Evolving Autonomous Networks

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Rakuten

Rakuten Mobile Innovation Studio

Evolving Autonomous Networks

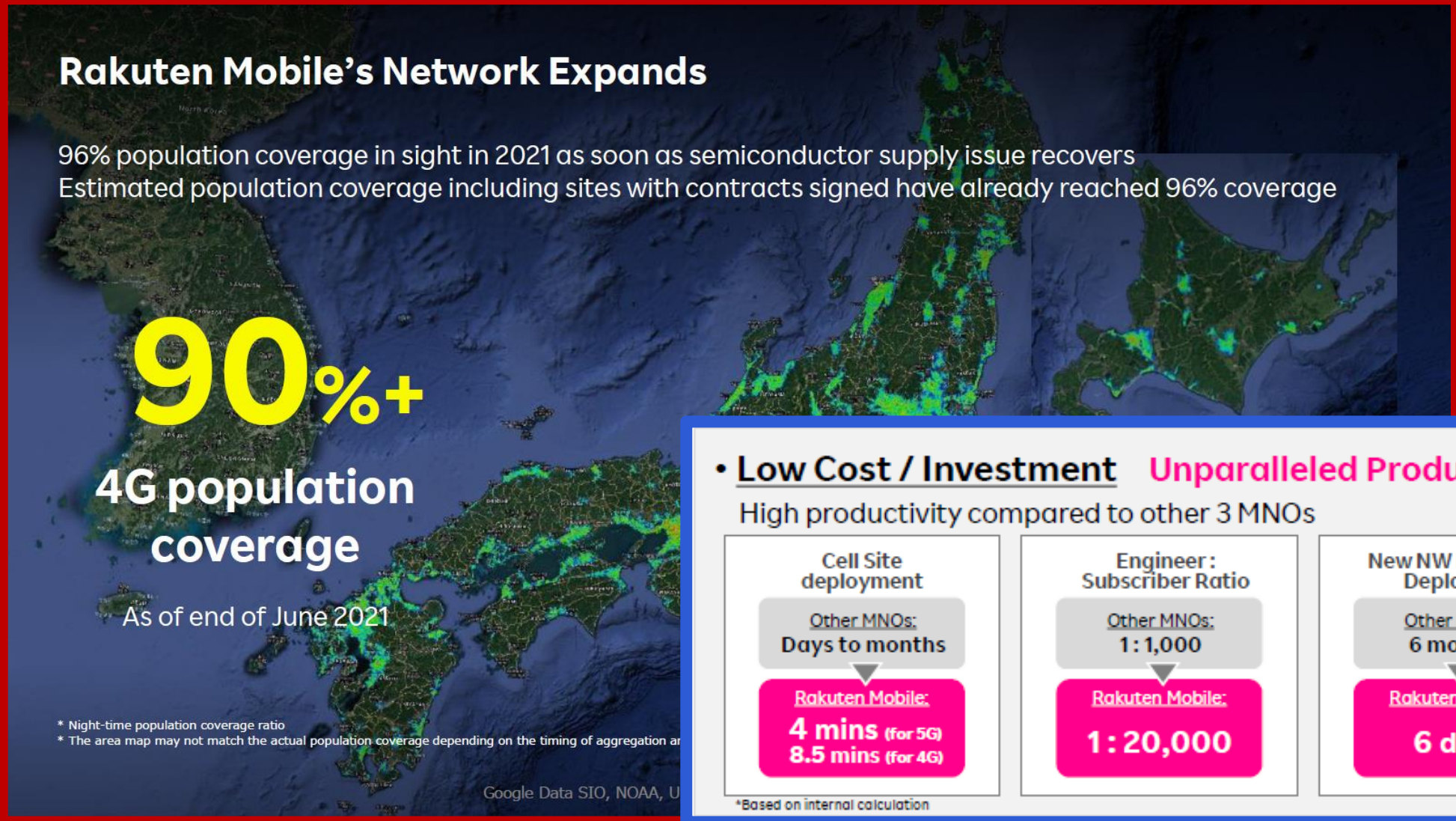
Content presented here is based on my colleagues work and art

They are much more expert than me on the inner workings and dirty details

All hard questions and complaints should be sent to them :-)

Thank you !

Rakuten Mobile



• **Low Cost / Investment** **Unparalleled Productivity**

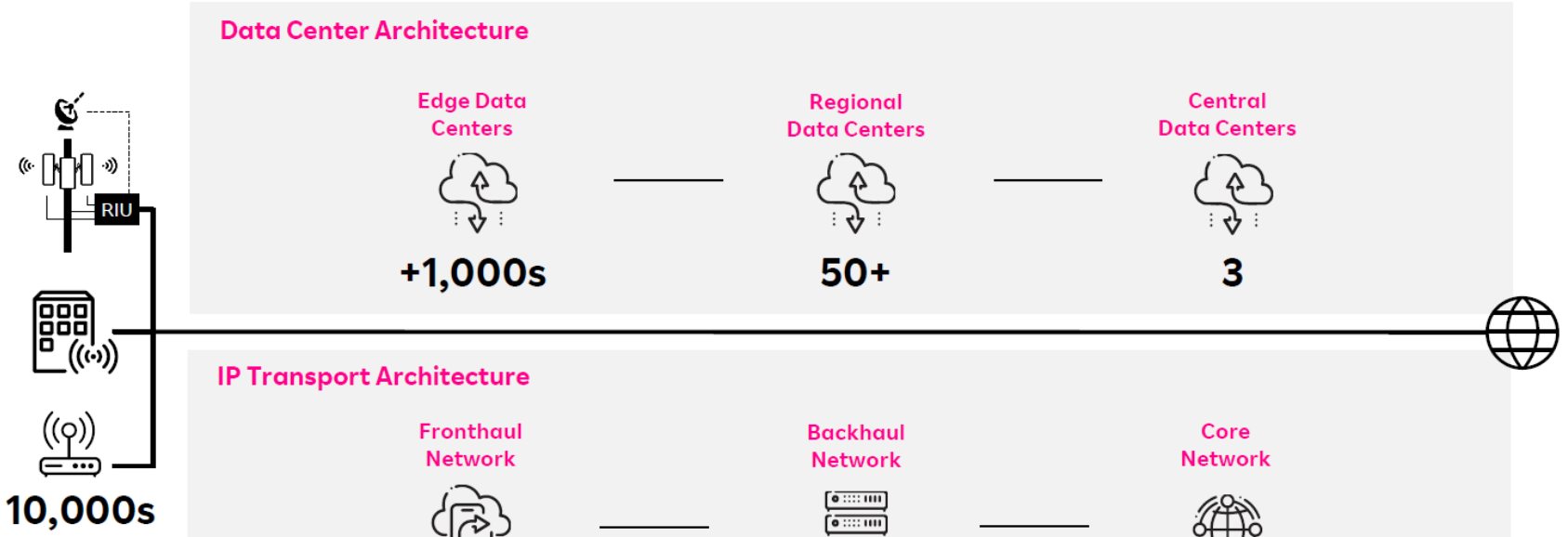
High productivity compared to other 3 MNOs

Cell Site deployment	Engineer : Subscriber Ratio	New NW Feature Deployed
Other MNOs: Days to months	Other MNOs: 1 : 1,000	Other MNOs: 6 months
Rakuten Mobile: 4 mins (for 5G) 8.5 mins (for 4G)	Rakuten Mobile: 1 : 20,000	Rakuten Mobile: 6 days

*Based on internal calculation

Rakuten Mobile

Highly Advanced Large Mobile EDGE Data Network

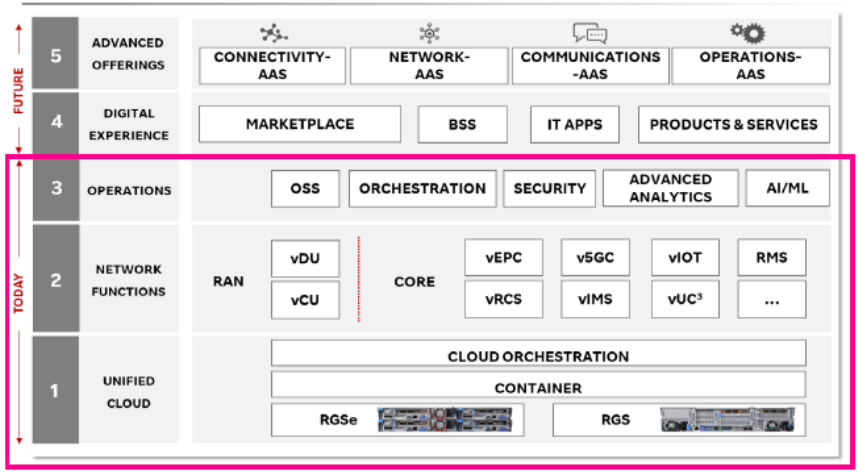


Rakuten Communications Platform (RCP)

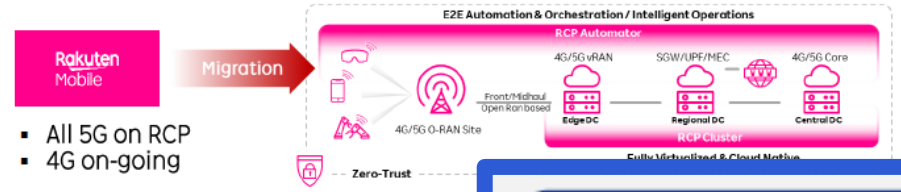
Global Deployment of Cloud-native 5G Network

Rakuten Communications Platform

RCP E2E Full Stack View

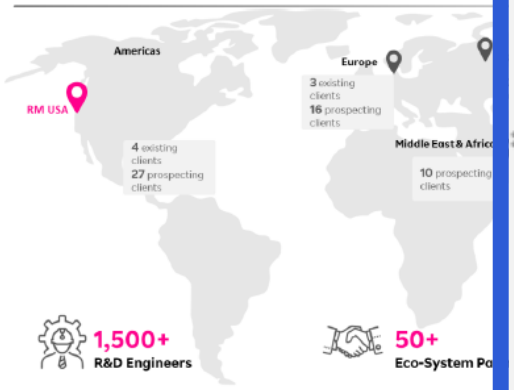


Rakuten Mobile Migration to RCP



- All 5G on RCP
- 4G on-going

RCP Global Presence



Key Design Principles

- Exchange and consumption of products and services
- Intuitive and simple digital experience
- Advanced automation for touchless operations
- 100% disaggregation from hardware
- Open architecture
- 100% cots hardware
- Elasticity with containers to scale at low cost

1&1 AG

- Green field 4G/5G NW deployment by 1&1, a leading telco in Germany
- Rakuten to support 1&1 with RCP technology
- 1&1 to become the first operator in Europe to deploy a nationwide cloud-native Open RAN mobile network

Rakuten Mobile Innovation Studio

Autonomous Networking Division

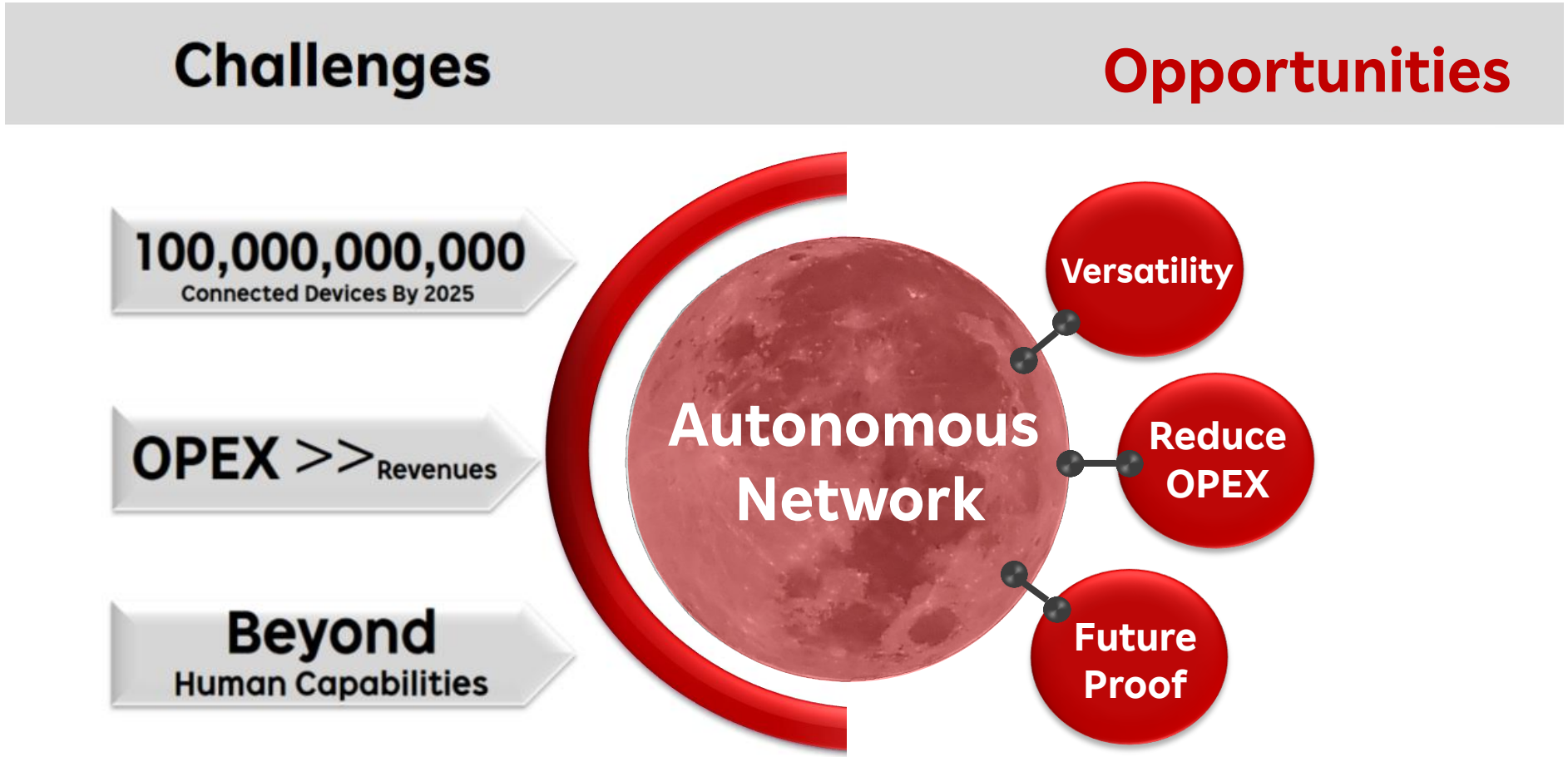
Dedicated to making **Truly Autonomous Networks** a reality

Team of PhD researchers, SW engineers & experienced Telco professionals

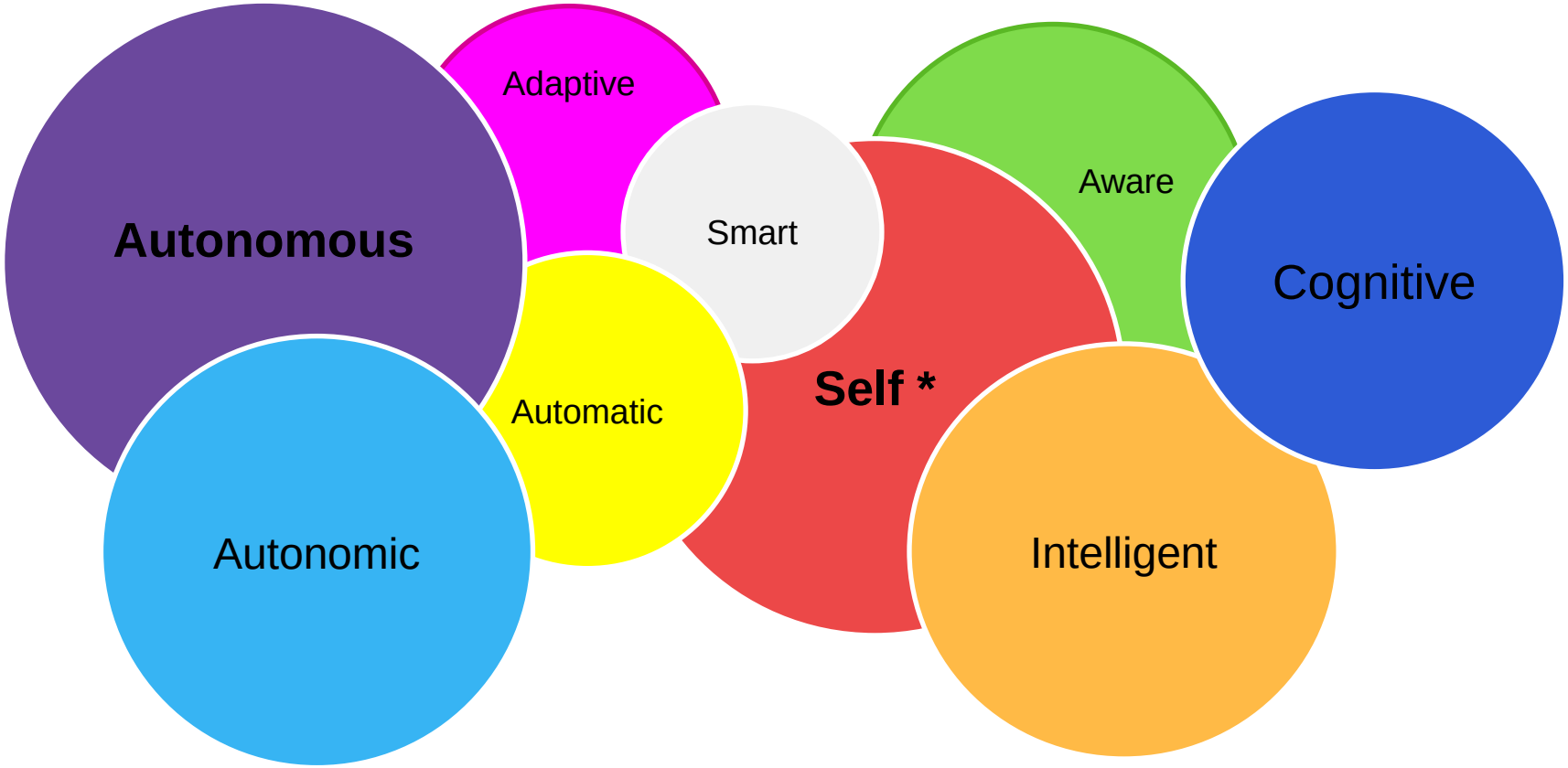
Why Autonomous Networks ?

Peter Baer

Why Autonomous Networks ?



What is Autonomy ?



No single, universally applicable and agreed definition of autonomous networking

But we can refer to common principles and properties

Self-CHOP [*]

Self-configuration

- Adapt to changing conditions by changing their own configurations
- Addition and removal of components or resources without service disruption

Self-healing

- Recognize and diagnose deviations from normal conditions and take action to normalize them
- Proactively circumvent issues that could cause service disruptions

Self-optimization

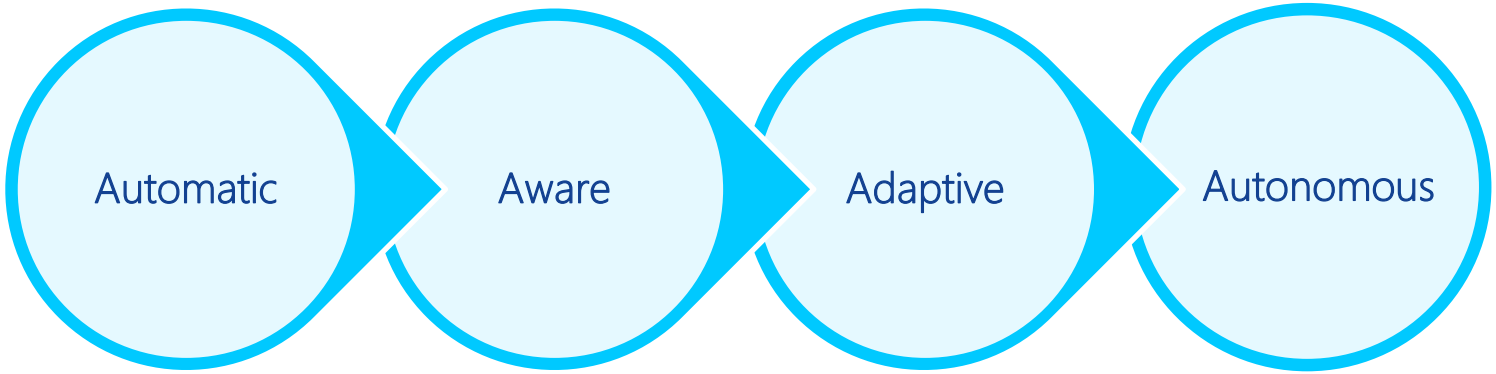
- Constantly monitor predefined system goals and performance levels to ensure that all systems run at optimum levels

Self-protection

- Incorporation of intelligence to recognize and circumvent security threats

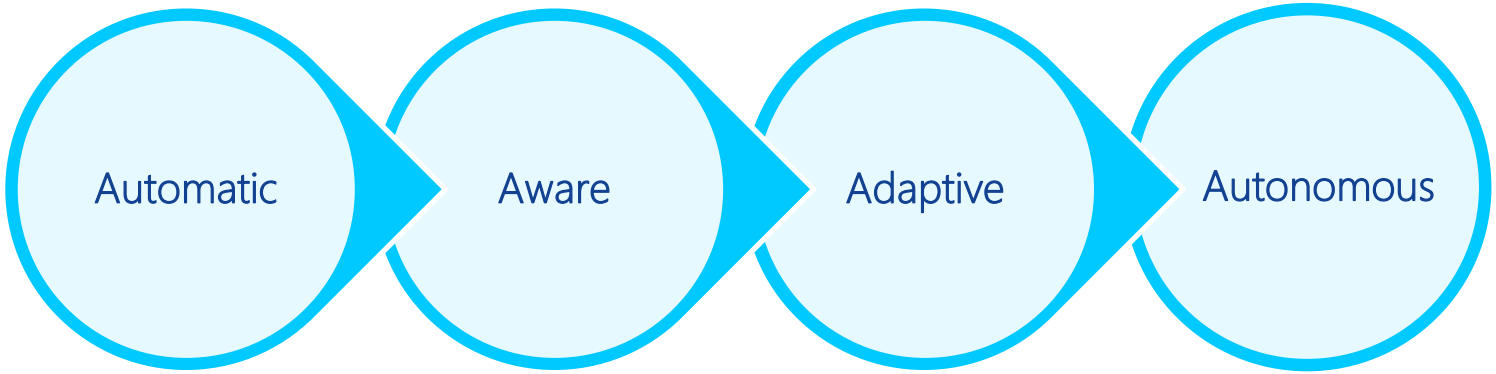
[*] "The vision of autonomic computing" by J.O. Kephart et al.

The four ‘A’



- **Automatic,** because machines are more proficient for systematic and exhaustive tasks than humans
- **Aware,** to gain situational awareness and guide reactive/proactive decision processes
- **Adaptive,** to change its decisions and operations to maintain value delivery ; because anomalies and (new) attacks are constantly detected
- **Autonomy,** as each event translates into different local actions

The four ‘A’



Collectively, the four properties qualify an autonomic system and are referred to as the 4 ‘A’.

Sometimes, a fifth ‘A’ is added:
- **Abstraction,** to enable coordination between heterogeneous equipment

Ultimately, this boils down to the essential coupling of automation with the intelligence that will drive it towards cognitive operation.

Tackling the automation challenge is necessary but not sufficient. Automation alone can only adapt within the function pre-defined scope and settings. Higher levels of (networked) autonomy can be reached by combining the automatic, aware and adaptive (and abstraction) properties [*].

[*] partially based on “Towards Autonomic Networks” by S. Schmid et al.

An attempt at terms disambiguation

Automatic, automated, automation

that occurs without human intervention

Autonomous, autonomic

that manages itself without external intervention

Cognitive, cognition

that involves intellectual processes involved in gaining knowledge, comprehension, problem solving and decision making…

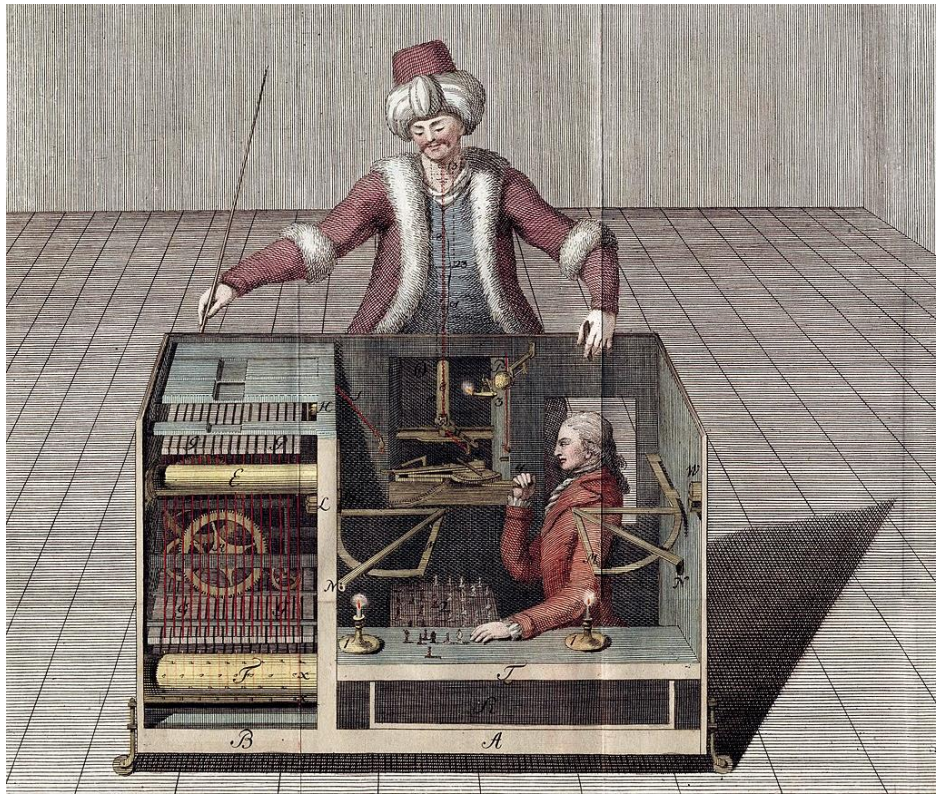
Self-organizing

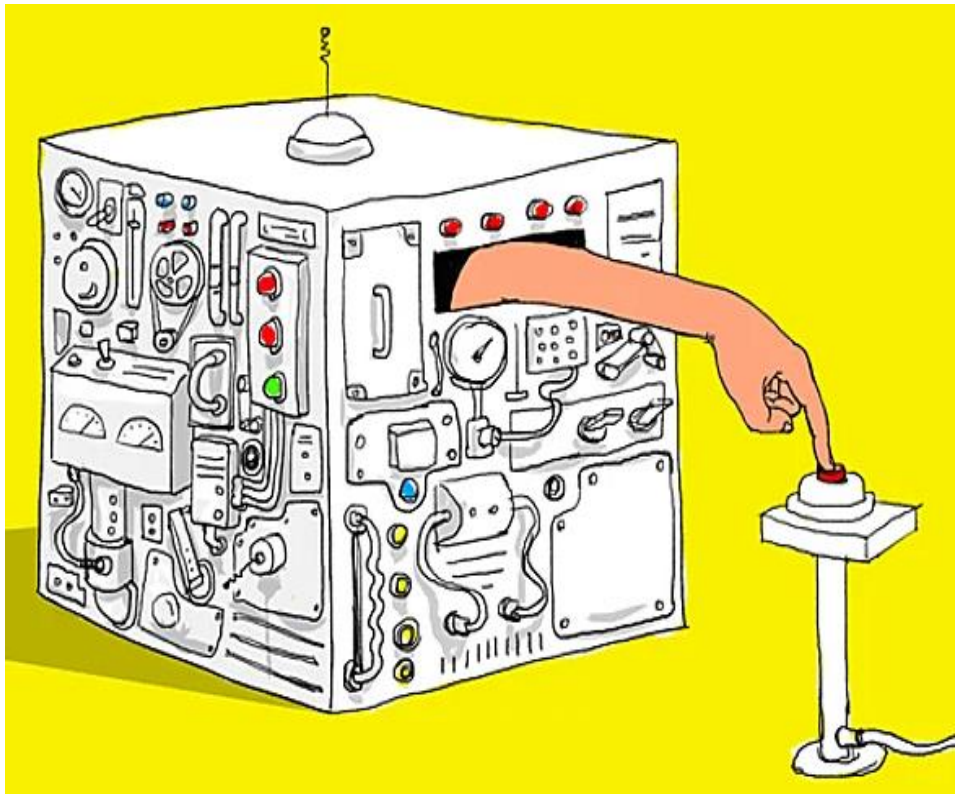
that achieves steady state without external control

Our Goal

Devise an “artificial engineer”

that has the capability to problem-solve with minimal to no human intervention



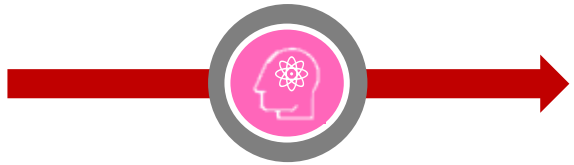


Beyond Automation towards Autonomy

Automation

Independent operation of a system:

- within well-defined parameters
- based on a limited set of predefined rules or constraints



Autonomy

Implies:

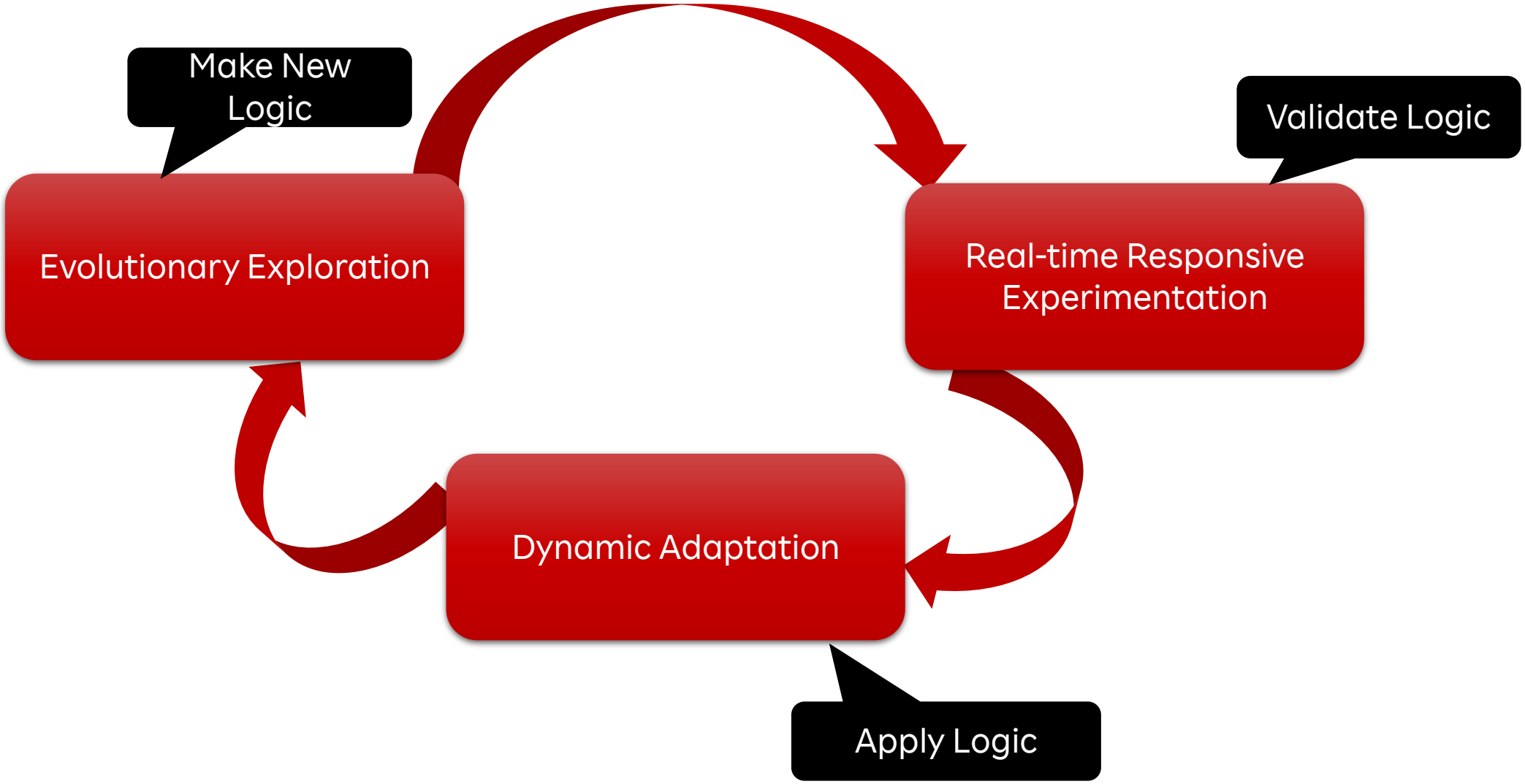
- large degree of adaptation,
- learning and decision making by the system itself.

01 Decide when to act ?

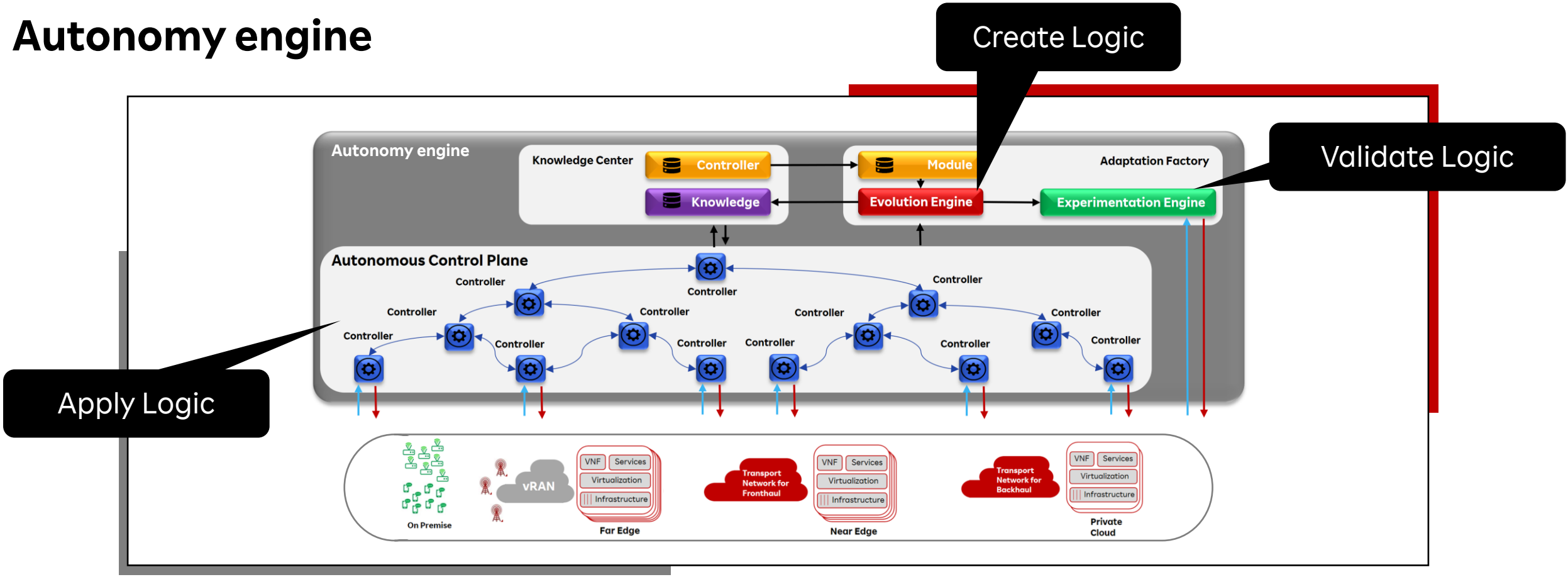
02 Deal with unknown situations ?

03 Invent a new approach ?

Evolving autonomous networks



Autonomy engine

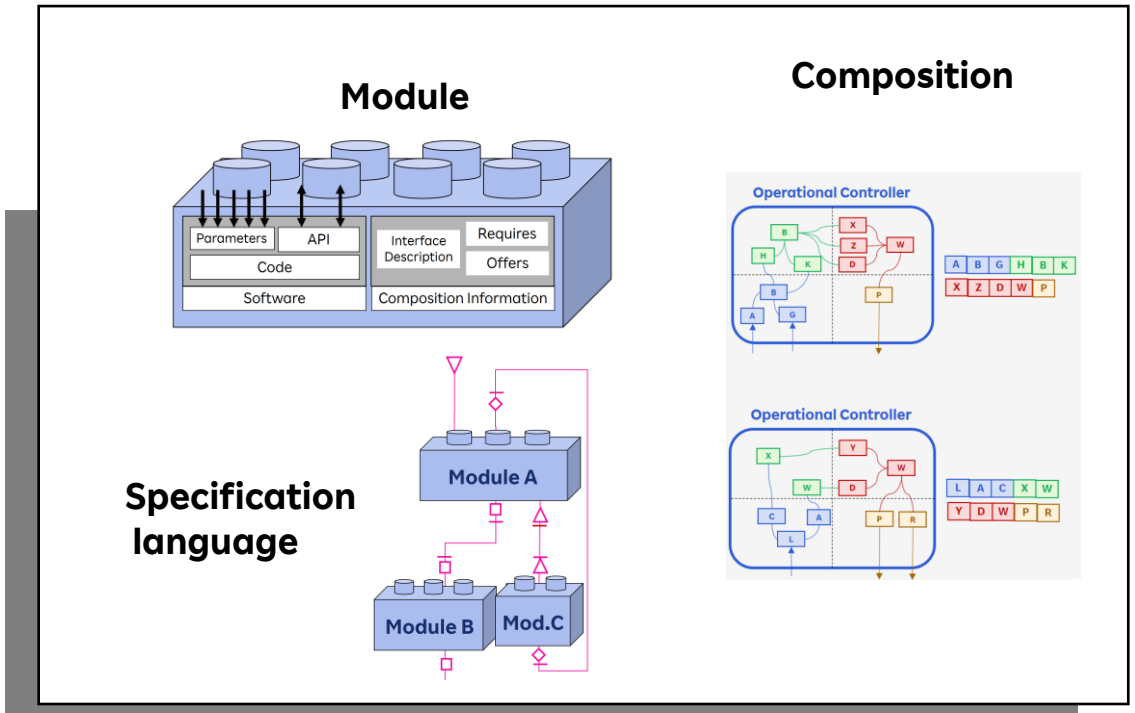


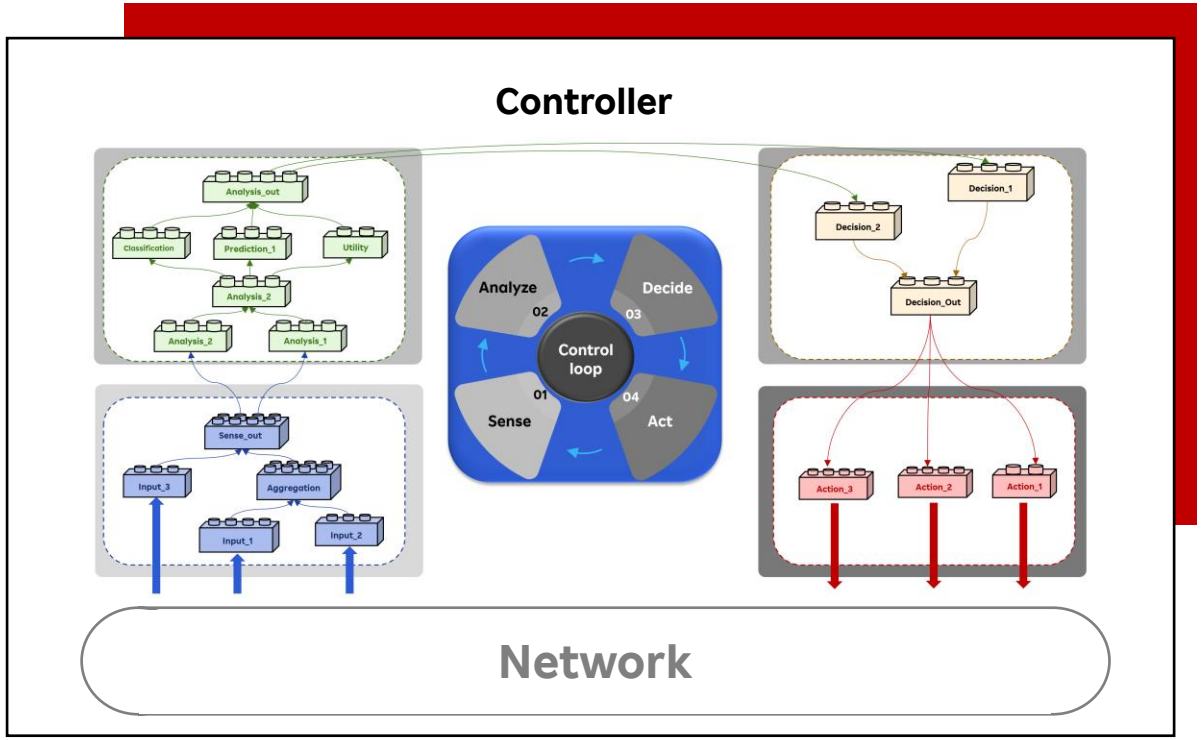
Adaptation Factory
Creating & Validating New Controllers

Autonomous Control Plane
Network Operation & Management

Knowledge Center
Storing Controllers & Knowledge of Different Types

Closed Loop (controller) : How to Apply Logic





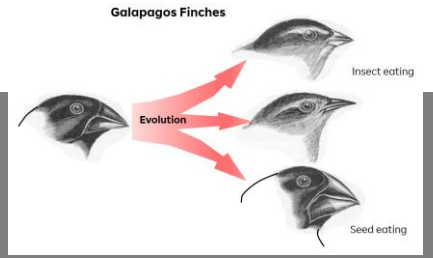
Modularization
What is an autonomous building block?

Specification
How to describe building blocks?

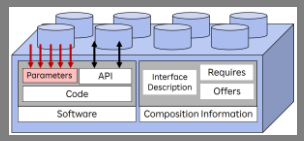
Standardization
What is the right form of interoperability?

Evolution: Make New Logic

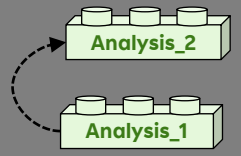
"Codify-able process of creativity."



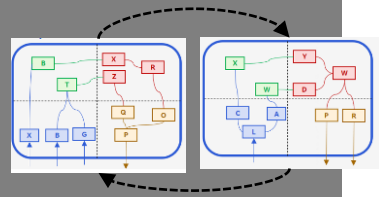
Parameters of a module

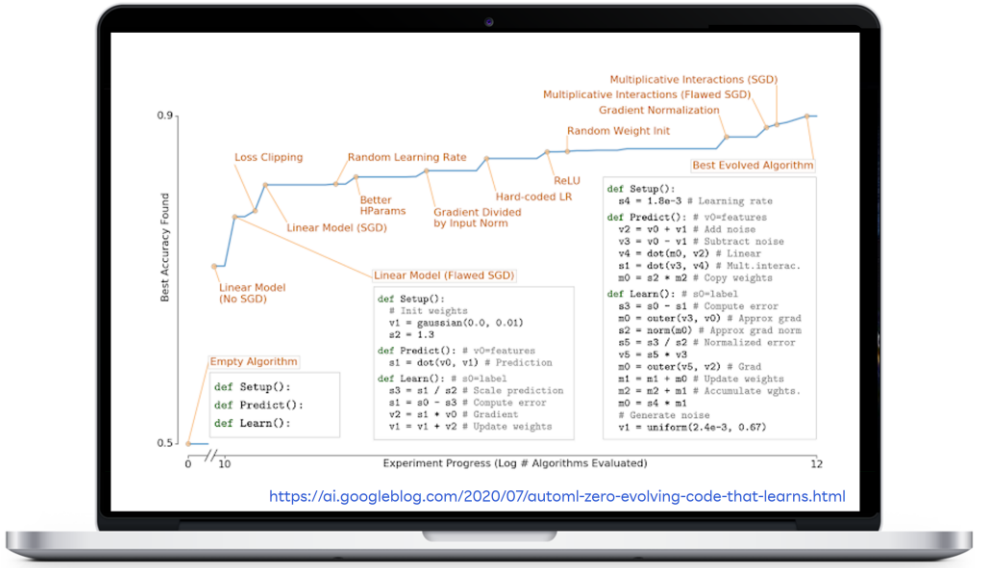


Choice of module



Topology of a controller





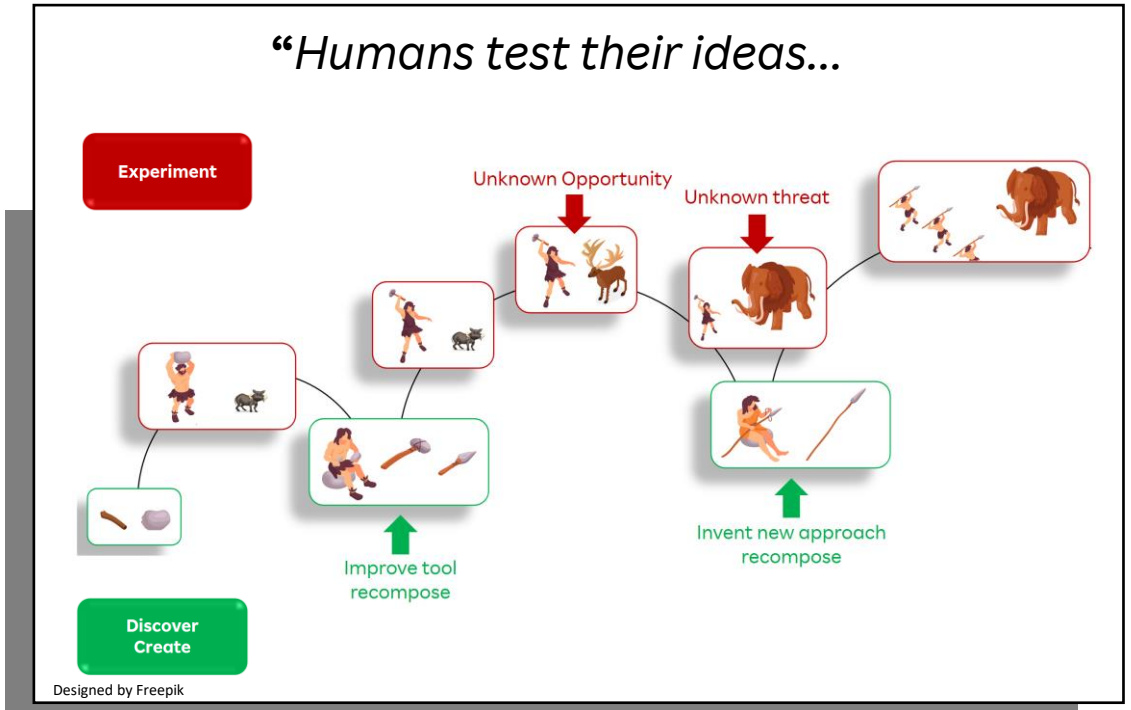
AutoML-Zero: Evolving Code that Learns

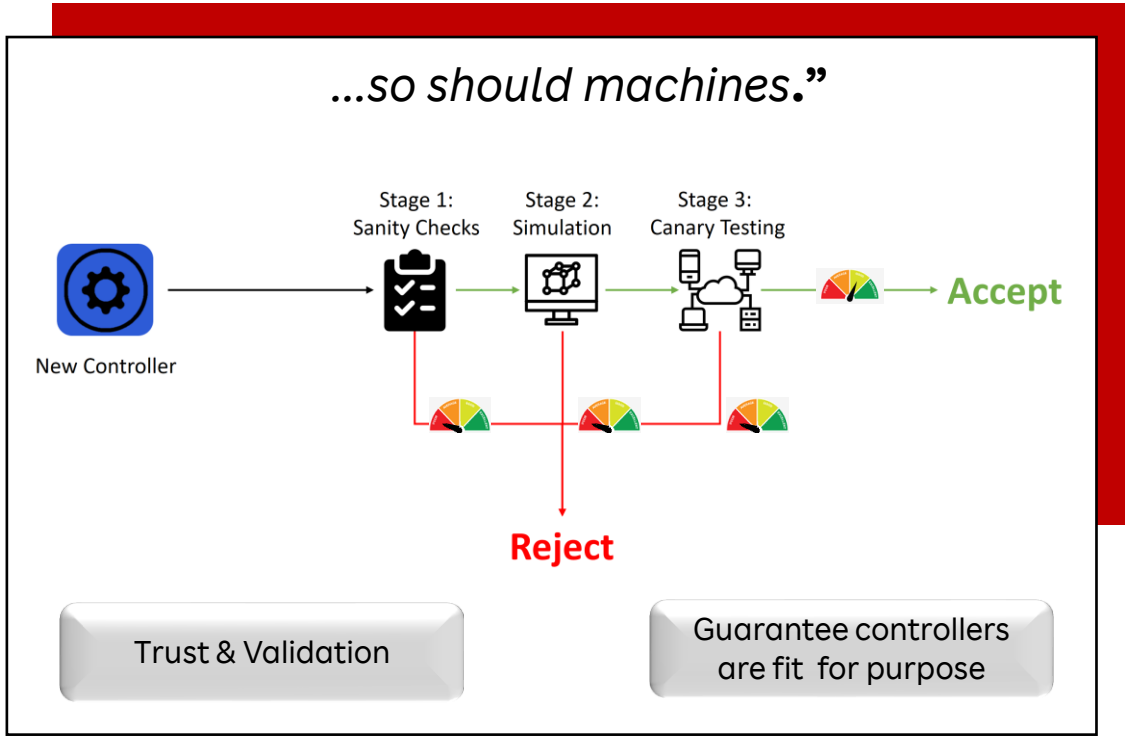
State space
How to reduce the number of possible choices?

Convergence Problem
How can we make the right choices in a reasonable time?

Exploitation vs Exploration
When is the right time to try something new?

Online Experimentation: Validate Logic



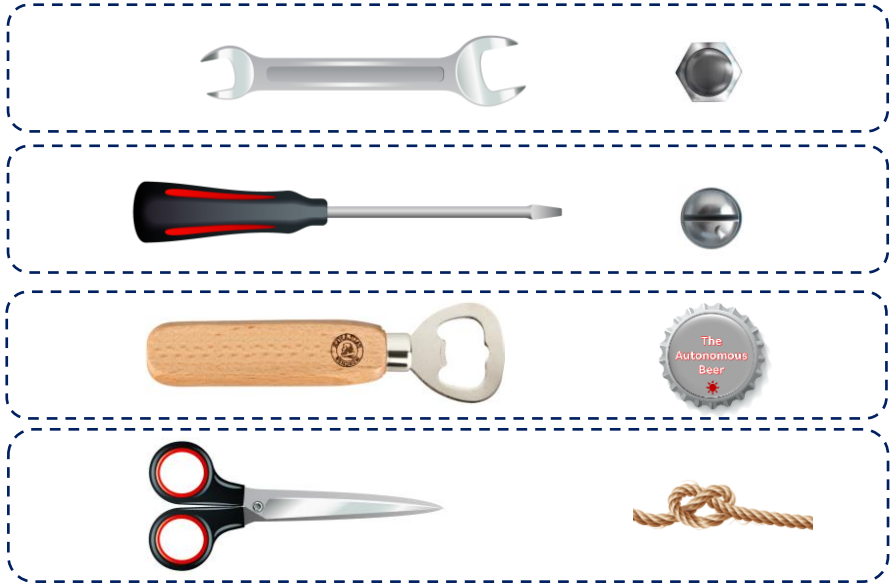


How to recreate an **effective environment** per use case automatically ?

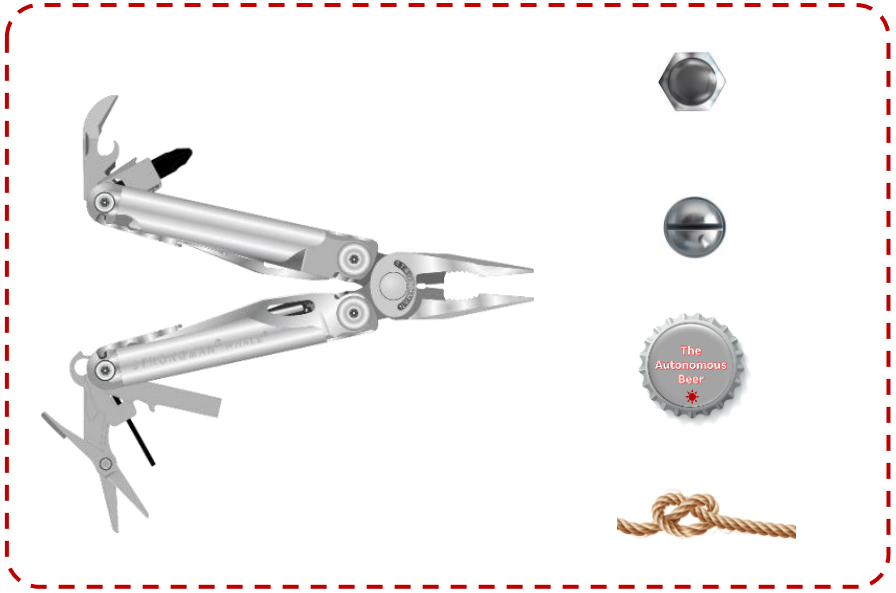
Simulation & Canary Testing
How to balance simulation and Canary testing ?

Digital Twin
How to experiment without breaking the real network?

Specialized approach :one tool per case



Generic approach : Framework

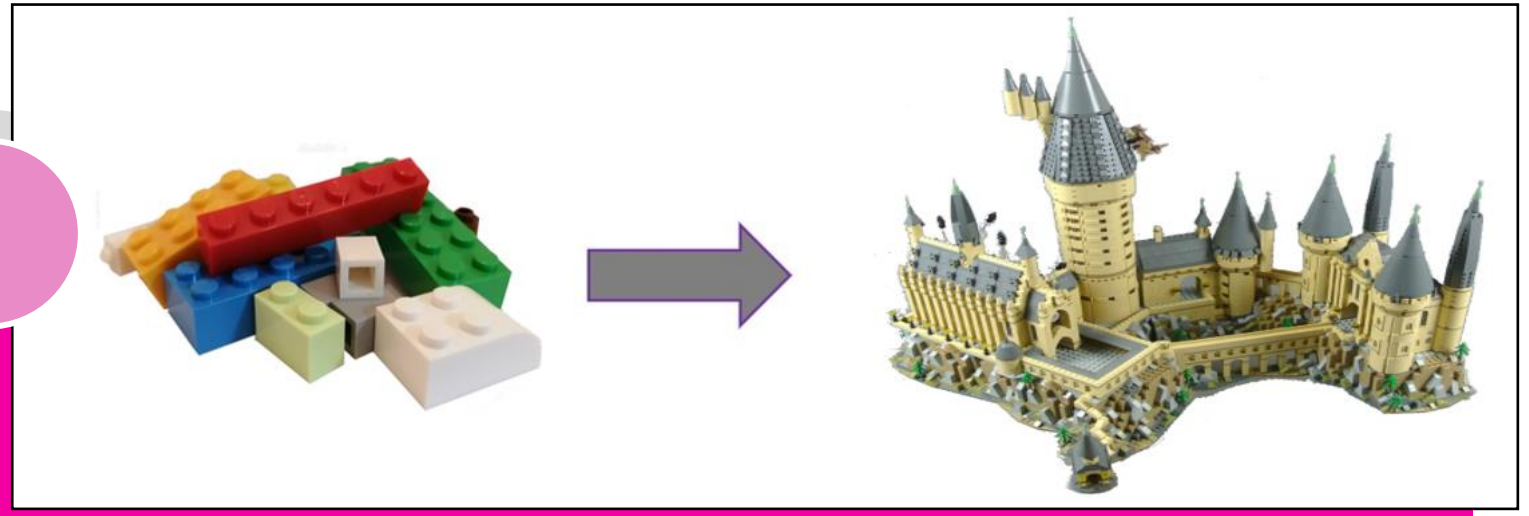


Motivations

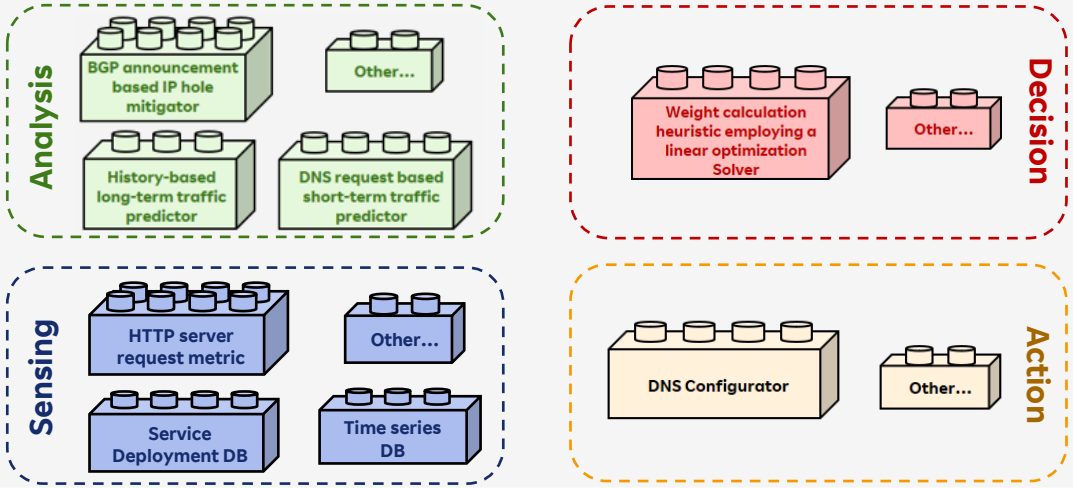
- ✓ Generalization reduces workload
- ✓ Reuse of technology becomes easy
- ✓ All knowledge and state is available

Building Blocks

“All functionality deconstructed into small atomic modules”



Use Case : Traffic Distribution



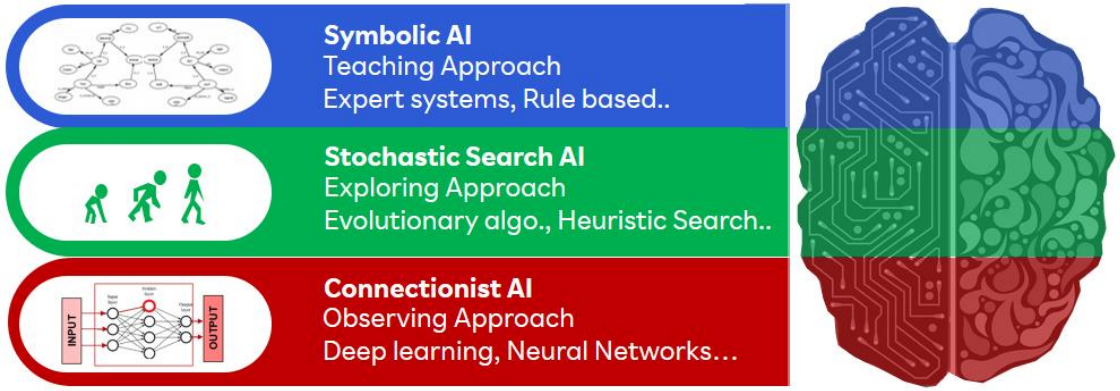
Motivations

- ✓ Re-use across domains
- ✓ Flexible and adaptable
- ✓ Extensibility

Hybrid Intelligence

“The AI / ML / EL to use is just another Functional Building Block . We can use better one, once available”

2



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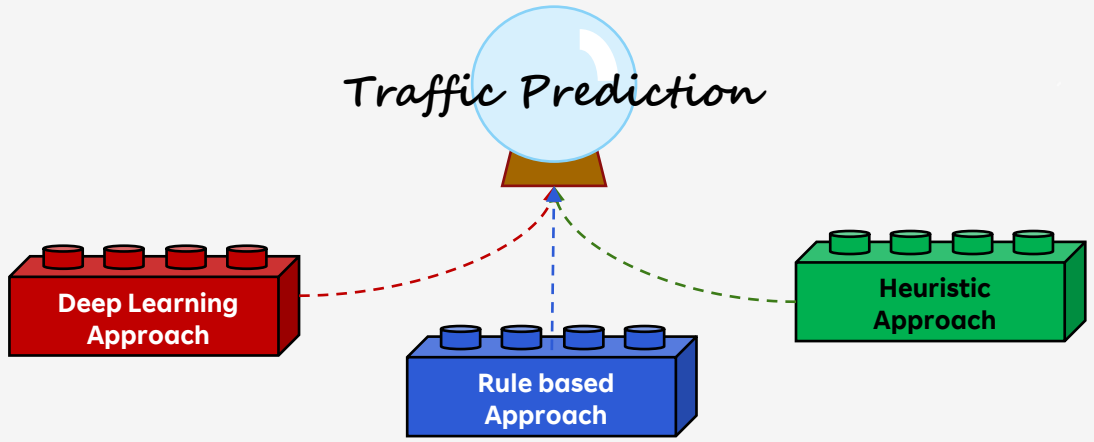


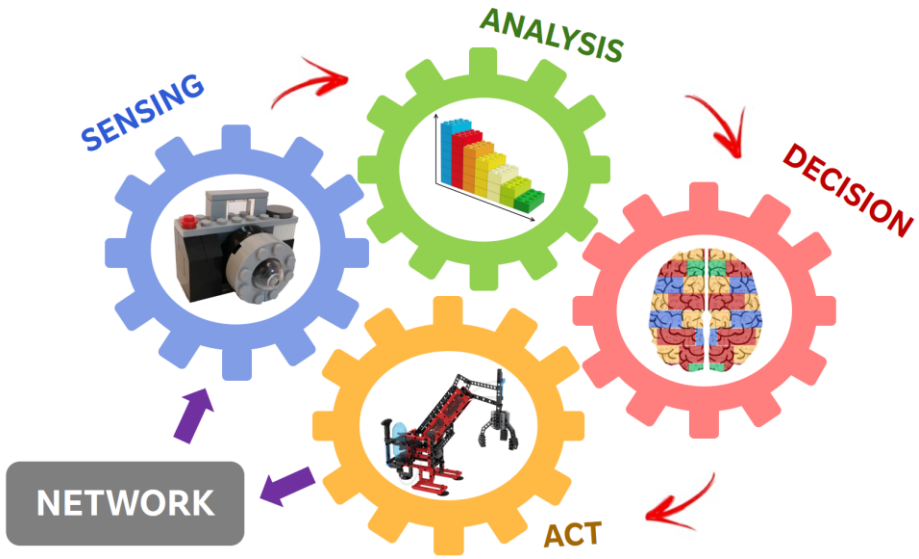
Motivations

- ✓ Ease of new algorithm intro
- ✓ Adaptable to use case / environment
- ✓ It’s just another building block

Cognitive Loop

“We build the fundamental cognitive loop out of atomic modules”

3



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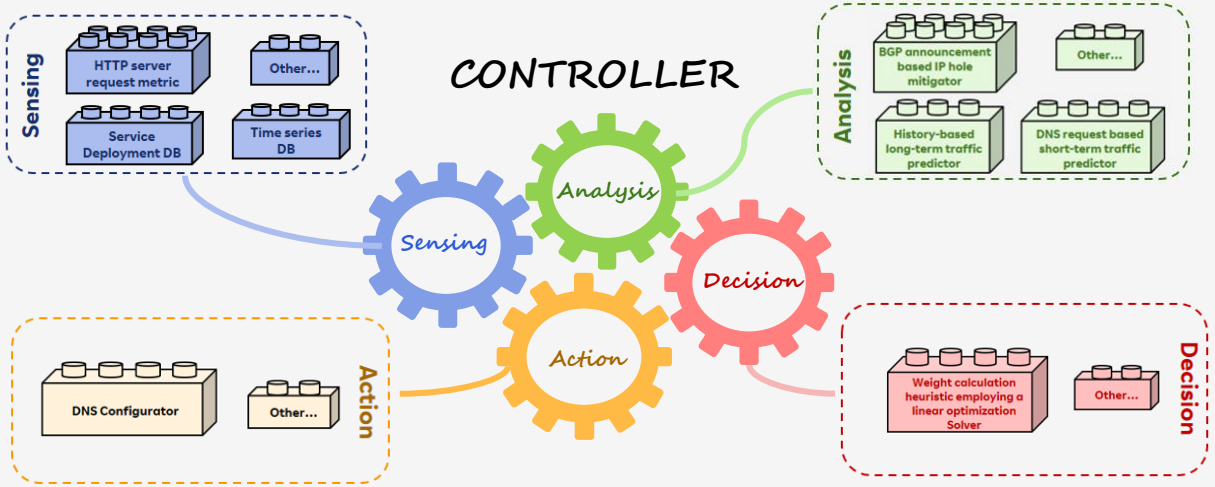


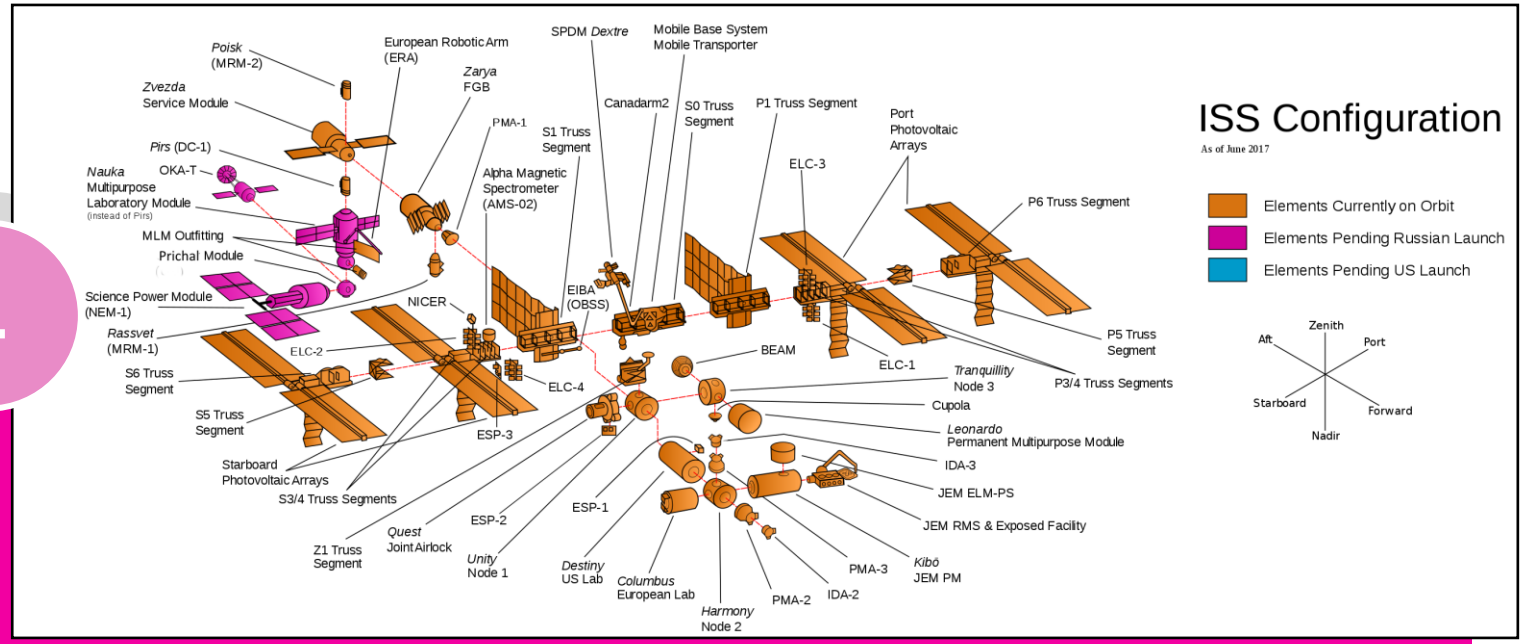
Motivations

- ✓ “Standard” representation of Cognition
- ✓ Same concept can be applied everywhere …and changed as needed.

Composition

“But not just anything can work together. So, we use specialized connectors to ensure modules dock only on to compatible ones.”

4



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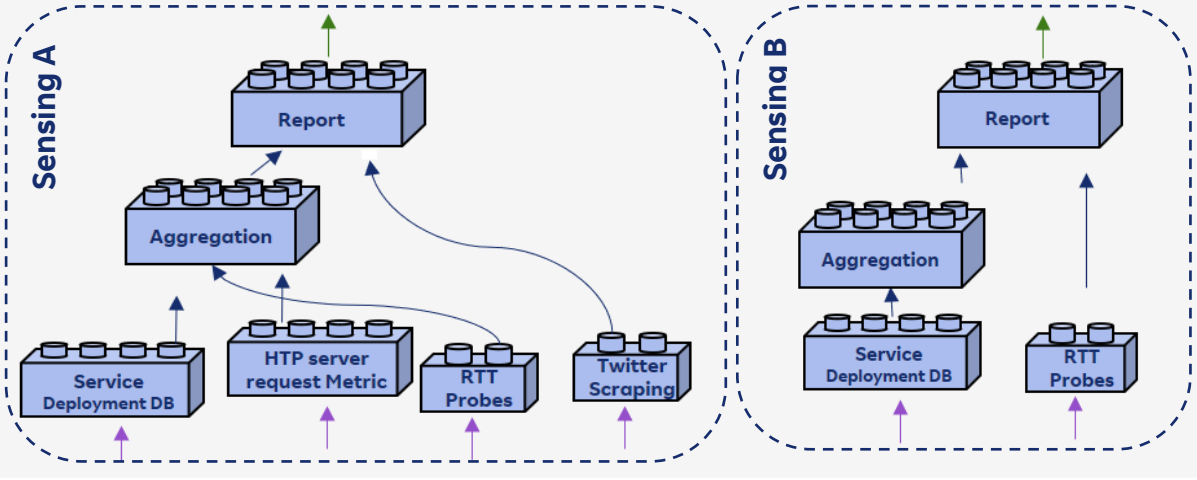


Motivations

- ✓ Ensure API/functionality compatibility
- ✓ Keep the research space manageable
- ✓ Standardized and generalized interfaces improve reuse and replaceability of similar modules.

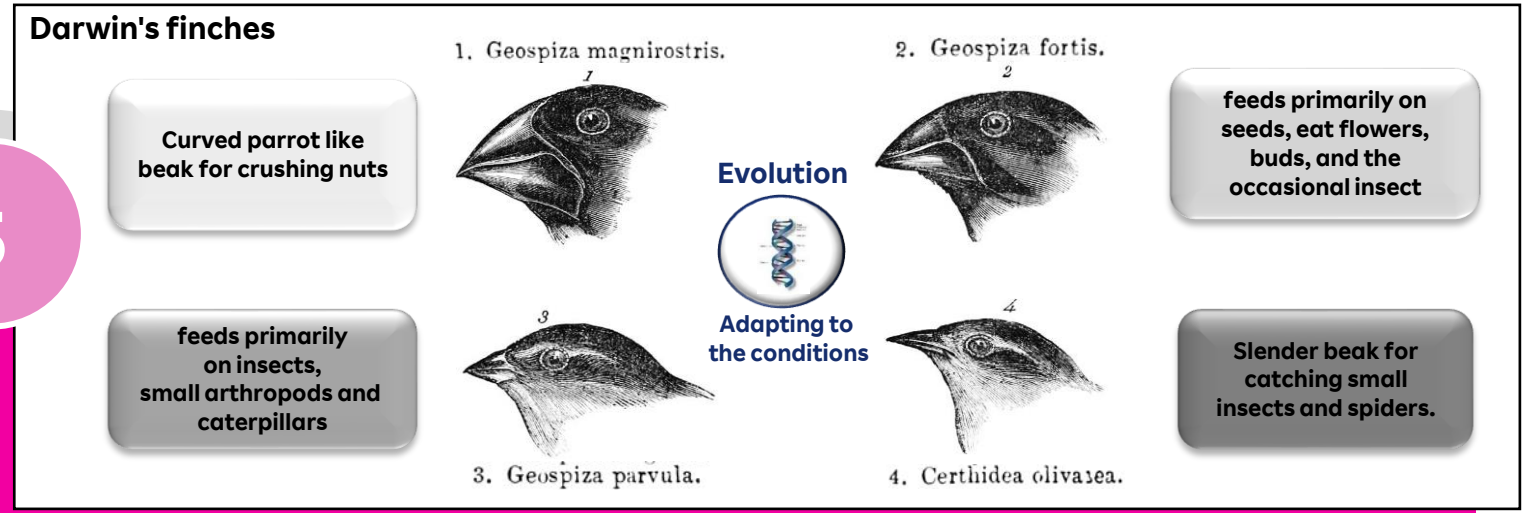
Online Evolution I

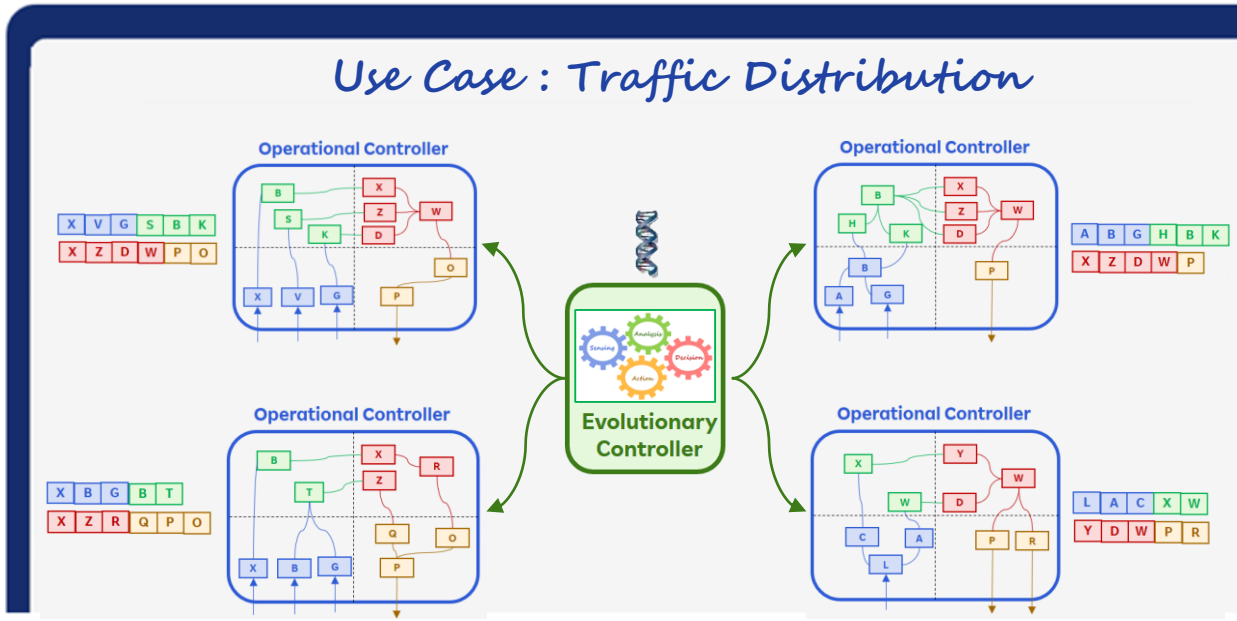
Genetic mutation and recombination

“ gives us the tools, we construct various loops, try them out, improve , so that utility improves

5

Darwin's finches





Motivations

- ✓ Modern networks becoming hard to reason about and simulate
- ✓ Evolution traverses massive search spaces easily.

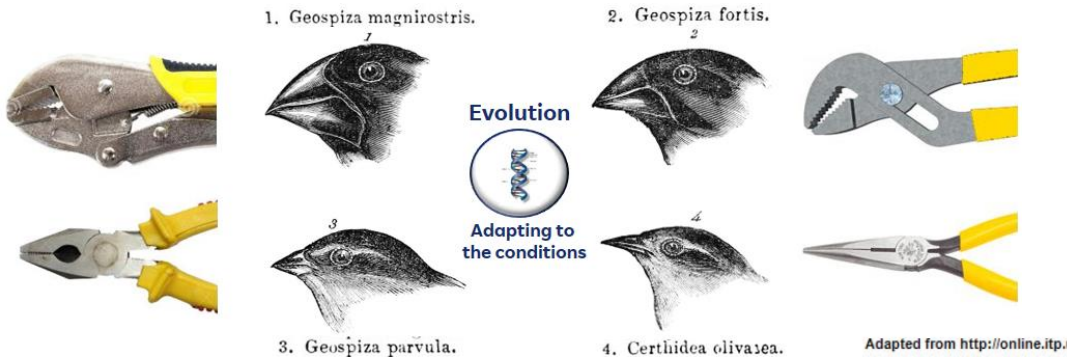
Online Evolution II

Natural Selection

“ trial and error experimentation.”

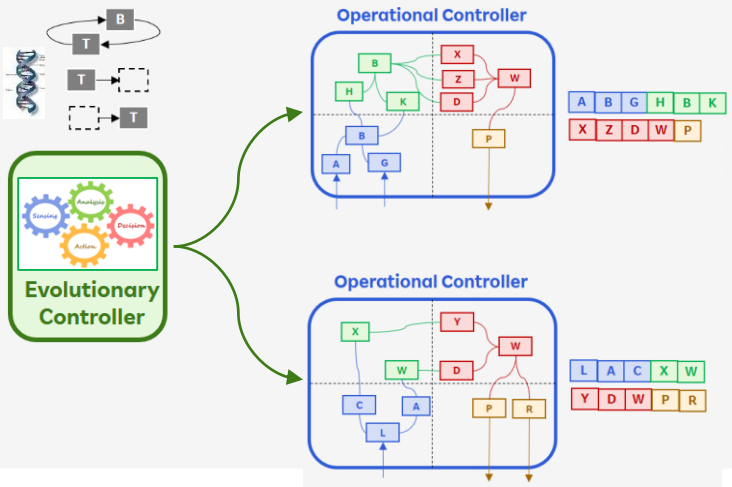
6

Developmental research in 2004 showed that the development of the different beak shapes in Darwin's finches are influenced by slightly different timing and spatial expressions of a **gene called calmodulin (CaM)** and the **bone morphogenetic protein 4 (BMP4)**.



Adapted from http://online.itp.ucsb.edu/plecture/nurse/oh/27.jpg

Use Case : Traffic Distribution



Motivations

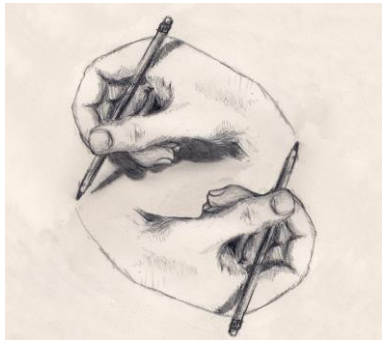
- ✓ Do not require domain knowledge
- ✓ Trying out novel solutions in the net can come out with unexpected Improvements, instead of reflecting the architects' knowledge.

Meta Evolution

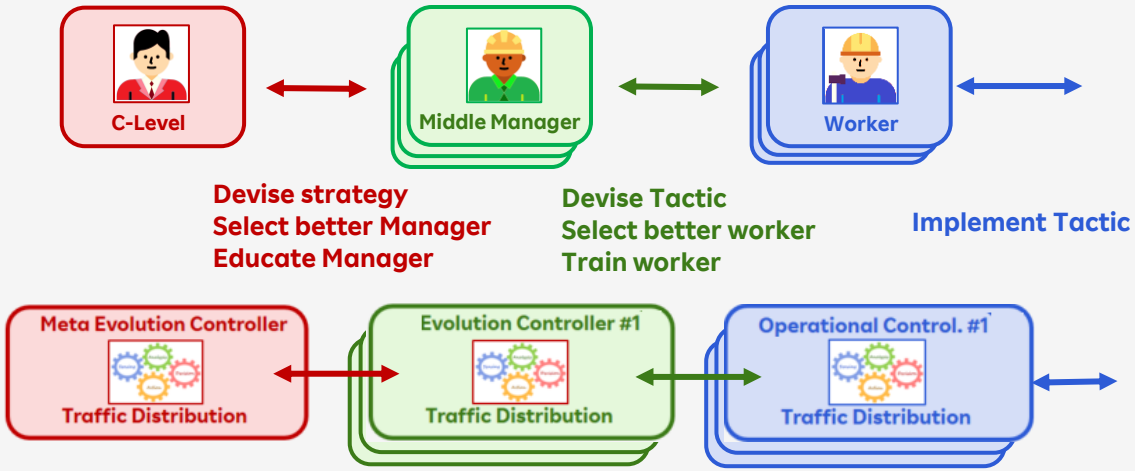
Self reflective

“We construct our loop by means of another loop.”

7



Use Case : Traffic Distribution



Motivations

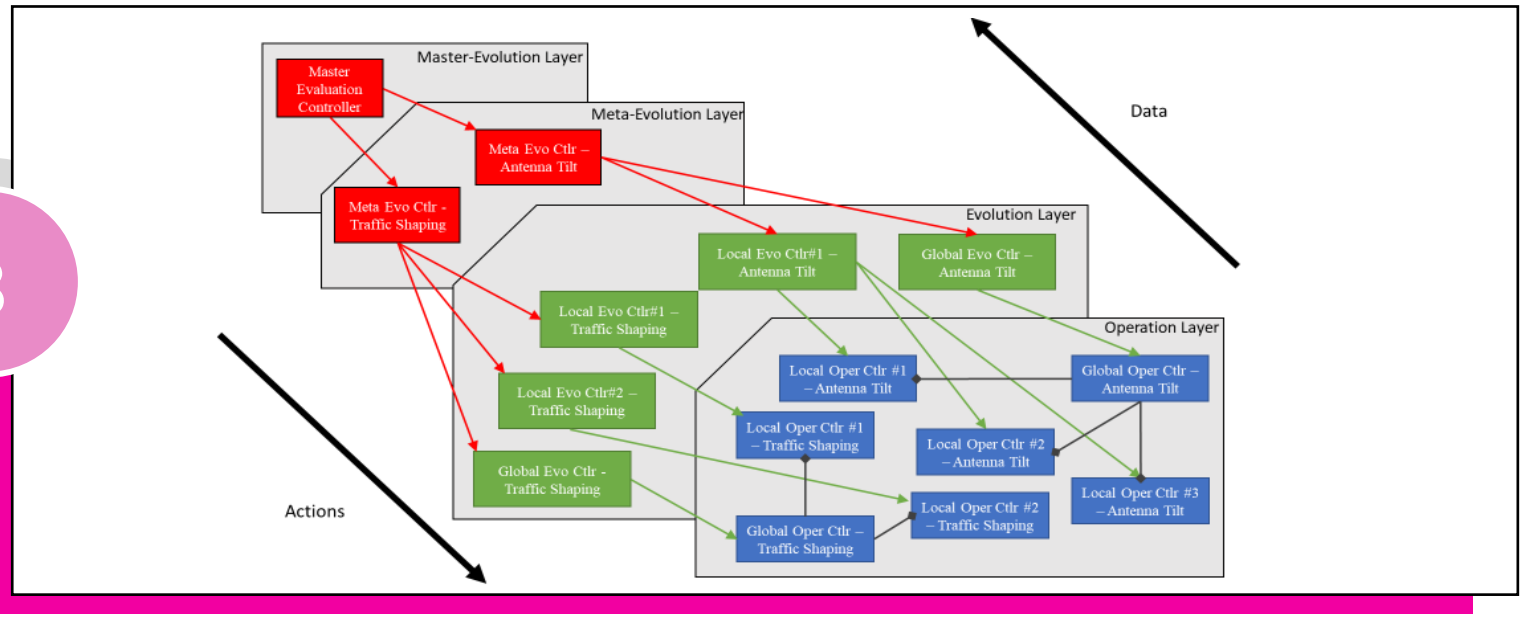
- ✓ Autonomy means self-reflection and self-improvement (self-*)
- ✓ Flexibility to find best solution requires ability to adapt framework
- ✓ Separate control loop to ensure that supervision does not deteriorate.

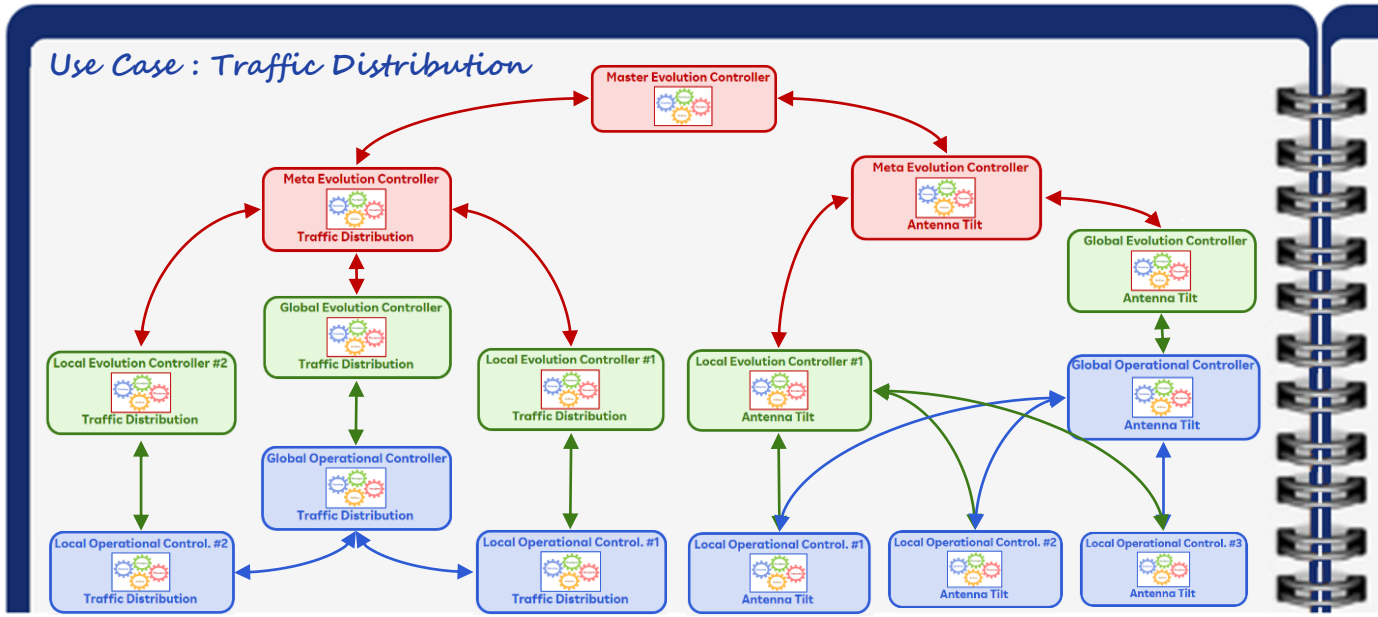
Credit: https://www.flickr.com/photos/30485180@N06/3967682030

Controller Hierarchy

“Just like a company upper level supervises and teach subordinates.”

8





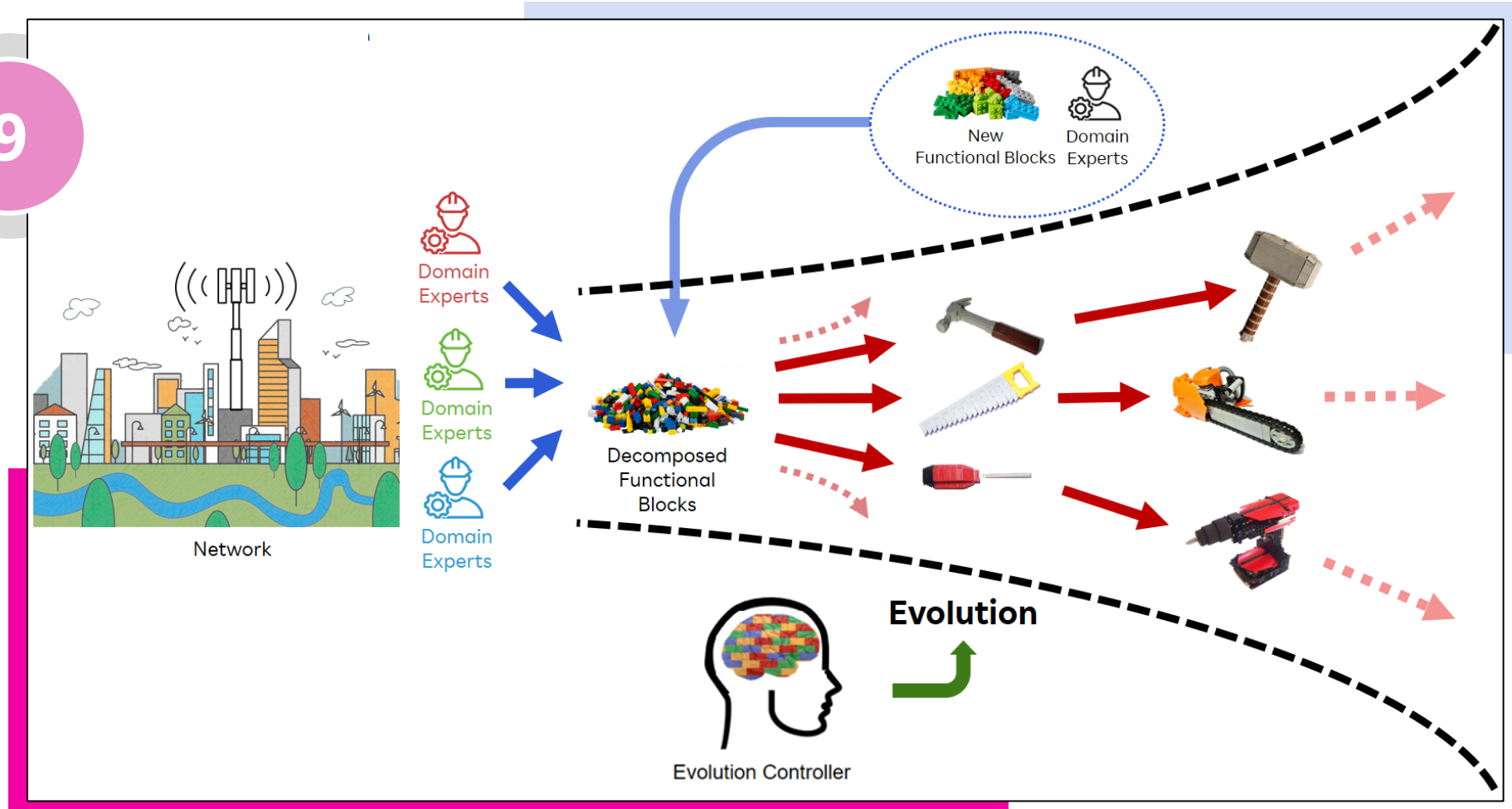
Motivations

- ✓ Can integrate all use cases
- ✓ Higher layers’ jobs get more abstract
- ✓ Clear responsibilities and auditing

Putting it all Together

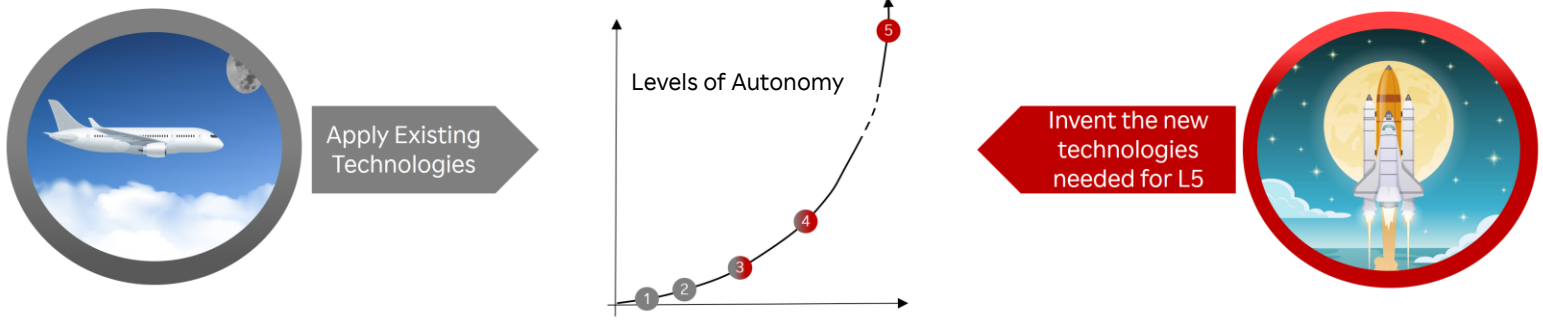
“Human’s still produce the modules until we can get emergent behavior right.”

9

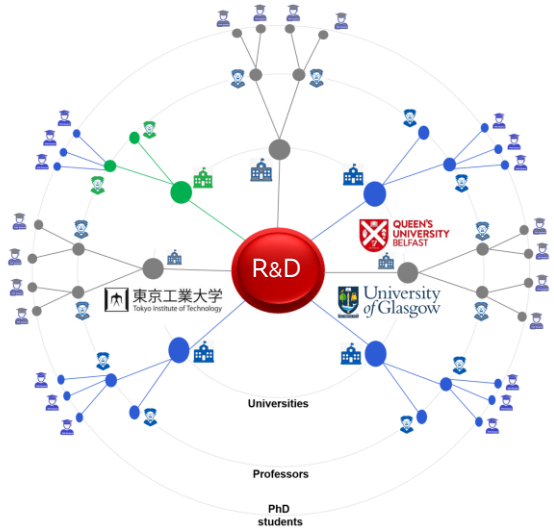


Ecosystem

"You will not reach the moon by trying to flight your plane higher..."

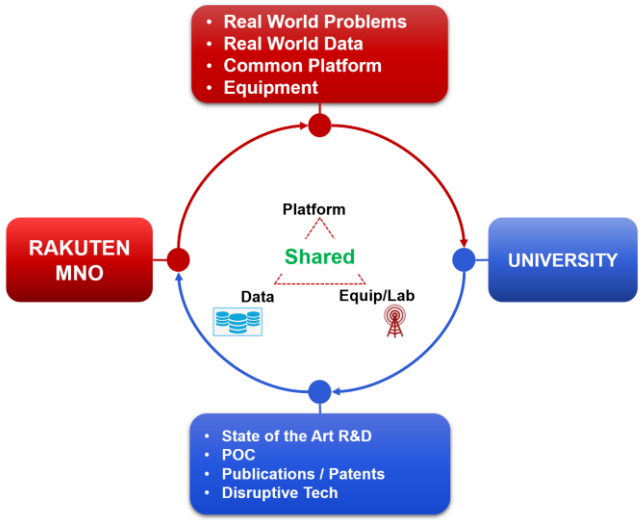


Partner With Academia



And more..

Win- Win relations and virtuous cycle



Overview of autonomous networks standardization landscape

The need for AN standards

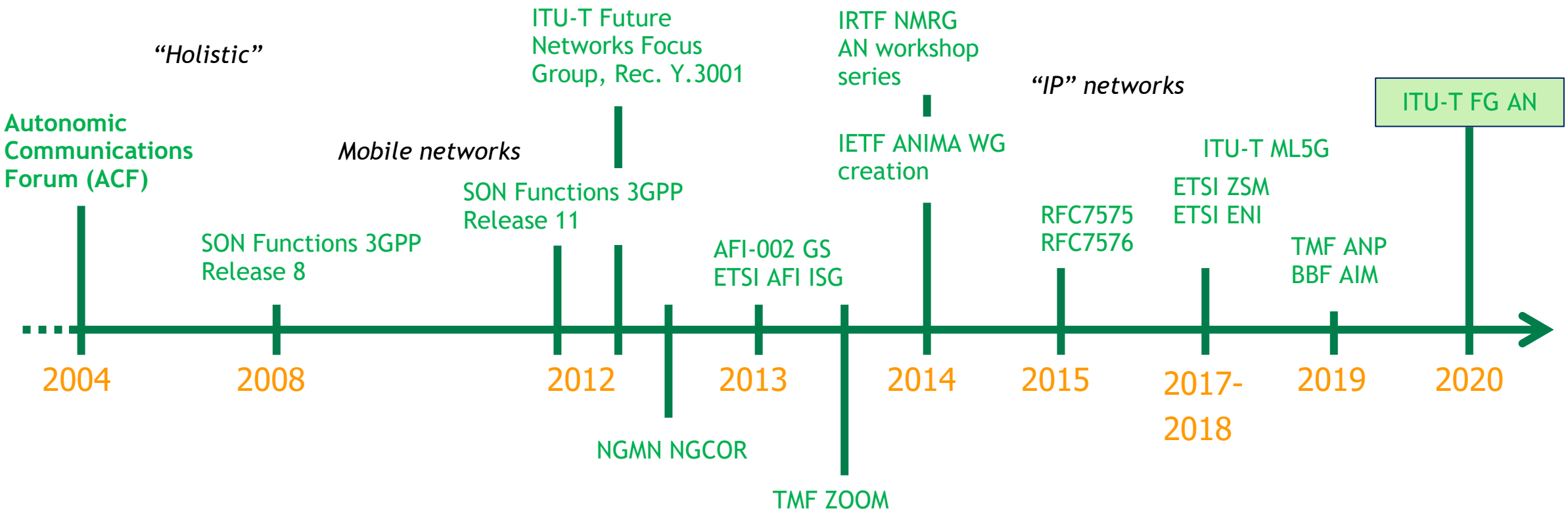
The need for standards is simple

- The problem and challenges are too big to be solved by individual initiatives
- Solutions will emerge from collaborative work and partnerships
- But global scale adoption will require interoperable systems

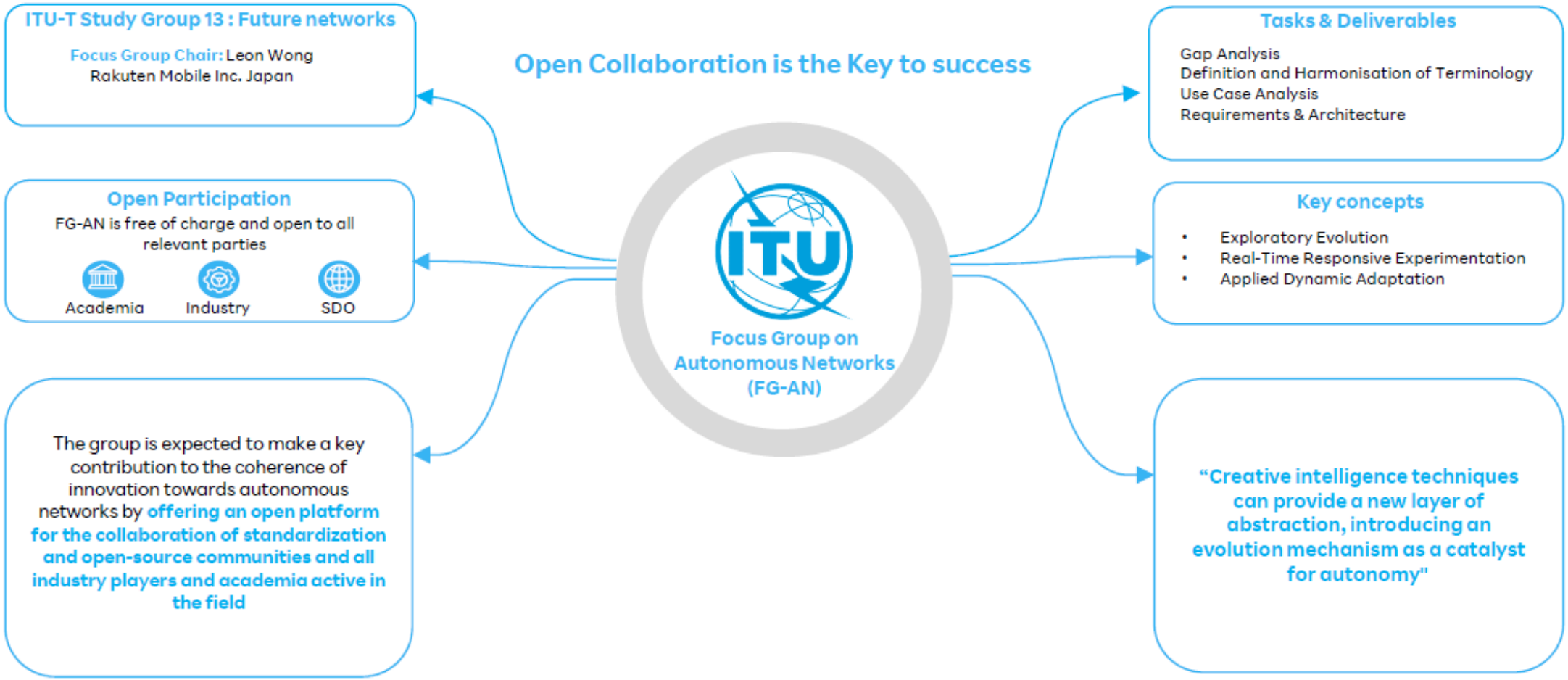
The key question is: What needs to be standardized ?

- Communication interfaces between functional blocks and devices
- Resource models
- Service interfaces
- Common and consistent management principles and language
- Context- and goal-oriented management

Autonomous networking standardization



ITU-T Focus Group on Autonomous Networks



AN (pre-)standardization in IRTF and IETF

NMRG

- Autonomic Networking (2013-2014)
  - RFC 7575 - Autonomic Networking: Definitions and Design Goals
  - RFC 7576 - General Gap Analysis for Autonomic Networking
- Intent-based Networking (2016-Present)
  - https://datatracker.ietf.org/group/nmrg/documents/

ANIMA WG

- Reference model
  - RFC 8993 - A Reference Model for Autonomic Networking
- Control Loops
  - https://datatracker.ietf.org/doc/html/draft-strassner-anima-control-loops-01
  - Good overview of control loops state-of-the-art and requirements; expired document

OPSAWG

  - RFC 8969 - A Framework for Automating Service and Network Management with YANG
- Network Telemetry Framework
  - https://datatracker.ietf.org/doc/html/draft-ietf-opsawg-ntf-07
- Service Assurance for Intent-based Networking Archietcture
  - https://datatracker.ietf.org/doc/draft-claise-opsawg-service-assurance-architecture/

Artificial Intelligence for Network and Service Automation

Joint evolution of AI and Ops

	2020 Raw AI & Automated Ops	2022-2023 Advanced AI & AI-assisted Ops	2025 Lean AI & AI-empowered Ops	Beyond 2025 Intuitive AI & Autonomous Ops
AI & Data	Limited view and use of AI potential Big dumb data	More diversified, network-adapted AI techniques Smarter data	Broad set of AI techniques for N&S environment Intelligent data	Zero-touch AI-Ops Machine Reasoning Symbiotic Human-AI interaction Mission autonomy Transparent, trusted, open AI Reliable, robust and distributed AI
Scale & Adoption	Use case-driven Isolated, small-scale solutions with limited re-use	Cross use cases Large scale application and penetration of AI-based N&S automation solutions	"AI-as-a-Service" Full scale deployment and applicability of AI-enabled, plug-n-play solutions	
Practice & Integration	Retrofit ML technologies for N&S automation Manually-intensive integration	AI know-how is leveraged for N&S automation Semi-automated design and integration	Designed with AI Seamless design and integration	
Confidence & Security	Controlled autonomy and confined in scope No AI-specific security measures	Towards operation autonomy Trust framework safeguards AI-based solutions AI-specific security techniques protect N&S operations	Towards mission autonomy AI continuously and reliably delivers on the business targets Guaranteed AI functional safety	
Standards & Regulation	Lack of standards Consultations with authorities and stakeholders	Emerging standards and basic interoperability First compliant AI-based N&S automation solutions	Comprehensive standards and increased interoperability Fully embedded policies and principles	

Source: ETSI ZSM, IRTF NMRG

Standardization scope

Enable innovation and differentiation with AI in multi-vendor network and service management environment

Key enablers and functionality	Support for deployment diversity	Trust and adoption
Mediation between data sources and data processing, augmented with meta-data models and data governance	Data: data sources, their locations and characteristics (local, ephemeral…), data distribution, data storage	On-par privacy and security environment; improvement and alignment to capabilities and constraints of AI-based solutions
Support for unified and expressive data formats to allow AI workflow automation and plug-and-play	Compute: computation elements locations, types and capabilities	Support for different levels of supervision and visibility for human operators
Coordination between multiple, distributed AI applications, ensuring compliance with intents, consistent end-to-end operational view and means to act on it	Operations: constraints and capabilities for various AI models training and inference options; connecting the AI applications to the orchestration and control end points	Support incremental evolution to AI/ML, integration of learnings from experience and deployments to the standardization process
AI models life-cycle management, re-usability of generated knowledge and acceleration of models deployment	Considering also other factors for regulatory and sustainable approach (energy, data sharing/replication, compute/data co-location)	Openness vs. trust dilemma: new disaggregated solutions add management complexity and call for more transparency and accountability

Source: ETSI ZSM, IRTF NMRG

Key enabling areas

Source: ETSI ZSM, IRTF NMRG

Relevant SDOs landscape

Generic concepts and core technologies for end-to-end AI-driven N&S automation

ETSI ZSM (ENI)	IRTF NMRG COINRG	tmforum AI & Data Analytics project	ITU SG13 SIG/FGonAI/ML
Generic AI enablers and related frameworks AI-empowered end-to-end and cross-domain N&S automation solutions	Research challenges in AI for N&S management Forum on latest advances, developments and practices	Elements and procedures related to AI for Service Management Collaborative projects (Catalysts)	Specifications for machine learning (ML) for future networks, including interfaces, network architectures, protocols, algorithms and data formats

Domain-level adaptation of AI concepts and technologies

Fixed access, backhaul, transport			Radio access and mobile core		Virtualization, cloud and edge cloud
broadband forum AIM project	MEF METRO ETHERNET FORUM	IETF	3GPP A GLOBAL INITIATIVE SA5 SA2 RANx	O-RAN ALLIANCE WG1 WG2 WG3	ETSI MEC NFV
			RAN and 5G Core management domain; RAN and 5G Core signaling plane	RAN optimization and management domain	Virtualized and cloud-native applications

Vertical scenarios

5GACIA

5GAA Automotive Association

...

Ensure federated, harmonized and complementary specifications across the multi-SDO landscape

Source: ETSI ZSM

To go deeper…

Rakuten Mobile Innovation Studio website

https://netlab.mobile.rakuten.co.jp/

Vision paper: Towards a Truly Autonomous Network

https://netlab.mobile.rakuten.co.jp/assets/pdf/towards_a_truly_autonomous_network.pdf

ITU-T Focus Group on Autonomous Networks

https://www.itu.int/en/ITU-T/focusgroups/an/Pages/default.aspx