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"Revolutionary Improvements in Cycle Time and Cost Through Virtual Product Development"

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Lockheed-Martin (L-M) employs 147,000 people. Its 1999 sales were \$25.5 billion. The company consists of 17 "legacy" companies and has facilities throughout the United States. Three major facilities include Marietta, Georgia, which makes the forward fuselage and does final assembly for the F22 (Raptor), Fort Worth, Texas which is headquarters and makes the F16, the Fighting Falcon and the mid fuselage for the F22, and Palmdale, California which makes the SR71 (Blackbird), F117A (Stealth), and U2. Lockheed-Martin is currently working on a preliminary design for the Joint Strike Force (JSF), which is a new generation plane for all of the U.S. military services as well as the U.K. Royal Navy. The JSF is potentially a \$200 billion contract. The company reorganized recently into four major business units, Technology Services, Space Systems, Systems Integration, and Aeronautical Systems. The Virtual Product Development Initiative (VPDI) was launched within Aeronautical Systems. L-M and Boeing won design contracts for JSF. L-M expects VPDI to help win the JSF production contract.

VPDI began in 1995 as a revolutionary approach to integrate lean production processes, leading-edge simulation technology, and enterprise data management. These three phases create what L-M calls the "Virtual Design Environment"

The first phase of VPDI was to introduce lean production processes so that the sophisticated software to be introduced would be applied only to the most efficient production process.. One step was to introduce as much engineering concurrency as possible into the product development process. L-M has partnered with Northrop-Grumman and British Aerospace on the JSF. They have agreed on a single set of "maturity gates" or exit criteria for their respective designs for the JSF and on a single solid 3-D model for product definition that would be used by design and manufacturing engineers. ARIS provided a data management architecture for the product development process. It defines process steps and data elements, delineates responsibilities, and facilitates data integration between the various phases.

Simulation tools from DENEb of Troy, Michigan were used in several product development phases.. For example, IGRIP creates a virtual robot that can interface with a virtual airplane part, e.g., vertical stabilizer, to develop a program that will drill holes in an actual part. Such programing was done manually previously, and kept an actual robot off-line for as much as two weeks. IGRIP can reduce this time to six hours, and has produced a savings of \$4 million. Envision and ERGO are two other DENEb simulation tools. Envision develops sequences by which parts can be assembled. ERGO assesses these sequences to assure that they do not cause physical stress and strain to workers who have to assemble these parts. Vericut is used to program NC machines to develop optimal cutter paths, and avoid machine collision, etc. These tools have been shown to reduce first-run scrap rates, trial runs, and robot downtime. QUEST is another DENEb tool which simulates factory layout, resource availability, passage of time, capital utilization, floor space, etc. DENEb also has simulation software to assess support and operations. For example, VEGA is used to assess support needs in the field, e.g., stress loads for aircraft carrier landings.

Metaphase by SDRC is the product data management software that L-M uses to organize and retrieve all of the data that the simulations produce. The overall product structure can be broken down into parts, and then into simulation files for each part. Each file can be assessed by a double-click on the file name. Graphic models of each part and simulations can be assessed in the same

way. A simplified version of the software exists if files only need to be viewed, but not changed. L-M, Northrop-Grumman, and British Aerospace have developed standard interfaces between the mid fuselage (N-G and BAE) and forward fuselage (L-M) for the JSF. The same standards apply to the interface between selected parts produced by each company. All three companies have agreed to use Metaphase for product data management. As BAE is a foreign national, L-M also has to comply with ITAR (International Trafficking in Arms Regulations) regarding what data on what parts can be exchanged. L-M has maximized the use of commercial off-the-shelf software for VPDI. The multidisciplinary team that has been assembled focuses primarily on its functional knowledge contributions.

L-M's efforts have demonstrated and validated simulation and virtual prototyping methods with very tangible results. The company has achieved significant benefits in reducing design cycles (two weeks to two days), analysis (two weeks to four hours), assembly simulation and visualization (two hours to fifteen minutes). Its simulation tools for NC programming and robot assembly have led to reduction of defects to three per million, which surpasses world-class standards.

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Last modified Sunday, 07-Oct-2001 21:52:40 EDT