Project Closure Report

Project Name: Secure5G – 10266

Project End Date: 31/07/2023

Project Partners:
Compound Semiconductor Applications Catapult Limited
Lime Microsystems Limited
Slipstream Engineering Design Limited
Arqit Limited

Status: Released
Author: Simon Maggs
Classification: Confidential

Contents

1 Reference Documents

MS2.1.1 to MS QRM 6	All MS milestone documents referred to by MS number

2 Definitions and Abbreviations

5G	5th Generation
ADPD	Adaptive Digital Predistortion
CSP	Control Signal Power
IMD	Inter-Modulation Distortion
LMBA	Load-Modulated Balanced Amplifier
O-RAN	Open Radio Access Network
PA	Power Amplifier

RFIC	Radio Frequency Integrated Circuits
SDR	Software Defined Radio

3 Project Review

The purpose of the Project Closure Report is to formally record the outcome of the project and to document its closure.

3.1 Project Scope and Achievements

The Secure5G project successfully advanced the development of secure, open source 5G connectivity. Led by Compound Semiconductor Applications (CSA) Catapult, the consortium comprised of Lime Microsystems, Slipstream Engineering Design, and Arqit. The project utilised UK-based expertise to develop a more efficient, and broadband, Power Amplifier (PA) for mobile phone base stations. Additionally, the project focused on creating a flexible and secure hardware and software platform to control and linearise the PA. This development was integrated with a radio architecture specifically developed by the project for the 5G Open Radio Access Network (O-RAN) platform.

To emphasise the key network challenges covered by the project, the remaining part of this report is divided into three main sections: Open Access Network (Section 3.1-A), Security (Section 3.1-B, and Power Amplifier (Section 3.1-C). The information presented in this report was gathered through consultations with consortium members, capturing the perspectives of each party regarding their future work and roadmaps respective to their contributions to the project.

3.1.A Open Access Network

Lime Microsystem developed an open access PA control circuit along with an adaptive digital predistortion (ADPD)
board. The board was then integrated in a private 5G base station box to control a Wideband PA designed by Slipstream Engineering Design. This section presents an overview of the Lime Microsystem in the following key areas.

3.1.1 Main Drivers in Applications and Use-Cases

Approximately 65% of the world lacks cellular and wireless broadband access due to costly solutions from limited vendors. The open-source hardware platform developed by Lime Microsystem provides affordable solution which is highly configurable and can adapt to different communication standards such as 5G network.

3.1.A-2 Leaders and Competitors in the Field

In the past, wireless networks were predominantly controlled by a select few vendors. However, with the growing momentum of the O-RAN initiative, there is now a significant opportunity for UK companies to offer flexible and innovative network solutions that seamlessly integrate into wireless networks. This presents a chance for these companies to contribute to the advancement of wireless technology and bring about positive changes in the industry.

3.1.A-3 Skills Gaps and Expertise

Lime Microsystems is privileged to have a diverse team comprising experts in various fields related to wireless networks, including RFIC designers, SDR developers, and system engineers. Their collective expertise enables the development of cutting-edge solutions for modern communication systems like 5G. With a broad range of skills and knowledge, Lime Microsystems is well-equipped to address the challenges and opportunities in the rapidly evolving wireless industry.

3.1. A-4 Development Partnerships

The Secure5G project has established essential partnerships to ensure a successful implementation. By closely collaborating with Artiq QuantumCloud, we were able to demonstrate a secure network connection using our 5G solution. Additionally, our collaboration with CSA Catapult and Slipstream played a pivotal role in developing a power amplifier (PA), a crucial component alongside the ADPD solution within the transceiver.

3.1. A-5 Product Roadmap and Key Features

The ADPD solution, which has undergone significant development, has reached an advanced stage. Unlike traditional DPD solutions, the developed ADPD board possesses the capability to adapt the linearization process to the PA output response, ensuring a robust and reliable linearization for enhanced connectivity. This highly flexible board can be utilized in various configurations, making it adaptable to diverse requirements. Additionally, a user-friendly interface has been developed for this solution, empowering users to easily configure and test the board according to their specific system needs.

3.1. A-6 Key Building Blocks and Technology Hurdles

The Secure5G project presented a valuable opportunity to develop essential building blocks for showcasing secure open source 5G connectivity. However, achieving complete adoption of the O-RAN network necessitates further standardization and collaboration with traditional network providers. This collaborative effort aims to create a platform that enables the utilization of open-source hardware and software solutions, fostering a more inclusive and innovative ecosystem for the future of 5G technology.

3.1. B Security

The Artiq QuantumCloud platform provided a robust symmetrical key encryption solution that was integrated with Lime Microsystem's 5G ORAN solution. Through collaboration with Lime Microsystem, Artiq successfully validated the robustness and applicability of their encryption solution for 5G O-RAN. This section presents Artiq's perspective on the following key areas.

3.1.B-1 Main Drivers in Applications and Use-Cases

The solution has been designed to accommodate the diverse requirements of different networks and SDR systems. Additionally, it offers flexibility in adapting to the unique security requirements of various vendors.

3.1.B-2 Leaders and Competitors in the Field

The secure encryption solution developed in this project has no direct competition. It offers a unique security solution based on Symmetric Key Encryption. This distinctive approach sets it apart from other solutions currently available in the market.

3.1.B-3 Skills Gaps and Expertise

There are no significant skills gaps identified for this project within Artiq engineering team. The project team possesses in-house expertise that covers various aspects of cybersecurity. In addition, valuable insights and expertise specific to 5G were obtained from Lime Micro. Moreover, it is recommended to actively promote and support the development of skills in wireless network security across the UK.

3.1.B-4 Development Partnerships

The project has established crucial partnerships to ensure successful implementation. Close collaboration with Lime Micro is ongoing to integrate the security solution seamlessly onto their hardware. Furthermore, general collaboration with CSA Catapult and Slipstream was an enabler to coordinate project progress and optimise outcomes.

3.1.B-5 Product Roadmap and Key Features

The secure encryption solution has reached an advanced stage of development. It offers a state-of-the-art encryption solution that eliminates the need for over-the-air key updates. The use of quantum-resistant encryption algorithms eliminates the risks posed by the computational power of quantum computers during the over-the-air

encryption key exchange process. This solution demonstrates flexibility, allowing integration with various SDR and open-RAN solutions. Future development plans include the creation of an Android app to extend secure encryption services to a broader user base.

3.1.B-6 Key Building Blocks and Technology Hurdles

The project has successfully established all the key building blocks required for the implementation of the secure encryption solution. The product is fully ready, and significant progress has been made. However, it is necessary to collaborate closely with radio access network (RAN) manufacturers to effectively implement the secure encryption solution.

3.1.C Power Amplifier

The Slipstream Engineering Design played a crucial role in the project, specifically related to the broadband energy efficient PA design. The CSA Catapult provided a state-of-the-art power amplifier test platform for characterising the power amplifier. The collaboration between Slipstream and CSA Catapult was critical in identifying the challenges in the development of broadband PAs and developing automated power amplifier test and DPD solutions. This section presents project partners perspective on the following key areas related to the PAs.

3.1.C-1 Main Drivers in Applications and Use-Cases

As the demand for the higher data increases the modern communication signals have a wider bandwidth to accommodate this demand. On the other hand, Development of compatible Wideband PAs is critical to be able to boast the signal energy to higher level so it can reach the users equipment. Energy efficiency is another key area which need to be considered as it's known that up to 80% of the energy within the mobile base stations is consumed by the PAs. The developed Wideband PA can be used in base stations with low power requirement.

3.1.C-2 Skills Gaps and Expertise

Designing highly broadband and efficient power amplifiers for modern communication standards is a formidable challenge, as they must meet stringent system requirements. Slipstream Engineering Design and CSA Catapult have harnessed their diverse expertise in design, testing, and validation, which proved instrumental in developing the wideband PA. However, it is strongly advised to make further investments in the development of expertise in power amplifiers and compound semiconductor technology across the UK. Such investment would strategically benefit the UK wireless network market, driving innovation and ensuring a competitive edge in the evolving landscape of wireless communication.

3.1.C-3 Development Partnerships

Slipstream Engineering Design and CSA Catapult have forged a close collaboration to successfully develop the Wideband PA. Accessing the state-of-the-art test and measurement capabilities at CSA Catapult was crucial in evaluating the performance of the PA throughout its development process. Furthermore, collaboration with Lime Microsystems and Artiq played a pivotal role in showcasing the PA's performance within a secure 5G network. This partnership enabled the demonstration of the PA's capabilities and further validated its effectiveness in real-world scenarios, emphasising its value in the industry.

3.1.C-4 Key Building Blocks and Technology Hurdles

A power amplifier (PA) module is a vital component of wireless transmitters since it affects signal quality and energy consumption. Base station PA performance requirements across a wide range of frequencies and in back-off regions (High PAR) are very demanding, often resulting in trade-offs between power, gain, efficiency and linearity.
It is well known that nonlinearity is largely caused by memory effects (device, matching and bias networks). While PA designers can minimize the impact of matching and bias network memory effects, device-level memory effects remain outside their control.

Memory effects in devices are less known and can potentially be controlled during fabrication of the device, for example, via the epi layer. CSA Catapult can help develop and validate this process (through design, model validation and measurements i.e., 2-tone IMD measurements at wafer level) by studying how device linearity

influences PA linearity. As a complement to this activity, we provide DPD measurements, which can help identify whether a device (or PA) can be linearized. CSA Catapult's unique capabilities enable it to assist PA design from the wafer stage to the device and board levels.

The choice of PA architecture is also critical to meeting energy efficiency and linearity requirements at both average and peak power levels. Among the most commonly used architecture to improve efficiency at back-off is the Doherty PA. It uses active load modulation to improve efficiency at average power levels and has contributed significantly to the deployment of 3G and 4G networks. However, its RF bandwidth limitation restricts its use in more flexible telecom networks.

A Chireix outphasing solution for load modulation has also been widely investigated, with limitations mainly related to bandwidth and signal driving complexity.
Active load modulation in power amplifiers has been widely used since the early 2000s to improve the average efficiency of base station power amplifiers (PAs). A more recent example of an active load modulated architecture is the Load Modulated Balanced Amplifier (LMBA), which can be used for increasing efficiency in back-off regions and for obtaining a more flexible and agile PA.

Based on a balanced PA topology, an RF signal (Control Signal Power, CSP) is injected at the isolated port which controls the modulation of the load on the balanced PA.

One of the main difficulties in the LMBA design is generating this CSP signal efficiently. Several variations of the LMBA architecture (OLMBA, RLMBA etc.) have been proposed to overcome this problem. In the case of output-input leakage, the injected signal at the isolated Balanced PA port can also cause Balanced PA devices to self-conduct, which reduces back-off efficiency.

Conclusion
The Secure5G project successfully advanced the development of secure, open source 5G connectivity. Led by CSA Catapult, the consortium included Lime Microsystems, Slipstream Engineering Design, and Artiq QuantumCloud. Significant achievements were made in power amplifier design, security solutions, and open-source network integration. Collaborative efforts and strategic partnerships played a vital role in the project's success. Further standardization and collaboration with traditional network providers, and hardware manufactures, are recommended. The project's outcomes pave the way for future advancements in 5G technology, benefiting the wireless communication industry.

3.2 Project Outputs and Deliverables

The project consisted of the following work packages:

Ref	Title	WP Leader
WP1	Project Management	Simon Maggs
WP2	Slipstream Electronic Devices Tasks	Ben Allmond
WP3	Lime Micro Tasks	Ebrahim Busheri
WP4	System Development	Scott Alexander
WP5	System Demonstration	Ehsan Azad

The following high-level deliverables, as stated in the DSIT Annex 5, were achieved:

Ref	Title	WP	Planned Date	Completion Date	Status
MS 2.1.1	Market Intelligence and Key Stake Holder Report	2	Q1	Q1	Approved
MS 2.2.1	Planning and Topology Design Review Complete	2	Q1	Q1	Approved
MS 2.2.2	Wideband PA Specification	2	Q1	Q1	Approved
MS 2.3.1	Wideband PA Breadboard Manufacturing Files	2	Q2	Q2	Approved
MS 2.3.2	Wideband PA Breadboard HW Built	2	Q2	Q2	Approved
MS 2.3.3	Wideband PA Breadboard Operational	2	Q2	Q2	Approved
MS 2.5.1	Wideband PA Demonstrator #2 Schematic Capture	2	Q3	Q3	Approved
MS 2.4.1	Wideband PA Breadboard Characterisation Report with CSA	2	Q3	Q3	Approved
MS 2.5.2	Wideband PA Demonstrator #2 Layout Complete	2	Q3	Q3	Approved
MS 2.5.3	Wideband Demonstrator #2 HW Built	2	Q3	Q3	Approved
MS 2.6.1	Wideband Demonstrator #2 Test Results	2	Q4	Q4	Approved
MS 2.6.2	Wideband PA Characterisation Report with CSA	2	Q4	Q4	Approved
MS 2.7.1	Wideband PA Demonstrator #3 Schematic Capture	2	Q4	Q4	Approved
MS 2.7.3	Wideband PA Demonstrator #3 HW Built	2	Q5	Q5	Approved
MS 2.8.1	Wideband PA Demonstrator #3 Test Results	2	Q5	Q5	Approved
MS 2.8.2	Wideband PA Demonstrator Ready for System Integration	2	Q5	Q5	Approved
MS 2.8.3	System Integration Test Results	2	Q6	Q6	Approved
MS 2.9.1	KSH Report and Exploitation Plan	2	Q6	Q6	Approved
MS 2.9.2	Wideband PA Demonstrator ready for customer trial	2	Q6	Q6	Approved
MS3.1a	Porting of the DPD and CFR on to Artix 7 Xilinx FPGA	2	Q1	Q1	Approved
MS3.2a	Publication of DPD and CFR Algorithms	3	Q1	Q1	Approved
MS3.1	Porting and optimisation of Lime's DPD/CFR Algorithms on target FPGA	3	Q2	Q2	Approved
MS3.3.2	Review of the feature sets and form factor of the Radio card	3	Q2	Q2	Approved

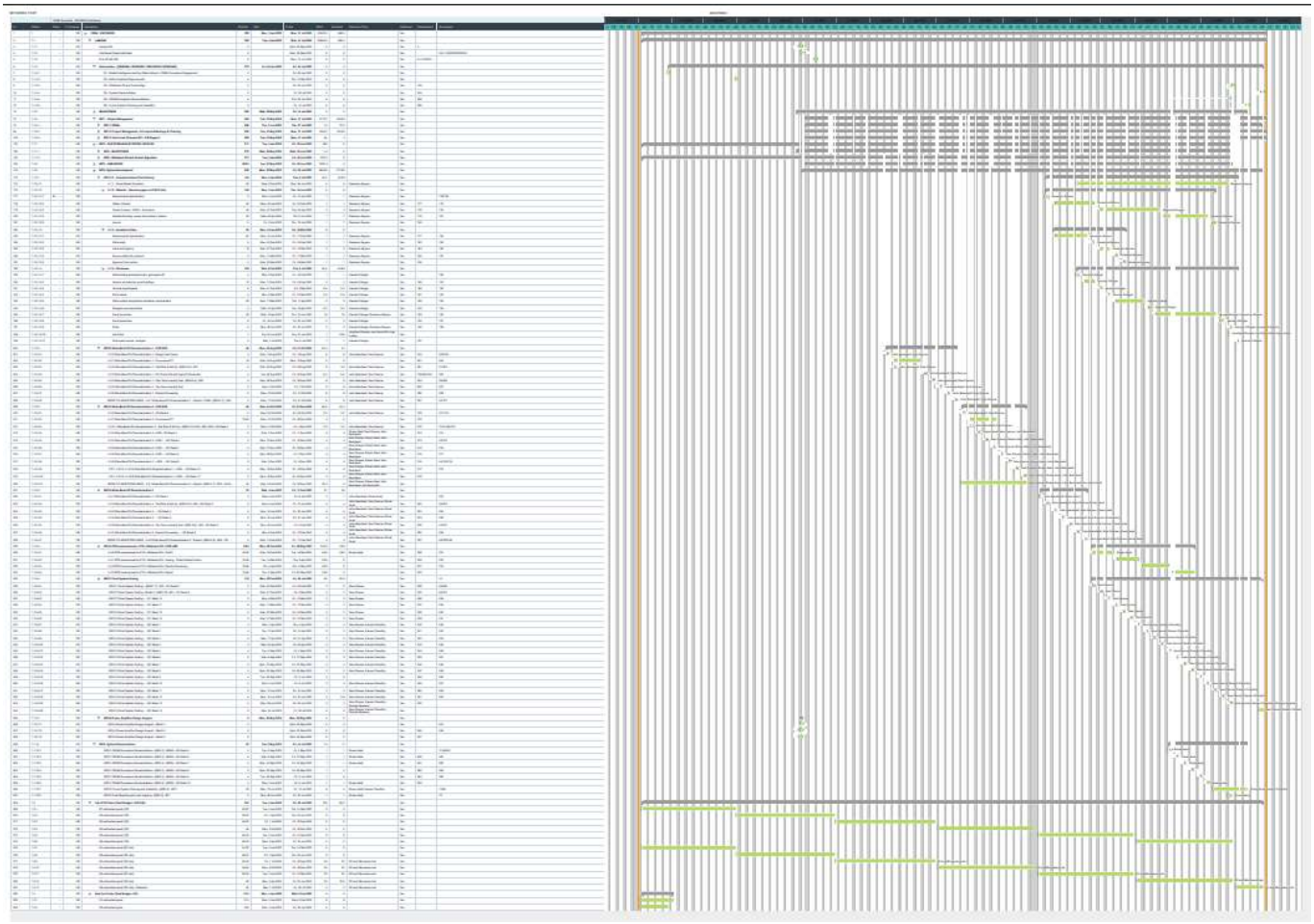
MS3.2	Evaluation and optimisation of Lime's Algorithm on wideband PA	3	Q4	Q4	Approved
MS3.3.1	Design/Manufacture of low-Power board for integrated SDR solution	3	Q5	Q5	Approved
MS3.3	Design/Manufacture of Radio module with SDR chipsets optimised for Wideband PA	3	Q6	Q6	Approved
MS3.4	Porting of the required IPs for the implementation of ORAN interfaces on FPGA	3	Q6	Q6	Approved
MS3.5	Software optimisation and integration on LimeNet 5G	3	Q6	Q6	Approved
MS5.1	O-RAN Ecosystem Demonstration in Testbed	3	Q6	Q6	Approved
MS 3.4.1	Project Inception Report for secure ORAN demonstrator	3	Q2	Q2	Approved
MS QRM 1	Security strategy issued at revision 1		Q2	Q2	Approved
MS 3.4.2-a	Secure ORAN community engagement with at least three other FRANC projects	3	Q3	Q3	Approved
MS3.4.3	Arqit platform	3	Q4	Q4	Approved
MS 3.4.4	QuantumCloud integration with StrongSwan with LimeNET design & validation	3	Q4	Q4	Approved
MS 3.5.2	Testing in Lime Facility	3	Q4	Q4	Approved
MS 3.4.2-b	Secure ORAN community engagement with at least three other FRANC projects - Engagement Activities	3	Q5	Q5	Approved
MS 3.4.5	QuantumCloud™ Software Development Kit	3	Q5	Q5	Approved
MS 3.5.1	QC software stack delivery	3	Q5	Q5	Approved
MS 3.5.3-a	Optimisation - Part 1	3	Q5	Q5	Approved
MS 5.1.1	Secure ORAN Testbed demo set-up	5	Q5	Q5	Approved
MS 5.2.2	Dissemination materials	5	Q6	Q6	Approved
MS 3.4.2-c	Secure ORAN community engagement with at least three other FRANC projects - Activity Report	3	Q6	Q6	Approved
MS 3.5.3-b	Optimisation - Part 2	3	Q6	Q6	Approved
MS 5.3.3	QCloud and secure ORAN Exploitation Plan	3	Q6	Q6	Approved
MS 5.3.4	Secure demonstrator ready for customer trials and pilots	5	Q6	Q6	Approved
MS QRM 1	Benefits Realisation Framework approved by issued. Meets requirements of the Authority as indicated under GFA section 26.	1	Q1	Q1	Approved
MS QRM 1	Draft dissemination & communications plan issued	1	Q1	Q1	Approved
MS4.1.10	Transistor Characterisation - Report - Update for load pull (Completion)	4	Q2	Q2	Approved
MS4.2.2	Wide-Band PA Characterisation 1 - Test Plan & Set Up	4	Q2	Q2	Approved
MS4.2.4	Wide-Band PA Characterisation 1 - One Tone Linearity Test	4	Q2	Q2	Approved
MS QRM 2	Final benefits realisation Framework approved issued to DCMS		Q2	Q2	Approved

MS QRM 2	Final dissemination and communications plan issued to DCMS		Q2	Q2	Approved
MS4.2.7	Wide-Band PA Characterisation 1 - Report	4	Q3	Q3	Approved
MS4.3.2-1	Wide-Band PA Characterisation 2 - Test Plan & Set Up – Part 1	4	Q3	Q3	Approved
MS4.3.2-2	Wide-Band PA Characterisation 2 - Test Plan & Set Up – Part 2	4	Q3	Q3	Approved
MS4.3.4	Wide-Band PA Characterisation 2 - One Tone Linearity Test - Cancelled	4	Q4	Q4	Cancelled
MS4.3.7	Wide-Band PA Characterisation 2 – Report - cancelled	4	Q4	Q4	Cancelled
MS 4.3.8	DPD optimisation and test bench development	4	Q4	Q4	Approved
MS 4.1.3	Provision of animation video, for use on website and social media	4	Q6	Q6	Approved
MS4.5.3	Wide-Band PA Characterisation 3 - Test Plan & Set Up	4	Q5	Q5	Approved
MS4.5.6	Wide-Band PA Characterisation 3 - Two Tone Linearity Test	4	Q5	Q5	Approved
MS4.5.8	Wide-Band PA Characterisation 3 - Report	4	Q5	Q5	Approved
MS4.1.2-New	Provision of website pages for secure 5G	4	Q6	Q6	Approved
MS4.71	Final System Testing - Month 1	4	Q6	Q6	Approved
MS4.72	Final System Testing - Month 2	4	Q6	Q6	Approved
MS5.2	Future System Planning and Feasibility	5	Q6	Q6	Approved
MS4.1.1-New	Social Media Posts	4	Q6	Q6	Approved
MS5.3	Final Reporting and road mapping	5	Q6	Q6	Approved
MS QRM 6	Summary project closure report issued		Q6	Q6	Approved
MS QRM 6	Final lessons learnt report for the project issued		Q6	Q6	Approved
MS QRM 6	Project closing event completed		Q6	Q6	Approved
MS QRM 6	Project Security Report issued		Q6	Q6	Approved
MS QRM 6	Project test exit report issued		Q6	Q6	Approved
MS QRM 6	Initial sustainability plan for the outcome of the project issued		Q6	Q6	Approved

- The following items were not delivered as expected, SED did not require a further round of power amplifier testing.
- MS4.3.7 & MS4.3.8 were cancelled with agreement from DSIT.

3.3 Project Timescales

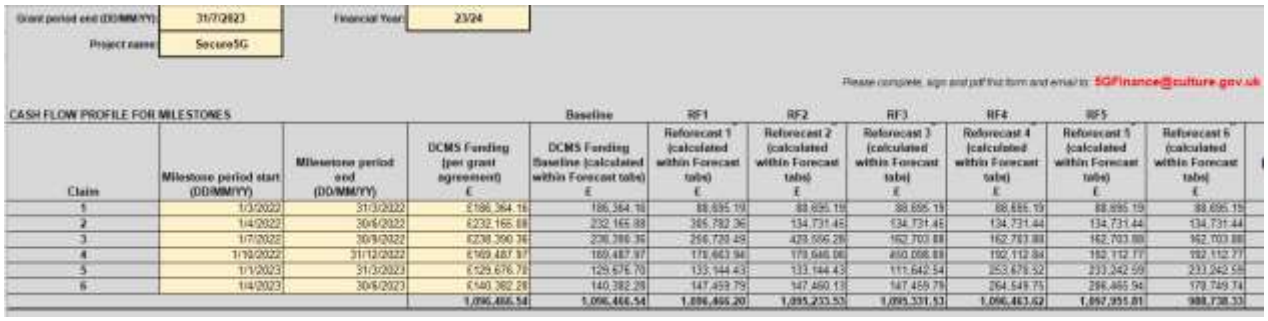
The project was delivered to the below timescales. The project was re-baselined on under PCR 001 due to the Grant Offer Letter being issued 5 months beyond project start date, on an 18 month project. Despite this, only a one month extension was required to complete the final deliverables.



4 Financial Outcome

4.1 Summary

The project was funded by Department For Science Innovation & Technology, (formerly Department For Digital, Culture, Media & Sport). LINK. DSIT funded the Secure5G project to £1,096,466.54, and the consortium consumed £988,738.33, which represents 90.17%. The table below is taken from Q6 Cash Flow Profile.



Grant period end (DD/MM/YY):	31/7/2023	Financial Year:	23/24
Project name:	Secure5G		

Please complete, sign and pdf this form and email to: 5Gfinance@culture.gov.uk

CASH FLOW PROFILE FOR MILESTONES

				Baseline	RF1	RF2	RF3	RF4	RF5	
Claim	Milestone period start (DD/MM/YY)	Milestone period end (DD/MM/YY)	DCMS Funding (per grant agreement) £	DCMS Funding Baseline (calculated within Forecast tabs) £	Reforecast 1 (calculated within Forecast tabs) £	Reforecast 2 (calculated within Forecast tabs) £	Reforecast 3 (calculated within Forecast tabs) £	Reforecast 4 (calculated within Forecast tabs) £	Reforecast 5 (calculated within Forecast tabs) £	Reforecast 6 (calculated within Forecast tabs) £
1	1/3/2022	31/3/2022	£186,364.16	186,364.16	88,695.19	88,695.19	88,695.19	88,695.19	88,695.19	88,695.19
2	1/4/2022	30/6/2022	£232,165.88	232,165.88	265,782.36	134,731.45	134,731.45	134,731.44	134,731.44	134,731.44
3	1/7/2022	30/9/2022	£238,390.76	238,390.76	256,728.49	429,566.28	162,703.88	162,703.88	162,703.88	162,703.88
4	1/10/2022	31/12/2022	£169,487.97	169,487.97	178,663.94	178,665.08	460,098.88	192,112.84	192,112.77	192,112.77
5	1/1/2023	31/3/2023	£129,676.70	129,676.70	133,144.43	133,144.43	111,642.54	253,676.52	233,242.59	233,242.59
6	1/4/2023	30/6/2023	£140,382.28	140,382.28	147,459.79	147,460.13	147,459.75	264,549.75	286,465.94	178,749.74
			1,096,466.54	1,096,466.54	1,096,466.20	1,095,233.53	1,095,331.53	1,096,463.62	1,097,951.81	988,738.33

The final payment for Q6 from DSIT to the consortium for £178,749.74 is outstanding, and is due for payment this week, (w/C 02/10/2023). DSIT will pay CSAC, and then CSAC will pay the project partners.

4.15 Unclaimed funds

As can be seen, the consortium will give back £ 107,728.21 from the project budget to DSIT as unclaimed funds. At project closure date, DSIT stated in the weekly call, that no further claims can be made after the project end date which was 31/07/2023. This led to CSAC committing to extensive detailed project closure documentation which both parties agreed could not be funded. Later on 02/10/2023, when work was nearing completion, DSIT stated that 'CSAC would need to confirm in writing that the £107k would be given back, unless the consortium has further claims to make, and it is not too late for that.' At this point CSAC had not booked hours to the project code as the project was financially closed. Therefore, traceability was lost, and no further claim was possible.

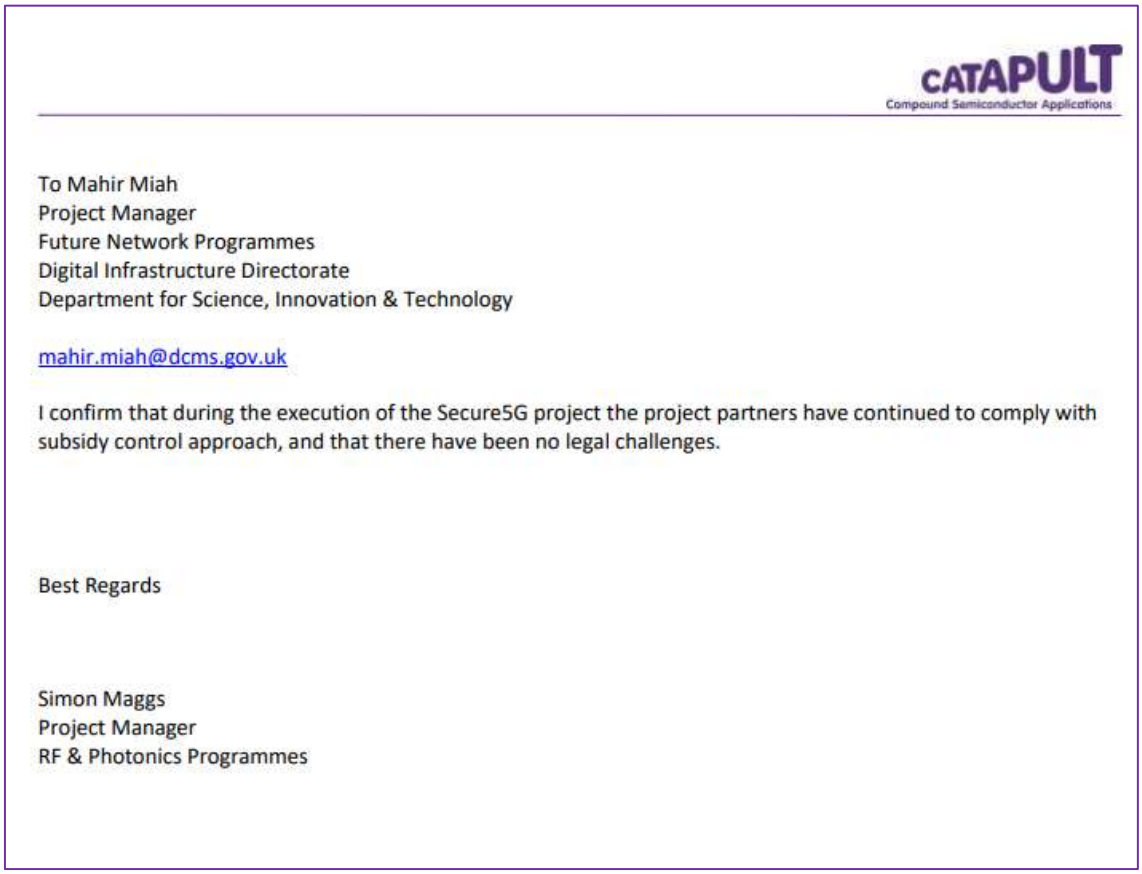
4.2 Breakdown

Below is the financial breakdown of the finances by expense type, from a Claim perspective;

Sum of DCMS Funding	Column Labels						
Row Labels	1	2	3	4	5	6	Grand Total
Arqit Limited	**£0.00**	**£14,156.24**	**£9,801.97**	**£21,166.14**	**£35,631.40**	**£38,321.67**	**£119,077.42**
Capital Usage	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Labour	£0.00	£10,156.97	£8,168.27	£14,305.12	£21,598.77	£24,817.93	£79,047.06
Materials	£0.00	£1,450.00	£0.00	£0.00	£0.00	£0.00	£1,450.00
Other Costs	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Overheads	£0.00	£2,031.39	£1,633.69	£2,861.02	£4,319.75	£4,963.59	£15,809.45
Sub Contract Costs	£0.00	£0.00	£0.00	£4,000.00	£9,712.88	£8,228.50	£21,941.38
Travel and Subsistence	£0.00	£517.88	£0.00	£0.00	£0.00	£311.66	£829.53
Compound Semiconductor Applications Catapult	**£0.00**	**£8,507.52**	**£24,145.07**	**£32,070.39**	**£45,486.37**	**£86,859.01**	**£197,068.36**
Capital Usage	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Labour	£0.00	£7,089.60	£15,702.96	£9,865.71	£13,238.93	£19,352.61	£65,249.81
Materials	£0.00	£0.00	£0.00	£0.00	£6.41	£10,727.78	£10,734.19
Other Costs	£0.00	£0.00	£4,795.74	£20,177.29	£29,593.24	£34,647.09	£89,213.37
Overheads	£0.00	£1,417.92	£3,140.67	£1,973.19	£2,647.79	£3,870.52	£13,050.09
Sub Contract Costs	£0.00	£0.00	£0.00	£0.00	£0.00	£16,475.00	£16,475.00
Travel and Subsistence	£0.00	£0.00	£505.70	£54.20	£0.00	£1,786.00	£2,345.90
Lime Microsystems Limited	**£14,968.15**	**£52,544.45**	**£73,508.86**	**£71,232.95**	**£72,640.64**	**£15,046.93**	**£299,941.99**
Capital Usage	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Labour	£0.00	£39,887.04	£48,676.22	£45,029.96	£40,075.61	£11,813.38	£185,482.21
Materials	£2,419.00	£0.00	£329.32	£17,196.78	£8,013.25	£0.00	£27,958.34
Other Costs	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Overheads	£6,690.71	£7,977.41	£9,735.48	£9,006.21	£8,015.12	£2,362.68	£43,787.60
Sub Contract Costs	£5,858.45	£4,680.00	£14,767.85	£0.00	£16,536.66	£870.88	£42,713.84
Travel and Subsistence	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Slipstream Engineering Design Limited	**£40,273.48**	**£59,523.24**	**£55,247.98**	**£67,643.29**	**£79,484.18**	**£38,522.12**	**£340,694.29**
Capital Usage	£759.00	£1,517.40	£1,517.40	£1,359.00	£1,359.00	£317.40	£6,829.20
Labour	£26,865.40	£32,985.64	£34,459.99	£43,149.53	£42,083.01	£29,145.40	£208,688.97
Materials	£5,954.69	£18,257.47	£11,878.90	£14,504.65	£27,241.38	£2,664.80	£80,501.90
Other Costs	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Overheads	£5,373.08	£6,597.13	£6,892.16	£8,630.11	£8,416.60	£5,829.08	£41,738.16
Sub Contract Costs	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00	£0.00
Travel and Subsistence	£1,321.31	£165.60	£499.53	£0.00	£384.19	£565.43	£2,936.06
Grand Total	**£55,241.63**	**£134,731.44**	**£162,703.88**	**£192,112.77**	**£233,242.59**	**£178,749.74**	**£956,782.06**

4.3 Residual Costs

There are no residual costs. CSAC makes the following statement in an email dated 22/09/2023, with regard to State Aid Compliance and a further statement in an email on 19/09/2023, with regard to Nothing to Declare on any Asset Register.



To Mahir Miah
Project Manager
Future Network Programmes
Digital Infrastructure Directorate
Department for Science, Innovation & Technology

mahir.miah@dcms.gov.uk

I confirm that during the execution of the Secure5G project the project partners have continued to comply with subsidy control approach, and that there have been no legal challenges.

Best Regards

Simon Maggs
Project Manager
RF & Photonics Programmes

State Aid Compliance - 22/09/2023

- No assets have been purchased. The 5G base station is not an asset as it has no commercial value.

Asset Register - 19/09/2023

5 Change Control

The following changes were raised during the course of the project.

PCR0001 – Cashflow and repurpose – The GFA, Grant Funding Authority is a process developed by DSIT, to guide the lead project partner in developing the business case, such that DSIT can issue a GOL, Grant Offer Letter. Therefore, the process sits at beginning of the project. The process is extensive and detailed in comparison to Innovate UK's and other funding body processes. As such minor changes in requirements from DSIT or the project consortium, result in extensive re-calculation. In addition, when Secure5G was in the GFA process, DSIT were closing many other projects and had resource challenges in their finance department. As a result, the GOL was received 5 months after the project start date, 01/01/2022.

Furthermore, an extensive list of deliverables was added by DSIT to the project requirements, after bid stage, which needed funding. These were not included in the original bid. For a Research Technical Office, such as CSAC, who is 100% government funded, 'not for profit / not for loss,' this is a critical area, as additional costs cannot be taken from core grant. CSAC has no other form of income for the project. The additional tasks included, communications requirements, which ultimately needed an event, and exploitation best served by a video and web pages. As measurement time had been lost, CSAC provided a cashflow reallocation PCR, such that funding from obsolete tasks could be repurposed to support the communications plan.

PCR0002 – Cashflow changes for Q2

PCR0003 Cashflow for Q4 and milestone definition changes

PCR0004 – Cashflow changes in later stage of project

6 Risk Management

The risk register was assembled at bid stage. No significant risks evolved into issues. By far the greatest issue on the project, was time pressure due to the 5-month administrative period at the start of the project, which led to a very late start and some rescoping of tasks into later periods.


CATAPULT

Project Risk Register

Top RISKS in the Reporting Period	Risk	Mitigation
1	Risk that some milestone deliverables will not be ready by 30/06/2023. due to commitment to showcase readiness, in particular hardware.	Extend project to 31/07/2023
2	Risk that OEM mobile phone company, would not engage with project team in full such that an extension can be applied for in time.	Extended project to 31/07/2023, but no comitment could be reached in that time - No extension applied for
3		
4		
5		

7 Exploitation

The success of the project was ultimately exploited in 2 ways:

Knowledge reports, produced as an output of the projects research, (see section 3.2 for the deliverable listing).

Communications Plan, whose outputs were:

- Showcase event and video – LINK
- Animation video - LINK
- Webpage - LINK

8 Project Handover

- The deliverables have been submitted to DSIT and are approved
- The deliverables will be used by project partners as reference for future development for ongoing product development.
- The 5G base station is at Lime Microsystems for final documentation by Lime Engineers. It will be returned to CSAC as a no commercial value article, which cannot be sold, during late October 2023. The unit will remain with CSAC for technology demonstration.
- The communications plan outputs are hosted by CSAC, and will continue to be available to the project partners and DSIT, (see section 7)

9 Follow-on Work

The project partners are engaged in further work following on from the successful completion of the Secure 5G Project.

Lime Microsystems are engaged in DSIT Open Networks Ecosystem Project:
HiPer-RAN (Highly Intelligent, Highly Performing RAN)
Location: 5G/6G Innovation Centre, University of Surrey, Guildford, UK
Funding amount: £7,895,362
Partners: University of Surrey, AWTG, Keysight technologies UK, Lime Microsystems, Viavi Solutions UK, Virgin Media O2, BT

Lime are continuing with the development of the Secure5G hardware. It will reach the open market in the coming years, following certification and further development, and size reduction.

Arqit are engaged in DSIT Open Networks Ecosystem Project:
ARIANE (Accelerating RAN Intelligence Across Network Ecosystems
Location: London.

Funding amount: £6,004,167.61
Partners: Telecom Infra Project, British Telecommunications plc, Accenture UK Limited, Amdocs UK Limited, Arqit UK Limited, HCL Technologies UK Limited, Reply UK Limited trading as Net Reply UK, Viavi Solutions UK Limited, VMWare UK Limited, Adtran (non-funded)

CSA Catapult is engaged in DSIT Open Networks Ecosystem Project:
5G SWaP+C (Size, Weight and Power + Cost)
Location: South Wales and Ipswich
Funding amount: £1,211,896.55
Partners: BT, Space Forge and Compound Semiconductor Applications Catapult

Slipstream are engaged in:
Future customer bids, due to the technology demonstrated on the Secure5G project. Due to military confidentiality, these cannot be listed in this report.

9.1 Residual Items

Arqit has one milestone deliverable which will be further developed on the Ariane DSIT ONE project, as part of a separate funded project.

9.2 Future Opportunities

Not listed due to confidentiality

10 Key Lessons Learned – From Monthly Reporting Sheet

	Phase	Lesson Description	Date	Details	Audience	What needs to change	Action	Owner	Status
1	GFA Development	GFA Development process is complex, due to use of multiple documents. This slows up issue of the GOL / GFA, and subsequent PCR approvals	27/09/2022	GFA development process is not optimised, for it's purpose, whch is to demonstrate that the project team are organised within the rules of the process. GFA development process is used to provide data for pasting into the GOL / CA	DCMS / CSAC	Integrate all documents into one spreadsheet that provides all data: Annex 5 Annex 5.2 Cash Flow Profile Cost Sheet Graphs for variance	Monthly feedback meetings with DCMS 31/08/2023 - DSIT to check that DSIT ONE Programme methodology uses this improvement point	DSIT	Open
2	GFA Development	GFA Development process is complex, due to integration of costs with milestones	27/09/2022	To achieve this, the lead PM for all partners has to create an excel spreadsheet, with all costs across all categories, per partner business, and develop a cash flow profile against each milestone to be achieved.This is a 2-3 week exercise for one person, which has to be run in conjunction with other tasks aside from the GFA development	DCMS / CSAC	Recommended, that milestones are de-linked from costs OR DCMS to roll out booking system / database OR Raise PCR Q3 for additional funding to CSAC, for PM hours	Look at process improvement opportunities Workshop, was held Monthly feedback meetings with DCMS 31/08/2023 - DSIT confirms through the Lead PPM for Orangan that costed milestones are necessary and are a way of ensuring value for money for the taxpayer.	DSIT	Closed
3	GFA Development	Claim process is complex and slow in preparation, due to integration of costs with milestones	27/09/2022	DCMS want to create an incentive to deliver, by paying upon successful approval of milestone delievry, based on milestone criteria being met. However, as PM lead I have no way to attibute costs climed against each milestone. This is because partner businesses, do not have a method for booking hours, and costs, day by day to milestones.	DCMS / CSAC	Recommended, that milestones are de-linked from costs OR DCMS to roll out booking system / database OR Raise PCR Q3 for additional funding to CSAC, for PM hours	Look at process improvement opportunities Workshop, was held Monthly feedback meetings with DCMS 31/08/2023 - DSIT confirms through the Lead PPM for Orangan that costed milestones are necessary and are a way of ensuring value for money for the taxpayer.	DSIT	Closed
4	GFA Development	Claim process is complex and slow in execution, due to integration of audit level data being required by DCMS, where as IUK would required this following a successful claim	27/09/2022	DCMS claim process is front loaded in audit level data, to smooth post payment auditing later. However, this slows the claims process. Secure5G claim 1 took 16weeks	DCMS / CSAC	Recommended, that milestones are de-linked from costs OR DCMS to roll out booking system / database OR Raise PCR Q3 for additional funding to CSAC, for PM hours	Look at process improvement opportunities Workshop, was held Monthly feedback meetings with DCMS 31/08/2023 - DSIT confirms through the Lead PPM for Orangan that DSIT is different to IUK. Project teams are to stop challenging the process and run with it.	DSIT	Closed
12	Deliverables	The programme should allow for flexibility with the completion of tasks within each quarter	18/07/2023	Submitting evidence against the milestones at the end of the quarter provides schedule flexibility	All	N / A	Carry this forward to future collaborative projects 31/08/2023 - Agreed	DSIT	Closed
13	Communications	A showcase event is an effective focal point for all aspects of development including marketing	18/07/2023	Events help to focus efforts, generate attention outside the FRANC community, and collate feedback	All	N / A	Carry this forward to future collaborative projects 31/08/2023 - Agreed	DSIT	Closed
15	Communications	Highlighting success for a highly complex subject matter can be supported with promotional video which appeals to technical and non-technical audience	18/07/2023	Promotional materials help to show achievements and generate interest in technologies where a standalone demonstrator will struggle to make an impact with a non-technical audience	All	N / A	Carry this forward to future collaborative projects 31/08/2023 - Agreed	DSIT	Closed
16	Communications	Greater input throughout the project from 3rd party organisations interested in these technologies may have helped hone requirements and add weight to the promotional activities	18/07/2023	Early nomination and active engagement from 3rd party organisations influencing the requirements and value of the project	All	Emphasise importance of 3rd party engagement to drive requirements for real-world applications in a wider system	Carry this forward to future collaborative projects 31/08/2023 - Agreed	DSIT	Closed

11 Confirmation of Project Close

The following items are now confirmed and the project is closed.

- All requirements have been met, or otherwise de-scoped via approved change control. – ***Confirmed***
- The Project Management Plan has been satisfied. – ***Confirmed***
- All deliverables have been approved as relevant. – ***Confirmed***
- Acceptance criteria has been met and approved by the appropriate customer or owner. – ***Confirmed, system working and demonstrated on showcase event day at CSAC Innovation Centre, 27th June 2023.***
- Benefits have been delivered, or otherwise accepted by an on-going owner. – ***Confirmed, benefits accepted by the Project Consortium***
- There are no outstanding risks, issues, opportunities or actions (or otherwise these have been handed over as per the 'follow on work' section. ***Confirmed, all items 100% closed***
- All appropriate stakeholders have been notified that the project is preparing to close. ***Confirmed***
- The Project Monitoring Committee has confirmed approval of project closure (or otherwise state the date of Handover & Close Gate, and update the report after approval has been given). ***Project closure documentation to be completed by Project Manager, to move project into gate 6 at CSAC. Target date 13/10/2023.***

12 Version History and Approvals

Version	Details of Change	Date
1	Initial Draft compiled by S Maggs	29/09/2023
2	Minor revisions to formatting following peer review	09/10/2023
3	Final Release	10/10/2023
4	Hyperlink added	18/10/2023

APPROVALS				
Compiled by	Name	Simon Maggs	Date	09/10/2023
Peer Reviewed by	Name	Jessica Veloza	Date	09/10/2023
Approved by	Name	Joe Gannicliffe	Date	10/10/2023

Appendices:

Please also refer to
MS 5.2 Future System Planning & Feasibility
MS 5.3 final Reporting and Road Mapping