BCG

Executive Perspectives

11

AI-Powered R&D

February 2025

Introduction

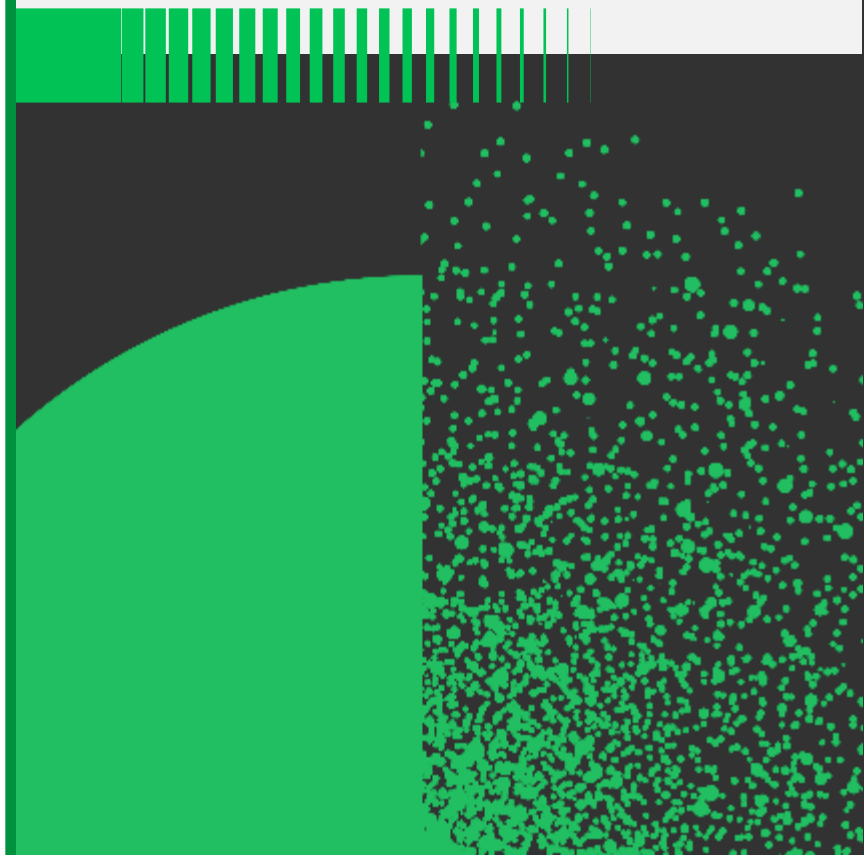
We meet often with CEOs to discuss AI—a topic that is both captivating *and* rapidly changing. After working with over 1,000 clients in the past year, we are **sharing our most recent learning in a new series designed to help CEOs navigate AI.** With AI at an inflection point, the focus in 2025 is on turning AI's potential into *real* profit.

In this edition, we delve into the transformative impact of AI on the R&D functions (innovation, engineering, and industrialization) within companies, exploring how to harness and build AI capabilities for a competitive edge. We tackle essential questions about building foundational capabilities and getting started in a world where disruptive innovations are becoming the norm:

- What are the groundbreaking impacts of AI on R&D and engineering?
- How can companies fully capitalize on this opportunity?
- What critical questions need to be addressed to lead in AI-powered R&D?

This document is a guide for CEOs, R&D heads, chief technology officers, and chief innovation officers from different sectors to cut through the hype around AI and understand what creates value now and in the future.

In this BCG Executive Perspective, we articulate the vision and value for R&D in the context of the AI revolution



Executive summary

What is the impact of AI for R&D?

R&D is undergoing a profound transformation, on track to become a **backbone of value creation. AI and agile**, combined, unlock incremental product improvements, drive the development of integrated systems, enhance productivity, and foster collaboration

The adoption of AI in R&D is expected to deliver meaningful impact, i.e., **10-20% reduction in time to market** and up to **20% lower R&D costs**

AI agents, autonomous systems capable of solving complex tasks, will be a **game changer in R&D activities**

AI's impact spans individual/team/company levels. Operating model transformation is essential **to unlock AI benefits at the company level**

How can you best benefit from this opportunity?

Five main levers are needed to successfully lead the journey:

- **Process reshape:** R&D process needs to be re-engineered end-to-end to integrate agile principles and AI tools
- **AI agents:** These are expected to **gradually cover more steps of the R&D process and deliver scaled impact,** with increasing reliability driven by a combination of generative and predictive AI
- **Data architecture:** New architecture with dedicated AI and data layers improves data ingestion from multiple sources and facilitates rapid AI tool deployment
- **IP-centric operating model:** Structured knowledge will be the key asset for companies to build agents, tailored to their needs and specific challenges, as vendors will focus on augmenting their core systems with generalist AI features
- **Talent development:** AI will impact all components of talent development, from skill sets requested to engineers/scientists to operating model

What are the key questions to address?

AI vision for data management is to **drive competitive advantage through improved data quality, expanded coverage, self-service analytics, and automated workflows,** transforming roles and democratizing data access with scalable, secure, and compliant solutions

AI-powered R&D transformation is already a reality across sectors with biopharma being one of the most advanced

AI journey is not just a tool topic: it necessitates a full transformation of processes, team engagement, talent strategy, and knowledge capture. It also requires mitigation of AI risks. **To start, efforts should be focused on the most advanced differentiating areas**

Collaboration is key to success, enabling access to advanced technologies and resources through **ecosystems and partnerships**

R&D has the potential to become the backbone of companies' value creation

From a function…

Delivering multi-year projects with a focus on speed, cost, and quality

Designing products centered on either hardware or software, not both

Securing expertise, engineering talent acquisition and retention

Operating as a company function and creating silos

…to the backbone of value creation

Enabling incremental innovation with frequent releases

Designing and operating **intelligent systems of systems**

Augmenting engineers/leaders with AI/digital twins

Orchestrating **open and distributed innovation**

Source: BCG

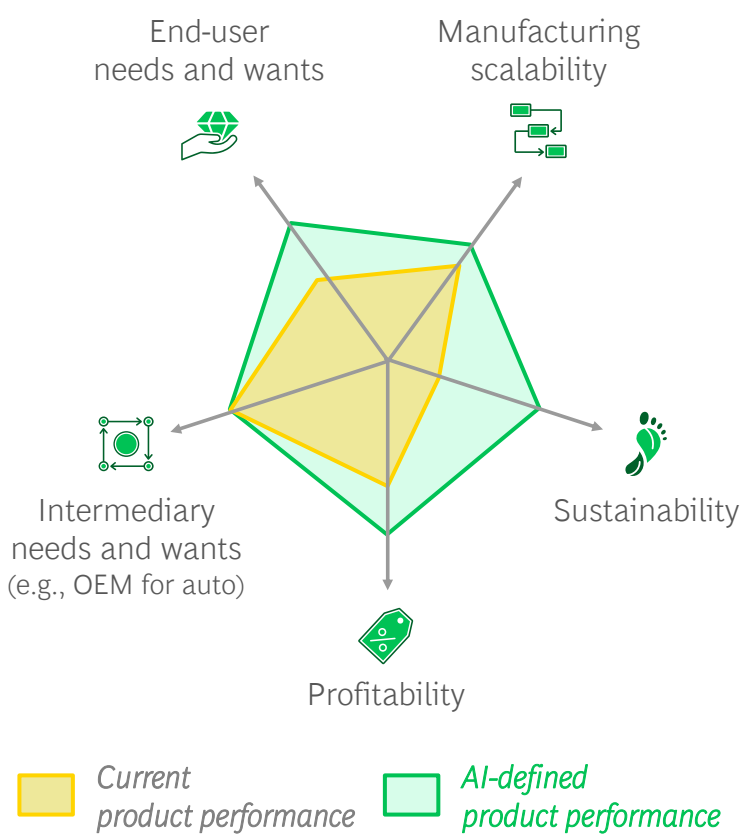
AI unlocks faster and more comprehensive framing of disruptive products…

New design opportunities unlocked with AI proposing and optimizing concepts

Improved risk forecasting via AI-powered simulations based on company-specific historical data

Seamless translation to the physical world enabled by digital twins providing data foundation to AI tools

Illustrative



Key benefits

- Disruptive concepts
- Company IP utilization
- Scalability in manufacturing
- Accelerated industrialization

...with AI agents serving as a game changer for R&D activities

Analyze documents and drawings to identify inconsistencies for targeted design review

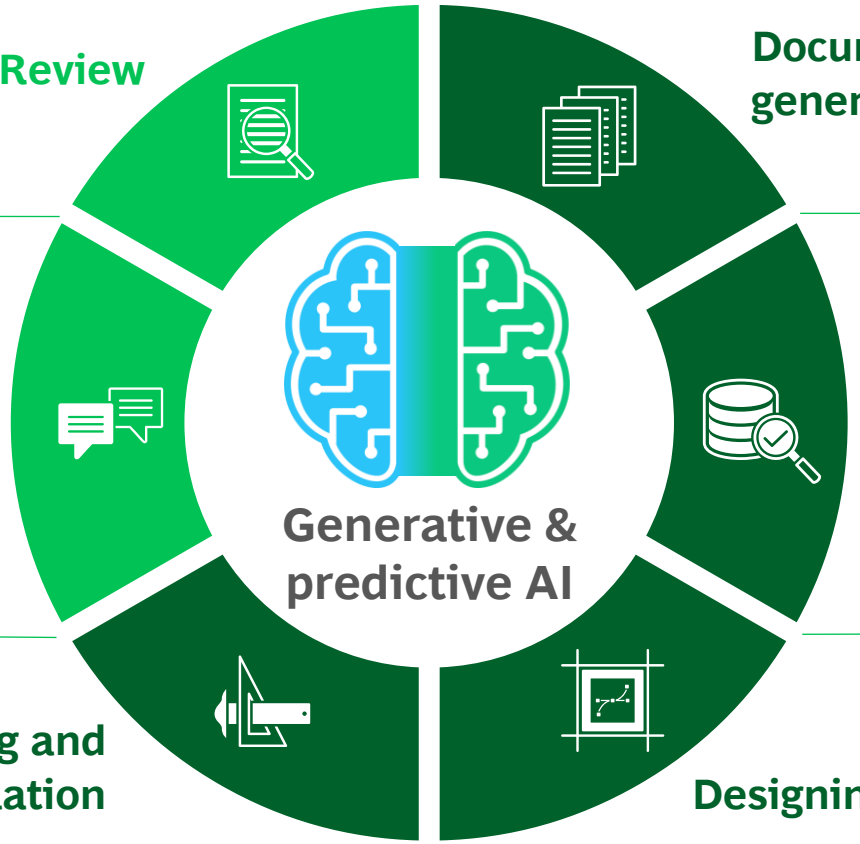
Review

Document generation

Generate technical, RFP, and permitting documentation

Frame solutions and assists in performing time-consuming integration activities

Integrating



Data/Info management

Perform routine and low-value-add operations, aiming to eliminate manual reporting tasks

Handle difficult and time-consuming calculations

Sizing and calculation

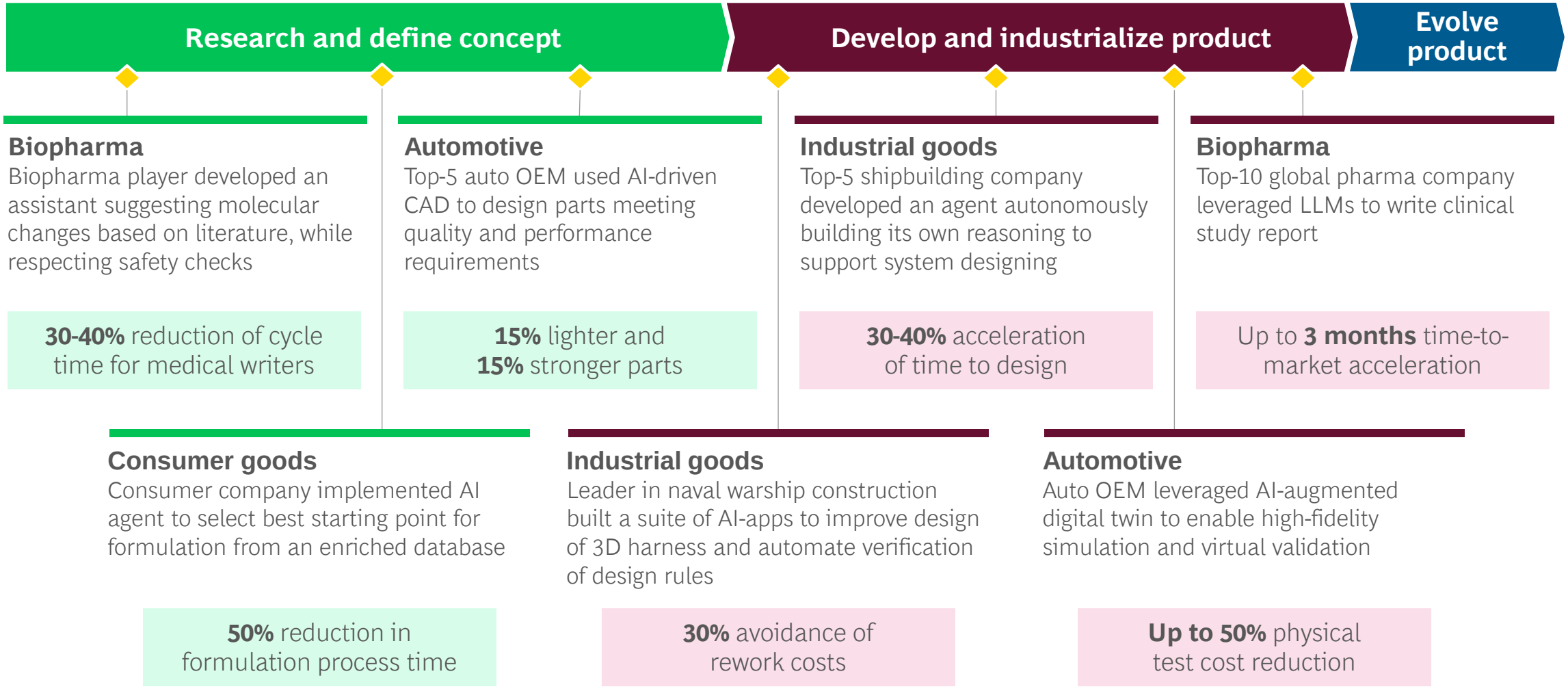
Designing

Support design engineers in optimizing for cost efficiency, quality, and aftersales performance

Content verification

Content generation

Transforming R&D with AI is already in progress across many industries



Deep dive | Use AI to boost productivity, efficiency, and time to market

AI-driven design optimization for ship decks

Global ship manufacturer aims to accelerate ship deck design by integrating AI for technical spec calculations and scupper placement to minimize water accumulation

Developed AI Gaia Agent to automate design tasks using **14+ tools, streamline processes into 6 steps with 12 tasks,** and record output in CAD files

- **80%** lead-time reduction per ship deck
- **40%** of engineering resources saved
- **Reduced** functional design errors

AI-augmented medical writing

Top-10 global pharmaCo seeks to **speed up drug commercialization,** starting with **revamping medical writing processes for clinical study reports & protocols (CSR)**

Built GenAI to handle **100% of clinical study report authoring. Revamped workflows,** enabling better anticipation of tasks and parallel activities. Deployed to **200+ medical writers, clinical research directors, and bio stats**

- **Up to 3 months** time-to-market acceleration
- **30-40% time saved** for medical and regulatory writers
- **60-90% accuracy and completeness** of written first draft documents

AI lab companion for product formulation

Leader in the CPG sector aims to **boost product formulation** by using AI to define **best starting point**

Developed the **Lab Companion,** an AI tool providing optimal starting **formulations based on 10+ criteria.** Features a user-friendly interface for refinement and risk assessment

- **Twice the pool** of candidate formulas
- **30–50% of expected reduction** for overall formulation process
- **User satisfaction increased** from 1.5/5 to 4/5

Operating model needs rewiring to fully unlock AI benefits at company level

- Faster task execution
- Improved access to knowledge
- Boosted simulation accuracy
- Quicker onboarding

Benefits only at individual level

- Broadened team scope
- Easier workforce management
- Greater team synchronization
- Facilitated knowledge formalization

Initial impact is visible at the company level

- Accelerated end-to-end processes
- Decreased R&D costs
- Higher value proposition
- Increased innovation
- Rapid invention of new products

Fully realized impact, after transforming the operating model (agile, talent)

10%–20%

Time-to-market acceleration[1]

Up to 20%

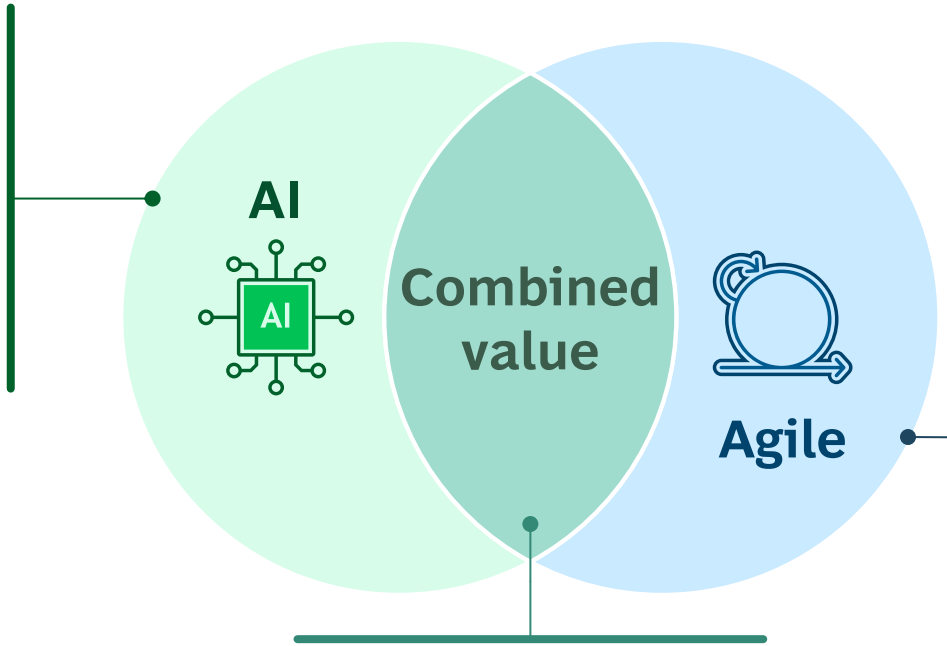
R&D costs reduction

1. From idea to go-to-market

Get value at the company level by combining AI and agile

AI's cascading impact—from individuals to teams to the organization—delivers maximum value when the operating model is purposefully rewired

- Streamlined access to IP
- Accelerated exploration of new concepts and materials
- Recognition of hidden patterns and correlations
- Improvement of product features
- Speeding up manual tasks



- Value-driven focus
- Ability to deal with more and more complex designs
- Higher autonomy level
- Incremental progress starting with foundational elements

Cycle time
Throughput acceleration
Team efficiency
Continuous learning

Achieve competitive advantage in R&D—5 pillars for strategic AI integration

Process reshape
(E2E vision + use cases)

- **Reshape R&D process to embed AI in new operating model.** AI should not improve old ways of working, but define new ones – at individual level, team level, and company level
- **E2E process redesign yields 3-4x higher ROI** vs. implementation of fragmented use cases

AI agents
(custom + partnerships)

- **R&D software vendors** are adding AI features to their platforms
- **Agents will incrementally be integrated** across E2E processes, using generative and predictive AI for **explainable, replicable** outputs. **Companies should focus on cross-systems, tailored AI agents** for complex tasks

Data architecture
(platform + access)

- Pursue **technology partnerships** to make a step change in the platform building:
  - Facilitate **aggregation of data** from multiple sources
  - Gain **access to cutting-edge solutions** and computational power
  - **De-couple** AI use case delivery **from time-consuming processes** of legacy modernization

IP-centric operating model

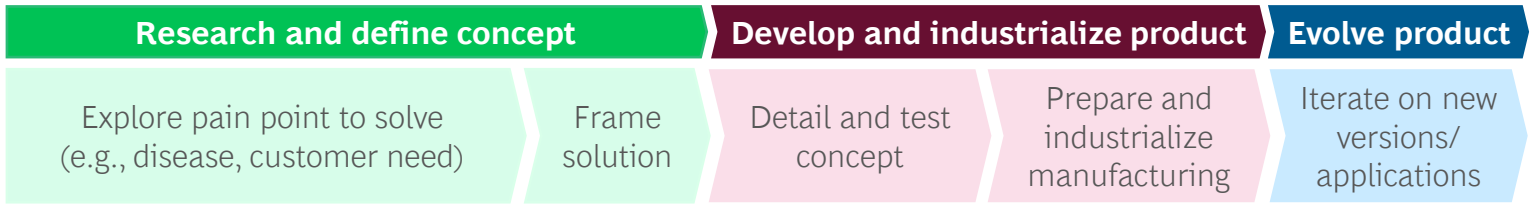
- **Fully embed agile principles** into operating model (team size, fragmentation, flexibility, project setup) to leverage access to knowledge and augmentation
- **Leverage accumulated IP/knowledge** to build unique competitive advantage
- **Drive AI deployment iterations centrally,** combining more and more generative and predictive AI

Talent development

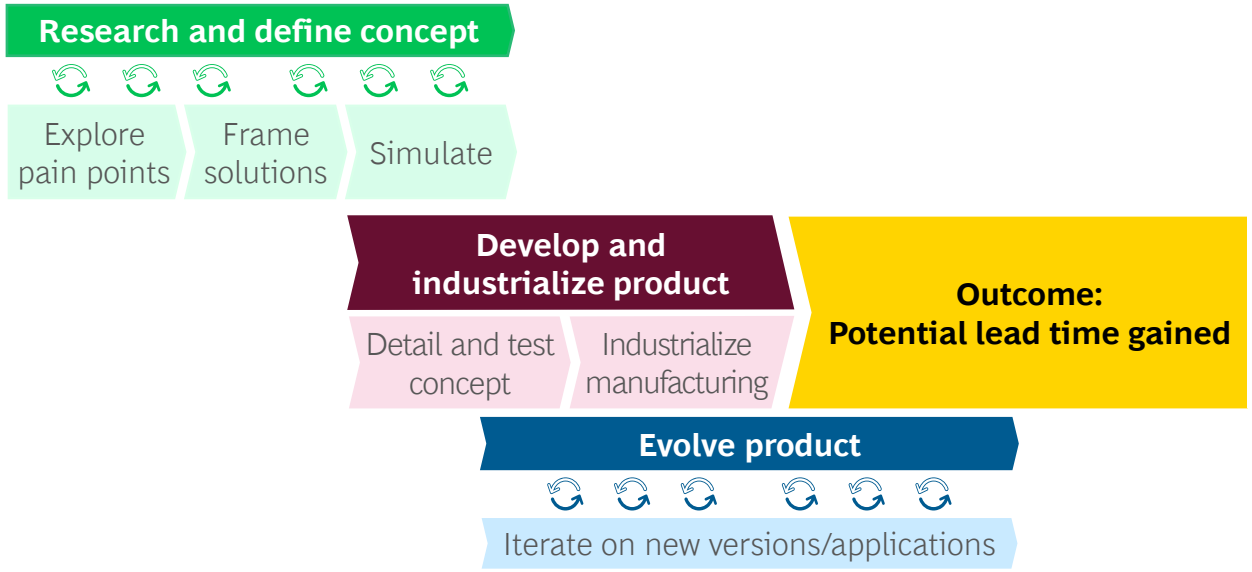
- **Reinforce tech-oriented roles:** AI engineers, data engineers, system engineers
- **Develop widespread AI skills:** Implement role-specific upskilling in effective and responsible use of AI

Process reshape | Boost is driven by quicker iteration loops

Current process



North Star process



Key evolutions in North Star

- **Accelerated process** up to 30%
- **More concepts investigated** in parallel during research
- **More extensive research phase,** including scalability simulation
- **Shorter development phase** thanks to digital simulations done earlier
- **More iterative process,** with shorter and faster loops
- Product **evolution to become a standard** practice

Process reshape | AI can accelerate and automate each step of R&D process

Research and define concept | **Develop and industrialize product** | **Evolve product**

	Idea, concept, and design	Development and testing	Manufacturing preparation	Industrialization and optimization
From	**Extensive manual market** research to fuel ideation process **Manual iterative design process,** with limited view on feasibility and costs **Fragmented design-simulation loops** across teams, often generating delays and loss of information	**Manually detailed product blueprints** For industrial goods, **iterative and costly prototyping simulations**	**Production planning once prototype is validated** **Manual design and set-up of manufacturing line** **First production pilots** for quality analysis and workflow optimization	**Progressive optimization of lines** until reaching run-rate costs **Manually updated demand planning** at regular intervals (e.g., each quarter) **Non-exhaustive reporting of manufacturing costs** for each product
To	**AI-automated trend reports,** leveraging weak signals analysis **Automatically generated and simulated product designs,** with associated costs from past projects **AI-based value assessment, risk analysis, and checks** of every feature	**AI-generated blueprints for product files, automatically tested and tuned** for value with respect to design standards/best practices **(Gen) AI-based Program Management Office,** including simulation management, validation plan, and product roadmap	**(Gen) AI-optimized production planning,** including tooling and material selection **Optimized production set-up** based on past projects **Automatic quality documents filled and checked** **Automated forecasts of procurement orders** to place in coming months	**Optimal line set-up designed as of Day 1** and rapid ramp-up of workers via access to lessons learned **Real-time updated sales forecasts** leveraging AI agent **Real-time and exhaustive cost reporting** to feed development assumptions of new products

Example for one engineered products company

AI agents | AI agents tailored to use case deliver maximum performance

What is an agent?

An agent can solve complex tasks by planning and executing a set of actions. It is a component that has access to a suite of tools and LLMs that can decide which tool to use based on the user's input

An agent allows the user to leverage the key AI capabilities

Illustrative

Insight generation[1]

Generate new and innovate ideas, concepts, materials, or designs (e.g., unique product solution, exploration of uncharted territories in scientific fields)

Content generation

Create specific types of content (e.g., text, images, videos, audio, code)

Conversation

Engage in interactive and dynamic engagement of information, ideas, or questions between humans and AI systems, responding to questions and generating appropriate responses

Knowledge extraction and summarization

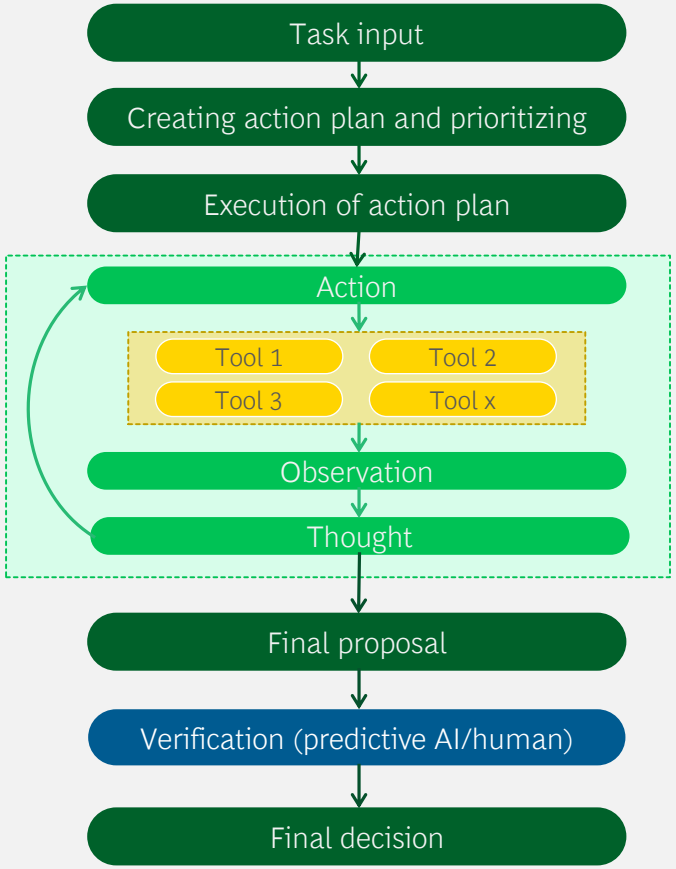
Extract structured knowledge from unstructured or semi-structured data sources

Problem solving

Utilize logical and reasoning process to make inferences and draw conclusions, make informed judgments, derive new insights based on available information, data, or knowledge

1. GenAI transformations can leverage multiple tech capabilities (e.g., ChatGPT leverages content generation and creativity)

Illustrative example of AI agent configured processes

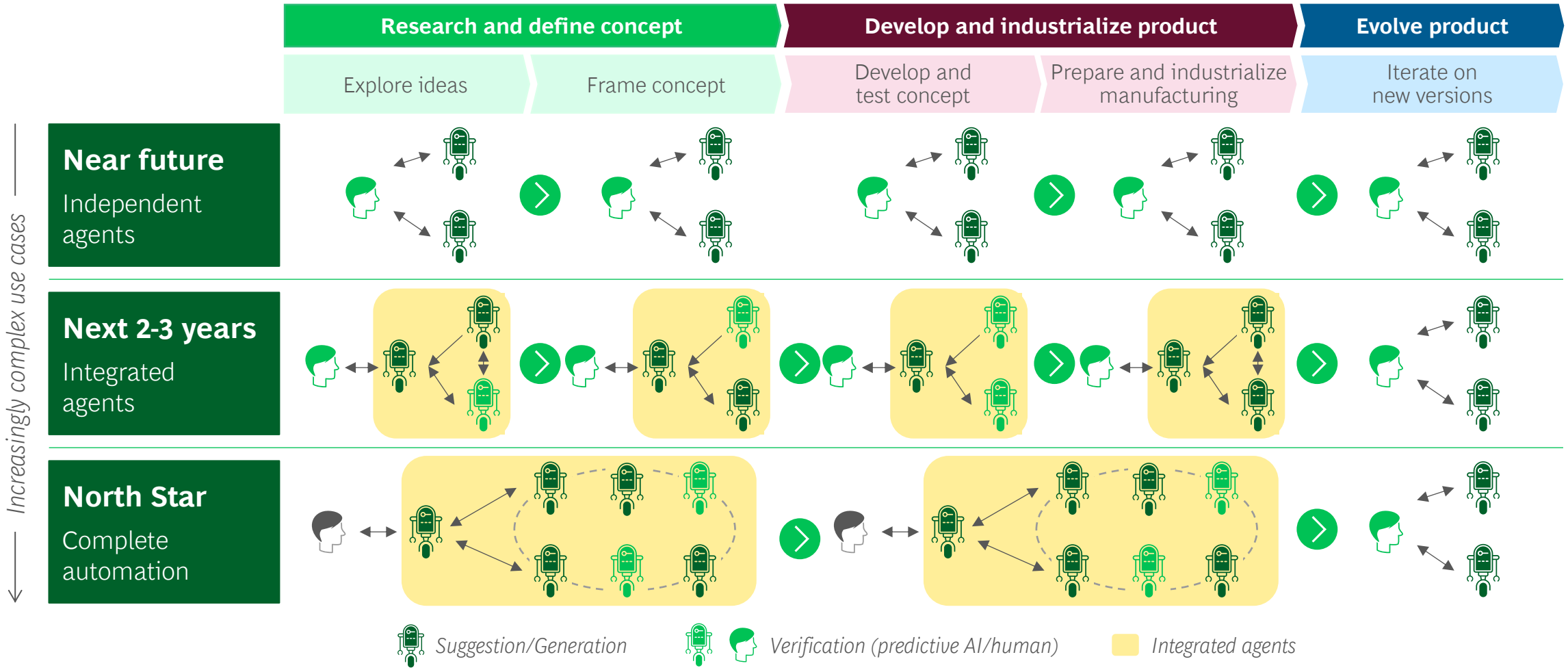


AI agents | Example user journey uses an AI agent for costing in the automotive industry

Exemplary agent interaction

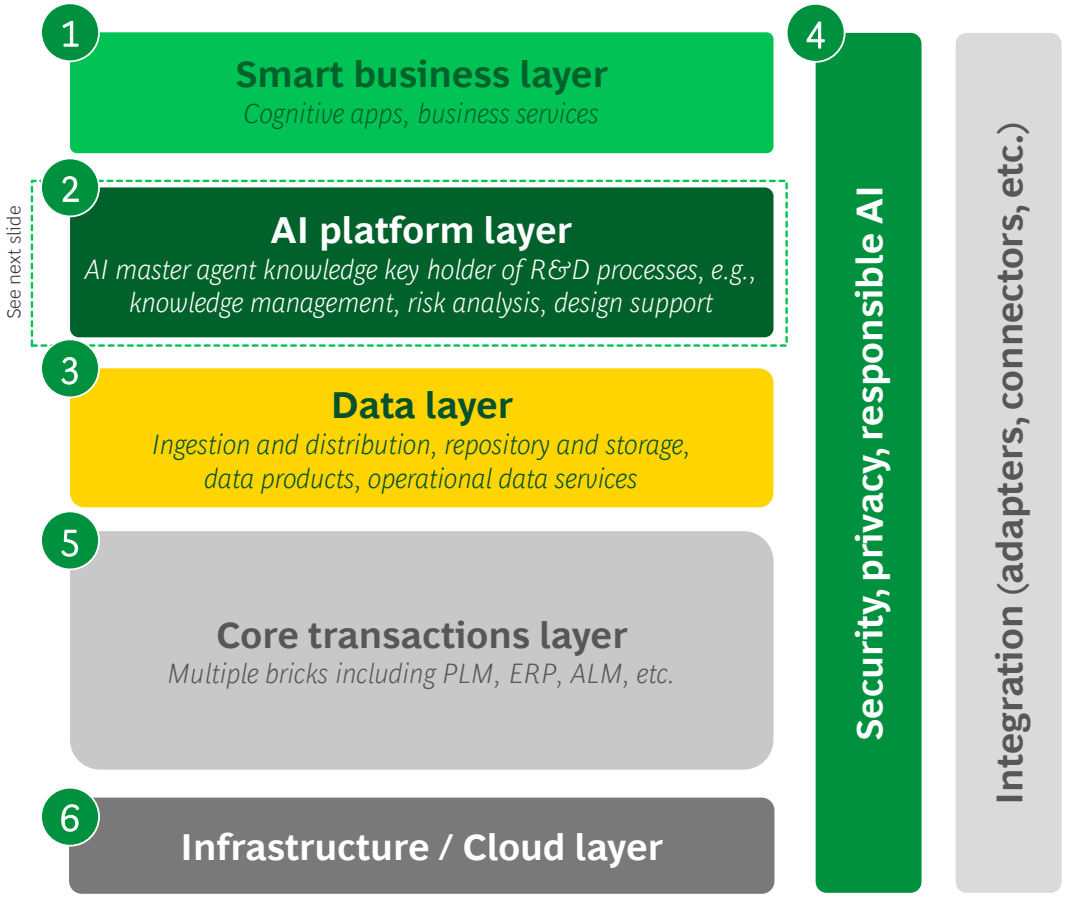
	Engineering and manufacturing data integration	Augmentation of costs data with internal and external data	Design recommendations with quality checks	Engineering pipeline analysis and risk analysis	Summarization and action points to support decision making
R&D engineer actions	Asks agent for cost breakdown per part of a given product	Requests cost structure of product and main cost drivers over past period	Asks for potential design modifications to reduce costs while keeping quality and performance level	Requests what would be the potential total impact if all eligible parts were replaced by cheaper alternatives	Requests summary of analysis to support decision making
AI agent outputs	**Shares breakdown of total product costs across** each part and ranks parts based on their total costs	**Lists cost components for each part** (e.g., materials, labor, maintenance) **and main drivers** for past evolution (e.g., material price increase)	**Proposes alternative parts** for most expensive ones **and mentions potential trade-offs associated with change**	**Reports list of all programs using eligible parts** with associated volume, current program status, **and total cost reduction estimate**	**Summarizes cost analysis, potential alternatives, trade-offs to investigate, and program managers to contact**

AI agents | AI agents will first be independent, specialized on specific tasks, then progressively integrated to cover larger scope of process



Data architecture | Layered architecture provides a robust data platform for GenAI

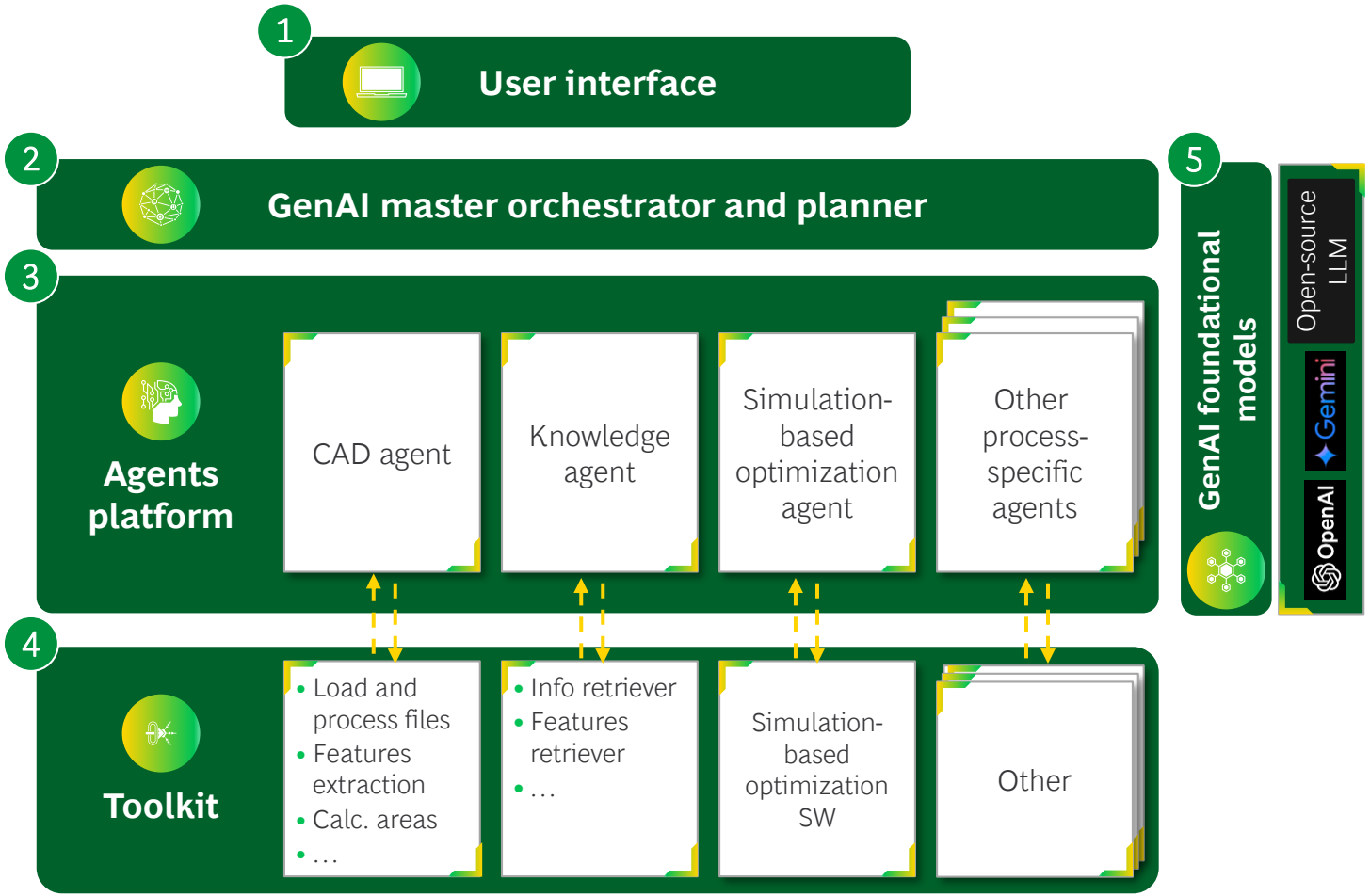
AI reference architecture



Priority updates to enable scaled AI capabilities

1. **AI-enabled application front-ends**
   - Integrate multi-modal capabilities (e.g., text, image, voice) into user workflows
   - Increasingly accessible interfaces will allow non-specialized users to perform complex tasks
2. **Dedicated AI platform layer**
   - Hosts AI agents, which are custom tools, bridging across systems and data sources to solve complex tasks by planning and executing a set of actions
3. **Expanded data capabilities**
   - Enable flexible exposure and access to data via APIs
   - Modern data-as-a-product governance and infrastructure is crucial to unlocking full potential of GenAI
4. **End-to-end AI guardrails**
   - Centralize RAI controls, user-level data restrictions, and cybersecurity tools to address new GenAI-based threats
5. **Vendor tools (PLM, ERP, ALM, etc.)**
   - Increasingly integrate AI features (focus on predictive AI), to improve efficiency of their specific processes
6. **Enhanced infrastructure and compute capabilities**
   - With hyper-scalers commoditizing cloud compute capabilities, GenAI infrastructure is becoming reliable, accessible, and economical

AI layer | Multi-agent system framework for AI used in R&D and engineering



Source: BCG

1 **User interface**
Point of interaction where users communicate with agent through chatbot

2 **GenAI master orchest. and planner**
Central agent that integrates components, defines action plan, and manages other agents, functioning through abstraction layer

3 **Agents' platform**
Hosting platform for all GenAI agents responsible for selected processes

4 **Toolkit**
Suite of tools with AI/GenAI embedded features linked to agents, which they can query to execute specific functionality

5 **GenAI foundational models (LLM)**
For contextual understanding and problem-solving capabilities

IP-centric operating model | Structured knowledge will be the main asset to build specialized agents tailored to a company's needs

1. Large LLMs will commoditize mainly general-purpose use cases, **as these models face two limits for more complex tasks: data availability for specific topics and suboptimal performance on reasoning-intensive tasks**

2. Companies will need to build **AI agents tailored to their needs and focused on high-value use cases.** Agents should combine generative and predictive AI to ensure explainable and repeatable outputs

3. **Quality and clear structure of IP are essential** for enabling rapid and most efficient development of AI agents

4. Operating model will need **to be augmented with team(s) steering and implementing AI strategy**

Structured knowledge is not just an asset, but an enabler for companies to foster differentiation

- Structured knowledge refers to organized, categorized, and systematically managed information that is easily accessible and usable for analysis
- AI agents can be fed and trained on this IP to accelerate R&D process—for example, by using all past formulas of cosmetics player to offer best starting point for a new product

Talent development | Reinforced tech roles and company-wide upskilling are required to fully unlock AI impact

New skill set will be required for each role; organizations must adapt development/upskilling strategy

- Routine or low complexity tasks will be automated/augmented by AI, freeing up capacity of higher value-add skills
- Engineers/Scientists will focus on more complex tasks but also will need to master AI tools (e.g., prompting, output verification)

For each step of the process, new organizational balance will need to be found between "knowers" and "doers"

- Experts will be able to complete more operational tasks by themselves, providing them with larger scope
- Operational teams will have access to company's expertise to augment their everyday tasks

AI is expected to have different impacts on engineering skills, redefining skill set for engineers/scientists

Illustrations for system engineer

GenAI highly disrupts skill

GenAI replaces routine activities, reducing the need for human skill sets to conduct the work

- Manual drafting
- Quality inspection
- Traditional CAD

GenAI partially disrupts skill

GenAI augments more basic skills, allowing humans to focus on higher value, strategic work

- Coding and scripting
- Modeling and prototyping
- Test case generation

Skills grow in importance

GenAI creates capacity for humans to focus on building and applying new skills

- System engineering
- Data validation
- Content expertise

Source: BCG research

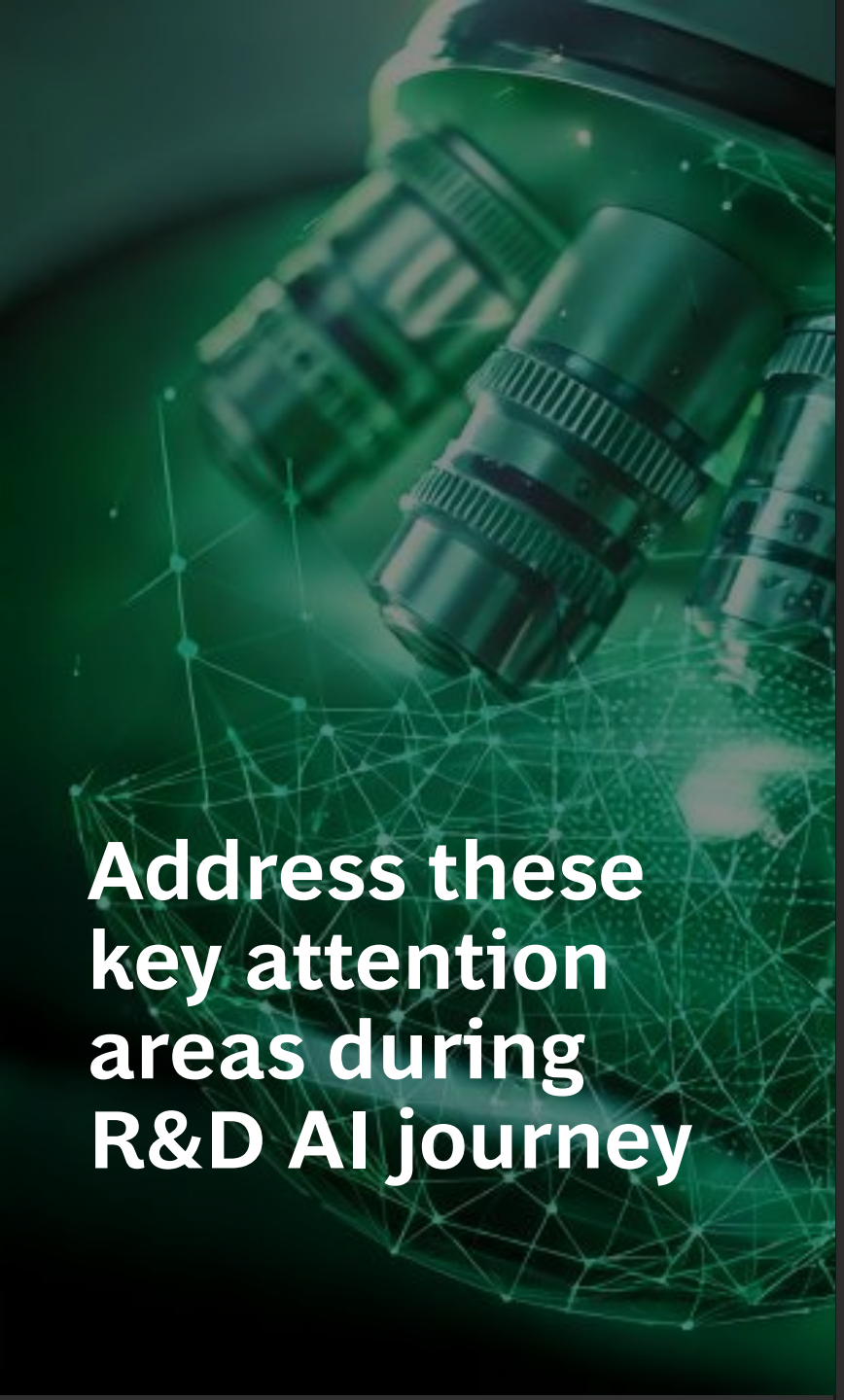
AI-powered R&D transformation should start with value ambition

	Phase 1: Blueprint and value proofs			Phase 2: E2E lighthouses	Phase 3: Scaling
	Framing	**Pilots**	**Roadmap and operationalization**		
Value delivery	Validate value pools and incoming prioritized pilots	Deliver pilot value proofs, capture workflow implications	Set business case and vision	Reinvent end-to-end workflows	Scale up across the organization, track ROI, and iterate
Tech and data	Assess as-is tech and data Set up pilot tech	Refine architecture and data platform requirements	Define tech evolution and roadmap, vendors	Implement tech, arch, and data solutions	Redesign and automate organization-wide
People and change mgmt.	Baseline ways of working; pilots' RAI implications	Outline change and program mgmt. needs; activity baselining and opportunity mapping	Formalize change mgt. plan and integrate roadmap	Redesign teams for new ways of working	Institutionalize changes and ensure alignment

Pilots ready to execute

Pilots executed, impact and requirements assessed, baseline validated

Integrated roadmap covering value, tech, and people



Address these key attention areas during R&D AI journey

- Strategize the application of AI in R&D by focusing on centers of excellence and use cases that present the greatest challenges and the highest potential for disruption
- AI journey is not just a tool topic: it is a deep transformation with mainly human enablers (e.g., agile, deep tech, talent strategy)
- Internal IP is the key asset to build differentiating AI tools and requires dedicated capabilities and organization to define and implement IP strategy
- AI agents require a mix of both generative and predictive AI, leveraging structured knowledge to train and verify AI outputs
- AI journey will require the development of new IT architecture model (e.g., AI layer) and the involvement of specific talent (e.g., AI engineer, data manager)
- Transformation can only be successful with team engagement, requiring close attention to change management, and the right ecosystem of partners

BCG experts | Key contacts for R&D AI transformation

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