

# NTS Force Limited Vibration Test Case Study

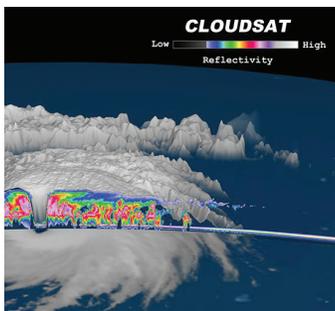
## CloudSat Spacecraft Radar Antenna



Artist's concept of the CloudSat Satellite from NASA.gov



CloudSat spacecraft at Vandenberg Air Force Base, Calif. from nasa.gov



A render of Typhoon Dolphin generated by CloudSat from nasa.gov

### Abstract

In vibration testing of high value aerospace hardware, over testing of light, high performance structures is a great concern. Discrepancies between the mechanical impedances and the force capabilities of the mounting structure and the vibration shaker can cause catastrophic structural and functional problems to test item. The effectiveness of the radar depends on it retaining its structural integrity over the entire surface of the antenna and that all its electronics are a) tested at, or near levels they will experience in its service life and b) the resonance of various parts of the radar follow those of the model. Consequently, the vibration test lab required 60 data channels to accurately verify the design of the instrument and its ability to withstand launch, cruise and deployment loads. To avoid over testing, NTS used Force Limiting Test Process using four force transducers to prevent exceeding total load of 1000 pounds.

### Introduction

Vibration tests in accordance with 1) TP 141- 0258-9; Date 11/05/02, 2) ANSI NCSL Z540-1, 3) Mil-I 45208 on Cloud Sat Cloud Profiling Radar (CPR) Antenna Subsystem were conducted in each of the three mutually perpendicular axis. The test item was subjected to sine, random and sine burst vibration with the objective that subsequent examination showed no evidence of physical damage resulting from the test.

### Test Item Description

The CloudSat is an experimental satellite that works with several other satellites and uses radar to measure the vertical structures of clouds and cloud properties from space. The CloudSat Mission is a partnership between Colorado State University, NASA's Jet Propulsion Laboratory, the Canadian Space Agency, the US Air Force, and the US Department of Energy. Ball Aerospace built the CloudSat. CloudSat's 94-GHz frequency nadir-looking radar allows for a reasonably sized antenna - 1.95 m - and relatively low level power requirements while meeting cloud profiling performance objectives. The structure of the radar can be divided into two parts: the omni directional patch antenna and the electronics in an enclosure below the dish. The test weight of the radar payload is 245 kg.

### Security

The critical nature of CloudSat mission (and integral part of formation with four other spacecraft) and the unit's \$12 million worth called for extensive security measures. JPL audited the NTS test site which is a gated, patrolled and alarmed facility. In addition, NTS fulfilled additional precautions including:

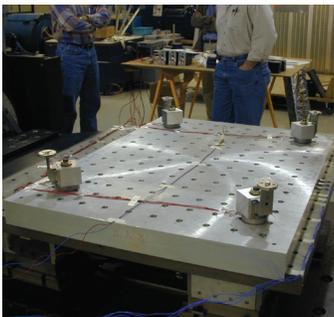
- ▶ Notifying LAPD
- ▶ Placing NTS security contractor on high alert
- ▶ Contacting Department of the Airports (shares jurisdiction with LAPD)
- ▶ 24 hour surveillance of Test Object
- ▶ JPL provided armed escort to, and from NTS



Side view of CloudSat main payload vertical vibration test



Front view, CloudSat main payload vertical vibration test



CloudSat satellite vibration fixture in the horizontal axis

## Test Set Up and Method

A Ling 340B shaker with hydraulically actuated slip bearings was utilized, with vertical setup armature/interface plate bolts torqued to 50 ft-lbs, head expander bolts torqued to 70 ft-lbs and fixture bolts torqued to 50 ft-lbs. Final free float setting on the horizontal slip axis was 1,800 psig to test free float and 2,300 psig operational pressure. Driver bar armature bolts were torqued to 50 ft-lbs, slip plate bolts to 40 ft-lbs and fixture bolts to 50 lbs. The shaker installation sits atop a substantial reaction mass, 14 ft x 18 ft x 8 ft cement base.

## Description of the Test Data

Four force transducers mounted to at the interface of the test item to the fixture to determine real force during the test and compare it with the test force limit. The CloudSat aggregate force limit of 1000 lbs is a result of the force transducers measuring along three axis, and combining the 12 signals into one set of xyz coordinates.

For the real-time force limiting capability, the vibration controller required two independent reference channels: one for controlling the required acceleration function and the second one for limiting the input, using the measured force. In addition to the independent reference channels, NTS set up the test to download data from 60 channels, hooking up real time acquisition for sine and random to avoid overwhelming computer resources.

Prior to testing on each of the three axis, fixture surveys in sine sweep, random and burst testing were successfully completed. After each survey, real qualification testing was performed. The entire test in all its sequences proceeded smoothly and was completed in one week.

## Conclusion

Sine, random and burst vibration tests of the CloudSat radar unit were successfully completed in one week. To protect the lightweight design of the unit, force limiting acceleration of 1000 lbs was successfully imposed. Data from 60 channels were downloaded, with sine and random information acquired in real-time. The resultant savings in the time it took to prepare the data meant that a printout was ready at the end of the test, ready to accompany the satellite to the next phase testing at TRW. As an added plus, the instrumented satellite could continue without changes, because TRW and NTS used the same signal conditioner.

## About NTS

At NTS, our heritage lies in the testing and certifications business. Over the last 50 years, through a combination of acquisitions, innovations and organic growth we have become the largest commercial test laboratory network in North America. Our capabilities span a very wide spectrum, covering Environmental, Dynamics, EMC, Wireless, Product Safety, Reliability, Quality Assurance, Ballistics and more. NTS engineers and technicians have extensive knowledge of current test and conformity requirements, both domestic and international to help clients build better, stronger, safer, more reliable products. We get you from test lab to market in the shortest possible time and with the least amount of effort, because helping you achieve your goals is how we achieve ours!



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