White Paper

Insertion Loss and Return Loss – Keys to FTTx Passive Component Reliability Testing

By Matthew Adams

When it comes to fiber-to-the home (FTTH) or the other fiber network architectures (FTTx), optical test and quality engineers are on the front line of the battle between cost and reliability. On one hand, the economics of deployment drive selection of the lowest cost optical components (splitters, cables, connectors, and frames) while the extreme cost to install drives expectations that these elements will last for 25 years or more. Physical connection failures cause prolonged service outages and lose customers; but if you canot afford to get fiber to your customers, you lose before you start. Solution—review the whole process for supplier qualification and insert audit programs that continually require environmental stress testing of manufactured components.

Introduction

A number of well-documented FTTx architectures are used today (Figure 1). Common for all is the need to push fiber optics deeper into the access network—the most ambitious directly to the home. With the recent announcements of 3 million homes with access to FTTx in the US, ramping production volumes of connectors, cables, splitters, and the enclosures required is a real challenge for manufactures. Also clear, is that as volumes ramp and price pressures amplify, relief is no where in sight regarding the pressing need to ensure the reliability of these connections. Manufacturers must show that their technologies will stand the test of time.

Insertion Loss (IL) and Return Loss (RL) are the critical performance parameters for all of these technologies. Accelerated aging and real-time test monitoring has become the standard approach to demonstrating equipment lifespan.

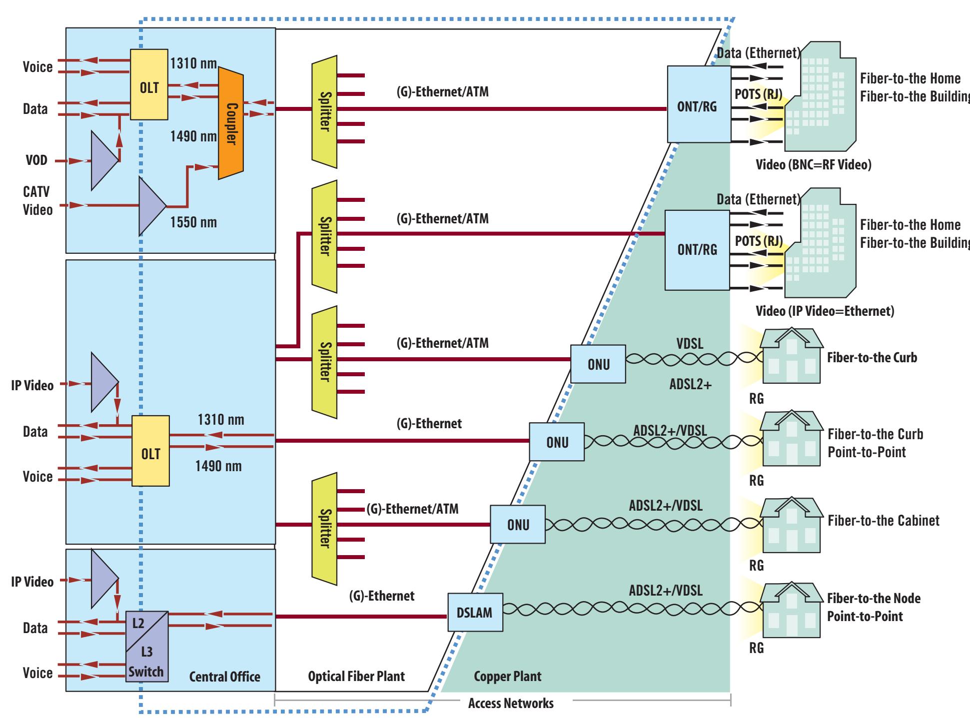

Figure 1: Typical FTTx architectures. The optical layer components are contained within the blue hashed box

As Figure 2 shows, many technologies are necessary to make these connections a reality. Obviously connectors, cables, and optical splitters are required, but equally critical are the enclosures and frames that hold the copious connection points to ensure the continuity of the signal between the optical line termination (OLT) and optical network unit (ONU). If the clamp that holds a splice or jumper fails and pinches a fiber, the impact on IL and RL can be as detrimental as the failure of a core component. Following sections review the key standards that influence the tests to perform and the key issues to address when building a test system to execute these tests.

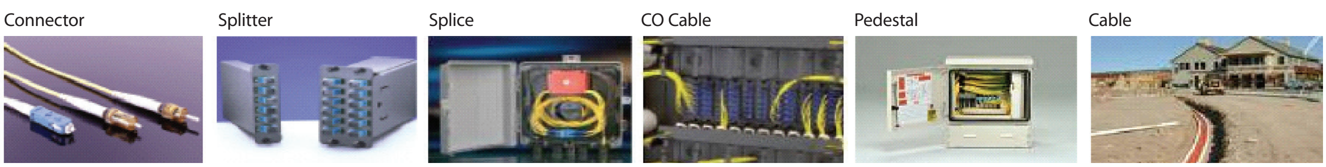

Figure 2: The array of optical layer technologies and packaging required to deploy an FTTx network. All of these elements must demonstrate long-term IL and RL performance prior to deployment.

Influential Standards

Standards heavily influence the structure and methodologies used to demonstrate the long-term reliability of FTTx optical components. Standards from various origins guide the industry in these pursuits. The key standards are highlighted here.

Telcordia General Requirements

The Telcordia General Requirements (GRs) are the historical and the most widely leveraged standards used today. These documents specify key performance and test requirements at a component or technology level. Figure 3 provides a snapshot of a clause for one of the most famous and demanding tests outlined in many of the GRs listed in Table 1. The 85/85 test directs the manufacturer to demonstrate IL and RL stability during exposure to 85°C, 85 percent relative humidity (RH) for up to 5000 hrs (6 months). For most technologies, this test is recognized as one of the harshest and will the likely result in a failure. Stress failures or shifts in optical alignment are common due to the stress placed on joints, seals, and extreme material corrosion.

Temperature:	85°C (±2°C)
Humidity:	85% (±5%) RH
Test Duration:	As specified by the packages (hermetic or not) and the operational environments (CO or RT/UNC) in Section 4 Table 3.

Note: The test at 85°C/85%RH according to the procedures specified in IEC Pub. 68-2-3 or MIL-STD-202 Method 103 is acceptable. The test shall meet the durations specified in Table 2 in Section 4, which may be different from those in the IEC or MIL-STD documents.

R6-12 **[142]** The functionality of the components under test shall be verified during the test by interim downtime measurements either at test temperature or at room temperature. Data shall be taken initially and at the end, as well as interim measurements, such as at 100, 168, 500, 1000, 2000, and 5000 hour intervals.

O6-13 **[143]** Insertion loss should be monitored in-situ for all ports.

R6-14 **[144]** Devices that are supplied with connectors shall have the entire assembly (device package, leads and connectors) subjected to the test conditions.

Figure 3: An extract of the famous 85/85 test that is at the heart of the accelerated aging test method. A critical challenge for optical test engineers is developing an IL/RL test system that can operate continuously for 6 months.

Document	Target Device Under Test (DUT)
GR910	Attenuators
GR2866	Fan outs
GR1435	Multi-fiber connectors
GR1209	Generic passive components
GR1221	Reliability requirements of passives
GR326	Fiber optic patch cords

Table1: Some common GRs used for FTTx components

It is important to note that the pass-fail criteria (the level of acceptable change), is typically agreed to between the buyer and supplier. System tolerances typically determine the amount of drift allowed.

International Electrotechnical Commission (IEC) 61300 Standards

The measurement definitions used for IL and RL are typically defined by IEC standards, which are published by Sub Committee 86B Working Group 4 (SC86B/WG4). The 61300-3 series defines most critical fiber optic measurements. IEC Standard 61300-3-4 defines IL, Standard 61300-3-6 defines RL, and Standard 61300-3-12 defines Polarization Dependent Loss.

Customer-Specific Standards

In many cases, customers will publish specific standards to supplement the above two bodies. For example, Verizon has been extremely active in the area of FTTx components. Of particular interest is Verizon Standard VZ-TPR-9413, which guides the procedures suppliers must use to validate their long-term IL/RL test systems for use in component stress testing. Verizon took this step due to the extremely tight performance demands placed on the angled physical contact (APC) connections used in their fiber optic services (FiOS) FTTh deployment. Vendors who supply connectors to Verizon must show that they have executed the GRs specified on test systems capable of measuring RL as high as 70 dB. TPR-9413 provides guidelines on demonstrating this capability.

Verizon, through their Field Operations Center (FOC) program, has issued a number of directives to suppliers in this area. One of the most interesting is the need to perform annual validation of test system performance, have tests witnessed and certified, and perform continual qualification audits of the production samples. This is just one example of the determination of operators to safeguard the reliability of their deployed optics—even in an environment that rewards strong cost reductions.

System Architecture and Critical Issues that Impact Performance

Figure 4 shows the standard architecture for long-term measurements of IL and RL. It is capable of executing the 85/85 test and measuring RL as high as 70 dB. The following section reviews the key issues to consider when developing or purchasing systems to perform these tests.

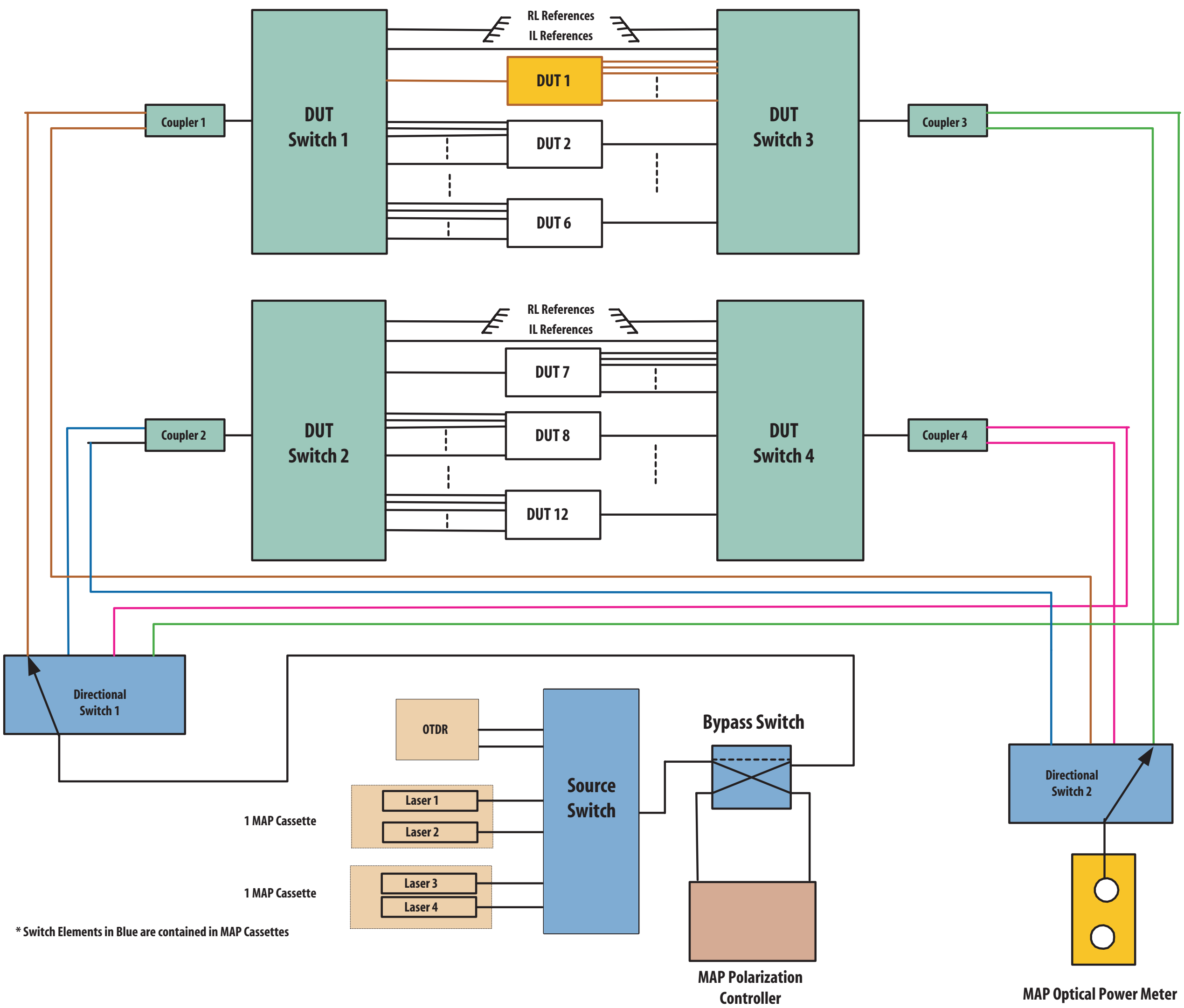

Figure 4: Block diagram of the JDSU OCETSplus system, which is capable of executing the 85/85 test and measuring 70 dB RLs.

Optical Switching

At the heart of the system are the large 1xN switches where the DUTs are connected. Given the long-term nature of the testing, loading several DUTs leads to these switches being very large, ranging from 1x55 up to 1x110 cascaded channels to create systems as large as 210 input and 210 outputs. As the figure shows, the most efficient method of loading asymmetric devices (1xN DUT, such as splitters) requires connecting the devices in alternate directions. In this manner, eleven 1x32 splitters can be loaded in a 210x210 channel system. This interleaving requires that the system test be capable of bidirectional IL and RL measurements. This capability can be accomplished by connecting the directional switches directly to the input of the large DUT switches. Bidirectional testing also requires extreme care and management of parasitic reflections that can destabilize test results.

The DUT switches are usually terminated with 5 to 10 meters of optical fiber, which is required for the free and easy insertion of the DUT into environmental chambers or other test fixtures (vibration for example). The optical performance of the switching directly impacts the performance of the system.

RL of the switches themselves is typically >65 dB with IL less than 0.5 dB. Equally important is the stability of the IL and RL over long periods of time. Over the lifetime of these systems, millions of switch cycles will accumulate. Although referencing schemes are typically implemented, the cycle-to-cycle repeatability of the switch connections can impact performance and increase the execution time of the test. (For example, reference frequency is a function of how fast the system may drift). For this application, expanded beam mechanical switches were shown to be the most reliable and delivered the performance required. These switches can have repeatability of 0.002 dB.

Laser Sources and Power Meters

Another critical area that can impact system performance is the selection of laser sources and optical power meters. Laser source qualification typically takes place at four wavelengths that define key operation windows: 1310, 1480, 1550, and 1625 nm. Given the automated nature of the test, the number of optical elements in the path and the length of the fiber required to connect the DUTs to test fixtures require low coherence length sources. In simple terms, coherence length is the distance over which the optical signal will constructively or destructively interfere with itself. Long coherence means that weak unstable reflections along the signal path can cause optical power instability. Sources of weak reflections can be fiber kinks or the background RL of the switches.

Figure 5 demonstrates that it is possible to select lasers that have coherence lengths <30 mm. For these sources, the reflections must be closer than 30 mm to cause instabilities. This is impossible with interconnect jumpers on the order of 300 mm; however, if laser 1 is selected, this interference could be a source of stability issues.

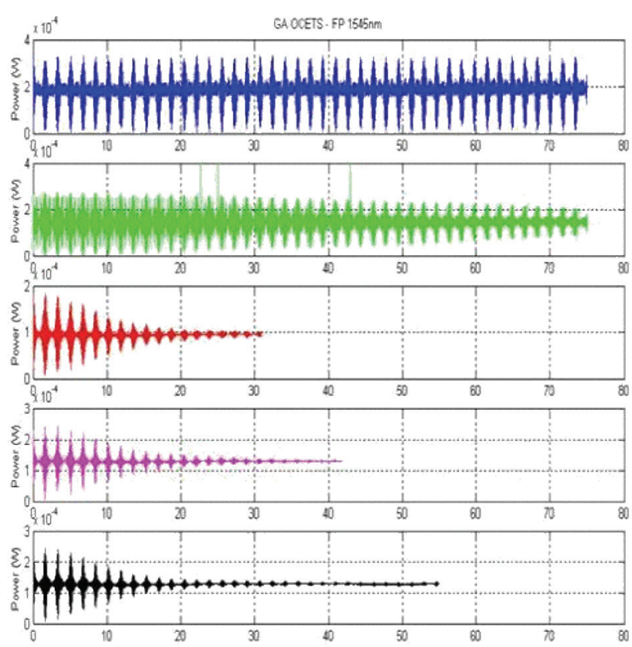

Figure 5: A JDSU OCETplus system is prepared for baseline referencing. The 5 m pigtails from the DUT switches are spliced together. Splices are managed on trays with strain relief holders.

Referencing and Stability Validation

Referencing is a general set of processes and algorithms by which the system samples and monitors the stability of all potential sources of drift during a measurement cycle. In the system shown previously in Figure 4, several monitoring points are available, including splice-through paths for monitoring IL drift, switch termination positions, and reflection artefacts to measure parasitic RL levels. These are used in the measurement algorithms that extract the IL and RL values of the DUT and subtract out system drift elements. These references are critical in achieving systems capable of resolving 70 dB RL connectors.

In general, prior to a new long-term test, the system is put into splice mode and a baseline set of measurements is taken (Figure 6), such as baseline power levels. As outlined in Verizon Standard VZ-TPR-9413, this is the configuration used to demonstrate the long-term stability of the system.

Figure 6: A JDSU OCETplus system is prepared for baseline referencing. The 5 m pigtails from the DUT switches are spliced together. Splices are managed on trays with strain relief holders.

Fiber Management and Device Preparation

Often forgotten is the impact that poor fiber management can have on system performance—in particular for the long fiber leads that are used to connect the switches to the DUT. Figure 7 shows the importance of keeping fiber leads as relaxed and ordered as possible. The IL stability graph on the left shows the IL drift caused by the relaxation of the IL generated by the micro-bends in the pile of fiber. When the fiber is managed in an organized fashion, the same system shows superior baseline IL drift.

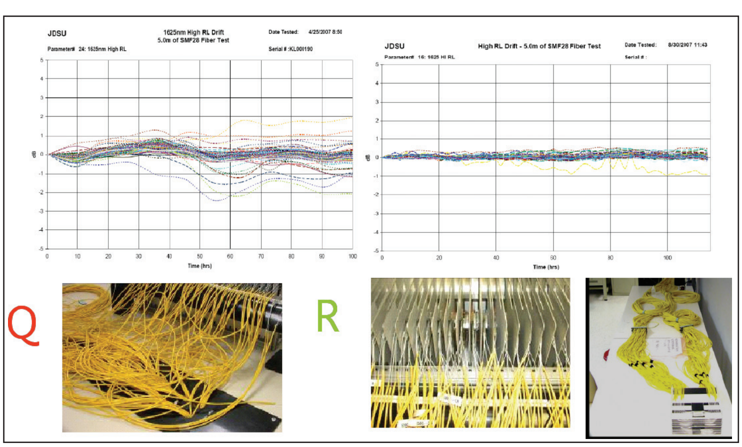

Figure 7: Bad fiber management can lead to poor system performance. Micro bends can cause IL that can change over time as the fiber relaxes.

Example Results and Discussions

This section reviews selected test results.

Temperature Cycling Example

Figure 8 shows a component being cycled repeatedly over a 75°C range, resulting in IL changes of 0.4 dB. Designers use this data to understand which aspects of the design may cause changes to the IL. In this case, over the time frame measured, the device appears to consistently go through the same change in loss as the temperature cycles—with no evidence of degradation present. By executing multiple cycles over long periods of time, it is possible to measure long-term changes to the integrity of the device due to stressing of joints and seals as materials expand and contract.

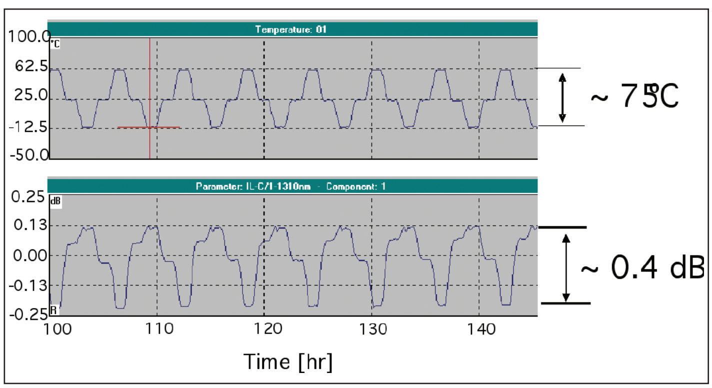

Figure 8: The shape and stability of the IL changes over temperature cycling can give the designer guidance on improvements to make.

Test to Failure at 85/85

Figure 9 shows the results for two separate batches of components tested at 85°C, at 85 percent RH for between 2000 and 4000 hours. The graph on the left shows a slow gradual change in transmitted power. The aging does not appear to have reached an end point. Had the device been tested for 1000 hours it may have passed. This type of failure is indicative of a tap coupler or a splitter, where the tap ratios are changing between output ports. In the case on the right, both samples experience catastrophic failure after 1000 hours.

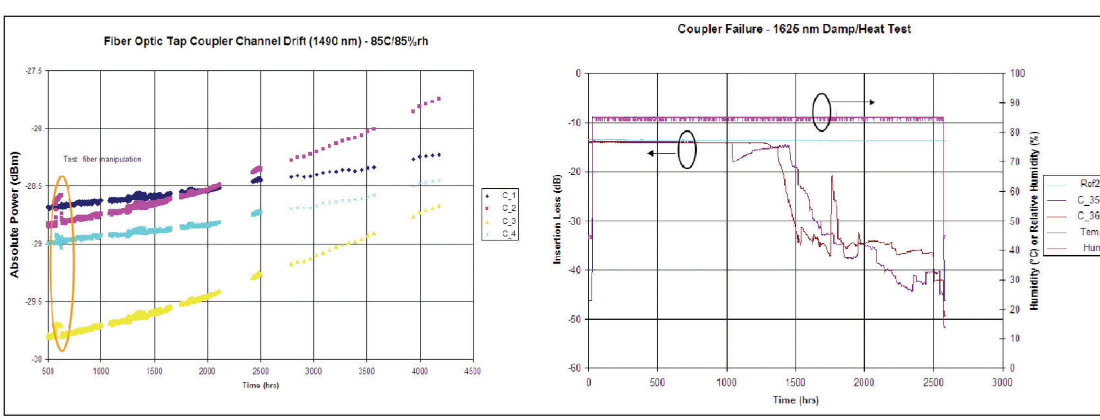

Figure 9: Test to failure examples. The first device shows a slow continuous change in loss where the second device fails catastrophically

Customer Qualification Report

Figure 10 shows a test result formatted for submission to a potential customer. IL/RL data shows excellent stability for all ports on the 1x32 splitter. Typically additional information about the test conditions (temperature and humidity) would be added.

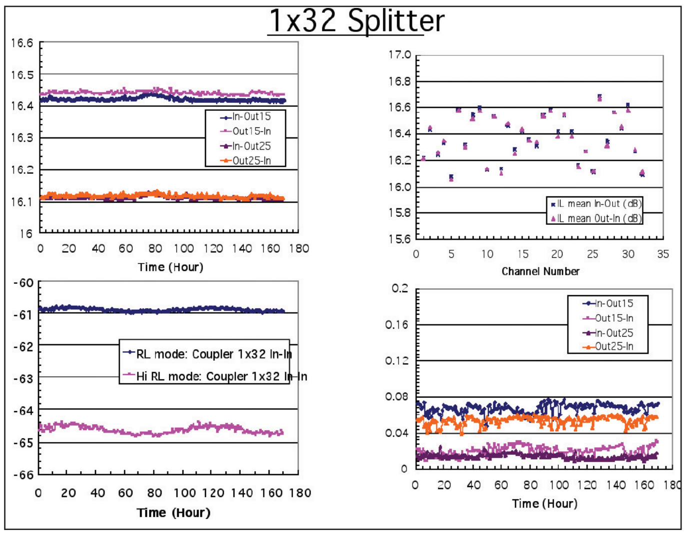

Figure 10: Example of a test report as might be submitted to a customer

Summary

This document reviewed the basic test motivations for long-term environmental stress testing of the passive optical components used in FTTx. One must understand the guiding standards and key issues for the design or specification of the required test systems before attempting this type of testing. JDSU has been helping customers execute these tests for more than 20 years through supply of turnkey systems like OCETSPlus or assisting customers in building their own.

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