

# Molding Tomorrow: Innovating with the Materials of the Future

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MWC24

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PUZZLE X

# MATTERVERSE

2

THE AGE OF EXPONENTIAL TECHNOLOGIES

PUZZLE X™



# MATTERVERSE



PUZZLE X™

The image features a dark background with a grid of glowing purple characters, including letters, numbers, and symbols, arranged in a perspective that creates a sense of depth. Overlaid on this grid are several horizontal, wavy lines of varying amplitudes, resembling a signal or data stream. The overall aesthetic is futuristic and digital.

# MATTERVERSE

PUZZLE X™



# STONE AGE



A cinematic scene set in a dense, misty forest. Four individuals, dressed in primitive, fur-like clothing, are positioned on a forest floor. From left to right: a person with a large, shaggy headpiece and a fur cloak is climbing a tree trunk; a woman stands holding a long spear; a child stands holding a bow; and a man stands holding a bow and a dog. The forest is filled with tall, thin trees, and sunlight filters through the mist, creating a dramatic, atmospheric effect. The ground is covered in fallen leaves and twigs.

# STONE AGE



**BRONZE & IRON AGE**

A wide-angle photograph of a rice paddy field at sunset. The sun is low on the horizon, casting a warm, golden glow over the scene. The rice plants in the foreground are in sharp focus, showing their long, slender leaves and developing panicles. The field extends to the horizon, where a range of dark mountains is visible under a clear blue sky with a few wispy clouds. The overall mood is peaceful and serene, highlighting the beauty of agricultural landscapes.

# MODERN AGRICULTURE

An aerial photograph showing a vast landscape covered in white, fluffy clouds. In the upper left corner, the wing and tail fin of an airplane are visible, extending from the left edge of the frame. The sky above is filled with horizontal, layered clouds, suggesting a sunset or sunrise. The overall tone is dramatic and atmospheric.

**AGE OF ALUMINUM**



**AGE OF SILICON**

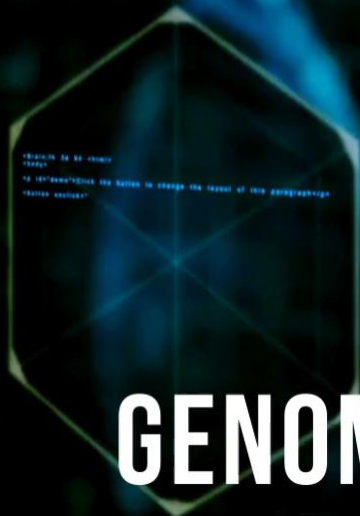
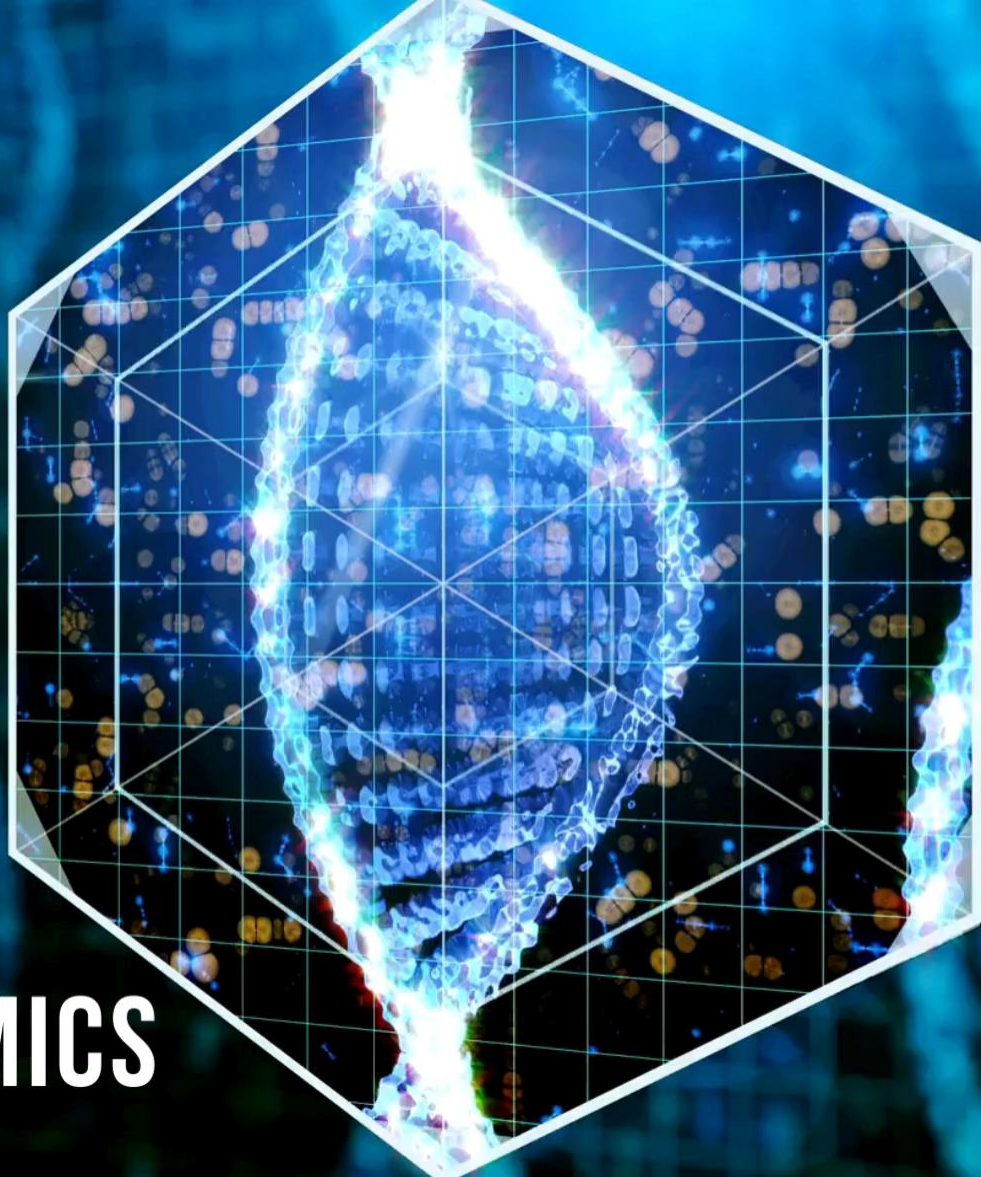




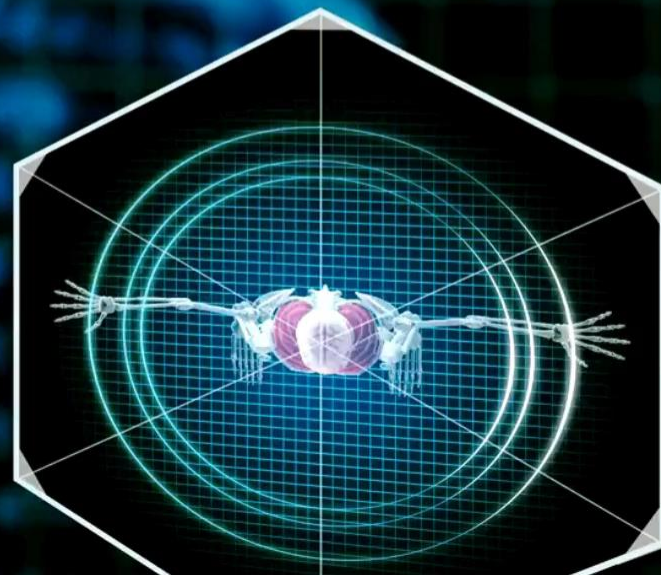




WELCOME TO THE ERA OF  
EXPONENTIAL TECHNOLOGY



# GENOMICS





**FRONTIER MATERIALS & NANO ASSEMBLY**

The image features two glowing, spherical objects with intricate, fractal-like patterns in shades of red, orange, and purple. These spheres are positioned on either side of the word "QUANTUM", which is written in a bold, white, sans-serif font. A thin, horizontal line connects the two spheres, passing through the text. The background is a gradient of dark blue and purple, with a bright light source in the upper right corner creating a lens flare effect.

**QUANTUM**



# AI & MACHINE LEARNING

e1 + e2 + e3 + t5



MACHINE LEARNING

QUANTUM

FRONTIER & NANO

GENOMICS

EXPONENTIAL TECHNOLOGIES

**MASTERS OF MATTER**



# FRONTIER MATERIALS





Graphene Tattoo | Akinwande Lab | University of Texas Austin



Graphene Flexible Brain Digital Interface  
Garrido et al. , ICN2





## WIFI SEEING THROUGH CONCERTTE

De la Torre et. al. | Carnegie Mellon University





# Spinach Sending Emails



Detecting Explosives & Communicating | Nano Bionics using Carbon Nanotubes  
Strano et al. , MIT

A hand in a dark suit jacket holds a large, clear glass dome over a glowing, spherical object. The object has a bright yellow-green center that fades into a white outer layer. The scene is set against a dark background with a light-colored, textured surface at the base of the dome.

EXTINCT WOOLLY MAMMOTH MEATBALL

Vow



# EXOTIC COMPUTING | BIO COMPUTING

Andrew Adamatzky lab | University of the West of England



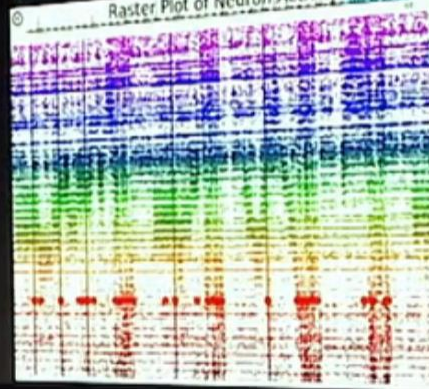


**PUZZLE X™**





```
00:18:47 [17.6, 61.0] [H/M: gain: (1.1, 0.3)]
```



00:18:47 [17.6, 61.0] [H/M: gain: (1.1, 0.3)]

Pong Game Environ

**PUZZLE X™**

The image features a dark background with vibrant purple, wavy lines that resemble digital signals or data streams. These waves are set against a backdrop of a dense field of binary code (0s and 1s) that appears to be receding into the distance, creating a sense of depth and digital space. The overall aesthetic is futuristic and data-driven.

# THE MATTERVERSE

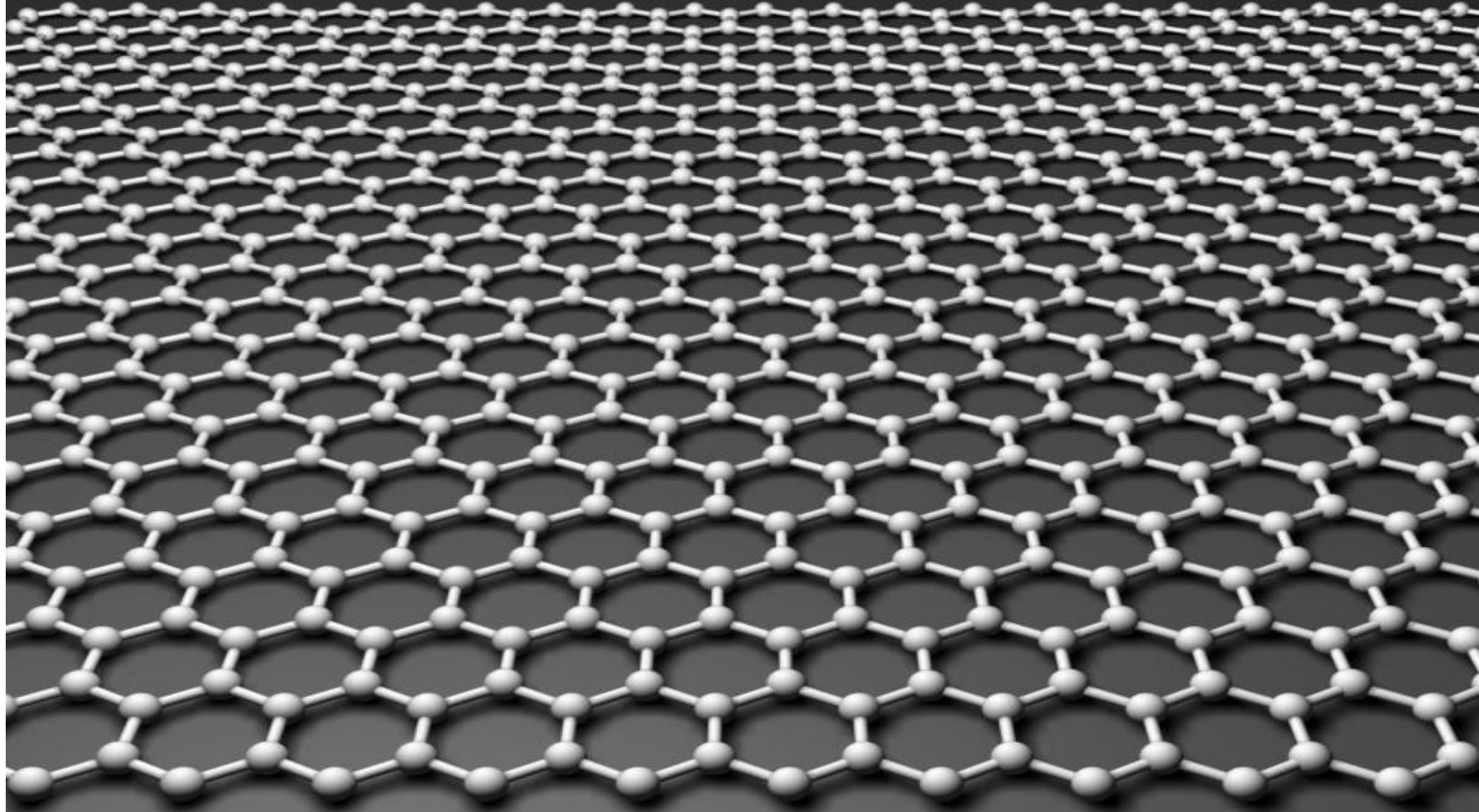
MWC24

Prof. Sir Konstantin Novoselov

Professor

National University of Singapore

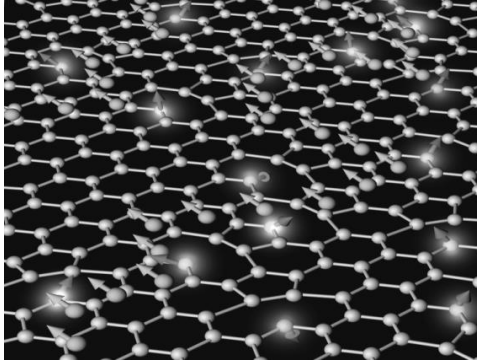
# Materials for the Future



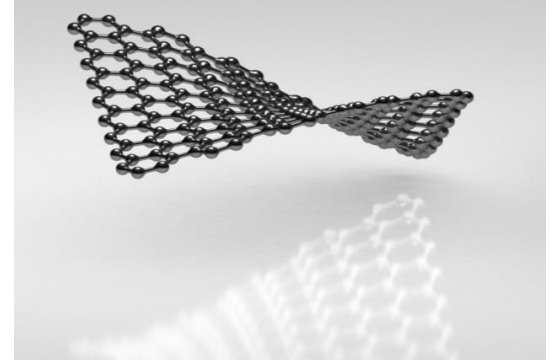
# Graphene Superlatives



Thinnest imaginable material  
Very transparent  
Most impermeable material  
Permeation can be controlled



Record thermal conductivity  
Highest current density  
Highest intrinsic mobility  
Ambipolar behavior

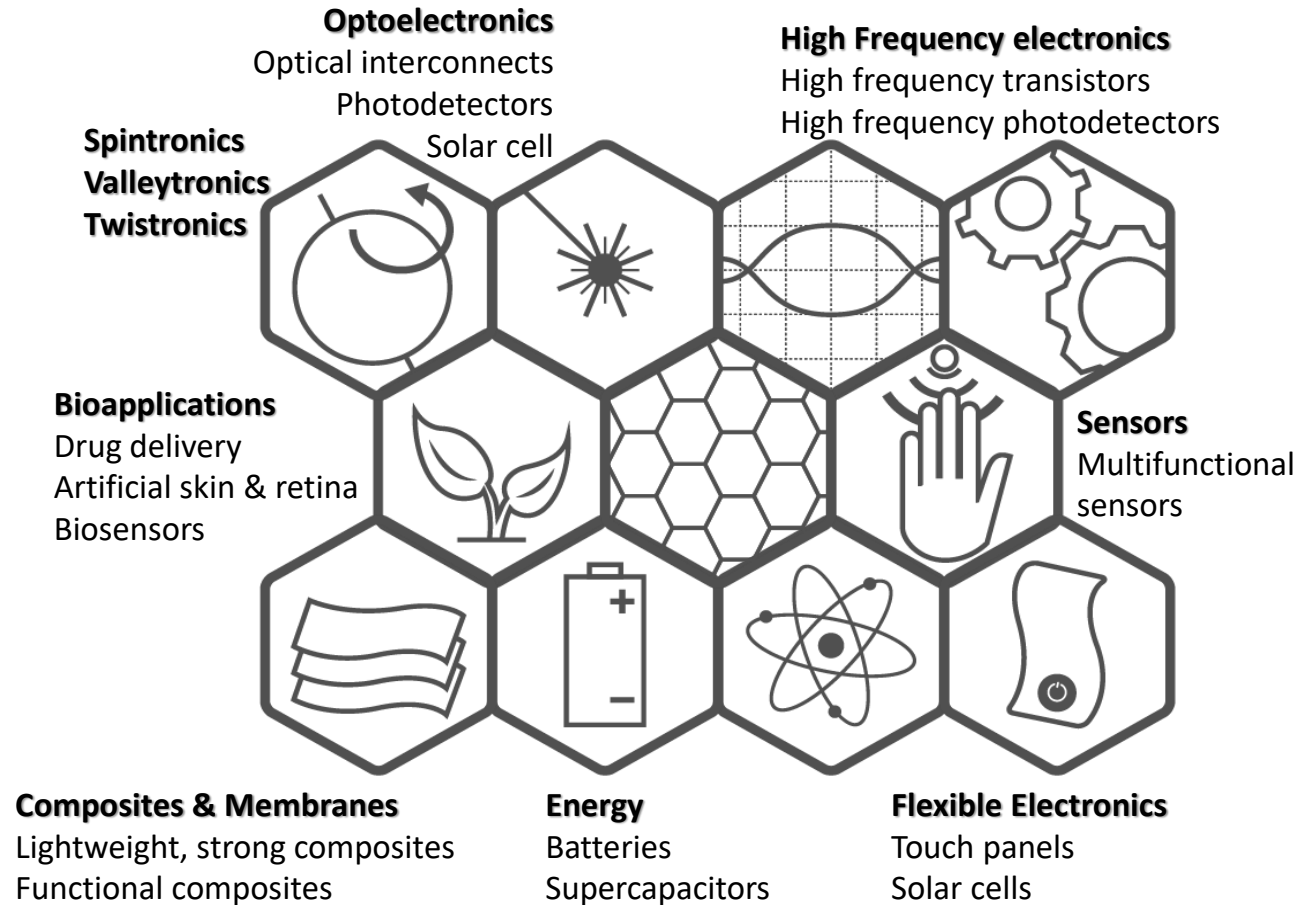


Strongest material  
Stiffest known material  
Strongly bendable  
Most stretchable crystal

All those unique properties are combined in one material

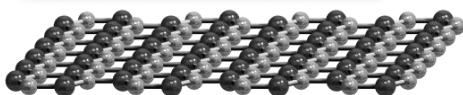
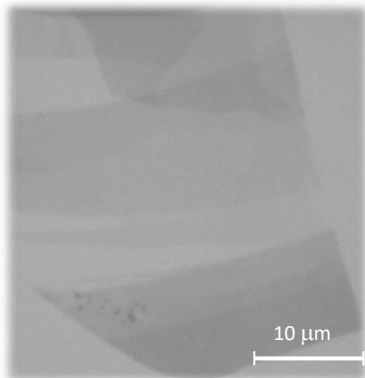


# Multiple possible applications

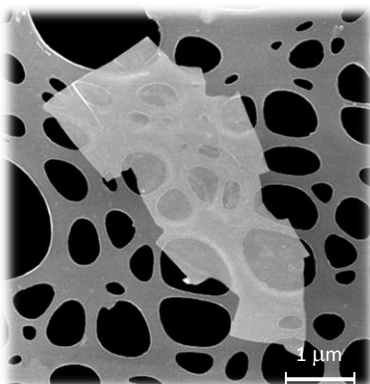


# Beyond graphene

2D boron nitride  
in optics



*Novoselov et al  
PNAS (2005)*

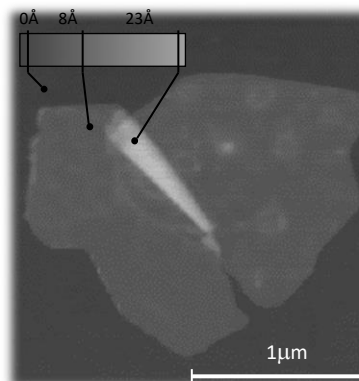


*SEM of  
2D Bi<sub>2</sub>Sr<sub>2</sub>CaCu<sub>2</sub>O<sub>x</sub>*

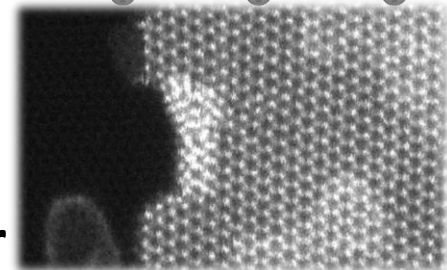
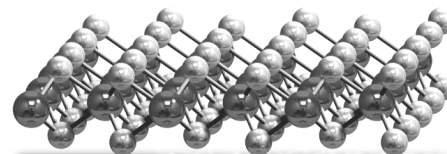
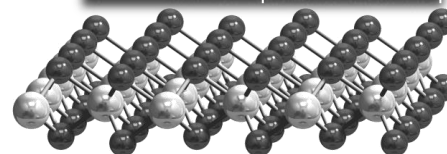
**2D crystals from other layered materials**



**High Quality  
Different From 3D Precursor**

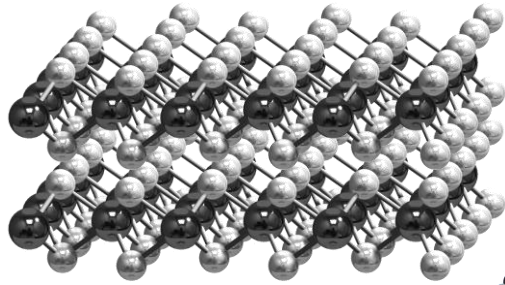


*2D NbSe<sub>2</sub>  
in AFM*



*2D MoS<sub>2</sub>  
in TEM*

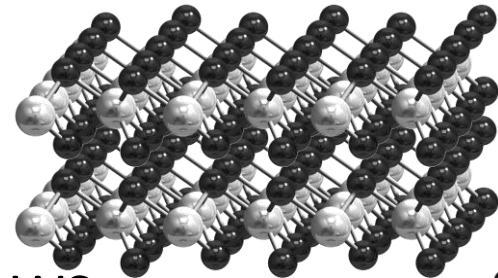
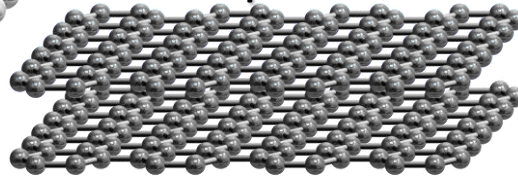
# Layer by layer material engineering



MoS<sub>2</sub>

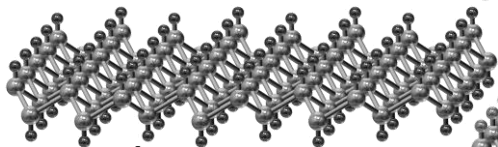
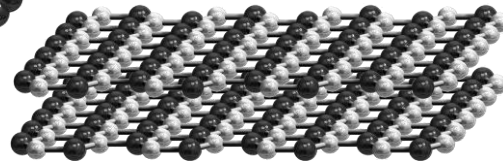
Large Variety of  
Material Properties

Graphene



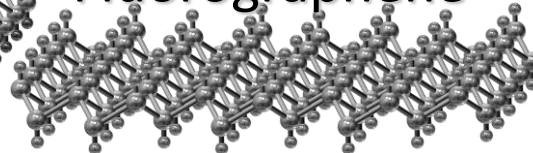
WS<sub>2</sub>

Boron Nitride



Graphane

Fluorographene



1991 expectations  
about 2029



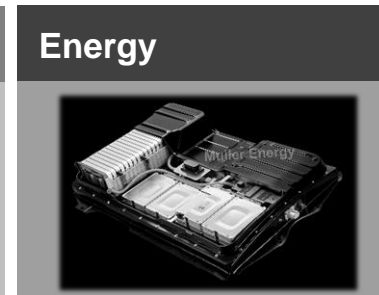
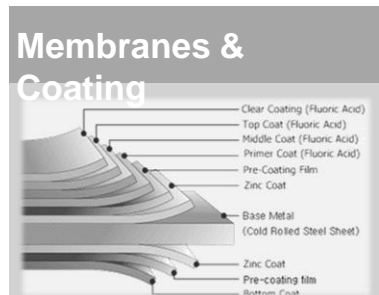
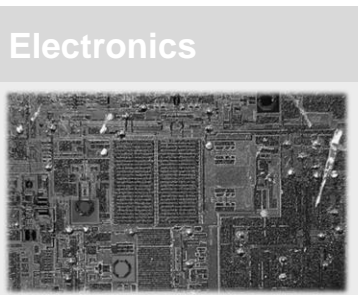
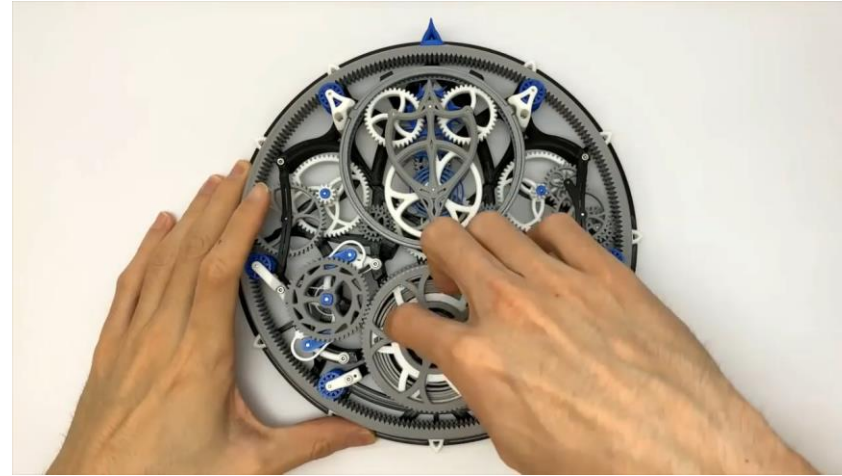
**Bottom-up functionality** at the  
material & structural levels

Reality in 2024  
(still got 5 years to fix it)



**Top-down functionality**  
at the structural level only

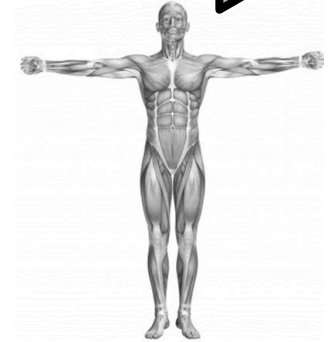
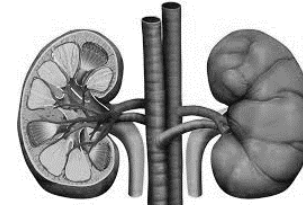
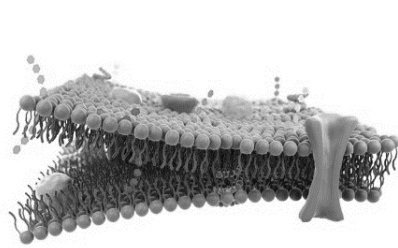
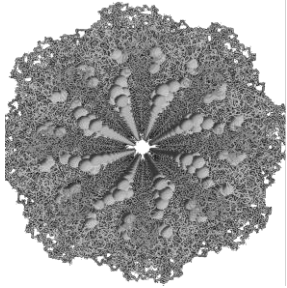
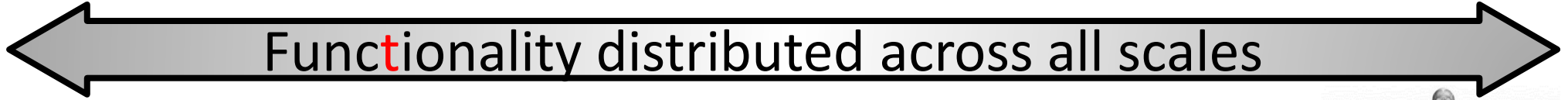
# Current technology: top-down functionality




Not adaptive  
Prone to faults

Requires constant control  
Energy inefficient

# Nature: bottom-up functionality

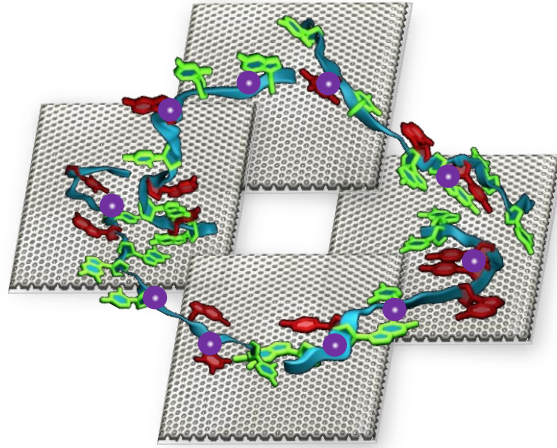
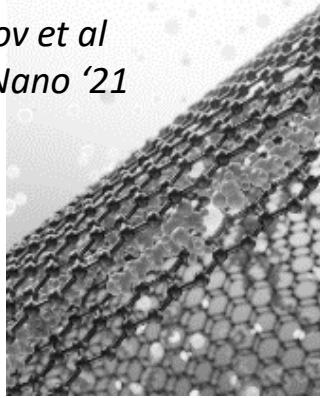


| Electronics  | Membranes & Coating              | Bio & Healthcare                               | Energy |
|--|----------------------------------|--|--------|
|  |                                  |  |        |
|  Adaptive<br>Versatile | Self-healing<br>Energy efficient | <b>Functionality at<br/>the Material Level</b> |        |

# Bottom-up functionality at the material level

## Smart Membranes

Novoselov et al  
*Nature Nano '21*



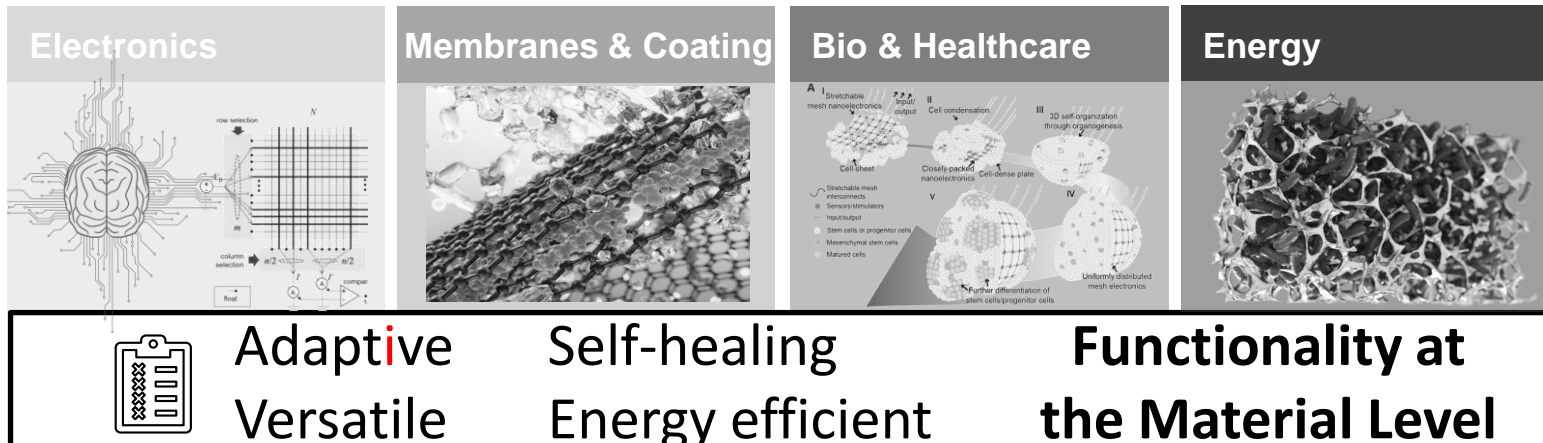
## Functional

Programmable to perform a complex response to external stimuli

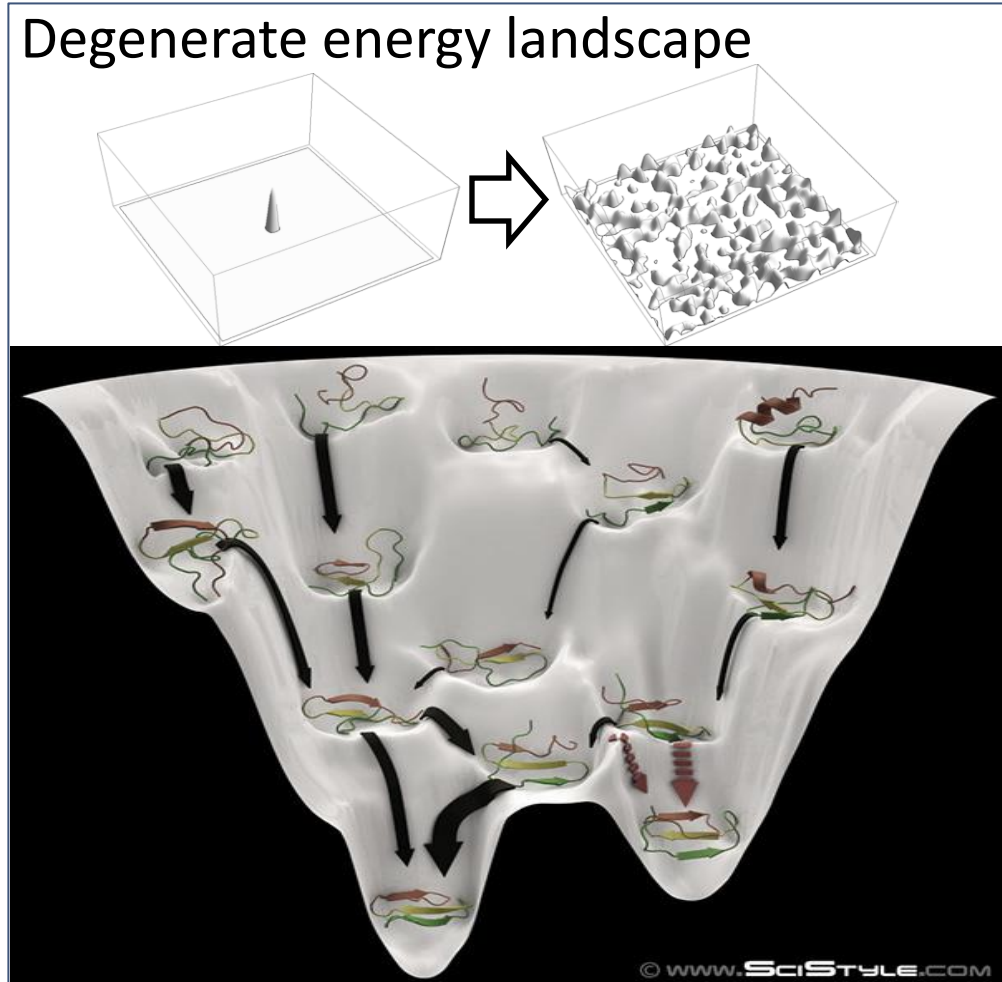
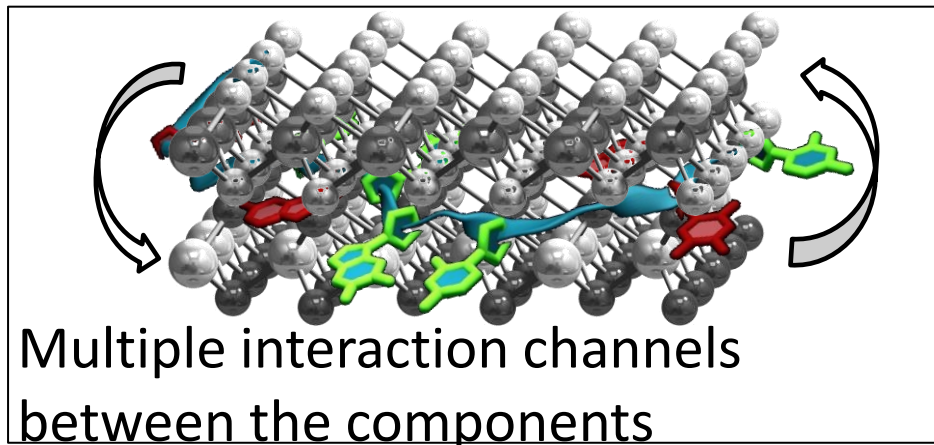
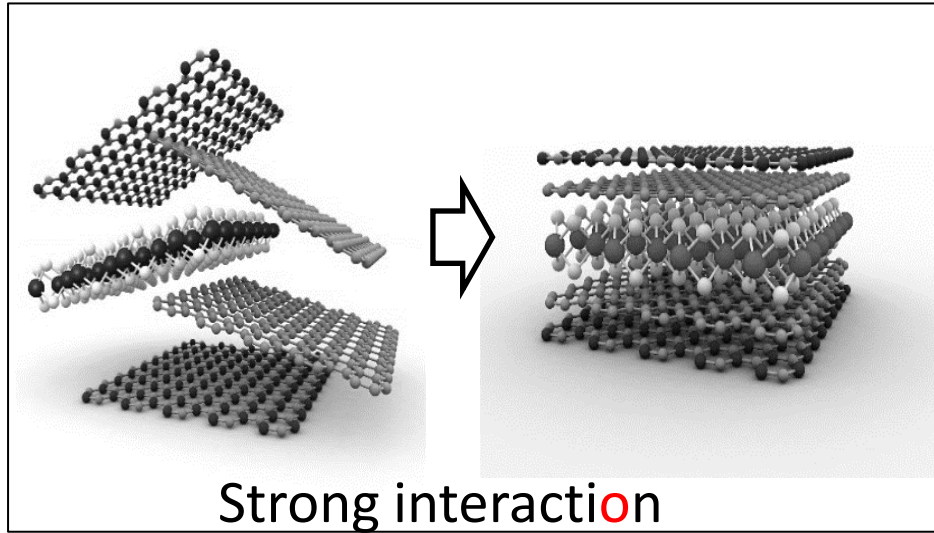
## Intelligent

Have memory: can learn to perform a particular function

## Materials



# Principles of materials design



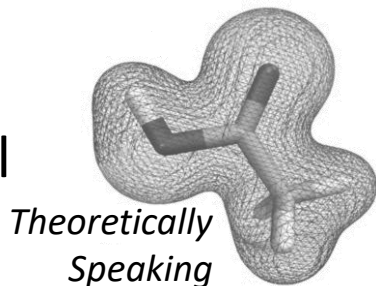


# Framework for the development of FIMs

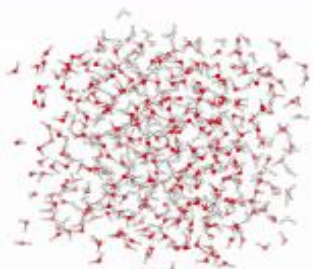
## Physical Formalism

Basic Physics  
Constrains  $i\hbar \frac{\partial \Psi}{\partial t} = \hat{H}\Psi$

Density  
Functional  
Theory



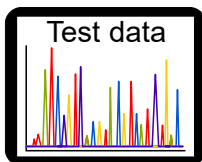
Molecular  
Dynamic  
Simulation



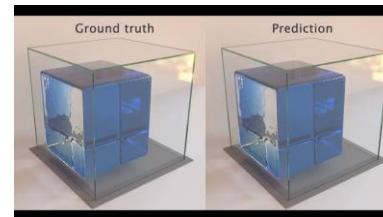
*Wikipedia*



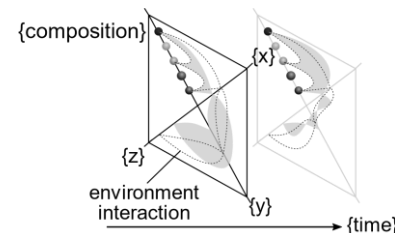
## Material Robotics Lab



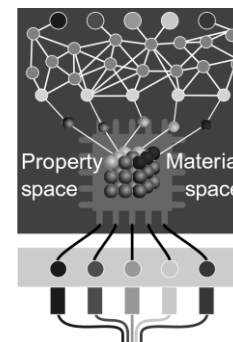
## Dynamic Machine Learning



Differentiable  
programming  
(e.g. JAX MD)



Identifying  
Memory  
States



Solving  
Inverse  
Problem



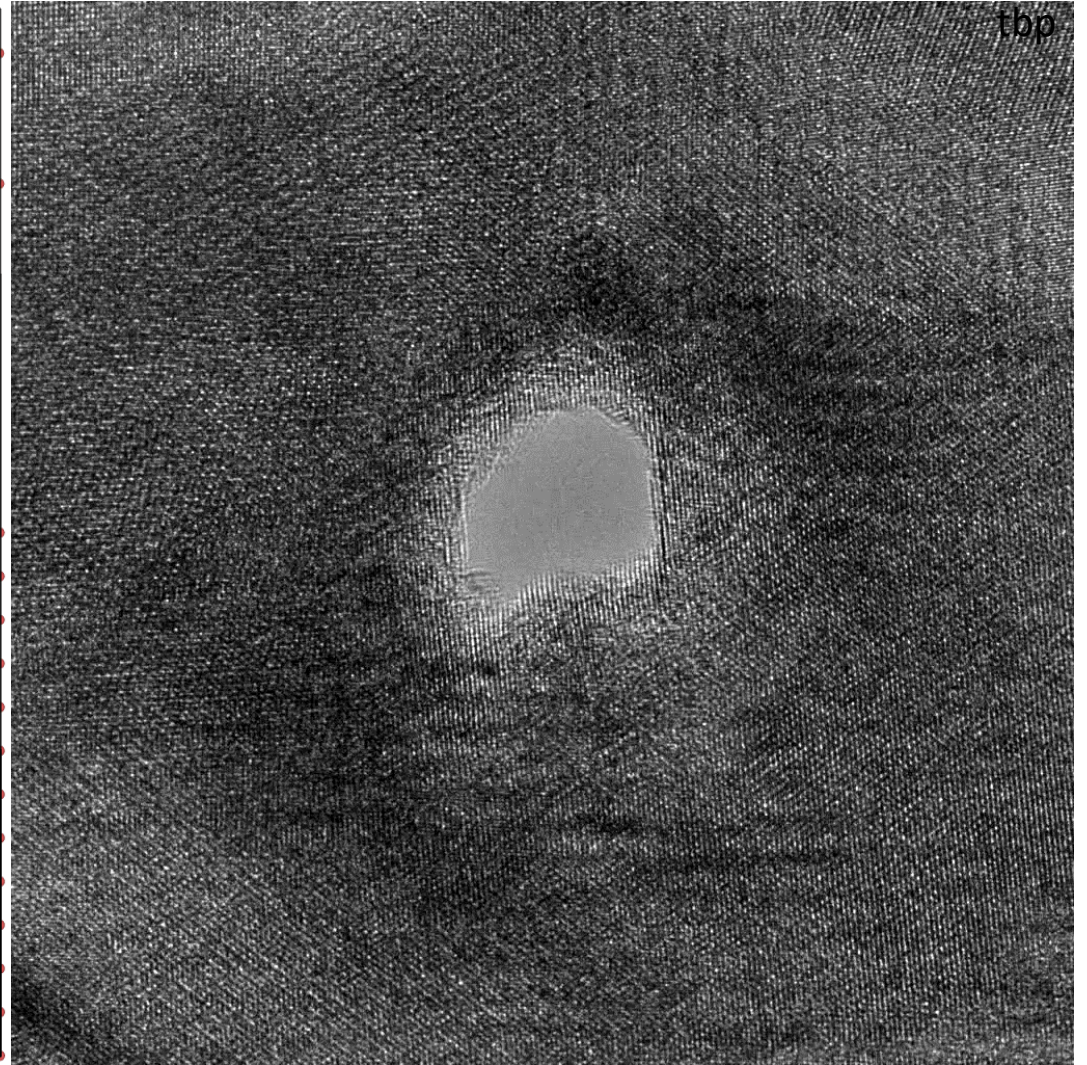
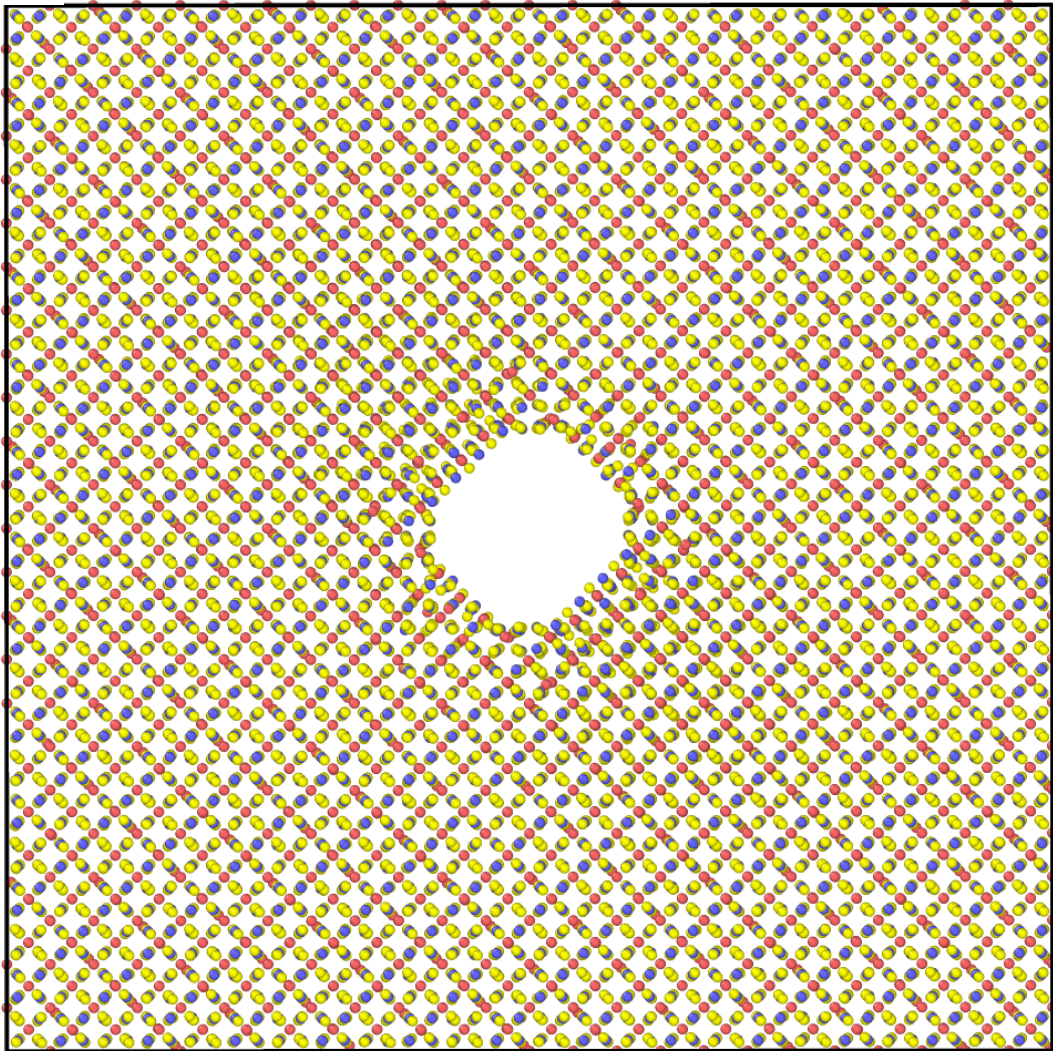
*Andreeva, Skorb et al. In preparation*

2020

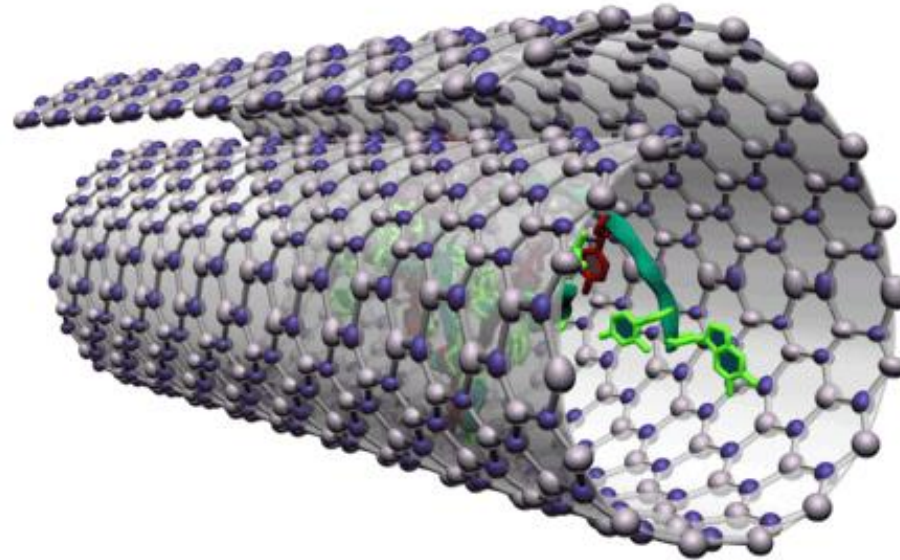
2020

# Out of equilibrium properties of materials

Zongwen Liu,  
Pengru Huang,

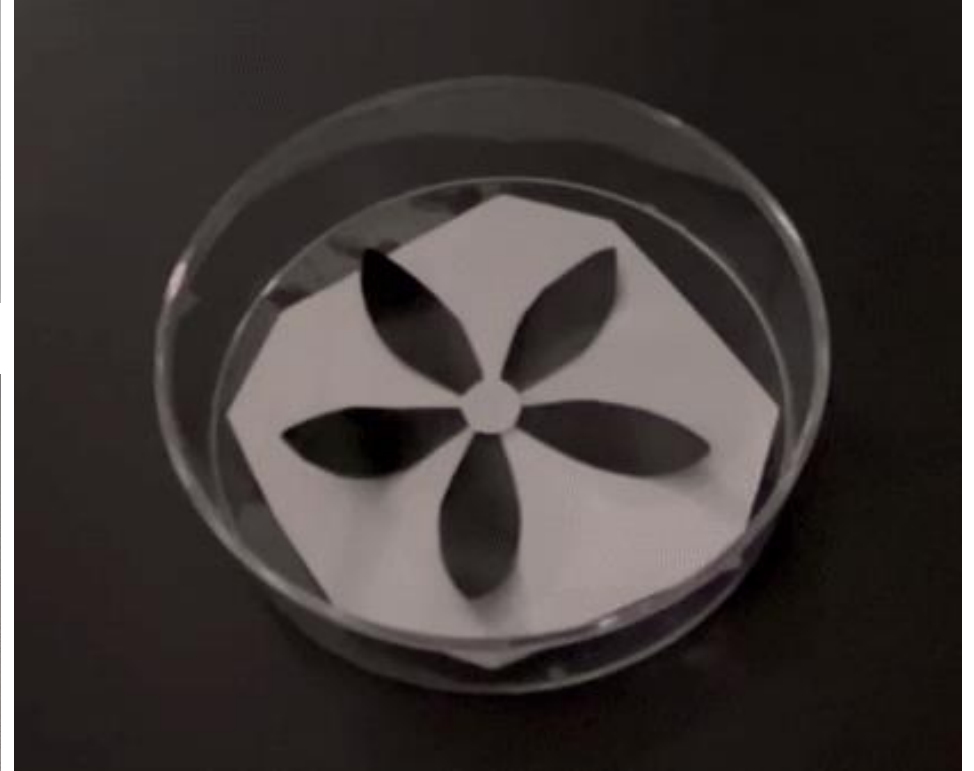
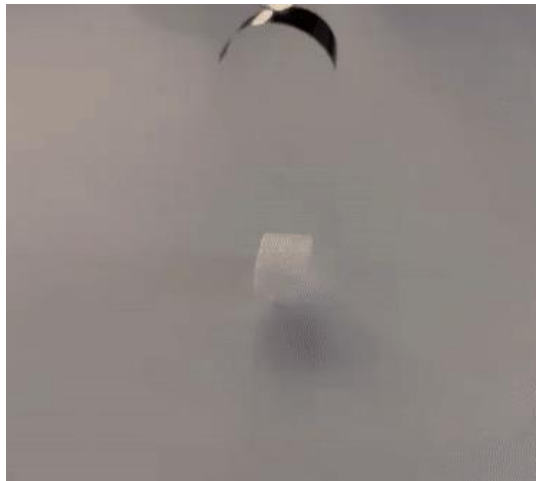
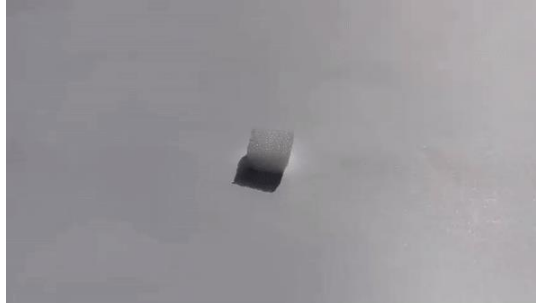


# Smart drug delivery



# 2D actuators

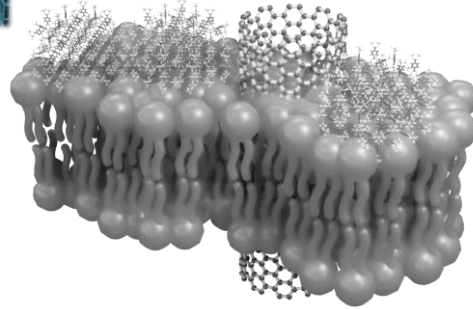
Qian Wang et al  
manuscript in  
preparation





*Courtesy Gui Bazan, Institute for Functional Intelligent Materials*

# Solving Worlds Most Important Sustainability Issues





MWC24

Rika Nakazawa

Group VP, New Ventures & Innovation

NTT DATA

# Innovating with Innovative Materials (Particles) of the Future

## Silicon Photonics and Sustainable Networks of the Future

Rika Nakazawa  
Group Vice President, New Ventures & Innovation  
NTT DATA Inc

# Using Alternative Power in Nature for Sustainable Growth through Technology

## Beyond Human

- Future Sensor + AI Systems
- **For the machine** (AI) to process
- That sense information humans can't recognize,
- Enables millisecond-order autonomous control

More valuable if you can control it on the **order of milliseconds.**

## For Human

- Traditional digital systems
- For human confirmation and use
- Information within human perception
- Transfer with a sense of speed of human activities

Communicated / transmitted **in a few seconds.**  
We can't respond in 0.1 seconds.

## Cognitive and Communication Capacity

How finely, precisely, and multisensory the system can capture objects in the physical world and process the captured data.



**Beyond Human (Natural)**  
20-150,000 Hz sound,  
120 FPS motion, etc.



**Human-Level (High-Quality Digital)**  
20-20,000 Hz sound,  
30 FPS motion,  
encoded at fine-for-human quality



**Low Quality Digital**  
10 FPS motion, etc.

## Response Speed

How responsively the system can react to an event. Can be represented with turn around time (TAT).



**Beyond Human (Natural)**  
Act in 10 msec

**Human-Level**  
Act in 0.1 second



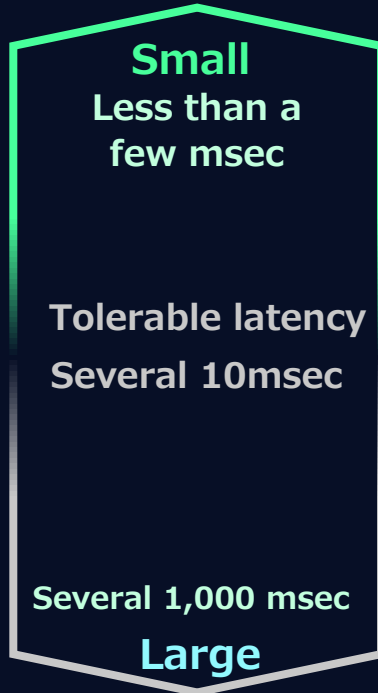
Act in a second



Act after several minutes

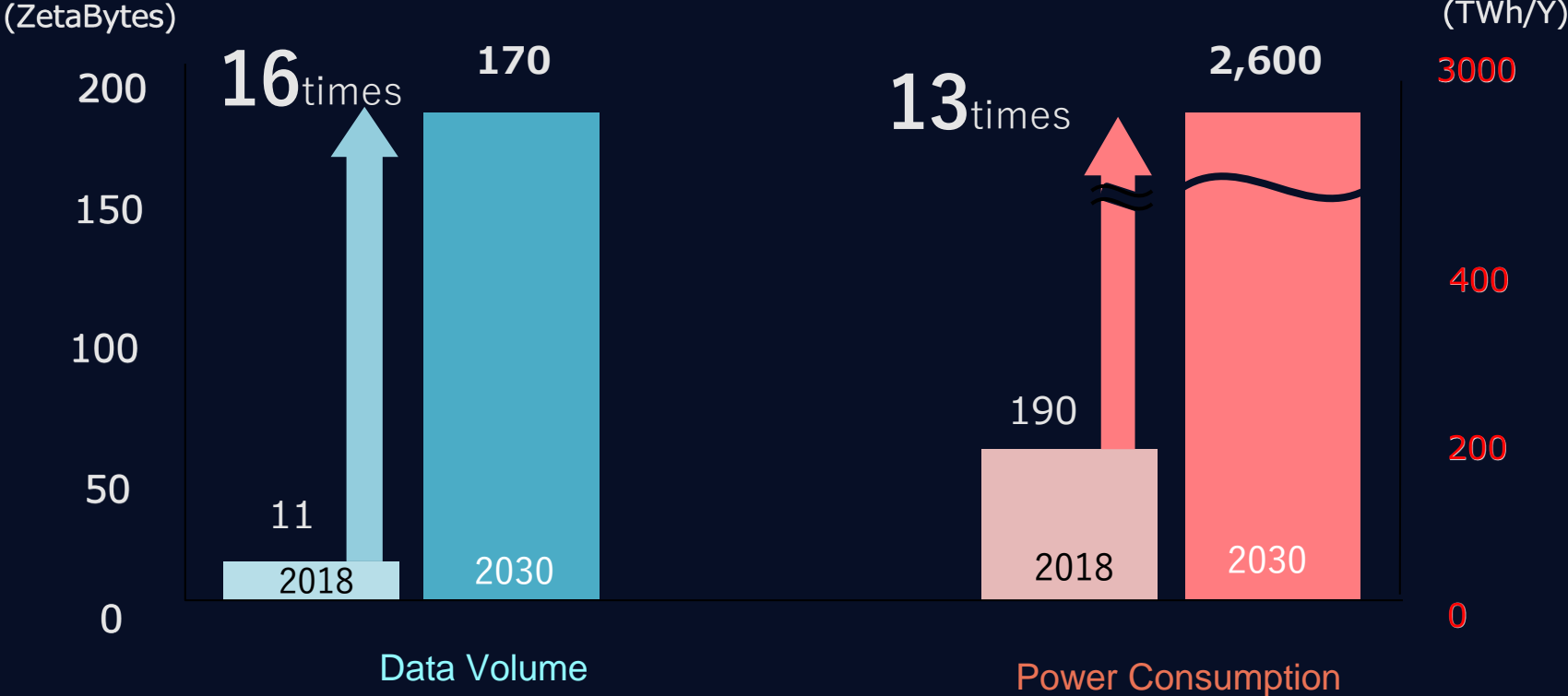
# Requirement from Advanced Applications

Reduction of network latency is essential for robotics, Autonomous driving, AR/VR, etc.



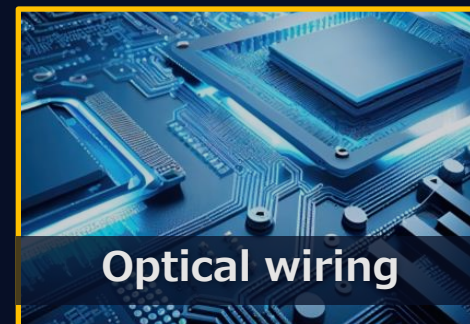
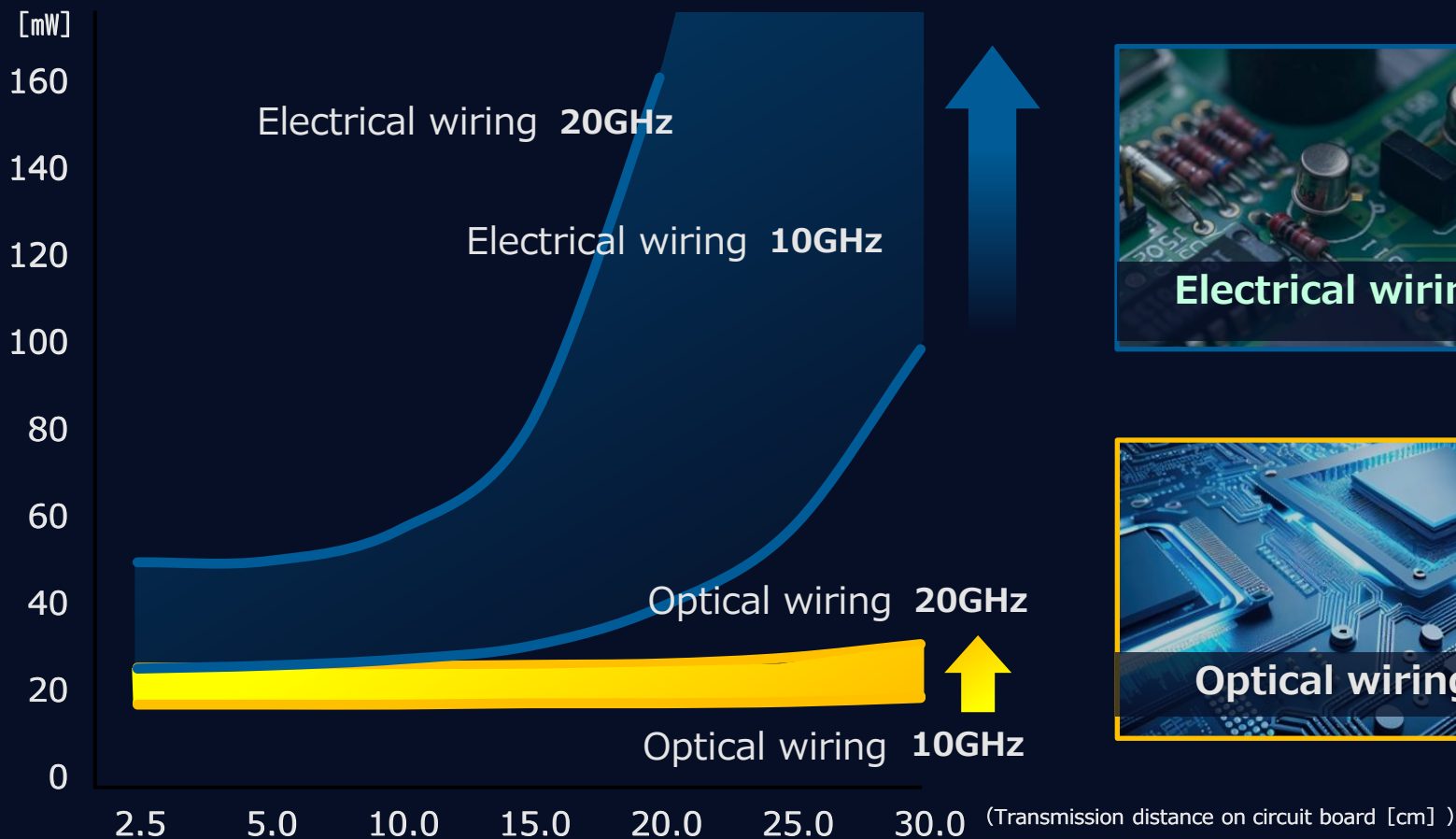
|                                     |  |
|-------------------------------------|--|
| Autonomous driving/ traffic control |  |
| Robots/drones                       |  |
| AR/VR                               |  |
| Teleconferencing                    |  |
| Video streaming                     |  |
| High-capacity storage               |  |

# Global Data Centers: Data Volume | Power Consumption



# **Innovative Optical and Wireless Network powered by Optics “Materials”**

# Why Optics





# IOWN:

Next Generation Optical Network & Computing Infrastructure

Data Center



High-capacity/  
high-quality



Low-power  
consumption



Low latency



## IOWN

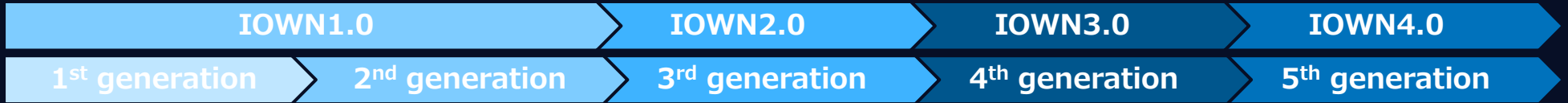
Innovative **O**ptical and **W**ireless **N**etwork

Optical network



6G Use Cases

# Power Efficient Photonics-electronics Convergence Devices

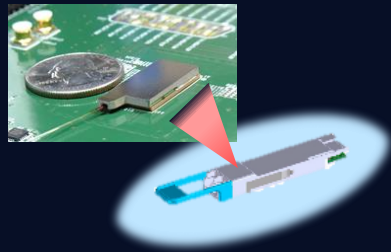


For relay devices



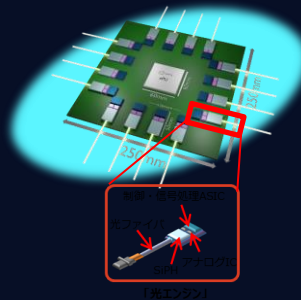
Telecom relay device

For pluggable transceivers



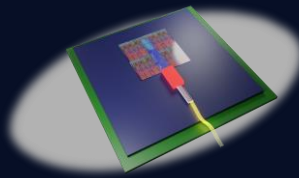
Transmission device between data centers

For board connection



· Ultrafast switch  
· SmartNIC

For chip connection



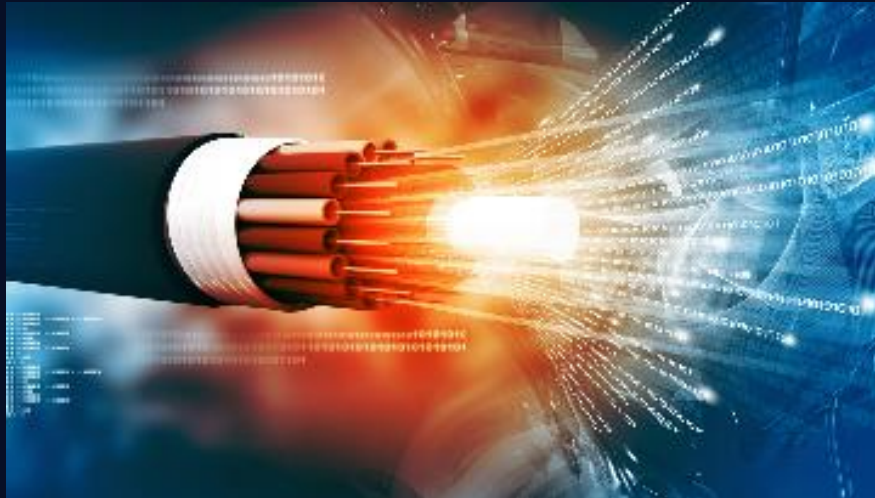
Photonic disaggregated computer

Fiber-less

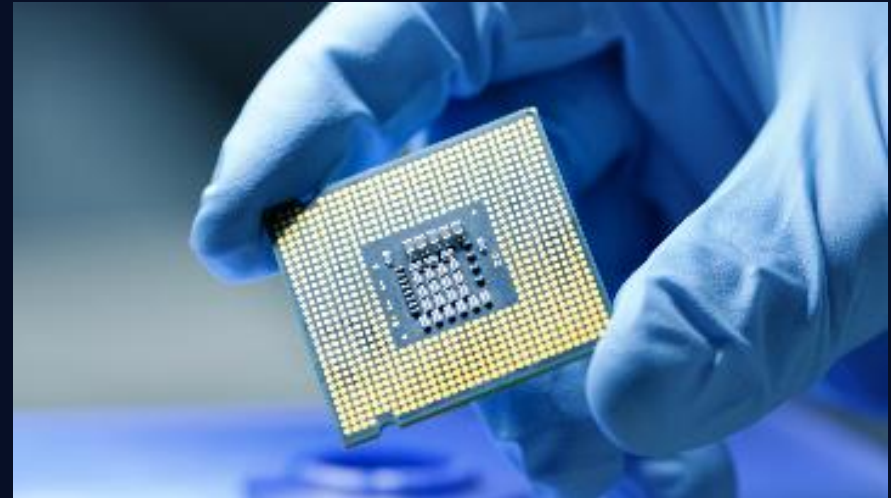


# Particles and Material Science

**“Transmitting”  
Photonics**



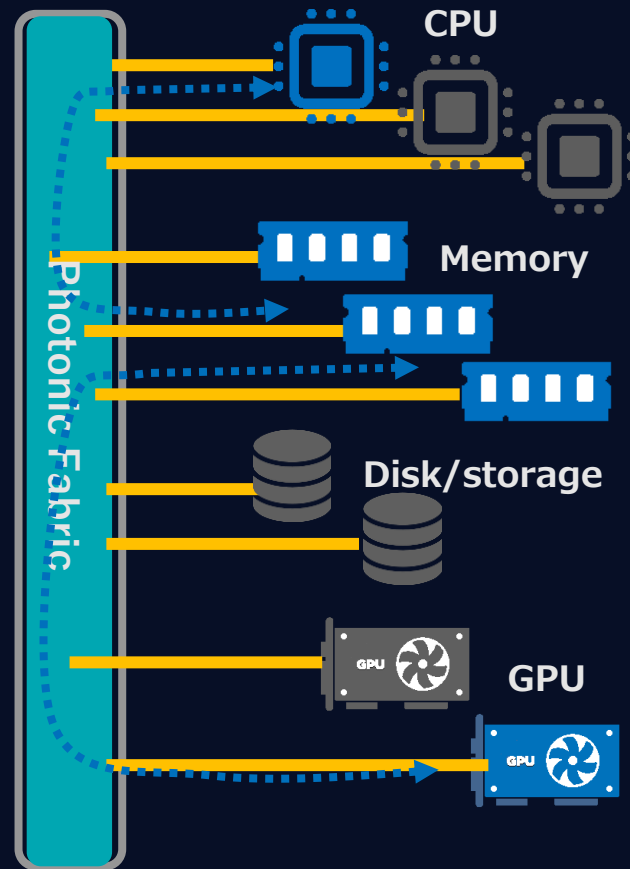
**“Data Processing”  
Electronics ⇨ Photonics**



# IOWN Computing

# IOWN computing: Photonic Disaggregated Computing

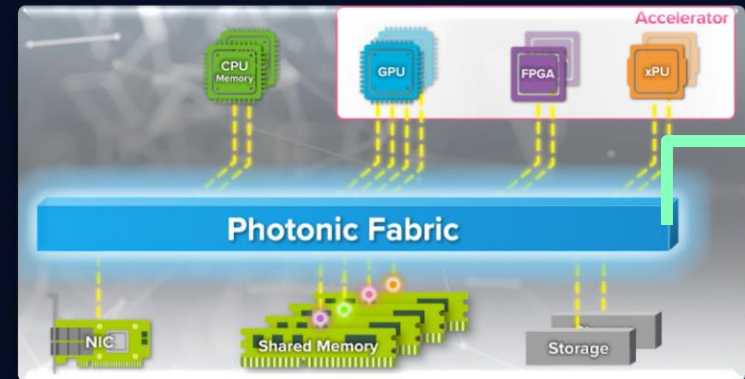
- Centers around data (memory) where only necessary components operate
- Connect devices over long distances using optical wiring



# Use Case: AI Analysis of Numerous Videos



IOWN APN





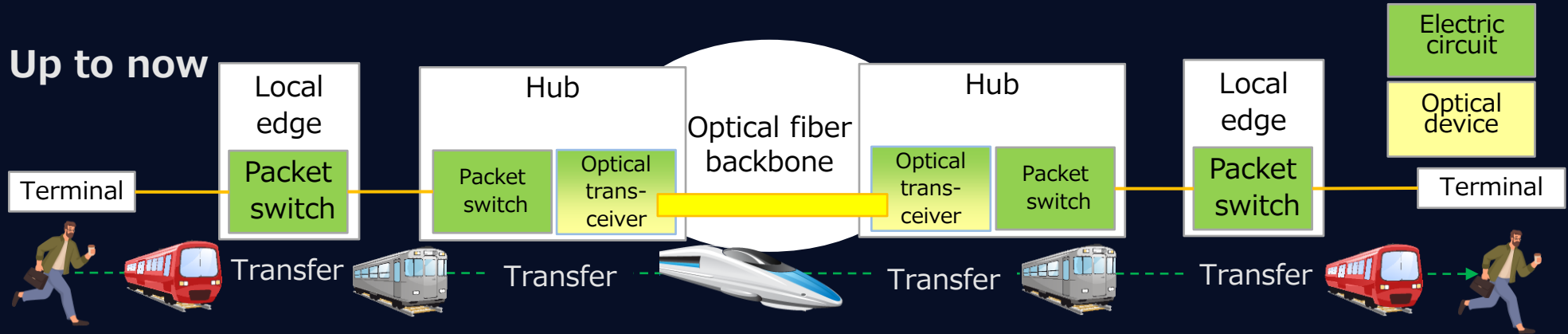
# **All-Photonics Network (APN) with Low Latency and Flexible Deployment**



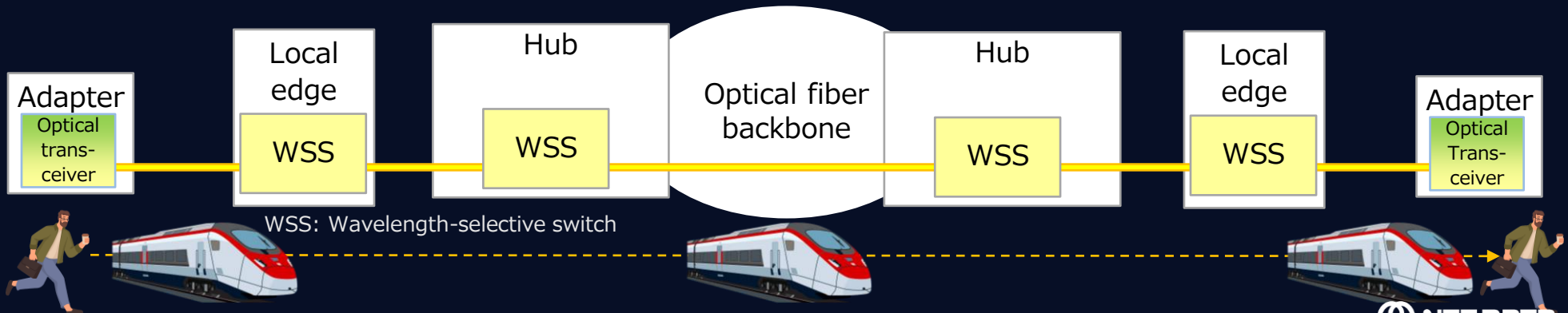
IOWN network:

# All-Photonics Network (APN)

Up to now



# All-Photonics Network (APN)



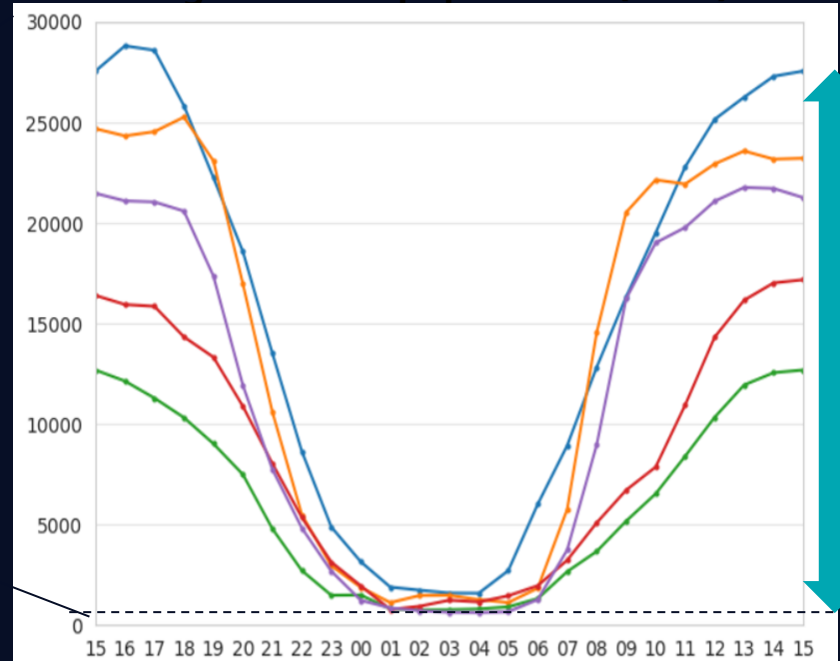
# Elastic Load Balancing

Dynamic control in response to changing area population  
→ High energy efficiency

Service area



Changes in area population (hour)



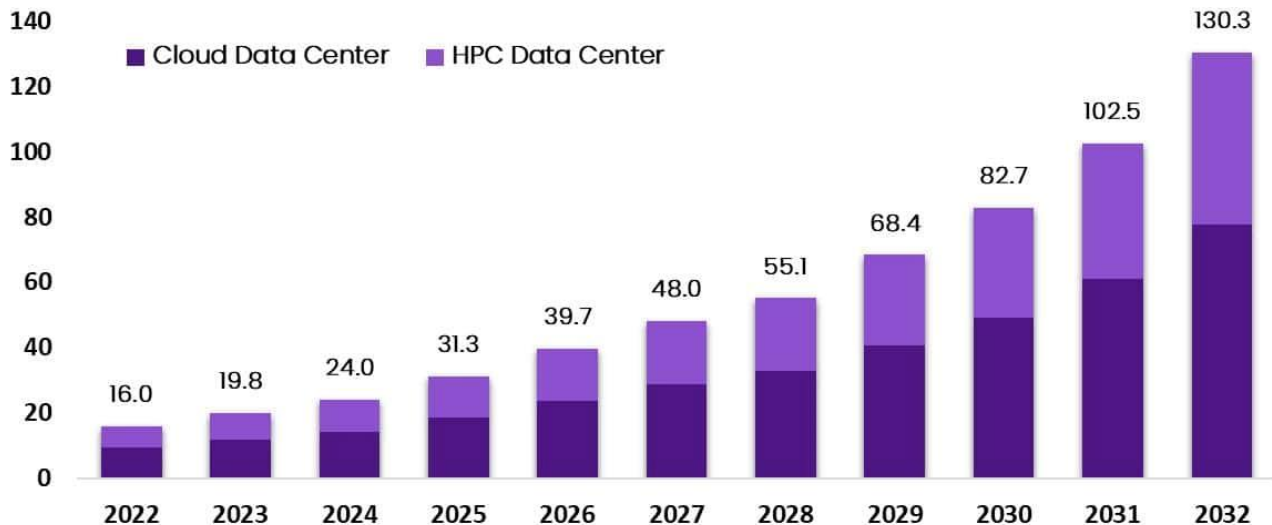
Population difference  
between day and night

# APN and Data Centers Footprints

# Data Center Market Growth Boom

## Global Data Center Accelerator Market

Size, By Type, 2022-2032 (USD Billion)



The Market will Grow  
At the CAGR of:

**24%**

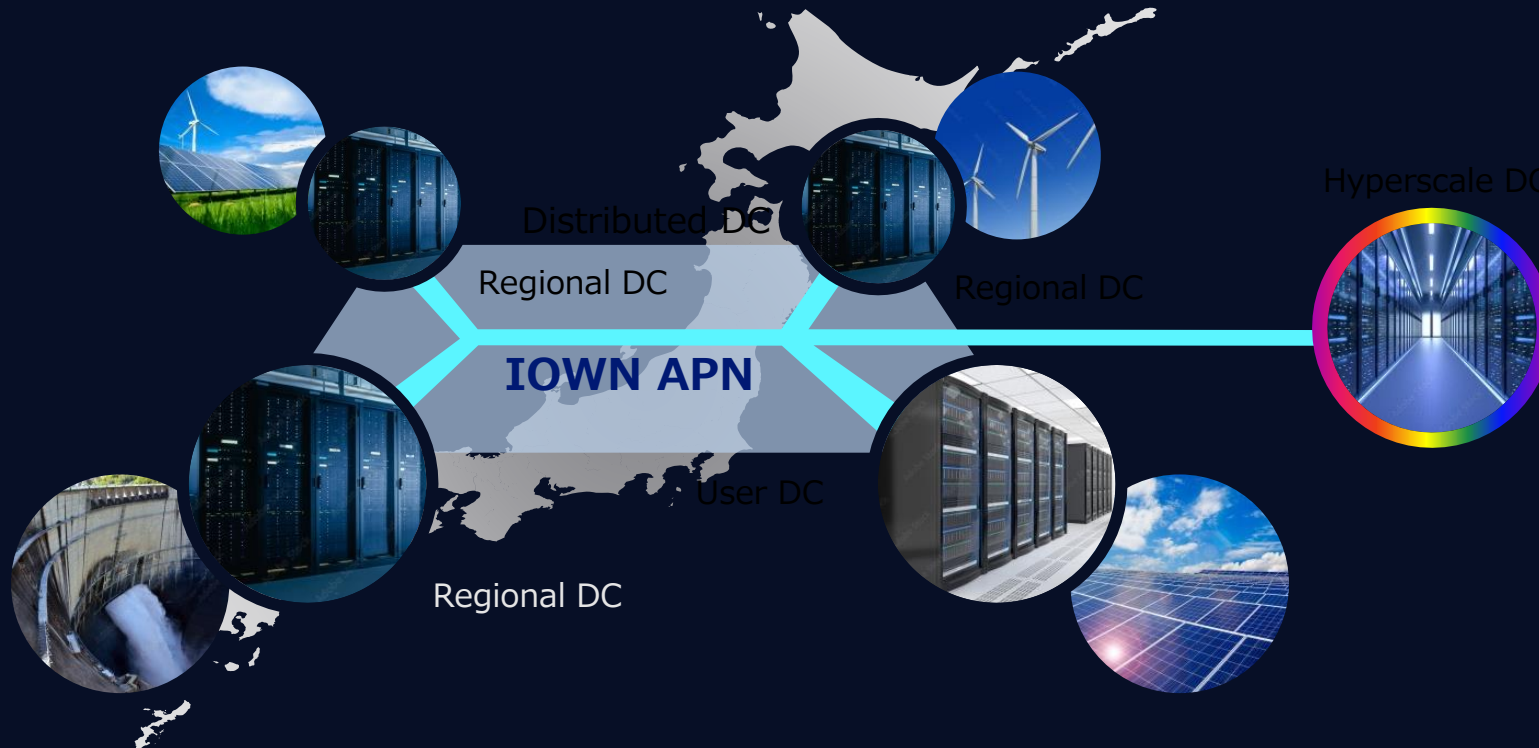
The forecasted market  
size for 2032 in USD:

**\$130.3 B**

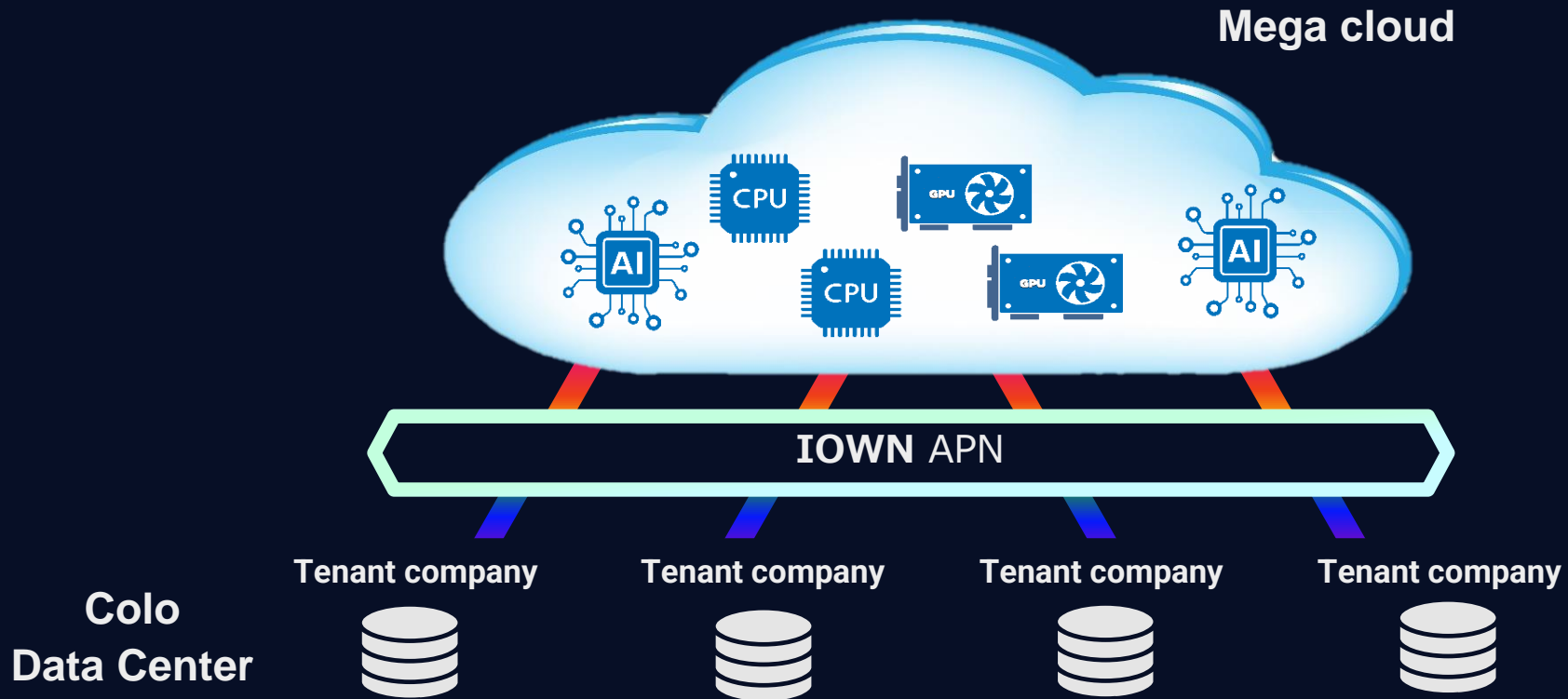
**market.us**  
ONE STOP SHOP FOR THE REPORTS

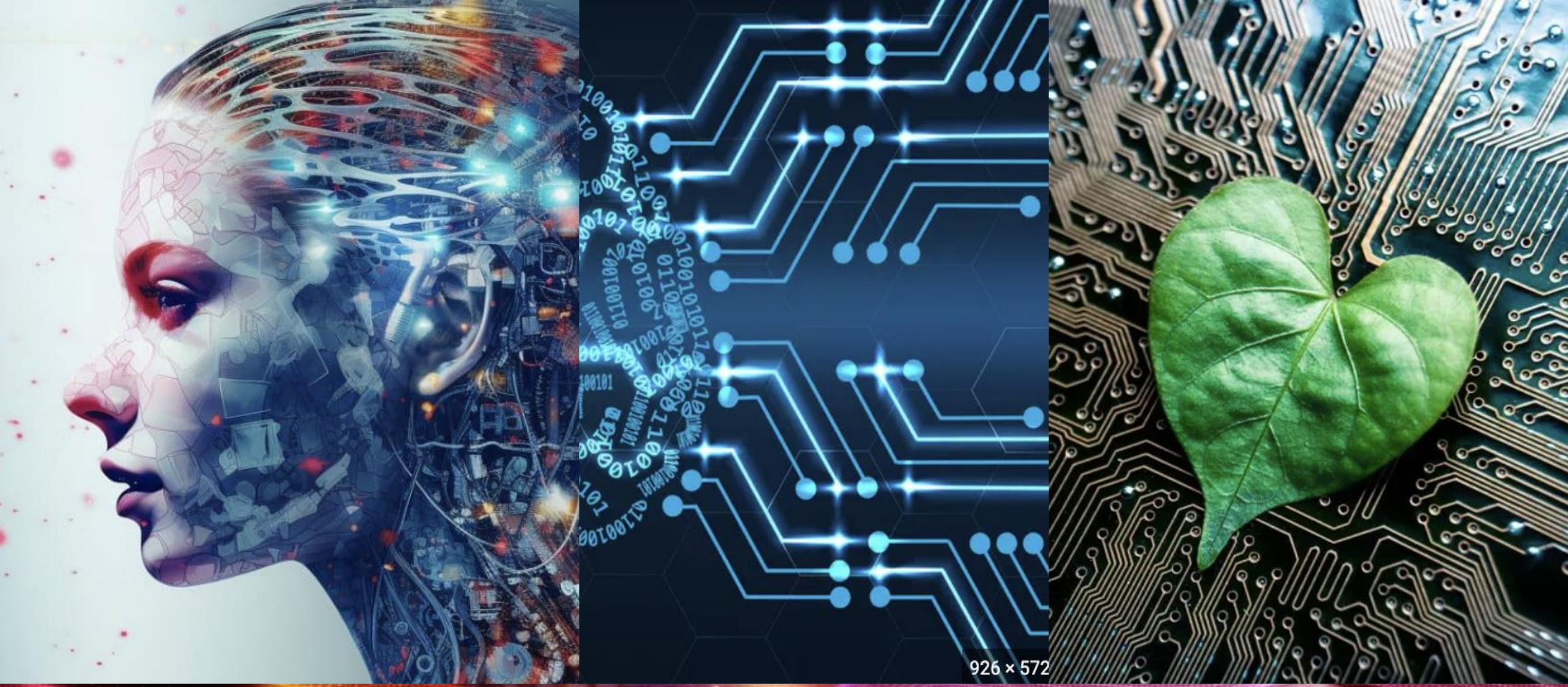
# Inter-datacenter Connection

Connecting datacenters (DCs) with the APN enables functional distribution and high availability



# Hybrid Sovereign Cloud





926 x 572

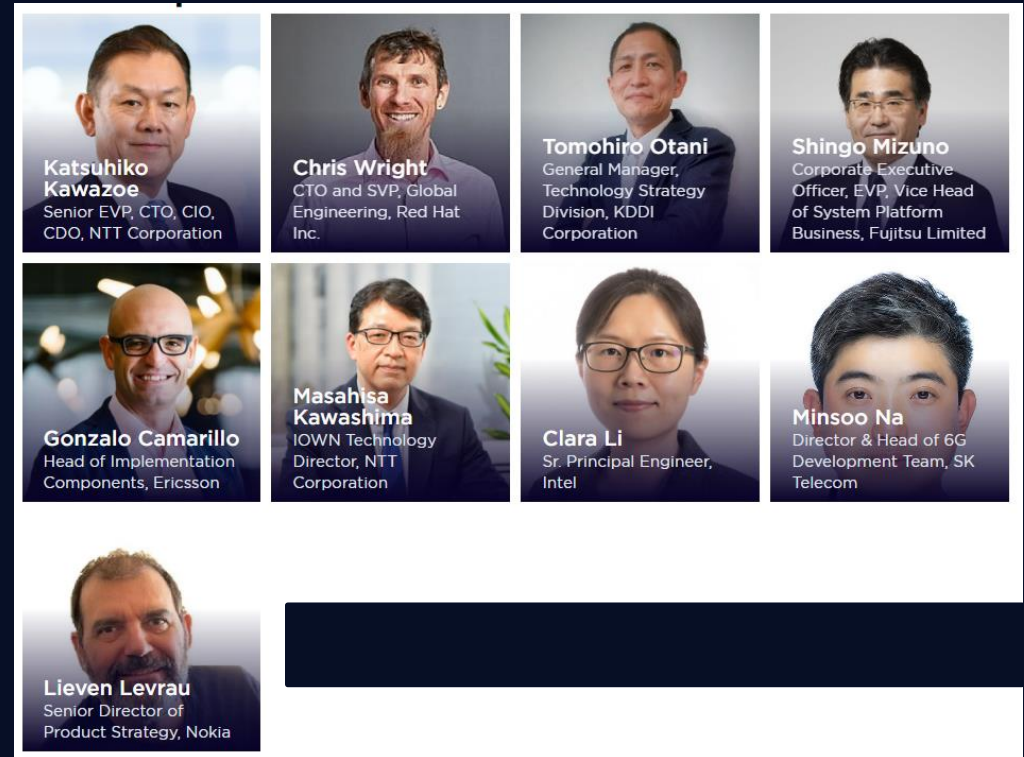
# IOWN Global Forum Session – Tomorrow

## Innovative Optical and Wireless Network for the Evolution of Mobile Networks

**When:** Thursday, 29-February 10am-11:30am

**Where:** Partner Theatre 6, Hall 8.0

IOWN Global Forum's technical leaders present an overview of IOWN Global Forum's Open APN and how this new network will contribute to the evolution of radio access networks (RANs) and multi-access edge computing (MEC).







# Innovating with Innovative Materials (Particles) of the Future

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MWC24

Balaji Krishnan

CEO & Founder

Displace

MWC24

# Up Next

FWA: Scaling the Success

16:15 - 17:00

MWC24