世界数字教育联盟
WORLD DIGITAL EDUCATION ALLIANCE

WDEA STANDARD

WDEAS 0003

Fundamental elements of an AI-empowered smart campus

Reference number
WDEAS 0003: 2026

World Digital Education Alliance
Standardization Committee

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Contents

Foreword

This document was drafted in accordance with the provisions of World Digital Education Alliance(WDEA) Standardization Committee Operation Procedure.

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This document was proposed by and is under the jurisdiction of the World Digital Education Alliance.

Introduction

This document provides a guiding framework for utilizing artificial intelligence (AI) to plan, design, and construct smart campuses. It outlines a general AI-driven architecture for smart campuses, specifying the core capabilities and implementation requirements for each logical layer. The framework is designed to enable personalized education, optimized management decisions, and intelligent campus services.

This document is applicable to educational institutions, relevant technology providers, and standards development bodies to guide the development, implementation, and evaluation of smart campus platforms.

Fundamental Elements of an AI-Empowered Smart Campus

1 Scope

This document describes the fundamental elements of AI-empowered smart campuses and specifies their functional and core capability requirements.

This document is applicable to educational institutions and technology service providers for the planning, design, and implementation of smart campuses.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 27001, *Information security, cybersecurity and privacy protection — Information security management systems—Requirements*

ISO/IEC 42001, *Information technology — Artificial intelligence — Management system*

WDEAS 0001, *Large model for education—Overall reference framework*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1
Smart Campus

A smart campus is an AI-empowered campus platform that utilizes technologies such as IoT, cloud computing, big data, AI, and mobile internet to create a digital education ecosystem where physical and information spaces are deeply integrated. It supports campus users in building and utilizing smart applications for teaching and research, faculty and student development, campus administration, and external collaboration.

3.2
AI Capability Platform

AI Capability Platform is a system that integrates multiple AI technologies and tools within a smart campus. It aims to provide users with full-chain service capabilities — from data processing and model training to deployment and application. The platform is designed to lower the barrier to AI adoption, improve R&D efficiency, and enable the rapid implementation of intelligent scenarios.

4 Abbreviated terms

AI Artificial Intelligence

API Application Programming Interface

ASR Automatic Speech Recognition

GPU Graphics Processing Unit

HPC High Performance Computing

HTTPS Hypertext Transfer Protocol Secure

IoT Internet of Things

MFA Multi-Factor Authentication

MQTT Message Queuing Telemetry Transport

NLP Natural Language Processing

NPU Neural Processing Unit

OCR Optical Character Recognition

ONVIF Open Network Video Interface Forum

RTP Real-time Transport Protocol

RTSP Real Time Streaming Protocol

SDK Software Development Kit

SSO Single Sign-On

TTS Text-to-Speech

5 AI-Empowered smart campus architecture

An AI-empowered smart campus, guided by technical specifications and standards, comprises end users, the portal layer, the application layer, the AI capability platform, the support layer, infrastructure, and the cybersecurity framework.

An AI-empowered smart campus is powered by its AI capability platform, with AI agents serving as the entry. It integrates campus functions such as teaching, research, administration, and services for students, faculty, administrators, and other users as a digital education ecosystem. For the reference architecture, see Figure 1.

Smart campuses should use energy-efficient inference technologies to minimize the carbon emissions of AI operations.

Construction of smart campus shall comply with ISO/IEC 42001.

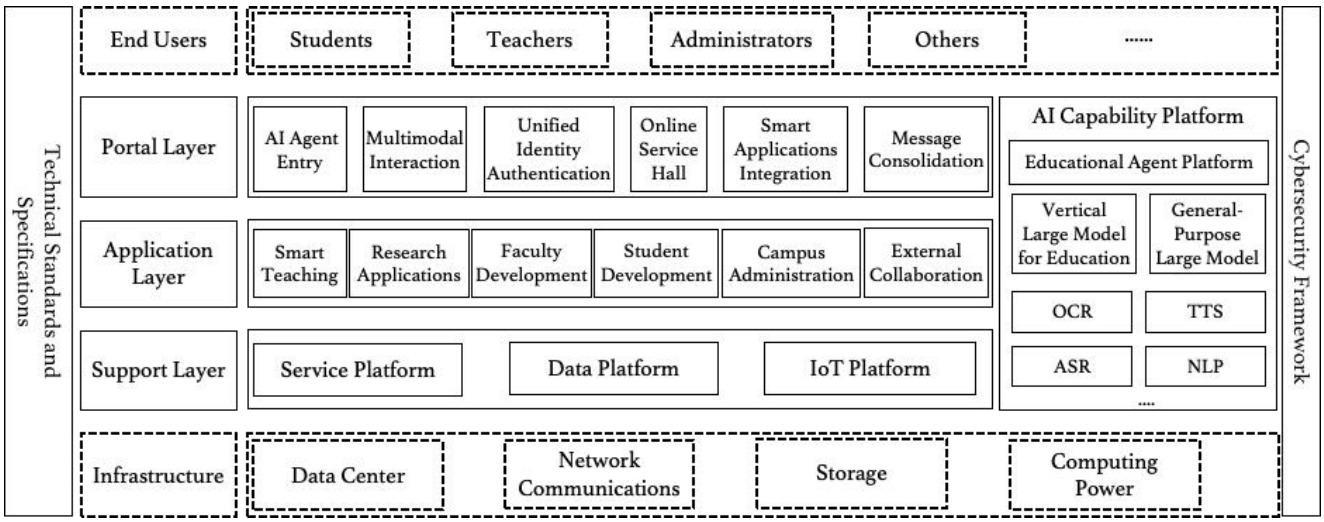

Figure 1 — AI-empowered smart campus architecture

6 Smart campus portal

6.1 Overview

Compared with a digital campus portal, the notable features of a smart campus portal include an AI agent entry and multimodal interaction. It provides users with functions such as unified identity authentication, an online service hall, smart application integration, and message consolidation.

6.2 AI agent entry

The Smart Campus Portal shall use AI to recognize user needs and guide users to the corresponding services.

The AI agent entry shall provide the following primary functions:

a) Allow users to submit requests;

b) Provide appropriate assistance in response to user requests;

c) Utilize the support of the AI Capability Platform to automatically match the corresponding service module and perform operations such as authorization verification, data retrieval, and process execution.

The AI agent entry should provide the following primary functions:

a) Possess multi-turn dialogue capability to actively ask for key information in complex requests;

b) Support personalized customization, generating a service interface based on the user's role and habits, and prioritizing the display of frequently used functions.

6.3 Multimodal iteraction

Multimodal interaction aims to provide users with a more natural, efficient, and accessible human-computer interaction experience. It can adapt to diverse user habits and application scenarios, enhancing the intuitiveness and inclusivity of the interaction.

Multimodal interaction shall provide the following primary functions:

a) Support multiple input and output modalities, such as voice, text, image, and gesture;

b) Support cross-modal understanding and fusion of information;

Example: Generate textual feedback based on a voice command, or recognize image content and convert it into actionable instructions.

c) Provide accessible interaction;

Example: Provide voice navigation for visually impaired users and text transcription for hearing-impaired users.

d) Support intelligent recommendation or automatic switching to the optimal interaction mode based on scenarios, device, and user preferences.

6.4 Unified identity authentication

Unified identity authentication aims to provide centralized, consistent, and reliable identity verification and authorization management for all smart applications. Its core value lies in enabling SSO and universal access.

Unified identity authentication shall provide the following primary functions:

a) Support electronic identity management, including the establishment of a unified digital identity catalog synchronized with the institution's metadata;

b) Implement specific access control policies based on roles and attributes, capable of dynamically adapting to the security requirements of different applications;

c) Support Single Sign-On (SSO), allowing users to access all authorized application systems with a single authentication;

d) Support Multi-Factor Authentication (MFA) and conduct full logging and auditing for all authentication events.

6.5 Online service hall

The Online Service Hall is the unified platform for processing and coordinating online services for the smart campus. It aims to transform offline and fragmented administrative and service procedures into one-stop online applications. Its core value lies in simplifying processes for students and faculty and enhancing campus administrative efficiency.

The Service Hall shall provide the following primary functions:

a) Service catalog and intelligent search engine for quickly locating required procedures;

b) Full-cycle process management supporting online application, document submission, progress tracking, result feedback, and service evaluation;

c) Online collaboration and automated workflow for complex, multi-departmental, multi-step service processes;

d) Guided assistance such as intelligent form filling, document pre-check, and FAQs.

6.6 Smart application integration

The Smart Campus Portal integrates various business systems of educational institutions, such as academic affairs, student affairs, human resources, finance, and logistics, to provide users with a unified access entry.

Smart Application Integration shall provide the following primary functions:

a) Support categorized search and personalized favorites;

b) Support custom configuration of homepage content based on user roles and habits;

c) Support intelligent proactive push of notifications, announcements, and calendar items;

d) Support online transaction completion via natural language interaction.

6.7 Message consolidation

Message consolidation aims to unify and proactively push key pending information scattered across various business systems. Its core value lies in helping users focus on important information, improving task-handling efficiency, and ensuring timely and accurate delivery of critical campus information to target users.

Message consolidation shall provide the following primary functions:

a) Support centralized aggregation of notifications, announcements, pending tasks, alerts, etc. from various business systems;

b) Support intelligent classification, prioritization, and personalized filtering of messages;

c) Support message delivery through multiple channels – such as portal internal messaging, mobile push notifications, SMS, email, and AI agents – and allow users to customize reception rules;

d) Support a unified processing entry for messages, batch operations, and status tagging.

7 Smart campus application layer

7.1 Overview

The Smart Campus Application constructs an intelligent and scalable application ecosystem to meet the requirements of various campus users. The applications primarily include: smart teaching, research applications, faculty development, student development, campus administration, and external collaboration.

7.2 Smart teaching

Smart teaching is the core application that intelligently reshapes the entire process of "teaching, learning, management, and evaluation". The core value of smart teaching is going beyond the limits of traditional teaching models and promoting the integration of large-scale education with personalized development.

Smart teaching applications should provide the following primary functions:

a) Scenario Coverage: Support core teaching stages including course design, classroom instruction, post-class assignments, hands-on training, assessment and evaluation, and teaching management, enabling a seamless online-offline digital teaching loop;

b) Data Collection: Achieve unified collection of teaching data through the data platform under the conditions permitted by laws and regulations;

c) Teaching Assistance: Provide teachers with tools such as intelligent lesson preparation, AI teaching assistants, automated assignment grading, intelligent assessment item bank, and real-time classroom interaction analysis to effectively reduce administrative burdens and enhance teaching efficacy;

d) Intelligent Recommendation: Intelligently recommend or dynamically generate personalized learning content, pathways, and resources based on students' knowledge base, learning styles, and competency goals, while ensuring alignment with predefined learning outcomes and expected study timelines, supporting stratified and categorized instruction;

e) Resource Development: Support the development, management, and sharing of a digital teaching resource repository, utilizing AI technology to assist in generating and optimizing teaching materials;

f) Process Management: Enable the recording, tracing, and analysis of instructional process data under the premise of privacy protection, thereby improving teaching quality and supporting the management of learning outcomes;

g) Intelligent Evaluation: Use teaching process data to construct a multi-dimensional teaching evaluation system, comprehensively analyze teacher effectiveness and student learning outcomes, and provide data-driven support for teaching and learning optimization.

7.3 Research applications

The core value of research applications lies in providing researchers with intelligent tools and platforms that enable knowledge discovery, accelerate research workflows, and facilitate the conversion of findings into viable applications, thereby enhancing the institution's overall research innovation capability and influence.

Research applications within the smart campus shall encompass the following primary functions:

a) Intelligent Literature Services: Provide semantic-based intelligent search, cross-database recommendation, trend analysis, and knowledge graph association to assist researchers in efficiently acquiring and gaining insights from academic information;

b) AI-Powered Data Processing: Support the integrated management, preprocessing, basic analysis, and visualization of multimodal research data, while offering scalable storage and computing resources, ensuring secure handling and compliance with data governance and research ethics;

c) AI-Powered Process Management: Leverage AI to streamline processes such as project proposal submission, progress tracking, funding management, and result registration, enabling compliance checks on materials and intelligent progress reminders;

d) Collaborative Research Environment: Provide secure online collaboration spaces supporting document co-authoring, online seminars, task management, and team knowledge accumulation;

e) Resource Mobilization & Knowledge Transfer: Establish a one-stop service platform for instrument and equipment sharing, matching research resources with demand, and promoting the publication and practical application of research outcomes, thereby fostering industry-university-research collaborative innovation.

7.4 Faculty development

Faculty development applications provide personalized and systematic support to enhance teaching proficiency, advance research innovation, and facilitate career progression for academic staff.

The applications should deliver the following primary functions:

a) Full-cycle Career Support: Provide tailored resources, tools, and guidance across key professional stages, including onboarding, training, teaching, research, performance review, and promotion under the conditions permitted by laws and regulations;

b) Personalized Development Pathways: Generate intelligent recommendations for teaching reflection, training courses, research collaboration opportunities, industrial training and improvement of instructional methods based on individual faculty profiles and goals; provide intelligent recommendations for expert teachers and peer mentors based on teachers' professional development needs, offer smart matching suggestions for forming professional learning communities, and promote school-based and cross-school collaborative teaching, research, and resource sharing;

c) Digital Professional Portfolio: Maintain a dynamic, comprehensive electronic record that automatically aggregates and updates teaching accomplishments, research outputs, training

history, and performance evaluation data for multidimensional analysis and presentation under the conditions permitted by laws and regulations;

d) AI-Enhanced Community Platform: Host an online platform for collaborative learning and exchange, enabling blended seminars, peer review, peer study matching, knowledge sharing, and joint research initiatives featuring integrated AI agents;

e) Feedback and Support for Development Needs: Establish efficient channels for submitting development needs and integrate analyzed feedback into related institutional processes, such as faculty management and resource allocation, supporting a closed-loop governance mechanism for demand diagnosis, resource matching, and effective feedback.

7.5 Student development

Applications for student development provide precise guidance and support for students' academic progress, physical and mental well-being, and career planning.

Student development applications shall provide the following primary functions:

a) Full-Cycle Growth Navigation: Guide students throughout their entire journey with tailored resources, tools, and support—from initial enrollment and academic planning to extracurricular involvement, psychological well-being, career placement, and alumni engagement;

b) Personalized Growth Support: Deliver personalized recommendations for learning resources, activity participation, and academic planning based on individual student profiles and behavioral analytics, while ensuring alignment with predefined learning outcomes and expected study timelines;

c) Comprehensive Competency Portfolio: Automatically aggregate multi-dimensional student data—including academic performance, physical and mental well-being, strengths and specialties, disciplinary records, community service, volunteer work, and innovative accomplishments—into a dynamic, holistic development record;

d) AI-Enhanced Community Platform: Host an online collaborative platform featuring intelligent agents to facilitate peer learning, interest-based communities, and knowledge exchange;

e) Cultivation of Digital Literacy and Future Competencies: Provide essential courses and training in digital competency, AI literacy, critical thinking, ethics, values, application security, and prevention of AI addiction to equip students with future-ready competencies.

7.6 Campus administration

Through process reengineering and data intelligence, Campus Administration applications enable integrated, fine-grained management of core institutional resources—personnel, finance, assets, and operations.

Campus Administration applications shall provide the following primary functions:

a) Data-Driven Decision-Making: Facilitate cross-departmental collaboration and data sharing to support institution-wide analysis and decision-making;

b) Online Workflow Management: Enable online handling of full service processes with compliance checks and AI-assisted review, while implementing intelligent monitoring and risk alerts at key stages;

c) Quick Inquiry: Provide a unified platform for querying administrative data and generating statistical reports;

d) Resource Management: Deliver digital management, status tracking, scheduling optimization, and efficiency evaluation for resources such as equipment, physical space, and computing power;

e) Evaluation and Feedback: Establish a service evaluation system and support feedback mechanisms for students and faculty.

7.7 External collaboration

External collaboration refers to cooperation between the institution and industries, other educational institutions, and research organizations.

Applications to support external collaboration should provide the following primary functions:

a) Cooperation Facilitation: Match collaborative needs with corresponding resources;

b) Resource Sharing: Aggregate and present information on available assets from both industry and institutional sources;

c) Achievement Exhibition: Display the results and achievements of collaborative projects.

8 AI capability platform for the smart campus

8.1 Overview

Positioned within the smart campus architecture, the AI Capability Platform provides, manages, and orchestrates artificial intelligence models and services. It primarily relies on the Education Agent Platform, and invokes vertical large models for education, general-purpose large models, and foundational AI capabilities to deliver AI support for all smart campus applications.

8.2 Educational agent platform

The Educational Agent Platform performs intelligent analysis and on-demand processing of various campus operation data, invokes vertical large models for education, general-purpose large models, and foundational AI capabilities, and provides teachers and students with the ability to build their own personalized, exclusive AI agents.

8.3 General-purpose large model

General-purpose large models provide broad artificial intelligence capabilities—such as natural language understanding, generation, and logical reasoning—to support fundamental intelligent interaction, content creation, and information processing. It shall meet the following standards and capability requirements:

a) Possess robust contextual understanding, multi-turn interaction, and content generation abilities;

b) Deliver stable and effective API service interfaces;

c) Consider security, compliance, and controllability.

8.4 Vertical large model for education

A vertical large model for education is a specialized model formed by deeply integrating educational knowledge, pedagogical logic, and institutional operational data on the basis of a general-purpose large model. It shall comply with WDEAS 0001 and possess the following primary functions:

a) Cover the core campus operations involved in its training;

b) Support secure storage, compliant use, and tiered access control of institutional operational data;

c) Support the construction of a domain-specific knowledge graph for educational scenarios and be able to answer domain-specific questions;

d) Support customized functions such as teaching resource generation, learning analytics, and research assistance;

e) Enable integration with campus service platforms, data platforms, and IoT platforms to automate operation processes and facilitate data exchange;

f) Support multi-turn dialogue and intent recognition to meet the personalized needs of different roles, including students, teachers, and administrators.

8.5 Fundamental AI capability units

The fundamental AI capability units can include but not litmited OCR, TTS, ASR, and NLP, which support the operation of advanced AI systems.

9 Support layer for the smart campus

9.1 Overview

The Support Layer is a collection of platforms within the overall smart campus architecture that provide generic and resource services. It employs a service-oriented, platform-based approach to deliver stable, efficient, and reusable technical support for the upper-layer smart applications and the AI Capability Platform.

The smart campus support layer should adopt cloud-based or shared infrastructure solutions.

9.2 Service platform

Based on a microservices architecture, the platform enables loosely coupled and extensible systems. It enables rapid service deployment to address evolving institutional needs, ensures precise access control through tiered management, and enhances the security and convenience of service invocations—by both users and the AI Capability Platform—via Single Sign-On (SSO). It thereby delivers stable, controllable, and orchestrated standardized service support for the AI Capability Platform.

The Service Platform shall meet the following primary requirements:

a) Service Modularity: Decompose services into independent microservices aligned with institutional operational areas, with each service focused on a single function to avoid redundancy;

b) Interface Specification: Standardize interface naming, parameter formats, return formats, and access permissions to facilitate data exchange and meet the service invocation and authorization needs of the AI Capability Platform;

c) Service Registry and Discovery: Support automated microservice registration;

d) Scalability: Enable dynamic scaling of service instances;

e) Service Governance: Incorporate circuit breaking, fallback, and rate-limiting mechanisms. Prioritize the recovery of high-priority services in the event of failure to prevent isolated faults from affecting the overall system and ensure stability for AI Capability Platform calls;

f) Version Management: Support concurrent operation of multiple service versions.

9.3 Data platform

The Data Platform provides high-quality, reusable, secure, and controllable data resources for the microservices architecture.

The Data Platform shall provide the following primary functions:

a) Data Ingestion: Support ingestion from multiple data sources, including databases from various service systems, third-party APIs, and IoT data;

b) Data Synchronization: Provide both real-time and scheduled synchronization modes;

c) Automated Data Correction: Incorporate a data-processing engine with validation and cleansing capabilities to automatically identify and handle missing values, outliers, and duplicate records—correcting or flagging them based on predefined rules—to prevent erroneous data from affecting decisions made by AI Capability Platform;

d) Data Tiered Storage: Support data warehouse layering by subject area, storing raw data, refined data, and aggregated data at separate tiers;

e) Data Governance: Enable the establishment of data standards and encoding rules, specifying codes, data types, and field definitions. Implement data lineage tracking to record the full data-flow lifecycle, ensuring traceability for the AI Capability Platform;

f) Data Service: Package integrated, analyzed data results as standardized data services, accessible via APIs for the AI Capability Platform, with support for custom output formats tailored to AI requirements;

g) Data Quality Management: Define data-quality dimensions—including accuracy, completeness, consistency, timeliness, and uniqueness. Establish monitoring mechanisms and issue feedback processes, and implement defined rules and methods for data cleansing and remediation;

h) Backup and Recovery: Define and implement data-backup and recovery policies, perform regular backups, and ensure rapid recovery in case of data loss or corruption to safeguard data security and availability.

9.4 IoT platform

The IoT Platform enables unified access, centralized management, and data aggregation for the campus's massive and heterogeneous array of IoT terminals and sensor devices, and provides open APIs.

The IoT Platform shall meet the following primary requirements:

a) Multi-Protocol Access: Provide standardized SDKs for device onboarding, supporting multiple protocols and compatibility with mainstream standards such as TCP/IP, RTP, RTSP, ONVIF, MQTT, HTTP, and HTTPS;

b) Edge Management: Deliver edge node management capabilities, supporting data preprocessing, local caching, and resume-from-breakpoint transmission for edge devices;

c) Centralized Device Management: Include functions such as real-time device status monitoring, remote control, fault alerting, and hardware updates;

d) Standardized Device Invocation: Provide standardized interfaces for device invocation;

e) Device Compatibility: Support the integration of intelligent devices from different brands and models;

f) Device Security Management: Enforce identity authentication during device onboarding and encrypt data in transit. Implement abnormal device behavior detection to prevent unauthorized access and malicious control, ensuring the security of IoT devices and data.

10 Smart campus infrastructure

Smart campus infrastructure is a physical facility and resource pool that provides network communications, computing, storage, foundational software runtime environments, and computing power. Under dynamic resource prioritization rules, it meets the resource demands of intelligent applications for core institutional operations.

Educational institutions may adopt on-premise deployment, cloud-based, or shared infrastructure solutions.

11 Smart campus cybersecurity framework

11.1 Security management system

The smart campus shall comply with ISO/IEC 27001, establish a systematic security management system, clarifying the organization, systems and responsibilities.

The Smart Campus Security Management System shall meet the following primary requirements:

a) Clarify information security responsibilities and establish management systems covering network security, data security, personal information protection, emergency response, etc.;

b) Adhere to relevant laws and regulations, actively adopt internationally recognized information security standards and practices, and encourage third-party security audits and certifications;

c) Regularly conduct security risk assessments, audit important user behaviors and security incidents, and keep logs;

d) Develop emergency response plans for network security incidents and conduct regular drills to ensure timely and effective handling of security incidents.

11.2 Security technical safeguards

The smart campus security technical safeguards shall meet the following primary requirements:

a) Ensure the physical security and reliability of environments and infrastructure, such as data centers, networks, and servers;

b) Implement network zoning and segmentation, deploying perimeter security measures including access control, intrusion prevention, and malware protection;

c) Harden operating systems, databases, and application systems by implementing identity authentication, access control, and security auditing;

d) Apply encryption or data masking to critical data and sensitive personal information, and establish data backup and recovery mechanisms;

e) Establish a platform content moderation mechanism to prevent the dissemination of illegal or harmful information;

f) Develop AI-specific security strategies, which should avoid collecting sensitive information unrelated to business purposes, perform anomaly detection on newly ingested training data to prevent malicious data from corrupting models, and adopt a multiple defense system to counter agent security risk attacks.

11.3 Privacy and ethical safeguards

The application of artificial intelligence technologies shall give special attention to the following privacy and ethical protection requirements:

a) AI model training shall adhere to the data minimization principle, avoiding the excessive collection of personal information;

b) Identify and mitigate algorithmic bias to ensure the fairness of AI services across different user groups;

c) For AI-assisted decision-making in critical operations, effective channels for human review, intervention, and appeal must be established;

d) Apply enhanced protection measures for sensitive data categories, including biometric data and personal information of minors;

e) Establish an AI ethics review mechanism and conduct related education on digital ethics and privacy protection.

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