Types of Prefabricated Modular Data Centers

White Paper 165

Revision 2

by Wendy Torell

Executive summary

Data center systems or subsystems that are pre-assembled in a factory are often described with terms like prefabricated, containerized, modular, skid-based, pod-based, mobile, portable, self-contained, all-in-one, and more. There are, however, important distinctions between the various types of factory-built building blocks on the market. This paper proposes standard terminology for categorizing the types of prefabricated modular data centers, defines and compares their key attributes, and provides a framework for choosing the best approach(es) based on business requirements.

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Introduction

Many terms, with varying definitions and scopes, have been used to describe data center systems or subsystems that are pre-assembled in a factory. A partial list includes:

- Containerized
- Self-contained
- Modular
- Prefabricated
- Portable
- Mobile
- Pod (based)
- Skid (based)

These terms create confusion and lead to dysfunctional discussions because they overlap and are ambiguous in meaning.

A prefabricated modular data center is defined here in this paper as a data center that is:

1. made up of at least one pre-engineered, factory-integrated, and pre-tested assembly of subsystems that have traditionally been installed separately onsite
2. mounted on a skid or in an enclosure

While the benefits of this type of approach to data centers is well-documented (such as in White Paper 163, *Prefabricated Power and Cooling Modules for Data Centers*), the lack of a common language and classification system has resulted in confusion over the differences in attributes and applications between them.

This white paper presents a framework for classifying the different types of prefabricated modular data centers, based on three attributes, so that ambiguity is eliminated. Definitions and categories are presented, along with guidance for choosing the right approach(es) for given business requirements. **Figure 1** illustrates the three attributes that, together, define the majority of prefabricated modular data centers.
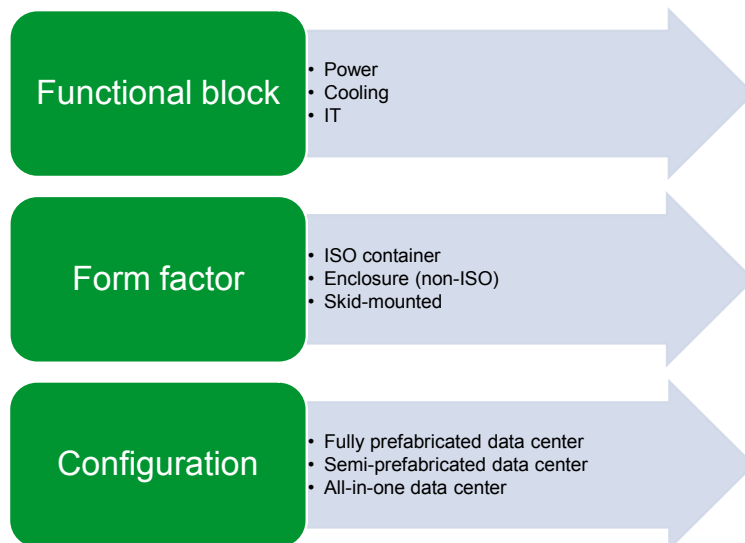
Figure 1

Framework for types of prefabricated data centers

Functional block
- Power
- Cooling
- IT

Form factor
- ISO container
- Enclosure (non-ISO)
- Skid-mounted

Configuration
- Fully prefabricated data center
- Semi-prefabricated data center
- All-in-one data center

Pre-engineered vs. Prefabricated data centers

The terms pre-engineered and prefabricated are sometimes used interchangeably, however there are important distinctions between the two.

A data center that is **pre-engineered** is designed to meet pre-determined performance specifications, and consists of, at minimum, a documented list of materials, system level specifications, and drawings of the integrated system.

A **prefabricated** data center is a data center that is pre-engineered *and* has its systems (hardware & software) pre-assembled, integrated, and tested in a factory environment to shorten deployment timeframe and improve predictability of performance.

A reference design is an example of a system that is pre-engineered but not necessarily prefabricated. A power or cooling facility module is an example of a prefabricated system.

One reason modular data centers are segmented by *functional block* is because data centers may only require a specific resource (just power, just cooling) due to stranded capacity in their existing facility. Another is because different personnel with different skill sets are needed to operate and maintain each (i.e. facilities staff vs. IT staff, mechanical operators vs. electrical operators). And yet another has to do with the physical constraint of the module's foot print. *Form factor* is the second key attribute that distinguishes prefabricated solutions. A form factor may be chosen based on the application (i.e. a data center may be required to be permanently mobile – on wheels – to meet a business need); or it may be constrained by its capacity (i.e. a power system in an ISO enclosure is generally limited to around 500 kW, but a skid-mounted design can support greater capacities).

The prefabricated functional blocks are deployed in various *configurations*. Some prefabricated data centers include a mix of prefabricated modules and traditional or "stick built" systems (such as modular power and cooling with traditional IT space). Others are fully prefabricated, meaning all three functional blocks – power, cooling, and IT – are prefabricated. Lastly, a specific configuration of a fully prefabricated facility is a micro data center, where the power, cooling, and IT co-exist in a single enclosure.

The three attributes – functional block, form factor, and configuration – are further defined and explained in the following sections.

Functional block

The functions of a data center can be broken down into three major categories – the power plant, the cooling plant, and the IT space. Prefabricated data center modules sometimes provide multiple functions (referred to as micro data centers), but often they provide one function of the data center, for the following reasons:

- A prefabricated module may be needed only for a specific resource (just power, just cooling, or just IT space) because of stranded capacity in their existing facility
- A greater IT capacity is needed than what an micro data center module can support, and a single IT space is required (physical space constraint of modules)
- There is a requirement to separate personnel (IT, mechanical, electrical) from a maintenance and operations perspective to reduce human error risks
- An optimized footprint is needed, and function-specific modules can utilize larger capacity components and share clearances to provide a greater kW per square foot or square meter

Power

A prefabricated power module (see **Figure 2**) is designed to provide bulk power to the data center. It may power a modular IT space or a traditional IT space within a building. The typical subsystems within a power facility module are switchgear / switchboards, ATS, UPSs with batteries, transformers, and panelboards. In addition, support systems such as lighting, security, cooling may exist in the module for enclosed form factors. Standby generators are generally a separate module that can be integrated with the power module.

Figure 2

Example of a "Power" functional block

Cooling

Today's data centers use a range of cooling architectures to support the IT space, based on requirements for cost, efficiency, reliability, etc. The physical location (climate) of the data center is also a big driver when determining the optimal approach. Schneider Electric's TradeOff Tool, Cooling Economizer mode PUE Calculator, helps illustrate the energy tradeoffs of the various architectures, and white paper 59, The Different Technologies for Cooling Data Centers, provides further details on the different cooling approaches. At a high level, the typical subsystems within prefabricated cooling modules are shown in **Table 1**.
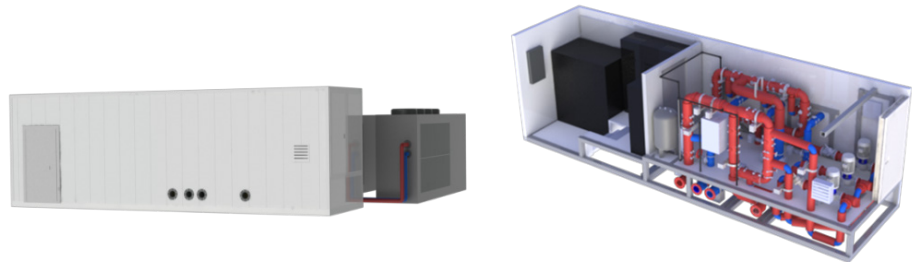
Table 1

Typical subsystems within prefabricated cooling modules

Chiller plant module	DX plant module	Indirect air module	Direct air module
• Air cooled chiller • Pumps / drives • Storage tank • Dry cooler / evaporative cooler	• Air cooled condenser or dry cooler • Pump package	• Air-to-air heat exchanger • Evaporative cooling • DX backup • Fans • Ducts	• Air filters • Evaporative cooling • DX backup • Fans • Ducts

Figure 3 illustrates a hydronics module consisting of pumps, VFDs, management, and connections for an air cooled chiller modular design.

Figure 3

Example of a "Cooling" functional block

IT Space

A prefabricated IT space is one that houses the IT equipment. It also houses the support infrastructure to distribute power and air to those systems, as well as provides a suitable work environment for the IT staff that must operate the space. Typically, such a module incorporates the following subsystems:

- IT racks to hold the IT equipment
- Power distribution units (PDUs)
- Rack PDUs
- Air distribution system (CRAHs, CRACs, air ducts, depending on architecture)
- Humidification / dehumidification system

- Cabling infrastructure / cable management
- Fire detection / protection
- Lights
- Security systems

In addition to having the systems pre-engineered and integrated, having the IT equipment in a module provides the added benefit of being a form of containment, to separate the hot and cold air streams, which is critical to effective and efficient air distribution. **Figure 4** is an example of an IT space module consisting of 10 IT racks and the supporting systems, but other form factors exist that increase the rack capacity.

Figure 4

Example of an "IT Space" functional block

The following is a general rule of thumb when it comes to the cost effectiveness of IT space modules:

The greater the IT density per rack, the more sensible IT space modules are, due to the increase in capacity of each module

Form factor

Prefabricated data centers can take on different form factors – meaning the type of structure, the size, and shape. The form of a particular solution impacts the transportability of it, the placement of it, and its location (inside vs. outside on the ground vs. on a rooftop). The three general forms of prefabricated data center modules are:

- ISO container
- Enclosure
- Skid-mounted

Which form factor or combination of form factors is suitable for a given data center project is based on requirements such as transportability, capacity, scalability, etc. **Table 2** summarizes how each compares in terms of location, placement, and transportation. In addition, the form of the module impacts the capacity of the module, since the specific dimensions of the module constrain the equipment that fits within it. There may also be permitting and tax implications in certain geographies.

These and other attributes are further described in the following sections along with examples to illustrate the form factors.

Table 2

Typical form factors

	Location	Placement	Transportation
ISO container	Generally, outdoors	Mount on concrete pad or other foundation	Standard dimensions; from ship to rail to truck
Enclosure	May be placed indoors or outdoors, depending on weather rating & application	May ship in parts that require assembly onsite; Mount on concrete pad or other foundation	Shipping preparations may be required if in parts; Delivery may require permits, escorts depending on width
Skid-mounted	Generally, indoors	Often placed directly on room floor	Shipping preparations required; Delivery may require permits, escorts depending on width

ISO container

ISO containers are standardized re-usable steel shipping enclosures, designed for safe, efficient, and secure storage and movement of materials from one from of transportation to another (i.e. ship to rail to truck). There are a number of ISO standards that regulate many aspects of freight containers from the classification, dimensions, to corner fitting specifications, to hooks for lifting the containers, to the markings/identification on the container.[1] These standards make transportation and handling simpler and standardized.

Standard footprints of these containers for use as data center modules are: 20 ft x 8 ft (6.10 m x 2.44 m) and 40 ft x 8 ft (12.2 m x 2.44 m). The 20 ft (6.10 m) containers come in a standard height of 8 ft 6 in (2.591 m), and the 40 ft (12.2 m) containers come in either the standard height of 8 ft 6 in (2.591 m) or the "high bay" height of 9 ft 6 in (2.896 m). Generally, the high bay containers are used, as they provide greater flexibility for equipment placement within the module.

Often times, when containers are used as the shell for data center modules, they are modified in the following ways:

- Cut-outs for doors and other mounted equipment
- Equipment installed that hangs off the side or top of container

With these types of modifications, the container may no longer be ISO certified, for example, limiting its ability to be stacked with other containers. However, having the standard footprint of an ISO container makes it simpler to transport, lift, and place than non-standard footprints which tends to reduce installation costs. It is also generally lower in cost to modify a standard shell than to construct one from the ground up.

ISO container modules generally have a practical limit on capacity of around 500 kW for power or cooling plants, and around 200 - 250 kW for an IT space. The IT module capacity constraint is based on the number of IT racks that can fit within the footprint, and there are space tradeoffs with different rack arrangements. For example, if the racks are placed along the back wall to provide a wide cold aisle, the hot aisle may only be accessible through panels or doors from the outside. If the IT racks are placed as a long row in the center, the

"Mobile" modules

Mobility is a benefit of *all* prefabricated module form factors, with ISO containers providing the best transportability; however sometimes a module is designed to be *permanently* mobile, meaning it is designed in a structure that includes wheels and axles.

These permanently mobile modules are often built as all-in-one modules that are used for temporary data center needs such as military applications or sporting events. The figure below illustrates two examples:

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[1] http://www.container-transportation.com/iso-container-standards.html (accessed 9/18/2013)

hot and cold aisle must be narrower. Lastly, if multiple short aisles are used perpendicular to the length of the container, a narrow aisle will be likely to move from row to row. In general, the capacity constraint of the IT modules make them more suitable for smaller data centers. Larger capacity needs would generally steer towards more traditional IT spaces.

Often times, this form factor requires lighting and security, since they are accessed by personnel for operation and maintenance.

Placement of ISO containers usually involves laying slab on grade (concrete pad) outdoors. A crane would be used to lift the container off the truck and onto the pad. When used to supplement capacity in a constrained existing brick and mortar facility, the container(s) are generally placed in close proximity to the perimeter of the building, near the data center they are supporting. Sometimes, a power or IT container is placed indoors in a warehouse environment – in order to protect the personnel from inclement weather during operation & maintenance activities, and to provide added security for their critical systems.

Figure 5 illustrates a power module and a cooling module, both designed with ISO containers and modified to meet the system requirements.

Figure 5

Examples of ISO container form factor

Enclosure

Another form factor, in this paper referred to as "enclosure", is less standard in terms of its dimensions, and therefore does not necessarily meet specific shipping standards like the ISO containers. Enclosures are also commonly referred to as shells, metal houses, and pods.

Relative to ISO containers, transporting and handling costs may be greater; and onsite work may be greater if the structure isn't fully assembled in the factory. For example, a wide enclosure may come in two sections, as **Figure 6** illustrates. Some enclosures, often referred to as modular rooms, are actually constructed in a factory, integrated with the data center equipment, tested and commissioned, and then disassembled and put back together at the customer site, much like a Lego building block kit.

The benefit of this form factor is that it offers more flexibility in terms of the IT capacity it can support as well as the layout of the equipment within the enclosure.

Figure 6

Examples of an IT space enclosure that ships in 2 parts

The majority of enclosures are rated for outdoor use and can be exposed to varying weather conditions, but there are some that are not, and should be installed indoors (i.e. inside a warehouse). Even ones that *are* rated for outdoor conditions may at times be installed indoors for reasons like security, personnel access, or shelter from inclement weather as personnel carry equipment (e.g. servers) to an enclosure. Some enclosures are rooms

where personnel can walk into them[2], for maintenance and operation, while others would be better described as enclosed "systems", where the primary access for personnel is through access panels on the outside of the enclosure (non-walk-in type). **Table 3** summarizes this further categorization of enclosures and provides examples of each.

Table 3

Categories of enclosures and examples

Personnel accessibility	
Indoor, enclosed "system" • **Non-weather proof** • **Personnel access only through access panels on outside of enclosure** X *(No practical examples)*	**Indoor, walk-in enclosure** • **Non-weather proof** • **Personnel have full access within enclosure**
Outdoor, enclosed "system" • **Weather proof for outdoors** • **Personnel access only through access panels on outside of enclosure**	**Outdoor, walk-in enclosure** • **Weather proof for outdoors** • **Personnel have full access within enclosure**

A key driver for choosing an enclosed form factor is the need for the data center subsystems to go outside, or be protected from other elements such as in a hazardous, rugged, or adverse indoor environment. Enclosures that are placed outdoors should have an appropriate level of security to prevent undesirable access (i.e. vandalizing).

Skid-mounted

"A *skid mount* is a method of distributing and storing machinery where the machinery at point of manufacture is permanently mounted in a frame or onto rails or a metal pallet. The equipment can then be easily and securely transported as and used as a unit."[3] **Figure 7** illustrates examples of skid-mounted data center modules.

Figure 7

Examples of skid-mounted form factors for modular data centers

Skid-mounted modules are generally not designed for outdoor use, as components are unprotected from the outdoor elements. Power modules are often in this form factor, as items like switchgear, UPS, transformers, and panelboards don't have a requirement to be outdoors

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[2] An enclosure designed for personnel occupancy, such as the one in **Figure 6** must have lighting, fire protection, security, and a means of egress.

[3] http://en.wikipedia.org/wiki/Skid_mount

like many cooling modules do. There are also fewer capacity constraints due to footprint limitations with skid-mounted power modules (vs. enclosures or ISO containers), enabling them to support greater capacity data centers. So, as the power requirement increases, the skid-mounted approach becomes more sensible. In general, the cost of a prefabricated skid-mounted module is less than the equivalent enclosure design, often by up to 40% less.

Note – skid-mounted systems for *IT spaces* are not logical because it leaves the equipment open to the space rather than separating hot and cold air from the IT equipment.

Configuration

There are several ways the functional blocks can be implemented in a data center. These approaches fall under three main categories:

- **Semi-prefabricated** – A data center comprised of a combination of prefabricated functional blocks *and* traditional "stick built" systems
- **Fully prefabricated** – A data center comprised completely of prefabricated IT, power, and cooling modules
- **Micro** – A data center that is self-contained in a single enclosure, with IT, power, and cooling systems
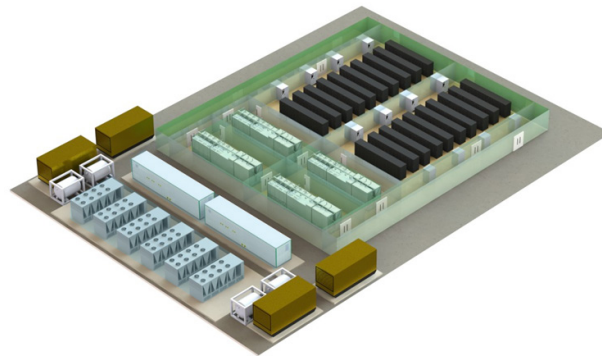
In this section, each configuration is explained, illustrated examples shown, and typical scenarios when each would be deployed are described. Common across all of the configurations is the need to deploy the data center in weeks rather than months or years, the ability to scale the data center if or when needed, and the desire for improved predictability of performance. There are also specific requirements (i.e. around space or cash flow or speed) that also influence the decision.

Semi-prefabricated data centers

A common deployment of prefabricated data centers consists of a mix of prefabricated modules and traditional "stick built" systems. This approach is referred to as "semi-prefabricated". **Figure 8** illustrates an example, where power and cooling modules support a traditional IT space within a building. Other combinations are possible as well, such as a traditional power and cooling plants with IT space modules outside. The specific combination of prefabricated and traditional systems deployed depends on the application and need of the data center. A retrofit project, where a particular resource is capacity constrained, is a common situation where this configuration would be deployed.

Figure 8

Example of semi-prefabricated data center with prefabricated power and cooling modules and traditional IT space

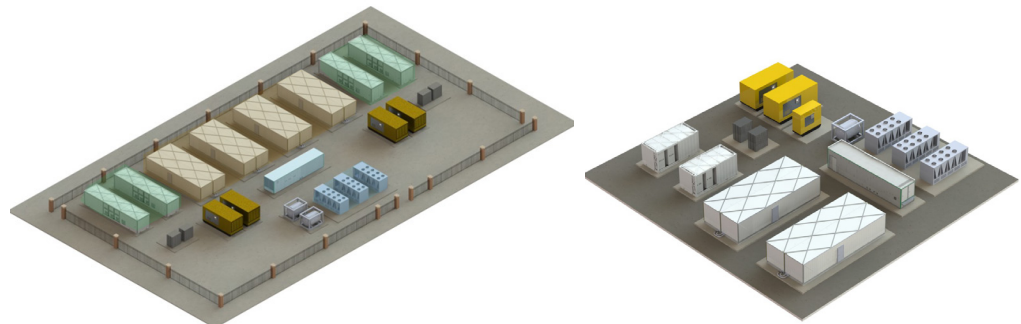**Semi-prefabricated data centers are generally implemented when:**

- An existing data center is out of bulk power capacity and is space constrained in the electrical room, but IT space is available for growth
- An existing data center is out of bulk cooling (heat rejection) capacity, but IT space is available for growth
- An existing data center is out of IT space due to a deployed density that was lower than the design density, and there's plenty of bulk power and cooling capacity
- A new enterprise-class data center has a mixed IT environment, which limits the application of IT modules, but power and cooling modules can be deployed
- A short-term plan is desired to address a gap in capacity and/or reliability until a long-term plan is implemented (at which time the modules would be re-purposed)

Fully prefabricated data centers

In a fully prefabricated data center, modules are implemented for all three functional blocks – providing the bulk power to the data center, providing heat rejection for the data center, and housing the critical IT equipment. **Figure 9** illustrates two examples of fully prefabricated data centers and how the modules may be laid out on the grounds. Deployments vary in form factor, power capacity, technology, and placement (inside or outside), based on the business requirements.

Figure 9

Example layouts of fully prefabricated data centers, based on Schneider Electric reference designs

Fully prefabricated data centers are generally implemented when:

- Scalability of the entire data center is a key business driver
- A multi-tenant data center wants to partition IT spaces by tenant, and requires scalability of power and cooling resources
- A large scale homogenous IT data center wants to deploy equipment in a step and repeat manner
- A high density, high performance computing data center deploys thousands of servers repetitively and wants to scale capacity as the servers scale
- A large disaster recovery data center is needed

Micro data centers

A micro data center is really a specific type of fully prefabricated data center, but is being highlighted as a separate configuration because of its unique characteristic of having all of the components co-located in a single structure. **Figure 10** is an example of a micro data center design. A micro data center is a self contained, secure computing environment that includes all the storage, processing and networking required to run the customer's applications. It ships in single enclosure and include all necessary power, cooling, security, and associated management tools (DCIM). Micro data centers, like all prefabricated types, are assembled and tested in a factory environment.

When multiple functions are combined into a single module, the capacity is generally more limited. A typical limit to an all-in-one (power, cooling, and IT) is approximately 150 kW in a single module such as an ISO container footprint. This limit is higher for modules that arrive in sections and snap together in the field. Beyond 2 or 3 micro data center modules on a site (approximately 500 kW), they become cost prohibitive.

Although these configurations are referred to as an "all-in-one" micro data center, there is often some additional support infrastructure outside of the module, such as the generator or chiller. And yet another variation may exist where only the IT and cooling is combined in a single enclosure, and the UPS is located in a separate module. This is common for fresh air cooling designs, where the IT space is adapted to allow either the fresh air directly in, or with air-to-air heat exchangers to indirectly cool the space.
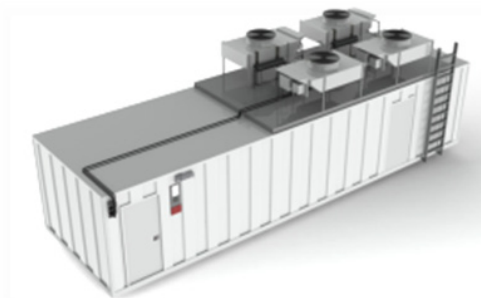
Figure 10

Example of all-in-one prefabricated data center

Micro data centers are generally implemented when:

- A real time or near real time data processing need exists. For example, factory automation (e.g. robots), industrial automation (e.g. cranes), etc.
- A temporary need exists such as for military use, sporting or other temporary event
- Mobility of the data center is important
- A remote branch site requires a small data center, less than 150 kW
- A small data center is in a mixed-use facility and desires ownership and control of all functions
- A data center will be located in a harsh environment like an industrial application, an oil rig, etc.
- A small disaster recovery data center is needed

Conclusion

There are many approaches to implementing prefabricated modular data centers; however, a lack of standard terminology for describing them has made selecting the appropriate type difficult. The optimal configuration, including the right functional blocks and form factors depends on the application and specific business requirements. In some cases, a fully prefabricated data center is the best approach, and for others, a semi-prefabricated approach with a mix of prefabricated modules and traditional systems is best. Understanding the limitations and benefits of each form factor helps ensure the optimal approach is selected. Ultimately, business needs around speed of deployment, scalability, space constraints, capacity, and cash flow drive the decision.

✎ About the author

Wendy Torell is a Senior Research Analyst at Schneider Electric's Data Center Science Center. In this role, she researches best practices in data center design and operation, publishes white papers & articles, and develops TradeOff Tools to help clients optimize the availability, efficiency, and cost of their data center environments. She also consults with clients on availability science approaches and design practices to help them meet their data center performance objectives. She received her Bachelors of Mechanical Engineering degree from Union College in Schenectady, NY and her MBA from University of Rhode Island. Wendy is an ASQ Certified Reliability Engineer.

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