

## Preliminary Component Integration Utilizing Rapid Prototyping Techniques

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### Abstract

One of the most costly errors committed during the development of an element to be used in the space industry is the lack of communication between design and manufacturing engineers. A very important tool that should be utilized in the development stages by both design and manufacturing disciplines is rapid prototyping. Communication levels are intensified with the injection of functional models that are generated from a drawing.

At the Marshall Space Flight Center, this discipline is utilized on a more frequent basis as a manner by which hardware may be tested for design and material compatibility.

### Background

Rapid prototyping in this text refers to a collective set of solid freeform fabrication technologies, which build physical models directly from computer aided design (CAD) data. The fixtureless processes operate in an additive fashion, whereas each model is built from the bottom upwards by adding thin horizontal layers of material.

The MSFC maintains a unique rapid prototyping laboratory, equipped extensively with each domestically available rapid prototyping technology; a total of seven processes in all. These include the following:

1. Stereolithography, a liquid-resin based technology which

employs an ultraviolet laser to selectively cure the epoxy into the shape desired.

2. Selective Laser Sintering, a powder-based process which uses a laser to melt cross sections of polymer or semi-metallic powders into the shape desired.
3. Laminated Object Manufacturing, a solid-based process which adheres layers of paper, plastic or composite and cuts each cross section with a laser.
4. Fused Deposition Modeling, another solid-based process which extrudes a semi-molten thermoplastic through a moving XY orifice to form the necessary shape.
5. Multi Jet Modeling builds solid wax patterns by printing layers of hot wax directly through standard print jets.
6. Three Dimensional Printing prints layers of binder into a polymer powder matrix.
7. Laser Engineered Net Shaping deposits a thin bead of metal powder into the focal point of a high-powered laser, while the part is moved in the XY plane underneath to form the cross sections properly.

These processes are employed at the MSFC for a variety of concurrent engineering tasks, including concept modeling, assembly verification, fit-check analysis, flow functionality testing and investment casting pattern making.

## **Applications at the MSFC**

### *Shooting Star Experiment*

During the initial stages of the Shooting Star Experiment, rapidly produced absorbers were cast of a superalloy to be used in thermal experiments, prior to the procurement of the rhenium hardware.

Early designs of the solar thermal engine housing and absorber inserts were rapid prototyped in an investment casting wax in a matter of days, and the parts were investment shelled and cast on-site within four weeks.

These hardware castings have been, and continue to be, tested extensively by thermal elevation and cycling in the MSFC Test Stand Area. Data from these inexpensive models allowed for early analysis of the functionality of the engine design, as well as saving the project just under \$300,000 and six to twelve months of lead time. (See Figures 1 and 2)

### *Simplex TurboPump*

Another application involved the Simplex TurboPump, a high pressure experimental turbomachinery design. The application of rapid prototyping prevented a costly mistake in the manufacturing of the pump's complex impeller.

Five of the components were set to be machined, at an individual cost of \$60,000 each. The drawings had already been delivered to the machine shop and tooling-up had begun when a rapid prototyped model was fabricated using MSFC's stereolithography apparatus.

The resulting plastic model verified that the blueprints designated

the impeller blades the exact reverse of what the final part needed to be, and hence production was altered to make the final correct designs. Approximately \$300,000 again was saved by a simple plastic model which cost about \$1,000 to prototype.

Additional savings in time and cost were then added throughout the life of the Simplex program by the application of rapid prototyping and investment casting to provide castability verification of candidate materials, fabrication planning and continuous auditing with functional models and hardware. (Figure 3)

### *Space Shuttle Main Engine Fuel Ducts*

During a redesign of the Space Shuttle Main Engine, it was determined that replacement of existing supply and drain fuel lines would reduce weight and increase safety and reliability.

The previously used lines were fabricated by welding various shaped sections of steel line together in order to access all of the required inlet/outlet ports of the engine.

The new design called for continuous feedlines to be custom-formed from tubing to reduce the weight of the welds, optimize flow and decrease the probability of fuel leakage.

Unfortunately, the first hot gas duct to be fabricated didn't integrate properly after additional hardware was attached to the engine during assembly. The process to correct the problem was costly and time consuming, and it was determined that rapid prototyping patterns be fabricated for the remaining five ducts for fit verification.

Each duct was approximately seven feet in length and six inches in diameter, with a complex three-dimensional curvature and precisely placed junctions. The prototypes were fabricated in twelve-inch sections using the laminated object manufacturing process at MSFC, and it took two to three weeks to fabricate the entire set. The engine contractor designed each section having dissimilar boss-and-socket alignments for proper assembly.

These prototyped lines were shipped to the engine contractor facility, where they were assembled and mounted to an actual main engine to verify the designs prior to manufacturing the remainder of the required lines. A potential cost saving of approximately \$35,000 per line was recognized by the application of the rapid prototyping models, resulting in an overall potential savings of about \$175,000 and several months of lead-time. (Figures 4)

#### *Meteorite Patch Kits*

One continuous application of rapid prototyping at MSFC involves a project that applies meteorite patch kits. The process requires precise mixing of a two-part solution to obtain the adhesive properties required for composite material bonding.

A special funnel was designed which allows for accurate delivery of each component of the adhesive mixture. Due to the low number of these funnels that are required, approximately two to four every year, it is not cost effective to have them mass-produced.

The solution is to directly fabricate the funnels using rapid prototyping. The materials used are

compatible and provide adequate strength and density to prevent permeation or breakage. The funnels are even chemically cleaned and reused several times prior to disposal.(Figure 5)

#### *Space Shuttle Main Engine Fuel Seals*

Another shuttle engine application of rapid prototyping occurred recently when, after a design change, it was found that a particular fuel line didn't match up properly with a pump.

The result was a need for a flexible seal, which consisted of a 270-degree rotation of an eccentric nature. The overall part required was about nine inches in diameter.

The contractor for the pump received several solid prototypes of the flange from the MSFC rapid prototyping lab. These parts were used to make molds, which in turn produced the final products required to satisfy the needs of the engine.

#### **Summary**

The application of rapid prototyping technologies at the MSFC continues to yield significant cost and timesavings to NASA projects. Increased use of these technologies is anticipated in order to cater to a concurrent engineering environment that has been realized due to decreased funding allocations and project time constraints mandated throughout the agency.

Similar applications and successes are seen throughout the private manufacturing industry, as well, where profit margins and a highly competitive market drive companies to deliver products quickly and efficiently.



Figure 1

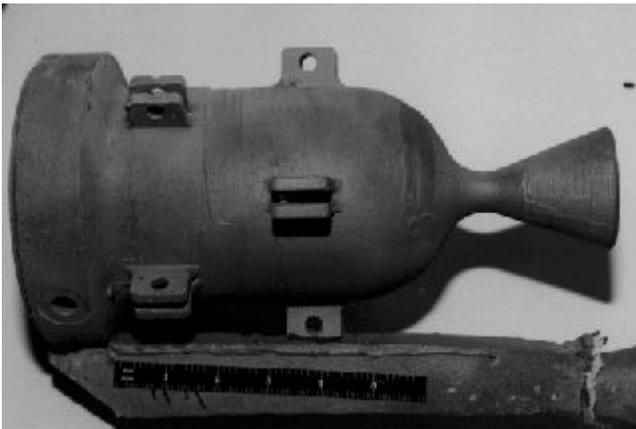


Figure 2



Figure 3



Figure 4



Figure 5