GE Oil & Gas DPS

ESRA Norge Seminar
Tilgjengelighet/Pålitelighet/RAMS

"Reliability & Technical Risk Management" – et "verktøy" for å levere pålitelige undervannssystemer

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Content

- Reliability & Availability Challenges Subsea
- Current RAM Performance
- Basis for Reliability Management (API 17N)
- Main Reliability Processes
- Selected Examples
- Conclusions

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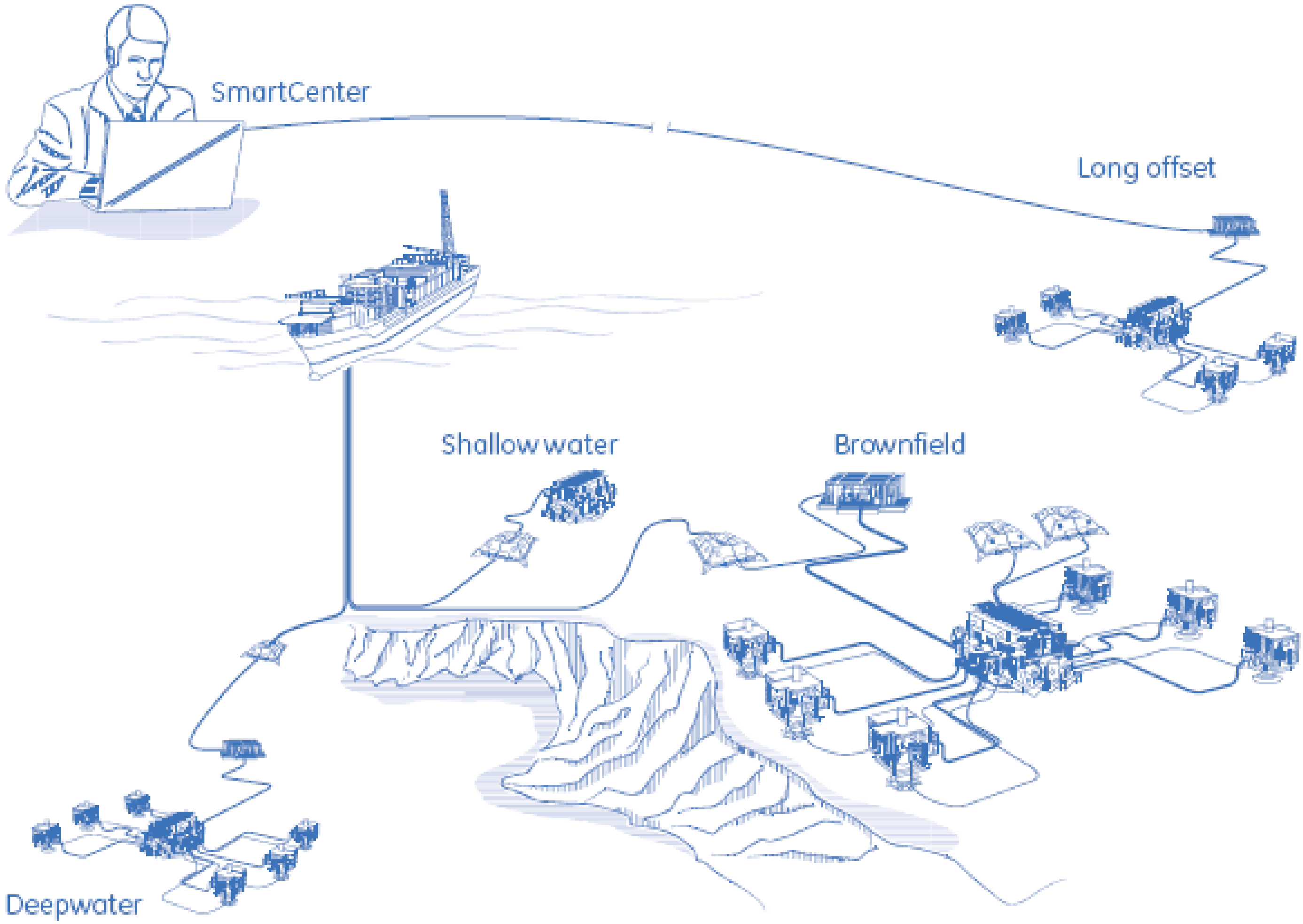
Typical GE Oil&Gas DPS Scope



Reliability & Availability Challenges

Operating environment

- ✓ Increasing water depths (> 2000 m)
- ✓ Harsh conditions
- ✓ Remote locations
- ✓ High internal (> 10k psi) & external pressure
- ✓ High temperatures (> 150 °C)
- ✓ Low temperatures (< -40 °C)
- ✓ Challenging fluids & Contaminations
- ✓ Seawater ingress

Project environment

- ✓ Fast track projects
- ✓ Tight budgets
- ✓ Project/customer specific solutions
- ✓ Limited time for testing
- ✓ High cost associated with production downtime

Product portfolio

- ✓ Relatively few components being produced
- ✓ Frequent modifications to "standard" products
- ✓ Strict requirements to qualification of equipment

Maintainability

- ✓ Increasing water depths (> 6000 ft)
- ✓ Remotely controlled maintenance operations
- ✓ Harsh weather conditions
- ✓ Remote locations
- ✓ Costly operations

Typical Intervention Resources with Resource Mobilization Times		
Description	Capabilities	Mobilisation Time Repair Time
DSV – Diving Support Vessel	DP Moonpool vessel with heave compensated crane capable of lifting up to 30-50 tons. Hosting component replacement tools & ROV.	Worst case 1 – 2 months Best case ~ 1 week MTTR ~ Days
MSV – Multipurpose Service Vessel	Larger version of DSV, sufficient deck space and crane capability to carry out major repairs including umbilical and flowline repair or replacement.	Worst case 3 – 9 months Best Case ~ 1 month MTTR ~ Weeks
MODU – Mobile Drilling Unit	DP rig required for well interventions and Xmas tree replacements.	3 – 9 months MTTR ~ Month
SUP – ROV Support Vessel	Used for light interventions such as valve operations and control jumper replacement involving ROV.	3 – 7 days MTTR ~ days

In-service availability achievements

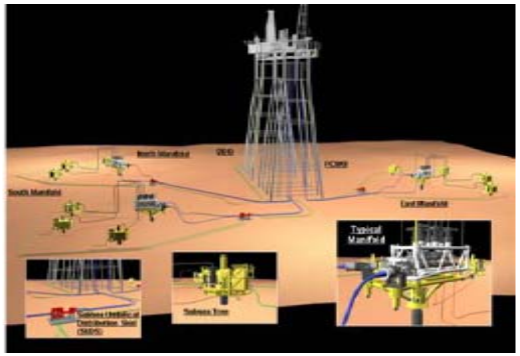
- GE DPS want to track the reliability of our systems after installation and commissioning
- Data challenge (Organizational & Practical)
- Where we get specific feedback our performance is excellent

Some Examples:

SNEPCo "Bonga"

Availability for subsea system **99.62%**

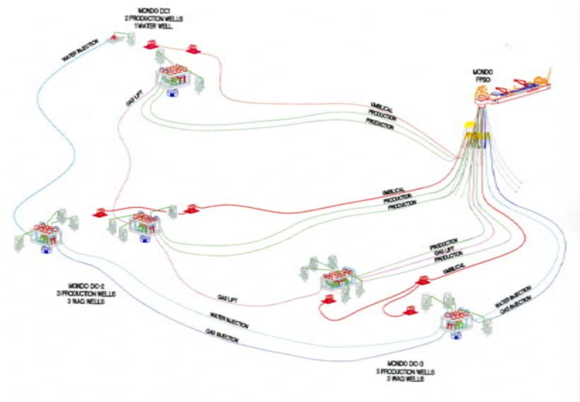
First Oil – November 2005



AIOC "Gunashli"

Availability for subsea system **99.5%**

First Water – May 2008



ExxonMobil "Kizomba C"

Availability for subsea system **99.9%**

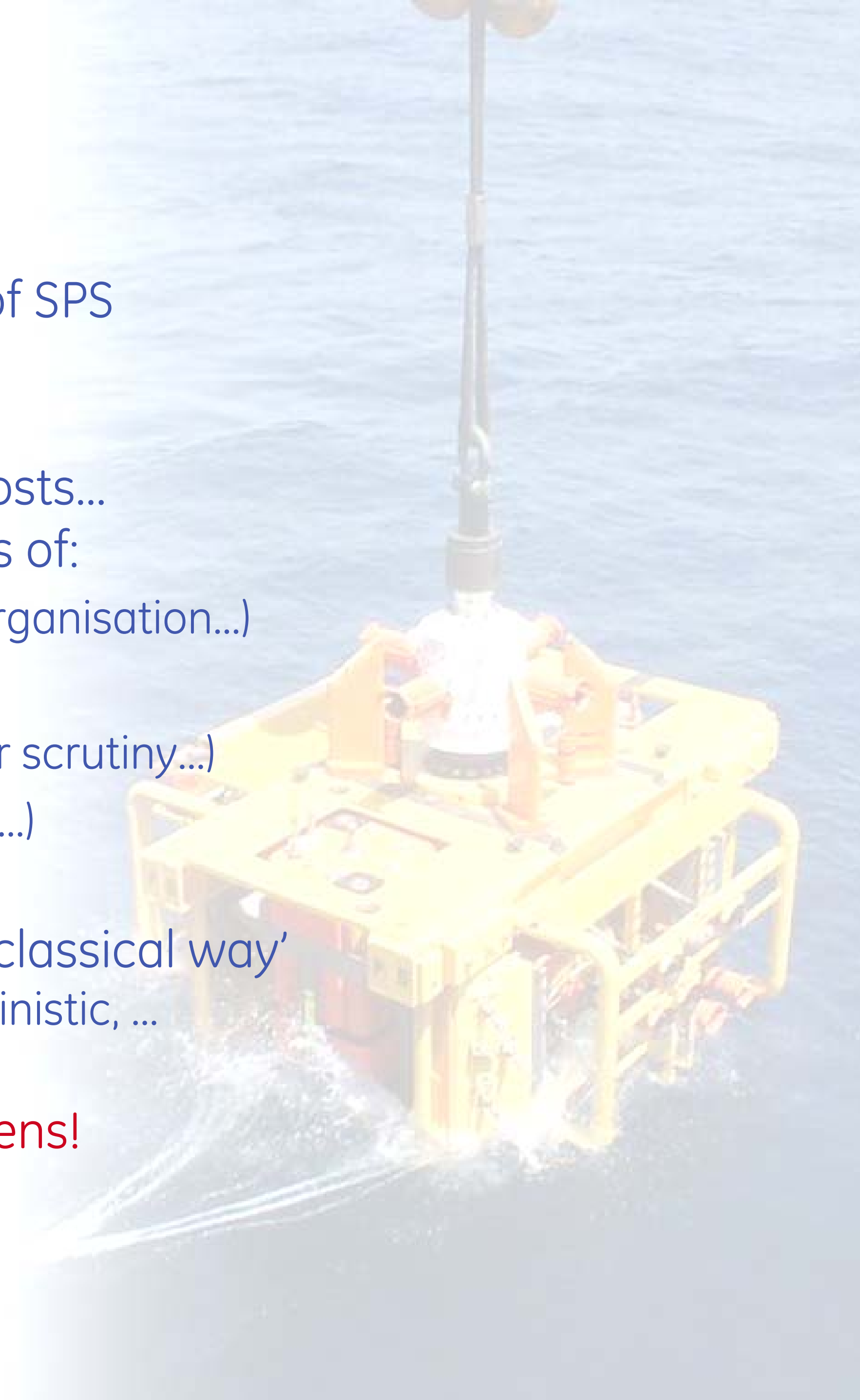
First Oil - January 2008

Current Situation....

- Generally High Production Availability of SPS

- Occassionally "Catastrophic Failures"
- High Intervention and Consequential costs...
- Root Causes typically involves elements of:
  - Novelties (in technology, application, organisation...)
  - Inproper QA/QS/QC
  - Schedule Issues (Shortcuts, not time for scrutiny...)
  - Supply Chain Issues (Failure to ID Gaps...)
  - Etc.
- Usually not related to Reliability in the 'classical way'
  - not repeating, no wear out/not deterministic, ...

- It is likely that something unlikely happens!



Example: Reliability Initiative by Clients

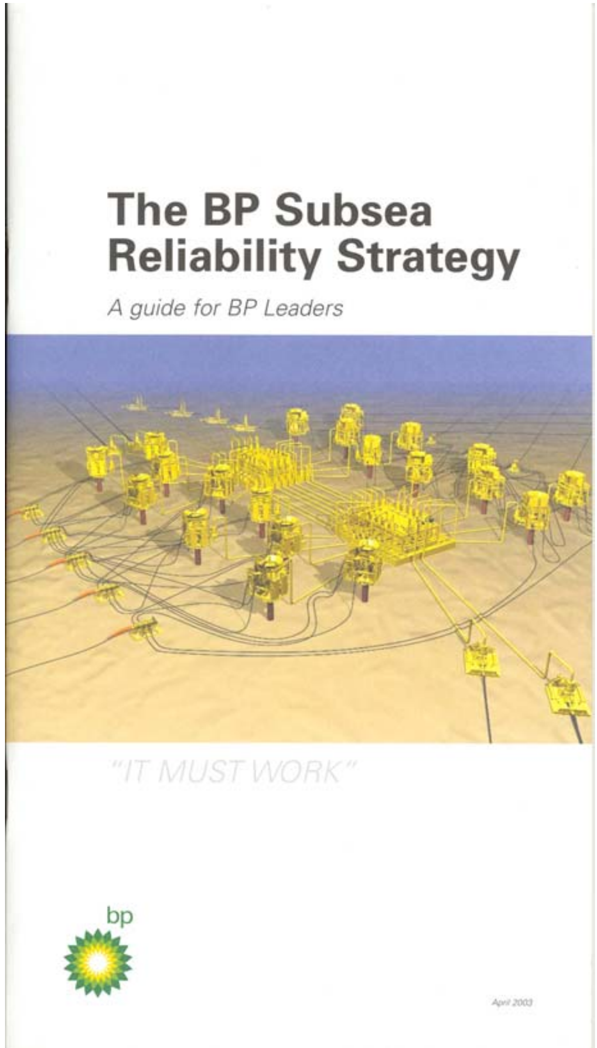
BP believe subsea equipment ***reliability can be improved***

Increasing value for BP and sector in driving ***Reliability rather than Maintainability*** *to* achieve Availability

Value is greatest when reliability improvements are made ***during design***

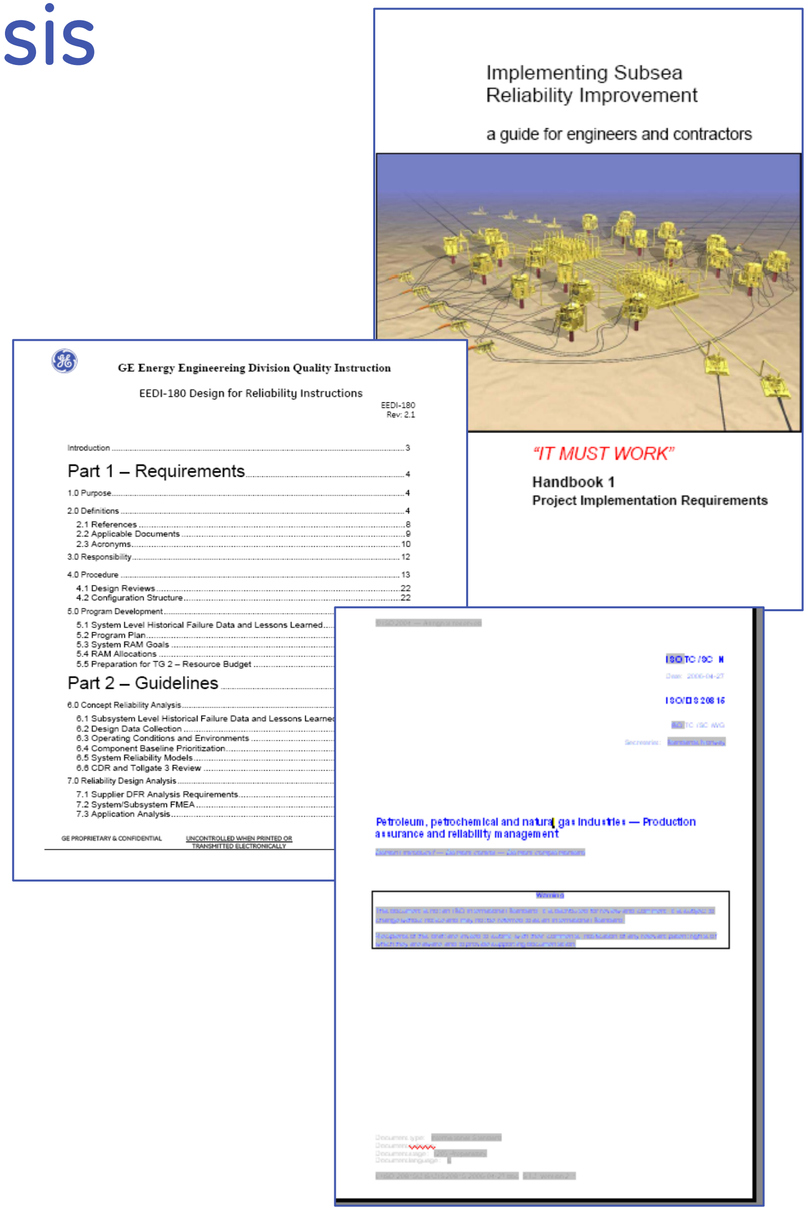
Objectives:

> Increase ***first year*** operability
> Reduce ***early life*** failures



Reliability Management Basis

- **ISO 20815** – Production Assurance and Reliability Management
- API Recommended Practice **17N** – Subsea Production System Reliability & Technical Risk Management
- DNV **RP-A203** – Qualification of new Technology
- Clients reliability and qualification guidelines (e.g. BP, Chevron, ExxonMobil, Statoil …)
- GE Oil & Gas Procedures



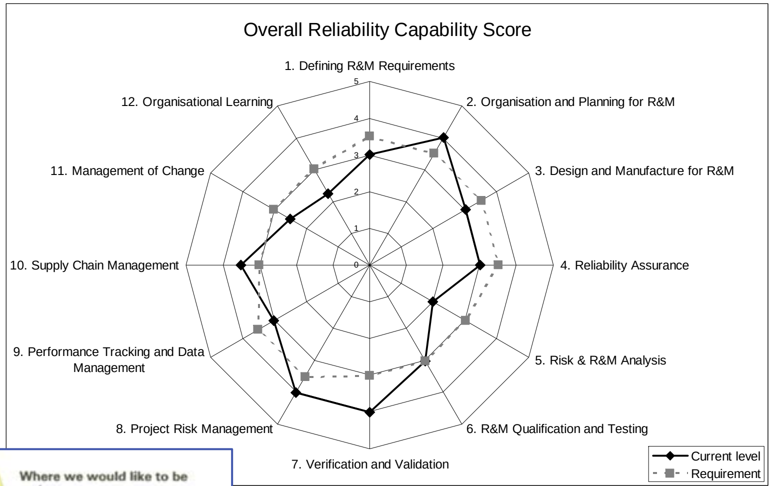
API 17N - Main Processes

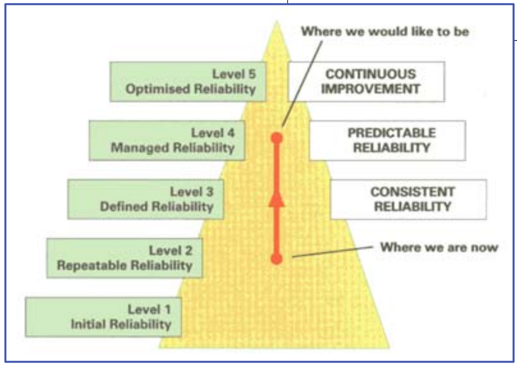
General Requirements

- Definition of Availability Goals & Requirements (Reliability Requirements)
- Organizing and Planning for Availability
- Design and Manufacture for Availability
- Reliability Assurance
- Risk and Reliability Analysis
- Verification and Validation
- Project Risk Management
- Qualification and Testing
- Performance Data Tracking and Analysis
- Supply Chain Management
- Management of Change
- Organizational learning

Framework for Improvement

- Qualitative Improvement of Main Processes will Improve Reliability & Availability
- Reliability Capability Maturity Assessment (Audits…)





Example output - Reliability Capability Maturity Assessment [API 17N]

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API 17N: Technical Risk & Reliability Effort

- The first activity should be an assessment of technical risk and uncertainty
- Formal process to ensure consistency
- Considers all sources of technical uncertainty which could impact performance
- Provide a qualitative "score" of risk to facilitate prioritization of mitigation effort

- Two categorization schemes introduced
  - TRC: Technical Risk Categorization
  - TRL: Technology Readiness Level

➢ Used to define set of activities and scope of reliability management programme

API 17N – Technical Risk Categorization (TRC)

	Technical System Scale and Complexity			Operating Envelope	Organizational Scale / Complexity
	Reliability	**Technology**	**Architecture / Configuration**	**Environment**	**Organization**
Key Words	• Reliability requirements • Maintainability • Availability • Failure modes • Risk • Uncertainty	• Materials • Dimensions • Design life • Design concept • Stress limits • Temperature limits • Corrosion • Duty cycle	• Equipment • Layout • Interfaces • Complexity • Diver/ROV • Deployment/ Intervention • Tooling	• Field location • Water depth • Seabed conditions • Reservoir conditions • Environmental loadings • Test location • Storage	• Location • Company • Contractor • Supply chain • Design • Manufacture • Install • Operate • Maintain
A (Very high)	**Reliability improvements (technology change)**: A significant reliability improvement requiring change to the technology involved	**Novel technology or new design concepts**: Novel design or technology to be qualified during project	**Novel application**: Architecture / configuration has not been previously applied by supplier	**New environment**: Project is pushing environmental boundaries such as pressure, temperature, new part of world, severe meteorological conditions or hostile on land test location	**Whole new team**: New project team, working with new suppliers in a new location
B (High)	**Reliability improvements (design change)**: Significant reliability improvement requiring change to the design but no change to the technology	**Major modifications**: Known technology with major modifications such as material changes, conceptual modifications, manufacturing changes, or upgrades. Sufficient time remains for qualification. Non mature for extended operating environments	**Orientation and capacity changes**: Significant architectural / configuration modifications such as size, orientation and layout; changes fully reviewed and tested where viable. Large scale, High complexity	**Significant environmental changes**: Many changes noted; extended and / or aggressive operating environment; risk requires additional review	**Significant team changes**: Project team working with new supplier or contractor within supply chain; key technical personnel changes from previous project
C (Medium)	**Minor Reliability improvements**: Reliability Improvements requiring tighter control over quality during manufacture assembly and fabrication	**Minor modifications**: Same supplier providing a copy of previous equipment with minor modifications such as dimensions or design life; modifications have been fully reviewed and qualification can be completed	**Interface changes:** Interface changes, either with different equipment or control system changes; where appropriate, configuration has been tested and verified	**Similar environmental conditions:** Same as a previous project or no major environmental risks have been identified	**Minor team changes:** Small or medium organization; moderate complexity; minor changes in contractor/supplier and project team
D (Low)	**Unchanged reliability:** No reliability improvements required, existing quality assurance and control is acceptable	**Field proven technology:** Same supplier providing equipment of identical specification, manufactured at same location; provide assurance no changes have occurred through the supply chain	**Unchanged:** Architecture / configuration is identical to previous specifications; interfaces remain unchanged, with no orientation or layout modification	**Same environmental conditions:** Same as recent project	**Same team as previous:** Same project team, contractors, suppliers, and supplier's supply chain; applies throughout project lifecycle

API 17N – Technology Readiness Level (TRL)

	TRL	Development Stage Completed	Definition of Development Stage
Concept	0	**Unproven Concept** (Basic R&D, paper concept)	Basic scientific/engineering principles observed and reported; paper concept; no analysis or testing completed; no design history
Proof-of-Concept	1	**Proven Concept** (Proof of Concept as a paper study or R&D experiments)	(a) Technology concept and/or application formulated
			(b) Concept and functionality proven by analysis or reference to features common with/to existing technology
			No design history; essentially a paper study not involving physical models but may include R&D experimentation
	2	**Validated concept** Experimental proof of concept using physical model tests	Concept design or novel features of design is validated by a physical model, a system mock up or dummy and functionally tested in a laboratory environment; no design history; no environmental tests; materials testing and reliability testing is performed on key parts or components in a testing laboratory prior to prototype construction
Prototype	3	**Prototype tested** (system function, performance and reliability tested)	(a) Item prototype is built and put through (generic) functional and performance tests; reliability tests are performed including; reliability growth tests, accelerated life tests and robust design development test program in relevant laboratory testing environments; tests are carried out without integration into a broader system
			(b) The extent to which application requirements are met are assessed and potential benefits and risks are demonstrated
	4	**Environment Tested** (Pre production system environment tested)	Meets all requirements of TRL 3; designed and built as production unit (or full scale prototype) and put through its qualification program in simulated environment (e.g., hyperbaric chamber to simulate pressure) or actual intended environment (e.g., subsea environment) but not installed or operating; reliability testing limited to demonstrating that prototype function and performance criteria can be met in the intended operating condition and external environment
	5	**System Tested** (Production system interface tested)	Meets all the requirements of TRL 4; designed and built as production unit (or full scale prototype) and integrated into intended operating system with full interface and functional test but outside the intended field environment
Field Qualified	6	**System Installed** (Production System Installed and tested)	Meets all the requirements of TRL 5; production unit (or full scale prototype) built and integrated into the intended operating system; full interface and function test program performed in the intended (or closely simulated) environment and operated for less than 3 years; at TRL 6 new technology equipment might require additional support for the first 12 to 18 months
	7	**Field Proven** (Production System Field Proven)	Production unit integrated into intended operating system, installed and operating for more than three years with acceptable reliability, demonstrating low risk of early life failures in the field

Project Specific Requirements – Risk & Reliability Management

- Clients typically specify minimum requirements; which processes to be complete during contract to satisfy the Reliability Strategy for the Project.

- Prioritizes a selection of key processes, e.g.
  - ✓ TRC & TRL Review of all components
  - ✓ FMECA
  - ✓ Lessons Learned from previous contracts
  - ✓ RAM Analysis
  - ✓ Definition of Reliability Requirements
  - ✓ Risk Management
  - ✓ Reliability Assurance Document (RAD)

- Focuses on Qualitative Improvement of Selected Reliability Processes
- Aiming at "significant step's" forward

➢ The following slides will provide details and relevant examples for a selection of main processes as implemented by GE Oil & Gas DPS.

KP#5: Risk & Availability Analysis

Incl. Reliability Analysis & RAM

Typical Activities undertaken by GE Oil & Gas DPS (driven by Risk Level)

Reliability Analysis in Design:

> EPCWW 6.02 - Reliability, Availability and Maintainability Analysis
> GE EEDI-180 Design for Reliability
> Physics of Failure modelling
> Relex/Telcordia Calculations for Electronic components
> Reliability Testing
> Reliability Growth Analysis
> SIL Analysis
> FMECA
> RBD
> etc

Risk Assessment in Design:

> Project Risk Assessment
> Preliminary Hazard Assessment (PHA)
> Failure Mode, Effects and Criticality Assessment (FMECA)
> Technical Risk Assurance Program
> Hazard and Operability Studies (HAZOP)
> Supply Chain Management (SCM) Risk Assessment
> API17N TRC/TRL Assessment
> etc

Differentiating between System Level and Product Level

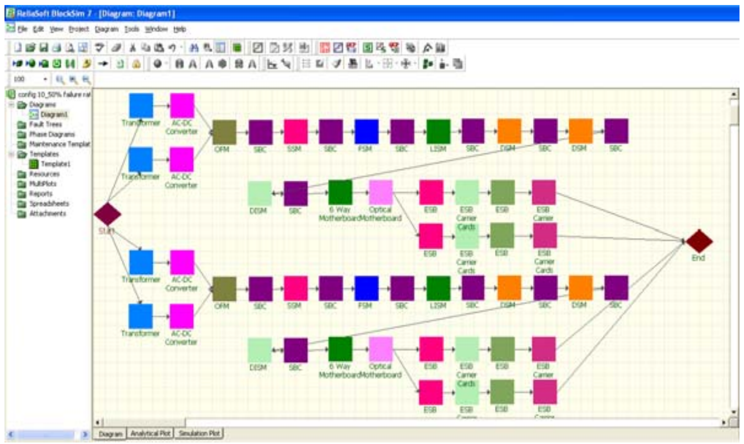
RAM Analysis at GE Oil & Gas DPS

Why RAM Analysis?

- Prediction of expected system performance (Baseline Performance)
- Demonstration of compliance with performance targets
- Provision of decision support.
  - ✓ Determine areas where improvements or changes (to procedures, training, operation etc.) may be necessary or closer investigation is recommended.
  - ✓ Investigate the effect of changes
  - ✓ Allocation of Requirements to sub-systems, components, and items
  - ✓ Maintenance & Repair Strategy
- Ensure proper consideration on safety, reliability and availability issues

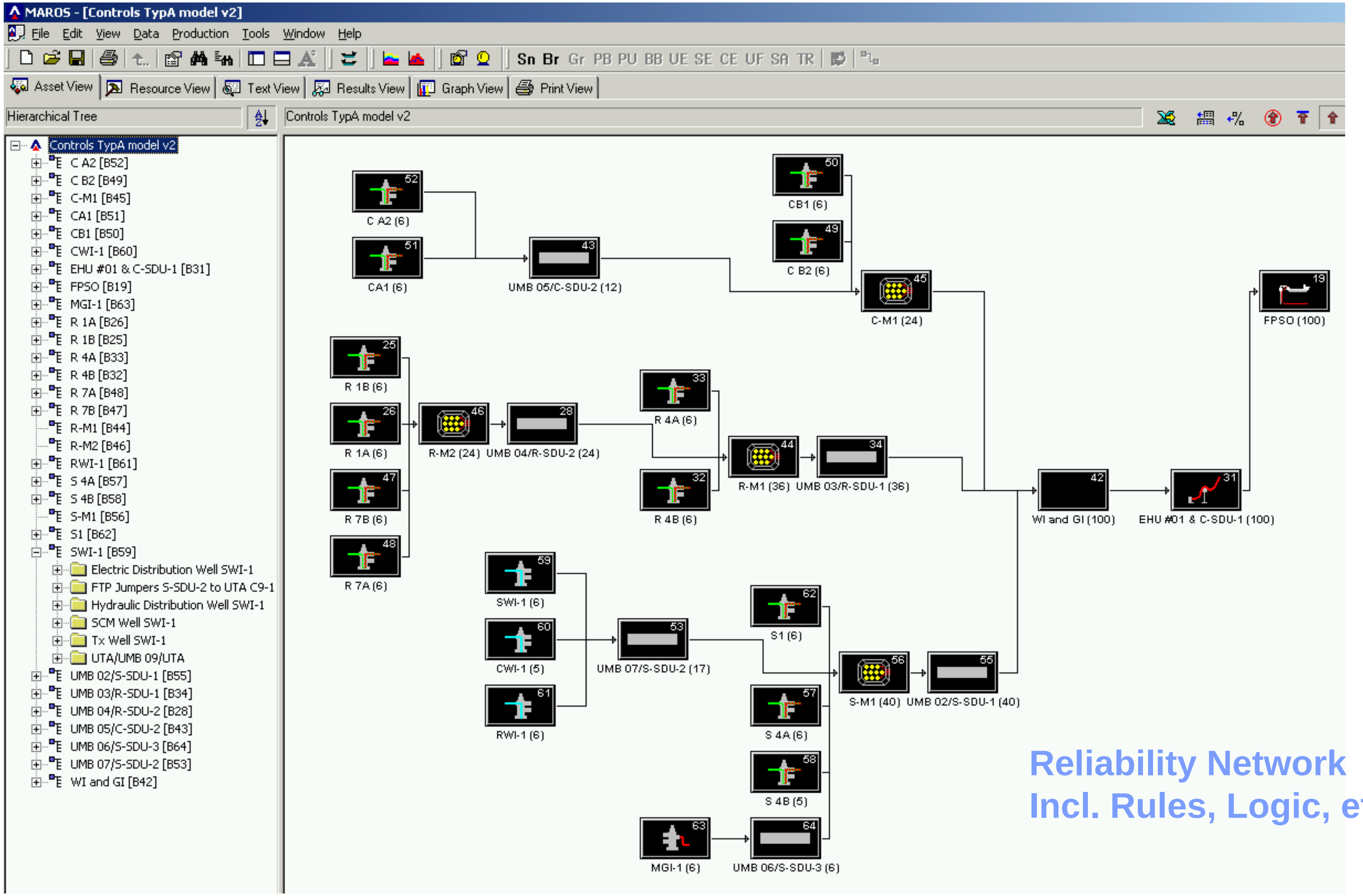
How?

- Standard Procedure for all projects
- Use of Standardized Baseline Data
- Standardized RAM Modeling Tools
  - ✓ MAROS (DNV/Jardine),
    - ➢ detailed example on following pages
  - ✓ Blocksim (ReliaSoft)



Example: Reliability Model for GE SEMStar5 using BlockSim7

MAROS Example I - GUI



Reliability Network
Incl. Rules, Logic, etc.

Note: Typical Model (Previous Project)

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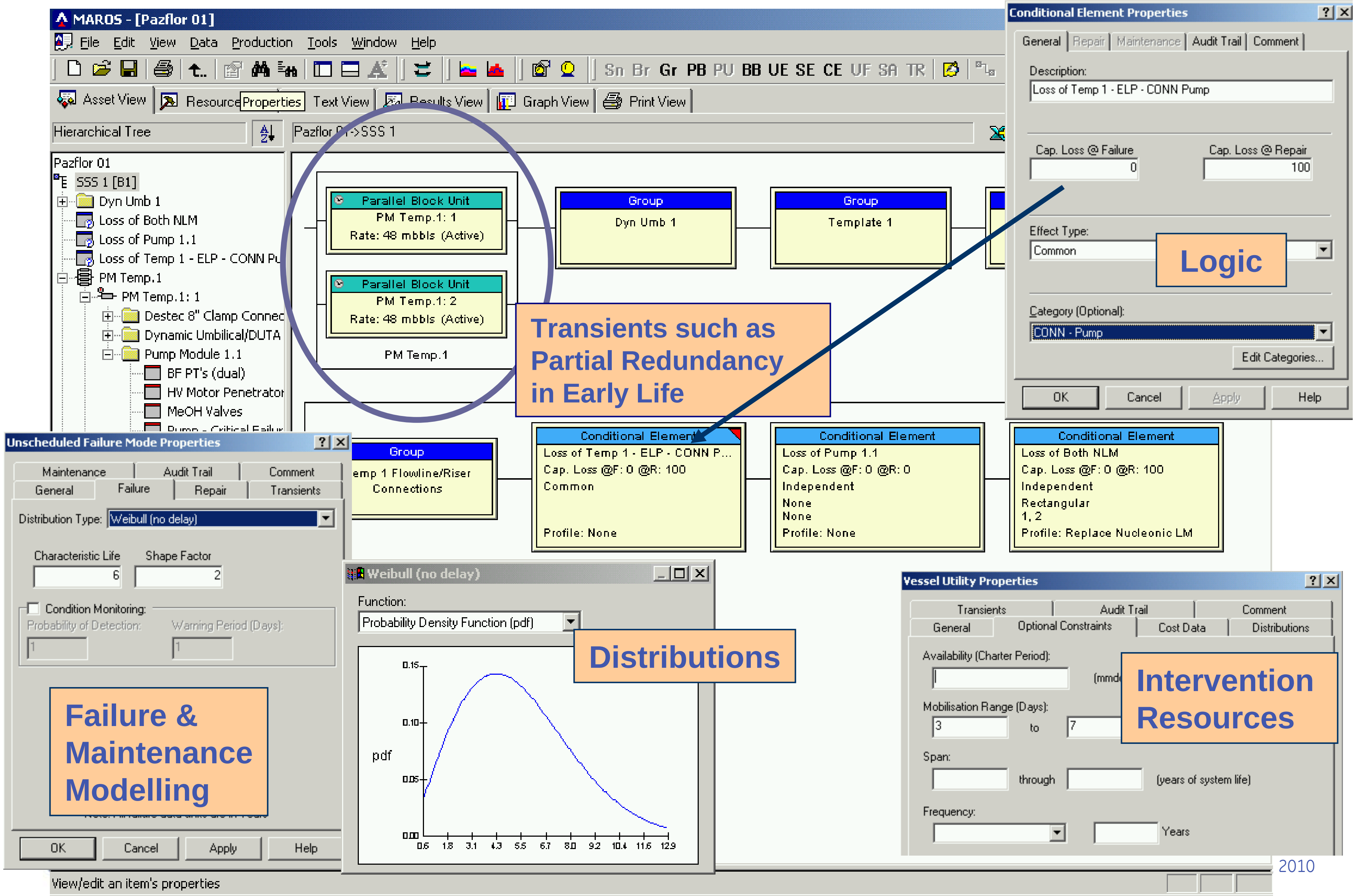
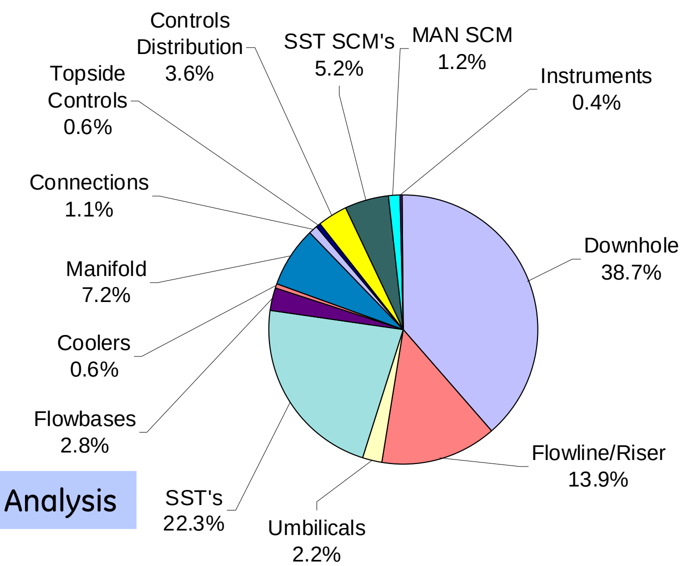
MAROS Example II – Typical Modelling Features



MAROS Example III – Typical Results

Production Availability Analysis

Performance Indicator	Value	
5 yrs. Production Availability (GE Oil & Gas DPS)	**99.40**	% +/- 0.6%
80% Confidence Level in 8 yrs. Prod Availability	99.0	%
Availability of Maximum Production Capacity	98.0	% +/- 2.7 %
Total shutdown time	0.10	% +/- 0.8 %



Equipment Criticality Analysis

Sensitivity Analysis

No.	Sensitivity Title	Estimated Prod. Availability	Absolute Impact [%]	Relative Impact [%]	Comments
S.0	Base Case	99.789 %	-	-	Bi-annual OM
S.1	Rare Opportunity Maintenance	99.752 %	-0.037%	-17.5%	OM every fifth year in average
S.2	SDU re-installable	99.790 %	0.001%	0.5%	SDU can be retrieved and re-installed
S.3	Spare COPS line in splitter-box	99.805 %	0.016%	7.6%	Reconfigurable spare COPS line available in EDU
S.4	Spare Hydraulic Line	99.791 %	0.002%	0.9%	Reconfigurable spare hydraulic line

Reliability Data Credibility

Data discrepancies is a well known fact

- Inaccuracies occur due to a number of reasons, e.g.
  - ✓ Data collection procedures (Definition of failure, life cycles phases covered…)
  - ✓ Competency of data recorders and collectors
  - ✓ Inadequate systems for data recording

Main strategies to overcome data uncertainty

- Establish a “Baseline Performance” Database
  - ✓ Collected and Calibrated w/Clients over 15 yrs
  - ✓ Comprising Baseline data taking no credit for Reliability Management Programme, Design for Reliability Initiatives, etc.
- Performing comparative assessment and sensitivity analyses
- Access to the detailed information the reliability data is based on

➢ Despite questionable quality of some data, access to this information is considered vital to ensure continuous improvement

Reliability Data Credibility - Example

Reliability of Wet-make electrical connectors:

Long term effects such as low IR

- Customer Data: MTBF = 260 years
  - ✓ 4 700 units, 15 000 years, 63 failures
  - ✓ Consistent with OREDA 2002 Hndb.

Includes failures introduced by 'use'

- GE Oil&Gas DPS Data: MTBF = 2 560 years

x10

  - ✓ 1 400 units, 5 000 years, 2 critical failures

Warranty period of two years...?

- Manufacturer Data: MTBF = 30 000 years

x10

  - ✓ 5 failures recorded for 70 442 units, 149 000 years in operation.

Includes failures 'solely attributed' to manufacturer only

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KP#9 – Performance Tracking & Analysis

GE Oil&Gas DPS Risk & Reliability Data Sources (selection)

- WELS – Worldwide Electronic Service Database
  - Implemented through eBiz (Same portal as ePIMS)
  - Cover all installations and intervention activities that GE Oil&Gas DPS are involved in
  - Statistical reporting tools
- Contractor OREDA – Offshore Reliability Database
  - Data collected by our customers (currently, 9 oil companies are participating) on subsea equipment supplied by GE Oil&Gas DPS
  - "True" reliability data containing failure rates and repair times
  - Only a subset of GE Oil&Gas DPS worldwide deliveries are covered in OREDA
  - Subsea OREDA is a combined Reliability Data Collection & Analysis Tool.
  - References: www.sintef.no/sipaa/prosjekt/oreda/index.html.
- Global Rejection System (NCR database)
- Other data sources
  - Relex/Telcordia Calculations
  - OREDA Data Handbooks
  - PARLOC (Riser, flowline and umbilical data)
  - Wellmaster (data on downhole equipment)
  - Vendor data etc.

Conclusions

- Numerical targets values are “tough”
- High cost and severe consequences associated with equipment failures
- Data discrepancies is a well known fact
- How can customer differentiate between “excellent reliability” and ”just another” marketing effort (… lies > damn lies > Statistics…)
- Subsea market > “years” before we can prove anything empirically…

➢ **Still need to convince the customer!**

➢ **There is a need for qualitative reliability processes in addition to quantitative**

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Holistic approach required to meet reliability challenges

ISO FDIS 20815 / API 17 N

Production assurance processes for asset development				Life Cycle Phase						
				Pre contract award		Post contract award				
Low Risk Projects	Medium Risk Projects	High Risk Projects	**Processes**	Feasibility	Conceptual Design	Engineering	Procurement	Fabrication/Testing	Installation	Operation
	X	X	1. Definition of Goals & Requirements	X	X	X	X			
X	X	X	2. Organizing and Planning for Availability	X	X	X	X	X	X	x
	X	X	3. Design and Manufacture for Availability		X	X		X	X	X
X	X	X	4. Reliability Assurance	X	X	X	X	X	X	X
	X	X	5. Risk and Reliability Analysis	X	X	X				
X	X	X	6. Verification and Validation	X	X	X				
X	X	X	7. Project Risk Management	X	X	X	X	X	X	X
		X	8. Qualification and Testing		X	X	X	X		
X	X	X	9. Performance Data Tracking and Analysis						X	X
		X	10. Supply Chain Management				X			
X	X	X	11. Management of Change		X	X	X	X	X	X
X	X	X	12. Organisational learning	X	X	X	X	X	X	X