



5GTT Connected Cowes Project

FINAL REPORT

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1 EXECUTIVE SUMMARY

As part of the DCMS 5G Testbed and Trials programme, the Connected Cowes project set out to build a new 5G network covering the waters of the Solent and - using the world-famous Cowes Week sailing regatta as a testbed - evaluate ways in which 5G-based technologies could significantly enhance the delivery of spectator experiences at non-stadium sporting events, build new revenue streams and support the creation of innovative education resources.

Among the project's successes having measurable benefit were:

- Completion of the initial phase of a Solent-area 5G network, providing the basis for further development to support the world-famous Cowes Week regatta and deliver lasting value to the wider Solent maritime sector.
- New Cowes Week App and TV production assets developed which leveraged the power of 5G to bring ground-breaking facilities such as remote cameras, onboard 360° cameras and sensors and virtual reality viewing to the Cowes Week regatta, significantly improving the event experience for both local and remote spectators and generating a high level of interest among potential sponsors and commercial partners.
- Development of a novel 5G-enabled 360° camera solution, which has considerable commercial potential beyond the project for both sailing and other non-stadium sports and all-weather activities.
- New national-curriculum-aligned STEM education resources for Key Stages 3 and 4 (11-16 years) delivered to bring alive the science of sailing through unique content enabled by the project's 5G technologies.

Key lessons learnt from the project included:

- The difficulties encountered by Connected Cowes with the deployment of UK-sourced 5G equipment suggests that there is work still to be done on realising the targets of the 5G Supply Chain Diversification Strategy and reducing dependence on established telecoms suppliers such as Nokia and Ericsson.
- Ofcom spectrum licenses and wayleaves for mast installations took far longer to acquire than anticipated.
- VR headsets coupled with 5G-enabled 360° cameras have significant potential to dramatically change the way spectators and fans consume sporting content, particularly for non-stadium events. However, current consumer and prosumer camera devices are largely unsuitable for all-day, all-weather, autonomous operation, while the unforgiving nature of VR headsets demands a high-quality, high-bandwidth source. These factors together mean that a custom solution is required to realise the full potential of this immersive content - especially in a live environment.

2 INTRODUCTION AND OBJECTIVES

As part of the DCMS 5G Testbed and Trials programme, the Connected Cowes project set out to build a new 5G network covering the Solent waters and to evaluate the ways in which 5G-based technologies could significantly enhance the delivery of spectator experiences at non-stadium sporting events.

Using the world-famous Cowes Week sailing regatta as its base, the project encompassed three key exemplars to analyse the benefits of 5G:

1. Enhancing the accessibility and appeal of the sport of sailing to a wider and younger audience through 5G-based technologies, enabling virtual reality and immersive TV and App-based facilities for spectators both at the event and online.
2. Deploying 5G technologies to enhance the delivery and value of the Cowes event for a wider group of stakeholders (for example, organisers, sponsors, local community, competitors) and developing initiatives for the extension of these benefits to other non-stadium events.
3. Creation of national-curriculum-aligned STEM education resources and interactive experiences for Key Stages 3 and 4 (11-16 years), which bring alive the science of sailing through unique content enabled by 5G technologies and promote understanding of the 5G network itself.

The project brought together the combined resources and experiences of three organisations:



Cowes Week Limited, the organisation responsible for running the Cowes Week regatta and who would create and deliver the new spectator and stakeholder facilities at its event.



aq Limited, the telecommunications company and 5G provider, who would deliver the cross-Solent 5G network and build on-board 360° camera and sensor kits to deploy on boats competing in the Cowes Week event.



1851 Trust, the innovative education charity, with responsibility for developing and delivering the education resources associated with the project.

The key objectives of the Connected Cowes project were to:

- Build valuable insight into the unique challenges of deploying 5G technologies over water and optimising the delivery of content for a disparate audience.
- Evaluate how 5G could enhance the spectator experience for sailing and other non-stadium sports (motorsports, eventing, cycling, running etc).

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- Assess the impact of 5G technologies on improving the accessibility of sailing and related non-stadium sports.
 - Evaluate the ways in which 5G technologies could bring added value for event sponsors, race crews and the local and regional communities around the Solent.
 - Explore the opportunities that 5G provides in unlocking new immersive learning experiences for young people.

The project ran from January 2021 to March 2022 and was split into two phases: an initial phase of development and deployment in readiness for the Cowes Week 2021 regatta in August 2021, and a second follow-up phase, using lessons learnt from the event to build out the full 5G network and perform further end-user evaluation in preparation for the post-project 2022 Cowes Week regatta.

3 PROJECT APPROACH

3.1 Key components

The key deliverables for the project were as follows:

- A local 5G network covering the main Solent area, providing granular edge-routing, high bandwidth and low latency communications.
- Onboard equipment rigs for racing boats consisting of a 360° camera and telemetry sensor, providing live VR video feeds and contextual position and performance data via the 5G network.
- A new Cowes Week dedicated smartphone App, available to all spectators and competitors and featuring 5G-enabled live content.
- TV outside broadcast facilities to provide coverage of the Cowes Week regatta via 5G-enabled content, with live streaming and highlights package production.
- Online Virtual Reality headset facilities to provide immersive 360° experiences of the live and pre-recorded action.
- 1851 Trust digital education platform to promote 5G-related education experiences to young people and teachers.

These technologies and the approach used for the components are described in further detail below.

3.1.1 Local 5G network

Mast sites for the 5G network were chosen to give good coverage of the central Solent area where the majority of racing at Cowes Week takes place, as follows:

- Royal Yacht Squadron (RYS), Cowes
- Royal London Yacht Club (RLYC), Cowes
- Lee-on-Solent Sailing Club
- Calshot Spit
- Lepe Country Park

Each antenna site was designed to have two or three sectors covering the 1800Mhz and 3.8-4.2Ghz spectrums, all operating at medium power and an initial deployment at 20Mhz bandwidth, with a target 100Mhz bandwidth reached during the project lifetime.

Backhaul to aql's 5G mobile core was designed around a primary 10Gb fibre link at the RYS site in Cowes, with all other sites connected to Cowes via 10Gbps mmWave links.

Configuration of the network was optimised to favour the uplink bandwidth necessary to support onboard camera and sensor feeds, with targets of 30Mbps upload speed and 100Mbps download speed, and latencies of <10ms towards edge handoff and <30ms towards the mobile core.

The masts sites and Phase 1 and Phase 2 coverage plans are shown in Figures 1 and 2.

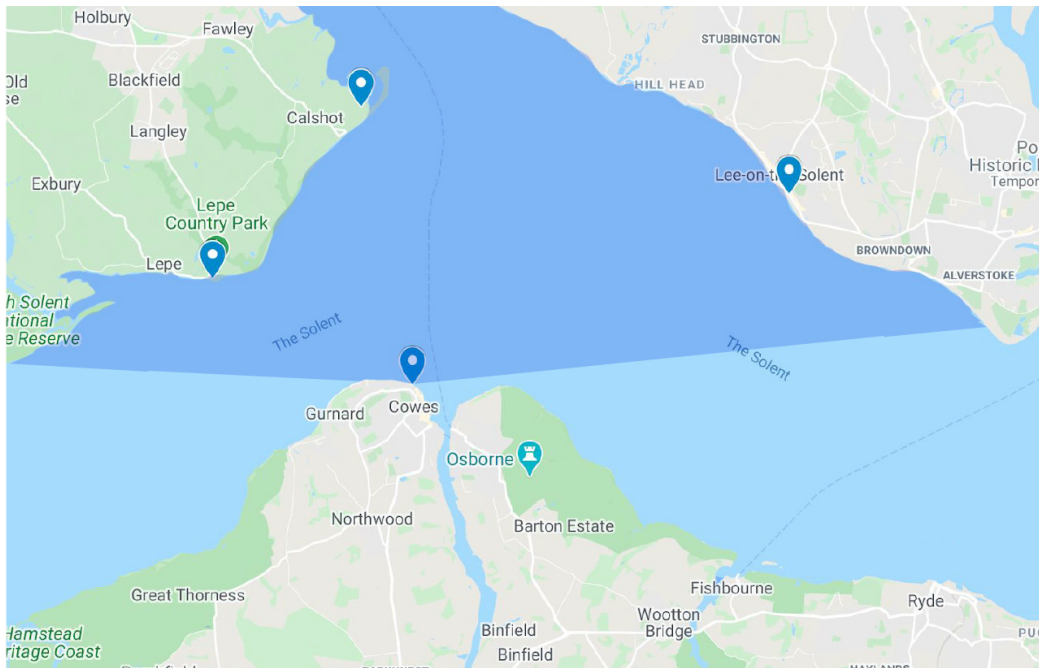


Figure 1 - Phase 1 coverage (Coves Week 2021)

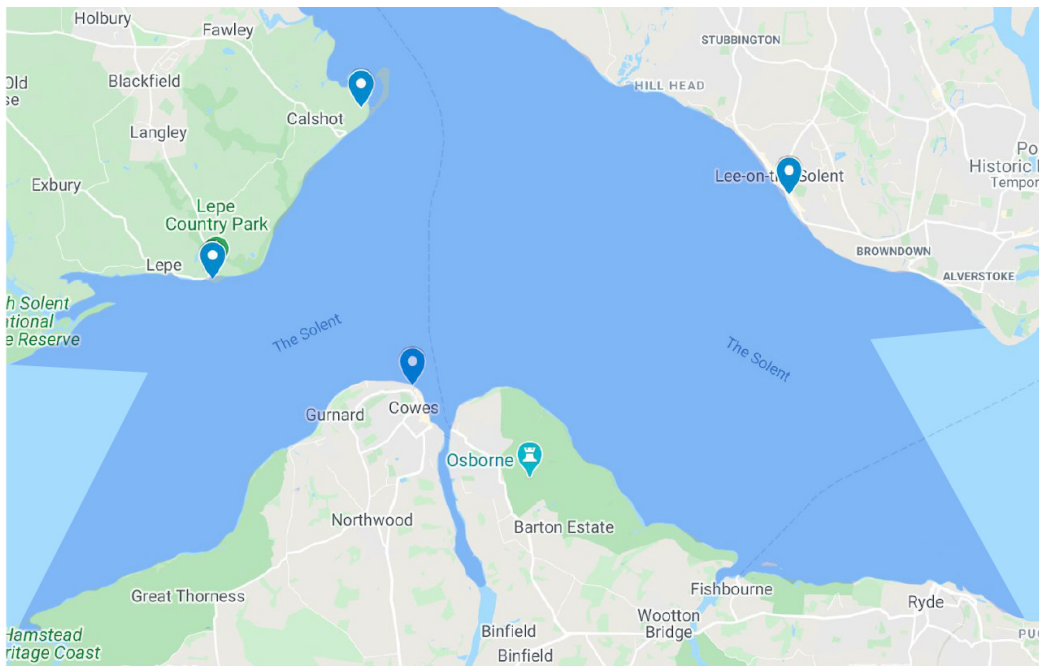


Figure 2 - Phase 2 coverage (End of project)

3.1.2 Onboard equipment

A flexible onboard equipment rig was designed for fitting on up to 50 racing yachts and comprised the following components:

- Ricoh Theta V camera with waterproof enclosure, providing a live 360° camera feed from a suitable location on the boat.
- IoT sensor board connected to the boat's existing NMEA 2000 data bus, to provide telemetry and position data.
- Netgear MR5200 5G modem, to provide connection to the 5G network and upstream link to store and forward video and data servers.

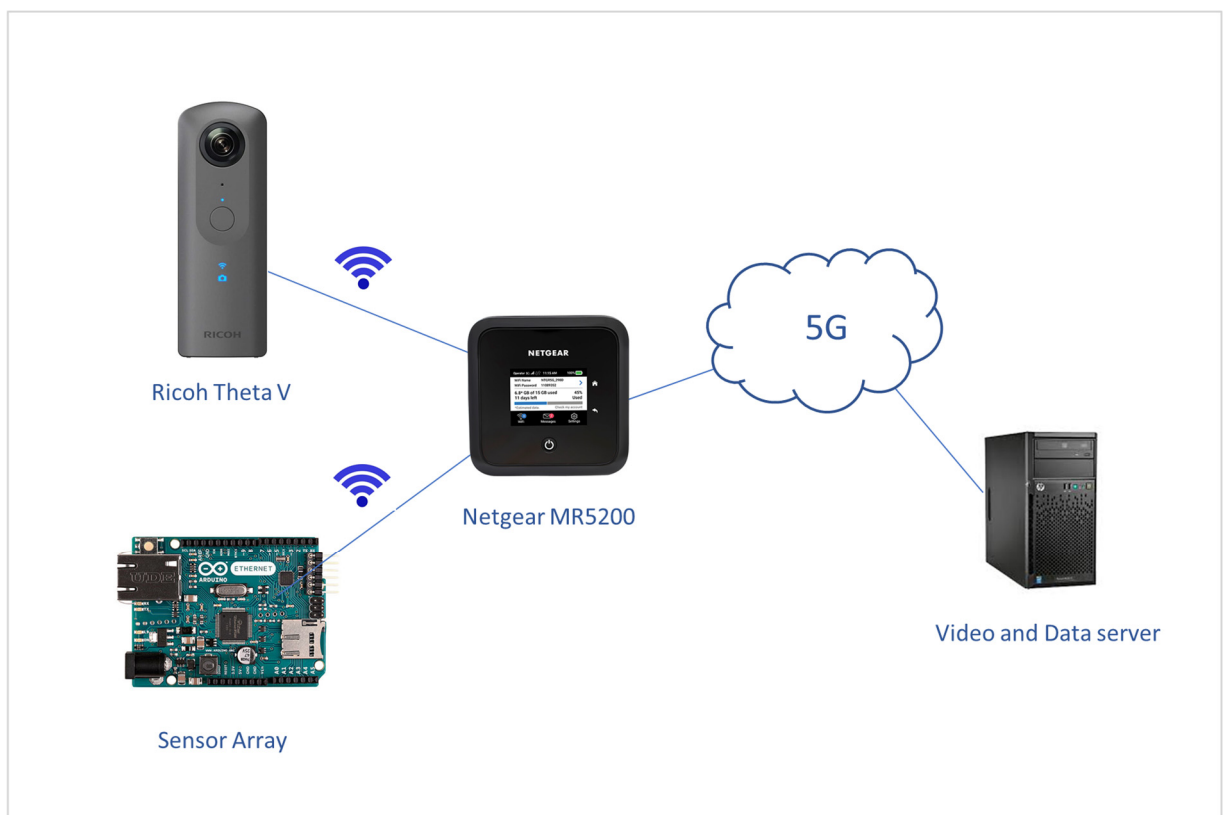


Figure 3 - Onboard camera, sensor and 5G modem

Following on-water testing and experiences at the Cowes Week regatta, the rig was modified to include an upgraded Ricoh Theta Z1 camera, an improved waterproof enclosure, waterproof power pack and a control unit for local recording and camera control.

3.1.3 Cowes Week App

A dedicated spectator/competitor smartphone App was designed and built for the Cowes Week 2021 regatta. As well as providing comprehensive news, weather and information about the racing programme and shoreside facilities, the App also featured live streaming of the TV programming and the ability to view any of the available 5G-enabled 360° cameras, with an on-screen steerable view of each feed.

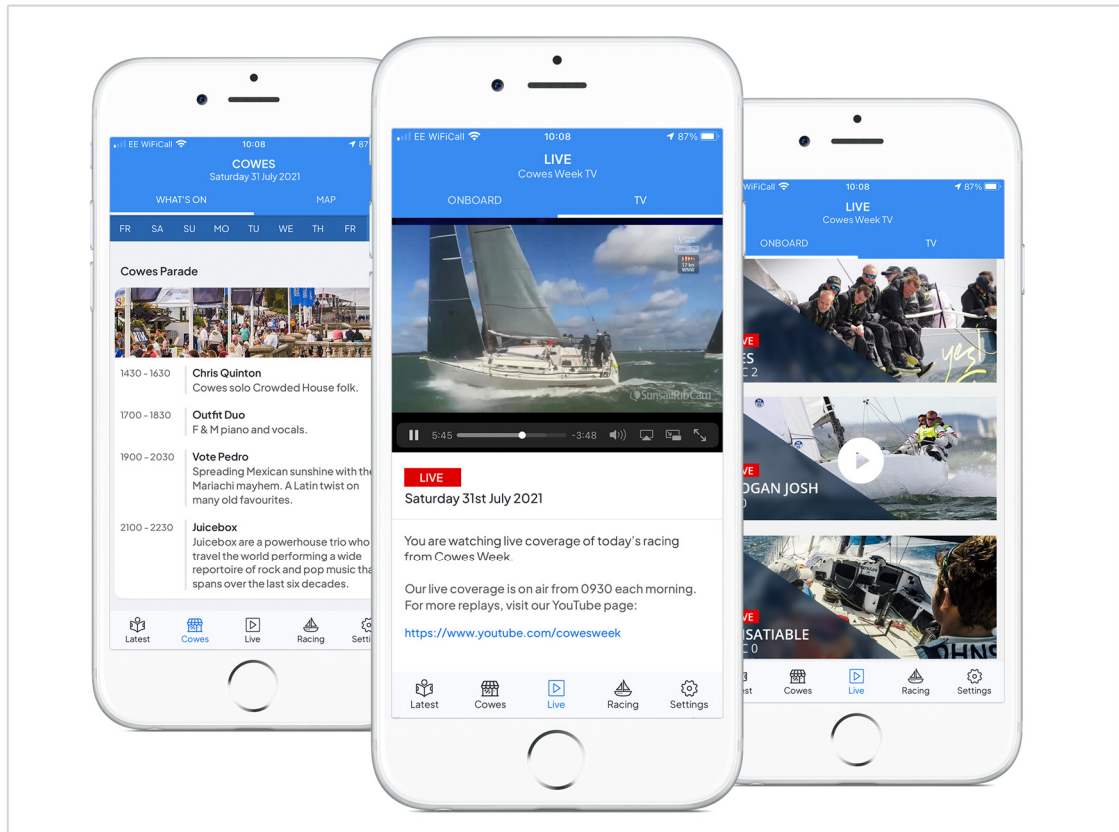


Figure 4 - Cowes Week App

To simplify the deployment of in-app 360° viewing, the App was designed to use the YouTube platform for the camera feeds and the built-in equirectangular format support within the YouTube mobile player to deliver the live content.

3.1.4 Cowes Week TV production

Temporary outside broadcast facilities were set up to provide up to four hours of live coverage each day of the Cowes Week regatta from the main start/finish line at the Royal Yacht Squadron. A production studio was created with the Regatta headquarters building, and conventional shore-based cameras and commentary team were complemented by the following 5G-enabled facilities:

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- DJI Mavic 3 camera drone, flown from a chase boat and connected to the studio via the 5G network.
 - Several chase boat handheld and stabilised cameras, also connected to the studio via the 5G network.
 - Ability to receive any 360° live camera feed, via 5G, with studio steerable control and conversion to a 2D picture.

Extensive on-water use was made of 5G-enabled LiveU equipment to provide high upload bandwidth and resilience using multiple bonded SIMs.

The live broadcasts were streamed online via the event's official website as well as YouTube, Facebook Live and the Cowes Week App. In Cowes, the broadcasts were shown on several big screens at key spectator locations and on smaller screens situated in Clubs and pubs within the town.



Figure 5 - Big Screen, Cowes Parade

3.1.5 VR facilities

To provide a fully immersive experience for spectators, the project made use of the YouTube VR platform to extend the available 360° camera feeds to VR headsets (such as the popular Oculus Quest 2).

The original intention was to have publicly available VR headsets for people to use during the regatta, but the necessary hygiene and distancing restrictions caused by the COVID-19 pandemic meant that this was not practical or safe to implement.

3.1.6 *Digital Education Platform*

Education deliverables were based around three key STEM learning areas in the Key Stage 3 & 4 curriculum:

- **Thermoregulation learning module** for the Biology national curriculum, covering the methods the body uses for thermoregulation, how energy is transferred via evaporative cooling and how different clothing helps the body respond to temperature, all seen through the eyes of a Cowes Week skipper and his or her crew.
- **Bearings leaning module** for the Maths national curriculum, covering how to calculate and write a bearing, how bearings and distances between waypoints are critical to navigation, and how these elements come together in setting and sailing courses at Cowes Week.
- **Data Handling learning module** for the Maths national curriculum, covering tally charts, frequency tables, complex data plotting and display, circles, sectors and arcs, and their collective use as building blocks in the design of the Connected Cowes 5G physical network.

Lesson plans and classroom resources were created for each module and made available to schools across the UK via the STEM Crew website. A pop-up Education Experience Centre was also provided at the Cowes Week 2021 regatta, showcasing the learning modules with experiments, challenges and VR experiences.

3.2 **Project use cases**

3.2.1 *Local spectator experience*

Over 100,000 people visit Cowes to attend the world-famous Cowes Week regatta each year and the event remains a popular social and sporting fixture. However, much of the sailing action takes place on the Solent away from the town, which limits the engagement that local spectators have with the regatta and with those taking part (a not uncommon challenge for all non-stadium sports).

The basis for the local spectator experience use case was to use ground-breaking 5G-based technologies - including live 360° cameras on race boats, drones, on-water cameras, telemetry sensors and VR headsets - to significantly enhance the engagement with the regatta. By making new content available to spectators on big screens and a mobile App, the aspiration was to bring a step-change in accessibility and improve the appeal of the sport to a wider and younger audience of visitors to the event.

3.2.2 *Remote spectator experience*

Building on the concepts introduced for the local spectator experience, the project's remote spectator use case aimed to deliver similar facilities to those following the event remotely around the world (estimated at 200,000 fans).

As well as providing streaming of the live TV coverage showing on screens in Cowes and tailoring the Cowes Week App content specifically for the remote spectator, the introduction of VR technologies and 360° camera feeds would allow a remote spectator to jump onboard any of the 5G-enabled boats and become a virtual crew member, giving an unprecedented immersive experience that would generate significant appeal for both the regatta and the wider sport of sailing with a new audience of remote fans.

3.2.3 *Education experience*

The primary objective of the education experience was the creation of national-curriculum-aligned STEM education resources and interactive experiences for Key Stages 3 and 4 (11-16 years) to bring alive the science of sailing through unique content enabled by the project's 5G technologies and to promote understanding of the 5G network itself.

By making the resources available on the Trust's STEM Crew website and showcasing them in an Education Experience Centre at the 2021 Cowes Week regatta, the project aimed to inspire more young people towards science and technology careers through cutting-edge learning experiences.

3.3 **Security approach**

In addition to ISO27001 practices, a defence-in-depth, secure-by-design approach was applied to the end-to-end design of the project, its use cases, the infrastructure design and implementation, along with the software controls within the application, network and radio layers.

Key elements included:

- No end-user personal details were stored, and consent was received from those taking part to appear in any filming or recording.
- All physical server equipment, routers, switches were installed within locked racks within controlled areas to prevent unauthorised physical access, with CCTV and other sensors deployed as required.
- Network terminations were in controlled, managed locations along with firewall and IPSEC endpoints to prevent in-transit data intercept/alteration.

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- All devices were protected by strong passwords under a trusted management policy, with configurations backed up to a controlled, remote environment and firewall rules defaulting to closed.
 - All network functions and MAC's were monitored via a central NOC function, with rule-based reporting, centralised syslogging of key systems and monitoring of the “outwards-in” threat surface for early identification of any issues caused by software vulnerabilities or accidental misconfiguration.
 - Regular SWG meetings were conducted in line with major changepoints or delivery rollouts of the project. Partners and third parties were included into the SWG discussions where there was a need to incorporate their technology into the networks.

4 RESULTS

4.1 5G Network

4.1.1 Phase 1

Phase 1 of the network deployment was completed just in time for the Cowes Week 2021 regatta.

Some significant difficulties were encountered in bringing the network online, primarily due to bugs in the Baseband Unit (BBU) and Remote Radio Head (RRH) firmware, lack of documentation and unavailability of upgrades to support 50Mhz and 100Mhz bandwidths. Problems in securing the necessary spectrum licences from Ofcom, as well as some initial teething problems with adjacent cell interference, also delayed the deployment. However, these issues did not prevent use being made of the network in the delivery of end-user facilities during the regatta.

Once established, the available 5G sectors provided moderate to good coverage of the primary start/finish line off the Royal Yacht Squadron (running approximately 500m N from the RYS), as well as in some areas further to the NW and E of Cowes. This enabled all of the RYS starts and finishes to be covered by the live filming (50% and 42% of races respectively).

Usable upload bandwidth on the 5G network was observed to be generally around 5-6Mbps, which was lower than anticipated due to the restricted 20Mhz configuration, but sufficient for most needs. The use of LiveU equipment (which bonds together multiple data channels from different SIMs) allowed bandwidth to be split over multiple 5G modems and to include some backup support from other networks (primarily EE and Three on 4G). This went a long way to maintaining reasonably high-resolution camera feeds and preventing dropouts, as the limits of the local 5G network were reached on the water.

4.1.2 Phase 2

Following the experiences from the Cowes Week 2021 regatta and reviewing the considerable difficulties encountered with the supplied 5G hardware, software and firmware, the project decided that it was not practical to continue with the Phase 2 network deployment using the existing equipment supplier. As it was not possible within the scope of the project to switch to a new supplier, the completion of the full network remains a post-project aspiration.

While it was naturally disappointing not to be able to complete the full Solent network as planned before the end of the project, there are nevertheless some useful learnings from the experience, particularly with regard to the UK's 5G Diversification Strategy.

4.2 Spectator App

The Cowes Week App was deployed as planned at Cowes Week 2021, with offerings for Android and iOS phone and tablet devices. The App was extremely well received by both spectators and competitors.

The Live TV section of the App was the most popular and utilised facility with both local and remote spectators, but the inclusion of race schedule and class information was a welcome addition for many watching as it provided helpful context to the live action. This is an important learning point and a key part of building the engagement for spectators who like (and need) to understand what they are watching.

The App was downloaded by 4,600 people, around half of which were competitors and half spectators. Penetration into the competitor audience was very high (an impressive 94% of all competitors downloaded and used the app), but lower than anticipated among spectators. This is probably due to two main factors:

1. Visitor numbers to the Regatta in 2021 were significantly lower than in 2019 due to the continuing COVID-19 pandemic.
2. The App was not widely promoted by CWL, due to the uncertainties surrounding the delivery of the 5G network.

Nevertheless, user engagement was high. The App generated a total of 19,240 hours of engagement, a significant proportion of which came from the 5G-enhanced Live TV coverage. The App also achieved an aggregate rating of 95% among users against a baseline of 73%.

4.3 TV Coverage

During Cowes Week 2021, the planned LiveU equipment (configured with a range of 5G and 4G modems) was successfully deployed to facilitate live drone and chase boat footage from the starts and finishes.

Some good results were achieved in covering racing slightly away from the start/finish area. This was somewhat experimental but worked better than expected and clearly demonstrated the potential for the significantly enhanced spectator engagement that the project was hoping to achieve.

The drone and chase boat cameras were also deployed in covering the start of the Rolex Fastnet Race, which took place two days after the end of Cowes Week. This provided a useful further opportunity for testing and for user feedback with a large worldwide audience.

Overall, the Live TV coverage received 31,000 views and generated 11,600 hours of viewer engagement - approximately 20% up on the 2019 event. The geographic split was 60% UK / 40% other countries and 68% of the audience was aged 55 or older (reflecting the generally older demographic in the sport of sailing).

4.4 360° Cameras

An unforeseen problem for the project was the difficulty in sourcing a single all-in-one waterproof 360° camera that supported the required live autonomous streaming, local recording, remote control, continuous power and full-day operation. Although many 360° cameras were on the market and investigated, none came close to fulfilling these requirements.

The original choice of camera, the Ricoh V, suffered with overheating problems. It's replacement, the Ricoh Z1 was trialled at the Cowes Week 2021 event, but problems with waterproofing, lack of a long-term power solution and an inability to recover from network dropouts meant that usable output was limited - although some excellent 360° footage was captured and used in a VR Headset Technology Preview.

Having concluded that a successful all-weather deployment of autonomous 360° cameras onto racing boats at an all-day event was not readily achievable with currently available hardware, the project conducted significant work after Cowes Week 2021 on creating a bespoke solution. Various hardware options were prototyped, with the selected configuration completing successful on-water testing once the sailing season resumed in late March, prior to the end of the project. Given the progress made and lack of suitable off-the-shelf equipment, we believe there is good commercial potential beyond the end of the project for further development and refinement of the autonomous 360° camera solution for both sailing and other non-stadium sports and all-weather activities.

4.5 Online and Virtual Reality

During Cowes Week 2021, the live TV content, together with a range of 30 highlights clips showing some of the 5G-derived content, were delivered on the event website and via the event's YouTube channel. The content was also live streamed on Facebook and YouTube.

360° captured content from a chase boat was used in a Virtual Reality Technology Preview and delivered via YouTube 360, putting the wearer right at the heart of the action with around a hundred boats rounding one of the racing marks. This proved to be an extremely popular trial and a very valuable showcase for the potential of the Connected Cowes project.

4.6 Sensors/Telemetry

Live sensor data was provided from a trial boat taking part in Cowes Week 2021 and displayed live on a large-screen dashboard in the 1851 Trust Education Experience on Cowes Parade.

The project plans to expand the deployment of sensors to run alongside the onboard 360° cameras, thus providing additional viewer context to support the live action.

4.7 Education

Deliverables for each of the key education modules were completed to plan and made available to schools across the UK via the STEM Crew website in the autumn of 2021.

To evaluate the take-up and success of the materials, the project undertook an email campaign and used a specialist education marketing company to send the resources to 47,000 secondary school STEM teachers and heads of department. Overall, the open rate and click rates were much higher than expected based on the performance of similar campaigns. Approximately 40% (1419) of those that opened the marketing campaign (3537) then clicked through to download. This higher click-through rate can be attributed due to the 5G content and exceeded the target of 25% and doubled the previous rate of 20% recorded previously from a similar campaign.

The 1851 Marine Trust also hosted a STEM visitor area during Cowes Week 2021 to showcase the resources. Of those attending, 4167 school children were counted using clicker counters. Half (50%) of the attending school children answered the smiley face survey. In addition, four school groups of thirty students (included in the 4167) answered a much more detailed survey about their experience. Overall, 96% gave positive feedback, which not only exceeded the target of 85% but also dramatically improved on the baseline feedback of 76% recorded at the previous Cowes Week event in 2019.

Combining the outcomes from both evaluations it can be concluded that the 5G content has had a major beneficial impact on STEM teaching.

5 SUMMARY OF IMPACTS AND BENEFITS

5.1 Technical impacts and benefits

- The foundation for a Solent-area 5G network has been established, providing the basis for further development to support the world-famous Cowes Week regatta and other sailing events and deliver lasting value to the wider Solent maritime sector.
- New Cowes Week App and TV production assets have been developed which leverage the power of 5G to bring ground-breaking facilities such as remote cameras, onboard 360° cameras and sensors and virtual reality viewing to the Cowes Week regatta, significantly improving the event experience for both local and remote spectators.
- Valuable work has been carried out on the on-water deployment of autonomous 5G-enabled 360° cameras, uncovering considerable demand for a novel solution. The prototype development completed by the project shows significant potential for use at both sailing events and other non-stadium sports.
- New national-curriculum-aligned STEM education resources for Key Stages 3 and 4 (11-16 years) have been created to bring alive the science of sailing through unique content enabled by the project's 5G technologies.

5.2 Business impacts and benefits

- The end-user facilities developed by the project will significantly enhance the Cowes Week event through improved engagement with both local and remote spectators and added value for those taking part. This has the potential to unlock new and exciting revenue streams for the event as it approaches its 200th anniversary in 2026.
- The introduction of new, innovative and immersive engagement opportunities, based around 360° cameras, App, TV and other 5G-enabled channels, provides an excellent opportunity to increase critical event sponsorship revenues and has already generated significant interest among potential partners.
- The successful development of a novel 360° camera solution has considerable commercial potential beyond the project for both sailing and other non-stadium sports and all-weather activities.
- Curriculum-linked digital education experience will remain available to teachers everywhere via 1851 Trust's STEM Crew education platform at www.stemcrew.org/connectedcowes and will continue to inspire pupils in their classrooms.

5.3 Could similar results have been achieved without 5G?

For obvious reasons, commercial network operators do not focus their coverage on large areas of water like the Solent, which prior to the project had limited 4G coverage and no 5G coverage. The use of 5G within the Connected Cowes project, together with the deployment of a bespoke network, was therefore critical to the project achievements which could not have been otherwise realised.

6 KEY LEARNINGS

6.1 Project management

- Project start-up efforts were under-estimated by the team and was significantly more involved than anticipated. If possible, a better understanding of likely effort should be communicated to the project team as part of the tender process.
- The COVID-19 pandemic necessarily restricted meetings and discussion to online only, whether the various teams and partners working remotely from each other (indeed, the majority of the project team have still never met face-to-face). This led to some communication difficulties across the team, particularly on key technical aspects, many of which would likely have been avoided by regular opportunities to meet in person. Face-to-face meetings should therefore be encouraged.

6.2 Network deployment

- The difficulties encountered with the deployment of UK-sourced 5G equipment suggests that there is work still to be done on realising the targets of the 5G Supply Chain Diversification Strategy and reducing dependence on established telecoms suppliers such as Nokia and Ericsson.
- Ofcom spectrum licenses took longer to acquire than anticipated. An appreciation of the likely effort required would be helpful for future projects intending to apply for spectrum licences.
- Wayleaves for mast installations took much longer to agree than anticipated. There is probably little that can be done about this, aside from starting the process as early as possible in the project.

6.3 360° cameras and VR

- The project's experience is that 360° cameras provide a great opportunity for increasing engagement among fans and spectators, with their potential to place the viewer right at the heart of the action. However, current consumer and prosumer devices are very focussed on hand-held or body-wearable use, with little regard for robust waterproofing, built-in networking, remote control, continuous power and full-day autonomous operation. Although many 360° cameras were on the market and investigated, none came close to fulfilling these requirements. Projects contemplating the use of 360° cameras with 5G connectivity would therefore need to bear this in mind when searching for a solution (for which Connected Cowes' own custom assembly may provide an answer).
- The project showed that VR headsets coupled with 360° cameras have significant potential to change the way in which spectators and fans consume sporting content, particularly for non-stadium events. A key learning, however, is that VR headsets are

currently very unforgiving of poor-quality content, because the viewer's eyes are so close to the built-in viewing screens within the headset. When creating VR content, therefore, it is important that the source material is of the highest quality possible with minimal compression - a consideration that has potential upload bandwidth implications for the network if the source is a live streaming 360° camera.

6.4 App and TV

- The project was very successful in its creation of new App and TV facilities for the Cowes Week event, which were very well received and highly rated. A key learning to improve engagement is that it is important to provide contextual information to accompany any video content, so that spectators and fans can gain a good understanding of what they are viewing (this is something that sports like F1 already do very well).

6.5 Education

- 5G is not included in the national curriculum, which made creating teaching resources that schools would actually use a challenge. The project addressed this by using sport and the Cowes Week regatta as exciting real-life contexts to link to the Physics & Maths curriculum and educating students about the uses and benefits of 5G - something that is very important in today's technology driven world.