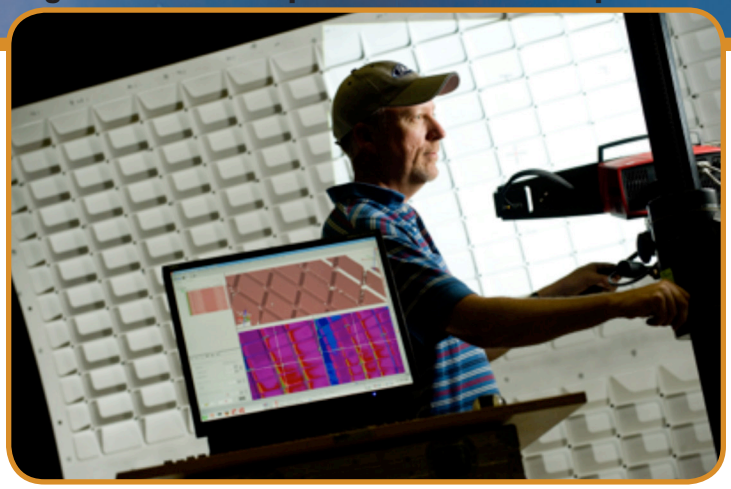
National Aeronautics and Space Administration

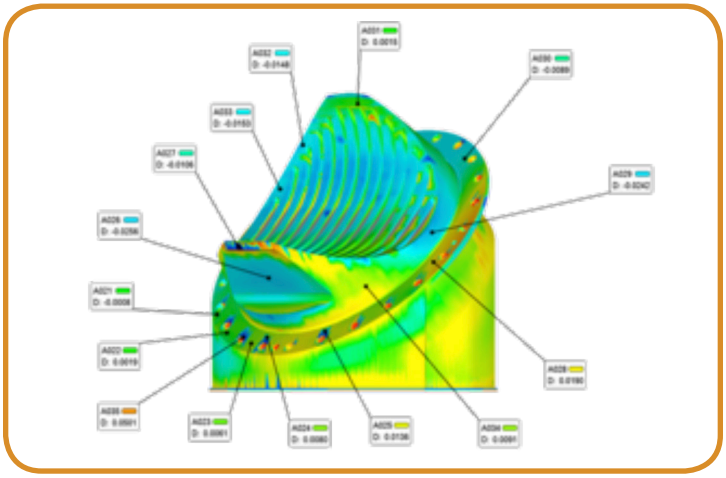
Marshall Space Flight Center
Digital Manufacturing

Engineering Solutions for Space Science and Exploration

The Digital Manufacturing capabilities located within Marshall Space Flight Center's (MSFC) Materials and Processes Laboratory provide various services that span the entire product life cycle. The Laboratory's three major digital manufacturing capabilities are manufacturing simulations, manufacturing execution systems (MES), and structured light scanning. Our manufacturing simulation tools focus on the design, development, and manufacture of a product, looking for ways to optimize manufacturing operations and identifying and correcting problems early in the lifecycle. Our MES tools offer configuration control of process plans, control work on the shop floor, and capture the as-built data record. Our structured light scanning tools allow for the creation of as-built computer aided design (CAD) models. These models are used to identify deviations from the as-designed part or assembly and become the input for additional analysis. The Laboratory's digital manufacturing capability is dedicated to developing, improving, and delivering the advanced processes and digital solutions needed to meet NASA's various goals and missions.



Structured Light Scan of a Orthogrid Panel



Comparison of As-Built to As-Designed Using Scan Data

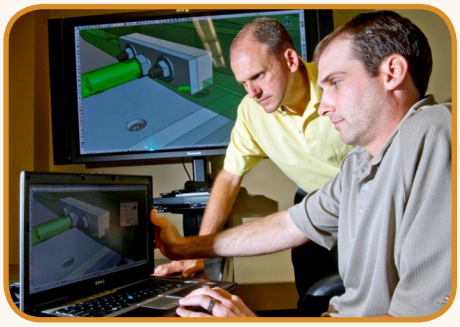
Structured Light Scanning and Photogrammetry

One of the fastest growing technologies in use at MSFC is structured light scanning and photogrammetry. The use of these techniques has provided a wealth of information about our tooling, equipment, and products that was previously unavailable. Through the use of optical measuring techniques, CAD models can be generated that represent the as-built parts. These CAD models can then be used for as-designed/as-built comparisons so that deviations can be identified. Since each as-built part is unique, this approach has allowed us to modify processes on-the-fly so that parts can be built within specification.

As each part of an assembly is scanned, a corresponding digital assembly is created. This digital assembly can be used to check for assembly problems of large-scale structures, such as the mating of different stages of a vehicle. It also allows for analyses to be performed on the as-built assembly, such as determining engine turbopump performance, holding capacity of a cryogenic fuel tank, or the erosion rate of a nozzle after each engine test.

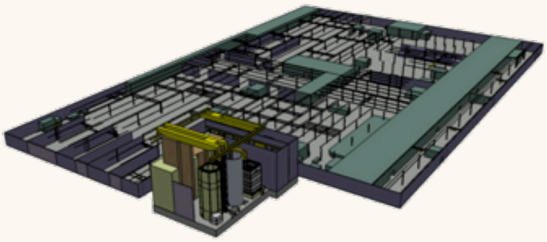
Heritage hardware exists that has no drawings or three-dimensional models. Scanning techniques have been used to reverse engineer hardware so that CAD models can be generated. This allows for design engineers to update or modify heritage hardware to increase capabilities or performance. One such example is the F1 engine.

Digital Manufacturing

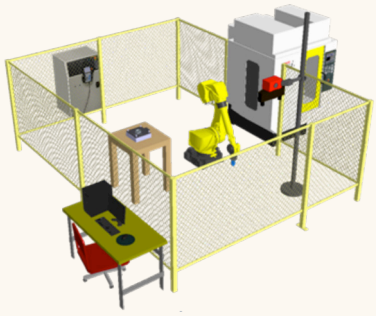


Our digital manufacturing tools provide a way to generate three-dimensional manufacturing simulations. Several analyses are performed that allow for problems to be identified early in the design cycle. Examples are as follows:

- Verification of facilities: Identification of process flow and assembly problems due to facility limitations.



- Interference analysis:
  - Gain understanding of the interactions between tooling, fixtures, GSE, etc.
  - Simulate assembly processes and identify interferences.
- Kinematic verification:
  - Definition of complex kinematic mechanisms, up to nine degrees of freedom.
  - Determine through process simulations whether planned operations are kinematically feasible.
- Off-line robotic programming:
  - Optimization of robotic systems in an offline, three-dimensional environment.
  - Deliver robotic programs to the manufacturing floor for execution.
  - Can include external axis such as rail and tower system or turntables.



Manufacturing Execution System

When it is time to build or assemble parts on the shop floor, it is important to maintain configuration control of process plans and to capture all critical data that is used, generated, or created on the floor. Our Manufacturing Execution System (MES) provides a very robust way to conduct process planning, process execution, and enforce process quality. This includes the following:

- Process planning:
  - Full configuration control of process plans.
  - Routing and approval of plans before they can be released to the shop floor.
  - eBOM to mBOM planning and reconciliation.
  - Allow planners to include rich instruction content such as CAD models, drawings, movies, documents, etc.
  - Effectivity assigned to plans (serial, lot, and date effectivity types).
  - Inclusion of model-based instructions (MBIs).
- Process execution:
  - Enforces that work is performed in the order/sequence defined by planning.
  - Captures as-built data such as serial number, lot number, temp, humidity, or any other process data.
  - Redlining of plans on the floor.
  - Provides method of superseding a work order with a later revision of a process plan.
  - Electronic buy offs.
- Process quality:
  - Discrepancy initiation, corrective actions, etc.
  - Allows for liens to be placed on parts.
  - Electronic quality buy offs.
  - Captures quality information from parts vendors.

For more information, please visit www.nasa.gov/centers/marshall/about/business.html

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