

Automated Metrology Solution to Reduce Downtime and De-Skill Tooling Recertification

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ABSTRACT

Wing and fuselage aircraft structures require large precise tools for assembly. These large jigs require periodic re-certification to validate jig accuracy, yet metrology tasks involved may take the tool out of service for a week or more and typically require highly specialized personnel. Increasing the time between re-certifications adds the risk of making out-of-tolerance assemblies. How can we reduce jig re-certification down time without increasing the risk of using out-of-tolerance tooling? An alternative, successfully tested in a prototype tool, is to bring automated metrology tools to bear. Specifically, laser tracker measurements can be automated through a combination of off-the-shelf & custom software, careful line-of-sight planning, and permanent embedded targets. Retro-reflectors are placed at critical points throughout the jig. Inaccessible (out of reach) tool areas are addressed through the use of low cost, permanent, shielded repeatability targets. Simple locators enable adequate location of the tracker for each position, while automated tools within off-the-shelf software such as Spatial Analyzer provide a vehicle for very rapid measurements. Custom software guides the non-expert through the use of the metrology system so that the periodic “quick checks” are de-skilled, low cost, and fast.

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INTRODUCTION

Aircraft manufacturers are constantly being challenged to improve quality, productivity and reduce costs in an effort to be more competitive in the global market. Many companies look to reducing manufacturing costs by reducing their tooling requirements. An area that has significant potential for cost savings is the process of performing tooling recertifications. Typically, an assembly tool will be removed from production from a few days to several weeks, while specialized technicians measure key features on the tools that establish the position of critical components on the assemblies in the tool. The ability to significantly reduce the amount of time a tool is out of production can improve production flow times and potentially eliminate the need for duplicate tools used to accommodate impacts caused by tooling recertifications.

Beyond the need to maintain tool up time is the desirability of more frequent checks in an effort to improve tool quality and thus improve both part quality and productivity (by reducing out of tolerance parts and consequent rework). In the conventional tooling scheme it is

possible to damage a tool immediately after a recertification but continue using the tool until the next recertification, with all the assemblies made during that interval being consequently out of tolerance, and causing assembly difficulties or necessitating rework.

A combination of off the shelf technologies opens the door to a methodology that significantly reduces tool down time and also enables a “deskilled” approach to tool verification. These technologies include laser trackers, low cost “repeatability” targets and metrology software with automation features, the sum of which shall be referred to as “Automated Metrology System” or AMS, for convenience.

The project began with the aircraft manufacturer and the metrology team establishing time goals for both a partial jig verification “PJV” and a comprehensive jig verification “CJV” for a wing assembly tool. Allowable jig down time for the PJV is 60 minutes, and 8 hours for the CJV. A rigid time goal was not set for the total jig recertification “TJR” because of the large number of factors involved (e.g. time to rework damaged tooling).

An additional goal is that this be a production process run by operators and not by engineers or metrologists. An appropriate set of hardware and software was combined and or developed to meet these goals. Targets were placed on a set of appropriate structures to approximate a tool, and the system was implemented in this test environment. These tests demonstrated that the goals were achievable and practical, and laid the groundwork for a future implementation.

METHOD OVERVIEW

A simplified method overview is given for the PJV process. The actual process is more robust and more complex, since it must handle the occasional requirement for a repeated measurement, blocked points, etc., but for the sake of understandability these issues are omitted here.

The following essential elements comprise the validation system:

- Permanent “repeatability” targets are placed around the tool, especially at critical locations
- A laser tracker for measurements
- A custom tracker stand to enable repeatable (to within 25mm) placement of the laser tracker
- Tracker stand pickup points embedded in the floor
- Metrology software
- Macro program to execute measurement routine
- A custom software interface to aid in de-skilling the process

Simplified Process:

- Stage laser tracker and tools just outside tool
- Check tracker calibration
- Clear the wing from the jig
- Roll tracker and stand into first station location
- Place a limited number of temporary targets
- Initiate orientation program;
 - the tracker seeks, finds, and measures three targets
 - the program best fits to the known targets and orients the station
 - the metrology software now “knows” where it is and where to find other points

- Initiate measurement routine
 - Tracker seeks and measures all permanent and any temporary targets
- Initiate analysis routine
 - Analysis macro best fits the data set to the nominals
 - Measured data is compared to actuals
 - Report is generated with a pass/fail determination
- Operator vacates metrology gear from jig

The CJV process is nearly identical, but with the addition of the placement of many temporary targets. The TJR process involves the placement of flags (removable details) and other tooling and inspection tools adequate to enable measurement of 100% of the tooling points. It also requires the repair and resetting of tools. Automated Metrology System (AMS) can significantly reduce the measurement and rechecking time for the TJR process but does not impact the flag setting, inspection tool placement or repair and doweling operations.

SYSTEM ELEMENT DETAILS

While most the elements of the system are off the shelf, they merit some detail discussion.

Targeting Concepts

There are two targeting concepts that are appropriate for AMS verification: permanently installed targets and temporary or “replaceable” targets. The objectives for targeting the wing jig are to maximize accuracy, minimize cost, maximize visibility, reduce placement time and ensure target survivability. The two concepts present differing benefits and limitations.

The following table provides a good overview of the contrast in approaches between the two target concepts:

To meet the 60 minute goal of a PJV requires that as many of the time-consuming aspects of a laser tracker survey be minimized. This warrants consideration of having laser tracker targets embedded in the tool permanently. The time to place and aim 100 or more SMRs or prisms on a 30m long jig at a height above the factory floor of at least 4 meters could consume the entire measurement window of 1 hour. However, it is expensive to place SMRs on a tool permanently, especially when there are going to be multiple duplicate tools in both a left hand and right hand

Target Concept	Cost (estimate)	Placement Time	Visibility	Damage Risk
Permanent	\$200/target	0 minutes/target	Very limited	High
Replaceable	\$600/target	1 minute/target	High	Low

* Replaceable targets can be moved between instrument positions and tools to reduce the overall total number required

configuration that will require targets. SMRs are also exposed to factory dirt and grease and are not easy to keep clean.

The team explored the two targeting alternatives and compiled the following summary information:

1. Permanent Targeting - The permanent targeting approach all but eliminates the time to place targets on the jig prior to measuring. This is crucial to meeting the significant time constraint for the PJV routine. There are two target types that could be used for permanent targeting: the ½ in SMR and the 3/8 in. Solid Prism. Either targeting option is intended to minimize the overall cost by keeping the target size relatively small, creating a protected mounting position to limit exposure to factory dirt and physical damage and to optimize visibility by placing the targets in an area in a clear line of sight to the laser tracker position.



Figure 1. Laser Tracker Target for Comparison

The benefits to using a ½ inch SMR are that it does not require accurate aiming and the physical position is very accurate and repeatable due to spherical shell. The limitations are the cost of each target (\$600), susceptibility to damage of mirrored faces, difficulty in cleaning and larger size than the prism option. The benefits of using the 3/8 in. prism are that it is lower cost (\$200) and smaller in size. The limitations are that its accuracy is highly dependent on accurate aiming back at the laser tracker (within ½ a degree of normal to laser tracker beam), non-repeatable mounting due to a lack of a mounting shell and the prism face will need to be kept clean. Solid targets are cleanable with acetone and a soft cloth.

2. Temporary Targeting - The use of temporary targeting is most viable when there is sufficient time to place targets prior to measuring them. For a PJV there is little or no time to place targets. However for a CJV enough time exists to allow factory personnel to place the targets in pre-defined locations on each jig interface. The goal would be to have at least 3 targets on each critical feature. The targets would need to be initially aimed at a specific tracker location but would be manually adjustable if those tracker locations should change. To mount the temporary targets on a jig interface or detail requires a target nest or adapter to accurately and repeatedly position the SMR. These locations need to be

carefully selected for optimal visibility, proper detection of jig interface movement and minimal interference to tool function and operation.

Below are examples of temporary targets on two primary types of jig interfaces:

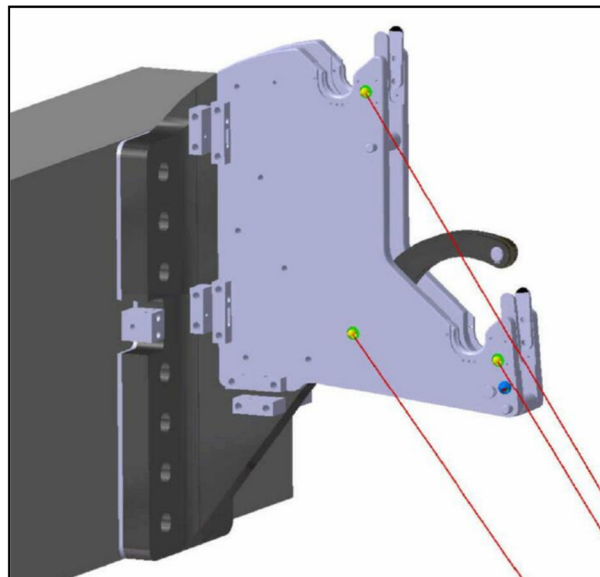


Figure 2. Jig - Flag Interface

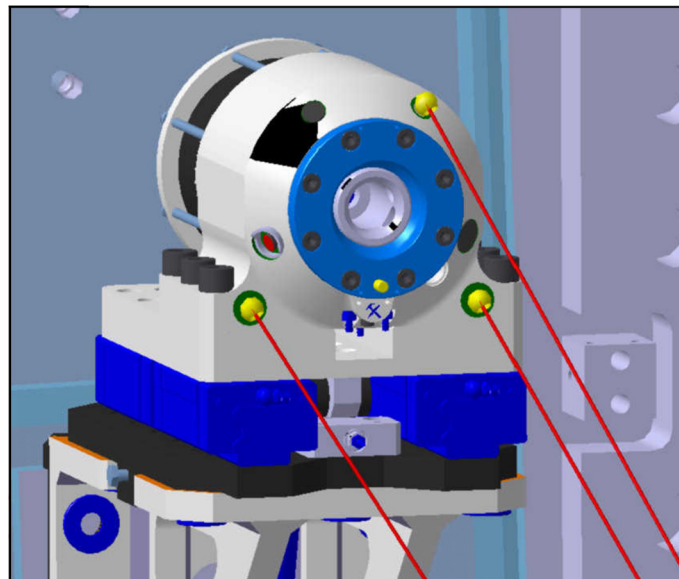


Figure 3. Ball Clamp Interface

An additional consideration for temporary or replaceable targeting is the efficient placement and aiming of each target. Concepts from using man-lifts to get an operator up to the target positions to the idea of using a target pole to reach the target positions from the factory floor have been considered. Ultimately, speed is going to be a prime consideration. If the target placement uses up a majority of the measurement