intelligent FactoryBuilt NETWORK™

LightRiver

WHITEPAPER

The Value of the intelligent Factory Built Network®

Introduction

LightRiver provides a full spectrum of engineering-rich services and automation solutions to operators of complex, best-of-breed transport networks. LightRiver services include network architecture and design, site surveys, site engineering, fiber optic characterization, fulfillment, installation, integration and automation via its netFLEX software platform.

For more than 20 years, LightRiver's mission has been to help operators of the most demanding transport networks achieve the highest possible levels of performance, reliability and cost-effectiveness. In pursuit of this mission, the LightRiver team has developed a novel approach to deploying complex networks, intelligent Factory Built Networks.

This white paper describes the process differences between an intelligent Factory Built Network (iFBN) and traditional field-built networks and reviews LightRiver's greatly enhanced network testing versus traditional approaches. It also quantitatively presents benefits to the customer of an intelligent factory built network including reduction of project time lines, minimization of time onsite, accurate project schedules, higher quality, and lower customer costs.

- **Accelerated Time to Market**
  Project timelines are reduced by 50% allowing for new business sooner.
- **Better Network Performance**
  Rigorous testing leads to higher quality and better performing networks.
- **Less Business Disruption**
  60% less onsite installation time reduces disruption to on-going business.
- **Lower Internal Costs**
  Internal resource requirements are drastically lowering costs.

intelligent Factory Built Network® Snapshot

As the name suggests, LightRiver's intelligent Factory Built Networks are constructed first in a state-of-the-art network factory, where networks are inventoried, installed, provisioned, audited and tested extensively by relevant experts at each specific stage of the process. Then the equipment is custom-crated and shipped to field locations. Upon arrival in the field, the iFBN is deployed rapidly and put through final testing, monitoring and baselined performance.

An Innovative and Patented Process

The process required to design, deploy and comprehensively test a new transport network is a complex one. LightRiver has taken the multiple tasks and combined them into one integrated and patented process to allow for a higher quality network at a lower cost, which is implemented in half the time of a traditional network build. The procedure frees the operator to select any vendor they believe most advantageous and begins with an engineer architecting the network. If the technology is new, LightRiver will vet the products through a proof of concept in its network interoperability lab.

Next, pre-deployment engineering takes place where fiber plant testing, site surveys and site engineering are conducted to ensure the physical infrastructure is ready for a next generation optical network. Engineering Design Packages are generated and reviewed with the customer, ensuring every detail – even down to the labeling nomenclature – is clearly understood and agreed upon.

In parallel, equipment and material are purchased, shipped, inventoried and kitted by site. The networks are then installed, turned up, provisioned and extensively tested in LightRiver's Factory. During factory testing, a baseline is established for later comparison against the field test baseline. Once the staged network arrives on site, the fiber optic plant is tested again to ensure reliable light transmission with minimal loss and reflection.

LightRiver optical field engineers, who are experts in final provisioning and testing, then rapidly install the FBN in racks or cabinets. The network is performance-tested to industry standards and its factory test baseline to ensure complete and reliable functionality including end-to-end bit error free transmission, low latency and committed bandwidth as well as span-by-span performance. With an iFBN managed service providing ongoing performance, capacity and inventory metrics against baseline thresholds, an operator has the opportunity to proactively mitigate any future network challenges and continue to meet or exceed original intent.

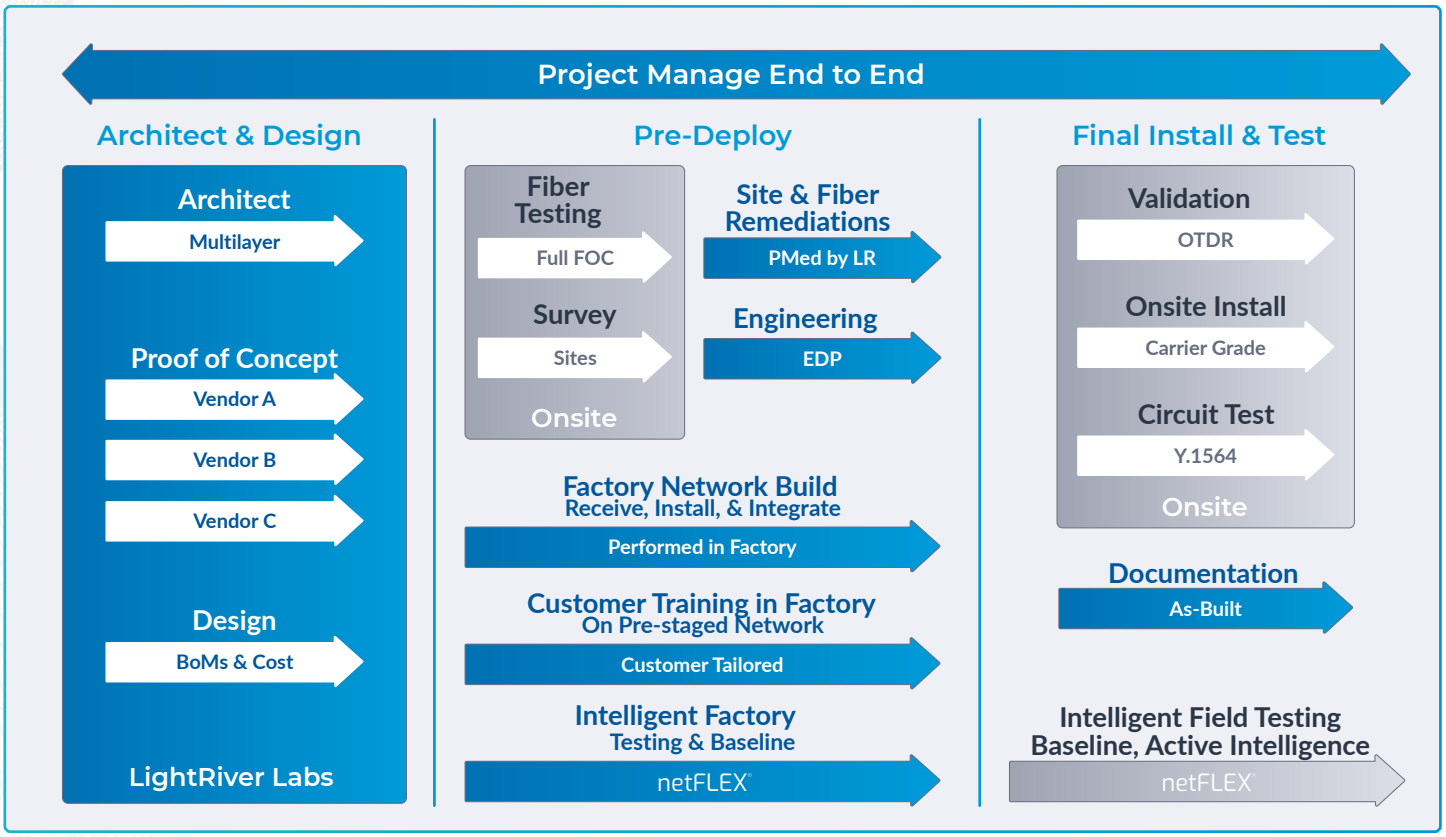

Figure 1: The intelligent Factory Built Network process integrates and overlaps tasks to improve quality, expedite timelines and save cost.

intelligent Factory Built Network Process vs. Traditional Field-Based Process

Traditional Field-Based Deployment Process:

In a traditional process, network deployment occurs in separate customer locations. Equipment is shipped piecemeal to each location and stored onsite until the time of installation or shipped to a central warehouse for handling and distribution. Field engineers travel to each location, validate the kit and complete the installation, provisioning and testing of the network, staying locally until the job is done.

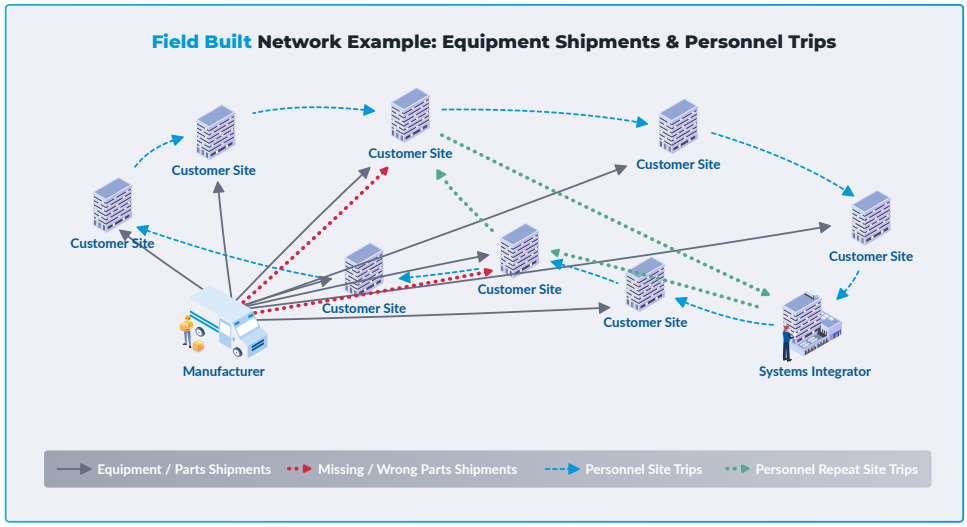

Figure 2: The inefficiencies of multiple shipments and return trips associated with a traditional built network approach.

Escorts are often required by customers to provide access to customer location or data centers for field network technicians and to oversee their work and, in some cases, perform basic remediations. In the event of a deployment delay or return visit, escorts would need to be scheduled again adding to project cost and administrative workloads.

intelligent Factory Built Network (iFBN®) Deployment Process

In contrast to a traditional field-built approach to network deployment, most of the work in a Factory Built Network process occurs in a central facility, or "factory." This difference allows LightRiver to implement a high quality production process. It also enables the use of experts for each step of the network build process including inventory, physical install, provisioning and testing before the networks leave the factory.

In the iFBN process, all network components are shipped to the factory initially and then organized and managed efficiently by inventory control experts. In a clean and environmentally controlled factory setting, LightRiver can organize all of the equipment and tooling to pre-build networks efficiently and to the highest quality standards. Integration, commissioning and custom tuning of each part of a system can be completed by the most appropriate expert for the specific type of equipment, software or network.

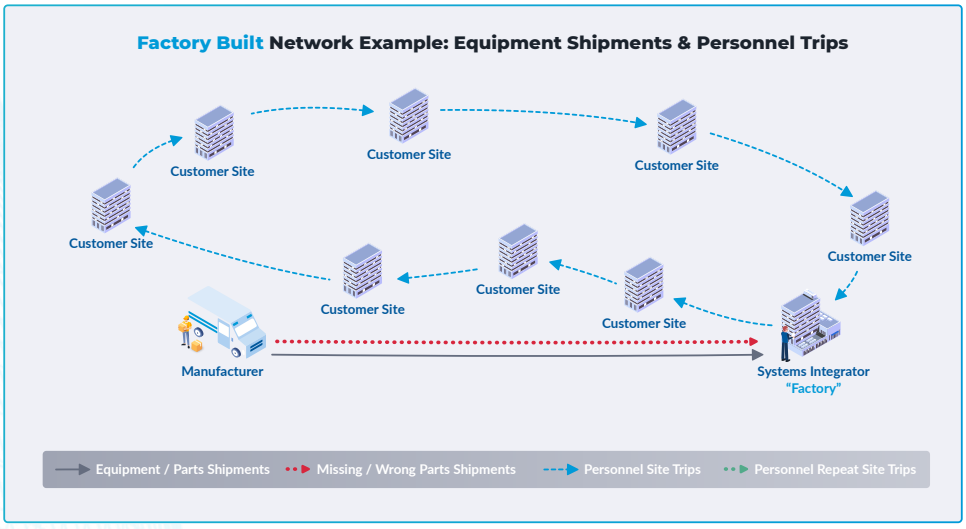

Figure 3: Streamlined Factory Built Network deployment methodology that minimized onsite complexity and time.

If a system design question arises, an in-house network design engineer can be readily consulted. The network is then thoroughly factory tested with failed parts identified and replaced early in the process before the staged network leaves the factory - eliminating the traditional need for extended stays at customer sites, extra trips to remote locations or increased expense for customer escorts. With the iFBN process, equipment arrives at customer sites in parallel with the LightRiver field deployment team, often via dedicated truck, ensuring staged networks arrive on time to the right site and in their entirety. This streamlined process reduces the time onsite by 60% over a field built network.

In a field-based deployment, there are common issues that regularly delay projects:

- **Missing hardware and miscellaneous material**

  Since products are shipped in dozens of individual boxes to multiple sites, it is a common occurrence that some products do not arrive onsite or arrive at the wrong sites. Once on site, an extensive amount of time is required to inventory all material at each site location by a field technician who neither has the logistics skills nor tools to efficiently inventory material.

- **Wrong or failed out of the box parts**

  Given an industry standard rate of roughly two percent for incorrectly packaged or out-of-the-box failure for individual line items within an optical node and there often being over 25 line items in a complex optical node, such failures often require return trips to sites. It is likely that these part problems would occur in multiple customer sites for a network deployment with a large number of network nodes.

- **Design, engineering or product defects**

  While design and product defects are less common than out of box failures, they are not infrequent when deploying new technologies or first office applications. When they do occur, field technicians require extensive remote support and time to isolate and identify root causes. Entire projects can come to a halt for days, or even weeks, as the proper resources are marshaled to remediate deficiencies.

intelligent Factory Built Network vs. Traditional Testing

Traditional Field-Based Network Validation and Testing

Auditing and testing tend to be relatively limited in a field deployment process, given the limited amount of time available in the field and the minimal expertise of most field installers. In fact, it is a common industry practice for field technicians to perform the physical installation while leaving the final provisioning and network auditing to remote engineering resources. This industry practice is a workaround to the high cost and travel expense associated with bringing optical engineering expertise and test equipment to customer locations for extended periods of time.

Unfortunately, this methodology prolongs troubleshooting time while severely limiting the complexity of performance testing. Most field test plans only include a short duration end-to-end bit error rate test with no span-by-span analysis. Physical installation quality audits are usually performed remotely, with spot checks done on a minimum number of low-resolution installation pictures. New network systems are burned-in for a very limited time or not at all. Failover testing is rarely performed, whether for a complete system or for individual hardware levels.

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intelligent Factory Built Network® Validation and Testing

LightRiver's Network Factory includes a purpose-built clean environment where each and every fiber jumper end-face and associated fiber port is inspected under a 400x scope before placement. Verified clean placement of patch cords is one of the most important validations in any high performing optical system and minimizes troubleshooting during testing. Patch cords are labeled, routed and meticulously managed. Networks are fully provisioned and custom tuned in the factory. Since networks are fully deployed in a single location, with resident onsite test engineers, they can be audited and tested far more extensively than a network deployed primarily in the field.

With a Factory Built Network, quality checks can be performed on 100% of labels and jumpers. The inspection of every patch cord via 400X scope can be supervised. Each label can be double-checked for proper placement and description. The neatness and routing of every optical patch cord can be verified. If required, corrections can be readily made before the equipment is shipped.

In a factory environment, systems can undergo 72 hours of "burn-in" to ensure successful functioning, rather than a few hours. In the factory, a full Y.1564 test is efficiently run on each provisioned circuit to determine bit rate, latency, jitter and frame loss with test systems geared towards testing multiple circuits simultaneously. In addition, comprehensive system failover testing can be conducted at all hardware levels.

In an average deployment, roughly half of the time spent on a customer site is spent on troubleshooting issues.

After Y.1564 factory testing, a final "intelligent" factory performance test can be performed via LightRiver's netFLEX® software platform to tune the network for optimized performance. Utilizing netFLEX 's analytics, including the netFLEX Circuit Analysis Tool®, all circuit paths and circuit performance are captured on a span-by-span basis and compared against targeted system design performance. This allows for a far better tested network and a comprehensive FBN Certification Report. If factory testing reveals a performance issue it can be resolved by a team of onsite packet optical engineers with a collective wealth of expertise in troubleshooting across multiple technologies.

In an average deployment, roughly half of the time spent on a customer site is spent on troubleshooting issues. With iFBN, almost all system issues are discovered and resolved in the factory. This saves a considerable amount of time at customer locations and in the deployment process overall.

When the system has been successfully integrated, quality-checked and fully factory tested, it is disconnected and packed in custom engineered shipping crates, which allow

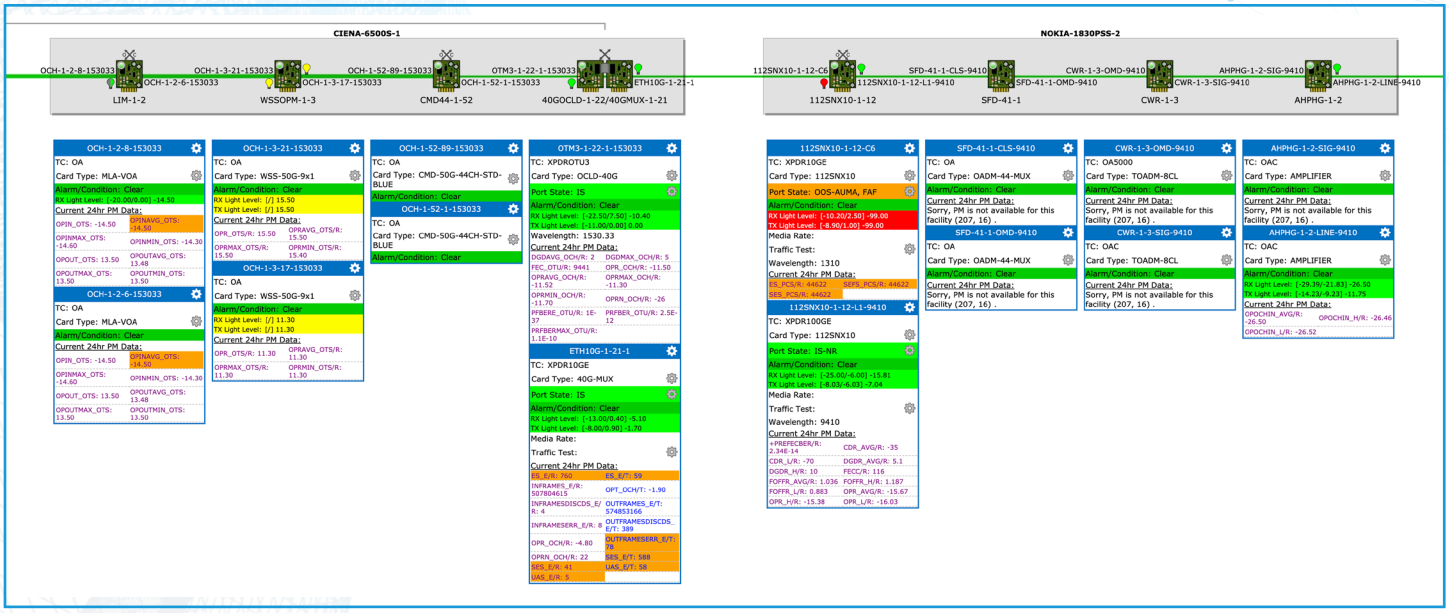

Figure 4: Span-by-span Circuit Analysis performed via netFLEX to provide an "intelligent" Factory Performance Baseline.

circuit packs and meticulously managed fiber patch cords to remain in place while being shipped to each customer site. Crates are shipped via dedicated trucks so they arrive at the site with the field engineers. Final field deployment is then completed in each customer location rapidly as the vast majority of the installation work was completed in the factory.

The large reduction in field install time not only streamlines the project, but also allows for extensive field testing by highly skilled field engineers (versus installers).

LightRiver field engineers begin each field implementation by verifying the fiber plant through Optical Time Domain Reflectometer (OTDR) testing. Final testing compares all critical network data captured at the time of the Factory Build against the data that is captured again via netFLEX at the completion of field installation. This data driven testing approach ensures the highest quality network implementation while providing a benchmark or "Golden Config" of the 'Day 1' network health and performance.

Experts Available in Factory Versus Field

	Network Design Engineers	Logistics Managers	Installers	Integration Experts	Hardware & Software Test Engineers	Network Auditors
LightRiver's intelligent Factory Built Networks	✓	✓	✓	✓	✓	✓
Industry Norm for Networks Built in the Field			✓			

Figure 5: Comparison of experts available to provide hands-on implementation and troubleshooting in factory versus field.

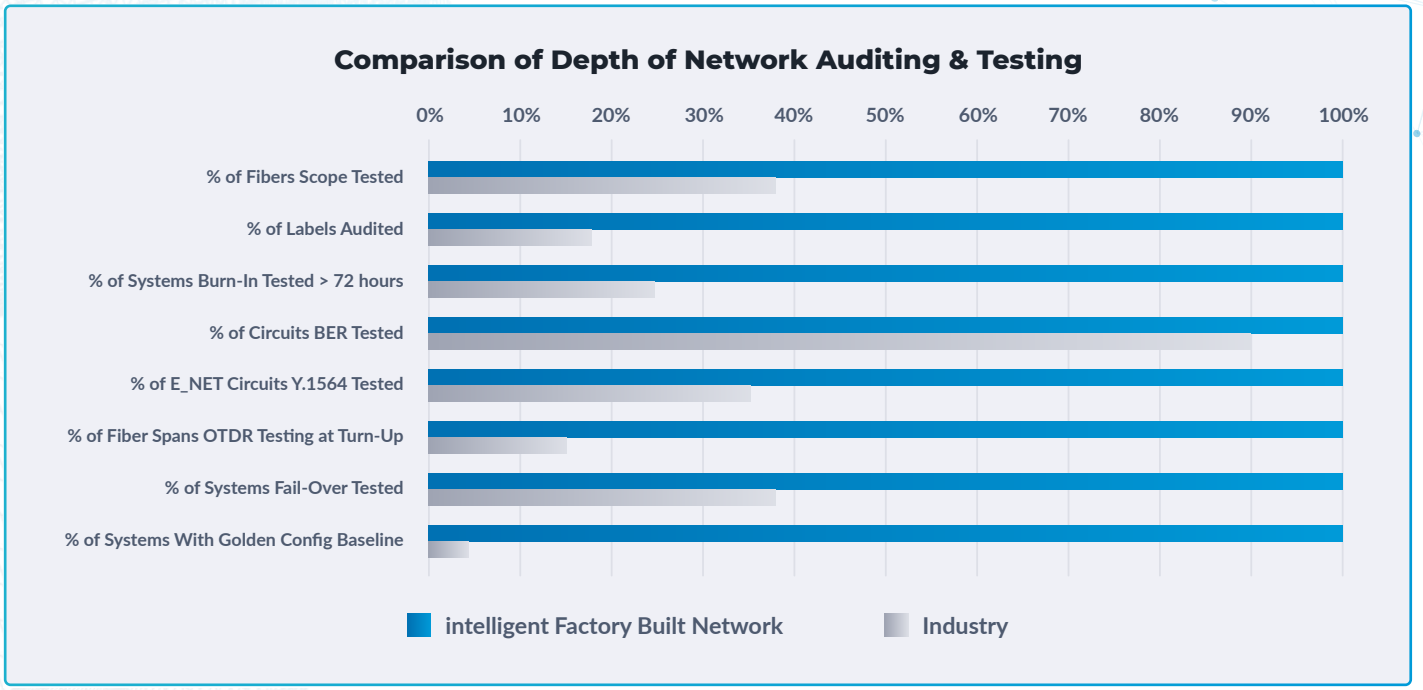

Figure 6: Comparison of network testing & auditing commonly done by the industry versus LightRiver's scope of work for iFBN.

intelligent Factory Built Network Customer Benefits

60% Less Time on Customer Sites

Advantages of LightRiver's intelligent Factory Built Network (iFBN) service is a state-of-the-art methodology engineered for today's integrated multi-layered networks. In 2020, LightRiver received a US patent for its innovative approach to network delivery along with several industry awards. LightRiver's intelligent Factory Built Network® offers significant advantages for today's integrated multi-layered networks four primary areas:
(1) Less time on customer sites; (2) Faster project time lines; (3) Better tested and performing networks; (4) more accurate project schedules; and (5) reduced customer costs.

With installation and troubleshooting work completed largely in a "factory" setting, LightRiver is able to spend 60% less time on customer locations. In most implementations, LightRiver visits each site only two times while performing multiple functions each visit via LightRiver's in-house highly trained field engineers. On the first visit, site survey, OTDR fiber testing and basic remediations are completed. During the second visit, OTDR, final installation, troubleshooting and performance testing are completed.

For example, the LightRiver team used the iFBN approach to deploy a 14 site C+L DWDM system between data centers in Chicago and Omaha and compared the average number of visits and average time on site for a Factory Built Network versus a traditional installation model. In this example, site visits were cut in half and total time on site was reduced by over 60%.

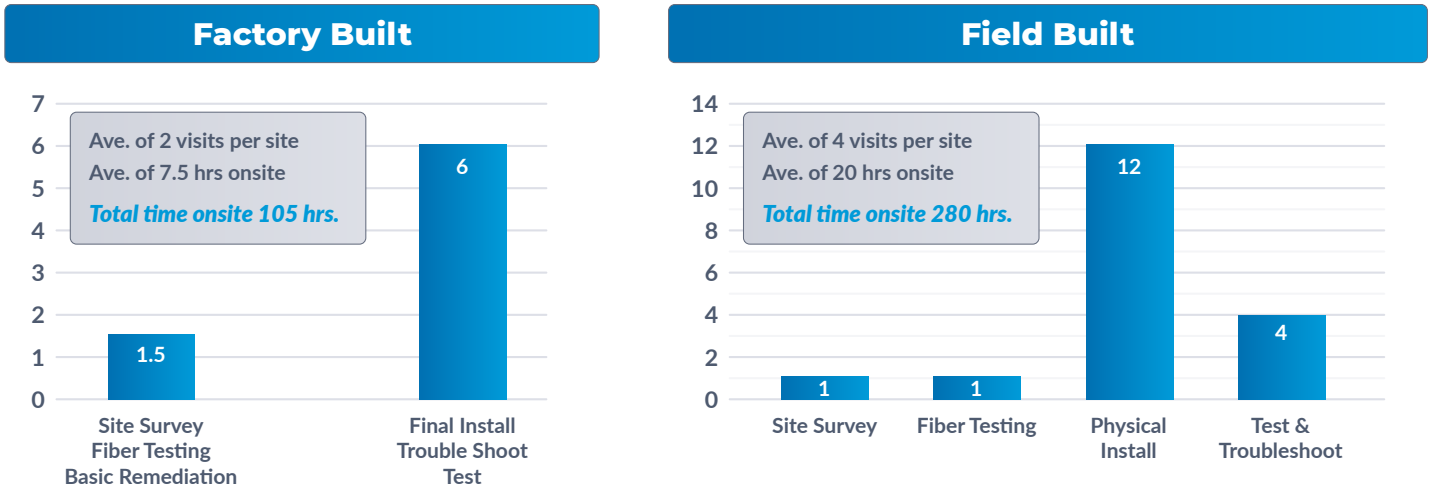

Figure 7: Comparison of visits per site, average time on each site and total time for 14 site long-haul DWDM network.

50% Faster Project Timelines

In LightRiver's patented intelligent Factory Built Network (iFBN)® process, the higher volume production setting enables significant efficiencies in logistics, pre-building and troubleshooting, which drive project timeline reductions. Equally important, these efficiencies allow for the cost effective deployment of highly skilled network engineers who can perform multiple field functions, thereby minimizing the number of site visits and time onsite, further driving project time savings. As illustrated in Figure 1, in Lightriver's FBN process, multiple tasks are overlapped to further create efficiencies. For instance, while site surveys, fiber testing and engineering design packages are being completed, the network is simultaneously being built in the factory and baseline tested. This innovative approach cuts the overall project timelines in half and establishes a far higher level of continuity.

This innovative approach cuts the overall project timelines in half

For example, LightRiver performed a multi-year, multi-vendor, statewide communications system upgrade for the control of water and power, deploying multiple technologies including CWDM, DWDM, Carrier Ethernet, TDM and timing across 150 customer locations. LightRiver was contracted to provide a turnkey solution, including all pre-deployment, procurement, deployment and post-deployment services (e.g. system engineering and design; fiber characterization; equipment hot staging: factory acceptance testing, installation, customer training, circuit cutovers, network management, maintenance and technical support).

LightRiver delivered the project more than two years ahead of schedule, having completed its work in approximately 50% of the expected time. The customer enjoyed minimal impact on its employees and operations and far lower-than-expected project support costs. Specifically, LightRiver caught 22 out-of-the-box card failures in the factory and replaced them with new parts before deployment on customer sites. When the 500-plus network elements were installed and tested across 150 customer sites, there were zero field failures. Perhaps most importantly, the customer was able to enjoy the operational and cost-reduction benefits of its new transport network more than two years sooner than it had planned.

Better Tested Networks

The LightRiver FBN process offers unprecedented opportunity for testing of the fiber plant and network. Starting with the fiber plant, LightRiver tests each span with an Optical Time Domain Reflectometer (OTDR) at time of site survey via both a "short shot" and a "long shot" test. **Over 20% of fiber spans tested fail at time of site survey** due to high reflection or high loss at splice and connector locations or due to breaks in continuity. These issues are logged and managed to resolution by the LightRiver project manager with LightRiver engineers readily available to discuss the fiber plant test results with dark fiber providers. This early identification and remediation management allows the necessary time to ensure the fiber plant is corrected to fully support the network installation.

On return to the sites for final installation, fiber spans are retested to ensure fiber plant remediations were completed successfully and no subsequent failure events have occurred. A marginal fiber plant must be remediated prior to install or it will cause network issues at turn-up and for years thereafter. This fiber validation is a critical step in the LightRiver FBN process of delivering better networks, faster.

Concurrent with the upfront field work to site survey and test the fiber plant, the network is being fully tested and fine-tuned within LightRiver's network factory including span-by-span analysis via netFLEX®. This allows a packet optical engineering expert time to perform the custom network tuning, including establishing performance thresholds within the element management system and netFLEX. The factory setting is the ideal place to do so since the factory staged network is constructed and interconnected within a single location. Virtually all part failures can be caught in the factory rather than on the customer site, facilitating a "failure free" deployment in the field. Approximately 1.8%

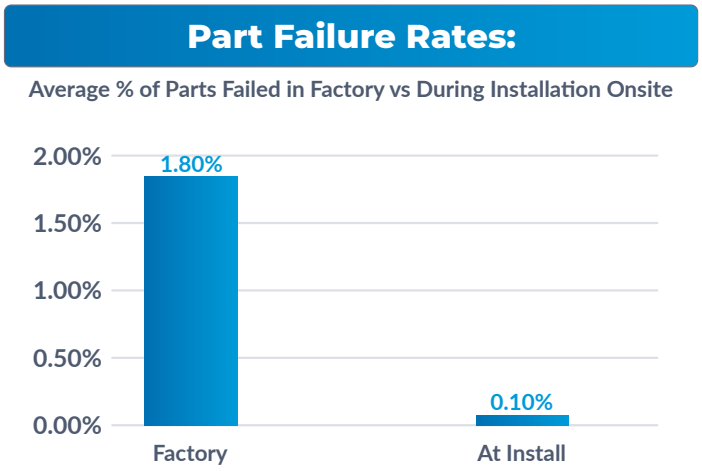

Figure 8: 94% of product defects are discovered during Factory Testing.

of parts are discovered defective during the factory build process and while that failure rate seems reasonable, **an average optical node has over 20 separate parts, so approximately one in nine nodes would be expected to have a failed part.** This is precisely why both factory and field-testing are so critical. See chart above (Figure 8) for average failure rates in the factory vs. at install after a network has been factory tested (based on data from actual LightRiver projects ranging in size from 50 parts to 10,000 parts).

Far More Accurate Project Schedules

As a result of LightRiver's highly optimized process, deployment schedules are far more accurate. Network issues are resolved in the factory. Fiber plant issues are discovered at time of site survey. Logistics are vastly simplified. All of these improvements combined make deployment schedules highly predictable. Over the past decade, LightRiver has analyzed every situation that can stop a deployment and implemented a process to minimize the risk. Unplanned return trips to the field have gone from being the norm to the rare exception. The key to this is active project management that tracks open items such as site and fiber readiness issues. LightRiver project managers work directly with third parties to ensure remediations are tracked to closure. Figure 9 is an example of the final installation schedule for the long-haul C+L DWDM network, previously referenced. Please note the speed at which the LightRiver team was able to deploy the next generation network and the accuracy of the schedule. The scheduling accuracy greatly benefited the customer as it minimized escort time, escort cost and escort scheduling complexity.

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Site Location	Planned Start Date	Planned Complete Date	Days on Site	Actual Complete Date
Chicago	20 - Aug	21 - Aug	2	21 - Aug
Morris	22 - Aug	22 - Aug	0.5	22 - Aug
Peru	22 - Aug	22 - Aug	0.5	22 - Aug
Sheffield	23 - Aug	23 - Aug	0.3	23 - Aug
Davenport	23 - Aug	23 - Aug	0.3	23 - Aug
Iowa City	23 - Aug	23 - Aug	0.3	23 - Aug
Cedar Rapids	24 - Aug	24 - Aug	0.3	24 - Aug
Victor	24 - Aug	24 - Aug	0.3	24 - Aug
Newton	24 - Aug	24 - Aug	0.3	24 - Aug
Des Moines	27 - Aug	27 - Aug	0.3	27 - Aug
Guthrie	27 - Aug	27 - Aug	0.3	27 - Aug
Harlan	27 - Aug	27 - Aug	0.3	27 - Aug
Logan	28 - Aug	28 - Aug	0.5	28 - Aug
Omaha	29 - Aug	31 - Aug	3	31 - Aug

Figure 9: Highly accurate schedules are an added benefit of LightRiver's optimized Factory Built Network process.

Lower Customer Costs

With the iFBN process, customers can spend significantly less as they transition to the benefits of a new network. The 50% reduction in the project timeline reduces customer's internal project management costs and with the time onsite reduced by 60%, there is far less disruption to business and minimized escort expense. Logistics costs are also decreased as the equipment arrives onsite consolidated and usually hand-delivered by the LightRiver implementation team at time of installation. This minimizes customer tracking and warehousing. LightRiver's complete turn-key approach also reduces the number of vendors and thus procurement costs. As an example, one LightRiver customer estimated the internal resource time saved as follows: procurement 60%, engineering 65%, logistics 80%, project management 65% and escorts 68% as demonstrated in the adjacent chart (Figure 10).

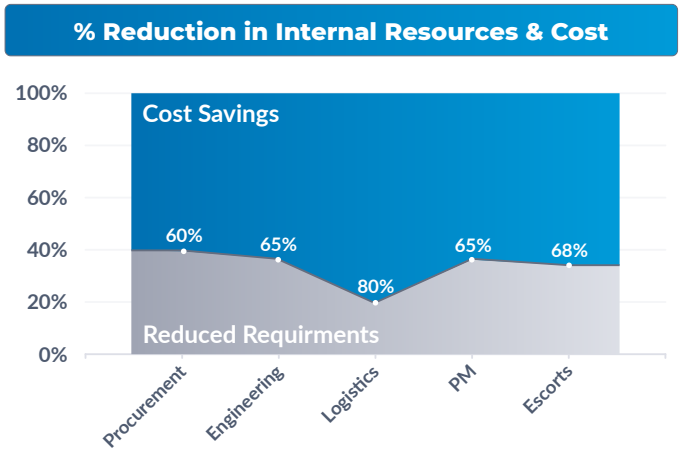

Figure 10: Percent reduction in customer resources with iFBN.

To recap the benefits of the intelligent Factory Built Network®

- **Frees up network operators to vet and select any equipment vendor(s)**
- **50% faster project timelines**
- **Eight times more auditing & testing to provide a better performing network**
- **94% of quality defects detected during factory testing**
- **Team empowerment via hands-on network training**
- **Over 60% less installation time on site including half as many site visits**
- **Predictable project and installation schedules**
- **65% reduction in customer staff requirements and associated cost**

All of these iFBN benefits result in expedited network use and revenue generation for your business. **Get a better network, faster. Profit from the benefits of a new iFBN and experience lower cost, higher revenue, better performance and less disruption along the way.**