



# OPEN DATA CENTER ALLIANCE<sup>SM</sup> : THE PRIVATE CLOUD STRATEGY AT BMW

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# OPEN DATA CENTER ALLIANCE<sup>SM</sup>: THE PRIVATE CLOUD STRATEGY AT BMW

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## EXECUTIVE SUMMARY

The focus of this document is the current private cloud strategy at the BMW Group. That strategy, driven by the idea that infrastructure services be provided by cloud delivery models free of technical and vendor dependencies and business downtime requirements, is divided into two phases. In the first phase BMW deploys a private cloud, and in the second phase the company extends its private cloud into a hybrid cloud. As widely defined, a hybrid cloud is a private cloud supplemented with computing capacity from public clouds. This document describes the first phase of the strategy, which includes the implementation of infrastructure as a service, the service platforms—platform as a service (PaaS) DB, PaaS Web, and PaaS SAP—and corporate software as a service. This document also describes how the private cloud strategy at BMW is driven by company-specific objectives and general conditions and therefore is technically characterized by strict layering and modularization. The services and platforms embedded in the BMW private cloud architecture may be implemented differently, but they follow the same general design principles.

The audience for this document consists of solution providers, technology vendors, and standards organizations. Solution providers and technology vendors can use the content to better understand end-user needs and to tailor products and services accordingly. Standards organizations can use the content for defining standards that are open and relevant to end users.

The purpose of this document is to do the following:

- Describe the private cloud strategy at BMW.
- Provide information about the mission, strategy, and business objectives of the company's IT-infrastructure organization (IT-Infrastructure) and the role of the cloud strategy therein.
- Illustrate the architecture, design, and technical approach behind the cloud strategy at BMW.
- Highlight the business and technical principles followed by IT-Infrastructure to ensure that the cloud strategy helps the BMW Group to successfully realize its corporate mission.

With this document BMW also strives to contribute to the larger discussion on cloud computing within the Open Data Center Alliance<sup>SM</sup> (ODCA) community and IT industry at large. The ODCA was formed to deliver a unified voice for emerging data center and cloud computing requirements, with a mission to speed the migration to cloud computing by enabling the solution and service ecosystem to address IT requirements with the highest levels of interoperability and standards. The BMW Group is a founding member of the ODCA steering committee and an active participant in the organization's workgroups.

## THE MISSION OF IT-INFRASTRUCTURE AT BMW

The BMW Group is the world’s leading provider of premium products and premium services for individual mobility, and its IT-infrastructure organization, IT-Infrastructure, is responsible for the company’s entire IT infrastructure.

At BMW, IT-Infrastructure supports approximately 1,000 web applications, with 4,700 application server instances and 8,400 web server instances. The organization also supports 90,000 desktop and laptop computers, 9,300 smartphones, and 48,000 mobile phones. The network encompasses 186,000 active LAN ports, 6,100 LAN switches or routers, and 4,900 WLAN access points under management. For database, the organization supports 1,900 database instances as well as 300 SAP systems in test, development, and production environments. Operating-system virtualization is approximately 50 percent with XEN/VMware ESX technology and 25 percent with virtualization via project servers.

While the corporate mission at BMW is based on unchanging core values, the IT services supporting that mission adapt as needed to a business climate that is changing constantly. One such adaptation is the pursuit of a private cloud strategy that is aligned with the definition of cloud computing put forth in a 2011 publication of the American National Institute of Standards and Technology (NIST): *“Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.”*

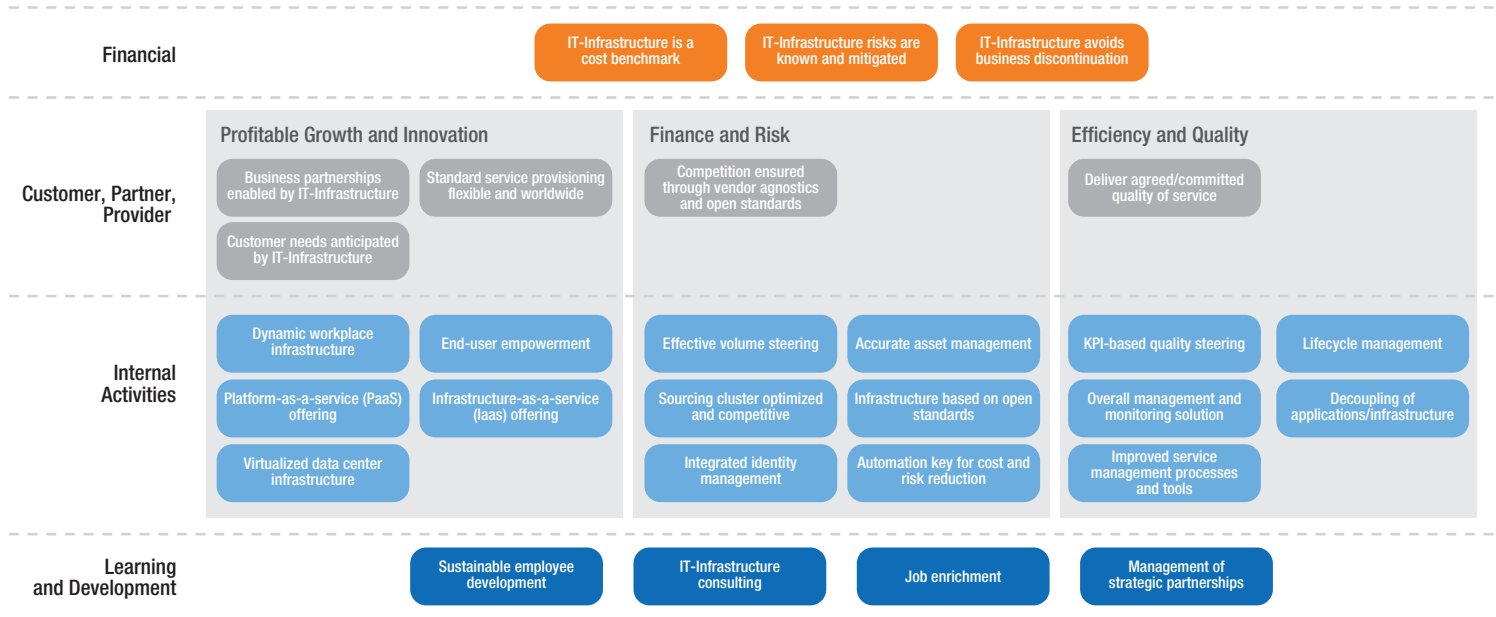
The BMW private cloud strategy is central to the company’s corporate vision for infrastructure services. That vision calls for such services to be:

- Provided by delivery models free of technical and vendor dependencies and business-downtime requirements.
- Managed with fully automated processes.
- Characterized by collaborative, pervasive, and seamlessly integrated workplace solutions designed to increase end-user productivity.

The BMW private cloud strategy is closely aligned with and follows numerous aspects of the [ODCA Compute Infrastructure as a Service](#) and [Service Orchestration](#) usage models. These usage models describe the strategy and tactics of moving from requirements to implementation.

Following a balanced scorecard approach, Figure 1 shows the strategy map for the organizational units within IT-Infrastructure and where the internal activities of each unit highlight the role of cloud services in the organization’s overall long-term strategy.

FIGURE 1: THE BMW IT-INFRASTRUCTURE FUNCTIONAL STRATEGY



## Open Data Center Alliance: The Private Cloud Strategy at BMW

At BMW, the functional strategy of IT-Infrastructure is based on the following:

- **Agility.** The IT infrastructure, with its operational as well as maintenance activities, should be controllable, expandable, and flexible.
- **Data, information, and knowledge.** The company should be prepared to handle increasing volumes of data and enable IT-Infrastructure users and staff to extract the information that they require.
- **Competence.** IT-Infrastructure staff members should be knowledgeable about state-of-the-art information technology and emerging developments in the field.
- **Sourcing.** Dependencies on IT providers should be minimized and an efficient vendor portfolio should be established.

For implementation of the IT-Infrastructure functional strategy, the organization has established an ongoing project known as “IT-i.” Central to their work, members of the IT-i team have defined two “breakthrough” objectives for 2012:

- **“We enable the post-PC era.”** This is a set of projects at BMW to deliver a standardized infrastructure platform that supports collaboration, mobility, and device and application independency.
- **“We build our private cloud.”** The private cloud infrastructure at BMW is designed to avoid issues surrounding security, data safety, provider dependencies, and integration deficiencies that are common to public cloud infrastructures.

In closing, as a founding member of the ODCA Steering Committee, BMW aligns its private cloud strategy closely with the enterprise cloud-maturity model published by the Alliance and incorporates guidelines from three of the [usage models](#) that ODCA has published to help organizations address existing and emerging challenges to the successful implementation of their cloud strategies. Those three usage models, referenced later in this document, are [Service Catalog](#), [VM Interoperability](#), and [Long-Distance Workload Migration](#).

### OBJECTIVES FOR THE PRIVATE CLOUD

In keeping with its breakthrough objectives and in supporting the ODCA enterprise cloud maturity model, members of the IT-i team have defined these further objectives specific to the private cloud strategy at BMW:

- **A target of zero downtime**, depending on the kind of service involved and its related business requirements.
- **Provision of self-service**, to enable access information and applications at any time (24 hours a day/7 days a week) and from any location (worldwide).
- **Automated, rapid, and elastic provisioning and release of services**, including transparent scalability according to demand. This means that available services should appear to be unlimited to users and that they can be allocated in any quantity, at any time for the different groups within the BMW Group.
- **User choice.** Members of the IT-i project will offer cloud computing to end users at BMW to make their jobs easier and help them work more productively. This means that IT-i will expand cloud service offerings based on end-user demand. If members of a given business organization or user group prefer to continue using the standard IT infrastructure for some or all of their work, IT-i will not require them to use the cloud.

In keeping with these objectives, IT-i is committed to supplier and product independency, supporting flexibility in the provisioning of services and use of external service providers for its private cloud strategy. To facilitate this, BMW is incorporating the ODCA [Service Catalog](#) usage model into its private cloud strategy. That usage model addresses the need for a well-implemented set of requirements and best practices that can enable precise standards for comparison of service offerings from diverse providers’ considerations.

### DESIGN GOALS AND CRITERIA

The design goals of the private cloud strategy at BMW are as follows:

- **Strong alignment of services with business requirements.** For some cloud services BMW chooses offerings that may not be typical candidates for cloud computing but happen to align strongly with the company's business requirements. (SAP platform services are one example, because of their minimal requirements for planned business downtimes.)
- **Tight integration of cloud services with existing infrastructure and processes.** To support this goal, IT-i requires that cloud services largely comply with processes following the IT Infrastructure Library (ITIL). ITIL is a set of industry best practices for IT Service Management (ITSM), a discipline for managing information technology that is centered on the customer's perspective of the contribution of IT to the business.
- **Openness to expansion with services from diverse providers and partners and retention and expansion of internal know-how related to installation and operation of internal cloud services.** Together, these goals support stronger internal control over installation and operation of services, and the selection and integration of partners.
- **A steadfast commitment to ensuring security.** A number of factors make security issues particularly pressing in cloud computing: the comparatively large number of threads, interfaces, and interacting configuration parameters; the potential loss of data; unauthorized access to information; and the risk of reduced access (or even no access) to cloud services. Security must be ensured not only for the day-to-day use of cloud computing resources, but also from the very start of cloud implementation.

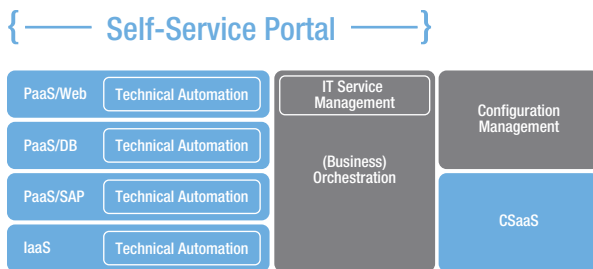
In keeping with these design goals, IT-i has established the following technical design criteria and requirements for all cloud service implementations:

- **Preclusion of direct service interaction between platform and infrastructure services.** Following a clear layering and modularity of services and technology in terms of platform as a service (PaaS) and infrastructure as a service (IaaS), all communication between them will take place through the Business Orchestrator and all service requests will be triggered through a self-service portal (SSP) or the Business Orchestrator. (Note that each of these components, which are central to the private cloud strategy at BMW, is defined and explained later in this document.)
- **Separation of business and technical orchestration.** To remain independent from operational models and provider/supplier contracts, business orchestration (hereafter referred to as "orchestration") will be separated from technical orchestration/automation (hereafter referred to as "technical automation"). All technical automation takes place within the services of the different platforms and infrastructure, while control remains in the hands of the current stakeholders. Wherever possible, all interfaces, automation processes, and techniques developed for the cloud are also used in standard operational services. A mix of proprietary and open source products can be modified and evolved as long as open interfaces and open standards are used.
- **Modularity based on open interfaces.** Layered architecture, modularity, and communication through open interfaces will be applied throughout the cloud services, and orchestration and technical automation will be separated to avoid dependencies on vendors, products, and specific technologies.
- **Generic cloud solution.** IT-i pursues a generic approach to its technical solution for cloud computing. This approach will enable the organization to expand the type and extent of offered services without having to modify the general architecture. It also will help to ensure the current private cloud concept does not preclude the possibility of a future move to a hybrid cloud, as outlined in the ODCA VM Interoperability and Long-Distance Workload Migration usage models.
- **Easy access to cloud services.** The user interface of the SSP will be user-friendly and fault-tolerant.

### TECHNICAL APPROACH FOR IMPLEMENTING THE PRIVATE CLOUD

The general architecture of the private cloud at BMW is based on a cloud stack as defined by the National Institute of Standards and Technology (NIST), on the company's business objectives and requirements, and on its design goals and criteria. BMW has also adapted the architecture to integrate existing processes such as IT services, identity, and configuration and to enhance these processes wherever possible.

FIGURE 2: GENERAL ARCHITECTURE OF THE PRIVATE CLOUD AT BMW



As shown in Figure 2, the following elements constitute the private cloud stack at BMW:

The **SSP** provides the orderable services of IaaS, PaaS, and, to some extent, corporate software as a service (CSaaS) to application owners (IT-Infrastructure users and staff). The SSP is “aware” of orderable services through input from two sources: the Business Orchestrator, which receives regularly updated status information from the service providers themselves, and a Service Catalog implemented following the guidelines defined by the ODCA Service Catalog usage model. The Service Catalog describes the services offered by different providers and the attributes of those services in a way that simplifies marketplace selection. (For more detail on the SSP, see the Self-Service Portal section, later in this document.)

Orderable services comprise the following:

- **IaaS**, which is responsible for subcomponents that are typically part of the data center infrastructure, such as servers, hypervisors, storage hardware (SAN/NAS/backup), and network (IP management and load balancing) components. (For more detail on the orderable services, see the respective subsections—[PaaS Web](#), [PaaS DB](#), and [Corporate Software as a Service](#)—under Service Architecture and Design.)
- **PaaS (PaaS Web, PaaS DB, and PaaS SAP)**, which are built on the IaaS infrastructure and therefore must be aligned with IaaS services and, if possible, mapped to generic IaaS services through the orchestration layer. PaaS also may have specific requirements for IaaS services.
- **CSaaS**, which encompass services for identity management, creation of Secure Sockets Layer (SSL) certificates, and monitoring. Identity management and other necessary components of the CSaaS are consumed as services through the orchestration interface.

The **ITSM** is responsible for service request management, which is triggered when the SSP generates changes from a service request. (For more detail on the ITSM, see the [IT Service Management](#) subsection, later in this document.)

Within the ITSM the business orchestration layer, or Business Orchestrator, is the controlling instance of the service platforms (IaaS, PaaS, and CSaaS). The Business Orchestrator composes complete services by requesting suitable subservices from IaaS, PaaS, and CSaaS. The Business Orchestrator is also responsible for handling the global Configuration Management Database (CMDB). Item-classed configuration items are maintained within IT-i in a single CMDB, irrespective of whether the IT infrastructure resides in the cloud or elsewhere. All information about configuration items that are created or changed during orchestration is recorded and updated in the CMDB.

According to the principle of modularity, the Business Orchestrator is the single external interface to the SSP. Business processes are completely supported by the SSP and orchestration. Through the orchestration interface, different service providers offer and consume services that conform with the ITIL, a set of practices for ITSM that focus on aligning IT services with business needs.

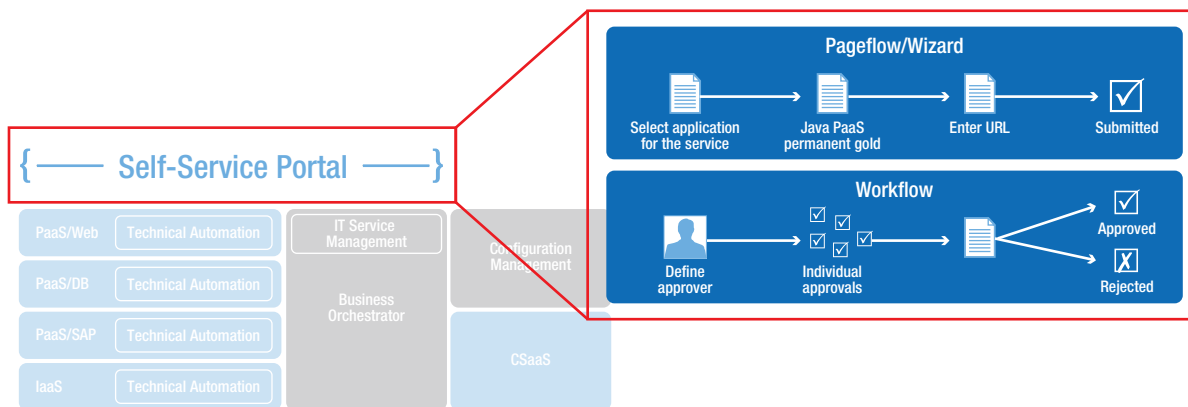
These services are designed according to business use cases, which are offered to application owners through the SSP. Internal processes are layered hierarchically, from low-level technology to the complete services provided at an infrastructure or platform level. The layering consists of technology-specific automation, accessed through technology service instances and assembled services and the service-internal orchestration layer. IaaS, PaaS (Web, DB, and SAP), and CSaaS experience a more or less sophisticated technical automation depending on the technology used and the variety of services offered.



### Self-Service Portal

The SSP provides web-based access to all IT services for IT-Infrastructure users and staff and external service providers. The SSP will be device-independent and, with the necessary security features in place, accessible from both the BMW intranet and the Internet. The SSP is functional beyond the BMW private cloud, but only those issues relevant to its role within the cloud are discussed in this document. Figure 3 shows the workflow via the SSP.

**FIGURE 3: WORKFLOW VIA THE SELF-SERVICE PORTAL**



The SSP offers access to the cloud service platforms (PaaS) and the IT Infrastructure (IaaS). Whenever the IT services are used, according to ITIL the ITSM and Business Orchestrator are the only systems responsible for managing these services, providing a common interface for IaaS, PaaS (Web, DB, and SAP), and CSaaS. With limited exceptions, this is true for all services related to operational business systems. Exceptions include software-development systems and others that might need setup of a new database. All orchestration and automation between these services is handled via the Business Orchestrator, which means that all business processes are completely supported by the SSP and ITSM, including the orchestration layer. The SSP handles all service requests, changes, and deletions, as well as temporary suspension of services, and the Business Orchestrator triggers all changes to the CMDB.

Additional requirements for the SSP include the following:

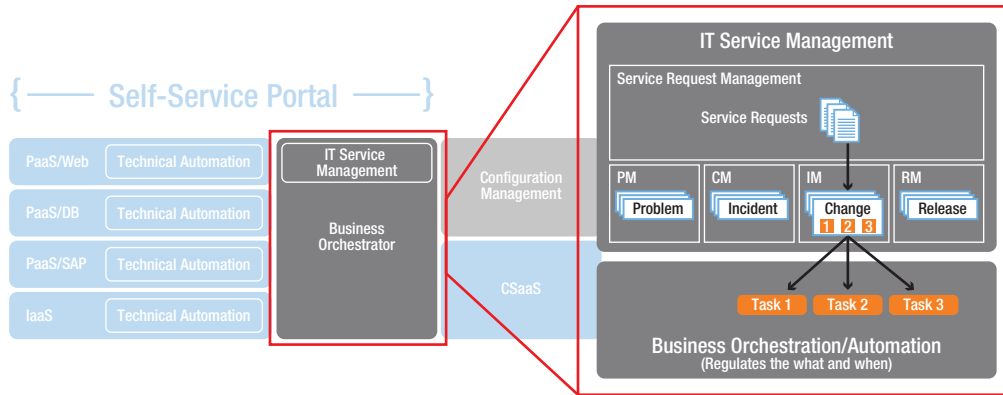
- Provision of IT services specific to the application owner’s user group, controlled by authorization and authentication procedures that support the user-specific presentation and provisioning of IT services
- Device independency
- Centralized and user-friendly access, search, and presentation of various IT services in keeping with the ODCA Service Catalog usage model, with well-defined parameters to prevent free-text input and support automation
- A high level of automation through well-defined services and detailed parameter specifications

**IT Service Management**

The **ITSM**, in keeping with ITIL and ISO 20000, is responsible for managing service requests triggered through the SSP. Note that the ITSM does not control what is done or when single tasks are executed; nor does it control technical automation within IaaS, PaaS, and CSaaS. That control is the province of orchestration. For the BMW private cloud, the SSP is fully integrated into the ITSM and so no additional interface is required.

Figure 4 illustrates the logical structure of the ITSM. It also shows how the Business Orchestrator generates and controls service requests, which depend on predefined changes and data-parameter-specific tasks.

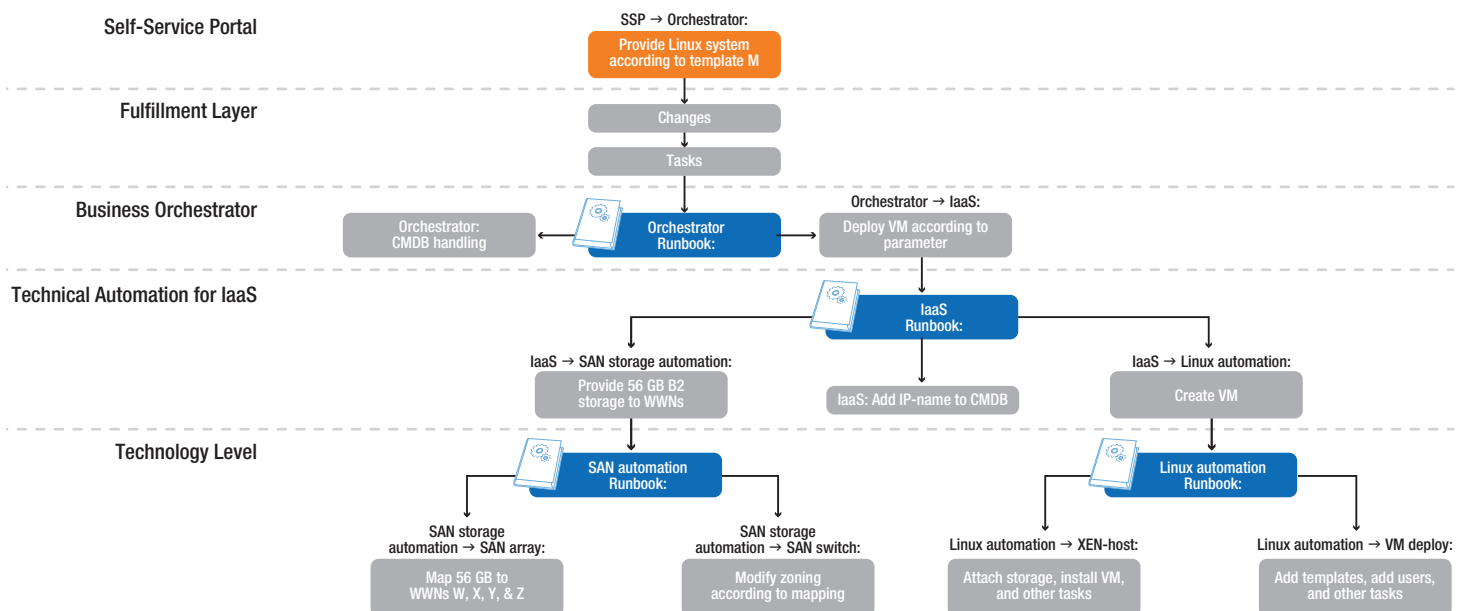
**FIGURE 4: SERVICE REQUEST MANAGEMENT AND ORCHESTRATION WITH THE ITSM AND BUSINESS ORCHESTRATOR**



Based on a service request and information obtained through the SSP, the Business Orchestrator dynamically generates one or more predefined changes. These changes relate to tasks, also known as runbooks, which are routine compilations of procedures and operations that are executed in line with established policies and service levels.

The Business Orchestrator then passes service requests and parameters to IaaS, PaaS, and CSaaS, which in turn generate runbooks. This process is illustrated in Figure 5, using a request for a virtual machine (VM) as an example.

**FIGURE 5: SERVICE WORKFLOW FOLLOWING A REQUEST FOR A NEW VIRTUAL MACHINE (VM)**



### Infrastructure as a Service

The current IT infrastructure at BMW is based on dedicated physical and virtual servers, with infrastructure-based high-availability mechanisms in place to minimize downtime for applications. Resource handling is static and, as a result, implementation times are long. BMW IT-i uses IaaS to increase flexibility and automation and reduce downtime and reaction times across the infrastructure. At BMW, IaaS comprises not only hardware (physical and virtual) but also operating-system instances, low-level software packages, storage, backup, and IP management, including load balancing. To maintain BMW standards and interfaces, IaaS also includes end-to-end monitoring, reporting, and capacity management.

Because its current IT infrastructure is so heavily dependent on virtualization—50 percent at the operating-system level and 25 percent at the project level—BMW is also working proactively to address potential challenges to virtualization in the cloud environment. Toward that end, BMW has incorporated requirements and guidelines from the ODCA VM Interoperability usage model in its private cloud strategy. The VM Interoperability usage model specifies which areas associated with VM interoperability must be resolved in a given cloud environment. The usage model also supports the creation of new management interfaces that are consistent across hypervisors and that comply with the Open Virtual Format (OVF) specification for migrating workloads at the container level.

#### BUSINESS AND TECHNICAL DESIGN OBJECTIVES

For alignment with IT-i strategy and design principles for implementing a private cloud, BMW bases design decisions for IaaS on the following:

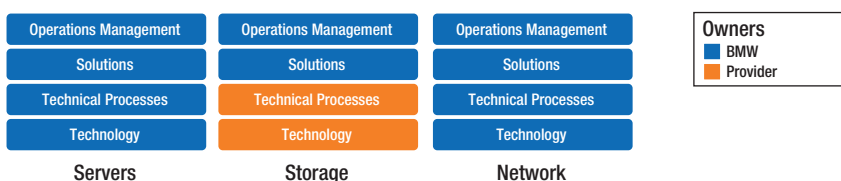
- IaaS layer services will be “black boxes” in terms of detailed technical implementation, with service functionality defined in the Service Catalog, implemented according to the guidelines of the ODCA [Service Catalog](#) usage model.
- The Business Orchestrator will be the sole interface for requesting IaaS services.
- The Business Orchestrator also will be responsible for the global configuration management on the service level.
- The underlying infrastructure of IaaS will be largely equivalent to the underlying infrastructure provided for the BMW legacy environment. This means that the two can coexist and that low-level automation need be implemented only once and can be leveraged for both environments.

Two other concepts inform the design decisions that BMW makes regarding IaaS: openness and ownership. In combination with modularity, openness of interfaces and products enables the IaaS to provide quick, reusable results without blocking further evolution of service or technology levels.

Ownership, of concepts and of changes in functional or technical requirements, enables BMW to maintain control of the entire IT-i project. As part of its concept of ownership, BMW is careful to avoid reliance on processes, functionality, organizational structures, or technologies that are dictated by the use of specific products. For example, IT-i avoids implementing an architecture that requires specific contract design not only at the level of IT-i but also within IaaS, which in turn requires strict layering of services and definition of services, processes, and interfaces so that responsibilities remain independent of provider contract design. This approach enables multiple teams within BMW to successfully manage the various subcomponents of IaaS, such as servers, storage, and other physical technologies supported by diverse providers.

That said, for the current IaaS at BMW, some processes and technologies are partially or fully controlled by external providers. Provider contracts range from calling for full direct control over infrastructure, operation, and processes, to calling for on-demand models in which only low-level infrastructure and processes fall within the responsibility of the provider (see Figure 6). This approach to distributed responsibility is bound to current sourcing models and for future contracts may be addressed with the individual (operation) service providers.

**FIGURE 6: CURRENT CONTROL OF IAAS INFRASTRUCTURE, OPERATIONS, AND TECHNICAL PROCESSES AT BMW**

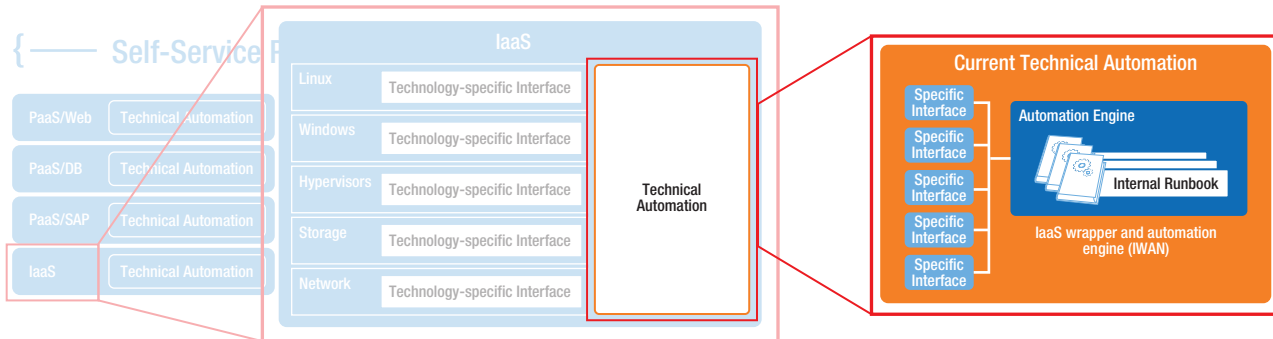


# Open Data Center Alliance: The Private Cloud Strategy at BMW

## TECHNICAL APPROACH

At BMW, every technology within IaaS is automated, with built-in resources and products. As a result, the legacy environment benefits from new automation methods and cloud implementation is easier, as existing automation can be reused. The automation still falls within the responsibility of the existing organizational structure (see Figure 7).

**FIGURE 7: IAAS ARCHITECTURAL OVERVIEW**



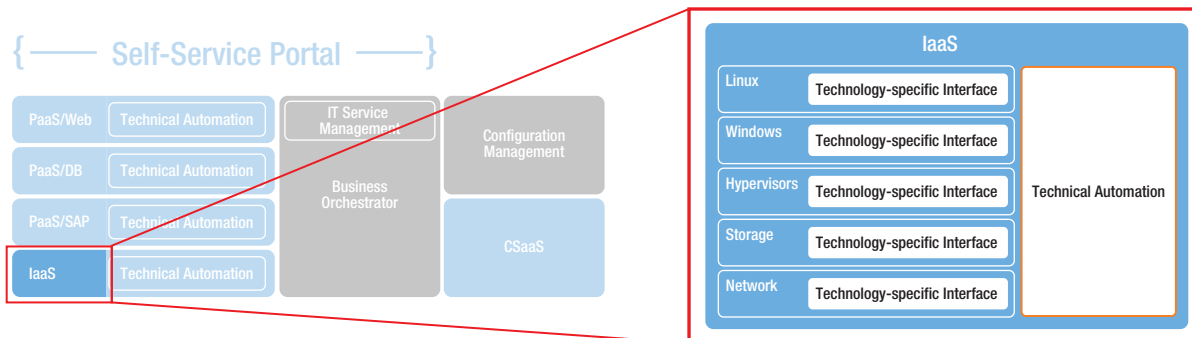
Within the IaaS at BMW, autonomous, technology-specific automation subsystems provide their services to both the existing operations teams and the IaaS Wrapper and Automation Engine (IWAN), which connects the subsystems to an enterprise message bus via adapter scripts. The runbook and automation engine consolidate numerous technology-specific subsystem tasks to complete the IaaS services, which are offered through a single interface to the outside world.

All interfaces are based on open standards and can easily be extended or replaced. Exchange, separation, or recombination of low-level technologies is just a matter of configuration of the runbooks (preferably XML-based). As cloud access is performed on already complete technology services, direct access to subcomponents is not necessary (essential for outsourced technologies without direct control).

The message bus provides a generic way for coordinating the subservices. For later revisions, additional management subsystems (e.g., for monitoring, reporting, capacity management) can be added without requiring changes to existing services.

The universal interface to the layers above IaaS (e.g., orchestration) also can be exchanged quickly, without affecting the lower layers (see Figure 8).

**FIGURE 8: TECHNICAL AUTOMATION OF THE IAAS**



In keeping with the requirement of separation of internal processes, services are layered hierarchically, from the low-level technology to the complete IaaS services offered to the IT-i system. The layering consists of technology-specific automation accessed via technology-service instances and assembled to IaaS services via the IaaS-internal orchestration layer.

For the connection of the IaaS/IWAN, native application programming interfaces (APIs) are accessed via remote call adapters or, if necessary, via a consolidating layer providing a Web Service Description Language (WSDL) interface. All such interfaces are used exclusively for internal communication.

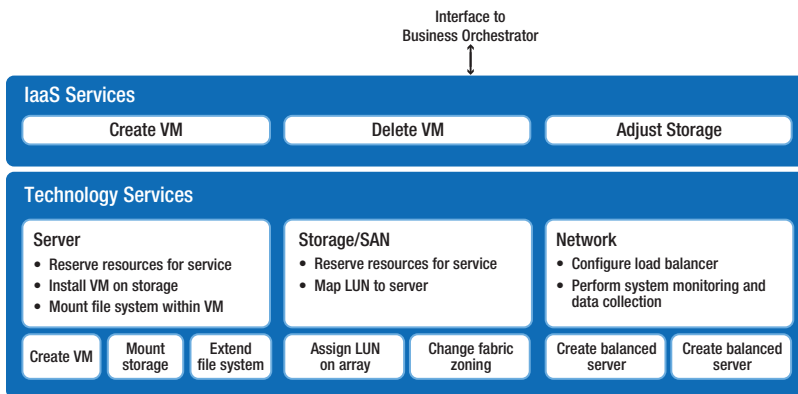
Notwithstanding contract issues, another advantage of this layering is the possibility it provides for using low-level automation independent from the cloud management. Because IaaS starts using the same technologies as used for the BMW legacy infrastructure, IT-i can develop low-level technological components synchronously.

In terms of reusability, support of automation methods, synchronized release cycles between automation and technology, and availability of skills, the low-level technology automation of the IaaS is independent from the cloud operational model and, ideally, is native to the technology. Modifications within the technologies may require changes or extensions to existing automation, but do not affect the stability of the interface to the higher levels. New technologies introduce their own automation and are connected to the technology services without requiring changes to the IaaS service layer.

While the technology services are aware of the lower-level technologies, they already combine single automation steps to a defined service. Typically, these technology services have a single technology as their scope and may require deliverables from other technology clusters. Such deliverables must be available so that the clusters can use the automation.

The IaaS service layer schedules and orchestrates the services from different technology clusters by calling their subservices (see Figure 9). It also communicates to the Business Orchestrator.

FIGURE 9: EXAMPLES OF AUTOMATION LEVELS WITHIN THE IAAS



The dependencies between the different layers can be configured via runbooks and may therefore change over time. In any case, a set of core services are necessary.

For the first version of IaaS, BMW developed a framework that is based on the Apache MQ as an enterprise message bus and that communicates with the subtechnologies via WSDL (XML-based web services). Using this method members of IT-i can implement a strict layering of services and, therefore, responsibilities and can reuse the different automation layers for its legacy environment.

### PaaS Web

#### Business and Technical Design Objectives

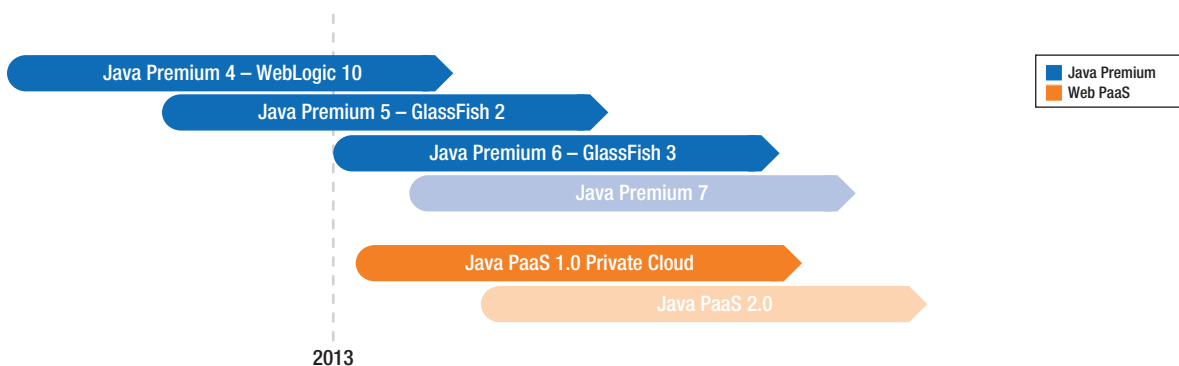
For a sustainable approach to software development in the PaaS Web component of its private cloud architecture, BMW uses the Java platform. As part of this approach BMW bases web containers (also known as servlet containers) on specifications, rather than on products. In addition, the company consistently aligns its web infrastructure solutions and services with established and open industry standards for enterprises in its sector. This approach results in the further decoupling of applications from infrastructure and the reduction of dependencies on specific web application servers.

BMW also calls for all web application containers to be identical and for more than 50 percent of the applications to run in the Java PaaS solution. Based on a high level of standardization the solution will be less open and flexible, but also less complex. This approach enables new features and advantages that can benefit all owners of applications that do not yet use the cloud services, for example:

- The **application admin user interface (self service)** available through the BMW Java PaaS solution simplifies administration of the Java environment, ordering, and patch and release management.
- The solution provides **fully automated application deployment and provisioning**, which enables provisioning in minutes instead of days, so that environments can be added and removed or scaled up and down as needed, for a vast reduction in idle time.
- The solution provides **zero-downtime functionality**, through an infrastructure that minimizes outages and visible changes and supports new application releases without downtime or session loss.

By integrating such Java PaaS solutions into the larger BMW infrastructure, the company can avoid having to develop or implement BMW-specific Java solutions (including frameworks). By aligning with Java standards and minimizing special requirements, BMW will enable the use of new cloud technologies, models, and features. It also will benefit from flexibility and easier handling, for cost savings in development, maintenance, and operations. Figure 10 depicts the alignment of the private cloud strategy at BMW with Java platform development.

**FIGURE 10: PAAS WEB AS ADDITIONAL BMW INFRASTRUCTURE SOLUTION**



BMW also works hard to achieve coherence between its cloud infrastructure and application development, for reducing application complexity; increasing application conformity, portability, stability, and robustness; avoiding vendor dependencies; and supporting the easy exchange of middleware components and other modules. As such, the company will rely on stringent guidelines for application development.

Use of the Java EE 6 web profile is part of one such guideline, as its security and web services extensions make it an excellent fit for reducing the complexity of most web applications as well as for reducing their runtime in the cloud infrastructure. Here is a high-level look at the other guidelines:

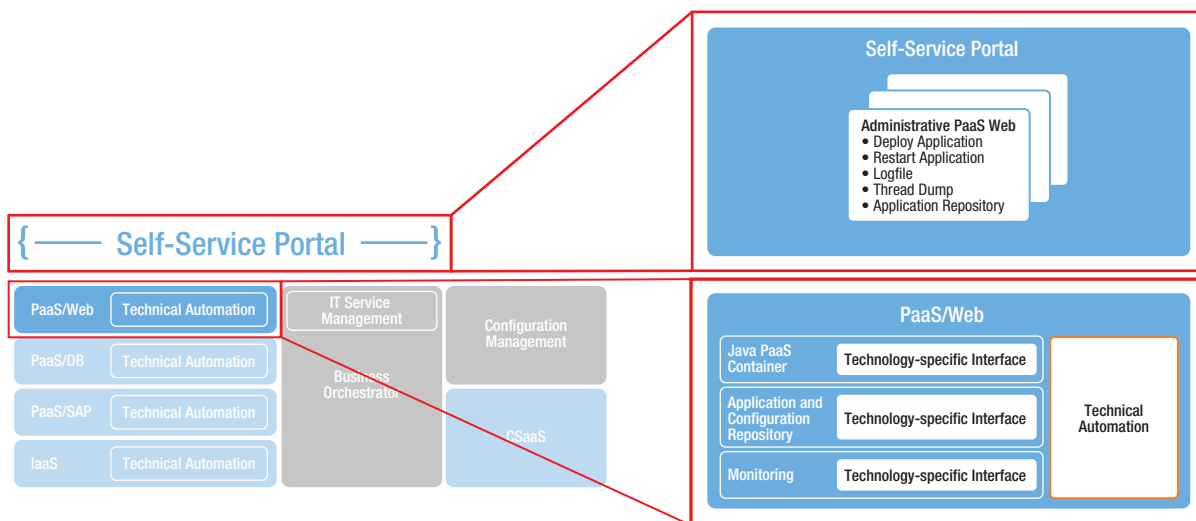
- **Keep it simple.** Choose the easiest solution available to avoid unnecessary complexity and to boost portability and robustness.
- **Use widely adopted, vendor-independent standards,** particularly for APIs. For Java SE and JEE, for example, use only BMW-approved APIs. Avoid the use of proprietary APIs in the runtime environment.
- **Avoid making special assumptions** regarding the runtime environment and depending on special characteristics hardware, operating systems, and application servers, to give just a few examples.
- **Avoid direct use of resources.** Instead, use standardized interfaces that enable the underlying PaaS runtime environment to control the resources.
- **Avoid potentially harmful third-party frameworks,** which may compromise stability and conformity to standards as well as violate PaaS runtime restrictions. Leverage approved Java SE and EE features before seeking alternatives.
- **Make fault-tolerance a priority.** Build applications to be robust in the event of temporary infrastructure problems.

Please note that the application guidelines cover rules on a technical implementation level that are beyond the scope of this white paper.

TECHNICAL APPROACH

Figure 11 illustrates the build-up of PaaS Web and its integration into the architecture of the BMW private cloud. It shows the offering of product-based containers based on Java EE5 as implemented by specific products, with product-independent but BMW-specific operations and business and technical automation. The service offerings with containers will be based on BMW-standard specifications and will enable a decoupling of applications and infrastructure.

FIGURE 11: PAAS WEB ARCHITECTURAL OVERVIEW



## Open Data Center Alliance: The Private Cloud Strategy at BMW

BMW based the interface between PaaS Web and the Business Orchestrator on the Simple Object Access Protocol (SOAP) and achieved technical automation with a Java application developed internally because, at the time, the required functionality was not available on the market. BMW implemented the technical interface for the various modules (e.g., monitoring, Java container, repository) using a variety of scripting languages.

Within the Business Orchestrator, a typical provisioning runbook for PaaS Web could include such tasks as the following:

- Provisioning VMs and load balancers, including SSL certificates (IaaS).
- Loading the application and configuration files from the repository (PaaS Web).
- Starting the application server (PaaS Web).
- Monitoring the Web application container (PaaS Web).

The modularity in the overall PaaS Web architecture allows for the exchange of specific technical automation solutions (e.g., storage provisioning) without the need for adjustment of runbooks or other technical automation of middleware components. This is the major advantage of having a central component that will act as the main interface to all connected automation and configuration systems.

For Java PaaS version 1, developers and application operation teams will handle and manage all administration with user-friendly tools in the SSP (see Figure 11). There will be no need for direct access to the VMs. Consequently, new deployments and middleware or infrastructure patching can be performed with relative ease and comparatively little effort.

## PaaS DB

### Business and Technical Design Objectives

As with PaaS Web, BMW has also established stringent business and technical design objectives for PaaS DB:

- **Rapid database commissioning and decommissioning**, with an interim target of two or three days and an end target of a single day.
- **High availability**, with a maximum of two planned downtimes yearly, each of which lasts no longer than two hours. (Note that downtime does not include a database switch, for example, during which connections are lost for a maximum of three minutes.)
- **High flexibility**, which means that database service parameters can be changed online without the need for a change request and without downtime, and that application owners can change those parameters and restart the database through the SSP. Similarly, CPU, memory, and other resources can be increased or decreased online without the need for change requests and without downtime.
- **Exchangeability**, which means that database systems can be exchanged through the use of open hardware and software systems as well as through database application standards such as the ISO Standard for SQL:2008 ISO/IEC 9075:2008. Exchangeability also refers to a high level of modularity in the different cloud layers.

### Technical Approach

In the current technical approach to PaaS DB, BMW has selected database systems that can cover a high percentage of current business cases. It will re-evaluate those systems on an ongoing basis to assess their suitability with respect to the company's business and technical design objectives for PaaS DB.

For availability, BMW has implemented mirroring, with two to three replicates, rather than clustering. This approach trades a slight performance advantage for a greater availability advantage and more convenient reporting and testing, as the replicates can be used for those functions as well.

All PaaS DB instances will be documented automatically in the CMDB, which will provide an interface to the inventory databases of the database operation.

One of the most important aspects of PaaS DB is automation, with automation scripts designed to "save," for example, without unexpected behaviors and designed as part of the interface between the SSP and the Business Orchestrator. Automation scripts are vendor-independent, which means that a given script set has the same name and parameters for every database vendor. This approach enables the SSP and the Business Orchestrator to use the interface scripts without requiring changes. Typical automation scripts include backup with parameters, restore with parameters, data import or export with parameters, user granting with parameters, and database creating with parameters.



FIGURE 12: PAAS DB ARCHITECTURAL OVERVIEW

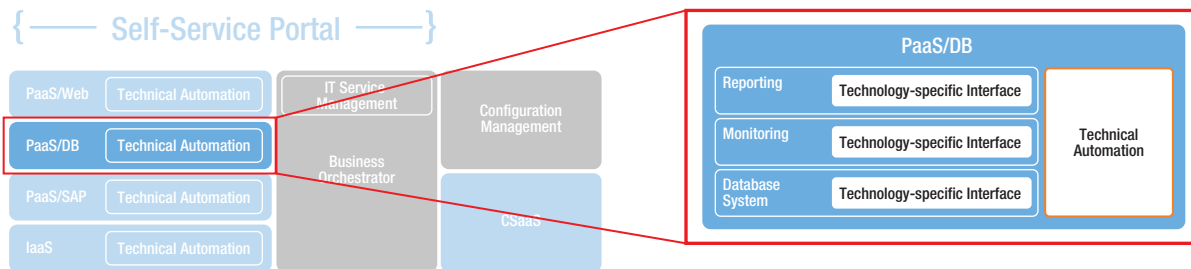


Figure 12 illustrates how the PaaS DB Service is implemented within the layered and modularized architecture of the BMW private cloud.

The Business Orchestrator receives a “Create Database” request from the SSP and through the SSP Web interface. It uses XML files to transfer the necessary parameters and to define the requested service runbook. The Orchestrator acts according to a predefined runbook: It checks to see whether an existing instance is set as a parameter or a new instance must be created. If there is an existing instance, the request goes directly to technical automation and the Business Orchestrator communicates with the CMDB in order to transfer the data in the request into the CMDB.

If a new instance must be created, the Business Orchestrator does the following:

1. Orders a technical user for the instance at the Identity Management Service.
2. Orders two virtual servers from IaaS.
3. Routes the request with parameters directly to technical automation.
4. Fills CMDB with data in the request.

Technical automation receives the “Create Database” request from the Orchestrator through a Web interface (XML file).

If there is an existing instance, technical automation starts a “Create DB” runbook by doing the following:

1. Creates database in the named instance.
2. Fills inventory database with all technical data.
3. Reports success back to the Business Orchestrator.

If a new instance must be created, technical automation invokes a “Create Instance” runbook, as follows:

1. Installs software package on VM 1.
2. Installs software package on VM 2.
3. Creates instance on VM 1.
4. Creates instance on VM 2.
5. Creates replication.
6. Fills inventory database with all technical data.

Then, technical automation starts a “Create DB” runbook as shown in the preceding section.

### PaaS SAP

#### Business and Technical Design Objectives

Even though SAP platform services are not typically candidates for cloud computing, they are part of the BMW private cloud strategy because BMW has identified them as central to two of the company's breakthrough objectives for IT-i. SAP platform services are central to the first objective, targeting zero downtime, because the company has extensive installations of business-critical applications based on SAP.

As of this writing, the BMW Group operates more than 250 SAP systems (about 60 of them in production), fully standardized on the Linux operating system and with a full virtualization of SAP development systems and SAP application servers. Thus, to continue realizing the business and technology benefits of these installed solutions while pursuing a private cloud strategy based largely on vendor independency, the IT-i team faces two challenges:

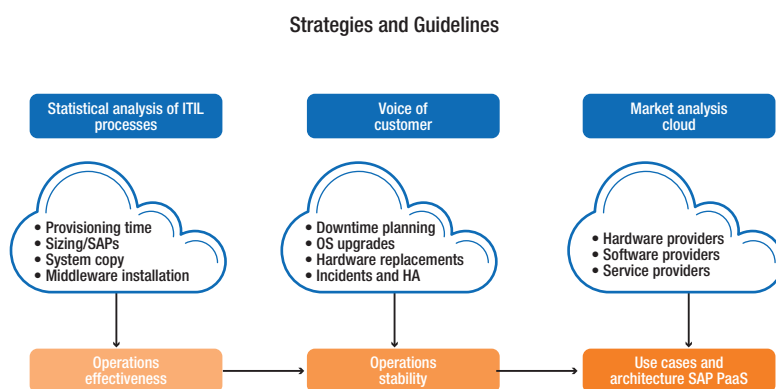
- Ensuring that a future private cloud solution that includes SAP will meet the company's business requirements in an efficient manner.
- Deriving a technical solution to cover these business requirements while preserving architectural flexibility on top of existing (ITIL) processes and infrastructure and avoiding vendor lock-in.

To address the first challenge, team members followed an approach based on the Six Sigma business management strategy, involving statistical analyses and direct interviews with IT and business users of SAP database and infrastructure services at BMW. Through these statistical analyses, team members pursued fact-driven transparency of the daily service-providing business that is largely represented within an IT organization by ITIL processes. As part of this activity, they performed extensive analyses on provisioning and on change and incident management.

While statistical analyses can deliver highly valuable information regarding automation and design of future self-services, they may fail to reveal valuable information regarding business requirements (use cases) and, as a result, lead to suboptimal resource allocation. For example, purely statistical data regarding incident management can result in an emphasis on unplanned downtimes, when in fact planned downtimes are a more significant issue for business users because of increasing change-coordination efforts. That is why team members are conducting thorough discussions with customers of the SAP infrastructure and basic services, in addition to performing extensive statistical analyses.

Figure 13 illustrates the results to date of these analyses and interviews, specifically in the focus areas of SAP operations effectiveness and SAP operations stability.

**FIGURE 13: PAAS SAP USE CASE AND ARCHITECTURE DEVELOPMENT**



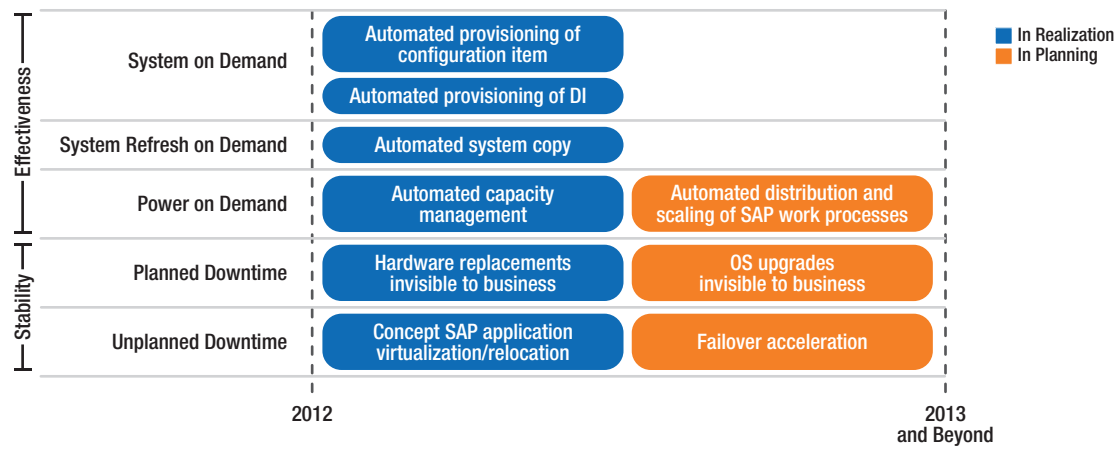
In further interviews with major players in the cloud market, team members decided on the PaaS SAP use cases, including related system architecture, to be implemented in the delivery of the BMW private cloud. Figure 14 provides an overview of the planned use cases.

As illustrated in Figure 14, during much of 2012 team members focused primarily on improving operational effectiveness and, as of this writing, are continuing this work. Specifically, they are pursuing a reduction in provisioning time and effort for SAP central instances, including middleware components, from 20 to 30 working days down to just one day.

Operations stability allowing for the reduction of planned and unplanned downtimes comprises the further rollout of virtualization technologies toward integration and production systems, while revising the existing high-availability configurations based on cloud concepts and technologies. The conception and implementation of the stability use cases will be more time-consuming as numerous input factors have to be considered in order to avoid a negative impact on existing or future production systems. Nevertheless the use-case for automated capacity management is seen as an important short-term enabler for operations stability. BMW will share more on its Zero Business Impact focus in future whitepapers.

The approach of the IT-i project team to the second challenge surrounding PaaS SAP—deriving a technical solution to cover business requirements while preserving architectural flexibility on top of existing (ITIL) processes and infrastructure and avoiding vendor lock-in—is discussed in the following section.

**FIGURE 14: EXAMPLE PAAS SAP USE CASES**



## Open Data Center Alliance: The Private Cloud Strategy at BMW

### TECHNICAL APPROACH

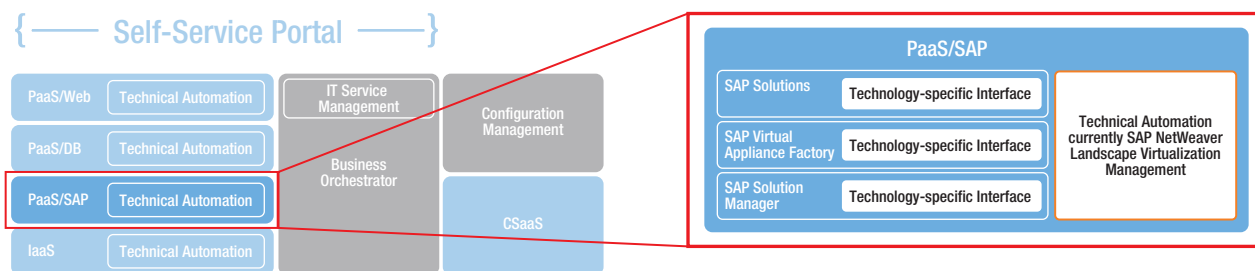
Because BMW scheduled an accelerated implementation of its private cloud strategy, members of the IT-i project team determined the best way to implement the initial technical automation for SaaS SAP was through a product offering pre-implemented use cases, provisioning, and refresh. That product is the SAP NetWeaver Landscape Virtualization Management (LVM). See Figure 15 for more on the role of LVM.

Because LVM is based, by necessity, on a more vertical, SAP-centric architecture, team members modified it to fit the fundamental approach to cloud computing at BMW: horizontally layered and based on diverse technologies. In ongoing work, team members are integrating LVM into existing ITIL processes and related tool structures.

To do this, a team comprising BMW experts on IaaS, PaaS, and orchestration and SAP experts on LVM are designing the PaaS SAP runbooks. In conjunction with the Business Orchestrator, these runbooks handle overall cross-organizational and cross-technology workflow as well as service calls to the IaaS (IWAN) layer.

One of the guiding technical principles used by team members in their design of the PaaS SAP runbooks is the use of clearly defined web-service calls from LVM into the IaaS (IWAN) layer via the Business Orchestrator, rather than through the storage and infrastructure libraries delivered by SAP or the respective storage vendors.

**FIGURE 15: PAAS SAP AND LVM ARCHITECTURAL OVERVIEW**



The technical approach followed by the IT-i team for implementing PaaS SAP is designed to deliver a clearly layered architecture and, with it, the following benefits:

- **Modularity and reusability** of IaaS services across runbooks and application platforms. For example, the runbook for the SAP system-refresh use case is simply a combination of runbook modules from other use cases, and all IaaS storage operations (e.g., “Create Mount Points,” “Attach Storage”) can be used by PaaS DB as well as by PaaS SAP.
- **Full transparency and control** of the organizational and technical workflow.
- **Full integration** into the company’s ITIL change-management process.
- **Vendor independency**, such that clear layers and well-defined reusable service calls to the IaaS layer as well as to the business orchestration layer (Business Orchestrator) will facilitate future replacement of technical automation tools, including open-source solutions.

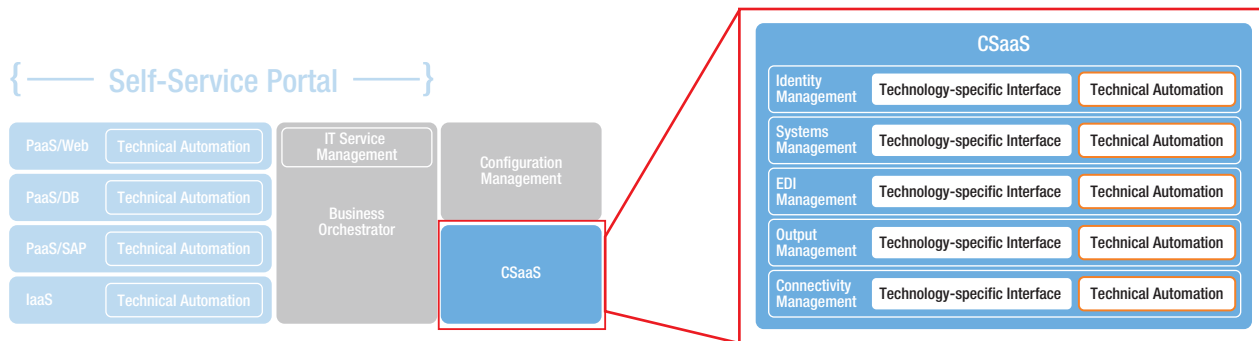
Although the technical approach that delivers a clearly layered architecture carries higher up-front costs than a non-layered approach, BMW has determined that those costs will be easily offset by these mid- and long-term benefits.

### Corporate Software as a Service

Like IaaS or PaaS, CSaaS is a key component of the private cloud strategy at BMW, but it is essentially different from IaaS and PaaS. This is because in the common understanding of cloud computing as well as in that of BMW, CSaaS, despite its name, does not serve as a SaaS. Instead, CSaaS provisions services for the implementation or runtime support of IaaS or PaaS services so as to integrate them into existing corporate solutions at BMW and to enable the future possibility of integrating the corporate solutions into a cloud computing environment.

As illustrated in Figure 16, these services, based largely on existing processes and corporate solutions and invoked by the workflow engine executing the runbooks that create the requested platform, provide for identity management, systems management, EDI management, output management, and connectivity management.

FIGURE 16: CSAAS ARCHITECTURAL OVERVIEW



**Identity management** encompasses the administration of identities and permissions/privileges of people, organizations, and technical objects. Its primary objectives are to provide necessary accounts and authorizations in a standardized, traceable, and efficient manner and to fulfill necessary security requirements for the handling of rights. For example, identity management helps to ensure that rights are granted to identities only when required permissions exist that rights are revoked when they are no longer necessary, and that all such activities are audited.

Identity management also helps to ensure compliance with legal restrictions. In the private cloud strategy at BMW, CSaaS identity management services connect IaaS and PaaS to the company's central identity management system (e.g., for technical identities or certificates). Such services include providing roles and rights to infrastructure and applications and enabling single-sign-on functionality and services to ensure more secure communication and encryption (e.g., PKI). For the exchange of authentication and authorization data, CSaaS identity management uses the Security Assertion Markup Language (SAML) protocol.

Because BMW considers identity management and its corresponding software central to privacy and security, in its cloud computing environment the company will provide that service itself rather than delegate it to a cloud provider. The company's approach to so doing is based on technical strategies and details described in the ODCA Identity Management Interoperability Guide Rev. 1.0.

**Systems management** encompasses services for monitoring infrastructure, middleware, and applications. For its cloud computing environment BMW will monitor the status of services and applications to gather information that is necessary for informing related services, for internal reporting on performance indicators, and for making high-level business process monitoring available. Therefore, systems management will deliver internal and external services information in an integrated event management/business service management layer, with standardized interfaces for event and performance management as well as standard sets of monitors and related automated alerts concerning the operating unit. For the private cloud, standardized interfaces and standard monitors for infrastructure, middleware, and applications are currently available.

**EDI management** provides for the exchange of data between and among the various applications of BMW business partners (mostly ERP systems). It also applies to SAP platforms.

**Output management** as provided by CSaaS is a service enhancement of standard output management functionality. In the BMW private cloud strategy it will be used most commonly to help ensure the processing of business-critical documents between SAP and output channels such as printer, fax, e-mail, and archives.

**Connectivity management** services provide infrastructure solutions (e.g., Connect Direct, MQSeries, EAI) that support the transfer of data and files between applications.

Behind all these services is the general objective of CSaaS, which is that they be provided to all IaaS and PaaS in a standardized and reusable manner and delivered automatically according to the cloud paradigm, and that they support the complete lifecycle of the IaaS and PaaS (creation, modification, decommission). The Business Orchestrator is the workflow engine executing the runbooks which invokes the different services creating the requested platform.

### CONCLUSION

As the world's leading provider of premium products and premium services for individual mobility, the BMW Group has consistently set and met high standards in serving not only external customers, but internal ones as well. Among those internal customers are IT staff members, employees in the business groups, and partners who use the company's IT infrastructure daily to help them access the information they need to perform their jobs and better support the company's corporate mission.

This document describes a private cloud strategy that can be implemented using delivery models that are free of technical and vendor dependencies as well as the need for business downtimes. That implementation will take place in two phases: the first of which focuses exclusively on the private cloud (as described in this document) and the second of which extends the private cloud into a hybrid cloud. BMW has specifically defined its cloud strategy as a long-term initiative with short development cycles and specific short-term objectives. This approach can result in early benefits.

This document pays special attention to the principle of vendor and provider independency, a central component of the company's private cloud strategy. For this, BMW believes that strict modularization is essential, with rigorous layering of platforms and infrastructure, particularly the business orchestration and technical automation. Also essential to achieving this goal are the use of standards, as guidelines for modifying existing products to a highly modularized architecture, and the development of internal expertise, not only for implementing but also for running a cloud service architecture.

In keeping with its commitment to standards in this project, BMW bases its private cloud implementation on several usage models published by the Open Data Center Alliance (ODCA), whose steering committee includes BMW as a founding member. As a result, the company is helping to promote the vision of the Alliance through practical implementations designed to solve real-world business problems faced by enterprise IT organizations today and in the future.

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## ACRONYMS AND TRADE NAMES

<b>API</b>	application programming interface
<b>CMDB</b>	configuration management database
<b>CSaaS</b>	corporate software as a service
<b>IaaS</b>	infrastructure as a service
<b>IT-i</b>	Project for implementing the IT-Infrastructure functional strategy
<b>ITIL</b>	IT Infrastructure Library
<b>ITSM</b>	IT Service Management
<b>IWAN</b>	IaaS wrapper and automation engine
<b>Java SE/JEE</b>	Java Enterprise Edition
<b>LVM</b>	SAP NetWeaver Landscape Virtualization Management
<b>NIST</b>	National Institute of Standards and Technology
<b>PaaS</b>	platform as a service
<b>SSL</b>	Secure Sockets Layer
<b>SSP</b>	self-service portal
<b>VM</b>	virtual machine
<b>VMware</b>	Specific software application for virtualization
<b>WSDL</b>	Web Service Description Language
<b>XEN</b>	Specific software application for virtualization

## **ABOUT BMW AND THE ALLIANCE**

The Open Data Center Alliance is an industry standards organization working actively to shape the future of cloud computing by encouraging the adoption of interoperable standards. For more information, please visit: <http://www.opendatacenteralliance.org>

The BMW Group is a founding member and active participant in the Alliance, and plays a leadership role on the Alliance's Steering Committee. Best practices for the BMW private cloud strategy are being shared in this white paper to help other organizations understand this company's ideas on the most effective ways of planning for and implementing a private cloud environment.