Integridade Sistemas de Estruturas de Plataformas Marítimas
Avaliações de Processos de Degradação

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Oriciclon Engineering ltd
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Integridade Sistemas de Estruturas de Plataformas Marítimas - Avaliações de Processos de Degradação

Objetivos:

Garantir **Linhas de Defesa de integridade e Segurança** dos sistemas de estruturas maritimas

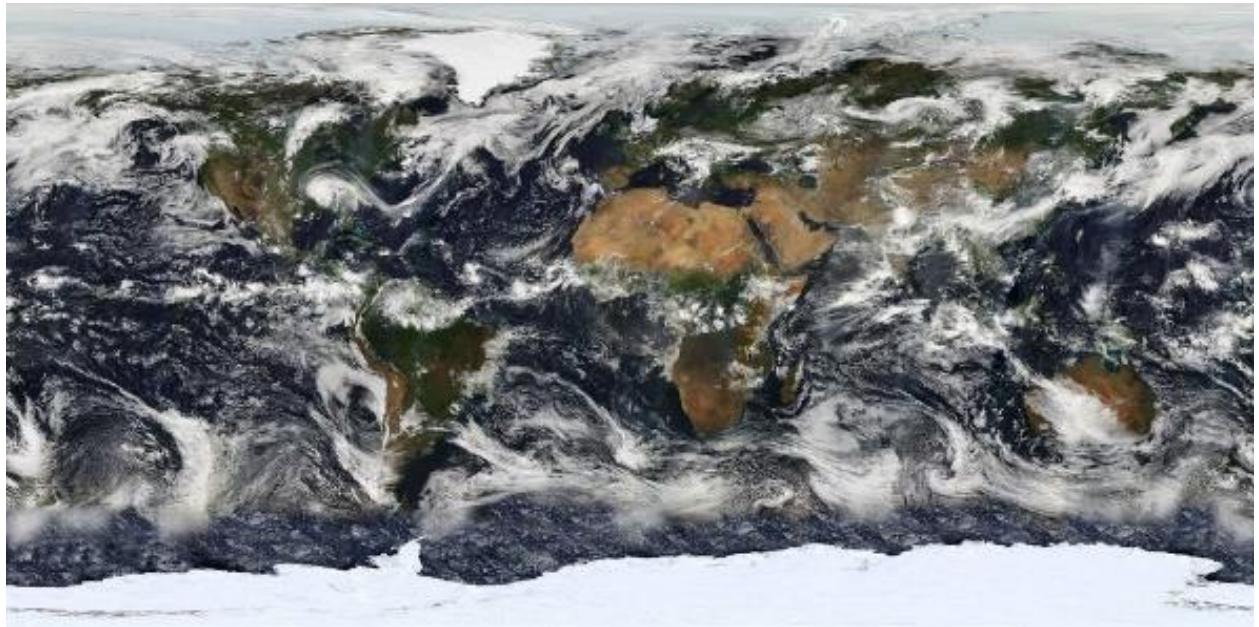
Mitigar **Riscos** a Pessoas, Ambiente e Ativos

Tópicos:

- ❑ Condições ambientais maritimo/offshore
- ❑ Sistemas de estruturas offshore Fixas/Flutuantes
- ❑ Carregamentos ambientais e condições de operação marítima/offshore,
- ❑ Processos de degradação de estruturas marítimas
- ❑ Avaliação de integridade de sistemas estruturais marítimos/offshore – BS-7910/DNV
- ❑ Gerênciamento de Condições de Integridade Orientada a Riscos **RBIM – Risk Based Integrity Management**

Contexto:

Infra-estruturas e recursos naturais marítimos/submarinos



- Niveis batimétricos:

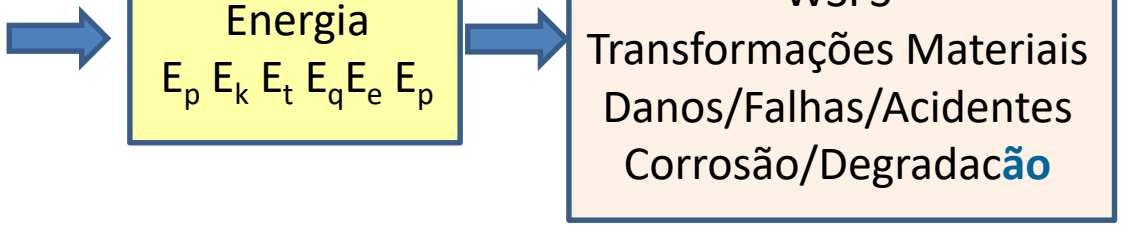
Costeiros	d < 50.0 m
Neríticos/A. Rasas	50.0 < d < 200.0 m
Mesopelagico/A. Profundas	200.0 <d < 1000.0 m
Batipelagico/ Ultra Profund.	1000 < d < 4000.0 m
Hadal	d > 4000,0 m

- Energéticos:
  - Neríticos: Ondas + Marés + Termóclinas
  - Eólicos offshore - 609 TWh/a BR
- Pesqueiros:
  - Sistemas de Producao e Processamento
  - Pescado + Algas
- Mineracao submarina
- Logísticos / Industriais / Cibernetica
- Estratégicos:
  - Plataformas aero-navais;
  - Sistemas flutuantes aero-espaciais
- Recursos hidro carbono O&G
  - 1/3 reservas mundiais offshore
  - Novas reservas → Águas profundas
- Infraestrutura Portuaria/Costeira/Urbana

Condições Meteorológicas / Metocean + Gelógicas/Geotécnicas

Transferências e Dissipações de Energias:

- Condicionantes meteorológicas e oceanográficas:
  - Normais (T = 10 - 30 anos)
  - Extremas (T = 50 - 100 anos)
  - Transitórias/Acidentais (T = 1-2 anos)
  - Ventos
  - Espectro de ondas (espectro de incidência de onda)
  - Correntes marinhas
  - Marés
  - Gradientes Termicos (Ar + Agua)
  - Salinidade
- Condicionantes Geologicas/Geotecnicas
  - Estratigrafia + Falhas + Erosividade + Rugosidade
  - Composicao + Estrutura granular/rochas
  - Sismos
- Batimetria /Orografia



Transferências e Dissipações de Energias

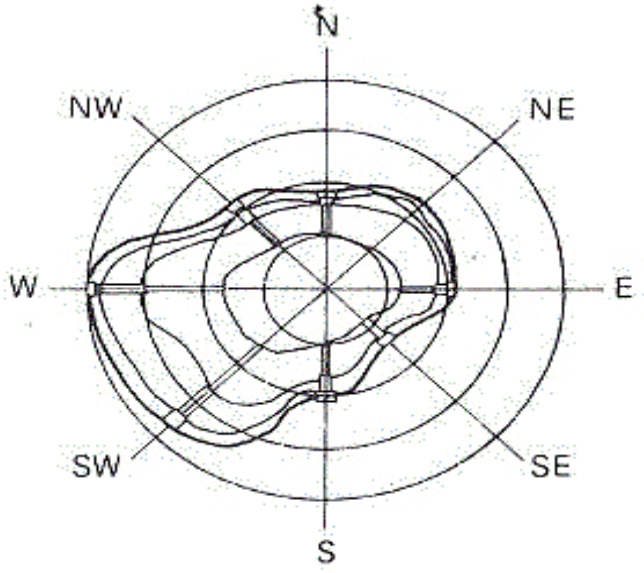
Controlam processos:

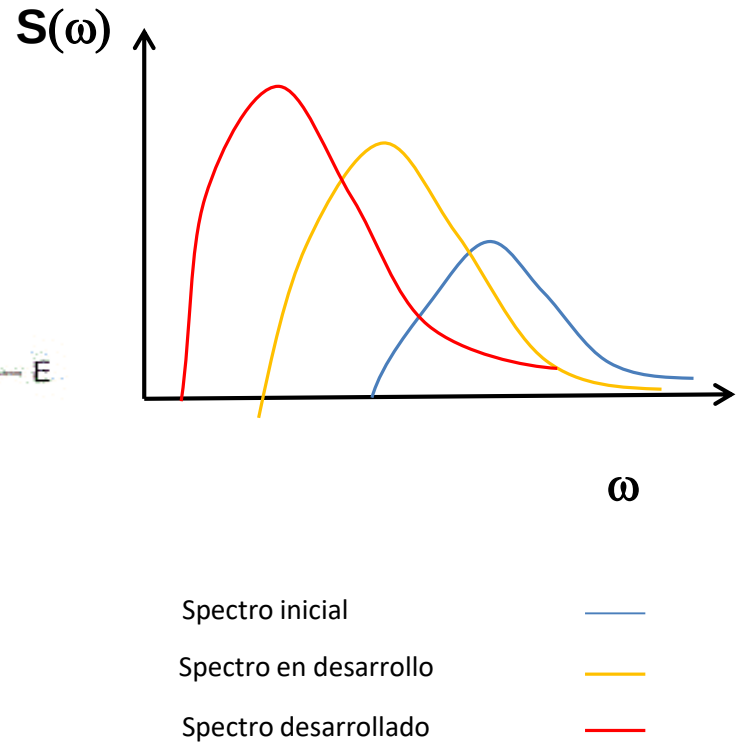
- Danificacao/deterioracao Estruturas Maritimas
- Integridade
- Seguranca e Confiabilidade
- Estados Limites: ULS / FLS / ALS

Estados de Mar – Desenvolvimento de Espectros de Ondas

Transferências e Dissipações de Energias: Ventos /Ondas

Wind Speed (km/hr)	Fetch (km)	Duration (hr)	Height (m)	Length (m)	Period (s)
20	24.	2.75	0.33	10.60	3.20
40	176.	11.50	1.80	39.70	6.20
60	660.	27.50	5.10	89.20	9.10
80	1662.	50.00	10.30	158.60	12.40

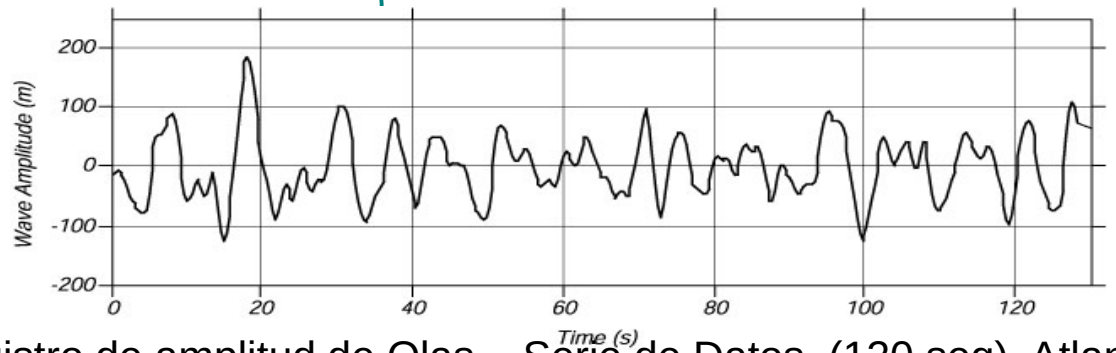




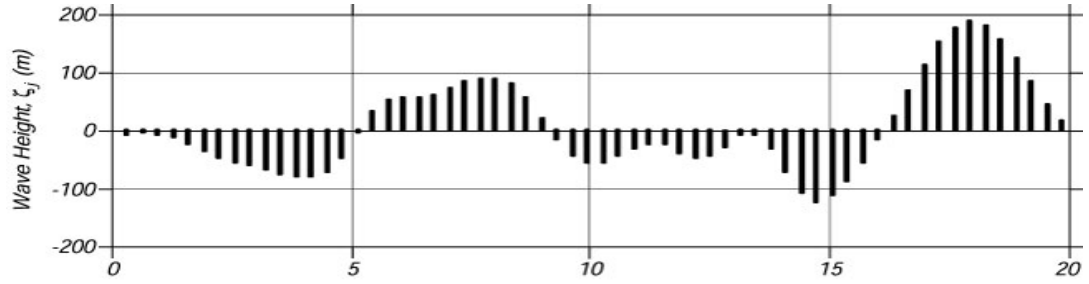
Estados de Mar – Sistemas de Monitoramento:

Medições de Ventos /Ondas / Dados Ocean.

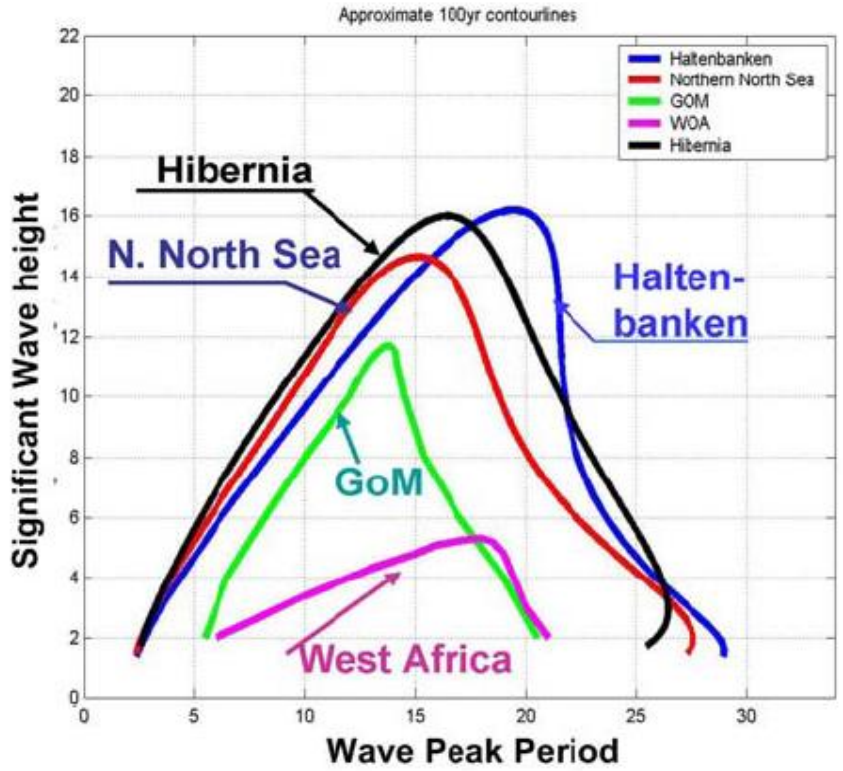
- Satellite Altimeters – Radio waves
- Sinthetic Aperture Radar/Satellite
- Meteocean Station Buoys
- Direct observation/optical measure
- Wave gages (height or pressure)

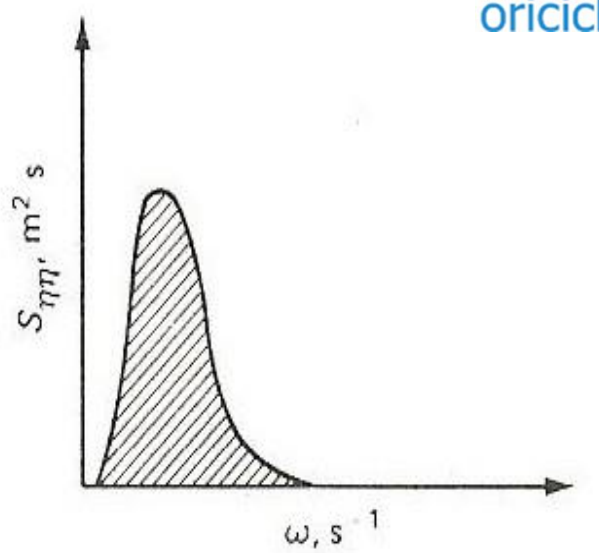


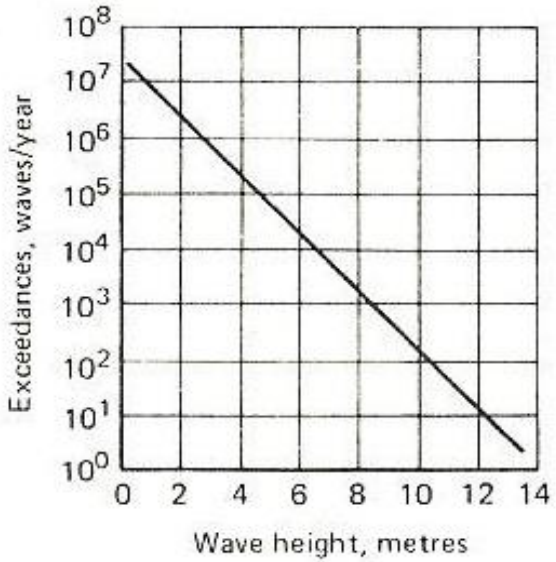
Registro de amplitud de Olas – Serie de Datos (120 seg) Atlantico Nord



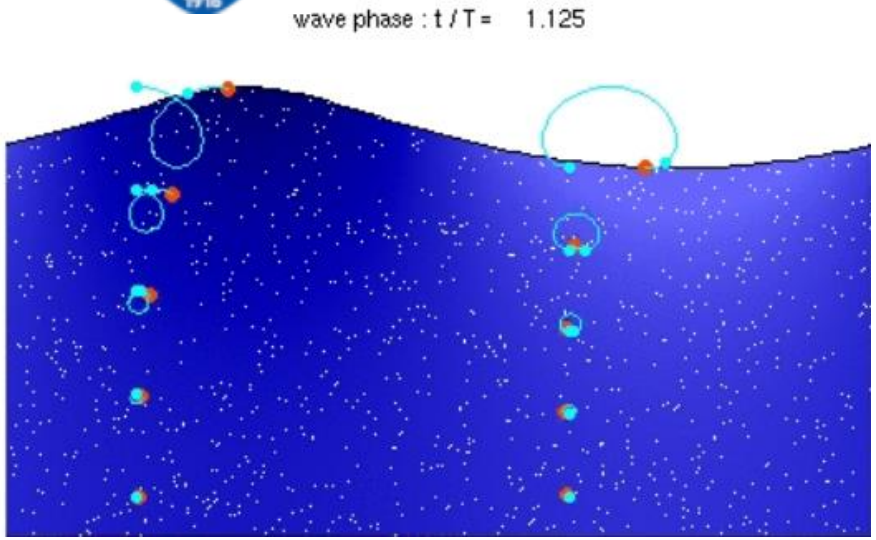
Serie de N datos amostrales digiltalisados 20 seg. (2 mediciones/seg Δ = 0.32s.) Ej.

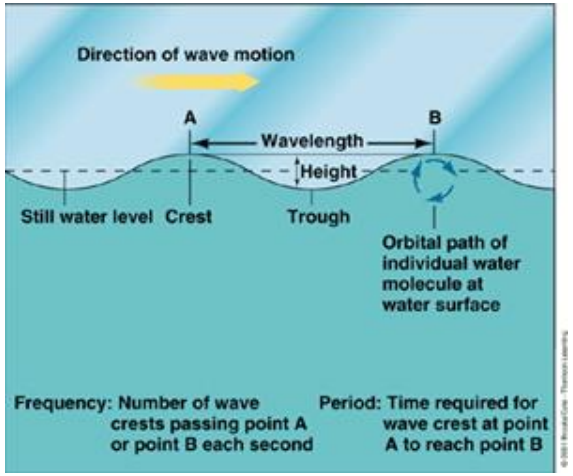






Espectro de alturas significativas de ondas no Atlântico Sul Brasil: Entre GOM e WOA
Em projetos espectros normativos Johnswap NNS
Interpretação física:
Densidade de Energia potencial **(Hs)** dos estados do Mar
Interpretação estatística:
Distribuicao probabilidade de energia potencial (Hs) - estrutura invariante

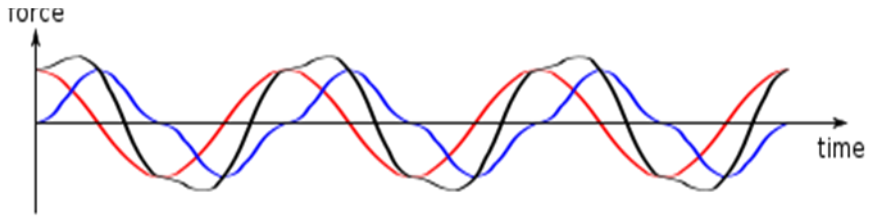


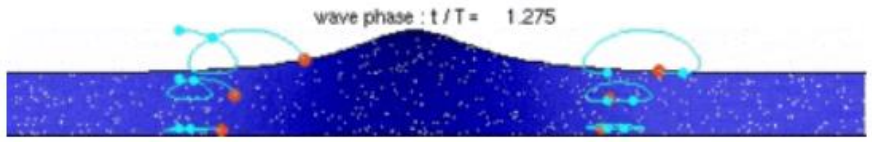


$$F = F_D + F_I = C_D \frac{w}{2g} A\, U|U| + C_m \frac{w}{g} V \frac{\delta U}{\delta t}$$

$$F = \rho C_m V \dot{u} + \frac{1}{2}\rho C_d A\, u|u|,$$

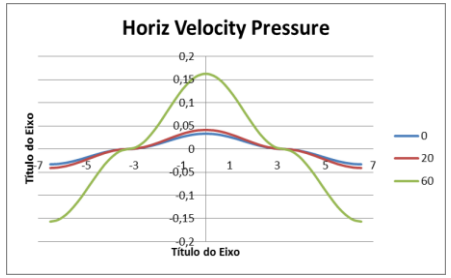
F_I F_D

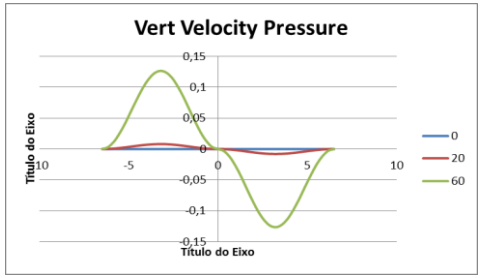


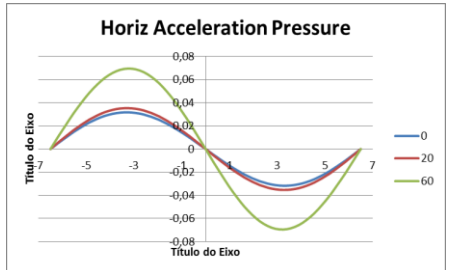


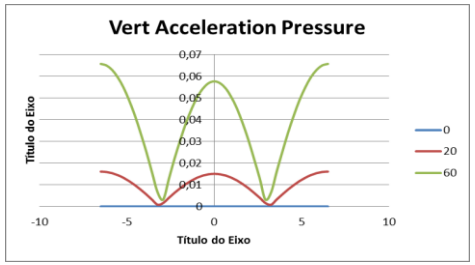
Effecto de Profundidad
Aguas profundas y someras

Velocidad de fase
Velocidad de grupo

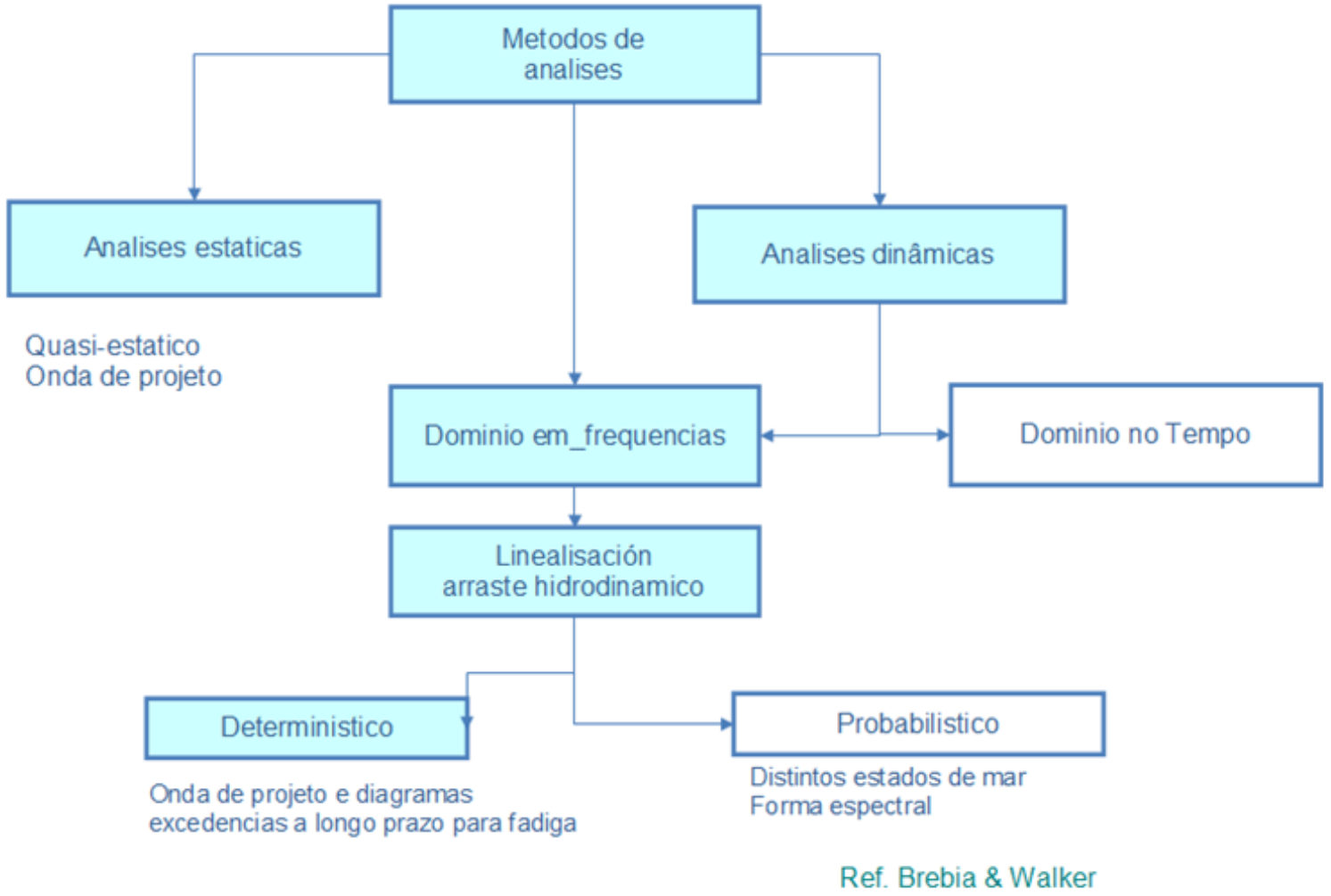








Metodologias de Análises



Ref. Brebia & Walker

- Modelo estructural global y subsistemas

Análisis In-Situ

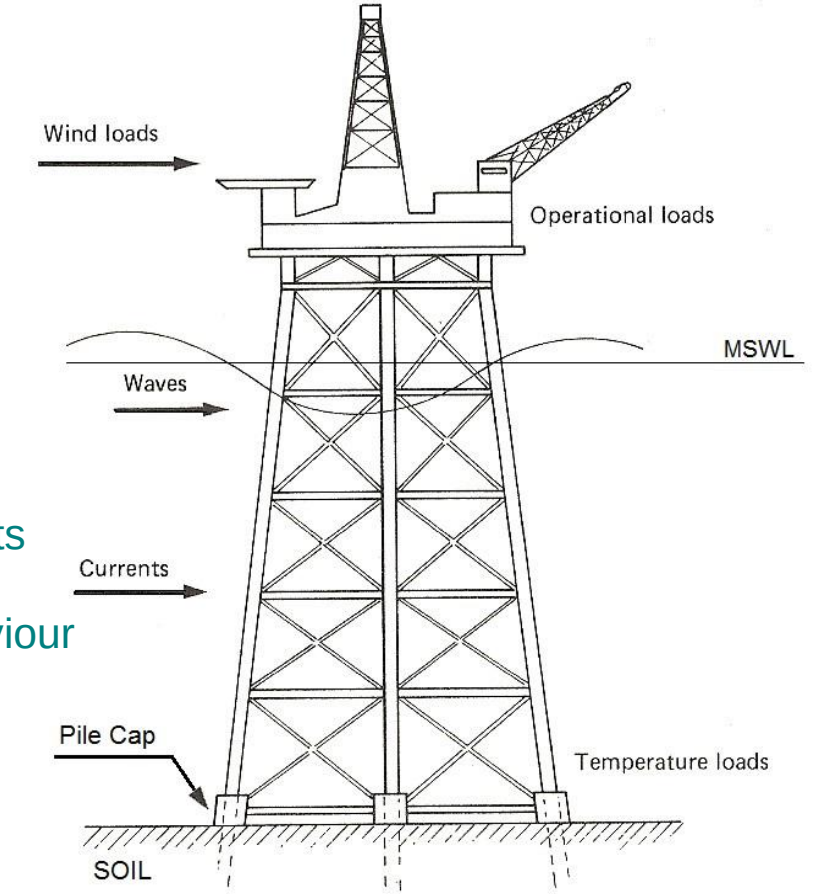
- Operational loadings
- Sea environment loadings

Structure – Foundation – Soil Interaction

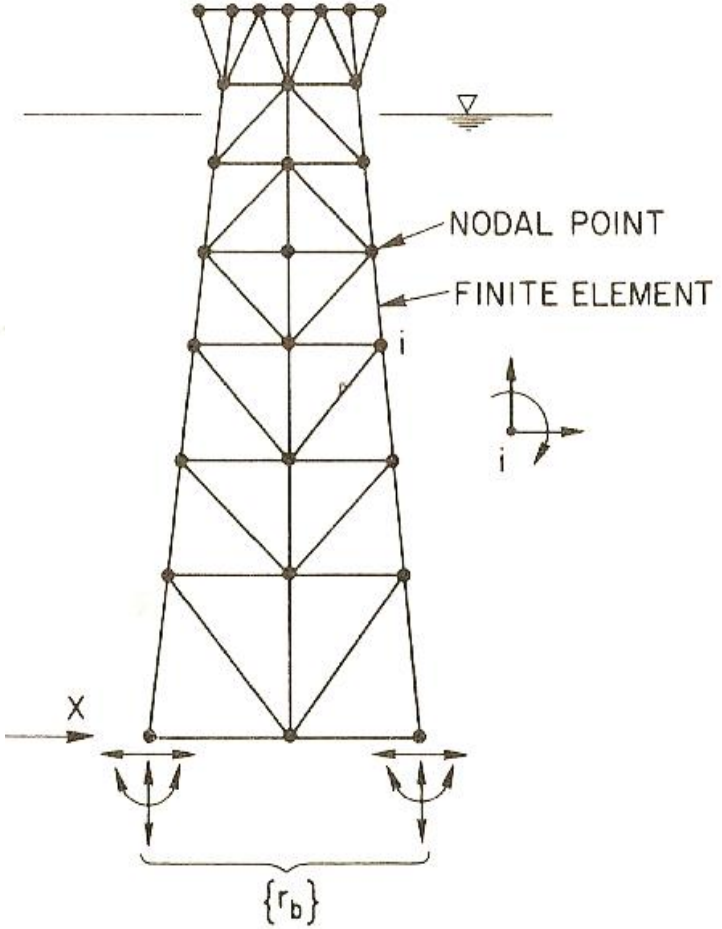
- Non linear pile /beam elements
- Non linear soil stiffness behaviour
- Soil layers properties

Design & Code Checking

- API RP-2A (ASD – LRFD)
- DNV – NORSOK



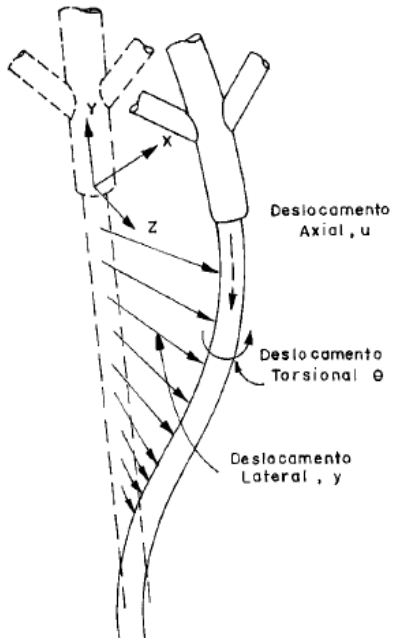
Loads acting on an offshore structure

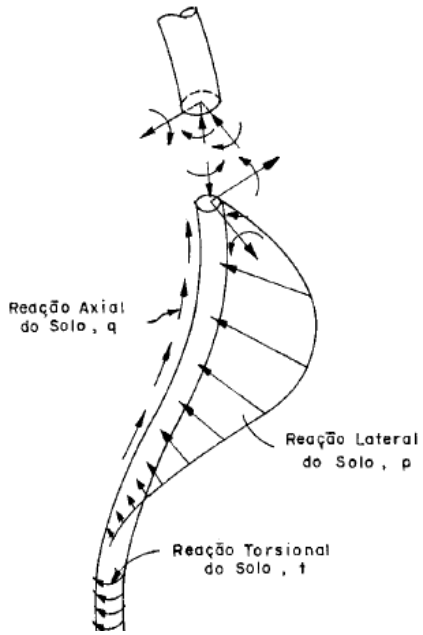


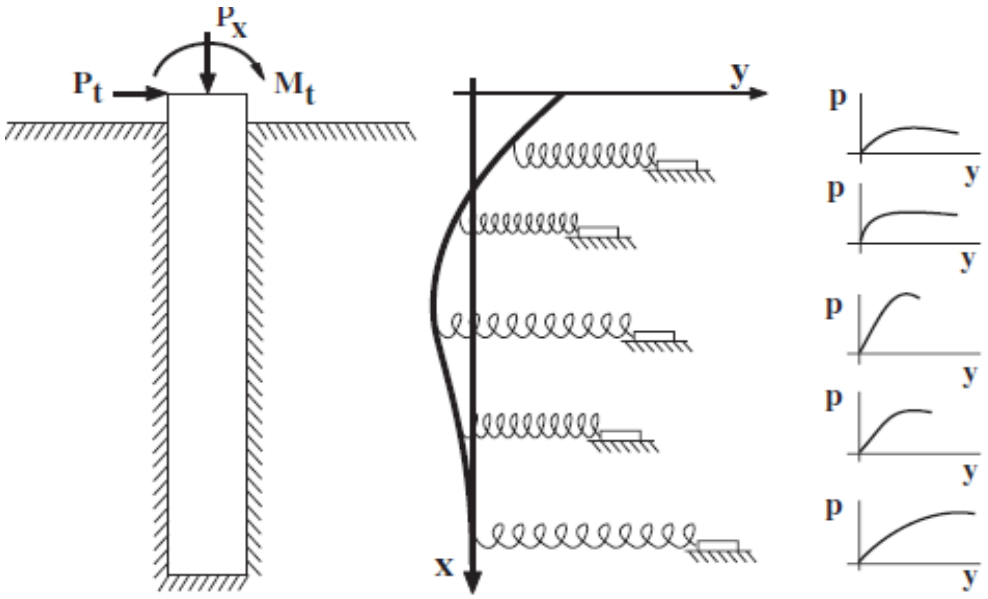
Discrete model of framed tower

Zienkiewicz, O.C " Numerical Methods in Offshore Structures

Interacción suelo-estructuras-fundación – Pile Soil-Structure Interaction
Fundaciónes profundas (Pilotes)
Metodologia API-RP-2A _ Curvas PQ-Y







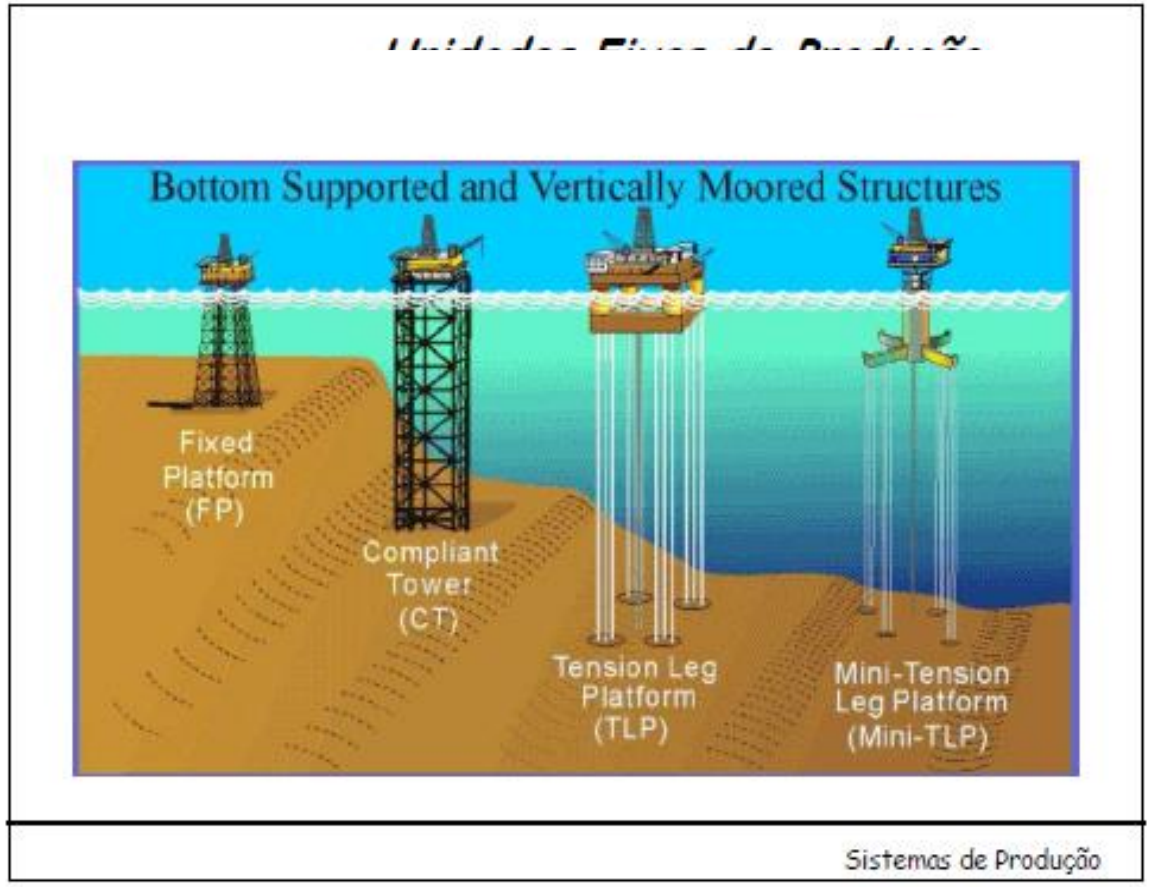
Zienkiewicz, O.C “ Numerical Methods in Offshore Structures

- **Infra-estruturas de Sistemas de Producao:**

Tipos e Classificacao de Sistemas:

- Sistemas Fixos rigidos/complacentes:
  - Jaquetas
  - Torres flexiveis
  - Plataformas de Gravidade
- Sistemas especiais – Eolico + Meteocean etc:
  - Monopiles, Tripods,
  - Gravidade e Flutuantes
- Sistemas flutuantes:
  - Semi-submersíveis(CSU)
  - TLP – Tension Leg Platform (CSU)
  - FPSO – Floating Production Storage & Offloading
  - Torre Spar
  - Monoboias
- Sistemas Hibridos Flutuantes/Fixos:
  - Jack-ups/ Plataformas Auto-Elevatorias
- Sistemas Submarinos:
  - Dutos + Risers + Equipamentos + Manifolds etc

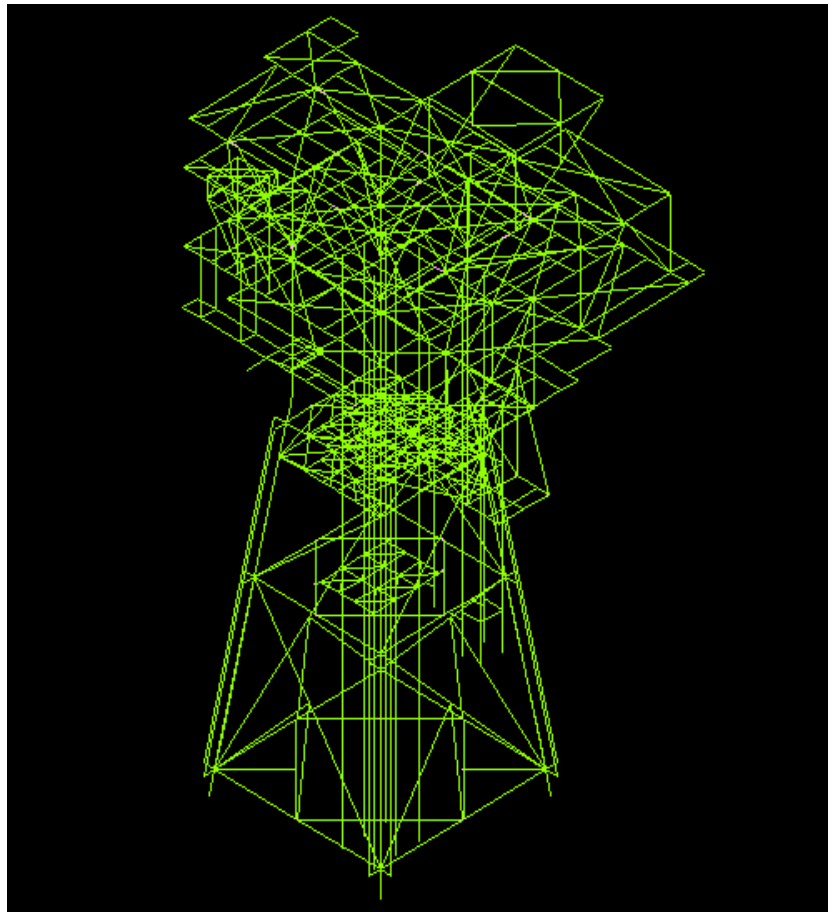
- **Infra-estruturas de Sistemas de Producao:**
- Sistemas Fixos rigidos/complacentes:



Plataforma Fija PRA-I
Santos SP – Unidad de Bombeo – 2010
Producción: 750000 BBP/d

PETROBRAS CENPES
GTSTRUDL Structural Analysis System
THEMAG Engineering Consultants
EXACTUM Engineering Consultants
Construccion ODEBRECHT CNO

- **Infra-estruturas de Sistemas de Producao:**



Plataforma Vermelho I

Modelo Estructural global
PETROBRAS CENPES
Sistema ADEP – STRUDL Structural Analysis System

Ref. Prof. Dr. A J. Ferrante Consultant

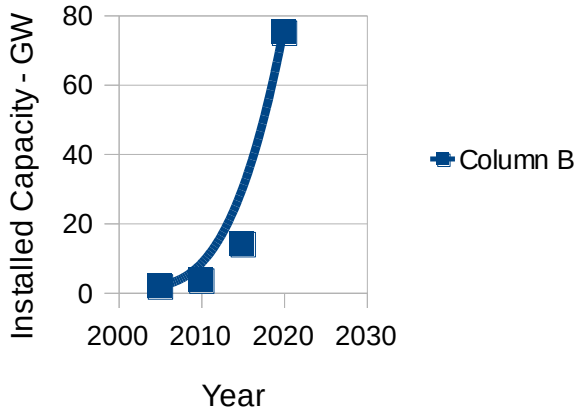
- **Infra-estruturas de Sistemas de Producao:**

Offshore Wind System
Denmark

Offshore Wind System
Sweden

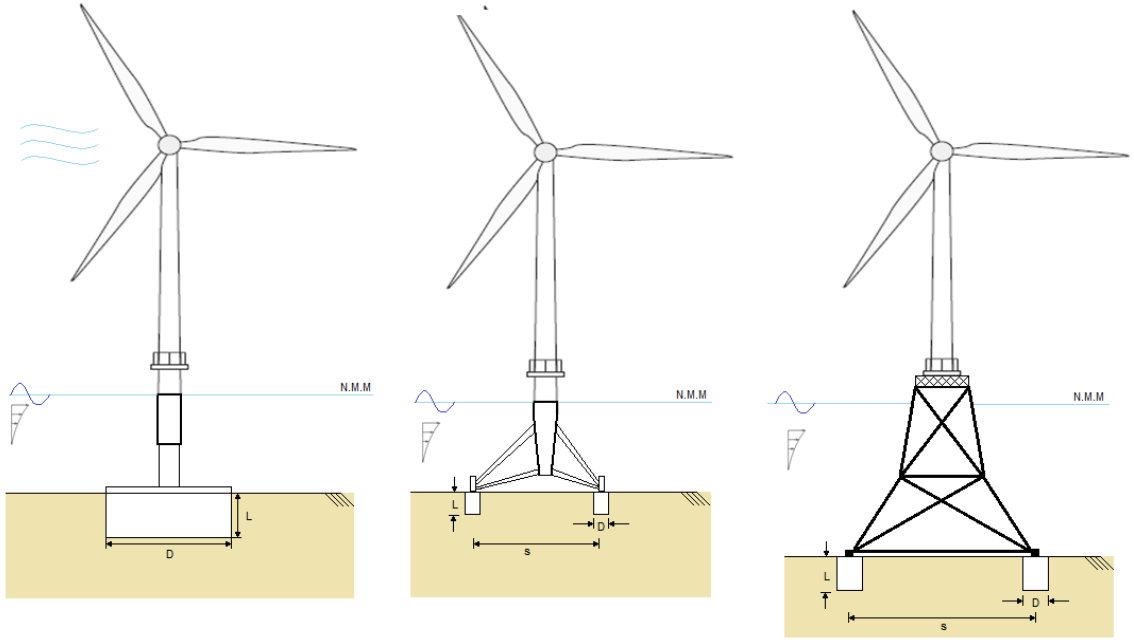
Offshore Wind
Monopiles

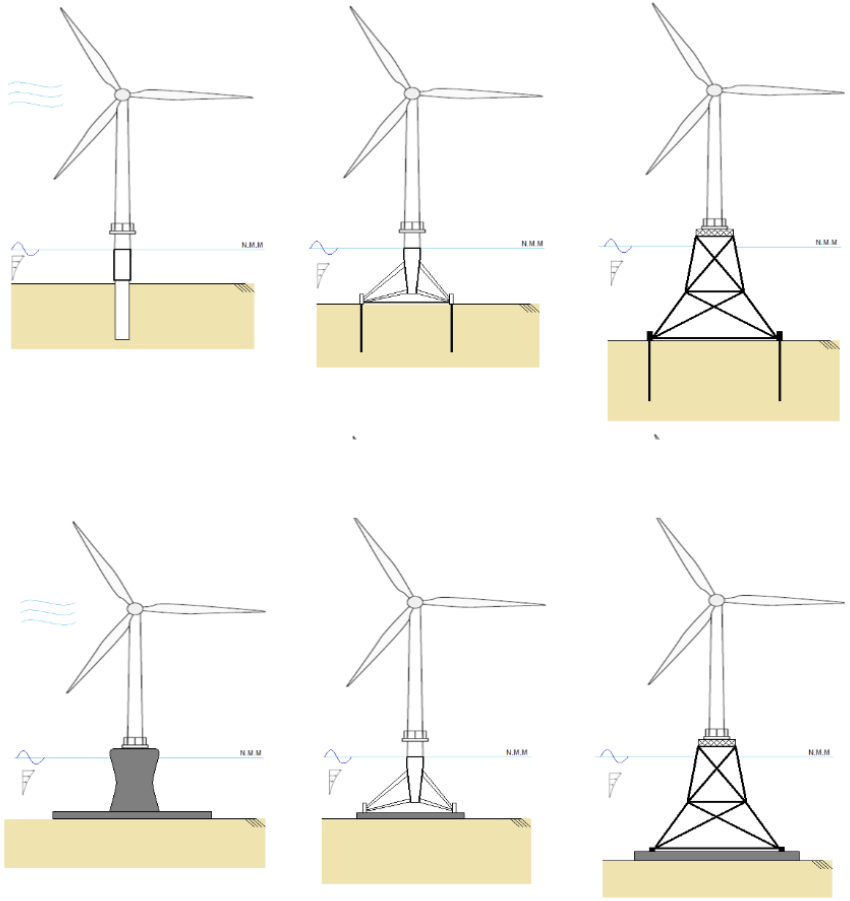
Global Offshore Wind Power



Brazil:
146 GW onshore
606 GW offshore 2010
Strategic resource

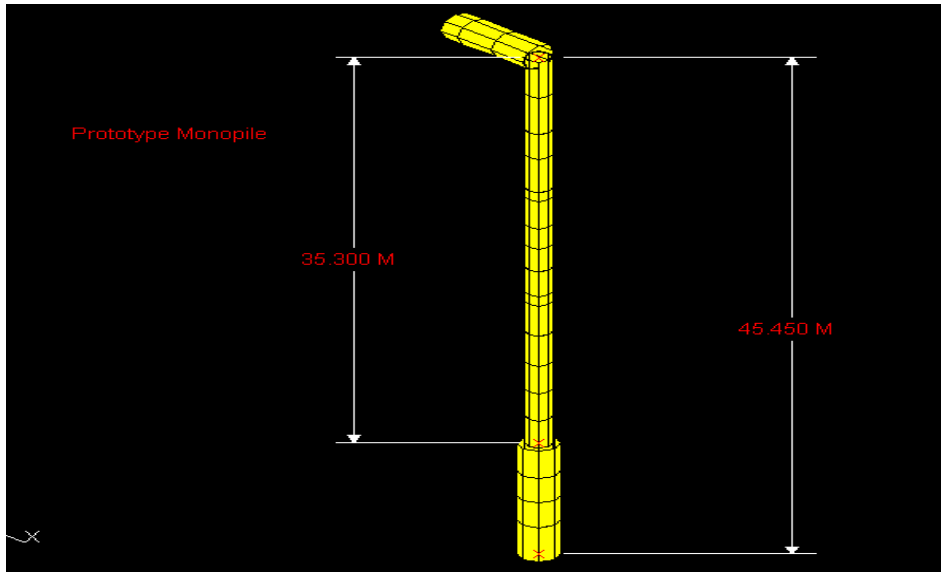
- **Infra-estruturas de Sistemas de Producao:** Offshore Wind Monopiles





Ref. Trovato, Euclydes
Rev. Fundações e Obras Geotécnicas 2012

- **Infra-estruturas de Sistemas de Producao:**

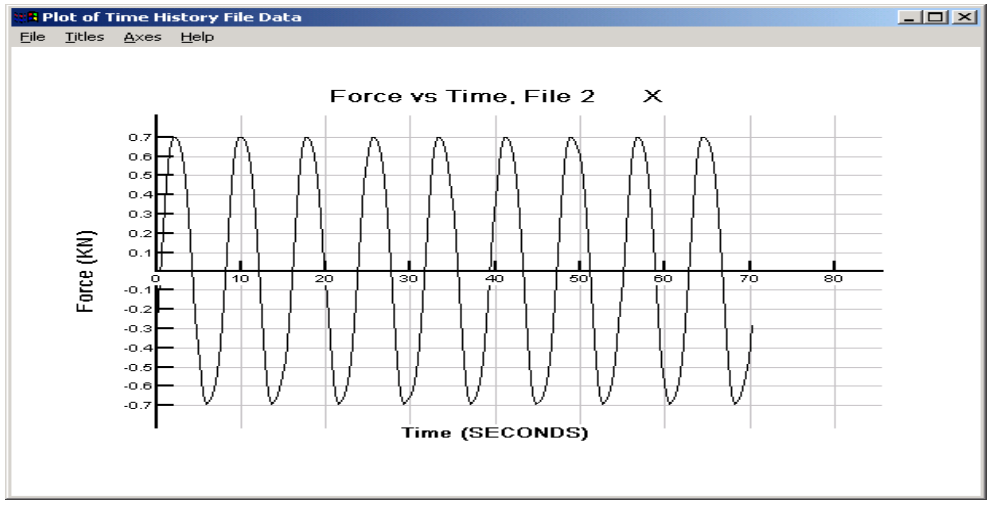


Offshore Wind power infra-structure
Global strutural model

- ULS – Cond. Normais + Extremas
- ALS – Colisoes / Falhas Sistemas
- FLS – Fadiga Sistemas Estruturas
- Avaliacoes Fundacoes

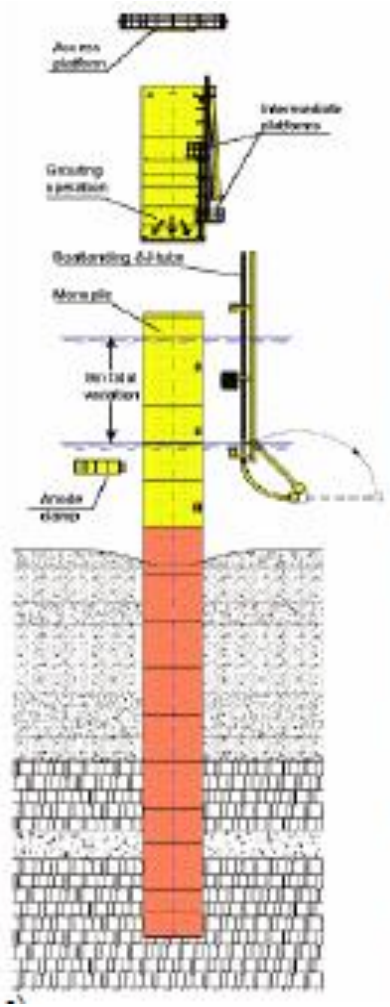
Dragados de España
GTSTRUDL Structural Analysis System
Prof. Dr. A J. Ferrante Consultant

Wave transient forces – Fuerzas transientes de Olas
Time domain – Domínio del tiempo

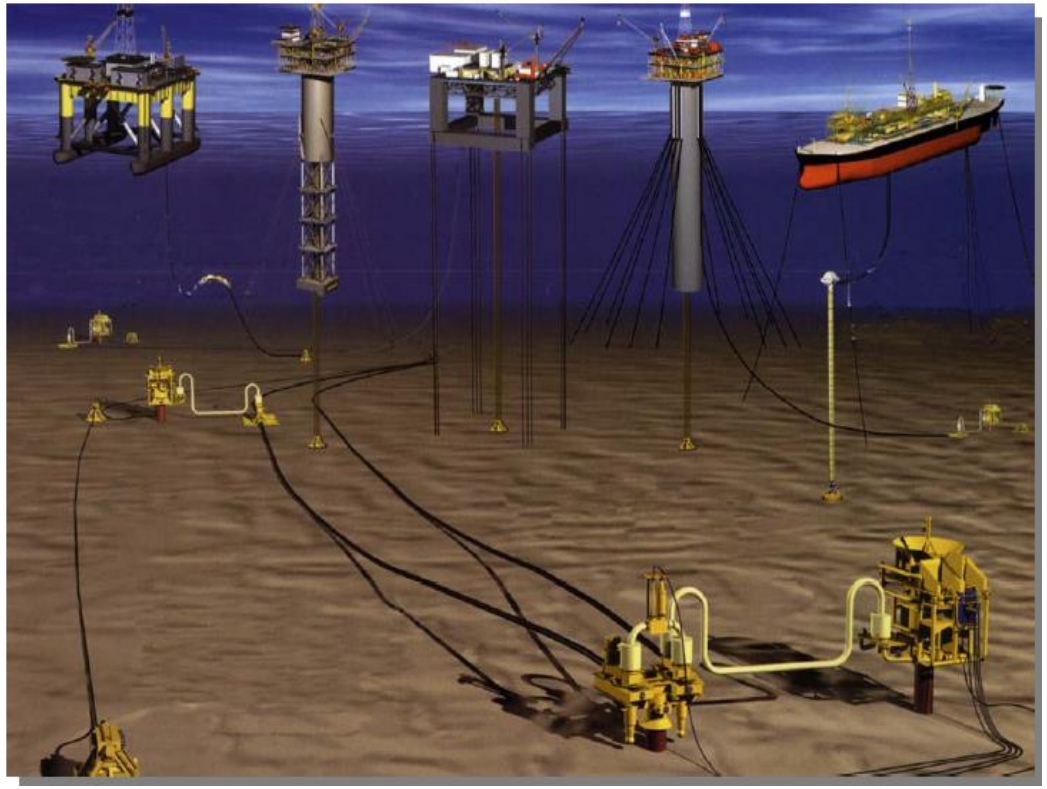


Operational Wind Turbine Forces- Fuerzas Operacionales
me domain – Domínio del tiempo

- **Infra-estruturas de Sistemas de Producao:**



- **Infra-estruturas de Sistemas de Producao:**



Componentes principales:
Plataforma en la superficie (Sistemas FPSO)
Risers –
Sistema Submarino Equipos /Manifolds
Sistema Submarino – Infra estructura ductos exportaciión Amarre tuberías
Sistemas y buques cisterna de transporte y alivio

Field Location /
Posición en Campo

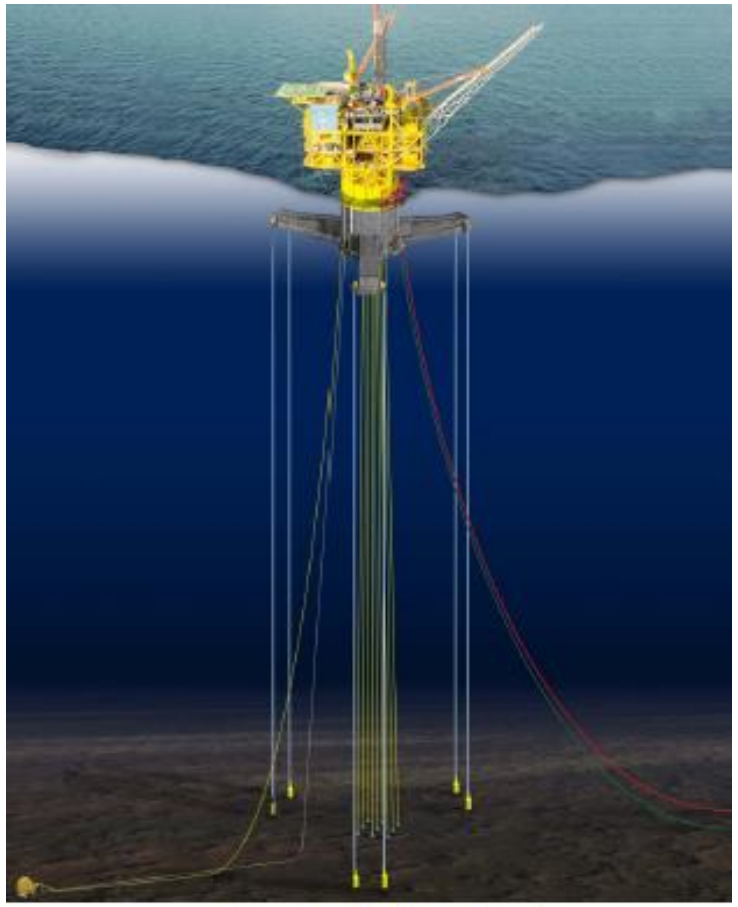
Unrestricted service
Sin restricción

Certification aspects:
Aspectos de certificación:
Aprobación por Clases

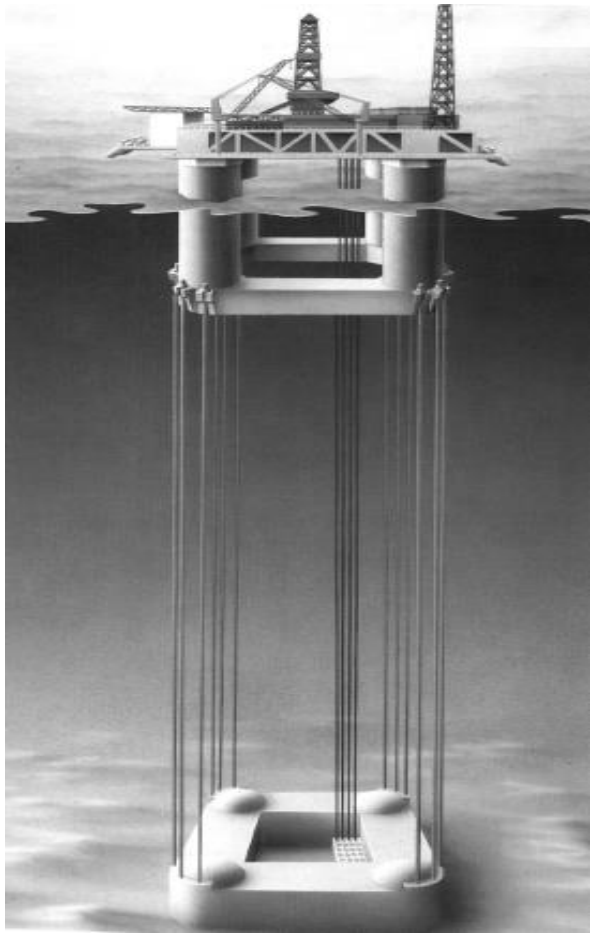
- Semisubmergibles
- TLP
- SPAR
- FPSO/ FSO

Notar:
Aguas profundas H > 300 m
Infra-estructura submarina

- **Infra-estruturas de Sistemas de Producao:**



Tension-Leg Platform (TLP)

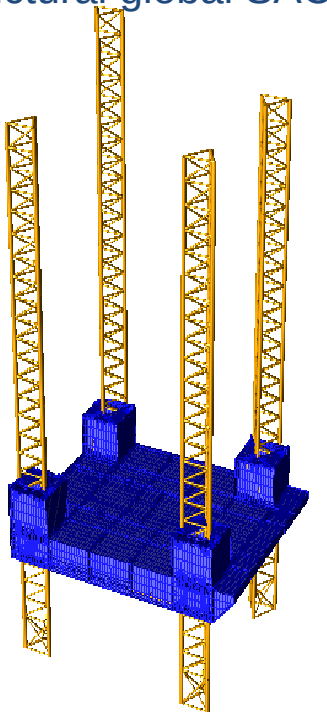


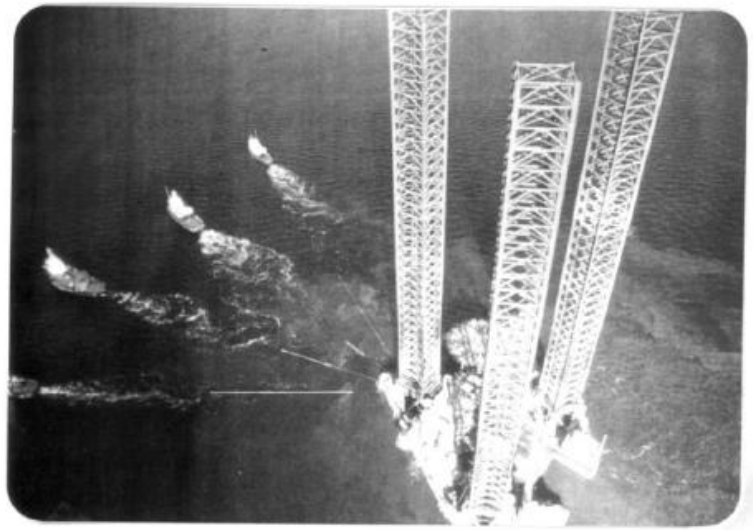
Field Location
Restricted service/area
Certification aspects

Ref. Gilberto Ellwanger - UFRJ

- **Infra-estruturas de Sistemas de Producao: Unidades Jack-Up**

Modelo Estructural global SACS System





Shearwater platforms & Maers Endurer

Jack Up Drilling Rig – Field Operation North Sea

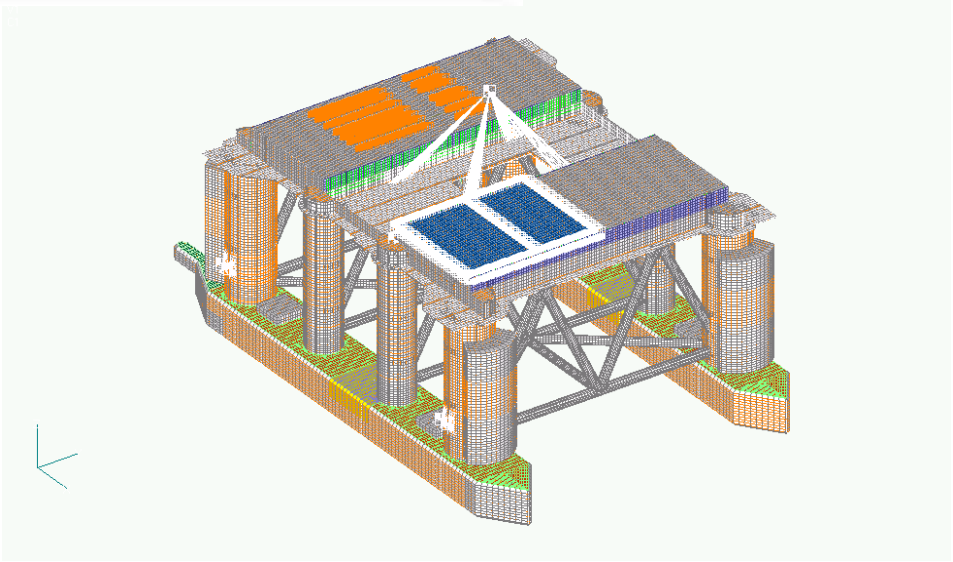
Operación perfuración / Sistemas de Producción

Unidades de apoyo operacional y de Instalacion

Unidades de Investigación y Oceanográfica/Geologica

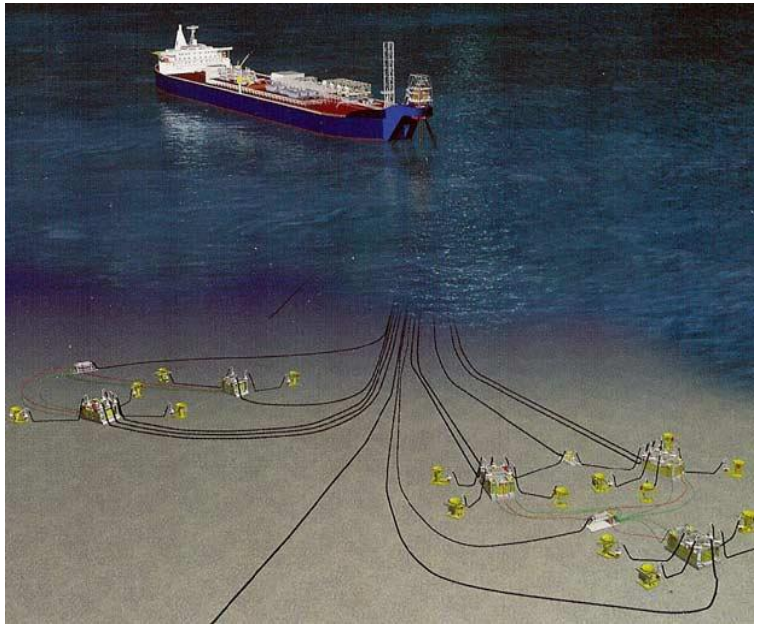
- **Infra-estruturas de Sistemas de Producao:**

Unidade Semi-Submergible
Modelo Estructural global
Plataforma P-10 PB
Profundidades 300m < H < 600 m
Operaciones de Perfuración y Desarrollo de campos
Sistemas de Producción
Unidades de habitación
Unidades estrategicas y operaciones militares



Modelo Estructural global MSC-NASTRAN

FPSO (Floating, Production, Storage, Offloading)



- Topside
- Hull
- Mooring/riser system

Courtesy of Linde AG. Used with permission.

Avaliações Críticas de Integridade (Critical Integrity Assessments)

- Avaliações de confiabilidade e segurança estrutural (Target β values);
- Caracterização de colapsos estruturais – **Estados Limites;**
- Condições Limites de **Ações Operacionais e Ambientais**
- Condições Limites de **Ações Extremas/Acidentais**;
- Caracterização de **Parâmetros Materiais** (Íntegros x Danificados x Degradados)
- Avaliações de **Instabilidade e Flambagem** etc
- Avaliações de **Fadiga**
- Avaliações de Mecânica de Fractura
- Avaliações de **Modos de falhas**Avaliações de Resistência Residual;
- Avaliações de **danos e consequências** colaterais;
- **Identificação de Riscos** estruturais ;
- Avaliações de **Riscos e consequências** Ambientais / Econômicas / Vidas Humanas;
- **Critérios de Inspeção** em Fabricacao/Montagem /Serviço
- Plano de **monitoramento e controle** de integridade
- **Bases de dados** de Integridade
- **Gerenciamento de integridade estrutural**

Premisas:

- Evaluación de defectos aceptables / tolerables (crack-like);
- Sistema/componente/detalle estructural bien diseñados/fabricados;
- Limites de deformación / dañoy comportamiento reológicos

  comportamento global Linear Elástico

  comportamento local (da fractura) MFLE / plasticida limitadas;
- MFLE Mecanica de Fractura Linear Elastica ;
- Procedimientos normalisados de evaluación – **BS7910- Nivel I-II-II**
- Metodos numericos consistentes y intensivos MEF

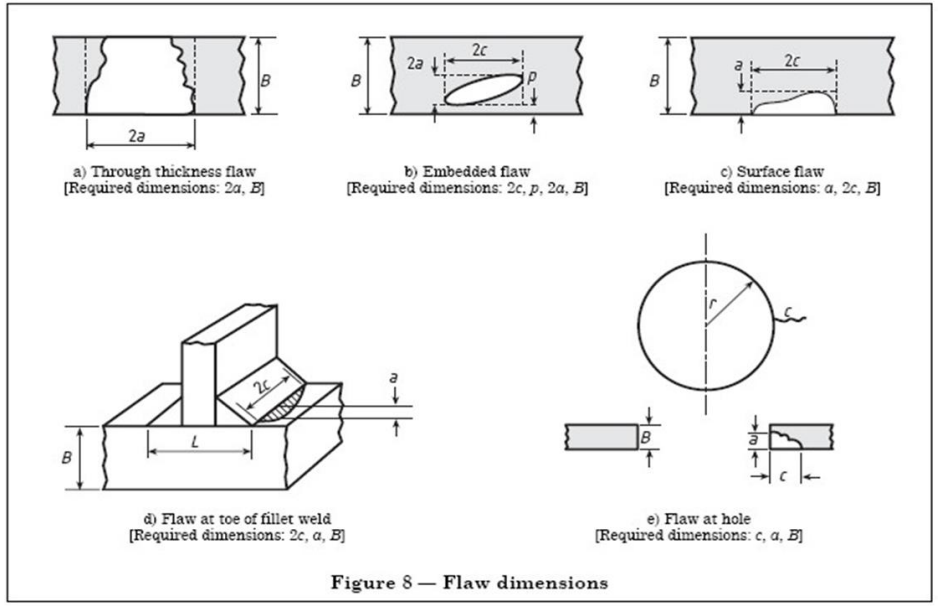


Figure 8 — Flaw dimensions

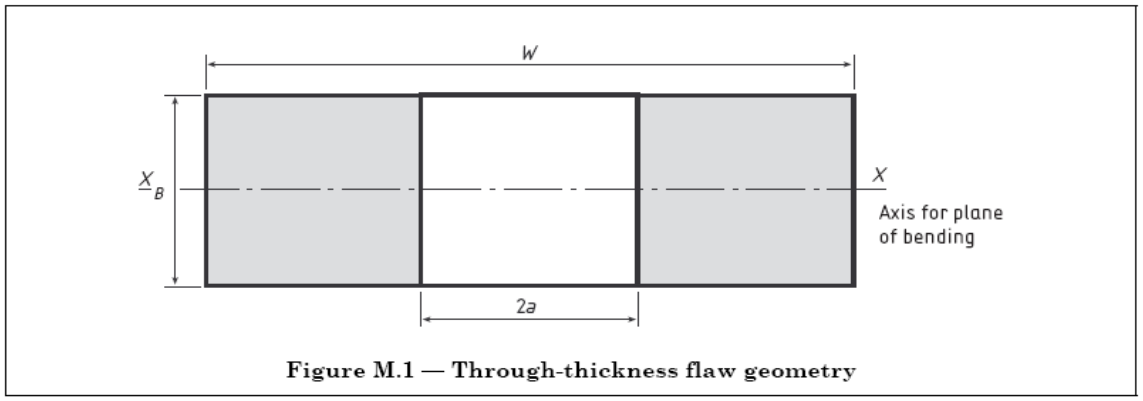


Figure M.1 — Through-thickness flaw geometry

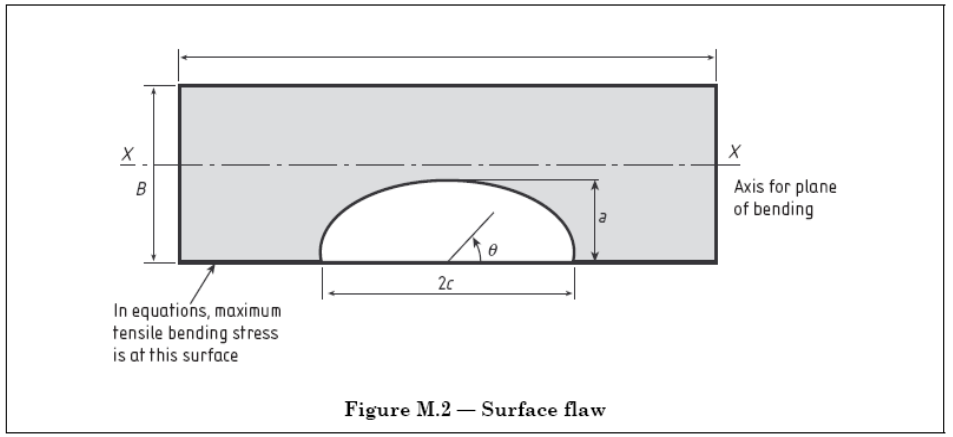


Figure M.2 — Surface flaw

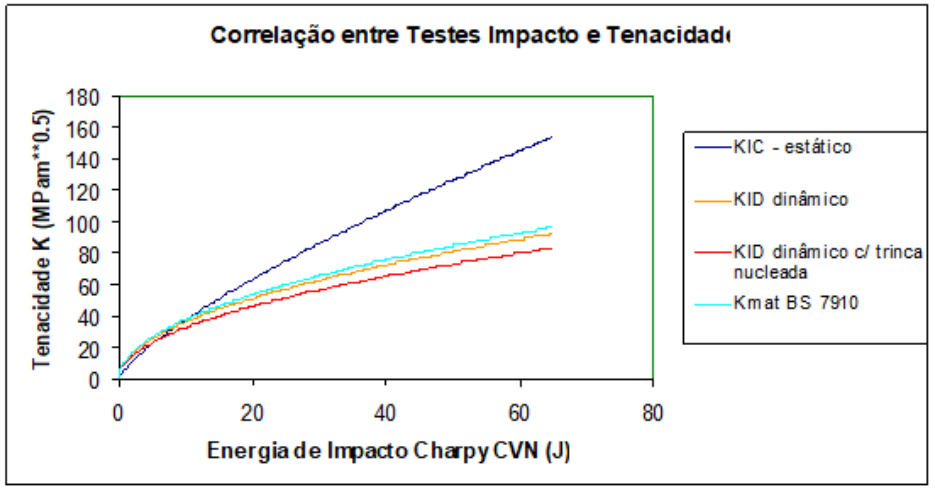
oriciclon

Premissas:

- Propriedades de Tenacidade Material – Correlacoes de Testes de Impacto
- Efeitos sobre Material Integro – Ensaios Estaticos e Dinamicos
- Material fraturado / fragilizado
- Material fraturado/fragilizado submerso / corrosao maritima
- BS-7910 / Degradacao de materiais submersos/corrosao - estatistica:
  Tensoes de escoamento Fy 16% SD
  Tenacidade Fratura/Fadiga: KIC 32% SD

- ABS AH-36 → regime ductilidad tipica de transición

- Tipo I – Condición estáticas de tenacidad
- Tipo II – Condiciónes dinâmicas de tenacidad
- Tipo III – Condições dinâmicas de tenacidade c/ trinca nucleada
- Correlaciones normativas BS-7910
- Tipo I entre 4.0J < CVN < 82.0 J
- Tipo II e III entre 2.0J < CVN < 62.0 J



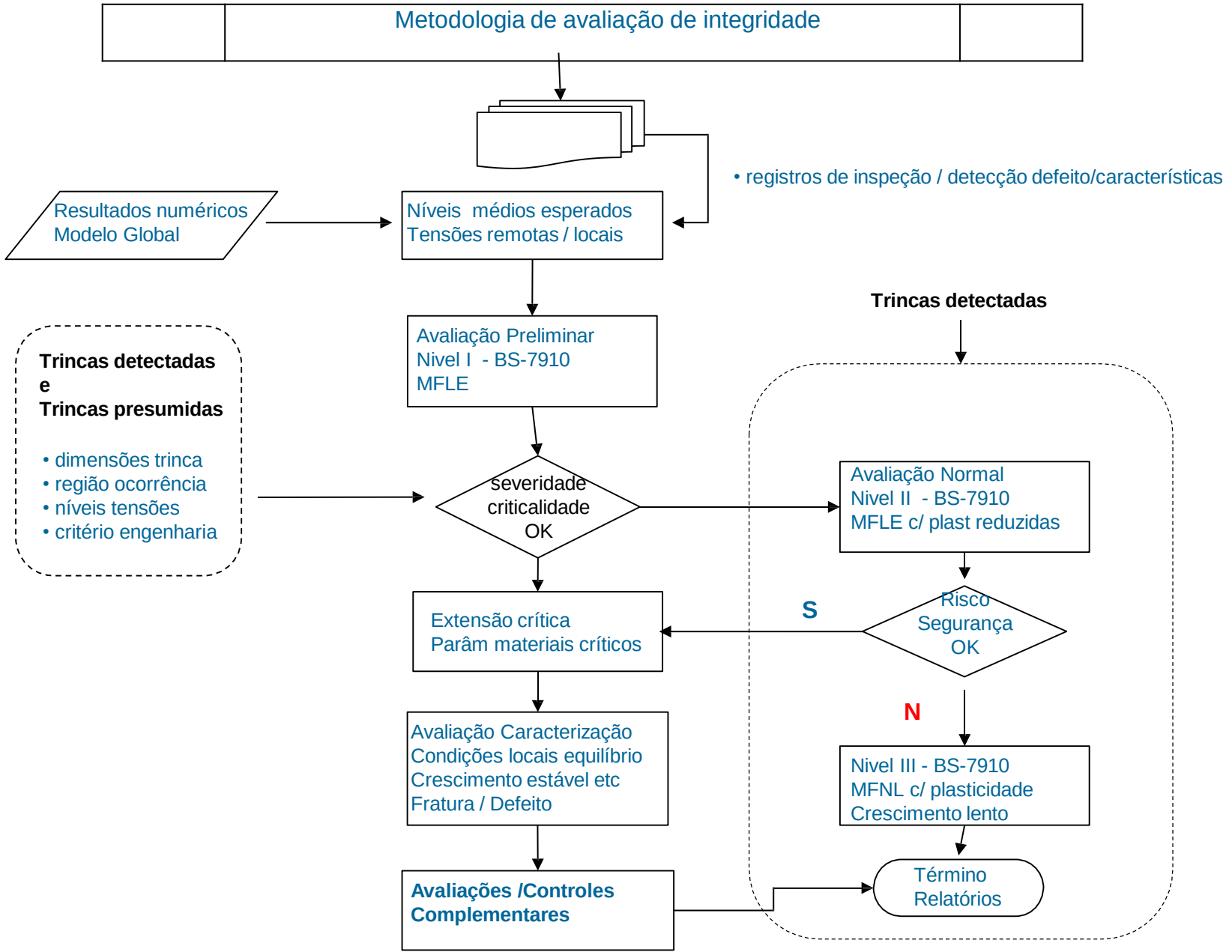
$$\frac{[K_{IC}]^2}{E} = 0.22[CVN]^{1.5}$$

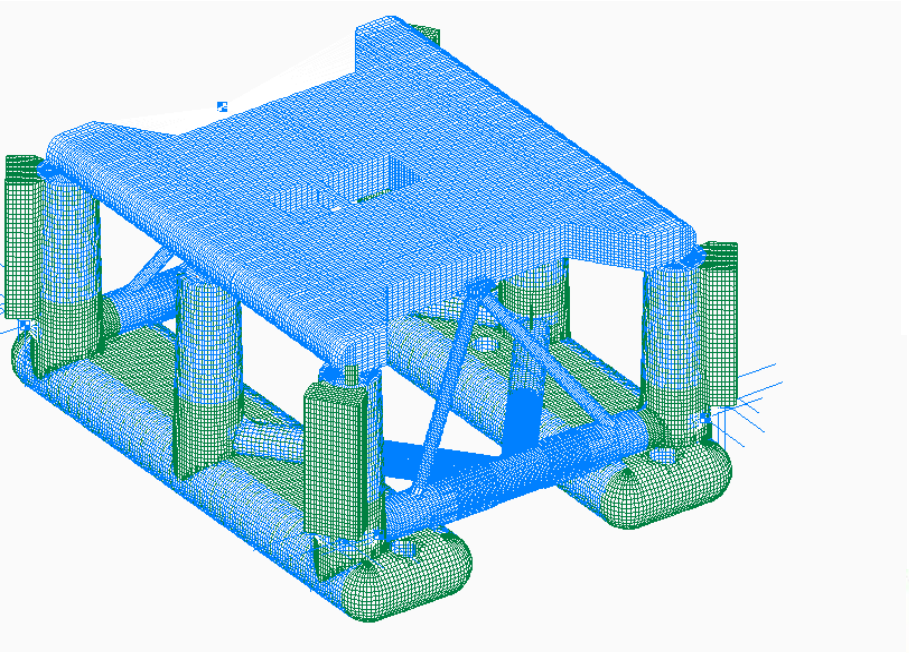
$$\frac{[K_{ID}]^2}{E} = 0.64[CVN]$$

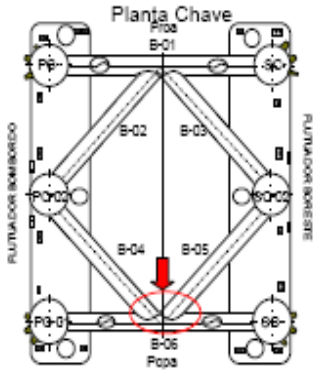
$$\frac{[K_{ID}]^2}{E} = 0.52[PCI]$$

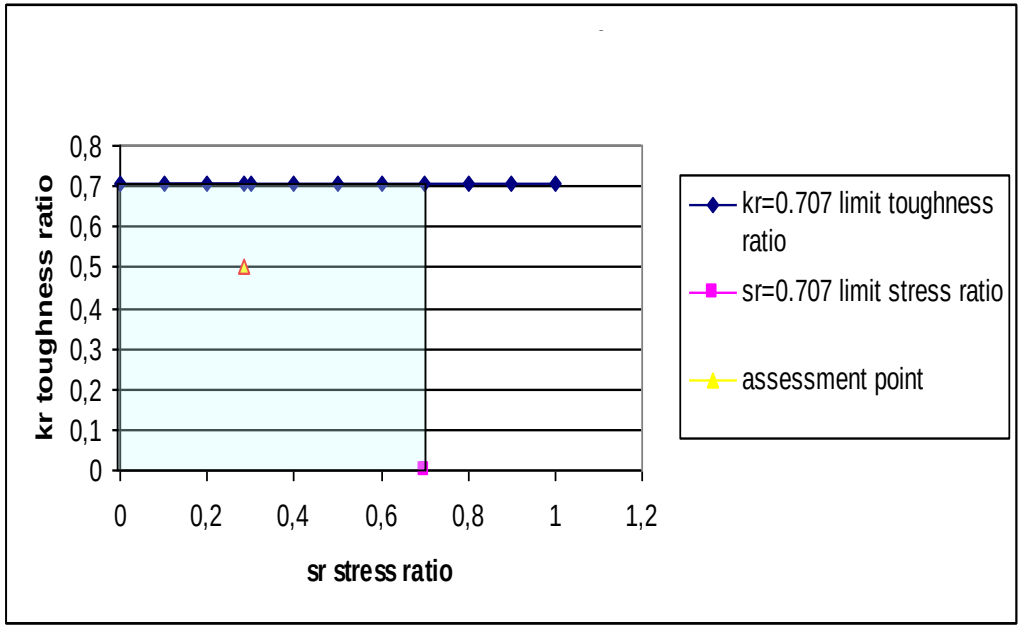
$$K_{MAT} = \left[\left(12\sqrt{CVN} - 20\right) \times \left(25/t\right)^{0.25}\right] +$$

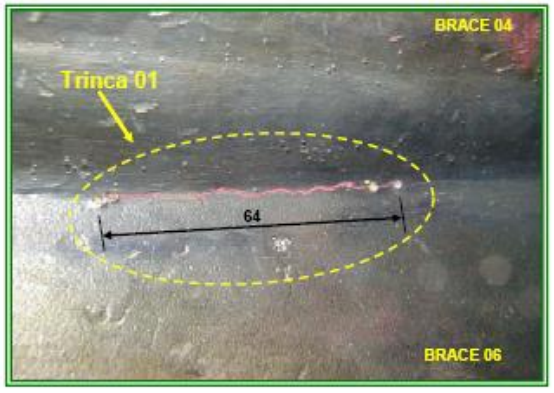
Metodologia de avaliação de integridade

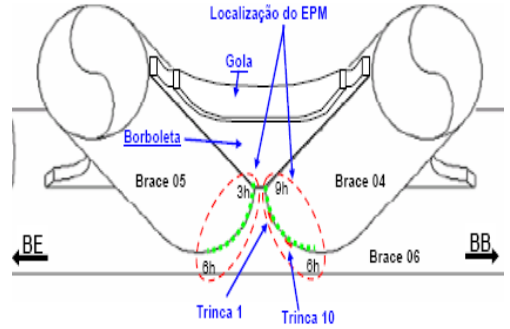




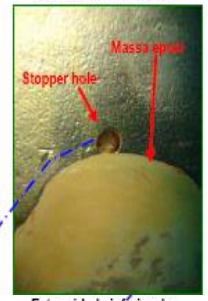

Planta Chave
Proa
B-01
B-02
B-03
B-04
B-05
B-06
Popa
FLUTUADOR BOMBORDO
FLUTUADOR BORESTE


kr toughness ratio
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0
0
0,2
0,4
0,6
0,8
1
1,2
sr stress ratio
kr=0.707 limit toughness ratio
sr=0.707 limit stress ratio
assessment point

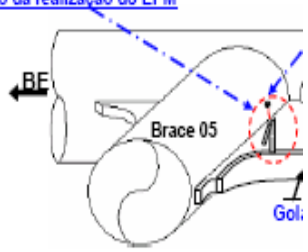

BRACE 04
Trinca 01
64
BRACE 06


Localização do EPM
Gola
Borboleta
Brace 05
Brace 04
Brace 06
3h
9h
6h
6h
BE
BB
Trinca 1
Trinca 10

Extremidade superior da Trinca 3 no brace 05



Região da realização do EPM

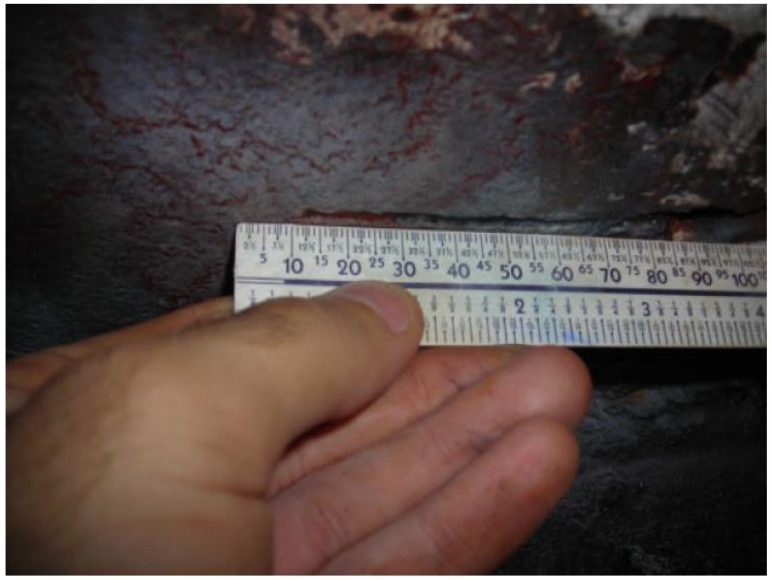


Extremidade inferior da Trinca 3 no brace 05

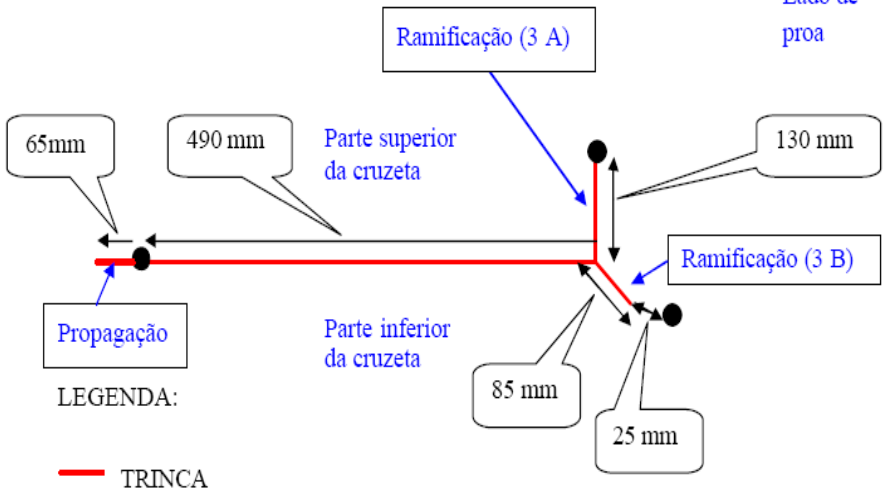
Monitoramento da Junta K de Popa

Extremidade inferior da Trinca 3 no brace 05

Monitoramento d

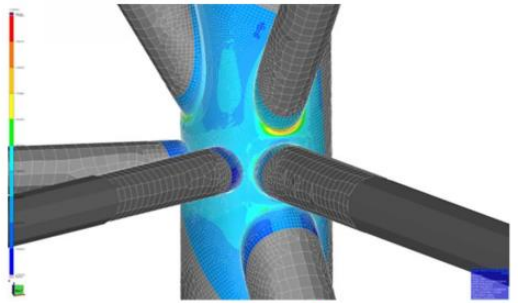


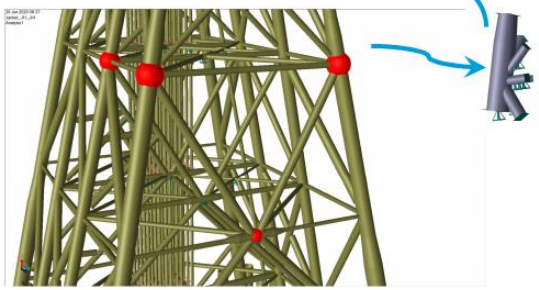
Lado de proa



DNV RP-C203 Fatigue design of offshore steel structures

- "DNV RP-C203 presents recommendations in relation to fatigue analyses based on fatigue tests (S-N data) and fracture mechanics"
  - NORSOK N-004, N-006 refers to DNV RP-C203 for fatigue
  - For offshore O&G: DNV-OS-C101 refers to RP-C203 for fatigue
  - For offshore wind turbine foundations: DNV-ST0126 and IEC IEC61400-3-1 refer to RP-C203 for fatigue
- "The aim of fatigue design is to ensure that the structure has an adequate fatigue life. Calculated fatigue lives also form the basis for efficient inspection programmes during fabrication and the operational life of the structure"
  - Fatigue is calculated from transportation, operation and life extension. The fatigue analyses are done with initial or part damage thereby computing accumulated damage
- "To ensure that the structure will fulfil its intended function, a fatigue assessment, supported where appropriate by a detailed fatigue analysis, should be carried out for each individual member, which is subjected to fatigue loading. It should be noted that any element or member of the structure, every welded joint and attachment or other form of stress concentration, is potentially a source of fatigue cracking and should be individually considered"
  - Various analysis approaches may be used from screening to very refined fatigue
  - Different fatigue methodologies may be used – and the choice is yours





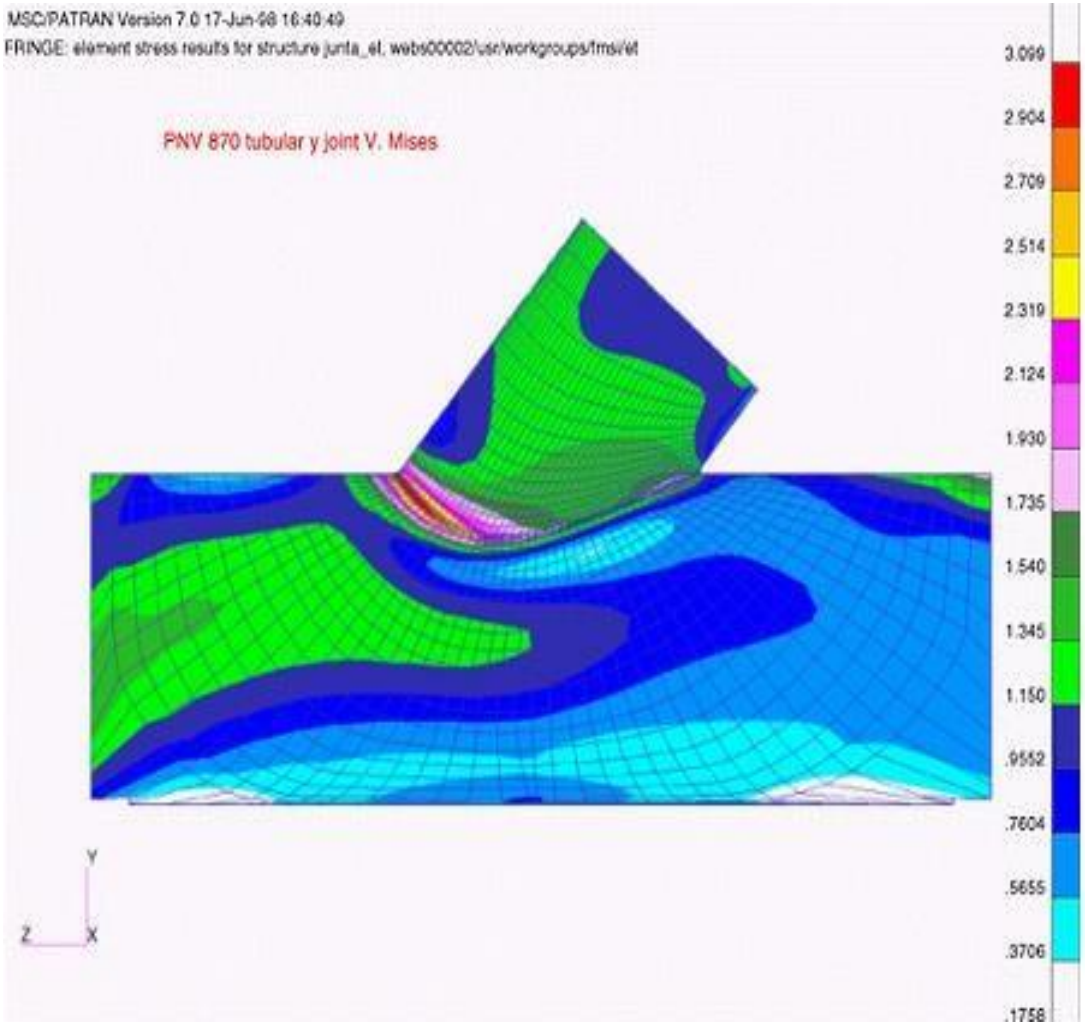
Estudo de Caso – Junta Tubular Principal – Estrutura Offshore

Verificações de Tensões Localizadas / Concentrações de tensões – Juntas tubulares

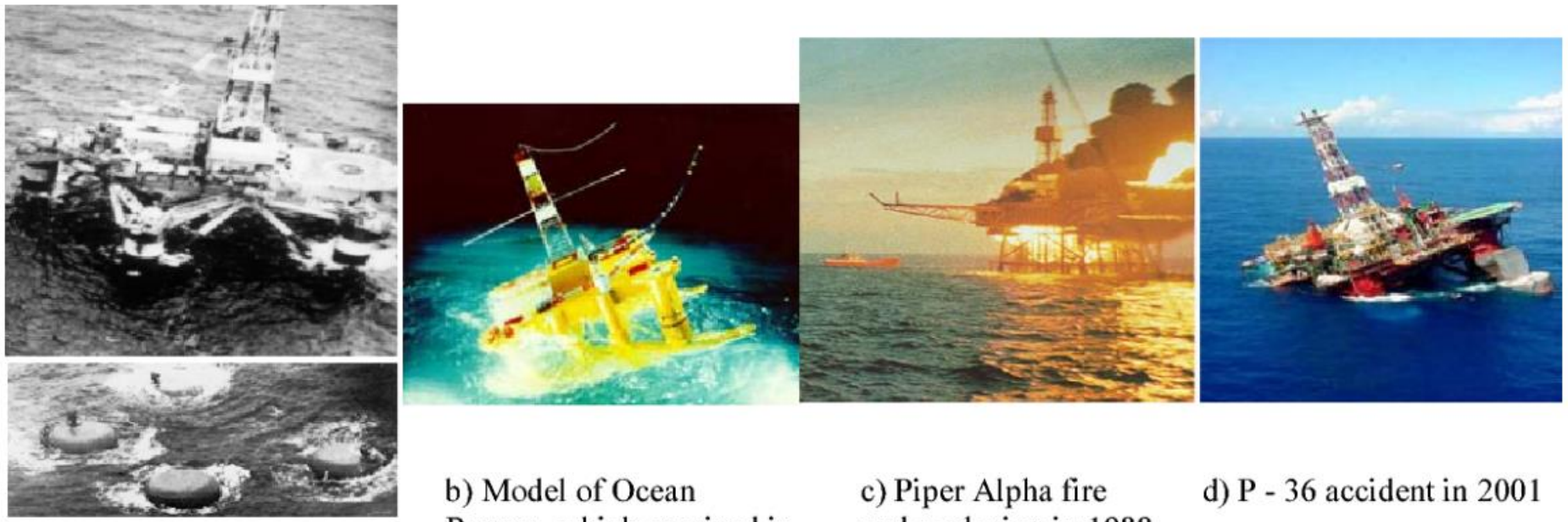
Metodologia: FEM - Numérico intensiva – DNV-RP-C203

Scope:
Local Strength Assessment tubular wellded connection.
Critycal Integrity Assessments
Hot Spot Stress evaluation

Analysis Description:
Non linear plastic procedure
Direct Stress concentration factor evaluation Weld
Strength Evaluation AWS D1.1 /API-RP-2A. GTSTRUDL
Analysis with Large Problem Solver



- **Acidentes severos perdas globais**



a) Alexander L. Kielland before and after capsizing in 1980

b) Model of Ocean Ranger, which capsized in 1982, during survival testing

c) Piper Alpha fire and explosion in 1988

d) P - 36 accident in 2001

Examples of accidents which resulted in a total loss.

Ref. T. Moan – Safety in Offshore Structures - 2004

- **Filosofia de Seguranca Estrutural**

  Estados Limites e Condições de Integridade

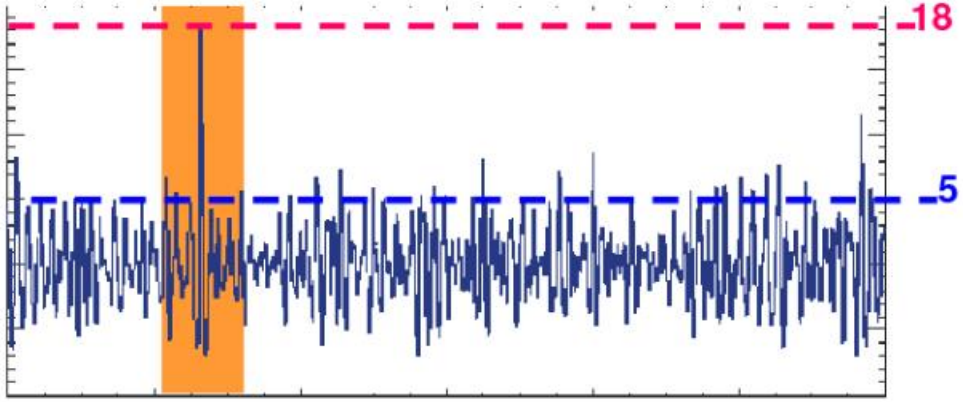
  Foco em Componentes /Sistema Estrutural x Sistema Global

Limit states	Physical appearance of failure mode	Remarks
Ultimate (ULS) -Overall "rigid body" stability - Ultimate strength of structure, mooring or possible foundation		Different for bottom – supported, or buoyant structures. Component design check
Fatigue (FLS) - Failure of welded joints due to repetitive loads		Component design check depending on residual system strength and access for inspection
Accidental collapse (ALS) - Ultimate capacity[1)] of damaged structure with "credible" damage		System design check

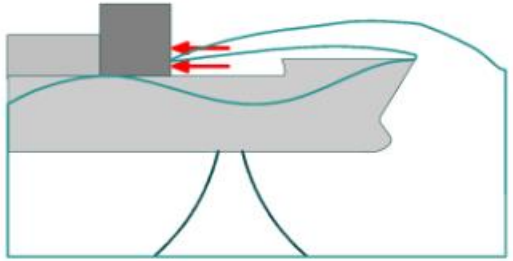
Limit State Criteria for safety – with focus on structural integrity

- **Acidentes severos limitadas**

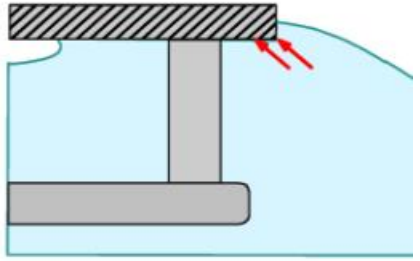
a)Severe damage caused on a jacket platform in the Gulf of Mexico by Hurricane Lilli



b) Wave record from a platform site in the North Sea on January 1. 1995.



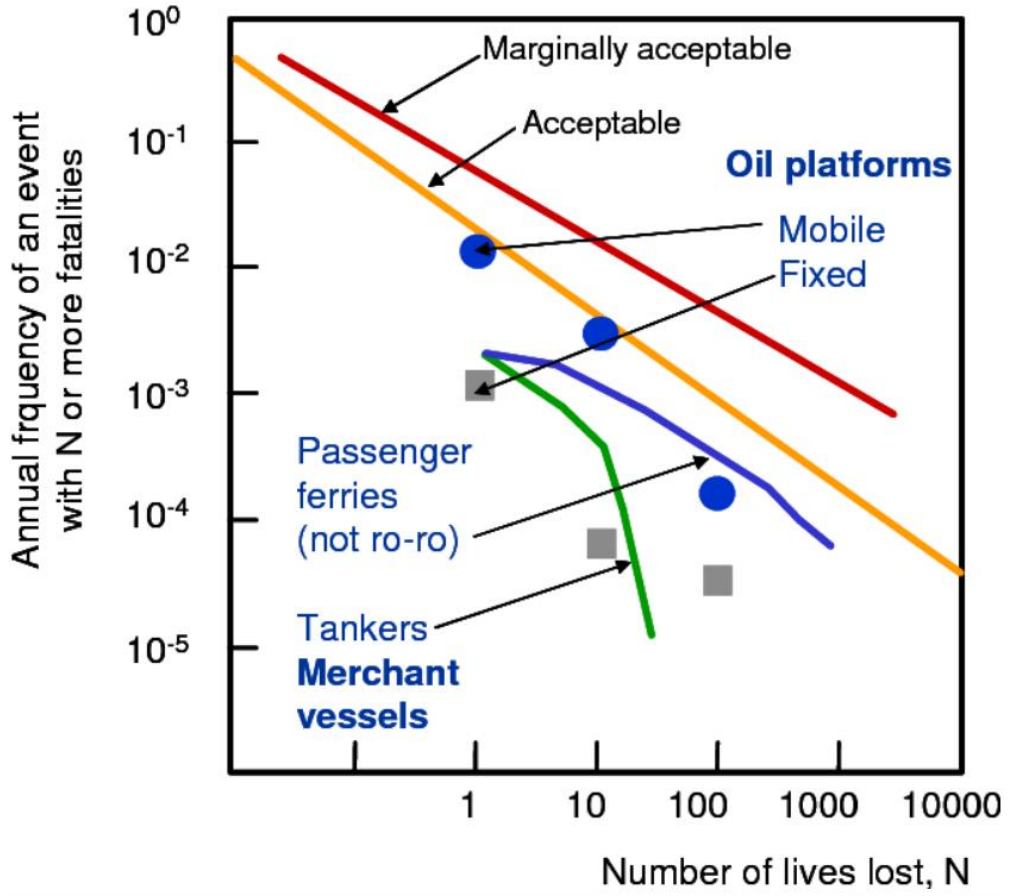
c) Green water and deck slamming on FPSO



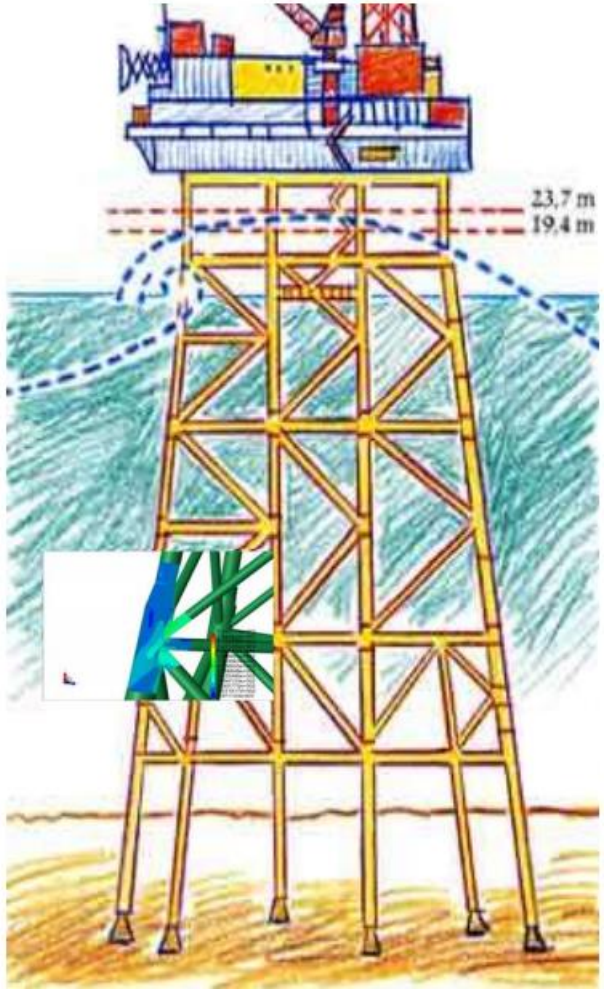
d) Deck slamming on semi-submersible platform

Structural concept	Failure mode	Relevant accidental load or condition
Fixed platforms	Structural failure	All
Floating platforms	Structural failure	All
	Instability	• Collision, dropped object, unintended pressure…, unintended ballast that initiate flooding
	Mooring system strength	• Collision on platform • Abnormal strength
Tension-leg platforms	Structural failure	All
	Mooring - slack system - strength	• Accidental actions that initiate flooding • Collision on platform • Dropped object on tether • (Abnormal strength)

Examples of accidental loads for relevant failure modes of platforms.



Extensao de Vida Util – Life Extension – Aging Structures



- Life extension and fatigue
  - Relevant standards
  - Assess the as-is condition
  - Convert legacy data to a modern data format
  - Simple life extension analysis based on traditional ULS and FLS
  - Advanced fatigue analysis based on calculated SCF and shell fatigue
  - Using refined fatigue analysis results when establishing inspection program
  - The role of Digital Twin models

Comparações entre Metodologias Avaliações de riscos:

Metodologias Tradicionais:

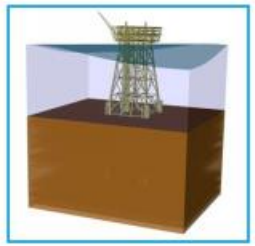
- Analises e critérios Qualitativos
- Inspeções baseadas em experiências ou históricos de falhas/patologias
- Instâncias de inspeções dirigidas pelas ocorrências de falhas (ad hoc)
- Padrão de atuação reativo (atuando conforme incidências/eventos de falhas
- Aplicação de técnicas/tecnologias limitadas de inspeção e monitoramento

Metodologia RBI:

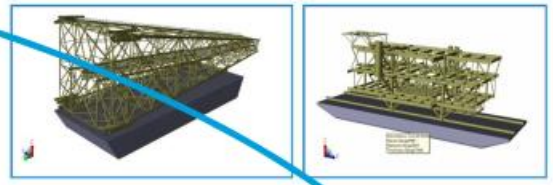
- Analises e critérios Qualitativos, Semi-Quantitativos e/ou Quantitativos
- Inspeções baseadas em experiência e Verificação Sistemática Condições de Riscos
- Inspeções dirigidas por fatores de risco (Probabilidade de Falha x Consequência)
- Padrão coordenado de Planos/Sistemas de Monitoramento/Inspeções
- Aplicação de Técnicas/Tecnologias sistemáticas de inspeção e monitoramento
- Structured Methods – Métodos Estruturados

Perform regular design analysis to prove life extension

- Assuming that all data has been updated to reflect history and as-is
- Code check (demo)
- Fatigue based on parametric SCF
- If it is required to prove structural integrity of a intact or damaged condition -> pushover analysis is done

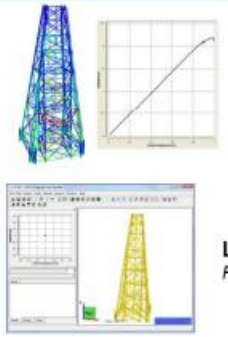


In-place and construction
Deflections, stresses, code-check, fatigue, earthquake, corrosion analysis, fire/explosion



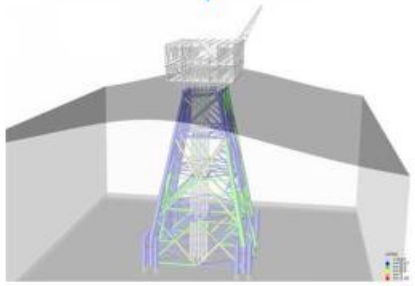
Transportation, lifting, launching
Deflections, stresses, code-check, fatigue

Demo in workshop session tomorrow (8 June 2022)

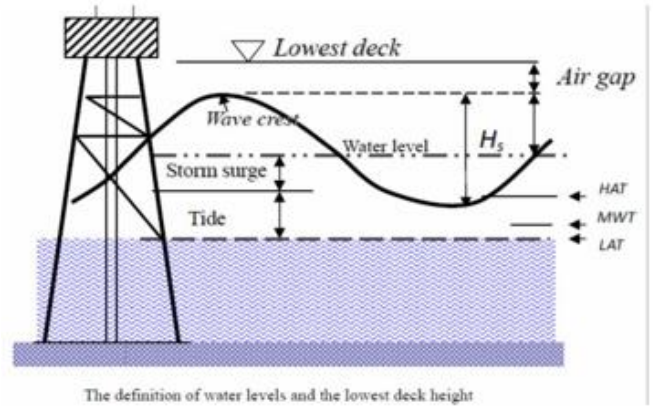


Life extension, requalification
Push-over, collapse, accidents, boat impacts

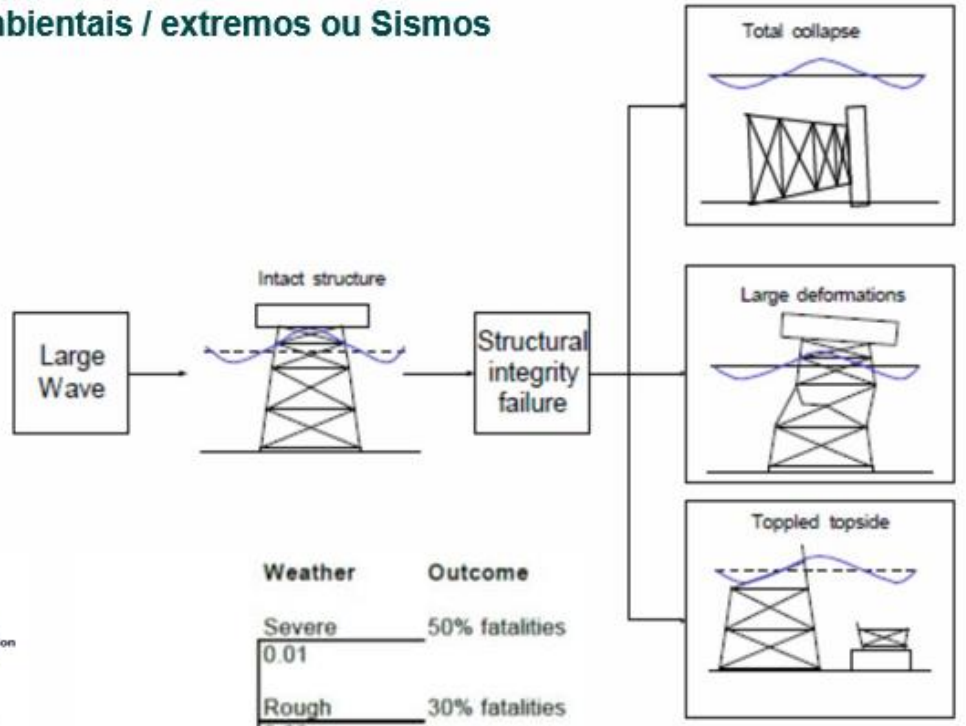
Operation, modification
Corrosion allowance &
Weight control
Deflections, Stresses,
Code-check, Fatigue

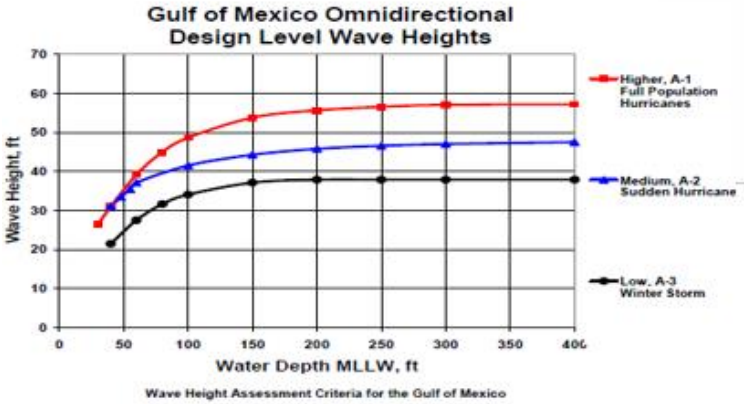


Analises Qualitativa de riscos
Avaliações de Integridade e consequências de danos
Modelos e fatores de carregamentos ambientais / extremos ou Sismos

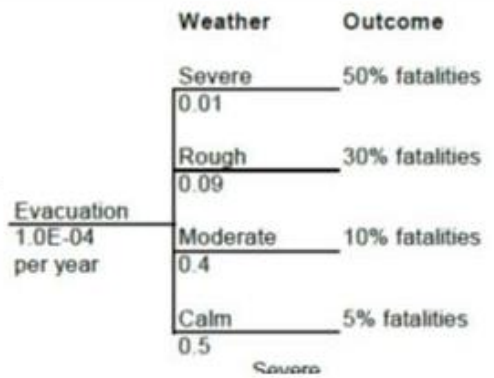


The definition of water levels and the lowest deck height





Wave Height Assessment Criteria for the Gulf of Mexico



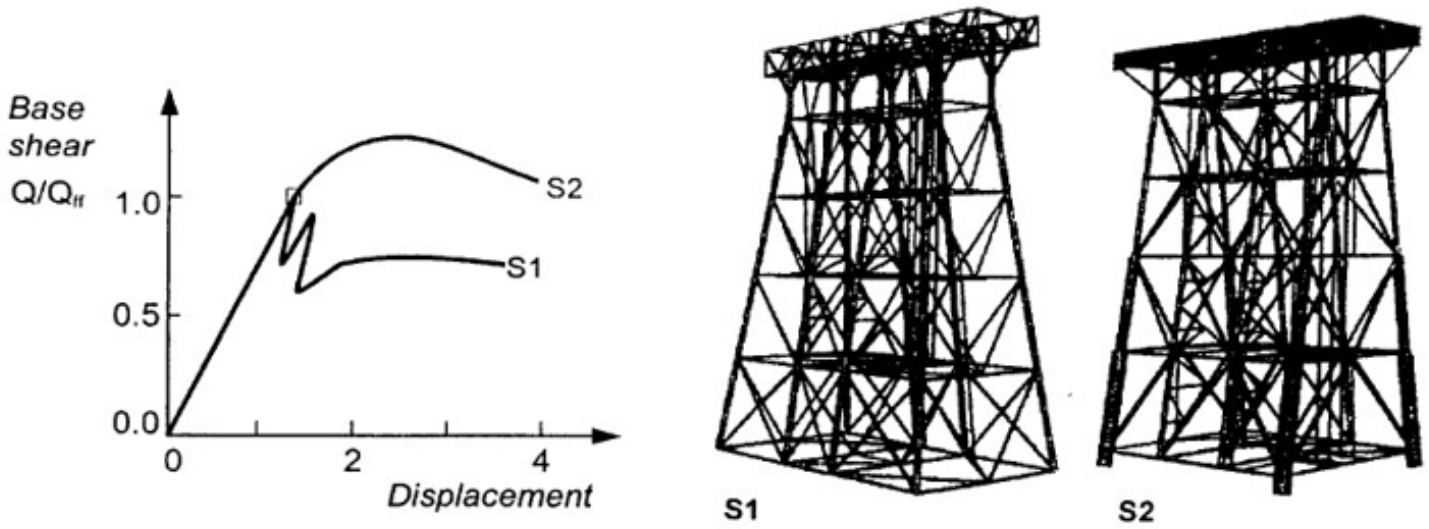
Análises Semi-quantitativa de riscos

Indicadores de Risco: Nível de solicitação estrutural (IR)

- Fatores de Interação (Interaction Rates) **IR < 1.0 Estrutura segura**
  Tensões atuantes / Tensões Admissíveis

- Reserve Strength Ratio ; **RSR = Q/Qff > 1.0**
  Cortante falha global / Cortante falha inicial

- **IR e RSR** Determinados com Análises Numéricas MEF



a) Load displacement behaviour. Q_{ff} is base shear at first member failure.

b) Lay-outs of jackets S1 and S2.

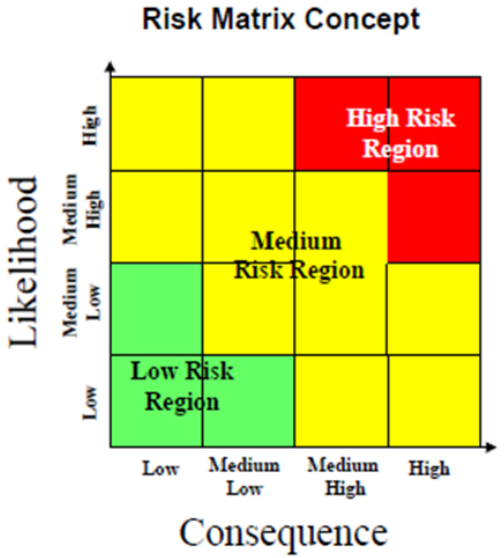
Global behaviour of jacket structures subject to broadside loading (Hellan, 1995).

Plataforma Deepwater Horizon - Explosión / 2010

- Plataforma de perforación en 2010
- Consecuencia en vidas:
  - 10 trabajadores e herió a 16
- Consecuencias ambientales:
  - Derrame masivo de petróleo en alta mar.
  - Contaminación de recursos pesqueros en escala
  - Perdidas turismo
- Consecuencias economicas / Liabilities
  - Riskex : Indeterminado 50E69 US$ asta 500E6 US$
- Consecuencias programaticas / Industriales / economcas

Factores de Riesgos x Modos de Fallas x Consecuencia
Matrix de Riesgos

- Degradación estructural
- Eventos extremos ambientales y sismicos
- Cargamentos operacionales
- Cargamentos accidentales



- Casos de Processos de Danificação – EKOFISK II - Noruega

Mar do Norte - Noruega.

Producao prevista ate 2050
Complexidade de condicionantes:

- Planejamento
- Geotecnia marítima
- Condições Ambientais Extremas
  - Espetro Mar do Norte
  - Baixas Temperaturas
- Fatores Econômicos
- Logística operacional
- Processos de Produção

- **Sistema Ekofisk 2 / 4 J**
  - Caracteristicas:
    - Jacket: 11400t f, eight-leg steel jacket
    - Pilotis/pernas: 5500tf 16 pilotis
    - Modulos de producao: 23500 tf
    - LDA: 76.1m / rated for 90.1m
  - Processos de danificacao:
    - Recalques (hundimiento) de solos/fundações em estratos calcáreos
    - Fraturamento e fadiga nos estruturais
  - Processos de producao
    - Processamento petróleo: 260000 bpd.
    - Exportacao hidrocarbono 420000 bpd,
    - Gas 21.2 E9 m3/ dia .
  - Unidades originais e auxiliares descomissionadas
  - Novas infraestruturas Submarinas:
    - Flowline STATPIPE p/ Pumping Plat B-11 y Export line
    - Lineas submarinas pré-existentes redirecionadas p/ Ekofisk 2/4 J
  - Custo de capital total:
    - EKOFISK II 200 E9 NK (CAPEX + OPEX) US$ 2.0 E9
  - Custos estimados de riscos:
    - 600 E9 NK (RISKEX) US$ 6.0 E9

- Casos de Processos de Danificação – Cuenca dde Talara - Peru

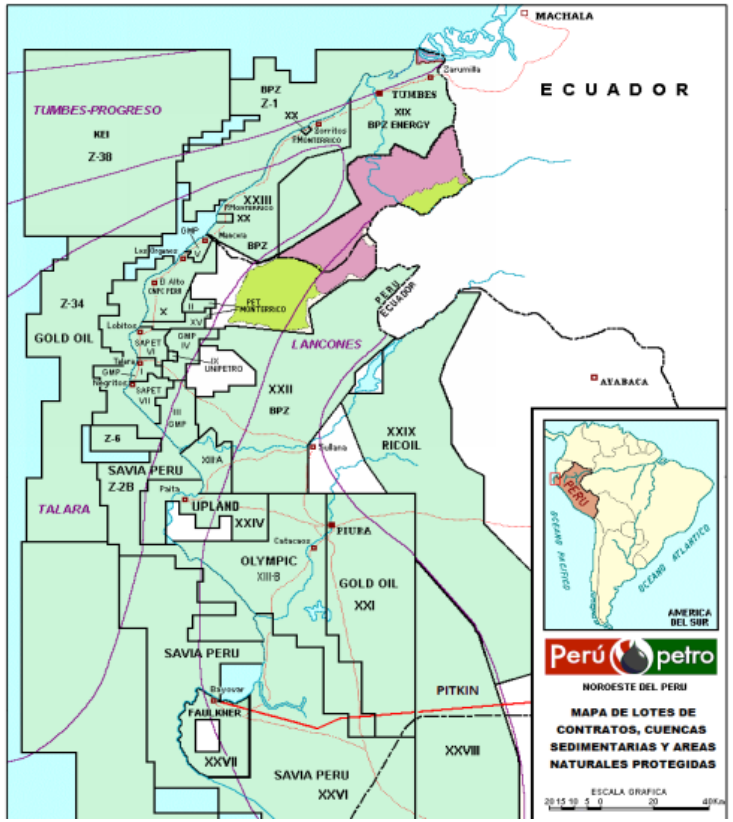


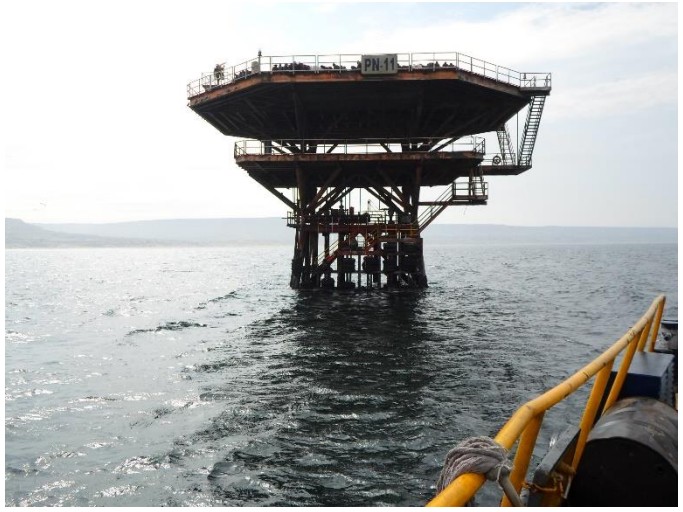
Figura 1. *El "cope" de los antiguos peruanos (Revista Copé PETROPERU S.A.).*

Oceano Pacifico – Piura Peru

Campo maritimo de Talara / SAVIA- ECOPETROL
85 plataformas Jacket total 9000 BRL/d
15 de 1960 a 1990 parcial 2000 BRL/d
Desenvolvimento mais antigo Hm Sul
Litoraneo / Costeiro 1890 a 1959
Maritimo/offshore desde 1960
Condicionantes:
–Geotecnia marítima
Falhas / sismicidade
-Ambientais moderadas
Correntes Humbolt
Baixas Temperaturas aguas
Ondas deterministicas / baixas

– Fatores Econômicos:
i) producao continuada limitada
ii) custos de manutencao crescentes
iii) investimentos e novas tecnologias (gas lift)
iii) riscos e consequências multiplos


4D


PN-11

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- Client companies credits:
  - ECOPETROL/Colombia
  - SAVIA/Peru
  - ABS Consulting
  - PETROBRAs
  - CRN Consultoria
  - Neft Gas Nehaio / Azerbaijan

Referências:

- API RP 2SIM American Petroleum Institute
- American Bureau of Shipping. Guidance Notes on Risk Assessment Application for the Marine and Offshore Oil and Gas Industries.
- ABS “Guide for Survey Using Risk-Based Inspection for the Offshore Industry”;
- API RP 581 American Petroleum Inst. Risk-Based Inspection Base Resource Do
- OSS-303 Risk Based Verification
- OSS-304 Risk Based Verification of Offshore Structures
- Marina de Guerra Perú - Dirección Geral de Capitanias y Guadacostas “CÓDIGO DE GESTIÓN DE SEGURIDAD Y PROTECCIÓN AMBIENTAL p/PLATAFORMAS MARINAS DE OPERACIONES CON HIDROCARBUROS”
- API RP 579, Recommended practice for fitness-for-service, 1st Edition;
- API RP 2A Recommended practice for Planning Designing and Constructing of Fixe Offshore Platforms,
- BS 7910, Guide on methods for assessing the acceptability of flaws in fusion welded structures
- DNV RP-C203:2001, Fatigue strength analysis of offshore steel structure, Det Norkse Veritas
- MIL-STD-882D –DoD Standard Practice for System Safety
- ANSI-GEIA-STD-0010 –Standard Best Practices for System Safety Program Development and Executi
- DOEnergy, ’Offshore Installations - Guidance on Design, Construction and certification’, HMSO, 1990
- NORSOK, ’Design of Steel Structures’ N-004, 199
- AWS D 1.1 - American Welding Society - Structural Welding Code - Steel" 2002
- AISC-Manual of Steel Construction, Allowable Stress Design 15th Edition, 2005
- DNV RP-C-205 « Recommended Practices Environmental Conditions Environmental Loads
- BS-7910 - BS 7910:2005, Guide to methods for assessing the acceptability of flaws in metallic structures.
- API-BUL-2U Stability Design of Cylindrical Shell
- HSE, ’Offshore Installations - Guidance on Design, Construction and Certification’, HSE Books, 1995
- DNV RP-C-204 Recommended Practice, Design Against Accidental Loads

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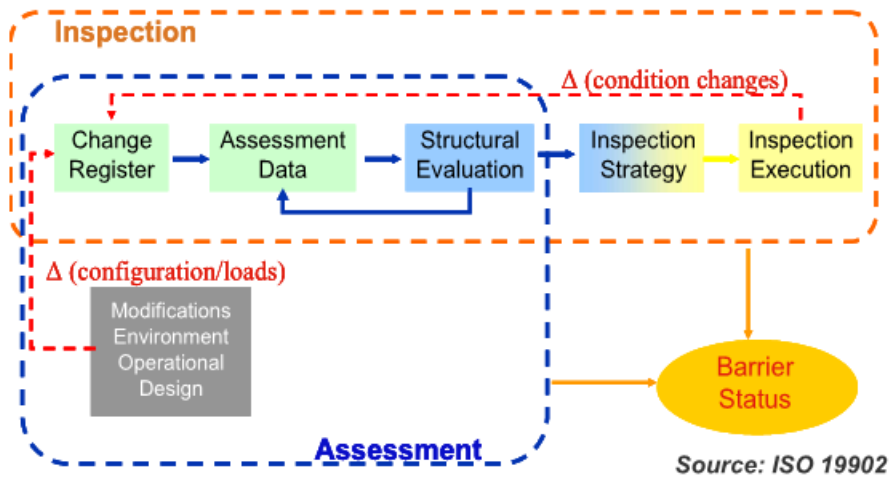
Subsidiary Information

Regulatory practices on the structural integrity of fixed structures

- USA
  - The leading practice for managing structural integrity is API RP 2A; Section 17 provides a standardized way of documenting the structural integrity of existing structures
  - API RP 2SIM for in-service assessment
- United Kingdom
  - Safety Case Regulations (HSE)
    - Life extension, modifications/repairs, decommissioning etc
  - Maintain the integrity of the installation through periodic assessments and rectify damage or deterioration
    - The ISO standard applies, primarily ISO 19902
- Norway
  - PSA (Petroleum Safety Authority)
  - Structural assessments NORSOK N-004
    - -> For fatigue DNV RP-C203
  - In-service assessment NORSOK N-006
    - -> DNV RP-C210

- Inspection and assessment play together
  - SIM is a continuous process used for demonstrating the fitness-for-purpose of an offshore structure from installation to decommissioning
  - A proper inspection program should be made during the design of an asset and include a Structural Re-analysis System (SRS)



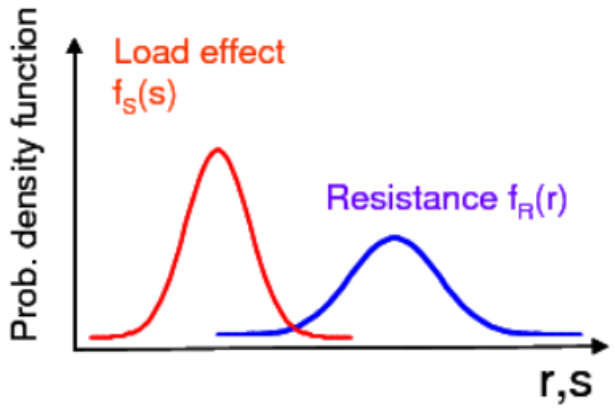
Source: ISO 19902

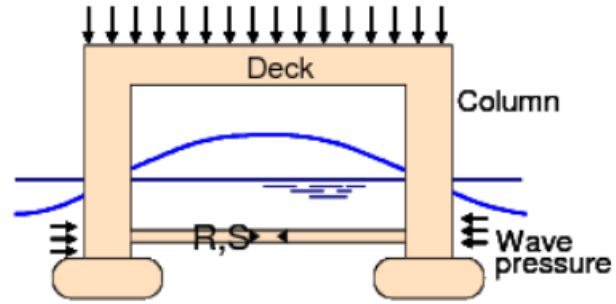
DNV

Table 2: Causes of structural failures and risk reduction measures

Cause	Risk Reduction Measure
• Less than adequate safety margin to cover "normal" inherent uncertain-ties.	- Increased safety factor or margin in ULS, FLS; - Improve inspection of the structure(FLS)
• Gross error or omission during - design (d) - fabrication (f) - operation (o)	- Improve skills, competence, self- checking (for d, f, o) - QA/QC of engineering process (for d) - Direct design for damage tolerance (ALS) – and provide adequate damage condition (for f, o) - Inspection/repair of the structure (for f, o)
• Unknown phenomena	- Research & Development

Structural reliability analysis

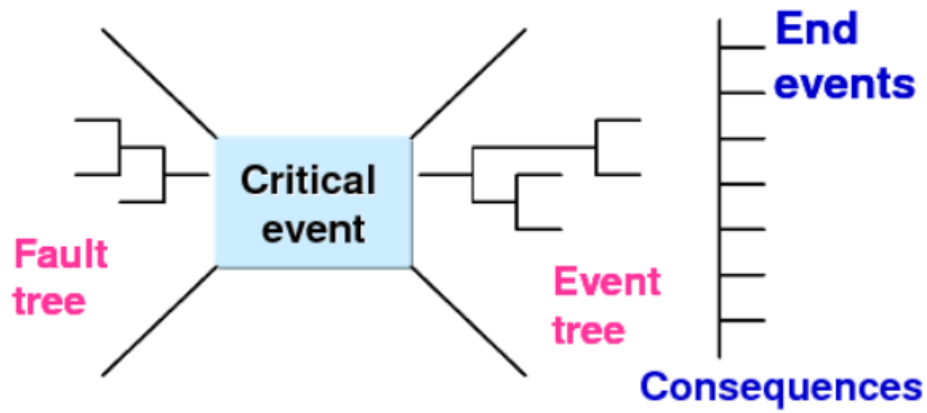


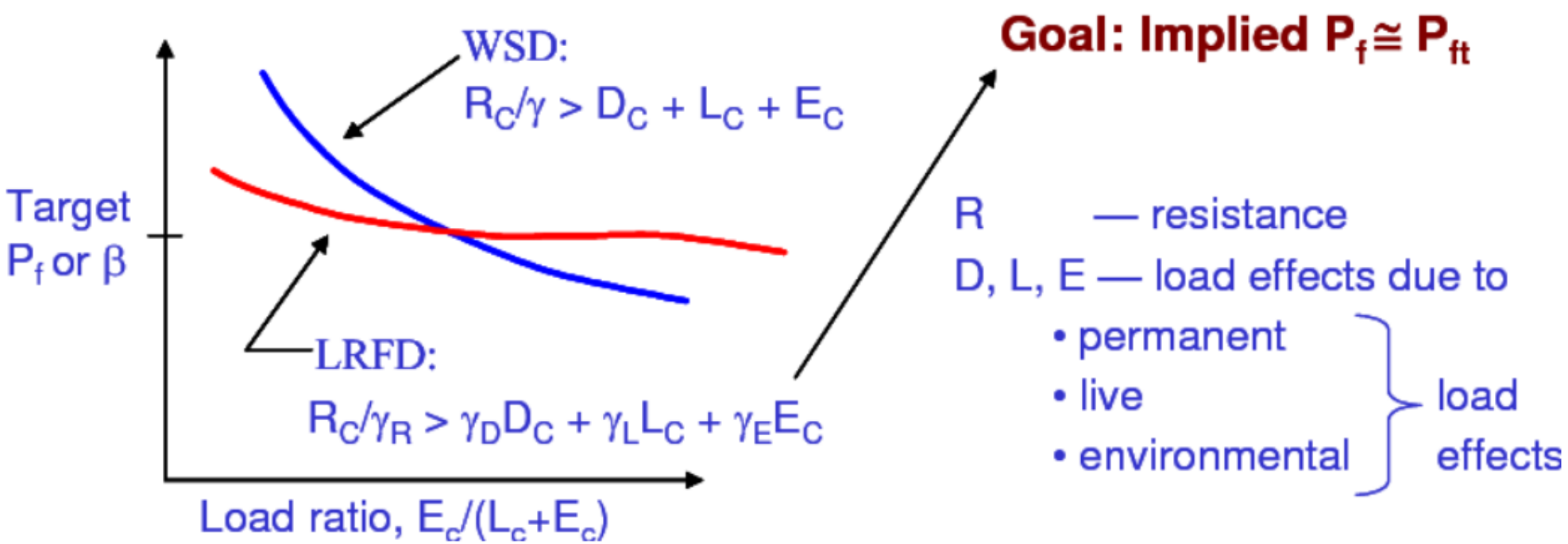


$P_F = P[R \leq S]$

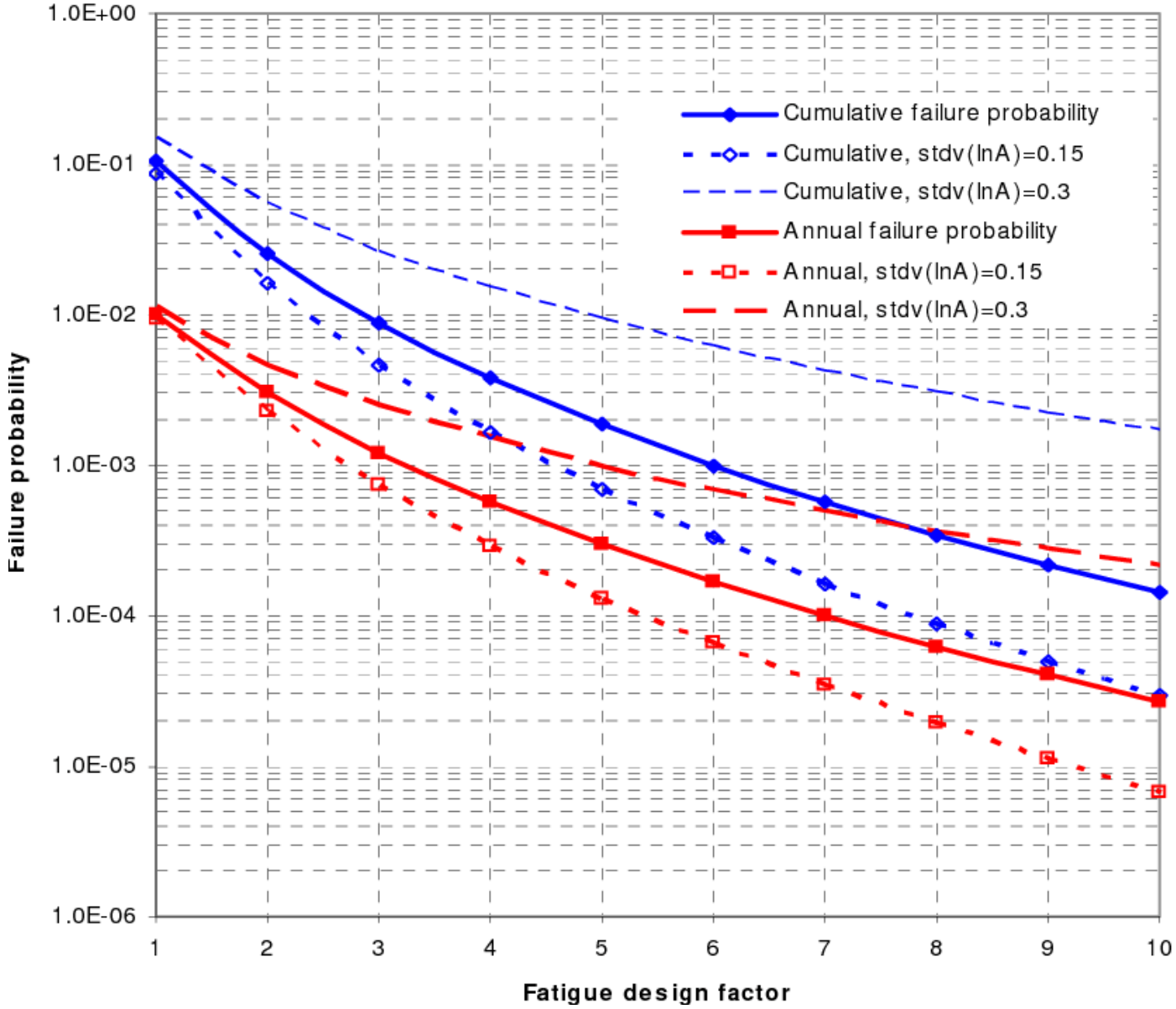
Uncertainty in R and S can be modelled by probability density

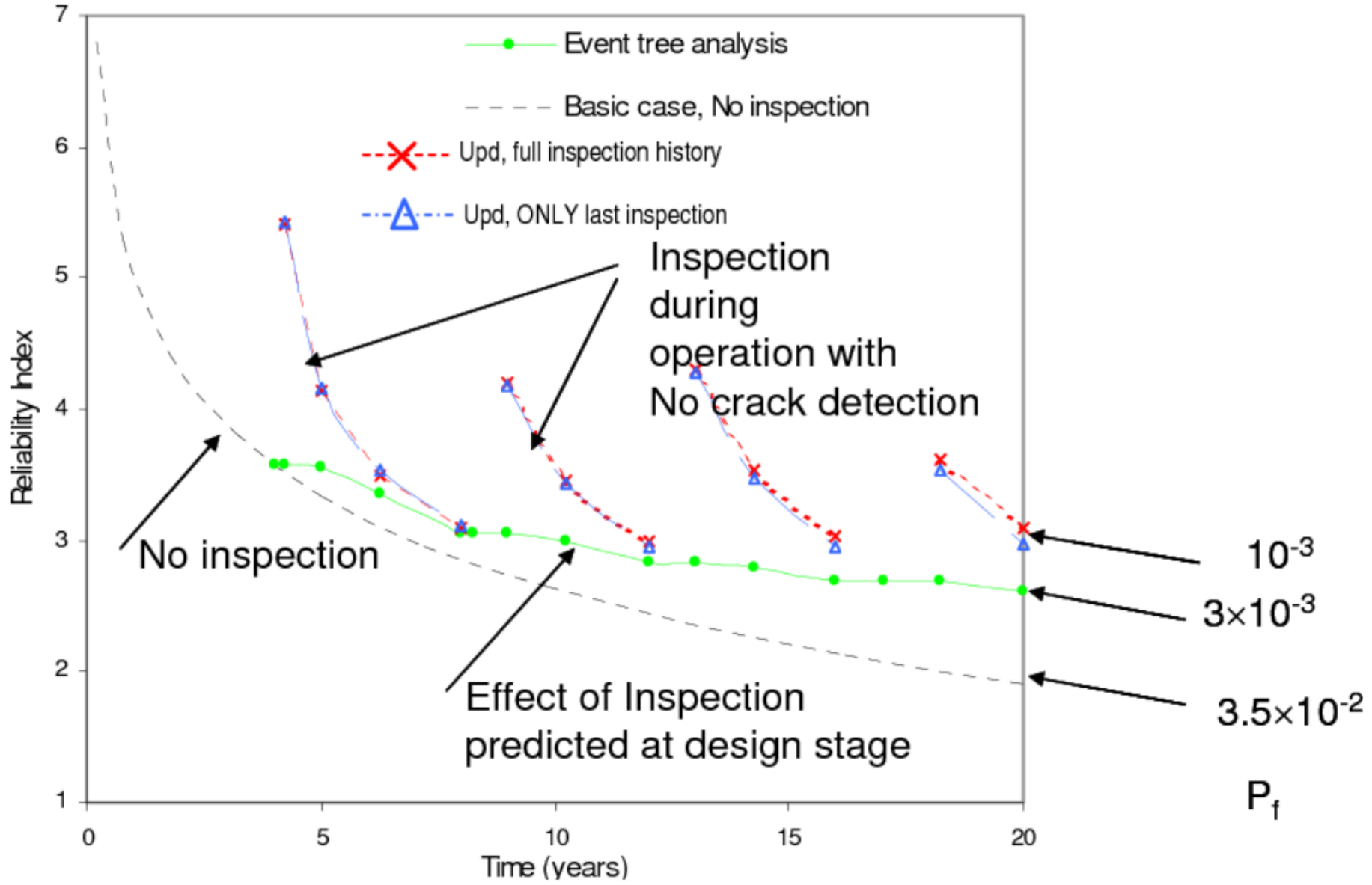
Quantitative risk analysis

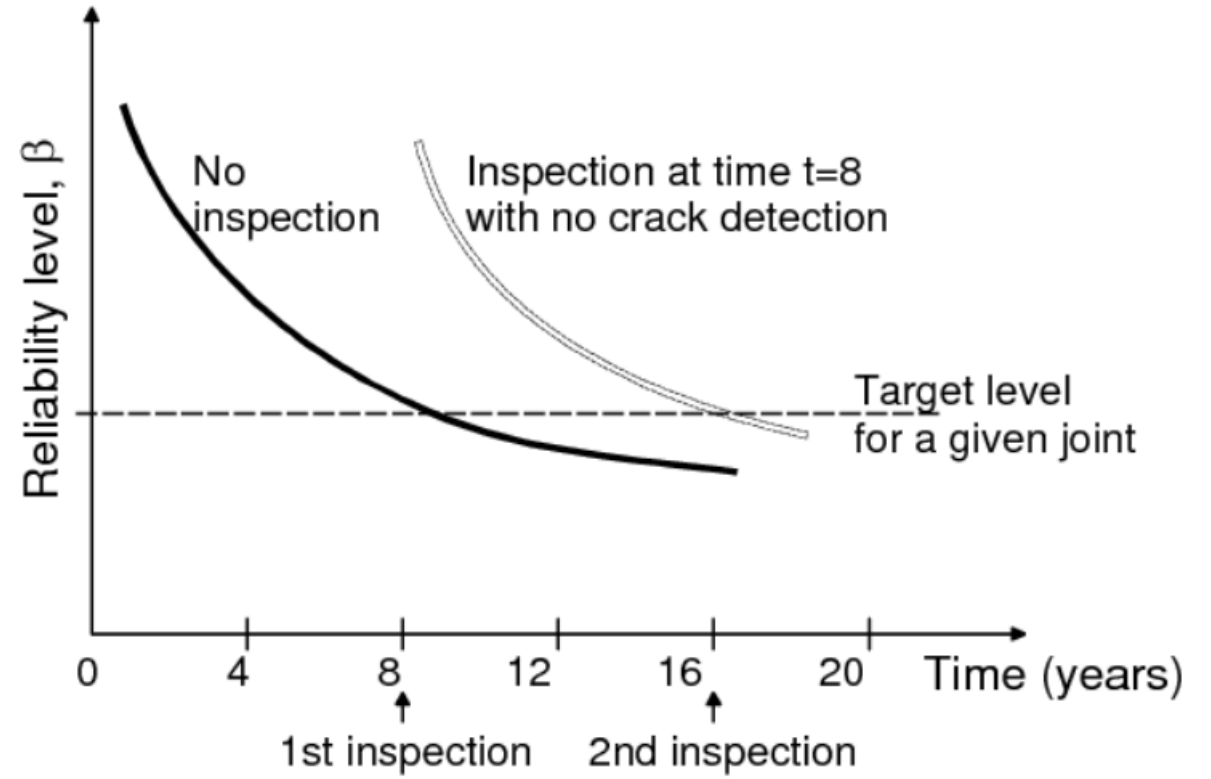


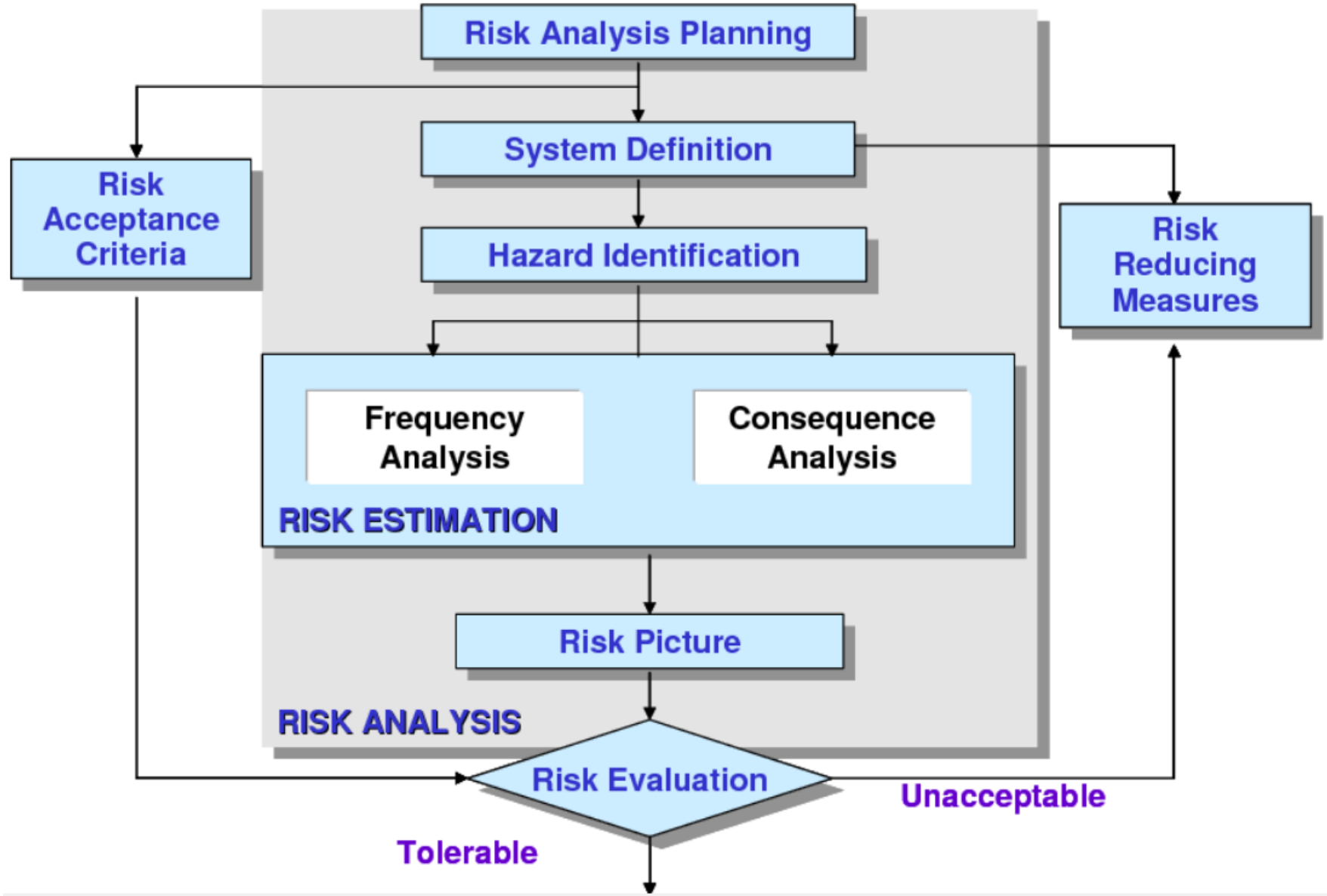


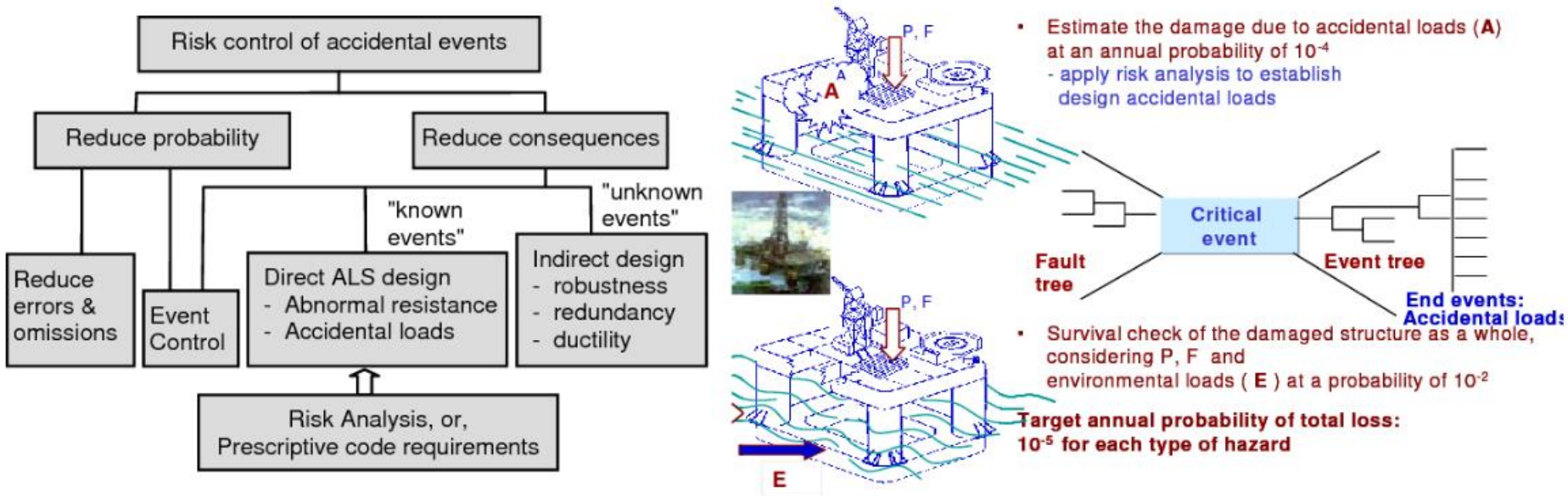
: Schematic illustration on how the implied safety level in a design code for ultimate strength can be calibrated


1.0E+00
1.0E-01
1.0E-02
1.0E-03
1.0E-04
1.0E-05
1.0E-06
Failure probability
1
2
3
4
5
6
7
8
9
10
Fatigue design factor
Cumulative failure probability
Cumulative, stdv(lnA)=0.15
Cumulative, stdv(lnA)=0.3
Annual failure probability
Annual, stdv(lnA)=0.15
Annual, stdv(lnA)=0.3


Event tree analysis
Basic case, No inspection
Upd, full inspection history
Upd, ONLY last inspection
Inspection during operation with No crack detection
No inspection
Effect of Inspection predicted at design stage
10-3
3×10-3
3.5×10-2
Pf
Reliability Index
Time (years)
0
5
10
15
20
1
2
3
4
5
6
7


Reliability level, β
No
inspection
Inspection at time t=8
with no crack detection
Target level
for a given joint
0
4
8
12
16
20
Time (years)
1st inspection
2nd inspection


Risk Analysis Planning
System Definition
Hazard Identification
Risk Acceptance Criteria
Risk Reducing Measures
Frequency Analysis
Consequence Analysis
RISK ESTIMATION
Risk Picture
RISK ANALYSIS
Risk Evaluation
Unacceptable
Tolerable



The role of ALS in risk control Fig. 18: Accidental Collapse Limit State (NPD, 1984)

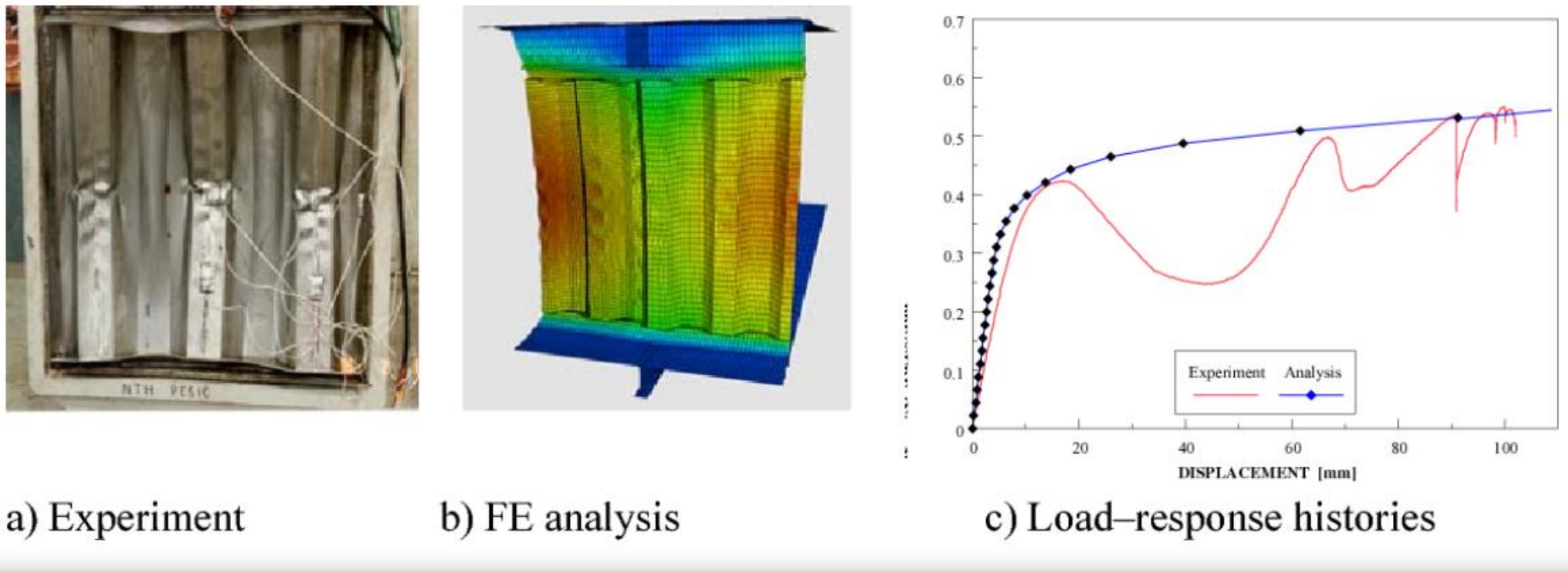
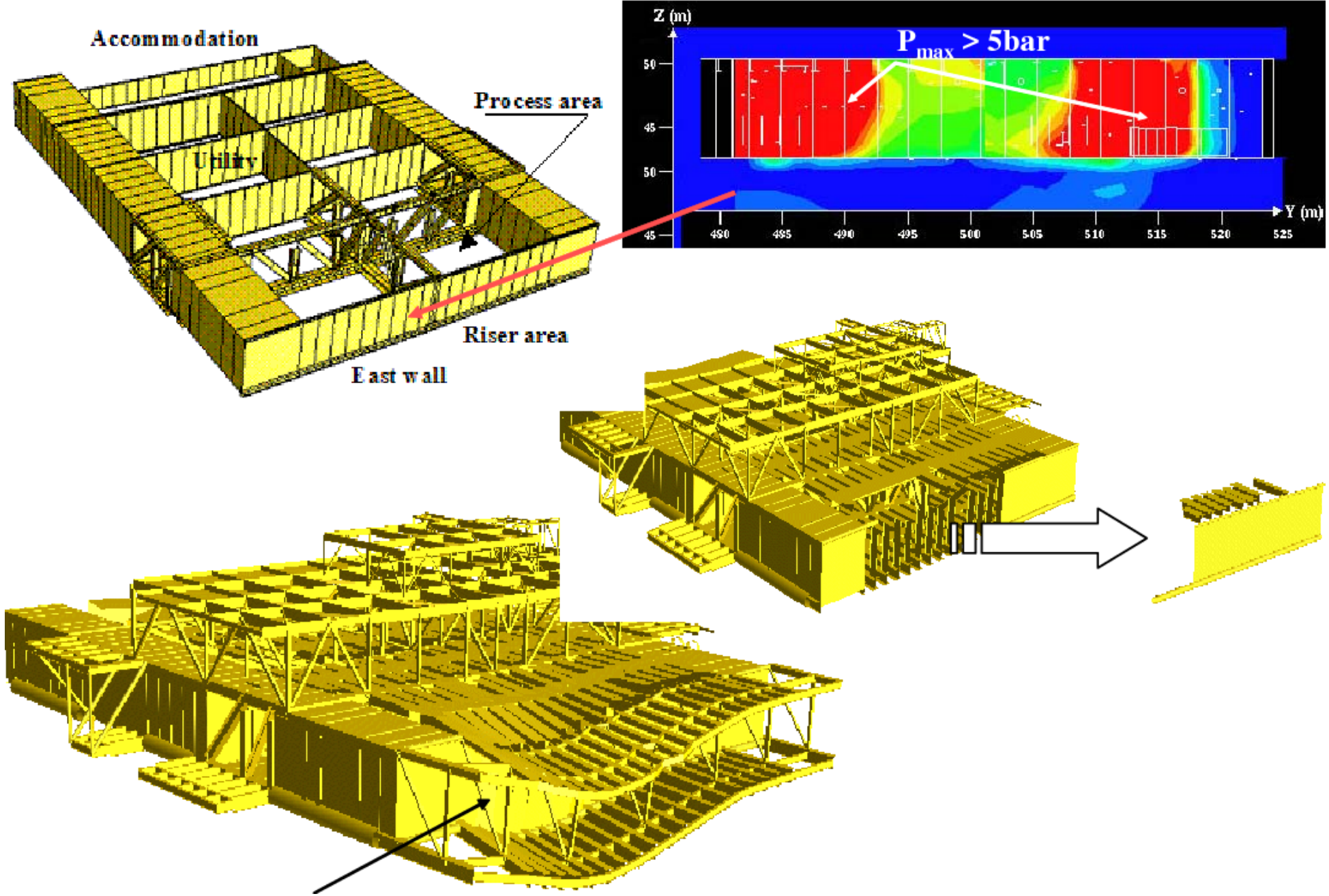


Fig. 21: Explosion response of an explosion wall (Czujko, 2001).



"Survival analysis" of a deck suffering explosion damage (Amdahl, 2003). Deformations in the lower figure are not to scale.

Type of accident	World wide		Gulf of Mexico	North Sea
	Mobile	Fixed	Fixed	Fixed
	1970-79 /80-95	1970-79 /80-95	1970-79 /80-95	1970-79 /80-95
Blowout	18.8/ 11.4	2.5/0.9	2.2/1.0	2.6/1.6
Capsizing/ foundering	24.0/ 19.5	0.5/0.8	0.3/1.1	2.6/0.5
Collision / contact	24.6/ 14.6	1.6/1.0	1.3/0.7	5.1/6.3
Dropped object	4.2/ 6.1	0.5/0.8	0.1/0.4	10.3/10.6
Explosion	7.4/3.3	0.7/1.6	0.3/0.4	2.6/8.3
Fire	12.3/ 11.9	2.0/7.5	1.0/7.8	18.0/42.5
Grounding	6.1/3.3	-	-	-
Spill/release	4.9/5.9	1.8/8.7	1.0/5.8	23.1/98.3
Structural damage	25.6/ 18.4	0.5/0.6	0.4/0.5	10.3/6.0