International Institute
For Future Industries
https://iifi.institute/



A FRAMEWORK FOR THE GLOBAL DIGITAL ECONOMY

- OUTCOMES
- SECURITY
- INTERNATIONAL
- NATIONS
- ORGANIZATIONS
- CUSTOMERS
- CHANNELS
- PRICING
- PRODUCTS
- PROCESSES
- INTEGRATION
- INTERFACES
- ARCHITECTURE
- APPLICATIONS
- ENGINES
- KNOWLEDGE
- DATA
- PLATFORMS
- SYSTEMS
- NETWORKS
- SUBSYSTEMS
- ELEMENTS
- PARTS
- FORM FACTORS
- FACILITIES
- ENVIRONMENTAL
- ENERGY
- MATERIALS
- LOGISTICS
- LOCATIONS
- RESOURCES

Publication Date: November 6, 2026

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

The Global Digital Economy

We are only at the beginning of the largest economic transformation in human history: the information age. To understand it requires a model that appropriately details all of the sociotechnical dimensions that are undergoing continuous transformation. Such a model must reflect everything from international relations, to national policies and emerging strategic business models, new technologies such as quantum computing, AI, photonics, and fusion energy, to the materials required to build these systems, new locations and facilities such as orbital data centers, and so on.

A 31-Layer Framework

There have been prior attempts to understand or communicate key aspects of the digital economy. For example, NVIDIA proposed 5 layers: Applications, Models, Infrastructure, Chips, and Energy.[1] Such a model may be useful to describe a particular company's focus, but doesn't reflect the complexity of the global digital economy, nor capture disruptors such as biological computing, export barriers, or business models such as open weight/open source AI. **The framework proposed here captures all of the layers required to transform resources such as capital and talent into outcomes such as revenue growth and sustainability.**

This document describes each layer, provides some examples to help understand each layer, and also provides examples of emerging trends and potential disruptors at each layer.

The TRIP MAP™ Approach

These 31 layers will form the basis of the 2027 report on the digital economy from the International Institute for Future Industries, which uses the Technology Readiness Inflection Points™ technology maturity scale (recognition, research, invention, realization, commercialization, scaling, diffusion, maturity, decline, redirection) to evaluate emerging disruptive technologies and offers.

1. "AI is a Five-Layer Cake," https://blogs.nvidia.com/blog/ai-5-layer-cake/

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

The 31 Layers of the Global Digital Economy

OUTCOMES	Personal, Organizational, National, Global, Economic, Societal and Environmental Outcomes
SECURITY	Physical and Cyber-Security, International Security, AI Safety and Alignment
INTERNATIONAL	International Relations and Agreements, e.g., WTO, UN, IMF, ASEAN, EU AI Act
NATIONS	National Legal, Regulatory, Policy, Governance, e.g., Taxation, CHIPS, Subsidies, 5-Year Plans
ORGANIZATIONS	Business and Organizational Leadership, Strategy, and Governance
CUSTOMERS	Customers, Markets, Communities, and Users
CHANNELS	Sales and Distribution Channels, Trading Platforms
PRICING	Business and Pricing Models, e.g., Freemium, Subscription, Pay-Per-Use
PRODUCTS	Products, Services, Solutions, and Product-Service Platforms and Ecosystems
PROCESSES	Business, Operational, and Support Processes, Metrics and Objectives
INTEGRATION	Workflow Integration of People, Process, and Technology, e.g., HITL, HOTL, Teleoperation
INTERFACES	Neural, Sensory & Muscular Interfaces, e.g., Video, BCI; Protocols, e.g., HDMI, 5G, MCP, AP2
ARCHITECTURE	Systems Architecture comprising Mechanical, Hardware, Software, and Network Dimensions
APPLICATIONS	S/W and H/W Applications, e.g., Agents, Chatbots, SCM, ERP, Surgical Robots, Social Media
ENGINES	Simulation and AI Model Engines, e.g., Coding, Translation, Multimedia, World, Physics
KNOWLEDGE	Models & Knowledge, e.g., Digital Twins, Large Language Models, Knowledge Graphs, Weights
DATA	Data and Information, e.g., Streamed Data Capture, Databases, and Data Warehouses
PLATFORMS	Platforms, e.g., Operating Systems, Run-Times, Compilers, Containers, Orchestration
SYSTEMS	Computing and Storage Systems, e.g., Quantum, Hypercomputers, Mobile Devices
NETWORKS	Wired and Wireless, Micro-scale, Local, Wide-Area, and Inter-satellite / Inter-planetary
SUBSYSTEMS	Computing, Memory, and Storage Subsystems, e.g., GPUs, TPUs, NPUs, LPUs, QPUs, HBM
ELEMENTS	Nano- and Micro-scale Elements, e.g., Field Effect Transistors, Quantum Dots, DNA
PARTS	Embodied Components, e.g., Transducers, Robotic Actuators, Power Supplies, Linkages
FORM FACTORS	Housings & Embodiments, e.g., Server Racks, Mobile Devices, Humanoids, Quadrupeds
FACILITIES	Physical Facilities, e.g., Fusion Plants, Server Closets, Cable Landing Stations, AI Factories
ENVIRONMENTAL	Thermal & Environmental, e.g., Evaporative Cooling, Water Treatment, Carbon Sequestration
ENERGY	Energy Capture, Generation, Conversion, Transmission, Transportation, and Storage
MATERIALS	Physical, Chemical, and Biological Cells, Organoids, Substances and Materials
LOGISTICS	Transportation and Logistics, e.g., Rare Earth Supply Chains, Launch Systems, Cable Ships
LOCATIONS	Terrestrial and Subterranean, Subsea and Oceanic, Low Altitude, Orbital, Lunar, Planetary
RESOURCES	Capital, Real Assets, Rights, People & Skills, Intellectual Property, Brand, Trust, Intangibles

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

Lifecycles at Each Layer

Each layer has its own lifecycle, which may not be apparent from the layer name.

For example, Computing, Memory, and Storage Subsystems today are often made of silicon chips. The lifecycle of these chips includes research into behaviors such as quantum tunneling effects; Computer-Aided Design and Electronic Design Automation tools and simulators to design and optimize the chips; advanced tooling such as high numerical aperture extreme ultraviolet lithography equipment to manufacture the chips and then package them into usable components; the actual use of those chips in a variety of contexts; and then end-of-life recycling.

Data and Information has a lifecycle that includes data capture, ETL (extract, transform, load) to transform raw data into information; data modeling; metadata acquisition; data storage and backup; provenance; data management; and archiving or destruction.

Models and Knowledge has a well-known lifecycle for AI that includes acquiring a corpus of data, pre-training, supervised fine tuning / post-training, and domain-dependent fine-tuning.

Even governance layers have a lifecycle, such as conception, drafting, requests for comment, consensus development, formalization, promulgation, enactment, entry into force, renewal, and sunsetting.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

Why Model?

There are several reasons for developing this model:

- **Understanding the factors that comprise the digital economy**. Everyone is focused on leading edge chips that are the engines of "AI Factories," but they can't be made without rare earths, and gigascale data centers can't run without power and building permits.

- **Understanding the complexity of digitally enabled sociotechnical systems.** While it's easy to focus on the latest frontier models, real deployments under real-world conditions need many factors to work. For example, physical AI requires suitable motors and actuators and recharging tech. Real business process integration requires suitable human interfaces.

- **Identifying the economic flows, investment opportunities, and profit pools in the digital economy.** Deployments of technology via workflow integration to impact reengineered processes will show up in corporate labor productivity and labor share of GDP.

- **Clarifying control points and bottlenecks.** Insufficient capital can constrain deployment, as can regulatory tightening, or rare material access, or scaling bottlenecks in model intelligence.

- **Tracking disruptors at each layer.** Emerging photonic, quantum, neuromorphic, and/or bioelectronic hybrid computing approaches may disrupt today's high-density, power-hungry GPU/Transformer based approaches. Or, effective commercial nuclear fusion may eliminate the issues associated with acquiring sufficient power.

- **Thinking beyond GenAI.** While generative AI and autonomous agents have become increasingly powerful and dominate the headlines, the systems driving the information economy include predictive/analytical AI, and traditional non-AI computing systems and software.

- **Engineering optimal solutions.** "Extreme co-design" recognizes that all layers of the stack must be aligned. A constraint at any given layer may mandate a new approach at a different layer. This holds beyond technology. For example, piecemeal regulatory approaches to full self-driving imply a need for greater software autonomy than designs with standardized connections to traffic management systems and vehicle-to-X communications.

- **Comparing the competitive advantage of nations.** Nations have shifting advantages and disadvantages at various layers. At the time of this writing, the U.S. lead in frontier models is narrowing; the West has advantages in semiconductor fabrication due to export controls; China has advantages in manufacturing cost and quality for embodied AI; etc.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

1: Resources

This layer comprises the physical, intellectual, human, and economic inputs required to enable the digital economy:

- Venture, sovereign, equity, and debt capital
- Real assets such as land, buildings, mineral & energy deposits
- Legal, regulatory, approvals, rights and permits
- Contracts and agreements
- People, talent, skills, organization, culture
- Intellectual property, e.g., trade secrets, patents, data, methodologies
- Brand, reputation, loyalty, market perception, and mindshare
- Social and trust capital
- Other intangibles, such as personal relationships and network effects

Creative financial strategies are being used to access the capital needed to build infrastructure such as vendor financing, circular financing, off-balance-sheet debt vehicles and obligations such as lease guarantees, and Special Purpose Acquisition Companies. For example, SoFi went public via a SPAC rather than IPO.

To build talent and acquire intellectual property, countries are investing in training students and also importing leading researchers, and companies are paying high premiums for talent, and acquihiring—getting leading minds by buying their companies.

For example, China recruited UC Berkeley's Omar Yaghi, a Nobel Laureate, to head a new AI-driven materials research institute at Tsinghua University. China has also created new AI-focused learning and entrepreneurship insitutions, such as the Zhongguancun Academy. NVIDIA "reverse acquihired" the Groq low-latency inference engine strategic and technology leadership via a nearly $20 billion licensing deal. Meta reportedly offered a US$1.5 billion compensation package to acquihire Andrew Tulloch from Thinking Machines Lab.

Personal relationships are also a resource. In 1995, NVIDIA was near bankruptcy when its CEO, Jensen Huang, used a personal relationship and affinity with Sega's CEO to seal a US$5 million cash infusion, saving the company.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

2: Physical Locations

The bits of the digital economy actually exist in the real world as atoms, molecules, photons, or electrons. These must exist in an actual physical location, and the range of variation of these locations is expanding:

- Traditional data center sites for cloud and enterprise data centers
- Sites with ambient energy, such as Iceland for geothermal or Inner Mongolia for ambient cooling, as well as wind and solar power
- Subterranean sites, for energy storage and physical data center security, EMP protection, and weather immunity
- Underwater sites, such as HiCloud's data center located just off the Shanghai coast, using seawater for cooling and offshore wind for energy; subsea cable routes; and undersea mining
- Ocean surface sites, that combine wave energy with ocean cooling for distributed floating "data centers"
- Atmospheric, such as Airbus / AALTO's Zephyr High-Altitude Platform Station
- Earth orbit, including today's communications satellite networks and emerging orbital data centers
- The Moon, with lunar data centers already in the planning phases, and someday, elsewhere beyond the Earth
- Edge locations, such as residences and roadsides. PulteGroup partnered with NVIDIA and SPAN, an energy company, to sell homes with attached AI units, intended to balance distributed compute workloads with normal home energy use variation.
- Mobile, such as in cell phones and tablets, in automobiles, on drones and planes.

Location selection can be complex, often requiring trade-offs between multiple factors. For example, today's leading edge Gigascale "AI Factories" require immense power and cooling, in turn requiring site permits, power guarantees, and community support. Orbital data centers offer the promise of continuous solar power but create new challenges in cooling due to the insulating properties of a vacuum.

Locations are also important well before we get to digital infrastructure, such as locations for mining rare earths needed to build semiconductors, or say, uranium or natural gas to power data centers.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

3: Transportation and Logistics

Moving resources to and from various locations is the next layer. This entails things like fuel transportation, such as supertankers and natural gas pipelines. Green hydrogen is a promising, environmentally sustainable fuel source to power data centers, but requires specialized tanker trucks that solve challenges such as “embrittlement,” where the highly reactive hydrogen corrodes the physical container, potentially creating leaks.

Other power sources have their own logistics issues, e.g., managing nuclear waste by transporting it to specialized waste sites.

High-tech hardware such as advanced server racks, EUV lithography optics, or specialized cooling fluids often requires climate-controlled, vibration-damped, or cleanroom-grade transport protocols. It also often requires real-time telematics, IoT environmental logging (e.g., shock, tilt, temperature), and tamper-evident digital chain-of-custody tracking to satisfy security and insurance requirements.

The creation of orbital or lunar data centers is driving new launch technologies. Reusable rocket vehicles is one approach, but others are emerging. Spaceplanes can take off from an airport to approach the edge of the atmosphere, whereupon boosters can take over. High-altitude balloons can accomplish something similar. There are kinetic launch systems under investigation, such as catapults and magnetic railguns.

The economics of satellite design and space logistics are also driving innovation in areas such as packaging. For example, standardized modular containers and form factors such as CubeSats help to maximize packing density and simplify launches.

This layer can be impacted by the highest layers, such as national and international policies. It can be made more difficult by tariffs, export controls, and sanctions, and ameliorated by agreements such as USMCA (U.S.-Mexico-Canada Agreement) or China’s “Belt and Road” Initiative.

It can also be impacted by lower layers. E.g., the logistics of putting server racks in space are very different than an enterprise data center.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

4: Materials and Substances

A variety of materials and substances are enabling today's technologies and laying a path to tomorrow's. These include chemical elements, substances, and compounds; physical substances and alloys; and biological building blocks.

At the atomic level, many elements have unique roles. For example,the Helium-3 isotope is essential for extremely-low-temperature quantum computers. It is extremely rare on earth, but enables dilution refrigerators to take the quantum processing chips down to a fraction of a degree above absolute zero. Hydrogen-3, better known as Tritium, is also extremely rare, but is currently key to a promising path to nuclear fusion. Hafnium Oxide is used in semiconductors to reduce quantum tunneling leakage. Other rare earths such as Lanthanum, Cerium, Yttrium, Erbium and others have their own unique roles in either digital components or the processes that produce them. Neodymium is used in precision servo motors needed in chip fabrication. Platinum and titanium are used in fuel cells.

Even "common" earths are important: silicon has traditionally been used to build the wafer substrate for chips; carbon has an emerging role, for carbon nanotubes for new transistor designs and carbon formed into synthetic diamond or diamond-copper substrates due to its thermodynamic properties and capacity to conduct heat and thereby help cool today's hot-running chips. Nickel and Iron form Invar NiFe, which maintains its dimensions even in environments with substantial temperature fluctuation.

Various other ultra-high-purity gases and specialized liquids are used in semiconductor fabrication to prepare, dope, or clean the surface, generate plasmas, cool the wafer, etch, clean, and rinse the wafer during manufacturing. Perhaps most important is ultra-pure water, with purity measured in the parts per trillion.

A new frontier in digital technologies is the use of biological substances and cells. Some computing and storage systems are now being built from DNA. Strands of DNA matching receptor strands provide parallel computation, and DNA itself has always been a data storage medium, only just now being used for manmade storage systems. Biological cells, such as human neurons, are also now being incorporated into bioelectronic systems that use synthetic brain organoids to create neuromorphic computing systems—in other words, mixing brain cells with electronic components to create viable computers.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

5: Energy

It's no secret that today's leading-edge AI systems demand seemingly unlimited power. But energy is also required to power mobile devices; robots, drones, and other digitally-enabled vehicles; launch rockets for today's AI-enabled satellites and tomorrow's orbital data centers; run extraction, purification, manufacturing and recycling facilities for materials and substances; etc. Consequently, there are a full range of energy needs in the digital economy:

- Energy capture, such as photovoltaics, wind turbines, hydroelectric dams, and wave energy electromechanical systems.
- Energy generation, such as coal, natural gas, and nuclear. In nuclear there are many existing variations such as typical large plants, small modular reactors, and now, nuclear fusion.
- Energy conversion, such as using energy and catalysts to split water into hydrogen and oxygen via electrolysis for use by fuel cells that then generate energy when they are recombined.
- Energy transmission, such as via superconducting transmission lines, wireless power, or backside power in integrated circuits.
- Energy transportation, such as green hydrogen transport or oil supertankers (addressed earlier)
- Energy storage. There are numerous strategies for storing energy to decouple energy generation from energy consumption. For example, molten salt columns, gravity storage, and new battery designs made of concrete and water.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

6: Thermal and Environmental

Using energy creates heat. Today's advanced systems require cooling, and special treatment for environmental reasons.

Cooling comes in many forms. Traditionally, data centers used cold air blown through the computing equipment, which became hot air that was then cooled using evaporative cooling "chillers". Most advanced, highly dense computing systems today use liquid cooling, via pipes that run through the components, or even channels carved into the chips for "in-chip" cooling. Another new strategy is "immersion cooling," where the entire system is "dunked" into a liquid bath.

Site selection can play a role, leading to data center construction underwater, where seawater cools everything, or in arctic regions or high-altitude locations, where there is ambient air, or where rock formations can enable geothermal heat sinks.

Minimizing hot spots in data centers can also be performed through the use of scheduling systems that determine on which servers in which part of the data center to run various workloads. There are other creative strategies, like using waste heat to heat water for use by communities as hot water or for floorboard heating.

Environmental control and atmospheric management also comes into play here, via heating, ventilation and air conditioning (HVAC) systems, and air quality, and emissions controls for facility enclosures and surrounding environments.

The microclimate within computing facilities has to be controlled via Computer Room Air Handling (CRAH/CRAC) units, hot/cold aisle containment systems, and dynamic pressure controls.

Finally, the facility environment needs to be managed using sensor networks to monitor temperature, humidity, and gas or liquid leaks, as well as through emissions control, carbon capture, particle filtration, and carbon tracking.

Whether it's semiconductor fabrication, data center operations, or energy infrastructure, thermal and environmental management are key to performance and sustainability.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

7: Data Centers and Facilities

A broad variety of physical facilities such as real estate properties, physical structures, specialized environmental shells, and operational sites is needed to house the computing and industrial infrastructure that forms the underpinning of the digital economy.

This includes:

- Hyperscale cloud computing, “AI Factories”, and supercomputing centers
- Enterprise data centers, i.e., on-premises corporate compute buildings designed for internal enterprise workloads
- Colocation, and managed services facilities, that is, multi-tenant physical data centers offering shared space, power, network, and physical security,
- Distributed, edge, & specialized sites, close to data generation or use.
- Micro-edge & local compute nodes collocated with cell towers or even street lighting.
- Marine platforms made up of sealed compute pods, barge-mounted floating facilities, and offshore ocean systems
- Network facilities, such as interconnection centers, subsea landing stations, cell towers, switching centers (formerly known as central offices), regen huts, etc.
- Orbital & extraterrestrial facilities operating in Low Earth Orbit (LEO) or planetary facilities operating in zero-gravity or extreme space environments.
- Human-centric physical structures and facilities that house employees, manufacturing, research, and residential operations.
- Office facilities and administrative centers
- Research labs & precision cleanrooms for semiconductor and hardware fabrication.
- Smart industrial & residential sites such as highly automated manufacturing plants, logistics fulfillment centers, smart residential homes, and commercial retail facilities.
- Power plants to power all of the above, and substations and transmission facilities, energy storage and logistics, and backup power.
- Control centers, security operations centers, emergency operations centers, and so forth.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

8: Form Factors

Within and outside the data center, there are numerous form factors, i.e., housings, platforms, and related physical embodiments for digital infrastructure:

- Enterprise & data center infrastructure, including server racks, liquid-cooled immersion tanks, containerized units.
- Industrial & infrastructure edge systems, such as ruggedized edge compute nodes, industrial gateway appliances, micro-edge servers, smart utility meters, and roadside intelligent transportation units.
- Personal, household & office devices, such as traditional mobile devices, desktops, AI PCs, smart TVs, and smart home appliances.
- Human-centric & wearable interfaces, including wearables, ingestibles, implantables, and smart glasses and head-mounted displays.
- Micro-scale & environmental sensing, such as micro-electromechanical systems (MEMS), smart dust, and distributed environmental sensors.
- Physical AI & robotics, including teleoperated equipment and robots in fixed, humanoid, quadruped, wheeled, or hybrid/transforming forms.
- Autonomous vehicles & transportation, such as cars, trucks, drones, planes, boats, autonomous underwater vehicles, unmanned surface vessels, spacecraft, and satellites.
- Off-grid, marine & remote compute infrastructure, such as floating surface buoys, remote power-harvesting environmental nodes, orbital satellite compute clusters, and tactical/field-deployable rugged cases.
- Multi-agent & system ensembles, including swarms, fleets, and heterogeneous ecosystems.

Form factors must balance cost, quality, functionality, maintainability and serviceability, hot-swappability, thermal management, resistance to extreme temperatures or other environmental factors such as moisture, dust, pressure, radiation, electromagnetic interference, flexibility, size, weight, agility, battery life, strength, security, rechargeability, and numerous other engineering criteria.

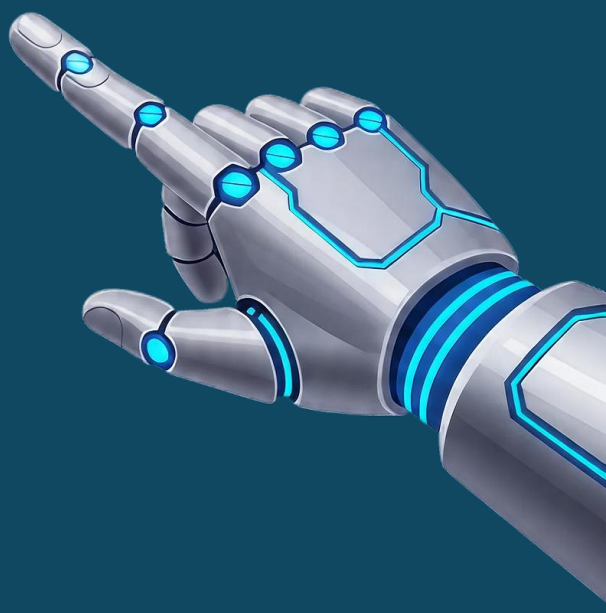
© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

9: Embodied Parts and Components

Whether the form factor is a mobile device, a robot, or an autonomous vehicle, there are numerous embodied components in addition to the "intelligence." These parts span:

- Sensing and perception, such as cameras, lenses, microphones, tactile skin sensors, accelerometers / vibration sensors, position sensors, and the like.
- Actuation and motion, such as high-torque brushless motors, wings and rotors, fluidics, artificial muscle, elastomeric actuators, electromagnetic subsystems, bearings, etc.
- Structural elements that equate to our skeletal bones and joints.
- Enclosures such as cabinets or vehicle bodies
- Power, typically via charged batteries, but also, say, through alternators in a gas-powered vehicle such as a car.
- Thermal management , such as passive dissipation or active cooling via fans, liquids, or the like.
- Internal interconnects for routing data and power.
- Environmental hardening and sealing to protect against dust, liquid, shock, vibration, etc.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

10: Nano- and Micro-scale Elements

Todays computing systems are built out of extremely small components, now measured in nanometers—a millionth of a millimeter. They include:

- Transistor & Logic elements, undergoing a planned evolution from Fin Field Effect Transistors (FinFETs), to Ribbon FETs, Nanosheets, and Gate-All-Around FETs that reduce quantum tunneling issues. On the current roadmap for the next few years are FETs made of carbon nanotubes, and those made from 2-dimensional Transition Metal Dichalcogenides

- Quantum & Photonic elements are needed to build quantum computers and photonic computing systems. They include Josephson junctions, trapped-ion micro-taps, quantum dots, Micro-Ring Resonators, and photonic waveguides

- Memristive & Neuromorphic elements help to build new memory and storage systems as well as neuromorphic storage-compute hybrids that emulate the human mind. They include: Oxide Random-Access Memory (OxRAM) cells, Phase-Change Memory (PCM) elements, and Spin-Transfer Torque (STT) junctions

- Bio-Hybrid & Biological primitives don't just emulate human neural systems, they actually incorporate biological neurons. They include: cultured neuronal units, Microelectrode Array (MEA) Interfaces, synthetic ion channels, and DNA-encoded memory strands

To actually create these elements requires state-of-the-art equipment, processes, and materials. For electronic, photonic and quantum systems, this spans high numerical aperture extreme ultraviolet lithography equipment, ultra-pure water, etc. For biological or bio-hybrid systems, bioreactors, incubators, and stem cells or cortex cells are needed.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

11: Computing, Storage, and Network Subsystems

These are the building blocks composed of nano- and micro-scale components that enable the creation of full systems:

- Compute Silicon & Specialized Processors, such as CPUs and GPUs and AI accelerators such as Tensor Processing Units, Language Processing Units, and Neural Processing Units. Also neuromorphic and spike-based processors that mimic biological neural networks, and bio-hybrid subsystems combining neural tissue with micro-electrode arrays. Finally, QPUs—Quantum Processing Units that execute non-Von Neumann probabilistic logic.

- Data Processing Units and Infrastructure Processing Units performing tasks such as network acceleration, virtualization hypervisors, and network security.

- Memory & Storage, such as volatile cache & system memory (SRAM, DRAM, & HBM); Solid-State & Non-Volatile Storage (NAND Flash); High-Capacity Magnetic Storage such as hard disk drives. There is also archival storage, such as 5-dimensional glass storage that can store information for billions of years.

- Network components, such as network interface cards and offload engines, high-speed interconnects, and fabric controllers. Also, routers and switches, such as Top-of-Rack and spine/leaf, that enable coherent memory sharing and ultra-fast direct communication. This often include optical transceivers to connect electronics to fiber optic cabling, and at the chip level, co-packaged optics and silicon photonics. Also, copper and optical cables are needed at various distances.

- Packaging & Environmental Subsystems such as silicon/organic interposers that bridge heterogeneous compute chiplets, printed circuit boards and power delivery, and thermal and cryogenic management systems such as immersion cooling systems and dilution refrigerators.

- Displays, monitors, sensors, and actuators, such as touchscreens, audio speakers, video monitors, etc.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

12: Wired and Wireless Networks

Data networking can occur at scales from a few feet to millions of miles. They can be roughly categorized as:

- Short-Range, Personal, & Low-Power Wireless: Bluetooth for low-energy device pairing and peripherals; Wi-Fi for high-bandwidth local wireless LAN coverage in homes, offices, and campuses; and LoRaWAN (Long Range Wide Area Network) for ultra-low-power, long-distance IoT sensor telemetry.

- Wired Local Area Networks (LAN): Ethernet standards (ranging from multi-gigabit copper to high-speed fiber) providing deterministic, high-bandwidth switching and frame routing within enterprise facilities, server rooms, and high-performance computing pods.

- Wide Area Networks (WAN) & Core Enterprise Transport: Multiprotocol Label Switching (MPLS) and advanced IP routing architectures that establish secure, predictable virtual circuits with guaranteed quality of service and traffic engineering across global telecommunications carrier backbones.

- Cellular Mobile Networks: 5G and emerging 6G wireless infrastructure utilizing advanced millimeter-wave (mmWave) spectrum, massive MIMO antenna arrays, and cloud-RAN architectures to deliver ultra-reliable low-latency communication (URLLC) and high-density mobile broadband.

- Satellite & Non-Terrestrial Networks: Low Earth Orbit (LEO), Medium Earth Orbit (MEO), and Geostationary (GEO) satellite constellations providing high-throughput backhaul, resilient global broadband, and redundancy for remote enterprise locations and mobile platforms.

- Interplanetary & Deep Space Communications: Delay/Disruption-Tolerant Networking (DTN) store-and-forward protocols and high-bandwidth optical (laser) space-to-ground links engineered to bridge astronomical distances characterized by extreme propagation delays, orbital motion, and intermittent line-of-sight.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

13: Computing and Storage Systems

These are the systems that integrate lower layers into full computing systems on which software runs, ranging from ingestible pills and wearables to hypercomputers that train AI and run weather and physics simulations.

- Mobile & edge devices, such as ingestibles, wearables, implantables, smartphones, ereaders, tablets, and smart wearables engineered for immediate personal interaction and contextual awareness.
- Autonomous and semi-autonomous physical systems: robots, drones, materials handling systems, industrial machinery, etc.
- Desktop systems and workstations, ranging from thin clients and cloud laptops to personal computers and laptops and powerful workstations.
- Enterprise Servers & Rack Nodes: Standardized rack-mounted and blade infrastructure designed for continuous operation.
- AI Superpods & Accelerated Clusters: Massively parallel computing arrays linking thousands of domain-specific accelerators (GPUs, TPUs, and DPUs) via ultra-low-latency fabrics (such as NVLink and InfiniBand) engineered specifically for large language model training, fine-tuning, and high-throughput inference.
- Scientific Supercomputers, high-performance computers, & exascale hypercomputers leveraging millions of compute cores and advanced liquid cooling to execute petascale and exascale complex physical simulations, climate modeling, and large-scale data analytics.
- Bioelectric Hybrids & Wetware Systems: Integrated systems that combine biological neural organoids or cultured cell arrays with digital CMOS substrates and microfluidic life-support incubators.
- Hybrid Quantum-Classical Systems: Frontier systems that couple classical high-performance supercomputing nodes with quantum processing units (QPUs), managed by heterogeneous orchestration layers to execute hybrid classical-quantum algorithms.

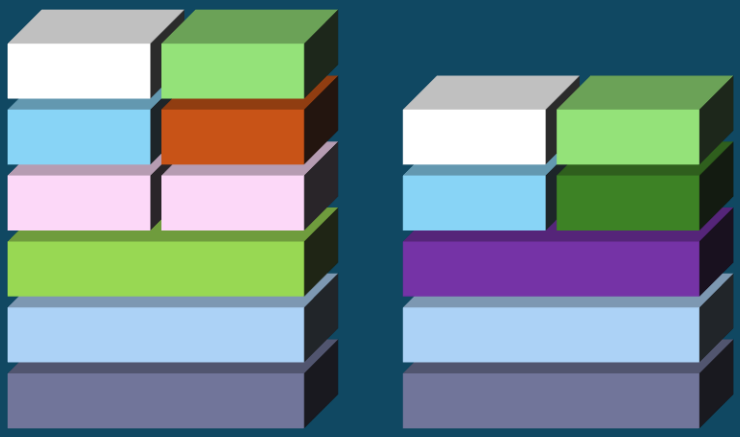
© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

14: Platforms

System-level software environments, developer tools, and compilers that enable application code to run on underlying compute hardware:

- Operating systems & system runtimes that provide core system abstraction and resource control, including operating system kernels, drivers and hardware abstraction, and resource managers.
- Compilers, optimizers & accelerators that optimize high-level source code for hardware-level execution, including those that optimize matrix operations and tensor math for AI. For example, NVIDIA CUDA and Huawei CANN play a role here.
- Developer environments & pipelines: engineering tools designed for building, testing, debugging, and deploying software, such as integrated development environments, (increasingly, AI) code authoring tools, and tools for continuous integration, development, delivery, and deployment.
- Containerization & Cloud infrastructure such as hypervisors, lightweight container runtimes, and isolated sandbox environments.
- Orchestration & cloud schedulers such as cluster management systems that schedule workloads across distributed physical hardware.

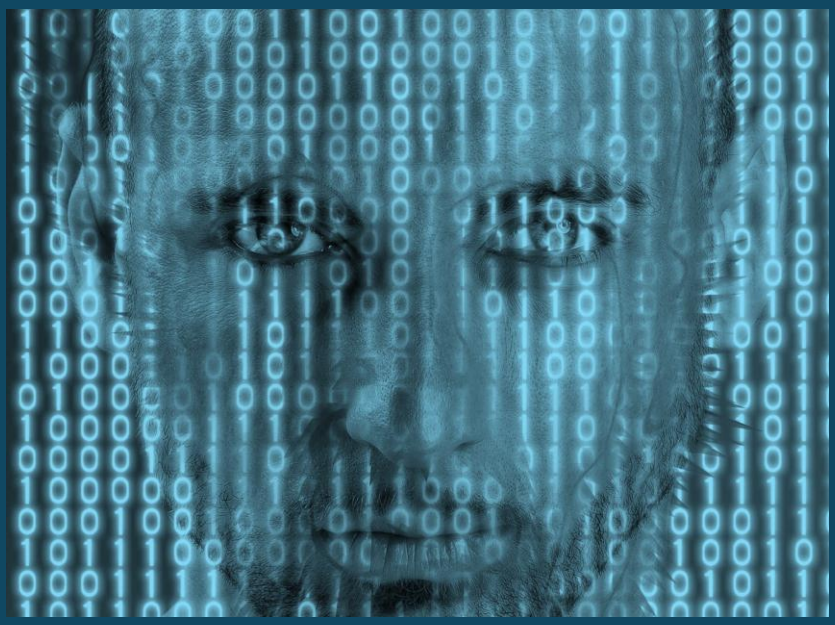


© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

15: Data and Information

Data capture, organization, management, archiving, and destruction, including:

- Data repositories & storage infrastructure designed for structured, unstructured, and specialized data, spanning relational and document databases, vector and search indexes, and unstructured data / media stores for objects like video and images.
- Data ingestion & pipeline orchestration to capture, transport, clean, deduplication, and format data for downstream consumption.
- MLOps & Model Lifecycle Operations: Systemic operations managing AI model development, validation, deployment, and monitoring, including labeling, synthetic data generation, evaluation frameworks, and support for continuous retraining.
- Governance, Security & Lineage to ensure regulatory compliance, anonymization, privacy, access controls, and full data lineage / provenance tracking.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

16: Models and Knowledge

The structured representations of logic, domain data, learned parameters, and physical laws that enable intelligence:

- Neural & Statistical Assets for AI, such as pretrained, post-trained, and fine-tuned foundation and large models including LLMs, Vision-Language Models, and multimodal models. This also includes predictive and statistical models such as decision trees and probability distributions.
- Semantic Knowledge Structures: Explicit, human- or machine-curated networks that map concepts, relationships, and ontologies. Examples include knowledge graphs and hierarchical classifications and rule sets.
- Latent & Vector Space Representations: Continuous mathematical vector spaces capturing similarity and contextual meaning.
- Physical, World & Spatial Models: Parametric representations defining physical geometry, physical laws (such as gravity and inertia), structural bounds, and environmental rules.



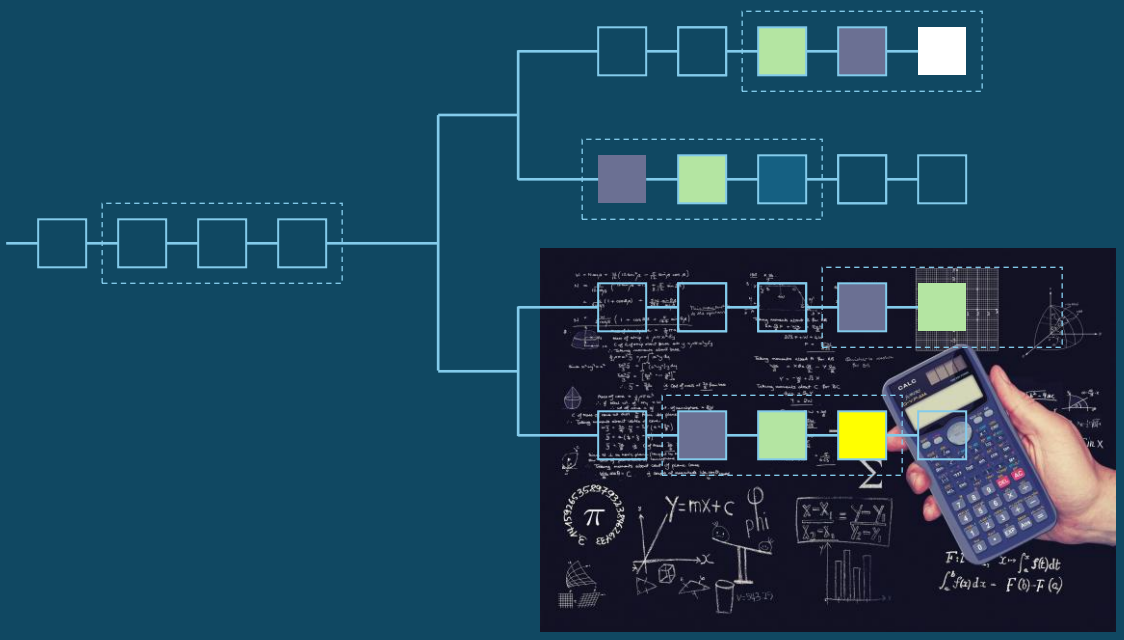
© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

17: Engines

The specialized computational runtimes and execution environments that process logic, evaluate algorithms, and run models:

- Deterministic & Rule-Based Engines that process hardcoded business logic, conditions, and state transitions, such as business rule engines, workflow orchestrators and complex event processors.
- Inference & AI Runtimes: Optimized execution frameworks that run statistical, probabilistic, and deep learning models, such as LLM runtimes, inference servers, and reasoning and agentic loops.
- Simulation & Physics Frameworks: Mathematical engines that model physical forces, environment dynamics, and complex systems, such as physics and dynamics solvers that calculate fluid dynamics or collisions, digital twin runtimes, and finite element analysis engines for stress or thermal simulations.
- Quantum & Emerging Execution Programs: Next-generation execution frameworks built for non-classical processing models such as quantum circuit solvers that run quantum algorithms or perform simulated annealing, and engines/solvers that divide optimization problems between CPUs/GPUs and QPUs.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

18: Applications

Software and hardware applications that solve business, personal, or government needs. These may include:

- Enterprise Operational Suites that manage core business workflows, resources, and customer relationships, such as Enterprise Resource Planning, Customer Relationship Management, Supply Chain Management, Manufacturing Resource Planning, and Human Capital Management systems.
- Productivity tools focused on document creation, collaboration, and project management, for example, word processing, spreadsheet, presentation, and document creation software, chat, video conferencing, and communication/collaboration tools, and project / workflow tracking, such as to-do-list / task managers, and team coordination tools.
- Industry & Vertical Solutions tailored to unique regulatory, operational, or technical requirements, e.g., for e-government, healthcare, banking, ecommerce, design and engineering, construction, real estate, etc.
- Consumer & End-User Apps built for individual communication, utility, or entertainment, such as social platforms and media, interactive gaming, VR/AR immersive environments, and personal utilities such as calorie counters or finance trackers.
- Soft AI applications, such as agents, agent swarms, personal assistants, chatbots, commerce agents, etc.
- Cyber-physical and embodied AI applications, such as full self-driving vehicles, drones, and robots for transportation, food delivery, content creation, search and rescue, surgery, and industrial / manufacturing



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

19: Architecture

The overall set of interconnected mechanical, hardware, software, and network applications and components, their integration logic, pricing and usage economics, and complex topology that together form a cohesive solution to support an individual, enterprise, or government.

This will vary by enterprise, but an example might be a streaming video service. It will have a library of transcoded media, systems to replicate that library to content delivery edge nodes such as ISP locations, customer support systems, customer ordering and billing systems, recommendation engines, a user device video player app that supports playback, downloads, catalogs, subscription services, etc.

These functions are deployed to optimize reliability, performance, and economics.[2] For example, intermittent transcoding might be performed using an on-demand, scalable, pay-per-use cloud, whereas costs and user-experienced latency are optimized using dedicated, owned, content caches that are deployed via edge colocation.

Key elements include the composition of lower-layer components into a more or less unified digital environment, and also typically that the architecture is composed of scalable, modular, heterogeneous components.



2. Joe Weinman, *Cloudonomics: The Business Value of Cloud Computing* (Wiley, 2012)

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

20: Human and Machine Interfaces

Both humans and machines need to interface to the architectures that exist at the previous layer.

Human interfaces include conventional approaches, such as physical buttons, sliders, and dials, voice, HTML/CSS, natural language and text, gestures, graphical user interfaces, and audio and video streams, via microphones and cameras and speakers and displays. There are also emerging strategies such as spatial orientation and head tracking, eye and gaze tracking, haptic and tactile feedback, olfactory and gustatory synthesis through techniques like micro-encapsulated scent generation, and thermal and environmental feedback and vestibular stimulation via low-current electrical signals to simulate acceleration or tilt.

A key emerging technology here is brain-computer interfaces, such as non-invasive brain sensing, invasive and minimally invasive neural implants. There are also physiological and biomechanical human-computer interfaces, such as surface electromyograpy for neuromuscular sensing, continuous biometric and metabolic sensing (like a smart watch heart rate sensor or a continuous glucose monitor), automated biochemical/drug delivery such as an insulin pump, and biomechanical exoskeletons.

Machine interfaces include machine-driven robots such as humanoids that interact with application architectures as if they were human, e.g., using a robotic finger to press a button, but clearly it is easier to have direct digital communication and control.

For this, there are any of a number of protocols, such as TCP/IP/HTTP/XML/JSON, HDMI, 5G cellular radio access network standards, etc. Machine-to-machine communications has existed for decades, with protocols such as EtherCAT and SECS—the SEMI Equipment Communications Standard.

The newest set of protocols involve those for AIs to “talk” with each other and prior existing systems, and include the Model Context Protocol (MCP) and its browser plug-in, WebMCP, Agent Payments Protocol (AP2), and Agent-to-Agent Protocol (A2A).

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

21: Workflow Integration

A digitally enabled individual or organization needs to integrate people and processes with technology. There are multiple dimensions to consider:

- Supervisory and Control Plane governance models that define human oversight (or lack thereof), including manual tasks with request-based AI augmentation, active approvals/gates (human in the loop), supervisory monitoring (human on the loop), or full autonomy (human out of the loop). Variations include dynamic fallbacks based on degree of confidence, and goal-bounded autonomy which bounds action based on budget or safety.

- Work Paradigms that define how the work actually gets organized and executed across workers, regardless of who is supervising, which can include an individual contributor, homogeneous scaling, heterogeneous division of labor, sequential pipelines, hierarchical orchestration, collaboration, consensus, adversarial, Socratic, and risk exploration.

- For all of this to work requires workflow integration building blocks, such as triggers, like a timer or arrival of an email or customer order; connectors and APIs, agents, skills, tools, context and memory to understand the whole and to remember past actions and data, a workflow graph that handles sequence, iteration, and conditional execution, guardrails and safety gates, and feedback loops for learning and improvement.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

22: Tasks, Functions, and Processes

The core of any business is its processes—the way things are done. Every process begins with a trigger, such as receipt of a customer order, and then follows a sequence or network of tasks, e.g., verify customer contact information, check stock levels, etc. Along the way, there are iterative loops and decision points, and inputs or resources that the tasks convert to outputs.

In the digital economy, information systems enable better processes that can create strategic competitive advantage and unique customer value through "information excellence"[3] in several ways:

- Closed-Loop Management & Control, using real-time sensors and data streams to verify process parameters remain within control limits, dynamically triggering automated or human intervention when variances occur.
- Data-Driven Continuous Improvement and Innovation, by aggregating error, defect, and performance data to support root-cause analysis and improve operations over time.
- Optimization, by using digital systems to reduce resource requirements or algorithmically improve process structure. An example is a package delivery routing algorithm that minimizes fuel and labor costs.
- Digital Twins and Predictive Simulation, creating and maintaining a virtual mirror representation of real-world operations and assets to run "what-if" scenarios.
- Exhaust Data Monetization, i.e., selling data that is a by-product of running the process, such as a navigation app that indirectlyand unintentionally generates data on pavement wear for municipal planners.

3. Joe Weinman, *Digital Disciplines: Attaining Market Leadership via the Cloud, Big Data, Mobile, Social, and the Internet of Things* (Wiley CIO, 2015).

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

23: Products, Services, Solutions and Ecosystems

The global economy is ultimately a system for trading products and services. The digital economy is a system for trading purely digital and digitally powered products and services. We use "digital" broadly to describe algorithmically enabled capabilities, even if these are analog, neural, mechanical, non-binary, or quantum technologies.

All of the prior layers empower digitalized products or digital service delivery infrastructure.

The products and services so created are typically "smart":

- Automated: Capable of performing a pre-defined sequence of actions. This needn't be digital; consider a pendulum-powered grandfather clock.
- Adaptive: Able to change configuration / functionality based on context.
- Modifiable: Able to change capabilities or functionality under user direction.
- Extensible: Able to have additional capabilities added based on usage needs or user direction.
- Learning: Able to augment capabilities over time based on experience and usage.

They also are typically "connected" to other products, services, or functionality, like a smartwatch that connects to a mobile device and ultimately the cloud. This connection may exist in one or more of the following relationships:

- Peer-Level: Connected to similar elements.
- Collaborative: Connected to disparate elements, but no element has immutable control over others.
- Orchestrating: In a control relationship with other elements.
- Responsive: Under the control of another element.

Digitalized products and services that represent the digital economy are often part of broader ecosystems, play a role as platforms for 3rd parties to build on, and ultimately thus become solutions that meet customer wants and needs.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

24: Business and Pricing Models

Digitalized commercial processes, products, and services and many government functions and services require sustainable business and pricing models.

Examples of business models include archetypes like two-sided markets and “razor and razor-blade”. However, the key to a sustainable business model is a pricing model that matches the operations structure and sustainably generates profits. There are numerous pricing models, some of which can be used in combination with others:

- Free: Unsustainable, but useful for brand-building or promotion.
- Loss-Leader: An unprofitable item, used to drive sales of profitable items.
- Pay What You Like: No fixed price, e.g., charitable donations.
- Open Source: Software or designs that are collaboratively created and free to use, copy, or modify. Monetization can occur through, say, support.
- Open Weight: AI models where trained weights are downloadable for self-hosting, monetized via developer platforms or infrastructure services.
- Freemium: Limited capability, with a potential upsell to a paid model.
- Ad-supported: The business *is* selling ads delivered to consumers; the "product" is how the ads are delivered or users engaged.
- Data-supported: The business *is* extracting data from consumers; the "product" is what incents customers to provide data.
- Third-Party-supported: The payer is different than the user, whether it's a parent buying toys or an NGO buying clean water filter straws.
- Purchase: Outright sale leading to ownership.
- License: Right to use software, assets, or intellectual property under specific contract terms.
- Subscription: Unlimited use for a fixed time period.
- Usage-Based: Metered pricing tied directly to consumption, such as API calls, active tokens processed, or daily active agents.
- Dynamic/Personalized: Varying price over time or by customer.
- Gainshare: Outcome based, where the business is compensated based on the benefits that the customer receives, e.g., a percentage of legal damages.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

25: Sales and Distribution Channels and Trading Platforms

Products and services need to be marketed to, purchased by, and delivered to customers. A variety of mechanisms exist which are undergoing rapid evolution:

- Traditional Distribution: Physical, institutional, and human-driven channels used to reach, sell to, and serve end customers, including direct sales teams, reseller partners, OEM integrators, and retail outlets. Even advanced digital products such as DVDs and smart TVs can be sold through legacy storefronts and channels.

- Digital Discovery: Methods focused on maximizing organic brand and product visibility across search engines and AI discovery tools.
    - Search Engine Optimization (SEO), to maximize ranking on traditional web search engines.
    - Generative Engine Optimization (GEO) by formatting structured knowledge, entities, and citations to ensure inclusion in AI-generated responses.
    - Paid & Inbound Channels: Programmatic advertising, sponsored media, and high-intent content strategies designed to drive inbound traffic.

- Digital Distribution: Content distribution, streaming video, Internet downloads, messaging, email, etc.

- Digital Sales/Service/Support such as eCommerce, IVR systems, FAQs, and chatbots

- Agentic Commerce: Programmatic frameworks and optimizations designed for autonomous AI agents carrying out discovery and transactions.
    - Answer Engine Optimization (AEO): Structuring product metadata and specifications so AI engines prioritize and cite your products.
    - Generative User Experience (GXO): Dynamically rendering interface elements and messaging tailored to personalized agents.
    - Autonomous Checkout APIs: schemas, inventory data, and payment protocols designed for automated agent transactions.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

26: Customers, Markets, Communities, and Users

Without customers, there is no economy, digital or otherwise.

A "customer" is actually a complex mixture of roles and personas that can be deconstructed into the individual or organization with the need, the one specifying the need, the one that selects a vendor, the one that makes the purchasing decision, the payor, the recipient of products or services, the user, and the beneficiary. For example, consider a parent of a sick child. A doctor may determine the need, a friend may recommend the doctor, further decided by in-network providers, the parent may make the decision to proceed with the treatment, an insurance company may be the payor, the child is the main beneficiary, but the parents are as well.

In the digital era, these roles may be partitioned between various people, algorithms, applications, processes, and intelligent autonomous agents. Understanding this structure can help avoid misaligned product design, go-to-market approaches, and pricing strategies. It also highlights that roles may be in conflict, whether when an insurer denies treatment, or a parent doesn't want to pay for a trip to a theme park.

In any event, communities—based on geography, demographics, or common needs—can also influence decisions through social proof, network effects, and shared norms. Multi-sided markets, platforms, and ecosystems also can complicate relationships and the business models to serve them.

The nature of customers, markets, and communities can drive shared digital functionality. For example, a unified domestic market can lead to the sticky adoption of super-apps usable for messaging, collaboration, and payment.



© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

27: Organizational Leadership, Strategy, and Governance

Organizations range across private, public, and social sectors, and can be commercial business enterprises, non-profits, non-governmental organizations, government agencies, and military bodies. Any modern organization must acquire, process, maintain, and/or output information, using a variety of technologies.

Ultimately such organizations must develop a vision and goals; define and pursue strategies to achieve them; acquire, develop, allocate, and prioritize resources including headcount, capital and expense, and management attention; structure and mobilize the organization and control execution to achieve their objectives; ensure compliance with applicable laws, norms, and practices; all under appropriate governance, oversight, and risk management. They also must adapt to unforeseen circumstances and continuously observe and innovate to remain relevant in a rapidly changing world.

Organizations impact the information economy in many ways, such as:

- Creating, distributing, monetizing, and supporting pure information goods, such as ebooks and streaming video, and digitally enabled smart goods and services, such as robot vacuum cleaners, smart TVs, and full self-driving vehicles.
- Setting policies, constraints, and rewards for organizational uses of information technology, such as eliminating shadow IT, constraining acceptable vendors or architectures, investing in hiring and training, or incenting technology use through policies such as “tokenmaxxing.”
- Investing in information technology for the organization, such as new patient records systems, customer support chatbots, or an ERP modernization effort.
- Creating new information-related technologies at any of the 31 layers, such as new foundation models, semiconductor fabrication methods, tele-operated mining and extraction machines, or the like.

New organizational forms such as Decentralized Autonomous Organizations and agent collectives will arise, but will still have the same main functions.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

28: National and Local Governance

Nations (and states/provinces, cities, localities) are the ultimate authority setting the context for the digital economy in a variety of ways:

National strategies, plans, initiatives, and investments, such as the U.S. CHIPS and Science Act and the Genesis Mission, which together allocate tens of billions of dollars annually to rebuild domestic semiconductor manufacturing, build supercomputing facilties, bolster fusion, supercomputing, and quantum research and infrastructure, develop a technical workforce, etc. China has its 5-year plans, the 15th of which directs a national focus on the New Quality Productive Forces, such as data and computing, to accelerate progress in AI, quantum, fusion, and the like.

Regional and city-wide initiatives fall into this context, e.g., the Shanghai city-wide urban management system that coordinates surveillance, weather, smart buildings, the electric grid, and traffic control. Local governments and their communities and constituents can also permit or deny land use for data centers, power plants, or space launch facilities, or authorize self-driving cars or delivery robots.

Tax policies encourage or discourage investment and outcomes in information technology, as do export controls and import tariffs, for example, on advanced semiconductors, high-end semiconductor lithography, or rare earths.

Laws and regulations drive broad economic and system effects. For example, consider state or national privacy regulations and laws like HIPAA or concerning Personal Idenfiiable Information, laws on deepfakes, misinformation, and AI attribution, those requiring kill-switches for soft or physical AI, or sovereign data residency requirements.

Court decisions play a role that influences the speed and direction of technology adoption, e.g., delays in mergers for digital streaming video services or Internet providers, or the recent Hangzhou Peoples' Court decision that just because a company decides to implement AI, it can't fire, demote, or lower the salary of the person whose job it replaces or augments. Courts will need to determine liabilities in the new AI era: who is responsible if a self-driving car runs someone over?

Governments can also create digital public infrastructure and data registries, and define the boundary between digital public goods and commercial market applications.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

29: International Context and Relations

Bilateral, multilateral, regional/bloc, and international agreements and organizations all impact the global information economy. Well known organizations include the UN and ITU, EU, WTO, IMF, World Bank / BIS, OECD, WIPO, ASEAN, APEC, BRICS+, G7, G20, IEEE. Cooperative research bodies such as CERN, ITER, and imec operate with government or corporate support. Some create binding commitments and treaties, some are consensus-based, some focus on standards or conduct research. Often, companies follow policies from commercially important regions so as to have one standard approach globally.

Examples of how these bodies and agreements impact the digital economy:

- Technology standards and governance, such as for cellular communications to facilitate interoperability between devices and networks.
- Governance, for global digital currency, radio spectrum, and for financial system cybersecurity.
- Taxation and customs duties rules, for example, for minimum corporate taxes or cross-border digital goods.
- Scientific research, such as ITER for nuclear fusion or imec for pre-competitive semiconductor research.
- Benchmarking, such as the UN E-government survey.
- Laws, such as the EU's General Data Protection Regulations and AI Act.
- Recommendations and campaigns, such as those concerning AI ethics or for meaningful universal connectivity.
- Cybersecurity emergency communications, such as the recently announced agreement to establish an AI incident communication channel between the U.S. and China.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

30: Physical and Cyber-Security, Safety, and Alignment

Requirements and mechanisms for security permeate every layer of the information economy. Arguably, one could place this layer just below layer 19, "Architecture," since any digital architecture must address security, such as encryption, trusted platform modules and the like, and any real-world implementation, such as a data center or transportation system, must address physical security.

However, because AI safety and alignment are now reaching the pinnacle of importance for continued human existence and arguably driving international processes and agreements, it is placed here. The group of related factors includes:

- Cyber-security, such as encryption, firewalls, zero-trust systems, zero-knowledge databases, confidential computing, etc.
- Physical Security & Environmental Hardening, such as perimeter defenses, physical access barriers, biometric checkpoints, environmental threat protection, and EMP/blast hardening across data centers and facilities.
- Data Privacy & Regulatory Sovereignty, including governance protocols covering PII redaction, differential privacy, data residency controls, sovereign cloud frameworks, and regulatory compliance (GDPR, HIPAA, CCPA).
- Ethics, Morality, & Values, i.e., the principles, alignment, governance frameworks, and ethical oversight governing fairness, accountability, transparency, anti-bias controls, and societal impact.
- AI Alignment & System Safety, e.g., operational guardrails, rigorous evaluations, and red-teaming to ensure models align with human intent, constitutional constraints, safety bounds, adversarial robustness, and runtime intervention mechanisms, aka kill switches.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

OUTCOMES
SECURITY
INTERNATIONAL
NATIONS
ORGANIZATIONS
CUSTOMERS
CHANNELS
PRICING
PRODUCTS
PROCESSES
INTEGRATION
INTERFACES
ARCHITECTURE
APPLICATIONS
ENGINES
KNOWLEDGE
DATA
PLATFORMS
SYSTEMS
NETWORKS
SUBSYSTEMS
ELEMENTS
PARTS
FORM FACTORS
FACILITIES
ENVIRONMENTAL
ENERGY
MATERIALS
LOGISTICS
LOCATIONS
RESOURCES

31: Personal, Organizational, Societal and Environmental Outcomes

The final layer represents the ultimate outcomes generated by all of the preceding layers. Most outcomes are hopefully beneficial, but to be fair, some will be negative, and others will represent trade-offs, such as reduced jet fuel consumption through algorithmic supply chain route optimization, but increased electricity consumption by the data centers running those algorithms.

Outcomes include:

- Personal, such as in Maslow's hierarchy and beyond, i.e., physiological, health and safety, social, esteem, self-actualization, transcendence, and experiences and entertainment, but at the risk of negative externalities such as increased stress, alienation, job loss, or cognitive atrophy and deskilling.

- Business, including improved financial metrics such as ROI, ROA, ROIC, and EBITDA, by moving to digitally enabled asset-light models, optimizing operations, and creating new revenue streams. Also, customer benefits such as reduced churn and increased lifetime value; internal performance gains in areas such as employee satisfaction and process yield.

- National, international, societal, and environmental benefits, such as improved climate, air and water quality, disaster prevention and relief, national or planetary defense, improved standard of living, job creation, reduced infant mortality and improved elder care, increased educational opportunity, and enhanced equity and access, but potentially being joined with existential risk.

This universe of outcomes is both quantitative and qualitative, and both positive and negative, but represents the significance of all of the layers that transform resources into outcomes.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

About the Author

Joe Weinman has been an executive in the technology industry, with technical and executive roles spanning Bell Labs, AT&T, HP. He most recently was Senior Vice President, Cloud Services and Strategy, at Telx (now Digital Realty). He received a Bachelor of Science in Computer Science at Cornell University, a Master of Science in Computer Science from UW-Madison, and has completed executive education at the International Institute for Management Development in Lausanne, Harvard University, and MIT. He has been awarded 27 U.S. and international patents in areas such as mobile and wireline voice and data communications, distributed storage and computing, homomorphic encryption, and consumer products. He is the author of multiple books and well over 100 technical, academic, and business strategy articles in leading publications.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.

Trademarks

International Institute for Future Industries™, IIFI™, the IIFI logo, the TRIP MAP™ industry evaluation framework, the TRIP™ maturity model, TRIP MAP™, Technology Readiness Inflection Points™, and the MAP™ assessment scale are trademarks of XFORMA LLC, d/b/a International Institute for Future Industries in the United States and other countries.

All other product names, logos, brands, trademarks, and registered trademarks mentioned or depicted in this document are the property of their respective owners.

Reference to third-party trademarks, company names, trade names, or products is made solely for descriptive, analytical, or educational purposes under nominative fair use.

The inclusion of third-party marks does not constitute or imply any endorsement, sponsorship, affiliation, or recommendation by or with the respective trademark owners, nor does it imply that such owners endorse International Institute for Future Industries or its methodologies.

Disclaimer of Warranties

This document is provided for informational and educational purposes only. While every effort has been made to ensure the accuracy of the information presented, International Institute for Future Industries makes no representations or warranties, express or implied, regarding the completeness or accuracy of the contents herein.

About

International Institute for Future Industries is a trade name of XFORMA LLC, established in 2016. Visit https://iifi.institute/ or contact info@iifi.institute for additional publications, our periodic technology reports, or for consulting, advisory, and speaking services.

© Copyright 2026 International Institute for Future Industries. All rights reserved.
TRIP MAP™, Technology Readiness Inflection Points™, MAP™, IIFI™ and the IIFI logo are trademarks of XFORMA LLC d/b/a International Institute for Future Industries.