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executive summary: 4D phasing

In 2003, U.S. General Services Administration (GSA) Public Buildings Service (PBS) Former Office of Design and Construction (ODC) established the National 3D-4D-BIM Program (http://www.gsa.gov/bim). As part of this program, ODC has evaluated an array of 3D-4D-BIM applications on a number of capital projects. The National 3D-4D-BIM program’s work in 4D phasing has been used to understand spatial and temporal relationships of the construction phase. 4D models visually communicate aspects of a phasing or construction schedule through the use of 3D (isometric or BIM) models and schedules.

About 4D Modeling

4D modeling combines a 3D model with time (via a schedule). The models combine building elements with construction activities to display the progression of construction over time; 3D objects are linked to specific activities, which can appear or disappear at specified times according to the schedule. Permanent building elements that are to be constructed appear during the time of construction, and remain throughout the rest of the schedule. Temporary spaces/objects such as swing space or construction supports appear only for a specified duration, and then disappear.

Objective of 4D models

“While it’s possible to create an image of a building in your mind, to see it take shape on screen, in sequence, creates much more effective shared understanding with the entire delivery team (Seliga 2007).” CPM scheduling has been the accepted method of choice for construction project scheduling since 1950s but CPM has downsides stemming out of inability in coping with non-precedence constraints, difficulty in evaluating and communicating activity interdependencies, and inadequacy in work-face planning situations (Sriprasert and Dawood 2002; Wang 2007). Traditionally, phasing plans have been communicated through 2D snapshots showing each phase. This requires reviewers to visualize, in their minds, what activities will be occurring at a particular time and space on the project. Many stakeholders may not have the ability to see the entire big picture based solely on the Gantt chart. The Gantt chart (used to show the CPM schedule) only provides the sequence of events, not physical objects, which can be more difficult to validate and evaluate (Retik 1993). The overall purpose for 4D models is to visually communicate the construction plan, scope of work, affected areas by the project and/or tenant’s movements in renovation projects to the stakeholders. 4D models provide a way to visually show an animated process to describe the phasing and construction plan. ODC anticipates this will allow of clearer communication and feedback between the GSA project teams and customers.
Benefits and Limitations of 4D Modeling

The private sector has seen many benefits of 4D modeling in all different phases of the project schedule. Projects on very tight construction schedules have incorporated 4D modeling to proactively coordinate subcontractors and manage the schedule and cost better. 4D modeling has been implemented by owners, designers, engineers and contractors alike.

The benefits of 4D modeling include increased coordination and visualization of the schedule. Stakeholders can work with the 4D model in renovation projects to see how tenants will be moved, what construction that is occurring around them, and to evaluate different alternatives. In new projects 4D models can be used to show the construction processes sequence and verify the space availability in addition to the logic and soundness of construction schedule. At present, 4D models are able to reflect the schedule, identify physical conflicts, improve the design team synchronization and help the constructors manage the flow of data and work better. In addition these models can help the developers to identify potentially unsafe activities due to time or location. However, 4D models are neither intelligent nor automated. These models cannot modify or optimize the schedule automatically. 4D models require intimate interaction with the project team to fully realize its benefits. Developing the models can be very time consuming and errors cannot be identified by the software.

Major points regarding modeling for 4D Phasing

- BIM modelers are responsible for managing and updating the 3D model, schedule, and 4D model. These may all originate from the 4D modeler, or from different sources. This task requires a constant and clear communication between the modelers and the owner, designers, engineers, and contractors responsible for the project.

- 3D models should have a layering scheme based on area and/or construction sequence and time which supports 4D models. This layering scheme may differ from the default layer scheme found in many 3D modeling applications which is typically based on building elements and location. This could also be achieved via a unique identifier, group or property definition that is used with rules because of the required level of detail in the model and the schedule.

- The construction scheduler or the modeler should ensure that all activities and activity types are represented in the schedule. Often, this may mean adding "non-constructional activities" for use by the 4D model. The schedule needs to include an exclusive activity for every physical object or space that is created or every movement that takes place during the construction phase. The vice-versa can be true where some activities such as commissioning or review meetings are not related directly to any 3D objects and these tasks do not need to be linked. As often the schedule is modified, it is important to constantly update the schedule in the model.

- If the 3D model and construction schedule are coordinated correctly, the process of creating the 4D model is simplified. It is recommended to optimize the schedule using a line-of-balance optimization process, before linking it to 3D model.
introduction

GSA’s mission is to “help federal agencies better serve the public by offering, at best value, superior workplaces, expert solutions, acquisition services and management policies.” Within GSA, PBS manages over 352 million square feet of workspace for the civilian federal government. GSA PBS Office of the Design & Construction (ODC) provides leadership and policy direction to all 11 GSA regions in the areas of architecture, engineering, urban development, construction services, and project management.

This “BIM Guide Series 04: 4D Phasing” guide has been developed to assist GSA associates and technical consultants on developing 4D phasing models for GSA capital projects. This Series will describe how aspects of project phasing, from the feasibility study through construction, can be incorporated into a 4D model. This Series will also describe how 4D models fit into GSA’s capital program delivery process. The objective of this series is not to cover the details of different projects and how BIM tools can be applied to each project specifically but to provide a generic guideline for 3D-4D-BIM implementation in construction projects. Examples used in the project are for illustration purposes and may not directly apply to every type of construction project.

4D models typically refer to any presentations of a project that includes the timeline and shows the progress through graphics with respect to the timeline. Figure 1 shows an example of development of a 4D model from Laser Scanned images to a tenant phasing model.

Figure 1 Dirksen Courthouse - 4D model generated from laser scanned 3D model

This BIM Guide Series 04 is also part of a collection of GSA BIM Guides from the National 3D-4D-BIM Program. The BIM Guide Series 01 - Overview provides an overview of the National 3D-4D-BIM Program, and is intended for both GSA associates and the wider AEC community. Topic specific guides provide best practices and guidance on a wide array of activities within the National 3D-4D-BIM Program. The following topic-specific guides are available:
• BIM Guide Series 02 - Spatial Program Validation
• BIM Guide Series 03 - 3D Laser Scanning
• BIM Guide Series 04 - 4D Phasing
• BIM Guide Series 05 - Energy Performance and Operations
• BIM Guide Series 06 - Circulation and Security Validation

Please visit http://www.gsa.gov/bim for the latest BIM Guides.

**DISCLAIMER:**

This Series is considered a living document that is constantly changing and being updated as the technology matures. While GSA has tried to highlight the major points of spatial program validation, GSA cannot take into account all the special cases and changing technology. Therefore, if you have any questions or comments regarding the content of this Series, please contact OCA for the most up-to-date information.
About this Guide

This Series is divided into three sections.

• **4D Phasing - The Basics**: This section of the Series is to assist GSA associates in determining whether or not to use 4D models on their projects. This section describes the situations in which 4D models may assist the project team, and what factors to consider before contracting 4D modeling services. This section describes the “Process for adopting 3D, 4D, and BIM technologies” diagram (from Series 01 - Overview) with respect to 4D phasing in particular.

• **Defining 4D Phasing Scope**: This portion of the Series is to assist GSA associates in analyzing the feasibility of implementing 4D phasing on their projects. This section describes the “Feasibility of Implementation” diagram (from Series 01 - Overview) in detail with respect to 4D phasing.

• **Technical Guidance for 4D phasing**: This portion of the Series is to assist 4D modelers and consultants on best practices in creating and maintaining 4D models.

Status of OCA-initiated 4D modeling activities

OCA has currently initiated eight projects across the nation. These projects have been in different phases, from early feasibility through construction documentation. The following table highlights these projects:

<table>
<thead>
<tr>
<th>Project Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Edith Green/Wendell Wyatt Federal Building</td>
<td>This federal building modernization required a detailed phasing plan to understand how tenant would move throughout the top-down construction process. A 4D model was constructed and snapshots of the model were taken and presented to the tenants to show their specific tenant movement.</td>
</tr>
</tbody>
</table>
300 NLA - The 4D model of this federal building modernization helped to reduce the construction schedule by 19%. In addition it enabled the owner to keep the building operational and saved moving costs and extra rent on swing space. Created in the design development phase, this 4D model was also used and updated during construction. The use of 4D model enabled the project team to transfer information much faster and more efficiently and gave all the stakeholders a better understanding of the process. The model was essential for building trust between the design team and contractors as well as tenants.

Pioneer Courthouse - The 4D model of the seismic upgrade of the Pioneer Courthouse allowed GSA to better communicate the scope of the project with the public, tenants, and GC bidders. The model was shown during a pre-bid meeting to allow bidders to better understand the project context. The extra information helped the contractors to lower their leverage and the bid spread was much narrower than bid spread for similar projects without 4D model.

Rodino Federal Building - The 4D model helped the project team to visualize the construction schedule and to determine impacts of changes/additions in scope on the construction schedule. The schedule was used to provide feedback on swing space usage and conflicts in tenant phasing and construction.
Champlain Port of Entry - The 4D model was used to better understand the coordination between installing new passenger inspection booths and demolishing existing booths. Since a minimum of seven booths must be open throughout the construction process, 4D was used to visualize the baseline schedule, as well as various alternatives.

Madawaska port of Entry - The 4D model was used to better understand the coordination between installing new passenger inspection booths and demolishing existing booths. In addition the model was used to demonstrate the process to the local residents and officials and reassure them that the project would not interfere with their local business. Also a minimum number of booths must be open throughout the construction process and 4D was used to visualize the baseline schedule, as well as various alternatives and test the “what if” scenarios.
Dirksen - To visualize the construction schedule and to study the impacts of the construction activities on the 30 story tall building, a 4D model was developed. The 4D model is also intended to be used to study the swing space usage and conflicts in tenant phasing and construction.

Salt Lake City Courthouse - The 4D model was used to understand and improve the construction schedule. The completed construction schedule was used for the model and the construction sequence was captured. The interesting part of this process was the fact that the project team built the model only a week after their first software training. As part of GSA’s effort in BIM implementation, general and specific trainings are provided for regions and project teams.

We have also provided project-specific contract language regarding 4D modeling services for several on-going projects.
section 01:
4d phasing - the basics
section 1: 4d phasing - the basics

This section is intended for GSA associates to evaluate the potential use of 4D modeling on their projects. It describes what types of business needs and goals are supported by 4D models, how these models can be used throughout the project lifecycle, and what main factors should be considered.

1.1 What is 4D Modeling?

4D modeling is the integration of a 3D (or BIM) model with a construction schedule in order to visualize the sequence of construction (Figure 2). 4D models can be created to various levels of detail, from high-level zone analysis during the design phase, to detailed sub-contractor coordination during construction. The same model can be updated and maintained throughout the project based on the updated schedule and 3D model.

![Figure 2 4D models link 3D components with activities in the phasing schedule](image)
4D elements are created by linking 3D components to an activity in the schedule. For example, Figure 3 depicts the high-level construction of a port of entry site.
1.2 Thinking the “4D Way”

4D modeling enables project planners to visualize related activities of the construction process (e.g. changing locations of traffic lanes, locations of swing space). These other aspects, however, require specific start and end dates, similar to regular construction activities. All construction and related activities must have specific start and end dates linked to specific 3D components in order to be visualized in the 4D model. Often times, these start and end dates are within the planner’s thinking, but not explicitly stated. This explicit statement of attaching specific start and end dates to specific locations and components is “thinking the 4D way”.

1.3 Using 4D modeling on GSA Projects: Process Overview

- **Business Needs**
  - What are the project opportunities that may require 4D modeling for phasing?
  
- **Exploration of Candidate Solutions**
  - What 4D phasing solutions should the project team consider?

**Iterative Process**

- **Scope Definition**
- **Select Technology**
- **Implementation & Evaluation**

**Figure 4 Process for adopting 4D phasing**
1.4 Understanding Business Needs: Project Opportunities for 4D Phasing

4D modeling can be utilized both in new construction projects as well as renovation projects. In renovation and modernization projects, one of the typical project challenges is where and how to utilize swing space and how to move tenants during construction. Often times, tenants will want to know exactly where they will be moving to, the duration, and how the construction within the building will affect them. 4D models allow project teams to explain these aspects of the project to each tenant. For new construction projects, project teams can use 4D models for managing the construction schedule, matching the schedule timeline with the location based schedule, predicting and avoiding interruptions between different crews and activities, as well as verifying the soundness and correct sequence of the activities. Engineers and superintendents can use snapshots of 4D model to communicate the short term objectives to the crew and evaluate the daily progress.

The following table shows highlights of some project challenges that may be improved using 4D modeling:

<table>
<thead>
<tr>
<th>Project Phase</th>
<th>Project Challenge</th>
<th>Goal</th>
</tr>
</thead>
</table>
| Pre-Design & Design Development | • How to best use swing space and optimize tenant phasing?  
• How to communicate phasing plan to tenants?  
• How to visualize construction alternatives?  
• What are the limitations factors? | Better understand swing space use; save time in schedule  
Better communication to tenants  
Visual analysis of construction alternatives and activities |
| Design | • How to integrate the design intent, structural specifications and construction schedule?  
• How to communicate schedule to potential bidders?  
• How to satisfy all potential tenants? | Better communication to project stakeholders about the construction process, duration and design intents |
| GC Selection & Construction | • How to manage the construction schedule and coordinate subcontractors?  
• How to maintain traffic flows during construction?  
• How to communicate the scope of each activity with stakeholders and workers during the process?  
• How to implement lean and efficient process? | Better coordination of subcontractors as well as activities and other occupants during construction  
Show the 4D model and snapshots of it to the appropriate group at the right time. |

4D models can help with enabling stakeholders to visualize the construction process and to optimize the schedule and save time. Although it is very difficult to quantitatively measure whether or not there is better communication between stakeholders, GSA associates can evaluate the success of the 4D model by understanding what the typical amount of questions or change orders there are using traditional phasing and coordination means, and compare those to the number using 4D modeling. Other metrics used to measure the success of 4D models can be: time saved on project, number of coordination detection, budget for 4D
model, number of activities, objects and linkages, time spent to do the 4D model, number of revisions, time spent to revise the 4D model, overall project’s duration and budget in comparison to similar projects and stakeholder’s satisfaction.

**4D models in the project lifecycle**

4D models can be used throughout the project lifecycle. While numerous industry cases have been documented on the use of 4D models throughout the project lifecycle, GSA can benefit from using 4D models in three specific stages:

*Pre-design:*

4D models have been used for strategic project planning during the feasibility phase. For example, the model can be used to determine different phasing sequences and swing space configurations or to optimize the construction schedule. These models allow comparison of different alternatives with detailed assessment at a relatively low cost to the team and the owner. In the following federal building project (Figure 5), 4D models were used to analyze different alternatives based upon whether or not a major tenant would move out of the building.

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**Figure 5 Snapshots of the 4D model to analyze different phasing and swing space alternatives**
Design Development:

4D models can be used to improve constructability of the design and to determine advantages of different construction processes. These models can be used to optimize the construction schedule, phasing, and/or tenant sequencing. In addition, the models can be used to communicate the phasing plan to the tenants as shown in Figures 6 and 7.

Figure 6 Snapshots of 4D model to show proposed top-down construction sequence and tenant phasing
Figure 7 4D model is used to communicate the scope of work and construction sequence

**GC Selection/Construction Bidding:**

4D models can also be required in the RFP to show the contractor’s ability and direction to execute the work. If work is complicated, 4D models can be used to understand tenant phasing and/or construction activities sequence during bidding. If the contractors understand the space and the constraints better, the bids may be more accurate.

On a GSA courthouse project, a 4D model was created by GSA and used at a pre-bid conference (Figure 8) to allow the bidders to understand the project constraints and expectations better for a seismic upgrade project.

Figure 8 Snapshot of 4D model to show proposed construction sequence of seismic upgrade
Construction:

4D models can be used for the temporal aspects of construction coordination and constructability review. These include understanding where and how trades will work over a period of time and understanding traffic and site flow processes. On-site, these models can be used for bi-weekly construction progress reviews and to compare as-built with as-planned schedules for management and claims purposes. 4D models can also be used to communicate with tenants during the construction process. In addition 4D models can be used to communicate the utility and control system changes required during specific periods and their impacts, especially for renovation projects. Since 4D models are based upon 3D models, 3D construction coordination (this is different from clash detection, for example coordination of different trades’ work-schedule in the same space and on the same objects or close-by objects) can be a by-product of 4D modeling; of course this varies depending on the level of detail and may not be true in all cases.

1.5 Exploring 4D Phasing Solutions

4D modeling software typically come within a suite of applications or as a stand-alone third party application. 4D modeling applications that are within a suite of applications allow the project team to create the 3D and 4D model all within one application family. 3D components are linked with time by either specifying specific phases within the modeling application, or importing a project schedule into the application.

Stand-alone 4D modeling applications will import both the 3D model and project schedule. The linkages are then created in these applications. Project teams should ensure that their 3D modeling and project scheduling applications are compatible with the 4D modeling application chosen.

1.6 Summary of Benefits

In summary, the benefits of 4D modeling may include:

In design:
- Increased stakeholder communication through visualization and better understanding
- Preliminary analysis of traffic flows, tenant phasing, construction activities
- Support development of construction sequencing alternatives

In construction:
- Improved sub-contractor coordination
- Reduced number of RFIs and COs
- Detailed analysis of constructions sequencing
section 02:
defining 4d phasing scope
section 2: defining 4d phasing scope

This section is intended for GSA associates to understand the process and the management requirements to develop a scope of work for specific projects. It describes the different concerns regarding 4D models, the required personnel, available software for modeling and a generic process of how to prepare for a 4D model.

2.1 Overview

Defining the appropriate scope for a 4D phasing project is essential for the success of the project. Figure 9 (modified from the Series 01 - Overview) shows the general process for analyzing and determining the scope of the 4D modeling. This section describes and defines the best practices for determining the scope, based upon this figure.

Figure 9 Feasibility of Implementing 4D Phasing

How can the project team implement 4D Phasing?

- Technology: What 4D Phasing technology is available?
- Project Team: Does the team have experience in 4D phasing?
- Budget/Schedule: Does the project have the time & money?
- How do we procure 4D phasing services?
- Is this the right time for 4D modeling?
- What will the information exchange process be between team members?
Often times, project teams may have more project opportunities for 4D modeling than available resources. Project teams, therefore, should prioritize the scope of the 4D work. This section is designed to help project teams understand the strengths and weaknesses of possible 4D scopes and to prioritize the scope.

2.2 Factors Affecting the Feasibility of 4D Phasing Implementation

2.2.1 Project team

Since 4D modeling combines both the design and schedule together, it is important to have various members of the project team on board. First, project teams must decide who will create the 4D model and who will provide the inputs. The following are examples, of who the project team consisted of, and in which phase the modeling occurred. This table is just a stereotype and the number of parties involved as well as the role of the participants can vary depending on the type of project and type of contract. Modified versions of this implementation process should be applied to fit the specific project requirements.

<table>
<thead>
<tr>
<th>Role</th>
<th>Responsibility</th>
<th>Project Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Modeler</td>
<td>Provide 3D model and updates per design</td>
<td>Architect</td>
</tr>
<tr>
<td>Scheduler</td>
<td>Provide construction schedule and updates</td>
<td>GC</td>
</tr>
<tr>
<td>4D Modeler</td>
<td>Link 4D model, provide guidance to 3D modeler and scheduler for updates</td>
<td>CM</td>
</tr>
<tr>
<td>Other Stakeholders (e.g., occupants)</td>
<td>Provide input into phasing requirements and constraints</td>
<td>Subcontractors Owner</td>
</tr>
</tbody>
</table>

2.2.2 Budget/Schedule

The majority of the time to create a 4D model is spent on creating the 3D model itself. This is a good example of synergies between multiple uses of a BIM model. If projects are already going through the spatial BIM validation process, a 3D model will already be created; thus, already contributing towards the cost of creating the 4D model. Project teams should discuss what additional detail and corresponding elements need to be modeled for the 4D model (e.g., MEP elements, temporary equipment, work zones, etc).

Since every project has a construction schedule, the only task remaining to achieve a 4D model is linking the objects to the schedule. However it is important to realize that the 4D model schedule may be different than the construction schedule. In most cases there are some activities that need to be added to the model to enable the correct visualization of the construction sequence. Since the models are not intelligent, removal of temporary objects or movement of tenants also need to be included in the schedule. For example in a 4D model to communicate the swing space schedule, the actual schedule will only state “tenant A
moves to swing space” but in the model there should be two different tasks for this process: 1. removing tenant A from original location and 2. placing tenant A in swing space. It is important to realize that the 3D model requires a higher level of detail and more components than the model used for spatial validation; however having the framework, simplifies achieving such model in a short period of time in most cases.

Based upon the project challenges, technology and available information, project teams must ensure that the timing of the 4D model creation is correct. 4D models created too early or too late yield less benefits than those created during the ideal time. Although BIM based projects encourage developing a 3D model early on the project, 4D models created too early are generally too superficial and cannot provide insight into the project challenges. During programming and schematic design phases, when objectives and elements will constantly change, a 4D model can convey little useful information. 4D models created too late usually do not allow for changes to be made on the project from new insights or cost more to do so.

### 2.2.3 Finding the Appropriate Scope and Level of Detail

First, the scope and level of detail (LOD) depend upon the minimum common information provided by the schedule and 3D model. Thus, even though a detailed 3D model is available, it is not even possible to create a detailed 4D model if the schedule is not at that level of detail. The vice-versa is also true and usually it is more time/effort consuming to increase the LOD in 3D model.

Project teams also need to understand what the scope and LOD should be. Typically, the LOD increases as more design and construction information becomes available throughout the project lifecycle. The following table can be used as a guideline to manage the level of detail but it may vary from project to project.

<table>
<thead>
<tr>
<th>Phase</th>
<th>3D Model Level of Detail</th>
<th>Construction Schedule Level of Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Feasibility Study</td>
<td>Project</td>
<td>Construction project</td>
</tr>
<tr>
<td>Concept Design</td>
<td>Buildings / Major Project Elements</td>
<td>Construction areas</td>
</tr>
<tr>
<td>Design Development</td>
<td>Systems / Components</td>
<td>Sub areas / Building Units / Disciplines</td>
</tr>
<tr>
<td>Construction Documents</td>
<td>Parts</td>
<td>Activities</td>
</tr>
</tbody>
</table>

The scope of the project should also be discussed. Often times, only specific aspects of the project need to be studied. For example, if one were to use a 4D model for MEP coordination, one would not need to model tenant moves.

### 2.2.4 Information Exchange

The main areas project managers should be aware of regarding the 4D technology are:

#### Software Integration Issues

What kinds of inputs can be put into the 4D model?
Some 4D software can only accept certain types of proprietary schedule and modeling formats. Members of the project team should make sure that the 3D model and schedule can be imported into the 4D software.

**User Interface Issues**

*Are viewers available for outside users to see the model?*

Not all stakeholders need create and edit the 4D model; however, it may be useful for all stakeholders (e.g., tenants) to be able to see the 4D model. Project managers should check to see how the model can be viewed by outside stakeholders. Viewers also allow GSA associates to view and track the 4D model without needing the entire 4D modeling software package. Some software offer the ability to create a video file or an animation of the 4D model that can be viewed by basic media players.

*How easy is it to navigate during a meeting?*

Coordination and communication of the schedule is usually accomplished in project meetings where navigation of the 4D model is required. Depending upon the level of usage during project meetings, project managers should decide how much control should be required by the presenter. In some meetings, model will be used only to communicate the objectives and/or building elements, without any model changes. In other meetings, the presenter may require extensive use and editing of the model for which the model may not be in the same format as the viewing model.

**4D Technical Process Issues**

GSA project managers should be aware of and discuss the following 4D technical process issues when procuring 4D modeling services. Please see section 3: technical guidance for 4D modeling for specific guidance on these topics.

*How can the model accommodate different LOD?*

If project managers would like to re-use the model in later stages of the project, the model needs to be able to accommodate increasing LOD, i.e. even at a low LOD the modeler must use individual objects for different building elements rather than creating a mass model.

*How easy is it to update the model?*

Since changes will occur during the lifetime of the model, it is important to understand how to update the model and the time requirements. It is also important to document the modeling process and the assumptions while the model is being created.

Project managers should understand and discuss solutions to these issues.
2.2.5 Scope of Work (SOW) Development and Procurement

GSA project teams can contact OCA to discuss the context of 4D modeling for their specific project. OCA can provide scope of services and contract language for 4D modeling services, as well as a consultant list.
Section 03:
Technical Guidance on 4D Modeling

GSA BIM Guide Series 04
www.gsa.gov/bim
section 3: technical guidance on 4d modeling

This section is intended for GSA associates to understand the process of developing a 4D model. The process is broken down into steps with guidelines and tips on how to accomplish each step. The section identifies the elements needed for different types of 4D and walks through validating process of the material. At the end of the section the process of making a 4D model using the BIM model and the schedule is explained.

3.1 Overview

The set-up of the 3D model, schedule, and 4D model is critical in effectively using a 4D model. Often times, if these three core components to the model are not set up correctly, it is very difficult to manage and update the model, reducing its effectiveness. The following sections give best practice guidance on creating and managing these core components effectively.

At a minimum, 4D models require 3D isometric object data and a schedule with a start date and finish date. While a BIM is not required for a 4D model, project teams should consider creating a BIM to enable the project team to have more opportunities to use 3D, 4D, BIM technologies later. The general tasks required for modeling are shown in Figure 10.

![Figure 10 4D Modeling Process](image-url)
3.2 Gather Initial Information

The first step in the 4D modeling process is to gather all necessary information to build the model as shown in Figure 11.

<table>
<thead>
<tr>
<th>Step 1. Gather Initial Information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Key Team Members</td>
</tr>
<tr>
<td>Key Activities</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

Figure 11 Process to create 4D model

3.2.1 Project Kickoff Meeting

A project kickoff meeting should be set up in order to coordinate information exchange and to develop a common understanding of the use of the 4D model. The agenda for the project kickoff meeting should include:

- Introduction of Stakeholders
- Status of GSA Project
- Intended use of 4D model on GSA Project
- Schedule of integration between 4D model and GSA Project
- Coordination of Information Exchange (Section 3.2.2)
- Follow-up Responsibilities and Next Steps

3.2.2 Information Checklist

The 4D modeler should ensure the following information is available:

- 2D drawings (if 3D models are not available)
- 3D models (if available)
- 3D renderings
- Construction schedule
- Other project metrics and schedule for analysis (e.g., tenant information, traffic lane schedule, etc.)
- Critical operations and major concerns during the construction process

The 4D modeler should also understand the LOD of each piece of information. In some cases, the LOD of each piece of information differs from the rest. The 4D model will only be as detailed as the minimum level of detail represented by the 3D model or schedule.
3.3 Create Model

Once the initial information is gathered, the 4D modeler can begin to create the model. The modeler should first examine all of the information gathered and develop a plan to create the model. Often times, this requires multiple iterations between the 3D model, schedule, and 4D model (Figure 12). Initial high level 4D models should be created first (Figure 13), such that any parts of the model can then be further developed based on the project team review of the model (Section 3.4).

Key Team Members

<table>
<thead>
<tr>
<th>Step 2. Create Model</th>
</tr>
</thead>
<tbody>
<tr>
<td>3D Modeler</td>
</tr>
<tr>
<td>Scheduler</td>
</tr>
<tr>
<td>4D Modeler</td>
</tr>
</tbody>
</table>

Key Activities

- Create 3D model (Section 3.5)
- Create Schedule (Section 3.6)
- Create 4D model (Section 3.7)

Figure 12 Process to create 4D model

Figure 13 Integration of 3D model and the schedule
3.4 Review Model

The project team should periodically review the model (Figure 14). The review of the model should ensure that:

- The modeling is on schedule with integration to the GSA Project
- The model can be used for its intended purpose
- The model is at the correct LOD
- The model visualizes the necessary components of the schedule
- The model is easy to understand (must consider the audience and provide the appropriate model)

### Step 3. Verify and Update Model

<table>
<thead>
<tr>
<th>Key Team Members</th>
<th>3D Modeler</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Scheduler</td>
</tr>
<tr>
<td></td>
<td>4D Modeler</td>
</tr>
<tr>
<td></td>
<td>Project Stakeholders</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Activities</th>
<th>Updating</th>
<th>Refinement and Presentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Section 3.4.2)</td>
<td></td>
<td>(Section 3.5)</td>
</tr>
</tbody>
</table>

Figure 14 Process to create 4D model

**Guidelines on Updating the Model**

The 4D modeler should also incorporate any insights or changes to the 3D model or schedule into the next revision of the model. The 4D modeler should also be responsible for managing and coordinating the 3D modeler and scheduler for updates to the 4D model. The 4D model should be updated as often as necessary. The schedule for updating depends upon the model usage and phase. For example, during feasibility, the model may be used for visualization and marketing purposes only, which requires little updating. However, during design development, the 4D model may be used to determine constructability and influence design changes. In this case, the 4D model, 3D model, and schedule may be updated frequently. During construction, the design is finished and managing the construction schedule becomes the main use for the 4D model. Therefore updates to the 4D model and schedule are frequent, while changes to the 3D model are limited.

3.5 3D modeling for 4D Phasing

3D models (isometric or BIM) have a specific layering scheme within the 3D modeling application. Objects are typically layered based on building elements (e.g., all slabs are on one layer, interior walls on another layer, etc). However, in the actual construction of the project (and the 4D model representation), building elements are never constructed all at once. Therefore, it
is essential for model management to have a 3D model layering scheme which supports the 4D modeling activities. Figure 15
describes how a 3D model can be transformed from a layering scheme by building elements to a layering scheme by schedule.
However there are other methods to make the 3D model and schedule correspond to each other. These methods are using a
unique identifier of elements and tasks such as their RSMeans code, and using a consistent naming convention recognized by the
modeling and scheduling software.

If the 4D modeling application is within a suite of applications, including the 3D modeling software, this is usually not a problem
because the software will link elements with activities without changing the layering scheme. However, if third-party software is
used, it is important to establish a layering scheme to support the 4D model. Otherwise, it is very difficult to manage and update
the 4D model. In addition some elements in the 3D model might have to be divided into segments to correspond to the schedule,
for example a large slab might have to be in 2 or more pieces to correspond to different pour schedules.

The 4D modeler must also understand how the model will be used and how often it will be updated. If the model will be updated
frequently, an information exchange process must be set up. If the 4D modeler is also the designer (i.e., A/E) the process will be
in-house. However, if the 4D modeler is different than the 3D modeler, an information exchange process must be established
where one party must update the 3D model per the construction schedule layers. This updated model can then be incorporated
into the 4D model. If the model is not updated frequently (e.g., it is used for marketing purposes or pre-bid meeting only), then
the information exchange process is not as critical.

3.5.1 Specifying Layering Standards in 3D Models

For some third party 4D-modeling software, 3D models are imported based on the layering standards in the 3D model. Therefore,
to save time and organize the model, it is important to have a specific layering scheme, which may be different from the
traditional PBS CAD Standard. While the layering standards required for 4D models do not replace the layering standards of the
PBS CAD Standard, it is important to realize that additional layers may be created to manage the 4D model. While the PBS CAD
Standard is organized by object type, 4D models need to be organized by construction. Therefore, it may be applicable to group
objects in terms of construction area location, not just construction material.

<table>
<thead>
<tr>
<th>Building Elements Layers</th>
<th>Construction Schedule Layers</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Slab</td>
<td>• Phase 1 Construction (Slab, Int. Walls, Ext. Walls, Doors, Structural Columns)</td>
</tr>
<tr>
<td>• Interior Walls</td>
<td>• Phase 2 Construction (Slab, Int. Walls, Ext. Walls, Doors, Structural Columns)</td>
</tr>
<tr>
<td>• Exterior Walls</td>
<td>• Tenant A Original Location</td>
</tr>
<tr>
<td>• Doors</td>
<td>• Tenant A Final Location</td>
</tr>
<tr>
<td>• Structural Columns</td>
<td>• Space</td>
</tr>
</tbody>
</table>

Figure 15 Feasibility of Implementing 4D Phasing
3.5.2 Additional Building Elements and Activities which Support Visualization

When building elements in the 3D model are not sufficient to describe the construction or phasing process, supporting building elements and activities need to be created.

For example, a project team may want to examine the use of traffic lanes during construction. If the traffic lanes are not present in the 3D model, additional building elements representing traffic lanes need to be created. Additional activities need to be created that represent traffic movements. Often times, these activities are correlated with existing construction activities.

3.5.3 Orienting the Model

Model orientation is important for outside stakeholders to understand the 4D model. Without orienting the model, project stakeholders may be confused at what they are seeing. Model orientation can include adding 3D text to locate street names or building levels or adding a high level site model. In addition when the model is used as a coordination tool for different trades, micro details (e.g. grid lines, room names) can be used to orient the model as well.

3.5.4 Required Building Elements

While building elements should be customized for each 4D modeling project, the following building elements should be required in the model:

3.5.5 Required for Phasing Schedules

- Walls
- Slabs
- Spaces
- Site Model

3.5.6 Required for Construction Schedules

- Building elements broken down to the same LOD as schedule (e.g., individual AHU units, columns, beams)

3.5.7 Optional (depending on project objectives)

- Traffic flows
- Temporary structures
- Workspace requirements
- Equipments
3.6 Scheduling for 4D Phasing

During feasibility through design development, the activities in the construction schedule are typically at the phase level, describing work areas.

3.6.1 Generic Activity Categories

Each activity in the schedule is assigned to one of three categories: Construct, Temporary, Demolish. These categories describe how components will be visualized during the activity dates in the 4D model. Elements attached to construct activities appear at the start of the activity and remain visible through the end of the schedule. Elements attached to temporary activities appear at the start of the activity and disappear sometime before end of the project. The temporary activities could be in two different line-items, such as erecting and removing shoring. Finally, elements attached to demolish activities are visible from the start of the schedule and disappear at the end of the activity.

3.6.2 Project-Specific Activity Types

The schedule should be broken down by different types of activities. For example, in a renovation project, where tenants are moving to swing space, the following activity types may appear: tenants move from original location, construction activity, moving to swing space, tenants move off-site. In the 4D model, these different activity types would appear in different colors.

Many times, a construction schedule will combine different activity types into one activity. Therefore, non-constructional activities need to be created to visualize the schedule correctly. For example, the activity “Move tenants to swing space” is actually composed of two parts: 1) Highlighting where the tenants are moving from (i.e. tenant original location) and 2) Highlighting where the tenants are moving to (i.e. swing space). Since these represent two different types of activities, two separate activities are required in the 4D model. Figure 16 shows these different types of activities highlighted.

Figure 16 Tenant snapshots taken from 4D model describe tenant moves during construction
September 30, 2016

This version of the GSA Building Information Modeling (BIM) Guide 07 - Building Elements is identified as version 1.0. The guide elucidates different forms of building information and provides guidance for how such information should be created, modified, and maintained in order to allow it to be utilized by multiple downstream business processes, including (but not limited to) portfolio and prospectus planning, facility operations and maintenance, and space and asset management.

GSA invites the public to submit feedback on this document, as it will continue to serve as the basis for further development, validation, and professional editing. GSA will continue to issue updated versions to address and incorporate on-going feedback in an open and collaborative process.

GSA recently published a BIM Glossary that defines many of the terms used in the BIM Guide series. Users can access the BIM Glossary and download the following BIM Guides at http://www.gsa.gov/bim:

- GSA BIM Guide 01 - 3D-4D-BIM Overview
- GSA BIM Guide 02 - Spatial Program Validation
- GSA BIM Guide 03 - 3D Laser Scanning
- GSA BIM Guide 04 - 4D Phasing
- GSA BIM Guide 05 - Energy Performance
- GSA BIM Guide 08 - Facility Management

Project teams are encouraged to review all available BIM Guides and apply them as appropriate. For further information about GSA's National 3D-4D-BIM Program or to submit comments or questions, please visit http://www.gsa.gov/bim.

The National 3D-4D BIM Program
U.S. General Services Administration
1800 F Street NW
Washington, DC 20405
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Foreword

The mission of the United States General Services Administration (GSA) is to deliver the best value in real estate, acquisition, and technology services to the government and to the American people.¹

GSA’s Building Information Modeling (BIM) program is focused on achieving agency priorities to meet this mission.² Since 2003, GSA’s BIM program has supported the efforts of the Public Buildings Service (PBS) to improve the quality and efficiency of building information management. Our earliest BIM requirements, which focused on better quality spatial data, led to more accurate space inventories, more accurate rent bills, and a better overall customer experience. Over time, GSA has added additional BIM requirements and optional uses to help meet our mission and sustainability goals. This has led to significant shifts in the project design and documentation processes as well as better support in both project management and downstream facility information uses, such as energy analysis and building operations. GSA continues to explore how technology can improve different aspects of PBS’s mission and business priorities, from internal communication, collaboration, and process improvement to innovation-driving partnerships with the architects, engineers, constructors, owners, and operators (AECOO) community.

GSA’s most recent BIM initiative has involved developing processes and tools for open-standard information sharing and reuse. GSA aims to remind ourselves and those around us that building information takes many forms and that all these forms can be used to improve facility and asset management. This guide is intended to elucidate different forms of building information and to provide guidance for how such information should be created, modified, and maintained in order to allow it to be utilized by multiple downstream business processes, including (but not limited to) portfolio and prospectus planning, facility operations and maintenance, and space and asset management.
Introduction
1 Introduction

The General Services Administration (GSA) collects and manages large amounts of information about its building portfolio that can significantly improve all aspects of its business, from forecasting and decision making on building new properties to operation and maintenance of existing facilities.

GSA recognizes that the information about its buildings is an asset of equivalent value to the buildings themselves. This awareness leads to the understanding that authorized users should have access to facility information from a single, accurate, reliable, and up-to-date information source.

GSA has therefore developed internal technology tools and a set of business processes to ensure that all Public Buildings Service (PBS) buildings are represented in accurate, reliable, current conditions models, or virtual facilities. The virtual facilities will provide the facility information consumed by other PBS business line applications for facility and asset management through the complete facility lifecycle—from planning through design, construction, operations, modernization, and eventually to disposal.

GSA BIM Guide 07 - Building Elements defines the building information modeling (BIM) deliverable requirements to support the technology tools and business processes as well as to ensure that for all GSA projects, GSA is

- Receiving and managing the same required set of information for all our buildings,
- Receiving all the information necessary to perform facility and asset management for all our buildings, and
- Receiving and managing building information in a consistent, open-standard format.

GSA BIM Guide 07 achieves this by specifying the data elements that must be in a GSA building information model (BIM).

1.1 File Formats and Software Tools

GSA is committed to open standards for BIM. GSA has adopted the Industry Foundation Classes (IFC) standard (ISO 16739) as the structure for defining and exchanging core building data. IFC is currently being maintained by buildingSMART International. GSA has also adopted Model View Definitions (MVDs) to facilitate more efficient exchange of specific types of information. More information about the MVDs that GSA uses is available in this and other guides in GSA’s BIM Guide series.

As a general rule, GSA requires that all BIM submissions be provided in two formats: the native format, which depends on the tool selected by the author of the information, and the IFC format. GSA does not mandate the use of any specific software tool; however, any software proposed for use on a GSA project or for managing GSA building information must be approved by GSA prior to use. For some uses, GSA may require specific formats for deliverables to enable GSA to perform quality control activities. In these situations, GSA may have templates available for use in creating these deliverables; these can be requested from the GSA project team or from the national BIM program office.
Section 2
Technical Guidance
2 Technical Guidance

The General Services Administration (GSA) uses open-standard Industry Foundation Classes (IFC) models to define requirements of, check, store, and manage building information model (BIM) data. Current BIM authoring software can not produce perfect IFC models when exporting from native models, and BIM authoring software cannot import IFC models without some loss in information quality. Therefore, GSA requires submissions in both the native and IFC formats at all stages of the facility lifecycle - from planning through design, construction (including as-built or record BIMs), and into operations. This section discusses performance requirements for the deliverables.

In addition to meeting GSA’s performance requirements, contractors must also know whether the content they are creating is covered by GSA’s directive on Document Security for Sensitive But Unclassified Building Information (P3490.2). For example, certain tenant agencies cannot be identified, and certain spaces and access routes cannot be shown on floor plans. Contractors must consult the GSA project team to clarify sensitive but unclassified (SBU) requirements for their projects and models in order to properly designate only the appropriate parts of their models as SBU. Section 2.2 provides more details on working with model elements.

2.1 Model Elements Overview

All models are composed of model elements that have properties and attributes. Each native BIM authoring tool, as well as IFC, uses its own unique terminology to describe these components. It is therefore important to first understand what is considered an element and how elements relate to one another in order to discuss them. Due to the complexity of buildings and BIMs, a simple hierarchy does not suffice to describe the relationship between model elements. A sophisticated ontology is required to develop an understanding of how model elements may relate to one another. All the levels in the model ontology have properties associated with them, and thus the properties of one model element are associated with related model elements. Section 2.1.1 uses one example to help clarify these relationships.
2.1.1 Model Ontology

*Federated Model and Single-Discipline Model*

Figure 1 shows a federated model - a model composed of multiple linked models - that contains architectural, structural, and mechanical, electrical, and plumbing (MEP) information of a building. Figure 2 shows only the stand-alone MEP model of the building.
System
Within any model, information is generally categorized into systems by function. Figure 3 shows a single system within the MEP model: the supply air system for the first floor of the building. Figure 4 shows the same system without the rest of the model. Properties of this system might include name (e.g. First Floor Supply Air), classification (e.g. mechanical), and components. Section 2.2 provides more details about required properties for different systems.

![Figure 3. Supply Air System Within an MEP Model](image1)

![Figure 4. Supply Air System by Itself](image2)
**Type and Component**

A system is composed of model elements called components, which can be categorized by type. In any model, there can be a single instance (i.e., a single component) of a component type or multiple instances (i.e., multiple components) of the same type. Figure 5 shows that there are multiple instances of the Variable Air Volume (VAV) component type in the supply air system. Figure 6 shows a single instance of the VAV component type. Properties of the VAV type can include manufacturer, model number, and product classification (e.g., single duct, dual duct). Properties of a specific VAV component can include spatial information (e.g., room number where the VAV is located), system to which this component belongs, or serial number. Figure 7 shows that there is a single instance of the Air Handling Unit (AHU) component type in this system.

**Figure 5. There are Multiple Instances of the VAV Component Type in the Supply Air System**

**Figure 6. A Single Instance of the VAV Component Type**

**Figure 7. There is One Instance of the AHU Component Type in the Supply Air System**
A component type can exist in multiple systems. For example, the VAV component type can exist in a system defined as “first floor supply air” and also in another system defined as “second floor supply air”. The same instance of a component type may also belong to multiple systems. For example, an AHU can be part of the “first floor supply air” system and also part of the “first floor return air” system. In addition, while the AHU would be categorized as a mechanical component, it is also a component of the electrical system that provides its power. Figure 8 shows the different systems associated with the AHU in our example.

Figure 8. The Different Systems Associated with the AHU

Model Elements
The term “model element” can describe any element in a model, regardless of its place in the ontology or its relation to other model elements; it can describe a component of a system or an instance of a component type. Thus, a model element can be a single part that is the smallest separable piece, or it can be an assembly that is composed of smaller elements (referred to as sub-elements). In Figure 9, both the AHU as a whole and its component sub-elements can be referred to as “model elements”.

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2.1.2 Levels of Detail and Levels of Development

The architects, engineers, constructors, owners, and operators (AECOO) community uses two similar terms - both represented by the acronym “LOD” - to describe the quality of model information. In 2008, the California Integrated Project Delivery (IPD) Task Force of the American Institute of Architects (AIA) defined Levels of Detail (LODs) to describe “the steps through which a BIM element can logically progress from the lowest level of conceptual approximation to the highest level of representational precision.” That same year, the AIA defined the term Level of Development (LOD) in EZ02-2008 as “the level of completeness to which a Model Element is developed.” In 2013, a working group of AECOO professionals published a Levels of Development (LODs) specification through the Associated General Contractors of America (AGC) BIMForum organization to further refine what “LOD” means in both design and construction:

“Level of Detail is essentially how much detail is included in the model element. Level of Development is the degree to which the element’s geometry and attached information has been thought through - the degree to which project team members may rely on the information when using the model. In essence, Level of Detail can be thought of as input to the element, while Level of Development is reliable output.”

All of these definitions are applicable for GSA, and the definition of LOD continues to evolve as industry further defines geometric and information requirements for building information. It is anticipated that new terms will be defined to separate these different
types of data requirements so that LOD for geometry and LOD for data or meta data can be defined separately. This guide will use the term “LOD” in a general way as context for the discussion of model development. As GSA further defines our geometric, data, and metadata requirements for a GSA BIM, this section will continue to evolve.

LOD levels start at LOD 100 and, in general, become progressively more detailed and more developed. LOD 500 represents as-built or actual conditions for various types of building information.

2.1.2.1 LOD 100

LOD 100 requires a low level of detail - roughly comparable to the level of detail traditionally associated with planning or conceptual design in a project. At this level, information is at its most primitive. For example, the building may be sited and roughly sized, and there may be a basic site layout. LOD 100 information is sufficient for performing some very preliminary types of engineering analysis that support high-level decision making about basic design. Examples include whole building energy analysis, building orientation daylight studies, conceptual cost estimates based on cost per square foot, and preliminary whole site construction phasing.

LOD 100 information may come in different formats because it can include engineering calculations, analysis data, and 2D drawings or sketches. LOD 100 information can be represented in a 3D model using generic “placeholder” objects that may or may not be accurately sized, dimensioned, or placed in the model. This would provide a framework for organizing other types of non-graphical or non-geometric information. However, a 3D model may not be the best way to represent the information. When possible, LOD 100 information should be in a format that will facilitate use of a BIM tool for further detail and development.

2.1.2.2 LOD 200

At LOD 200, generic model elements show approximate dimensions, quantities, locations, attributes, and relationships. There is sufficient information to inform design development and to answer high-level specific questions about spaces and systems. However, LOD 200 information is not necessarily sufficient for detailed analyses.

2.1.2.3 LOD 300

At LOD 300, specific model elements are fully defined in the BIM with exact dimensions, quantities, locations, attributes, and relationships. LOD 300 information should include all information that a design team would specify for a complete, biddable design package as delineated in the Facilities Standards for the Public Buildings Service (P100). LOD 300 information is sufficient for an estimator or contractor to provide a cost estimate for a project or to plan for the purchase, construction, and/or installation of specific building elements.

2.1.2.4 LOD 350

LOD 350 is a level in the AGC BIMForum LOD specification. Model elements at LOD 350 are defined with relationships within overall building systems, while model elements at LOD 300 are fully defined as specific, independent elements, assemblies, and systems.
2.1.2.5 LOD 400

LOD 400 provides sufficient detail in the BIM for fabrication and assembly. The information required for fabrication models is not necessarily the same as the information needed for design or as-built models, so LOD 400 models may have more or less information than LOD 300 or LOD 500 models, depending on the discipline. GSA does not specify information requirements for LOD 400; this is at the discretion of the contractor and fabricator.

2.1.2.6 LOD 500

LOD 500 fully defines the actual conditions of the facility. It is a virtual representation of the actual current conditions of the facility.

As-built documentation of a facility, intended to provide a snapshot in time of the actual facility condition at the conclusion of a project, must be at LOD 500. Project team members, including the architect/engineer (A/E) of record, the construction manager (CM), and the general contractor (GC), must collaborate in order to incorporate design changes and field changes in a complete, coordinated as-built submittal that accurately represents the facility condition at the conclusion of the project. The as-built submittal for a construction project should have field-verified LOD 500 information, including commissioning test results and other field inspection data. All commissioning test reports must be in digital format and must link to the appropriate BIM objects in the model. As GSA moves toward information-driven facility and asset management, GSA will require any data that is tested and verified by the commissioning authority be reconciled and included in the BIM deliverable as open standard [i.e. Construction Operations Building Information Exchange (COBie) compliant] data. Information related to operations and maintenance requirements must be provided in digital format as links to digital documents (such as operations and maintenance manuals) or as object data attributes in the BIM database. An LOD 500 as-built submittal does not necessarily contain all of the LOD 300 and LOD 400 information; it may incorporate a combination of LOD 300 and LOD 400 information for some building elements with the addition of commissioning test results and other field inspection data. Models need not show excessive fabrication level detailing. For example, ductwork must be sized and located correctly as installed but need not have flanges modeled.

GSA requires field-verified as-built BIMs that can be relied on for facility and asset management, not just information for design and construction. As GSA moves toward information-driven facility and asset management, GSA intends to continue to maintain a current conditions model of the facility, incorporating changes to the building condition in the as-built documentation. GSA field personnel, including building managers and operating engineers, will work with the GSA Building Information Manager to ensure that the information in a current conditions model of a facility continues to meet the definition of LOD 500.

At LOD 500, the model must be compliant with COBie as specified in GSA BIM Guide 08; models must be geometrically accurate and provide spatial data as specified in GSA BIM Guide 02; and models must be fully compliant with all published GSA model view definitions (MVDs) as of the project design start.
2.1.2.7 Changes to LODs

There is discussion in industry about whether the LODs as currently defined sufficiently meet the needs of all phases of the asset or facility lifecycle. If industry chooses to redefine existing LODs or to define new LODs for uses beyond the regular project lifecycle, GSA will review and incorporate them as appropriate.

2.1.3 Model Progression Matrix (MPM)

For every project, the project team must create a custom model progression matrix (MPM) to indicate the LOD for various types of data and disciplines, as required by project needs, and the MPM must be a part of the project BIM execution plan (BEP). For example, a tenant fit-out project may need higher LOD information about architectural finishes early in the project but require only a low LOD for mechanical information throughout the project, whereas a mechanical upgrade project may require low LOD architectural information even at project close-out but will require higher LOD mechanical information at early design stages. Similarly, a project scope of work may define that a Design Development deliverable for a historic restoration project must be at LOD 200, but the MPM may define that certain historic architectural details must be defined to LOD 300 even at this early stage.

A general LOD can be defined for a specific project deliverable. The project MPM must clearly delineate which spaces, disciplines, or equipment are at a higher or lower LOD than the general LOD set for the deliverable. For example, a partial building modernization may require LOD 200 for the Design Development deliverable but may indicate that areas outside the specific area of work may remain at LOD 100 throughout the design and construction process.

Various organizations have published sample MPM formats, including the following:

- The National BIM Standard-United States Version 3 (NBIMS-US V3) Section 5.8.4.3.5 outlines “Minimum Modeling Requirements”.
- AGC BIMForum 2015 LOD Specification provides an MPM template and an element attribute table that specifies the properties required for various elements at different LODs.

In some cases, the different standards may contain variations in LOD definitions. The project team must be careful to specify which standard and definition is in use for a given project. For more information, contact the national BIM program office or the regional BIM champion.
Figure 10. Sample Model Progression Matrix

<table>
<thead>
<tr>
<th>Model Progression Matrix (MPM) Example</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PROJECT NAME:</strong> Colorado Federal Building</td>
</tr>
<tr>
<td><strong>ADDRESS / CITY / STATE:</strong> 1254 Main Street, Denver, CO 80220</td>
</tr>
<tr>
<td><strong>DATE:</strong> 1 June 2015</td>
</tr>
<tr>
<td><strong>REVISED DATE:</strong> 25 July 2016</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Model Element Name</th>
<th>In Project Scope?</th>
<th>Model Element ID</th>
<th>Master Format ID</th>
<th>Object Class Table 21 ID</th>
<th>Object Class Table 23 ID</th>
<th>FACTS Code</th>
<th>Design Dev.</th>
<th>Constr. Bid</th>
<th>Model Element Author</th>
<th>As-Builts</th>
<th>Model Element Author</th>
<th>As-Builts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>FOUNDATIONS</strong></td>
<td>Yes</td>
<td>A10</td>
<td>21-01-10</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>100</td>
<td>Engineering Firm</td>
<td>300</td>
<td>Engineering Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Slabs on Grade</strong></td>
<td>No</td>
<td>A03</td>
<td>31 25 23</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>100</td>
<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Substrates</strong></td>
<td>No</td>
<td>B10</td>
<td>31 31 00</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>200</td>
<td>Structural Firm</td>
<td>300</td>
<td>Structural Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Supports</strong></td>
<td>No</td>
<td>E10</td>
<td>40 40 40</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>200</td>
<td>Structural Firm</td>
<td>350</td>
<td>Structural Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Exterior Vertical Enclosures</strong></td>
<td>No</td>
<td>B20.50</td>
<td>03 01 00</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>200</td>
<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td>Exterior Walls</td>
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<td>B20/10</td>
<td>21-01-10.10</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
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<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
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<td></td>
</tr>
<tr>
<td><strong>Exterior Doors</strong></td>
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<td>B20/40</td>
<td>08 56 00</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>200</td>
<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Exterior Horizontal Enclosures</strong></td>
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<td>B30.50</td>
<td>10 74 00</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
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<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Interior Construction</strong></td>
<td>Yes</td>
<td>C10</td>
<td>21-01-10.10</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>100</td>
<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Interior Partition</strong></td>
<td>Yes</td>
<td>C10/10</td>
<td>21-01-10.10</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>100</td>
<td>Architecture Firm</td>
<td>400</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
<tr>
<td><strong>Interior Fixed Partition</strong></td>
<td>No</td>
<td>C10/10.10</td>
<td>21-01-10.10</td>
<td>25-11-11</td>
<td>20000104-01-01-01</td>
<td>100</td>
<td>Architecture Firm</td>
<td>300</td>
<td>Architecture Firm</td>
<td>500</td>
<td>Civil / AE / GC</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** This Model Progression Matrix is only an example. All MPMs must be customized to fit only project scope items pertinent to each project.
2.2 Model Element General Requirements

GSA has general and specific requirements for model elements. This guide discusses GSA’s general requirements. GSA will utilize a combination of tools as appropriate to provide more specific requirements. These tools include MVDs, common object libraries, data dictionaries, and model element matrices. Industry and government entities use these more specific tools to address relationships and attributes of model element information as well as relationships of model elements to each other, to project milestones, and to project and building stakeholders. GSA has published some MVDs within the NBIMS-US, and GSA intends to publish additional MVDs in support of this guide.

This section is organized in parallel to the P100 for ease of use by the GSA design and construction community. As with all design requirements, project teams must comply with the P100 BIM requirements in terms of information to include in the model for each design submission and to what LOD to define that information. The GSA Project Manager and the GSA national BIM program must approve any proposed deviation from the P100 BIM requirements, and the project team must document the deviation in the project BEP.

Note that this section discusses general information. In some cases, this may apply to the design team, the construction team, third-party quality managers, or any combination thereof. The exact timing and responsibilities for providing information in the BIM should be documented clearly in the BEP.

Project teams must identify SBU information in the BIM(s) during all phases of the project. They must reference GSA’s directive on Document Security for Sensitive But Unclassified Building Information for labeling and handling SBU information, and they must tag the SBU information in a way that allows displaying and hiding the SBU information appropriately and at the authorized level. Note that SBU information must be specific to the model elements, and project teams shall not label an entire BIM as SBU by default. Contractors must coordinate with the GSA project team and comply with SBU requirements for projects and models in order to properly designate and label only the appropriate parts of the models as SBU. The BEP or the narrative submittal for the deliverable should include a narrative describing what project information is designated as SBU, and the BEP should also indicate how SBU is designated within the model. GSA intends to maintain a current conditions model of the facility, incorporating changes to the building condition in the as-built documentation. GSA field personnel, including building managers and operating engineers, will work with the GSA Building Information Manager to validate that the BIM correctly identifies SBU information in an ongoing manner during normal building operations.

2.2.1 Urban Development and Landscape Design

2.2.1.1 Base Points

All GSA building information models (native and IFC) - including site-only models - must contain site information that is properly positioned in accordance with a coordinate system in the model space and with a geographic coordinate system in the real world. Note that models that do not include site information in their primary authoring tool will not be able to export the required location information to IFC.
Every model must have a site base point, or survey point, that provides a measurable location in the physical world to help correctly orient the building. The site base point must be in the BIM of any building or project on the site. The site base point data must be properly mapped so that it exports to the IFC footprint and IFC survey point elements.

For a model of a single building, the site base point should correspond to the latitude and longitude that GSA has on record for the building. For a site with multiple buildings, all the individual BIMs on the site shall use the latitude and longitude that GSA has on record for the largest building on the site as their site base point. The site base point should also include the elevation of the point. Coordinate with the GSA asset manager and the GSA national geographic information systems (GIS) program to determine what geospatial information is on record. GSA recommends using an actual United States Geological Survey (USGS) survey point, if available, to establish this base point, which facilitates georectification of the model.

For a specific project, the project team may establish a convenient project base point at a different location from the site base point for the building. A project base point is especially useful when a project touches only a portion of a building or when a building is located on a multi-building site. In general, the project team should select a project base point that is compatible with the needs and structures of the various software platforms that will be used on the project. This project base point defines the origin (0,0,0) of the coordinate system of the BIM data for that project. The project team shall document in the project BEP a project base point that is different from the site base point.

If there is a project base point in an existing BIM, any subsequent project in the same building shall use the same project base point, unless there is a compelling reason to select a new project base point. If a project team selects a new project base point, the BEP must document the reason for selecting a new project base point.

The BEP must define Project North in relation to True North. All BIM data for the project must use these defined directions consistently.

2.2.1.2 Site and Campus Models

Site models must include civil utilities to the maximum extent practicable. In particular, the site model for a campus that is wholly owned or managed by GSA must include modeling of civil utilities. Civil utilities must be mapped to IFC civil data elements and classified by OmniClass’ Table 21, and they should include vaults, raceways, etc., as required. In order to ensure accurate data for modeling, utilities should be a part of the site survey. Direct burial utilities should be located by a qualified utility location service, with a special flag at any turn or deviation from straight-line run.

Any GSA property that is part of a campus - including, but not limited to, land ports of entry and urban federal center campuses - requires a separate site model. This site model shall show the geographic locations of all the individual buildings on the campus and shall also contain the locations and civil engineering data associated with the site utilities, roads, parking areas, and service structures. The buildings shown on the site model shall be lightweight models illustrating only the general size and shape of the building and the utility penetrations to the buildings. When applicable, the site model shall clearly indicate that the buildings share utilities.
The site model shall also show whether each building on the campus is in use. For a building that is in use, the site model shall link to the detailed individual building model or the main model of a set of federated BIMs for the building. For a building that is not in use and that has an existing BIM, the site model shall link to the representation of the building. For a building that is not in use and that does not have an existing BIM, the site model can include the relevant minimal information directly as properties of the element representing the building, instead of linking to a separate, specially created, detailed BIM for that building.

2.2.2 Architecture and Interior Design

Architectural BIMs can include information about both the building’s structural composition (i.e. core and shell architecture) as well as the interior finishes and space layouts (i.e. tenant improvement architecture). As a general rule, these two types of information should be modeled in two separate BIMs. The BIM containing the information about interior finishes and space layouts should be linked to the overall architectural BIM.

Architectural model elements can be physical products and construction, such as walls, ceilings, and windows. However, architectural model elements can also be abstract objects such as rooms, spaces, and zones.

Abstract architectural objects carry data and properties about the building’s uses and management throughout the building lifecycle, not just about the physical materials that make up the building. These abstract objects are often created with parametric relationships or boundaries comprised of physical architectural model elements. For example, room, space, and zone elements are abstract architectural objects. GSA BIM Guide 02 has more information on properties of room, space, and zone elements in a BIM. In addition to the requirements delineated in GSA BIM Guide 02, all spaces in a model must be classified using OmniClass Table 13.

For all architectural objects that represent physical products or physical construction, model elements shall include all product information as properties of the model element to the maximum extent practicable. At a minimum, model elements must have the properties traditionally shown in 2D drawing schedules. All schedules should be derived from the model and should not be generated independently using spreadsheet or other tools. Hazardous material content is required to be included as a property for all materials in the BIM, as applicable. In addition to these properties, model elements representing physical products should include a property called “product data” whose property value is a hyperlink to a product data sheet [portable document format (PDF) or other format deemed acceptable by the GSA team] stored on a GSA server, as directed by GSA, to ensure that product data is not lost if a manufacturer updates their product information library. Hyperlinking in the model must be done in such a way that hyperlinks will continue to function if product data sheets need to be migrated between GSA servers (i.e. hyperlinking must utilize relative links to a specific document so that a single universal edit to the host server name will update all hyperlinks in the model. See section 3.1.1). In some cases, there may need to be multiple “product data” properties.

2.2.3 Structural Engineering

The structural model must accurately define the building structure and all its components, including the elements, geometry, and materials. It must include the material and material properties for each structural model element. Hazardous material content is required to be included as a property for all materials in the BIM, as applicable. The required model element properties for each structural feature will vary based on the material used for that element.
The structural model must contain clearly labeled and fully dimensioned beam, column, and foundation elements. The structural elements of a building must capture reinforcing and connections explicitly, along with connection details, material properties, cross-section properties, assigned structural analysis models, load cases (including wind, snow, thermal expansion, seismic, and others as required), load combinations, and load results for the relevant combinations. Similarly, model elements which are part of progressive collapse and blast mitigation shall be explicitly identified and defined, at a minimum, as SBU. Some or all of these elements may require a higher security classification, depending upon building type and occupancy. Consult the GSA Project Manager to clarify SBU status.

The structural model shall contain all necessary elements needed to evaluate and analyze the building structure either by traditional methods or by any commonly used structural simulation software under load assumptions set by governing building codes [such as those published by the American Concrete Institute (ACI), the American National Standards Institute (ANSI), and the American Institute of Steel Construction (AISC)]. Due to the complexity of the many different types of structural load cases, it is crucial that the structural system be correctly modeled so that the linear and nonlinear analyses commonly performed to evaluate seismic loads on building structures are reliable and accurate.

At a minimum, structural models must contain the following elements:

- Foundations: All components of the foundation, including but not limited to isolated pads, bearing and retaining footings, stem walls, structural slabs, and piers, must be fully modeled.
- Horizontal elements: All beams, joists, slabs, and precast slabs must be fully modeled. The model must show slab perimeters and structural edges; penetrations for shafts, holes, or other slab discontinuities; and cantilevered sections.
- Vertical elements: All columns, walls, and cross bracing must be fully modeled. All connections and start/end points of such elements must be modeled to allow load continuity.
- Inclined planes: Any inclined structural element, including but not limited to non-plumb walls, stairs, ramps, and roofs.
- Abstract structural elements, including but not limited to loads and load distributions.

In addition to the elements listed above, the structural model shall include any additional structural elements as required by the building design. All structural elements shall be properly joined so that the structural design model can be used for analysis, fabrication, and other purposes.

Projects involving historic buildings require special care with structural elements. In many cases, the building structure must be preserved due to historic or cultural interests; in these cases, it may be necessary to model the building structure to a high LOD earlier in the process and to maintain a high LOD structural model. The design team should use the appropriate tools, including laser scanning, to accurately represent these elements for use in both structural analysis and historic preservation. More information about laser scanning and other imaging technologies is available in GSA BIM Guide 03.

2.2.4 Mechanical, Electrical, Plumbing (MEP) and Fire Protection (FP) Engineering

The MEP model(s) shall accurately depict the building’s MEP systems, including (but not limited to): boilers, chillers, geothermal and solar energy systems; pumps and piping distribution systems, water-side terminal units; fans, air handlers, air distribution and evacuation systems, air-side terminal units, VAV boxes; electrical feed and distribution systems, transformers, electrical panels and switchgear, lighting, emergency circuitry, emergency generators; all public utility systems from tap, all control systems, data and
phone wiring and terminal devices, data switches, data rooms. The default set of assets that should be included in the MEP model(s) is all assets that were traditionally shown in 2D drawing schedules. See GSA BIM Guide 08 for additional detail.

Fire protection models must include information regarding fire ratings based on UL for standardized assemblies; material properties for combustion for all physical elements; sprinkler locations, sprinkler medium, sprinkler head temperatures, pressure and flow volume based on field measurements.

For modeling related to a project, consult a GSA Facility Manager [or Equipment Manager or building automation system (BAS) Specialist] familiar with the building to determine if there is any special equipment that must be modeled or if there are any asset types that do not need to be modeled. Consult the GSA Facility Manager for every deliverable review for which there is mechanical design content at the concept level or beyond. Document any additions or subtractions from the default set of assets in the project BEP.

For all products in MEP in models, the model elements must include all appropriate data and properties to store schedule information traditionally embedded in a 2D drawing schedule. Hazardous material content is required to be included as a property for all elements in the BIM, as applicable. The model elements must also include a property called “product data”. The property value for this property should be a hyperlink to a product data sheet stored on a GSA server, as directed by GSA, to ensure that product data is not lost if a manufacturer updates their product information library. Hyperlinking in the model must be done in such a way that hyperlinks will continue to function if product data sheets need to be migrated between GSA servers (i.e. hyperlinking must utilize relative links to a specific document so that a single universal edit to the host server name will update all hyperlinks in the model. See section 3.1.1). In some cases, there may need to be multiple “product data” properties. For example, a chiller may have multiple documents associated with it, including an equipment cut sheet, an operation and maintenance (O&M) manual, and a warranty document. This data must comply with all COBie requirements and all requirements of GSA BIM Guide 08.

It is important to note that some architectural or structural model elements may have associated mechanical or electrical properties. For example, building envelope elements such as curtain wall panels and roof materials are required to include the mechanical or energy design properties such as insulation thickness, roof reflectance, and glazing thermal coefficients.

It is also important to check that the MEP systems in the model are properly split to show which equipment is serving which spaces or floors. Modelers must be careful to ensure that system assignments made in the native authoring software are properly reflected in the IFC deliverable.
2.2.5 Other

Numerous specialties are involved in the design of a building, and the specialty information must be recorded in the model.

For some specialties, the necessary information can be included as a property of an element in the model. For example, hazardous materials can be identified by a simple yes/no property directly associated with the element. Similarly, the level of classification of a design feature (e.g. not sensitive, sensitive but unclassified, classified) or the historic status of a building or a model element (e.g. listed on the national register, eligible to be registered) can also be identified by a simple designation on the model element.

However, some specialties will require more information to be included in the model than can be captured in a single property. For example, security equipment may or may not be in the electrical model. If security equipment is modeled in a separate security model, it must be properly referenced for inclusion in the federated model. Many security features of a building will require a different set of properties from regular electrical equipment.

2.3 Naming Conventions

Standardized naming conventions are required to achieve clear and concise naming for BIM-related data and promote effectiveness when working with BIM. The guidelines listed below apply to any object present in a dataset at the time of delivery to the GSA.

2.3.1 General Guidelines

The intent of using standardized naming conventions is to enable human users of files or data to effectively and efficiently locate relevant information. Therefore, whenever possible, use plain language descriptive text, rather than any sort of alphanumeric code, to name files or objects. All descriptive text (in file names, object labels, or attributes, etc.) should be in English. Non-English manufacturer names are acceptable.

Files and objects may not be named using personal designations. For example, “John’s working model” is not an acceptable file name.

Consult the GSA project team for GSA standard naming conventions. Where there is no GSA standard naming convention, use a consistent naming convention for the project. Any project-specific naming convention must be approved by the GSA project team and noted in the project BEP.

Consult the GSA project team for GSA standard abbreviations. Where there is no GSA standard abbreviation, use a consistent abbreviation for the project. Any project-specific abbreviation must be approved by the GSA project team and noted in the project BEP.
2.3.2 File Naming Conventions

2.3.2.1 Metadata Required for Internal GSA Current Conditions File Management

GSA is managing building information with a focus on clear identification of current building information, or “current conditions”. The following metadata is required for all files:

- GSA Building Number
- GSA Building Name
- Region
- Building Address
- Building City
- Building State
- Building Zip Code
- Floor (or Floors)* (see below for additional discussion)
- File Name
- File Status (Pending, Current, Archive)
- File Created Date
- File Created By (Author)
- File Modified Date
- File Modified By (Author)
- File Type
- Data Type
- Discipline** (see below for additional discussion)
- Long Description
  - Include version of authoring software
  - Include any region-specific metadata with appropriate tags

For computer-aided design (CAD) drawings, the following additional fields are required:

- Drawing Number
- Drawing Title

For any file generated in the context of a project, the following additional fields are required:

- Project Number
- Project Title
- Project Description
- Project Phase (Concept, Construction Documents, As-Builts)
- Submission Date
- Design Complete Date
- Construction Complete Date
- A/E Name
- A/E Contract Number
- GC Name
- GC Contract Number
- GSA Project Manager

*Floors/Levels in a BIM file or a sheet view shall be named in accordance with the latest version of the PBS CAD Standards. In the March 2012 version of the PBS CAD Standards, floor naming conventions are found in Item 15 (page 3).

**Current conditions information for a GSA building is organized by discipline, utilizing the framework provided by the P100. Therefore, information provided to GSA by project teams must be clearly identifiable by these disciplines. Discipline naming conventions are indicated in the PBS CAD Standards (Item 14 of the March 2012 version; later versions will govern when published). In general, code disciplines in accordance with the United States National CAD Standard (NCS), with adjustments as described in the PBS CAD Standards.

### 2.3.2.2 File Naming Conventions for Projects

Naming conventions for CAD and for sheet views extracted from BIM must comply with the PBS CAD Standards. Naming conventions for BIM files should comply with Table 1:

**Table 1. Naming Convention for BIM Files**

<table>
<thead>
<tr>
<th>Building Number</th>
<th>Number of Characters</th>
<th>Example</th>
<th>Notes</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discipline designator</td>
<td>1 or 2 followed by an underscore</td>
<td>A_</td>
<td>Typically 1 character for the major discipline. In cases where there are multiple models for the same discipline, a second character may be added to indicate the minor discipline.</td>
<td>NCS (latest version) + PBS CAD Standards (latest version)</td>
</tr>
<tr>
<td>Floor Number or Range</td>
<td>2-5</td>
<td>01-07</td>
<td></td>
<td>PBS CAD Standards (latest version)</td>
</tr>
<tr>
<td>End with file extension</td>
<td>3</td>
<td>.ifc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Some sample file names that comply with this schema are below:

- DC0021ZZ_A_01-07.rvt (multi-floor architectural model)
- CO0009ZZ_M_SB.ifc (sub-basement mechanical model)

### 2.3.3 Model Element Naming Conventions

Model element names should be in compliance with naming conventions established for a specific discipline. For example, maintainable equipment must be classified and named in compliance with GSA’s Facility Asset Component Tracking System (FACTS), which is also published as ASTM Standard E3035-15. Similarly, space objects must be classified and named in compliance with GSA’s National Business Space Assignment Policy (NBSAP). Consult the GSA project team or the National BIM Program Expert for discipline-specific information about model element naming.

In addition, model elements must be classified and designated with the appropriate Omniclass codes.
Section 3
Practical Guidance for Modelers
3 Practical Guidance for Modelers

This section includes practical guidance for working with building information modeling (BIM) files, creating accurate Industry Foundation Classes (IFC) models, and checking models against the General Services Administration’s (GSA’s) requirements.

In general, GSA requires compliance with the BIM guidance in the following documents, in order of precedence:

- Facilities Standards for the Public Buildings Service (P100),
- GSA BIM Guide series,
- GSA PBS CAD Standard,
- National BIM Standard-United States (NBIMS-US), and
- United States National CAD Standard (NCS).

3.1 Best Practices for Modeling

3.1.1 Model References

Graphical files (i.e. drawings or models) should always be referenced base point to base point [i.e., (0,0,0) to (0,0,0)]. Different models of the same building must all utilize the same base point. See section 2.2.1.1 for more information on establishing base points for a model.

All references must have relative paths, rather than absolute paths. The relative path should begin from the main model directory, as demonstrated below.

- Examples of valid use:
  - Concrete\Warranty Info\Warranty.pdf
  - .\Concrete\Warranty Info\Warranty.pdf
- Example of invalid use:
  - E:\Models\Concrete\Warranty Info\Warranty.pdf

References to objects in other models and links to external documents must also use relative paths.

Avoid reference nesting, especially on project-based BIM platforms. Each reference should be a direct reference to the required information, so that there is no need for multiple click-throughs from reference to reference.
3.1.1.1 Referencing vs. Inserting

When referencing information in a model, the information remains in its original location and is managed and edited in its original location. When inserting information into a model, the information becomes natively a part of the model and will be managed and edited in the model going forward.

In general, only reference - do not insert - information that is located in a database or file repository. However, it is sometimes desirable to insert information from an external source directly into a model. This usually only occurs when the information is a model object in another model.

Consider these basic rules when deciding whether to reference or insert information:

- Each real world object shall exist in only one model. If the information is useful in more than one model, locate it natively in one model, then reference it in the other models.

- The model in which an object is natively located is the model that “owns” that object. Inserting an object into your model means that you are taking ownership of that object: you will continue to manage and edit the information related to that object. If you are not the party responsible for managing and editing that information, reference the object instead of inserting it.

- When there is a genuine need to insert information into a model, ensure that the inserted object and the model are of the same data format. When this is not the case, convert the information into the format of the model before insertion. For example, it is preferable to convert 2D DWG data into 3D BIM data prior to inserting the 2D data into the building information model (BIM) even though it is possible to insert 2D data directly into the BIM.

3.1.2 Federated or Linked Models

If there is more information for a building or a project than can be reasonably contained in a single model, it may be appropriate to divide the building information into a federated set of models. It is important to consult the downstream GSA users of the BIM deliverables, including the building’s facility manager, before deciding how to assign the different sets of information into the separate models and how to link the models into a federated model. When doing this for a project, the contractor must document these decisions in the BIM execution plan (BEP).

Modelers should check to ensure that linked models are properly scaled and positioned so that they align when opened simultaneously. For example, it is important to ensure that a mechanical, electrical, and plumbing (MEP) model is properly referenced to the architectural model so that when they are linked together and loaded together, the MEP systems appear inside the building, in the correct positions, and at the correct scale.
When a federated model is a project deliverable, it must include the main model and all linked models. The main model must include all necessary links between models, and each model must open independently without any opening errors.

When a modeler links to a file for working purposes [for example, when a modeler links to a computer-aided design (CAD) background as a basis for modeling], but the file is not required in the final model deliverable, then the modeler must unlink and unload the unnecessary file from the main model prior to submitting the deliverable. The project deliverable shall only include live and necessary files.

3.1.3 Collaboration on Models

During a project, modelers often use workflow tools within a model authoring software to aid collaboration. All workflow assignments must be removed from the model prior to submission as a project deliverable.

3.1.4 Standard and Custom Model Views

GSA recommends including standard model views to isolate the major systems and major assets identified in the Construction Operations Building Information Exchange (COBie) information delivery plan. Other standard model views, such as those for spaces of interest to general or specific building tenants, may also be useful. The project team should consult with downstream model users, such as the building management team, to determine what additional default model views to include in the model and document the determinations in the BEP. Contact the national BIM program office or a regional BIM champion for more information.

If the project team sets up custom model views for the convenience of project execution, it may choose to leave them in the final model deliverable for downstream users. The project team must document such a decision in the BEP.

3.1.5 Modeling Existing Buildings

When it is advantageous to model an existing building in whole or in part, it is not always practical to meet all the requirements defined in section 3. There are two major instances where less information may be more appropriate:

• For limited scope projects, a limited scope BIM (LS-BIM) would document only a limited amount of building information, with “limited” defined either spatially (e.g. all the information for a single floor or floors) or by discipline (e.g. only mechanical equipment, either for an entire building or for a limited and defined portion of the building). Since the LS-BIM will later merge with other LS-BIMs to compile a complete current conditions model for the building over time, it is not appropriate to invest resources to document the building to a higher level of detail than is immediately required, as that additional detail may ultimately make merging the models more difficult. In general, use LS-BIMs for limited scope projects, and limit the level of detail required in the model according to the level defined in the project scope. For these limited scope projects, focus only on information required for the project or application that is driving the scope limitation.
• For non-project-related modeling efforts, a BIM of an existing building (EB-BIM) would document all the disciplines and all the spaces but would not necessarily include all the detail required in a design or construction model. For example, information about constructability or purchasing may be less relevant. The required level of detail for EB-BIMs may vary greatly, depending on the reason for developing the EB-BIM. See section 3.1.5.1 for additional information.

LS-BIMs and EB-BIMs may include basic spatial arrangements and relationships, basic shell and fenestration details, basic properties of how the building is constructed, e.g., foundation, wall, floor, and roof thicknesses and materials. These two types of BIMs are often produced using as-built CAD drawings as the basis of the model and then enhanced with field investigation. These BIMs represent a snapshot in time and serve as “information platforms” to accurately represent buildings as they stand. They can be used for many ongoing applications in facility and asset management, including work order management, preventive/periodic maintenance, building controls management, spatial data management, and documentation and maintenance of current conditions.

3.1.5.1 LOD for EB-BIMs

EB-BIMs will require varying levels of detail (LODs) and levels of development (LODs) based on their intended use:

1. For EB-BIMs intended for ongoing management of the building/facility, LOD 500 may be required for all model elements representing managed assets. However, assets that are not managed (such as fixtures or spaces) may be modeled only as needed to provide context for the managed assets.

2. For EB-BIMs intended as a platform for spatial data and rent bill management, space and architectural information may require LOD 500, while model elements for other disciplines, or even some model elements within the architectural discipline, may only require LOD 100 or require no model at all.

3. For EB-BIMs intended to serve as the basis of design for subsequent construction projects, during which normal due diligence investigatory work would be undertaken by the project architect/engineer (A/E), the required LOD may be only 100 or 200 for model elements of any discipline, as the EB-BIM will be merged with higher LOD LS-BIMs from future projects.

Over time, the lower LOD elements in any EB-BIM can be supplemented by merging higher LOD LS-BIMs with the EB-BIM. The EB-BIM can sometimes become the current conditions model for the building, to be used across GSA business lines for many purposes.

3.1.5.2 Determining LOD for EB-BIMs

LOD requirements will vary according to building type, size, age, use, and potential for modernization, and they will need to be tailored specifically for each building in order for the BIM to be sufficiently representative. Sometimes more complex model elements (such as structural components or MEP systems) can and should be included if accurate as-built drawings exist, but only if the intended use merits it. Generally, some indication of all major system components should be included, but only to the extent required for model context or immediate use.
Setting the appropriate LOD for an EB-BIM project is important because the goals of modeling an existing building can vary widely, and they are not as clearly defined as the goals of modeling for a design or construction project. There tends to be a direct relationship between LOD and modeling cost, so it is important to clarify the goals of the modeling effort in order to determine the appropriate LOD and thus justify the cost of modeling. Note that the LOD does not need to be uniform for all disciplines even within a single building. Some buildings may require only a very low LOD for the building architecture, but a high LOD for the building MEP, and vice versa.

Listed below are some guidelines for determining the appropriate LOD for different situations:

- **Building Types:** Some building types are significantly more complex than others. A higher level of complexity may necessitate a higher LOD for the building model. For example, laboratory facilities often have complicated infrastructures and thus may warrant a higher LOD than a standard office building. Similarly, large data centers may be architecturally simple but have complex heating, ventilation, and air conditioning (HVAC) and electrical systems, therefore requiring a higher LOD.

- **Building Size:** Since larger buildings tend to have more complex building systems, larger buildings often require a higher LOD. Conversely, models of very small buildings can have less detail while still being sufficiently representative.

- **Building Age:** The age of a building can have an impact on the LOD needed. For example, many historic structures are more ornate and will require more detailed architectural models to accurately document the condition of the building. On the other hand, a newer building might have more complex building systems or control systems that could necessitate a higher LOD for the mechanical model.

- **Building Use:** The use of a building can drive complexity. For instance, an office building with judicial tenants may seem like a regular office building. However, it may require a higher LOD to properly document the building or specific spaces within the building due to security requirements - such as blast protection or circulation controls - as well as special space types - such as holding cells or sally ports - within the building.

- **Potential for Modernization:** If a major investment is planned for a building within 3-5 years, it is necessary to consider whether modeling the building:
  - in conjunction with the modernization project is more cost effective and efficient for the project team, or
  - prior to the modernization project will allow for a more focused modeling effort, provide a better baseline for the project, and enable a more rapid project start.

If modeling is done in advance of an expected project, a higher LOD may be appropriate in order to ensure that the baseline BIM provided to the project team contains all relevant information. On the other hand, a lower LOD may be appropriate as some of the detail of the existing building may be changed by the upcoming project and can be filled in later by the project team.
3.2 IFC Models

3.2.1 Exporting to IFC

3.2.1.1 General Guidelines for Exporting to IFC

While GSA is vendor-neutral and allows the use of any native authoring tool, it highly recommends using an IFC-certified tool. Use the latest (or most appropriate) version of IFC, the native authoring tool, and the IFC export tool. As a best practice, use a native authoring tool that incorporates a fully supported IFC export tool. Document in the BEP the version of the native authoring tool and the version of IFC approved for project submissions.

For each submission, ensure that the native and IFC models are coordinated and contain the same information. The IFC model submission must be exported after the last save date of the native model submission.

The native model objects must be correctly mapped to ifcElements in order for export tools to work correctly. Objects that are incorrectly mapped in the native model can cause serious issues in the IFC model. For example, in the figure below, native model door objects were incorrectly mapped to ifcWall objects, so when the IFC model is supposed to show only walls, it also shows doors.

![Figure 11. Model View Showing Door Objects Incorrectly Mapped to ifcWall Objects](image-url)
Avoid this type of issue by carefully checking the object mapping document prior to exporting to IFC. When necessary, the modeler can directly edit the IFC mapping document in the native authoring tool to ensure that objects are exported correctly. For example, it may be necessary to edit the mapping document in the native tool to ensure a proper export to a given model view definition (MVD).

Use the correct MVD to export information from the native model. Consult with a regional or national BIM expert to determine the correct MVD for a specific project need. When an MVD is specified as a project deliverable, extraneous model objects should not be included, as they will make analysis of the IFC data less efficient. For example, submission of a spatial validation MVD should not include external site objects. Eliminate any superfluous information prior to export.

3.3 Quality Control

The goals of quality control during a project are many. First and foremost, the project contractor and the GSA project team have the responsibility to ensure that the submitted BIM or BIMs meet the project contract requirements.

A quality control report (QCR) is required for each project submission that includes BIM deliverables, in both the design and construction phases of a project. The contractor must certify in the QCR that all required quality control activities, as outlined in this guide and in the project BEP (see section 4), were performed successfully and that the results meet the requirements described below. See Figure 12 for a sample QCR template.
Figure 12. Sample Quality Control Report Template

**Basic Information**

*Project Information*

Name __________________________________________

Number _________________________________________

Address _________________________________________

Description ______________________________________

**List of Included Data**

<table>
<thead>
<tr>
<th>File Name</th>
<th>Description of File</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Type of Submit**

- [ ] Informal
- [ ] Formal
- [ ] Final (Project Close Out)
- [ ] Design Concept Phase
- [ ] Design Development (DD) Phase
- [ ] Construction Documents (CD) Phase
- [ ] Construction Delivery Phase
- [ ] Closeout Phase (As-Built and Record Drawings)
Standards and Auditing

Standards Compliance

All submitted files conform to:

☐ Spatial Data Management (SDM) Standards per GSA BIM Guide 02
☐ Model Element Standards per GSA BIM Guide 07
☐ Facility Management Standards per GSA BIM Guide 08
☐ The BIM Execution Plan for the project
☐ The Model Progression Matrix (MPM) definition for the project phase

Auditing

All submitted files have:

☐ Passed all GSA supplied auditing tools
☐ Been visually inspected and found to be free of errors
☐ Been purged of unnecessary data

Notes

Add any relevant information that has not been covered above.

Quality Representative

Name ____________________________________________

Phone Number _____________________________

Email Address ____________________________________
Section 3.3.1 discusses best practices for checking BIMs, and section 3.3.2 discusses best practices and benefits of clash detection. Figure 13 below highlights key quality control actions from planning, design, construction, to completion.

**Figure 13. Key Quality Control Actions**

<table>
<thead>
<tr>
<th>WHO</th>
<th>PROJECT TEAM</th>
<th>DESIGN TEAM OR CONSTRUCTION CONTRACTOR</th>
<th>QUALITY CONTROL TEAM</th>
<th>PROJECT TEAM</th>
<th>BIM FACILITATOR</th>
</tr>
</thead>
<tbody>
<tr>
<td>WHEN</td>
<td>At each BEP submission</td>
<td>Every project submission that includes BIM deliverables</td>
<td>Every project submission that includes BIM deliverables</td>
<td>During each BIM-facilitated coordination meeting</td>
<td>After each BIM-facilitated coordination meeting</td>
</tr>
<tr>
<td>WHAT</td>
<td>1) Outline quality check procedure and tools (2) Document model structure (3) Document relevant software considerations</td>
<td>Submit: (1) native and IFC files (2) QCR (3) Clash Detection Report (CDR)</td>
<td>(1) Open the native and IFC models on an independent computer (2) Perform independent clash detection on all BIM deliverables and validate CDR (3) Review deliverables for compliance with project requirements</td>
<td>Review CDR and resolve clashes</td>
<td>Update coordination BIM</td>
</tr>
</tbody>
</table>

**3.3.1 Checking the Model**

As a best practice, at least the next downstream user of the information should be involved in reviewing the BIM. For example, when possible, the general contractor should participate in reviewing the design BIM. It is advisable to also include the facility manager and/or the commissioning agent in reviewing the design BIM. Similarly, the facility manager and/or the commissioning agent should be engaged in reviewing the construction BIM prior to turnover.
The simplest form of quality control for both designers and reviewers is to open the native and IFC models on a computer other than the one used to author the model. Often, basic errors in how the model is organized, or in how multiple models are linked together, will come to light by opening the model with the BIM authoring tool on a different computer. This basic check should be followed by more thorough checking methods as further described in the following sections.

3.3.1.1 Coordination between Native and IFC files

GSA requires native and IFC file formats for every BIM submission. Modelers are required to ensure that the exported IFC files are completely aligned with the native files and contains all the information required in section 2. This quality check must be performed prior to submitting the deliverable. The quality check procedure and tools shall be outlined in the project BEP. Consult with the GSA BIM champions or national BIM program to discuss quality control tools available.

Project contractors - both design teams and construction teams - must certify that native and IFC model files in each deliverable are coordinated and contain all the required data. If an automated model checker program is used to perform the quality check, provide the quality control report (QCR) from the automated checker as part of the quality certification.

3.3.1.2 GSA-specific Model Checking

Designers are required to comply with the Facilities Standards for the Public Buildings Service (P100) requirements for BIM and CAD deliverables at every design milestone. GSA and designated reviewers should check that all P100 requirements are met. This includes checking that 2D sheets and schedules are derived from the model and that the native model has spatial data management (SDM) and COBie data properly populated to export to IFC for official GSA data checking. GSA project teams should consult with the regional Building Information Manager or with the national BIM program office for assistance on BIM quality control.

GSA utilizes automated model checking to perform quality control on IFC deliverables. It is recommended that A/E utilize GSA-specific model checking rulesets, where available, to perform preliminary quality control analysis to meet the GSA requirements outlined in the GSA BIM Guide series. A/E should consult with the GSA project team to determine the methodology that will be used for compliance checking; it may be possible for A/E to gain access to compliance checking tools that GSA uses. A/E will bear any costs associated with gaining access to these tools. A/E may also coordinate with the GSA project team, and where available, submit preliminary deliverables for pre-submission checking and feedback to ensure conformance of final deliverables. Consult the GSA Project Manager for more information.

These automated model checks can identify whether or not required information is present in the model and is in a valid format. Similarly, automated model checking can determine if field values comply with values in a pre-determined lookup list.
Automated model check reports will show different categories of errors, and reviewers will need to determine which errors are due to model-checker software issues, which errors are due to file exports from the native model to IFC, and which errors are due to actual issues in the native file. For errors related to file exports from the native model to IFC, the IFC data points should be traceable back to the original native data points by using the file export mapping provided by the authoring software tool. In cases where there are adjustments to the mappings provided by the authoring tool, the IFC data points should be traceable using the file export mapping documented in the project BEP.

However, automated model checking will not be sufficient to determine if the data in the fields correctly conveys design intent for a specific project. This type of checking would need to be done manually by someone familiar with the project scope. This manual model checking would be similar in intent to traditional design review activities. Note that BIM-specific manual checking includes:

- Visually inspecting the combined federated models in a simplified model viewer tool to ensure that the models all utilize the same origin point and are scaled correctly (to ensure that clash detection will actually work) and that the models visually look like the right project.
- Reconciling discrepancies between spatial reports and the project Program of Requirements.
- Reconciling discrepancies between the mechanical reports and any schedules or specifications provided with the deliverable.
- Checking that schedules and any 2D sheets are automatically created from the BIM (rather than generated and managed independently). This checking generally needs to be done in the native BIM, as IFC BIMs do not contain schedules or sheet views.
- Spot-checking attribute field content for compliance with the project design intent.
- Spot-checking sensitive but unclassified (SBU) and non-SBU components of the model to ensure they are properly designated.
- Spot-checking embedded document links to ensure that the correct documents are linked to the correct BIM objects.

3.3.2 Clash Detection

Clash detection is an important part of the quality control process for design and construction BIM. Design teams should use clash detection tools to ensure a fully coordinated design within each discipline, across all disciplines, and across all authoring platforms as well as to confirm that the design meets all requirements defined in GSA references and applicable codes. Construction contractors should use clash detection to ensure that subcontractor work is fully coordinated before field installation begins.

Clashes can be considered “hard” or “soft” clashes. A hard clash is when two (or more) physical objects occupy the same space. An example of a hard clash would be if mechanical ductwork is placed where there is a structural member. Such a clash could be resolved by re-routing the duct, moving the structural member, or creating a space for the duct in the web of the structural member (preferably in the steel shop, rather than in the field).

A soft clash is when the positioning of two (or more) objects interfere with necessary clearances, tolerances or access spaces - for example, if a piece of equipment is placed so that it blocks an access door, does not allow the access door to be opened fully, or takes up the space where a building operator or technician would need to do work.

In both design and construction, GSA requires the creation, submission, and use of Clash Detection Reports (CDRs) to illustrate design and construction coordination and to serve as a basis for discussion when clashes cannot be resolved by a single party. A sample CDR is shown in Figure 14; project teams can use various tools to generate a CDR. CDRs do not replace the need for actual
coordination in either design or construction. Design and construction teams should incorporate CDRs as a tool in their coordination and quality control processes. Project teams may also add fields to the CDR to help track clash resolutions. Such determination should be documented in the BEP.

**Figure 14. Sample Clash Detection Report**
In addition to CDRs, some projects will find it helpful to track how many clashes were found and resolved or not resolved over time. Project teams should determine what kinds of clashes to track over time and document the determinations in the project BEP. For example, the project team may decide to track individual clashes or to group together clashes and track them as a single issue. This can help project teams ensure that the final product, in both design and construction, is fully coordinated. One way of tracking this information is shown in Figure 15. This information is extremely valuable in demonstrating change order avoidance and preemptive cost savings.

Figure 15. Number of Clashes Over Time

3.3.2.1 Clash Detection in Design

GSA requires CDRs from the design team at each design milestone. The CDR shall be included as a part of or as an appendix to the QCR for that submission. CDRs must include the results from automated model checking software to indicate level of model coordination and compliance with P100 and other applicable codes. The design team can choose to utilize any automated model checking software to perform clash detection. Both hard and soft clashes should be included in the model checking process.

The GSA defines three tiers of clash types as described below:

- Tier 1 clashes can be internally resolved by a single entity (consultant or subcontractor) independently. The goal of clash detection and resolution for Tier 1 clashes is to reduce error propagation in the design and to ensure compliance with good design practices and applicable codes and regulations.
  - The resolution of these clashes should be incorporated into the BIM directly.
  - These clashes need not be included in a CDR. However, the CDR needs to include a report from the automated model checking software showing that there are no remaining Tier 1 clashes.
• Tier 2 clashes require coordination between multiple entities (consultants or subcontractors) within a single contract. For example, a Tier 2 clash could be a clash between the structural and mechanical engineering designs. The goal of clash detection and resolution for Tier 2 clashes is to reduce the number and impact of field changes during the construction phase of the project.
  ◦ These clashes should be resolved prior to submission of a design deliverable, and the resolution of these clashes should be incorporated into the BIM directly.
  ◦ The CDR for the design deliverable must include the list of Tier 2 clashes found and their corresponding resolutions. It should also include an order-of-magnitude estimate for the construction cost savings from finding this clash during design.

• Tier 3 clashes are clashes that identify larger issues either with the executed design, or with the design program and can only be resolved by an adjustment to the Project Program of Requirements or budget, or both. The goal of clash detection and resolution for Tier 3 clashes is also to reduce the number and impact of field changes during the construction phase of the project.
  ◦ As a best practice, Tier 3 clashes should be resolved prior to submission of a design deliverable, and the resolution of these clashes should be incorporated into the BIM directly.
  ◦ Resolution of these clashes requires input from the GSA team and other stakeholders, as necessary.
  ◦ The CDR for the design deliverable must include the list of Tier 3 clashes found and their corresponding resolutions. It should also include an order-of-magnitude estimate for the construction cost savings from resolving this clash during design.

For any unresolved clashes indicated in a final CDR for a deliverable, the design team must provide a separate narrative explaining why the clash could not or need not be resolved.

While design quality is ultimately the responsibility of the design team, the project stakeholders with responsibility for quality control [typically the GSA project team and the construction manager as agent (CMa) contractor] must also perform clash detection on all BIM deliverables using automated model checking tools. Project stakeholders must ensure that clashes marked as resolved in the CDR are properly resolved, and that there are no unresolved or unexplained clashes in the deliverable.

3.3.2.2 Clash Detection in Construction

Clash detection during construction is primarily a coordination tool. As in design, both hard and soft clashes should be considered during the coordination process.

Contractors are required to continue to update the project BIM throughout the construction phase of the project to ensure that complete and accurate facility and asset management information is turned over at project substantial completion. Contractors are also required to submit interim deliverables at mid-construction milestones (30%, 60%, and 90% construction completion, unless specified otherwise in the project scope of work or BEP). It is recommended that contractors utilize information from the construction BIM, as validated in BIM-facilitated pre-installation coordination meetings.
For BIM-facilitated pre-installation coordination meetings:

- Designate a BIM facilitator for coordination meetings. Identify the BIM facilitator in the project BEP.
- Prior to each meeting, each trade subcontractor shall perform clash detection between their fabrication model or shop drawings and the design BIM. Where there are clashes, the subcontractor shall adjust the fabrication model to conform to contract requirements and submit the updated fabrication model to the BIM facilitator. The subcontractor shall report either of the following circumstances to the BIM facilitator:
  - The subcontractor identifies an issue for which they cannot adjust the fabrication model to conform to contract requirements, or
  - The fabrication model already conforms to contract requirements and the clash is due to other factors.
- Prior to each meeting, each trade subcontractor shall provide their coordinated fabrication model or shop drawings to the BIM facilitator.
- Prior to each meeting, the contractor’s BIM facilitator shall perform clash detection on subcontractor fabrication models. A CDR similar to the design-phase CDR shall be distributed to the meeting attendees prior to the meeting start.
- During each meeting, the CDR shall be reviewed by all meeting attendees jointly. As clashes are resolved, the BIM facilitator or the BIM lead for the affected subcontractor, as identified in the project BEP, shall update the coordination BIM to reflect the group decision to resolve the clash.
Section 4
BIM Execution Planning
4 BIM Execution Planning

4.1 General BEP Requirements

Per the Facilities Standards for the Public Buildings Service (P100), a BIM Execution Plan (BEP) must be developed for every project. The BEP should be developed as a collaborative effort by all the project team members, and it should document how, when, why, to what level, and for which project outcomes building information modeling (BIM) will be used. Section 4.3 shows suggested roles in BEP development at various project phases, for various project delivery methods.

The BEP shall address all required BIM uses for General Services Administration (GSA) projects, including but not limited to:

- BIM-based design
- 2D deliverables extracted from the building information model (BIM)
- 3D visualization for stakeholder and customer communication
- Automated clash detection
- BIM-based collaborative design reviews
- BIM and Construction Operations Building Information Exchange (COBie) data updates in the construction phase
- Industry Foundation Classes (IFC) export tools and mapping document
- Record modeling

The BEP shall also address potential BIM uses for the project, as listed in the project scope of work (SOW), including but not limited to:

- 4D schedule analysis (for the entire project schedule or for selected portions of the project schedule)
- Quantity takeoff / cost estimating
- BIM-based engineering analysis

If the project team determines that any or all of the potential or optional BIM uses will not be implemented on a particular project, this decision should be documented in the BEP.

The BEP can be embedded in or attached to a larger Project Management Plan; however, the BEP must remain a complete document that can be understood independent of a larger plan. The BEP should be developed immediately upon project inception; however, it should remain a living, changing document that is updated as project team members are added or removed, as project requirements evolve, and as the project progresses from one project phase to the next. In general, the initial version of the project BEP should be submitted by the responsible party within 30 days from Notice to Proceed on the project.

The BEP must contain all the information necessary to use BIM tools most effectively to execute the project, produce required deliverables, and meet overall project goals. The BEP should explicitly define the software to be used for design, analysis, coordination, and all other project activities. The BEP should specifically address which version of the selected software will be used, and the project team should make certain that the specified software is available to all parties who will need it. GSA approval is required prior to upgrading to a new version of any software.
The BEP should also explicitly define the roles and responsibilities of the project team members - both by company or agency and by individual role.

Pay attention to how different tools, software, data, and team members interact with each other in order to optimize project processes. The BEP should identify ways to optimize work and data flow. The BEP should be aligned with the GSA requirements for BIM deliverables as outlined in P100 and GSA's standard construction specifications. This includes compliance with model-based design, completion of a model progression matrix (MPM), determination of where and why 2D supplemental deliverables may be required, and planning for creation and maintenance of COBie information (stored within a BIM or in a spreadsheet or database format) throughout the project lifecycle. The BEP must also include quality control procedures for each activity it describes. A workflow diagram can be helpful in highlighting the processes and milestones for complying with requirements, and it is recommended to include such a diagram in the BEP.

In addition to the information required for the initial BEP, information about the tools used to export from the native model to IFC must be included in the BEP updates. Provide the mapping file that shows how native model objects are mapped to IFC objects. The BEP must address any expected inconsistencies between the native and IFC models and must provide a clear plan for ensuring that all BIM information submitted to GSA is aligned between the native and IFC submissions.

There are numerous BEP templates developed by government, academic, and private entities. GSA does not require the use of a specific BEP template, but GSA has a BEP template available to project teams upon request. Approval of any BEP template and of the BEP is the prerogative of GSA.

All project team members shall sign off on the BEP to document an agreement on how to execute the project. At a minimum, each organization represented on the project team is required to sign off on the BEP; however, best practice is to have each individual identified in the BEP as responsible for a critical task or process sign off. Having individual team members sign the BEP will ensure that each team member understands his or her contribution to the project’s success.

At each BIM submission, as defined in the P100 and the project SOW, the BEP shall be updated and resubmitted. Each submission of the BEP must be formally accepted by the government.

- Part of the acceptance process must include a live over-the-shoulder (preferably in-person) demonstration by each responsible party.
  - The initial BEP acceptance process shall include a demonstration of all BIM tasks, tools, and workflows in the BEP.
  - For subsequent submissions, only new BIM tasks, tools, or workflows require a demonstration to the government to ensure that the task can be performed as planned.

- The key BIM Personnel identified in the BEP shall demonstrate how each task in the approved BEP will be performed using the software and hardware specified. If any tasks are not performed to the satisfaction of the government, the BEP shall be revised to indicate an alternative method of meeting the required BIM use.
4.2 BEP Content and Development by Project Phase

Roles and responsibilities depend on the project delivery method; see section 4.3 for recommendations.

4.2.1 Planning

During the planning phase of a project, there is no formal BEP. This stage of the project is when project teams should be considering which optional BIM technologies may be applicable to the project. The evaluation of various BIM technologies can be assisted by use of the GSA BIM Guide series and by market research into industry standards of care. Evaluations and any decisions reached should be documented in the project solicitation documents as scope requirements.

The planning phase is also when the GSA project team should determine what types of BIM expertise should be included in the selection criteria for the design architect/engineer (A/E) team, based on the BIM requirements outlined in P100 and the additional BIM technologies that were determined to be relevant and applicable to the specific project.

4.2.2 Design

During the design phase of a project, the project team grows to include the design professionals who will make some of the decisions that inform the BEP. Specifically, this is when software tools for design authoring, analysis, and quality control will be selected and documented in the BEP.

The BEP should include an MPM that identifies the Level of Detail (LOD) or Level of Development (LOD) for each discipline or specific model element type for each design deliverable. In addition, the BEP should document how models will be separated and linked as a federated model, if applicable for the project.

The BEP should also include a COBie information delivery plan that addresses who is responsible for generating and documenting COBie information during design and at which specific design milestones (i.e. deliverable submittals) COBie information will be checked. The COBie information delivery plan shall also clearly delineate the scope of assets that must be included in the COBie deliverable. This scope shall be defined in compliance with BIM Guide 08 requirements and in coordination with the Office of Facility Management representative for the project. This collaboration can begin as early in design as mechanical systems are defined (often at about 65% design). At a minimum, the complete GSA-approved list of assets to be included in the COBie submissions shall be defined in the COBie information delivery plan by the project team by 100% Construction Documents. Additional information about the COBie information delivery plan can be found in specification section 013600 of the project specification. (If this section is not included specifically in the project contract, it remains required under this GSA BIM Guide. Contact the project BIM representative for additional information.) A template for a COBie information delivery plan (which must be customized to meet GSA and project requirements) is available through the [buildingSmart alliance](http://www.buildingSmart.org).
The BEP shall indicate what processes and tools will be used for model quality control and for COBie checking. GSA project teams can utilize the A/E COBie Requirements guidance document to specify in the contract and/or the BEP what COBie information is required at each design milestone. GSA project teams can obtain this guidance document through their regional BIM champions.

The BEP shall be updated as the design progresses to reflect changes to the BIM processes that are in use and to document any model-specific information that a downstream user would require to use the final design deliverables. At the conclusion of design, the BEP shall be converted into a BIM Manual for the completed design deliverable.

Figure 16. BEP Content and Development During Design

4.2.3 Construction

During the construction phase of a project, the project team expands to include the builder, construction manager, and commissioning agent. This phase of the project is when the specific information about actual installed construction will be gathered and verified. The BEP must clearly delineate the roles and responsibilities, tools, processes, and schedule that will be used to gather and verify the accuracy of the information being added to the BIM, including the information being added to the COBie dataset.
Additional information about the COBie deliverables and related responsibilities shall be updated in the COBie information delivery plan section of the BEP. Additional information about the COBie information delivery plan can be found in specification section 013600 of the project specification. (If this section is not included explicitly in the project contract, it remains required under this BIM Guide. Contact the project BIM representative for additional information.) A template for a COBie information delivery plan (which must be customized to meet GSA and project requirements) is available through the buildingSmart alliance.

GSA requires that in-progress BIMs and in-progress COBie submissions be submitted periodically during construction to ensure that information is gathered in real time as construction progresses. This also allows for periodic data audits to ensure quality. In-progress submissions are required to be cumulative; that is, each subsequent submission shall include the information from previous submissions so that the in-progress BIM grows through the construction phase into a complete record BIM. In addition, product information from a previous submission (or project phase) shall not be duplicated in subsequent submissions; information from a previous phase or submission that is relevant to a later phase or submission shall be referenced or reused in the subsequent submission.

The BIM submission must include relevant documentation consistently organized and linked to the native and IFC models, as required in the project specification (section 017810). (If this section is not included explicitly in the project contract, it remains required under this GSA BIM Guide. Contact the project BIM representative for additional information.) At a minimum, relevant documentation includes approved product data sheets and operating manuals. All links in the BIM must have relative, not absolute, file paths to allow GSA to incorporate the BIM in GSA’s BIM systems. The file naming standard, file organization structure, and link structure must be documented in the BEP. In general, it is expected that the file structure for the project shall be based on the electronic Project Management (ePM) tool’s submittal processing system. The link structure documented in the BEP must address how links will be structured in both the native and IFC formats of each BIM submission.

At each submission, the BIM submission and the COBie submission must be fully coordinated. The COBie dataset must be generated from the BIM. If COBie information cannot be generated from the BIM and must be supplemented by input from another tool or method, this must be documented in the BEP and be approved by the GSA project BIM representative.

The milestone dates for the in-progress BIM submissions and the tools and procedures for quality control data audits must be documented in the BEP. The BEP must define the automated checker tools that will be used to verify the compliance of COBie data with the COBie specification. A COBie Quality Control Report (QCR) must be part of each in-progress BIM/COBie submission. The BEP must identify the party responsible for generating the COBie QCR for each submission.

At each milestone submission, the BIM and COBie information in the BEP shall be updated to reflect changes to the BIM processes that are in use and to document any model-specific information that a downstream user would require to use the final as-built deliverables. At the conclusion of construction, the BEP shall be converted into a BIM Manual for the completed record deliverable.
4.2.4 Commissioning and Turnover

At project turnover, the information that has been documented in the BEP shall be organized and consolidated into a BIM Manual. The BIM Manual should contain the most updated information about the BIM uses that were accomplished on the project. It should also document the decisions that were made that affected the structure of the record model, so that downstream users of the model understand the modeling considerations and are able to efficiently use the model and embedded data. As in the BEP, information about the tools and processes used to export from the native model to IFC must be included. The mapping file that shows how native model elements are mapped to IFC elements must be included in the BIM Manual.

The BEP/BIM Manual should also be updated to include the results of final model commissioning. Final model commissioning involves a combination of the same BIM and COBie quality control procedures that have been in place throughout the design and construction phases and some additional tasks to ensure that the final record model is accurate, current (as of the date of project closeout), and usable as a building performance baseline and maintenance reference.
4.3 BEP Considerations by Project Delivery Method

The sections below utilize RACIQ matrices to define the expected roles and responsibilities for BEP development, updates, and execution. The letter designations are as follows:

- **R**: Responsible - Those who do the work to achieve the task.
- **A**: Approver - The Approver must sign off (approve) work that Responsible provides.
- **C**: Consulted - Those whose opinions are sought and who are typically subject matter experts.
- **I**: Informed - Those who are kept up-to-date on progress, often only on completion of the task or deliverable.
- **Q**: Quality Review - Those who check whether the product meets the quality requirements.

### 4.3.1 Traditional Delivery (Design-Bid-Build)

The below is a recommendation for how to handle BEP creation, updates, execution, and enforcement by project phase for a traditional delivery project; however, the project team can adapt this to meet project-specific needs or to take advantage of the expertise provided by various team members. Adaptations of this approach should be documented in the project contract documents and/or the project management plan. If the adaptation is made after project contracts are already awarded, the roles and responsibilities for the BEP can be documented in the project management plan or the BEP itself.

**Table 2. RACIQ Matrix for Traditional Delivery**

<table>
<thead>
<tr>
<th>Phase</th>
<th>GSA</th>
<th>CMA</th>
<th>A/E</th>
<th>GC</th>
<th>CxA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>R, A</td>
<td>C, Q</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>A</td>
<td>C, Q</td>
<td>R</td>
<td></td>
<td>C</td>
</tr>
<tr>
<td>Construction</td>
<td>A</td>
<td>C, Q</td>
<td>C</td>
<td>R</td>
<td>R, C</td>
</tr>
<tr>
<td>Turnover</td>
<td>A</td>
<td>C, Q</td>
<td>C</td>
<td>R</td>
<td>R, C</td>
</tr>
</tbody>
</table>
4.3.2 Design-Build Delivery

The below is a recommendation for how to handle BEP creation, updates, execution, and enforcement by project phase for a design-build project; however, the project team can adapt this to meet project-specific needs or to take advantage of the expertise provided by various team members. Adaptations of this approach should be documented in the project contract documents and/or the project management plan. If the adaptation is made after project contracts are already awarded, the roles and responsibilities for the BEP can be documented in the project management plan or the BEP itself.

Table 3. RACIQ Matrix for Design-Build Delivery

<table>
<thead>
<tr>
<th>Phase</th>
<th>GSA</th>
<th>CMa</th>
<th>GC</th>
<th>CxA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>R, A</td>
<td>C, Q</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>A</td>
<td>C, Q</td>
<td>R</td>
<td>C</td>
</tr>
<tr>
<td>Construction</td>
<td>A</td>
<td>C, Q</td>
<td>R</td>
<td>R, C</td>
</tr>
<tr>
<td>Turnover</td>
<td>A</td>
<td>C, Q</td>
<td>R</td>
<td>R, C</td>
</tr>
</tbody>
</table>

4.3.3 Design-Build/Bridging Delivery

The below is a recommendation for how to handle BEP creation, updates, execution, and enforcement by project phase for a design-build/bridging project; however, the project team can adapt this to meet project-specific needs or to take advantage of the expertise provided by various team members. Adaptations of this approach should be documented in the project contract documents and/or the project management plan. If the adaptation is made after project contracts are already awarded, the roles and responsibilities for the BEP can be documented in the project management plan or the BEP itself.

Table 4. RACIQ Matrix for Design-Build/Bridging Delivery

<table>
<thead>
<tr>
<th>Phase</th>
<th>GSA</th>
<th>CMa</th>
<th>A/E</th>
<th>GC</th>
<th>CxA</th>
</tr>
</thead>
<tbody>
<tr>
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<td>C, Q</td>
<td>R</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridging Design</td>
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<td>C, Q</td>
<td>R</td>
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<td></td>
</tr>
<tr>
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<td>A</td>
<td>C, Q</td>
<td>I, Q</td>
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<tr>
<td>Construction</td>
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<td>C, Q</td>
<td>I</td>
<td>R</td>
<td>R, C</td>
</tr>
<tr>
<td>Turnover</td>
<td>A</td>
<td>C, Q</td>
<td>I</td>
<td>R</td>
<td>R, C</td>
</tr>
</tbody>
</table>
4.3.4 Construction Manager as Constructor Delivery

The below is a recommendation for how to handle BEP creation, updates, execution, and enforcement by project phase for a Construction Manager as Constructor (CMc) project; however, the project team can adapt this to meet project-specific needs or to take advantage of the expertise provided by various team members. Adaptations of this approach should be documented in the project contract documents and/or the project management plan. If the adaptation is made after project contracts are already awarded, the roles and responsibilities for the BEP can be documented in the project management plan or the BEP itself.

Table 5. RACIQ Matrix for CMc Delivery

<table>
<thead>
<tr>
<th>Phase</th>
<th>GSA</th>
<th>CMa</th>
<th>A/E</th>
<th>GC</th>
<th>CxA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planning</td>
<td>R, A</td>
<td>C, Q</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design</td>
<td>A</td>
<td>C, Q</td>
<td>R</td>
<td>C, Q</td>
<td>C</td>
</tr>
<tr>
<td>Construction</td>
<td>A</td>
<td>C, Q</td>
<td>I</td>
<td>R</td>
<td>R, C</td>
</tr>
<tr>
<td>Turnover</td>
<td>A</td>
<td>C, Q</td>
<td>I</td>
<td>R</td>
<td>R, C</td>
</tr>
</tbody>
</table>
Section 5
Conclusion
5 Conclusion

GSA sees BIM as a way to connect all the different phases of a facility’s or asset’s lifecycle, from planning through design, construction, operations, modernization, and eventually to disposal. GSA uses open-source and open-standard technology to enable use and reuse of BIM model elements across GSA business lines. As our business needs are the primary driver of how we prioritize the creation, maintenance, and use of building information, we fully expect this Guide and the related information requirements to continue to evolve, as GSA more fully incorporates BIM into our work processes.
Section 6
Acknowledgments
Acknowledgements

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Andrew Black, GSA Office of Communications and Marketing
Patricia Cheng, GSA Office of Public Buildings IT Services
Stephen Devito, BIM Program Manager, Procon Consulting
Richard Gee, LEED AP, GSA Great Lakes Region
Ilana Hellmann, P.E., LEED AP, National BIM Program Expert, GSA Office of Public Buildings IT Services
Timothy Kyer, PM, Architect, R8 BIM Manager, LEED BD+C, GSA Rocky Mountain Region
Charles Matta, FAIA, Deputy CIO, GSA Office of Public Buildings IT Services
Horatio McDowney, GSA Office of Public Buildings IT Services
Jennifer Roth, GSA Office of Public Buildings IT Services

Section 3 Focus Group: Kristen Beard, Stephen Devito, Timothy Kyer, Horatio McDowney, Nikkola Monnig, Dale Williams
Section 7
Endnotes
Endnotes


2“Id

3 DeVito, Stephen. Figures 1 - 8 are model ontology examples based on a BIM provided by buildingSMART alliance. Digital images.

4 Graphic courtesy of Louis Hearn.


10 Smith and Erwin, RACI

11 Smith and Erwin, RACI

3.6.3 Activity Attributes

Activities in the schedule can also be loaded with information to be visualized in the 4D model (e.g., cost, resources, and spatial attributes). These attributes must be broken down into a “per activity LOD” (e.g., cost per activity).

3.7 Linking the 3D model and schedule

If the 3D model and schedule are set up correctly, the linking of the two components together to create the 4D model should be a straightforward process; however depending on the complexity of the model, the task can become very tedious and time consuming. During this task, attention to details is required to ensure that the links are correct. Some software even offer an automated linking process based on the unique identifiers defined in both 3D modeling and 4D modeling software but a human check and verification is always necessary.

3.7.1 Dealing with Different Levels of Detail

In some cases, the LOD of the 3D model may be different from the LOD of the schedule. The 4D model will only be as detailed as the minimum detail represented by the 3D model or schedule.

3.7.2 Creating Groups within the 4D model

Objects within the 4D model can be arranged in groups, such that stakeholders can focus on specific parts of the model. Typically, these groups should include: per tenant, per floor, permanent objects, and site model. Grouping can be done either for components or activities that will later be detailed out separately.

These groups allow different stakeholders to focus on pertinent details related to each stakeholder. For example, if this were shown to a specific tenant, only that tenant’s movement should be shown. However, for overall phase planning, all tenants and construction activities should be shown. By setting up the model with these specific groups, OCA is better able to use the model for a variety of needs. Another benefit of grouping and naming convention is to take advantage of automated linking. Although Navisworks is not an intelligent modeling tool, still activities and objects can be automatically linked together when they have matching names.
References:


December 2011

This version of the GSA Building Information Modeling Guide Series: 08 - GSA BIM Guide for Facility Management is identified as Version 1. With its publication, this GSA BIM Guide Series 08 becomes available for public review and comment. Since the area of BIM and Facility Management is emerging and dynamic, the BIM Guide will continue to serve as the basis for further development, pilot validation, and professional editing. All readers of this provisional guide are encouraged to submit feedback to GSA’s National 3D-4D-BIM Program. Updated versions will continue to be issued to address and incorporate on-going feedback in an open and collaborative process.

For further information about GSA’s National 3D-4D-BIM Program, additional BIM Guide Series, or to submit comments or questions, visit the National 3D-4D-BIM webpage at http://www.gsa.gov/bim.

The National 3D-4D-BIM Program
Office of Design and Construction
Public Buildings Service
U.S. General Services Administration
1800 F Street NW, Suite 3300
Washington, DC 20405
GSA
BIM Guide For Facility Management
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executive summary: facility management

As one of the largest building owners in the U.S. with a portfolio of buildings designed for 50+ years of use, GSA sees great benefits for developing and maintaining lifecycle data for our facilities. In 2003, the U.S. General Services Administration (GSA) Public Buildings Service (PBS) Office of Design and Construction (ODC) established the National 3D-4D-BIM Program. As part of this program, ODC has evaluated an array of 3D-4D-BIM applications on a number of capital projects.

The ODC, which is responsible for the BIM Program, has been working with its counterparts in the Office of Facilities Management and Services Program (FMSP) and the Office of Portfolio Management’s Spatial Data Management Program (SDM) to ensure that the appropriate BIM deliverables are required to address facility management needs upon facility occupancy. This Guide has been reviewed by the GSA BIM and FM Working Group which consists of national and regional stakeholders.

Objective of Using BIM for Facility Management
The overall purpose of utilizing BIM for facility management is to enable GSA to leverage facility data through the facility lifecycle to provide safe, healthy, effective and efficient work environments for our clients. Facility data is created throughout the design and construction process. GSA intends to use and update this data throughout the facility lifecycle - through Small Projects, Operations & Maintenance, and Major Renovations & Alterations. The maintenance of this data will create greater efficiencies such as: having accurate as-built information to reduce the cost & time required for renovations; increasing customer satisfaction; and optimizing the operation and maintenance of our building systems to reduce energy usage.

Requirements and Deliverables
At a minimum, GSA requires BIMs to have the following objects in a valid 3D geometry representation in support of facility management. GSA BIM Guide Series 08 requirements build upon the existing spatial program BIM modeling requirements defined in GSA BIM Guide Series 02, located on the GSA website at http://www.gsa.gov/bim. Deliverables shall be provided in both native BIM-authoring formats and open-standard formats such as IFC and COBie. Project teams shall develop a BIM Execution Plan outlining how the BIM requirements will be met.

Objects
The following object types are required in the Record BIM for facility management submitted to GSA:

- All objects required by BIM Guide Series 02
- Ceilings
- Lighting systems, fixtures and equipment
- Communications systems and equipment
- Electrical systems and equipment
• Mechanical systems and equipment
• Plumbing systems and equipment
• Irrigation system and equipment
• Fire protection systems and equipment
• Vertical and horizontal transportation equipment
• Furniture and specifications
• Specialty systems and equipment

Spaces and equipment must include the following information:

• 
• 
• 

GSA project teams in conjunction with the PBS Service Center should define the minimum list of equipment types and attributes required in the BIM Execution Plan (BEP).

These requirements are in addition to all current submission requirements set forth in Appendix A of the *Facilities Standards for the Public Buildings Service* (PBS P-100). A/E s should also follow the PBS CAD Standards for creating 2-D drawings (www.gsa.gov/cifm). To the greatest extent possible, A/E should utilize BIM as the authoritative source for building information, and derive 2D drawings from the model.

**Conclusions**
In referencing this Guide, GSA expects to obtain high-quality BIMs for use in facility management. While full adoption of BIM within facility management will be incremental, this BIM Guide Series lays the foundation for the vision, the technical paths, business processes, as well as the minimum technical requirements. GSA welcomes any expert input, collaboration opportunities and recommendations to this BIM Guide and the process of creating and maintaining facility lifecycle information.
**introduction**

**About this Guide**

A facility management BIM allows GSA to use facility information effectively through all phases of a facility’s lifecycle. This Series is part of a multi-series document on 3D-4D-BIM applications. Users of this document should also refer to the GSA BIM Guide Series: 01 - Overview of GSA’s National 3D-4D-BIM Program for program-wide motivations and policies on 3D-4D-BIM applications and the GSA BIM Guide Series 02 for technical requirements of a spatial program BIM. The BIM for facility management requirements in this Guide build on the spatial program BIM requirements.

This GSA BIM Guide Series is intended for incorporation by reference in PBS contracts for the design and construction of New Construction, Major Renovation projects, Small projects, and Operations and Maintenance projects. As such, the designers, the contractors, the PBS Project Managers, and Contracting Officers administering the contracts are its primary audience. This Guide has been prepared to assist design and construction teams in producing BIMs to support BIM for facility management contract requirements.

This Series will also be of general interest to other members of GSA project teams, including PBS building managers, staff, customer agencies, and contracted parties such as construction managers, construction and design-build contractors, and consultants. In addition, construction industry software solution providers will find this Guide useful, in particular those who offer BIM-authoring applications and downstream applications which use BIM.

**Objective of this Series 08**

The main objective of this Series is to provide the vision, requirements, and technology review for GSA’s use of BIM for facility management. GSA BIM Guide Series 08, therefore, aims to meet several purposes:

- Identify the work processes and information requirements during facility management. This determines the information that should be included in the Record BIM at the end of construction
- Evaluate methods for capturing and recording information updates
- Provide implementation guidance for GSA associates, solution providers, technology vendors and the broader industry
- Define the scope of information that should be included or updated in the Record BIM at the end of a facility project
  - Take a vendor-neutral approach
  - Identify “core” information that shall be required in every as-built BIM submission
- Define technology requirements for accessing and updating BIMs, by both GSA personnel and external architects and contractors
  - Identify necessary interfaces with existing systems
Document GSA case studies involving BIM and FM

How to use this Series 08 - Facility Management
This series is divided into 5 major sections:

- **Section 1: BIM and Facility Management** - This section describes the overall vision and objectives for using BIM during facility management.
- **Section 2: Implementation Guidance** - This section provides implementation guidance to GSA associates and consultants.
- **Section 3: Modeling Requirements** - This section describes the BIM object and attribute requirements for use during facility management.
- **Section 4: Technology** - This section describes the technology requirements for creating and using BIMs for facility management.
- **Section 5: Pilot Projects** - This section describes on-going GSA pilot projects and implementation approaches.
Key Definitions

**Construction-Operations Building Information Exchange (COBie):** A vendor neutral, IFC-based data exchange specification that describes the information exchange between the Construction and Operations phases of a project.

**Design Intent Building Information Model (BIM):** Building information model(s) created by and conformed to the bid addenda by the A/E. Elements are modeled per BIM Guide Series 02 and are accurate in terms of quantity, size, shape, location and orientation. The Design Intent BIM includes the Spatial Program model. Elements also contain unique asset identification numbers that link them to the COBie data. The Design Intent BIM must be submitted in both .ifc and native format.

**Construction Building Information Model (BIM):** Building information model typically representing a single building system created for purposes of planning, scheduling, coordinating, fabricating components and executing construction. Model elements are accurate in terms of size, shape, location, quantity and orientation and may include fabrication, assembly, detailing and non-geometric information. MEP/FP systems models include Equipment Primary Keys that link them to the COBie data. Construction BIMs are maintained in the native format of the authoring software.

**Coordination Building Information Model (BIM):** Composite model that includes multiple Design and/or Construction BIMs, registered spatially, used for the purposes of interference checking (clash detection), visualization and additional BIM analyses during construction. Coordination BIMs are maintained in the native format of the modeling software.

**Record Building Information Model (BIM):** Multiple Construction BIMs, organized by building system and floor and registered spatially, that represent the final as-constructed building and components configuration, including Architectural Supplemental Instructions, Change Notices, and field changes. Base building model (architectural and structural) conforms to BIM Guide Series 02 specification. MEP/FP systems models include unique asset identification numbers that link them to the COBie data. Record BIMs must be submitted in both .ifc and native format. The Record BIMs will be archived as part of the project record and also copied to the Central Facility Repository as the As-Built Building Information Model (BIM).

**As-Built Building Information Model (BIM):** Editable copy of the Record BIM that is constantly updated to represent the current completed state of the building and systems configuration.
section 01:
BIM for facility management
section 1: BIM for Facility Management

This section provides an overview of the origin and motivation behind the use of BIM during facility management. This section describes various use cases for BIM and facility management.

1.1 Why BIM for Facility Management?

As the largest property owner in the US, GSA manages 362 million rentable square feet in 9,624 buildings in all 50 states, 6 U.S. territories, and the District of Columbia. GSA designs, constructs, operates and manages a variety of facility types including federal office buildings, courthouses, and land ports of entry. As a building owner and property manager, GSA’s Public Buildings Service (PBS) analyzes the asset performance of complexes and buildings by operations costs, energy efficiency, and a physical condition survey of major building systems and structural components.

Facility management provides safe, healthy, and efficient work environments for our clients. Achieving such work environments requires the ability to track facility components accurately, identify inefficiencies in building operations, and respond quickly to client requests. Each facility component or asset has a cost associated with the installation, replacement and/or scheduled maintenance for the component. An accurate equipment inventory is essential for budgeting repair/replacement and maintenance costs. Facility management activities depend on the accuracy and accessibility of facility data created in the facilities’ design and construction phases and maintained throughout the operations and maintenance phase. Lack of this information can result in cost overruns, inefficient building operations, and untimely resolution of client requests.

The National Institute of Standards and Technology (NIST) study Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry (NIST GCR 04-867) shows that all stakeholders in the capital facilities industry - designers, contractors, product suppliers, and owners - waste a huge amount of money looking for, validating, and/or recreating facility information that should be readily available. The total cost of these activities within the capital facilities industries was conservatively estimated at $15.8 billion in 2002, with two-thirds of that cost occurring during the facilities’ operations and maintenance phase. When applied to GSA’s $18 billion construction program in 2010, NIST’s findings equate to an annual $774 million of waste and rework on GSA’s facilities before adjustment for inflation.

A BIM for facility management provides visualization, access to the precise location and relationships of building systems and equipment, and access to accurate existing condition attribute data. Building Information Modeling provides several advantages over traditional 2D drawings. BIM is a data-rich, object-based, intelligent and parametric digital representation of the facility.

- BIM objects know:
  - What they are, (walls, doors, spaces, lights, plumbing fixtures, etc.)
- Where they are located

- BIM provides a unique identifier that can be used to link the components in the Model files with other facility management systems.

- BIM software tools support the creation of zones that can identify areas serviced by common components. For example: Rooms 1, 2, and 3 are supplied by Air Handling Unit 21, or supplied electrical service from circuit panel L-1.

- BIMs capture building system relationships. For example: each electrical panel knows which transformer supplies its power.

The purpose of defining a BIM for facility management is to specify the information needed to be passed from design and construction to operations and maintenance. A BIM for facility management can automate the creation of equipment inventory lists, populate facility management systems such as a Computerized Maintenance Management System (CMMS), and reduce redundancy in the maintenance of facility data for facility management activities. The potential benefits are not only a reduction in operating costs, but also quality gains in responding to tenants faster.

1.2 The Business Need for BIM for Facility Management

The NIST study on the Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry noted the importance of effectively maintaining facility data for improved building services. Effective facility data maintenance enables more effective work processes at multiple levels of PBS and across business lines.

For GSA Maintenance Workers:

- Reduces time by eliminating additional trips to the same location to carry out unscheduled work orders by providing accurate field conditions and maintenance information before leaving the office

- Increases completeness in preventive maintenance work orders through accurate equipment inventory

- Reduces costs for repairs by providing faster response times to emergency work orders (e.g., a major leak in the wall and the water needs to be shut off immediately)

- Mobile access to BIM and other linked/integrated data in the field allows access to all documentation without making trips back to the office.

For GSA Building Operators:

- Reduces the operations and maintenance (O&M) contract costs from incomplete equipment inventories. An accurate equipment inventory can reduce O&M contracting costs from 3% to 6% by identifying and tracking facility equipment and facility square footage.
• Reduces time creating equipment inventories from plans, specifications, and submittals. An accurate equipment inventory can generate a return on investment of 3% in energy savings by identifying all facility components that affect energy usage, require maintenance, and assist in safe operations.

• Reduces risk and uncertainty of performing work orders by identifying building components that are not easily identified.

• Maintains links to equipment histories facilitating equipment condition assessments. An accurate equipment inventory reduces the possibility of catastrophic costs for unforeseen repairs by identifying accurate equipment locations and components.

• Optimizes building performance by comparing actual to predicted energy performance. BIM can provide access to design and commissioning data for reference.

Provides business analytics through integration of BIM, BAS, EMS, and CMMS data, allowing better review and access to building controls, schedules, readings, and inventory. Cost and performance trending can be used to troubleshoot high tenant work order areas and identify customer satisfaction or building performance issues. For GSA Design and Construction Teams:

• Reduces costs of re-documenting “as-built” conditions and field surveys for building renovation projects. Savings could occur from reduction in time to verify field conditions, change orders due to unforeseen conditions, reduction in destructive testing and repair costs to confirm existing conditions.

• Meets federally mandated energy targets through greater accuracy in model assumptions and better estimation of energy performance

• Designs higher quality building systems from better equipment selection and specifications based on feedback from building operations

• Better commissioning through understanding impacts of individual HVAC components on overall HVAC system. For example, a VAV box in Room 1 is adjusted for a tenant. All other VAV boxes within the same HVAC system are affected because of the change in air flow. As adjustments are made to each individual box, the overall system performance can be analyzed and adjusted.

For GSA Spatial Data Managers:

• Increases precision in existing condition information, which is used for accuracy of rent bill management, reduction in costs for audits and re-walks.

• Reduces time to polyline spatial program drawings through automation process using BIM Guide Series 02.

For GSA Building Tenants:

• Increases satisfaction from quicker resolutions to unscheduled work orders.

• Reduces unscheduled work orders and increased communication between tenants and building maintenance workers regarding scheduled work orders.
1.3 The Data Requirements to Support GSA Business Needs

Acknowledging that each GSA project has a unique set of project opportunities and constraints, GSA has identified three tiers of data requirements that are necessary to support GSA Business Needs. Each of these tiers builds on the previous one, allowing GSA project teams to choose the appropriate level of requirements to meet project conditions. These requirements range from:

- **Tier 1**
  - Spatial Program BIM
  - Accurate As-Built Geometry for equipment
- **Tier 2**
  - Equipment information - ID, Make, Model, Serial Number, warranty information, maintenance instructions, etc.
- **Tier 3**
  - As-designed BIM with energy analysis predictions

1.3.1 Accurate As-Built Geometry and Spatial Program BIM (Tier 1)

The value of an accurate 3D geometric model to many downstream users should not be underestimated. The GSA BIM FM Group has discussed the value of being able to calculate accurate areas of floor covering types for maintenance contracts and also the value of being able to identify locations of building systems and equipment concealed in walls or above ceilings without opening those walls or ceilings.

1.3.1.1 Providing Accurate Data for Renovations

Providing accurate as-built data prior to a major renovation or small project reduces the amount of time and resources to field verify existing conditions.

1.3.1.2 Spatial Program Model

The As-Built BIM shall incorporate the Spatial Program model, updated to correspond with the realities of the facility as-constructed. This requirement is detailed in the BIM Guide Series 02 and incorporated in BIM Guide Series 08 by reference. GSA intends to build on existing BIM requirements to streamline modeling requirements for project teams.

1.3.1.3 BIM Equipment Objects

Each BIM equipment object in the As-Built BIM shall contain geometric data and a minimum set of attributes:

- The BIM object GUID is a machine-interpretable unique identifier that maintains the linkage between the facility management system (including BAS, EMS, CHMS, and others) and the BIM authoring-application. This is detailed further in Section 3.
- The BIM object location primary key is the identifier that provides quick identification of the equipment location.
• The Asset Identification Number - A unique, human interpretable naming convention that allows for easy equipment identification by facility management in the 3D model and facility management systems.

1.3.2 Equipment Inventory for O&M Management (Tier 2)

Equipment inventories or facility equipment lists form the basis for many facility management activities. Equipment inventories are used for equipment condition assessments, energy management, emergency response, warranties, man power calculations, and so forth. This is illustrated in Figure 1 below. Operations and maintenance incurs additional time, manpower, and costs with inaccurate or lack of equipment inventories. The failure to properly track equipment inventories reduces the reliability of project scopes and cost estimates, impairs emergency response, and degrades the ability to make executive decisions.

Figure 1: Facility’s Equipment Inventory and Finances (Keady 2009)
BIM authoring applications have the ability to populate BIM objects with standard object attributes and add custom object attributes. In addition, COBie allows the creation and management of additional data external to the BIM authoring application. This is discussed further in Section 3.

At project closeout, equipment attribute data can be extracted from the BIMs and COBie files and loaded into a centralized database for access by multiple facility management applications.

1.3.2.1 Negotiate Operations and Maintenance (O&M) Contracting
An accurate equipment inventory can properly define the scope of work for O&M contracting. An accurate equipment inventory creates better alignment of Independent Government Estimates (IGEs) and O&M contractor bids, reduces turnaround times for O&M contractor bids, and produces more accurate and complete O&M contractor bids.

1.3.2.2 Populating BIM Data into CMMS at Project Turnover
A CMMS is used to manage facility assets, maintenance transactions, and store facility data during the facility’s operation and maintenance phase. Specifically, a CMMS manages equipment inventories, work orders, preventive maintenance, predictive maintenance and condition based monitoring programs. Typically, CMMS is populated at project turnover with facility information created during the design, construction, and commissioning phases.

Data required by a CMMS will be created either in the Design and Construction BIMs or in an external format such as COBie. See Section 3 for further discussion on COBie. At project turnover, this data will then be loaded into a CMMS or database used in the Region. The BIM for facility management is to be linked to the CMMS, as well as other systems, for visual coordination of facility assets with operations and maintenance (O&M) data.

The equipment data in the Equipment Inventory and CMMS shall contain the same equipment attributes identified in Section 1.3.1.3 for the As-Built BIM:

- BIM object GUID,
- BIM object location, and
- Asset Identification Number - Human interpretable naming convention.

This will allow cross-referencing and automated updating of data between systems.
1.3.2.3 Sustainable Facility Management

In the *Sustainability Matters* report published by the GSA, sustainable facility management is identified: “...as a building practice that helps facility managers upgrade and operate their buildings to achieve long term human and ecosystem balance.”

Facility management can make informed building operational decisions with access to accurate, current facility data. BIM supports a reliability centered maintenance program in the following ways:

- Equipment Inventory
- Preventative Maintenance - BIM provides accurate equipment inventories and maintenance instructions
- Work orders
- Predictive Maintenance
- Condition based Monitoring
- Access to system monitoring and controls

1.3.3 As-Designed BIM with Energy Analysis (Tier 3)

If as-designed BIM with energy analysis is captured, the data can eventually be integrated with a facility BAS, enabling model-based analysis and optimization. Ideally, the BIM energy analysis would enable building operators to understand when and how actual performance differs from predicted performance. This allows a feedback loop of lessons learned and troubleshooting. During operations, it enables building operators to understand how to building was intended to be operated to achieve optimum performance. Feedback regarding the actual operation of the building, as compared to the design assumptions, will then be critical to creating more realistic and accurate energy predictions during design. This work will build on energy analysis requirements and guidance found in the existing BIM Guide Series 05 - Energy Performance.

1.3.4 The use of open standards for data transfer

In addition to the specific data required at FM handover, GSA requires data to be delivered with open standards. In order to maintain the greatest flexibility for our project teams, GSA does not mandate a specific BIM-authoring software. Project teams are free to choose whichever BIM-authoring software is suitable for their project workflows, as long as these softwares are able to export the data in open formats, such as IFC. Since GSA currently has multiple CMMS systems, the need for open standards becomes even greater.

1.4 The Vision for BIM and Facility Management

BIM represents both an enhanced technology and a process change for the architecture-engineering-construction-facilities management practices at GSA. Currently GSA has established national processes for New Construction, Major Renovation and Alterations, and Small Projects. While a national process for Operations and Maintenance (O&M) does not exist today, there are
discussions on whether to implement a national CMMS solution and in doing so, develop a standardized O&M process with that implementation.

The business processes were evaluated from a holistic point of view through the lifecycle phases of Planning, Design, Construction, and Post-Construction. How BIM is integrated into the end to end project lifecycle and coordinated throughout the lifecycle plays a significant factor in the quality and comprehensiveness of the BIM-FM information that is achieved at the completion of the project. Furthermore, processes identified can always be improved. As GSA Integrates BIM into the project lifecycle, successes and lessons learned should be factored into a continuous cycle of process improvement.

Figure 2 depicts the vision for managing facility lifecycle data through a national standardized business process addressing BIM-FM Integration.

GSA’s vision is to streamline how BIM is used in support of BIM-FM integration throughout the facility’s lifecycle from Planning through Operations. GSA is responsible for federal real estate and its associated assets, such as drawing sets and equipment information. A Central Facility Repository\(^1\) will be a key component in managing the facility information. The Central Facility Repository plans to integrates and houses 3D object parametric data, MEP system layouts, asset management data, facility management data, building materials and specifications, 2D data, laser scanning data, and real time sensor data and controls. Through the Central Facility Repository, it is envisioned that buildings’ BIMs would be managed and maintained for all types of projects including New Construction, Major Renovation / R&A, Small Projects, and O&M. Furthermore, O&M personnel would be able to view the BIMs. Software tools would “sit on top” of the Central Facility Repository to provide security, search and view capabilities, version control, notifications on updates, and analysis and reporting.

\(^1\) Further details on the mechanics of the Central Facility Repository are described in Section 4: Technology.
Figure 2: Vision for BIM for Facility Management Integration
section 02: implementation guidance
section 2: Implementation Guidance

This section provides implementation guidance to GSA project teams. Project teams are also encouraged to read the GSA BIM Guide Series 01 - Overview which further provides guidance on implementing 3D-4D-BIM technologies.

2.1 Identify Project Opportunities

Section 1-2 identified GSA business needs for BIM and Facility Management. To identify project opportunities, GSA associates are encouraged to gather appropriate team members (e.g., project manager, facility manager, spatial data manager, Regional BIM Champion) to discuss potential opportunities.

2.2 Define an implementation strategy

Implementing BIM for facility management requires:

- Defining information required and how it is to be used. This is covered in Sections 1 and 3.
- Knowing when in the facility life cycle you are starting implementation.
- Understanding of when in the facility life cycle the information is initially created and by whom.
- Assessing how the project delivery approach (Traditional, Design/Build-Bridging, or other alternative project delivery methods) will affect the contractual responsibility for information delivery.
- Developing appropriate contract terms to require the information deliverables.
- Creating a BIM Execution Plan (BEP) to provide a master information/data management plan and assignment of roles and responsibilities for model creation and data integration at project initiation. The BEP will reference the Modeling Requirements defined in Section 3.
- Putting technology in place to allow GSA to monitor compliance and validate the quality of the deliverables. This is discussed in Section 4.
- Establishing the responsible GSA party for monitoring compliance with the BEP and validating the completeness and quality of the deliverables.
- Putting the central repository in place at GSA to receive the deliverables. This is discussed in Section 4.
- Establishing responsibility within GSA for ensuring that the information is maintained, secured and updated to reflect existing conditions of the building.

2.2.1 Identify the phase of the facility lifecycle

Implementation approach will need to be adjusted based on when in the facility life cycle you are beginning implementation and what the vehicle for taking the first step will be. For example:

- There may be no BIM or CMMS for the facility, but you need to conduct an Equipment Inventory and would like to use the inventory as an opportunity to move into BIM for facility management. By capturing your equipment data in COBie format, or
even in a spreadsheet, adhering to GSA standardized terminology and using the eSmart Space ID as the Space Primary Key, you will be able to submit your equipment inventory to a central facility repository and also visualize the equipment location.

- A Small Project may be affecting just a portion of a facility or a single building system. By creating a BIM for that project and registering that BIM to the 2D floor plan, you can begin to create a 3D model of the facility. If the project involves reconfiguring rooms, require a Spatial Program BIM (see BIM Guide Series 02). In addition, if the project involves equipment, adhere to the COBie format and GSA standardized terminology and use the eSmart Space ID as the Space Primary Key.
- New Construction offers the best opportunity to do a full BIM for facility management implementation, as described below.
- Major Renovations in which a facility is substantially gutted permit an implementation similar to New Construction. If the scope of a Major Renovation is limited, then the implementation will follow the Small Project model.

2.2.2 Identify Impact of Project Delivery Approach on Implementation

Under a Traditional (Design/Bid/Build) project delivery approach, there will be multiple contracts and multiple responsible parties for BIM development and deliverables. Requirements and contract language must be geared to the scope and responsibilities of the respective parties.

Alternative project delivery approaches, such as Design/Building, Design/Build-Bridging, CMc (CM at risk), and Integrated Project Delivery (IPD) blur the distinctions between the design and construction teams. In the cases of D/B-B, a single entity would be responsible for the delivery of the information required for facility management. In the case of Traditional (Design/Bid/Build) delivery as indicated above, the A/E and the contractor would each have BIM and COBie deliverables defined in their contracts.

2.2.3 Develop a BIM Execution Plan

project-based A project based BIM Execution Plan (BEP) is developed to provide a master information/data management plan and assignment of roles and responsibilities for model creation and data integration at project initiation. The BEP shall align the project acquisition strategy needs and requirements with GSA technical standards, team member skills, construction industry capability, and technology maturity. Through this process, the team members and GSA project management shall jointly agree on how, when, why, to what level, and for which project outcomes BIM will be used. The BEP brings together the modeling and attribute requirements defined in Section 3 with the format requirements (COBie, IFC, etc.), the current extent of BIM implementation for the facility, and the project-specific conditions and work processes to ensure that GSA receives the facility management information it requires dependably, timely, and cost-effectively. The BEP must also address the team members’ information exchanges amongst themselves. The project team member(s) holding a contract with GSA should have the responsibility for producing the BEP. For New Construction, Major Renovation, and larger scope and dollar Small Projects, project specific BEPs would be developed. The BEP is considered a living document and shall be continually developed and refined throughout the project development lifecycle and be used as a means to keep the various contractor’s use of BIM consistent. Project teams shall produce a BIM Execution Plan based on the BIM Project Execution Planning buildingSMART alliance™ (bSa) Project.

The Building Information Modeling (BIM) Project Execution Plan Content includes the following sections major sections:

- BIM PROJECT EXECUTION PLAN OVERVIEW
2.2.4 Determine When and By Whom Information Is Created

On new construction, the A/E is responsible for the building configuration, accommodation of the spatial program, sizing of building systems (structure, MEP/FP) and location and specification of major equipment. This information is developed during Design. Details of the building systems and sometimes the enclosure system, as well as specific product details are provided by the trade contractors and fabricators and developed during construction. However, in alternative project delivery approaches, responsibilities may change and some tasks, such as detailing building systems, may be performed earlier in the design/build process. In addition, there is equipment information generated during Commissioning, by the Commissioning contractor.

The COBie specification assigns specific information to be entered by the A/E and the contractor. See Section 3 for COBie deliverables from design, construction, and commissioning.

2.2.5 A/E Requirements

In Traditional (Design/Bid/Build) project delivery, the A/E contract should contain requirements for BIM and COBie deliverables, as well as a requirement that the A/E deliver for GSA approval a project BEP.

2.2.5.1 BIM deliverables

BIM deliverable requirements include:
- Spatial Program BIM, per BIM Guide Series 02, delivered at Final Concept Design. Project teams are still required to submit 2D drawings per PBS CAD Standards.
- Design Intent BIM: Building information model(s) created by and conformed to the bid addenda by the A/E. Elements are modeled per BIM Guide Series 02 and are accurate in terms of quantity, size, shape, location and orientation. The Design Intent BIM includes the Spatial Program model. Elements also contain unique asset identification numbers that link them to the COBie data. The Design Intent BIM must be submitted in both .ifc and native format.
• MEP/FP BIM, created by and conformed to the bid addenda by the A/E, that includes all GSA-required equipment. MEP/FP BIM must be submitted in both .ifc and native format.
  – All GSA-required equipment shall include the following attributes:
    o Equipment GUID
    o Asset Identification Number
    o Space Primary Key
• Extract all major plans, sections and elevations from the BIM. The design, three-dimensional location, size and relationships of the building elements and equipment required by GSA in the BIMs shall be included in and derived from the BIMs only.
• Transition BIM to Contractor for the Construction phase. The BEP shall outline the transition process including changes in roles and responsibilities to ensure Design BIMs are appropriately used and leveraged during construction.

2.2.5.2 COBie deliverables
A COBie submittal during the design phase is required. See Section 3 for more about COBie requirements.
• Include the following COBie worksheets: Contact, Facility, Floor, Space, Zone, Type, Component, System, Document, and Attribute.
• Use the same coordinate system, model origin, and units used in the BIMs.
• Handover COBie submittal to the contractor for the Construction phase.
• Use unique asset identification numbers for COBie and corresponding BIM objects.
• GSA Project Managers shall contact their Regional BIM Champions for specific contract language.

2.2.6 Contractor Requirements
Best practice in construction phase BIM use is for the designer, construction manager or a third party to create the base building BIM (architectural and structural components) and for the trade contractors to create the BIMs for the systems they are fabricating. These are the Construction BIMs, which are merged to form the Coordination BIM. By resolving building system conflicts in the Coordination BIM, the construction team can minimize field problems and improve budget and schedule conformance. In order to perform accurate interference checking, the Construction BIMs are updated throughout construction.

An important point is that the various trades should build to the model, to ensure that coordination benefits are achieved. If this is the case, the coordinated Construction BIMs represent an immediate, extremely complete, accurate and useful physical description of the building to inform a broad range of facility management activities.

Again, for Traditional (Design/Bid/Build) delivery, the contractor must provide an updated project BEP, BIM, and COBie deliverables. These requirements can be included in Division 1 specifications.
2.2.7 Monitoring Compliance and Submittals

Quality control checks on BIM Models are performed at key project milestones defined in the BEP and incorporated into the contractor’s Quality Service Plan (QSP) and Construction Quality Control (CQC) Plan. The quality control checks occur across the project lifecycle. GSA develops the means and methods to properly enforce contract BIM requirements throughout the project delivery and O&M process. This includes enforcement of standards and guidelines (e.g., attributes, naming conventions) and assurance that the virtual building is being maintained in conjunction with the constructed building at designated project checkpoints. GSA is also developing a VDC scorecard to measure the quality of BIM use and compliance on projects. The scorecards will be evaluated at project milestones defined in the BEP.

BIM models are validated against the standards established in the BIM Guide Series to ensure accuracy and completeness of the model. The BIM Project Coordinator, identified in the BEP, will lead this effort and leverage other project resources as needed to assist. Automated validation, as is possible for Spatial Program Validation, is the target approach. The output of the validation effort is a list of deficiencies and when they should be corrected, e.g. at current or next project milestone. The latter is important to ensuring that the accuracy of time sensitive information is addressed at the current milestone. An example of time sensitive information is what is needed by SDM to determine impacts to an Occupancy Agreement (OA) and whether the OA needs to be re-signed. If a deficiency is reported in the validation and it may have an effect on the OA, then the model should be updated immediately so that impacts can be determined.

GSA plans to utilize a BIM scorecard to provide on-going evaluation of BIM use and compliance on GSA projects. The scorecard is intended to ensure project objectives and goals outlined in the BEP are being met. The scorecard will also highlight potential areas of improvement during the project. Project teams should contact their Regional BIM Champion and Central Office BIM Program to obtain a copy of the scorecard.

2.3 Standardizing the identification, classification and coding of equipment

One early Lesson Learned from Pilot Projects is the importance of standardizing what information is required, what that information is called (e.g., Asset Identification Number) and the allowable terminology for that information. For example: The Equipment Identification consists of the standard Equipment Acronym and a Sequence Number.

In one Pilot Project, HNTB received an export of 1,018 Maximo records in .xls format for Building 105 in the GSA’s Good Fellow Complex in St. Louis, MO. One of the goals of the project was to match the Maximo records to the corresponding equipment in a Revit BIM. Despite comprehensive review of existing building documentation as well as field verification efforts, HNTB was able to match only 176 out of 1,018 Maximo® records (17%) in the BIM. They recommended that the integration of CMMS and BIM required more standardization and structuring of the data within both systems.
Today CMMS systems are not standardized nor do all Regions use a CMMS. There is value in Integrated Facility Management, having a shared CMMS solution in all Regions will be beneficial. At this time, a national team within GSA is collaborating with regions to develop and implement a National CMMS. However, standardizing the system without standardizing the data will be ineffective. Accurate inventories are critical for a CMMS, and validation of PBS’ equipment inventory is needed before loading to the CMMS.

GSA is working towards a comprehensive, standard list of building element and equipment types, and their attributes. A number of GSA internal as well as industry-wide initiatives have partially addressed this issue:

- GSA’s National Equipment Standard Team (NEST) has done considerable work to standardize the identification, classification, collection, and coding of equipment within facilities across the regions.
- For the Richard Bolling Federal Office Building BIM Pilot Project, Region 6 provided a list of required equipment types and attributes for loading into their Computer-Aided Facility Management System (CAFM).
- For the Rodino BIM for FM Pilot Project, the GSA Service Center prioritized a long list of equipment types and defined their attributes, based on PBS Operations and Maintenance Standards, Draft 2.1, April 24, 2007.
- As part of the National Building Information Model Standard effort, the Inter-Agency Federal Asset Classification Team (IFACT) is addressing the problem that, without an industry standard, users have been unable to cross-reference equipment and other asset data between organizations, agencies, industry, disciplines, and software solutions. Knowing that this creates inaccuracies and inefficiencies that have a major impact on effective maintenance, operations, and management of assets and facilities, IFACT has contributed to OmniClass Table 23 - Products and the United States National CAD Standard®, and created a cross-reference database to improve equipment asset object identification and tracking, and asset information management. These enhancements will allow a higher degree of data integration for all related software solutions and facility management systems. Participating Agencies include:
  - General Services Administration
  - Department of Veteran Affairs
  - Department of State
  - Department of Homeland Security

  This group has addressed the harmonization of acronyms across multiple industry standards and organizations. See www.wbdi.org/pdfs/bim_fs_ifact.pdf.

- Specifiers’ Properties Information Exchange (SPIE) is a NIBS/buildingSMART Alliance project to create an open schema to allow manufacturers to export product data into a format that can be consumed by designers, specifiers, builders, owners, and operators. This initiative aims to turn specifications into property sets that can be applied to the appropriate BIM objects. The focus is on the properties needed for specification, discovery, selection, and verification of products against those specifications. See http://www.buildingsmartalliance.org/index.php/projects/activeprojects/32.
The International Framework for Dictionaries (IFD) is, in simple terms, a standard for terminology libraries or ontologies, based on internationally-accepted open standards that have been developed by ISO (ISO 12006-3:2007). It is multi-lingual. See www.buildingsmart.com/content/ifd.

GSA project teams should see their Regional BIM Champion and Central Office BIM Program for guidance.
section 03: modeling requirements
section 3: Modeling Requirements

While design and construction BIMs are produced throughout the project lifecycle, this section focuses on the modeling requirements for a Record BIM. The Record BIM is submitted at project turnover to document the final as-constructed building and is archived as part of the project record. The As-Built BIM is an editable copy of the Record BIM that is maintained by GSA for updates to the building and systems configuration. Section 3.2 describes which components should be modeled for each building system and the object properties that should be included in the Record BIM.

Equipment attributes required for facility management activities, such as manufacturer, capacities, model number, etc. should be submitted in the current version of the Construction Operations Building Information Exchange (COBie) format. Section 3.3 describes the minimum COBie requirements. It is important to note that this information will be entered by various project team members at various points in the design and construction phases. Project teams should define how COBie requirements will be met in the project BEP.

3.1 High-Level Modeling Requirements

3.1.1 BIM-Authoring Applications

Project teams are required to use BIM-authoring applications which are IFC compliant to meet GSA BIM requirements. The BIM-authoring application, at a minimum, should be able to create IFCs in compliance with the coordination view, spatial program validation view (BIM Guide Series 02), and COBie. BIM-authoring applications, unlike traditional CAD applications, enable project teams to provide object intelligence for building elements. CAD applications that primarily focus on producing printed or plotted drawings, often referred to as 2-D CAD applications, are generally not adequate for a BIM design process and do not satisfy the BIM requirements in this Guide. Further, 3-D functionality in a CAD application does not automatically imply that the system is capable of producing a BIM. Project teams should consult with GSA Central Office to determine if a software application will meet GSA BIM requirements.

Note: The ability of BIM-authoring applications to manage components and spaces with complex geometric shapes varies. BIM Modelers should be aware that in some situations, IFC BIM export from a BIM-authoring application may fail to preserve such complex shapes. This could be a limitation in some applications’ level of support for the IFC standard. BIM Modelers should work with their BIM-authoring vendor to understand if any such limitations exist in the IFC export to be used for submission to GSA. Limitations that may affect submissions to GSA shall be documented in the BEP.

3.1.2 Model Containment Hierarchy

The model structure (or containment hierarchy) of BIM is normally generated by the BIM-authoring application. Users have little if any possibility to influence it. In situations where the user can define the model containment hierarchy, it should be structured...
as in the IFC data model. Typically, spaces and building elements are contained in a building floor, building floors are contained in buildings, buildings are contained in a site, and a project can contain one or more sites. In the submission to ODC, the site object is optional (in which case the building is contained directly by the project).

This containment hierarchy can be summarized as follows:

- Project
  - Site
    - Spaces
    - Building Elements
  - Buildings
    - Building Floors
      - Spaces
        - Building Elements

Spaces can also be members of one or more Zones (e.g., daylighting, HVAC, or even an organizational department). See BIM Guide Series 02 for more detail on Spaces and Zones.

In general, the BIM-authoring application will manage this for the BIM modeler, but it is important to be aware of this containment hierarchy in order to better understand the requirements for developing a BIM. As always, BIM modelers are encouraged to consult with their BIM-authoring application vendor for more information if this topic is unclear.

### 3.1.3 Asset Identification Number

A major feature that differentiates CAD from BIM is the fact that BIM provides a computable description of a building. The lifecycle view of a BIM requires tracking what changes are made, when and by whom, over the life of the facility. To be useful, changes must be tracked at the element or component level, not at the file level. Thus, each object within a BIM needs to have a unique identity that can be referenced as changes occur. Within the software community, this unique identifier is implemented as a Globally Unique Identifier, or GUID. The concept is that a GUID is a totally unique number - one that will never be generated twice by any computer in existence. While each generated GUID is not guaranteed to be unique, the total number of unique keys is so large that the probability of the same number being generated twice is very small.

GUIDs are typically managed by the software and not under control of the user. Some early BIM adopters discovered that certain BIM analysis applications “recreated” the model and assigned all new GUIDs to the BIM objects. In order to ensure that GSA and
its consultants and contractors can manage each BIM object’s unique identifier, each equipment object shall have an Asset Identification Number in addition to the GUID.

3.2 Design, Construction, and Record BIMs
Throughout the project, various types of BIMs are created and modified. Project teams will start with a design intent BIM, move to multiple construction BIMs, and ultimately, create a Record BIM. At the end of construction, there are multiple, building system specific Construction BIMs. Typically, the architectural and the structural models are those produced by the design team with minor modifications. In the case of a steel structure, a fabrication model may be available. The mechanical/electrical/plumbing/fire protection (MEP/FP) models are frequently produced by the trades using very specialized software packages that interface with cost estimating, inventory, and/or fabrication systems. As the BIMs are created for the project, the project team should follow the BEP in demonstrating how the virtual building is being maintained in conjunction with the constructed building at designated project checkpoints.

3.2.1 Required BIM Objects and Properties

Objects
The following object types are required in the Record BIM submitted to GSA:

- All objects required by BIM Guide Series 02
- Ceilings
- Lighting systems, fixtures and equipment
- Communications systems and equipment
- Irrigation system and equipment
- Furniture manufacturers and specifications
- Electrical systems, equipment, and clearances
- Mechanical systems, equipment, insulation, and clearances
- Plumbing systems, equipment, insulation, and clearances
- Fire protection systems, equipment, and clearances
- Specialty systems, equipment, and clearances
GSA project teams in conjunction with the Service Center should define the minimum list of equipment types required in the BEP. See Section 2.2.4. The BEP should spell out specific, detailed modeling requirements. These will vary depending on building type, building system types, and location. If no attribute information is listed in the BEP, project teams are required to submit accurate geometric representations and object properties (see below) for all objects listed above.

GSA project teams shall contact regional BIM Champions for specific contract language for submitting COBie files. This GSA-specific language is based on a general specification found on the Whole Building Design Guide (http://www.wbdg.org/resources/cobie.php).

Object Properties
The minimum set of properties that should be associated with each required BIM equipment object:

- Equipment GUID,
- Equipment Asset Identification Number, and
- Space Primary Key (i.e., object location)

Space objects must include GSA space properties, as defined GSA BIM Guide Series 02.

3.2.2 National Equipment Standard
GSA is currently developing a National Equipment Standard to be used on GSA projects. The overall purpose of utilizing national equipment standards is to enable GSA to leverage equipment data through the facility lifecycle. GSA intends to utilize and update this data throughout the facility lifecycle—through new construction, small projects, building operations, and major renovations.

3.2.3 Organization of Record BIMs
To be at all useful, the Record BIMs will need to be partitioned by floor and building system. The structural model should be partitioned to include the slab for the relevant level up through the framing for the level above. The slab at the level above should not be included, to allow visualization of the MEP/FP systems at each level. If the building floor plate is very large, then additional partitioning may be advisable. A composite model can always be assembled from multiple sub-models. Organization of models shall be determine by the project team and documented in the BEP.

3.2.4 Modeling Precision
The system of measure for modeling PBS new construction projects is hard metric (e.g., 250mm). The system of measure for modeling renovation and alteration projects can be soft metric (e.g., designations such as 1 inch or 25.4mm in which metric equivalents are attached to International System of units (SI)). Measurement accuracy shall be in accordance with the PBS CAD Standard (June 2010).
3.2.5 Consistent Units and Origin
In order to properly register all building models in 3D space, a common coordinate system and units must be used. Scale will be 1:1 (world scale), units for existing buildings will follow that the current building measure system, or per P100. Imperial inches is the unit standard for models for Spatial Data Management (SDM). Models used to represent a single building will use a common reference point for each model assembly, example 0, 0, 0 for the south west exterior finish of the ground floor with north being the top of a sheet or screen view.

3.2.6 Prior to submittal of Record BIMs
Prior to submittal of Record BIMs the following are required:
- Verify that all Construction BIMs (building, structure, finishes, and building systems) represent as-built conditions, including Architectural Supplemental Instructions, Change Notices, and field changes and include the minimum attributes required by GSA.
- Create, for each discipline or system, a Record BIM for each floor of the building. Save in native format of authoring application.
- Verify that the Record BIMs for each floor register in X, Y and Z dimensions.
- MEP/FP BIMs: verify that primary keys correspond to those in equipment inventory.
- Create .ifc version of each Record BIM.
- Create a composite model of the Record BIMs in .ifc format.

3.2.7 Maintaining and Updating As-Built BIMs
Record BIM serves two purposes: to document the as-constructed building and components for use in future projects and O&M activities, and as the project record archive. The As-Built BIM is maintained by GSA to capture building and component updates throughout the facility lifecycle. GSA has identified several major issues that must be resolved in order to efficiently maintain BIMs during facility operations. Internally, GSA has been identifying potential work processes and the technology requirements to support these new processes, but no future process has been established yet. GSA welcomes any feedback or comments on these major issues.

What needs to be maintained in the BIM versus externally?
For the most part, non-geometric data about a facility will be more easily accessed and updated if maintained in a database external to the parametric model. This will not necessarily be a standard relational database but could be a model based central repository. A common unique identifier for each item of interest must be maintained in the BIM authoring application model and the database to maintain association. Additional attributes may be included in the BIM authoring application model by designers or contractors to meet their own needs, such as generating wall, window and door schedules and extracting quantities for cost estimating.
BIM authoring tools use proprietary methods to manage the parametric relationships among building components and assemblies. This means that “perfect” data transfer between unlike BIM authoring tools via a neutral standard such as IFC is not possible at this time. This needs to be taken into consideration when discussing the maintenance and updating of as-built BIMs. This may change in the future as greater IFC support becomes available across the broad range of BIM authoring applications used by designers and trade contractors. Currently, it is possible to move any AutoCAD-based model to IFC through a multi-step process:

- Convert proxy objects to AutoCAD-native elements
- Load into AutoCAD MEP
- Create IFC file

When loaded into a BIM-viewing application or Model Checker, these files have little property information but do contain GUIDs. These GUIDs could be assigned as primary keys and could be coordinated with the external database or COBie submittals containing the property information.

**How should GSA update the As-built BIM to reflect ongoing facility changes?**

The update process will depend on the type of information that needs to be updated:

- Update attributes: can be accomplished by updating the external database
- Replace equipment: if a new primary key needs to be assigned, the change must be made in both the BIM and external database. This would probably require a delete/add operation in the BIM authoring tool; if the primary key remains the same, then this operation is the same as above
- Reconfigure space or building systems: this requires use of a BIM authoring tool to add, delete, move building elements: walls, doors, windows, ducts, pipes, light fixtures, etc. For extensive renovations, the IFC file should probably be used as an underlay to create a new model of the portion of the facility being reconfigured. When such a project affects only a portion of the floor, selective updating of the as-built model will be tricky. This is true of CAD as well, but a requirement to maintain primary keys on existing-to-remain building elements will further complicate the issue.

### 3.3 COBie Submittals

The Construction Operations Building Information Exchange (COBie) is an open standard approach to handing design and construction information over to facility management. The Army Corps of Engineers and NASA have been the primary developers of COBie, with several other agencies (including GSA) adopting this open standard. For the current version of COBie and a more detailed explanation, please visit the Whole Building Design Guide (http://www.wbdg.org/resources/cobie.php).

COBie provides an open standard format for capturing project data, particularly equipment data, when it is generated during the design, construction, and commissioning phases. COBie minimizes information exchange loss and associated costs from the physical handover of project information at the end of a project. COBie maximizes the chances of receiving relevant information
when the information is created. It has been demonstrated through NIBS sponsored “COBie Challenges” that COBie data can be imported into a facility management system such as a CMMS to update and track facility asset data.

Not all attribute information must be in a BIM, but required information should be transferred via COBie-compliant files. Required COBie space, zone, and equipment data must be linked to the objects in the Record BIMs. A common primary key should be assigned in both COBie and the model to link the BIM objects to their associated attributes. Project teams shall document how they will comply with COBie requirements in their BIM Execution Plan.

The COBie-compliant Excel file consists of 16 separate spreadsheets or worksheets that capture project data from different facility lifecycle phases. The following table identifies each COBie worksheet, the purpose of the worksheet, and the facility lifecycle when the data is captured.

<table>
<thead>
<tr>
<th>GSA Required</th>
<th>COBie Worksheet</th>
<th>Purpose</th>
<th>Lifecycle When Data is Captured</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Contact</td>
<td>Capture data providers and manufacturers contact information.</td>
<td>All</td>
</tr>
<tr>
<td>Yes</td>
<td>Facility</td>
<td>Facility description and measurement standards.</td>
<td>Design</td>
</tr>
<tr>
<td>Yes</td>
<td>Floor</td>
<td>Identifies floors or levels.</td>
<td>Design</td>
</tr>
<tr>
<td>Yes</td>
<td>Space</td>
<td>Identifies rooms or spaces.</td>
<td>Design</td>
</tr>
<tr>
<td>Yes</td>
<td>Zones</td>
<td>Identifies zones.</td>
<td>Design</td>
</tr>
<tr>
<td>Yes</td>
<td>Type</td>
<td>Identifies equipment, parts, or materials and warranty information.</td>
<td>Design/Construction¹</td>
</tr>
<tr>
<td>Yes</td>
<td>Component</td>
<td>Identifies each equipment, part, or material instance and installation information.</td>
<td>Design/Construction²</td>
</tr>
<tr>
<td>Yes</td>
<td>Systems</td>
<td>Associates building components with building systems.</td>
<td>Design/Construction</td>
</tr>
<tr>
<td>No</td>
<td>Job</td>
<td>Identifies operations and maintenance procedures.</td>
<td>Construction/Commissioning³</td>
</tr>
<tr>
<td>No</td>
<td>Resource</td>
<td>Special materials, tools or training required to complete a Job Task.</td>
<td>Construction/Commissioning</td>
</tr>
</tbody>
</table>

¹ The worksheet is created in the first facility lifecycle and updated in the second facility lifecycle.
² The worksheet can be completed in either facility lifecycle phase.
### Table 1: COBie Requirements

<table>
<thead>
<tr>
<th>No</th>
<th>Spare</th>
<th>Identifies spare parts lists.</th>
<th>Construction/Commissioning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>Documents</td>
<td>Indexes submittal documents.</td>
<td>All</td>
</tr>
<tr>
<td>No</td>
<td>Issues</td>
<td>Identifies other issues including operational safety issues.</td>
<td>All</td>
</tr>
<tr>
<td>No</td>
<td>Coordinates</td>
<td>Applies coordinates to a facility, floor, space or component.</td>
<td>All</td>
</tr>
<tr>
<td>Yes</td>
<td>Attributes</td>
<td>COBie2 extensibility alternative for user defined columns in other worksheets.</td>
<td>All</td>
</tr>
<tr>
<td>No</td>
<td>Connections</td>
<td>Identifies logical connections between components.</td>
<td>All</td>
</tr>
</tbody>
</table>

### 3.3.1 Minimum COBie Requirements

For GSA, a COBie deliverable in accordance with Table 1 shall be submitted for all projects that involve space, zone, building systems or equipment changes.

The COBie deliverable should contain attribute data for all BIM objects required by the GSA project team, as outlined in the BIM Execution Plan. The Record BIM and the COBie deliverable should contain the same Equipment Primary Key, Equipment Identification, and Space Primary Key for each BIM equipment object. The Equipment Primary Key and the Equipment Identification link the equipment attribute data in the COBie deliverable to the BIM equipment object in the Record BIM. Electronic copies of product information and shop drawings shall be linked to the model.

### 3.3.2 Creating COBie Deliverables

COBie deliverables can be created and updated one of four ways:

- Manually enter data in the COBie spreadsheet,
- Extract BIM attribute data into a COBie compliant file, and
- Direct use of COBie compliant software.
- Exporting an IFC file with correctly structured property sets.

The method selected for creating and updating the COBie deliverable should be defined in the BEP. Project teams should consider the capabilities and resource requirements among the different methods to deliver COBie data when determining which method to use.

Standardized terminology is required. GSA project teams should consult their Regional BIM Champion or Central Office BIM Program for COBie templates and specifications.
section 04: technology
section 4: technology

This section describes various technologies for BIM for facility management.

4.1 Technology Requirements

4.1.1 Central Repository of Facility Information

Key to using BIM effectively for facility management is the establishment of a centralized repository of facility data. The data may actually be stored in multiple, linked repositories but the data must serve as a centralized resource, available to all appropriate users.

The question of whether there is one repository for all of PBS or each Region has its own repository does not affect the technology requirements. What is important is having the data captured in the same standard format across all regions.

4.1.2 Infrastructure

Software tools and communication links must be responsive if users are expected to access and maintain facility information in a central repository. Necessary technology infrastructure includes:

- Adequate, high-speed data storage
- Adequate server capacity
- Adequate desktop computer processing capacity
- Adequate numbers of software licenses
- Adequate network bandwidth
- Responsive license servers

4.1.3 Security

All facility management information and FM BIMs should be maintained inside GSA firewalls. However, external repositories, accessible to GSA, A/Es and construction teams, are needed to allow copies of Design, Construction, Record, and As-Built BIMs to be made available to project teams, to permit the sharing and collaborative updating of the project models, and to support the submission of the As-Built BIMs and other electronic deliverables. These repositories must meet security requirements for sensitive but unclassified (SBU) information.

4.1.4 Functionality

From the project process through the update and maintenance of facility information throughout the lifecycle, there are a number of different technology requirements:
• During project execution, the design and construction teams need the ability to collaborate on the development of the facility model. Multiple groups within GSA, including Design & Construction and Spatial Data Management, also need to be able to monitor progress and compliance to GSA requirements throughout this process.
• At project closeout, the facility information must be handed over and uploaded into the central facility repository inside the GSA firewall.
• During Operations and Maintenance phase, tools are needed to update the As-Built BIMs and synchronize those updates with activity in the CMMS and Equipment Inventory Database, as well as with eSmart (GSA’s 2D drawing repository).

4.2 The Vision: Technology Overview

The diagram, Overview of Central Facility Repository, in Appendix A details the ultimate vision for the contents and functioning of a central repository system. Its components are described below.

4.2.1 PBS Central Facility Repository

The diagram envisions a single repository that contains many data packages in a range of formats. It defines specific applications that “own” each data package - that is, applications that can change the data. For most data packages there are two “owner” applications:

• BIM and CMMS:
  – Equipment
  – Warranty
  – O&M Manuals
  – Materials and Finishes
  – Commissioning
  – Energy

• BIM and eSMART
  – Spatial data related to Design, Construction, and As Built

• CMMS and SBS
  – Performance Data

• BIM only
  – Cost Estimate
4.2.1.1 Repository of Files
The Central Facility Repository manages a range of file types, including:

- BIM models
- COBie compliant files
- 2D drawing files
- Project documents
- Equipment lists
- Preventive maintenance schedules
- Warranty documents
- O&M manuals
- Laser scanning files

4.2.1.2 Versioning of Files
The Central Facility Repository manages multiple versions of all files and assigns the following statuses:

- Pending - represents changes to the building as a result of a project which has not reached substantial completion yet
- Current - represents existing conditions of the building inclusive of cumulative set of changes on all projects that have reached substantial completion
- Archived - past history of drawings, objects, and equipment related to the building

4.2.1.3 Functionality
The key functionalities provided directly by the Central Facility Repository are:

- Data Security: security requirements for compliance with federal government security
- Search and View: easy and intuitive searching and viewing of data
- Version Control: versioning of files and data; maintenance of multiple versions
- Audit trail: tracking each version’s creation date and author, as well as other metadata, to maintain history of changes
- User Notifications Upon Update: stakeholder notification when data or files change - sent to those users who have checked out that data or file and to those users who registered to receive notifications such as O&M and SDM personnel.
- Analysis and Reporting: tools to support analysis and reporting of the data such as identifying equipment down time, failure history, repair/restoration cost history, operation/maintenance man-hours, efficiency, and energy consumption (if metered).
- System Review and Control: access to various facility management systems
- File and Data Naming Standards: communication of standards and conversion to those standards where applicable
- GUID Generation / Maintenance: ensures uniqueness of GUIDs in a building, across buildings, and across Regions
4.2.1.4 Middleware Layer
All data entering the Central Facility Repository passes through an automated data conversion and standards compliance checking layer.

4.2.1.5 Synchronization
The Central Facility Repository should support two-way synchronization with GSA internal systems such as:
- Smart Building Systems (SBS)
- Building Automations System (BAS)
- Energy Management System (EMS)
- Computerized Maintenance Management Systems (CMMS)
- eSMART
- ePM
- RExUS (maybe 1-way only)
- Business Intelligence (1 way only - for analysis)

4.2.1.6 Primary Data Sources
Primary data sources are projects: New Construction, Major Renovations and Small Projects. This data may be submitted by either external consultants or contractors or internal GSA staff.

4.2.1.7 Check-Out/Check-In
The Central Facility Repository envisions a Check-Out/Check-In process, but not the one that is commonly understood from traditional electronic document management systems.

4.2.1.7.1 Check-Out
Checking out does not lock the data. Rather, multiple check-outs of the same package are supported. The Check-out process determines if the info package has already been checked out. If it has, the process notifies all users who have it checked out. If any changes occur in the package after check-out, all users are notified.

4.2.1.7.2 Check-In
Checking in involves the following steps:
- Notify QC review/approval process
- Determine if the data package has changed since check-out
- Create an historical record of the information package
- Update the information package based on the change
- Notify stakeholder(s) of change
4.3 Current Technology Challenges/Recommendations for Immediate Implementation

Despite the fact that BIM is a relatively young technology, it has developed to the point where it can be effectively deployed for facility management. Figure 3 revises the Central Facility Repository vision for current BIM deployment.
Facility Data Workflow - DRAFT

System Interfaces
- eSmart
- Smart Building Systems (SBS)
- RExUS
- CMMS
- BIM Viewer

Facility Data
- Space and Lease Data
- Utilities Data
- As-Built Geometric Data
- Equipment List/Work Order Data

Derived Documents
- Work Orders
- Drawings
- Tenant Rent Charges
- Equipment Lists

Notes:
1. BA51 is the GSA acronym for New Construction.
2. BA4 is the GSA acronym for Small Projects.
3. BA55 is the GSA acronym for Major Renovations & Alterations.
4. BA61 is the GSA acronym for Operations and Maintenance.
5. BA80 is the GSA acronym for Reimbursable Work.

Last Updated: December 22, 2010

Figure 3: Facility Data Workflow for Current BIM Deployment

section 4: technology
The following discusses current technology challenges and provides recommendations for immediate implementation.

### 4.3.1 Multi-User Update

New construction projects will provide the initial facility information. That information will be updated in multiple ways:

1) Exchanging data with other GSA systems
2) Capturing changes resulting from both small projects and major renovations

Within any facility, multiple change activities will overlap. Therefore the multi-user access requirements are quite complex. The type of Check-Out/Check-In system envisioned in 4.2.1.7 does not exist today and would be extremely cumbersome to manage. If multiple users have modified the same data, whose changes take precedence? The last check-in? What if that is old data whose check-in was delayed, rather than data that represents the latest building modification? It is for this reason that Check-out typically locks the data and permits Check-in of changes to that data by only one user.

Increasingly, BIM software products support access to and updating of building information at the component level. However, only one user has update access at any one time. There are a few products that support Web services for updates. This scenario would permit something like database record locking, with the lock released the moment the change transaction is completed. This appears to be the direction in which the industry is moving.

### 4.3.2 Management of Updates

Today, most BIM data, particularly the geometric information, is managed at best at the level of a checked out and locked set of components. Managing updates of the As-Built BIM in the environment of many GSA facilities where there are multiple, overlapping major renovations, small projects and maintenance activities underway simultaneously is challenging.

Projects pose additional challenges:

- When should the project data replace the official existing conditions information?
- How can a project model for a specific area of a building be inserted into the overall model?
- How can such an update be accomplished while accurately managing the primary keys of GSA-required COBie objects so that primary keys of:
  - Items that remain are unchanged
  - Items that are removed during the project are removed from other systems (e.g., CMMS)
  - New items are identified and transferred to other systems

Recommendations are:

- Project work should not be incorporated into the As-Built BIM for the overall facility or CMMS until such time as the construction is complete and the project’s As-Built BIMs have been checked and accepted.
• The A/E should produce a report indicating the primary keys of COBie objects that will remain and those that will be removed as a result of the project.
• Contractor should ensure that primary keys on items remaining are not changed in the As-Built BIMs. This will be a difficult requirement to get across, but it will be possible to validate that primary keys are unchanged based on the A/E’s report.
• The incorporation of the project As-Built BIM into the overall facility AS-Built BIM cannot be completely automated at this time, unless the renovation is so extensive that an entire As-Built BIM file can be replaced. In other circumstances, an experienced and knowledgeable BIM user will need to knit the modifications into the existing fabric of the building. This is currently the case with FM CAD as well.

4.3.3 Multi-User Access and Viewing
Access to facility information can be facilitated through 3D visualization. However, BIM authoring tools are not the correct application to provide this access to users who need view-only access. Easy-to-navigate, low-cost or free viewers are preferred.

Similarly, capturing and extracting needed facility data (attributes) using a BIM authoring tool becomes cumbersome and difficult to manage. The BIM file size becomes very large and slow to manipulate with all the required facility data. Every user requires high-powered hardware and access to and training in expensive BIM authoring tools.

4.3.4 Vendor Neutral Options
GSA is committed to the interoperability of data as a strategic management issue to ensure GSA’s access to building information over the life of the capital asset. This implies,

There are vendor neutral options. The GSA National Equipment Standard Team has suggested that capturing design and construction data in an open, ODBC-compliant database format supports GSA’s policy on vendor neutral software. This format provides for easy interoperability with similar database-structured facility management systems.

COBie (Construction to Operations Building Information Exchange) provides a vendor neutral format to capture design, construction, and commissioning data. The COBie format data can be used to populate CMMS or other database structured
facility management systems. COBie data can be entered manually and/or extracted from BIMs into COBie compliant format. BIMs can be linked to the COBie file. In National Institute of Building Sciences (NIBS)-sponsored COBie Challenges, BIMs in both native and IFC format have been demonstrated to transfer data to COBie.

Recommendations are:
- Use the COBie file to synchronize As-Built project data with CMMS and other facility management systems.
- Use Equipment Primary Key to link BIM equipment objects with external equipment data that is created by multiple project and O&M activities.
- Use the current version of the COBie file.

4.3.5 Multiple Paths for Data Transfers
With current technology, there are some limitations as noted above, but also many opportunities for harvesting useful BIMs and linked data for facility management (Figure 4).

![Figure 4: Multiple Paths for Data Transfer (Image courtesy of Onuma, Inc. with edits)
4.4 Emerging Technology: Model Servers

There is an emerging class of BIM software product referred to as “model servers.” Model Servers provide the type functionality envisioned for the Central Facility Repository shown in Appendix A, discussed in Section 4.2 above. A number of GSA Pilot Projects are examining this category of technology. A preliminary list of model server requirements includes:

- Manages models in IFC format
- Manages related files in multiple formats
- Manages associated object properties in ifcXML format
- Assigns an object’s GUID as an explicit property
- Provides viewers for all formats managed
- Allows volumes and/or components of a model to be associated with a particular project
  - Project properties include start/end date range
  - Supports queries such as:
    o Find all projects that have affected this part (volume) of the building in the last <number> years
    o Find any projects scheduled to affect this part of the building between <date range>
    o Find any maintenance projects currently underway in this part of the building
    o Find all changes that have been made to this branch of the HVAC system since the building was constructed
- Allows model elements associated with a project to be copied to a “working model”
  - Can notify other users who have copies of any of the same model elements
- Can use Web Services to permit the model to be updated in real time on a component-by-component basis
- Has the ability to update the primary model by “Checking In” project models:
  - Can route Check-In data through validation and compliance checks
  - Can compare the incoming model to the current version and identify changes
    o Changes to geometry
    o Changes to properties, including primary keys
  - Can replace each (and only) changed components with a new version
  - Can maintain an audit trail for each version of each component
  - Can apply a status to each model checked in, at a minimum:
    o Pending
    o Current
    o Archive
- Can notify other users who have copies of any of the changed components or properties
- Has ability to perform real time and batch updates of models and component properties based on data transfers from other systems
- Provides integration tools for automating such updates
- May incorporate tools for direct model update
- Has the ability to perform coordinate transformations (translation and rotation) so that a project with a local coordinate system can be accurately registered to a building, campus, city, and so forth.
- Is FISMA compliant, based on GSA security category mappings.