Traditionally, quality assurance tests for doors have been divided into multiple classes of test scenarios, with each class requiring a separate, specialized measurement system:

- Door Closure
- Seal Deformation
- Flush and Gap

This paper describes how 3D point-cloud surface capture and real-time dynamic motion tracking can be combined in an ‘all-in-one’ verification test platform. Quantitative data is captured and maintained within a comprehensive metrology solution that addresses each test class for door closure systems of virtually any size and/or complexity.

The door verification and QA test scenarios documented in this white paper have application across a diverse range of industries: aerospace, automotive, marine and rail amongst others. These scenarios additionally demonstrate how an integrated verification platform can provide QA operators with significant improvements to measurement speed, accuracy and throughput.

**Solution Platform Description**

The platform consists of advanced metrology hardware and analysis software that provide freeform laser scanning and real-time motion tracking. The following hardware components from NDI are integrated within a mobile cart for shop-floor portability:

- PRO CMM Optical Tracker
- Targets for OptoTRAK Dynamic Measuring Machine (DMM)
- ScanTRAK Handheld 3D Laser Scanner
- Multi-Sided Probe (MSP)
- Large-screen monitor with swivel action for positioning

Measurements are compiled and analyzed by NDI’s DMM software for real-time motion tracking, and pre-integrated 3D imaging software (any one of several Tier-1 software packages) for point-cloud surface capture.

The platform is based on the high-speed photogrammetry technology of the PRO CMM optical tracker (portable armless CMM), which delivers accuracy up to 35µm over a measurement volume of up to 35m³. The OptoTRAK Dynamic Measuring Machine builds on the functionality of the optical tracker by adding real-time motion tracking of 3D objects through six degrees of freedom (6DoF) via the use of specially designed targets. The OptoTRAK tracks how the door’s movements (dynamic measurements) change over time. This level of shop-floor versatility allows operators to work efficiently towards the goal of accurate measurement to ensure complete door quality.
The purpose of the door closure verification is to analyze the motion of the door as it travels and closes on the latch. This motion must conform to a specific door latch signature that is comprised of separate interconnected movements, each with a distinct measurement profile: Door Velocity, Over Travel, and Lift and Drop Off. If any one of those movements is off the latch mechanism will not function as specified. This could negatively affect the durability (longevity) of the latch, resulting in door squeaks and rattles.

The verification process is conducting by placing small, lightweight targets at four locations on the body of the car surrounding the door. This creates a frame of reference that the optical tracker uses to subtract car movement as the door is closed. Movement subtraction is achieved through Dynamic Part Referencing, in which part coordinates are automatically referenced and re-referenced to maintain accurate measurement alignment. A fifth target is placed on the door immediately outboard to the latch itself. This target captures the door’s motion.

NDI’s DMM software is used to register the targets with the optical tracker and configure a tracking rate up to 4600Hz to receive maximum motion capture detail. For this application, the tracking rate is set to 500Hz.

Operators click the record button in the software, and close the door at different rates of force; the measurement profile of each closure is then tracked and recorded. Recorded data is saved to a (TSV) Tab Separated Value format. The DMM software processes the results into graphical form for analysis, as shown in Figure 4.

Figure 2: Body-Side Target Group

Figure 3: Data Acquisition Target Added

Figure 4: Door Latch Signature Measurement Profiles
In the past, the quality of a door's closure was typically judged using qualitative analysis that comes from years of experience and observation. The sound the door makes when it closes; the degree to which it vibrates; and its movement across the arc of closure, are all key points of focus. This expertise and understanding can now be combined with the quantitative analysis offered by DMM motion analysis. A strange closing sound or behavior can be immediately correlated to the door latch signature, with any abnormalities serving as quantitative evidence for qualitative observations.

**Seal Deformation**

Wind noise and water leaks caused by a poor door seal fit or compression are difficult problems to identify and solve. Seals cannot be measured with traditional tactile systems because they deform when touched. If the car is moved during measurement the entire measurement observation could be populated with bad data. Trying to align data sets into a common coordinate system while measuring with the door in both open and closed positions is difficult, with all the pitfalls associated with iteratively aligning multiple data sets.

To offset this challenge, non-contact laser scanning can provide meaningful, empirical data for header deflection and seal analysis, as captured and reported as a single data set. By incorporating the ScanTRAK handheld 3D laser scanner into the solution platform operators are able to capture point-cloud data. The lightweight ScanTRAK is designed for freeform agility when capturing the surface details of complex geometries. Alignment with one coordinate system is maintained when scanning from multiple locations and while covering large surface areas.

The first part of the measurement procedure is similar to the door closure verification use case. Four targets are placed on the door, and four targets on the car body, creating two corresponding reference frames that are registered with the optical tracker. The solution uses the body reference frame to track the motion of the entire car during the scanning procedure, and subtracts the car body movement from the scan data.

Using Dynamic Part Referencing the door can be opened and closed without introducing data noise or the difficulty of re-aligning data sets. The operator can even sit inside the vehicle while scanning without causing measurement error; vehicle movement is automatically subtracted from the measurement observation.

The goal of the procedure is to scan all of the seals and seal surfaces into a common coordinate system. First, with the door open, the door header is scanned, as shown in Figure 6.

Then the body side seals and mating surfaces are extracted from the scan data and saved separately, as shown in Figures 7 through 9.
Data is scanned directly into the 3D imaging software. The results can be processed with or without a CAD model; however, the CAD data would provide the operator with a base line for comparing the results. It would also allow the ‘root cause’ to be better isolated if there is a problem with the seals.

Figure 10: Indicates Deflection from Unconstrained (Open) to Constrained (Closed)

Once all surfaces are scanned, analysis can be performed immediately using either a rich set of color-coded dimensional visualizations or simple cross-sections at various locations. Either option would allow the quality assurance operator to quickly determine whether the door system has been properly designed and/or manufactured.

Figure 11: Seal Surface Interference Cross-Section
Flush and Gap

Flush and Gap measurement tests can be applied to any door closure, from an exterior door and trunk lid, to a glove box compartment. Proper flush is a critical aspect of overall door quality. As it pertains to an exterior door, an improperly set flush disrupts the performance of the car’s aerodynamic and hydrodynamic flow, causing drag and wind noise. To ensure correct flush and gap positioning, the forward edge of the door must be set slightly higher than the trailing edge. However, the definition of ‘slightly’ cannot be left to interpretation.

The following Flush and Gap measurement scenario uses a car door. As with the Seal Deformation test case, four targets are placed on the body side of the vehicle, and four targets placed directly on the door. With the car door open, the operator scans inside the body side, and along its surrounding surface, creating a data model.

A second data model is created by scanning the door itself, along the hem edge, and across the adjacent area. The two data models are scanned directly into a common inspection reporting software, where they are aligned as if the door was closed. This technique provides actual flush and gap measurements as well as color-coded positioning visualization and cross-section images. If required, a data model can be aligned to object coordinates at known XYZ locations.

Unlike with other measurement methods, the inspection plan is not static. If an error occurs or an inspection point was missed, the operator does not need to re-measure the entire door and create a new data model. A single measurement can be taken and added where necessary to the inspection plan. A sampling record within the inspection software is also available for re-check, allowing the operator to sample numerous inspection locations from anywhere within the scanned measurement area.
CONCLUSION

For the verification of any door closing system, the PRO CMM ScanTRAK Laser Scanning System with OptoTRAK Dynamic Tracking provides an integrated approach for completing several test scenarios with high accuracy. With traditional measurement tools, completing Door Closure, Seal Deformation, and Flush and Gap tests could take several days. Measurement data may also be fixed, limiting the ability to retake or review measurements if follow-up analysis is required. Alternatively, NDI’s PRO CMM solution platform reduces measurement time to just hours, and measurement data is readily accessible for further analysis.

The all-in-one usability and multifaceted capabilities of the PRO CMM solution complement the most valuable asset of the platform—its results. Data is captured within one common coordinate system for a single data set that reports detailed quantitative dynamic measurements and point-cloud data. Direct integration with 3D imaging software further allows for streamlined comparison to CAD models for root cause analysis of any failed tests. These results augment traditional analysis points, and enhance overall quality assurance insights to the benefit of car manufacturers and consumers alike.

For more information about the PRO CMM optical tracking solution, please contact us or schedule a demo at www.ndigital.com/demo.