

# Subsea Oil & Gas Developments



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UNIVERSITY *of* NICOSIA

# Overview

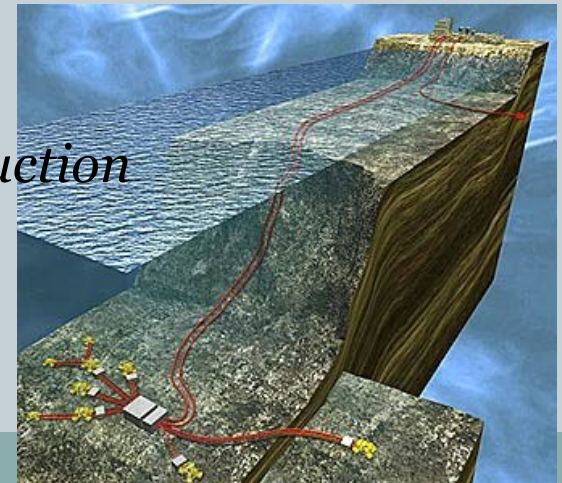
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- Subsea systems & concise history
- Subsea layout & architecture
- Subsea layouts
- Subsea field architecture
- Subsea components & installation
- Improved recovery: subsea compression & separation

# Subsea systems

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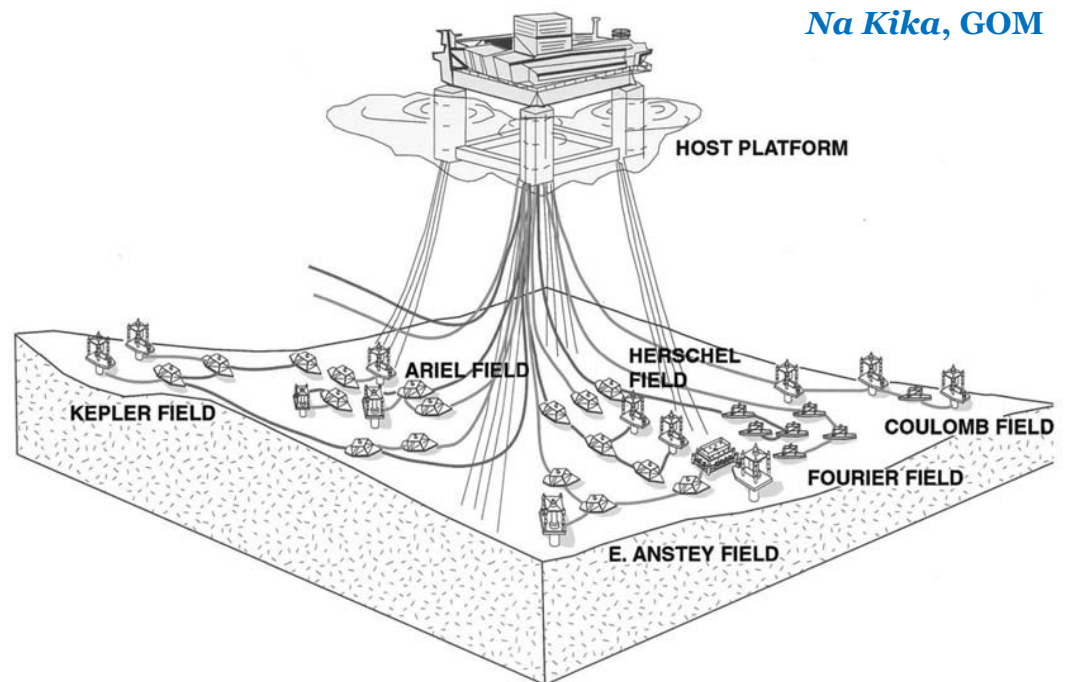
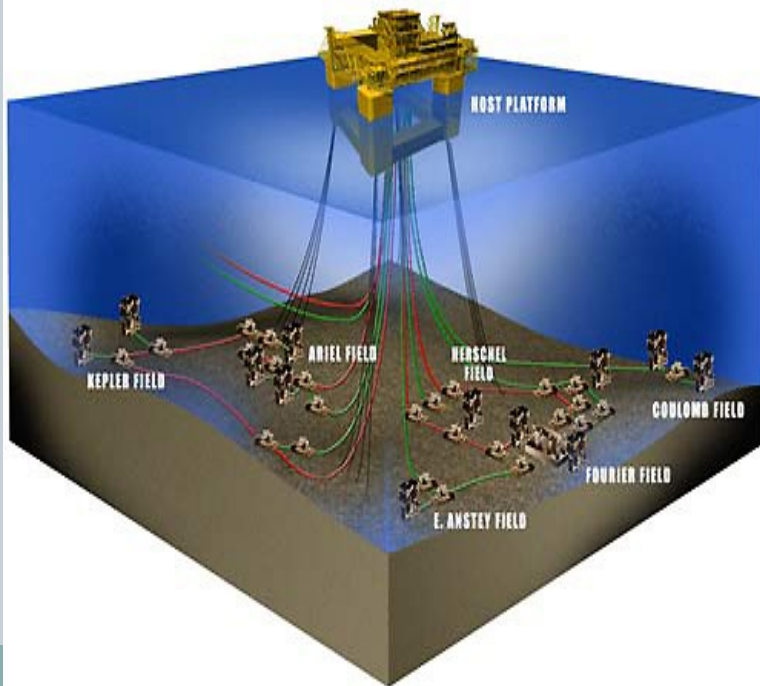
- Subsea development connected to:
  - a) Floating facility (FPSO, TLP, Spar, ...)
  - b) Onshore (eg, Ormen Lange)
  - c) Fixed foundation installation (Compliant platform, gravity based platform)
- No water depth limitations...
- Costly & time consuming to install or replace
- Distance btw components is measured via acoustic transponders, lasers, calibrated steel tapes
- Platform operations are manned
- 'Platformless' development is unattended
- Note distinction btw offshore *exploration* & *production*



# Concise history of subsea systems

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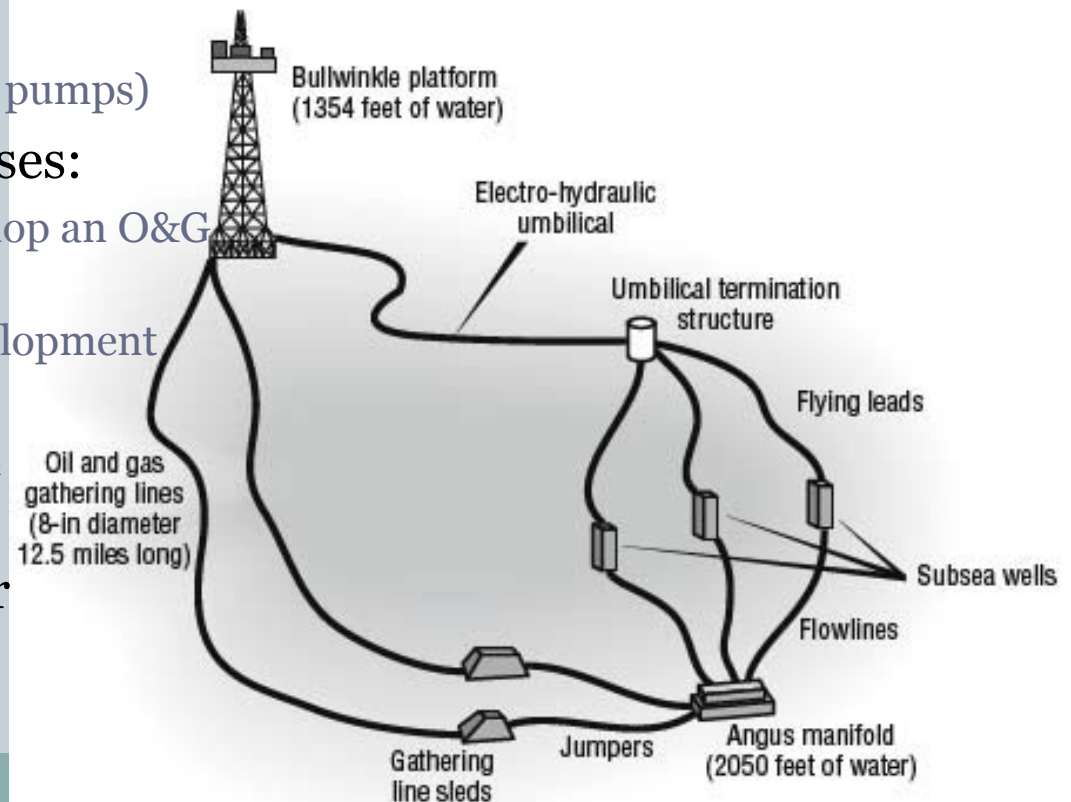
- **1961**: First subsea completion in GOM by Shell @ 28m water depth
- **1980s**: Petrobras developed subsea fields
  - Increased density of subsea (satellite) fields → lowered O&G costs
- **1990s**: Dispersed fields were developed at low(er) costs
- **Post-1990s**: Progress in ROVs enhanced subsea installations



# Today

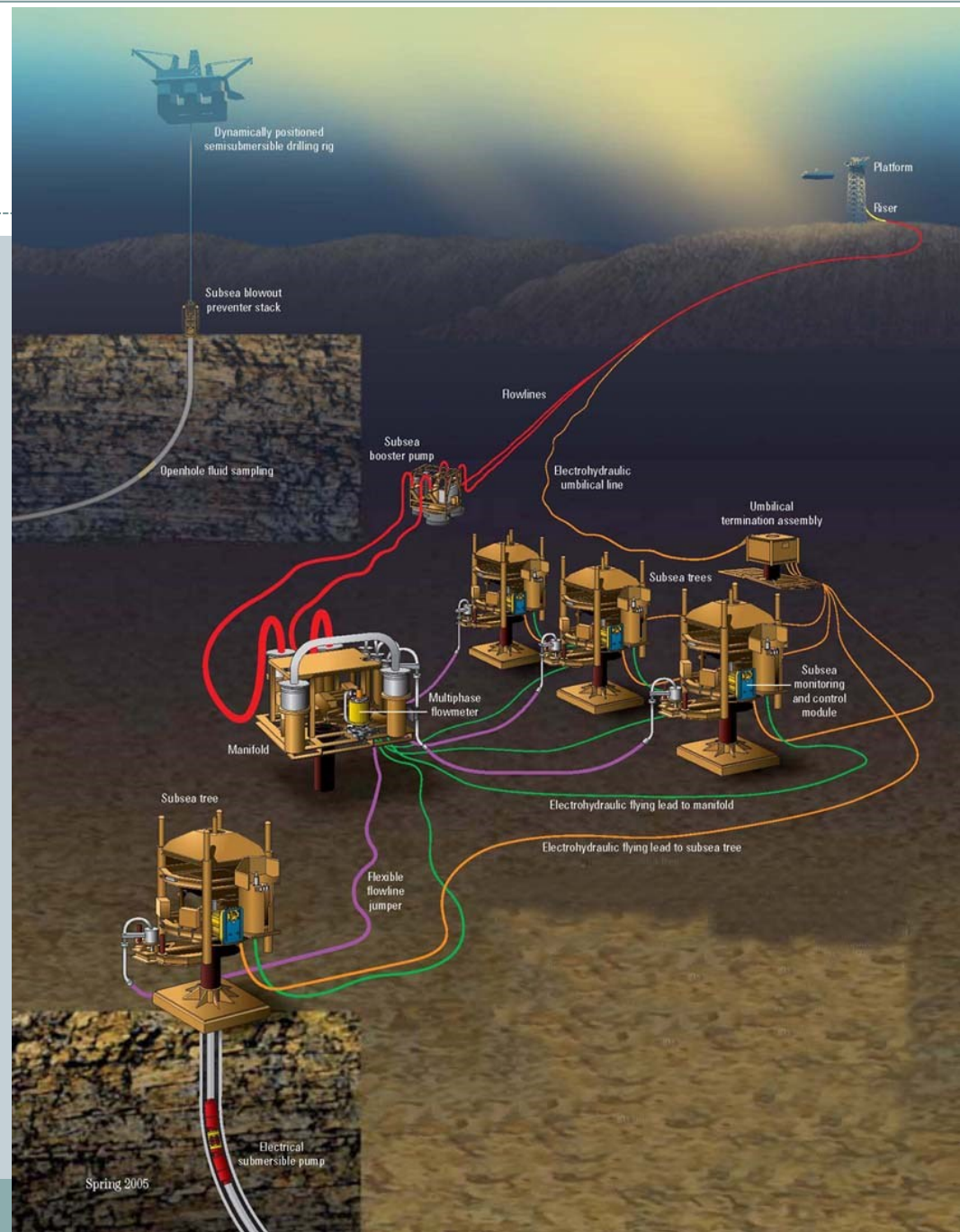
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- Emphasis upon:
  - Lower capex;
  - Life-cycle costs;
  - Reduced subsea intervention costs;
  - Augmented reliability;
  - Life-cycle of equipment (subsea pumps)
- Subsea systems used in 2 cases:
  - a) Part of an initial plan to develop an O&G field (eg, Na Kika)
  - b) Expand an existing field development (eg, Bullwinkle)
- Subsea production often the lowest cost option for marginal fields in deepwater

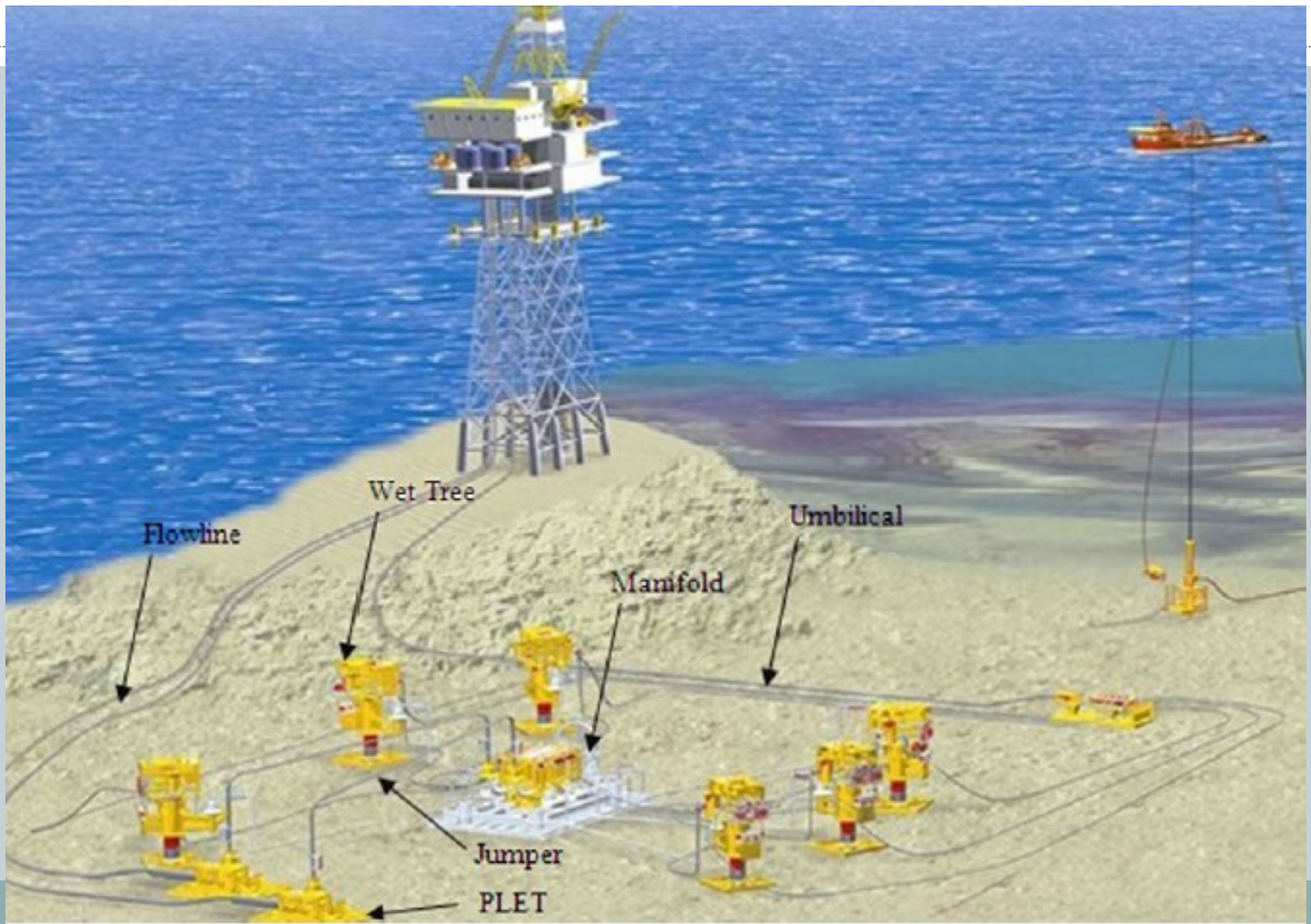


# Subsea Layout

- Subsea boosting is a relatively new technology
- Distinction btw *flowline* & subsea *export pipeline*
- Subsea terrain is hard to map let alone *visualise*



# Major subsea components



# Subsea field architecture

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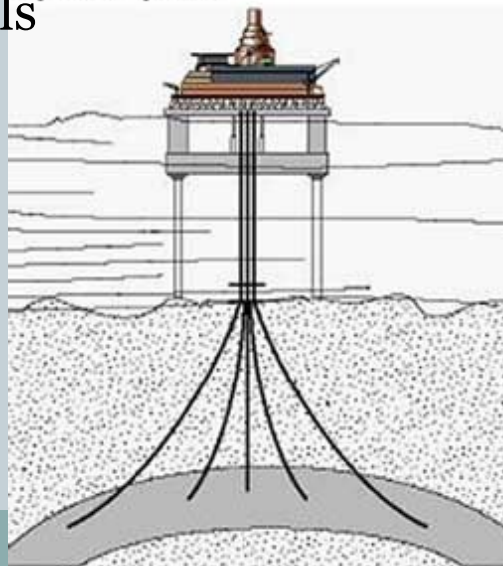
- Refers to the layout of key components of:
  - Wells, flowlines, manifold(s);
  - Umbilicals & host facility
- Some factors defining subsea architecture:
  - -- Produced fluids;
  - -- Bathymetry & flow assurance;
  - -- Host facility capabilities & location
- Subsea layouts are divided into:
  - 1. **Satellite wells**. Wells connected to a host via a flowline;
  - 2. **Clustered well system**. Wells tied to manifold using jumpers & from flowlines to host platform;
  - 3. **Template structures**. Central welded element for >2 clustered wells;
  - 4. **Daisy chain**. Satellite wells tied to common flowline. Permits 'two way' production & pigging

# Subsea field architecture (2)

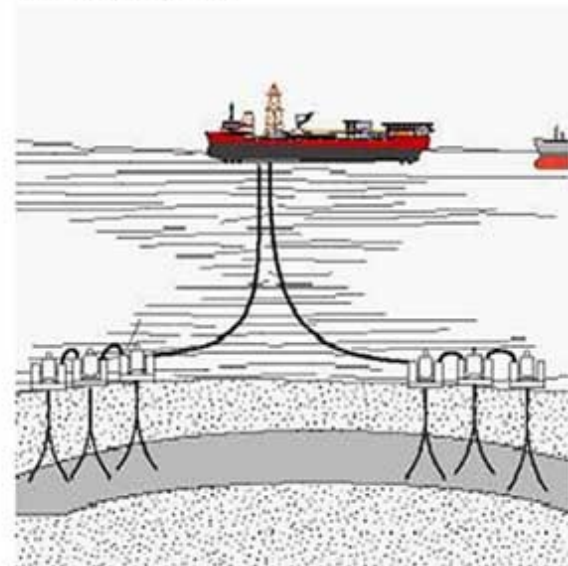
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- Subsea systems are characterised by:
  - Flexibility
  - Modular designs
  - Reliability
- Concurrent deployment, eg, sleds, jumpers permit independent installation
- Provisions for different suppliers
- Trade-off btw grouping wells (cost savings) & recovery

Dry Tree System



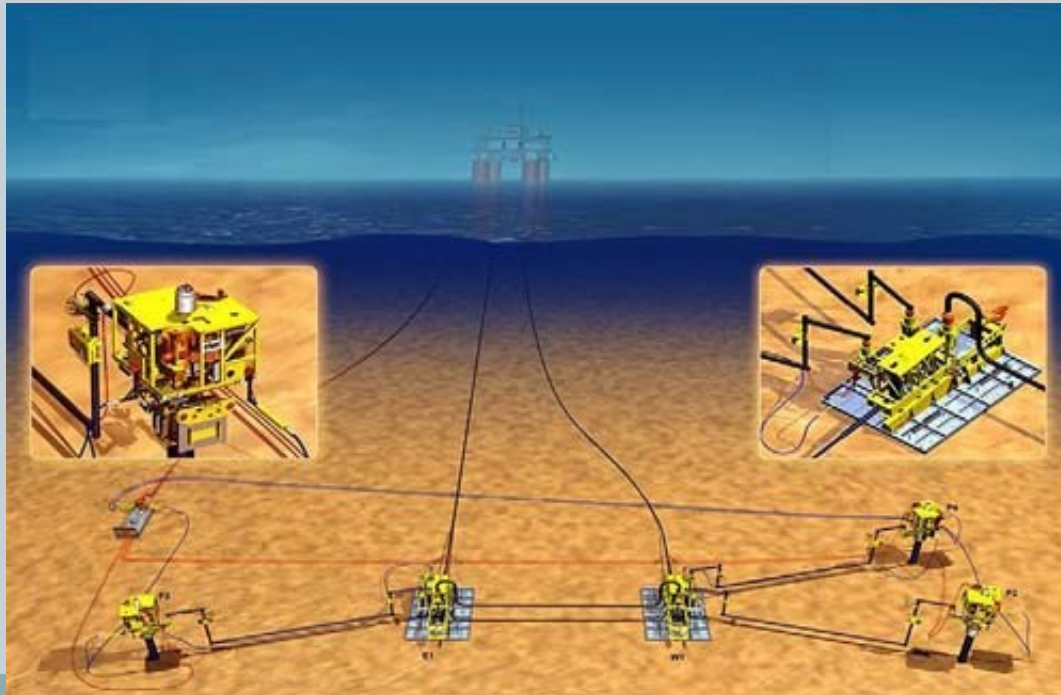
Wet Tree System



# 1.Satellite wells

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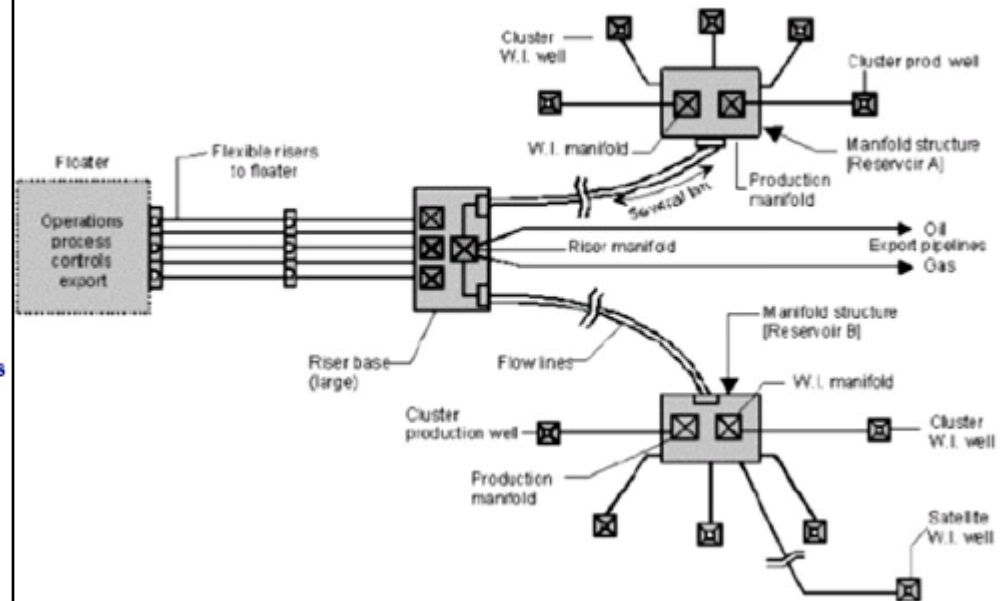
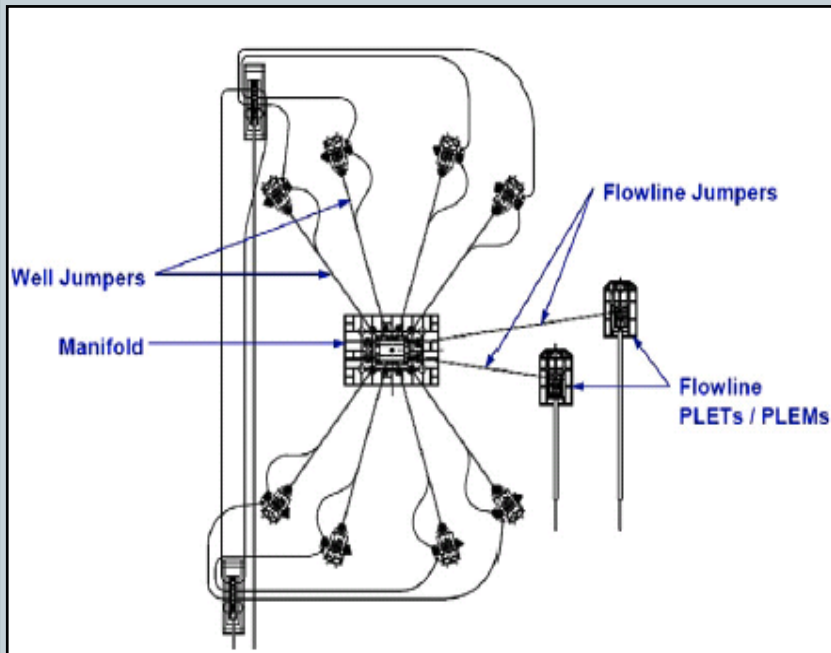
- Configurations appropriate for small fields
- Wells connected to a sleds via jumper
- Fluids sourced to host facility via flowline & risers
- Umbilical provides services



## 2. Clustered well system

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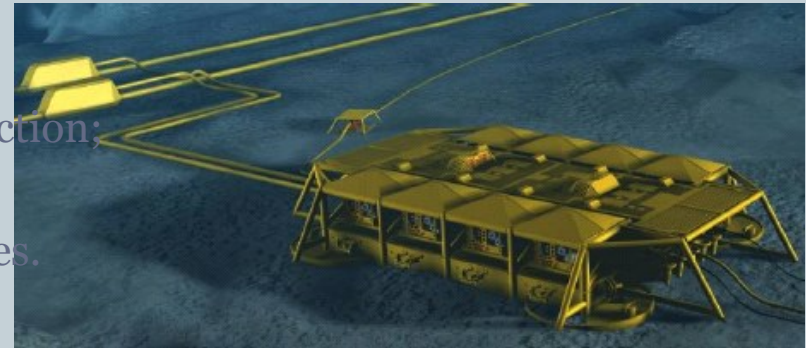
- Lower development costs by pooling wells:
  - Shorter flowlines, umbilical, flying leads, ...
- Wells can be horizontally deviated
- More than one manifold may be installed



### 3. Template structure

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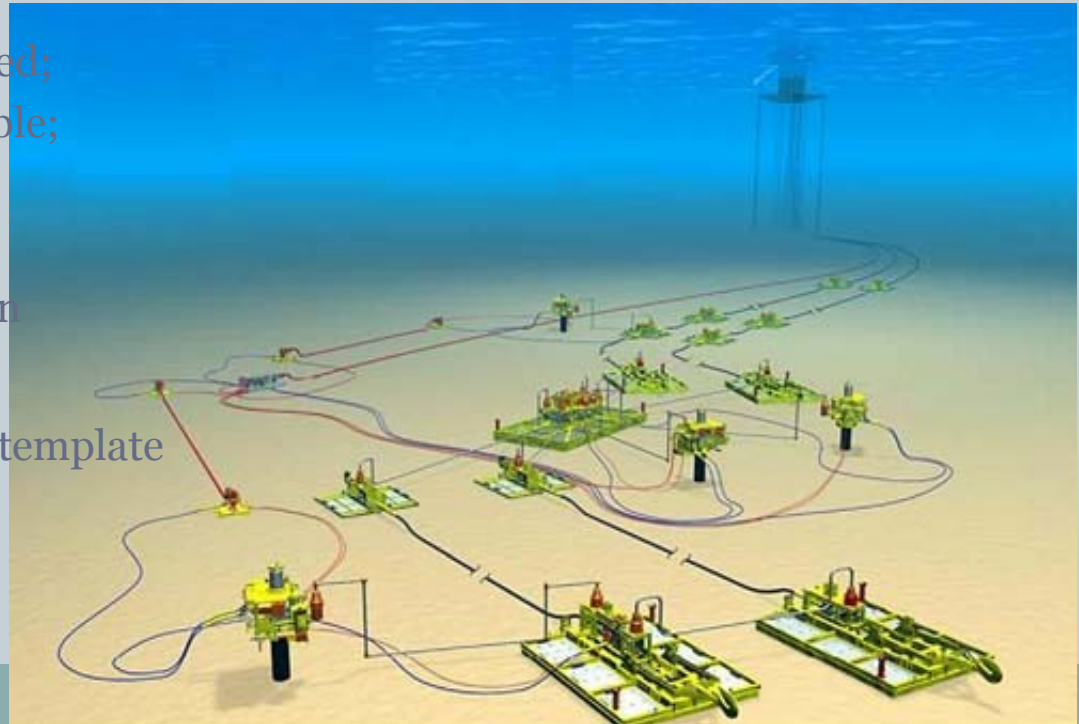
- Designed to cluster wells & lower costs
- Can support from 2 to >12 wells
- Template size limited by hoisting capacity of ship
- Benefits:
  - Manifold piping & valves are incorporated;
  - Horizontal drilling loads supported by template;
  - Short flowline lower risk of gas hydrates;
  - Piping and umbilical connections are less costly,
  - Shorter-installation time frame thru modularisation;
- Drawbacks:
  - Longer construction times due to complexity;
  - Safety issues from concurrent drilling & production;
  - Limited ROV access;
  - Heavy templates sensitive to seabed instabilities.



## 4. Daisy chain

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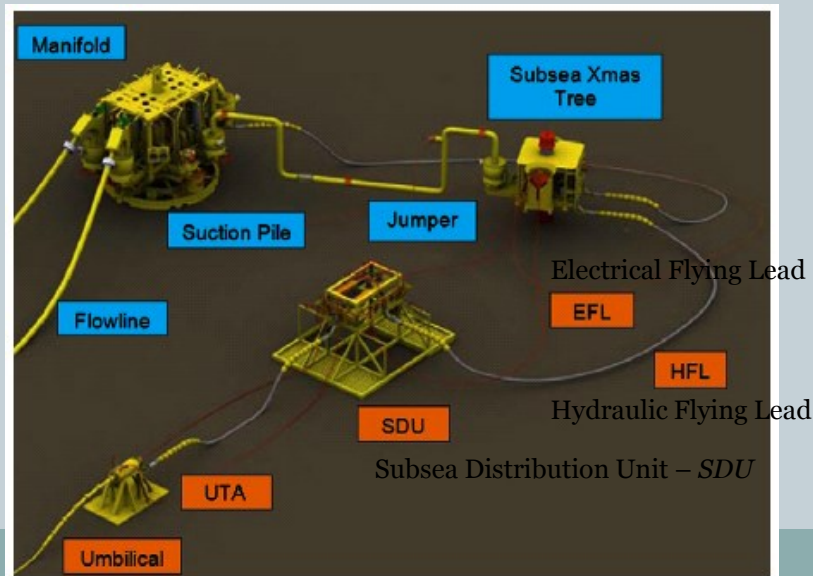
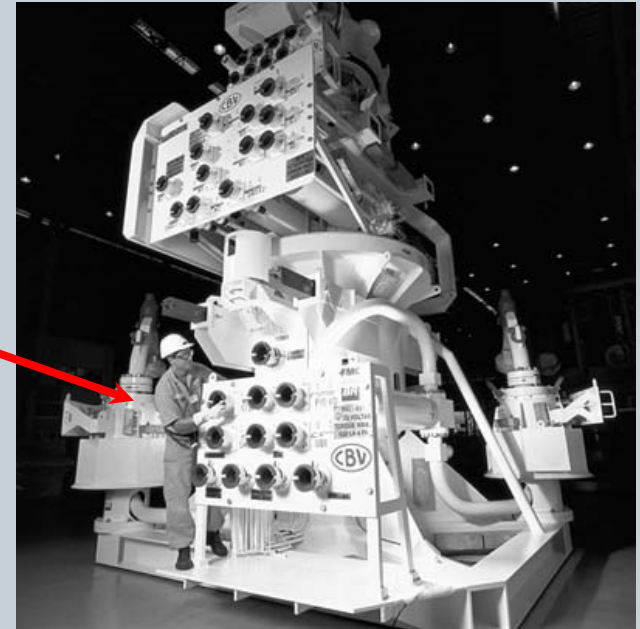
- Two or more satellite wells tied to a common flowline
- Choke regulates pressure
- Provide a loop for round-trip pigging
- Dual flow lines offer redundancy if one flowline fails.
- Merits:
  - Components bought when needed;
  - Some sharing of flowlines possible;
  - Wells can be spread out;
  - Easier access by ROV;
  - Concurrent drilling & production
- Drawbacks:
  - If more wells are needed then a template can be used;
  - Need for subsea chokes;
  - Involved flowline links



# Subsea components

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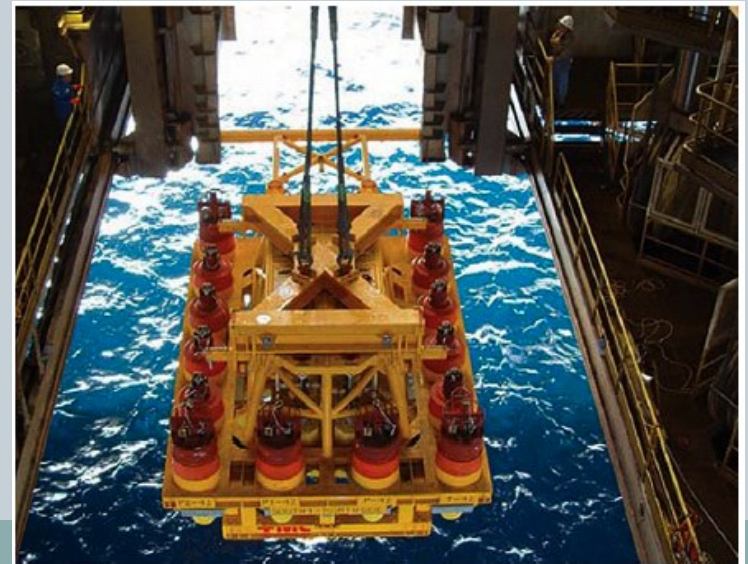
- Subsea trees
- Manifolds and sleds
- Flow lines & export line(s)
- Electrical & hydraulic umbilicals
- Jumpers and flying leads
- Subsea & surface controls & sensors



# Manifolds

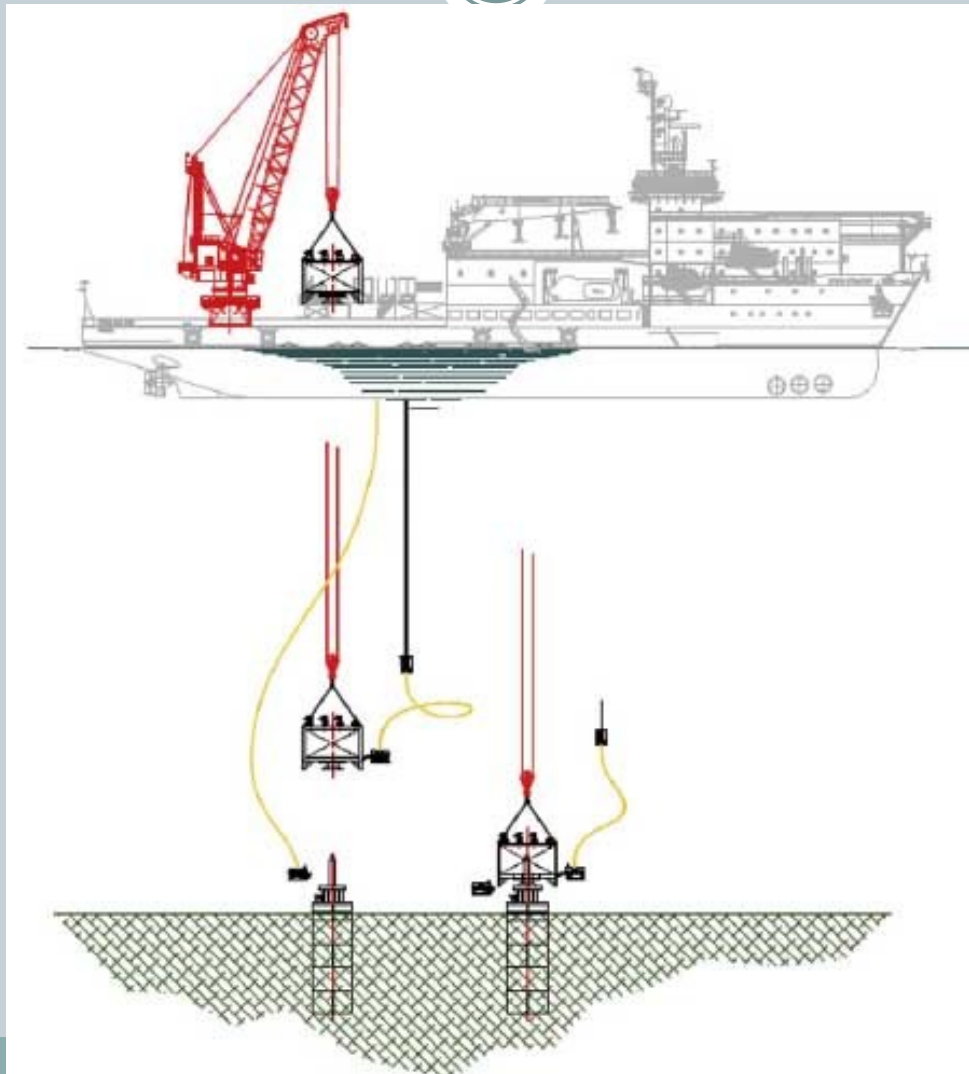
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- Designed for:
  - Simplifying the subsea development;
  - Minimise length of subsea flowlines & risers;
  - Optimise fluid flow
- Two types: 1) Water injection & 2) Production manifolds
- Simple to sophisticated designs which monitor & control flow
- Combine fluids from clustered wells to single flowline
- Designed for 2, 4, 6, 8, or 10 slots
- Pressure ratings: 5, 10 or 15 kpsi



# Manifold installation

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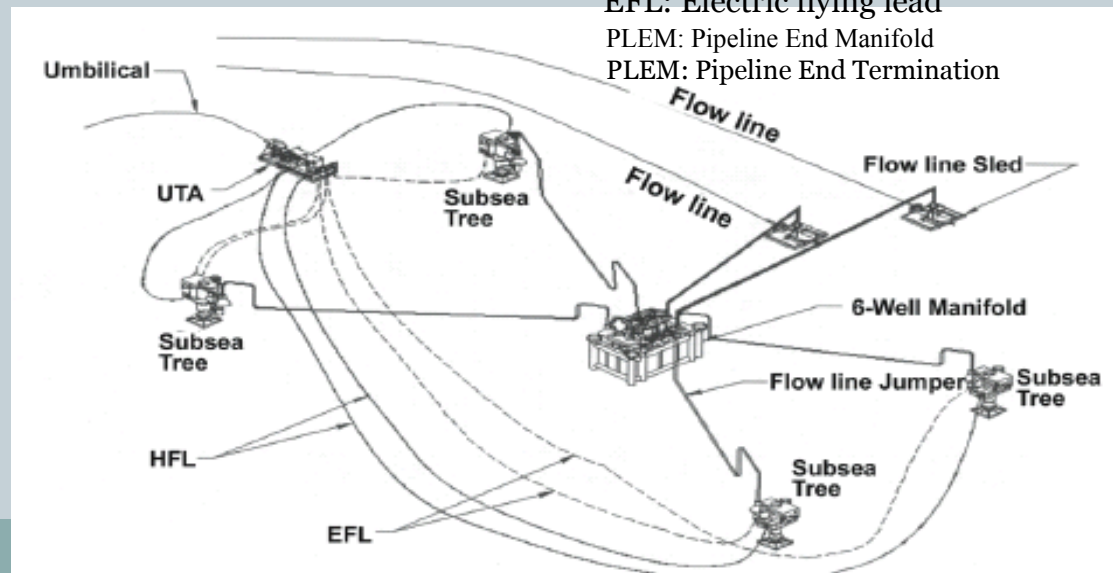


# Sled (PLET/PLEM)

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- One or two flowlines transfer H/Cs from manifold to host facility
- A sled connects manifold or subsea tree to a flowline & vice versa
- Sleds permit complex subsea architectures
- Manifolds & sleds are mounted on suction piles

UTA: Umbilical termination assembly  
HFL: Hydraulic flying lead  
EFL: Electric flying lead  
PLEM: Pipeline End Manifold  
PLET: Pipeline End Termination



# Template

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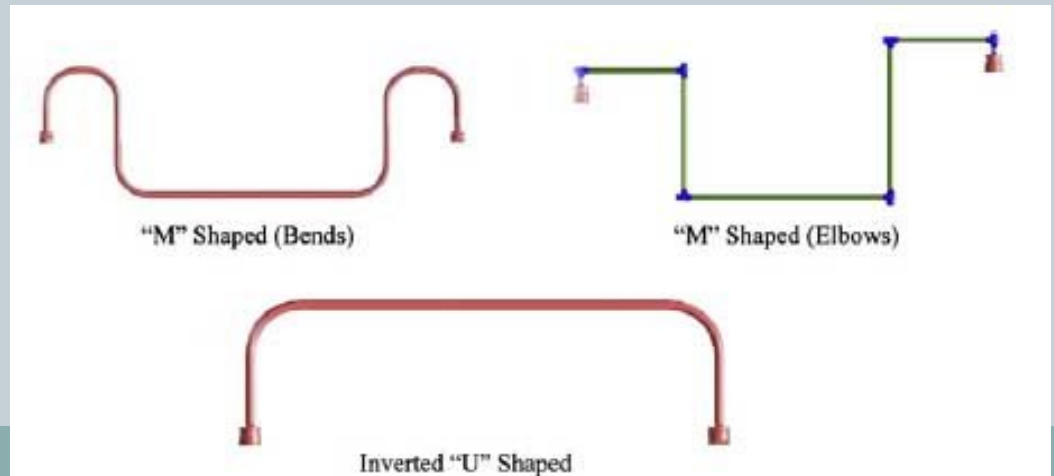
- The *manifold* functions are:
  - Gathering node
  - Commingling fluids from wells
  - Controls &
  - Often monitors H/Cs flow
- Lower costs by housing several wells (eg, Ormen Lange)
- Permits parallel development
- Difficulty of positioning drill string
- Risk of falling materials on structure
- Smaller environmental footprint



# Jumpers

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- Prefabricated custom-made *steel pipes* connecting trees to manifold
- If distance >15m use flowlines
- Option of using flexible jumpers
- Need to withstand thermal expansion & vibrations
- Pressure tightness is critical
- Feature special connections for fitting
- Length, orientation, dimensions, angles taken only after sleds, manifolds & subsea trees are installed



# Umbilicals

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- Bundled configuration of tubes, electrical & fibre optics
- Connects, controls & monitors host facility to subsea systems
- Carry chemicals to manifold for hydrate & paraffin inhibition
- Provide hydraulic fluid and/or electrical current
- Fibre optic cables
- Diameter up to 25 cm



# Poseidon submarine cable

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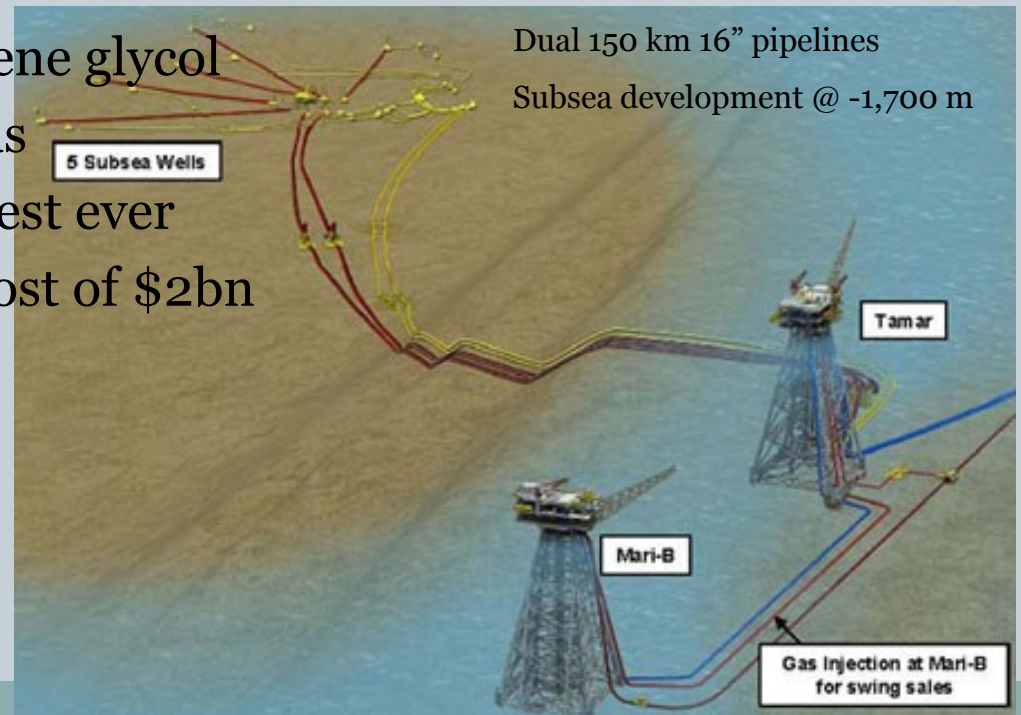
- 02/04/14: Radius Oceanic inc. commissioned & tested the cable
- 800km long



# Tamar Gas field

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- Tamar: GIP: 275 bcm (1,700 m)
  - Discovery: Jan 2009 -> Production: April. 2013
  - Development costs: \$3.25bn
- 5 wet wells in clustered well layout; 1.2bcf/d
- 330 km umbilicals
- Gas hydrate stm: Monoethylene glycol
- 11,000t topside Igleside Texas
- 150km flowlines; one of longest ever
- By 2014, 19 new wells for a cost of \$2bn



# Component installation

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- Drilling rig, crane ship, offshore support vessel (OFS), ...
- Place acoustic transponder on component, sea floor, and vessel
- Manifold installed  $\pm 1.50\text{m}$  from target,  $\pm 5^\circ$  orientation,  $< 5^\circ$  off-level
- Designers invest in min. installation interdependencies
- Motivation to lower logistics efforts
- Subsea connectors:
  - For umbilicals, jumpers, sleds, flying leads, ...
  - Diameters sizes: 0.05m to 90cm (2"-36")
  - Divided into:
    - ✦ a) Vertical connectors &
    - ✦ b) Horizontal connectors



# Systems design

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## Contingency planning

- What if some things go wrong?
- If  $p$  (too) high or (too) low control units feature 'fail' 'safe' functions
- ROV can operate valves or other operations
- Formation of wax and/or gas hydrates?

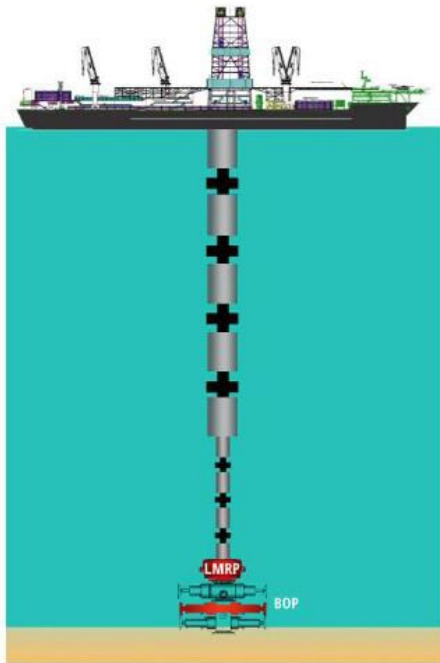
## Reliability

- Operational uptime of subsea systems as good as surface facilities
- Subsea well problems are usually reservoir related (vs hardware)
- Emphasis on redundancy
- ROV friendly design

# Failure of subsea bolts

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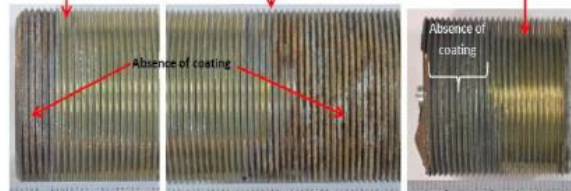
## Failure 3: Blow Out Preventer (BOP) Flange Bolt Failure (2014)



(A) Before cleaning at SES. Major scale divisions are in inches.



(B) After ultrasonic cleaning in an Alconox® solution. Major scale divisions are in inches.



(C) Close-up view of Stud #19 showing difference in coating coloration. Scale divisions are 0.1 inch.

- Flange bolting plated with zinc is missing where cracking occurs in stud threads
- High hardness in excess of HRC 34
- Arrows point at areas with consumed sacrificial coating

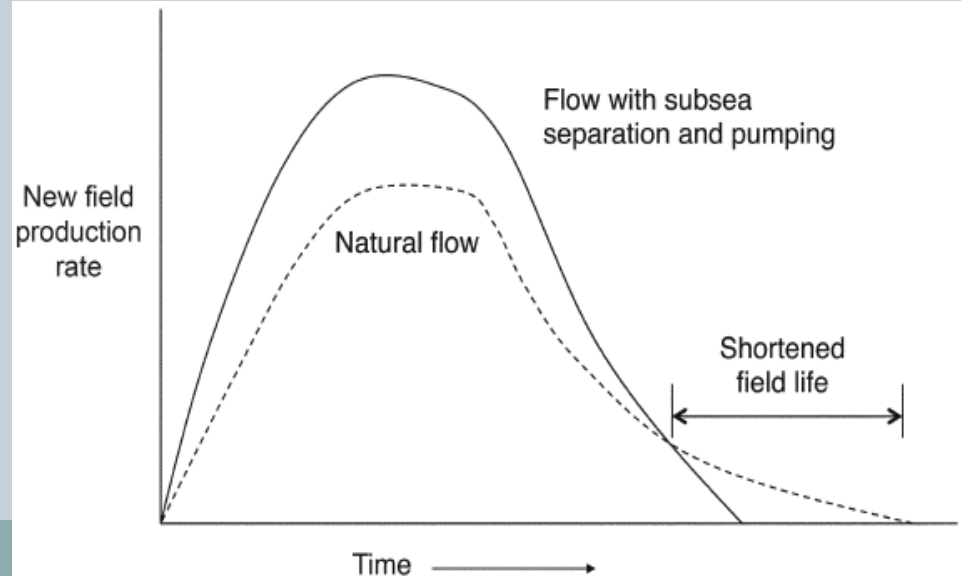
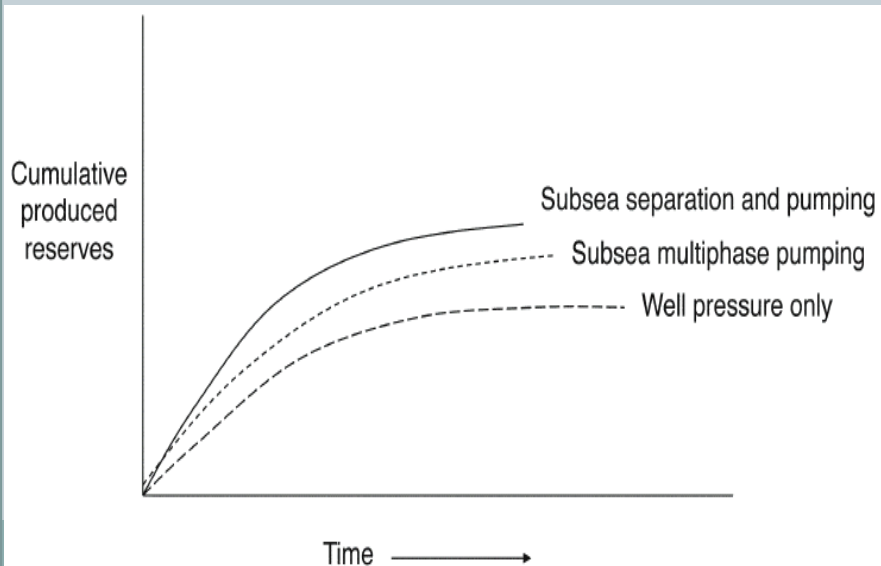


Figure 4: Hydraulic connector flange/fasteners showing failures and first engaged threads

# Improved recovery

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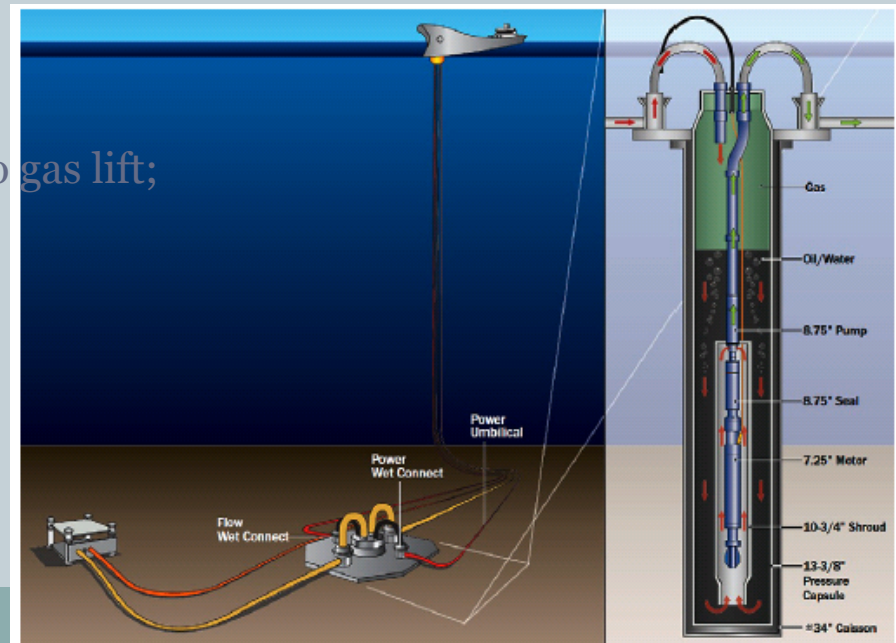
- Primary motivations:
  - Lower capital & operation costs of submarine O&G development
  - Boost ultimate recovery of H/Cs
- With depletion of oil/gas, well reservoir pressure drops
- Point where fluids cannot overcome systems resistance (well bore, flowline  $\Delta h$ , ...)
- Still significant oil remains in reservoir. What do you do?



# Improved recovery (2)

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- Advantage of separating water from gas
- Possibility of increasing recovery by 20-30%
- Electric submersible pumps (ESP):
  - 1. Vertical pump station
  - 2. Horizontal booster station
- 1. Vertical ESP:
  - Installed downhole;
  - Large power demand but more efficient than gas lift;
  - Can be installed horizontally or vertically;
  - Difficult to access.

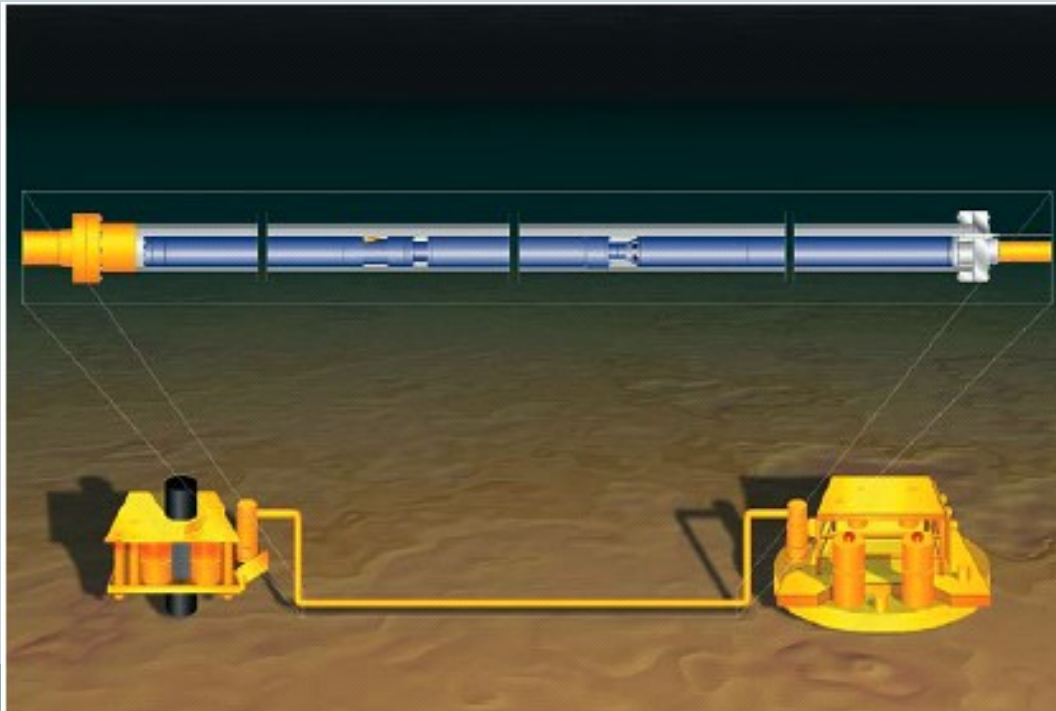


# Improved recovery (3)

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- **2. Horizontal ESP:**

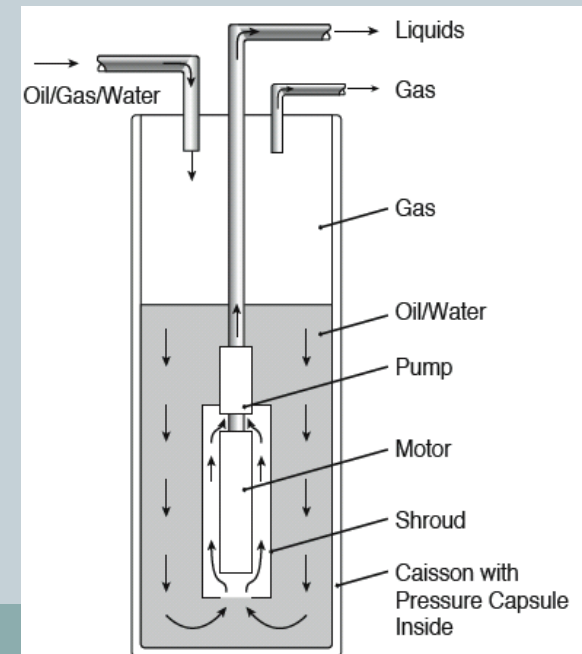
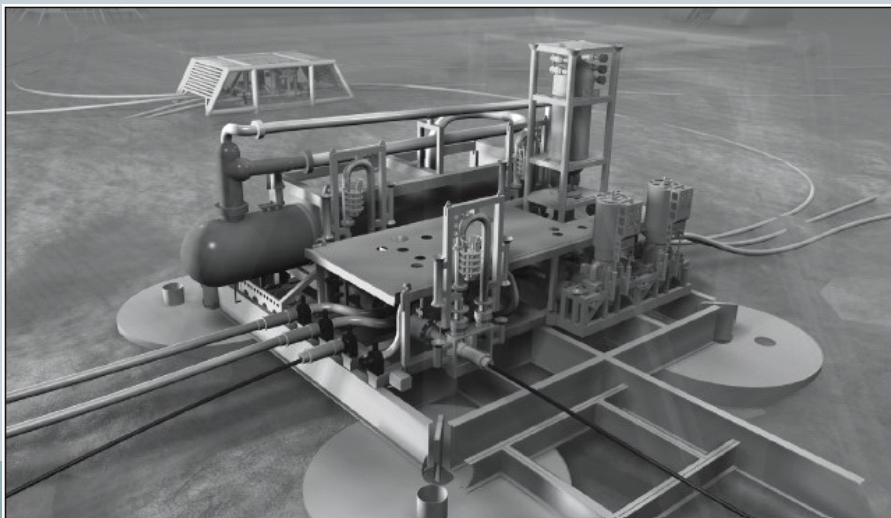
- Variant of the ESP jumper mounted on subsea base;
- Ease of changing equipment;
- High(er) uptime;
- Can be deployed in several configs & EOR.



# Subsea separation

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- Oil, gas and water can be separated
- Installed in *Perdido & Parque da Conchas*
- Cylindrical separator (1m in diameter by 105m tall)
- Water can be re-injected in well
- Centrifugal force separates liquids from gases
- An ESP fitted in the separator 'lifts' the liquid
- Little gas does not require full separation



# Subsea intervention

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- Number of offshore wells continue to increase
- Well intervention comprises:
  - Zone isolation;
  - Chemical use for scale & wax removal;
  - Re-perforation;
  - Logging, coiled tubing, etc
- Necessity:
  - Lower service costs;
  - Faster mobilisation;
  - More efficient intervention
- Small ships (lower cost) conduct subsea intervention
- *Riserless well intervention* (RWI): A wire is lowered to the subsea systems



# Closing remarks

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- Subsea developments is the “new surface”
- Formidable challenges to be tackled: MWD to gas hydrates
- Aging infrastructure, operational & environmental hazards
- Simulation tools will play an increasing important role
- Subsea processing, compression & boosting will become prevalent
- Reliability, redundancy & access to ROVs are critical
- Creative ways to lower costs will be vital
- Scope for technical innovations
- ‘Secretive’ nature of industry does not help
- Tackling the problems is beyond ‘traditional engineering’
- Low oil price environment.
- Rewarding, challenging & mobile careers await!

Embrace the challenges & turn them into opportunities!

Thanks for your attention!