

### 3D-Enabled/Lean Design/Construction

Over five years ago the World Wide Facilities Group (WFG) of General Motors (GM) began working with GHAFARI Associates, LLC on what was then called Virtual Factory - an initiative to bring the same lean (waste eliminating) and 3D math-based advantages to construction that their product colleagues had achieved for vehicle development – where waste currently accounts for 26% of the manufacturing value stream versus 57% of the construction supply chain. After pioneering the techniques with the Design/Build team over three projects, GM WFG Executives are passionate that the use of 3D BIM catapulted their facility lean efforts toward manufacturing levels of efficiency.

WFG continues to drive 3D-Enabled Lean for project-to-project benefits built around a highly collaborative, teaming approach requiring the collocation of owner, Architect/Engineer, General Contractor, subcontractor and fabricator partners to facilitate 3D model-based decision making and schedule acceleration. (Project One: Lansing Delta Township – GC: Alberici Constructors, Inc.; Project Two: Global V6 Engine – GC: Ideal Contracting).

The D/B Team has made particularly good progress on eliminating waste along the design/fabrication/construction supply chain by replacing 2D drawings with bi-directional digital exchange with fabricators and subcontractors to assemble a 3D install level (near as-built) facility model for on-board model reviews for design integration, automated collision detection, constructability reviews and value engineering. (*Exhibit A*).

The second manufacturing project in the 3D-enabled series was so successful that it was spotlighted as the cover story for the Oct. 10, 2005 issue of Engineering News Record (ENR).

This project, using a 3D-enabled lean and automated collision detection approach (*Exhibit B*), was delivered with NO field interferences for a 5+% cost savings, 50% reduction in RFI (Request for Information), reduction in owner changes, 15% ahead of schedule with virtually no field overtime - all supporting a safer and greener construction site. The use of direct digital exchange accelerated steel mill order placement by 67% while 2D drawing generation has been minimized and generation/handling/review of shop drawings significantly reduced since reviews can now be done within the model environment.

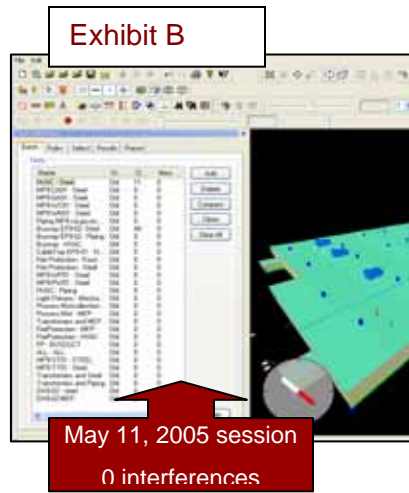
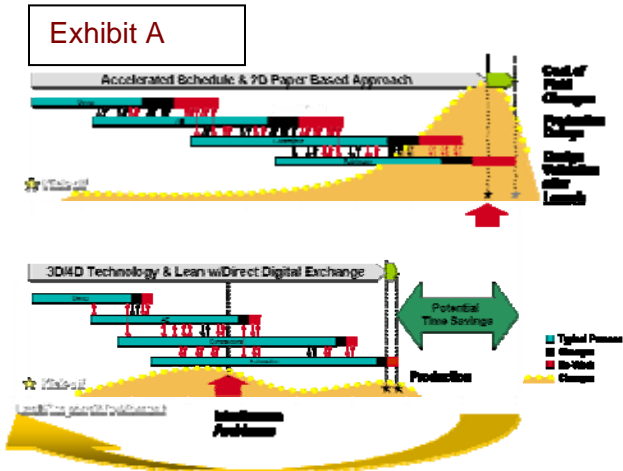


With use of off-site fabrication the HVAC ductwork used model data to drive CNC equipment and cut to exact lengths (no scrap). Fabricated components were then subassembled, shipped and installed Just-In-Time (subcontractor had no lay-down area at site). (*Exhibit C*).

Subcontractors were, literally, "building-to-the-model" (*Exhibit D*) with the confidence and pride of workmanship in knowing that the model derived solution was collision free. Overall the job site produced less clutter (with increasing use of off-site fabrication), encountered less trades overlap, and benefited from improved trades morale with rework virtually eliminated.

Recognizing the significance of the gains in adopting a manufacturing inspired 3D enabled/lean approach to the design/construction value stream, GM WFG and GHAFARI have co-presented at several National forums including: CURT (Construction Users Roundtable), U.S Chamber of Commerce, AISC (American Institute of Steel Construction) and SMACNA (Sheet Metal & A/C Contractors of N. A.) - hoping that these real project results will inspire the construction industry to embrace the same lean methods and technologies already deployed by in more progressive industries such as aerospace, manufacturing, and electronics.

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- 11-29-2004 - 3D Design Review
- 12-06-2004 - 3D Design Intent Model Reveal
- 01-06-2005 - 3D Integration Meeting
- 01-10-2005 - 3D Integration Meeting
- 01-18-2005 - 3D Integration Meeting - FAB Steel 50%
- 01-25-2005 - 3D Integration Meeting - FAB Steel 80%
- 01-31-2005 - 3D Integration Meeting
- 02-07-2005 - 3D Integration Meeting - FAB Steel 100%
- 02-14-2005 - 3D Integration Meeting
- 02-17-2005 - 3D Integration Meeting
- 02-22-2005 - 3D Integration Meeting
- 02-24-2005 - 3D Integration Meeting
- 02-25-2005 - 3D Integration Meeting
- 02-28-2005 - 3D Integration Meeting
- 03-03-2005 - 3D Integration Meeting
- 03-08-2005 - 3D Integration Meeting
- 03-10-2005 - GLOBAL V6 ENGINE FACILITY - IFC MODEL
- 03-21-2005 - 3D Review Proposed ISS Platform Changes
- 04-07-2005 - Proposed Process Changes
- 04-14-2005 - 3D Review - DESIGN CHANGES
- 05-02-2005 - GLOBAL V6 ENGINE FACILITY - IFC MODEL - R1

Exhibit C

Lean Principles – Design for Manufacturing  
*HVAC Sheet Metal – JIT Delivery*

