Outline

Introduction
Risk Based Methodology
Safety Assessment in Maritime
Systems Engineering
Summary

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Introduction

Safety is
- "freedom from danger" – *Oxford Dictionary*
- "a perceived quality that determines to what extent the management, engineering and operation of a system is free of danger to life, property and environment – *C. Kuo*

Environment of Maritime Systems Safety

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Trends to System Safety

Conventional	New
Reactive	Proactive
Prescriptive	Goal-setting
Regulation	Self-regulation
Deterministic	Probabilistic (risk-based)
Conformance-based	Performance-based
Compulsory	Safety-culture
Disciplinary-oriented (sectional)	Integrated (total)
Experimental	First principles
	(calculation /simulation)
Hardware focus	Balance of safety elements
Short-term	Life-cycle
Irrational	Rational
(subjective/emotional/political)	(scientific/cost-benefit analysis)

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Approaches to Maritime System Safety

- Rule-based (deterministic) approach
- Risk-based (probabilistic) approach
- Performance-based (Simulation Based) approach

Perfect design

First-principles design

Reducing ignorance
=> increasing
competitiveness

Rules-based design

[Safer EURORO,2003]

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IMO Regulations for Ship Safety [as of 2004]

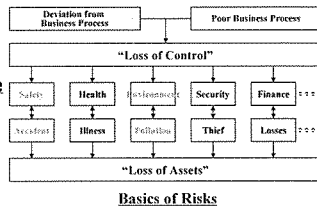| Ship Safety	SOLAS Convention 74	Protocol 78, Protocol 88
	Stockholm Agreement 96	
	LOAD LINES Convention 66	Protocol 88
	TONNAGE Convention 69	
	COLREG Convention 72	
	CSC Convention 72	Amendment 93
	SFV Convention 77	Protocol 93
	SAR Convention 79	
	STP Agreement 71	Protocol 73
	INMARSAT Convention 76	Amendment 94, Amendment 98
	INMARSAT OA 76	
Human Factors	STCW Convention 78	
	STCW-F Convention 95	

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Risk Based Methodology

Risk Is
"A combination of probability (P) and consequence (C) " :
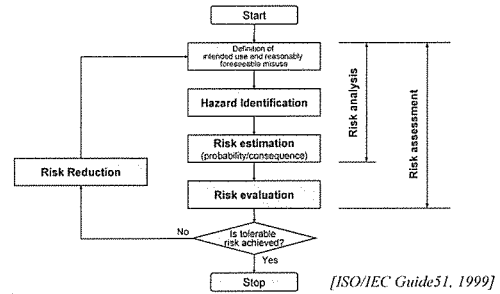$R = P \times C$

Domains of Risk
- Cost
- Schedule
- Technical Performance
- Safety
- Environmental
- Legal
- Political
- ...

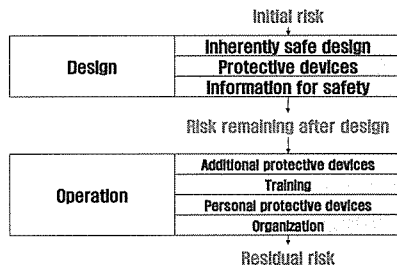| Deviation from Business Process		Poor Business Process

"Loss of Control"

Safety	Health	Environment	Security	Finance	...
Accident	Illness	Pollution	Thief	Losses	...

"Loss of Assets"

Basics of Risks

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Risk Assessment and Reduction Process

[ISO/IEC Guide51, 1999]

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Risk Reduction Precedence

Initial risk

Design	Inherently safe design
	Protective devices
	Information for safety

Risk remaining after design

Operation	Additional protective devices
	Training
	Personal protective devices
	Organization

Residual risk

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Risk Assessment Techniques

- HAZOP (Hazard and Operability studies)
- What-If Analysis
- FTA (Fault Tree Analysis)
- ETA (Event Tree Analysis)
- FMECA (Failure Modes Effects and Criticality Analysis)
- RCT (Risk Contribution Tree)
- Influence Diagram
- ....

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Limitations of RBA

- **Problem Definition**
  - Scope of the Analysis
  - Generic model
- **Identification of hazards and risk analysis**
  - Analysis of data : ambiguous, insufficient, not proactive, ..
  - Use of accident data vs. modeling
- **Risk control options and cost benefit analysis**
  - Interaction of RCOs
  - Clarity on defining RCOs
  - Risk acceptance criteria
- **Presentation of the results**
- **Management Issues**
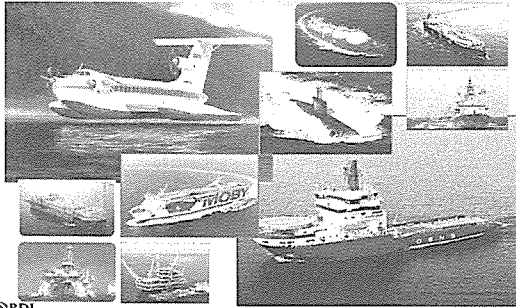- ....

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Safety Assessment
in Maritime Systems Engineering

Introduction to Maritime Systems
SA Framework for Maritime Systems

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Introduction to Maritime Systems
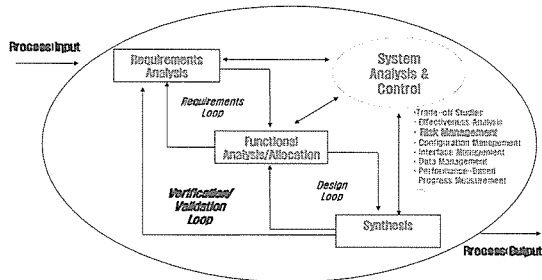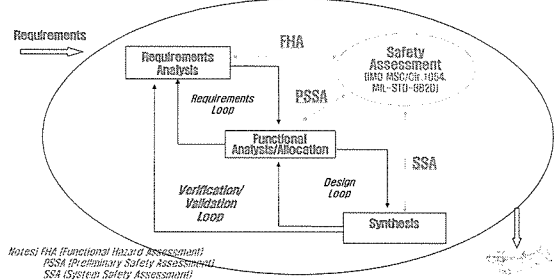

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SA Framework for Maritime Systems

"A structured process and methodologies for establishing the GBS for the new type of ships, based on:

- Systems Engineering principles
- Risk-based methodology
- Modeling and Simulation Tools

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SE Process

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Safety Assessment on SE Process

Notes) FHA (Functional Hazard Assessment)
PSSA (Preliminary Safety Assessment)
SSA (System Safety Assessment)

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FHA (Functional Hazard Assessment)

Purpose of the process
- To establish the Safety Objectives

Methodologies:
1) Identification of all craft and system functions;
2) Identification and description of failure conditions associated with these functions;
3) Determination of the effects of the failure condition;
4) Classification of failure condition effects;
5) Assignment of safety objectives/probability requirements; and
6) Identification of means of compliance

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FHA work sheet (Example)

					Sheet ___ of ___
Functional hazard analysis worksheet					Issue :
					Date :
System/Subsystem: Navigation Control System		Function: Collision avoiding			
Item No.	Failure condition	Mission phase	Failure effects	Classification	Objec. lives	Remarks
1	Loss of control	amphibian	collision w/ light damage	marginal	10^3	
2		planning	collision w/ damage	critical	10^5	
3		cruising	collision w/ structural damage and fatalities	catastrophic	10^6	
4		take-off	total loss & fatalities	catastrophic	10^6	
5						

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Risk Model in RCT (Risk Contribution Tree)

Event Tree for Consequences

"Minor" "Significant" "Severe" "Catastrophic"

Evacuation
Stability/Buoyancy
Structural Protection

Accidents Categories

| Flooding/ Foundering | Collision | Fire / Explosion | Grounding | |

Fault Trees for Direct Cause and Initiating Events

| System Failure | Pilot Error | Bad weather |

| H/W failure | Control system failure | Display failure | Regulation violation | Poor operation | | Storm/gust | Fog | Wave |

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Risk Categories and Evaluation Criteria

심각도 지수 (Severity Index: SI)

SI	Severity	Effects on Human Safety	Effects on Ship	S (Equivalent fatalities)
4	Catastrophic	Multiple fatalities	Total loss	10
3	Severe	Single fatality or multiple severe injuries	Severe Damage	1
2	Significant	Multiple or severe injuries	Non-severe ship damage	0.1
1	Minor	Single or minor injuries	Local equipment damage	0.01

빈도지수 (Frequency Index: FI)

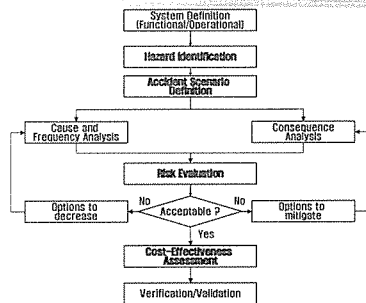| FI	Frequency	F (per hour in ground effect operation)
7	Frequent	10^{-3}
5	Reasonably probable	~ 10^{-5}
3	Remote	~ 10^{-7}
1	Extremely remote	~ 10^{-9}

Risk Index (RI)

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List of RCOs

- Sea Worthiness (Buoyancy, Stability, ...)
- Structural Integrity (Materials, Sub-division, Damage Control, .)
- Accommodation and Escape Measure
- Control Systems (Directional/Attitude/Altitude)
- Outfitting systems (Mooring / Anchoring/ Towing /Berthing)
- Fire safety (Structural fire protection/Detection/Fighting, ..)
- Life-saving appliance and arrangement
- Machinery
- Auxiliary systems
- Remote control, Alarm and Safety Systems
- Electrical Installations
- Navigational Equipment
- Radio communication
- Operating compartment layout
- Aerodynamic Stabilization Systems
- Handling, Controllability and Performance
- Operational Provisions
- Inspection & Maintenance Provisions, ...

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PSSA (Prel. System Safety Assessment)

Purpose of the Process
- To establish the safety requirements for systems & components

Analysis Techniques:
- Fault Tree Analysis (FTA)
- Failure Modes Effects and Critically Analysis (FMECA)
- Failure Modes and Effects Summary (FMES)
- Zonal Hazard Analysis (ZHA)
- ...

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Risk Assessment Process in PSSA

System Definition (Functional/Operational)

Hazard Identification

Accident Scenario Definition

Cause and Frequency Analysis — Consequence Analysis

Risk Evaluation

Options to decrease — No — Acceptable ? — No — Options to mitigate

Yes

Cost-Effectiveness Assessment

Verification/Validation

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SSA (System Safety Assessment)

Purpose of the process
- Verify the safety requirements defined in FHA and PSSA are satisfied

Methodologies:
- Modeling & Simulations
- Demonstrations
  - Performance trials
  - Deadship test
  - Test for operational compartment functionality

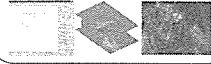KORDI

Simulation Based Safety Assessment tools

Product Modeling
- Geometric Model
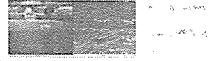- Loading and damaged conditions

Structural Safety Analysis
- Structural Integrity
- Damage propagation

Motion Prediction
- Various Wave Conditions
- Damaged Conditions

Survivability Analysis
- Emergency Response based on Knowledge Base

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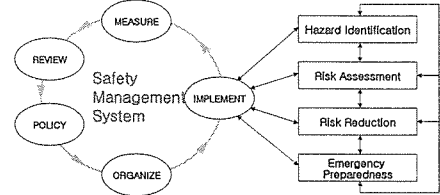## SMS (Safety Management System)

- Ensure the acceptable safety level through life-cycle
- Certified Safety Management System linked with Risk-based Engineering process

MEASURE
REVIEW
Safety Management System
POLICY
IMPLEMENT
ORGANIZE

Hazard Identification
Risk Assessment
Risk Reduction
Emergency Preparedness

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Summary

- **Maritime Systems: "System of Systems"**
  - One-of-a kind / Multi-functional / Large scale / ...

- **SA Framework for Maritime Systems**
  - Risk-Based Approach
  - Based on SE Principles

- **Supporting Tools**
  - MBSE (Model Based Systems Engineering)
  - M&S for verification/validation
  - PLM (Product Life-cycle Management)
  - ....

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Thank you for your attention.

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