Analysis of reporting systems in safety critical domains to develop the SHIELD HF taxonomy. Results from EU funded SAFEMODE Project.

Luca Save, Simone Pozzi, *Deep Blue srl* luca.save@dblue.it

Sybert Stroeve, *Netherlands Aerospace Centre NLR* sybert.stroeve@nlr.nl

Osman Turan, Rafet Kurt, Beatriz Navas de Maya, *Strathclyde University, Department of Naval Architecture, Ocean & Marine Engineering* o.turan@strath.ac.uk

Barry Kirwan, Andrew Kilner, *EUROCONTROL* barry.kirwan@eurocontrol.int

Alexander Efremov, *Moscow Aviation Institute* pvl@mai.ru

ABSTRACT

The paper presents a comprehensive review of sixteen Safety Occurrence Reporting and Analysis Systems (SORAS) adopted in safety critical domains such as aviation, maritime, railway, nuclear, and space operations. The aim of the review is the analysis of the taxonomies adopted within these systems, in order to derive the most relevant features useful to define the HF Taxonomy of the EU funded SAFEMODE project. SAFEMODE deals with the consideration of the human element in the safety of aviation and maritime operations. As a result of the review, five best-in-class taxonomies are identified: HERA, HFACS, TRACEr, HEIST, and NASA-HFACS. In conclusion, a proposal to combine their most relevant elements to define the specific SAFEMODE SHIELD HF Taxonomy for aviation and maritime domains is formulated and recommended for future incident and accident analysis efforts.

Keywords: *taxonomy, human factors, safety occurrences, maritime, aviation.*

1. INTRODUCTION

Over the years, and especially since the nineties, major safety improvements have been made possible through the analysis of meaningful and valuable data included in incident reports. In this respect, taxonomies represent an essential instrument in describing and categorizing events, states, conditions, and factors affecting the performance of a safety critical system. Due to the variety of approaches and professional communities involved in such an effort, this has often resulted in a proliferation of different proposals, with only a limited number of cases in which a unique and widely accepted taxonomy has been established. This is partly due to the fact that the reliability of the human performance is considered a critical element in safety management, but it is far from being the single cause for accidents and, in most of the cases, it cannot be fully understood without taking into consideration all the other elements of a given safety critical system (e.g., the procedures, equipment, tools and organizational factors). Therefore, even when there is a specific focus on the human element, it is not easy – and in most cases, not appropriate – to extrapolate it from the organizational and technological context in which its performance is taking place. In addition, a taxonomy is only one component of the Safety Management System, which may adopt different strategies, involve different stakeholders, and pursue different objectives, in a way that affects how the elements and categories of the taxonomy are interpreted and determines the required level of granularity. The review presented hereafter tries to capture the variety of these elements in order to identify the best in class taxonomies to consider in the development of the SHIELD (Safety Human Incident & Error Learning Database) HF Taxonomy adopted within the SAFEMODE EU funded Project[1].

Therefore, Section 2 of this paper introduces and reviews the concept of Safety Occurrence Reporting and Analysis System (SORAS), within which current individual taxonomies are studied. Section 3 provides the criteria for the selection of SORAS and their distribution amongst sectors. Section 4 includes the emerging features of the selected SORAS and their analysis in a combined framework. Section 5 compares the taxonomies that have been identified within the various SORAS of the previous sections and elaborates on the criteria to select a group of best-in-class taxonomies which could become a reference for the definition of the SHIELD HF taxonomy Section 6 defines the requirements to design the SHIELD HF taxonomy. Finally, concluding remarks are included on Section 7.

2. THE REVIEW OF SORAS

Generally speaking, taxonomies do not exist as independent objects but are always part of a process, methodology or tool with specific goals. Since SHIELD is intended to enable a learning process from the analysis of errors and incidents, the review encompassed all the systems that have been put in place at a research, industrial or institutional level to improve safety after an accident, an incident or a near miss. For this reason, the analysis started from the definition of a generic Safety Occurrence Reporting and Analysis System (SORAS) articulated in different phases: (i) Reporting, (ii) Data Collection, (iii) Data Analysis, (iv) Storing, (v) Recommendations (see Figure 1).

The assumption made was that a HF Taxonomy plays a different role depending on the specific phase in which it is employed, when considering the generic process, we have illustrated. Some SORAS cover all the described phases, while others specialize in one or more. Therefore, the taxonomy used for each SORAS is influenced by the specific needs and goals of each phase.

3. SELECTION OF SORAS

Following an agreement among the SAFEMODE partners involved in the specific activity, it was decided to review 16 different SORAS, from different safety critical domains (SAFEMODE, 2019). The two main sectors were the aviation and maritime domains which represent the official SAFEMODE domains. However, considering that other domains are also represented in the consortium, and that some of the partners had previous experiences from them, it was decided to extend the review to SORAS from three other domains, i.e., the railway transport, the nuclear domain and the sector of space operations.

3.1 Selection Criteria

Two main criteria were considered in the decision to select the SORAS for the review.

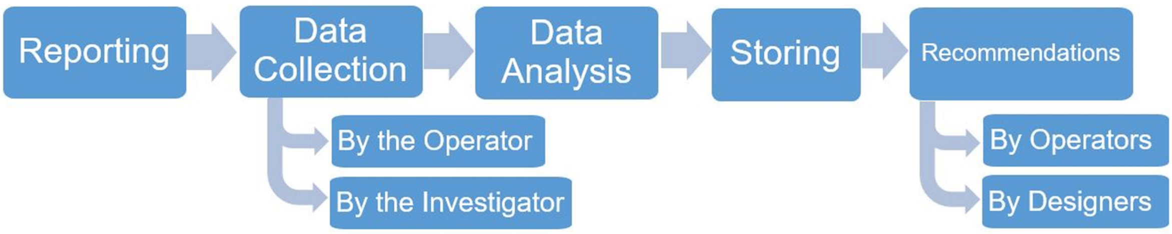

Figure 1. The different phases of a generic Safety Occurrence Reporting and Analysis System

[1] https://www.safemodeproject.eu/

The first one was to include only the SORAS that addressed at least partially the role played by the human in causing or contributing to accidents, incidents and near misses. The second one was to include in the review the SORAS that are used (or have been used) at industrial or operational level or that have been formally adopted by official regulation or policy making entities. Techniques, methods, and other processes that are considered promising but have remained at academic/research level were not included.
It is worth noting that the number of SORAS selected for the maritime domain was considerably lower than the one for aviation. A variety of reasons motivates such a difference, including: the fragmented nature of the maritime sector, a general difficulty to find information on the most relevant experiences, a historically less consistent application of HF methods compared to the aviation domain.

3.2 Distribution among sectors

Overall, the analysed SORAS were distributed as follows among the different sectors: 8 from aviation, 3 from the maritime, 3 from the railway, 2 from the nuclear domain and one from space operations (SAFEMODE, 2019).

Table 1. The sixteen selected SORAS

Acronym	Taxonomy	Domain
ADREP	Accident and Incident Data Reporting	Aviation
RAT	Risk Assessment Tool	Aviation
HERA	Human Error in ATM	Aviation
HFACS	Human Factors Analysis and Classification System	Aviation
CAST	Commercial Aviation Safety Team	Aviation
ACAFSS	Automated Civil Aircraft Flight Safety System	Aviation
AAG	Accident Analysis Group	Aviation
IATA	International Air Transport Association	Aviation
EMCIP	European Marine Casualty Information Platform	Maritime
CASMET	Casualty Analysis Methodology for Maritime Operations	Maritime
TRACErM	Technique for the retrospective & predictive analysis of cognitive errors – Maritime.	Maritime
HEIST	Human Error Investigation Software Tool	Railways
10 IF'S	The Human Performance and 10 Incident Factors	Railways
COR	Common Occurrence Reporting	Railways
SACADA	Scenario Authoring, Characterization, and Debriefing Application	Nuclear
NASA HFACS	National Aeronautics and Space Administration Human Factors Analysis and Classification System	Space Operations

In most cases the name of the identified taxonomy corresponds to the one of the SORAS that was analyzed. However, it is only one part of it and - once again - cannot be fully understood without an analysis of the roles it in the overall SORAS.

4. EMERGING FEATURES

4.1 Epidemiological vs Model-based

A taxonomy can be defined *epidemiological* when it tends to introduce a new category or attribute every time an event identified as new has occurred. Epidemiological taxonomies can be quite detailed, and their advantage is that they cover many possible cases. A disadvantage is that they may grow to an extent in breadth and complexity that makes them difficult to use, or that means different people classify the same event in different ways. Since they are continuously evolving, epidemiological taxonomies may become difficult to use for the identification of trends over a long period of time (e.g., a decade), as similar events may be classified differently at different moments, due to the introduction of new taxonomic terms or elements.

Conversely, a taxonomy can be defined as *model-based* if the categories and attributes are defined considering a specific conceptual model: in this context, a human performance model. These types of models aim to reduce a potentially infinite number of possible tasks to a finite set of behavioural patterns. Models typically used to classify human performance are information processing models (e.g., Wickens, 1992), models classifying errors and violations at an individual level, and models classifying the factors contributing to errors and violations (e.g., Shappel. & Wiegmann, 2000). Model-based taxonomies have the ambition to highlight not only WHAT happened in relation to a specific event, but also HOW and WHY. In this respect they have a greater analytical power compared to epidemiological taxonomies and they are more likely to be used in a consistent manner by different human factors experts. However, they require a reasonable mastery of the human performance models on which they are based. In addition, they might be very difficult to use, without sufficient background information and evidence data on the event which is being classified.

Clear examples of epidemiological taxonomies from those analysed in the review made in previous chapters are ADREP in the aviation domain and EMCIP in the maritime (EMSA, 2018). Both taxonomies are characterized by a huge number of categories and attributes, organized in a number of hierarchical levels, and can be used to classify a very large variety of events. Examples of model-based taxonomies are HERA and HFACS (aviation), as well as TRACEr (maritime). Although they possess a different level of granularity, they are all clearly linked to specific human performance models.

4.2 Domain transversal vs domain specific

An obvious difference among the 16 taxonomies analysed is the amount of categories and attributes that can be applied to all safety critical domains, against those that are specific of a given domain. Generally speaking, epidemiological taxonomies are more likely to be also domain specific, as they are characterized by a lower level of granularity. On the contrary, model-based taxonomies are more focused on human performance aspects that are common to all domains. Therefore, they can be fully transversal or at least easily adaptable to different domains. In a number of cases, the model-based taxonomies have been tailored to a specific domain, in order to account for the domain specific contributing factors affecting the performance at individual and organizational levels.

Clear examples of domain transversal taxonomies are HFACS (aviation), and HEIST (railway sector). Examples of domain specific taxonomies are ADREP (aviation) and EMCIP (maritime). Besides these more extreme cases, taxonomies such as HERA (specifically for Air Traffic Control in the aviation domain), TRACEr (as used in the maritime) and NASA-HFACS (for space operations) include both transversal elements used to characterize the human behaviour, and domain-specific elements to enrich the understanding of all contributing factors affecting it.

4.3 Analysis in a combined framework

The distinction between *epidemiological and model-based* taxonomies on one side and *transversal and domain-specific* taxonomies on the other side do not allow a discrete and univocal categorization. Some taxonomies are clearly epidemiological but have also some kind of relationship with a conceptual model guiding their structure. Vice-versa, some taxonomies have a very explicit reference to a human performance model, but also include elements deriving from the need to classify very specific types of events, independently from human performance aspects. At the same time, there may exist taxonomies developed within a very specific domain that have been structured in a way to be adaptable to other domains. Similarly, other taxonomies have been developed to be applicable to a large variety of sectors, but their structure is clearly influenced by the history and specificities of the domain from which they originate. It was therefore proposed to consider the four criteria as two axes representing a continuum of gradual changes from one characteristic to the other. If combined together, the two axes form a framework identifying four different quadrants (Figure 1).

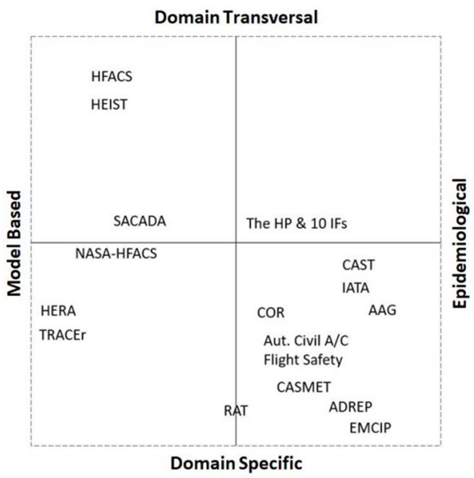

Figure 2. A combined framework for taxonomy analysis

When analysing the 16 taxonomies addressed so far, it was observed that the largest number of them concentrate into the bottom-right quadrant combining domain specific and epidemiological taxonomies: CAST-ICAO, IATA, COR, AAG, CASMET, ADREP, EMCIP and the Russian taxonomy that has been translated as “Automatic Civil Aircraft Flight Safety” taxonomy. While the top-right quadrant is nearly empty and includes only the “Human Performance and 10 Incident Factors” taxonomy from the railway domain. The reason for such peculiar positioning, very close to the centre of the framework, is the fact that it includes a limited number of domain specific terms, it addresses Human Performance Factors (HPFs) that can be considered transversal, but also includes generic Incident Factors that appear strongly influenced by the peculiarity of the railway transport organizations in the UK. Nearly all the remaining taxonomies are equally distributed on the top-left and bottom-left quadrants.

The top left quadrant includes HFACS, HEIST and SACADA. HFACS is clearly model based and does not include any element explicitly referring to a domain, despite being originally developed in the aviation part of the US navy. The HEIST taxonomy, coming from an adaptation of HFACS, is slightly more articulated, but does not include any explicit reference to a domain. Similarly, SACADA includes generic terms to classify human performance, but its organization is strongly influenced by the way simulations are conducted in the nuclear domain and was therefore positioned closer to domain specific taxonomies.

The bottom left quadrant includes TRACEr, HERA and NASA-HFACS. HERA and TRACEr have strong commonalities, because the first was originally derived from the second in the Air Traffic Control domain, even if in this context we have analysed the version of TRACEr adapted to the maritime domain. As mentioned before, both taxonomies are based on a specific human information processing model but have also been enriched with a large set of domain specific elements to highlight the role of the contributing factors affecting the performance of individual operators. Nevertheless, the transversal and domain specific part of such taxonomies are quite easy to distinguish, therefore they can easily be adapted to different domains, just by removing domain specific elements and integrating them with the elements of another domain. Finally, NASA-HFCAS has the same basic structure of HFACS but has been enriched with organizational and contributing factors at a lower level of granularity and with a limited number of domain specific elements. In this respect, NASA-HFCAS is more similar to a domain specific taxonomy, but it is clearly located at the border with the transversal ones.

A peculiar case is RAT. The taxonomy used for the Risk Analysis Tool is domain specific, since it is intended to classify the risk associated to very specific events in Air Traffic Management. It cannot be considered epidemiological, because it identifies few distinctive criteria to classify the risks, which are not expected to grow up in number or evolve significantly over time. It actually refers to a risk analysis model taking into account the different barriers that are available between a hazard and the actual occurrence of an accident.

But it does not refer to a human performance model, since it is strongly focused on the consequences of safety occurrences, rather than on precursors and causal factors, including the human element. This is why it has been considered as clearly domain specific, but with a hybrid nature between all the model-based and epidemiological taxonomies.

5. IDENTIFICATION OF BEST IN CLASS TAXONOMIES

5.1 Expected use of the taxonomy on the SAFEMODE context

In the context of SAFEMODE, it is expected that the SHIELD Human Factors Taxonomy will serve two main purposes: (i) To derive design and redesign recommendations for aviation and maritime industries and operators, (ii) To help setting priorities when defining how to improve the safety of aviation and maritime operations. The first use (support to design and redesign) consists of allowing an in-depth analysis of human behaviour in case of accidents, incidents and near misses. The analysis consists in understanding what went wrong in terms of human performance, considering all organizational, contextual and contributing factors affecting it. The assumption is that future design/redesign activities of equipment, procedures and training that will take into account such an analysis will achieve higher levels of safety for operations. Target users who are likely to benefit from this use of the taxonomy are designers working for a manufacturer and investigators working for an operator. The second use (help in setting priorities) consists in supporting the labelling of individual events and clustering of similar events in order to compile a database of safety occurrences. The database is expected to help in the identification of the areas where there is more room for improvement. Target users who are likely to benefit from this use of the taxonomy are the investigators working for an operator and policy makers/regulators.

For the first type of use, a model-based taxonomy is expected to be more suitable for two main reasons. The first one is that the analysis of human behaviour in case of incidents is likely to be insightful only if based on categories and attributes that are coherently referring to a state-of-the-art human performance model. The second reason is that epidemiological taxonomies tend to be very detailed and grow to an extent that makes the consistent classification of the same behaviour by different experts very challenging. Similarly, the taxonomies that are too domain-specific may become difficult to manage due to their potential huge number of categories and attributes. For the second type of use, epidemiological taxonomies are in principle suitable, since a detailed understanding of the causal and contributing factors, including the specific role played by human operators, may be indispensable in identifying safety related trends, which also relate to the most frequent outcomes of the safety events. Nonetheless, taxonomies too detailed, with too many attributes, are likely to be also unfit for the identification of trends, due to the higher probability of having inconsistent classifications amongst different users.

5.2 Selection of model based taxonomies

Based on the considerations made above regarding the expected use of a taxonomy in the context of SAFEMODE, the model based ones were considered the best reference to guide the definition of the specific SHIELD Human Factors Taxonomy. In addition, since the project is addressing both the aviation and maritime domains, it was important to generate a taxonomy adaptable to the specific needs of both domains. On one side, the number of domain specific elements had to remain manageable, to minimize the risks of misclassifications and make the taxonomy easy adaptable to one domain or the other. On the other side, it was important to prevent the risk of disregarding the contextual and contributing factors affecting human performance, which are typically linked to the peculiarities of each specific domain.

For such reasons, the following five taxonomies - among the sixteen addressed in the review - were identified as those to be considered as reference for elaborating the SHIELD Human Factors Taxonomy: TRACEr (Shorrock & Kirwan, 1998), HERA (EUROCONTROL, 2003), NASA-HFACS (Dillinger and Kiriokos, 2019), HEIST (Reinach, Viale, Green 2007) and HFACS (Shappel & Wiegmann, 2000). All of these taxonomies are distributed over the left side quadrants of the framework described in Figure 2, representing the model-based taxonomies. However two of them are domain transversal, i.e. HFACS and HEIST, while the other three are domain-specific, i.e. TRACEr, HERA and NASA-HFACS.

6. RECOMMENDATIONS AND PROPOSAL FOR THE SHIELD HF TAXONOMY

Incident reports often contain little information. Operators are obliged to file a report, but beyond that requirement, there is little additional detail on what the report should contain. Even when there is a structure the investigators must follow, the framework for capturing information is not derived by considering the needs of designers and safety analysts. Furthermore, it is clear that the adoption of some taxonomies has significantly affected the language seen in incident reporting. The taxonomy is in effect limiting the language and freedom of expression seen in incident reporting. In the context of SAFEMODE it was therefore agreed that the taxonomy to be adopted for SHIELD had to provide the opportunity, and in effect the ‘language’ that enables the safety analyst or an operator to describe, both in as much detail as possible, and as easily as possible the human centred issues that have caused or contributed to an incident. The taxonomy also has to specifically provide information that enables design decisions to be made as a function of the data contained within SHIELD.

The following subsections present the requirements that have been identified for the SHIELD HF Taxonomy and the actions agreed by SAFEMODE partners in order to develop it, based on the previous review.

6.1 Identification of requirements for the SHIELD HF Taxonomy

Given the findings described in the previous sections 4 and 5, a list of requirements for the SHIELD taxonomy has been identified, dividing them in three main areas: 1) level of granularity, 2) link with HF Concepts, and 3) link with the application domain. The requirements are briefly summarized in Table 2.

Table 2. Identified Requirements for the SHIELD HF Taxonomy

REQUIREMENTS		
1. LEVEL OF GRANULARITY	1.1	Be **sufficiently generic** to minimize the risk of inconsistent interpretations of the same terms
	1.2	Be **sufficiently detailed** to allow for an adequate understanding of the human performance cognitive mechanisms contributing to an accident
	1.3	Be **sufficiently detailed** to allow for an adequate understanding of the role played by organizational and contributing factors in contributing to an unsafe human performance
2. LINK WITH HF CONCEPTS	2.1	Directly refer on one or more state of the art **HF models**
	2.2	Assume an **adequate HF competence or training** for its use
	2.3	**Minimize the risk of blaming the individual** when trying to understand how the human performance contributed to an accident
3. LINK WITH DOMAIN	3.1	Use **transversal terms**, applicable to both the aviation and maritime domain
	3.2	Use **domain specific terms** when needed to understand the role of organizational and contextual factors in contributing to an unsafe human performance

One could remark that some of the requirements are slightly contradictory, however the motivation associated to each of them is a reference to decide how to balance among them the different criteria. For example, in group 1, the requirement 1.1 aims at a high level of granularity, while 1.2 and 1.3 aim at a lower level of granularity. However it is clarified that high-level detail (i.e. low granularity) is preferable to reduce the risk of inconsistent interpretations of the same terms, while a deeper level of detail (higher granularity) helps to both capture the different cognitive mechanisms entering in play in the human performance and facilitates an adequate understanding of the role played by organizational and contributing factors in determining possible unsafe acts at an individual level. In addition, in group 3, 3.1 requires the use of transversal terms and the 3.2 requires the use of domain specific terms. However, it is clarified that transversal terms facilitate the application of the taxonomy in both the aviation and maritime domain, while the use of domain specific terms is preferable to capture the role of organizational and contextual factors in contributing to an unsafe human performance.

6.2 Mapping of the five best in class taxonomies on the requirements

Following the definition of the requirements, a mapping of the five best in class taxonomies identified in sec. 5.2 has been conducted. Table 3 shows a matrix combining TRACEr, HERA, NASA-HFACS, HFACS and HEIST with the eight requirements. As can be seen, each taxonomy has strengths, however individually none provide a complete solution to the needs of SHIELD.

6.3 Identification of the taxonomies better addressing the requirements

The best approach to accommodate the needs of the SAFEMODE SHIELD is the one which is able to adequately account for higher level organisational issues and has a common bridge at the level of the individual performance. That is, it should allow a natural transfer of individual incidents, as assessed in HERA, with an organisational model, such as NASA-HFACS.

HERA. The primary purpose of HERA is to classify human errors. This provides it with great diagnostic capabilities with respect to root cause analysis, but provides little in the way of building up an overall picture relating to higher level (organisational) concerns. TRACEr is very similar to HERA (which was actually derived from it), but is less informative when establishing a link with contextual and organizational factors.

NASA-HFACS. NASA-HFACS provides a framework for a taxonomy that has been developed further than HFACS and considers a broad range of contributions that affect human performance. However, it does not have great diagnostic capabilities for the description of individual error mechanisms.

Table 3. Evaluation five best in class taxonomies against the eight requirements

REQUIREMENTS			LEVEL OF COMPLIANCE **H**=High **M**=Medium **L**=Low				
			TRACEr	**HERA**	**NASA-HFACS**	**HFACS**	**HEIST**
1. LEVEL OF GRANULARITY	**1.1**	Be **sufficiently generic** to minimize the risk of inconsistent interpretations of the same terms	M	M	M	H	M
	1.2	Be **sufficiently detailed** to allow for an adequate understanding of the human performance cognitive mechanisms contributing to an accident	H	H	M	L	L
	1.3	Be **sufficiently detailed** to allow for an adequate understanding of the role played by organizational and contributing factors in contributing to an unsafe human performance	L	M	H	H	H
2. LINK WITH HF CONCEPTS	**2.1**	Directly refer on one or more state of the art **HF models**	H	H	H	H	H
	2.2	Assume an **adequate HF competence or training** for its use	H	H	M	M	M
	2.3	**Minimize the risk of blaming the individual** when trying to understand how the human performance contributed to an accident	M	M	H	H	H
3. LINK WITH DOMAIN	**3.1**	Use **transversal terms**, applicable to both the aviation and maritime domain	M	M	H	H	H

REQUIREMENTS			LEVEL OF COMPLIANCE **H**=High **M**=Medium **L**=Low				
	3.2	Use **domain specific terms** when needed to understand the role of organizational and contextual factors in contributing to an unsafe human performance	H	H	M	L	L

Compared to HEIST, NASA-HFACS has simpler categories that minimize the risk of inconsistent interpretations by different experts. This characteristic is valuable particularly in domains with more limited HF knowledge, such as the maritime.

On closer inspection of NASA-HFACS and HERA, it is clear that there is a direct relationship between the lower level taxonomy of NASA-HFACS and the description of error mechanisms conditions in HERA. The HERA taxonomy provides a natural bridge to a lower level of detail than is offered in NASA-HFACS. The approach proposed for the SAFEMODE taxonomy was then to categorize incidents at the level offered by NASA-HFACS and examine them in detail at the level of HERA – i.e. the error mechanisms that describe how things went wrong at a cognitive level. In this way a high level entry point is provided by NASA-HFACS and a natural transition to a detailed level is held in HERA.
HERA and NASA-HFACS were also considered the two best candidates to work towards a standardised safety data analysis. At least the original HFACS component is well-known in both the aviation and maritime communities, thus minimising costs of adoption and reluctance to adoption. They are based on well-known established references and have been successfully used for a number of years by different organisations. They also meet the requirement of being pragmatic and providing an effective classification system for detecting trends and for informing design decisions.
Both HERA and NASA-HFACS are domain-specific. While they both have origins in aviation, NASA-HFACS has been adapted for the use in space, and HERA has focussed very heavily on the ATM domain. Similarly neither taxonomy individually maps directly to the top events or incident types described by authorities such as EASA and EMCIP. There remained therefore, significant work to generalise both approaches so that they reflected both aviation and maritime environments. The process of 'generalisation' should have included, for example, at a detail level, removing references to 'ATCO' and 'Controller' and replacing them with 'Operator'. This detail level was expected to allow the same reference point for each domain – maritime and aviation when classifying incidents. Maintaining a common lower level taxonomy meant that at a higher level, the organisational element could reflect the specificities of each domain, thus considering the factors that affect maritime at an organizational level, without restricting air traffic or aviation.

7. CONCLUSIONS

The review of sixteen Safety Occurrence Reporting and Analysis Systems (SORAS) in a selection of safety critical domains was the main strategy to derive the most relevant features useful to define the HF taxonomy of the SAFEMODE project. Considering the large variety of characteristics of the taxonomies, it was important to make a selection which was not arbitrary and took into account the actual role played by the taxonomies in the different SORAS. Therefore the selection of 5 best-in-class taxonomies (out of the initial list of 16) was based on both a framework combining criteria agreed among the SAFEMODE partners and a consideration of the expected uses of the taxonomy within the project.
The criteria composing the framework included: (a) the difference between model-based and epidemiological taxonomies and (b) the difference between transversal and domain-specific taxonomies. The expected use of the taxonomy was twofold: (i) to derive design and redesign recommendations, (ii) to help setting safety-related priorities. These criteria

were then used to define a set of 8 requirements to be addressed by the SHIELD taxonomy. These requirements played a double role: they helped to select the two best candidate taxonomies to take as reference (namely HERA and NASA-HFACS) and they provided guidance on the following work necessary to develop the SHIELD taxonomy.
Finally, it is worth highlighting that the SHIELD HF Taxonomy is currently a work in progress since minor corrections are being added into the taxonomy as shortcomings are identified while applying the taxonomy for accident analysis. Nevertheless, the results can still be of significant contribution for accident analysis not only in the maritime and aviation sectors but also in other safety critical domains.

8. ACKNOWLEDGMENTS

This publication is based on work performed in SAFEMODE which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 814961. Any dissemination reflects the author's view only and the European Commission is not responsible for any use that may be made of information it contains.

9. REFERENCES

Dillinger T., Kiriokos, N., 2019, "NASA Office of Safety and Mission Assurance Human Factors Handbook. Procedural guidance and tools", NASA/SP-2019-220204.

EMSA, 2018, "Safety Analysis of Data Reported in EMCIP. Analysis of marine casualties and incidents involving fishing vessels", April 2018.

EUROCONTROL 2003, "The Human Error in ATM Technique". HERA-JANUS Editions.

ICAO, 2010, "ICAO ADREP 2000 Taxonomy", 17 September 2010.

Reinach, S., Viale, A., Green, D., 2007, "Human Error Investigation Software Tool (HEIST)" (No. DOT/FRA/ORD-07/15): U.S. Department of Transportation, Federal Railroad Administration.

SAFEMODE, 2019, Deliverable 2.1 "SHIELD human factors taxonomy for risk analysis", version 2.0, December 2019.

Shappel, S.A., Wiegmann, D.A., 2000, "The Human Factors Analysis and Classification Systems – HFACS", U.S. Department of Transportation/FAA, DOT/FAA/AM-00/7".

Shorrock & Kirwan, 1998. "The development of TRACEr: a technique for the retrospective analysis of cognitive errors in ATM". Paper presented at the 2nd Conference on Engineering Psychology and Cognitive Ergonomics. Oxford: 28 - 30 October.

Wickens C. D., 1992, "Engineering Psychology and Human Performance (Second Edition)". New York: Harper-Collins.221-226.-226.