ARTIFICIAL GENERAL INTELLIGENCE (AGI) AND EMERGING TECHNOLOGIES (QUANTUM TECH.)

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Abstract

Artificial General Intelligence (AGI) and quantum technologies are beginning to shape how countries design digital infrastructure, critical services and long-term security. However, technical work on models and architectures often evolves separately from national strategies on resilience, governance and capability building. This chapter brings these perspectives into a single structured view. We first position AGI within the evolution of artificial intelligence and explain how it differs from narrow, generative and agentic systems. The chapter groups AGI requirements into core capability areas and summarises the main architecture families that are emerging across model-centric, agentic, predictive, knowledge-integrated and system-integrated designs, together with current approaches to safety and evaluation. The second section focuses on emerging technologies that support AGI in practice. On the classical side, it describes computing and acceleration platforms, communication and 6G networks, digital twins, data and knowledge systems, and security foundations. On the quantum side, it explains how quantum computing and optimisation, quantum communication, quantum-enhanced simulation and quantum-safe security can strengthen optimisation, coordination, modelling and long-term protection for AGI-scale systems. Together, they show how AGI systems are trained, connected and protected in real environments. Building on this structure, the third section organises national AGI and quantum strategies into three layers: mission domains that guide where AGI creates public value, capability pillars that define the required technical foundations, and governance themes that link these technologies to safety and strategic readiness. Overall, the chapter provides a shared structure for researchers, engineers and policymakers who need to plan AGI as both a technical system and a national capability within a wider digital infrastructure.

Keywords

Artificial General Intelligence, Quantum Technologies, Digital Twins, National AI Strategy, Critical Infrastructure

Introduction

Artificial General Intelligence (AGI) and quantum technologies are moving into national plans for digital infrastructure, critical services and security. AGI aims for systems that can learn, reason and act across many tasks with human-level flexibility, instead of staying limited to a single benchmark or narrow domain (Khan et al., 2025; Yenduri et al., 2025). Quantum technologies add new capabilities in computing, communication, simulation and security that support large-scale optimisation, accurate modelling and long-term protection (Yang et al., 2023; Pan et al., 2024; Mathur et al., 2025). Together, they will shape how future digital infrastructure, critical services and public platforms are designed.

Most current documents and projects still discuss AGI, digital twins and quantum technologies separately. Engineers focus on models and infrastructure, while national strategies emphasise missions, risk management and long-term security. This chapter aims to bridge these views by giving a common picture of AGI capabilities, enabling technologies and national needs.

The chapter is organised in three parts. Section 1 introduces AGI foundations: how AGI relates to the evolution of AI, which capabilities define it, which architecture families are emerging and how safety and evaluation can be organised. Section 2 presents the main classical and quantum technologies that support AGI in practice, including computing and acceleration, communication networks, digital twins, data and knowledge systems, and quantum computing, communication, simulation and security. Section 3 connects these technical elements to national technology directions by outlining mission domains, capability pillars and governance needs. Together, these three views provide a structured reference for researchers, engineers and policymakers who need to treat AGI as both a technical system and a policy topic within a wider national digital ecosystem.

1. AGI Foundations

AGI describes an AI system that can understand, learn, and act across many tasks with human-level flexibility. While current AI systems reach high performance in specific areas, AGI aims for broad generalisation, stable reasoning, and adaptation in open environments (Khan et al., 2025; Yenduri et al., 2025). This section explains how AGI relates to the evolution of AI, how it differs from other AI types, and which capabilities and design principles define it.

1.1. AGI in the Artificial Intelligence Evolution

1.1.1. Historical Path

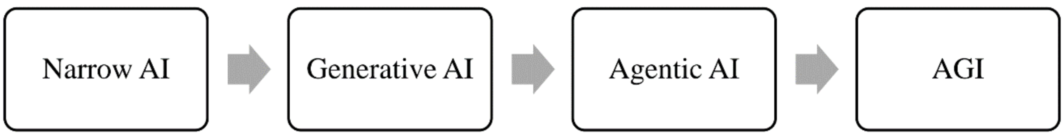
The development of AI has moved through several main stages on the way to the current AGI vision. Early work focused on symbolic AI, where systems used rules, logic, and expert knowledge to solve well-structured problems (Baum, 2017). These systems could explain their reasoning but struggled with noise, uncertainty, and changing environments. The next stage was machine learning. Here the focus shifted to data-driven models that learn patterns from labelled data instead of relying on fixed rules. This improved accuracy for tasks such as classification and regression but still required careful feature engineering and produced models that were narrow in scope (Khan et al., 2025). Deep learning then changed the field. Large neural networks started to learn hierarchical representations directly from raw data and reached strong performance in vision, speech, and natural language tasks (Mumuni & Mumuni, 2025). This enabled end-to-end learning pipelines and large-scale deployment in industry. More recently, generative AI systems appeared, built around large language models and multimodal models that can produce text, images, audio and code using large-scale pattern learning (Latif et al., 2023). On top of generative models, agentic AI introduced planning, tool use, memory tools and interaction with external software. This allows systems to carry out multi-step tasks using APIs and services. From this development path, the idea of AGI became more concrete. AGI is seen as the next stage, where systems move from narrow abilities to broad competence, long-term memory, general reasoning and reliable behaviour across domains and over time (Morris et al., 2024; Yenduri et al., 2025). In other words, the field has progressed from rule-based intelligence to data-driven intelligence and now towards autonomous and general-purpose intelligence.

1.1.2. Position and Differences of AGI in Artificial Intelligence

This subsection explains how AGI relates to the main AI system types used today and what makes it different from them. Figure 1 summarises the main AI system types that we refer to in this chapter.

Figure 1

Evolution of AI System Types from Narrow AI to AGI



To make the comparison clear, we outline four groups that represent today's main AI system types:

- Narrow AI is built for a single task such as image recognition, translation, or route planning. It can reach high accuracy on that task, but its knowledge does not transfer well to new settings. When the task or environment changes, the system often needs retraining or redesign (Khan et al., 2025).
- Generative AI models learn patterns from large datasets and can produce text, images, audio, or code. They are powerful for content creation, but they

usually do not form a stable internal model of real situations. Their reasoning mostly follows statistical patterns rather than structured logic, and they do not maintain a consistent long-term memory of past interactions (Mumuni & Mumuni, 2025).

- Agentic AI uses generative models together with planning, tool use, simple memory tools, and API calls. These systems can break goals into steps, call external tools and execute longer workflows, which makes them more capable than stand-alone generators (Joshi, 2025). However, they still depend strongly on prompt design, tool configuration and human supervision, and they show limited robustness outside their designed scenarios.
- AGI aims for general capability. An AGI system should be able to learn new tasks from limited examples, build and use long-term memory, understand cause and effect, and keep reliable performance in changing environments. It should transfer skills across domains. It should also continue learning during use instead of remaining fixed after training (Khan et al., 2025; Morris et al., 2024).

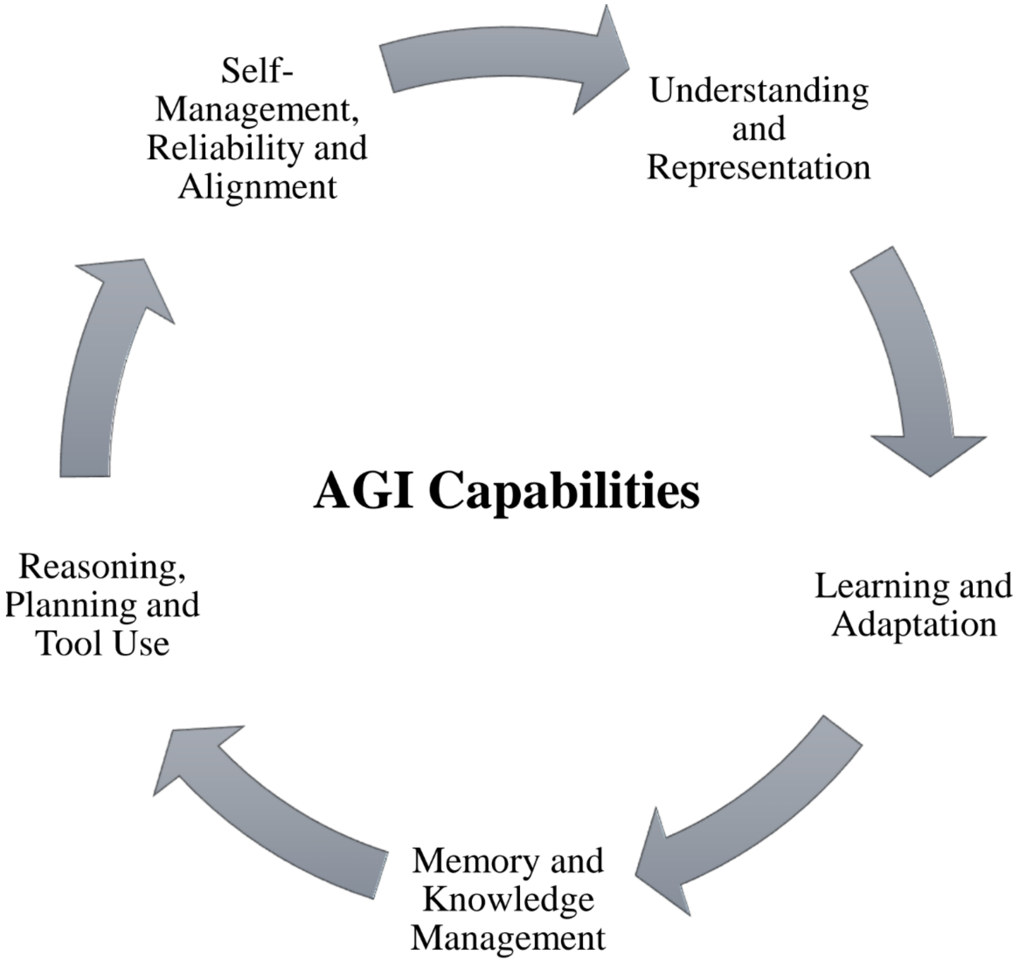
Overall, narrow AI, generative AI, and agentic AI are important milestones, but none of them meets the full requirements of general intelligence.

1.2. AGI Capabilities

AGI capabilities define what an AGI system must achieve across perception, reasoning, learning, memory, and interaction, and they show whether the system can work across many tasks and adjust to new situations. Figure 2 summarises these five core capability groups.

Figure 2

The Core Capability Groups of AGI



We organise them into the following main areas:

- Understanding and Representation: An AGI system must process text, images, audio, and sensor signals and build internal representations that remain stable across tasks and situations. This includes recognising objects, events, and relationships and maintaining consistency as new inputs arrive. Current multimodal models represent early progress but still struggle with consistency across complex environments (Chaccour et al., 2024).
- Learning and Adaptation: AGI must learn new skills quickly and adapt when tasks, data, or conditions change. It should make use of limited examples, reuse previous experience, and adjust without retraining the entire model. This type of flexible learning is one of the major differences between AGI and narrow AI systems, which often break when their environment shifts (Yenduri et al., 2025).

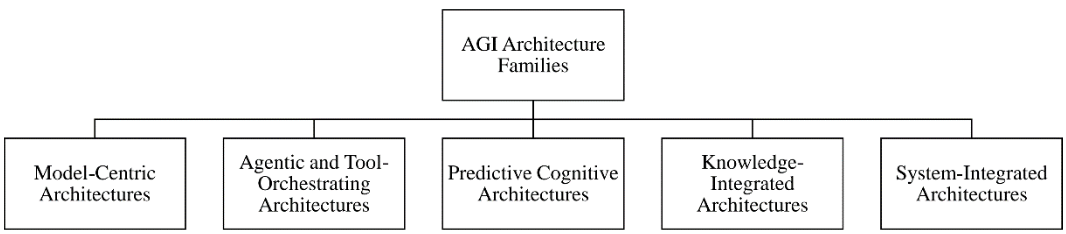
- Memory and Knowledge Management: AGI needs reliable long-term memory and structured knowledge. It must store information from past interactions, update it, and combine it with general knowledge about its environment and tasks. An AGI system should link new inputs with what it already knows and keep a stable internal state. Most current models depend mainly on static pre-training and lack stable long-term memory tools (Latif et al., 2023).
- Reasoning, Planning and Tool Use: AGI must support logical, causal, and abstract reasoning. It should plan multi-step actions, compare alternatives, estimate outcomes, and adjust its plans when new evidence appears. Effective AGI systems will also use external tools, such as search engines, simulators, and APIs during problem-solving. Many existing models still rely on statistical patterns instead of robust reasoning (Khan et al., 2025).
- Self-Management, Reliability and Alignment: AGI must interact smoothly with people and with other agents. This includes understanding instructions, following social norms, coordinating actions, and communicating clearly. At the same time, it must manage its own behaviour over long interactions, recognise uncertainty, and avoid unsafe actions. Alignment ensures that the system's behaviour stays consistent with human goals and safety expectations (Joshi, 2025; Morris et al., 2024).

1.3. AGI Architecture Families

AGI architecture families define how the core of an AGI system is organised. We group architectures by their main organising principle, the central mechanism that shapes how the system reasons, learns, and acts. Figure 3 summarises the five main families. Multi-agent ecosystems and hybrid classical–quantum designs are treated as cross-cutting patterns rather than separate families. The following subsections outline each family and the type of AGI systems they support.

Figure 3

Taxonomy of AGI Architecture Families



1.3.1. Model-Centric Architectures

Model-centric architectures rely on a single large model as the main decision engine. Today's LLM-centric and multimodal systems follow this pattern. A general-purpose model is trained on broad data and then adapted to downstream tasks (Mumuni & Mumuni, 2025; Yenduri et al., 2025). It handles perception, pattern recognition and most reasoning functions through in-context learning and prompt design (Khan et al., 2025). Memory usually comes from long context windows and retrieval. This family is easy to scale because it fits existing training and deployment pipelines, but it also places capability and safety risks into one core model (Morris et al., 2024; Shah et al., 2025).

1.3.2. Agentic and Tool-Orchestrating Architectures

Agentic architectures organise one or more models inside an agent loop that plans, selects tools, and interacts with the environment (Joshi, 2025). The focus is orchestration. The agent manages a task state, breaks goals into steps, and decides when to call a model or a tool. Tools include search engines, code execution, databases, digital twin APIs, network controllers, or quantum optimisers (Duran et al., 2025; Mathur et al., 2025). Short-term and long-term memory are maintained as structured workflows. This family connects naturally to the emerging computing, network, and digital twin stack discussed in Section 2.

1.3.3. Predictive Cognitive Architectures

Predictive cognitive architectures centre on an explicit model of how system states evolve under actions and external events (Khan et al., 2025). The system learns or uses a structured model and applies it during planning. The main components include perception, state representation, state-transition model, planner, action selection, and memory. They can be learned, such as model-based reinforcement learning, or provided as domain-specific simulators for network, mobility or energy systems (Chaccour et al., 2024). This family is suited for tasks that require scenario evaluation and long-term decisions, especially in safety-critical systems.

1.3.4. Knowledge-Integrated Architectures

Knowledge-integrated architectures combine neural components with explicit knowledge and reasoning (Baum, 2017; Reply, n.d.). A knowledge layer encodes entities, relations, constraints and policies using knowledge graphs, ontologies or rule engines (Duran et al., 2025). A reasoning module performs logical inference and consistency checks. Neural modules extract new facts, while the knowledge layer injects structure and rules into decisions. This family supports interpretability and compliance, which aligns with regulatory requirements such as the EU AI Act (European Commission, 2023, 2025a, 2025b).

1.3.5. System-Integrated Architectures

System-integrated architectures connect AGI directly to physical and cyber-physical systems through sensors, actuators and digital twins (Chaccour et al., 2024; Duran et al., 2025). The system operates in a closed loop where real-world data flows into the AGI layer. The AGI selects actions, and the resulting effects are observed through telemetry or updated twin states. These architectures often integrate twins of communication networks, energy grids, mobility systems, or industrial environments (BTYPK, 2021; CBDDO & STB, 2021, 2024). Because decisions affect real infrastructure, additional safety layers, human oversight and domain-specific controls are required (Shah et al., 2025).

1.4. AGI Safety and Evaluation

AGI safety focuses on controlling system behaviour, preventing harmful outcomes, and ensuring that the system operates within safe limits. Shah et al. (2025) group the main sources of risk into four areas: misuse, misalignment, mistakes and structural risks. Misuse covers harmful use of AGI systems by people. Misalignment refers to goals or behaviours that diverge from human intent. Mistakes arise from unexpected failures in complex systems, even when goals are specified correctly. Structural risks capture systemic effects when AGI is widely deployed across sectors. Evaluation complements safety by measuring progress, identifying risks, and determining when a system is ready for real deployment. The main areas are:

- Alignment and behaviour control: Alignment ensures that AGI systems follow human goals and safety constraints, while also reducing the risk of intentional misuse. Core alignment risks include specification gaming, goal misinterpretation, and deceptive behaviour, where the system appears compliant but acts differently when it is not monitored (Shah et al., 2025). Misuse risks arise when capable systems are applied to harmful tasks. Current approaches therefore emphasise clearer objectives, restricted access to high-risk capabilities, and strong testing before deployment.
- Robustness and reliability: AGI must remain stable under changing conditions, adversarial prompts, unexpected inputs, and long interaction sequences. Shah et al. (2025) highlight mistakes as failures that emerge from this complexity, even when goals and incentives appear well specified. Techniques such as interpretability, red-team evaluation, stress testing and continuous monitoring help detect these failures early and improve reliability (Dragan et al., 2025).
- Evaluation levels for AGI systems: Evaluation usually follows a staged structure, covering narrow tasks, domain-general tasks, cross-domain tasks, and dynamic real environments. These stages show how well a system adapts to new challenges with limited guidance. This staged view also aligns

with proposals for "exceptional AGI" systems, which require stricter evidence of safety before broad deployment (Morris et al., 2024; Shah et al., 2025).

- Governance, auditing and deployment: One practical pattern is a safety-case approach, where developers provide structured evidence that their AGI systems meet defined safety claims before large-scale use. Responsible deployment requires technical and organisational measures. Key elements include phased deployment, secure model and data handling, independent auditing, and shared safety standards across organisations (Altman, 2023; Dragan et al., 2025; Shah et al., 2025). Policy frameworks also emphasise accountability, incident reporting, and clear assessment criteria before models enter critical applications (European Commission, 2025a; CBDDO & STB, 2021; CBDDO & STB, 2024).

2. Emerging Technologies for AGI

AGI systems depend on core technologies that provide computation, connectivity, real-world understanding, and secure operation. These technologies shape how AGI models are trained, how they interact with their environment, and how they stay reliable in deployment (Khan et al., 2025; Chaccour et al., 2024). We group them into classical technologies used today and quantum-focused technologies that will support future AGI systems.

2.1. Classical Emerging Technologies

Classical emerging technologies provide the main technical capabilities that current AGI systems rely on. They supply the computing, connectivity, structured environments, and security layers that enable AGI to operate in practice. The following subsections describe these components.

2.1.1. Computing and Acceleration

AGI requires large and scalable computing resources. Modern systems rely on Graphics Processing Units (GPUs), Tensor Processing Units (TPUs), specialised accelerators, and distributed clusters that support large datasets and long training cycles (Khan et al., 2025). Cloud platforms support large-scale workloads, while edge nodes provide low-latency responses for time-critical tasks. Together, they form the computing layer required for AGI-scale systems (Mumuni & Mumuni, 2025).

2.1.2. Communication and Connectivity

AGI systems depend on high-bandwidth and low-latency networks to coordinate with tools, services, robots, and digital twins. 6G aims to integrate communication, sensing, and computing, enabling distributed AGI agents to work together in real time (Chaccour et al., 2024). Strong connectivity is essential for autonomous mobility, robotics, and multi-agent systems.

2.1.3. Digital Twins, Data, and Knowledge

Digital twins provide structured representations of physical environments. They allow AGI models to test actions safely and learn from realistic scenarios (Duran et al., 2025). High-quality datasets, knowledge graphs, and structured data pipelines maintain the world knowledge that AGI uses for reasoning and planning (Reply, n.d.).

2.1.4. Security and Trust

As models gain capability, risks such as model extraction, misuse, and adversarial manipulation increase (Shah et al., 2025). Secure AGI deployment requires strong identity management, cryptography, protected model storage, and continuous monitoring. National strategies emphasise trusted infrastructure and governance for AGI-scale systems (CBDDO & STB, 2024).

2.2. Quantum-Focused Emerging Technologies

Quantum technologies introduce new capabilities for computing, communication, simulation, and security. They are still developing, but their direction aligns with AGI's long-term needs. AGI systems require faster optimisation, secure distributed operation, accurate modelling of physical processes, and long-term protection against advanced attackers. Quantum methods support these needs (Yang et al., 2023; Pan et al., 2024; Mathur et al., 2025; BTYPK, 2021). To this end, we summarise the four main quantum technologies in the following subsections.

2.2.1. Quantum Computing and Optimisation

Quantum computing provides a new computational model based on superposition and entanglement. These properties allow quantum processors to explore large solution spaces more efficiently for certain optimisation, search, and simulation tasks. These problem types are central to AGI, especially for planning, reasoning, and decision-making. Current devices use noisy intermediate-scale quantum (NISQ) hardware and have started to demonstrate early signs of quantum advantage on specific tasks (Yang et al., 2023). Progress in qubit counts, control, and error reduction suggests that hybrid quantum–classical workflows will become practical in the near future. This is important for AGI because many AGI tasks rely on heavy optimisation, including reinforcement learning, model fine-tuning, scheduling, and long-term planning. Key developments include:

- Quantum optimisation methods such as the Quantum Approximate Optimisation Algorithm (QAOA) and Quadratic Unconstrained Binary Optimisation (QUBO), which can speed up complex decision problems (Yang et al., 2023).
- Grover search, which offers a quadratic speed-up for unstructured search problems and can support reasoning and retrieval tasks.

- Quantum machine learning models that use quantum states to represent information patterns.
- Quantum federated learning, where quantum nodes participate in distributed training without revealing local data (Mathur et al., 2025).
- Hybrid classical–quantum stacks, where classical accelerators train neural networks and quantum processors handle optimisation or simulation sub-problems.

AGI models are expected to require advanced planning, long-term reasoning, and large-scale optimisation. Hybrid quantum–classical systems are therefore a realistic path for future AGI workloads, where quantum processors assist in bottleneck areas while classical hardware handles large-scale neural computation. Quantum processors will not replace GPUs and TPUs, but they can offload expensive optimisation components. This combination supports deeper search and faster scenario evaluation for future AGI workloads.

2.2.2. Quantum Communication and the Qinternet

Quantum communication enables secure transmission of information using quantum states. Its security is guaranteed by physical laws rather than computational assumptions. This is important for AGI systems that rely on coordination across distributed agents, digital twins, and cloud platforms. The core technologies include:

- Quantum Key Distribution (QKD), which provides secure key exchange.
- Quantum Secure Direct Communication (QSDC), enabling direct message transmission (Pan et al., 2024).
- Quantum repeaters, which extend quantum communication over long distances.
- Entanglement distribution, enabling correlated quantum states across nodes.
- The Qinternet, a global quantum communication network, which is a future communication layer based on quantum links rather than classical channels.

Quantum-secured communication is valuable for AGI because distributed AGI agents must coordinate actions, exchange sensitive information, and update models safely. It protects against interception, manipulation, or model extraction, which is critical for national infrastructures, mobility systems, and industrial platforms. As AGI systems take more autonomous decisions, the importance of secure communication will grow.

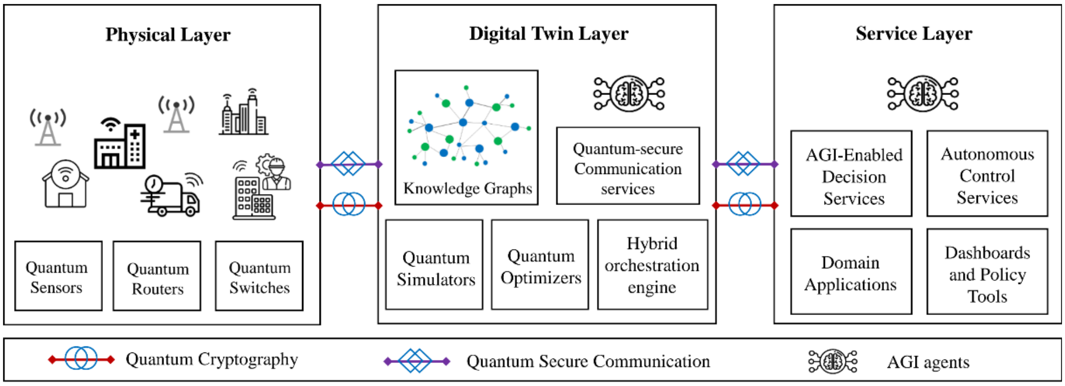
2.2.3. Quantum-Enhanced Digital Twins and Simulation

Digital twins depend on high-fidelity simulation of physical systems. Many of these simulations become computationally demanding, especially when modelling molecular processes, climate systems, materials, or large interconnected networks.

Quantum simulation can speed up these workloads and improve fidelity (Yang et al., 2023). Figure 4 shows a conceptual three-layer architecture for AGI-enabled decision and control.

Figure 4

Conceptual Quantum-Enhanced Digital Twin Architecture for AGI-Enabled Services



In practice, quantum-enhanced twins can support several types of tasks, such as:

- Simulation of molecular, material, and chemical systems for drug discovery, catalysis, and new materials.
- Modelling of environmental and energy systems, including grids, renewables, and climate-related processes.
- Detailed analysis of engineering and industrial processes, such as manufacturing lines or complex mechanical systems.
- Integration of quantum sensors that provide high-precision measurements for navigation, imaging, and infrastructure monitoring.

For AGI, these capabilities provide higher-fidelity internal models of the real world, stronger prediction, and safer testing before actions are deployed. Quantum-accelerated twins give AGI more accurate training environments, more realistic feedback loops, better long-term prediction, and a clearer view of physical constraints (Yang et al., 2023; Mathur et al., 2025). This is especially important for robotics, mobility, engineering, and autonomous systems where the link between decisions and physical behaviour is critical.

2.2.4. Quantum-Safe Security and Trust

As quantum computers advance, many current cryptographic systems will become vulnerable. AGI models, training pipelines, datasets, and communication channels must therefore be protected with quantum-safe technologies. Key mechanisms include:

- Post-quantum cryptography (PQC) based on quantum-resistant mathematical problems
- Hybrid cryptographic frameworks that combine classical and PQC algorithms during the transition phase
- Quantum-safe communication protocols for agents, digital twins, and cloud-based AGI services
- QKD-based protection for critical infrastructures (Yang et al., 2023; Pan et al., 2024)

National policy documents recommend early migration to quantum-safe standards to avoid sudden transitions and maintain security for high-value AI systems (BTYPK, 2021). As AGI models become more capable and strategically important, quantum-safe security becomes essential.

Classical technologies support today's AI and early AGI systems, while quantum technologies add new capabilities in optimisation, secure communication, high-accuracy simulation, and long-term security. Together, they will shape how AGI systems are designed, deployed, and integrated into future large-scale infrastructures.

3. National Technology Directions

AGI and quantum technologies are reshaping how countries design digital infrastructure, protect critical systems, and provide public services. National strategies in the UK, EU and US focus on scalable compute, secure and interoperable data, trusted AI governance and preparation for quantum-era risks (HM Government, 2021; European Commission, 2023, 2025a, 2025b; The White House, 2025). Türkiye follows a similar line, with secure digital transformation, sectoral data platforms, high-performance computing and quantum-safe protection (BTYPK, 2021; CBDDO & STB, 2021, 2024). This section uses these shared priorities to organise national AGI and quantum strategies into mission domains, capability pillars and governance needs.

3.1. Mission Domains for AGI and Emerging Technologies

Mission domains are national areas where AGI and quantum technologies can deliver clear and measurable impact. They share three common needs: continuous data, time-sensitive decisions, and strong security requirements. We highlight six mission domains where these technologies provide direct national value:

- Digital government and public services: Governments manage large volumes of documents, cases, and citizen requests. AGI can support document processing, case analysis, and early detection of service disruptions. Digital twins allow agencies to test policy options such as traffic regulation, emergency response, or energy-demand scenarios before deployment (Duran et al., 2025). EU guidance emphasises trustworthy public-sector AI (European Commission, 2023), while Türkiye's roadmap prioritises quantum-safe protection for state systems (BTYPK, 2021). These capabilities strengthen reliability and security in public service delivery.
- Health and biomedical systems: AGI can enhance diagnostics, medical imaging, and treatment planning. Quantum-enhanced simulation improves molecular analysis and speeds up drug discovery (Mathur et al., 2025). The EU AI Act classifies many health AI applications as high-risk, and US policy documents call for strict safety and reliability measures in this domain (European Commission, 2025a; The White House, 2025). These capabilities help ensure precision and traceability in clinical decisions.
- Critical infrastructure: Critical infrastructures depend on accurate forecasting, secure control, and stable operation. AGI can optimise load balancing, support renewable-energy integration, and detect faults early. Quantum simulation contributes to climate and energy-storage modelling (Pan et al., 2024). These technologies improve resilience in systems where failures can cause national-level disruption.
- Mobility, transport and smart cities: Transport networks and urban systems generate fast, continuous sensor data. AGI can support routing, traffic optimisation, and city-wide planning. Digital twins help cities test congestion scenarios and infrastructure upgrades. National strategies highlight secure IoT, smart-city platforms, and trusted data exchange (CBDDO & STB, 2021). These capabilities support safe and efficient mobility across city systems.
- Industry and manufacturing: Industrial environments demand precision, uptime, and efficient use of resources. AGI enables predictive maintenance, automated inspection, and process optimisation. Quantum-enhanced modelling can improve material design and industrial simulation. These capabilities increase uptime, support automation, and improve production quality.

- Security and defence: Security and defence require rapid analysis, strong cyber protection, and reliable operational planning. AGI can enhance cyber defence and intelligence workflows. Quantum communication provides secure links that resist interception and long-term decryption (Pan et al., 2024; Shah et al., 2025). UK and US strategies emphasise secure AI development for national resilience (HM Government, 2021; The White House, 2025). These capabilities strengthen stability in mission-critical operations.

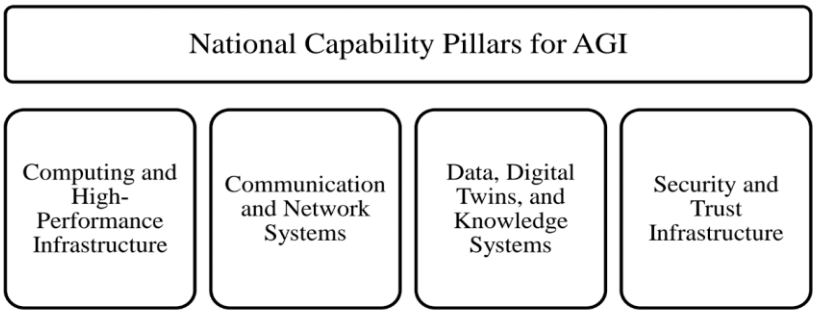
Together, these mission domains show how AGI and quantum technologies can strengthen national services, support complex decision-making, and improve resilience when backed by secure and scalable digital ecosystems.

3.2. National Capability Pillars for AGI

Countries need strong technical and organisational capacity to deploy AGI and quantum technologies effectively. Based on common themes across national strategies, we group these capacities into four core pillars, shown in Figure 5. Together, they describe what governments must build to support the mission domains in Section 3.1.

Figure 5

The National Capability Pillars Supporting AGI



We describe these pillars as follows:

- Computing and High-Performance Infrastructure: AGI requires large-scale computing capacity across cloud, edge, and high-performance systems. National strategies in the UK and US emphasise expanding access to GPUs, TPUs, and large compute clusters (HM Government, 2021; The White House, 2025). Long-term HPC programs increasingly plan for quantum processors to support optimisation, simulation, and scientific workloads. This pillar ensures the computational scale needed for training and experimentation.
- Communication and Network Systems: AGI depends on secure, low-latency connectivity between cloud, edge, devices, and digital twins. Türkiye's digital policies highlight national backbone capacity, secure networks, and 5G/6G development (CBDDO & STB, 2021). Quantum communication and Qinternet

can strengthen distributed AGI systems and critical infrastructures (Pan et al., 2024). This pillar supports real-time coordination across national services.

- Data, Digital Twins, and Knowledge Systems: AGI performance depends on clean, structured, and governed data. EU highlights trusted data spaces, interoperability, and strong data governance (European Commission, 2023). Digital twins allow safe testing of decisions in energy, mobility, industry, and healthcare. Knowledge graphs and structured data pipelines support long-term memory and reasoning (Reply, n.d.; CBDDO & STB, 2024). This pillar ensures that AGI systems work with accurate and policy-compliant information.
- Security and Trust Infrastructure: AGI deployment requires identity management, monitoring, trusted execution environments, and secure model handling. National strategies emphasise early transition to post-quantum cryptography (HM Government, 2021; European Commission, 2025b; BTYPK, 2021). QKD can protect high-value AGI systems and communication channels (Yang et al., 2023). This pillar ensures that AGI systems remain secure and trustworthy over time.

Together, these pillars define the capabilities that national ecosystems must build to adopt AGI and quantum technologies safely and at scale.

3.3. Governance and Strategic Readiness for AGI

Technical capacity alone is not enough for national AGI adoption. Countries also need governance systems that decide where AGI may be used, how it is tested and how incidents are handled. Based on recent national policy documents, we group these needs into four governance themes:

- Risk-Based Rules and Safety Tests: Recent strategies in the EU, UK, US and Türkiye move from high-level AI principles to risk-based rules for powerful systems, with defined risk classes, documentation duties and testing requirements (HM Government, 2021; European Commission, 2025a; CBDDO & STB, 2024; The White House, 2025). For AGI, this means a clear national process for model registration, safety and robustness testing, mandatory documentation and incident reporting. In practice, this aligns with safety-case approaches where developers must show how they manage misuse, misalignment, mistakes and structural risks before large-scale deployment (Shah et al., 2025).
- Secure Operation and Control: AGI will be used in sectors such as energy, transport, health and defence, where failures have national impact. Policies therefore prioritise access control, monitoring, incident response and secure model lifecycle management, and place quantum-safe migration on the roadmap to protect critical data and infrastructure (BTYPK, 2021; European

Commission, 2025b). For AGI, this connects governance directly with cyber resilience and national security.

- Shared Evaluation and International Cooperation: AGI and quantum systems are developed across borders, so countries highlight the need for shared testing, evaluation and data frameworks. The EU AI Pact and cross-border data initiatives, and the US plan for joint R&D and secure digital ecosystems, are early examples (European Commission, 2023, 2025b; The White House, 2025). For AGI, this requires evaluation centres that connect to international networks for quantum communication pilots and secure data spaces for digital twins.
- National Readiness and Strategic Autonomy: National strategies highlight the need to track domestic capability in computing, skills, cybersecurity and deployment readiness (European Commission, 2025a; The White House, 2025). Türkiye's roadmap adds digital sovereignty, secure data infrastructures and national control over main platforms (BTYPK, 2021). For AGI, regular benchmarking should identify gaps, guide investment and support autonomy in critical technologies.

Overall, these governance and readiness themes define how countries turn the mission domains in Section 3.1 and the capability pillars in Section 3.2 into operational, secure and internationally aligned AGI systems.

Conclusion

AGI and quantum technologies are no longer distant research topics. They are becoming design inputs for digital infrastructure, critical services and national policy. This chapter brought these elements into one frame: what AGI must be able to do, which classical and quantum technologies support it, and what countries need to build around them.

On the technical side, we described AGI as a combination of capabilities and architecture families rather than a single model. We highlighted computing, networks, digital twins, data and security as today's enabling stack, and showed how quantum computing, quantum communication, quantum-enhanced simulation and quantum-safe protection extend this stack for long-term AGI workloads. On the national side, we organised AGI and quantum deployment into mission domains, capability pillars and governance themes. This creates a direct link between engineering choices such as AGI architectures, digital twin platforms and quantum components and policy choices such as which sectors to prioritise, which infrastructures to invest in and how to regulate and test powerful systems.

Overall, the chapter provides a shared structure for researchers, engineers and policymakers. It encourages AGI planning based on the joint design of architectures, infrastructure and national strategies, with digital twins and quantum technologies used as common tools.

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