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Editorial

2023 Global Engineering Fronts

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An *engineering front* is a key direction in engineering that is forward looking, cutting edge, and exploratory. It plays a leading role in the future development of engineering science and technology, serving as an important guide for innovation in engineering science and technology. According to its innovation stage, an engineering front is categorized into either an engineering research front, which focuses on theoretical exploration, or an engineering development front, which focuses on the practical application of engineering science and technology [1,2].

To track development trends in engineering science and technology, the Chinese Academy of Engineering (CAE)—relying on its nine academic divisions and academic journals, and in collaboration with the Clarivate data analysis team—has been organizing a project known as the Global Engineering Fronts every year since 2017. This research identifies and releases a list of nearly 200 engineering research fronts and engineering development fronts every year in order to guide academic development and promote innovation in engineering science and technology.

The research for the Global Engineering Fronts is carried out via multi-round interaction and iterative selection between experts and data. The data sources used in engineering research front selection are Science Citation Index (SCI) journal papers and conference papers in the Web of Science database, and the data sources used in engineering development front selection are Derwent Innovation patent retrieval data. The basic process of Global Engineering Fronts selection includes: ① data preparation, in which subject-area experts and library and information experts conduct paper retrieval and patent-data retrieval based on the technical systems of each subject area; ② data analysis, in which co-citation clustering is used to create literature clustering topics and co-word clustering is used to form patent maps, in order to identify cutting-edge topics; and ③ expert review, in which cutting-edge topic screening, cutting-edge name revision, expert seminars, and other methods are used to gradually screen the data to determine cutting-edge fronts. To compensate for a lack of cutting-edge topics due to the limitations of data-mining algorithms or data lag, domain experts are encouraged to modify, merge, and expand the cutting-edge topics based on quantitative analysis results.

In the 2023 Global Engineering Fronts, a total of 93 engineering research fronts and 94 engineering development fronts have been selected in nine fields: mechanical and vehicle engineering; information and electronic engineering; chemical, metallurgical, and materials engineering; energy and mining engineering; civil, hydraulic, and architectural engineering; environmental and light textile engineering; agriculture; medicine and health; and engineering management (Tables 1–9).

Table 1
Fronts in mechanical and vehicle engineering.

Engineering research fronts	Engineering development fronts
• Hypersonic flight vehicle technology • Low-carbon and zero-carbon fuel engine technologies • Dynamically reconfigurable mobile micro-robot swarms • Flexible self-powered wearable sensors • Intelligent performance test for automatic driving in an adversarial environment • Multi-material 4D printing • Wireless charging system for underwater autonomous vehicles • State-of-the-art vascular robotic system development • Transfer learning-based machine fault diagnosis • Robot-assisted milling and polishing	• Multi-robot collaborative operation optimization technology • Low-cost reusable spacecraft • Underwater unmanned rescue vehicle • Unmanned aerial vehicle path planning technology • Precision guidance technology for MUAV • AI-based precise target recognition • Multi-functional high-performance aerospace composites technology • Energy integration and propellant management technology for space transportation systems • Micro high-performance combinational sensing technology • Control and perception system of intelligent mobile robot

4D: four-dimensional; AI: artificial intelligence; MUAV: micro unmanned aerial vehicle.

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Table 2
Fronts in information and electronic engineering.

Engineering research fronts	Engineering development fronts
• Theory and technology of large models and their computing systems • Networking theories and key technologies of satellite internet • Ultra-large-scale silicon-based quantum chips • Photon-integrated lasers for quantum applications • Extra-large-scale and ultra-wideband antenna array communication theory and technologies • Optoelectronic in-sensor computing devices and their integration • Automatic development of software assisted by artificial intelligence • Systematized gaming and intelligent control for multiagent systems • Cyber-physical security of industrial control systems • Chip-based satellite laser communication terminal	• Light-controlled phased-array technology • Control technology of unmanned systems based on brain–computer interface • Computing power network construction technology for diverse computing • Flexible intelligent tactile sensor • High-speed free-space optical communication technology • Terahertz solid-state phased-array IC • Artificial-intelligence-based fault diagnosis and detection • Large-size silicon carbide materials and power chips • Naked-eye 3D technology based on light-field technology • Augmented-reality space operating system

IC: integrated circuit; 3D: three-dimensional.

Table 3
Fronts in chemical, metallurgical, and materials engineering.

Engineering research fronts	Engineering development fronts
• Renewable energy-driven bioconversion of carbon dioxide to chemicals, fuels, and materials • Chaotic nonlinear enhancement technology of metallurgical flow field • High-performance electrocatalysts and electrolysis systems for CO_2 conversion and utilization • *In situ* molecular-/atomic-scale characterization of heterogeneous catalysts under reaction conditions • Design and process optimization of low-carbon and energy-saving metallurgical reactors • Rational design and fabrication of special alloys for cryogenic environments • Integrated monolithic electrodes for highly efficient electrochemical energy storage • Research on high-strength, high-toughness, and low-density steel • Efficient preparation and catalytic mechanism of super-dispersed single-atom alloy catalysts • Selective confined mass-transport membrane for ion separation • Intrinsically safe battery systems for renewable energy storage	• Metallurgical low-carbon utilization of renewable energy • Integration of large language models for the design and synthesis of advanced chemical engineering materials • Design and preparation of metal matrix composites for high-temperature environments • Efficient and energy-saving separation technologies for energy-intensive chemical processes • Chaotic enhancement technology for heating process in metallurgical furnaces • Construction and large-scale manufacturing technology of high-efficiency photovoltaic devices • Low-temperature and low-pressure thermal catalytic ammonia synthesis over a wide loading range • Development of ironmaking technology for hydrogen-rich carbon-cycle blast furnaces • Development and application of ultra-high-energy-density aluminum–air batteries • Key preparation technologies and applications of high-purity metals, alloys, and materials • Molecular design and large-scale preparation of new bio-aviation fuels

Table 4
Fronts in energy and mining engineering.

Engineering research fronts	Engineering development fronts
• Research on direct hydrogen production from seawater • Mechanism of high-temperature superconductor (HTS) material in a compact fusion reactor • Detecting method of remote-sensing image change for energy resources • Multiscale fractured modeling and simulation of coupled thermo-hydro-mechanical processes in rocks for geothermal systems • Power-to-X technologies based on renewable energy sources • High-energy-density lithium metal batteries • Research on hydrogen production process route and critical material by nuclear energy • Critical technology in geological disposal of high-level radioactive waste • Drilling-speed prediction model based on artificial neural networks • Characteristics and effects of reservoir stimulation in hydraulic fracturing • Theoretical research on quality enhancement and efficiency improvement in the development of oil and gas in complex deepwater geological formations • Advancements in deep rock mechanics modeling for safe and efficient underground mining	• Fast charging and management technology for batteries • Long-term and large-scale thermal energy storage and thermo-mechanical energy storage technologies • Data-driven technology for security operation and monitoring system of intelligent power-distribution network • Fast reactor metal fuels, nitride & carbide fuel, and fuel cycles • Deuterium tritium operation experiment of device Tokamak • Nuclear energy hydrogen production–industrial application coupling technology • Exploration method for mineral deposits utilizing high-precision ground gravity measurement • Seismic data interpretation and utilization based on deep learning • Research and development of portable geological exploration and sampling device • Research on intelligent collaborative platform for oil and gas exploration and development • Optimal and rapid drilling technology of long horizontal well on large platform in shale reservoir • Research and development of intelligent perception drilling detection equipment for coal mines under complex conditions

Table 5
Fronts in civil, hydraulic, and architectural engineering.

Engineering research fronts	Engineering development fronts
• AI-based structural damage identification and performance prediction • Methods and technologies for carbon-emission reduction in urban regeneration • Spatio-temporal distribution and intelligent evaluation of giant geological disaster chains • Performance perception assessment and rehabilitation of in-service road, rail, and airport infrastructure • Life-cycle disaster resilience of structural and engineering systems • Co-fermentation of municipal sludge and refuse for efficient resource utilization • Coordinated evolution of groundwater quantity, quality, and environmental impact and groundwater sustainable utilization • Multi-scale spatial optimization of high-density urban built environments, guided by safety and resilience • Risk identification and control of pathogenic microorganisms in urban water systems • Intelligent object detection in high-resolution remote sensing images	• Intelligent detection and rehabilitation technology of drainage pipe leakage • Core technology for 1 mm-level global and regional coordinate frame • Digital technology for the protection and utilization of urban historical and cultural resources • Generation technique for space programming of large public buildings supported by artificial intelligence • Advanced technologies for the construction and maintenance of road, rail, and airport infrastructure in extreme environments • *In-situ* observation technologies and equipment in complicated and extreme underwater environments • The technology of preparing carbon-negative building materials from multi-source industrial byproducts • Large-depth-efficient drilling and perception technology in complex geological environment • Prefabricated structures with components and modular units • Smart irrigation and drainage technology and equipment for high-productivity farmland

Table 6
Fronts in environmental and light textile engineering.

Engineering research fronts	Engineering development fronts
• Environmental risks of emerging contaminants in soil • Non-CO_2 greenhouse gas emission reduction and utilization • Technologies for prevention and remediation of micro-pollution of drinking water sources and safe utilization of micro-polluted water • Frontier interpretation of greenhouse gas emissions from aquaculture • Neural-network-based ensemble prediction method • Research on the impact of urbanization on hourly extreme precipitation • Estimation of global air–sea carbon dioxide flux and its regulation mechanism • Research on the precision nutrition and healthy engineering • Research and development of biomass textile materials for low-carbon environmental protection • Research on whole-component utilization of bulk biomass	• Low-carbon source wastewater denitrification technology • River and lake eutrophication ecological management technology and equipment • Cross-media collaborative prevention and control technology for emerging and traditional pollutants • Integrated soil-pollution reduction and carbon-emission control technologies for chemical industrial park • Laser detection technology of bio-optical profile in upper ocean water • Development of a regional earth system model with convective resolution scale • Construction technology of large-scale aquaculture platform in deep sea • Antimicrobial textile derived from cellulose • Research on the bioaugmentation of food functional components • Cell factory technology for sustainable production of lactic acid from lignocellulose

Table 7
Fronts in agriculture.

Engineering research fronts	Engineering development fronts
• Crop pan-genome • Mechanisms and methods for synergistic improvement of crop yield, quality, and efficiency • Genetic basis and regulatory network for the quality formation of horticultural crops • Intelligent identification mechanism and real-time monitoring technology for crop diseases and pests • Straw modification and rapid decomposition technology • Mechanisms of host inflammatory response regulation mediated by significant animal pathogens • Antibiotic-free nutritional regulation techniques for the intestinal health and growth of livestock and poultry • Functional gene identification by multi-omics in animals • Intelligent collaborative operation technology for multiple agricultural machinery • Diagnosis of forest diseases and pests based on deep learning	• Development and application of genome editors in crops • Crop green super-high-yield cultivation technology • Development and utilization of high-quality germplasm resources for horticultural crops • Molecular design of green pesticides based on structural biology • Synergistic technology for efficient conversion of organic matter and reduction of pollutants during composting • Creation of novel and efficient animal vaccines • Preparation of feed by pre-digestion fermentation bioprocessing • Genomic mating breeding technology for livestock and poultry • Key technologies for unmanned farms • Bio-refinery of wood waste • Ecological breeding technology of aquatic animals

Table 8
Fronts in medicine and health.

Engineering research fronts	Engineering development fronts
• Multi-omics traits of complex diseases • Mechanism of persistent virus infection and reactivation and analysis of intervention targets • The core human microbiome and host–microbiome interaction • Reprogramming of aging • Regulation and remodeling of immune homeostasis in organ transplantation • Monoclonal antibody therapy for Alzheimer's disease • Biomacromolecular phase separation and membraneless organelles • Research on the mechanism of organoid construction and development in primates • The human pan-genome and disease pan-genome • Mechanisms of chromatin dynamic modification on tissue and organ development	• T-cell receptor engineered T-cell therapy • Combining antibody–drug conjugates with immunotherapy for malignancies • Single-cell spatial transcriptomics technology • Chimeric antigen receptor natural killer cell therapy • Application of medical nanorobots in cancer treatment • Technologies for synthetic immunology • Small nucleic acid drugs • Single-molecule protein sequencing • The application of large language model in digital healthcare • Epigenetic editing technology

Table 9
Fronts in engineering management.

Engineering research fronts	Engineering development fronts
• Research on human–machine symbiotic intelligent manufacturing under Industrial 5.0 environment • Research on unmanned aerial vehicle dispatching and path optimization in logistics • Research on symbiotic logic and governance of major engineering innovation ecosystems • Research on enhancing and ensuring the resilience of transportation networks • Research on evolution and governance of public safety incidents driven by big data • Research on product quality and reliability technology in a big data environment • Research on interactive mechanism and coordinated development rules of energy economy and environmental systems • Research on intrinsic mechanism of digital empowerment value creation in manufacturing enterprises • Research on precision medical process optimization • Research on pricing and revenue-sharing mechanism of digital elements	• Linear and integer programming solvers • Intelligent factory operation and maintenance systems based on Industrial Internet and big data • Methods and systems for automatic building design generation based on deep learning • Smart home health care systems for the elderly • Comprehensive urban safety risk monitoring and early warning platform • Supply chain risk management platform based on intelligent simulation • Industrial equipment health monitoring and data fusion analysis system • Prediction and early warning system for external shocks and internal disturbances in energy systems • Financial risk management system based on federated learning • Network audio-visual recommendation algorithms and content-supervision intelligent platform

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