Telstra InfraCo Express Intercity Fibre Network

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As the global COVID-19 pandemic continued to unfold through 2021, Telstra InfraCo commenced work on a new Australian intercity long-haul transport network (Express Network) to address exponential traffic growth from cloud and internet service providers.

A global fact-finding mission was undertaken—studying the latest network technologies and architectures—to ensure a solution was developed based on deep understanding of lead offerings in the industry.

The technical needs quickly became clear: high capacity, high data rate, high reliability, low latency, as well as flexibility and scalability. Voice of customer and market intelligence highlighted that environmental stewardship and sustainability were vital concerns for Australian and global hyperscale customers.

The Express Network required a strong standalone business case and clear differentiation with competitive offerings in the market.

Concurrent with building a new long-haul network, Telstra InfraCo sought to renew its existing intercapital fibre network (Foundation Network) to enhance existing capacity, connectivity, and performance both between capital cities and in regional areas. The global fact-finding mission also helped identify technologies and architecture for this renewal project.

Construction of the two new national fibre networks (Express and Foundation) demanded an innovative approach to architecture and construction, to satisfy economic imperatives. Consequently, Telstra InfraCo's Dual Cable Diverse Architecture was developed.

This white paper showcases Telstra InfraCo's innovative Dual Cable Diverse Architecture, focusing on the Express Network which utilizes an innovative fibre solution, advanced cable design, and novel construction methodology.

> *"When built, the network could be considered the largest, most advanced long-haul terrestrial network deployed anywhere in the world to date."*
>
> —Duane Robbins, Global Product Line Manager, Advanced Fibers, Corning Optical Communications

Telstra InfraCo's Intercity Fibre Project: What is Dual Cable Diverse Architecture?

Simply put—Dual Cable Diverse Architecture is two separate fibre networks (Express and Foundation) built simultaneously, connecting Australian capital cities with a minimum of two diverse paths between each city.

The Express Network is a high-performance network for customers who need reliable, ultra-high bandwidth between capital cities and international submarine cable landing stations. It is a completely new network providing greater performance and capacity and built primarily for high-data-rate, dark fibre services. It is designed with flexibility to provide connectivity to non-capital city data centres (DCs) and DC hubs as future needs arise.

The second network (Foundation Network) is a renewal of the existing intercity network with technically improved fibre, cable, and architecture. In addition to providing additional capacity between capital cities, it will provide enhanced performance and improved connectivity to regional Australia with enhanced performance to support the anticipated growth in bandwidth over the next 25+ years.

Express Intercity Fibre Project – Key Design Considerations

The Express Network was designed to meet today's bandwidth and network route requirements as well as future needs. Telstra InfraCo intends for the network to meet customer demands for the next 25+ years.

There were two key design considerations:

1. **Network resiliency:**
   Fundamental to this approach was the need for a diverse network with at least two routes between major cities to provide an increased network resilience.

2. **International submarine cable connectivity:**
   Given Australia is quickly becoming a regional hub for major international submarine cable systems, the network needed to connect to all international submarine cables that land on the continent.

Building such a diverse, interconnected network required a thoughtful and strategic approach to fibre choice and physical cable design.

Fibre Design Parameters

Meeting these critical network goals started with selection of an optical fibre, which ultimately resulted in an ultra-low-loss, ITU-T G.654-compliant fibre. Telstra InfraCo required a fibre capable of high bandwidth today, with future-ready capability for even higher rates over very long spans.

With direct burial of the cable a critical design feature (detailed below), fibre tolerance to macro- and micro bending was an essential requirement.

This will provide further protection, in addition to cable design, against optical losses that may result from the numerous load mechanisms to which direct buried cables can be subjected, particularly in reactive soils.

The Express Network design also required a fibre that would allow maximum design flexibility in terms of amplifier needs and optimal placement, a real challenge when considering the remote geographical locations that the inter-city paths will transit. Bounding these constraints was the need to maintain high bandwidth throughout the network.

Only a silica-core, ultra-low attenuation fibre, Corning's SMF-28® ULL fibre with advanced bend, could meet these rigorous bandwidth and design constraints.

Cable Design Parameters

The parameters of Express Path cable itself are bound to meet these high-performance challenges. Within the Dual Architecture network build, the Express Network path is physically separate but co-located with Telstra's existing route, and most of the path is direct buried.

Parts of the direct buried path pass through reactive soils that create unique challenges for cable design, particularly in relation to axial compression. Telstra InfraCo, in conjunction with cable partner Prysmian, developed a new small form factor cable suitable for direct burial deployment in reactive soils. The design was derived from existing know-how proven over many years in Australian soils and adapted for Express Network requirements. Central to this work was a proprietary axial compression resistance test that had been previously developed by Telstra and Prysmian.

The new cable designs for the project have been subjected to extended ageing testing, to validate their suitability for the anticipated lifetime of the network (25+ years) and to assess whether bend-tolerant fibres may extend lifetime beyond that expectation.

Telstra InfraCo has applied strict design criteria to the cable to maximize performance. For example, the routes are comprised of long cable drum lengths up to 12 km to minimize splices. Additionally, fusion splices have an average loss target of 0.04 dB, which may be the tightest splice loss specification imposed in the industry to date. Similarly, Telstra has minimized connector loss and ancillary equipment in the Express Path network to help preserve every precious decibel of transmission performance.

With Sustainability in Mind

To further promote the economics and sustainability of installing two networks, several choices to streamline deployment were made.

First, Telstra InfraCo utilized a Dual Plough method. Both networks are to be installed at the same time – streamlining installation resources. This approach is also better for the environment as one burial, instead of two, minimizes environment and cultural disruption. The cable design itself is deliberately a smaller form factor to facilitate the use of a Dual Plough approach.

Second, the physical parameters of the cable were key to achieving the following benefits:

a. **14.8 mm cable diameter** compared to 23.0 mm (59% smaller by cross-sectional area).
b. Only **180 kg/km** instead of 394 kg/km (54% lighter).
c. Up to 12000 m cable drum size compared to 5000 m (an increase of 2.4x), increasing the **distance between joints**.

Cable lengths, as discussed above, were deliberately long to enable fewer truck rolls (and associated carbon emissions) per network segment. The smaller cable design also reduced raw material usage, especially polymers used in cable jacketing.

Fibre Choice: Corning® SMF-28® ULL fibre with advanced bend

Future-ready fibre is the bedrock of the Express Network. Corning's SMF-28 ULL fibre with advanced bend was chosen following an exhaustive evaluation of fibres from leading global manufacturers.

The inter-city network requires Telstra to manage urban as well as very remote assets. The benefits and performance advantages of SMF-28 ULL fibre under this constrained environment are evident.

SMF-28 ULL fibre with advanced bend offers best-in-class, ultra-low attenuation, which allowed Telstra InfraCo maximum design flexibility to manage amplifier placement, while maintaining high data rates over long routes and spans. This minimized the added cost and reduced latency, a critical performance parameter for the international traffic carried over the Express Path.

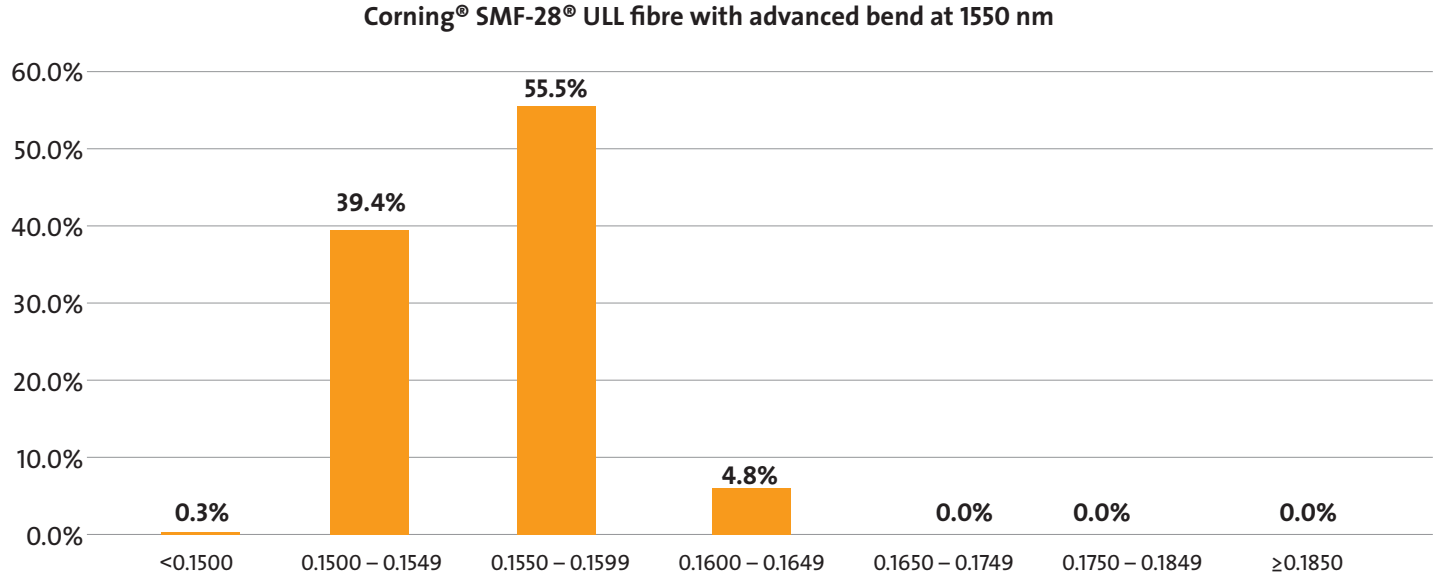
The combination of SMF-28 ULL fibre with advanced bend together with high fibre count cables empowered the Express Network with ultra-high data rates over long-haul links. As shown in the system design modelling table (Table 1), an optical link connection between Melbourne and Sydney (>1200 km) with optimal optical amplifier spacing could support >600 Gb/s per wavelength with 51 Tb/s (51 thousand Gb/s) per fibre pair, an aggregated cable capacity of >3.6 Petabit/s. The optical link connection between Perth and Sydney, a distance of almost 4000 km, with optimal optical amplifier spacing could support > 2 Pb/s per cable. With a market prediction of 35% traffic CAGR, Telstra's ultra-high-capacity Express Path network is designed to meet customer demands for the next 25+ years.

To complement the cable design, SMF-28 ULL fibre's high bend tolerance, with macrobend specifications meeting and exceeding ITU G.657.A1 requirements, also allowed Telstra InfraCo to leverage advanced cable designs that can withstand the pressures and demands of direct burial deployment. Direct-burial can subject cables and fibre to compression and bend challenges that could compromise performance for fibres without adequate bend performance. Lastly, SMF-28 ULL fibre's 10.5 µm nominal mode field at 1550 nm is splice-compatible to legacy single-mode networks, allowing for ready-made connections with Telstra's existing network.

SMF-28 ULL fibre has been widely used throughout the world, with millions of kilometers deployed in some of the harshest environments and most demanding long-haul applications. In 2019, Lumen (then CenturyLink) announced the creation of the largest low-loss network in North America with SMF-28 ULL fibre. In 2022, EXA Infra announced upgrades to its leading pan-European network, leveraging hybrid cables with SMF-28 ULL fibre to achieve data rates needed to meet the needs of hyperscale data centers and submarine system connectivity.

Under Axial Compression Resistance testing, a joint Prysmian/Telstra test that measures fibre loss when cables are subjected to compressive axial loads such as experienced in reactive soils, SMF-28 ULL fibre with advanced bend demonstrates the same tolerance to bending as G.657.A2 fibres, despite having a bending specification equivalent to G.657.A1. This attribute helps preserve the superior low cabled attenuation of SMF-28 ULL fibre once installed in the ground.

The following graph shows the excellent cabled SMF-28 ULL fibre attenuation distribution of production cables that are being installed in the Express Network.



Graph 1: No. of production cables > 20; No. of fibres > 3000

System Design Performance

Modelling of two major routes by Ciena shows the performance expected of the Express Network. Ciena's RLS compact intelligent photonic line system and WaveLogic 5 Extreme programmable 800G coherent optics along with SMF-28 ULL fibre allow for optimal capacity and flexibility of the network, as highlighted in the table below:

	Mel – Syd (inland) (No Raman)	**Mel – Syd** (inland) (Raman)	**Per – Syd** (inland) (No Raman)	**Per – Syd** (inland) (Raman)
System	Ciena 6500 RLS WL5e*	Ciena 6500 RLS WL5e*	Ciena 6500 RLS WL5e*	Ciena 6500 RLS WL5e*
Fibre	Corning® SMF-28® ULL	Corning® SMF-28® ULL	Corning® SMF-28® ULL	Corning® SMF-28® ULL
Design Life (years)	25+	25+	25+	25+
Distance (km)	1247	1247	3937	3937
Optical Amplifier Spacing (km)	~90	~105	~80	~95
Amplifier Strategy	EDFA only	EDFA + Raman	EDFA only	EDFA + Raman
Spans	14	12	50	41
Wavelength Capacity	43 x 600G C-Band 42 x 600G L-Band	43 x 650 C-Band 42 x 650 L-Band	43 x 400G C-Band 42 x 400G L-Band	43 x 400 C-Band 42 x 400 L-Band
Total Capacity per FP (Tbps)	**51**	**55**	**34**	**34**
Latency (ms)	**6.14**	**6.14**	**19.31**	**19.31**

*Ciena WaveLogic 5 extreme

Table 1: Optical Transmission System modelling

Future Technology Enablement

The use of SMF-28 ULL fibre with advanced bend will better support the introduction of nascent quantum technologies, such as Quantum Key Distribution (QKD). QKD will provide additional security against cyber-attacks in optical fibre networks compared to traditional encryption methods. QKD adoption is projected in some parts of fibre networks in the near future, evident from recent conference debates, product demonstrations, and announcements by carriers. This makes it important to start preparing infrastructure today for future QKD technology.

Quantum signals are weak (consisting of single or few countable photons) and cannot be easily amplified. This is where the ultra-low attenuation of SMF-28 ULL fibre with advanced bend comes in—it enables quantum signal transmission over longer distances, therefore reducing the number of trusted nodes needed to receive and retransmit the quantum information across the entire network. Trusted nodes are very expensive as they are housed in a guarded facility to prevent tampering. Hence, the reduction in the number of trusted nodes makes a direct and positive impact on the cost-effectiveness of the network.

Conclusions

Telstra InfraCo's Express Network, when built, has the potential to lead the world in scale, cost-effectiveness, and high data rate performance. The quest to exceed customer expectations required Telstra to design a network that provided high bandwidth intercity connections over long distances – while minimizing latency and cost. The investment in this network also needed to be future-ready for upgrades in next-generation optical transmission equipment. Leveraging Corning's SMF-28 ULL fibre in Prysmian cable design has allowed Telstra to develop a market-leading solution that customers can rely on for decades to come.

InfraCo

About Telstra InfraCo

As Telstra's specialist infrastructure business, Telstra InfraCo is committed to opening up newer and easier ways for customers to access Telstra's infrastructure portfolio. Serving three customer segments, with more than 200 customers in total: Wholesale in Australia, nbn Co, and the broader Telstra organisation. InfraCo's asset boundaries include mobile towers, all fibre, and network supporting infrastructure. PSTN, legacy fixed, and satellite infrastructure. Currently, Telstra InfraCo is accountable for 250,000 kilometres of fibre optic cable, 360,000 kilometres of ducts, 8,000 mobile towers, masts and poles, 5,000 exchanges, two data centres, and access to 400,000 kilometres of sub-sea cables

CORNING

About Corning Incorporated

Corning is transforming the way the world connects. Since inventing low-loss optical fibre in 1970, we have been continually innovating to increase the speed and capacity of optical networks around the globe, while reducing installation costs. Corning remains the worldwide market leader in optical fibre, offering a full line of single-mode and multimode optical fibre for all network applications. **www.corning.com/opticalfiber**

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