The Future of IFC:

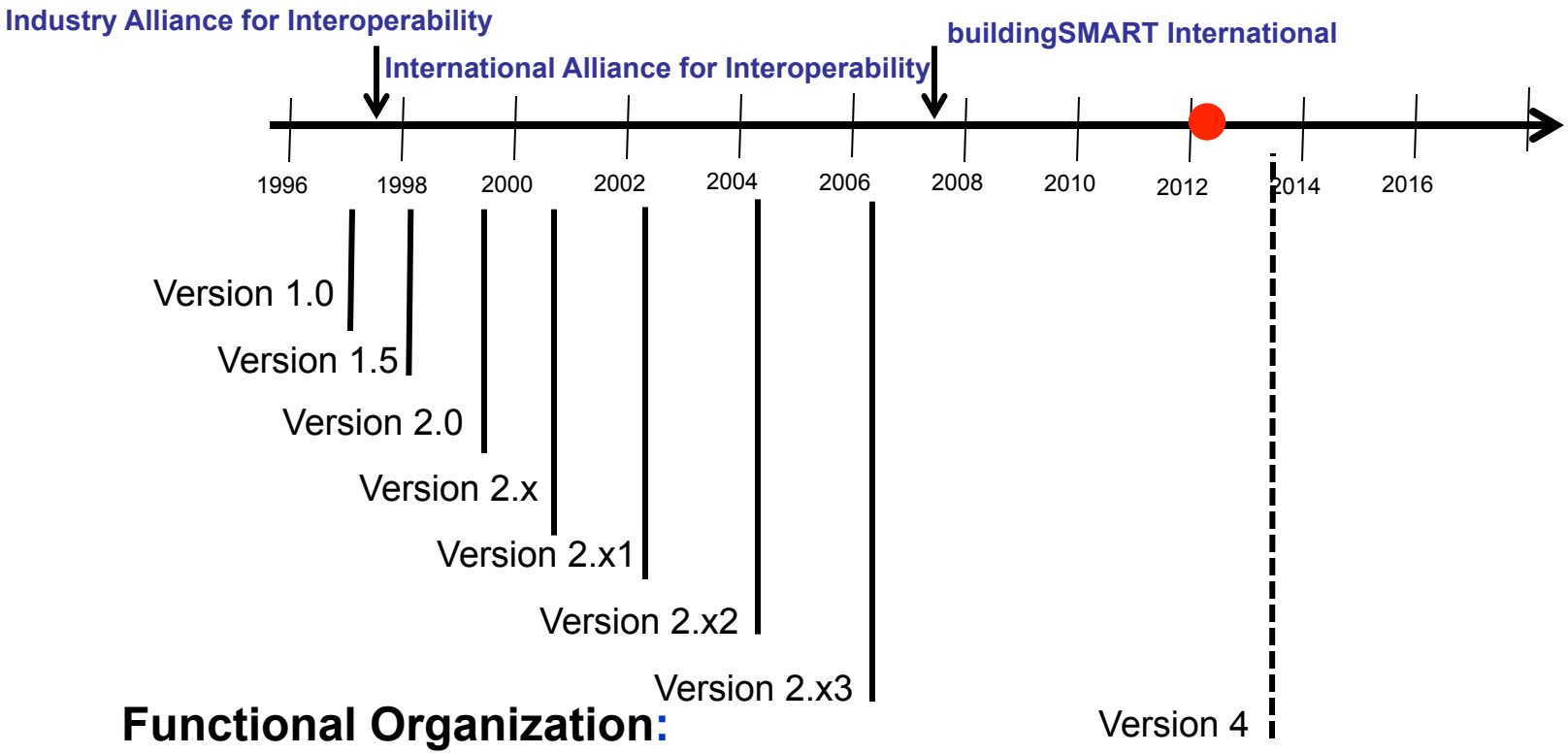
Rationale and Design of a SEM IFC Layer

Chuck Eastman
Director, Digital Building Lab
College of Architecture
Georgia Tech

Precast concrete, sructural steel, reinforced concrete

History of IFC

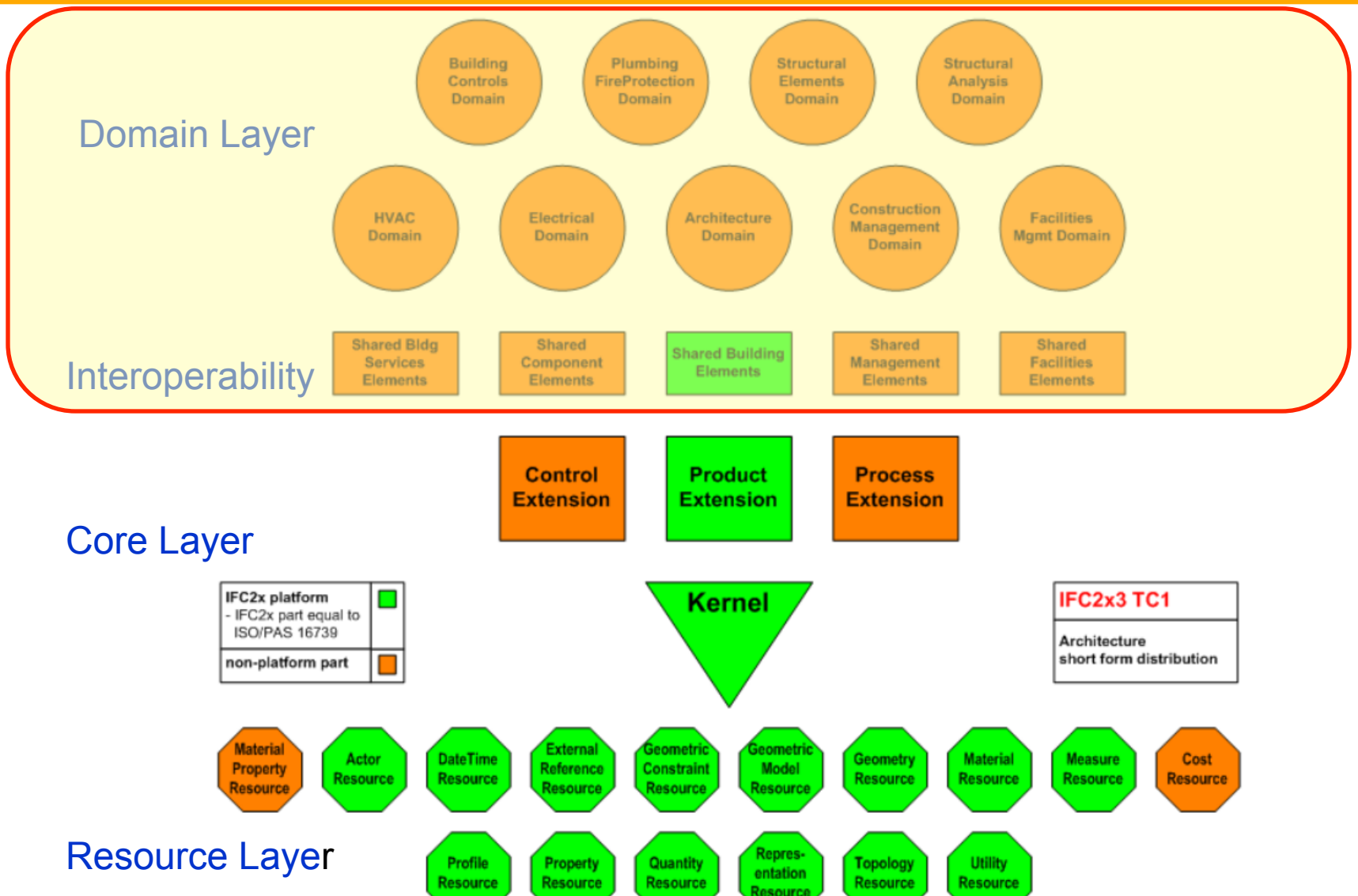
buildingSMART
International home of openBIM



Functional Organization:

- Addresses the full domain of constructed buildings, components for design, fabrication, operation
- Highly Object oriented: inheritance, polymorphism, extensibility
- Objectified relationships: attributes on relations
- Multiple kinds of geometry
- Open-ended kinds of properties: value-based properties

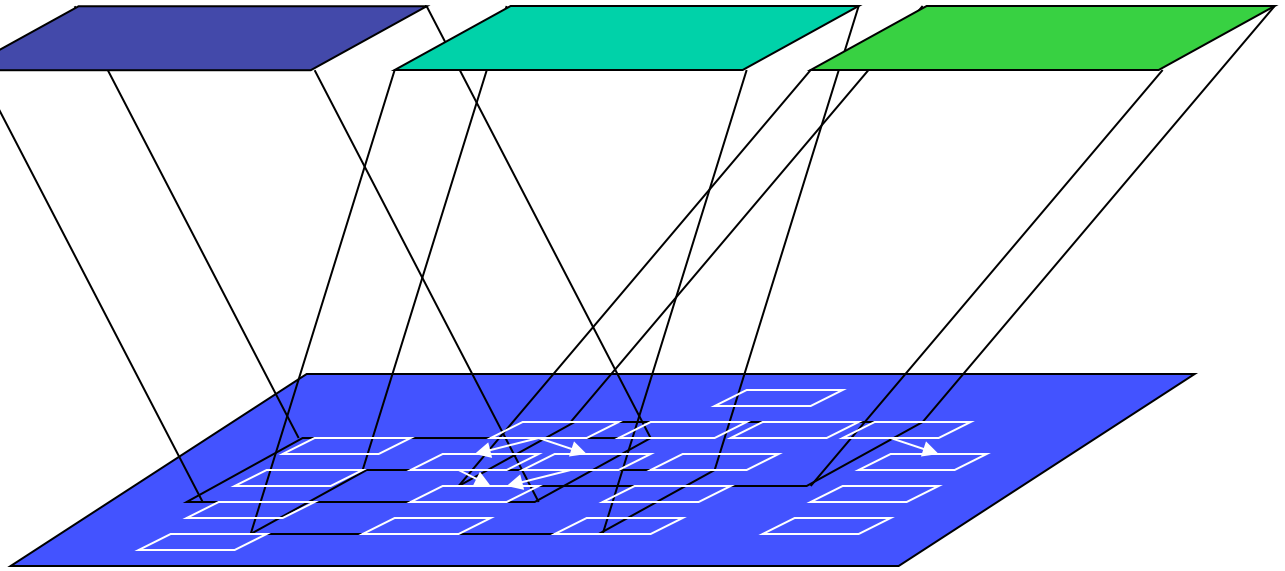
Industry Foundation Classes



Why is there a need Model Views?

Example Use Cases

precast engineering scheduling fabrication



IFC, CIS/2 or others Model Schema

Highly redundant

Schema is a rich set of structures covering most information needed for design, analysis, procurement, fabrication planning and fabrication automation

What is the National BIM Standard?

We are following and validating the national BIM standard process, defined in:

National BIM Standard Version 1 - Part 1: Overview, Principles, and Methodologies

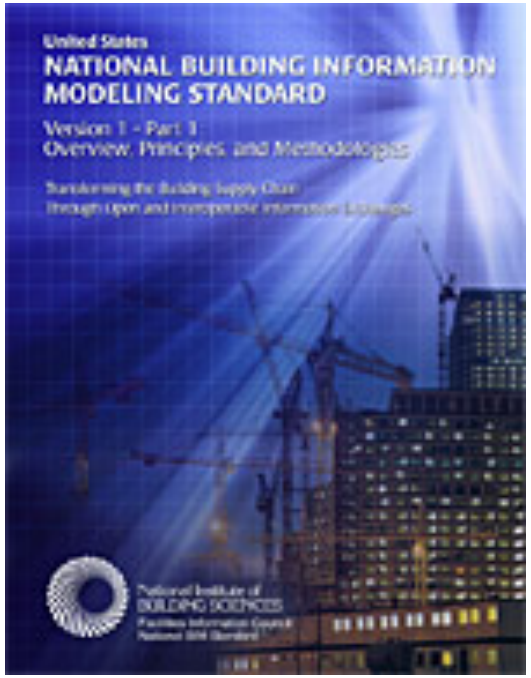
Draft: January 14, 2008

National Institute of Building Science

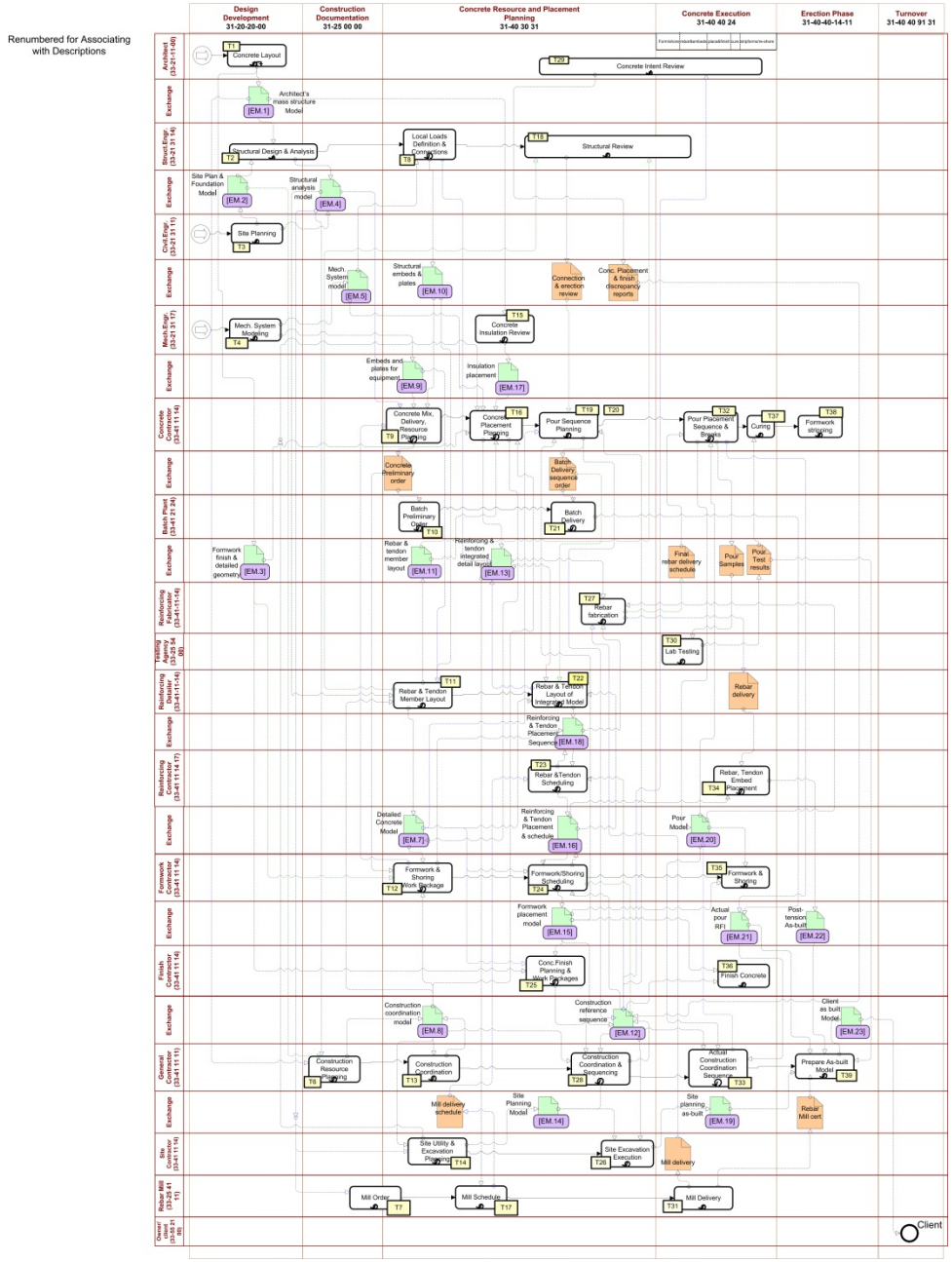
BuildingSMART

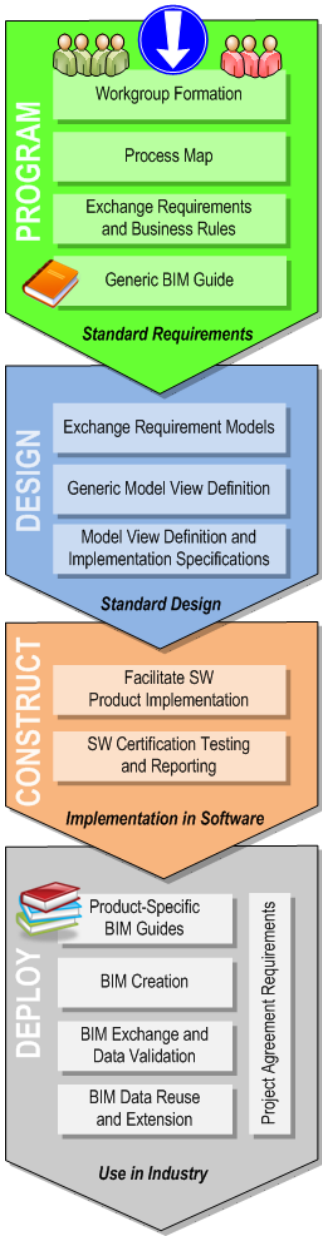
Federal Facility Council

National Institute of Standards and Technology



Available in:
http://www.facilityinformationcouncil.org/bim/publications.php


Renumbered for Associating with Descriptions
Design Development 31-20-20-00
Construction Documentation 31-25 00 00
Concrete Resource and Placement Planning 31-40 30 31
Concrete Execution 31-40 40 24
Erection Phase 31-40-40-14-11
Turnover 31-40 40 91 31
Architect (32-01 13 66)
Exchange
Struct Engr (32-01 13 66)
Exchange
Civil Engr (32-01 13 71)
Exchange
Mech Engr (32-01 13 71)
Exchange
Concrete Contractor (33-41 11 14)
Exchange
Batch Plant (33-41 13 24)
Exchange
Reinforcing Fabricator (33-41-11-14)
Testing Agency (32-14 13 00)
Reinforcing Detailer (33-41-11-14)
Exchange
Reinforcing Contractor (33-41 11 14 17)
Exchange
Formwork Contractor (33-41 11 14)
Exchange
Finish Contractor (33-41 11 14)
Exchange
General Contractor (33-41 11 11)
Exchange
Site Contractor (33-41 11 14)
Rebar Mill (33-25 41 11)
Owner/ Client (33-01 91 00)
T1 Concrete Layout
T29 Concrete Intent Review
[EM.1] Architect's mass structure Model
T2 Structural Design & Analysis
T3 Local Loads Definition & Connections
T18 Structural Review
Site Plan & Foundation Model [EM.2]
Structural analysis model [EM.4]
T5 Site Planning
Mech. System model [EM.5]
Structural embeds & plates [EM.10]
Connection & erection review
Conc. Placement & finish discrepancy reports
T4 Mech. System Modeling
T15 Concrete Insulation Review
Embeds and plates for equipment [EM.9]
Insulation placement [EM.17]
T9 Concrete Mix, Delivery, Resource Planning
T16 Concrete Placement Planning
T19 T20 Pour Sequence Planning
T32 Pour Placement Sequence & Breaks
T37 Curing
T38 Formwork stripping
Concrete Preliminary order
Batch Delivery sequence order
Batch Preliminary Order T10
T21 Batch Delivery
Formwork finish & detailed geometry [EM.3]
Rebar & tendon member layout [EM.11]
Reinforcing & tendon integrated detail layout [EM.13]
Final rebar delivery schedule
Pour Samples
Pour Test results
T27 Rebar fabrication
T30 Lab Testing
T11 Rebar & Tendon Member Layout
T22 Rebar & Tendon Layout or Integrated Model
Rebar delivery
Reinforcing & Tendon Placement Sequence [EM.18]
T23 Rebar &Tendon Scheduling
Rebar, Tendon Embed Placement T34
Detailed Concrete Model [EM.7]
Reinforcing & Tendon Placement & schedule [EM.16]
Pour Model [EM.20]
T12 Formwork & Shoring Work Package
T24 Formwork/Shoring Scheduling
T35 Formwork & Shoring
Formwork placement model [EM.15]
Actual pour RFI [EM.21]
Post-tension As-built [EM.22]
T25 Conc.Finish Planning & Work Packages
T36 Finish Concrete
Construction coordination model [EM.8]
Construction reference sequence [EM.12]
Client as built Model [EM.23]
T8 Construction Resource Planning
T13 Construction Coordination
T26 Construction Coordination & Sequencing
Actual Construction Coordination Sequence T33
Prepare As-built Model T39
Mill delivery schedule
Site Planning Model [EM.14]
Site planning as-built [EM.19]
Rebar Mill cert
T14 Site Utility & Excavation Planning
T28 Site Excavation Execution
Mill delivery
T7 Mill Order
T17 Mill Schedule
T31 Mill Delivery
Client



Scope of Process Phases

Program: What is the requirement?

- *organize domain experts in target area*
- *determine scope of coverage*
- *define process model of exchanges*
- *specification of exchange requirements by domain experts*

6-10 Months

Design: How to solve the requirements?

- *definition of model views as Concepts*
- *mapping required semantics to schema structures*
- *define IFC bindings* *6-12 months*

Construct: How to build it?

- *binding to native data models*
- *verify software implementation*
- *develop test model views for each exchange*

6-14 months

Time: 18-36 months

Deployment: Use in Industry

Results to date:

Completed:

- Coordination View (used in IFC Certification process) (.95)
- COBie – handover for building operations & maintenance (.9)
- PCI precast Model View (.75)

Others underway: AISC, ACI, Spie,….

Large ‘mountain’ to climb

Relies on volunteer labor that is difficult to maintain

Results only weakly successful (testing not as strong as other commercial SW efforts)

Model View Modularity

Recognized early

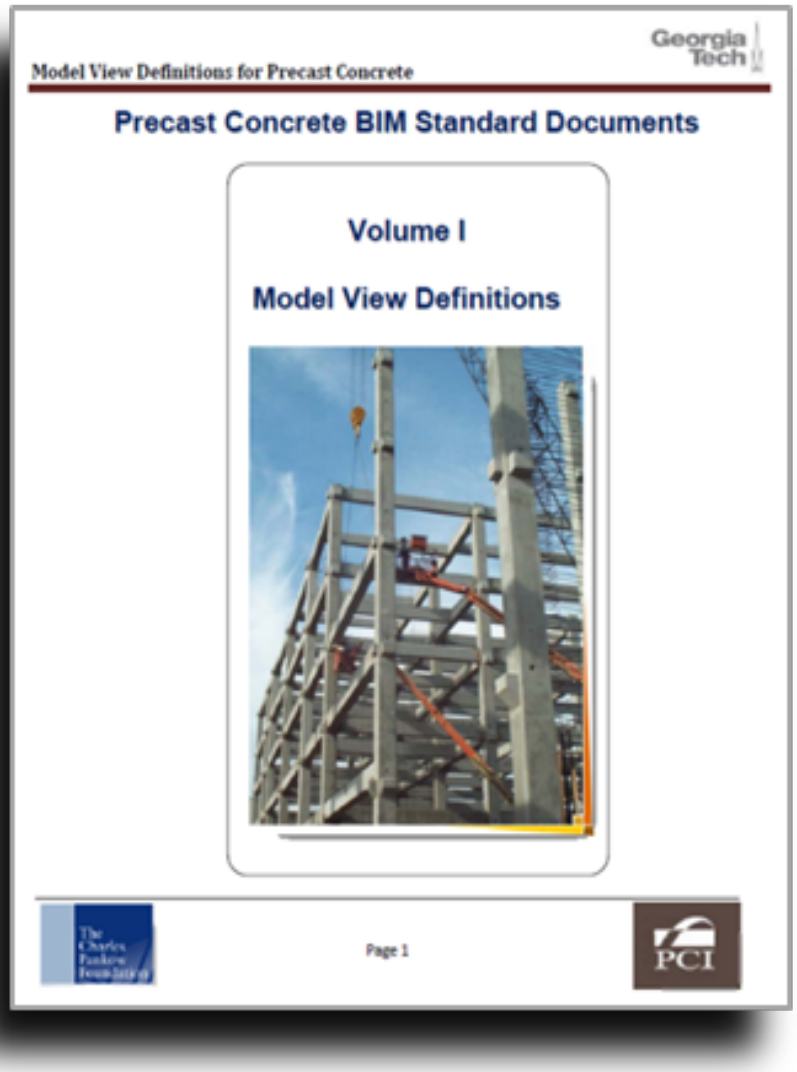
Model views are full of repetitions:
Same type of geometry used in different places, for different systems; spatial structures are used globally; some components used multiple places: rebar, connection embeds

Worked on from 2007 timeframe on

Repetitive specifications called **IFC Concepts can be re-used in specifying different exchanges**:
Re-use model view specifications where possible

Developed in early 2000s timeframe on

ISO-10303 Application Modules **allow re-use of model view specifications** : Can re-use model view specifications where possible



Current Status of Model View BIM Standards:

Concepts defined incompletely – not general or defined to be re-usable

Concepts too low level: many can be combined for testing without eliminating flexibility

Concepts not formally defined so that criteria are applied to their generality or well-formedness

MVD too time consuming to develop – 18-36 mos. multiple man years

MVDs are very rigid: satisfactory for contractual pass-offs, poor for collaboration

Testing is onerous; SW companies will be reluctant to support many MVDs

What is the next step in Model Exchange?

Model View Modularity

Recognized early

Model views are full of repetitions:
Same type of geometry used in different places, for different systems; spatial structures are used globally; some components used multiple places: rebar, connection embeds

Worked on from 2007 timeframe on

Repetitive specifications called IFC Concepts can be re-used in different exchanges:
Re-use model view specifications where possible

Developed in early 2000s timeframe on

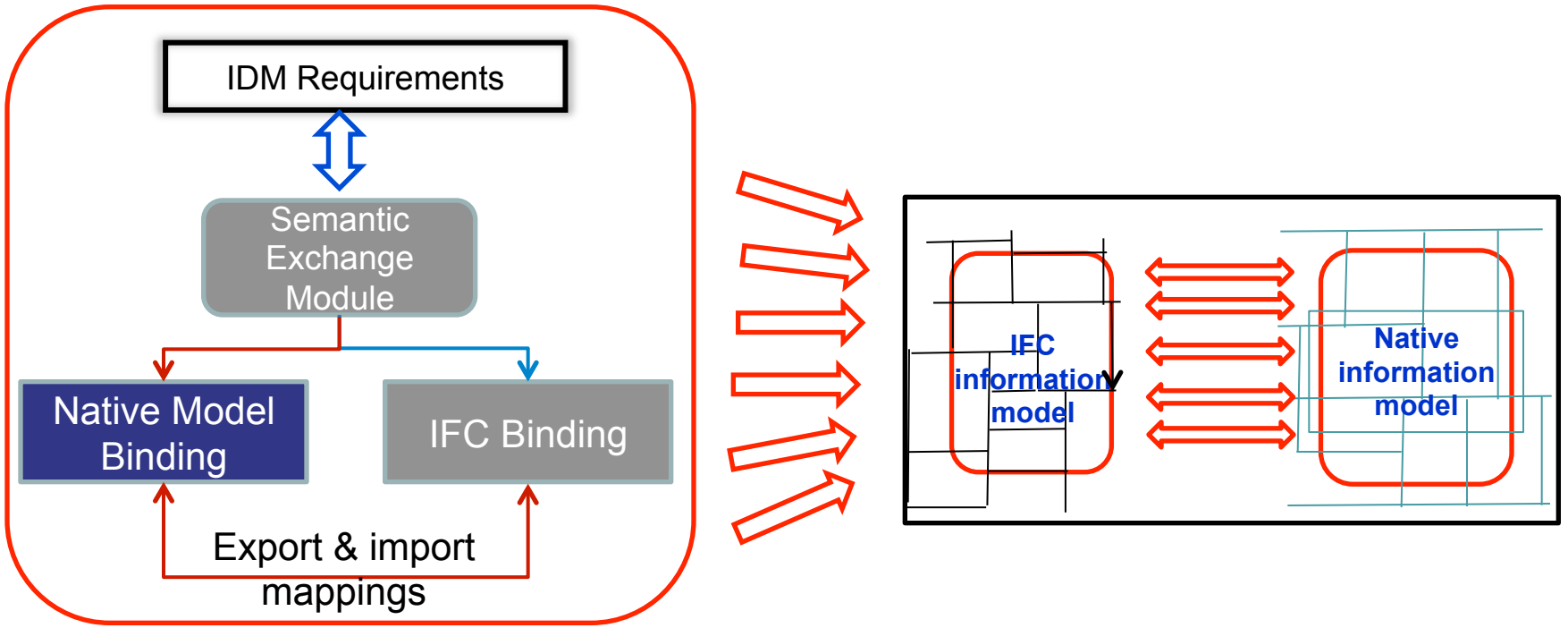
ISO-10303 Application Modules allow re-use of model view specifications :
Re-use model view specifications where possible

New idea; being developed

Module includes implementation of mappings to/from native model; if fully resolved once, need not be tested again: repetitive implementations should be done once and fully tested for re-use in all relevant contexts; allows re-definition of MVDs, ultimately interactively by users.

New form of Concept: Semantic Exchange Module (SEM)

SEM is Concept extended to include both IFC and native bindings;
a logical structure above IFC that eliminates “plumbing connection details”;
can be implemented to support dynamic composition by users, to define new MVDs for collaborative needs.



If SEMS can be combined and automatically compiled, then the mapping from IDM to MVD can be done interactively, in afternoon.

If SEMS can be tested and certified, then the total effort by SW companies is greatly reduced, because a SEM module need only be implemented & tested once

The next generation of improvement of exchange concepts or modules

If re-use of Concepts is to be realized, they need **formal definition** that guarantees their potential re-use and can be defined and implemented widely.

Concept is potentially more than an implementation module; it defines a **semantic unit** to be defined in a model for exchange (identifying user intent and software capability)

Concepts should be **modular**, so that different concepts can be composed for re-use in different constructs without modifying module interfaces.

Concept should be at the **highest level of aggregation** that does not eliminate any re-use case

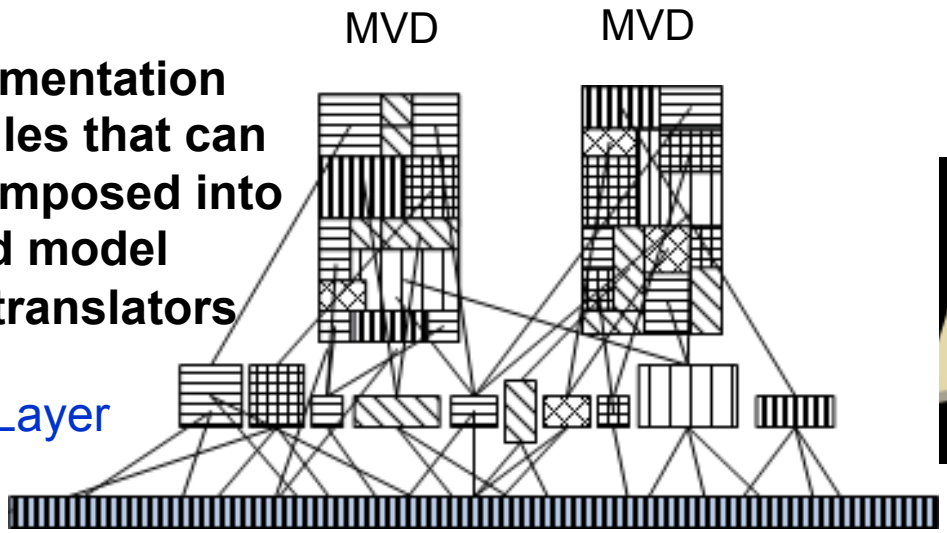
Concepts are **organized hierarchically**, as an acyclic graph, where some Concepts (like geometry, materials and other properties) qualify existing objects. Generality of implementation encourages a breadth-first implementation

SEM System Idea

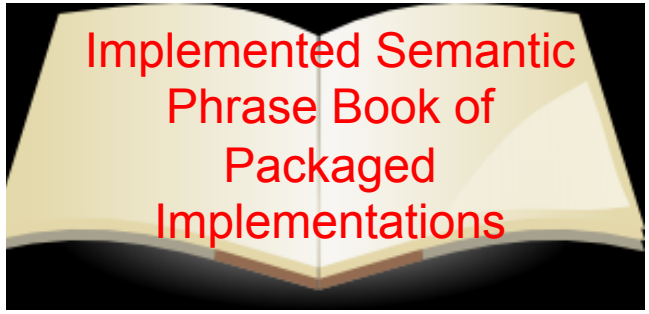
SEMS provide a higher level composition of IFC, that allows definition of translators, provide semantic units of meaningfulness, supports unit testing, and re-use.

Implementation modules that can be composed into varied model view translators

SEM Layer



Need rigorous specification standard of Concept;



800+ IFC entities, plus appx. 800 properties, relations

Variable number of SEMs implemented and tested by each SW company

SEMS can be composed into MVDs by knowledgeable users

Concepts are tested once and validated, not requiring internal testing again

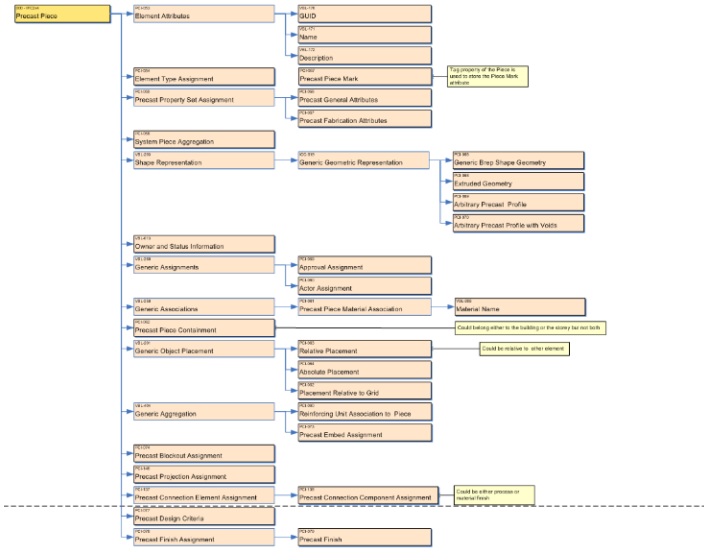
Automated Model Exchanges

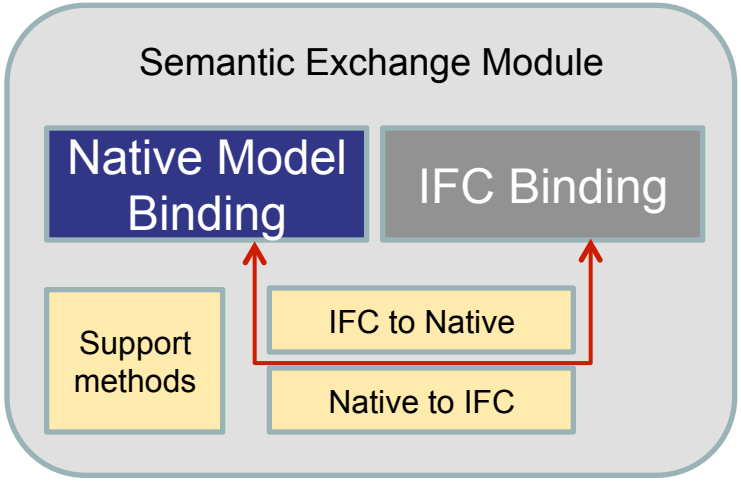
Proposed extension of Concept – Implementable Concepts

Structures repeated use in Exchanges in different contexts

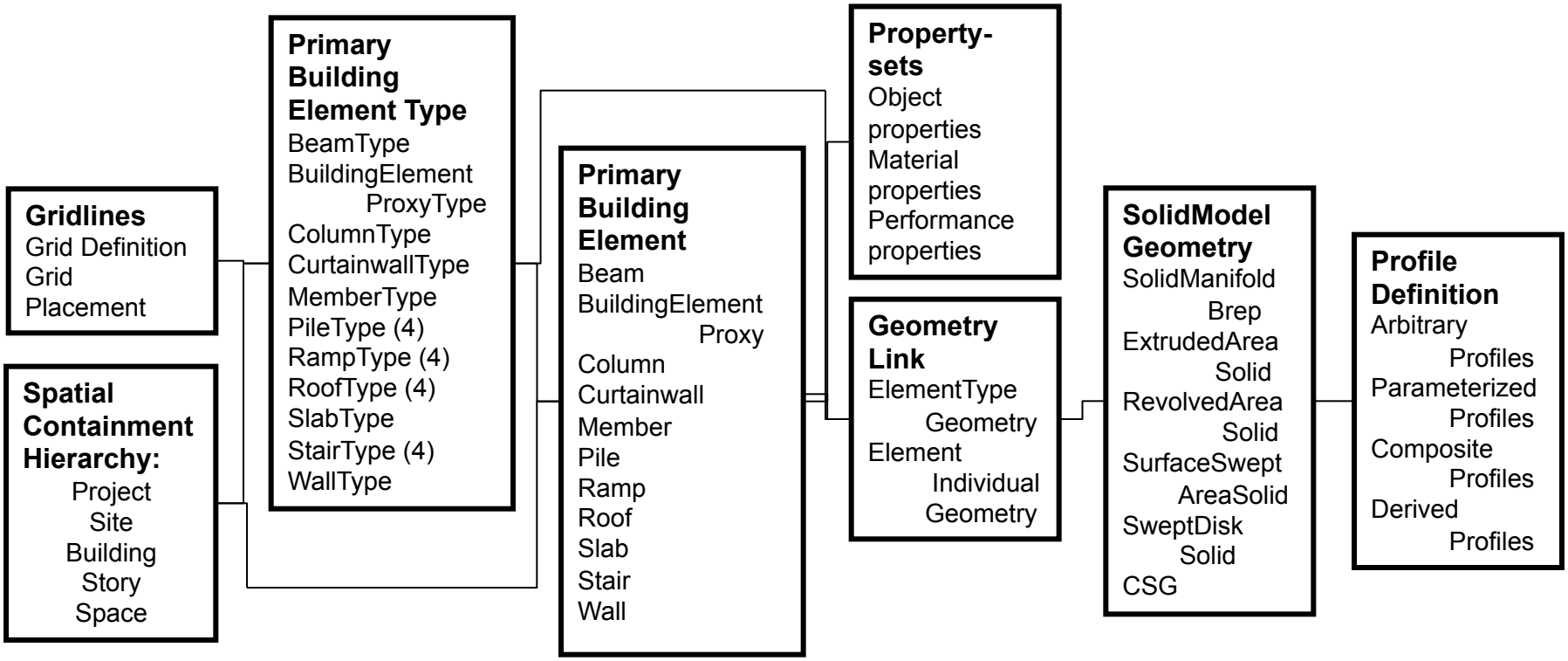
Modularity of substructures is used in MVD specification and testing

Includes native model bindings and mappings between public Model View and native model





Sequential Implementation of SEM Families



A Model View is a directed sequence of Elements that incrementally map to the existing IFC structure

Model Views can be saved, re-used and modified

Semantic Exchange Module (SEM)

IFC would benefit fro a clean-up, due to failed earlier specs, evolving best practices. Cleanup is realized by a macro layer above it;

IFC must include a dictionary, backed up by an ontology that will help in the classification of future extensions

If MVDs are to become more than black boxes, then the modules of functionality need to associated with semantic meaning in the information

Users should be able to take existing implemented SEMs and restructure them into a new specification – different geometry structure, different levels of assembly, properties, for the collaboration task at hand, in less than an hour

Higher level set of definitions are learnable by users for specification, are units for unit testing and validation

Implementation Template for a SEM

SEM Object #XX

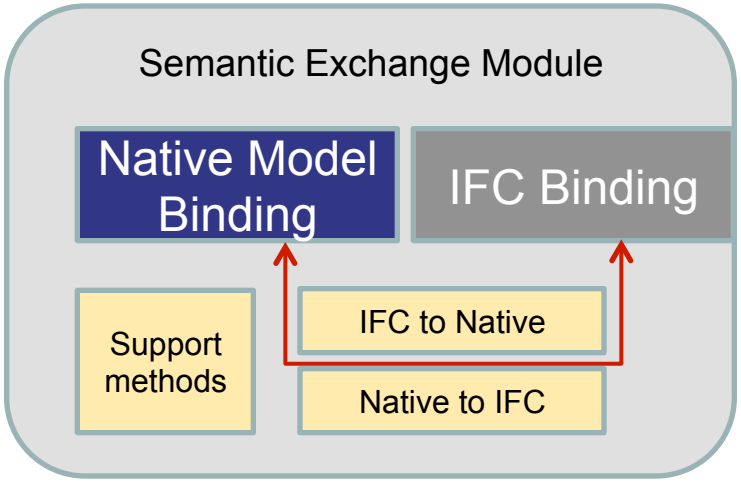
```
/* IFC Methods (prestructured)  */
#INCLUDE IFC Declarations
IFC Read Methods
IFC Write Methods
```

```
/* Native Methods Thru API  (new) */
#INCLUDE Native Declarations
Native Read Methods
Native Write Methods
```

```
/* Functions linking this structure to existing
*/
/* function to write or modify YY
```

```
/* Testing Suite for Native Implementation
*/
```

Dictionary of Implemented SEMs; defining semantics for re-use



SEMs are compiled to DDL; are composed and linked into MVD; MVDs are stored for later use or adaptation

Each SEM can include its own unit test suite

Need for global namespace management

Implications for Model Exchange (30,000 ft)

Process models will become common in future construction contracts

Contractual deliverables will be specified as Model Views, customized as needed for the project

Collaboration workflows will be facilitated by easy customization of exchanges, possibly defined as needed

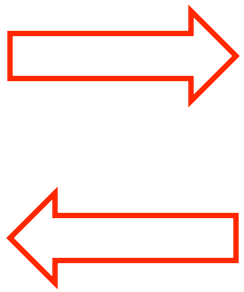
SEMS can be used for DB queries as well as specifying an exchange.

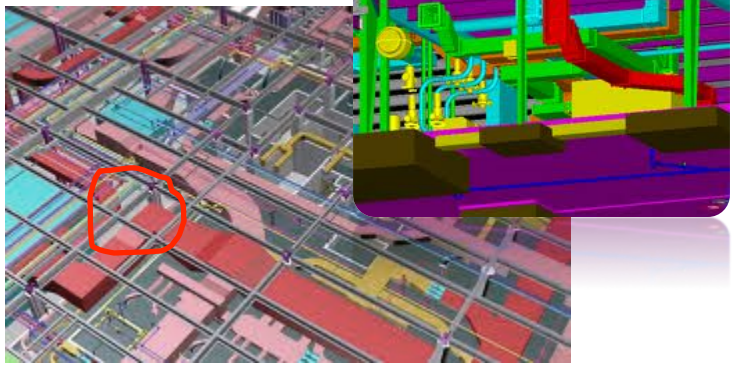
Workflows consist of model views and non-model engineering information: RFIs, Change Orders, coordinated parallel changes during virtual Design and Construction as well as during the real thing (tolerance tracking)

Workflows consist of model views and non-model engineering information: RFIs, Change Orders, during virtual Design and Construction as well as during the real thing (tolerance tracking)

BIM Collaboration Format (BCF):

Broader range of transactions needed & will be developed





Design Review/Assessment:

XML dataset:

- Unique issue ID
- Screen image with annotation
- Camera placement in project
- Description of issue
- status
- Author/time/application

Design Authoring Platform:

Imported XML data:

- List of action Items (can be appended & managed)
- Resolved with editing capability
- Maintains original camera placement in project
- New proposed status
- Author/time/application

What will Interoperability be like in 2030?

- Standard exchanges can be smooth and seamless
- It will be not difficult to compose a new IfcObject (not a new IfcEntity) and compose the Object to reflect a new object type
- New exchange definition will be similar in difficulty to setting up a webpage, or forms-based Word document.
- Many services will be provided by subscription on cloud servers (with reasonable security)
- Cloud servers will become a major AEC technology.
- Many BIM/VDC applications, for authoring design data, running analyses, scheduling, etc. will be cloud based
- High level query systems for accessing desired objects are needed and will have two levels: classes desired, then instances

Thank you