SPACECHAIN

THE WORLD'S LEADING INTEGRATOR OF SPACE, SECURITY, AND BLOCKCHAIN

Version 3 (2023)

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INTRODUCTION:
Changing Data, Changing Space

01

Digital technology over the last decade has been defined by the upflow of individual data. We are its generators and so too are its unwilling donors: The consumers of the products generated and sold through it and, as data is increasingly used to define us, we too in turn have become partially its product. The relationship is seldom reciprocal, for as we sign away our data, we relinquish our rights as owners, collaborators, analysts, and initiators.

The result is our present internet: Centralized and dominated by large actors, with an almost impossibly high barrier to entry for challengers. Data security is poor and collaboration between different actors is eschewed. Trust in tech giants to handle our personal data is low (Guskin 2021) and part of this is because our data is frequently sold. It is increasingly clear that the organizational structures of Web 2.0 no longer represent the best way to organize our web experiences. With the development of blockchain in 2008, the notion of immutable public ledgers, managed by peer-to-peer interaction is no longer brand new, but it has taken a decade of digital turmoil for an increasing number of start-ups and legislators to see its necessity.

Where Web 2.0 is fed by a mono-directional flow of our data, Web 3.0's aim has always been to flatten this hierarchy and facilitate the secure, reciprocal transfer of data between nodes within a network. The failure of centralized exchanges, potentially through malfeasance, further demonstrates how dangerous it is to place control in the hands of so few. Facilitating this, however, is not easy. Centralization typically begets greater centralization.

Space is just one, fast developing component within modern web infrastructure, facing many of the same issues faced by the rest of the industry. In the field of satellite communications, high entry costs and a lack of inter-organizational collaboration to establish universal standards and shared tenancy has reduced cooperation. This in turn has effectively kneecapped accessibility and thus as a corollary, collaborative innovation.

We are potentially decades behind where we could have been. Where bandwidth and satellite capacity cannot be easily exchanged, repurposed, and reworked, it breeds inefficiency and waste. Three billion still have no access to the internet and over 500 million have no access to reception of any kind (Michel 2022). Satellite coverage is worldwide but is often deployed to other, more singular uses, or kept behind paywalls beyond the reach of most. Given the size of an SMS message only comes to around 140 bytes, the fact that so many still have no access to communication of any kind demonstrates the inefficiency of current systems.

Until we at SpaceChain created it, there wasn't an easy way for us to pool capacity (and thus capabilities) between non-homogenous satellites. Buying capacity is far cheaper than a solo launch, but the inability to do so has kept costs high and has restricted the impacts of those that have launched. As a result, private individuals, communities, small/medium enterprises, or even poorer governments have largely been unable to establish their own competitive data infrastructure – whether for secure payments, satellite internet, or climate monitoring. As the internet and our freedom to use it are increasingly considered human rights (Regelitz 2020), the benefits of decentralization are becoming imperative.

To do so will require open-source tech and extensive collaboration. It has become SpaceChain's mission to facilitate this.

THE SYNERGY OF BLOCKCHAIN AND SPACE

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2.1 Why Blockchain?

SpaceChain's overarching aim is to deliver access to space for all. The cost, however, is a massive potential hurdle. According to Mckinsey (Daehnick et al. 2020), a large, operational LEO constellation would likely cost anywhere between $5-10 billion to launch, with further costs of around $1-2 billion per year to service and replace existing satellites. This places comprehensive satellite infrastructure beyond all but the largest industry players, further exacerbating data upflow.

To overcome this, SpaceChain has proposed encouraging shared tenancy and collaboration between multiple smaller actors in the space industry, enabling the effective pooling of resources. The creation of a Decentralized Satellite Infrastructure (DSI) to help facilitate communication between satellites is essential if this aim is to be achieved, but it is not without its technical hurdles. To enable efficient, smooth cooperation, a universal, but broad set of technical standards needs to be laid out. This is not a simple task and the issues with competing standards have been well documented (Breeman et al. 2022), but it is a challenge that nevertheless needs to be overcome if universal connectivity and data equality are to be achieved.

SpaceChain has frequently positioned itself as a vertical integrator for satellites developing hardware and software components and enabling efficient communication between different devices in a network. It is blockchain technology that is best suited to aiding in this. In focusing on open-source software that maximizes the number of

satellites that might meet this minimum standard, SpaceChain has sought to maximize its effective reach and open up the shared tenancy to many. It is for this reason that blockchain has proved to be perfectly suited. As blockchains typically work in the form of open-source software mediated between nodes by an immutable ledger, they can be uploaded via uplink to any satellite processor that has the hardware capacity. In this way, a new node can seamlessly join the peer-to-peer network.

As the number of nodes increases, these blockchain nodes on satellites, built through decentralized network infrastructure such as Ethereum Virtual Machine, will act as part of a worldwide network of data processing and storage that can facilitate access to: Transactions, smart contracts, satellite imagery, and data via decentralized apps (dApps) and many other tools that will prove beneficial to end users. Much of SpaceChain's innovation will be made open source and thus as the ecosystem grows, our infrastructure can be built on. This system is a cost-effective, trust-driven method to enable secure, collaboration-mediated data access and security.

Because of the simplicity of uploading and installing blockchain-based software via uplink, it will be possible to join the network even after launch. We see that the main hurdle in establishing a truly decentralized satellite network is developing protocols that are so beneficial, that companies wish to implement them. This invitation is thus extended at any time, to all who meet the standards to join us.

SpaceChain does not have large institutional backing at the moment and much of our growth has been fueled by clients working with our technical team. It is also for this reason that we have had to develop technology specifically for field usage. This is a testament to our capacity for innovation and delivering real-world implementation quickly. Where other companies work on longer deadlines and hypotheticals, we are pragmatically testing our work and getting results.

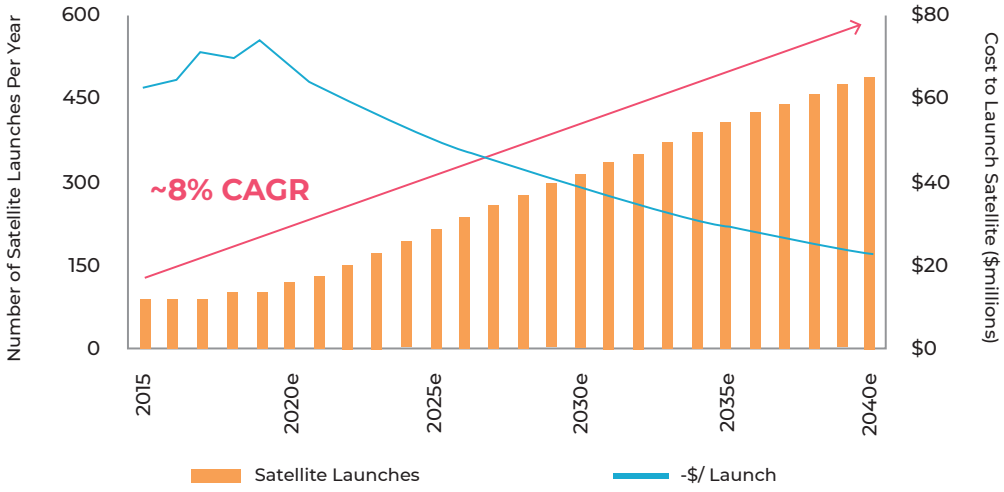
2.2 Why Space?

Space is a fast-expanding field within data networks; both as a platform through which data can be sent, stored, and received, and also as a place for data collection on the state of the earth below. At SpaceChain, we believe that space is essential if we are to advance the possibilities of communication beyond what it currently is.

Space as an environment is uniquely suited to offering worldwide services due in part to its detachment from the earth. Where a satellite is further away, it can receive and send a signal to a greater proportion of the earth's surface. It is this which opens up access to large swathes of the earth on a scale not available to ground infrastructure.

There has never been a better time to work in space. The space industry is one of the fastest-growing sectors. According to The Space Foundation, the industry grew to $469 billion (Porterfield, 2022), or around 9% year-over-year. Commercial space ventures make up a record 77% of this indicating a gradual shift from government-led projects to company-led projects.

Satellite Launches v. Cost to Launch



SpaceChain's focus on developing technology that can improve access across the three main tenets outside exploration: Earth Observation (EO), Communication (Including IoT - Internet of Things), and Navigation, opens up vast swathes of the industry.

Until relatively recently, slow satellite build cycles and prohibitive launch costs have put space beyond the reach of all but telecom giants and government initiatives. As launch costs have decreased (Sweeting 2018) and smaller satellites are increasingly able to carry out the role of what once would have been undertaken by far larger payloads, harnessing these benefits across a wider range of use cases has become more realistic. Furthermore, as smaller satellites are built in greater quantities, there has been a greater standardization of components, further reducing cost.

The benefits of connectivity could be far-reaching. As has already been demonstrated by Starlink (Michel 2022), constellations of Low-Earth Orbit (LEO) satellites may help connect some of the 3 billion people still without internet access (and over 500 million without phone signal) by bypassing expensive ground infrastructure. Nevertheless in its centralized format, for $110 per month and with areas of service predominantly covering the West, it will be unable to help most. Whilst the number of active satellites more than doubled between 2018 and 2020 alone (Salas 2022), the benefits of these new satellite networks have arguably not extended far enough.

SpaceChain over the past few years has strived to create a decentralized network between heterogeneous satellites across different orbits. We believe it is only through the development of protocols for sharing tenancy on satellites that they can be utilized to their full potential: Whether that is for reducing barriers to access to Earth Observation data, to enabling quick secure transactions across the globe.

This development has continued alongside developing minimum software and hardware standardization to enable efficient, resilient communication, whilst driving down costs. We have already used this to implement a blockchain-based payment infrastructure in space alongside enabling the upload of dApps. In the future, this may enable an ever-wide range of uses including; even faster, higher-capacity payment systems, satellite internet, data security and even acting as a receiver for deep-space infrastructure.

THE SPACECHAIN JOURNEY:
From 2017 to Present

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Even though SpaceChain was established in 2017, we have already made remarkable progress regarding new launches, collaborations, funding, and projects. Over this period, we have conducted seven launches and currently have two operational nodes on satellites and a further three on NASA's International Space Station (ISS).

By entering into uncharted territory, our history has seen us undergo rigorous experimentation to develop what we believe to be the best format to bring DSI to the world. In just five years we have developed a comprehensive ecosystem of software, hardware, and launch management.

This is our story.

2017: The Beginning

Early 2017: *Jeff Garzik, a Bitcoin pioneer, and Zee Zheng, a venture capitalist, specializing in space, meet and agree to collaborate on a platform to make space accessible to all by using blockchain technology.*

End of 2017: *Zee Zheng and Jeff Garzik launch SpaceChain*

2018: Two Nodes Launched

Feb 2018: *SpaceChain launches the first Qtum-based blockchain node into space*

March 2018: *Within a month it is fully integrated into the SpaceChain OS*

May 2018: *Integration with Ethereum begins*

Oct 2018: *The second node is launched*

Dec 2018: *Integration is completed. SpaceChain has two nodes successfully integrated*

2019: Expanding the Network

Jan 2019: *First Qtum-based transaction in space is performed*

Sep 2019: *Partnership with European Space Agency begins. SpaceChain is assigned a contract to work with the International Space Station (ISS)*

Dec 2019: *The third payload is launched, this time to ISS – able to process 100 times more transactions per transmission*

2020: Investing in Development

June 2020: *Execution of first Bitcoin multisignature blockchain transaction in space*

Sep 2020: *Commencement of work with European Space Agency and Elecnor DEIMOS to create an e-commerce platform with blockchain credit management systems*

Nov 2020: *Further development of SPC token to be compatible with Ethereum blockchain – This signaled the beginning of SpaceChain's shift to EVM to enable greater compatibility and efficiency*

2021: Two Launches in One Month and a Whole Lot of Development

April 2021: *Release of the first open-hardware board: Callisto*

May 2021: *Awarded with Innovate UK Eureka Grant to develop DSI for satellite industry upgrade.*

May 2021: *Signed deals with Eurasian Space Ventures*

June 2021: *First Ethereum blockchain payload is launched to ISS and another blockchain-enabled payload with space nodes is launched for three customers*

Sep 2021: *Partnership with satellite service operator Spire Global*

2022: Two Launches, Decentralization Beckons

Jan 2022: *Sent the Velas blockchain the world's fastest Ethereum Virtual Machine (EVM) blockchain and decentralized ecosystem into orbit. The test was completed in July 2022.*

Mar 2022: *Initiate our presence and develop a commercial relationship within the MENA region*

June 2022: *Co-founder and executive chairman Zee Zheng makes the Forbes 30 Under 30 Asia List*

Aug 2022: *Cliff Beek joins to lead global and U.S. expansion as CEO*

Sep 2022: *Teamed up with SpaceBelt to foster digital asset storage and payment services growth in the new space economy*

Nov 2022: *The second EVM payload is launched to the ISS, also marking the second integration of our payload with Velas.*

TECHNOLOGY

04

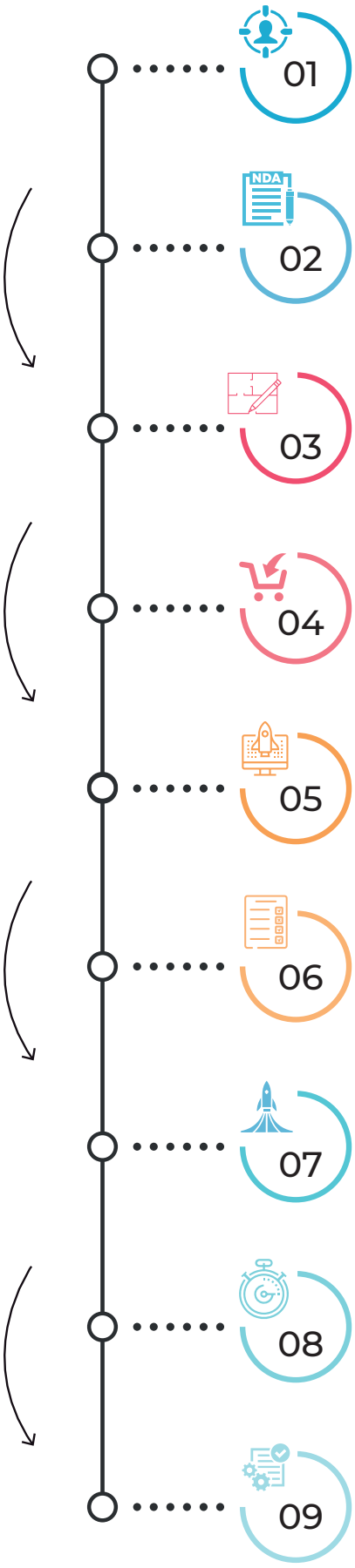
4.1 Space for Blockchain

4.1.1 Space Node and Space Multisignature Wallet Service

Delivering an end-to-end solution for payload deployment has been key to SpaceChain's mission from the get-go. It has always been our intention that a client, even without detailed prior knowledge of the satellite industry, can come to us and we can collaborate with them on developing a mission goal, building the software, designing the payload, integrating it into satellite templates, and then brokering the launch and delivery.

Such comprehensive integration between our software, hardware, and mission management helps clients to avoid supplier conflicts, delays, imperfect integration, and the extra costs that such setbacks naturally cause.

HOW OUR PROCESS WORKS



01 When a client first approaches us, as part of pre-planning, we discuss and develop a proposal with them, including evaluating requirements and budget

02 Upon agreement we sign a contract and NDA and begin the planning process

03 We share a more fleshed out technical plan with the client for their approval, which they then can revise further or sign off on

organizing

04 Once planning has been completed, we purchase, configure and design hardware and software to meet the client's needs

05 On the operations side, we coordinate with a launch service provider on a rocket launch, software and hardware standards and organizing the delivery of the payload for launch

06 As launch day approaches we conduct final tests, before sending off the node to the launch site

07 Lift-off! The payload is delivered into orbit and begins its mission

08 After a successful launch, we will conduct node performance tests in orbit and full function tests

09 The client's space node is complete and operational

Case Study: SpaceChain as a Vertical Integrator for the Velas Satellite Launches in 2022

Our work with Velas, the world's fastest Ethereum Virtual Machine (EVM) blockchain for smart contracts and dApps, offers excellent insight into what we can achieve for a client. The International Space Station (ISS) launch project has gone from a March commencement to its November 2022 delivery in less than nine months. Proof of what can be done in a short time when efficient structures are put in place.

An Out of This World Solution

Velas sought to collaborate with us on a comprehensive and complex brief, underpinned by a need for a secure system that is simple to use for its end users.

They came to us for two reasons, the first of which was security concerns. They had seen that satellite ground segments (especially those used for the ISS) often have aerospace/military-grade protection. This would ensure that any space node utilizes the most secure connection possible via an encrypted uplink and downlink channel, whilst negating the risk of physical tampering.

Secondly, as one of the first of its kind, the installation was designed to push forward the envelope as to what was possible, and a smooth operation was vital to ensure successful proof of concept. Velas wanted to push the boundaries for decentralized networks, enabling users to create streamlined crypto transactions, even with poor ground internet infrastructure.

Building,Testing,Launching, and Testing Again

To enable this, a three-tier program was developed for a gradual rollout of capabilities. The first of these was an uplink which installed software on existing satellites to enable basic uploads and downloads. It is this which represents part of SpaceChain's goal of forming a wider mesh network between new and existing satellites.

To expand capacity further, two launches were planned: One as a small satellite or light node launch and the other as a full node launch on the ISS, to be installed as part of a re-supply mission. The aim was to deliver in less than a year, the installation of two future-proofed nodes within a decentralized orbital network.

This in turn required negotiating launch costs, passing NASA's ISS Safety Panel, full system design, and integrating software with hardware. For the satellite, a Spire Global LEO nanosatellite was chosen to act as the template around which the hardware would be built. The hardware board and software were designed internally by SpaceChain and tested thoroughly to meet the most rigorous standards.

The software was designed to be compatible with Ethereum Virtual Machine (EVM). This widely used system is easily accessible to developers and can be adapted to a variety of use cases, increasing the long-term viability of the scheme.

A direct, encrypted API connection between the satellite and the ground station has ensured that data security is far superior to what could be expected on a ground-based node.

Proof of Concept

Farhad Shagulyamov, co-founder and CEO of Velas described the mission as part of '*A new epoch in the development of blockchain... part of the progressive, technology-led decentralization of finance and a great step in handing back security and power to individuals.*'

As part of Velas' new expanded capabilities, the node can securely sign and store the ledger in space for simple transactions such as sending VLX tokens and NFTs, whilst also expanding its remit to more complex functions such as multisignature payments and smart contracts.

Both launches were conducted through SpaceX's Falcon 9 rocket. The space node that launched in January 2022 has been successfully implemented and orbit tested, and the network is fully up and running. The latest space node launched in November 2022 is installed onto the ISS, thereafter we are conducting the orbit test.

4.1.2 Open Source and Open Hardware Board

Decentralized infrastructure works better when complex systems use and adapt similar blueprints and it is for this reason that SpaceChain has sought to create its own adaptable open hardware board, where even new iterations of it will be back-compatible something we have achieved with Callisto. It is this effort to enable developers to collaborate and innovate which minimizes waste and maximizes efficiency. Similarly, where a board is widely used, costs decrease.

Callisto is a dual operating system board utilizing two Cortex A-9 Cores to run Linux OS and SpaceChain OS simultaneously. This is mediated by a network interface card which enables the two to communicate with each other whilst maintaining their own memory so that blockchain information and spacecraft operation environments are kept separate for better security.

The board also features a Zynq-7000 SOC programmable logic based on Xilinx SoC architecture similar to that which is used in apple products and can provide up to 100Gb/s of I/O bandwidth. It is this high bandwidth that enables rapid multisignature transactions and provides adaptability for a range of different payload uses. These can include adding components and sensors to deliver a wide range of use cases.

Development and Uses

The use of a Linux OS enables easy compatibility and maintains high performance. Furthermore, as an open-source operating system, it is easy to work with, modify and enhance according to requirements. It is this which creates greater adaptability to a wide range of uses.

SpaceChain OS

Blockchain Apps

DApp | Wallet | ....

Local Apps

IoT Apps | Edu Apps | Chat Apps | ....

Blockchain

EVM | EVM-compatible | Layer2

3rd part software & tools & LIB

SQLite3 | STL | GOAHead WebSever | | Lua | libcrypto++ | libdb | libbitcoin

SDL | FFmpeg | Qt | iniparser | sypkg | libboost | libleveldb | ....

HAL

Star Sensor | Magnetom Eter | Temperature Transducer | Flying Wheel

Sun Sensor | Mems | Magnegic Torquer | GPS

SYSTEM SERVICE

App Manager | Update Service | Power Management | Critical Monitor

System Monitor | Network Service | Test Service | ....

POSIX

pthread | Semaphore | Sched | Mqueue | Mman

Dil Lib | Async I/o | Multi I/o | Spwan | Fnmatch

Libc | Shell | GOB

Loader & Symbol

Module.ko

Library.so

P-MIB | SunRPC

FTP | SNTP | Telnet

TFTP | Ping4/6 | Syslog

I/O System

Select | poll | Epoll | Eventfd

Timerfd | Signalfd | Power | Hotplug

System BSD socket

AF_INET/AF_INET6 | AF_UNIX | AF PACKET

DNS | DHCP

UDP | TCP

IGMP | IPv4/V6 | ICMP

ARP | Ad Hoc

Dual-pipe

Cred

Fd-trans

Mmap

Queue

Standard device module

File System

Root Fs

proc FS

yaffs + mtd

TPS | NFS | Romfs | Ramfs | Fatfs | partition

ATA | SD | BLOCK | CAN

DMA | RTC | GRAPH | SPI

IIC | TTY | PTY | USB

MII | GPIO | SHM | PIPE

PCI | AHCI | 15538 | SRIO

Nand Cache | Disk Cache | Keyboard | Mouse | Sound

PPPOE | PPP | NAT | VPN

Net Packet Filter

Wireless Net Framework | LOWPAN

SylixOS LongWing(TM) Kernel

SMP rt schedule | MMU | Cache | Monitor Trace | C++ Run Time Lib

Interrupt | RMS | Timer | Message | Event

Memory | Coroutine | Thread | Work Queue | ....

Architecture

ARM | PowerPC | MIPS32/64 | x86/x64 | SPARC | DSP | RISC-V

At present, satellites are principally used for:

Earth Observation

Navigation

Communication

This board is designed to work with all three principal use cases. The ability to connect sensors makes the Callisto board not only ideal for processing a range of blockchain-based transactions but also enables it to run a range of Earth Observation dApps which will be discussed in greater detail later in this paper. For SpaceChain, these three primary uses are likely to remain our key area of focus our role is to simply change how they are conducted and distribute their benefits to a wider audience.

These boards have already been used by Velas and we have sold several more to other firms who are currently working on deploying theirs to a variety of use cases.

4.1.3 Mobile Blockchain Satellite Terminal

Global Access

SpaceChain's mission is to deliver vertically integrated, decentralized satellite infrastructure from the ground up. The development of a portable satellite device to enable digital asset transactions via direct satellite communication is a key part of this. This device is designed to enable quick, secure Blockchain transactions from anywhere on earth.

SpaceChain developed a mobile device that lets you perform digital asset transactions for Bitcoin, Ethereum, and stablecoin at any time and anywhere, allowing you to connect to a network anywhere you are. No ground infrastructure is needed as it communicates directly with satellites.

Securing Transactions

Security of access to data and digital wallets is a pressing issue within both Web 2.0 and Web 3.0 infrastructure. Unauthorized access and security are concerns both to institutional finance organizations and cryptocurrency transactions. Cybercrime is predicted to cost the global economy around $10.5 trillion by 2025, up from $3 trillion in 2015 (Morgan 2020). The explosive growth of cloud-based data storage, some of which are protected by outdated technology, is only set to add to vulnerabilities for average consumers.

While no solution is perfect, a portable satellite terminal offers broader access to controlling your digital assets, simultaneously minimizing the vectors for attack. Currently, most device-to-satellite communication is mediated by ground stations. Many ground stations are extremely secure due to space-grade protocols, and devices used to communicate with these ground stations are far more vulnerable. They connect to local, insecure wifi networks, they can download viruses and can be stolen, lost, or simply breached.

This device minimizes this. SpaceChain has worked with a general security principle: The greater the number of central mediators within a system, the higher the risk of a breach. Packaging a ground station and access device into one reduces this number, and a corollary reduces vulnerability substantially. Private keys are stored in the device and cannot be exported, the network used is thoroughly isolated from much of the net and the hardware is of a high standard.

A Stable Future for Transactions

Use cases for this go beyond just security and ask us to reconsider how cross-border transactions might work. Where cryptocurrency has long been associated with market volatility, stablecoins are challenging this. Stablecoins are a form of cryptocurrency pegged to fiat money or other exchange-traded commodities including metals, which currently make up around 17% of the total crypto market, up from 4% in 2020 (Partz 2022). Avoiding much of the volatility of crypto markets can accelerate transactions between currencies; using stablecoins as a medium through which to exchange.

This growth comes as governments such as the Central African Republic (CAR) and El Salvador are rolling out cryptocurrencies as acceptable payment across the country. Whilst for these particular examples, the rollout has been poorly planned and thus a failure (Encila 2022), this doesn't necessarily have to be the case. There is a profound need for such technology. Cross-border transactions for many countries with volatile currencies are done through SWIFT, often in US dollars and often taking several days per transaction. This breeds an inherent inefficiency in doing business that disproportionately affects poorer nations (Nseke 2018). This device has the potential to flatten those barriers and offer a substantial economic contribution.

Building on our recent achievements SpaceChain is actively engaged with developing a handheld interface with satcom for an industry opportunity.

4.1.4 Spacecraft for Secure Payments, and Key and Content Storage

A Storage Conundrum

For those who need to store large quantities of data as securely as possible, most consumer devices leave something to be desired. Cloud computing is perpetually in an arms race against hackers. Even this year, companies such as Ronin, Binance, and Crypto.com have been targeted by hacks that have cumulatively cost users over 1 billion dollars (Guardian Staff and agencies 2022).

The solution for some has been offline media, which mitigates risks against hacking as the media simply isn't connected to any digital system to make it accessible. With the enterprise storage market estimated to have a value of around $82 billion in 2021 with an expected compounded annual growth rate of 14% over the next eight years (Grandview Research 2022), innovation is essential.

However, even offline media on earth is inherently not theft-proof. Force and violence can gain entry where hackers can't. Space provides physical separation from vulnerable terrestrial infrastructure, a barrier against theft, enabling offline media to become entirely inaccessible where needed. It is this which SpaceChain has sought to develop to offer security beyond what has been offered before to those with data that is simply too valuable to be stolen.

Developing Security and Retrieval

In reality, needs are often more complex than simply just cold storage. Some may wish to have periodic access to their data without beginning an arduous process of retrieval and thus SpaceChain has developed ways in which data access can be made as secure as possible, with different tiers to meet different requirements. Connections can be activated where needed.

Others may want continual access to their data via an uplink, which due to the secure connection is far safer than most other cloud-storage networks. Furthermore, these can be managed to occur at specific times of day to further enhance security and increase barriers to attack. Keeping data secure in the modern era requires layered secure data storage, including some traditional and other less traditional methods.

On the backend, standard data security protocols are used, with encryption and access control. SpaceChain payloads have passed NASA cybersecurity assessments and various ground stations are managed by partners such as Spire Global, which have advanced security protocols of their own. Firewalls filter out any erroneous data access requests for outbound connections. Antimalware and anti-ransomware software protect the servers from malicious files.

Harnessing Separation for Security

Improving the efficacy of encryption is where SpaceChain's use of innovative technology begins to make a difference. All encryption requires a user's private key to decrypt it. Keeping this key safe, however, can be difficult, as if someone accesses a device where this key is stored, your data is there for the taking. SpaceChain has worked on offering solutions to keep the key safer than before, adapting blockchain innovations such as multisignature wallets. With these wallets, a key is split between several entities, all of which need to sign in to ensure access, meaning that it is safer and thus there would need to be a far wider set of breaches for access to be gained.

This notion of separation is at much of the core of SpaceChain's strategy. The Callisto board keeps applications and its operating system on separate memory. Whilst they currently communicate via CAN connections (a type of multi-master serial bus for connecting electronic control units), in the future SpaceChain will switch to more secure ethernet systems. Similarly, servers for wallets and SpaceChain itself are also separated. As a result, it is possible to further mitigate damages in the event of a breach.

Explaining SpaceChain's Payment Architecture

To explain how such a multisignature system delivers secure, reliable data transfer in more detail, it is important to understand the exact structure of SpaceChain's network infrastructure and how it communicates with itself.

The principal aim of this system is to ensure that a normal device can connect with a space node in the most secure manner possible so that data is not tampered with during transmission. The process of verification and decryption represents perhaps the most vulnerable part of any transaction, but SpaceChain has sought to make this more secure.

The verification process is completed utilizing a multi-stage cryptographic protocol. The general process of public key verification is as follows:

1. Before launch, the SPC server and space node will pre-set a secret known only to both parties alongside a private key, which is split between both parties

2. After receiving the other party's public key, both parties encrypt the secret with the received public key and obtain the ciphertext a piece of plain text that has been encrypted using an encryption algorithm. This makes the public key unreadable, without decryption

3. The two parties split the ciphertext into upper and lower parts, and send the upper part of the ciphertext to the other party in the first verification communication

4. After receiving the above text, both parties send the ciphertext text to the other party in the second verification communication to confirm its receipt

5. The two parties splice the context, decrypt it with their private key (SPC servers and space node cannot see this), and verify the secret

6. If the verification is passed, the public key will be used in the subsequent communication. If the verification fails, it indicates that the communication channel has been compromised and the communication public key needs to be replaced. It is only at this point that further communication can continue

After the public key verification is completed, the SPC server can start data communication with the space node. In each communication, the hash value of the data will be calculated, and the hash value will be signed with its private key, and then the data, data hash, and a signature will be sent to the space node together.

After the space node receives the data, it will perform a hash calculation with this data to obtain the hash value and compare it with the received hash value, and then use the public key of the SPC server to verify the signature.

This serves three purposes:

1. If the data is tampered with, the hash value of the data will change, and it will fail to pass the verification when verifying the signature of the hash

2. The private key signature ensures the source of the data is correct

3. This takes place separate from the Wallet Server meaning direct access cannot be directly brute-forced

For the end user, up to this point, this process of verification is largely done between devices, without much in the way of complex or confusing user input.

It is only once the connection between the SPC server and the space node is securely established, that the wallet server begins to connect with the space node, this time using an OTP (One-Time Password) dynamic key which is generated using an OTP generator. This technology consists of three parts: key root, dynamic variable, and OTP generator.

When users have the same key root and input the same dynamic variable (perhaps a one-time randomly generated chain of numbers and/or letters sent to a user), they will receive the same dynamic password. A new secret key is generated by the space node itself to ensure security.

1. To establish a connection between the wallet server and the space node, the wallet sends its public key and in return, it sends an encrypted secret key or ciphertext, along with the public key.
2. The space node then performs a second layer of encryption on this same ciphertext. This is downloaded by the ground station and sent to the SPC server by the ground station.
3. The SPC server receives it and decrypts one layer of encryption with its private key, but it cannot obtain the original text of the secret key. This helps to check if the connection is still safe.
4. After verification, the ciphertext is sent to the wallet server, at which point its private key decrypts the second layer to get the secret key. In this way, neither the SPC server nor the satellite operator can obtain the secret key, minimizing the nodes that handle the unencrypted information.

When data or a transaction is sent by the wallet to the space node, there is a similar process on the reverse. This prevents the SPC server and satellite operators from monitoring and tampering with data as it is all transmitted in full ciphertext.

Be in Control of Your Security

In the end, where data does not need to be transferred regularly, nothing is safer than a satellite that can have its connection with the ground station switched off where needed. Whilst at the moment this would need to be conducted via an interface, this will soon progress to implementation via smart contract. The data will thus be inaccessible by all until its connection with the ground station is switched back on again.

For high-value data, this can ensure that it is kept as secure as physically possible. It is this which makes SpaceChain's systems unique in its broad consideration of a wide range of both software and hardware features that enable enhanced data security.

4.2 Blockchain For Space

4.2.1 Decentralized Satellite Applications

Democratizing Earth Observation (EO) data is emblematic of SpaceChain's shift away from the top-down structures that characterize Web 2.0's rigid centralization. At the present, satellite data is expensive, at around $14-25 per square kilometer (Vailshery 2022). When covering regions of any-reasonable size (such as floodplains), often spanning several tens, maybe hundreds of thousands of kilometers, the price becomes prohibitive for small-scale or citizen analysts.

It is this which will go beyond the current open-source data networks that currently exist and enable organizations to deliver their own specific observation payloads built for specialized tasks such as measuring flooding. Where previously data has largely been collected and analyzed centrally, SpaceChain's open hardware board allows a wide range of sensors to be attached to EO data to be collected, shared, and analyzed. It is this that not only opens up access to data but also the type of data that is being collected.

A Radical Overhaul of EO Data

Data and its usage will be transparent and trackable in its own right, therefore, ensuring that it is clear as to who is using what, which offers a greater understanding of who is accessing this data. SPC tokens will be used as access tokens and will enable an easy method to collaboratively share the cost for data satellites. The integration will be done via an API provided by Open-Hub such as Sentinel, as well as commercial partners of SpaceChain. This will allow the amalgamation of both Open-Source and Cooperative data.

When paired together, this also allows the amalgamation of several data sources to create a system designed to tackle specific needs and create real-time cross-analysis, the so-called 'Cortices'. An example application for these 'Cortices' would be combining live satellite data on urbanization, temperature, and rainfall paired with data on foliage cover, and river size in response to these pressures to better understand how moisture run-off profiles are changing over certain geographical regions. Local governments might also be able to see when crop failures are likely before they happen and thus put in place necessary measures to mitigate against this.

There are potential future uses when paired with IoT processors which could enable real-time visualization of these combined data sources. Tools such as TensorFlow when paired with SpaceChain's open-source platform will give developers the much-needed latitude to test and refine these programs. It is this which may lead to rapid advancements in the way we use EO data to help better calibrate our responses to climate change, natural disasters, and even land-use management.

Using EO Data and Other Applications for dApps

If we look at the proposed working of one of these DSAs, the blockchain envelope in effect becomes a tool for registration, acting as a leger of access and use as well as data ownership. Developers looking to build their own apps can develop code and build on these protocols to develop their own. Beyond this, it also takes on another use as a coordinator, deploying and managing the very data infrastructure and servers that can power it.

Additionally, we see that dApps might be useful for other purposes when paired with other use cases such as communication and geolocation. It is through a similar mechanism that dApps for blockchain transactions wi operate.

4.2.2 Decentralized Satellite Infrastructure

We propose the Decentralised Satellite Infrastructure (DSI) that constructs a distributed, transparent and collaborative environment for space. An Ethereum-alike Blockchain network is chosen to support DSI network, as it is:

- Transparent - transactions are trackable and viewable to the whole internet.
- Turing-complete - smart contract can be deployed to manage the DSI consortium.
- Integration with the financial system - network transactions are naturally affiliated with financial transactions of cryptocurrency and stablecoins.

Blockchain introduces open protocols to constellation governance, allowing participating satellites to join the network efficiently and securely. A hardware requirement is proposed that any satellites that meet the requirement can participate in the DSI.

DSI further connects to the ground internet via ground stations and blockchain nodes, which brings the two networks together while maintaining the advantage of each. Finally, blockchain capabilities extend to sandboxing, which sharply increases the security of the constellation.

The DSI development will be a long-term procedure with the revolution of spacecraft, satellite communication, and networking technologies. We here divide them into its front-end - which is the decentralized satellite application (DSA), and its embedded backend and hardware.

The research and development topic can be classified into the following categories.

Data and Service Integration

Tackling the high price of satellite imagery is the first major issue that SpaceChain seeks to address. The aim is that datasets should be simple to access, even via web browser extensions such as MetaMask. Here APIs developed by our partners Sentinel Open-Hub should enable advanced developer-led features for the analysis of open-source and SpaceChain satellite partner data.

Complex deep-learning image analysis tools ranging from ship detection to vegetation coverage will be developed and opened to the public for further improvement/development. Here we have the underpinning of what will form part of the Decentralised Satellite Applications (DSA).

Currently, SpaceChain has developed one open EO data source and has integrated this with one data analysis tool on ship detection as part of a test bed.

Security

Ensuring reliability and safety are extremely important to the success of such a project. Where SpaceChain wishes to change the way we own our data, this loses all meaning if it is stolen. There will be three main elements within SpaceChain's security protocol.

1. Standard security protocols with a detailed assessment offered before deployment as outlined by ISO27001 One of the best-known International Information Security Standards.

2. Physical separation of the Blockchain component with the satellite on-board operations.

3. Logical separation of the on-chain and off-chain environment by a smart contract. Smart contracts will manage and track the flow of information, but any key personal information will be encrypted by users' public keys and can only be accessed by users defined in contracts. This keeps data private unless authorized.

Endpoint Construction, Interfacing via Blockchain Smart Contract

Where part I enables multiple accessible satellite data sources to be integrated with analysis tools, part II focuses on increasing the ability of developers to contribute. Files can be shared via decentralized protocols, in this case, InterPlanetary File System (IPFS), using peer-to-peer networks. Smart contracts will be used to manage information to avoid malicious modification.

Open-source

DSI is a platform that allows for the easy integration of various services and applications, providing a seamless and streamlined experience for users, and allowing them to access and utilize multiple services through a single interface. DSI offers APIs and other integration tools that make it easy for third-party developers to connect their services to the platform. This can include everything from integrating with existing payment systems to adding new data sources to integrating with other software applications.

DSI is designed to be flexible and scalable, allowing it to accommodate the integration of new services as they become available. This can be particularly important for businesses and organizations that are constantly seeking to expand their offerings and stay ahead of the curve. It brings the crowdsourcing power of individual developers and parties and helps organizations streamline their operations and improve their overall efficiency by providing a single, centralized location for accessing and utilizing a wide range of services.

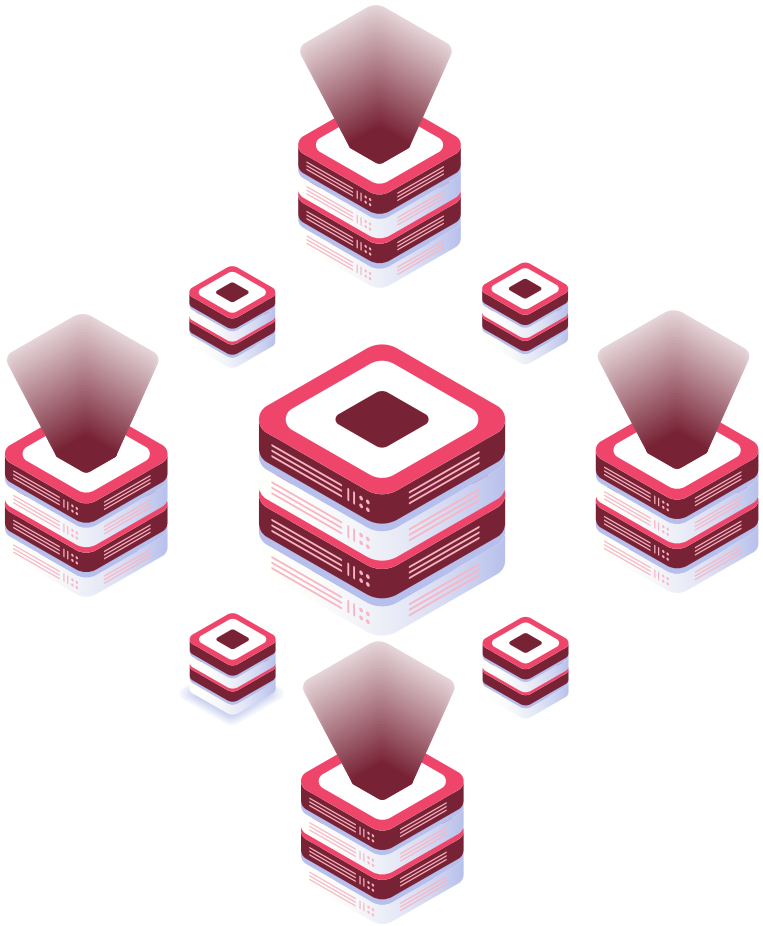
Expanding Decentralization

Once SpaceChain has delivered our decentralized data and service platform along with a decentralized access and service scheme, we hope to explore other avenues to enhance this experience. This will likely include decentralized servers and the development of zero-knowledge-based applications.

Decentralized Inter-Satellite Link

The DSI decentralized inter-satellite link is a communication system that enables direct communication between satellites across multiple companies and jurisdictions. The satellites communicate directly with each other using wireless communication technologies, such as laser or radio frequency links, supported by Blockchain infrastructure enabling transparency and end-to-end encryption.

The decentralized nature of the inter-satellite link allows for flexible and efficient routing of data and enables satellites to operate independently yet collaboratively in the future space environment.



TOKENOMICS

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SpaceChain is building a Decentralized Satellite Infrastructure (DSI) for blockchain with satellite-based applications. As the economic backbone of SpaceChain's platform, the SPC token will lead the industry enabling developers to create applications across various satellite applications.

The SPC token works like a digital currency in the SpaceChain ecosystem. Utilities including access to space data will be added to the DSI as a benefit to all SPC token holders and much more.

The community can also look forward to SpaceChain's DSA portal, allowing SPC token holders to access satellite data from our partners and some other space-related services. For a start, the SPC token can be used to unlock more financial products with its DeFi features. Holders will soon have the opportunity to access orbital satellites and transact assets, store data and send messages via space. With the release of this platform token holders will originally gain access to the Beta which will show the potential for democratizing access to space via a terrestrial and space-based network. Upon the anticipated increase in satellites joining the multi-tenant DSI, the various satellites will be added to the digital platform where token holders will be able to access and eventually execute advanced commands onboard the satellite while also being able to directly order and task-specific data from satellites in exchange for SPC tokens establishing the first in-space financial economy.

With access being at the core of SpaceChain's motto, we also hope to involve commercial space companies to expand the reach of this newly formed financial

economy as humanity sets out to land on the Moon and various other planets within our solar system. SPC token will act as a gas fee for the transfer of both physical and digital assets as we become a multi-planet species.

SpaceChain has been exploring various market trends including the rise of Non-Fungible Tokens (NFTs). NFTs are on-chain assets that have the potential to act as real-world assets and provide the foundations for digital ownership. Typically NFTs are minted on Layer 1 Blockchain networks such as Ethereum in the ERC-721 or ERC-1155 standard. Even as we explore the potential to deploy NFTs for the tokenization of space assets such as Earth Observation imagery. We are also looking at the prospect of utilizing NFTs as a form of access, for our community, to bespoke space services.

This innovation has led to the digitization of asset classes or more popularly known as the tokenization of assets. As more efficient launchers come to market, with a lower cost per kg, it will become more affordable to launch a satellite. SpaceChain aims to initiate the concept of fractionated ownership of satellites. NFTs can be utilized to tokenize a satellite asset into fractions, introducing fractionalized ownership. As this becomes ever more plausible SPC tokens can be used to purchase the tokenized satellite asset and the NFT holder will be able to generate revenue from the satellite as it delivers data to various customers. These NFT holders will quite literally hold a piece of space while it is in orbit.

SUMMARY:
Establishing a Future Synergy of Space and Blockchain

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It is through the construction of flexible and vertically integrated networks and components, that SpaceChain seeks to progressively build toward a Decentralized Satellite Infrastructure (DSI). Where transactions are possible, so is a marketplace: Whether that is exchanging cryptocurrencies for valuable services and data, or simply enabling secure transactions across the globe to all.

As specified in our roadmap, over the next decade, we hope to add products beyond our current offerings of vertical integration for satellite missions, open-source hardware, software, and payment security. Where these first steps represent the basis of what is to come in the future, as these systems grow, we will begin to see the true benefits of Decentralized Satellite Infrastructure - worldwide access to connectivity and secure payments, cheaper satellite imagery, and the development of collaborative open-source tools to compile and analyze it, as well as a more efficient, open use of space.

These systems will be managed by a blockchain registry. Spacecraft will be able to join or depart this registry via blockchain as long as they meet the minimum hardware and regulatory requirements. The primary focus in recruiting for this mesh system will be on Low Earth Orbit satellites. As greater numbers join and the user base expands, so too does the potential for benefits to be felt by all parties.

As previously stated, we wish to build a set of protocols and systems that are so good, it would be unwise not to join the mesh network. It is only through building on our previous successes in delivering ambitious technical projects that we can break the rigid hierarchy and inefficiency of such a profoundly hierarchical and capital-intensive communications and data industry.

As these resources are opened up to a wider audience, we hope to watch innovation, and the capacity to share, build, collaborate, and communicate blossom.

If you wish to collaborate with us on this journey, get in touch: info@spacechain.com

Executive Team and Advisors

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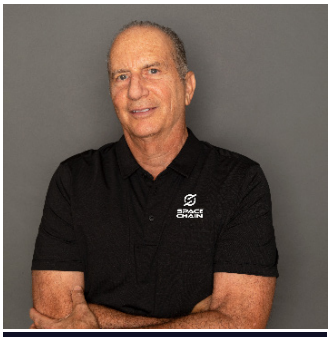
Executive Team



Clifford Beek
Chief Executive Officer

Cliff is an accomplished executive with expertise in managing equity-backed companies, particularly within aerospace, cyber-security, defense intelligence, and cloud infrastructure. Having 25 plus years of progressive experience providing leadership and strategic direction to high-growth technology companies, their board of directors, and senior management. Today, Cliff serves as CEO of SpaceChain, developing the world's first decentralized blockchain platform distributed across Low Earth Orbit [LEO] satellite infrastructure. Cliff earned an MBA from Wharton School, University of Pennsylvania, and a BA from George Washington University.

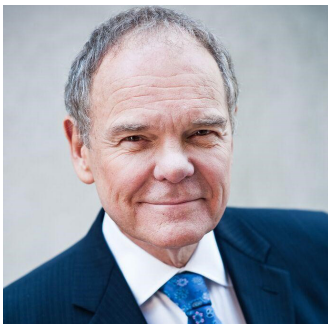
Zee Zheng
Co-founder and
Executive Chairman

Championing the fusion of blockchain and space, Zee Zheng believes that these technologies will enable a new era of seamless global collaboration. Having launched 7 blockchain-enabled satellite payloads into orbit within SpaceChain's first 5 years of operation, Zee has been recognized as a pioneer in this industry and has been sought as a speaker at events like Space Tech Summit, SpaceTide, and Space Forum. Zee is a notable honoree of the Forbes 30 under 30 Asia List of 2022. He honed his entrepreneurship at Draper University, his space expertise at the International Space University, and is a graduate of Columbia University. He is also a Lee Kuan Yew Senior Fellow at the Lee Kuan Yew School of Public Policy, National University of Singapore.

Jeffrey Garzik
Co-founder, Chief
Technology Officer

Jeff Garzik is the key Bitcoin core developer who worked under Satoshi Nakamoto for 2 years. His work can be found in every bitcoin and miner. Previously, he worked in the Linux industry for over 15 years under Linus Torvalds and he was the key Linux kernel engineer. Jeff's code can be found in every Android phone and data center. The co-founder of Bloq, Jeff is also the leader of the Ethereum protocol networking subsystem.

Advisors



Don Tapscott

- Ranked the 2nd most influential management thinker in the world by Thinkers50
- Co-founder of the Blockchain Research Institute
- Co-author of the book Blockchain Revolution: How the Technology Underlying Bitcoin is Changing Business, Money, and the World

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Eric Anderson

- Chairman & CEO of Planetary Holdings
- Chairman & Co-founder
- of Space Adventures
- Chairman of the board
- of Booster Fuels
- Director of X Prize Foundation
- Well-known aerospace engineer & entrepreneur
- Pioneered the development of the space tourism industry

Jeffrey Manber

- President of International and Space Stations at Voyager Space
- Chairman of the Board for Nanoracks
- Board member of StarLab Oasis

Matthew Roszak

- Chairman of the Chamber of Digital Commerce
- Managing partner at Tally Capital
- Chairman & Co-founder of Bloq
- Co-founder of Vesper
- Board member of BitGive
- Producer of the documentary The Rise & Rise of Bitcoin

Tim Draper

- Renowned VC capitalist from Silicon Valley
- Co-founder of DFJ Venture Capital
- Headmaster at Draper University
- Founding partner of Draper Associates

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