U.S. General Services Administration
Public Buildings Service
Office of the Chief Architect

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This version of the *GSA Building Information Modeling Guide Series: 02 – GSA BIM Guide for Spatial Program Validation* is identified as Version 0.95 to indicate its provisional status. With its publication, the GSA BIM Guide, for the first time, becomes available for public review and comment. As its provisional status denotes, however, it 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 the National 3D-4D-BIM Program. Updated versions will continue to be issued to address and incorporate on-going feedback in an open, collaborative process.

Currently, GSA Building Information Modeling Guide Series: 01 – Overview of GSA's National 3D-4D-BIM Program, version 0.50 is also available for review and comment.

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.

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GSA

BIM Guide For Spatial Program Validation

GSA BIM Guide Series 02

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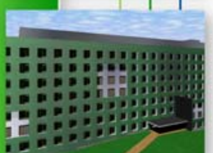

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Version 0.85 — August 2006
Version 0.50 — December 2005
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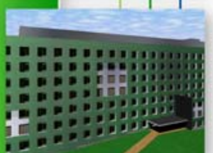




executive summary: space program validation

In 2003, U.S. General Services Administration (GSA) Public Buildings Service (PBS) Office of the Chief Architect (OCA) established the National 3D-4D-BIM Program. For more information, visit the National 3D-4D-BIM Program webpage at http://www.gsa.gov/bim. As part of this program, OCA has evaluated an array of 3D-4D-BIM applications on a number of capital projects. Since the calculation of space (e.g., rentable area, usable area, etc) is one of the most essential business metrics for GSA, OCA has been working with a number of PBS offices, BIM vendors, the building industry, leading research institutions, and professional organizations to establish requirements for a spatial program BIM. All new and major modernization projects in Fiscal Year (FY) 2007 and beyond that receive design funding are required to submit a spatial program BIM to OCA for Final Concept Approval.

This guide is a result of the work the GSA BIM team has done to ensure that high-quality models will be submitted for spatial analysis. GSA has been working with a number of BIM-authoring software vendors to ensure that architects and engineers (A/Es) are able to comply with the new GSA spatial requirements using a broad range of available software, via the Industry Foundation Classes (IFC) open standard. GSA is also testing and validating these requirements on pilot projects with A/E teams across the nation.

Objective of Spatial Validation using BIM

The overall purpose of validating a spatial program using BIM is to efficiently and accurately assess design performance, relative to GSA space program requirements. In the past, GSA validated a spatial program using manually-created 2D polygons in plan drawings during early design stages. This process was both time-consuming and led to discrepancies when GSA's spatial data management (SDM) team measured and reported on the actual building spaces. The SDM report is the basis for rent calculations. By using BIM models, GSA can automate the spatial validation process to ensure that all designs in the Final Concept phase adhere to the spatial requirements set forth by the housing plan and *PBS Business Assignment Guide*. GSA will also use this analysis to benchmark performance and generate measurement reports based upon equivalent space types and building type.

Requirements and Deliverables

At a minimum, A/Es are required to have the following objects in a valid 3D geometry representation. In addition, spaces must include the following information (See sections 2.1 and 3 of this guide for more information):

- Space objects over 9 s.f. with the following attributes:
  - GSA BIM Area (formerly GSA Net Area in previous versions)
  - Space Name (in accordance with approved space names in appendix C)
  - Space Number
  - Occupant Organization Name

    - GSA STAR Space Type
    - Full-Floor Space
- Wall objects
    - Openings
        - Door objects
        - Window objects
- Slab objects
- Column objects
- Beam objects

In addition to these requirements on individual space objects, A/Es must also create a full building floor space (with a space name and number) for every floor that represents the GSA Design Gross Area. A/Es should consult their regional GSA project team and OCA to determine if additional requirements are necessary.

There may be additional zone requirements, depending upon the type of project (e.g., courthouses, historic buildings). A/Es must consult with OCA and the GSA project team to determine if additional requirements are necessary. A/Es are also encouraged to provide additional information above the minimum requirements.

The BIM deliverables required in the Preliminary and Final Concept submission include:

- A single BIM file in IFC 2x2 format (preferred) or IFC 2x format.
- BIM file(s) in the native format of the BIM-authoring application(s).

These requirements are in addition to all current Concept stage submission requirements set forth in Appendix A of the *Facilities Standards for the Public Buildings Service* (PBS P-100 March 2005). A/Es should also follow the PBS CAD Standards for creating 2-D drawings. A/Es may submit preliminary deliverables to OCA for pre-submission checking and feedback to ensure conformance of final deliverables (see section 1.3.4 of this guide).

Major points regarding modeling for GSA

The purpose of this guide is to aid A/Es in their BIM modeling efforts related to spatial program validation. For more information on any one of these topics, please consult the appropriate section of the BIM Guide. The following points highlight the most important modeling requirements for the BIM. If the following are not defined properly, automatic calculations of other types of areas (e.g., gross, usable, rentable) will be incorrect.

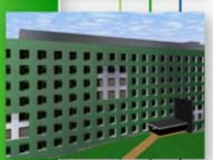
- A/Es must designate GSA BIM Area (formerly GSA Net Area in previous versions), when defining a space (see section 2.1.4 of this guide).

- A/Es should use the appropriate BIM tool to create objects. For example, “Wall” objects should be created using a “Wall” tool. If an object is not directly supported with an appropriate BIM tool, A/Es should consult with their BIM-authoring vendor to determine the best way to model those objects (see section 3 of this guide).
- A/Es should ensure that all names (e.g., space name, occupant organization name) match established GSA naming conventions (see section 2.1 of this guide).

Conclusions

GSA expects that, in referencing this Guide, both GSA and A/Es will be able to gain efficiencies and accuracy in measuring space. By automating spatial validation, GSA can validate space during earlier design stages with more confidence, while allowing A/Es to spend more time on design tasks rather than spatial calculations. GSA welcomes any constructive comments and recommendations to the BIM Guide and spatial validation process.

introduction



About this Guide

A spatial program BIM allows GSA project teams to automatically analyze and assess whether or not the A/E concept design conforms to GSA spatial program requirements. These requirements can be from area measurements (e.g., rentable or usable) and building efficiency measurements (e.g., fenestration ratio). This Series is a result of two years of establishing, planning, and testing of the spatial program validation requirements. 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 policies on 3D-4D-BIM applications.

This Series on Spatial Program Validation is intended for incorporation by reference in PBS A/E contracts for design of new construction and major modernization projects. As such, these A/E design teams, the PBS Project Managers, and Contracting Officers administering the contracts are its primary audience. The Guide has been prepared to assist design teams in producing BIMs in support of their Preliminary and Final Concept design submissions as outlined in Appendix A, Submission Requirements, of the *Facilities Standards for the Public Buildings Service* (PBS P-100 March 2005).

This Series will also be of general interest to other members of GSA project teams, including PBS 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. Several contributing major providers are listed in Appendix A, BIM-Authoring Application Specific Instructions of the appendix supplement to this guide.

Objective of this Series 02

The main objective of this Series is to enable designers developing Final Concept design submissions for PBS to meet new requirements for an IFC BIM submission. This document describes requirements and guidance for creating building information models with specific object types and associated properties (information). These models will be submitted to PBS in IFC BIM file format, as part of Concept design submissions.

> *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.*

How to use this Series 02 – Spatial Program Validation

This series is divided into 4 major sections:

- **Section 1: Spatial Program BIM** – This section describes the overall objective, history, and process for submission of the spatial program BIM. It describes the high-level modeling requirements for creating the BIM and for the IFC BIM submission.
- **Section 2: Spaces and Zones** – This section describes how and where to create the space boundaries and describes how to assign the required spatial information to space objects.
- **Section 3: Building Elements** – This section describes the required building elements for spatial validation.
- **Section 4: BIM-analysis Rules** – This section describes the BIM-analysis rules that the A/E submissions will be checked against. This section also highlights special cases that may affect the BIM analysis. A/Es should read carefully through this section to understand these cases.

section 01:
spatial program bim

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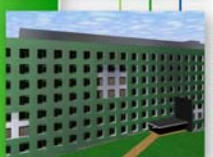


section 1: spatial program bim

This section provides an overview of the origin and motivation behind spatial program BIM requirement. This section is useful to any person wishing to understand why GSA has mandated a spatial program BIM. This section is useful for A/Es to understand the submission process and the high-level modeling requirements.

1.1 Why Spatial Program Validation?

Within GSA, the PBS manages over 342 million square feet of workspace for the civilian federal government. As the largest owner of commercial space in the United States, GSA must measure all of its space in a consistent and efficient manner. PBS has adopted the ANSI/BOMA Standard Method for Measuring Floor Area in Office Buildings (ANSI/BOMA Z 65.1 – 1996), with minor variations as defined in the *PBS Business Assignment Guide*, as its standard for space measurement.

In the past, GSA has required A/Es to validate their own spatial program at the Concept stage. A/Es had to understand the *PBS Business Assignment Guide*, which outlines how GSA measures space, and then create 2D polygons in the appropriate locations to measure the space. This was neither consistent nor efficient.

The purpose of this spatial program BIM is to allow A/Es to spend less time understanding the PBS Assignment Guide, and to spend more time doing a more value-added activity: design. A spatial program BIM allows A/Es to easily define a space in terms of one definition (i.e., GSA BIM Area (formerly GSA Net Area in previous versions) – see section 2.1.2 of this guide) instead of using multiple definitions and conditions. GSA is then able to automatically validate the spatial program portion of the A/Es' Concept design submission. GSA's goal is to automate the checking of model integrity and design performance relative to the space program given to the A/E.

GSA hopes to leverage the use of building information modeling and interoperability between BIM programs to help project teams better validate the required spatial program. GSA has developed a "GSA Concept Design View" of the PBS Requirements for spatial data management. This view is built upon IFC 2x and 2x2 and is currently supported by Autodesk Revit and Architectural Desktop, Bentley Architecture, Graphisoft ArchiCAD, Onuma Planning System, and Solibri Model Checker. These applications have gone through several rounds of validation using a GSA test case building. For more information on BIM and IFCs, please consult the *BIM Guide Series: 01 –Overview of GSA's National 3D-4D-BIM Program*.

With a BIM-analysis application (such as the example described in Appendix B of the appendix supplement to this guide), GSA associates and project teams can:

- Generate spatial measurement and efficiency reports, which can be compared with benchmark measures for equivalent space types and building type (category).
- Understand the building design by visually experiencing the proposed facility in a virtual environment.



- Compare spatial measurements and efficiency metrics with established GSA spatial program requirements to quantitatively assess design proposals.

1.2 The Spatial Program BIM Requirement

For all projects receiving design funding in Fiscal Year 2007 and beyond, a spatial program BIM will be the minimum requirement for all major (new and modernization) projects submitted to the Commissioner and/or the Chief Architect of the Public Buildings Service for Final Concept approvals.

The BIM will be required in addition to all current Concept stage submission requirements set forth in Appendix A of the *Facilities Standards for the Public Buildings Service* (PBS P-100 March 2005). In addition to P-100, the following important reference documents apply as described within this Series:

- *ANSI/BOMA Standard Method for Measuring Floor Area in Office Buildings* (ANSI/BOMA Z 65.1 – 1996)
- *PBS Business Assignment Guide* (October 1, 2005)
- *PBS CAD Standards* (March 25, 2004)

This deliverable should be seen as a tool to aid OCA's review of the Concept Design submission. Similar to the Quality Assurance and Quality Control (QAQC) and Independent Government Estimate (IGE) submissions, the spatial program BIM is only part of a variety of requirements needed at Concept Design.

Currently, OCA does not consider spatial program BIM submissions as a substitute for any of the documents required in the P-100. Instead, these BIM submissions are considered to be a complement to the traditional Concept stage documents. OCA encourages project teams to gain efficiencies through creating the required 2D drawings from the BIM. It is OCA's intent that the BIM submission and design documents submission are consistent (i.e., that the BIM files and document files are consistent). OCA will utilize automated BIM-analysis tools to verify that BIM submissions comply with requirements defined in this Guide and with those defined by specifications for the IFC BIM standard. OCA will use this BIM information for:

- Verification of design quality and integrity
- Comparison of the project as designed with GSA original program of requirements

A/Es will be required to submit BIMs during:

- Preliminary Concept design
- Final Concept design

OCA intends for the development of the spatial program BIM to be an integral part during development of the Concept design, performed by the design team, with the aid of a specialty consultant if necessary. OCA encourages project teams to use the BIM to serve as a platform for conveying the approved Final Concept design, including all refinements and corrections, into design development.

The A/E is responsible to quality control check all submissions. OCA will check these submissions to verify compliance. OCA will reject and require correction of any required deliverables or formats that do not meet requirements. For the deliverables listed below, the A/E shall verify that the required files contain only the content required in accordance with this Guide.

In addition to the Concept design stage deliverables specified in P-100 Appendix A, the BIM deliverables required in Preliminary and Final Concept submissions, at a minimum, include:

- A single BIM file in IFC 2x2 format (preferred) or IFC 2x format, including all of the content in the native format file described below, and purged of any content not relevant in the subject Concept design.
- BIM file(s) in the native format of the BIM-authoring application(s), purged of any content not relevant in the subject Concept design. The submission shall include instructions and all data files necessary to reload the BIM into the original BIM-authoring application such that the IFC BIM can be regenerated by GSA or its consultants.

Also, A/Es should consult with OCA and the GSA project teams to determine what additional properties are required.

The Preliminary and Final Concept designs for the building shall be submitted as single, compressed IFC BIM files and one or more native files for the BIM-authoring application as described above. If the BIM-authoring application allows the user to separate the model into multiple files, A/Es must either (a) merge them into a single model file or (b) package the file set together with clear instructions for loading the complete BIM. It should allow GSA to re-generate the single IFC BIM from the native BIM-authoring application files.

Deliverables shall not replace or alter other 2D CAD requirements set forth in the PBS CAD Standards. Production of CAD drawings directly from the BIM software application is not required, but is encouraged because of its potential benefits on design efficiency and coordination.

See Appendix A of the appendix supplement to this guide for more specific instructions on preparation of both IFC BIM and native BIM file sets for submission to GSA.

1.3 The Spatial Validation Process for A/Es

1.3.1 Overview of the Process

The following flowchart shows the process for submission and analysis of the spatial program BIM.

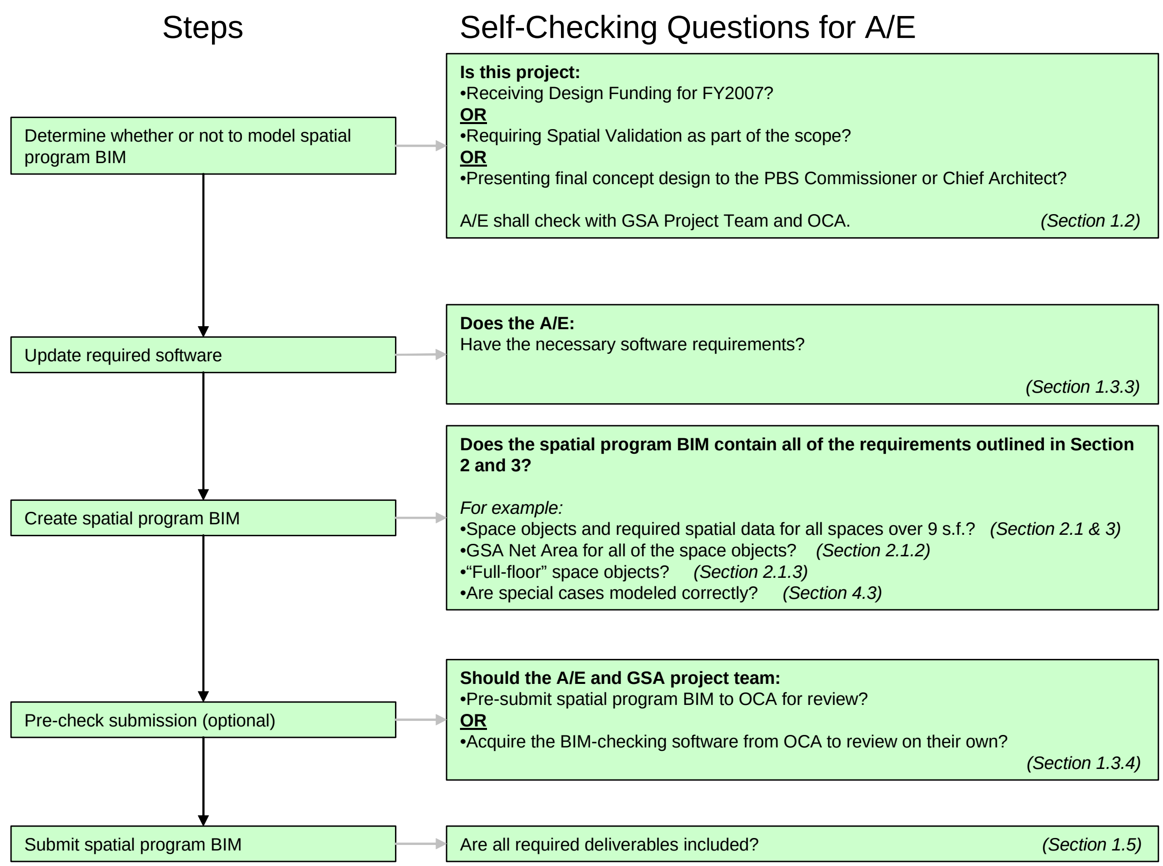


Figure 1: The spatial validation process for A/Es

Note: Although the minimum requirement for submission of the spatial program BIM is during Preliminary and Final Concept design, the process outlined above and in this Series is also applicable to other project phases (e.g., design development, construction documentation).

1.3.2 Updating Software Requirements

Since GSA has been working closely with several BIM-authoring vendors, many of the GSA requirements are available in out-of-the-box software. See Appendices A and B of the appendix supplement to this guide for applications that have demonstrated support for these requirements as of the publication of this Guide. At most, A/Es may have to install additional functions to conform with GSA requirements. Other products may also be fully capable of generating BIMs that conform. Please consult with OCA and the GSA project team if you are unsure about an application you are considering.

1.3.3 Pre-Submission Checking

If the A/Es would like to check their model before the submission deadline, they have the option to do so in several ways:

- Some of the BIM-authoring vendors have incorporated spatial program reporting functionality into their programs. For the participating BIM-authoring applications listed in Appendix A, OCA has validated that GSA BIM Area (formerly GSA Net Area in previous versions) and GSA Design Gross Area conform to the BIM-analysis application. OCA encourages all BIM-authoring vendors to calibrate and validate additional measurements (e.g., rentable area, usable area, etc.) with OCA. Until those calibrations are completed, these additional measurements have not been validated by OCA. However, OCA encourages A/Es to use this additional measurement functionality to gain more insights into the performance of their spatial program.
- OCA encourages A/Es to submit their BIM models to OCA for pre-submission review and feedback.
- If the A/E team has a demonstrated competence with BIM, OCA may provide the A/E team the BIM-analysis software to use on a per-project basis.

  Note: Regardless of results from pre-submission validation, A/Es will be judged solely upon their submissions at Preliminary and Final Concept design.

If there are errors as a result of the pre-submission checking, A/Es should first determine the underlying source of the errors. First, A/Es should ensure that BIM models are free from modeling errors that may affect the spatial program analysis and validation. Please see section 4 of this guide for more information about particular known cases in which this may happen. The following list highlights some typically errors found in the BIM model:

- Missing individual spaces
- Missing design gross area spaces
- Missing spatial information
- BIM object modeling errors

1.3.4 What Happens if the Submission Does Not Pass the Validation?

If the model does not meet the required spatial program, OCA and the project team will determine the appropriate next steps, which may include reconciliation and redesign.

1.4 High-Level Modeling Requirements

1.4.1 BIM-Authoring Applications

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.

Some BIM-authoring applications use a single building model approach and store all information about the building design in a single file or database. In these cases, it is straightforward for the user to select portions of the model for export to a single IFC BIM file for submission to PBS.

In other BIM-authoring applications, the design can be divided into several files. This separation may be based on building floors, building sections, or certain building elements or systems. Content from these multiple files is then combined for drawings of the entire building. It is important that all building elements in a BIM share a single spatial coordinate system. If the BIM is created in multiple, separate files, A/Es should take care to ensure the spatial coordinate origins are coincident at the same 3D point. Additionally, if the BIM spans multiple files in the BIM-authoring tool, A/Es will need to load all files necessary to compose a single integrated BIM before generating (exporting) the IFC BIM submittal for PBS. See section 1.2 of this gudie for file submission requirements.

CAD systems have been used for years mainly to produce printed drawings. Consequently, most organizational processes and software tools have been developed to optimize such drawings. In model-based design, many of these processes must be adapted and modified to optimize development and documentation from BIM. A/Es making the transition from CAD to BIM are encouraged to work with the vendors of their BIM-authoring tool about process recommendations for developing BIMs for both design documentation and analysis.

> *Note: The ability of BIM-authoring applications to manage components and spaces with complex geometric shapes varies. A/Es 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. A/Es 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.*

Additionally, in BIM environments, it is increasingly important to have standardization and consistency in naming conventions and associated properties.

1.4.2 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 BIM standard. 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 OCA, the site object is optional (in which case the building is contained directly by the project) and the building floor object is also optional (in which case spaces and building elements are directly contained by the building).

This containment hierarchy can be summarized as follows:

- Project
  - Site
    - Spaces
    - Building Elements
    - Buildings (same as below)
  - 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 section 2 for more detail on Spaces and Zones.

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

1.4.3 Required BIM Objects & Properties

Objects in the BIM must be structured using the containment hierarchy defined in section 1.4.3 of this guide using containment relationships (e.g., a building is made from one of more building floors). This should normally be handled automatically by your BIM-authoring application.

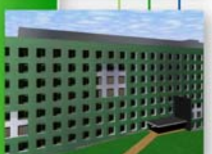
Objects

The following object types are required in IFC BIM(s) submitted to GSA for Concept Design submissions:

- Project
  - Site
    - Buildings
      - Building Floors
  - Spaces
  - Walls
    - Openings
      - Doors
      - Windows
  - Slabs
  - Columns
  - Beams

Object Properties

- As shown in the structure above, BIMs typically have a defined hierarchy of objects. 3D geometric objects are the foundation of the BIM. BIM-authoring applications typically have "tools" to model these objects. These include all objects under Building Floors. For example, Walls are created using the application's Wall tool, Slabs using the Slab tool, and so on.
- 3D geometric objects are also the basis for higher-level conceptual objects. For example, a building floor can be made up of multiple instances of walls and spaces, while a building is made up of several building floors. All objects except Project, Building, and Building Floor (story) must have a valid 3D geometry representation in the IFC BIM submitted to GSA.
- Space objects must also include GSA space properties, as defined in section 2.1 of this guide.
- Wall objects must include the "interior or exterior" property as defined in IFC. The BIM-authoring application will include this in export to IFC, but the user may be required to "set'" the property value in some cases. Please see vendor documentation for instructions on how this property is set.
- In order to ensure that all instances of each object type in the BIM are complete and meet the requirements defined in this Guide, users are advised to use one of the BIM-authoring applications listed in the appendix supplement to this guide, or independently validated as compliant with these requirements.



1.4.4 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 alternation 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 must be 3mm (approximately $1/8^{th}$ inch) per section 8.1.2 of the *PBS CAD Standard* (March 2004).

The coordinate system origin for BIM files submitted must be located logically and in close proximity to the building geometry (e.g., at a grid intersection). This origin must not be moved during the course of the project since most objects in an IFC BIM use relative placement, which traces back to the project coordinate system origin.

1.4.5 Retaining Original Global Unique Identifiers (GUIDs)

One cornerstone of the IFC BIM schema is a unique identifier assigned to each object in the model. These IDs are used in cross-object references, relationships, and to enable tracking of what has changed in a model between two states or versions. All software applications that support export of IFC BIMs are able to generate unique object identifiers called Global Unique Identifiers (GUIDs). If a BIM-authoring application provides the option to keep the original GUID, this option should always be selected.

1.4.6 Use of Drawing Layers

This section only applies to BIM-authoring applications that use layers as the primary mechanism for filtering and structuring content.

The constructs of drawing layers and drawing layer sets in CAD systems were developed to obtain desired subsets of 2-D drawings. BIMs submitted in accordance with this Guide must include 3-D assemblies, and do not inherently require drawing layers, as content filtering can be accomplished in a number of other ways. However, in some BIM-authoring applications, certain properties of objects and building elements are set using layers. For example, separation of exterior versus interior walls may be done using layers. A/Es are encouraged to consult with their BIM-authoring vendor about drawing layer strategies that will support drawing production and the BIM requirements outlined in this Guide, and if/how these can impact object properties.

Drawing Layers for BIM Objects

BIM model objects should be assigned to appropriate drawing layers to provide control for visibility in drawings as in the past. Additionally, if the BIM-authoring application only exports to the IFC BIM what is currently visible and layers are the primary 'filter' for what elements are visible, organizing objects onto layers is essential to controlling what is exported to the IFC BIM. In such applications, it is highly recommended that users create and use a layering scheme that will support display of the BIM objects only. Drawing layer requirements for 2-D CAD on PBS projects are defined in the *PBS CAD Standards* (March 25, 2004). Structures, spaces, sketches, and the like not belonging to the BIM should be drawn on layers separate from the BIM layers so that they can easily be switched off and excluded from the BIM export.

1.4.7 Application-Dependent Special Requirements

CAD vendors, importers, and retailers have developed their own IFC BIM Guidelines. These guidelines should be read carefully because this Guide cannot take into account all of the special features of individual BIM-authoring applications. If there are contradictions between this Guide and vendors' instructions, the BIM Program Manager in the PBS Office of the Chief Architect shall be contacted for clarification. See the Acknowledgements section at the end of this Guide for contact information.

1.4.8 Exporting IFC BIMs

BIM-authoring applications have different ways to export IFC BIMs. Generally, the BIM-authoring application's Save As command is used, selecting the appropriate IFC BIM version. In some cases, a special tool or command is required. Please consult with the documentation provided with the BIM-authoring application.

BIM-authoring applications generally allow the user to identify a model subset (or filter) when exporting to an IFC BIM. In some cases, this is done by exporting only the layers that are currently visible in the BIM-authoring application. This allows users to export only the parts of the model relevant to the purpose of the export. Please refer to the BIM-authoring application vendor's specific instructions on how to filter the objects to be included in the export to an IFC BIM.

Regarding a BIM submission to PBS, all non-BIM related layers, objects, text styles and other elements not used in the Final Concept design configuration shall be purged before submission. For example, early phase "what if" scenarios that have been abandoned but were left in the model should be deleted from the native file before the complete native model file(s) and exported IFC BIM are generated.

When sending or uploading IFC BIMs in either .IFC or .IFX formats, users should always, unless explicitly agreed otherwise, compress the files (e.g., using WinZip®). This can reduce the size of the files by up to 90%.

1.4.9 Handling Multiple BIM Versions

A BIM exists as a digital model of the building at a given point in time. It may be produced by a number of parties using various software tools. BIMs submitted to GSA should only contain the current state of the design. Submissions should not contain alternative or abandoned design schemes. Several versions of the BIM may be created during the design process. BIM versions may be published for specific uses by various project stakeholders. In each case, the BIM version normally needs to contain only the subset of information that is relevant to the intended user at the current phase of the project. For example, a BIM shared for the purpose of energy performance simulation normally would not need to include cabinetry, furniture, or plumbing fixtures.

Each design alternative included in the Preliminary Concept design submission to PBS shall be supported by a separate BIM in IFC format that contains only the information relevant to the subject design alternative. Similarly, Final Concept design submission to PBS shall be supported by a BIM in IFC format containing only information relevant to the Final Concept design.

section 02:
spaces and zones

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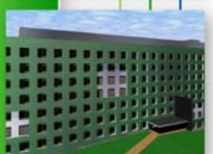


section 2: spaces and zones

This section describes the spatial program BIM requirements for spaces and zones. This section describes how and when spaces should be created and the required information each space contains. All A/Es are required to understand the contents of this section and adhere to all requirements.

2.1 Spaces

Spaces are one of the most important object types in conceptual building design. During pre-design, many, if not most, client requirements are described in terms of spatial program requirements; furthermore, throughout building design and operation many performance metrics utilize spatial data. Consequently, modeling spaces accurately is one of the most important tasks in creating BIMs. Space objects are normally represented in plan drawing view with a data tag (e.g., name, number, etc.). Refer to section 1 of the *PBS Business Assignment Guide* for a sample data tag.

Spatial information will be used for design assessment relative to the spatial program issued by GSA to the A/E. This will include space area calculations and comparisons to the original Space Program, using *PBS Business Assignment Guide* (ANSI/BOMA-based) area calculation rules.

When spaces are defined by its surrounding walls, the area inside them is defined precisely. In a BIM process, the space itself is a 3-D object. The space object is typically created by aligning its geometry with the inside faces of surrounding building elements (e.g., walls, floors, ceilings, etc.). If the geometry of these building elements changes, the space object must also be updated to reflect the new geometry of the space. Some BIM-authoring applications maintain relationships between the space and surrounding building elements, and thus are capable of automatically updating the space. Others require that such updates are done by the A/E, and generally provide tools for doing this. See product-specific instructions to learn how this is done in the application you use.

> *Note: Some physically bound volumes may have several functional spaces inside them. See more in section 4.3.2 in this guide on how to model these spaces.*

According to the *PBS Business Assignment Guide*, spaces should be represented and broken down into functional spaces (i.e., office area, storage area, building common area, vertical penetration, etc.) as defined in the GSA spatial program even though they may be parts of a larger physical space. A physical space may contain several areas that are treated individually in the GSA spatial program. If two areas have different functional space classifications, even though they are within the same physical space, they shall be modeled as two separate spaces. For example, there may be a security checkpoint area within a lobby. In this case, the security checkpoint area (Office) and the remainder of the lobby area (Building Common) must be modeled as separate non-overlapping spaces. These spaces might also be grouped into a Zone, for visualization and analysis purposes (e.g., to differentiate private vs. public zones, for thermal simulation calculations).

Some BIM-authoring applications have several ways to create space objects. Users should consult with the BIM-authoring application vendor to learn the recommended method for creating space objects that will be exported to an IFC BIM. Some details about how this is done in BIM-authoring applications are provided in Appendix A.

2.1.1 Required Spatial Information for all Projects

A/Es shall define a space for any area over 9 s.f. For areas under 9 s.f. that do not have a defined space object, the BIM-analysis rules will treat this area as if it were a wall. For all individual spaces over 9 s.f., A/Es are required, at a minimum, to designate the following:

Table 1: Required Spatial Information

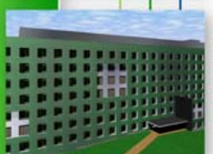
GSA Requirement	Example	Reference Source
Space Name	OFFICE	*PBS Business Assignment Guide* (Room Names) and BIM Guide Series 02 – Appendix C
Space Number	08006	PBS Business Assignment Guide (Space ID)
Occupant Organization Name	General Services Administration	PBS Business Assignment Guide (Agency Bureau Name)
GSA STAR Space Type	TTO (Total Office)	PBS Business Assignment Guide (Space Type)
GSA BIM Area (formerly GSA Net Area in previous versions) *	114.27 m^2	BIM Guide Series 02
"Full_Floor Space" Name *	GSA_DesignGross_Floor_B1	BIM Guide Series 02

* GSA BIM Area (formerly GSA Net Area in previous versions) is a specific type of area calculation (described in section 2.1.2 of this guide), and is not found in the *PBS Business Assignment Guide* or the ANSI/BOMA standards. In addition to these requirements on individual space objects, A/Es must also create a full building floor space (with a space name and number) that represents GSA Design Gross Area (section 2.1.3).

Space Name

A naming convention must be used in identifying space objects. This convention follows space requirements in the GSA spatial program and uses PBS established space descriptors (see Appendix C). These space descriptors are used to categorize the space function.

> *Note: A/Es may choose to create new fields for additional room descriptions (e.g., Director's Office); however, the "Space Name" field must contain an approved name.*



Space Number

All spaces must be uniquely identified with a space number. Typically, the A/E should choose a reasonable space numbering convention throughout the entire project. If space numbers already exist, A/Es should use these numbers and add additional numbers accordingly.

Occupant Organization Name

A/Es shall contact OCA and the GSA project team for the project-specific approved Occupant Organization Names. This property can be selected or entered through the space property dialogs of BIM-authoring applications that support this BIM Guide. For more information about where these properties are entered in your BIM-authoring application, please see Appendix A of the appendix supplement of this guide and your BIM vendor documentation.

If a space could be assigned to a tenant, but is vacant, the Occupant Organization Name is “Vacant Unassigned Space.” If the space belongs to building or floor common, the Occupant Organization Name should be “Building Common” or “Floor Common,” respectively. GSA’s Spatial Data Management (SDM) team currently does not use “Floor Common” in post-construction area measurements. Instead, all “Floor Common” spaces are rolled up into “Building Common.” For the spatial program BIM, A/Es are required to separate “Floor Common” and “Building Common” in order to maintain flexibility in area calculations.

GSA STAR Space Type

Appropriate GSA STAR Space Types can be found in the *PBS Business Assignment Guide*.

> *Note: Special attention should be given to using proper Space Names and Occupant Organization Names, as they will be checked by BIM-Analysis tools and then used to derive and populate ANSI/BOMA Space Categories as defined in the PBS Business Assignment Guide. These categories will be utilized for verifying the documented space calculations directly from the BIM files.*

A/Es should consult OCA and their regional GSA project team to determine if additional requirements are necessary.

2.1.2 GSA BIM Area (formerly GSA Net Area in previous versions)

Space areas (e.g., GSA BIM Area) and volume are calculated from the geometry of the space object by the BIM-authoring applications and will be updated each time the size of a space object is modified.

> *Definition: GSA BIM Area (formerly GSA Net Area in previous versions) is the area bounded by the inside face of surrounding walls, minus the area bounded by the outside faces of any contained full height columns.*

See Figure 2. In general, this can be considered similar to the area one would actually be able to use (e.g., the area one would actually be able to vacuum). Please see sections 3 and 4 of this guide for specific information about modeling columns.

GSA Usable Area will be calculated automatically from the spatial information contained in the IFC BIM. Space objects in the model must represent GSA BIM Area. If 2-D drafting features of the BIM-authoring application are used to represent GSA Usable Area, these 2-D elements must be on separate layers and must be excluded when exporting to an IFC BIM.

Figure 2 depicts the space geometry in the IFC BIM that will be used by GSA analysis tools to calculate GSA BIM Area (outlined in blue) and GSA Usable area (outlined in red).

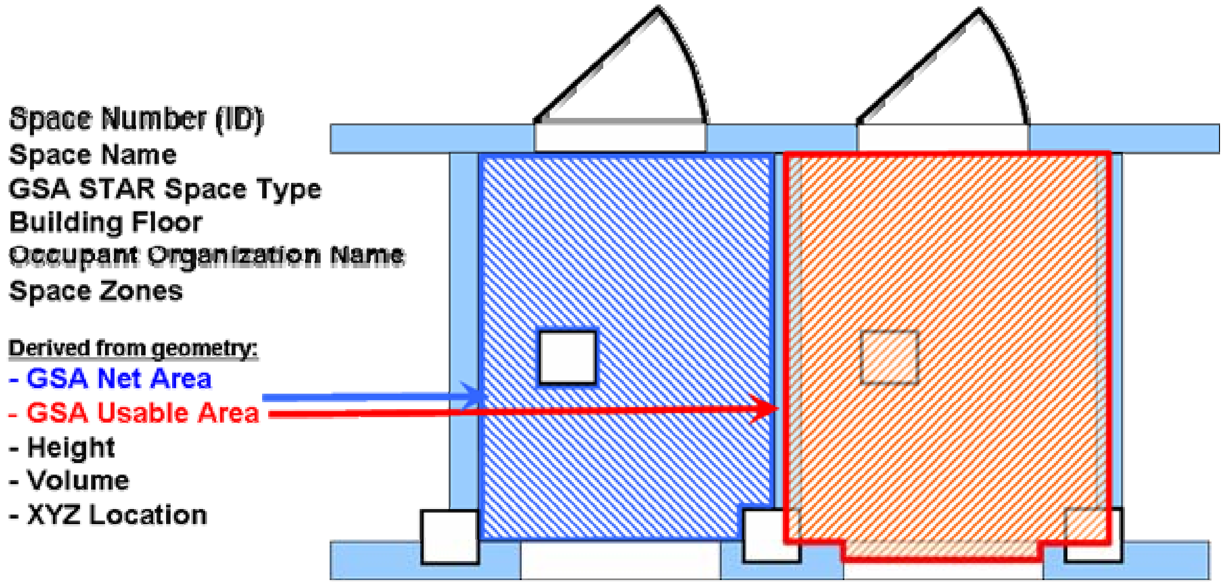


Figure 2: Spatial information in the model (top view)

2.1.3 "Full Building Floor" Spaces

In addition to modeling individual spaces, A/Es will need to model "full building floor" spaces. The PBS Design Gross Area (also called ANSI/BOMA Gross Building Area) of each building floor will be modeled as a single, composite space. This space shall be named with the following naming convention: "GSA_DesignGross_Floor_[XX] (e.g., GSA_DesignGross_Floor_01, GSA_DesignGross_Floor_B1). Please see Appendix C of the appendix supplement to this guide for the approved alphanumeric floor-naming convention. *The outer faces of this space object shall be aligned with the outer face of the exterior walls*. This represents the GSA Gross Building Area (i.e., Design Gross, according to *PBS Business Assignment Guide*), which is different from the GSA Gross Measured Area (as referenced in ANSI/BOMA). This spatial representation of the building floor will be used for spatial analysis and comparison to PBS target utilization rates. This "Full Building Floor" space is also useful in checking that spaces have not been accidentally left out of the model containment hierarchy. The net areas of all the spaces, combined with the geometric information of all required BIM objects should add up to the full building floor space.

2.2 Examples of Spatial Program BIM requirements

2.2.1 Example of Assigning Spatial Information to Space Objects

Table 2 describes several different situations the A/E may encounter when assigning spatial data (i.e., Space Name, Occupant Organization Name, GSA STAR Space Type) to each space object. This table highlights the importance of differentiating between usable office space, vertical penetration, and common areas with respect to the Occupant Organization Name and GSA STAR Space Type. Every space must have an approved Space Name (even if it is TBD).

Note: Use of "Undefined", "No Occupant", or "Unknown" in any of these data fields is not acceptable.

Table 2: Examples of Space Situations Typically Encountered by A/E

Spatial Situation	Space Name	Occupant Organization Name	GSA STAR Space Type
Full Floor Spaces			
A full floor space *Every floor must have a design gross full floor space, in addition toevery individual space*	GSA_DesignGross_Floor_[XX] *GSA_DesignGross_Floor_01, GSA_DesignGross_Floor_02, GSA_DesignGross_Floor_03*		
Individual Tenant Spaces			
A space that serves a specific tenant	From Approved List (Appendix C)	Occupant Organization Name	TTO, AUD, CLD,CRJ, etc..
A space that is known to not have an occupant at move-in (however, it may have an occupant in the future)	From Approved List (Appendix C)	Vacant Unassigned Space	From GSA STAR Space Type List (from PBS Business Assignment Guide)
Parking-Related Spaces			
Parking Stall (exterior)	PARKING STALL EXT	PRKN	
Parking Stall (Interior)	PARKING STALL INT	PRKN	STP
Other parts of the exterior parking spaces	PARKING CIRCULATION EXT	PRKN	
Other parts of the interior parking structure (e.g., ramps, stairs)	PARKING CIRCULATION INT	PRKN	STP
How Occupant Organization Name affects space measurement			
Space that serves the entire building *For example, a mens room in the lobby of the building*	From Approved List (Appendix C) *MENS*	BLDG *BLDG*	From GSA STAR Space Type List (from PBS Business Assignment Guide) *TLT*
Space that serves the entire floor *For example, a mens room on a floor for use by multiple tenants*	From Approved List (Appendix C) *MENS*	FLOOR *FLOOR*	From GSA STAR Space Type List (from PBS Business Assignment Guide) *TLT*
Space that serves a specific tenant *For example, a mens room on a floor for use by one tenant*	From Approved List (Appendix C) *MENS*	Occupant Organization Name *Occupant Organization Name*	From GSA STAR Space Type List (from PBS Business Assignment Guide) *TLT*
How Occupant Organization Name and GSA STAR Space Type affect space measurement			
Vertical Penetration Space (belonging to the building) *For example, an elevator that services the entire building*	STAIR, ELEV, SHAFT, VERT. PEN. *ELEV*	Vertical Penetration *BLDG*	CRV *CRV*
Vertical Penetration Space (belonging to a specific tenant) *For example, a marshall's elevator specifically serving the US Marshalls*	STAIR, ELEV, SHAFT, VERT. PEN. *ELEV*	Occupant Organization Name *US Marshalls*	TFC *TFC*
Unknown Space Name			
A space (> 9 sf) that has an unknown function, but is surrounded by spaces with a specific occupant	TBD	Occupant Organization Name	TBD
A space (>9 sf) that has an unknown function, but is surrounded by building common or floor common spaces	TBD	BLDG, FLOOR	TBD
A space (> 9sf) that has an unknown function, but is touching a vertical penetration	TBD	Vertical Penetration	TBD
A space (. 9sf) that has a known function, but unknown tenant during design	From Approved List	TBD	From GSA STAR Space Type List
A space (< 9 sf) that has an unknown function, but is NOT touching a vertical penetration	Treated as a thick wall		

2.2.2 Example of Modeling a Space Object

Figure 3 demonstrates how net area is defined and the resulting impact upon the usable area. It shows an example of an office space (GSA STAR Space Type TTO), along with various surrounding space types.

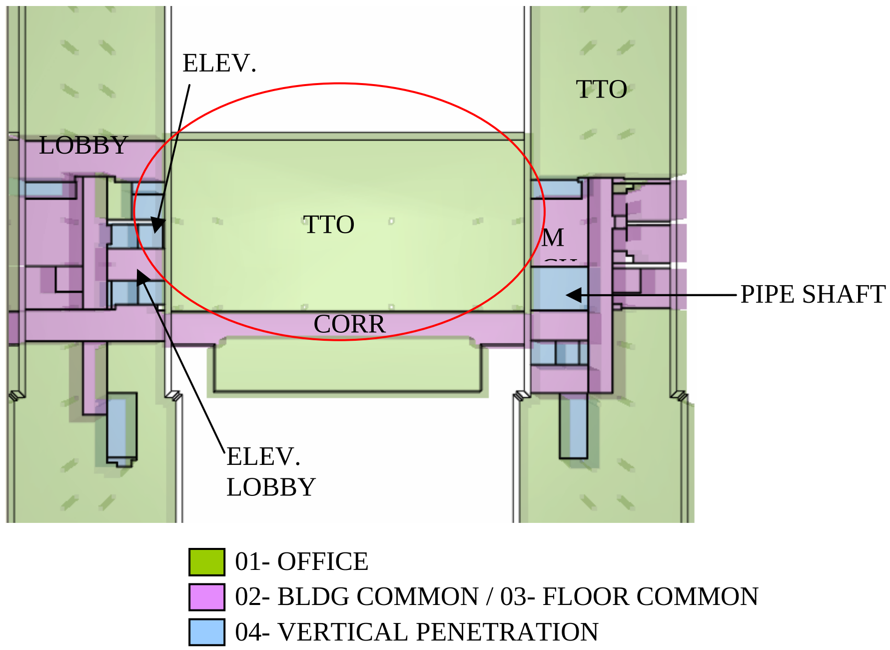


Figure 3: Sample spatial program BIM labeled with GSA STAR Space Types and color-coded by ANSI/BOMA Category

Based upon this figure, the net area space is shown below. Note that the boundary is to the inside face of all of the walls, and that the columns are deducted from the net area.

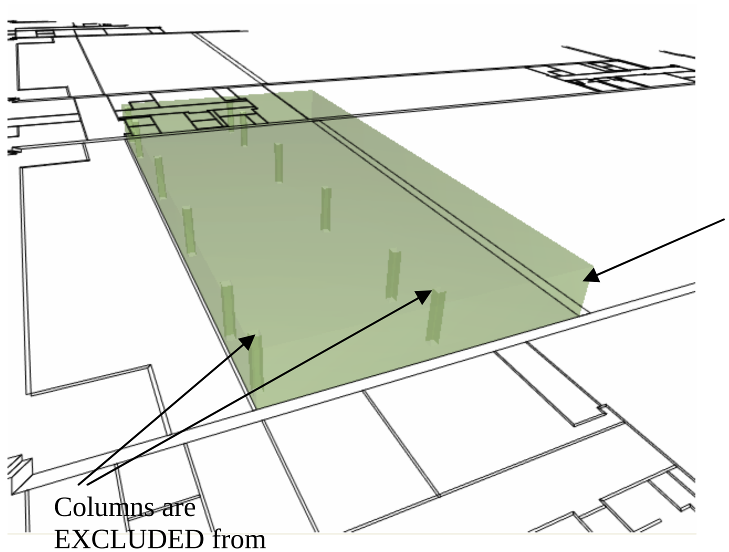


Figure 4: Net Area space boundary, defined by A/E during concept design

Finally, based upon the net area defined and the types of spaces surrounding this particular space, the usable area can be automatically calculated through BIM-analysis rules. Please see section 4 of this guide for specific area calculation rules.

Note: New construction projects require metric units. This particular example contains imperial units because it was taken from an existing renovation project.

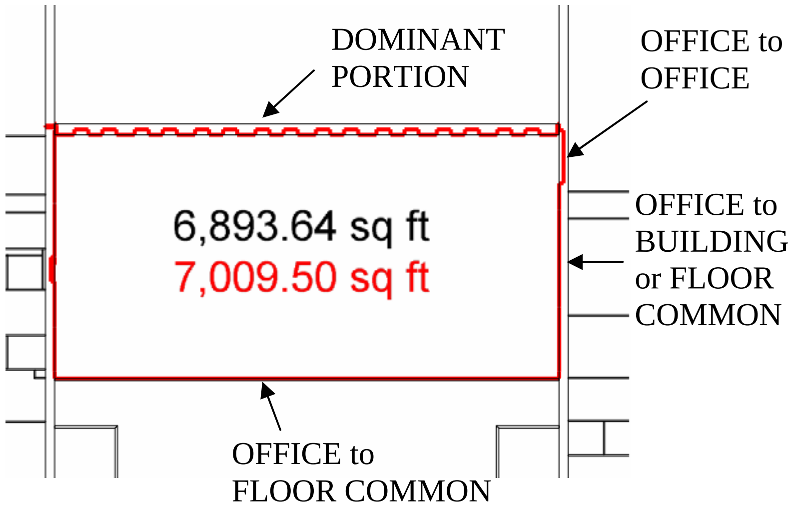


Figure 5: Resulting space boundary for GSA rent calculations

2.2.3 Space Height

Spaces shall be defined and modeled with a vertical extent from finished floor to finished ceiling. This definition will work correctly in typical cases and gives reliable area and volume information. Suspended ceilings are optional in these cases, but the space heights must be modeled to the intended height of the suspended ceiling.

Zone heights may be set differently from space heights, depending on the purpose for defining a zone. See section 2.3 of this guide.

Note: Spaces should be checked visually in 3-D to ensure they are modeled with the correct vertical extent (and thus height). Since many designers still work in 2-D, a typical space modeling error is for spaces to be modeled with zero height.

2.2.4 Copying Spaces

When copying a space in a BIM-authoring application, the user must ensure that the Space Number is updated for the copy so that each Space Number is unique. Vendor-specific instructions about manipulating spaces (e.g., mirror, copy, and mirror-copy) are discussed in Appendix A of the appendix supplement of this guide.

2.2.5 Updating Space Boundaries

Modeling building spaces properly in BIM requires a good deal of care and attention to detail. The properties associated with these spaces are used in many calculations and analyses by GSA, so they must be accurate and correct as entered. Additionally, users must ensure that space object geometry is updated when surrounding walls, floors, or ceilings are moved or changed. It is common, as the design evolves and changes, that spaces are not updated to maintain alignment with the walls. This results in area calculation errors. Changes to any elements that bound spaces should be followed by a corresponding update to the spaces they bound. In many BIM-authoring applications, updating spaces to re-align to the inside face of bounding elements can be automated or semi-automated. The user must learn how to ensure that such updates in the BIM-authoring application are occurring correctly.

Some BIM-authoring applications are designed to automatically resize contained space objects when space-bounding elements are moved. If a space-bounding element is converted to another object type (e.g., changing a wall to a column) and subsequently moved, the affected space may not resize properly. In this case, the user may need to manually invoke a "resize" of the space object. Please see Appendix A of the appendix supplement of this guide for specific BIM-authoring application instructions.

Inaccurate or careless modeling of walls, partitions, floors, and ceilings can result in problems with space objects. For example, in some BIM-authoring applications, a small gap between walls that appear to be connected can cause the space object to "leak" into an area that should really be another space. Space objects should be checked to ensure there are no missing space areas. Users should look for missing space areas, overlapping spaces, or gaps between spaces and adjacent bounding elements.

Some BIM-authoring applications capture and maintain relationships between spaces and surrounding building elements such as walls, spaces, doors, and windows. These relationships are included in the IFC BIM exported for use by downstream analysis applications. For example, doors and windows in walls that bound a space should have a "connects to" relationship with the space. This relationship is used by thermal performance analysis applications, by applications checking fire escape routes, and by specialized area calculation routines. End users should check documentation for their BIM-authoring application to ensure they are modeling spaces and surrounding building elements in the manner recommended by the application vendor in order to ensure that these relationships are included in the IFC BIM. While these relationships are not necessary for Space Program evaluation, they should be established in the Final Concept stage BIM for later-stage application of other analysis tools.

2.2.6 Dealing with Uncertain Information

GSA anticipates that the A/E may not have all of the required spatial information at the Final Concept design stage. This uncertainty may come from various sources (e.g., unknown existing building information, unknown tenant information). If the

spatial information of a space is unknown (e.g., unknown Occupant Organization Name, unknown Space Name) and does not fall into one of the situations described in section 2.2.1 of this guide, A/E shall contact OCA for additional information. Additionally, please see section 4.3.1 of this guide for more information on dealing with uncertain information.

2.3 Zones

Spaces can be grouped for many different analysis and organizational purposes. Often, these are referred to as Zones. A space can belong to several such zones and the members of any particular zone do not have to be adjacent. For example, in a historic preservation project, there may be multiple historic zones in the building, but these zones may be in different areas of the building. In addition to being a historic zone, some of these zones may also be a part of a security zone or belong to an organizational department zone.

Zones are only required in some projects (e.g., courthouses, historic buildings). A/Es should consult with OCA and the GSA project teams to determine what additional properties are required. The following list highlights some typical zones on GSA projects.

- Space Zones
  - Security Zone
  - Preservation Zone
  - Privacy Zone
  - Project-Specific Zones
    - Fire Zones
    - Daylighting Zones
    - HVAC Zones
    - Occupant Zones

A/Es should consult their BIM-authoring application documentation for instructions on how to create such zones for export to an IFC BIM.

section 03:
building elements

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section 3: building elements

This section describes the building elements required in a spatial program BIM and is intended primarily for A/Es. Properties of each building element are described as well as guidelines for creating these building elements. This section is not intended to prescribe a method to create building elements, but to highlight best practices in creating building elements for a spatial program BIM.

3.1 Modeling Building Elements

The physical elements (as opposed to spaces) in a building model are objects defined in the IFC BIM schema as Building Elements. These include walls, doors, windows, floors, ceilings, roofs, beams, columns, and the like. In order for these objects to be included as the intended object types when exporting to an IFC BIM, they must be either (a) created using authoring tools for the intended object type (e.g., a wall creation tool), or (b) created from an IFC-compatible library provided by the vendor or others for the BIM-authoring application.

> *Note: BIM users often create Building Elements using the wrong toolset in a BIM-authoring application. For example, inclined beams are sometimes modeled as roof elements, and columns are often modeled as very short walls. Although such cases may serve the purposes for drawing production (they look correct in the drawing), they become an issue when exporting to an IFC BIM as they will be exported with the wrong object types.*

Whenever a tool is available in the BIM-authoring application to create the correct object type, it should be used.

In cases where such tools are not available, or they are limited in some way (e.g., some applications cannot create sloped beams), the user should create a generic object that can be assigned a Building Element type. Most BIM-authoring applications support creation of such generic objects and mapping of such elements to IFC object types so that the resulting model contains elements with correct geometries and correct object types.

With respect to the capital program delivery process, A/Es should create BIM models during the Concept design stage. While GSA realizes that A/Es may prefer to use stacking and bubble diagrams at this stage, GSA requires basic Building Elements at Final Concept design. A/Es should be able to use the traditional techniques of stacking and bubble diagrams while still being able to produce a spatial program BIM that meets the requirements outlined in this Series.

At a minimum, A/Es are required to have BIM elements for spaces, interior walls, exterior walls, doors, windows, slabs, beams and columns. The following sections provide information for each of these Building Element types that are required for spatial validation. Please see section 2 of this guide for information on modeling spaces.

Table 3: Building Elements Required for Spatial Validation

Building Elements	Section
• Walls	3.2.1
– Openings	
o Doors	
o Windows	
– Curtain Walls, Storefronts, and Window Assemblies	
• Slabs	3.2.2
• Beams	3.2.3
• Columns	3.2.4

3.2 Building Elements Required for Spatial Validation

3.2.1 Walls

Wall elements define enclosure of spaces and are used in the spatial program BIM analysis. For this analysis, A/Es will need to differentiate between interior and exterior walls.

In IFC BIMs, walls must have relationships to their adjoining (connected) walls and the spaces they bound. The 'connected' relationship between walls is typically created automatically by the BIM-authoring application when the wall's base lines are connected. The bounding relationship to spaces is also created automatically when the faces of the wall and the space are coplanar. Users should consult with their BIM-authoring application documentation for instruction on how to ensure that these relationships will be included in the export to an IFC BIM.

In conventional building designs, the vast majority of walls are straight and of uniform height. These are easily modeled using the Wall tool found in most BIM-authoring applications. If the BIM-authoring application supports the use of multiple or generic tools for component creation, the user must ensure that components are assigned the correct Building Element types so that they are exported as the correct types to an IFC BIM.

Openings

Doors

Door objects should be created using the Door tool in the BIM-authoring application. In most cases, Door tools can also model passageways or other access openings that do not necessarily have doors. Doors should always be inserted into a wall component and they must not extend outside the wall geometry.

Creating a door by first cutting an opening in the wall and inserting a door may cause problems because the wall object is not linked to the door object. Therefore, BIM-authoring applications must keep track of two different relationships (i.e., opening-wall relationship and door-opening relationship). If doors are created using the Door tool, only one relationship (i.e., wall-door relationship) is needed.

Door accessories should be associated to doors via properties (i.e., the hardware group for the door).

Windows

Window objects should be created using the Window tool in the BIM-authoring application. Windows should always be inserted into a wall component and they must not extend outside the wall geometry.

Creating a window by first cutting an opening in the wall and inserting a window may cause problems because the wall object is not linked to the window object. Therefore, BIM-authoring applications must keep track of two different relationships (i.e., opening-wall relationship and window-opening relationship). If windows are created using the Window tool, only one relationship (i.e., wall-window relationship) is needed.

Window accessories should be associated with windows via properties (i.e., the hardware group for the window).

Curtain Walls, Storefronts, and Large Window Assemblies

Many building designs include configurations in which an entire wall or face is filled with windows and possibly also doors (e.g., a storefront) (see Figure 6). In these cases, GSA requires that the windows & doors be modeled as "contained" in a wall object. Care should be taken to ensure that doors and windows don't extend outside the wall area. It is easy to accidentally create this situation in the corner of the building (corner windows) or in daylight staircases, where windows can span multiple floors. Special attention must be given to setting the relative height for the window.

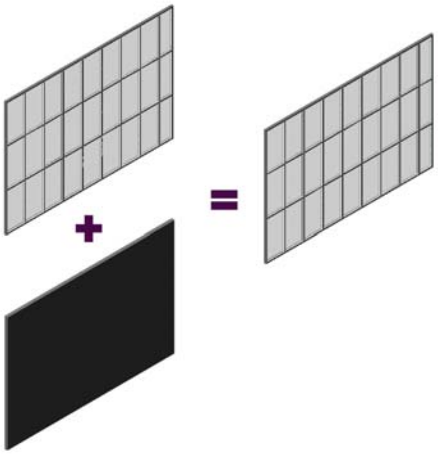


Figure 6: Wall component that is fully covered with windows

In cases where walls are modeled separately for each building floor and windows span floors, the user must ensure that there are openings in the walls for each building floor. Without a host wall, a window will be orphaned and floating, without the expected bounding relationship to spaces. This will then cause errors or unexpected results in analysis such as energy simulation calculations. Another option when such openings cover most of the wall area and span multiple floors is for the wall to be modeled as one spanning or multi-story wall.

An example of a window area spanning multiple floors is shown in Figure 8.

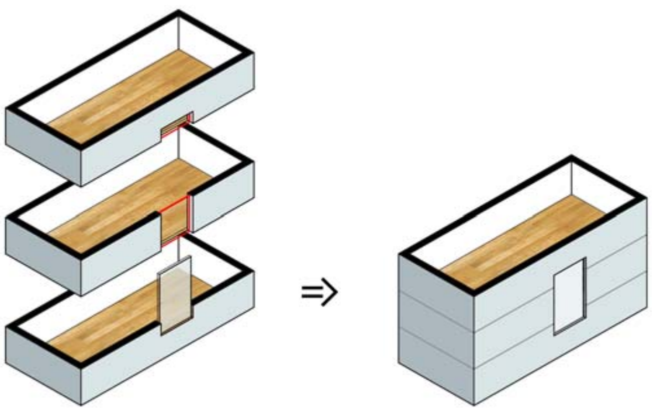
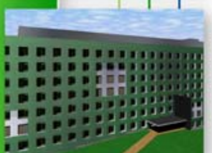


Figure 7: Window on the first floor may require openings added on next two floors



3.2.2 Slabs

Floor and Roof Slab objects should be created using the Slab tool in the BIM-authoring application. If the BIM-authoring application does not include such a tool, or is limited in some way (e.g., does not support slabs with irregular profiles), the user should create a generic object that can be assigned a Building Element type (in this case, Floor Slab or Roof Slab). Most BIM-authoring applications support creation of such generic objects and mapping of such elements to existing IFC BIM object types so that the resulting model contains elements with correct geometries and correct object types.

For model consistency, it is essential that the floors are modeled as slab objects and that the joints between walls and slabs are modeled as accurately as possible, with the information known at that time.

3.2.3 Beams

Beams should be created using the Beam tool in the BIM-authoring application. If the BIM-authoring application does not include such a tool, or is limited in some way (i.e., does not support sloped beams), the user should create a generic object that can be assigned a Building Element type (in this case, Beam). Most BIM-authoring applications support creation of such generic objects and mapping of such elements to existing IFC BIM object types so that the resulting model contains elements with correct geometries and correct object types.

3.2.4 Columns

Columns should be created using the Column tool in the BIM-authoring application. If the BIM-authoring application does not include such a tool, or is limited in some way (e.g., does not support columns with irregular profiles), the user should create a generic object that can be assigned a Building Element type (in this case, Column). Most BIM-authoring applications support creation of such generic objects and mapping of such elements to existing IFC BIM object types so that the resulting model contains elements with correct geometries and correct object types.

Columns can be modeled in three ways:

- As a single piece structural column (e.g., a steel column)
- As a single form-based structural column (e.g., concrete column)
- As an enclosure (e.g., a column enclosed with drywall)

For more information on how these different columns are analyzed according to the BIM-analysis rules, please see section 4 of this guide.

section 04:

bim-based spatial program analysis

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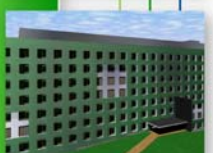


section 4: bim-analysis rules

This section describes the rules used to analyze the spatial program BIM submitted by the A/E. While it is worthwhile to understand the area analysis calculations and downstream derivations, A/E are only required to understand and adhere to the requirements found in sections 1-3 of the BIM Guide Series 02. This section may be helpful in clarifying any special modeling cases. This section is also useful for BIM-authoring and analysis vendors wishing to incorporate spatial program BIM functionality into their products.

4.1 Measuring GSA Spaces

The *PBS Business Assignment Guide* provides national guidelines on how GSA measures space. These documents shall be used as the authoritative standard and guideline for space assignment and measurement represented in all BIM submissions. All A/Es must adhere to the *PBS Business Assignment Guide*. The *PBS Business Assignment Guide* builds upon the ANSI/BOMA rules, with some minor variations. Each ANSI/BOMA category is mapped to a specific GSA STAR space type and GSA STAR space category. Currently, there are 27 GSA STAR space types, 15 GSA STAR space categories and 5 ANSI/BOMA categories. Mappings and descriptions of these types and categories can be found in the *PBS Business Assignment Guide* and ANSI/BOMA document. The following figures detail and contrast how space can be measured from the Administration Office of the US Courts (AOUSC) perspective, the spatial program BIM method, and the traditional polyline method. The AOUSC uses space measurement methods for the programming phase, while the BIM method and polyline method are used in the Design phase and Construction phase, respectively. The polyline method is used by the Office of Real Property Management during the Initial Measurement and Verification phase, which occurs around the completions of at least 75% construction.

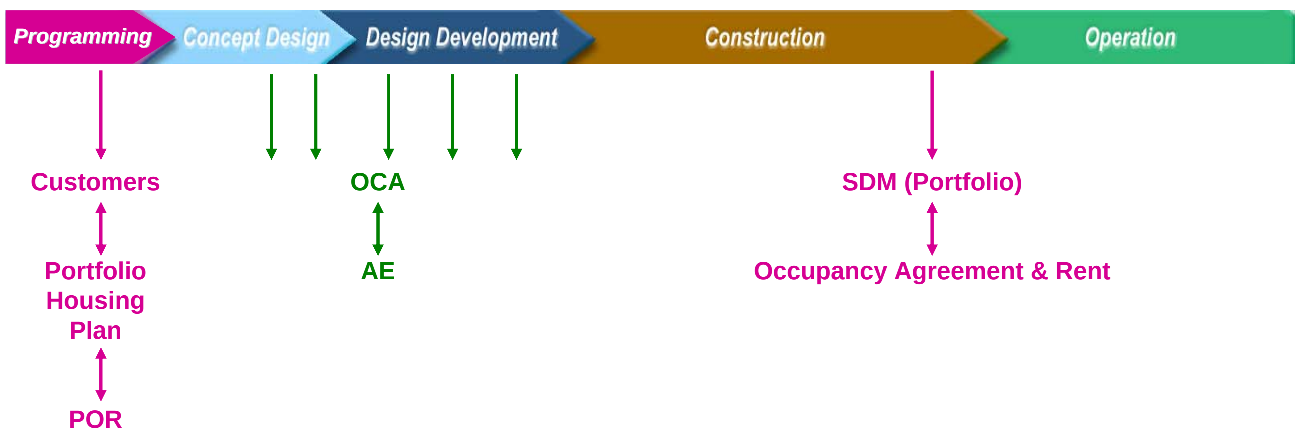


Figure 8: Different space measurement methods are used during different phases of the project lifecycle

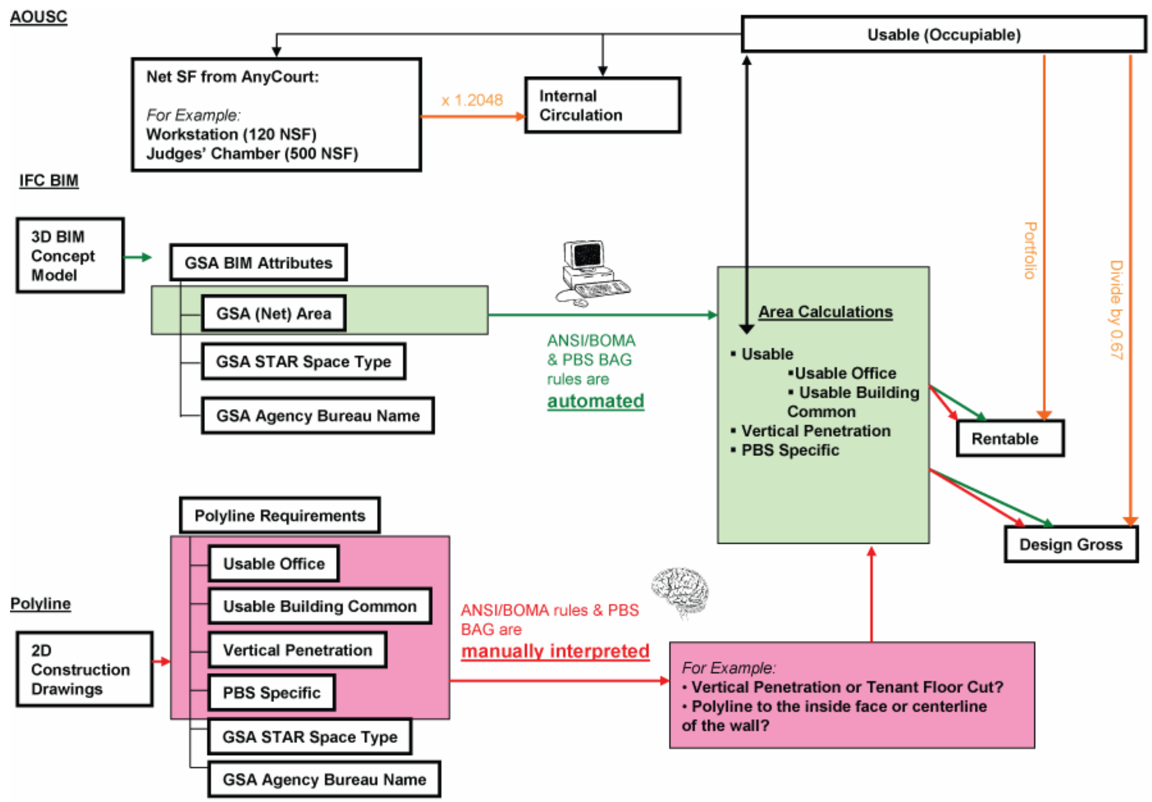


Figure 9: Comparison of space measurement methods and processes

Based upon the ANSI/BOMA categories, there are different ways to measure space. For example, if a wall is shared by two offices, then the space boundary of the space is shared by both walls. However, if a wall is shared by an office and a vertical penetration (e.g., public elevator shaft), then this space boundary is drawn along the inside face of the office. These rules are described in detail by the referenced documents in section 4.4. Traditionally, space measurement experts must manually decide how to draw the polyline for usable area calculations. IFC BIMs and BIM-analysis tools allow GSA to automatically measure space based upon these rules.

Measuring Court Space

For courthouse projects, space measurement processes are used to benchmark the overall design gross area, and are described in detail in the *US Courts Design Guide* (December 1997). This benchmarking process, which takes place during the Programming phase (before design starts), uses Net SF and specific circulation factors to determine the benchmark Gross Building Area. Figure 11 shows how the Net SF detailed in the AnyCourt document relates to the ANSI/BOMA space measurement calculations. A/Es should understand the AOUSC measurement process and how it relates to the spatial program BIM measurement process.

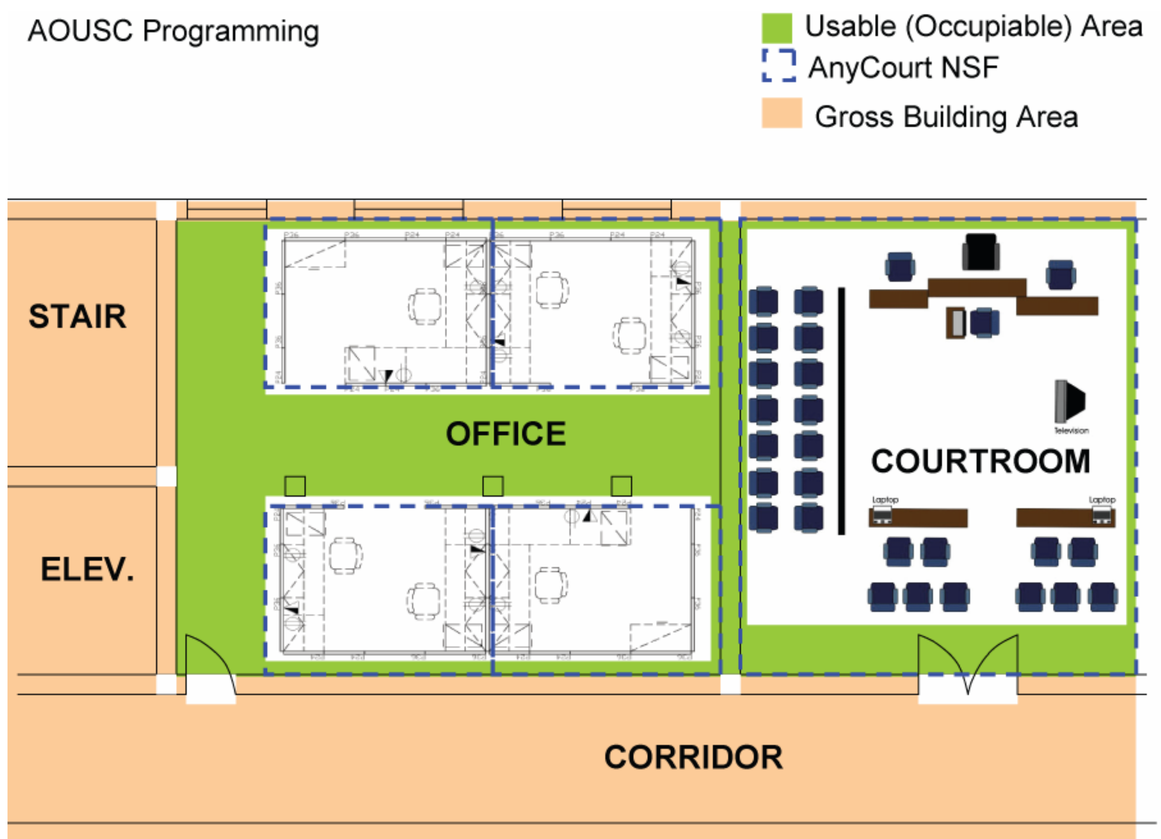


Figure 10: Courthouse space measurement

4.1.1 Using IFC BIMs to Measure GSA Spaces

BIM-analysis applications allow users to automate the generation and evaluation of a spatial program based upon the design proposal (e.g., a Concept design scheme) and the established requirement (e.g., GSA Program of Requirements). BIM-analysis applications use the required BIM objects (see section 1.4.3 of this guide) to generate a spatial program based upon rules in the *PBS Business Assignment Guide*. These applications can then automatically evaluate the spatial program based upon GSA's program of requirements. The BIM-authoring application provides the following properties for each space automatically:

- Global Unique Identifier (GUID)
- Building Floor (via containment hierarchy)
- Space Areas (GSA BIM Area (formerly GSA Net Area in previous versions), GSA Usable Area, GSA Rentable Area, GSA Design Gross Area, GSA Building Common Area – all calculated based on space *geometry*)
- Space Volume (*via geometry*)
- XYZ Coordinates (*via geometry*)

By requiring IFC BIM submission, the development of BIM-analysis applications can be founded upon one common and extensible data standard. This minimizes the inconsistency or variance when dealing with BIMs generated from different BIM-authoring applications. To ensure these space objects (and calculated areas) are accurate, BIM-analysis applications will validate that such Space objects are modeled precisely in relationship with the geometry of the surrounding Building Elements (as discussed in sections 2 and 3 of this guide).

The GSA BIM spatial program analysis tool currently performs the following functions:

- Verifies the BIM model structure, completeness, and integrity
  - Information model structure can be verified relative to the industry-standard IFC BIM schema.
  - Completeness (of the object set and properties) can be verified relative to those required by the "GSA Concept View" of IFC, as defined in the underlying "IAI Coordination View" of IFC and in this GSA BIM Guide (e.g., room naming, unique room numbers).
  - Geometric integrity can be verified by checking for proper fit and alignment of object geometry (e.g., space objects are aligned with the surrounding walls without gaps or overlaps. Such gaps or overlaps can be flagged for resolution by the A/E.
- Assesses the Design Program relative to the space program defined by a GSA Housing Plan or a Program of Requirements pertaining to the building
- Calculates, reports, and visualizes a variety of metrics based on ANSI/BOMA, the *PBS Business Assignment Guide*, and the GSA BIM Guide.

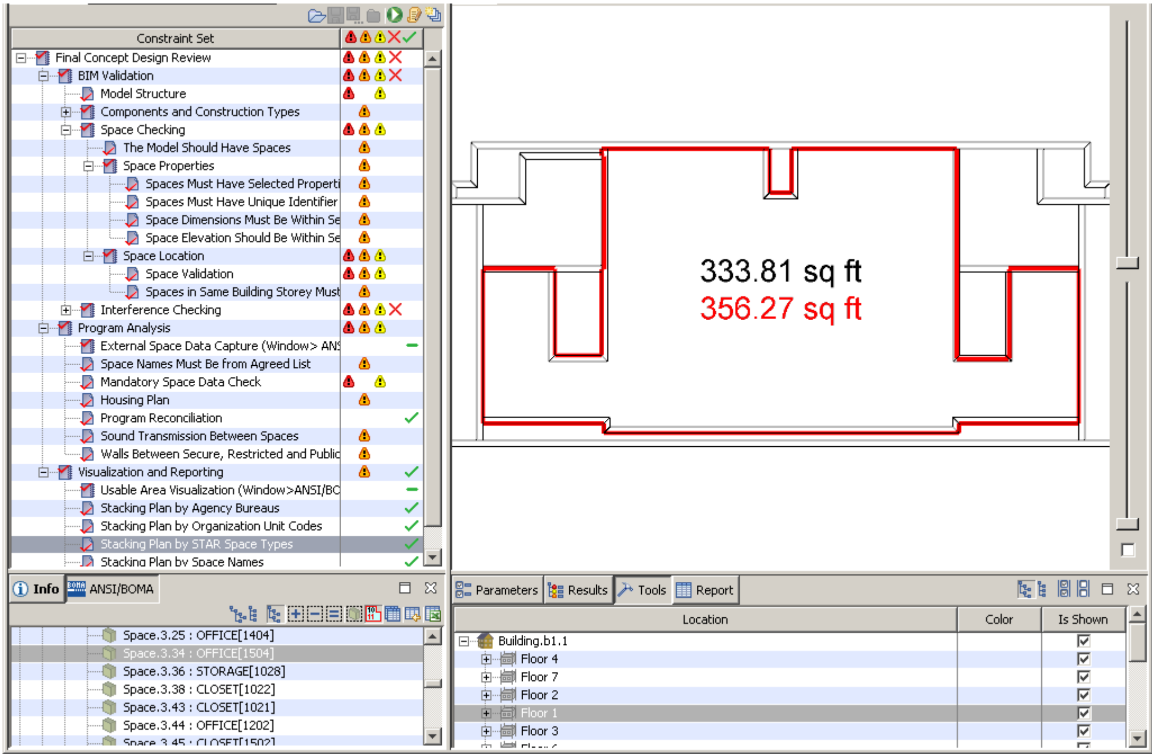


Figure 11: Analysis Visualizing "GSA BIM Area" versus "GSA Usable Area" (line in red)

In order to automatically generate a spatial program based upon the BIM submission, GSA BIM spatial analysis rules are based upon the *PBS Business Assignment Guide*, which are based upon ANSI/BOMA calculations. ANSI/BOMA calculations are defined automatically based on rules implemented in the analysis system. Each space has a unique identifier (Space Number) that is associated with an Agency Bureau Abbreviation, ANSI/BOMA Category, STAR Space Type, etc. (see section 2.1 of this guide).

Automatically updating the usable area

OCA hopes to leverage the use of BIM during the Concept design, when the functional use of the spaces in the design may be changing. Figure 12 compares two different designs. The designs differ only in the upper right hand space, in which one is a stair space, and the other, an office. By using a spatial program BIM, OCA is able to quickly and automatically adjust the location of the usable area and quickly assess the new design. Traditionally, space measurement experts would have to manually update the usable area polyline in the drawings.

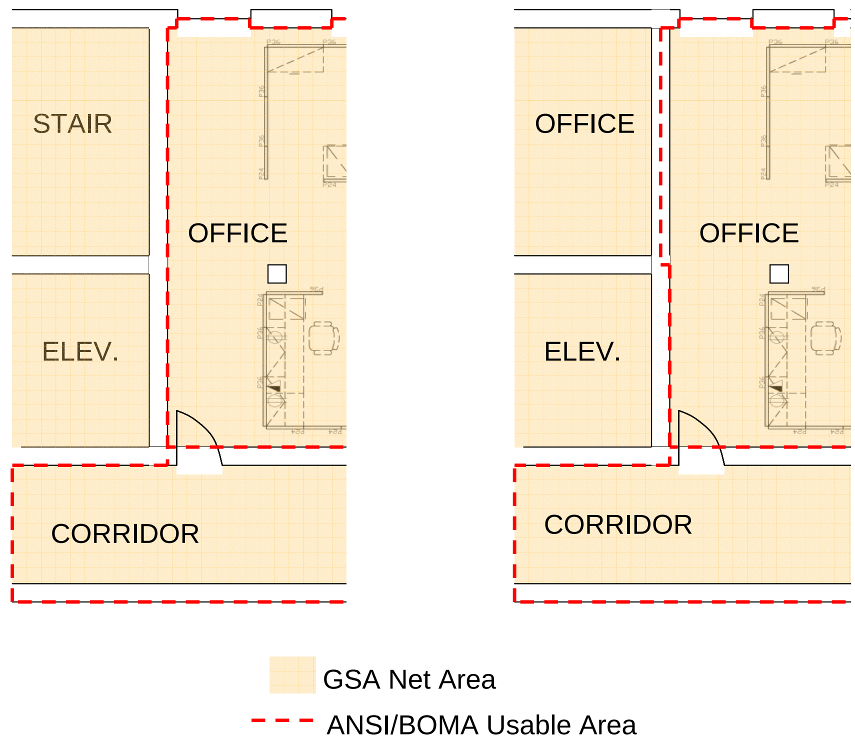
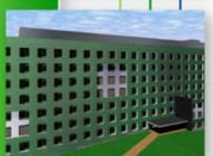


Figure 12: Using a spatial program BIM, the usable areas can be automatically updated when a design change occurs.



4.2 BIM Analysis Rules

GSA has created BIM-analysis rules that "understand" the rules defined by ANSI/BOMA and the PBS BAG. By inputting geometric and spatial information (as described in section 2), these BIM-analysis rules are able to define the space boundaries within the A/E's design.

4.2.1 Properties Derived from A/E Inputs

When these properties are included in the 3D space objects and the building elements bounding these spaces are also modeled in 3D, BIM-analysis applications (and some BIM-authoring applications) can use "rules" to derive and populate the following spatial data based on *PBS Business Assignment Guide* processes:

Table 4: Properties Derived from A/E Inputs

Derived Property	Example	Reference Source
Occupant Organization Abbreviation	GSA	PBS Business Assignment Guide (Agency Bureau Abbreviation)
Occupant Organization Code	4700	PBS Business Assignment Guide (Agency Bureau Code)
Occupant Sub-Organization Code	PMAC	PBS Business Assignment Guide (Organizational Unit Code)
Occupant Billing ID	TX0063720	PBS Business Assignment Guide (Client Billing Record)
GSA STAR Space Category	02 (Building Common)	PBS Business Assignment Guide (GSA STAR Space Category)
ANSI/BOMA Category	01 (Office)	PBS Business Assignment Guide (ANSI/BOMA Category)

4.2.2 Calculations Derived from PBS BAG and ANSI/BOMA

The following rules are used for the BIM analysis:

- **Space Usable Area -** Defined based on space geometry, walls, and spaces around the space
- **Space Basic Rentable Area -** Floor Rentable to Usable (R/U) Ratio multiplied by the Space Usable Area
- **Space Rentable Area -** Building RU Ratio multiplied by the Space Basic Rentable Area
- **Floor Gross Area -** Total area of the floor including all walls, columns, and spaces subtracted by GSA Floor Gross Area
- **Floor Gross Measured Area -** Sum of usable areas of all spaces on one floor; Exterior walls not included in this area
- **Floor Vertical Penetration Area -** Sum of all Vertical Penetration spaces' Usable areas on one floor
- **Floor Building Common Area -** Sum of all Building Common spaces' Usable areas on one floor
- **Floor Office Area -** Sum of all Usable Office, Store, and PBS specific areas on one floor

- **Floor Usable Area -** Floor Office Area + Floor Building Common Area
- **Floor Rentable Area -** Floor Gross Measured Area - Floor Vertical Penetration Area
- **Floor Common Area -** Floor Rentable Area - Floor Usable Area
- **Floor RU Ratio -** Floor Rentable Area / Floor Usable Area
- **Building Rentable Area -** Sum of all Usable Office, Store, PBS specific, and Building Common areas in the building
- **Basic Rentable Building Common Area -** Sum of all Basic Rentable Building Common Area areas in the building
- **Building RU Ratio -** Building Rentable Area / (Building Rentable Area - Building Common Area)

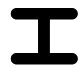
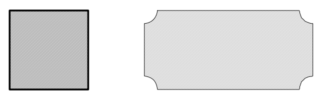
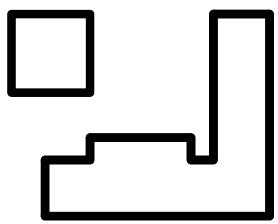
4.2.3 Rules Specifically for BIM Analysis

The following rules and modeling requirements are not defined in existing GSA documents. These rules are specific for analyzing the BIM for spatial program validation.

Columns in Spaces

In GSA BIM Area calculations, columns shall be excluded so that the area of the column is subtracted from the room area. Effectively, this means that spaces that have large columns in them should be modeled as if they had holes or voids, from a space calculation point of view. This is accomplished differently in each of the major BIM-authoring applications. See more details about how this is done by some BIM-authoring applications in Appendix A of the appendix supplement of this guide.

Table 5: Columns in Spaces

Column Type	Example	Effect upon GSA Net Area
	Exposed steel column	No deductions required
	Exposed concrete column	GSA BIM area should not include this column. However, this area is counted towards usable area.
	Drywall enclosure (it may or may not be known what is inside the column)	If the enclosure is greater than 9 sf, A/Es are required to have a space tag. If the space type is unknown, A/Es should use "TBD" as the GSA STAR Space Type. These spaces will then inherit the surrounding GSA STAR Space Type.

Spaces between walls

Spaces between walls (e.g., furrings, unknown spaces behind walls), should be considered as walls. Thus, instead of having a space between two walls, the entire void will be considered as one thick wall.

Walls configured such that voids are created to enclose building services shafts, columns, or other non-occupied spaces are typically referred to as cavity walls. Such wall/void conditions can be modeled in two basic ways as shown in Figure 13.

Method A

Method B

Figure 13: Alternate Methods for Modeling Cavity Walls

The optimal method for modeling such conditions is often dependent upon design circumstances.

Method A and Method B provide different levels of detail to BIM analysis tools. As it is GSA's intention to leverage as much information from a growing library of BIMs in the future, it is critical that the method of "constructing" the BIM does not give false information about the building (existing or to be built).

Method A would be appropriate for new construction. It would also be appropriate for existing construction if exploratory demolition was used or reliable as-built documentation was available to accurately verify and document the wall cavities. The individual thicknesses of the walls, which create the assemblage of the perceived thick wall, would also be field verified. This method suggests that the walls are accurately modeled and that there are columns and a cavity as noted. See Figure 16. If this cavity is over 9 sf, a separate space object along with associated spatial data must be created.

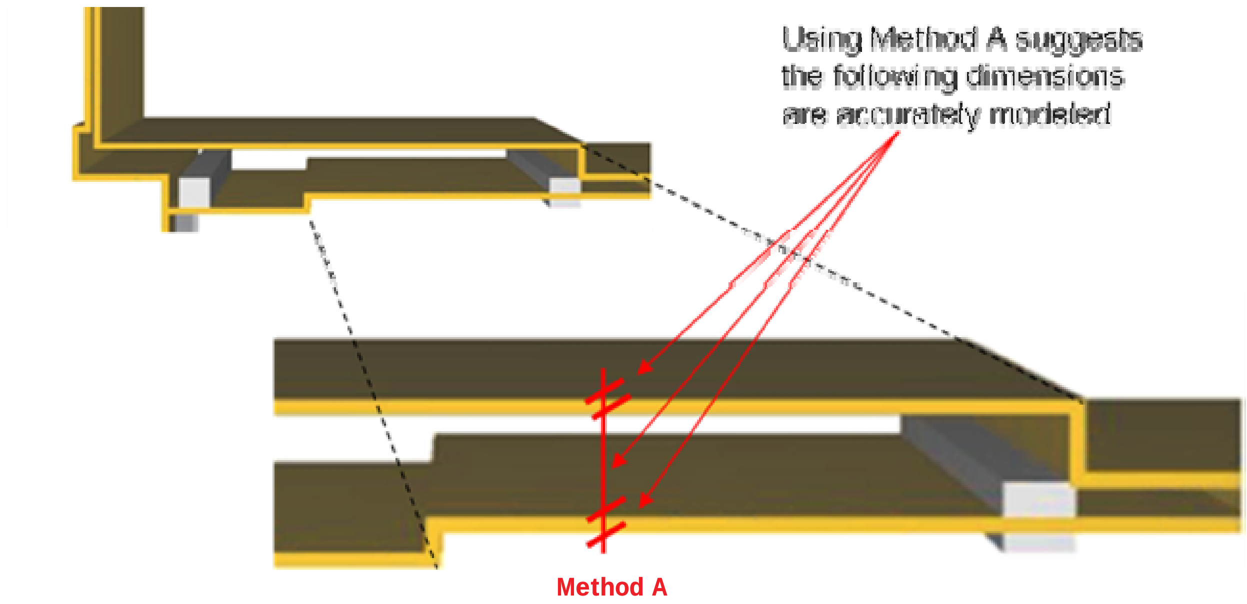


Figure 14: Method A – where wall types are known

Method B would be appropriate if a BIM was constructed based solely on information that was readily visible. For example, if exploratory demolition was not used, it is still possible for one to measure the overall exterior dimensions of a building. Then the interior face-to-face dimensions would supply enough information to complete the model at this level of detail.

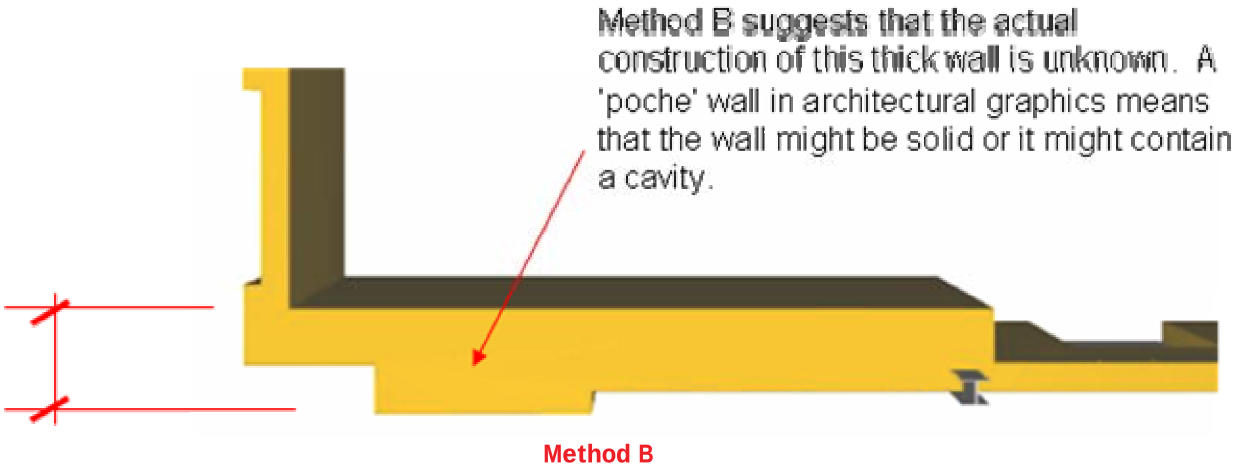


Figure 15: Method B – where wall types are unknown or monolithic (as with concrete)

Method B also would NOT be appropriate for new construction (except in the case where the wall is intended to be monolithic - as with concrete). For example, if a column actually is being planned inside the cavity and it is NOT shown in the BIM, then information about the structure of the new construction would be incomplete and therefore misleading.

Method B could, therefore, be the preferred method in one process, such as documenting an existing building, but it would not be appropriate for new construction.

As is illustrated in Figure 15, the appropriate level of model detail and information is dependent on the process and intended use of the BIM. It is important to provide the proper level of detail and to document any assumptions used in developing the BIM.

Alcove Spaces

The BIM Area of alcove spaces (and all spaces) shall be drawn to the bounding walls between the corridor and office areas. A/Es should note, however, that the usable area of this space is calculated differently from the typical rules. According to GSA SDM practice, "where alcoves, recessed entrances or similar deviation from the corridor line are present, the usable area is computed as if the deviation were not present." For alcoves including a door opening from office to floor common (or building common) space, the space boundary is drawn straight across, so the area of the recess is included in the tenant space.

4.3 Special Cases

This section will clarify any rules and special cases that may affect modeling or spatial information assignment, and their effect upon the BIM analysis. Based upon our validation process, the following special cases are highlighted. This is not an exhaustive list of possible cases that may arise.

4.3.1 Modeling Building Elements

Protruding Walls

Unless specifically intended, A/Es should make sure that walls are appropriately joined and do not unnecessarily protrude.

Pilasters and columns touching walls

Pilasters touching the exterior wall are deducted from the space measurement. In Figure 16, the GSA BIM Area (formerly GSA Net Area in previous versions) boundary (and dominant portion) would alternate along the wall. Columns touching walls (but not embedded) are treated the same as any other column. Please see section 3 of this guide for more information. Columns partially embedded in external walls are partly included in the usable area.

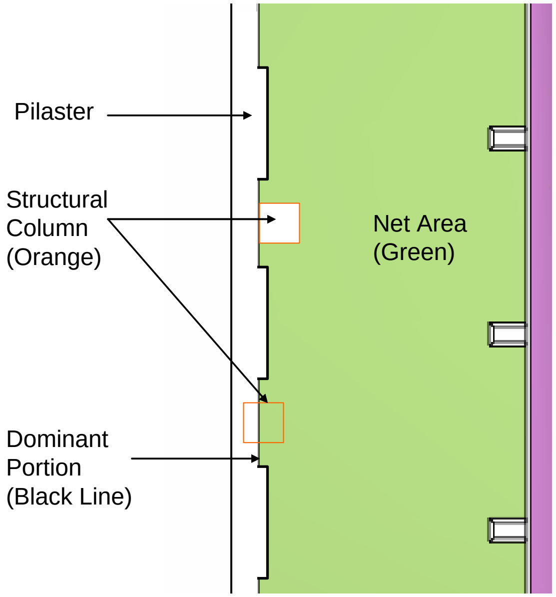


Figure 16: Pilasters and columns touching walls

Spaces with unknown space functions

A/Es shall define a space for any area over 9 s.f. For areas under 9 s.f. that do not have a defined space object, the BIM-analysis rules will treat this area as if it were a wall. Areas with unknown space functions next to vertical penetration spaces (e.g., Space B), without a defined space object, should be included in vertical penetration areas. The following scenario is of an existing bathroom layout in which some spaces are unknown.

> *Note: A/Es should attempt to label all spaces with a specific approved space name according to the space function. As a last resource, if the space name cannot be determined, A/E shall use "TBD" as the Space Name. GSA anticipated "TBD" space functions to be a minimal percentage of all the spaces.*

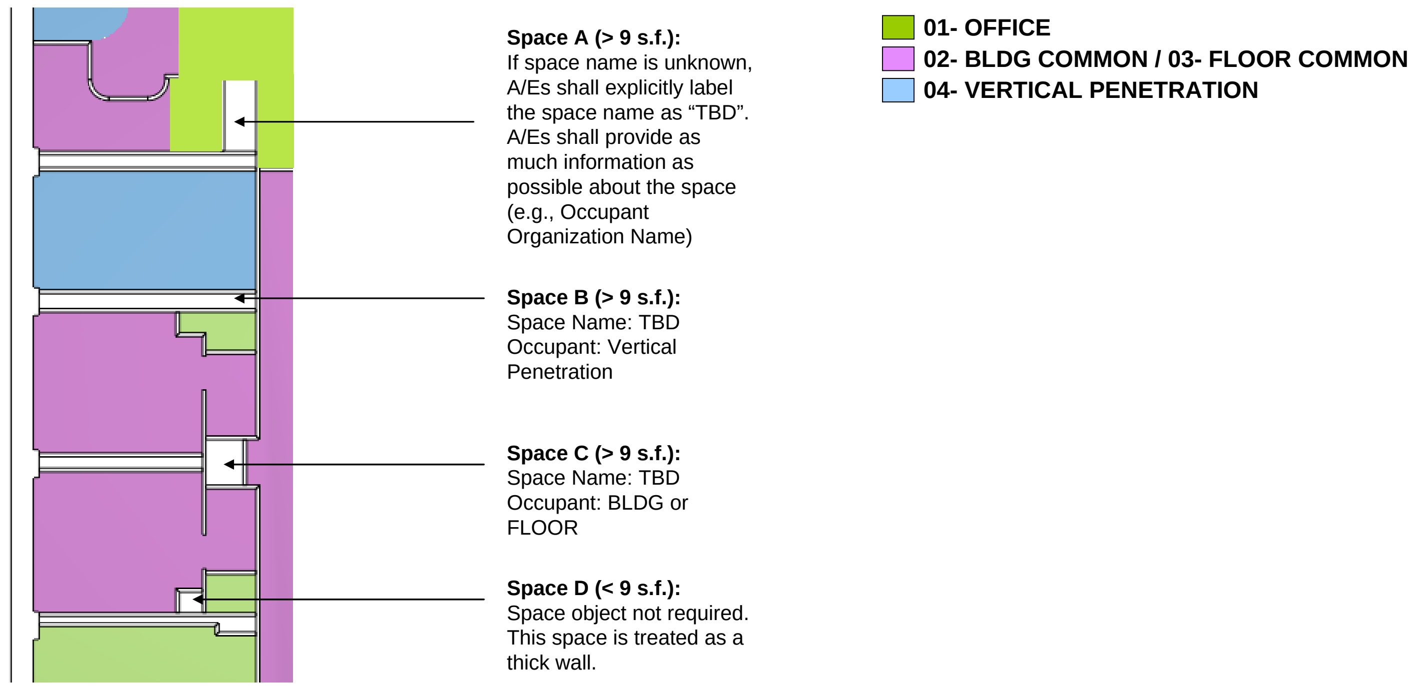


Figure 17: Empty Areas and Voids

Parallel Walls

If there are two parallel walls next to each other (with no space in between), both walls should be totally included in their respective neighboring space, for usable area calculations. For example, in Figure 18, if the yellow space were a vertical penetration, then all of the tan walls would be included in the usable area calculation. If the red space is an office space, then the green wall will be included in the red usable area. No additional calculations (e.g., mid-points between walls) are necessary.

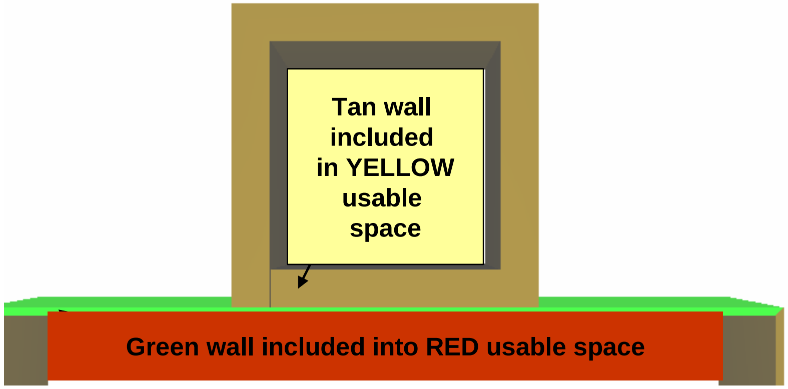


Figure 18: Parallel walls

Handling Uncertain Information

A/Es should model the building to the best of their knowledge. For major renovations, however, this may not be possible. If the space is over 9 sf, A/Es should create a space for the unknown area and label this as “TBD.” For spaces with an unknown function (i.e., unknown Space Name) under 9 sf, the entire space will be treated as a wall, unless the adjacent space is a vertical penetration. In these cases, the unknown space will be considered part of the vertical penetration space. A/Es should provide as much information as possible about these spaces (e.g., if the tenant is known, please indicate appropriately under Occupant Organization Name). Please see section 2.2.1 of this guide for additional guidance on working with spaces with unknown functions.

4.3.2 Modeling Spaces and Assigning Spatial Information

Multi-Story Spaces

Physical spaces that are higher than one story are often complicated to model in BIM-authoring applications. According to the *PBS Business Assignment Guide*, multi-story spaces are measured differently based upon its usage. Therefore, in order to analyze these conditional cases, multi-floor spaces shall be modeled as one space for *each* building floor. See the following examples.

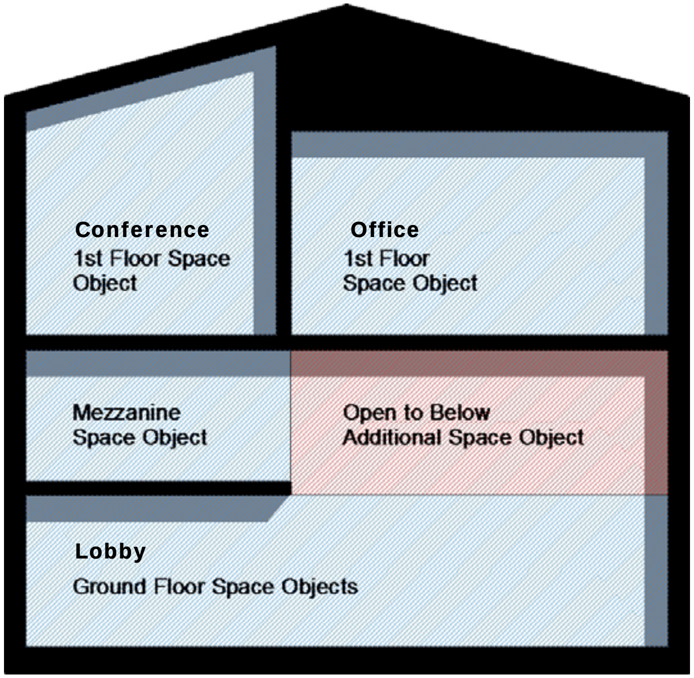


Figure 19: Multi-Story Space Example 1

Care must be taken that there are no gaps or overlaps in the vertical direction between these spaces so that the total volume remains accurate. For example, spaces in upper floors should be given a base elevation equal to the top of the space below, not starting at the next floor datum. These spaces will be named as Open to Below, as per PBS space-naming conventions. This is further illustrated in the Figure 20:

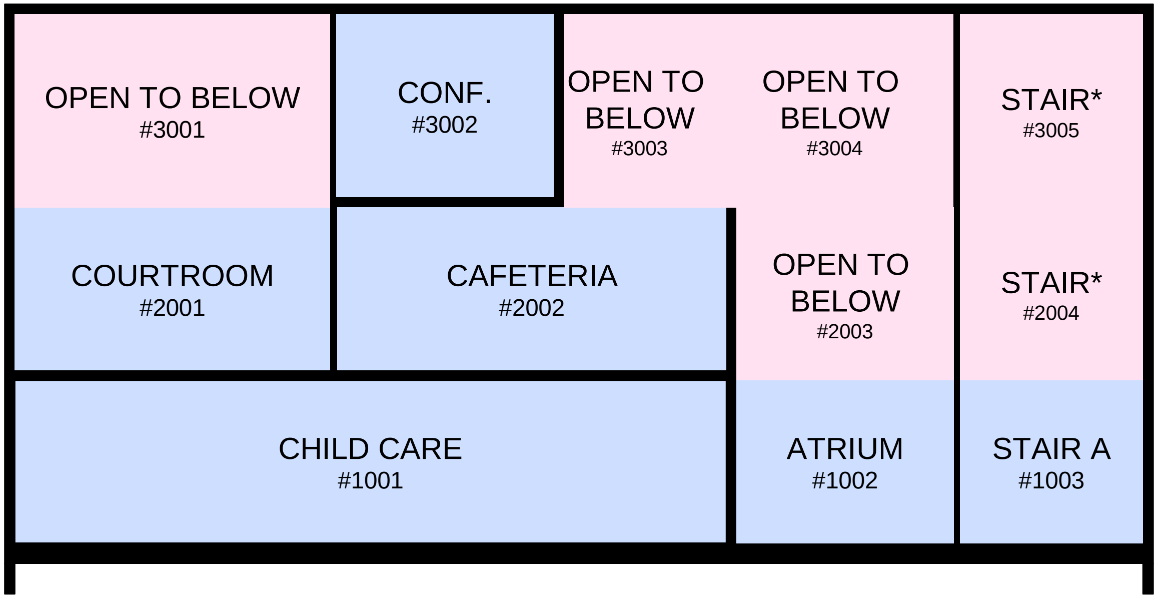


Figure 20: Multi-Story Space Example 2

Table 6: Spatial Data for Example 2

Space Number	Space Name	Occupant Organization Name	GSA STAR Space Type
1001	CHILD CARE	**Building Common**	CLD
1002	LOBBY	**Building Common**	CRH
1003	STAIR A	**Building Common**	CRV
2001	COURTROOM	Court of Appeals Courtrooms	CRJ
2002	CAFETERIA	**Joint Use**	**FDS**
2003	OPEN TO BELOW	**Building Common**	CRV
2004	STAIR*	**Building Common**	CRV
3001	OPEN TO BELOW	Court of Appeals Courtrooms	TFC
3002	CONFERENCE	Probation	CFT
3003	OPEN TO BELOW	**Joint Use**	**TFC**
3004	OPEN TO BELOW	**Building Common**	CRV
3005	STAIR*	**Building Common**	CRV

In Figure 20 and Table 6, if the lowest level of a multi-story space is Building Common, the space(s) above are categorized as vertical penetration. If the lowest level is tenant space, the space(s) above are categorized as Tenant Floor Cut (TFC). Please note that Tenant Floor Cut (TFC) is a GSA STAR Space Type, which has an Occupant Organization Name of a specific tenant. This is different from a floor common space, which has "FLOOR COMMON" as the tenant, and a separate GSA STAR space type (depending upon the function of the common space).

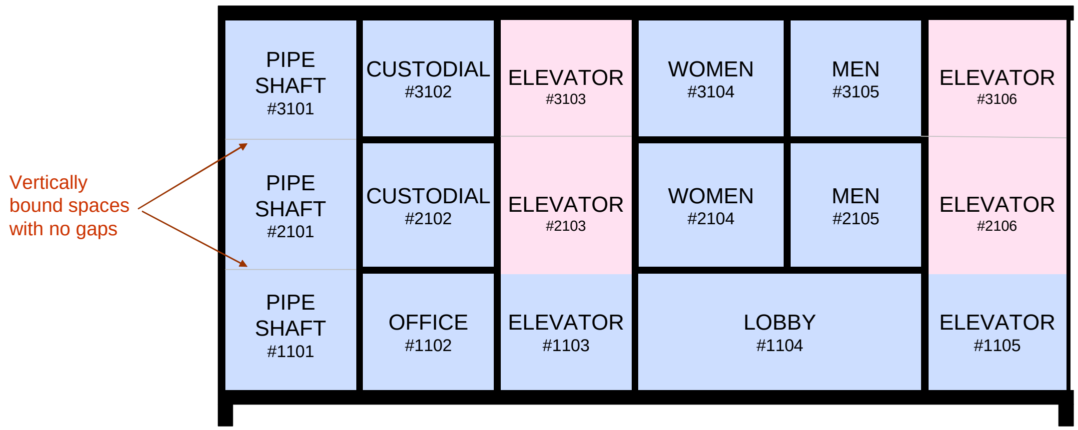


Figure 21: Multi-story Example 3

Table 7: Spatial Data for Example 3

Space Number	Space Name	Occupant Organization Name	GSA STAR Space Type
1101	PIPE SHAFT	Building Common	CRV
1102	OFFICE	US Marshals Service	TTO
1103	ELEVATOR	US Marshals Service	CRV
1104	LOBBY	Building Common	CRH
1105	ELEVATOR	Building Common	CRV
2101	PIPE SHAFT	Building Common	CRV
2102	CUSTODIAL	Floor Common	CST
2103	OPEN TO BELOW	US Marshals Service	TFC
2104	WOMEN	Floor Common	TLT
2105	MEN	Floor Common	TLT
2106	ELEVATOR	Building Common	CRV
3101	PIPE SHAFT	Building Common	CRV
3102	CUSTODIAL	Floor Common	CST
3103	OPEN TO BELOW	US Marshals Service	TFC
3104	WOMEN	Floor Common	TLT
3105	MEN	Floor Common	TLT
3106	ELEVATOR	Building Common	CRV

Spaces containing stairs shall always be modeled by using the space name "STAIR," with one space in each building floor. Spaces above the lowest stair space shall be labeled as "STAIR A."

Spaces containing mechanical shafts shall always be modeled by using the space name "PIPE SHAFT," with one space in each building floor. Spaces above the lowest mechanical shaft shall be labeled "OPEN TO BELOW."

> *Note: As with all multi-story physical spaces, the stacked stair and shaft spaces must bound each other vertically with no gaps or overlaps (Figure 21).*

Private Stairs and Elevators

Sally Ports and Judge's elevators are considered vertical penetrations. According to ANSI/BOMA, vertical penetrations take the entire wall surrounding the penetration (e.g., public stairs and elevators), and are assigned the 04 - ANSI/BOMA category. However, for private stairs and elevators, these vertical penetrations will still take the entire wall surrounding the penetration, but will be assigned 01 – Assigned ANSI/BOMA Category. In order to do this correctly, the BIM-analysis rules will first treat vertical penetrations as "regular" (04 category) penetrations when defining the space boundary, but will then use the provided spatial information to assign the correct category.

Parking Areas and Stalls

All parking areas and stalls (exterior and interior) should be modeled. Parking stalls should have the space name PARKING STALL INT or PARKING STALL EXT (depending upon location). Other parking areas (e.g., ramps, corridors) should be labeled PARKING CIRCULATION (INT or EXT). Interior parking areas (i.e., within the gross building area) should be assigned to ANSI/BOMA category 05: PBS Specific and GSA STAR Space Type 09: Structured Parking.

MCH and CST – ANSI/BOMA Assignment

The BIM-analysis rules are based upon the assumption that every GSA STAR space type can be directly mapped to one ANSI/BOMA category. However, for STAR space types MCH and CST, these can mapped to both 02 – Building Common and 03 – Floor Common. The default value for MCH is 02 – Building Common and CST is 03 – Floor Common.

Spaces Without Bounding Elements

In many cases, two adjacent spaces will not be separated by a physical bounding element (e.g., wall, partition, floor, or ceiling). See Figure 22:

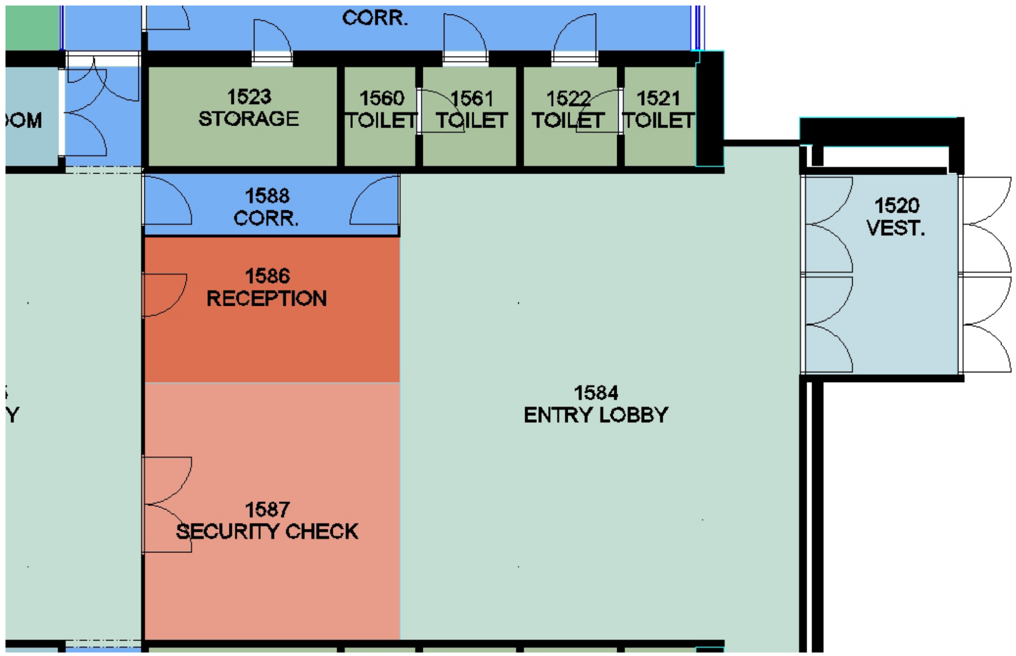


Figure 22: Reception, Security Check, and Entry Lobby as Separate Functional Areas

All of the major BIM-authoring applications support modeling this condition and the IFC BIM schema supports this as well. As with the stacked spaces in the Multi-Story Spaces section above, care must be taken to ensure that no gaps or overlaps (horizontally or vertically) exists between these spaces.

4.3.3 Vertical Penetrations in Spaces

In some area calculations, building services shafts shall be included if the space is greater that 9 s.f. Effectively, this means that spaces that have large shafts in them should be modeled as if they had holes or voids, from a space calculation point of view. This is accomplished differently in each of the major BIM-authoring applications. See more details about how this is done by some BIM-authoring applications in Appendix A. Shafts and vertical penetrations are defined according to the *PBS Business Assignment Guide*.

4.3.4 Balconies and Terraces

Balconies and terraces should be modeled as spaces. Their height should be bounded by the ceiling (as with other spaces) or other surface above, where a surface exists. If one does not exist, the height should be set equal to the height of adjacent spaces in the same building floor.

4.3.5 Compound Objects or Assemblies

In some BIM-authoring applications, it is possible to use parametric components to model objects (e.g., stairs, balconies, bathrooms, etc.). While these tools provide great benefit during design, the resulting design objects might not be included in the export to an IFC BIM. In these cases, these assemblies are modeled as a single special 3-D object instead of an assembly of semantically correct BIM objects (i.e., walls, doors, windows, curtain wall, etc.).

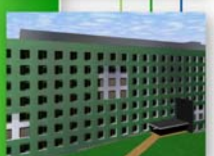
If compound object or assembly tools are to be used to create the objects required in this Guide, the user must ensure that the requisite objects and their associated properties are included in export to an IFC BIM to ensure that all space calculations are correct. Contact the BIM-authoring application vendor for instructions if this becomes a problem. See Appendix A for more information.

4.4 References

This section describes how GSA will use the IFC BIM submission to validate the spatial program. BIM-analysis rules and special cases will be described. The majority of these rules are based upon three documents:

- *PBS Business Assignment Guide* (October 1, 2005)
- ANSI/BOMA Standard Method for Measuring Floor Area in Office Buildings (ANSI/BOMA Z 65.1 – 1996)
- Region 3 SDM Formatting Standard (May 1, 2005)

Further guidance and clarifications of these rules were provided by the GSA PBS Office of Real Property Asset Management.



acknowledgements

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Participating Vendors and Products

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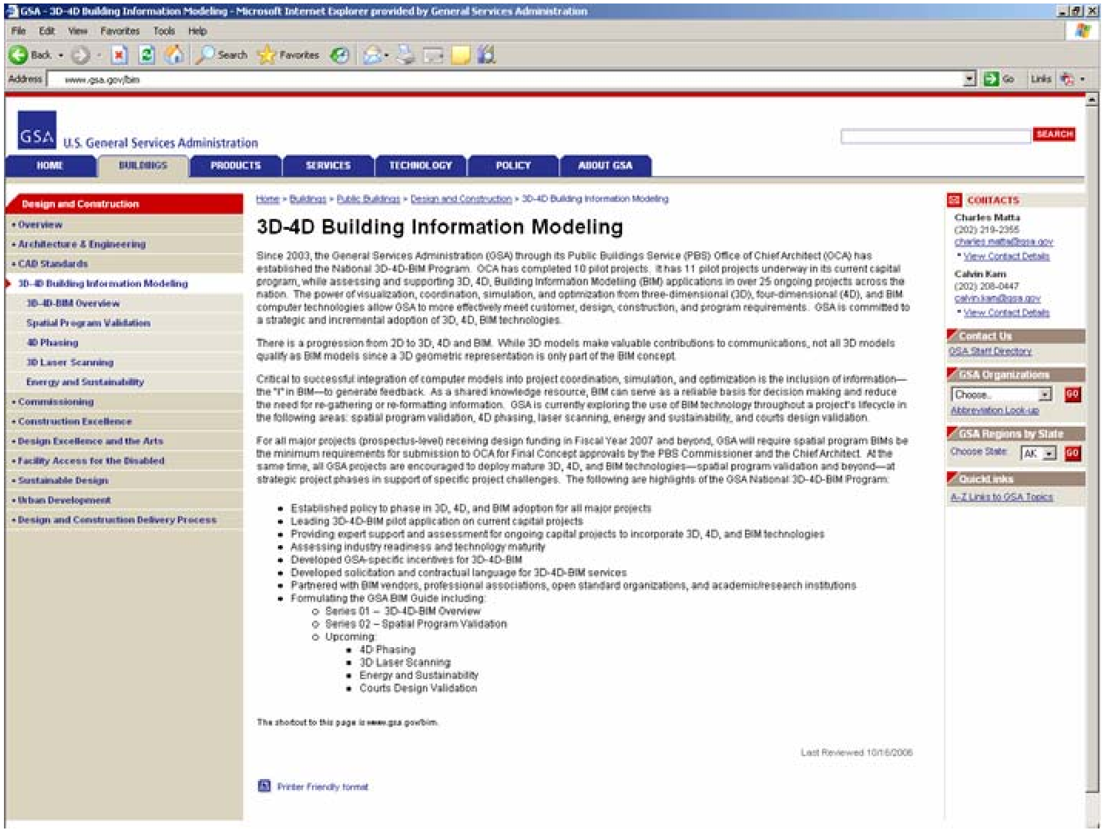
- Onuma Planning System – Pasadena, CA, USA



For further information about this GSA BIM Guide Series: 02 – BIM Guide For Spatial Program Validation or to submit comments or questions, please visit the National 3D-4D-BIM webpage at http://www.gsa.gov/bim or contact:

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