Automated Modelling Functional Design Spec
Project# 3D Auto Pipe

Contents

1.0 Advanced 3D Laser Solutions Ltd

1.1 About the Company

Advanced 3D Laser Solutions (A3D) is an engineering grade surveying company, specializing in the process industry, including oil and gas; using modern 3D laser scanning technology to accurately map client sites for modelling, analysis, and general compliance documentation.
Website: www.lasersurveying.com
Brochure: https://lasersurveying.com/Downloads/A3D2020.pdf
LinkedIn Business Profile: https://www.linkedin.com/company/advanced-laser-surveying

1.2 The Directors / Co-Owners

1.2.1 Colin Pittman - Commercial and Marketing specialist with wealth of experience in both the publishing and Energy sectors; his vision and determination has helped establish A3D as a global brand. Colin's role in the business has always to be open our business up to new clients, make our brand and voice as open and global as possible, not only do we get seen in the UK but the world.
To date Colin has been able to get A3D recognized in multiple oil and gas, pharmaceutical and chemical storage companies, using techniques such as magazine articles and adverts, company website, heavy LinkedIn research and events such as the TSA and consortiums such as Tank Storage Consortium.
LinkedIn: https://www.linkedin.com/in/colin-pittman-56391424/

1.2.2 Graham Boxer - A3D's principal engineering authority with over 40 years' experience working in petro-chemical, chemical, pharmaceutical, detergents industries implementing multi-disciplined projects and offering strategic support for the company's initiatives.
Grahams role in the business has been to support the operations team with his wealthy engineering expertise, manage accounting and general administration, support Colin with new client introductions, job and workload planning and become the engineering voice of the company.
Please See "Roles and Responsibilities - Graham Boxer"
LinkedIn: https://www.linkedin.com/in/graham-boxer-76782973/

1.2.3 Lewis Boxer - Drawn from 15 years' experience working in the Oil & Gas sector, Lewis gained considerable experience in surveying and preparation of engineering records including P&IDs using both 2D & 3D CAD packages.
Lewis' role has evolved drastically over the years, in the early stages of the company his time was spent 90% of the time producing client deliverables such as P&Ids, 3D Models, Tank Reports and with Graham surveying.
Lewis' role has now developed to become a support member to the operations team in all software and hardware requirements, build marketing material, including the building of technical articles, with the support and guidance of Colin Pittman, maintaining the website with Ben Pittman, building and maintaining the internal training system, which has grown to over 400 videos and most importantly the research and development of new technology.
LinkedIn: https://www.linkedin.com/in/lewis-boxer-92b92a29/

1.3 Our Services

1.3.1 3D Laser Scanning

Website: *https://lasersurveying.com/3d-laser-scanning/*
Simple Terminology: A3D utilise laser technology to capture site data, this approach being simpler, safer, faster than traditional survey methods. Our experienced engineering surveyors can therefore collect in days, what traditional methods can take months or even years. Human error can be avoided and the overall saving in time and effort passed back to our clients as savings. Traditional methods are expensive, involve large teams spending long periods on client sites. Accessing data at height requires temporary access where our 3D laser scanners capture from ground level.
A surveying technique which uses similar technology to LIDAR. The 3D Laser Scanner weighs about 5-10kg and goes on a tripod, during operation it goes through two phases, the first fires out nearly a million points per second, which produces an accurate 3D map of its surroundings, the second phase produces hi-resolution images which can later be used alongside the point cloud for measurements.
Detailed Terminology: A3D are proud to have established point cloud technologies, now recognized as the preferred method for accurately capturing measured site data in using 3D laser scanning instruments. Traditional methods being time consuming and subject to error, are being consigned to history in regards surveying practice. 3D laser scanning instruments continue to improve with their accuracy and streamlining of scan file registration a cost-effective solution. These improvements alongside A3D developing our surveying methods, has resulted in our accomplished surveyors being able to complete large scan surveys using multiple
instruments efficiently. Large sites, for instance 100-200 tank storage terminals requiring 1000-2000 scans, are now completed in days, to the benefit of our clients.
A3D process modelling projects are undertaken by our in-house team who return from surveying to process client's 3D models and P&IDs. This approach along with our engineering background and training, ensures A3D deliver the quality of scan data and accuracy in 3D modelling that is the envy of our competitors. Added to this, where A3D are contracted for P&ID deliverables, our trained surveyors will also record equipment specific data using our Go-Pro cameras. Our internal training videos cover all aspects of both laser surveying and modelling, ensuring a consistent approach un-rivalled by other companies. As the laser scanning market grows, A3D are proud to have established us as the 'go-to' competitive company who deliver the best results for the process industries
Hiring Equipment: Until a new scanner becomes available that allows A3D to survey faster, I see no reason why we would need to stop renting. It comes with great benefits such as not having to keep it calibrated and software up to date; it also allows us to fluctuate the number of scanners we require per job.

1.3.2 3D Process Models

Website: https://lasersurveying.com/3d-modelling/
Simple Terminology: We are able to produce 3D process models by accurately tracing over the top of the point cloud data, the 3D models we produce are built against a database which allows us to file detailed information about every single component we model, including size, spec, material and pressure class.
Detailed Terminology: The vast engineering experience from over 30 years working within process industries has resulted in A3D now leading in the production of 'brown field' technical process models. A3D recognised the importance of our skilled 3D laser surveyors site familiarity being utilised when producing technical process models. Their job specific training, for which A3D have prepared over 400 training videos, ensures our modelling team prepare good quality technically correct process models. As a company we rejected the use of overseas modelling companies, concentrating on developing our own modellers skill set to identify site assets and recognise assets requiring new component build within our growing component library.
It is this ability to give the attention to technical details that sets A3D apart from would be competitors and key to development of our 'Intelligent' models and P&IDs being linked to client asset management systems. Our policy of continual development ensures A3D maintain a principal role with software companies in our supply chain. As a result, A3D offer our clients a technical point of reference where new client challenges are addressed, and solutions provided. Our client relationships are fundamental in our company's growth and remain core to all new developments.
There has been thorough research regarding streamlining the modelling process for pipework from point cloud data, which can there later be used in a system such as Autodesk's Plant 3D (P3D), which can then later be used for a range of client output requirements. Now A3D use tools which are pre-built into P3D, they are simple to use but is also completely manual and slow. Edgewise Plant was a system built by an American company, which A3D had development input with, unfortunately it was developed as an external package, which meant the conversion back into P3D was limited and caused issues, issues which took time to fix. The third system was a German package called Kubit, which was later bought by Faro as part of their "as-built" site, A3D had training and gave direct input too Kubit regarding issues, this was largely a manual process and though it was built inside the P3D software it was actually being modelled in their Plant Piping format, which then later had to be constrained and exported, the constraining function had big issues!

1.3.3 NDT Inspection Packs

Website: https://lasersurveying.com/api570-ndt-inspections-drawings/
Simple Terminology: Process sites need to have there on site pipework tested to determine its thickness overtime, the technology they use is Non-Destructive Testing (NDT) but to be able to do this they first need inspection drawings known as piping isometrics, these are a linked output from our 3D process models.
Detailed Terminology: From the huge amount of data captured by our 3D laser instruments, A3D have the range of processing software that allows us to quickly and accurately model out our 3D Plant Models. For processes A3D use Autodesk Plant 3D, which allows us to model out specific pipework from all recognised piping catalogues along with specialty specifications A3D download from suppliers. Once A3D have created your 3D model, we can automatically export a full range of piping isometrics, fully dimensioned with a full list of bill of materials as required.
Isometrics are all customised around our client's standards including drawing sizes and borders and can be tailored to align with NDT inspectors data entry fields.
Alternatively, A3D can offer piping orthographics, a 2D snapshot from the 3D model that holds more information including surrounding features to add clarity. The greatest benefit though, is that we can reduce to around 10-20% , the total number of piping isometrics required to cover any process.

1.3.4 Piping and Instrumentation Diagrams (P&ID's)

Website: https://lasersurveying.com/pids-drawings/
Simple Terminology: P&ID's are classed as the bible document of any process site, if they get a visit from HSE or the Environment Agency, this would be the first piece of compliance documentation they would want to see. Most sites will have them but can't vouch for their accuracy. The P&IDs are a 2D schematic layout of the sites pipework and safety systems, so if there is an accident HSE can review these and determine the root cause of the event.
Detailed Terminology: Process and Instrumentation Drawings (P&ID's) are considered fundamental for companies running process systems. P&IDs play a significant role in the maintenance and modification of the process that it describes and should be maintained to reflect an up to date status. These drawings are critical in demonstrating the physical sequence of equipment and systems, as well as how these systems connect. During design, the P&ID provides a basis for the development of control systems allowing safety and operational investigations including a hazard and operability study commonly known as a HAZOP.

1.4 A3D Premises

Website: https://aru.ac.uk/arise
A3D currently only operate in a single office location, which is situated in Chelmsford, Essex, UK, in the Arise Building which is situated on the Anglian Ruskin University (ARU) Campus. The offices are specifically designed for young business operating either in the medical or advanced engineering industry. The benefits of this office are that the internal networking (commercially) opportunities, its location being close to a train station and a city town and that all the IT networking is setup by the building.

2.0 Understanding Laser Scanning Data

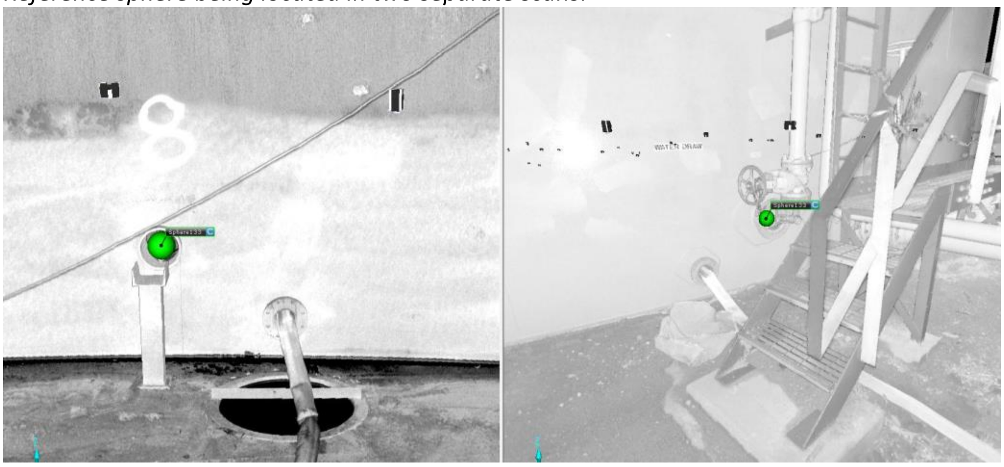
How Laser Scanning Works: https://www.youtube.com/watch?v=iHUJe2VfnMU

2.1 Laser Scanning Process

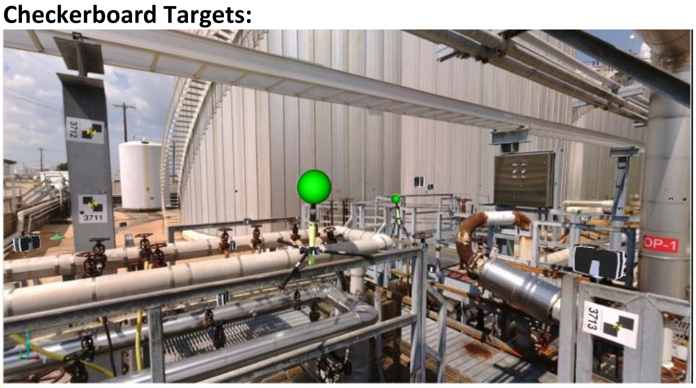
Laser scanning typically goes through two phases, the first phase of producing point cloud data and the second phase of producing hi-res photos, the scanner has built in sensors giving the scan files meta data such as inclinometer, altimeter, GPS and compass. A3D typically use long range scanners (LR) which have multiple variants from different manufacturers, each one has a benefit over the other, some scan faster, some have greater accuracy and some have better built in functionality such auto registration. You can also have short range (SR) laser scanners, which are designed for sub millimetre accuracy that can be used to measure corrosion on materials or reverse engineer components.
When scanning you have two settings before starting:
Resolution which determines the amount of points you want the scanner to fire out, this does not necessarily determine that they all return due to range and environmental factors.
Quality which determines the strength of the laser beam, the longer the beam the more likely the beam wont record dust n the air of refract from an acute subject.

2.2 Scan Targets

Reference Spheres:
Reference sphere being located in two separate scans:

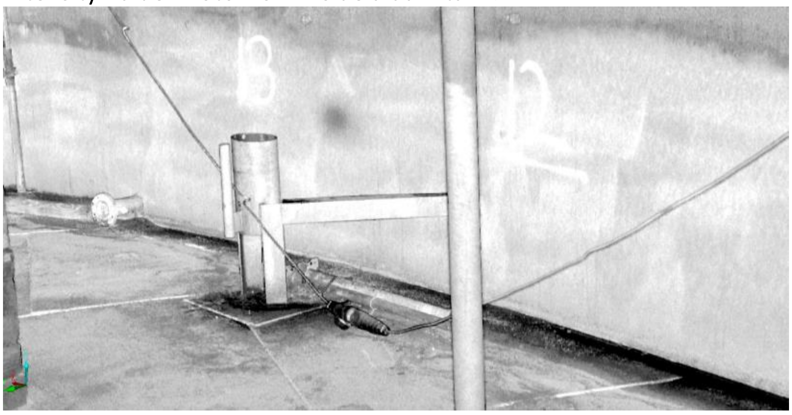


Checkerboard Targets:

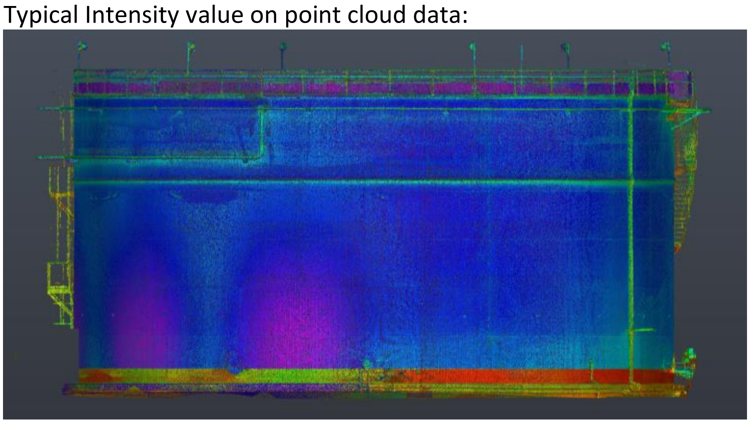


2.3 About Point Cloud Data

Example of Point Cloud Data: *https://youtu.be/6TAQR_w2eLs*
When a laser scanner is going through its first phase of producing point cloud data, its fires a pulse based laser 360 degrees of itself and each point that hits its subjects returns an:
X,Y & Z co-ordinate which gives it its 3D value in space, this can be as accurate as +/-1mm for a LR scanner.
Normal value which determines which way the point is facing in relation to the laser scanner, this is important as when use automatic feature extraction as the software needs to know if the cylinder is inside or outside. This also is difficult to reconstruct, if the value is missing because of conversion of point cloud data.
Intensity value, which gives the point a basic grey or colour scale value, the benefit of this is that the scanner is able to produce B&W photos with out using a camera functionality, the huge benefit of this is that it doesn't require light, so you would be able to scan in pitch black.
Intensity Value Photo from inside a dark tank:



Typical Intensity value on point cloud data:



RGB, which stands for Red Green and Blue can not be recorded from point cloud scanning, to be able to colourise scan data you need to record photos whilst scanning and the registration software aligns the photos with the point cloud and copies the RGB value across.

2.3.1 Point Cloud Formats

FLS - A lot of the laser scanning we undertake internally is done using a FARO Focus because it's a good middle of the standard piece of kit, its accurate enough for what we require but is also fast and reliable; a FARO Focus' native format is .FLS.
https://knowledge.faro.com/Software/FARO_SCENE/SCENE/SDK_File_Download_and_Installation_for_SCENE
E57 – This is a widely known point cloud format for most scanning software, the only issue with this format is that it cant hold the photo image.

http://www.libe57.org/
PTS –
PTX -

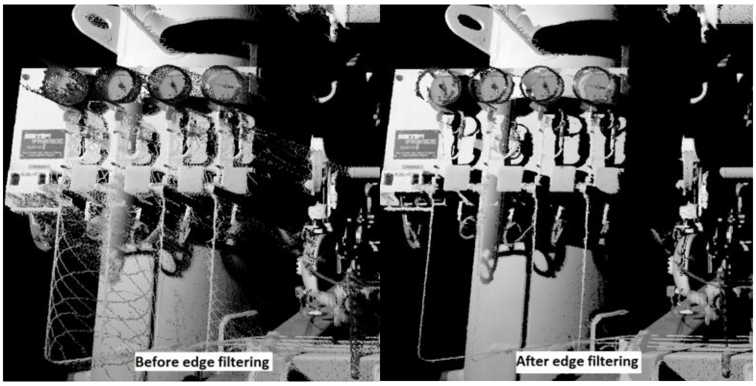
2.3.2 Point Cloud registering

Example Video: https://youtu.be/cOXAWWk4H1Y
LinkedIn Article: https://www.linkedin.com/pulse/planning-large-scan-projects-lewis-boxer/
When laser scanning the scan data gets recorded on to a standard SD card (for a FARO Focus), which gets plugged into a laptop and the data dragged over into the FARO Scene software where we register the scans together.
Registering scans is the process of joining the scans together to build a unified point cloud of an area, think of it like building a jigsaw puzzle. There are typically two processes of doing this and there is multiple applications that can achieve this, either by using reference targets such as spheres and checkerboards or by using cloud2cloud systems, which uses the actual point cloud data to match it against other data sets.
Reference Spheres:


2.3.3 Point Cloud Filtering

When registering point cloud data we typically run a range of filter on the point cloud data to help clean up certain aspects of unstructured data:
Stray Point Filter – This picks up on points which have ever reflected of a shinny surface and have disappeared in space or they have hit water and have made a mess.

Edge Filter – This cleans up stray points on edges of a subject, you find this when the scanner has been at an acute angle of the subject or the subject is small causing a refracting affect:



Uniform Filter – Also called sub sampling, which basically aligns point cloud data onto a grid and deletes neighbouring points, it's a great way of minimising the file size, we do this is post processing.
Range Filter – We stated earlier that a laser scanner can have an accuracy of +/-1mm this is true at a set range and environmental conditions. So because of the accuracy we typically filter out points from point cloud data over 30 meters.

2.4 A3D Workflow

3.0 Understanding Plant Modelling

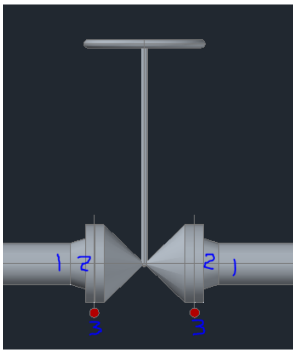
3.1 About Autodesk Plant 3D

Website: https://www.autodesk.co.uk/products/autocad/included-toolsets/autocad-plant-3d
All of our process pipework modelling is completed in a software package called Autodesk AutoCAD using one of there available toolsets called Plant 3D, which is designed specifically for process industry pipework. The software is intended for new builds, but can be used to model existing sites for as-built documentation.
Plant 3D doesn't work in the same way as you would typically use AutoCAD, with standard AutoCAD you do your 2D or 3D drafting, and all the data gets saved on .DWG file. But with Plant 3D there is a project folder, which holds specs, catalogues, database files, symbology files, templates files and a built-in filing structure.

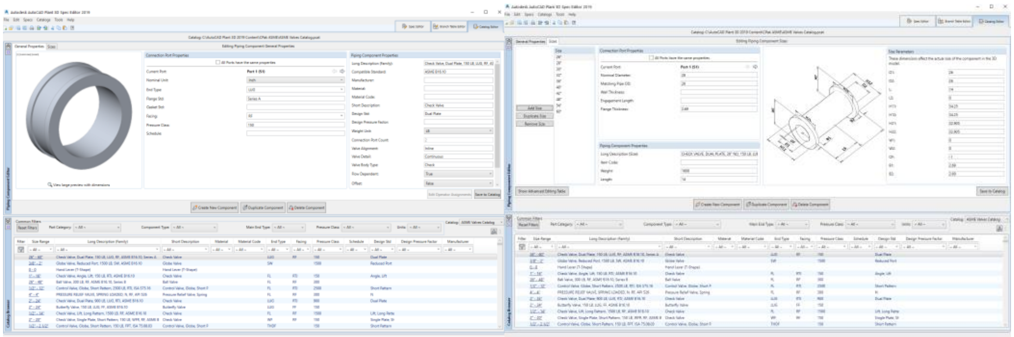
3.2 About Specs and Catalogues

All pipework modeling done inside of Plant 3D is modelled with a list of properties, so we are not just modelling a cylinder we are modelling a 6" NB (Nominal Bore) – 150LB – Carbon Steel – Schedule 40 Pipe, as well as this we are able to tag the pipe with a line number set by the customer.
These properties are also relevant for components which can be added to a pipeline, this means when I add a valve to a pipe, it will auto adopt that pipes properties such as NB Size and Material. Depending on the component type will depend on its end type that corresponds to how it joins to a pipe for instance it could be flanges, welded, screwed, glued or compression fitted.
If a flanged Valve is added to a line a multitude of things happen:

- The spec of the line checks its compatible with the valves spec
- The pipe gets broken and the valve is added
- Two flanges are added either side of the valve
- Between each flange and the valve a gasket is added
- Between each flange and the pipe a weld is added



Plant 3D uses specs and catalogues to allow the modeler to have access to pipework, components, equipment and connection standards.
Spec – A project has multiple specs, each one has a specific pressure class and material, inside of the spec will be a list of pipework sizes (NB), elbows, tees, valves and other available components. Each component is broken down into a sub set of NB sizes. So if we had a gate Valve in the spec, it would have a subset of sizes 1", 2", 3" 4"….
Catalogue – The catalogue is what allows the project administrator to build specs and update old specs with new sizes or components. This will allow us to add a full list of critical dimensional data about each component and its relative size.
Being able to add a valve to a line is only possible though if firstly its available in the projects spec file, the spec file is the components the modeler has available, the spec has the correct end types available, the reason for all this is for new builds to set a standard in how they want the site built.



3.3 Piping Isometrics & PCF files

The properties and specs we build into each model are used to build 2D Isometrics, these isometric drawings hold full dimensional data, weld points, valves details allowing a fabricator to build the pipe. These isometrics can also be used for inspection purposes allowing the non destructive tester (NDT) to record there reading on to the drawings, this is a popular output with our customers.

These are not technically produced directly from the model as the function, it produces a PCF file that contains co-ordinates of each components port, details about each component and their properties. Its this PCF file that is used to create the piping isometrics.
Plant 3d has a PCF file importer which is what external point cloud pipework modeling systems use to export their models into a PCF file, which is then re-translated back into a model inside of Plant 3D.

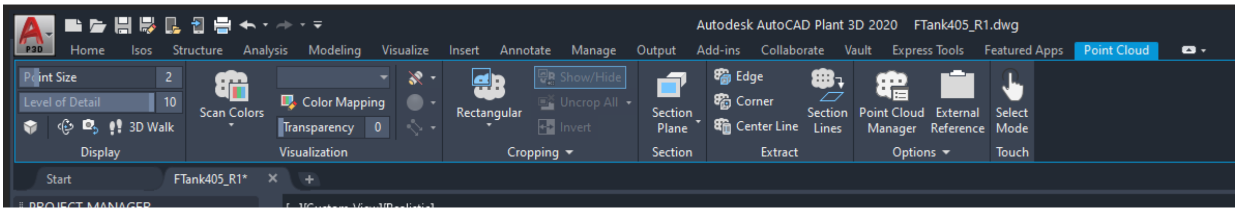
```
PIPE
    END-POINT        -3651.0345    2687.4847    871.6138    100.0000
    END-POINT        -3651.0345    3785.1549    871.6138    100.0000
    ITEM-CODE  CS300-1001
    ITEM-DESCRIPTION  PIPE, SEAMLESS, PE, ASME B36.10, ASTM A106 Gr B SMLS, Sch 40
    FABRICATION-ITEM
    PIPING-SPEC  CS300
    TRACING-SPEC
    COMPONENT-ATTRIBUTE1   BOMCOLUMN_Material_CS
    COMPONENT-ATTRIBUTE2   BOMCOLUMN_SCHClass_40
WELD
    END-POINT        -3651.0345    2687.4847    871.6138    0.0000
    END-POINT        -3651.0345    2687.4847    871.6138    0.0000
    SKEY  WW
    FABRICATION-ITEM
    PIPING-SPEC  CS300
    TRACING-SPEC
    COMPONENT-ATTRIBUTE1   BOMCOLUMN_Material_
    COMPONENT-ATTRIBUTE2   BOMCOLUMN_SCHClass_
ELBOW
    END-POINT        -3543.2714    2535.0847    763.8507    100.0000  BW
    END-POINT        -3651.0345    2687.4847    871.6138    100.0000  BW
    CENTRE-POINT     -3651.0345    2535.0847    871.6138
    SKEY  ELBW
    ITEM-CODE  CS300-280
    ITEM-DESCRIPTION  ELL 90 LR, BW, ASME B16.9, ASTM A234 Gr WPB SMLS, Sch 40
    FABRICATION-ITEM
    ANGLE   9000
    PIPING-SPEC  CS300
    TRACING-SPEC
    COMPONENT-ATTRIBUTE1   BOMCOLUMN_Material_CS
    COMPONENT-ATTRIBUTE2   BOMCOLUMN_SCHClass_40
```

PCF Example File: http://cloud.lasersurveying.com/Downloads/SampleIsoPreview.pcf

There is a document that has a breakdown of how PCF files are structured:
http://ftp.cloud.lasersurveying.com/Downloads/PCFReferenceGuide2016.pdf

3.3 Using Point Cloud Data in Plant 3D

Recap Website: https://www.autodesk.co.uk/products/recap/overview
Before being able to use point cloud data in Plant 3D, it needs to be converted into the Autodesk format, this is done using their application Autodesk Recap. So once the scan data has been registered its exported and imported into Recap, once finished it produces an .RCP file and a support folder which holds an .RCS file per scan.
Once it has been converted in Recap, the user is able to crop the point cloud data down into a manageable size to help allow Plant 3D to handle it. Some sites can be as large as 8TB in full point cloud size, so trimming it down into manageable chunks is necessary.
Once we have the point cloud data inside of Plant 3D, we have a range of tools to be able to manipulate it:



Point Size – Allows us to change the pixel size of the loaded points, this is useful to help us visualize point cloud
Level of Detail – This does a live subsample, releasing stress on the GPU
Scan Colors – Allowing us to change how the point cloud colors itself, this is a visual benefit for the operator
Cropping – A range of cropping tools to allow the operator to focus on a small area
Section Plane – Allows a cut to be done through the point cloud data, useful for buildings
Edge Extract – Detects edges in point cloud data like a curb
Corner Extract – Detects a corner from multiple edge in point cloud data
Center Lines – This is the main tool all our modelers use, this allows the user to hover his mouse pointer over a point cloud pipe and it will autodetect and put in a center line, once the user has that he is able to use the Plant 3D command to convert the line into a plant 3d pipe, not a cylinder.

3.4 Current Automation Systems

There are currently only a handful of different systems designed to either semi-automate or provide useful tools to allow you to model pipework accurately. A few of the systems are able to auto-identify or follow pipelines but none of them can auto identify / find components such as valves.

3.4.1 FARO As-Built (Formally Kubit)

YouTube Walkthrough: [*https://www.youtube.com/watch?v=iGXyoolnUAs*](https://www.youtube.com/watch?v=iGXyoolnUAs)
This system is a plugin for Plant 3D, it was originally owned by a German company called Kubit, it was deigned to allow you to click on two areas of a pipe and it would auto identify the pipe and would start to extend the pipe forward, if the pipe came up to something it would try to identify the component, if the point cloud data had an empty spot it would jump/extend a further meter and if it still didn't come across more point cloud data matching the original diameter it would stop.
One of the things to understand with Kubit is that the pipework it models from the point cloud, isn't Plant 3D pipework, but its own version, which later has to be converted with its built-in functionality. The reason for this is because Plant 3D is known to only give a small window of functionality to people doing plugins.
Benefits: The walk the run command worked well and allowed you to focus on modelling a line at a time
Dis-Advantages: Because its running in Plant 3D, its not very stable, mostly because of Plant 3D and can be slow

3.4.2 Clearedge Edgewise Plant

YouTube Walkthrough: [*https://www.youtube.com/watch?v=ma4IyaWR4ko*](https://www.youtube.com/watch?v=ma4IyaWR4ko)
White Paper on the Edgewise Functionality: https://ftp.cloud.lasersurveying.com/Downloads/EG-ICE2018_012_final_v43.pdf
This is an external standalone system, developed by a company called Edgewise who also produce a couple of other applications designed around the building industry. There system requires the point cloud data to be imported into their system which converts it into their own, un-reusable, point cloud format. During the point cloud conversion, it also does auto detection of cylinders, not pipework, once its finished the user is presented with a 3D GUI, where he can go through and delete out false positives such as hand rails, corrugated roofs and even curved curbs. You then run an elbow dete3ction algorithm which look for two pipes that are open ended near each other and have an angle difference of either 90 or 45 degrees with about a 10 degree tolerance. Any pipework missed can be added with a simple click of a few button and once you are happy with all this you run another command to convert the cylinders into pipework, what this means is that if a pipework is 23mm in diameter it will auto convert it to 1" and from here you can set its spec.
Benefits: Fast and semi-automated
Dis-Advantages: Everything was given a single spec, when importing back into Plant 3D it left a lot of drips and modellers were left with thousands of pipes to go through and fix / delete false positives

3.4.3 Leica Cyclone CloudWorx

I have no experience with this.

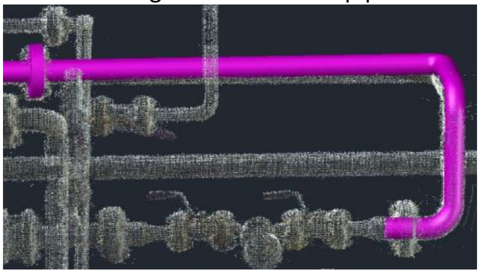
3.5 Internal Training

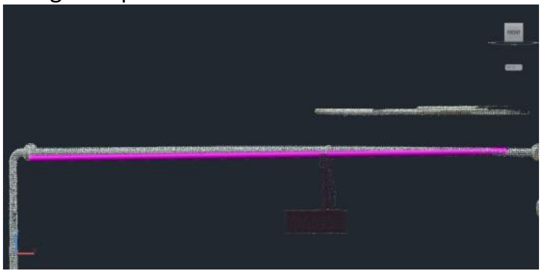
A3D was aware that there was always a possibility we would need to upscale internally very quickly, but finding people with Plant 3D experience is pretty non-existent unless we were prepared to spend big money on piping designers, so as a company we have taken on individuals from outside the industry and trained them internally, there is external courses available but these are firstly expensive, not local and are too open, where we only need our operators to know specific functions. So we internally built hundreds of training videos for every aspect of our business services and loaded them into our internal intranet system, this would mean we can bring people in from outside the industry set them up with a machine, software and access to the intranet and within 4-5 days they were trained and ready to work on live client data, this workflow has been tried and tested, with great results and also means there is minimal disruption to the rest of the team.

Intranet Access: http://cloud.lasersurveying.com/INTRANET/
!!! PLEASE BEAWARE THIS LINK IS COMPLETELY CONFIDENTIAL !!!

3.6 Green vs Brown Field Modelling

We scan and model brownfield sites, which means we are scanning sites that are already there and built, a green field site refers to a brand new site, which isn't built yet, but is being designed. But you can model a brownfield site as either a brownfield or a greenfield model, by this we mean if we model it as brownfield we will try to model every sag / movement in the pipe; but if we model it in green field we take an average and model the pipework as straight as possible.





We only model a site as brownfield if we want to stay as accurate as possible to what the site truly is for design purposes, the issue with this is that we have to put in multiple weld lines, as each weld line gives us about 3 degrees bend, but because of this it affects the isometrics as they try to take into account each weld.
So we typically model most sites as greenfield, it simplifies the model, produces good isometrics and simpler .PCF files, and they still keep an accurate representation of the site.

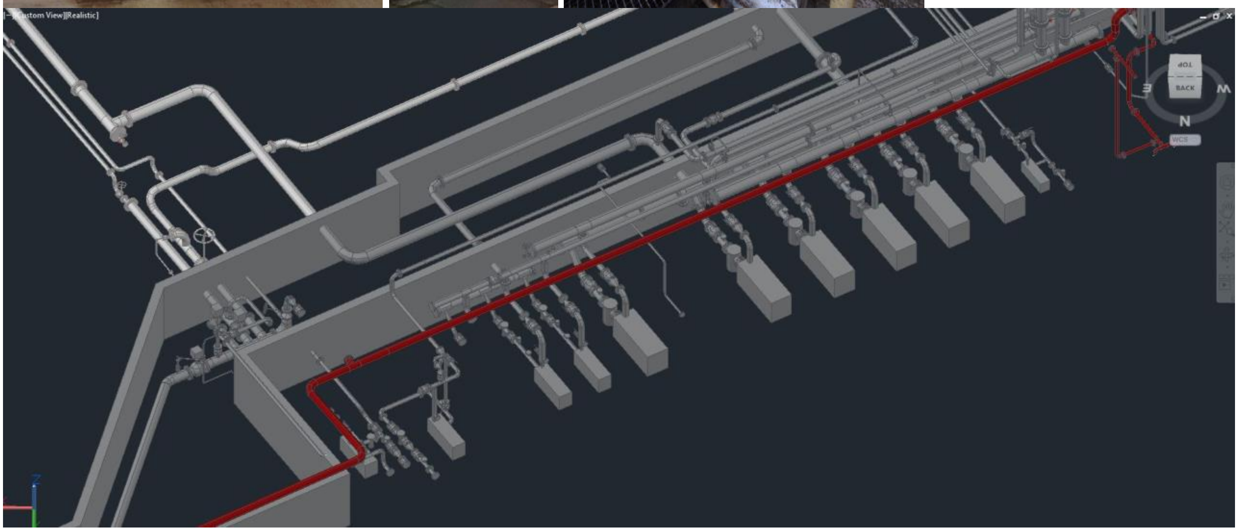
4.0 Understanding Site Components

4.1 Major Equipment

At the moment we have no intention in trying to auto identify any major pieces of equipment, as this is a simple task already, also the equipment models are there for visual purposes only, are clients are interested in the pipework and there components. A lot of our internal services have documented and have video procedures, I will have a link against each equipment type.

Pumps - https://www.youtube.com/watch?v=foe_GP4E5Jw&feature=emb_logo
Below are some photos of a few different type of pumps we come across, when it comes to modelling these we don't typically model in detail, but just model as a simple cube/block, this is to simplify the model size and to make it easier to model.



Tanks - https://youtu.be/E2HAylKf3as & https://youtu.be/ldKcBB5xVNU
Typical Oil & Gas storage tanks are just big cylinders, so we decided to model them as such, you will see in the videos above that we take a slice of the point cloud data to give us the external diameter of tank and then we take a vertical cut to give us the height of the tank, this gives us enough detail.

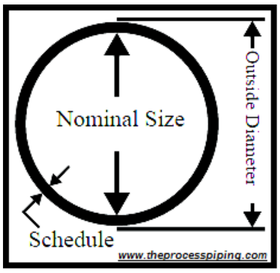


Heat Exchangers

We don’t come across a lot of these as a lot of our client sites hold finished product, which doesn’t require heating or cooling, the only exception is for some site which hold bitumen.

4.2 Pipework

A quick intro to pipework, the outer pipework diameter is called the OD (Outer Diameter), the inner diameter is called the NB (Nominal Diameter) and lastly the pipes wall thickness is called the schedule.

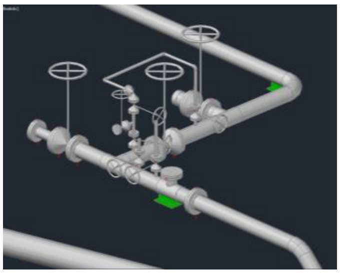


Non-Insulated Pipework –

Insulated Pipework – This can cause issues when modelling because its difficult for the modeler to know what the pipe size is behind the insulation, not just that but also the components inside the insulation like valves.

Elbow Identification – This would again run like Clearedge, in the sense we would try to find pipework that had a neighboring pipe which was within 45 or 90 degrees of its counterpart, it would then check to see if that cylinder was roughly the same diameter, if it was it can connect it with an elbow, the elbow dimensions will be taken from the imported Component Dimensions.CSV file.





90 degree Elbow *45 degree Elbow*

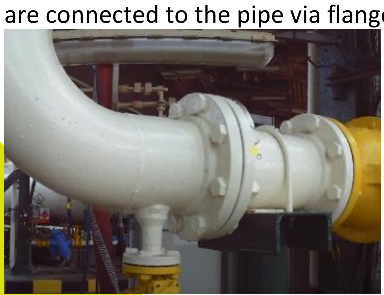
Tee Identification – This would look for pipelines (Branches) that look like they are going to intersect another pipe (header), unlike elbows these can fluctuate in size, you can get equal tees which both the header and branch are the same diameter pipes or reducing tees, where the header will always be larger and the branches smaller, these dimensions will be taken from the imported Component Dimensions.CSV file.


Equal Tee *Reducing Tee*

Reducers – Designed to reduce the nominal bore of the pipe, which in turn reduces the pressure and flow rate, they typically come in eccentric and concentric designs.


Eccentric *Concentric*

Flanges & Gaskets - https://youtu.be/7DRjQi2oS5Y
Typically we see either Slip On Flanges or Weld Neck Flanges, but for all flanges between the two flanges there is a gasket, which is why you see a gap. Most components that are 2" in diameter size like valves are connected to the pipe via flanges.

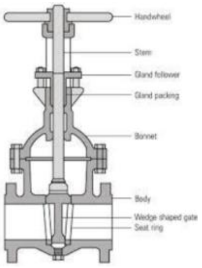



4.3 Valve Body Types

Ball Valves - https://youtu.be/BD73k5TPiK8

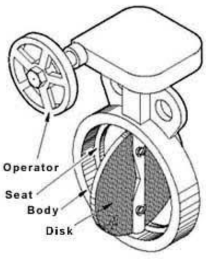

Gate Valves - https://youtu.be/hU3sQUs23pk



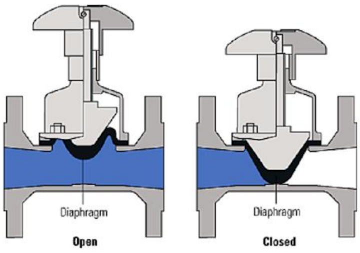


Butterfly Valves - https://youtu.be/TnBhAx3zcHA

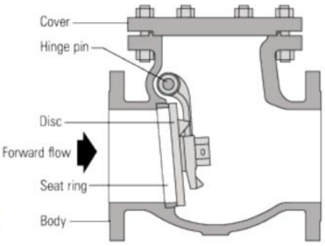




Diaphragm Valves

Check Valves – https://youtu.be/tXYD8z-sMDg

Pressure Relief Valves (Angled and Inline) - https://youtu.be/pMPrTtxMWVA



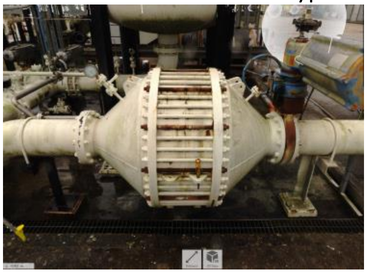
4.4 Other Components

Pipe Supports
Required to allow pipework to be kept straight and for thermal expansion to allow the pipe to move in the direction designed, pipework is designed to allow for movement but that movement is controlled by pipe supports to move in specific locations.

Strainers
Usually found on the output line of a pump, to catch any rust / debris before the finished product is pumped into a road tanker.


Instrumentation

Blast & Flame Arrestors
Used to dampen any fire or blasts the internal structure typically melts causing the fire to be exhausted.

4.5 Component Dimensions and Characteristics

The images and videos in this section were to give some clarity and understanding on the typical types of piping components found, but one of the issues we have if want to try and auto identify these from point cloud data is that there are multiple manufacturers of these components, which makes there body characteristics varied. Some components such as some valves have typical dimensions, this data can be extracted from the Autodesk Plant 3D Spec editor system.

5.0 Requirements

This section is to briefly talk about the requirements and hopes from Business Owners, Stake Holders and Clients, but this will not talk about the system specific functionality. This will only be based on knowing the system can Auto model from point cloud data.

5.1 Business Owners

The A3D business owners are looking for a unique product to market and rent out, being cost effective enough that we could sell our services cheaper than we have done before, to make it feasible for clients to warrant having their sites re-scanned periodically to keep asset / compliance documentation updated and allowing our business revenue to show repeat constant work.
I think it's important for the company to have a clean source of analytical data to help market the system with true to life metrics for use in infographics.

5.2 Stake Holders

Our stake holders, Vopak, are investing heavily in companies to help them produce "Digital Twins" of all their 60+ terminals, this is to push their business processes completely digital, by collating data to produce big data sources, to help them push this data towards predictive and preventative maintenance. They are already looking at using 3D models as a 3D graphical user interface to allow them to find asset information quickly and accurately.
By using this automated modelling system, it would help keep their terminal documentation up to data, to allow their terminal staff to have better faith in the models and eventually help sell this technology to other oil and gas companies.

5.3 Customers

Our customers want to start unifying their data, making it easier to keep as-built documentation up to data and have a system in place, which doesn't warrant having it priced matched, especially if the system is unique enough that it can't be price matched. Also, if the models are accurate and up to data any design changes can be undertaken in house or at least the prices brought down by EPC contractors because they are using pre-built data.

6.0 System Breakdown

6.1 Basic Introduction about the system

We are looking to have our pipework and piping component modelling workflow automated as much as physically possible, we are looking for something that can work with point cloud data and convert that into a Plant 3D process model.

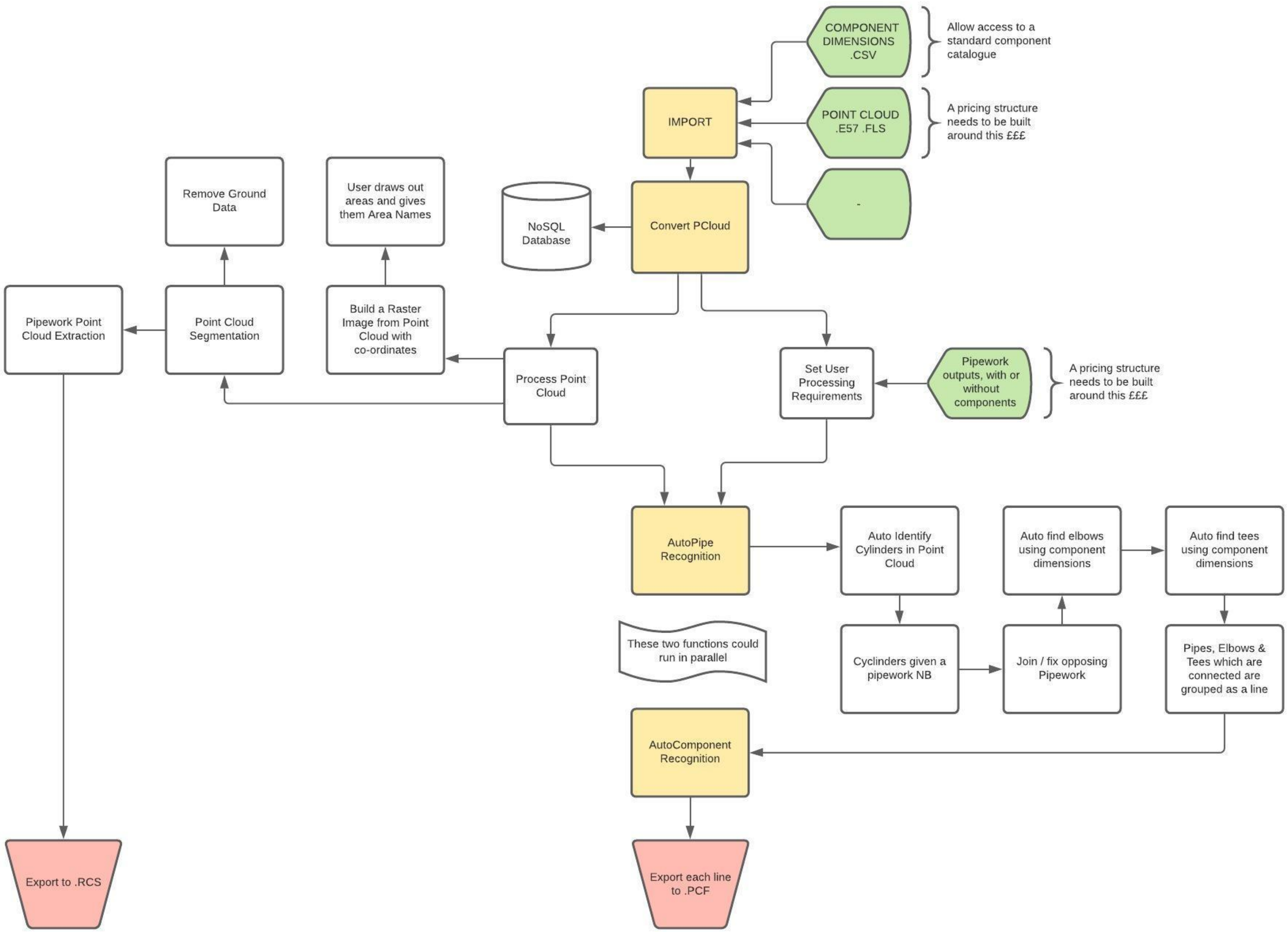
6.2 Options

Our options are to either build the system as an internal plugin for Autodesk Plant 3D or as an external system:
Internal – The system will be a plug in for Autodesk Plant 3D, my concerns about doing this is that the system is already a little bit un-stable, I eventually want to upscale our application to run in the cloud, also apparently Autodesk only give a limited window of functionality to their system.

External – The system will be completely independent to Autodesk Plant 3D, this will allow us to have full control over the system, it would mean we need to look into bringing the file back into Plant 3D via a .PCF file, but this is not too much of an issue, as firstly the .PCF file is a pretty standard file and could be used in other systems such as Aveva PDMS, CloudWorx and Solidworks.

There is a document that has a breakdown of how PCF files are structured:
http://ftp.cloud.lasersurveying.com/Downloads/PCFReferenceGuide2016.pdf

6.3 System Breakdown



6.3.1 Interface

The system will eventually be setup to be accessible by the outside world, allowing users to be able to upload their own point cloud data, select the area of point cloud data they want to process, set output requirements and manage their data.
The system will need to be completely cloud based, allowing us to upscale hardware requirements as we see fit, which possibly could give the function for users to upgrade their processing, so it happens quicker! Also, by having it cloud based it allows users to access the system without the need for any pre-installed software.
Eventually I would like a UX designer to go through the interface to have it be as user friendly, accessible system as possible. There is always the possibility of systems being replicated buy other companies, so I would like it to be seen as a well-oiled and professional looking system, which users couldn't justify rebuilding.

6.3.2 Import

The system will need to be able to import point cloud data sets such as .FLS and .E57, I think having that data converted into our own database system would be ideal as this would give us greater control over the data. The upload and storage of this data needs to be secure and the connection needs to be stable, to allow the upload to be tracked, as the chances are this will be done overnight so clients don't waste bandwidth during office working hours.
This is a big processing cost, which obviously will be given to the client, but it's a chicken and egg situation, as we need them to upload the data first for us to understand how much data they are uploading first to gauge a cost.
We also need to think about the idea of importing our own component dimensions, so when the system finds pipes and elbows it can match the dimensions. We can export these dimensions from Plant 3D Spec Editor as a csv file, but we should also have a pre-built component sheet, for customers to use. This needs to be thought about as the CSV needs to be a standardized layout, to allow our system to be able to understand the data layout it stores, as we can't assume it's going to be uploaded from Plant 3D.

6.3.3 Convert Point Cloud

People will be looking to import entire sites of point cloud data into the system, this means we could be looking at data sets as large as 2 -3 TB, Non SQL databases are designed for working with large datasets.

6.3.4 Initial Point Cloud Processing

With our uploaded and converted point cloud data, we need to produce a Birdseye, orthographic raster image of the pcloud (6.3.4.1) and to do some point cloud segmentation (6.3.4.2).

6.3.4.1 Raster Image

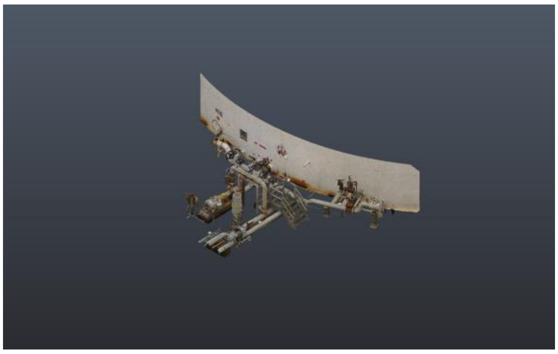
I want the user to have the ability to segment the point cloud data into logical areas, as they may want to upload a whole sites worth of data but they may only want to AutoPipe (6.3.6) certain sections for multiple reason:

- The eventual outputted .PCF files which will get exported may want to be separated by logical on site areas, this is equally important for when the .PCF file gets converted into a 3D model, because if you try to convert the .PCF files for a whole site you system will crash due to the huge amount of 3D data its trying to render.
- Or it might be because the client only wants the data for one area.

6.3.4.2 Ground Point Cloud Segmentation

By design 3D laser scanners record everything 360degress of itself, there is a lot of data collected from the ground, which adds zero value when modelling but adds a lot of un-necessary storage requirements, example:

Untrimmed Data 206mb



Trimmed Data 88mb

By removing just the ground we can drastically reduce the size of the point cloud data, this will firstly be super useful for a modeler to be able to work with because of the reduction in size so it will be a lot more resource friendly and it will make it easier for them to focus on just the pipework.

6.3.4.3 Pipework Point Cloud Segmentation

A future option could be to use the found cylinders from the AutoPipe system to be used as a clipping box to remove anything a meter diameter from the pipes and download that data so it could be used directly inside of AutoCAD as an .RCP or .RCS file.

6.3.5 User Requirement Screen

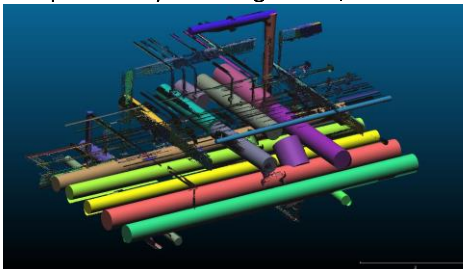
Unknown user input parameters

6.3.6 AutoPipe Recognition

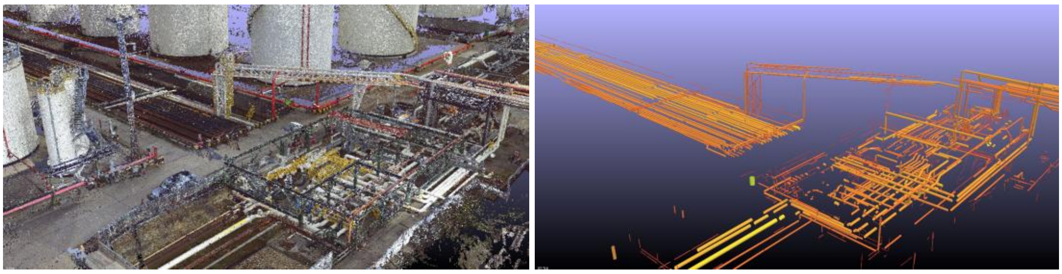
This is function is to auto identify cylinders within point cloud data, clean out false positives, convert the cylinders into pipework and add in elbows and tees.

6.3.6.1 Cylinder Identification

The ability to be able to auto identify cylinders within point cloud data, this is nothing too unique and has been tested on oil and gas data sets before because of the pipework. I believe the system could achieve this is two ways, by either using 3D cylinder models with object recognition or using a complicated cylinder algorithm, like found here.



Cylinders found in Cloud Compare using RANSAC

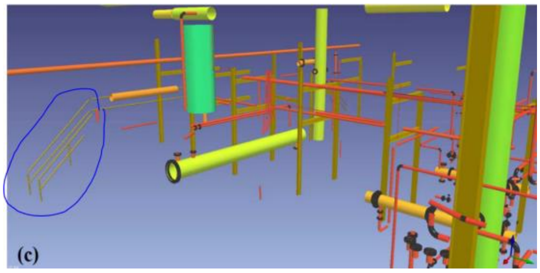


Clearedge Point Cloud to Cylinders

6.3.6.2 Cylinder Cleanup & Manual Identifying

One of the things we noticed when using Clearedge's Edgewise Plant was the huge amount of false positives found when looking for pipework, because we are looking for cylinders at this stage, there is a huge amount of other cylinders that are found on site, such as corrugated roofs, hand rails, curbs corners, lamp posts, sign posts and the list goes on.
One of the parameters, which could be set at the beginning is a max and minimum pipework size, because if people only want pipework from 2"onwards you will remove a lot of false positives below that size.

Cylinders found in corrugated roof



Found Hand Rails

As well as some automated functionality, we will need to look into the possibility to have some manual interaction with the model, to allow the user to select and delete out what is not required; can we use this manual interaction to be training material for the system to develop?
As well as removing false positives we need to think about the manual interaction of allowing the user to add in missing pipework and/or link pipe runs.

6.3.6.3 Cylinders Converted to Pipework

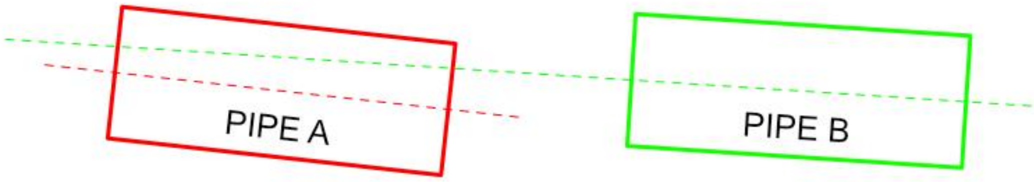
Up to this point we have only found cylinders within the point cloud data and we need to convert the cylinder dimensions, specifically its diameter into pipework standardized diameters, this can be done via a piping standards sheets upload or a standardized / default document we have uploaded. These dimensions can vary depending on pressure, class, material, and insulation.
For Instance if we found a cylinder which was 98mm in diameter, we would classify that as a 4" pipe.

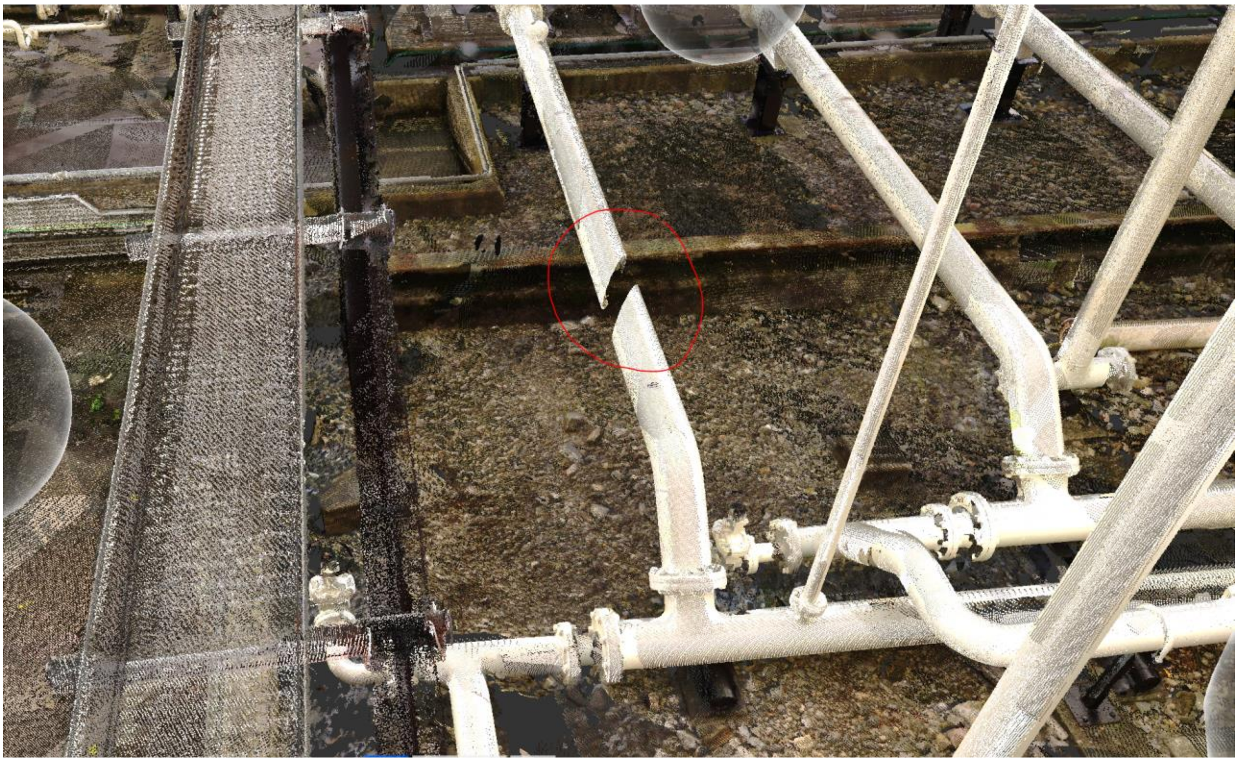
If insulation is present on a pipeline we need to think of a way of allowing the user to give a piping diameter offset to take into account the insulation thickness.
For instance if you had a 6" NB Pipe with 50mm of insulation that pipework could be recognized as a 10" pipe.

6.3.6.4 Join Opposing Pipework

When laser scanning there is times in which data is missed because of steel work or pipework is obstructing the scanner, this is not an issue when modelling manually, but for AI it can cause issues because its assumes the pipe has ended, what the AutoPipe system needs to say is that once its found all the pipework is look in front of itself to see if there is any matching pipework, with the same diameter and join them.
My current question is what trajectory does the new pipe take?

- Start of Pipe B connects to End of Pipe A
- Or do we take an average of both

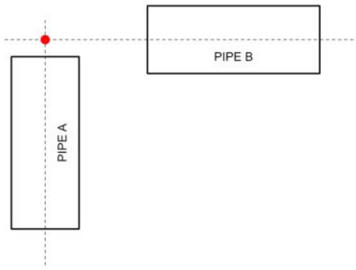


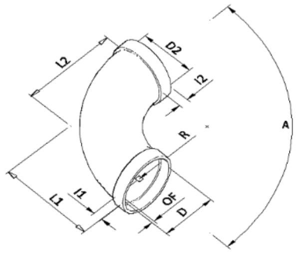


6.3.6.5 Elbow Identification

Once we have the pipework, we need to identify the piping elbows, which typically come in a 45 or 90 degree radius, I believe we need to work out if two pipes center lines intersect (example), if they intersect this intersection point becomes the center point of the elbow and from here using the dimensions from the component dmensions.csv file we can accurately add in the elbows. SO the rules would be:

- Do both pipes have the same diameter
- Are they 90 or 45 degrees from each other
    - (With a 5 degree tolerance)

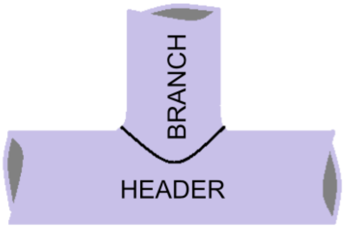




My first question is that these lines will not be exactly 90 or 45 degrees, so what happens?

6.3.6.6 Tee Identification

Looking for tees is going to be a similar approach too elbows, but will need to detect that the header pipe continues its trajectory past the branch not joins the branch like an elbow.



Similar to how we connected elbows, we are looking for are looking for the following rules:

- Is the branch within a 90 degree angle to the header
    - (With a 5 degree tolerance)
- Does the branch trajectory intersect with another pipe
- Is the header pipe equal or larger (diameter) than the branch

6.3.6.7 Pipework Grouping

We need to group pipes up with their connected elbows and tees, this will be the basis of how the individual PCF files are broken down. This will also give the user to option to batch change a whole groups NB size, also it could give us the function to change piping specs for specific lines.

6.3.6.8 Pipework Greenfield Aligning

Need a way of cleaning up the pipework and aligning everything as straight as possible, this is quite key for the PCF file, as once Autodesk Plant 3D or any system takes the PCF file and tries to convert it into a 3D model it will cause broken-connections, there is usually a tolerance factor of a couple of degrees this could be set by the user, the higher the tolerance the more accurate the model will be, but is more likely to disconnect on conversion. I think this will need testing, to understand the best fit.
Also need a checking system, which checks port co-ordinates because some ties matching ports have slightly different co-ordinates.

6.3.7 AutoComponent Recognition

Need to research this further

6.3.8 Export to PCF

The PCF files are only basic text files so are very small in size and so could be emailed to the user once the conversion is completed, but we can have the function to store these files in the cloud system also.

6.4 Error Handling

This will outline a couple possible errors I expect the system to have:

- Badly registered Point Cloud
- Unknown Components found

6.5 Unknowns

My current unknowns / questions I have:

- How much cloud processing would be required and the cost that's involved in it
- How much is required to keep the system running affectively
- How the AutoComponent recognition would work:
  - Using Object Recognition
  - Deep Learning

6.6 Concerns

- How to connect elbows to elbows, some connections do not have pipework in between them
- Connecting components between elbows or tees

6.7 Future Development

The Future development of the software and its avenues to grow.

- The ability to auto model other components such as:
  - Steel Work
  - Hand Rails
  - Ground Profiles
  - Concrete Plinths
  - Electrical Cabinets
- Build the system to learn from user's manual input

7.0 Marketing and Sales

7.1 Target Audience

End Users for Digital Twinning
EPC Companies for design work and Tie ins

7.2 Marketing Material

Including Analytical Data from System

7.2.1 Email Newsletters

7.2.2 Branding

Including Logo, Fonts and Color Palettes, Style Guide

7.2.3 Social Media Channels

Instagram, LinkedIn and Twitter

7.2.4 Website

Including keyword research & Optimization, AdWords, Blog Articles, Case Studies

7.2.5 Events

Conferences, Pitch Stories, Case Studies

7.3 Joint Ventures

Possibilities of linking our services with others

8.0 Document Notes / Additions

Notes for Tech Road Map Build

- **TRL Levels 1-9**
- **Cloud Compare ?**
- **Need to think about turning brownfield pipework into greenfield**