Evolution of HIPS & Using Risk Analysis Tools to Define SIL

(Prevention First 2012)

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Key Topics

- Evolution of Offshore Facility SMS Regulatory Requirements
- Hazards Analysis SEMS Requirements
- Key Design Guidelines
- Offshore Facility Protection Systems Evolution & Interface with Other SMS & Analysis Techniques
- References & Resources
- Questions

Evolution of Offshore Facility SMS Regulatory Requirements

How Did We Get Here?

Observations from Major Incidents Safety Management Systems Concepts

- Major Accidents have Caused Significant Loss of Life and Property, as well as Significant Indirect Costs, e.g.:
  - Business Interruption
  - Lost Confidence and Contracts
  - Increased Regulation
- Typical Characteristics of Major Accidents:
  - Relatively-Simple Precursors & Initiating Events
  - Root Causes – Failure to Maintain Design Intent (first line of defense)
- MOST EFFECTIVE MECHANISM FOR IMPROVEMENT – Not by Addressing Specific Actions, but by Effecting Changes in the Way Business is Done (i.e., **SAFETY CULTURE & "MANAGEMENT SYSTEMS**")

Evolution of SMS Guidelines & Regulations to Performance (Goal) – Based Standards

1987 – CCPS
1990 – API RP 750
1992 – PSM
1996 – RMP

Onshore Process Safety (USA)

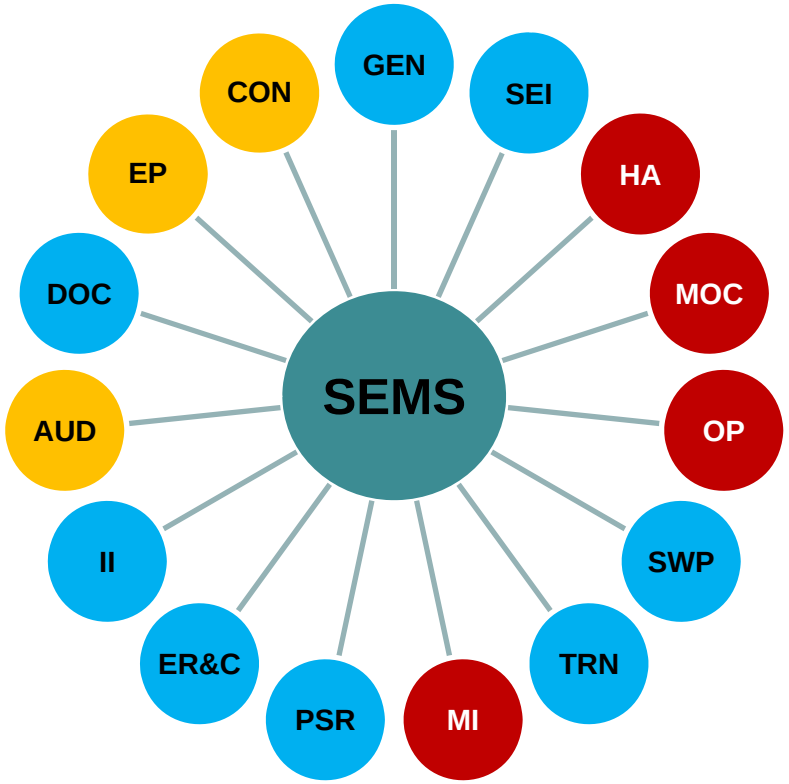
1989 – PSSDS
1991 – SEMP Concept
1993 – API RP 75
2004 – API RP 75
2006 – SEMS Concept
2009 – SEMS Prop. Rule
2010 – SEMS Final Rule

Offshore Safety Management Systems (USA)

1992 – UK Safety Case
2005 – UK SC Update
2009 – MODU HSE Case

Offshore Safety Management Systems (UK)

SEMS Elements



- General Provisions
- Safety & Environmental Information
- Hazards Analysis
- Management of Change
- Operating Procedures
- Safe Work Practices
- Training
- Mechanical Integrity
- Pre-Startup Review
- Emergency Response & Control
- Investigation of Incidents
- Audit of SEMS Elements
- Records & Documentation
- Employee Participation
- Contractor Safety

Hazards Analysis
SEMS Requirements

§250.1911 General Clarifications

- Offshore Facility Definition
  - All Types of Offshore Structures Permanently or Temporarily Attached to the Seabed (i.e., Mobile Offshore Drilling Units; Floating Production Systems; Floating Production, Storage and Offloading Facilities; Tension-leg Platforms; and Spars)
  - DOI-Regulated Pipelines
- Two Types of HA Requirements
  - Facility-Level Hazards Analysis
  - Job Safety Analysis (operations/task level)

§250.1911 General Clarifications

- Analysis & documentation must be maintained for the life of the operation of the facility.
- Applicability to similar systems/processes is allowable.
- HA must be completed by 15Nov11.
- HA must be periodically updated and at the same time as compliance audit performance – At **3-year Intervals** Starting on the **Second Year After Initial** SEMS Program Completion
- JSA must be completed/approved “prior to the commencement of the work.”

Facility-Level HA Techniques

- §250.1911(a) "… must be appropriate to the complexity of the operation and must identify, evaluate, and manage the hazards involved in the operation."
- API RP 14J identifies the following methods as acceptable:
  - What-If
  - Checklist
  - Hazard and Operability (HAZOP) Study
  - Failure Modes and Effects Analysis (FMEA)
  - Fault Tree Analysis
  - An Appropriate Equivalent Methodology

  Effective applications capitalize on the unique characteristics of these methods.

Facility-Level HA Techniques

- The HA shall address:
  - Hazards of the process/operation
  - Previous incidents
  - Engineering and administrative controls
  - Qualitative evaluation of consequences (safety/health, human/marine environments, equipment) of failure of controls
  - Human factors (also addressed via JSA)
- System to promptly address Team findings & recommendations
- Other Objectives – QUALITY

Facility-Level HA Team

- The Team must be made up of representatives from:
  - Engineering
  - Operations
  - Other specialties, as needed
- and must include:
  - Person with experience & knowledge specific to the process being evaluated
  - Person with experience & knowledge in the HA methodology

Key Design Guidelines

- API
- ISA
- IEC
- NFPA
- ASME
- ANSI

API RP 14C/14J Overview

- **API RP 14C** – "Analysis, Design, Installation, and Testing of Basic Surface Safety Systems for Offshore Production Platforms"
- Representative Safety System Designs
  - Component Configurations
  - Process Flow Diagrams
  - P&IDs
  - Alarm Features
  - Associated Safety Analysis Checklist
- Safety Analysis Methods & Development of SAFE Charts

- **API RP 14J** – "Design and Hazards Analysis for Offshore Production Facilities"
- Details for Support of Two Critical SEMP Elements
  - Safety & Environmental Information
  - Hazard Analysis
- Identification of Good Design Practices
- Primary Applicability – Offshore Production Facilities and Production Processing Systems of Mobile Offshore Units

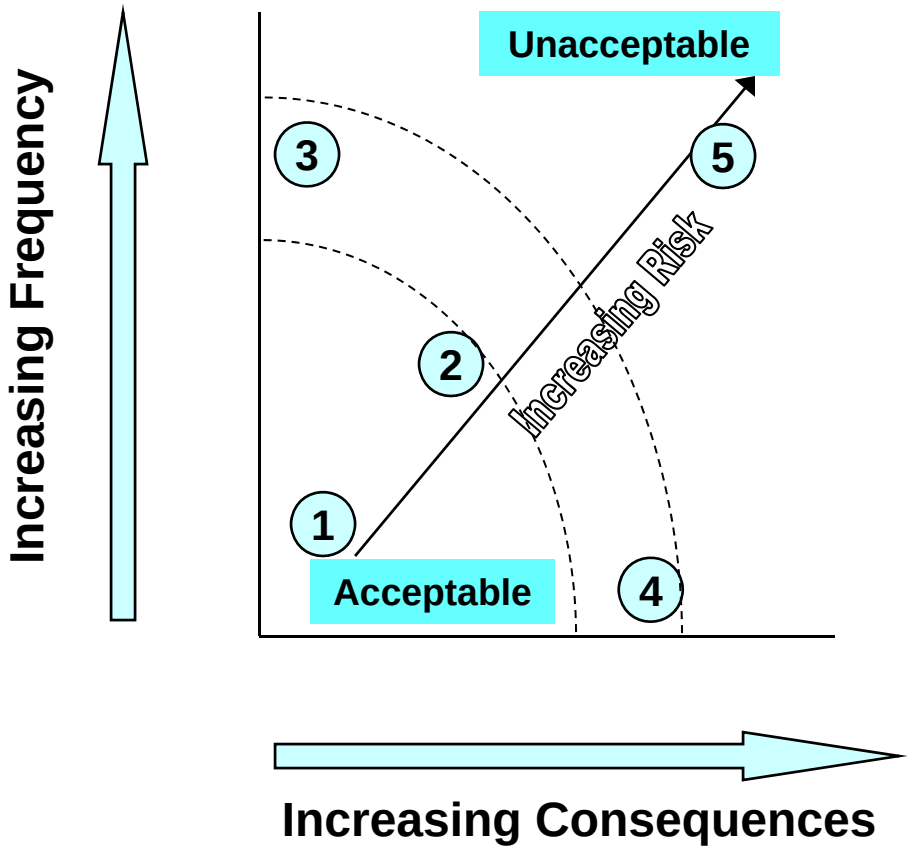
IEC 61508/61511 Overview

- **IEC 61508** – "Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems"
- Provides a Risk-Framework for the Identification of Hazards
- Risk Analysis Using the "Familiar" Likelihood/Severity/Risk-Ranking
- Defines Safety Integrity Level

- **IEC 61511** – "Functional Safety - Safety Instrumented Systems for the Process Industry Sector"
- Focus on Safety Instrumented Systems (SIS)
  - Electrical, Electronic, and Programmable Electronic Equipment
  - Electronic Logic Solvers
  - Also Addresses Pneumatic or Hydraulic Systems to Manipulate Final Elements
- Primary Applicability – Process Industries
- Key Elements
  - Requirements
  - Application Guidelines
  - SIL Determination
- Stresses the Importance of a Management System

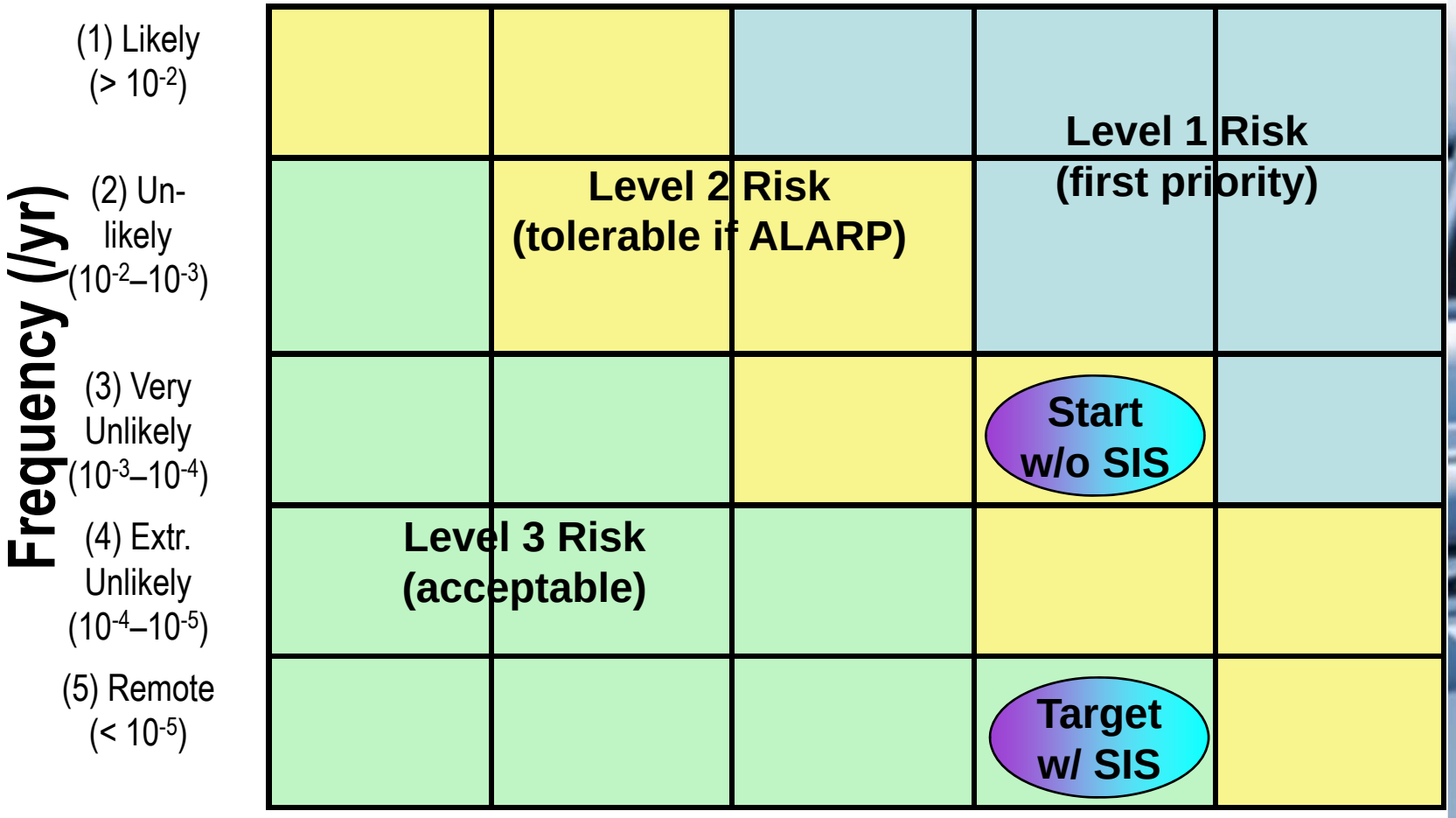
Offshore Facility Protection Systems Evolution
&
Interface with Other SMS and Analysis Techniques

Focusing on the Objective
(The "Big Picture")



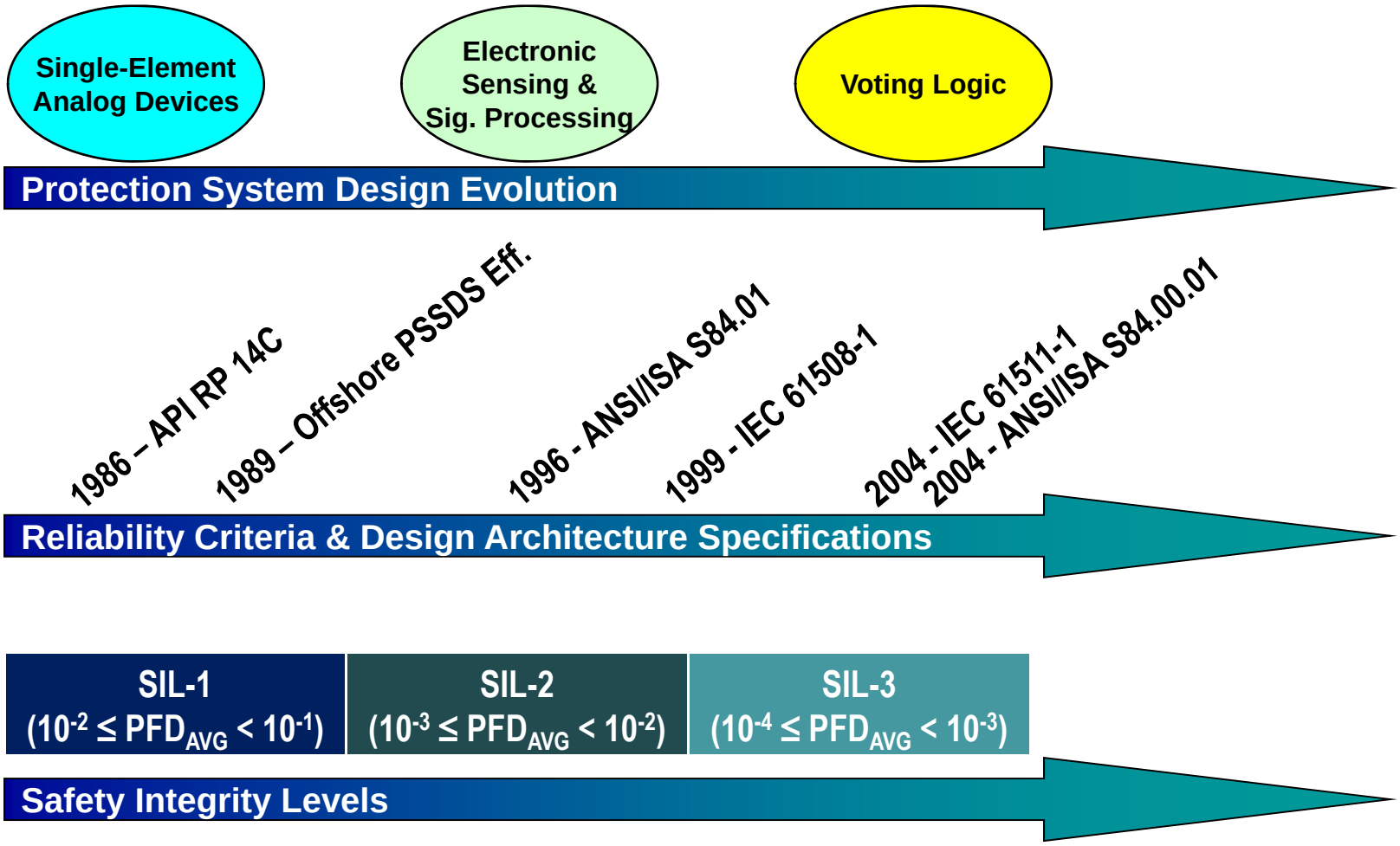
- **RISK = PROBABILITY * CONSEQUENCES**
  - **Probability = Likelihood of Occurrence**
  - **Consequences = Effects of Occurrence**
- For Engineered Systems:
  - **Risk = Σ $P_i * C_i$**

Risk/SIL Ranking



Note: Risk/SIL Ranking bases typically come from operating company.

Tandem Advances in Protection System Design Architectures & Analysis



Control/Protection System Spectrum – BPCS & SIS/HIPS

Increasing Reliability & Larger SIL (SIS-Only, ANSI/ISA-S84.01 & ANSI/ISA-S84.00.01)

Smart Sensors

Redundancy

Voting Logic

Electronic Sensing & Sig. Processing

Diversity

Single-Element Analog Devices

High Pedigree Devices

End Device Feedback Loops

Separation of Control & Protection

Decreased Cost

Increased Redundancy, Diversity, Pedigree

BPCS = Basic Process Control System, SIS = Safety Instrumented System,
HIPS = High Integrity Protection System

Safety Instrumented Systems (SIS)

- **Concept**
  - Diversity
  - Redundancy
  - Separation
- **Objectives**
  - Highly reliable safety features should have a low Probability of Failure on Demand (PFD)
  - Ensure that the likelihood of high/medium consequence events have an acceptably low risk contribution.
- **Design Guidelines**
  - 1996 - ANSI/ISA S84.01 (United States)
  - 2004 - ANSI/ISA S84.00.01 (United States)
  - 1999 - IEC 61508-1 (International)
  - 2004 - IEC 61511-1 (International)
- **Safety Integrity Level (SIL)** – Measure of SIS reliability

Layer of Protection Analysis (LOPA)

- LOPA was created as a bridge between a detailed QRA and HAZOP.

Increased Complexity
Increased Insights

- **HAZOP**
- **LOPA**
- **QRA**

- LOPA uses relatively standard initiating cause frequencies and independent protection layer PFDs to keep the analysis simple, but to yield quantitative results.

LOPA Ratio Calculation

- LOPA is a subset of the QRA Framework; however, it has its own set of acronyms and terminology to focus the analysis:
  - IC – Initiating Cause (i.e., Initiating Event)
  - ICL – Initiating Cause Likelihood (Frequency)
  - IPL – Independent Protection Layer
  - PFD – Probability of Failure on Demand
  - TF – Target Frequency
  - VF – Vulnerability Factor – Conditional Modifiers

$$LOPA\ Ratio\ (Safety) = \frac{TF_{Safety}}{ICL * PFD_1 * PFD_2 * PFD_3 ... * VFi * VFp}$$

Using LOPA Results

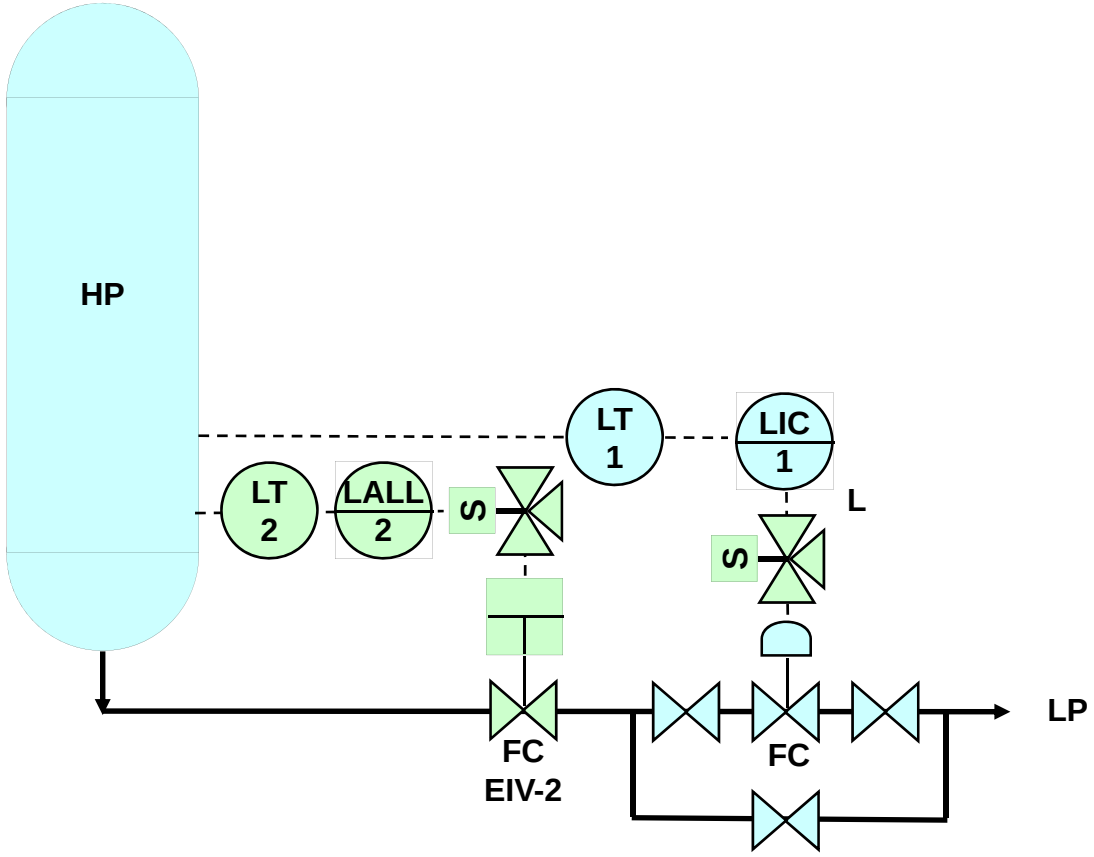
- Calculated LOPA Ratio is the primary decision-making basis.
  - To meet safety targets, if no SIS features exist, adjust BPCS to increase the LOPA Ratio to be ≥ 1 or add SIS feature.
  - To determine SIS pedigree, safety targets may be achieved by assigning SIL Allocation Target (see previous SIL Matrix).
  - Related integrity levels for environmental (EIL) and commercial (CIL) issues can be defined.

LOPA Ratio (w/o SIS)	SIL
10^{-0} - 10^{-1}	No special integrity requirements
10^{-1} - 10^{-2}	SIL 1
10^{-2} - 10^{-3}	SIL 2
10^{-3} - 10^{-4}	SIL 3

LOPA Summary

- LOPA utilizes a simplified quantification process to:
  - Determine if risk targets are met (e.g., acceptability of high-risk scenarios.
  - Determine adequacy of BPCS and SIS/HIPS protection features.
  - Compare the benefit-cost associated with improvements.
  - Identify if risk targets can be achieved with BPCS rather than SIS/HIPS.
  - Determine SIL Allocation Target for SIS/HIPS features.
- Implementation
  - Initial LOPA during HAZOP Study can reinforce SIL.
  - More-detailed LOPA can provide a more formal basis for scenario risk and needed SIS/HIPS SIL.

Simple SIS/LOPA Example



2-50% capacity relief valves exist on downstream LP vessel.

LOPA Ratio Calculation Details

IC	Chain of Events (Consequences)	IPL 1	IPL 2
LV-1 malfunctions open, possibly due to a failure of LT/LIC-1, or bypass valve inadvertently open.	Gas blow-by resulting in overpressurization of downstream equipment and resultant release of hydrocarbons and H2S, Potential for severe injury or fatality.	LAL-1, if LT/LIC-1 is not the cause of the malfunction.	2-50% capacity relief valves on downstream LP vessel
0.1/yr		----	2*0.01/demand

Scenario Frequency = 0.1/yr * 2*0.01/demand

Vulnerability Factor = 0.5 (People are present in the hazard zone for less than 12 hours/day.)

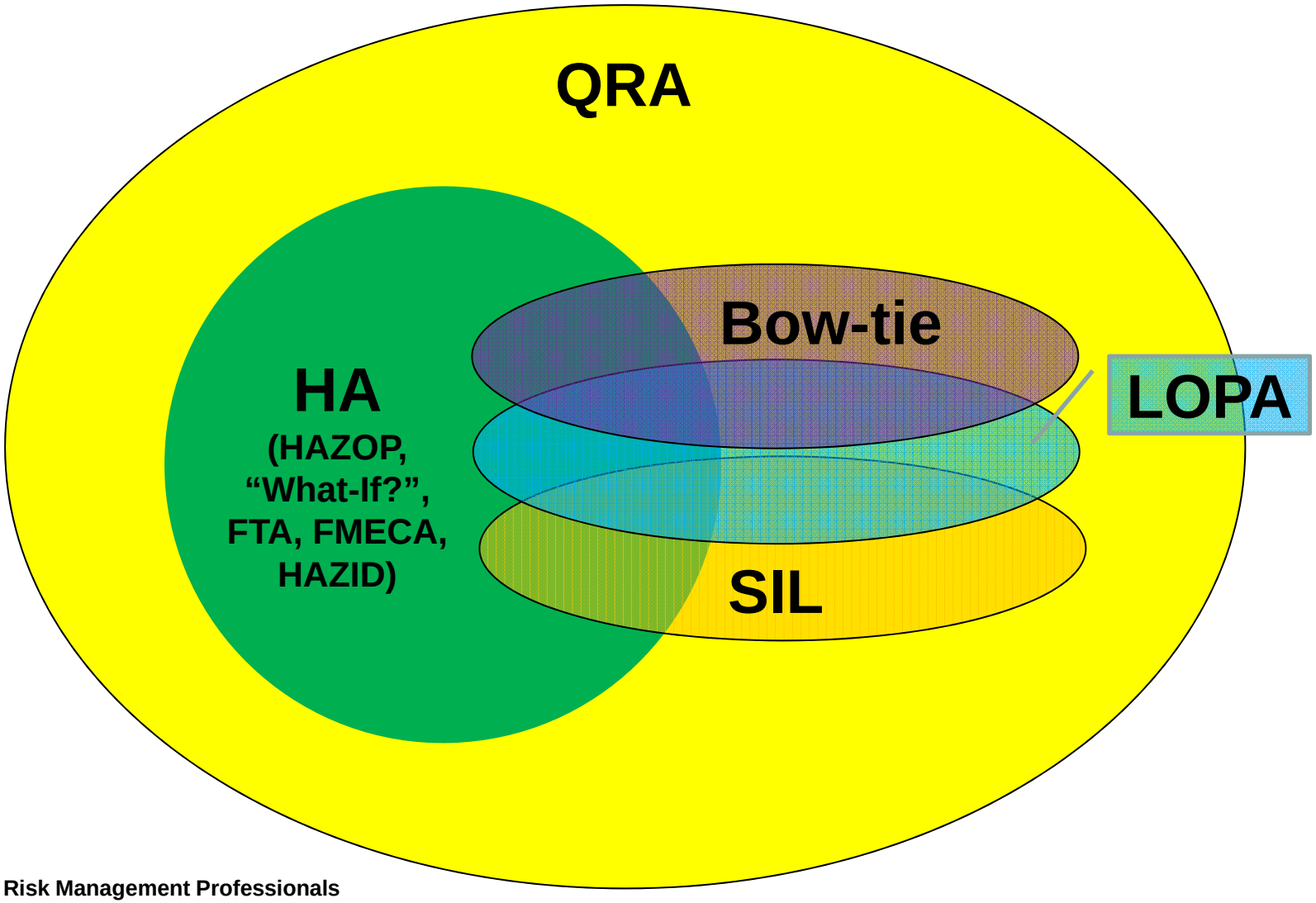
Target Frequency = $1X10^{-5}$/yr

Departure From Target (LOPA Ratio) = 0.01

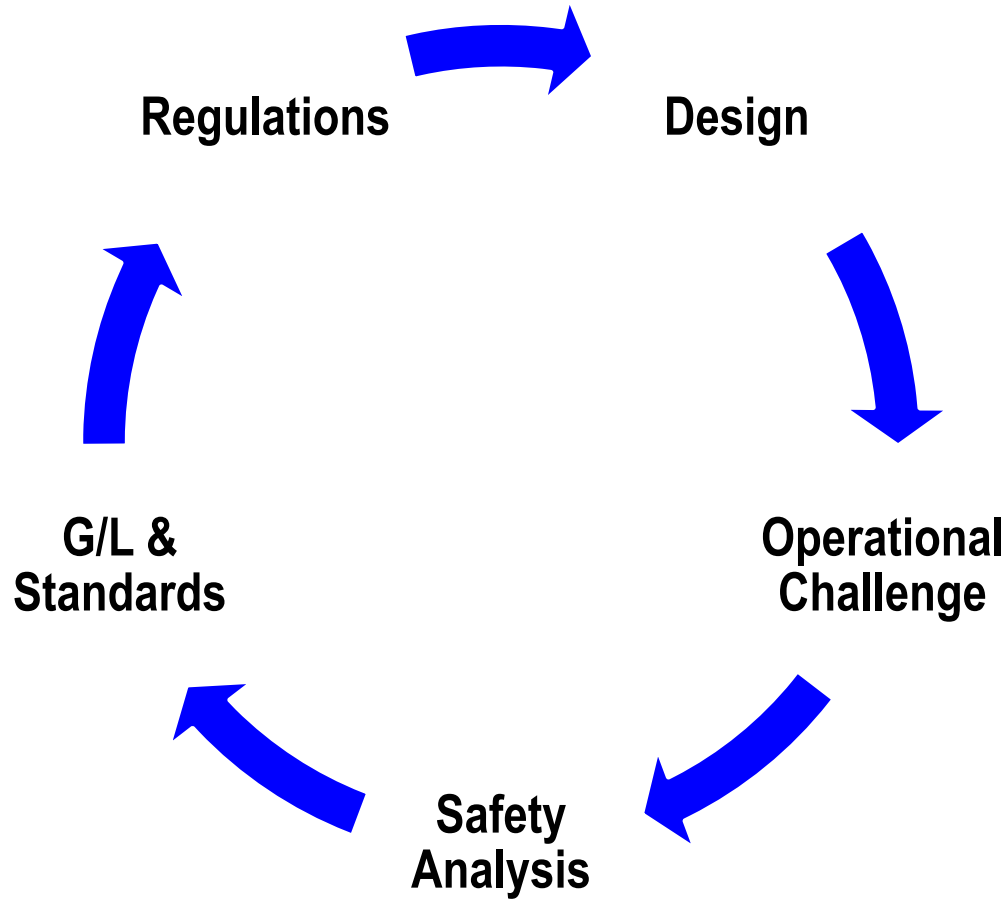
Conclusions: Need a factor of 100 improvement in safeguard reliability, e.g.:

- Installing a separate emergency isolation valve fed by an independent level transmitter (if SIS, SIL 2 target)
- Reconfiguring LV-1 to include a separate SIS closure feature (SIL 2)

Overlap Between Key Risk Analysis Tools



Interdependency of Design, Analysis, and Standards



Hazards Analysis Tool Spectrum

Each of these tools provides a different perspective & different insights.

Allows Risk Quantification

- Bow-tie
- LOPA
- ETA
- FTA

- HAZID
- JSA
- What-If/ Checklist
- API RP 14C Review
- Checklist
- What-If
- FMECA
- HAZOP

Less Effort ⟷ Increased Effort, with Increased Insights

References & Resources

Recent Webinars in Offshore Facility Process Safety Series

- **July 22, 2010** – Offshore Facility Process Safety Overview (Risk Management Professionals + Guest Speaker, Mark Steinhilber)
- **September 14, 2010** – Effective Creation & Appropriate Application of Safety Cases (Risk Management Professionals + Guest Speaker, Ian Sutton)
- **October 14, 2010** – Offshore Facility Process Safety Systems Overview (SEMS – A New Paradigm)
- **November 18, 2010** – SEMS Update and HAZOP Study, LOPA, & SIL Assessment Integration Made Easy
- **December 14, 2010** – Practical SEMS Mechanical Integrity (MI) Program Implementation
- **January 12, 2011** – SEMS Update, Hazards Analysis Basics, and Practical Approaches
- **March 3, 2011** – Safety & Environmental Information Tips (Including Quality P&IDs)
- **March 8, 2011** – Paradigm Shift in the Regulatory Application of SMS

Recent Webinars in Offshore Facility Process Safety Series

- **May 5, 2011** – Sensible Operating Procedures for Offshore Facilities
- **June 2, 2011** – Application of Bow-tie Analysis to Offshore Facilities
- **June 7, 2011** – Practical Approaches to Implementing Management of Change and Pre-Startup Reviews for Offshore Facilities
- **July 21, 2011** – SEMS Program Elements, Audit Requirements, Practical Approaches, Gap Analysis, and Audit Tips
- **October 18, 2011** – SEMS Program Elements, Hazards Analysis Basics, and Practical Approaches
- **October 27, 2011** – Practical SEMS Mechanical Integrity (MI) Program Implementation
- **December 8, 2011** - Practical SEMS Implementation, Auditing Techniques and Gap Analysis
- **June 12, 2012** – Contractors and Operations - The SEMS Rule
- **September 6, 2012** – Paradigm Shift in the Regulatory Application of SMS to Offshore Facilities

Other Resources

- www.BSEE.gov – Bureau of Safety and Environmental Enforcement
- www.RMPCorp.com – RMP Home Site with Offshore Facility SEMS Series & Other Training Tracts
- www.SEMS-Solution.com – Broad-Spectrum SEMS-compliance Software System
- www.CenterforOffshoreSafety.org – Center for Offshore Safety
- www.oilspillcommission.gov – National Commission on the BP Deepwater Horizon Oil Spill and Offshore Drilling
- www.API.org – American Petroleum Institute Publications & Recommended Practices

Questions?

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