Towards a Practice of Token Engineering

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#Data
#Incentives

The Economist

The world's most valuable resource

Data and the new rules of competition

amazon
UBER
Microsoft
Google

Silo mo' data

↓

Mo' accuracy

↓

Mo' $

Default incentive: hoard the data

“Show me the incentive
and I will show you the outcome.”

-Charlie Munger

You can get people to do stuff

by rewarding them with tokens.

This is a superpower.

Change the incentives!

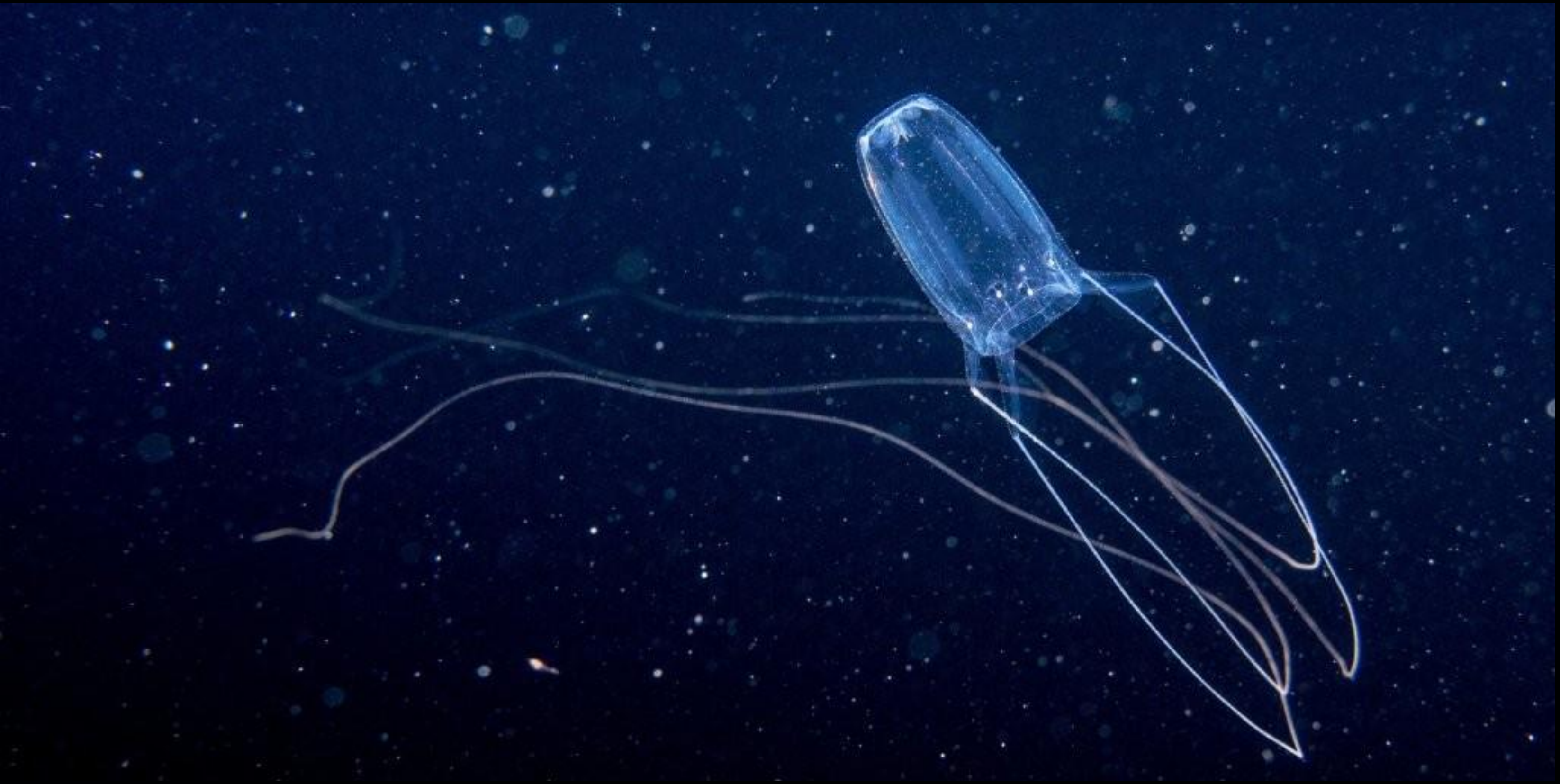
~~Silo~~ *Pool* mo' data

↓

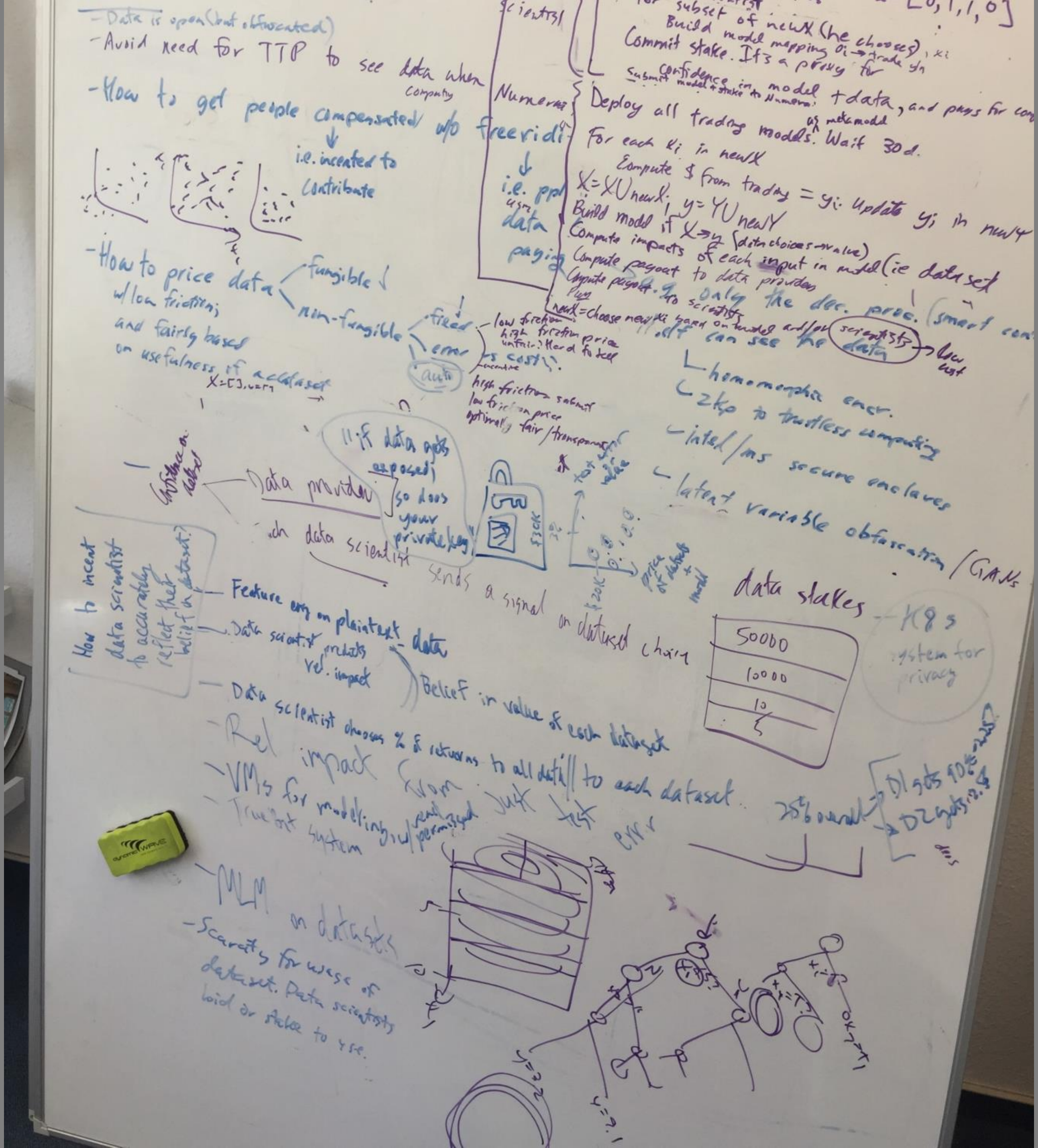
Mo' accuracy

↓

Mo' $



Early iterations

</br>

- Data is open (but obfuscated)
- Avoid need for TTP to see data when company
- How to get people compensated w/o freeriding
  - i.e. incented to contribute
- How to price data w/ low friction; and fairly based on usefulness of a dataset
  - fungible
  - non-fungible
    - fixed – low friction, high friction price, unfair? Hard to tell
    - error – cost?! incentive
    - auto – high friction submit, low friction price, optimally fair/transparent

X=[ ], v=[ ]

scientist

Numerai

i.e. ppl using data paying

```
    subset of newX (he chooses), xi
    Build model mapping oi → trade yn
  Commit stake. It's a proxy for
    confidence in model + data, and pays for co[...]
    Submit model + stake to Numerai
Deploy all trading models as metamodel. Wait 30d.
For each xi in newX
    Compute $ from trading = yi. Update yi in newY
X = X ∪ newX; y = Y ∪ newY
Build model of X → y (data choices → value)
Compute impacts of each input in model (ie dataset
Compute payout to data providers
Compute payout. % to scientists
Plus
newX = choose new xi based on model and/or
```

[0, 1, 1, 0]

only the dec. proc. (smart con[...]) itself can see the data

scientists → low cost

- homomorphic encr.
- zkp to trustless computing
- intel/ms secure enclaves
- latent variable obfuscation / GANs

// if data gets exposed, so does your private key

$30K

$20K

text of dataset value

price of dataset + model

Data provider – confidence on dataset

data scientist sends a signal on dataset chain

data stakes

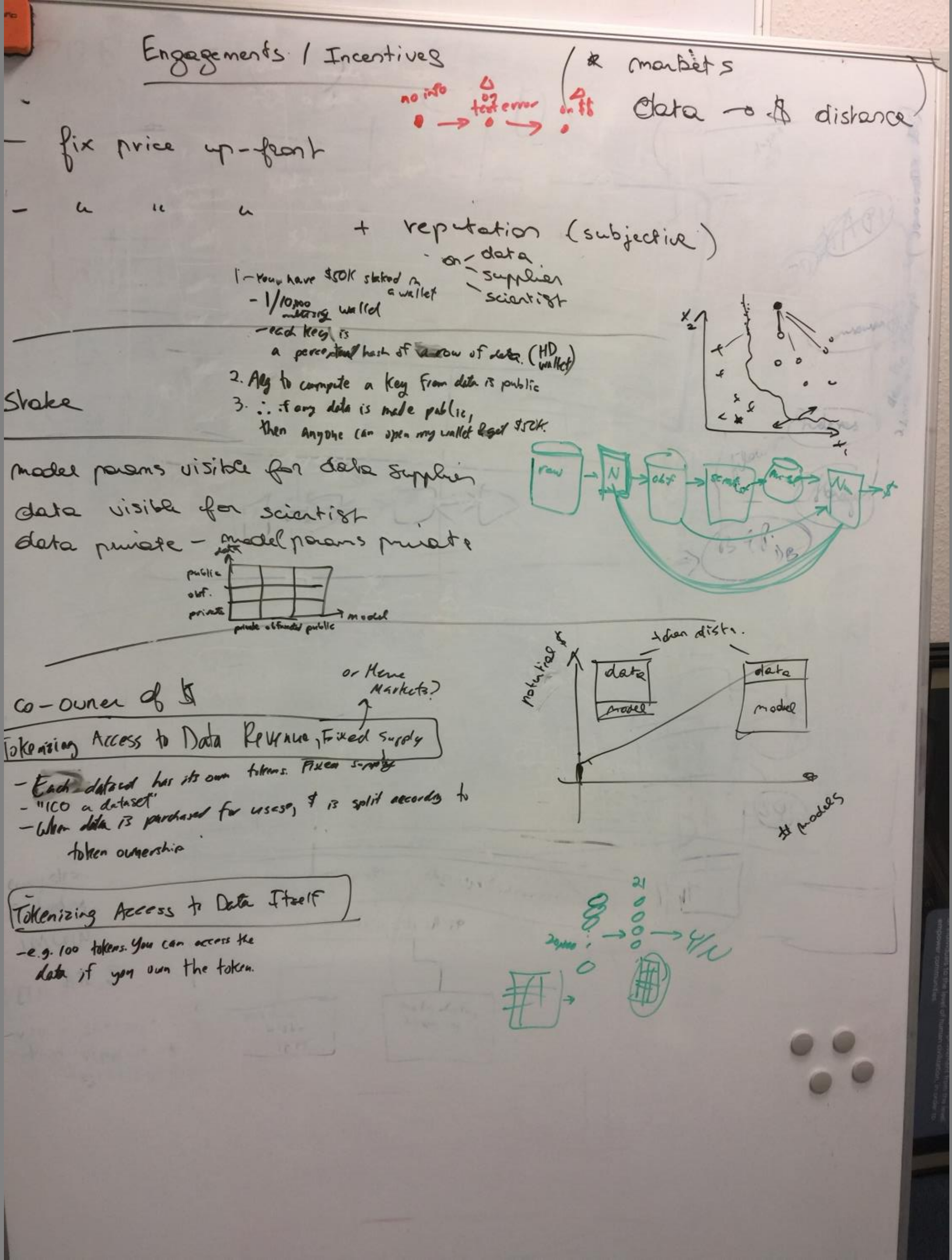
50000
10000
10
5

K8s system for privacy

How to incent data scientists to accurately reflect their belief on dataset?

- Feature eng on plaintext data
- Data scientist predicts rel. impact
  - Belief in value of each dataset
- Data scientist chooses % of returns to all data to each dataset
- Rel impact from just test error
- VMs for modeling w/ permissioned
- Trusted system
- MLM on datasets
- Scarcity for usage of dataset. Data scientists bid or stake to use.

25% overall → D1 gets 90% of 25% → D2 gets 2.5% does



Engagements / Incentives

- fix price up-front
- " " " + reputation (subjective)
  - on data
  - supplier
  - scientist

(* markets

data → $ distance)

Stake

1. You have $50K staked in a wallet
   - 1/10,000 matching wallet
   - each key is a perceptual hash of a row of data. (HD wallet)
2. Alg to compute a key from data is public
3. ∴ if any data is made public, then anyone can open my wallet & get $50K.

model params visible for data supplier

data visible for scientist

data private – model params private

co-owner of $

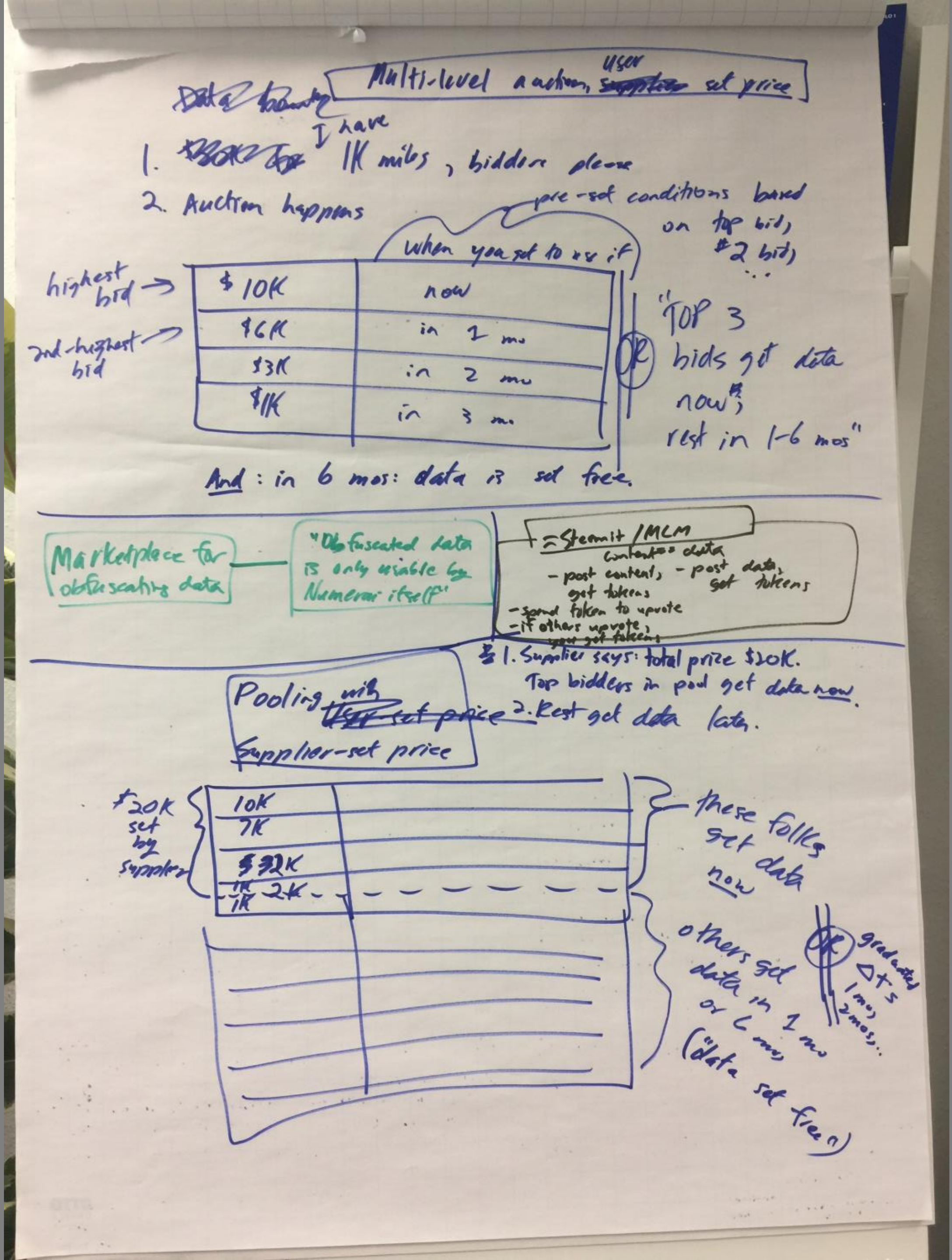
Tokenizing Access to Data Revenue, Fixed Supply

or Meme Markets?

- Each dataset has its own tokens. Fixed supply
- "ICO a dataset"
- When data is purchased for use, $ is split according to token ownership

Tokenizing Access to Data Itself

- e.g. 100 tokens. You can access the data if you own the token.



~~Data [illegible]~~ Multi-level auction, ~~supplier~~ user set price

1. ~~[illegible]~~ I have 1K miles, bidders please

2. Auction happens

pre-set conditions based on top bid, #2 bid, ...

when you set to xx if

highest bid →

2nd-highest bid →

$10K	now
$6K	in 1 mo
$3K	in 2 mo
$1K	in 3 mo

OR "TOP 3 bids get data now"; rest in 1-6 mos"

And: in 6 mos: data is set free.

Marketplace for obfuscating data

"Obfuscated data is only usable by Numerai itself"

=Steemit / MLM

content == data

- post content, get tokens
- post data, get tokens
- spend token to upvote
- if others upvote, you get tokens

Pooling ~~with User-set price~~

Supplier-set price

1. Supplier says: total price $20K. Top bidders in pool get data now.
2. Rest get data later.

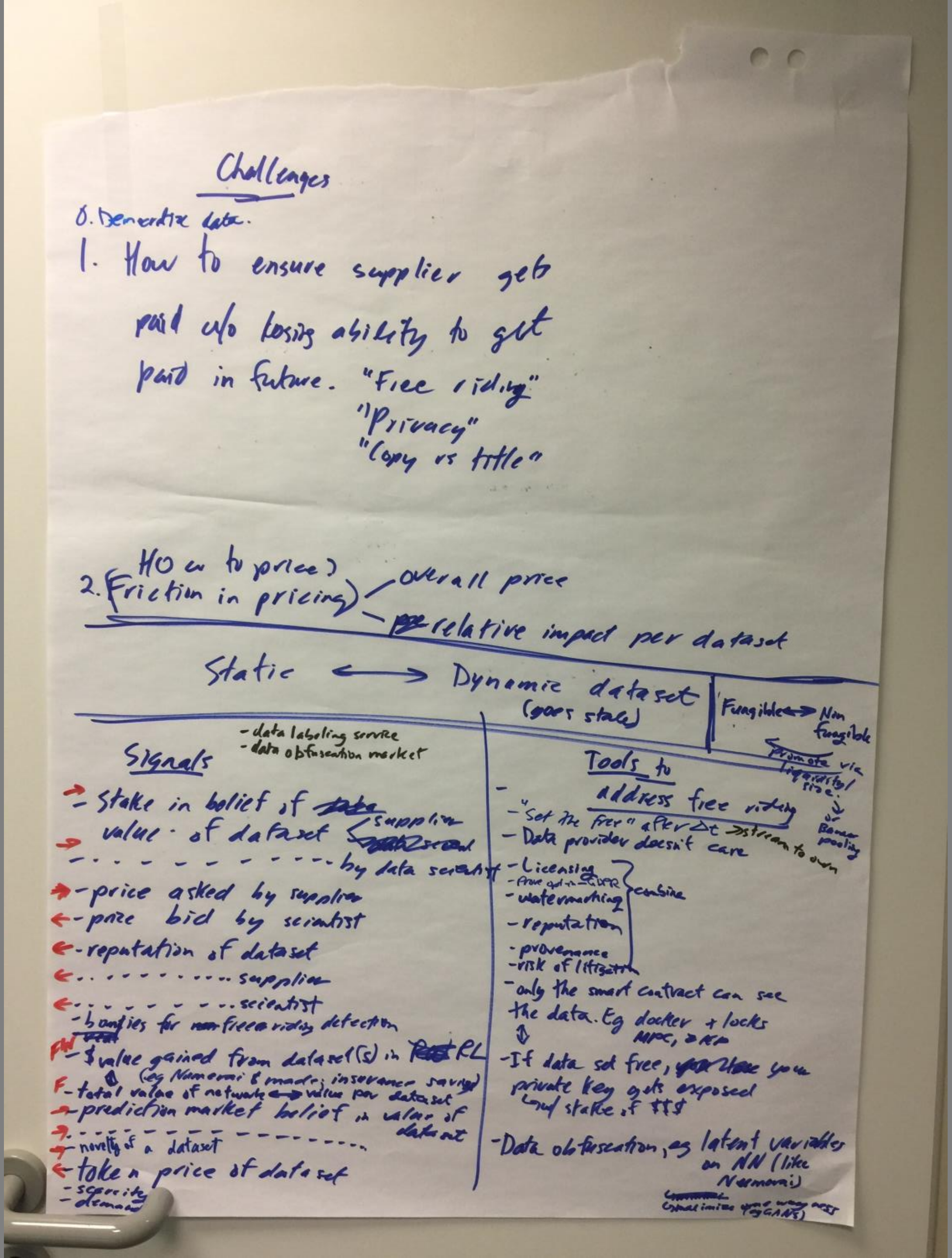
$20K set by supplier

10K	
7K	
$32K	
1K 2K	
1K	

these folks get data now

others get data in 1 mo or 6 mos ("data set free")

OR graduated Δts 1 mo, 2 mos...



Challenges

0. Democratize data.

1. How to ensure supplier gets paid w/o losing ability to get paid in future. "Free riding"
"Privacy"
"Copy vs title"

2. Friction in pricing (How to price?)
- overall price
- ~~per~~ relative impact per dataset

Static ⟷ Dynamic dataset (goes stale)

Fungible → Non fungible
promote via liquidity/size.
or Bancor pooling

- data labeling service
- data obfuscation market

Signals

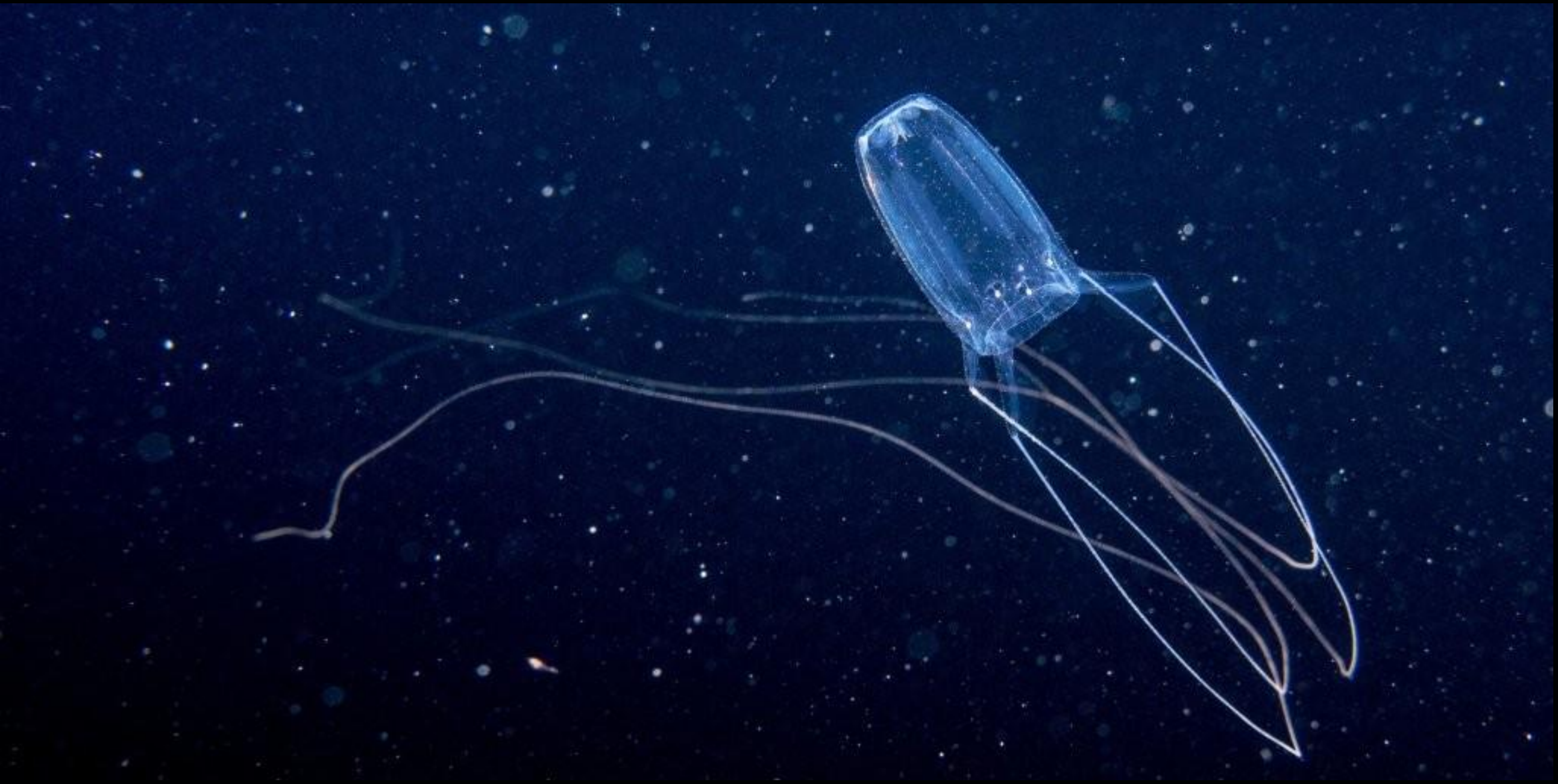
- stake in belief of ~~data~~ value of dataset
  - supplier
  - ~~[illegible]~~ second
- . . . . by data scientist
- price asked by supplier
- price bid by scientist
- reputation of dataset
- . . . . supplier
- . . . . scientist
- bounties for ~~non~~ free riding detection ~~[illegible]~~
- $ value gained from dataset(s) in ~~Rest~~ RL
  (eg Numerai & model; insurance saving)
- total value of network ⟷ value per dataset
- prediction market belief in value of dataset
- . . . .
- novelty of a dataset
- take a price of dataset
- scarcity
- demand

Tools to address free riding

-
- "Set the free" after Δt → stream to own
- Data provider doesn't care
- Licensing
- Prove opt-in - GDPR
- watermarking
- reputation
- provenance
- risk of litigation

combine

- only the smart contract can see the data. Eg docker + locks
  MPC, ZKP
  ⇕
- If data set free, ~~your~~ ~~[illegible]~~ your private key gets exposed
  w/ stake of $$$
- Data obfuscation, eg latent variables on NN (like Numerai)
  ~~[illegible]~~
  (small image [illegible] GANs)



Early iterations: *Flailing*

Can we structure this better?

Realization: Tokenized Ecosystems
Are a Lot Like Evolutionary Algorithms!

What		Tokenized ecosystem		Evolutionary Algorithm
Goals		Block reward function E.g. “Maximize hash rate”		Objective function E.g. “Minimize error”
Measurement & test		Proof E.g. “Proof of Work”		Evaluate fitness E.g. “Simulate circuit”
System agents		Miners & token holders (humans) In a network		Individuals (computer agents) In a population
System clock		Block reward interval		Generation
Incentives & Disincentives		You can’t control human, Just reward: give tokens And punish: slash stake		You can’t control individual, Just reward: reproduce And punish: kill

We can approach token design as optimization design.

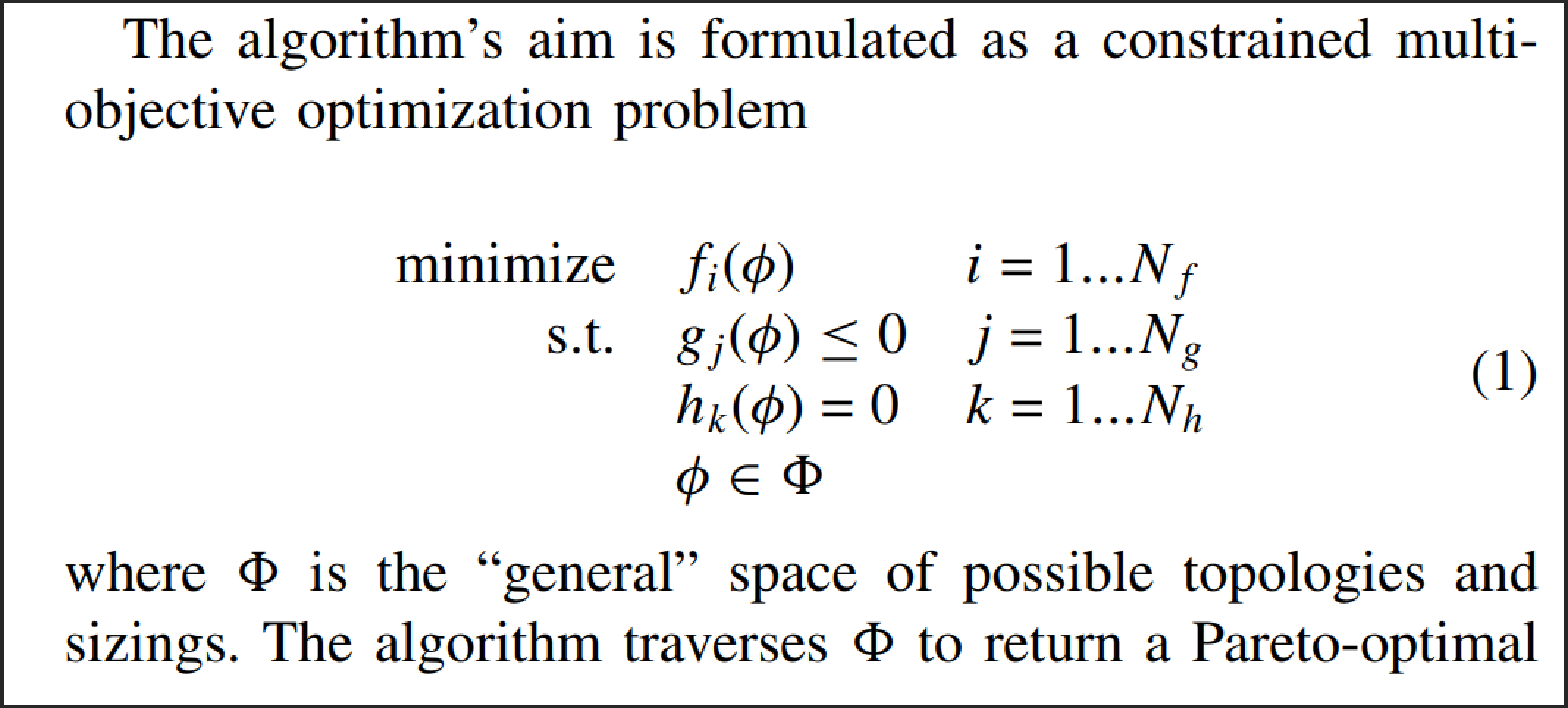
Optimization Design

Steps in Optimization Design

1. **Formulate the problem.** Objectives, constraints, design space.
2. **Try an existing solver.** If needed, try different problem formulations or solvers.
3. **Design new solver?**

1. Formulation of an optimization problem

Objectives & constraints in a design space

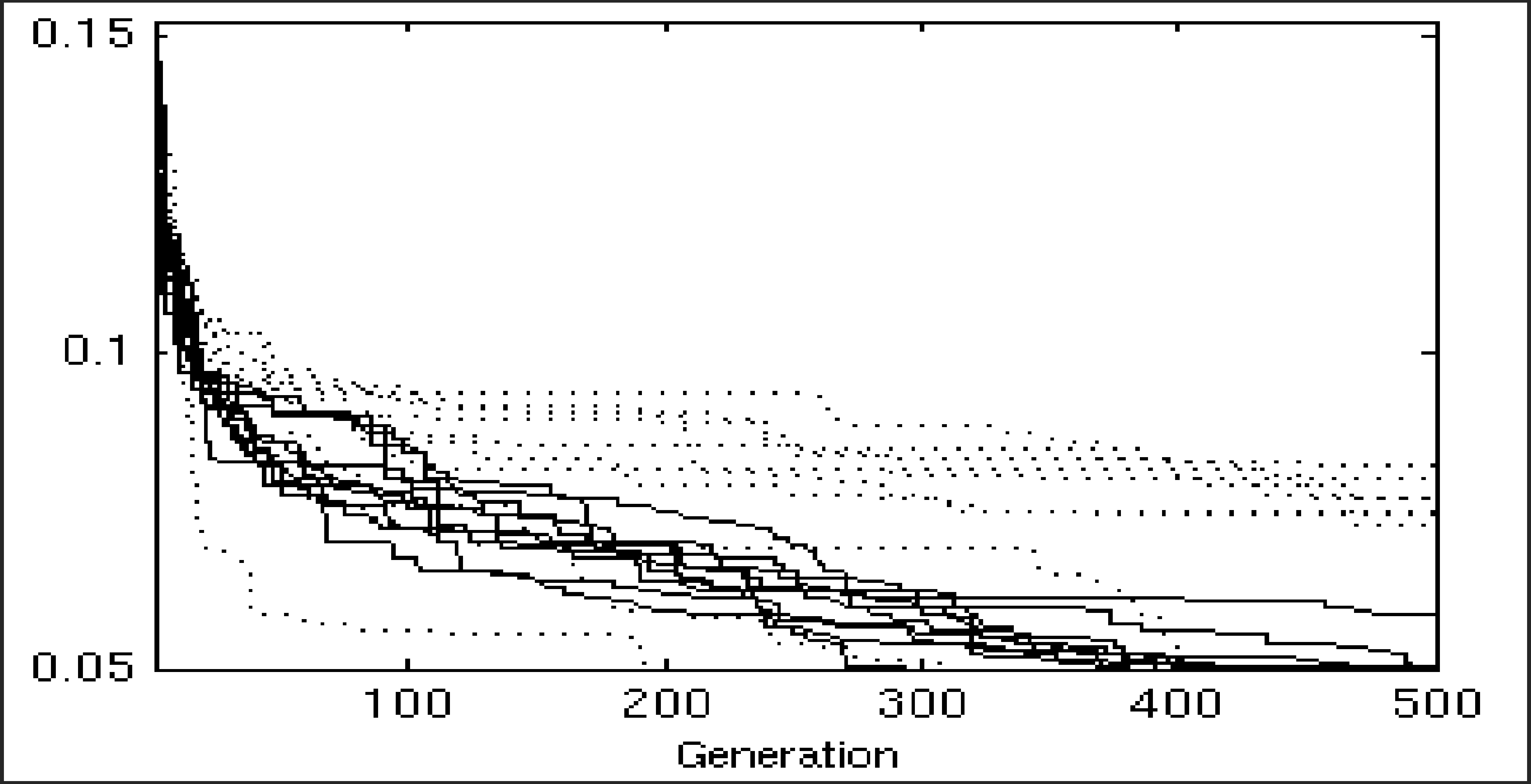


The algorithm's aim is formulated as a constrained multi-objective optimization problem

$$\begin{array}{rll} \text{minimize} & f_i(\phi) & i = 1 \ldots N_f \\ \text{s.t.} & g_j(\phi) \leq 0 & j = 1 \ldots N_g \\ & h_k(\phi) = 0 & k = 1 \ldots N_h \\ & \phi \in \Phi & \end{array} \qquad (1)$$

where Φ is the "general" space of possible topologies and sizings. The algorithm traverses Φ to return a Pareto-optimal

2. Try an existing solver. Does it converge?



3. Design new solver

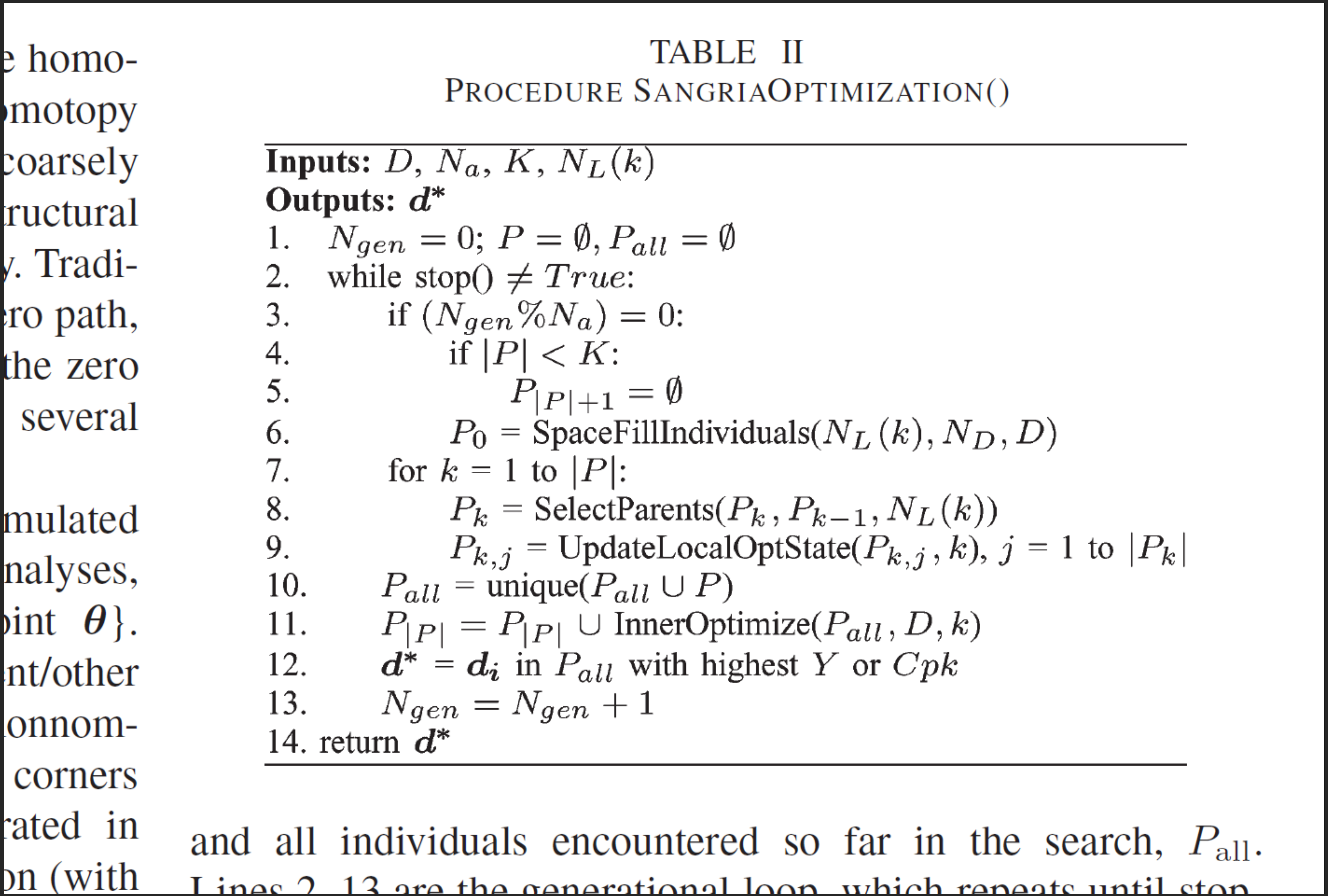


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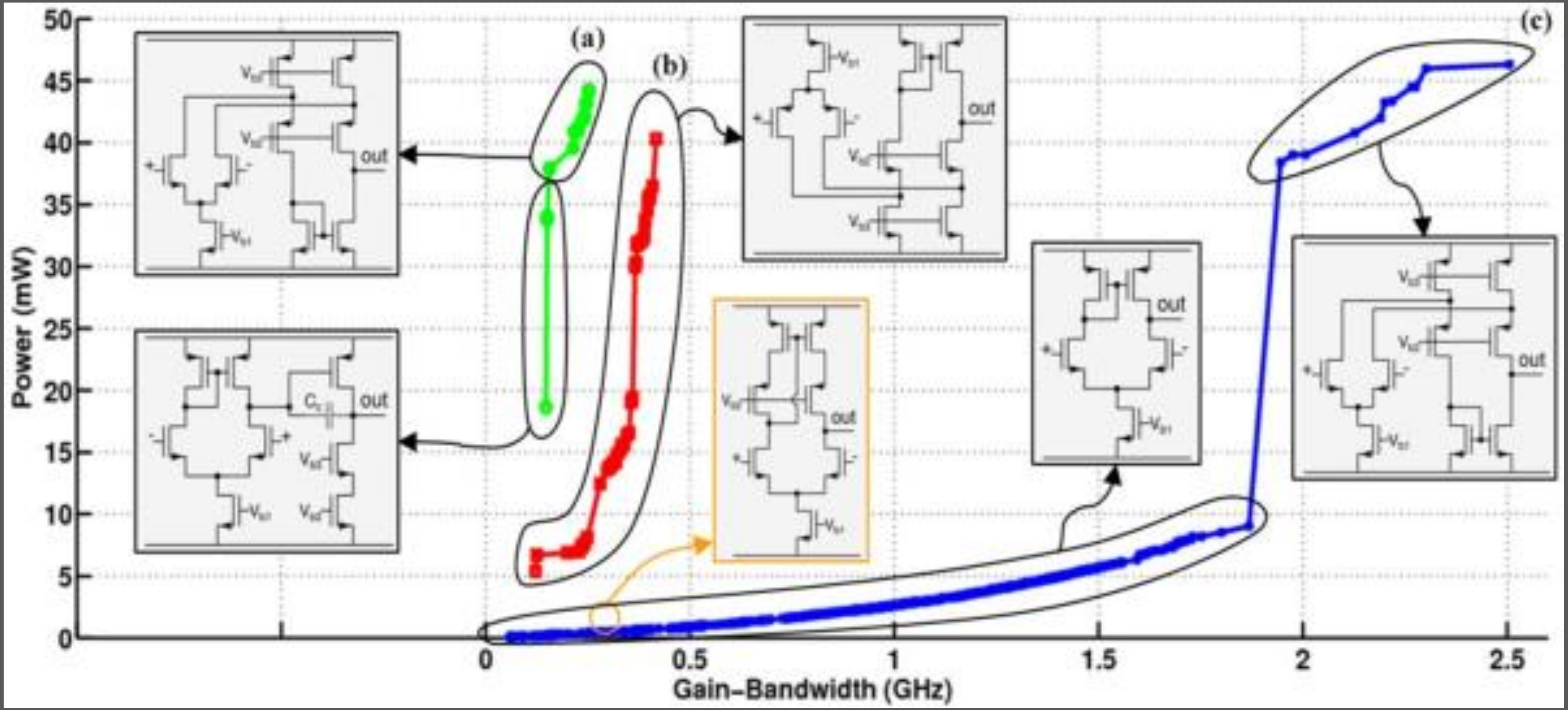
TABLE II

PROCEDURE SANGRIAOPTIMIZATION()

```
Inputs: $D$, $N_a$, $K$, $N_L(k)$
Outputs: $\boldsymbol{d}^*$
1.  $N_{gen} = 0$; $P = \emptyset$, $P_{all} = \emptyset$
2.  while stop() $\neq True$:
3.      if $(N_{gen} \% N_a) = 0$:
4.          if $|P| < K$:
5.              $P_{|P|+1} = \emptyset$
6.          $P_0$ = SpaceFillIndividuals($N_L(k), N_D, D$)
7.      for $k$ = 1 to $|P|$:
8.          $P_k$ = SelectParents($P_k, P_{k-1}, N_L(k)$)
9.          $P_{k,j}$ = UpdateLocalOptState($P_{k,j}, k$), $j$ = 1 to $|P_k|$
10.     $P_{all}$ = unique($P_{all} \cup P$)
11.     $P_{|P|} = P_{|P|} \cup$ InnerOptimize($P_{all}, D, k$)
12.     $\boldsymbol{d}^*$ = $\boldsymbol{d_i}$ in $P_{all}$ with highest $Y$ or $Cpk$
13.     $N_{gen} = N_{gen} + 1$
14. return $\boldsymbol{d}^*$
```

and all individuals encountered so far in the search, P_{all}. Lines 2–13 are the generational loop, which repeats until stop

Example of a Successful Outcome



Token Design as Optimization Design

Steps in *Token* Design

1. **Formulate the problem.** Objectives, constraints, design space.
2. **Try an existing pattern.** If needed, try different formulations or solvers.
3. **Design new pattern?**

1. Formulate the Problem

(a) Ask

- Who are my potential **stakeholders**?
- And what do each of them **want**?
- What are possible **attack vectors**?

(b) Translate those into objectives and constraints.

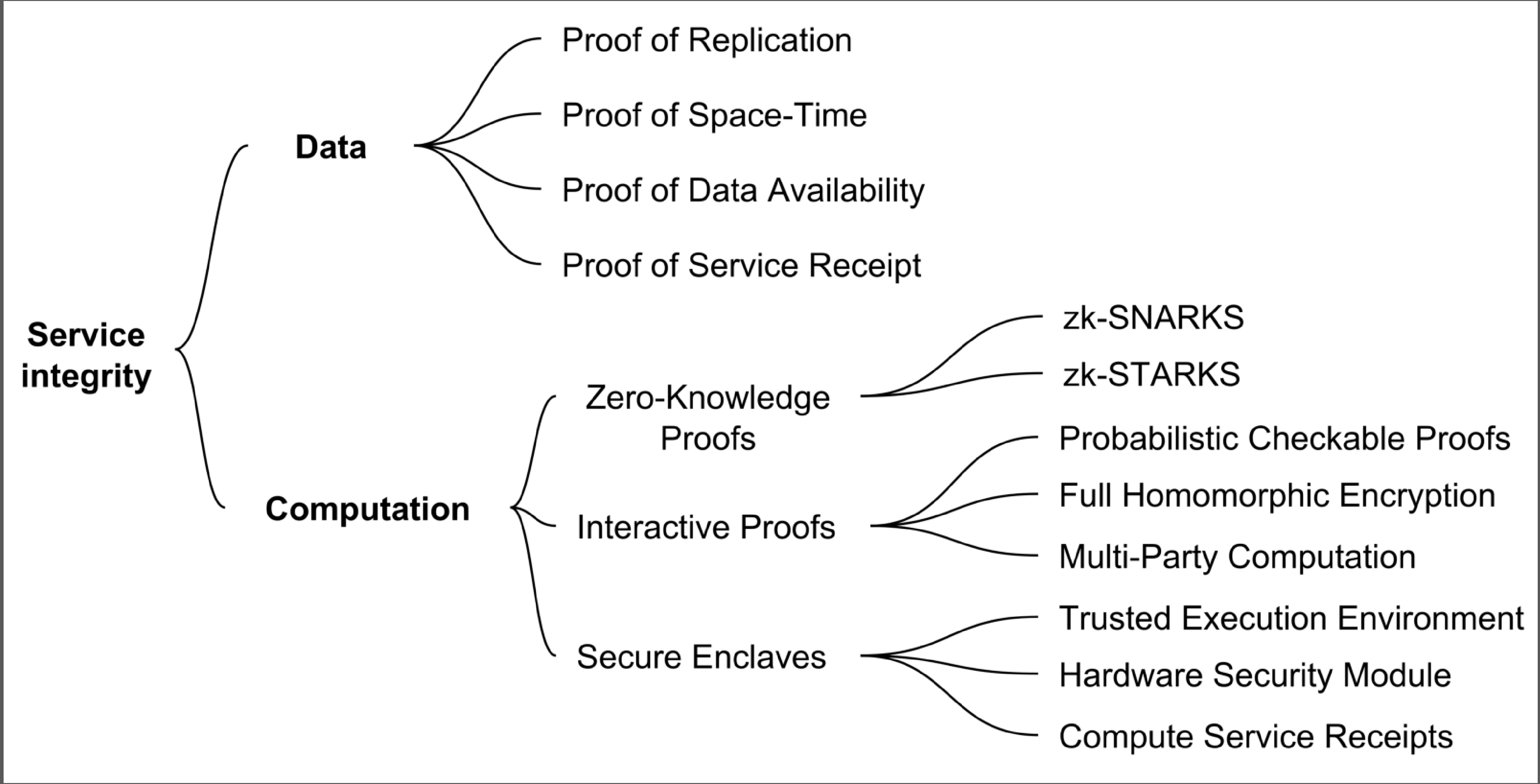
2. Try Existing Patterns

1. **Curation**
2. **Proofs of human or compute work**
3. Identity
4. Reputation
5. Governance / software updates
6. Third-party arbitration
7. …

2.1 Patterns for Curation

- **Binary** membership: Token Curated Registry (TCR)
- **Discrete-valued** membership: Stake Machines
- **Continuous-valued** membership: Curation Markets characterized by bonding curve
- **Hierarchical** membership: each label gets a TCR
- **Work** tied to membership: Proofed Curation Market
- **Non-fungible** tokens: Re-Fungible Tokens

2.2 Patterns for Proofs of Compute Work



Case Study: Analysis of Bitcoin

Bitcoin objective function

Objective: Maximize security of network

- Where “security” = compute power
- Therefore, super expensive to roll back changes to the transaction log

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Objective: Maximize security of network

- Where “security” = compute power
- Therefore, super expensive to roll back changes to the transaction log

$$E(R_i) \; \alpha \; H_i * T$$

E() = expected value

block rewards

hash power of actor = contribution to “security”

# tokens (BTC) dispensed each block

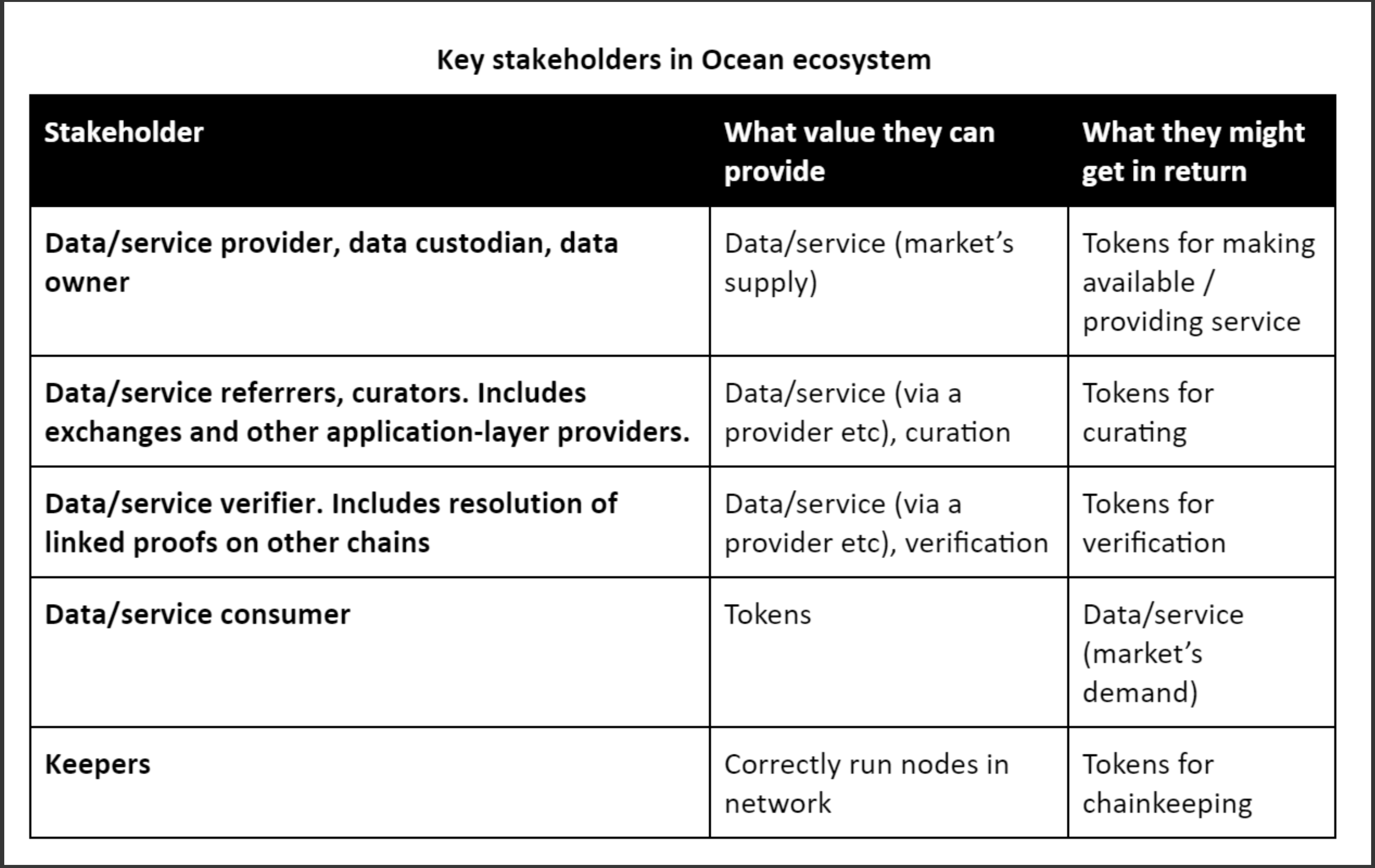
Result of Bitcoin’s objective function:

People are maximizing security! = Maximizing electricity

More power than USA by mid 2019

Case Study: Design of Ocean

1. Formulate the Problem:
(a) Who are stakeholders? What do they want?



Key stakeholders in Ocean ecosystem

Stakeholder	What value they can provide	What they might get in return
Data/service provider, data custodian, data owner	Data/service (market's supply)	Tokens for making available / providing service
Data/service referrers, curators. Includes exchanges and other application-layer providers.	Data/service (via a provider etc), curation	Tokens for curating
Data/service verifier. Includes resolution of linked proofs on other chains	Data/service (via a provider etc), verification	Tokens for verification
Data/service consumer	Tokens	Data/service (market's demand)
Keepers	Correctly run nodes in network	Tokens for chainkeeping

1. Formulate the problem:
(b) Translate into objectives and constraints

Objective function: maximize supply of relevant data

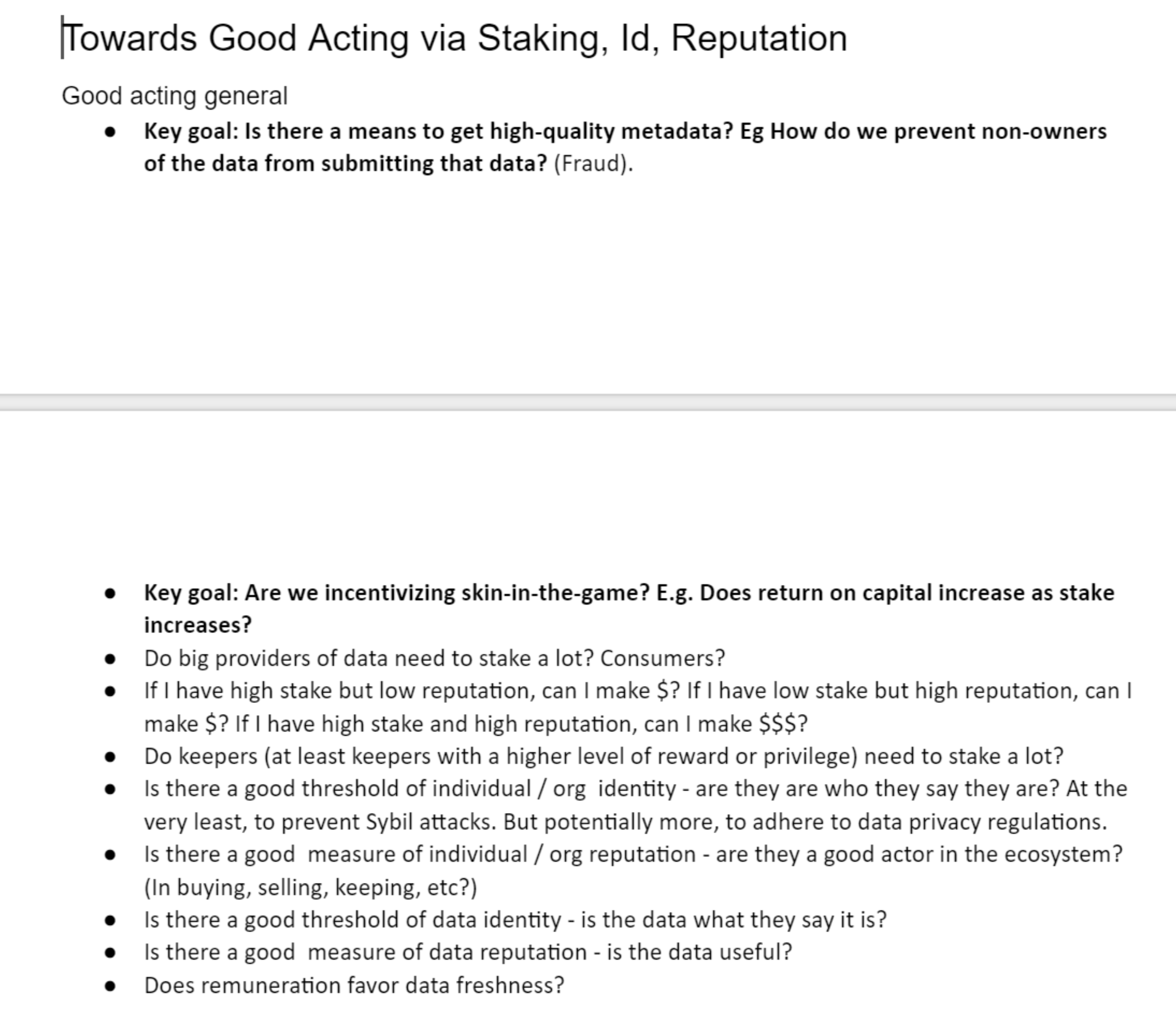
Token rewards if: supply relevant data
Token rewards if: supply data, and curate it

1. Formulate the problem: (b) Translate into objectives & constraints

Constraints = checklist:

- For priced data, is there incentive for supplying more? Referring?
- For priced data, good spam prevention?
- For free data, is there incentive for supplying more? Referring?
- For free data, good spam prevention?
- Does the token give higher marginal value to users of the network versus external investors? Eg Does return on capital increase as stake increases?
- Are people incentivized to run keepers?
- Is it simple? Is onboarding low-friction?

1. Formulate the problem:
(b) Translate into objectives & constraints



Towards Good Acting via Staking, Id, Reputation

Good acting general

- **Key goal: Is there a means to get high-quality metadata? Eg How do we prevent non-owners of the data from submitting that data?** (Fraud).

- **Key goal: Are we incentivizing skin-in-the-game? E.g. Does return on capital increase as stake increases?**
- Do big providers of data need to stake a lot? Consumers?
- If I have high stake but low reputation, can I make $? If I have low stake but high reputation, can I make $? If I have high stake and high reputation, can I make $$$?
- Do keepers (at least keepers with a higher level of reward or privilege) need to stake a lot?
- Is there a good threshold of individual / org identity - are they are who they say they are? At the very least, to prevent Sybil attacks. But potentially more, to adhere to data privacy regulations.
- Is there a good measure of individual / org reputation - are they a good actor in the ecosystem? (In buying, selling, keeping, etc?)
- Is there a good threshold of data identity - is the data what they say it is?
- Is there a good measure of data reputation - is the data useful?
- Does remuneration favor data freshness?

2. Try Existing Patterns
Some patterns:

1. Actor registry
2. Data registry
3. Actor registry + data registry
4. Data registry + free-as-in-beer data curation market.
   Curation: Pay tokens to listen.

2. Try existing patterns: evaluate on objectives & constraints. None passed…

Key Question	1	2	3	4
For priced data: incentive for supplying more? Referring?	✗	≈	✓	≈
For priced data: good spam prevention?	≈	✓	✓	✓
For free data: incentive for supplying more? Referring?	✗	≈	✗	✓
For free data: good spam prevention?	≈	✓	≈	✓
Does token give higher marginal value to users of the network, vs external investors? Eg Does return on capital increase as stake increases?	✓	✓	✓	✓
Are people incentivized to run keepers?	≈	≈	✓	✓
It simple? Is onboarding low-friction? Where possible, do we use incentives/crypto rather than legal recourse?	✓	✓	≈	≈

3. Try New Patterns
Some patterns:

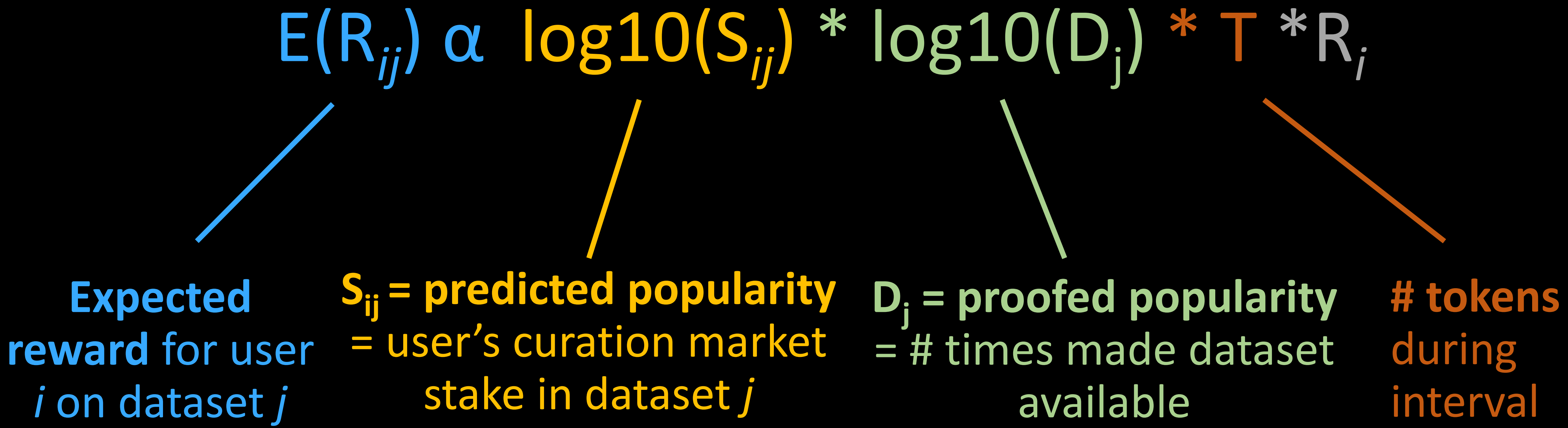
1. Actor registry
2. Data registry
3. Actor registry + data registry
4. Data registry + free-as-in-beer data curation market. Curation: Pay tokens to listen.
5. **Data registry + free data curation market. Curation: Stake tokens as belief in reputation. Auto CDN.**
6. **Actor registry + free&priced data curation market. Curation: Stake tokens as belief in reputation. Auto CDN. "Proofed Curation Market"**

3. Try new patterns: evaluate on objectives & constraints

Key Question	1	2	3	4	5	6
For priced data: incentive for supplying more? Referring?	✗	≈	✓	≈	≈	✓
For priced data: good spam prevention?	≈	✓	✓	✓	✓	✓
For free data: incentive for supplying more? Referring?	✗	≈	✗	✓	✓	✓
For free data: good spam prevention?	≈	✓	≈	✓	≈	✓
Does token give higher marginal value to users of the network, vs external investors? Eg Does return on capital increase as stake increases?	✓	✓	✓	✓	✓	✓
Are people incentivized to run keepers?	≈	≈	✓	✓	✓	✓
It simple? Is onboarding low-friction? Where possible, do we use incentives/crypto rather than legal recourse?	✓	✓	≈	≈	✓	✓

Objective: maximize supply of relevant data

- **Reward curating data (staking on it) + making it available**
- **New pattern: Proofed Curation Market**



$$E(R_{ij})\ \alpha\ \log10(S_{ij}) * \log10(D_j) * T * R_i$$

Expected reward for user *i* on dataset *j*

S_{ij} = predicted popularity = user’s curation market stake in dataset *j*

D_j = proofed popularity = # times made dataset available

# tokens during interval

From AI data to AI *services*

Motivations:

- **Privacy, so compute on-premise or decentralized**
- **Data is heavy, so compute on-premise**
- **Link in emerging decentralized AI compute**

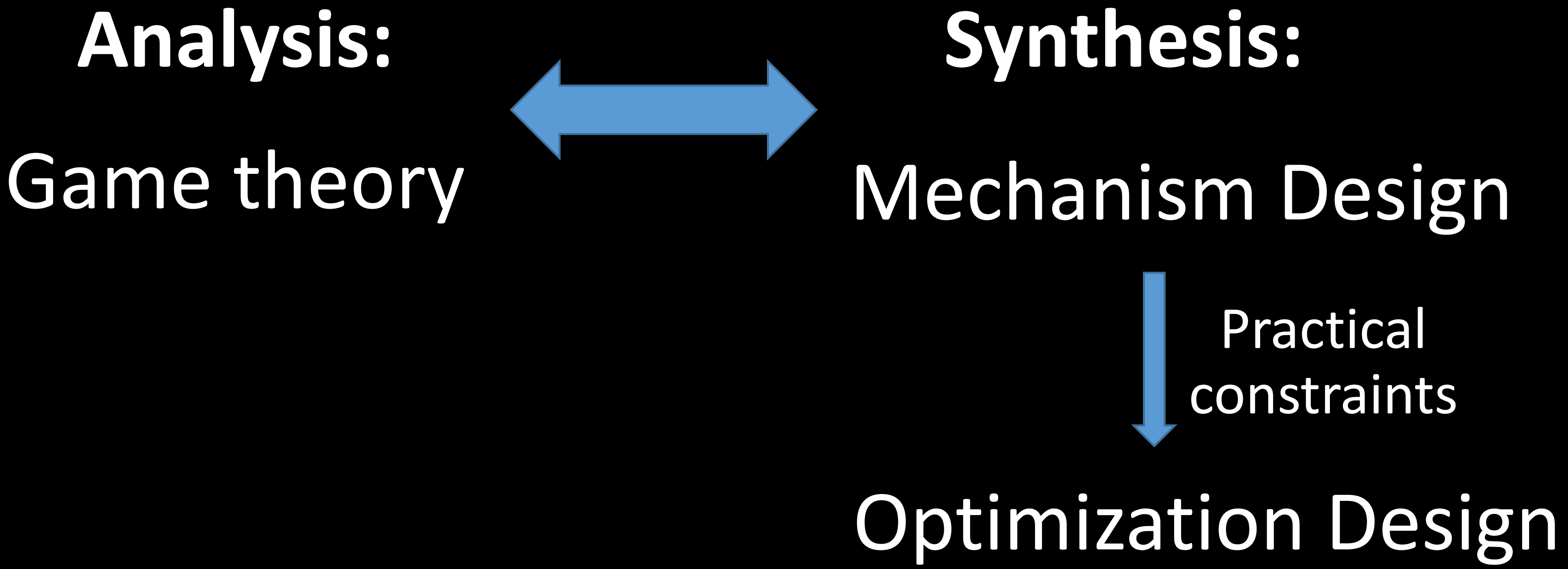
Objective function: Maximize supply of relevant *services*

=reward curating *services* + proving that it was delivered

$$E(R_{ij})\ \alpha\ \underbrace{\log10(S_{ij})}_{\textbf{predicted popularity}\ \text{of}\ \textit{service}} * \underbrace{\log10(D_j)}_{\textbf{proofed popularity}\ \text{of}\ \textit{service}} * T * R_i$$

#TokenEngineering

Design of Tokenized Ecosystems
From Mechanism Design to *Token Engineering*



Analysis:

Game theory

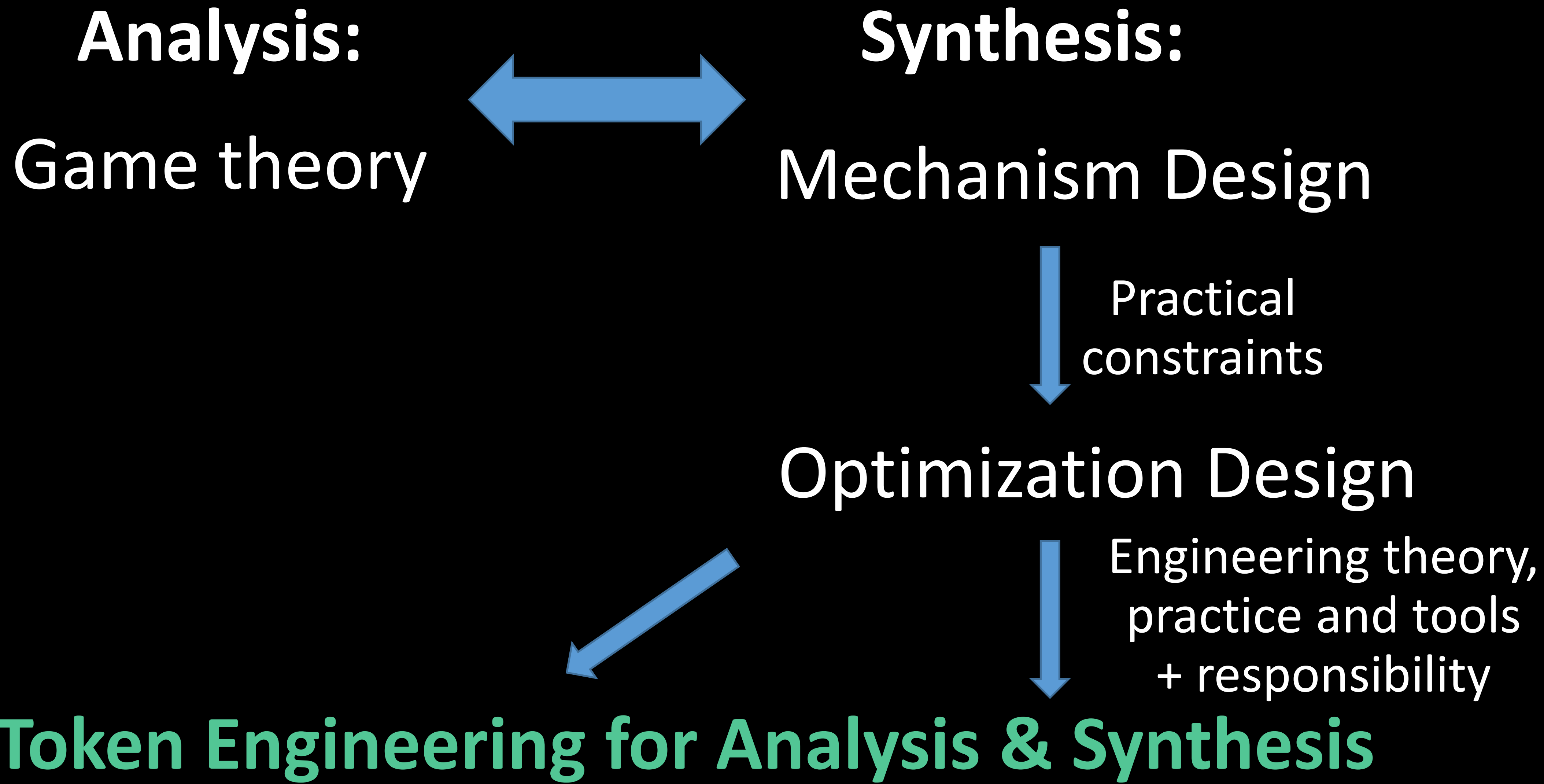
Synthesis:

Mechanism Design

Practical constraints

Optimization Design

Design of Tokenized Ecosystems
From Mechanism Design to *Token Engineering*



Analysis:

Game theory

Synthesis:

Mechanism Design

Practical constraints

Optimization Design

Engineering theory, practice and tools + responsibility

Token Engineering for Analysis & Synthesis

Conclusion

Conclusion:
Towards a Practice of #TokenEngineering

- Token design ≈ optimization design
- So, approach token design as optimization design!
  1. Formulate problem. Objectives, constraints.
  2. Try existing patterns. Iterate.
  3. If needed, try new design.
- This process helped a *lot* for designing Ocean (so far)
- Token Engineering = Theory + practice + tools + responsibility

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ocean