The Shape of Things to Come

How AlliedSignal used stereolithography to save time and money on a helicopter gearbox prototype.

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Top: Distinctive square-hatch pattern of the QuickCast™ build style. Middle: Cutaway section of AlliedSignal's upgraded gearbox for the T55 engine. Bottom: Delphi Harrison Thermal Systems' SL masters for vacuum sand casting tools.

An engineer's responsibility for verifying a new design or product concept as manufacturable early in the development cycle is a tough challenge. What appears to work on a blueprint or in a three-dimensional CAD file on a computer screen may not work on the factory floor; and the downstream impact on the manufacturing process of an undetected design flaw can be enormous. Costs can run into the millions.

Increasingly, manufacturers are turning to stereolithography (SL) for rapid prototyping of new or re-engineered products to fully visualize, verify, iterate, optimize and test parts before making any commitment to hard production tooling. Developed by 3D Systems of Valencia, CA, the SL process enables transformation of a 3-D computer model directly into a tangible part using the combined technologies of computers, optical scanning, lasers and photochemistry. Complicated product concepts, assemblies and systems are easily verified and/or modified before costly production is ever undertaken. Parts that would take weeks to machine can now be produced in hours with stereolithography.

Stereolithography—How It Works

SL creates three-dimensional plastic parts directly from CAD/CAM data. A Stereolithography Apparatus (SLA) receives design data from the CAD file and "slices" it into thin cross sections. Next, an ultraviolet laser traces each successive cross section of the object onto the surface of a vat of photosensitive resin. The liquid plastic hardens only where touched by the laser beam. A new liquid layer is then spread over the solidified layer, and the next contour is drawn by the laser. The process repeats automatically and unattended until the part is complete.

Good for the Gear Business

While SL has been in widespread use in the aerospace, automotive, computer and consumer electronic industries on every product from complex propulsion systems to computer mice, gear manufacturers have been slow to test its mettle. That may change as the gear industry learns how hundreds of companies, both small and large, throughout the U.S., Europe and Asia report reductions in tooling costs, improvements in product quality and the ability to cut their product development time by half or more using SL.

An excellent example of how SL can make a critical difference in gear manufacturing is offered by AlliedSignal Engines (formerly Textron Lycoming) of Stratford, CT. Like many companies in the military sector, AlliedSignal, a leading manufacturer of military/commercial aerospace engines, sought ways to cope with fewer large government contracts and the business realities of doing more with less in a downsized economy. The company resolved to create new markets through technology infusion and the development of value-added components that would meet or exceed program objectives without running up costs.

Allied's Pilot Program

One of the first opportunities to exercise AlliedSignal's new competitive posture took place when the company led a pilot program to upgrade its T55 gas turbine engine, which powers the CH-47, twin-engine Chinook helicopter, the Army's workhorse transport. In order to infuse new life into this reliable, but aging helicopter engine, AlliedSignal offered a technology package to attract the interest of the Great Lakes Composite Consortium (GLCC).

Among the parts slated for improvement were several external engine components, such as gearboxes, accessories and oil lines. Priority was placed on weight reduction, maintainability, longer life cycle and lower cost. Due to the potential for high payback, special attention was paid to the top- and bottom-mounted gearboxes. A newer, more compact, top-mounted design was formulated to replace the existing gearbox.

To help secure additional contract funding, newer technologies, such as composites, and short cycle time methodologies were required. That meant the development team, consisting of Ted Westerman, composites development manager; Jennifer Finch-Johnson, components group development engineer; Frank Leech, gear development manager; George Milo, manager of components engineering, and others had to pursue visionary approaches to meet these objectives.

As a result, AlliedSignal was awarded a multiyear contract from GLCC and NAVAIR, which administers the U.S. Navy's naval air programs, to develop composite gearbox technology that could be directly transferable to larger components. AlliedSignal entered Phase One of a three-year program that would ultimately require the company to infuse new technology into the larger developmental V-22 Osprey tilt-rotor helicopter, as well as into the Chinook. A joint effort between Bell Textron and AlliedSignal, the U.S. Navy's V-22 represented a valuable opportunity to introduce lightweight components into both helicopters.

The initial plan called for newer, more advanced composite technology to be applied to highly loaded structural components, such as the accessory gearbox, which utilizes internally cored passageways and bearing liners. What's more, the new gearbox would have to be reliable to 25,000 hours, a quantum leap in performance from the standard 6,000 hours of useful life.

Given the time and weight constraints, AlliedSignal's skill in rapid prototyping would be essential. SL was selected as the most effective proof-of-concept tool to validate a new design on a small scale quickly and with confidence.

AlliedSignal reasoned that because so much development work had been done on the composite inlet housing unit for the T55 engine, SL technology would provide the additional confidence needed to build the entire T55 gearbox to scale (12" x 4") and to develop a top-mounted, high-speed, composite gearbox on the larger 3.5' scale needed for the V-22. Ideally, the development effort would benefit both the CH-47 and the V-22, giving the company a double-header of technology infusions. The design synergy to be gained would net tremendous cost reductions in tooling alone.

With AlliedSignal at the design helm, a three-dimensional solid model was built in the Unigraphics® CAD system. The file was then turned over to specialist Dan Domeracki, a development assembly technician, who built the gearbox prototype on AlliedSignal's Stereolithography Apparatus, the SLA-500 model. Kaman Aerospace of Bloomfield, CT, was selected to do the 2D braiding and Resin Transfer Molding (RTM), a process where dry reinforcement braiding is held in a closed mold. Low viscosity resin is then injected into the mold and cured to form the part.

Once Kaman was able to view the SL prototype, a real "eye-opener" occurred. The company now understood what they were up against with regards to the complex passageways, bearing bores and highly loaded areas. As a result, several important design changes were made.

Although AlliedSignal did not initially intend to cast metal, the team opted to use SL in 3D Systems' QuickCast™ build style because of its high level of accuracy. QuickCast replaces traditional wax patterns for investment casting with patterns created in a robust, durable material without tooling or loss of time. QuickCast builds highly precise, thin-walled parts down to 0.050".

The outcome was better than imagined: two functional SLA prototypes of a top-mounted, high-speed gearbox that feature more than 30 moving parts, including seven different gears and six shafts. The planned engine gearbox will also incorporate other high technology components, such as composite bearing cages, composite sintered air oil separators and new corrosive resistant stainless steel bearings. SL enabled the team to do fit checks, implement assembly procedures, and, most important, provide a reliable visual aid for a perplexing concept.

But the best was yet to come. Feeling they were on a roll, the design team worked through the Christmas holidays to be ready for an Army review meeting. When they removed their one-of-a-kind gearbox from its protective air bag, the customers stood in "disbelief," says George Milo. "No one imagined we'd get the job done with such success. That made it worth giving up our Christmas holidays."

High-tech prototyping was a smart investment. AlliedSignal estimates that the use of stereolithography for rapid prototyping will net a 30% reduction in program cost and development time, the equivalent of $500,000. Better yet, the advantage of having an exact physical representation of the gearbox to present to their customer may have paved the way to secure multimillion-dollar, follow-on contracts—not bad for a little work over Christmas vacation. ○

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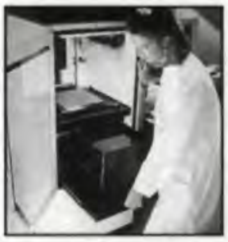
AlliedSignal's team knew it had to go beyond traditional design methods to meet the demanding new standards.



Top: 3D Systems' SLA-250 rapid prototyping system. Bottom: The SLA-500 gives high-throughput part building capability.

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