Title	**ONP Final Project Report Template**
Versions	**V.02**

NAME OF PROJECT DSIT NAVIGATE

List of partners	NEC, Freshwave
Locations	NEC Europe lab, Central London

Executive Summary

Maximum word count: 300 words

This should be seen as an executive summary giving a plain English overview about what the project was looking to achieve over the funding period including the aims and objectives.

Project NAVIGATE is aimed to design, deploy, test and validate a JOTS (Joint Operators Technical Specifications) compliant blueprint for deploying open, sharable, public mobile networks capacity in High Density Deployment (HDD) environments at scale using Open RAN architecture. The project seeks to validate that the chosen blueprint is technically and operationally viable, more cost-effective and energy efficient compared to legacy Single Operator RAN Macrocell approaches.

- *The outcomes of this project will assist the UK in the technical approaches to the deployment of High-Density Deployment (HDD) networks in the practicalities of deployment and management and the influencing of the supply chain via procurement and standardisation channels.*

NAVIGATE leverages DSIT initiatives for street-works cell sites, in partnership with local government across London. The project's primary HDD application environment is business districts, the beating hearts of major cities. Secondary HDD application environments such as business parks, campus zones and transport networks would be assessed within the project, applying lessons learned from this initial blueprint implementation.
UK Mobile Network Operators (MNOs) will be the primary beneficiary of this project – and to this effect, they will act in an advisory capacity to ensure that

- *MNO requirements, inputs and success criteria are well understood and accommodated within the solution specification*
- *MNOs can evaluate the outputs and outcomes of the project at key points throughout its lifecycle*

NEC and Freshwave are also engaged towards making this a commercially attractive solution for UK MNOs to deploy a Neutral Host based shared Small Cell deployment. This in turn would open a new way of RAN sharing, that would further benefit UK MNOs and promote sharing of infrastructure.
In summary:
Neutral Host – connected to multiple MNOs

Outdoor Deployment – Non-Standalone (NSA) (4G & 5G)

NEC CU/DU Solution

IOT (Inter-Operability Testing) of new 4G & 5G Radio Units

Lab Deployment & Test

Field Deployment (with live service)

In this project, NEC and Freshwave consortium had enough expertise, partner engagements and ambition to achieve the project's goals but the project effectively ran out of time. Developing critical national infrastructure for an MNO to confidently run services for its business customers on, in the heart of London was always going to be a challenge. So solution testing Phases where MNO core should have been involved were re-scoped to NEC lab testing in order to achieve all possible milestones in time.
Extended planning and delivery timeframes of a tier 1 MNO compared to the relatively short timescales of the project can explain the inherent challenges in building a live neutral host solutions.

Deployment Summary

Maximum word count: 500 words
Methods, technologies used and deployment approaches.
Description of the products or use cases.

NEC together with Freshwave developed the phased deployment approach in this project to reach the final technically ready solution for HDD area in Central London: Deployment had to be performed in three phases: Lab Phase 1, Lab Phase 2, Live Phase 3.

Lab Phase 1 allowed NEC to perform integration, validation and testing activities independently of MNO and Freshwave in NEC laboratory in South Ruislip office. In this phase, the RedHat cloud platform was built and NEC ORAN software was deployed on top. This phase activity allowed NEC to perform Fronthaul IoT testing with RU vendors for 4G and 5G: BTI and Benetel accordingly. Also, NEC used lab extensively to perform end-to-end services testing with CoreNetwork simulator, identify any possible software issues/bugs and report it to RnD team in timely manner. This gave the project some time to improve the software and adjust the software delivery planning.

Lab Phase 2 stage was initiated soon after Lab Phase 1 environment readiness. Main use case for Lab Phase 2 environment was to establish second parallel setup which could be used for integration with Test Core Network of MNOs. Deployment team had time to work on Phase 2 setup while in parallel MNO engagement was worked on. Significant amount of required parameters were discussed in weekly design meetings with MNO and it built a base for Low Level Design document for Lab Phase 2. Another important activity for Lab Phase 2 setup was to perform the RedHat cluster upgrade to later version which was required for addressing the known issues and vulnerabilities. In preparation to Lab Phase 2, Freshwave established a private link between NEC South Ruislip lab and Freshwave Central Datacenter termination point. Having the existing link to MNO Core Network from Central DC allowed Freshwave and NEC to verify end to end physical connectivity between NEC lab and MNO Test core. This was a steppingstone to start Test Core Network integration with MNO. This Lab Phase 2 is considered as the most important testing Phase where functionality and performance should be demonstrated to MNO so that MNO can give permission to go live with NAVIGATE solution.

Live Phase 3 stage is where HW for live deployment in City of London is installed in Freshwave Central and Edge DCs as well as on actual Cell sites. Prior to moving the HW to Freshwave Central Data Center, NEC team performed careful prestaging in NEC lab to make sure that CDC installation only takes one day and NEC team can have remote access to the HW immediately after installation. Currently, HW is installed in CDC and accessible remotely via secure Freshwave VPN connection for authorised users.
During joint design sessions with MNO, NEC presented the feature set and planned solution roadmap. As per MNO initial feedback, the feature set was considered suitable for commercial deployment. Focus of discussion was to avoid direct feature comparison with traditional RAN vendors and estimate the benefits that the features bring.
Datacenter and cell site design work showed that proposed design is suitable for commercial deployment and fits in Freshwave architecture. Confirmation of design feasibility by MNO strengthened the Project design decisions and solution readiness for commercial deployment in the HDD environment.

Results and Benefits Achieved

Maximum word count: 500

Results and key findings, with supporting evidence.
Impact of the results including key impacts and benefits using qualitative and quantitative data.
Drawing on and/or referring to the benefits realisation.
How are the results better than what has come before?
How will the results affect your or someone else's business?
This section should answer the 'so what?' question
How could others repeat the successes? If someone else wanted to achieve the same benefits, how might they do it?

NAVIGATE project introduces quite a unique architecture with a mixture of ORAN and JOTS NHOD principles. It benefits from HW selection openness, diversity and efficiency demonstrated on top of Neutral host outdoor architecture principles. This architecture shows advantages for both MNOs and Neutral host providers.
In order to build the end-to-end solution for NAVIGATE, NEC conducted extended market and technical research to select the Radio Unit (RU) vendors. Research was driven not only by ORAN compliance principles, but also by product availability on the market and precise physical requirements (power consumption, size, weight, volume) to fit into existing Freshwave street cabinets and MNO-defined radiation power requirements.
Selected RU vendors were available on the market and considered as lower risk at the RU selection stage. It is important to acknowledge that RU market is evolving continuously and new RUs are becoming available to suit the requirements of NHOD providers. That is why NEC also did analysis of several deployment scenarios covering multiple combinations of RUs (single-band and multi-band) and sever hardware combinations for up to 3 MNOs. The analysis shows that proposed solution can be deployed in multiple scenarios and is flexible, scalable and adjustable. This analysis will be submitted to DSIT as part of Sustainability report.
Lab IoT and E2E testing activity was the next step to prove that selected RU products work fine with NEC ORAN solution and don't have IoT issues. This allowed to demonstrate the diversification benefit in O-RAN HDD solutions - demonstrating successful integration and operation of NEC DU, CU and other vendors' RU products i.e. demonstrating feasibility of multi-vendor O-RAN HDD solutions.
During IoT phase, RU vendors and NEC RnD had to issue several versions of SW to fix the issues identified during testing.
Freshwave and NEC technical teams (10+ staff) gained valuable experience in O-RAN NHOD Solution design, HW deployment in both datacenter and cell site, RAN configuration, identifying the issues and driving to issues resolution or finding the applicable workarounds. Cloud platform deployment, RAN components onboarding, upgrading and integration knowledge was also obtained during the project execution phases. In general, this joint team is now capable of designing, building and supporting the solution. This is contribution to the development of Open RAN JOTS NHOD skills and capabilities within the UK. The project served to provide hands on skills training to staff and contractors across the two partners, specifically in the architecture, design, specification, deployment, management and operation of the proposed "next generation" JOTS NHOD Neutral Host Open RAN platform being tested by the project. Project is on track to achieve the technical performance target by End of March 2025.

In parallel, NEC pre-sales team together with Real Wireless experts did the TCO exercise where NEC ORAN solution was compared against traditional RAN solutions. Theoretical calculations show that in proposed NHOD deployments, ORAN solution can be more power-efficient when deployed even is small scale. Power efficiency can achieve 12% and this is another benefit added to the more open and cost-effective

solution benefits. Reduced energy consumption is achieved through network sharing of active cell-site and data centre assets between the multiple Operators.

NAVIGATE project was presented to two MNOs in UK and both showed interest and willingness to participate. This opened a path to potential commercial engagements for Freshwave and NEC.

Security

Maximum word count: 500 words

Summary of the projects approach to security
This should be a publishable summary of the security report touching on the ambitions outlined in the security strategy, best practice, standards testing, and results and lessons learnt. This will complement the separately required final security report.

Project Navigate Security Summary

Project Navigate aimed to design, deploy, test, and validate a blueprint for deploying open, sharable, public mobile 5G capacity in High Density Deployment (HDD) environments using O-RAN technology. This summary outlines the project's approach to security, touching on the ambitions outlined in the security strategy, best practices, standards testing, and lessons learned.

Security Strategy and Ambitions

The security strategy for Project Navigate was governed by NEC Europe's standard Quality and Sustainability processes, which define how employees and subcontractors should perform their daily responsibilities. Central to this approach is the NEC Way, which emphasizes solving social issues, strengthening risk management, enforcing compliance, and promoting communication with stakeholders.

The project aimed to ensure that all products and services met customer and legal requirements through a robust Quality Assurance process and follow the guidelines of Telecommunications Security Act and the associated Code of Practice and NCSC Vendor security assessment criteria.

Through the engagement of Freshwave as a partner, the project sought to benefit from their practical experience as a leading Neutral Host to address the needs and concerns of the intended target Operator customers.

O-RAN Solution Standard Compliance and Testing

The NEC vRAN solution is built on a security-by-design principle, considering threat analysis from O-RAN standards. The O-RAN Security Threat Modelling and Remediation Analysis helps stakeholders understand threats to O-RAN assets. This analysis consolidates information from 5G standards and best practices (e.g., 3GPP, ETSI, NIST,

ENISA, GSMA). It identifies critical assets to protect in terms of integrity, availability, confidentiality, replay, and authenticity.

The NEC vRAN solution groups security requirements into categories and applies enhancements for the NAVIGATE project. Key areas include physical security, host OS security, network perimeter security, network segmentation/isolation security, Kubernetes security, container application security, interface level security, centralised security log and access management, secure software update and patch management.

Security test cases are created based on 3GPP and O-RAN standards to ensure the solution complies with the security requirements captured in the security strategy.

Results and Lessons Learned

One of the key outputs of the Navigate Project, has been the creation of an architecture that demonstrates an implementation of the JOTS Neutral Host Out-Door specification (NHOD) security requirements. As a stated objective of the project is to ultimately enable engagements with multiple Mobile Network Operators sharing a Neutral Hosted infrastructure to provide improved capacity and coverage in high density deployments, successfully addressing the requirements of the JOTS NHOD Specification has been a significant project achievement.

In addition to the architecture creation, the project has highlighted several key lessons learned:

- **Implementation of security requirements**: Although security is relevant in all markets, the interpretation and application of security principles varies between regions, with the UK and Europe being among the most stringent. Through engaging in this project, vendor awareness around security has been increased and initiatives triggered to enhance processes and techniques within the development organisations to be better prepared for the global market.
- **Increased Threat Surface**: The O-RAN architecture introduced new components and interfaces, significantly increasing the threat surface. NEC's security implementation was based on O-RAN security requirements to address these threats.
- **Complexity in Security Management**: Implementing security for containerized applications and Kubernetes was more complex than traditional solutions. However, guidelines from organizations like CIS and NIST provided a framework to improve the cybersecurity posture of O-RAN solutions.

- **Significance of Automation in Security Testing**: The shift towards DevSecOps and automated security scanning helped identify and fix security threats early in the development stages, reducing the time taken to apply security fixes.
- **Real-Time Monitoring of Security Events**: The project utilized a logging solution based on RHOCP logging framework for real-time monitoring. For large-scale commercial deployments, advanced features of Security Information and Event Management (SIEM) frameworks were recommended.

Freshwave Datacenters

Freshwave datacenters implemented high level security mechanisms to control access and secure the infrastructure. A VPN was used to ensure network access control, and a firewall was set up for applications that required internet access to reduce the chance of malware infection.

Next Steps

As the O-RAN solution continues to evolve, new security requirements will emerge. The complexity of managing security will also increase with the scale of commercial deployments. Here are the detailed next steps for Project Navigate:

- **Shift Left Security Testing**: Shift left testing involves identifying security vulnerabilities and insecure coding errors earlier in the software development process. This can be achieved by integrating relevant security tools to automatically check for insecure coding, security misconfigurations, and vulnerabilities. This approach reduces costs, increases delivery speed, and improves product quality. Currently, we are working on automating security testing and incorporating DevSecOps frameworks into the solution. This will enable us to deliver our O-RAN solution faster without compromising security.
- **O-RAN Security Assurance Validation**: The O-RAN Alliance Working Group 11 (WG11) is collaborating with GSMA to establish an O-RAN NESAS (Network Equipment Security Assurance Scheme). The current GSMA NESAS SCAS (Security Assurance Specifications) does not cover the O-RAN architecture and its additional open interfaces. WG11 and the Testing and Integration Focus Group (TIFG) are defining the O-RAN Security Assurance Program and adapting the O-RAN Security Test Specifications into the GSMA NESAS framework, in alignment with GSMA documents FS.47 and FS.50. We plan to achieve O-RAN NESAS compliance certification once it becomes available from the O-RAN Alliance.
- **Compliance with Evolving Security Requirements**: The current scope of Project Navigate does not include the AI/ML framework, SMO (Service Management and

Orchestration), and RIC (RAN Intelligent Controller) functionalities. However, NEC solutions comply with O-RAN Alliance security requirements for AI/ML framework, SMO, and RIC solutions. Security requirements will continue to evolve due to new feature additions or newly identified security gaps. NEC is an active member of the O-RAN Alliance and contributes to the standards. We will continue to comply with and adapt to the evolving O-RAN Alliance security requirements.

High level summary of project costs

Maximum word count: 500 words

High level summary of project costs (to DSIT and project participants). (Equipment and deployment costs of any networks are also of interest)

The consortium's costs fall into following main areas:

- Equipment Purchase
- Resource
- Sub-contractor costs
- Cell Site / Datacenters Readiness & Connectivity cost
- Cell Site Preparation, Design, Construction & Deployment cost

<u>Equipment Purchase</u>

As a part of the project, NEC has designed & built a 4G & 5G non standalone small cell solution to meet the needs of the Mobile Network Operators (MNOs) for this type of deployment.

From a hardware perspective, this involves the purchase of a number of different servers which are suitable to host the different elements of the software, both for deployment in the NEC test lab & also in the data centre in preparation for live service with the selected MNO.

In addition to the servers, NEC has also provided Radio Units for 4G & 5G for both environments.

<u>Resource</u>

A significant part of NEC's cost base has been the engineering resource to build & design the solution. This has included the initial solution definition & design, the selection of the correct Radio Units meeting the project requirements & the subsequent physical implementation of this solution in the test lab.

In parallel with the physical implementation, the NEC team have initially performed IOT (inter-operability test) alignment with the selected Radio Unit vendors which involved a detailed technical engagement to confirm that the Radio Units could interact successfully with the NEC vRAN SW. This also involved some development by the Radio Unit vendor which was closely monitored & supported by the NEC technical team.

Upon the completion of both of the above activities, the engineering team have conducted extensive testing to confirm that the end-to-end solution performs as designed.
The Engineering teams, NEC & Freshwave, have also led the technical discussions with our lead MNO, to define an end-to-end design for the introduction of the solution into the MNO network. This has involved multiple workshop type engagements to ensure that this design can be built prior to attempting to connect to the MNO network.
Sub-contractor cost
NEC's sub-contractor costs have been driven by the requirement to ensure that the project team have the required support from the product design & delivery teams to design & build the solution both in the test labs & data centers.
This in-depth product support engagement has been essential to driving the successful outcome of the project activities.

Cell Site/ Datacentre Readiness & Connectivity
Freshwave is responsible for datacentre aspects including providing space, rack, power, cooling, switches, SFP, fibre patch leads, fibre connectivity to NEC lab, between other Freshwave datacentres and MNO lab & live core network. In addition, Freshwave's subcontractors provide professional services such as HW/SW support, managing the datacentre operations and provide remote access. A significant portion of the datacentre cost has been spent on fibre connectivity between datacentres.

Cell Site Preparation, Design, Construction & Deployment
Freshwave is responsible for the site design, construction and deployment. The following tasks incur Freshwave/subcontractor charges.

- Engage with local authorities/companies such as council, lamppost owners, power providers, fibre supplier, highways, etc.
- Site cabinet design, construction, installation and commissioning
- Site lamppost design, construction, installation and commissioning
- Antenna design, construction, installation and commissioning
- Various testing such H&S, wind load testing, rigging certificates
- Dark fibre routing design, connectivity and civil work between sites and datacentres
- Commissioning and integration of 4G/5G radios at each site location

Project Highlights

Maximum word count: 500

This could include project awards, events.
As project highlights, unique Solution design creation can be mentioned as well as MNO engagement and getting a green light from MNO to start the trial in Central London HDD

area. Project achieved the first lab ENDC call with the solution, which is based on completely new architecture combining ORAN and JOTS NHOD principles.

Going through the defined Phases of the project and dealing with daily activities as well as issues helped to significantly improve the SW maturity and wider interoperability capability of the NEC solution and to develop and trial the unique solution architecture. These valuable inputs are documented and accepted by product suppliers and corresponding actions are taken accordingly.

Project Conclusions

Maximum word count: 500

This should include the final findings from the projects and talk about the conclusions gleaned from the activity within the project. Suggestions for policy, regulation or programmes or other things that may need adjustment arising from the project.
Why was the project worth undertaking.

The NAVIGATE project was intended to demonstrate the feasibility and benefits of deploying open, sharable public mobile network capacity in High Density Deployment (HDD) environments using Open RAN architecture. The project's primary objective was to validate that the chosen blueprint is technically and operationally viable, more cost-effective and energy-efficient compared to legacy Single Operator RAN Macrocell approaches.
Throughout the project, NEC and Freshwave collaborated closely to develop a phased deployment approach, which included Lab Phase 1, Lab Phase 2, and Live Phase 3. Each phase was meticulously planned, allowing for thorough testing, integration, and validation of the solution. Engaging with Mobile Network Operators (MNOs) was a key to successful project execution and while it took more time than initially expected, this highlighted the importance of MNO engagement for the success of such projects and strengthened collaboration between the Project and MNO.
The project also demonstrated the benefits of a multi-vendor O-RAN HDD solution, showcasing successful integration and operation of NEC DU, CU, and other vendors' RU products. This diversification is a key advantage, providing flexibility and efficiency in network deployment. Introducing new vendors to existing RAN market is a benefit achieved by the project: increased number of RU vendors and RAN platform suppliers can be considered for mobile network deployments.
Project team designed and built the solution, which met the MNO requirements and is now ready to be deployed for the field trial and one of the major achievements of the project was the hands-on skills training provided to staff and contractors across the two partners, specifically in the architecture, design, specification, deployment, management, and operation of the proposed "next generation" JOTS NHOD Neutral Host Open RAN platform. This has contributed to the development of Open RAN JOTS NHOD skills and capabilities within the UK.

The equipment purchased for the project will be partially retained in line with the provided list for potential future activities. The remaining equipment bought for the project will be scrapped, primarily radio units.

- The project was able to cancel the final delivery of 4G radio units to save cost, albeit for a 50% cancellation fee
- The project utilised existing NEC assets for the servers which will be used for the next project. This as well proves that the same HW can support different vRAN SW therefore proving one concept of ORAN

The project's theoretical calculations indicated that the proposed NHOD deployments could be more power-efficient, achieving up to 12% energy savings compared to traditional RAN solutions. This is a significant benefit, adding to the more open and cost-effective solution advantages.

In conclusion, the NAVIGATE project has provided valuable insights and demonstrated the potential of Open RAN architecture for HDD environments. The project's findings suggest that policy, regulation, and programs should support the continued development and deployment of such innovative solutions. The project was worth undertaking as it has paved the way for future advancements in mobile network technology, promoting infrastructure sharing and enhancing network efficiency.

Next Steps

Maximum word count: 500

What the project looks to achieve following the funding. This could be explaining plans for commercialisation or further research needed to achieve that. Were there things you couldn't do that could be done in future? What could help? Next step?

Following the completion of the NAVIGATE project, the next steps involve several key areas to ensure the continued progress and eventual commercialisation. The primary focus will be on further development, collaboration and addressing the challenges encountered during the project.
Firstly, NEC will continue to advance the development of the Open RAN (ORAN) technology, with a particular emphasis on improving the quality of the ORAN software. Additionally, NEC will seek further collaboration opportunities within the Neutral Host business sector, including private networks with 5G SA solution. These collaborations will help to expand the reach and applicability of the ORAN technology, making it more attractive to potential commercial partners. We believe that this solution has a higher potential from market diversification perspective as well as it is aligned with MNO strategies. Proposed solution is flexible enough to address multiple market segments.

One of the project suggestions towards future could be addressing the MNO entrance issues. MNOs normally consider low risk approach when planning future rollouts, which

makes it challenging for new vendors to enter the MNO supply chains. Considering high commercial costs for suppliers to enter MNO market, ORAN vendors may want to ask for regulatory support in ORAN introduction not only through funding, but also through diversification policies.

As a summary, to facilitate the next steps, several factors could help. Funding and support from authorities and industry stakeholders will be essential to continue the development and deployment of the ORAN technology. Policy and regulatory adjustments may also be necessary to encourage the adoption of open and shared network architectures. Programs that promote collaboration between different stakeholders, including MNOs, technology providers, and regulatory bodies, will be crucial to the project's success.

Media Library

This should include any links to project websites, social media handles, key documents etc.

It should also include any videos or photos from the project that would effectively showcase what it achieved.

1) Press: *https://www.nec.com/en/press/202310/global_20231016_01.html*
2) Press: *https://freshwavegroup.com/nec-and-freshwave-collaborate-on-open-ran-project-to-deliver-next-generation-multi-operator-neutral-host-small-cell-solution-for-high-traffic-areas/*
3) Press: *https://uktin.net/navigate*
4) Article: *https://www.telecoms.com/wireless-networking/nec-and-freshwave-chosen-for-uk-open-ran-neutral-host-project*
5) Article: *https://networkingplus.co.uk/news-details?itemid=5636&post=freshwave-and-nec-corporation-to-participate-in-project-navigate-958321*
6) Article: *https://www.telecomstechnews.com/news/nec-and-freshwave-project-selected-uk-open-ran-competition/*
7) Article: *https://www.rcrwireless.com/20231020/featured/nec-freshwave-collaborate-o-ran-project-uk*
8) Article: *https://insidetowers.com/nec-freshwave-tackle-open-ran-small-cells-in-u-k-competition/*
9) Article: *https://www.gov.uk/government/publications/open-networks-ecosystem-competition-successful-projects/open-networks-ecosystem-competition-successful-projects*
10) Article: *https://www.telecompaper.com/news/nec-freshwave-collaborate-on-project-navigate-open-ran-study-in-uk--1479187*

11) Social: *https://www.linkedin.com/posts/nec-open-networks_nec-and-freshwave-collaborate-on-open-ran-activity-7119607922736709632-Pr21/?trk=public_profile_like_view*