

Rise of the Machines: Deep Research on the Most Important Work and Breakthroughs in AI Robotics from the Past 7 Days

Introduction: The Week the Machines Began to Talk

The long-prophesied "Rise of the Machines" arrived in the first week of September 2025, not with the ominous overtones of science fiction, but with a conversational query. The period of September 2-9, 2025, will be remembered as a pivotal inflection point in the development of general-purpose robotics. The convergence of advanced conversational Artificial Intelligence (AI) with a humanoid form factor, exemplified by the demonstration of a new Tesla Optimus prototype, marks a definitive shift away from pre-programmed, task-specific automation towards a new paradigm of dynamic, language-driven physical agents. This week, the central challenge in robotics began to pivot from pure mechanical agility to the seamless integration of sophisticated cognition. The most significant development was not an improvement in hardware or software in isolation, but the *synthesis* of the two.

Historically, robot control software has been highly specialized, a complex and brittle set of instructions tightly coupled with the specific hardware it operates. The emergence of Large Language Models (LLMs) represents a move towards generalized intelligence that can reason about a wide range of tasks from text-based inputs. The demonstration of Tesla's Optimus, integrated with the Grok AI, provided the first high-profile glimpse of a direct pipeline from a natural language instruction to a planned sequence of physical actions.¹ This implies a future where a robot's capabilities are not limited by its bespoke programming but by the reasoning capacity of its integrated AI model. The true breakthrough is the demonstration of a plug-and-play intelligence layer, which dramatically accelerates development and broadens the scope of potential applications without needing to re-engineer the robot's core software for every new task. This report will analyze the key breakthroughs, demonstrations, and strategic undercurrents of this transformative week, charting the ascent of embodied, intelligent agents and their profound implications for industry and society.

Major Breakthroughs: Foundational Research in Humanoid Motion and Manipulation

While high-profile demonstrations captured public attention, foundational academic research published this week addressed the core physical challenges that enable an AI "brain" to effectively command a robotic "body." Two papers accepted at the prestigious IEEE-RAS International Conference on Humanoid Robots (Humanoids) 2025 stand out, tackling the difficult problems of locomotion under non-ideal conditions and the manipulation of unpredictable, real-world materials.

Learning to Walk in Costume: Solving for Aesthetics and Instability

A critical paper by Alvarez et al., "Learning to Walk in Costume: Adversarial Motion Priors for Aesthetically Constrained Humanoids," addresses a novel and commercially vital problem: enabling stable locomotion in a humanoid robot whose design is dictated by aesthetics rather than optimal engineering.³ The research platform, a custom-built humanoid named "Cosmo," was designed for entertainment applications and embodies severe physical constraints. Its disproportionately large head accounts for 16% of its total mass, creating an extreme top-heavy weight distribution that poses immense challenges to balance and control.³ Furthermore, the robot is equipped with limited sensing and protective outer shells that restrict its range of motion, a scenario that will be common for consumer-facing robots where form and character design take precedence over mechanical efficiency.

To solve this, the researchers employed a sophisticated Reinforcement Learning (RL) technique known as Adversarial Motion Priors (AMP). This method utilizes a discriminator network, a secondary AI model that is trained to distinguish between the robot's generated movements and a reference dataset of natural human motions. During the RL training process, the robot receives a "style reward" for producing movements that can fool the discriminator into thinking they are human-like.³ This dual-objective approach forces the robot not just to learn

how to walk without falling, but to do so in a manner that is natural, graceful, and aesthetically pleasing, all while compensating for its inherently unstable physical design.

A crucial element of the research was the successful sim-to-real transfer. Deploying untested algorithms on expensive, custom hardware is perilous. The researchers developed tailored

domain randomization techniques in simulation and implemented specialized reward structures that penalized movements that could damage the robot's aesthetic shells or cause aggressive impacts on its feet.³ This work serves as a vital bridge between the worlds of entertainment robotics and high-performance locomotion. It proves that modern learning-based approaches can overcome non-ideal hardware constraints imposed by product design. Most academic humanoid research focuses on platforms engineered for optimal stability, but commercial robots will need to conform to brand identities and character designs. This research provides a viable pathway for companies to create physically mobile characters, decoupling the aesthetic design from the need for a perfectly optimized mechanical platform.

Interactive Shaping of Granular Media: A Proxy for Real-World Messiness

The second key paper from the week, "Interactive Shaping of Granular Media Using Reinforcement Learning" by Kreis et al., tackles the complex task of manipulating non-rigid, unpredictable materials like sand.⁶ Such materials are notoriously difficult for robots to handle due to their high-dimensional configuration space and complex, often chaotic dynamics. Traditional physics-based models struggle to predict their behavior accurately, making pre-programmed manipulation sequences ineffective.⁸

The research presents an RL framework where a robotic arm, equipped with a stereo camera, learns a visual policy to shape the granular media into a desired target structure. The key innovations lie in making this complex problem tractable for an AI. First, the system converts high-dimensional depth images from the camera into a compact height map representation, giving the AI a simplified yet effective understanding of the material's current state. Second, the researchers developed a novel reward formulation that guides the learning process efficiently, encouraging the robot to make progress toward the goal shape without getting stuck in non-productive behaviors.⁸ The approach was validated not only in simulation but also with a physical robot, demonstrating successful real-world deployment and outperforming baseline methods.⁶

While the experiment utilized a standard robotic arm, the fundamental principles are directly applicable to the future of humanoid robotics. A truly general-purpose humanoid designed for tasks in construction, agriculture, disaster relief, or even complex household chores will inevitably have to interact with and manipulate "messy," non-solid, and unpredictable materials. Most robotics research focuses on handling rigid objects, but the real world is filled with soil, debris, liquids, and pliable goods. This research provides a foundational model for how to approach such problems, establishing a proof-of-concept for learning-based

manipulation of the complex, unpredictable substances that define real-world environments. It is a critical step towards developing the dexterous, adaptive manipulation capabilities that humanoids will require to be useful outside of sterile factory settings.

Paper Title & Authors	Conference	Core Problem	Key Methodology	Major Finding/Contribution	Relevance to Humanoid Commercialization
Learning to Walk in Costume: Adversarial Motion Priors for Aesthetically Constrained Humanoids <i>Arturo Flores Alvarez, et al.</i> ⁴	IEEE-RAS Humanoids 2025	Achieving stable and natural locomotion in a humanoid with a physically sub-optimal, aesthetic-driven design (e.g., top-heavy).	Reinforcement Learning with Adversarial Motion Priors (AMP) to learn human-like gaits while maintaining stability.	Demonstrates that learning-based methods can overcome severe hardware constraints imposed by design choices, generating stable walking behaviors.	Provides a viable path for developing commercial, entertainment, or consumer-facing humanoids where appearance and character design are prioritized over pure mechanical efficiency.
Interactive Shaping of Granular Media Using Reinforcement Learning <i>Benedikt Kreis, et al.</i>	IEEE-RAS Humanoids 2025	Enabling a robot to autonomously manipulate and shape complex, non-rigid materials (granular	Reinforcement Learning using a visual policy trained on compact height map representat	Presents an effective RL framework for manipulating granular media, validated with successful	Establishes a foundational approach for handling the "messy," unstructured, and non-solid

7		media) with unpredictable dynamics.	ions derived from depth images.	sim-to-real deployment on a physical robot.	materials that general-purpose humanoids will encounter in real-world applications like construction, disaster relief, and domestic work.
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Demonstrations and Prototypes: The Humanoid Form Factor Takes Center Stage

Moving from academic theory to tangible engineering, the past week was dominated by a series of high-profile demonstrations that brought the humanoid form factor into the global spotlight. From a landmark AI integration in the United States to a massive ecosystem showcase in China, these events highlighted the accelerating pace of hardware development and the divergent strategies shaping the industry.

The Tesla Optimus V2.5 Reveal: A Dialogue with the Future

On September 3, 2025, a new Tesla Optimus prototype was revealed in a video shared by Salesforce CEO Marc Benioff, who was with Tesla CEO Elon Musk.¹ The demonstration instantly became the week's most discussed development, not for the robot's physical prowess, but for its cognitive capabilities.

The prototype, later clarified by Musk to be a V2/V2.5 iteration, featured several hardware updates.¹ It was housed in a sleek, gold-colored cosmetic shell, a significant aesthetic

upgrade from previous, more utilitarian versions.¹ The hands were visibly more detailed and human-like, though they appeared to be non-functional prototypes in this specific video.² This aligns with Musk's prior statements about a next-generation hand design where actuators are moved to the forearm to reduce weight and complexity in the hand itself, operating the fingers via cable "tendons" in a manner analogous to human anatomy.¹ In terms of mobility, the robot was shown taking slow, tentative steps, indicating that dynamic bipedal locomotion for this version is still in an early stage of development.²

The centerpiece of the demonstration, however, was the integration of xAI's Grok AI assistant. The video showed the robot understanding and responding to conversational commands, with Benioff asking it to retrieve a beverage from another room.² This showcased a system capable of parsing natural language, understanding intent, and formulating a basic action plan. The event was a masterclass in strategic communication. Public perception of advanced humanoids has been heavily shaped by Boston Dynamics' viral videos of its Atlas robot performing complex parkour and acrobatics. Tesla's Optimus, in its current demonstrated form, cannot compete on this axis of raw agility. Instead of attempting a less impressive physical demo, Tesla chose to highlight a completely different and arguably more disruptive capability: conversational AI interaction. This plays to Tesla's core strengths in AI and software and reframes the competition around the robot's intelligence and usability. The demonstration presented a vision of an "AI you can talk to that can also do things," a concept that may be more relatable and commercially viable in the near term than a backflipping automaton. It was a strategic move to redefine the metrics of success in the humanoid race, shifting the focus from brawn to brain.

China's Humanoid Ecosystem on Full Display

Concurrently, events in China underscored a profoundly different, state-driven strategy for humanoid development. The 2025 World Robotic Conference in Beijing and the World Smart Industry Expo in Chongqing showcased the sheer scale and ambition of the country's efforts.¹² Over 60 different humanoid robots were displayed at the Beijing conference alone, a clear signal of a massive national investment in the sector.¹² Projections indicate the Chinese humanoid market is expected to skyrocket from approximately \$2 billion this year to \$41 billion by 2032.¹²

The robots on display were not merely research projects; they were aimed at a wide and pragmatic range of applications. These included advanced manufacturing and logistics, but also sectors of strategic national importance, such as healthcare and the "silver economy," with a strong focus on developing robots for elderly care.¹³ This highlights a clear objective to use robotics to address pressing demographic challenges, such as an aging population. The

sheer volume and diversity of humanoids shown in China indicate a different strategic approach compared to the West. While Western efforts are often concentrated in a few high-profile, venture-backed startups like Tesla, Figure, and Agility Robotics, China's strategy appears to be a broad, ecosystem-level push. This involves numerous companies, significant state support, and a clear focus on rapid industrial and societal deployment. The global humanoid race is therefore shaping up to be a competition not just between individual companies, but between two distinct industrial models: the breakthrough-driven, venture-capital-fueled model of the United States versus the state-guided, ecosystem-wide, problem-driven model of China.

The Humanoid Olympiad: A New Arena for Competition

The conclusion of the first-ever International Humanoid Olympiad in Olympia, Greece, on September 2 marked another milestone for the industry.¹⁴ The event, featuring robots from companies such as Unitree and Booster Robotics, was designed to showcase and benchmark the capabilities of humanoid systems through a series of athletic demonstrations, technical talks, and workshops.¹⁴

The establishment of such an event is a strong indicator of a maturing field. It signals a critical transition from the era of one-off, carefully curated corporate demos to a new phase of standardized, competitive evaluations. This development is poised to accelerate progress across the entire industry. By creating clear performance benchmarks, it allows for objective comparison between different hardware designs and software approaches. This fosters a "competitive innovation" cycle, where teams are driven to outperform one another on a level playing field. The dynamic is reminiscent of the pivotal role the DARPA Grand Challenge played in the early 2000s, which brought autonomous vehicle technology out of the lab and catalyzed the progress that led to today's self-driving systems. While still in its infancy, the Humanoid Olympiad represents the beginning of a move towards open, objective benchmarking, which will be essential for separating genuine capability from marketing hype and for driving meaningful engineering progress in the years to come.

Platform/Event	Lead Organization(s)	Key Demonstrated Capability	Underlying AI Approach	Target Application	Current Development Stage
Optimus	Tesla / xAI	Conversational AI	Large Language	General Purpose	Advanced

V2.5		Tasking; Natural language understanding and response.	Model (LLM) Integration (Grok). ²	(Industrial, Commercial, Domestic). ¹ ₆	Prototype
Chinese Humanoids	Various (Gov't supported)	Broad application diversity and scale; dozens of models for specific sectors.	Varies by developer; focus on practical deployment. ¹²	Industrial Automation, Logistics, Healthcare, Elderly Care ("Silver Economy"). ₁₃	Multiple Prototypes to Early Production Models
Humanoid Olympiad	Acumino / Endeavor Greece	Competitive benchmarking of physical capabilities (agility, precision, intelligence).	Varies by team; platform for comparing control algorithms. ¹ ₄	R&D / Performance Testing and Standardization.	Emerging Standard / Inaugural Event

AI Integration: The Ghost in the Machine Becomes the Brain

The disparate events of the past week all point toward a single, overarching trend: the deep and transformative integration of advanced AI, particularly large-scale foundation models, as the central nervous system of next-generation robots. This represents a fundamental architectural shift that redefines not only how robots are controlled, but what they are capable of becoming.

The Optimus-Grok Symbiosis: From Voice Commands to Conversational Tasking

The integration of Grok into the Optimus platform is far more significant than a simple voice-control feature. It represents a paradigm shift from the rigid logic of traditional robotic programming to the fluid reasoning of conversational AI. A conventional robot operates on explicit, pre-defined commands ("move arm to coordinate x,y,z"). The Optimus demo showcased a system that can interpret ambiguous, high-level human intent ("get me a Coke") and begin to formulate the multi-step plan required to execute it.² This enables a conversational loop where the robot can understand context, reason about a task, and potentially ask clarifying questions—the difference between a tool and a partner.

This architecture can be conceptualized as a modular "Brawn" and "Brain" system.¹⁵ The "Brawn" consists of the robot's physical hardware, its actuators, sensors, and the low-level control software responsible for fundamental actions like maintaining balance, moving limbs, and actuating grippers. The "Brain" is the LLM, which serves as the high-level reasoning and planning engine. This modularity is a key catalyst for rapid development, as the AI "Brain" can be upgraded independently of the physical "Brawn." This is a prime example of "embodied AI," where a powerful digital intelligence is given a physical form to perceive, interact with, and directly affect the real world.¹⁷

The true power of this integration lies in its ability to handle ambiguity and the "long tail" of real-world tasks. A pre-programmed robot can only perform the finite set of tasks for which it was explicitly coded. An LLM-driven robot, however, can potentially reason about how to perform a novel task it has never encountered before. By leveraging its vast, pre-trained knowledge base about the world, it can understand the language used to describe the task and relate it to its existing knowledge of objects, actions, and outcomes. The LLM acts as a "common sense reasoning engine," bridging the vast gap between high-level human intent and the low-level motor commands required for physical action. This is the single most critical capability for unlocking the dream of a truly general-purpose robot.

Foundational Models as the Central Nervous System for Robotics

The Optimus-Grok integration is the most visible manifestation of a much broader and more profound industry trend: the adoption of large, pre-trained "foundation models" as the core intelligence for all types of robots.¹⁸ Research is rapidly emerging on universal locomotion controllers that can be applied to dozens of different robot types, multi-modal perception systems that fuse vision, touch, and sound, and LLM-based planners that generate complex

action sequences.¹⁸ Companies like Physical Intelligence are already open-sourcing their own robotics foundation models, designed to be tuned for a range of tasks from folding laundry to scooping coffee beans.²⁰

This marks the "ChatGPT moment" for robotics. Just as large language models transformed how we interact with digital information, large robotics foundation models are poised to transform how we interact with the physical world. The goal is to move away from the painstaking process of training a new, bespoke AI for every robot and every task. Instead, the industry is moving towards a model where a single, powerful base AI, pre-trained on vast amounts of simulation and real-world data, can be fine-tuned for specific applications or hardware. The future of robotics development may look less like mechanical engineering or low-level coding and more like "prompt engineering" for physical agents. A developer would not program a robot to assemble a chair; they would instruct a foundation model, "Here is the manual for an IKEA chair and a video of a human assembling it. Generate a policy for this robot to do the same." This decouples the intelligence from the hardware, creating a scalable and adaptable software platform that could accelerate progress across the entire field of robotics. The Optimus-Grok demo was the first major commercial step in this direction.

Comparative Advances: The World of Specialized Robotics

To fully appreciate the strategic bet on general-purpose humanoids, it is essential to view it in the context of parallel breakthroughs in the world of specialized robotics. This week also saw significant announcements for machines designed not for versatility, but for supreme excellence at a single, well-defined mission.

The Industrial Workhorse: Universal Robots' UR8 Long

On September 9, Universal Robots (UR), the global leader in collaborative robots (cobots), unveiled its new UR8 Long model at FABTECH in Chicago.²¹ This robotic arm is a marvel of specialized industrial design. It features an extended reach of 1750 mm and a payload capacity of 8 kg, all within a slim profile designed to operate in space-constrained manufacturing cells.²³ Its improved joint architecture delivers up to 30% faster cycle times compared to previous generations, and its IP65 and Class 4 cleanroom certifications allow it to operate in harsh or sterile environments.²³ The UR8 Long is a purpose-built tool, engineered

for high-precision, repetitive tasks like complex welding, machine tending, and dunnage picking in the automotive and electronics industries.²¹ It is the epitome of a specialist: a machine designed to perform a narrow set of tasks with superhuman speed, precision, and endurance.

The Lifesaving Specialist: DARPA's MASH Program

On September 8, the Defense Advanced Research Projects Agency (DARPA) announced a program with a profoundly different, yet equally specialized, mission: the Medics Autonomously Stopping Hemorrhage (MASH) program.²⁵ The program's ambitious goal is to develop sensor-guided, AI-driven robotic systems that can autonomously perform surgical procedures to stop severe, non-compressible internal bleeding on the battlefield.²⁵ Such a system would need to operate under the most extreme and unstructured conditions imaginable, stabilizing an injured soldier for up to 48 hours to allow for evacuation.²⁵ MASH represents the ultimate specialist: a system designed to execute one of the most complex and critical tasks possible to save a life in a scenario where no human surgeon is available.

The Generalist vs. Specialist Dichotomy

The UR8 Long and the MASH robot represent the pinnacle of specialized robotics. They are designed with a singular purpose and are being optimized to perform it with a level of performance far exceeding human capabilities. A humanoid robot, by contrast, is the ultimate generalist. It is not designed to be the best welder, the fastest palletizer, or the most precise surgeon. It is designed to be *good enough* at a vast variety of tasks in environments that were built for humans.

The simultaneous advancement of both specialist and generalist robots is not a contradiction; it reveals a bifurcating and maturing market for automation. Specialized robots will continue to dominate structured, predictable environments like factories, warehouses, and operating rooms, where tasks are repetitive and the environment can be controlled. The massive economic and strategic bet on humanoids is that they will be the first form of automation to successfully and economically tackle *unstructured*, unpredictable, human-centric environments—the small businesses, construction sites, hospitals, and homes that constitute the vast majority of the physical economy. A factory needs a robot that can perform the same weld 10,000 times a day with sub-millimeter precision; the UR8 Long is the right tool for that job. A small business owner, however, may need a robot that can stock shelves one hour, clean

the floors the next, and take inventory overnight. No single specialized robot can do all three. This is the specific economic niche the humanoid aims to fill. The value of the humanoid is not in its peak performance at any one task, but in its versatility across many.

Applications and Implications: Charting the Path to a Robotic Future

The convergence of increasingly capable hardware with powerful AI brains is accelerating the timeline for humanoid deployment, prompting a re-evaluation of market potential, corporate strategy, and the formidable challenges that lie on the path to mass adoption.

The Multi-Trillion Dollar Bet: Market Outlook and Corporate Strategy

The financial and strategic commitments being made to humanoid robotics are staggering. Market forecasts from firms like Goldman Sachs project an addressable market reaching \$38 billion by 2035, with annual shipments of new robots skyrocketing to 1.4 million units.¹⁷ This optimism is fueling a wave of investment and strategic repositioning among major technology players.

Nowhere is this more evident than at Tesla. Elon Musk's public statements this week, asserting that the Optimus program represents a "fundamental transformation" for society and could ultimately account for roughly 80% of Tesla's long-term valuation, signal a profound strategic pivot.¹ This is a declaration that Tesla sees its future not primarily as an automaker, but as a leader in AI and robotics. This enormous bet is predicated on a single, powerful assumption: that the bipedal, two-armed humanoid form factor is the "master key" that unlocks automation for the vast majority of the economy that does not take place on a structured assembly line. The world—its doorways, its tools, its workspaces—is built for the human form. To automate tasks within these environments, one must either expensively re-engineer the environment for a specialized robot or engineer a robot that can operate within the human environment. The humanoid is the ultimate expression of the latter approach. If a humanoid robot can successfully navigate and manipulate objects in a world built for people, it can theoretically perform any physical task a human can. This explains the immense potential market size and why the company that solves this problem could become one of the most valuable in the world.

Deployment Roadblocks: A Sober Assessment of the Challenges Ahead

Despite the palpable excitement, the path from a compelling demo to a mass-market, reliable, and profitable product is long and fraught with immense engineering and logistical challenges. While the AI "brain" is advancing at an exponential rate, the physical "brawn" is still constrained by the more linear progress of the physical sciences.

- **Battery Technology:** Power remains a critical bottleneck. The most advanced humanoid batteries, such as the third-generation unit from Figure, can run for approximately five hours at peak performance.¹⁷ This is insufficient for a full industrial work shift and highlights the urgent need for breakthroughs in energy density and efficiency.
- **Production and Cost:** No company is currently producing humanoids at scale. Figure's new BotQ facility, for example, aims to produce 12,000 robots in 2025, a tiny fraction of the millions projected for the market in the coming decade.¹⁷ Concurrently, achieving an affordable unit price—Musk has targeted around \$20,000 for Optimus—remains a distant goal that will require massive economies of scale and manufacturing innovation.¹¹
- **Dexterity and Sensing:** While improving, robotic hands, actuators, and sensors still lack the combination of delicacy, strength, and rich feedback of human hands. Tasks requiring fine motor control or the ability to sense subtle changes in texture, pressure, and temperature remain exceptionally difficult.¹⁷
- **Safety and Regulation:** Perhaps the greatest challenge is ensuring that powerful, autonomous machines can operate safely around unpredictable humans in dynamic environments. This is not just a technical problem of perception and control; it is a societal one that will require the development of new safety standards, robust testing and validation protocols, and clear regulatory frameworks.¹⁷

The gap between the rapid progress in AI software and the more measured pace of hardware development will be the primary determinant of the deployment timeline. The Optimus demo perfectly illustrates this disparity: a highly advanced conversational AI running on a body with early-stage locomotion and prototype hands. The key challenge for the entire industry will be to make the hardware's development curve catch up to the software's.

Concluding Analysis: An Accelerated Timeline

The events of September 2-9, 2025, taken in aggregate, suggest a significant acceleration in

the humanoid robotics timeline. The successful integration of a powerful conversational AI into a humanoid prototype is a landmark achievement that effectively solves the "user interface" problem for a general-purpose robot, making it potentially accessible to anyone who can speak. We are no longer witnessing separate fields—AI, mechanics, power systems—advancing in isolation. They are now converging in integrated systems, creating a powerful feedback loop where an advance in one area immediately unlocks new potential in the others.

The "Rise of the Machines" is indeed happening, but it looks less like a Hollywood spectacle and more like a profound and rapid integration of physical AI into the fabric of our economy and society. The key takeaway from the past seven days is that the "brain" is now ready. The global race is on to build a "body" that is cheap, reliable, and safe enough to bring that intelligence out of the digital cloud and into our physical world.

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