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R3 CORDA: A DISTRIBUTED LEDGER TECHNOLOGY FOR FINANCIAL SERVICES

Michael R. King wrote this case solely to provide material for class discussion. The author does not intend to illustrate either effective or ineffective handling of a managerial situation. The author may have disguised certain names and other identifying information to protect confidentiality.

In December 2016, David Rutter, founder and chief executive officer of R3, was preparing for an offsite meeting with his management team to discuss the future of his company. R3 was a blockchain technology company with headquarters in New York. The company was leading a network of over 100 banks, financial institutions, and technology companies to develop Corda, a distributed ledger technology (DLT) designed specifically for the financial services industry. Since founding R3 in 2014, Rutter had built up the start-up's global team to comprise over 180 professionals in nine countries.

R3 had crossed many milestones in its brief four-year history. A first milestone had been the strategic decision not to pursue the traditional Silicon Valley route of partnering with venture capitalists but instead create a consortium with banks to collaboratively explore the new technology. A second milestone had been the strategic decision to abandon existing DLTs and build from scratch an enterprise-grade blockchain called Corda. At the end of 2016, R3 was at another turning point. Rutter had to decide which strategy to pursue to create and capture the most value from Corda. Rutter wondered how best to monetize Corda without alienating R3's bank members and other partners.

FOUNDING OF R3

By early 2012, Rutter had been the chief executive officer of British brokerage firm ICAP Plc's electronic brokerage businesses for 10 years, with responsibility for the fixed income platform Brokertec and the foreign exchange platform EBS. In this role, Rutter had been responsible for convincing bank customers to adopt new electronic trading platforms that disrupted the traditional voice brokerage business. In March 2012, Rutter left ICAP Plc to pursue other opportunities.

In early 2013, Rutter started two businesses: Liquidity Edge LLC and R3CEV (later renamed R3). Liquidity Edge LLC focused on developing an electronic trading platform for U.S. Treasuries, whereas R3CEV invested in technology ventures and consulted on exchanges. Rutter recruited Jesse Edwards and Todd McDonald as partners for R3CEV where the initial R represented Rutter's name, 3 was the number of partners, and CEV captured the focus on crypto,[1] exchanges, and ventures. The three partners were

[1] Crypto is a term used for the field of cryptoassets and cryptocurrencies that included bitcoin.

fascinated by emerging technologies, particularly the blockchain technology underlying the digital currency bitcoin. In November 2016, the CEV initials were formally dropped and the company became known simply as R3 (see Exhibit 1).

Explorations in Silicon Valley

In early 2014, Rutter and his R3 partners went to Palo Alto in California's Silicon Valley to meet with more than 20 bitcoin and blockchain companies. The goal was to find new ventures in which to invest. Rutter was amazed at the number of young and inexperienced entrepreneurs with a PowerPoint presentation and a shallow business plan who believed that they could disrupt the industry's huge financial incumbents, such as the Depository Trust & Clearing Corporation, CLS Bank, and J.P. Morgan. Rutter concluded that these entrepreneurs were "completely unaware of the crucial role these institutions play in global financial markets."[2] They had no idea how deep the foundations of finance were poured. And yet, despite having no understanding of how Wall Street actually worked, these entrepreneurs were raising millions of dollars in capital from Silicon Valley venture capitalists at ridiculous company valuations.

Having spent over half of his career introducing new technologies to the financial industry's incumbents, Rutter was uniquely positioned to understand the promise of blockchain for solving a major pain point for financial market participants—namely, the clearing, settlement, and record keeping of financial assets. Clearing referred to the process of transmitting, reconciling, and confirming transactions prior to settlement. Settlement referred to a business process whereby securities were delivered in simultaneous exchange for payment of money. Rutter saw an opportunity to move this non-proprietary, back-office function out of individual banks and into the cloud, where the expense could be shared across firms and where cryptographic tools could be used to create trust among participants. Driving back from the meetings along California's Highway 405, Rutter had an epiphany. He suddenly realized that "distributed ledgers could be to finance what the Internet was to media." When he got back to New York, Rutter started calling banks to tell them about what he had seen and his vision of a shared, cryptographically-secured ledger. Given his years of experience and credibility, the banks were interested and encouraged him to put together a plan.

By the end of 2014, Rutter's family office[3] was a seed investor in several financial technology (fintech) start-ups, including Align Commerce (later renamed Veem), the first global payments platform to use blockchain technology, and Digital Asset Holdings, the distributed ledger company headed by Blythe Masters. But Rutter thought that the company should create its own solution. Realizing that the three partners lacked technical knowledge of blockchain, Rutter reached out to IBM's Richard Gendal Brown after reading some of his blogs online. After six months of conversations, Rutter convinced Brown to leave IBM and join R3 as chief technology officer in September 2015. Two months later, Rutter hired James Carlyle and Mike Hearn as chief engineer and lead platform engineer, respectively (see Exhibit 2).

Creating the R3 Consortium

Rutter chose a novel approach to learn what the banks needed and what they were doing in-house. R3 hosted three roundtables to debate blockchain and its applications with bankers, venture capitalists, technology companies, and other stakeholders. The first roundtable discussion was held in New York in September 2014,

[2] Tom Osborn, "David Rutter: Gambling on Blockchain and a Treasuries Revolution," Digital Risk, May 5, 2016, accessed August 3, 2018, www.risk.net/derivatives/2456959/david-rutter-gambling-on-blockchain-and-a-treasuries-revolution.
[3] The term "family office" referred to a private wealth management advisory firm that served ultra-high-net-worth investors, offering a total outsourced solution to manage the financial and investment side of an affluent individual or family; "Family Offices," Investopedia, accessed August 13, 2018, www.investopedia.com/terms/f/family-offices.asp.

the second one took place in California in December 2014, and the third session was held back in New York in May 2015. These eight-hour sessions were part-educational, part-sales opportunity. The focus was to reach agreement on the underlying problem and the architecture for a solution, without deciding whether it would involve the bitcoin blockchain or another DLT, as Rutter explained:

> We held several roundtables . . . to deeply consider what the possible implications of the blockchain were, and what it could possibly do to save money, and time, and to create a better paradigm for the world of Wall Street and finance.[4]

These meetings led to a set of wish lists in areas where blockchain technology could reduce back-office costs, covering everything from security issuance, to clearing and settlement, to smart contracts. Smart contracts were software programs coded on a blockchain that converted the terms of financial agreements into executable code. Smart contracts typically took the form of a decision tree: "if X, then Y." The code executed when the contract terms were met without human intervention.

Over his career, Rutter had put together four bank consortiums. He knew from experience that the banks were hard to convince on an idea, were quick to write a cheque once they were on board, but liked to boss around their partners. Rutter also knew that a shared distributed ledger would disrupt part of their business models, so he anticipated that there would be disagreements along the way. He needed to propose a model where he could maintain control and avoid giving any bank too much power. It also had to satisfy the banks' lawyers who were concerned about antitrust issues and the perception of collusion.

Rutter spent 10 months putting together a complicated but novel investment deal. R3 would create a joint venture with the banks to develop a blockchain solution. The banks would buy memberships at three price levels: $1 million, $2.5 million, and $5 million.[5] The largest amount would come with a board seat and other special privileges. The members were encouraged to contribute staff to join different working groups. Using a gym membership analogy, Rutter explained that members would get out what they put into it. In hindsight, Rutter realized that the smartest decision he made over this period was not to sell his equity too early, but to build a viable business first, while maintaining control.

The negotiations with the banks concluded at the end of the summer of 2015. On September 15, 2015 R3 issued a press release announcing that nine of the world's leading banks had formed a partnership to design and deliver advanced DLTs for the global financial markets. The initial banks were a mixture of leading global banks: Barclays, BBVA, Commonwealth Bank of Australia, Credit Suisse, Goldman Sachs, J.P. Morgan, State Street, Royal Bank of Scotland, and UBS. Although it was often referred to by the media as a *consortium*, Rutter preferred to describe it as a massive collaboration among a network of partners. From the initial nine banks, the membership grew rapidly to 42 banks by mid-December 2015.

The September 15 announcement was widely reported by the media. Rutter told *The Financial Times*, "This partnership signals the first significant commitment by the banks to collaboratively evaluate and apply this emerging technology to the global financial system."[6] Speaking to the *Wall Street Journal*, Rutter explained that

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[4] Katherine Fletcher, "Major Banks Form Consortium to Bring Blockchain Technology to Financial Markets," CoinReport: Global Digital Currency News, September 17, 2015, accessed August 3, 2018, https://coinreport.net/major-banks-form-consortium-bring-blockchain-technology-financial-markets.

[5] All currency amounts are in US$ unless otherwise specified.

[6] Philip Stafford, "Blockchain Initiative Backed by 9 Large Investment Banks," *The Financial Times*, September 15, 2015, accessed August 3, 2018, www.ft.com/content/f358ed6c-5ae0-11e5-9846-de406ccb37f2.

the effort had three main goals.[7] The first goal was to develop a platform that could handle the billions of dollars' worth of transactions that occur in the financial industry. The second goal was to build a sandbox for experimenting with these new blockchain and DLT tools. The third goal was to learn from these experiments what worked and where the technology could best be used in financial services. In addition to developing a blockchain solution, the project would seek to establish consistent standards and protocols for this emerging technology in order to facilitate broader adoption across the financial industry and gain a network effect.

DISTRIBUTED LEDGERS VERSUS BLOCKCHAINS

From the beginning, the R3 team faced confusion from bank partners and other stakeholders about the difference between a blockchain and a distributed ledger. Even experienced bankers had little idea how the two concepts were related, and often incorrectly treated them as the same. This confusion arose because most people first heard about blockchain when also learning about bitcoin—the digital currency launched in 2009 that recorded transactions on a public, cryptographically-secured, distributed ledger.

Although the two technologies were often used interchangeably, there was a specific difference. A distributed ledger was only one of several components that made up the bitcoin blockchain, but not all distributed ledgers necessarily batched unrelated transactions together into blocks. Confusingly, the term "blockchain" rapidly became a generic term referring to all varieties of encrypted distributed ledgers even those that did not aggregate transactions in blocks for batch processing (similar to the brand name Aspirin becoming the generic term for all headache medications, for example).

Centralized, Decentralized, and Distributed Ledgers

A ledger was an accounting term that referred to a record of the ownership of some asset. A cash ledger, for example, showed the amount of cash held by a company and recorded any increases and decreases. In financial markets, ledgers recorded ownership of financial assets, such as the number of shares issued by a company, the names of shareholders, and any transfers of ownership due to purchases or sales. Historically, ledgers consisted of physical books (hence the term "bookkeeping"). However, electronic or digital ledgers had become the norm with the rise of computers.

A ledger could be centralized, decentralized, or distributed. A centralized ledger was a single complete record of the ownership and the transactions in an asset. The ledger was centralized because one true copy was held by a party who maintained it. The ledger verified legal title to an asset, such as a stock or a bond. Typically securities ledgers were entrusted to a third party such as a custodian or securities depository. The shortcoming of a centralized ledger was that it could be accidentally or maliciously altered, shut down, lost, or destroyed, which presented a single point of failure.

A decentralized ledger was a system (or network), where the ledger was broken up into parts held and updated in different locations. Decentralized ledgers needed to be aggregated into a centralized ledger to create a single, definitive record. For example, a department store chain could have many stores, with each keeping a ledger of its inventory at its location. The head office could then keep a centralized ledger, recording all inventories across the company, for use in accounting and planning. A decentralized ledger

[7] Paul Vigna, "BitBeat: Wall Street, City Banks Join Blockchain-Focused Consortium," *Wall Street Journal*, September 15, 2015, accessed August 3, 2018, https://blogs.wsj.com/moneybeat/2015/09/15/bitbeat-wall-street-city-banks-join-blockchain-focused-consortium.

created more potential sources of error or points of failure. If any one of the decentralized ledgers was inaccurate, the centralized ledger would be inaccurate by extension.

A distributed ledger was a complete record of ownership and transactions for a given asset, with multiple identical copies held in different locations. The duplication avoided the chance of a single point of failure. However, a distributed ledger needed to be synchronized frequently to ensure its accuracy and alignment across the network. If an entry differed across ledgers, the correct entry could be verified by using the values recorded by the majority of the ledgers. The prospect of synchronizing distributed ledgers in the traditional physical book form would have been complex and time-consuming. However, current computer algorithms could synchronize electronic ledgers instantly, economically, and securely without the need for a central bookkeeper. The computer programs and protocols for recording, sharing, and synchronizing distributed ledgers were referred to generically as DLT.

A DLT was a form of computer software that information technology (IT) specialists called middleware. Middleware referred to a computer program that acted as a bridge between an operating system and database, and the applications built to provide functions for users. Those software systems were collectively called the "stack" with the operating systems and databases at the bottom, applications at the top, and middleware in-between (see Exhibit 3). Middleware played a particularly important role when running distributed applications (dapps) on a network of computers. From the perspective of a bank, middleware connected easy-to-use graphical user interfaces with the legacy IT systems built in the 1970s and 1980s on mainframe computers using computer languages such as C++ and COBOL. As banks grew organically or through mergers across national borders, bank back-office functions became a hodgepodge of incompatible IT systems with databases siloed in different parts of the organization, making it difficult to get a centralized picture of a bank's assets and earnings.

According to a 2017 report from the consulting firm Capgemini, maintaining legacy IT systems consumed 90 per cent of bank technology budgets with the ten largest investment banks having employed two middle- or back-office staff for every front-office staff member.[8] More than half of the submitted paperwork for opening customer accounts got rejected, which required a time-consuming and expensive follow-up. Ten to twenty per cent of contact centre volumes were a result of execution issues in the back-office. Capgemini estimated that automating back offices could help banks to reduce annual back-office costs by 30 per cent.

Security and Transparency of Ledgers

An important feature of ledgers was how they handled security, which referred to the ability to make changes to the ledger. Given that a ledger recorded legal ownership, the level of security depended on the value of the assets and the degree of trust among participants. Two extremes were permissioned versus permissionless ledgers. On a permissioned ledger, participants needed authority to make changes to the ledger. Typically, some participants were certified as trusted counterparties (or nodes) and were able to make changes. On a permissionless ledger, any participant (or node) could change or update the ledger. However, the participants needed to agree to a set of consensus protocols to avoid unwanted accidental or malicious alterations.

A ledger could offer a wide range of transparency or privacy levels, from public and fully transparent, with anyone able to see its contents, to private and unavailable to the public. For example, records of land titles and property assessments held by a municipality were public. Residents could access a database containing a property's lot dimensions, boundaries, and the assessment value used for calculating property taxes.

[8] Capgemini, "Backing up the Digital Front: Digitizing the Banking Back Office", Capgemini, 2017, accessed September 20, 2018, https://www.capgemini.com/wp-content/uploads/2017/07/backing_up_the_digital_front25_11_0.pdf.

However, although the records of land titles were public and transparent, the ledger itself was permissioned. Therefore, only the land registry office could make changes to the records.

On the other hand, most ledgers used for business (i.e., enterprise ledgers) were private, which meant that the information they contained was commercially sensitive and not available to the public. Transactions were recorded privately by a trusted intermediary who maintained the ledger. An example of a private ledger was the list of records of share ownership used for voting on corporate actions and the distribution of dividends. The owners of shares (i.e., shareholders), and changes in their holdings, were not broadcast publicly. Transactions were known to the counterparties to a trade and sent to a depositary institution that was delegated authority to modify the corporation's share ledger. In this example, data privacy was important for the business because the information had commercial value that could benefit a company's competitors.

Bitcoin, Blockchain, and Altcoins

Bitcoin was the creation of an anonymous individual using the name Satoshi Nakamoto. The founder published a nine-page white paper on the Internet in 2008 titled "Bitcoin: A Peer-to-Peer Electronic Cash System."[9] Although other developers had proposed the idea of electronic money before, their efforts had failed because users could not solve the double-spend problem—how to exchange money electronically without a trusted intermediary to verify that the money had not been spent twice.

Nakamoto's solution to the double-spend problem relied on a peer-to-peer network of independent computers (called nodes), where transactions were time-stamped, collected in blocks for batch processing, and hashed to make these records immutable. Each time-stamped block included the previous block's hash, stringing the transactions together in a chain, or blockchain. Each block was append-only, meaning that a record could not be altered once it was verified. Participants on this network would agree on a single history of transactions when a majority of the nodes reached a consensus. A node (called a *miner*) would be selected at random to verify the transactions and receive new bitcoins as a reward. To ensure fairness in the distribution of these rewards, the miners would compete for the right to hash the block using *proof-of-work*, where the reward went to the first node that found a numerical value (called a *nonce*). When hashed with the transactions, the nonce led to a hash beginning with a specific number of zeros.

In 2009, Nakamoto launched the bitcoin network online with various rules and protocols described in the code published on GitHub. Nakamoto arbitrarily set the maximum number of bitcoins that would be created at 21 million. Transactions in bitcoin would be collected and batched every 10 minutes into 1-megabyte blocks. This ledger would be secured using the 256-bit Secure Hash Algorithm (or SHA-256). Because bitcoin transactions were hashed in blocks and chained together, bitcoin's distributed ledger came to be known as the bitcoin blockchain. Because the bitcoin blockchain was fully transparent, permissionless, and distributed, anyone could download and view the ledger to see the ownership of bitcoin. All transactions were broadcast publicly across the bitcoin network. The ownership of bitcoin funds was publicly available but hidden behind the owner's pseudo-anonymous public key.

The reward for adding a block to the bitcoin blockchain was initially set at 50 bitcoin, with the reward halved every 210,000 blocks (or approximately every four years). The difficulty of finding the nonce was adjusted so that the number of blocks created remained constant at six blocks per hour, or one block every 10 minutes. As more computing power was devoted to mining on the bitcoin network (measured in hashes per second across all nodes), the bitcoin difficulty increased automatically to maintain this fixed rate of

[9] Satoshi Nakamoto, "Bitcoin: A Peer-to-Peer Electronic Cash System," Bitcoin, 2008, accessed August 3, 2018, https://bitcoin.org/bitcoin.pdf.

block creation. Nakamoto never explained or justified these architectural choices, but they have come to dominate the operation of the bitcoin network.

Because the bitcoin source code was available online, programmers who wanted to modify the design for a different-use case were able to launch competing cryptocurrencies. Hundreds of alternatives to bitcoin (or *altcoins*) emerged with different characteristics, but they all shared one feature in common: they were supported by a cryptographically-secured distributed ledger, or blockchain. For this reason, altcoins were known generically as cryptocurrencies, due to the use of cryptography to secure the permissionless, public, distributed ledger.

THE FINANCIAL INDUSTRY'S SHARED PAIN POINT

The main pain point facing banks and other investors was the expensive and time-consuming process of clearing, settlement, and record keeping when trading financial assets. A financial asset was a broad term referring to any tradeable instrument that would confer some likely future economic benefit. Financial assets could be divided into distinct categories, depending on their physical and legal characteristics. Stocks and corporate bonds, for example, were contracts issued by a corporation that entitled the holder to a claim on the corporation's assets and cash flows. Other financial assets were foreign exchange (or currencies), money market instruments, fixed income securities, property, commodities, and related derivative securities.

Over time, each financial asset had developed its own trading rules and settlement procedures with some shared conventions but many idiosyncratic characteristics. Some financial assets were traded on exchanges in standardized amounts with the exchange acting as an intermediary between the counterparties. But the majority of financial assets were bought and sold in the over-the-counter market directly between counterparties. Over-the-counter trades were unstandardized, with no intermediary between the buyer and seller. To complicate matters further, many financial assets were traded cross-border, denominated in different currencies, and with different regulatory and compliance requirements.

Clearing and settlement was the name given to this complex process of transferring ownership of a financial asset from one holder to another. Because counterparties did not trust each other, they needed to agree on the terms of each trade, sign documentation, and complete delivery versus payment on an agreed settlement date. Some trades were still agreed to verbally and processed manually, leading to human error and failures to settle. This problem was so pervasive that it had a special name: settlement risk—the risk that a counterparty failed to deliver a security or transfer payment by the settlement date.

Financial market participants spent billions of dollars each year on this complex and time-consuming process. One consultancy estimated that the application of DLT could reduce banks' infrastructure costs attributable to cross-border payments, securities trading, and regulatory compliance by between \$15 billion and \$20 billion per year by 2022.[10] Rutter's goal was to solve this massive industry pain point. He convinced R3's member banks that it made better economic sense to pool their resources and to collectively develop an encrypted distributed ledger in the cloud for this back-office process, rather than each bank struggling individually through a painful and expensive process of three to five years to develop its own technological solution. After all, trading was a network problem. Therefore, for the trade to be effective, any solution had to be adopted by both counterparties.

[10] "The Fintech 2.0 Paper: Rebooting Financial Services," Santander InnoVentures, 15, June 2015, accessed July 23, 2018, http://santanderinnoventures.com/wp-content/uploads/2015/06/The-Fintech-2-0-Paper.pdf.

Modelling Asset Lifecycles

To achieve this goal, R3 worked with its bank partners to map out the life cycle for different assets traded in financial markets. This step was crucial because any DLT solution had to accommodate the many idiosyncratic features of a variety of financial assets. Their conclusions were published in an *Asset Modelling* white paper in November 2016.

The *Asset Modelling* white paper divided asset lifecycles into pre-trade and post-trade processes. Pre-trade processes included the negotiation and transactional activities that financial firms undertook prior to the point of individual trade execution. Depending on the type of business, this included complex portfolio management or risk rebalancing activities that generated many trades. Post-trade processes included all the activities undertaken after the point of trade execution that were directly related to managing or reporting on the trade itself. These activities included clearing, settlement, and record keeping. The counterparties to a trade needed to agree on the exact security traded, the price, the quantity, the settlement date, and the cash that needed to be delivered, including any accrued payments owing.

The white paper explained how a shared DLT solution could reduce the complexity and costs of post-trade processes. It outlined the trading model for financial assets and illustrated how smart contracts could be used for trading bonds and foreign exchange.

EXPERIMENTS WITH EXISTING BLOCKCHAINS

Having mapped out the problem and the functional requirements of the member banks, the R3 team set about finding a solution. Being a pragmatist and a business man, Rutter cared most about solving the problem and was agnostic about the chosen technology. Guided by the mantra “adopt, adapt, or build,” Rutter divided the bank staff into two working groups that began sprinting as fast as they could to find a solution. The first working group, known as the Lab and Research Centre (LRC), was based out of New York. Its mandate was to test existing DLTs and blockchains to see if they could be adopted and adapted to meet the banks’ technical requirements. The second working group, known as the Architecture Working Group (AWG), was based out of London, U.K., and began developing a new DLT from scratch.

Project Genesis

Between January 19 and February 29, 2016, the LRC ran a trial project code-named Project Genesis, with 42 member banks. The group simulated the issuance, trading, and redemption of commercial paper[11] on a variety of distributed ledgers. Project Genesis evaluated the strengths and weaknesses of DLT solutions from five vendors: Chain, Eris Industries, Ethereum, IBM Hyperledger, and Intel Sawtooth. The investment product commercial paper was chosen due to its relative simplicity and ability to compare the five vendors and how they modelled the commercial paper life cycle.

Project Genesis simulated both bilateral trades between two counterparties and multilateral trades between multiple counterparties. The simulation covered four scenarios in the lifecycle for commercial paper: the issuer created (or issued) the commercial paper; the issuer sold the commercial paper to a securities dealer; the dealer sold the commercial paper to a trader; and the issuer redeemed the commercial paper to a dealer or a trader.

[11] Commercial paper was a short-term debt instrument issued by a corporation, typically to finance accounts receivable, inventories, and short-term liabilities. Commercial paper was usually issued at a discount from face value and reflected prevailing interest rates; “Commercial Paper,” Investopedia, accessed August 13, 2018, www.investopedia.com/terms/c/commercialpaper.asp.

These transactions were recorded on distributed ledgers hosted on cloud computing services provided by Microsoft Azure, IBM Cloud, and Amazon AWS. Project Genesis's ledgers were permissioned, which meant that only the banks involved in the project had a copy. The ledgers were programmed with smart contracts that updated the ledger when specific events occurred. By using smart contracts with a permissioned distributed ledger, Project Genesis avoided the time-consuming and expensive proof-of-work consensus protocol used by bitcoin and many cryptocurrencies.

The high-level of collaboration and engagement between the banks and the vendors on Project Genesis provided several valuable insights. First, it demonstrated how DLT could be applied to real-world, financial market processes by deploying smart contracts for an actively traded asset class. Second, as the project unfolded, it became apparent that there was a wide range of experience with, and understanding of, DLT solutions across the banks. Project Genesis allowed the LRC participants to share their knowledge, to compare findings, and to share insights on the strengths and weaknesses of each of the five blockchain solutions. Third, Project Genesis demonstrated that it was possible, with the right structure and governance, for banks and other partners to collaborate on the development of a shared distributed ledger.

The fourth insight provided by Project Genesis was that R3's members were not looking for proprietary DLT solutions but rather an open-source industry standard that included opportunities for hands-on development, code review, and testing against a comprehensive set of evaluation criteria. Banks were risk-adverse, particularly when it came to risk management, compliance, regulation, and information technology systems. Being able to review and modify the code to meet their privacy and scalability requirements was a critical feature for R3 members. Open source had the advantage of code accessibility, familiarity, and as a result, potentially quicker adoption as an industry standard.

Finally, Project Genesis demonstrated that none of the five distributed ledgers reviewed, despite being considered the most advanced, was enterprise-grade or near-production. Rutter and the R3 team made the decision to put all of their resources into developing a DLT for financial services from scratch.

A DISTRIBUTED LEDGER FOR FINANCIAL SERVICES

Starting in mid-September 2015, Brown led the AWG as it began putting ideas on a white board for an enterprise-grade DLT. Brown, R3's chief technology officer, had understood from the start that the bitcoin blockchain would be inappropriate for financial markets, both from a processing workload and from an information security point of view. The bitcoin blockchain was permissionless and consensus-based, with costly proof-of-work, slow verification of transactions, and low throughput due to the restriction on the block size. Because it was built to be fully transparent, every node on the network saw and received all data that was distributed across the system. This transparency was anathema to financial market participants, who wanted their transactions and holdings to be kept private. The bitcoin blockchain was also a self-contained system that recorded transactions in only one asset: bitcoin. It was not interoperable with other blockchain networks. For these reasons, Brown's starting point was that simply "forking" or cloning the bitcoin blockchain was a non-starter.

The AWG began the arduous process of filtering the functional and non-functional requirements that regulated financial institutions had to comply with when managing back-office post-trade processes. To be successful, their distributed ledger would need to meet three main goals. First, it had to provide an immutable record of financial events that encompassed the banks' decision-making logic. Second, it had to combine cryptography and smart contracts with features such as privacy and interoperability, which were standard in financial markets. Third, it also had to satisfy the risk and compliance requirements demanded in the highly-regulated, financial services industry.

Brown explained the need for creating the right technology:

> The reality is that solutions based on selecting the design first and then trying to apply it to arbitrary problems never work out well. Every successful project I've worked on started with the requirements, not some cool piece of technology, and I was determined to bring that discipline into our work at R3.[12]

The Problem of Untrusting Nodes

A key problem was how to tackle the trust problem in financial markets; or more specifically, the *lack of trust*. This lack of trust was the source of most of the costs and difficulties with post-trade processes. Counterparties kept their own internal ledgers that needed to be reconciled after every trade. When the records did not match, back-office staff from both sides needed to reach agreement. Because one side's profit often came at the other's expense, this process was inherently contentious and counterparties invariably disagreed. If these disputes escalated, lawyers and the courts might get involved, making the process expensive, time-consuming, and frustrating for everyone involved.

One solution was to pay a trusted intermediary to manage a centralized ledger and to verify transactions between counterparties. In securities markets, this entity might be a central securities depositary, such as the U.S. Depository Trust Company. But a trusted intermediary was expensive and still did not solve all post-trade processing problems.

R3's solution was to design a distributed ledger to reflect the fact that counterparties did not trust each other, which Brown referred to as the problem of untrusting nodes. As he explained, "Distributed ledgers are systems that enable parties who don't fully trust each other to form and maintain consensus about the existence, status, and evolution of a set of shared facts."[13] Nodes on R3's distributed ledger would need to independently verify data they received from each other and only share data they were happy to broadly share.

The Solution: R3 Corda

By March 2016, the AWG had developed a new DLT called Corda that featured a unique set of attributes. Corda was not a traditional blockchain. It did not bundle transactions in blocks but instead validated each transaction (or agreement) individually, speeding up the processing time. Corda was a permissioned distributed ledger. No wasteful mining was required to reach consensus on transactions. Instead trusted intermediaries called *notaries* recorded facts on an immutable ledger. Corda maintained privacy with no unnecessary global sharing of data. On Corda only the nodes to whom the information pertained—for example, the counterparties to a trade—were sent the data. Consensus occurred between parties to a transaction, not between all participants.

Corda featured smart contracts, with an explicit link between human-language legal documents and the smart contract code. Smart contracts facilitated trusted peer-to-peer transactions and enabled settlement to occur directly on the ledger without the need for an intermediary. Corda's design also directly enabled regulatory and supervisory observer nodes to meet compliance needs. Corda was interoperable with other

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[12] "Introducing R3 Corda: A Distributed Ledger Designed for Financial Services," Richard Gendal Brown, April 5, 2016, accessed August 3, 2018, https://gendal.me/2016/04/05/introducing-r3-corda-a-distributed-ledger-designed-for-financial-services.
[13] "On Distributed Databases and Distributed Ledgers," Richard Gendal Brown, November 8, 2016, accessed August 3, 2018, https://gendal.me/2016/11/08/on-distributed-databases-and-distributed-ledgers.

networks. Any party could transact freely with any other node while still supporting private business networks. Finally, Corda did not require a native cryptocurrency or crypto-token to operate.

On April 5, 2016, Brown published the first public description of Corda on his blog. Although he praised the bitcoin blockchain and other DLTs, he stated clearly that Corda was different. This blog was followed by the publication of a non-technical Corda white paper.[14]

Brown published a light-hearted explanation of "The Corda Way of Thinking" using a simple analogy based on a bet between two individuals on whether it will rain on a given day. This bet relied on physical letters, signatures, filing cabinets, the newspaper, and the postal service.[15] Each feature of the bet corresponded to a feature in Corda (see Exhibit 4).

MAKING A DECISION

By the fall of 2016, R3 had launched the first version of Corda: the first DLT built to meet the demanding security, privacy, scalability, reliability, and throughput requirements of the regulated financial services industry. Rutter and his team then had to decide how best to monetize their investment. After the business model issue was resolved, the secondary issue of how to finance the future growth of the company would also need to be addressed.

Heading into the management meeting offsite, Rutter saw at least three possibilities for monetizing Corda. One option was to follow the traditional software product strategy (such as Microsoft) or software-as-a-service strategy (SAAS). In this business model, R3 would sell or license the Corda as a plug-and-play middleware software solution. A second option was to go further and pursue a full-stack, vertically-integrated strategy. R3 would provide an end-to-end back-office solution for its customers, developing top-of-stack distributed applications (dapps) and a bottom-of-stack operating system and database, with Corda running as middleware. A third option was to pursue a platform-as-a-service strategy built around Corda where R3 would build a technology ecosystem involving 3rd party developers, consultants and other suppliers interacting with banks, insurance companies, and other financial institutions. All three business models had the potential to generate revenues but they had different implications for costs, staffing, and relationships with R3's members and partners (see Exhibit 5).

Rutter knew this decision would be contentious. Some of R3's bank members favoured a proprietary solution; others were concerned that R3 might become a direct competitor. Holding the consortium together as Corda was developed had been a difficult balancing act. Rutter realized that the decision could easily open divisions among R3's members, causing the joint venture to fall apart. Any appearance of dissent or conflict would also jeopardize plans to raise capital, possibly through a private or public sale of equity. Rutter wondered what business strategy to follow. He also wondered how best to finance the next stage of R3's growth. Should he continue with the membership model, sell equity in R3 privately, or take the company public through an initial public offering?

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[14] Richard G. Brown, James Carlyle, Ian Grigg, and Mike Hearn, "Corda: An Introduction," Corda, August 2016, accessed August 3, 2018, https://docs.corda.net/_static/corda-introductory-whitepaper.pdf.
[15] "The Corda Way of Thinking", Richard Gendal Brown, February 21, 2017, accessed August 3, 2018, https://gendal.me/2017/02/21/the-corda-way-of-thinking.

EXHIBIT 1: R3 TIMELINE, 2012 TO 2016

Date	Event
2012	David Rutter leaves ICAP Plc, where he was head of electronic brokerage.
January 2013	Rutter founds R3CEV (later renamed R3), a blockchain technology solutions group, with Jesse Edwards and Todd McDonald as the first two hires.
January 2014	R3 founders meet with bitcoin and blockchain companies in Palo Alto, California, with the purpose of finding ventures to invest in. They instead decide to create their own company.
September to December 2014	R3 organizes round-table talks with banks in New York and San Francisco.
September 15, 2015	R3 announces the formation of a partnership to design and deliver advanced distributed ledger technologies to global financial markets with nine banks: Barclays, BBVA, Commonwealth Bank of Australia, Credit Suisse, Goldman Sachs, J.P. Morgan, State Street, Royal Bank of Scotland, and UBS.
September 29, 2015	An additional 13 banks join the R3 consortium.
December 31, 2015	The R3 consortium reaches a total of 42 banks and closes membership for the next 12 months.
January 20, 2016	R3 and 12 member banks execute transactions on a global distributed ledger using Ethereum tools running on Microsoft's Azure cloud.
January to February 2016	R3 and 40 banks strike Project Genesis to simulate the issuing, trading, and redemption of commercial paper via blockchain technology. The tests trial five distributed ledgers built by technology providers Chain, Eris Industries, Ethereum, IBM, and Intel.
June 16, 2016	R3, Payments Canada, the Bank of Canada, and Canada's five largest banks complete tests of the viability of Ethereum as the basis for wholesale interbank payment settlements (Project Jasper, Phase 1).
July 13, 2016	R3, Barclays, ISDA, Norton Rose Fullbright, and UCL collaborate to address the challenges of developing master templates for smart contracts.
August 10, 2016	R3 and over 15 banks trial smart contracts for invoice financing and letter of credit transactions for international trade.
August 24, 2016	The first non-technical Corda white paper is released.

Source: Company documents.

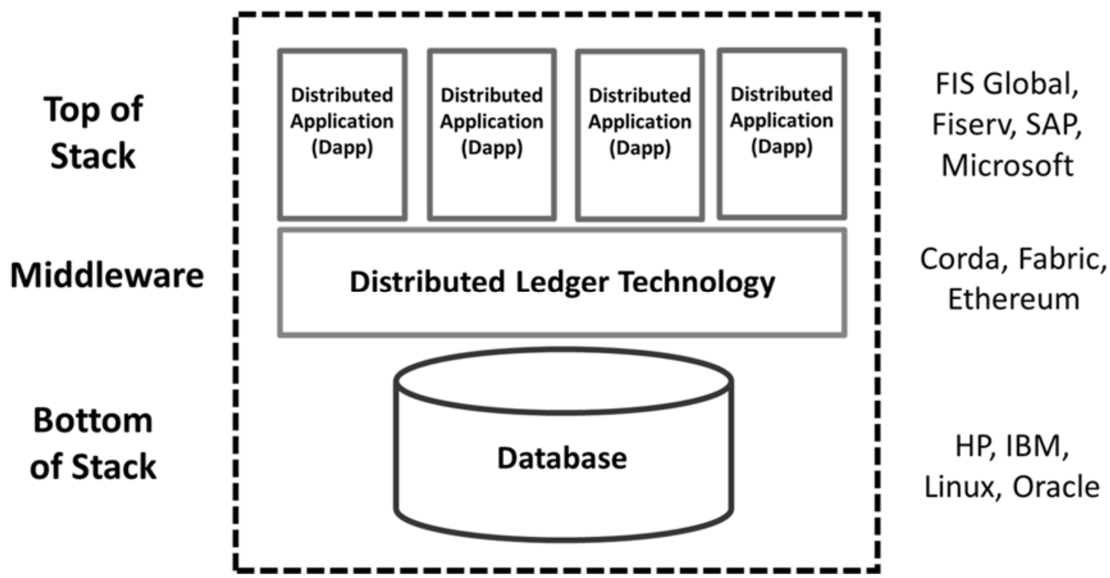
EXHIBIT 2: R3 MANAGEMENT TEAM

David E. Rutter: Founder, Chief Executive Officer With over 30 years of experience leading some of Wall Street's top institutions, David Rutter is a long-time creative thought leader in financial markets and innovation and has played a significant role in the adoption of electronic trading in the global over-the-counter derivatives industry. Rutter served for 10 years as the chief executive officer (CEO) of electronic brokerage at ICAP Plc, the world's largest interdealer brokerage firm, where he led the Brokertec fixed income platform and the EBS foreign exchange platform. Prior to ICAP Plc, Rutter was co-owner and CEO (Americas) of Prebon Yamane.
Todd McDonald: Co-Founder, Head of Partnerships Todd McDonald is a co-founder of R3 and head of ecosystem development. McDonald focuses on building the partner application ecosystem for R3's Corda platform. Prior to R3, McDonald spent 14 years at Standard Chartered Bank as a managing director in the financial markets group, where he held positions such as global head of electronic foreign exchange (FX) trading and head of FX for the Americas. McDonald holds a bachelor of arts degree in economics and political science from Colgate University.
Jesse Edwards: Co-Founder, Head of Corporate Development Jesse Edwards is a co-founder of R3 and serves as the firm's executive vice-president and head of corporate development. Edwards helps lead execution of the firm's strategic vision and directs investments and partnerships. Prior to founding R3, Edwards was an investment banker at Sandler O'Neill & Partners and more recently at AGC Partners, where he advised large global financial institutions and financial technology companies. Edwards holds a bachelor of science degree and an MBA from Cornell University.
Richard Gendal Brown: Chief Technology Officer Richard Brown is the chief technology officer at R3 and is one of the world's leading authorities on distributed ledger systems and architectures. Previously, Brown was the executive architect for banking and financial markets industry innovation at IBM United Kingdom. His previous roles with the company, for whom he worked for almost 15 years, included lead account architect for a global investment banking client and a consultant for IBM software products. Brown is a chartered engineer and holds an MBA with distinction from Warwick Business School and a first-class degree in mathematics from Trinity College, Cambridge.
James Carlyle: Chief Engineer James Carlyle is focused on defining a candidate architecture and building out a collaborative lab for experimentation by network members. Previously, Carlyle was chief engineer within corporate banking at Barclays, where he designed and delivered the bank's corporate Internet channel and the bank's US banking and dollar clearing platforms. Before Barclays, Carlyle co-founded two start-ups. He holds patents in mobile data search and directory technology. He is a chartered engineer and holds a degree in engineering science from University College, Durham.
Mike Hearn: Lead Platform Engineer Mike Hearn is lead platform engineer at R3. He has over five years of experience with bitcoin, blockchain, and distributed ledger systems. He spent nearly eight years at Google, where he was a senior software engineer. Hearn was one of the world's first developers of software for the bitcoin platform, including its smart contract capabilities. He developed the world's most popular bitcoin wallet software.

Source: Company documents.

EXHIBIT 3: ILLUSTRATION OF SOFTWARE STACK

This figure illustrates a stylized software stack for a bank. At the bottom of the stack sits the computer operating system and databases. At the top of the stack are distributed applications run by users throughout the organization. The middleware is the software that acts as a bridge between the operating system and databases at the bottom and the distributed applications at the top. Collectively, all three levels are known as the full stack. Bank applications were historically developed by Fidelity National Information Services Inc. (FIS) Global, Fiserv Inc. (Fiserv), Microsoft Corporation, and SAP SE (SAP). Mainframe operating systems were developed by Hewlett-Packard (HP), IBM, and Linux.org (Linux) with database software provided by Oracle Corporation and International Business Machines Corporation (IBM), among others. Examples of distributed ledger technology (DLT) middleware were R3 Corda, Hyperledger Fabric, and Ethereum.



Note: Fidelity National Information Services Inc. (FIS) Global, Fiserv Inc., SAP SE (SAP), Microsoft Corporation, Hewlett-Packard (HP), International Business Machines Corporation (IBM), Linux.org, and Oracle Corporation.,
Source: Created by case author based on case information.

EXHIBIT 4: CORDA KEY CONCEPTS—THE WEATHER BET ANALOGY

Richard Brown, R3's chief technology officer, used the following analogy to explain Corda:

Imagine that two friends, Richard and Albert, make a bet that it will rain next Wednesday. If it does, Albert owes Richard $10. Otherwise, Richard owes Albert. They agree on the rules: the winner will be decided by looking at the weather report in a specific newspaper next Thursday. They write out the bet on a piece of paper, and both sides keep a signed photocopy in their filing cabinets. On Thursday, the newspaper reports that it rained the previous day so Albert wins the bet. Albert mails the newspaper weather report with a signed letter to Richard asking for payment of $10. Albert's letter is delivered by postal service to Richard's address.

Analogy	Responsibility	Corda Component	Digital Ledger Technology Role
Bet written on a sheet of paper	Represents contract or deal	State object	Stores smart contract with references to legal prose (i.e., the "rulebook")
Filing cabinet	Keeps track of papers	Vault	Stores state objects
Rulebook	Provides rules that govern the bet	Contract Code	Provides verifications and rules that govern the state object's evolution
Newspaper weather report	Provides weather on day of bet	Oracle	Third-party trusted data source referenced for specific deal
Cover letter sent with newspaper report	One party updating the other party on the outcome of the bet, with evidence attached	Transactions	Method of evolving the state objects as governed by contract code
Signature	Proof that the letter really did come from who it claims to be from	Signature (digital)	Proof that a transaction was really done by who claims to have done the transaction (i.e., prevents repudiation)
Postal service	Ensures that letters are sent to the correct parties and delivered reliably	Network Map Service & Point-to-Point Messaging Network	Provides a reliable way of ensuring that transactions are delivered to precisely the right parties and nobody else

Source: Company documents.

EXHIBIT 5: DIFFERENT BUSINESS MODELS TO MONETIZE CORDA

Software-as-a-Service Strategy

The first option is to follow a traditional *software product strategy* (such as a Microsoft's model) or *software-as-a-service strategy* (SAAS). R3 could sell or license Corda as a digital ledger technology (DLT) solution for banks and institutional investors. Customers that buy Corda would need to integrate it into their information technology (IT) systems, replacing their back-office processes with Corda's state-of-the-art, cryptographically-secure ledger, which can be connected with their trading counterparties. Much like Microsoft, who sells an operating system but does not build the computer, R3 would focus on developing the best DLT on the market but not on building or configuring the hardware. In addition to revenues from software sales and licensing, R3 would earn additional revenues from customer support, training, and customization of the product. And as Corda's software is improved, R3 can sell or licence the latest release, creating a recurring revenue stream.

Full-Stack, Vertically-Integrated Strategy

The second option is to go further and pursue a *full-stack, vertically-integrated strategy,* where R3 provides an end-to-end DLT solution for its customers. This full-stack approach allows R3 to bypass incumbents who provide back-office services (such as depositaries and clearing houses) and deal directly with the end customer. A good example is Apple's strategy for its desktop computer, the popular Apple Macintosh series. Apple manufactures the computer, develops the operating system (i.e., Mac OS) and software applications (e.g., Apple Mail, iPhoto, iTunes, and Safari), and controls the distribution and support (through Apple stores). By controlling the end-to-end customer experience and the value-chain, R3 would capture a greater portion of Corda's economic value.

Platform-as-a-Service Strategy

The third option is to pursue a *platform-as-a-service strategy* built around Corda. Under this business model, which some call *technology ecosystem*, R3 would give away the proprietary Corda software to encourage adoption, much like Google did with the Android operating system. R3 would seek to establish Corda as the industry standard DLT and build network effects around a community of users. For this to happen, Corda's software would need to be open-source and available free to download, encouraging a community of third-party developers and IT experts to modify it to meet their customers' needs. R3 would monetize the Corda platform by selling add-ons such as technical support, training, reporting, middleware, storage, testing, and other services. R3 could also sell a more sophisticated version of Corda that contains more features.

Source: Case writer.