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# Application Of 3D Laser Scanner In Spacecraft Assembly

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**Abstract**. Spacecraft equipment layout is complex, and there are often many differences between real product and three-dimensional design models because of flexible components and sampling parts, some spacecraft components which have high assembly precision can't be installed due to component interference or small safety distance in assembly and integration process of spacecraft. The traditional method using the ruler is not easy to measure the spatial distance of interested place, so 3D laser scanner can be used in many situations which is a key detection step in AIT Process of Spacecraft. The 2 typical applications in this paper show that these detection method extracting redundant mounting holes with large span improve the assembly efficiency.

## 1. Introduction

Spacecraft equipment layout is complex, and there are many flexible parts and sampling parts in the spacecraft, flexible parts include multilayer insulation blankets, low frequency cable and flexible high frequency cable; Sampling parts include pipe, semi-rigid cable and waveguide assemblies. So it is important to detect the interference and check the safety distance of the components and structures by using the three-dimensional modeling of the spacecraft in the design stage, however, many differences between real product and three-dimensional design models occurred, and some spacecraft component can't be installed due to component interference or small safety distance in assembly and integration process of spacecraft. Some precision assembly parts need to be detected after installation, such as the waveguide assemblies which is across the cabin. Waveguide assemblies are usually docked manually in assembly and integration process of spacecraft. Sometimes, position and attitude deviation of the waveguide assemblies is too big to install the antenna because of accumulation error due to long installation path in the cabin of spacecraft; many critical operations which can increase risk in AIT process of spacecraft are used to readjust the waveguide assemblies in the cabin of spacecraft. Spacecraft deck docking is a key step in AIT process of spacecraft, interference detection of flexible components and sampling parts on the board and in the cabin must be carefully examined before the cabin board installation, if it doesn't meet the requirements, the flexible components need to be rearranged, or even the equipment layout must be modified. The traditional method using the ruler is not easy to measure the spatial distance of interested place before deck docking, so visual inspection is usually used by many operators while installing the cabin board step by step. If the area of interest cannot be visually inspected because of the spacecraft configuration constraints, the endoscopy can be used as an auxiliary tool for inspection, but it cannot measure quantitatively especially when the safety distance is critical. So a non-contact detection technique using 3D laser scanner is designed to solve those problems.

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Optical non-contact three-dimensional measurement method is preferred due to the sensitivity of the part to be tested, such as charged batteries and flange of waveguide assemblies. Commonly used Optical non-contact three-dimensional measurement method include interferometry of coherent lights [1,2], laser radar imaging[3,4], stereoscopic vision measurement[5], and structure light measurement[6~10]. Interferometry measurement is not suitable for rapid measurement of industrial online manufacturing process because of complex system; laser radar imaging system cannot be moved during the testing, so the target cannot be observed due to the special test condition; stereoscopic vision measurement can only measure the feature points and the feature points are difficult to matched and extracted in online manufacturing process; structure light measurement can measure the surface of the object by projecting laser strip, so it is suitable for interference detection of flexible components and sampling parts in AIT process of spacecraft.

## 2. The Measurement Principle of the 3D Laser Scanner

The first paragraph after a heading is not indented (Bodytext style). The Handyscan 700 laser scanner which is portable used in this paper takes into account the measurement speed and accuracy. It uses 7 laser crosses as the light source, the scanning area is about 275mm*250mm, the volumetric accuracy is 0.02mm+0.06mm/m, 56~60 images are scanned per second, each image collected about 600 points, and the measurement rate can meet 480000measures/s. The 3D scanner which consists of laser projector and CCD sensor is a triangulation system, as showed in Figure.1, the baseline and the position and attitude between them are calibrated and fixed. The illuminated light emitted by the laser projector is spatially modulated by the surface of the object to be measured. Changing the angle of the imaging beam, the position of the structured light on the CCD sensor changes, so according to the change of the position of the imaging spot and the geometric parameters between the camera and the laser projector, the coordinates of the measured object can be calculated [10].

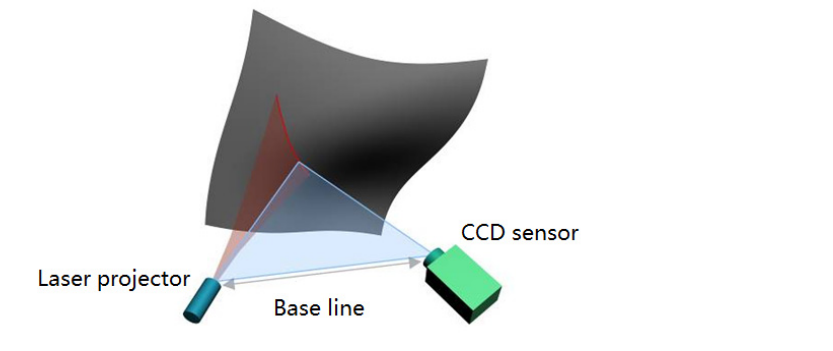


Figure 1. Basic Measurement Schematic of Handyscan 700

The scanning data is extracted and analyzed by the Geomagic Control software in this paper. Geomagic Control has a powerful three-dimensional detection function; the work piece can be measured through the visual comparison between the measured point cloud data and the model. In recent years, reverse engineering design, deviation and interference detection applications are more and more widely used [11-17].

## 3. Deck Docking Of Spacecraft Board

Deck docking of Spacecraft board is a key step in AIT process of spacecraft, spacecraft cabin and board are tested on respective mechanical ground support equipment before deck docking as showed in Figure.2, interference detection of flexible components and sampling parts on the board and in the cabin must be carefully examined before the cabin board installation.

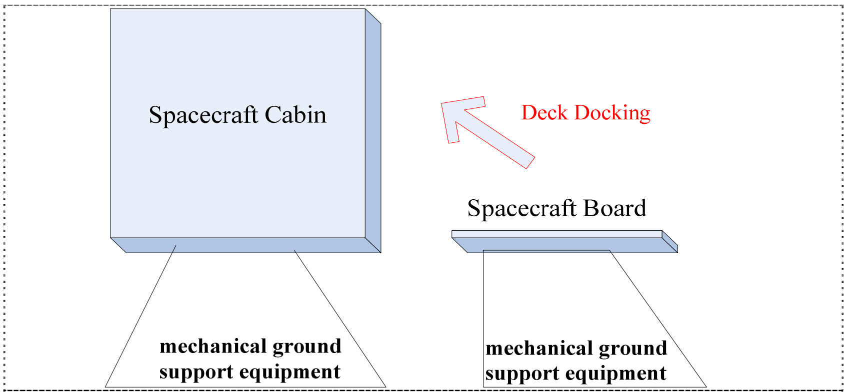


Figure 2. Deck docking of Spacecraft board

## 4. The Process of Application of 3D laser scanner

A non-contact detection technique based on Handyscan 700 laser scanner and Geomagic Control software is designed to detect the interference of flexible components and sampling parts on the board and in the cabin before the cabin board installation, the flow chart of the detection method is showed in Figure.3. Compared with the traditional method by using the ruler and endoscopy, this method can measure arbitrary spatial distance of interested place without deck docking, and the result is more accurate.

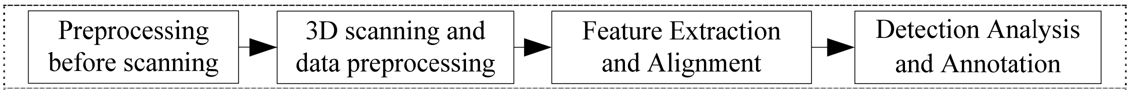


Figure 3. Flow Chart of the Process of Application of 3D laser scanner

### *4.1. Preprocessing before Scanning*

Reflective positioning points which are used to patch the scanned data need to be pasted nearing the measurement target before scanning by Handyscan 700 laser scanner. In addition to positioning points paste, some other preprocessing works are needed. Optical sensitive equipment in spacecraft needs to be shielded; because some surface of spacecraft components reflective serious, such as multilayer insulation blankets and aluminized film, no reflective film is needed to paste temporary.

### *4.2. 3D Scanning and Data Preprocessing*

Mounting holes or the Positioning pin of spacecraft board and the surface where the surface is interested are the key scanning areas. The scanning results can be viewed at any time via the notebook's browser. Data preprocessing which removes unrelated scan data by Grid Doctor function on Polygon menu in the Geomagic Control software can optimize point cloud data and improve the follow-up software processing speed.

### *4.3. Feature Extraction and Alignment*

The plane features which include board of spacecraft and other objects, such as the docking surface of Waveguide can be extracted accurately and quickly by the Geomagic Control software，as is showed in Figure.4~6. The accuracy of scanning and extraction of cylinder features is relatively poor because the mounting holes and the positioning pin are not big; the method in this paper performs redundant scanning and extraction of multiple mounting holes with large span to improve accuracy of feature alignment. Virtual docking assembly can be realized by aligning board scanning data to cabin scanning data by features of mounting holes, Analysis of assembly deviation can be realized by aligning measured data to CAD model.

Figure 4. Feature Extraction of docking surface of Waveguide

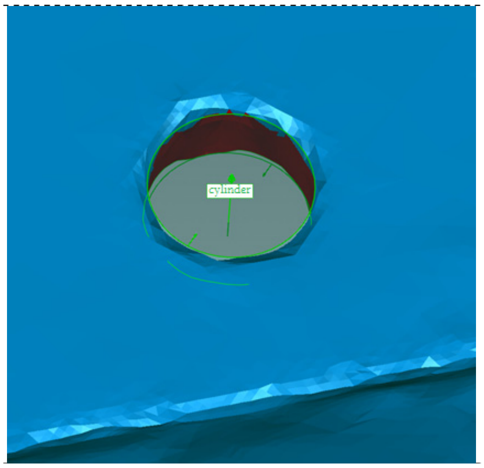


Figure 5. Feature Extraction of Mounting Hole

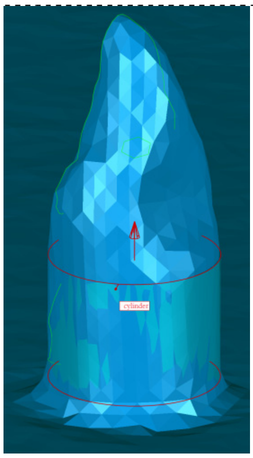

Figure 6. Feature Extraction of Positioning pin

### *4.4. Detection Analysis and Annotation*

Many detection analysis and anotation can be carried out by using Geomagic Control software after feature alignment. Section Through Object is a basic function under Analysis menu, It can generate a cross-section in point cloud data by the plane specified to measure the data easily; 2D Dimensions is another basic function which can mark the dimensions on the cross-section. 3D comparison under Analysis menu can display the deviation in the form of a chromatogram, and the specific deviations can be obtained by the function of create annotations under Analysis menu.

## 5. Comparison of the Hole Distance Precision

Feature extraction of 7 mounting holes on a cabin board is tested, the design value of the hole distance is 100mm, comparison of the measured value and design value of hole distance is showed in Table 1, the deviation value is less than 0.1mm, so the feature extraction of mounting holes is of high precision.

Table 1. Comparison table of the measured value and design value of hole distance

| **Item Compared** | **design value** | **Measured value** | **Deviation value** |
|---|---|---|---|
| Hole 1- Hole 2 | 100.0 mm | 100.011 mm | 0.011 mm |
| Hole 2- Hole 3 | 100.0 mm | 99.919 mm | - 0.081 mm |
| Hole 3- Hole 4 | 100.0 mm | 99.964 mm | - 0.036 mm |
| Hole 4- Hole 5 | 100.0 mm | 100.024 mm | 0.024 mm |
| Hole 5- Hole 6 | 100.0 mm | 100.028 mm | 0.028 mm |
| Hole 6- Hole 7 | 100.0 mm | 99.923 mm | - 0.077 mm |

## 6. The Typical Application of 3D laser scanner in AIT Process of Spacecraft

3D laser scanner can be used in many situations in AIT Process of Spacecraft, such as position and posture measurement of parts, virtual docking assembly, interference detection and safety distance checking, et al. there are 2 typical application of 3D laser scanner in AIT process of spacecraft.

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### *6.1. Position and Attitude Measuring Method of Space-craft Docking Waveguide Assemblies*

Waveguide assemblies on a spacecraft board of a structure satellite are tested in this paper, which is showed in Figure.7 and Figure.8; the design diameter of mounting holes is 6.5mm, 7 mounting holes with large span to improve accuracy of feature alignment. Positional deviation of waveguide assemblies interface before adjusting are showed in Figure.9~11, the deviation of the flange of waveguide assemblies is about 3mm forward, 2.5mm to the left and 0.3mm upwards, after adjusting, the deviation of the flange of waveguide assemblies is less than 0.3mm; The experiment shows that this measuring method can confirm that the waveguide assemblies in the cabin can docked into the antenna outside the cabin of spacecraft before cabin is closed, it can reduce the risk of the AIT process of spacecraft and improve the assembly efficiency of waveguide assemblies.

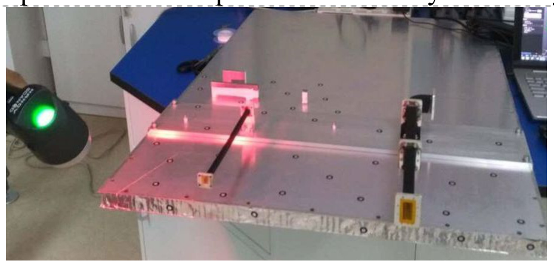

Figure 7. Experiment of Position and Attitude Measuring Method of Space-craft Docking Waveguide Assemblies

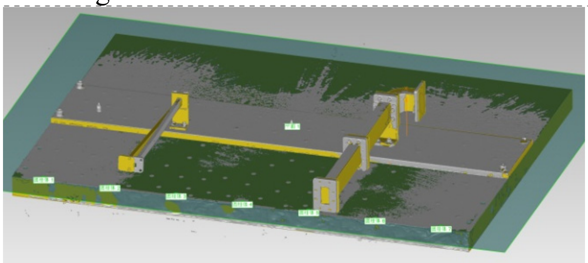

Figure 8. Alignment of Space-craft Docking Waveguide Assemblies

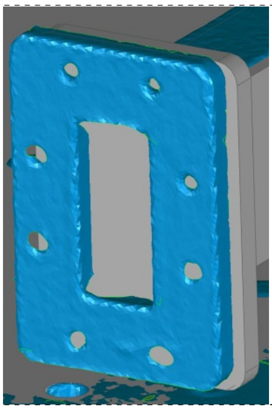

Figure 9. 3D comparison of Waveguide Assemblies

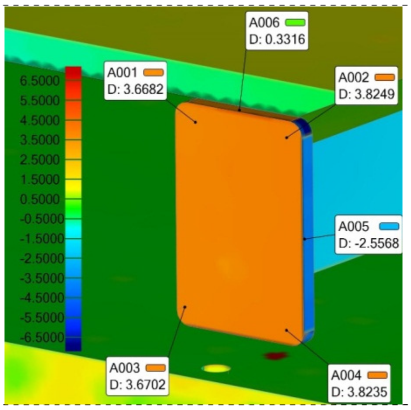


Figure 10. Deviation before Adjusting

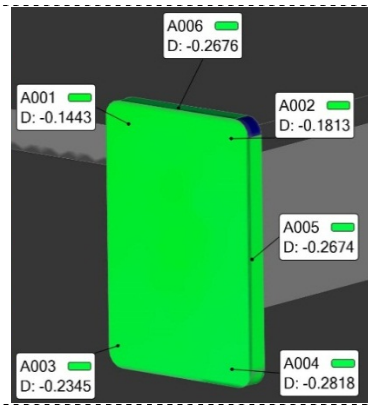


Figure 11. Deviation after Adjusting

### *6.2. Interference Detection of Spacecraft Before Deck Docking*

Interference detection between battery on the cabin board and the pipe in the cabin during the AIT process of a remote sensing satellite is tested, as showed in Figure.12; Flexible parts include multilayer insulation blankets on the pipe and thermal shield outer the battery; Battery thermal shield consists of lining and battery multilayer, a black film is attached to the battery lining to simulated battery multilayer, because the battery lining is transparent and the actual battery multilayer hasn't manufactured in this stage. The pipe multilayer is also covered by a no reflective film temporary. Some strong reflective areas on the satellite are covered with white paper to reduce the scanning interference point. Reflective positioning points are placed near the battery, pipe, and the mounting holes; due to restrictions on satellite components, positioning points uses 3M tape as substrate to not leave glue on satellite. 15 mounting holes which layout on two adjacent mounting edges are used to dock the battery board virtually, as is showed in Figure.13.

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Interference detection between battery simulated multilayer and pipe after the virtual assembly is showed in Figure.14. Interference exists if the battery multilayer is installed as can be seen from the figure. Because battery thermal shield is flexible and the envelope is bigger than Battery, safety distance checking between battery structure and pipe should be further reviewed, as it is showed in in Figure.15. Scanning data of simulated battery multilayer surface curved on top of the battery, but the plane of battery structure near the pipe can be fitted by the scanning data of simulated battery multilayer surface below the side of the battery, the envelope of battery structure can be fitted by the height battery and the scanning data of battery board plane. The green point in Figure.15 mark the battery structure nearing the pipe, the distance between battery structure and pipe which is showed in Figure.16, 1.84mm is not big enough, so the battery layout should be modified accordingly to increase the safety distance.

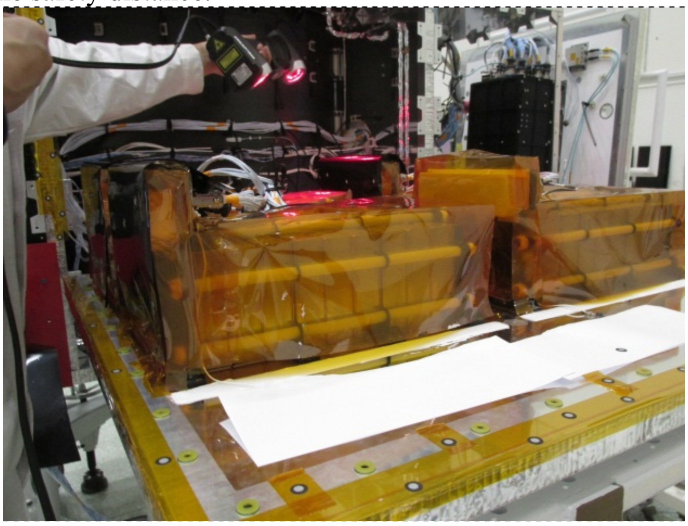

Figure 12. Interference Detection Between Battery Simulated Multilayer and Pipe

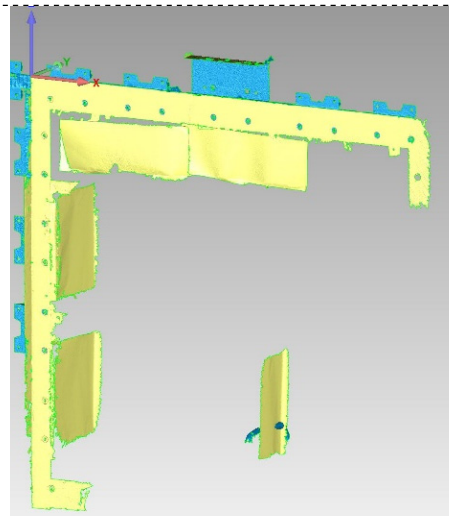

Figure 13. Alignment of Battery Cabin and Battery Board

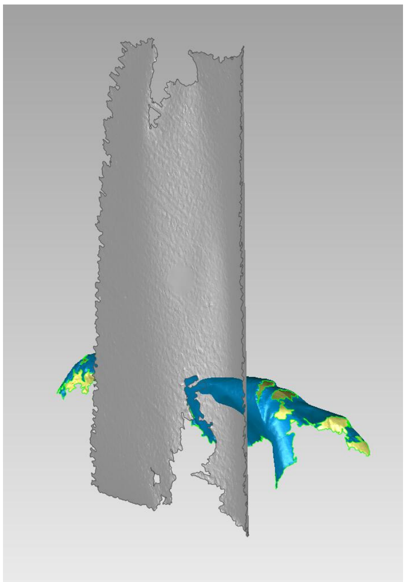

Figure 14. Safety Distance Checking Between Battery Simulated Multilayer and Pipe

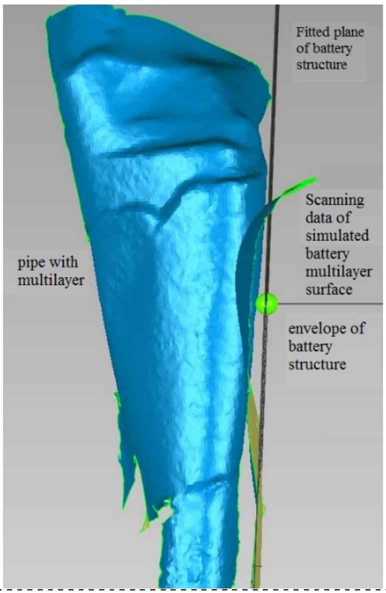


Figure 15. Safety Distance Checking Between Battery Structure and Pipe

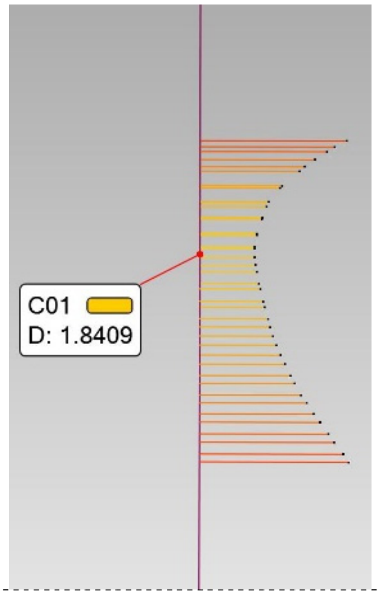


Figure 16. 2D Dimensions Detection of the Distance

## 7. Conclusion

The Handyscan 700 which is a portable scanner takes into account the measurement speed and accuracy. It can be used in many situations in AIT Process of Spacecraft, such as position and posture measurement of parts, virtual docking assembly, interference detection and safety distance checking, et al. The 2 typical experiments show that this detection method can reduce the risk of the AIT process of spacecraft and improve the assembly efficiency of deck docking, and can be generalized in other non-contact interference detection field.

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