Institution: Cardiff University		
Unit of Assessment: Computer Science and Informatics (11)		
Title of case study: A new blockchain method to improve logistics in national UK defence, and global industries		
Period when the underpinning research was undertaken: January 2013 – December 2020		
Details of staff conducting the underpinning research from the submitting unit:		
Name(s):	**Role(s) (e.g. job title):**	**Period(s) employed by submitting HEI:**
I Taylor A Preece	Professor Professor	31/08/2002 – present 01/12/2007 – present
Period when the claimed impact occurred: January 2017 – December 2020		
Is this case study continued from a case study submitted in 2014? No		

1. Summary of the impact (indicative maximum 100 words)

Blockchain technology enables a secure system for recording transactions but its scalability and complexity require computationally expensive calculations. Cardiff research in off-chain storage enabled a method where smart contracts can be used to verify external data transactions and integrate these with blockchains to provide fast and secure ledgers. The research was a central concept to the foundation of SIMBA Chain Inc., a US-based company offering a smart-contract-as-a-service platform. SIMBA Chain have since attracted £1.5M in capital funding and secured the first blockchain-based commercial contracts from the US Military, with over £9.1M in contracted services for the US Air Force, US Navy, and the Department of Defense.

2. Underpinning research (indicative maximum 500 words)

Smart contracts allow transactions that are traceable, irreversible, and without third party verification, making them well suited for managing distributed resources such as government assets and supply chains. The decentralised structure and enhanced security of blockchain architectures is an ideal basis for smart contracts, but its complexity makes specifying a single architecture for smart contracting extremely challenging. Storing a large number of transactions on a blockchain can also rapidly become computationally expensive and highly inefficient. Research at Cardiff investigated methods of integrating the strengths of blockchains, smart contracts and data stores into a single framework.

2.1 Integration of blockchains, smart contracting and data stores

Workflows provide a structured way of describing complex functional execution and data pipelines into a single process. Taylor's research at Cardiff (later, also via his joint appointment with Notre Dame in 2015) developed a workflow method that facilitated structured representations for task coordination and data movement between distributed processes and transactions. A key benefit of this method was the ability to build a scalable platform for multiple partners within a complex workflow **[3.1]**.

Building on this workflow expertise, Taylor and Preece (Cardiff) conceived a blockchain-based distributed ledger approach, which enables the encoding of a trusted audit trail for data sharing agreements **[3.2, 3.3]**. The work includes a set of case studies on how the method integrates multiple levels of information about materials through stages of a project supply chain in a tamper-proof blockchain system. The design approach enables two key benefits: it identifies points at which accountability for assets can be transferred into a blockchain and allows the use of a blockchain to instantiate trust between unknown parties.

This new approach achieves scalability of blockchain-based approaches through selective storage of data "off-chain", where non-transactional data too large to be efficiently deposited in a blockchain is stored elsewhere. Instead, only a manageable fixed-size fingerprint of the

stored data is bound on a blockchain, which enables smart contracting to occur, mediated by the security requirements of the scenario and transaction **[3.4]**. In other words, lower security activity does not require all data to be directly represented on a blockchain. The off-chain storage approach represents a significant advancement of blockchain architecture, specifically in validating the order of transactions and rules defining the conditions that take place at each stage of the process.

Further research **[3.5]** involved the use of emerging standards, such as decentralized identifiers and verifiable credentials, to enhance the visibility of data, products and services. This research initiative **[3.6]** uses verifiable credentials for establishing trust in Internet-of-Things (IoT) devices and services in tactical edge military scenarios. Such approaches are being written into industry proposals to establish the verifiability of data and physical assets including IoT devices for 5G, health department data, digital twins, and additive manufacturing among others.

2.2 Application of blockchain-based smart contract

These research developments **[3.2, 3.3, 3.4]** were motivated by a military partnership between the UK and US designed to resolve the problem of complex asset management. This culminated in the founding of SIMBA Chain Inc. to provide novel blockchain solutions to the US military. Taylor and Preece's research **[3.3, 3.4]** made a distinct and material contribution to the design of SIMBA Chain's *Smart Contract as a Service* product, which enables simplified mechanisms for interaction with a blockchain in terms of the underlying architecture, security risk management, and interface design. Scenario analysis identified specific toolkits requiring integration and how they should interact, which helped manage complexity and structure fundamental system requirements. This impacted the platform's data scalability to enable off-chained files to be integrated within blockchain transactions.

3. References to the research (indicative maximum of six references)

[3.1] Rogers, D., Harvey, I., Huu, T.T., Evans, K., Glatard, T., Kallel, I., **Taylor, I.**, Montagnat, J., Jones, A., Harrison, A. Bundle and Pool Architecture for Multi-Language, Robust, Scalable Workflow Executions. *J Grid Computing* 11**,** 457–480, 2013. DOI:10.1007/s10723-013-9267-2

[3.2] Barclay, I, **Preece, A**, **Taylor, I** 2019. A conceptual architecture for contractual data sharing in a decentralized environment: In SPIE Defense & Commercial Sensing 2019 (DCS), Artificial Intelligence and Machine Learning for Multi-Domain Operations Applications, Baltimore, MA, USA, April 14-18 2019. DOI:10.1117/12.2518644

[3.3] Barclay, I, **Preece, A**, **Taylor, I**, Verma D 2019. Towards traceability in data ecosystems using a bill of materials model: Presented at International Workshop on Science Gateways, Ljubljana, Slovenia, 12-14 June 2019. Available in REF 2.

[3.4] Verma, D, Desai, N, **Preece, A** and **Taylor, I** 2017. A blockchain based architecture for asset management in coalition operations. Presented at: Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR VIII, Anaheim, USA, 10 - 13 April 2017. Proc. SPIE 10190, Ground/Air Multisensor Interoperability, Integration, and Networking for Persistent ISR VIII. SPIE, 101900Y. DOI:10.1117/12.2264911

[3.5] Certifying Provenance of Scientific Datasets with Self-sovereign Identity and Verifiable Credentials, Barclay, I., Radha, S., **Preece**, **A.**, **Taylor, I.** and Nabrzyski, J. In Proceedings of 12th International Workshop on Science Gateways (IWSG), 10- 11 June 2020, Cardiff (Virtual). Available in REF 2.

[3.6] Barclay, Iain, Simpkin, Christopher, Bent, Graham, La Porta, Tom, Miller, Declan, **Preece, A, Taylor, I**, and Verma, Dinesh 2020. Enabling discoverable trusted services for highly dynamic decentralized workflows. Presented at: 15th IEEE/ACM Workshop on Workflows in Support of Large-Scale Science (WORKS 2020), Virtual, 11 November 2020. Available in REF 2.

4. Details of the impact (indicative maximum 750 words)

Research at Cardiff enabled a new business, SIMBA Chain Inc., to develop applied blockchain solutions through a *Smart-Contract* as a Service platform. Since forming in 2017, SIMBA Chain have secured contracts worth over £9.11 million, including the first public awards by the US military for blockchain-based technology, and development of secure messaging and data systems for the US Navy, US Air Force, and the Department of Defense (DoD). SIMBA Chain have drafted white papers on blockchain applications endorsed by a sitting US congressperson, which are being used to lobby Congress for wider application.

4.1 Founding and growth of SIMBA Chain Inc.

SIMBA Chain was founded to deliver a grant from the Defence Advanced Research Projects Agency (DARPA, an agency of the DoD) **[5.1]** to develop a secure, unhackable messaging and transaction platform for the United States Military. Taylor was approached by project lead, Joel Neidig, from the Indiana Technology and Manufacturing Company (ITAMCO). Drawing upon his research, Taylor provided theoretical understanding of blockchain applications, as well as the development of various 'use cases' created at Cardiff and Notre Dame to formulate the application of blockchain technology alongside smart contracts **[5.1]**.

Neidig stated that "*these early "use cases" subsequently enabled the SIMBA Chain Smart Contract-as-a-Service (SCaaS) platform to represent assets and transactions in a structured way*" **[5.1]**, allowing them to "*seamlessly integrate off-chain data with blockchain technology and smart contracts*" **[5.1]**. The SCaaS is a comprehensive, fault tolerant, secure environment that provides scalable production enterprise applications and enables developers to seamlessly integrate blockchains and smart contracts into their applications by providing simple interfaces to aid development and resilient infrastructure.

Taylor's theoretical and applied research was essential in establishing the SCaaS platform, according to Neidig: "*The SCaaS platform is the key technological advancement that underpins SIMBA Chain and these key aspects could not have been developed without Prof Ian Taylor's expertise*" **[5.1]**.

SIMBA Chain was subsequently formed from this partnership, with Neidig becoming CEO and Taylor the Chief Technology Officer. In two funding rounds in February 2019 and January 2020, SIMBA Chain secured private seed financing to develop the company and raised US$2 million (£1.5 million) **[5.2a, 5.2b]**. SIMBA Chain now employs 21 full-time members of staff at their five offices across the world, including five previous Cardiff University employees and research students. SIMBA Chain is in the process of establishing a UK-based entity within Cardiff with support from Welsh Government **[5.1]**.

4.2 Secure messaging for US Naval Air Command

In December 2019, the Naval Air Warfare Centre (NAVWAR), the cross-platform arm of the US Navy that provides information and communications solutions for Air and Naval Fleet forces across the world, awarded SIMBA Chain a contract to deploy a secure, blockchain-based messaging and transaction platform with a total value of US$9.5 million (£7.6 million) **[5.3]**.

The NAVWAR contract to SIMBA Chain is the first time a US military organisation has publicly adopted blockchain technology, representing a significant shift in the willingness to adopt the new system **[5.4]**. SIMBA Chain will provide a customized Distributed Ledger Technology with a broad package of applications including secure messaging, research of supply chain and logistics, evaluation of engineering life-cycles, software modernisation, and financial transactions **[5.3]**.

4.3 Protecting additive manufacturing supply chains for the US Air Force

The US Air Force is expanding its capacity for additive manufacturing: the use of 3D printing in design, production, and repair of field components. Safeguarding 3D designs and component data from external manipulation is therefore critical, as is ensuring a secure record of all components accessed and built. In August 2019, SIMBA Chain was selected by the US Air Force to develop the prototype blockchain-based platform, BASECAMP (Blockchain

Approach for Supply Chain Additive Manufacturing Parts) to protect their distribution links for additive manufacturing **[5.5]** by creating an unalterable record of components throughout their entire lifecycle.

Jeffery Slayton, US Air Force Director of Special Programs, Strategy and Policy, highlighted how SIMBA Chain is helping contain the increased complexity of supply chains and data integration: "*Emerging technologies like SIMBA Chain's blockchain platform have the potential to achieve the reliable exchange of information over an unreliable network where not all participants can be trusted*" **[5.6]**.

Following the immediate success of BASECAMP, the US Air Force awarded SIMBA Chain a two-year US$1.5 million (£1.2 million) contract in June 2020 to enhance logistics and supply chain management solutions and introduce blockchains into the Air Force's research and training curriculum in cybersecurity, logistics, and programming **[5.6]**. The new contract includes a partnership with Boeing, securing component designs for US Air Force using BASECAMP **[5.7]**. To integrate the system, SIMBA Chain installed a node within Tinker Air Force Base, Oklahoma, a central hub for Air Force supply chain logistics and headquarters of the 448th Supply Chain Management Wing **[5.7]**.

In October 2020, the US Air Force hosted an open competition to demonstrate additive manufacturing capability, promoted as the "Advanced Manufacturing Olympics" **[5.8]**. SIMBA Chain competed in a scenario requiring a strategy to assist a besieged military base isolated from their supply chain, including manufacture of aircraft equipment, infrastructure, and protective equipment. Competing against 16 organisations including Boeing Global Services and Stratasys - the largest additive manufacturing company in the world - SIMBA Chain won the Gold Medal and a prize of $100,000 for their additive manufacturing strategy **[5.8].**

4.4 Safeguarding R&D Data for the US Department of Defense

In May 2020, the DoD awarded a two-year Small Business Innovation in Research (SBIR) Phase I contract worth US$200,000 (£159,820) to SIMBA Chain to develop a single, proof-of-concept blockchain-based system to improve the integration, security, auditability, and controlled access to R&D Data within the Defense Technical Information Center (DTIC) **[5.9]**.

The project, ALAMEDA (Authenticity Ledger for Auditable Military Enclaved Data Access), is rooted in SIMBA Chain's SCaaS to develop a platform that can share documents and datasets for collaborative working while maintaining a tamper-proof system for accountability. ALAMEDA will support the DoD archive of R&D projects, accounting for 40% of all US Federal research grants **[5.9]**.

4.5 Influencing US Congress investment in blockchain

Cardiff's critical success in enabling SIMBA Chain's blockchain application has elevated awareness of the potential of blockchains within the US Military. Taylor co-authored and co-edited the Value Technology Foundation whitepaper, *Potential uses of blockchain by the U.S. Department of Defense* **[5.10a]**, alongside IBM, CGI, Deloitte, Amazon, and Consensys. The whitepaper includes a foreword endorsement from US Congressman Darren Soto (Florida), who submitted the whitepaper for inclusion in the 2021 National Defense Authorization Act, which outlines the annual budget and expenditure for the DoD.

Subsequently, in July 2020, Soto added two key provisions to the 2021 National Defense Authorization Act, requiring a report on blockchain application and recommendations for additional research and development, and to define "distributed ledger technologies" as an emerging technology. With support from SIMBA Chain, Soto is currently lobbying Congress to establish a national blockchain center for innovation and research **[5.10b]**.

4.6 Summary

Cardiff's blockchain-based research underpinned the formation of SIMBA Chain Inc., raising £1.5 million in private funding and now employing 21 people. SIMBA have since secured the first ever blockchain contract from the US Military and won multiple military contracts worth over £7.8 million from the US Naval Air Command, US Air Force, and DoD. SIMBA's

blockchain experience is now being applied to encourage further investment in the technology, supporting US lawmakers to promote blockchains in their annual defense budget.

5. Sources to corroborate the impact (indicative maximum of 10 references)

[5.1] Testimonial from Joel Neidig, CEO of SIMBA Chain Inc.

[5.2] (a) SIMBA Chain blog, "SIMBA Chain closes $1.5 million seed investment round, sets stage for strategic growth in 2020" (13 January 2020) **(b)** News Article from Blockchain in Transport Alliance (BITA) "SIMBA Chain raises $500,000 in pre-seed funding" (February 2019)

[5.3] SIMBA Chain blog, "SIMBA Chain awarded contract from US Navy to deploy secure messaging solutions" (6 February 2020)

[5.4] Yahoo news article, "US Navy invests $9.5m in blockchain-based systems" (7 February 2020)

[5.5] SIMBA Chain blog, "SIMBA Chain chosen for Air Force supply chain security" (26 August 2019)

[5.6] SIMBA Chain blog, "SIMBA Chain secures a $1.5 million contract with the US Airforce" (16 June 2020)

[5.7] Coindesk news article, "US Airforce gives blockchain firm $1.5M to build supply chain network" (15 June 2020)

[5.8] Simba Chain news article "SIMBA Chain brings home the Gold Medal in the US Air Force's first Advanced Manufacturing Olympics" (29 October 2020)

[5.9] SIMBA Chain blog "Blockchain-based system for securing R&D data for DoD" (12 May 2020)

[5.10] (a) Report: "Potential uses of Blockchain by the US Department of Defense" (March 2020), Value Technology Foundation; **(b)** Congressman Darren Soto's press release "Soto Blockchain bills pass out of Energy and Commerce Committee" (10 September 2020)