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Addressing Key Challenges to Making Enterprise Blockchain Applications a Reality

Many enterprises have not progressed their blockchain solutions beyond proofs-of-concept. Daunting managerial challenges in the areas of standards, regulations, shared governance models and viable ecosystems impede progress. We describe the strategies that LO3 Energy, Moog, Inc. and the Center for Supply Chain Studies are pursuing to address these challenges.[1,2]

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Growing Business Interest in Blockchain Technology

A blockchain application is a peer-to-peer system for validating, time-stamping and permanently storing transactions and agreements on a shared ledger that is distributed to all participating nodes.[3] Bitcoin was the original blockchain, described by Satoshi Nakamoto in a 2008 white paper.[4] The Bitcoin application was coded—presumably by Nakamoto—and went live in January 2009. Since then, many traditional enterprises as well as startups have been exploring the possibility of adapting Bitcoin's blockchain technology for business applications.

Blockchain applications potentially offer several advantages compared to centrally controlled applications. Specifically, blockchain applications promise a significant amount of business value, including transacting directly with trading partners, eliminating the need for reconciliations, instantly tracking and tracing assets, providing data provenance, settling transactions quickly and cheaply, and enabling a security model that is fault tolerant, resilient and available. (Appendix A describes the advantages of blockchain applications.) In the words of Antony Lewis, founder of Bits on Blockchain, in essence, *"distributed ledgers 'confirm as you go' rather than 'confirm after the fact'."*[5]

1 Martin Mocker is the accepting senior editor for this article.

2 This research was supported by MIT's Center for Information Systems Research (CISR). The author acknowledges and thanks Jeanne Ross, Principal Research Scientist, and Kate Moloney, Research Specialist.

3 Lacity, M. C. *A Manager's Guide to Blockchains for Business*, SB Publishing, 2018.

4 Nakamoto, S. "Bitcoin: A Peer-to-Peer Electronic Cash System," 2008, available at https://bitcoin.org/bitcoin.pdf.

5 Lewis, A, "Avoiding blockchain for blockchain's sake: Three real use case criteria," *Bits on Blocks*, July 24, 2017, available at https://bitsonblocks.net/2017/07/24/avoiding-blockchain-for-blockchains-sake-three-real-use-case-criteria/.

However, blockchain technology is immature, with known challenges in the areas of scalability, performance and interoperability with other systems. In addition to technical challenges, enterprises face daunting management challenges because blockchain applications must be assimilated within complex institutional, regulatory, social, economic and physical systems.[6] Given the challenges, it is not surprising that, at the beginning of 2018, most blockchain applications were still in test environments (i.e. "sandboxes").[7] Only 10% of respondents to our 2018 survey reported that their organizations had deployed at least one blockchain application, and none of these deployments had been fully scaled up. (Appendix B describes the research on which this article is based.) However, more than 52% of respondents in the survey indicated that their organizations were "actively considering" blockchain technologies, compared to only 19% in the equivalent 2017 survey.[8] This increase indicates a growing interest in blockchain applications.

Focus of our Blockchain Research and Selection of Cases

Our multi-year research project (see Appendix B) seeks to understand how enterprises are building blockchain-based business applications and overcoming the challenges to deliver real business value. We have investigated enterprise adoption journeys from initial business visions, the proposed blockchain-enabled solutions, proofs-of-concept and plans to deploy solutions into production. We also asked research participants to describe practices for addressing known managerial challenges in the areas of:

1. *Standards*: How are organizations defining standards for access rights, data structures and allowable transactions for their blockchain solutions, given that no single blockchain standard has yet emerged?[9]
2. *Regulations*: How are organizations ensuring blockchain applications will comply with regulations, given that regulators around the world are struggling to adapt laws because of the newness of the technology?[10]
3. *Shared governance*: Given that no single organization owns or controls a blockchain application, how will the blockchain solution be governed?
4. *Viable ecosystem*: How will organizations attract a critical mass of adopters of a blockchain solution beyond the core originators?

From our research, we have created dozens of blockchain case vignettes covering a variety of industries, enterprise types and development stages. However, for this article, we selected three case studies—LO3 Energy, Moog, Inc. and the Center for Supply Chain Studies—as examples of enterprise blockchain journeys.[11] The cases represent three common types of organizations that are undertaking enterprise blockchain initiatives—startups, traditional enterprises and consortia. Each organizational type has its own advantages and disadvantages for making enterprise blockchains a reality.

Startups. Startups are a large part of the global blockchain ecosystem. By May 2018, there were nearly 2,500 blockchain startups, with

6 Lacity, M. C. and Willcocks, L. P. *Robotic Process and Cognitive Automation*, SB Publishing, 2018.

7 A 4th-quarter 2017 study of 200 blockchain projects by HfS, a research and consulting firm, found that 90-95% of enterprises were still conceptualizing blockchains, conducting proofs-of-concept or piloting blockchain applications. Only 5-10% of pilots were progressing to production. For more information, see Gupta, S. and Mondal, T. *HfS Blueprint: Enterprise Blockchain Services*, HfS Research, November 17, 2017, available at https://www.hfsresearch.com/blueprint-reports/hfs-blueprint-enterprise-blockchain-services.

8 Lacity, M. C., Babin, R. and Willcocks, L. P. "Research Center: Service Automation Trends Survey," *Pulse Magazine* (28), 2017, pp. 40-44.

9 The lack of standards is a well-documented challenge. Many traditional standards organizations are in the process of defining blockchain standards, including the Institute of Electrical and Electronics Engineers (IEEE), International Organization for Standardization (ISO), and American National Standards Institute (ANSI). In addition, new blockchain consortia like the Hyperledger Project and the Enterprise Ethereum Alliance are also working to define standards.

10 See, for example, Tena, M. *7 regulatory challenges facing blockchain*, BBVA Research, 2017, available at https://www.bbva.com/en/7-regulatory-challenges-facing-blockchain/.

11 From a practical point of view, the three cases were also chosen because of participants' willingness to be identified. Other case study participants requested anonymity, which lessens the value of the cases for readers of *MIS Quarterly Executive*.

an average valuation of $4.6 million.[12] While the majority of startups will likely fail due to the inherent risks,[13] the theory of disruptive innovation[14] suggests that many blockchain innovations will likely come from nimble startups because they have no legacy barriers. LO3 Energy is a powerful example of a startup that is creating a whole new peer-to-peer energy market using a proprietary blockchain-enabled platform.

Traditional Enterprises. Corporations invested more than $1.2 billion in blockchain technologies between 2012 and 2017, including major organizations such as Citi, CME Group, JP Morgan, MasterCard, Maersk, NYSE, USAA, Visa, Wal-Mart and Wells Fargo, to name just a few.[15] Compared to startups, traditional enterprises have the advantages of established reputations and powerful networks of business relationships with customers and trading partners. One disadvantage, however, is that it's very difficult for traditional enterprises to break their successful business models by cannibalizing revenues from existing products and services. The theory of disruptive innovation suggests that incumbent enterprises should create an independent spin-off when they are serious about disrupting themselves. Moog, Inc. is an example of a traditional enterprise that plans to do just that.[16] It is a seeking to disrupt its traditional manufacturing model with a blockchain-enabled decentralized manufacturing model.

Consortia. As of August 2017, Deloitte had identified 40 major consortia that were defining blockchain standards and developing code bases for business applications.[17] The broad membership of consortia increases the likelihood of blockchain adoption by a large number of enterprises, but the inclusion of so many players might result in slower progress compared to startups and traditional enterprises. Our third case, the Center for Supply Chain Studies, is a nonprofit pharmaceuticals industry consortium that is defining requirements for a blockchain application proof-of-concept to trace pharmaceuticals across the U.S. supply chain.

These three cases illustrate compelling reasons why blockchains are a suitable enabler of a business vision. However, they are using a variety of methods to address the challenges associated with standards, regulations, shared governance and building a viable ecosystem. The cases are summarized in Table 1 and described in detail below. For each, we provide a case overview and describe the business vision, the proposed blockchain-enabled solution, proofs-of-concept and the next steps for "making the solution real" by overcoming the four managerial challenges.

LO3 Energy's Microgrid

> *"The next time a superstorm comes through and knocks out all of the power, the Brooklyn Microgrid will make sure the power stays on in critical areas so you have a safe place to charge your phone, get food or send out emails to let people know you are okay."* Neighbor featured in the Brooklyn Microgrid introductory video[18]

Case Overview

LO3 Energy, a private U.S.-based company, is building a technology platform to create peer-to-peer markets to enable neighbors to buy and sell their locally produced energy. The platform

12 Websites that track blockchain startups include AngelList's *Blockchain Startups* (https://angel.co/blockchains) and Innovation Enterprise's *50 blockchain startups to watch out for*, available at https://channels.theinnovationenterprise.com/articles/50-blockchain-startups-to-watch-out-for-20-1.

13 Between 60% and 79% of startups fail. See Griffith, E. "Conventional Wisdom Says 90% of Startups Fail. Data Says Otherwise," *Fortune Magazine*, June 27, 2017, available at http://fortune.com/2017/06/27/startup-advice-data-failure/.

14 The theory of disruptive innovation was developed by Clayton Christensen over two decades, beginning with his first book published in 1997, *The innovator's dilemma: when new technologies cause great firms to fail*, Harvard Business School Press. For a thoughtful and current synopsis of the theory, see Christensen, C., Raynor, M. and McDonald, R. "What Is Disruptive Innovation?," *Harvard Business Review* (93:12), December 2015, pp. 45-53.

15 Hackett, R. "Blockchain in Review: Investment Trends and Opportunities," CB Insights, October 2017, available at https://www.cbinsights.com/research/briefing/blockchain-trends-and-opportunities/.

16 Christensen et al., op. cit., 2015.

17 Gratzke, P., Schatsky, D. and Piscini, E. "Banding together for blockchain – Does it make sense for your company to join a consortium?," Deloitte, August 16, 2017, available at https://dupress.deloitte.com/dup-us-en/focus/signals-for-strategists/emergence-of-blockchain-consortia.html - endnote-sup-7.

18 *Brooklyn Microgrid Introduction*, available at https://vimeo.com/195896508.

Table 1: Summary of the Cases

	LO3 Energy	Moog, Inc.	Center for Supply Chain Studies (CSCS)
Enterprise Type	Startup	Traditional enterprise	Nonprofit organization serving as industry consortium coordinator
Business Vision	Allow neighbors to produce, buy and sell locally produced electricity	Allow military and commercial customers to print aircraft parts where they need them, when they need them	Allow U.S. pharmaceuticals supply chain partners to comply with a new regulation called the DSCSA
Blockchain-enabled Solution	A peer-to-peer trading platform for energy microgrids	A peer-to-peer trading platform for 3D printed parts	Defining the blockchain application requirements to trace pharmaceuticals
Why is Blockchain Better than Existing Technologies?	LO3 Energy needed a highly secure distributed technology solution that would operate if the incumbent utility grid failed	Moog needed a highly secure distributed technology solution at the point of printing that multiple parties could trust	While existing technologies were considered, members concluded that a blockchain solution was the best option for complying with the new regulation
How are Participants Agreeing to Standards?	LO3 Energy defined proprietary standards	Moog is working with established standards organizations to adapt current standards	CSCS adopted GS1's Electronic Product Code Information Services (EPCIS) standards where applicable
How are Participants Ensuring the Blockchain Application will Comply with Laws Given the Regulatory Uncertainty?	LO3 Energy built the platform to comply with existing regulations and is applying for licenses under existing laws	Moog is actively lobbying regulators to adapt existing regulations	CSCS is designing the blockchain solution to comply with the DSCSA
How will the Blockchain Application Be Governed?	A nonprofit foundation will help local communities govern the microgrids	By establishing a joint venture and consortium for each industry vertical (e.g., aerospace, healthcare, automotive)	By creating a governance submodel that executes global rules, as well as through trading partner agreements defined by a wide range of representatives
How will Participants Attract a Critical Mass of Adopters?	Grass roots strategy: each community will educate, recruit and manage its own local microgrid	Enticement strategy: Moog will give away valuable digital content for free to attract participants	Mimetic (or copycat) strategy: Some of the largest players in the pharmaceuticals supply chain are driving the solution, which should attract other participants
Status as of Mid-2018	By the end of 2017, the Brooklyn Microgrid, one of LO3's projects, was running in a test market of 60 prosumers and approximately 500 consumers; live transactions will begin once required licenses from regulators are obtained (anticipated in 2018)	Moog is actively working with partners and regulators to move the platform to market in 2019	CSCS had finished the first study to define blockchain scenarios; two more studies are underway to build prototypes

is already operating in a shadow market[19] in Brooklyn New York. It will go live in 2018 after completing the licensing process required by the State of New York. LO3 intends to sell its platform around the world to communities that will own and manage the local microgrids.

The Business Vision

Lawrence Orsini founded LO3 Energy in 2012 in Brooklyn, New York. Orsini envisioned a future of energy production and consumption that is sustainable, local, reliable, efficient and self-governing. He wanted to build a platform where neighbors with solar panels (called "prosumers") could sell excess energy capacity directly to other neighbors using a mobile app. His vision came into sharp focus in the aftermath of Hurricane Sandy, which hit New York City in October 2012. It was the largest hurricane on record—a whopping 1,100 miles in diameter. As Hurricane Sandy flooded the streets of New York City, over 800,000 residences and businesses were without power for days.[20] Even residents with solar panels could not use their own power because the photovoltaic panels that connected them to the utility grid were shut off. The pain and aftermath of Hurricane Sandy made consumers receptive to LO3 Energy's value proposition.

Blockchain-enabled Solution

To accomplish Orsini's vision, LO3 Energy is building "Exergy," a platform comprising hardware and software that will allow people to buy and sell locally produced electricity. The hardware includes smart meters[21] and controllers. The software includes the proprietary blockchain application and a mobile user interface (see Figure 1). LO3 calls the platform a "transactive energy platform." It chose a blockchain solution because it did not want to rely upon a third party (like a utility provider) to control the platform and because it needed the application to be available if the main utility grid was offline.

LO3 is building the Exergy components through partnerships. For example, it is working with Siemens to build the physical grid that will be separate from the main utility grid so that locally generated power can be rerouted to critical locations in times of need.[22]

Hardware. The Internet of Things (IoT) smart meters are installed in prosumers' properties (typically in basements) to measure production and consumption of electricity. The control system, which was still being built in 2018, will be able to isolate a part of the existing physical electricity grid so that power can be rerouted, say to hospitals or community shelters, during a blackout.[23] (See Figure 2 for a first-generation hardware installation). The hardware feeds data to the proprietary and patented blockchain-based application every second. Only the prosumers need the specialized hardware installed; consumers interact with the platform through a web-based browser.

Software. The blockchain application and data are embedded within the hardware. The application records information collected from the smart meters onto the blockchain ledger about the state of the grid, the time and location of production, the consumption requirements, and buy and sell offers of market participants. Orsini explained the suitability of a blockchain for the platform as follows: *"The architecture is very well aligned with our decentralized infrastructure. So the ledger needs to be on the grid; it needs to be distributed amongst the grid. If you're going to run a physical microgrid, or even a virtual microgrid, and you're incorporating a resiliency plan, then you can't have cloud hosting—because when the grid goes down, you have no communication."* By powering the blockchain application with solar energy from prosumers, the digital ledger will continue to track consumption, and consumers can connect to the app through their cell phones, even when the main utility grid is offline.

19 A shadow market allows prosumers and customers to simulate the buying and selling of electricity before the live service actually exists. Its purpose is to obtain critical feedback as to whether or not people are willing to use the platform.

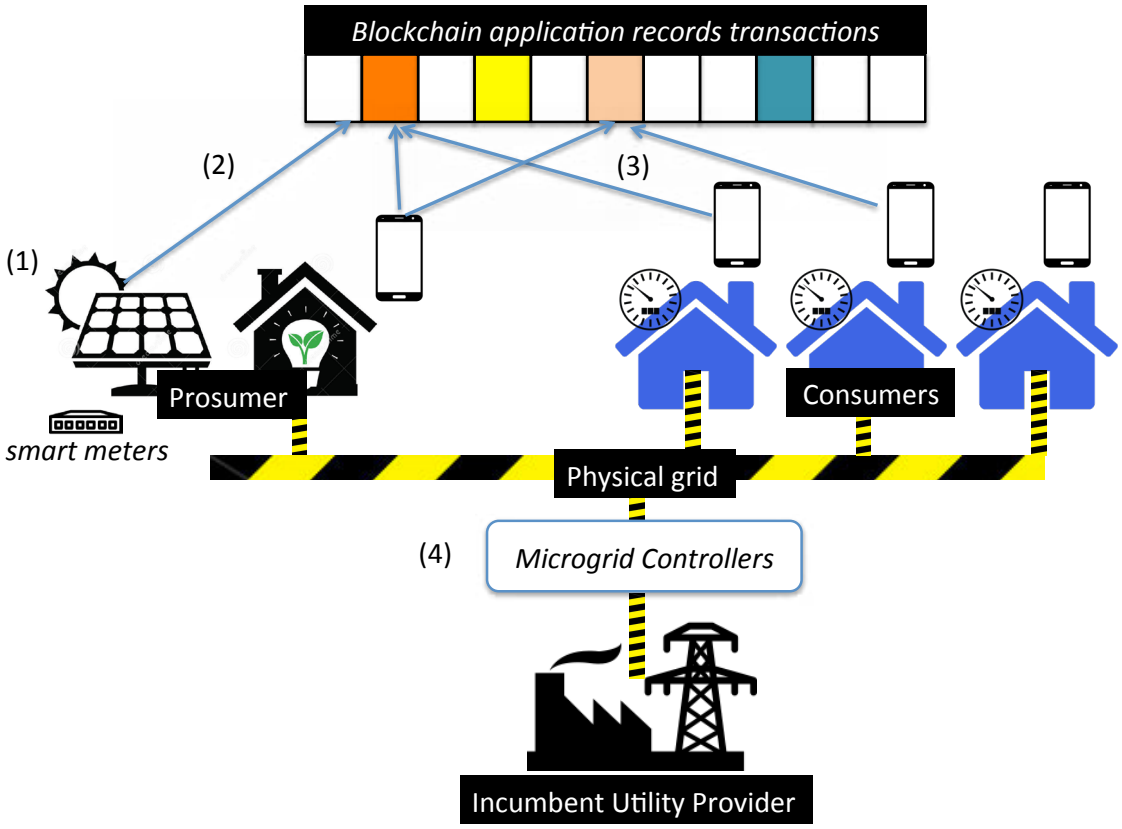
20 Spurlock, C. "Hurricane Sandy New York City Power Outage Map: Thousands Without Electricity In Metro Area," *Huffington Post*, December 6, 2017, available at https://www.huffingtonpost.com/2012/10/31/hurricane-sandy-new-york-city-power-outage-map_n_2050380.html.

21 The smart meter measures a prosumer's "energy production and communicates with the network to collectively manage energy." (Source: LO3 Energy homepage, https://lo3energy.com/.)

22 Orsini, L. *Industry Impact: Peer-to-Peer Energy Transactions*, presentation at the Business of Blockchain conference, MIT, Cambridge, Massachusetts, April 18, 2017.

23 Lempriere, M. "The Brooklyn microgrid: blockchain-enabled community power," Power Technology, available at http://www.power-technology.com/features/featurethe-brooklyn-microgrid-blockchain-enabled-community-power-5783564/.

Figure 1: Overview of an LO3 Microgrid Comprising Hardware and Software



Source: Adapted from LO3 video and LO3 white papers[24]

The mobile app connects neighbors to the blockchain to allow peer-to-peer transactions; neighbors use the app to place and execute buy and sell orders. Essentially, prosumers are selling their excess capacity credits to neighbors rather than back to the utility company. The mobile app is a white-label product that other communities can rebrand. (Figure 3 shows the user interface for the Brooklyn Microgrid project.)

Proofs-of-Concept

As LO3 continues to build and improve the Exergy platform, it is conducting live tests through the Brooklyn Microgrid project. In 2016, LO3 tested the microgrid concept in one residential neighborhood on President Street in Brooklyn, New York. This street was chosen for the proof-of-concept because it had a high concentration of solar adopters on one side of the street and a high concentration of neighbors interested in green energy on the other side. Orsini said: *"It was an obvious choice. These are neighbors across the street from each other; they had good relationships."* The test proved that the smart meters could successfully record the electricity generated from solar panels, store the data on the prototype blockchain (initially built on the Ethereum[25] blockchain app platform) and make the data accessible to prosumers and consumers. This test also proved that consumers were willing to pay a little bit more for electricity produced by their neighbors. Orsini explained: *"What we are doing is enabling consumer choice. Many consumers don't want cheap; they want theirs. Just like many consumers are willing to pay*

24 "The future of energy is local," Brooklyn Microgrid homepage, available at http://brooklynmicrogrid.com/.

25 https://ethereum.org/.

Figure 2: Example of LO3 Smart Meters

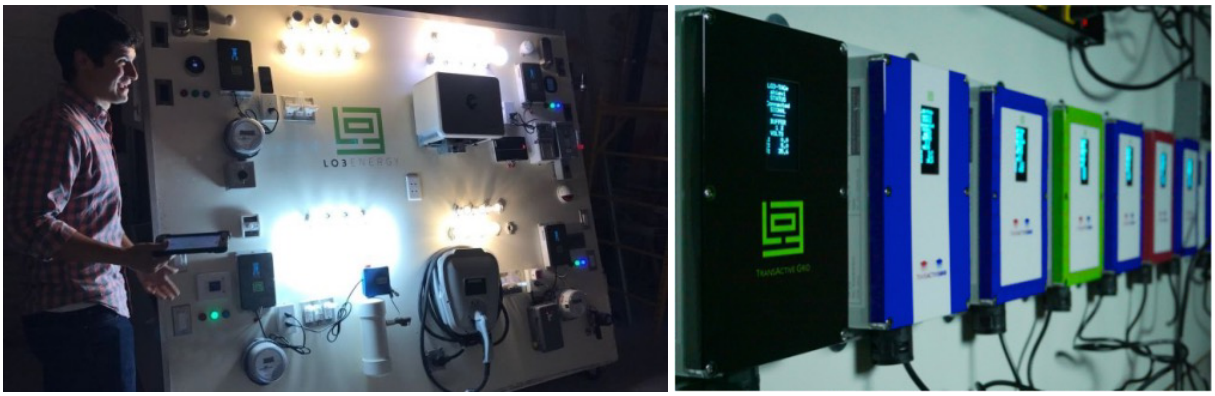


Photo credits: Left, Emma Foehringer Merchant;[26] Right, LO3 Energy

more for locally produced food, many are willing to pay more for locally produced electrons, and we empower them to do that. If they're looking for cheap, then they will have access to cheap as well. Our model has everything to do with providing choice."

After the initial proof-of-concept, LO3 was ready to scout for a location to expand the Brooklyn Microgrid project to a full-scale, live test of the business model and platform. After six months of searching, LO3 decided on Brooklyn's Gowanus and Park Slope neighborhoods. Orsini explained: *"This neighborhood was the right place to do it. So, from a social strata perspective, we've got some of the poorest of the poor in New York living here in Brooklyn, all the way up to some of the most expensive properties in the city, right along the park. Mayor De Blasio [mayor of New York City] and Chuck Schumer [U.S. Senator from New York State] live in Park Slope. From [a] business perspective, the [neighborhood includes] manufacturing, light industrial and local retail, all the way up to the highest-end retail businesses. So, that's why we chose this location."* By December 2017, LO3 had installed 60 smart meters in the neighborhood and 500 consumers had downloaded the mobile app. Initially, the grid is operating in a shadow market until all the regulatory requirements can be met.

Making the Solution Real

The actions LO3 Energy is taking to tackle the four management challenges to make its transactive energy platform a reality are described below.

Standards. LO3's approach to defining access rights, data structures and allowable transactions is unique among our cases because it decided to embed a proprietary blockchain application in its smart meters. Its first proof-of-concept was based on Ethereum, but LO3 was dissatisfied with the transaction speeds. Orsini explained: *"[After the first test] we spent a fair amount of time developing a very-fast-acting and transacting blockchain. So our block speeds are [now] about a second a piece."* LO3 will eventually release its source code so that others can verify that the code executes as promised.

Regulations. To ensure the blockchain application will comply with relevant (and uncertain) regulations, LO3 is becoming a licensed utility provider. Since its inception, LO3 has worked very closely with New York regulators and policy makers to explain the concept of microgrids. It has also met with the U.S. Federal Energy Regulatory Commission. Orsini said: *"We have a very good relationship with the regulators. The regulators in New York are pretty excited about and engaged in what we're doing."* The same regulatory permission process will need to be repeated as communities in other U.S. jurisdictions adopt the platform, and also in other countries. Orsini has already met with regulators

26 Foehringer Merchant, E. "Can LO3 Energy Cut Through the Hype on Blockchain?," *Greentech Media*, November 1, 2017, available at https://www.greentechmedia.com/articles/read/can-lo3-cut-through-the-hype-on-blockchain#gs.bE4bMV0.

Figure 3: Brooklyn Microgrid's Mobile App Interface

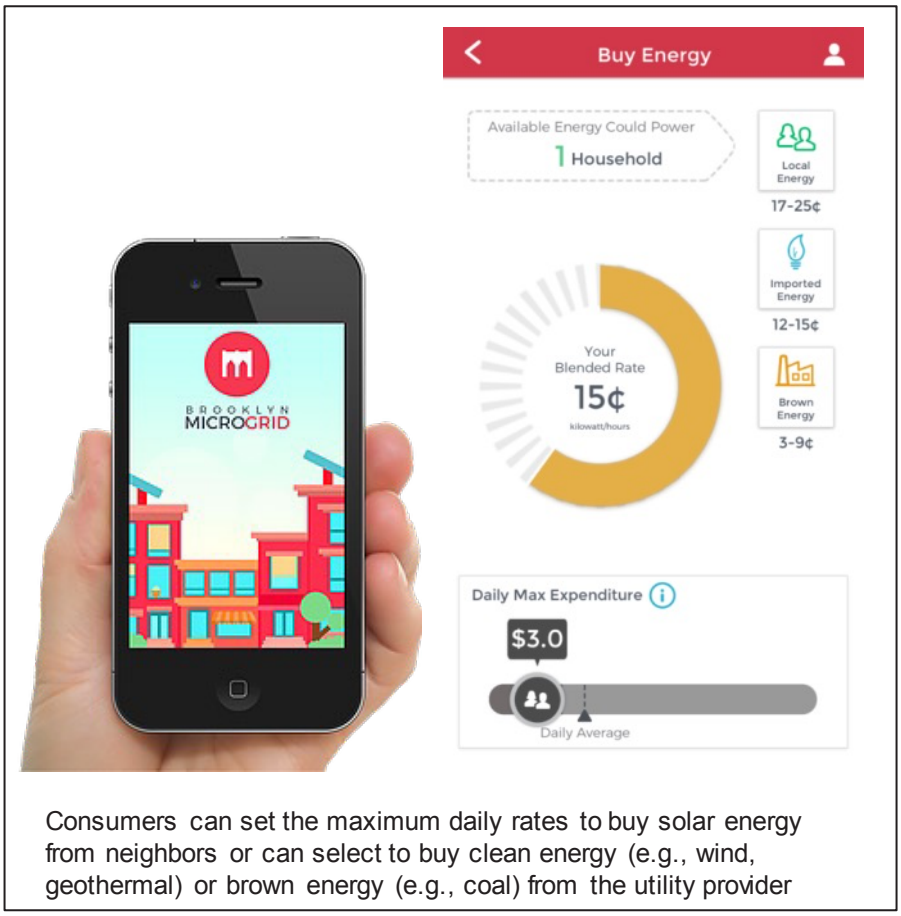


Photo credits: Left, https://www.sacramento.energy/video-gallery; Right, Author's mobile app screenshot

from Australia and Europe to pave the way for future adoptions.[27]

Shared Governance: LO3's approach to governance of its blockchain platform is to establish the Exergy Foundation as a not-for-profit (501(c)3)[28] organization to serve as an independent governance and advisory body for community adopters. According to the foundation's website:

> *"As a not-for-profit, 501(c)3, the Exergy Foundation exists as a governance body for the network of Exergy users, and an agency interested in advancing policy and technology of the transactive energy system. The foundation is chartered to advance market participation in line with token distribution,[29] monitoring adoption and ensuring that the benefits of the Exergy system are being realized fully in the real world. The foundation is set to invest in installation and integration of distributed energy resources including IoT hardware, electricity storage, generation assets and smart appliances."[30]*

Building a Viable Ecosystem. For Exergy, the ecosystem comprises a "project's" prosumers and

27 Orsini, L., op. cit., April 18, 2017.

28 A 501(c) organization is a nonprofit organization in the federal law of the United States; as such, it is exempt from some federal income taxes.

29 The foundation will release a digital token called "Exergy" (symbol XRG) to help fund the distribution, installation and deployment of community adoptions. For more information, see "Exergy Token: The first energy marketplace for the new energy consumer," available at https://exergy.energy/wp-content/uploads/2017/12/EXERGY-ExecSumm-FINAL-1.pdf.

30 "Exergy Business White Paper," April 24, 2018, available at https://lo3energy.com/wp-content/uploads/2018/04/Exergy-BIZ-Whitepaper-v11.pdf.

consumers (e.g., the nonprofit community for the Brooklyn Microgrid). However, with the Exergy business model, it would be untenable for LO3 to lead the efforts for subsequent adoptions beyond the Brooklyn Microgrid project. Therefore, going forward, LO3 Energy will sell its transactive energy platform directly to other communities or institutions interested in adoption, but LO3 will not own the projects. Local adopters are in the best position to build their own viable ecosystems by rallying neighbors, educating users and securing local regulatory permission. Several other community-based efforts are underway, including projects in Sacramento,[31] South Australia,[32] Germany[33] and across Europe.[34] Orsini said that hundreds of interested communities have approached LO3 about adopting Exergy.

Orsini is well on his way to realizing his vision for sustainable, local, reliable, efficient and self-governing energy production and consumption. LO3 Energy is ahead of other players in this space because Orsini and his team knew that they needed to do more than just build a great platform—they needed to prove they could get the platform legally and socially embedded into a real community.

Moog's 3D Printing Parts Verification Application

> *"Moog made a deliberate business decision to be part of the disruption caused by 3D printing and blockchain [rather than] being disrupted by them. We realized the greatest impact on our business was going to be how these technologies upended the business models and supply chains employed by manufacturers today."* George Small, Principle Engineer, Moog, Inc.[35]

> *"Coasian economics says firms exist because you have trust inside the company. Blockchain has allowed us to take trust outside of the four walls of the firm and distribute it, so we have distributed trust."* James Allen Regenor, Business Unit Director, Transformative Technologies, Moog, Inc.[36]

Case Overview

Moog, Inc. is a $2.5 billion U.S.-based industrial manufacturer and provider of integrated control systems for aircraft, space and industrial systems. Moog anticipates that centralized manufacturing increasingly will shift to decentralized "additive" manufacturing, otherwise known as 3D printing. Moog is building VeriPart, a blockchain-based service to verify that instructions for 3D printed parts are authentic. Once a part has been printed, VeriPart will trace it through the supply chain until it is decommissioned. A joint venture between Moog and at least four equal partners will manage the VeriPart platform, with a separate consortium governing each industry vertical. Moog's blockchain journey began in the Aircraft Controls division and is led by Colonel James Allen Regenor.

The Business Vision

After serving in the U.S. Air Force for 31 years, Colonel Regenor joined Moog in 2013 as Director of Business Development and Strategy. He was hired, in part for his scenario-based planning skills, to help Moog envision future business directions. One of the scenarios went as follows:

> *"Imagine a scenario where lives depend upon a mission being flown off the deck of an aircraft carrier far out at sea. The only available aircraft has just been grounded with a failed critical part. There is no part inventory on the carrier. But we do have a 3D printer and a stock of powder aboard. A technical data package is available for the part, and a replacement is quickly printed. You are the responsible person who needs to get this part quickly fitted to the aircraft and to sign the plane off as safe and ready*

31 "Sacramento Microgrid," available at https://www.sacramento.energy/.

32 Bailey, M. "LO3 to trial peer-to-peer energy sharing in South Australia," *Financial Review*, October 10, 2017, available at http://www.afr.com/business/energy/lo3-energy-to-trial-peertopeer-energy-sharing-in-south-australia-20171010-gyxw3s#ixzz53VrCB6MY.

33 "US start-up LO3 Energy begins two German projects," LO3 Energy Press Release, November 17, 2017, available at https://lo3energy.com/us-start-lo3-energy-begins-two-german-projects/.

34 De, N. "Blockchain Startup LO3 Partners With Power Exchange," *Coindesk*, December 13, 2017, available at https://www.coindesk.com/blockchain-startup-lo3-partners-power-exchange/.

35 Small, G. "Additive Manufacturing Reshaping Logistics," Moog, Inc., 2017, available at http://www.moog.com/news/blog-new/IntroducingVeripart_Issue3.html.

36 Regenor, J. "Industry Impact: Aerospace Supply Chain," presentation at the Blockchain for Business Conference, MIT, Cambridge Massachusetts, April 18, 2017.

to fly. How would you know if the newly printed additive manufacturing part you are holding in your hand is good for use?"[37]

Essentially, Regenor imagined a completely decentralized manufacturing process in which military and commercial customers could print parts where they need them, when they need them. The potential business value is enormous, including significantly less downtime, lower inventory costs, lower customs fees and lower shipping and transportation costs.[38]

The challenges in realizing a decentralized manufacturing process—particularly in such a highly regulated context—are enormous. What if the 3D printing instructions had been tampered with by a cyberterrorist? Or what if the instructions were counterfeit? Moog needed a way to guarantee that the part that came off the printer was authentic and ready for use. Furthermore, the newly printed part would need to be tracked over its entire lifetime, so it would need an embedded unique ID when it came off the printer. To achieve all of this, Moog needed a decentralized network with the highest security. Regenor and his team quickly realized that blockchain technologies might be the ideal technical solution: a distributed blockchain application for distributed additive manufacturing.

Blockchain-enabled Solution

Moog is now building VeriPart—a platform-based business model—to manage the entire lifecycle of 3D printed parts from part design to part decommissioning (see Figure 4). The platform will integrate 3D printing, blockchain and AI technologies. Moog chose a blockchain solution because it believes supply chain partners will not want to rely on one trusted third party to control the service. It also wanted the security and resiliency that a blockchain solution provides.

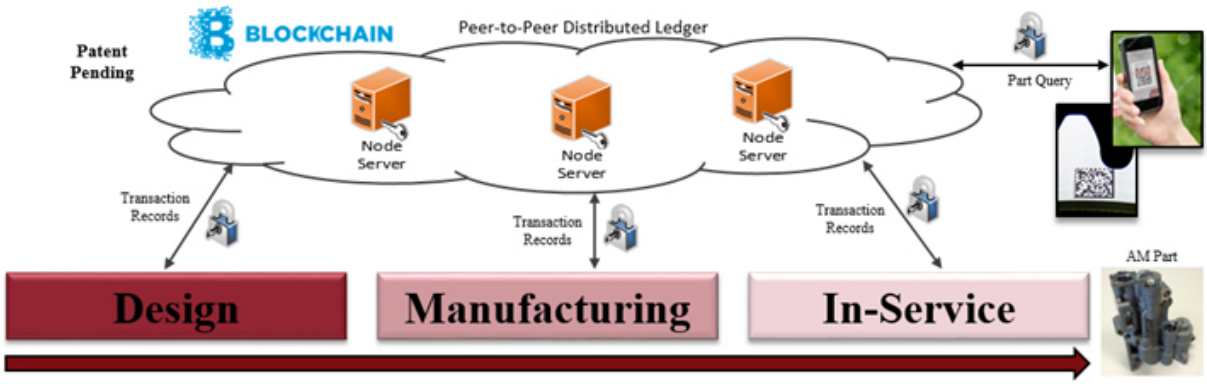
Moog is initially building the VeriPart platform for the aerospace industry, but it is actively exploring automotive, medical and other industries that use 3D printed parts. When VeriPart is completed, Moog will create a joint venture with other partners to manage the platform, along with a separate consortium to govern each industry vertical.[39]

Unique, Embedded IDs on 3D Printed Parts. Moog created a two-layer authentication protocol to ensure the integrity of the parts in the supply chain. First, each part is printed with an embedded unique hash "watermark" that can be viewed with a camera on a smart phone app. Second, the hash is permanently stored on the blockchain at time of origin. The blockchain application will also store the part's every movement and every transfer of ownership, thus enabling the part to be tracked through the supply chain.[40]

Blockchain Platform. Moog is working with blockchain partners to build the solution because

37 Small, G., op. cit., 2017.
38 Ibid.
39 Source: Ibid.
40 Regenor, J., op. cit., 2017.

Figure 4: Moog's Blockchain Application for Verifying 3D Printed Aircraft Parts[39]



The main components of VeriPart are described below.

no single blockchain standard has yet emerged. It is possible, for example, that VeriPart will need to connect to multiple blockchains. One partner is Nuco, a Toronto-based blockchain startup that is building an interoperable blockchain network called Aion.[41] Aion will serve as the hub to VeriPart. Regenor said: *"Aion will allow us to move data between the multiple blockchains that could be present in our supply chain. We think this is a very important step, and we're glad to be participating in it."*[42] Moog is also working with a major ERP supplier because the VeriPart platform needs to connect not only with other blockchains, but also to legacy ERP systems, particularly for Moog's enterprise customers. It is also working with Microsoft on a major proof-of-concept and on plug-in extensions for the platform.

Proofs-of-Concept

Moog has been conducting several proofs-of-concept in partnership with industrial customers and technology providers. On February 7, 2018, Moog and Singapore Technology Aerospace (STA) announced the completion of a demonstration of the first digital end-to-end manufacturing of a 3D printed part for the aerospace industry on a blockchain. In the demonstration, STA bought a digital part from Moog using Microsoft's Azure blockchain application and then printed the part on its own premises. When STA downloaded the file, the financial settlement happened instantaneously; the payment used a symbolic token that moved value from STA's address to Moog's address.

In another proof-of-concept, Moog, Nuco and one of Moog's largest aerospace customers tested the use of the blockchain for parts provenance using traditionally manufactured parts (rather than 3D printed parts). Moog wanted to involve its major aerospace clients early in the development of VeriPart rather than wait for the certification agencies to finalize regulations on 3D printed parts.

The U.S. Department of Defense (DoD) is also funding a proof-of-concept involving Moog, other government agencies and an undisclosed blockchain company to test the blockchain for parts provenance of 3D printed parts made out of plastic and metals. During the first phase of this project, the defense agencies will request the part designs, print the parts and inspect the parts to test the efficacy of VeriPart to prevent counterfeit parts being produced and its resilience against cybersecurity attacks. During the next phase, the Defense Logistics Agency will buy digital parts from a digital catalog using smart contracts.[43]

Making the Solution Real

Moog is pursuing several initiatives to make VeriPart a reality. The critical first steps are defining standards and regulations for 3D printed parts. Once these are established, Moog can then ensure the blockchain solution complies with 3D printed parts standards and regulations.

Standards. Moog is working with the American Standards Association (ASA) to develop standards for 3D printed parts, called *America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC).*[44] The AMSC program published a roadmap for additive manufacturing in February 2017.[45] A first draft of the standards is expected in 2018.

Moog is also working with a nonprofit organization that conducts research and manages several U.S. national laboratories, and with other partners, on an industry consortium for additive manufacturing in the aerospace industry. Regenor said: *"When they started with standards for aircraft, the standards were based on wood, glue and fabric. Since then, they've helped develop standards for forgings and castings of metals, plastics, composites and everything else."* The consortium is building a digital library for general properties of 3D printed materials. This library is needed so that manufacturers can switch from

41 "Moog announces partnership with aion," Aion Foundation, October 5, 2017, available at https://blog.aion.network/moogaion-partnership-6d37ce15b2fd.

42 Galang, J. "Nuco raises $27 million to build interoperable blockchain network," *BetaKit*, October 10, 2017, available at https://betakit.com/nuco-raises-27-million-to-build-interoperable-blockchain-network/.

43 A smart contract, a concept developed by Nick Szabo, is "a piece of software that stores rules for negotiating the terms of a contract, automatically verifies the contract and then executes the terms." See Szabo, N. "Formalizing and Securing Relationships on Public Networks," *FirstMind* (2:9), September 1997, available at https://doi.org/10.5210/fm.v2i9.548.

44 "America Makes & ANSI Additive Manufacturing Standardization Collaborative (AMSC)", American National Standards Institute, available at https://www.ansi.org/standards_activities/standards_boards_panels/amsc/.

45 "Standardization Roadmap for Additive Manufacturing," American National Standards Institute, available at https://share.ansi.org/Shared Documents/Standards Activities/AMSC/AMSC_Roadmap_February_2017.pdf.

"point approvals" to "design allowables." Regenor explained: *"Currently, when you make a part, you have to take it to the military or the FAA (Federal Aviation Authority) and seek approval for a particular part made from a particular pattern on a particular machine [i.e., a "point approval"]. It's extremely narrow. With additive manufacturing, we need to get approval for a family of parts from a family of patterns on a family of machines [i.e., a "design allowable"]. In order to get there, you have to create the data, so that is what we have been doing."*

Regenor foresees that the data will become part of an open digital catalog available to VeriPart users. While some of Moog's competitors are building proprietary digital catalogs that will have to be built on proprietary machines, Regenor believes that real customer value is generated from open architectures.

Regulations. To make VeriPart a reality, Moog needs the U.S. government to create 3D printing regulations for DoD acquisitions. Regenor described how he first approached getting regulations updated: *"In the Federal Acquisition Regulations for electronic parts, it says that there has to be provenance. So I sat down with my pen and everywhere it said 'electronic' I put in the words 'additive manufacturing.' I went to our lobbyist and said, 'Hey, let's put this in front of committee. Let's get this added to the Federal Acquisition Regulations.' So we decided to use federal regulation to help create market space."*[46]

Moog informed the U.S. House Armed Services Committee about the threat of counterfeiting for additive manufactured parts. Regenor explained: *"With 3D printing, you have to worry about complex parts being counterfeit. Anybody can print something that looks like the part they are holding in their hand. It won't have the same material properties or the same characteristics, but the guy pulling it off the shelf will not know the difference."* Legislators understood the concern; the National Defense Authorization Act of 2018 includes funds for additive manufacturing technology development and requires briefings on blockchain technologies from agencies.

Shared Governance. Moog is still defining the governance structure for its blockchain-based VeriPart system. For example, it has not yet established the exact roles and duties of the joint venture and vertical consortia. By the first quarter of 2019, however, Moog aims to have established its joint venture with other trading partners, defined a shared governance model and created a consortium of 30 members. Although that deadline may seem aggressive, Regenor is more sanguine: *"People say the Internet took 10 years, so blockchain will take 10 years. But blockchain is built on the Internet, so we'll leverage the Internet protocols and fold those into blockchain, so we can have an exponential acceleration rather than a linear acceleration."*

Building a Viable Ecosystem: To attract customers to the VeriPart platform, Regenor foresees that Moog will follow Apple's iTunes launch strategy. Apple initially offered a seed catalog of music to attract customers and then updated the catalog each week to keep customers coming back. Similarly, Moog is seeding the digital catalog for general properties of 3D printed materials. This catalog will allow customers to move from "point approvals," where regulators approve each physical part, to "design allowables," where regulators will approve the designs. Customers will initially go to the VeriPart platform to access the digital catalog, but as the ecosystem grows, other parties will be able to offer more services on the platform.

In summary, by mid-2018, Moog had made a lot of progress on realizing the vision of building a blockchain-enabled platform that provides parts providence for additive manufacturing.

Center for Supply Chain Studies

> *"We are trying to figure out how can we use blockchain technology to meet the DSCSA regulation, and just overall, how do we track and trace the product to secure the supply chain."* Enterprise Architect for a U.S. healthcare company

Case Overview

The Center for Supply Chain Studies (CSCS) is a nonprofit organization started by Bob Celeste in 2015. It carries out group-funded studies to identify ways to improve efficiency and compliance across the pharmaceuticals supply chain. In February 2017, CSCS launched

46 Regenor, J. op. cit., 2017.

a study called "DSCSA and Blockchain," with 50 representatives from across the supply chain tasked with developing proposals for meeting the requirements of the new industry-wide DSCSA[47] regulation. Competitors came together to consider the best ways to use blockchain technologies to comply with the DSCSA. The study produced a white paper[48] with three different reference models, or versions of possible tracking systems. Subsequent studies will build a blockchain-based prototype based on one or more of the reference models.

Business Vision

In the case of CSCS, the business vision was prompted by a new U.S. government regulation. The U.S. Drug Supply Chain Security Act (DSCSA) was passed in November 2013. The purpose of the act is to better trace pharmaceuticals throughout the entire supply chain. It requires all parties in the supply chain to participate, including pharmaceutical manufacturers, repackagers, wholesale distributors and dispensers such as hospital and retail pharmacies. The act is being implemented in stages. Pharmaceutical manufacturers and repackagers needed to affix a unique product identifier on each package by November 2017. By 2023, the product's entire history must be traced as ownership passes through supply chain partners. The act requires that each party in the supply chain:

- Participates in an electronic traceability system
- Trades only with authorized partners
- Provides transaction information to trading partners in electronic format
- Responds to verification requests from trading partners
- Quarantines and investigates suspect products
- Identifies and removes illegitimate/counterfeit products and notifies the FDA
- Matches original transactions with returns
- Facilitates the gathering of previous transaction information.[49]

Additionally, product records will need to be maintained for six years, plus an additional six years if there is an investigation of the product. Thus, the regulation requires full data provenance and record immutability for over a decade. Most significantly, the act requires that pharmaceuticals supply chain participants share an electronic system that currently does not exist. The requirements of the act seem ideally suited for a blockchain-based application.

Blockchain-enabled Solution

The 50 participants in CSCS's DSCSA and Blockchain study included representatives from competitors like Cardinal Health, Amerisourcebergen, Becton Dickinson, Johnson & Johnson and McKesson, who came together to consider the best ways to comply with the new regulation using a blockchain application.

The participants documented the main reason for exploring a blockchain solution in their draft working paper:

> *"Blockchain technology has demonstrated a strength in creating a single source of truth that is highly resistant to corruption—either accidental or intentional. It also holds promise for being able to restrict access to competitively valuable transaction data only to those parties with a defined "need to know," providing the confidentiality sought by trading partners. Current blockchain platforms offer an environment of simplified electronic connections between parties, distribution and synchronization of data, data immutability, programmability, visibility, security and, potentially, confidentiality—all characteristics of an effective environment where trading partners can enforce business and*

47 The Drug Supply Chain Security Act (DSCSA) was passed into U.S. Federal law in 2013 (see https://www.fda.gov/Drugs/DrugSafety/DrugIntegrityandSupplyChainSecurity/DrugSupplyChainSecurityAct/). Its purpose is "to outline steps to build an electronic, interoperable system to identify and trace certain prescription drugs as they are distributed in the United States. This will enhance FDA's (U.S. Food & Drug Administration's) ability to help protect consumers from exposure to drugs that may be counterfeit, stolen, contaminated or otherwise harmful."

48 CSCS's "Drug Supply Chain Security Act and Blockchain" white paper was published on June 21, 2018, and is available at https://static1.squarespace.com/static/563240cae4b056714fc21c26/t/5b3103ae575d1f67042a9324/1529938866020/C4SCS+White+Paper_+DSCSA+and+Blockchain+Study_FINAL2.pdf.

49 The timeline for each party's compliance requirements can be found at http://www.pewtrusts.org/en/multimedia/data-visualizations/2014/timeline-for-the-drug-supply-chain-and-security-act.

regulatory rules and securely automate the exchange of data."

While some consortia seek a consensus on a single standard, CSCS's DSCSA and Blockchain study initially produced nine reference models and whittled these down to three. The models varied from full transparency of all the data to a very minimal set of encrypted data stored on the blockchain. Bob Celeste noted: *"The exploratory models helped us envision possibilities and work around regulatory, operational and technology constraints."*

The study explored various rules for participation, shared governance models, services (such as maintaining master data and licensing) and the data that would actually be stored on the blockchain or in another "data persistent" database (see Figure 5). CSCS built and ran various simulations so study participants could see how the data would flow through an application and be permanently stored in a blockchain application.

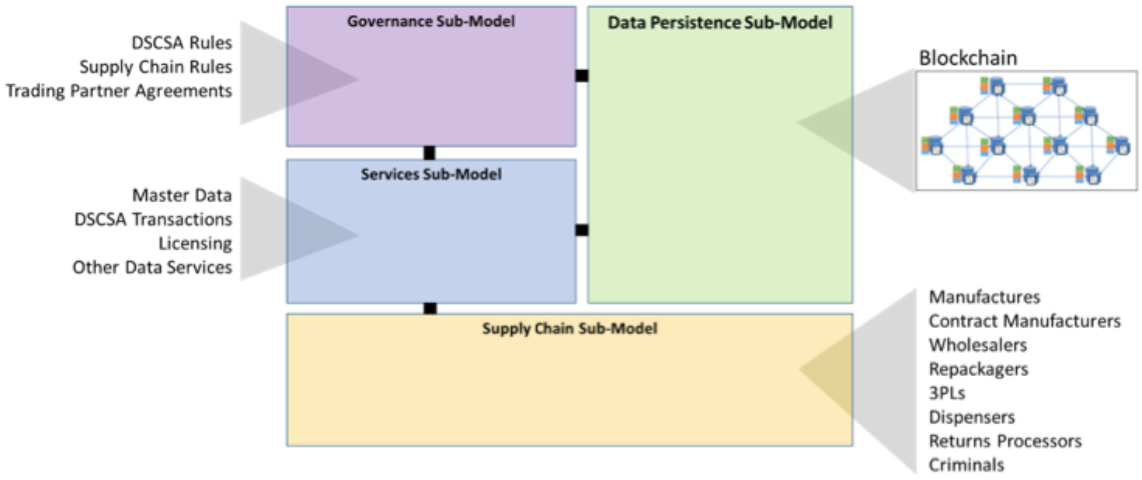
The study participants tackled tough questions about shared governance, industrial espionage, counterfeiters, shared intellectual property and investment. The specific questions they addressed were:

- Who decides who sees which data under what circumstances?
- Will competitors learn too much about my volumes and trading partners?
- Will our design keep counterfeit drugs out of the supply chain?
- How do we protect the intellectual property we've built as a team?
- How will we finance the blockchain application development and ongoing operations?

Proofs-of-Concept

CSCS launched Phase 2 of the DSCSA and Blockchain study in January 2018. During this phase, the study team will create proofs-of-concept based on the reference models identified in Phase 1. Technology companies participating in the study will build the test applications based

Figure 5: CSCS's Framework for Exploring Blockchain Solutions



"To aid in the exploration, the team established a framework for discussing and understanding the interrelationships between the supply chain participants (supply chain submodel), services (services submodel) that may provide access to the blockchain and provide access to off-blockchain data, the blockchain and distributed network (data persistence submodel) and the governance body (governance submodel) which might be the gatekeeper to a private, permissioned blockchain platform, determine consensus data access rules and oversee the management of the system." (Source: CSCS's *The Drug Supply Chain Security Act and Blockchain* white paper, June 21, 2018)

on industry-provided test data. The aim is to demonstrate functioning proofs-of-concept at 2018 conferences in the pharmaceuticals sector.

Making the Solution Real

The actions CSCS is taking to address the four management challenges of blockchain applications are described below.

Standards. CSCS adopted GS1's EPCIS standards for identification, transaction, data, and process. Overall, study participants want to post the minimum amount of data to the distributed ledger that will enable the blockchain application to comply with the law. They envision that their internal systems of records will send posting events to the shared ledger. Digital signatures, data encryption, zero-knowledge proofs[50] and smart contracts will be used to ensure that only authorized trading partners can view transactions stored in the ledger.

Regulations. CSCS's initiative was prompted by the Drug Supply Chain Security Act (DSCSA). By definition, therefore, the proposed blockchain application will comply with this regulation.

Shared Governance. At the time of writing, study participants were still debating the governance structure for the blockchain application and anticipated that the governance effort would be considerable. Celeste explained: *"All supply chain stakeholders posting data will, most likely, want representation during data visibility rule making (who gets to see what, under what circumstances). Implementation of the rules and validation of the programming code will also be complex."*

Building a Viable Ecosystem. Even if the 50 members of the study team agree on the design and build the blockchain application, they will still face the daunting task of attracting a critical mass of adopters that will make the blockchain solution the de facto industry solution. There are over 85,000 participants in the U.S. pharmaceuticals supply chain. The Head of Innovation for a U.S. healthcare company hopes that the government will mandate adoption. He said: *"If the government had one iota how much fraud and abuse they could stop in pharmaceuticals, how they can purge the opioid thing, they would mandate blockchains tomorrow. [They should mandate that] you must participate in this within two years."*

50 A zero-knowledge proof is a method that enables one party to verify possession of a piece of information to other parties without revealing the information.

Five Key Questions When Considering a Blockchain Application

The three case organizations described above are still on their journeys to make their blockchain applications a reality. They are pursuing different strategies to answer five key questions:

1. Is a blockchain the right solution?
2. How are blockchain standards being established?
3. How can a blockchain solution comply with legislation given the regulatory uncertainty?
4. How should a blockchain solution be governed?
5. How can a viable ecosystem be established?

1. Is a Blockchain the Right Solution?

> *"From a business perspective, I'd always advise clients to ask themselves: 'Is there a need for decentralization?'"* Practice Head for Financial Services, Analytics & Blockchain at a global technology and consulting organization

Contributors to our research from LO3 Energy, Moog and CSCS first asked themselves: "Why do we need a blockchain solution when we already have distributed databases?" It's also a question every CIO should ask. Distributed databases encompass many different architectural designs where data is stored in multiple places and where agreement is maintained through computer algorithms that lock and time stamp records. Given that definition, *blockchains can be thought of as special kinds of distributed database systems.* Whereas traditional distributed databases are centrally controlled so that a single organization can decide to alter records or change access rules, blockchains have distributed control—no one entity has the power to roll back or alter

history. Thus, we advise CIOs to phrase their question as: *Under what circumstances are the distributed controls of blockchains preferable to the centralized controls of traditional distributed databases?"* The LO3 Energy, Moog and CSCS cases suggest there are two situations when blockchain solutions are better than today's distributed databases.

i) When Participants Don't Want to Rely on Trusted Third Parties. LO3 Energy's business model seeks to remove the monopoly power of incumbent utility providers by offering consumers a choice as to where they can buy and sell electricity. The entire model is about local empowerment, enabled by the peer-to-peer distributed blockchain solution. No one person or entity will own or control the local microgrids. Moog also sees the importance of no one entity controlling the blockchain solution. Its peer-to-peer platform seeks to welcome "Mom & Pop" shops as well as traditional manufacturers. CSCS also does not want one entity controlling the distributed ledger.

ii) When Security Trumps Performance. LO3 Energy, Moog and CSCS also chose blockchain applications because their business contexts required highly secure decentralized solutions with no single points of failure. As of 2018, blockchain technologies promise heightened security compared to centralized systems (see Appendix A for reasons why). However, tighter security comes at the price of slower performance, at least for now. In comparison to today's trusted third parties like Visa and MasterCard, blockchains process considerably fewer transactions per second (TPS). For example, Visa is able to process 24,000 TPS compared to Ripple's[51] 1,500 TPS and Bitcoin's 7 TPS.[52] Security trumped performance in the three cases in the following contexts:

- *Lack of trust.* LO3 Energy, Moog and CSCS are all building applications for use by multiple trading partners where counter-party risks are substantial. Blockchains allow multiple parties who do not trust each other to share and update information safely.
- *Multiple writers.* Blockchains are suitable when each party relies on others to complete a transaction. LO3 Energy needs to track electricity production and buy and sell orders from many participants; Moog aims to track the design, printing, use, storage and ownership transfers of 3D printed parts across a global supply chain; CSCS aims to trace pharmaceuticals from commissioning to decommissioning across a complex supply chain ecosystem.
- *Need for data sharing.* Even when multiple writers are not involved in a transaction, some processes require enterprises to share information with "observers," such as regulators. CSCS is planning a blockchain application that can store the minimal data needed for compliance and safely share it with authorized observers. LO3 Energy, Moog and CSCS envision sharing "digital keys" with regulators and auditors so they can observe blockchain transactions to verify compliance.
- *Need for data permanency.* Blockchains are suitable when parties need to rely on one shared historical audit trail of transactions that will never be altered. Again, all three cases need data provenance to keep track of assets like electricity generated, parts or drugs from points of origin through every transfer of ownership.

2. How are Blockchain Standards Being Established?

To make blockchain solutions real, there must be agreed upon standards. Participants must decide which information, message types and formats to store on a blockchain, what access rights should be given to whom and which transactions are allowable. Three strategies for agreeing blockchain standards were evident from our cases:

- *Create a proprietary blockchain protocol.* LO3 Energy is building a proprietary blockchain solution that is embedded in its hardware. LO3 chose this strategy because it could not wait for the performance of

51 Ripple uses blockchain technology to connect banks, payment providers, digital asset exchanges and corporates to provide a frictionless experience to send money globally.

52 Raul "Transactions Speeds: How Do Cryptocurrencies Stack Up To Visa or PayPal?," *Howmuch.net*, January 10, 2018, available at https//howmuch.net/articles/crypto-transaction-speeds-compared.

blockchain technologies to improve; it needed a robust blockchain that could settle transactions every few seconds.

- *Work with existing standards groups to adapt standards for blockchains.* As a precursor to the VeriPart blockchain solution, Moog needs industry standards for 3D printed parts. It did not want to create its own proprietary standard and wanted the know-how and clout of existing standards groups like ASA to help define new standards. Moog is also working with a nonprofit organization that conducts research and manages several U.S. national laboratories, and with other partners in an industry consortium to define standards for additive manufacturing in the aerospace industry.
- *Join an industry blockchain consortium.* Some consortia—like the Hyperledger Project and the Ethereum Enterprise Alliance—are broadly defining standards for enterprise blockchains, while others, like CSCS, R3 and B3i,[53] are focused on particular industry solutions. Some companies in our wider study participated broadly with many consortia at first, but then narrowed participation to those highly relevant to their industry.

Existing standards groups like ASA or consortia may take longer to define standards than proprietary solutions, but they likely have a better chance of creating de facto standards.

3. How Can a Blockchain Solution Comply with Legislation Given the Regulatory Uncertainty?

> *"We don't know how the regulators are going to respond. At the end of the day, I think the early indications suggest that they're as intrigued by the value proposition associated with blockchains as anybody. No regulator has come out of the gates telling you what you can and cannot do yet. That's a big unknown in our world."* Head of a blockchain center of excellence for a global financial services firm

Regulators Worldwide are Beginning to Engage with Blockchain Issues. Some regulators are supportive of blockchain developments, some are not and still others have yet to deliberate. Many participants in our broader research study wanted to educate regulators about blockchains, but at the same time, they did not want regulators participating too closely in consortia lest their compliance weaknesses be exposed. While there are many types of regulations that may affect blockchain solutions, such as data privacy, banking and securities regulations, our research participants focused on industry regulations. Of the 30 enterprises we interviewed, LO3 Energy, Moog and CSCS were the most proactive in dealing with regulators. As described below, they used two different, yet effective, approaches.

Design the Blockchain Solution to Comply with Existing Regulations. LO3 Energy and CSCS spent significant effort on understanding current regulations to make sure their solutions complied with existing laws. LO3 hired lawyers early on to work closely with regulators and policy makers so it could be licensed as a utility provider in the State of New York. It has also had to educate regulators around the world on the new blockchain distributed model. LO3 has proactively met with regulators at the U.S. Federal and State levels, and with European and Australian regulators to pave the way for future expansion. CSCS's blockchain initiative was prompted by the DSCSA regulation, so by definition its proposed blockchain application will comply with this regulation.

Actively Lobby to Change Regulations. As a precursor to the VeriPart blockchain solution, Moog needs regulations for 3D printed parts. Under current federal acquisition regulations, Moog would not be able to sell 3D printed parts to its military customers. Thus, Moog has lobbied for the U.S. Federal Acquisition Regulations to be expanded to include 3D printed parts and has met with the U.S. House Armed Services Committee to convince legislators of the need to devote resources to study blockchain solutions.

53 R3 leads a consortium of more than 200 firms in research and development of distributed ledger usage in the financial system and other areas of commerce; B3i is a blockchain initiative for the insurance industry.

4. How Should a Blockchain Solution be Governed?

LO3 Energy, Moog and CSCS are all considering the structures for shared governance for their blockchain applications. LO3 has set up a nonprofit foundation to help local communities govern their microgrids. Moog plans to launch a joint venture that will create a consortium to govern each industry vertical (aircraft parts, healthcare instruments, etc.). CSCS plans for some form of representative governance. Our participants identified several potential types of shared governance models, including democratic, representative and regulatory. Although it is still too early to define concrete shared governance models from the three cases, it is possible to consider various choices.

Democratic Shared Governance. With a democratic governance model, each participating member has an equal vote in deliberations. The communities that adopt LO3 Energy's transactive energy platform, for example, will democratically decide which premises to route power to during blackouts.

Representative Governance. With a representative governance model, decision makers are elected or appointed to their roles. For example, CSCS has representatives from manufacturers, distributors, retail pharmacies and independent physicians who will govern the blockchain application. A representative shared governance structure will be able to make decisions quicker than a democratic one, but cabals may form where representatives collude. For example, the representatives of manufacturers might vote as a block against the will of retail pharmacies.

Regulatory Governance. Blockchain governance could be delegated to a regulatory body. For example, CSCS study participants considered a governance structure where a regulatory body would allow any licensed pharmacy to participate in the shared blockchain application. The benefits of this model would be guaranteed regulatory compliance. The downside is that the model is centralized in that it places trust in one institution.

5. How Can a Viable Ecosystem be Established?

Metcalfe's law[54] states that the value of a network is proportional to the square of the number of connected users in the system. LO3 Energy, Moog and CSCS each have a strategy to attract a critical mass of adopters once their blockchain applications are in production.[55] We call these strategies, "grass roots," "enticement" and "mimetic."

Grassroots Strategy. This strategy for building a viable ecosystem relies on local participants recruiting more participants. LO3 Energy's business model is to sell its transactive energy platform to local communities, because those communities are in the best position to educate and recruit local prosumers and consumers. LO3 invested in the Brooklyn Microgrid project as the test case to prove that neighbors would welcome the opportunity to buy locally produced energy. LO3 has documented practices that other neighborhood projects could emulate to build a viable ecosystem of adopters.

Enticement Strategy. This strategy attracts participants with free content and is being used to attract customers to Moog's VeriPart platform. Moog plans to offer, for free, a digital catalog for general properties of 3D printed materials. This catalog will allow customers to move from "point approvals," where regulators approve each physical part to "design allowables," where regulators approve the designs. Customers will initially go to the VeriPart platform to access the digital catalog, but as the ecosystem grows, other parties will be able to offer more services on the platform.

Mimetic Strategy. With the mimetic (or copycat) strategy, additional participants follow the lead of industry leaders who promote the blockchain application. "Mimetic influences"[56] spark interest in and ultimate adoption of the blockchain solution. This strategy is being followed by CSCS, which has involved some of

54 Metcalfe, B. "Metcalfe's law after 40 years of Ethernet," *IEEE Computer* (46:12), December 2013, pp. 26-31.

55 Among our other case studies, two enterprises were using blockchains to connect systems of records across geographic divisions within the same firm and were thus less concerned about building a viable ecosystem.

56 Mizruchi, M. S. and Fein, L. C. "The Social Construction of Organizational Knowledge: A Study of the Uses of Coercive, Mimetic, and Normative Isomorphism," *Administrative Science Quarterly* (44:4), December 1999, pp. 653-683.

the largest manufacturers, distributors and retail pharmacies in its blockchain project. The hope is that other supply chain participants will become copycats and join the blockchain ecosystem.

Concluding Comments

> *"Most of the organizations that we're speaking to [about blockchain] are at an exploratory phase—pretty much saying, 'we're trying to understand this.' Very few have really identified use cases that they're going to production scale and get a critical mass of partners within the next six to 10 months."* Practice Head for Financial Services, Analytics & Blockchain at a global technology and consulting organization

> *"We're definitely several years away from large [blockchain] applications. A few applications will be in production maybe in three years. But mass production won't likely be here for five years."* Nilesh Vaidya, SVP and Head of Banking & Capital Market Solutions, Capgemini

Enterprises of all types are increasingly interested in blockchain technologies because of the promise of significant business value. Blockchain solutions provide the ability to transact directly with trading partners, eliminate the need for reconciliations, track and trace assets instantly, ensure the provenance of data and settle transactions quickly and cheaply. They also provide a security model that is fault tolerant, resilient and available.

At present, however, there is a huge gap between promised business value and actual business value delivered. Before the full business value of blockchain solutions can be realized, the technology needs to mature to address issues such as scalability, performance and interoperability. Enterprises need to work together to define standards, and regulators need to clarify compliance requirements. Our aim in presenting the blockchain experiences of LO3 Energy, Moog and CSCS is to inspire managers in other organizations to take on the work that needs to be done. By doing so, they have an opportunity to help architect the blockchain future rather than be overwhelmed by it.

At the very least, managers need to know enough about blockchains to decide whether their respective organizations want to lead, be fast followers or take a slower pace to exploring enterprise blockchains.

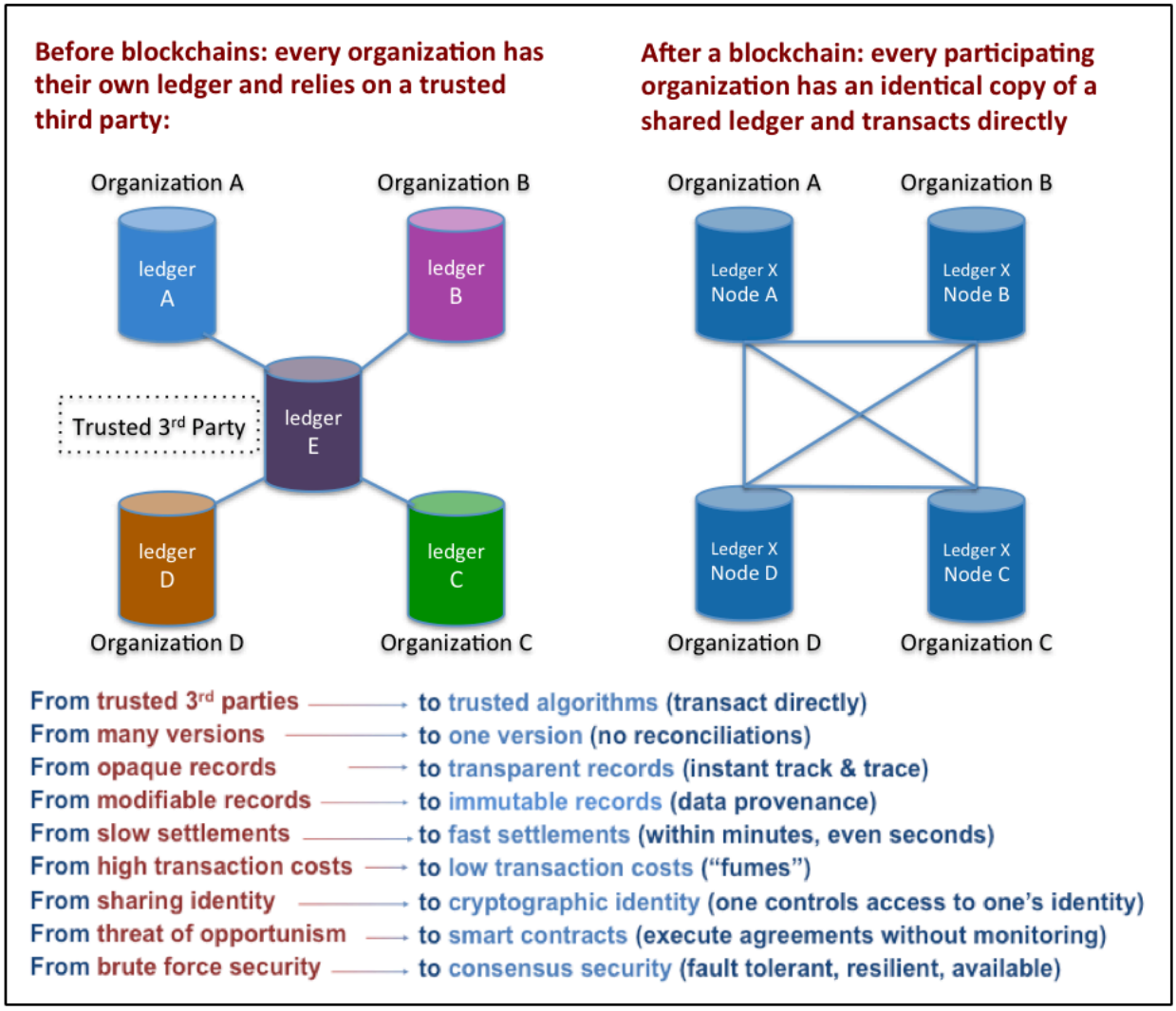
Appendix A: The Relative Advantage of Blockchain Applications

This appendix compares the relative advantage of blockchain applications to the established ways trading partners transact today. This comparison demonstrates that blockchain applications have the potential to unlock a significant amount of business value compared to today's centralized trading systems.

At present, trading partners face counter-party risks—the risk each party bears that the other party will not fulfill its contractual obligations. Trading partners pay fees to trusted third parties (TTPs) like banks, certificate authorities and credit card companies to mitigate such risks. TTPs perform many vital functions to facilitate trade, such as verifying asset ownership and authenticity, and ensuring that accounts are funded to prevent double spending. The left side of the figure below illustrates a simple trading configuration comprising four trading partners and one TTP, and contrasts it with an equivalent blockchain application.

While TTPs provide important functions, they have some serious limitations, like high transaction fees, slow settlement times, low transaction transparency, multiple versions of the truth and security vulnerabilities. As a consequence of each institution maintaining its own ledger, centralized trading systems provide little transparency—it is very difficult to determine which party has control over a transaction at any given point in time. Trading partners spend a lot of time and money reconciling and settling transactions to make sure records agree. Some transactions, like cross-

Multiple Centralized Systems vs. a Shared Blockchain Application



border payments and trade finance, can take days, weeks or even months to settle.[57, 58]

Moreover, consumers routinely turn over much of their personal data, including national identification numbers, home addresses, credit card numbers, birth dates, employment records, utility bills and more, simply to verify their identity to the institutions that sit in the middle of their transactions. The risk of information leakage is high, as any partner might use the data for something other than the original transaction.[59] Centralized trading systems are vulnerable to attack and can cost an organization billions of dollars to protect or remedy.[60]

Blockchain applications aim to overcome the limitations of centralized systems. A distributed blockchain application performs the vital functions of TTPs by using computer algorithms and cryptography to confirm asset

57 "Improving Cross-border Retail Payment Services: The Eurosystem's View," European Central Bank, September 1999, available at https://www.ecb.europa.eu/pub/pdf/other/retailpsen.pdf.

58 "Global Payments 2015: A Healthy Industry Confronts Disruption," McKinsey & Company, October 2015, available at http://www.mckinsey.com/~/media/mckinsey/dotcom/client_service/financial services/latest thinking/payments/global_payments_2015_a_healthy_industry_confronts_disruption.ashx.

59 Catalini, C. and Gans, J. "Some Simple Economics of the Blockchain," MIT Sloan Research Paper 5191-16, November 2016.

60 Ross, A., "11 data breaches that stung US consumers," Bankrate.com, September 9, 20115, available at http://www.bankrate.com/finance/banking/us-data-breaches-1.aspx.

authenticity, authenticate asset ownership and validate transactions. Blockchains enable trading partners to *transact directly* with each other. With a blockchain application, every participating organization has an exact copy of the same digital ledger. Furthermore, transactions on the shared ledger are immutable, which means every party can be confident they are dealing with the same data. With one version of the truth transparent to all parties, there are *no reconciliations*, enabling *faster settlement times* and *lower transaction costs*.

With blockchains, consumers and institutions control their own identities with cryptographic digital signatures, thus *reducing the risks of information leakage* and identity theft. Smart contracts apply rules to automatically execute agreements based on pre-agreed upon conditions, so there is *no need for contract monitoring* and no worrying that trading partners are not fulfilling their obligations.

Blockchain applications also promise heightened security because they ignore faulty, malicious or suspicious transactions and nodes. A blockchain application will continue to operate normally even if a high percentage of nodes are attacked. If, for example, an enterprise's node goes offline, the other nodes in the network will continue to function properly, and those other nodes will update the enterprise's node once its back online. Thus, blockchain applications promise *resiliency* and *100% availability*. In theory, the only way to break a blockchain application is to commandeer more than 50% of the nodes before any of the other nodes notice.

Appendix B: Research Methods

The research reported in this article forms part of a broader program that uses interviews, surveys and participant observation to investigate blockchain adoption journeys.

Interviews

In 2017, the author joined MIT's Center for Information Systems Research (CISR) as a Visiting Scholar to lead a research project on how enterprises were exploring blockchains. The research team included Jeanne Ross, Principal Research Scientist, and Kate Moloney, Research Specialist. During interviews, we asked managers about their blockchain adoption journeys, their participation in blockchain ecosystems, and the practices and lessons they have learned so far. We asked interviewees the following questions:

- How is your organization building blockchain capabilities? What strategies are being considered? Which applications are deemed to be the most promising, are already under development or have been deployed?
- What challenges do organizations need to overcome to deploy blockchain applications into production? What are the key project and change management practices? How well have expectations been met so far? What are the preliminary outcomes and lessons learned?

At the time of writing, we had conducted confidential interviews with 30 organizations (including the three described in this article). The interviews were recorded and transcribed. The three cases for this article were drafted by the author and reviewed by study participants for accuracy and for permission to cite. Participants made suggested revisions to improve clarity, and in all three cases, deleted sensitive information.

Surveys

The author conducted surveys of attendees at both the 2017 and 2018 Outsourcing World Summit, asking about their blockchain adoption journeys (as well their robotic process and cognitive automation initiatives). Respondents provided information about their organizations' stages of technology adoption and satisfaction with the business value derived. We received 127 completed surveys in 2017 and 98 in 2018. Respondents represented financial services, service providers, manufacturing, biotechnology, healthcare, public sector and other industries.

Participant Observation

The author participated in the Center for Supply Chain Studies' project to define blockchain standards for tracing pharmaceuticals through the U.S. supply chain. Online meetings were held every Friday during 2017 and culminated in a white paper.[61] This experience helped the author to understand the perceived benefits, challenges

61 CSCS's Drug Supply Chain Security Act and Blockchain white paper, op. cit., 2018.

and concerns that supply chain partners have about shared blockchain applications.

About the Author

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Mary Lacity (MLacity@walton.uark.edu) is Walton Professor of Information Systems and Director of the Blockchain Center of Excellence at The Sam M. Walton College of Business at the University of Arkansas. She has held visiting positions at MIT's Center for Information Systems Research (CISR), The London School of Economics, Washington University and Oxford University. She was also Curators' Distinguished Professor at the University of Missouri-St. Louis. Lacity's latest book is *A Manager's Guide to Blockchains for Business* (2018, SB Publishing). Her publications have appeared in *Harvard Business Review*, *Sloan Management Review*, *MIS Quarterly*, *MIS Quarterly Executive*, *IEEE Computer* and *Communications of the ACM*, among others.