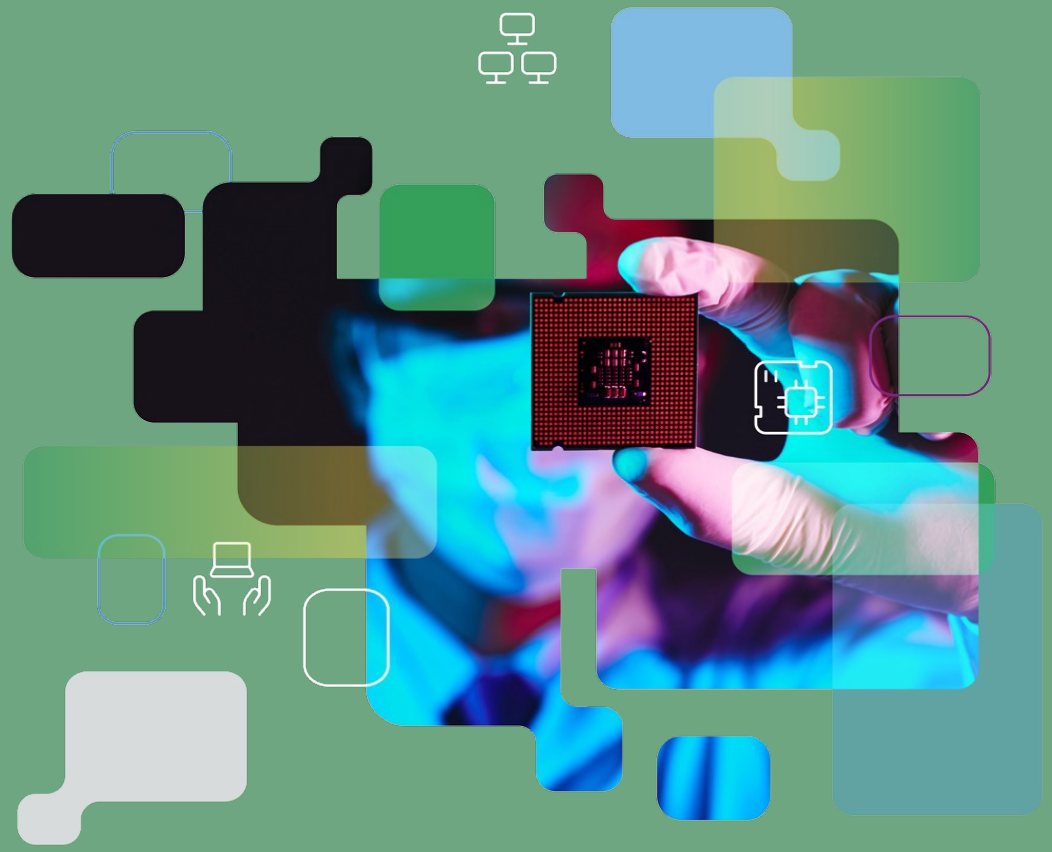
Future of Computing

Edge to Exascale and beyond

Application first computing



Impact on future Challenges

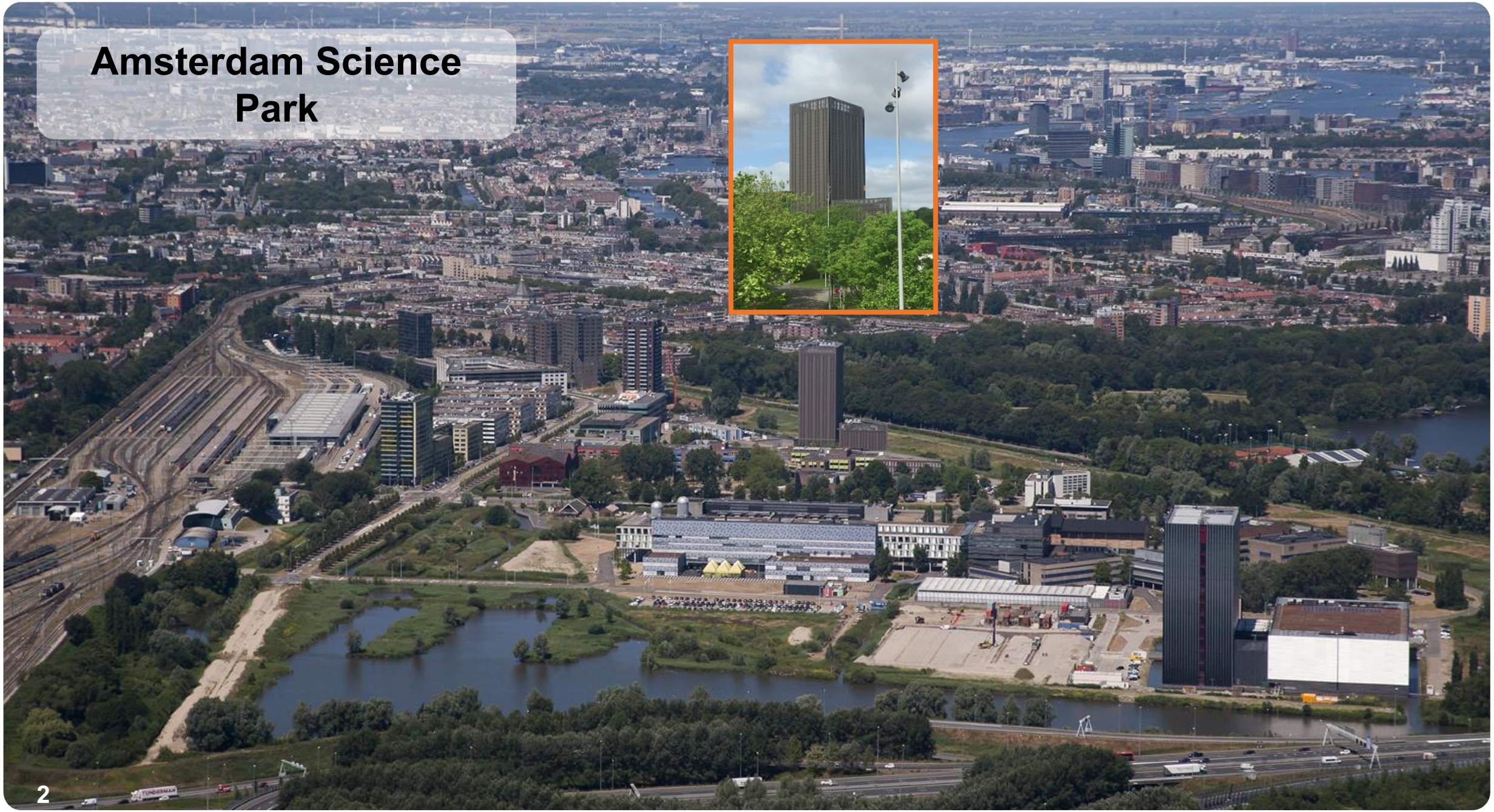
Sagar Dolas

Program Manager, Future Computing & Networking

Innovation Team, SURF

SURF

Amsterdam Science Park



SURF Open Innovation Lab

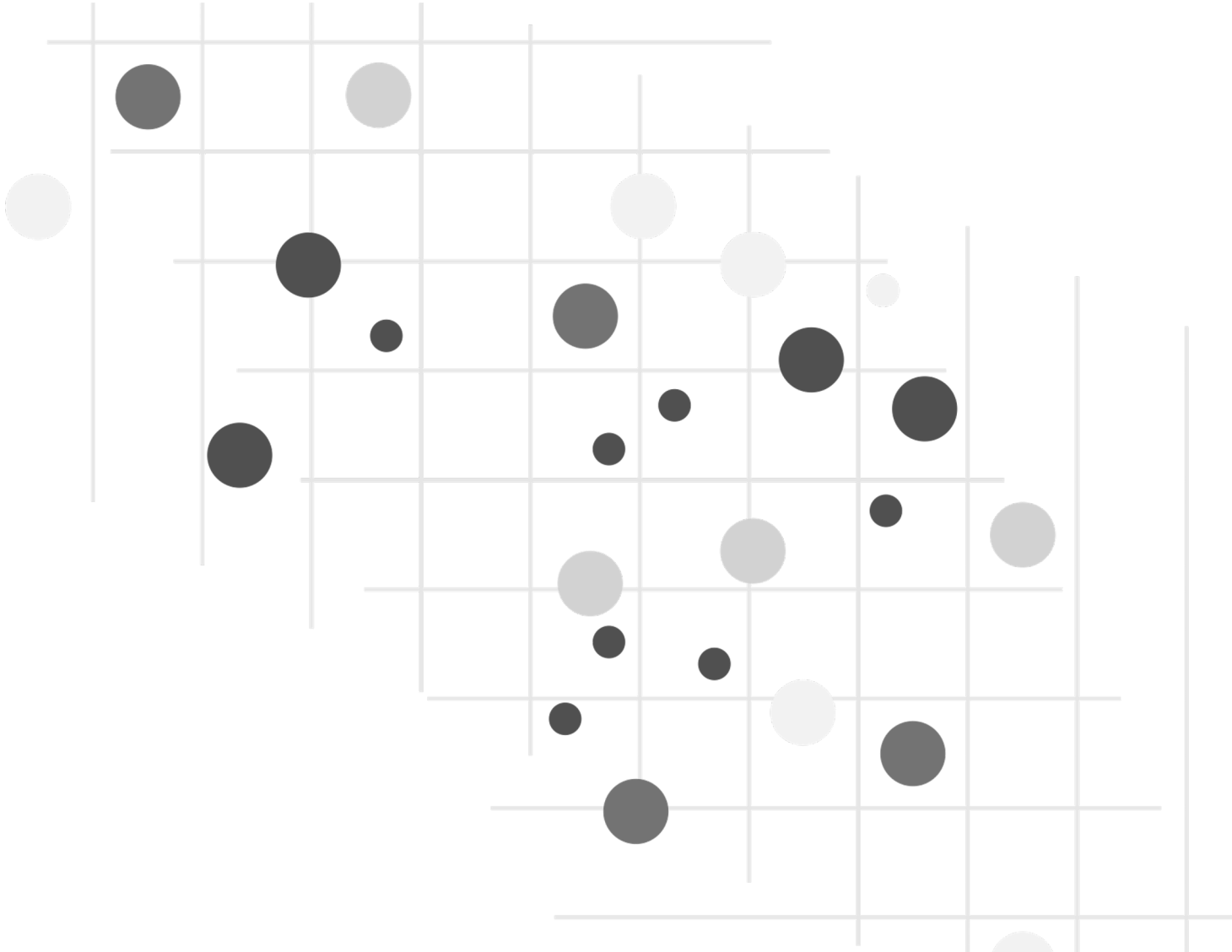
- SURF portfolio for early innovation
- Experiments, prototypes, PoCs

Open
Innovation
Collaboration
Experiments

- Open Collaboration with SURF institutions, NLeSC, and industry

- Open knowledge sharing

Contributing to the innovation power and knowledge position of SURF and its members



Quantum Computing will take over HPC

Everything will be Deep Learning

Extreme specialisation will push Moore's Law

Everything will run on accelerators (e.g GPUs)

Reconfigurable hardware will be give you 100x speedup

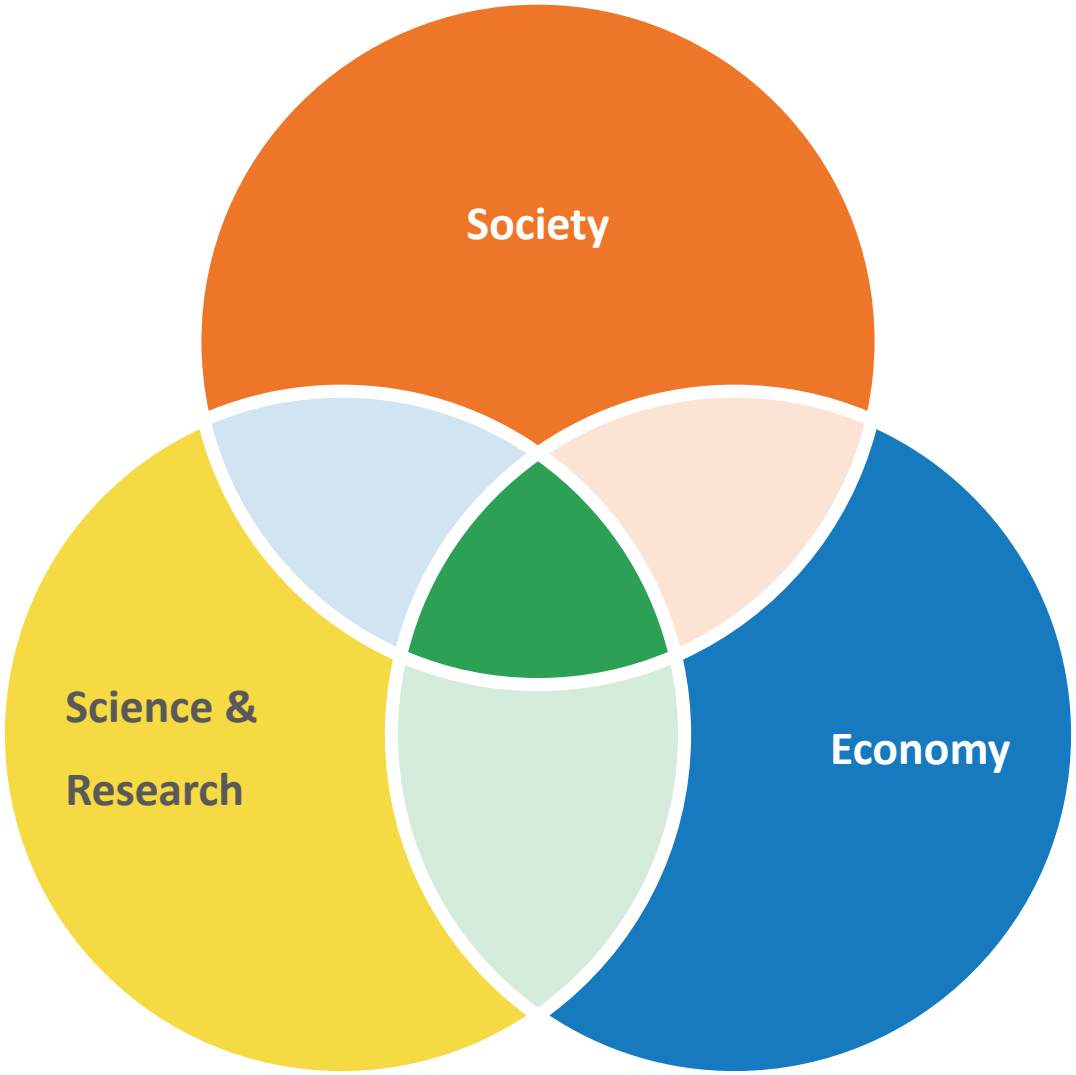
FORTRAN in dead

Scientific computing will fully pivot to mixed precision or low precision

All HPC will be eaten by clouds

Long term value of Advanced (Research) Computing

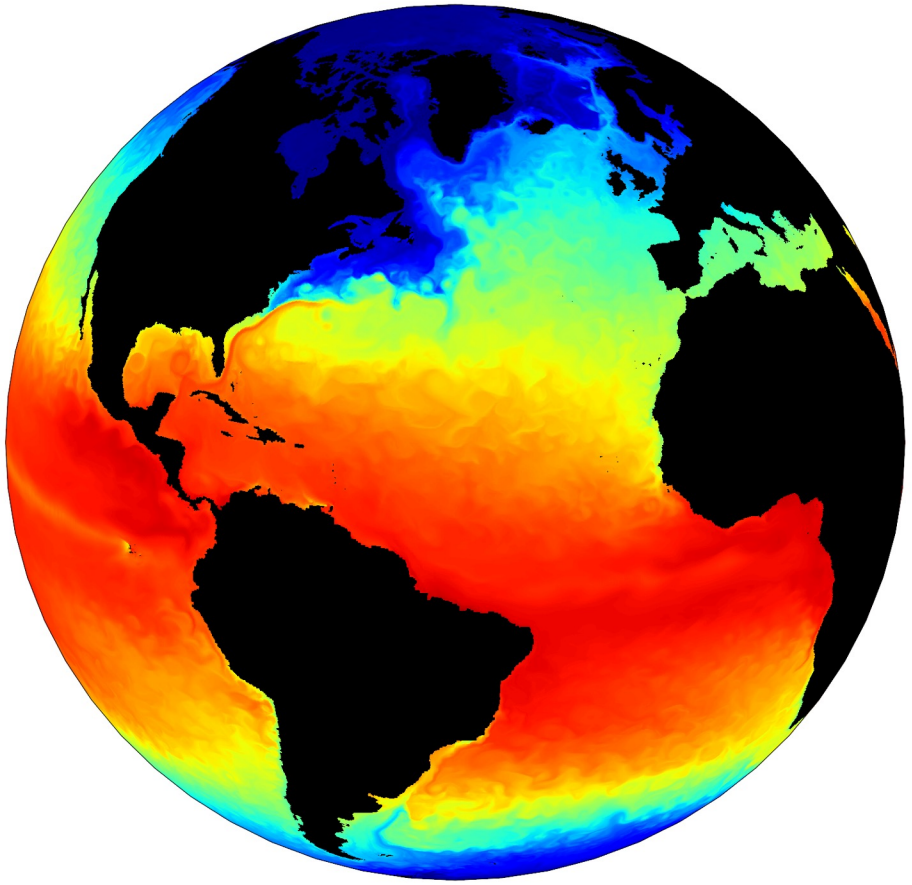
Tools for Addressing societal challenges and questions



High Fidelity Simulations & Analysis

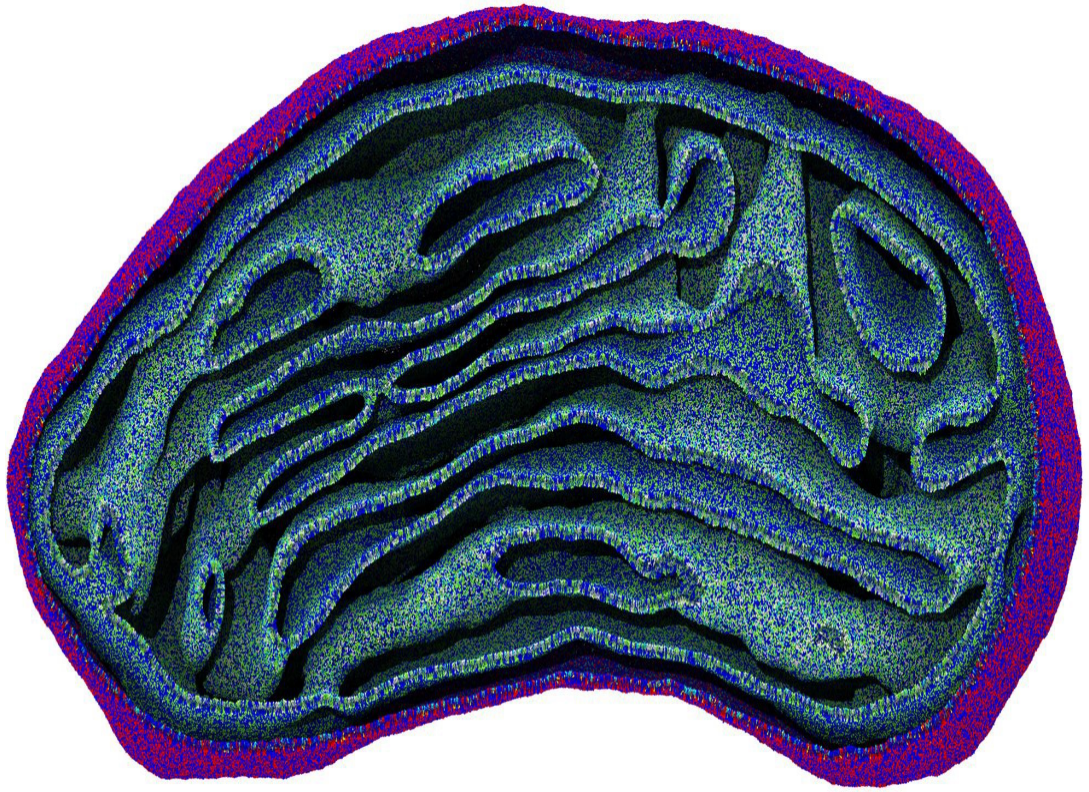
Think about **global** climate simulations.

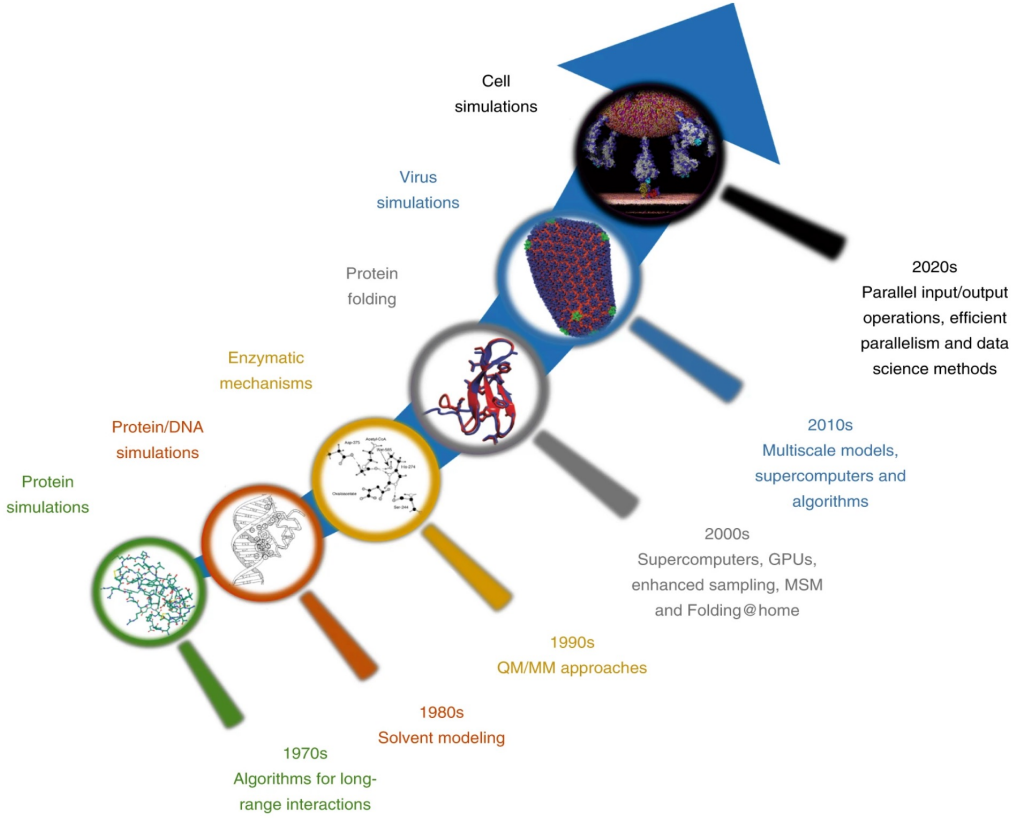
10x more fidelity in space & time needs O(10^6) mixed precision information processing



Ocean component output of an Earth System Model simulation - Rene van Westen, Henk Dijkstra, Ocean Eddies Strongly Affect Global Mean Sea-level Projections - Science Advances 7, 2021

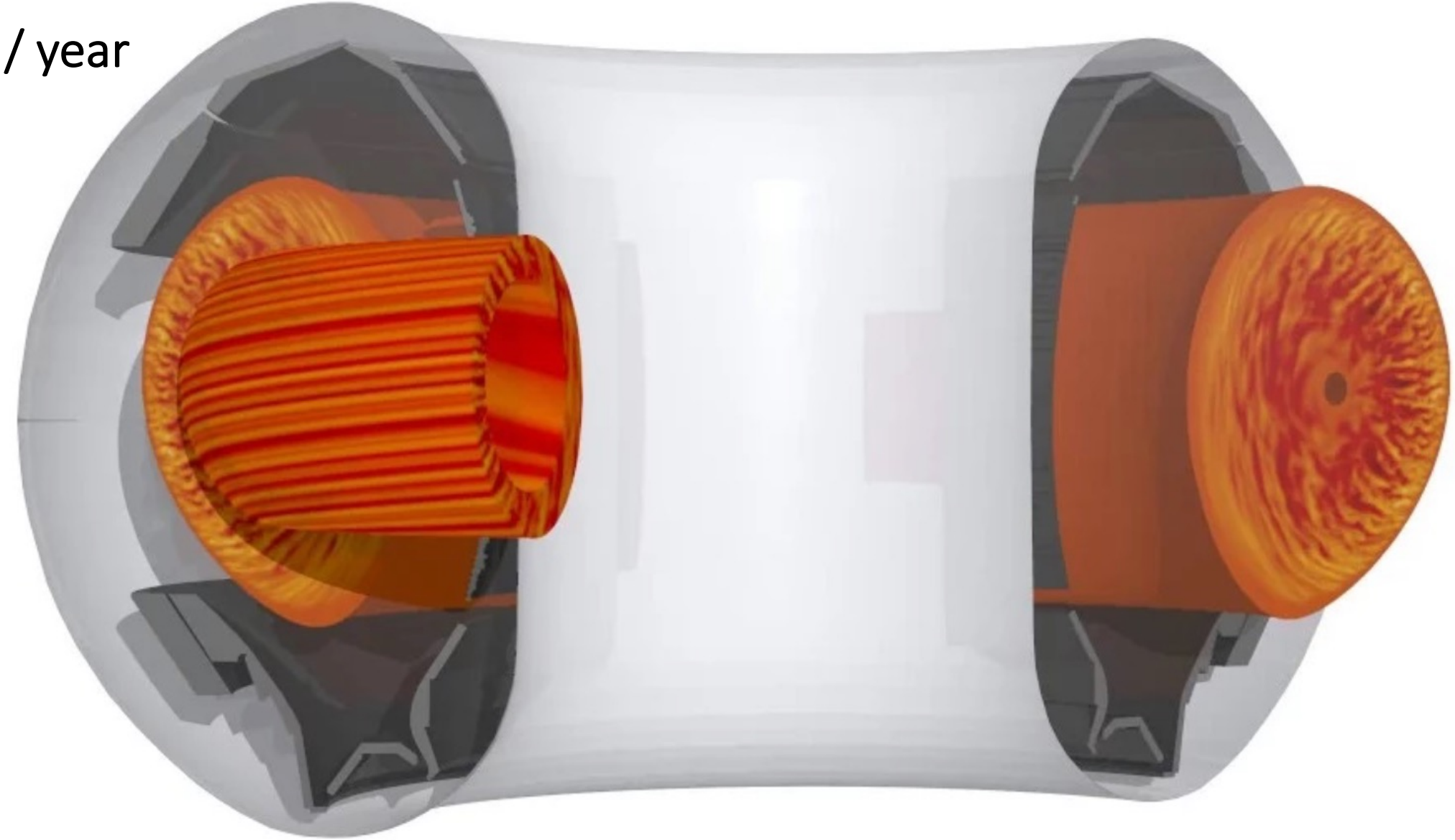
Multi-scale ensemble-based workflows





Mitochondrial membranes at the molecular level - Weria Pezeshkian, Siewert-Jan Marrink et al., Backmapping triangulated surfaces to coarse-grained membrane models - Nature Communications 11, 2020 - Groningen Biomolecular Sciences and Biotechnology Institute and Zernike

ExaBytes / year



GENE computer simulation of plasma turbulence in the Garching tokamak experiment ASDEX Upgrade. Graphic: IPP

Applying Artificial Intelligence to NOAA's Mission

Providing more accurate weather forecasts by improving models

Operating uncrewed systems for bathymetric mapping and geographic surveys

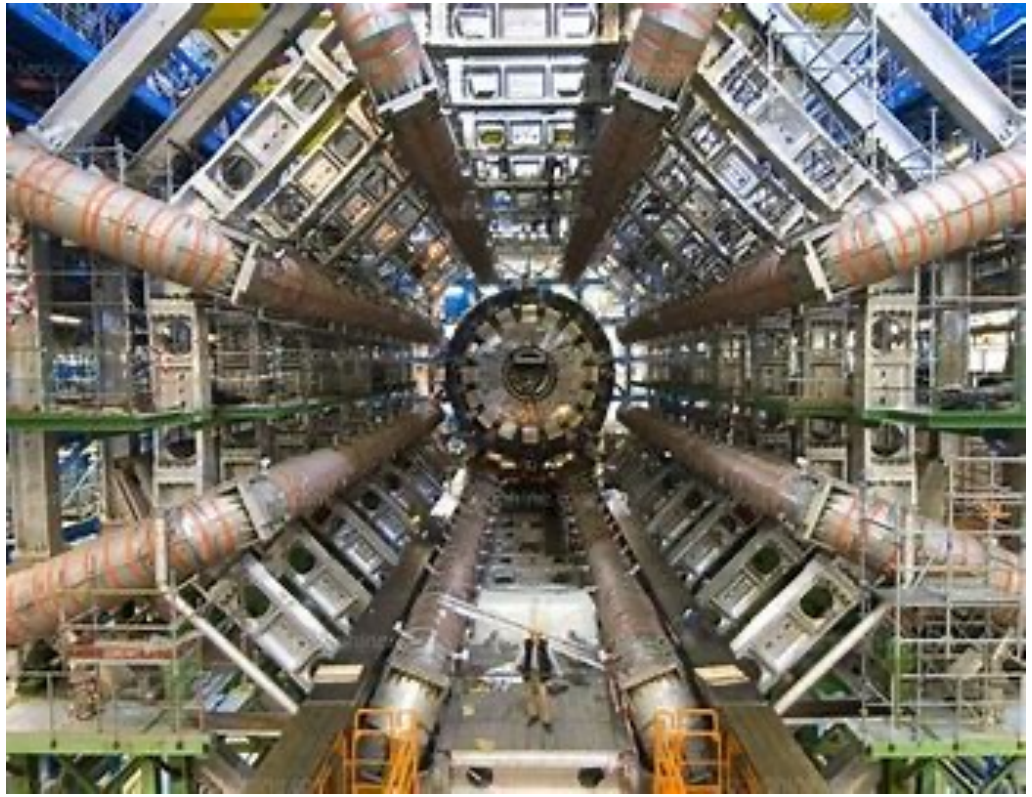
Predicting space weather by identifying solar events in real time

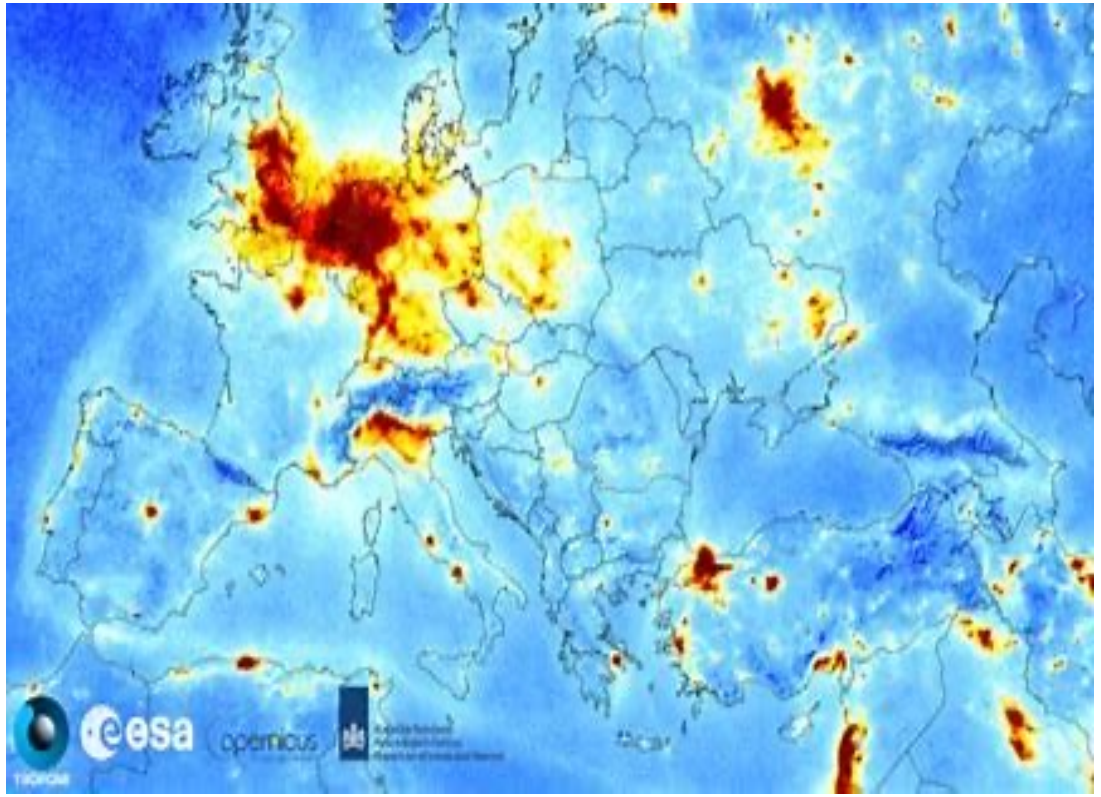
Reviewing aerial and underwater surveys to assess fish populations

Studying protected species with images and acoustic recordings

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

Advanced-Data processing workflows

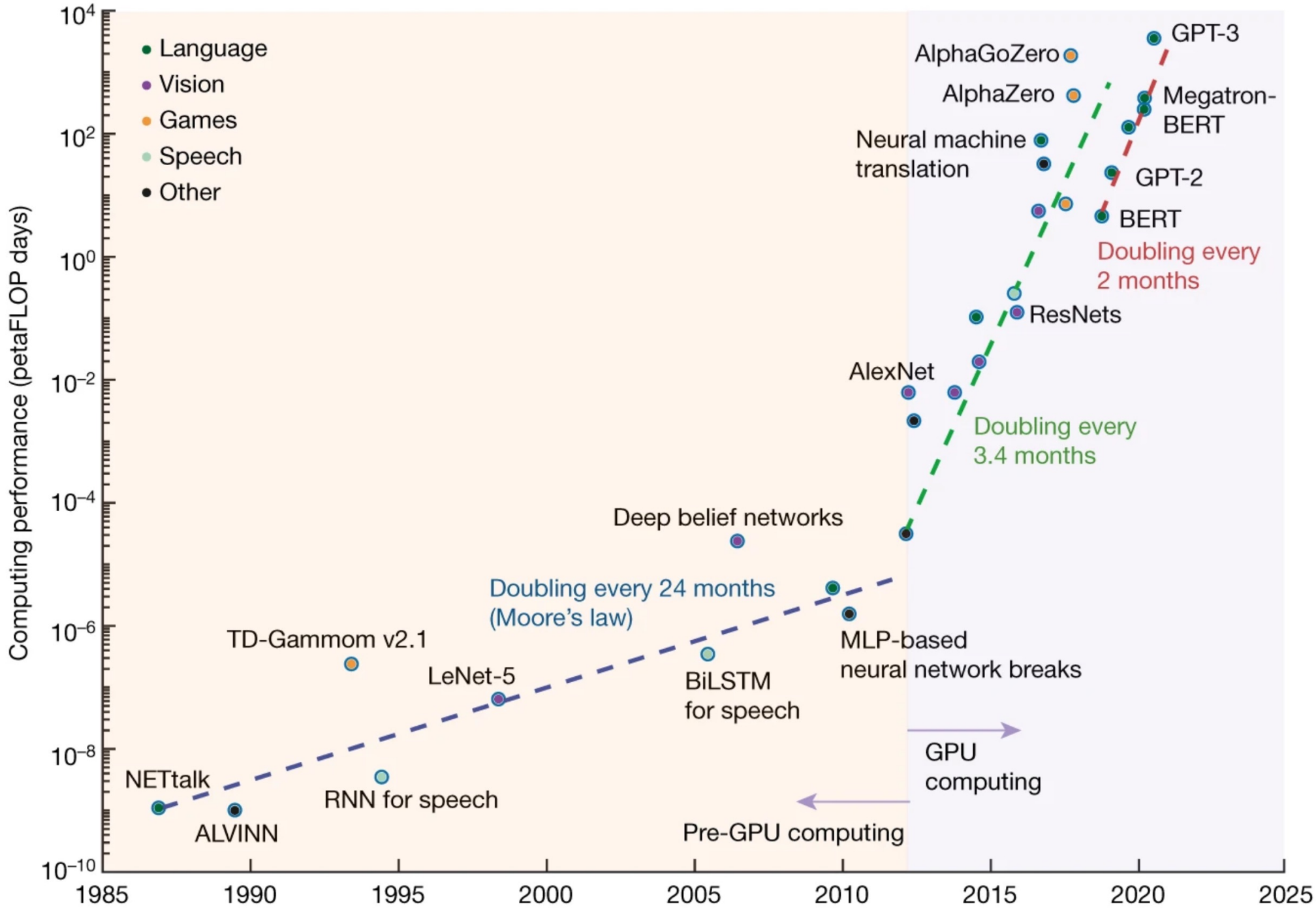




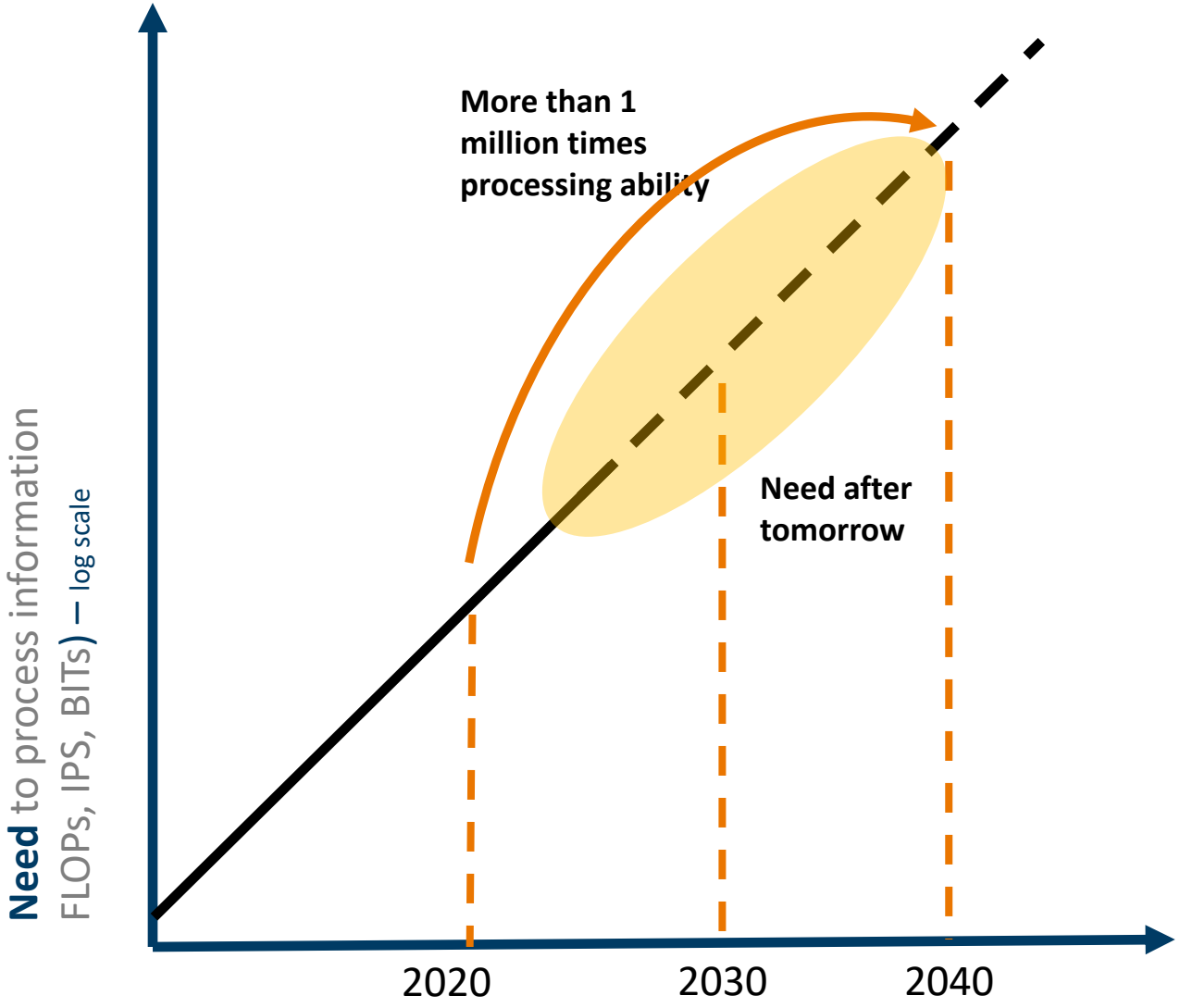
100 Petabytes / year ---> ExaBytes / year

Large scale global science collaboration

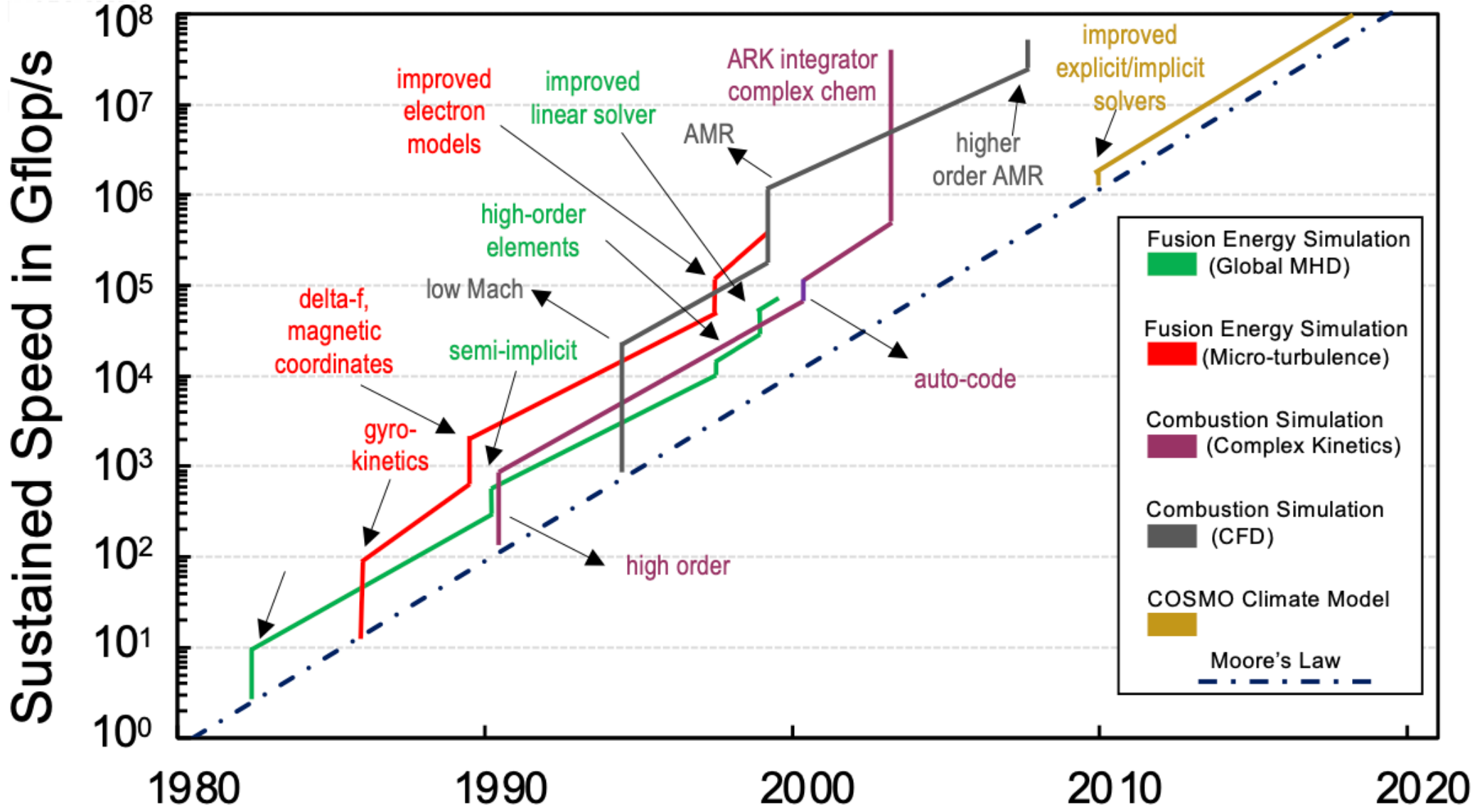
Research demands ***completely unconstrained*** by the physical location of instruments, computational resources, or data

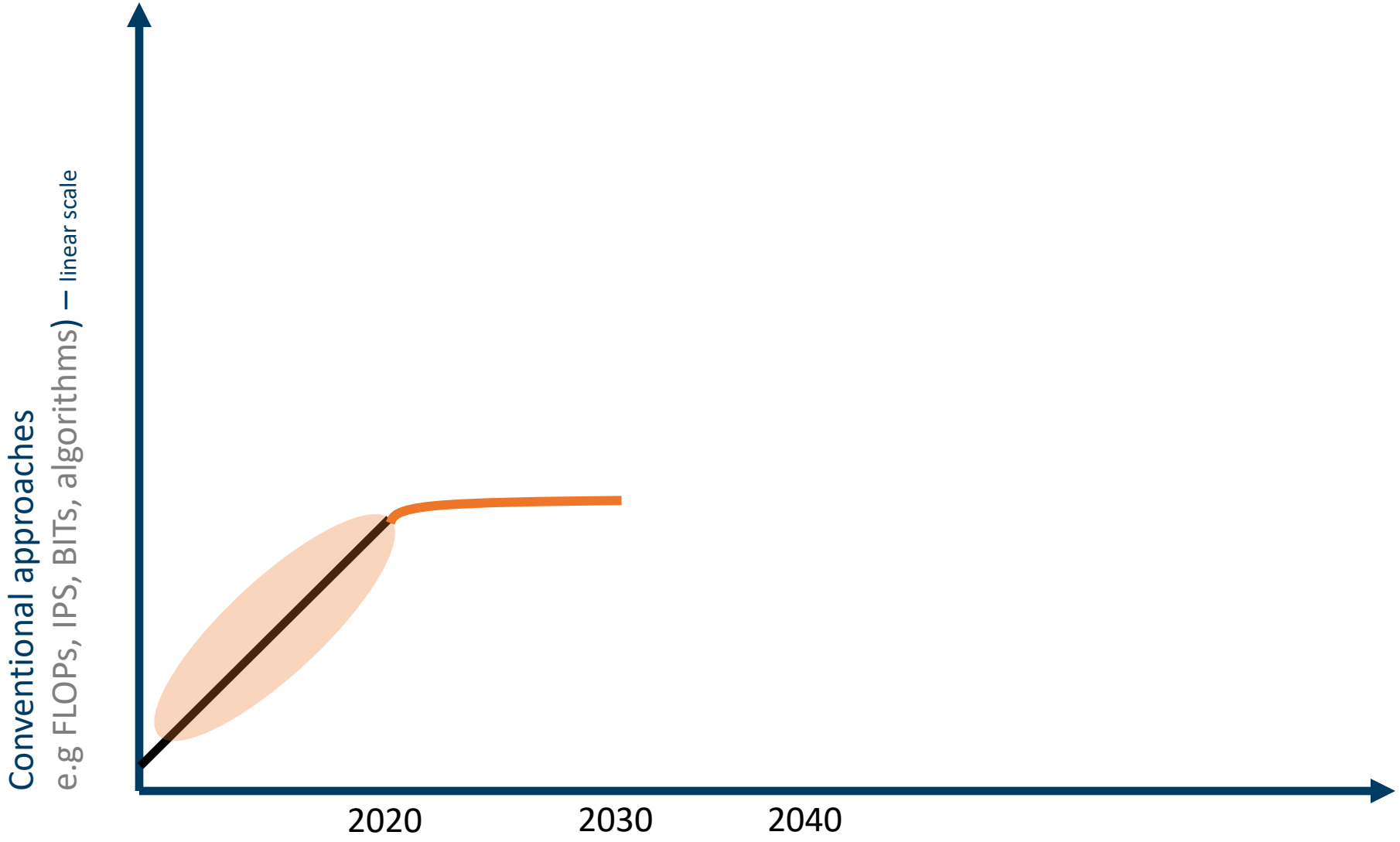


Brain-inspired computing needs a master plan

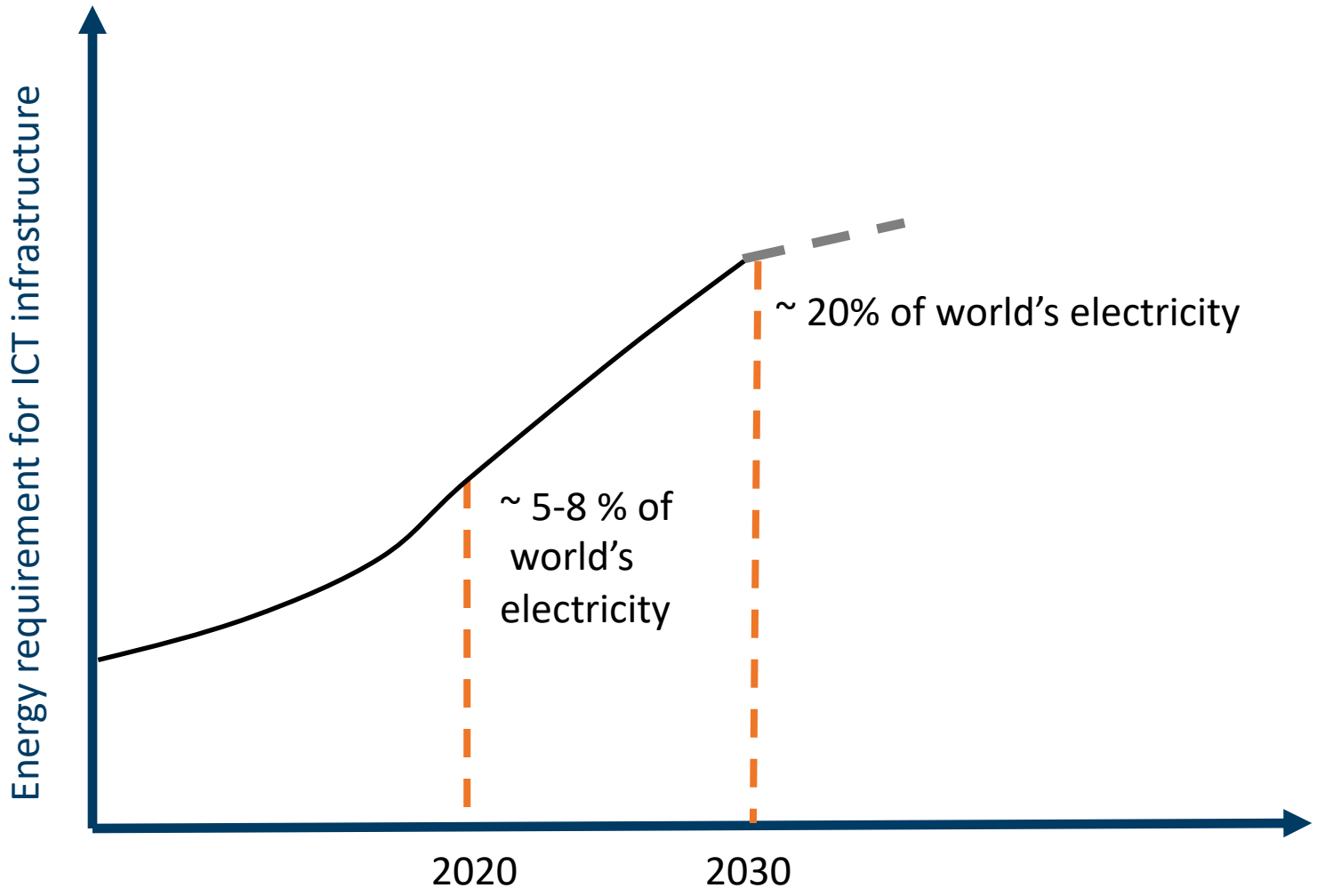


HTTPS://WWW.SRC.ORG/ABOUT/DECADAL-PLAN/

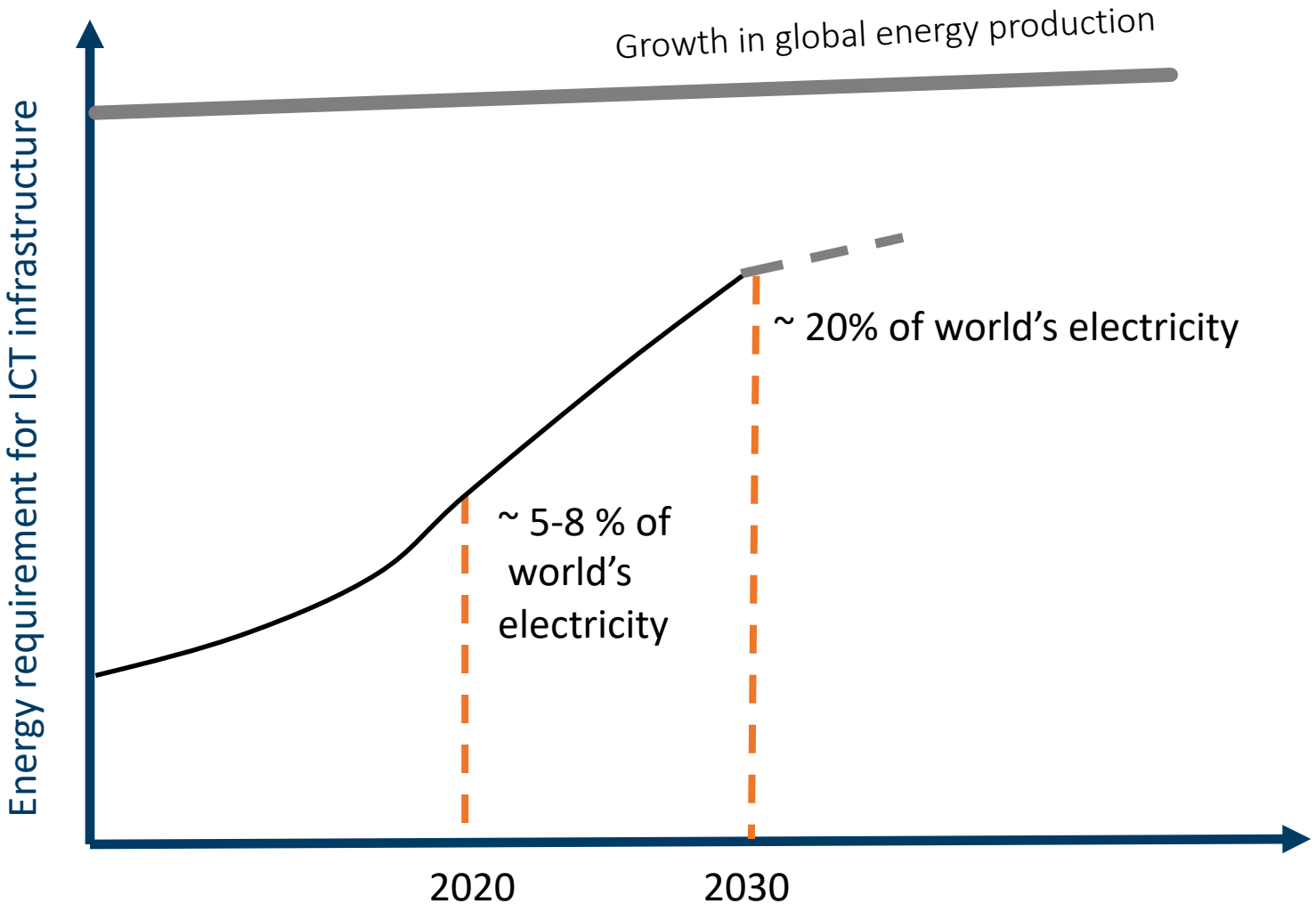

Sustained Speed in Gflop/s
10^8
10^7
10^6
10^5
10^4
10^3
10^2
10^1
10^0
1980
1990
2000
2010
2020
improved electron models
improved linear solver
ARK integrator complex chem
AMR
higher order AMR
improved explicit/implicit solvers
high-order elements
low Mach
delta-f, magnetic coordinates
semi-implicit
gyro-kinetics
auto-code
high order
Fusion Energy Simulation (Global MHD)
Fusion Energy Simulation (Micro-turbulence)
Combustion Simulation (Complex Kinetics)
Combustion Simulation (CFD)
COSMO Climate Model
Moore's Law



HTTPS://WWW.SRC.ORG/ABOUT/DECADAL-PLAN/



HTTPS://WWW.SRC.ORG/ABOUT/DECADAL-PLAN/

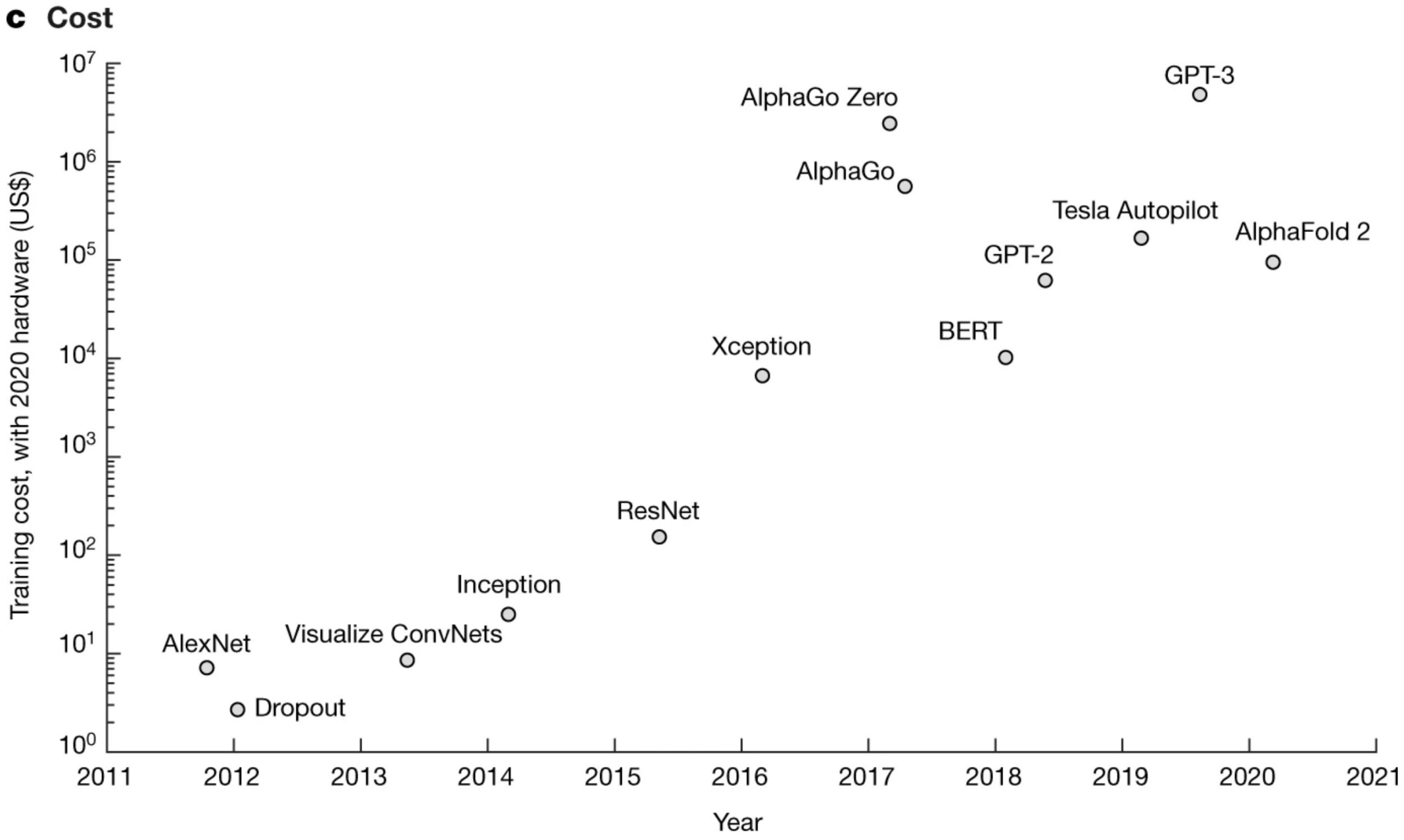


HTTPS://WWW.SRC.ORG/ABOUT/DECADAL-PLAN/

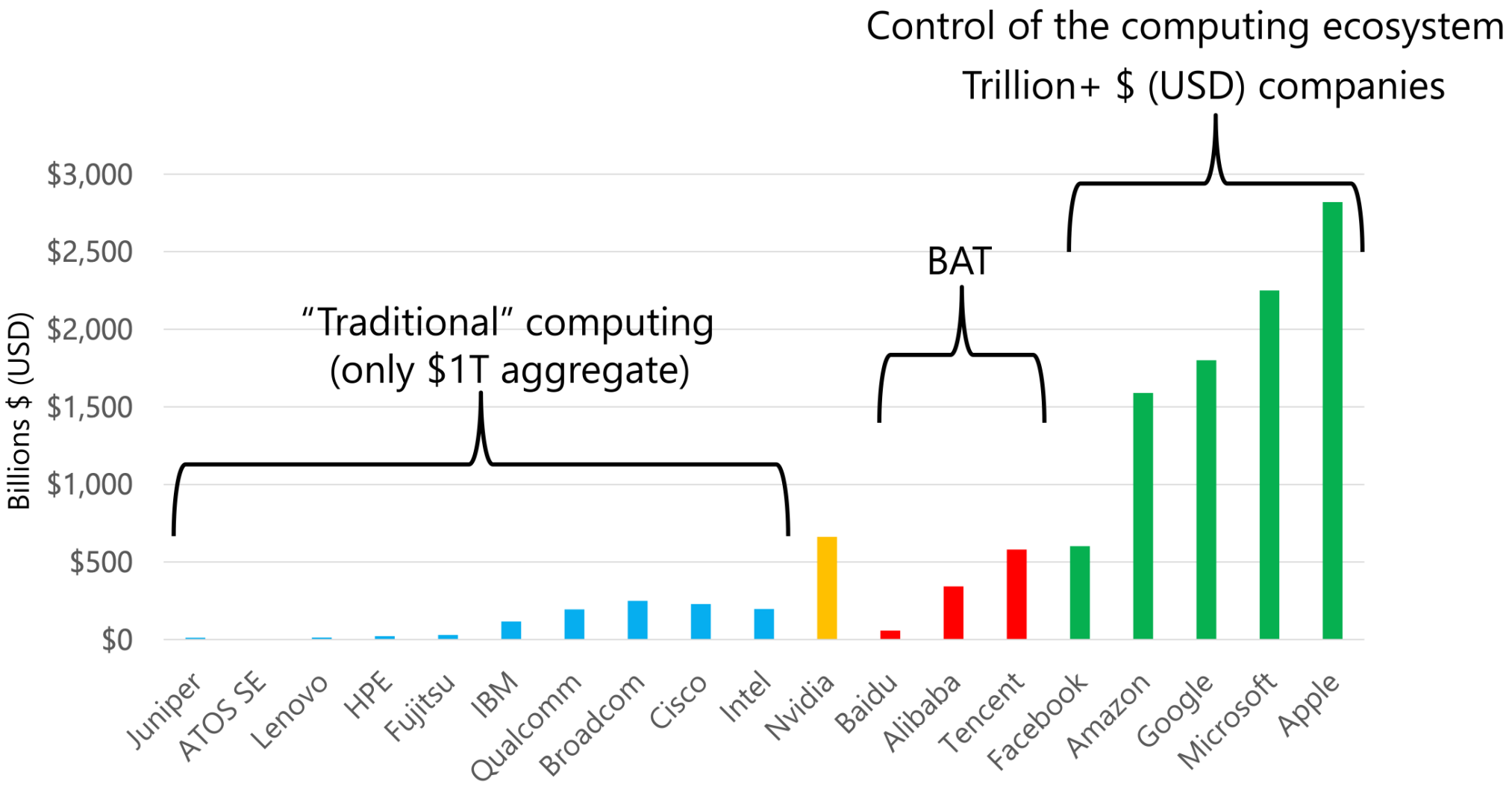
An electric car consumes 25KWh for 100 miles ~ 0.9 million joules for 1 mile

Moderately scaled Molecular dynamics simulation on CPUs can use up to 15 million joules or 15KW for 1000s ~ sufficient chunk of current energy envelop

Moderately scaled Machine learning training on GPUs can use upto 4 million joules for 20KW for 3 minutes



Brain-inspired computing needs a master plan

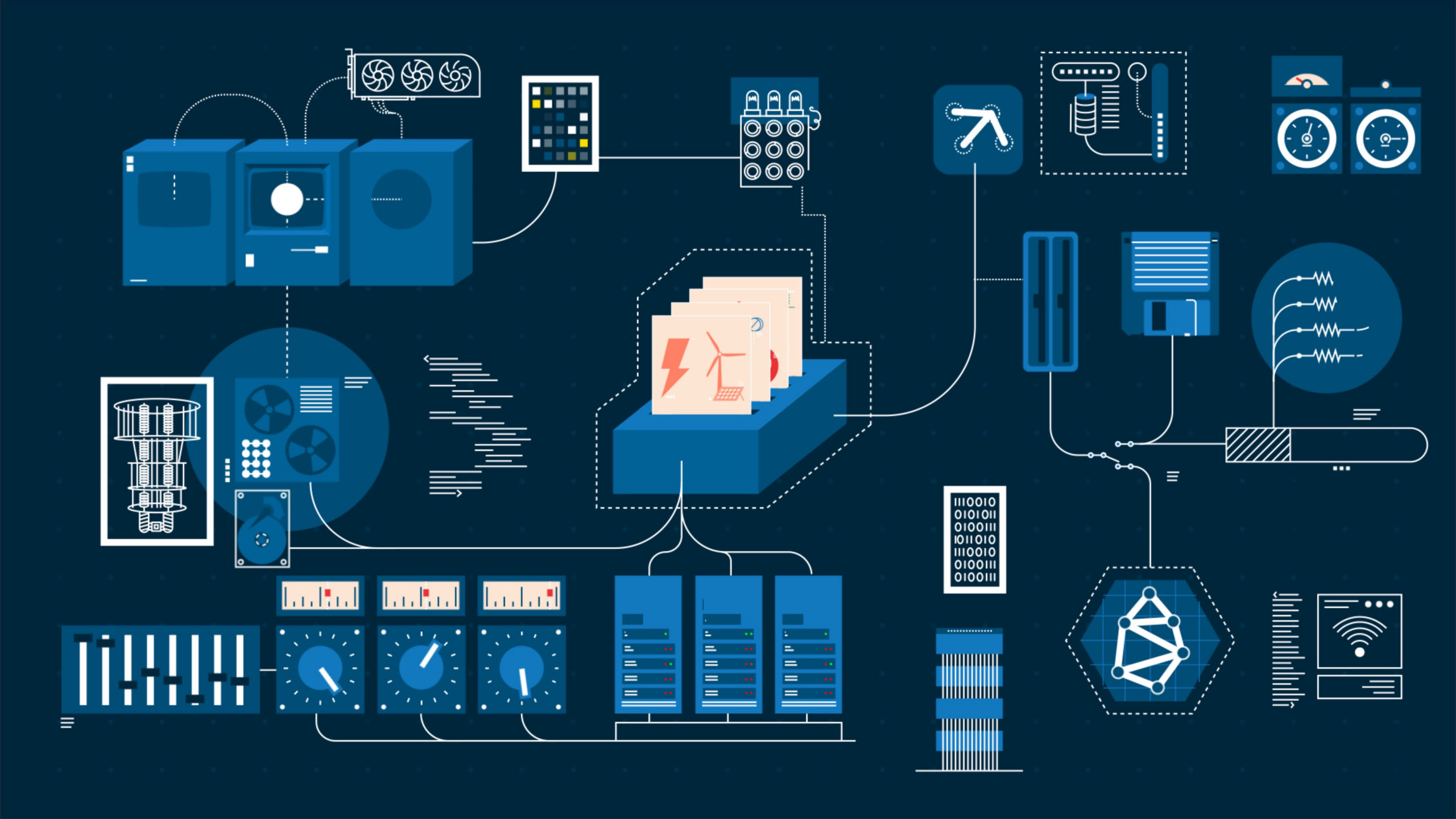


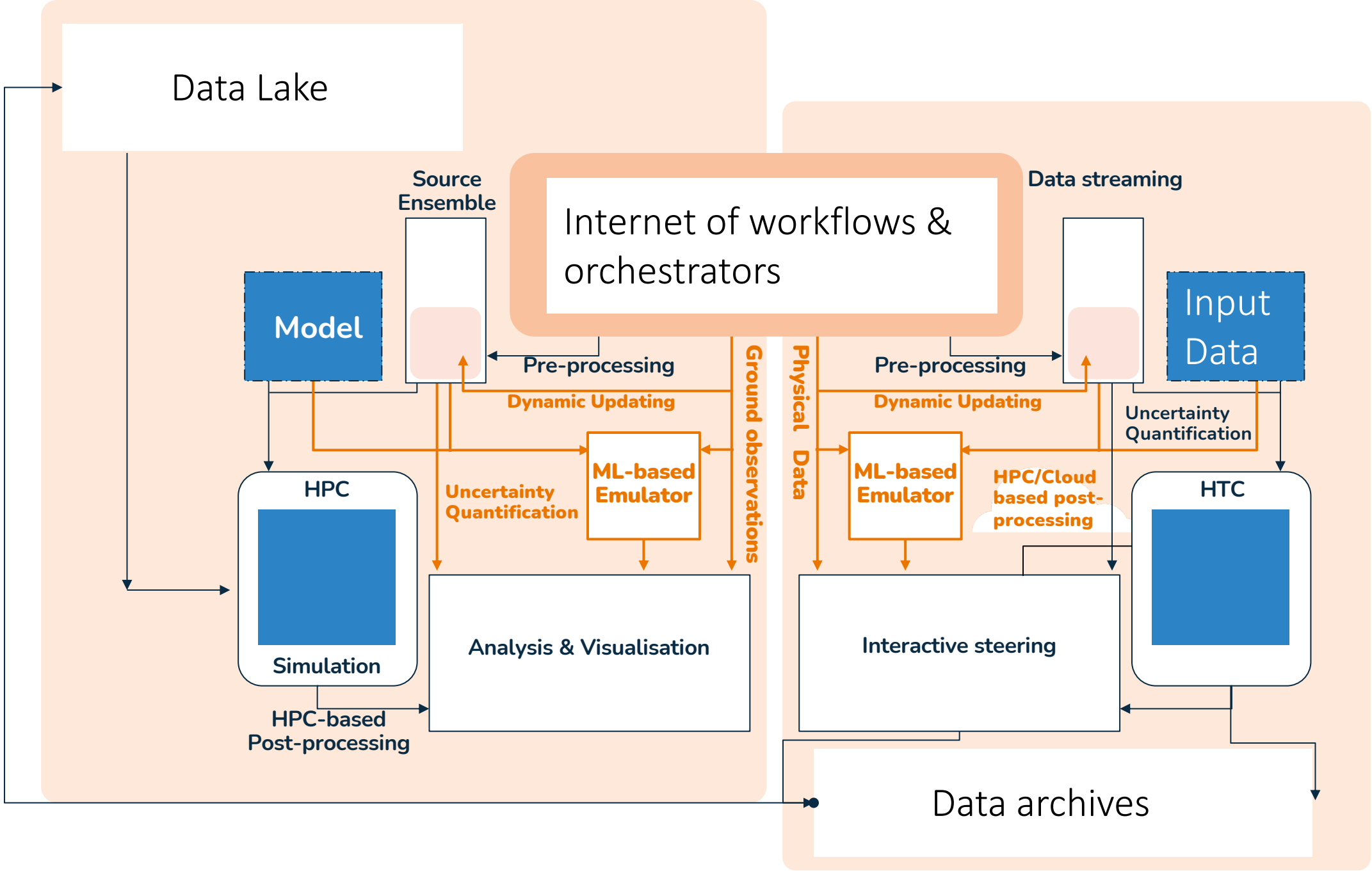
February 15 2022

Conventional approches are maturing (*but not there use*) & computing is becoming (energy) costly

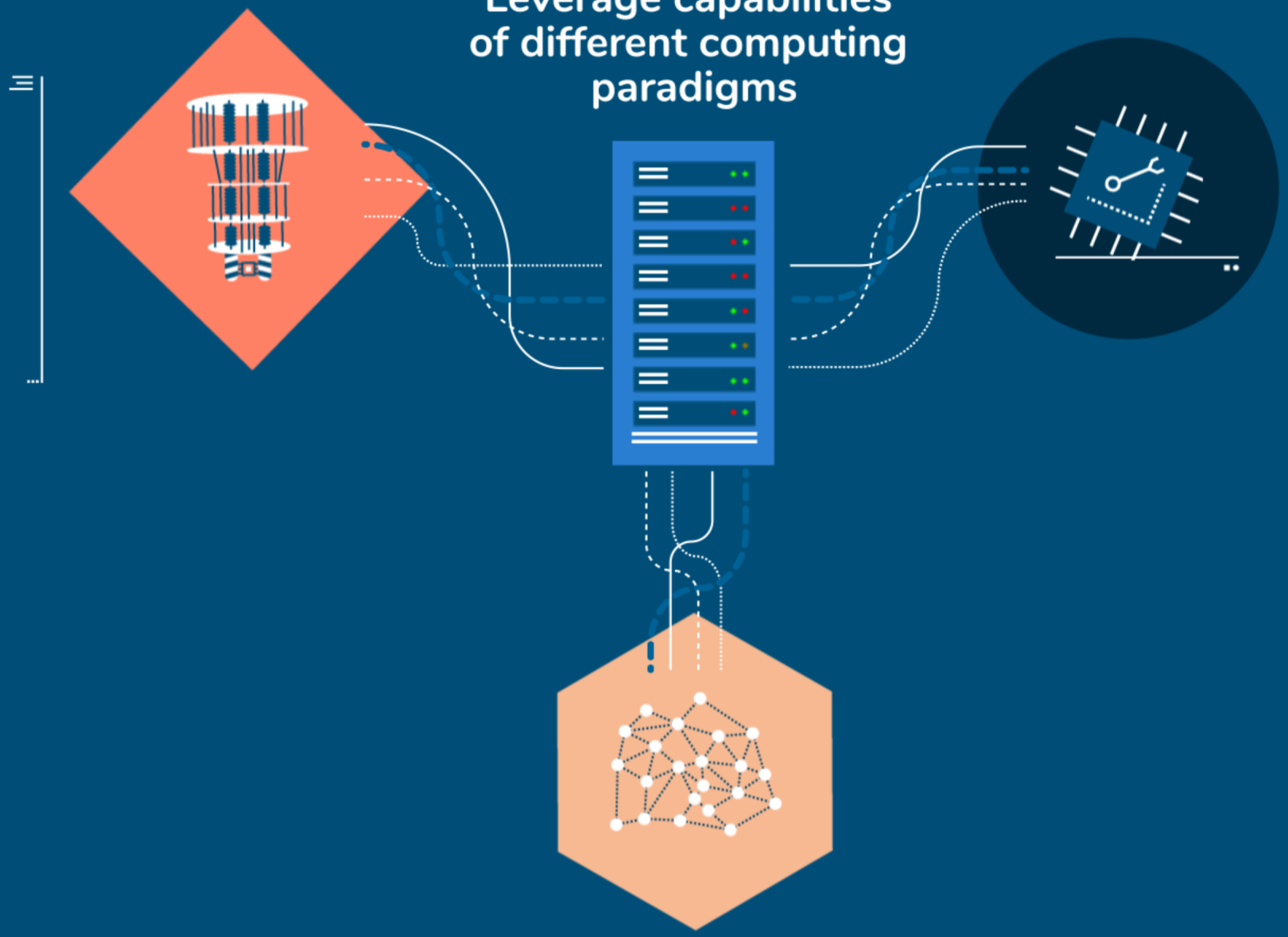
The drive should not be just to ***compute faster*** but enable science to cross ***barriers*** of what is possible.

Some directions for Future of Computing & intervention points

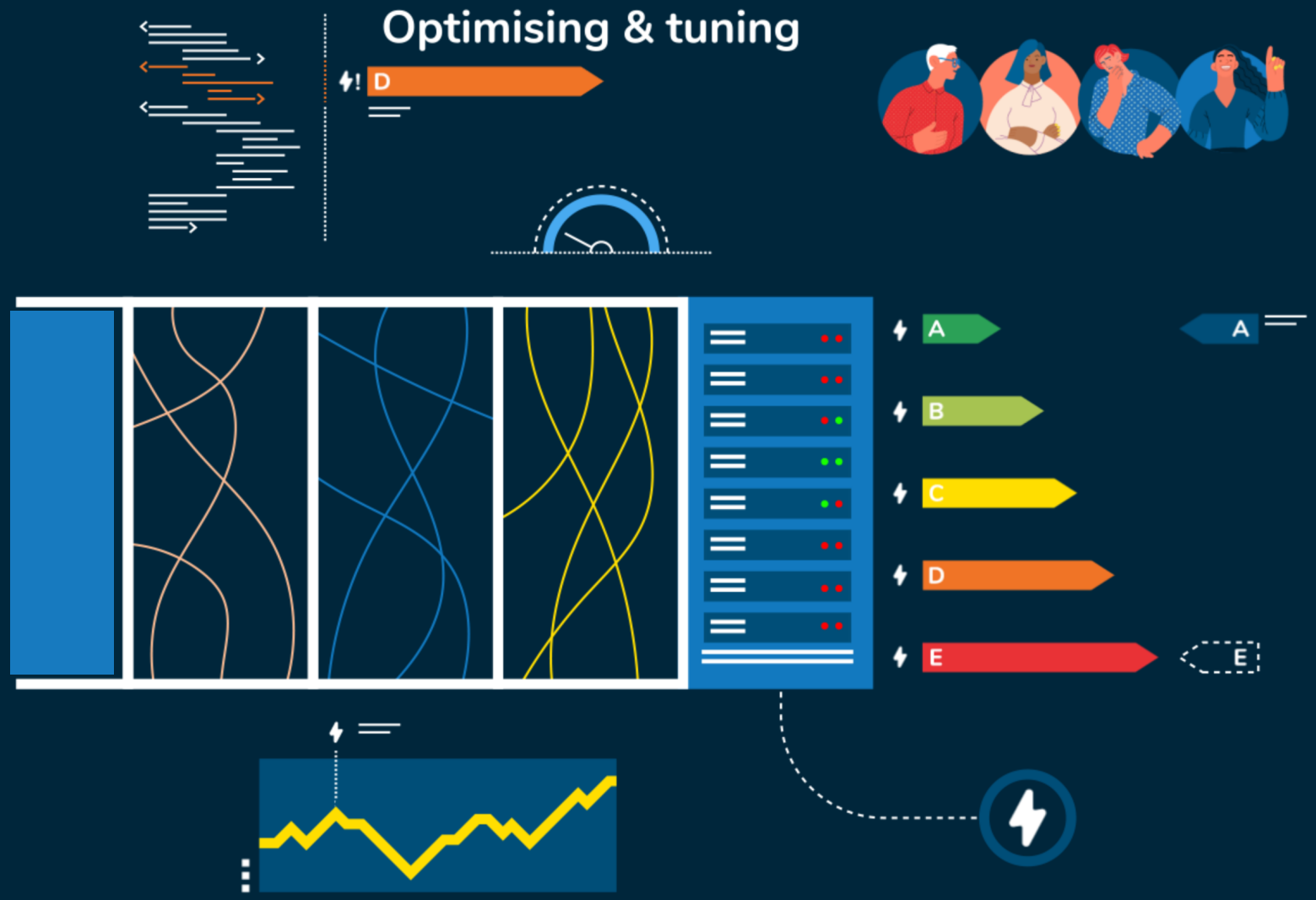

1110010
0101011
0100111
1011010
1110010
0100111
0100111

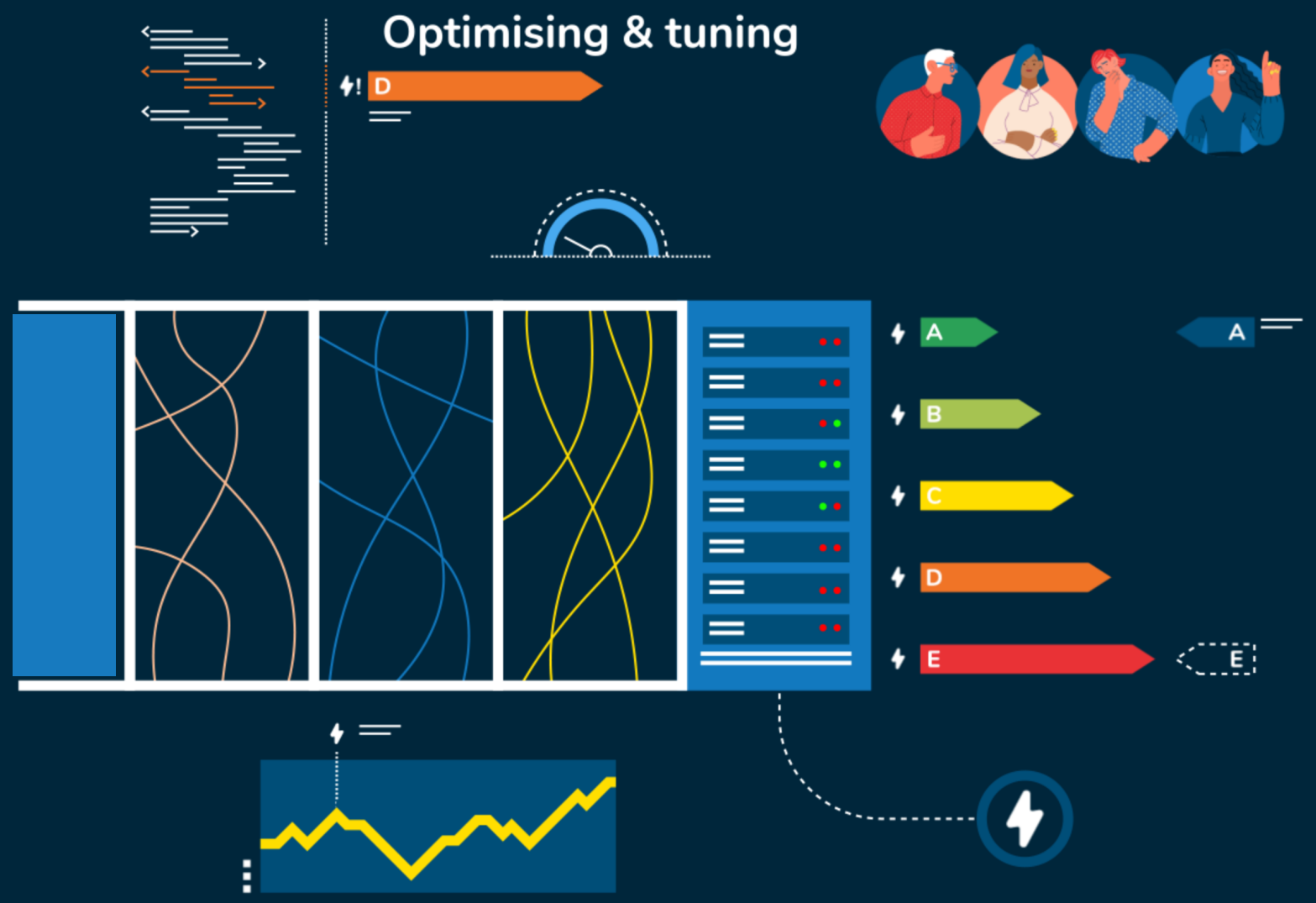

Data Lake
Source Ensemble
Internet of workflows & orchestrators
Data streaming
Model
Input Data
Pre-processing
Pre-processing
Dynamic Updating
Dynamic Updating
Ground observations
Physical Data
Uncertainty Quantification
ML-based Emulator
ML-based Emulator
HPC/Cloud based post-processing
Uncertainty Quantification
HPC
HTC
Simulation
Analysis & Visualisation
Interactive steering
HPC-based Post-processing
Data archives

Leverage capabilities of different computing paradigms

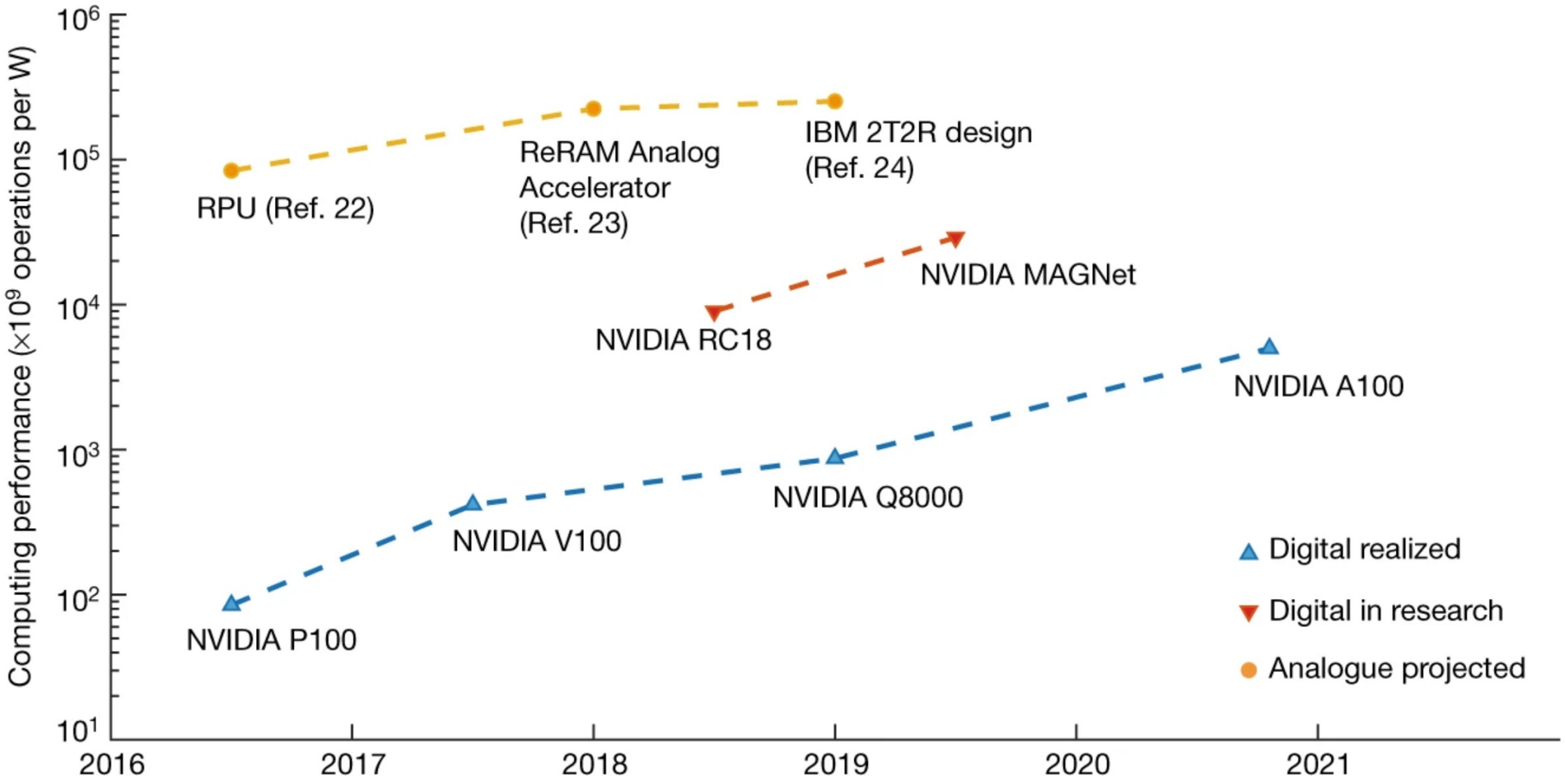


Optimising & tuning





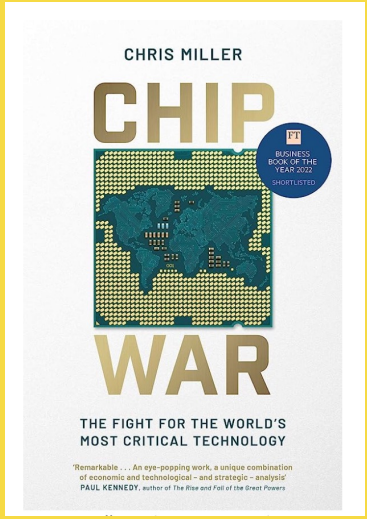
Energy becomes fundamental design principle for future of computing



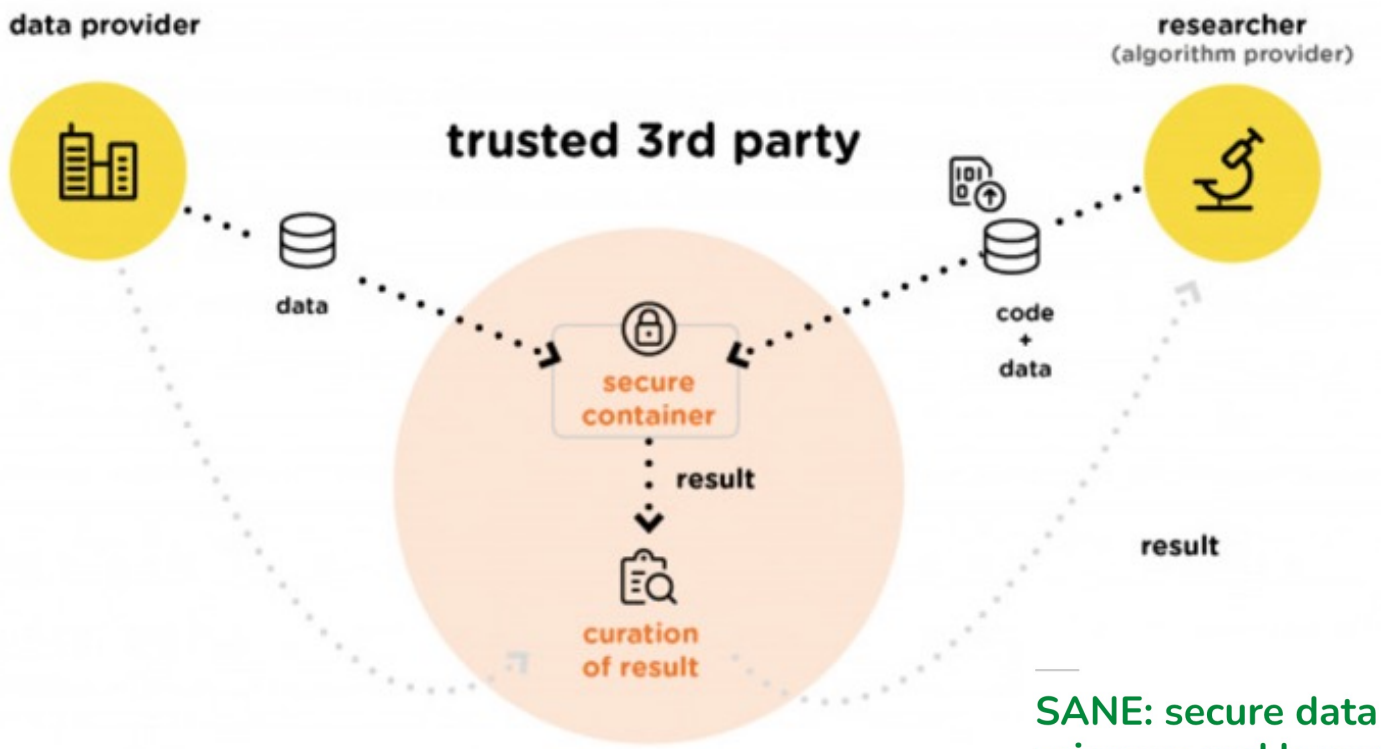
Brain-inspired computing needs a master plan

International Science collaboration + Technology Sovereignity

International Science collaboration + Technology Sovereignty



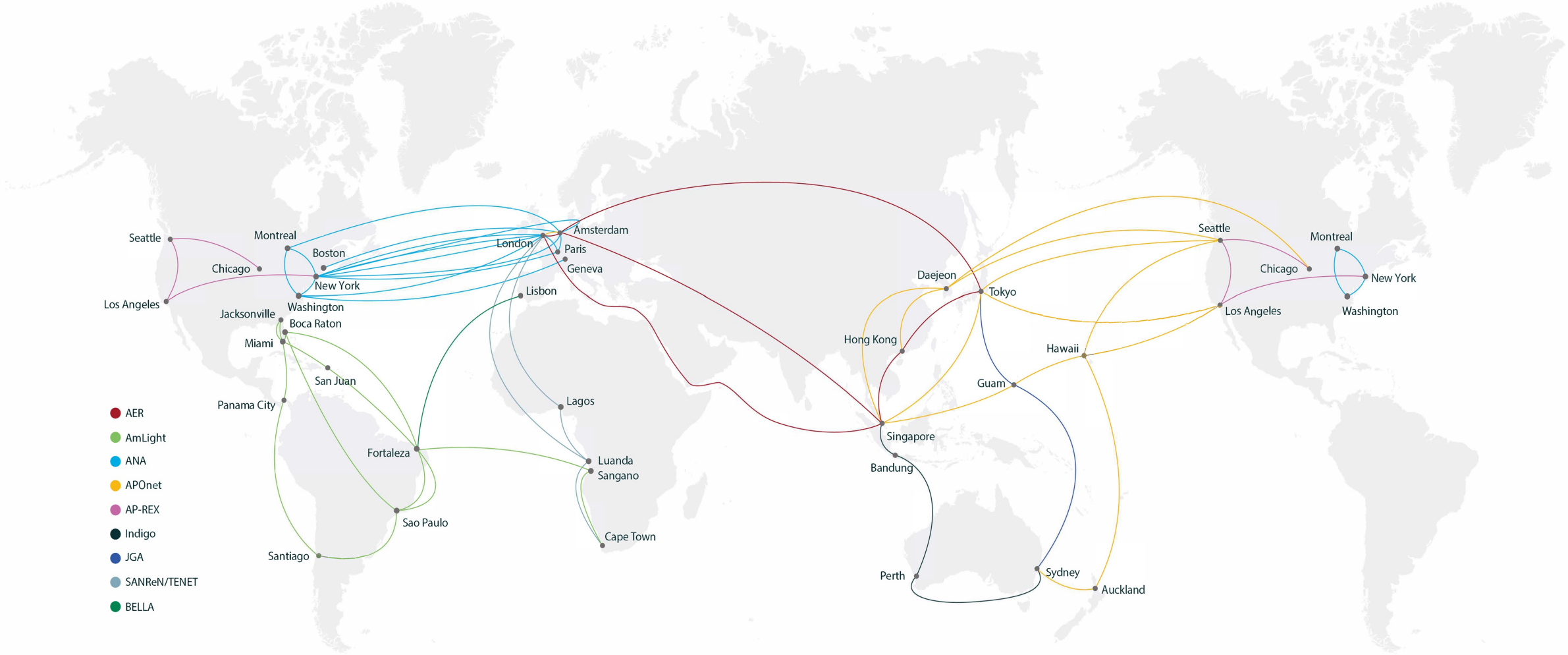
Trusted data exchange, secure processing & confidential computing



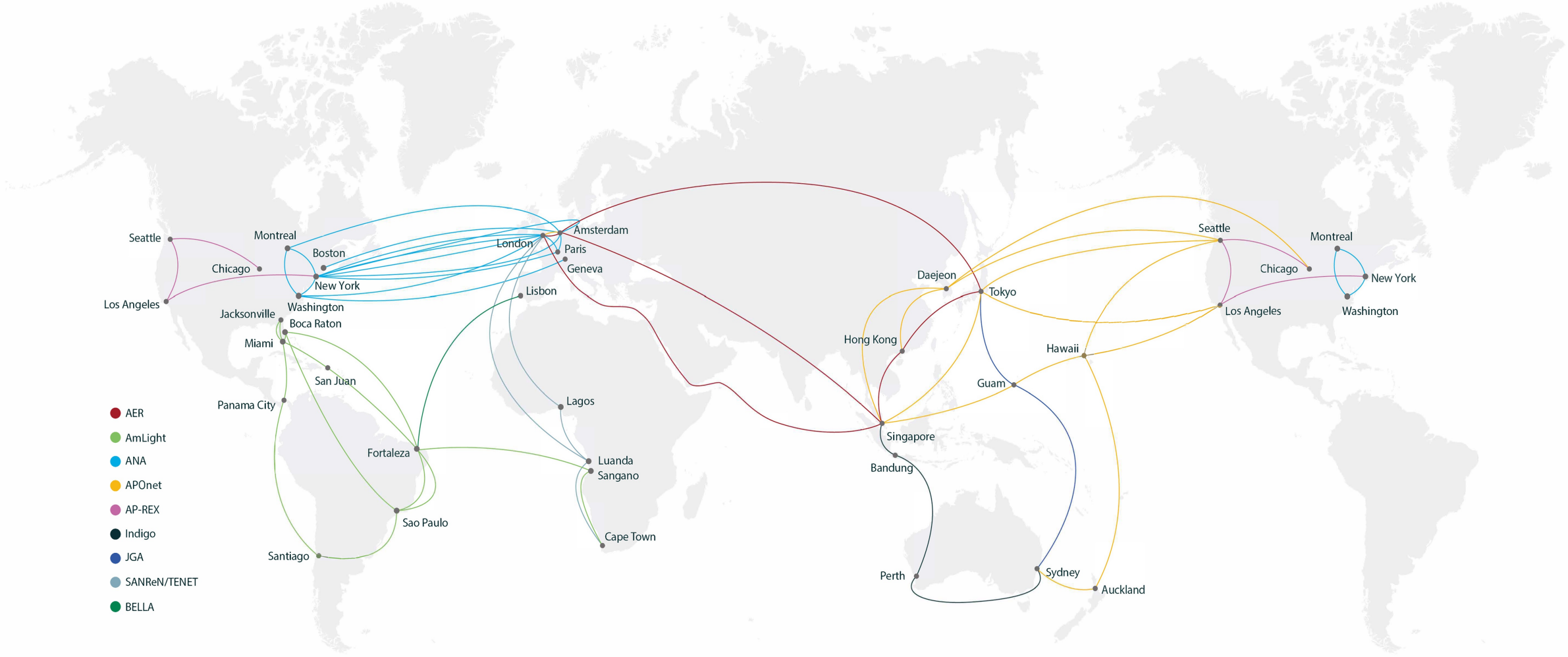
Using the ODISSEI Secure Supercomputer

SANE: secure data environment for social sciences and humanities

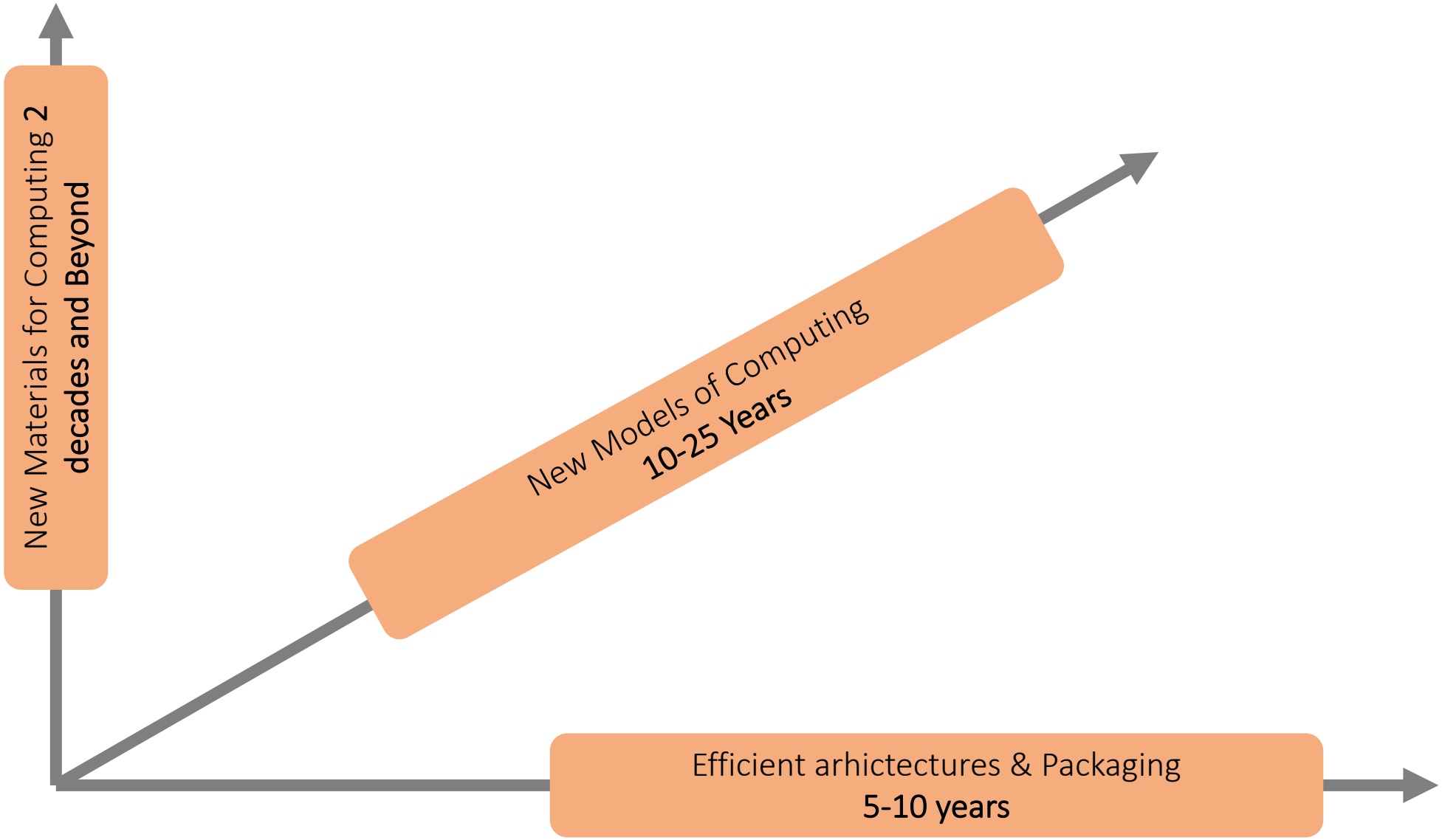
Privacy, copyright and competition barriers limit the sharing of sensitive data for scientific purposes. Together with several partners, SURF is working on a Secure ANalysis Environment (SANE). A virtual container in which the researcher can analyse sensitive data, but the data owner retains full control. This makes new research possible.

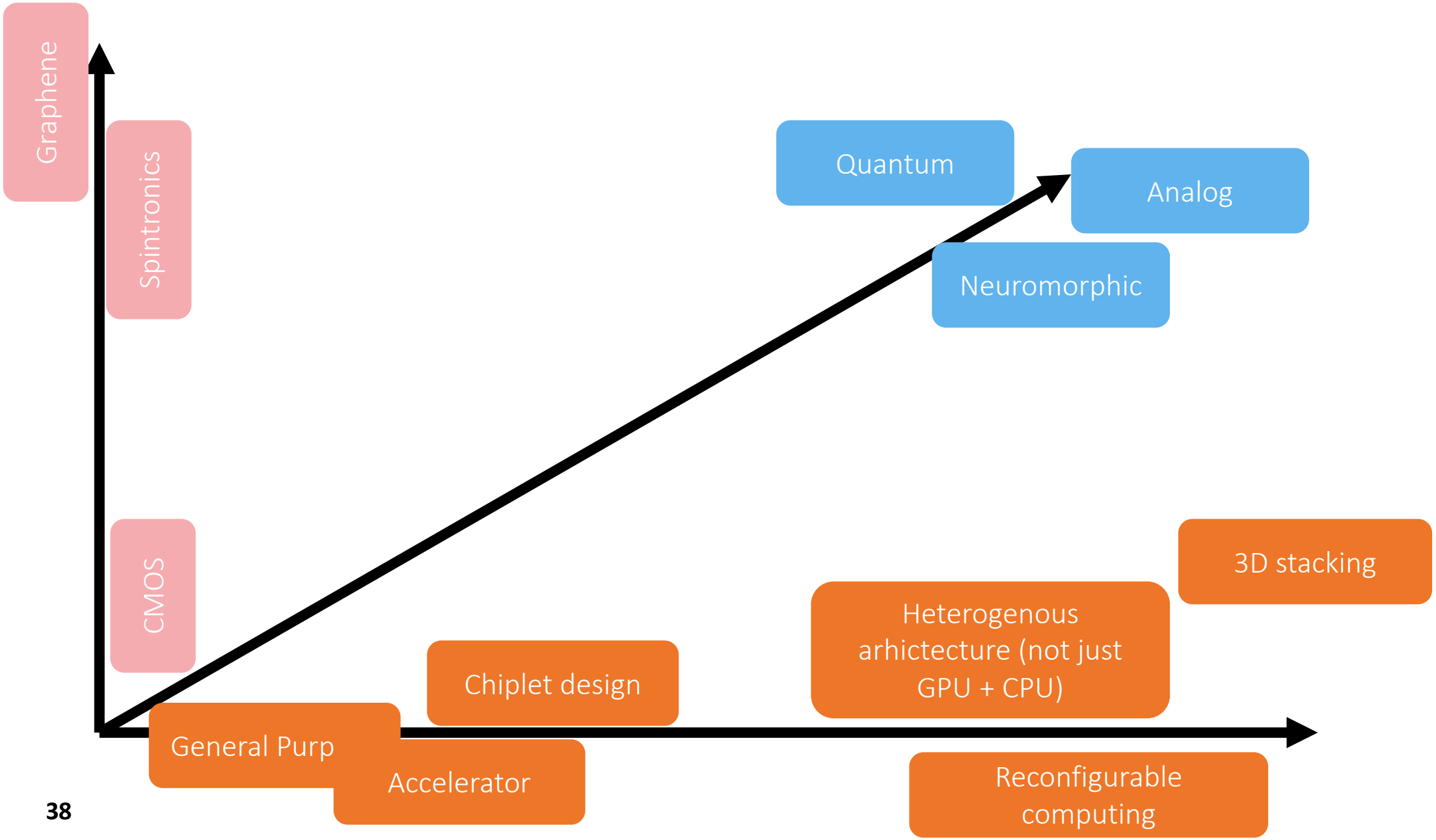


> Capability of 1 Terabit/s



Science beyond cultural & geographical boundaries becomes the norm

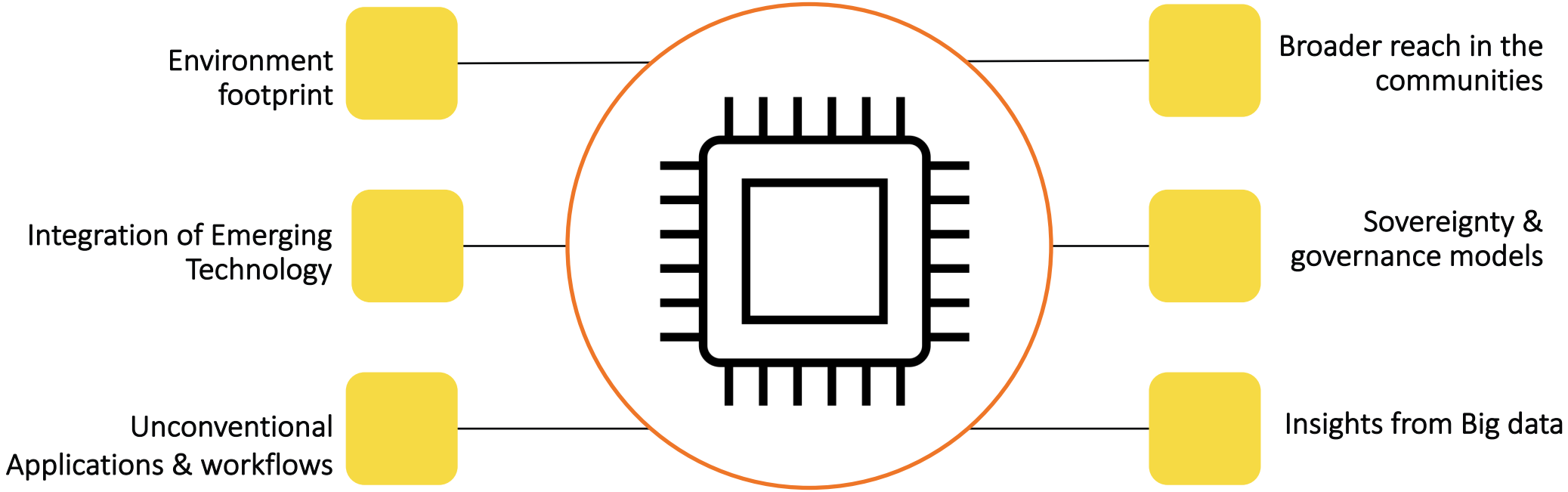

New Materials for Computing 2
decades and Beyond
New Models of Computing
10-25 Years
Efficient arhictectures & Packaging
5-10 years


Graphene
Spintronics
CMOS
Quantum
Analog
Neuromorphic
3D stacking
Heterogenous arhictecture (not just GPU + CPU)
Chiplet design
General Purp
Accelerator
Reconfigurable computing

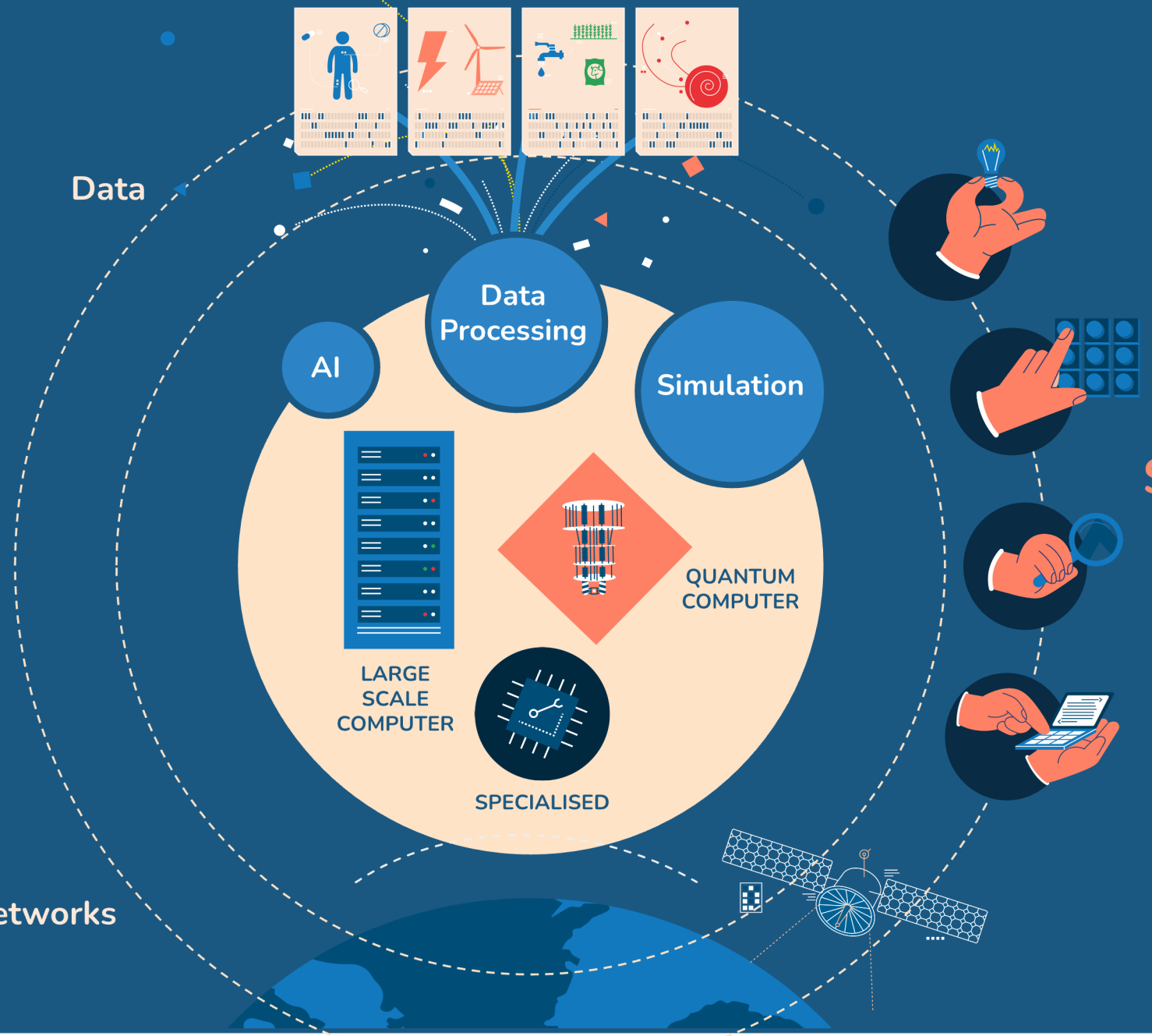
What next for Algorithms ?

- Explore data sparsity; data compression e.g in data processing workflows
- Algorithms moving from matrix-vector to matrix-matrix
- Algorithms to minimize data movement; significantly pivoting during matrix manipulation (e.g space-filling curves)
- Embrace mixed & low-precision arithmetic or maybe custom precision (half precision, Integer precision)
- Randomized than deterministic solvers (numerical stability*)

Future Computing



Future of applications
e.g in Energy, Weather, Medicine, High Energy Physics, Digital twins, social sciences, humanities etc etc



Stakeholders

SURF

“Challenging the ***hypothesis***, framing ***experiments*** & understanding ***value & impact for future of science & research***