UDT 2019 – Trends, transitions, and challenges in modern penetrators for UUVs, Sea Floor Systems, Towed arrays, and Submarines

Abstract — The Maritime business climate is moving in a positive direction: investment is returning, thus driving the desire for innovative new products. Users are demanding new capabilities and the connectivity products must evolve with the technologies. The associated Market, Technical, and Business Trends impact the Connectivity / Penetrator Suppliers as they adapt to these strenuous new user requirements: accommodating the demands for increasing bandwidth, power, a diversity of signal types, and the demand for lower size and weight.

1 Introduction

The Undersea Business Climate is moving in a positive direction: investment is returning, thus driving the desire for innovative new products. Users are demanding new capabilities and the connectivity solutions must evolve. The evolution of new products are impacted by the associated Market, Technical, and Business Trends impact the Connectivity / Penetrator Suppliers as they adapt to these strenuous new user requirements: accommodating the demands for increasing bandwidth, power, a diversity of signal types, and the demand for lower size and weight.

2 Penetrator / Connectivity Overview

Subsurface vehicles and payloads need a method to connect to the outside world. The interconnects with penetrations provide the essential links for the eyes (imaging optics), ears (acoustics), and nose (chemical sensing) for these subsurface solutions. Legacy designs consisted primarily of power conductors and low bandwidth signal lines. Technology advances in communication and sensing technologies are providing users with greater fidelity in all areas of data and video. These advances are challenging interconnect designers to incorporate higher power, higher frequency RF, Faster Ethernet and complex fibre optic sensing signals.

Penetrators Are The Gateway To The Outside World For Undersea Systems

Penetrators provide connectivity to the 'senses' of undersea systems: Sight (Cameras, Sonars, LIDARs), Sound (Hydrophones / Acoustic Sensing), Touch (Command / Control / Temperature / Strain / Stress / Health), Smell / Taste (ChemBio / Salinity)

Penetrators maintain pressure boundaries and form an interface to allow interaction between a controlled environment on the inside, to the ambient and hostile outside environment. Penetrators protect humans as well as sensitive electronics. A penetrator failure may cause a mission failure at a minimum or at worst have catastrophic and life-threatening effects.

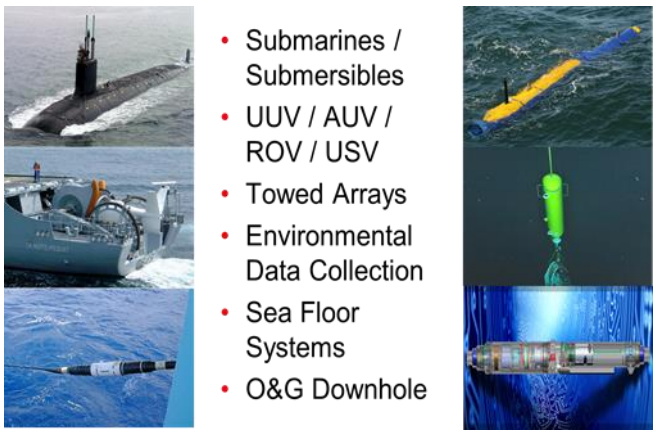

Figure 1 – Penetrators are used across many solutions

Penetrators are used to bring a circuit (electric, fibre optic, and/or RF) from outside a submarine pressure hull to the inside, while assuring under all operating and failure modes there is no leak path to the inside of the submarine.

Building hull penetrators and the associated connectivity elements, i.e., cables and connectors, for manned, unmanned, or fixed undersea systems is a disciplined business requiring engineering expertise, precise materials, and verifiable manufacturing processes with documentation.

Program Managers and Engineering System Architects need to include connectivity engineers as active parts of their Collaborative Design, Integrated Project Team (IPT), or System Engineering processes.

2.1 Penetrator Types

Penetrators carry multiple signal types including electrical, ethernet, fibre, RF, or power. They can utilize a variety of connector styles including industry standards such MIL-C-24231 or MIL-STD-38999.

Fibre Optic Feedthrough (FOFT) - Optical Compression Glass Seal Type (hermetic) contacts at ferrule mating interface and feedthrough / penetrator

Typical Applications: O&G Downhole, Harsh / High Pressure Environments

Coax - DC to 3 GHz, Open face pressure of 10,000 psi, Multi-Contact Subsea Coax. Typical Applications: UUVs, GPS / Iridium Antenna, Wifi, Buoys, Retractable Buoys

Elite Dry Mate - Design Life 25 Years, Dual O-ring Seals at All Points of Seawater Entry. Typical Applications: Fibre Bragg Gratings (FBGs) to measure Stress, Strain, And Vibration, Distributive Temperature Sensing (DTS), Distributive Acoustic Sensing (DAS), Chemical sensing.

High Pressure High Temperature - Glass-to-Metal hermetic sealed with insulating sleeves to boost electrical resistance. Typical Applications: Oil & Gas Downhole

RF and Mixed Signal - MIL-STD-24231 / MIL-STD-24217 design for 2000 / 10,000 psi ratings. Typical Applications: Photonics Mast, Antenna Mast penetrators,

Submarine Hull - Multiple Connectors with MIL-STD-24231 / MIL-STD-24217 design for 2000 / 10,000 psi ratings. Typical Applications: Sonar, Torpedo Control, Hydrophones, Lighting

Bulkhead - Pressure Tight Bulkhead Power, Control/Signal Penetrators, Junction Boxes. Typical Applications: Radar and ESM Antenna System

Power - Shock and pressure rated bus bars designed to carry up to 830VDC at 476 Amps (395 Kilowatts). Typical applications: Motor Control, Power Distribution

Figure 2 – Penetrator have a variety of sizes and styles

2.2 Penetrator Optimization

For a Submarine design we saved a customer two tons per platform via disciplined System Engineering where connectivity was considered and included in the design phase.

We are seeing more a willingness from Solution Designers to engage earlier with our Connectivity System Engineers so that a totally optimized solution may be developed. Many Solution Designers still do not understand that tangible savings may be obtained through the connectivity design. We hope this trend accelerates.

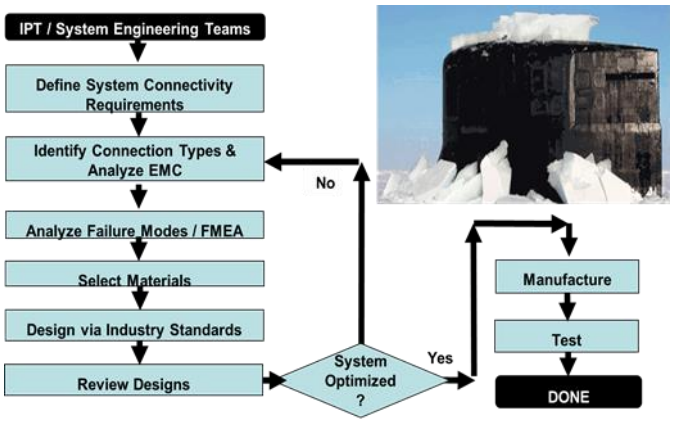

Figure 3 – Tangible benefits can be obtained via an optimized connectivity design

The inclusion of connectivity experts early in the design processes resulted in tangible benefits for: Weight Reductions, Cost Savings, Increased Mission Availability, Increased Mission Capability, Enhanced Maintainability, Insitu Repairs, and Schedule Improvements.

For a large vehicle, this process may occur over several years. Each system must be scrutinized to understand the electrical properties and functional requirements required by the system owner. As systems are analysed for Electromagnetic Compatibility (EMC) and the material issues surrounding each of the conductor requirements for all control signals and power requirements, they are assigned to penetration. The next sequence of selections matches similar systems in proximity of each other that can be supported through one hull penetration or, in some cases, such as large systems, a reduced number of penetrations for each. At this point, system requirements are again reviewed for improvements to minimize penetrations.

In some systems, it is an easy selection, and very straightforward with the numbers of conductors, cable sizes and performance issues.

At the same time, many systems can be challenging in respect to system required conductors, including fibre-optic and copper, standard copper conductors that may be large power conductors or data signal paths, and the ever-changing screening requirements. With all these variables, the selection process for a hull penetration is performed by a team and reviewed by several individuals followed by the System Design Authority.

A very similar analysis is being performed on each of the cable requirements on the outboard side of the system to determine which is the best path to use. As systems are reviewed for EMC and functional requirements, there is an exercise to minimize paths to a hull penetration by bringing systems together into a splice block and then a larger multi-core cable to the hull penetrator.

3 Market Trends

From a connectivity / penetrator perspective, let's take a quick look at how maritime market activity is trending. For discussion / argument, each market will be rated with the following Market Age / Life Cycle scale:

- Declining or Stagnant Sales
  - Only legally required sales
  - Equipment may be allowed to deteriorate
- Introductory or Recovering Sales
  - Engineering prototype activity
  - Pre-Production
- Emerging Or Re-emerging Sales
  - Low Rate Production
  - Field Testing
  - Proof of Concept
- Peak Or Expanding Sales
  - Full Rate Production
  - Engineering Change Orders
  - Repeat Orders
- Maintenance Sales
  - Equipment kept near 100% operating efficiency
  - No new capabilities introduced

Market Stage	Declining Or Stagnant Sales	Introductory Or Recovering Sales	Emerging Or Re-emerging Sales	Peak or Expanding Sales	Maintenance Sales
Characteristics	• Only legally required sales • Equipment may be allowed to deteriorate	• Engineering prototype activity • Pre-Production	• Low Rate Production • Field Testing • Proof of Concept	• Full Rate Production • Engineering Change Orders • Repeat Orders	• Equipment kept near 100% operating efficiency • No new capabilities introduced

Figure 4 – Our model for discussing market stages

3.1 Submarines

The worldwide Submarine market is generally trending toward Growing and Peak sales. The US is currently building two Virginia Class Submarines per year. The 2020 US government budget is proposing to increase that number to three per year. Initial fabrication has begun on the Columbia Class (Ohio replacement) submarines. Outside the US, there is peak interest in the UK Dreadnought, and growing interest in the Australian Collins Replacement, several Asian projects and others.

Submarket	2017	2018	2019	2020
USA				
UK				
Australia				
Asia				
Non-UK Europe				
South America				

Figure 5 –The Submarine market is trending upward

3.2 UUV / AUV

The market trends for UUV / AUVs depends on the size of the vehicle. Medium sized vehicles such the Hydroid Remus or GD Bluefin 9/21 Series are approaching maturity as a market and Peak sales behaviour. Small or Micro sized vehicles appear to be Growing as a market, but adoption of them is slow due to their limited mission time and distance capability. Large and Extra Large UUVs are still Introductory and primarily experimental.

Submarket	2017	2018	2019	2020
Small				
Medium				
Large – LDUUV				
X-Large – XLDUUV				

Figure 6 – Undersea drones are an emerging market

3.3 Towed Arrays

Towed Arrays continue to be a desired solution due to the increase in worldwide Submarine building. Most markets are Mature or Maintenance in behaviour with potential opportunities coming from emerging economies.

Submarket	2017	2018	2019	2020
Ships				
Subs				
UUV				
O&G /Energy				

Figure 7 –Towed Arrays are emerging or re-emerging in UUVs and Energy

3.4 Sea Floor Systems

The Sea Floor sector is Recovering and has seen an upswing in activity with solutions like undersea vehicle tripwires, harbour security, and mines.

3.5 Energy

The Energy sector is Recovering and has seen an upswing in activity due to the global recovery of oil prices. Companies appear to be preparing for exploration.

3.6 Scientific / Environmental

The Scientific and Environmental market is stable and slow growing primarily behaves as a Mature or Maintenance market. There is no strong customer demand since most projects are sponsored by governments. Projects tend to be extremely cost sensitive and there is little customer investment in the products brought to the market, so there is less incentive for new suppliers to attempt to penetrate the market.

Submarket	2017	2018	2019	2020
Energy / O&G				
Energy / Green				
Scientific / Environmental				
Sea Floor - Commercial				
Sea Floor - Defense				

Figure 7 –Energy is emerging or re-emerging

4 Technical Trends

4.1. Speeds And Feeds

High definition video is pushing many of our connectivity products due to the increased bandwidth requirements. Higher power demands have also challenged connectivity product developers.

Photonics, LIDAR, Side Scan SONAR and other Imaging and Video technologies are at the top of every User's wish list for technology. Great improvement has been made with these technologies, but at the cost of much higher bandwidth requirements.

Figure 8 – Video technologies are a primary driver for connectivity solutions

4.2. Higher Density Connectors

Solution designers want to maximize the mission capability while minimizing or maintaining the number and size of hull penetrations. This results in the need to keep adding additional signals and pins in penetrators and connections. In addition to the mechanical challenge this presents, the design is now exposed to greater Electro-Magnetic interference challenges.

Figure 9 –Connectors continue to become denser

4.3. Higher Power Requirements

Higher bandwidth technologies and longer duration missions require increased power and energy. Higher power requirements result in thermodynamic issues that must be accommodated.

Figure 10 – The use of Lasers will demand solutions capable of accommodating higher power

4.4. MTBF - Mean Time Between Failure

In many applications, customers are demanding 20 years or more service life for a product. To obtain this level of service life the requirements needs to be fully understood by the customer and the manufacturer. Also, the customer needs to have a total system view to maximize the service life. The manufacturers must have credible experience because of the need for material selection and manufacturing process expertise.

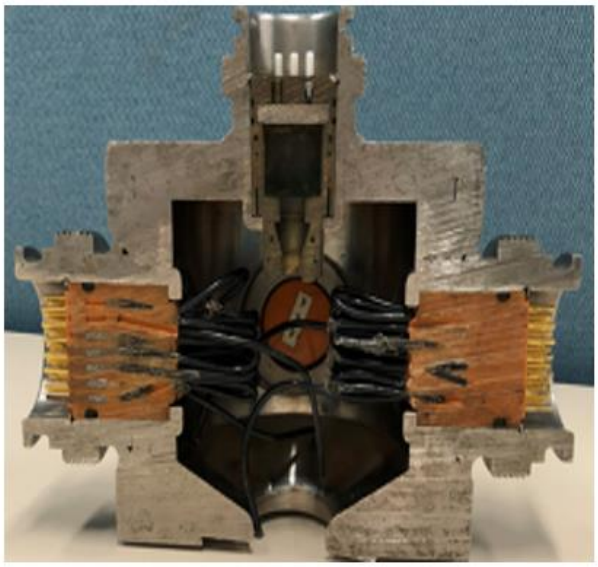

Figure 11 – Demands for higher reliability push material selection

3.5. Fibre Optics

Fibre Optics (FO) on mobile platforms is a relatively new phenomenon. Fibre Optics is not as robust or rugged as copper therefore additional training is needed for the proper design, manufacture, handling, and installation of FO. Fibre Optics in motion, e.g., towed arrays or periscope dip loops are tricky as well. Fibre Optics as a material presents itself as a technology enabler for new solutions such as Lasers or a sensor itself for Distributed Temperature Sensing.

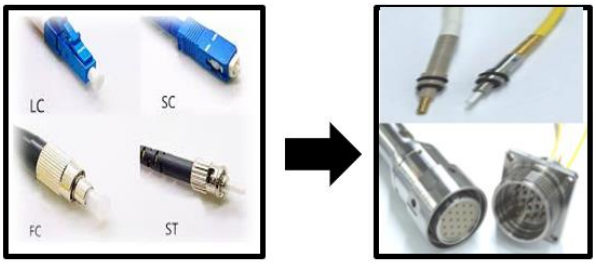

Figure 12 – Fibre Optics are emerging as a key technology, but they are a more challenging material than copper

5 Business Trends

5.1. Market Consolidation

In the connectivity market, bigger companies continue to acquire smaller ones at a rapid pace. Since 2000, there have been approximately 500 acquisitions of smaller suppliers.

5.2. Supply Chain

In the U.S. one area of great concern is with the current build-up of new activities, can the supply chain keep up. After the fall of the Berlin wall, Undersea Defence was not a priority, and several companies even exited the industry. But with new threats emerging, Undersea Defence has returned to the forefront.

To increase competition and continue downward pricing pressure, customers are creating constant churn in the supply base. The downside being that suppliers eventually leave the market, new vendors do not risk entering the market, and thus producing the long-term effect of reducing the amount of competition.

5.3. Political

May you live in interesting times is an oft quoted Chinese saying and speaking politically, our days are very "interesting." BREXIT is, of course, causing uncertainty across Europe. In the US, new Tariffs are causing price increases in certain raw materials and threatening continuity of supply.

6 Conclusions

I hope paper has given you an appreciation for the challenges encountered in the Connectivity Industry. Many people are not aware of the connectivity engineering challenges we are encountering and solving.

Undersea markets are generally trending in a positive direction and are providing multiple opportunities for suppliers. New technologies continue to push interconnect designers to the limits of physics. Customers who wish to optimize their total solution should include an interconnect expert as part of the design team.

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Author/Speaker Biographies

Charlie Westerfield is the Director of Business Development for the AMETEK Subsea Connector Products (SCP) division. He is responsible for securing new programs and introducing new products to undersea markets. He has secured new programs-of-record for missions such as mine hunting, counter measures, decoys, and towed arrays.

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