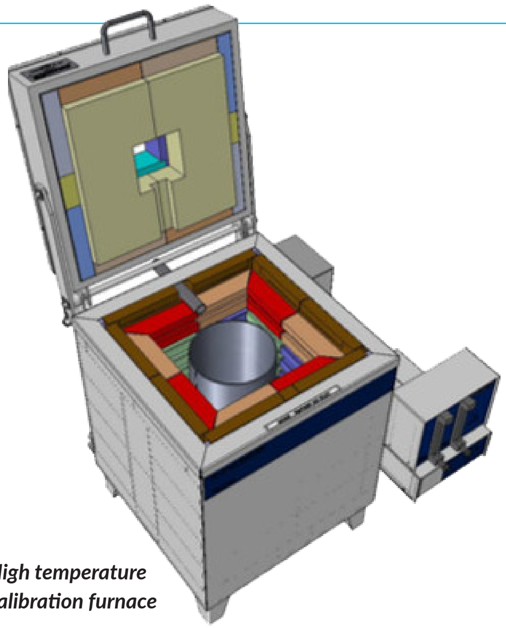
HOW CAN WE WORK TOGETHER?

If you are looking for a quote for a design project then the best bet is to start by sending over as much information as you have. If you need me to sign a non-disclosure agreement before I review anything then please don't forget to attach one.

With regards to payment; I can work for a fixed price or on an hourly rate depending upon the nature of the project. If you need my services for a specific number of hours per week on an ongoing basis then I can and have worked on a retainer agreement in the past. For an up-to-date copy of my rates please get in touch.

For your reference my business fluctuates in size depending upon the nature of project I am working on. Normally I will work on my own from my home office but as I have done in the past, I can hire additional staff and extra office space in order to form and manage a design team for a fixed duration.

More than anything I wish to stress that I offer a well-priced and flexible service, so if you have any mechanical design requirements, be they from the design of a full machine down to simple routine draughting tasks please get in touch today.



High temperature calibration furnace

"Kinetic Traction Systems Inc. engaged LoSiento Ltd to develop the mechanical design of a 300kW generator and support the manufacture of a prototype system. The generator is turbine driven and powered by low grade heat, utilising an Organic Rankine Cycle.

LoSiento were able to recruit additional experienced design engineers, with five engineers working on the project at its peak.

The project has been a success with a number of novel features well engineered. I found Mr Reynolds personally to be a very competent design engineer. He established a comprehensive and effective project methodology, which was particularly important since the engineering was conducted on three sites.

His conceptual design skills are of a high standard, well matched by his analytical and detail design ability and expert knowledge of the Solidworks design software"

Nigel Lloyd CEng @ Kinetic Traction Systems

SECTION 2

THE TYPE OF WORK I PERFORM

Because I continue to encounter such a wide variety of mechanical design projects that range in both complexity and duration, I felt it would be best to loosely categorise the work I perform into five different groupings in order to give you a better idea of what it is that I do.

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1. Selection Design

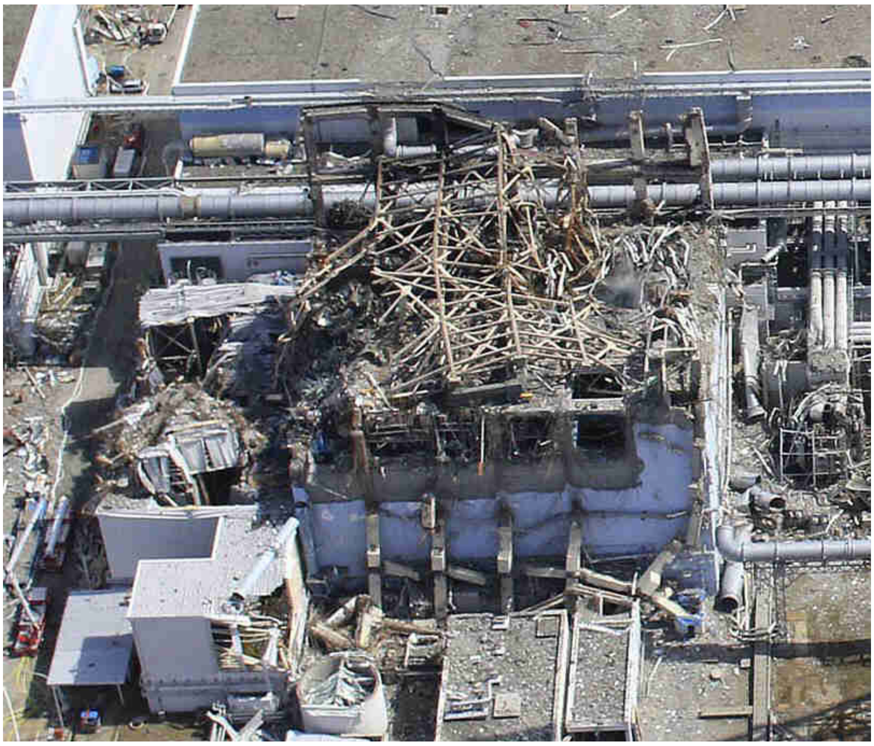
Selection Design is what I would call a job when I have a design problem that consists of sourcing commercial items to meet a specified function for my client.

Selection design is deceptively simple as extensive research and calculations might well be needed in tandem with guidance from the manufacturer to ensure the final design specification is met in full.

A past example was the selection and specification of a pair of Tolomatic linear actuators used on an exploratory arm for a UK based client.

The exploratory arm is to be inserted into one of the failed Fukushima Daiichi reactors in order to ascertain the extent of damage resulting from the catastrophic 2011 nuclear disaster.

A worker measuring radiation levels at the site of the Fukushima nuclear disaster



Failed Reactor

Tolomatic Linear Actuators

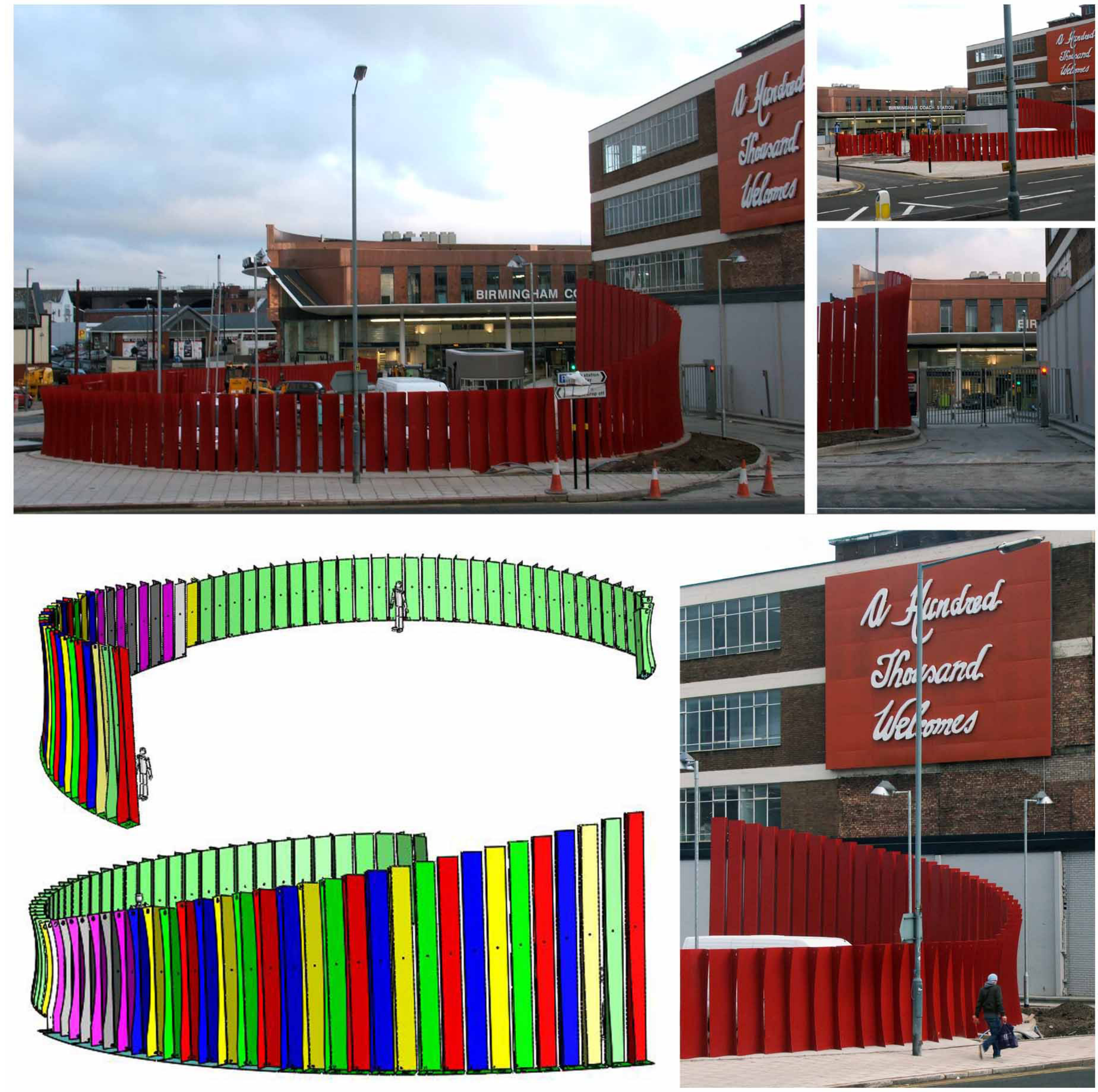
2. Configuration Design

Under Configuration Design I am given an idea or a set of components that might or might not be fully defined. My job is then to put them all together to create a working mechanical solution in the most cost effective manner.

Configuration Design can be seen in the public art project 'Boundary' which is a 181m long fence spanning the perimeter of Birmingham's main transport terminal.

Working with metal fabricators XtraWeld and the artists Rob Colbourne and Stuart Mugridge I had the responsibility of transforming a site plan and an artist's sketch into a final design. Deliverables included fabrication drawings, 3D models and site assembly templates.

The fence at Digbeth Coach Station is made up of 320 individual steel haunches varying in height from 2.1m to 6.1m. It was included in the winning entry of the 2009 Jaguar Land Rover Arts & Business Award.



Digbeth Coach Station CAD model and associated site photos

3. Component Studies

Often a request is made to study or design an individual component or assembly to solve a particular problem.

A UK based company wanted to devise a portable lifting solution to raise and lower the powertrains used on their tidal turbines. The truss based conceptual solution that I proposed offered an 80% reduction in mass when compared to their original cantilevered design.

Component studies are not just related to optimisation. Staying on the theme of marine related work I embarked upon what is my largest component study to date with a project to help reduce the cost of monopile design for a £1.3bn wind farm that has since been constructed in the

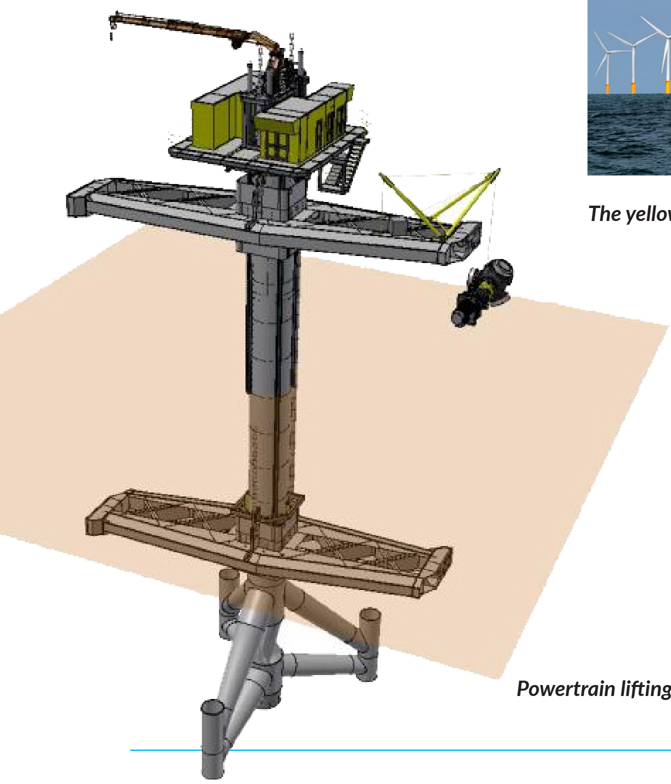
English Channel eight miles off the Sussex coast.

A monopile is simply a large tube that is driven down into the seabed. The wind turbine will then sit on top of the monopile. The problem is that the design of each monopile differs to account for local site characteristics meaning there is the potential to create a huge amount of repetitive design and draughting work.

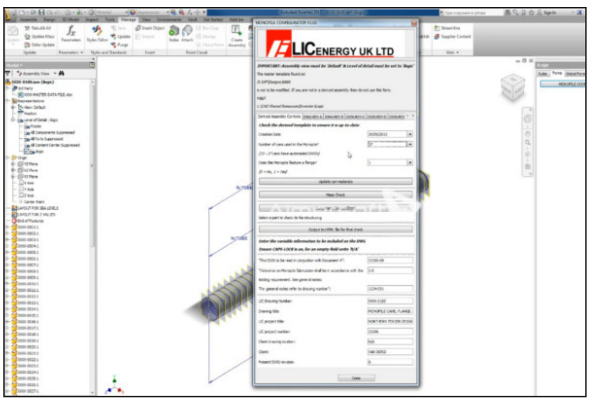
Using Autodesk Inventor and iLogic I created a configurable master Monopile that allowed key dimensions approved by the senior monopile engineers to be inserted into a form within the software. This form then generated a bespoke 3D assembly along with all of the associated manufacturing drawings.

The new approach reduced the time spent drawing up a monopile tower from one week to less than an hour. With responsibility for 116 monopiles the investment spent in establishing the new procedure was repaid in a short period of time.

The yellow part of the wind turbine assembly is the monopile



Powertrain lifting concept



Custom iLogic software

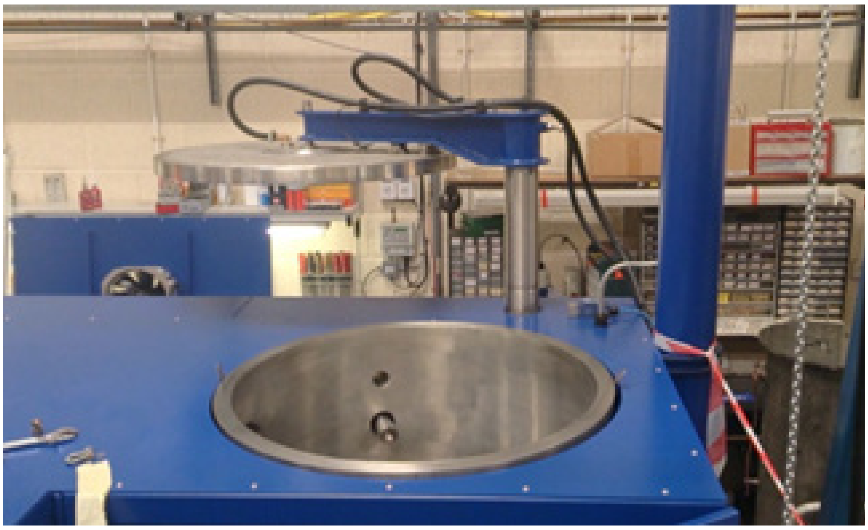
4. Evolutionary Design

If tasked with improving upon work that is based largely upon a client's existing product then I would I classify this work as either evolutionary or incremental

Evolutionary design means substantial product improvements are required whilst incremental design covers relatively minor design changes.

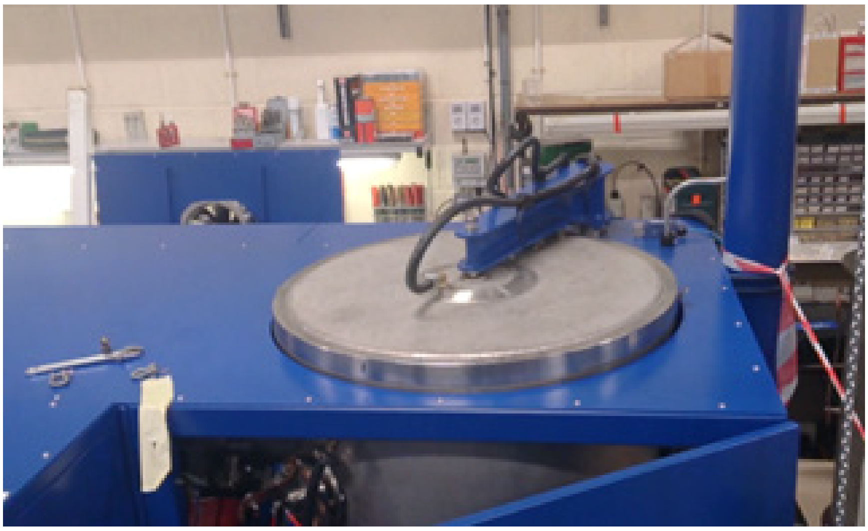
An example of evolutionary design was where I needed to create a new lifting arm assembly for a bespoke vacuum chamber as the previous approach to lifting the lid had been deemed both unreliable and expensive.

For specific reasons the lid of the vacuum chamber needed to be raised 250mm vertically and then rotated about a fixed axis by 110 degrees. The estimated weight of the lid when in use was taken to be no less than 160kg. A unique cam roller solution was designed, built, tested and is in successful operation today.



Vacuum chamber lid in its open rotated position

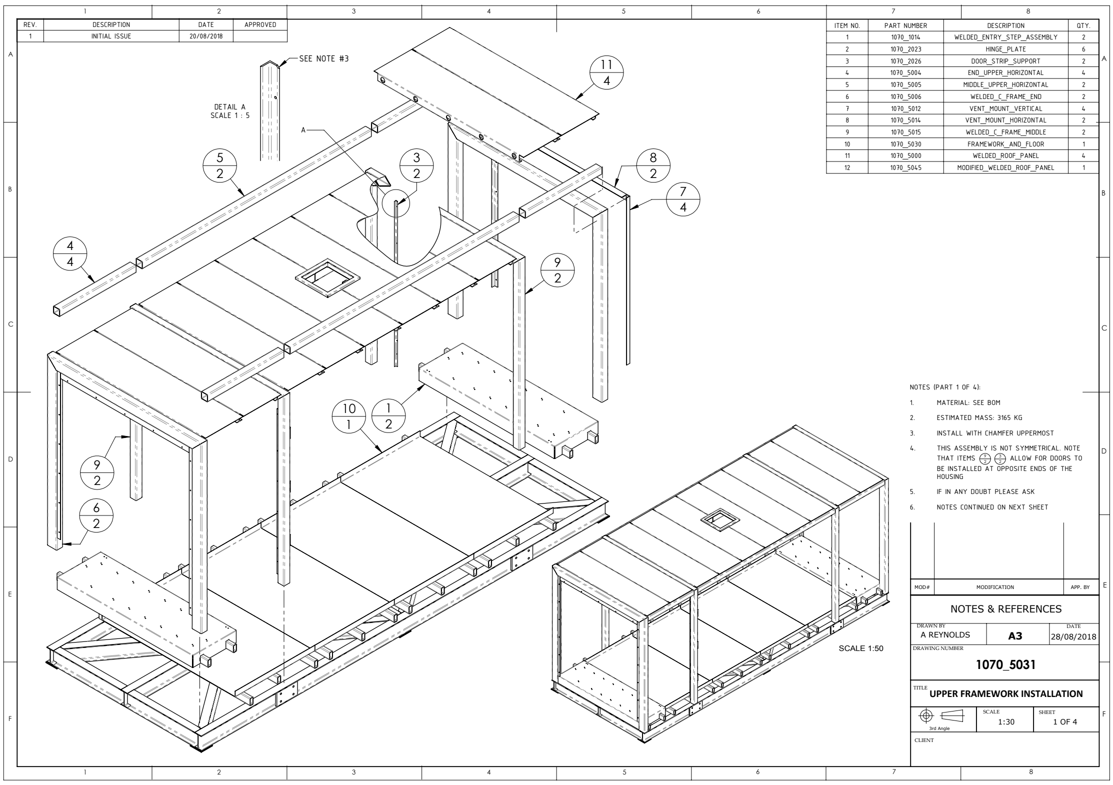
CAD assembly showing the actuator and cam roller assembly

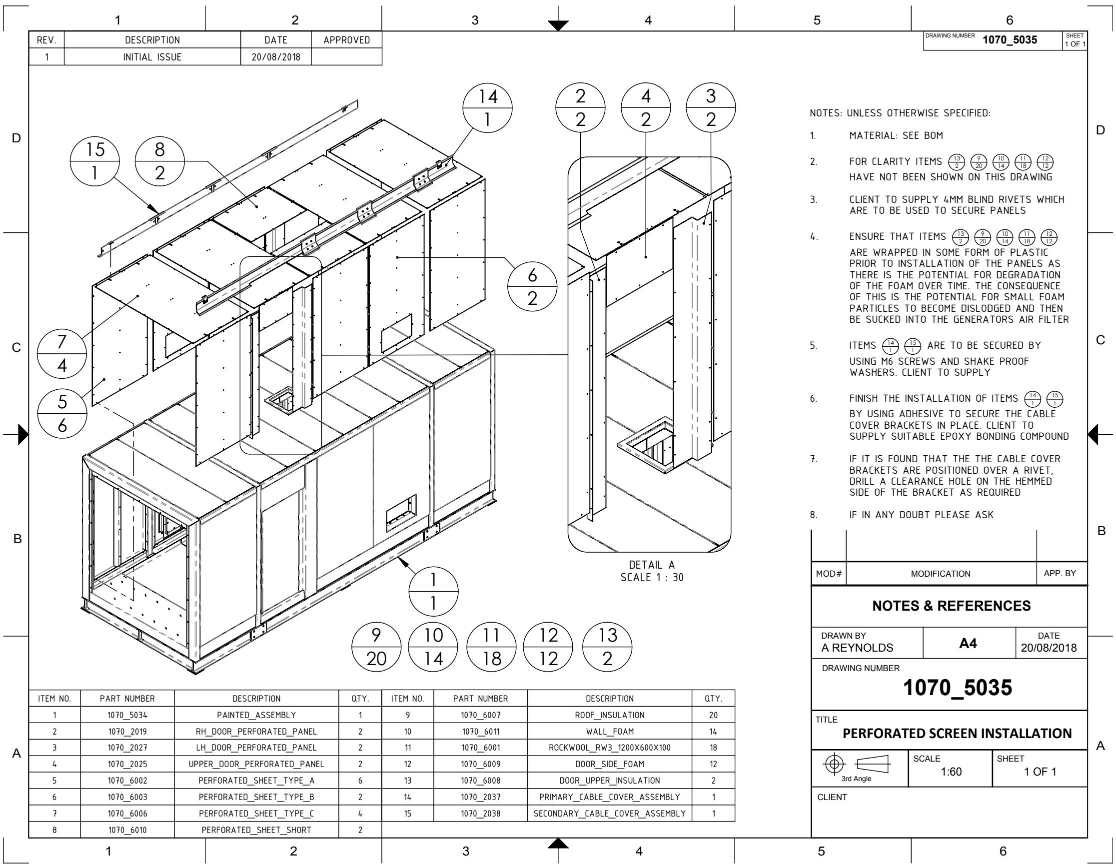


Vacuum chamber lid in its closed position

Another client wanted a set of fabrication drawings for a 30 ft diesel generator housing. They already had something similar on site but they lacked the necessary manufacturing drawings to get a second one commissioned.

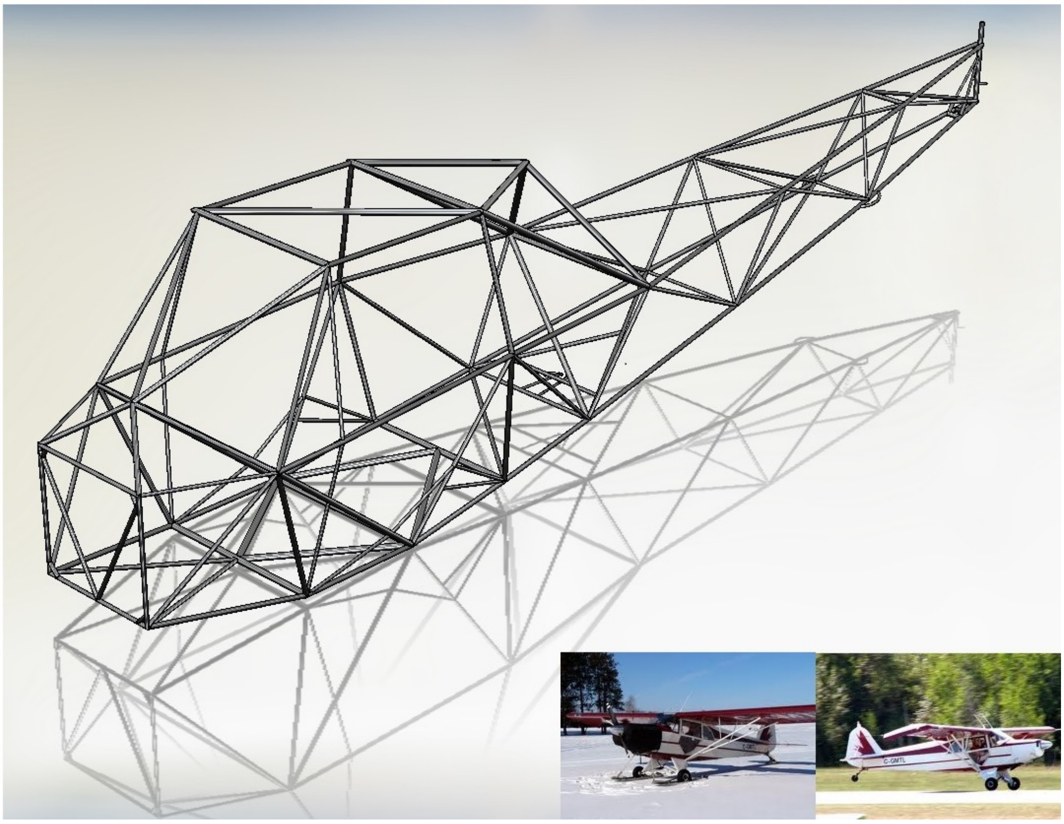
I would classify this type of work as evolutionary design as whilst we did start from scratch we had something to start from that acted as a useful benchmark.



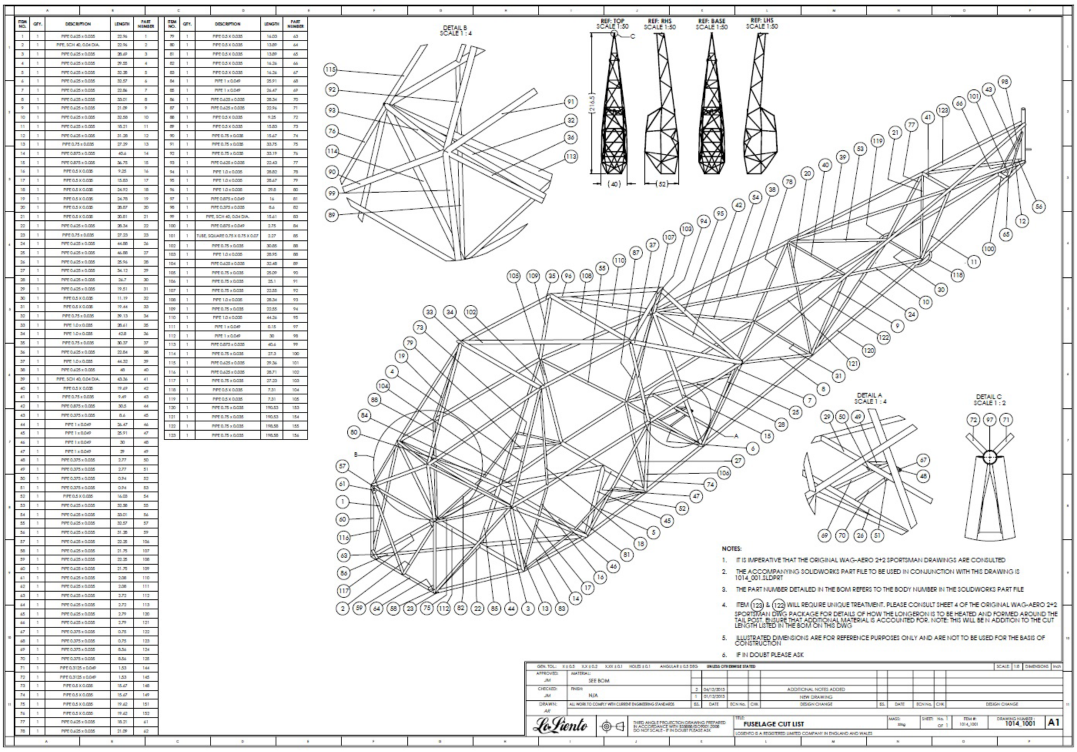


Manufacturing assembly drawings

Incremental design means only relatively minor changes are required to solve a technical problem, but they can sometimes be just as much of a challenge as an evolutionary design task. An example of which was when I worked with an aeroplane builder based in the USA. The goal was to transfer an original paper-based kit design into CAD in tandem with making small modifications that he wished to be incorporated into the welded fuselage.



CAD assembly of the welded fuselage



Manufacturing cut list showing all of the individual parts fit together

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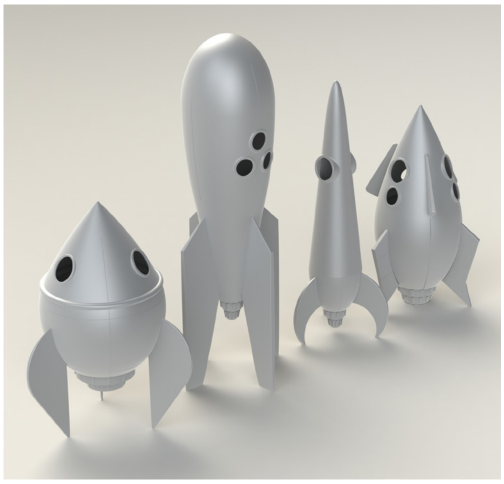
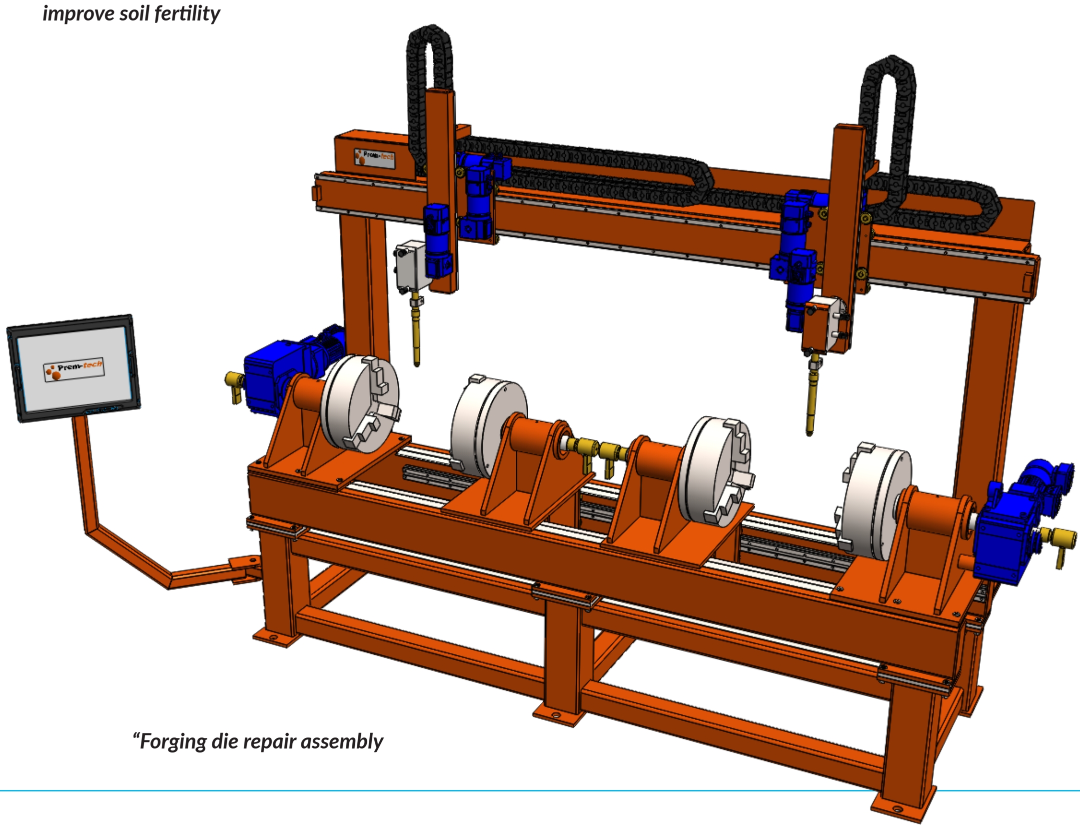
Most incremental designs that I become involved with normally involves transforming loose sketches from a client into fully finished working designs; further examples are the development of a biochar unit, a range of children's toys and a forging die repair unit all of which have been completed for separate UK based clients.

Biochar unit designed to help farmers improve soil fertility



Prototyping children's toys



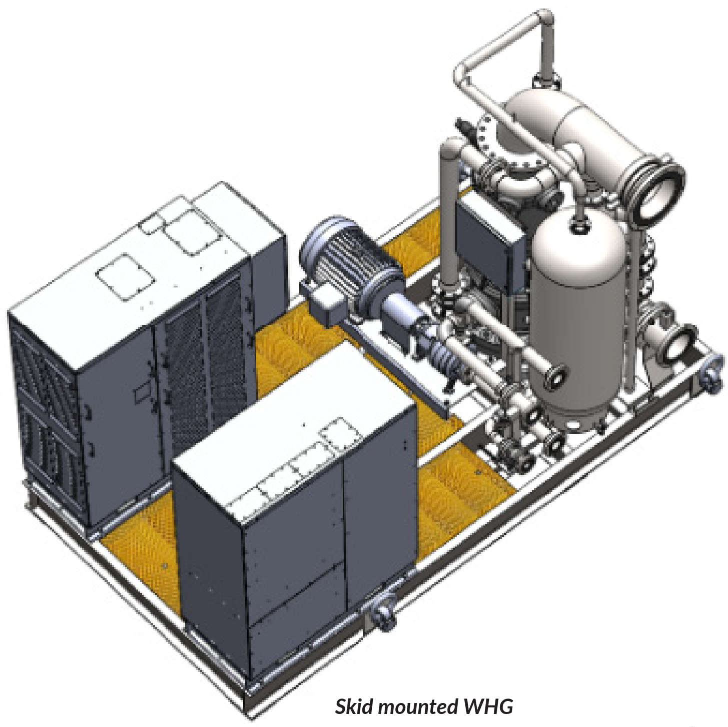
"Forging die repair assembly

5. Original Design

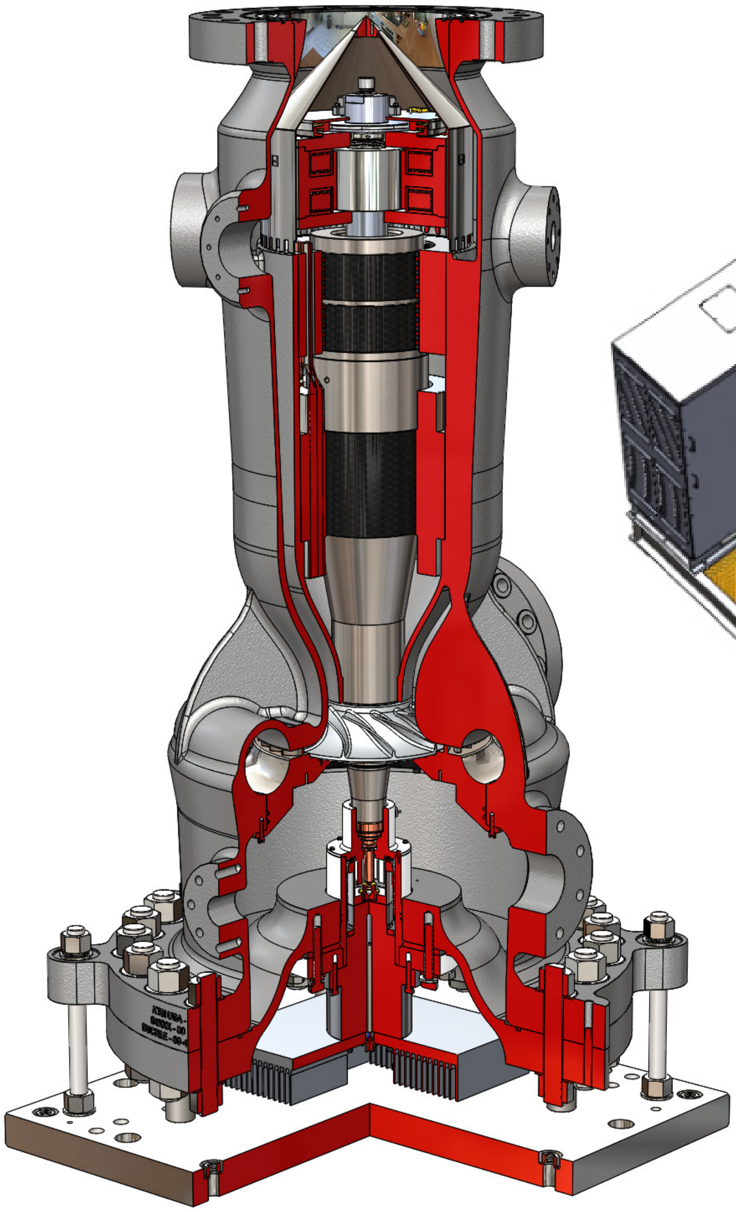
Any time that I am called upon to develop a product that does not exist then we move into original design. This without doubt is my favourite type of work as it is always the most challenging.

The illustration below is of a sectioned view of a waste heat generator that I designed for the American company KTSi. The machine is based on the Organic Rankine Cycle which uses Pentafluoropropane to convert low temperature heat into mechanical work. Mechanical work is then converted via a generator into electricity.

Based on a hot water supply at 110° C, the WHRG 300™ provides electrical power from 200kWe to 380kWe depending on the available temperature of the cooling water.



Skid mounted WHG



Sectional view of the WHG

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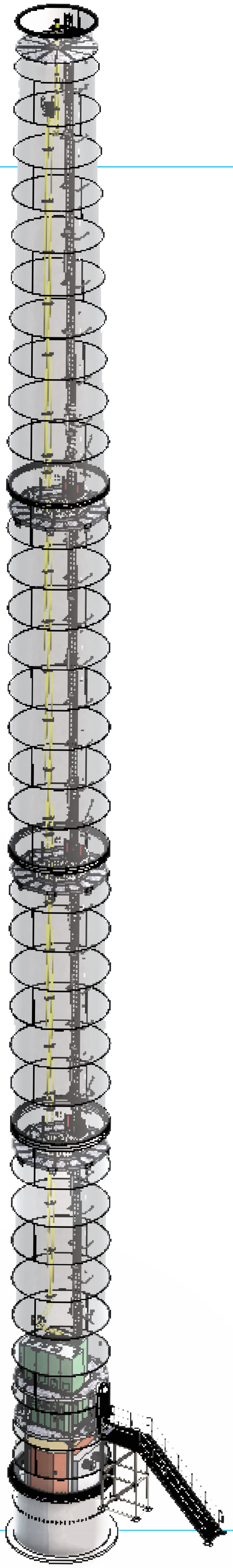
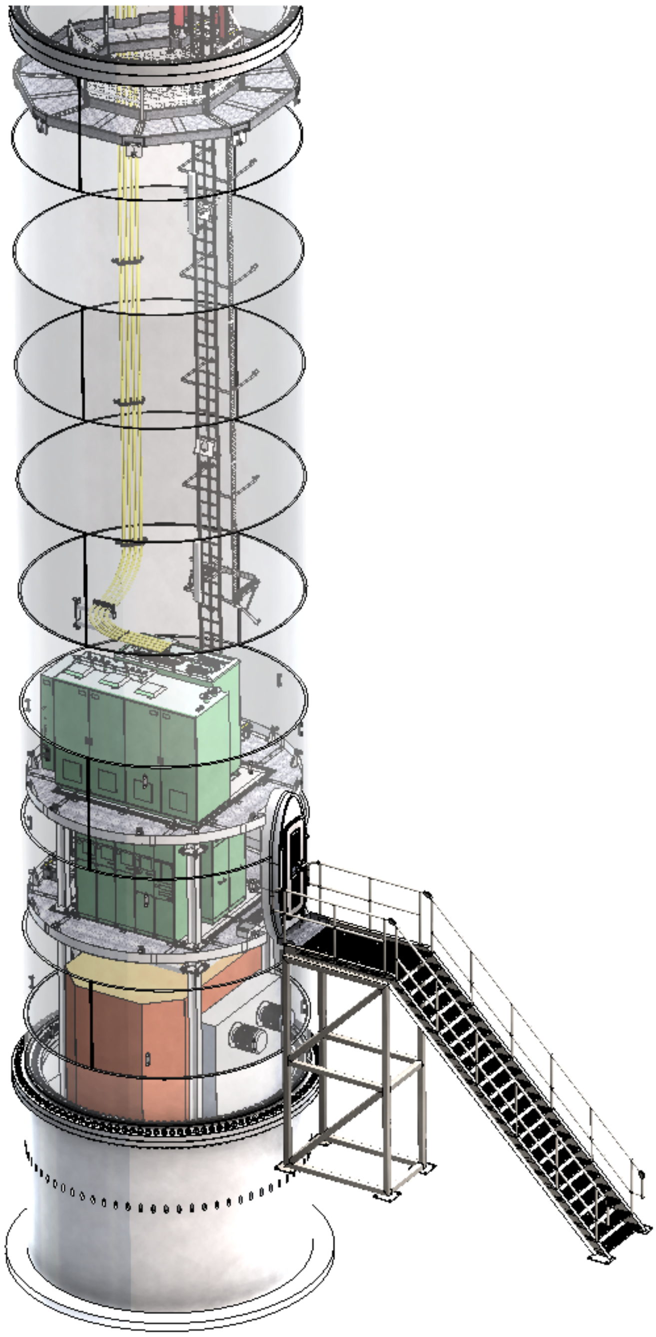


Another example of original design that I have conducted is the design of all of the associated internal parts and layout for a Chinese companies offshore 67m 5MW wind turbine tower.

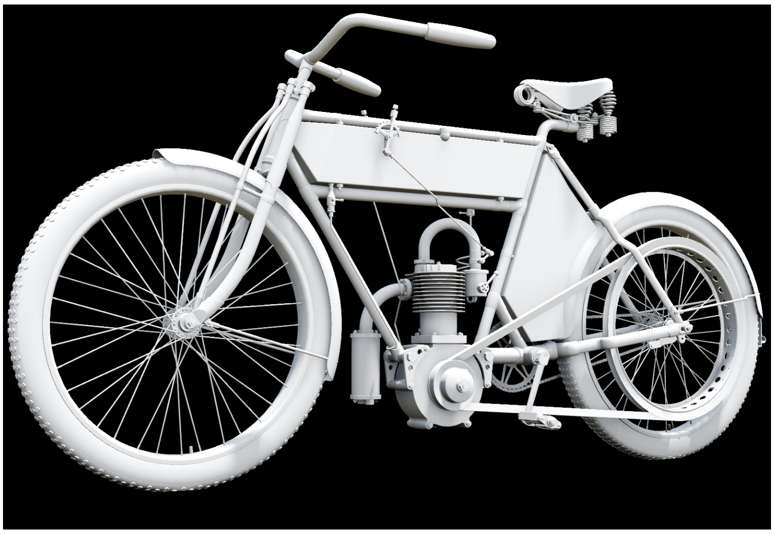
Given drawings specifying the dimensions of the empty tower my responsibility was to design all of the internal platforms, ladders, cabling assemblies etc.



5MW 67m wind turbine tower

Another project that comprises original design is a vintage motorcycle I designed as a long running personal project. The motorcycle is based around plans for a single cylinder 3.5 hp engine that were first published back in 1903. All of the rest of the equipment and controls are in line with both the technology and production methods of the era, hence the conspicuous absence of a front brake!

Rendered CAD model



Initial clay render used to analyse the form of the model

“It was an excellent experience working with LoSiento. I will hire LoSiento again on future projects”

Dave @ BlueFlame

“I am incredibly satisfied – hit the mark right on. Very good results and quick response. Exactly what I was looking for. Once again it was great to work with LoSiento. He is thorough, accurate and timely. I will work with him again without question”

Reid @ Farr Solutions

SECTION 3

THE TOOLS I USE

Design is a process and that process can always be improved upon. On this basis this list of tools that I use remains very much a work in progress as I continually search for better ways to develop new design solutions.

Action Method

The 'Action Method' is a productivity approach that I find is the most practical approach to getting tasks done efficiently.

Discover more: *read "Making Ideas Happen" by Scott Belsky*

Analytical Hierarchy Process (AHP)

The analytic hierarchy process (AHP) is a structured technique for organising and analysing complex decisions, based on mathematics and psychology. It was originally developed by Thomas L. Saaty in the 1970s and remains to this day a great tool for evaluating potential solutions to complex problems.

AutoCAD

AutoCAD first came out in 1982 and I encounter companies with legacy files on a regular basis. For this reason I hold a license of the software.

Axiomatic Design

Axiomatic Design is a modern approach to engineering design. The ultimate goal of its developer Dr Suh Nam Pyo is to build a scientific basis for design that is based upon a logical and rational thought process.

Axiomatic Design is focussed primarily around just two axioms, namely:

- **Axiom 1:** The Independence Axiom - Maintain the independence of a functional requirement
- **Axiom 2:** The information Axiom - Minimise the information content of the design

I believe that Axiomatic Design helps in making the correct design decisions and fosters creativity by its ability to integrate well with **TRIZ**.

Axiomatic Design has been proven to reduce the time it takes to develop a product and due to its structured nature it helps greatly in the design of complex systems.

BASIC

I still have a number of legacy programs that I run that where originally coded in BASIC. The primary one that is extremely useful despite its age is a stress and strain failure analysis program that was originally written back in the early 1980's. If you are interested in running BASIC code then I recommend the open source emulator PC-BASIC.

Bond Graphs

Bond Graphs were developed by Henry Paynter at MIT in the 1960's. Bond Graphs are essentially diagrams that show the flow of power in a system. The approach is relatively simple but extremely powerful when working across different fields and is a great way of checking different approaches when creating mathematical models of dynamic systems.

CAD

If a picture is worth a thousand words, then a CAD model must be worth a thousand pictures. CAD is short for Computer-Aided-Design. CAD is primarily focussed on the ability to create a virtual 3D model of a 'part'. We can put these virtual 'parts' together to form a virtual 3D 'assembly'. CAD data can then be used for different purposes; **Draughting**, **Finite Element Analysis** or even directly by a manufacturer to generate tool paths to make physical components.

I have a number of fully licensed CAD applications that I use for different tasks, as at the time of writing no one package can do everything that I need so the current list I have available to use is as follows:

SW	**Solidworks**
	Autodesk Inventor
Onshape	**Onshape**
	Alias
	Mudbox
	3DsMAX

The major difference in the software I use is in the way the 3D model is built:

Solid Modelling

When I need to work with simple closed volumes (sheet metal, weldments etc.) then I will be using a solid

modelling tool. The choice between using SolidWorks, Inventor or Onshape will normally be dictated by what the client has requested.

Surface Modelling

SolidWorks and Inventor both feature somewhat limited surface modelling tools so for industrial design and challenging modelling problems I use Alias.

Freeform Modelling

For extremely detailed complex forms I move towards digital sculpting where I will use Mudbox and/or 3Ds-Max.

Costing

To estimate the cost of a component whilst it is still on the drawing board, I use a practical rule based methodology based on the work of Booker and Swift. I have found their system to be invaluable as getting an early cost prediction in place for a part or an assembly is essential for **Value Analysis**.

Delphi Method

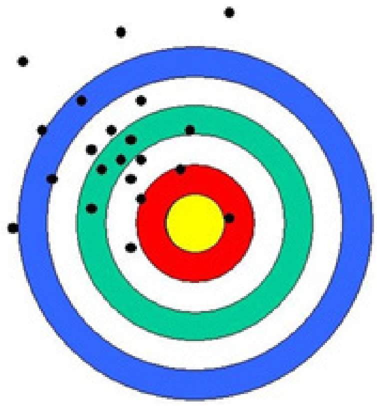
The Delphi Technique is an iterative process that leads to a consensus by a panel of experts. I have found it to be very useful as it allows all parties to have an equal input, it avoids personality clashes and input from experts unavailable for meetings can still be included.

Design for Six Sigma

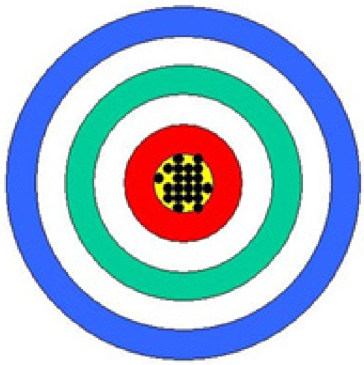
Design for Six Sigma (or DFSS in its abbreviated form) is an extension to Six Sigma and can be simply thought of as a collection of tools that aim to deliver Six Sigma levels of quality.

The Six Sigma approach started at Motorola in the 1980's and is now used by many of the world's leading companies* who wish to eliminate waste and be assured of providing quality products to their customers.

When you hear talk of Six Sigma levels of quality what is meant is having 99.99966% (i.e. ± 6σ) of the process or products response within range of the target mean value. Put simply; we aim to hit the bullseye and achieve our quality target 99.99966% of the time.



99% is good enough



Six Sigma Quality

99% is good enough (3.8σ)	99.99966% is good enough (6σ)
20,000 lost articles of mail per hour	7 lost articles of mail per hour
Unsafe drinking water for almost 15 minutes a day	Unsafe drinking water for 1 minutes every 7 months
5,000 incorrect surgical operations every week	1.7 incorrect surgical operations every week
200,000 wrong medical prescriptions per year	68 wrong medical prescriptions per year
No electricity for 7 hours every month	No electricity for 1 hour every 34 years
11.8 million shares incorrectly traded on the NYSE per day	4,021 shares incorrectly traded on the NYSE per day

Source: Butler & Lazarus

Which approach to quality would you favour as a customer?

**Amazon, BAE Systems, Boeing, Caterpillar, Dell, Ford Motor Company, General Electric and Raytheon to name but a few all use Six Sigma*

If the decision is made to actively pursue quality then the DFSS approach I use covers five distinct phases.

- The first two phases; **Identify** the project and **Define** the requirements, focus on getting the right product.
- The last two phases; **Optimise** the design and **Validate**, focus on getting the product right.
- The middle phase; **Design** is the bridge between getting the right product and getting the product right.

Compared to traditional design practices Design for Six Sigma is a lot more structured as it focuses heavily on the use of statistics and it also fundamentally changes the way that we perceive quality.

Quality is no longer something that we test for at the end of the production line; instead we must take the responsibility to design quality into the product from the very start which is the essence of robust design.

The accumulation of the DFSS approach is a greater understanding of the physics behind the product, a challenge to continuously aim for world class levels of quality and a product that has been designed to meet the needs of your customer.

Design for X (DFX)

Design for 'X' refers to Design for Excellence and is a family of tools that broadly take the form of guidelines and formal methodologies which I use as an aid to develop reliable and cost-effective designs.

You might already be aware that the 'X' in DFX changes depending upon the particular objective we are looking at. For example:

- Design for Manufacturing and Assembly can be used to improve a product by reducing its part count and simplifying assembly operations
- Design for Reliability anticipates potential failures and allows for the reliability of the design to be improved upon
- Design for Environment addresses potential environmental concerns
- Design for Serviceability concentrates on making sure that a product can be easily repaired whilst Design for Maintainability assures that the design will perform satisfactorily throughout its intended life with a minimum expenditure of budget and effort
- Design for Aesthetics and Design for Ergonomics are both used when particular values need to be added to a product by an industrial designer
- Design for Logistics focuses on the supply chain partners and involves anticipating packaging and shipping requirements
- Design for Cost concentrates on the profitability of a design

Draughting

I create engineering drawings to British Standard BS8888 using traditional limit-based dimensioning and if requested by the more modern geometrical dimensioning & tolerancing (GD&T) approach.

Fault Tree Analysis (FTA)

Fault Trees became popular in the nuclear industry in the 1960's to help avoid scenarios where a chain of events that are the accumulation of small malfunctions and mistakes could lead to total disaster.

A Fault Tree is a powerful diagnostic tool for analysing the reliability of complex systems by combining it with Monte Carlo analysis to run hundreds of thousands if not millions of trials.

Finite Element Analysis (FEA)

FEA is a practical and reliable tool that can both shorten a products development time and strengthen its competiveness.

We could test real objects to see if they might bend or break under loading but as you can well imagine this is going to be a slow and expensive process. So instead we make use of mathematical models.

A FEA study is simply a mathematical representation of a problem which is solved by breaking a CAD model down into small pieces. The small pieces are known as elements. Elements are connected by nodes and collectively they are commonly called a mesh. Material properties, loads and constraints which aim to mimic the physical scenario in question are added and then a solution is derived to determine the properties at key points of interests within the model.

The FEA process can be done by hand for relatively small problems but for the majority of work I use Autodesk software, or I commission the work to be done in Ansys by a trusted supplier.

The reader should be made aware that FEA is a demanding tool that is at best an approximation of reality. I always try to arrive at an answer by a different route and I would stress that the correct selection of elements, materials, loads, constraints and analysis parameters can only come from experience and sound engineering judgement.

FMEA

Failure Mode-Effect Analysis (FMEA) is a proactive method that is used to improve either a product or a process by asking primarily *"what can go wrong?"* and *"where can variation come from?"*

I conduct FMEA's at various levels of the design hierarchy with the aim of reducing risks by eliminating failure modes.

FMEA studies also provides a structure for collaboration as it allows experts from differing backgrounds to be brought together to critique a design.

Functional Modelling

To prevent a design problem from becoming overwhelming it is essential that is broken down into more manageable pieces. I believe that studying functions is the key to tackling difficult engineering problems and concentrating on the functionality of a product is at the very heart of DFSS, Value Analysis, TRIZ, Robust Design and Axiomatic Design.

Selecting the functions of a system sounds like a simple step but you might be surprised at how often the wrong function is picked. The apocryphal tale about how NASA spent millions developing a special pen to use in space whilst the Russians used a simple pencil might not be strictly true but it illustrates the question we need to continually ask; *"what do we actually want our system to do?"*

FORTRAN

FORTRAN was the first high level programming language launched back in the 1950's by IBM, it then subsequently went on to dominate the scientific and engineering fields.

It still lives on to this day in many serious applications and although by no means perfect, it is fast, reliable and a well proven practical tool.

I use FORTRAN to create bespoke programs that mainly focus around either Optimisation or Probabilistic Design.

Discover more: *An open source FORTRAN compiler: https://gcc.gnu.org/fortran*

Hand Calculations

Hand calculations are primarily sanity checks. It is all well and good having powerful software but how do you know that the results derived are in fact correct?

I gain confidence in my work by doing things the old fashioned way; by hand. That is not to say that I want to use log tables and work cube roots out by hand if I don't have to, but sometimes it is important not to let computers do all the work and think carefully about the calculations being made.

Doing things the old fashioned way forces you to be engaged with the work you are doing and can help pick up a missed step, a decimal place in the wrong place or some other innocent error that can trick a computer into blowing up a program.

Discover more: *Not strictly pencil and paper but SMath is an invaluable open source mathematical notebook program similar to Mathcad. https://en.smath.info/view/SMathStudio/summary*

Interference Analysis

A **CAD** based tool for detecting which surfaces are touching within a virtual assembly of parts to avoid embarrassing and costly moments in the real world.

Interference analysis is also very good for a final check on manufacturing tolerances to make sure everything stacks up as intended. Both **Autodesk Inventor** and **SolidWorks** feature built in commands to run an interference analysis

Kano Model

In 1984 the Japanese researcher and consultant Professor Noriaki Kano published a set of ideas and techniques that can help us determine a customer's satisfaction with a products features. Kano's technique is commonly called the Kano Model.

The benefit of using the Kano Model is that it allows us to interview the customer and then clearly establish the importance of their needs.

Kano's approach ensures that we concentrate our time and resources in the correct places to achieve the maximum possible level of customer satisfaction.

Material, Shape & Process Selection

"When in doubt, make it stout, out of things you know about!"

D. Ullman

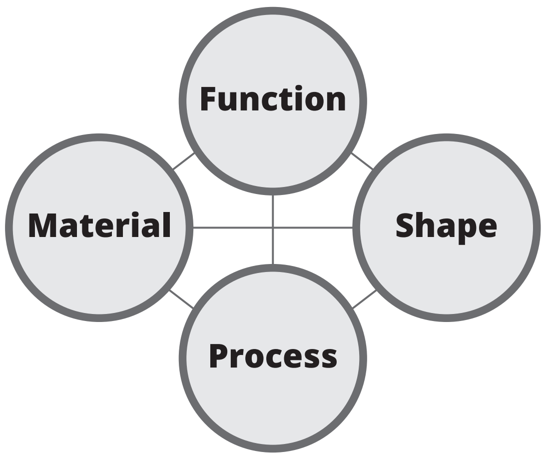
We have roughly 120,000+ commercially available materials to choose from at the time of writing. If you factor in processing, by which I mean how any one of these materials can be shaped, joined or finished then even more options become available.

Let us confuse matters further with the practical matter of economics; what about the cost of the selection relative to the quantity required?

With all this in mind how does one develop a high level of confidence that the final selection of both the material and the manufacturing process for a particular mechanical design problem is the correct one?

Professor M. Ashby of Cambridge University has devised an extremely powerful methodology for answering these questions with a systematic approach that assists with our experience in selecting the correct material, shape and associated process for a defined function.

I use Ashby's approach extensively throughout my work as his method concentrates on the four key interrelated aspects of mechanical design, namely; function, shape, material and process.



It should be noted that Ashby's approach has parallels to **Johnson's Method of Optimum Design** so the two can very often be used to validate the work of one another.

Minitab

For the statistical analysis of data, I believe the best in the field is Minitab.

Discover more: *minitab.com*

Modelica

Modelica is both an open source language and an exchange specification for the modelling and simulation of physical and technical systems.

Building and simulating virtual prototypes is a way to determine and optimise the properties of a product without building costly physical prototypes. Multi-domain systems are now a part of everyday life and Modelica is extremely powerful because it allows differential equations to be written and solved in a logical manner. The dynamic behaviour of systems that comprise to varying degrees of; mechanical, electrical, hydraulic, thermal, chemical or control oriented subcomponents can be analysed.

Discover more: *modelica.org*

Mood Boards

I create mood-boards for clients and team members to make sure that we are all on the same page. Feelings, visions and ideas can be difficult to communicate verbally so to manage expectations I will compile a series of images that help to convey a specific theme or style.

Morphological matrix

A Morphological matrix is a powerful tool for linking new ideas together quickly within an established framework. It works well within a group environment and has the added benefit of forming a database of the design ideas as the project progresses. At the time of writing I am in the process of coding a genetic algorithm that will create design concepts from a morphological matrix that has been populated with design options.

Non-disclosure agreement (NDA)

Due to the nature of the work I perform client confidentiality is taken very seriously and for that reason I use NDA's on a regular basis. Please contact me directly for a copy of my current NDA that can be adapted to suit your own purposes.

Online Collaboration

As a lot of the work that I do is performed remotely I have focussed on building an effective communication system. The tools listed below have evolved from a long process of attrition.

Basecamp

Basecamp is a web based piece of project management software that allows tasks to be assigned and tracked.

I have found it to be almost perfect for keeping technical conversations in one place and for sending drawings backwards and forwards during the design approval process. Whilst Basecamp facilitates remote working I am such a strong proponent of its approach that I will still use it when a team is sat together in the same room. It is important to note that access to a Basecamp group is limited by the project manager and at the conclusion of the project the complete Basecamp database will be transferred over to the client's ownership.

Discover more: *basecamp.com*

GrabCAD Workbench

Implementing a secure remote access PDM can be both tiresome and expensive. I favour a cloud based approach called GrabCAD Workbench that is independent of the software I use. I used to pay for a large number of seats and then out of the blue they made it available for free! Data security is high and revision control is fantastic. Parts and assemblies can be viewed and manipulated in your web browser meaning that you can even use your phone to check on matters whilst out and about.

Discover more: *grabcad.com/workbench*

TeamViewer

TeamViewer software is used to share screens and remotely control the desktop of anyone connected on the internet. It works in both directions meaning that we can flip back and forth between computer screens making it a perfect tool for remote collaboration.

Discover more: *teamviewer.com*

Optimisation

Optimisation is simply the process of manipulating the values of the design variables to either minimise or maximise a specific design characteristic. The decision over which optimisation technique I use depends primarily upon the problem I am facing. A computer is normally essential in the practise of optimal design and hence I write bespoke programs featuring well tested FORTRAN subroutines for the majority of my work. A summary of the different optimisation approaches I have to hand at the time of writing are listed below in alphabetical order:

CODA

CODA stands for Concept Design Analysis and comes from the work of Scanlan, Woolley and Eres. It is used within the Quality Function Deployment process as a complementary tool. CODA aims to address a weaknesses found within the traditional Quality Function Deployment process which is the difficulty of selecting optimal values to maximise the potential customer satisfaction. CODA makes use of utility curves that allow an optimisation search routine to evaluate different potential design trade-offs to seek out the best combination of values to maximise the overall worth of the design.

Dynamic Programming

When faced with a complex problem that can be broken down into stages then it can often be desirable to use Dynamic Programming. Dynamic Programming is a technique that was developed by Richard Bellman in the 1950's. Bellman's approach works on the basis that some problems lend themselves to being solved sequentially; that is decisions have to be made at different points of time, space or levels.

Linear Programming

During World War II the U.S. Air Force sought more effective procedures of allocating resources and developed linear programming. Linear problems are not particularly common within mechanical engineering but there are occasions when it is a useful tool to have.

Multi-Objective Optimisation

There are many times when we might wish to optimise two or more aspects of a design simultaneously. These problems are known as multi-objective optimisation problems. The most common occasion to have a multi-objective optimisation problem is in the selection of materials. We want to design an item that is both 'light' and 'strong' or 'stiff' and 'cheap'. For problems such as these then graphical plotting or ranking will normally suffice.

For problems that become more difficult a good choice when appropriate is the use of subjective weightings hence a utility function or an inverted utility function based approach can often be used to arrive at the optimal answer.

Non-linear Optimisation

Most mechanical engineering optimisation problems are non-linear. Unlike linear problems the method of finding the global optimum solution can be much more difficult and it is useful to have a number of different methods quickly available to try on the problem. I use a range of well tested non-linear search strategies that fall under two main groupings; gradient methods with penalty functions or random search strategies.

Johnson's Method of Optimum Design (MOD)

The late R. C. Johnson proposed in many writings on the topic an ingenious optimisation process that lends itself to being used early in the conceptual design phase once the fundamental layout of the design has been selected. Equations are developed for the system that is being studied and these equations are then manipulated algebraically to develop a final system of equations that are structured in such a way as to allow the optimal result to be determined. To assist in the determination of the optimum design point another of Johnson's ideas; three dimensional variation diagrams, can often be used.

Statistical Methods

If I wish to optimise an item that I am unable to easily build a mathematical model for then I can always try and analyse it by experimental design methods. I strongly favour the Taguchi approach and use it for all manner of purposes, the main one being Robust Design.

Patents

Patent searching is not normally an easy task but it can be beneficial as both a source of ideas and to check against potential patent infringements.

Probabilistic Design

Uncertainty lies everywhere within the world of engineering. The traditional approach for uncertainty is to apply a factor of safety.

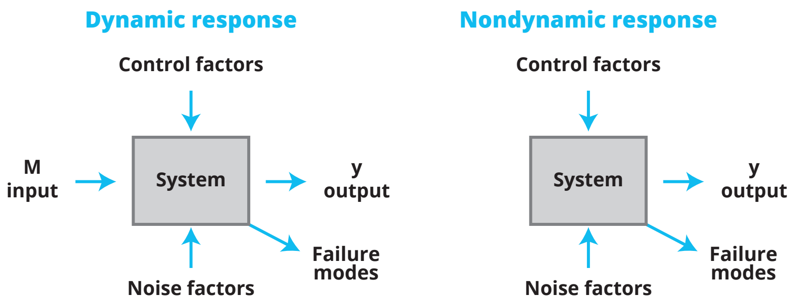
A factor of safety is often called a factor of ignorance as it can be at times a relatively crudely selected number that is used to make sure variations in materials, loads etc. will not end in a design failure. Hence the more uncertain you are the bigger the factor of safety becomes. A factor of safety does not tell us how reliable our product is, nor does it ensure that it is not over-engineered. When circumstances dictate that a more accurate approach is needed then we can codify our uncertainty with probability density functions.

A probability density function is simply a curve that is plotted to describe the statistical uncertainty of a certain design variable. The aim is then to derive a statistical indication of a certain aspect of the design that we are interested in.

For probabilistic design I use several approaches. The first and most simple will be to employ Taylor series approximations to estimate the mean and standard deviation of the function in question by hand. When the functions and probability density curves start becoming more complicated then I use a series of well tested FORTRAN programs that employ the Monte Carlo method, The Transformation of Variables Technique or Moment Transfers.

P-Diagram

The P-Diagram is a graphical approach to system modelling. It allows an input to be converted into an output via a transfer function with the addition of noise and design parameters.



The great thing about P-Diagrams is that they can then be linked together to simulate the functionality of our system to see what changes need to be made and if we are meeting the needs of the customer.

Project Planning

With respect to project planning every project is unique but the one common question my clients always have is in relation to time.

Estimating the amount of manpower and time required in design work is always dependent upon the complexity and scope of the project. As a rough guide the table below aims to give you a general indication of the time it takes for various pieces of mechanical design work:

Task	Manpower / Time Required
Routine design work of simple parts – or – Straightforward modifications to an existing part or assembly	1 designer for 1 week
Design of a simple assembly – or – Design of a complex single part	1 designer for 1 month
Design of a complete machine with most work being mainly routine and only a limited amount of original design required	2 designers for 4 months
Design of a complex machine that requires original design with associated extensive analysis and testing	5+ designers for 8+ months

Prototyping

I use a lot of prototypes in the course of my design work. The majority of the prototypes I develop will be virtual simulations in order to keep the design process moving along and to keep costs down.

I will however make physical prototypes for a sanity check. This means foam board, modelling clay, paper clips, sticky back plastic and anything else that proves the point will be used.

When requirements start getting more professional then I will outsource my prototyping requirements to a trusted supplier.

Pugh Matrix

The Scottish professor Stuart Pugh developed the Pugh Matrix in the 1980's as a quick and easy way to quickly compare design choices via a decision matrix.

A more thorough approach than Pugh's method is the use of the **Analytical Hierarchy Process**.

QFD

In the shipyards of Japan they call it 'hin shitsu, ki nou, ten kai'. In English the closest translation is 'Quality Function Deployment' or QFD for short. QFD is a proven business technique used by some of the world's leading companies.

QFD is simply a way for a design team to listen to the voice of the customer and then translate their needs into specific and measurable design requirements. QFD does take more time at the start but it will save time in the long run when it is applied correctly.

Reliability

The reliability of a design is simply the probability that it will perform satisfactorily within a specified time frame. The reliability of a system is assessed by the types, combinations and numbers of components in the equipment and the conditions under which they are working for which statistical data is available.

I use **Probabilistic Design** methods to assess the reliability of components.

Rendering

Rendering is a communication tool. Having a visual representation – even if it's basic – helps with collaboration and soliciting feedback. I use rendering techniques that vary in levels of complexity depending upon what I am trying to convey:

Level 1

The old fashioned approach is fast but unforgiving. Whilst I don't have 'ctrl-z' to undo a mistake, creating a design presentation by hand can still be an expedient solution. I use sketching, marker pens, pastels and gauche.

Level 2

A more formal method is with the use of 2D Digital techniques. Alias and Sketchbook Designer are the main tools I use for this type of work in combination with a Wacom monitor.

Level 3

3D renders aim to create a photorealistic 2D image. To achieve this level of detail then I will use either Alias, 3Ds Max or Showcase. Working in 3D also allows for the creation of animated renderings.

Rules based modelling

SolidWorks and Inventor both have means by which we can use rules to control a **CAD** model. Inventor leads the field in this area with their iLogic add-in which comes as standard with the software.

Why would we wish to control a **CAD** model with rules though? Imagine that you are in the business of fabricating a product that can be sold in different configurations; the traditional approach has been to create a product with a range of options that your customer can pick from.

For many products every new bespoke customer order means new CAD models and associated manufacturing drawings are required. This approach is slow, expensive and can tie up staff.

In order to increase your company's level of productivity I can create a master rules-based model. So now when a customer places an order, your staff simply open up the rules-based assembly, enter the values from the customer into a bespoke form and out pops a finished set of manufacturing drawings with an associated CAD model.

If we really wish to push the boat out then this system can be integrated into a website so your customers can pick and choose configurations of your products online. A CAD model showing their chosen configuration can be embedded into the website and the crucial manufacturing drawings are created upon completion of the purchase. These drawings can then be automatically forwarded to your manufacturing department in order to automate the sales to manufacturing process.

Robust Design

The Robust Design approach means quality is designed into a product from the start instead of inspecting for it at the end of the assembly line. This is a subtle but very different way of looking at the quality of a product.

Robust Design ensures that the most economical product from both the manufactures and customers perspective can be developed with the confidence that it will function as intended regardless of the variations it will encounter out in the real world.

The key concept to understanding the Robust Design process is to recognise noise. Noise is simply uncontrolled variation, or put another way, everything that we cannot control within a design. The traditional way of coping with noise was to tighten up the tolerances and then react to any customer problems. The problem with this approach is that it is akin to playing 'whack-a-mole'. As you fix one issue another unexpected one raises its head.

There is a way around this problem and it is to simply accept from the start that there will always be variation. By recognising and accepting the noise it is then possible by using various techniques to design a product that is insensitive to this inherent variation.

To perform Robust Design I primarily make use of **Taguchi's** approach.

Sketching

I have found that sketching is under represented in many design offices. The danger is that you jump straight into **CAD** and start creating shapes on a screen without thinking through the problem by hand.

Sketching is a form of visual thinking. Sketches allow a designer to think through different scenarios and configurations very quickly. Sketches can also infer details and be much 'looser' allowing the recipient of the work to see and imagine different aspects of a design without them being fully detailed which can save enormous amounts of time when all we wish to do is quickly convey an idea.

Taguchi

Taguchi methods are named after the prominent Japanese engineer/statistician Genichi Taguchi.

Taguchi developed a method of using statistics to help improve the quality of manufactured items. His approach was to use designed experiments and what he called orthogonal arrays (also known as fractional factorial designs) derived from the work of Sir Ronald Fisher.

The primary benefit of Taguchi's approach is that it gives us a very practical approach to tackling complex problems. Taguchi's view of focussing on quality at the earliest stage of the design process and quantifying quality as the deviation from a specific target via a quality loss function has also been hugely influential and forms a large part of the **DFSS** methodology.

Technical Articles and Trade Journals

Published engineering journals contain submitted papers that often contain valuable ideas and information.

Tolerance Design

"Don't measure in millimetres what will be marked with a crayon and cut with an axe." - Shop floor saying

Manufactured parts will always vary slightly in size and shape so I need to use tolerances to indicate to the person manufacturing the product I have designed what is and what is not acceptable. Tighter tolerances nearly always cost more money to produce so my aim is always to use the widest tolerances I can get away with whilst still meeting the needs of the customer.

My tolerancing approach has been transformed by the methods devised by **Taguchi**. His approach gives a hard value in pounds/euros/dollars for an improvement in quality balanced against the increase in the unit manufacturing cost.

Topological Optimisation

At the present state of technology topological optimisation software guides us into how a shape 'could' be which gives us a very strong hint as to the direction in which to proceed for an optimum design when balanced against the inevitable manufacturing constraints.

Trade off curves

Trade off curves are a graphical tool used for a number of different purposes during the optimisation process. They give confidence that convergence has been obtained and can be used to indicate a feasible starting point or an over constrained problem. Trade off curves can also be used in the **optimisation** of interacting systems.

Transfer Function

Within the context of **DFSS** I see a transfer function as analogous to that of a recipe.

Imagine if you will that I asked you to bake a cake from memory alone. What would your inputs be? Sugar, eggs, flour, milk, butter...?

How would you then go about processing these ingredients without consulting a recipe book? I would imagine you would make up some form of cake batter and then bake it in an oven for say 1 hour at perhaps 180 degrees?

Would that be the perfect cake? Almost certainly not.... What was missed out was the recipe to convert the ingredients or inputs in the right manner.

We can see that a transfer function is akin to the 'recipe' or 'formula' for how we process our inputs into our desired response.

Transfer functions in the world of mechanical engineering are equations that are based upon the fundamental laws of physics. From these solid foundations we can design and build systems that will operate as we intend.

TRIZ

TRIZ (pronounced "Trees") is a powerful methodology for systematic technological innovation.

TRIZ is the Russian acronym for "теория решения изобретательских задач" which translates as **"Theory of Inventive Problem Solving"**.

TRIZ comes from the work of Genrikh Altshuller (1926 – 1998) who lived and worked in the former Soviet Union. Altshuller worked within a patent office and became interested in creativity and how inventions arose. Altshuller believed it was possible for people to become inventors by learning as opposed to waiting for sparks of inspiration.

He set about proving his theory by initially studying 200,000 patents with his colleagues. From his research he found that there are only about 1,500 basic problems that exist. Each of these problems can be solved by applying one or more of the 40 universal answers that Altshuller then went on to list.

It might sound remarkable that every answer to every problem is contained within these 40 basic concepts, but TRIZ does work. 3 million patents have been reviewed thus far and the theory still holds true.

For political reasons Altshuller was sent to a Gulag prison camp from 1950 – 1954 by Joseph Stalin. Amazingly he still persisted in developing his theory and his work cumulated in a series of tools that assist us today in solving complex engineering and design problems.

For the majority of problems these individual TRIZ tools will suffice. However for non-standard problems that are too difficult for solution by the standard TRIZ tools I use ARIZ.

ARIZ is short for "Algorithm Rezhenija Izobretatelskih Zadach"; in English we know it as the "Algorithm of Inventive Problems".

ARIZ was initially developed by Altshuller in 1968 as an algorithm for tackling the most difficult of problems by taking the user through a sequence of highly directed steps to help move towards a solution. ARIZ uses all of the standard TRIZ methodologies, techniques and databases and after going through a number of revisions the last official version is the one I use today, namely; ARIZ-85C.

It is worth mentioning that TRIZ was almost unknown in the West until the early 1990's when small consulting groups began to appear, staffed usually by immigrants from the former Soviet Union. Today awareness of the power of TRIZ is still growing.

Utility Curves

Synonyms for utility are desirability, attractiveness, worth, etc.

Utilities cannot be measured with accuracy, yet every person who has ever made a decision amongst alternatives has at some point made complex utility judgment's that are based upon feelings and intuition. I favour the use of utility curves for subjective decision-making problems and find them to be very helpful when translating customer requirements into specification targets.

Value Analysis

Lawrence D Miles (1904 – 1985) was the father of Value Analysis, a topic which has a broad appeal.

Value Analysis is an extremely powerful methodology that focuses on trying to achieve the lowest price that we must pay to reliably accomplish a given function. This gives us a proven problem solving system to identify unnecessary cost within a product.

Wacom

I use a Wacom Cintiq tablet for all of my digital sketching and CAD work. Once you have the ability to be able to draw on your screen you will never go back.

Wiki

In the past I have used Wiki's for storing the project knowledge of a team. This can be very handy when it comes to the transfer of information between different groups.