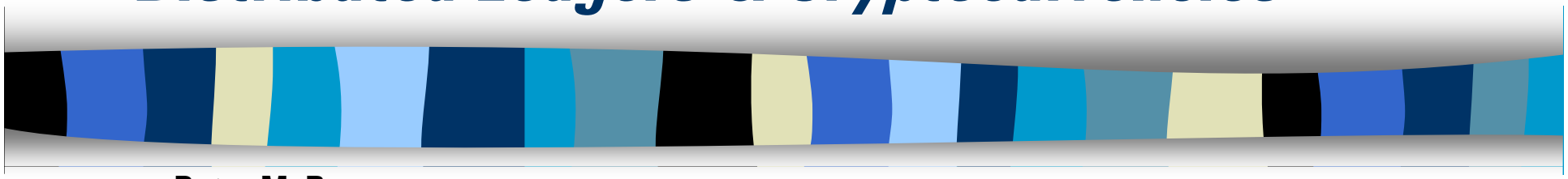
# *7CCSMDLC:*
# *Distributed Ledgers & Cryptocurrencies*



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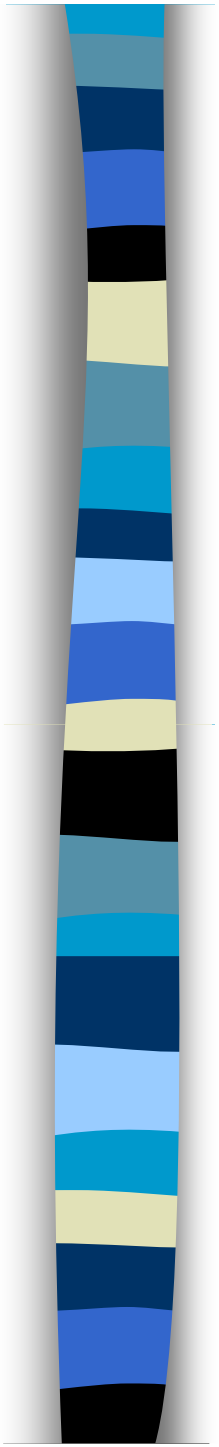
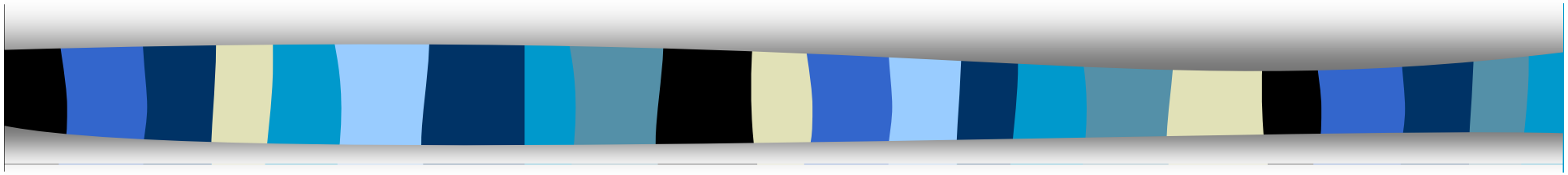
**Bush House Central Block North – Office 7.15**

**15 January 2020**



# Outline

- Course Information & Arrangements
- Bitcoin and Blockchain
- Distributed Ledger Technology
- Smart Contracts
- Current Landscape



# 7CCSMDLC: Course Information

# The Team

- Peter McBurney

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- Jacob Swambo

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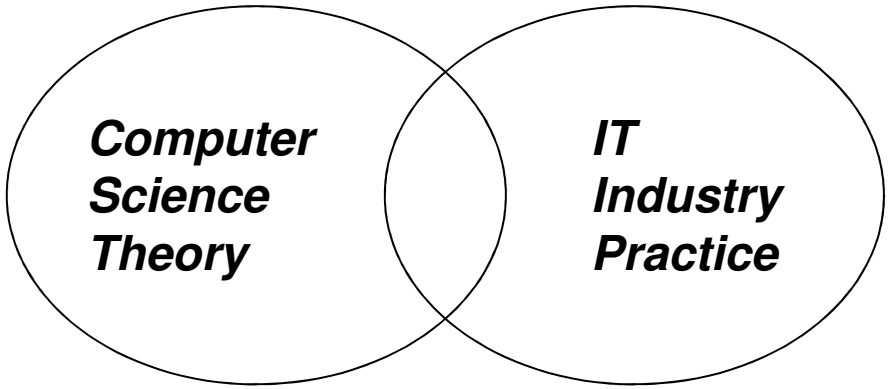
Department of Informatics
Bush House – Central Block
Level 7 North.

# 7CCSMDLC – Syllabus

Electronic crypto-currencies such as bitcoin, and more generally the concept of a blockchain or distributed ledger, have the potential to revolutionise financial transactions and the role of financial institutions and regulators. This module will provide a foundation in the distributed ledgers and crypto-currencies, and will include the following topics: consensus in distributed systems, the CAP theorem, economic consensus, block-chains, Bitcoin, P2P contracts.



# Learning aims

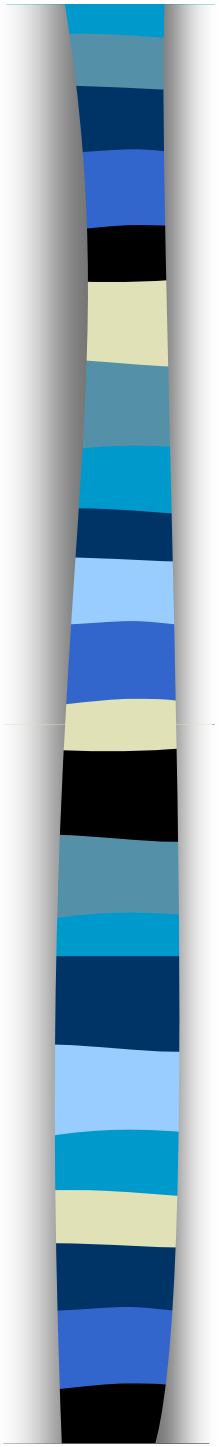
This course aims to provide students with:

- An understanding of distributed ledger and related technologies, their provenance in electronic currencies, and their emerging applications, particularly in financial domains.
- An understanding of the underlying component technologies and their application to distributed ledger technologies - distributed systems, cryptography, consensus protocols, and crypto-currencies.
- An understanding of the current landscape of enabling distributed ledger platforms and technologies, and their respective strengths and weaknesses.

# Intended learning outcomes

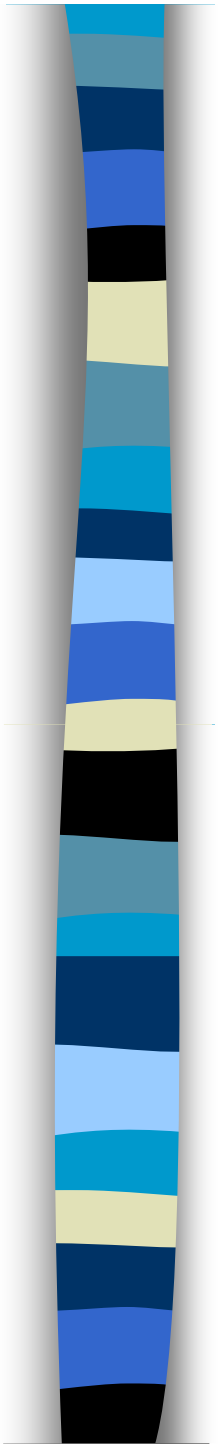
After successfully completing this module, students will be able to:

- Understand the role of consensus protocols in distributed systems
- Understand the inherent trade-offs between consistency, availability and partition-tolerance (CAP), and be able to state the CAP Theorem
- Understand economic consensus protocols
- Understand the concepts of a distributed ledger (or blockchain), permissioned and non-permissioned ledgers, mining, proof-of-work and proof-of-stake, and smart contracts
- Understand the applications of cryptography and encryption to distributed ledger technologies
- Understand how distributed ledgers can be used to implement cryptocurrencies
- Understand potential and existing applications of distributed ledger technologies, especially in finance
- Understand the main advantages and weaknesses of current distributed ledger platforms and technologies
- Implement a simple distributed ledger.



# Themes

- This area is very new
  - Mostly since 2008
- Theory and technology are both still emerging & both still immature
  - Different people have different views
  - No one knows all of it
- So – please feel free to disagree
- What do we mean by understanding something?
  - In CS, there is almost always a lower level of understanding
  - Some people need to build a model before they understand
  - Some people need to write some software or create a prototype
  - Some people need to be able to write about it in their own words.



# Approach to learning

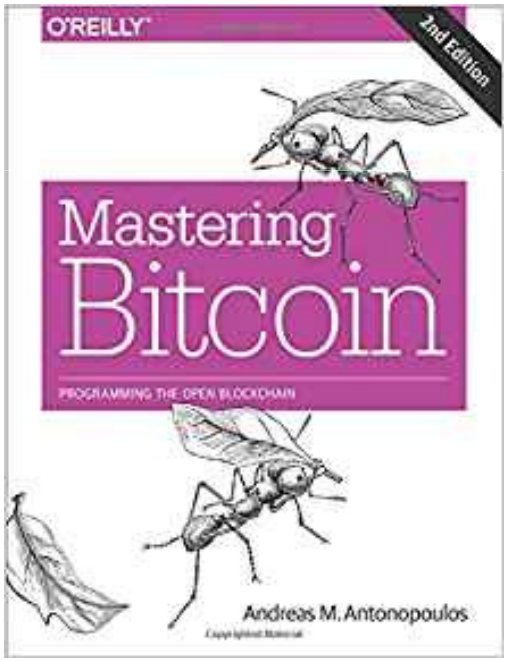
- Lectures will present a high-level narrative
  - To help you frame your learning
  - To understand what parts are important
- I am expecting you to fill in the details
  - Almost all the knowledge in this domain is on the Web
  - It is also changing rapidly
  - You need to learn how to find it, and how to learn from it
  - I am not going to spoon feed you with details!
- Class exercises and labs will provide related materials and experiences
  - In particular, we will discuss some live case studies, so that you appreciate the tradeoffs being made in industry in this space.

# References

- Satoshi Nakamoto [2008]: *Bitcoin: A Peer-to-Peer Electronic Cash System*

- Andreas Antonopoulos [2017]: *Mastering Bitcoin.* 2nd Edition. O'Reilly.

- Andreas Antonopoulos & Gavin Wood [2018]: *Mastering Ethereum*. 1st Edition. O'Rielly.




[Both available free on GitHub]

*Plus:*

Lots of published reports & presentations

Lots of material on the WWW.

# Lecture Outline

*January*

- Session 1 (16/1): Overview + History + Bitcoin
- Session 2 (23/1): Cryptography + Mining
- Session 3 (30/1): Protocols & Consensus Mechanisms

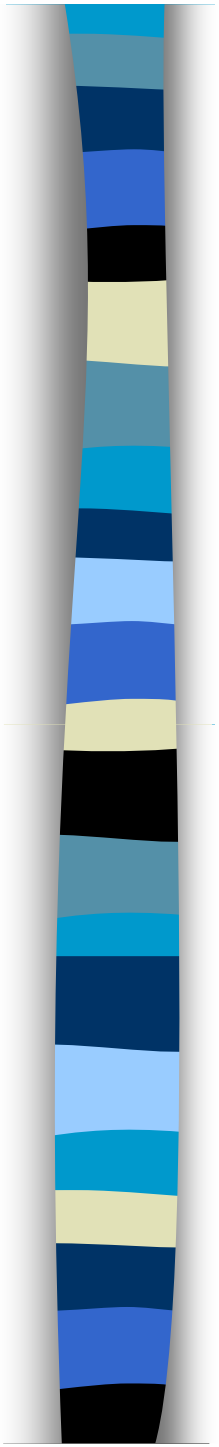
*February*

- Session 4 (6/2): Money and e-Money
- Session 5 (13/2): ICOs and TGEs
- Session 6 (20/2): Smart Contracts

*No lectures the week of 24-28 February*

*March*

- Session 7 (5/3): DLT Infrastructure & Platforms
- Session 8 (12/3): Applications & Ecosystems
- Session 9 (19/3): Project presentations



# Labs

Time: Thursdays 12.00 – 14.00
OR 16.00 – 18.00
Location: Bush House Central Block /South Wing Lab 6.02

- A mix of activities
  - Designed to give you additional insight or experience
  - Led by Mr Swambo
- For example:
  - Acquiring and spending a cryptocurrency (Dogecoin)
  - Learning about object-oriented programming
  - Computing a proof-of-work
  - Creating a hash object.

# Assessment

- Final Exam
  - 80% of total marks for course
  - 2 hours / Closed book exam
  - Structure of exam:  A mix of multiple-choice & long-answer questions.
  - Long-answer questions
    - Answers may be essays or bullet points
    - Annotated diagrams also acceptable
  - Questions will test understanding & judgment not factual knowledge
    (This is an MSc course)
  - I will provide some sample questions later in the semester.

- Coursework
  - 20% of total marks for course.

# Coursework: Team Projects

- 20% of total course mark
- Team projects (teams of 3-5 students)
  - Either
    - Undertake research, write a report & give a presentation (10 minutes)
  - OR
    - Build a simple prototype, write a report & give a demo (10 minutes)
- Presentations/demos on Thursday 19 March 2020
- Reports due (via email): Monday 30 March 2020
- Topic to be agreed with us by Monday 3 February 2020
  - We are open to your suggestions.
  - Please email us both with
    - Your team name & team members
    - Your proposal.

# Possible project topics

- Implement a simple smart contract application on top of Ethereum Testnet (or on another platform).
- A detailed analysis (technical, commercial & regulatory) of a particular ICO (Initial Coin Offer)
  - Eg, Tezos, Polkadot
- Comparison of Crypto currencies, crypto-tokens
- Undertake a financial valuation of a particular cryptocurrency
- Explain the regulatory process for approval of a new ICO in a particular market (eg, UK, USA, Singapore)
- Compare the top 10 cryptocurrencies or the top 10 ICOs in terms of technology features, intended applications, intended users, actual users, etc
- Undertake a detailed assessment of potential use-cases for DLT in a particular sector (eg, finance, insurance, supply chains).

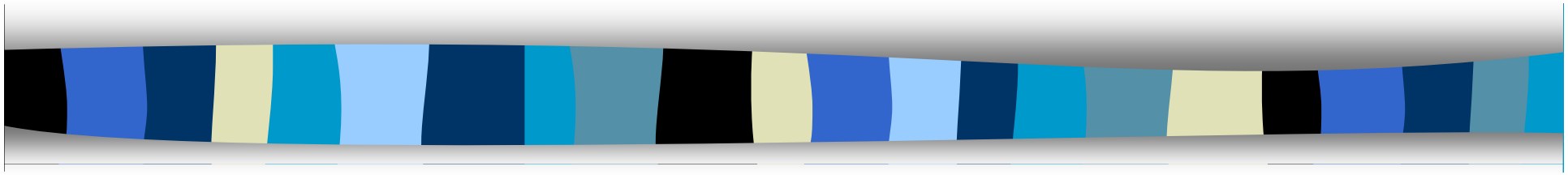
# Blockchains are the new black

***"We may be witnessing one of those potential explosions of creative potential that catalyse exceptional levels of innovation."***

Sir Mark Walport
Chief UK Government Scientific Advisor
January 2016.

***"I wish I was 30 years younger because this is really interesting stuff!"***

Jeremy Wilson, Vice-President Corporate Banking,
Barclays Bank. July 2015.



# Bitcoin and Blockchain

# The Problem

We desire an electronic money system that ensures

- The e-money is authentic (not counterfeit)
- The same e-money cannot be spent more than once (*double-spend problem*).

How to do this?

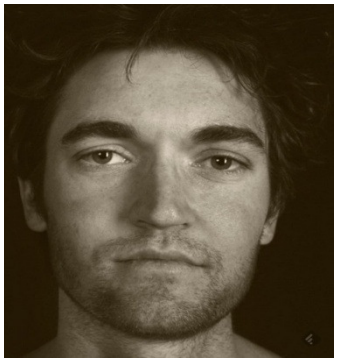
- Need a trusted person or organization to issue the money and record all transfers.


How to do this without such a person?

# Precursers

- Bitcoin was first truly decentralized system for e-money
- Previous technologies
  - Asymmetric key cryptography
  - eg, Hashcash (1992) – a Proof-of-Work (PoW) system to hinder spam and DDoS attacks
  - b-money (1998) – application of Hashcash to e-money, with transactions broadcast to all participants
  - Protocols for distributed consensus
- Underlying philosophy
  - **Cypherpunk Movement** (from 1992 onwards): Advocates of cryptography and privacy technologies for social & political change
  - See e-money as a way to avoid Government control
  - Still a large section of the cryptocurrency community.

# Satoshi Nakomoto

Andrew O'Hagan [2016]: The Satoshi Affair.
*London Review of Books*, 38 (13) 30 June 2016, pages 7-28.

# The Bitcoin Blockchain

- Cryptographic currency: Bitcoin
  - White paper published in 2008

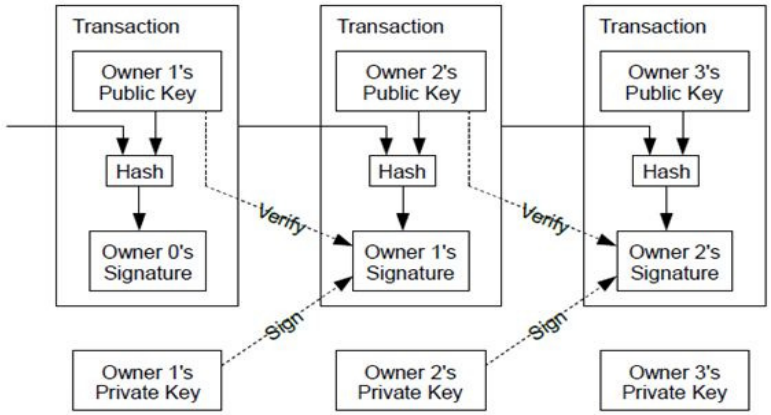
    Satoshi Nakamoto [2008]: *Bitcoin: A Peer-to-Peer Electronic Cash System.*
  - First code released 2009

- Design properties:
  - No central authority
  - Decentralized
  - No double-spending of currency
  - Open and public
  - Anonymous (actually Pseudonymous)

- Enabled by Blockchain technology.

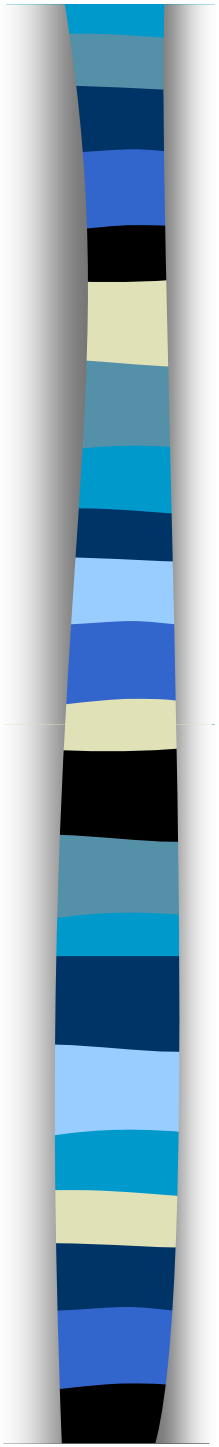
# Bitcoin Blockchain

- Transactions
  - Transactions represent & are exchanges of Bitcoin
  - Transactions signed by digital signatures
  - Transactions aggregated into blocks & uploaded
  - Blocks chained together
- Aggregation and chaining done by Miners
  - Doing this takes processing power (some work)
  - Miners paid in bitcoin
- Blockheaders have dynamic-membership multi-party signatures based on computation power (not on knowledge or permission).
- Chaining done by hashing.


Transaction
Owner 1's Public Key
Hash
Owner 0's Signature
Verify
Transaction
Owner 2's Public Key
Hash
Owner 1's Signature
Verify
Transaction
Owner 3's Public Key
Hash
Owner 2's Signature
Sign
Owner 1's Private Key
Sign
Owner 2's Private Key
Owner 3's Private Key

# A metaphor — coffee transactions

*Credit: World Barista Championship*



# Blockchain for Bitcoin

- Focus: Crypto-currency transactions
- No central authority
  - No central bank
  - No need to trust anyone
- Witnessing done by entire community on the blockchain
- Chaining makes it very difficult to alter past records
  - Need to alter all the records since then
- Witnessing makes it hard to alter or create false past records
  - Have to get 50% + 1 participants to agree your new chain is the correct one
  - Forking
- Coins tagged
  - So cannot double spend.

# Bitcoin process

- A bitcoin (or part) is represented by a chain of current and past owners
  - Represented by their wallets (effectively their public keys).

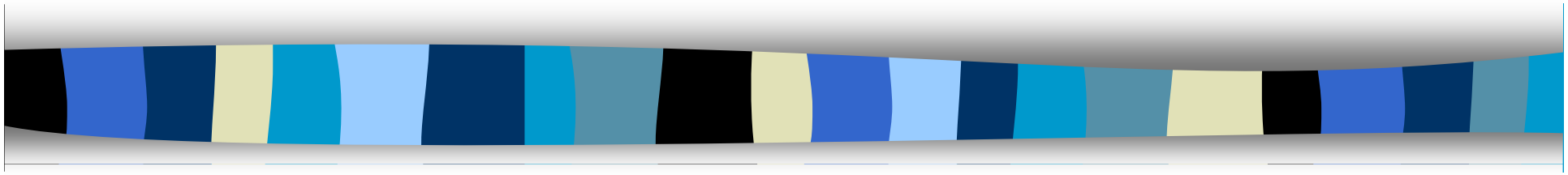
- The process
  1. Sender A creates new transaction
     - Sender A signs with his private key
     - Sender A signs with the public key of Receiver B
  2. New transactions sent to all nodes
  3. Each miner (mining node) bundles recent transactions into a block
  4. Each miner tries to solve a difficult mathematical problem (Proof-of-Work)
  5. When solved, the miner informs all nodes
  6. Nodes check for validity and accept (or not-accept) the block
  7. If accepted, miners start working on the next block (using the hash of the block just accepted)
  8. Accepted blocks are linked into the main chain. If competing chains exist, nodes accept the chain with the most PoW.
  9. Successful miner paid in new bitcoin (reward for PoW) and transaction fees.

# Proof of Work

- PoW is part of the protocol for validation and consensus
- Why is it necessary?
  - Bitcoin is open, and we need to motivate the validation & uploading process.
  - So we reward the validators/uploaders (fees + new bitcoin)
  - But how to ensure honesty? How to distinguish between different nodes seeking payment?
- For a closed system, we may not need PoW.
- Other Protocols include:
  - Proof of Stake (PoS)
  - Proof of Authority (PoA)
  - Proof of Identity (PoI)
  - Proof of Elapsed Time (PoET)
  - etc

# Who are the users of Bitcoin?

- Online gambling (original use-case?)
- Criminals and people laundering money
- Governments & people evading international sanctions
  - eg, DPRK, Iran, Russia
- People in countries with capital export controls, hyperinflation or with high levels of corruption
  - eg, Zimbabwe, Venezuela, Indonesia, North Korea
- Anyone having a need for money for any legal or illegal purpose.



# Distributed Ledger Technology

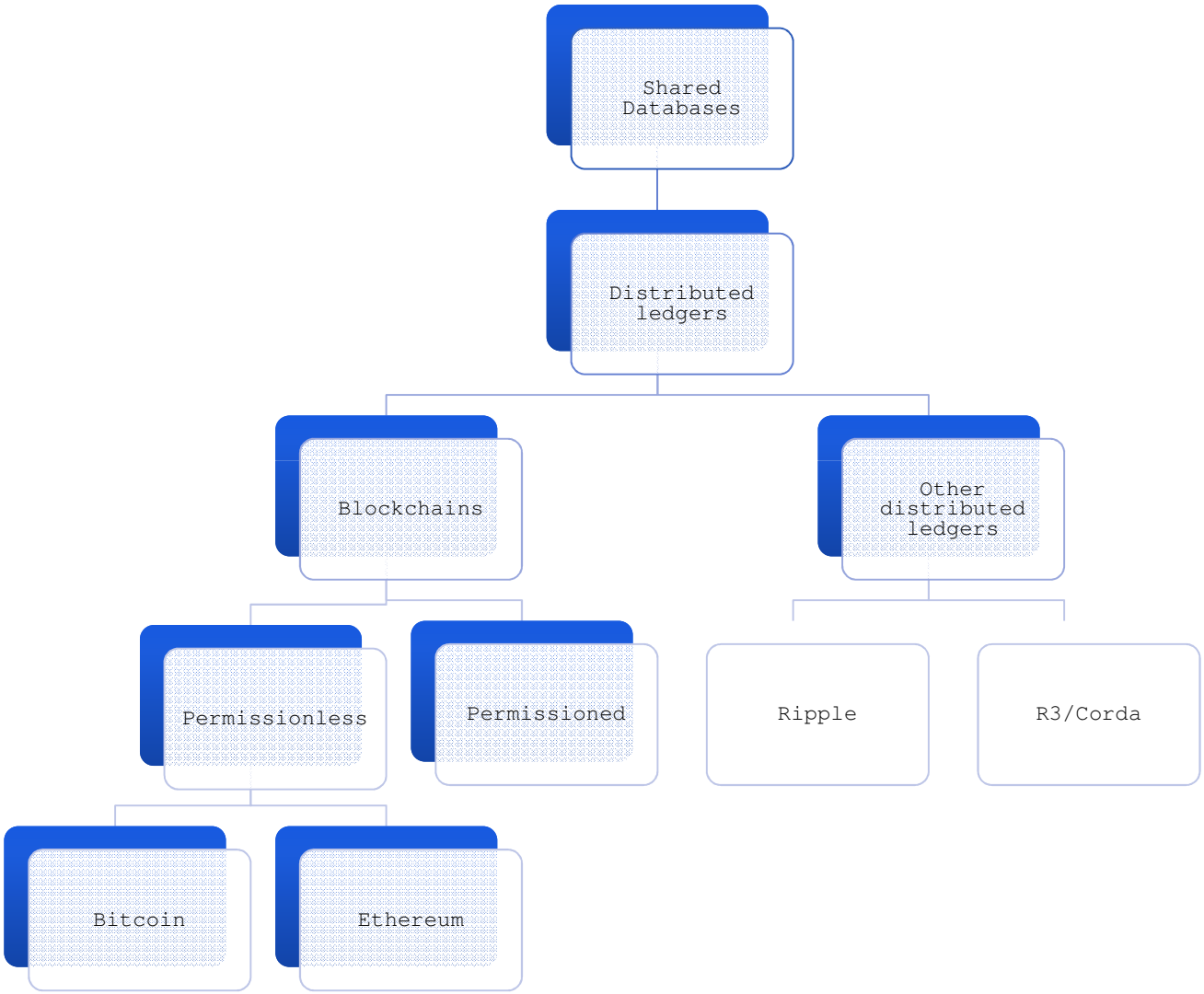
# A Blackboard metaphor

# Stateful shared state

In Computer Science parlance:

- All nodes on a distributed ledger agree on the values of the variable(s) on the ledger. They have a **shared state**.
- The ledger also preserves past states (the history), so the protocol is **stateful**.
  - In contrast, HTTP (Hyper-Text Transfer Protocol) is state-less.
- Distributed Ledgers have **stateful shared state**.
- This property can prevent “double-spending” of some currency or asset.

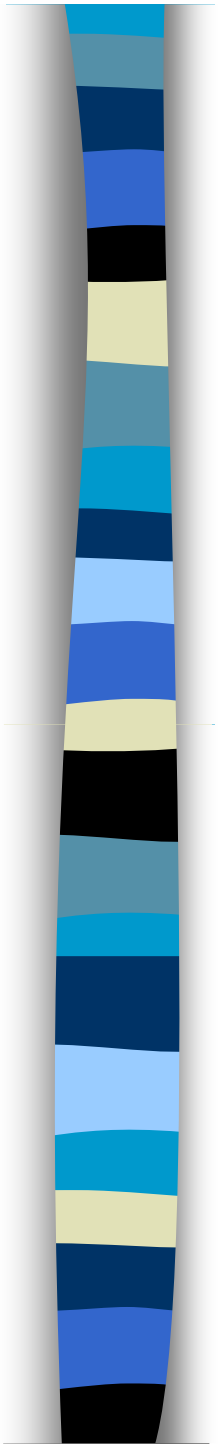
# Shared databases



# DLTs – Evolving thinking over last 3 years

Distributed Ledger Technologies appropriate for:

- Cryptocurrency transactions
- Currency transactions
- Transactions involving exchanges of ownership of assets
  - eg, chains of custody
- Records of information
  - eg, personal identity, chains of custody
- Promises and commitments
  - eg, futures contracts, trade flows, insurance, regulatory compliance.



# Blockchains and Distributed Ledgers

Several computer technologies are combined:

- Duplicated databases
- Hashing
- Asymmetric key cryptography
- Agreement protocols

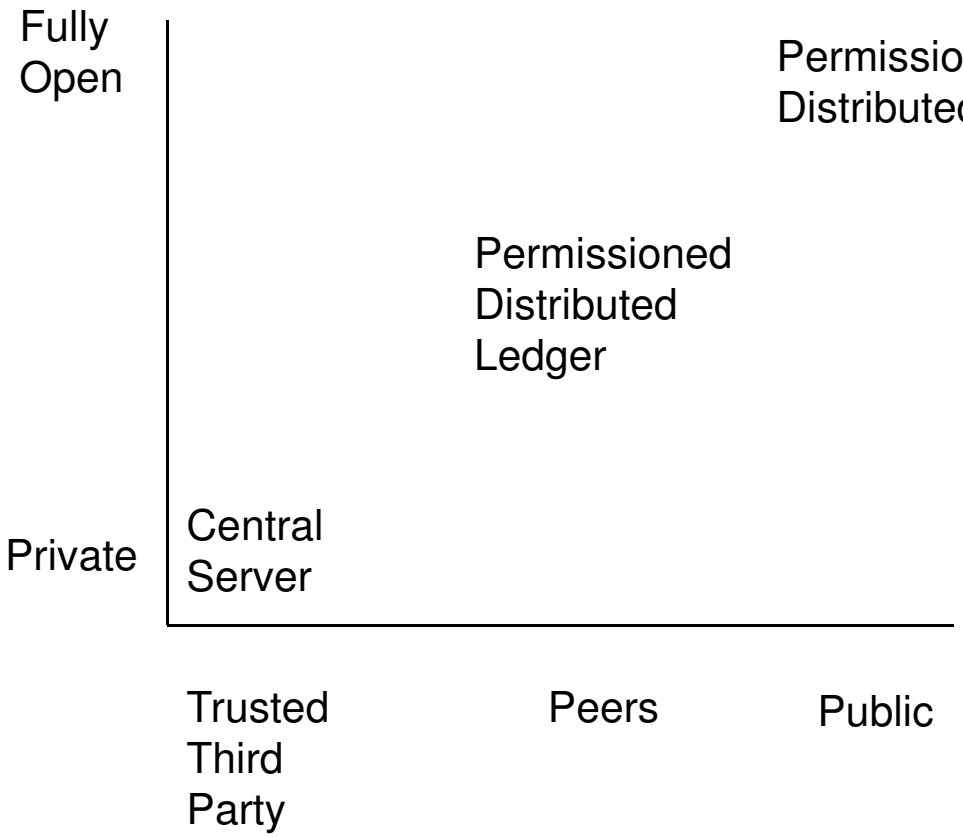
**Features**

**Redundancy & robustness**
**No central authority**
**Transactions observable**
**Immutable records**
**Non-repudiable records**
**Encrypted records**
**Content agnostic**
**Programmable (potentially)**

# The Design Space for DLTs

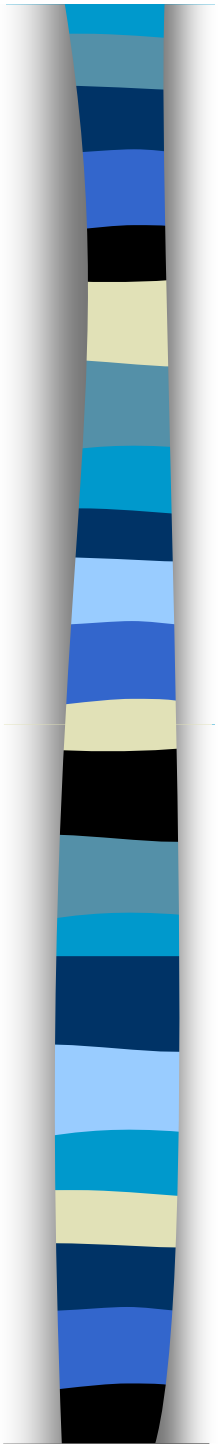
- Closed or open ?
  - Permissioned or Permission-less
  - Who is the witnessing/voting community?
- Payments for mining?
  - What currency? (Bitcoin, Ether, XRP, Citicoin, etc)
- Consensus & voting protocols?
- Blocking & chaining?
- Records
  - Who can see? Where stored? Who owns? Who may use?
- Smart contracts
  - vs. software architecture
- How is differential access ensured?
- How are privacy and security ensured?

# Trade-off: Confidentiality vs. Trustlessness




Who is the community?

- One organization
- Multiple organizations
- Public
  - Permission-less



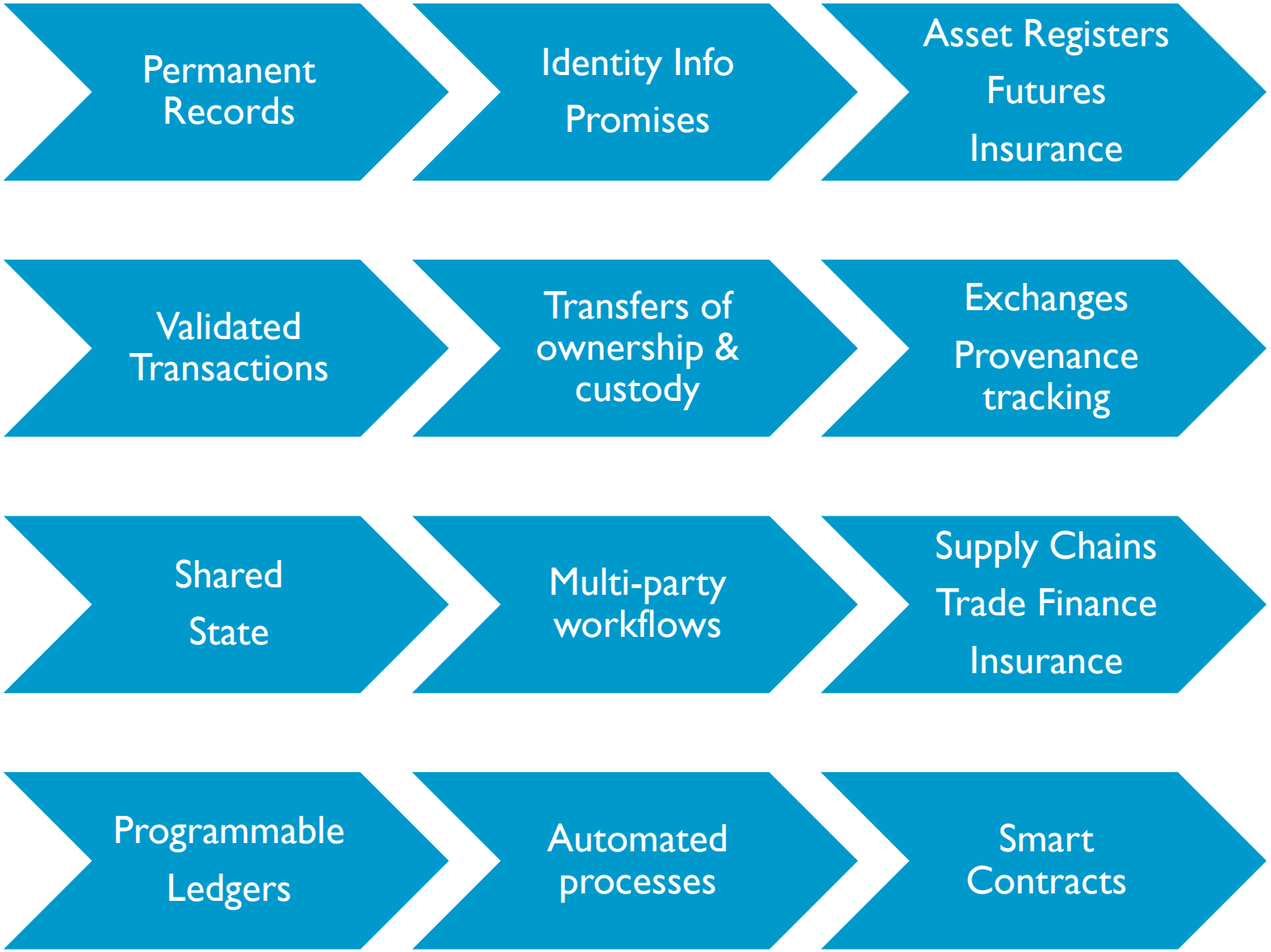
# Trust moves to software

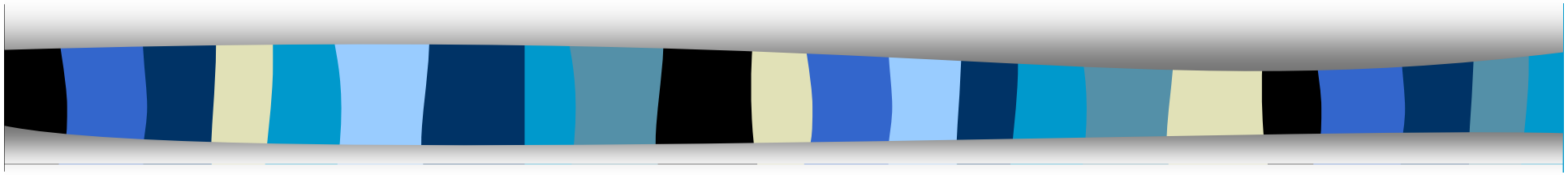
- Trustless transactions
  - The connected community acts to witness transactions
  - So no need of trusted third parties

- But trust is still required
  - Who specifies, designs and creates the software?
  - Who verifies the software properties?
  - Who identifies and fixes bugs?
  - Who maintains & updates the software?

- Example:
  - 2016 Exploitation of DAO (Decentralized Autonomous Organization).

# DL features and enabled applications

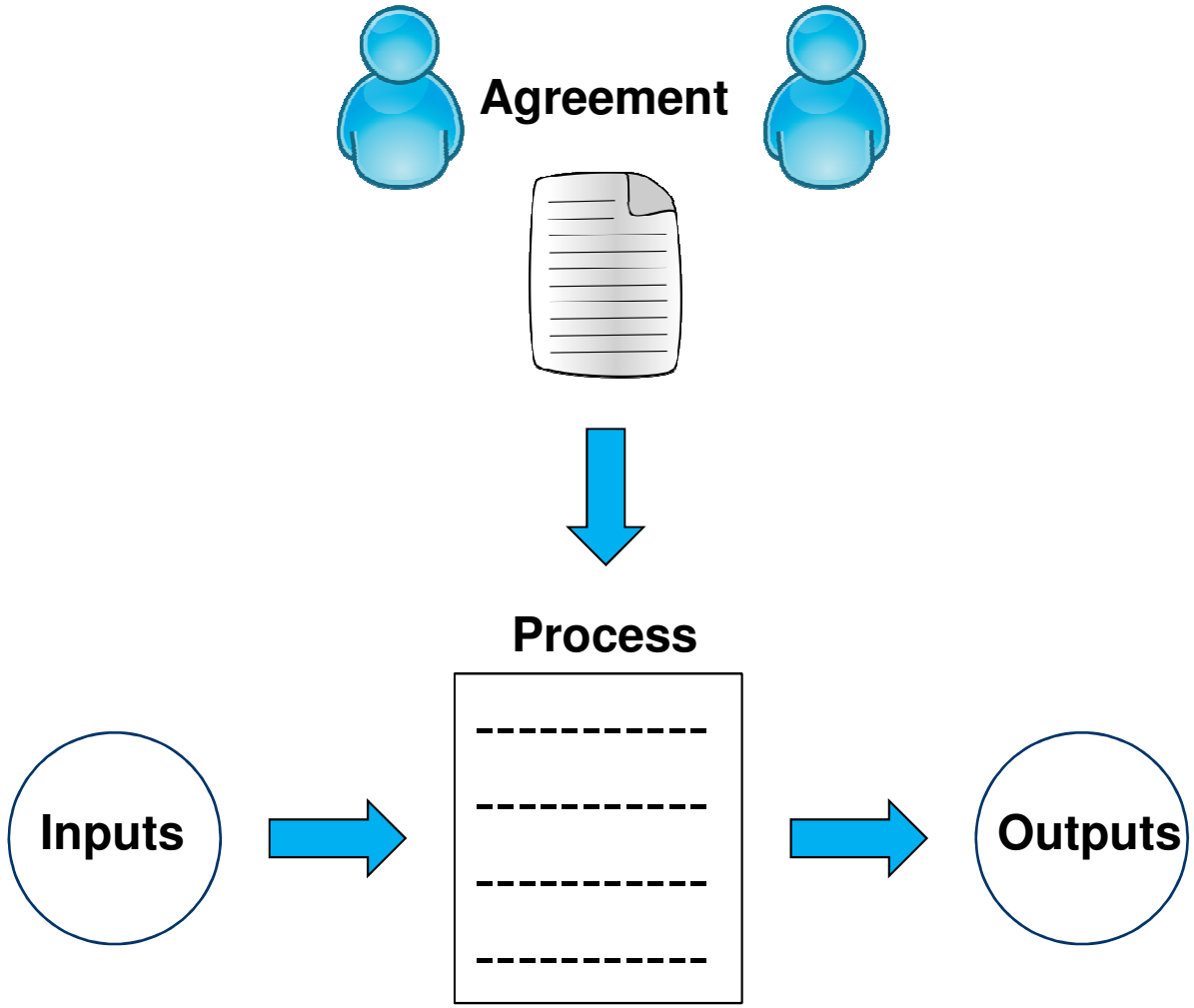




# Smart Contracts

# A smart contract . . .

. . . is an automated process, usually based on agreement between two or more parties, that autonomously executes at a trigger

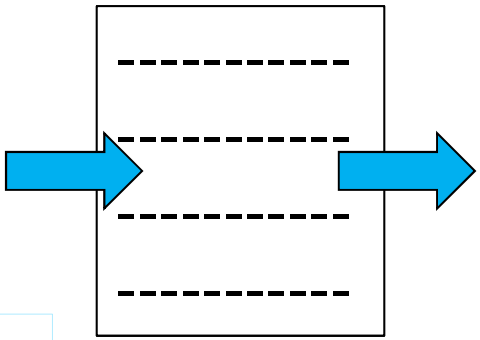


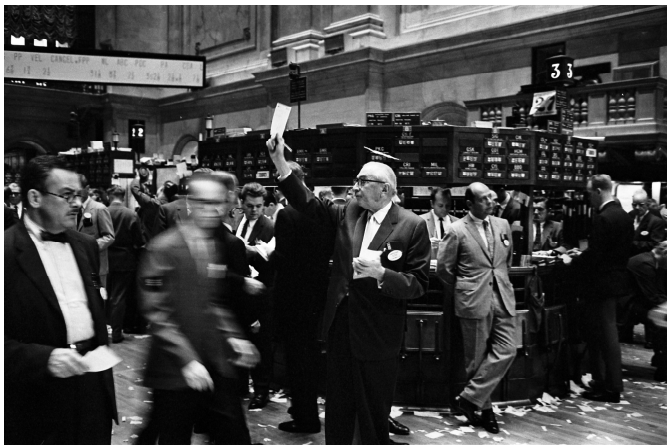

*Smart Contracts are Automated Performance Scripts*

# Example

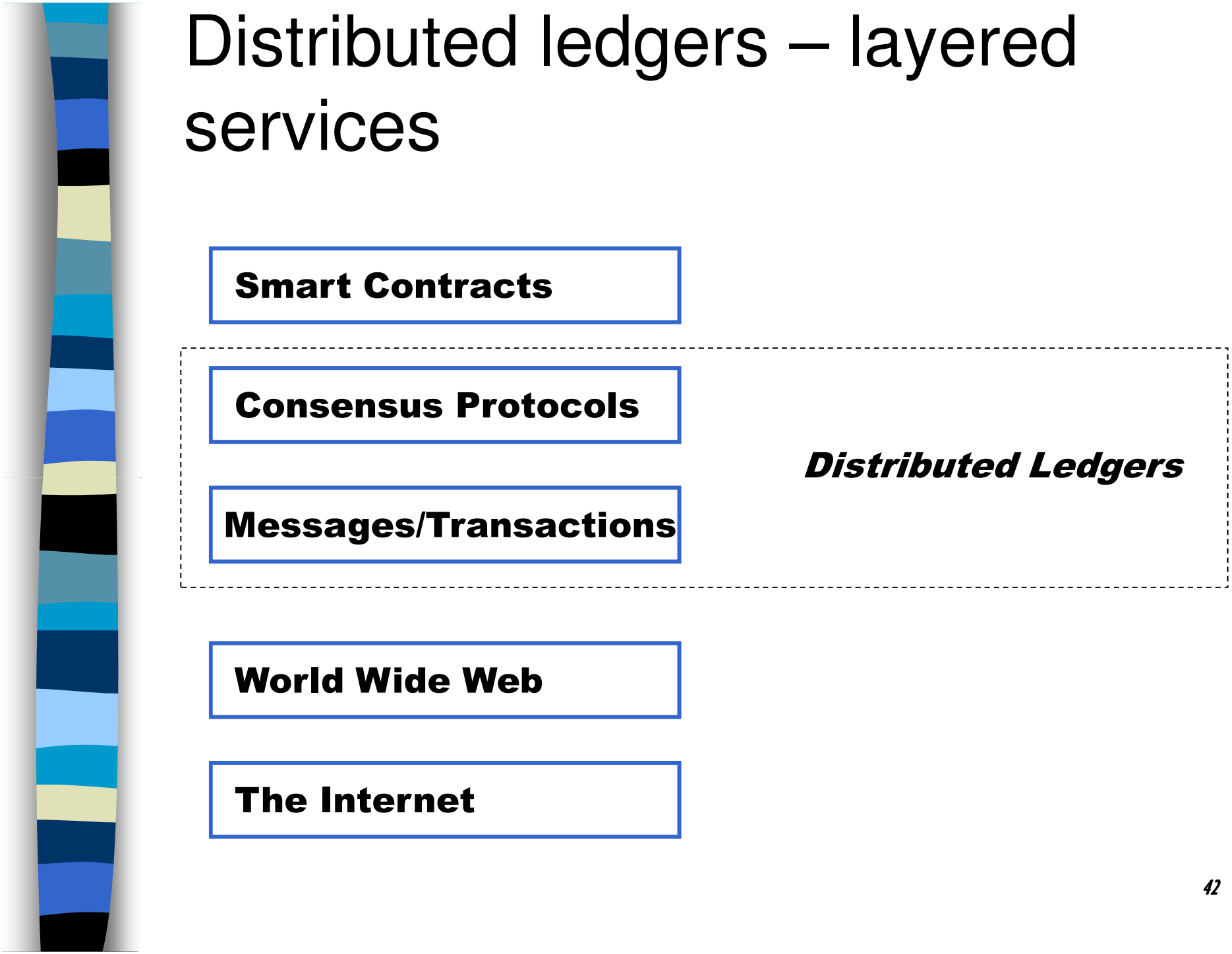
Inputs: Satellite images of wheat fields
Weather forecasts
(To forecast harvest dates and crop quality)

Outputs: Execution of wheat futures contracts.

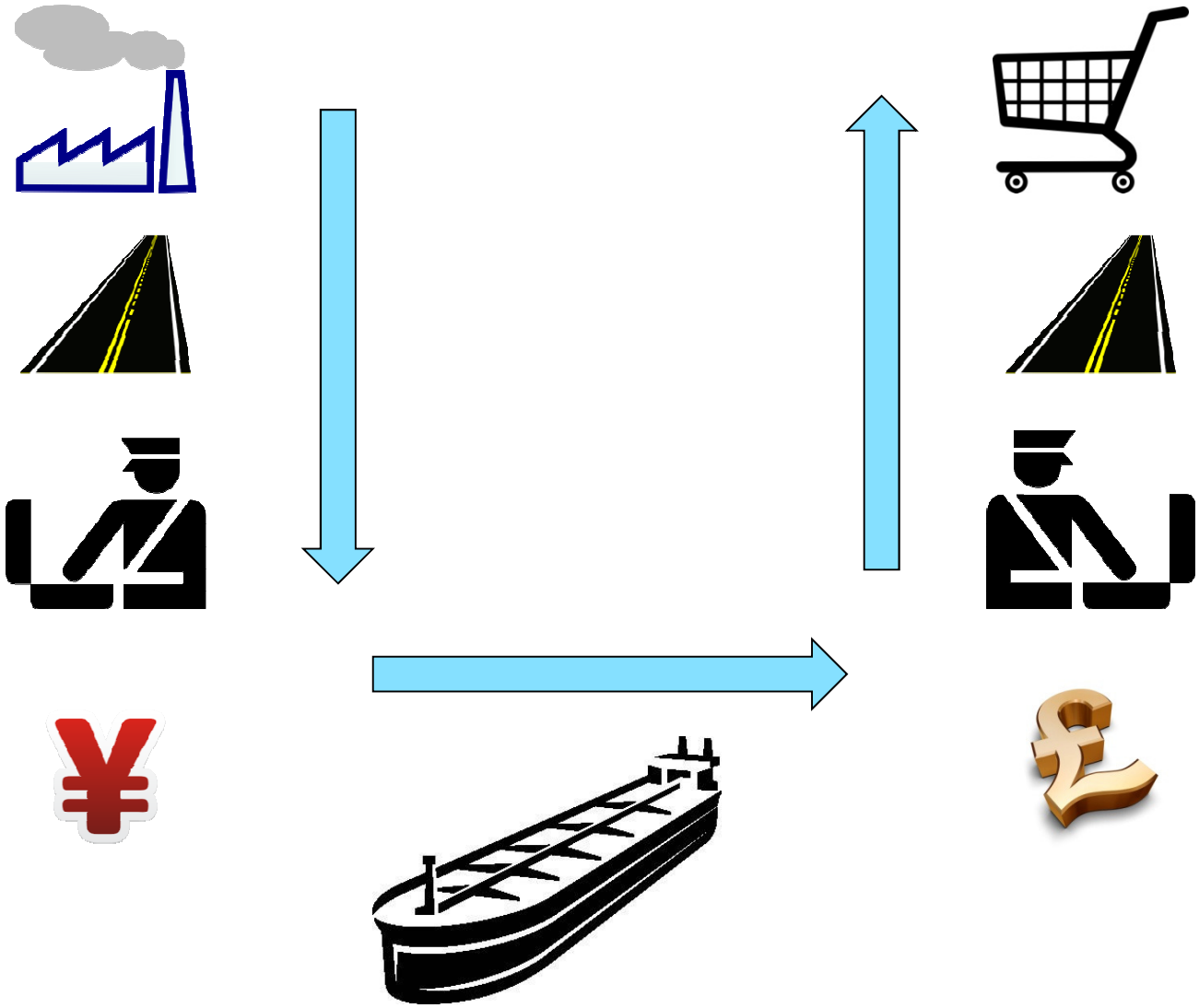


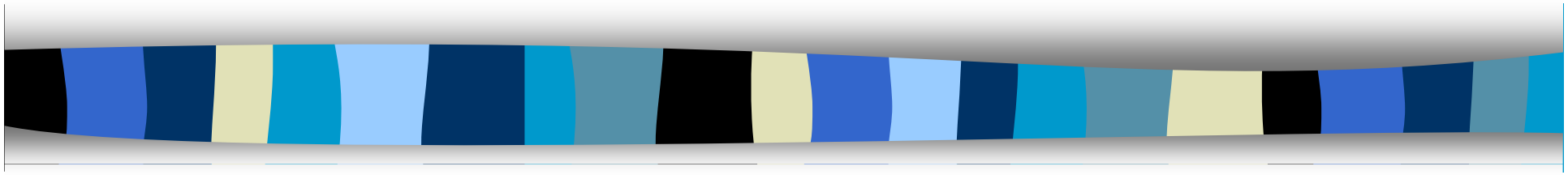


# Distributed ledgers – layered services



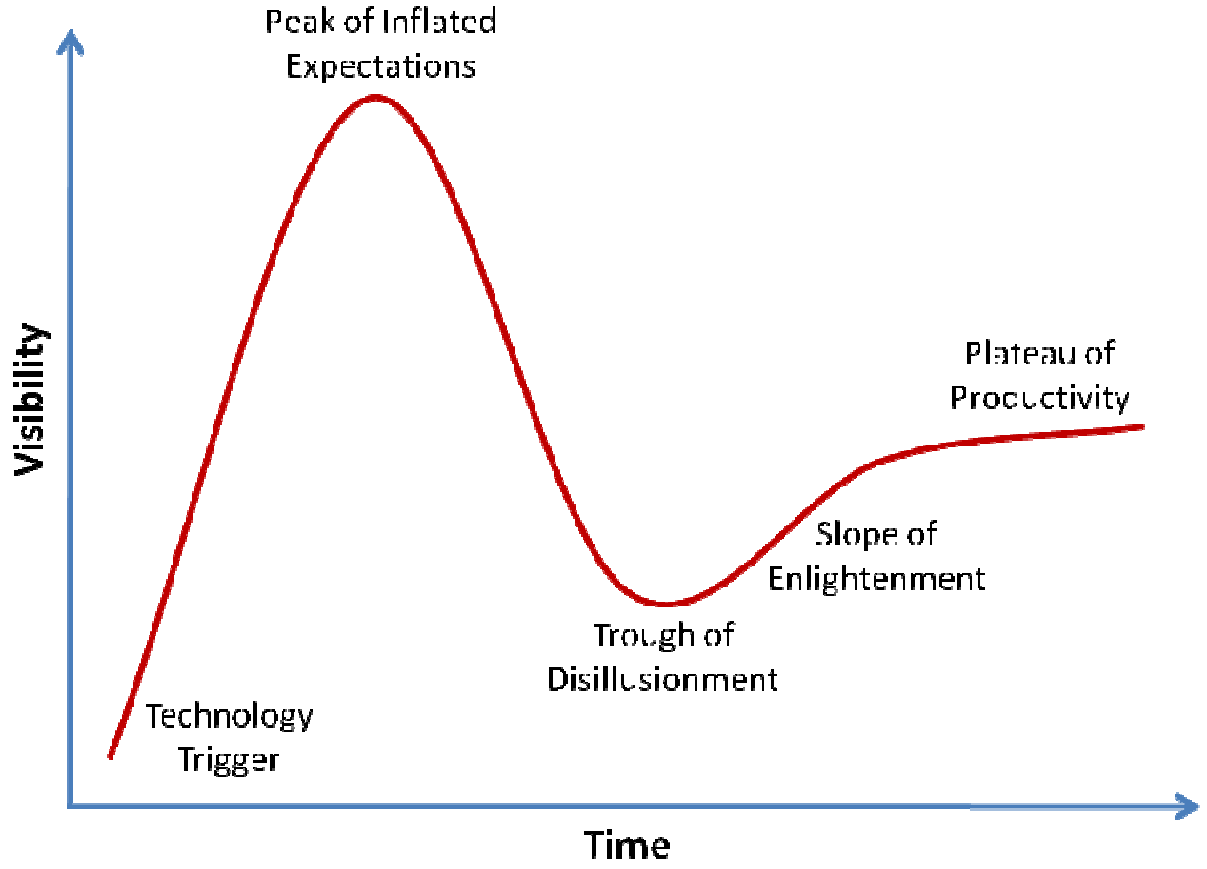
# Application: Trade Finance





# The Current Landscape

# The Gartner Technology Hype Cycle

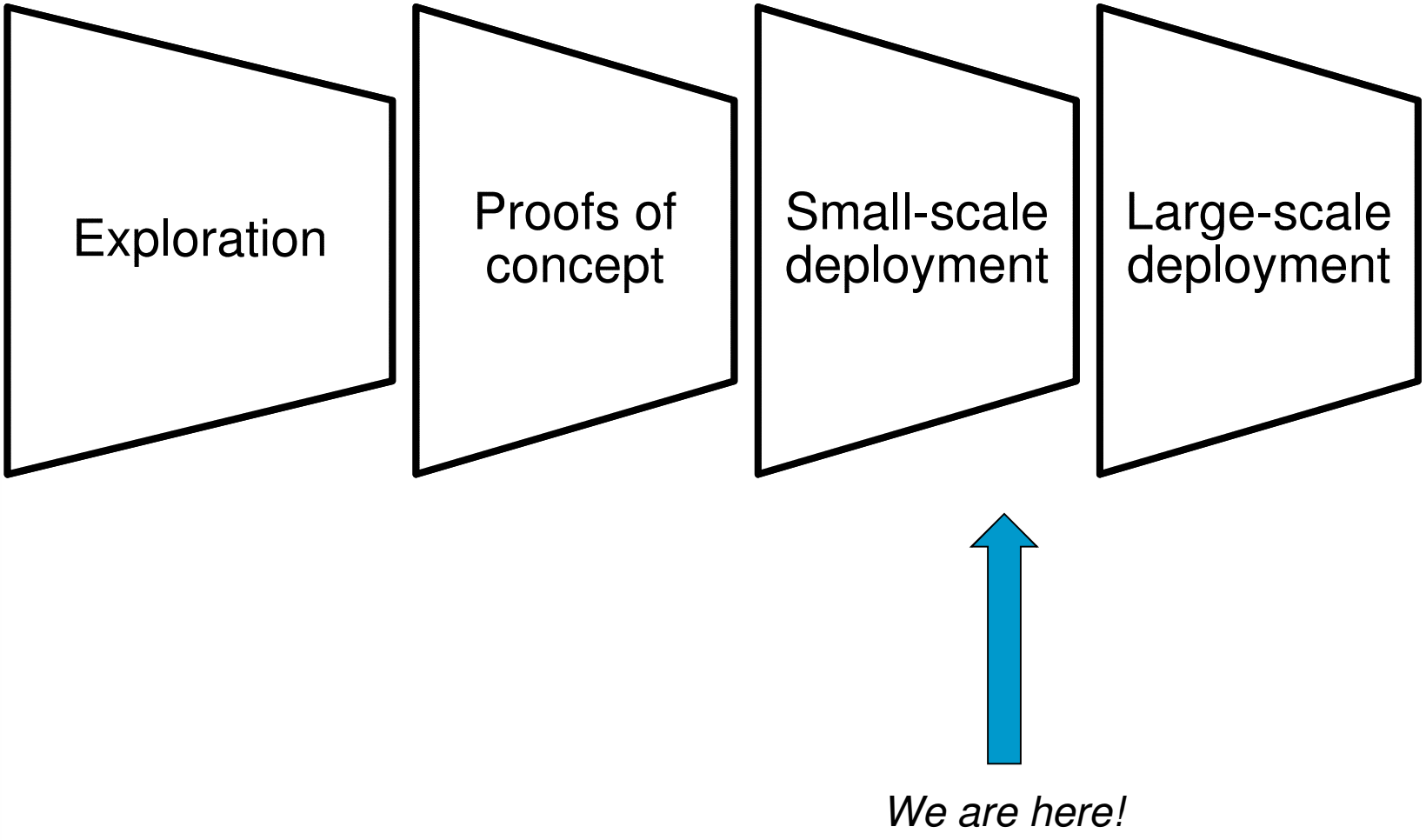



*Source: The Gartner Group*

# Initial Coin Offerings (ICOs)

- Initial Coin Offerings (ICOs) or Token Generation Events (TKEs)
  - Pre-sales of future tokens
  - Raising funds on the basis of future system development (a white paper)
- *Funding your start-up airline by pre-selling the frequent-flyer miles!*
- As much as $4 billion raised (Block.one)
- Risks
  - Regulatory: are these securities?
  - Class-action law suits
  - Promises only
- A bubble!

# DLT: Stages of development




*Source:*
*Kwôri & NRF Report*

# Applications of DLT

- Permanent identity information
  - eg, University degrees
  - Land registers
- Trading Platforms
  - High-value, low-frequency transactions
- Asset registers & tracking
  - eg, diamonds, works of art
- Automated data aggregation
  - eg, management accounting
- Workflows across multiple organizations
  - eg, Supply chains, BoLs, trade finance
  - Post-trade commodities management.

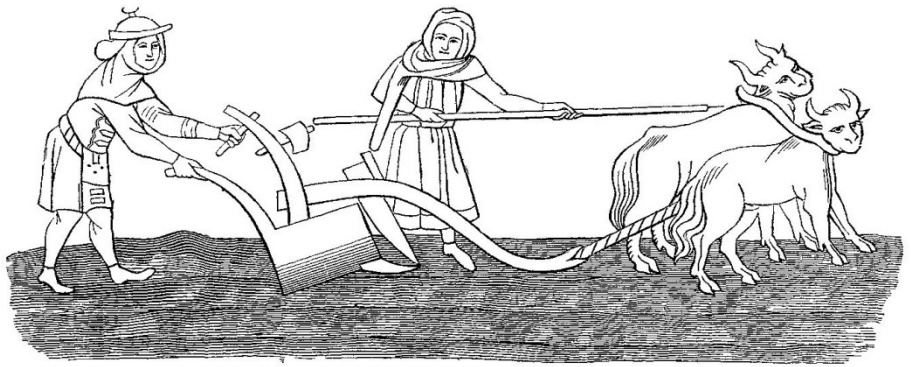




# Research Challenges

- Conceptual framework
  - What is the space of possible designs?
  - What is the fit between designs and applications?
    - For instance: what level of privacy is appropriate for each application

- Technical
  - Platforms & dev tools still immature
  - Scale
  - Speed
  - Appropriate designs
  - Verification
  - Robustness against attack
  - Privacy on networks.



# Implementation challenges - Technical

- Data Management
  - Privacy, confidentiality, storage, ownership, exploitation, IP
- Production readiness
  - eg, security, compliance & monitoring requirements, analytics capabilities
    - William Mougayar: 18-24 months to finalize after a PoC!
- Integration with legacy systems
- User-friendly interfaces and APIs
- Managing multiple DLs
  - Different underlying technologies
  - Different interfaces
  - Data reconciliation between DLs
  - Key management.

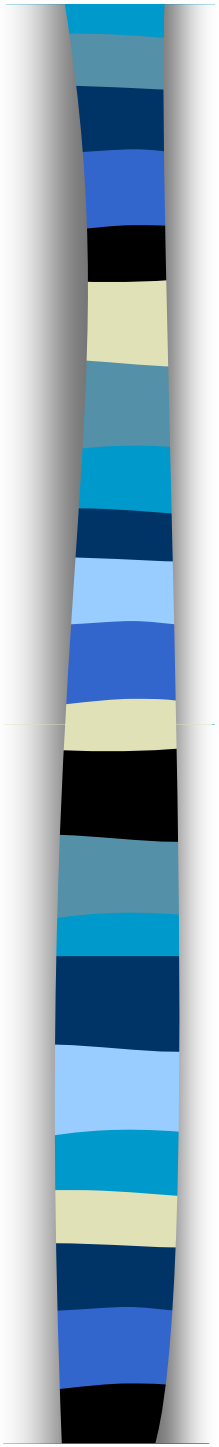
# Implementation Challenges: Organizational & Legal

- Organizational challenges
  - Managing stakeholders
  - Managing revocation & cancellation
  - Business Process Engineering/Re-engineering
    - Especially for inter-organization workflows
  - Governance & Management
    - eg, of permissions
  - Data ownership, privacy & usage

- Legal and Regulatory aspects
  - Competition (Anti-Trust) Law
  - Ownership of IP
  - Data privacy & management
  - Legal status of smart contracts.

# The Future

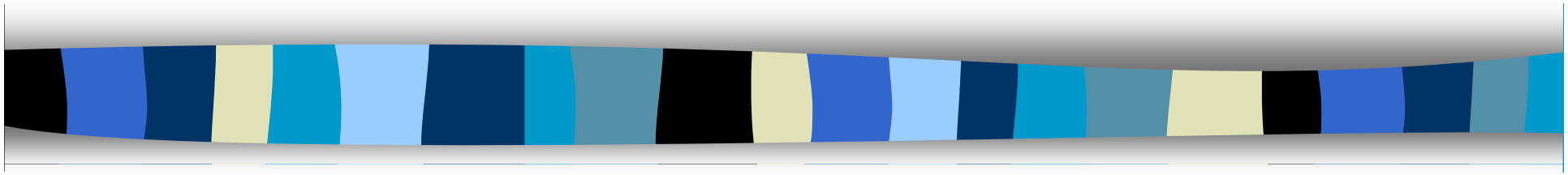
| When | Innovation | Enables | Era | "Native" Applications | Organization Impact |
|---|---|---|---|---|---|
| 1993-7 | World-Wide-Web | Easy dissemination of Information | Information Society | Advertising<br><br>e-Commerce<br><br>Database access | BPE/BPR inside organizations |
| 2015→ | Blockchains & Distributed Ledgers | Agreement on shared information & actions<br><br>Stateful Shared State | Joint-Action Society | Identity records<br><br>Exchanges<br><br>Chains of custody<br><br>Complex workflows<br><br>Insurance | BPE/BPR across organizations. |



# Exercises

1. List the sequence of events involved in acceptance of new blocks by nodes.
2. Describe the mathematical problems used in Bitcoin for PoW.
3. What is the total maximum number of Bitcoin to be issued? How many have been issued so far? What will miners be paid after the maximum is reached?
4. What is a wallet? What is the difference between wallets held on personal machines versus wallets held on an exchange?
5. List the major Bitcoin exchanges and their country of location. Is there a major exchange which has not been hacked at least once?

# Thank you!



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