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## ➤ High-Rate Data-Capture for an Airborne Lidar System

**Potential applications are in laser altimeter systems, mass spectroscopy, x-ray radiometry imaging, and high-background-rate ranging lidar.**

*Goddard Space Flight Center, Greenbelt, Maryland*

A high-rate data system was required to capture the data for an airborne lidar system. A data system was developed that achieved up to 22 million (64-bit) events per second sustained data rate (1408 million bits per second), as well as short bursts (<4 s) at higher rates. All hardware used for the system was off the shelf, but carefully selected to achieve these rates. The system was used to capture laser fire, single-photon detection, and GPS data for the Slope Imaging Multi-polarization Photo-counting Lidar (SIMPL). However, the system has applications for other laser altimeter systems (waveform-recording), mass spectroscopy, x-ray radiometry imaging, high-background-rate ranging lidar, and other similar areas where very high-speed data capture is needed.

The data capture software was used for the SIMPL instrument that employs a micropulse, single-photon ranging measurement approach and has 16 data

channels. The detected single photons are from two sources — those reflected from the target and solar background photons. The instrument is non-gated, so background photons are acquired for a range window of 13 km and can comprise many times the number of target photons. The highest background rate occurs when the atmosphere is clear, the Sun is high, and the target is a highly reflective surface such as snow. Under these conditions, the total data rate for the 16 channels combined is expected to be approximately 22 million events per second.

For each photon detection event, the data capture software reads the relative time of receipt, with respect to a one-per-second absolute time pulse from a GPS receiver, from an event timer card with 0.1-ns precision, and records that information to a RAID (Redundant Array of Independent Disks) storage device. The relative time of laser pulse firings must also be read

and recorded with the same precision. Each of the four event timer cards handles the throughput from four of the channels. For each detection event, a flag is recorded that indicates the source channel. To accommodate the expected maximum count rate and also handle the other extreme of very low rates occurring during nighttime operations, the software requests a set amount of data from each of the event timer cards and buffers the data. The software notes if any of the cards did not return all the data requested and then accommodates that lower rate. The data is buffered to minimize the I/O overhead of writing the data to storage. Care was taken to optimize the reads from the cards, the speed of the I/O bus, and RAID configuration.

*This work was done by Susan Valett, Edward Hicks, Philip Dabney, and David Harding of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-16018-1*

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## ➤ Wavefront Sensing Analysis of Grazing Incidence Optical Systems

**As a metrology tool, this method allows integration of high-angular-resolution optics without the use of normal incidence interferometry.**

*Goddard Space Flight Center, Greenbelt, Maryland*

Wavefront sensing is a process by which optical system errors are deduced from the aberrations in the image of an ideal source. The method has been used successfully in near-normal incidence systems, but not for grazing incidence systems. This innovation highlights the ability to examine out-of-focus images from grazing incidence telescopes (typically operating in the x-ray wavelengths, but integrated using optical wavelengths) and determine the lower-order deformations. This is important because as a metrology tool, this method would allow the integration of high angular resolution optics without the use of normal incidence interferometry, which requires direct access to the front surface of each mirror.

Measuring the surface figure of mirror segments in a highly nested x-ray telescope mirror assembly is difficult due to the tight packing of elements and blockage of all but the innermost elements to normal incidence light. While this can be done on an individual basis in a metrology mount, once the element is installed and permanently bonded into the assembly, it is impossible to verify the figure of each element and ensure that the necessary imaging quality will be maintained. By examining on-axis images of an ideal point source, one can gauge the low-order figure errors of individual elements, even when integrated into an assembly. This technique is known as wavefront sensing (WFS).

By shining collimated light down the optical axis of the telescope and looking

at out-of-focus images, the blur due to low-order figure errors of individual elements can be seen, and the figure error necessary to produce that blur can be calculated. The method avoids the problem of requiring normal incidence access to the surface of each mirror segment. Mirror figure errors span a wide range of spatial frequencies, from the lowest-order “bending” to the highest-order “micro-roughness.” While all of these can be measured in normal incidence, only the lowest-order contributors can be determined through this WFS technique.

During integration, typically only the low-order shape changes. The stress introduced does not affect the higher-order ripple or roughness, so one can use the measurements done in normal

incidence to characterize the mirror in the mid- and high-frequency domains, and WFS measurements for the low-frequency domain.

By analyzing multiple out-of-focus images at different positions, the path of each photon can be determined, and the figure error necessary to generate that array of photon paths can be deduced. The method is applicable to any wavelength being examined, though the range of spatial periods that

can be examined depends on what wavelength of light is being imaged, due to diffraction blurring out the focused image.

The innovation is unique in that it determines physical surface errors using a method that requires neither normal incidence access nor contact of the optical surface. The primary advantage of the technique is the ability to probe surface figure errors when the mirror is in a system that denies ac-

cess to the front surface of the mirror, such as during x-ray testing (requiring the mirror to be in a vacuum chamber) or after it has been integrated into a highly nested structure. This software is capable of determining figure errors at the sub-micrometer level for up to 4th order errors.

*This work was done by Scott Rohrbach and Timo Saha of Goddard Space Flight Center. Further information is contained in a TSP (see page 1). GSC-15926-1*

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## Foam-on-Tile Damage Model

*Lyndon B. Johnson Space Center, Houston, Texas*

An impact model was developed to predict how three specific foam types would damage the Space Shuttle Orbiter insulating tiles. The inputs needed for the model are the foam type, the foam mass, the foam impact velocity, the foam impact incident angle, the type being impacted, and whether the tile is new or aged (has flown at least one mission). The model will determine if the foam impact will cause damage to the tile. If it can cause damage, the model will output the damage cavity dimensions

(length, depth, entry angle, exit angle, and sidewall angles).

It makes the calculations as soon as the inputs are entered (<1 second). The model allows for the rapid calculation of numerous scenarios in a short time. The model was developed from engineering principles coupled with significant impact testing (over 800 foam impact tests). This model is applicable to masses ranging from 0.0002 up to 0.4 pound (0.09 up to 181 g).

A prior tool performed a similar function, but was limited to the assessment of a small range of masses and did not have the large test database for verification. In addition, the prior model did not provide outputs of the cavity damage length, entry angle, exit angle, or sidewall angles.

*This work was done by Michael Koharchik, Lindsay Murphy, and Paul Parker of The Boeing Company for Johnson Space Center. Further information is contained in a TSP (see page 1). MSC-24913-1*