



OBSOLESCENCE ENGINEERING & SUPPLY-CHAIN DEVELOPMENT FOR EXISTING COMPONENTS

GS ENGINEERING INC.
906.482.1235

OBSOLESCENCE ENGINEERING & SUPPLY-CHAIN DEVELOPMENT FOR EXISTING COMPONENTS

GSENGINEERING.COM



CAL FIRE S-2T AIRTANKER

IN TODAY'S ENVIRONMENT, planners are challenged to do more with less. Often this results in personnel depending on systems which have long since exceeded their planned lifespan to complete the mission. It is common for airframes, hulls, and ground vehicle platforms to be in use decades after their introduction in configurations which never could have been envisioned by the original designer.

The fact that these platforms are able to successfully perform these roles and maintain the USA's dominant position on the globe is a testament to the men and women who operate and maintain them, as well as to the original designers and manufacturers.

Nevertheless, there are challenges with operating aging systems. Foremost among these is the availability of components. Too often, the original manufacturer is either no longer in business or no longer supports that product line. In those cases, once the stock of parts is exhausted, a source must be found or valuable equipment is rendered useless. In 2016, the State of California faced such a challenge with firefighting aircraft.

The California Department of Forestry and Fire Protection (CAL FIRE) operates and maintains a fleet of 23 Grumman S-2T 1,200 gallon airtankers, which it uses to battle wildfires across the state. These aircraft are converted from S-2 Tracker aircraft which were first introduced in 1952 and saw service in the United States Navy as anti-submarine warfare aircraft until the mid-1970s before being converted to the present tanker configuration. CAL FIRE and the residents of California depend on these nearly 60-year-old aircraft to protect life and property.

CAL FIRE's aviation division was finding it increasingly difficult to source wheels. When a main landing wheel failed—whether catastrophically during a particularly hard landing, or when it failed an inspection due to a crack or a dimension being outside of acceptable

Challenges with operating aging systems typically includes availability of components... once the stock of parts is exhausted, a source must be found or valuable equipment is rendered useless.

limits—typical practice had been to source a wheel from a retired aircraft in a boneyard. However this supply was eventually exhausted, and the State of California's ability to protect its citizens from wildfires was put at risk due to the lack of suitable wheels.

A wheel is a deceptively complex component, with many critical interfaces and complex loading requirements. Simply copying the geometry would not be sufficient to guarantee performance equivalent to the legacy wheels, and the consequence of failure would be great. The teams at GS Engineering and L'Anse Manufacturing accepted the challenge of providing replacement wheels to CAL FIRE, enabling uninterrupted service to the residents of California.

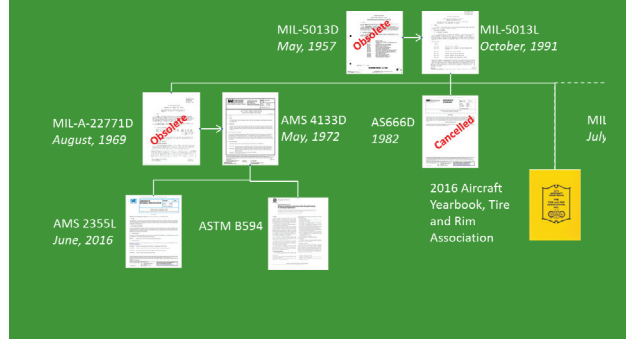


ORIGINAL WHEEL



SCANNING PROCESS USED TO GENERATE SURFACE MODEL OF EXISTING GEOMETRY

ILLUSTRATION OF RELEVANT STANDARDS & SPECIFICATIONS



This effort started with gathering all available requirements on the wheel. In this case, no engineering drawings or data were available, only a Grumman wheel standard from 1962. This document referenced contemporary Military and industry standards, many of which were since obsolete or canceled. In order to ensure replacement wheels would meet not only the original design intent, but also meet current specifications, this document trail was traced and understood. With a firm understanding of the requirements governing the original wheel, modern standards were substituted to ensure equivalent or greater performance.

Next, the geometry was defined. This started with a 3D scan and CMM inspection of a representative legacy wheel using GS Engineering's in-house equipment and capabilities. The result of this data collection is a surface model of the component.

The 3D scanning and CMM equipment provide a remarkably precise "snapshot" of the component within .003". This capability is becoming more and more ubiquitous and producing a surface model which looks like the component can be done using these tools relatively quickly. However, while this is a great way to determine what a component is, it does nothing to tell you what it is allowed to be. As any experienced engineer or machine shop will tell you, the key to producing a functional component economically is in the proper definition of tolerances.

In order to sufficiently constrain these tolerances, GS Engineering's design team converted the scan and probe data into a fully featured CAD model of the components so that each parameter could be adjusted and controlled. In order to understand the function and requirements of each feature of the wheel, GS Engineering worked with CAL FIRE maintenance personnel to identify every component that interfaced with the wheel. This included the tire, o-rings and seals, bearings, fasteners, brake hardware, and other components.

In all, 18 individual items were identified and their individual requirements were defined. This differed for each component, but included interface dimensions and tolerances, surface finish requirements, concentricity and runout, and alignment. This exercise allowed definition of tolerances which would be sufficient to ensure performance of the wheel assembly, but not overly tight so as to drive unnecessary cost into the manufacturing.

Next, GS Engineering performed an investigation of material properties, which included mass spectroscopy to determine chemical composition of the alloy and tensile tests to gain insight into the strength and elongation properties of the material.

Of course, documenting the wheel is of no use if it cannot be produced economically in the required quantities.

In this situation, a fully-closed-die forging tool would be prohibitively expensive. Therefore, GS Engineering and L'Anse Manufacturing adapted the design to be produced utilizing an open-die forging process.

This process has a much lower initial tooling cost, but results in subtle differences in material properties which must be understood and accounted for in the design. This required GS Engineering to deploy its analysis capabilities to evaluate stresses in the wheel under design load cases. These stresses are then compared to the material properties resulting from the varying forging processes to determine suitability for the application.

GS Engineering also took the opportunity at this point to add thickness to selected sections to address historical failure modes, based on feedback and data from CAL FIRE.

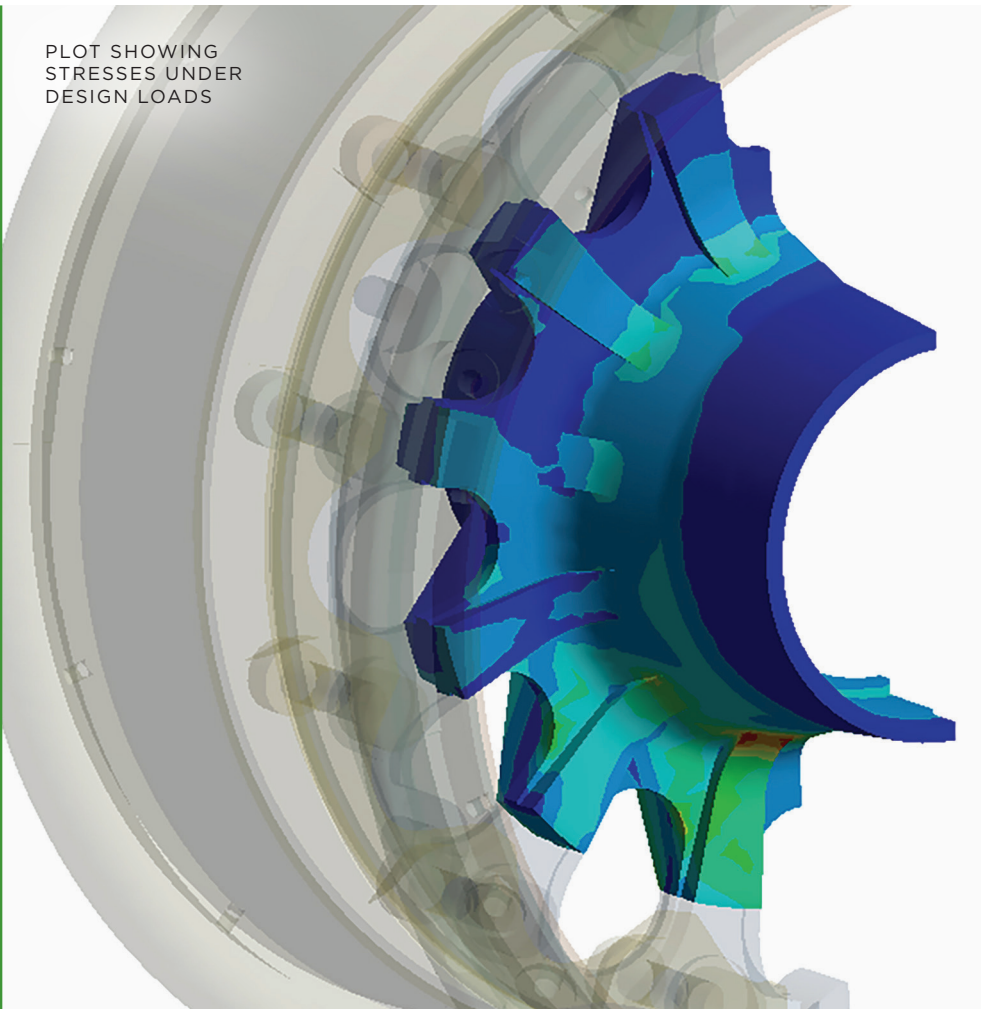
“As any experienced engineer or machine shop will tell you, the key to producing a functional component economically is in the proper definition of tolerances.”

GS Engineering then produced a full technical data package to enable production of the wheel components and to control the configuration of the wheel. The close collaboration between GS Engineering and L'Anse Manufacturing led to a seamless transition from design to prototype production. L'Anse Manufacturing's "low-volume, high-mix" production model allows for fast transition from a CAD model to high-precision prototype components.

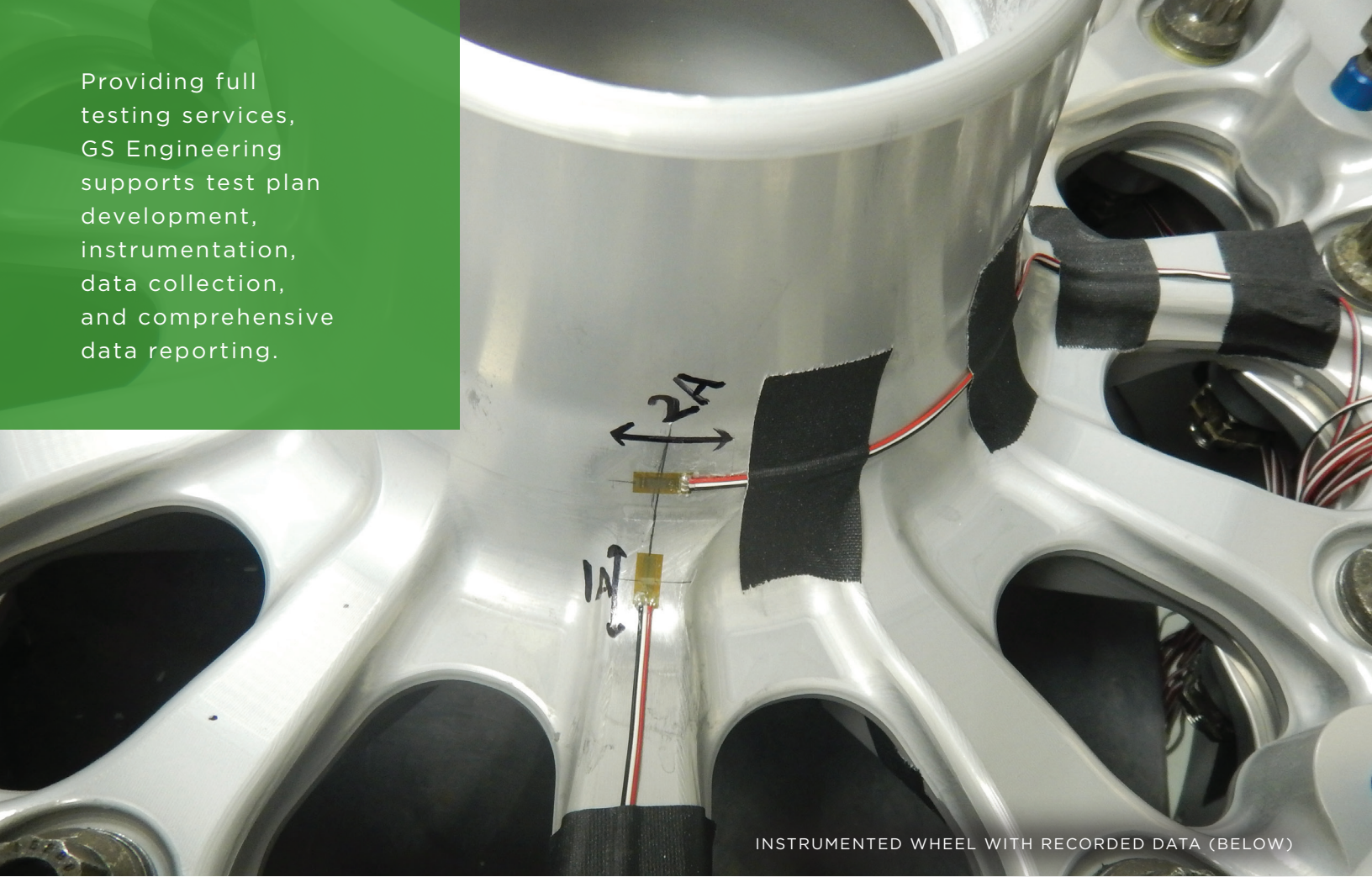
Following prototype production, GS Engineering coordinated a testing phase to ensure the wheel was suitable to proceed to flight testing. This consisted of various tests which challenged different aspects of the wheel's performance, including instrumented load testing involving application of strain gauges, data collection, and post processing. These results were used to validate modeling and compare strain values against threshold values established in the specification.

With positive test results in hand, serial production of the components could begin. L'Anse Manufacturing is perfectly structured for production of components of this type. L'Anse Manufacturing's AS9100 certified processes, state of the art CNC machining and inspection equipment, and dedicated and talented personnel are able to produce complex components on-time and within spec at volumes which meet the needs of the customer.

PLOT SHOWING STRESSES UNDER DESIGN LOADS



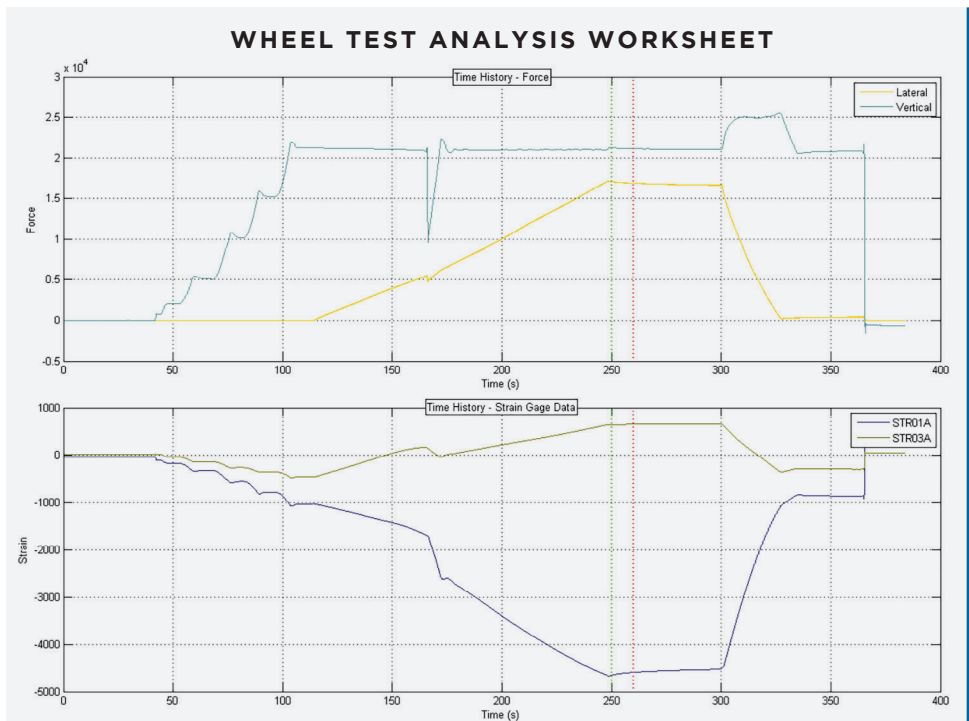
Providing full testing services, GS Engineering supports test plan development, instrumentation, data collection, and comprehensive data reporting.



INSTRUMENTED WHEEL WITH RECORDED DATA (BELOW)

Often, the reason legacy components are out of production is because the required volumes are too small to justify maintaining a production line. L'Anse Manufacturing's production model lends itself to short runs of components. During this effort, the strong partnership between engineering and production teams allowed CAL FIRE to keep their planes flying and meet the firefighting needs of the State of California.

NO MATTER THE COMPONENT OR SYSTEM, GS ENGINEERING AND L'ANSE MANUFACTURING HAVE THE TOOLS TO RAPIDLY DEVELOP AND DELIVER AN OPTIMIZED SOLUTION.



GS Engineering, Inc. Proprietary