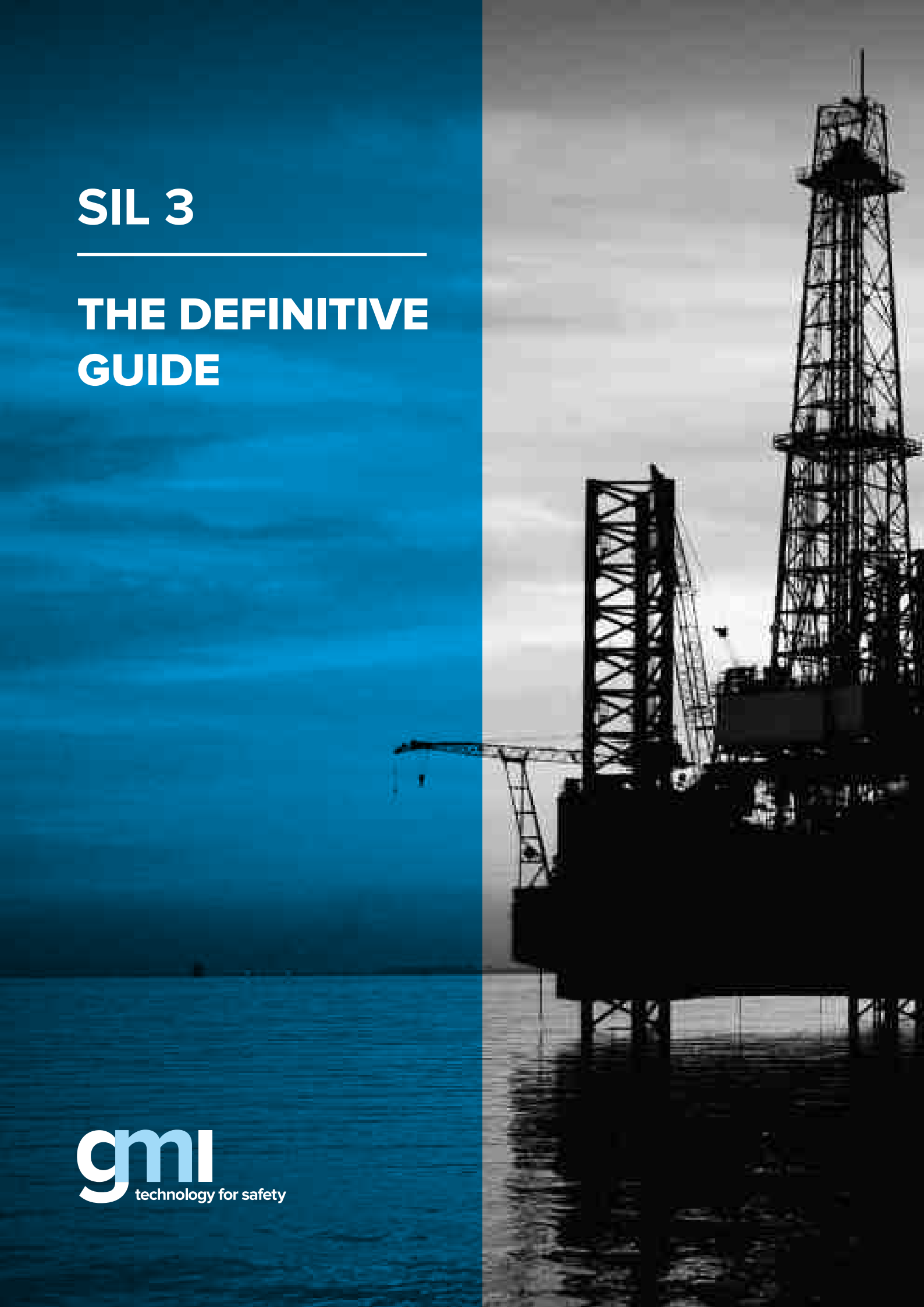
SIL 3

THE DEFINITIVE GUIDE



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The implementation of **Safety Instrumented Systems** (**SIS**) is a common way to address hazards.
The eventual need for such instrumented protection must always be determined. If needed, the appropriate **Safety Integrity Level** (**SIL**) must be identified in order to achieve the required level of safety. This process is crucial for achieving safety.
As we will see, SIL 3 is the appropriate level in rare and quite dangerous situations.

1 Safety Integrity Levels

The **Safety Integrity Level** (**SIL**) is based on the value of risk reduction associated with a **Safety Instrumented Function** (**SIF**) protecting against a specific hazardous event, or how the risk has to be reduced to reach an acceptable level.

Therefore it is a relative level of risk-reduction provided by a safety function, and, in other words, provides a measurement of the performance of a safety instrumented Function (SIF).

In **IEC 61508 standard**, Safety is defined as "freedom from unacceptable risk of harm", while risk is the combination of the probability of occurrence of harm and the severity of that harm (**R=FxC**, where F is the Frequency of accidents and C is their Consequences, evaluated as a cost; therefore R is defined as cost per time unit).

Not all of the functional safety standards provide the same requirements for given SIL's. IEC 61508 defines four SIL's, with SIL 4 the most dependable and SIL 1 the least.

SIL is a measure of reliability and risk reduction used in several standards; Among them:

- **ANSI/ISA S84** (Functional safety of safety instrumented systems for the process industry sector)
- **IEC 61508** (Functional safety of electrical/electronic/programmable electronic safety related systems)
- **EC 61511** (Safety instrumented systems for the process industry sector)
- **IEC 61513** (nuclear industry)
- **IEC 62061** (safety of machinery)
- **EN 50128** (railway applications – software for railway control and protection)
- **EN 50129** (railway applications – safety related electronic systems for signalling)
- **EN 50402** (fixed gas-detection systems)
- **ISO 26262** (automotive industry)
- **MISRA**, various (guidelines for safety analysis, modelling, and programming in automotive applications)
- **Defence Standard 00-56 Issue 2** – accident consequence

The determination of a SIL is based on quantitative and qualitative factors such as **development process** and **safety life cycle management**. For example, the safety lifecycle includes a hazard and risk assessment phase, in which all significant hazardous events have to be identified and then subjected to an assessment to determine the level of risk reduction required from a safety instrumented function (SIF) to achieve a target level of risk.

The SIL expresses the required risk reduction or performance for the SIF. This assessment, called SIL determination, defines the required performance or "target SIL" for the SIF, and a target Average Probability of Failure on Demand (PFD), representing the maximum value allowed in the range of a target SIL.

The SIL determination methods commonly used are: **Safety Layer Matrix** (**SLM**); **Risk Graphs** (**RG**); **Layer of Protection Analysis** (**LOPA**); **Fault Tree Analysis** (**FTA**); and **Event Tree Analysis** (**ETA**), and they are normally used in combination, with LOPA being the most commonly used by large industrial facilities, SLM the simplest, FTA and ETA the most flexible and therefore suitable to complex cases. SLM and RG are used for initial screening assessments. Because of its flexibility and orientation to details, FTA is especially suitable for the reassessment needed when a SIL 2, SIL 3 or SIL 4 level is determined.

Generally speaking, the assignment of a SIL is made as follows: the risk associated with a specific hazard is calculated without the risk reduction effect of the SIF. Then, the risk determined is compared to a risk target considered acceptable. The risk reduction of the SIF must address the difference between the unmitigated risk and the tolerable risk, with the SIL target corresponding in a correlation relationship to the required risk reduction, where the greater the reduction required, the higher the required SIL.

The **International Electrotechnical Commission**'s (**IEC**) standard IEC 61508 groups the requirements into the two categories of hardware safety integrity and systematic safety integrity. According to the standard the requirements for both categories must be met for a device to achieve a certain SIL. For hardware safety integrity, the requirements are statistical, with specific targets to reach, as the maximum probability of dangerous failure and the minimum safe failure fraction. In **IEC EN 61508**, the requirements for **PFD** (probability of failure on demand) and **RRF** (risk reduction factor) for different SIL's for low demand operations are:

SIL	PFD	PFD (power)	RRF
1	0.1 - 0.01	10^{-1} - 10^{-2}	10 - 100
2	0.01 - 0.001	10^{-2} - 10^{-3}	100 - 1000
3	0.001 - 0.0001	10^{-3} - 10^{-4}	1000 - 10.000
4	0.0001 - 0.00001	10^{-4} - 10^{-5}	10.000 - 100.000

and for high demand of operation or continuous operation (Probability of failure per hour) are:

SIL	PFH	PFH (power)	RRF
1	0.00001 - 0.000001	10^{-5} - 10^{-6}	100.000 - 1.000.000
2	0.000001 - 0.0000001	10^{-6} - 10^{-7}	1.000.000 - 10.000.000
3	0.0000001 - 0.00000001	10^{-8} - 10^{-9}	10.000.000 - 100.000.000
4	0.00000001 - 0.000000001	10^{-9} - 10^{-10}	100.000.000 - 1.000.000.000

The condition of a device meeting a particular SIL level is certified based either on demonstrating that a rigorous development process has been established, or on historical data proving that the device has sufficient operating history to be considered safe according to a certain level.

2 The need for SIL 3

Need for a **SIL 3 safety function** is rare at process plants. At process plants, most SIF won't require higher than SIL 1. For safety functions requiring above SIL 2, several questions have to be addressed, regarding the use of the correct formula for reliability calculation, the consideration of common cause failure, the use of the right method to select appropriate values for common cause factors, the inclusion of the contributions from human error in the calculation of PFD, the inclusion of all relevant factors in the assessment, the evaluation of the appropriateness of the methodology used (if suitable or not; RG, LOPA and SLM aren't appropriate for SIL 3, which requires a review of the assessment with a fault tree.

In fact, the reassessment can lead to reassigning a SIL 3 requirement for the SIF to a target PFD in the range of a lower SIL, with a consequent reduction in both capital and operating costs).

When SIL 3 is necessary, the combination of hardware configuration and human interactions with the safety function must be accurately examined, with the determination of the demand frequency requiring particular attention and a systematic approach (through the use a demand tree), covering normal operation, abnormal operation, start-up, shutdown and demands initiated from outside the plant (loss of services, power, etc.), since these factors added together are very significant.

3 SIL 3 determination

SIL 3 determination requires care. Any prospective SIL 3 SIF demands reassessment. Three aspects of SIL determination deserve special mention for SIL 3: **team competencies**, **alarms** and **personnel exposure**.

With regards to **team competencies**, effective SIL determination requires input from many professionals, managed for example through meetings with a leader and representatives of all the relevant disciplines, chosen according to professional skills and personal attitudes, since they have to work well together. Such meetings can work well for initial screening purposes and may provide sufficient detail to justify SIL 1 safety functions, but for the higher SIL's, requiring more details, appointing an independent professional to carry out the assessment could be more appropriate.

With regards to **alarms**, SIL determinations must consider potential risk reduction from operator response to alarms, which could be influenced by his availability at the time the alarm enters in function, by the eventually insufficient time to respond and by the number of alarms in function at the same time. It may be difficult for the operator to decide what to do, and every effort must be put in place to guarantee that he has all the proper directions to make the right decision and initiate the correct actions.

With regards to **personnel exposure**, and the potential consequences on the workers of a failure, there's the need to consider the proportion of time that the person at risk may be in the area of the plant where an injury could occur, taking in consideration that, even if for a high hazard zone the proportion of the working day spent there is quite small (for example less than 10%), the person could be asked to go to the hazard area to investigate just when the incident occurs. In that case, the proportion changes drastically, because it would be in practice 100% of the time the hazardous event occurs.

4 Achieving SIL 3

Achieving and **maintaining in the long term** (that is to say, for the entire duration of the function) SIL 3 performance is a very hard task. As a consequence, when the need for a SIL 3 SIF is determined, the people involved in the Risk Reduction projects find themselves in the complex situation of demonstrating that SIL 3 performance is achieved by the combination of hardware and human interactions, such condition being very likely to be put in discussion at a further examination by company stakeholders or external regulatory authorities.

For example, one of the major implications of SIL 3 is that it requires a high degree of duplication, a condition that is related with what is described in international standards as “hardware fault tolerance.”, a requirement for continuous functioning (even if one or more faults occur) determining the need of more than one sensor and more than one means of output to guarantee that the function will continue to work in case of failures occurring between periodic tests. In addition, achieving the necessary PFDavg for SIL 3 (that is to say, in the range 0.001 to 0.0001) implies that the SIF’s unavailability to respond successfully over a 1 year (8760h) period can be maximum 8.76 hours or less, a value that must include the time when the organization is unaware that the function isn’t working.

Furthermore, SIL 3 is achieved only when the following four conditions are satisfied in the calculation of the PFD: **1)** the failure rates used are those properly applicable to the situation, as direct field-failure ones; **2)** an appropriate assessment of dependency is performed in order to guarantee that calculations are not grossly optimistic; **3)** the unavailability of the function during testing is accounted for; and, especially, **4)** the human interactions with the safety function are taken in consideration, because humans are involved in the maintenance, calibration and testing of SIF and the probability of mistakes by them (for example the same having little effect on a SIL 1 PFD) may make SIL 3 unachievable.

As a consequence, differently from a SIL 1 function, accurate design of the human tasks and assessment of the probability of human error (and its inclusion in the PFDavg calculation) are needed for a SIL 3 function. Such activities require specialist skills.

5 SIL 3 Costs

Compared to a SIL 1 function, SIL 3 features **additional operating costs**.

Those, for example incurred in proof testing duration and frequency, which is more frequent and longer than for a SIL 1 function because of the higher number of elements to test, of the greater complexity of the systems and the higher frequency of tests (SIL 3 proof test interval could be at least once a year but will depend on the proof test coverage achievable during the proof test of that SIF).

6 Conclusions

The **main concepts** with SIL 3 are the following:

1. SIL 3 is a **Safety Integrity Level** that is appropriate for very specific and rare situations, in which a high level of **risk-reduction** performance by a SIF is required.
2. The actual need for SIL 3 must be determined through an accurate and thorough **SIL determination**, and through a **reassessment**, also in consideration of the additional costs associated with achieving and maintaining a SIL 3 level.
3. Achieving SIL 3 has several **implications**, among which designing the safety performance of the **combination of hardware and human interactions**, and therefore requires the involvement of specialists from various disciplines in the risk reduction project.

In conclusion, SIL 3 is at the same time a target and a challenge and approaching it entails the use of the best skills and know-how owned by individuals and organizations. When the need for a SIL 3 Safety Integrity Level is determined, technology and human behaviors must be fit to the challenging goal.

Achieving safety, as “freedom from unacceptable risk of harm”, must be a fundamental objective in every productive activity and SIL 3 is a new frontier in **Risk Reduction**.

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