Fundamentals of Managing the Data Center Life Cycle for Owners

White Paper 195

Revision 0

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Executive summary

Just as good genes do not guarantee health and well-being, a good design alone does not ensure a data center is well-built and will remain efficient and available over the course of its life span. For each phase of the data center's life cycle, proper care and action must be taken to continuously meet the business needs of the facility. This paper describes the five phases of the data center life cycle, identifies key tasks and pitfalls, and offers practical advice to facility owners and management.

Introduction

However long a data center owner requires their facility to last; the physical infrastructure systems are expected to continuously live up to the facility design's performance specifications even as business and IT requirements change. Management's understanding of the data center life cycle phases and their interconnectedness helps ensure this happens. Understanding the bigger picture – what occurs in each of the phases, what the key management tasks are, what pitfalls exist, and how one phase impacts the next – can help organizations achieve their data center's cost, speed of deployment, availability, and efficiency goals. This paper seeks to provide data center owners and managers with this understanding.

Figure 1 shows the data center life cycle being composed of five fundamental phases: plan, design, build, operate, and assess. This view of the life cycle is applicable to new data center builds as well as to retrofit and consolidation projects. The life cycle of a project, it should be noted, would be represented in its entirety by only the plan, design, and build phases.

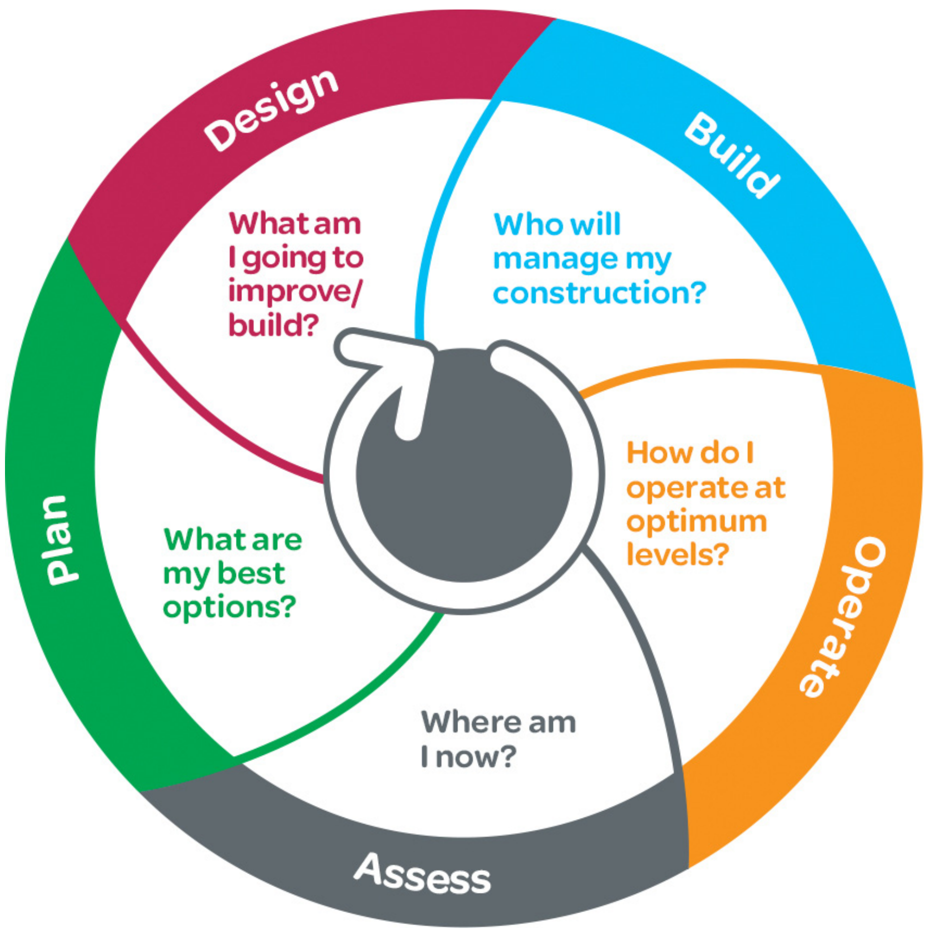


Figure 1

The data center life cycle contains 5 different phases

Plan phase

The plan[1] phase, often referred to as "programming", is the first phase in the overall data center (or project) life cycle. Although it should be the shortest and least expensive of all of

[1] In this paper, only system planning is covered. System planning refers to the power, cooling, racks, and other support infrastructure systems. Planning related to the IT equipment is not discussed here.

the phases, it has the potential for having the greatest impact on both the costs and capabilities of the data center. Organized and managed properly, data center projects will go more smoothly and quickly with less surprises occurring later in the design and build phases that often result in costly delays, large numbers of design iterations, and rework. Handled well, this early planning phase can take as little as a few weeks. Managed poorly this phase can last for months and negatively impact the length of subsequent phases as well.

In this phase it is typically the owner's Facilities and IT departments, their executives, the CFO, and perhaps a real estate group within the company who have a series of meetings to begin to determine what it is they want to build in the project. **This planning phase should determine the key project parameters of the physical system to be created (system concept), site selection, and the project process that will determine them.**

Ideal project process[2]

Successful execution of a project depends in large part upon the process that pilots it through development and realization, from concept to commissioning. A major problem common to many data center projects is wasted time, wasted money, or defects due to flaws in the process – dropped handoffs, ambiguous responsibility, mis-informed decisions, and other errors of communication or execution. This is not necessarily due to flaws in the activity of the various parties to the process – the end user, the hardware provider(s), the design engineers – but rather to the lack of an overarching, shared process guiding all parties as a team, clarifying responsibilities and communication.

To avoid these problems, a formal, standardized, and documented process should be used. White Paper 140, "Data Center Projects: Standardized Process", offers a detailed definition and description of such a process. Regardless of the particular methodology used, the process must conduct the project efficiently, reliably, and understandably, with safeguards in place to eliminate problems such as missed handoffs, ambiguous responsibility, and lost information. The process should detail and be clear about who the key stakeholders are and who should be involved in making each decision and milestone approval. It should include strategies for management of unplanned occurrences such as project changes and defects. It should be modular and configurable so it can be adapted to projects of different types and sizes.

A standardized process that meets the above general requirements will have the following characteristics:

- Every activity necessary for completion of the project is included in the process.
- Each step has clearly defined inputs and outputs.
- Every output produced is either the input to another step, or is a final output of the project. No effort is wasted on extraneous outputs that do not contribute to the progress or ultimate outcome of the project.
- Every step of the process has clearly assigned ownership responsibility, so there is no "dropping the ball" due to unassigned or ambiguous ownership of steps.
- There are no "cracks" or dead space between steps – every step is linked to prerequisite and subsequent steps by its inputs and outputs. Once a step has received all its inputs, it can complete its tasks and make its outputs available to other steps that depend on them.
- There are special "asynchronous" functions that remain on standby during the course of the project, to systematically deal with unplanned changes or defect correction.
- Steps can be deleted to configure the process appropriately for the project at hand.

> How Schneider Electric uses this project process

The process described in White Paper 140 was developed by Schneider Electric as a best-practice blueprint for data center physical infrastructure projects.

Schneider Electric itself follows a similar version of this process, internally, when it becomes involved in a customer project (as a vendor of physical infrastructure products and services). Schneider Electric 's internal process includes additional vendor-related activities – risk assessment, order fulfillment, invoicing, and so on – but it also includes every customer-side step shown in this paper, to make sure that all are accounted for and executed, no matter who "owns" them.

Some process elements – or the whole process – are offered by Schneider Electric as services to customers who wish to hand off some or all responsibility. Regardless of who actually performs which steps (customer, Schneider Electric , or third party provider) Schneider Electric 's internal version of the process always includes tracking the ownership and completion of every step, to ensure that everything gets done.

[2] This section is largely an excerpt from White Paper 140, "Data Center Projects; Standardized Process"

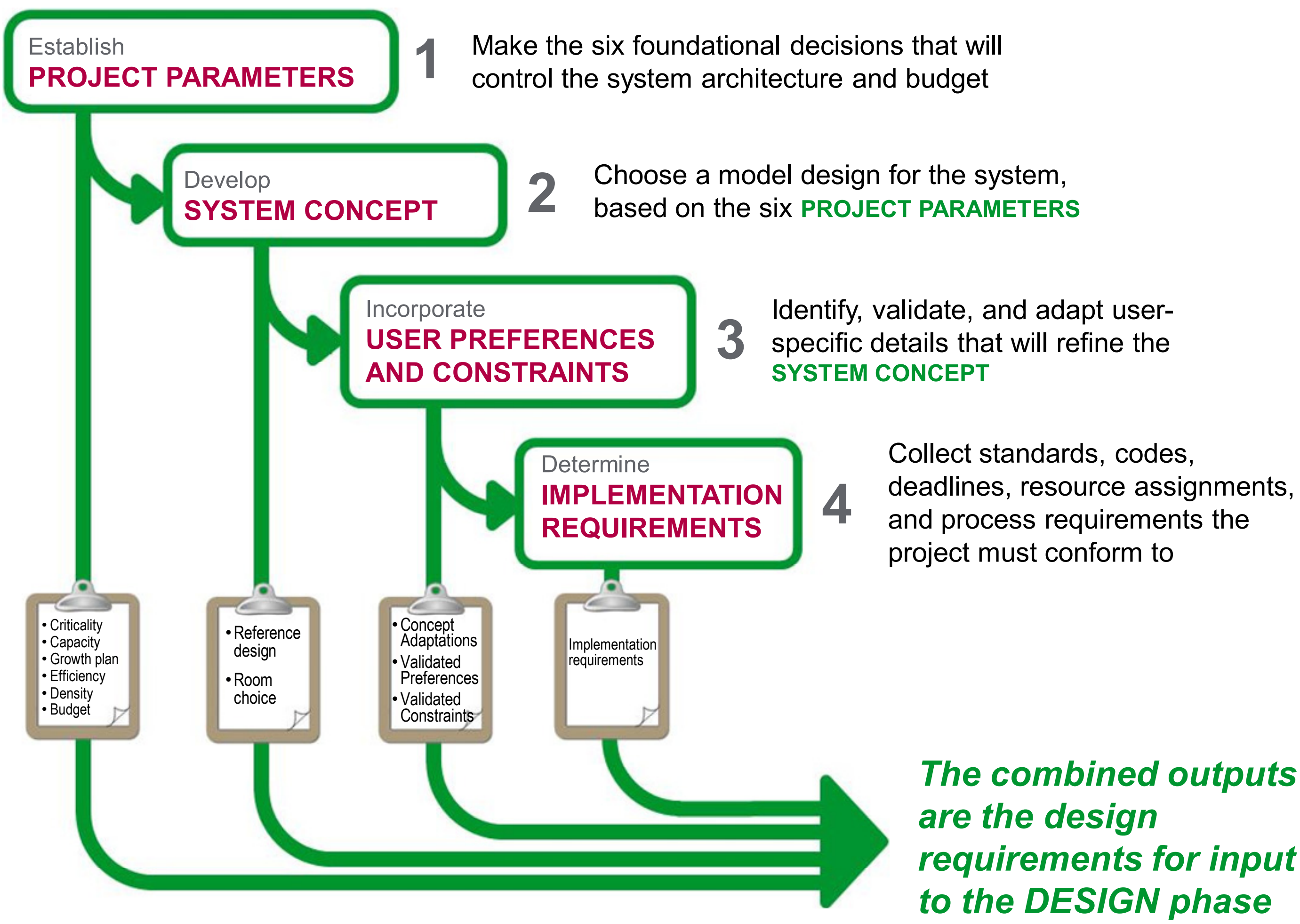
- A Web-based tracking and status system is accessible to all stakeholders (both the customer and any parties providing project services), for shared documentation, data, and reports.

System concept

The principal output of the plan phase should be a high level description of the system (a system concept) to be built including validated user preferences and constraints, as well as any standards, codes, resource assignments, deadlines, and process requirements that the project must conform to. This validated and agreed upon package of information (design requirements) becomes the input for the design phase. White paper 142, "Data Center Projects: System Planning", defines and describes a planning sequence that properly develops this set of inputs for the design phase. The planning sequence is the logical flow of thought, activity, and data that transforms the initial project idea into a compact set of requirements and documents that should control the performance and cost of the built data center. In Schneider Electric's implementation of the standardized project process mentioned above, system planning is sequenced into four tasks that take place during the plan phase of the project as illustrated in **Figure 2**.

Figure 2

The four tasks of the "system planning sequence"



> **Common planning mistakes**
>
> **1. Focus on CAPEX and not TCO** – system design choices will impact both capital and operating expenses, so be aware of both
>
> **2. Poor cost-to-build estimate** – common cause of schedule slip and design re-iteration. Work closely with design team and include contractor to ensure accurate cost estimates; understand TCO, not just CAPEX
>
> **3. Improper design criteria** – not understanding the cost/time impacts of design choices leads to waste and re-design
>
> **4. Choosing site before design criteria** – design requirements will drive suitability of a given site
>
> **5. Planning space before design criteria** – power density specification should create the space specification
>
> **6. Designing into a dead end** – use flexible, modular designs to protect against future uncertainty
>
> **7. Misunderstanding PUE** – leads to unnecessary CAPEX expense
>
> **8. Misunderstanding LEED** – can upset budgets and schedule
>
> **9. Overcomplicated designs** – leads to expense waste and possibly lower reliability
>
> For more information see white paper 145, "The Top 9 Mistakes in Data Center Planning".

The planning of projects is often a challenge for many organizations. Plans are often poorly communicated among the various business stakeholders within the organization. Decision makers may be presented with proposals that are described in excruciating technical detail, yet still appear to lack the information they need to make good business decisions. Seemingly small upfront changes in plans can have major cost consequences downstream when the data center enters the construction / build stage. The planning and approval process can consume a significant part of the calendar time of a project, and it is common that unwelcome surprises or changes occur late in the planning process, causing planning rework that results in significant delay in project completion.

Our experience with many data center projects suggests that many of these problems can be avoided if…

- The right decision makers are given the right information in the right sequence
- Focus is exclusively on ensuring a shared understanding and eventual consensus on key project parameters: criticality, capacity, growth plan, efficiency, density, and budget
- Detailed design work is avoided until validated and agreed upon design requirements are in hand signaling the end of the plan phase

White paper 142, "Data Center Projects; System Planning", details how to make this happen.

To ensure the validity and usefulness of the design requirements package described above in the design phase - where detailed design work is done to create buildable designs - it is important that design engineers (or consulting engineering firms) are involved in the early planning phase. They can technically validate design assumptions and choices early and, thereby, reduce or avoid rework and numerous design iterations that lead to wasted time, effort, and money. Construction consultants can also be helpful in this stage by reviewing the key project parameters in the context of structural requirements which will help ensure total project cost estimations are more accurate and also further validate these early project choices.

Particularly if an engineering firm is not yet involved in the project, reference designs should be used as models of system concepts to aid in making rapid comparisons and trade-off calculations during this early planning phase. Offered by some vendors, a data center reference design is a validated and documented high level plan for how the physical infrastructure systems are to be engineered, configured, and laid out, as well as for describing which specific components are used. Being pre-engineered and based on previous experience (i.e., they have been validated to work); reference designs are a valid and reliable way to develop a system concept that encompasses the key project parameters agreed upon by stakeholders. See white paper 147, "Advantages of Using a Reference Design" for more information.

Site selection

Only after the system concept has been determined and agreed on, should project teams begin evaluating sites. The problem with selecting a site too early is that the site selected may very well end up not meeting the design requirements of the data center that is eventually designed. When evaluating an existing or new site, consider all risks to availability and its financial benefits. Each site has risks related to geography (e.g., tornadoes, hurricanes, earthquakes, etc), the local site conditions (e.g., labor skills, municipal infrastructure, taxes), and the building itself (e.g., age of building, types of loads running). Key financial considerations include energy costs, tax preferences/incentives, and labor costs. To learn more about how to select a data center site, see white paper 81, "Site Selection for Mission Critical Facilities".

Design phase

This next phase of the data center life cycle involves the detailed design work required to translate the plan phase outputs (**Figure 2**) into detailed, site-specific schematics and buildable construction documents (drawings and specifications). These documents are stamped and approved by consulting firm engineers, approved by the owner, and ultimately used for permitting by the governmental authorities-having-jurisdiction (AHJs). It is also during this phase that construction contractors are evaluated and selected. In a well-managed "design/build" model (see **sidebar**) this phase can take about 4-6 weeks. In a well-managed "design/bid/build" model, this phase will take about 8-10 weeks due to the time required for the bidding process and the inability to start construction before drawings are finalized. What specifically happens, when, how long it takes, and who is involved in this phase will vary depending on many factors including the type of construction delivery method used (see **sidebar**), size/scope of the project, as well as the particular needs, preferences, knowledge, and skills the data center project team has. But, at a high level, **Figure 3** illustrates what typically occurs during the design phase for a new data center project.

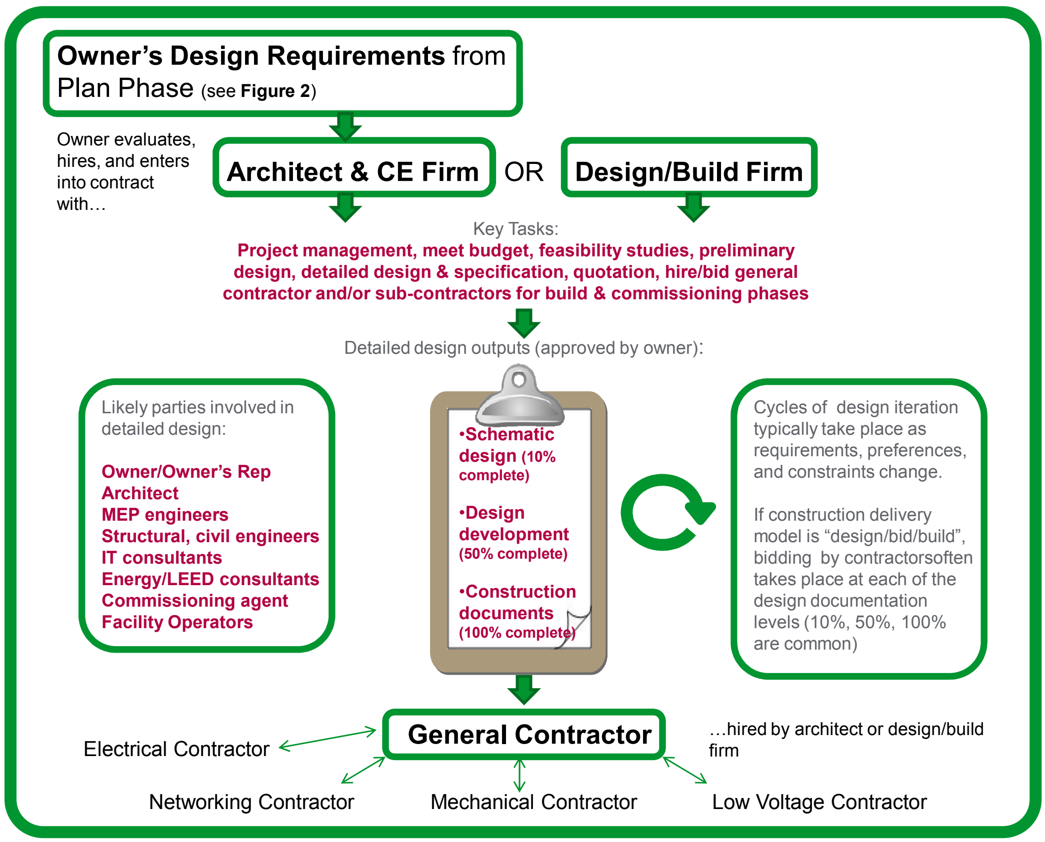


Figure 3

This shows a typical, high level overview of what happens in the design phase and the eventual transition to the build phase. The arrows represent the flow of information from its starting point as high level design parameters down to detailed, stamped & approved construction documents ready for use by the general contractor and their sub-contractors.

The owner or their representative typically hires an architect who in turn hires a consulting engineering (CE) firm (if one is not already on staff or call) to begin to translate the high level owner's requirements into detailed design documents. Alternatively, there are "design/build" firms that offer architectural, mechanical-electrical power (MEP) engineering, structural and other related services under one company's umbrella. Some of these all-in-one firms who specialize in data center projects may also offer commissioning, facility operations, energy management and even construction management services. Know that architects, consulting engineering, and design/build firms vary widely in terms of their scope, capabilities, and experience. In some cases, these firms will sub-contract out elements of the statement of work (SOW, the record of the work to be done) to other firms who might have an expertise or capability the SOW owner (i.e., the firm) does not.

> ## Construction delivery models
>
> In the data center industry, two types of models are most common:
>
> **"Design/Bid/Build"**
> Traditional approach where contractors bid during or throughout design development, the lowest priced responsible bidder who meets requirements is selected, and construction begins.
>
> **PROs:**
> Possibly lower cost (if design change orders are well-controlled)
>
> Typically presented with more choices from more vendors for a given design
>
> **CONs:**
> Bid process can add months to project schedule
>
> **"Design/Build"**
> Owner or architect hires one team who is responsible for both design and construction. Selection is based on merits and price. Price is guaranteed and change orders typically not allowed by contractor.
>
> **PROs:**
> Shortens schedule by months by eliminating time needed for bidding process and by starting construction in parallel with design documentation development
>
> Owner is more likely to get the exact equipment, systems, and design they specified
>
> Enables early involvement in design by contractors which possibly reduces risk and the number of design iterations
>
> Fosters close cooperation between designers and contractors
>
> **CONs:**
> Likely not the lowest cost

Also note that this white paper gives a general, typical description of the design and construction phases. There are many possible variants of this process. For example, larger end users may have a dedicated real estate or facilities/construction services group that manages the architect, CE firm, and the general contractor. Some companies may elect to hire a construction manager specifically to perform this function. Other times a construction manager may also act as the constructor and work with the data center owner to hire and manage both the design and construction teams (sub-contractors).

As shown in **Figure 3**, in a "design/bid/build" construction delivery (see **sidebar**) model, construction general contractors and sub-contractors are chosen through a process of bidding at each of the design documentation completion levels. Although this process is typically owned and managed by either the architect or design firm, the owner should be involved and have final approval on firm and contractor selections.

When selecting a firm or contractor, it is critical for the owner to have a clear understanding of who they are and how it matches up to the owner's needs and preferences. As an owner, consider these questions when making or approving choice of firms or contractors:

- How do partners and previous clients regard them?
- Is local, on-site support required or can the firm be located remotely?
- Are they knowledgeable about local code requirements and other regulations?
- How much experience do they have designing/building data centers? And does that experience match the complexity of the project?
- What services do they offer and do they match the needs of the project?
- Although a firm may offer many types of services, are they necessarily the best (or sufficient) for what is needed for a given service in terms of capability?
- Are the skills/resources available internally to manage the project or must the firm provide that service (or should a separate construction manager be hired)?
- Are they good listeners? Are they willing to design to your needs and preferences? Or are they more inclined to simply use designs they prefer or have done in the past? (Re-use of proven designs can be beneficial, but only if those designs fit your validated requirements.)

Unfortunately, it is common to go through multiple design iterations as requirements, preferences, and constraints change or surprises occur. If the early planning phase is managed properly as described above, these costly, time-consuming iterations will be minimized. A key part of making this process work is having the right people involved, at the right time, and focused on the right things. Throughout the planning and design phases it is important that the right people are involved during the detailed design phase to ensure all stakeholders' expectations, agreements, and requirements are being met. **Table 1** below lists those people and describes what their principle roles are in the process.

An important tool for ensuring the "right people are involved, at the right time, and focused on the right things" is the owner's contract with the architect or design/build firm (and/or with the construction manager if one is used). This contract defines and documents key stakeholders' roles and responsibilities by phase, defines compensation and insurance requirements, describes the cost of work, dispute resolution methods, change order process and limitations, and termination grounds and processes. The scope of the contract should span both the design and construction phases. A good contract memorializes the proper relationships that foster trust and cooperation between parties. A good contract will incent parties to work together and ultimately promote and protect the owner's best interests throughout the project. Parties should write and sign this contract before detailed design work begins.

Table 1

Key project participants for plan and design phases

Project Participants	Principle role in Plan/Design phases for physical infrastructure systems
Owner (or Owner's Rep)	Define and agree on the key project parameters that drive the design: criticality, capacity, growth plan, density, efficiency, and budget. This should be done in collaboration with MEP engineers, commissioning agent, facility operators, IT dept/consultant and the architect. Select architect/CE firm or design/build firm. Review and approve on-going design development and Contractor bidding process. Ensure key project parameters are in detailed design. Cooperate with architect or design/build firms to conduct site surveys and secure permits and licenses.
Architect	Manages and designs the facility's physical structures. Sometimes hires and manages the MEP engineers. Some architects may have engineers on staff in which case the architect manages the MEP design as well. Creates and manages the structural design in conjunction with the electrical and mechanical designs. Some architects will handle the hiring and management of the general contractor as well.
CE firm (MEP engineers)	Manages and creates the detailed design documents for the electrical, mechanical and IT systems. They are responsible for ensuring the design and build meet the owner's budget and key project parameters. Sometimes the CE firm will hire and manage the general contractor instead of the architect. CE firms vary widely in capabilities with some offering commissioning, project/construction management services, and more.
IT Dept or Consultants	The IT dept and/or consultants should be involved in the project to define the specific IT requirements (service delivery type/SLAs, server hardware, networking and storage bandwidth/hardware, and software/app requirements, etc.). These requirements, in turn, determine the physical infrastructure requirements. IT should be involved in the physical infrastructure planning & design process to ensure it yields the power, cooling, and space resources necessary to meet their IT requirements for the project.
Energy/LEED Consultants	These are specialist consultants who measure, monitor, report, and/or advise on energy consumption. Some manage and advise on how to make the facility LEED (Leadership in Energy & Environmental Design) certified. In the planning and design phases, these consultants can help ensure the detailed design reflects owner's requirements for energy efficiency and environmental impact before the data center is built. In some cases the architect or design/build firm will have this expertise.
Commissioning Agent	Acting either independently or on staff with the CE (or design build) firm, they test and ensure installed systems and their communications perform and operate as expected. During the plan and design phases, the agent develops a time-sequenced, order-based, detailed program for testing all critical infrastructure systems. Ideally this is developed under the supervision of the CE firm designers. Working together collaboratively in these early phases helps ensure a smoother and faster transition to having a reliably operating data center.
Facility Operations	The staff who will operate and maintain the facility on a day-to-day basis should be involved in these early phases. Their practical expertise can help validate and advise on design choices. Their involvement can help ensure the data center is better optimized for efficient and reliable operation over the long term. And by being involved early, staff can more effectively develop Operations & Maintenance (O&M) program documentation and develop/implement the necessary operator training program.
General Contractor	Has a direct contract with architect or design/builder to perform all or a portion of the construction work. A contractor, however, can also be consulted, before the project is awarded for construction, to help validate, comment, or advise on architectural and MEP design choices from the perspective of cost, time, permitting, and other regulatory or legal requirements. They are typically awarded a construction project towards the end of the design phase.
Sub-contractor(s)	Have a direct contract with the general contractor to perform a specific portion of the work to be done for a given project. Typical sub-contractors include electrical, mechanical, network, and low voltage specialists. The contractor (with owner's approval) typically selects them late in the design phase or early in the construction phase. Their specialty knowledge can be very helpful in identifying and resolving design or construction-related problems.
Equipment Vendors	They design, manufacture, test, deliver, and often install/configure and maintain the equipment. During these early phases, equipment vendors create submittal documents containing product specifications to bid on the project. Vendors are selected towards the end of the design and beginning of the construction phase with the owner's approval. Vendors can assist the early phases of the project by providing design advice, training operations staff, and helping ensure delivery deadlines are met.

Whether these people or disciplines are involved or not in a given project depends largely on the size and scope. Generally, the larger and more complex the project is, the larger the number of actors involved in the project will be. For example, simply increasing power and cooling capacity for an existing data center that has plenty of unused space will likely not require an architect or LEED consultants.

It is common within a data center project for stakeholders to refer to “design and construction teams”. The design group is typically composed of the architect, MEP engineers, and IT. The construction team primarily includes the general contractor, sub-contractors, and equipment vendors.

Before the build phase begins, this construction team develops a project plan with a clear identification of critical path items, creates a commissioning plan, budget, billing plan, and a schedule. It is important for the construction team to work closely with the design team as design and construction documents are finalized to ensure these plans, schedules and budgets reflect reality. And the owner should be reviewing and approving this work as it is done.

Build phase

The construction documents (described above) developed during the detailed design phase are used to bid (if “design/bid/build”) for contractors, secure building permits, and are used in the end as the basis for what is actually built at the chosen site. With the owner’s permission, the construction team led by either the design/build firm, architect, or the general contractor will begin construction in accordance with the project plan. Team members will focus on their assigned disciplines such as civil construction, QA/QC, mechanical, electrical, equipment integration and so on. Regular quality assurance and audits should be performed and reported. Weekly meetings should be held and reports generated for the owner as work progresses. The owner’s focus should be on the status of progress, quality performance, and identifying schedule risks early.

As systems are built, installed, and integrated together, the build (or construction) phase offers a good opportunity for training the owner and the facility operations team. One aspect of this training is the construction team’s responsibility for developing the punch list, as-built drawings, equipment manuals, sequence of operation documents, material safety data sheets (MSDS), and warranty documents. This documentation combined with hands-on training by equipment vendors on the physical infrastructure systems together form the source content for developing the emergency operating procedures (EOPs) and methods of procedure (MOPs). These documented procedures are a key aspect of an effective facility operations & maintenance (O&M) program.

The build phase should only be considered complete when…

- Quality assurance confirms work is complete to project requirements
- Final certification of completion is issued to owner by construction team lead
- Commissioning test results in passing score (if part of project)
- Owner issues letter of formal acceptance of project

The owner has key roles and actions to take that will help ensure the build phase goes smoothly and efficiently:

- Review and approve construction documents before building begins
- Assist construction team with preparation and filing of documents for necessary approvals from AHJs
- Review and decide on acceptability of any proposed change orders

- Regularly meet with construction team to review progress and quality
- Ensure any owner-supplied equipment is delivered and installed on time
- Formerly approve construction project once completed

Commissioning

Commissioning (Cx) is defined as a reliability science that documents and validates the result of a data center's design and build processes. This is very different from typical "start-up" services where equipment vendors simply install, configure, power-up devices, and then provide the contractor with a certificate of completion for each individual device. The problem with this straight-forward approach is its inability to detect system-level problems that can lead to reduced efficiency, lost productivity, safety hazards, or downtime. Data centers represent a diverse and highly integrated eco-system of power and cooling devices, sensors, meters, and control software all managed and controlled by human beings. Effective commissioning accounts for this complexity by testing and documenting the overall system's response to various real world inputs and changes. Testing in this way serves as an effective insurance policy for ensuring the design and its implementation in the construction phase is sound. Commissioning is a recommended phase for all new data center projects. It is also recommended for any retrofit project where there have been significant changes made to the overall system particularly if the control system or the connections between devices and systems have been altered. It is the owner's choice as to whether commissioning is performed or not.

As described in previous sections, the commissioning process begins long before testing occurs towards the end of the build phase. Hired by the owner typically in the design phase, commissioning agents work with the design and construction teams to develop a commissioning plan and schedule. Their plan is based on component start-up data and the data center's design parameters (Tier level, density, floor plan, etc). Together this information enables the commissioning agent or team to develop a strategy for scripting and ultimately testing the integrated systems. Due to the nature of their work, Cx agents often have a lot of practical expertise and experience that makes them a valuable resource for both the design and construction teams. Their detailed understanding of programming, networking and the behavior of these complex systems as conditions change makes their input quite practical and useful. So, the commissioning agent should get involved early in the project process. Further, early engagement provides the cleanest, least filtered information for accurate planning and enhances the ability of the Cx team to identify potential single points of failure. Involving a commissioning agent early on also reduces the possibility of having the commissioning process fall victim to budget cuts, should the project experience cost overruns.

The knowledge gained from the commissioning exercise should be documented. The following three documents are typically (and should be) produced as outputs of the phase:

1. "As built" script report – provides a line by line report on what passed/failed
2. Component error log report – describes what failed and what was impacted
3. Trending report – executive summary of performance trends

The owner, design, and construction teams should meet with the Cx agents to review the results and agree on remediation plans for any failed tests. Once it is agreed that commissioning is over, the Cx reports should be given to the facility operations team and kept as supporting documentation for their operations and maintenance program. To learn more about the commissioning process and its outputs see white paper 148, "Data Center Projects: Commissioning". To understand common pitfalls related to commissioning, see white paper 149, "Ten Errors to Avoid When Commissioning a Data Center".

Once construction is complete and commissioning tests have passed per the project's requirements, management and operations of the facility is transferred to the facility operations team. The contractor should conduct training for this team to provide them with information needed to safely operate and maintain all equipment and systems. This information combined with construction "as-built" drawings and commissioning output documents form the basis for developing the facility's operational policies and procedures used during the Operate phase.

Operate phase

This is the longest and costliest phase of the data center life cycle. This operations phase often lasts 10, 15, or even 20 years. It is during this long period that the physical infrastructure is doing what it was intended to do: to house, power, cool, and secure IT servers, storage, and networking gear. The physical infrastructure must continuously function even as equipment ages, is serviced, and is eventually replaced. Operations must be continuously maintained even as IT and business demands fluctuate. Operating a mission critical facility like a data center is quite unlike managing any other. Some have likened it to "maintaining an airplane while flying it". Failure is not an option, particularly since business success is so often tied to IT performance (or IT IS the business). It is important for owners and managers to understand this when organizing and managing an operations and maintenance (O&M) program for the data center.

A properly designed, implemented, and supported O&M program will minimize risk, reduce costs, and even provide a competitive advantage for the overall business the data center serves. A poorly organized program, on the other hand, can quickly undermine the design intent of the facility putting its people, IT systems, and the business itself at risk of harm or disruption.

"Mission Critical Mindset"

An effective O&M program begins with having management and the operations team embrace a "mission-critical mentality" that focuses on risk mitigation and grasps the interconnectedness of facility and IT systems. This philosophy forms the foundation of a good O&M program. **Table 2** below describes its core principles and outcomes.

Table 2

A description of the mission critical management philosophy

"Mission Critical Mindset" principles	Impact
Focused on risk mitigation in all operational and maintenance activities, work processes, and procedures	Proactively deals with all potential threats to system availability and worker/occupant safety
Acting with confidence and patience that is an outgrowth of careful planning and preparation	Prevents risks from becoming problems; enables faster response times and fewer errors if problems do arise
Analytical, process-driven approach to risk avoidance and problem solving	Helps identify and mitigate risk in complex environments; ensures predictable and safe operation
Comprehensive understanding of the function and interconnectedness of facility systems and components	Quickly identify and resolve potential threats or actual problems; avoid or reduce system downtime
Commitment to continuous learning and process improvement	Increases skills and operational efficiency to maintain an edge in a constantly changing environment

12 Essential Elements

Table 3 below shows the critical elements for operating a data center facility reliably and efficiently. The owner or facilities management team should ensure these items are present, well-implemented, and supported within their O&M program. White paper 196, "Essential Elements of Data Center Facility Operations", provides a more detailed and complete description of each of the program elements listed here.

Table 3

12 fundamental elements of a data center O&M program

O&M Program Element	Description
Environmental Health & Safety	Program should cover injury and illness prevention, electrical safety, hazard analysis, and hazard communication.
Personnel Management	Element involves the hiring and development of competent, team-oriented people; having subject matter experts in the following disciplines: electrical, mechanical, controls, fire detection/suppression, quality management, training, and computerized maintenance management systems (CMMS); and developing an appropriate staffing model.
Emergency Preparedness & Response	Program includes the development and practice of emergency operating procedures (EOPs) for high risk scenarios, regular training and review of procedures as conditions change, and failure analysis performed after emergencies occur and have been responded to.
Maintenance Management	Involves asset intelligence combined with a proactive preventative and predictive maintenance plan. Three key tasks for this element are asset management, work order management, and spare parts management.
Change Management	Managing change in the data center should rely on the use of MOPs, or methods of procedure, detailed checklists for each step in a specified process such as a preventative or corrective maintenance activity.
Documentation Management	Management system to automate processes and facilitate document processing, storage, retrieval, and archiving should be in place.
Training	Program should organize all operational and maintenance tasks into categories that correspond to specific levels of capability. All activities should be mapped to these levels. Training should enable new technicians to be brought to a minimum level of competency and achieve steady progress until fully qualified. Program should also ensure personnel maintain certifications and expertise through regular re-certification.
Infrastructure Management	Using data center infrastructure management (DCIM) software tools to provide facility monitoring, capacity planning & management, and to facilitate facilities/IT integration and cooperation.
Quality Management	This element should include quality assurance (process and procedure standardization), quality control (checks, inspections, and audits), and continuous quality improvement.
Energy Management	The program involves three core tasks: performance benchmarking, efficiency analysis, and strategic energy sourcing. DCIM is used to accurately collect and analyze data to uncover energy savings opportunities. The program should manage both internal (i.e., energy efficiency/use) and external (sourcing) energy savings opportunities.
Financial Management	Financial management processes should be in place that focus on purchasing, invoice matching, and financial reporting/analysis.
Performance Monitoring & Review	This is a program that regularly collects, reviews, and analyzes well-defined, quantifiable KPIs and associated facility SLAs.

Facilities-IT cooperation

It is advantageous, of course, for owners and management teams to foster a sense of cooperation and teamwork amongst their staff. Cooperation helps make what would otherwise be a complex ecosystem of components, interconnected systems, and diverse trades simpler and more manageable. Unfortunately in many organizations, a "silo mentality" often exists between the facilities and IT groups. Each tends to operate in their own world using their own separate management tools with little to no cross-functional visibility between the two. Given IT's reliance on the facility team's power, cooling, and space resources and given that IT is, in effect, a customer of the facility team, it is helpful for the two groups to communicate and work together. Cooperation will…

- Make capacity planning more accurate and day-to-day operations more efficient
- Minimize impact to SLAs and the business when problems occur
- Reduce the disruption caused by facility or IT equipment moves, adds, changes

While effective implementation of modern DCIM tools[3] can help bring facilities and IT closer together, it is largely the owner and management's responsibility to encourage and foster this cooperation. Some organizations have found success by having a common reporting structure with the head of facilities and the head of IT both reporting into the same person. Management should also create and structure team and individual goals in a way to encourage better teamwork.

Assess phase

With the original data center project complete and the facility in active operation, the Assess phase begins. Although concurrent with the Operate phase, Schneider Electric views the critical task of monitoring and formally evaluating performance as a separate and distinct phase of the overall life cycle. And of all the phases, it is arguably the one most often neglected. As shown in **Table 3**, regularly assessing performance is an important element of an effective O&M program. Understanding how operators and the physical infrastructure systems are performing on an on-going basis yields useful and actionable information including:

- Degree to which the design intent and facility objectives are being met by the current infrastructure in operation
- Energy efficiency of physical infrastructure in supporting IT
- General health and current risk profile of the physical infrastructure
- Current power, cooling, and space capacities and use trends
- Effectiveness and experience levels of personnel
- Facility operations & maintenance program maturity and effectiveness

Regularly monitoring performance, formally reviewing and acting on the results uncovers negative trends and potential problems. Effectively assessing your data center helps make it more safe, efficient, and reliable.

Assessing performance is most effectively done though the use of key performance indicators (KPIs) (see **sidebar**), which are used to provide focus and drive program improvements. This yields several benefits, including the alignment of operational activities with business goals and providing positive reinforcement for innovation and process improvement.

Recommended facility KPIs…

- Critical load uptime
- Load redundancy maintained
- Support system uptime
- Maintenance completion
- Staffing coverage
- Security policy conformance
- Emergency preparedness drills
- Emergency response procedure adherence
- Safety policy and procedure adherence
- Procedure development, management and use
- Quality control/improvement
- Training compliance
- Process improvement
- Operational reporting
- Proper event notification and escalation
- Timely and accurate cost reporting

[3] For practical advice on how to effectively implement DCIM tools, see White Paper 170, "Avoiding Common Pitfalls of Evaluating and Implementing DCIM Solutions".

The structuring and measurement of KPIs and their associated SLAs is the key to a good performance monitoring & review program. Clearly define each metric in discrete terms that are quantifiable, rather than being based on subjective criteria. Derive metrics from measured data that comes from facility monitoring and control systems such as DCIM software, CMMS tools, security logs, and other operational support systems. Each metric should have success target and failure levels defined including what levels are considered "acceptable". Good KPIs provide leading indicators of failure that make them more predictable and preventable. Collect these metrics continuously and tabulate them on a monthly basis, with a formal quarterly review recommended. Note and address immediately any deviations from "acceptable" levels of performance. Finally, administer the program in a way that fosters an atmosphere of teamwork and cooperation rather than one of fear. Place focus on providing positive monetary incentives to meet or surpass goals and targets instead of punishing people, departments, or vendors who fail to reach these goals.

Data center owners and management play a key role in this phase. Management needs to make performance monitoring and review a priority. There must be a continuous commitment of time, resources, and effort to be successful. And management needs to commit to regularly reviewing the results and taking the consequences seriously. Without these commitments, assessments are likely to either fall entirely by the wayside or be only partially done in a way that amounts to wasted effort.

Life Cycle Services

- **Plan & Design phases**
Project management
Concept & detailed design
Site selection services
Build vs. outsource determination

- **Build phase**
Construction management
HW/SW startup/integration
Equipment configuration
Commissioning
Equipment operations training

- **Operate phase**
Facility operations management
3rd party vendor management
Energy procurement services
Preventative Maintenance

- **Assess phase**
Energy assessments
Facility operations maturity eval
Breaker coordination & arc flash studies
CFD airflow analysis
Risk & reliability assessments

Outsourcing services

For each phase of the data center life cycle, there are vendors who offer services to advise, manage, startup, configure, train, assess, test, and operate. The "Life Cycle Services" **sidebar** shows a list of commonly available services by life cycle phase. Procuring these services can offer several potential advantages including:

- Benefiting from the experience and expertise of others
- Freeing up internal resources to focus on other key tasks and responsibilities
- Avoiding the natural learning curve and the mistakes that might be expected when tasks are being done for the first time
- Providing an alternative means to achieve goals when resources are lacking internally to learn required skills or perform some function.

It is important for owners and their management teams to be aware of and understand the availability of services for the facility in question; i.e., what is specifically offered, what service levels are possible, and what its costs are. Compare service providers and vendors in terms of capabilities, expertise, experience, coverage, and cost. Then evaluate all of this information in the context of what the facility internally offers today in terms of staffing coverage, skills, and experience. For those who lack the required expertise and resources, effective use of third party services can make owning and operating data centers easier and more efficient.

Conclusion

This paper provides owners and management teams with a basic understanding of leading and managing mission critical facility projects and operations in the context of the data center life cycle. What happens in each of the phases, how the phases are interconnected, who are the principal actors, and what are the key areas of focus and attention are all described and identified. This information and the other supporting white papers give people a sense of the effort and basic elements required to create and operate a facility reliably and efficiently over its life span.

About the author

Patrick Donovan is a Senior Research Analyst for the Data Center Science Center at Schneider Electric. He has over 18 years of experience developing and supporting critical power and cooling systems for Schneider Electric's IT Business unit including several award-winning power protection, efficiency and availability solutions. An author of numerous white papers, industry articles, and technology assessments, Patrick's research on data center physical infrastructure technologies and markets offers guidance and advice on best practices for planning, designing, and operation of data center facilities.

Resources

Data Center Projects: Standardized Process
White Paper 140

Data Center Projects: System Planning
White Paper 142

Data Center Projects: Advantages of Using a Data Center Reference Design
White Paper 147

The Top 9 Mistakes in Data Center Planning
White Paper 145

Site Selection for Mission Critical Facilities
White Paper 81

Data Center Projects: Commissioning
White Paper 148

Ten Errors to Avoid When Commissioning a Data Center
White Paper 149

Essential Elements of Data Center Facility Operations
White Paper 196

Avoiding Common Pitfalls of Evaluating and Implementing DCIM Solutions
White Paper 170

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