THE GLOBAL CHALLENGES OF COMPREHENSIVE UNDERSEA JOINTING

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Abstract: Undersea systems are made up of cable and amplifiers, the joints that connect them together, and terminal equipment that link the systems to terrestrial networks. Leading suppliers have developed and refined their various jointing platforms to meet similar needs worldwide. In this paper, we consider the challenges of developing and deploying a new global jointing platform in the current market climate. Furthermore, we examine the costs that suppliers face in pursuing the rewards associated with successfully developing the next generation of connecting hardware that breaks away from the pack. We offer a simple tool for comparing costs of introducing a new global platform vis-à-vis continuing with the existing jointing technologies and advancing via incremental improvements. Finally, we discuss the road ahead and the philosophy for driving forward.

1. HISTORY

Undersea communications systems consist of cable, amplifiers, joints that connect them together, and terminal equipment that provides an interface to the terrestrial networks. These systems have been around in various forms for well over 100 years. The factory interconnection processes for these systems have been modified and adapted for the shipboard environment throughout this timeframe.[1]

As cable, system technologies, and applications evolved, jointing has kept up and advanced as well. This becomes evident when considering how pairs of wires (or conductors) gave way to coaxial cables which, in turn, were overtaken by optical fiber cables.[2] *"Competing, but similar, jointing technologies have been developed over the years."* [3] See Figure 1.

2. CUSTOMER NEEDS

Customers are diverse and, in addition to telecommunications companies, have expanded to include scientific and educational institutions, internet content providers, government entities, private investors, investment funds, and mixes of these.

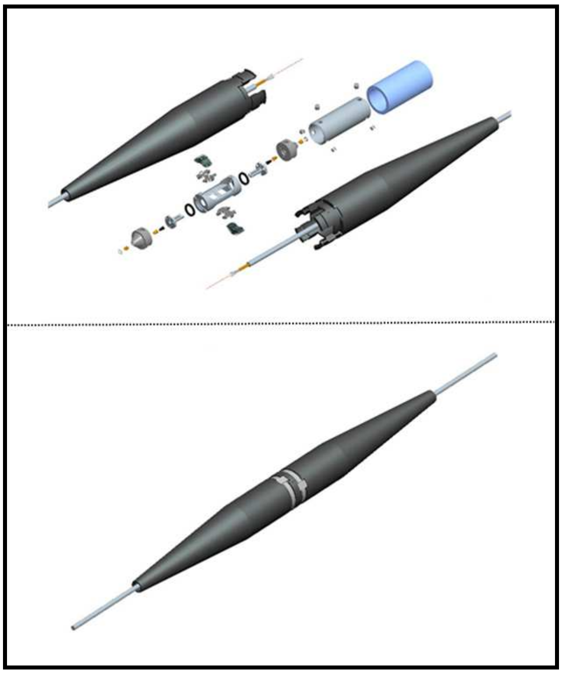

Figure 1: Exploded view of armorless fiber-optic splice joint (top) and as assembled (bottom)

As this mix has changed, so have the qualified cable combinations and interconnections needed to support a broader array of cable designs.

Typical jointing needs and applications include the following:

- System assembly (factory)
    - Cable joints
    - Repeater couplings
    - Branching unit couplings
    - Gain equalization & shape compensation
- Interconnection joints (between dissimilar cable types)—factory & field
- System installation and repair
- Land jointing
- Oil platform connections
- Fiber distribution canister (FDC) connections
- Deployment pallet (DP) connections
- Non-repeatered systems

All of these demand reliability, ease of assembly, high-performance, and reasonable cost. They must also adhere to industry standards and all environmental, health, and safety regulations.

3. PRESENT PLATFORMS

Various platforms have been developed based on similar needs for factories around the world. Factory and field jointing largely follow similar approaches—primarily using a "splice box" arrangement for storing splices and their associated fibers followed by polyethylene molding for insulation restoration. See Figure 2. With microprocessor and computer-controlled thermal cycles, jointing uses repeatable and faster restoration of electrical insulation, water ingress protection, and jacketing but not at the expense of reliability.

Most major system and cable suppliers use their own proprietary jointing methods in their factories. In some cases, they may also use a *universal jointing* platform—for example, Universal Joint (UJ), Millennia® Joint, or Universal Quick Joint (UQJ).

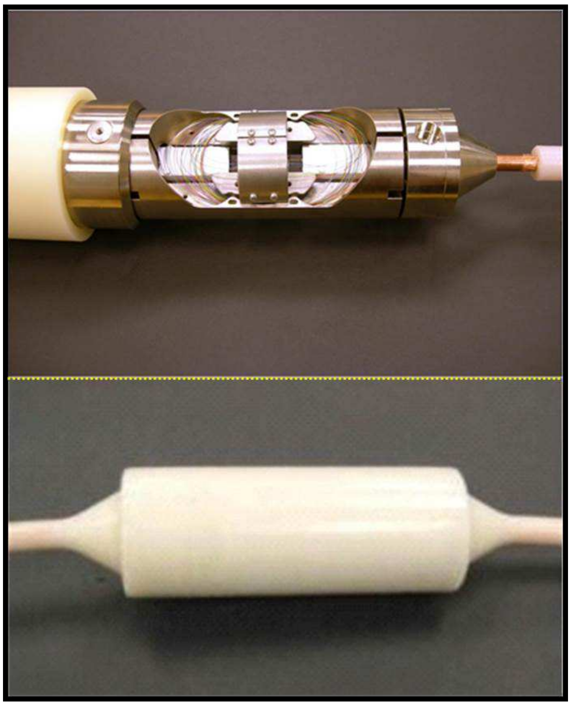

Figure 2: Jointing "splice box" approach (top) and over-molded (bottom)

These organizations have already invested heavily in development, qualification, tooling, training, and parts. As they develop new cables, they qualify them using their own jointing products as well as *universal jointing* for shipboard use.

Factories have few constraints with respect to space, harsh-environment regulations, environmental fluctuations, and equipment portability. They acquire and maintain sufficient equipment to assemble multiple simultaneous joints and have spares on hand for quick substitution while equipment is being repaired.

In contrast, shipboard (or field) operations require ruggedness and portability. Cable ships around the world typically carry a minimum of two sets of complete jointing

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® Millennia is a trademark owned by Tyco Electronics Subsea Communications LLC equipment as well as liberal quantities of jointing part kits and spares to minimize operational risk. This redundancy is crucial in keeping operations moving in the event of an equipment failure, thereby preventing unnecessary ship time on station.

Shipboard (Field)

For the most part, system repairs are made using *universal jointing* platforms—either UJ, Millennia Joint, or UQJ. The majority of shipboard equipment required is common among them, thereby reducing duplication and the expense of outfitting ships with exclusive suites of equipment.

As for the jointing components, these follow a modular approach (Figure 3), piecing together cable-specific parts and common component parts from within their respective platform families. This modular approach reduces the redundancy of parts, reduces cost, and reduces storage space.[4]

4. FIELD JOINTING DIRECTION

Increasingly, new system owners and new suppliers are entering the undersea market. They look to increase market share and reduce operating costs for their businesses. This puts pressure on all parties to improve in all areas of jointing including performance, cost, and reliability.

Although system providers are pressed to provide cost-effective solutions, they must continue to meet performance, qualification, and reliability targets. This will continue to drive improvements in the areas of kit cost, jointing time, and rework.

Older installed systems have cables, optical fibers, and repeaters that are essentially manufacturer-discontinued. These require maintenance and repair using newer cables and joints that must be compatible with these legacy installations which often leads to constraints on the jointing approaches.

Jointers and testers are required to gain broader expertise and knowledge to handle the range of cables encountered. Training and equipment become more comprehensive and complex.

Figure 3: Modular kit approach for jointing and tooling

5. GLOBAL CHALLENGES

As reported in previous SubOptic publications, many competing factors form barriers to arbitrarily advancing undersea jointing.[5]

For the existing platform(s), major investments have been made in development, qualification, and global deployment—equipping fleets, stockpiling of parts kits, and training of personnel. Thus, changes to these jointing methods have been incremental. In view of current market and structure, benefits of a radical change of jointing platforms have not been brought to light.

Suppliers, owners, maintenance authorities, and marine operators have a stake in jointing capabilities.[3] Attaining their backing for added costs—and risks—associated with new jointing development, for an ever-broadening range of cables, has proven difficult.

Industry cooperation, like that between American Telephone & Telegraph (AT&T), Kokusai Denshin Denwa (KDD), British Telecom (BT), and Alcatel that led to the Universal Jointing Consortium (1990s), is needed to support a new single-platform approach and manage the associated complexities. Today's consortia do not fund their own developments but rather the individual members do for themselves. Competition has generated pressure to advance the jointing arts.[4] Moreover, support for older systems and interworking is becoming increasingly scarce as cost-cutting pressures continue.

Modern network design has greatly reduced the need for ultra-rapid cable repair capabilities. Similarly, the structure and requirements of maintenance contracts continue to be influenced as well.

Non-traditional markets such as Oil & Gas, scientific research, and defense, procure commercial off-the-shelf (COTS) equipment to satisfy their need for cost effectiveness. Largely, they use the same parts, training, suites of equipment, and some of the same architectural elements as are used in traditional undersea telecommunications markets.

6. JOINTING ECONOMICS

Since factory jointing is unique to individual suppliers, we focus on shipboard (field jointing) applications where a couple of similar universal platforms are in use. We are exploring the cost vs. benefit of introducing an entirely transformed and superior comprehensive platform all at once, vis-a-vis staying with existing jointing technologies that make incremental improvements here and there.

The three main challenges to major advancement are centered on cost, performance, and inertia. Since the latter two were laid out in detail in previous publications, here we concentrate on the economic aspects which fall into three categories: cost responsibilities, global platform technology development, and global platform deployment.

For discussion purposes, it is assumed that a supplier can conceive of, and propose, a completely new jointing platform design for worldwide use. Therefore, we consider the costs involved with bringing it to the market all at once or within a short time span.

In this exercise, we assume that the development cost is borne by the supplier(s) and that the deployment costs are borne by the system owners and maintenance authorities—or something similar. This is detailed in Table 1 and a high-level view of how costs might be allocated.

Responsibility	**Entity**
Functional Requirements	System Owners; Maintenance Authorities
• Jointing Hardware & Process • Development Jointing • Hardware & Process Qualification • Supply Chain Development • Jointing Tooling & Process Documentation	Cable, System, and/or Jointing Supplier(s)
• Jointing & Splicing Equipment • Outfitting Vessels (if required) • Training • Mobilization(s)	Maintenance Authorities
Cable Families Qualification	System Owners, Cable, System, and/or Jointing Supplier(s)
Quality Assurance	Cable, System, and/or Jointing Supplier(s); Third Parties

Table 1: Shipboard jointing assumed cost responsibilities

Global Platform Development

We now address the development cost for hardware, processes, documentation, quality, and supply chain issues. This may be quite variable (platform design and entities performing the work). Therefore, we provide a case in point—albeit with large uncertainty.

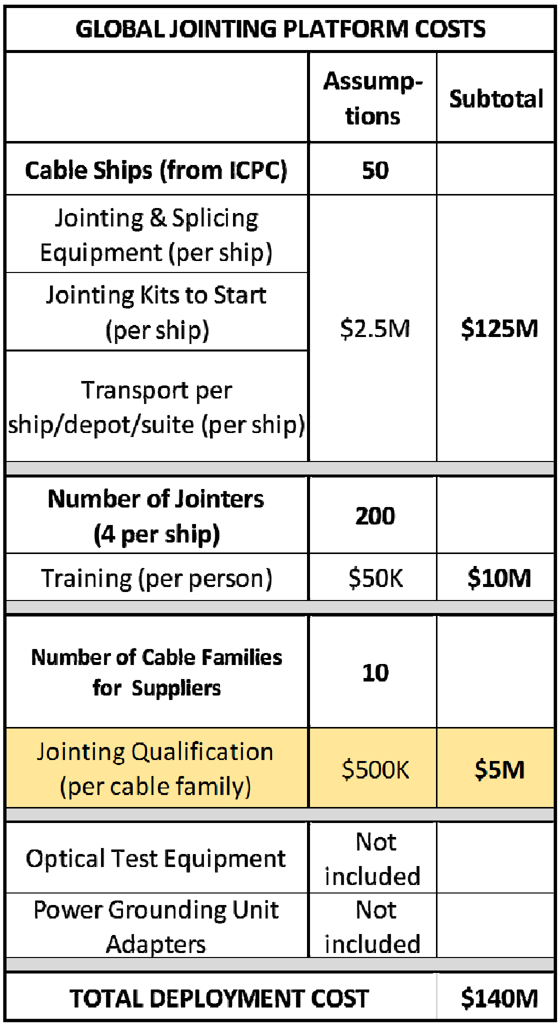
Table 2, below, shows the development activity breakdown. We assumed $135K for an average monthly cost. This produced a nominal estimate of about $10M±20% and require about 6 years to accomplish.

Development Scope of Work	
Activity	Cost
• Functional Requirements • Fundamental Research • Materials & Process Studies • Jointing Hardware & Process Development • Jointing Hardware & Process Qualification • Supply Chain Development • Jointing & Process Documentation • Outfitting Vessels (if required) • Training Development • Quality Assurance	**Nominal** **$10M**

Table 2: Global jointing platform development costs

Global Platform Deployment

Here, we address deployment costs. Substantial investment is required to deploy a new platform and outfit vessels around the world. Table 3 provides the estimated costs associated with cable qualifications, jointing equipment including splicing equipment, stocks of initial parts, and training.[6]



GLOBAL JOINTING PLATFORM COSTS		
	Assump- tions	**Subtotal**
Cable Ships (from ICPC)	**50**	
Jointing & Splicing Equipment (per ship)	$2.5M	**$125M**
Jointing Kits to Start (per ship)		
Transport per ship/depot/suite (per ship)		
Number of Jointers (4 per ship)	**200**	
Training (per person)	$50K	**$10M**
Number of Cable Families for Suppliers	**10**	
Jointing Qualification (per cable family)	$500K	**$5M**
Optical Test Equipment	Not included	
Power Grounding Unit Adapters	Not included	
TOTAL DEPLOYMENT COST		**$140M**

Table 3: Global platform deployment cost estimate

There are roughly 50 cable ships in the world according to the International Cable Protection Committee (ICPC) website as of January 2016. We assume all will require the new jointing platform. The total global deployment cost, starting from the beginning, is approximately $2.8M per vessel. We do not address costs associated with inventory (parts kits and tools) already deployed in depots and on ships worldwide. The equipment and kits are typically owned by the system owners. Understandably, system owners are not eager to add to their costs—and look to use their existing inventory. A new platform would obsolete current stocks or, at best,

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would require the operation of duplicate jointing platforms for an extended transition period between the two.

Incremental Improvement

Next, we consider the costs associated with incrementally improving the existing technology platform as has been done for the last 15 years or more.

Generally, changes/improvements vary in their scope, are backwards compatible, do not require wholesale modifications, and fall into one of four categories.

1. Discard all existing parts / documents and implement the new design immediately.
2. Rework all existing parts and implement the new design immediately.
3. Exhaust supply of existing parts before using the new design.
4. Changes do not affect the design of the part.

The first two categories have higher associated costs than the last two. In many cases, additional training is not required. In others, existing kits do not require changing.

Consequently, there are *major* (expensive) improvements that may consist of replacing or upgrading splicing, molding, or x-ray equipment. We assume the associated deployment cost includes replacing two $100K machines on every vessel and adding $25K to cover all other associated expenses (Table 4).

More realistically, customers can expect to perform a major improvement every few years, as it is difficult to justify rather than making an equipment repair at a fraction of the purchase cost.

At the other end of the spectrum, there are *typical* (low-cost) improvements that generally include part & kit upgrades or improved tools. To obtain a *nominal* (average) deployment figure, we assumed a ratio of *1 major* to *5 typical* deployments—or about $50K per ship.

Equipment or tool modification $100,000 each (two per ship)	$200K
Change to existing jointing kit	$25K
Training (if required)	
Logistics	
Single Change Cost	**$225K**

Table 4: Estimated deployment cost per ship for an average major change

Based on the global platform deployment cost per ship ($140M/50 or ~$2.8M) and the typical incremental deployment (~$50K), we calculate an allowable *incremental deployment limit* of **56.**

Next, we define a *development cost limit*[*] for the *incremental deployment limit* (56). Each increment development could average **~$180K** to equal the total platform development cost.

Using the same ratio (*1 major* to *5 typical)* and the same average monthly development cost ($135K) that we used for the new platform calculation; we estimate the *nominal* increment development to be about $63K.[**] Note that this is about one-third of the *development cost limit* above.

Approach Comparison

Based solely on an *incremental deployment limit* basis and the nominal incremental deployments (~$50K), one could perform 56 incremental improvement cycles for the cost of deploying a new platform.

We also find that the *development cost limit* is nearly three times the estimated *nominal* incremental development cost. Therefore, based solely on development,

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[*] This is set as the global platform development cost spread over the number of incremental improvements expected.

[**] For proprietary reasons, we omitted the supporting details.

the platform approach appears more costly.

Relative to the incremental approach, the platform approach may be hindered in both deployment and development. Furthermore, incremental improvement costs are spread out over many years—decreasing the front-loaded expenditure of the platform case. However, the total incremental improvement will be spread out over many years as well.[*]

A new technology platform needs to be sufficiently improved or enhanced relative to the existing methods to justify the large initial expenditures. For example, it may need to be faster to assemble, require less expensive parts, use simpler tools, be more reliable, easier to learn, and be applicable to all cable types with minimal qualification.

Not included in the platform case are the cost of additional inventory beyond that to be deployed on the ships initially, the front-loaded spending, and the risk of failure (performance, delivery, or expenditure). In the incremental improvement approach, we have omitted the risk associated with performance deficiencies.

Trade-Off Modeling (example)

To quantify this comparison, we derived a simple formula to obtain a single numerical indicator either positive (+), negative (-), or zero (0) by finding the difference between the sum of platform technology's development, deployment, & unknowns and the sum of the same for incremental improvement.

$$X=[P_{dt}+(P_{cv}\times V_n)+C_p]-[I_n\times((V_n\times I_{cv})+(I_c))+C_i)]$$

where "P" stands for Platform Technology, "V" stands for Vessel, "I" stands for Incremental Improvement, and "C" stands for unknown Costs as listed below:

X: Indicator for which option to choose in \$'s
P_{dt}: Platform technology development cost in \$'s
P_{cv}: Platform technology deployment cost/vessel in \$'s
I_c: Development Cost/Increment in \$'s
I_{cv}: Increment deployment cost/vessel in \$'s
I_n: Number of Incremental Improvements
C_p: Unknown cost associated with both replacing inventory, front-loaded platform spending, and risk of failure in \$'s
C_i: Unknown cost associated with performance deficits (if any) in \$'s
V_n: Number of Vessels

If $X < 0$, then the Global Platform approach is indicated
If $X > 0$, then the Incremental Improvement approach is indicated
If $X = 0$, then either approach may be pursued

In this example, we assume C_p and C_i are equal to 0 and that the number of incremental development cycles averages two (2) per year for 15 years or 30 incremental improvements.

Using the following values:

P_{dt} = \$10M
P_{cv} = \$2.8M
I_{cv} = \$50K/vessel
V_n = 50
I_n = 30
I_c = development cost (variable)
C_p: = \$0
C_i: = \$0

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[*] We assume that incremental improvements eventually approximate the new global platform performance.

We plot X versus Development Cost per Incremental Improvement. See Figure 4. The transition point for development cost is $97K. In other words, if each of the 30 incremental improvements average more than $97K, it would be advantageous to introduce a new jointing platform. Unless the “C_p and C_i values are very significant, it would appear that the incremental approach at a nominal development cost of ~$63K, as described earlier, has the advantage.[*]

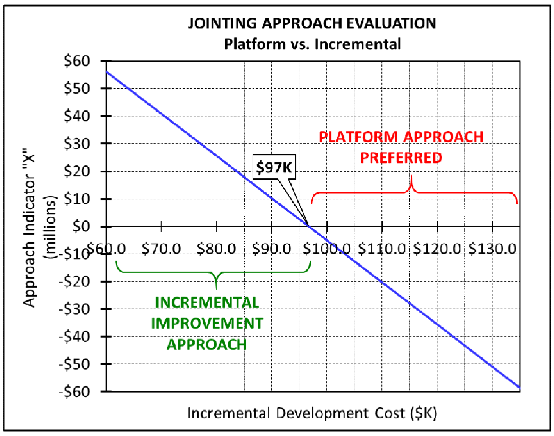

Figure 4: Development cost per increment plotted against total approach differentials

Furthermore, positive values indicate the projected savings relative to the global platform approach while negative values indicate global platform savings over the incremental approach. Alternatively, we could choose a nominal development cost for each increment and use the number of increments as the variable on the x-axis.

7. SUCCESS and REWARDS

To reap the benefits and rewards of a new jointing platform, it is assumed that improvements must be sufficiently better than existing methods to justify the large development and deployment expenditure.

The global platform must excel at some or all of the following characteristics:

- Be as reliable as existing methods,
- Be faster to assemble,
- Use less expensive parts,
- Use simpler tools,
- Be easier to learn,
- Be applicable to many cable types with minimal qualification, and
- Be as safe as—or safer than—existing joints.

Showing a strong business case or cost/benefit for a new global platform is imperative and not easily done. Furthermore, the wide-spread use of a global platform demands collaboration or, at least, acceptance among many parties.

The cost of developing a global platform requires a major investment by a single party or collaboration among a wide number of parties. These have not been common in today’s environment. The former is driven by cost-cutting initiatives and the lack of investment capital while the latter is mainly due to competition.

System owners, jointing suppliers, maintenance authorities, and cable factories are reluctant to assume additional cost without a clear indication of value being increased significantly so as to offset the inherent development risk.

For success, the new approach needs to significantly shake up the current marketplace paradigm. If the financial aspect and legacy investment obstacles cannot be overcome, a new global platform will be difficult to bring to market to replace the current methods.

Previous jointing studies have suggested market segmentation as a way to overcome the barriers to entry. As an example, a new platform could be deployed only to cover specific new systems or systems in a well confined regional market or segment. However, this would not be a global

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platform and make it less economically attractive.

Another approach is to look at how costs are structured in the industry. The industry should take a fresh look at how maintenance agreements and contracts are constructed; how jointing services and parts are procured; and how to fund a new platform collectively through a consortium approach.

Until there are specific needs to drive advances, it remains unlikely that progress via a new platform will be undertaken by a single party, at its own expense, and shared with all.

Additionally, the global platform would need to account for or accommodate competition, customer acceptance, variable demand, open access, international regulations, intellectual property rights, and the longevity of jointing support.

8. CONCLUSION

An all-new global jointing platform/approach remains elusive largely due to a lack of clear and persuasive analyses balancing an immense upfront investment (platform) with uncertain returns. This is quite problematic and hinders advancement along this approach.

We have presented a simple model for comparing deployment and development costs for incremental improvements versus a new global platform approach. The new technology platform is significantly handicapped, as gains cannot be shown to outweigh associated costs. Consequently, the incremental improvement approach will likely remain the reigning advancement methodology.

Finding an innovative way to plan, organize support for, and develop a global platform that maintains the history of high-reliability and performance while innovating and expanding markets, remains elusive. Unless suppliers, alone or together, find a way to change the current paradigm, abundant rewards are not anticipated. The successful development and deployment of the next global undersea jointing technology platform will undoubtedly position the provider(s) as the leading industry competitor both technically and commercially. Until then, we can expect jointing improvements to continue incrementally rather than comprehensively.

9. ACKNOWLEDGMENTS

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10. REFERENCES

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[1] Gould CA and Mitchell AF, 'Universal jointing for optical submarine systems', IEEE Colloquium on Submarine Optical Transmission Systems, March 1988.

[2] Thomas R, Rapp RJ, Spalding MA, Stix, RK, Kordahi ME, Bergano NS. 2015. 'Technology in Undersea Cable Systems – 50 Years of Progress', Marine Technology Journal, 49(6): 88-109, November/December 2015.

[3] Kordahi ME, Mendez J, Sanders MM, Stix RK, Wilkison R, 'Undersea Jointing Hardware—Gathering No Moss', SubOptic 2013, May 2013, Paris, France

[4] Kordahi ME, Mendez J, Stix RK, Grassi SW, Ash S and Beech C, 'Undersea Cable Jointing Time Analysis- Worldwide', SubOptic 2004, May 2004, Monte Carlo, Monaco.

[5] Kordahi ME, Mendez J, Sanders MM, Stix RK, 'Undersea Jointing Challenges: Past, Present, and Future', SubOptic 2010, May 2010, Yokohama, Japan.

[6] TE SubCom Internal Communications and Discussions — Private, January 2016.