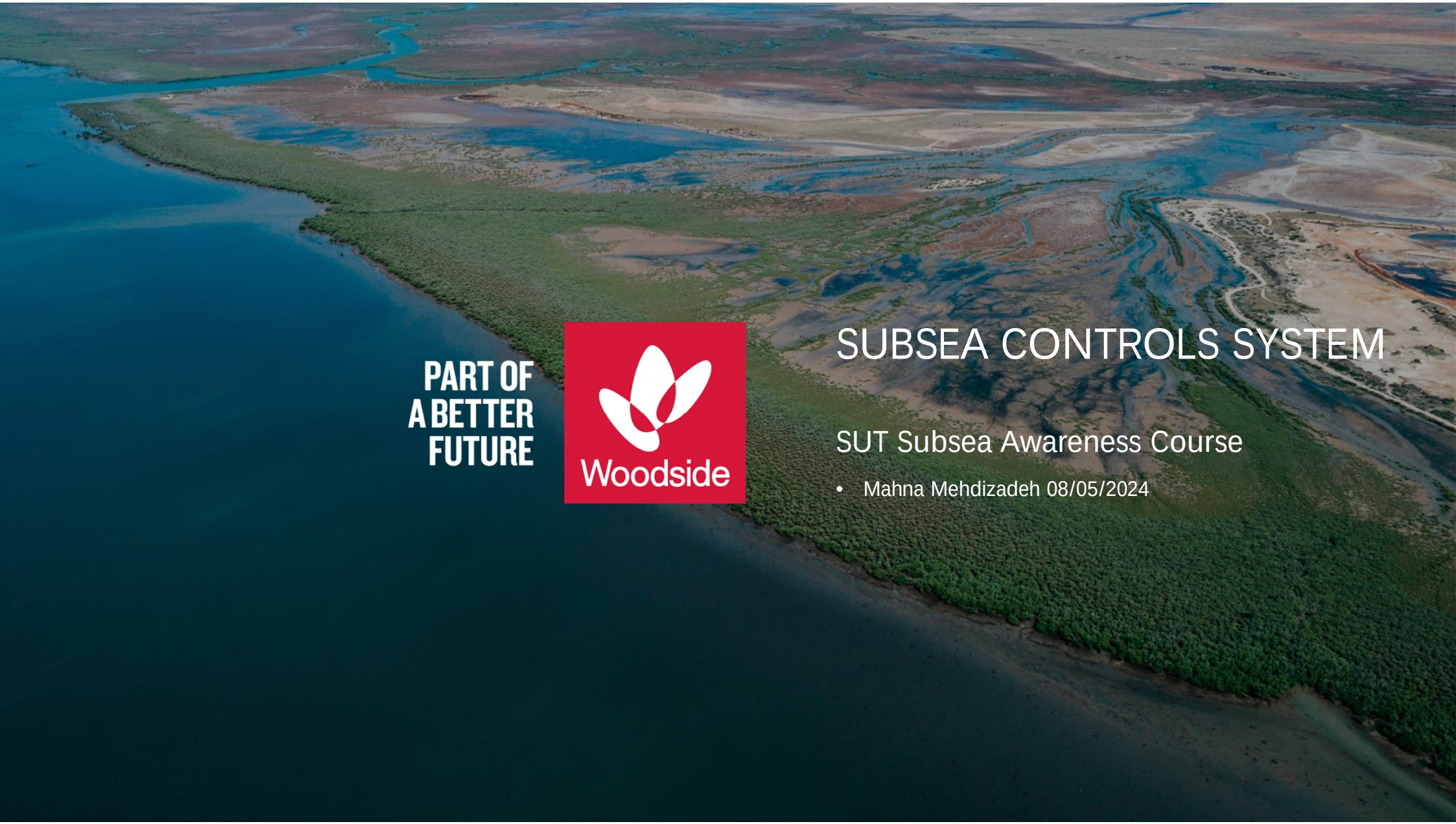

SUBSEA CONTROLS SYSTEM

SUT Subsea Awareness Course

- Mahna Mehdizadeh 08/05/2024

Agenda

- Introduction to Subsea Controls System
- Subsea Controls System Types
- Subsea Controls System Equipment
- Operational Challenge

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Table of Acronyms

Acronyms	Description
ASD	Acoustic Sand Detector
CCR	Central Control Room
CIU	Chemical Injection Unit
E SCM	Electrical Subsea Control Module
EFL	Electrical Flying Lead
EP	Erosion Probe
EPU	Electrical Power Unit
ESD	Emergency Shut Down
FL	Flying Lead
HFL	Hydraulic FL
ICSS	Integrated Control and Safety System
JB	Junction Box
MCC	Motor Control Centre
MCS	Master Control Station
MPFM	Multi Phase Flow Meter
OFL	Optical Flying Lead

Acronyms	Description
PCS	Process Control System
PHPU	Production Hydraulic Power Unit
PT	Pressure Transmitter
SCM	Subsea Control Module
SDA	Subsea Distribution Assembly
SDU	Subsea Distribution Unit
SIIS	Subsea Instrumentation Interface Standardization
SIS	Safety Instrumented System
SPCU	Subsea Power and Communication Unit
SPFM	Single Phase Flow Meter
TT	Temperature Transmitter
TUTU	Topside Umbilical Termination Unit
UPS	Uninterruptable Power Supply
UTA	Umbilical Termination Assembly
UTH	Umbilical Termination Hub
VSD	Variable Speed Drive
XT	Christmas Tree

• INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Subsea Controls Interface with other disciplines

Agenda

- Introduction to Subsea Controls System
- Subsea Controls System Types
- Subsea Controls Systems Equipment
- Operational Challenge

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- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Overview of Subsea Production System (SPS)

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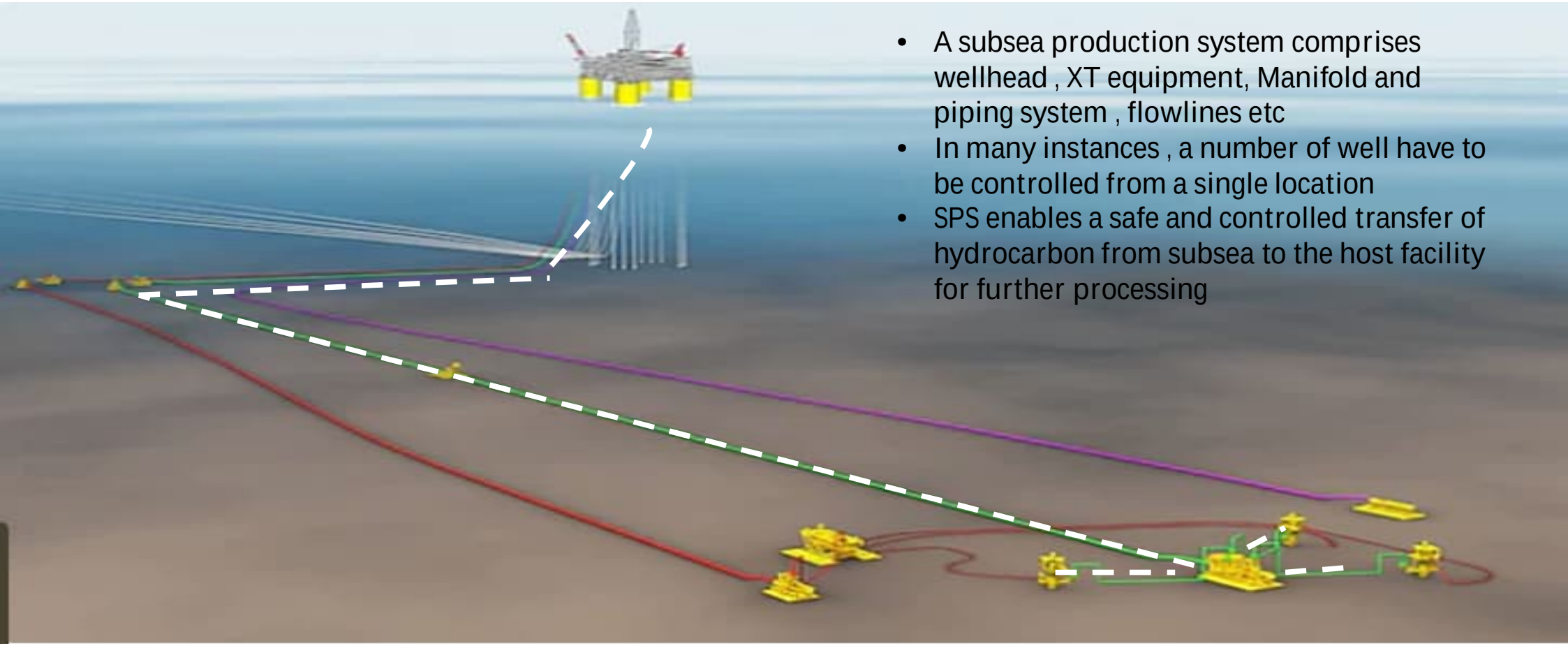
- INTRODUCTION TO SUBSEA CONTROL SYSTEM

Overview of Subsea Production System (SPS)



- A subsea production system comprises wellhead , XT equipment, Manifold and piping system , flowlines etc
- In many instances , a number of well have to be controlled from a single location
- SPS enables a safe and controlled transfer of hydrocarbon from subsea to the host facility for further processing

- INTRODUCTION TO SUBSEA CONTROL SYSTEM

Overview Of Woodside Senegal Project SPS

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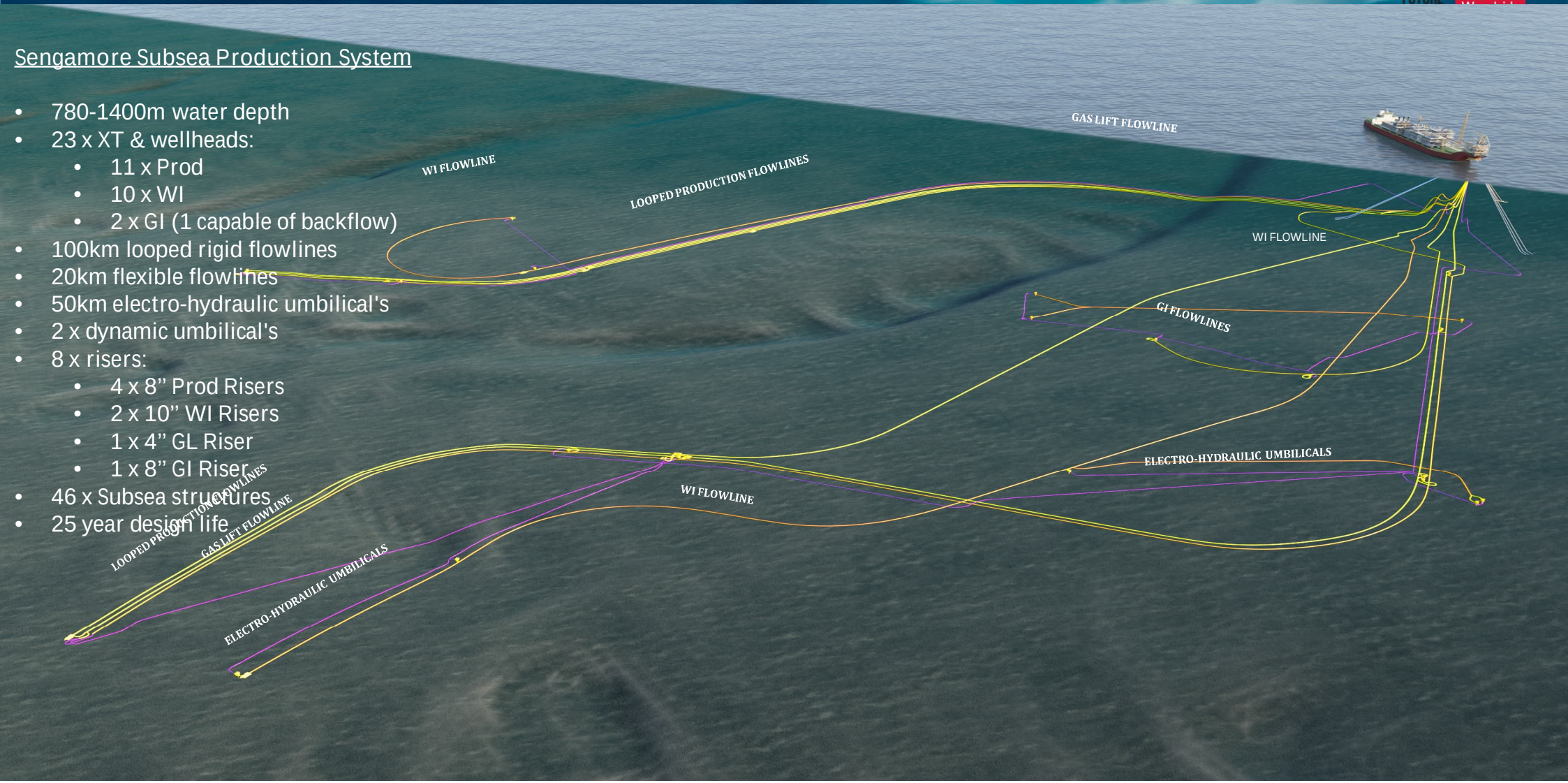


<u>Sengamore Subsea Production System</u>

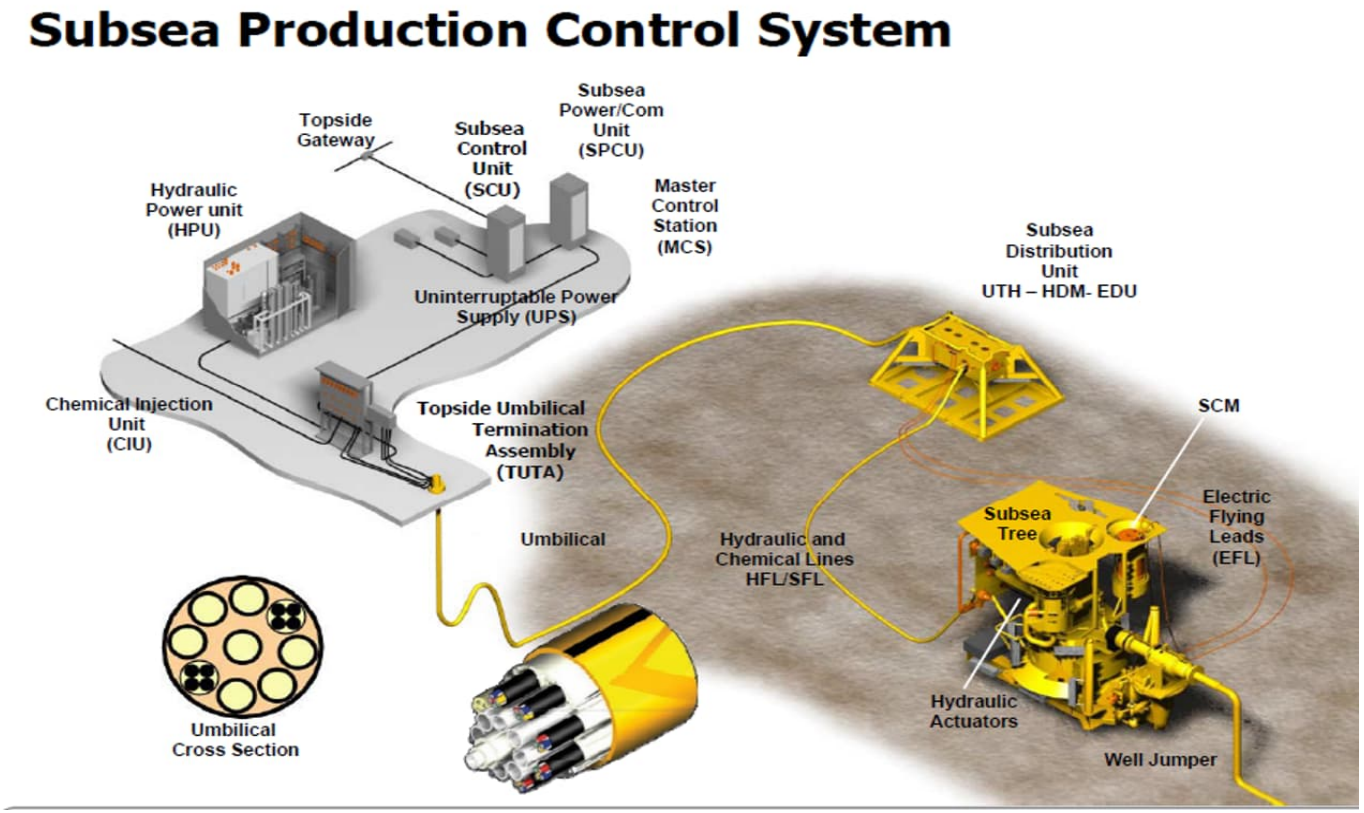
- 780-1400m water depth
- 23 x XT & wellheads:
  - 11 x Prod
  - 10 x WI
  - 2 x GI (1 capable of backflow)
- 100km looped rigid flowlines
- 20km flexible flowlines
- 50km electro-hydraulic umbilical's
- 2 x dynamic umbilical's
- 8 x risers:
  - 4 x 8" Prod Risers
  - 2 x 10" WI Risers
  - 1 x 4" GL Riser
  - 1 x 8" GI Riser
- 46 x Subsea structures
- 25 year design life

- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

What is the Purpose of Subsea Production Control System ?

- A subsea control system is part of subsea production system , and proper performance of the control system is the critical factor in ensuring its reliable and safe operation

- The fundamental purpose of a control system is to open and close subsea valves. However, other properties, such as instrumentation, provide chock control and important diagnostics.



- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Analogy – human body has a control system …

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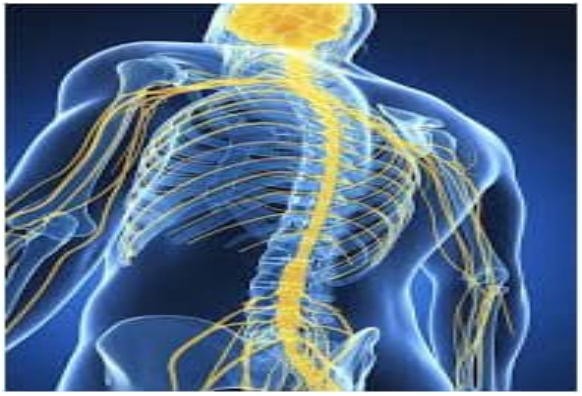
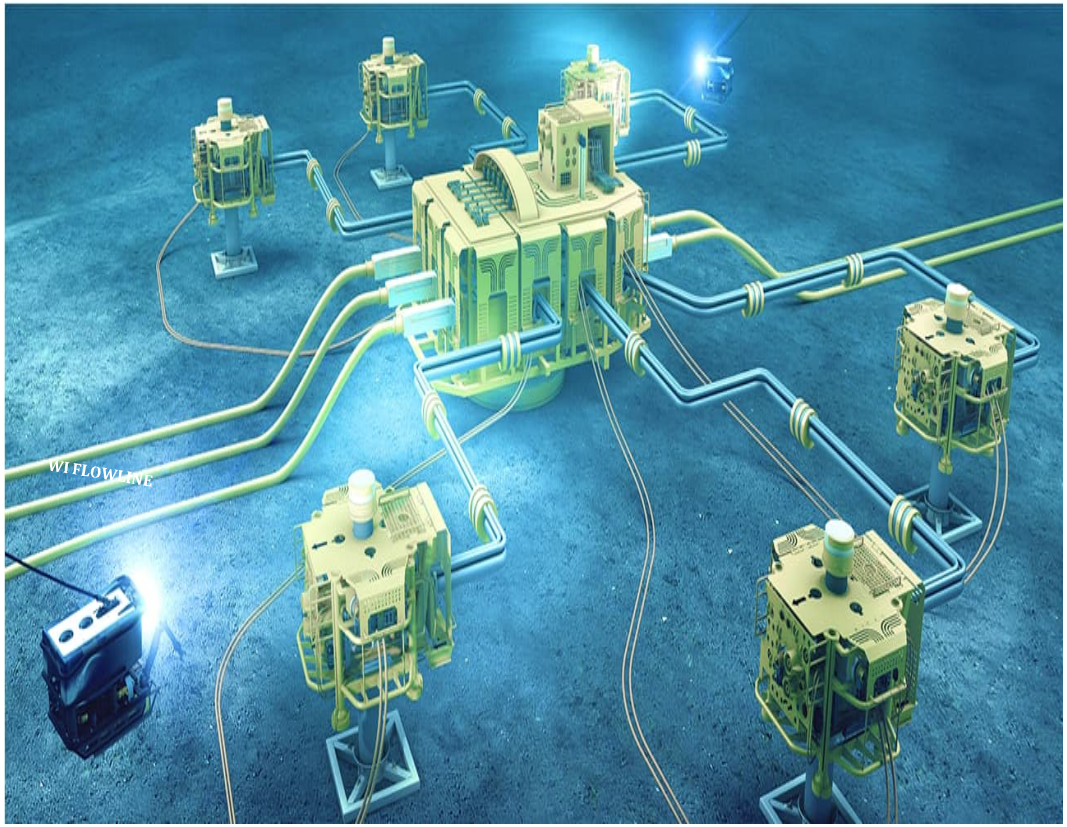
Human heart and circulatory system

Human brain and nerves system



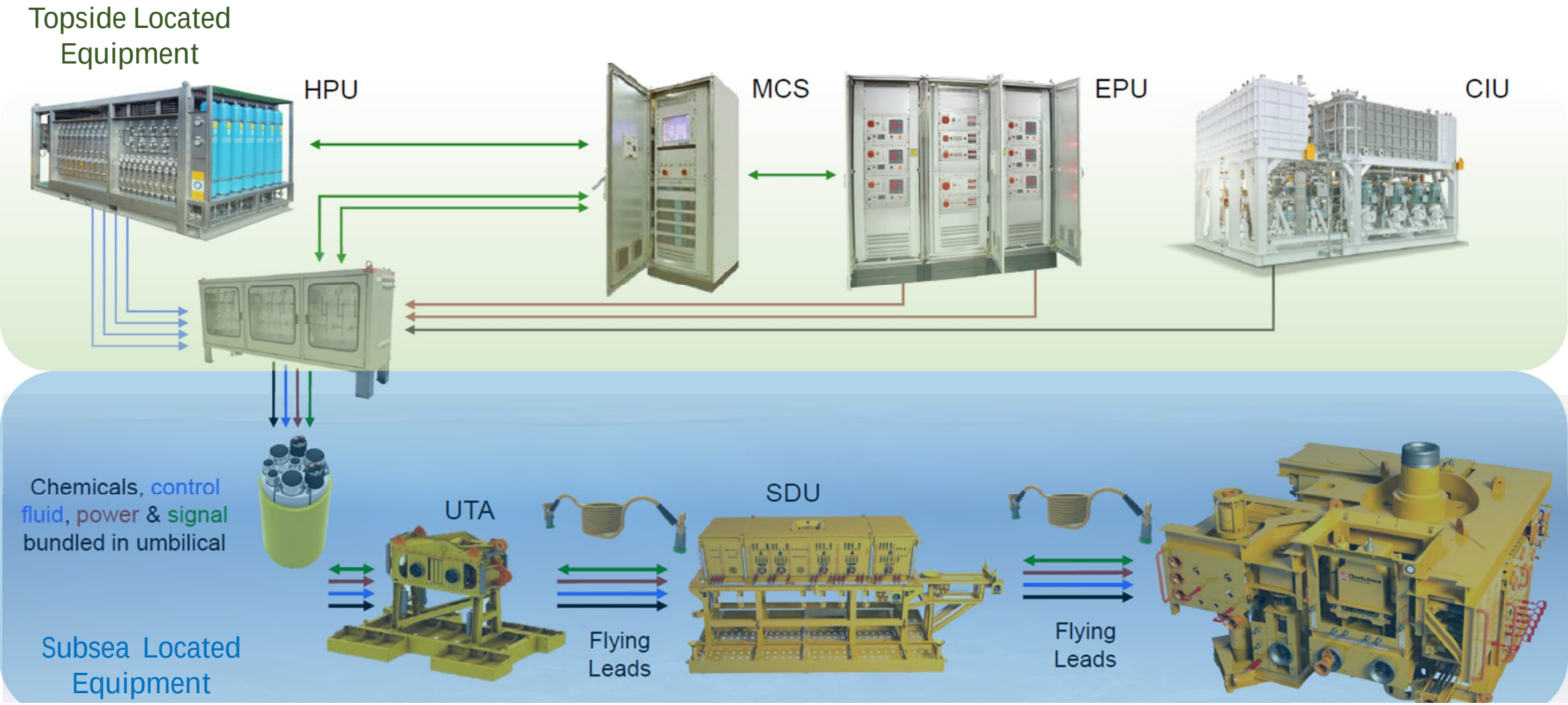
Hydraulic Pumps, Umbilical and Distribution Equipment

Subsea Controls system, Controller, Power and Communication lines, Instruments



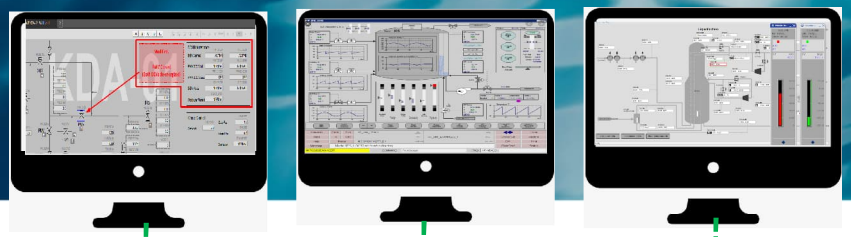
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Typical Subsea Controls Equipment

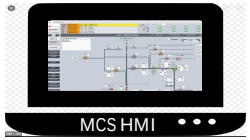


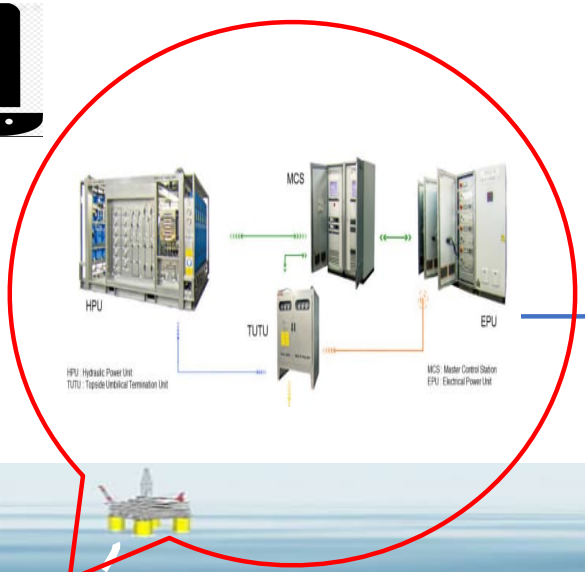
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

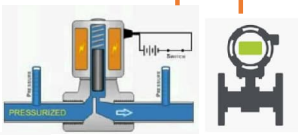
How Subsea Controls System fits in the host facility's integrated control and safety system?



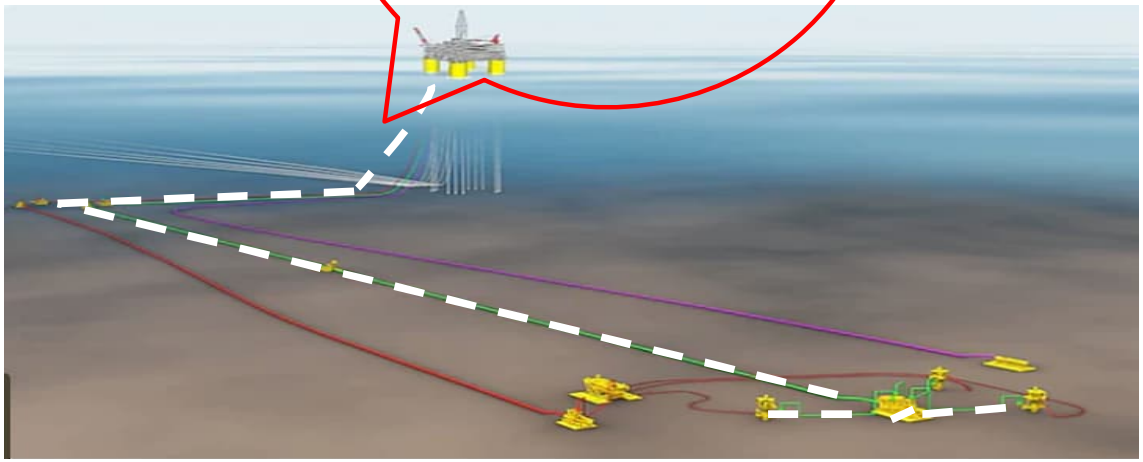
MCS (Master Control Station)







DCS (Distributed Control System)



• 12

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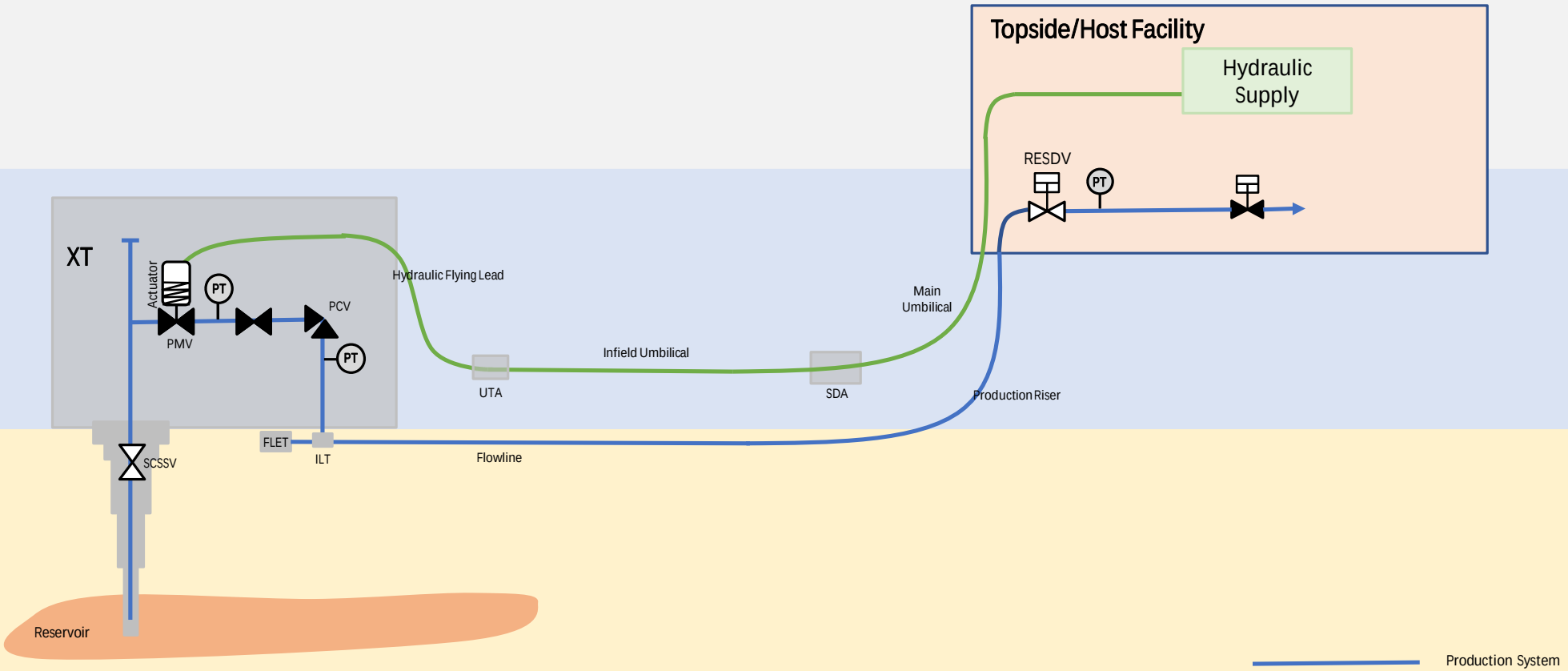
The Control of the component of a subsea production system is managed by the subsea production controls system . Control functions include:

- Function subsea valves
  - Production ,annulus, cross over valves
  - Chemical injection valves
  - Manifold, flowline, riser base and pigging valve
  - Adjusting choke position
- Monitor pressure, temperature, and other data from subsea mounted instrumentation
- Distribute chemicals to subsea production system
- Execute subsea emergency shutdown upon shutdown demand

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Basic Demonstration: Remote Opening of a Subsea Valve



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Basic Demonstration: Remote Closing of a Subsea Valve

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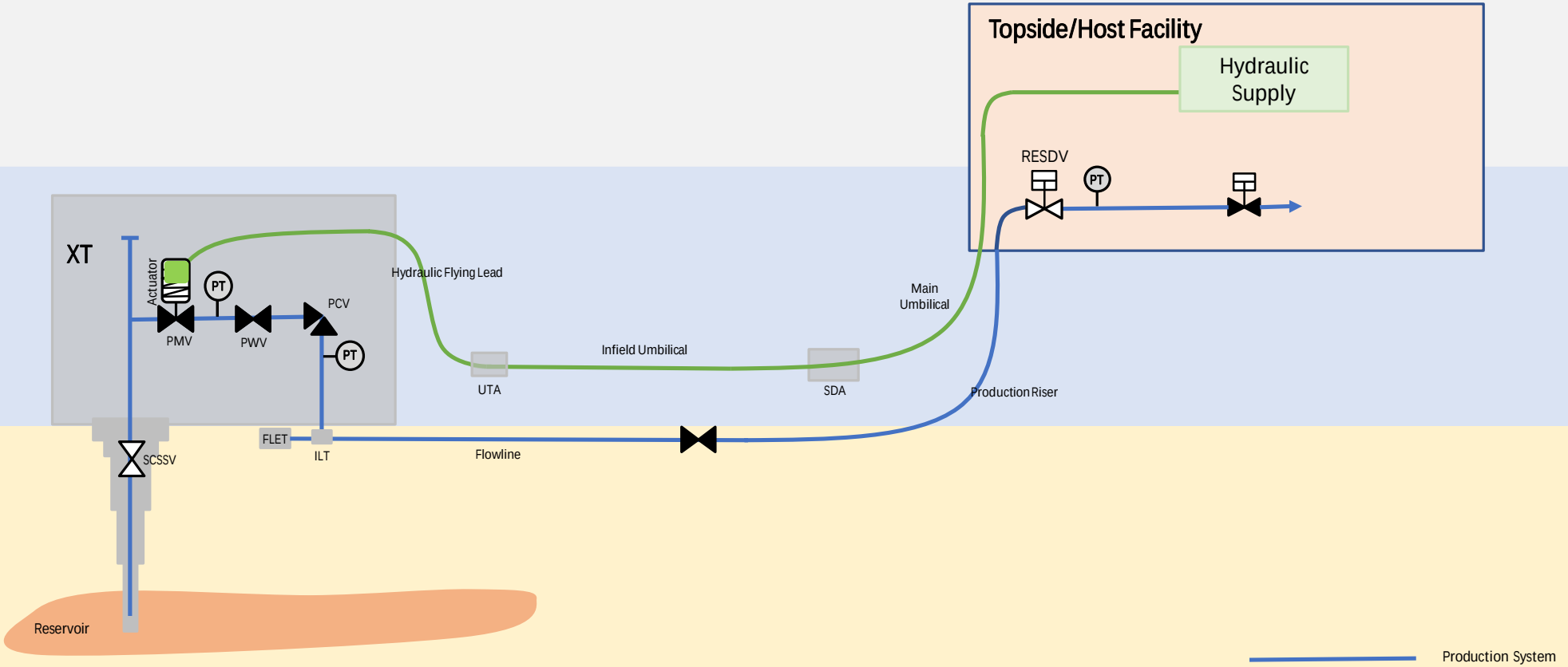
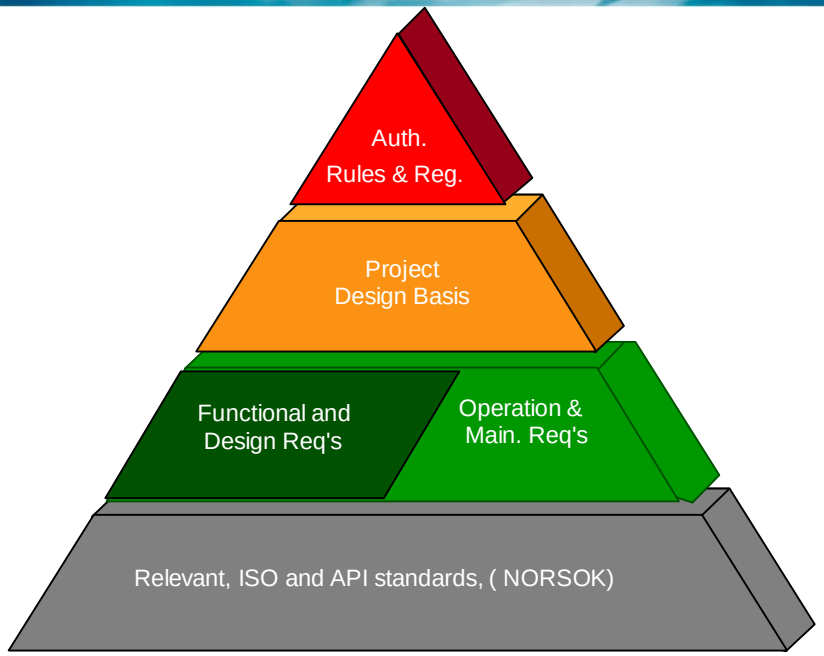


Legislation, Codes and Standard

- To ensure reliable and safe operation of the subsea system , the design, operation and testing of a control system are regulated by industry , national and international standards

- The systems are subjected to stringent quality review processes like failure modes, effects and criticality analysis, RAMs, FAT, eFAT and so on
- Subsea Production Controls System design and verification follows API 17F



Frame agreement specifications

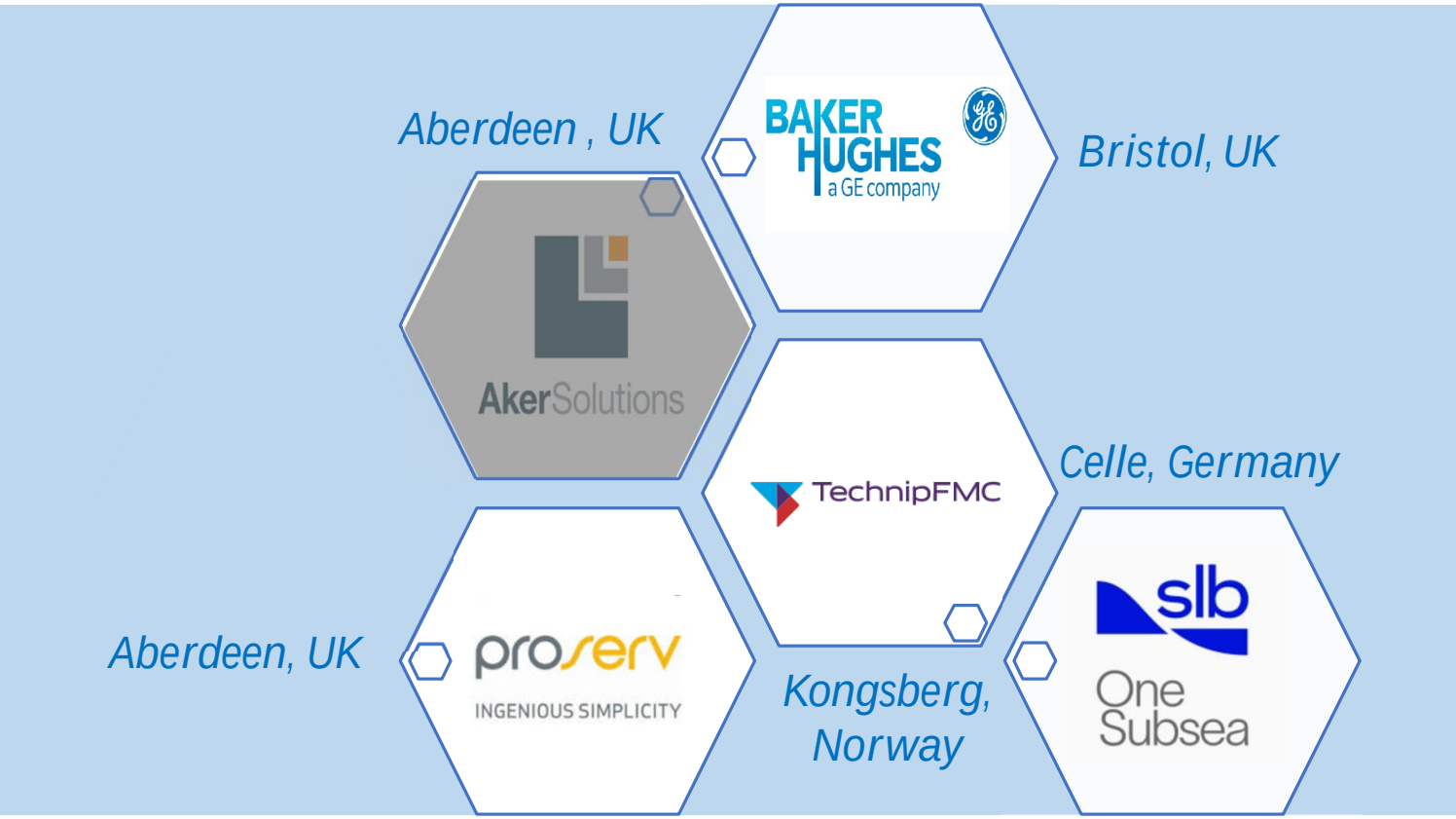
ISO International Organization for Standardization

API American Petroleum Institute

NATIONAL STANDARD

- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Subsea Controls System Vendors



- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Controls and Automation Company

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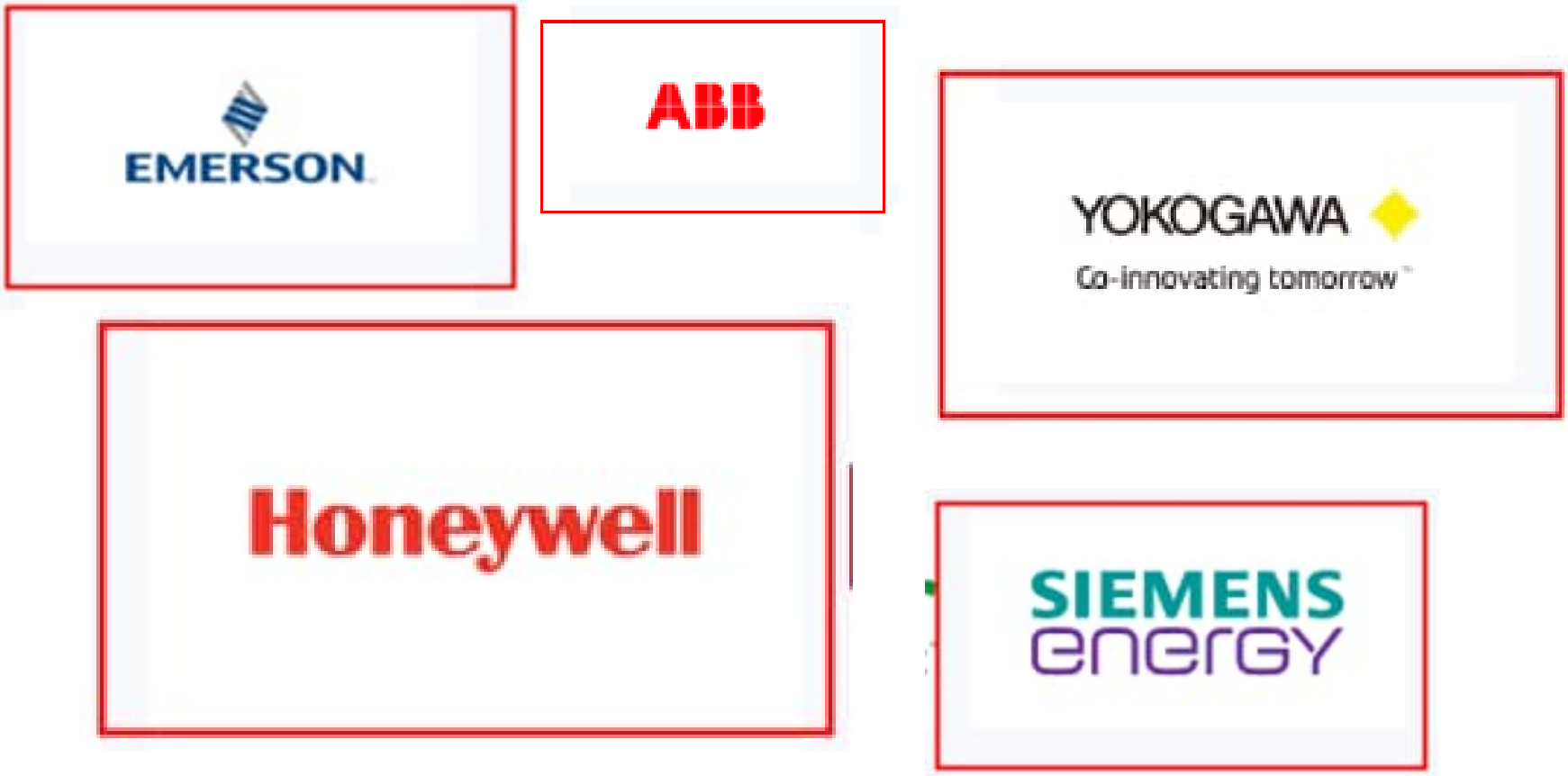
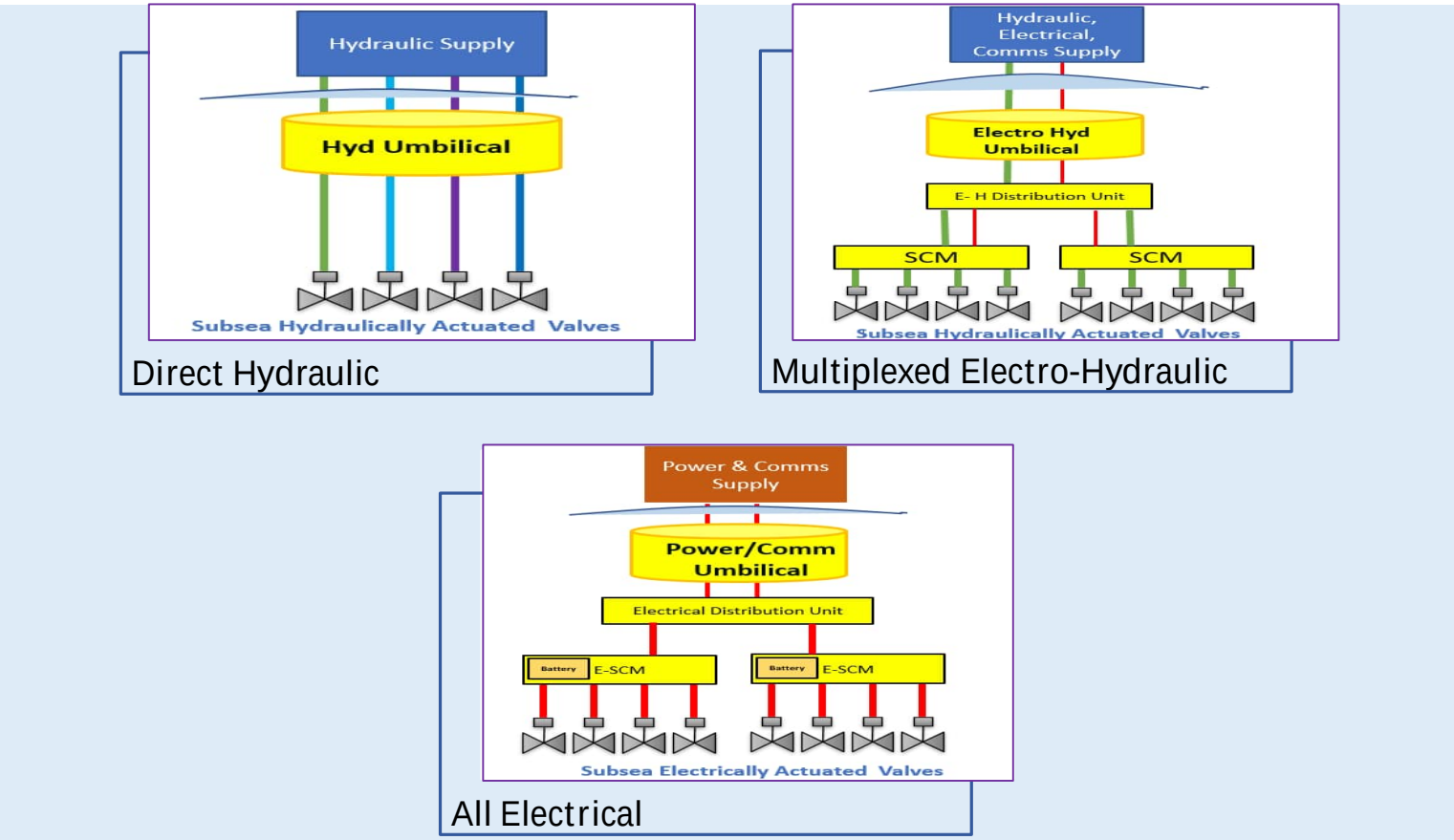


Agenda

- Introduction to Subsea Controls System
- Subsea Controls System Types
- Subsea Controls Systems Equipment
- Operational Challenge

Woodside

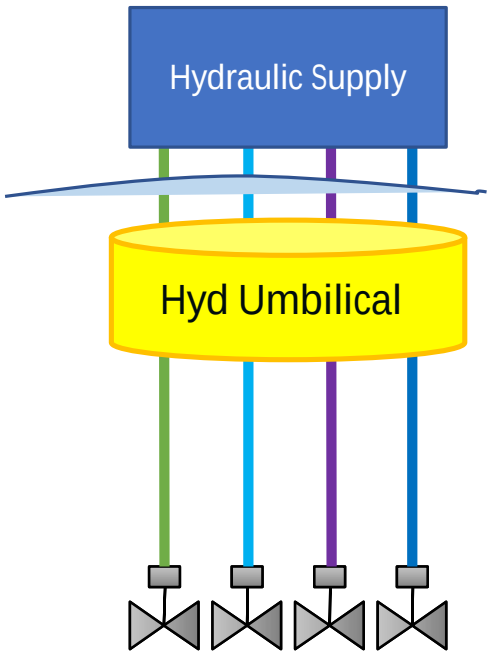
- SUBSEA CONTROL SYSTEM TYPE



- SUBSEA CONTROLS SYSTEM TYPE

Direct Hydraulic Control System

Direct Hydraulic



Subsea Hydraulically Actuated Valves

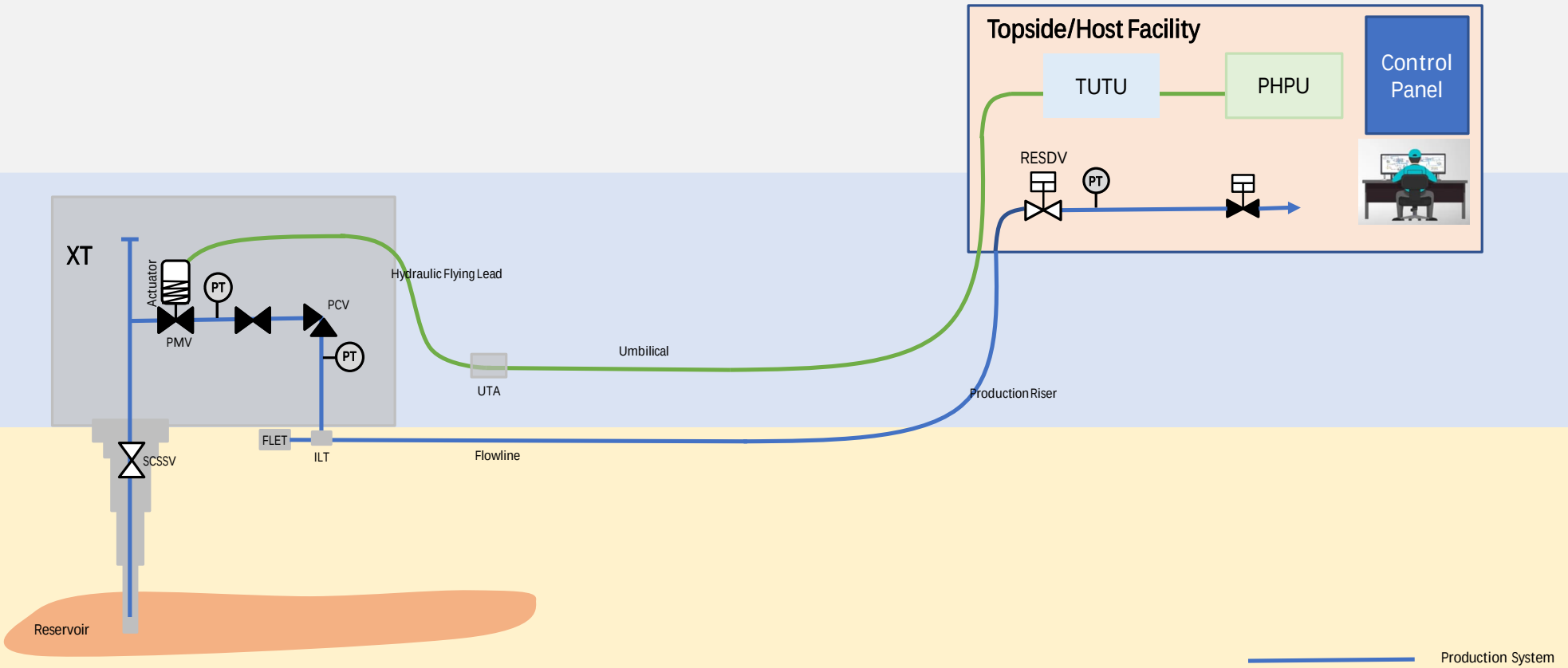
- How it works?
  - Single hydraulic line from topsides per valve, directly to valve actuator
  - When the operator sets the control valve to open, the direct hydraulic pressure control fluid flows to the actuator. To close the valve, the operator sets the wellhead control panel valve to the closed position, venting hydraulic fluid from the actuator back to the reservoir.
- Pros:
  - Simple to use, design and maintain
  - Low cost
  - Reliable
- Cons:
  - Extended ESD Response
  - On/Off Control (doesn't suit remote choke actuation)
  - Large umbilical with many tubes/hoses required
  - Very limited step-out distance (Max 5Km)

Legend

- Hydraulic line 1 for actuation of valve 1
- Hydraulic line 2 for actuation of valve 2
- Hydraulic line 3 for actuation of valve 3

- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Direct Hydraulic : Remote Opening of a Subsea Hydraulically Actuated Valve



• INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Direct Hydraulic : Remote Closing of a Subsea Hydraulically Actuated Valve

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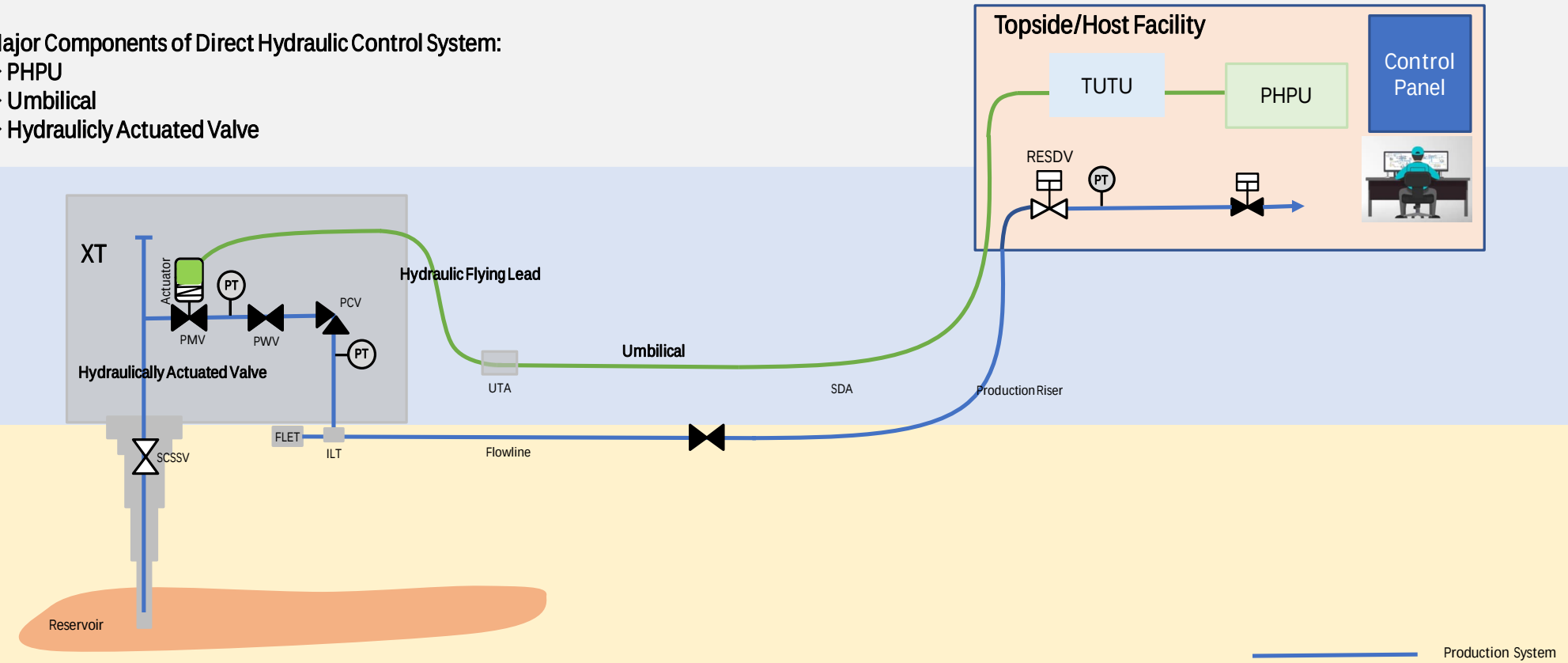
Major Components of Direct Hydraulic Control System:

- ❖ PHPU
- ❖ Umbilical
- ❖ Hydraulicly Actuated Valve



- SUBSEA CONTROLS SYSTEM TYPE

Multiplexed Electro Hydraulic Control System

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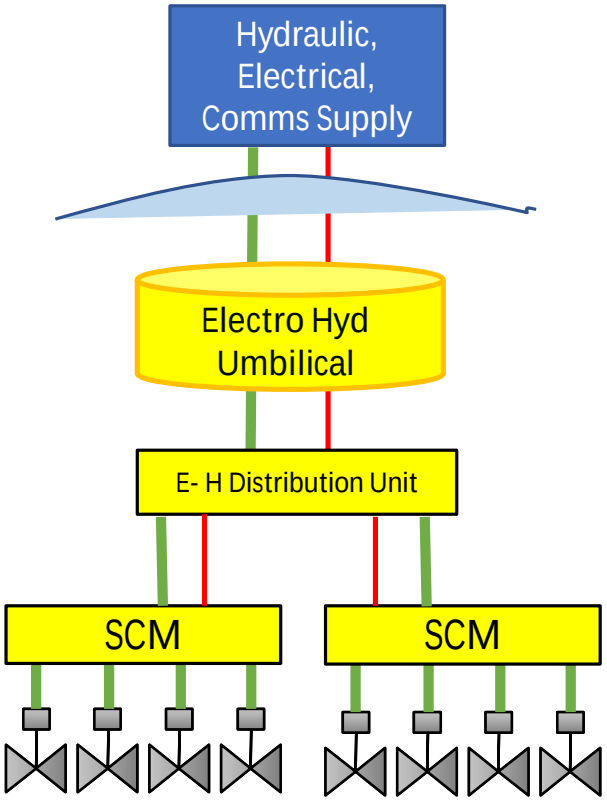
Multiplexed Electro-Hydraulic



$ubsea Hydraulically Actuated Valves

- How it works ?
  - The multiplexed electrohydraulic system allows several SCMs to be connected to the same communications, electrical, and hydraulic supply lines
  - Single hydraulic supply line in Umbilical shared for all actuators
  - Communication signal supplied to SCM (normally superimposed on power supply)
  - Electric operated Directional Control Valves (DCVs) dedicated to each valve within SCM directs the flow from single hydraulic supply to individual valve actuator
  - DCVs allow for single hydraulic lines to supply multiple valves, while still allowing for the individual control of multiple valves
  - Modem in SCM interprets signal from topsides and routes signal to correct DCV
- Pros:
  - Full, independent control of a large number of valves
  - Minimized umbilical cross-section
  - Good oversight of valve position and production temperature and pressure
  - Quick response times
- Cons:
  - Complicated SCM containing electronics
  - Less reliable comparing to direct hydraulic

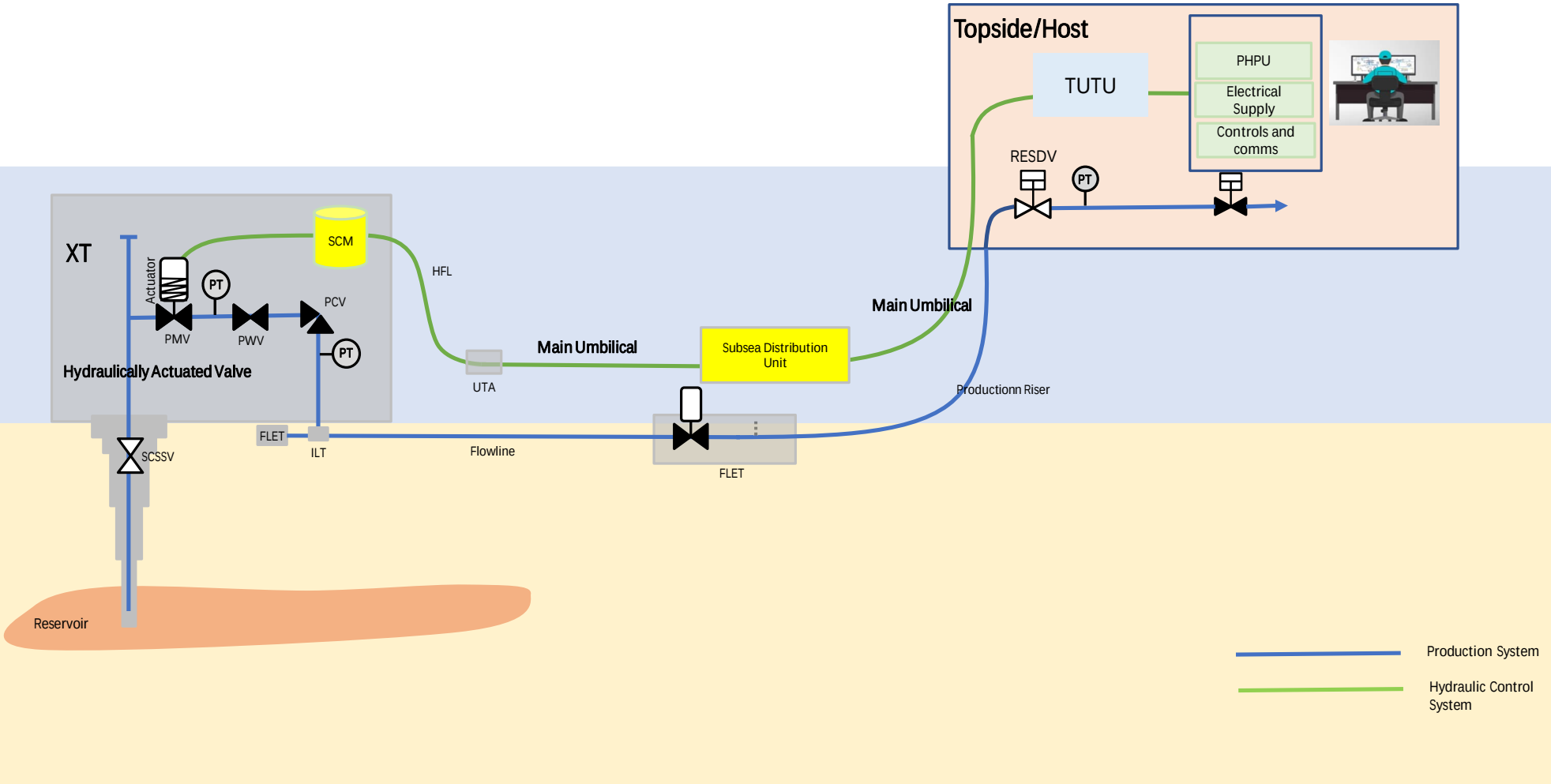
Legend

Hydraulic line for actuation of all valves

Electrical / comms line

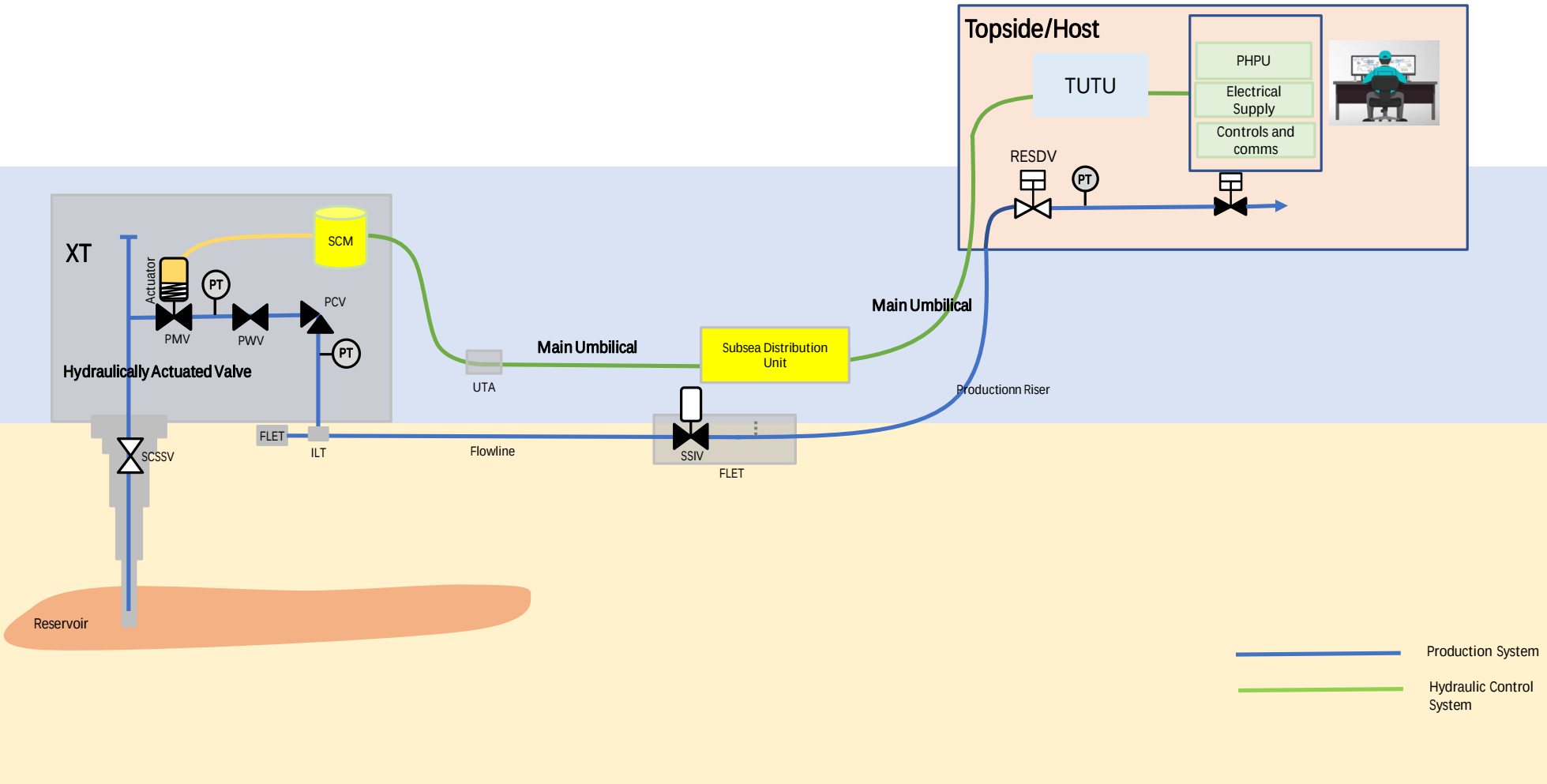
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

E-H Multiplexed: Remote Opening of a Subsea Hydraulically Actuated Valve



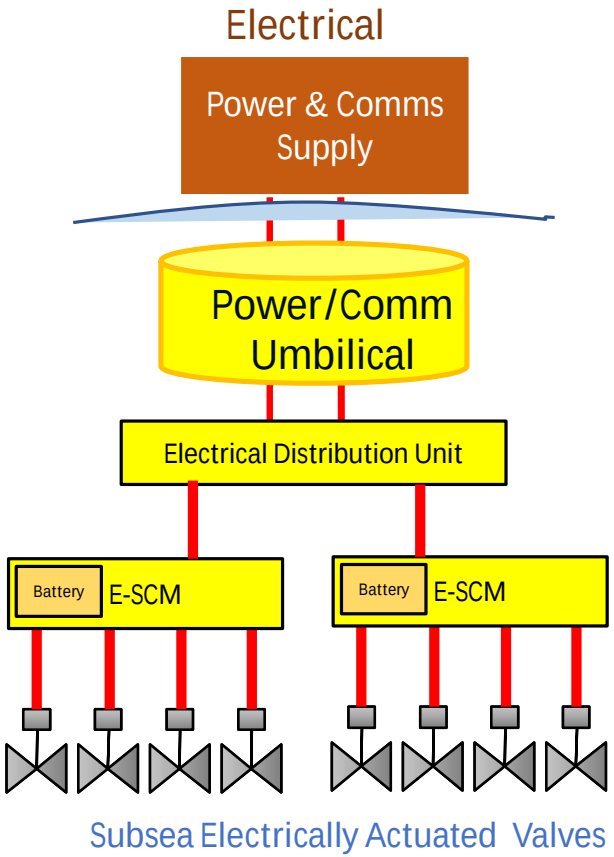
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

E-H Multiplexed: Remote Closing of a Subsea Hydraulically Actuated Valve



• SUBSEA CONTROLS SYSTEM TYPE

All Electrical Control System



How it works?

- The all-electric control system is an all-electric–based system without the conventional hydraulic control of subsea components. The main feature of this system is that the operation of the electric motors in valve actuators is performed by locally stored power from rechargeable batteries.
- The tree contains dual, all-electric subsea control modules (SCM), which supply power and signal to individual actuators
- The elimination of hydraulics means that any control system commands are sent in rapid succession without the usual retardation time required for accumulators to charge.

Legend

Electrical / comms line

- **Pros:**
  - Rapid response time
  - Suitable for long step out
  - higher degree of flexibility when expanding an existing system and when introducing new equipment into the system
  - Erases environmental and economic problems related to the leakage of hydraulic control fluids and the complexity of working with hydraulics.
- **Cons:**
  - Further concern in Australia given our history of premature subsea electrical cable/connector failures. Less reliable comparing to direct hydraulic due to electronic components of the system
  - Delivery of Chemicals, SPS requires fluid conduit from host facility to subsea
  - SCSSV developed but in infancy

Agenda

- Introduction to Subsea Controls System
- Subsea Controls System Types
- Subsea Controls Systems Equipment
- Operational Challenge

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• SUBSEA CONTROLS SYSTEM EQUIPMENT

PART OF A BETTER FUTURE

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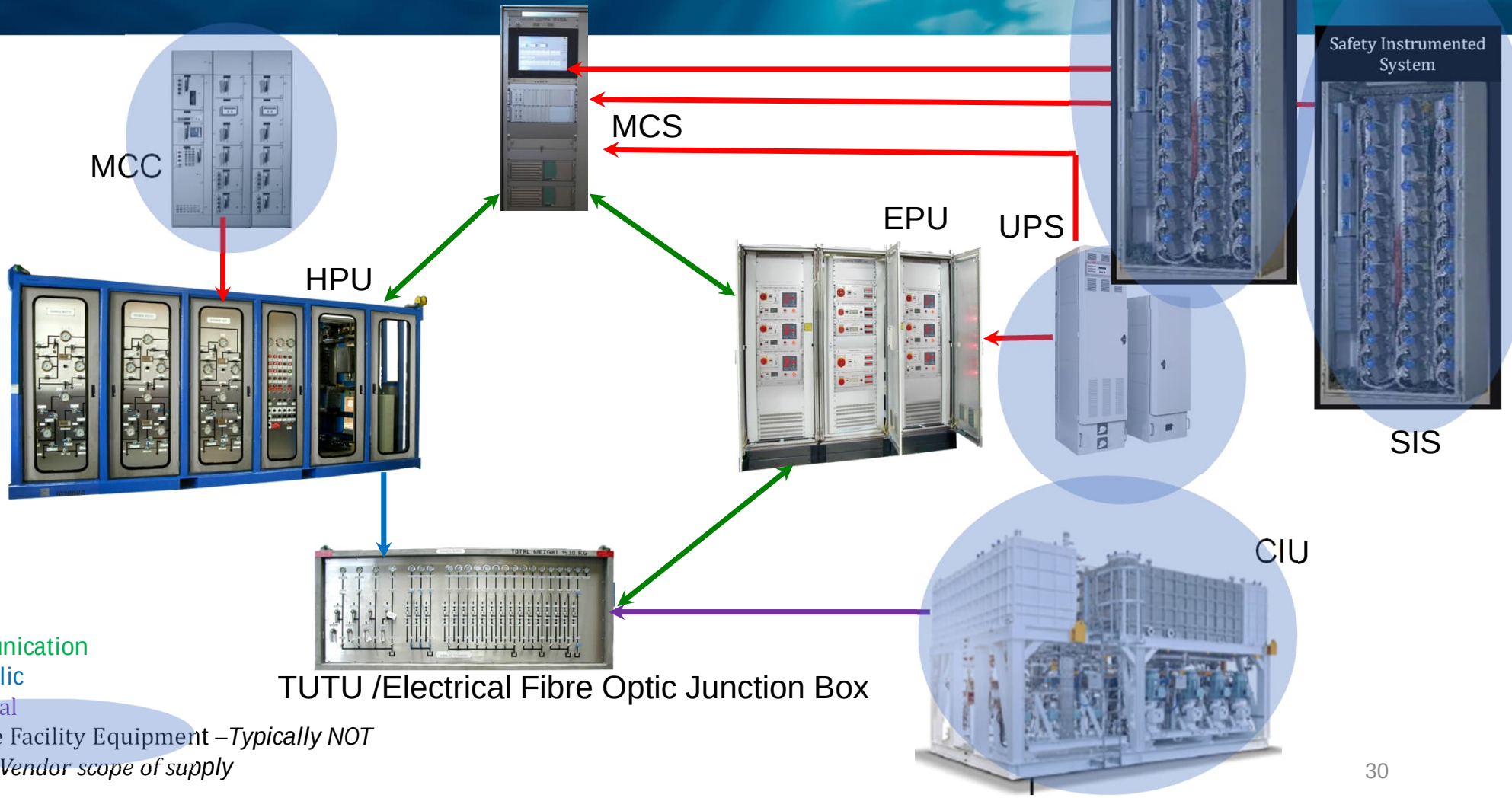
- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - ❑ CIU
    - ❑ UPS
    - ❑ MCC
    - ❑ PCS, SIS, ICSS
  - Subsea Vendor's scope of work and supply
    - ❑ MCS, EPU
    - ❑ PHPU , TUTU
- Subsea Located Equipment
  - Subsea Distribution Equipment
    - ❑ Umbilical
    - ❑ UTA, UTH,SDA
    - ❑ HFL, EFL
  - XT and Manifold Mounted Control Module and Instrument
    - ❑ SCM
    - ❑ FM (SPFM, MPFM)
    - ❑ PT, TT, EP, ASD
- Hydraulic Fluid

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment



- Power
- Communication
- Hydraulic
- Chemical
- Topside Facility Equipment –*Typically NOT Subsea Vendor scope of supply*

PART OF A BETTER FUTURE
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- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - ❑ CIU
    - ❑ UPS
    - ❑ MCC
    - ❑ PCS, SIS, ICS
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    - ❑ PT, TT, EP, ASD
- Hydraulic Fluid

- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Located Equipment- Motor Control Centre (MCC)

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Motor Control Centre (MCC): Controls the hydraulic pump's motors through electrical supply to a VSD or direct drive motor system.

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment – Uninterruptable Power Supply (UPS)

PART OF A BETTER FUTURE

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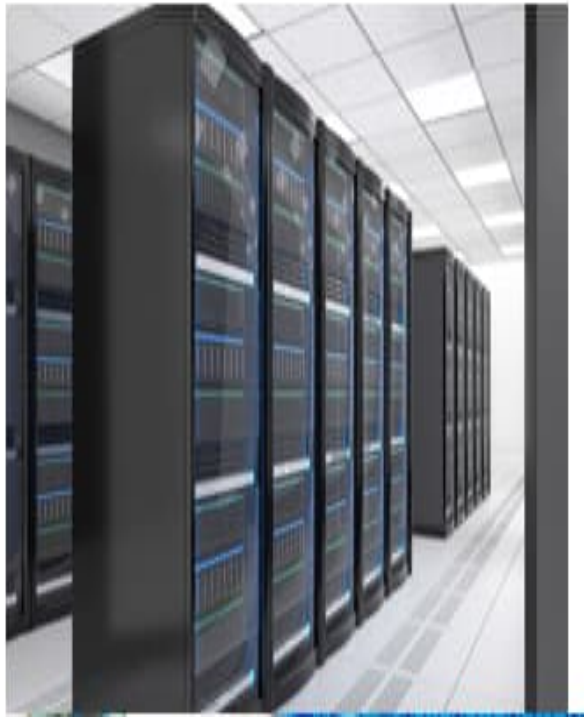
- UPS and Battery bank to supply power for the SPCU /MCS/EPU.
- Must be able to maintain a steady supply, even when the main source fluctuates or fail
- Normally supplied by facilities and are project specific



• INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Located Equipment- Process Control System (PCS)

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Mining, Chemical , offshore and onshore gas plant and other manufacturing facilities could be dangerous places to work due to the presence of the risk. Risk due to fire explosion, gas release or chemical exposure

- ❖ In order to minimize these risk , process control system are in place to maintain a controlled and safe operation of the plant assisted by robust alarm detection and reporting system which is operated by trained qualified personnel
- ❖ Alarms are configured to allow the operator to react to abnormal conditions and take corrective actions before a risk become an accident
- ❖ The basic process controls system is installed with instrument controls and monitoring logic to allow the facility to be operated within the safest ranges of pressure temperature and flow rate
- ❖ Regardless of types of risk , the basic process control system , alarm and operator intervention provides the first layer of protection for the process

The PCS has the following functionality:

- Provides human machine interface (HMI) to topside operator(s).
- Monitors the wellhead instrumentation and valves via the SPCU/SCM communications and displays their status/readings to operator(s).
- Communications and integration of subsea system into the existing platform control room.
- Perform Well and manifold valve and SS choke operation
- Provide safe operation with logic interlocks of subsea valves and PHPU skid. Interlocks ensure valves are not operated until a given set of conditions are met

PCS/SPCU Interface

• INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Located Equipment- Safety Instrumented System (SIS)

PART OF A BETTER FUTURE

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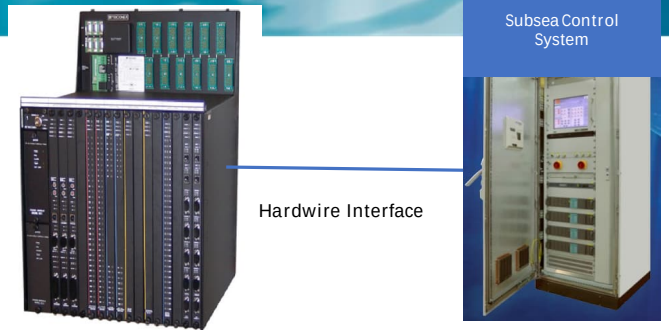

- ❖ PCS assist with operating of a safe system. But often these measures alone cannot reduce the risk of injury environmental impact , fire explosion gas release to a tolerable level. Even with all layers of protection in place as explained in prev slide the risk may still be too great to prevent an accident from happening
- ❖ The way functional safety would be addressed in a plant in order to reduce functional risk was to install a separate well-designed safety instrumented system (SIS)
- ❖ SIS represent an additional layer of protection above the first three layer discussed before
- ❖ A safety instrumented system (SIS) consists of an engineered set of sensor logic solver final control element for the single purpose of taking the process to a safe state when a pre-determined condition is violated
- ❖ A SIS is engineered to perform "specific control functions" to failsafe or maintain safe operation of a process when unacceptable or dangerous conditions occur.
- ❖ Safety Instrumented Systems must be independent from all other control systems that control the same equipment in order to ensure SIS functionality is not compromised.

SIS Function:

- SIS interfaces with both topside and subsea Controls systems.
- Initiates the Process Shutdown (PSD), Emergency Shutdown (ESD) and Total Platform Shutdown (TPSD) sequences, which all close valves in a required sequence to isolate the subsea and topside infrastructure.
- Normally will send PSD/ESD shutdown commands directly to the SPCU. The SPCU then sends valve shutdown sequence commands to the SCMs.

PART OF A BETTER FUTURE
Woodside

- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - ❑ CIU
    - ❑ UPS
    - ❑ MCC
    - ❑ PCS, SIS, ICS
  - Subsea Vendor's scope of work and supply
    - ❑ EPU, MCS (SPCU)
    - ❑ PHPU , TUTU
- Subsea Located Equipment
  - Subsea Distribution Equipment
    - ❑ Umbilical
    - ❑ UTA, UTH,SDA
    - ❑ HFL, EFL
  - XT and Manifold Mounted Control Module and Instrument
    - ❑ SCM
    - ❑ FM (SPFM, MPFM)
    - ❑ PT, TT, EP, ASD
- Hydraulic Fluid

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment – Electrical Power Unit (EPU)

PART OF A BETTER FUTURE

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- The EPU provides a redundant power supply for the subsea control equipment.
- The EPU is a self-contained fully enclosed standard design cabinet, which contains converter , transformers , voltage and current monitoring, short circuit protection, Line Insulation Monitoring (LIM) for each subsea line

- Subsea comms on power Output : Comms being super imposed on power

• SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment - Master Control Station (MCS)

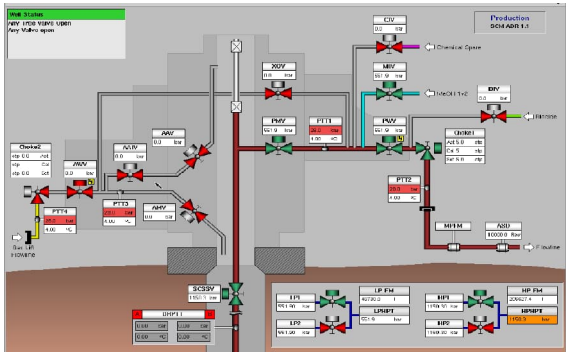
PART OF A BETTER FUTURE

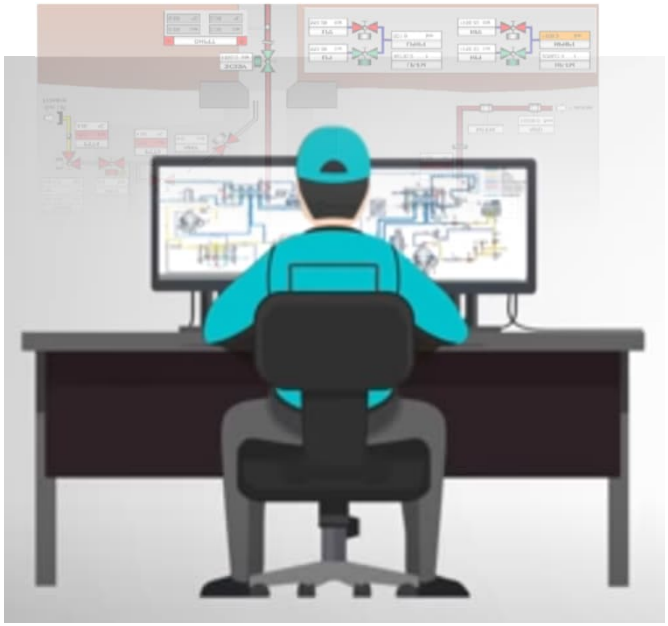
Woodside

- The unit that controls and monitors the subsea production system (SPS),Ref API 17F The control console is the primary interface to subsea production controls system obtaining all subsea instrument data and communicating with subsea.

- The MCS provides control and monitoring for the complete subsea production control system, covering both the surface and subsea installed equipment interface. Data acquired from this equipment is displayed to the user on the MCS' Human Machine Interface (HMI) to allow monitoring and control
- The MCS enclosure consists of:
  - Server
  - PLC and network infrastructure
  - NTP clock
  - Additional interface or 3rd party servers (optional)

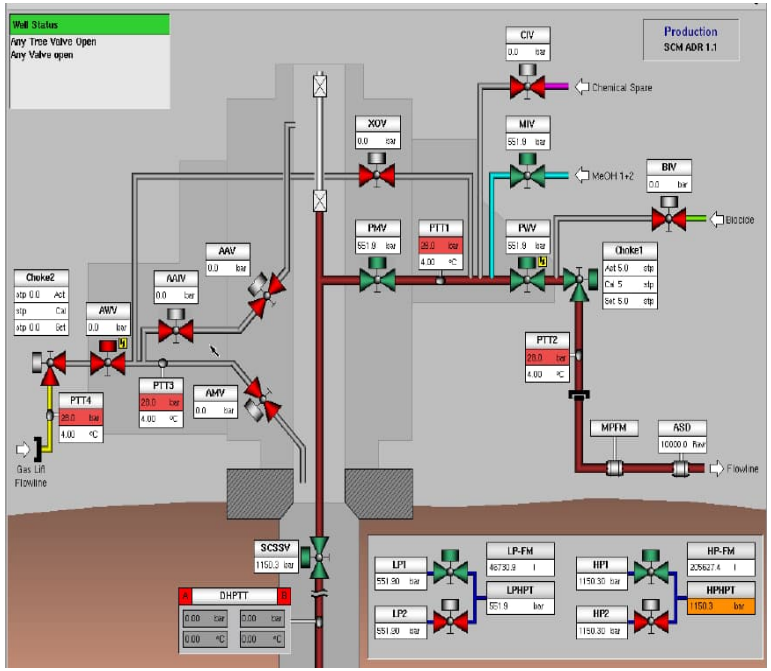
- Depending on the Operational philosophy , subsea production controls system can be controlled and monitor via MCS or PCS





- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment - Master Control Station (MCS)



- SUBSEA CONTROLS SYSTEM EQUIPMENT

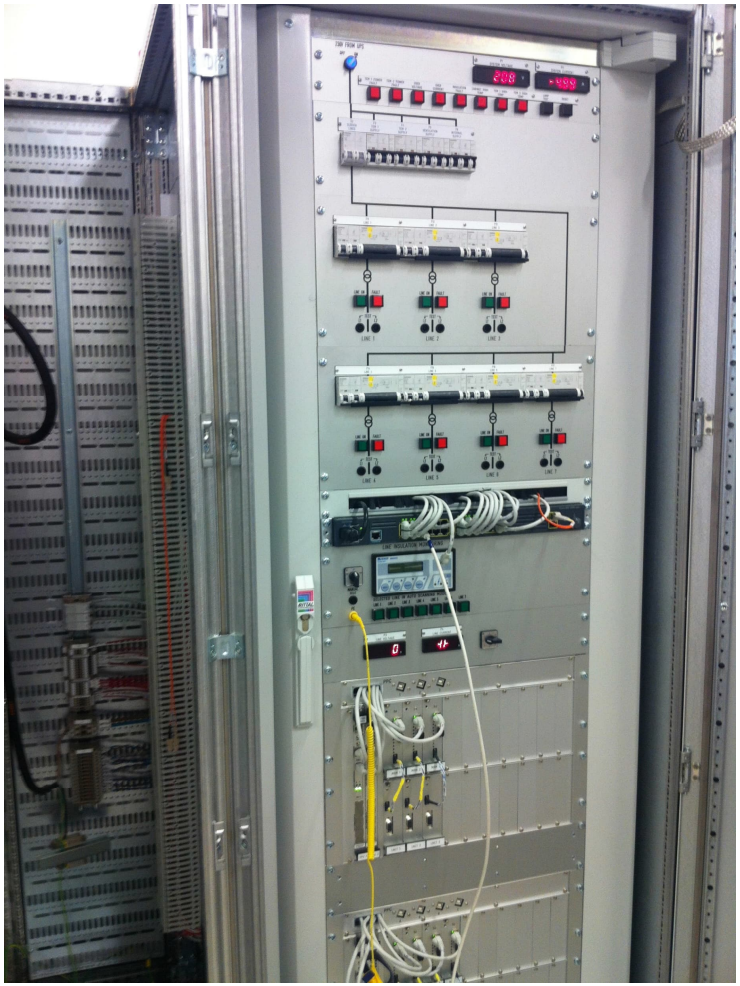
Topside Located Equipment – Subsea Power and Communication Unit (SPCU)

PART OF A BETTER FUTURE

Woodside

- Interchangeably used for ‘MCS and EPU’
- Integrated unit /cabinet that provides electrical power and communications to subsea controls system .
- Distribute electrical power and communication to the equipment in subsea control modules.
- Redundant System A and B are in separate cabinets.
- Each system has TEM rack. Communication signals from the TEM are mixed with electrical power on each subsea line.
- Key Components : Subsea output, Communication with SS via Modem (MRM) , processor TPU/SGB, transformer , LIMs,

- Subsea vendor’s design specific for power and communication supply :
  - Technip FMC: integrated SPCU unit
  - Aker Solutions, OneSubsea: standalone MCS and EPU units



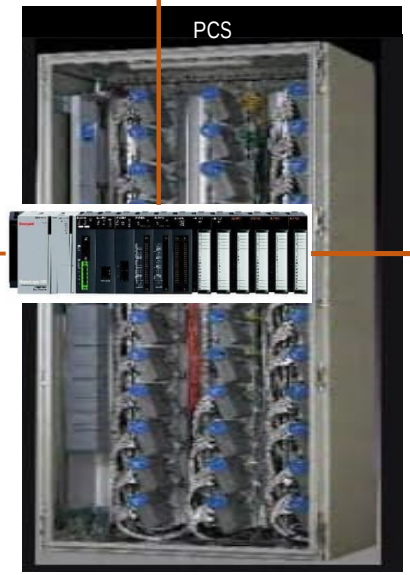
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Located Equipment- PCS/SIS/MCS Interface

PART OF A BETTER FUTURE

Woodside

CCR (Central Control Room) or operating stations in DCS is the heart of the system, where operator can monitor production , view process warnings and alarms



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside and Subsea Communication : Subsea to Topside

Host Facility Control and Shutdown Logic

Safety Instrumented System

D A T A

L I N K T O S H O R E

Riser Monitoring

D a t a

PHPU

D a t a

CIU/ MRU

D a t a

D a t a

S P C U

MCS HMI

H I T Y

Subsea Control Module

Data

Subsea valves & Instrumentation

Data

Data

S U B S E A

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside and Subsea Communication –PCS to Subsea

Close PWV

HOST FACILITY

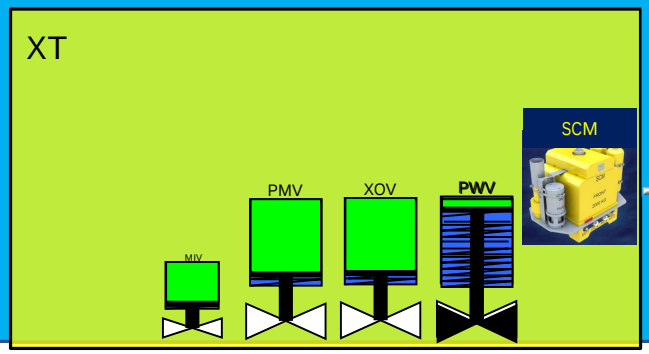
Host Facility Control

Safety Instrumented System

LINK TO CCR

INTERFACE PROTOCOL

SPCU



Subsea Cables

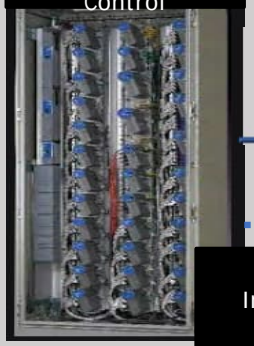
SUBSEA

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside and Subsea Communication –SIS to Subsea

HOST FACILITY

Host Facility Control



LINK TO CCR

Emergency Shutdown Demand

Safety Instrumented System

E S D

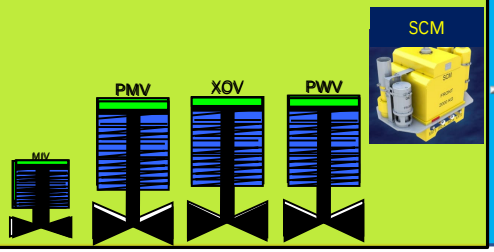
SD Complete

SPCU

Shutdown Seq
- Close PWV
- Close XOV
- Close PMV
- Close MIV

Shutdown Feedback
- PWV Closed
- XOV Closed
- PMV Closed
- MIV Closed

XT



Close PWV
Close XOV
Close PMV
Close MIV

SUBSEA

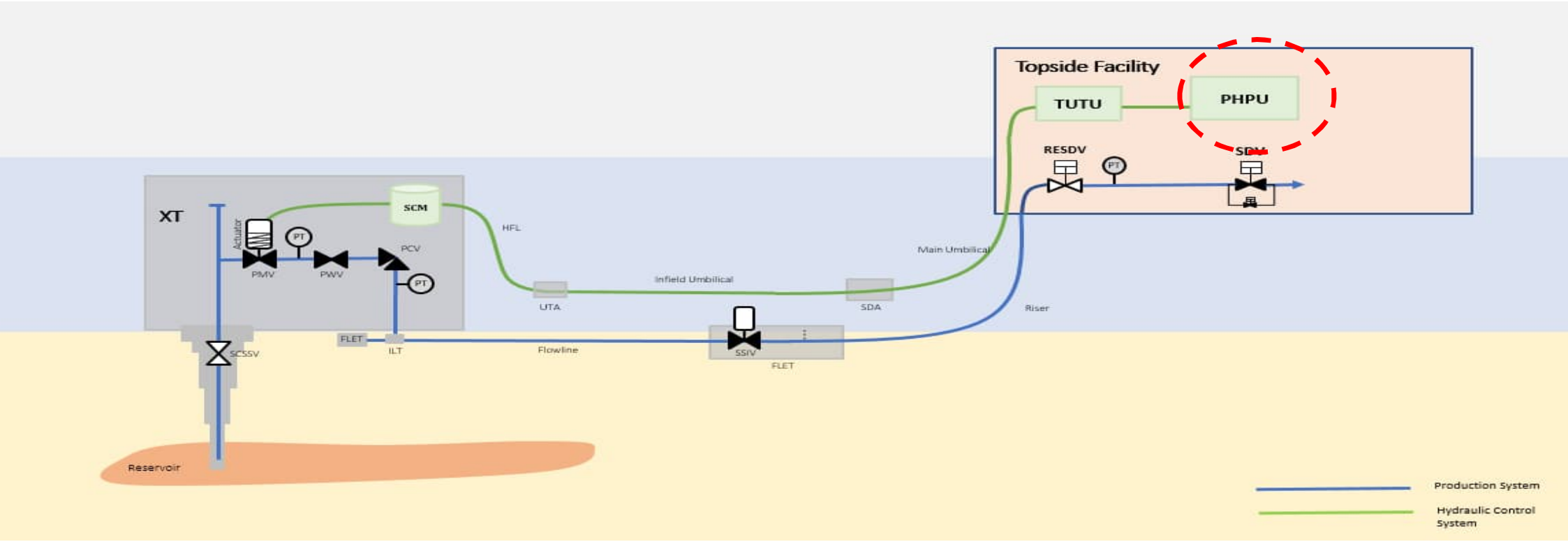
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment- Production Hydraulic Power Unit (PHPU)

PART OF A BETTER FUTURE

Woodside

- PHPU provides the hydraulic power to the subsea system.
- The unit is generally constructed to provide an accumulated supply using a bank of accumulator bottles. A bank of filters for the hydraulic fluid is also included, with bypass redundancy in case of filter fouling and replacement.
- A reservoir is also needed to store fluid an to accept fluid back from the subsea system when the subsea is depressurized .
- Each hydraulic system, has redundancy to maintain the availability of the hydraulic system .

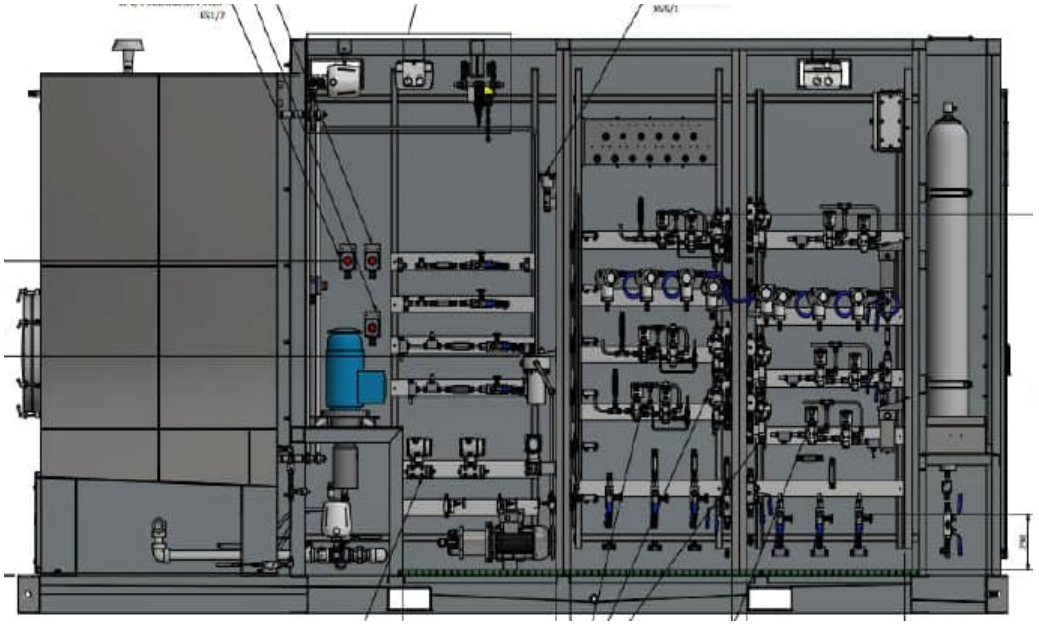


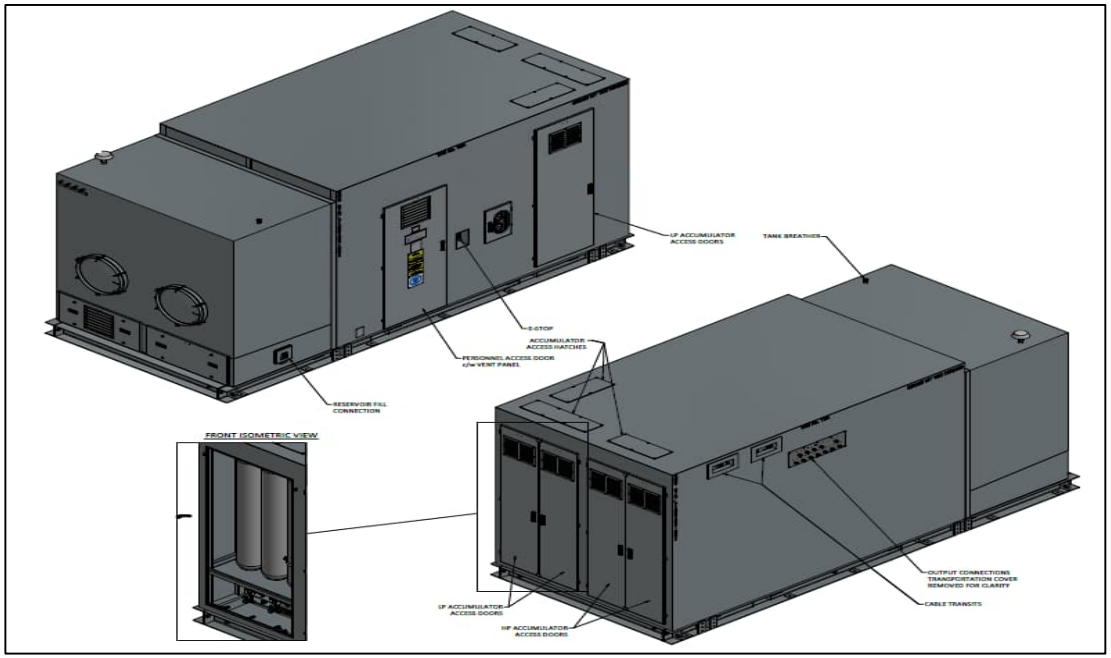
- INTRODUCTION TO SUBSEA CONTROLS SYSTEM

Topside Located Equipment- Production Hydraulic Power Unit (PHPU)

PART OF A BETTER FUTURE

Woodside





- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment- Production Hydraulic Power Unit (PHPU)

PART OF A BETTER FUTURE

Woodside

Hydraulic Fluid tank – consisting of return (dirty) and supply (clean) sides.

Circulation pump and filter – allowing new fluid to be transfer from drum into the return tank. Allowing return hydraulic fluid to be cleaned (polished) and circulated into the supply side.

Supply line filters – to keep control fluid clean and prevent damage to the hydraulic system components, including SCM directional control valves (DCVs).

Pressure regulators – regulate (lower) pressure to the subsea supply pressure.

Pressure transmitters (PT) – monitor and provide digital pressure readings to SPCS & SIS.

Relief valves (RV) – also known as pressure safety valves (PSV). Set to vent pressure at the system design pressure.

Return lines – allowing for the return of hydraulic fluid from topside components to the return tank (dirty).

Double block and bleed valves (DBBVs) – Allowing for components to be safely isolated for maintenance activities, isolating supply lines, and troubleshooting issues.

Emergency Shutdown (ESD) valves– Located on all hydraulic supply lines (LP/HP/SSIV). Solenoid actuated and used to vent the umbilical hydraulic lines when a PSD/ESD is unsuccessful. Controlled directly by the SIS system.

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment- Production Hydraulic Power Unit (PHPU)

PART OF A BETTER FUTURE

Woodside

Hydraulic Pumps – dual redundant LP and HP pumps, which control the hydraulic system pressure. Can be VSD or direct drive controlled.

Accumulators – providing stored volume of pressurized hydraulic fluid to allow for the control of multiple valves, and to maintain system pressure

Variable Speed Driver(VSD) : Allows hydraulic pumps to function at different speeds, allowing for fine control of hydraulic system pressure. VSDs are more expensive, larger and more complicated than direct drive. However they use less power, low pressure variation, low pressure cycle fatigue, low maintenance, low accumulation.

Direct Drive – Provides simple on/off control to motors which drive the hydraulic pumps. Simple, low cost. Usually higher accumulation required and more frequent pump starts

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Installed Equipment- Topside Umbilical Termination Unit (TUTU)

PART OF A BETTER FUTURE
Woodside

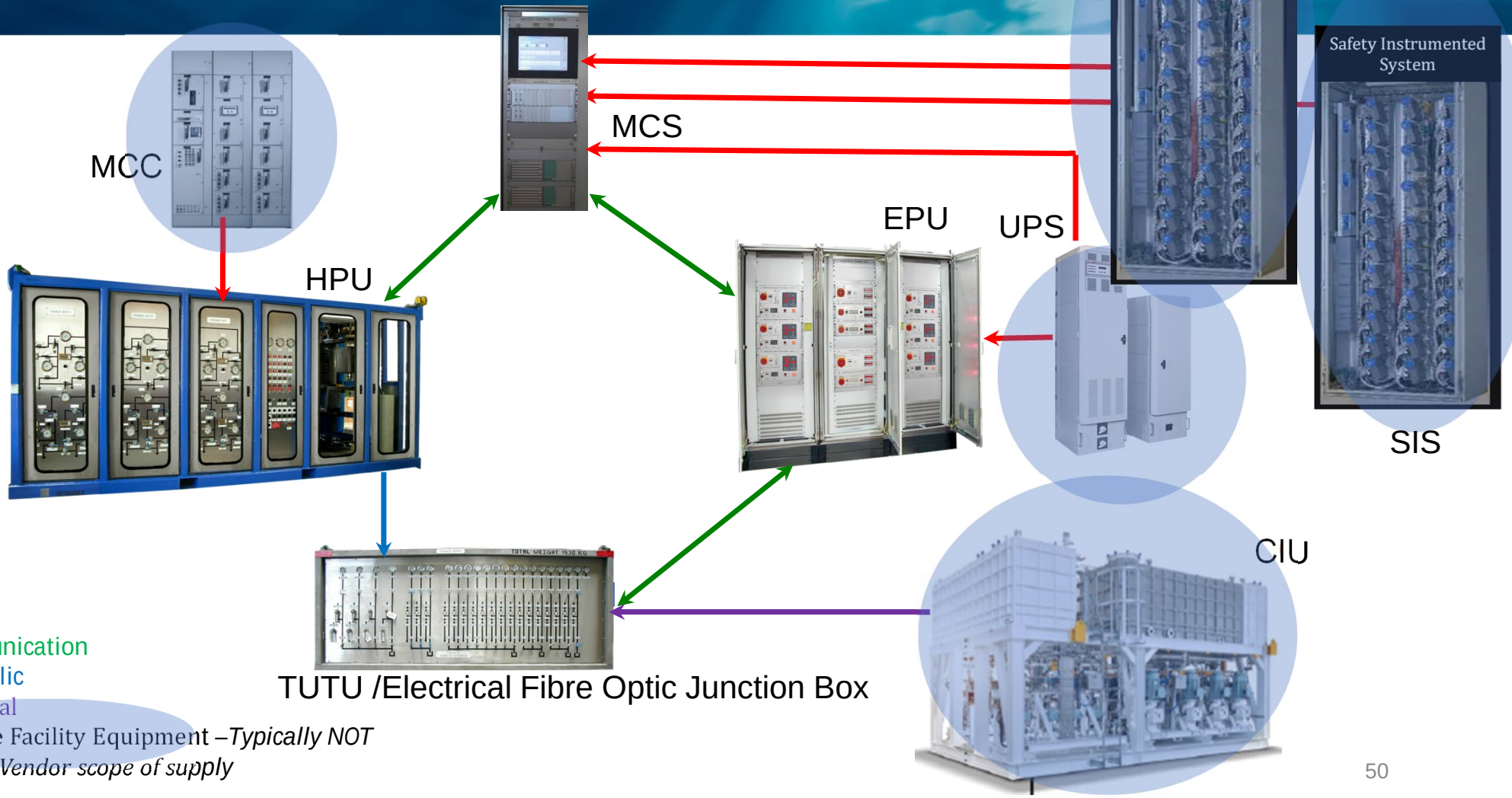
- Topsides Interface/termination for Subsea umbilical
- Contains hydraulic, chemical and electrical lines
- Isolation, block and bleed valves provided for all hydraulic and chemical lines
- Panel design configured with the correct number of valves and connections for each specific umbilical
- Stainless Steel construction and valves as required
- Ex-rated Electrical Junction Boxes (EJB) for electrical Power and Communications cables.

Umbilical Electrical Cable Junction Box

Umbilical Tube Termination Unit

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment -Wrap up…



- Power
- Communication
- Hydraulic
- Chemical
- Topside Facility Equipment –*Typically NOT Subsea Vendor scope of supply*

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Topside Located Equipment

PART OF A BETTER FUTURE

Woodside

- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - ❑ CIU
    - ❑ UPS
    - ❑ MCC
    - ❑ PCS, SIS, ICS
  - Subsea Vendor's scope of work and supply
    - ❑ EPU, MCS
    - ❑ PHPU , TUTU
- Subsea Located Equipment
  - Subsea Distribution Equipment
    - ❑ Umbilical
    - ❑ UTA, UTH,SDU
    - ❑ HFL, EFL
  - XT and Manifold Mounted Control Module and Instrument
    - ❑ SCM
    - ❑ FM (SPFM, MPFM)
    - ❑ PT, TT, EP, ASD
- Hydraulic Fluid

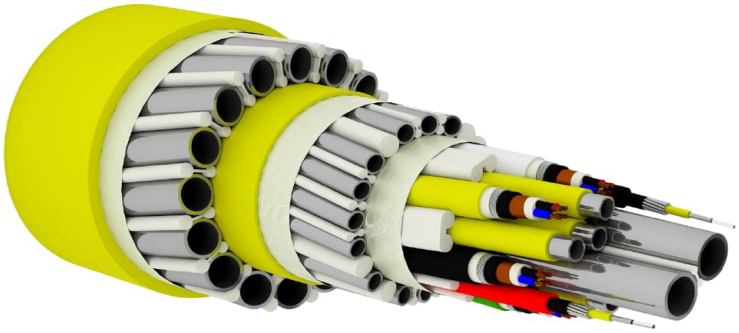
• SUBSEA CONTROLS SYSTEM EQUIPMENT

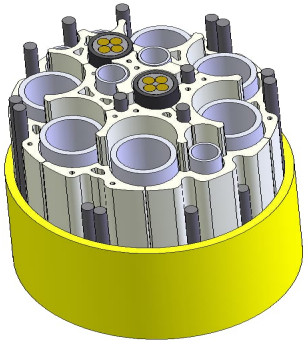
Subsea Installed Equipment – Umbilical

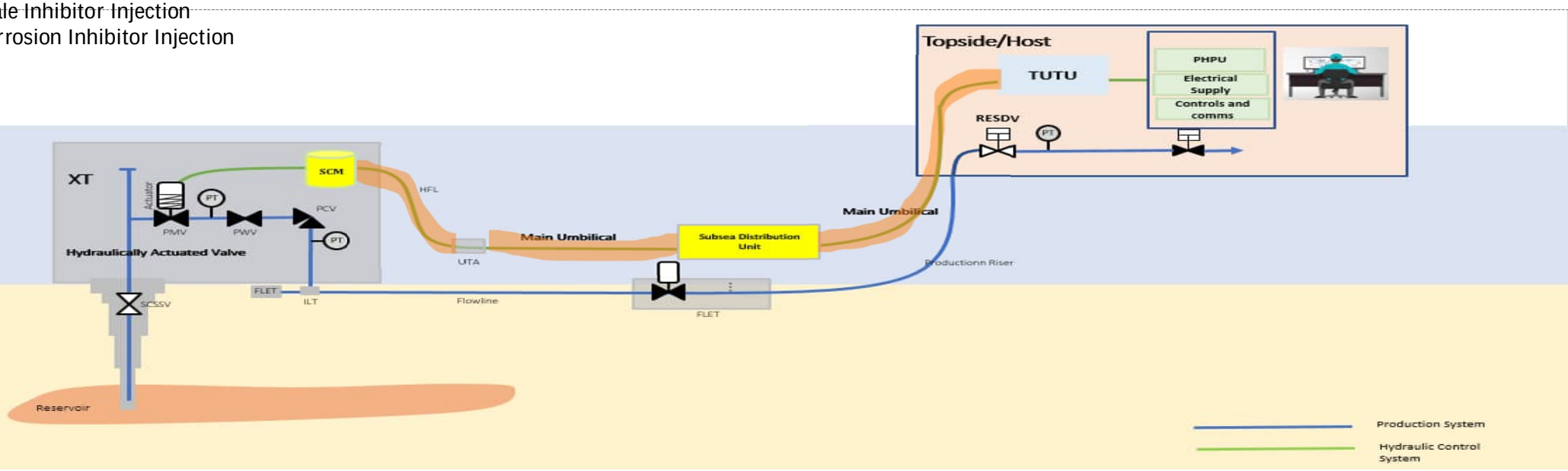
PART OF A BETTER FUTURE

Woodside

- Power and signal cable
  - ❑ Transport of power and communication to the (SCM) computer and instrumentatic
- FO cable
  - ❑ Transfer/receive signals to/from the subsea control module
- Hydraulic lines
  - ❑ Transport of hydraulic fluids to operate valves (including safety valves) on x-mas tree/manifold
- Chemical lines
  - ❑ MEG
  - ❑ Wax inhibitor
  - ❑ Scale Inhibitor Injection
  - ❑ Corrosion Inhibitor Injection







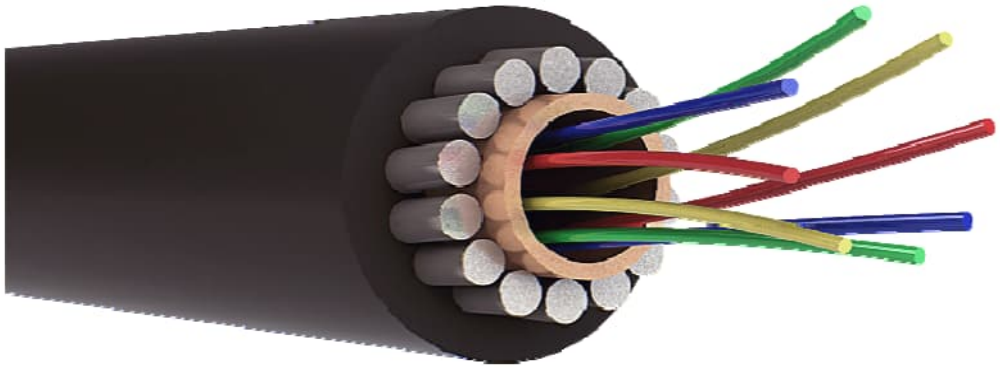
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Umbilical Electrical and Fibre Optic Cable

PART OF A BETTER FUTURE

Woodside

Standard Range Cable

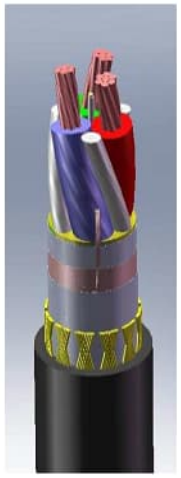


Designed for water depth up to 6000m with up to 144 fibres

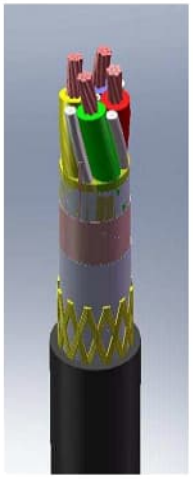
Maximum un-repeater transmission distance for single mode fibres approx. 300km and EX1000 fibres approx. 400km

Twisted Pair

Twisted Triad



Twisted Quad



Field proven for water depth up to 3000 m.

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment – Umbilical Termination Assembly (UTA)

PART OF A BETTER FUTURE

Woodside

Each subsea end of an umbilical is usually terminated into a UTA. UTA's allow for the umbilical termination to take place at the umbilical manufacturing facility. Terminations are completed in a controlled environment and connections are not exposed to subsea conditions, improving reliability.

Umbilical Termination Assembly (UTA)

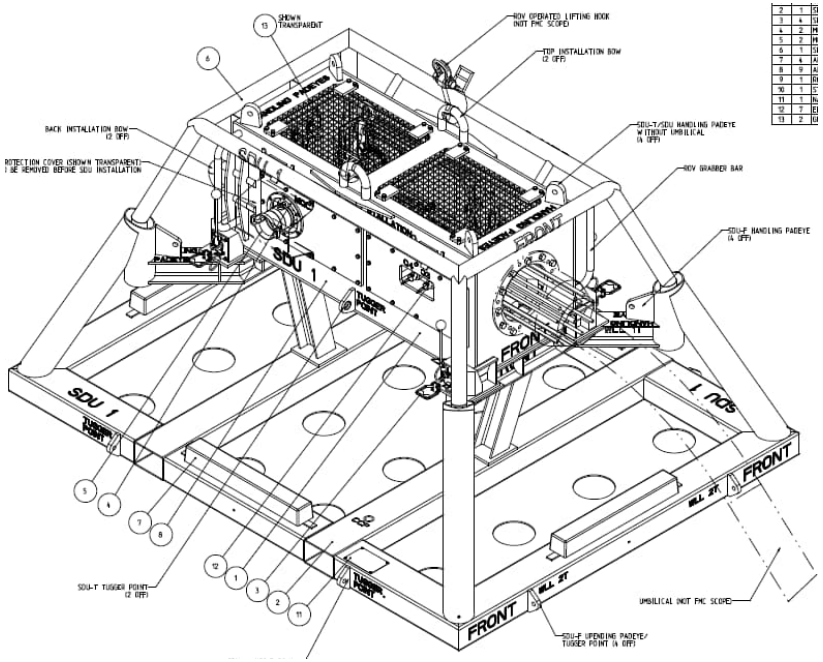
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment – Umbilical Termination Assembly (UTA)

PART OF A BETTER FUTURE

Woodside

UTA's are installed with the umbilical, and are designed to be stored within, and deployed from, the umbilical reel or carousel.



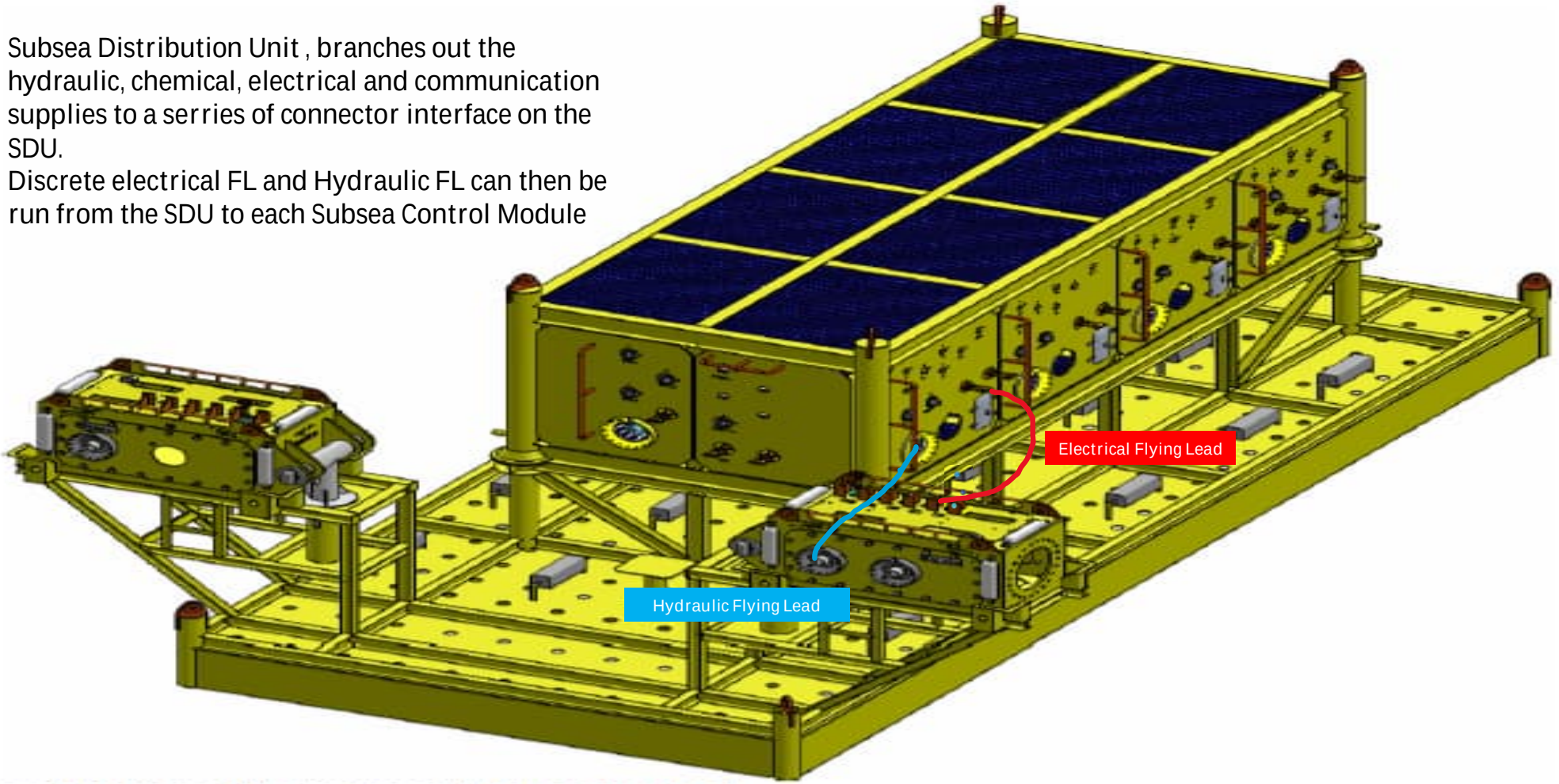
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Distribution Unit (SDU)

PART OF A BETTER FUTURE

Woodside

- Subsea Distribution Unit , branches out the hydraulic, chemical, electrical and communication supplies to a serries of connector interface on the SDU.
- Discrete electrical FL and Hydraulic FL can then be run from the SDU to each Subsea Control Module



Assembly between SDU Production UTA's and mudmat

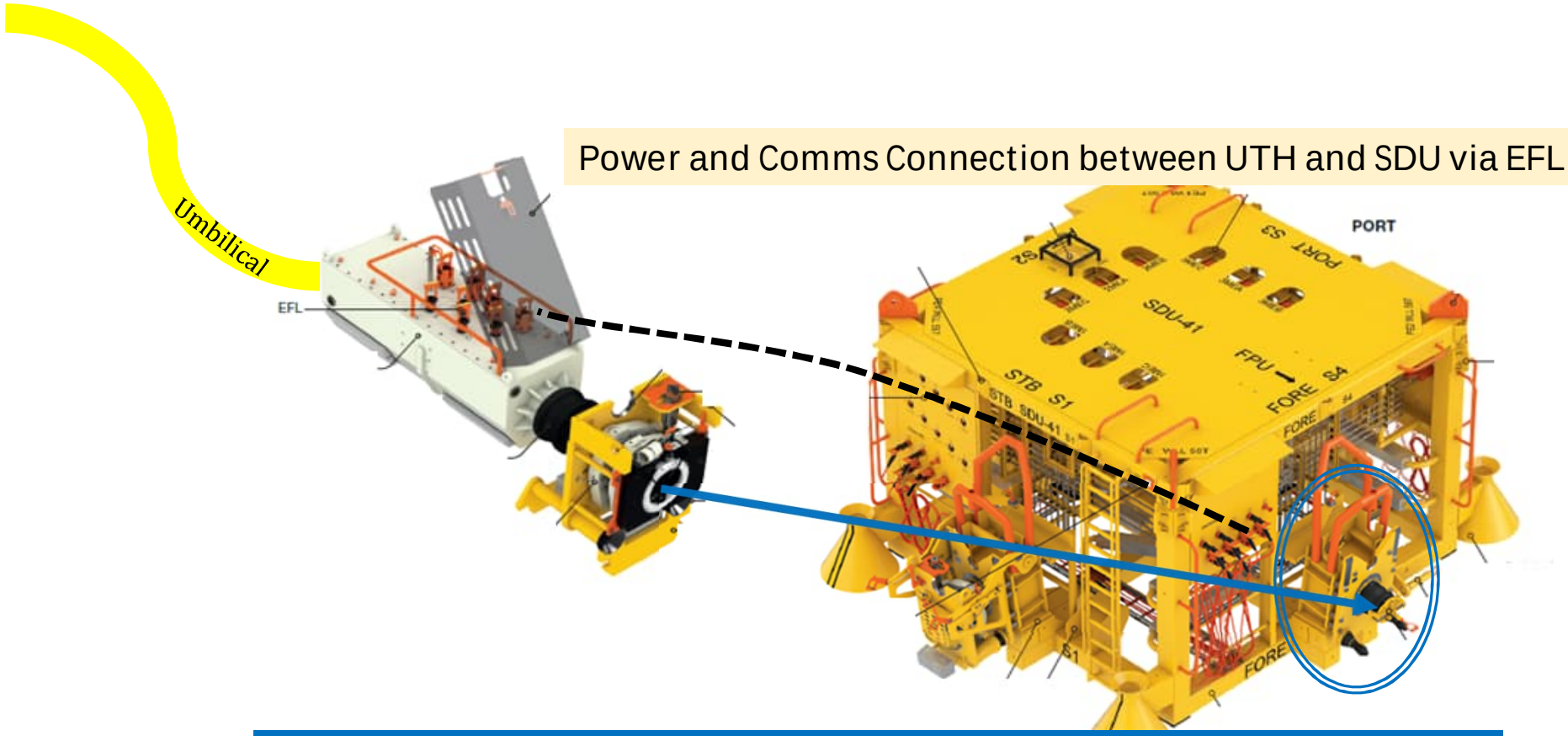
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment - Umbilical Termination Hub (UTH)

PART OF A BETTER FUTURE

Woodside

Power and Comms Connection between UTH and SDU via EFL



UTH MBH directly stabs in to the SDU stab plate for hydraulic connection

- SUBSEA CONTROLS SYSTEM EQUIPMENT

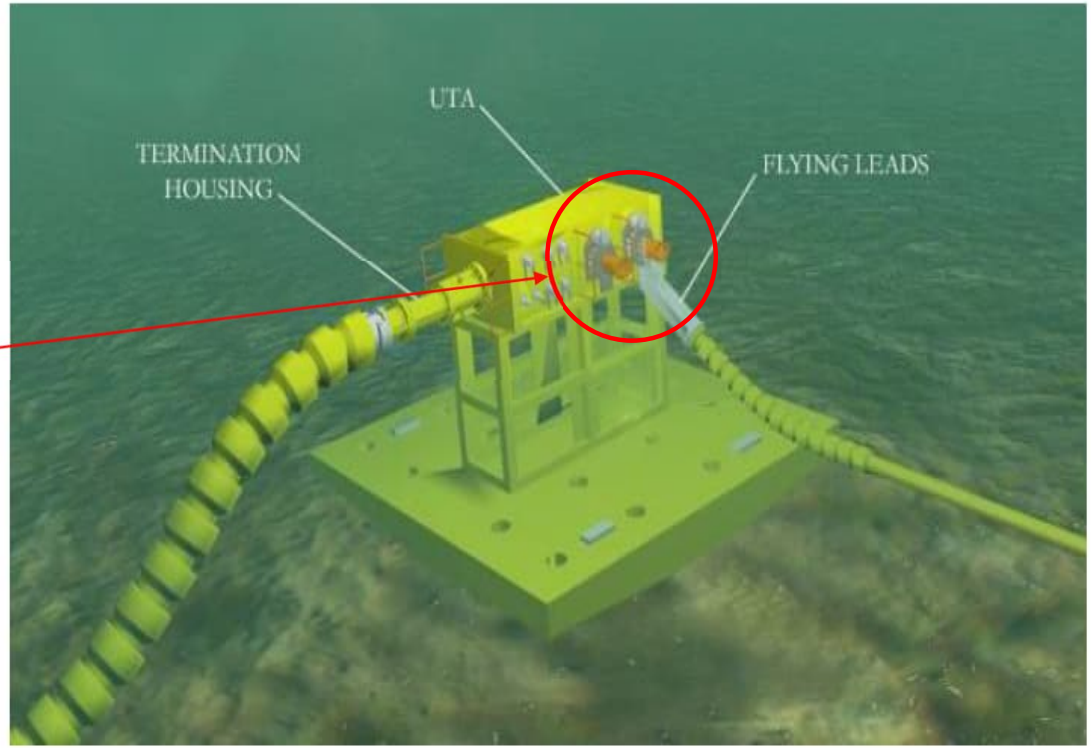
Subsea Installed Equipment- Hydraulic Flying Lead (HFL)

PART OF A BETTER FUTURE

Woodside

- Hydraulic flying leads are used to distribute hydraulic fluid and chemical services across subsea structures (UTA, SDU, Manifold, Xtree)
- Thermoplastic hoses with hydraulic connectors that are usually of the stab type where a male coupler seals against a female part.
- When unmated, flow is obstructed by a metal sealing device, this is pushed aside when the final mating of the couples is achieved

EXAMPLE OF FLYING LEAD - CONNECTED TO A SEABED UMBILICAL TERMINATION ASSEMBLY (UTA)



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Hydraulic Flying Lead (HFL)

PART OF A BETTER FUTURE

Woodside

- HFL couplers have self-sealing design that avoids ingress of sea water and dirt when being mated.
- Correct design and manufacturing tolerances and proper installation of hydraulic flying lead will determine their success

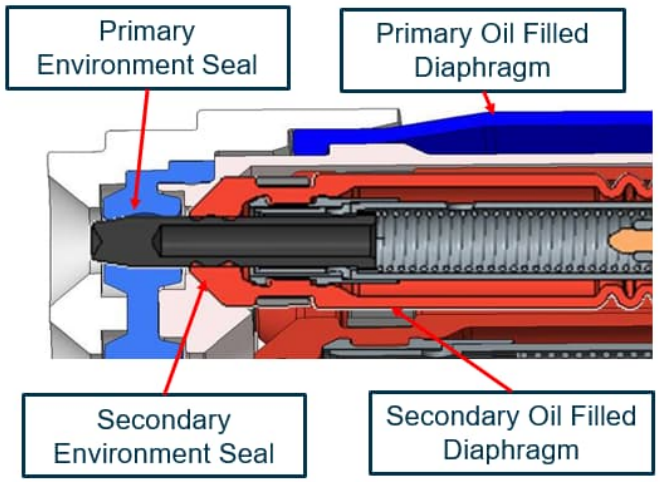
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Wet mate able Electrical and Fibre Optic Flying Lead (EFL & OFL)

PART OF A BETTER FUTURE

Woodside

- Electrical flying leads are used to distribute electrical services across subsea structures (UTA, SDU, Manifold, Xtree), and from the Xtree SCM to Xtree Instrumentation .

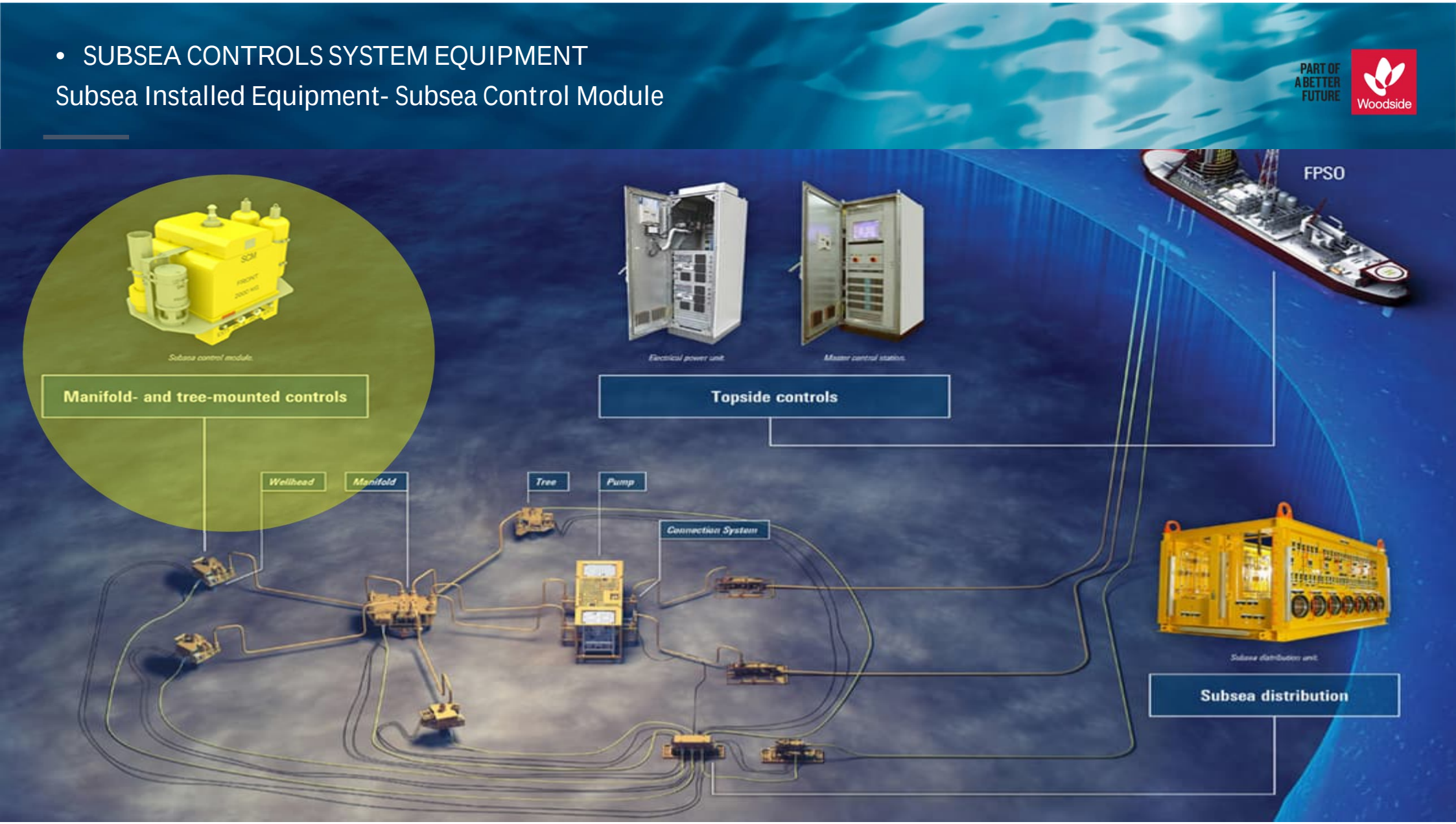


PART OF A BETTER FUTURE
Woodside

- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - ❑ CIU
    - ❑ UPS
    - ❑ MCC
    - ❑ PCS, SIS, ICS
  - Subsea Vendor's scope of work and supply
    - ❑ EPU, MCS
    - ❑ PHPU , TUTU
- Subsea Located Equipment
  - Subsea Distribution Equipment
    - ❑ Umbilical
    - ❑ UTA, UTH,SDU
    - ❑ HFL, EFL
  - XT and Manifold Mounted Control Module and Instrument
    - ❑ SCM
    - ❑ FM (SPFM, MPFM)
    - ❑ PT, TT, EP, ASD
- Hydraulic Fluid

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Control Module



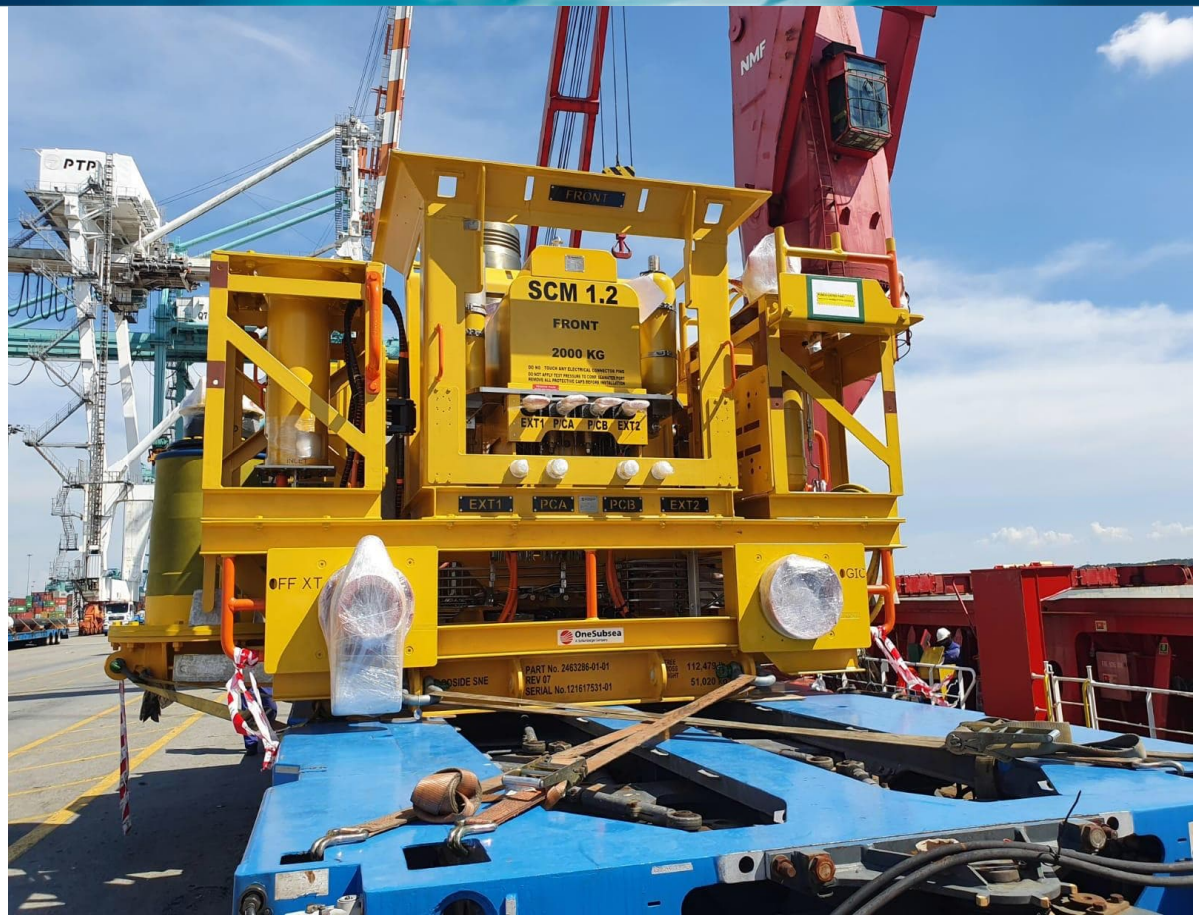
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- SCM mounted on XT

PART OF A BETTER FUTURE

Woodside

- Individual tree and manifold control is provided via SCMs.
- These Modules contain the valving and multiplexing software required for routing of hydraulic fluid to the various valve and choke actuators.
- All Monitoring of subsea systems status is accomplished in this module
- Each SCM contains two subsea electronic modules (SEM), SEM A&B. For redundant operation.
- These SEM's are continuously active and communicate with Master Control Station
- The SCM is supplied with pressurized hydraulic fluid, electrical power and control signals via the Umbilical
- The SCM controls the subsea valves by routing hydraulic fluid to the valve actuator via the Directional Control Valves (DCV's).
- The DCV's can be commanded to a return or close position which vents the hydraulic fluid from the valve actuators.
- The SCM's transmits data from the Xtree to the MCS via the communication channel in Umbilical and distribution system



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea XT

PART OF A BETTER FUTURE

Woodside

Subsea Control Modul mounted on XT

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Control Module (SCM)

PART OF A BETTER FUTURE

Woodside

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment - Subsea Control Module's Component

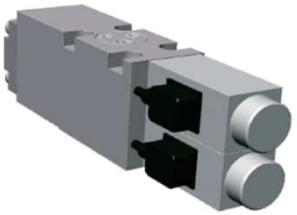
PART OF A BETTER FUTURE

Woodside

SCM Components:

- Subsea Electronic Module
- Directional Control Valve
- Pilot Valve
- Changeover Valve/Shuttle valve
- Pod Housing
- Hydraulic couples
- Electrical Connectors
- Accumulator
- Hydraulic Couplers

Directional Control Valve



Subsea Electronics Module (SEM)

Electrical Connector

- SUBSEA CONTROLS SYSTEM EQUIPMENT

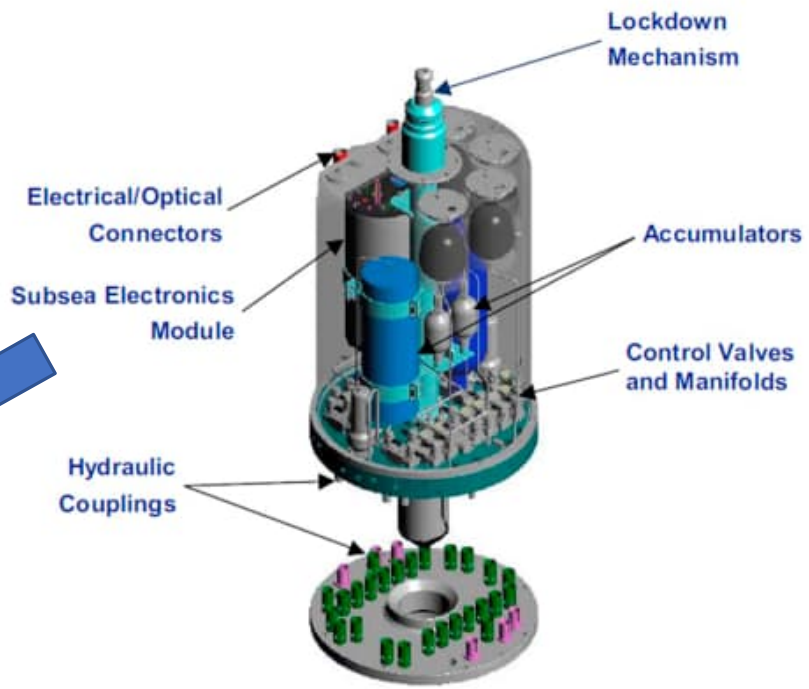
Subsea Installed Equipment –Subsea Control Module's Component

PART OF A BETTER FUTURE

Woodside

Subsea Electronic Module :

- SCM contains typical two redundant SEM
- SEM can receive signal , analyzing them for proper addresses and selecting the correct function and activating and solenoid pilot valve or transducer and transmitting data to the surface.



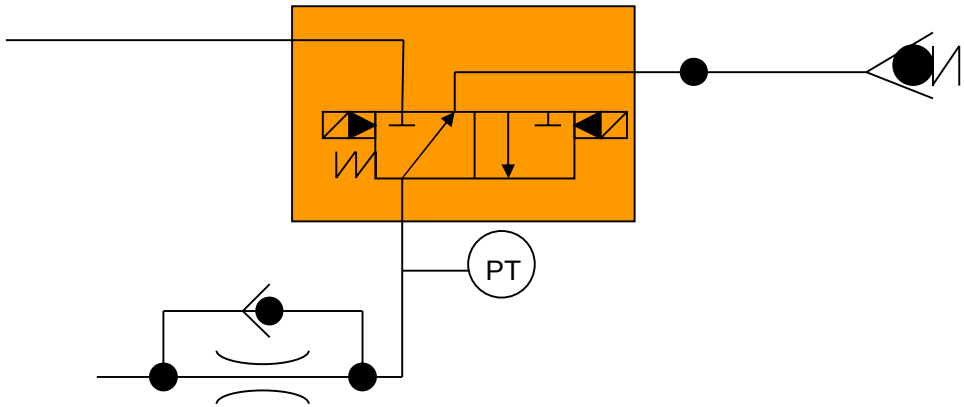
Subsea Installed Equipment - Subsea Control Module's Internal Component

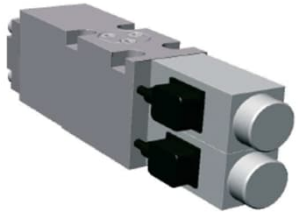
PART OF A BETTER FUTURE

Woodside

Directional Control Valve:

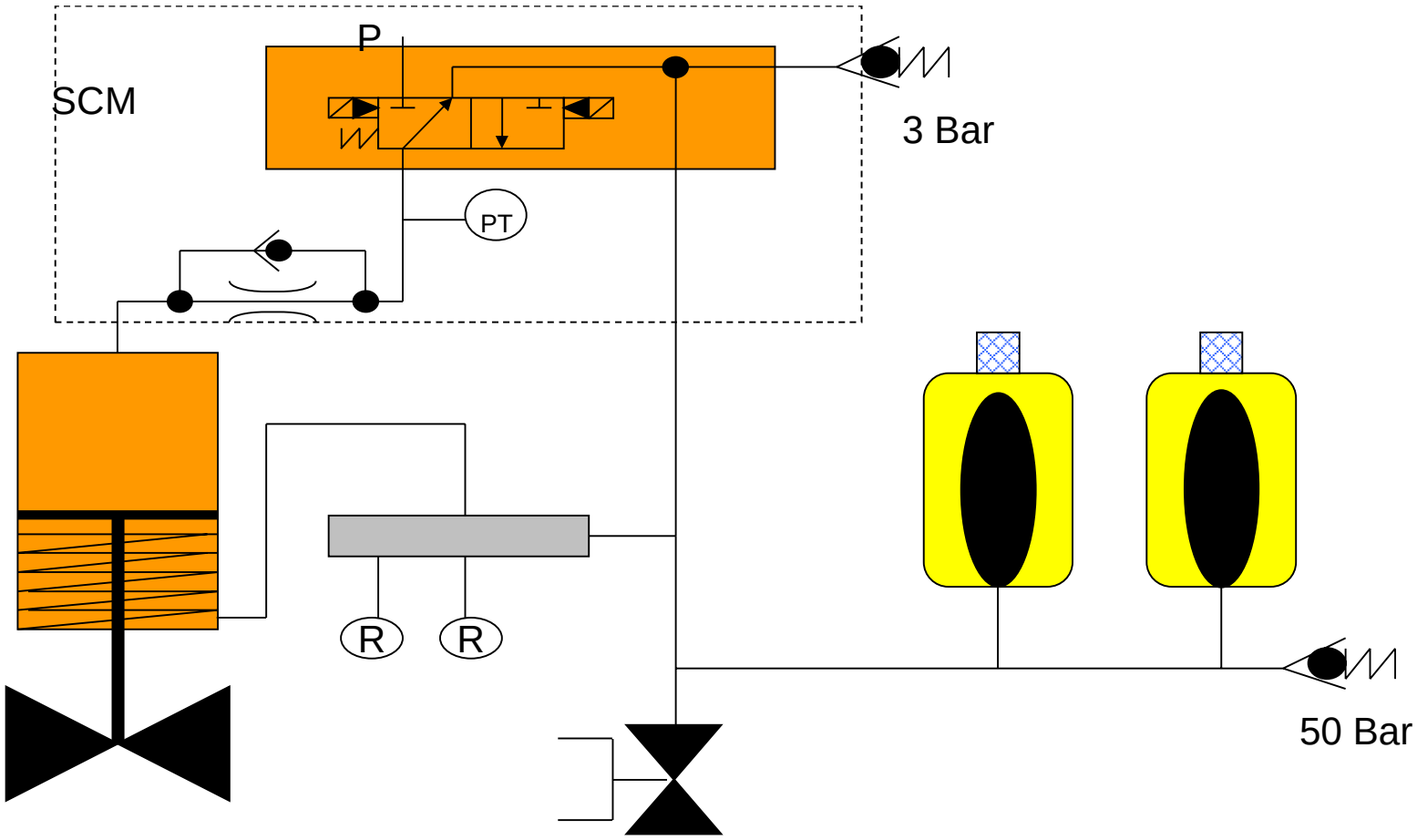
- The SCM contains directional control valves (DCV).
- The DCVs are used to pressurize and bleed the function lines to Manifold and X-Tree valves.
- DCVs are 3 way, 2 position, electrically pulsed, solenoid operated, dual coils.
- The DCV is hydraulically latched with spring return to vent position at loss of Hydraulic supply pressure.
- Each DCV is designed to leak hydraulic fluid at 0.1ml/min, which keeps the DCV internals lubricated





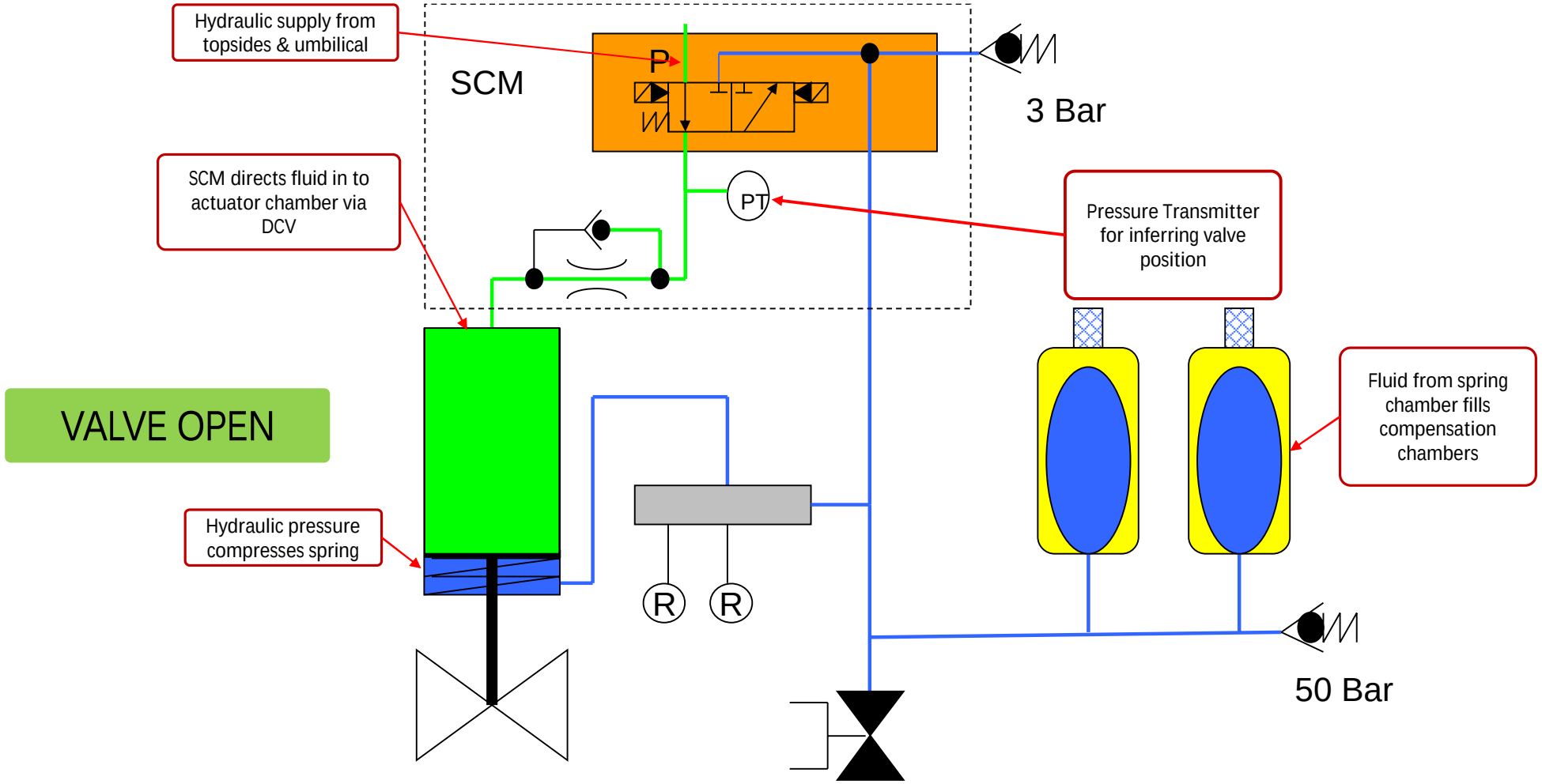
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment – Subsea Valve Actuation



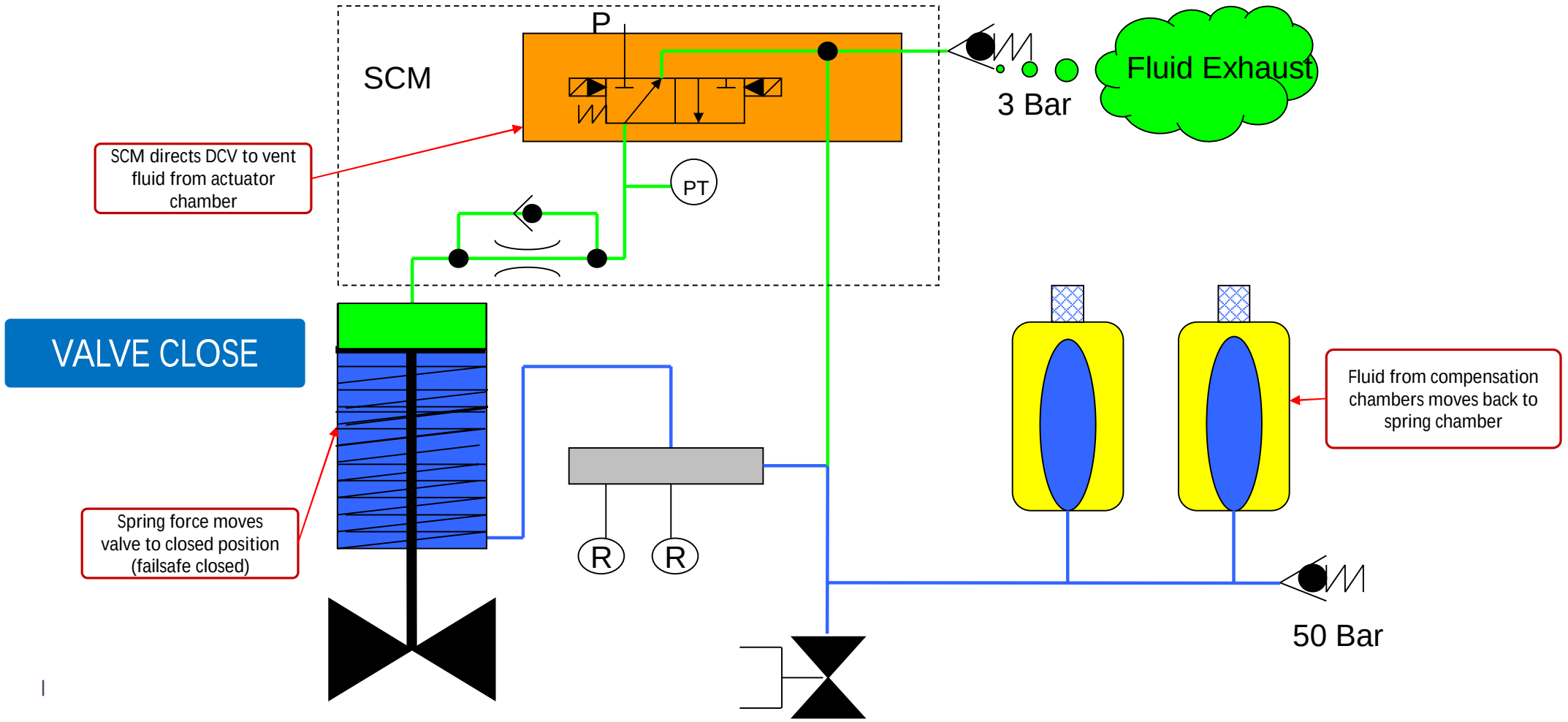
- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Valve Actuation



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Valve Actuation



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment - Subsea Valve Actuation

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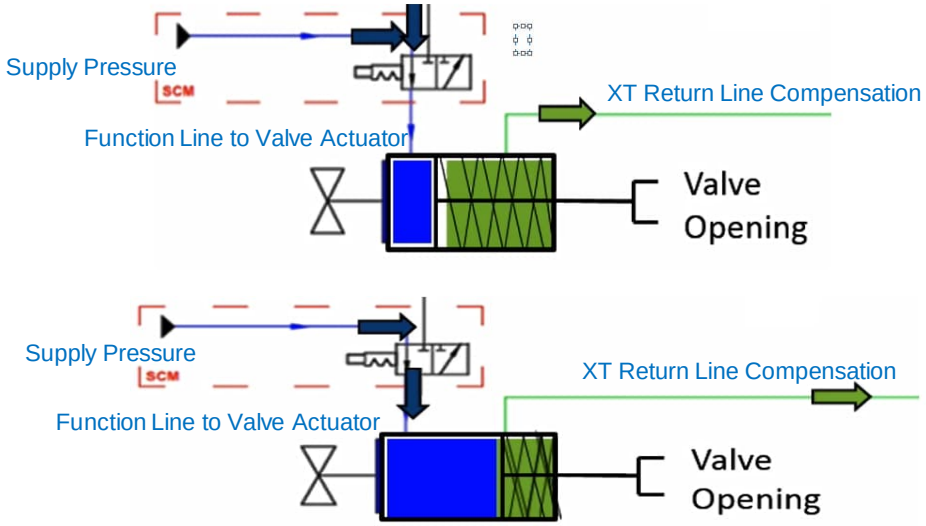
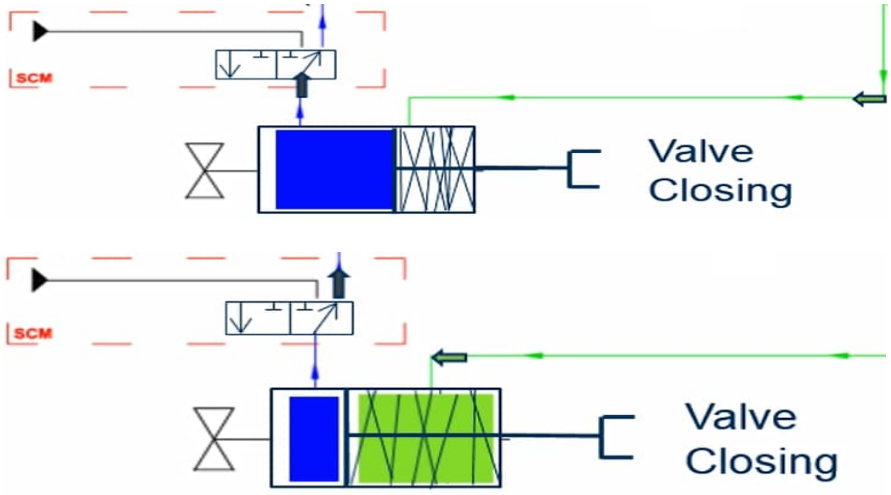
Valve Opening

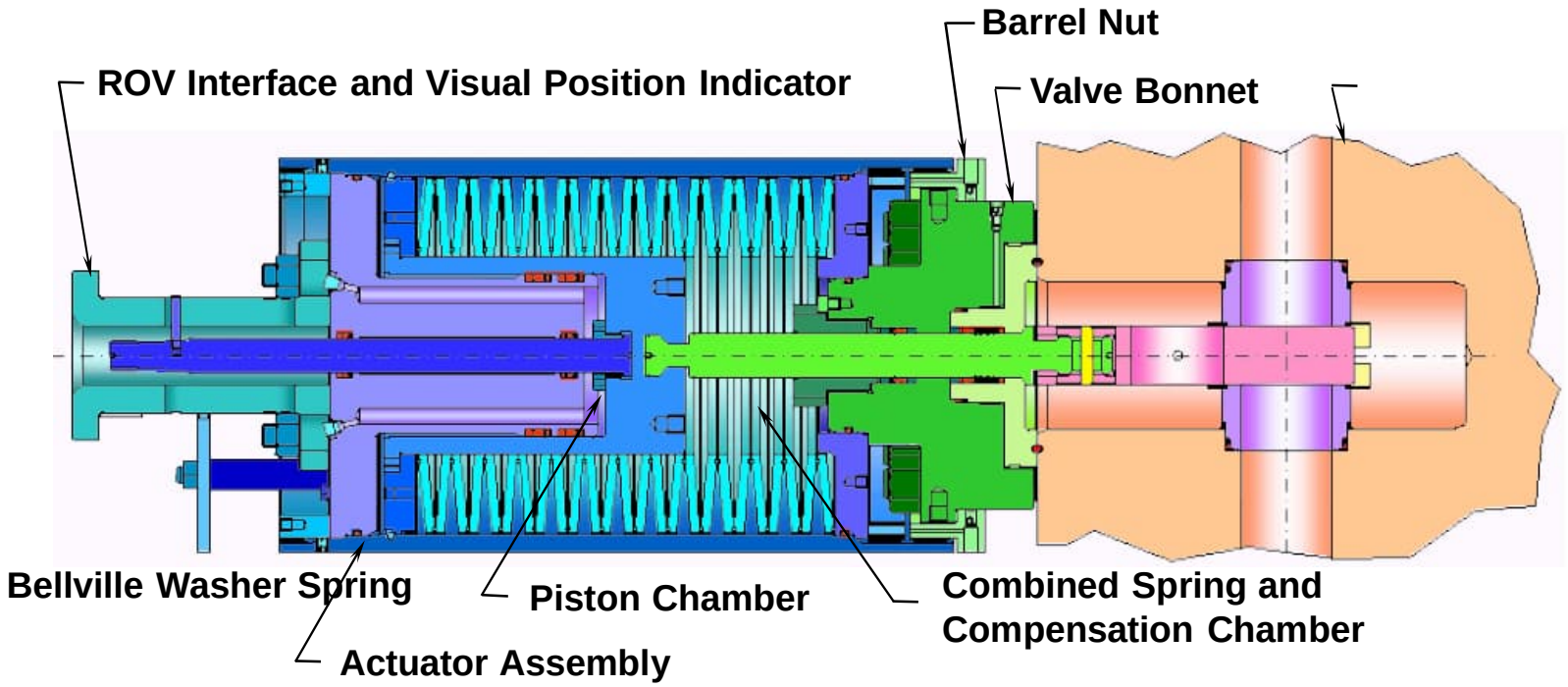


Valve Closing



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Valve Hydraulic Actuator



- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Valve Actuation Video

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[Subsea Hydraulic Directional Control Valve (HCV) | Oceaneering - YouTube]

- SUBSEA CONTROLS SYSTEM EQUIPMENT

Subsea Installed Equipment- Subsea Instruments

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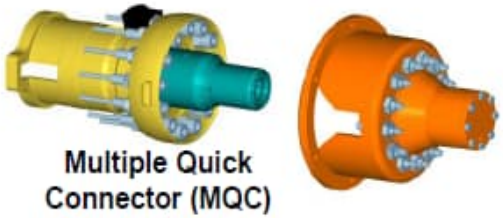
Tree & Manifold Mounted Controls



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Subsea Instrumentation Interface Standardisation (SIIS):

Defines the communication protocols between Subsea Sensors and the SCM

Analog Devices - SIIS Level 1

- Sensors with current connection to control system
- Complexity: low
- Data transfer rate: low

Digital Serial Devices - SIIS Level 2

- Relatively complex instruments with serial digital connection to the control system
- Complexity: medium
- Data transfer rate: medium

Ethernet Devices - SIIS Level 3

- Intelligent Seabed Devices (ISD) with TCP/IP Ethernet communication protocol to the control system
- Complexity: high
- Data transfer rate: high

- Speed
- Resolution
- Redundancy
- Fault Reporting
- Transparent Link

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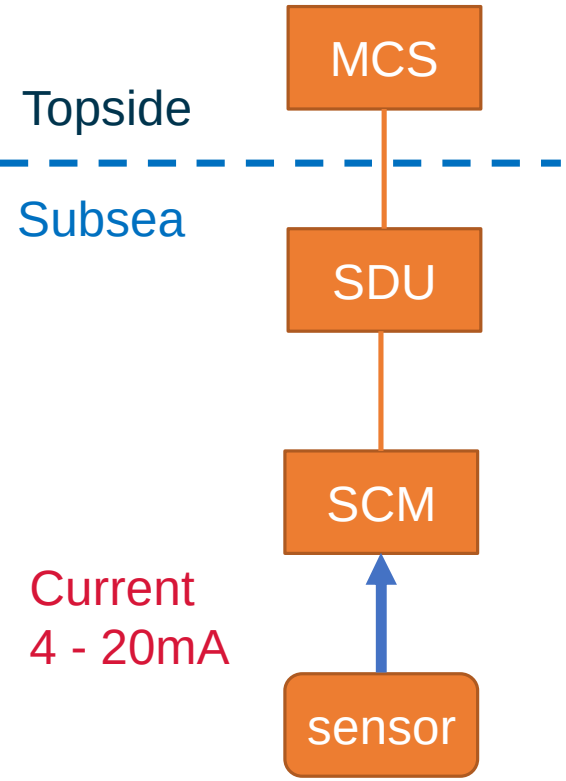
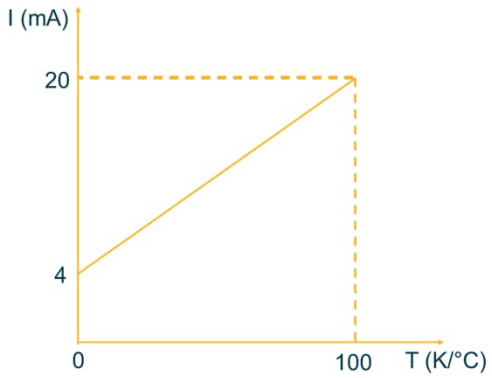
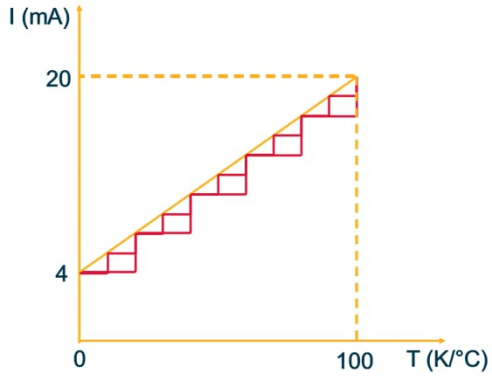
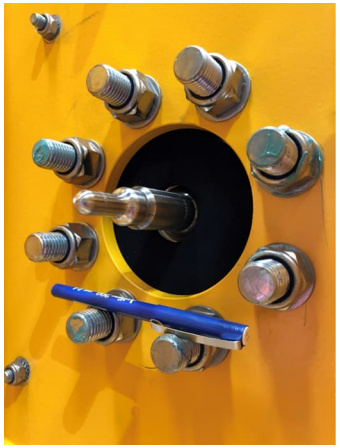
Analog Devices - SIIS Level 1







- Simple sensing devices, single-measurement
- 2 Wires, positive and negative terminals
- Voltage: 12 - 27V; Output Current: 3.8 - 20.5mA
- Calibrated over 4 - 20mA range
- Fault defined by reading outside of output range
- Resolution limited to 4096 bits (steps)
- Typical for choke position indicators



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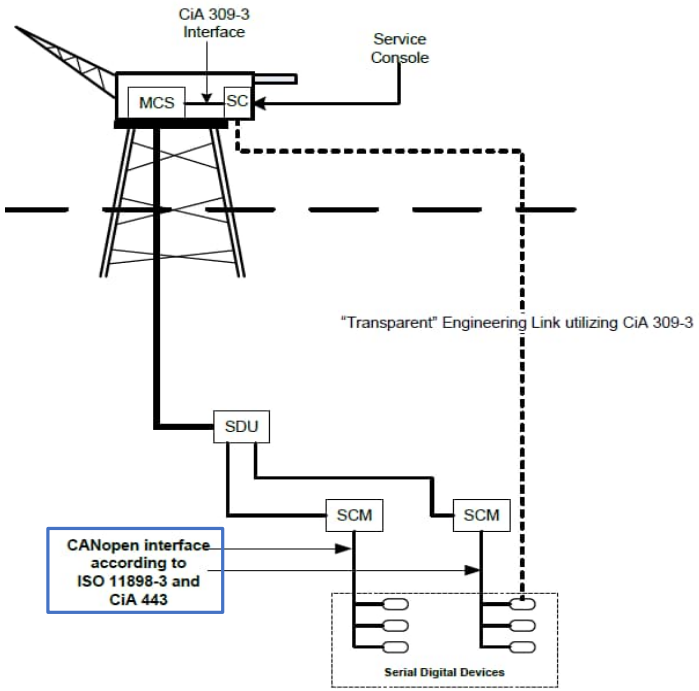
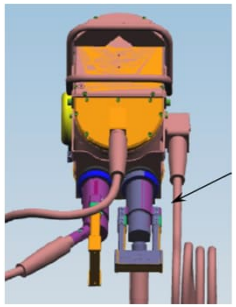
Digital Serial Devices - SIIS Level 2

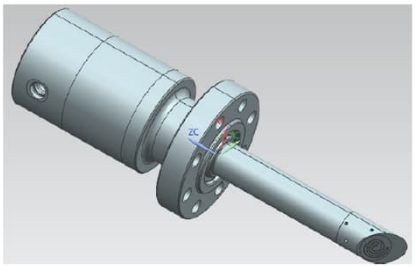


- Controller Area Network (CAN)
- Distributed System
- Default bit rates of 50 kbits/s
- Transparent links can be established for recalibration or software download
- High resilience to noise, low cost, reliable and simple wiring
- Prioritization of messages
- Latency time minimal



Electric Actuator

Acoustic Sand Detector



Erosion Probe

Ethernet Devices - SIIS Level 3

- Used for high resolution and/or complex, smart devices (Intelligent Seabed Devices (ISDs)) with high data throughput requirements
- IP/Ethernet interface, 12 pins required
- Minimum 115 kb/s data rate
  - Having multiple ISDs can drive requirement for fibre-optic backbone to facility
- Example applications:

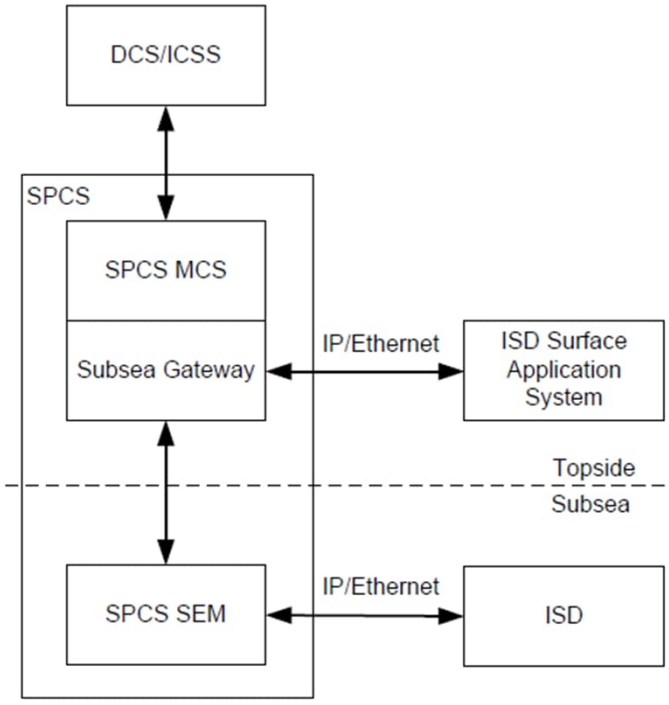


Figure G.1—SIIS Level 3 Overview

IWIS Interface Card

Multiphase pump

Future technology

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- Topside Located Equipment
  - Topside Vendor's scope of work and supply
    - CIU
    - UPS
    - MCC
    - PCS, SIS, ICS
  - Subsea Vendor's scope of work and supply
    - EPU, MCS
    - PHPU , TUTU
- Subsea Located Equipment
  - Subsea Distribution Equipment
    - Umbilical
    - UTA, UTH,SDU
    - HFL, EFL
  - XT and Manifold Mounted Control Module and Instrument
    - SCM
    - FM (SPFM, MPFM)
    - PT, TT, EP, ASD
- Hydraulic Fluid

• SUBSEA CONTROLS SYSTEM EQUIPMENT

Controls Fluid

Hydraulic fluid is assessed based on the following:

- ❑ Thermal stability
- ❑ Compatibility (with metals, seawater, thermoplastics, other control fluids, completion brines)
- ❑ Lubrication & wear
- ❑ Environmental rating
- ❑ Additives (hydrate inhibitor, corrosion inhibitor,etc)
- ❑ Compressibility

Mineral oil base control fluid:

- Improved lubricity, anti-corrosion and anti-freezing properties.
- Higher compressibility (slower long distance pressure response).
- Lower density than water, will cause seawater ingress at leak due to pressure differential.

Water based control fluid:

- Cost effective.
- Lower compressibility (better pressure response).
- Equal/higher density than water, will cause fluid ingress at leak.
- Fire resistant.
- More compatible with seawater.
- Better environmental compliance.

Agenda

- Introduction to Subsea Controls System
- Subsea Controls System Types
- Subsea Controls Systems Equipment
- Operational Challenge

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- OPERATIONAL CHALLENGE

Subsea Controls Degradation

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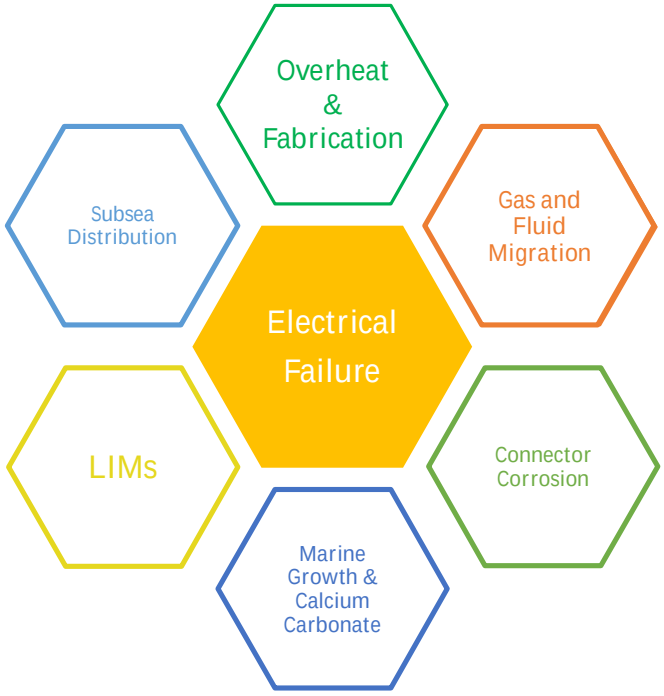
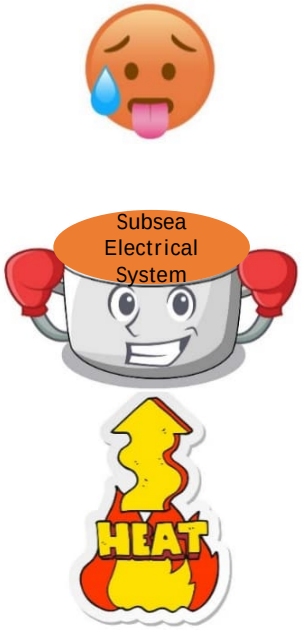
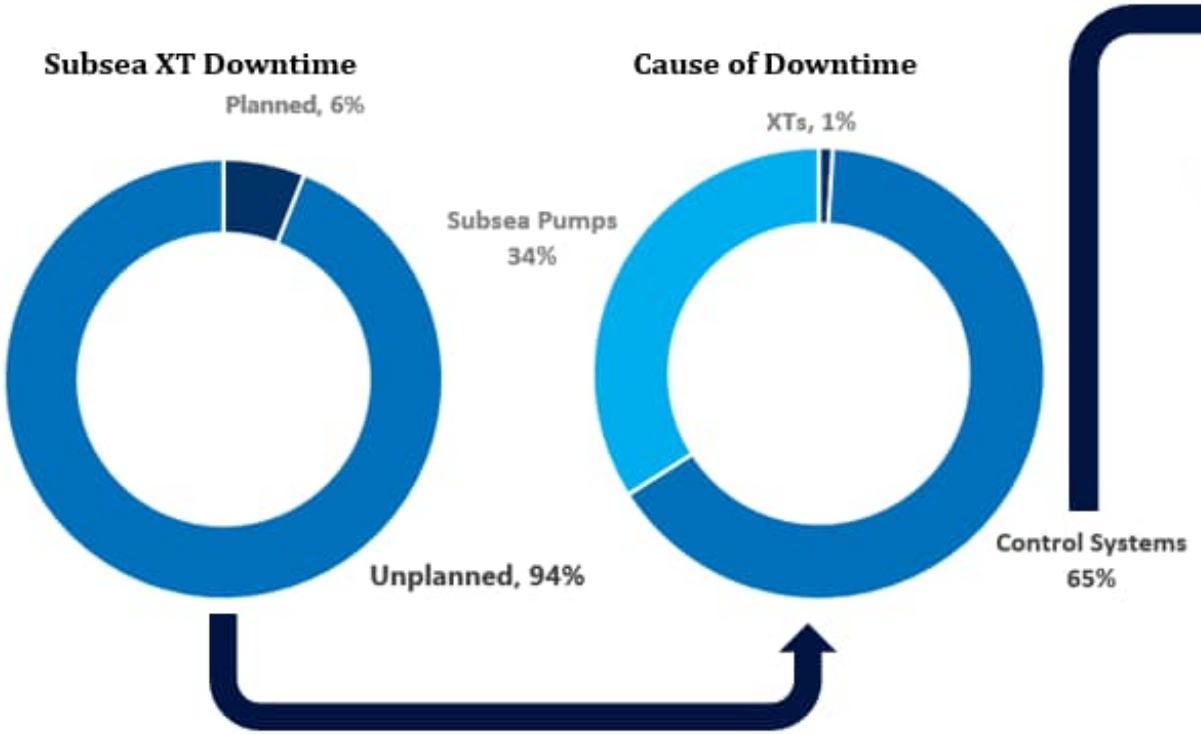
- Subsea Controls Degradation :
  - Operational Impact : Production lost
  - Intervention : Multiple ROV interventions
  - Production Loss and Intervention = OPEX





- OPERATIONAL CHALLENGE

Operational Downtime

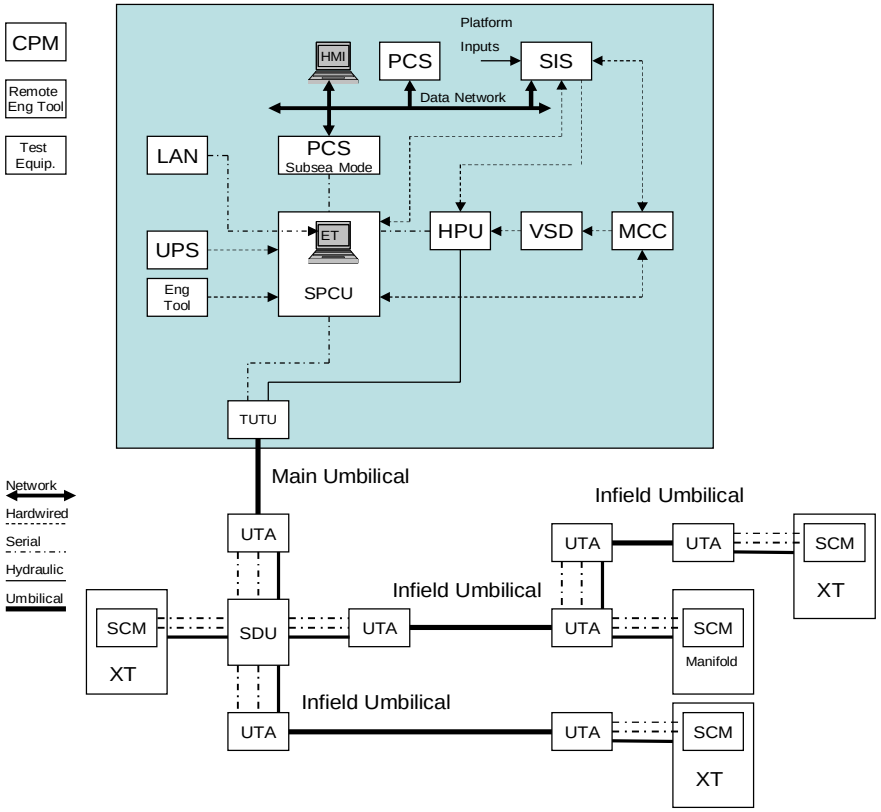


60% electrical distribution failures

14.1 days vessel time to remediate

- OPERATIONAL CHALLENGE

Subsea Controls Integration to the Host Facility



Improvements – Learnings/interfaces

- PCS / Subsea interface
- SIS / Subsea interface
- PHPU Operation and Maintenance
- Obsolescence Management – API17F
- Operational Technology OT
- Gas mitigation in Junction Boxes

- OPERATIONAL CHALLENGE

Marine Growth and Calcareous Deposit

• OPERATIONAL CHALLENGE

Line Insulation Monitoring System

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- Insulation Resistance (IR) degradation is a major cause of expenditure for subsea operations. Continuous monitoring of the IR levels of a subsea production controls system is in order to proactively remediate IR faults.

- Cables are purchased with a design life of 25 years. However, in shallower waters, they usually fail after 10 years, resulting in expensive interventions in order remediate the issues and maintain high system availability.

- OPERATIONAL CHALLENGE

Subsea Connector Termination

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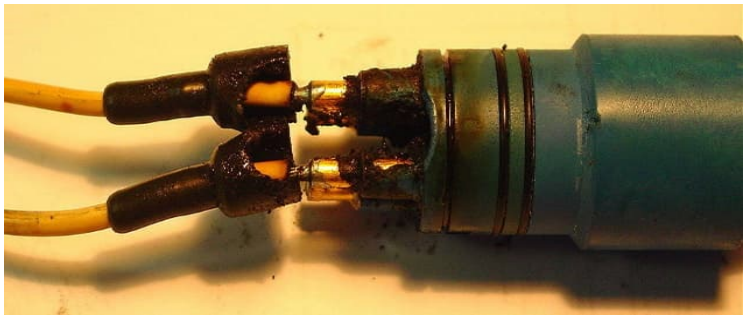

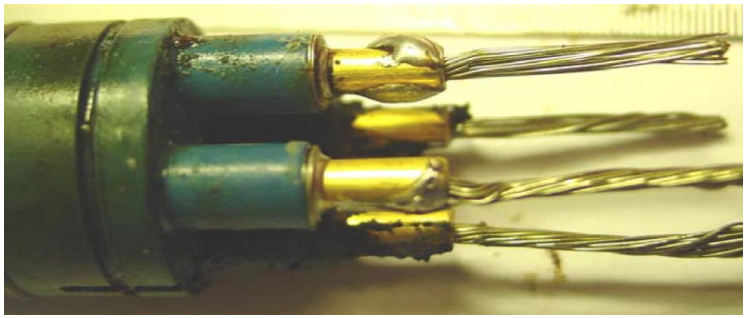

- OPERATIONAL CHALLENGE

Subsea Connector Termination

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Quality / Interface failure in Connector /Cable Termination

Improvement :

All Subsea Connectors must be terminated by the original subsea connector manufacturer using their most up to date procedures and processes.

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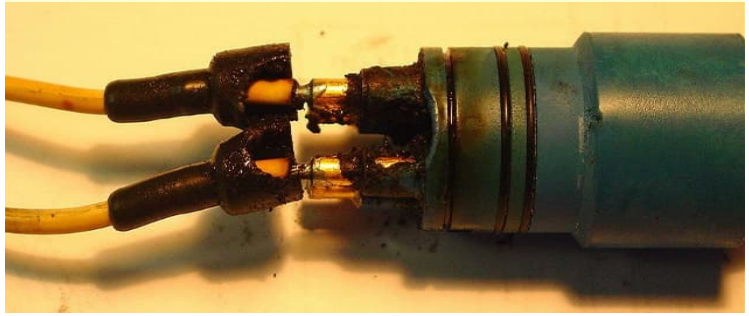

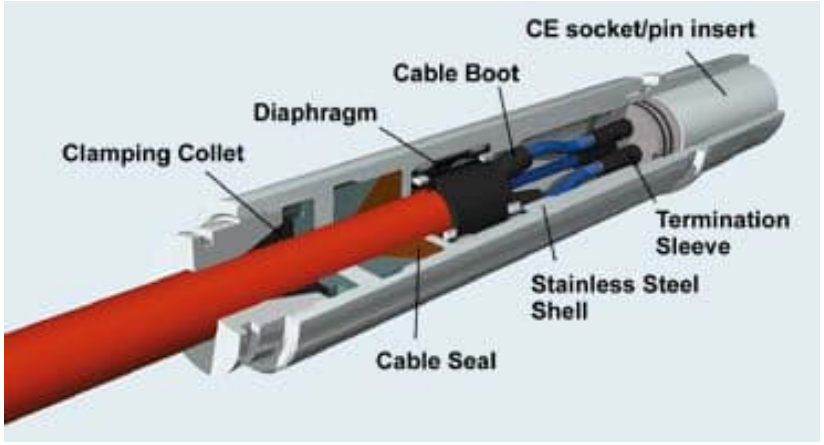

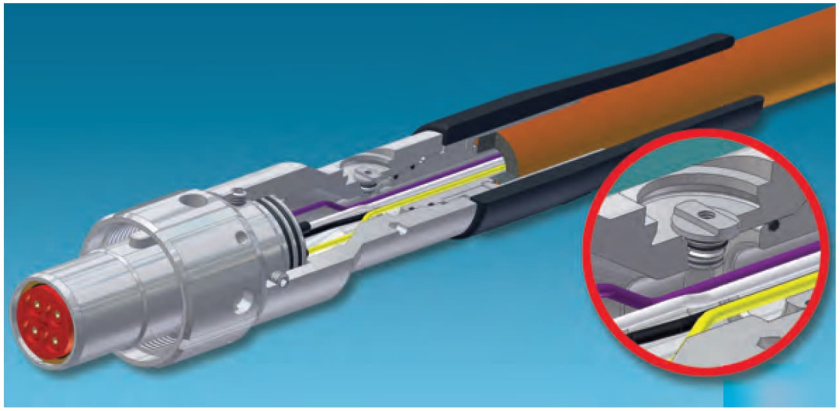

- OPERATIONAL CHALLENGE

Connector Corrosion and failure

Figure 26 – Corrosion to plug body

Figure 41 – Corrosion on internal surface and screw threads of back shell