



WHITEPAPER

Transitioning to the **autonomous campus**

A framework for smart university transformation

[siemens.com/hs-mainz](https://www.siemens.com/hs-mainz)

SIEMENS

Table of Contents

Contents	2
 1	
Introduction	3
What's new: The novelty of this approach	4
A new approach: From silos to strategic pillars	4
New technology: Convergence of IT, OT, and AI	5
New value: Measurable impact beyond cost savings	6
 2	
The journey to autonomy: A phased approach	7
 3	
The Key to interoperability: The Asset Administration Shell	8
 4	
Best practice in action: Hochschule Mainz	9

Introduction

University campuses today operate as complex ecosystems, similar to small cities. Serving thousands of students, faculty, and staff, they encompass a wide array of facilities from classrooms and laboratories to data centers and hospitals.

This complexity, coupled with rising sustainability mandates and the expectation for a seamless campus experience, necessitates a shift towards smarter, more autonomous infrastructure. Many institutions still rely on siloed, manually controlled systems, leading to operational inefficiencies and missed opportunities for optimization.

To remain competitive and fulfill their core mission, universities must embrace the transformation to autonomous campuses – environments that leverage digital technologies, data, and automation to continuously self-optimize in support of institutional goals.

An autonomous campus represents the peak of digital transformation in higher education facilities. It is a campus where building systems are deeply integrated, where a constant flow of data from sensors feeds AI-driven analytics, and where core operations from energy management to space allocation run with minimal human intervention.

This vision promises to advance both sustainability, by cutting energy waste and achieving carbon-neutral targets, and the occupant experience, by enhancing comfort, safety, and personalization. Achieving this, however, requires a structured, outcome-oriented roadmap.

A strong initial focus is on the technological foundation required for this transformation, with a special focus on the interplay between foundational infrastructure based on building automation systems and open smart building management platforms, starting with standardization at the asset level, with the Asset Administration Shell (AAS) playing a crucial role as a supporting standard for achieving true interoperability.

The goal is to provide a clear, actionable roadmap for university leaders to collaborate on transforming their campuses from traditional, reactive environments into the intelligent, proactive, and autonomous ecosystems of the future.

What's new: The novelty of this approach

Traditional campus management has long relied on isolated point solutions, such as standalone BMS for HVAC, separate security systems, unconnected energy meters, and manual facility processes.

While individual technologies have matured, the higher education sector has lacked a unified, outcome-oriented framework that connects infrastructure investments to institutional strategy.

The target is to give an example of a fundamental departure from that legacy paradigm in three dimensions: approach, technology, and value creation.

A new approach: From silos to strategic pillars

Unlike conventional vendor portfolios organized by product category (fire, HVAC, access, metering), this approach is structured around institutional outcomes, the strategic priorities that university leadership actually cares about.

By clustering solutions under campus experience, research facility optimization, decarbonization and energy management, and smart campus, this approach speaks the language of provosts, CFOs, and sustainability officers rather than facility engineers alone. The outcome-first architecture enables cross-functional conversations and breaks the silos that have historically prevented holistic campus transformation.

The approach also introduces a maturation pathway: a structured evolution from foundational connectivity through data-driven visibility to AI-powered autonomy. Other than a common one-time capital project, this continuous journey enables institutions to start where they are and progress at their own pace while maintaining a clear line of sight to the autonomous campus vision.

New technology: Convergence of IT, OT, and AI

The technological novelty lies in the convergence of three previously separate domains into a single operational layer:

- **IT/OT convergence:**

For the first time, all operational technology data across all disciplines from sensors, actuators, and controllers is natively accessible through cloud APIs alongside IT systems. This eliminates the middleware complexity that has historically made cross-domain analytics prohibitively expensive for universities.

- **AI-native operations:**

Rather than focusing on retrofitting analytics onto legacy systems, the approach is based on embedding machine learning capabilities at the platform level. Moving beyond visualization and reporting, these capabilities enable systems to progressively support autonomous decision-making, from solutions that adapt to occupant preferences to predictive maintenance models that anticipate equipment failures weeks in advance.

- **AAS as interoperability standard:**

The adoption of the AAS as the vertical integration layer ensures that campus investments are future-proof. Unlike proprietary integrations that create vendor lock-in, the AAS provides a standardized digital representation of every physical asset, enabling interoperability as new technologies emerge.

- **Digital twin at scale:**

Moving beyond single-building pilots, the framework enables campus-wide digital twins that simulate energy flows, occupancy patterns, and maintenance scenarios across entire portfolios, turning reactive facility management into predictive campus orchestration.



New value: Measurable impact beyond cost savings

The most significant novelty is the expansion of the value proposition beyond traditional energy savings and maintenance cost reduction:

- **Student attraction and retention:**

For the first time, building infrastructure is directly linked to enrollment KPIs. A campus that adapts to occupant needs in real time becomes a competitive differentiator in a market where students increasingly choose institutions based on experience quality.

- **Financial de-risking:**

The approach quantifies infrastructure ROI in terms that CFOs and governing boards understand: deferred maintenance backlog reduction, energy cost stabilization, and capital planning transparency.

- **Research competitiveness:**

Optimized laboratory environments directly support grant success rates and research output, connecting facility investment to the institution's academic mission and revenue generation.

- **Regulatory readiness:**

With ESG reporting becoming mandatory across jurisdictions, automated carbon tracking and transparent sustainability dashboards transform compliance from a burden into a strategic advantage.

- **Workforce amplification:**

Rather than replacing facility staff, the autonomous campus amplifies their capacity, enabling smaller teams to manage larger, more complex portfolios through AI-prioritized workflows and automated routine tasks.



The journey to autonomy: A phased approach

The transition to an autonomous campus is not a single leap or a disruptive transformation but an evolutionary journey through distinct stages of technological and operational maturity.

This progression ensures that institutions can build capabilities incrementally, delivering value at each step while moving towards a fully autonomous state.

To illustrate this concept, five stages are defined to outline a progressive transformation journey.

Stage	Characteristics	Key Enablers
1. Traditional	Siloed systems, manual operations, reactive maintenance. No integration between building systems.	Basic BMS, standalone fire and security systems
2. Connected	Systems are networked and share data. Central monitoring becomes possible, providing visibility across the campus.	BMS integration, IP-based networks, sensor deployment
3. Intelligent	Data analyses generate insights. Dashboards and reporting tools enable informed decision-making.	Building IoT platforms, IoT data aggregation, AAS-structured data, IT/OT security cloud analytics
4. Smart	Advanced analytics and AI are implemented. The campus leverages digital twins and predictive models for optimization in specific domains, with human operators moving to supervisory roles.	AI/ML models, digital twins, including standardized data and open ontologies, predictive maintenance and cross-domain data correlations
5. Autonomous	The campus operates as an intelligent, self-driving ecosystem. AI agents coordinate systems end-to-end, making autonomous control decisions across all operational domains.	AAS-enabled interoperability and cross-domain data connectivity, AI agents, closed-loop automation

It is critical to understand that each stage builds upon the previous one. The foundational infrastructure established in the connected and intelligent stages is the prerequisite for the advanced capabilities of the smart and autonomous stages.

Without robust data collection, integration, and a standardized data architecture, AI and autonomous control have nothing to work with. This is why focusing on foundational infrastructure and getting the digital backbone right is the single most important strategic decision a university can make on its journey to autonomy.

The Key to interoperability:

The Asset Administration Shell

For an ecosystem of diverse technologies to function as one, a common language is needed. The AAS provides such a common framework. As a standardized digital twin model based on international standards such as IEC 63278, the AAS provides every asset on campus with a unique digital identity and a structured set of attributes. Importantly, the AAS is not a component of the foundational infrastructure itself, but rather a supporting standard that ensures consistent information exchange across the different layers of the technology stack. It provides a machine-readable and semantically consistent description of asset data and facilitates interoperability across systems, regardless of manufacturer or communication protocol.

The value of the AAS in the context of building management and operation lies in standardizing asset data and making it exchangeable across systems. In this way, it provides a standardized interface between the physical world of building assets and the digital world of cloud-based analytics.

When a controller manages a building asset, the AAS ensures that the associated asset information is available in a standardized format that can be used by building automation systems to immediately ingest, analyze, and act upon the data. This eliminates the costly and error-prone process of manual data mapping and custom integrations, which have historically represented a significant challenge in campus-wide digitalization efforts.

By adopting the AAS as a supporting standard, universities create a future-proof data architecture that delivers four key benefits:

- A standardized data model ensuring that all asset information is harmonized and machine-readable
- True interoperability enabling seamless cross-system communication and vendor independence
- Full lifecycle transparency, with all data and events captured throughout the asset lifecycle from operation to decommissioning, enabling improved maintenance scheduling and supporting circular economy principles
- An inherently future-proof architecture that is adaptable to new technologies and evolving requirements such as the EU Digital Product Passport

This standardized approach is the critical enabler for true, scalable autonomy. It allows AI agents and explainable AI to understand and control assets across the entire campus, regardless of their manufacturer. It transforms the campus from a collection of isolated digital islands into a unified, intelligent ecosystem where data flows freely and decisions are made holistically. For universities, this means faster deployment of new capabilities, lower integration costs, and a clear path to the autonomous campus of the future.

Best practice in action:

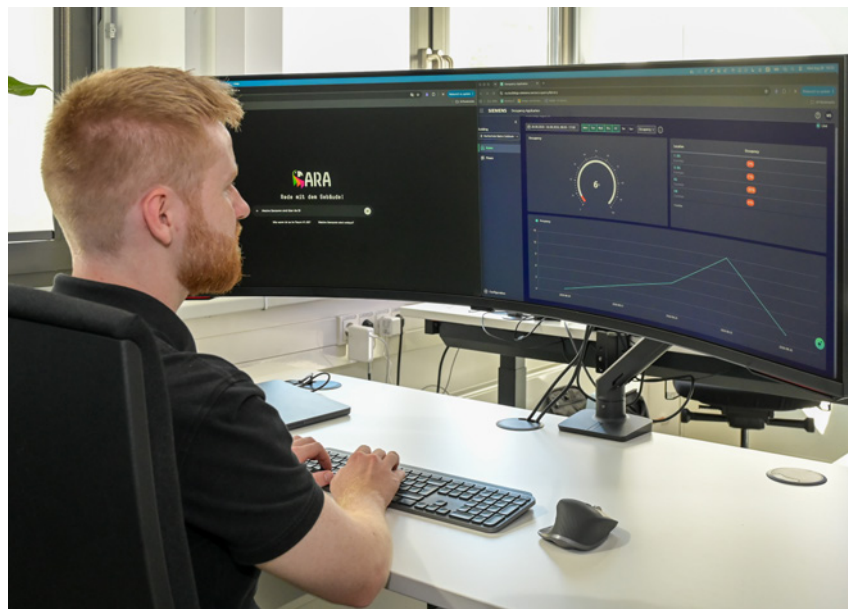
Hochschule Mainz

A compelling real-world example is the “Smart Building Living Lab” at Mainz University of Applied Sciences.

As part of the “Gebäudebetrieb 4.0” research initiative, the project transforms the entire university campus into a living laboratory that captures the full complexity of a mixed-use urban quarter: different building types, varying ages, heterogeneous technical infrastructure, and diverse usage patterns. A central objective is to generate real-world operational data for research and teaching, enabling students, researchers, and industry partners to work with live building data.

The underlying system architecture reflects this heterogeneous reality. For part of the portfolio, Siemens’ building management solutions and the building IoT platform Building X are used, integrating HVAC, occupancy data and other operational processes into a unified view. Other buildings are managed using different vendor solutions, deliberately mirroring the diversity of real-world portfolios. In an initial pilot project, wireless Siemens LoRaWAN IoT sensors have been deployed in one building to gather multiple data points, with the sensor data integrated and made available directly through Building X.

The technology was chosen for its rapid, non-invasive installation, making it ideal for retrofitting occupied buildings and scalable across the wider campus quarter. The generated data feeds into applications for space utilization analysis, demand-driven cleaning, and adaptive HVAC control.



Siemens Building X was selected as a central component due to its openness: documented APIs and standardized interfaces allow the university to extract and recontextualize operational data within a fully independent research environment, enabling the evaluation and combination of solutions from different vendors.

This independence is important because the project's research objectives extend beyond any single platform. In complex building portfolios and urban quarters, the open interplay of diverse systems is essential. Against this background, the Smart Building Living Lab investigates how data from Building X and other BMS solutions can converge in an open integration layer.

A central element is an operator data model based on linked data, W3C standards, and domain-driven design, acting as a semantic backbone that classifies, links, and contextualizes building information within a machine-interpretable graph. Rather than creating new ontologies, the approach integrates existing standards.

The AAS complements this as an interoperability mechanism, with particular emphasis on supporting EU data sovereignty through controlled and transparent data exchange. This semantically rich foundation also enables AI applications ranging from analytical support to LLM-based and agent-driven approaches with a focus on explainability and operational reliability.

The Mainz University of Applied Sciences case illustrates a key principle: autonomous building operations require genuinely open platforms, while long-term success depends on industry-wide interoperability and ecosystem thinking. By researching how linked data and graph-based models connect heterogeneous systems beyond the platform level, the project demonstrates that future developments depend on effective connections between solutions, with an architecture designed to integrate with federated European data spaces, smart city platforms, and district-level ecosystems.

Published by

Siemens Switzerland Ltd

Smart Infrastructure
Global Headquarters
Theilerstrasse 1a
6300 Zug
Switzerland
Tel +41 58 724 24 24

For the U.S. published by

Siemens Industry Inc.

3617 Parkway Lane
Peachtree Corners, GA 30092
United States

Subject to changes and errors. The information provided in this brochure contains merely general descriptions or characteristics of performance which in case of actual use do not always apply as described or which may change as a result of further development of the products. An obligation to provide the respective characteristics shall only exist if expressly agreed in terms of contract.

© Siemens 2026