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V-Discover

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THEME : TARGETED DRUG DELIVERY SYSTEM (TDDS)

VIVEKANANDHA EDUCATIONAL INSTITUTIONS FOR WOMEN
1992
WOMEN EMPOWERMENT

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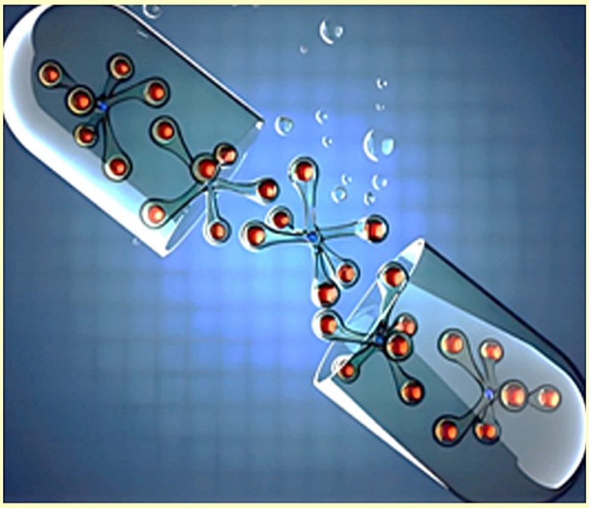
TARGETED DRUG DELIVERY SYSTEM USING ARTIFICIAL INTELLIGENCE

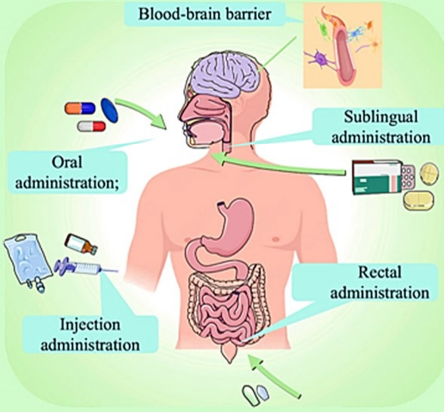
INTRODUCTION

A targeted drug delivery system (TDDS) is an advanced method of delivering medication directly to specific cells, tissues, or organs - minimizing side effects and improving treatment efficiency. With the integration of Artificial Intelligence (AI), stem becomes more precise, adaptive, and personalized.

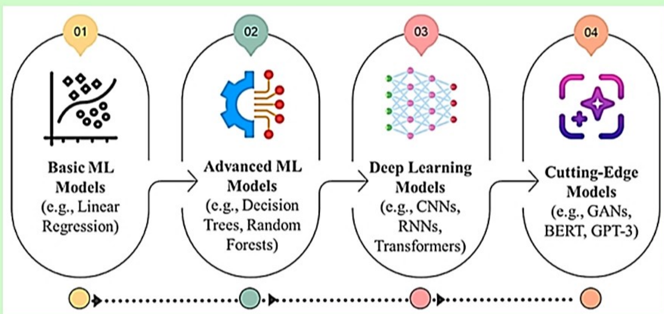


In recent years, the integration of artificial intelligence (AI) into pharmaceutical research has opened new frontiers in drug development and delivery. Traditional drug delivery systems often face limitations such as poor bioavailability, systemic toxicity, and lack of specificity toward the diseased site.

To overcome these challenges, targeted drug delivery systems (TDDS) have been developed to ensure that therapeutic agents reach specific tissues or cells while minimizing effects on healthy tissues.



AI technologiessuch as machine learning (ML), deep learning (DL), and computational modeling - play a crucial role in optimizing various stages of targeted drug delivery. These include predicting drug - target interactions, designing nanocarriers, and personalizing treatment strategies based on patient-specific data. By analyzing complex biological and chemical datasets, AI enhances the precision, efficiency, and predictability of drug delivery systems. Thus, the combination of AI and TDDS represents a significant advancement toward personalized and precision medicine, offering improved therapeutic outcomes, reduced adverse effects, and accelerated drug development processes.



What is Targeted drug delivery system???

In traditional drug delivery, medicine spreads throughout the body, affecting both diseased and healthy cells.

In contrast, targeted delivery:

- Directs the drug only to the diseased site (e.g., cancer cells, infected tissues).
- Reduces drug waste and minimizes toxicity.
- Ensures controlled release over time.

Types of formulations used in targeted drug delivery systems

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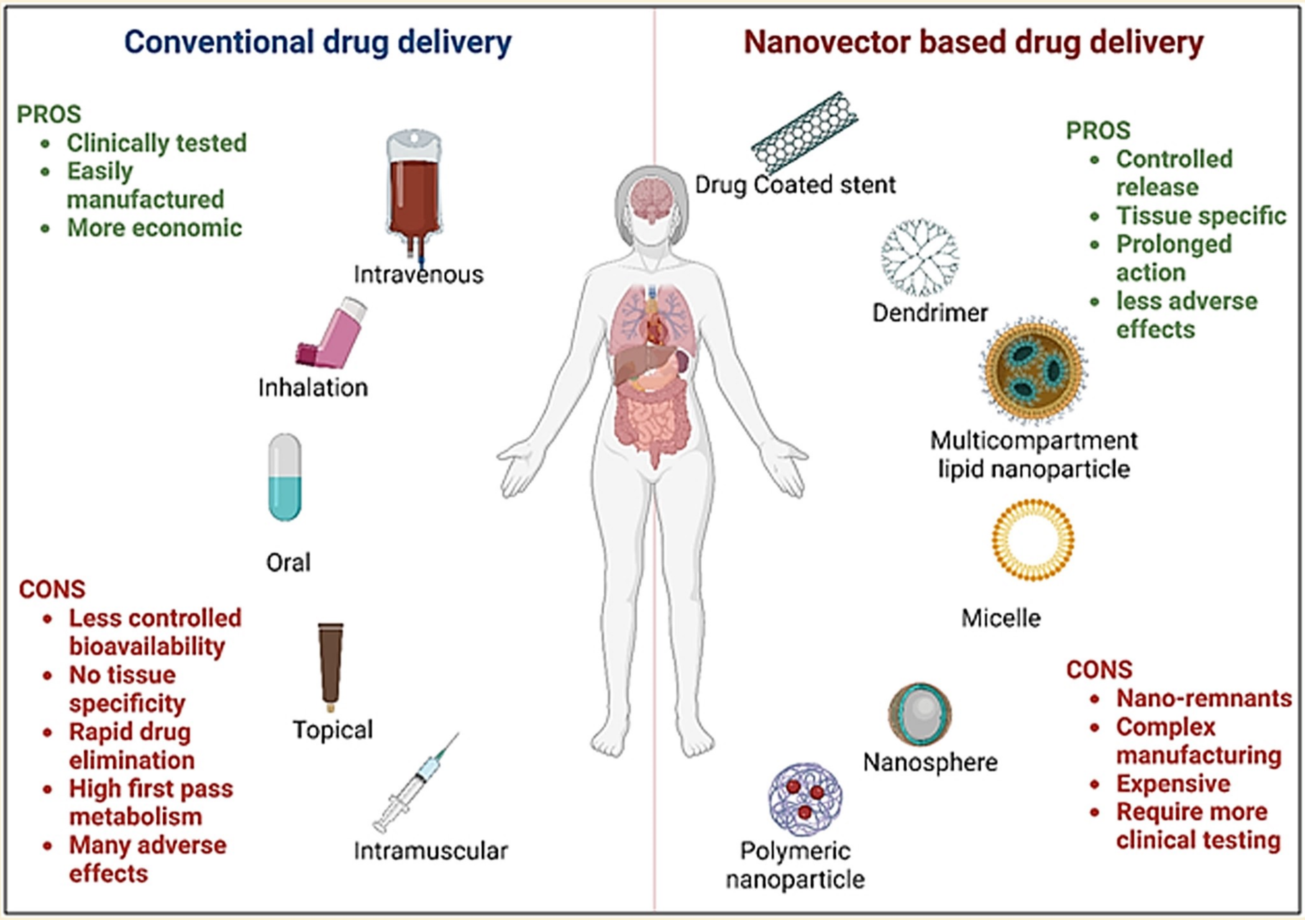


Nanoparticles, Nanocarriers, Hydrogen, Hydrogel, Molecular syringes, Nano emulsion etc.

Common carriers include:

- Nanoparticles (liposomes, dendrimers, polymeric particles).
- Microspheres.
- Biodegradable polymers.

Role of artificial intelligence in Targeted drug

AI can process vast biomedical data and identify patterns invisible to humans, helping in every stage of drug design and delivery.

Drug Design & Discovery	**AI models predict:** • Best drug-target interactions • Optimal chemical structures • Potential toxicity and efficacy **Example:** Deep learning models simulate how a drug molecule binds to its receptor on cancer cells.
Nanocarrier Design	**AI helps in:** • Selecting the ideal nanoparticle (size, charge, coating) • Predicting drug release profiles • Enhancing biocompatibility **Example:** Machine learning algorithms predict how changes in nanoparticle composition affect delivery efficiency.
Patient-Specific Delivery	• AI integrates patient data (genomics, imaging, health records) to design personalized treatment plans. • "Right dose, right time, right place." **Example:** In cancer therapy, AI analyzes MRI/CT scans to target tumors precisely and decide drug dosage.
Smart Drug Delivery Devices	• AI-controlled systems (like smart implants, biosensors, or microchips) can: • Monitor real-time biological signals • Release drug when needed • Adjust dosage automatically **Example:** AI-guided insulin pumps that deliver insulin based on glucose levels.

Growing area of Astro biomedicine deliver

1. The Problem:Why Targeted Drug Delivery Matters in Space

Spaceflight changes how the human body works for example:

- Muscle and bone loss in microgravity.
- Weakened immune system and altered cell responses.
- Difficulty in traditional drug absorption because fluids shift differently in the body.
- Limited medical supplies — astronauts can't carry a full pharmacy.

So, astronauts need precise, efficient, and automated drug systems that deliver exactly what's needed, when and where it's needed — without a doctor's present.

2. Role of AI in Targeted Drug Delivery

AI enhances targeted drug delivery in several smart ways:

a. Personalized Monitoring AI systems can analyze astronauts' health data (like heart rate, oxygen, stress hormones, etc.) in real-time.It predicts when a disease or inflammation might occur and triggers drug release automatically.	**b. Smart Nanocarriers** Drugs can be packaged into AI-guided nanoparticles or molecular "syringes." These can be programmed to seek out specific cells (like damaged tissues) and release medicine only there. In space, where precision and minimal side effects are vital, this saves dosage and reduces waste.
c. Adaptive Dosing AI can adjust the drug dose dynamically depending on how the astronaut's body responds (since metabolism changes in microgravity).It ensures optimal effect without overdose or underdose.	**d. Predictive Maintenance** AI can monitor the stability of medicines (since cosmic radiation can degrade them). It predicts when medicine might lose potency and suggests alternatives or timing changes.

3. Example Concepts

Molecular Syringes: Nano-machines that inject drugs directly into target cells under AI control perfect for precise delivery in microgravity.

AI-driven Microneedle Patches: Patches that release medicine automatically based on body signals.

Smart Capsules: Ingestible capsules that release drugs in response to AI-analyzed gut conditions or biomarkers.

4. Benefits for Space Missions

Challenge	AI Targeted drug delivery solution
Limited medical staff	Autonomous ai monitoring drug release.
Storage constraints	Efficient micro/nano drug doses.
Microgravity drug distribution issues	Targeted molecular systems.
Space radiation	AI tracking drug stability.
Health unpredictability	Personalized, adaptive medicine.

5. Long-Term Vision

In future Mars or deep-space missions, AI-driven targeted delivery systems could form part of onboard "bio-medical AI labs" constantly monitoring astronauts, manufacturing small drug batches, and releasing them safely.

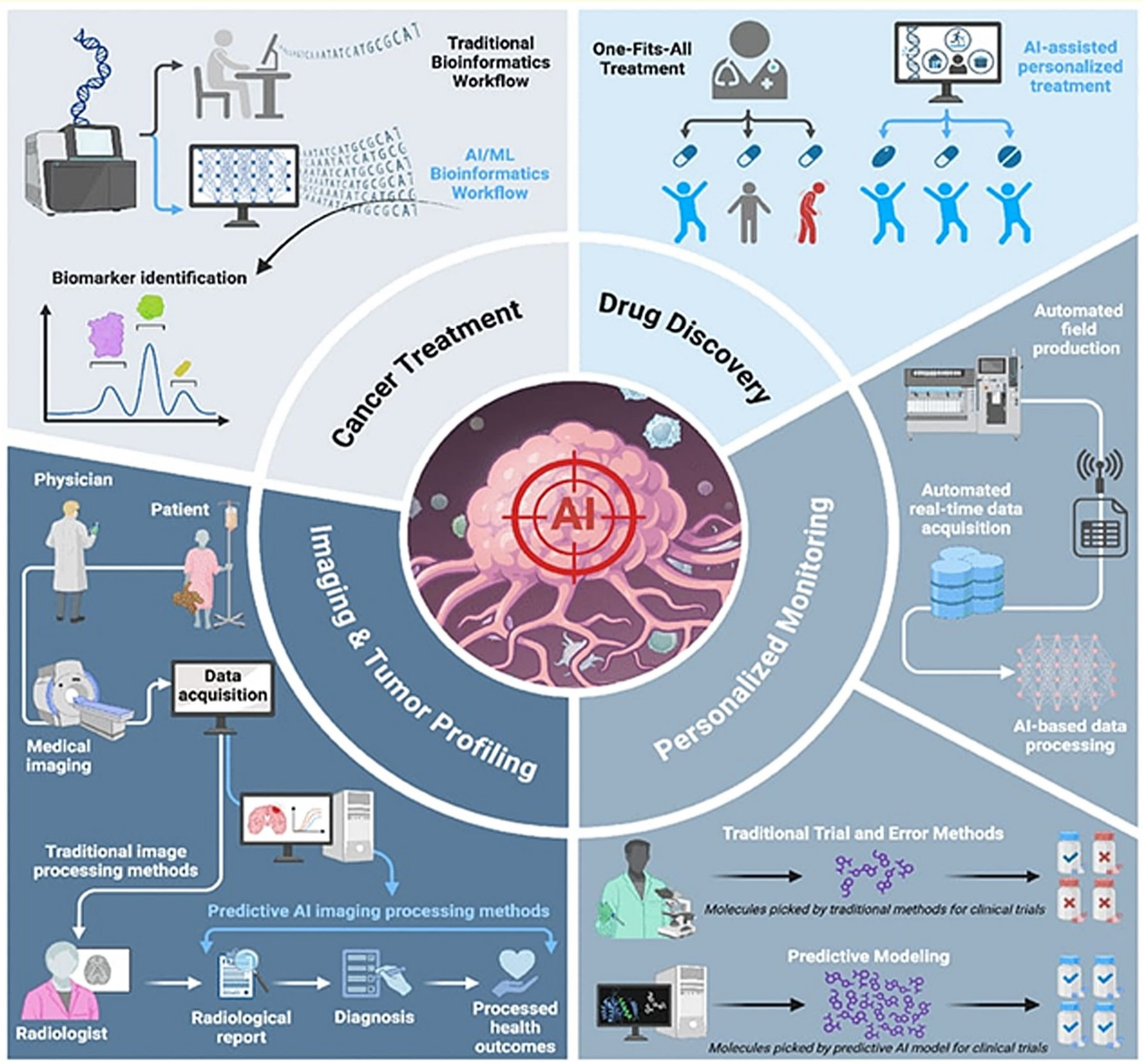
Application

- Cancer therapy (targeting tumor cells)
- Neurological diseases (crossing the blood-brain barrier)
- Cardiovascular disorders
- Diabetes management
- Antimicrobial drug targeting

Future Prospects

AI will enable:

- Fully autonomous drug delivery systems
- Real-time adaptive therapies
- Integration with Internet of Medical Things (IoMT)
- Greater use in precision and regenerative medicine.



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KEY COMPONENTS OF TARGETED DRUG DELIVERY

Component	Role	AI's Contribution
Nanocarriers (e.g. liposomes, nanoparticles)	Encapsulate drug for controlled	AI models predict optimal particle size, shape, and surface chemistry for tissue targeting.
Targeting ligands	Direct carriers to specific cell receptors	AI helps with screen ligand-receptors affinities and binding kinetics.
Stimuli-responsive materials	Release drugs under specific conditions (PH, temperature, enzymes)	Machine learning predicts responsiveness and stability.
Drug release control	Time and rate of drug delivery	Reinforcement learning can optimize dynamic control systems (e.g. insulin pumps).

A NEWS ABOUT TARGETED DRUG DELIVERY

The most recent news reports on AI for targeted drug delivery highlight significant progress in using AI to design, optimize, and control smart nanocarriers and nanorobots for personalized medicine. Researchers are developing AI models that can analyze vast amounts of patient data to tailor drug formulations and predict patient-specific responses.

RECENT NEWS AND RESEARCH HEADLINES

Duke University engineers use AI for improved nanoparticle design

Duke Pratt School of Engineering: A September 2025 news report details how Duke engineers used a new AI platform, Tuna-AI, to design and optimize nanoparticles for drug delivery. The AI was used to identify new nanoparticle formulations and improve existing ones, with experiments showing preserved drug efficacy and improved distribution in mouse models.

Nature study details intelligent deep learning for cancer drugs

Nature: A May 2025 article in Nature showcases an "intelligent deep learning model for targeted cancer drug delivery". The framework uses an AI bio-cyber interface to regulate drug concentration at a tumor site, minimizing exposure to healthy cells and improving therapeutic efficacy. The model uses bio- nanomachines to deliver drugs like doxorubicin to malignant tissue.

Wiley reports on AI-driven "nano architectonics" for targeted delivery

Wiley Online Library: In August 2025, a publication in Advanced Materials outlined an AI-driven "nano architectonics" framework for developing smart targeted drug delivery systems. It details how AI facilitates three key phases:

Target identification: Using AI and bioinformatics to profile molecular targets.

Surface engineering: Using machine learning to enhance targeting specificity for nanoparticles.

Delivery optimization: In-silico modeling predicts delivery dynamics and distribution to refine and improve outcomes.

AI Driven innovation in the design

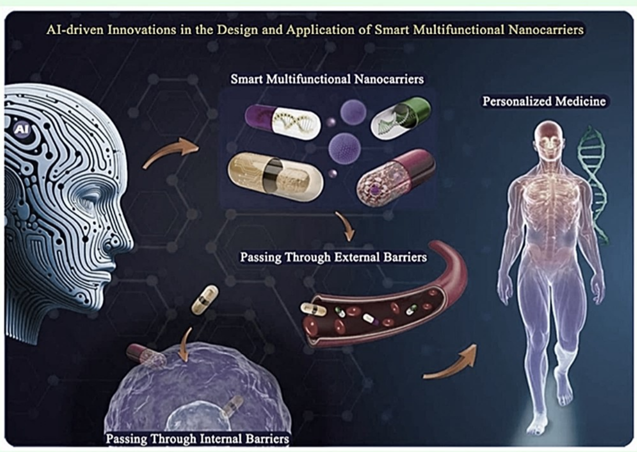
Molecular Syringes: AI, such as DeepMind's AlphaFold, is being used to design molecular syringes that use modified bacterial proteins to precisely deliver drugs into target cells, potentially eliminating the need for traditional needles and reducing side effects.

Nanoparticle Design: AI helps predict how different nanocarriers (like liposomes and polymeric nanoparticles) will interact with biological systems, allowing researchers to fine-tune their properties for enhanced targeting, drug loading, and controlled release.

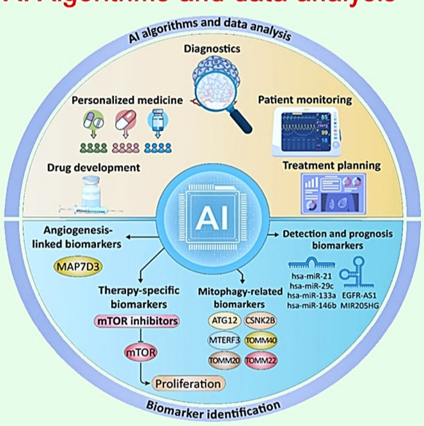
Personalized Drug Delivery: AI/ML enables data-driven decision-making to optimize formulations, tailor drug release strategies to individual patients, and predict how well a drug delivery system will perform in real-time.

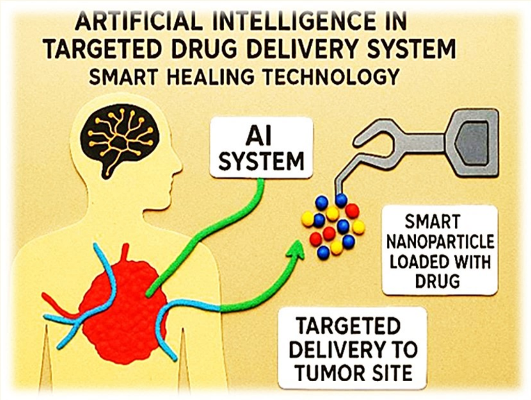
Smart Nanocarriers: AI is used to design dynamic, smart nanocarriers that can respond to specific triggers in the body, such as changes in pH or the presence of certain enzymes, to release their drug payload at the precise location.

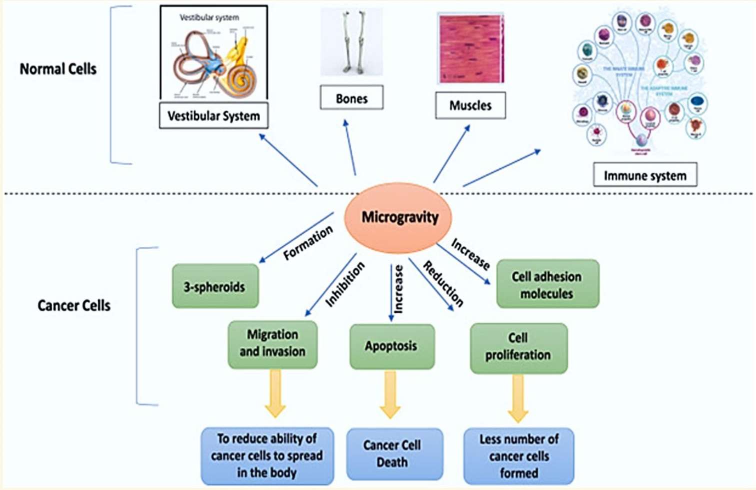
Accelerated Development: By leveraging complex datasets and predictive modeling, AI helps accelerate the entire process from designing and testing formulations to predicting clinical trial outcomes, reducing the time and cost of drug development.



AI Algorithms and data analysis







AI -GUIDED NANOCARRIERS FOR TARGETED DRUG DELIVERY IN MICROGRAVITY

Research in microgravity has shown its potential for advancing drug manufacturing and delivery. The unique environment affects crystal growth, which can produce more uniform, higher-quality crystalline proteins for therapeutics. Microgravity also impacts nanoparticle behavior, potentially leading to improved drug targeting and controlled release.

ROLE OF AI IN MICROGRAVITY IN CANCER RESEARCH

Modeling tumor growth: Some researchers use simulated microgravity to model tumor growth and metastasis, revealing how cancer cells proliferate and migrate in ways that cannot be accurately replicated in ground-based labs.

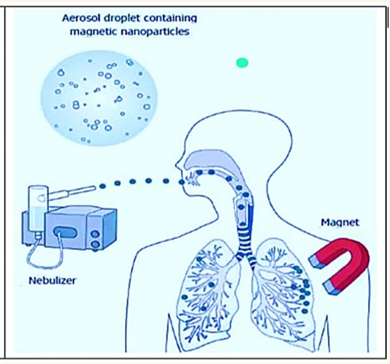
Altered drug response: Studies have found that microgravity can alter the response of cancer cells to chemotherapy. For example, some leukemia cells treated with the drug daunorubicin show enhanced migration in microgravity compared to normal gravity, highlighting the need for space-based drug development.

Targeting tumor blood vessels: Microgravity cell cultures have provided a more representative model of the human body for studying vascular-targeted cancer drugs. In the AngieX Cancer Therapy study on the ISS, researchers evaluated a treatment that targets endothelial cells (which provide blood supply to tumors) to cut off oxygen and nutrients to cancer cells.

ROLE OF AI IN MICROGRAVITY IN CANCER RESEARCH

Aerosols containing magnetic nanoparticles use artificial intelligence to control and guide tiny magnetic particles for specific purposes. This smart technology helps in targeted drug delivery, pollution control, and advanced research by improving accuracy and efficiency through AI.

By dispersing magnetic nanoparticles through aerosols, scientists can guide and control their motion using external magnetic fields, while AI enhances accuracy, stability, and efficiency. This innovative approach holds great promise for applications in medicine, environmental protection, industrial processes, and even space research, where smart, adaptable aerosol systems can perform complex tasks autonomously.



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