Human Factors Integration: Technical Guide for Human Factors and Safety Management

	RACI Matrix			
PSI Objectives	**Responsible**	**Accountable**	**Consulted**	**Informed**
Appoint a person responsible for HF (the HFIF) within the DT.	*DTL*	*DTL*	*PSM*	*Other DT members*
Identify the key contacts and define roles and responsibilities.	*HFIF*	*DTL*	*PSM*	*Other DT members*
Understand HF within the programme through an initial scoping and proportionality review.	*HFIF*	*DTL*	*DTL, PSM, Other DT members*	*Other DT members*
Determine whether the HFIF is a Safety Management stakeholder and/or required on the PSC.	*PSM*	*DTL*	*HFIF*	*Other DT members*
Communicate the role of HF to the DT.	*HFIF*	*DTL*	*PSM*	*Other DT members*

David Pennie discusses recent technical guidance that has been published by the MOD on improving integration of Human Factor considerations in System Safety Management.

The Integration of Human Factors (HF) with Safety Management (SM) in high hazard sectors, such as nuclear, rail and oil and gas has been instigated by significant and high-profile accidents such as: Windscale (1957), Three Mile Island (1979), Chernobyl (1986), Flixborough (1974), Piper Alpha (1988) and Clapham (1988). These accidents led to significant changes in Safety Case (SC) legislation.

1988 Piper Alpha disaster (petrochemical). An oil platform that was later converted to gas production. An explosion on the platform and the resulting fire killed 167 men with only 59 survivors. The publication in 1990 of Lord Cullen's report into the Piper Alpha disaster paved the way for the introduction of formal safety case requirements in the UK offshore industry. In 1992 Safety Case Regulations (SCR) were adopted for UK offshore industry.

Over time and with greater knowledge and understanding of accident causation there has been an increasing requirement for the comprehensive integration of HF and SM within the SC regime. This is supported by institutions such as the Health and Safety Executive (HSE), who provide guidance, review SC documentation and carry out inspections.

Whilst notable accidents, such as Nimrod (2006), have occurred in the defence sector, it has not precipitated the same level of regulation. The reasons for this are multifaceted, complex and not entirely clear, but this has resulted in regulatory drivers from HF integration with SM in defence not being as strong as in other high hazard sectors. Despite this, MOD recognise the need to strive to enhance the integration of HF and SM from within and identified that the way to achieve this was through the development of new guidance. It also recognised that there was the opportunity of learning from and applying Relevant Good Practice from other sectors.

A new publication titled: "Technical Guide for Human Factors and System Safety", has therefore been developed and published on the Human Factors Integration Management System (HuFIMS) website on behalf of Defence and Equipment Support (DE&S) services to help better integrate HF with the MODs Project Oriented Safety Management System (POSMS). The POSMS has 13 Safety Management Procedures (SMPs) as follows:

- Project Safety Initiation (PSI)
- Project Safety Committee (PSC)
- Safety Planning
- Preliminary Hazard Identification and Analysis (PHIA)
- Hazard Identification and Analysis (HIA)
- Risk Estimation
- Risk and As Low As is Reasonably Practicable (ALARP) Evaluation
- Risk Reduction
- Risk Acceptance
- Safety Requirements and Contracts
- Hazard Log
- Safety Case (SC) and Safety Case Report (SCR)
- In-Service Safety Management System (SMS).

These TGs are available for free for those signed-up to the MOD Knowledge in Defence (KID) website. The development of HFI and SM TG demonstrates MOD commitment to positioning HF in a central role in safety management. It also recognises how developing the understanding and knowledge of System Safety assessors and Delivery Team Leads (DTL) on the human contributions to safety will be very beneficial.

The purpose of the TG

The purpose of the TG is to provide an across-services publication to help better integrate HF with the System Safety aspects of DE&S acquisition projects, by:

- Improving understanding about the benefits of effectively integrating HF and acquisition System Safety
- Providing specific advice on how to integrate HF with the POSMS
- Supporting alignment of the activities conducted by safety and HF specialists by increasing the awareness and understanding of each other's areas of responsibility
- Providing a summary of HF analytic tools and methods that support Human Factors Integration (HFI) with System Safety, along with links to more detailed information and guidance.

Study rationale - Overall Approach to develop guidance

This TG was produced by Greenstreet Berman Ltd (GSB) in collaboration with HuSys Ltd as part of the Defence Science and Technology Ltd Defence Human Capability Science and Technology Centre (DHCTSC) programme. The development of the TG was based on a multi-method approach to use several data gathering activities to develop an understanding of:

- How HF is currently integrated with SM in defence projects
- What guidance or information supports this integration
- What is done elsewhere - in other safety critical industries
- What information should be included in the TG
- How it should be presented.

Finally, the research to develop the TG also explored what else might need to happen to further integrate HF and SM.

Methodology

What does MOD currently provide – Initial Review

An initial review was carried out to explore the extent to which the MOD already provides guidance on the integration of HF with SM. The findings indicated that:

- The current suite of HuFIMS TGs provides 'general' good practice guidance that could be referenced as a source for use by HF experts when linking with SM, for example, to develop HF risk reduction
- Current TGs provide guidance on specific activities like Early Human Factors Analysis (EHFA) that could support 'Safety Planning' as well as helping to inform 'Preliminary Hazard Analysis (HAZAN)'
- The current suite of HuFIMS TGs does not, however, comprehensively cover the POSMS SMPs or the types of HF analytic tools to support safety assessment and SM decision-making.

Analysis Matrix

In addition to the initial review, more detailed analysis was carried out to identify HF in-puts/outputs/touchpoints relevant to each POSMS SMP to help inform where HF could most effectively support SM. This, in turn, indicated the information to be included in the TG.

The work to develop the Matrix was carried out in several phases, including a three-quarter day workshop to explore, discuss and agree the content of the Matrix with Subject Matter Experts (SMEs). The findings indicated that HF should be an integral part of all the POSMS SMPs with HF inputs in four key areas:

- Physical participation at formal meetings/sessions (e.g. attendance at Hazard Operability Study (HAZOP) sessions)
- Tangible formal input (i.e. outputs from HF analysis or assessment activity)
- Informal input (i.e. ad-hoc discussions between HFI and SM specialists)
- HFI activity being so closely aligned to the POSMS SMP process, such that it becomes fully integrated, leading to adaptation either of the whole process or a key element of the POSMS SMP.

Interviews

Interviews were conducted with HF and SM specialists (as well those covering roles such as Design, Engineering and Assurance) to explore how well current internal MOD processes (e.g. Policies, Procedures and Guidance) support HFI with SM for military systems acquisition.

Nine people, from six defence projects took part covering Land, Air and Maritime domains.

The findings from the interviews indicated:

- Most respondents wanted improved guidance on how HF integrates with SM
- Interviewees listed several areas where additional guidance would help support HF and SM, such as human error analysis
- Interviewees noted that there was limited regulation driving HFI with SM
- There seemed to be a lack of understanding of the application of human failure probabilities in Fault Tree Analysis and reliance on qualitative assessment
- Both HF and Safety SMEs consider there would be benefits from possessing a greater understanding of each other's roles.

Learning from other sectors

The aim of the review of other sectors was not to critique existing information or formally indicate and rate the value of guidance, but rather, to seek ideas and inputs to inform the development of the TG. In total, 42 guidance materials were identified. Of these, 25 were reviewed in more detail following the application of screening criteria.

The findings indicated that that the most value that the Defence sector could gain from advice provided from other sectors was in HAZID, HAZAN, risk estimation, risk reduction and ALARP Evaluation. Some limited additional advice was also provided concerning the development of Safety Cases (SCs) and the transition of safety assessment to In-Service SM.

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Stakeholder engagement

The findings from the initial review, Analysis Matrix, interviews and learning from other sectors were collectively reviewed by the project team to support the development of the TG. Emergent ideas on the content and style of the TG were set out in a User Requirement Document and skeleton draft. These were reviewed during a 3-hour Face-to-Face workshop session. In total 10 people took part in the workshop representing HF and SM specialisms working for DE&S or embedded in defence projects.

The findings from the review and workshop indicated that there was broad agreement from the target audience, with the proposed structure, scope and form of the HF and System Safety TG. There was also agreement that the TG should be aligned to the 13 POSMS SMPs. Other more specific comments were incorporated into the development of the TG.

Staged approach to TG development

The TG was delivered to stakeholders at the following stages in its development:

- Skeleton draft
- 20% complete
- 90% complete
- 100% complete – completed and proof-read document.

Following delivery of each draft, stakeholders were given the opportunity to comment on the TG. This staged approach helped to ensure that stakeholder had early sight of the document, ensuring its development was in line with their expectations and requirements. This was considered particularly important given the dual nature of the intended audience.

What the TG contains

Intended audience

The TG is primarily aimed at both HF and SM specialists working within the DE&S acquisition community, who support the design, specification, assurance, purchase and supply of Product (e.g. weapons, platforms): System and Services (PSS).

It is also aimed at other Project-based team members who interface with HF and SM or, who have a vested interest in effective SM (e.g. the Delivery Team Leader (DTL), Principal/Chief Engineer, Requirements Managers etc.).

About HF/HFI and its importance to SM

The guidance provides a summary of the five fundamental aspects of HF and HFI considered important for effective SM and demonstration that a system is safe to operate; these were:

- Designing out failure: ensuring that PSS are designed to be intuitive, easy to operate and tolerant to human failure (e.g. reduce opportunities for errors and violations and if errors do occur, ensure they are easy to detect and recover from)
- The human contribution to safety: explaining how humans can either positively or negatively contribute to safety
- Human failure: explaining the different types of error and violations that can lead to human failure
- Performance Shaping Factors: explaining how applying an understanding of psychology, physiology and sociology) can identify and elaborate on the aspects of work that influence human failure
- Human Based Safety Claims: outlining the importance of identifying and understanding the human based controls that reduce the potential for the hazard to occur and the likelihood of the hazard being realised, such as, performing a task in a certain way that helps to maintain safety (e.g. not flying an aircraft below a certain altitude) to responding to an emergency condition (e.g. a person in a control room identifies and responds correctly to an alarm).

Key best practice principles

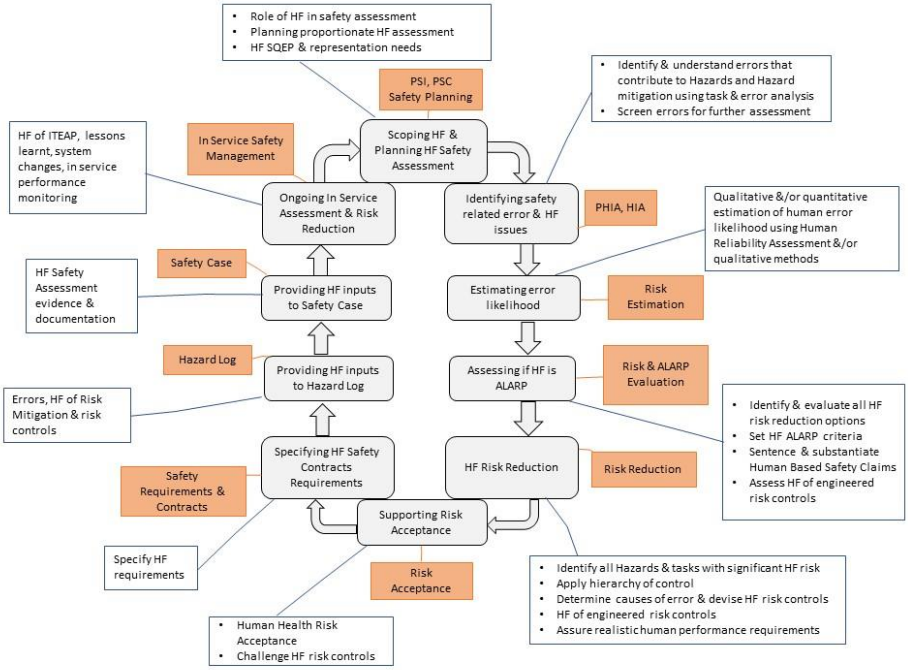
The guidance outlines around 20 best practice principles, summarised throughout the TG, aimed at both HF and SM specialists to help support more effective project-wide interactions

and to enhance and improve HF and SM integration. A selection of these is provided below.

- Conduct a scoping and proportionality review of HF based on the information available to the Project
- The Safety Management Plan and HFIP should be developed so they can be easily aligned (e.g. use the same method and terminology to indicate breakdown of work - what activities will be carried out, by whom and when)
- There is an expectation that some level of Task Analysis (TA) and associated error analysis will be carried out because of its importance in understanding human failure - justify if it has not been applied
- The decision to undertake further HF analysis walkthroughs, TA etc. should be a safety-led decision and informed by outputs from HAZID/HAZAN
- All safety claims made on people should be identified, defined and substantiated (e.g. demonstrates through argument and evidence that humans are capable of fulfilling the safety claim placed on them)
- HF specialists should be given the opportunity to review and challenge any outputs from Risk Acceptance, especially where HF measures have been adopted that place a claim on humans in the system.

Specific advice on how to integrate HF with the POSMS

As stated previously, the core content of the TG (e.g. advice and guidance to support the integration of HF with SM) was presented to align to the POSMS and the 13 POSMS SMPs – as shown in the diagram.



The POSMS SMPs describe the processes and procedures that are designed to assist with the identification and management of the safety risks of equipment and services throughout the acquisition process.

The guidance provided in the TG also used the same headings as the POSMS SMPs and these subsections in turn used the same standardised headings used by the POSMS SMPs. The purpose of structuring the guidance in this way was to help emphasise the link between HF and SM and to make the process of integration more straightforward and ensure consistency of language and terminology throughout.

For each section, a RACI (Responsible, Accountable, Consulted, Informed) table is provided, that outlines shared HF objectives for the POSMS SMP. An example RACI table is provided for SMP1 - Project Safety initiation is as follows:

	RACI Matrix			
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Specific guidance is provided aligned to each objective; an example is provided below.

"The DTL has overall accountability for the consideration of HF within the Project and DT. In large Projects, or, Projects with a clear human element, the DTL should appoint a person to act as the HFIF, the person responsible for managing HFI contribution to safety particularly within the early stages of the programme (e.g. Pre-Concept and Concept). As the Project develops and evolves a Human Factor Integration Manager (HFIM) should be appointed to take on the additional work of ensuring that the contracted HFI Plan (HFIP) is implemented and to manage day to day HFI activities.

In smaller Projects, or during the pre-concept phase, the DTL may decide to act as the HFIF, however, as the Project develops it may be necessary for the DTL to delegate this responsibility to another DT member

The person responsible for HF at this stage of the Project (e.g. the person appointed as the HFIF) should support HF integration by:

- *Establishing points of contact and stakeholders;*
- *Engaging with the PSM;*
- *Understanding the Project and establishing the role of HF in Safety Management (e.g. scope, resource requirement etc.);*
- *Communicating the role of HF in Safety Management to the PSM to support stakeholder identification and PSC membership decisions;*
- *Developing an HF Strategy; and*
- *Developing Project awareness of HF e.g. the importance of considering the importance human contribution to safe and reliable operations)."*

Summary of HF analytic tools and methods that support Human Factors Integration (HFI) with System Safety

In addition to the specific advice, a series of tables is provided that provide a summary of Human Error Identification and Analysis methods as well as HF analytical tool and techniques that support SM. The methods and techniques are aligned to a category or area with a brief description of what they provide, a link to relevant POSMS SMP, an explanation of how they might be applied and references to additional guidance/information.

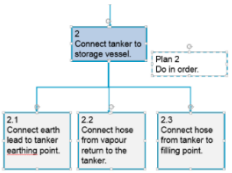
A small snapshot of 2 of the tables is provided below to illustrate the typical content.

Table 1: Human Error Identification and Human Error Analysis Techniques

Method	**Brief Method Description**	**Application to Safety Assessment**
Human Error Assessment and Reduction Technique (HEART) HEART – A Proposed Method for Assessing and Reducing Human Error. A Guide to Practical Human Reliability Assessment - This guide provides a practical overview of a range of Human Reliability Assessment methods, including APJ, PC, HEART and THERP.	HEART provides two tables: The first is a list of nine generic tasks allowing the assessor to select the task that most resembles the one being assessed. Each has a nominal human unreliability, e.g. 'Complex task requiring a high level of comprehension and skill' = 0.16 The second is a list of Error Producing Conditions (EPC), each of which has an associated figure that may be applied to modify the nominal human unreliability, e.g. 'A low signal-noise ratio' with a maximum assessed proportional of effect = 10. Using a simple mathematical formula, the method allows for multiple EPCs to be applied to each task, and for the proportion of effect of each EPC to be adjusted, thus leading to the final predicted HEP. HEART also provides suggestions for means of reducing error likelihood.	Supports quantitative Risk Estimation and derivation of HEPs. HRA also supports qualitative Risk Estimation.
Technique for Human Error Rate prediction	THERP is a means of quantifying HEP. The THERP manual (NUREG/CR-1278) provides tables, each with a set of HEPs which can be	Supports quantitative Risk Estimation and derivation of HEPs. HRA also supports

Method	Brief Method Description	Application to Safety Assessment
(THERP) Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications. A Guide to Practical Human Reliability Assessment.	modified by the assessor to reflect the impact of PSFs (known as Error Factors), addressing errors of omission, commission and diagnosis of abnormal events. THERP manual Table 20-12 item 9: 'Set a rotary control to an incorrect setting', HEP = 0.001, Error Factor = 10 The method is suitable for use with fault and event trees, thus allowing detailed modelling of human failures. Unlike other methods, it can also account for dependency between related errors (see Human Error Inter-Dependence below) and can provide HEPS for error-recovery paths.	qualitative Risk Estimation.

Table 2: HF Tools and Techniques

Method	Brief Method Description	Application to Safety Assessment
Hierarchical Task Analysis (HTA) A Guide to Task Analysis. A Practical Guide for Engineering and Design.	HTA provides a graphical representation of a goal-based scenario broken down into tasks and sub tasks (operator activities required to achieve the goal). The sub tasks-are arranged in hierarchical levels of detail.  HTA is one of the most commonly applied HF techniques. HTA as with other forms of TA should be based on how work is actually carried out and should not just rely on procedures but use knowledge about how tasks are carried out from data gathering techniques such as walkthroughs etc.	Helps to improve understanding about how a task is carried out and what tasks are particularly dependent on people and therefore, potentially more vulnerable to error. Helps to show dependencies between tasks. HTA is frequently used in conjunction with TTA, to identify and better understand human failure.

Method	Brief Method Description	Application to Safety Assessment
Tabular Task Analysis (TTA) A Guide to Practical Human Reliability Assessment. A Practical Guide for Engineering and Design.	TTA is an approach that presents data (identified from TA, such as an HTA) in a tabular format to facilitate the identification and understanding of human failure. Each identified task is considered in detail to help identify and understand human failure. The approach to TTA is flexible but typically table columns would include: sub task, operator, potential errors (using a classification approach such as SHERPA), Consequence of the failure. Control measures to prevent against failure (e.g. safeguards); PSFs and recommendations (e.g. additional control measures or ways to enhance performance.	TTA is an important method used to identify and analyse errors in support of HAZID and HAZAN.

Recommendations

Recommendations were also made with the aim of enhancing HFI over and above provision of the TG. In summary these were:

- Develop a suite of training courses to be delivered to both HF and SM specialists to provide comprehensive understanding of each other's role and methods and to build upon the information provided in the TG
- Provide greater Regulatory and Policy Over-Sight to encourage the integration of HF with SM, e.g. cite the TG in selected policy documents such as Joint Service Publication (JSP) 912 - Human Factors Integration for Defence Systems (V1.0 Oct 15)
- Conduct future research to identify, adapt, validate and if necessary, develop new HF safety assessment methods to meet the specific needs of the Defence sector
- Identify and capture case studies of good HF safety assessment in Defence and/or work examples that exemplify and disseminate good practice
- Enhance the suite of HF TGs to provide additional guidance on topics important to safety, such as, Error prevention and error risk reduction (e.g. preventing error interdependency).

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David has over 15 years' experience in the application of Ergonomics and Human Factors (HF) in high-hazard industries (e.g. defence, nuclear, rail & oil and gas). This experience includes consultancy (e.g. undertaking research, delivering training etc) but he also has extensive experience of providing embedded HF support working directly with both safety management specialists and engineers.

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