

SUTTER MEDICAL CENTER CASTRO VALLEY
IPD PROCESS INNOVATION WITH BUILDING INFORMATION MODELING

SUTTER MEDICAL CENTER CASTRO VALLEY

An Innovative \$320M Hospital Replacement Project in Castro Valley

Project Description

An Integrated Project Delivery (IPD) team, including the owner, design teams, General Contractor and Trade Subcontractors involved during schematic design, is challenged with designing and delivering a new 130-bed, \$320 million hospital project for Sutter Health in Castro Valley, California, within an accelerated schedule and aggressive budget targets. The IPD team included the following members: (Note that firm names removed to meet submission requirements)

Core IPD Team

Sutter Health: Owner

Lean/VDC Project Integrator & BIM Technology Manager

Architect

General Contractor

Mechanical Engineer

Structural Engineer

Electrical Engineer

Mechanical Trade Partner

Plumbing Trade Partner

Electrical Trade Partner

Fire Protection Trade Partner

Contract Method: Sutter Integrated Form of Agreement (IFOA).

The project utilizes for the first time a 11 party IFOA where the owner, the architect, the GC, key design consultants, key sub-contracts, and Lean/BIM consultant are all co-signatories of the agreement and members of the core team. The IFOA requires the team to work collaboratively, use 3D BIM technologies, and to implement lean practices to drive waste from the delivery system. Realized savings if the project is delivered below its target cost are shared among the IFOA signatories.

Key Project Goal: Design and deliver a facility of the highest quality, at least 30% faster, and for no more than the target cost.



KEY PROJECT CHALLENGES

Schedule: The current legislative requirement to comply with California new seismic safety standards creates new challenges for design and construction. The design/construction team is working to meet fixed deadlines for design, permitting, and construction in order to satisfy the new codes. The hospital needs to be designed and built at least 30% faster than what had been done in the past for comparable projects in California.

Budget: The budget for the new hospital has an aggressive target of \$320 million. The team has to design and build a state of the art facility with an aggressive schedule and a very challenging site within this cost target. Under no circumstances, the target cost can be exceeded.

Phased Plan Review (Permit Process): The project is one of the first to use OSHPD's phased reviews to accelerate the permitting process. Typically in California hospitals take over 24 months in OSHPD reviews after the completion of the design documents. Using the phased plan review process, the team was able to deliver the complete structural package on time at the end of 2008 and is on target to receive a construction permit six months later to start construction. The team had to completely revise the traditional design workflow of schematic, design development, detailed design approach and create a new workflow that supported intense early 3D model-based design coordination that aimed at minimizing the risk of downstream changes.

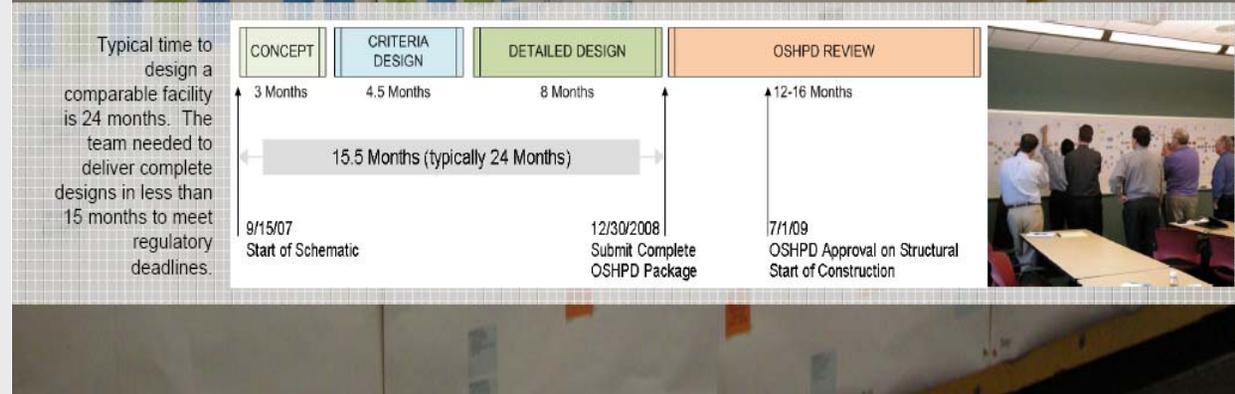
Site: The project sits on a very challenging site with sloped grade and limited space for use in construction. In addition, the existing hospital must remain fully operational during the construction of the new hospital.



TOOLS, PROCESSES, AND IMPLEMENTATION STRATEGIES

The team identified a number of strategies to achieve the project objectives. Notable among them:

1. **Project as laboratory:** to create opportunities to assess various evolving tools and technologies quickly and adopt what is appropriate to meet project goals. (Examples: Model based estimating, and automated code checking.)
2. **Understand the process:** before starting design, the team will allocate adequate time to plan the design process. The IPD team used Value Stream Mapping, a lean tool, to map their workflow steps at appropriate levels of detail to have meaningful cross discipline discussions to identify value added steps and reduce rework loops.
3. **Manage by Commitments:** once flow of value is understood (via value stream mapping) members of the team make commitments to each other to complete the released activities and remove constraints to release downstream activities.
4. **Offsite fabrication and Preassembly:** designers work with the trade partners to make design decisions that lead to increased use of offsite fabrication and pre-assembly.
5. **Building Information Modeling:** the IPD team will use BIM to the extent possible to coordinate constantly, share information, and increase the reliability and certainty in the design so it can be directly used for fabrication and pre-assembly.
6. **Direct Digital Exchange:** information will be reused rather than recreated to the extent possible (Examples: model based estimating, detailing, coordination, automated fabrication, and scheduling).
7. **Real-time Access to Information:** all team members will be able to access project information at any time and regardless of where this information is created or stored.



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

The Big Room Concept

The project team is distributed in various cities including Sacramento, Pasadena, Redwood City, Utah, Phoenix, Dearborn, among others. The team needed to come up with effective strategies for collocation (a big room) without having to relocate the entire team into one location for an extended period of time which is not only costly but impractical given that there are over 240 people working on the project.

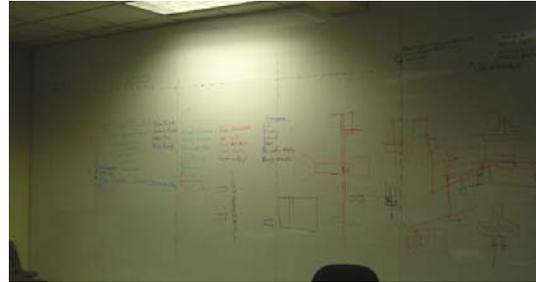
It is interesting to note that at the start of the project the team had to work hard to move away from conventional compartmentalized concepts for the layout of the big room (see original big room concept sketches, lower left) and to recognize that we needed to let the ideal layout emerge as we started to use the space.

The entire team collocates in the big room once every two weeks for 3 days to review the design, assess the design schedule, value stream map the workflow, and update the project budget. The MEP team meets in the big room weekly for their detailed and model based design coordination.

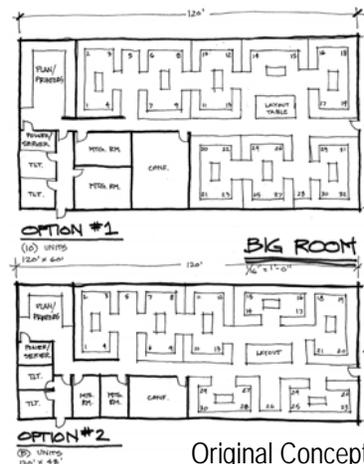
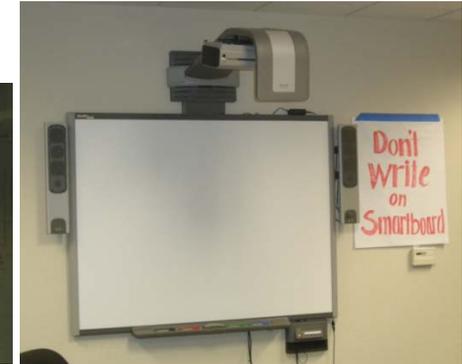
Finding for key elements of a successful big room:

- Not everyone needs to be at the big room meeting all the time but when team members are not present, we seem to need them the most.
- Large configurable meeting space to allow 30+ peoples to work comfortably.
- A mix of hardwired and wireless networking solution (wireless did not work well for a large team).
- Space for planning the process (big wall) with enough room for 30+ people to stand and work)
- Space for planning the design (wall sized marker board) that can be used for both planning and sketching design ideas.
- Smartboard (s) – two or more to project the 3D model, plans, schedule, and be able to share them remotely with other team members.
- Planning tables so small teams can focus on refining their plans.
- Small team meeting rooms.

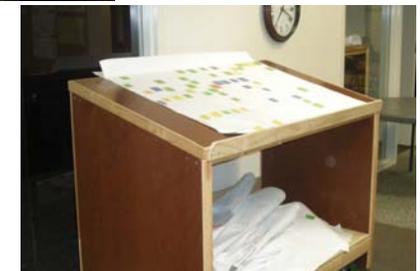
Permanent marker board (wall to wall)



Smart Board



Original Concept - abandoned



© Planning Tables

KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Design not only the facility but also the processes of the design

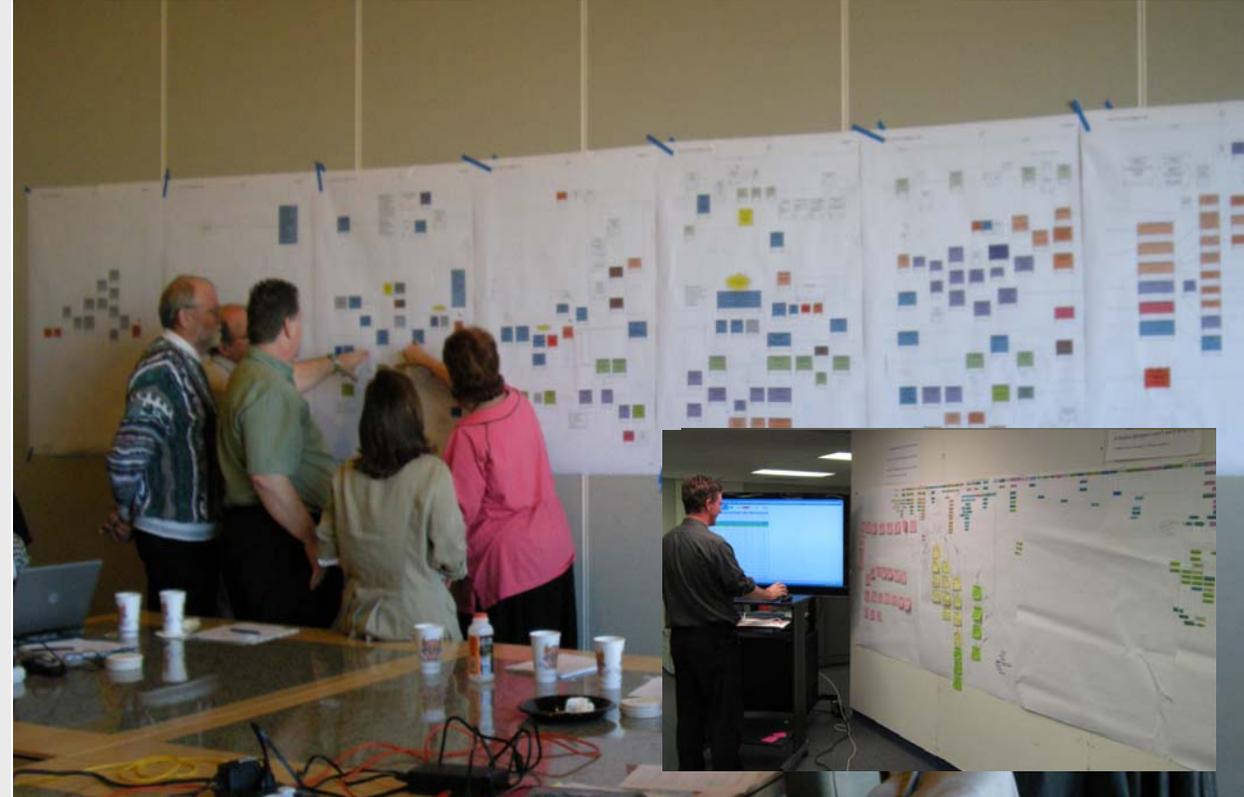
Tools:

Value Stream Mapping: a tool for documenting all the steps in the workflow that add value to the final deliverable from the perspective of the customer. The team as they create the map discuss their tasks and how they connect to other tasks in the workflow and negotiate what they need to produce and at what level of detail so that downstream work can proceed with more certainty. In addition, they make requests to others so that they can get what they need before they start their own tasks. The plan is reviewed on a regular basis and as more information becomes available, and the design evolves, the plan also evolves. New tasks as added, existing tasks are made more specific, and tasks that no longer add value are removed.

Navisworks: a tool for multi-discipline design reviews that allows the entire team to participate and review all the current design information as it is created and regardless of its authoring application. The entire IPD team meets at least once a week to review the design using the 3D model and the entire MEP team meets at least twice a week to do full MEP coordination using the 3D model. During the model review multi-discipline design issues are identified, discussed, resolved, or added to the plan depending on the type and complexity of the issues.

Successes: with time the team is becoming more effective at identifying and solving problems that would normally have been construction changes. In recent weeks, the team was able to conduct very detailed room-by-room reviews using only the 3D model, clarify the design, and resolve many detailed design issues.

Challenges: most teams are used to receiving drawings in order to review the design at key milestones. Adjusting to a model-based and more frequent multi-discipline design review process was not easy to many team members initially.



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

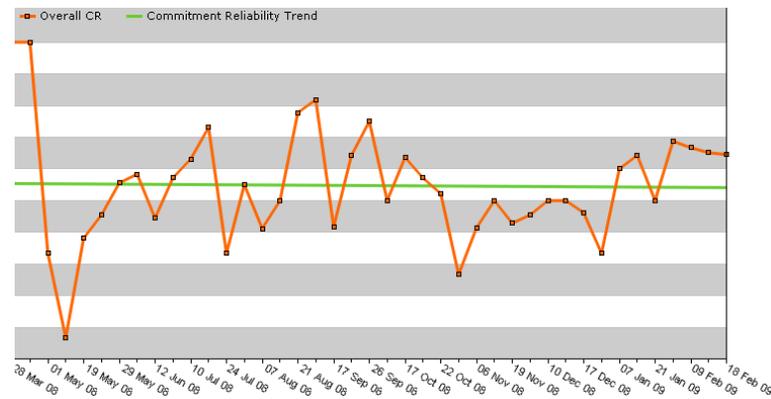
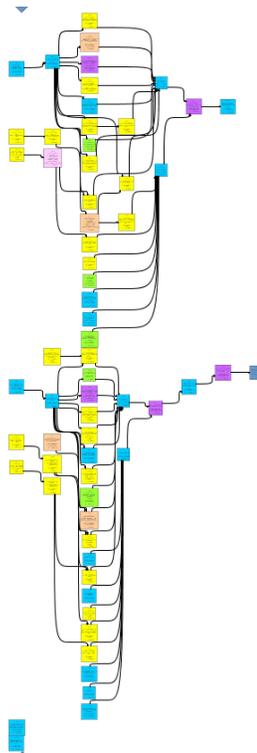
Managing by Commitments

Rather than manage the project by tracking high level milestones. This project is managed at the task level based on the plan from the value stream mapping process. Tasks are assigned to milestones and if their forecast start date starts affecting the due date for the milestone, the team must re-plan the work to get back on track.

The SMCCV IPD team meets regularly and only works on tasks that have no constraints in front of them and completes as many of those tasks as possible before the next planning cycle, then the team will move with more certainty towards completing its deliverables. Each planning meeting team members make public commitments that they will complete their specific tasks before the next meeting and if they are missing information, they will negotiate with other team members to remove those constraints so that they can complete their work. At the next planning each team member will update the status of their committed tasks. If a task is not complete, the responsible team member must provide a root cause for why the work could not be completed.

Tools: The team evaluated various commitment based tools to support the design process and selected SPS|Production Manager a tool originally developed to track construction activities.

Challenges: The most difficult part of planning design at the task level is that designers are not used to planning their work at this level of detail and frequency. Design activities typically have very long durations and through gate reviews, (e.g., at SD, DD, CD, and construction side coordination) missing information is added and corrections are made until a final design is built. Trying to plan design so that it can proceed with more iteration up front and less rework towards the end of the process can seem counter intuitive.



ID	S3	Desc	Team	Member	Dur	LRM Start	LRM Finish	Δ	Forecast Start	Forecast Finish	MS	Prty	Status	Docs
10 Entitlements & Permit Packages / 60 Inc 3: Bldg Enclosure / 20 Seg 2: Final / - / - / -														
>	2913	-	Coordinate with Randy the location of the fire risers in Stair 3 in podium	DGL+	CherieIr	1.00D	28 Aug 09	28 Aug 09	0	28 Aug 09 ▲	28 Aug 09	Normal	Rel	None
10 Entitlements & Permit Packages / 70 Inc 4: MEP, Arch, Drs, Sec / 30 Seg-3 Podium Arch. / - / - / -														
>	2916	2nd Floor	Laying out on the 2nd floor the walls and floors/ceilings that require lead. (confirm duration)	DGL+	AndrewF	5.00D	5 Aug 09	11 Aug 09	0	5 Aug 09 ▲	11 Aug 09	Normal	Rel	None
>	2918	-	URGENT: Hire MRI design/build contractor	DPR+	MarkW	1.00D	11 Aug 09	11 Aug 09	0	11 Aug 09 ▲	11 Aug 09	Normal	Rel	None
>	2915	-	From 3/10 coord meeting	CORE+	DigbyCh	1.00D	12 Aug 09	12 Aug 09	0	12 Aug 09 ▲	12 Aug 09	Normal	Constr	None
>	2393	-	[Target 8/13/09] OSHPD Inc 4 Seg 3 Podium Interior ARCH Detailing package submitted to OSHPD	DGL+	CherieIr	1.00D	13 Aug 09	13 Aug 09	0	13 Aug 09 *	13 Aug 09	Normal	Constr	None

ID	S1	S2	S3	Desc	Member	Next Plan	No Plan	Dur	LRM Start	Δ	Forecast Start	Prty	At Risk	Docs	Compl- NP	Insert Constr
Start: 18 Mar 09 (Wed) * Finish: 24 Mar 09 (Tue) * * Dates valid if committed today. Click here to change.																
10 Entitlements & Permit Packages / 30 Inc 1 : Structural / Seg 5: Full Structural / 10 BackCheck #1 / - / - / -																
>	2290	-	-	Spire design and support incorporated into structural drawings	DonMon	○	☑	5.00D	17 Mar 09 (2)		18 Mar 09 ▲	Normal		None	Compl- NP	Insert
>	2249	-	-	Review structural design of curb	DonMon	○	☑	1.00D	19 Mar 09	0	19 Mar 09 ▲	Normal	X (2250)	None		Insert
>	2237	-	-	Architectural review of metal panel connection	DonMon	○	☑	1.00D	23 Mar 09	0	23 Mar 09 ▲	Normal		None	Compl- NP	Insert

KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

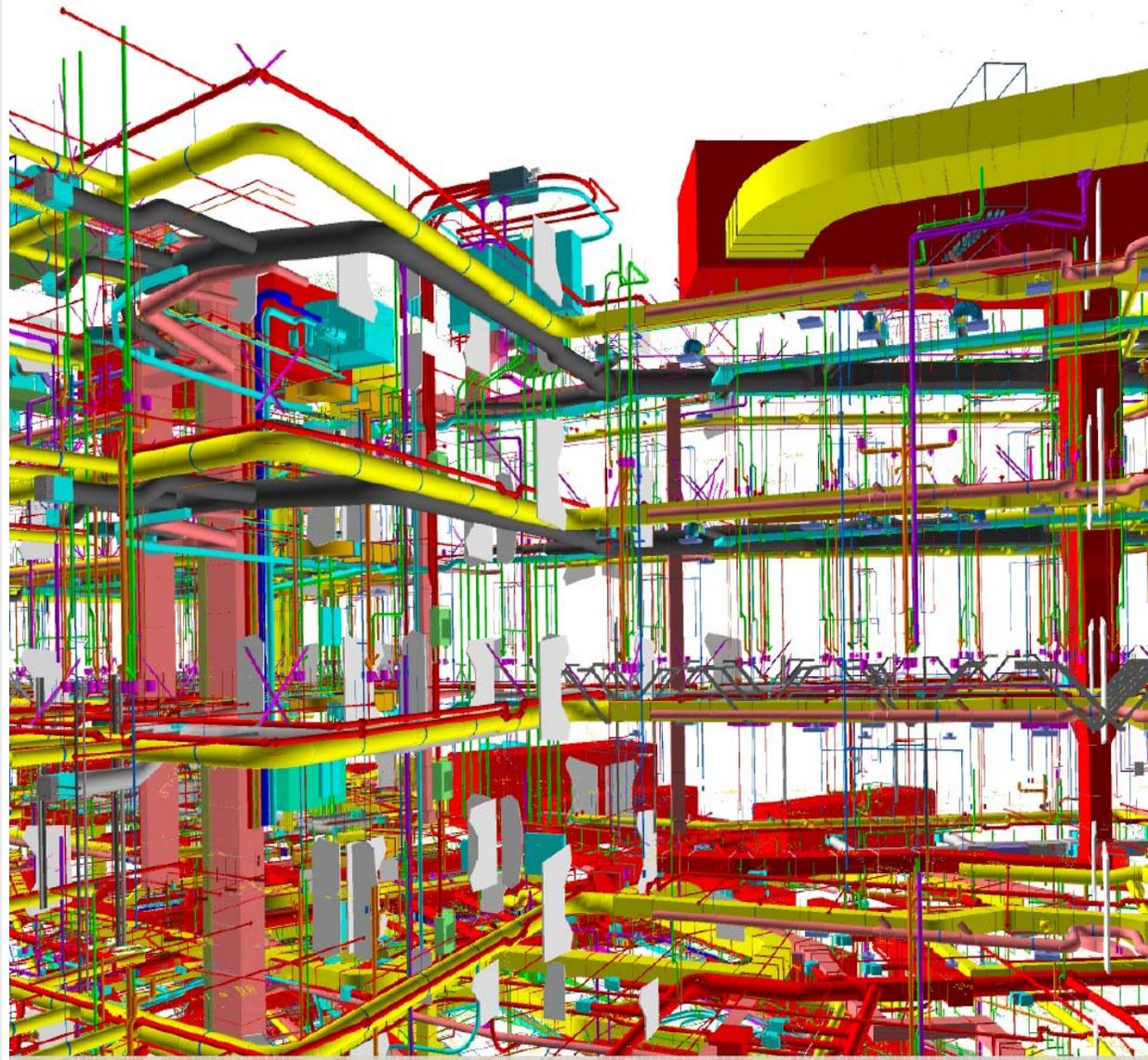
Building Information Modeling

The team has been working to establish workflows that will facilitate direct digital exchange and design to fabrication without having to recreate the information generated in the design models during construction. There is no pre determined criteria for what should be included in the model and at what level of details. The team continuously evaluates the design and adds new systems to the model if the team determines that those systems are required to increase certainty in the design.

Various software 3D tools are being used including: Revit, CAD Duct, CAD Pipe, AutoCAD Civil 3D, AutoCAD MEP, CAD Sprink, Teckla, and MWF, among others.

The following facility systems/components are included in the model:

1. Building interior
2. Building exterior, curtain wall and pre-cast
3. Stairs and elevators
4. Structural steel and concrete
5. Slabs and slab openings
6. All mechanical and plumbing systems
7. All electrical systems including conduit
8. Fire protection
9. IT and low voltage systems
10. Nurse call systems
11. Furniture
12. Fixed medical equipment
13. Rebar detailing
14. Foundations
15. All underground utilities
16. Civil site
17. All seismic restraints
18. Drywall Framing



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Model-Based Estimating

With speed and accuracy of real-time information being critical, the general contractor needed to provide regular cost feedback to changes made by the design team. Automating cost estimating allowed the contractor's estimating team to generate cost estimates more frequently and in less time (weekly compared to once every month). The estimating team used Innovaya Visual Estimating to map the BIM objects with their respective cost assemblies in Sage Timberline Estimating – See right.

To automate the estimating process, a perfect mapping was required between the model objects and the cost assemblies. This was made possible by a collaborative effort between the Architects, Structural Engineers and the Contractor's Estimators, where the estimators modified their cost assemblies in Sage Timberline and designers added object properties specific to these cost assemblies changes. The designers created the model in accordance with the Contractor's "Modeling Guidelines for Cost Estimating" document. The result is shown in Figure 2.

Once this mapping between the objects and cost assemblies was established, it became possible for both the Estimator and GC's BIM engineer to estimate the cost associated with the model elements weekly and share the quantity and cost variation with the project team.

Benefits

Generating estimates from the model at shorter intervals helped bring all team members quickly up to speed on the status of the design and quantity output from the model.

The time and labor it traditionally takes to do manual takeoffs and estimates from a set of drawings was reduced from one month to one week, giving the team more time to focus on other areas, such as productivity rates, crew sizes and escalation factors.

Less paper was used. It was no longer necessary to print out a full size set of drawings for manual takeoffs.

3D Objects with properties; At Present: AutoCAD, Revit
In Progress: CAD-Duct/Mech/Pipe and Tekla

Timberline Cost Assemblies

Innovaya Visual Estimating

Estimated Items Highlighted in the Model

Mapping of 3D Object Properties with Timberline Assembly Line Items

Property	Value	Unit	Variable	Value	Unit	Mapping
Count	362		Quantity	1.000		
TimberlineAssemblyName	1 hr wall		Type of Structure	3.000		
TypeName	Interior - P4 - USG - ...		OSHPD?	Yes		
UnconnectedHeight	15.5	ft	Fire Rated Wall?	Yes		
CeilingHeightPartition01Arestudstobottomofceiling	Yes		Acoustic Wall?	No		
Drywall01AcousticWall	Yes		Wall Length'	4,012.879	lf	Length ()
ShaftWall01Adddeckclosure	No		Wall Height'	15.500	lf	UnconnectedHeight ()
Drywall02CeilingHeight	10	ft	Ceiling Height'	10.000	lf	Drywall02CeilingHeight ()
Drywall04CountDrywallLayers	2		# of Drywall Layers	2.000	ea	Drywall04CountDrywallLayers ()
Drywall05CountLayersTaped	2		Stud Calc Method	2.000		
Drywall06StudGauge	16		Stud Size	400.000		Drywall07StudSize ()
Drywall07StudSize	400		Stud Gauge	16.000		Drywall06StudGauge ()
Drywall08StudSpacing	16		Stud Spacing"	400.000		Drywall07StudSize ()
Length	4012.879	ft				
DoorOpeningCount	230		Taping Condition	2.000		
WindowOpeningCount	66		Taping Method	3.000		
			# of Layers Taped	2.000	ea	Drywall05CountLayersTaped ()
			Slip Track Required?	Yes		
			Type of Slip Track	2.000		
			# of Wall Segments	362.000	ea	Count ()
			Corner Factor	0.750		
			Additional Studs			
			Waste Factor %	10.000	%	
			# of Door Openings	230.000	ea	DoorOpeningCount ()
			# of Window Openings	66.000	ea	WindowOpeningCount ()
			# Rows of Backing	3.000	ea	
			Type of Backing	2.000		
			# of HVAC Openings			
			Percent of Level 5 Finish	45.000	pct	

DPR Object Properties added by Designers in Revit Model

KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Model-Based Estimating

The process also allowed for rapid decision-making based on actual, real-time data. The project team, including the owner, had timely access to cost information on design changes and was able to evaluate which design options were most cost effective. The following example shows a cost comparison provided to the owner that helped determine whether all interior walls (other than fire rated and smoke rated) should be full height or ceiling height.

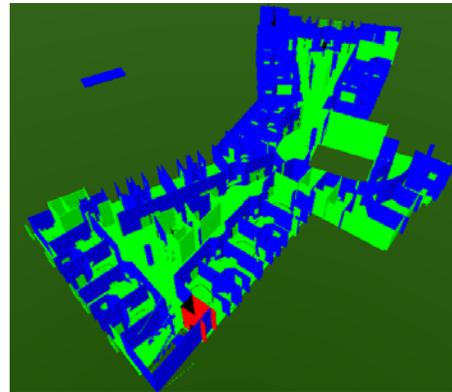
This cost comparison was done using the variance report functionality in Sage Timberline. This study helped the team conclude that any wall that is not fire rated or smoke rated should be made ceiling height and not full height as it was more cost effective. Even though diagonal braces were an added cost for ceiling height walls, the reduction in metal stud material, framing and drywall labor, and the reduced need for scissor lift equipment outweighed the diagonal bracing cost. Ceiling height walls could be built at 11 feet, where full height walls would have varied from 16 to 19 feet.

To the General Contractor's knowledge, this is the first instance of Model Based Estimating using Innovaya being executed on a large California Office of Statewide Health Planning and Development (OSHPD) hospital project. The GC worked hand-in-hand with Innovaya to tailor the technology for the needs of this project, which also resulted in some key improvements in the software. One example of a key improvement is being able to segregate cost by the Work Breakdown Structure, by enabling WBS code mapping with 3D objects on the project.

Model-based estimating also facilitated the team's focus on Target Value Design, where the design is tailored to the cost based on more accurate, and timely cost feedback on a bi-weekly basis.

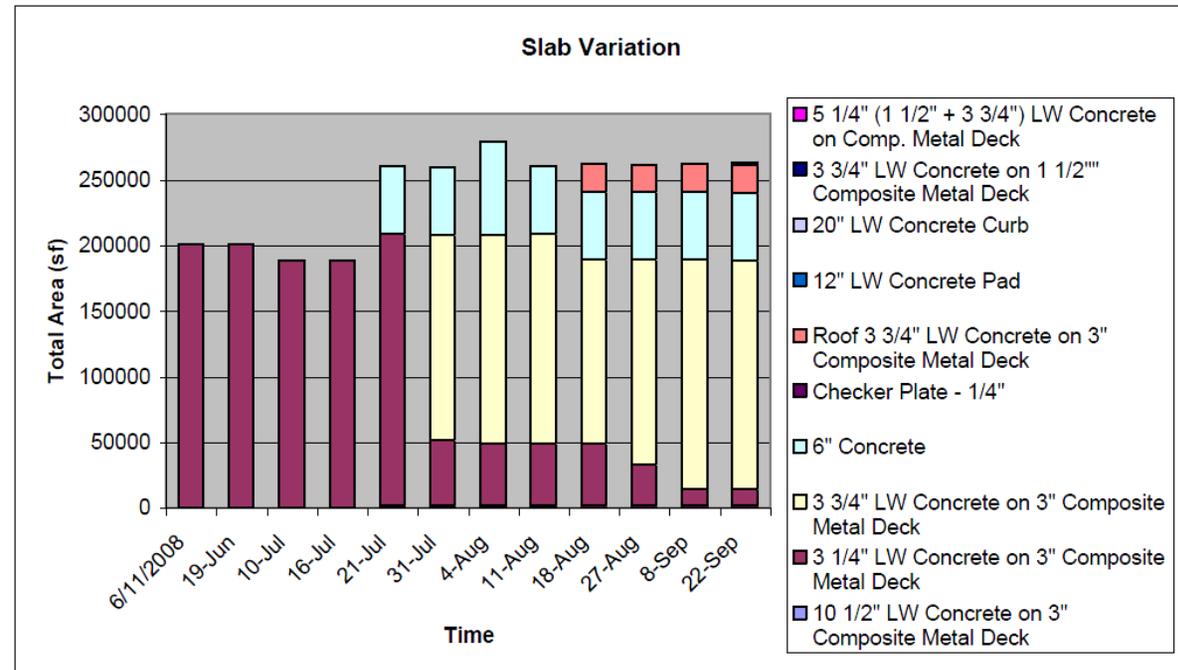
Variance Report

	Unit Cost			Amount		
	CeilingHt_Report/Version	FullHt_Report/Version	Variance	CeilingHt_Report/Version	FullHt_Report/Version	Variance
Estimate Totals						
Labor	94,581.196hrs	99,113.543hrs	-4,532.347hrs	7,324,519	7,672,694	(348,175)
Material				2,526,753	2,575,697	(48,944)
Subcontract				135,481	135,481	0
Equipment	515.920hrs	816.560hrs	-300.640hrs	155,588	176,231	(20,643)
Other				19,106	18,496	610
				<u>10,161,447</u>	<u>10,578,599</u>	<u>(417,152)</u>
Total				<u>10,161,447</u>	<u>10,578,599</u>	<u>(417,152)</u>



This feature helped the team visualize the differences between model updates for what was deleted, modified, added from the previous weeks model.

SMCCV STRUCTURAL QUANTITY TRENDING



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Direct Digital Exchange for M/P

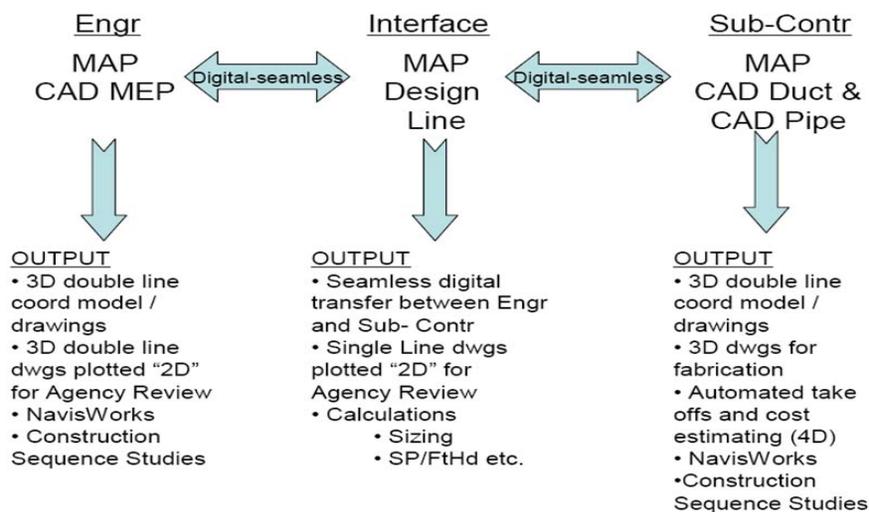
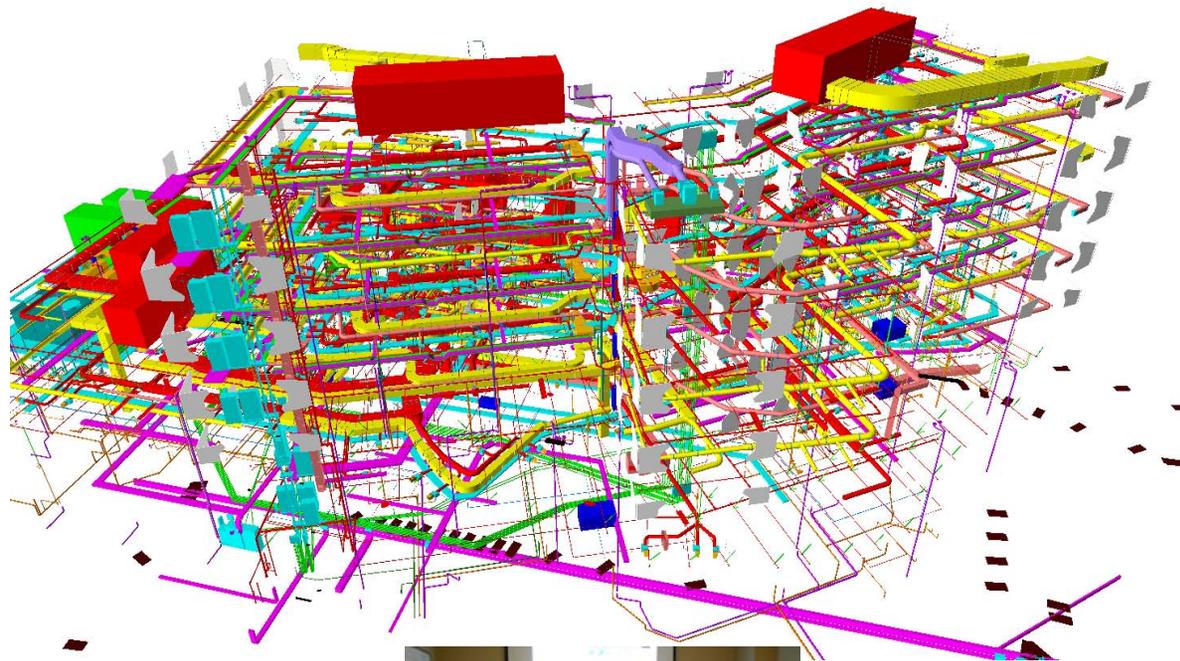
The Mechanical/Plumbing team set an aggressive goal from themselves to design, detail, estimate, coordinate, and fabricate their systems directly in the 3D model with as little use of 2D drawings as possible.

The design team and the trade partners used the same software from TSI to design and detail the M/P components. This software has two modules one for use during design called MAP Design Line and the other typically used by the detailers called MAP CAD Duct for sheet metal & CAD Pipe for plumbing detailing and fabrication. This created an opportunity for using a complete digital and model based workflow from design to fabrication. Unfortunately there was no successful implementations to learn from as most teams that had tried to use this workflow in the past failed and abandoned this for a more traditional workflow.

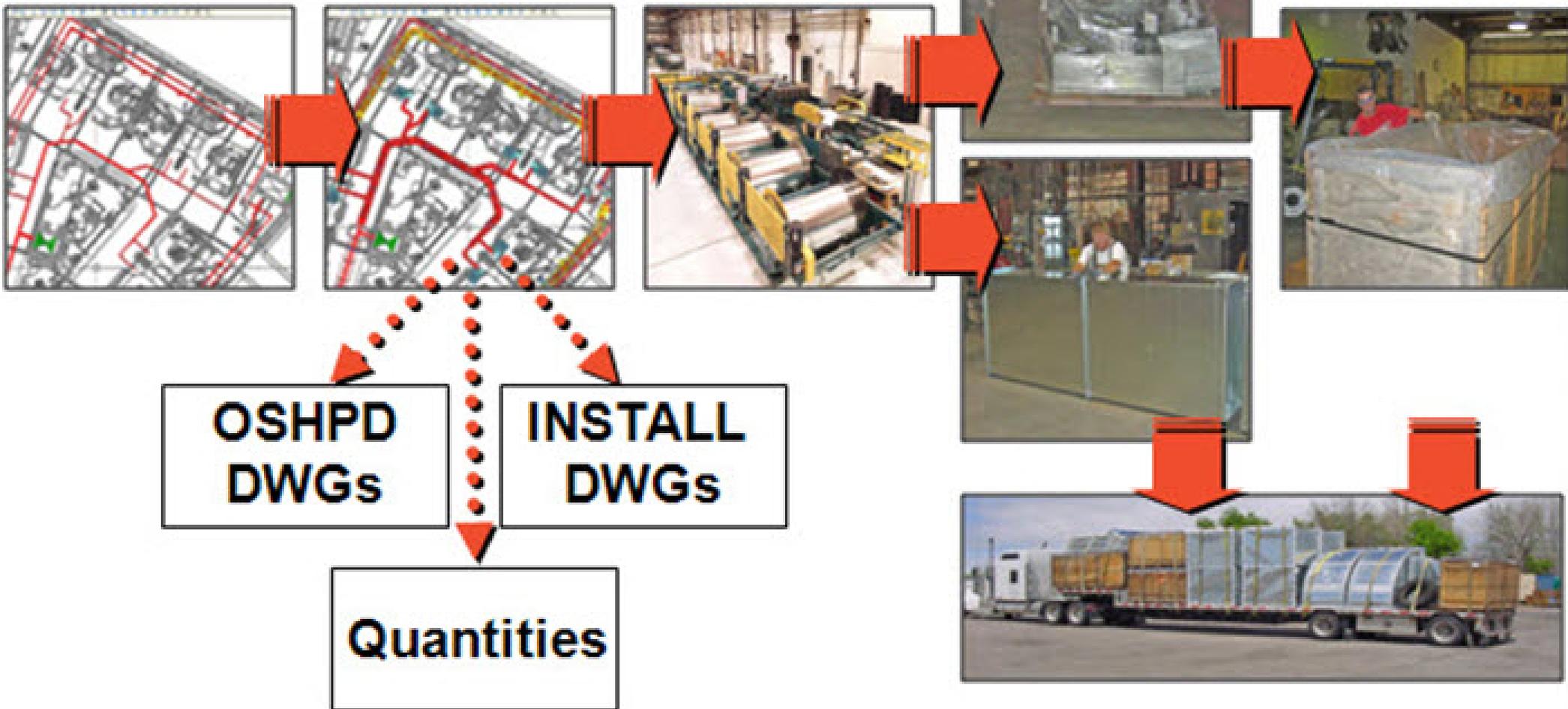
Determined to make this work, key members of the design team and the detailing team collocated for almost an entire week at the offices of TSI, the software vendor, in Austin, TX working with their technical team to align the setups, software libraries, and configuration options so that the design models can be directly imported by the detailers, worked on, and then converted back to simplified design models. The goal was to use the best features of the design modules to do early routing and calculations, then have the detailers immediately apply fabrication logic to the route then have the design team incorporate that input onto the final drawings without having to recreate models or drawings.

This template is now serving as template and being implemented for other parts of the model and the design including shared responsibility for completing the design and detailing of the drywall and exterior elements between the architectural design team and the trade partners.

The next challenge for the M/P team is to implement automated quantity takeoffs and automated estimating to the extent possible. There are software limitations that the team is working to resolve with TSI as well as established estimated practices that are difficult to change.



Single Coordinated 3D BIM used for multiple Purposes



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Immediate, Controlled, and Continuous Access to All Project Information

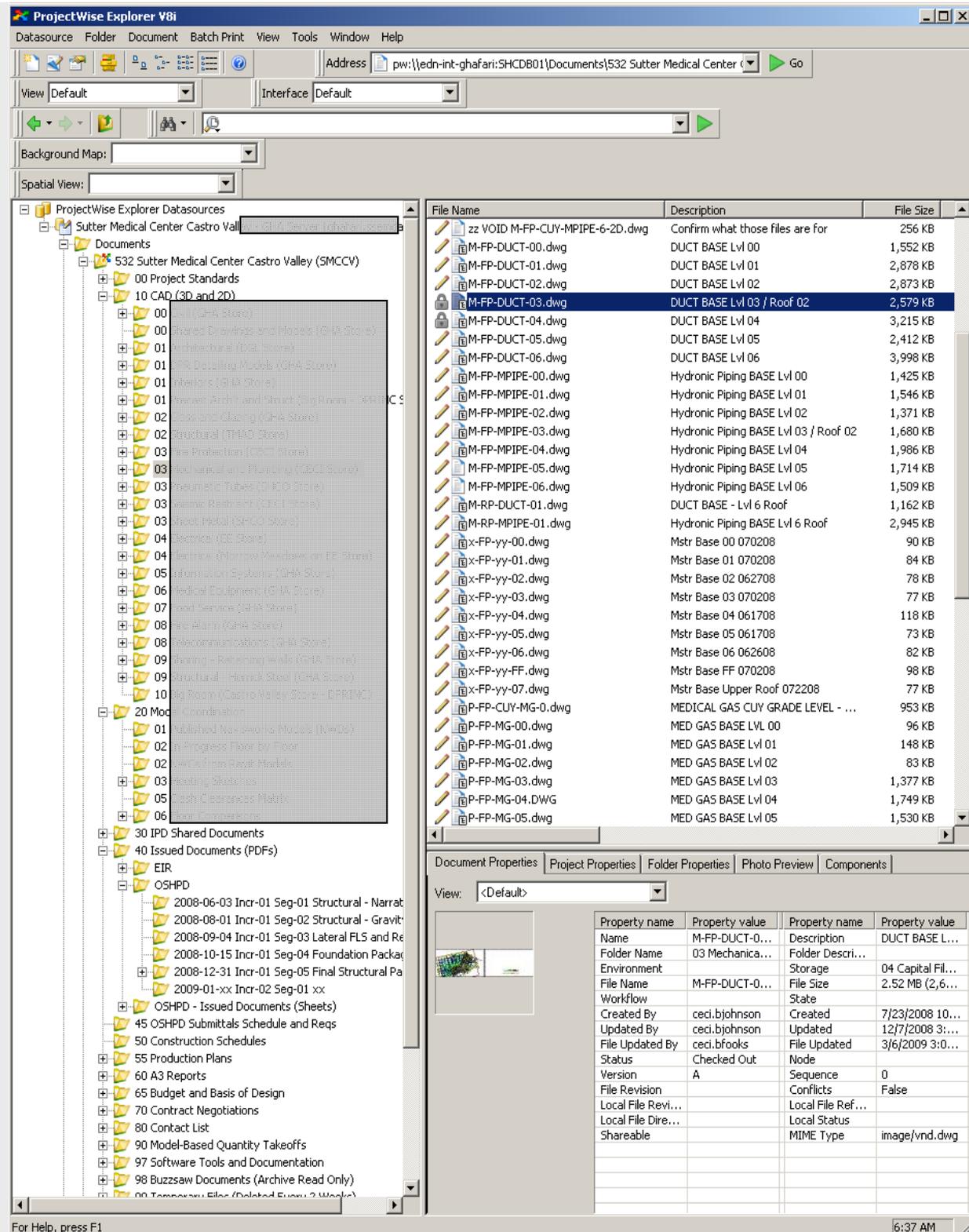
Given that the key team members were distributed in multiple office in various states, it became very important from the beginning to design a method for the team to have full and real time access to all project information and models regardless of location.

Portal solutions where models and files are worked on locally and then a copy is uploaded to a shared site so that other team members can download do not promote close collaboration and cross office VPN solutions are not practical.

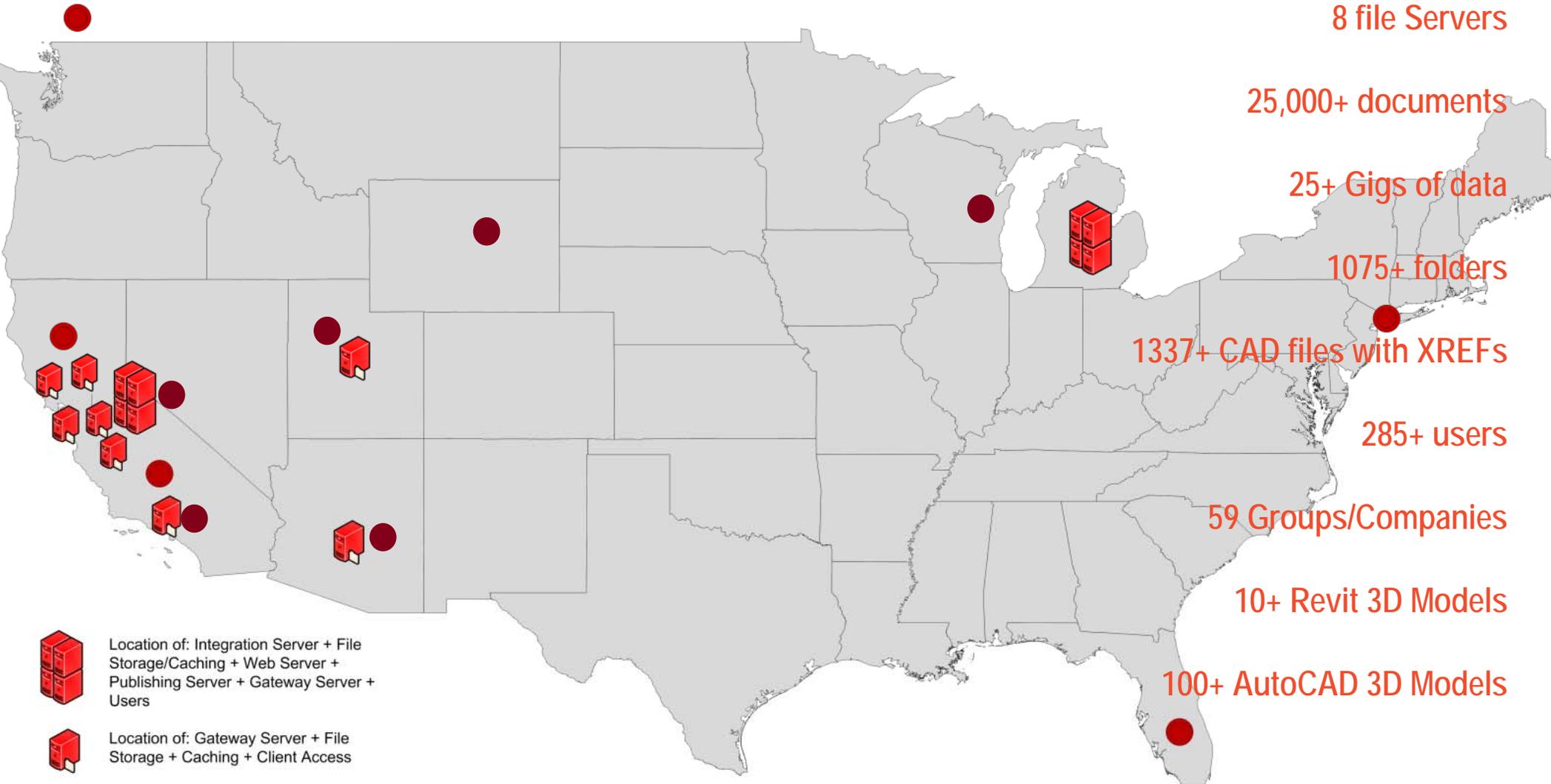
The team is currently using ProjectWise from Bentley Systems (a distributed client/server document control system) that allows each team to keep their files stored locally on their server yet provide direct and controlled access to those same files to all other team members. By strategically locating ProjectWise Caching servers at the various offices, the system automatically synchronizes those files across the network so that any team member can have the exact same view of the project files regardless from the location they access those files.

For shared project documents (especially CAD files), each team member who needs to modify a file will check out the file to work on it then check it back in when work is complete so that it is immediately available to all other team members who need the changes. The system manages the references between files and insures that when a team member views or works on a file that they receive the most up to date copies of the file and its references regardless where those files are stored on the network, transferring only the changes made to those files to optimize download times.

Currently there are over 14,000 files and over 21GB of data that is distributed on the various servers and accessible from any location to all team members.



DATA EXCHANGE NETWORK



Location of: Integration Server + File Storage/Caching + Web Server + Publishing Server + Gateway Server + Users



Location of: Gateway Server + File Storage + Caching + Client Access

Latest copies available to the team at any time and from any location

KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

BIM and Interoperability Challenges

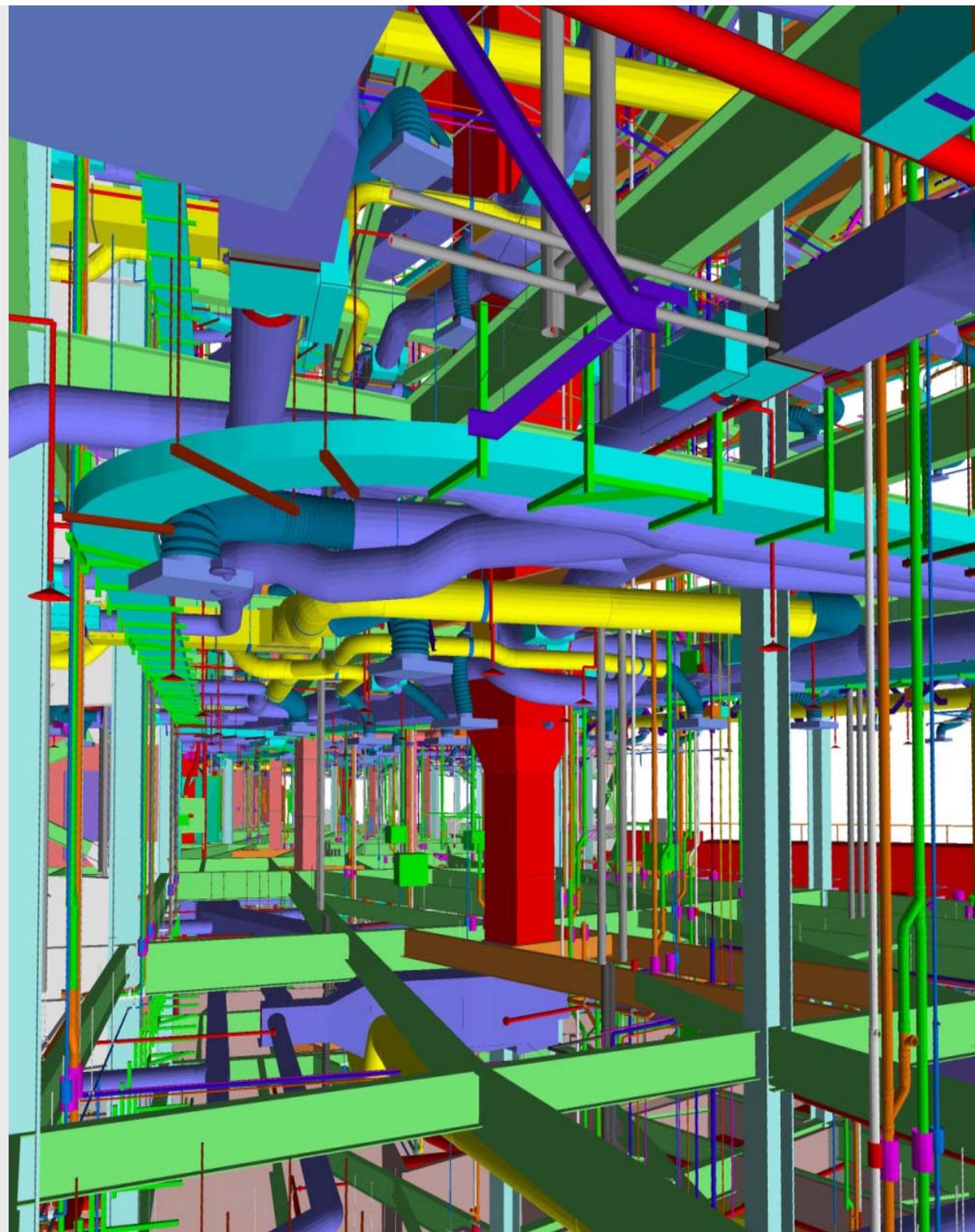
The team is always reminded that their goal is to design for fabrication not to simply use BIM especially when they run into technical problems and tend to default back to traditional workflows.

The architectural team when they started to run out of memory due to increasing model complexity rather than defaulting back to standard workflows of simplifying the design (which goes at odds with design to fabrication), had to split their model into smaller models and had to do that twice during the development of the design as the complexity of the model after the first split continued to grow beyond software and hardware limitation. The team had to think hard about strategies for model creation so that they can continue to add detail required by other disciplines for detailed coordination.

The GC and the architect are exploring workarounds so that the GC's detailing team can have access to the architect's model during design to add top of wall details and refine the elevations of walls in the model. Currently it is not possible nor recommended to share Revit files directly over the network.

The MEP team are AutoCAD based while the architectural and structural teams are Revit based. For a cross discipline team this created cross platform interoperability challenges and almost impacted the team's ability to deliver the project. Workarounds continue to be explored to lessen the impact of the lack of interoperability between AutoCAD and Revit especially when it comes to exchanging highly detailed 3D model information.

Direct model based estimating remains to be a goal that the team strives to achieve. Despite successes in pulling architectural and structural quantities from the model, the estimating team continues to also do manual takeoffs to validate model based quantities. The M/P team continues to work on changing workflows and resolving software limitations so that they can take full advantage of the detailed information they are building into their 3D models.



KEY LEARNINGS, SUCCESSES, AND LESSONS LEARNED

Some Early Results

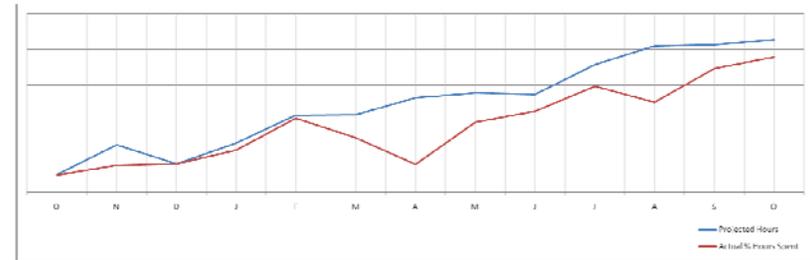
PLANNING AND PREPLANNING: both are fundamental skills for any IPD project team. Both require investment in time and resources but are critical to insure proper alignment of work expectations. Careful planning of the design tasks and the team's ability to identify the last responsible moment to release work for production allowed the design to evolve with as little rework as possible. This allowed the team to produce a highly coordinated design using less time and resources than they would have been able to produce otherwise.

MODEL BASED COODINATION: the team using the collaborative 3D model design review process was able to identify and resolve hundreds of cross discipline design issues much earlier than can be achieved using 2D processes including elevator design, stair coordination, ceiling space coordination, among many others.

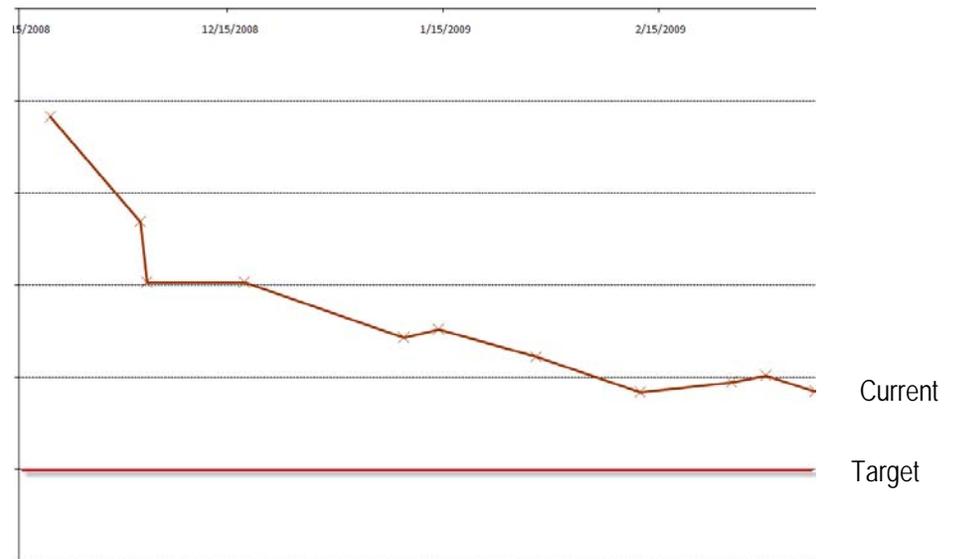
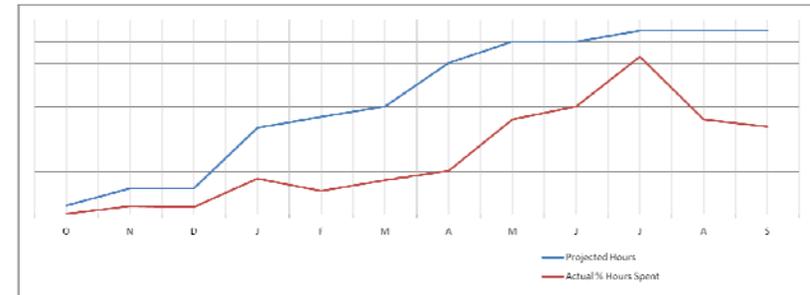
TARGET COSTING: As the team aligns their assumptions and gain confidence in the coordinated design the overall project budget continues to trend down towards the target cost without having to value engineer the design. (see next page)

THERE ARE NO MINOR DESIGN CHANGES: the team is learning that small design changes that one team might consider minor, might cause significant problems for other disciplines. The team is learning to break away from the traditional design then check workflow to a more proactive approach where potential changes are communicated to the cross discipline team, options are explored early, and solutions with the least cross discipline impact are selected for further refinement.

SHARING INCOMPLETE SOLUTIONS: the team is also learning that it is acceptable and actually better to share an incomplete solution than to wait until they are done with the design. By sharing incomplete solutions, they are able to get more frequent feedback from the assembled IPD team and to incorporate that input into their thinking early rather than having to go back and rework a design after it is completed.



Monthly trending of architectural design hours against baseline



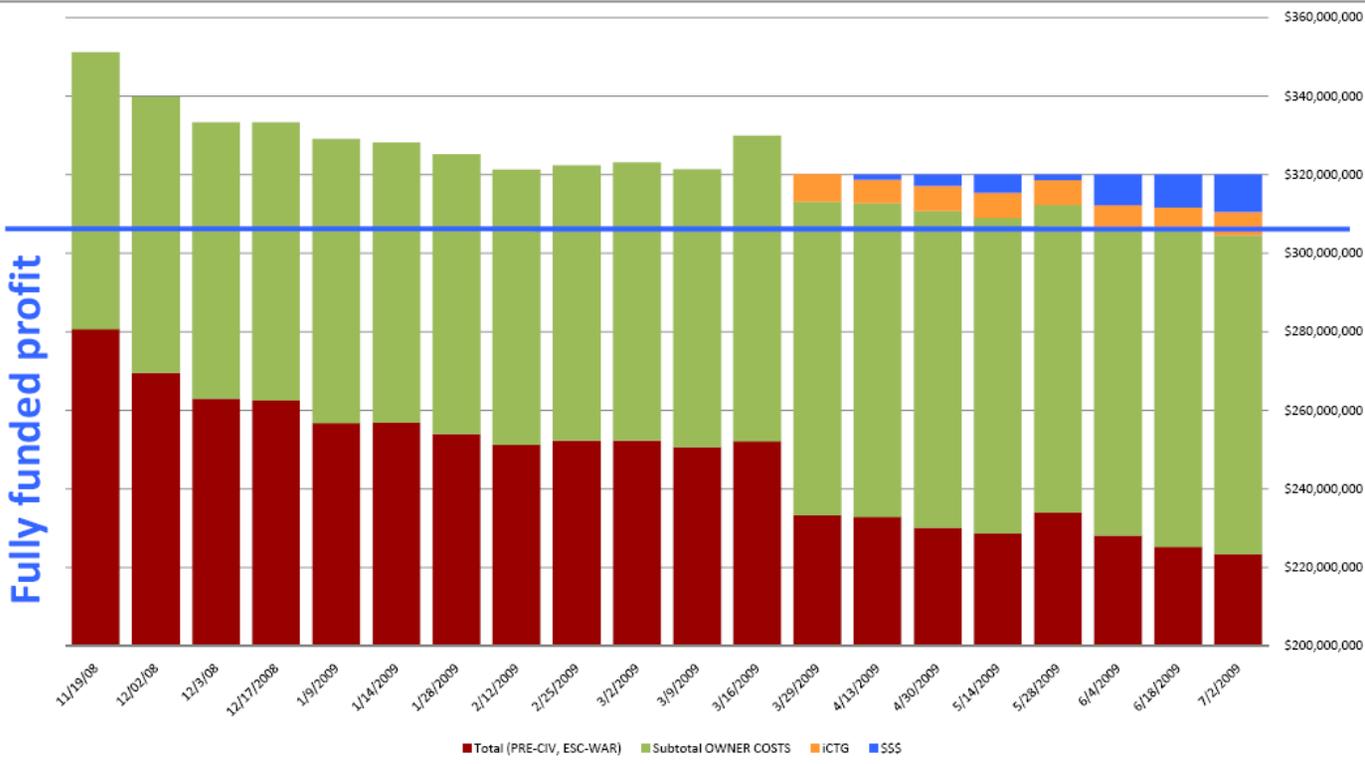
Monthly trending of overall project budget towards the target budget.

Sutter Medical Center Castro Valley

Target Value Design

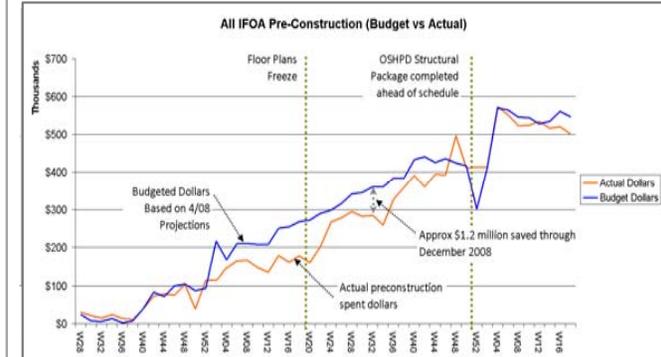
Total Construction Budget Update

Update Date: July 2, 2009

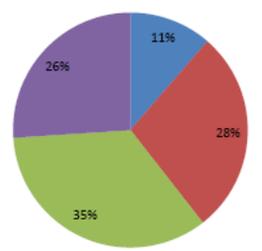


Total Construction Budget Information

Budget Target	\$ 304,983,194
Current	\$ 310,540,418
Cost Reduction Required	\$ 5,557,224
Cost Reduction Targeted	\$ 5,200,000

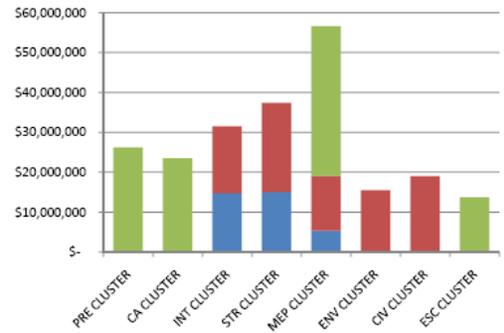


Estimate Source



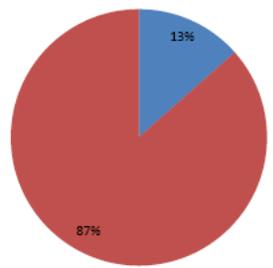
- Model Based Estimates
- Manual Based Estimates
- Conceptual Based Estimates
- NON IFOA CLUSTERS

Estimate Source



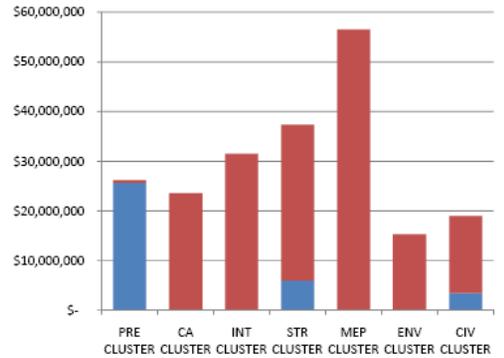
- Model Based Estimates
- Manual Based Estimates
- Conceptual Based Estimates

Project Cost Commitments



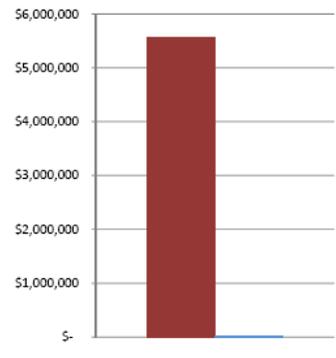
- Committed Costs
- Uncommitted Costs

Committed Costs

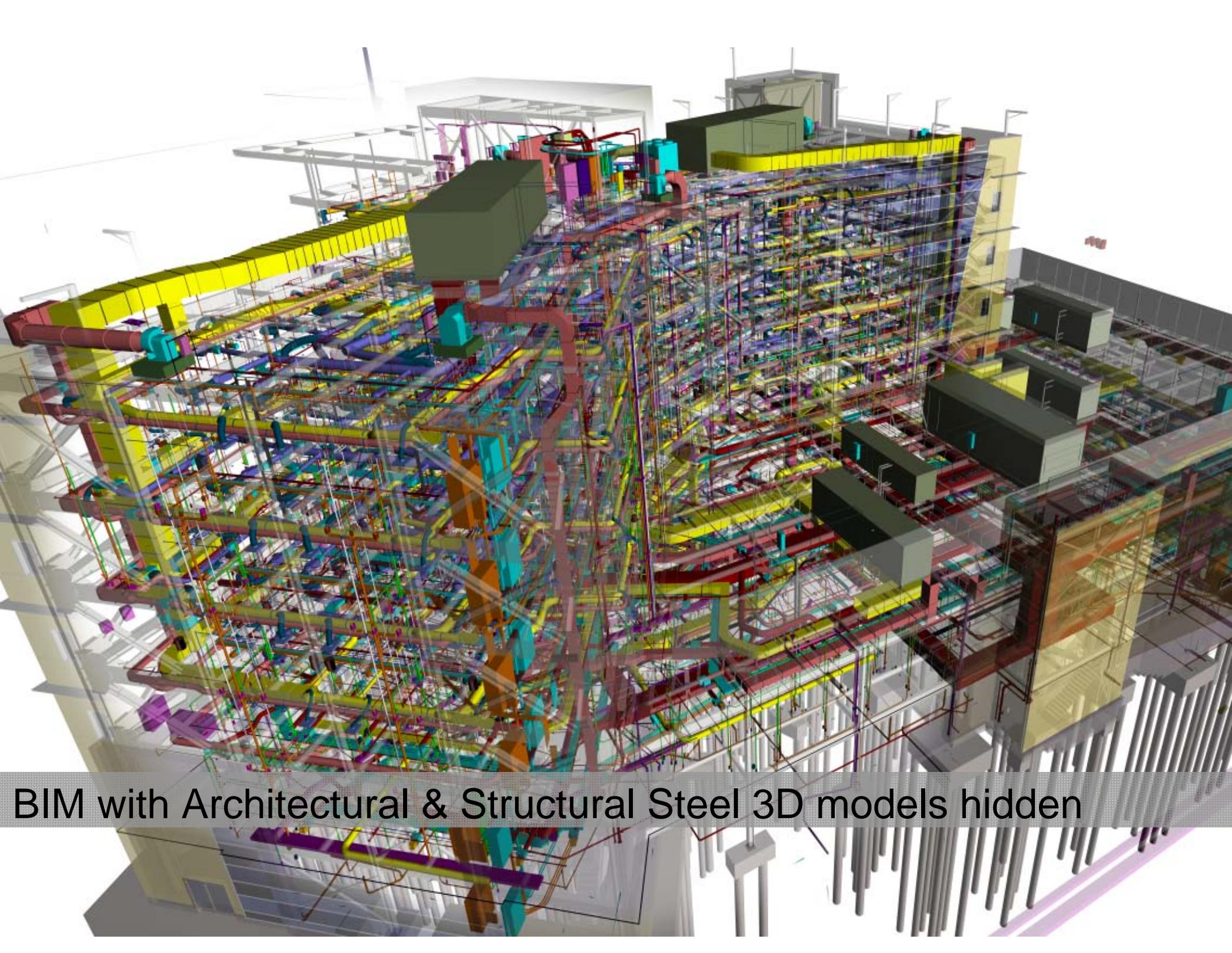


- Committed Costs
- Uncommitted Costs

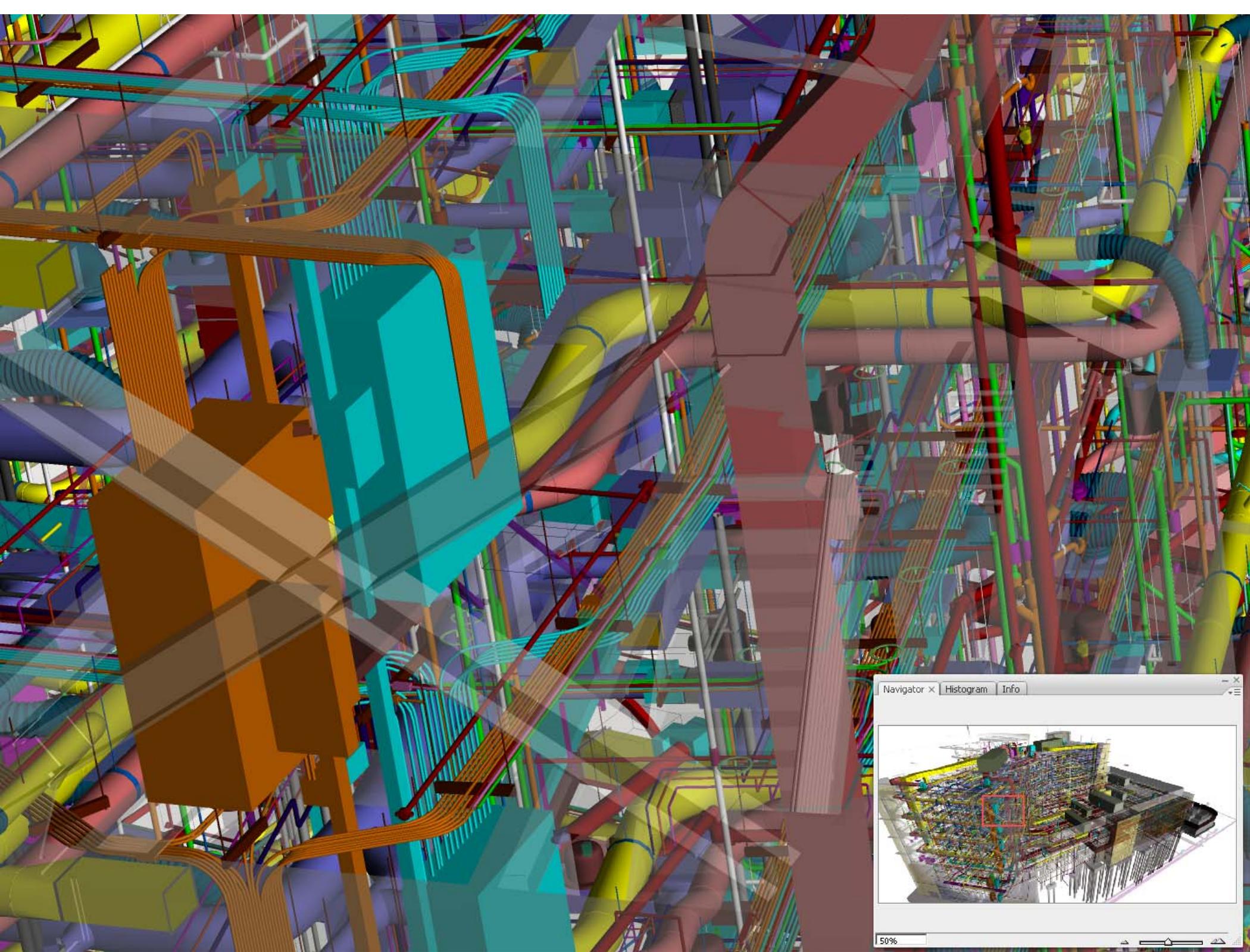
Targeted Cost Innovations

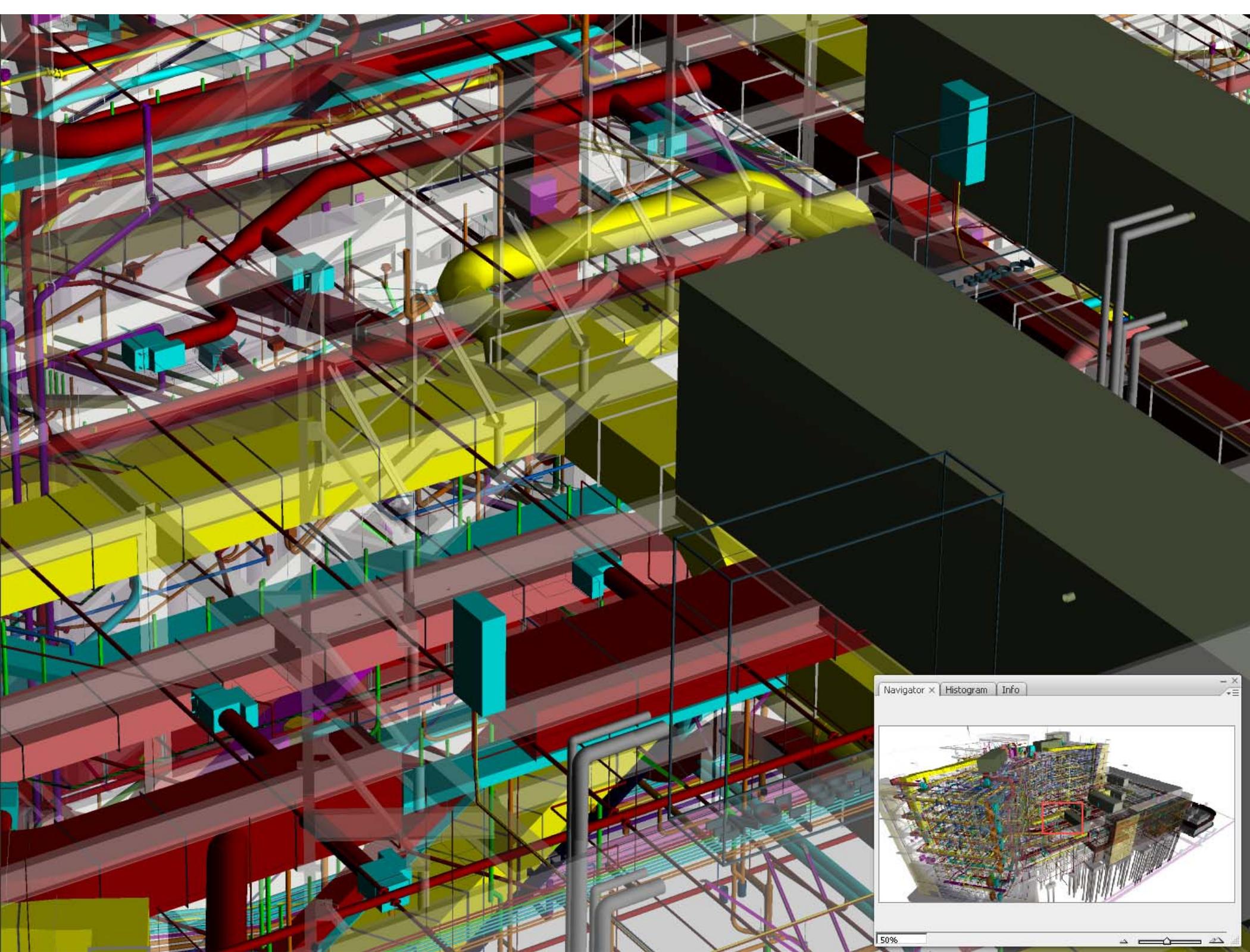


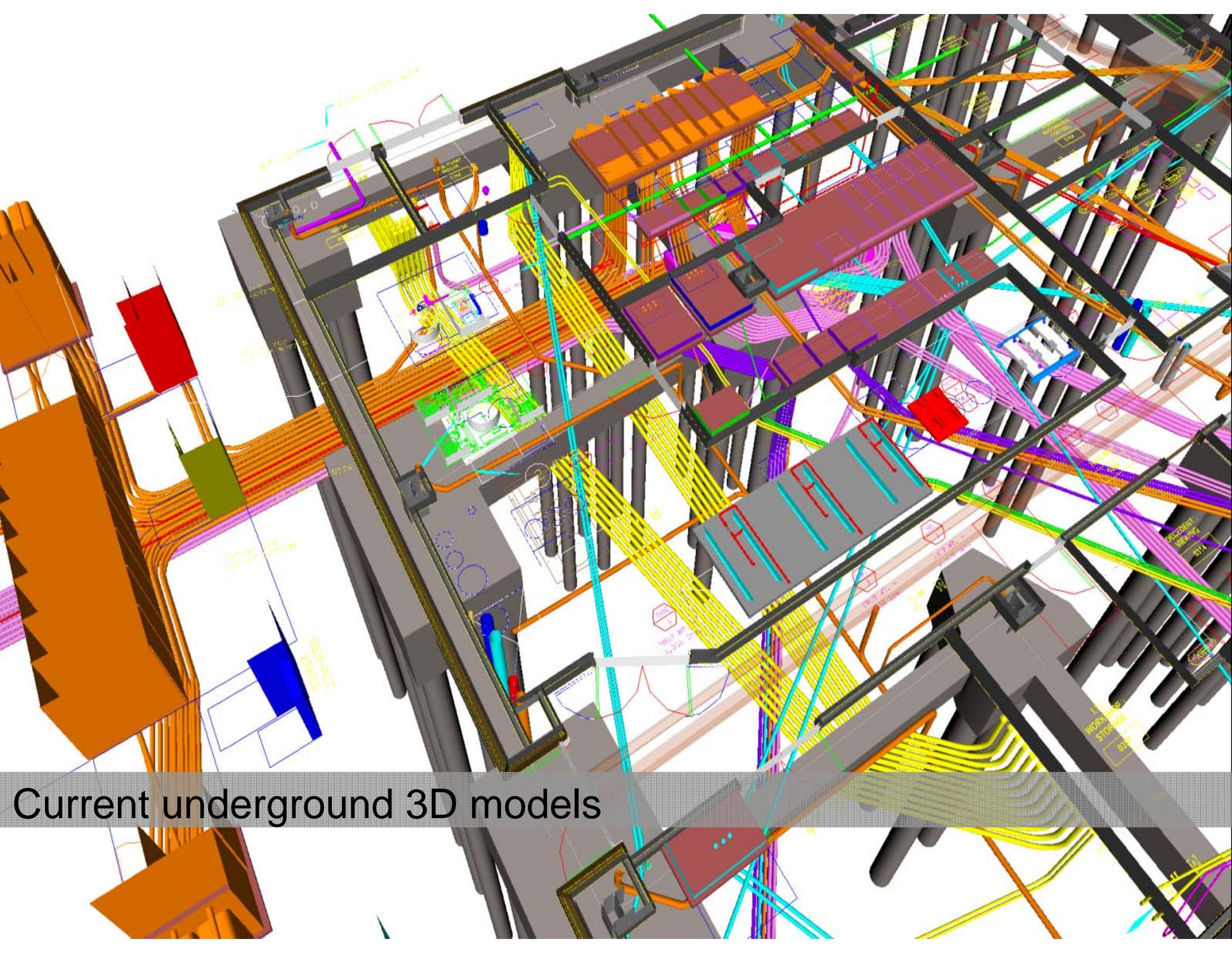
- Over/(Under) Budget Amount
- Cost Innovations/Exposures



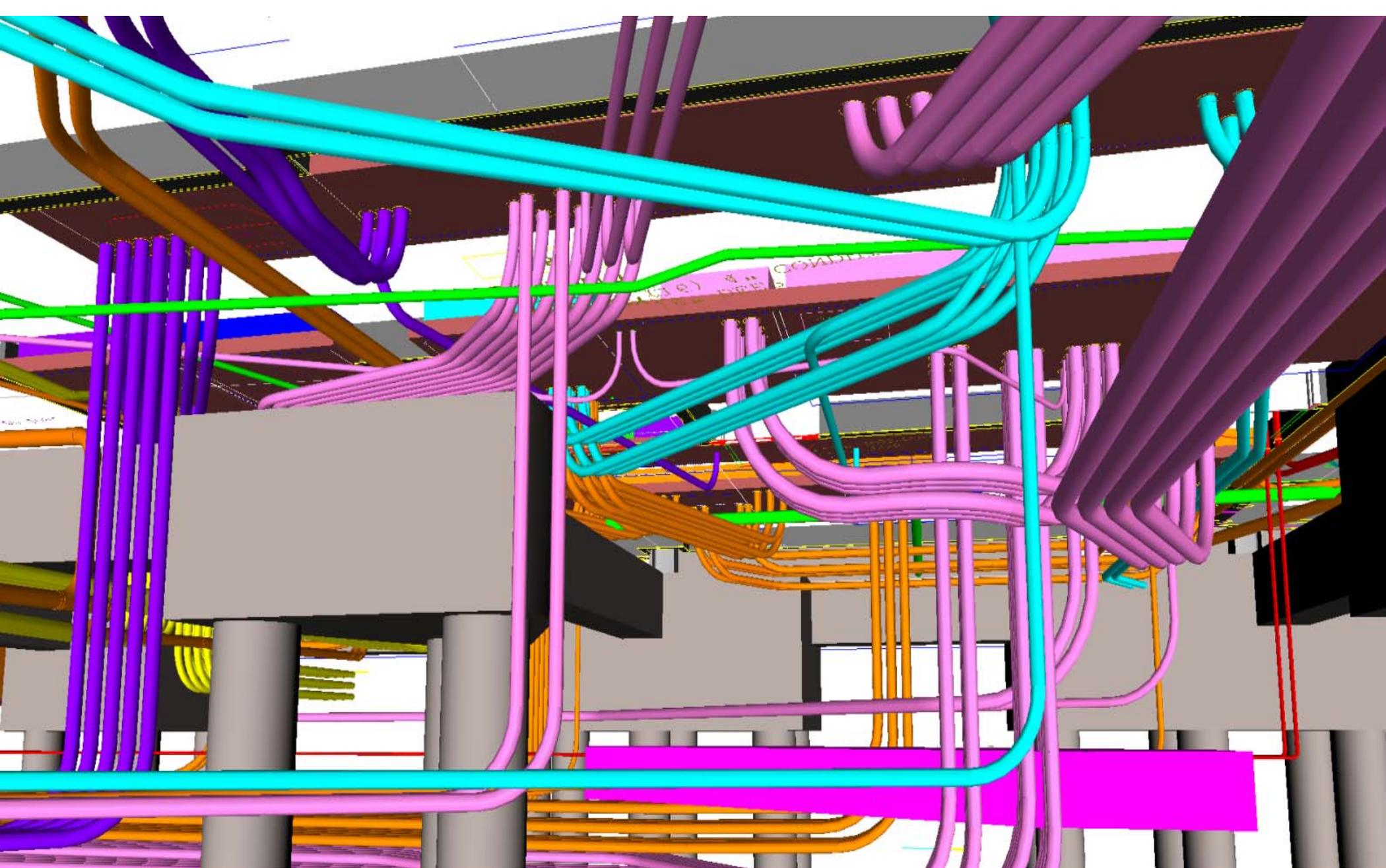
BIM with Architectural & Structural Steel 3D models hidden







Current underground 3D models



Current underground 3D models



Photo-match of 3D models to construction progress – Feb 2010