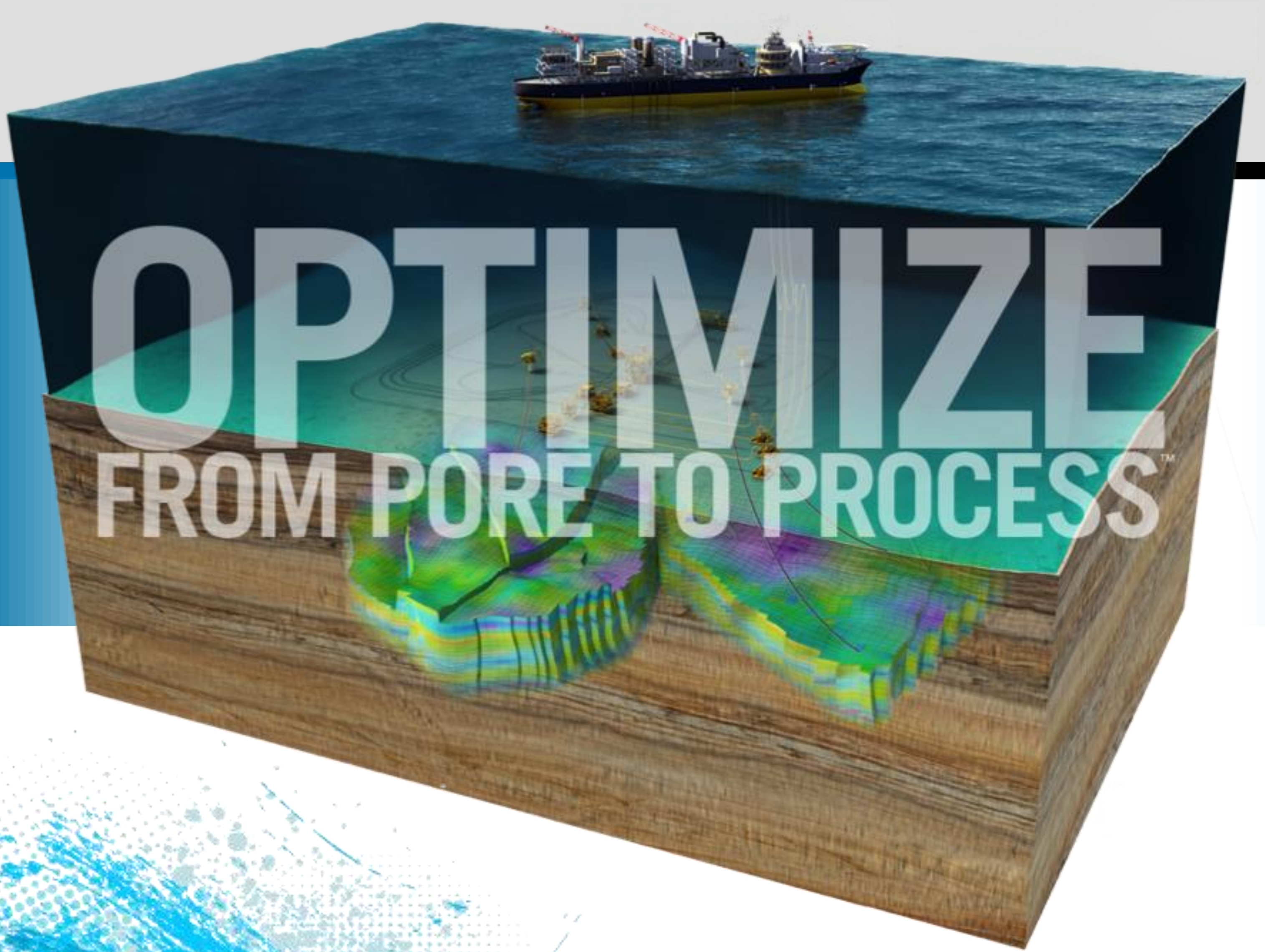

Subsea Control Systems

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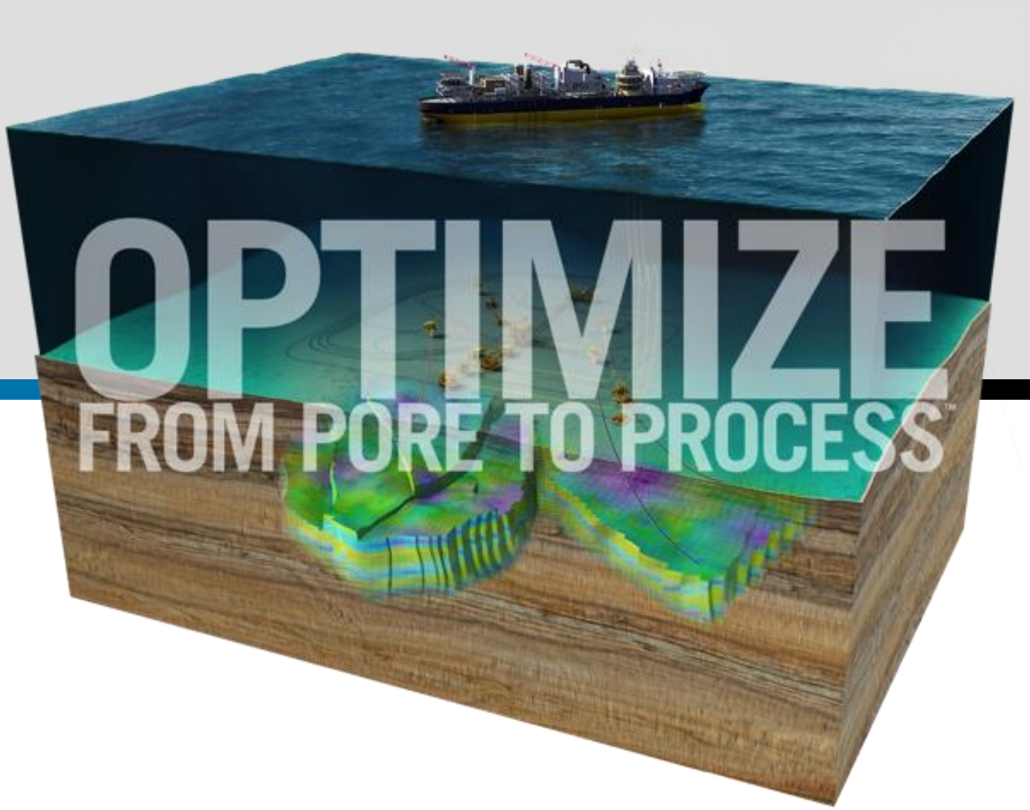
Acronyms

CIU	Chemical Injection Unit
COE	Centre of Excellence
DCS	Distribution Control System
DCV	Directional Control Valve
DH	Downhole
EFL/HFL	Electric/Hydraulic Flying Leads
EH MUX	Electro Hydraulic Multiplex
EPU	Electrical Power Unit
ESD/FGS	Emergency Shutdown/Fire & Gas System
HPU	Hydraulic Power Unit
IWOCS	Installation Workover Control System
MCC	Motor Control Center
MCS	Master Control Station
PETU	Portable Electronic Test Unit
SAM	Subsea Accumulator module
SCM	Subsea Control Module
SCSSVs	Surface Controlled Subsurface Safety Valve
SDU	Subsea Distribution Unit
TUTA	Topside Umbilical Termination Assembly
UPS	Uninterruptible Power Supply
UTA	Umbilical Termination Assembly



Content:

Subsea Controls Introduction

Types of Control Systems

Equipment Overview

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The Subsea Production System (SPS)

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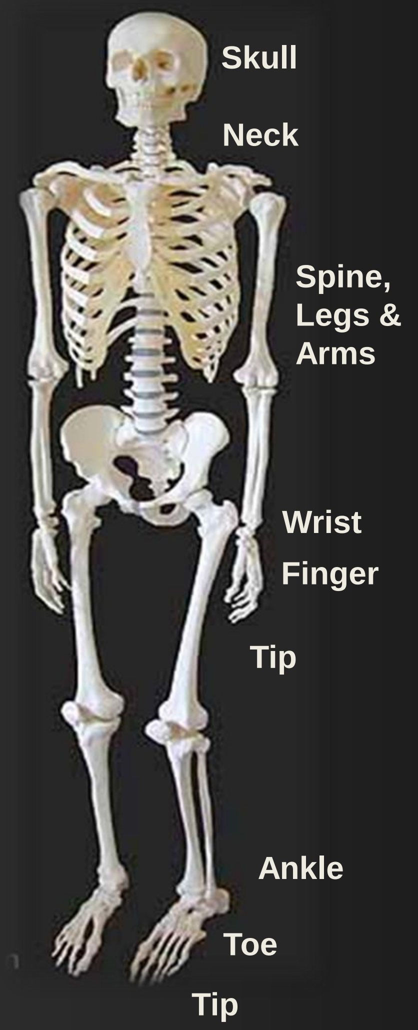
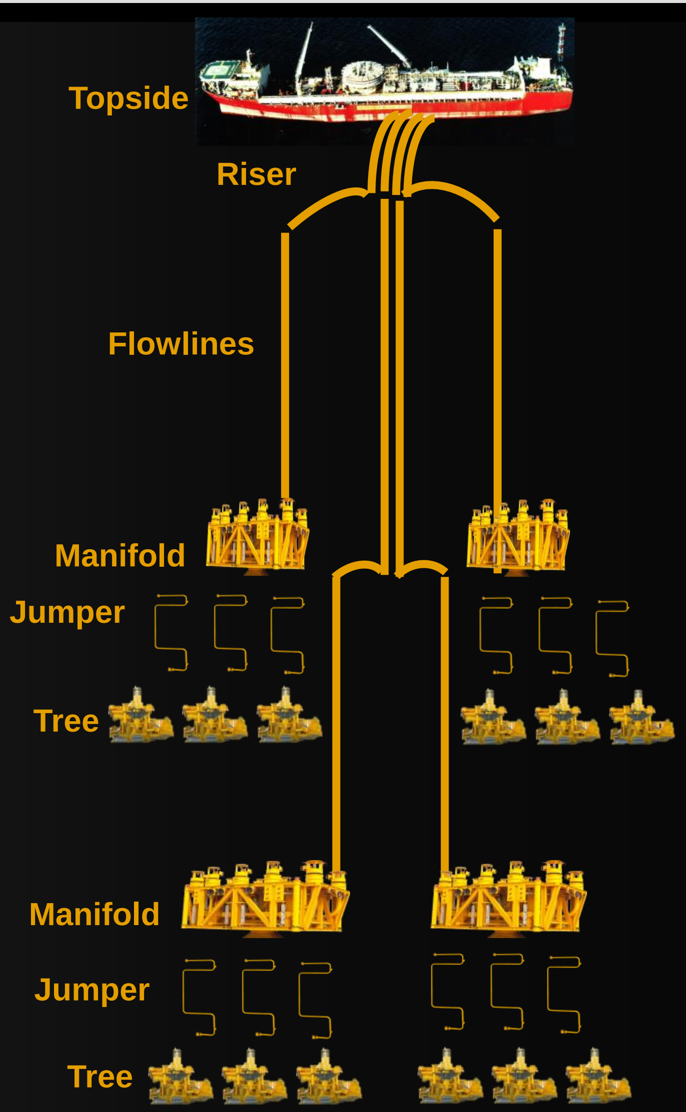
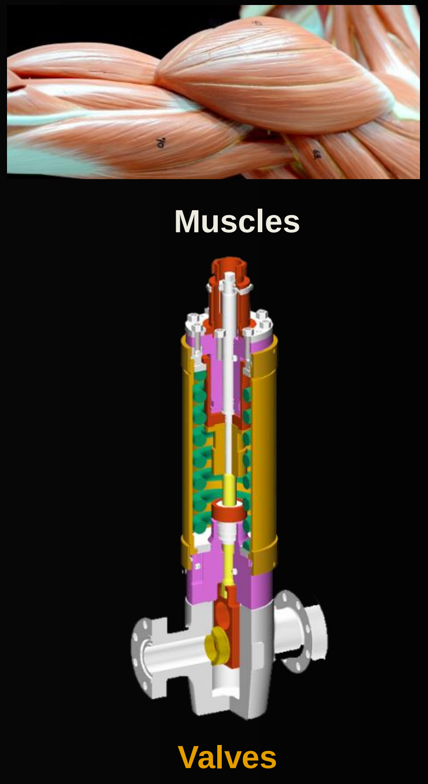
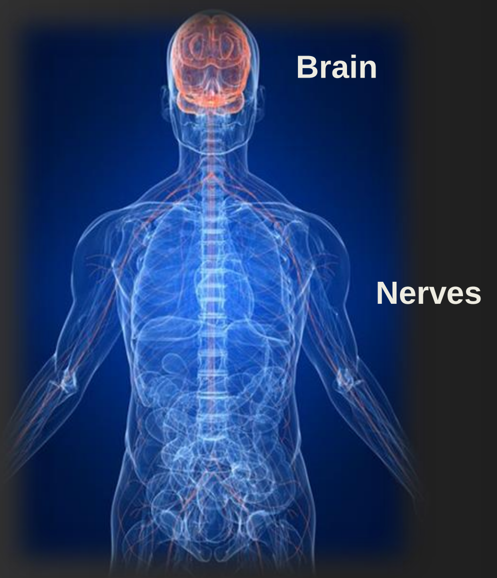






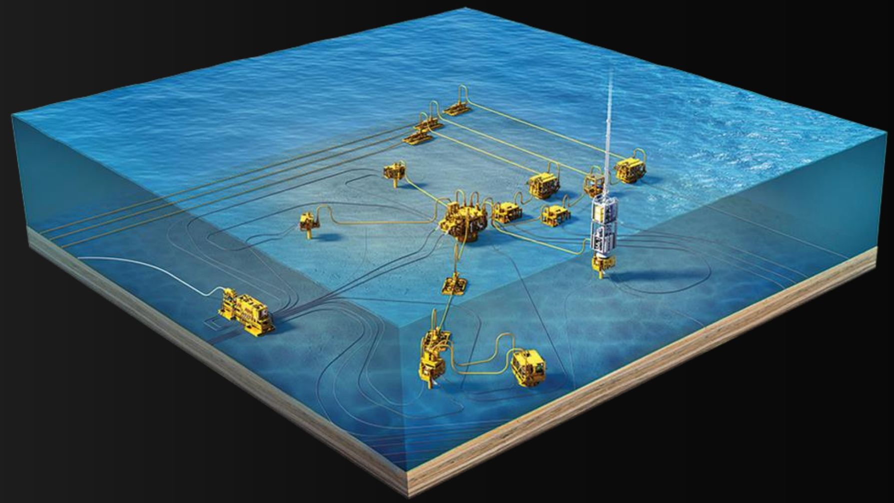
The Subsea Control System (SCS) design



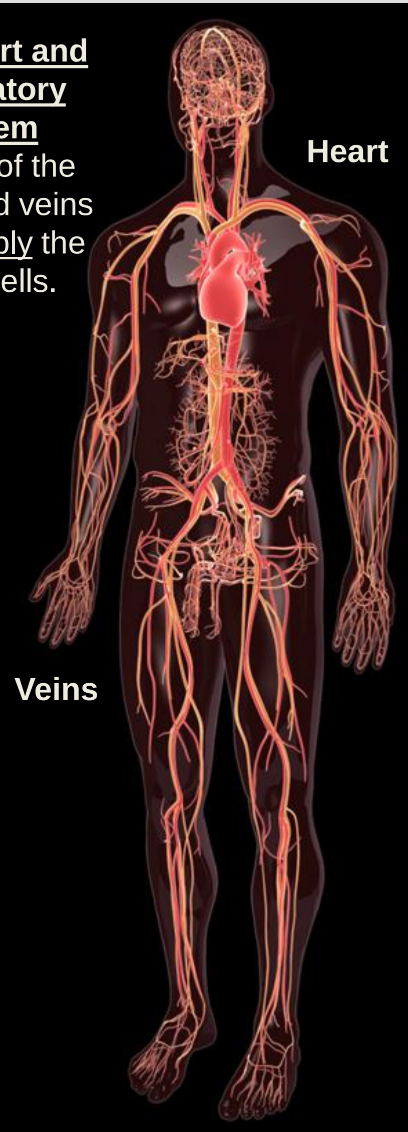
<u>The nervous system</u>
consists of the brain, spinal cord, sensory organs, and all of the nerves that connect the organs with the rest of the body. Together, these organs are responsible for the <u>control</u> of the body and <u>communication</u> among its parts.

<u>The Subsea Control System</u>

consists of the Subsea Power and Communication unit, umbilical, sensors, and all of the flying leads that connect the subsea components with the rest of the system. The SCS is responsible for the control of the Production System and communication among its parts.

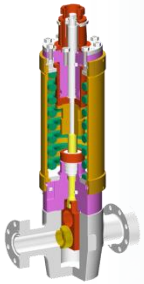


<u>The Heart and Circulatory System</u>
consist of the Heart and veins that <u>supply</u> the body cells.



To Control & Monitor the entire SPS including all associated Topside Equipment

- Actuate Tree / Manifold Valves & Chokes



- Control Downhole Safety Valve

- Monitor Sensors

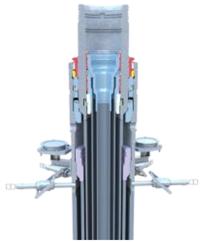
- Distribute & Control Chemicals (Methanol / Scale Inhibitors etc)

- Perform Shutdowns (Production Shutdowns/Emergency Shutdowns)

- Control & Monitor Topside Equipment

- ISO 13628 Part 6 (API 17F) Specification For Subsea Production Control Systems

Subsea Controls Overview

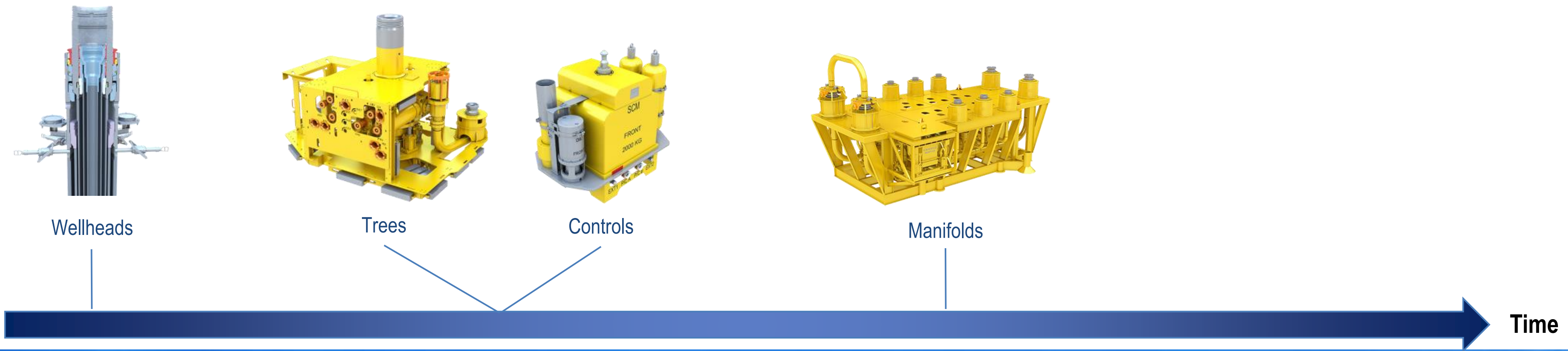


Wellheads

Time

Subsea Controls Overview

Subsea Controls Overview



Subsea Controls Overview

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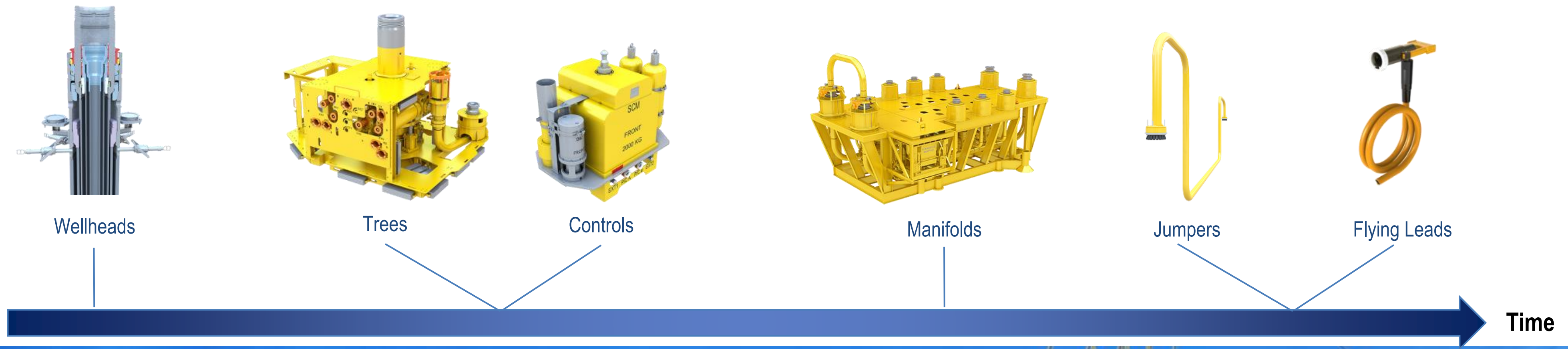

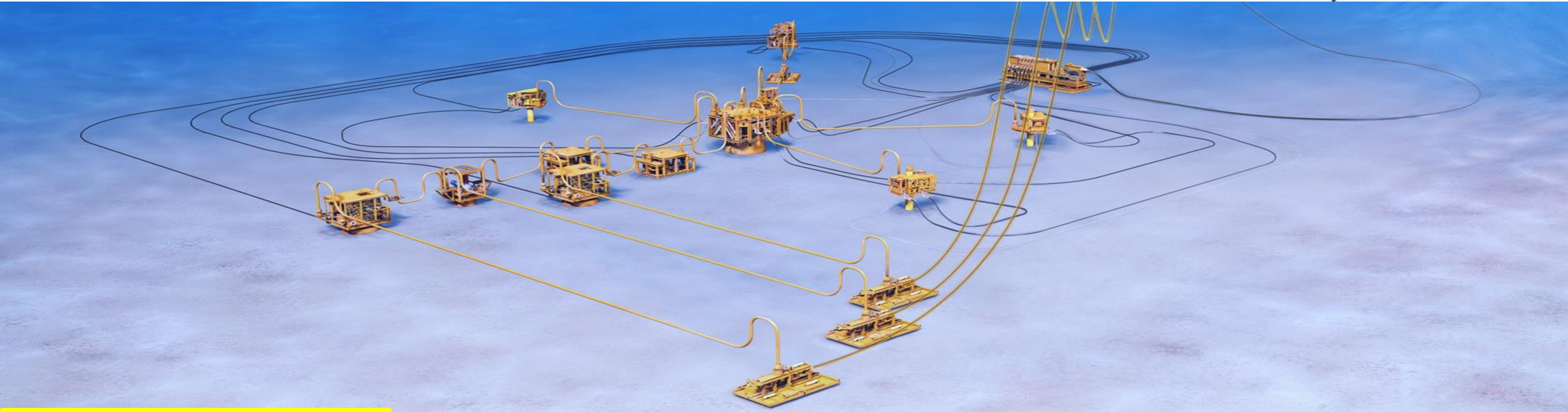

Subsea Controls Introduction | Types of Control Systems | Controls Equipment Overview

Overview | Direct Hydraulic | EH MUX | All Electric System | Distribution Equipment | SCM / CDU | Instruments

Video


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Integrated Subsea Control System of the Future

Control Systems Vendors

AkerSolutions

Controls COE Aberdeen, UK
Controls division was Kværner FSSL until 2008

GE Oil & Gas

Controls COE Bristol, UK
was Vetco International until 2007
was ABB Vetco Gray until 2004

TechnipFMC

Controls COE Kongsberg, NO
was Kongsberg Offshore until 1993
Was FMC until early 2017

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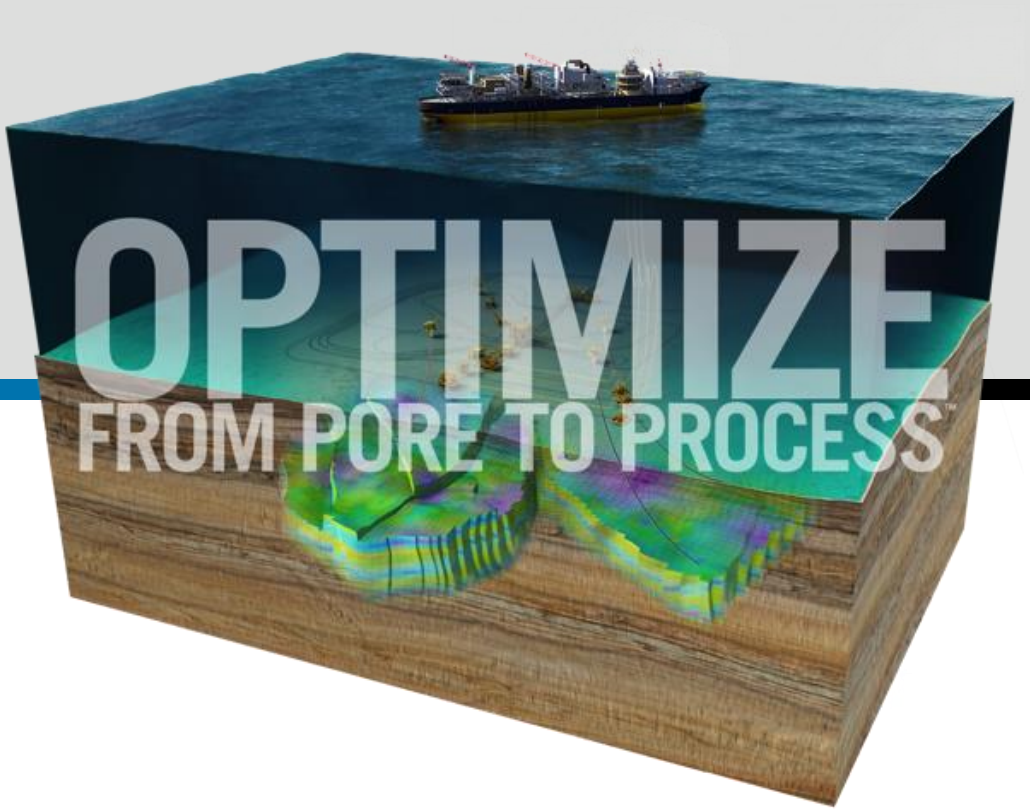
Controls COE Celle, DE
was Cameron Controls until 2013

proserv

Controls COE Aberdeen, UK
was Weatherford International subsea controls business until 2012

DRIL-QUIP

Controls COE Houston, USA



Content:

Subsea Controls Introduction

Types of Control Systems

Equipment Overview

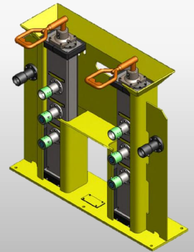
Types of Control Systems

Direct Hydraulic

- Direct hydraulic system
- No SCM

EH MUX, comms on power

- Electro-Hydraulic Multiplex System
- Most common system deployed



All Electric System

- No hydraulics, no batteries
- High reliability and availability
- Environmentally friendly
- High operational flexibility and performance feedback

EH MUX, Broadband

- Open architecture communications via TCP/IP
- Fibre optic subsea Ethernet switch

Types of Control Systems

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1963
First subsea control system

1979
First multiplexed EH subsea control system

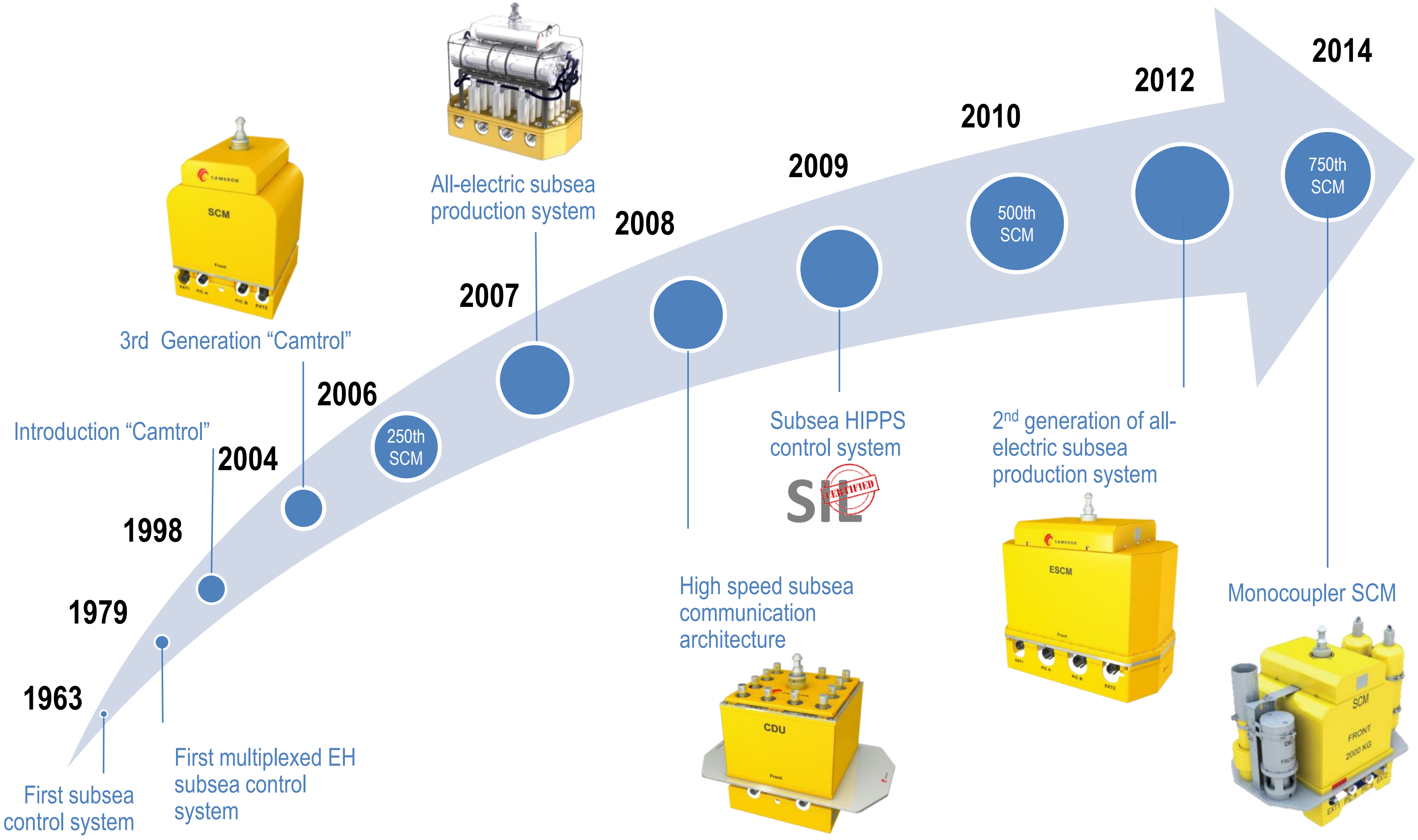
2007


All-electric subsea production system

2008
High speed, broadband, ultra-far operating subsea communication architecture


2011
2nd generation of all-electric subsea production system


Types of Control Systems



Types of Control Systems

Typical factors affecting control system selection:

- Step-out distance
- Field architecture / layout of development
- Number & type of subsea wells
- Water depth / hydrostatic head
- Operating pressure and temperature
- Future expansion & tie-ins (phased development)
- Existing subsea infrastructure
- Instrumentation
- Maintenance philosophy
- Reliability, availability and maintainability targets

Direct Hydraulic Control System

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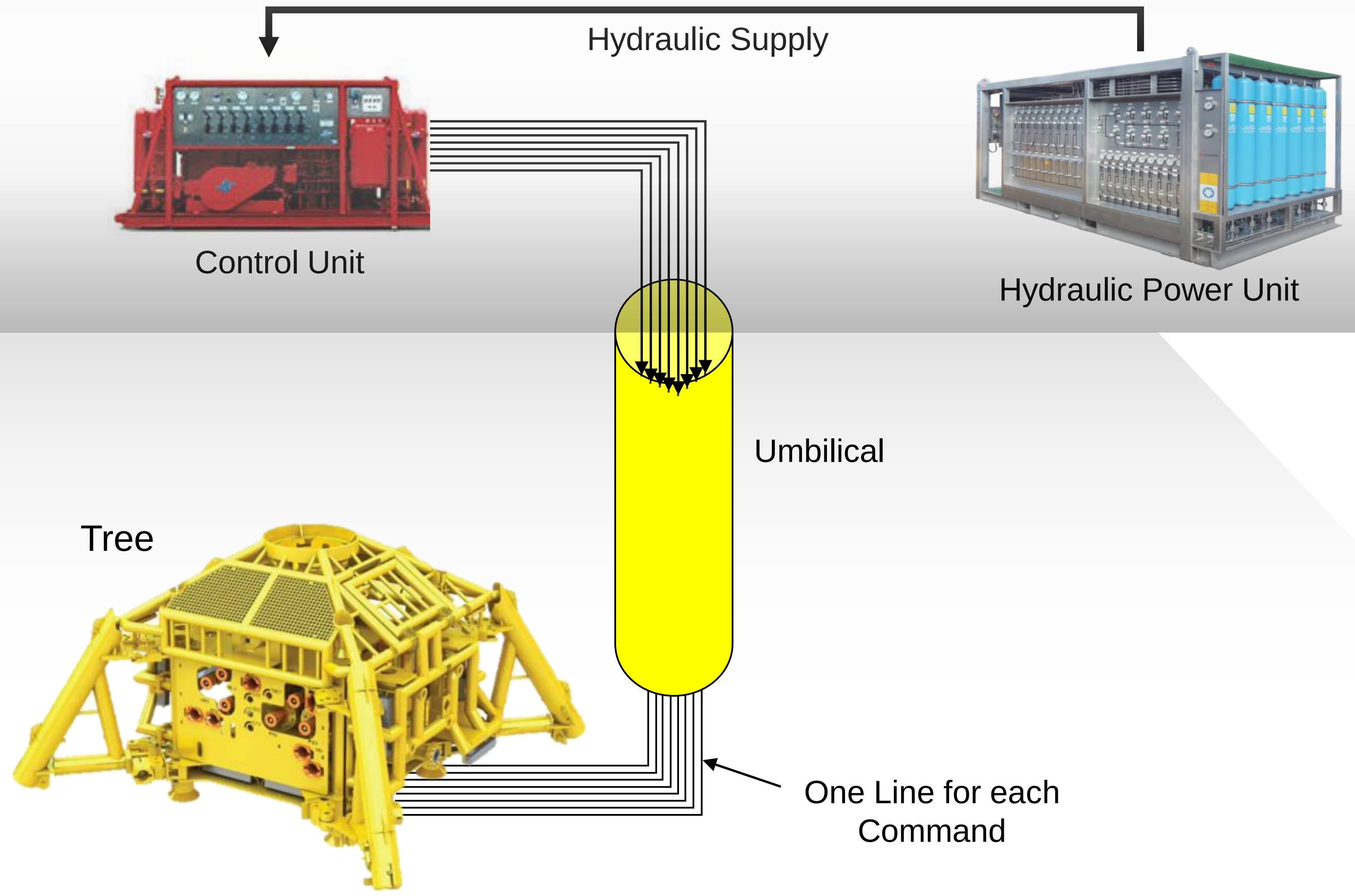
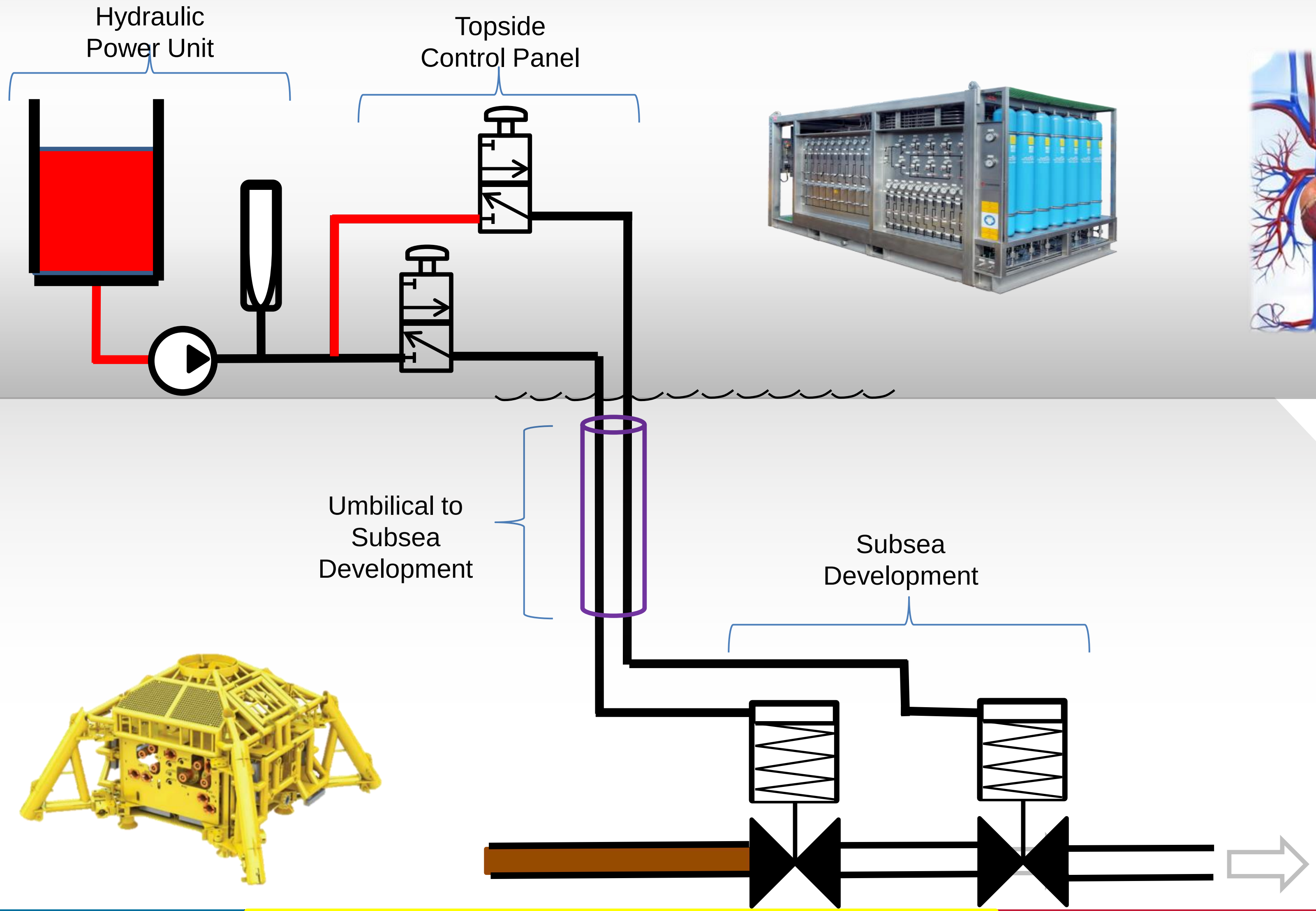
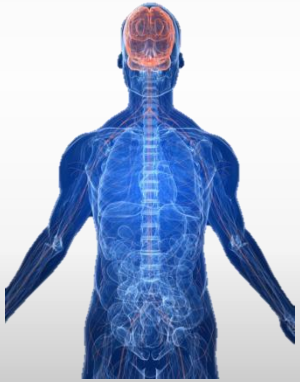


Direct Hydraulic Control System





Direct Hydraulic Control System

Video, basic operations of Direct Hydraulic Control System

Direct Hydraulic Control System

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Advantages

- Few system components, low cost
- Simple operation
- Reliable

Limitations

- Hydraulic response times increase with distance
- Increase umbilical cost with distance & size
- Sensor & Instrumentation limitations with distance

Applications

- Used for Production Control System over short distances (< 3Km)
- Often used for Intervention Control Systems (from a boat above a well)

Electro-Hydraulic Multiplex Control System

Electro-Hydraulic

- Uses electricity to send command signals over a long distance.
- Signal converted into hydraulic power which then actuates valves & chokes

Multiplex

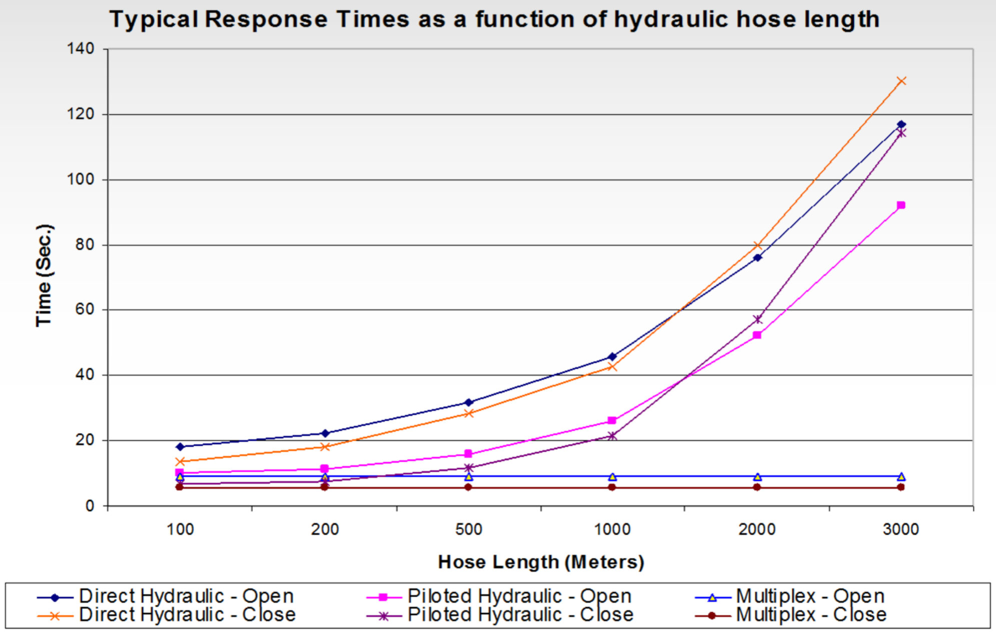
- Relating to or being a system of simultaneous communications of two or more messages on the same wire or channel
- Suitable for tie-back over great distances without loss of response
- Subsea data monitoring via the communications line

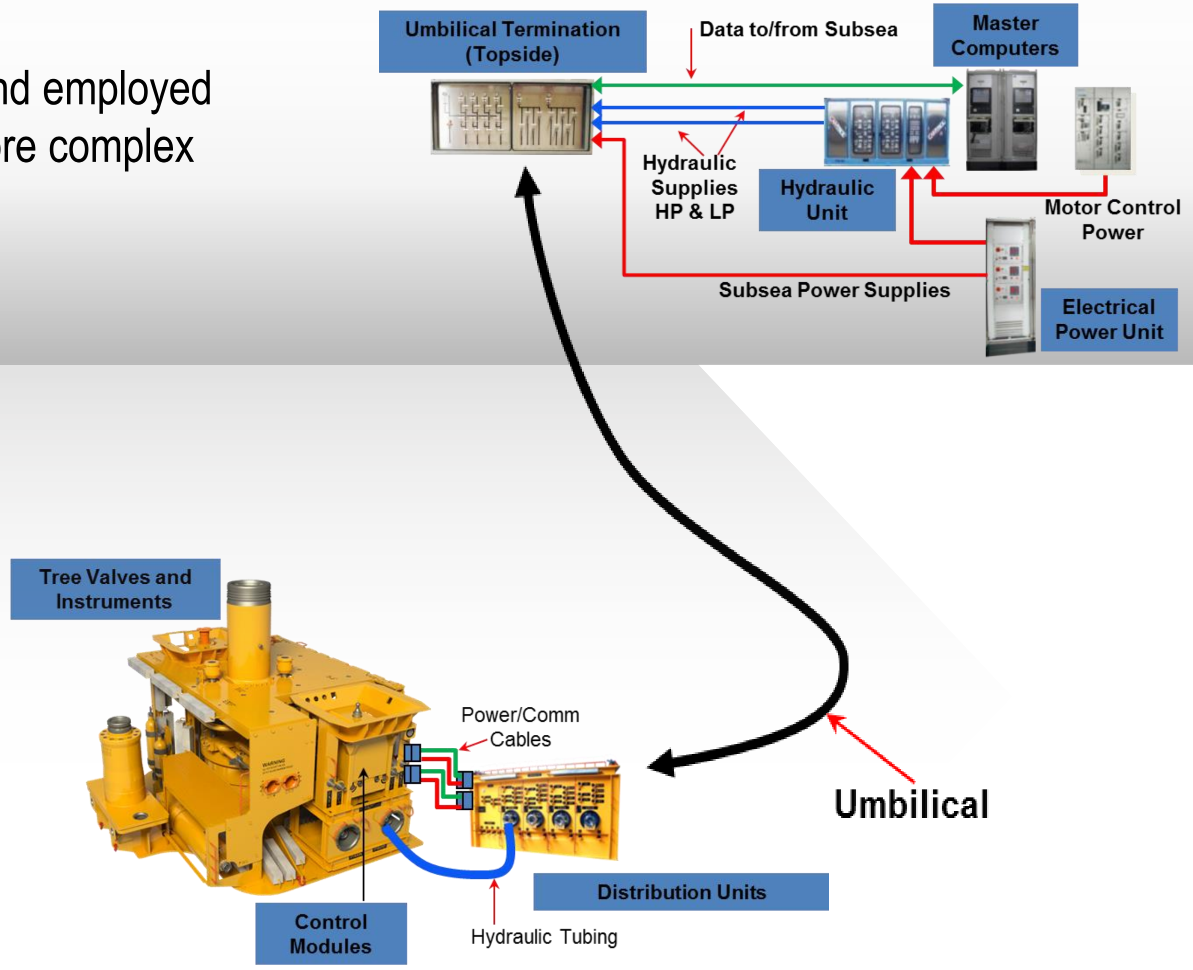
Various Options

- Discrete Power and Communication channels
- Combined Power & Signal channels (CPS)

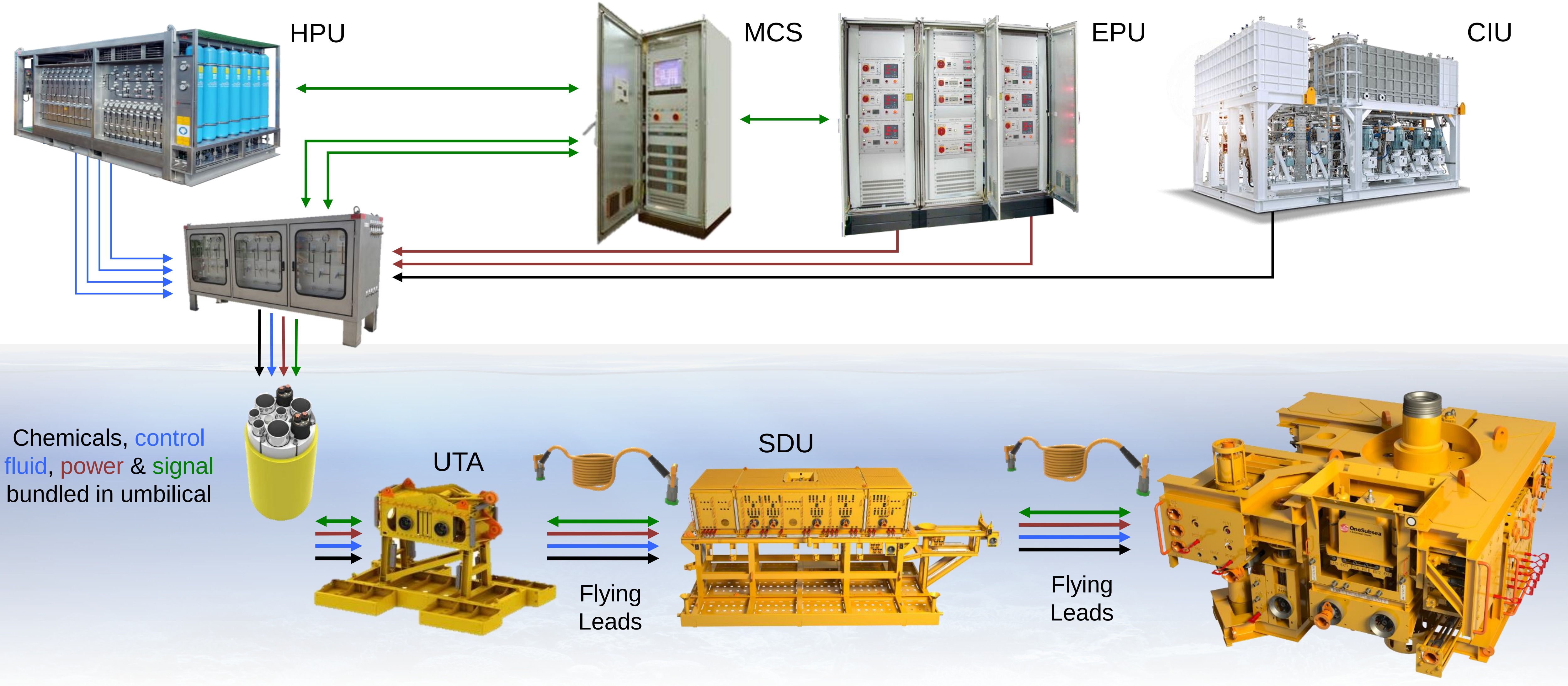
Electro-Hydraulic Multiplex Control System

The Electro-Hydraulic Multiplex (EH-MUX) System was developed and employed to solve technological challenges that came with further, deeper, more complex developments:





Electro-Hydraulic Multiplex Control System



Electro-Hydraulic Multiplex Control System

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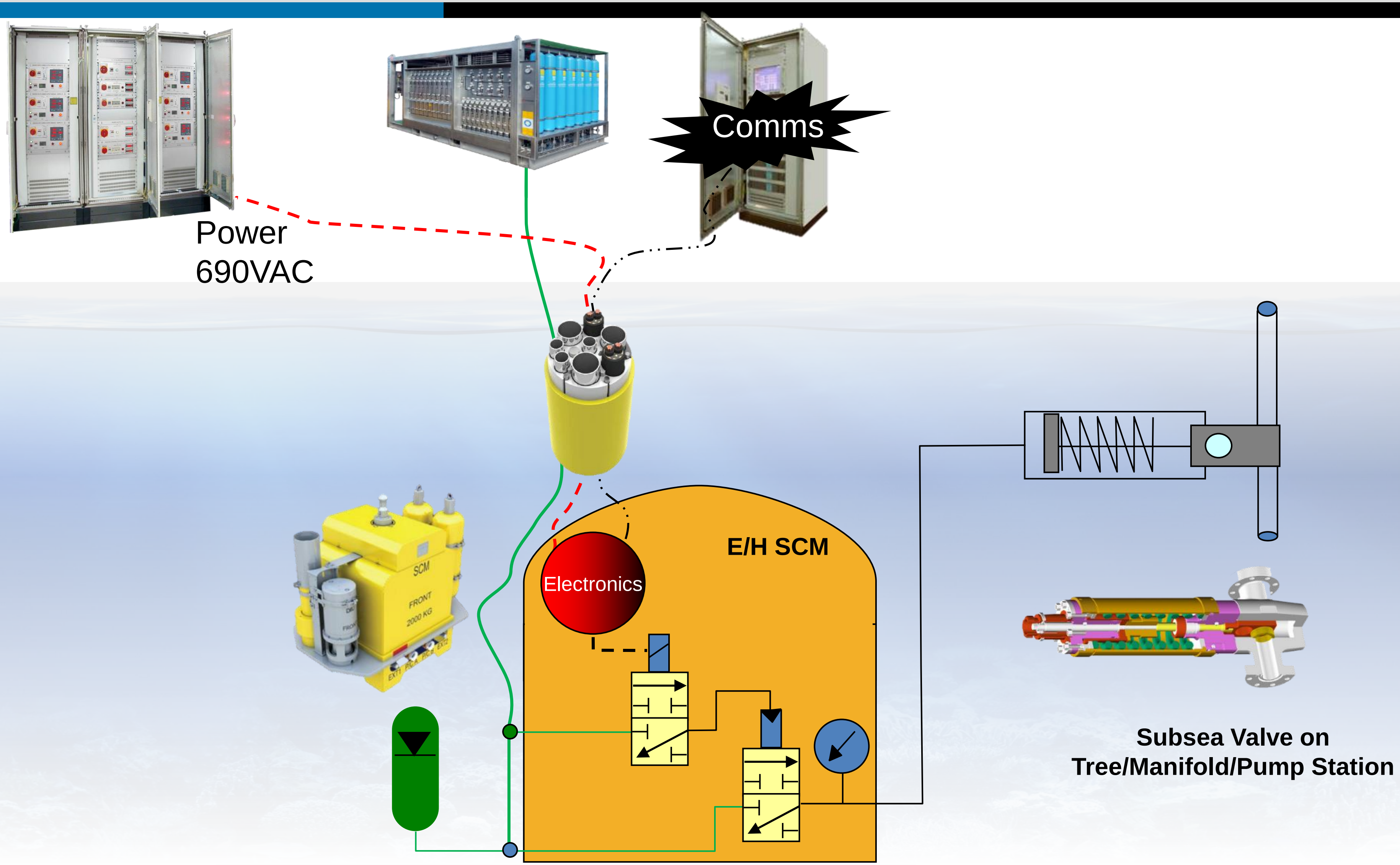


Electro-Hydraulic Multiplex Control System

Advantages

- Instantaneous response for valve commands
- Reduced Umbilical size
- High level of system flexibility
- Suitable for tie-back over greater distances without loss of response

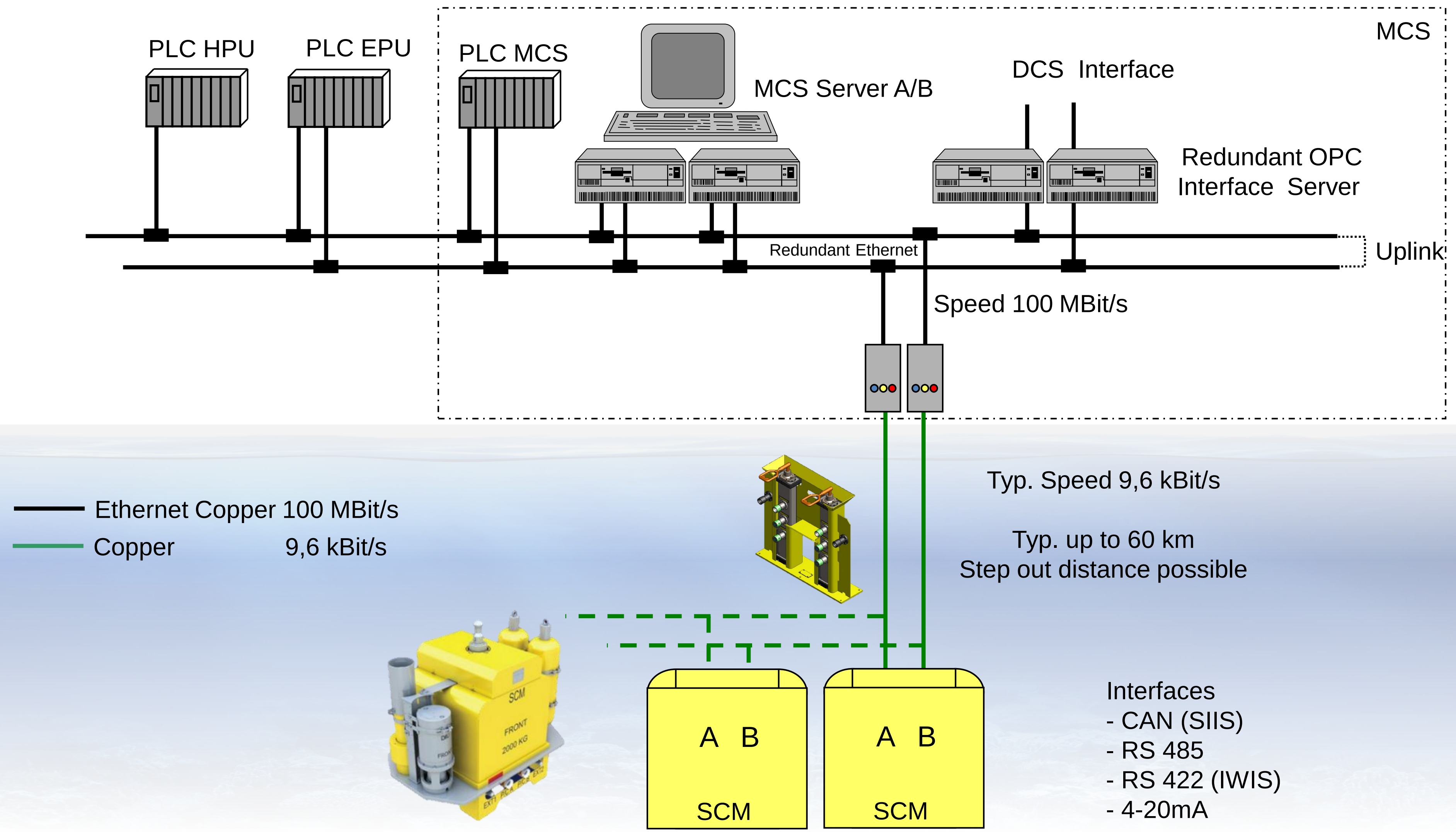
Drawbacks

- Higher level of system complexity
- Increase number of surface and subsea components

Applications

- Standard for Subsea Production Control Systems

EH MUX Comms – Comms on Power



EH MUX Comms – Comms on Power

Advantages

- Only two pairs for all SCMs (typically up to 6 SCMs per pair)
- Low cost Electrical Distribution Unit
- Suitable for tie-back typ. up to 40km

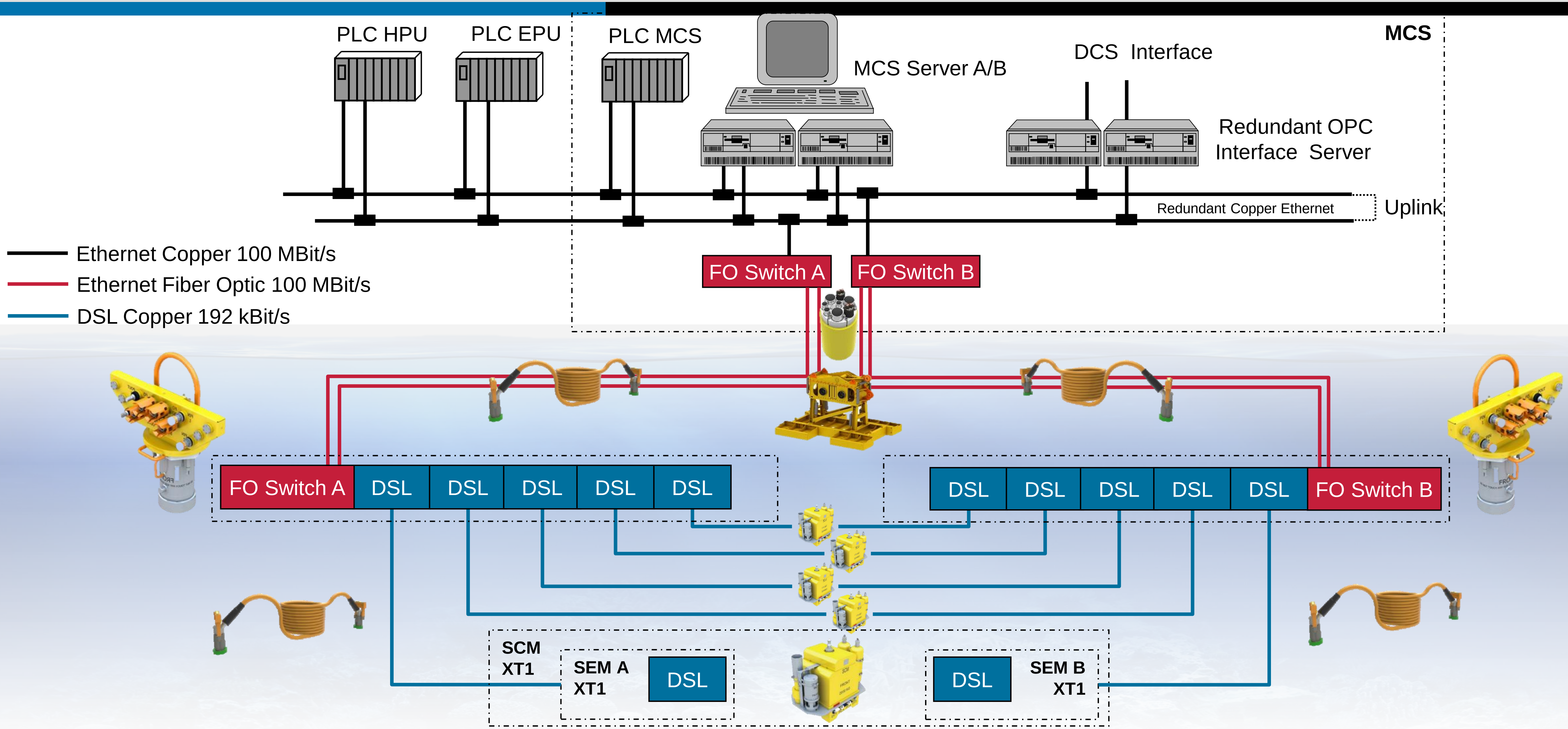
Drawbacks

- Subject to limitations due to noises and signal attenuations
- Typically limited to approx 40 km step-out
- Limited bandwidth, typ. 9.6 kBits/s

Applications

- Standard for Subsea Production Control Systems with up to 40km step out (typ.)

EH MUX Comms – Broadband (FO / DSL)



EH MUX Comms – Broadband (FO / DSL)

Why did telecom companies opt for FO / DSL communication systems?

- transmit digital data using existing telephone network which uses the public switched telephone network. DSL service is delivered simultaneously with wired telephone service on the same telephone line.

Why did Subsea Controls opt for FO / DSL communication systems?

- Enable the use of the same electrical components (connectors and EFLs) from the CDU to SCM
- Field proven
- Lower costs

Comms on Power vs. Broadband (FO / DSL)

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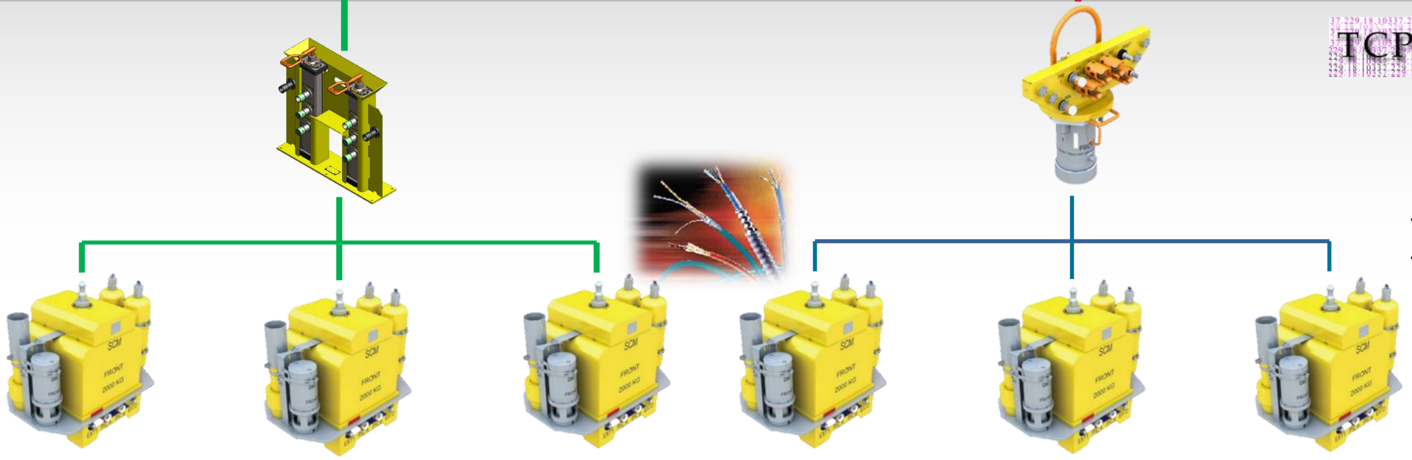
- Copper 9,6 kBit/s
- Ethernet FO 100 MBit/s
- DSL Copper 192 kBit/s

Comms on Power

Proprietary Interface
Typ. Speed: **9,6kBit/sec**
half-duplex
Copper up to 60km

Broadband (FO / DSL)

FO “Fast Ethernet”
100 MBit/s
full-duplex
Singlemode fibre up to 160km



TCP/IP

ETHERNET

DSL:
Typ. 192 kBit/s per SCM
Typ. up to 30km

DSL

EH MUX Comms – Broadband (FO / DSL)

Advantages

- Suitable for long tie-back
- Enable the use of standard electrical equipment (EFL, connectors) from CDU to SCMs
- Suitable for long step out from CDU to SCM
- Possibility to increase the amount of redundancy
- Low impact on the umbilical cross section (fibres are small…)
- FO communications are immune to noises

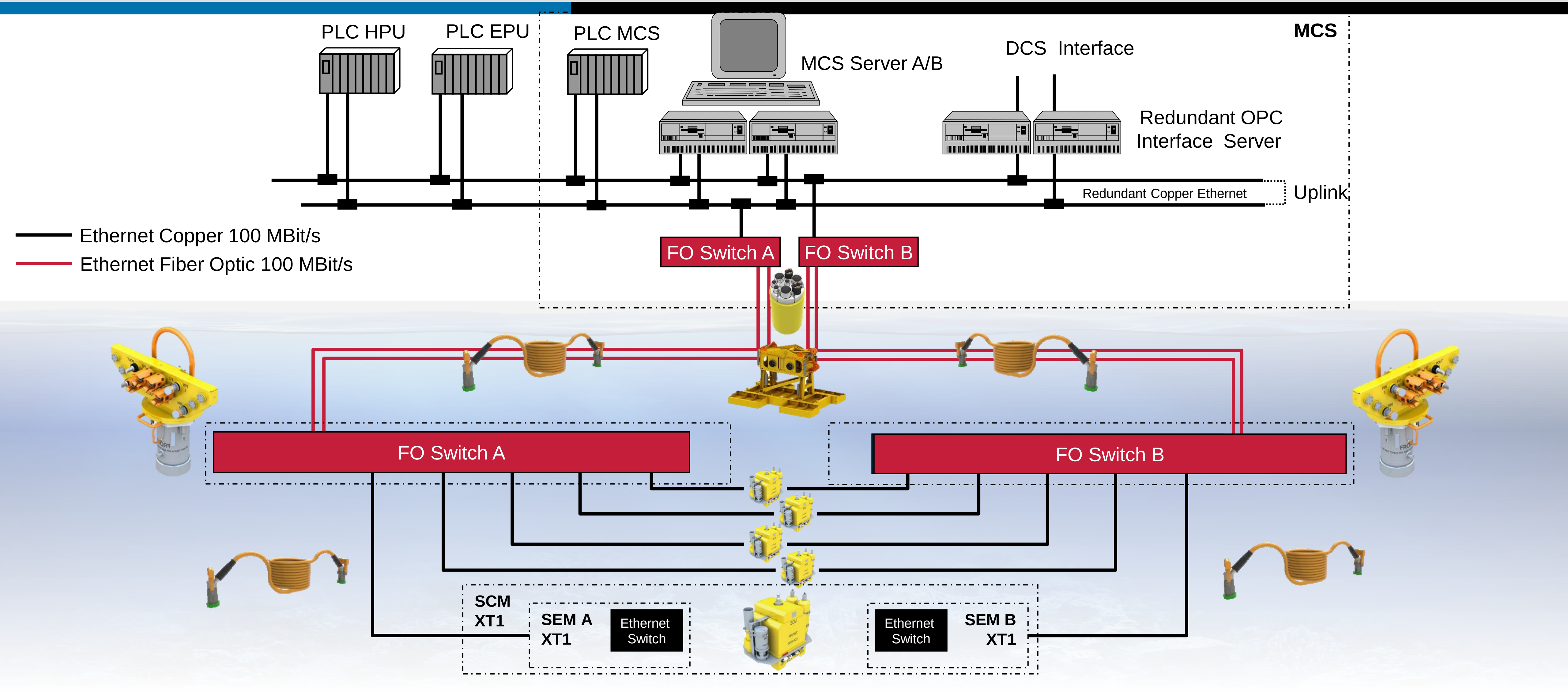
Drawbacks

- Higher cost, mainly due to FO connectors, OFL and CDU
- Two communication systems (FO Ethernet + DSL)

Applications

- Standard for Subsea Production Control Systems with more than 40km step out (typ.)

EH MUX Comms – Broadband (FO / Copper Ethernet)



EH MUX Comms – Broadband (FO / Copper Ethernet)

Advantages

- Suitable for long tie-back
- Possibility to increase the amount of redundancy
- Low impact on the umbilical cross section (fibres are small…)
- FO communications are immune to noises

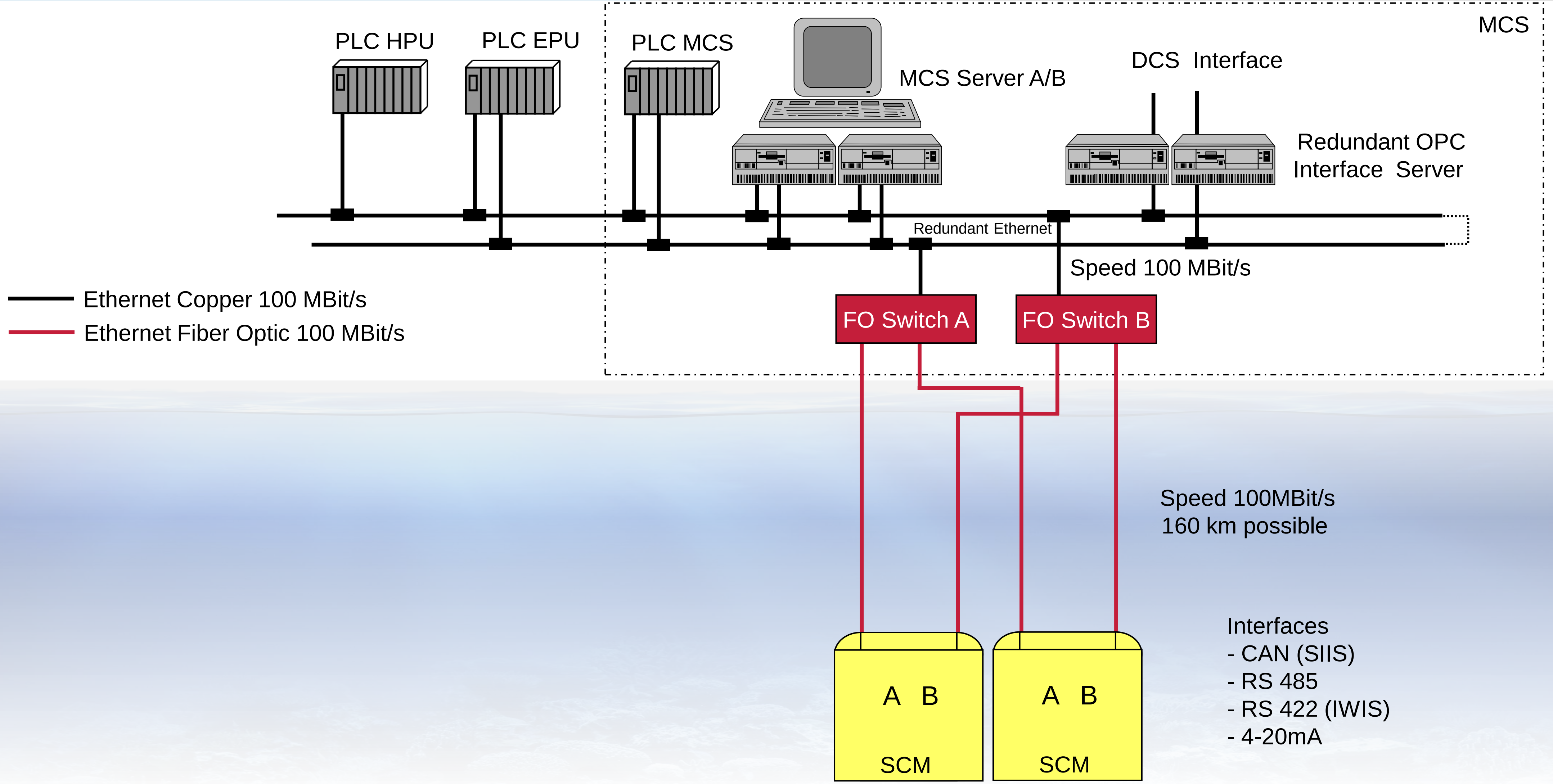
Drawbacks

- Prevent the use of standard electrical equipment (EFL, connectors) from CDU to SCMs
- Higher cost, mainly due to FO connectors, OFL, Copper Ethernet connectors and EFLs and CDU
- Limited step out from CDU to SCM (typ. 100m)

Applications

- Suitable for Systems with tight drill centers (e.g. templates)

EH MUX Comms – Broadband (FO / FO)



EH MUX Comms – Broadband (FO / FO)

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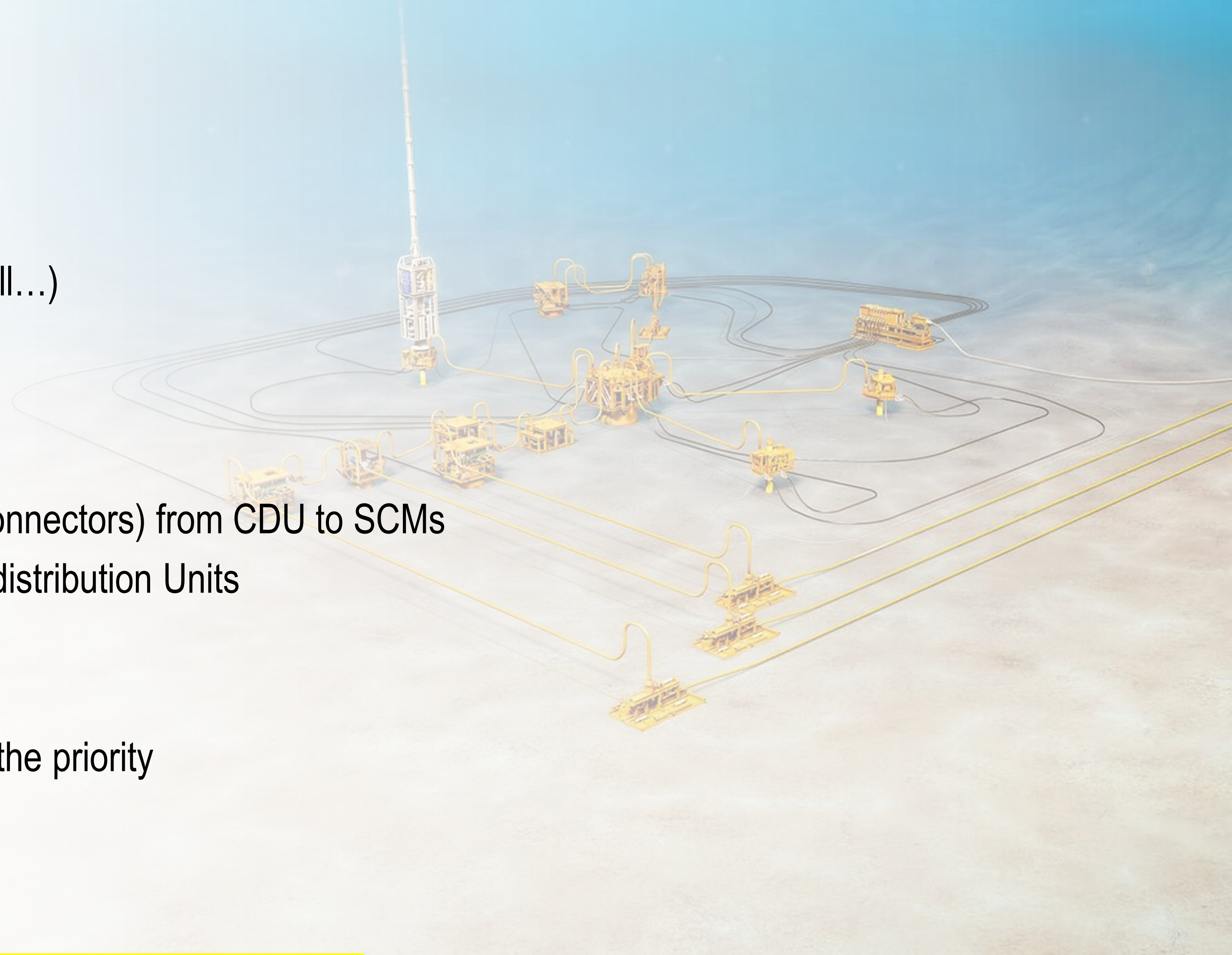

Advantages

- Suitable for long tie-back
- Possibility to increase the amount of redundancy
- Low impact on the umbilical cross section (fibres are small…)
- FO communications are immune to noises

Drawbacks

- Prevent the use of standard electrical equipment (EFL, connectors) from CDU to SCMs
- Higher cost, mainly due to FO connectors, OFL, and FO distribution Units

Applications

- Suitable for those projects where cost optimization is not the priority

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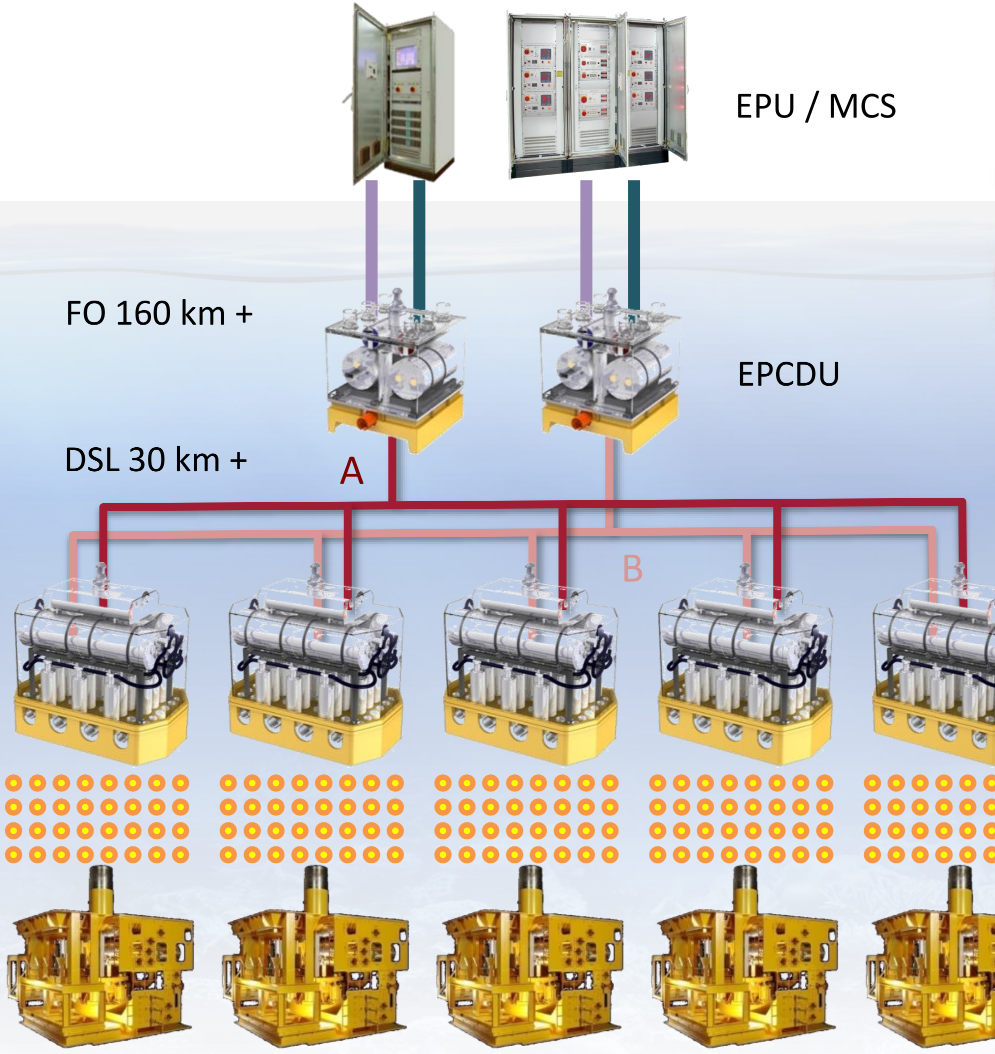
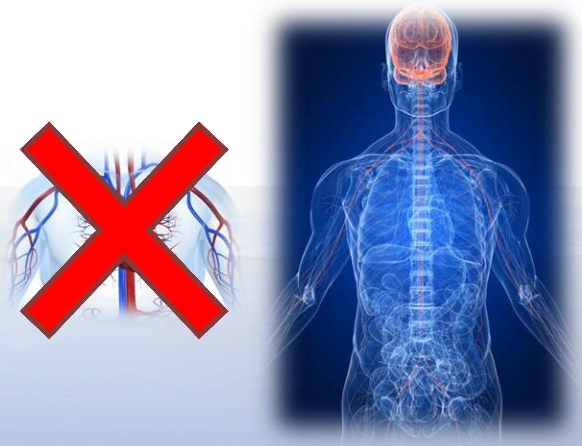
Why All Electric?

- Subsea Production Systems, which have:
  - Environmental demand for zero discharge
  - High availability requirements
  - Extreme offset and/or water depth
- Subsea Processing which needs:
  - Continuous valve actuation
  - Ultra fast control
  - Integrated control

All Electric System



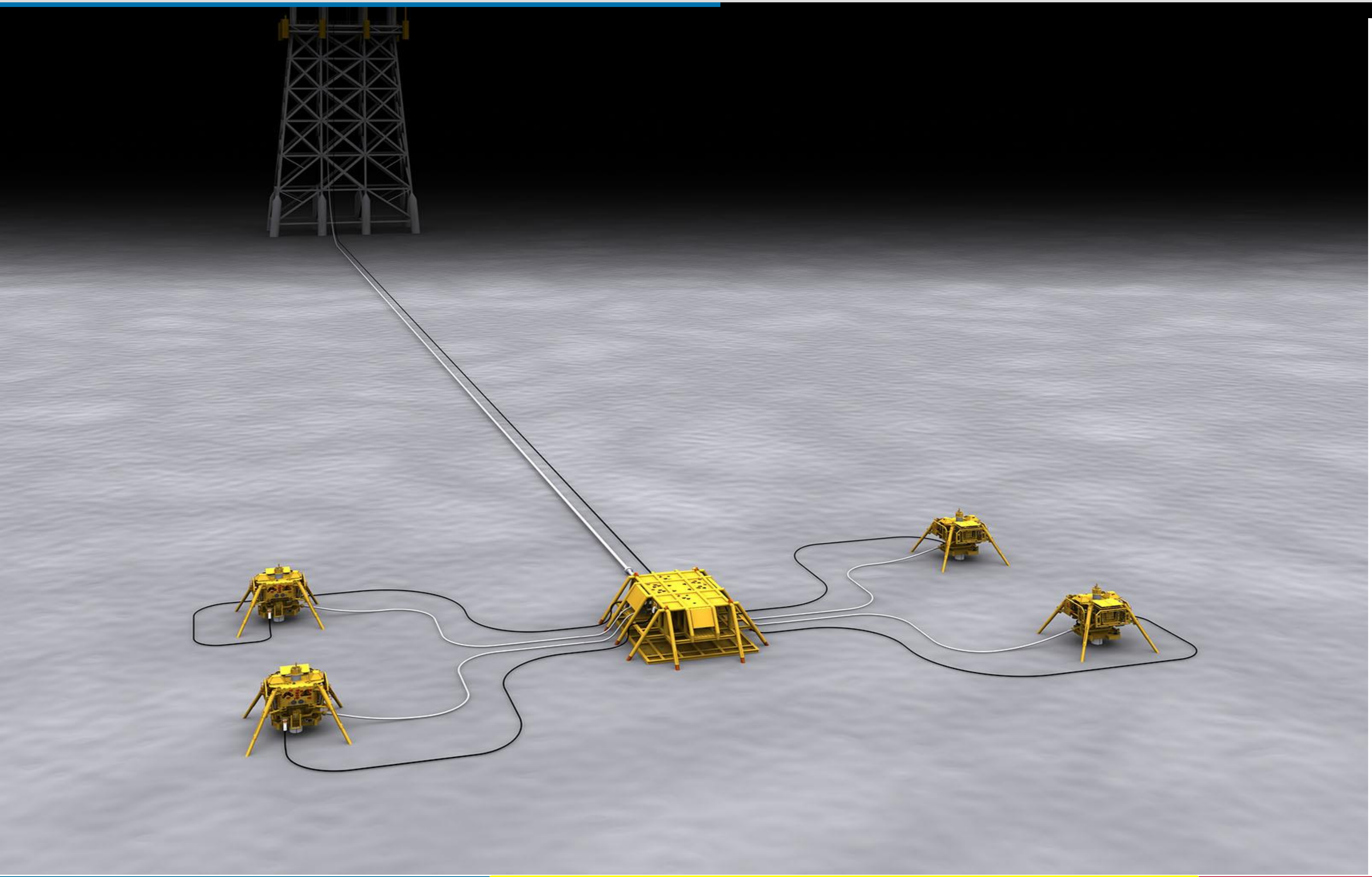


Types of Control Systems

Exercise, select the Control Systems type for the scenarios from the following options:

1. Direct Hydraulic
2. EHMUX
3. Broadband FO / DSL
4. Broadband FO / Copper Ethernet
5. Broadband FO / FO

Types of Control Systems: Scenario #1



- 20km stepout distance
- 4 off Trees
- Low number of instruments

Types of Control Systems: Scenario #2

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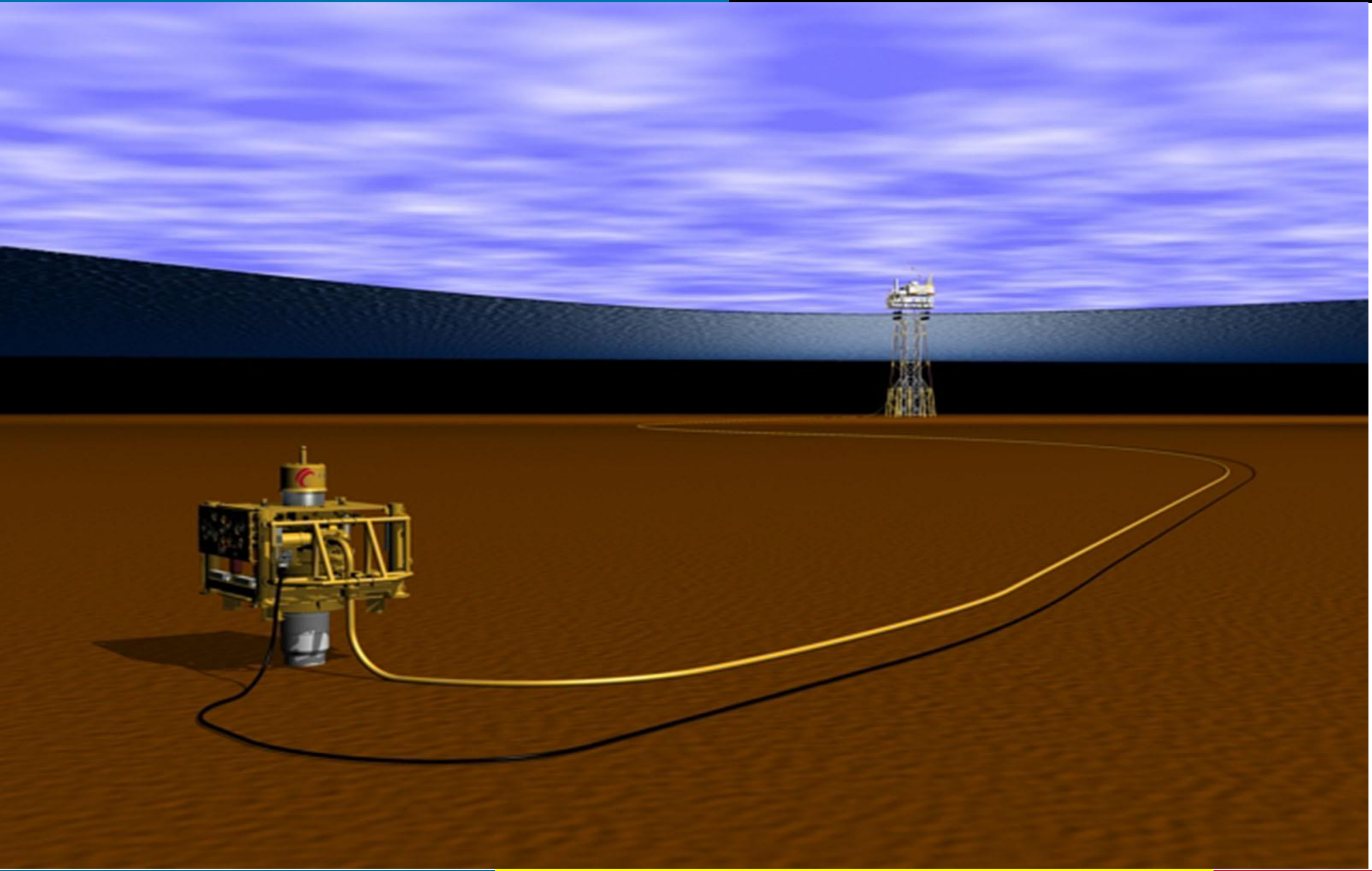
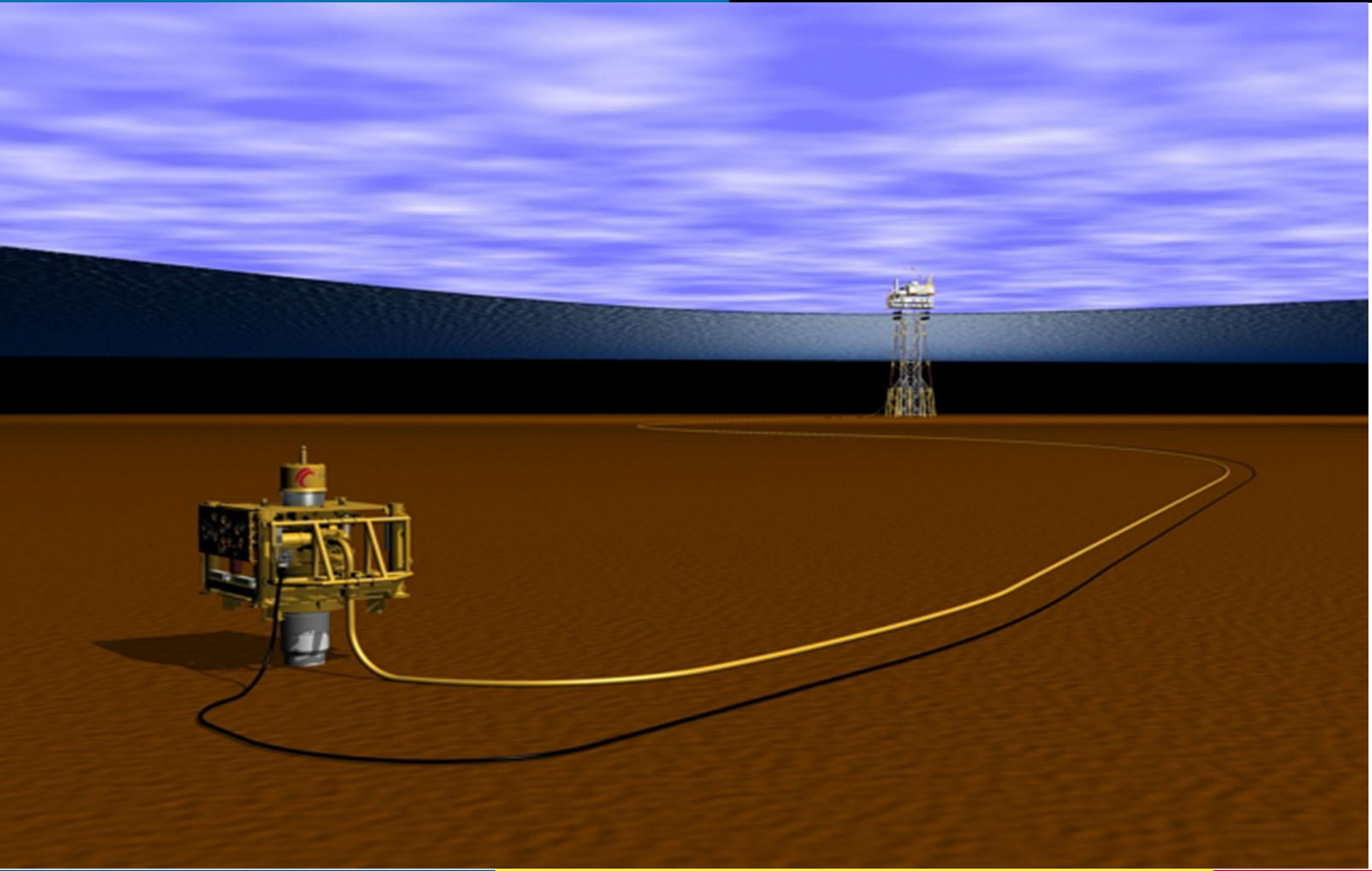


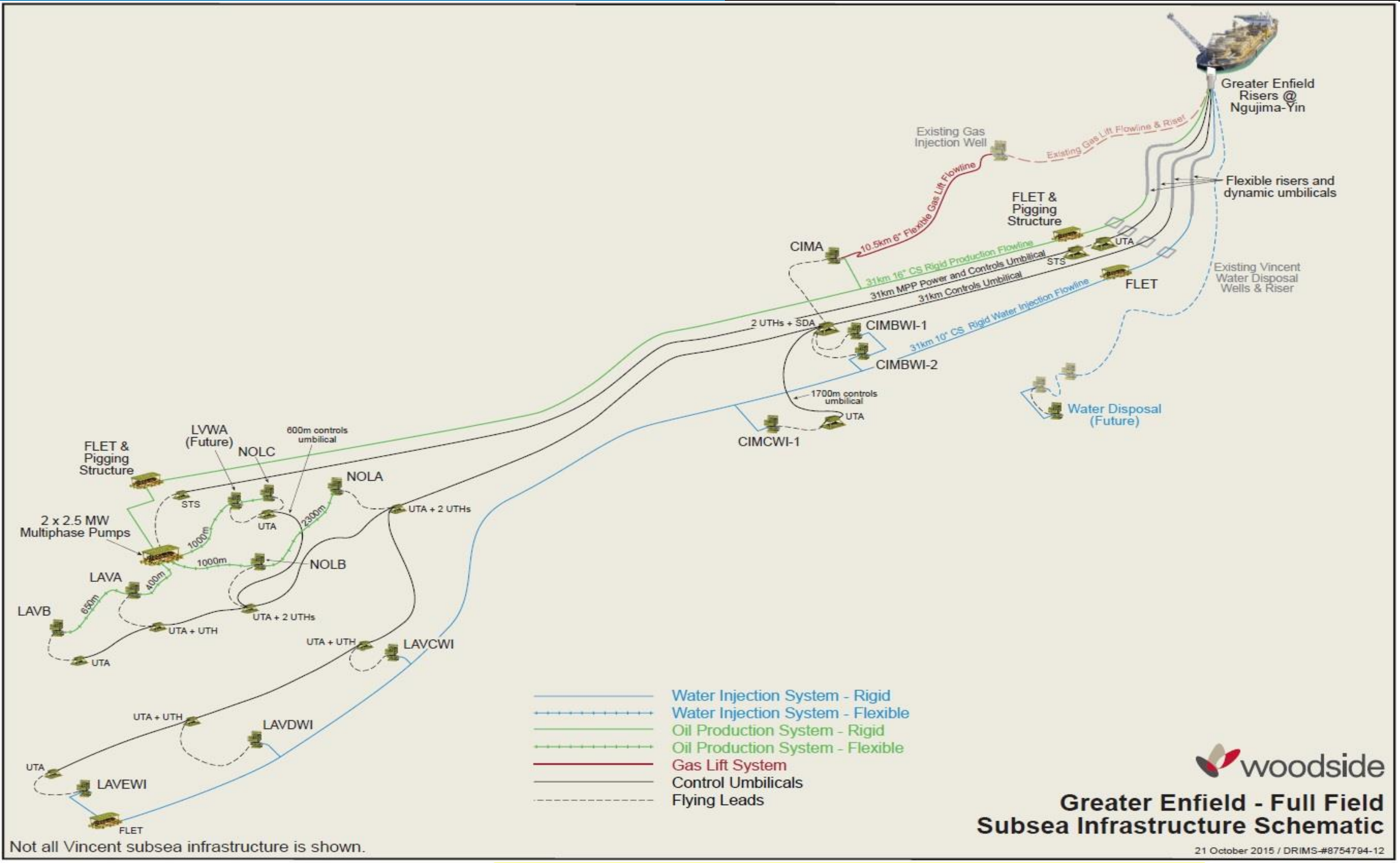
- 2km stepout distance
- 1 off Trees
- Low number of instruments

Types of Control Systems: Scenario #3

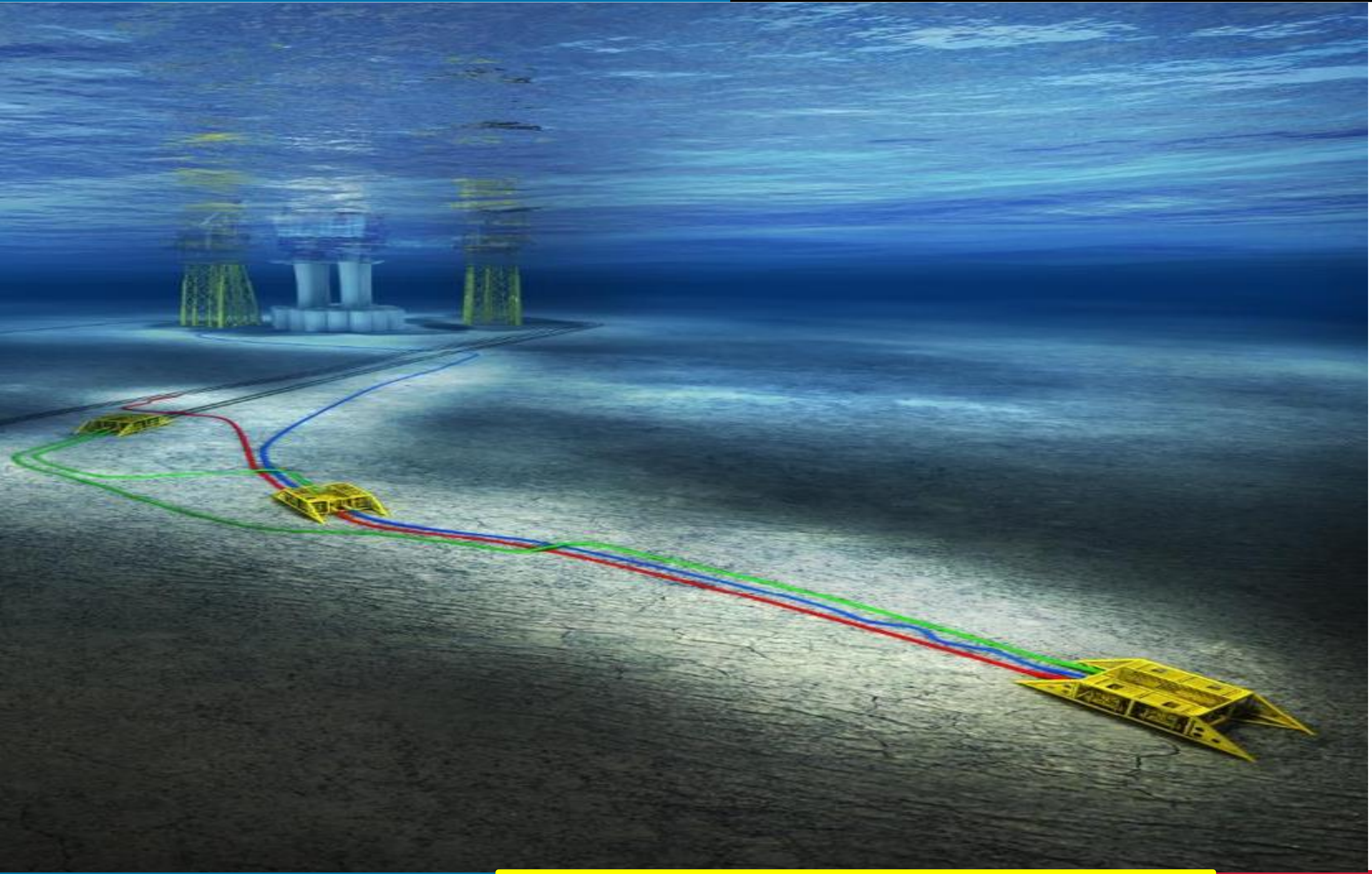


- 80km stepout distance
- 1 off Trees
- Low number of instruments

Types of Control Systems: Scenario #4

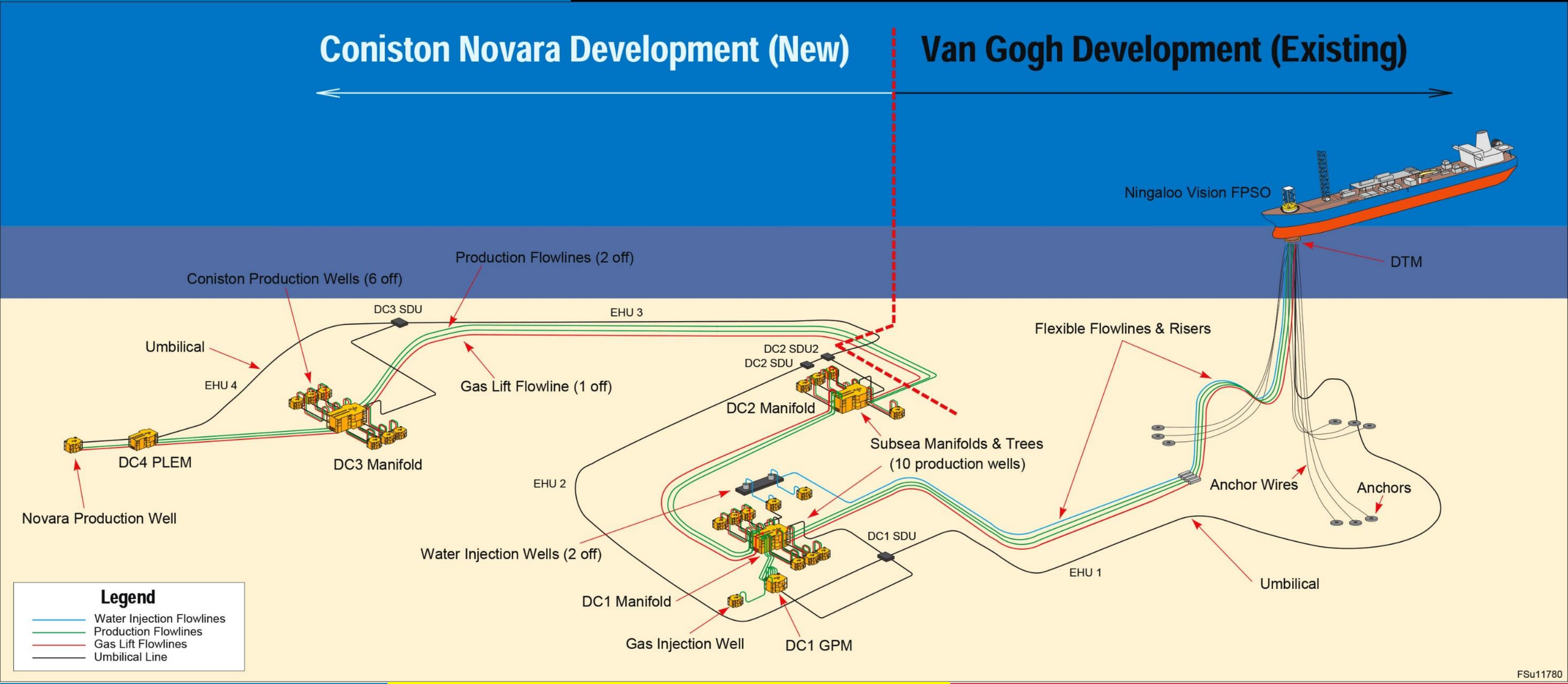


Types of Control Systems: Scenario #5



- 60km stepout distance
- 12 off Trees
- High number of instruments

Types of Control Systems: Scenario #6



Types of Control Systems: Scenario #7

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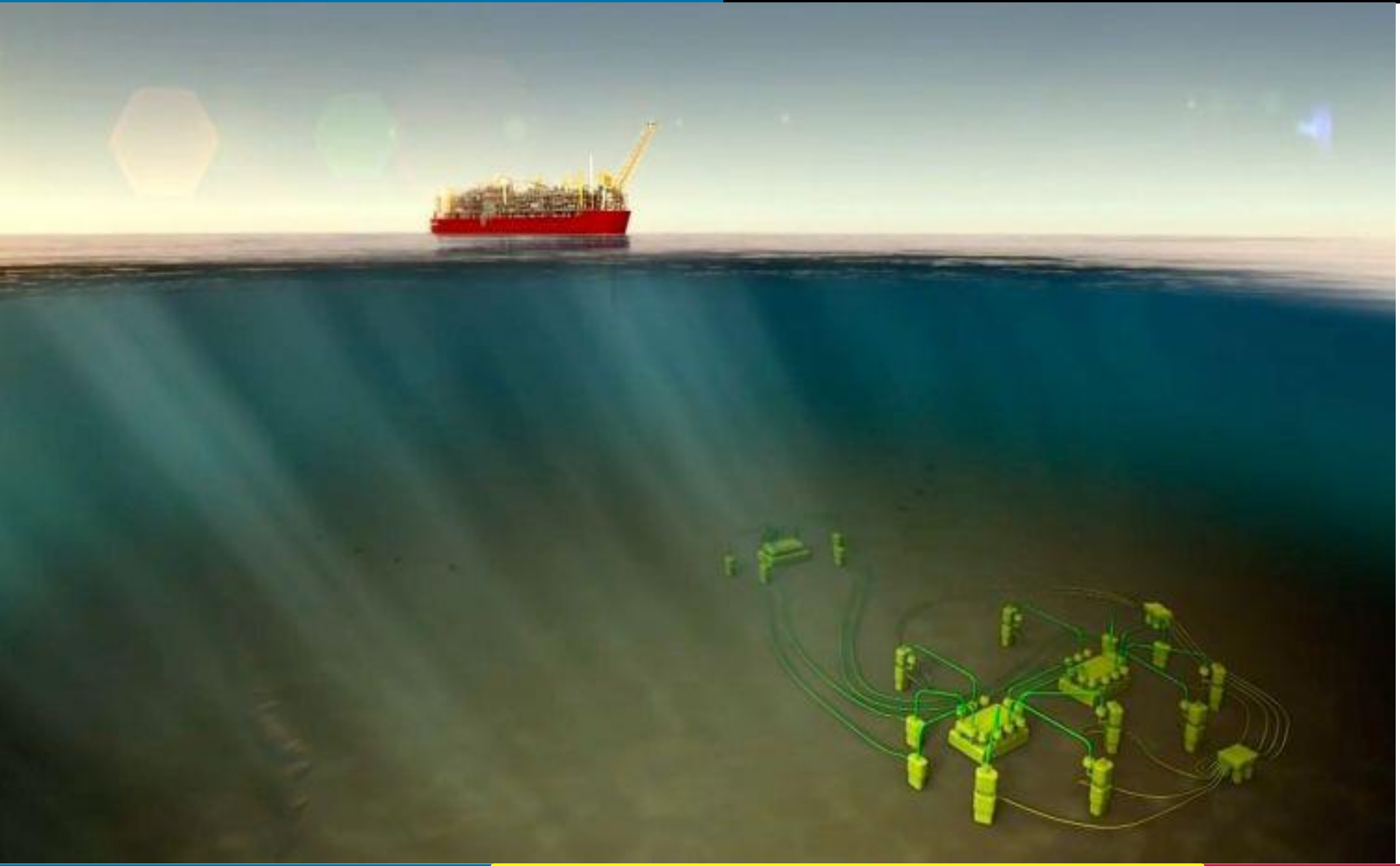
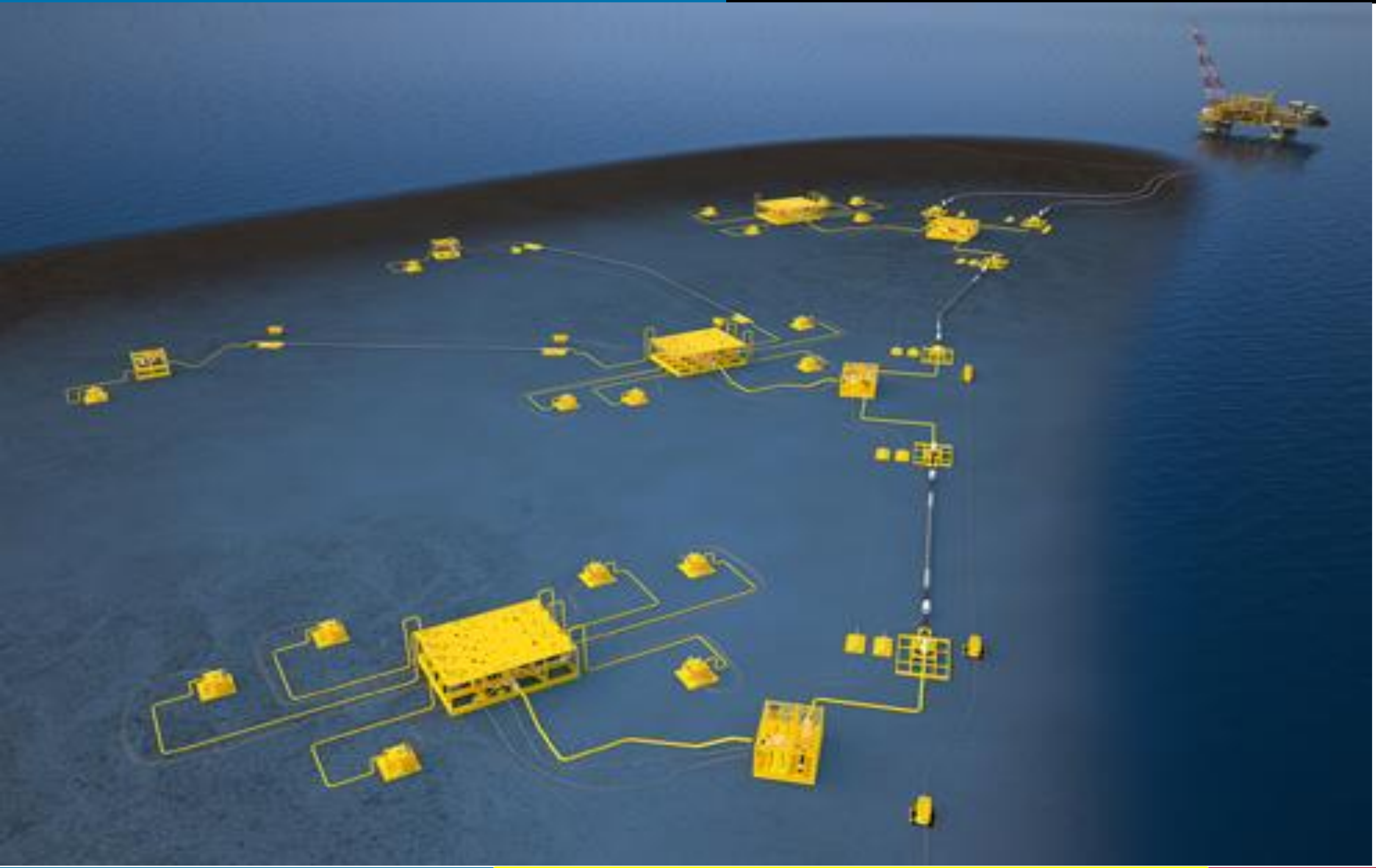
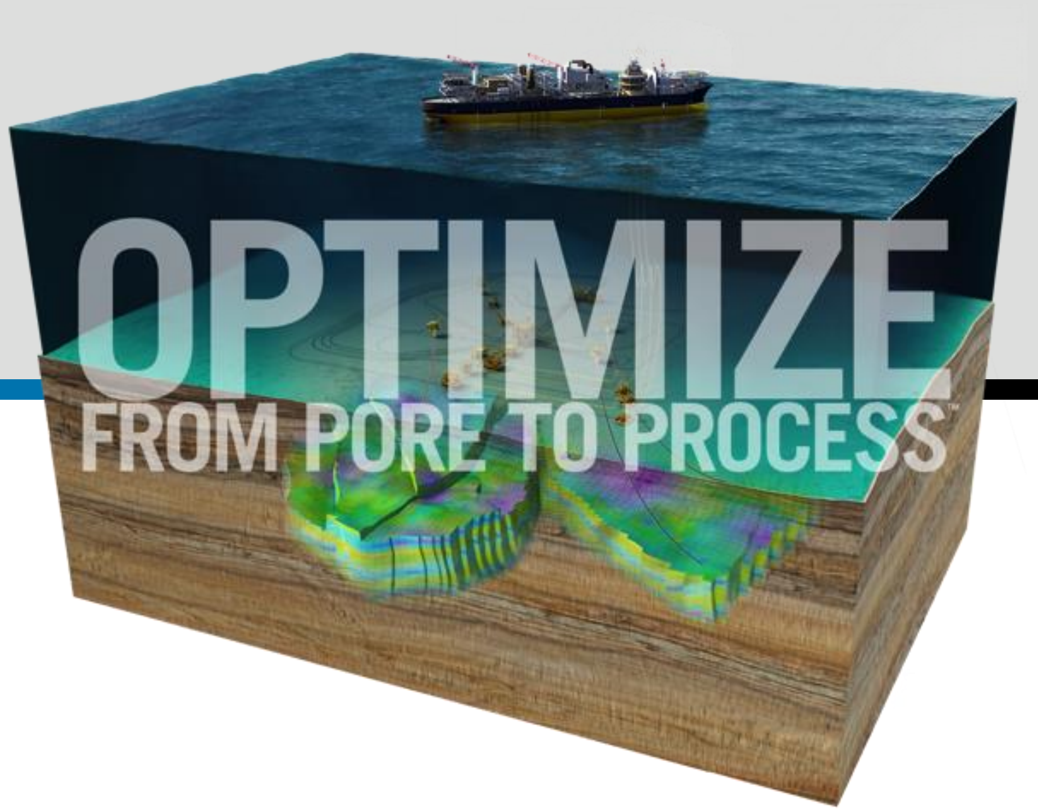


- 20km stepout distance
- 14 off Trees
- High number of instruments

Types of Control Systems: Scenario #8



- 60km stepout distance
- 15 off Trees
- Medium number of instruments



Content:

Subsea Controls Objectives

Types of Control Systems

Equipment Overview

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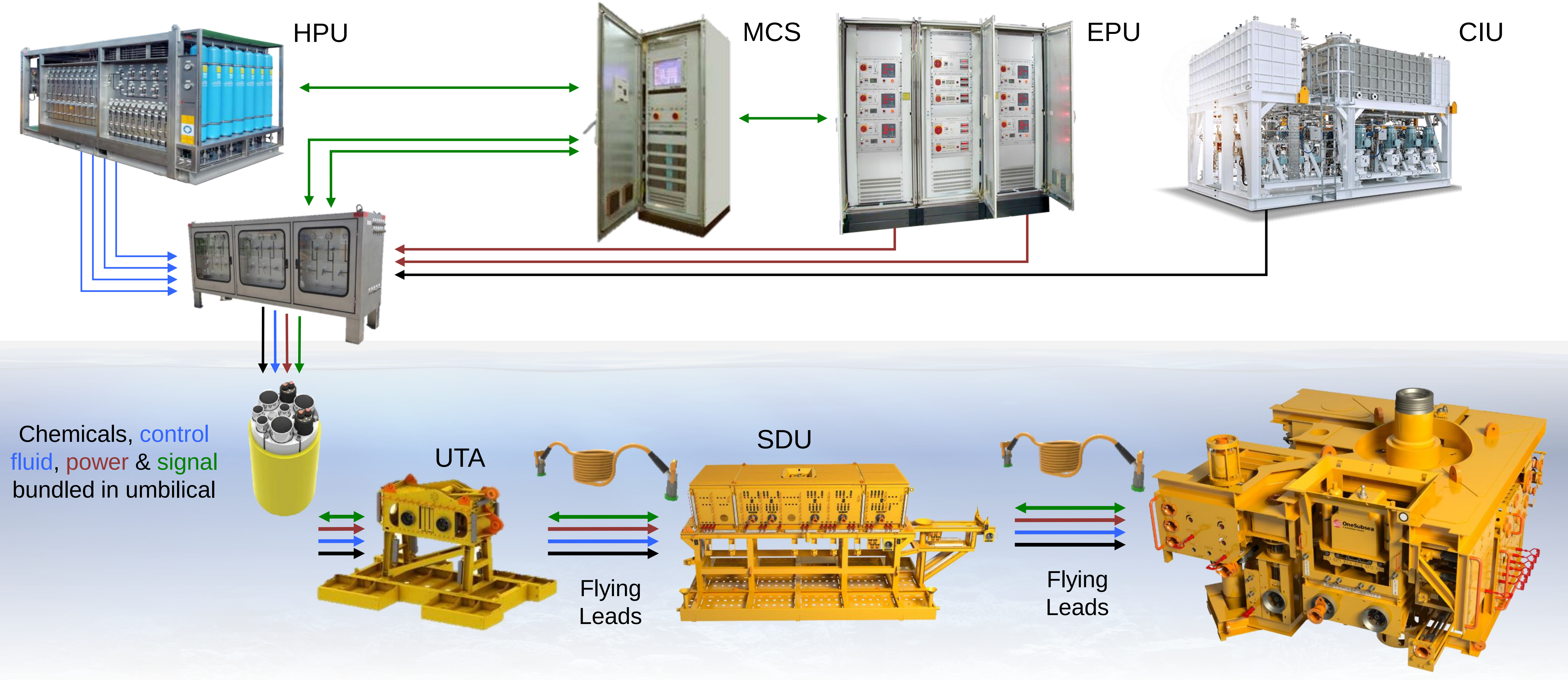
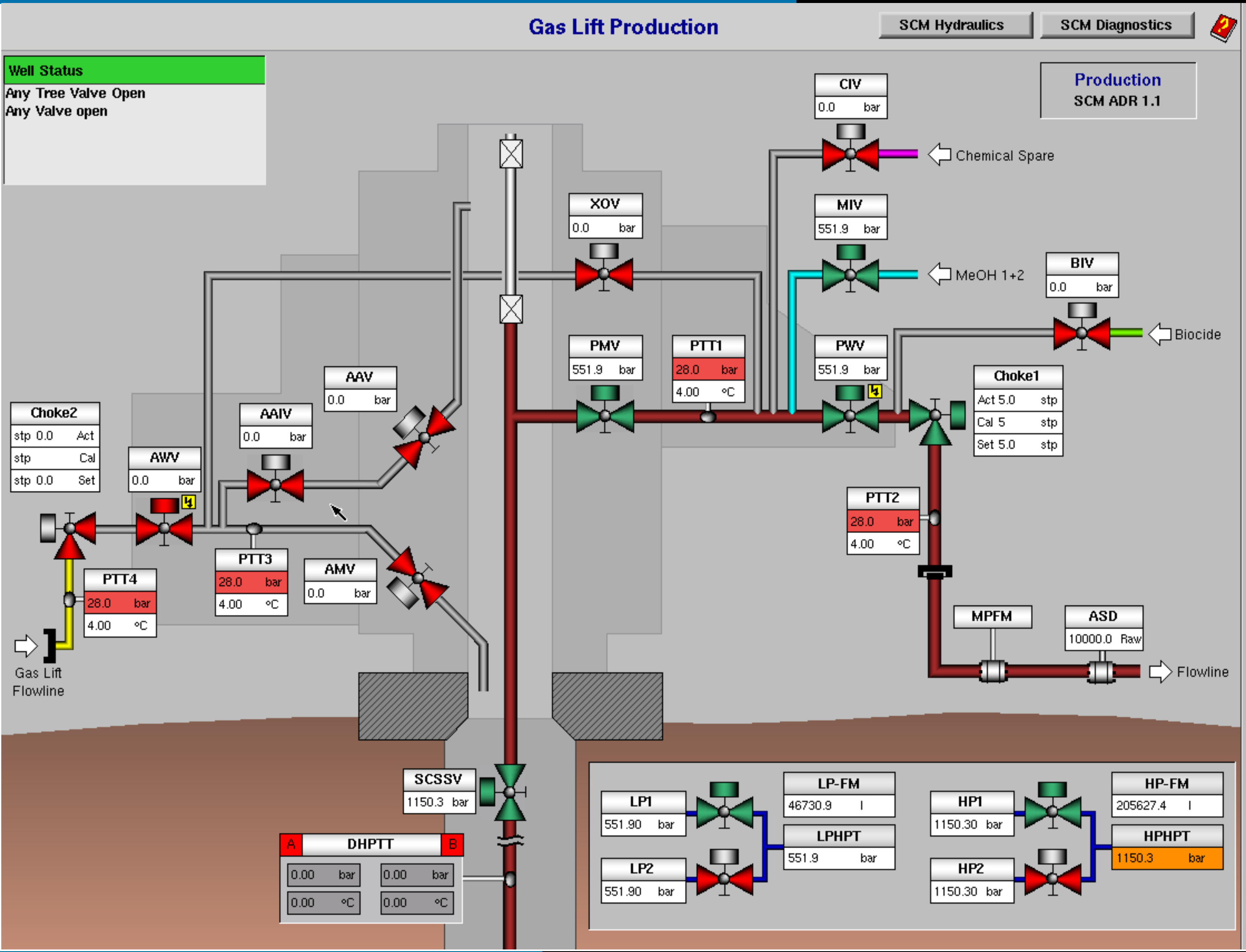
Electro-Hydraulic Multiplex Control System



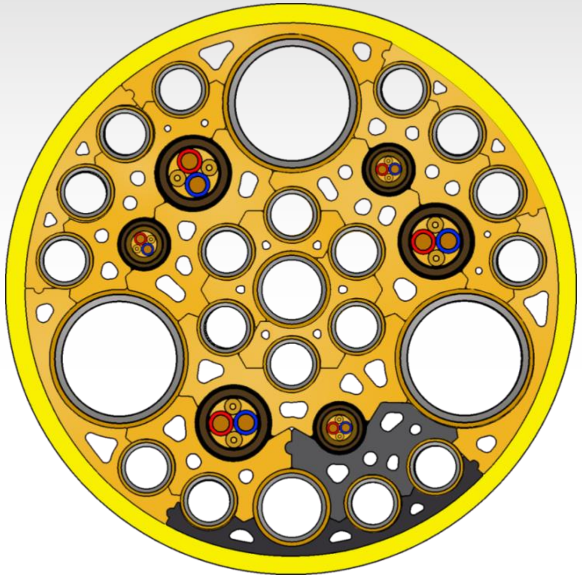
Master Control Station



Umbilical

Routes the supplies from the TUTU on the topside to the subsea equipment. Umbilicals typically contain lines for:

- Electrical power
- Hydraulic fluid (LP & HP)
- Communication
- Chemicals



Distribution Equipment

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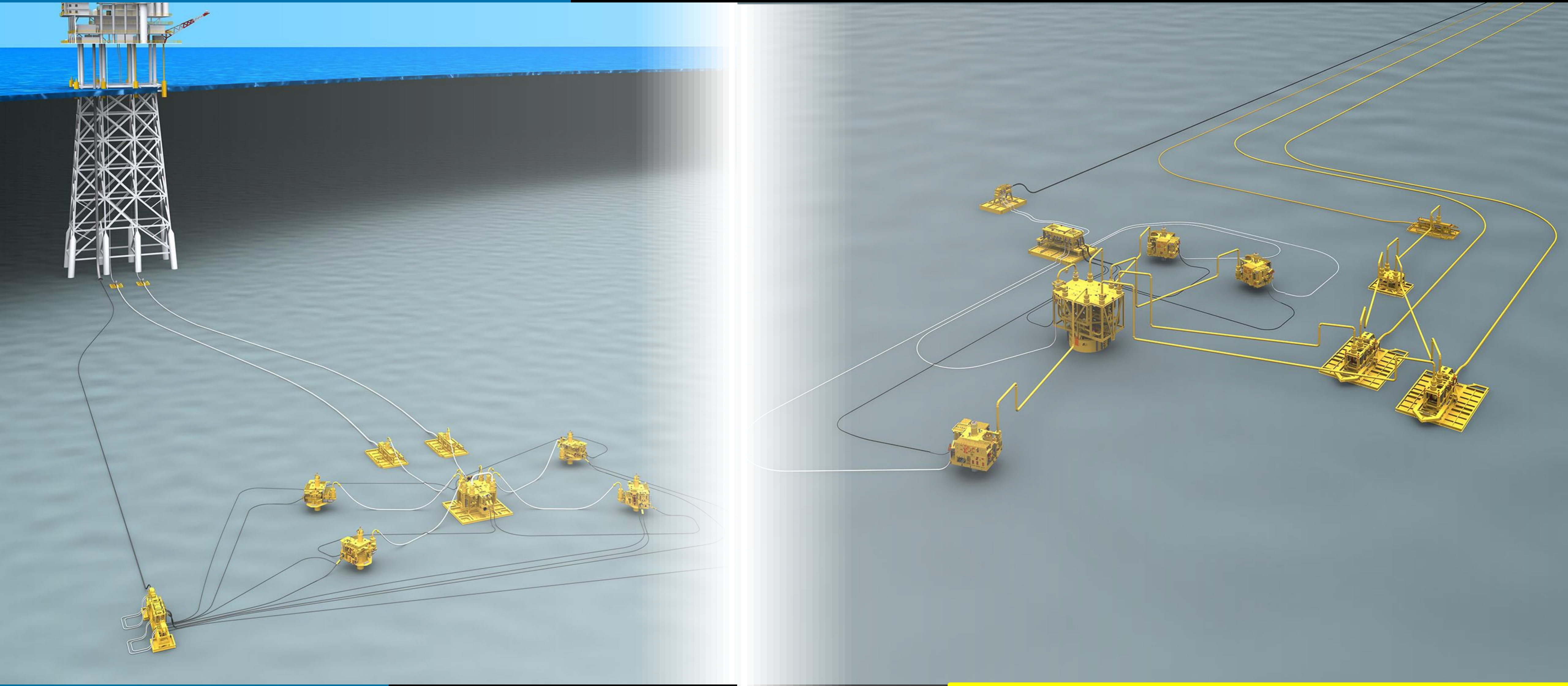

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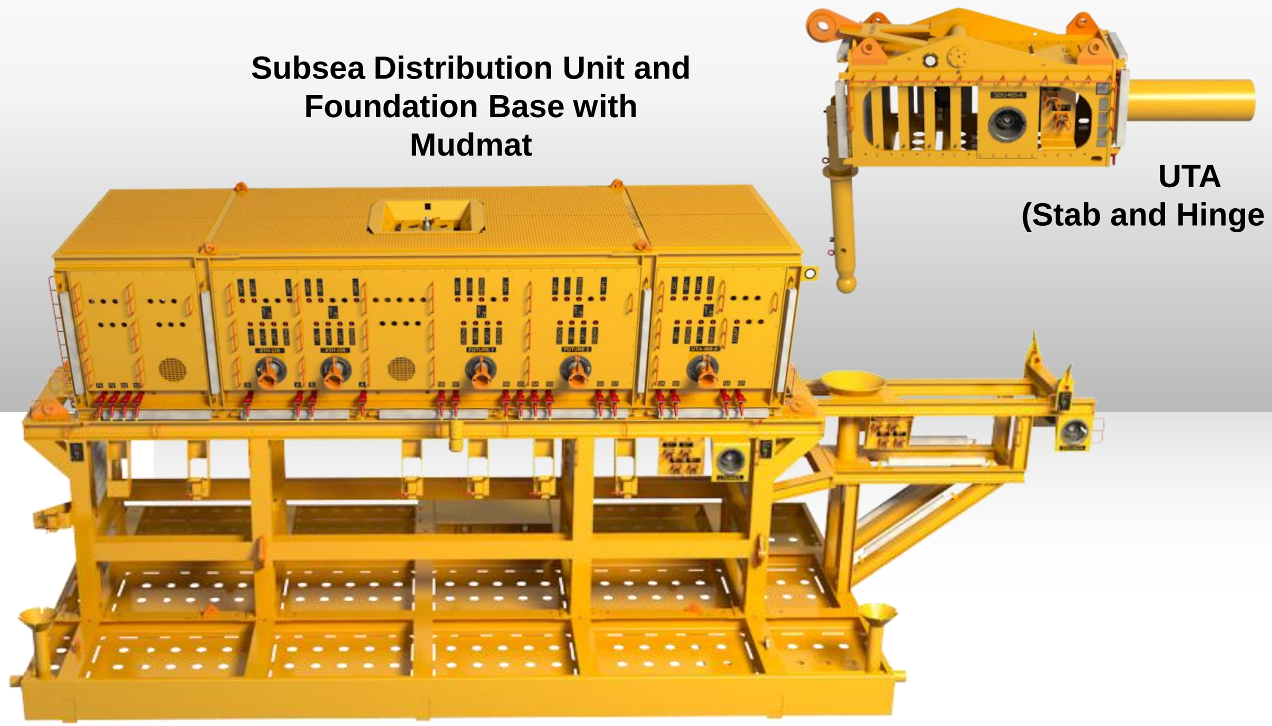
Umbilical Termination Assemblies:

- Connect umbilical fluids and power/comm to other Distribution structures and/or to Manifolds & Trees

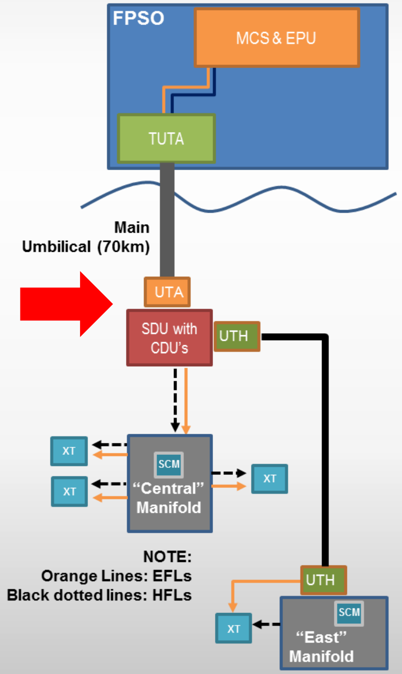
Subsea Distribution Unit

- Central point of distribution between the UTA and subsea units such as Trees and Manifolds



Subsea Distribution Unit and Foundation Base with Mudmat

UTA
(Stab and Hinge Over)



Distribution Equipment

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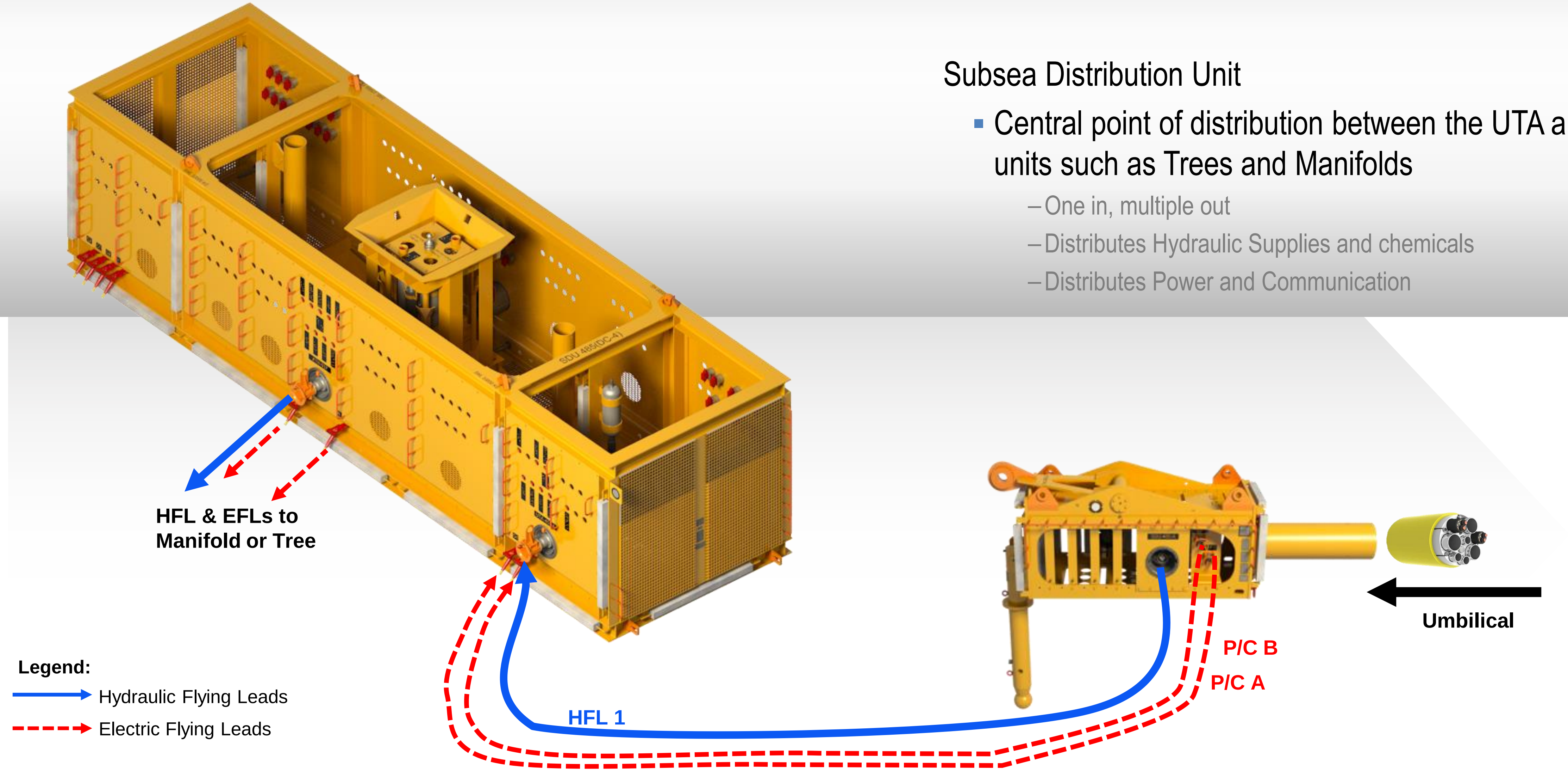
Subsea Distribution Unit

- Central point of distribution between the UTA and subsea units such as Trees and Manifolds
  - One in, multiple out
  - Distributes Hydraulic Supplies and chemicals
  - Distributes Power and Communication



UTA and Bridge Jumper installation animation movie

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UTA and Bridge Jumper installation animation movie

Hydraulic Interconnections & Stabplates

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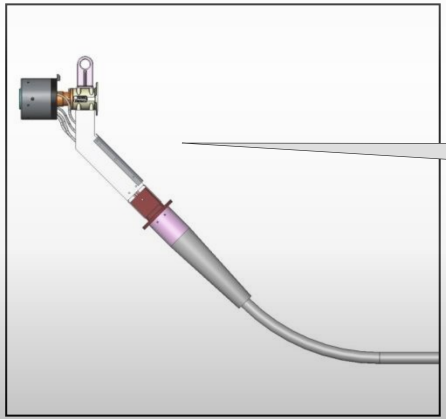

Hydraulic Stabplate

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Hydraulic Flying Lead installation, clump weight method animation movie

Distribution Equipment (Flying Leads installation video)

Hydraulic Flying Lead installation, deployment frame method animation movie

Electrical & Fibre Optical Interconnections

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Stab plate

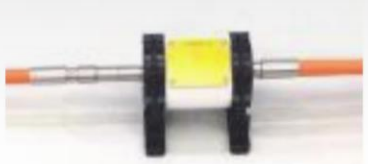
Sensor Harness

Diver Mate

Electrical Flying Leads

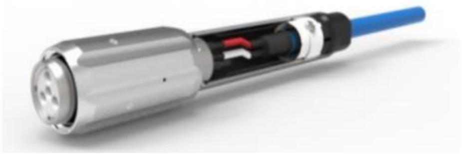
Flying ROV

Junction Box's

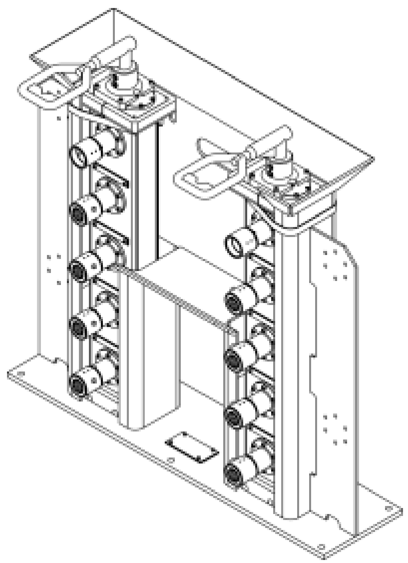


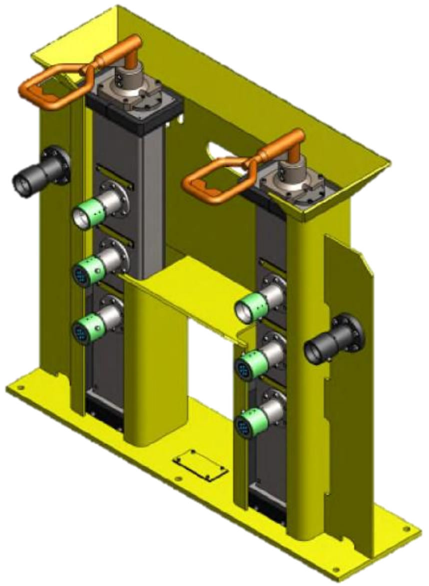
Bulkhead ROV

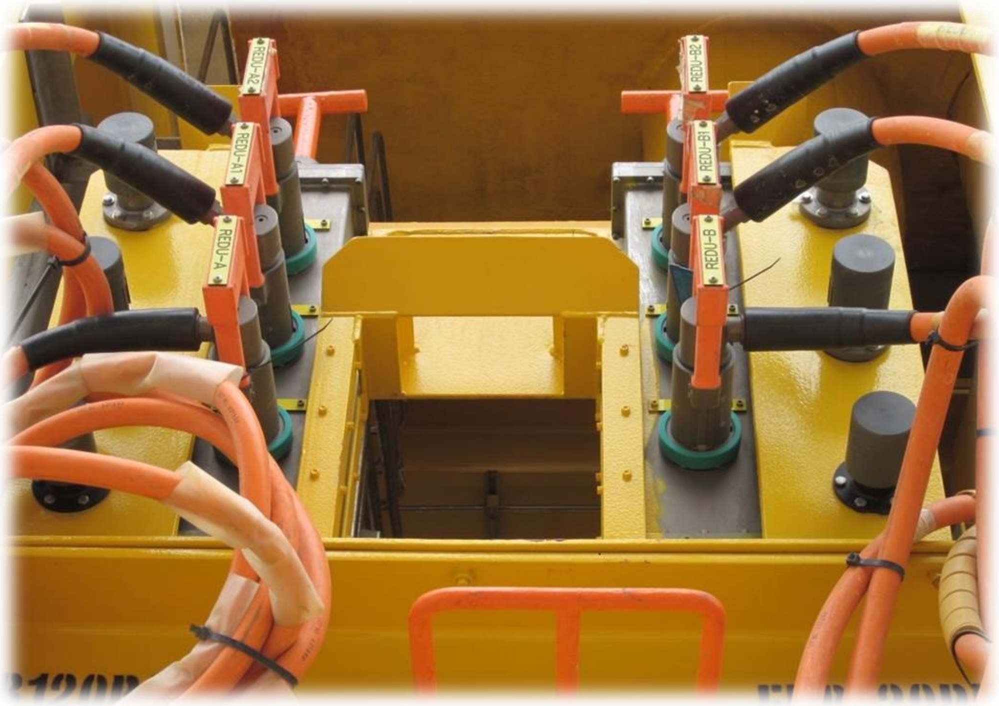
Umbilical terminations & XOver



Electrical Distribution Unit







Communication Distribution Unit (CDU)

FO Switch	DSL	DSL	DSL	DSL	DSL

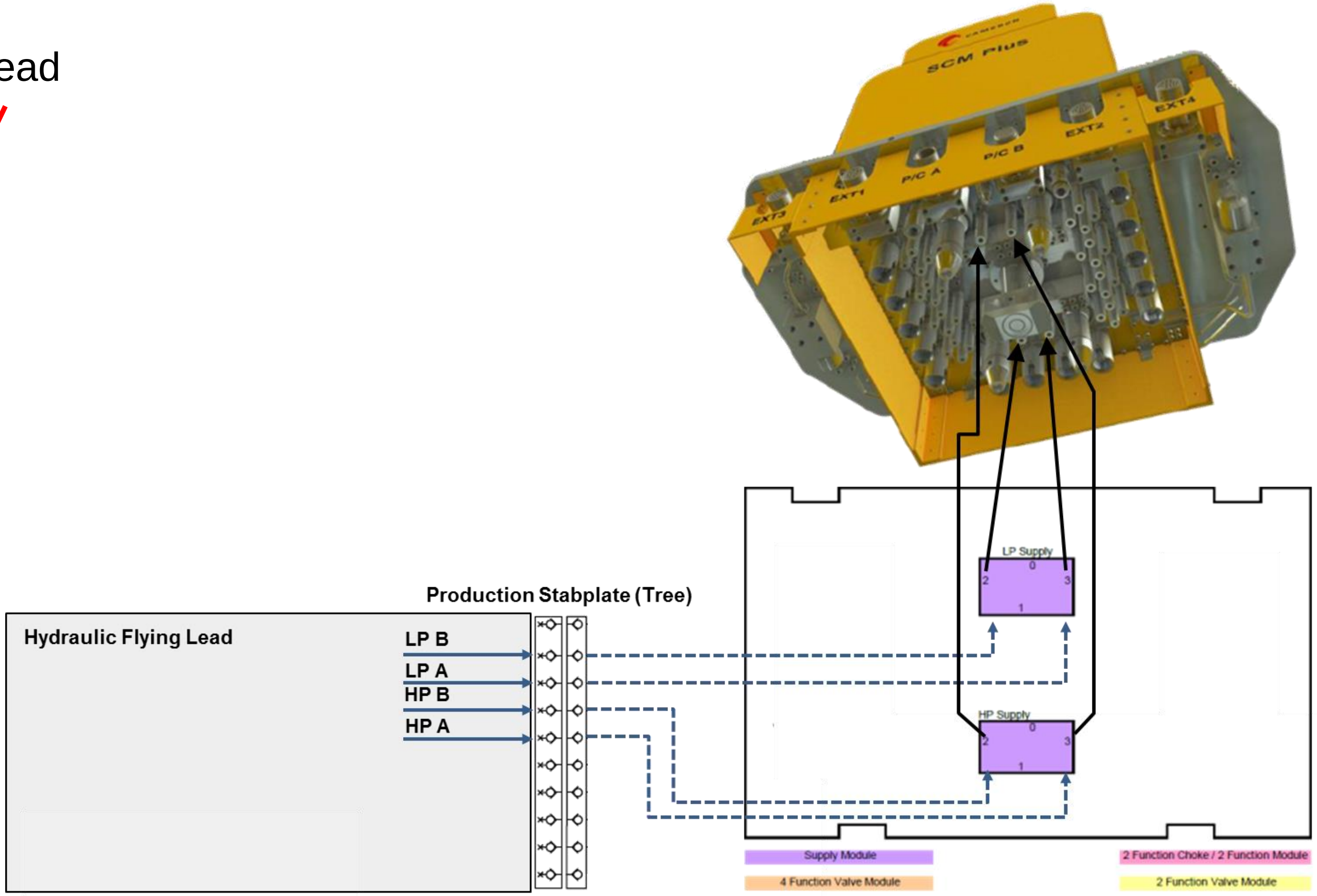

OneSubsea
SCM
Front
EXT1
P/C A
P/C B
EXT2


SCM
FRONT
2000 KG

SCM Overview

Electrical Flying Lead Connection

Hydraulic Flying Lead Connection



Demo of XT PMV Open operation

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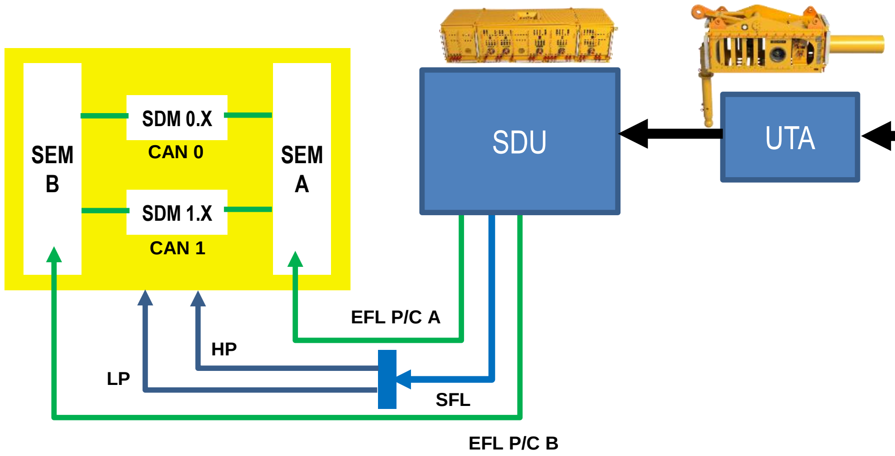
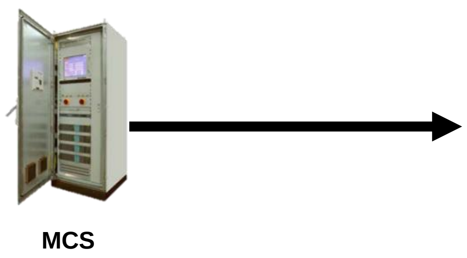
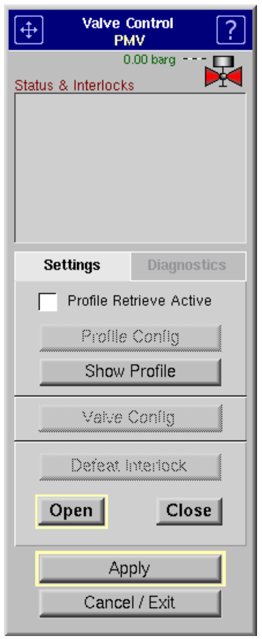




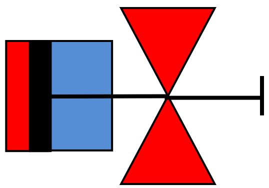


From here, your Open Command is processed by the SEM, and the SCM internal components respond to open PMV

Subsea Controls Distribution Provides:

- **Your Open Command and Power to the SCM**
- **Hydraulics to the SCM**

PMV



Demo of XT PMV Open operation

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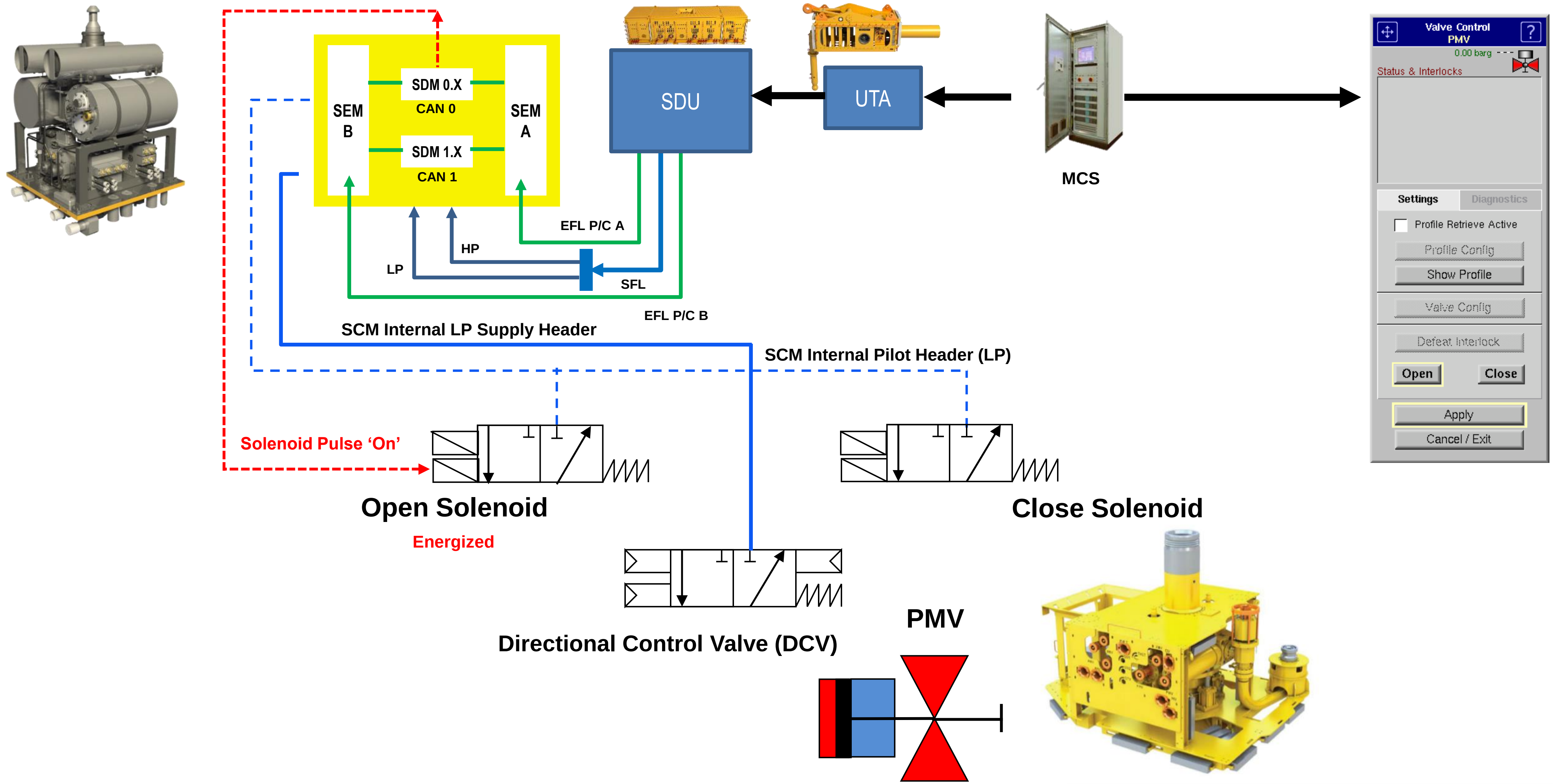
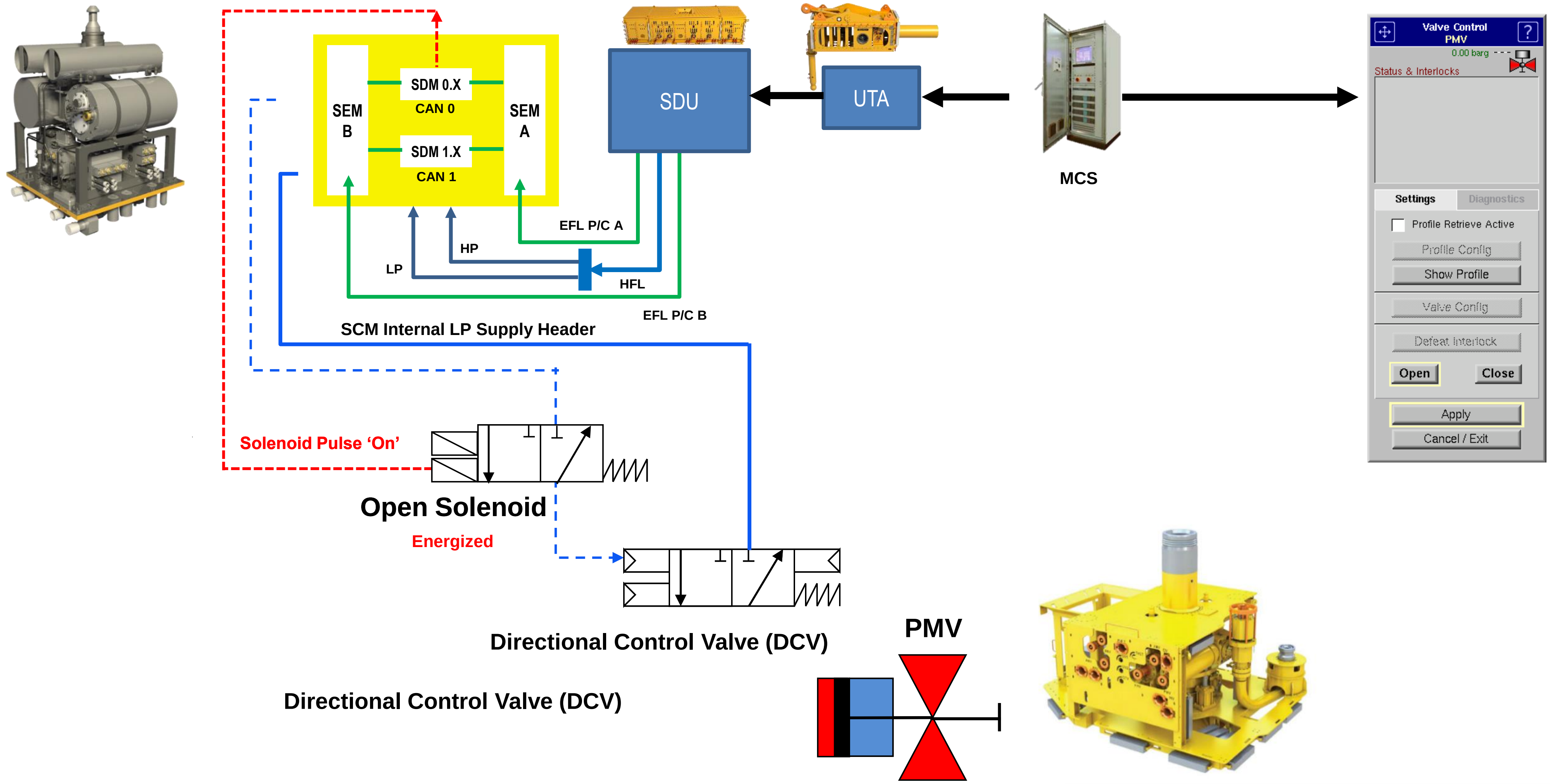


Demo of XT PMV Open operation



Directional Control Valve (DCV)

Demo of XT PMV Open operation

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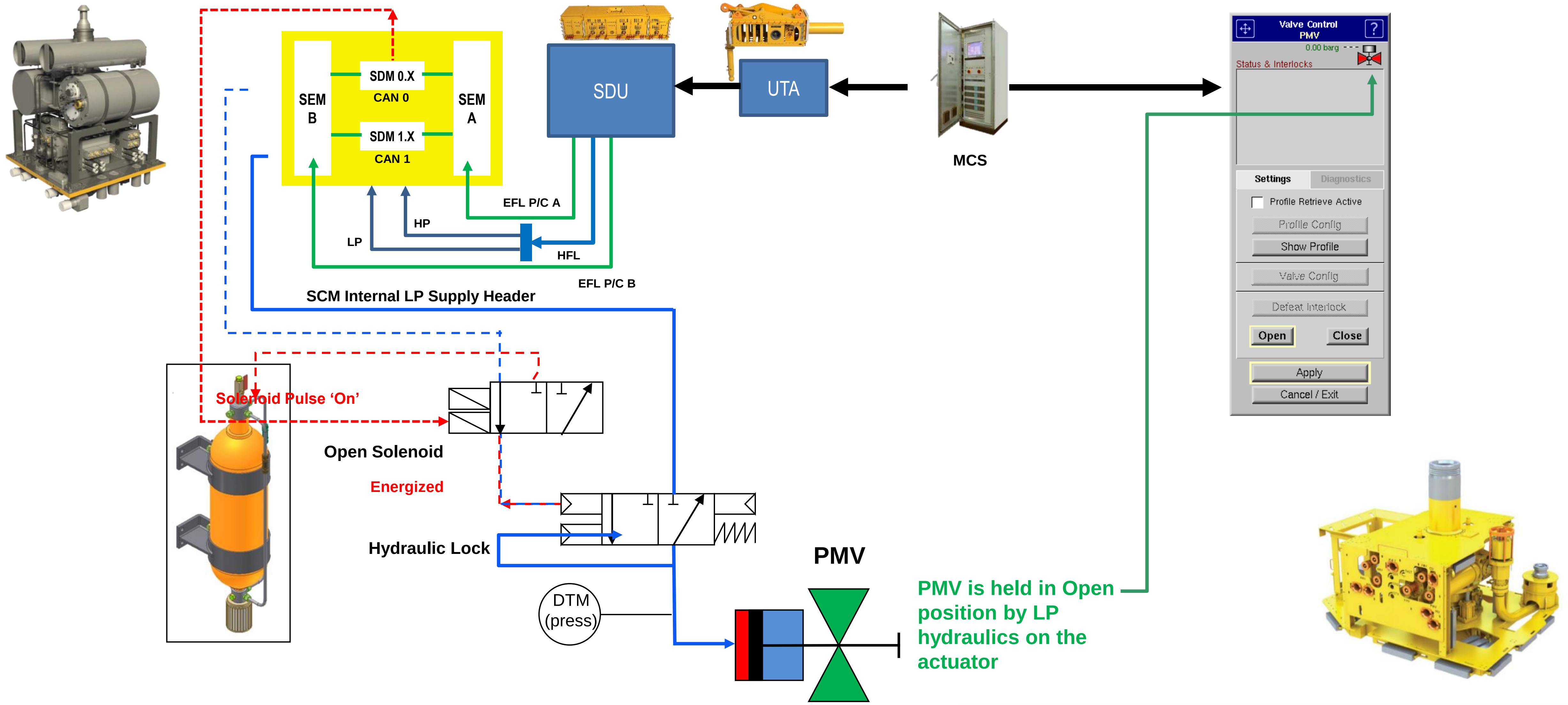
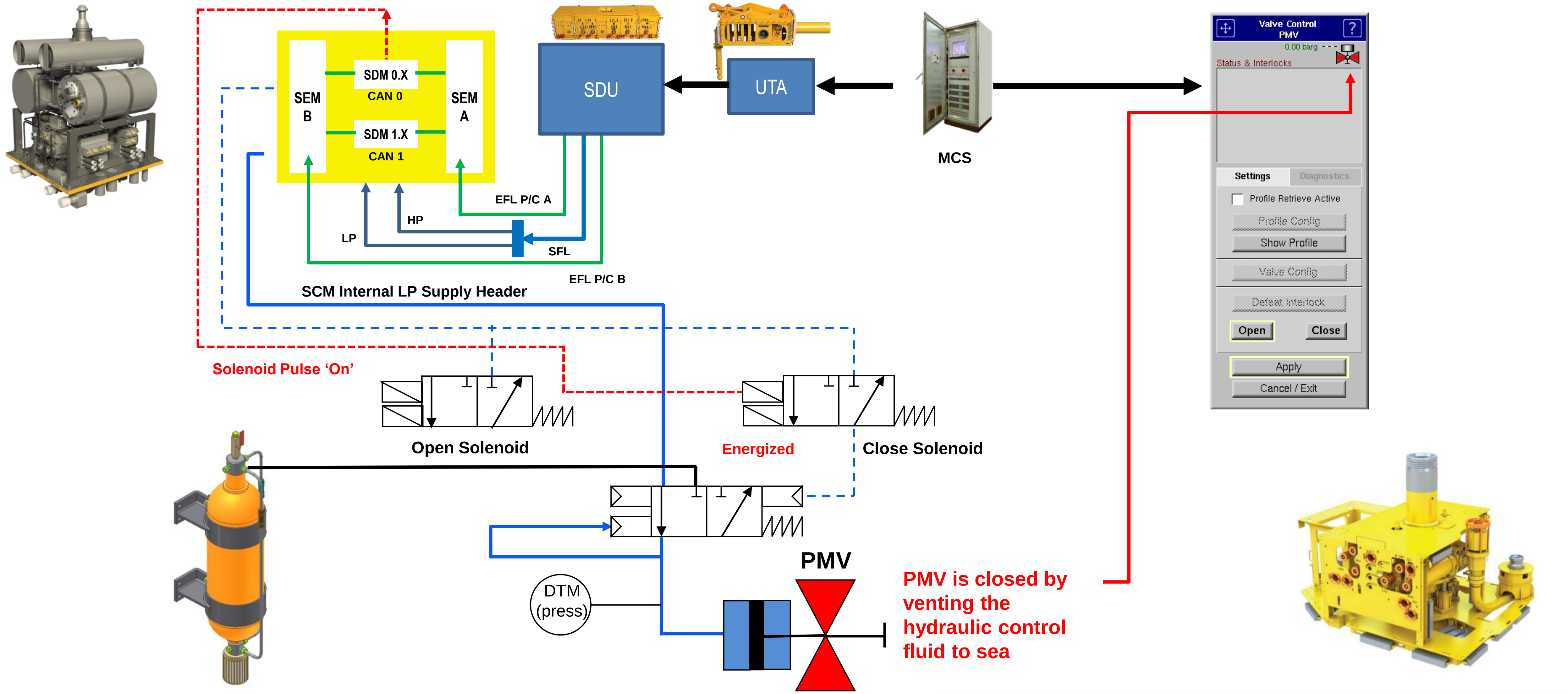


Demo of XT PMV Open operation



SCM Overview (instruments)

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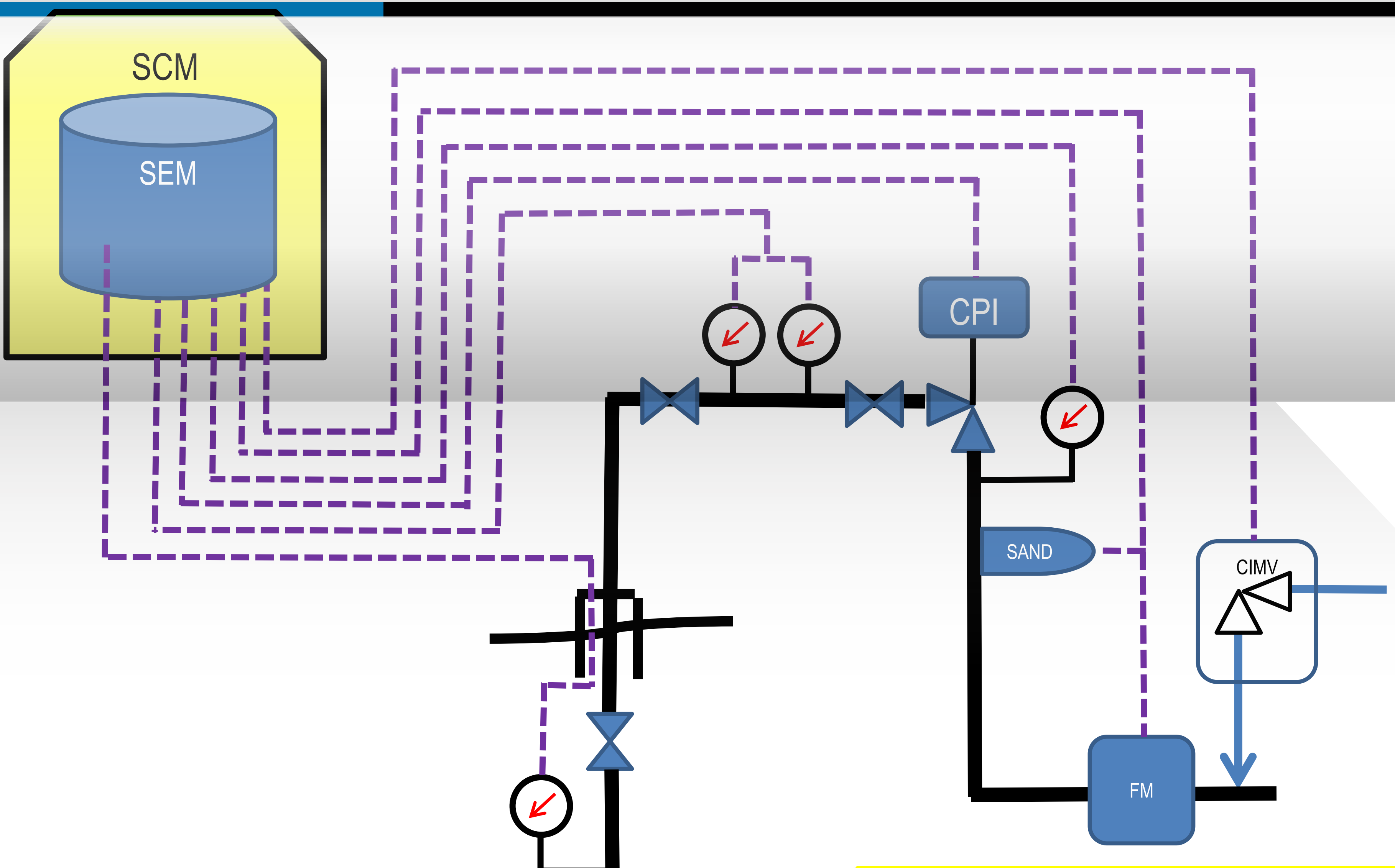


SCM Overview (video)

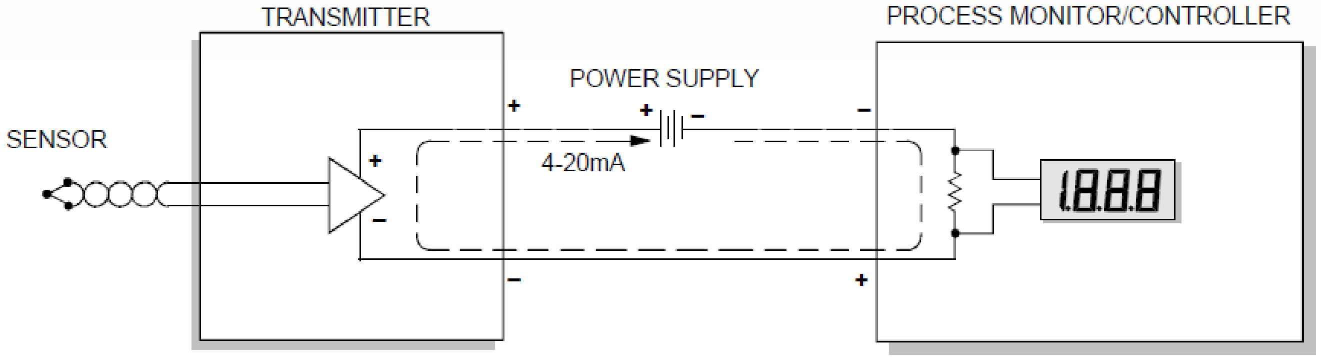
SCM Overview video

SIIS

- originated with BP and Shell in 2003.
- standardisation of interfaces for greater reliability for subsea field developments and reduce risks to functionality and schedule.
- limited to subsea production system instruments interfacing directly to the SCM.
- three-level classification system for control system-to-sensor interfaces.

SIIS Level 1 *Analogue Devices* (typically for Choke Position Indicator)

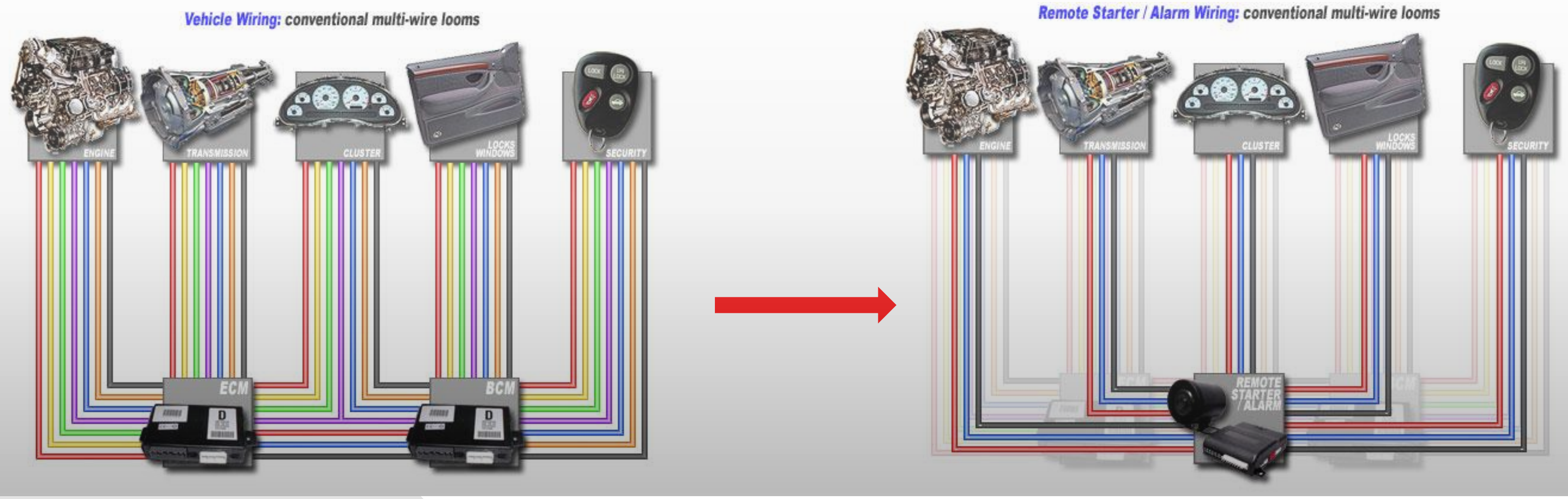
- 4-20 mA signal



SIIS - Controller Area Network (CAN)

- Developed by the Robert Bosch GmbH from 1983 to 1986
- original area of application was the automotive.
  - Minimization of wiring effort (no screen required)
  - High error safety (fail-safe), robustness
  - Small latency time (i.e. time between desired start of sending and actual start of sending is as small as possible)
  - Distributed systems
  - Good extensibility
  - Priorization of messages
  - Lower-cost
- First cars from Mercedes-Benz used CAN network :
  - Reduced the vehicles wiring by 2km
  - overall weight was significantly reduced by at least 50kg
  - only half the connectors
- In 2006, over 70% of all automobiles sold in North America utilize CAN Bus technology.
- Beginning of 2008, the Society of Automotive Engineers (SAE) requires 100% of the vehicles sold in the USA to use the CAN Bus communication protocol while the European Union has similar laws.
- Airbus and Boeing opened the door for CAN bus in their superjumbo A380 and B-787.

- Up until the release of CAN-bus, vehicles contained enormous amounts of wiring which was necessary to interconnect all of the various electronic components.



- Before CAN-bus:
  - Numerous connections
  - highly knowledgeable installers, intensive labor
  - countless hours of lost time on troubleshooting
  - expensive claims for damaged OEM equipment

IWIS

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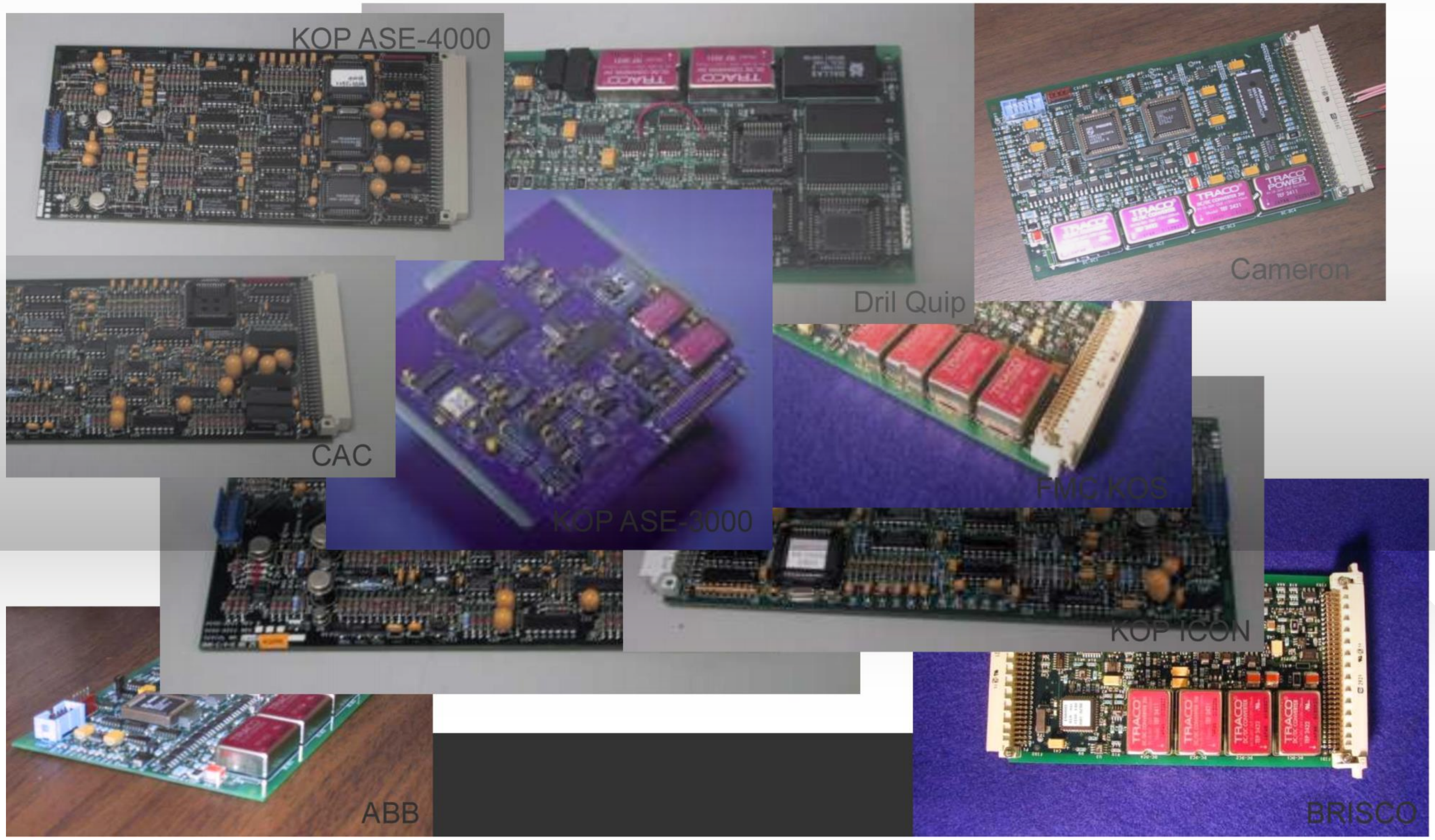
- To assist the integration of downhole power & communication architectures, subsea control systems and topsides
- In 1996, the IWIS JIP was kicked off by BP, AGIP, ELF, STATOIL, SAGA, Norsk Hydro and Shell. 33 members to date.
- The IWIS Recommended Practice was finalised at the September 2007 workshop. IWIS-RP-A2 was released April 2011.
- This is now available to industry in support of ISO 13628 - 6.

Wood Group interface cards 2006



IWIS video

Sensors & Flowmeters

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Pressure / Temperature Sensor

Erosion / Corrosion Sensor

Acoustic Sand detector

Multi Phase Flowmeter

PTT

- Enables accurate process measurements (Accuracy <± 0.1%) to be made directly on trees and manifolds.
- Pressure, temperature and combined pressure/temperature transmitters.
- Specifically designed for long term use in subsea locations.
- Transmitter Type: Single or Dual redundant; Analogue or Digital

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- The sensor measures corrosion with high accuracy and rapid response. Utilizing the ER (Electrical Resistance) measurement principle, this highly durable sensor measures the corrosion rate as an increase in electrical resistance of a corrosion-sensing element, exposed to in-line corrosion.
- The increase in resistance is proportional to the accumulated corrosion within the measurement period.
- Suggested locations:
  - Subsea trees
  - Pipeline Manifolds
  - Risers

Erosion Probe

- Used in order to detect sand production at an early stage
- Measures actual metal loss due to erosion with ER (Electric Resistance) principle elements facing flow
- Multiple elements
- Redundancy
- Cover entire pipe diameter
- Can quantify sand production using the Surface computer and software

ER (Electric Resistance)

Acoustic Sand Detector (ASD)

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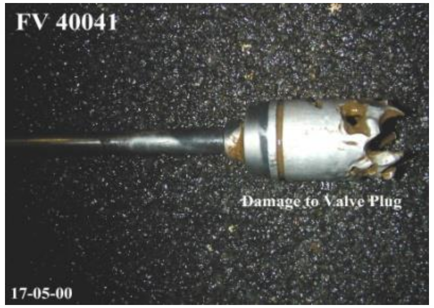
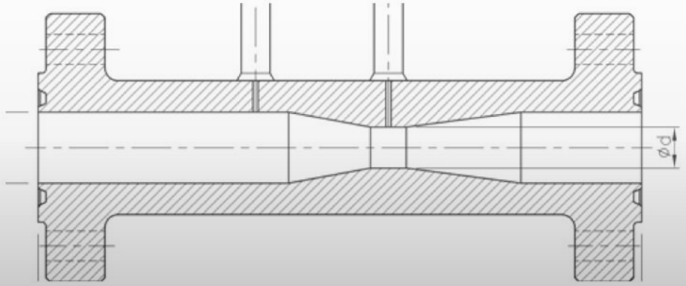
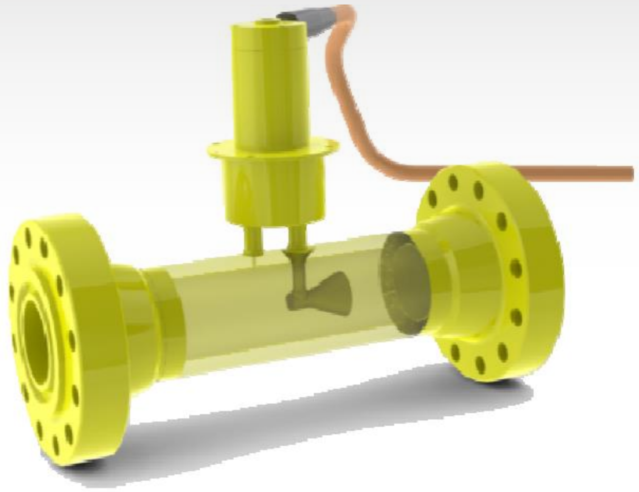
- Keep sand production under control
- Optimize production
- Minimize sand removal cost
- Avoid erosion issues
  Safety, Maintenance cost, Environmental consequences
- Avoid reservoir damage
  or even well collapse?



Single Phase FlowMeter

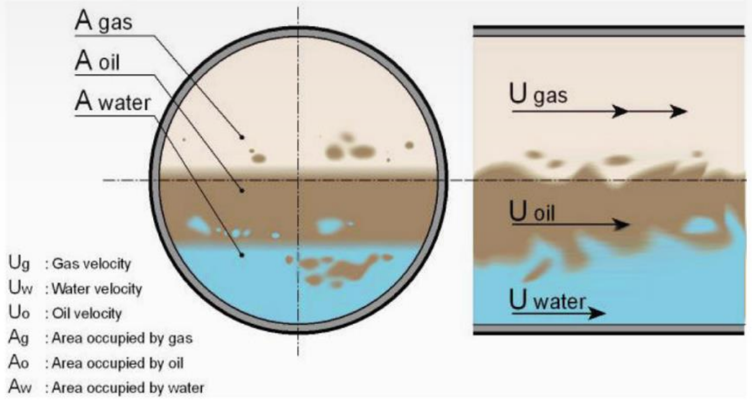
- Measures single phase (due to differential pressure across a venturi; temperature)
- Typically used for water or gas injection systems

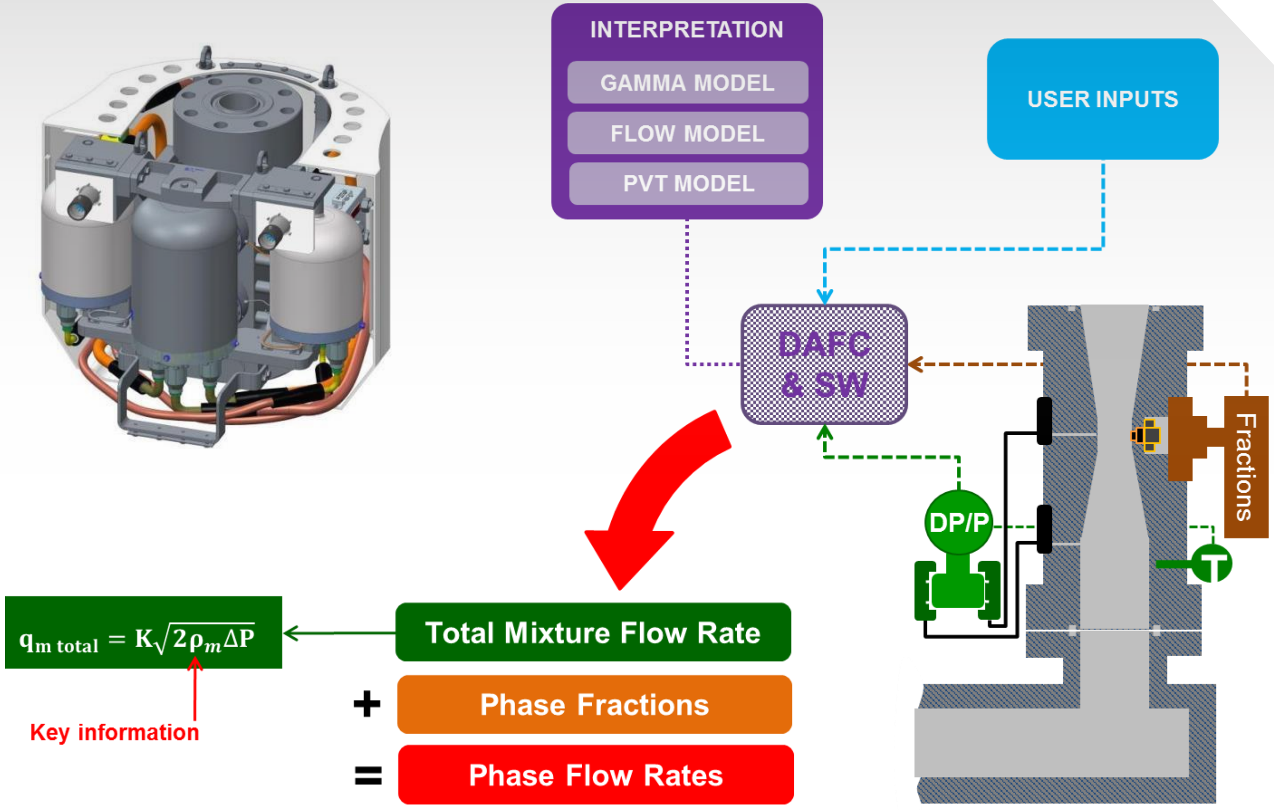




MultiPhase FlowMeter

- Measures real-time flow rates of water, gas and condensate by measuring the dielectric properties of the fluid





Subsea Chemical Injection Valve

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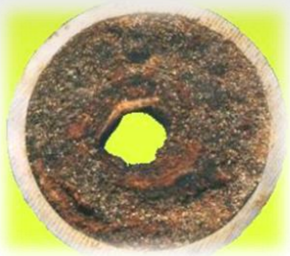
Why Subsea Chemical Injection through a Metering Valve?

- Provides accurate and reliable chemical delivery at the point of injection
- Multi Well Subsea developments supplied by one umbilical
- Provides accurate and adjustable injection of only the required amount of chemical
- Reduces over-dosing and therefore OPEX through:
- Reduced Chemical costs
- Reduced deck storage on platforms / FPSO
- Reduced umbilical costs
- Reduced size of recovery plant or recovery cost at refinery
- Reduces under-dosing and associated problems through:
- Reduced SPS down time



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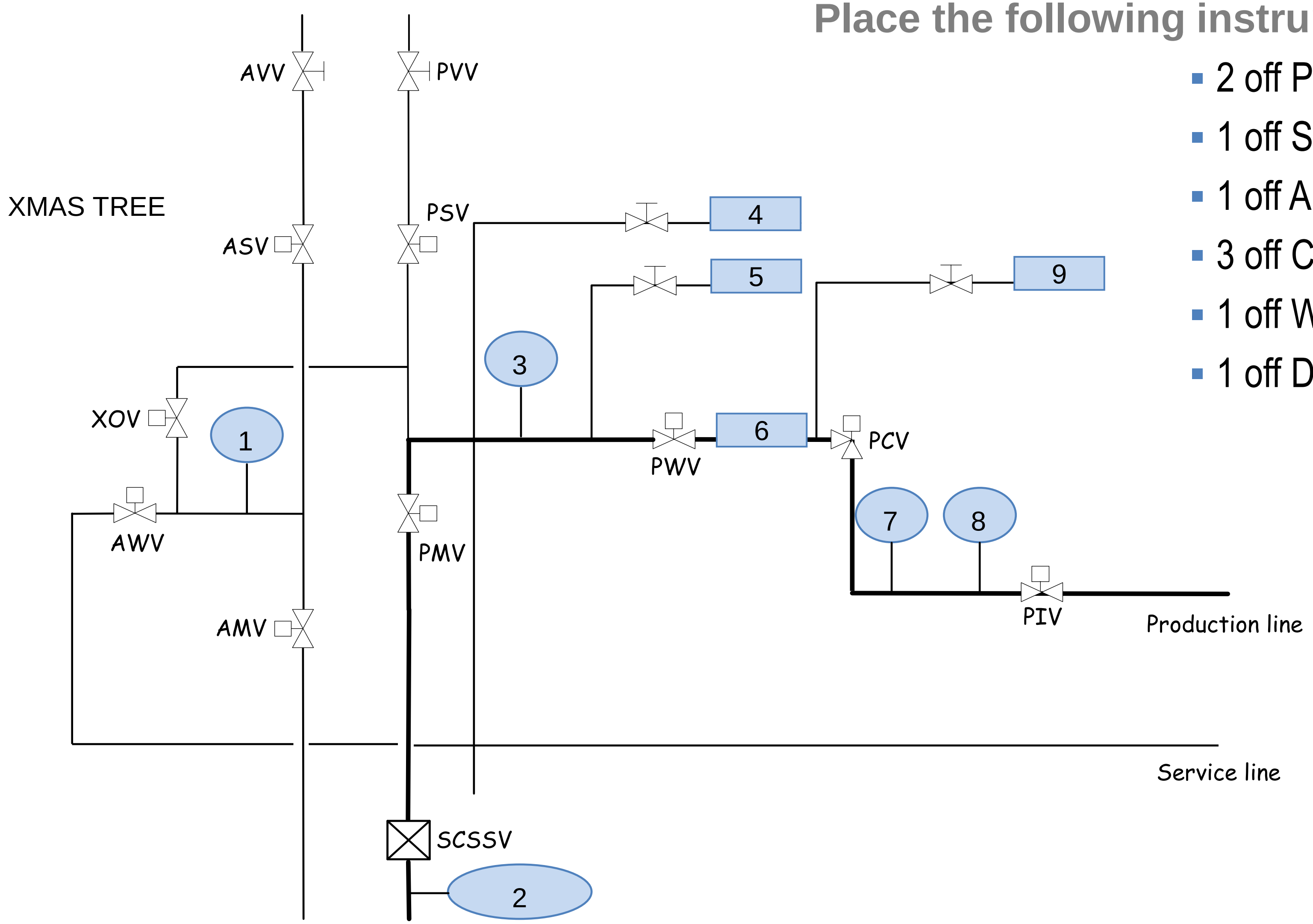

Place the following instruments in the right location

- 2 off PTT
- 1 off SEPT
- 1 off ASD
- 3 off CIMV (MeOH, MEG, SI)
- 1 off WGFM
- 1 off DHPT