British manufacturers unite to build ventilators for the NHS

As we all have experienced, the COVID-19 pandemic truly changed how we work, live, and communicate. However, back at the start of the year, no one could have predicted the wide-ranging effects the virus would have on our communities.

Emerging from these times are stories of people coming together to help. While we were socially distanced, we came together to support each other. Neighbours helped others get shopping. People moved to their doorsteps to clap for key workers. And an extraordinary group of British organisations came together to support the government and help produce critically needed ventilators.

Back in March, it became clear to the government what the true scale of the COVID-19 pandemic could look like in the UK. COVID-19 affects the lungs, requiring use of ventilators to help manage severely ill patients. At that time, there were only 5,900 ventilators available within the NHS. This was around 20,000 ventilators short in a worst-case scenario for the NHS. And at the time, the UK had no local manufacturing base for ICU ventilators. Global demand meant that importing ventilators through established overseas suppliers was unlikely. It was clear that to meet demand, it would require a national effort.

The UK government launched its 'call to arms' asking British industry to help produce critical ventilators.

An urgent government request

In a briefing to over 100 UK manufacturers, the government made a formal request for help to start producing ventilators to support the NHS. Dick Elsy, the CEO of the High Value Manufacturing Catapult offered to help co-ordinate industrial support. So, he started to make calls. Just three days after the briefing, a consortium of nine UK industrial, technology, and engineering businesses from the aerospace, automotive, motorsport, and medical sectors officially came together. This was the start of Ventilator Challenge UK consortium. By the end, it grew to include many more businesses.

> This consortium brings together some of the most innovative companies in the world. Every day, their highly skilled staff collaborate to create solutions that help millions of people, and this project is no different. They are working together with incredible determination and energy to scale up production of much-needed ventilators and combat a virus that is affecting people in many countries.

Dick Elsy, CEO, High Value Manufacturing Catapult

View video

Uniting with a common goal

Faced with a major challenge, these organisations, often competitors, all had a common goal:

To build at least 20 years' worth of ventilators in 12 weeks because every ventilator built has the potential to save a life.

This shared purpose saw all these companies, with incredible determination and energy, come together. Every ventilator built would have the potential to save a life. With the help of tools and technology to enable collaboration, the Ventilator Challenge UK consortium was able to work together both selflessly and effectively. Most importantly, when you work together with trust and openness, you can achieve amazing things.

Microsoft Teams

Consortium members used Microsoft Teams to meet and share information in a secure place across all the organisations.

It allowed them to share intellectual property while keeping it protected within channels. Members could easily chat, have meetings, and hold live training sessions across all the organisations remotely. Having had no prior experience with using Microsoft Teams the site was set up in a day and in little more than a weekend it had over 600 users using it as the main tool for collaboration across the consortium. Given that most of the users had no experience using Teams, this almost instant adoption would not have been possible had it not been such a user-friendly and multi-functional platform.

> “It's astounding to think that for several weeks of the ventilator project many of us had not met face-to-face and only over the virtual medium of Microsoft Teams. It's been a rapid education in how it can make our teams more effective and efficient and we see the positive impact it can have on our businesses going forward.”
>
> **Mark Mathieson**, Lead Partner Technology Services, McLaren Racing

Two ventilators, two programmes

Led by a coalition of leaders from the principal businesses, the consortium met regularly via video call, often day and night. This helped them stay aligned, coordinated, and laser-focussed on their objective.

They decided to support existing manufacturers to rapidly scale up the manufacture of existing ventilators as this would allow them to produce more ventilators quickly.

The Smiths paraPAC plus™ ventilator was tried and tested, but to scale-up UK production to the level needed to support the NHS and Government in the timeframe required, extra capacity was needed.

By the end of March, the government confirmed initial orders for both the Penlon and Smiths devices

The consortium was also approached by the government to similarly mobilise around a ventilator concept from Penlon. The Penlon ESO 2 Emergency Ventilator modified existing proven clinical equipment, and rapidly became the clinician's number one choice as an Emergency Ventilator for the treatment of COVID-19 patients in an expanded intensive care setting.

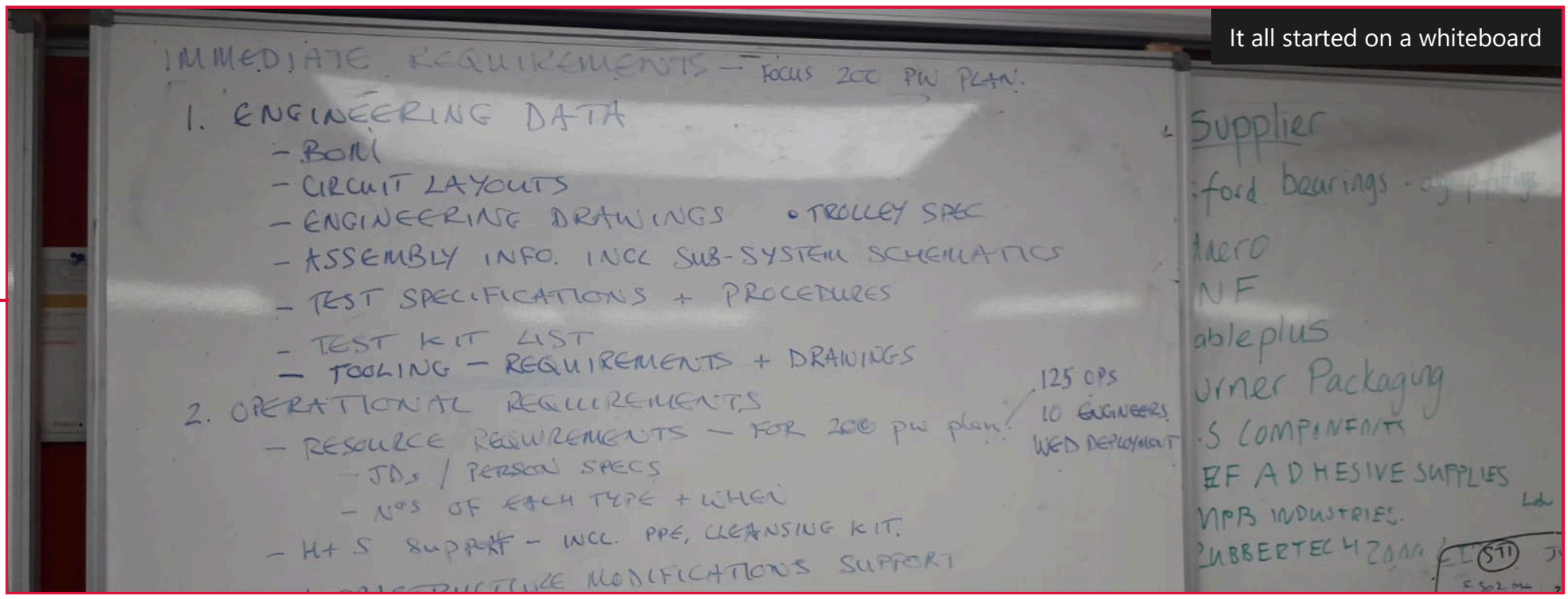
To work most efficiently two separate programmes were set up. Ford took the project management lead on the Penlon programme and Smiths established contracts with GKN Aerospace and Rolls-Royce to help deliver their programme.

Penlon was making only 12 devices a week and the scale of the challenge to produce 2,500 a week required a massive multi-business undertaking. A new Penlon consortium was formed as the delivery mechanism and our story follows this in more detail.

Going from years and months to hours and days

To get access to the design drawings and intellectual property from Penlon, and to enable open collaboration, Non-Disclosure Agreements (NDAs) had to be signed by all parties. This could have taken weeks in normal circumstances, but all NDAs were signed in a matter of hours. This allowed the teams to start to get down to the details and understand the true scale of the challenge.

Within days, the teams had started to analyse the designs and parts list. The scale of the programme presented a range of complex and time sensitive issues including standing up a supply chain and a complex logistics network at a time when countries were starting to lock down borders and access to suppliers was becoming increasingly difficult. It was also clear that the massive challenge to build thousands of ventilators in a matter of weeks would not be possible in the existing manufacturing facilities at Penlon and further sites would need to be set up.



It all started on a whiteboard

All this was possible because everyone had the same core mission and were driven by the same goal - to help supply our NHS. When done collaboratively, there was a shared sense of achievement for every milestone reached. Bringing so many organisations and people together brings its own challenges.

Securing regulatory approval

Adherence to the medical regulatory requirements was a fundamental part of this programme. The Penlon ESO 2 is an intricate and highly complex piece of equipment with 700 parts. Any medical device in the UK needs to be approved for use by an accredited notified body. However, in this crisis situation, a special dispensation can be requested for

emergency devices such as the Penlon ESO 2, which then has to be approved for use by the UK Competent Authority Medicines and Healthcare Products Regulatory Agency (MHRA).

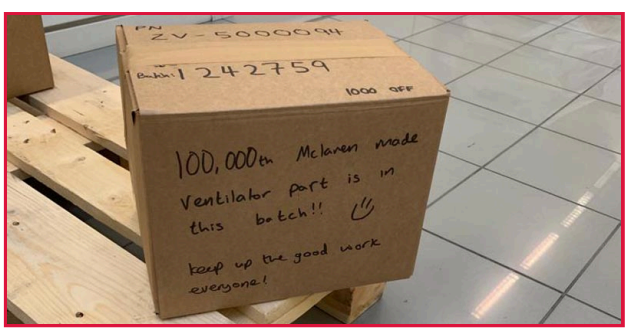
The Penlon ESO 2 achieved full approval three weeks after the consortium pitched the idea to the government, NHS and MHRA.

To put that into context, approvals normally take up to 270 days.

Building a supply chain for a complex system

Over 15 million parts were acquired from 88 suppliers worldwide in four weeks through a complex logistics network. Many parts had two, three, four or even five suppliers out of necessity to meet the rate required and to ensure there was always a back-up plan.

McLaren managed the supply chain, deploying engineering, project management, purchasing, logistics and manufacturing teams. They worked with around 100 suppliers and deployed their own machine shop and inspection capacity to support the work whilst coordinating input from other UK-based Formula 1 teams. McLaren itself produced over 70,000 complex parts with zero defects in five weeks to fill gaps in the supply chain.



Microsoft Dynamics 365

Microsoft Dynamics 365 Supply Chain Management including Procure 2 Pay was launched for the consortium in three weeks, instead of the usual 12 months. This enabled them to order parts and oversee the whole process through to the manufacture and assembly of the finished product, allowing them to respond to changing needs quickly and effectively. Power BI was also used to give the consortium information reports including work in progress, supply chain, and logistics.

> “Microsoft's technology has been a significant tool in making a project of this size simple to handle and manage.”
>
> **Guru Krishnamoorthy**, CEO, Penlon

Built to support now and in the future

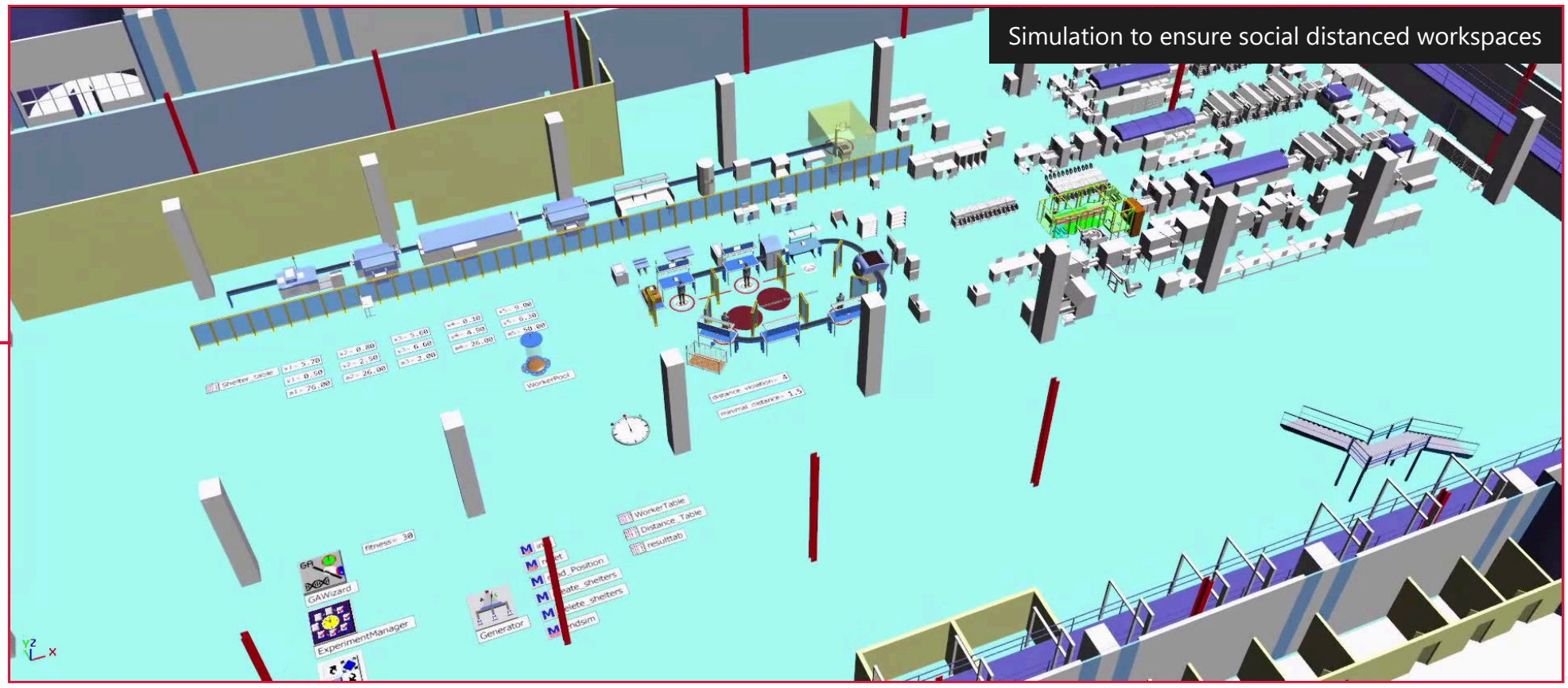
Penlon maintains an accredited Quality Management Systems and, in partnership with Siemens Healthineers and others, was able to bring over 100 new suppliers into its approved supply chain through desk top assessments, audits, and site visits. A huge effort was also needed to qualify the partnering sites of Airbus, McLaren, Ford, STI, and DHL with all facilities and processes needing auditing before production ramp up could commence.

The joint quality teams worked very closely together in the delivery of training, alignment of production processes, inspection, documentation, digital aids, supplier quality, and the legality of the device history records that accompany every Penlon ESO 2 ventilator; ensuring a single voice to assist in the quality message and drive consistency.

After 190 document submissions, opening test laboratories that were closed, stretching their technical and regulatory competencies, together with an immense level of technical scrutiny by MHRA and notified body; Penlon received its internationally recognised CE Certificate. It is believed that this is the first time a product that changed its intended use (from anaesthesia device to ventilator) has achieved a CE marking and is the quickest that one has been achieved. This permits the Penlon ESO 2 ventilators to continue in service post-COVID-19 for the expected lifetime of the device.

How do you train 3,500 people?

Not only did the teams involved have a significant knowledge gap to overcome to assemble these lifesaving devices, but they faced the added complexity of recruiting and training over 3,500 people under new and challenging workplace guidelines set by the government.



Simulation to ensure social distanced workspaces

[View video]

The knowledge, understanding and years of experience gained by Penlon in manufacturing these devices had to be passed on to all the operators who build, calibrate, and test the ventilator control systems with the same degree of quality and consistency. This required compressing the timeline for the selection, training, and deployment of operators from what would normally take several months to a few days. At Ford alone, the sub-assembly plant inducted over 850 people and completed over 18,000 hours of training (that's over two years of training) in seven weeks.

Building ventilators with the HoloLens 2

[View video]

Microsoft HoloLens 2

How do you train 3,500 people? By using Microsoft HoloLens 2 and mixed reality. Balancing the twin imperatives of speed of delivery with the absolute adherence to regulatory standards that is needed to ensure patient safety, the HoloLens 2 were used to train the teams quickly and safely without close-contact assistance. This allowed expertise from Penlon to be shared with sites up and down the country as they worked to assemble, and test ventilators for the first time.

Not only did it accelerate training, but it allowed employees to get help and guidance by connecting with remotely located technical experts. This minimised unnecessary travel and the risk of social contact, particularly as several technical specialists were required to shield at home.

100 HoloLens 2s were configured to help train and remote assist technicians building ventilator parts.

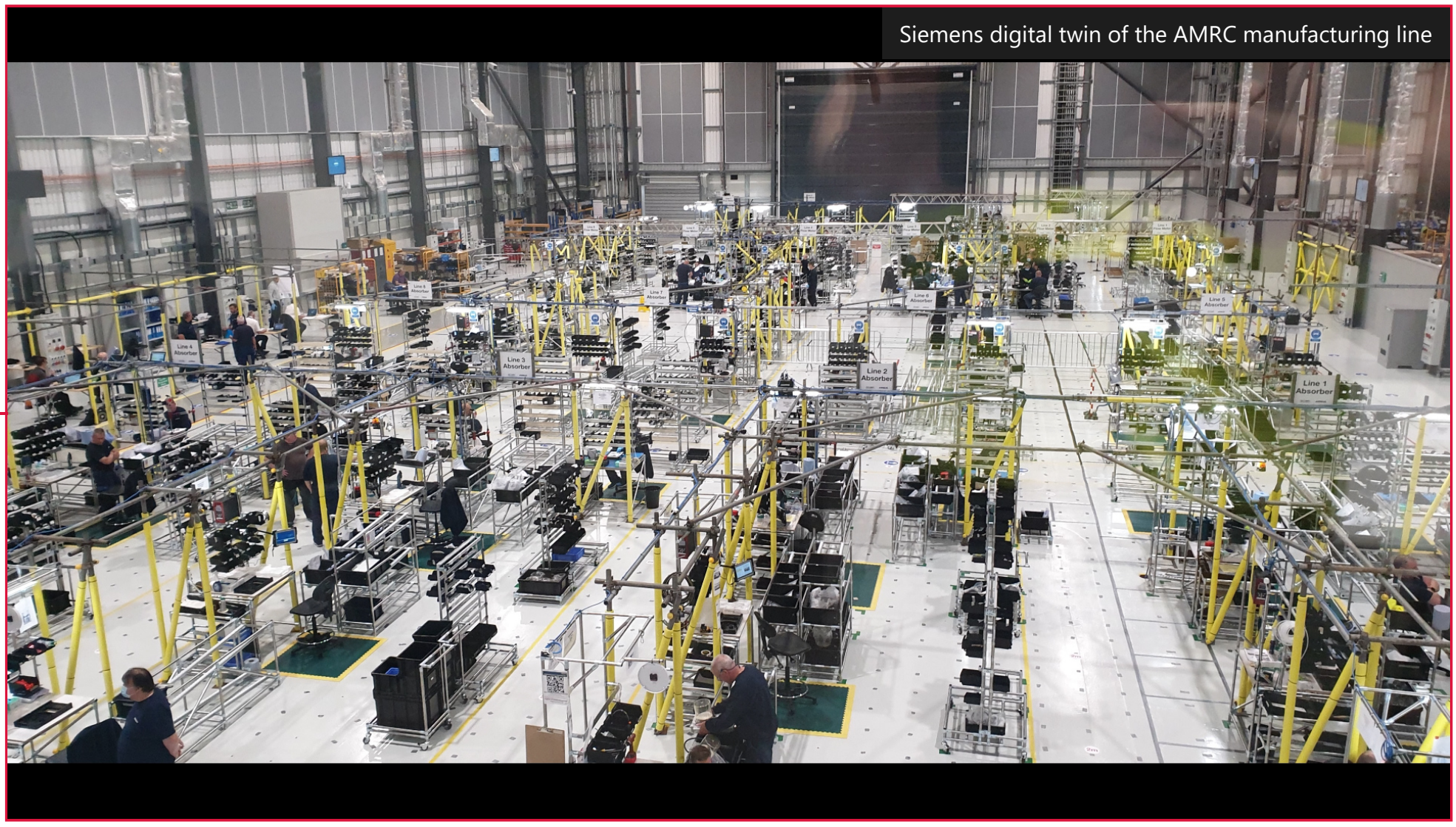
> “Microsoft's mixed reality headset has been used to capture the highly specialised ventilator production process to train and upskill the consortium's new workforce in multiple manufacturing sites across the UK - many of whom have been brought in overnight and are used to manufacturing aerospace and automobile parts. A step by step guide has been added to training footage captured on HoloLens 2 for workers to use across the country as they build replica assembly lines from scratch and begin production.”
>
> **Dick Elsy**, CEO, High Value Manufacturing Catapult

Unifying across the country

Once the supply chain was created, the Penlon ESO 2 was broken down into four sub-assemblies that were scaled up at various sites across the country before being brought back together into a final assembly.

Airbus was responsible for producing and assembling the absorber and flow meter sub-assemblies of the Penlon ESO 2 ventilator.

Working with Siemens, they used a digital twin approach to design the new Production Systems remotely without sight of the physical product or plan. Manufacturing lines were designed, validated, and delivered within three weeks. Normally, this takes between 12 months to three years.



Siemens digital twin of the AMRC manufacturing line

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550 Airbus employees worked across shifts to enable round the clock working, some changing their day to day activities from repairing and inspecting aircraft in Singapore to building ventilators for the NHS in north Wales.

Even the local community got involved, with hardware stores staying open late for the teams to pick up basic tools, to engineering firms coming in on a weekend to support.

Airbus produced the absorber and flow meter sub-assemblies of the Penlon ESO 2 ventilator

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At the Ford factory, over 10,000 hours of manufacturing engineering in two weeks allowed them to transform a building at their Dagenham Engine Plant into a sub-assembly production site manufacturing the AVS vent box and remote display screen for the Penlon ESO 2.

Ford transformed their factory to produce sub-assemblies for the ventilator

View video

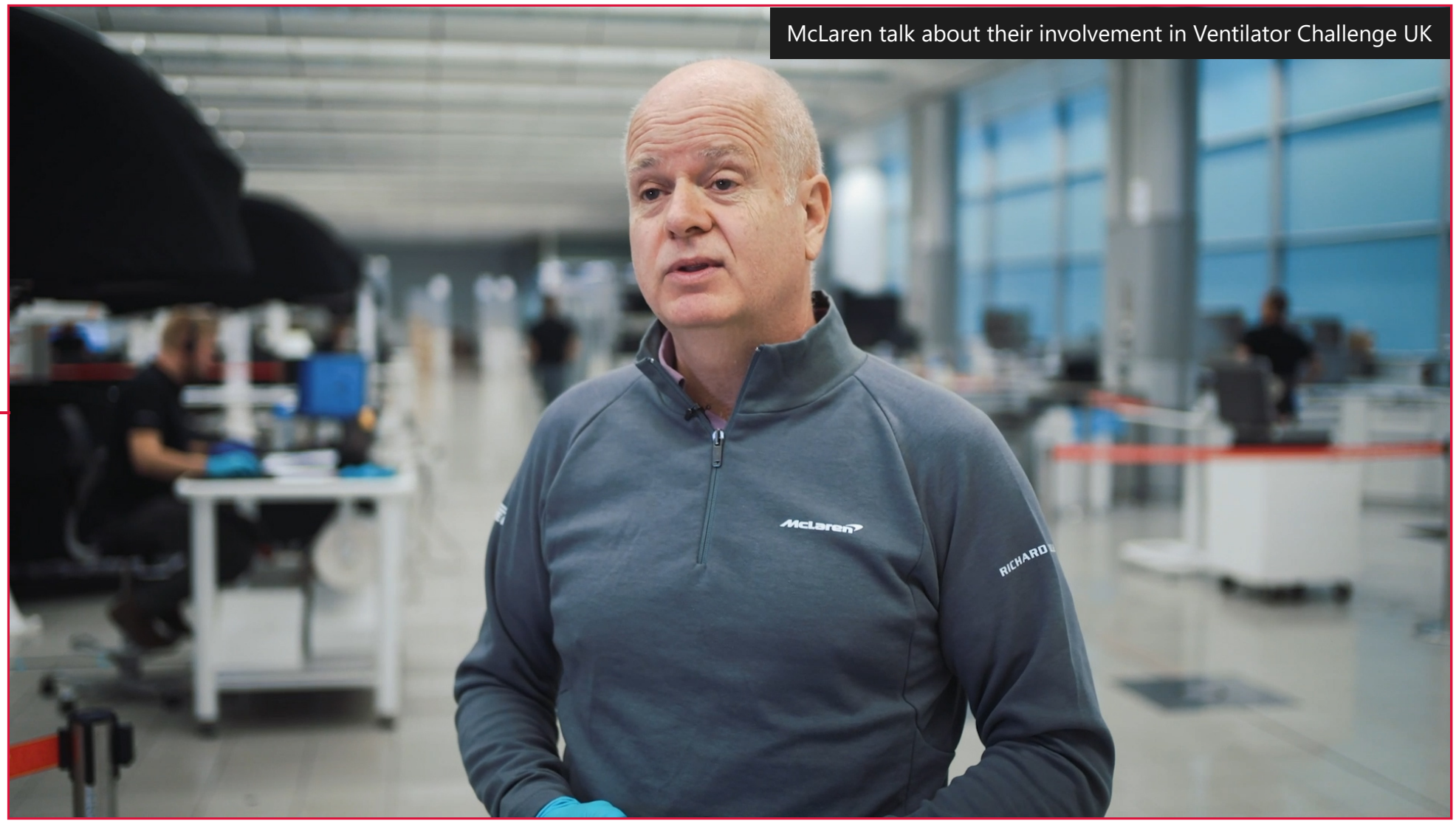
650 Ford employees worked together across 190 individual workstations in a social distanced production line over three shifts a day, before sending the sub-assemblies to STI.

Ford sends sub-assembly parts to STI, with love

McLaren transformed their trophy and F1 car-filled factory into a facility to design and produce bespoke trolleys on which the ventilators are fixed, and which are suitable for use in clinical settings.

McLaren built 250 ventilator trolleys a day

They used their design and engineering expertise in lightweight, user-friendly design to develop a solution that was quickly scaled to allow them to produce 250 trolleys a day.



McLaren talk about their involvement in Ventilator Challenge UK

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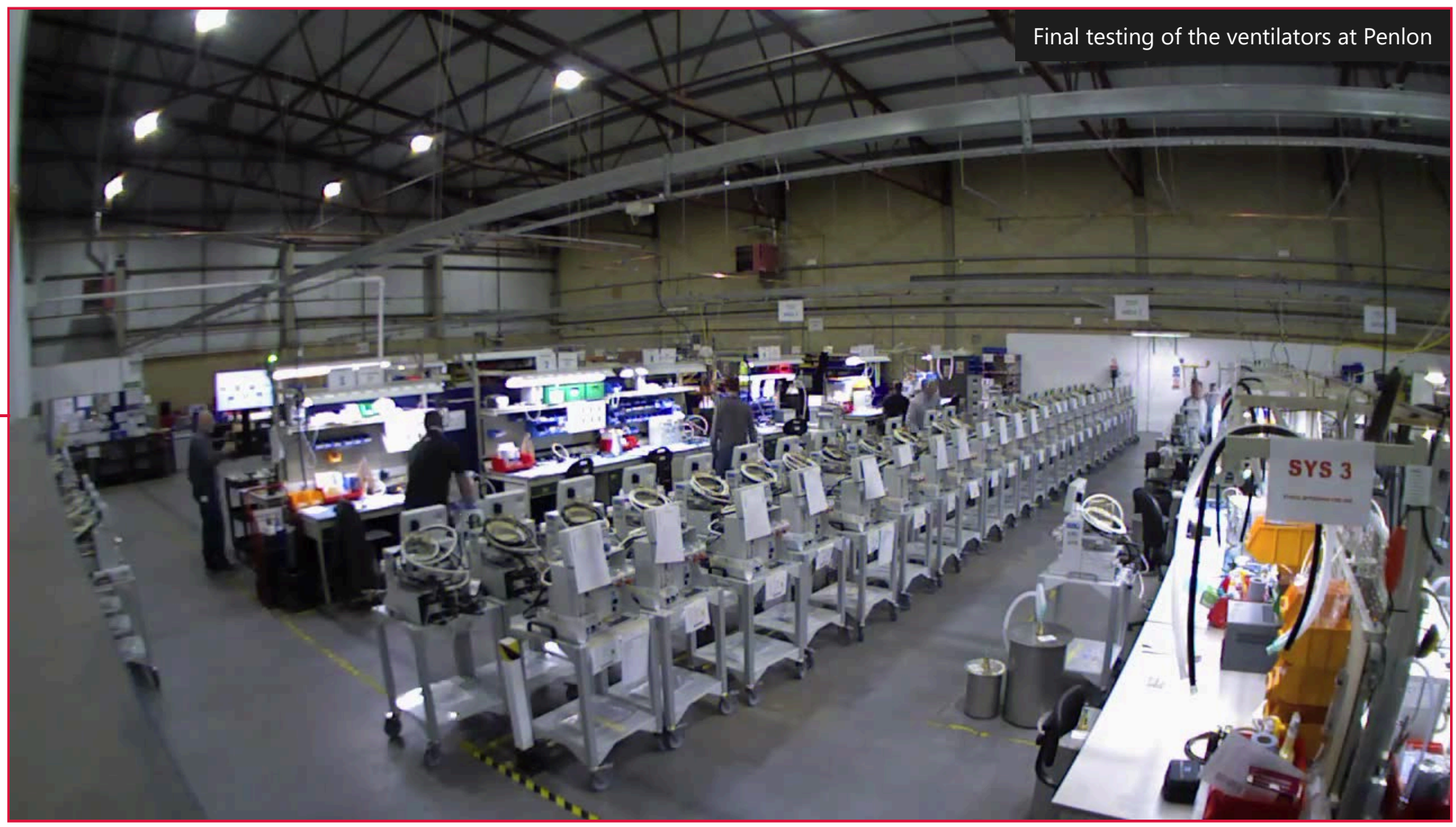
The trolley, AVS vent box, absorber, and flow meter sub-assemblies from McLaren, Ford, and Airbus are then sent to Surface Technology International (STI) where 130 specially trained staff assembled the parts into the final product. To facilitate this project STI took on and trained 70 additional staff, including friends and family of STI employees as well as people from the local area.

A ventilator is completed every 88 seconds.

STI with assembled ventilators

The final ventilator then went to Penlon. Previously, they would produce the whole ventilator but here, their role became to perform final testing and product release. The whole Abingdon factory, as well as a second site of 60 people at GKN Automotive, was converted into final test stations.



Final testing of the ventilators at Penlon

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Penlon went from 55 people working in production to 550 people, including the UK F1 teams, working over six shifts. Once approved, the ventilators were then shipped on to the NHS to help them treat patients.

First shipment of ventilators from Penlon

Penlon's range of medical device equipment, which they normally export 95 percent of, was all put to one side so that they could focus exclusively on the Penlon ESO 2 for the NHS.

Last shipment of ventilators from Penlon

Continued support for the NHS

Once a ventilator reaches the NHS, it doesn't just stop there. Inspiration Healthcare expanded their 24/7 service to include all ventilators produced by the consortium. Trained by experts at Penlon, they were able to provide bedside support for doctors and nurses needing guidance on the machines when in use on critical care patients.

What happens when we unite

Building thousands of ventilators was a compelling purpose that intrinsically appealed to each consortium member. This was a challenge beyond what they had done before - and there was no book on this.

This powerful motive pushed a team who self-organised around the task. People were picked for their skills and passions, with a flat workstream structure. There were no badges or hierarchy - results always trumped stripes and the team worked cohesively.

Decisions were made at the point of greatest knowledge, using openly accessible data, which in turn drove agile processes. Processes and product were produced in parallel. With well managed communications and project boundaries, the team was kept autonomous.

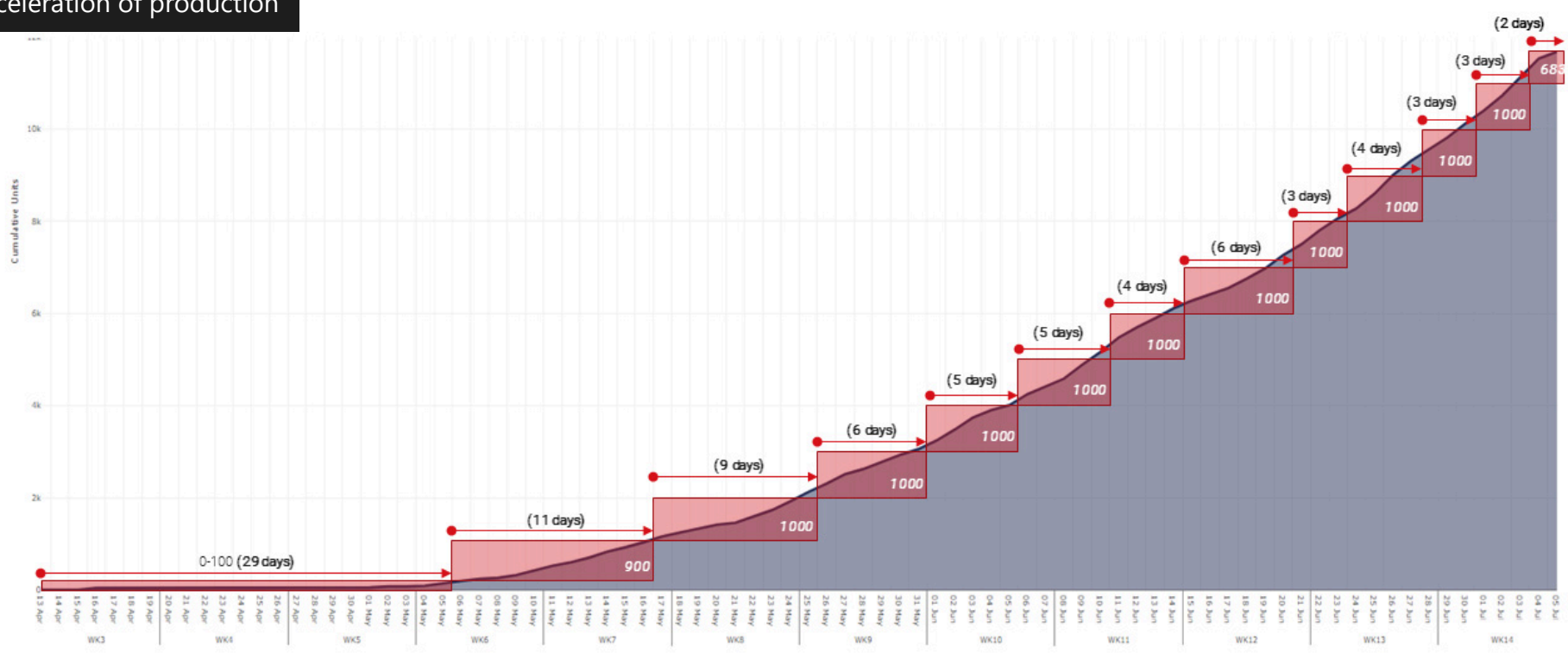
With this built trust, everyone was empowered to go beyond a can-do attitude to a will-do attitude. The focus was on output, with the acceptance that this extraordinary circumstance meant that the normal 9-5 workday wouldn't work. This inspirational culture spread to every corner of the consortium driving a deep common bond between people, many who had not actually met each other.

At full scale up the consortium was producing around 320 ventilators per day

Ventilator Challenge UK just proves that when humans come together, they can solve a problem - no matter the risk. When you combine trust, openness, selfless teamwork, with inspiring people, and the great British 'will-do' attitude, you can achieve the impossible.

The acceleration of production was exponential as teams gained knowledge and solved issues. The first 100 devices took four weeks to build, the final 1,000 took 2.4 days. By the end of the programme, production was ~150 times quicker than previously achieved in Penlon. Penlon would ordinarily have been producing about 50 ventilators per month.

Acceleration of production



The consortium produced a total of 13,437 ventilators in this period.

> Ensuring the NHS has enough ventilators to treat patients with advanced COVID-19 symptoms has been critical to the UK's continued battle against the disease. Microsoft and its partners have been instrumental in providing the tools that have enabled the Ventilator Challenge UK consortium members to collaborate effectively, manage complex supply chains and train staff in new manufacturing procedures. In doing so, we've been able to gear up to manufacture 20 years' worth of ventilators in just 12 weeks.

Dick Elsy, CEO, High Value Manufacturing Catapult

View video

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Consortium members

Discover how some of our Ventilator Challenge UK consortium members and suppliers contributed to the challenge.

accenture

aerospace

AIRBUS

AMRC ADVANCED MANUFACTURING RESEARCH CENTRE / The University Of Sheffield.

Anomalous

ARROW

AUTODESK

avanade

CMC Precision Engineering

Content + Cloud

DELL Technologies

DHL

DIRECT HIRE & SCAFFOLDING LTD

DS Smith

ESSENTRA COMPONENTS

Ford

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Inspiration HEALTHCARE

INTERSURGICAL COMPLETE RESPIRATORY SYSTEMS

McLaren

MEGGITT

AMG PETRONAS FORMULA ONE TEAM

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