

FORTIS PRODUCTION LINE TRANSFER PROJECT

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ACMA6013 – Independent Project

Declaration of Authenticity

This thesis is the result of the author's original research. It has been composed by the author and has not been previously submitted for examination which has led to the award of this degree.

Signed: **B. Shears**

Date: **18/05/2023**

Renishaw's Confidentiality Policy

Renishaw plc have a strict company confidentiality policy to protect its products and processes from the public and potential market competitors. Some of the figures used in this report such as timings, costings and capacity capabilities etc. are not accurate as the University does not have a Non-Disclosure Agreement (NDA) with Renishaw. It is also due to the fact that all university dissertations become published online after completion.

Although the figures do not give an accurate representation of costings, for the educational purposes of this major project, they are more than sufficient to demonstrate a successful project execution.

Acknowledgment

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Abstract

This report consists of the planning, preparation and activities carried out to accommodate the transfer of Renishaw's FORTiS encoder production line from their New Mills site in Gloucester, England to their Miskin site in South Wales.

The project aim was to transfer a singular FORTiS production line down to Miskin without halting the production of FORTiS at New Mills. To accomplish this task, the duplication of production rigs was required which would result in both sites having the ability to run production in parallel. A partial transfer was selected as the best method due to the size of FORTiS and the workload involved. The main aims were to ensure minimal disruption to production at both sites, along with ensuring the transfer was carried out in a safe manner without risk of injury, risk to product quality, or damage to equipment or buildings.

Another goal to achieve while carrying out the transfer was to improve the process, therefore the below study began with an extensive literature review. This covered various pieces of literature related to production line transfers and process optimisation. From this research along with the skills acquired over the five years in the industry and involvement in local line moves, a thorough plan was developed to ensure that the transfer ran as smoothly and as efficiently as possible, while leaving an improved production line at Miskin post transfer. Methods such as value stream mapping and other six sigma tools were used to analyse key pieces of data on the existing FORTiS line at New Mills before planning an improved process which would be implemented at Renishaw's Miskin Site. The report encompasses a wide range of aspects including project planning, process optimisation, communication, transfer strategies, risk assessing and continuous improvement measures.

The project enhanced the products overall process flow and therefore reduced non-value added time from the process. This was achieved by creating a fully optimised layout within the allocated space assigned, reducing walking distances by around half the distance in comparison to the New Mills process. This optimisation saved labour time, therefore reducing customer lead times and the labour cost of assembling the product which had a positive impact on the cost of manufacturing the product.

To summarise, the project resulted in the successful transfer of the FORTiS production line without any significant problems or any damage/injuries arising. The project was successful due to the extensive preparation that went into planning each aspect of the transfer. Clear communication channels keeping the key stakeholders updated on progress also helped this transfer become a success.

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Glossary

Glossary in order of appearance:

Table 5a – Glossary

Acronym	Full Term	Further Description if Applicable
NDA	Non-Disclosure Agreement	Confidentiality policy.
WIP	Work in Progress	Mid production cycle.
CoQ	Cost of Quality	Cost incurred from poor quality products that do not meet quality standards and get scrapped from production.
R&D	Research & Development	
CNC	Computer Numerical Control	Automated control of machining tools.
CMM	Coordinate Measurement Machines	Renishaw metrology product.
HQ	Headquarters	
SAJ	System Assembly Jig	Production rig that is used to assemble FORTiS assemblies.
SAT	System Accuracy Test	Production rig that is used to test FORTiS assemblies and provide accuracy certificates.
DMAIC	Define, Measure, Analyse, Improve & Control	Six Sigma tool.
5S's	Sort, Set, Shine, Standardise & Sustain	Six Sigma tool.

PFMEA	Process Failure Mode Effects Analysis	Six Sigma tool to highlight potential process failures and put preventative measures in.
VSM	Value Stream Mapping	Six Sigma tool for reviewing value and non-value added time.
NVA	Non Value Added Time	Where labour is carried out, but no value is added to the product.
VA	Value Added Time	Where value is added to the product.
BOM	Bill Of Materials	Materials that go into a given assembly.
FIFO	First In First Out	Six Sigma tool.
2D	Two Dimensional	
IP	Ingress Protection	Liquid and dust/particulate resistance rating.
NPI	New Products Integration	Renishaw department where new products get introduced prior to mass manufacture.
CAD	Computer Aided Design	Computer modelling software.
ESD	Electrostatic discharge	
HGV	Heavy Goods Vehicle	
CEA	Capital Expenditure Authorisation	Renishaw purchasing system.

1.0 Introduction



1.1 Personnel Introduction

The role of a Process Improvement Technician within the encoders engineering team at Renishaw includes the following responsibilities:

- Ensuring a fully functioning production line is maintained by repairing jigs and equipment including automated machinery.
- Carrying out preventative maintenance and calibrations on production jigs and equipment.
- Performing process improvement activities and cost saving exercises to reduce the Cost of Quality (CoQ), improve product quality, process step locking and the overall process flow of production.

The long term goal is to obtain a degree in Mechanical and Manufacturing Engineering, which will aid in my ongoing development to become a Process Improvement Engineer. This will allow the concentration and resource to be focused on the design and process elements of the job which are of most interest and where it is believed the biggest positive impact on production can be made.

1.2 Company Introduction

Renishaw is a British company founded in 1973 by Sir David McMurtry & John Deer. It remains a large employer in the UK. Renishaw employs over 3,000 people across all the UK sites in a variety of roles such as Research and Development (R&D) as well as manufacturing.

Renishaw is a global, high precision, metrology, and healthcare technology company. Renishaw predominantly specialises in making a range of encoders for machine axis such as CNC's. Renishaw also manufacture Coordinate Measurement Machines (CMM) probes for measuring high precision parts within multiple sectors such as the automotive and aerospace industry. Renishaw have also recently started producing metal 3D printers that can print medical and dental parts to a high standard with great precision from materials such as Titanium, Cobalt Chrome, and Aluminium.

(Renishaw plc, 2022)

1.3 Site Introductions

Renishaw New Mills Site (HQ), Wotton Under Edge, Gloucestershire:



Figure 8a – Image of Renishaw’s New Mills Site - (Wotton Blues Festival, 2018)

Renishaw Miskin Site, Miskin, South Wales:

The section of the site highlighted in Red is the existing site that is currently occupied by production facilities. As shown in Figure 9b there are additional plans to expand the site to include additional halls, a distribution centre, office buildings and multiple car parks.



Figure 8b - Image of Renishaw’s Miskin Site - (Renishaw plc, 2022)

1.4 Project Introduction

The scope of the project is to plan and implement a successful transfer of the FORTiS encoders production line from Renishaw's 'New Mills' Gloucester site to the Miskin site in South Wales. The reason behind this is Renishaw's Miskin site is Renishaw's largest manufacturing site. Therefore, most of Renishaw's new products (such as FORTiS) are designed and developed within Renishaw's HQ at New Mills, before getting transferred across to its Miskin manufacturing site to allow the production lines to expand and reach the products capacity requirements. This is done when both the product/process is robust enough to handover for mass manufacturing. This project will involve organising the transfer of one FORTiS production line whilst utilising lean and six sigma tools such as value stream mapping to optimise the process flow of the new layout based at Miskin.

2.0 Project Aim

Due to the size of the equipment that is involved in assembling FORTiS products, the full transfer of all equipment plus duplicated equipment for long term capacity requirements is going to be split into multiple stages which are detailed below. Within this project the main focus will be stage 1 below:

Stage 1:

This projects aim is to transfer a singular FORTiS encoder production line to Renishaw's Miskin site from their New Mills site in Gloucester, by the 15th of May 2023. The production line will consist of one SAJ (system assembly jig) and one SAT (system accuracy test). To ensure the project is a success, jigs currently located at New Mills will need to be transferred to the Miskin site as well as some jigs requiring duplication.

Stage 2:

Stage 2 of the project will involve the transfer of two SAJ's and one SAT rig to Miskin which is planned to take place November 2023.

Stage 3:

Duplication of two additional SATs scheduled for build at Miskin in 2024/2025.

To ensure a successful project is achieved, a thorough transfer plan needs to be generated to ensure the move runs smoothly and goes according to plan, thus ensuring that the project aim is met within the given timescale and no mistakes or damage to equipment occurs. The transfer plan will have to be very detailed and clear as the move will be carried out by a team of people who won't all have been involved a great deal in all aspects of the transfer planning. Key stakeholders will also need to be in agreement with the proposed transfer plan.

3.0 Justification for Transfer

The reason for transferring the FORTiS production line to Renishaw's Miskin site is to allow the production line to expand before capacities are forecast to increase. The transfer allows FORTiS production capacities to increase by around 235%.

By transferring the production line to Miskin it allows for the process flow to be optimised as much as possible, whereas New Mills does not have the space to optimise further due to FORTiS currently being sat in the NPI building with new products and development work going on everywhere around it. This optimisation will also allow sufficient room for maintenance activities to be carried out on every rig with ease.

The transfer is mainly due to factory floor space and Renishaw's logistical setup. While Renishaw's 'New Mills' Gloucester site is large stretching across 26 acres. The Miskin South Wales site spans across an impressive 193 acres. That is why the majority of Renishaw's manufacturing is done at Miskin. Renishaw's New Mills site is also set up as a research and development (R&D) site, so therefore once a line has been developed past a certain point, it needs to move elsewhere to make room for new product development.

Along with the factory floor space, due to New Mills being very secluded in the countryside, they often struggle to find operators in the area to employ that are willing to travel for the offered salaries. Whereas Miskin on the other hand is in a much more built up area where operators won't have to travel as far to work. The fact that Miskin is just off the M4 is also another reason it makes sense to move the production line, as logistically it is much easier and lower risk to despatch products worldwide from its well-located plant with great transport links.

By transferring a production line, this also gives Renishaw's higher management and asset team the confidence in the process's robustness and ensures them that if anything were to happen to the line such as a fire etc. Renishaw would have sufficient knowledge in build and validation documentation to completely rebuild the process if required, as in years to come, all the Design/Process Engineers may not be in the company to assist.

4.0 Research

4.1 Literature Review

4.1.1 Six Sigma

What is Six Sigma?

Six Sigma is a process improvement technique. It is used to improve production process efficiencies and productivity, with the aim of reducing product defects down to 3.4 parts per million, therefore meaning 99.99966% of products are defect free. It does this by removing potential issues from the process to reduce the probability of an error occurring.

It is beneficial for any business process as it significantly improves the businesses efficiency and profits by identifying weaknesses in the process and targeting them.

The key to using Six Sigma correctly is applying the correct tools for the challenge, finding the root causes of product and equipment problems, then developing and testing the correct and necessary solutions.

(Pyzdek, 2019)

Where did Six Sigma originate and where is it used now?

The Six Sigma methodology was originated in the company Motorola in 1986 by the engineer Ben Smith. It was created for the use of utilising their factory floor space. It has since been applied to various applications in every type of industry. However, Toyota the well-known car manufacturer are the leaders in the field.

(Six Sigma US, 2017)



Figure 11a – Six Sigma Sign (T&E Inc, 2023)

Types of Six Sigma tools:

DMAIC – The DMAIC six sigma tool is one of the most used and probably one of the most effective tools depending on the situation at hand. DMAIC standing for: Define, Measure, Analyse, Improve, Control. Is a five step process that helps drive continuous improvement. The engineer must first define the problem at hand and measure the size of the impact the problem is having. They must then analyse the problem by looking at data such as downtime, efficiencies/throughput. After all the research and data has been gathered, it must then be devised into a solution to improve the process. Once the improvement has been made, a control measure must be put in place such as step lock or maintenance to ensure this improvement is maintained and followed at all times therefore preventing the issue reoccurring. The DMAIC loop then starts again.

(Pyzdek, 2019)



Figure 11b – DMAIC Diagram - (Pyzdek, 2019)

4.1.2 5S's

5S's is another technique used which comes under six sigma. The five S's stand for Sort, Set, Shine, Standardise and Sustain. This technique is used to manage and better organise tools and materials to reduce the waste produced by poor and cluttered workspaces.

Sort – Only leaving the required items out in the workspace, all extra items should be removed.

Set (in order) – All items within the workspace to be organised, labelled, and given a 'home' therefore everything has a location to be returned to.

Shine – Keep your work area clean and inspect everything in it regularly.

Standardise – Try and keep everything standardised throughout the production line to enable easy compatibility and improve production habits everywhere.

Sustain – Create and apply standards within productions work instructions to make sure everyone follows them as a habit regularly.

The 5S technique was originated in Toyota motor company Japan in the 1970's, but later adopted as a worldwide engineering tool. The original Japanese terms can be seen below in Table 12a:

Table 12a - Japanese/English 5S's - (Rodriguez, 2021)

Japanese	English
Seiri	sort
Seiton	set in order
Seiso	shine
Seiketsu	standardize
Shitsuke	sustain

PFMEA – PFMEA stands for Process Failure Mode Effect Analysis. This six sigma tool used for analysing a process to identify and categorise the processes potential failure modes. Once all the failure modes and associated consequences are identified, they are categorised by severity and occurrence then put in order of priority. The company can then create a plan of action to implement preventative measures to mitigate the risk of failures occurring. When carrying out a PFMEA, the larger and more diverse team you have the better, a mix of experiences and job roles is advised as different people see potential failures/risks in different ways.

This tool is most effective during the design stage of a process where preventative measures are more easily implemented before the process has been set in stone. Once the preventative/step locked improvements have been applied to the process it guarantees the robustness and reliability of the process.

A suitable format for documenting the failure modes can be seen below in Table 13:

Table 13a - PFMEA Template Example

Function	Potential Failure Mode	Potential Effects of Failure	S	Potential Causes of Failure	O	Current Process Controls	D	RPN	C R I T	Recommended Action(s)	Responsibility and Target Completion Date	Action Results					
												Actions Take	S	O	D	RPN	CRIT
Dispense process fluid	Blocked Discharge	Pump Deadhead	8	Scale build up in discharge line	5	Suction line pressure point	5	200	40								

S = Severity (How bad the potential impact would be to product)

O = Occurrence (How likely the failure is to occur)

D = Detection (How easily/quickly the failure would be identified)

CRIT (Criticality) = Severity x Occurrence

RPN (Risk Priority Number) = Severity x Occurrence x Detection

(WhatIsSixSigma, 2023)

4.1.3 Value Stream Mapping

Value stream mapping is a lean manufacturing tool that is used to analyse and improve the flow of material and resources required to manufacture a finished customer ready product. Items/operations are mapped out and labelled as value added time or non-value added time from a business point of view. Value stream mapping helps identify waste and streamline a process, therefore shortening lead times but also saving money by bringing the products cost down. To conclude the main aim when value stream mapping is to cut down on waste.

Examples of different types of waste:

- Waiting – This is where any product is not being worked on or transported.
- Motion/Transport/Double handling – Motion waste is the cost of all the motion by person or machine that could be minimised.
- Overprocessing – Overprocessing refers to any step of the manufacturing process that could be deemed unnecessary.

Types of operations in VSM:

Yasuhiro Monden identified three types of operations in 1994 and they can be seen below –

1. **Non-value adding operations (NVA):** Actions that should be eliminated, such as waiting time.
2. **Necessary but non-value adding (NNVA):** Actions that are wasteful but necessary under current operating procedures.
3. **Value-adding (VA):** Processing of assembly materials via manual labour.

(Mukherjee, 2023)

4.1.4 FIFO

FIFO is the abbreviation for 'First In First Out'. FIFO is a material management method which ensures that materials that arrive to their designated location first, leave their location first. This not only allows a natural flow of inventories, but it ensures that any materials with expiry dates such as adhesives, get consumed within their use by dates and don't go to waste or worse get used on product. FIFO also assists greatly when a quality concern is discovered. If the concern relates to a consumable within the products BOM and the defective batch is identified, then the quality issue can be more easily contained. If production have a register where they can see when they started using the supplier's batch that was manufactured in a certain month etc, they can work quickly to contain all affected products that contain the consumable from within the given timeframe.

(Kenton, 2022)

4.1.5 Production Line Transfers

How to plan a move:

Plan the move early – Every move has a deadline, but it is important to allow as much time as you can for the planning phase of the move. The reason for this is the more planning and risk assessments that are carried out beforehand the more likely it is for the move to be successful and run smoothly.

Pick your team – Every factory relocation project needs a team of people that are capable of managing every aspect of the move. From the engineers to the production managers to the lorry driver and health & safety representative, each person is essential to the move and its success. It can have a huge impact if the team is engaged in the planning stages, as not only do they feel like their opinion matters but issues that some people in different roles may overlook get detected and rectified early in the project.

Layouts – Create an accurate 2D drawing of the existing production line layout. Then ensure the factory space intended for it to be located into is measured and drawn up accurately before sketching the final layout with everything such as supplies included. This new intended layout will be a useful tool for everybody involved in the transfer, so it is important for it to be accurate and achievable.

Schedule – Create a transfer schedule that allows you to meet your goals within your designated timescale. This should include when each piece of machinery/tooling is being moved (stopping it producing) and when it will be commissioned and back running again at the new location.

(Flegg Projects, 2018)

7 Flows to Consider When Designing Your Factory Layout:

Raw Materials – Are raw materials close enough to the bench that they are going to be used on to reduce non-value added time in the process? Is the raw material located in such a position that it can be easily replenished?

WIP – How is WIP moved around the cell? Is there sufficient storage for the necessary amount of WIP that may be required?

Finished Products – Where does the finished final assembly go? Does it go straight to packing/despatch? Do they collect? Does product pile up before being moved?

Consumables – What consumable items are used and where are they stored?

People – How and why do people move around within the cell?

Information – Where are the necessary instructions/information stored to be able to run production?

Waste – Has the waste/scrap aspect of the cell been considered? How and when will the waste be removed from the cell?

(TXM Lean Solutions, 2021)

4.2 Product Review

The product 'FORTiS' is one of Renishaw's newest encoder products.

4.2.1 What is an Encoder?

An encoder is an electromechanical device that is fitted to a machine's axis to convert linear or rotary motion into electrical signals that provide information on position, speed, and direction to machines such as CNC's. This allows them to move and machine with extreme accuracy.

(Renishaw plc, 2023)

Unlike Renishaw's other encoder products, FORTiS is fully enclosed which provides the encoder protection against liquids and solid debris ingress with a sealing performance of up to IP64. This encoder can also obtain ± 3 microns accuracy during any stage of its travel.

(Renishaw plc, 2023)

FORTiS encoders are sold in two sizes (18mm & 37mm) depending on its intended use and what machine it will end up being fitted in. Both the 18mm & 37mm encoders can be seen below in Figure 15a. Although there are two types of FORTiS, the customer determines the length of the product. Currently the longest length that Renishaw sells is 3.1 metres, but Renishaw's design team are continuously working on extending that for customers, while trying to maintain the same level of accuracy.



Figure 15a - FORTiS Encoders - (Renishaw plc, 2023)

4.2.2 Types of Encoders:

Renishaw currently manufacture nine different variants of encoders. Each variant has its own speciality such as speed/accuracy etc and they all sell for different prices. Ultimately there are two types of encoders. **Absolute** and **Incremental** encoders.

An Incremental encoder functions by homing itself then counting the number of ablated positions on the Renishaw incremental scale it has moved from its home position. The way an absolute encoder works is similar to a barcode scanner, it can turn on and detect exactly where it is without having to home, this is down to the Renishaw absolute scale the readhead looks at to calculate its position having a unique pattern ablated onto it. Due to the absolute encoders being more advanced they have a higher price point. FORTiS falls within the absolute encoder's family, although it is the only encoder enclosed in a singular unit with its scale.

4.2.3 How does an absolute encoder work?

Below in Figure 16a is the optical setup within a FORTiS encoder head.

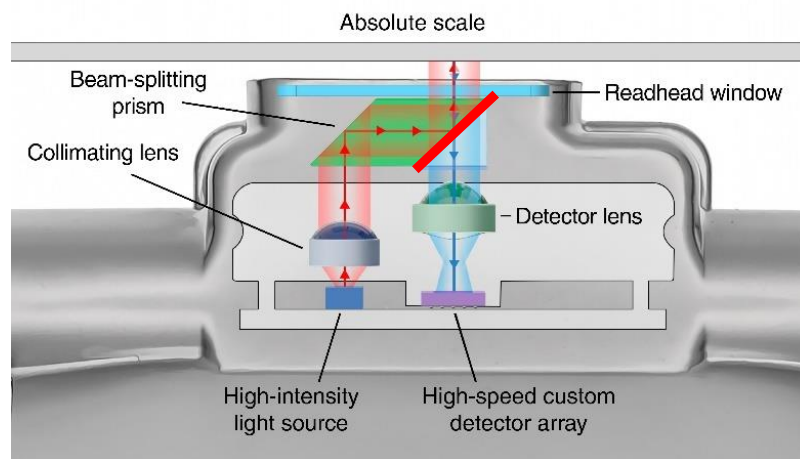


Figure 16a – Absolute encoder optical setup - (Renishaw plc, 2023)

The readhead works by shooting a high intensity light source through a collimating lens to focus the light before it enters a beam splitting prism which allows light to pass through in one direction and then take a different path in the reverse direction after it has bounced onto the absolute scale.

Renishaw scale is essentially a long length of stainless steel ribbon that is ablated/engraved using a high precision laser at certain intervals along its length creating a type of 2D barcode format.

The light reflects off the scale and bounces back through the beam splitting prism, this time it doesn't bounce off any surfaces and simply passes through the red angled surface seen above. The light is then received onto the detector lens and high speed detector array which acts as a super-fast high tech camera to record the reflections from the scale.

The light array fed back to the high speed detector array is then converted into a position due to the ablated lines on the scale giving off a different reflection intensity than the main surface of the scale. The encoder reports its position to the machine's controller through its cable. This is then how the machine knows the location of each of its axes.

The process mentioned above happens in a fraction of a second.

4.3 Process Review

4.3.1 Process Flow

The top level process flow of the FORTiS system cell that is planned to transfer to Miskin can be seen below in Figure 17a:

KEY:

Material
Operation

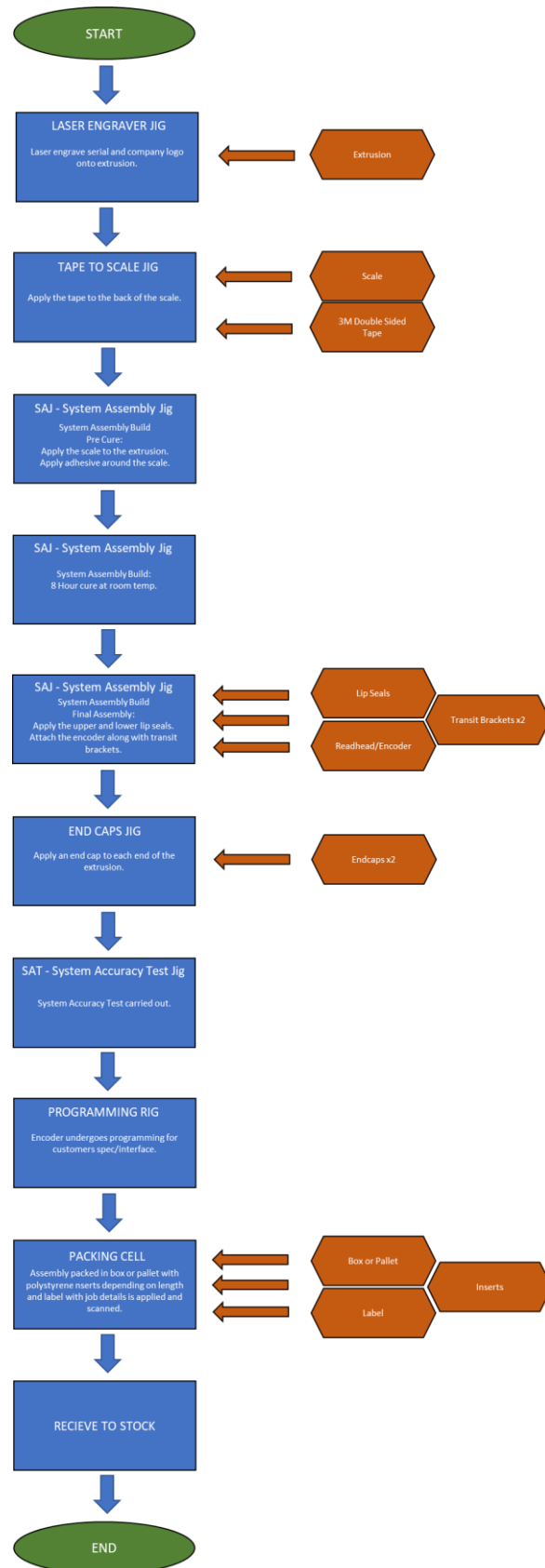


Figure 17a – FORTiS Process Flow Diagram

4.3.2 Current Layout

As explained above due to the production environment at New Mills, products and processes are constantly getting moved around and developed. Therefore, the below process layout is nowhere near fully optimised as you can see by the cell currently being split up across the factory in Figure 18a below.

For company confidentiality the surrounding bench descriptions of the other developing processes outside of this project scope have been removed.

The benches you can see highlighted in blue are related to FORTiS, however, these are new rigs that have been under development control and therefore aren't in production yet, but they are now ready for use upon transfer and validation/commissioning.

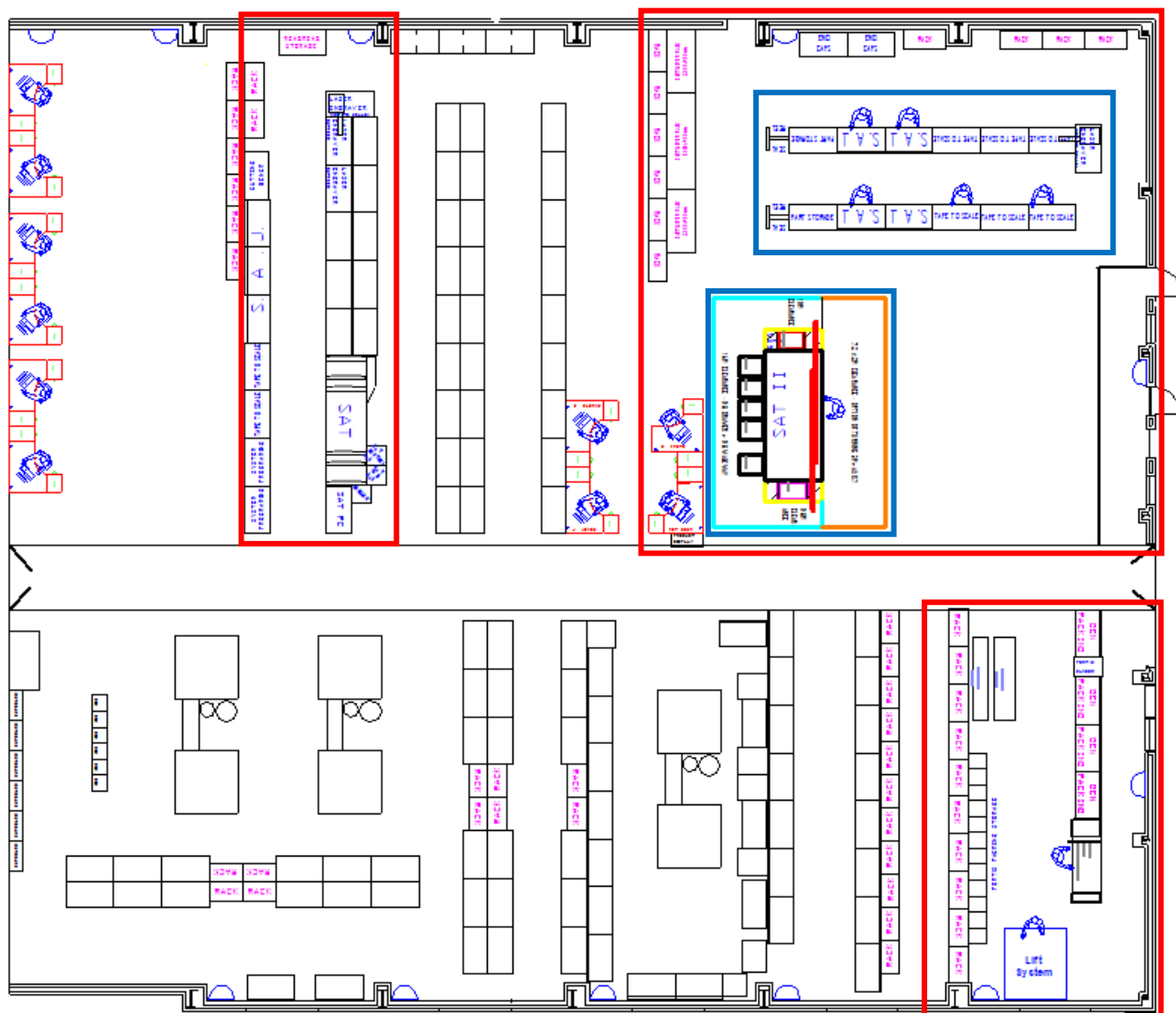


Figure 18a – Current FORTiS layout

4.3.3 Spaghetti diagram of current layout

The below spaghetti diagram in Figure 19a is of the current cell layout and allows you to easily visualise the operators movements and the product/materials transportation distances between each operation/process. Each step is numbered from 1 to 14 in order of execution. This not only helps visualise the operator/material path, but it is useful to use as a work to list when value stream mapping to review and remove non value added time.

Close up of the assembly cell:

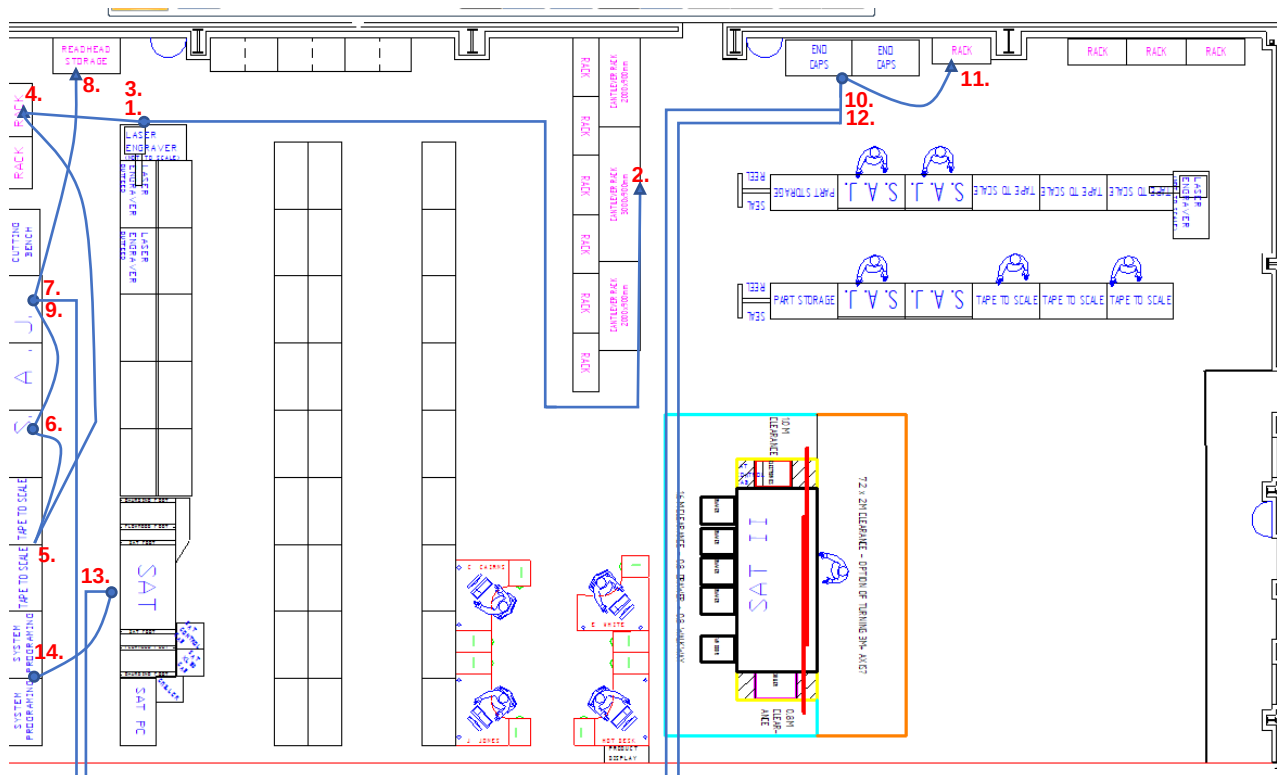


Figure 19a – Spaghetti diagram of current FORTiS layout

Due to the packing cell being so condensed and the operation being so basic, a spaghetti diagram was not drawn for this section of the process as the product comes in from the left gets packed and simply leaves in the same way. See Figure 19b below for a close up of the packing cell and Table 19 for a description of each stage.

Table 19a - Description of each stage of the process

Location 1	Laser Engraver Operation	Location 9	SAJ Part 2
Location 2	Raw Extrusion Storage	Location 10	End Caps Operation
Location 3	Laser Engraver Operation	Location 11	End Caps Storage
Location 4	Scale Storage	Location 12	End Caps Operation
Location 5	Tape to Scale Operation	Location 13	SAT
Location 6	SAJ Part 1	Location 14	System Programming
Location 7	SAJ Part 2	Location 15	Packing
Location 8	Readhead Storage	Despatch	

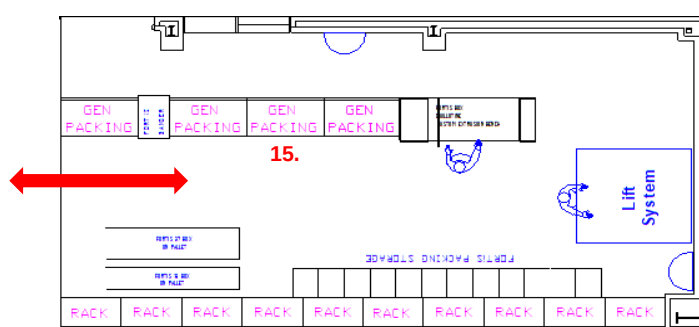


Figure 19b – FORTiS Packing current layout

4.3.4 Initial value stream mapping

The existing process was analysed at top level to identify value and non-value added time. This was analysed so that post transfer to Miskin it could be reduced and improved on.

The below value stream mapping (VSM) block diagram was created along with a timeline of both value added and non-value added time to help visualise the larger NVA contributors.

VSM Block diagram:

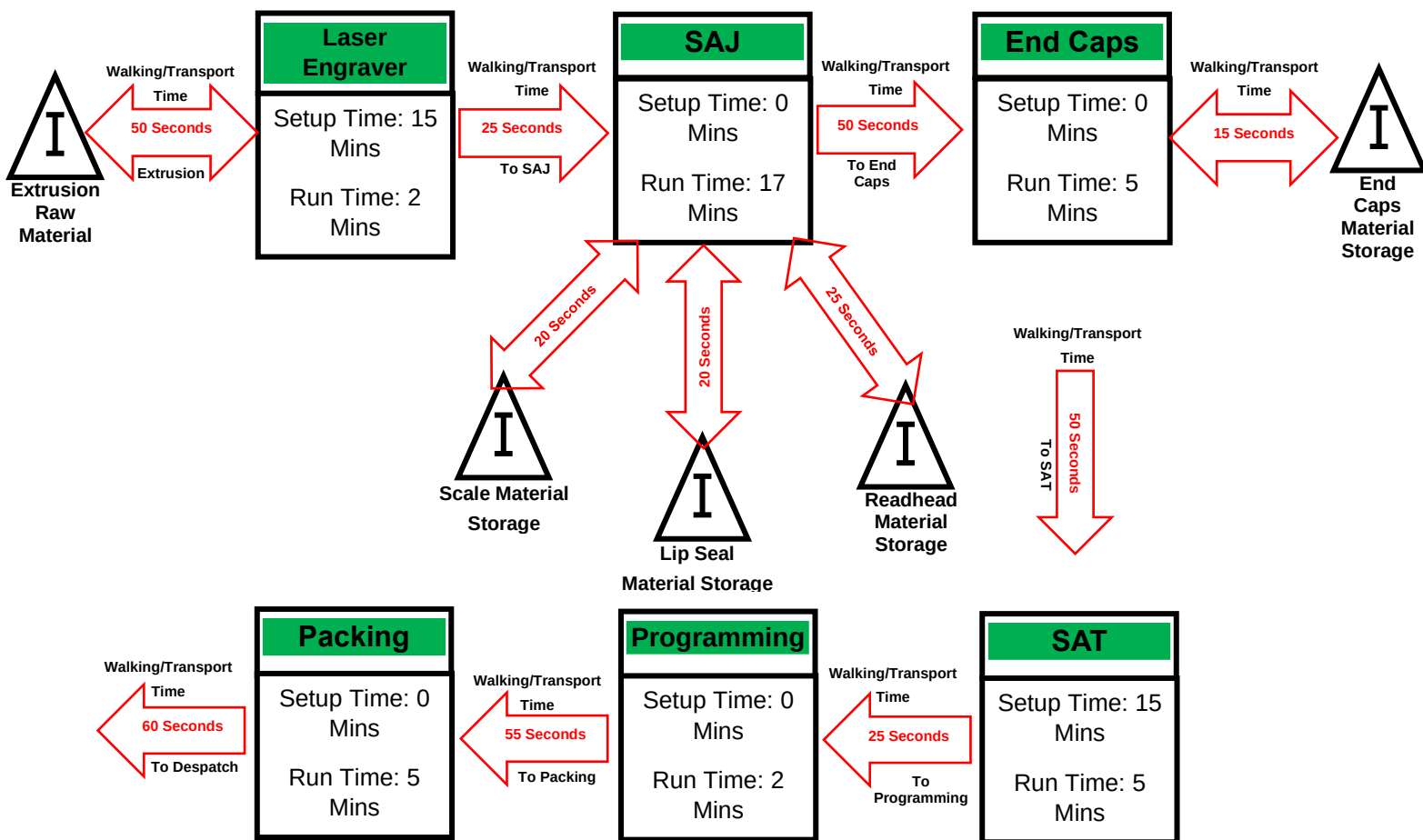


Figure 20a – VSM Block Diagram

Timeline of Value added and Non-value added time:

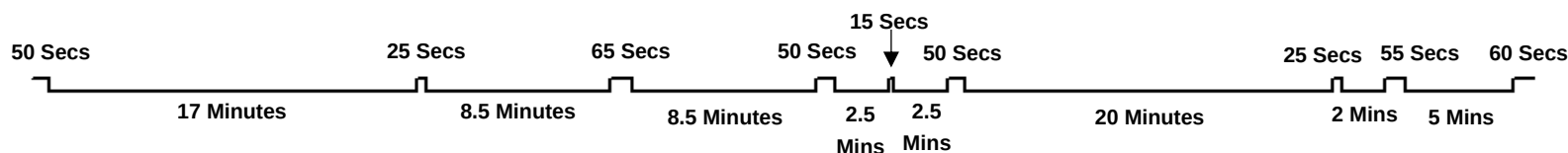


Figure 20b – VA & NVA Timeline

The above diagram and timeline show the biggest issue within the controls of this project scope is the walking distance between each operation/storage location. Totalling to **6 minutes 35 seconds**. This is something that was strongly considered and improved on when optimising the process flow and layout at the Miskin site.

4.3.5 Capacity Review

To be able to plan efficiently and eliminate bottle necks within the process flow, the achievable capacity per rig had to be assessed.

A bottle neck within a production process is a point of congestion that occurs when products arrive at an operation faster than they can be handled and progressed through the specific operation. This then means that WIP builds up before the operation which can lead to inefficiencies of equipment and operators on other workstations of the process both upstream and downstream.

Below you can see a table of every rig/operation in the process, along with its maximum capacity on a single shift per week/month:

Table 21a – FORTiS rig capacity on single shift:

Equipment/Rig:	Output achievable per week:	Output achievable per month:
Laser Engraver	220	880
Tape to Scale	225	900
SAJ	200	800
End Caps	210	840
SAT	150	600
Programming	220	880

This data was collected by taking average timing from production across multiple operators. As you can see from the above table, the bottle neck of the process is SAT with it achieving a maximum capacity of 600 units per month. Although this is a bottle neck, this still allows production to reach their initial target of 500 units per month without needing to duplicate any additional jigs to facilitate this target.

The above capacities are also based on a singular shift pattern, therefore if the sales forecast and demand for FORTiS rapidly increased suddenly. Production capacities could be doubled to allow production to achieve the below through each jig:

Table 21b – FORTiS rig capacity on double shift:

Equipment/Rig:	Output achievable per week:	Output achievable per month:
Laser Engraver	440	1760
Tape to Scale	450	1800
SAJ	400	1600
End Caps	420	1680
SAT	300	1200
Programming	440	1760

Capacity capability is critical to ensure Renishaw gives customers satisfying lead times and entices them into buying Renishaw products to allow them to introduce quick solutions. The more capable production lines are of making more products also means the more capable they are of making the business profit if the demand is there. Therefore, this is something that will be closely monitored by the sales team and production upon its transfer to Miskin.

5.0 Planning

5.0.1 Gantt Chart

The project Gantt chart can be found in Figure 43a of the Appendix located on Page 43 below. The gantt chart will be used to help the project stay on track and progress as scheduled. It will be used to monitor and update progress to ensure that the project deadline is met, and the date of the transfer is not affected by any potential delays.

5.0.2 Top level plan

The production line that is getting transferred to Miskin is the FORTiS Systems production line. The aim is to transfer the production line down to Miskin while still leaving a functioning production line at New Mills. This decision was made due to New Mills having duplicate rigs in production that can be transferred without needing to plan for downtime, therefore giving the transfer contingency in case issues arise. The end goal is to transfer the rest of FORTiS systems along with the FORTiS readhead build to Miskin by the end of 2024/2025. However, the main focus of this project is phase 1 to transfer a fully functioning FORTiS systems line to Miskin before the 15th of May 2023.

5.0.3 Equipment being transferred or duplicated

Below is a list of the processes/equipment getting transferred to Miskin or duplicated at Miskin:

Laser Engraver Process – This process will be getting duplicated at Miskin due to New Mills only having one laser engraver process currently and it being shared with another production line in NPI. This will relieve the pressure on the transfer as it can be duplicated and set up ahead of schedule.

Tape to Scale Jig – This jig is being transferred due to New Mills having two rigs, however it cannot be transferred ahead of schedule due to production capacity requirements, therefore it will transfer when production is ready to commence at Miskin.

SAJ (System Assembly Jig) – There are currently three SAJ rigs at New Mills. Two in production and one new addition that is still under development. Initially only one of the SAJ rigs will be getting transferred to Miskin, followed closely by the second in a separate project around November 2023 when the second SAT rig transfers. Then the third SAJ rig will transfer sometime before the end of 2024 when the final SAT is transferred to Miskin.

End Caps Jig – There is only currently one end cap jig at New Mills, but similar to the laser engraver process, this jig will be duplicated ahead of schedule at Miskin.

SAT (System Accuracy Test) – New Mills currently have three SAT rigs. Initially only one SAT will be transferring to Miskin for May 2023 due to the risk of moving two very heavy and high tech pieces of equipment at once. The second will follow in a separate project around November 2023 then the third sometime before the end of 2024 or start of 2025.

Programming – This process is mainly software based and New Mills only have one programming station, so this will be duplicated at Miskin.

Packing – Packing consists of mainly benches with a few pieces of equipment such as a bander, pneumatic staple gun and a guillotine. These will be purchased and duplicated ahead of the move.

Table 22a – Breakdown of what is being transferred/duplicated:

Equipment/Process:	QTY required:	Transferring or Duplicating:
Laser Engraver	1	Duplication
Tape to Scale	1	Transfer
SAJ	1	Transfer
End Caps	1	Duplication
SAT	1	Transfer
Programming	1	Duplication
Packing	N/A	Duplication

5.1 Pre Move

5.1.1 Available floor space

The available floor space at Miskin was discussed with the Miskin site manager and the relevant higher management team. It was then discussed with Jack Brooks & Sarah Chappell-Smith from an Engineering point of view. A factory floor space of 11.4m by 20.8m for the FORTiS assembly cell was agreed on and an area of 6.4m by 11.2m was agreed for the FORTiS packing cell. This allocated space was given due to Miskin having very limited space until the third and fourth halls under construction are completed and ready to be occupied.

5.1.2 Miskin proposed layout

Below are the main points considered when producing the proposed layout for the Miskin floorspace which can be seen in Figure 25a on the following page.

1. Factory floor space was one of the major considerations when creating this proposed layout due to being extremely constrained on the floor space that the production line could occupy after being allocated a footprint of 11.4m x 20.8m by the Miskin site manager.
2. Process flow was the second highest consideration upon drafting the below layout as it directly contributes to lead times and prevents mix ups and mistakes being made by inexperienced operators. Due to the VSM conducted above, highlighting quite a lot of non-value added time in the process. The walking distances to operations and material storage were targeted with the aim to reduce waste. In an ideal situation the FORTiS process flow would be very linear but this had to be compromised due to floorspace allocations.
3. Most of the benches require power (230v or 3 phase) and some also require a network connection and an air supply. The supplies are run from the roof and down the factory support pillars, due to this the placement of the benches had to be considered around the ease of supplying them with services from these pillars without the services having to cross walkways etc. Therefore, benches were attempted to be placed next to one another or in line with each other so that the services could be carried along the benches if possible.
4. Storage space for WIP was considered. Due to the small volumes New Mills are currently producing, they are managing to get away with having very little WIP storage and often use spare bench space as a temporary WIP storage solution. Due to the capacity requirements ramping up it was important to accommodate enough WIP storage space at Miskin to prevent product being stored inappropriately and causing a risk to product quality and potentially the health and safety of staff in the working environment.
5. The health and safety of the layout was considered, legal working space was researched and implemented to the proposed layout to ensure that every bench has enough area for operators to safely work in while complying with working regulations. The layout and process were also assessed for any additional hazards that had the potential to cause harm such as trips hazards etc, this was carried out to ensure the production environment would be safe.
6. As with any factory floorspace, it needs to be fully utilised to reduce waste, therefore no large empty spaces within the layout were going to be acceptable and the layout had to fill the space.
7. Due to Renishaw having the intention for expanding FORTiS systems with additional equipment in the near future, the layout had to be future proofed as much as feasibly possible.
8. The access room required for maintenance was thought about and considered for each bench/piece of equipment.
9. The cost of the layout was also being monitored closely and alternative suppliers were being contacted to try and bring the cost of equipment required to facilitate the transfer to a minimum.

Below is the 2D CAD model of the proposed layout drawn on Siemens Solid Edge software:

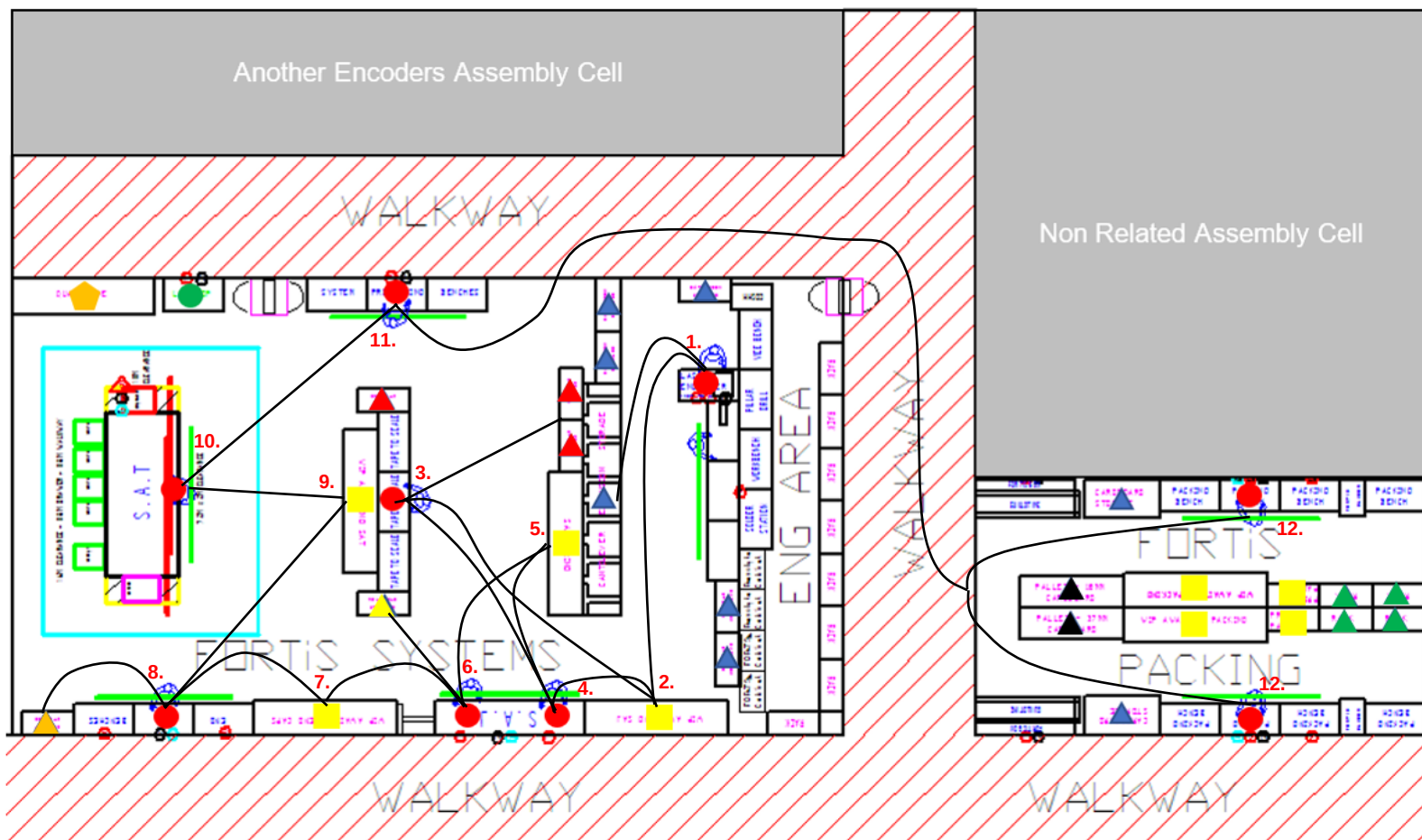


Figure 24a - Proposed FORTiS layout

Key –

Operations: ●

Material Storage: ▲▲▲▲▲ (Note: The material storage that share the same colours, store the same materials.)

Lead Operator: ●

WIP Storage: ■

Quarantine: ⬠

Table 24a - Description of each stage:

Location 1	● Laser Engraver Operation	Location 6	● SAJ Part 2
Material	▲ Raw Extrusion Storage	Material	▲ Readhead Storage
Location 1	● Laser Engraver Operation	Location 6	● SAJ Part 2
Location 2	■ WIP awaiting SAJ	Location 7	■ WIP awaiting End Caps
Location 3	● Tape to Scale Operation	Location 8	● End Caps Operation
Material	▲ Scale Storage	Material	▲ End Caps Storage
Location 3	● Tape to Scale Operation	Location 8	● End Caps Operation
Location 4	● SAJ Part 1	Location 9	■ WIP awaiting SAT
Location 2	■ WIP awaiting SAJ	Location 10	● SAT
Location 4	● SAJ Part 1	Location 11	● System Programming
Location 5	■ WIP awaiting curing	Location 12	● Packing

5.1.3 Improved value stream mapping

Due to the initial VSM highlighting the long walking times between operations, this was targeted when creating and optimising the new layout for Miskin with the aim to reduce walking/transport times between each operation to a minimum.

VSM Block diagram:

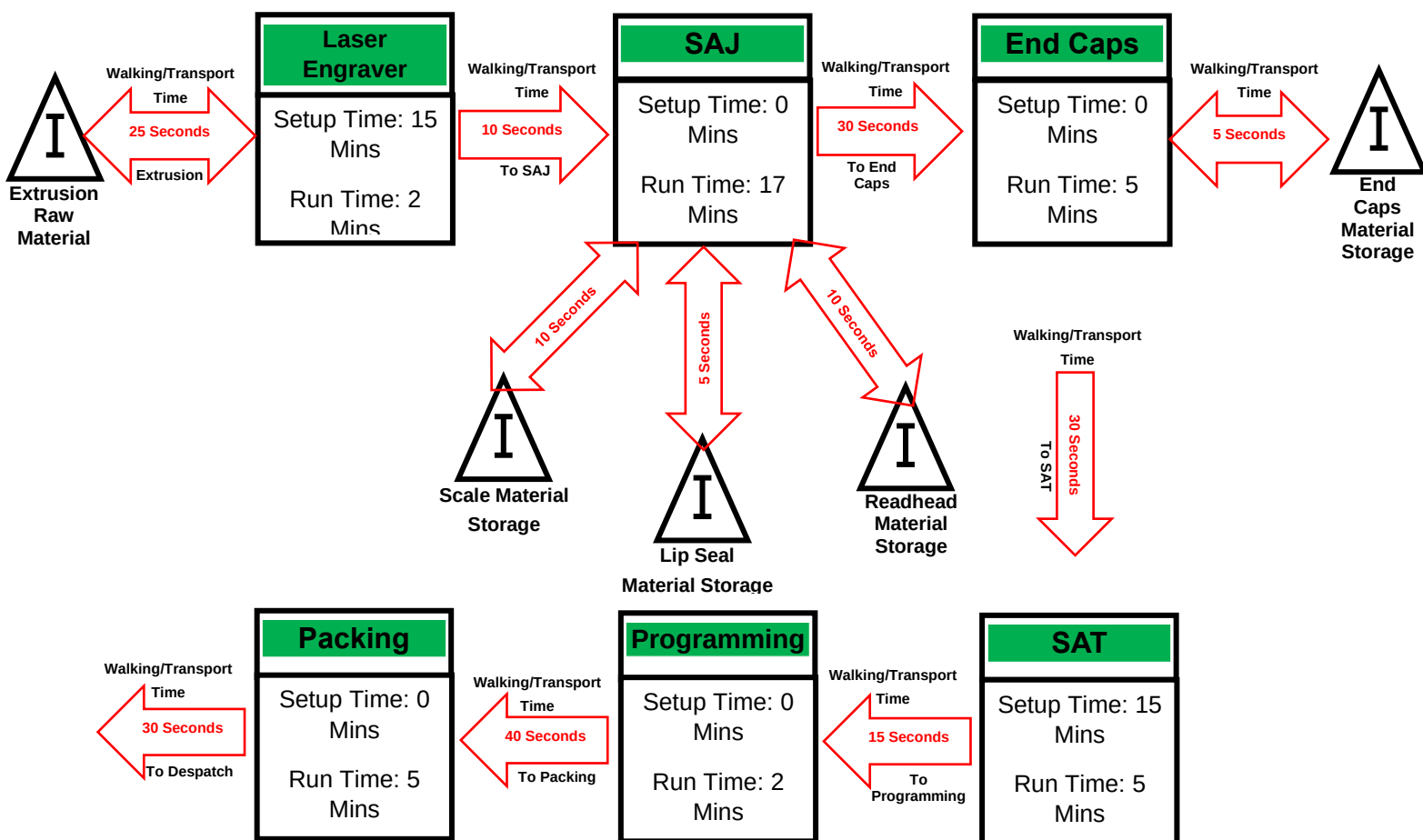


Figure 25a – VSM Block Diagram

Table 25a – Non-value added time comparison:

Operation:	Original layouts nonvalue added time:	New layouts non-value added time:	Time savings from process flow improvements:
Extrusion storage to Laser Engraver	50 Seconds	25 Seconds	25 Seconds
Laser Engraver to SAJ	25 Seconds	10 Seconds	15 Seconds
SAJ to Scale Storage	20 Seconds	10 Seconds	10 Seconds
SAJ to Lip Seal Storage	20 Seconds	5 Seconds	15 Seconds
SAJ to Readhead Storage	25 Seconds	10 Seconds	15 Seconds
SAJ to End Caps	50 Seconds	30 Seconds	20 Seconds
End Caps to End Cap Storage	15 Seconds	5 Seconds	10 Seconds
End Caps to SAT	50 Seconds	30 Seconds	20 Seconds
SAT to Programming	25 Seconds	15 Seconds	10 Seconds
Programming to Packing	55 Seconds	40 Seconds	15 Seconds
Packing to Despatch	60 Seconds	30 Seconds	30 Seconds

The total time saved from improving the overall process flow and reducing walking distances between operations and material storage was **3 Minutes and 5 Seconds**. The financial benefit this new optimised layout brings to production in the form of the manufacturing cost of the product could not be reviewed in the costings section below, as the product costs are strictly confidential. However, you can see that it has dramatically decreased the time it takes to build each product.

5.1.4 Layout Review

Below in Table 26a are the successes and compromises of the proposed layout.

Table 26a - successes and compromises of the proposed layout:

Successes:	Compromises:
Managed to accommodate all equipment within the compact floorspace assigned.	Slightly compromised process flow with multiple rotations required which isn't ideal due to the size of the product.
Process flows well and there is no stage where the operator must walk long distances to the next operation or to collect materials.	Tape to scale operation couldn't fit directly next to SAJ operation. This means the scale must be transported in long length to SAJ rather than it being slid across onto the next operation.
Services can easily be run to every operation that requires them without running services across walkways and causing hazards.	Quarantine rack is not easily accessible for every operation.
WIP storage before and after the critical operations when there may be a bottle neck.	No WIP storage before programming due to lack of floorspace, although this is the quickest operation to complete so there is no reason product should get held there for long before getting taken to packing.
Legal working distance compliant.	
Utilised floorspace with very minimal excess space unfilled.	
Room for an additional SAJ and SAT in the floorspace for future proofing reasons if required. Only minimal shuffling of mechanical operational benches would be required.	
None of the benches back onto walls so therefore the rigs have plenty of maintenance access where required.	

The proposed layout as seen in Figure 24a above was presented to senior management, both from engineering and production. They were walked through the process and storage requirements along with the rig capacity data was presented to help them understand the process in further detail. The agreement to proceed with this plan was then granted.

5.1.5 Communication

Now that the transfer is feasible and it has proven to fit within the limited floor space at Miskin, it is important to communicate the transfer to the wider audience that may or may not already be aware that the transfer will be taking place. Therefore, an email was sent to the below people to ensure everyone either involved or potentially affected by the transfer is aware of the top level plans.

- The Works Engineering Manager & Senior Maintenance Engineer were both made aware as they would be required to install the services such as air, electricity & network to the line prior to its arrival.
- The Encoders Marketing Manager & Senior Sales Advisor were also both made aware, as in the short period between when the equipment is taken out of production at New Mills and it being commissioned at Miskin, the production capacity will be impacted therefore customer lead times may need to be extended during this period.
- The relevant Production & Engineering teams at both Miskin and New Mills were made aware, although most were already briefed on the situation in person.

To ensure everyone involved was kept updated on progress, actions and potential changes, a bi-weekly meeting was set up. The meeting was chaired by the project lead and meeting notes including actions were sent out after each meeting.

5.1.6 Miskin site preparations

To ensure the floor space at Miskin is ready to receive the equipment from New Mills at the time of transfer, it is critical to do as much preparation work as possible before the transfer of the SAJ, SAT and the Tape to Scale rigs begins. Below is a list of actions that can be executed before the move:

- Firstly, the area needs to be cleared of the pallets of stock that are being stored in there. Due to this equipment not belonging to the same department/area an email was sent to the owner of the stock for them to kindly remove and relocate it within a week so preparation work within the area could commence.
- Next the locations of both bench and machine locations are to be marked out on the floor using tape and the layout as a guide for dimensions. Each location marked must be clearly labelled. By doing this it not only removes the need to have the layout available constantly, but it allows everyone to have a rough idea of the bench spacing and general arrangement in real scale rather than on CAD. By doing this as early as possible any issues can be picked up sooner and rectified without causing any delays to production or the transfer.



Figure 28a – Floor Markings

- The benches for the equipment/processes being duplicated can be purchased and built ahead of the move. These can then be wheeled into their correct locations and be fitted with ESD earth bonding points along with basket trunking on the backs of them for the services to be run in.



Figure 28b - Production Bench
(DC Graves, 2023)

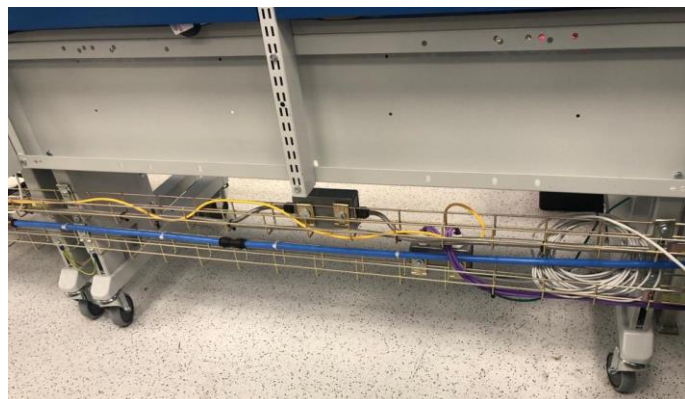


Figure 28c - Basket for services to be run in

- All necessary network ports on the walls can be patched in and connected to the servers by Renishaw's Business Systems Department to prevent startup delays.
- Additional storage racking that is being purchased can also be built up ahead of schedule and put into place.



Figure 29a - Production Racking for Storage - (Schafer, 2023)

- Services for the duplicated process can be run into the baskets on the backs of the benches to ensure that the validation work and calibrations on the rigs can begin as soon as the equipment arrives.
- Services such as electricity, network and air for the additional benches that are transferring down can be mapped out and placed into their trunking baskets ready to be mounted to the benches upon their arrival. This will prevent the maintenance team having to run cables/pipes in downtime and means they will only have to connect the trunking baskets to the backs of the benches and turn the air/power on once baskets are secured.
- Since production documentation such as work instructions etc. won't be transferring, production can ensure that all the relative documentation is printed at Miskin and place in suitable folders ready for production usage.

5.1.7 Transport strategy and arrangements

The production line can either be moved in gradual phases or all at once. Both methods were discussed below:

Option 1 – Moving the whole production line at once

Table 30a – Advantages / Disadvantages of a singular move:

Advantages:	Disadvantages:
The whole transfer will be completed faster.	Less attention to detail due to moving so much equipment in such a concentrate time period.
	Less time to validate each stage of the production process.
	More logistical support will be required.
	Nick and I won't be able to oversee every piece of equipment being loaded/unloaded from the lorry to ensure care is being taken.
	High risk to production if problems are incurred.

Option 2 – Moving the production line in gradual stages

Table 30b – Advantages / Disadvantages of a phased move:

Advantages:	Disadvantages:
Jigs that are being duplicated can be moved ahead of schedule to reduce the pressures of the transfer.	Transfer process will be dragged out over multiple weeks.
Services won't all have to be live/completed at once.	
Each piece of equipment can have the dedicated time spend on it to transfer and validate thoroughly without it being rushed.	

The phased move was chosen due to it being the obvious choice and impact the risk to production the least.

Vehicles:

Therefore, the vehicles involved in this transfer other than the company cars that the transfer team will be using will be x2 Mercedes Sprinter High top company vans and a hired HGV from Opex whom Renishaw have good connections with. The lorry will transport SAT and the vans will transport everything else due to the SAT (System Assembly Test) rig being such a large and heavy machine it would not fit into a van.

To be able to fit everything required into the vans or lorry, certain jigs would have to be broken down into smaller sections. This would be carried out by the transfer team to ensure everything that is disassembled can be reassembled without confusion at Miskin.

Method of Loading/Unloading:

The method of loading and unloading at each site would be carried out using the 5 Tonne forklifts they have in despatch at both sites. In order to be able to use a forklift safely the driver must have been trained and granted a forklift license, therefore a member of the despatch department who holds a forklift license at both sites must be present on the days of the move.

Exit and Entry Paths:

To ensure all the equipment leaving New Mills/entering Miskin would be able to be taken down the planned route without any issues, a trial run of the chosen routes at each site was carried out. During the trial, all access requirements including flooring, corridor and door widths, possible pedestrian traffic was accessed and deemed achievable.

5.1.8 Risk assessment

It is not possible to consider every risk in this report, but I have considered the following aspects:

Health and Safety Risks:

Transport –

Moving large and heavy equipment causes a health and safety risk of injury to the employees involved in the move.

Transporting a production line can often be a risky procedure that requires extensive planning. During transit, equipment will likely be subject to vibrations and impacts that could cause significant damage to the courier vehicle and potentially cause the equipment to become displaced and unsecure. This could result in a road traffic collision if the equipment is heavy enough or the movement is loud enough to distract the driver. It also poses a risk of injury when opening the doors to unload as if the load has become displaced or loose it may fall out onto the driver.

Forklifts will need to be involved to load and unload equipment onto the vans/lorry for transportation, forklifts are known for posing large hazards to the surrounding environment.

To reduce the risks of the above points, the area surrounding the loading/unloading will be restricted to the transfer team only and everyone involved with the transfer will be required to wear hi visibility clothing when assisting with loading or unloading.

Production Risks:

Transport –

As mentioned above, during transit, equipment will likely be subject to vibrations and impacts that could displace equipment and cause significant damage to production equipment. This could result in costly repairs but more importantly timely delays before production can commence. To reduce this risk the securing of the load will be buddy checked and equipment will be packaged in foam and bubble wrap as well as possible.

There is also a risk that equipment will be dropped when being loading/unloaded by the forklift, therefore the loading/unloading procedure will take place in the despatch area where the ground is flat, and space is vast. The most experienced and competent forklift operator will be chosen to carry out the task of loading/unloading at each site to reduce risk as much as physically possible.

Delays –

There is a risk to production output if the transfer gets delayed meaning that production cannot commence when intended.

Equipment –

As with all equipment, especially equipment that includes a lot of electronics and software, it may not want to configure and function correctly post transfer, meaning it may need some specialist support which may prolong the transfer and cause delays.

5.1.9 Validation/Commissioning plan

Before production can commence and start assembling products, each rig/process must be checked and validated to ensure it is fit for purpose and produces good quality parts that conform to their design specification and Renishaw's quality standards.

In order to do this, each rig/process required a validation/commissioning document specific to that piece of equipment, with the goal being if everything conforms to the validation checklist it can be handed straight to production.

The validation documents were the responsibility of the engineers at New Mills along with the engineers involved in the transfer to write.

Each validation document should include the below criteria:

- Clearly states the purpose of the document, which is to validate the rig after transportation to ensure it is functioning as intended and producing good parts.
- Defines the scope of the validation, and what aspects of the rig the document intends to cover and validate.
- Validation instructions/checklist along with expected results.
- If the validation fails by not conforming to every point, what the corrective actions are to ensure the rig can be fixed for production use.
- Conclusion and most importantly sign off to ensure the person carrying the validation out knows that they are responsible.

5.1.10 Costings

To be allowed to spend a substantial amount of money on a project within Renishaw, a CEA (Capital Expenditure Authorisation) form must be completed, justified, and sent to the Renishaw board of executives to approve and grant the money to be used on the project.

A CEA was created but cannot be shown due to Renishaw's confidentiality policy. For the purposes of this report, non-accurate prices have been listed in the Table32a below:

Table32a – Equipment cost to accomodate the facilities for the duplication and transfer:

Item:	Cost:	QTY:	Line Cost:
Sovella Benches	£1,600	19	£30,400
ESD Bench top mats	£35	19	£665
ESD Chairs	£260	3	£780
Racking	£200	10	£2,000
Cantilever Racking	£220	6	£1,320
Anti Fatigue Mats	£89	3	£267
Bins	£34	5	£170
Air Guns	£45	3	£135
Standard PC Setup	£980	3	£2,940
Scanners	£310	3	£930
WIP Storage Racks	£1,300	7	£9,100
Bench Accessories	£800	1	£800
Trolleys	£580	6	£3,480
ESD Compliance Equipment	£870	1	£870

Total - £53,857

Table32b – Transportation costs:

Item:	Cost per day:	Number of days required:	Line Cost:
Cost of Lorry hire	£450	3	£1350
Fuel	£30	Approx 30	£900

Total - £2,250

As seen above in Table 32a & 32b, the total planned cost of the transfer is **£56,107** and this is what was granted by the Renishaw financial board to spend on the transfer. This CEA was backed up with a supporting document and presentation to justify the spend which unfortunately cannot be shown due to Renishaw's confidentiality policy.

These costs do not consider the potential requirement for overtime payments. Currently there is no plan to working outside of standard working hours, however if it is required to stay on track then this will be utilised and authorised by management.

5.1.11 Projected Benefits

Below are the projected benefits from carrying out the transfer of FORTiS:

1. This transfer allows FORTiS to expand production and increase capacity capabilities by around 235%.
2. It improves the production lines overall process flow and therefore decreases walking times by 3 minutes and 5 seconds. This will positively impact the ability to achieve customer lead times and reduce labour costs to assemble the product, benefitting the product cost of manufacture and profit margins.
3. More storage solutions will be introduced to the new cell layout to ensure production have room for the necessary WIP at each operation, this will ensure the line can cope with required storage if run rates were to increase. But it also prevents other operations from having to stop producing if a single operation breaks down.
4. The new layout accommodates space for maintenance access to all equipment in the cell.
5. The FORTiS layout that has been proposed utilises the production floorspace with minimum waste.

5.1.12 Proposed Transfer Plan Summary

To summarise the planning section above, see the below list of actions which discuss the top level plans:

1. Get the duplicated rigs built at New Mills, as comparisons can be made, and any issues experienced can be ironed out with the relevant support there.
2. Prepare the Miskin floorspace to receive the equipment.
3. Transfer all the duplicated equipment to Miskin on scheduled dates shown in Figure 34b below.
4. Validate all the duplicated equipment.
5. Transfer SAT to Miskin first as planned, this is due to it taking the longest to commission and it not currently being in production at New Mills.
6. Validate and commission SAT.
7. Transfer SAJ to Miskin next by removing it from production at New Mills.
8. Validate and commission SAJ.
9. Tape to Scale rig to transfer to Miskin last, as it will be the quickest to commission so for the sake of effecting production capacity at New Mills it's not worth transferring it any sooner.
10. Production to commence on the 15th of May 2023.

5.1.13 Timeline of Transfer

Below in Figure 34a and 34b you can see the timeline plan of the transfer from start to finish of phase 1. This was sent out to everyone involved in the transfer as soon as it was confirmed to allow everyone to be prepared and look back on for key dates.

FORTiS Systems Transfer to Miskin 2023

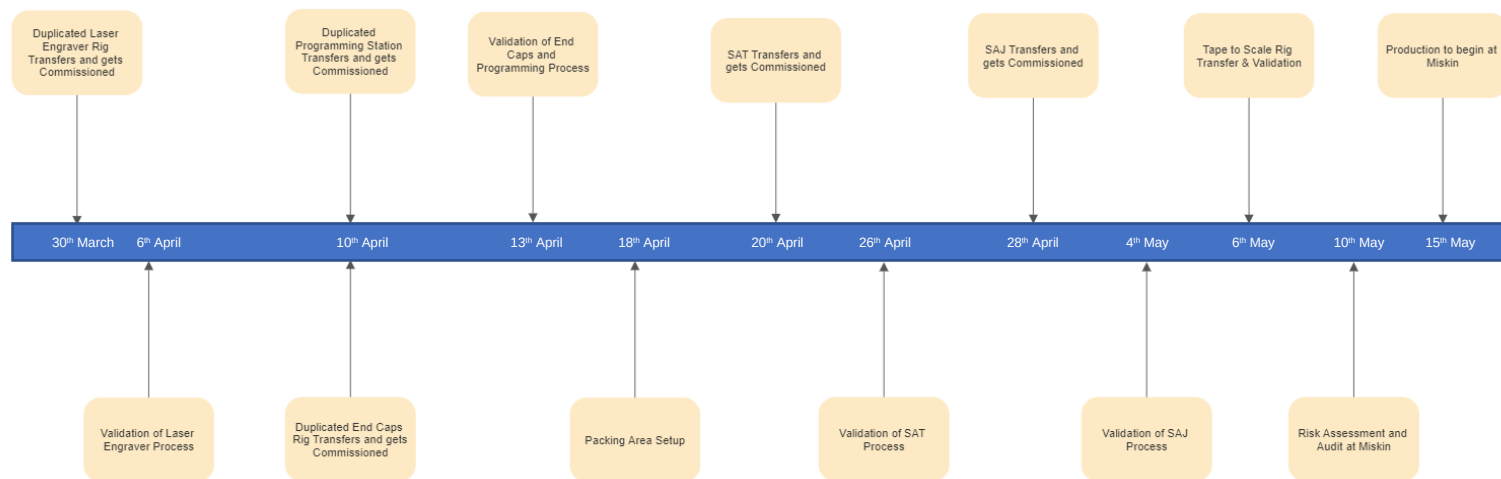


Figure 34a – Transfer Timeline

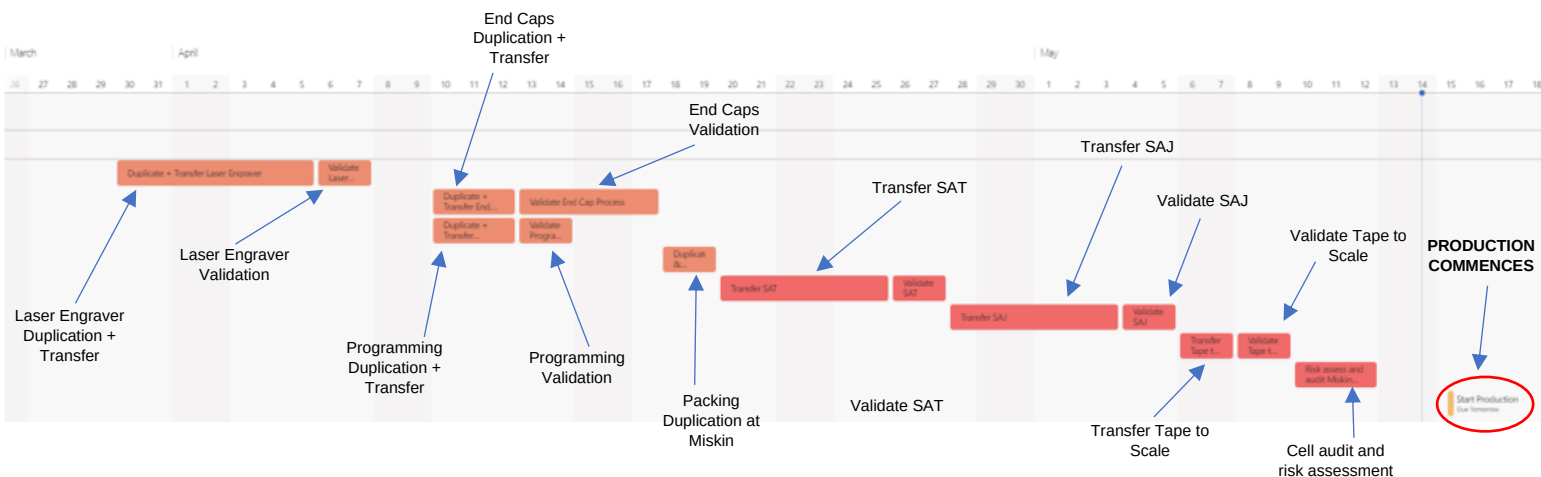


Figure 34b - Transfer Timeline Gantt Chart

6.0 Executing Transfer

6.1 The Move

6.1.1 Initial meeting

The day before the first move was about to commence, a meeting was held with key stakeholders. This meeting was held to confirm that the move was going ahead as planned, and it was a chance for everyone to discuss the points with the highest risk that require more precaution. In this meeting the responsibilities of the team were run through so that come the morning of the transfer everyone was ready to start their duty immediately.

6.1.2 Team & Responsibilities

The transfer team consisted of:

Ben Shears – Project Lead

Project coordinator, ensuring that everyone involved was aware of their roles and the duties they had to carry out as and when required. The responsibility would include instructing the team on where equipment was going, due to creating the layout plan for the factory floorspace.

Jack Brooks – Senior Engineer

Jack was the Senior Engineer overseeing the transfer, so if any issues were to arise a discussion between the project lead, Jack and potentially production would have had to take place.

Nick Gammage – Engineer

Nick is the Engineer that has been working alongside the project lead for this project so is fully up to speed with the transfer plan and would be liaising and coordinating with the departments apprentices for additional resource where required. He would also be heavily involved on the setup and validation stage.

James Needs – Senior Engineer

James is the Engineer supporting from the New Mills site that the Ben and Nick have been working alongside for this project. He would be heavily involved on the decommissioning stage up at New Mills.

Steven Evans – Production Management

Production management would be overseeing the transfer of materials and stock along with the relevant material controllers they delegate to.

Gary Thomas – Despatch/Logistical Manager

The logistical manager would be providing the transfer team a forklift along with a qualified driver and the drivers for the lorry we would be hiring.

Renishaw Security

Renishaw Miskin Security team would be responsible for allow the transfer vans/lorries access to site by escorting them from the security gates to the factory entrance. They would then be responsible for assisting in setting up a safe perimeter around the HGV to allow for the equipment to be unloaded safely with minimal people in range to prevent accidents occurring.

Delegation and people management was key to this transfers success. It was crucial that everyone stuck to carrying out their specified role above and executed in a confident and timely manner.

Unfortunately, due to Renishaw's confidentiality policy, images of the rigs, equipment, and factory space prior, during and after the transfer are unable to be shared.

6.1.3 Decommissioning & Preparing for Transportation

As all the decommissioning work would need to be done before transporting each piece of equipment. The New Mills engineering team were responsible for turning each rig off and isolating the rig the evening before it was due to transfer. Therefore, the rigs simply needed unplugging and disconnecting from the network and air supply where applicable then they were packaged using sheets of foam and bubble wrap. For the larger rigs such as SAJ and SAT, they were isolated and then broken down into three sections for transport before being packaged individually. Any connecting components were placed in clearly labelled bags and packaged in with the equipment to avoid losing them prior to reassembling at Miskin.

6.1.4 Loading

Each piece of equipment once it had been decommissioned and packaged to protect it for transit, was taken out of the building at New Mills and taken to the despatch yard along the same route that was previously scoped out in the planning stage.

Depending on the size and weight of the equipment it was either transported to the transfer vehicle(s) using a pallet and pump truck or using the forklift. The route had been assessed for both eventualities previously in the planning phase.

Once outside the factory in the despatch yard, a member of despatch with a valid forklift license loaded the larger equipment onto the lorry or with the small equipment on pallets this was lifted onto a new pallet in the back of the company's transfer vans.

It was the driver and despatch teams' responsibility to secure the load at this point, to aim to reduce the movement and risk of damaging the equipment to a minimum. Once the vehicles were full or the equipment scheduled to move that day had been loaded, the driver was given the green light to travel to Miskin. It was reiterated to the drivers that due to the value of the cargo they were transporting they would have to drive responsibly and take corners slowly to prevent damaging the load.

6.1.5 Transportation route

Although some of the loads were extremely heavy and large, they could still be disassembled enough to be loaded onto a standard lorry for transportation. This meant that a direct route from the Renishaw New Mills site to the Miskin site could be taken, and no special alternative routes were needed.

The direct route chosen was from the Renishaw New Mills site (Wotton-under-Edge) to Junction 14 of the M5, then onto the M4 at the Almondsbury Interchange, before coming off the M4 at Junction 34 for Llantrisant and travelling around 600 yards to the Renishaw Miskin Site. This route proved to be ideal and was only around a 1.5 hour journey (one way).

The transportation route for transfer was assessed the morning of the transfer to ensure no road traffic accidents had occurred that would slow the transfer down significantly. Luckily the roads were clear, so no route diversions were necessary.

When in transport this was communicated to Miskin so they could expect the equipment to arrive imminently and let security at the gates know to expect it.

6.1.6 Additional work being carried out at Miskin while in transport

Once the call had been made to notify Miskin that the equipment had left New Mills, the Miskin team was briefed on where that piece of equipment was going to be situated. They then started setting up barriers to accommodate the unloading of the vehicle(s).

Not much else could be carried out at Miskin on the initial drop of the first piece of equipment (laser engraver). However, after the first drop off, the Miskin team had plenty of work to do with connecting the services and validating equipment etc.

6.1.7 Unloading

When arriving at Miskin the driver was directed by security to the nearest roller doors to where the FORTiS line would be situated. When the vehicle had stopped and it was safe to do so, the barriers were readjusted around the vehicle to allow a safe space for the forklift to unload within. Again, depending on the equipment it was either unloaded onto pallets and pump trucked into the factory or transported inside using the forklift using the already scoped out routes for each scenario.

6.1.8 Cell Setup

When each piece of equipment had been dropped off and the transport had left Miskin. The unpacking and inspection of the equipment was carefully carried out to check for damage. Then the fine adjustments of the equipment's positioning within the allocated floorspace were made. Once the equipment was in place, it was then connected to all the necessary services it required before validation testing commenced as planned.

6.1.9 Issues Encountered

As with all projects and production line transfers, no matter how much planning goes in, it is still expected that some issues will occur. Below are the issues that were faced when transferring:

- There was a larger lead time than expected on the production storage racking and some of the Sovella benches were on back order. To overcome this issue, benches/racks from other departments and production lines across Miskin and New Mills were managed to be freed up and temporarily consumed for FORTiS.
- Delay in validating the laser engraver due to the marking file not aligning as expected. To combat this issue the supplier had to be contacted who then instructed the team to place an XY offset into the marking file to eliminate the issue. This offset was thought to have been introduced through vibrations during transportation.
- Although the commissioning space around SAT was considered and factored into the Miskin layout, the initial drop of the machine and forklift turning space was not, and therefore the forklift did not have enough access to be able to drop SAT into the correct place and manoeuvre out, due to all the benches being in the way. To overcome this issue, the tape to scale benches had to be moved out of place temporarily. Luckily the tape to scale rig had not transferred at that stage so the need for revalidating wasn't required.
- The New Mills engineering team assisting in the commissioning of SAT detected a larger moisture reading in the incoming air before commencing the commissioning of the machine. They felt uncomfortable continuing to validation due to the air being required for the air bearing that moves the test carriage within SAT. The moisture within the incoming air was overlooked and not checked prior to transferring. Due to the accuracy and delicacy of the air bearing, an air filter was required to remove any moisture in the incoming air. This caused a delay on the commissioning of SAT as one of the engineers had to go out and purchase an appropriate filter from a store.
- Due to some of the above setbacks, the project did temporarily go off schedule and therefore risk delaying the startup date of production. To combat this, engineers from the transfer team came in on overtime and worked longer hours to get the project back on track for the scheduled startup date. This did have a cost impact on the project as overtime payments were not factored into the costings due to it initially not being required.

6.2 Commissioning, Validating & Starting Production

6.2.1 Commissioning/Validation Summary

To summarise, the commissioning & validation work on the rigs went really well. Every rig was assessed and calibrated to plan. Due to the SAJ and the SAT rigs being the most complex, the expertise of the New Mills NPI engineering team was required at a couple of stages. This was more so because it was the most involved the Miskin engineering team had been on the rigs, so questions that had not previously been asked were coming up just to confirm the correct process and process order was being followed. The Miskin team also discovered some mechanisms of the rigs which had not been considered as part of any maintenance schedules, so these were added to a schedule to improve the life expectancy and efficiencies of the rigs. During the validation of the laser engraver process, the Miskin engineering team also opted to move away from using physical standards and decided to include visual standards into the work instructions due to physical standards having the potential to get damaged.

6.2.2 Production Startup

Production were given the go ahead to start assembling at **9am on the 15th of May**, which is what was agreed on. The startup went smoothly as the rigs had been turned on, validated, and prepared for production use on Monday 15th May. The delayed start of 9am instead of a 6am was due to us wanting to carry out a cell walk with the section leader and lead ops/trainers to gather feedback on the transfer and ensure everyone was happy to commence production at Miskin. This was production's opportunity to raise issues or suggest additional improvements. Engineering also took the opportunity to reiterate the importance of product quality and communication, stating to production that if they notice something isn't right, for them to raise it immediately with engineering no matter how small.

6.2.3 Voice of the Customer

As with every project it is important to get feedback from your customers. In the case of this project the customers were production at Miskin but also the engineering team at New Mills who were handing the production process over.

Miskin lead operator feedback

Both lead operators who will be running the FORTiS system cell on a day to day basis were asked how they felt the transfer went and their responses can be seen below:

Lead Operators – “I thought that the move went pretty well, our training that was provided to us at New Mills was to a good standard and I felt like the Miskin engineering team supported any issues we mentioned promptly when we flagged them.”

Miskin production management feedback

Section Leader – “Communication was to a good standard throughout the transfer planning and execution period, and the Miskin engineering team did a great job of conducting the project successfully.”

Production Manager – “Overall summary from my point of view is that this transfer went well and met its initial deadline set, which is often rare with product line transfers. And seeing as this product line is newly developed and came from NPI, I am quite impressed the deadline didn't slip and everything ran so smoothly.”

New Mills Engineering team feedback

Senior Process Development Engineer and process owner at New Mills – “Really great working with the Miskin team. The team got to grips with the process quite quickly and were keen to get the ball rolling with transfer plans in the very early stages. The transfer went well, small issues were encountered along the way as always, but the transfer team worked really hard to overcome them and prevent them from effecting the date of the transfer. A really well planned and excellently executed transfer.”

7.0 Project Reflection

It is believed that the project as a whole went well. The transfer was completed on time and production were back running when they were scheduled to be, despite the small issues that occurred. The feedback for production and engineering staff at both the New Mills and Miskin sites were positive showing that collectively everyone was pleased with the way the project had gone.

Project Successes:

- None of the equipment was damaged upon transportation between sites.
- The layout accommodated everything comfortable as expected to visually on 2D CAD.
- Everyone within the team knew their roles and responsibilities and everyone was practising good communication throughout.
- Nobody was injured and there were no near misses reported.
- All departments including Works Engineering, IT and Production worked well alongside one another.
- The project stuck to the proposed timeline for most of the transfer despite a few delays towards the end.
- Fully optimised the layout in the allocated space given and reduced the non-value added time in the process by around half compared to what it was in New Mills.
- Feedback from all personnel involved was positive post transfer.
- Still managed to future proof the layout even after being given such limited floorspace.

Lessons Learnt:

- Larger lead times for production benches and racking were experienced causing the transfer team to have to temporarily borrow equipment from other departments. Luckily the amount required could be sourced, otherwise this would have severely impacted the project. The lead times should have been discussed with suppliers before the transfer timeline plan was proposed to allow the lead times to be accounted for in the plans.
- There was a small delay in validating the duplicated laser engraver due to its marking file not aligning as expected. This was believed to have been introduced during transportation. To prevent this from occurring the engraver could have potentially been packaged better for transit. Other than that, the transfer team handled this issue quite effectively by getting the supplier involved immediately to prevent large setbacks.
- Delivery space should always be considered along with commissioning space, this would have prevented the tape to scale benches from having to be moved to allow the forklift access to drop SAT into its correct location.
- The need for a specific moisture level within the incoming air to SAT was failed to be mentioned in the SAT transfer review meetings, therefore it comes down to a communication error from the New Mills engineering team. More specific questions will be asked on the phase 2 and 3 of the FORTiS transfer.

8.0 Conclusion

In conclusion, the transfer of the FORTiS production line from Renishaw New Mills site to the Miskin site was a great success despite encountering some minor setbacks. Although the project faced some challenges, the careful planning, proactive problem solving and collaborative efforts from the transfer team involved, led to the scheduled deadline being met.

The key factors that contributed to the success of this production line transfer were frequent communication, collaborative teamwork and in depth planning. The project team conducted a comprehensive analysis of the existing production line in New Mills and identified potential risks of transferring along with opportunities for process optimisation that could be actioned. With that data a detailed roadmap of how the team wanted the transfer to be carried out was created. This proactive approach along with regular meetings and progress updates ensured the transfer team was well prepared for the transfer to commence. The collaborative approach used fostered a sense of unity and teamwork, enabling the transfer team to overcome obstacles and collectively keep the project on track.

While the transfer was underway, the project did experience some minor setbacks. These setbacks ranged from unexpected supplier delivery delays to unforeseen technical issues with the laser engraver. However, the transfer team handled these issues promptly and were able to overcome them quick enough for them not to cause major project delays.

To conclude, although the transfer encountered some minor setbacks, the project can be deemed a success as the teams' dedication ensured that the deadline for production startup was met and there were no major delays in the project. By maintaining commitment to continuous improvement opportunities, the team was able to enhance the production lines productivity by optimising the process flow and cell layout to reduce non-value added time. Ultimately, the successful FORTiS production line transfer serves as a testament to the team's dedication and ability to adapt and overcome unforeseen issues to achieve the project goal.

9.0 Recommended further projects to improve the process

Short Term Actions – (Up to 6 months)

Carry out a 5S activity on each operation within the assembly process:

- Sort – Declutter each bench/operation of any unused equipment that is not mentioned in the work instructions used to build product to reduce the risk of error and confusion for operators.
- Set in Order – Ensure every tool or piece of equipment has a home/place to be returned to so that it reduces the likelihood of anything going missing.
- Shine – Clean the work area thoroughly to prevent the product from becoming contaminated and ensure the operator has a clean and pleasant space to work within.
- Standardise – Standardise equipment and work instructions as much as possible within the cell.
- Sustain – Set up regular production and engineering schedules to ensure the above tasks are stuck to and maintained regularly.

Long Term Actions – (Around 1-2 Years)

Six sigma DMAIC approach to the cell as a whole:

- Define the main issues causing a significant amount of CoQ every month to target.
- Measure how much these issues have cost the company to date and how much of an impact is has on the product, is it definitely scrap?
- Analysis the issue to find the root cause, is it a supplier issue, a jig issue or maybe it's an operator problem.
- Implement a solution to reduce/prevent the issue.
- Control the issue from increasing or reoccurring by putting suitable inspections and maintenance activities into the process.

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Appendix

To comply with Renishaw's confidentiality agreement mentioned at the top of this report, no official transfer or validation documentation could be shared in the Appendix below.

The project Gantt Chart can be found below in Figure 43a:



Gantt Chart.xlsx

Figure 43a – Gantt Chart

PDF of the new and improved FORTiS layout at Miskin can be seen below in Figure 43b:



FORTiS New
Layout.pdf

Figure 43b – New FORTiS Layout