

# **West of Shetland Case Study**

**Presented by:  
Mark Siegmund**

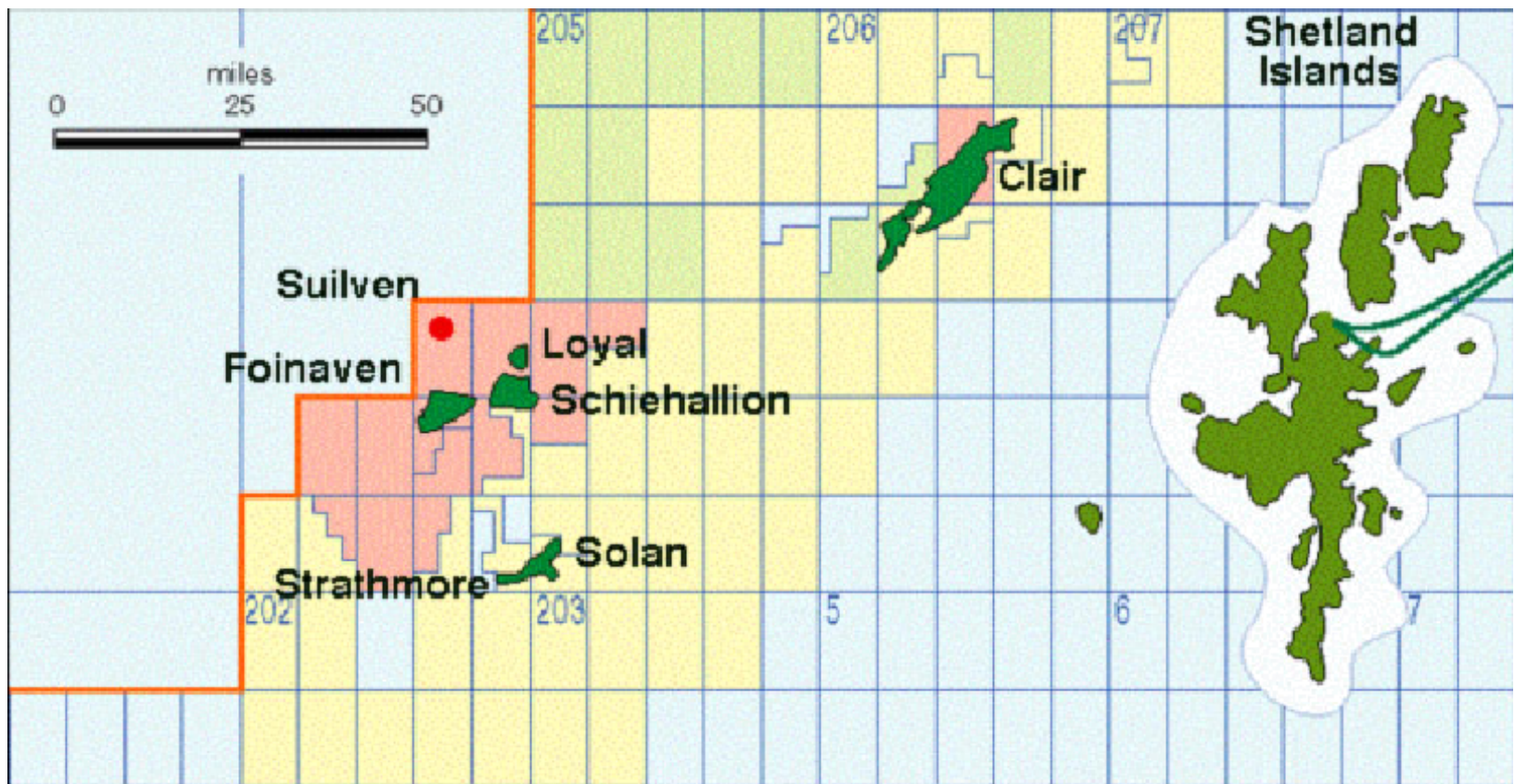
**Prepared by  
Multiple SUT Houston Volunteers**

# Subsea Operations Case Study

# WoS Overview

- Situated in Atlantic Ocean, 180km West of Shetland
- UKCS block 204
- Jointly owned by BP, Shell, Amerada Hess and others
- Over 650 million barrels reserves
- Fields discovered in early 1990s
- Foinaven started production November 1997, Schiehallion June 1998.

# WoS Overview - Location



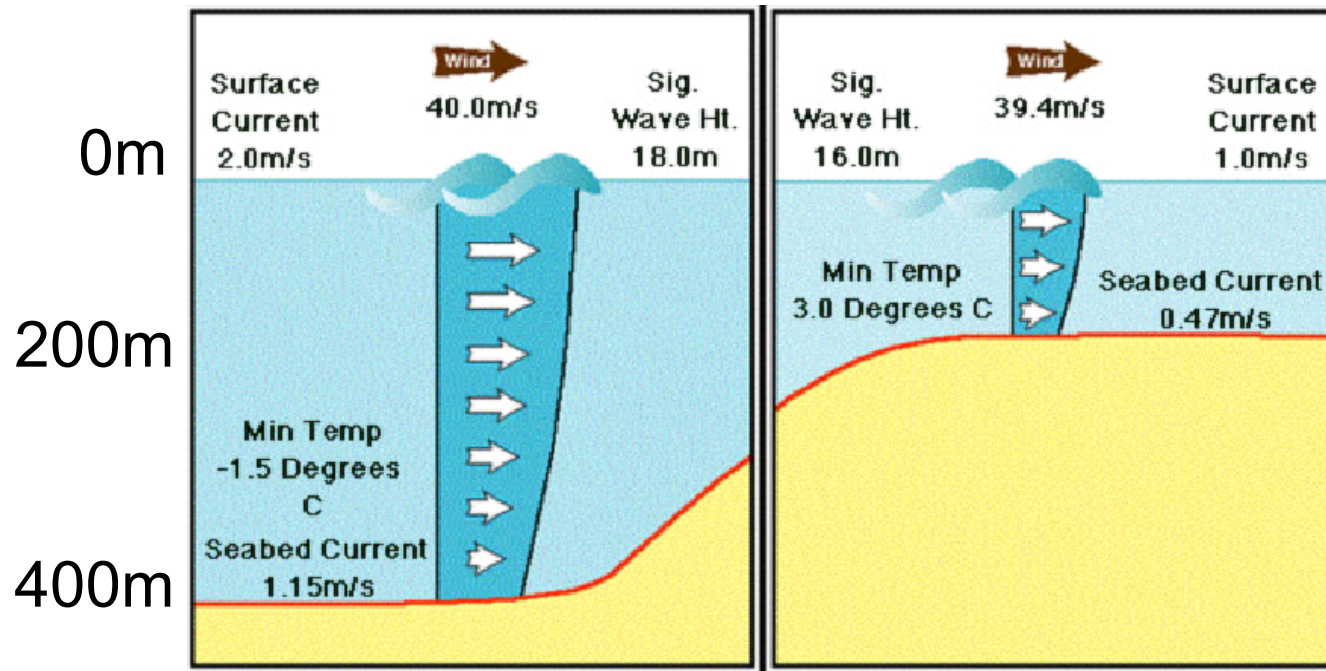


# WOS Overview - Challenges

- Water depth 350 to 500 metres
  - Formidable technical challenge
  - Too deep for divers
  - Totally reliant on unmanned intervention
- Remote from infrastructure of existing UKCS facilities
- Harsh environmental conditions and complex subsea currents
- Complex seabed architecture

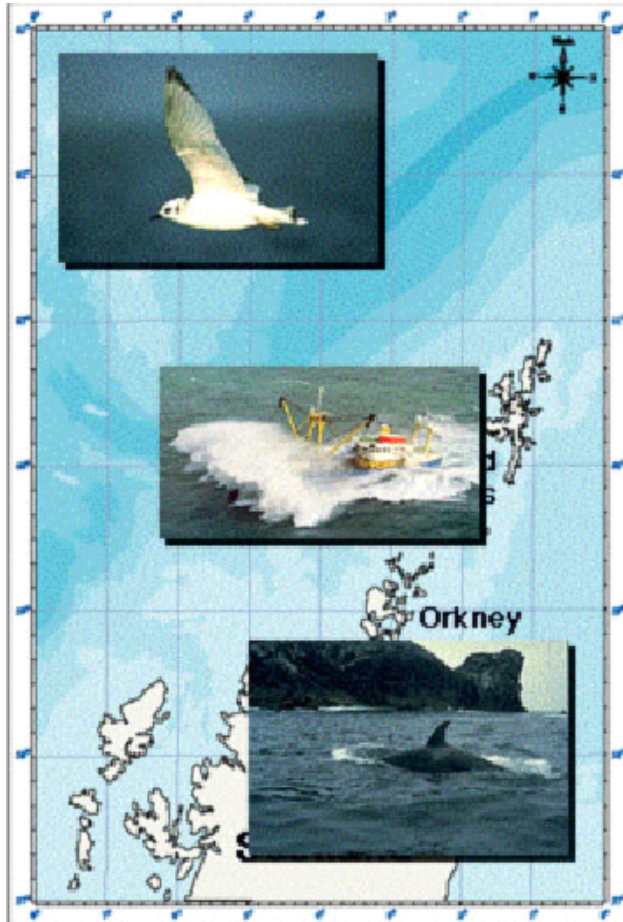
# WoS Overview - Environment

- Met ocean conditions & currents



West of Shetland (Foinaven) Vs. East of Shetland (Magnus)

# WoS Overview - Community



## Environmental Sensitivities

- SEABIRDS
  - internationally important colonies
- FISHERIES
  - offshore and inshore
- CETACEANS
- COLDWATER CORALS
- ISLAND COMMUNITIES
  - Shetland & Orkney



# Development Options

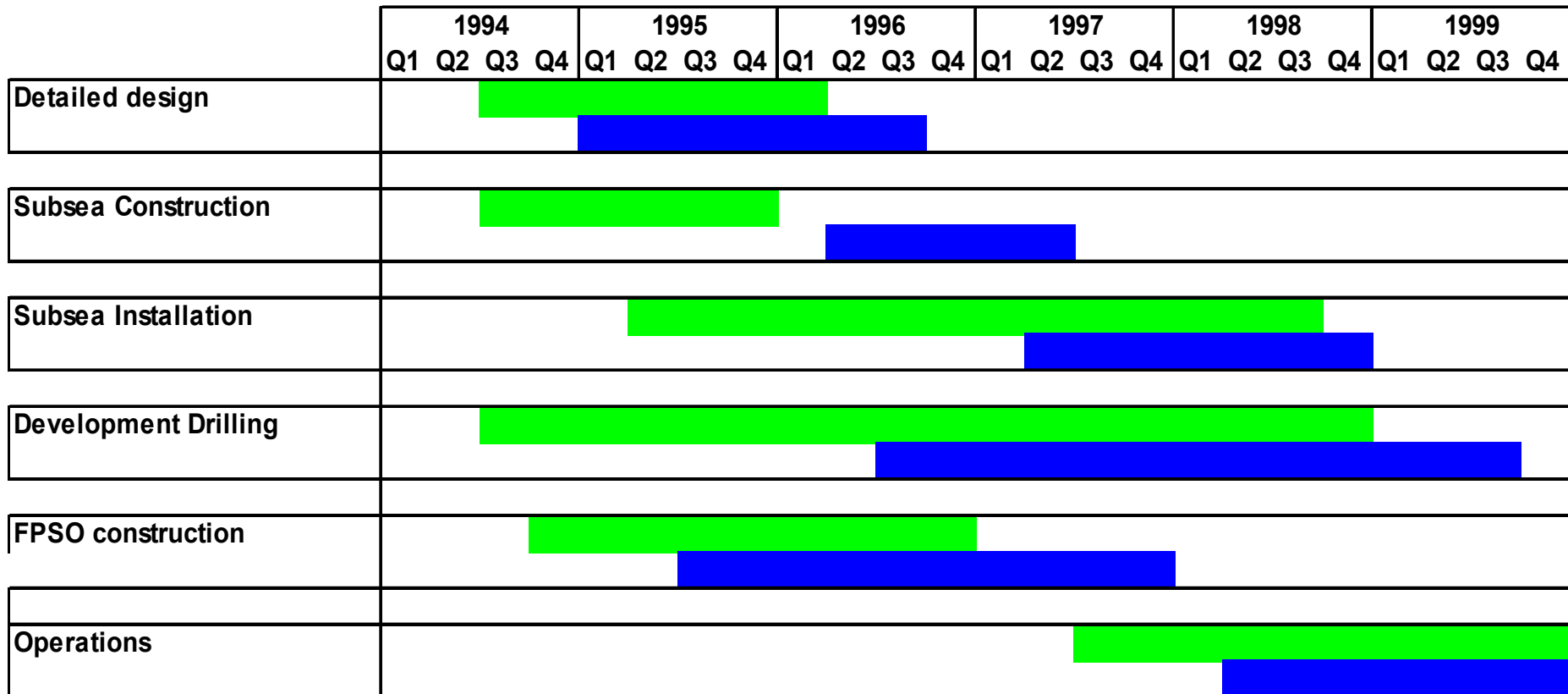
- TLP /Semi plus pipeline export –  
too expensive - pipeline needed approx 500kbpd to be economic
- Semi (MODU) plus FSU
- FPSO Conversion
- New build steel FPSO

# Development Selection

- The final selection driven by pace.
- The original Invitation to bid was based on a throughput of 55kbpd and a desire for early oil. FPSO conversion promised 18 months or less delivery. In the tender evaluation this was increased to 75kbpd (and later at sanction to 85Kbpd) . Given the pace demanded new build semi's were out and only the Steel Semi/FSU and the FPSO conversion were serious contenders
- FPSO conversion selected

# Project Schedule

 Foinaven  
 Schiehallion



# FPSO

- Uses proven technology
- Flexible - can accommodate changes in design basis
- Requires relatively short project schedule
- CAPEX requirement relatively low
- Oil storage inherent in design
- Can be relocated - minimize abandonment costs

# FPSO

## FOINAVEN

- Conversion of submarine support vessel Anadyr (Astano, Spain)
- Consortium built. Owned and operated by GNO - leased by BP
- Max throughput 120mbd
- Storage capacity 300,000 bbls
- Full thruster system
- Length 250m

## SCHIEHALLION

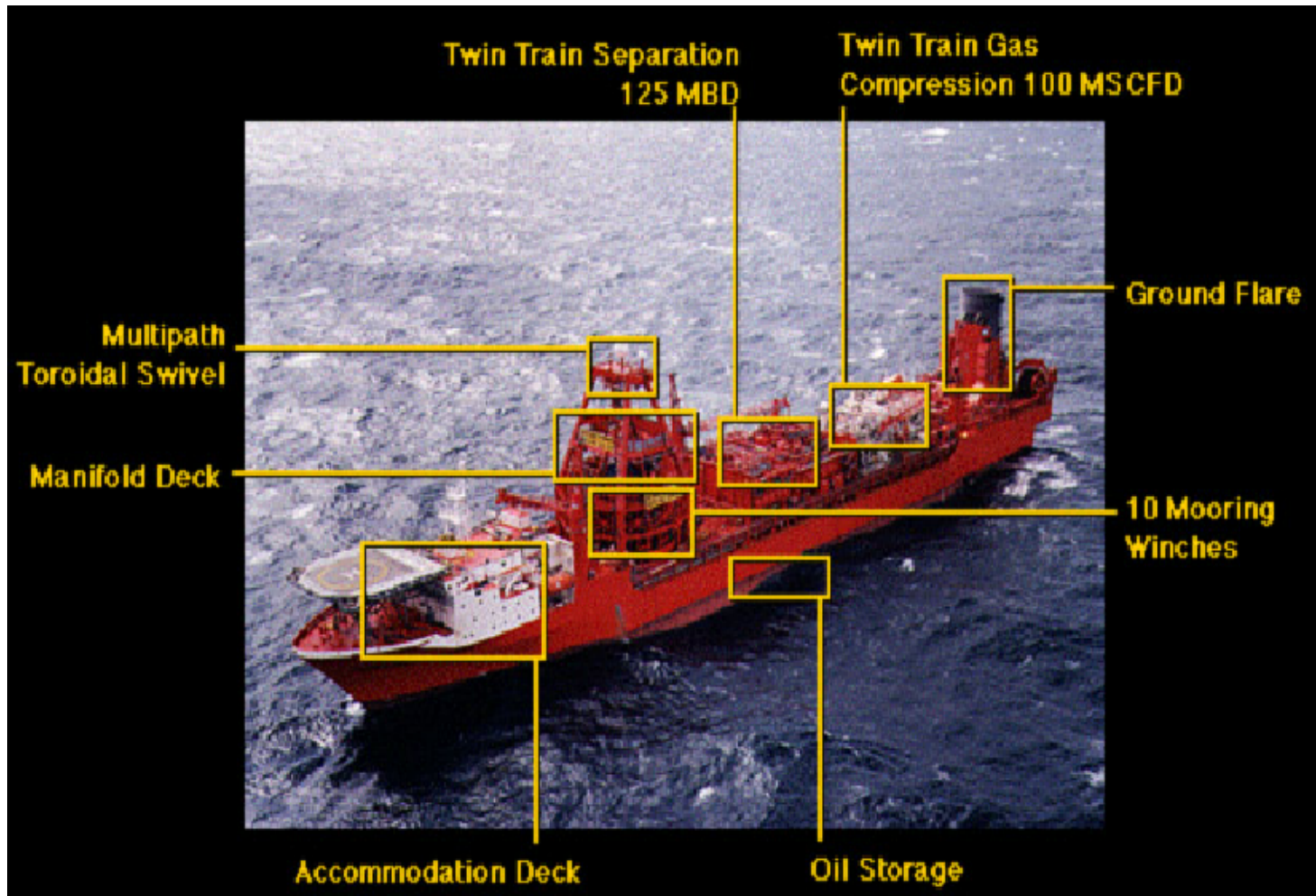
- New Build (Harland and Wolff, Belfast)
- Owned and operated by BP
- Max throughput 220mbd
- Storage capacity 950,000 bbls
- Limited thruster power
- Length 250m



# Foinaven



# Foinaven

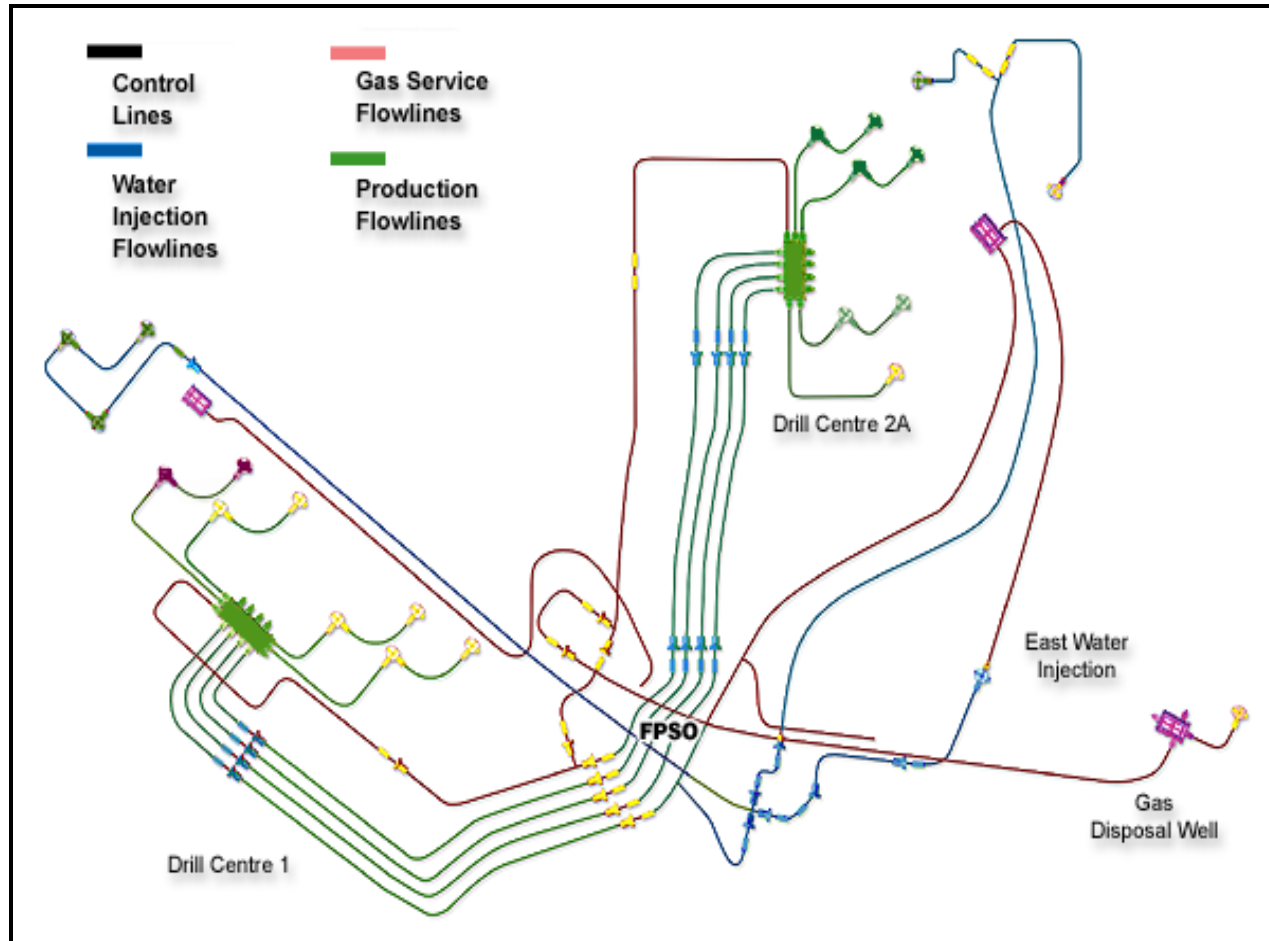




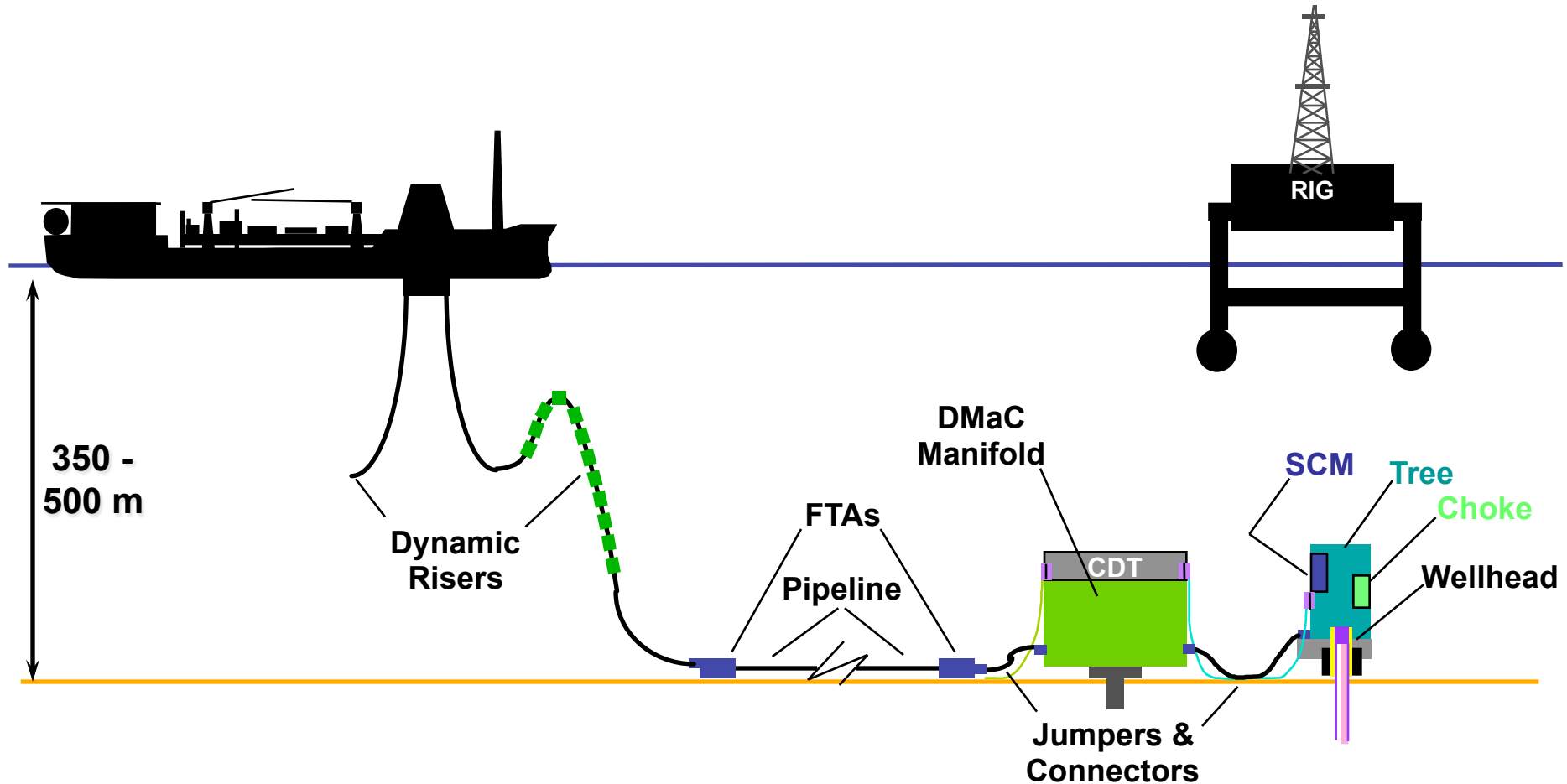
# Schiehallion



# Subsea Architecture

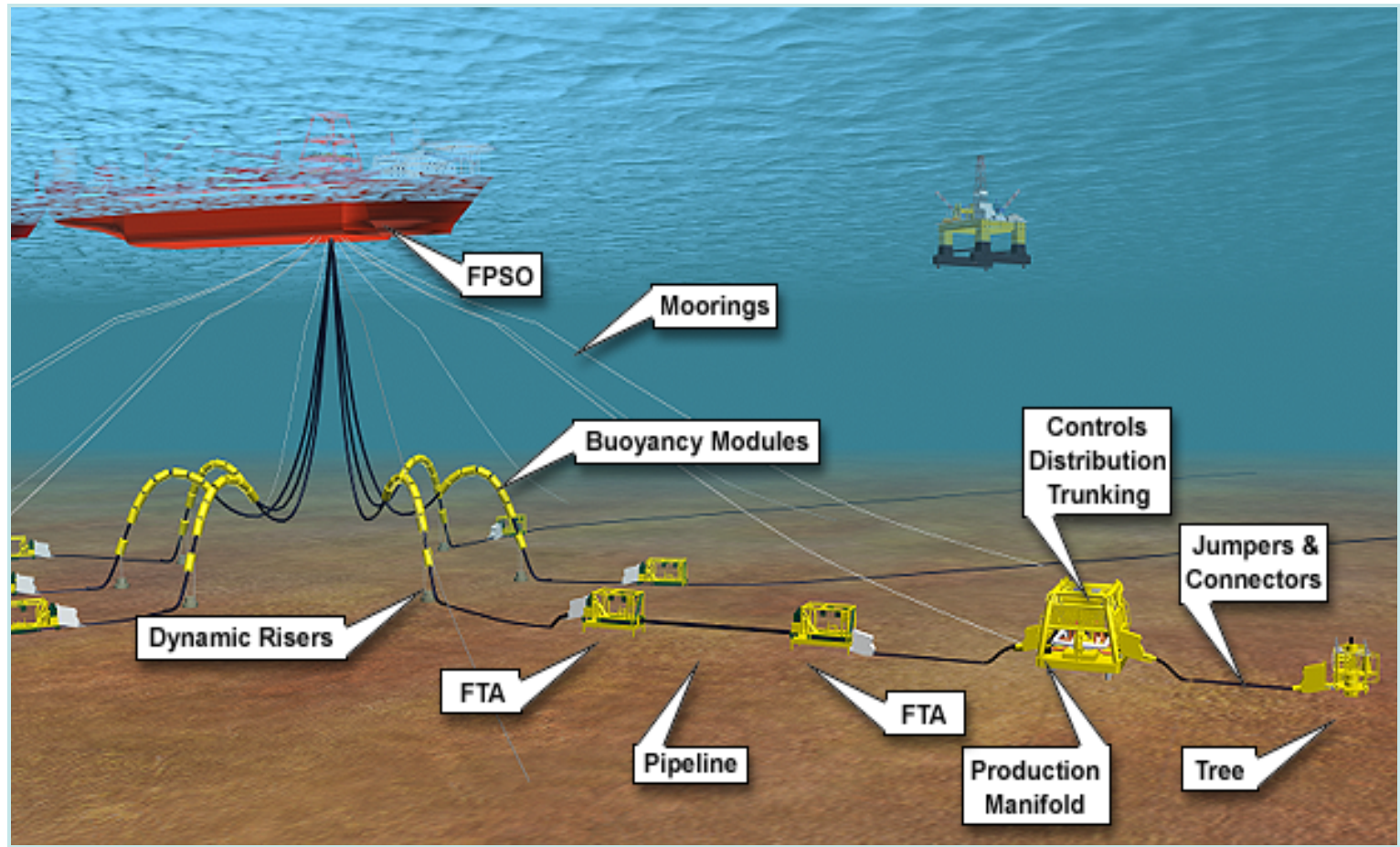


# Subsea Layout





# Subsea Facilities and Equipment



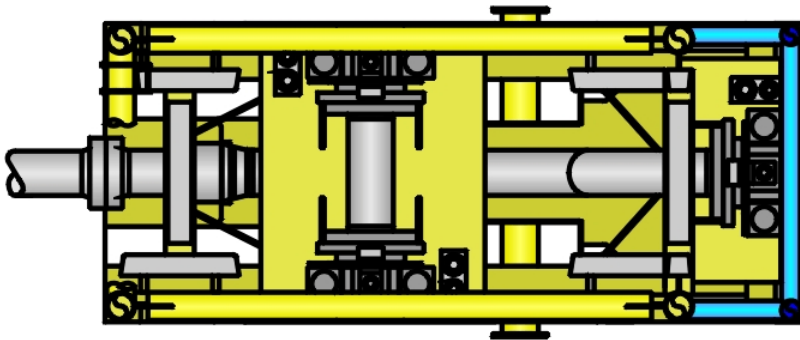
# DMaC Concept

## Diverless Maintained Cluster

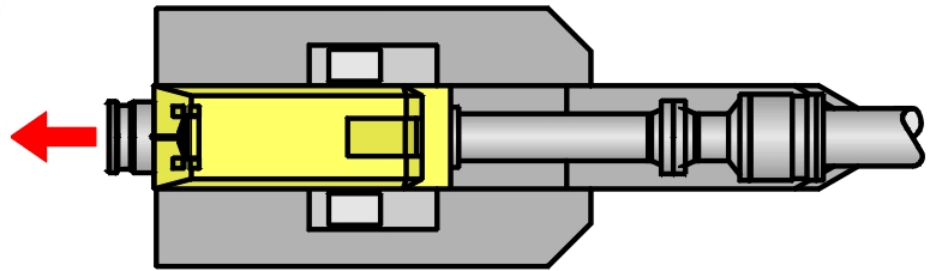
- Diverless pull-in and connection of flexible pipe
- Fly to place installation of umbilical jumpers
- Choke and control module changeout
- Manifold removable valve module (RVM) changeout

# DMaC Concept

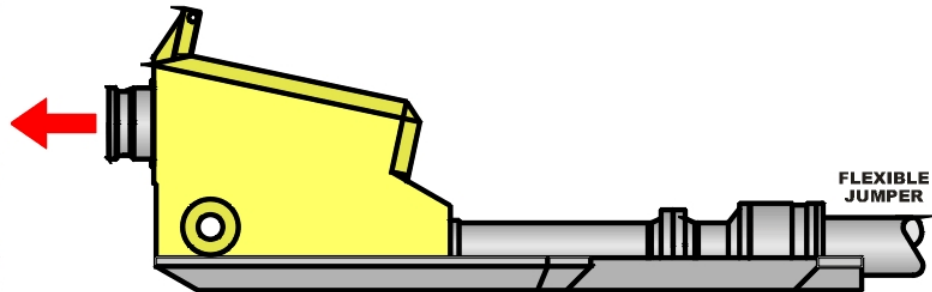
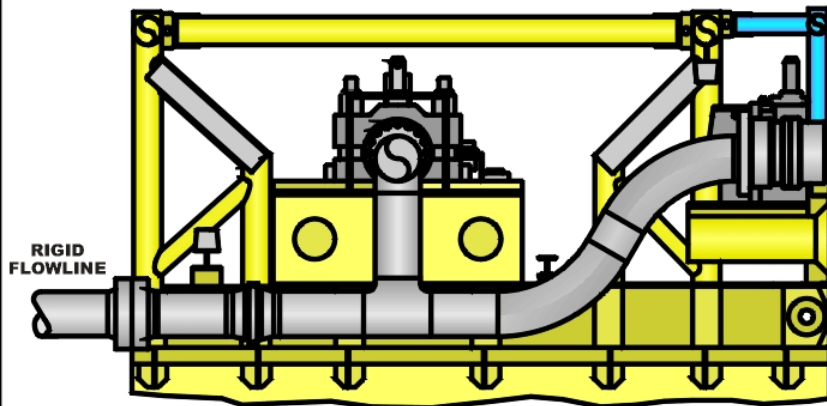
## TYPICAL DIVERLESS FLOWLINE CONNECTION



TYPICAL FLOWLINE  
TERMINATION ASSEMBLY



TYPICAL PULLHEAD ASSEMBLY



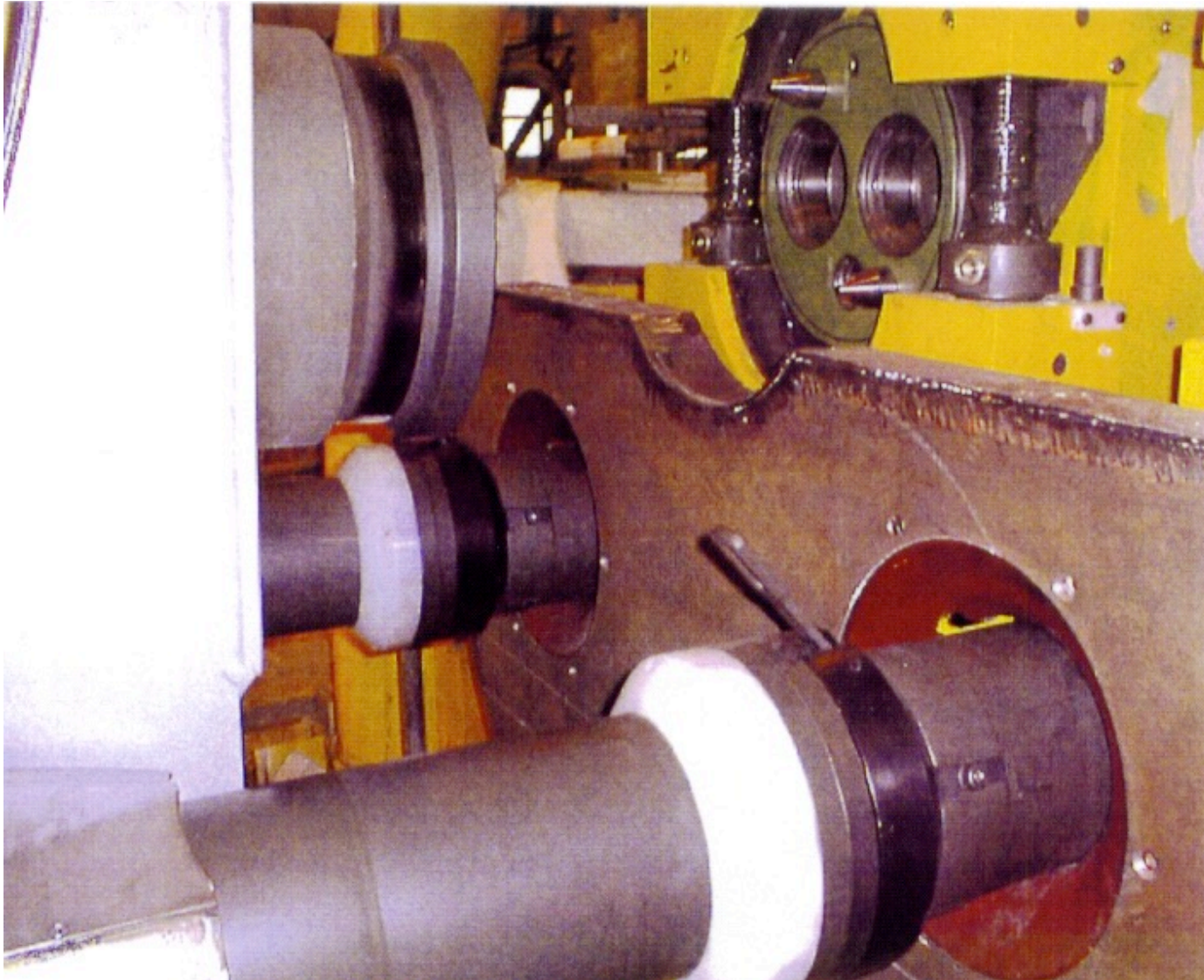


# DMaC Pull-in-Tool & ROV





# DMaC Tie-in

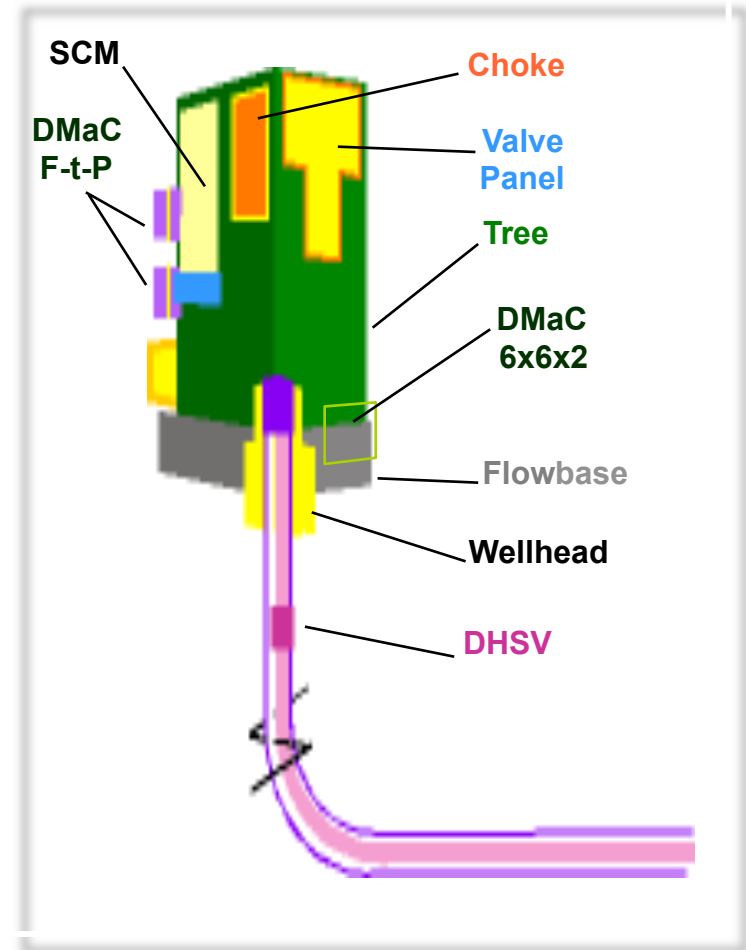
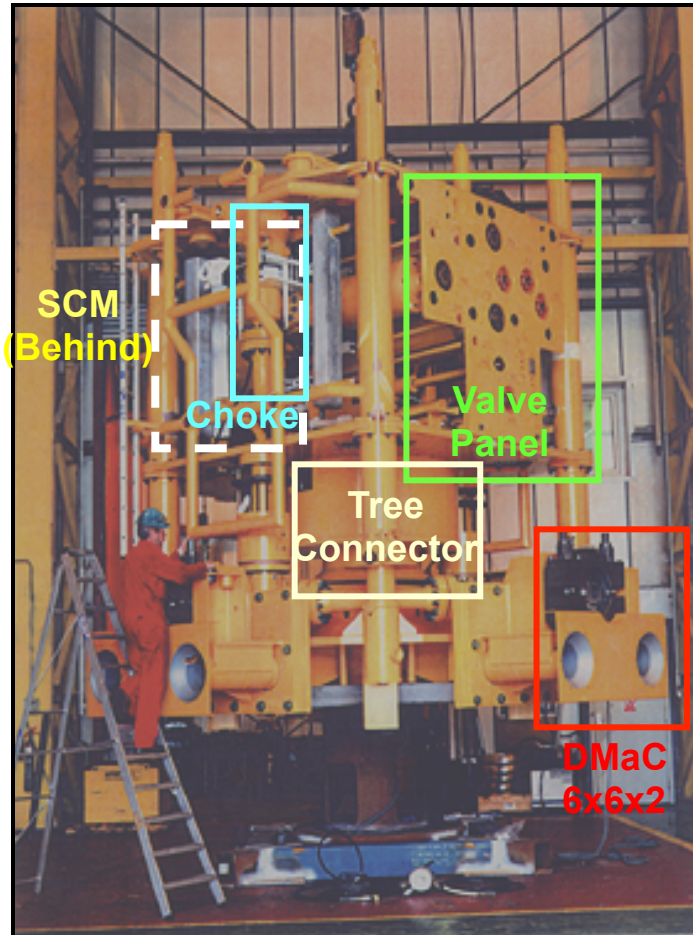




# DMaC “Fly-to-Place” Umbilical Jumper Connection



# Tree



# Development Features

- **74 Well Development**
- **11 Drill Centres**
- **12 Production manifolds**
- **6 Water injection manifolds**
- **3 Gas injection manifold**
- **66 Flowline Termination Assemblies**
- **155km Linepipe**
- **40km Static umbilical**
- **3km Dynamic Umbilicals**
- **17km Dynamic risers**
- **280 Fly to Place Connections**

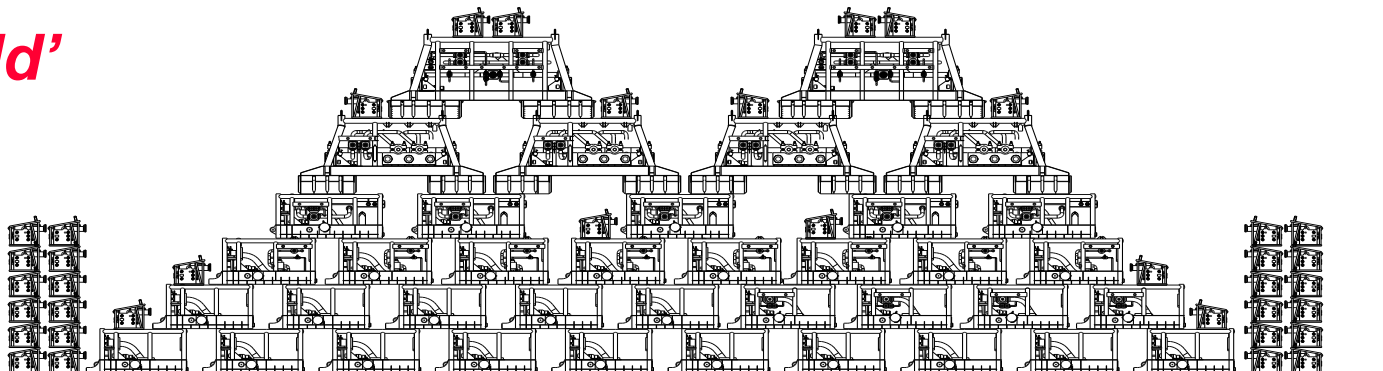
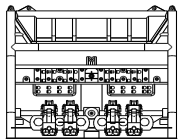


# Schiehallion Subsea Equipment

## Those *'Other Bits'*

(8 Production Manifolds, 6 Water Injection Manifolds, 1 Gas Injection Manifold, 36 FTA's)

### *'The Manifold'*

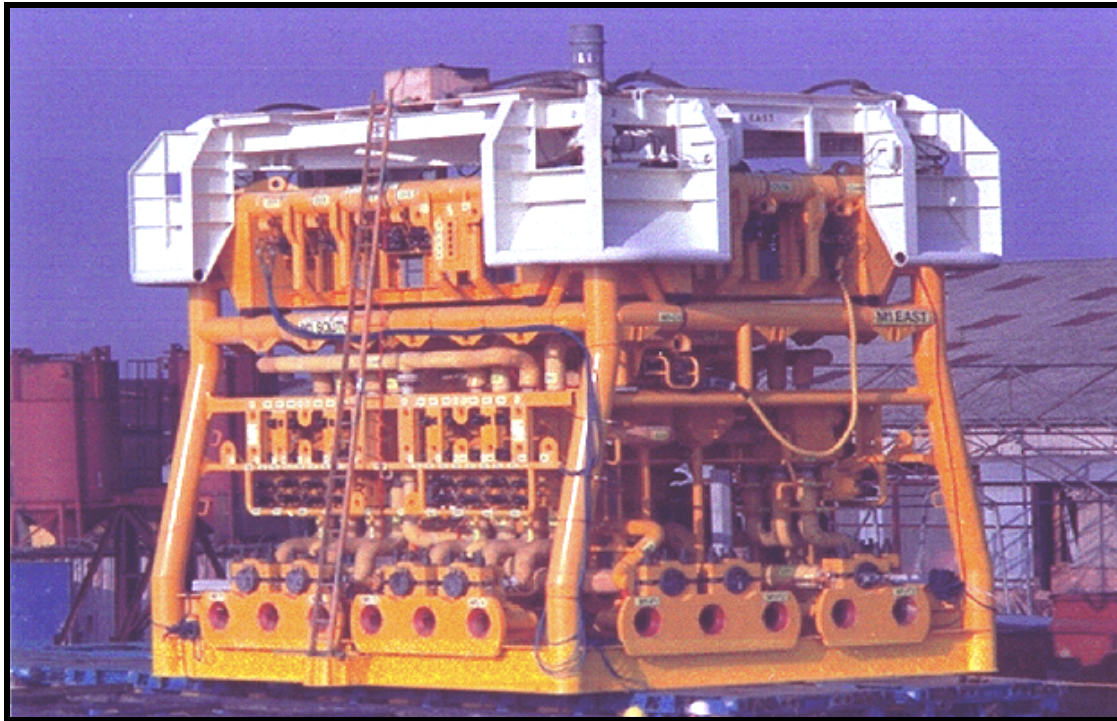


**Plus :** 21 Production XT's, 21 Water Injection XT's, 1 Gas Disposal XT, 85 Km Linepipe, 4 Km of Flexible Jumpers, 14 Flexible Risers, 16.7 Km Control Umbilicals, 2 Dynamic Umbilicals, 5.9 Km of Control Jumpers, 25 Control Structures, 146 DMaC Connections & Pullheads, 126 FTP Connections, 14 Suction Anchors, 25 Km of Mooring Lines

**Repeat all of the above for Foinaven**

# Foinaven Lessons Learned

## Central Production Manifold With Lift Frame



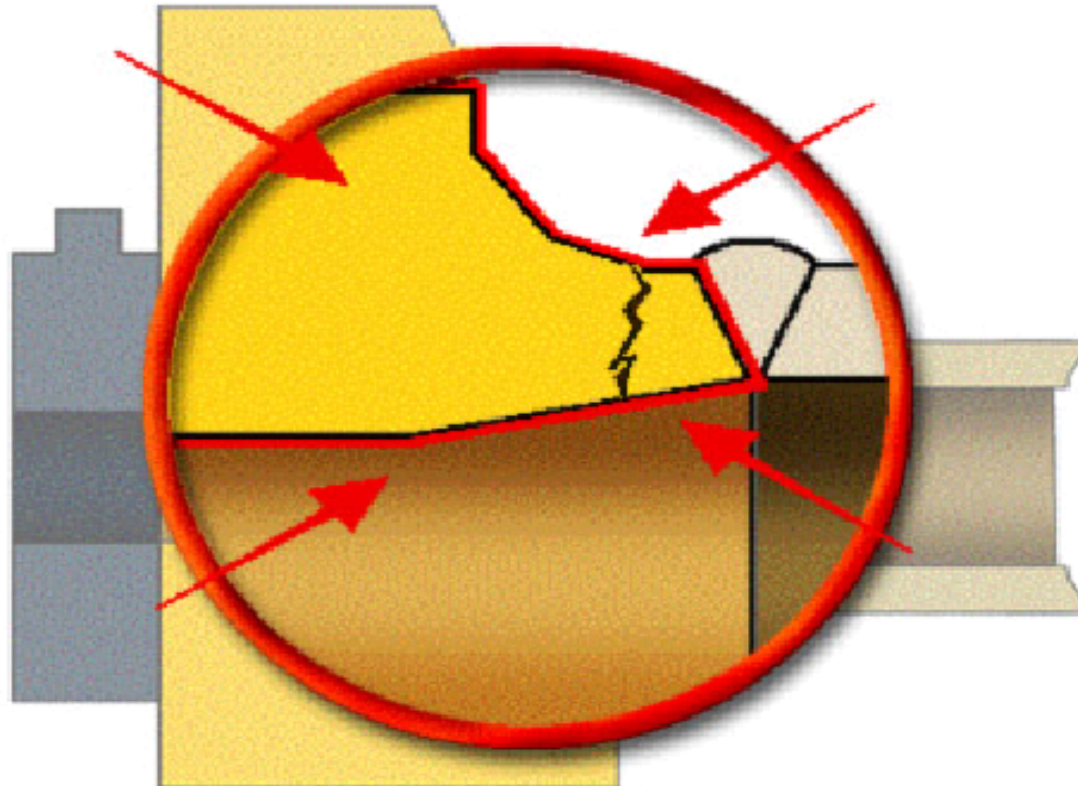
Dimensions 24ft x 36ft x 36ft high

# Manifold - Hubs

- Manifold and hubs made of super duplex steel.
- Cracks at hubs discovered during testing of installed manifolds.
- Manifold recovered and reworked to reduce strength of CP system and reduce build in stresses in pipe work.



# Manifold - Hubs

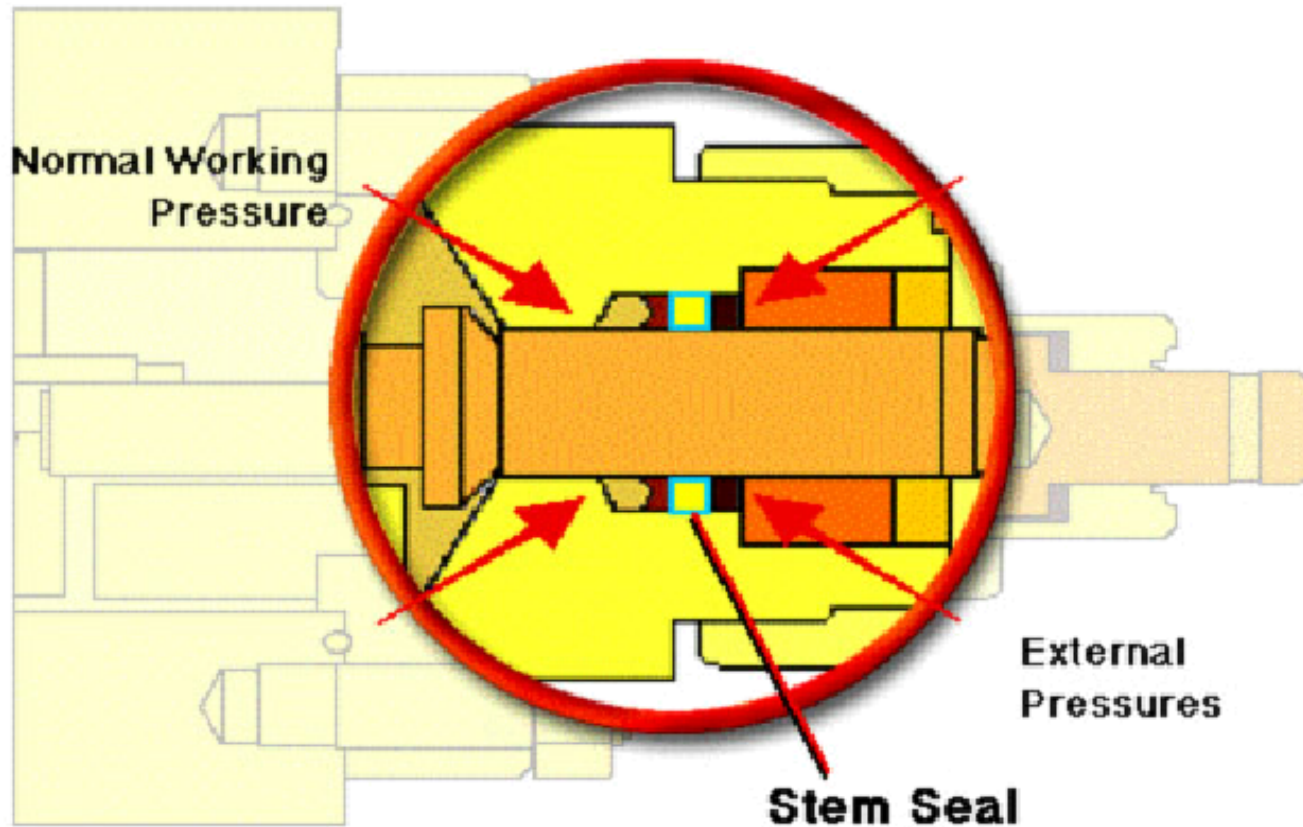


**Susceptable Material** **+** **Free Hydrogen from CP system** **+** **Combined Surface Stress Levels** **=** **Manifold Crack**

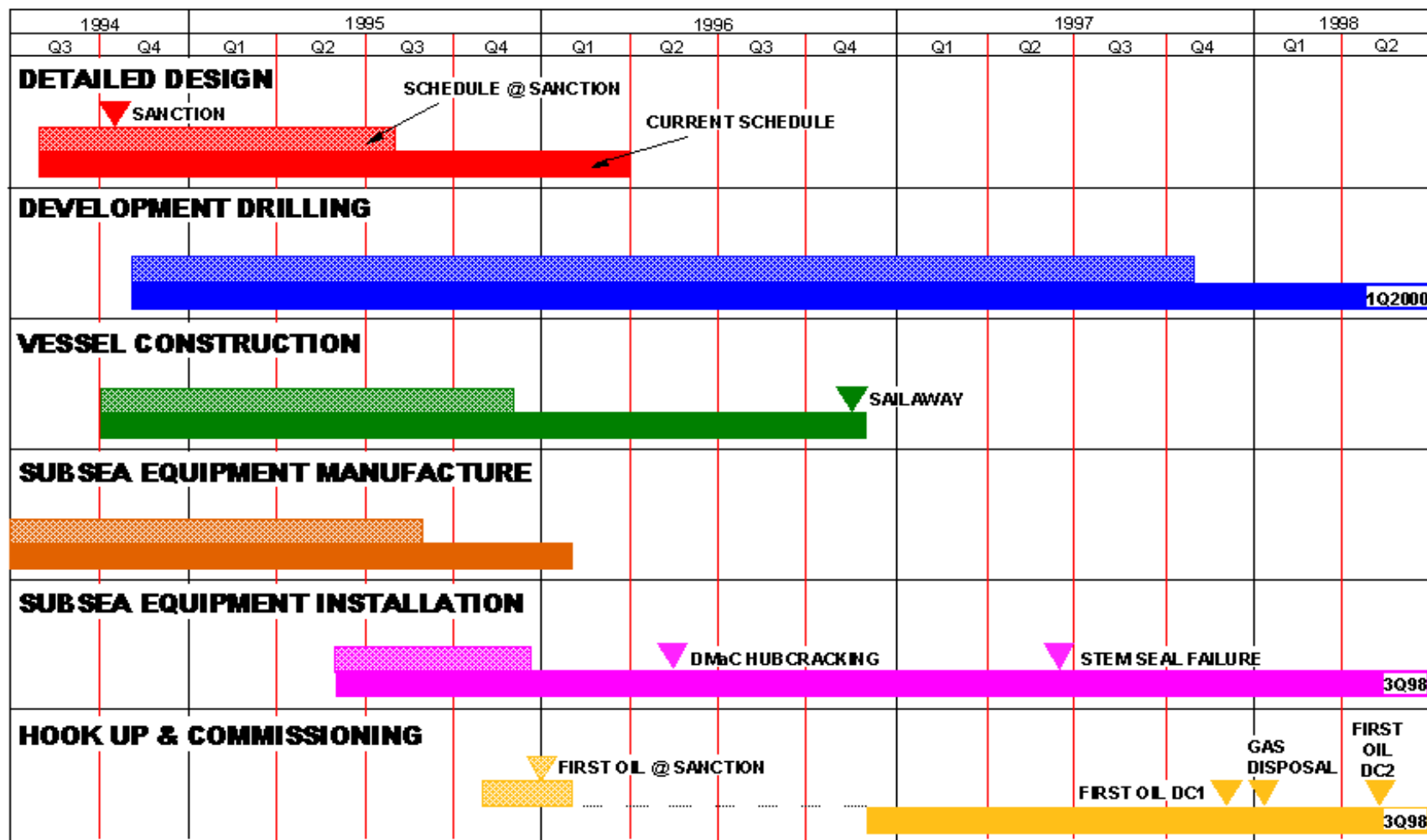
# Manifold - Stem Seals

- Deformation and leakage of valve stem seals discovered during testing
- Manifold installed with atmospheric pressure trapped inside
- Stem seals exposed to external seawater pressure
- Stem seals modified to eliminate problem during manifold re-work

# Manifold - Stem Seals

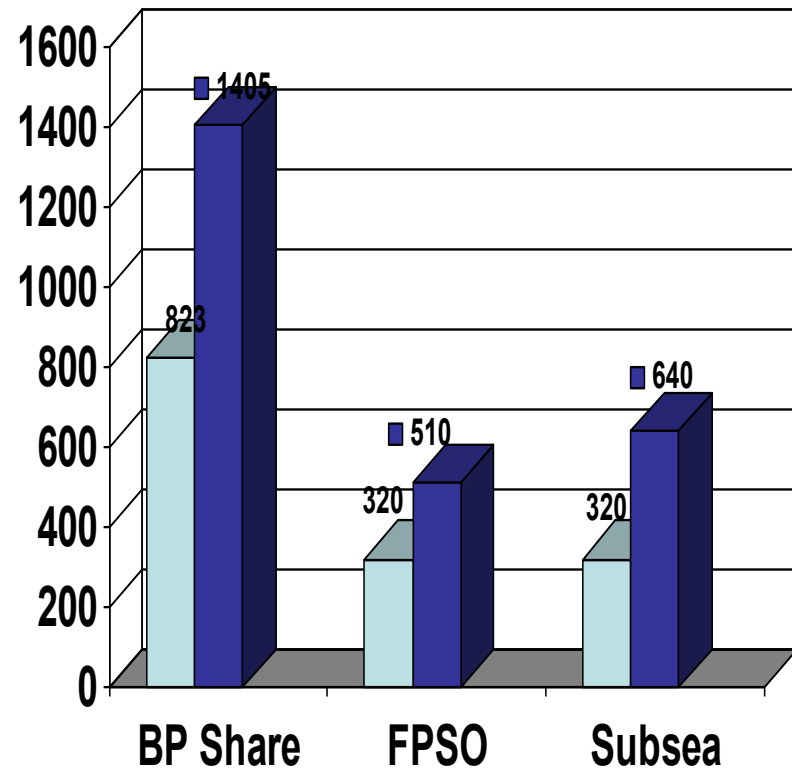


# Foinaven Development Schedule



# Impact

- Project delivery  
37 vs. 15 months
- Subsea CAPEX  
640 vs. 320 \$mm
- FPSO CAPEX  
510 vs. 320 \$mm
- BP share  
1405 vs. 823 \$mm



# DCV's



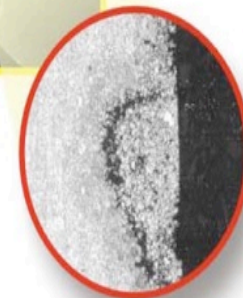
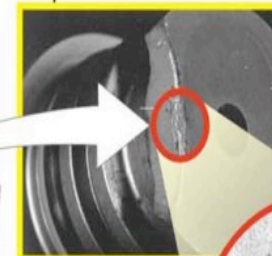
Scanning electron micrograph showing the extensive loss of metal from surface of balls used in pilot stage of Directional Control Valve



**Directional Control Valve (DCV)**

Used to direct water based hydraulic fluid to tree and valve manifold actuators

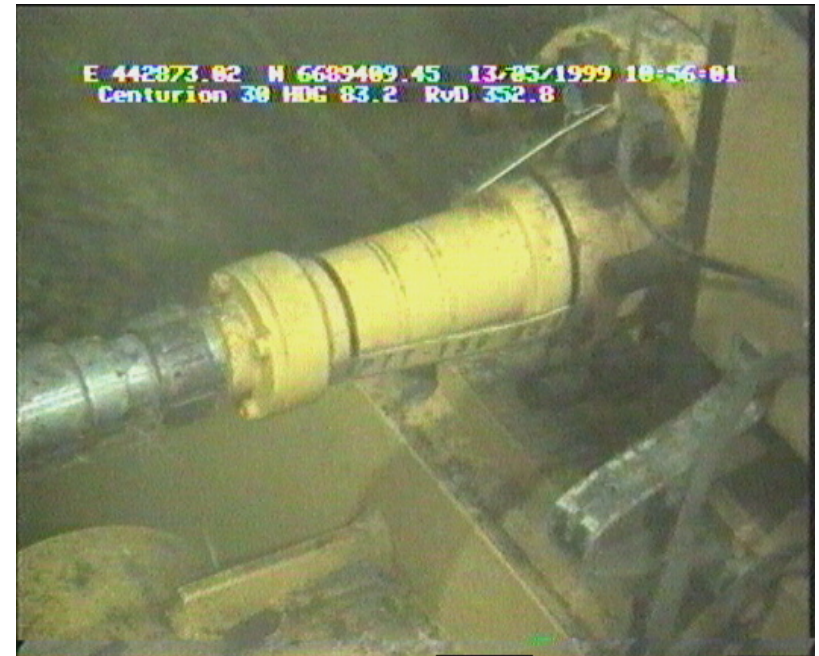
Cracked seal plate caused by Hydrogen Induced Stress Corrosion Cracking



**Micrograph showing intergranular corrosion attack**



# Tree Sensors

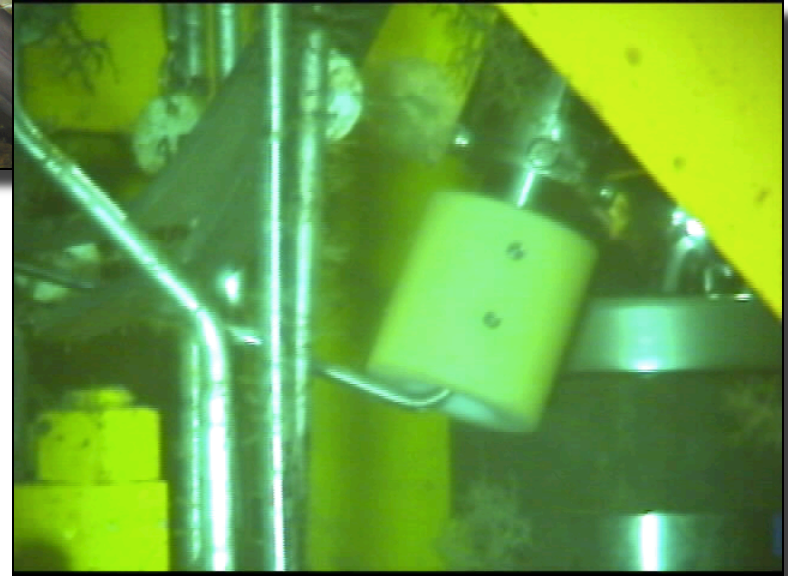
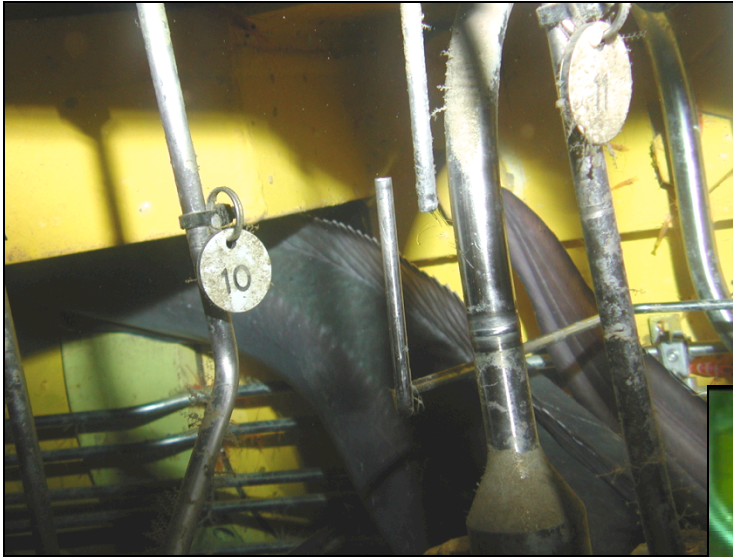


# Connectors / Penetrators





# Choke Hydraulic line failure

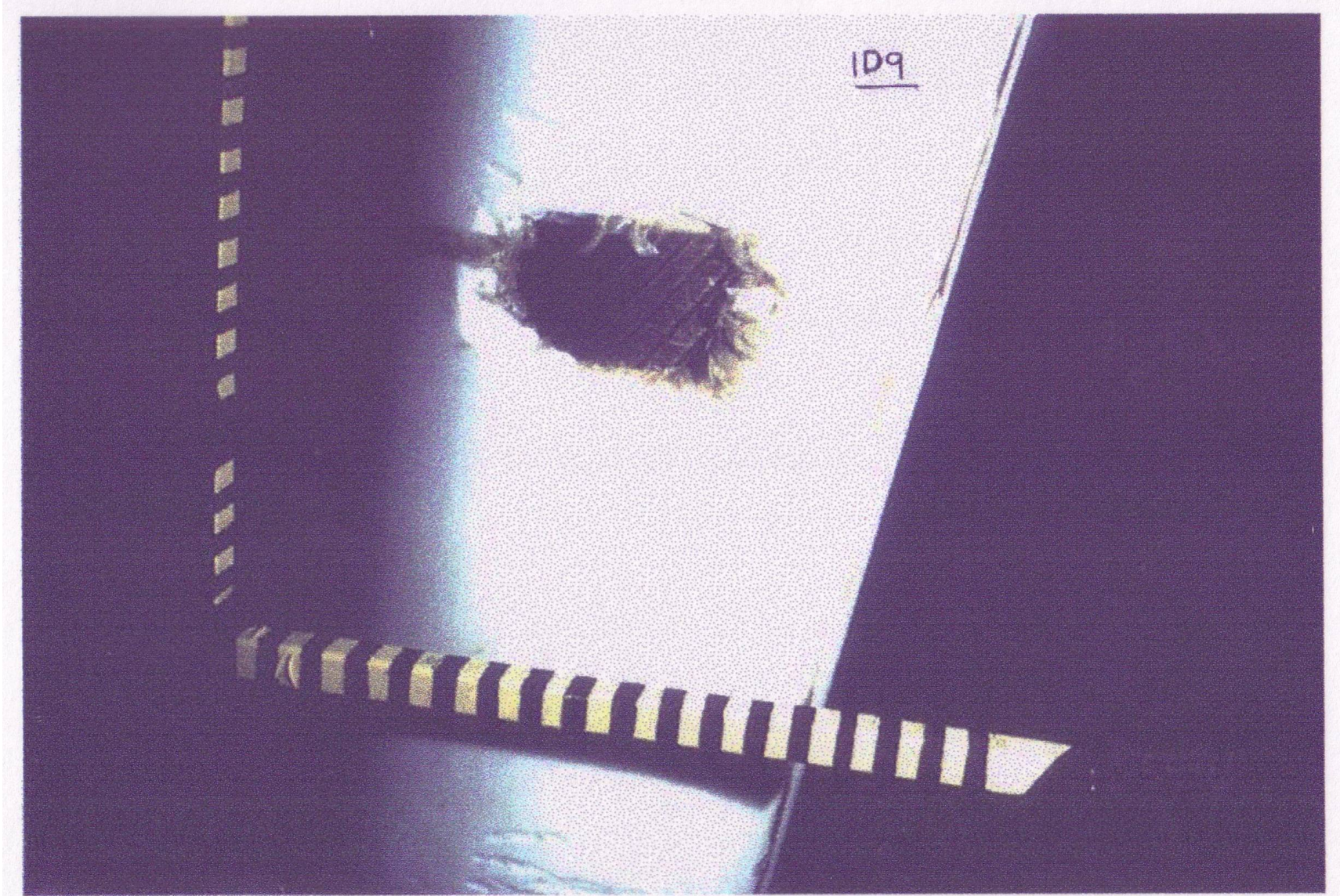


# Hydraulic Coupler Circlips





# Riser Damage



# Conclusion

- Foinaven and Schiehallion are amongst the most successful subsea producing fields in the BP portfolio with over 120 wells drilled
- The projects have been a significant source of learning given the early set backs
- Unique set of failures was a catalyst to launch the BP subsea reliability initiative – BP ETP's & API 17N
- WOS remains a source for continued Innovation and Lateral thinking – eg. Drill Through Trees

.....Questions?