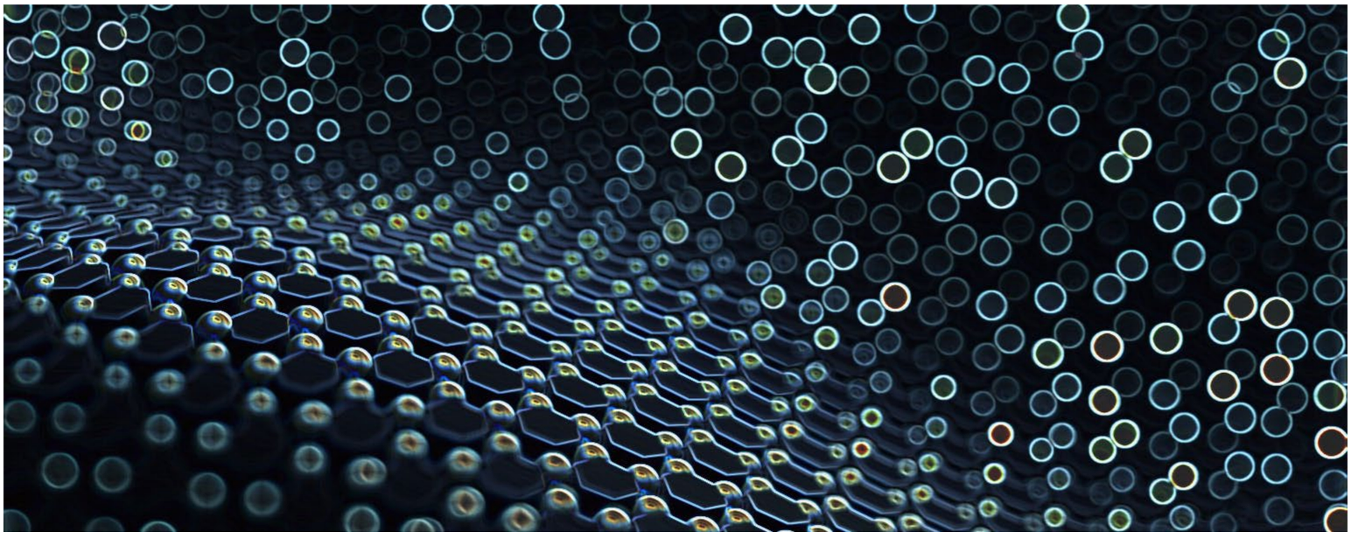
# MEASUREMENT AND VALIDATION OF STRAIN IN NEW MATERIALS AND COMPLEX STRUCTURES



HIGH DEFINITION FIBER OPTIC SENSING (HD-FOS) PROVIDES MORE THAN 1,000 STRAIN MEASUREMENTS PER METER AND IS DESIGNED TO ADDRESS TESTING CHALLENGES FOR ADVANCED MATERIALS AND SYSTEMS

# Introduction

As the automotive and aerospace industries transition to new and advanced lightweight composites, new design challenges are created that require advanced methods for test, measurement and validation.

High-definition fiber optic sensing (HD-FOS) is a new measurement technology that is ideally suited to test and characterize these new materials. Small, flexible and lightweight, HD-FOS sensors can be embedded and installed in critical locations. They deliver full strain and temperature mappings for better insight and more complete data for the development and manufacturing of advanced materials.

Traditional data acquisition (DAQ) systems employ discrete electrical sensors (foil strain gages, thermocouples, RTDs, etc.) that are located and installed at a few, most critical locations.

Each electrical sensor requires a multi-wire copper cable that is relatively bulky and heavy, and being metallic, is vulnerable to electro-magnetic phenomena.

Fiber optic sensors, on the other hand, are very small, low profile, and lightweight. Optical fiber is completely non-metallic and immune to electro-magnetic interference. Additionally, HD-FOS uses unaltered optical fiber as an essentially continuous strain or temperature sensor, delivering thousands of measurements on a single optical fiber.

Since HD-FOS can provide a virtually continuous array of strain measurements, it is perfect for measuring areas with high strain gradients or evaluating strain over a larger area to pinpoint critical locations not identified by models or simulations.

Very low profile and nearly weightless, fiber optic sensors can go where strain gages and traditional temperature sensors cannot – in tight bends, on small details, and even embedded inside composite materials or joints. Sensors are flexible and can be routed along complex geometries, providing a full field view of strain.

HD-FOS will help manufacturers speed new technologies to market while lowering the risks associated with the introduction of new materials and processes. The high definition data can fully map the contour of strain for a structure under test or during manufacturing.

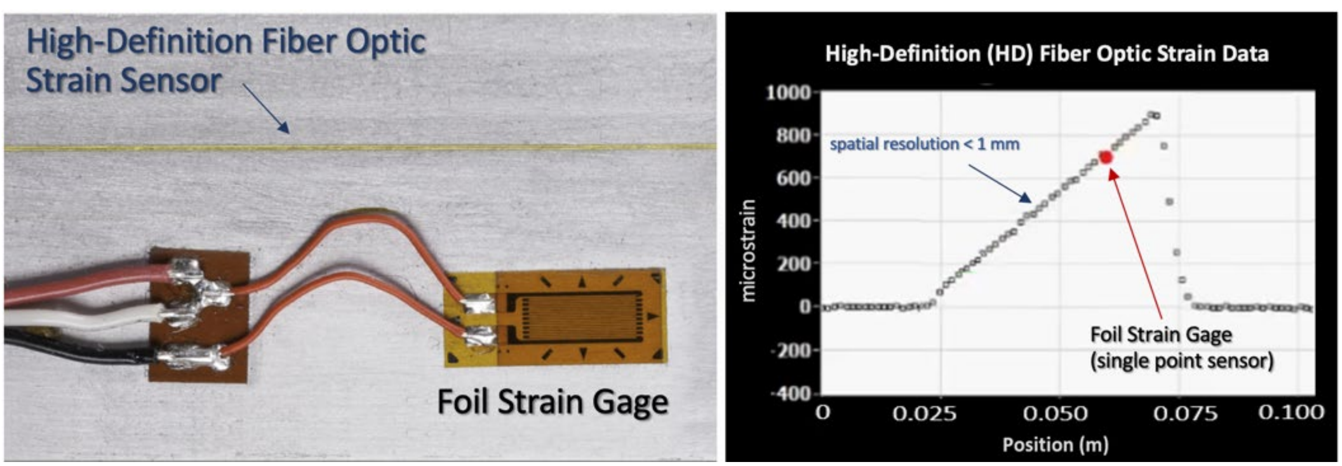



*Figure 1. High-definition fiber optic sensors measure strain along the fiber with spatial resolution as low as 0.65 mm. A single-point foil strain gage is shown for comparison.*

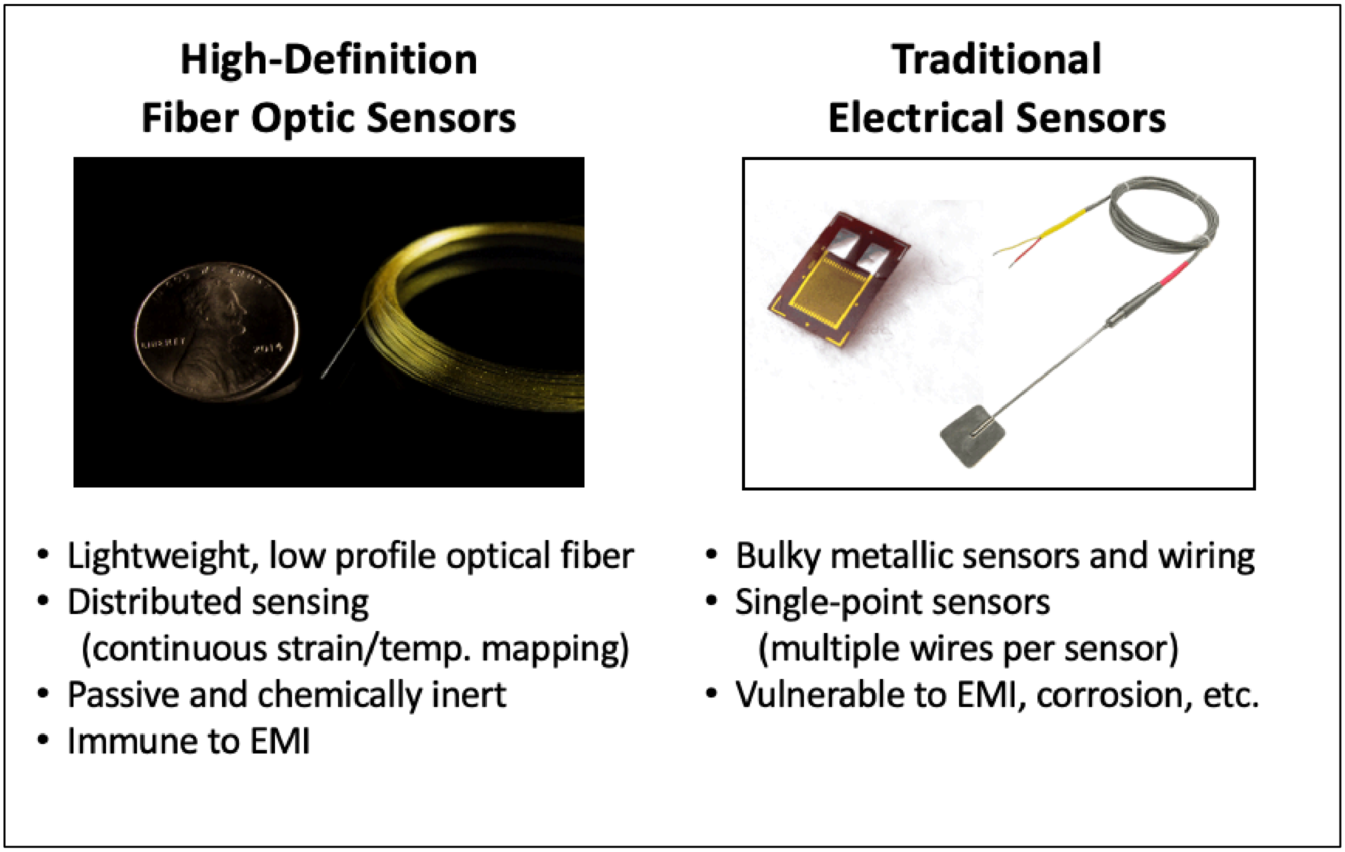



*Figure 2. HD-FOS compared to traditional electrical sensors, such as foil strain gages, RTDs and thermocouples*

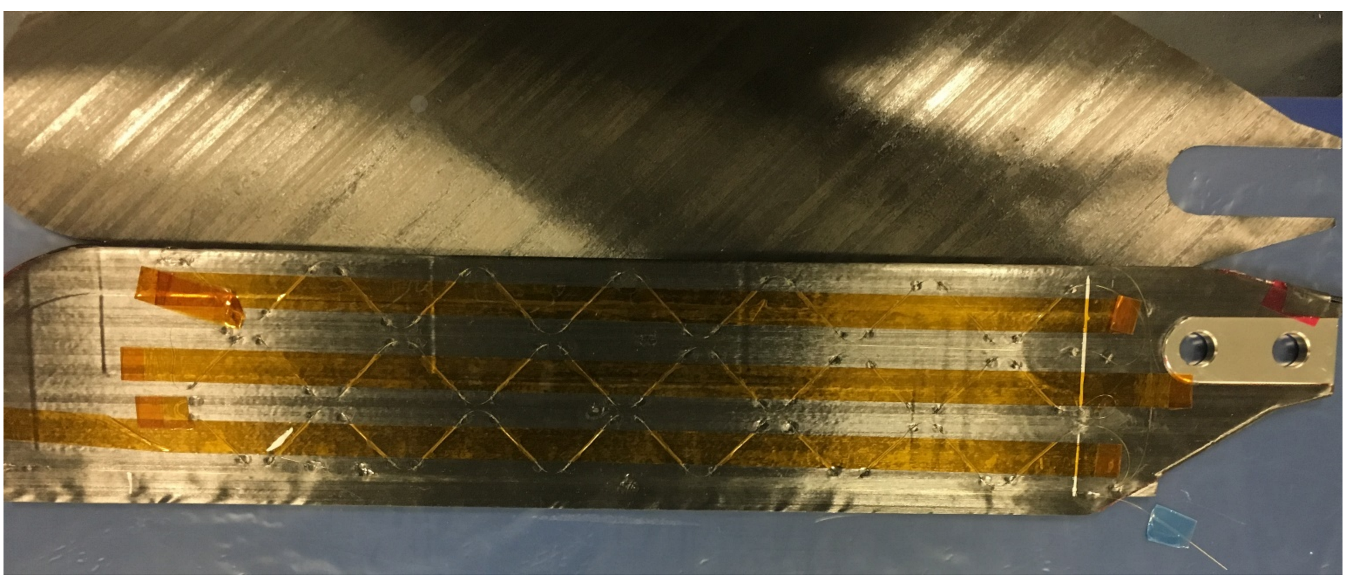


*Figure 3. Fiber optic sensor installed in grid pattern on blade*

# Optimize Structural Design

Reducing the weight of a vehicle’s frame or an aircraft’s structural components is key to lightweighting. Weight reduction can be achieved by adopting new design methods, using advanced lightweight materials or employing a hybrid approach. Adoption of new materials also introduces new methods to join assemblies and a greater use of adhesives.

Fiber optic sensors can be bonded to a structure's surface in a similar fashion to traditional strain gages. In addition, they are flexible enough to be routed in a serpentine pattern, around curves or embedded within structures. The fiber sensor comprises a series of densely spaced virtual strain gages.

For automotive body in white structural testing as well as aircraft design validation, a significant reduction in instrumentation time and a far more detailed and illustrative data set is created from HD-FOS.

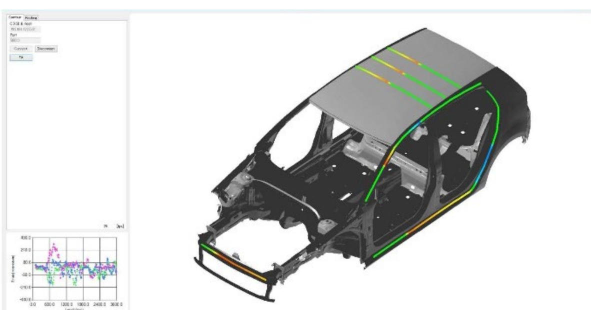


*Figure 4. Body in white structural testing viewed with 3D visualization software*

# Verify Finite Element (FE) Models

The complexity of composite materials and the variability of manufacturing processes pose a significant challenge for designers attempting to accurately model composite components and systems. As models and simulations continue to develop and improve, more complete experimental data can close the gap and accelerate the development and certification on new materials and new manufacturing processes.

HD-FOS, with its ability to provide a very high density of measurements, can provide more comprehensive validation and improvement of finite element (FE) models. Additionally, the small size and flexibility of HD-FOS sensors mean that phenomena in the most critical locations can now be experimentally measured and validated.

Traditionally, foil strain gages are used to check a few of the most critical stress points or hot spots predicted by the model. With HD-FOS, designers can acquire essentially thousands of measurement points and experimentally determine those critical locations or hot spots. HD-FOS sensors deliver a much more complete characterization of strain fields and develop more accurate and precise FE models.

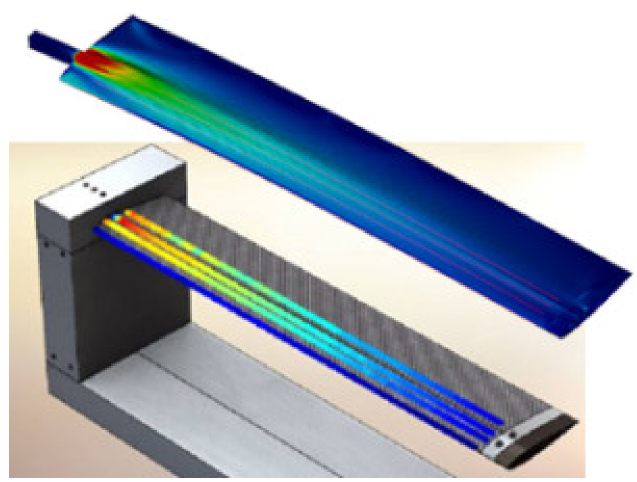


*Figure 5. Predicted strains of a composite airfoil under load compared to actual strain measurements using a 3D visualization tool*

Evaluate Joining Methods and Interlaminar Stress

# Evaluate Joining Methods and Interlaminar Stress

Low-profile, high-definition sensors are ideal for verifying the integrity of bonding and joining methods. With unobtrusive embedding and the ability to measure difficult geometries and locations, fiber optic sensors can map hard-to-reach areas with high strain gradients.

## Evaluate Multi-Material Joining

Designing and manufacturing composites requires new processes and methods for fastening and bonding. These areas can exhibit high strain gradients and represent potential failure points. Fiber sensors can be routed across a splice connecting two structures or embedded along a bond line or weld line, providing direct measurement of the performance of the bond.

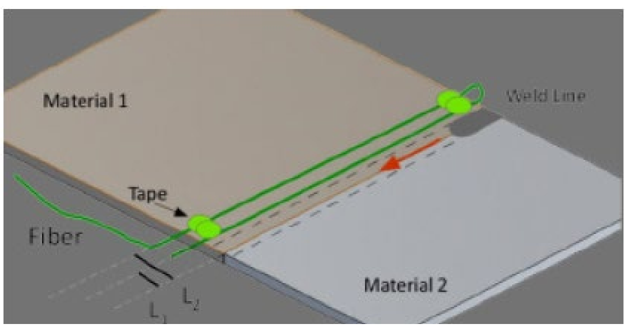



*Figure 6. Sensors routed across a splice*

## Measure Interlaminar Stress

Interlaminar stress creates failure mechanisms specific to composite materials. Fiber optic sensors are small enough to be embedded during manufacturing between layers without changing the characteristics of the material. Such embedded fiber optic sensors provide the unique ability to directly measure interlaminar stress at the interfaces between layers in laminated composite material.

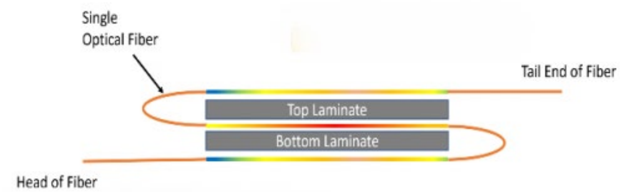



*Figure 7. Embedded fiber optic sensors between layers*

# Monitor Structural Health

Because fiber optic sensors are small and lightweight enough to embed within composite structures during their fabrication, they can provide valuable data for components and systems in service. “Smart parts,” with permanently embedded sensors, can generate valuable data about a structure or component’s operational health throughout its entire lifecycle. The embedded sensors can be monitored continuously to immediately detect damage or unexpected stresses, or periodically interrogated during routine maintenance checks.

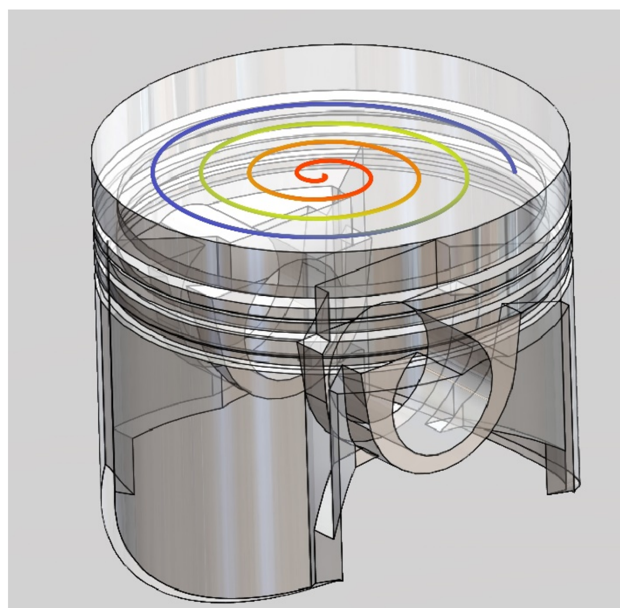


*Figure 8. “Smart part” with embedded sensors for structural health monitoring*

# Luna ODiSI 6000 Series

Luna’s high definition fiber optic sensing (HD-FOS) technology offers continuous, millimeter-resolution strain measurement that is ideal for composite materials and components. The ODiSI 6000 Series sensing platform is a high-perforance multichannel interrogator for HD-FOS. The ODiSI 6000 Series delivers real-time strain and temperature data from up to eight optical fiber sensors. It can act as a stand-alone data logger or easily integrate into larger test management platforms. Luna’s HD-FOS sensors, available in lengths from 1 m to 50 m, “plug and play” with the ODiSI system for fast and easy setup and configuation. ODiSI 2D and 3D Visualization Software allows strain data to be visualized directly on a 3D model, on a 2D image or on a photo. The 2D and 3D data visualization can be generated in real-time using live data from an ODiSI 6000 system or from logged data files.

*Figure 9. Luna ODiSI 6000 Series HD-FOS System*

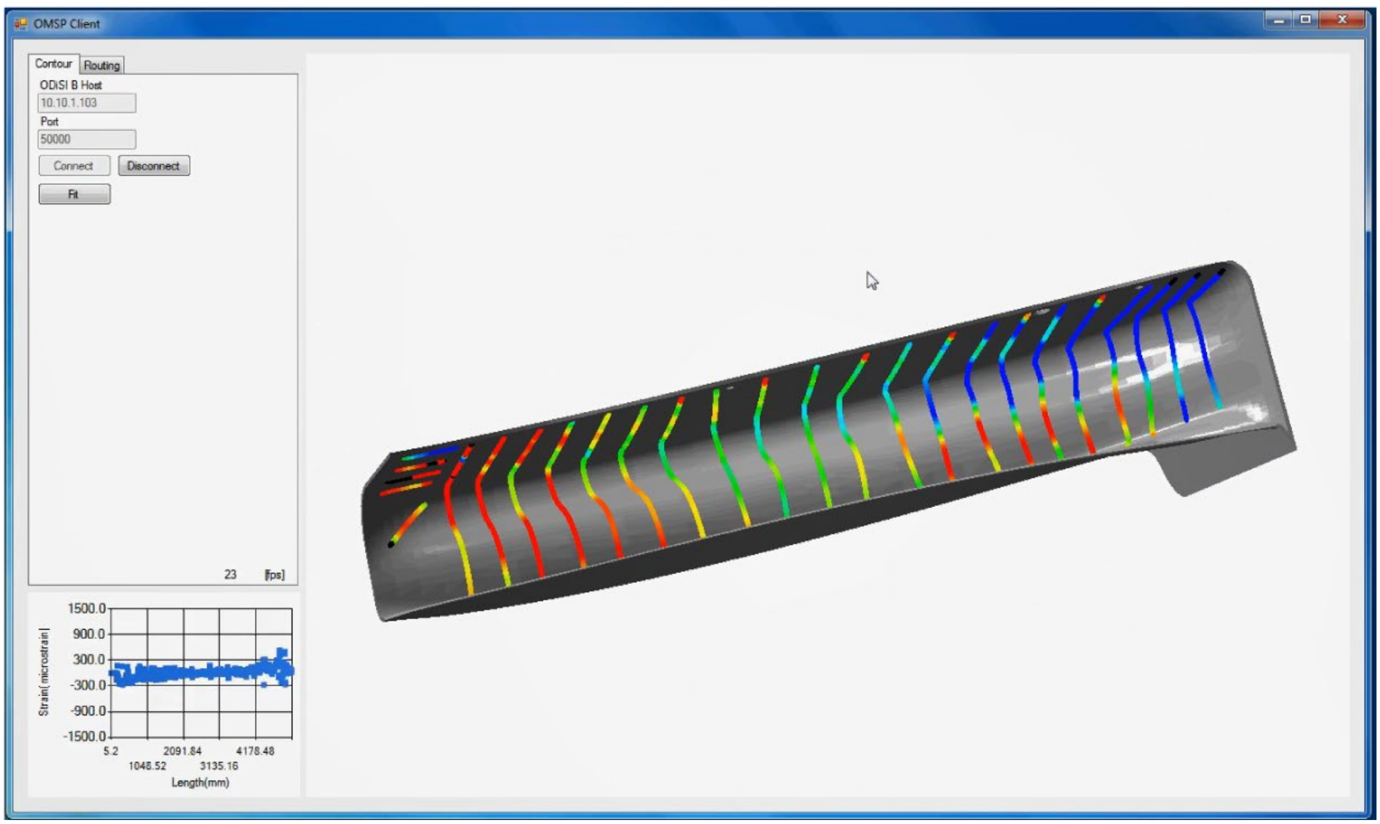



*Figure 10. 3D Visualization Software*

## Learn More

Transform structural testing, accelerate design and ensure quality with the ODiSI 6000 platform. Contact Luna Innovations today to speak to a sensing expert and discuss how the ODiSI 6000 Series can benefit your organization.

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